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MASTER

TABULATION OF THE ^{228}Th TOTAL NEUTRON CROSS SECTIONS
FOR THE 1.9 AND 7.5 eV RESONANCES

O. D. Simpson, R. P. Schuman and J. R. Berreth

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IN NUCLEAR SCIENCE ABSTRACTS

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FOR THE 1.9 AND 7.5 eV RESONANCES

by

O. D. Simpson, R. P. Schuman and J. R. Berreth

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Tabulation of the ^{228}Th Total Neutron Cross Sections
for the 1.9 and 7.5 eV Resonances

O. D. Simpson, R. P. Schuman and J. R. Berreth

Abstract

The total neutron cross section of ^{228}Th has been measured in the regions of 1.9 and 7.5 eV, with the Materials Testing Reactor (MTR) fast chopper. Breit-Wigner single level resonance parameters are quoted for the two resonances observed.

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Tabulation of the ^{228}Th Total Neutron Cross Sections
for the 1.9 and 7.5 eV Resonances

O. D. Simpson, R. P. Schuman and J. R. Berreth

Total neutron cross section measurements⁽¹⁾ of ^{232}U were started in April 1963 and continued until September 1964. During the course of the ^{232}U cross section measurements ^{228}Th was produced from the alpha decay of ^{232}U . The ^{228}Th appeared as a contaminant in the ^{232}U samples, with inverse thicknesses ranging from 90,200 to 26,500 barns/atom. The latter number corresponds to about 8 mg of ^{228}Th . Two resonances were observed, at 1.896 and 7.55 eV, which could be attributed to ^{228}Th .

At one time the ^{232}U was purified by removing the ^{228}Th . The ^{228}Th obtained from this separation, approximately 2 mg, was mixed with about 1 g of aluminum powder and pressed into a solid compact of a size suitable for measurements on the Materials Testing Reactor (MTR) fast chopper⁽²⁾. Because of the small quantity of material the sample was adequate only for identifying the strong resonance at 1.9 eV in ^{228}Th . In the ^{232}U which had been freshly separated, the resonance at 7.55 eV was observed to be growing in, with a half-life consistent with the decay times of ^{232}U and ^{228}Th . The only member of the ^{232}U decay chain which can adequately account for the 7.55 eV level is ^{228}Th .

The total neutron cross section of ^{228}Th for the two observed resonances is shown in Figs. 1 and 2. The data were obtained by the same technique as for the ^{232}U measurement, which has been previously described⁽³⁾. The off-resonance cross sections (i.e., the cross section in the valleys between resonances) could not be measured because of the small quantities of sample material available. The parameters are listed in Table I. The contribution from the resonances to the 2200 meter/sec

cross section is calculated to be 37 barns. This is considerably lower than 120 barns quoted elsewhere⁽⁴⁾, which can be an indication that there is a contribution from a strong negative-energy level or that there is a small low energy resonance, not observable in the present measurement.

A tabulation of the ²²⁸Th total neutron cross sections in the regions of 2 and 7.5 eV is given in an appendix.

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Table I

²²⁸Th Neutron Resonance Parameter

E_0 (eV)	Γ_γ (mV)	Γ_n^0 (mV)
$1.896 \pm .002$	36 ± 2	0.57 ± 0.04
$7.55 \pm .02$	70 ± 30	0.44 ± 0.15

Fig. 1. The total neutron cross section of ^{228}Th times the square root of the neutron energy in the region of 1.9 eV. The solid line is a single-level Breit-Wigner fit to the data.

Fig. 2. The total neutron cross section of ^{228}Th times the square root of the neutron energy in the region of 7.5 eV. The solid line is a single-level Breit-Wigner fit to the data.

Appendix

Tabulation of the ^{228}Th Data

Operating Condition Using a Flight Path of 20 Meters

<u>IBM Run Number</u>	<u>Rotor Speed (rpm)</u>	<u>Channel Width (μsec)</u>	<u>Resolution* ($\mu\text{sec}/\text{meter}$)</u>	<u>Sample Thickness (barns/atom)</u>
1749	3000	2	0.18	90,200
1767	3000	2	0.18	87,100
1768	3000	2	0.18	86,700
1897	3000	2	0.18	26,700
1910	3000	2	0.18	51,500
1960	6000	1	0.10	26,500

*The following assumptions were made: triangular burst width with full width at half maximum of $1.6 \mu\text{sec}$ at 6000 rpm, rectangular effective counter thickness of 4.8 cm and a Maxwellian distribution of $0.5 \mu\text{sec}$ width at half maximum for the counter jitter. Effect of detector thickness for measurements above 1 eV computed at 5 eV.

