SAMMY Workshop Part 5a

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Part 5a, SAMMY's Integral Quantities

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Integral Quantities

which may be included in evaluation process in SAMMY

(1) Thermal cross section

$$\sigma_{0x} = \sigma_x(E_0) \qquad \text{for } E_0 = 0.0253\text{eV}$$

(2) Maxwellian average at thermal energy

$$\bar{\sigma}_x = \int_{E_1}^{E_2} \sigma_x(E) \, \frac{E}{E_0} \, e^{-E/E_0} \, dE \Bigg/ \int_{E_1}^{E_2} \frac{E}{E_0} \, e^{-E/E_0} \, dE$$

where $E_1 = 10^{-5}$ eV and $E_2 = 3$ eV

(3) Westcott's *g*-factor

$$g_x = \frac{2}{\sqrt{\pi}} \frac{\bar{\sigma}_x}{\sigma_{0x}}$$

(4) Resonance integral

$$I_x = \int_{E_3}^{E_4} \sigma_x(E) \frac{dE}{E} + X_{4x}$$

(5) Average integral

$$\hat{\sigma}_x = \int_{E_5}^{E_6} \sigma_x(E) \; dE \Big/ (E_6 - E_5)$$

(6) Watt spectrum average

$$\bar{\sigma}_{Wf} = \int_{E_1}^{E_7} \sigma_f(E)\ \Phi(E)\ dE \Bigg/ \int_{E_1}^{E_7} \Phi(E)\ dE$$

with $E_7 = 20$ MeV

and $\Phi(E)$ = Watt fission spectrum

$$\Phi(E) = e^{-E/a} \sinh(\sqrt{bE})$$

$$= e^{-E/a} \left(e^{\sqrt{bE}} - e^{-\sqrt{bE}} \right) / 2$$

(7) $K1$ (indicative of K_{eff} for thermal benchmarks)

$$K1 = \nu \sigma_{0f} g_f - \sigma_{0a} g_a = (\nu \bar{\sigma}_f - \bar{\sigma}_a) \frac{2}{\sqrt{\pi}}$$

(8) Alpha

$$\alpha = I_c / I_f$$

(9) Thermal alpha integral (NJOY's α),

$$\alpha_{NJOY} = \int_{E_1}^{E_2} \frac{\sigma_c(E)}{\sigma_f(E)} \; \frac{E}{E_0} \; e^{-E/E_0} \, dE \Bigg/ \int_{E_1}^{E_2} \frac{E}{E_0} \; e^{-E/E_0} \, dE$$

(10) Thermal eta integral (NJOY's η),

$$\eta_{NJOY} = \int_{E_1}^{E_2} \frac{\nu \, \sigma_f(E)}{\sigma_a(E)} \; \frac{E}{E_0} \; e^{-E/E_0} \, dE \Bigg/ \int_{E_1}^{E_2} \frac{E}{E_0} \; e^{-E/E_0} \, dE$$

Recent Addition to SAMMY

Flux-weighted group cross sections:

$$\bar{\sigma}_g = \int_{E_g}^{E_{g+1}} \sigma(E)\ \Phi(E)\ dE \Bigg/ \int_{E_g}^{E_{g+1}} \Phi(E)\ dE$$

with several options for $\Phi(E)$ —

Option 1: Bondarenko narrow-resonance weighting scheme,

$$\Phi(E) = \frac{C(E)}{\sigma_0 + \sigma_t(E,T)}$$

where

$C(E)$ = smooth function of energy

σ_0 = dilution

$\sigma_t(E,T)$ = Doppler-broadened total cross section

Option 2: flux is given numerically on energy grid (for intermediate spectrum, useful in criticality predictability) (not yet included in SAMMY, but "on the drawing board")

<u>Covariances are calculated for the group cross sections</u>. (However, fitting is not permitted, only calculations.)

Example: ^{235}U

Differential measurements: 14 data sets analyzed via SAMMY

Details for ^{235}U can be found in

L. C. Leal, H. Derrien, N. M. Larson, and R. Q. Wright, *R-Matrix Analysis of* ^{235}U *Neutron Transmission and Cross Sections in the Energy Range 0 to 2.25 keV*, ORNL/TM-13516, Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory (November 1997). Also *Nucl. Sci. and Eng.* **131** 230 (February 1999).

