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SUBJECT: Recommended Photon Production Data for Thermal Neutron Capture in Copper Isotopes

I. Introduction

This research note assesses the photon production data at incident thermal neutron energies for the two stable isotopes of copper. As with previous research notes (see for example XTM-RN(U)97-020,[1] XTM-RN(U)97-010,[2] and XCI-RN(U)97-031[3]), this work is motivated primarily by the ACTI CRADA,[4] which requires high-quality photon production data at thermal energies. For a more complete background on this project and the motivation behind this work see the research note XTM-RN(U)97-008.[5]

The purpose of this research note is to present the best possible thermal-neutron capture spectrum for each stable isotope of copper. These spectra will be referred to as the "recommended ACTI spectra." To accomplish this task, several sources of data were analyzed; standard ENDF/B-VI,[6] ENSDF,[7] the preliminary ACTI data produced by T-2, and experimental papers.

The Evaluated Nuclear Data File (ENDF/B-VI) photon production data for the copper isotopes contain no discrete gamma-ray information. The photon production data are binned in 200 keV-wide (or greater) energy bins, and are not useful for isotope identification. Therefore ENDF/B-VI will not be considered further in this paper. Data compilations such as Lone[8] and Orphan[9] (which are identical for copper) contain only elemental information and provide about six times fewer gamma-rays than recent experimental papers. These two compilations were also shown to be inferior to experimental papers in a similar analysis of chlorine (see XTM-RN(U)97-008[5]). Since we are interested in providing isotopic spectra that are as complete as possible, data compilations such as these will also not be discussed further. Because the preliminary ACTI data for the copper isotopes was based on Orphan[9] it will also not be presented here. This research note will therefore compare the ENSDF data and experimental papers in detail to derive the best possible spectra.

The ENSDF spectra were extracted from the National Nuclear Data Center (NNDC) online data retrieval service (accessed by following the NNDC Online Data Service link at the URL "http://www.nndc.bnl.gov/"). The experimental papers compared in this research note were obtained through an exhaustive search process. First, searches employing many different sets of keywords were performed using LANL's SciSearch. All

available years (1974-1997) were repeatedly searched. Second, the “Recent References” sections of all volumes of Nuclear Data Sheets from the present back to 1966 were combed. Third, the Nuclear Science References (NSR) section of the National Nuclear Data Center’s online data service was extensively searched. Finally, all papers found were in turn searched for additional references. Papers published prior to 1968 were not sought since the best and most detailed spectral data for each isotope were likely contained in more recent papers.

The natural abundances, thermal-neutron radiative capture cross-sections (σ^{th}), relative contributions to the thermal gamma-ray spectrum of natural copper, and Q-values for thermal neutron capture are listed in Table 1 for the stable copper isotopes. Each isotope will now be discussed in turn.

Table 1: The stable isotopes of copper

Isotope	Natural Abundance (Atom Fraction)	σ^{th} (barns)[a]	Contribution to Thermal Natural Cu Spectrum	Q-Value for Neutron Capture (keV)[b]
^{63}Cu	0.6917	4.47	82.2%	7915.96
^{65}Cu	0.3083	2.17	17.8%	7065.93

[a]Values taken from “Chart of the Nuclides”.[10]
[b]Values taken from Audi.[11]

II. ^{63}Cu

A. Comparison of Data

The search for experimental data resulted in only four recent papers containing appreciable amounts of thermal-neutron capture data for ^{63}Cu. Brief information for each data set as well as the ENSDF data for ^{63}Cu is listed in Table 2. Included in Table 2 are the designations that will be used to refer to each data set, the date and number of gamma-rays in each paper, and the total gamma-ray yields per neutron capture.

Table 2: Summary of data sources for ^{63}Cu

Author(s)	Designation	Year	Number of gamma-rays	Total Yield (keV)
M. G. Delfini et al.[12]	Del83	1983	322	7916.37
B. Maier et al.[13]	Mai68	1968	40	---[a]
E. Shera and H. Bolotin[14]	She68	1968	67	6399.76
R. Alves et al.[15]	Alv69	1969	28	6173.75
ENSDF[7]	ENSDF	1983[b]	325	7940.78

[a]Intensities were not listed for all gamma-rays.
[b]The latest paper referenced in the evaluation is Del83.

Of all the papers found for ^{63}Cu, the measurements of Del83 are by far the most recent and comprehensive. Del83 refers to the older experiments as “exploratory measurements” with poor detector resolutions, although the resolutions available to the other experimenters are not clear from the documentation. The measurements of Del83 were performed at two different facilities, the High Flux Reactor in Petten, The Netherlands, and the High Flux Beam Reactor at Brookhaven National Laboratory. In the Petten measurements, a metallic target highly enriched in ^{63}Cu and housed in a teflon container was used. In the Brookhaven measurements, a CuO target highly enriched in ^{63}Cu and housed in an aluminum container was used. Since each facility had a considerably different experimental set-up, and different target fabrications were used, the background spectra were substantially different at the two sites. By comparing the spectra from each site, the experimenters were able to very accurately determine which gamma-rays were from copper and which were from background sources. Only Del83 performed experiments at two different sites. Of the 322 gamma-rays measured, Del83 was able to place 299 of them in the ^{64}Cu level scheme, far more than any other source.

Even though Del83 represents the best experimental data overall, it was compared to all the other spectra to try and identify any specific problems with it. Two indications of problems were sought. First, gamma-rays seen by two or more experimenters but *not* by Del83 could indicate a missed line in the Del83 spectrum. Second, two or more experimenters in agreement with each other *and* in disagreement with Del83 (either gamma-ray energy or intensity) could indicate an erroneous value in Del83. The spectrum from each ^{63}Cu data source is listed in Table 3.

A careful examination of Table 3 reveals no significant problems with Del83. There are no gamma-rays observed by two or more experimenters but *not* Del83. There is only one gamma-ray for which a majority of the other authors agree well but disagree with Del83; the 6015.7 keV gamma-ray. For the 6015.7 keV gamma-ray, Mai68 and Alv69 measured intensities of 1.7 and 2.0, respectively, compared to only 0.229 by Del83. However, Del83 also observed a gamma-ray at 6010.83 keV with an intensity of 1.59. Since the detector resolutions of Mai68 and Alv69 were about 5 keV, it is likely they measured the combined intensity of the 6010.83 and 6015.7 keV lines. The sum of the Del83 intensities of these two lines is 1.819, which agrees well with the other authors’ measurements.

Finally, a few remarks about the ENSDF spectrum will be made. The vast majority of the ENSDF data is identical to Del83. For some low-energy gamma-rays ENSDF adopts the energy values from Mai68, but it is not clear why ENSDF adopts some Mai68 values and not others. However, all of the Mai68 energies adopted agree within experimental uncertainty of their corresponding Del83 values. Also, ENSDF includes two lines observed only by She68, the 5824 and 6553 keV lines. Again, it is not clear why ENSDF included these two lines observed only by She68 but not others. The ENSDF documentation indicates both of these lines are tentative inclusions. ENSDF also includes a gamma-ray that was not identified in any data source we examined, the 1074.49 keV line. The ENSDF documentation does not indicate who measured this gamma-ray.

Table 3: Comparison of thermal-neutron capture spectra for ^{63}Cu

Del83		She68		Mai68		Alv69		ENSDF	
Eγ (keV)	Iγ[a]	Eγ (keV)	Iγ[a]	Eγ (keV)	Iγ[a]	Eγ (keV)	Iγ[a]	Eγ (keV)	Iγ[a]
159.34	15.2	159.2	10.5	159.280	----	----	----	159.280	15.0
184.76	0.19	184.6	0.2	184.612	----	----	----	184.612	0.19
192.53	0.177	----	----	----	----	----	----	192.53	0.177
203.01	4.9	202.7	3.5	202.948	----	----	----	202.948	4.9
212.400	1.04	212.1	0.6	----	----	----	----	212.388	1.04
214.97	0.31	----	----	----	----	----	----	214.97	0.31
247.58	0.33	----	----	----	----	----	----	247.58	0.33
261.33	0.264	----	----	----	----	----	----	261.33	0.264
264.911	0.81	264.9	0.7	264.882	----	----	----	264.882	0.81
278.29	24	278.1	19.5	278.244	----	----	----	278.244	24
291.71	0.055	----	----	----	----	----	----	291.71	0.055
318.9	0.30	----	----	319.05	----	----	----	318.9	0.30
320.7	0.18	320.0	0.6	----	----	----	----	320.7	0.18
330.6	0.25	330.2	1.0	330.466	----	----	----	330.47	0.25
343.94	5.9	343.8	4.5	343.932	----	----	----	343.94	5.9
362.30	0.116	----	----	362.07	----	----	----	362.30	0.116
376.851	0.70	376.8	0.5	----	----	----	----	376.851	0.70
381.34	0.215	----	----	----	----	----	----	381.34	0.215
384.74	1.52	384.6	2.0	384.67	----	----	----	384.74	1.52
395.28	0.106	395.2	0.1	395.20	----	----	----	395.28	0.106
427.4	0.020	----	----	----	----	----	----	427.4	0.020
440.13	0.069	----	----	----	----	----	----	440.13	0.069
449.512	1.07	449.4	0.9	449.423	----	----	----	449.512	1.07
460.792	0.377	460.5	0.2	460.74	----	----	----	460.792	0.377
467.992	1.81	467.9	1.3	----	----	----	----	467.992	1.81
494.852	0.66	495.2	0.7	----	----	----	----	494.852	0.66
503.7	1.6	503.5	2.3	503.64	----	----	----	503.65	1.6
532.94	0.17	533.9	0.6	----	----	----	----	532.94	0.17
534.11	0.72	----	----	----	----	----	----	534.11	0.72
565.43	0.060	558.4	0.1	----	----	----	----	565.43	0.060
579.753	2.48	579.7	2.4	579.708	----	----	----	579.753	2.48
583.22	0.140	----	----	----	----	----	----	583.22	0.140
587.0	0.041	595.3	0.1	----	----	----	----	587.0	0.041
608.75	7.8	608.7	7.1	608.91	----	----	----	608.75	7.8

Table 3: Comparison of thermal-neutron capture spectra for ^{63}Cu (Continued)

Del83		She68		Mai68		Alv69		ENSDF	
Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]
617.433	0.742	616.9	0.8	----	----	----	----	617.433	0.742
625.35	0.147	----	----	----	----	----	----	625.35	0.147
632.34	0.255	----	----	----	----	----	----	632.34	0.255
634.78	0.089	----	----	----	----	----	----	634.78	0.089
648.80	2.86	648.6	2.7	648.76	----	----	----	648.80	2.86
663.06	2.03	662.9	1.9	663.06	----	----	----	663.06	2.03
689.08	0.168	----	----	----	----	----	----	689.08	0.168
695.41	0.059	----	----	----	----	----	----	695.41	0.059
711.94	0.096	----	----	----	----	----	----	711.94	0.096
736.52	0.075	----	----	----	----	----	----	736.52	0.075
739.12	0.267	----	----	738.2	----	----	----	739.12	0.267
747.34	0.112	----	----	----	----	----	----	747.34	0.112
767.795	0.679	767.8	0.6	768.10	----	----	----	767.795	0.679
775.9	0.018	----	----	----	----	----	----	775.9	0.018
779.65	0.099	----	----	----	----	----	----	779.65	0.099
782.29	0.051	----	----	----	----	----	----	782.29	0.051
804.29	0.048	----	----	----	----	----	----	804.29	0.048
814.45	0.225	814.3	0.2	----	----	----	----	814.45	0.225
822.33	0.104	----	----	----	----	----	----	822.33	0.104
831.176	0.243	----	----	----	----	----	----	831.176	0.243
846.87	0.123	----	----	----	----	----	----	846.87	0.123
858.09	0.107	859.6	0.3	----	----	----	----	858.09	0.107
878.277	1.016	878.5	1.1	----	----	----	----	878.277	1.016
890.26	0.161	----	----	----	----	----	----	890.26	0.161
897.06	0.286	896.6	0.2	----	----	----	----	897.06	0.286
912.37	0.097	----	----	----	----	----	----	912.37	0.097
924.91	0.170	----	----	----	----	----	----	924.91	0.170
927.05	0.331	926.8	0.4	----	----	----	----	927.05	0.331
937.01	0.127	----	----	----	----	----	----	937.01	0.127
946.64	0.188	946.8	0.3	----	----	----	----	946.64	0.188
953.97	0.118	----	----	----	----	----	----	953.97	0.118
957.27	0.147	----	----	----	----	----	----	957.27	0.147
960.63	0.180	959.7	0.7	----	----	----	----	960.63	0.180
962.68	0.426	----	----	----	----	----	----	962.68	0.426
974.17	0.138	----	----	----	----	----	----	974.17	0.138
992.11	0.085	----	----	----	----	----	----	992.11	0.085

