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DATA TESTING RESULTS FOR THE LLL EVALUATED NUCLEAR DATA LIBRARY (ENDL-78)

R. J. Howerton

August 13, 1979

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MASTER

FOREWORD

The UCR1-50400 series describes an integrated and computer-oriented system for the production and application of neutronics and photonics calculational constants.

The system must supply reliable up-to-date data, select specific types of data on request, provide output in a variety of forms (ultimately in the form of input to other computer codes), and function rapidly and efficiently. The system has now been developed to a point where we are achieving these goals.

The UCR1-50400 series, *An Integrated System for Production of Neutronics and Photonics Calculational Constants*, comprises the following volumes:

- Vol. 1, Part A, Rev. 3, *ECSSIL: A System for Storage, Retrieval, and Display of Experimental Neutron Data*, September 1976.
- Vol. 1, Part B, *Program ECSS4 (Version 78-1): Conversion of Experimentally Measured Cross-Section Data from the Four-Center-Exchange (X-4) Format to the Livermore ECSSIL Format*, December 1978.
- Vol. 2, Rev. 2, *A Bibliography of the Experimental Data of Neutron-Induced Interactions*, July 1976.
- Vol. 3, Rev. 2, *An Index of Experimental Data of Neutron-Induced Interactions*, July 1976.
- Vol. 4, *Evaluated Nuclear Cross-Section Library*, April 1971.
- Vol. 5, Part A, Rev. 1, *CLYDE: A Code for the Production of Calculational Constants from Nuclear Data*, September 1975.
- Vol. 5, Part B, Rev. 1, *Relativistic Transformations between Center-of-Mass and Laboratory Systems for Two-Body Nuclear Reactions*, April 1978.
- Vol. 6, Rev. 2, *Tables and Graphs of Photon-Interaction Cross Sections from 1 keV and 100 MeV*, December 1978.
- Vol. 7, Part A, Rev. 1, *Major Neutron-Induced Interactions ($Z \leq 55$): Graphical, Experimental Data*, July 1976.
- Vol. 7, Part B, Rev. 1, *Major Neutron-Induced Interactions ($Z > 55$): Graphical, Experimental Data*, July 1976.
- Vol. 8, Part A, Rev. 1, *Supplemental Neutron-Induced Interactions ($Z \leq 35$): Graphical, Experimental Data*, July 1976.
- Vol. 8, Part B, Rev. 1, *Supplemental Neutron-Induced Interactions ($Z > 35$): Graphical, Experimental Data*, July 1976.
- Vol. 9, *Thresholds of Nuclear Reactions Induced by Neutrons, Photons, Deutrons, Tritons, and Alpha Particles*, September 1970.
- Vol. 10, Rev. 1, *Tabulated Experimental Data for Neutron-Induced Interactions*, July 1976.
- Vol. 11, *Experimental Data, Indexes, and Techniques of Obtaining a Selected Set of Neutron Resonance Parameters*, May 1972.
- Vol. 12, *An Atlas of Resolved Neutron Resonance Parameters*, July 1972.
- Vol. 13, *An Atlas of Unresolved Neutron Resonance Parameters*, September 1972.
- Vol. 14, *TARTNP: A Coupled Neutron-Photon Monte Carlo Transport Code*, February 1976.
- Vol. 15, Part A, *The LLL Evaluated-Nuclear-Data Library (ENDL): Evaluation Techniques, Reaction Index, and Descriptions of Individual Evaluations*, September 1975.
- Vol. 15, Part B, Rev. 1, *The LLL Evaluated-Nuclear-Data Library (ENDL): Graphs of Cross Sections from the Library*, October 1978.
- Vol. 15, Part C, *The LLL Evaluated-Nuclear-Data Library (ENDL): Translation of ENDL Neutron-Induced Interaction Data into the ENDF/B Format*, April 1976.
- Vol. 15, Part D, Rev. 1, *The LLL Evaluated-Nuclear-Data Library (ENDL): Descriptions of Individual Evaluations for $Z = 0-98$* , May 1978.
- Vol. 15, Part E, *Data Testing Results for the LLL Evaluated Nuclear Data Library (ENDL-78)*, August 1979.
- Vol. 16, Rev. 2, *Tabular and Graphical Presentation of 175 Neutron-Group Constants Derived from the LLL Evaluated-Nuclear-Data Library (ENDL)*, October 1978.

