Title

SUMMARY OF NEUTRON CROSS SECTION MEASUREMENTS FOR 14 Mev TO 280 Mev NEUTRONS

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During 1950 several groups completed neutron cross section measurements which were not available for the summaries of Leith[1] and Adair.[2*] Thus the previous summaries were prepared before any measurements had been made between 95 and 270 Mev and before the measurements at 42, 95 and 270 had been completed.

Using the results indicated in the reference list of this report we have prepared curves of cross section vs. energy for 12 elements and cross section vs. atomic weight at 7 energies from which one may estimate the cross section of any element at any energy from 14 to 280 Mev by interpolation. Most of the light element cross sections may be found directly from the σ vs. E curves. In drawing the curves an attempt has been made to consider the errors quoted for the measurements and to make the two families of curves agree. Thus the dotted σ vs. A curves at 115 and 156 Mev could not be drawn through the measured points at high A unless one assumed a rather complex shape for the σ vs. E curves of heavy elements. The σ vs. A curve at 14 Mev is also dotted because the spread of the measured points is relatively large. It would be desirable to have more information for the regions below 40 Mev and between ~~100 and 200 Mev~~.

Table I is included for convenience in calculating half thicknesses. Besides atomic weights and densities, columns are included giving the

* The data above 40 Mev in this paper are the same as that of Ref. 1

products $\sigma x_{1/2}$ and $\rho\sigma x_{1/2}$. To find the half thickness $x_{1/2}$ in cm corresponding to the given density ρ in gm cm^{-3} one divides the number in the $\sigma x_{1/2}$ column by the cross section in barns. For any other density one must use the $\rho\sigma x_{1/2}$ column and divide by ρ and σ.

Table II gives information on attenuation of neutron beams in concrete and Table III gives ratios of inelastic to total cross sections for use in calculating poor geometry attenuation.

Table I. List of Elements Arranged for Calculation of Half Thicknesses

$x_{1/2}$ = Half thickness in cm

σ = Cross section in barns (see Figs. 1-3)

ρ = Density in gm cm^{-3}

A = Atomic weight

N = Avogadros number = 6.0235×10^{23} atoms per mole $\log_e 2 = x_{1/2}/\lambda = 0.6931471806$

$\frac{\log_e 2}{N \times 10^{-24}} = 1.1507$

		Element	Atomic Weight	Density gm cm^{-3}	$\sigma x_{1/2} = \frac{(\log_e 2) A}{N\rho \times 10^{-24}}$	$\rho\sigma x_{1/2} = \frac{(\log_e 2) A}{N \times 10^{-24}}$
1	H^1	Hydrogen	1.0080			1.1599
1	H^2	Deuterium	2.015			2.319
2	He	Helium	4.003			4.606
3	Li	Lithium	6.940	0.534	14.95	7.986
4	Be	Beryllium	9.02	1.8	5.77	10.38
5	B	Boron	10.82	2.45	5.08	12.45
6	C	Carbon	12.010	1.6	8.64	13.820
7	N	Nitrogen	14.008			16.120
8	O	Oxygen	16.			18.412
9	F	Fluorine	19.000			21.864
10	Ne	Neon	20.183			23.225
11	Na	Sodium	22.997	0.971	27.25	26.464
12	Mg	Magnesium	24.32	1.74	16.1	27.99
13	Al	Aluminum	26.97	2.699	11.50	31.04
14	Si	Silicon	28.06	2.42	13.34	32.29
15	P	Phosphorus	30.98	2.20	16.20	35.65
16	S	Sulfur	32.066	2.	18.4	36.900
17	Cl	Chlorine	35.457			40.802

