National Institute of Standards and Technology

Nuclear Data Verification and Standardization Program

PROGRESS REPORT

USNDP Meeting
April 18-20, 2001

Staff (total of about 1 FTE):
Allan Carlson (NIST Project Leader, soon to retire and then be a contractor working on this program), David Gilliam (NIST), Paul Huffman (NIST), and Roald Schrack (Guest Worker).

Nuclear Structure Activities:
None are supported by DoE funding. A modest effort in structure and decay studies is supported by NIST funds.

Nuclear Reaction Activities:
Neutron cross section standards
Introduction
The measurements of most neutron cross sections are made relative to neutron cross section standards. Improvements in these standards increase the accuracy of all measurements made relative to them. The last complete evaluation of the standards, which was for ENDF/B-VI, took place almost 15 years ago. These standards are used internationally. The need for improved evaluations of the neutron cross section standards is universally accepted. Significant improvements have been made in the standard cross section experimental database since that time, particularly for the H(n,n), ^{10}B(n,α), and ^{235}U(n,f) reactions. Evaluations continue to be done using standards which are now out-of-date. Requests for new evaluations of the standards have led to the formation of working groups by a number of nuclear data organizations. The U.S. Cross Section Evaluation Working Group (CSEWG) formed a Task Force, the Nuclear Energy Agency Nuclear Science Committee's Working Party on International Nuclear Data Cooperation (WPEC) formed a subgroup, and the International Atomic Energy Agency (IAEA) is forming a Coordinated Research Project (CRP). These groups are working cooperatively to update the previous work by including standards measurements made since that evaluation was completed and to improve the evaluation process. NIST has a leadership role in each of these working groups. Direct involvement in these working groups now includes Austria, China, France, Germany, Japan, Russia and the USA. The new international evaluation will include the H(n,n), ^{3}He(n,p), ^{6}Li(n,t), ^{10}B(n,α), ^{10}B(n,$\alpha_1\gamma$), Au(n, γ), ^{235}U(n,f), and ^{238}U(n,f) standard cross sections. A new evaluation is not planned for the C(n,n) cross section since the few new measurements which have been obtained since the ENDF/B-VI evaluation are in excellent agreement with that evaluation.

In order to effectively motivate and monitor standards experiments which are needed for the standards evaluation, NIST has become an active participant in a number of experiments including measurements of the angular distribution of neutrons scattering from hydrogen which is one of the most important standards.

Progress on the evaluation

Chaired WPEC Standards Subgroup: NIST has taken the lead role in encouraging, motivating and coordinating of new measurements which can be used in the standards evaluation. Many experiments have been completed; however, most of the experiments are still in the data taking or data analysis stage. New measurements at Obninsk are now planned for the $^{10}B(n,\alpha)$ standard.

With the increasing need for cross section data at energies above 20 MeV, it is important to have evaluated standards available in that higher energy region. Thus for some standards, the decision was made to extend the energy region to about 200 MeV. Gerry Hale (LANL) plans to evaluate the hydrogen cross sections up to 150 MeV neutron energy. There is a need for fission standards up to 200 MeV. The measurements of the $^{235}U(n,f)$, and $^{238}U(n,f)$ standards which are relative to the hydrogen standard will have to rely on another evaluation for the energy region from 150 to 200 MeV.

NIST continues to investigate possible experiments for inclusion in the standards database: The process which is being used includes checking the documentation for corrections that may need to be made and looking for possible errors or missing information. For example, investigation of the Nakamura hydrogen scattering experiment revealed an error in the conversion from the laboratory to the center of mass system, the lack of corrections for proton scattering and problems with tails in the experimental distributions. The investigative procedure leads to estimates of the uncertainties and correlations within an experiment and correlations with other experiments. In table 1, standards related experiments which are under investigation are listed. Only experiments for which data have been obtained or measurements are underway (or nearly started) are listed. The initial emphasis has been on the traditional standards in their normal regions of applicability.

