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X-RAY ABSORPTION IN THE 2-to-200 A REGION

B. L. Henke, R. L. Elgin, R. E. Lent, and R. B. Ledingham

Department of Physics, Pomona College, Claremont, California

June 1967

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ABSTRACT

Physical and chemical analysis, x-ray astronomy and high temperature plasma diagnostics which utilize the ultrasoft x-radiations have made evident a strong need for filling the gap in measured absorption coefficient data for the radiations between the conventional x-rays and the extreme ultraviolet. More than one hundred new coefficients have been recently measured in this laboratory on the gas state, atomic or molecular, containing He, C, N, O, F, Ne, S, Cl, Ar, Kr and Xe using eleven fluorescent, characteristic wavelengths Al-K_α (8.34 A) through Be-K (113.8 A). The radiations were isolated by Bragg reflection from multilayer analyzers of the Langmuir-Blodgett type and by pulse height discriminating proportional counter intensity measurements. Using these data and data previously published, a complete table has been determined for He through Ar and for wavelengths below the L_{III} edges and in the region 2-to-200 A. Absorption cross sections have been calculated for many compound materials which are commonly encountered in low energy x-ray analysis. The transmission of x-rays from a source above the earth has been tabulated as a function of altitude and wavelength.

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CONTENTS

This report is in three parts. Presented first are the tabulated results on ultrasoft x-ray absorption including the new measured data, tabulated "best fit" functions, and a comparison of the predicted attenuation coefficients with available experimental values. The second part is a description of the methods employed in this work on the measurement of ultrasoft x-ray attenuation coefficients and of the procedures adopted for the determination of the "best fit" functions. The third part is a direct application of the laboratory measurements as reported here on the gas state of N_2, O_2, and Argon to the prediction of the transmission of x-rays through the atmosphere from a source above the earth.

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μ (cm²/gram) vs. λ(Å)