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Run 1749

Delay (μ sec)	Trans.	E(eV)	$\sigma(b)$	$\sigma \sqrt{E.}/(b \text{ eV}^2)$
1081.5	0.9814	1.78747	1691.48	2261.44
1079.5	0.9741	1.79410	2367.56	3171.21
1077.5	0.9849	1.80077	1375.15	1845.35
1075.5	0.9924	1.80747	691.98	930.31
1073.5	0.9867	1.81421	1205.96	1624.34
1071.5	0.9713	1.82099	2622.36	3538.72
1069.5	0.9421	1.82781	5383.21	7277.91
1067.5	0.9577	1.83467	3895.61	5276.59
1065.5	0.9385	1.84156	5725.76	7770.09
1063.5	0.9404	1.84849	5542.97	7536.18
1061.5	0.9134	1.85546	8173.89	11134.10
1059.5	0.8997	1.86248	9534.43	13011.88
1057.5	0.8722	1.86953	12337.56	16869.23
1055.5	0.8420	1.87662	15513.61	21252.05
1053.5	0.8226	1.88375	17619.57	24182.83
1051.5	0.8080	1.89092	19233.79	26448.55
1049.5	0.8043	1.89814	19644.24	27064.45
1047.5	0.8277	1.90539	17055.12	23542.20
1045.5	0.8333	1.91269	16448.99	22748.95
1043.5	0.8795	1.92003	11578.11	16043.21
1041.5	0.9014	1.92741	9362.26	12997.73
1039.5	0.9123	1.93483	8283.67	11522.44
1037.5	0.9299	1.94230	6555.71	9136.46
1035.5	0.9526	1.94981	4377.90	6113.11
1033.5	0.9621	1.95736	3481.86	4871.33
1031.5	0.9583	1.96496	3840.31	5383.23
1029.5	0.9633	1.97260	3370.30	4733.56
1037.5	0.9808	1.98029	1750.71	2463.65
1025.5	0.9991	1.98802	77.53	109.32
1023.5	0.9922	1.99580	710.54	1003.79
1021.5	0.9899	2.00362	916.58	1297.41
1019.5	0.9847	2.01149	1393.07	1975.75

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Run 1767

Delay (μ sec)	Trans.	E(eV)	$\sigma(b)$	$\sigma\sqrt{E}_{1/2}$ (b eV ^{1/2})
1084	0.9817	1.77924	1607.32	2143.98
1082	0.9947	1.78582	461.68	616.97
1080	0.9801	1.79244	1751.98	2345.58
1078	0.9966	1.79910	292.89	392.86
1076	0.9717	1.80579	2499.13	3358.33
1074	0.9763	1.81252	2092.44	2817.05
1072	0.9865	1.81929	1187.36	1601.53
1070	0.9828	1.82610	1514.74	2046.92
1068	0.9591	1.83295	3638.96	4926.66
1066	0.9411	1.83983	5290.74	7176.38
1064	0.9394	1.84676	5447.59	7403.03
1062	0.9166	1.85372	7584.47	10326.36
1060	0.8889	1.86072	10254.94	13988.58
1058	0.8860	1.86776	10542.00	14407.33
1056	0.8426	1.87484	14917.60	20425.91
1054	0.8353	1.88196	15675.85	21504.87
1052	0.8173	1.88913	17577.06	24158.88
1050	0.8179	1.89633	17505.64	24106.54
1048	0.8208	1.90357	17202.67	23734.54
1046	0.8247	1.91086	16785.92	23203.84
1044	0.8403	1.91819	15150.79	20983.65
1042	0.8597	1.92556	13164.67	18267.89
1040	0.8977	1.93297	9401.20	13070.62
1038	0.9234	1.94043	6938.91	9665.85
1036	0.9323	1.94793	6109.67	8527.16
1034	0.9532	1.95547	4174.88	5838.07
1032	0.9586	1.96306	3678.88	5154.44
1030	0.9798	1.97069	1778.99	2497.37
1028	0.9807	1.97836	1696.39	2386.04
1026	0.9762	1.98608	2096.94	2955.18
1024	0.9888	1.99385	981.57	1386.01
1022	0.9797	2.00166	1788.91	2530.96

