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NEUTRON TOTAL AND CAPTURE CROSS SECTION MEASUREMENTS...OF TUNGSTEN...

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[Total and Capture] Neutron Cross Section Measurements and Resonance

Parameter Analysis of Tungsten from 0.01 eV to 200 eV

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Natural tungsten metal was measured using neutron time-of-flight spectroscopy at the Rensselaer Polytechnic Institute (RPI) Gaertner Laboratory linear accelerator to determine the tungsten resonance parameters. Three separate measurements were performed: transmission, capture, and self-indication. Previous measurements did not employ all three experiment types and used less sophisticated methods. The current work improves on the published tungsten data base and reduces resonance parameter uncertainties.

The current measurements utilize two different neutron-producing targets. The first is a thermal target, developed at RPI, utilizing a tantalum photoneutron target, a graphite reflector, and a polyethylene moderator optimized for the production of thermal neutrons. The second target is the bounce target which is also a tantalum photoneutron target, but with only a polyethylene moderator optimized for the 1 eV to 10 keV neutron energy range. The bounce target is used in all three experiments in the neutron energy range of 2 to 200 eV. Data were taken at two different flight paths. Epi-thermal

measurements were made at the 25 meter flight path, while thermal measurements were made at 15 and 25 meters.

Neutron detection for the transmission experiments was accomplished using lithium glass scintillation detectors. At the 15 meter station, a 0.3-cm-thick NE 905 lithium glass scintillator was used; and at the 25 meter station a 1.27-cm-thick NE 905 glass was used in the detector. Sample thicknesses of 0.001, 0.002, 0.005, 0.01, 0.02, 0.035, 0.05, 0.1, and 0.2 inches were chosen to obtain transmissions between 0.20 and 0.80. Background correction of transmission data was done using the notch filter extrapolation method.

Capture gamma ray detection for both neutron capture and self-indication experiments was achieved using a 16-segment sodium-iodide multiplicity detector. Sample thicknesses of 0.003, 0.001, 0.002, 0.005, 0.02, and 0.05 inches were used to perform the capture measurements. Thicknesses of 0.002 and 0.005 inches were used for the capture and transmission samples in the self-indication measurements. The optimum sample thicknesses for these experiment types were chosen in order to obtain capture and self-indication yields between 10 and 100 % for the resonances of interest, while minimizing the effects of multiple scattering. The capture and self-indication background correction was performed by subtracting the empty sample holder counts from the tungsten sample plus sample holder data. The flux shape was measured using a  $^{10}\text{B}_4\text{C}$  sample and was normalized to the yield of the 0.02 inch thick tungsten sample at the 4 eV saturated resonance.

The raw data obtained from these measurements were dead-time and background corrected and then converted to neutron transmission or capture and self-indication yields for analysis over the neutron energy range from 0.01 eV to 200 eV. A complete resonance analysis of the transmission, capture and self-indication data was performed using the least squares, multi-level R-matrix code REFIT<sup>1</sup> to obtain a single set of resonance parameters from all three types of measurements. Total and capture cross sections were calculated from resonance parameters and plotted in Figures 1a, 1b, 2a, and 2b. The RPI and ENDF/B-VI<sup>2</sup> curves are similar in most of the resonance region. The most significant difference was in the thermal region where the total and capture cross sections determined at 0.0253 eV from the present measurements are  $20.03 \pm 0.12$  barns and  $17.09 \pm 0.14$  barns, respectively. The corresponding ENDF/B-VI<sup>2</sup> cross sections are 23.17 and 18.19 barns. Another significant contribution of the present work is the determination of spin  $J=1$  for the 101.3 eV resonance in <sup>183</sup>W. The ENDF/B-VI resonance spin assignment for the 101.3 eV resonance is  $J=0$ . A complete set of tungsten resonance parameters up to 200 eV has been developed.

The resonance integral for natural tungsten using the RPI parameters is 384 barns, about 6% higher than the ENDF/B-VI<sup>2</sup> value of 360 barns. The present tungsten measurements from thermal to 200 eV for transmission, capture, and self-indication are an improvement over the previous measurements that were evaluated for the ENDF/B-VI parameters. The ENDF/B-VI parameters are based on measurements dating back to the 1960s and earlier. In particular, the ENDF/B-VI thermal resonance parameters were based on a capture-only measurement performed in 1966. The single set of RPI parameters was

obtained using data from three different types of measurements fitted simultaneously over a neutron energy range from 0.01 eV to 200 eV using REFIT. The improved consistency of such a method is expected to improve the accuracy of the tungsten resonance parameters.

