Proceedings of the Korean Nuclear Society Spring Meeting
Gyeongju, Korea, 2004

Neutron Data Library for Sm-150, Sm-151 and Sm-152

Y. D. Lee and J. H. Chang

Korea Atomic Energy Research Institute
P.O. Box105, Yusung, Taejon, Korea 305-600
Tel:82-42-868-2635, FAX:82-42-868-2636, Email:ydlee@kaeri.re.kr

Abstract

The neutron data library for Sm-150, Sm-151 and Sm-152 were completed from thermal to 20 MeV. The fast energy data were calculated and evaluated from unresolved region to 20 MeV using Ecis-Empire combination. The fast results were merged with the resonance part. For fast energy region, optical model, full featured Hauser-Feshbach model, multistep direct and multistep compound model were used in the calculation. The direct and semi-direct capture model in pre-equilibrium and the direct coupled-channels contribution to discrete levels were introduced to improve capture and inelastic scattering cross sections. The theoretically calculated cross sections were compared with the experimental data and the evaluated files. The model calculated total, capture and other threshold reaction cross sections were in good agreement with the experimental data. The evaluated fast energy part results were compiled to ENDF-6 format and with the general description files, the full data libraries were ready to submit to ENDF/B-VII.

1. Introduction

Neutron capture cross sections of samarium isotopes in several keV region are important because these isotopes are significant fission products in a fission reactor concerning neutron absorption loss. The selected samarium isotopes have a high yield, long lifetime and high capture rate in a reactor. In ENDF/B-VI, Sm-150, Sm-151 and Sm-152 were evaluated in 1992, 1988 and 1992, respectively. Total, elastic and capture were revised for Sm-150 Sm-152 for fast energy region and total, elastic, and capture are set to zero in the resolved resonance range for Sm-151.

Neutron induced nuclear reaction data for fission products are important for predicting burnup performance in a fission reactor, criticality for spent fuel storage design, advanced fuel performance and radiation damage estimation of structural material. The absorbed neutrons by fission products are large portion of the total loss of neutrons in a reactor.

The neutron cross section data production work is actually divided into two regions: resonance region including thermal energy and upper resonance region up to 20 MeV. For resonance energy region, the evaluation was done for the samarium isotopes[1] and the results were adopted in release 8 of ENDF/B-VI up to unresolved energy region. Therefore, the current fast energy evaluation complements the resonance region in making full data library. From the different evaluations, the merge was done in the unresolved region, based on the experimental data.

Ecis-Empire code combination[2] was used in cross section calculation of the deformed Sm-150, Sm-151 and Sm-152 nuclei for total, elastic scattering and reaction cross sections. The optical model potential depending on the incident neutron energy was decided. Nuclear reaction cross sections were calculated using the Hauser-Feshbach model for equilibrium energy region and the quantumn mechanical approach in the pre-equilibrium energy region. The width fluctuation correction was involved in Hauser-Feshbach particle decay. The Empire offers several built-in libraries including the ENSDF nuclear level, deformation parameters and decay information. The data library involves the information on (n, tot), (n, n), (n, n'), (n, 2n), (n, 3n), (n, na), (n, np), (n, γ), (n, p) and (n, α) cross sections. The all results were formatted to ENDF-6 format. The full data files are checked using physics checking codes. The data library involves from thermal to 20 MeV and is ready for ENDF/B-VII.

2. Fast Region Calculation

In this paper, (n, γ) and (n, α) cross sections are partly presented. However, the other reaction cross sections are summarized and formatted in the library file. Fig. 1 is the capture cross section for Sm-150. Unfortunately, there is no experimental data. Therefore, the default parameters were used. However, the calculation and ENDF/B-VI are quite close together. Specially, the calculation shows the fast neutron capture contribution in the pre-equilibrium, around 14 MeV. The (n, α) cross section is presented in Fig. 2. ENDF/B-VI does not include the (n, α). The current calculation is in good agreement with the experimental data[3,4]. (n, α) cross section is usually small. The threshold is 14 keV in the current calculation, but JEF starts 0.1 eV.

The capture cross section experimental data for Sm-151 does not exist either. Fig. 3 represents the calculated capture cross section with the other evaluated files. The difference between the current calculation and the ENDF/B-VI is shown at high energy, above 200 keV. For Sm-151 case, (n, α) cross section exists at thermal and resonance energy region, from the reference[5]. Therefore, the (n, α) cross section was considered in that region. 1/v rule was applied from resonance energy to the thermal. The Empire calculated (n, α) cross section in the fast energy region was combined with the resonance and thermal region. The smooth connection in the unresolved region was checked. Fig. 4 shows the (n, α) cross section from the thermal to 20 MeV.