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Run 1768

Delay (μ sec)	Trans.	E(eV)	σ (b)	$\sigma \sqrt{E_{1/2}}$ (b $eV^{1/2}$)
1084	0.9868	1.77924	1151.61	1536.11
1082	0.9750	1.78582	2191.16	2928.15
1080	0.9772	1.79244	1996.33	2672.73
1078	0.9882	1.79910	1031.61	1383.70
1076	0.9846	1.80579	1346.81	1809.84
1074	0.9682	1.81252	2800.05	3769.71
1072	0.9772	1.81929	2003.59	2702.47
1070	0.9679	1.82610	2832.01	3826.99
1068	0.9498	1.83295	4466.38	6046.88
1066	0.9459	1.83983	4824.36	6543.78
1064	0.9249	1.84676	6770.19	9200.37
1062	0.9279	1.85372	6487.16	8832.35
1060	0.8966	1.86072	9461.37	12906.08
1058	0.8791	1.86776	11175.09	15272.55
1056	0.8649	1.87484	12586.90	17234.60
1054	0.8297	1.88196	16189.68	22209.76
1052	0.8224	1.88913	16956.26	23305.61
1050	0.8027	1.89633	19049.62	26232.72
1048	0.8205	1.90357	17149.38	23661.01
1046	0.8193	1.91086	17275.18	23880.15
1044	0.8631	1.91819	12764.41	17678.55
1042	0.8718	1.92556	11899.51	16512.30
1040	0.8940	1.93297	9712.63	13503.60
1038	0.9160	1.94043	7606.23	10595.42
1036	0.9464	1.94793	4774.58	6663.80
1034	0.9542	1.95547	4069.01	5690.03
1032	0.9596	1.96306	3575.15	5009.11
1030	0.9769	1.97069	2027.04	2845.58
1028	0.9784	1.97836	1893.16	2662.81
1026	0.9813	1.98608	1638.01	2308.42
1024	0.9825	1.99385	1531.85	2163.04
1022	0.9766	2.00166	2054.57	2906.80

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Run 1897

Delay (μ sec)	Trans.	E(eV)	$\sigma(b)$	$\sigma\sqrt{E}_{1/2}$ (b eV ^{1/2})
1083	0.9649	1.78253	954.29	1274.09
1081	0.9678	1.78913	873.55	1168.45
1079	0.9459	1.79577	1485.40	1990.53
1077	0.9368	1.80244	1744.38	2341.92
1075	0.9418	1.80915	1602.38	2155.28
1073	0.9339	1.81590	1826.63	2461.48
1071	0.8880	1.82269	3171.65	4281.95
1069	0.8791	1.82952	3440.22	4653.23
1067	0.8662	1.83638	3835.80	5198.02
1065	0.8278	1.84329	5045.21	6849.77
1063	0.7855	1.85023	6445.45	8767.31
1061	0.7285	1.85721	8456.54	11524.54
1059	0.6521	1.86423	11417.77	15589.48
1057	0.6095	1.87130	13217.74	18081.25
1055	0.5669	1.87840	15154.64	20770.14
1053	0.5147	1.88554	17731.17	24347.55
1051	0.5169	1.89272	17621.28	24242.71
1049	0.5076	1.89995	18106.77	24958.11
1047	0.5135	1.90721	17797.93	24579.28
1045	0.5035	1.91452	14385.55	19904.74
1043	0.6423	1.92187	11819.74	16385.89
1041	0.6955	1.92926	9696.30	13467.95
1039	0.7561	1.93670	7465.95	10390.01
1037	0.8078	1.94417	5697.85	7944.72
1035	0.8536	1.95169	4227.01	5905.27
1033	0.8678	1.95926	3785.93	5299.30
1031	0.9081	1.96687	2573.37	3609.03
1029	0.9331	1.97452	1848.92	2598.06
1027	0.9391	1.98222	1677.23	2361.40
1025	0.9711	1.98996	784.10	1106.10
1023	0.9631	1.99775	1002.53	1416.99
1021	0.9772	2.00558	615.11	871.11

