National Institute of Standards and Technology

Neutron Cross Section and Fluence Standards Program

PROGRESS REPORT

USNDP Meeting
Brookhaven National Laboratory
November 6, 2014

THE NEUTRON CROSS SECTION STANDARDS

Reaction	Energy Range
H(n,n)	1 keV to 20 MeV
^{3}He(n,p)	thermal to 50 keV
^{6}Li(n,t)	thermal to 1 MeV
^{10}B(n,α)	thermal to 1 MeV
^{10}B(n,$\alpha_1\gamma$)	thermal to 1 MeV
C(n,n)	thermal to 1.8 MeV
^{197}Au(n,γ)	thermal, 0.2 to 2.5 MeV
^{235}U(n,f)	thermal, 0.15 to 200 MeV
^{238}U(n,f)	2 to 200 MeV

Nuclear Structure Activities:

- None are supported by DOE funding.

- A modest effort, largely experimental, (about 1 FTE) in structure and decay studies continues to be supported by NIST. The effort is in support of needs for radioactivity and radiopharmaceutical applications.

Nuclear Reaction Activities: **Neutron Cross Section Standards –Measurements**

- **H(n,n)H Angular Distribution Work**

- This work was initiated to resolve problems with the hydrogen database.

- We previously made measurements at 10 and 14.9 MeV at the Ohio University accelerator facility. The data were obtained by detecting the recoil proton.

(collaboration of NIST with Ohio University, LANL and the University of Guelma)

H(n,n)H Angular Distribution Work (cont.)

- At small CMS scattering angles it is difficult to obtain small uncertainties for data obtained by detecting the recoil proton. There is only one experiment where measurements were made at very small scattering angles. Those data have very large uncertainties with large scatter.

- We started an experiment where the primary objective is detection of the scattered neutron instead of the scattered proton so that measurements can be made at small scattering angles.

- The work is being done at the Ohio University accelerator facility. Preliminary data with limited uncertainty were obtained at laboratory neutron scattering angles from 20 degrees to 65 degrees in 5 degree steps for 14.9 MeV incident neutrons.

- To reduce the uncertainties and make measurements at smaller angles, it is essential to accurately determine the efficiency of the neutron detector.

(collaboration of NIST with Ohio University, LANL and the University of Guelma)

Neutron Detector Efficiency Measurements

- Below about 7 MeV the efficiencies are known. For neutron energies above 7 MeV, a technique using reactions where the projectile and target are identical is being examined. Because they are identical, the angular distribution **must** be symmetrical in the CMS. So the neutron yield at an angle Θ must be the same as that at 180- Θ in the CMS.
- But the energies of the neutrons are different in the LAB system. Thus in the LAB system, for a bombarding energy such that the backward portion of the angular distribution falls in the energy range below 9 MeV where the efficiencies are known, we can deduce the efficiency for the higher energy group in the forward hemisphere.
- Several studies of suitable reactions have been made. The best candidate, the $^{6}Li(^{6}Li,n)^{11}C$ reaction, unfortunately has very large backgrounds for both the ^{6}LiF and $^{6}LiCl$ targets that were tried. Measurements with C(C,n) were successful however the Q value of -2.6 MeV is a limitation.
- The D(d,n) reaction having a Q-value of 3.3 MeV will allow data to be taken at small angles for the 10 MeV neutron measurements. Data obtained with CD_2 and TiD_2 targets had large backgrounds. A gas target should minimize background problems. One is being fabricated.
- (collaboration of NIST with Ohio University, LANL and the University of Guelma)

Nuclear Reaction Activities: Neutron Cross Section Standards–Measurements

^{6}Li(n,t) Work

- At the NIST Neutron Center for Neutron Research a measurement was made of the ^{6}Li(n,t) cross section standard. The preliminary value obtained is 2587.6 ± 7.8 b for a neutron energy of 3.3255 ± 0.0016 meV.

- This is the first direct and absolute measurements of this cross section in this neutron energy range using monoenergetic neutrons.

- A primary effort was focused on measuring the neutron fluence accurately. It was determined with an uncertainty of 0.06%.

