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memorandum

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Symbol: X-6:HGH-93-77
Date: January 28, 1993

SUBJECT: Information on the MCPLIB02 Photon Library

A new photon interaction library, MCPLIB02, covering the energy range 1 keV -- 100 GeV for elements Z = 1 -- 94 is now available. This library is the first product arising from my investigations of the Livermore Evaluated Photon Data Library (EPDL).[1] With this memorandum, I present the relevant files, give a brief description of the data, and show the results of some comparisons and tests.

I. Contents of the New Library

The EPDL contains considerably more detail than MCNP is currently prepared to use. For example, the EPDL distinguishes between pair and triplet production cross sections, tabulates real and imaginary anomalous scattering factors, and includes photoelectric subshell cross sections for shells as high-lying as Q1. As a long-term project, it would be desirable to incorporate all of this detail into MCNP. For the first implementation of EPDL data, I have chosen to take a more gradual approach, and have used the EPDL only to extend our existing photon library, leaving the sampling algorithms unchanged. Specifically, I have retained MCPLIB data in the energy range 0.001--10.0 MeV, incorporated the new EPDL data above the maximum energy available in MCPLIB, and made a smooth transition from MCPLIB to EPDL between these limiting energies. The maximum energy in MCPLIB is usually 100 MeV, but for seven elements (Z = 84, 85, 87, 88, 89, 91, and 93) it is 15 MeV.[2] For each element, five blocks of MCPLIB data have been extended. These are the incoherent, coherent, photoelectric, and pair production cross sections, and the heating numbers. The remaining blocks of data (incoherent, coherent, and integrated coherent form factors, and fluorescence data) remain unchanged. Since MCPLIB data are used at low energies, the new database will be backward-compatible with most existing MCNP photon calculations; but high-energy applications up to the limit of the electron data (1 GeV) will now be possible.

Unlike the MCPLIB data, the EPDL uses a different energy grid for tabulating each separate photon cross section. By comparing these various energy grids, I selected an appropriate common grid on which to tabulate all new data above 10 MeV. This grid is based on the EPDL grid for pair production cross sections, both because the pair production energy grid has the greatest resolution, and because pair production is the most important process at high energies. Both the EPDL and the MCPLIB cross-section data (and the MCPLIB heating numbers) rely on logarithmic interpolation to evaluate quantities at energies between tabulated points:

$$\sigma = F(E_1, E_2, \sigma_1, \sigma_2, E) = \exp\left(\frac{\left\{ \ln\left[\frac{E}{E_1}\right]\ln[\sigma_2] + \ln\left[\frac{E_2}{E}\right]\ln[\sigma_1] \right\}}{\ln\left[\frac{E_2}{E_1}\right]}\right). \tag{1}$$

The EPDL also calls for the use of linear interpolation for certain quantities. For present purposes, the important quantities relying on linear interpolation are the average energies ΔE of secondary particles.

My procedure for merging MCPLIB and EPDL data for each element into the new library is as follows. For energies between 1 keV and 10 MeV, the MCPLIB energy grid and data are included unchanged. The maximum energy Emaxavailable in MCPLIB is identified. (Emax is either 15 MeV or 100 MeV.) The maximum energy ε available in MCPLIB was identified. (ε is either 15 MeV or 100 MeV). For energies E in the transition range 10 MeV < E < ε, the MCPLIB cross section σ_E was determined for each process. An interpolated cross section

$$\sigma = F(10.0, \varepsilon, \sigma_M, \sigma_E, E) \tag{2}$$

is used for that process in the new library. Above E_{max}, the EPDL cross section is determined, interpolating as needed, and used unchanged. Whenever a pair cross section must be extracted from the EPDL, the sum of the pair and triplet cross sections is used, since MCPLIB does not separate the two processes. There is no quantity comparable to the MCPLIB heating numbers in the EPDL, so heating numbers are constructed according to the formula

$$H(E) = \frac{\sum_i \Delta E_i(E)\sigma_i(E)}{\sigma_{total}(E)}, \tag{3}$$

where $H(E)$ is an MCPLIB-style heating number as a function of energy E; the summation index i labels the incoherent, photoelectric, pair, and triplet processes; and $\Delta E_i(E)$ is the average secondary electron energy from process i, except in the case of photoelectric absorption, when $\Delta E_i(E)$ also includes the energy of those fluorescent X-rays not explicitly accounted for in the EPDL. Since the EPDL accounts for X-rays from many more shells than does MCPLIB, Eq.3 is not strictly consistent with the MCPLIB heating numbers. Fortunately, at the high energies of present interest, this inconsistency is completely negligible.