Attended IAEA Consultants' Meeting: The NIST representative was asked to chair this meeting. This CM is on the improvement of the standard cross sections and will be held on April 2-4, 2001, shortly before the USNDP meeting. The focus of this meeting will be the topics for study by the CRP on the neutron cross section standards and those to be considered for membership in the CRP. This CRP will increase involvement in the evaluation and it will result in an international body validating the evaluation process, especially concerning the uncertainties. In order to most effectively use the resources which will be available under the CRP, the time schedule for completion of the standards evaluation should be extended. The normal programmatic process for the CRP would lead to a three year effort which begins in 2002.

An important task for the CRP is to try to understand in detail how standard error propagation in simultaneous evaluation or R-matrix analyses can result in such small uncertainties, and whether there are more reasonable corrections or algorithms to employ. The first phase of this work will focus on understanding and resolving the differences in the mean value and the output covariance of the results obtained using common input test data for a number of R-matrix, and generalized least squares codes. This work should lead to identification of possible differences between R-matrix and generalized least squares fitting that may have contributed to the small error estimates that resulted from the 1987 ENDF/B-VI evaluation. Under consideration for use in this study are R-matrix codes used at LANL (EDA); ORNL (SAMMY); the Ohio University, USA (ORMAP); the Kyushu University, Japan; the University at Erlangen, Germany; and the Tsinghua University, China. The generalized least squares codes being considered are those used at Obninsk and the University of Vienna (GLUCS); those used at ANL and JAERI (GMA) and the Kyushu code used in conjunction with KALMAN.

Also under consideration for the CRP or a continuation of the CRP will be methods for doing the evaluation, such as a single step global process, which were not feasible with the computer capability available in 1987 when the ENDF/B-VI evaluation was completed. Following this first phase, using the tools developed from that activity and the critically reviewed and assembled experimental data, the new evaluation will be done. The time frame for the completion of the evaluation will depend on a number of factors such as the difficulties associated with an improved method for performing the evaluation process, if a method for implementing that procedure is practical. The deadline after which experiments will not be considered for inclusion in the standards evaluation will be decided at some later date, dependent on the progress of the CRP.

If a new method for doing the evaluation does not become available, plans have been made for performing the evaluation using a procedure which is somewhat improved compared with the ENDF/B-VI standards evaluation. The evaluation would then be performed using EDA, by Hale for the R-matrix analysis and GMA, by Shibata for the simultaneous evaluation. The combination procedure used for the ENDF/B-VI standards evaluation will not be used. Instead, the output cross sections and their variance-covariance matrices from the ^{6}Li+n and ^{10}B+n analyses from EDA will be used as input to GMA.

A meeting to discuss the progress made on the experimental and evaluation efforts on the standards is planned during the 2001 International Conference on Nuclear Data for Science & Technology (ND2001).

Experimental and other work:
The hydrogen scattering angular distribution measurements at 10 MeV neutron energy have been completely analyzed and have been submitted for publication. A new experiment at 15 MeV neutron energy is now being designed to improve the understanding of this important standard. The NIST National Repository for Fissionable Isotope Mass Standards continued to acquire and monitor samples. RPI was provided ^{235}U samples for capture cross section measurements from NIST inventory. The NIST member of the International Technical Program Committee for the ND2001 conference assisted in the definition of the technical program, reviewed papers and other performed other program committee functions.

Dissemination:
NIST is preparing an invited talk on this international evaluation of the neutron cross section standards for the ND2001 conference.

Table 1. New Experiments for the Standards Database

$^{++}$ means the data have been reviewed and are in the library

$^{+}$means the data are available and the review process is underway

no superscript means that final data are not available (possibly final data not taken yet)

H(n,n)

$^{+}$Nakamura, J. Phys. Soc. Japan 15 (1960) 1359, 14.1 MeV; error in transformation from laboratory to CMS angles; needs correction for proton scattering, an estimate of error associated with neglecting these corrections was made; tail problems; note Table II uncertainty is statistical only (mb/sr).

$^{+}$Shirato, J. Phys. Soc. Japan 36 (1974) 331, 14.1 MeV, needs correction for proton scattering; tail problems

$^{+}$Ryves, 14.5 MeV, σ(180°)/σ(90°), Ann. Nucl. Energy 17, 657 (1990)

$^{+}$Bateman, 10 MeV, angular distribution from 60° to 180°, Fusion Eng. & Design 37, 49 (1997); additional work was done on this experiment. Data is now finalized and submitted for publication (Boukharouba et al.)

