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COMPARISON OF MEASURED AND CALCULATED ^{238}U CAPTURE SELF-INDICATION RATIOS FROM 4 TO 10 keV

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COMPARISON OF MEASURED AND CALCULATED ^{238}U CAPTURE SELF-INDICATION RATIOS FROM 4 TO 10 keV

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From 4 keV to 149 keV the ^{238}U cross sections are represented in ENDF/B-V by unresolved-resonance parameters (URP). The purpose of this representation is to enable the calculation of resonance self-protection as a function of temperature and dilution. Since the URPs are not defined unambiguously by the cross-section data, it is important that the unresolved representation be tested with appropriate experiments, such as capture self-indication ratio (SIR) measurements.[1–3] In this paper we compare ^{238}U capture SIR measurements in the 4- to 10-keV energy range with calculations done with ENDF/B-V and with recently published resolved resonance parameters.[4]

The experimental arrangement has been described in a previous paper[5] where we discuss the measurements and their interpretation in the resolved-resonance region (below 4 keV). Briefly, the Oak Ridge Electron Linear Accelerator provided a pulsed source of neutrons. The time-of-flight technique was used to measure the capture rate as a function of energy in a 0.0031-atom/barn (a/b) sample of ^{238}U placed at the center of a capture gamma-ray detector on a 40-m flight path. Four ^{238}U transmission samples (0.0038, 0.0124, 0.0341, and 0.0521 a/b) were alternated in and out of the incident-neutron beam. All samples were at room temperature. For a given transmission-sample thickness and for a given energy group, the capture SIR was obtained as the ratio of the net capture rate (proportional to the net counting rate divided by the incident-neutron flux) with the transmission sample in the incident-neutron beam to the net capture rate with the open beam.

For 1-keV wide groups, the statistical error in the measured SIR was less than 1%. The main systematic error arises from the uncertainty in the background levels and varies with energy and thickness from about 2% for the thinnest sample to 10% for the thickest sample.

The capture SIR expected for ENDF/B-V for a transmission sample of thickness n (a/b) was computed by the Probability Table Method.[6] The probability distribution of the total cross section, $P(\sigma_t)$, and the corresponding average capture cross section, $\bar{\sigma}_c(\sigma_t)$, were obtained by the Monte Carlo technique. The capture SIR was then computed as

$$SIR = \frac{\int \bar{\sigma}_c(\sigma_t)\ P(\sigma_t) e^{-n\sigma_t}\ d\sigma_t}{\int \bar{\sigma}_c(\sigma_t)\ P(\sigma_t)\ d\sigma_t} ,$$

where the cross sections are Doppler broadened for 300 K. These calculations were repeated for each energy at which ENDF/B-V specifies unresolved-resonance parameters in the range 4 to 10 keV.

From 4 to 6 keV the capture SIRs were also computed directly using capture and total cross sections calculated with recently published resolved-resonance parameters.[4]

The results of the capture SIR measurements and of the two sets of calculations described above are shown in Fig. 1. In the interval 5.5 to 6.5 keV the measurements were judged to be unreliable and are not shown. A background due to the capture of 5.9-keV neutrons in structural aluminum near the detector could not be properly evaluated.

For comparison with the calculation, the measured capture SIR should be corrected for the effect of multiple scattering in the capture sample. The multiple scattering effect tends to reduce the self-shielding and hence to increase the SIR. The magnitude of this effect was estimated by calculating the resolved-resonance parameters both with and without including the multiple-scattering contribution to the capture rates. In the range 4 to 6 keV the magnitude of the multiple scattering correction varied from 0.3% for the thinnest sample to 3.1% for the thickest sample.

The comparisons of Fig. 1 suggest that:

1. The measured ^{238}U capture SIR has a considerable amount of structure as a function of energy, as had been observed previously by Byoun et al.[7]

2. The ENDF/B-V unresolved-resonance representation fails to reproduce this structure.

3. Calculations done with available resolved-resonance parameters in the 4- to 6-keV interval reproduce the structure fairly well.

4. From 6.5 to 10 keV, ENDF/B-V underestimates resonance self-protection for the thicker samples.

5. Below 5.5 keV, ENDF/B-V overestimates resonance self-protection for the thin samples but is in agreement with the measurements for the thick samples.

6. Calculations based on resolved parameters agree significantly better with the measurements than those based on ENDF/B-V.

These considerations underscore the need to extend the ^{238}U resolved-resonance representation of ENDF/B to higher energies if the 1% accuracies in computed ^{238}U self-shielding factors requested by reactor designers[8] is to be achieved.

