Present Status and Plans of JENDL FP Data Evaluation Project

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The Fission Product (FP) data evaluation is one of the key issues for the next revision of JENDL, since many data were carried over from JENDL-3.2 to 3.3. The new FP Working Group (FPWG) was organized in the Japanese Nuclear Data Committee (JNDC) to perform new evaluations of FP data for JENDL. In the present review of FP data evaluation, we show the history and current status of FP nuclear data, requirements of FP data, new measurements, the international cooperation, and the future plans toward the new JENDL.

1. Introduction

Although nuclear data of fission products (FP) are essential for various reactor calculations such as burn-up, gas production, decay heat, radiation damage etc., to meet of this requirement is very hard because there exists a large number of FP nuclides/isotopes, and the experimental data for many isotopes and reactions in a specific energy range are scarce. For example, 185 nuclides (from Ga to Eu) are stored in JENDL-3.3. Figure 1 shows a chart of nuclides compiled in JENDL-2, 3.2, and 3.3. To evaluate such a large number of nuclear data, nuclear model calculations get more important nowadays, and reliability and accuracy of the evaluated nuclear data depend on the quality of input variables. FP Working Group (FPWG) in the Japanese Nuclear Data Committee (JNDC) had continuously developed evaluation tools for resonance and smooth regions, as well as methods to validate the evaluated nuclear data.

During the last decade, the FP data evaluation became one of the key issues in the international cooperation. Subgroup 10, 17, and 21 in WPEC (Working Party on International Nuclear Data Evaluation Cooperation)[1, 2] were organized under OECD/NEA, some resonance parameters of FP were evaluated at BNL and KAERI for ENDF/B-VI, a series of FP cross section measurements were performed at several institutes, and an evaluation work for CENDL was also made at CIAE. In this good circumstances we restarted FP Working Group in 2002 to update the FP data in JENDL. We aim to brush up the old evaluations in the current JENDL, and hopefully we shall complete our new evaluation within several years. This FP data file will be a part of the next JENDL general purpose file. In order to complete this we need to survey new resonance parameters available, to inspect input parameters used, and to replace them by more reliable ones. This report summarizes current status of FP nuclear data and the future plans toward the new JENDL.

[1]S. Chiba, M. Igashira, M. Ishikawa, M. Kawai, T. Kawano, M. Matsunobu, T. Murata, T. Nakagawa, K. Shibata, T. Sugi, T. Watanabe, and A. Zukeran

2. International Activities

There are several international cooperative projects relating to the FP data evaluation. OECD/NEA organized the following three subworking groups:

Subgroup	Coordinator	Project Name	status
10	M. Kawai	Inelastic scattering cross sections for weakly absorbing FP nuclides	published[1]
17	H. Gruppelaar	Pseudo-fission-product cross sections for fast reactors	published[2]
21	P. Oblozinsky	Assessment of neutron cross sections for the bulk of fission products	new, 2001

and the subgroup 21 (SG21) is now working on an inter-comparison of FP data those are selected randomly. Quantities to be reviewed are the total, capture, elastic, inelastic, $(n, 2n)$, (n, p), and (n, α) cross sections, resonance parameters, and thermal values. The results are open to public at the BNL web site (`http://www.nndc.bnl.gov/sg21/`).

Reference Input Parameter Library (RIPL)[3] was compiled at IAEA, which is a library containing nuclear model parameters mainly for the statistical Hauser-Feshbach model calculation. Nuclear masses, excited levels, optical potential parameters, level densities, GDR parameters, fission barriers are stored in RIPL. In 2002 they finalized the second edition, and a new task (phase III) was initiated. This library has an apparent benefit of FP data evaluations, since model calculations are essential in the FP region, and we need reliable global parameters and systematics in order for automatic input parameter setting and a cost-effective method to generate bulk data.

Figures 2, 3, and 4 show some examples in which RIPL was used to calculate the optical and Hauser-Feshbach-Moldauer models. Those calculations were made without any parameter adjustments in order to see adaptability of RIPL in the FP region.