The calculated capture cross section is shown at Fig. 5 with the measured data and the evaluated files. The current calculation and ENDF/B-VI are in good agreement with the experimental data[6,7]. However, in the pre-equilibrium, ENDF/B-VI is higher than the calculation. Also, the calculation shows the feature of direct capture at pre-equilibrium energy region. Fig. 6 is (n, α) cross section. All experimental data are around 14 MeV. At that energy, the current calculation and other evaluations are in good agreement with the data[3,8], but the total shapes are different in the whole region.

3. Full Data Library

The fast energy evaluation results are connected to the resonance part and it makes full data library from the thermal to 20 MeV. The overlapping usually happens in an unresolved energy region. The general information file (MF1) was created for each nucleus. MF1 includes evaluated file history, resonance evaluation, fast region information (OMP, levels, codes, parameters) and each reaction description. The data library file experience physics checking using several codes, such as CHECKR, FIZCON and PSYCHE. NJOY[9] code was run to check the continuity and the file processing for applications. The general rules for merging were created. Sometimes, a discontinuity happened at the merging energy. Therefore, if necessary, backgrounds and adjustments were put based on the experimental data.

4. Conclusion

By adding direct and semi-direct model, fast neutron capture was substantially improved in the pre-equilibrium energy region. The evaluation process for deformed nuclei was applied and the most proper model theories were applied for the evaluation. The results are successful. The decided energy dependent optical model potential was proper in producing the cross sections. Empire was successful in producing the threshold reaction cross sections. The connection to the resonance was smooth and continuous. Evaluated cross sections are in good agreement with the experimental data. The current evaluation represented improvement over ENDF/B-VI. The all calculated results were converted into the ENDF-6 format and with the MF1 neutron data library was made for each isotope. The final files are ready to submit to ENDF/B-VII.

Acknowledgements

This work is performed under the auspices of Korea Ministry of Science and Technology as a long-term R&D project.

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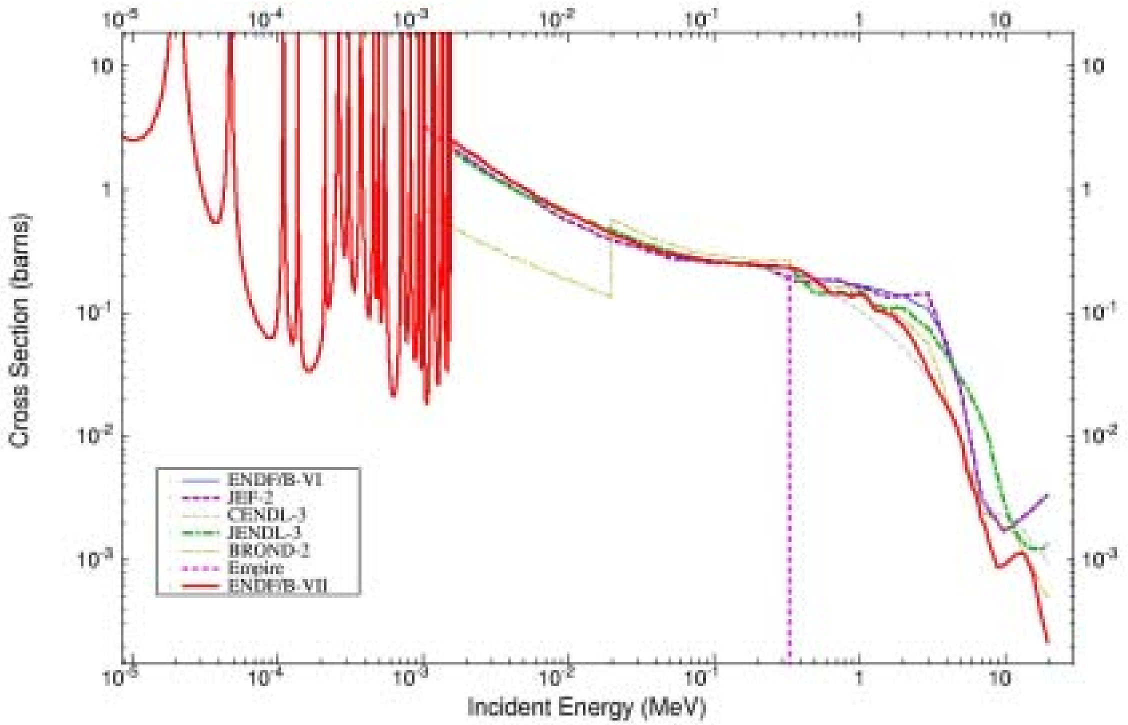

Fig. 1. Capture cross section for Sm-150.

