Thermal Total Cross Section Measurement for ^{63}Cu and ^{65}Cu at the MIT Reactor

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INTRODUCTION

Transmission measurements in the thermal energy region were made for two isotopes of copper (^{63}Cu and ^{65}Cu) at the Massachusetts Institute of Technology (MIT) Reactor (MITR). The sample thicknesses were 0.0375 atoms/barn and 0.0215 atoms/barn, respectively. Previously, there were no experimental data for energies below 30 eV for copper in the Experimental Nuclear Reaction Data (EXFOR) database. [1] Data were collected at more than 230 energy points between 0.01 eV and 0.1 eV.

The Nuclear Data Advisory Group (NDAG) established by the Department of Energy (DOE) maintains and constantly updates lists of materials that are considered important for applications in nuclear criticality safety. The two copper isotopes were identified on this list because they appear as constituents in structural materials and are used as a reflector in some critical benchmark experiments. The purpose of this experiment was to determine the shape of the total cross section and the associated uncertainty in support of the DOE Nuclear Criticality Safety Program (NCSP).

METHODS

A previously existing neutron time-of-flight (TOF) setup at MITR (Fig. 1) was used to measure the total neutron transmission through ^{63}Cu and ^{65}Cu sample targets versus TOF of the neutrons. Neutron bursts were created by using a cadmium chopper wheel with slit widths of 0.95 mm. The bottom D_2O reflector of MITR served as the thermal neutron source. TOF was recorded by a BF_3 detector located 124.46 cm from the chopper wheel.

In Fig. 1, the neutron beam comes at an angle from the direction of the viewer, passes through the precollimator, and then passes through the chopper wheel to begin TOF. From there, the neutron beam is attenuated by the sample and makes its way to the BF_3 detector at the end of the table. Finally, the beam ends up in the beam dump.

A 13.5-hour run was conducted for the unattenuated beam, a 12.5-hour run was conducted for the ^{65}Cu sample, and an 11-hour run was conducted for the ^{63}Cu sample at an average reactor power of 5 MWth. The data were normalized by both the run time and the average reactor power during the run (determined to be linearly proportional to the total number of neutrons in the beam). The reactor neutron power was logged by two independent detectors in 1 minute intervals.

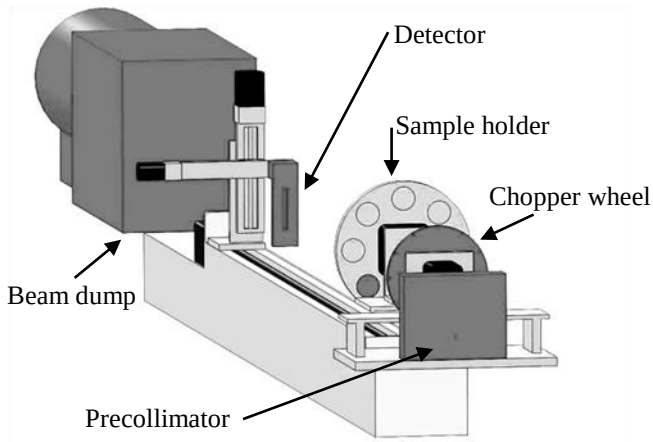

Fig. 1. A graphical representation of the experimental setup at MITR.

A detailed MCNP (Monte Carlo N-Particle) [2] model of the experimental setup was created. This model was used to estimate the percent of neutrons from the beam that made first flight collisions in the detector. The neutron source distribution for the problem was obtained from a full core MCNP model of MITR. Finally, the measured data were normalized to the experimental data at the thermal value reported by Mughabghab [3] because this research aims only to obtain the shape of the cross section in the thermal region and not its absolute value.

RESULTS

After the data reduction and considering the Poisson error on the detector counts, the measured ^{63}Cu and ^{65}Cu total microscopic neutron cross sections were input to the SAMMY computer code. [4] Figure 2 presents a plot generated by SAMMY comparing the experimental data, denoted with error bars (crosses), and the theoretical total cross section, plotted as a solid line. The Evaluated Nuclear Data File (ENDF/B-VII.0) resonance parameters for both ^{63}Cu and ^{65}Cu were used in the SAMMY calculation.