Integral Standards: six quantities
have been included in analysis

Details can be found in

N. M. Larson, L. C. Leal, and H. Derrien, "Integral Data Analysis for Resonance Parameters Determination," ORNL-TM-13495, Oak Ridge National Laboratory, Lockheed Martin Energy Research, Inc. (1997). Also *Nucl. Sci. and Eng.* **131** 254 (February 1999).

Selected Measurements for ^{235}U

Reference	Energy range (eV)	Data set #	Data
de Saussure (RPI/1967)[10]	0.01 - 2250.0	5,6	**Fission & capture** at 25.2 m
Perez (ORNL/1972)[11]	0.01 - 100.0	7,8	**Fission & capture** at 39.7 m
Weston (ORNL/1984)[28]	14.0 - 2250.0	14	**Fission** at 18.9 meters
Gwin (ORNL/1984)[47]	0.01 - 20.0	9	**Fission** at 25.6 meters
Spencer (ORNL/1984)[3]	0.01 - 1.0	10	**Transmission** at 18 meters and sample thickness of 0.001468 atom/barn
Harvey (ORNL/1986)[2]	0.4 - 68.0	1	**Transmission** at 18 meters. Sample thickness of 0.03269 atom/barn cooled to 77 K
Harvey (ORNL/1986)[2]	4.0 - 2250.0	2	**Transmission** at 80 meters. Sample thickness of 0.00233 atom/barn cooled to 77 K
Harvey (ORNL/1986)[2]	4.0 - 2250.0	3	**Transmission** at 80 meters. Sample thickness of 0.03269 atom/barn cooled to 77 K
Wartena (Geel/1987)[24]	0.0018 - 1.0		**Eta** at 8 meters
Wagemans (Geel/1988)[31]	0.001 - 0.4	11	**Fission** at 18 meters
Schrack (RPI/1988)[32]	0.02 - 20	4	**Fission** at 8.4 meters
Weigmann (ILL/1990)[25]	0.0015 - 0.15		**Eta** (Chopper)
Weston (ORNL/1992)[4]	100.0 - 2000.		**Fission** at 86.5 meters
Moxon (ORNL/1992)[26]	0.01- 50.0		**Fission Yield**
Gwin (ORNL/1996)[27]	0.01- 4.0	12,13	**Absorption and fission**

References for "**Selected Measurements for ^{235}U**"

2. J. A. Harvey, N. W. Hill, F. G. Perey, G. L. Tweed, and L. C. Leal, *Proc. Int. Conf. On Nuclear Data for Science and Technology*, Mito, Japan (May 30-June 3, 1988).

3. R. R. Spencer, J. A. Harvey, N. W. Hill, and L. Weston, *Nucl. Sci. Eng*. **96**, 318 (1987).

4. L. W. Weston and J. H. Todd, *Nucl. Sci. Eng.* **111**, 415 (1992).

10. G. de Saussure, R. Gwin, L. W. Weston, and R. W. Ingle, *Simultaneous Measurements of the Neutron Fission and Capture Cross Section for ^{235}U for incident neutron energy from 0.4 eV to 3 keV*, ORNL/TM-1804, Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory, Oak Ridge, TN (1967).

11. R. B. Perez, G. de Saussure, and E. G. Silver, *Nucl. Sci. Eng*. **52**, 46 (1973).

24. J. A. Wartena, H. Weigmann, and C. Burkholz, Report IAEA Tecdoc 491, p.123 (1987).

25. H. Weigmann, P. Geltenbort, B. Keck, K. Shrenckenbach, and J. A. Wartena, *Proc. Intern. Conf. on The Physics of Reactors*, Marseille 1990, Vol. P1, p. 133 (1990).

26. M. C. Moxon, J. A. Harvey, and N. W. Hill, Private communication ORNL (1992).

27. R. Gwin, To be published in *Nuclear Science Engineering* and as ORNL/TM (1997).

28. L. W. Weston and J. H. Todd, *Nucl. Sci. Eng.* **88**, 567 (1984).

31. C. Wagemans, P. Schillebeeckx, A. J. Deruyter, and R. Barthelemy, "Subthermal fission Cross Section measurements for ^{233}U and ^{239}Pu," *Nuclear Data for Science and Technology*, p. 91, Mito, Japan (1988).