A comparison of calculated total cross section of ^{90}Zr with the experimental data is shown in Fig. 2. The optical potential used is the global potential parameter of Koning and Delaroche[4], which is adequate in the energy range from a few keV up to 200 MeV. The calculated cross section with the well-known Walter-Guss potential is also shown by the dotted line in this figure. In the case of ^{90}Zr the global potential of Koning-Delaroche gives better fit to the data than JENDL-3.3. Of course the quality of fitting may depend on the target nuclide and we need a quantification study of adaptability of such global parameterization. However it is apparent that this global potential becomes a powerful tool to evaluate the FP nuclear data.

Figure 3 shows an example of calculated inelastic scattering to the first (1.761 MeV, 0^+) and second (2.186 MeV, 2^+) levels of ^{90}Zr. The Koning-Delaroche global potential was used to generate the neutron transmission coefficients, and the level density parameters were taken from RIPL (phase I). The direct inelastic scattering was not included since its contribution is not so large below 4 MeV. In this case the calculated cross section underestimates the experimental data of Guenther *et al.*[5]

The comparison of capture cross section is shown in Fig. 4. Resonance parameters are given below 0.17 MeV, and the cross sections in the resonance region were averaged to compare with the statistical model calculations. The γ-ray transmission is often re-normalized to the experimental strength function $2\pi\langle\Gamma_\gamma\rangle/D_0$ if available. RIPL also contains this strength function, and the solid line is the calculated cross section with this re-normalization. The dotted line shows the calculation without re-normalization, which is about three-times larger than the experimental data.

3. Resonance Region

There are some activities of FP cross section measurements at low energies. The major contributions from our country is, Tokyo Institute of Technology, Kyoto University Research Reactor, Japan Nuclear Cycle Development Institute, and so on. Accelerator facilities in abroad such as GELINA at IRMM or ORELA at ORNL also produce transmission data of FP nuclides, though they are not mass production of nuclear data, but sometimes they are related to fundamental physics.

In general FP resonance parameters in JENDL-3.3 are the same as those in JENDL-3.2, however the parameters of ^{99}Tc, ^{140}Ce[6], and ^{106}Cd were replaced by new sets. Gunsing *et al.*[7] carried out a transmission measurement of ^{99}Tc from 3 eV to 150 keV and they analyzed their experimental data to obtain the resonance parameters up to 10 keV. Those parameters (up to 6 keV) were adopted for JENDL-3.3. Notable improvements between two parameter sets are the thermal cross section σ_γ^0 and the resonance integral I_γ. The new resonance parameter set was evaluated so as to reproduce the experimental data σ_γ^0 of Harada *et al.*[8] which is larger than the evaluation of Mughabghab *et al.*[9]. The following table compares σ_γ^0 and I_γ values.

Library	σ_γ^0 [b]	I_γ [b]	notes
JEF-2	19.1	304	same as Mughabghab
ENDF/B-VI	20.0	312	Ref. [10]
JENDL-3.2	19.6	311	
JENDL-3.3	22.8	323	almost the same as Gunsing
Gunsing *et al.*	23.1	323	Ref. [7]
Mughabghab *et al.*	20.0 ± 1.0	340 ± 20	Ref. [9]
Harada *et al.*	22.9 ± 1.3	398 ± 38	Ref. [8]

The resonance parameter of ^{99}Tc was also revised for ENDF/B-VI by Oh *et al.*[10]. Recently Kobayashi *et al.*[11] measured the neutron capture cross section of this important FP up to about 3 keV. Those information may also make it possible to update the resonance parameters in the next revision.

4. Conclusion

We have reviewed the current status of FP nuclear data evaluation in Japan, as well as some international activities relating to the FP data. WPEC Subgroup 21 is making some inter-comparison of FP data in the nuclear data libraries. There are some activities of nuclear data production, but the experimental data are still insufficient for many FP nuclides.

In the resonance region, some new evaluations of resonance parameters are available, and it is also possible to derive a new parameter set by new measurements, like the ^{99}Tc capture cross section measurement at KUR.