- Vol. 17, Part A, *Program LINEAR (Version 77-1): Linearize Data in the Evaluated-Nuclear-Data File/Version B (ENDF/B) Format*, January 1977.
- Vol. 17, Part B, *Program SIGMAI (Version 77-1): Doppler Broaden Evaluated Cross Sections in the Evaluated-Nuclear-Data File/Version B (ENDF/B) Format*, January 1977.
- Vol. 17, Part C, *Program RECENT: Reconstruction of Energy-Dependent Cross Sections from Resonance Parameters in the ENDF/B Format*, 1979.
- Vol. 17, Part D, *Program GROUPIE: Calculation of Self-Shielded Cross Sections and Multiband Parameters for Evaluated Data in the ENDF/B Format*, 1979.
- Vol. 17, Part E, *Program EVALPLOT: Plot Data in the Evaluated-Nuclear-Data File/Version B (ENDF/B) Format*, February 1979.
- Vol. 18, *ACTL: Evaluated Neutron Activation Cross-Section Library*, 1979.
- Vol. 19, *Neutron-Induced Angular and Energy Distributions: Graphical Experimental Data*, April 1977.
- Vol. 20, *Bonderenkko Self-Shielded Cross Sections and Multiband Parameters Derived from the I.L.L. Evaluated-Nuclear-Data Library (ENDL)*, July 1978.
- Vol. 21, Part A, *Maxwell-Averaged Reaction Rates ($\langle\sigma v\rangle$) for Selected Reactions Between Ions with Atomic Mass ≤ 11* , February 1979.

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DATA TESTING RESULTS FOR THE LLL EVALUATED NUCLEAR DATA LIBRARY (ENDL-78)

ABSTRACT

The LLL Evaluated Nuclear Data Library (ENDL-78) has been tested for validity by comparing calculated and experimental values of k_{eff} for 67 critical assemblies and emission neutron spectra for 22 spheres that were pulsed with 14-MeV neutrons.

INTRODUCTION

The validity of a collection of evaluated nuclear data can, in general, be established in one of two ways. First, the evaluated data can be compared on a point-by-point basis with experimental determinations of the same values, where such experimental data exist. Since the evaluated data are largely developed from experimental results, such a comparison will usually uncover only oversights or errors in transcription. It does nothing to resolve discrepancies between sets of experimental data that do not agree, nor is it useful in determining the validity of a great bulk of the data for which no experimental values have been determined. For the 1976 version of ENDL (ENDL-76), a graphical comparison of evaluated and experimental data was published in Vol. 7, Parts A and B, and Vol. 8, Parts A and B,¹⁻⁴ of this series. An equivalent set of documents for ENDL-78 will not be issued because of the excessive costs of printing and distribution, and because I believe that a more cost-effective testing of the validity of ENDL-78 can be accomplished.

ENDL exists only to provide a collection of

data that can be used for design and effects calculations of engineering configurations that depend upon the interaction of neutrons and light charged particles with nuclei for their operation. The second and, in my opinion, more powerful method of establishing the validity of ENDL-78 is to compare the values of appropriate calculated parameters of simple geometric configurations with the equivalent experimental values of the same parameters, using the calculational method that most closely approximates physical reality—the Monte Carlo method. In what follows, calculated values of k_{eff} for 46 spherical⁵ and 21 cylindrical⁶ assemblies will be compared with the just-critical experimental value of unity. In general, these assemblies have a core of fissile material and are reflected by various thicknesses of several reflector materials. The second set of comparisons is for the time spectra of neutrons emitted from spheres of various materials having a nominal 14-MeV source at the center.⁷⁻⁹ These comparisons will serve to test important parts of ENDL for neutron-induced interaction data.

COMPARISONS OF k_{eff} CALCULATIONS WITH EXPERIMENT

Tables 1 through 4 present comparisons of calculated k_{eff} values using the TARTNP computer code¹⁰ with the nominal experimental value of unity for 67 just-critical assemblies. Other than inadequacies of the evaluated data, there are several possible sources of discrepancies between the calculated value and the experimental value of unity. First, the Monte Carlo neutronics calculations

have an intrinsic statistical uncertainty that is specified as an input parameter to the problem. The calculation proceeds until the statistical uncertainty is less than that specified. At that time the calculation ends and the corresponding k_{eff} value is written out. For all critical calculations reported here, the statistical uncertainty used was 0.3% in k_{eff} . Because of other uncertainties to be described, it was deemed

TABLE 1. Spherical critical assemblies with ^{233}U core.

