National Institute of Standards and Technology

Nuclear Data Verification and Standardization Program

PROGRESS REPORT

USNDP Meeting
Brookhaven National Laboratory
November 7, 2008

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,α$_1$γ)	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, (1 FTE) in structure and decay studies is 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

•Measurements have been completed at laboratory angles of 0 degrees, ± 12 degrees (one on each side of the beam direction), ± 24 degrees, ± 36 degrees, ± 48 and ± 60 degrees at the Ohio University accelerator facility. A paper on this work Is being written for journal publication. The data are obtained at 14.9 MeV neutron energy. The data were obtained by detecting the recoil proton.

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

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

•A new experiment has been designed using the method of detecting the scattered neutron at laboratory neutron scattering angles from about 60 to 15 degrees at the Ohio University accelerator facility. Data can be obtained at smaller CMS scattering angles by detecting the scattered neutron compared with proton recoil detection. Data will be obtained at 14.9 MeV neutron energy. Diagnostic work will be done at lower energies where the angular distribution is nearly isotropic.

•Plans are being made to continue hydrogen angular distribution measurements using a Time Projection Chamber which will provide higher counting rates than are possible with the other methods.

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

Nuclear Reaction Activities: Neutron Cross Section Standards –Measurements (cont.)

^{3}He(n,p) Work

•Work has been completed for a measurement of the spin-dependent portion of the n- ^{3}He coherent scattering length using a polarized neutron beam and a polarized ^{3}He target. The work has been submitted for journal publication. The data obtained from this measurement will allow separation of the real part of the two spin channels of this interaction. These data can be used in R-matrix evaluations to improve the ^{3}He(n,p) standard cross section.

(collaboration with Indiana University and the University of North Carolina)

Nuclear Reaction Activities: Neutron Cross Section Standards–Measurements (cont.)

^{6}Li(n,t) Work

•NIST collaborative measurements are being made of the ^{6}Li(n,t) cross section standard at ~ 4 meV. These will be the first direct and absolute measurements of this cross sections in this neutron energy range using monoenergetic neutrons. The major effort to date has been focused on making fluence measurements with very high accuracy.

- •The neutron fluence measurements for this experiment are based on counting prompt gamma-rays that originate from neutron capture in a totally absorbing boron target. The gamma-ray efficiency is known accurately from alpha-gamma coincidence measurements using a thin ^{10}B target and also indirectly from measurements using a standard alpha source. A thin ^{6}Li target whose geometry and target mass are both well known was used for the ^{6}Li(n,t) cross section measurement. This procedure is capable of achieving an accuracy of ± 0.25%.

(collaboration with the University of Tennessee and Tulane University)

^{10}B(n,α) Work

•The same basic experimental setup being used for the NIST collaborative measurements of the ^{6}Li(n,t) cross section at ~ 4 meV will be used to measure the ^{10}B(n,α) cross section also.

Fluence Determination Work

•Several cross section measurements have been made using NBS-I as a standard neutron source. Improvements in the determination of its source strength and uncertainty will have an impact on those measurements and any future measurements made using that source.

•An independent determination of the neutron intensity of NBS-I has been made to compare with the established value obtained from manganese sulfate bath measurements and calculations. The new determination is in principle only limited in accuracy by the uncertainty in nu-bar of ^{252}Cf, 0.12%. The determination was made by measuring the neutron source intensity of a bare ^{252}Cf source (from the fission fragment rate into a well defined solid angle measured with a solid state detector and nu-bar), comparing this source to a sealed ^{252}Cf source (by relative counting with ^{3}He neutron detectors) to determine the sealed source intensity, and comparing this result with that obtained from a calibration of the sealed source relative to NBS-I in a large manganese sulfate bath. Preliminary results indicate a 1.7 % difference with a 0.9 % uncertainty for this determination compared with the NBS-I value.

•It may be possible to reduce the uncertainty in nu-bar of ^{252}Cf by comparing the results obtained using the various fluence measuring methods available at NIST with that obtained using this ^{252}Cf method.

Nuclear Reaction Activities: Neutron Cross Section Standards –Evaluations

•A detailed IAEA technical report was published documenting the evaluation activities of the IAEA Coordinated Research Project on the international evaluation of the neutron cross section standards. NIST chaired the Research Coordination Meetings and made significant contributions to the technical report.

•Improvements continue to be made to the experimental data in the standards database as a result of NIST involvement or encouragement.

•An invited talk on the status of the neutron cross section standards was given at the International Symposium on Reactor Dosimetry-13. The implication of the changes in the neutron cross section standards on dosimetry cross sections was discussed.