I have make one additional enhancement to the new library. For 87 of the 94 elements in MCPLIB, an artificial, small pair production cross section (1 microbarn) is included at the pair production threshold (1.022 MeV). This prevents MCNP's interpolation scheme from returning zero for the pair cross section all the way up to the first real data point (1.5 MeV). The seven elements whose maximum MCPLIB energies were only 15 MeV also lacked this special starting point for the pair cross section. I have inserted an energy point at 1.022 MeV for these seven elements, so that the treatment of pair production is now consistent across the entire database. I derived the other cross sections and heating number at this point by logarithmic interpolation, so that the sampled values for these quantities will not be affected.

II. Comparisons Between MCPLIB and EPDL-based MCPLIB02

In the energy range of interest for the transition from MCPLIB to EPDL, the two photon libraries are in reasonable agreement for the important processes. To make this conclusion more quantitative, I have made a global survey of the two data sets. For each Z 1....94, I identify E_{max}, the maximum energy in the MCPLIB table. Then I distribute 1000 energies, equally spaced in the logarithm, between 10 MeV and Emax . At each energy, for each process (coherent, incoherent, photoelectric, and pair production cross section, and heating number), I find the MCPLIB and EPDL values, σ_M and σ_E, respectively. I calculate the magnitude of the relative difference

$$r=| (\sigma_M - \sigma_E)/ \sigma_E |$$

and retain the maximum value of r for each process over the entire energy range. This is a severe test of the similarity of the two data sets, since only the overall largest relative difference is reported. The results are given in Table I, which shows the maximum relative difference in the range (10 MeV -- E_{max}) for each process as a function of Z. At high energies, the coherent and photoelectric cross sections are negligible compared with the incoherent scattering and pair (plus triplet) production cross sections. In addition, heating numbers are also needed at high energies. For these three significant categories, the two databases agree quite well, with the largest relative differences being 1.2% for the incoherent cross section, 5.3% for the pair (plus triplet) production cross section, and 0.53% for the heating number. The agreement for the coherent cross section, for the 87 elements with ENDF data, is also satisfactory; the maximum relative difference among these elements is only 0.82%. For the seven elements that rely on older data, the agreement is not quite as good; the maximum relative difference is 16%. The photoelectric cross section fares less well, with relative differences as large as 56%. However, the insignificance of the coherent and photoelectric processes at high energies makes these disagreements unimportant.

To reinforce this last statement, I have created Table II, which again shows maximum differences in the range (10 MeV -- E_{max}) as a function of Z. Here, however, the difference between MCPLIB and EPDL is compared not to the EPDL value for the individual process, but to the total cross section. The tabulated quantity is

$$R=| (\sigma_M - \sigma_E)/ \sigma_T |$$

where σ_T is the total cross section from the EPDL library. The relative unimportance of the differences in the coherent and photoelectric cross sections is easily seen in this table. Here the maximum fractional differences are 0.01% for the coherent cross section, 0.786% for the incoherent cross section, 0.0721% for the photoelectric cross section, and 4.37% for the pair plus triplet cross section.

III. Testing the New Library

Since the new photon database is identical to MCPLIB up to 10 MeV (except for the addition of a threshold point for pair production for seven elements), MCNP calculations using the new library should track most old calculations. In fact, using MCPLIB02 with the standard set of 25 test problems results in 24 cases of exact tracking. The sole exception is problem 8, which includes photons with energies higher than 10 MeV. It is initially difficult to judge the consistency of the old and new calculations, because of the poor statistics typical of the short-running test problems. A much longer execution of problems 7 and 8, however, reveals a satisfying similarity between the old and new results. I have shown selected tallies (those dealing with photons and electrons) from the two versions of problem 8 in Table III.