Element			Atomic Weight	Density gm cm^{-3}	$\sigma x_{1/2} = \frac{(\log_e 2)\ A}{N\rho \times 10^{-24}}$	$\rho\sigma x_{1/2} = \frac{(\log_e 2)\ A}{N \times 10^{-24}}$
18	A	Argon	39.944			45.965
19	K	Potassium	39.096	0.87	51.7	44.989
20	Ca	Calcium	40.08	1.55	29.8	46.12
21	Sc	Scandium	45.10	3.02	17.2	51.90
22	Ti	Titanium	47.90	4.5	12.2	55.12
23	V	Vanadium	50.95	5.96	9.84	58.63
24	Cr	Chromium	52.01	7.1	8.4	59.85
25	Mn	Manganese	54.93	7.2	8.8	63.21
26	Fe	Iron	55.85	7.86	8.18	64.27
27	Co	Cobalt	58.94	8.9	7.6	67.82
28	Ni	Nickel	58.69	8.90	7.59	67.54
29	Cu	Copper	63.57	8.94	8.18	73.15
30	Zn	Zinc	65.38	7.14	10.54	75.24
31	Ga	Gallium	69.72	5.91	13.57	80.23
32	Ge	Germanium	72.60	5.36	15.58	83.54
33	As	Arsenic	74.91	5.73	15.04	86.20
34	Se	Selenium	78.96	4.8	18.9	90.86
35	Br	Bromine	79.916			91.963
36	Kr	Krypton	83.7			96.3
37	Rb	Rubidium	85.48	1.53	64.3	98.37
38	Sr	Strontium	87.63	2.54	39.7	100.84
39	Y	Yttrium	88.92	5.51	18.57	102.32
40	Zr	Zirconium	91.22	6.4	16.4	104.97
41	Nb	Niobium	92.91	8.4	12.7	106.92
42	Mo	Molybdenum	95.95	10.2	10.8	110.41
43	Tc	Technetium				
44	Ru	Ruthenium	101.7	12.2	9.6	117.0
45	Rh	Rhodium	102.91	12.5	9.5	118.42
46	Pd	Palladium	106.7	12.16	10.10	122.8
47	Ag	Silver	107.880	10.50	11.82	124.14
48	Cd	Cadmium	112.41	8.65	14.95	129.35
49	In	Indium	114.76	7.28	18.14	132.06
50	Sn	Tin	118.70	7.3	18.7	136.59
51	Sb	Antimony	121.76	6.691	20.94	140.11
52	Te	Tellurium	127.61	6.24	23.53	146.85
53	I	Iodine	126.92	4.93	29.6	146.05
54	Xe	Xenon	131.3			151.09
55	Cs	Cesium	132.91	1.873	81.65	152.94
56	Ba	Barium	137.36	3.5	45.2	158.07
57	La	Lanthanum	138.92	6.155	25.97	159.86
58	Ce	Cerium	140.13	6.90	23.37	161.25
59	Pr	Praseodymium	140.92	6.5	24.9	162.16
60	Nd	Neodymium	144.27	6.95	23.9	166.02
61	Pm	Promethium				
62	Sm	Samarium	150.43	7.7	22.5	173.11
63	Eu	Europium	152.0			174.9
64	Gd	Gadolinium	156.9			180.6
65	Tb	Terbium	159.2			183.2
66	Dy	Dysprosium	162.46			186.95
67	Ho	Holmium	164.94			189.80

		Element	Atomic Weight	Density gm cm^{-3}	$\sigma x_{1/2} = \frac{(\log_e 2) A}{N\rho \times 10^{-24}}$	$\rho\sigma x_{1/2} = \frac{(\log_e 2) A}{N \times 10^{-24}}$
68	Er	Erbium	167.2			192.4
69	Tm	Thulium	169.4			194.9
70	Yb	Ytterbium	173.04			199.12
71	Lu	Lutetium	174.99			201.37
72	Hf	Hafnium	178.6	13.3	15.5	205.5
73	Ta	Tantalum	180.88	16.6	12.54	208.15
74	W	Tungsten	183.92	19.3	10.96	211.64
75	Re	Rhenium	186.31	20.53	10.44	214.39
76	Os	Osmium	190.2	22.48	9.735	218.9
77	Ir	Iridium	193.1	22.42	9.910	222.2
78	Pt	Platinum	195.23	21.37	10.51	224.66
79	Au	Gold	197.2	19.32	11.74	226.9
80	Hg	Mercury	200.61	13.546	17.042	230.85
81	Tl	Thallium	204.39	11.85	19.85	235.20
82	Pb	Lead	207.21	11.35	21.01	238.44
83	Bi	Bismuth	209.0	9.747	24.67	240.5
84	Po	Polonium				
85	At	Astatine				
86	Rn	Radon	222.			255.
87	Fr	Francium				
88	Ra	Radium	226.05			260.12
89	Ac	Actinium	227.05			261.28
90	Th	Thorium	232.12	11.3	23.6	267.11
91	Pa	Protoactinium	231.			266.
92	U	Uranium	238.07	18.68	14.66	273.96