In the smooth region, we have a nuclear model parameter library, RIPL, which enables us to calculate various cross sections even though the experimental data are inaccessible. We have shown some simple examples of use of RIPL. This is the starting point, and we need some quantification study of adaptability of such global parameterization.

References

[1] M. Kawai, H. Gruppelaar, "Evaluation Method of Inelastic Scattering Cross Sections for Weakly Absorbing Fission-Product Nuclides," KEK Preprint 2002-54, NEA/WPEC-10 (2002).

[2] H. Gruppelaar, "Status of Pseudo-Fission-Product Cross-Sections for Fast Reactors," NEA/WPEC-17, ECN-R–98-014 (1998).

[3] "Handbook for Calculations of Nuclear Reaction Data — Reference Input Parameter Library —," IAEA-TECDOC-1034, International Atomic Energy Agency (1998).

[4] A.J. Koning, J.-P. Delaroche, *Nucl. Phys. A,* **713**, 231 (2003).

[5] P. Guenther, A. Smith, J. Whalen, *Phys. Rev. C,* **12**, 1797 (1975).

[6] T. Nakagawa, O. Iwamoto, A. Hasegawa, "Re-evaluation of Neutron Nuclear Data for ^{242m}Am, ^{243}Am, ^{99}Tc and ^{140}Ce," JAERI-Research 2002-035, Japan Atomic Energy Research Institute (2002).

[7] F. Gunsing, A. Leprêtre, C. Mounier, C. Raepsaet, *Phys. Rev. C,* **61**, 054608 (2000).

[8] H. Harada, S. Nakamura, T. Katoh, Y. Ogata, *J. Nucl. Sci. Technol.,* **32**, 395 (1995).

[9] S.F. Mughabghab, M. Divadeenam, N.E. Holden, "*Neutron Cross Sections*" Vol.1: "*Neutron Resonance Parameters and Thermal Cross Sections*", Academic Press, New York (1981).

[10] S.Y. Oh, J.H. Chang, S. Mughabghab, "Neutron Cross Section Evaluations of Fission Products Below the Fast Energy Region," BNL-NCS-67469, ENDF-362, KAERI/TR-1511/2000, Brookhaven National Laboratory (2000).

[11] K. Kobayashi, private communication (2003).

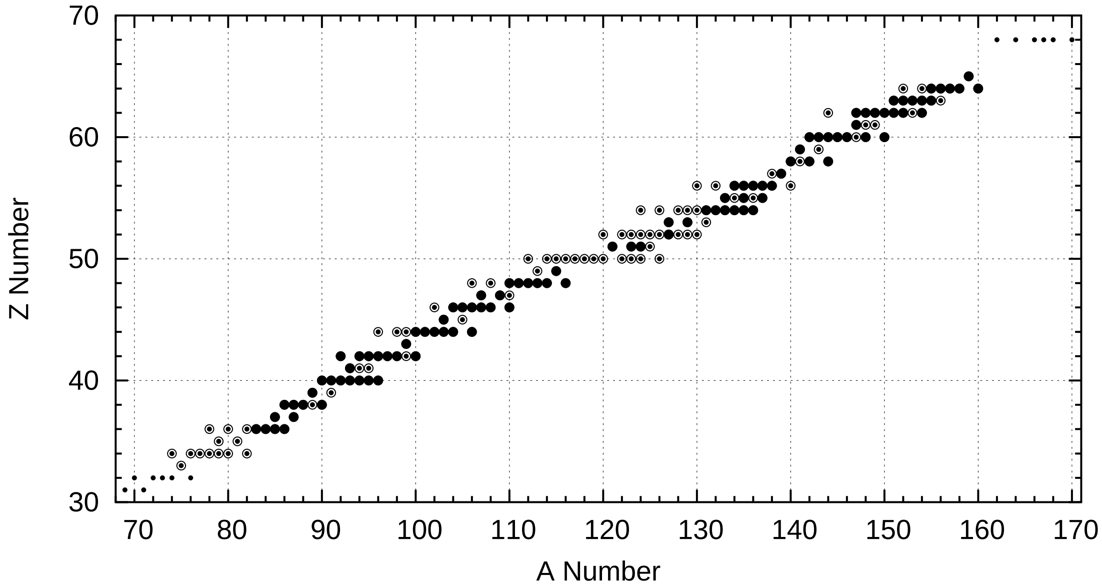

Fig. 1: Nuclides compiled in JENDL-2 (closed circle), JENDL-3.2 (open circle), and JENDL-3.3 (dot).