•A talk and paper were prepared for the Covariance Workshop describing the process used to obtain the covariances for the neutron cross section standards. Justification was given for the so-called small uncertainties obtained in the evaluation for some of the standards. It was emphasized that the use of covariances (including cross-material covariances) is essential in practical applications.

Summary of the First IAEA Consultants' Meeting (Oct. 2008) on the Nuclear Data Development Project "Maintenance of the Neutron Cross Section Standards".

The meeting was chaired by the NIST participant. The topics of the meeting were:

- Updating of the standards database.
  - More than 20 experiments completed or underway since the completion of the standards evaluation were reviewed. In most cases there is good agreement with the standards evaluation.
- Neutron spectra
  - Update for an evaluation of the ^{252}Cf spontaneous fission neutron spectrum.
    - Of the experiments done since the ENDF/B-VI evaluation, only 2 appear to be acceptable for inclusion in a new evaluation and they differ at high energies. These data do not resolve the spectra shape above 15 MeV. A new evaluation is not encouraged at this time.
  - Update for an evaluation of the ^{235}U(n_{th},f) neutron spectrum.
    - Only a few experiments recent experiments are acceptable. There are problems at high energies with these data. A new evaluation should only be considered after the completion of the analysis of a new measurement performed at IRMM.

Summary of the First IAEA Consultants' Meeting (cont)

- Neutron spectra (cont.)
  - Accelerator produced spectra, e.g. Al(d,n), B(d,n)
    - Difficulties getting reasonable ^{252}Cf deposits and thermal neutrons for obtaining ^{235}U spectra suggest that other methods for obtaining spectra be used. Ohio University has characterized the spectra for a number of (d,n) sources. Such sources should be investigated as possible standards.

- Adding "Reference" cross section to our evaluation effort. These are not standards but they are used in some applications as pseudo-standards. It is preferred that the standards community review and evaluate them.
  - Reference cross sections for measurements of prompt gamma-ray production cross sections.
    - Several candidates were investigated taking into account factors such as structure and magnitude of the cross section, status of the database, sample properties, and evaluations performed. Both (n,n'γ) and (n,2nγ) reactions were considered. It is recommended that the Fe (n,n'γ) cross section be used since considerable work has been done on this reaction, however work should be done on the inherently better reference cross section, Nb(n,n'γ).

Summary of the First IAEA Consultants' Meeting (cont)

- Adding "Reference" cross sections (cont.)
  - Au(n,γ) reference cross section for capture cross section measurements for astrophysics (below the standards energy region).
    - Due to the evaluation process used for the standards evaluation, data for the Au(n,γ) cross section were obtained for energies below 200 keV. These results are consistently higher than the Ratynski evaluation (by about 5-7% from 15 to 25 keV) which is used in astrophysics applications. The Ratynski evaluation relies on Macklin capture data and Karlsruhe Maxwellian capture data. The standards evaluation uses a large database of various types of data. An examination of the database is now underway. New experiments underway by Wallner of the ^{238}U(n,γ)/Au(n,γ) cross section ratio and Schillebeeckx of the Au(n,γ) cross section should be helpful.
      The results of WPEC Subgroup 4 support the standards evaluation.

Summary of the First IAEA Consultants' Meeting (cont)

- Developing a procedure to improve the smoothing process.
  - The objective is to remove non-physical fluctuations (structure) and maintain real structure such as the cusps that occur from competition with inelastic scattering. In the standards evaluation, a 3-point smoothing was used. The present effort used statistical model calculations for the Au(n,γ) and ^{238}U(n,γ) cross sections as shape data in GMAP with high correlation between neighboring points. The procedure appears to have been successful.

Summary of the First IAEA Consultants' Meeting (cont)

- Additional work on covariances related to the standards.
  - Covariances were obtained for the ^{235}U(n,f), ^{238}U(n,f), ^{239}Pu(n,f), Au(n,γ), and ^{238}U(n,γ) cross sections for those energy ranges necessary to cover the entire ENDF/B-VII energy range when the standards energy range is included, using a number of methods.
  - By merging these covariances with those from the standards evaluation, covariances are now available for the entire ENDF/B-VII energy range.
    - These covariances could be put into the next mod of ENDF/B-VII thus allowing the very well determined covariances from the standards evaluation to be used more easily.
  - These covariances are being submitted to the dosimetry community to provide covariances for the full energy range they need in order to be able to use these important dosimetry cross sections.

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 had members of the International Program Committee for the International Symposium on Radiation Dosimetry-13 (2008). The activities they performed were planning and chairing sessions, and reviewing the abstracts and submitted papers.

Recommendations

•Though the international evaluation of the standards has been completed, maintaining an active program of measurements and evaluation activities is essential for improvement of the standards. Some of these activities are being done under the IAEA Nuclear Data Development Project "Maintenance of the Neutron Cross Section Standards". 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.