Problem 8 from the test set is not a very severe test of the new library, since very few photons are found in the high-energy regime. It will be important to test the new data as extensively as possible using applications in which the significant aspects of the transport occur at high energies. I am currently undertaking some investigations both to validate the new photon library and to satisfy certain other programmatic tasks, and I hope to report further on these matters in the future.

IV. References

[1]. D. E. Cullen, M. H. Chen, J. H. Hubbell, S. T. Perkins, E. F. Plechaty, J. A. Rathkopf, and J. H. Scofield, “Tables and Graphs of Photon-Interaction Cross Sections from 10 eV to 100 GeV Derived from the LLNL Evaluated Photon Data Library (EPDL),” Lawrence Livermore National Laboratory report UCRL-50400, Vol. 6 (October 31, 1989).

[2]. R. C. Little, “New Photon Library from ENDF Data,” Los Alamos National Laboratory memorandum (February 26, 1982).

Table I: Maximal Relative Differences for All Processes.

Z	Coherent	Incoherent	Photoel.	Pair	Heating
1	1.30E-03	1.20E-02	4.80E-01	2.80E-02	3.70E-03
2	9.20E-04	1.10E-02	5.60E-01	2.40E-02	3.70E-03
3	9.20E-04	1.10E-02	4.10E-01	2.20E-02	3.70E-03
4	1.50E-03	1.10E-02	3.40E-01	2.10E-02	3.70E-03
5	4.60E-04	1.20E-02	2.50E-01	2.10E-02	3.70E-03
6	6.90E-04	1.10E-02	2.20E-01	2.00E-02	3.70E-03
7	8.20E-03	1.20E-02	2.00E-01	2.00E-02	3.60E-03
8	7.60E-03	1.10E-02	1.70E-01	2.00E-02	3.60E-03
9	2.10E-03	1.20E-02	1.60E-01	2.00E-02	3.60E-03
10	1.70E-03	1.20E-02	1.50E-01	2.00E-02	3.70E-03
11	1.70E-03	1.20E-02	1.20E-01	2.00E-02	3.90E-03
12	1.40E-03	1.10E-02	1.10E-01	2.10E-02	4.00E-03
13	8.60E-04	1.10E-02	1.40E-01	2.10E-02	4.00E-03
14	6.20E-04	1.20E-02	1.10E-01	2.10E-02	4.10E-03
15	2.70E-04	1.20E-02	1.00E-01	2.10E-02	4.20E-03
16	2.10E-04	1.20E-02	1.00E-01	2.10E-02	4.30E-03
17	4.10E-04	1.20E-02	9.70E-02	2.10E-02	4.30E-03
18	4.60E-04	1.10E-02	8.80E-02	2.10E-02	4.30E-03
19	1.90E-04	1.10E-02	6.10E-02	2.10E-02	4.40E-03
20	5.60E-04	1.10E-02	1.10E-01	2.10E-02	4.40E-03
21	9.30E-04	1.20E-02	5.30E-02	2.10E-02	4.50E-03
22	1.30E-03	1.20E-02	7.70E-02	2.10E-02	4.50E-03
23	1.70E-03	1.10E-02	1.10E-01	2.10E-02	4.50E-03
24	1.80E-03	1.10E-02	1.20E-01	2.00E-02	4.40E-03
25	2.00E-03	1.10E-02	1.00E-01	2.00E-02	4.50E-03
26	2.10E-03	1.10E-02	1.10E-01	2.00E-02	4.50E-03
27	2.20E-03	1.20E-02	7.00E-02	2.00E-02	4.50E-03
28	2.30E-03	1.20E-02	8.30E-02	2.00E-02	4.60E-03
29	2.30E-03	1.20E-02	1.10E-01	2.10E-02	4.60E-03
30	2.10E-03	1.20E-02	6.80E-02	2.10E-02	4.60E-03
31	1.90E-03	1.10E-02	2.20E-02	2.10E-02	4.70E-03
32	1.90E-03	1.10E-02	2.30E-02	2.20E-02	4.70E-03
33	1.50E-03	1.10E-02	2.30E-02	2.30E-02	4.70E-03
34	1.20E-03	1.20E-02	3.00E-02	2.30E-02	4.70E-03
35	1.10E-03	1.20E-02	2.90E-02	2.40E-02	4.80E-03
36	9.60E-04	1.20E-02	2.00E-02	2.40E-02	4.80E-03
37	5.50E-04	1.20E-02	3.00E-02	2.40E-02	4.80E-03
38	4.80E-04	1.20E-02	3.30E-02	2.50E-02	4.80E-03
39	6.50E-04	1.20E-02	2.30E-02	2.50E-02	4.80E-03
40	6.40E-04	1.20E-02	3.40E-02	2.50E-02	4.80E-03
41	5.90E-04	1.10E-02	6.10E-02	2.50E-02	4.80E-03
42	6.60E-04	1.10E-02	3.30E-02	2.60E-02	4.80E-03
43	7.50E-04	1.10E-02	3.50E-02	2.60E-02	4.80E-03
44	7.90E-04	1.20E-02	4.00E-02	2.70E-02	4.80E-03
45	7.20E-04	1.20E-02	4.40E-02	2.80E-02	4.90E-03
46	6.20E-04	1.20E-02	2.80E-02	2.80E-02	4.90E-03
47	4.30E-04	1.20E-02	5.80E-02	2.90E-02	4.90E-03
48	2.90E-04	1.20E-02	3.80E-02	2.90E-02	4.90E-03
49	3.60E-04	1.10E-02	2.80E-02	3.00E-02	4.90E-03
50	4.20E-04	1.10E-02	5.40E-02	3.00E-02	4.90E-03
51	6.10E-04	1.10E-02	7.60E-02	3.10E-02	4.90E-03
52	9.00E-04	1.10E-02	5.60E-02	3.10E-02	4.90E-03
53	1.20E-03	1.10E-02	4.10E-02	3.20E-02	4.90E-03
54	1.20E-03	1.10E-02	5.90E-02	3.20E-02	4.90E-03
55	1.30E-03	1.10E-02	5.20E-02	3.30E-02	4.90E-03