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MASS ATTENUATION COEFFICIENTS BELOW L3 EDGE

WAVELENGTH	HELIUM	LITHIUM	BERYLLIUM	BORON	CARBON	NITROGEN	OXYGEN	FLUORINE	NEON	ENERGY (EV)
2.0		0.8	2.2	4.9	9.8	16.	26.	35.	51.	6199.0
3.0	0.7	2.8	7.6	17.0	33.9	56.	85.	116.	164.	4132.7
4.0	1.8	6.7	18.5	41.2	81.	132.	199.	265.	371.	3099.5
5.0	3.5	13.3	36.9	82.	159.	255.	379.	498.	690.	2479.6
6.0	6.0	23.3	65.	142.	274.	433.	640.	830.	1140.	2066.3
7.0	9.7	37.7	104.	227.	432.	680.	980.	1270.	1730.	1771.1
8.0	14.7	57.	157.	338.	640.	990.	1420.	1820.	2470.	1549.8
9.0	21.3	82.	226.	480.	900.	1370.	1960.	2500.	3360.	1377.6
10.0	29.6	114.	311.	660.	1210.	1840.	2610.	3300.	4420.	1239.8
11.0	40.1	154.	416.	870.	1590.	2390.	3370.	4230.	5700.	1127.1
12.0	53.	202.	540.	1120.	2030.	3030.	4240.	5300.	7100.	1033.2
13.0	68.	258.	690.	1410.	2530.	3760.	5200.	6500.	8600.	953.7
14.0	86.	325.	860.	1740.	3110.	4580.	6300.	7800.	10400.	885.6
15.0	107.	402.	1050.	2120.	3750.	5500.	7600.	9300.	780.	826.5
16.0	132.	491.	1270.	2540.	4470.	6500.	8900.	11000.	920.	774.9
17.0	160.	590.	1520.	3020.	5300.	7600.	10400.	12700.	1080.	729.3
18.0	192.	700.	1800.	3540.	6100.	8800.	11900.	14600.	1250.	688.8
19.0	228.	830.	2100.	4110.	7100.	10100.	13700.	960.	1450.	652.5
20.0	268.	970.	2440.	4730.	8100.	11500.	15500.	1100.	1660.	619.9
21.0	313.	1130.	2810.	5400.	9200.	13000.	17400.	1240.	1890.	590.4
22.0	363.	1300.	3210.	6100.	10300.	14600.	19500.	1400.	2140.	563.5
23.0	418.	1480.	3640.	6900.	11600.	16300.	21700.	1570.	2410.	539.0
24.0	479.	1680.	4110.	7700.	12900.	18000.	1250.	1760.	2700.	516.6
25.0	540.	1900.	4610.	8600.	14300.	19900.	1390.	1960.	3010.	495.9
26.0	620.	2140.	5100.	9600.	15800.	21900.	1530.	2170.	3340.	476.8
27.0	690.	2390.	5700.	10500.	17300.	23900.	1690.	2390.	3690.	459.2
28.0	780.	2670.	6300.	11600.	18900.	26100.	1850.	2630.	4060.	442.8
29.0	870.	2960.	7000.	12700.	20600.	28300.	2020.	2880.	4460.	427.5
30.0	970.	3270.	7600.	13800.	22400.	30700.	2210.	3140.	4880.	413.3
31.0	1070.	3600.	8400.	15100.	24300.	1550.	2400.	3420.	5300.	399.9
32.0	1180.	3950.	9100.	16300.	26200.	1690.	2600.	3710.	5800.	387.4
33.0	1300.	4320.	9900.	17600.	28200.	1820.	2810.	4020.	6300.	375.7
34.0	1430.	4710.	10700.	19000.	30300.	1970.	3030.	4340.	6800.	364.6
35.0	1560.	5100.	11600.	20400.	32400.	2120.	3260.	4680.	7300.	354.2
36.0	1710.	5600.	12500.	21900.	34600.	2270.	3500.	5000.	7800.	344.4
37.0	1860.	6000.	13400.	23400.	36900.	2440.	3750.	5400.	8400.	335.1
38.0	2020.	6500.	14400.	25000.	39200.	2600.	4010.	5800.	9000.	326.3
39.0	2190.	7000.	15400.	26600.	41700.	2780.	4280.	6200.	9600.	317.9
40.0	2360.	7500.	16500.	28300.	44100.	2960.	4560.	6600.	10300.	309.9
42.0	2750.	8600.	18700.	31800.	49300.	3340.	5100.	7400.	11600.	295.2
44.0	3170.	9800.	21100.	35600.	2270.	3740.	5800.	8400.	13000.	281.8
46.0	3620.	11100.	23600.	39500.	2550.	4180.	6500.	9400.	14500.	269.5
48.0	4120.	12500.	26300.	43600.	2840.	4630.	7200.	10400.	16100.	258.3
50.0	4670.	14000.	29100.	47900.	3140.	5100.	7900.	11500.	17800.	248.0
52.0	5300.	15600.	32100.	52000.	3460.	5600.	8700.	12700.	19600.	238.4
54.0	5900.	17300.	35200.	57000.	3790.	6200.	9600.	13900.	21400.	229.6
56.0	6600.	19100.	38500.	62000.	4140.	6700.	10500.	15200.	23300.	221.4