Table 3: Comparison of thermal-neutron capture spectra for ^{63}Cu (Continued)

Del83		She68		Mai68		Alv69		ENSDF	
Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]
998.28	0.207	----	----	----	----	----	----	998.28	0.207
1009.35	0.186	----	----	----	----	----	----	1009.35	0.186
1019.59	0.390	----	----	----	----	----	----	1019.59	0.390
1032.68	0.043	----	----	----	----	----	----	1032.68	0.043
1059.95	0.086	----	----	----	----	----	----	1059.95	0.086
----	----	----	----	----	----	----	----	1074.49	0.068
1076.35	0.275	----	----	----	----	----	----	1076.35	0.275
1081.74	0.321	1080.3	0.9	----	----	----	----	1081.74	0.321
1119.55	0.036	----	----	----	----	----	----	1119.55	0.036
1127.84	0.236	----	----	----	----	----	----	1127.84	0.236
1136.59	0.181	----	----	----	----	----	----	1136.59	0.181
1138.821	0.823	1138.2	0.9	----	----	----	----	1138.821	0.823
1158.831	0.747	1158.7	0.5	----	----	----	----	1158.831	0.747
1165.21	0.120	----	----	----	----	----	----	1165.21	0.120
1177.04	0.033	----	----	----	----	----	----	1177.04	0.033
1194.89	0.291	1195.7	0.3	----	----	----	----	1194.89	0.291
1198.75	0.069	----	----	----	----	----	----	1198.75	0.069
1220.84	0.205	----	----	----	----	----	----	1220.84	0.205
1232.13	0.307	----	----	----	----	----	----	1232.13	0.307
1241.50	0.55	----	----	----	----	----	----	1241.50	0.55
1242.56	0.50	1242.5	0.8	----	----	----	----	1242.56	0.50
1250.45	0.088	----	----	----	----	----	----	1250.45	0.088
----	----	1262.2	1.2	----	----	----	----	----	----
1279.41	0.194	----	----	----	----	----	----	1279.41	0.194
1287.40	0.035	----	----	----	----	----	----	1287.40	0.035
1293.92	0.069	----	----	----	----	----	----	1293.92	0.069
1298.134	0.408	----	----	----	----	----	----	1298.134	0.408
1303.90	0.066	----	----	----	----	----	----	1303.90	0.066
1316.24	0.108	----	----	----	----	----	----	1316.24	0.108
1320.315	0.732	----	----	----	----	----	----	1320.315	0.732
1327.62	0.067	----	----	----	----	----	----	1327.62	0.067
1339.88	0.226	----	----	----	----	----	----	1339.88	0.226
1354.68	0.052	----	----	----	----	----	----	1354.68	0.052
1361.76	0.467	----	----	----	----	----	----	1361.76	0.467
1391.25	0.077	----	----	----	----	----	----	1391.25	0.077
1398.70	0.083	----	----	----	----	----	----	1398.70	0.083

Table 3: Comparison of thermal-neutron capture spectra for ^{63}Cu (Continued)

Del83		She68		Mai68		Alv69		ENSDF	
Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]
1401.66	0.079	----	----	----	----	----	----	1401.66	0.079
1407.08	0.089	----	----	----	----	----	----	1407.08	0.089
1417.27	0.270	----	----	----	----	----	----	1417.27	0.270
1428.17	0.058	----	----	----	----	----	----	1428.17	0.058
1435.3	0.021	----	----	----	----	----	----	1435.3	0.021
1438.75	0.133	----	----	----	----	----	----	1438.75	0.133
1447.69	0.193	----	----	----	----	----	----	1447.69	0.193
1476.10	0.179	----	----	----	----	----	----	1476.10	0.179
1481.75	0.060	----	----	----	----	----	----	1481.75	0.060
1484.85	0.045	----	----	----	----	----	----	1484.85	0.045
1499.54	0.143	----	----	----	----	----	----	1499.54	0.143
1501.94	0.087	----	----	----	----	----	----	1501.94	0.087
1508.68	0.115	----	----	----	----	----	----	1508.68	0.115
1521.20	0.396	----	----	----	----	----	----	1521.20	0.396
1535.70	0.053	----	----	----	----	----	----	1535.70	0.053
1541.56	0.053	----	----	----	----	----	----	1541.56	0.053
1556.84	0.099	----	----	----	----	----	----	1556.84	0.099
1560.94	0.114	----	----	----	----	----	----	1560.94	0.114
1570.22	0.045	----	----	----	----	----	----	1570.22	0.045
1574.36	0.223	----	----	----	----	----	----	1574.36	0.223
1594.42	0.122	----	----	----	----	----	----	1594.42	0.122
1619.24	0.245	----	----	----	----	----	----	1619.24	0.245
1630.1	0.051	----	----	----	----	----	----	1630.1	0.051
1641.70	0.053	----	----	----	----	----	----	1641.70	0.053
1649.52	0.083	----	----	----	----	----	----	1649.52	0.083
1670.92	0.163	----	----	----	----	----	----	1670.92	0.163
1683.09	0.476	----	----	----	----	----	----	1683.09	0.476
1729.70	0.079	----	----	----	----	----	----	1729.70	0.079
1742.83	0.089	----	----	----	----	----	----	1742.83	0.089
1747.3	0.055	----	----	----	----	----	----	1747.3	0.055
1761.01	0.083	----	----	----	----	----	----	1761.01	0.083
1782.20	0.197	----	----	----	----	----	----	1782.20	0.197
1790.30	0.041	----	----	----	----	----	----	1790.30	0.041
1799.48	0.127	----	----	----	----	----	----	1799.48	0.127
1808.5	0.036	----	----	----	----	----	----	1808.5	0.036
1826.2	0.024	----	----	----	----	----	----	1826.2	0.024

Table 3: Comparison of thermal-neutron capture spectra for ^{63}Cu (Continued)

Del83		She68		Mai68		Alv69		ENSDF	
Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]
1830.34	0.089	----	----	----	----	----	----	1830.34	0.089
1834.22	0.083	----	----	----	----	----	----	1834.22	0.083
1844.67	0.049	----	----	----	----	----	----	1844.67	0.049
1852.64	0.418	----	----	----	----	----	----	1852.64	0.418
1900.25	0.241	----	----	----	----	----	----	1900.25	0.241
1904.80	0.190	----	----	----	----	----	----	1904.80	0.190
1910.18	0.080	----	----	----	----	----	----	1910.18	0.080
1918.69	0.100	----	----	----	----	----	----	1918.69	0.100
1929.5	0.033	----	----	----	----	----	----	1929.5	0.033
1972.59	0.175	----	----	----	----	----	----	1972.59	0.175
2037.53	0.169	----	----	----	----	----	----	2037.53	0.169
2048.90	0.113	----	----	----	----	----	----	2048.90	0.113
2082.45	0.137	----	----	----	----	----	----	2082.45	0.137
2123.06	0.085	----	----	----	----	----	----	2123.06	0.085
2141.73	0.259	----	----	----	----	----	----	2141.73	0.259
2153.71	0.302	----	----	----	----	----	----	2153.71	0.302
2280.36	0.130	----	----	----	----	----	----	2280.36	0.130
2291.42	0.318	----	----	----	----	----	----	2291.42	0.318
2365.32	0.155	----	----	----	----	----	----	2365.32	0.155
2413.70	0.077	----	----	----	----	----	----	2413.70	0.077
2465.43	0.128	----	----	----	----	----	----	2465.43	0.128
2497.89	0.82	----	----	----	----	----	----	2497.89	0.82
2533.53	0.139	----	----	----	----	----	----	2533.53	0.139
2572.03	0.214	----	----	----	----	----	----	2572.03	0.214
2605.2	0.12	----	----	----	----	----	----	2605.2	0.12
2656.8	0.20	----	----	----	----	----	----	2656.8	0.20
2666.6	0.04	----	----	----	----	----	----	2666.6	0.04
2724.8	0.090	----	----	----	----	----	----	2724.8	0.090
2732.13	0.240	----	----	----	----	----	----	2732.13	0.240
2772.2	0.183	----	----	----	----	----	----	2772.2	0.183
2776.8	0.110	----	----	----	----	----	----	2776.8	0.110
2811.1	0.06	----	----	----	----	----	----	2811.1	0.06
2830.1	0.115	----	----	----	----	----	----	2830.1	0.115
2838.2	0.14	----	----	----	----	----	----	2838.2	0.14
2885.3	0.099	----	----	----	----	----	----	2885.3	0.099
2904.6	0.025	----	----	----	----	----	----	2904.6	0.025

Table 3: Comparison of thermal-neutron capture spectra for ^{63}Cu (Continued)

Del83		She68		Mai68		Alv69		ENSDF	
Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]
2932.06	0.272	----	----	----	----	----	----	2932.06	0.272
2993.91	0.216	----	----	----	----	----	----	2993.91	0.216
3001.4	0.057	----	----	----	----	----	----	3001.4	0.057
3018.1	0.086	----	----	----	----	----	----	3018.1	0.086
3022.8	0.101	----	----	----	----	----	----	3022.8	0.101
3052.2	0.21	----	----	----	----	----	----	3052.2	0.21
3074.9	0.072	----	----	----	----	----	----	3074.9	0.072
3108.0	0.070	----	----	----	----	----	----	3108.0	0.070
3111.6	0.078	----	----	----	----	----	----	3111.6	0.078
3133.9	0.120	----	----	----	----	----	----	3133.9	0.120
3140.0	0.157	----	----	----	----	----	----	3140.0	0.157
3145.4	0.117	----	----	----	----	----	----	3145.4	0.117
3153.05	0.278	----	----	----	----	----	----	3153.05	0.278
3175.26	0.154	----	----	----	----	----	----	3175.26	0.154
3232.3	0.066	----	----	----	----	----	----	3232.3	0.066
3253.2	0.135	----	----	----	----	----	----	3253.2	0.135
3257.26	0.243	----	----	----	----	----	----	3257.26	0.243
----	----	----	----	----	----	3270	8.0	----	----
3312.4	0.20	----	----	----	----	----	----	3312.4	0.20
3316.58	0.29	----	----	----	----	----	----	3316.58	0.29
3361.6	0.075	----	----	----	----	----	----	3361.6	0.075
3366.8	0.144	----	----	----	----	----	----	3366.8	0.144
3385.73	0.173	----	----	----	----	----	----	3385.73	0.173
3431.6	0.159	----	----	----	----	----	----	3431.6	0.159
3442.6	0.094	----	----	----	----	----	----	3442.6	0.094
3464.55	0.26	----	----	----	----	----	----	3464.55	0.26
3472.2	0.183	----	----	----	----	----	----	3472.2	0.183
3478.0	0.103	----	----	----	----	----	----	3478.0	0.103
3482.9	0.115	----	----	----	----	----	----	3482.9	0.115
3506.7	0.070	----	----	----	----	----	----	3506.7	0.070
3510.5	0.123	----	----	----	----	----	----	3510.5	0.123
3521.02	0.172	----	----	----	----	----	----	3521.02	0.172
3552.9	0.080	----	----	----	----	----	----	3552.9	0.080
3588.52	0.34	----	----	----	----	----	----	3588.52	0.34
3591.38	0.50	----	----	----	----	----	----	3591.38	0.50
3597.1	0.127	----	----	----	----	----	----	3597.1	0.127