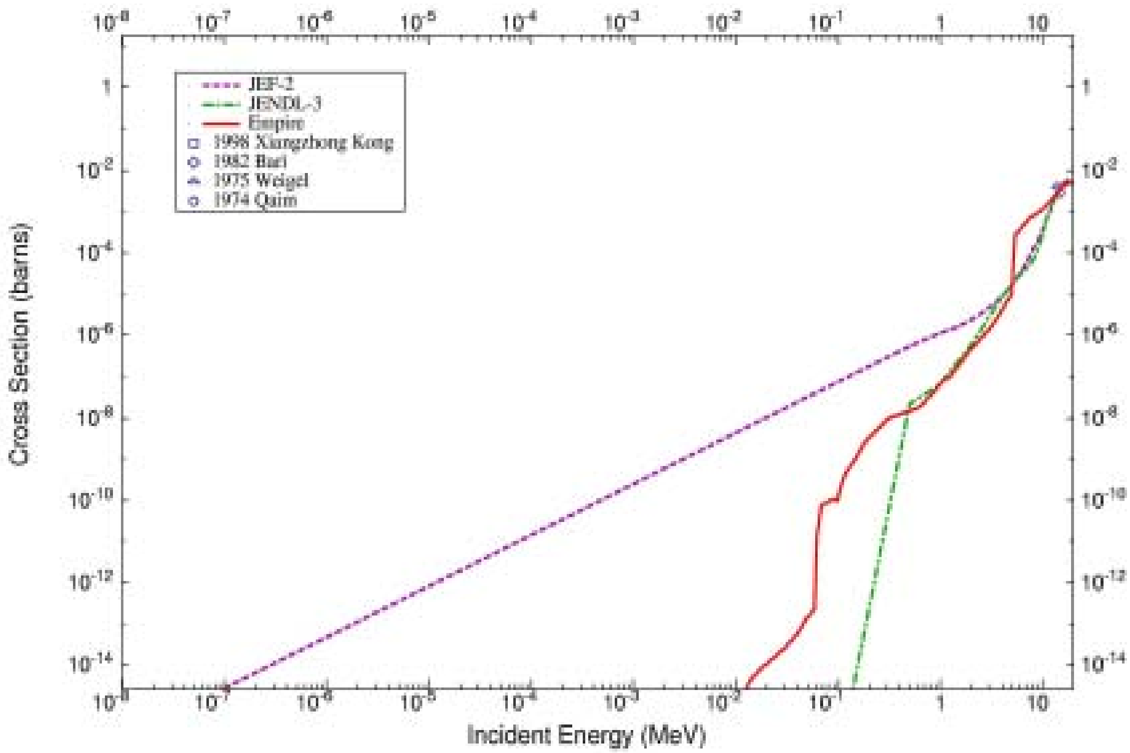

Fig. 2. (n, α) cross section for Sm-150.