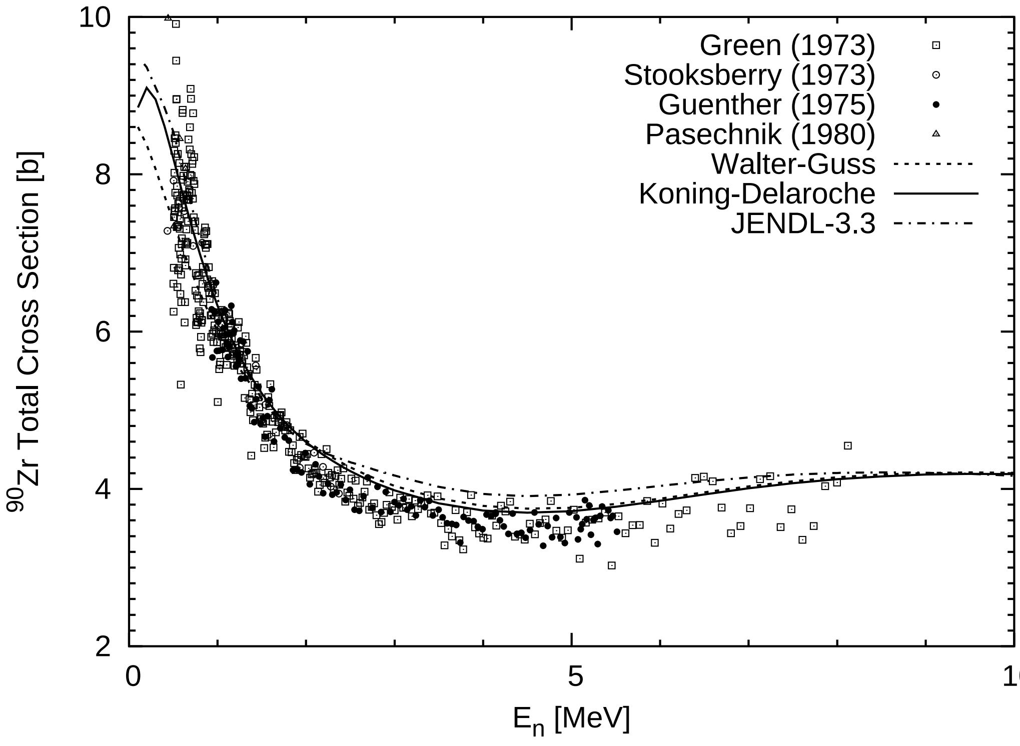

Fig. 2: Comparison of calculated total cross section for ^{90}Zr with some global optical potential with the experimental data.