Table II. Attenuation of a Broad Beam of Neutrons by Concrete Slabs*

Concrete Density 149 lbs/ft^3

Neutron Energy	Half Thickness
90 Mev [3]	$9\frac{1}{2}$"
270 Mev [4]	17" - 18"

* Except for transition effects limited to the first two or three feet, the attenuation measured in concrete is independent of the threshold of the detector used and is, for example, the same if measured with indium foils or with carbon detectors with a 20 Mev threshold.

Table III. Ratios of Inelastic Cross Sections to Total Cross Sections

Element	83 Mev	95 Mev	270 Mev
C	$0.31 < \frac{\sigma_i}{\sigma_t}$ [5]	0.46 ± 0.015 [7]	0.505 ± 0.02 [7]
Al	$0.38 < \frac{\sigma_i}{\sigma_t} < 0.44$ [6]	0.42 ± 0.015 [8]	
Cu	$0.36 < \frac{\sigma_i}{\sigma_t} < 0.42$ [6]	0.39 ± 0.005 [7]	0.50 ± 0.02 [7]
Pb	$0.38 < \frac{\sigma_i}{\sigma_t} < 0.41$ [6]	0.40 ± 0.01 [7]	0.51 ± 0.01 [7]

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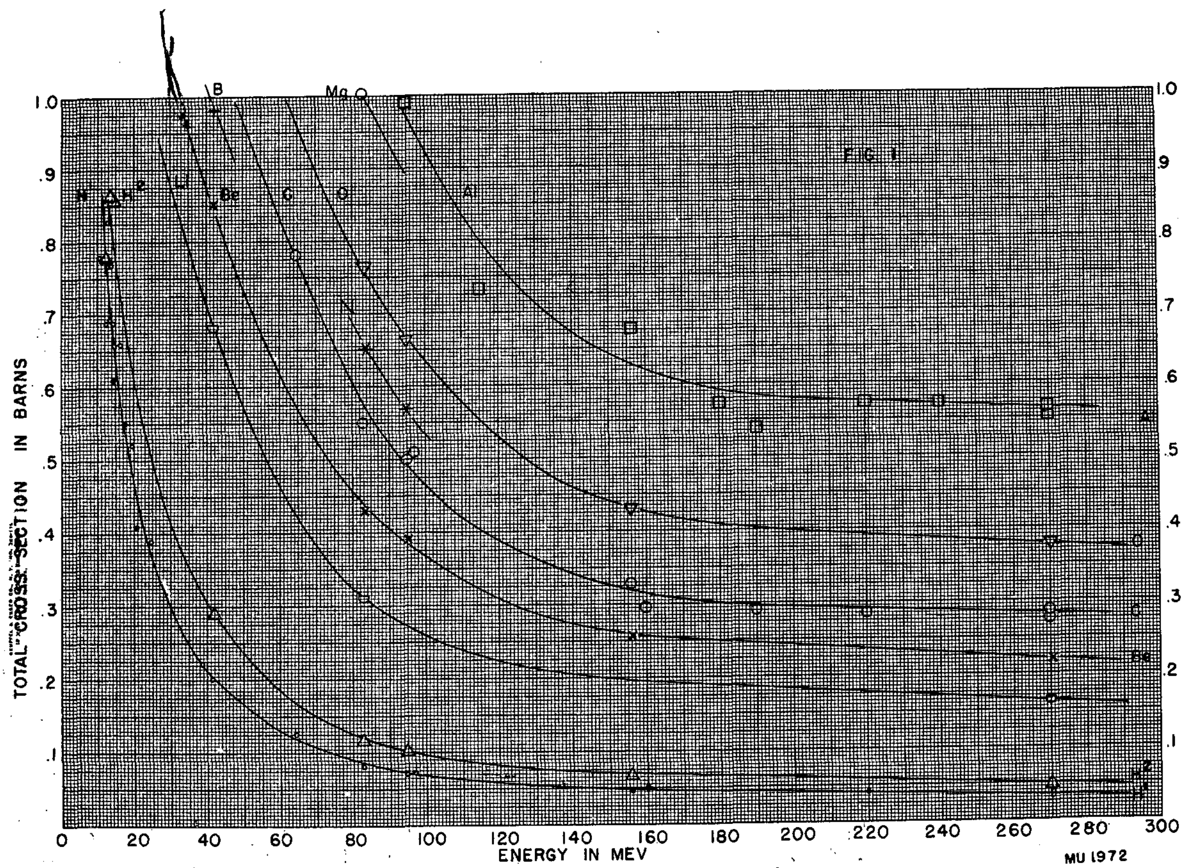