58.0	7300.	21000.	41900.	67000.	4510.	7300.	11400.	16500.	25300.	213.8
60.0	8000.	23000.	45500.	72000.	4890.	7900.	12400.	17900.	27300.	206.6
62.0	8900.	25000.	49200.	77000.	5300.	8600.	13400.	19400.	29400.	200.0
64.0	9700.	27200.	53000.	83000.	5700.	9200.	14400.	20900.	31500.	193.7
66.0	10600.	29500.	57000.	3130.	6100.	9900.	15500.	22500.	33800.	187.8
68.0	11600.	31900.	61000.	3390.	6600.	10700.	16700.	24100.	36000.	182.3
70.0	12600.	34400.	65000.	3650.	7000.	11400.	17900.	25800.	38400.	177.1
72.0	13700.	37000.	70000.	3920.	7500.	12200.	19100.	27500.	40800.	172.2
74.0	14800.	39700.	74000.	4190.	8000.	13000.	20400.	29300.	43200.	167.5
76.0	16000.	42500.	79000.	4480.	8500.	13800.	21700.	31100.	45700.	163.1
78.0	17200.	45400.	83000.	4770.	9000.	14700.	23000.	33000.	48200.	158.9
80.0	18500.	48400.	88000.	5100.	9500.	15600.	24400.	34900.	51000.	155.0
82.0	19900.	51000.	93000.	5400.	10100.	16500.	25900.	36900.	53000.	151.2
84.0	21300.	55000.	98000.	5700.	10600.	17400.	27400.	38900.	56000.	147.6
86.0	22700.	58000.	103000.	6000.	11200.	18400.	28900.	40900.	59000.	144.2
88.0	24200.	61000.	109000.	6300.	11800.	19400.	30400.	43000.	61000.	140.9
90.0	25800.	65000.	114000.	6700.	12400.	20500.	32000.	45100.	64000.	137.8
92.0	27400.	68000.	119000.	7000.	13000.	21500.	33700.	47300.	67000.	134.8
94.0	29100.	72000.	125000.	7400.	13700.	22600.	35300.	49500.	69000.	131.9
96.0	30800.	76000.	131000.	7700.	14300.	23700.	37000.	52000.	72000.	129.1
98.0	32600.	80000.	136000.	8100.	15000.	24900.	38800.	54000.	75000.	126.5
100.0	34500.	83000.	142000.	8500.	15700.	26000.	40600.	56000.	78000.	124.0
105.0	39400.	94000.	157000.	9400.	17500.	29100.	45200.	62000.	85000.	118.1
110.0	44700.	104000.	173000.	10400.	19400.	32300.	50000.	68000.	92000.	112.7
115.0	50000.	116000.	5400.	11500.	21300.	35700.	55000.	74000.	99000.	107.8
120.0	56000.	127000.	6100.	12600.	23400.	39300.	60000.	81000.	106000.	103.3
125.0	63000.	139000.	6700.	13700.	25600.	43000.	66000.	87000.	114000.	99.2
130.0	69000.	152000.	7400.	14900.	27900.	46900.	71000.	94000.	121000.	95.4
135.0	76000.	165000.	8100.	16100.	30300.	51000.	77000.	100000.	128000.	91.8
140.0	84000.	179000.	8800.	17400.	32800.	55000.	83000.	107000.	135000.	88.6
145.0	92000.	192000.	9600.	18800.	35400.	59000.	89000.	114000.	141000.	85.5
150.0	100000.	207000.	10300.	20100.	38100.	64000.	95000.	121000.	148000.	82.7
155.0	108000.	221000.	11100.	21500.	40900.	69000.	101000.	127000.	155000.	80.0
160.0	117000.	236000.	11900.	23000.	43900.	73000.	108000.	134000.	161000.	77.5
165.0	126000.	252000.	12700.	24500.	46900.	78000.	114000.	141000.	168000.	75.1
170.0	136000.	267000.	13600.	26100.	50000.	83000.	121000.	147000.	174000.	72.9
175.0	146000.	283000.	14400.	27700.	53000.	88000.	127000.	154000.	180000.	70.8
180.0	156000.	299000.	15300.	29400.	56000.	94000.	134000.	161000.	186000.	68.9
185.0	166000.	316000.	16200.	31100.	60000.	99000.	141000.	167000.	192000.	67.0
190.0	177000.	333000.	17100.	32800.	63000.	105000.	147000.	174000.	197000.	65.3
195.0	188000.	350000.	18000.	34700.	67000.	110000.	154000.	180000.	203000.	63.6
200.0	200000.	367000.	19000.	36500.	71000.	116000.	161000.	187000.	208000.	62.0