Table 3: Comparison of thermal-neutron capture spectra for ^{63}Cu (Continued)

Del83		She68		Mai68		Alv69		ENSDF	
Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]
3603.9	0.056	----	----	----	----	----	----	3603.9	0.056
3615.0	0.21	----	----	----	----	----	----	3615.0	0.21
3617.7	0.16	----	----	----	----	----	----	3617.7	0.16
3623.1	0.088	----	----	----	----	----	----	3623.1	0.088
3628.36	0.166	----	----	----	----	----	----	3628.36	0.166
3651.6	0.062	----	----	----	----	----	----	3651.6	0.062
3667.6	0.081	----	----	----	----	----	----	3667.6	0.081
3714.0	0.055	----	----	----	----	----	----	3714.0	0.055
3718.1	0.056	----	----	----	----	----	----	3718.1	0.056
3729.6	0.035	----	----	----	----	----	----	3729.6	0.035
3751.20	0.269	----	----	----	----	----	----	3751.20	0.269
3757.5	0.104	----	----	----	----	----	----	3757.5	0.104
3775.27	0.202	----	----	----	----	----	----	3775.27	0.202
3781.8	0.069	----	----	----	----	----	----	3781.8	0.069
3802.0	0.096	----	----	----	----	----	----	3802.0	0.096
3819.5	0.080	----	----	----	----	----	----	3819.5	0.080
3844.44	0.49	----	----	----	----	3848	3.0	3844.44	0.49
3874.7	0.09	----	----	----	----	----	----	3874.7	0.09
3883.0	0.146	----	----	----	----	3885	0.8	3883.0	0.146
3911.8	0.094	----	----	----	----	----	----	3911.8	0.094
3916.78	0.320	----	----	----	----	----	----	3916.78	0.320
3923.83	0.320	----	----	----	----	----	----	3923.83	0.320
4033.4	0.098	----	----	----	----	----	----	4033.4	0.098
4050.00	0.194	----	----	----	----	----	----	4050.00	0.194
4089.11	0.254	----	----	----	----	----	----	4089.11	0.254
4133.08	0.381	----	----	----	----	----	----	4133.08	0.381
4144.69	0.198	----	----	----	----	----	----	4144.69	0.198
4166.7	0.051	----	----	----	----	----	----	4166.7	0.051
4204.37	0.254	----	----	----	----	----	----	4204.37	0.254
4286.62	0.337	----	----	----	----	----	----	4286.62	0.337
4297.87	0.195	----	----	----	----	----	----	4297.87	0.195
4312.8	0.28	----	----	----	----	----	----	4312.8	0.28
4320.24	1.35	----	----	----	----	4336	2.4	4320.24	1.35
4391.9	0.133	----	----	----	----	----	----	4391.9	0.133
4405.00	0.304	----	----	----	----	----	----	4405.00	0.304
4423.12	0.140	----	----	----	----	----	----	4423.12	0.140

Table 3: Comparison of thermal-neutron capture spectra for ^{63}Cu (Continued)

Del83		She68		Mai68		Alv69		ENSDF	
Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]
4440.9	0.195	----	----	----	----	----	----	4440.9	0.195
4444.35	0.251	----	----	----	----	----	----	4444.35	0.251
4450.86	0.172	----	----	----	----	----	----	4450.86	0.172
4475.66	0.478	----	----	----	----	----	----	4475.66	0.478
4497.01	0.368	----	----	----	----	----	----	4497.01	0.368
4504.04	0.487	----	----	4506	0.3	4503	1.2	4504.04	0.487
4518.3	0.090	----	----	----	----	----	----	4518.3	0.090
4562.95	0.313	----	----	----	----	----	----	4562.95	0.313
4572.5	0.100	----	----	----	----	----	----	4572.5	0.100
4580.2	0.061	----	----	----	----	----	----	4580.2	0.061
4603.07	0.543	----	----	----	----	----	----	4603.07	0.543
4610.8	0.093	----	----	4610	----	4611	1.2	4610.8	0.093
4658.53	0.770	----	----	----	----	----	----	4658.53	0.770
4708.9	0.085	----	----	----	----	----	----	4708.9	0.085
4790.7	0.107	----	----	----	----	----	----	4790.7	0.107
4803.8	0.119	----	----	----	----	----	----	4803.8	0.119
4828.8	0.057	----	----	----	----	----	----	4828.8	0.057
4835.1	0.030	----	----	----	----	----	----	4835.1	0.030
4847.4	0.109	----	----	----	----	----	----	4847.4	0.109
4883.0	0.039	----	----	----	----	----	----	4883.0	0.039
4903.08	0.151	----	----	----	----	----	----	4903.08	0.151
4983.51	0.202	----	----	----	----	4939	0.8	4983.51	0.202
5019.5	0.190	----	----	----	----	----	----	5019.5	0.190
5023.2	0.183	----	----	----	----	----	----	5023.2	0.183
5085.30	0.328	----	----	----	----	----	----	5085.30	0.328
5139.86	0.179	----	----	----	----	----	----	5139.86	0.179
5152.11	0.269	----	----	----	----	----	----	5152.11	0.269
5183.89	0.366	----	----	----	----	----	----	5183.89	0.366
5190.09	0.668	----	----	5192	0.5	5198	0.9	5190.09	0.668
5240.0	0.067	----	----	----	----	----	----	5240.0	0.067
5258.67	1.031	----	----	5262	0.7	5267	1.2	5258.67	1.031
5269.4	0.080	----	----	----	----	----	----	5269.4	0.080
5280.67	0.250	----	----	----	----	----	----	5280.67	0.250
5321.3	0.055	----	----	----	----	----	----	5321.3	0.055
5355.2	0.029	----	----	----	----	----	----	5355.2	0.029
5385	0.011	----	----	----	----	----	----	5385	0.011

Table 3: Comparison of thermal-neutron capture spectra for ^{63}Cu (Continued)

Del83		She68		Mai68		Alv69		ENSDF	
Eγ (keV)	Iγ[a]	Eγ (keV)	Iγ[a]	Eγ (keV)	Iγ[a]	Eγ (keV)	Iγ[a]	Eγ (keV)	Iγ[a]
5408.88	0.399	----	----	----	----	----	----	5408.88	0.399
5418.49	1.85	----	----	5420	1.3	5425	2.3	5418.49	1.85
5450.75	0.158	----	----	----	----	----	----	5450.75	0.158
5492.5	0.035	----	----	----	----	----	----	5492.5	0.035
5528.2	0.124	----	----	----	----	----	----	5528.2	0.124
5555.78	0.274	----	----	----	----	----	----	5555.78	0.274
5600.5	0.097	----	----	----	----	----	----	5600.5	0.097
5615.01	0.494	----	----	----	----	5614	0.8	5615.01	0.494
5636.18	0.410	----	----	----	----	5634	0.6	5636.18	0.410
5728.7	0.056	----	----	----	----	----	----	5728.7	0.056
5771.48	0.509	5771	1.0	5775	0.3	5776	0.8	5771.48	0.509
----	----	5824	0.3	----	----	----	----	5824	0.3
5866.16	0.144	5866	0.2	----	----	----	----	5866.16	0.144
6010.83	1.59	6010	3.0	----	----	----	----	6010.83	1.59
6015.7	0.229	----	----	6014	1.7	6017	2.0	6015.7	0.229
6063.65	0.607	6062	0.9	6064	0.5	6067	0.8	6063.65	0.607
6136.05	0.197	6136	0.3	----	----	----	----	6136.05	0.197
6166.9	0.166	6169	0.3	----	----	----	----	6166.9	0.166
6233.0	0.109	6233	0.2	----	----	----	----	6233.0	0.109
6308.61	0.167	6309	0.2	----	----	----	----	6308.61	0.167
6321.54	0.361	6322	1.6	6322	----	6322	0.4	6321.54	0.361
6365.6	0.106	----	----	----	----	----	----	6365.6	0.106
6394.86	1.392	6394	1.9	6396	1.4	6394	2.1	6394.86	1.392
6416.9	0.095	6418	0.2	----	----	----	----	6416.9	0.095
6477.15	0.172	6476	0.2	----	----	----	----	6477.15	0.172
----	----	6553	0.1	----	----	----	----	6553	0.1
6595.63	0.631	6594	0.8	----	----	----	----	6595.63	0.631
6618.15	1.13	6617	1.4	6619	1.7	6621	1.3	6618.15	1.13
6628.9	0.099	6628	0.2	----	----	----	----	6628.9	0.099
6674.85	1.99	6674	2.5	6673	1.7	6677	2.0	6674.85	1.99
6988.96	3.51	6988	3.9	6992	3	6989	3.2	6988.96	3.51
7037.83	0.388	7036	0.6	----	----	7035	0.5	7037.83	0.388
7170.10	0.303	7168	0.4	----	----	----	----	7170.10	0.303
7177.07	2.56	7176	2.8	7177	2.4	7177	2.5	7177.07	2.56
7253.05	4.15	7252	4.5	7252	3	7252	3.4	7253.05	4.15
7307.31	8.96	7307	9.4	7306	7	7306	7.9	7307.31	8.96

[a]Number of photons per 100 neutron captures.

B. Recommended ACTI spectrum for ^{63}Cu

Table 4: Recommended ACTI spectrum for ^{63}Cu[a] (Continued)

Eγ (keV)	Iγ[b]	Eγ (keV)	Iγ[b]
617.43	0.742	1009.35	0.186
625.35	0.147	1019.59	0.390
632.34	0.255	1032.68	0.043
634.78	0.089	1059.95	0.086
648.80	2.860	1076.35	0.275
663.06	2.030	1081.74	0.321
689.08	0.168	1119.55	0.036
695.41	0.059	1127.84	0.236
711.94	0.096	1136.59	0.181
736.52	0.075	1138.82	0.823
739.12	0.267	1158.83	0.747
747.34	0.112	1165.21	0.120
767.80	0.679	1177.04	0.033
775.90	0.018	1194.89	0.291
779.65	0.099	1198.75	0.069
782.29	0.051	1220.84	0.205
804.29	0.048	1232.13	0.307
814.45	0.225	1241.50	0.550
822.33	0.104	1242.56	0.500
831.18	0.243	1250.45	0.088
846.87	0.123	1279.41	0.194
858.09	0.107	1287.40	0.035
878.28	1.016	1293.92	0.069
890.26	0.161	1298.13	0.408
897.06	0.286	1303.90	0.066
912.37	0.097	1316.24	0.108
924.91	0.170	1320.32	0.732
927.05	0.331	1327.62	0.067
937.01	0.127	1339.88	0.226
946.64	0.188	1354.68	0.052
953.97	0.118	1361.76	0.467
957.27	0.147	1391.25	0.077
960.63	0.180	1398.70	0.083
962.68	0.426	1401.66	0.079
974.17	0.138	1407.08	0.089
992.11	0.085	1417.27	0.270
998.28	0.207	1428.17	0.058

Table 4: Recommended ACTI spectrum for ^{63}Cu[a] (Continued)