Reflector material	Reflector thickness, cm	Calculated $k_{\text{eff}} \pm 0.003$
None	0	0.994
Be	2.05	0.996
Be	4.20	1.003
W	2.44	1.000
W	5.79	0.994
Oy ^a	1.21	1.002
Oy ^a	1.98	1.005
Oy ^a	4.82	1.006
U	2.30	1.000
U	5.31	0.999
U	19.91	0.998

^aUranium enriched to approx 94% ^{235}U .

unnecessary to use a smaller value than 0.3%. The second source of uncertainty is in the experimental determination of the just-critical configuration. For safety reasons, most so-called critical experiments are the result of extrapolating to zero the reciprocal neutron multiplication obtained from a series of subcritical determinations. Especially for thick reflectors, the extrapolation method introduces an

TABLE 2. Spherical critical assemblies with approx 94% enriched ^{235}U core.

Reflector material	Reflector thickness, cm	Calculated $k_{\text{eff}} \pm 0.003$
None	0.	0.999
Be	2.22	1.001
Be	3.26	1.006
Be	4.71	1.007
Be	5.44	1.005
Be	9.27	1.002
Be	11.79	1.004
Be	20.27	1.000
C	10.16	0.999
C	15.24	0.992
Ni	4.94	1.018
Cu	5.03	1.007
Cu	10.56	1.018
W	5.08	1.005
W	10.16	1.002
Pb	8.99	1.000
Pb	17.22	0.991
U	1.76	1.008
J	4.47	1.008
U	9.96	1.009
U	18.01	1.006

TABLE 3. Spherical critical assemblies with ^{239}Pu core.

Reflector material	Reflector thickness, cm	Calculated $k_{\text{eff}} \pm 0.003$
None	0.	1.001
Be	3.69	1.002
Be ^a	5.222	1.000
Be	5.25	1.003
Be ^a	8.17	1.001
Be ^a	13.00	0.997
C	3.83	1.005
Ti	8.00	1.000
W	4.70	1.000
Oy ^b	0.66	1.005
U	1.93	1.001
U	4.13	1.007
U	6.74	1.008
U	19.60	1.004

^aCore material was α -phase plutonium. All others were δ -phase plutonium.^bUranium enriched to approx 94% ^{235}U .

uncertainty in specification of the just-critical configuration. Finally, the calculational models of the

TABLE 4. Cylindrical critical assemblies with approx 94% enriched ^{235}U core. Reflectors are the same thickness top, bottom, and cylindrical walls.

Reflector material	Reflector thickness, cm	Calculated $k_{\text{eff}} \pm 0.003$
Be	1.27	0.993
Be	2.54	0.992
C	1.27	1.004
C	2.54	0.997
Mg	1.27	0.994
Mg	2.54	0.990
Al	1.27	0.995
Al	2.54	0.993
Ti	1.27	0.990
Ti	2.54	0.991
Fe	1.27	0.999
Fe	2.54	0.998
Ni	1.27	0.995
Ni	2.54	1.001
Cu	1.27	0.997
Cu	2.54	0.998
Mo	1.27	1.007
Mo	2.54	1.011
Mo Alloy	0.0	1.006
W	1.27	0.992
W	2.54	0.992

experiments usually do not take into account support mechanisms, room return of neutrons or holes in the assemblies. In short, the calculational models are idealized approximations of the physical configurations. When all the sources of uncertainty are combined, there is a final uncertainty of about 1% in k_{eff} . This means that any calculated value between 0.99 and 1.01 is as valid as a value of unity. In Tables 1 through 4 there are three assemblies that have calculated k_{eff} values outside the range of 0.99 to 1.01. For the two ^{235}U (94%) spherical cores that yield k_{eff} outside the 0.99 to 1.01 range, one is reflected by 4.94 cm of nickel and the other by 10.56

cm of copper. These reflectors are special cases that will be discussed in the last section of this report.

The 67 critical assemblies listed in Tables 1 through 4 have median energies of neutrons inducing fission that range from about 600 keV to 1.2 MeV, depending upon the type of reflector. Thus these assemblies tend to test the evaluated data from a few hundred keV to a few MeV incident neutron energy. The agreement of calculated and experimental k_{eff} values seems to be reasonably satisfactory. The mean value of the calculated k_{eff} for the 67 assemblies is 1.0008.