56	1.50E-03	1.10E-02	6.20E-02	3.30E-02	4.90E-03
57	1.50E-03	1.10E-02	4.50E-02	3.40E-02	4.90E-03
58	1.50E-03	1.10E-02	6.50E-02	3.40E-02	4.90E-03
59	1.70E-03	1.10E-02	4.80E-02	3.50E-02	4.90E-03
60	1.60E-03	1.20E-02	4.00E-02	3.50E-02	5.00E-03
61	1.30E-03	1.10E-02	4.60E-02	3.50E-02	4.90E-03
62	1.30E-03	1.10E-02	4.80E-02	3.60E-02	4.90E-03
63	1.30E-03	1.10E-02	4.50E-02	3.60E-02	4.90E-03
64	1.20E-03	1.10E-02	4.90E-02	3.60E-02	4.90E-03
65	8.80E-04	1.20E-02	4.70E-02	3.70E-02	5.00E-03
66	8.10E-04	1.10E-02	4.50E-02	3.70E-02	4.90E-03
67	6.20E-04	1.20E-02	5.90E-02	3.70E-02	4.90E-03
68	5.20E-04	1.10E-02	4.00E-02	3.80E-02	4.90E-03
69	7.80E-04	1.10E-02	3.80E-02	3.80E-02	4.90E-03
70	9.70E-04	1.10E-02	3.00E-02	3.80E-02	4.90E-03
71	1.00E-03	1.10E-02	3.40E-02	3.80E-02	4.90E-03
72	1.20E-03	1.10E-02	6.10E-02	3.80E-02	4.90E-03
73	1.50E-03	1.10E-02	5.60E-02	3.80E-02	4.90E-03
74	1.60E-03	1.10E-02	9.10E-02	3.80E-02	4.90E-03
75	1.80E-03	1.10E-02	6.80E-02	3.80E-02	4.80E-03
76	2.00E-03	1.10E-02	3.20E-02	3.80E-02	4.90E-03
77	1.90E-03	1.20E-02	3.00E-02	3.80E-02	4.80E-03
78	2.10E-03	1.20E-02	3.60E-02	3.80E-02	4.80E-03
79	2.20E-03	1.20E-02	3.40E-02	3.80E-02	4.80E-03
80	2.10E-03	1.20E-02	3.80E-02	3.80E-02	4.80E-03
81	2.10E-03	1.20E-02	5.50E-02	3.80E-02	4.80E-03
82	1.80E-03	1.20E-02	9.00E-02	3.80E-02	4.80E-03
83	1.80E-03	1.10E-02	4.50E-02	3.80E-02	4.70E-03
84	1.30E-01	6.70E-03	1.90E-02	5.20E-02	5.30E-03
85	1.40E-01	7.40E-03	2.20E-02	4.90E-02	5.10E-03
86	1.60E-03	1.20E-02	3.20E-02	3.90E-02	4.70E-03
87	1.40E-01	6.00E-03	2.60E-02	4.80E-02	5.10E-03
88	1.40E-01	6.00E-03	2.10E-02	4.90E-02	5.00E-03
89	1.50E-01	6.70E-03	2.40E-02	4.90E-02	5.00E-03
90	8.30E-04	1.20E-02	4.60E-02	3.90E-02	4.70E-03
91	1.50E-01	8.80E-03	2.90E-02	5.30E-02	5.10E-03
92	5.20E-04	1.10E-02	6.30E-02	3.90E-02	4.60E-03
93	1.60E-01	6.20E-03	2.90E-02	4.70E-02	4.80E-03
94	1.10E-03	1.10E-02	4.30E-02	3.80E-02	4.50E-03