Eγ (keV)	Iγ[b]	Eγ (keV)	Iγ[b]
1435.30	0.021	1904.80	0.190
1438.75	0.133	1910.18	0.080
1447.69	0.193	1918.69	0.100
1476.10	0.179	1929.50	0.033
1481.75	0.060	1972.59	0.175
1484.85	0.045	2037.53	0.169
1499.54	0.143	2048.90	0.113
1501.94	0.087	2082.45	0.137
1508.68	0.115	2123.06	0.085
1521.20	0.396	2141.73	0.259
1535.70	0.053	2153.71	0.302
1541.56	0.053	2280.36	0.130
1556.84	0.099	2291.42	0.318
1560.94	0.114	2365.32	0.155
1570.22	0.045	2413.70	0.077
1574.36	0.223	2465.43	0.128
1594.42	0.122	2497.89	0.820
1619.24	0.245	2533.53	0.139
1630.10	0.051	2572.03	0.214
1641.70	0.053	2605.20	0.120
1649.52	0.083	2656.80	0.200
1670.92	0.163	2666.60	0.040
1683.09	0.476	2724.80	0.090
1729.70	0.079	2732.13	0.240
1742.83	0.089	2772.20	0.183
1747.30	0.055	2776.80	0.110
1761.01	0.083	2811.10	0.060
1782.20	0.197	2830.10	0.115
1790.30	0.041	2838.20	0.140
1799.48	0.127	2885.30	0.099
1808.50	0.036	2904.60	0.025
1826.20	0.024	2932.06	0.272
1830.34	0.089	2993.91	0.216
1834.22	0.083	3001.40	0.057
1844.67	0.049	3018.10	0.086
1852.64	0.418	3022.80	0.101
1900.25	0.241	3052.20	0.210

Table 4: Recommended ACTI spectrum for ^{63}Cu[a] (Continued)

Eγ (keV)	Iγ[b]	Eγ (keV)	Iγ[b]
3074.90	0.072	3718.10	0.056
3108.00	0.070	3729.60	0.035
3111.60	0.078	3751.20	0.269
3133.90	0.120	3757.50	0.104
3140.00	0.157	3775.27	0.202
3145.40	0.117	3781.80	0.069
3153.05	0.278	3802.00	0.096
3175.26	0.154	3819.50	0.080
3232.30	0.066	3844.44	0.490
3253.20	0.135	3874.70	0.090
3257.26	0.243	3883.00	0.146
3312.40	0.200	3911.80	0.094
3316.58	0.290	3916.78	0.320
3361.60	0.075	3923.83	0.320
3366.80	0.144	4033.40	0.098
3385.73	0.173	4050.00	0.194
3431.60	0.159	4089.11	0.254
3442.60	0.094	4133.08	0.381
3464.55	0.260	4144.69	0.198
3472.20	0.183	4166.70	0.051
3478.00	0.103	4204.37	0.254
3482.90	0.115	4286.62	0.337
3506.70	0.070	4297.87	0.195
3510.50	0.123	4312.80	0.280
3521.02	0.172	4320.24	1.350
3552.90	0.080	4391.90	0.133
3588.52	0.340	4405.00	0.304
3591.38	0.500	4423.12	0.140
3597.10	0.127	4440.90	0.195
3603.90	0.056	4444.35	0.251
3615.00	0.210	4450.86	0.172
3617.70	0.160	4475.66	0.478
3623.10	0.088	4497.01	0.368
3628.36	0.166	4504.04	0.487
3651.60	0.062	4518.30	0.090
3667.60	0.081	4562.95	0.313
3714.00	0.055	4572.50	0.100

Table 4: Recommended ACTI spectrum for ^{63}Cu[a] (Continued)

Eγ (keV)	Iγ[b]	Eγ (keV)	Iγ[b]
4580.20	0.061	5600.50	0.097
4603.07	0.543	5615.01	0.494
4610.80	0.093	5636.18	0.410
4658.53	0.770	5728.70	0.056
4708.90	0.085	5771.48	0.509
4790.70	0.107	5866.16	0.144
4803.80	0.119	6010.83	1.590
4828.80	0.057	6015.70	0.229
4835.10	0.030	6063.65	0.607
4847.40	0.109	6136.05	0.197
4883.00	0.039	6166.90	0.166
4903.08	0.151	6233.00	0.109
4983.51	0.202	6308.61	0.167
5019.50	0.190	6321.54	0.361
5023.20	0.183	6365.60	0.106
5085.30	0.328	6394.86	1.392
5139.86	0.179	6416.90	0.095
5152.11	0.269	6477.15	0.172
5183.89	0.366	6595.63	0.631
5190.09	0.668	6618.15	1.130
5240.00	0.067	6628.90	0.099
5258.67	1.031	6674.85	1.990
5269.40	0.080	6988.96	3.510
5280.67	0.250	7037.83	0.388
5321.30	0.055	7170.10	0.303
5355.20	0.029	7177.07	2.560
5385.00	0.011	7253.05	4.150
5408.88	0.399	7307.31	8.960
5418.49	1.850	7555.10	0.084
5450.75	0.158	7572.32	1.740
5492.50	0.035	7638.00	16.199
5528.20	0.124	7756.91	1.580
5555.78	0.274	7916.26	33.098

[a]All values are from Del83.[12]
[b]Number of photons per 100 captures, normalized to Q-value of Audi.[11]

III. ^{65}Cu

A. Comparison of Data

The search for thermal-neutron capture data for ^{65}Cu resulted in four recent experimental papers with appreciable amounts of data. The most recent paper was a 1983 paper by Delfini et al.[16] The other three were the same papers found for ^{63}Cu; She68, Mai68, and Alv69. Brief summaries of each paper as well as the ENSDF data for ^{65}Cu are given in Table 5. Included in Table 5 are the designations that will be used to refer to each data set, the date and number of gamma-rays in each paper, and the total gamma-ray yields per neutron capture.

Table 5: Summary of experimental papers for ^{65}Cu

Author(s)	Designation	Year	Number of gamma-rays	Total Yield (keV)
M. G. Delfini et al.[16]	Del83	1983	424	7063.92
B. Maier et al.[13]	Mai68	1968	26	---[a]
E. Shera and H. Bolotin[14]	She68	1968	56	3983.62
R. Alves et al.[15]	Alv69	1969	29	4022.14
ENSDF[7]	ENSDF	1983[b]	424	7068.55

[a]Intensities were not listed for all gamma-rays.
[b]The latest paper referenced is Del83.

Of these four papers, the most recent (Del83) is again by far the best source of data. Del83 was able to resolve more than four times the number of ^{65}Cu lines measured by all other experimenters *combined*, and the measurements were performed at two different facilities (the High Flux Reactor in Petten, and the High Flux Beam Reactor at Brookhaven National Laboratory). As with ^{63}Cu, performing the experiment at two different facilities allowed for very accurate background subtractions and much improved spectral measurements. Of the 424 gamma-rays measured, Del83 was able to place 346 of them in the ^{66}Cu level scheme, far more than any other experimenter.

Even though Del83 represents the best experimental data, it was compared to the other spectra to try and find specific problems with it. Two indications of problems were sought. First, gamma-rays seen by two or more experimenters but *not* Del83 could indicate a missed line in the Del83 spectrum. Second, two or more experimenters in agreement with each other *and* in disagreement with Del83 (either gamma-ray energy or intensity) could indicate an erroneous value in Del83. The secondary gamma-ray spectrum from each ^{65}Cu data source is listed in Table 6.

A careful examination of Table 6 reveals no obvious problems with Del83. There are no gamma-rays observed by two or more experimenters but *not* Del83. There are also no cases in which there is clear agreement between everyone *except* Del83. There are quite a few cases where there is generally no consistent agreement between the experimental sources. In these cases, the Del83 values were assumed to be superior to the others.

The ENSDF spectrum is identical to Del83 except for the 714.66 keV line. For this gamma-ray ENSDF used the Del83 energy, but listed an intensity of 0.72, while Del83 lists an intensity of 0.072. Since the ENSDF documentation does not indicate that values from any other data sources were adopted, it's likely this is simply a typographical error in ENSDF.

Table 6: Comparison of thermal-neutron capture data for ^{65}Cu

Delfini 1983		Shera 1968		Maier 1968		Alves 1969		ENSDF 1983	
Eγ (keV)	Iγ[a]	Eγ (keV)	Iγ[a]	Eγ (keV)	Iγ[a]	Eγ (keV)	Iγ[a]	Eγ (keV)	Iγ[a]
-----	-----	-----	-----	79.38	-----	-----	-----	-----	-----
89.18	10.9	89.11	7.0	89.142	-----	-----	-----	89.18	10.9
100.15	0.14	-----	-----	105.911	-----	-----	-----	100.15	0.14
111.93	0.16	-----	-----	-----	-----	-----	-----	111.93	0.16
114.36	0.107	-----	-----	-----	-----	-----	-----	114.36	0.107
186.01	41	185.79	24.4	-----	-----	-----	-----	186.01	41
190.10	0.83	-----	-----	190.028	-----	-----	-----	190.10	0.83
194.47	0.76	194.4	0.2	-----	-----	-----	-----	194.47	0.76
199.90	0.60	200.1	0.3	199.666	-----	-----	-----	199.90	0.60
217.0	0.024	-----	-----	-----	-----	-----	-----	217.0	0.024
234.26	0.19	-----	-----	-----	-----	-----	-----	234.26	0.19
237.821	4.0	237.7	2.4	-----	-----	-----	-----	237.821	4.0
247.48	0.193	-----	-----	-----	-----	-----	-----	247.48	0.193
274.92	0.152	-----	-----	274.95	-----	-----	-----	274.92	0.152
279.33	0.35	278.7	0.5	-----	-----	-----	-----	279.33	0.35
283.38	0.28	-----	-----	-----	-----	-----	-----	283.38	0.28
289.2	0.057	-----	-----	-----	-----	-----	-----	289.2	0.057
291.8	0.028	-----	-----	-----	-----	-----	-----	291.8	0.028
315.711	4.1	315.6	2.8	-----	-----	-----	-----	315.711	4.1
334.03	0.16	-----	-----	-----	-----	-----	-----	334.03	0.16
335.73	0.25	-----	-----	-----	-----	-----	-----	335.73	0.25
338.03	0.169	-----	-----	-----	-----	-----	-----	338.03	0.169
340.19	0.157	-----	-----	-----	-----	-----	-----	340.19	0.157
357.561	0.49	357.5	0.3	357.47	-----	-----	-----	357.561	0.49

Table 6: Comparison of thermal-neutron capture data for ^{65}Cu (Continued)