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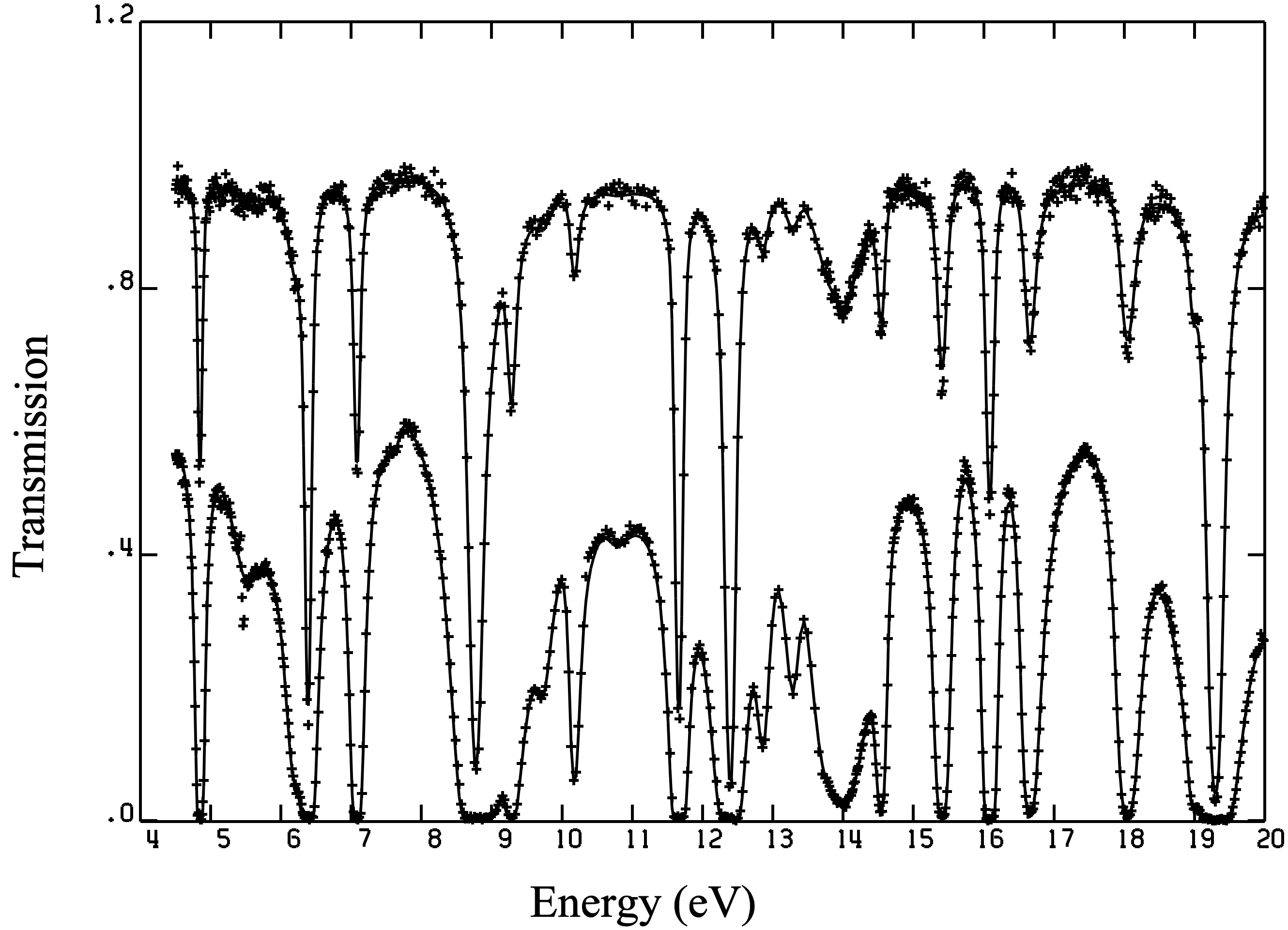

^{235}U Transmission data of Harvey et al. for two sample thicknesses (0.03269 barns and 0.00233 barns)

Comparison between experimental and calculated thermal values and integral quantities for ^{235}U

Quantity	Measured, recommended, and standard values	Fit to differential data	Fit to differential plus integral data
σ_{0f} (barn)	584.25 ± 1.11	584.28	584.88
$\sigma_{0\gamma}$ (barn)	98.96 ± 0.74	99.18	98.66
σ_{0s} (barn)	15.46 ± 1.06	15.44	15.67
$K1$ (barn)	722.7 ± 3.90	717.48	722.43
g_f	0.9771 ± 0.0008	0.9743	0.9764
g_a	0.9790 ± 0.0008	0.9774	0.9785