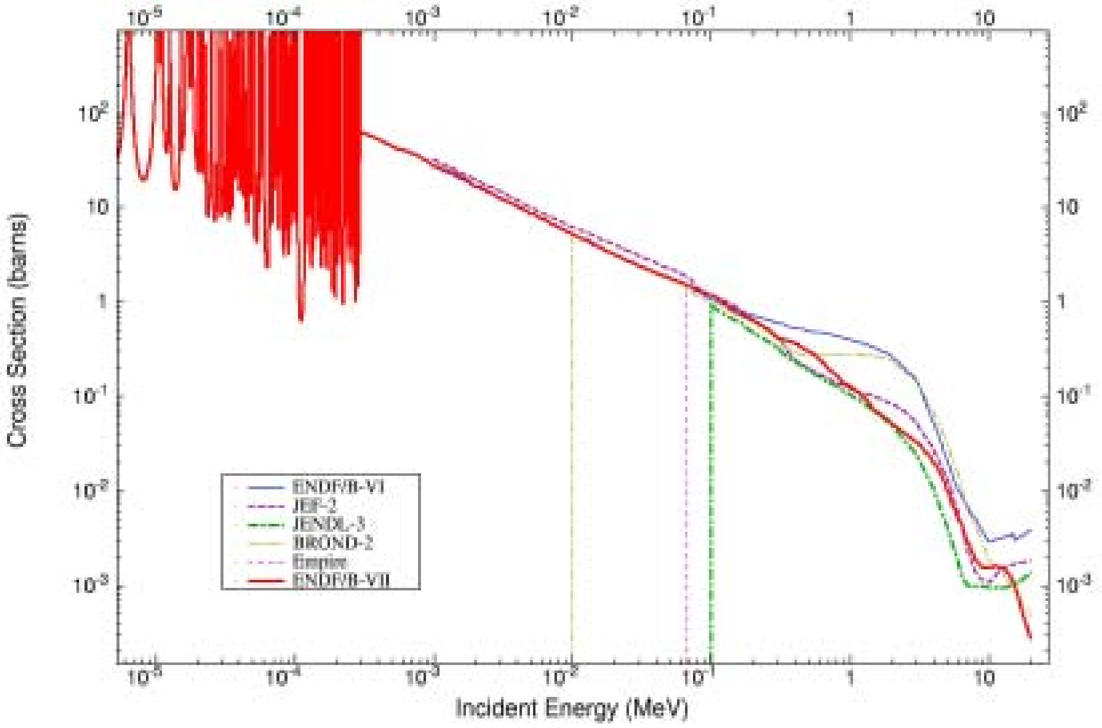

Fig. 3. Capture cross section for Sm-151.

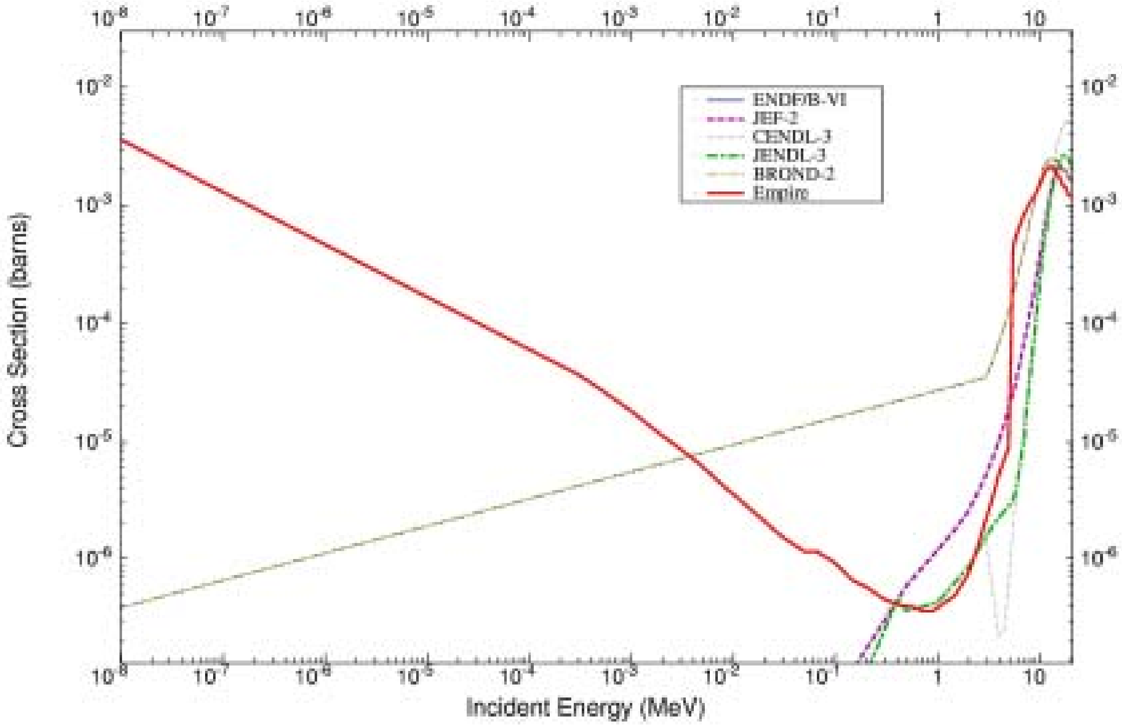

Fig. 4. (n, α) cross section for Sm-151.