Table II: Maximal Differences as Fractions of the Total Cross Section.

Z	Coherent	Incoherent	Photoel.	Pair
1	1.99E-10	7.86E-03	7.37E-10	8.06E-03
2	2.28E-09	6.52E-03	1.76E-08	7.77E-03
3	3.59E-09	5.86E-03	6.72E-08	5.78E-03
4	1.23E-08	5.36E-03	1.76E-07	5.34E-03
5	2.80E-09	5.14E-03	3.07E-07	5.93E-03
6	1.02E-08	4.51E-03	5.38E-07	6.92E-03
7	1.91E-07	4.28E-03	8.55E-07	7.12E-03
8	2.15E-07	3.82E-03	1.20E-06	7.31E-03
9	7.17E-08	3.86E-03	1.69E-06	7.88E-03
10	6.92E-08	3.57E-03	2.34E-06	8.46E-03
11	7.50E-08	3.69E-03	2.56E-06	9.06E-03
12	6.38E-08	3.15E-03	3.33E-06	9.58E-03
13	3.77E-08	3.11E-03	5.49E-06	1.02E-02
14	2.42E-08	3.18E-03	5.37E-06	1.05E-02
15	2.59E-09	3.04E-03	6.30E-06	1.08E-02
16	1.67E-08	2.94E-03	7.90E-06	1.11E-02
17	3.61E-08	2.84E-03	9.32E-06	1.14E-02
18	4.31E-08	2.61E-03	1.02E-05	1.17E-02
19	6.21E-09	2.51E-03	8.14E-06	1.19E-02
20	3.61E-08	2.46E-03	1.85E-05	1.22E-02
21	7.66E-08	2.61E-03	9.86E-06	1.22E-02
22	1.24E-07	2.50E-03	1.75E-05	1.22E-02
23	1.79E-07	2.24E-03	2.95E-05	1.26E-02
24	2.04E-07	2.18E-03	3.68E-05	1.26E-02
25	2.47E-07	2.16E-03	3.66E-05	1.27E-02
26	2.81E-07	2.14E-03	4.44E-05	1.24E-02
27	3.01E-07	2.14E-03	3.15E-05	1.30E-02
28	3.33E-07	2.16E-03	4.16E-05	1.33E-02
29	3.43E-07	2.05E-03	6.14E-05	1.39E-02
30	3.28E-07	2.15E-03	4.18E-05	1.42E-02
31	3.01E-07	1.94E-03	1.51E-05	1.43E-02
32	2.99E-07	1.83E-03	1.73E-05	1.52E-02
33	2.33E-07	1.81E-03	1.19E-05	1.55E-02
34	1.78E-07	1.91E-03	2.67E-05	1.59E-02
35	1.74E-07	1.85E-03	2.78E-05	1.66E-02
36	1.40E-07	1.81E-03	1.94E-05	1.67E-02
37	5.04E-08	1.77E-03	1.29E-05	1.71E-02
38	4.03E-08	1.79E-03	4.11E-05	1.77E-02
39	3.42E-08	1.76E-03	2.23E-05	1.78E-02
40	3.65E-08	1.64E-03	4.93E-05	1.83E-02
41	3.14E-08	1.54E-03	9.32E-05	1.84E-02
42	5.51E-08	1.52E-03	5.47E-05	1.88E-02
43	8.79E-08	1.55E-03	2.37E-05	1.94E-02
44	1.10E-07	1.54E-03	2.97E-05	1.99E-02
45	1.02E-07	1.57E-03	3.60E-05	2.06E-02
46	8.20E-08	1.58E-03	2.85E-05	2.11E-02
47	3.46E-08	1.57E-03	1.31E-04	2.15E-02
48	1.79E-08	1.56E-03	3.59E-05	2.20E-02
49	5.25E-08	1.35E-03	3.74E-05	2.24E-02
50	5.90E-08	1.33E-03	1.44E-04	2.29E-02
51	1.01E-07	1.32E-03	1.05E-04	2.35E-02
52	1.84E-07	1.32E-03	7.17E-05	2.39E-02
53	2.85E-07	1.28E-03	4.88E-05	2.44E-02