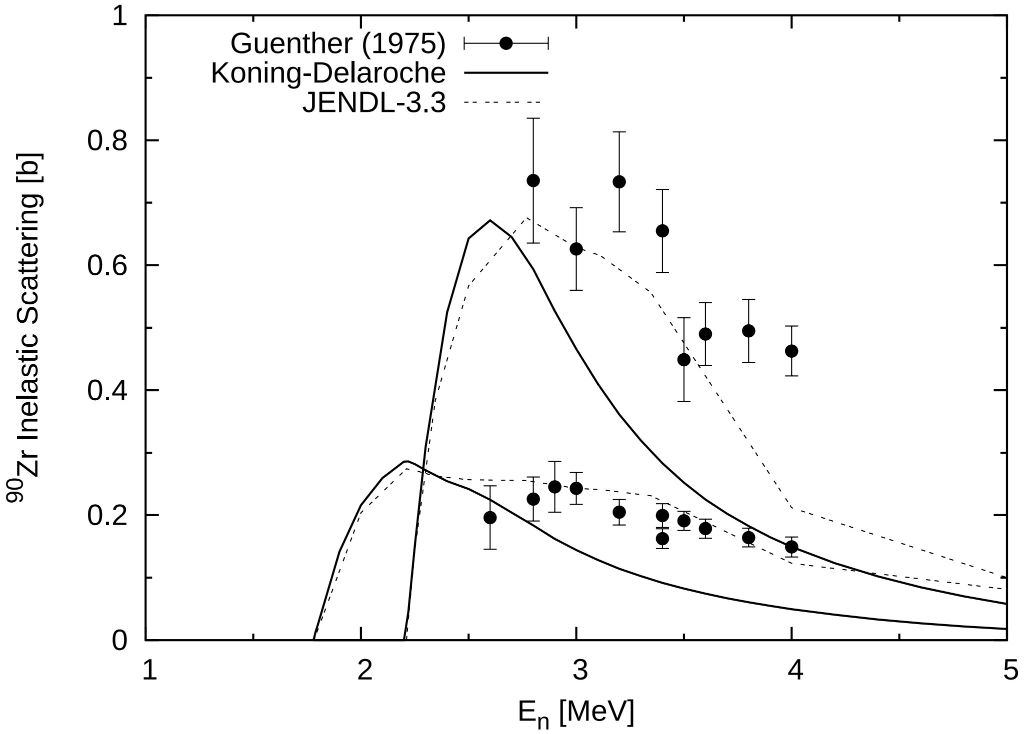

Fig. 3: Comparison of calculated inelastic scattering cross sections for ^{90}Zr to the 1.761 and 2.186 MeV levels with the experimental data.

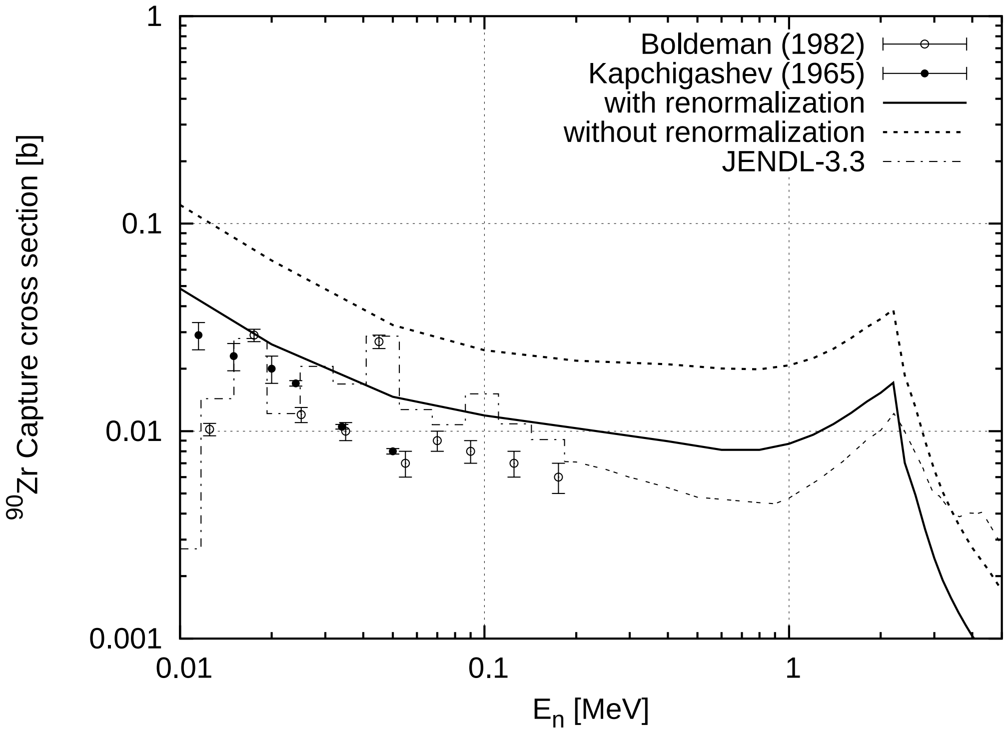

Fig. 4: Comparison of calculated neutron capture cross sections for ^{90}Zr with the experimental data.