#### REFERENCES

- (1) M.C. Moxon, "REFIT, A Least Square Fitting Program for Resonance Analysis of Neutron Transmission and Capture Data," AEA-InTec-0470, 1991.
- (2) Brookhaven National Nuclear Data Center (NNDC) ENDF/B-VI Nuclear Cross Section on-line data service.

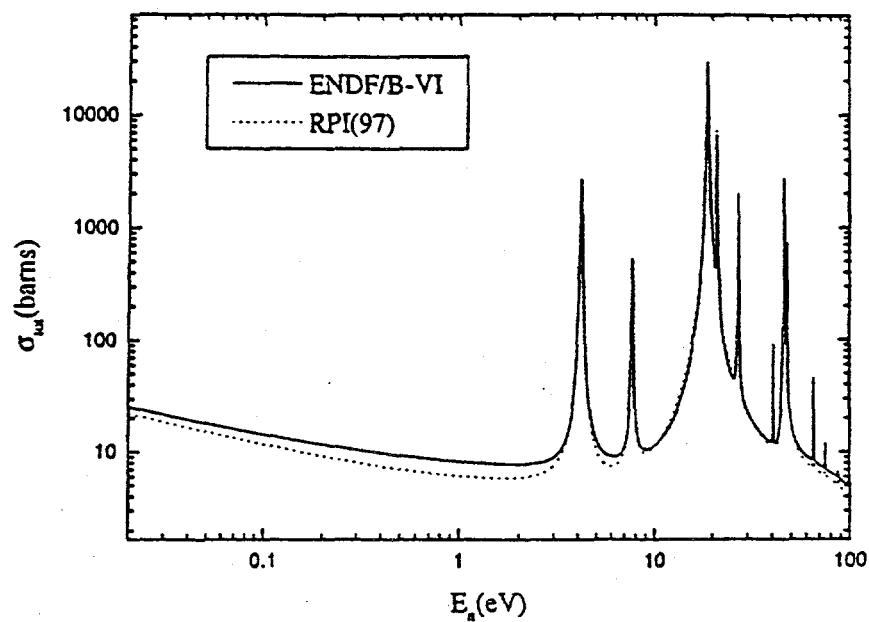


Figure 1a - Total neutron cross section for tungsten from the ENDF/B-VI and RPI parameters from 0.02 to 100 eV.

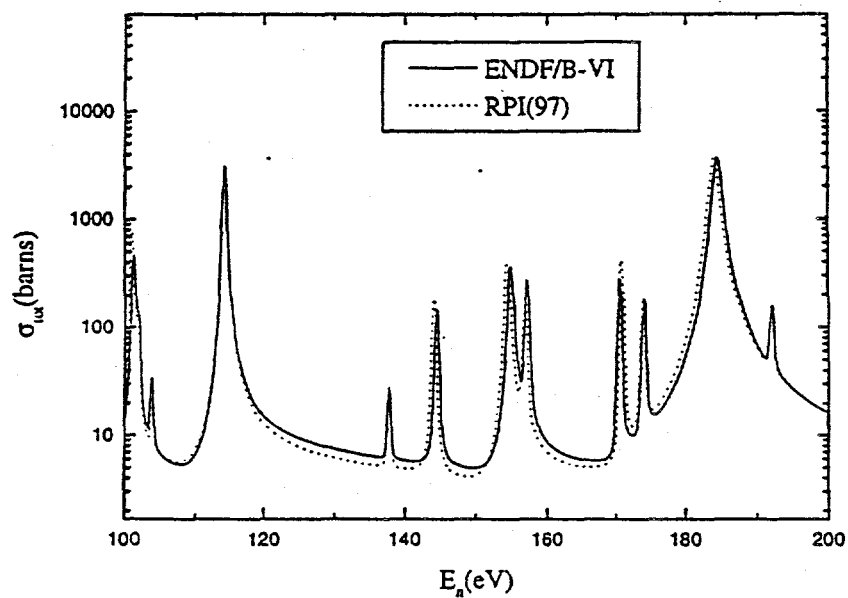


Figure 1b - Total neutron cross section for tungsten from the ENDF/B-VI and RPI parameters from 100 to 200 eV.