54	2.80E-07	1.26E-03	8.30E-05	2.50E-02
55	3.10E-07	1.26E-03	7.21E-05	2.55E-02
56	3.78E-07	1.24E-03	9.56E-05	2.60E-02
57	3.94E-07	1.21E-03	6.49E-05	2.64E-02
58	3.87E-07	1.18E-03	1.10E-04	2.67E-02
59	4.65E-07	1.18E-03	7.80E-05	2.71E-02
60	4.32E-07	1.27E-03	6.14E-05	2.74E-02
61	3.57E-07	1.15E-03	7.90E-05	2.79E-02
62	3.41E-07	1.14E-03	8.45E-05	2.82E-02
63	3.71E-07	1.13E-03	8.02E-05	2.86E-02
64	3.14E-07	1.15E-03	9.29E-05	2.89E-02
65	2.05E-07	1.19E-03	9.23E-05	2.92E-02
66	1.78E-07	1.11E-03	8.98E-05	2.95E-02
67	1.20E-07	1.18E-03	1.33E-04	2.96E-02
68	9.61E-08	1.08E-03	9.68E-05	3.01E-02
69	4.80E-08	1.08E-03	1.13E-04	3.04E-02
70	1.27E-07	1.07E-03	1.74E-04	3.05E-02
71	1.40E-07	1.06E-03	1.64E-04	3.04E-02
72	2.28E-07	1.07E-03	1.61E-04	3.09E-02
73	3.76E-07	1.04E-03	4.25E-04	3.11E-02
74	4.39E-07	1.05E-03	7.21E-04	3.11E-02
75	5.20E-07	1.03E-03	2.17E-04	3.09E-02
76	6.67E-07	1.03E-03	2.68E-04	3.12E-02
77	6.14E-07	1.08E-03	2.67E-04	3.08E-02
78	7.21E-07	1.06E-03	2.80E-04	3.13E-02
79	7.80E-07	1.06E-03	2.08E-04	3.11E-02
80	7.60E-07	1.09E-03	1.94E-04	3.09E-02
81	7.82E-07	1.07E-03	3.20E-04	3.10E-02
82	6.82E-07	1.10E-03	6.38E-04	3.10E-02
83	6.61E-07	9.74E-04	2.35E-04	3.13E-02
84	7.50E-05	1.13E-03	1.19E-04	4.24E-02
85	7.77E-05	1.15E-03	1.41E-04	3.93E-02
86	6.13E-07	1.05E-03	3.35E-04	3.20E-02
87	8.22E-05	1.01E-03	1.78E-04	3.89E-02
88	8.47E-05	9.09E-04	1.47E-04	3.96E-02
89	8.81E-05	1.01E-03	1.71E-04	4.06E-02
90	2.72E-07	1.02E-03	2.35E-04	3.25E-02
91	9.35E-05	1.31E-03	2.22E-04	4.37E-02
92	1.35E-07	9.41E-04	2.85E-04	3.25E-02
93	1.00E-04	9.84E-04	2.35E-04	3.84E-02
94	4.95E-07	9.07E-04	2.26E-04	3.13E-02