COMPARISONS OF CALCULATED AND EXPERIMENTAL SECONDARY NEUTRON SPECTRA FROM 14-MeV PULSED SPHERES

The LLL pulsed-sphere program is documented in Ref. 7, so only a general description of the experimental program will be given here. A hollow sphere of the material to be investigated has a tritiated target assembly at the center. A beam hole gives access for a deuteron beam to impinge upon the target, thus producing neutrons ranging in energy from 13.2 to 15.1 MeV, depending upon the angle the direction of the emergent neutron makes with the direction of the incident deuteron beam. A neutron counter is placed at 30° and another at 120°, both angles relative to the incident deuteron beam. The counters are at distances that range from about 7 to 10 m for different experiments. The time of arrival of neutrons after the deuteron pulse (in bin widths of 2 ns) is recorded together with the counts per bin. What is reported is the ratio of the number of counts with the sphere in place to the number of counts with the sphere not in place.

Graphical comparisons of calculated and experimental neutron spectra are presented for 20 elements or isotopes ranging over the periodic table from ^6Li to ^{239}Pu and for H_2O and D_2O in Figs. 1 through 22. The characteristic shape of each spectrum shows a rapid rise to a peak followed by a rapid fall to a relatively wide region with shape that is characteristic of the material being investigated. The initial peak represents the transmitted and forward-elastic-scattered neutrons. For arrival times greater than those characterized by the peak, the spectrum is of neutrons resulting from non-

elastic reactions and, in the case of the lightest targets, large-angle elastic scattering. Table 5 presents a comparison of calculated and experimental integrals over the transmission and elastic peak, over the remainder of the spectrum, and over the entire spectrum. Because the experiments were done with different flight paths and different detectors, the scales of the abscissas of Figs. 1 through 22 and the limits of the integrals in Table 5 are not uniform.

The materials selected for presentation here are characteristic of the results obtained in the entire program. For almost all materials, measurements were made at both 30 and 120° (with respect to the direction of the incident deuteron beam), and in many cases for more than one thickness of the spherical shell. The calculational results for the two angles showed about the same agreement with experiment in each case, as is illustrated in Figs. 6(a) and 6(b) and in Figs. 20(a) and 20(b). This is understandable in terms of the significance of the angles where the data were taken. At 30° the energy of the transmitted neutrons is 15.0 MeV, whereas at 120° the energy of the transmitted neutrons is 13.6 MeV. For most materials, most cross sections that would yield neutrons with energies greater than about 1.5 MeV (corresponding to the longest flight times) are relatively smooth from 13.6 to 15.0 MeV. Since, for both angles, neutrons in the sphere will range from 13.2 to 15.1 MeV and contributions to the counting will come from all parts of the sphere, a built-in reciprocity is in effect.

FIG. 1. Comparison of calculated and experimental neutron spectra at 30° for the 1.9 mfp of H_2O pulsed sphere. The experimental values are designated by the symbol $\bullet$, and the calculated values are designated by the solid line with calculational statistical uncertainties given by the error flags for representative points. Uncertainties in the experimental data are estimated to be 10% at any point.

Materials for which more than one sphere thickness was investigated showed the same general characteristics for the emitted spectra for all thicknesses. Deficiencies that were apparent for spheres with a relatively small radius were amplified for spheres having large radii. This is demonstrated

in Figs. 21(a), (b) and 22(a), (b). For that reason, a single thickness is presented for all but two materials. The thickness used in each case where multiple thicknesses were available was that closest to one mean-free-path for 14-to-15-MeV neutrons.

FIG. 2. Comparison of calculated and experimental neutron spectra at 30° for the 2.1 mfp of D_2O pulsed sphere. The experimental values are designated by the symbol $\bullet$, and the calculated values are designated by the solid line with calculational statistical uncertainties given by the error flags for representative points. Uncertainties in the experimental data are estimated to be 10% at any point.

FIG. 3. Comparison of calculated and experimental neutron spectra at 30° for the 1.0 mfp of ^6Li pulsed sphere. The experimental values are designated by the symbol $\bullet$, and the calculated values are designated by the solid line with calculational statistical uncertainties given by the error flags for representative points. Uncertainties in the experimental data are estimated to be 10% at any point.