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Run 1910

Delay (μ sec)	Trans.	E(eV)	$\sigma(b)$	$\sigma \sqrt{E_{1/2}}$ (b eV ^{1/2})
1081.5	0.9861	1.78747	722.14	965.48
1079.5	0.9855	1.79410	752.31	1007.67
1077.5	0.9704	1.80077	1545.28	2073.66
1075.5	0.9487	1.80747	2710.38	3643.89
1073.5	0.9722	1.81421	1451.79	1955.46
1071.5	0.9521	1.82099	2530.57	3414.86
1069.5	0.9416	1.82781	3101.53	4193.16
1067.5	0.9285	1.83467	3822.87	5178.07
1065.5	0.9047	1.84156	5158.47	7000.25
1063.5	0.8922	1.84849	5872.52	7984.24
1061.5	0.8486	1.85546	8451.79	11512.63
1059.5	0.8474	1.86248	8527.64	11637.89
1057.5	0.7709	1.86953	13402.13	18324.82
1055.5	0.7431	1.87662	15293.02	20949.87
1053.5	0.7132	1.88375	17403.33	23886.03
1051.5	0.6885	1.89092	19223.99	26435.07
1049.5	0.7186	1.89814	17015.21	23442.35
1047.5	0.7260	1.90539	16490.12	22762.29
1045.5	0.7487	1.91269	14905.12	20613.78
1043.5	0.7975	1.92003	11656.10	16151.29
1041.5	0.8191	1.92741	10278.56	14269.85
1039.5	0.8586	1.93483	7850.11	10919.37
1037.5	0.8870	1.94230	6173.73	8604.10
1035.5	0.8875	1.94981	6144.55	8579.98
1033.5	0.9200	1.95736	4291.47	6004.01
1031.5	0.9588	1.96496	2168.34	3039.52
1029.5	0.9614	1.97260	2026.48	2846.18
1027.5	0.9577	1.98029	2223.19	3128.54
1025.5	0.9645	1.98802	1860.11	2622.70
1023.5	0.9968	1.99580	163.19	230.54
1021.5	0.9948	2.00362	270.02	382.21

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Run 1897

Delay (μsec)	Trans.	E(eV)	$\sigma(b)$	$\sigma\sqrt{E}_{1/2}$ (b eV ^{1/2})
544	.9881	7.0647	320.4	851.6
542	1.0043	7.1170	-114.8	-306.3
540	1.0119	7.1698	-320.4	-857.9
538	.9884	7.2232	311.1	836.1
536	.9886	7.2772	305.7	824.7
534	.9713	7.3318	777.0	2103.9
532	.9915	7.3870	227.0	617.0
530	.9593	7.4429	1109.4	3026.6
528	.9288	7.4994	1971.8	5399.6
526	.9027	7.5565	2732.7	7511.9
524	.9163	7.6143	2333.6	6439.3
522	.9589	7.6728	1120.0	3102.4
520	.9867	7.7319	357.8	994.9
518	1.0013	7.7917	-34.7	-96.9
516	.9929	7.8522	189.6	531.3
514	.9951	7.9135	130.8	368.0
512	.9932	7.9754	181.6	512.9
510	.9940	8.0381	160.7	455.6

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Run 1960

Delay (μ sec)	Trans.	E(eV)	$\sigma(b)$	$\sigma\sqrt{E}/(b\text{ eV}^{1/2})$
545	.9754	7.0388	664.8	1763.8
544	1.0149	7.0647	-400.5	-1064.5
543	1.0193	7.0908	-520.7	-1386.6
542	.9752	7.1170	670.2	1788.0
541	1.0113	7.1433	-303.0	-809.8
540	.9741	7.1698	700.9	1876.7
539	1.0201	7.1964	-542.0	-1454.0
538	.9932	7.2232	181.6	488.1
537	.9700	7.2501	813.0	2189.0
536	1.0242	7.2772	-654.2	-1764.8
535	.9834	7.3044	445.9	1205.1
534	.9963	7.3318	98.8	267.5
533	.9727	7.3593	739.6	2006.4
532	.9363	7.3870	1756.9	4755.1
531	.9555	7.4149	1214.9	3308.2
530	.9614	7.4429	1050.6	2866.1
529	.9361	7.4710	1762.2	4816.6
528	.9253	7.4994	2071.9	5673.7
527	.9076	7.5279	2588.6	7102.3
526	.8911	7.5565	3078.5	8462.5
525	.9151	7.5853	2368.3	6522.5
524	.9452	7.6143	1504.5	4151.5
523	.9091	7.6435	2544.5	7034.8
522	.9406	7.6728	1634.0	4526.2
521	1.0092	7.7022	-245.6	-681.6
520	.9912	7.7319	235.0	653.4
519	.9953	7.7617	125.5	349.6
518	.9785	7.7917	579.4	1617.3
517	.9711	7.8219	782.3	2187.9
516	.9821	7.8522	481.9	1350.4
515	1.0182	7.8828	-489.9	-1375.4
514	.9888	7.9135	300.4	845.1
513	1.0199	7.9443	-536.7	-1512.7
512	1.0311	7.9754	-843.7	-2382.7
511	1.0273	8.0067	-739.6	-2092.8
510	.9942	8.0381	154.9	439.2