$^{+}$Buerkle, 14.1 MeV, angular distribution from 89.7° to 155.7°, Few-Body Systems 22, 11 (1997)

Olsson (Uppsala group), 96 & 162 MeV, angular distribution from 70° to 180°

Benck, (Louvain la Neuve) 28-75 MeV, angular distribution from 40° to 140°

Peterson (IUCF) 185-195 MeV, angular distribution form 90° to 180°. In progress but new leadership on the experiment and analysis (Yuezheng Zhou)

^{3}He(n,p)

$^{++}$Borzakov, 0.26 keV to 142 keV, relative to ^{6}Li(n,t), Sov. J. Nucl. Phys. 35, 307 (1982)

^{3}He total cross section

+Keith, 0.1 to 500 eV, BAPS DNP Oct 1997 paper IG.03 and thesis of D. Rich

^{6}Li(n,t)

Bartle, 2 to 14 MeV, angular distribution, Proc. Conf on Nuclear Data for Basic and Applied Science, Sante Fe (1985), p. 1337

Koehler, 1 keV to 2.5 MeV, angular distribution data (ratio of forward and backward hemispheres responses), private comm.

Gledenov, .025 eV, ??, 87KIEV 2 237

Zhang Guohui, 3.67 and 4.42 MeV, angular distribution, Comm. Of Nuclear Data Progress No.21 (1999) China Nuclear Data Center, also NSE 134, 312 (2000)

$^{10}B(n,\alpha_1\gamma)$
++Schrack, 0.2 MeV to 4 MeV, relative to Black Detector (at ORNL), NSE 114, 352 (1993)

+Schrack, 10 keV to 1 MeV, relative to H(n,n) prop ctr (at ORNL), Proc. Conf. on NDST, Gatlinburg (1994)p. 43

+Schrack, .3 MeV to 10 MeV, relative to ^{235}U(n,f) ion chamber (at LANL), Private comm.

$^{10}B(n,\alpha)$ Branching Ratio
++Weston, 0.02 MeV to 1 MeV, Solid State detectors, NSE 109, 113 (1991)

Hambsch and Bax, keV to MeV, Frisch gridded ion chamber, Van de Graaff and linac data, in progress.

$^{10}B(n,\alpha)$
Haight, 1 MeV to 6 MeV, angular distribution at 30°, 60°, 90° and 135°, private comm.

^{10}B total cross section
Wasson, 0.02 MeV to 20 MeV, NE-110 detector, Proc. Conf. on NDST, Gatlinburg (1994), p. 50

Plompen, 0.3 MeV to 18 MeV, scintillator, LiI and Li-glass detectors, Proc. Conf. on NDST, Gatlinburg (1994), p. 47 and Proc. Conf. on NDST, Trieste (1997), p. 1283

Brusegan, 80 eV to 730 keV, Li-glass detector, Proc. Conf. on NDST, Gatlinburg (1994)p. 47 and Proc. Conf. on NDST, Trieste (1997)p. 1283

$^{10}Be(p,n)\,^{10}B$
Massey, E_p from 1.5 MeV to 4 MeV, data at 0°, private comm. New measurements to be made at lower energies (~.5 MeV). Also possibly ^{10}Be (p,α)

Au(n,γ)
++Sakamoto, 23 keV and 967 keV, photoneutron source, activation experiment, NSE 109,215 (1991)

++Davletshin, .16 MeV to 1.1 MeV, relative to H(n,n), Sov. J. At. Energy 65, 91 (1988),
(Corrected data from Sov. J. At. Energ. 58, 183 (1985))

++Davletshin, .16 MeV to 1.1 MeV, relative to H(n,n), Sov. J. At. Energy 65, 91 (1988),

++Davletshin, .62 MeV to .78 MeV, relative to ^{235}U(n,f), Sov. J. At. Energy 65, 91 (1988), Kazakov, Yad Konstanty, 44, 85 (1990)

Demekhin, 2.7 MeV, Proc. 36th All Union Conf. on Nuclear Data, p. 94 (1986)

Voignier, ~.5 MeV to ~3 MeV, private comm.