FIG. 4. Comparison of calculated and experimental neutron spectra at 30° for the 1.0 mfp of ^7Li pulsed sphere. The experimental values are designated by the symbol $\bullet$, and the calculated values are designated by the solid line with calculational statistical uncertainties given by the error flags for representative points. Uncertainties in the experimental data are estimated to be 10% at any point.

FIG. 5. Comparison of calculated and experimental neutron spectra at 30° for the 1.0 mfp of beryllium pulsed sphere. The experimental values are designated by the symbol $\bullet$, and the calculated values are designated by the solid line with calculational statistical uncertainties given by the error flags for representative points. Uncertainties in the experimental data are estimated to be 10% at any point.

FIG. 6(a). Comparison of calculated and experimental neutron spectra at 30° for the 0.5 mfp of carbon pulsed sphere. The experimental values are designated by the symbol $\bullet$, and the calculated values are designated by the solid line with calculational statistical uncertainties given by the error flags for representative points. Uncertainties in the experimental data are estimated to be 10% at any point.

FIG. 6(b). Comparison of calculated and experimental neutron spectra at 120° for the 0.5 mfp of carbon pulsed sphere. The experimental values are designated by the symbol $\bullet$, and the calculated values are designated by the solid line with calculational statistical uncertainties given by the error flags for representative points. Uncertainties in the experimental data are estimated to be 10% at any point.

FIG. 7. Comparison of calculated and experimental neutron spectra at 30° for the 1.1 mfp of nitrogen pulsed sphere. The experimental values are designated by the symbol $\bullet$, and the calculated values are designated by the solid line with calculational statistical uncertainties given by the error flags for representative points. Uncertainties in the experimental data are estimated to be 10% at any point.

FIG. 8. Comparison of calculated and experimental neutron spectra at 30° for the 0.7 mfp of oxygen pulsed sphere. The experimental values are designated by the symbol ●, and the calculated values are designated by the solid line with calculational statistical uncertainties given by the error flags for representative points. Uncertainties in the experimental data are estimated to be 10% at any point.

FIG. 9. Comparison of calculated and experimental neutron spectra at 30° for the 0.7 mfp of magnesium pulsed sphere. The experimental values are designated by the symbol $\bullet$, and the calculated values are designated by the solid line with calculational statistical uncertainties given by the error flags for representative points. Uncertainties in the experimental data are estimated to be 10% at any point.

FIG. 10. Comparison of calculated and experimental neutron spectra at 120° for the 0.9 mfp of aluminum pulsed sphere. The experimental values are designated by the symbol $\bullet$, and the calculated values are designated by the solid line with calculational statistical uncertainties given by the error flags for representative points. Uncertainties in the experimental data are estimated to be 10% at any point.

FIG. 11. Comparison of calculated and experimental neutron spectra at 30° for the 1.2 mfp of titanium pulsed sphere. The experimental values are designated by the symbol ●, and the calculated values are designated by the solid line with calculational statistical uncertainties given by the error flags for representative points. Uncertainties in the experimental data are estimated to be 10% at any point.

FIG. 12. Comparison of calculated and experimental neutron spectra at 30° for the 0.9 mfp of iron pulsed sphere. The experimental values are designated by the symbol $\bullet$, and the calculated values are designated by the solid line with calculational statistical uncertainties given by the error flags for representative points. Uncertainties in the experimental data are estimated to be 10% at any point.

FIG. 13. Comparison of calculated and experimental neutron spectra at 30° for the 1.0 mfp of copper pulsed sphere. The experimental values are designated by the symbol $\bullet$, and the calculated values are designated by the solid line with calculational statistical uncertainties given by the error flags for representative points. Uncertainties in the experimental data are estimated to be 10% at any point.

FIG. 14. Comparison of calculated and experimental neutron spectra at 30° for the 1.0 mfp of niobium pulsed sphere. The experimental values are designated by the symbol ●, and the calculated values are designated by the solid line with calculational statistical uncertainties given by the error flags for representative points. Uncertainties in the experimental data are estimated to be 10% at any point.

FIG. 15. Comparison of calculated and experimental neutron spectra at 30° for the 1.0 mfp of tin pulsed sphere. The experimental values are designated by the symbol $\bullet$, and the calculated values are designated by the solid line with calculational statistical uncertainties given by the error flags for representative points. Uncertainties in the experimental data are estimated to be 10% at any point.