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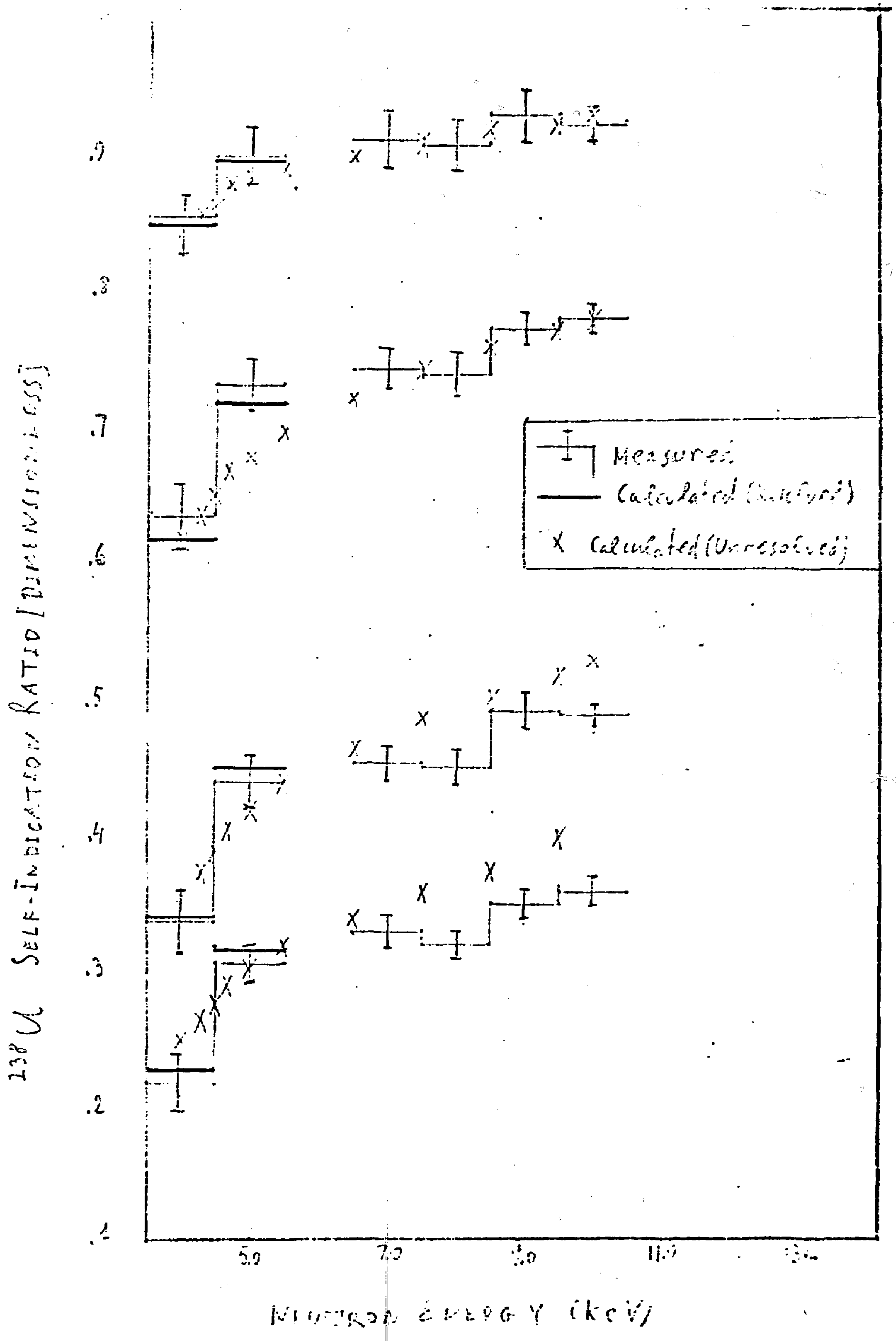
FIGURE CAPTION

Figure 1. ^{238}U capture self-indication ratios versus incident neutron energy, 4 to 10 keV. The four histograms with error flags show the results of the measurements for transmission samples of 0.0038, 0.0124, 0.0341, and 0.0521 a/b respectively. The other histograms show results of a calculation with resolved resonance parameters. The crosses denote the results obtained with ENDF/B-V unresolved resonance parameters.


238U Self-Indication Ratio (Dimensionless)
.9
.8
.7
.6
.5
.4
.3
.2
.1
Measured
Calculated
Calculated (Unresolved)
5.0
7.0
9.0
11.0
Neutron Energy (keV)