^{235}U(n,f)
Newhauser, 34, 46, and 61 MeV MeV, absolute, needs additional analysis.

$^{+}$Carlson, 0.3 MeV to 3 MeV, relative to black detector, Proc. IAEA Advisory Group Meeting on Nuclear Standard Reference Data, Geel Belgium, p.163, IAEA-TECDOC-335 (1985)

$^{+}$Carlson, 2 MeV to 30 MeV, relative to H(n,n), Proc. Spec. Meeting on Neutron Cross Section Standards for the Energy Region above 20 MeV, Uppsala, Sweden, 1991, Report NEANDC-305, "U", p. 165

$^{+}$Johnson, 1 MeV to 6 MeV, relative to a dual thin scintillator, Proc. Conf. on NDST Mito (1988) p.1037

$^{+}$Iwasaki, 14 MeV, relative to H(n,n) and associated particle, Proc. Conf. on NDST Mito (1988) p. 87

$^{+}$Lisowski, 3 MeV to 200 MeV, relative to H(n,n), Proc. Spec. Meeting on Neutron Cross Section Standards for the Energy Region above 20 MeV, Uppsala, Sweden, 1991, Report NEANDC-305, "U", p. 177, and private communication.

Merla, $^{++}$2.56, $^{+}$4.45, $^{++}$8.46, $^{+}$14.7, $^{+}$18.8 MeV ?, associated particle, Proc. Conf. on NDST Juelich (1991) p.145

^{238}U(n,f)
Newhauser, 34, 46, and 61 MeV MeV, absolute

Baba, 0.5 MeV to 7 MeV and 14 MeV, relative to ^{235}U(n,f), J. Nucl. Sci. & Techn.,26,11 (1989)

$^{+}$Lisowski, 0.8 MeV to 350 MeV, relative to H(n,n), Proc. Spec. Meeting on Neutron Cross Section Standards for the Energy Region above 20 MeV, Uppsala, Sweden, 1991, Report NEANDC-305, "U", p. 177, and private communication.

$^{+}$Merla, 5 MeV +?, associated particle, Proc. Conf. on NDST Juelich (1991) p.145

Shcherbakov, 1-200 MeV, relative to ^{235}U(n.f), ISTC 609-97, see also Fomichev, 0.7 MeV to 200 MeV, relative to ^{235}U(n.f), Proc. Conf. on NDST, Trieste (1997), p.1283

$^{++}$Winkler, 14.5 MeV, relative to Al(n,α) & ^{56}Fe(n,p), Proc. Conf. on NDST Juelich (1991), p.514

$^{238}U(n,\gamma)$

++Kobayashi, 0.024 MeV, 0.055 MeV, 0.146 MeV, relative to $^{10}B(n,\alpha_1\gamma)$, Proc. Conf. on NDST Juelich (1991), p. 65

+Quang, 23 keV and 964 keV, photoneutron source, activation experiment, NSE 110, 282 (1992)

++Adamchuck, 10 eV to 50 keV, relative to $^{10}B(n,\alpha_1\gamma)$, J. Atomic Energy, 65, 920 (1989)

++Buleeva, 0.34 MeV to 1.39 MeV, relative to H(n,n) and $^{235}U(n,f)$, Sov. J. Atomic Energy, 65, 930 (1989)

Voignier, ~0.5 to 1 MeV, private comm.

$^{239}Pu(n,f)$

Shcherbakov, 1-200 MeV, relative to $^{235}U(n.f)$, ISTC 609-97

+Staples, 0.5 MeV to 400 MeV, relative to $^{235}U(n,f)$, NSE 129, 149 (1998)

Lisowski, 0.8 MeV to 350 MeV, relative to H(n,n), Proc. Spec. Meeting on Neutron Cross Section Standards for the Energy Region above 20 MeV, Uppsala, Sweden, 1991, Report NEANDC-305, “U”,