Fig. 1

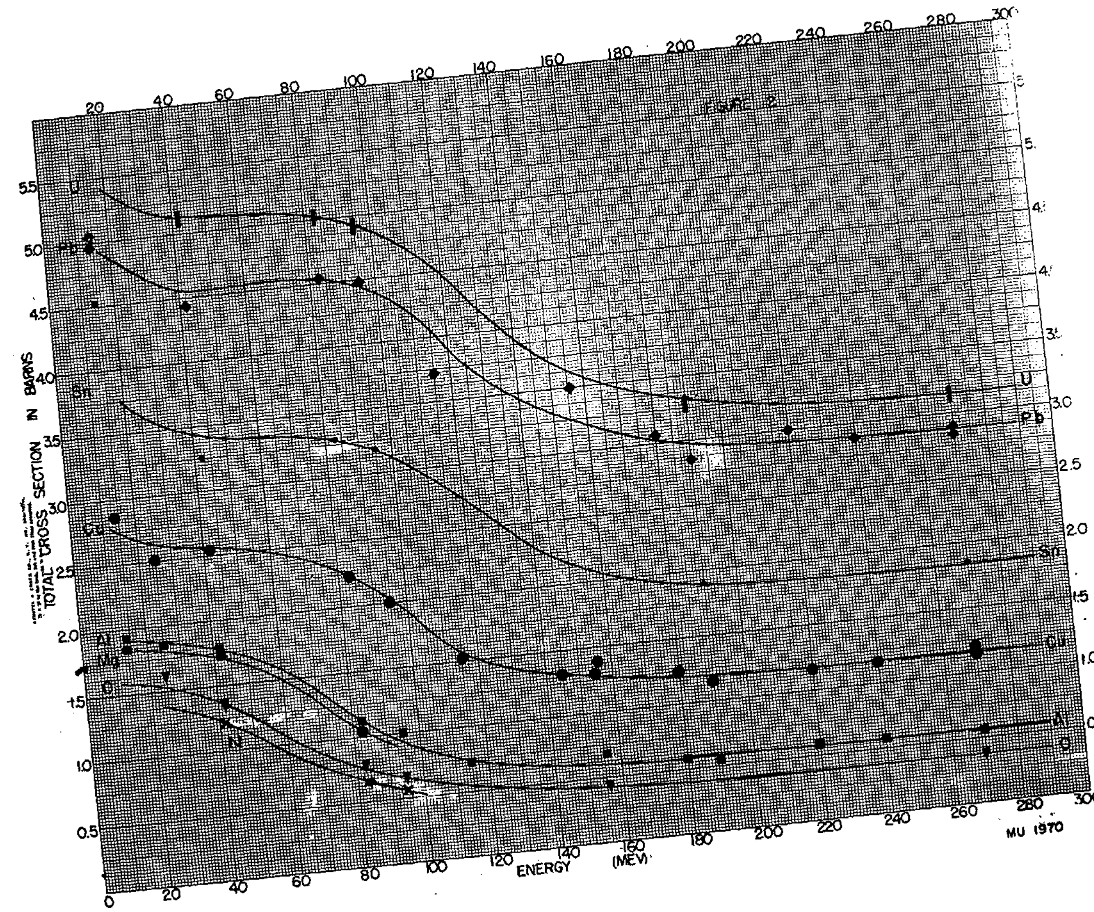

FIGURE 2
TOTAL CROSS SECTION IN BARNS
ENERGY (MEV)
U
Pb
Sn
Cu
Al
Mg
C
N
MU 1970

Fig. 2

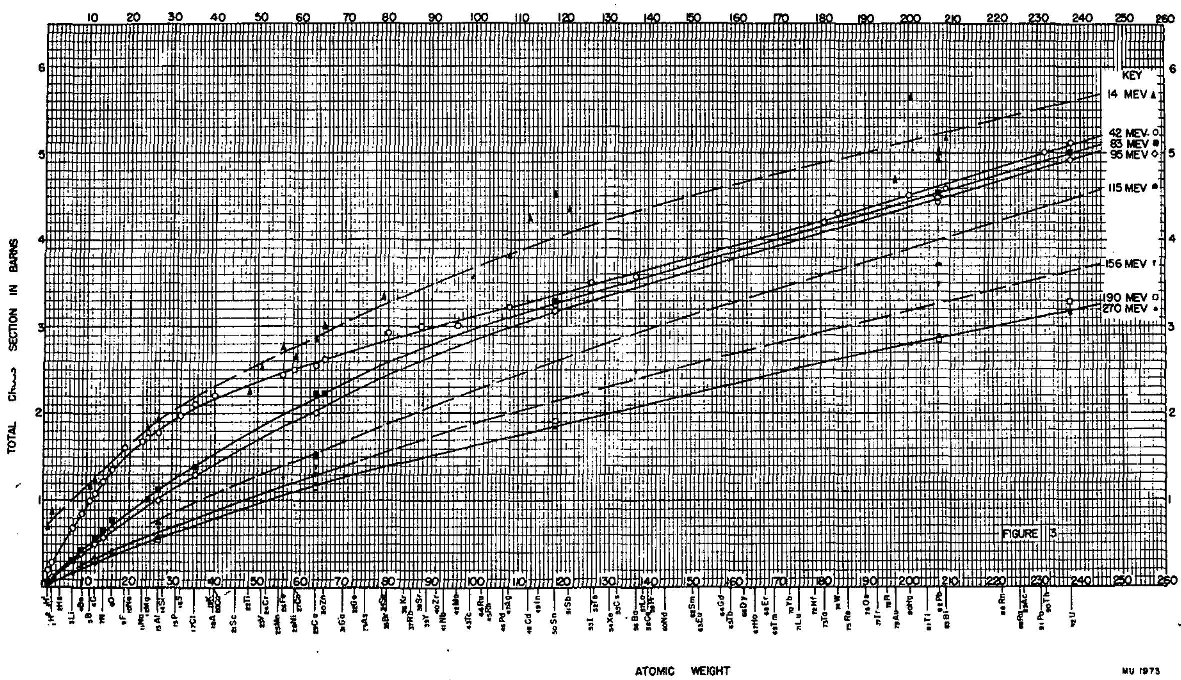
KEY
14 MEV
42 MEV
83 MEV
95 MEV
115 MEV
156 MEV
190 MEV
270 MEV
FIGURE 3
TOTAL
SECTION IN BARNS
ATOMIC WEIGHT
MU 1973

Fig. 3

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