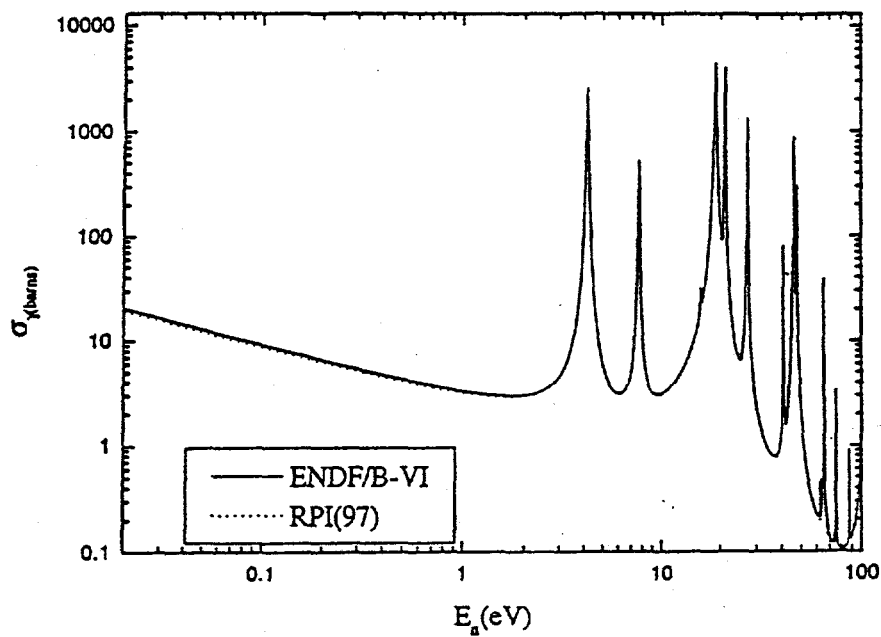


Figure 2a - Neutron capture cross section for tungsten from the ENDF/B-VI and RPI parameters from 0.02 to 100 eV.

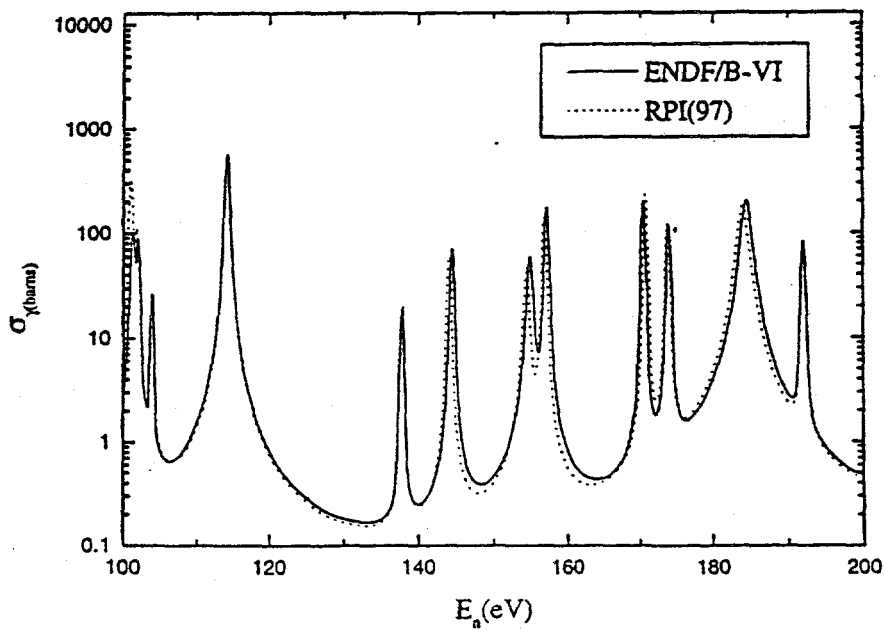


Figure 2b - Neutron capture cross section for tungsten from the ENDF/B-VI and RPI parameters from 100 to 200 eV.