Delfini 1983		Shera 1968		Maier 1968		Alves 1969		ENSDF 1983	
Eγ (keV)	Iγ[a]	Eγ (keV)	Iγ[a]	Eγ (keV)	Iγ[a]	Eγ (keV)	Iγ[a]	Eγ (keV)	Iγ[a]
385.781	19.0	385.7	13.7	385.711	-----	-----	-----	385.781	19.0
417.03	0.135	-----	-----	-----	-----	-----	-----	417.03	0.135
422.01	0.096	-----	-----	-----	-----	-----	-----	422.01	0.096
426.372	0.56	426.3	0.3	-----	-----	-----	-----	426.372	0.56
436.912	1.90	436.6	1.4	436.8	-----	-----	-----	436.912	1.90
454.8	0.44	-----	-----	-----	-----	-----	-----	454.8	0.44
457.6	0.39	-----	-----	-----	-----	-----	-----	457.6	0.39
460.8	0.30	-----	-----	-----	-----	-----	-----	460.8	0.30
465.152	22.3	465.1	16.2	465.033	-----	-----	-----	465.152	22.3
482.69	0.44	478.0	1.4	-----	-----	-----	-----	482.69	0.44
525.96	0.053	-----	-----	-----	-----	-----	-----	525.96	0.053
531.24	0.113	-----	-----	-----	-----	-----	-----	531.24	0.113
533.96	0.120	-----	-----	-----	-----	-----	-----	533.96	0.120
537.55	0.107	-----	-----	-----	-----	-----	-----	537.55	0.107
543.852	4.19	543.9	3.4	-----	-----	-----	-----	543.852	4.19
547.552	0.74	-----	-----	-----	-----	-----	-----	547.552	0.74
551.953	0.486	-----	-----	-----	-----	-----	-----	551.953	0.486
556.46	0.055	-----	-----	-----	-----	-----	-----	556.46	0.055
567.35	0.169	-----	-----	-----	-----	-----	-----	567.35	0.169
583.62	0.206	-----	-----	-----	-----	-----	-----	583.62	0.206
586.79	0.333	586.7	0.2	-----	-----	-----	-----	586.79	0.333
622.69	0.090	625.0	0.6	-----	-----	-----	-----	622.69	0.090
632.67	0.140	-----	-----	-----	-----	-----	-----	632.67	0.140
636.68	0.293	637.2	0.3	-----	-----	-----	-----	636.68	0.293
645.99	0.110	-----	-----	-----	-----	-----	-----	645.99	0.110
651.10	0.086	-----	-----	-----	-----	-----	-----	651.10	0.086
661.22	0.099	-----	-----	-----	-----	-----	-----	661.22	0.099
665.60	0.097	-----	-----	-----	-----	-----	-----	665.60	0.097
679.30	0.166	-----	-----	-----	-----	-----	-----	679.30	0.166
695.35	0.080	-----	-----	-----	-----	-----	-----	695.35	0.080
714.66	0.072	-----	-----	-----	-----	-----	-----	714.66	0.72
723.99	0.537	-----	-----	-----	-----	-----	-----	723.99	0.537
729.19	0.258	-----	-----	-----	-----	-----	-----	729.19	0.258
738.15	0.079	-----	-----	-----	-----	-----	-----	738.15	0.079
741.94	0.384	-----	-----	-----	-----	-----	-----	741.94	0.384
747.48	0.386	-----	-----	-----	-----	-----	-----	747.48	0.386

Table 6: Comparison of thermal-neutron capture data for ^{65}Cu (Continued)

Delfini 1983		Shera 1968		Maier 1968		Alves 1969		ENSDF 1983	
Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]
753.91	0.469	-----	-----	-----	-----	-----	-----	753.91	0.469
758.83	0.171	-----	-----	-----	-----	-----	-----	758.83	0.171
768.305	1.00	769.9	0.8	-----	-----	-----	-----	768.305	1.00
770.64	0.094	-----	-----	-----	-----	-----	-----	770.64	0.094
788.42	0.160	-----	-----	-----	-----	-----	-----	788.42	0.160
797.9	0.039	-----	-----	-----	-----	-----	-----	797.9	0.039
808.21	0.23	-----	-----	-----	-----	-----	-----	808.21	0.23
810.47	0.26	-----	-----	-----	-----	-----	-----	810.47	0.26
814.27	0.79	815.8	0.9	-----	-----	-----	-----	814.27	0.79
822.676	4.03	824.5	4.0	823.5	-----	-----	-----	822.676	4.03
826.8	0.125	-----	-----	-----	-----	-----	-----	826.8	0.125
831.196	2.71	833.0	3.1	-----	-----	-----	-----	831.196	2.71
834.10	0.358	-----	-----	-----	-----	-----	-----	834.10	0.358
847.42	0.41	-----	-----	-----	-----	-----	-----	847.42	0.41
860.85	0.142	-----	-----	-----	-----	-----	-----	860.85	0.142
878.816	1.014	881.5	1.0	-----	-----	-----	-----	878.816	1.014
883.03	0.365	-----	-----	-----	-----	-----	-----	883.03	0.365
899.14	0.141	-----	-----	-----	-----	-----	-----	899.14	0.141
903.18	0.079	-----	-----	-----	-----	-----	-----	903.18	0.079
909.99	0.043	-----	-----	-----	-----	-----	-----	909.99	0.043
927.35	0.073	-----	-----	-----	-----	-----	-----	927.35	0.073
937.507	1.143	938.7	0.7	-----	-----	-----	-----	937.507	1.143
948.09	0.382	-----	-----	-----	-----	-----	-----	948.09	0.382
956.74	0.53	-----	-----	-----	-----	-----	-----	956.74	0.53
958.25	0.36	958.3	0.6	-----	-----	-----	-----	958.25	0.36
961.26	0.364	-----	-----	-----	-----	-----	-----	961.26	0.364
972.108	1.94	973.9	1.9	-----	-----	-----	-----	972.108	1.94
976.27	0.349	-----	-----	-----	-----	-----	-----	976.27	0.349
983.21	0.176	-----	-----	-----	-----	-----	-----	983.21	0.176
987.18	0.522	-----	-----	-----	-----	-----	-----	987.18	0.522
993.48	0.087	-----	-----	-----	-----	-----	-----	993.48	0.087
997.648	1.46	998.9	1.0	-----	-----	-----	-----	997.648	1.46
1006.19	0.229	-----	-----	-----	-----	-----	-----	1006.19	0.229
1014.07	0.231	-----	-----	-----	-----	-----	-----	1014.07	0.231
1017.1	0.086	-----	-----	-----	-----	-----	-----	1017.1	0.086
1019.46	0.404	-----	-----	-----	-----	-----	-----	1019.46	0.404

Table 6: Comparison of thermal-neutron capture data for ^{65}Cu (Continued)

Delfini 1983		Shera 1968		Maier 1968		Alves 1969		ENSDF 1983	
Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]
1026.67	0.190	-----	-----	-----	-----	-----	-----	1026.67	0.190
1042.86	0.30	-----	-----	-----	-----	-----	-----	1042.86	0.30
1052.19	1.99	1052.6	2.5	-----	-----	-----	-----	1052.19	1.99
1053.88	0.31	-----	-----	-----	-----	-----	-----	1053.88	0.31
1081.95	0.120	-----	-----	-----	-----	-----	-----	1081.95	0.120
1088.64	0.142	-----	-----	-----	-----	-----	-----	1088.64	0.142
1115.48	0.099	-----	-----	-----	-----	-----	-----	1115.48	0.099
1120.8	0.057	-----	-----	-----	-----	-----	-----	1120.8	0.057
1135.78	0.075	-----	-----	-----	-----	-----	-----	1135.78	0.075
1139.65	0.404	-----	-----	-----	-----	-----	-----	1139.65	0.404
1146.79	0.195	-----	-----	-----	-----	-----	-----	1146.79	0.195
1161.63	0.112	-----	-----	-----	-----	-----	-----	1161.63	0.112
1164.71	0.166	-----	-----	-----	-----	-----	-----	1164.71	0.166
1180.8	0.041	-----	-----	-----	-----	-----	-----	1180.8	0.041
1197.21	0.71	1197.2	1.6	-----	-----	-----	-----	1197.21	0.71
1208.8	0.05	-----	-----	-----	-----	-----	-----	1208.8	0.05
1212.52	1.78	1212.6	1.9	-----	-----	-----	-----	1212.52	1.78
1220.4	0.10	-----	-----	-----	-----	-----	-----	1220.4	0.10
1253.28	0.184	-----	-----	-----	-----	-----	-----	1253.28	0.184
1261.72	0.137	1261.7	2.6	-----	-----	-----	-----	1261.72	0.137
1272.32	0.628	-----	-----	-----	-----	-----	-----	1272.32	0.628
1280.20	0.227	-----	-----	-----	-----	-----	-----	1280.20	0.227
1288.63	0.076	-----	-----	-----	-----	-----	-----	1288.63	0.076
1293.71	0.405	-----	-----	-----	-----	-----	-----	1293.71	0.405
1298.87	0.50	-----	-----	-----	-----	-----	-----	1298.87	0.50
1303.03	0.14	-----	-----	-----	-----	-----	-----	1303.03	0.14
1313.29	0.133	-----	-----	-----	-----	-----	-----	1313.29	0.133
1322.16	0.165	-----	-----	-----	-----	-----	-----	1322.16	0.165
1343.4	0.034	-----	-----	-----	-----	-----	-----	1343.4	0.034
1355.18	2.25	1355.6	1.7	-----	-----	-----	-----	1355.18	2.25
1374.41	0.241	-----	-----	-----	-----	-----	-----	1374.41	0.241
1394.90	0.273	-----	-----	-----	-----	-----	-----	1394.90	0.273
1401.26	0.074	-----	-----	-----	-----	-----	-----	1401.26	0.074
1408.4	0.045	-----	-----	-----	-----	-----	-----	1408.4	0.045
1416.38	0.129	-----	-----	-----	-----	-----	-----	1416.38	0.129
1428.18	0.76	-----	-----	-----	-----	-----	-----	1428.18	0.76

Table 6: Comparison of thermal-neutron capture data for ^{65}Cu (Continued)

Delfini 1983		Shera 1968		Maier 1968		Alves 1969		ENSDF 1983	
Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]
1435.26	0.219	-----	-----	-----	-----	-----	-----	1435.26	0.219
1439.37	1.88	1440.3	1.7	-----	-----	-----	-----	1439.37	1.88
1450.6	0.14	-----	-----	-----	-----	-----	-----	1450.6	0.14
1468.56	0.52	-----	-----	-----	-----	-----	-----	1468.56	0.52
1471.05	0.76	-----	-----	-----	-----	-----	-----	1471.05	0.76
1489.90	0.164	-----	-----	-----	-----	-----	-----	1489.90	0.164
1506.57	0.225	-----	-----	-----	-----	-----	-----	1506.57	0.225
1509.64	0.175	-----	-----	-----	-----	-----	-----	1509.64	0.175
1515.3	0.054	-----	-----	-----	-----	-----	-----	1515.3	0.054
1523.0	0.054	-----	-----	-----	-----	-----	-----	1523.0	0.054
1532.4	0.070	-----	-----	-----	-----	-----	-----	1532.4	0.070
1553.1	0.39	-----	-----	-----	-----	-----	-----	1553.1	0.39
1557.4	0.42	-----	-----	-----	-----	-----	-----	1557.4	0.42
1559.86	5.6	1560.7	6.2	-----	-----	-----	-----	1559.86	5.6
1574.0	0.096	-----	-----	-----	-----	-----	-----	1574.0	0.096
1582.51	1.60	1584.2	1.5	-----	-----	-----	-----	1582.51	1.60
1589.79	0.119	-----	-----	-----	-----	-----	-----	1589.79	0.119
1607.34	0.107	-----	-----	-----	-----	-----	-----	1607.34	0.107
1629.2	0.18	-----	-----	-----	-----	-----	-----	1629.2	0.18
1633.89	1.09	-----	-----	-----	-----	-----	-----	1633.89	1.09
1637.49	2.37	1638.7	3.3	-----	-----	-----	-----	1637.49	2.37
1647.33	0.390	-----	-----	-----	-----	-----	-----	1647.33	0.390
1652.01	0.53	-----	-----	-----	-----	-----	-----	1652.01	0.53
1658.91	0.231	-----	-----	-----	-----	-----	-----	1658.91	0.231
1666.15	0.173	-----	-----	-----	-----	-----	-----	1666.15	0.173
1670.32	0.211	-----	-----	-----	-----	-----	-----	1670.32	0.211
1678.19	0.78	-----	-----	-----	-----	-----	-----	1678.19	0.78
1682.00	0.143	-----	-----	-----	-----	-----	-----	1682.00	0.143
1723.07	0.167	-----	-----	-----	-----	-----	-----	1723.07	0.167
1728.01	0.441	-----	-----	-----	-----	-----	-----	1728.01	0.441
1732.27	0.127	-----	-----	-----	-----	-----	-----	1732.27	0.127
1743.40	2.34	1745.9	5.0	-----	-----	-----	-----	1743.40	2.34
1746.2	1.08	-----	-----	-----	-----	-----	-----	1746.2	1.08
1748.0	0.59	-----	-----	-----	-----	-----	-----	1748.0	0.59
1761.6	0.064	-----	-----	-----	-----	-----	-----	1761.6	0.064
1773.5	0.109	-----	-----	-----	-----	-----	-----	1773.5	0.109