- Work continues on trying to reduce the mass uncertainty of the ^{6}Li target. The deposits were made at IRMM.

- Studies to compare the mass with the value obtained when it was characterized a number of years ago indicate a possible 0.10% loss. Comparisons have also been made with a number of other deposits made at the same time at IRMM. The uncertainty in the deposit mass is 0.28%.

(collaboration of NIST with the University of Tennessee and Tulane University)

Nuclear Reaction Activities: Neutron Cross Section Standards –Fluence Data

Fluence Determination Work

- Improvements in the determination of the source strength for NBS-I continue. This work will have an impact on cross section measurements that have used this source as a standard and any future measurements made using this source.

  - Work continues on a determination of the neutron intensity of NBS-I for comparison with the established value obtained from manganese sulfate bath measurements and calculations.

  - This work relies on an absolute determination of the fission rate of a bare ^{252}Cf source using a well-defined solid angle for detection. That rate is converted to neutron fluence using nu-bar of ^{252}Cf.

  - Then the absolute neutron rate from that source can be compared with that of NBS-I by measurements of the activation produced in a $MnSO_4$ bath by the two sources.

  - The new work is in principle only limited in accuracy by the uncertainty in nu-bar of ^{252}Cf, 0.12%. Preliminary results with a 0.9 % uncertainty have been obtained. Additional work is underway, that includes two new ^{252}Cf sources, that should lead to a 0.3% uncertainty in the calibration.

  - Work is planned in which NBS-I will be absolutely calibrated using a technique employing an α-γ coincidence with the $^{10}B(n,\alpha_1\gamma)$ reaction.

Nuclear Reaction Activities: Neutron Cross Section Standards –Evaluations

- At a recent CSEWG meeting the decision was made to have a new ENDF/B evaluation.
  - It is necessary to evaluate the standards before such an evaluation can be undertaken.
  - Several meetings helping us prepare for the new evaluation were held at the IAEA headquarters. These meetings resulted from an IAEA Nuclear Data Development Project "Maintenance of the Neutron Cross Section Standards" that was initiated through NIST efforts. Each of the meetings was chaired by the NIST representative.
  - At these meetings the focus was on improvements in the experimental database, considering additional standards and maintaining evaluation codes with an end result of updating the standards for ENDF/B-VIII. Other libraries are also preparing for new versions and they will be able to use the results of these efforts.
  - The next meeting is scheduled for this December.

Nuclear Reaction Activities: Neutron Cross Section Standards - Evaluations

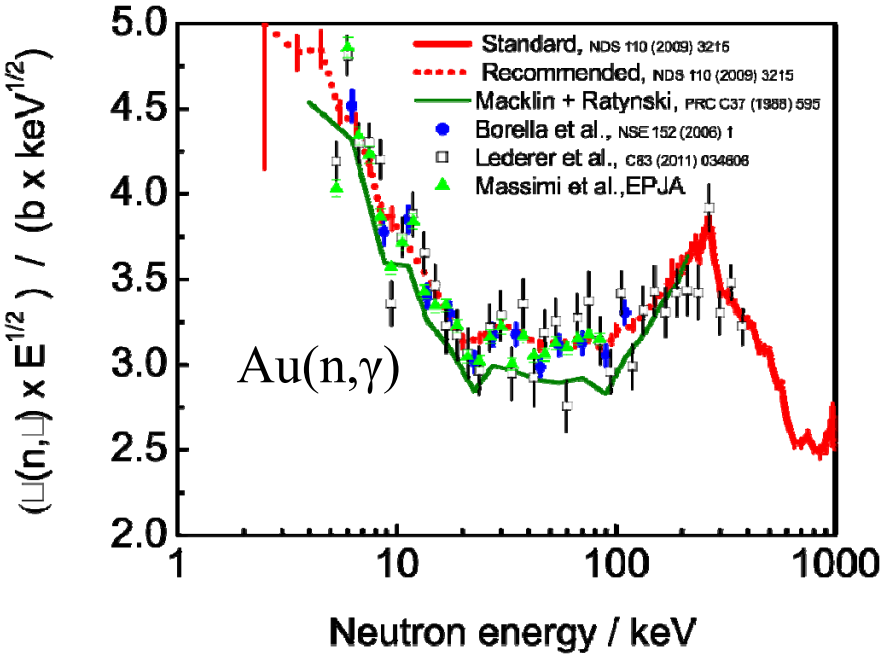
- Experimental data in the standards database have been improved as a result of NIST involvement or encouragement.
- These data will be used in the evaluation of the neutron cross section standards.
- All data, except hydrogen measurements, to be included in the new evaluation of the standards must be provided by December of this year.
- All hydrogen cross section measurements had to be provided by July of this year.