Table III: Selected Tallies from Test Problem 8

Old Photon Library			New Photon Library		
tally 14			tally 14		
cell 7			cell 7		
energy			energy		
1.0000E-01	1.84487E-10	0.1847	1.0000E-01	1.84506E-10	0.1847
1.0000E+00	5.93596E-09	0.1017	1.0000E+00	6.13097E-09	0.1055
1.0000E+01	1.16635E-08	0.0702	1.0000E+01	1.16579E-08	0.0702
1.0000E+02	2.44636E-11	0.0600	1.0000E+02	2.44809E-11	0.0600
total	1.78084E-08	0.0643	total	1.79978E-08	0.0650
tally 15			tally 15		
total			total		
2.30869E-08	0.1569		2.31866E-08	0.1564	
uncollided			uncollided		
1.63878E-08	0.2089		1.65034E-08	0.2077	
tally 26			tally 26		
cell: 6			cell: 6		
energy			energy		
1.0000E-02	3.97447E-13	0.1417	1.0000E-02	3.97447E-13	0.1417
1.0000E-01	9.27573E-12	0.1049	1.0000E-01	9.27544E-12	0.1049
1.0000E+00	7.97194E-11	0.1094	1.0000E+00	7.97709E-11	0.1094
5.0000E+00	7.09343E-10	0.1067	5.0000E+00	7.35742E-10	0.1093
1.0000E+01	4.28407E-10	0.1145	1.0000E+01	4.28435E-10	0.1145
2.0000E+01	1.59890E-11	0.0395	2.0000E+01	1.59911E-11	0.0395
total	1.24313E-09	0.0808	total	1.26961E-09	0.0822
cell: 7			cell: 7		
energy			energy		
1.0000E-02	1.16693E-13	0.3619	1.0000E-02	1.16693E-13	0.3619
1.0000E-01	3.81103E-12	0.2436	1.0000E-01	3.81088E-12	0.2436
1.0000E+00	7.81185E-11	0.0975	1.0000E+00	8.00518E-11	0.0998
5.0000E+00	5.73599E-10	0.1109	5.0000E+00	5.73405E-10	0.1109
1.0000E+01	1.52313E-10	0.1483	1.0000E+01	1.52312E-10	0.1483

2.0000E+01	5.40356E-12	0.0596	2.0000E+01	5.40890E-12	0.0595
total	8.13361E-10	0.0873	total	8.15106E-10	0.0872

tally 24 cell 7 energy			tally 24 cell 7 energy		
1.0000E-02	3.85743E-12	0.2196	1.0000E-02	3.84604E-12	0.2202
1.0000E-01	3.05849E-11	0.2015	1.0000E-01	3.06428E-11	0.2012
1.0000E+00	2.37711E-10	0.2580	1.0000E+00	2.36864E-10	0.2589
1.0000E+01	2.71241E-10	0.3894	1.0000E+01	2.71270E-10	0.3894
1.0000E+02	8.94309E-15	0.2392	1.0000E+02	8.94309E-15	0.2392
1.0000E+03	0.00000E+00	0.0000	1.0000E+03	0.00000E+00	0.0000
total	5.43403E-10	0.3132	total	5.42631E-10	0.3137