FIG. 16. Comparison of calculated and experimental neutron spectra at 30° for the 1.0 mfp of tantalum pulsed sphere. The experimental values are designated by the symbol $\bullet$, and the calculated values are designated by the solid line with calculational statistical uncertainties given by the error flags for representative points. Uncertainties in the experimental data are estimated to be 10% at any point.

FIG. 17. Comparison of calculated and experimental neutron spectra at 30° for the 1.0 mfp of wolfram pulsed sphere. The experimental values are designated by the symbol $\bullet$, and the calculated values are designated by the solid line with calculational statistical uncertainties given by the error flags for representative points. Uncertainties in the experimental data are estimated to be 10% at any point.

FIG. 18. Comparison of calculated and experimental neutron spectra at 30° for the 2.0 mfp of gold pulsed sphere. The experimental values are designated by the symbol $\bullet$, and the calculated values are designated by the solid line with calculational statistical uncertainties given by the error flags for representative points. Uncertainties in the experimental data are estimated to be 10% at any point.

FIG. 19. Comparison of calculated and experimental neutron spectra at 30° for the 1.0 mfp of thorium pulsed sphere. The experimental values are designated by the symbol $\bullet$, and the calculated values are designated by the solid line with calculational statistical uncertainties given by the error flags for representative points. Uncertainties in the experimental data are estimated to be 10% at any point.

FIG. 20(a). Comparison of calculated and experimental neutron spectra at 30° for the 1.5 mfp of ^{235}U pulsed sphere. The experimental values are designated by the symbol $\bullet$, and the calculated values are designated by the solid line with calculational statistical uncertainties given by the error flags for representative points. Uncertainties in the experimental data are estimated to be 10% at any point.

FIG. 20(b). Comparison of calculated and experimental neutron spectra at 120° for the 1.5 mfp of ^{235}U pulsed sphere. The experimental values are designated by the symbol $\bullet$, and the calculated values are designated by the solid line with calculational statistical uncertainties given by the error flags for representative points. Uncertainties in the experimental data are estimated to be 10% at any point.

FIG. 21(a). Comparison of calculated and experimental neutron spectra at 30° for the 0.8 mfp of ^{238}U pulsed sphere. The experimental values are designated by the symbol ●, and the calculated values are designated by the solid line with calculational statistical uncertainties given by the error flags for representative points. Uncertainties in the experimental data are estimated to be 10% at any point.

FIG. 21(b). Comparison of calculated and experimental neutron spectra at 30° for the 2.8 mfp of ^{238}U pulsed sphere. The experimental values are designated by the symbol $\bullet$, and the calculated values are designated by the solid line with calculational statistical uncertainties given by the error flags for representative points. Uncertainties in the experimental data are estimated to be 10% at any point.

FIG. 22(a). Comparison of calculated and experimental neutron spectra at 30° for the 0.7 mfp of ^{239}Pu pulsed sphere. The experimental values are designated by the symbol $\bullet$, and the calculated values are designated by the solid line with calculational statistical uncertainties given by the error flags for representative points. Uncertainties in the experimental data are estimated to be 10% at any point.

FIG. 22(b). Comparison of calculated and experimental neutron spectra at 30° for the 1.25 mfp of ^{239}Pu pulsed sphere. The experimental values are designated by the symbol $\bullet$, and the calculated values are designated by the solid line with calculational statistical uncertainties given by the error flags for representative points. Uncertainties in the experimental data are estimated to be 10% at any point.

TABLE 5. Time integrals of emergent neutrons from pulsed spheres.