Nuclear Reaction Activities: Neutron Cross Section Standards –Evaluations

- Updating of the standards database.
  - At the meeting this December all experiments completed since the completion of the previous standards evaluation will be reviewed.
  - Improvements have been made for the H(n,n), ^{6}Li(n,t), ^{10}B(n,α), Au(n,γ), and ^{238}U(n,γ) cross sections.
  - There are some inconsistencies for the ^{3}He(n,p), C(n,n), ^{238}U(n,f) and ^{239}Pu(n,f) cross sections

New Work Related to Standards

- Au(n,γ) cross section below the standards energy region - near 25 keV
  - Values used by astrophysicists disagree with the standards evaluation.



  - All new measurements agree with the "Recommended" values from the standards evaluation as seen above.
- $^{235}U(n_{th},f)$ prompt fission neutron spectrum with thermal neutrons
  - Being evaluated simultaneously with the ^{252}Cf spectrum and separately
- Prompt γ-ray production reference cross sections
  - Used for measurements of γ-ray production cross sections
  - Best candidates now are $^{7}Li(n,n'\gamma)$ and $^{48}Ti(n,n'\gamma)$

Milestones for the Standards Release

- **December 2014 –** Deadline for submission of experimental data to be included in the new standard and reference evaluations.
  - A Technical Meeting will take place to discuss:
    - The R-matrix evaluations
    - Preliminary GMA fit with inclusion of all data
    - Preliminary combined least squares fit of ^{252}Cf(sf) and ^{235}U(n_{th},f) prompt fission neutron spectra. Also separate non-combined evaluation
    - Preliminary least squares fit of (n,n'γ) reference gamma-ray production cross sections
    - Preliminary evaluation of other reference cross sections
- **January 2016** - Release of the standard and reference evaluations for validation
- **Summer 2016** – The final technical meeting where the decision will be made about the final release of standard and reference evaluations. Documentation in the form of working papers will be published.

Other Work

- The NIST National Repository for Fissionable Isotope Mass Standards continues to acquire and monitor samples. A number of laboratories have borrowed samples from the Repository.

- NIST has members on the International Program Committee for the International Symposium on Radiation Dosimetry, ISRD-15 (2014). The members of the ISRD use cross section data to determine the fluence in reactor applications. The ENDF standards are part of the data used.

Publication Metrics Table

Publications 3

Invited Talks 1

Staff Data (Working on the Standards Program for the next contract)

(not including structure work of 1 FTE, entirely supported by NIST)

STAFF	FTE	HEADS	FTE (USNDP)
Permanent	0.2	1	0.10
Temporary	0.4	1	0
Admin/Prof/Student	0	0	0
Contractors	1.0	2	0.10
Total	1.6	4	0.2

Recommendations

- Since there is a need for improved standards for the new evaluations, we continue working with the IAEA Nuclear Data Development Project "Maintenance of the Neutron Cross Section Standards" to supply them. With that project we have been maintaining an active program of measurements and evaluation activities that are essential for improvement of the standards.

- We also maintain a modest experimental program and encourage work on the standards through collaborations and independent research.

- When the new standards evaluation has been completed, we will continue the activities being done under the IAEA Nuclear Data Development Project. This project will pursue improvements in the experimental database, consider additional standards, maintain evaluation codes and periodically update the standards so they are available for new versions of nuclear data libraries.