CONCLUSIONS

For many isotopes, including the two copper isotopes, experimental data points are available only at 0.0253 eV, measured by activation analysis. The

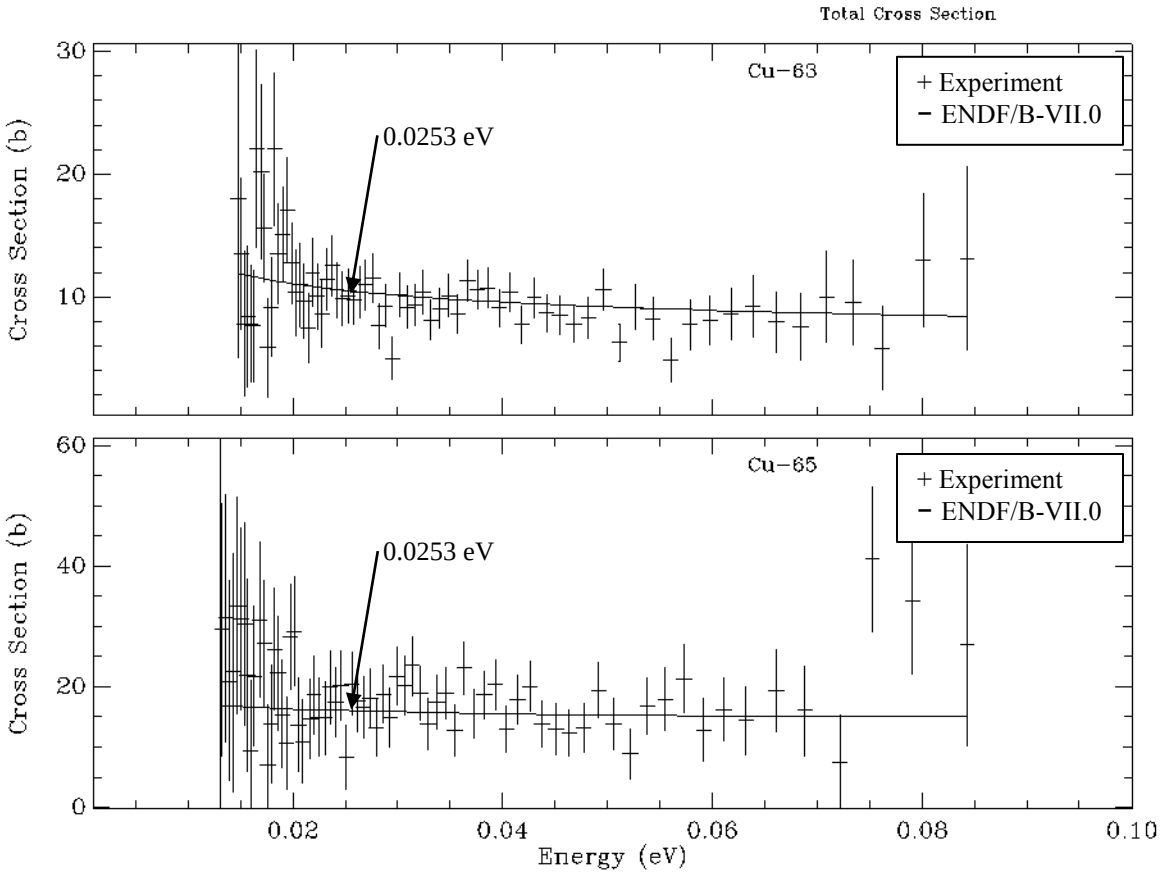

Fig. 2. A plot of the experimental data points (crosses) with error bars versus the evaluated cross section (solid line).

assumption is usually made that the shape of the cross section in the low energy range follows a *1/v* shape. Furthermore, the uncertainty on the single datum point measured by the activation analysis technique is extended to the fitted cross section in the entire thermal region. However, as described by Wigner in his 1948 paper, [5] the radiative capture cross section is only *1/v* in the first order approximation and is dependent on *v* in the next order term. Therefore, simply assuming the *1/v* dependence may be inaccurate for some isotopes. Moreover, extending the uncertainty of a measured datum point at one energy value across the entire region is not justified. In the future, the results of this work will be used to verify the validity of the *1/v* assumption. The data points collected from this experiment will be evaluated using the SAMMY fitting code with experimental data in the other energy regions from the EXFOR database. A complete resolved-resonance evaluation for ^{63}Cu and ^{65}Cu, including the uncertainty, will be performed. The low energy data measured in this work will be crucial in the evaluation process.

There are also plans to conduct radiative capture cross section measurements at the MITR facility using a modification of the experimental setup shown in Fig. 1. Experimental data points in the thermal region for the radiative capture cross section will further reduce the uncertainty on the evaluated cross section.

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REFERENCES

1. *Experimental Nuclear Reaction Data (EXFOR),* rev., NNDC, International Network of Nuclear Reaction Data Centers, IAEA (March 23, 2011).
2. *MCNP – A General Monte Carlo N-Particle Transport Code, Version 5*, LANL, Los Alamos, NM (2003). Available from RSICC at ORNL as CCC-740.
3. S. F. MUGHABGHAB, *Atlas of Neutron Resonances*, Elsevier, Amsterdam (2006).
4. N. M. LARSON, *Updated Users' Guide for SAMMY: Multilevel R-Matrix Fits to Neutron Data Using Bayes' Equations,* ORNL/TM-9179/R6, Oak Ridge National Laboratory, Oak Ridge, TN (2003).
5. E. P. WIGNER, "On the Behavior of Cross Sections Near Thresholds," *Phys. Rev*., **73**, 1002 (1948).