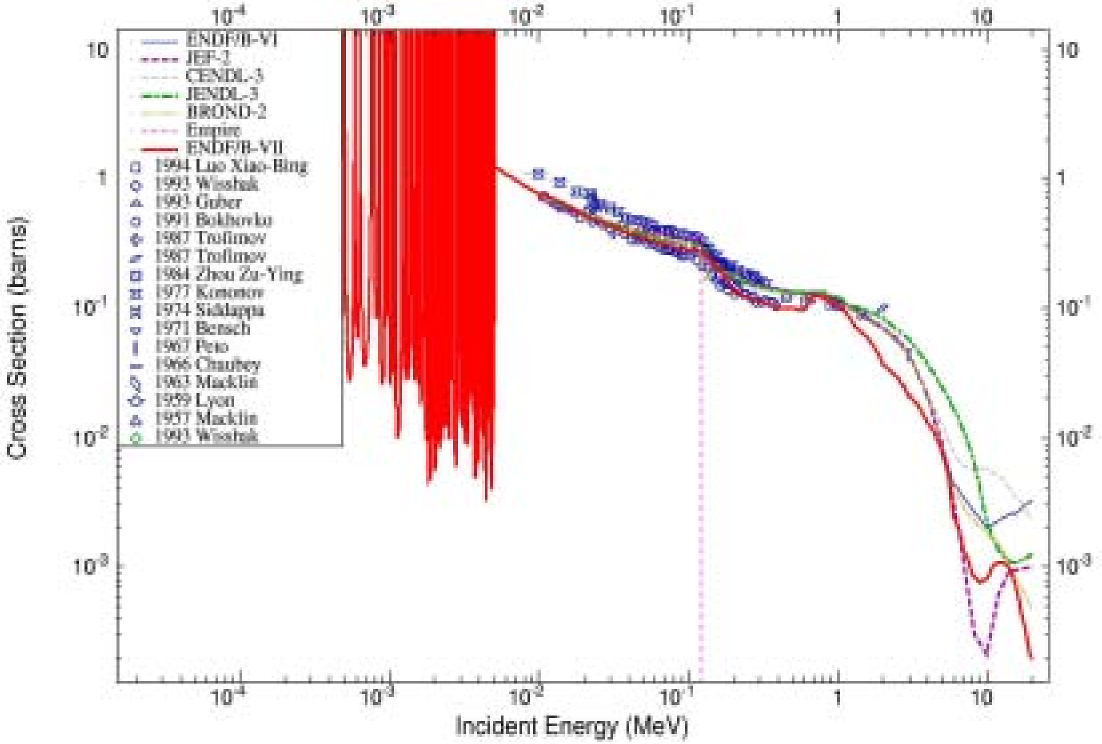

Fig. 5. Capture cross section for Sm-152.

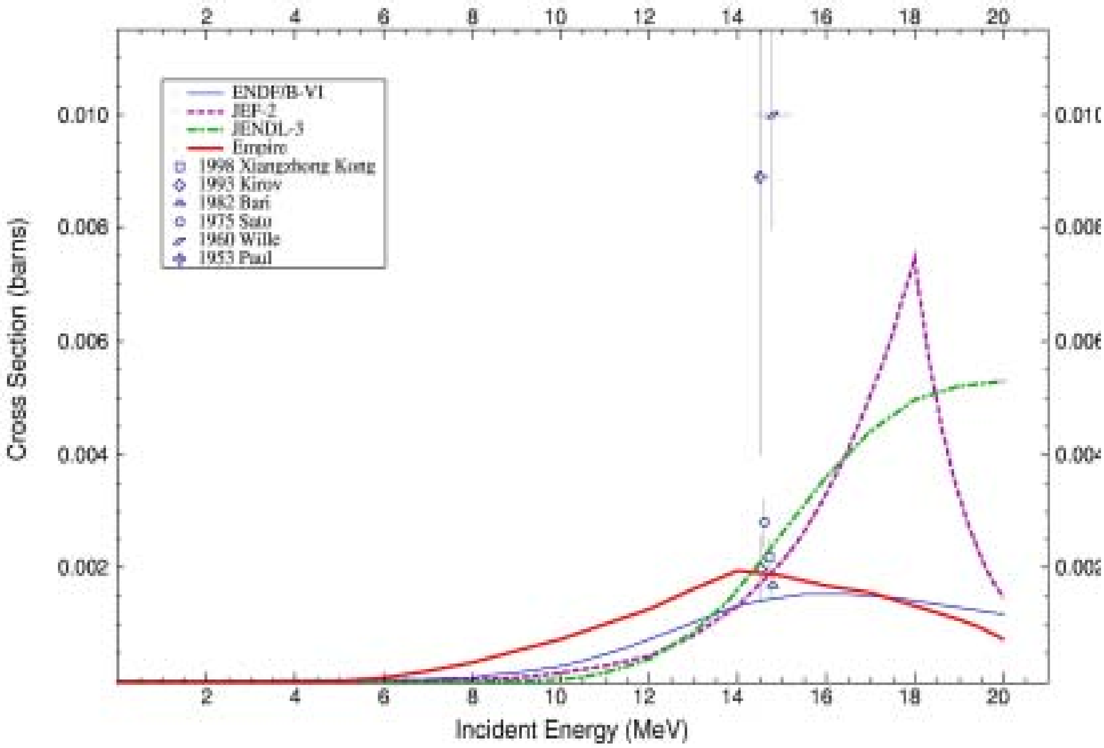

Fig. 6. (n, α) cross section for Sm-152.