Material	Thickness, mfp	Angle, deg	Transmission and elastic peak			Nonelastic			Total ~15 to 1.5 MeV		
			Expt(l)	Calc	% Deviation	Expt(l)	Calc	% Deviation	Expt(l)	Calc	% Deviation
H ₂ O	1.9	30	0.310	0.310	0.0	0.225	0.234	+4.0	0.535	0.544	+1.7
D ₂ O	2.1	30	.381	.379	-0.5	0.215	0.247	+14.9	0.596	0.626	+5.2
⁶ Li	1.0	30	.627	.635	+1.3	0.239	0.227	-5.0	0.866	0.862	-0.5
⁷ Li	1.0	30	.646	.648	+0.3	0.258	0.244	-5.4	0.904	0.892	-1.3
Be	1.0	30	.656	.702	+7.0	0.290	0.276	-5.1	0.946	0.978	+3.3
C	0.5	30	.755	.762	+0.9	0.151	0.163	+5.3	0.906	0.925	+2.1
C	0.5	120	.839	.858	+2.3	0.137	0.140	+2.2	0.966	0.998	+3.3
N	1.1	30	.575	.575	0.0	0.220	0.235	+6.8	0.795	0.810	+1.9
O	0.7	30	.695	.662	-4.7	0.208	0.226	+8.7	0.903	0.888	-1.7
Mg	0.7	30	.675	.724	+7.3	0.123	0.134	+8.9	0.798	0.858	+7.5
Al	0.9	120	.648	.630	-2.8	0.258	0.223	-13.6	0.906	0.853	-5.8
Ti	1.2	30	.519	.508	-2.1	0.203	0.207	+2.0	0.722	0.715	-1.0
Fe	0.9	30	.608	.606	-0.3	0.168	0.175	+4.0	0.776	0.781	+0.6
Cu	1.0	30	.632	.645	+2.1	0.362	0.331	-8.6	0.994	0.976	-1.8
Nb	1.0	30	.721	.722	+0.1	0.324	0.298	-8.7	1.045	1.020	-2.5
Sn	1.0	30	.678	.693	+2.2	0.425	0.410	-3.5	1.103	1.103	0.0
Ta	1.0	30	.681	.669	-1.8	0.125	0.108	-13.6	0.777	0.806	+3.6
W	1.0	30	.691	.670	-3.0	0.106	0.137	+29.2	0.797	0.807	+1.3
Au	2.0	30	.427	.437	+2.3	0.525	0.482	-8.2	0.952	0.919	-3.5
Th	1.0	30	.647	.640	-1.1	0.473	0.433	-8.5	1.120	1.073	-4.2
²³⁵ U	1.5	30	.480	.469	-2.3	1.313	1.260	-4.0	1.793	1.729	-3.6
²³⁵ U	1.5	120	.579	.536	-7.4	1.487	1.447	-3.0	2.066	1.978	-4.3
²³⁸ U	0.8	30	.670	.652	-2.7	0.721	0.679	-5.8	1.391	1.331	-4.3
²³⁸ U	2.8	30	.239	.225	-5.9	0.315	0.317	+0.6	0.554	0.542	-2.2
²³⁹ Pu	0.7	30	.689	.686	-0.4	0.689	0.642	-6.8	1.378	1.328	-3.6
²³⁹ Pu	1.25	30	0.521	0.504	-3.3	2.619	2.414	-7.8	3.140	2.918	-7.1

DISCUSSION

Since the upgrading of ENDL evaluations is a continuing process, the information presented in Tables 1 through 5 and Figs. 1 through 22 serves to indicate where work should be done to improve ENDL. From Tables 1 through 4 there is an indication that nickel and copper evaluations should be looked at since critical assemblies having thick reflectors of these materials yield calculated k_{eff} values outside the limits of acceptability. There is, however, another item of information that needs to be added. Both nickel and copper are resonant in the range being tested with these critical assemblies. The Monte Carlo code, TARTNP, that was used for the calculations uses group-averaged cross sections with continuous neutron energies. Where there are resonant energy regions the group cross sections can lead to erroneous answers due to the self-shielding phenomenon. Another Monte Carlo neutronics code, ALICE, uses the probability table method¹¹ to calculate properly in the energy regions where the cross sections are resonant. Results with ALICE give values of k_{eff} of 1.000 for the critical

assembly that is reflected by 4.94 cm of nickel, and 1.009 for the 10.56 cm of copper reflected assembly. There still remains the problem with the cylindrical assembly that is reflected by 2.54 cm of molybdenum. ALICE calculates the same value for k_{eff} as does TARTNP. This is understandable since the resonance region for molybdenum is at lesser neutron energies than for nickel and copper.

The agreement shown in Table 5 and in Figs. 1 through 22 between calculated and experimental data of the LLL pulsed-sphere program ranges from excellent to fair. In general, the integrals under the transmission plus elastic peaks and the total integrals agree well with experiment. Several cases will be examined where deficiencies appear in details of the spectra for times greater than the latest time associated with the peak. In the case of the W sphere, both the detail and the integral of the later-time portion of the spectra are not good. Details of the evaluation for W will be looked at in the near future.

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