Table 6: Comparison of thermal-neutron capture data for ^{65}Cu (Continued)

Delfini 1983		Shera 1968		Maier 1968		Alves 1969		ENSDF 1983	
Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]
1799.84	0.137	-----	-----	-----	-----	-----	-----	1799.84	0.137
1806.57	0.108	-----	-----	-----	-----	-----	-----	1806.57	0.108
1820.21	0.93	-----	-----	-----	-----	-----	-----	1820.21	0.93
1832.39	1.22	-----	-----	-----	-----	-----	-----	1832.39	1.22
1837.44	0.71	-----	-----	-----	-----	-----	-----	1837.44	0.71
1843.71	0.145	-----	-----	-----	-----	-----	-----	1843.71	0.145
1849.4	0.18	-----	-----	-----	-----	-----	-----	1849.4	0.18
1854.3	0.054	-----	-----	-----	-----	-----	-----	1854.3	0.054
1866.68	0.95	-----	-----	-----	-----	-----	-----	1866.68	0.95
1874.41	0.083	-----	-----	-----	-----	-----	-----	1874.41	0.083
1890.61	0.140	-----	-----	-----	-----	-----	-----	1890.61	0.140
1901.52	0.152	-----	-----	-----	-----	-----	-----	1901.52	0.152
1912.13	0.139	-----	-----	-----	-----	-----	-----	1912.13	0.139
1916.35	0.104	-----	-----	-----	-----	-----	-----	1916.35	0.104
1929.63	0.158	-----	-----	-----	-----	-----	-----	1929.63	0.158
1939.87	0.36	-----	-----	-----	-----	-----	-----	1939.87	0.36
1944.97	0.19	-----	-----	-----	-----	-----	-----	1944.97	0.19
1966.29	0.194	-----	-----	-----	-----	-----	-----	1966.29	0.194
1975.26	0.187	-----	-----	-----	-----	-----	-----	1975.26	0.187
1980.01	0.338	-----	-----	-----	-----	-----	-----	1980.01	0.338
1985.73	0.236	-----	-----	-----	-----	-----	-----	1985.73	0.236
1988.92	0.36	-----	-----	-----	-----	-----	-----	1988.92	0.36
2004.42	0.246	-----	-----	-----	-----	-----	-----	2004.42	0.246
2023.55	0.47	-----	-----	-----	-----	-----	-----	2023.55	0.47
2039.33	0.083	-----	-----	-----	-----	-----	-----	2039.33	0.083
2046.00	0.143	-----	-----	-----	-----	-----	-----	2046.00	0.143
2059.9	0.067	-----	-----	-----	-----	-----	-----	2059.9	0.067
2068.26	0.149	-----	-----	-----	-----	-----	-----	2068.26	0.149
2082.6	0.071	-----	-----	-----	-----	-----	-----	2082.6	0.071
2091.36	0.294	-----	-----	-----	-----	-----	-----	2091.36	0.294
2095.76	0.205	-----	-----	-----	-----	-----	-----	2095.76	0.205
2110.44	0.61	-----	-----	-----	-----	-----	-----	2110.44	0.61
2114.78	0.159	-----	-----	-----	-----	-----	-----	2114.78	0.159
2120.25	0.146	-----	-----	-----	-----	-----	-----	2120.25	0.146
2123.95	0.161	-----	-----	-----	-----	-----	-----	2123.95	0.161
2131.25	0.114	-----	-----	-----	-----	-----	-----	2131.25	0.114

Table 6: Comparison of thermal-neutron capture data for ^{65}Cu (Continued)

Delfini 1983		Shera 1968		Maier 1968		Alves 1969		ENSDF 1983	
Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]
2144.22	0.186	-----	-----	-----	-----	-----	-----	2144.22	0.186
2147.27	0.202	-----	-----	-----	-----	-----	-----	2147.27	0.202
2151.31	0.265	-----	-----	-----	-----	-----	-----	2151.31	0.265
2160.4	0.130	-----	-----	-----	-----	-----	-----	2160.4	0.130
2163.22	0.40	-----	-----	-----	-----	-----	-----	2163.22	0.40
2177.87	0.164	-----	-----	-----	-----	-----	-----	2177.87	0.164
2215.88	1.63	-----	-----	-----	-----	-----	-----	2215.88	1.63
2254.5	0.09	-----	-----	-----	-----	-----	-----	2254.5	0.09
2278.2	0.071	-----	-----	-----	-----	-----	-----	2278.2	0.071
2315.7	0.21	-----	-----	-----	-----	-----	-----	2315.7	0.21
2371.4	0.13	-----	-----	-----	-----	-----	-----	2371.4	0.13
2380.34	0.21	-----	-----	-----	-----	-----	-----	2380.34	0.21
2389.3	0.100	-----	-----	-----	-----	-----	-----	2389.3	0.100
2400.0	0.16	-----	-----	-----	-----	-----	-----	2400.0	0.16
2402.83	0.22	-----	-----	-----	-----	-----	-----	2402.83	0.22
2411.58	0.36	-----	-----	-----	-----	-----	-----	2411.58	0.36
2423.94	0.191	-----	-----	-----	-----	-----	-----	2423.94	0.191
2436.7	0.13	-----	-----	-----	-----	-----	-----	2436.7	0.13
2439.35	0.42	-----	-----	-----	-----	-----	-----	2439.35	0.42
2448.7	0.15	-----	-----	-----	-----	-----	-----	2448.7	0.15
2450.91	0.29	-----	-----	-----	-----	-----	-----	2450.91	0.29
2457.66	0.183	-----	-----	-----	-----	-----	-----	2457.66	0.183
2478.2	0.17	-----	-----	-----	-----	-----	-----	2478.2	0.17
2488.4	0.24	-----	-----	-----	-----	-----	-----	2488.4	0.24
2492.0	0.11	-----	-----	-----	-----	-----	-----	2492.0	0.11
2508.3	0.11	-----	-----	-----	-----	-----	-----	2508.3	0.11
2539.3	0.07	-----	-----	-----	-----	-----	-----	2539.3	0.07
2545.2	0.08	-----	-----	-----	-----	-----	-----	2545.2	0.08
2553.1	0.15	-----	-----	-----	-----	-----	-----	2553.1	0.15
2557.8	0.093	-----	-----	-----	-----	-----	-----	2557.8	0.093
2561.3	0.068	-----	-----	-----	-----	-----	-----	2561.3	0.068
2569.26	0.176	-----	-----	-----	-----	-----	-----	2569.26	0.176
2584.3	0.090	-----	-----	-----	-----	-----	-----	2584.3	0.090
2603.3	0.23	-----	-----	-----	-----	-----	-----	2603.3	0.23
2608.5	0.26	-----	-----	-----	-----	-----	-----	2608.5	0.26
2612.1	0.27	-----	-----	-----	-----	-----	-----	2612.1	0.27

Table 6: Comparison of thermal-neutron capture data for ^{65}Cu (Continued)

Delfini 1983		Shera 1968		Maier 1968		Alves 1969		ENSDF 1983	
Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]
2615.2	0.12	-----	-----	-----	-----	-----	-----	2615.2	0.12
2619.14	0.28	-----	-----	-----	-----	-----	-----	2619.14	0.28
2629.61	0.71	-----	-----	-----	-----	-----	-----	2629.61	0.71
2641.3	0.20	-----	-----	-----	-----	-----	-----	2641.3	0.20
2664.17	0.34	-----	-----	-----	-----	-----	-----	2664.17	0.34
2673.42	0.32	-----	-----	-----	-----	-----	-----	2673.42	0.32
2680.38	0.48	-----	-----	-----	-----	-----	-----	2680.38	0.48
2687.88	0.52	-----	-----	-----	-----	-----	-----	2687.88	0.52
2700.26	0.72	-----	-----	-----	-----	-----	-----	2700.26	0.72
2708.2	0.13	-----	-----	-----	-----	-----	-----	2708.2	0.13
2713.3	0.10	-----	-----	-----	-----	-----	-----	2713.3	0.10
2758.8	0.15	-----	-----	-----	-----	-----	-----	2758.8	0.15
2766.2	0.12	-----	-----	-----	-----	-----	-----	2766.2	0.12
2770.7	0.08	-----	-----	-----	-----	-----	-----	2770.7	0.08
2781.5	0.10	-----	-----	-----	-----	-----	-----	2781.5	0.10
2806.9	0.14	-----	-----	-----	-----	-----	-----	2806.9	0.14
2821.76	0.73	-----	-----	-----	-----	-----	-----	2821.76	0.73
2824.8	0.12	-----	-----	-----	-----	-----	-----	2824.8	0.12
2856.36	0.263	-----	-----	-----	-----	-----	-----	2856.36	0.263
2862.63	0.44	-----	-----	-----	-----	-----	-----	2862.63	0.44
2866.61	0.39	-----	-----	-----	-----	-----	-----	2866.61	0.39
2870.7	0.078	-----	-----	-----	-----	-----	-----	2870.7	0.078
2876.19	0.171	-----	-----	-----	-----	-----	-----	2876.19	0.171
2890.6	0.125	-----	-----	-----	-----	-----	-----	2890.6	0.125
2896.9	0.087	-----	-----	-----	-----	-----	-----	2896.9	0.087
2901.2	0.119	-----	-----	-----	-----	-----	-----	2901.2	0.119
2912.57	0.158	-----	-----	-----	-----	-----	-----	2912.57	0.158
2918.0	0.065	-----	-----	-----	-----	-----	-----	2918.0	0.065
2935.05	0.254	-----	-----	-----	-----	-----	-----	2935.05	0.254
2949.5	0.19	-----	-----	-----	-----	-----	-----	2949.5	0.19
2952.64	0.33	-----	-----	-----	-----	-----	-----	2952.64	0.33
2968.8	0.112	-----	-----	-----	-----	-----	-----	2968.8	0.112
2986.9	0.074	-----	-----	-----	-----	-----	-----	2986.9	0.074
2991.1	0.120	-----	-----	-----	-----	-----	-----	2991.1	0.120
2996.78	0.33	-----	-----	-----	-----	-----	-----	2996.78	0.33
3009.32	0.297	-----	-----	-----	-----	-----	-----	3009.32	0.297

Table 6: Comparison of thermal-neutron capture data for ^{65}Cu (Continued)

