

Final Report of Subgroup 7

Nuclear Data Standards

An International Evaluation of the Neutron Cross Section Standards

Coordinator: A .D. Carlson

Members of Subgroup 7 : S. A. Badikov,¹ A. D. Carlson,² Z. Chen,³ E. V. Gai,¹ G. M. Hale,⁴ F.-J. Hamsch,⁵ H. M. Hofmann,⁶ T. Kawano,⁷ N. M. Larson,⁸ S.Y. Oh,⁹ V. G. Pronyaev,¹⁰ D. L. Smith,¹¹ S. Tagesen,¹² and H. Vonach¹²

SUMMARY: Work is reported on the results of an international evaluation of the neutron cross section standards. The evaluations include the H(n,n), ⁶Li(n,t), ¹⁰B(n,α), ¹⁰B(n,α₁γ), ¹⁹⁷Au(n,γ), ²³⁵U(n,f), and ²³⁸U(n,f) standard reactions. In addition evaluations were produced for the non-standard ²³⁸U(n,γ) and ²³⁹Pu(n,f) reactions. This evaluation was performed to include new experiments on the standards that have been made since the ENDF/B-VI standards evaluation was completed and to improve the evaluation process. Evaluations were not done for the ³He(n,p) and C(n,n) standards. These standards will be carried over from ENDF/B-VI. The interest in standards above 20 MeV led to the extension of the ²³⁵U(n,f) and ²³⁸U(n,f) cross sections to 200 MeV. The ²³⁹Pu(n,f) cross section was also extended to 200 MeV. The general trend observed for the evaluations is an increase in the cross sections for most of the reactions from fractions of a percent to several percent compared with the ENDF/B-VI results.

Introduction

The standards are the basis for the neutron reaction cross section libraries. Significant improvements have been made in the standard cross section database since the last complete evaluation of the neutron cross section standards, almost 20 years ago. It is important to re-evaluate these cross sections taking into account new experimental data and improved evaluation

¹Institute of Physics & Power Engineering, Obninsk, Russia.

²National Institute of Standards and Technology, Gaithersburg, MD, USA, 20899.

³Tsinghua University, Beijing, China.

⁴Los Alamos National Laboratory, Los Alamos, NM, USA.

⁵Institute for Reference Materials and Measurements, Geel, Belgium.

⁶Erlangen-Nürnberg University, Erlangen, Germany.

⁷Los Alamos National Laboratory, Los Alamos, NM, USA, formerly at Kyushu U., Kasuga, Japan.

⁸Oak Ridge National Laboratory, Oak Ridge, TN, USA.

⁹Korea Atomic Energy Research Institute, Yuseong, Daejeon, Republic of Korea.

¹⁰Institute of Physics & Power Engineering, Obninsk, Russia, formerly at the IAEA, Vienna, Austria.

¹¹Argonne National Laboratory, Argonne, IL, USA.

¹²Vienna University, Vienna, Austria.

techniques. In response to requests for improvements in the standards, the Cross Section Evaluation Working Group (CSEWG) formed a Task Force, the Working Party on International Evaluation Cooperation of the Nuclear Energy Agency Nuclear Science Committee formed a Subgroup and the International Atomic Energy Agency (IAEA) formed a Coordinated Research Project (CRP). These groups have worked cooperatively to improve the evaluation process. The emphasis has been on the H(n,n), $^{10}\text{B}(n,\alpha)$, and fission standards. Table 1 shows the standards and the energies where they are considered standards. Extended energy ranges compared with the ENDF/B-VI results were obtained for the cross sections for $^{235}\text{U}(n,f)$ and $^{238}\text{U}(n,f)$ from 20 MeV to 200 MeV; and for $^{10}\text{B}(n,\alpha)$ and $^{10}\text{B}(n,\alpha_1\gamma)$ from 250 keV to 1 MeV. Work is continuing on the extension of the H(n,n) standard to 200 MeV.

The $^{238}\text{U}(n,f)$ cross section, which is an NEANDC/INDC standard, was accepted as an ENDF standard at the Fall 2004 CSEWG meeting. However 2 MeV was recommended as the lower bound for use of this cross section as a standard. The use of this cross section from threshold to 2 MeV is discouraged as a standard due to the very rapid change of this cross section in that energy range and the very small cross section in the threshold energy region. The present evaluation of this cross section does extend down to 1 MeV so it can be used at the lower energies that are needed for applications.

TABLE 1- The Neutron Cross Section Standards

Reaction	Standards Energy Range
H(n,n)	1 keV to 20 MeV
$^3\text{He}(n,p)$	0.0253 eV to 50 keV
$^6\text{Li}(n,t)$	0.0253 eV to 1 MeV
$^{10}\text{B}(n,\alpha)$	0.0253 eV to 1 MeV
$^{10}\text{B}(n,\alpha_1\gamma)$	0.0253 eV to 1 MeV
C(n,n)	0.0253 eV to 1.8 MeV
Au(n, γ)	0.0253 eV, 0.2 MeV to 2.5 MeV
$^{235}\text{U}(n,f)$	0.0253 eV, 0.15 to 200 MeV
$^{238}\text{U}(n,f)$	2 MeV to 200 MeV

Evaluation Objectives

The largest contribution to the evaluation process has been made by the IAEA CRP. The CRP has included membership from Austria, Belgium, China, Germany, Japan, the Republic of Korea, Russia and the USA. The main objectives of the evaluation are the following: Improve the methodology for determination of the covariance matrix used in cross section evaluations; Upgrade the computer codes using this methodology; Study the reasons for uncertainty reduction in R-matrix and model independent fits; Evaluate cross sections and covariance matrices for the light elements, H(n,n), $^3\text{He}(n,p)$, $^6\text{Li}(n,t)$, $^{10}\text{B}(n,\alpha_1\gamma)$, and $^{10}\text{B}(n,\alpha)$; Establish the methodology and computer codes for combining the light element with the heavy element evaluations leading to a final evaluation of the neutron cross section standards. The evaluation work includes improvements to the experimental data in the standards database and methods for handling discrepant data; R-matrix evaluation of the hydrogen scattering cross section and conversion of measurements relative to the hydrogen cross section to the new standard; studies of the effect of