Delfini 1983		Shera 1968		Maier 1968		Alves 1969		ENSDF 1983	
Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]
3021.72	0.216	-----	-----	-----	-----	-----	-----	3021.72	0.216
3025.77	0.47	-----	-----	-----	-----	-----	-----	3025.77	0.47
3045.46	0.23	-----	-----	-----	-----	-----	-----	3045.46	0.23
3052.91	0.230	-----	-----	-----	-----	-----	-----	3052.91	0.230
3067.2	0.16	-----	-----	-----	-----	-----	-----	3067.2	0.16
3071.8	0.13	-----	-----	-----	-----	-----	-----	3071.8	0.13
3090.95	0.161	-----	-----	-----	-----	-----	-----	3090.95	0.161
3111.4	0.096	-----	-----	-----	-----	-----	-----	3111.4	0.096
3121.3	0.11	-----	-----	-----	-----	-----	-----	3121.3	0.11
3131.70	0.173	-----	-----	-----	-----	-----	-----	3131.70	0.173
3137.18	0.30	-----	-----	-----	-----	-----	-----	3137.18	0.30
3165.8	0.21	-----	-----	-----	-----	-----	-----	3165.8	0.21
3169.4	0.20	-----	-----	-----	-----	-----	-----	3169.4	0.20
3172.95	0.73	-----	-----	-----	-----	-----	-----	3172.95	0.73
3184.49	0.81	-----	-----	-----	-----	-----	-----	3184.49	0.81
3208.1	0.110	-----	-----	-----	-----	-----	-----	3208.1	0.110
3225.8	0.076	-----	-----	-----	-----	-----	-----	3225.8	0.076
3230.1	0.057	-----	-----	-----	-----	-----	-----	3230.1	0.057
3241.9	0.14	-----	-----	-----	-----	-----	-----	3241.9	0.14
3251.26	0.24	-----	-----	-----	-----	-----	-----	3251.26	0.24
3270.78	0.57	-----	-----	-----	-----	-----	-----	3270.78	0.57
3275.2	0.08	-----	-----	-----	-----	-----	-----	3275.2	0.08
3285.85	0.33	-----	-----	-----	-----	-----	-----	3285.85	0.33
3293.49	0.72	-----	-----	-----	-----	-----	-----	3293.49	0.72
3307.4	0.11	-----	-----	-----	-----	-----	-----	3307.4	0.11
3316.04	0.33	-----	-----	-----	-----	-----	-----	3316.04	0.33
3322.2	0.08	-----	-----	-----	-----	-----	-----	3322.2	0.08
3327.2	0.08	-----	-----	-----	-----	-----	-----	3327.2	0.08
3348.5	0.113	-----	-----	-----	-----	-----	-----	3348.5	0.113
3361.11	0.152	-----	-----	-----	-----	-----	-----	3361.11	0.152
3383.6	0.124	-----	-----	-----	-----	-----	-----	3383.6	0.124
3402.63	0.240	-----	-----	-----	-----	-----	-----	3402.63	0.240
3424.85	0.225	-----	-----	-----	-----	-----	-----	3424.85	0.225
3429.40	1.05	-----	-----	-----	-----	-----	-----	3429.40	1.05
3450.3	0.093	-----	-----	-----	-----	-----	-----	3450.3	0.093
3456.2	0.063	-----	-----	-----	-----	-----	-----	3456.2	0.063

Table 6: Comparison of thermal-neutron capture data for ^{65}Cu (Continued)

Delfini 1983		Shera 1968		Maier 1968		Alves 1969		ENSDF 1983	
Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]
3465.00	0.64	-----	-----	-----	-----	-----	-----	3465.00	0.64
3476.9	0.078	-----	-----	-----	-----	-----	-----	3476.9	0.078
3482.51	0.33	-----	-----	-----	-----	-----	-----	3482.51	0.33
3486.2	0.076	-----	-----	-----	-----	-----	-----	3486.2	0.076
3530.56	0.71	-----	-----	-----	-----	-----	-----	3530.56	0.71
3548.6	0.128	-----	-----	-----	-----	-----	-----	3548.6	0.128
3556.99	0.42	-----	-----	-----	-----	-----	-----	3556.99	0.42
3560.1	0.28	-----	-----	-----	-----	-----	-----	3560.1	0.28
3563.7	0.120	-----	-----	-----	-----	-----	-----	3563.7	0.120
3578.0	0.116	-----	-----	-----	-----	-----	-----	3578.0	0.116
3586.2	0.075	-----	-----	-----	-----	-----	-----	3586.2	0.075
3606.6	0.115	-----	-----	-----	-----	-----	-----	3606.6	0.115
3613.8	0.135	-----	-----	-----	-----	-----	-----	3613.8	0.135
3627.9	0.107	-----	-----	-----	-----	-----	-----	3627.9	0.107
3633.54	0.142	-----	-----	-----	-----	-----	-----	3633.54	0.142
3668.23	0.093	-----	-----	-----	-----	-----	-----	3668.23	0.093
3687.2	0.073	-----	-----	-----	-----	-----	-----	3687.2	0.073
3695.05	0.146	-----	-----	-----	-----	-----	-----	3695.05	0.146
3724.08	0.470	-----	-----	-----	-----	-----	-----	3724.08	0.470
3732.12	0.245	-----	-----	-----	-----	-----	-----	3732.12	0.245
3736.53	0.248	-----	-----	-----	-----	-----	-----	3736.53	0.248
3743.9	0.061	-----	-----	-----	-----	-----	-----	3743.9	0.061
3760.0	0.055	-----	-----	-----	-----	-----	-----	3760.0	0.055
3772.25	0.121	-----	-----	-----	-----	-----	-----	3772.25	0.121
3778.38	0.482	-----	-----	-----	-----	-----	-----	3778.38	0.482
3782.18	0.281	-----	-----	-----	-----	-----	-----	3782.18	0.281
3788.97	0.283	-----	-----	-----	-----	-----	-----	3788.97	0.283
3794.16	0.192	-----	-----	-----	-----	-----	-----	3794.16	0.192
3814.2	0.065	-----	-----	-----	-----	-----	-----	3814.2	0.065
3818.14	0.505	-----	-----	-----	-----	-----	-----	3818.14	0.505
3835.8	0.038	-----	-----	-----	-----	-----	-----	3835.8	0.038
3857.00	0.418	-----	-----	-----	-----	-----	-----	3857.00	0.418
3871.04	0.427	-----	-----	-----	-----	-----	-----	3871.04	0.427
3881.7	0.037	-----	-----	-----	-----	-----	-----	3881.7	0.037
3891.7	0.056	-----	-----	-----	-----	-----	-----	3891.7	0.056
3896.3	0.110	-----	-----	-----	-----	-----	-----	3896.3	0.110

Table 6: Comparison of thermal-neutron capture data for ^{65}Cu (Continued)

Delfini 1983		Shera 1968		Maier 1968		Alves 1969		ENSDF 1983	
Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]
3900.18	1.21	-----	-----	-----	-----	-----	-----	3900.18	1.21
3914.0	0.066	-----	-----	-----	-----	-----	-----	3914.0	0.066
3923.8	0.037	-----	-----	-----	-----	-----	-----	3923.8	0.037
3955.1	0.097	-----	-----	-----	-----	-----	-----	3955.1	0.097
3966.99	0.428	-----	-----	-----	-----	-----	-----	3966.99	0.428
3974.97	0.391	-----	-----	-----	-----	-----	-----	3974.97	0.391
3988.21	0.129	-----	-----	-----	-----	-----	-----	3988.21	0.129
4000.15	0.222	-----	-----	-----	-----	-----	-----	4000.15	0.222
4016.95	0.33	-----	-----	-----	-----	-----	-----	4016.95	0.33
4020.3	0.099	-----	-----	-----	-----	-----	-----	4020.3	0.099
4024.9	0.046	-----	-----	-----	-----	-----	-----	4024.9	0.046
4039.82	0.75	-----	-----	-----	-----	-----	-----	4039.82	0.75
4055.62	0.248	-----	-----	-----	-----	-----	-----	4055.62	0.248
4078.2	0.134	-----	-----	-----	-----	-----	-----	4078.2	0.134
4102.6	0.056	-----	-----	-----	-----	-----	-----	4102.6	0.056
4109.7	0.04	-----	-----	-----	-----	-----	-----	4109.7	0.04
4113.25	0.62	-----	-----	-----	-----	-----	-----	4113.25	0.62
4117.22	0.88	-----	-----	-----	-----	-----	-----	4117.22	0.88
4122.91	0.330	-----	-----	-----	-----	-----	-----	4122.91	0.330
4153.80	0.153	-----	-----	-----	-----	-----	-----	4153.80	0.153
4167.3	0.036	-----	-----	-----	-----	-----	-----	4167.3	0.036
4174.2	0.034	-----	-----	-----	-----	-----	-----	4174.2	0.034
4198.32	1.09	-----	-----	-----	-----	4205	1.0	4198.32	1.09
4221.20	0.350	-----	-----	-----	-----	-----	-----	4221.20	0.350
4243.7	0.036	-----	-----	-----	-----	-----	-----	4243.7	0.036
4251.95	0.128	-----	-----	-----	-----	-----	-----	4251.95	0.128
4266.54	0.115	-----	-----	-----	-----	-----	-----	4266.54	0.115
4271.7	0.088	-----	-----	-----	-----	-----	-----	4271.7	0.088
4276.58	0.591	-----	-----	-----	-----	-----	-----	4276.58	0.591
4298.14	0.227	-----	-----	-----	-----	-----	-----	4298.14	0.227
4326.66	0.846	-----	-----	-----	-----	-----	-----	4326.66	0.846
-----	-----	-----	-----	-----	-----	4330	7.3	-----	-----
4377.75	0.77	-----	-----	-----	-----	-----	-----	4377.75	0.77
4385.13	3.50	-----	-----	-----	-----	4390	2.9	4385.13	3.50
4401.69	1.03	-----	-----	-----	-----	-----	-----	4401.69	1.03
4435.2	0.055	-----	-----	-----	-----	-----	-----	4435.2	0.055

Table 6: Comparison of thermal-neutron capture data for ^{65}Cu (Continued)

Delfini 1983		Shera 1968		Maier 1968		Alves 1969		ENSDF 1983	
Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]	Eγ (keV)	Iγ [a]
4440.6	0.082	-----	-----	-----	-----	-----	-----	4440.6	0.082
4457.73	0.223	-----	-----	-----	-----	-----	-----	4457.73	0.223
4468.58	0.267	-----	-----	-----	-----	-----	-----	4468.58	0.267
4479.82	1.07	-----	-----	-----	-----	4485	0.8	4479.82	1.07
4506.9	0.055	-----	-----	-----	-----	-----	-----	4506.9	0.055
4545.2	0.044	-----	-----	-----	-----	-----	-----	4545.2	0.044
4562.96	0.335	-----	-----	-----	-----	4564	0.8	4562.96	0.335
4572.4	0.051	-----	-----	-----	-----	-----	-----	4572.4	0.051
4576.8	0.093	-----	-----	-----	-----	-----	-----	4576.8	0.093
4612.55	0.382	-----	-----	-----	-----	-----	-----	4612.55	0.382
4617.8	0.172	-----	-----	-----	-----	-----	-----	4617.8	0.172
4671.20	0.196	-----	-----	-----	-----	-----	-----	4671.20	0.196
4699.0	0.044	-----	-----	-----	-----	-----	-----	4699.0	0.044
4703.4	0.051	-----	-----	-----	-----	-----	-----	4703.4	0.051
4795.39	0.289	-----	-----	-----	-----	-----	-----	4795.39	0.289
4805.30	0.232	-----	-----	-----	-----	-----	-----	4805.30	0.232
4900.15	0.32	-----	-----	-----	-----	-----	-----	4900.15	0.32
4903.09	0.77	-----	-----	4903	-----	4904	0.6	4903.09	0.77
4941.94	0.372	-----	-----	4938	-----	4937	3.4	4941.94	0.372
5043.00	5.86	5042	6.2	-----	-----	-----	-----	5043.00	5.86
5047.98	3.50	5048	3.9	5046	7.4	5047	6.6	5047.98	3.50
5138.98	0.263	5139	0.4	-----	-----	5139	0.4	5138.98	0.263
5245.88	7.30	5245	7.6	5246	6.8	5247	5.5	5245.88	7.30
5320.23	6.15	5320	6.3	5320	5.5	5323	4.1	5320.23	6.15
5388.12	0.532	5387	0.5	-----	-----	-----	-----	5388.12	0.532
5488.65	0.093	5490	0.1	-----	-----	-----	-----	5488.65	0.093
5505.56	0.095	5504	0.1	-----	-----	-----	-----	5505.56	0.095
5518.73	0.659	5518	0.6	5516	0.5	5516	0.7	5518.73	0.659
5626.9	0.045	-----	-----	-----	-----	5620	0.3	5626.9	0.045
5722.03	0.383	5721	0.3	5720	0.5	-----	-----	5722.03	0.383
5853.41	1.112	5853	1.0	5852	0.8	5853	0.7	5853.41	1.112
5907.9	0.035	-----	-----	-----	-----	-----	-----	5907.9	0.035
-----	-----	-----	-----	-----	-----	5957	0.3	-----	-----
6013.46	0.120	6014	0.2	6014	1.2	6015	0.8	6013.46	0.120
6048.84	1.71	6049	1.4	6049	1.2	6050	1.7	6048.84	1.71
-----	-----	6057	0.1	-----	-----	-----	-----	-----	-----

Table 6: Comparison of thermal-neutron capture data for ^{65}Cu (Continued)

Delfini 1983		Shera 1968		Maier 1968		Alves 1969		ENSDF 1983	
Eγ (keV)	Iγ[a]	Eγ (keV)	Iγ[a]	Eγ (keV)	Iγ[a]	Eγ (keV)	Iγ[a]	Eγ (keV)	Iγ[a]
-----	-----	-----	-----	-----	-----	6065	0.7	-----	-----
-----	-----	-----	-----	-----	-----	6115	0.6	-----	-----
6243.19	2.44	6243	1.9	6242	3	6243	2.2	6243.19	2.44
-----	-----	-----	-----	-----	-----	6266	0.8	-----	-----
6336.16	0.144	-----	-----	-----	-----	6338	0.5	6336.16	0.144
-----	-----	-----	-----	-----	-----	6393	1.4	-----	-----
-----	-----	-----	-----	-----	-----	6417	0.8	-----	-----
6600.66	14.4	6600	10.4	6600	18.2	6600	11.3	6600.66	14.4
6680.01	13.80	6680	9.7	6677	16.8	6679	10.8	6680.01	13.80
6790.64	2.63	6791	1.8	6789	2.9	6791	1.7	6790.64	2.63
6828.1	0.022	-----	-----	-----	-----	-----	-----	6828.1	0.022
6879.82	0.351	6880	0.3	-----	-----	6880	0.3	6879.82	0.351
7065.72	2.23	7066	1.4	7063	2.4	7063	1.4	7065.72	2.23

[a]Number of photons per 100 neutron captures.

B. Recommended ACTI spectrum for ^{65}Cu

The recommended ACTI spectrum for ^{65}Cu is listed in Table 7. It is simply the spectrum from Del83, normalized to the Q-value of Audi[11] (7065.93 keV). The normalization factor applied to each Del83 intensity was 1.0003.

Table 7: Recommended ACTI spectrum for ^{65}Cu[a]

Eγ (keV)	Iγ[b]	Eγ (keV)	Iγ[b]
89.18	10.903	247.48	0.193
100.15	0.140	274.92	0.152
111.93	0.160	279.33	0.350
114.36	0.107	283.38	0.280
186.01	41.012	289.20	0.057
190.10	0.830	291.80	0.028
194.47	0.760	315.71	4.101
199.90	0.600	334.03	0.160
217.00	0.024	335.73	0.250
234.26	0.190	338.03	0.169
237.82	4.001	340.19	0.157

Table 7: Recommended ACTI spectrum for ^{65}Cu[a] (Continued)

Eγ (keV)	Iγ[b]	Eγ (keV)	Iγ[b]
357.56	0.490	753.91	0.469
385.78	19.005	758.83	0.171
417.03	0.135	768.31	1.000
422.01	0.096	770.64	0.094
426.37	0.560	788.42	0.160
436.91	1.901	797.90	0.039
454.80	0.440	808.21	0.230
457.60	0.390	810.47	0.260
460.80	0.300	814.27	0.790
465.15	22.306	822.68	4.031
482.69	0.440	826.80	0.125
525.96	0.053	831.20	2.711
531.24	0.113	834.10	0.358
533.96	0.120	847.42	0.410
537.55	0.107	860.85	0.142
543.85	4.191	878.82	1.014
547.55	0.740	883.03	0.365
551.95	0.486	899.14	0.141
556.46	0.055	903.18	0.079
567.35	0.169	909.99	0.043
583.62	0.206	927.35	0.073
586.79	0.333	937.51	1.143
622.69	0.090	948.09	0.382
632.67	0.140	956.74	0.530
636.68	0.293	958.25	0.360
645.99	0.110	961.26	0.364
651.10	0.086	972.11	1.941
661.22	0.099	976.27	0.349
665.60	0.097	983.21	0.176
679.30	0.166	987.18	0.522
695.35	0.080	993.48	0.087
714.66	0.072	997.65	1.460
723.99	0.537	1006.19	0.229
729.19	0.258	1014.07	0.231
738.15	0.079	1017.10	0.086
741.94	0.384	1019.46	0.404
747.48	0.386	1026.67	0.190

Table 7: Recommended ACTI spectrum for ^{65}Cu[a] (Continued)

Eγ (keV)	Iγ[b]	Eγ (keV)	Iγ[b]
1042.86	0.300	1450.60	0.140
1052.19	1.991	1468.56	0.520
1053.88	0.310	1471.05	0.760
1081.95	0.120	1489.90	0.164
1088.64	0.142	1506.57	0.225
1115.48	0.099	1509.64	0.175
1120.80	0.057	1515.30	0.054
1135.78	0.075	1523.00	0.054
1139.65	0.404	1532.40	0.070
1146.79	0.195	1553.10	0.390
1161.63	0.112	1557.40	0.420
1164.71	0.166	1559.86	5.602
1180.80	0.041	1574.00	0.096
1197.21	0.710	1582.51	1.600
1208.80	0.050	1589.79	0.119
1212.52	1.781	1607.34	0.107
1220.40	0.100	1629.20	0.180
1253.28	0.184	1633.89	1.090
1261.72	0.137	1637.49	2.371
1272.32	0.628	1647.33	0.390
1280.20	0.227	1652.01	0.530
1288.63	0.076	1658.91	0.231
1293.71	0.405	1666.15	0.173
1298.87	0.500	1670.32	0.211
1303.03	0.140	1678.19	0.780
1313.29	0.133	1682.00	0.143
1322.16	0.165	1723.07	0.167
1343.40	0.034	1728.01	0.441
1355.18	2.251	1732.27	0.127
1374.41	0.241	1743.40	2.341
1394.90	0.273	1746.20	1.080
1401.26	0.074	1748.00	0.590
1408.40	0.045	1761.60	0.064
1416.38	0.129	1773.50	0.109
1428.18	0.760	1799.84	0.137
1435.26	0.219	1806.57	0.108
1439.37	1.881	1820.21	0.930

Table 7: Recommended ACTI spectrum for ^{65}Cu[a] (Continued)

Eγ (keV)	Iγ[b]	Eγ (keV)	Iγ[b]
1832.39	1.220	2163.22	0.400
1837.44	0.710	2177.87	0.164
1843.71	0.145	2215.88	1.630
1849.40	0.180	2254.50	0.090
1854.30	0.054	2278.20	0.071
1866.68	0.950	2315.70	0.210
1874.41	0.083	2371.40	0.130
1890.61	0.140	2380.34	0.210
1901.52	0.152	2389.30	0.100
1912.13	0.139	2400.00	0.160
1916.35	0.104	2402.83	0.220
1929.63	0.158	2411.58	0.360
1939.87	0.360	2423.94	0.191
1944.97	0.190	2436.70	0.130
1966.29	0.194	2439.35	0.420
1975.26	0.187	2448.70	0.150
1980.01	0.338	2450.91	0.290
1985.73	0.236	2457.66	0.183
1988.92	0.360	2478.20	0.170
2004.42	0.246	2488.40	0.240
2023.55	0.470	2492.00	0.110
2039.33	0.083	2508.30	0.110
2046.00	0.143	2539.30	0.070
2059.90	0.067	2545.20	0.080
2068.26	0.149	2553.10	0.150
2082.60	0.071	2557.80	0.093
2091.36	0.294	2561.30	0.068
2095.76	0.205	2569.26	0.176
2110.44	0.610	2584.30	0.090
2114.78	0.159	2603.30	0.230
2120.25	0.146	2608.50	0.260
2123.95	0.161	2612.10	0.270
2131.25	0.114	2615.20	0.120
2144.22	0.186	2619.14	0.280
2147.27	0.202	2629.61	0.710
2151.31	0.265	2641.30	0.200
2160.40	0.130	2664.17	0.340

Table 7: Recommended ACTI spectrum for ^{65}Cu[a] (Continued)

Eγ (keV)	Iγ[b]	Eγ (keV)	Iγ[b]
2673.42	0.320	3090.95	0.161
2680.38	0.480	3111.40	0.096
2687.88	0.520	3121.30	0.110
2700.26	0.720	3131.70	0.173
2708.20	0.130	3137.18	0.300
2713.30	0.100	3165.80	0.210
2758.80	0.150	3169.40	0.200
2766.20	0.120	3172.95	0.730
2770.70	0.080	3184.49	0.810
2781.50	0.100	3208.10	0.110
2806.90	0.140	3225.80	0.076
2821.76	0.730	3230.10	0.057
2824.80	0.120	3241.90	0.140
2856.36	0.263	3251.26	0.240
2862.63	0.440	3270.78	0.570
2866.61	0.390	3275.20	0.080
2870.70	0.078	3285.85	0.330
2876.19	0.171	3293.49	0.720
2890.60	0.125	3307.40	0.110
2896.90	0.087	3316.04	0.330
2901.20	0.119	3322.20	0.080
2912.57	0.158	3327.20	0.080
2918.00	0.065	3348.50	0.113
2935.05	0.254	3361.11	0.152
2949.50	0.190	3383.60	0.124
2952.64	0.330	3402.63	0.240
2968.80	0.112	3424.85	0.225
2986.90	0.074	3429.40	1.050
2991.10	0.120	3450.30	0.093
2996.78	0.330	3456.20	0.063
3009.32	0.297	3465.00	0.640
3021.72	0.216	3476.90	0.078
3025.77	0.470	3482.51	0.330
3045.46	0.230	3486.20	0.076
3052.91	0.230	3530.56	0.710
3067.20	0.160	3548.60	0.128
3071.80	0.130	3556.99	0.420

3560.10	0.280	4016.95	0.330
3563.70	0.120	4020.30	0.099
3578.00	0.116	4024.90	0.046
3586.20	0.075	4039.82	0.750

Table 7: Recommended ACTI spectrum for ^{65}Cu[a] (Continued)

Eγ (keV)	Iγ[b]	Eγ (keV)	Iγ[b]
4617.80	0.172	5505.56	0.095
4671.20	0.196	5518.73	0.659
4699.00	0.044	5626.90	0.045
4703.40	0.051	5722.03	0.383
4795.39	0.289	5853.41	1.112
4805.30	0.232	5907.90	0.035
4900.15	0.320	6013.46	0.120
4903.09	0.770	6048.84	1.710
4941.94	0.372	6243.19	2.441
5043.00	5.862	6336.16	0.144
5047.98	3.501	6600.66	14.404
5138.98	0.263	6680.01	13.804
5245.88	7.302	6790.64	2.631
5320.23	6.152	6828.10	0.022
5388.12	0.532	6879.82	0.351
5488.65	0.093	7065.72	2.231

[a]All values are from Del83.[16]
[b]Number of photons per 100 captures, normalized to the Q-value of Audi.[11]

IV. Summary

Several sources of thermal-neutron capture data for the stable copper isotopes have been analyzed, and the best possible photon production spectrum for each isotope has been presented. These spectra are recommended for use by ACTI and any other applications requiring high-quality photon production data from thermal-neutron capture in copper. A similar analysis of photon production data for aluminum is planned next.

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