Henke et al (1967)

μ (cm²/gram) vs. λ(Å)

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MASS ATTENUATION COEFFICIENTS BELOW L3 EDGE

WAVELENGTH	SODIUM	MAGNESIUM	ALUMINUM	SILICON	PHOSPHORUS	SULFUR	CHLORINE	ARGON	ENERGY (EV)
1.0	9.	12.	15.	19.	23.	29.	33.	36.	12398.0
2.0	66.	87.	107.	137.	160.	196.	221.	240.	6199.0
3.0	208.	274.	332.	418.	486.	590.	660.	720.	4132.7
4.0	466.	610.	730.	910.	1060.	1280.	1440.	167.	3099.5
5.0	860.	1110.	1330.	1660.	1920.	2330.	261.	296.	2479.6
6.0	1410.	1810.	2160.	2690.	278.	357.	421.	479.	2066.3
7.0	2120.	2720.	3230.	339.	419.	540.	640.	720.	1771.1
8.0	3020.	3850.	361.	486.	600.	770.	910.	1040.	1549.8
9.0	4100.	5200.	496.	670.	830.	1070.	1260.	1430.	1377.6
10.0	5400.	510.	660.	890.	1100.	1420.	1670.	1890.	1239.8
11.0	6800.	660.	860.	1160.	1430.	1840.	2160.	2440.	1127.1
12.0	580.	830.	1090.	1470.	1810.	2320.	2720.	3080.	1033.2
13.0	720.	1040.	1360.	1830.	2250.	2880.	3370.	3800.	953.7
14.0	880.	1270.	1660.	2230.	2750.	3500.	4090.	4600.	885.6
15.0	1070.	1530.	2000.	2690.	3300.	4200.	4890.	5500.	826.5
16.0	1270.	1830.	2390.	3200.	3920.	4970.	5800.	6500.	774.9
17.0	1500.	2150.	2810.	3760.	4590.	5800.	6700.	7590.	729.3
18.0	1750.	2520.	3280.	4380.	5300.	6700.	7800.	8600.	688.8
19.0	2030.	2910.	3790.	5000.	6100.	7700.	8900.	9800.	652.5
20.0	2330.	3340.	4340.	5800.	7000.	8700.	10000.	11100.	619.9
21.0	2660.	3810.	4930.	6500.	7900.	9900.	11300.	12400.	590.4
22.0	3020.	4310.	5600.	7400.	8800.	11000.	12600.	13800.	563.5
23.0	3400.	4850.	6200.	8200.	9900.	12300.	13900.	15200.	539.0
24.0	3810.	5400.	7000.	9100.	10900.	13600.	15300.	16700.	516.6
25.0	4250.	6000.	7700.	10100.	12100.	14900.	16800.	18300.	495.9
26.0	4710.	6700.	8500.	11100.	13200.	16300.	18300.	19900.	476.8
27.0	5200.	7400.	9400.	12200.	14400.	17700.	19900.	21500.	459.2
28.0	5700.	8100.	10300.	13300.	15700.	19200.	21500.	23200.	442.8
29.0	6300.	8800.	11200.	14500.	17000.	20700.	23100.	24900.	427.5
30.0	6800.	9600.	12200.	15700.	18400.	22300.	24800.	26700.	413.3
31.0	7400.	10400.	13200.	16900.	19700.	23900.	26500.	28400.	399.9
32.0	8100.	11300.	14200.	18200.	21100.	25500.	28200.	30200.	387.4
33.0	8700.	12200.	15300.	19500.	22600.	27200.	30000.	32000.	375.7
34.0	9400.	13100.	16400.	20800.	24100.	28900.	31800.	33800.	364.6
35.0	10100.	14100.	17500.	22200.	25600.	30600.	33500.	35600.	354.2
36.0	10900.	15000.	18700.	23600.	27100.	32400.	35300.	37400.	344.4
37.0	11600.	16100.	19900.	25100.	28600.	34100.	37200.	39200.	335.1
38.0	12400.	17100.	21100.	26500.	30200.	35900.	39000.	41000.	326.3
39.0	13300.	18200.	22400.	28000.	31800.	37700.	40800.	36100.	317.9
40.0	14100.	19300.	23700.	29500.	33400.	39400.	42600.	37800.	309.9
42.0	15900.	21600.	26300.	32600.	36700.	43000.	46200.	41100.	295.2
44.0	17700.	24000.	29100.	35800.	40000.	46600.	49800.	44400.	281.8
46.0	19700.	26500.	31900.	39000.	43300.	50000.	45100.	47600.	269.5
48.0	21800.	29100.	34800.	42300.	46600.	54000.	48400.	51000.	258.3
50.0	23900.	31700.	37700.	45600.	50000.	57000.	52000.	54000.	248.0
52.0	26100.	34500.	40800.	48900.	53000.	61000.	55000.	.	238.4
54.0	28400.	37300.	43800.	52000.	57000.	54000.	58000.	.	229.6
56.0	30800.	40200.	46900.	56000.	60000.	57000.	61000.	.	221.4
58.0	33300.	43100.	50000.	59000.	63000.	60000.	64000.	.	213.8
60.0	35800.	46100.	53000.	62000.	66000.	63000.	66000.	.	206.6
62.0	38300.	49100.	56000.	65000.	69000.	66000.	.	.	200.0
64.0	41000.	52000.	59000.	69000.	72000.	69000.	.	.	193.7
66.0	43700.	55000.	63000.	72000.	64000.	72000.	.	.	187.8
68.0	46400.	58000.	66000.	75000.	66000.	74000.	.	.	182.3
70.0	49200.	61000.	69000.	78000.	69000.	77000.	.	.	177.1
72.0	52000.	65000.	72000.	81000.	72000.	79000.	.	.	172.2
74.0	55000.	68000.	75000.	84000.	74000.	82000.	.	.	167.5
76.0	58000.	71000.	78000.	87000.	77000.	.	.	.	163.1
78.0	61000.	74000.	81000.	90000.	79000.	.	.	.	158.9
80.0	64000.	77000.	84000.	92000.	81000.	.	.	.	155.0
82.0	66000.	80000.	87000.	81000.	83000.	.	.	.	151.2
84.0	69000.	83000.	90000.	83000.	85000.	.	.	.	147.6
86.0	72000.	86000.	92000.	86000.	87000.	.	.	.	144.2
88.0	75000.	90000.	95000.	88000.	89000.	.	.	.	140.9
90.0	78000.	93000.	98000.	90000.	91000.	.	.	.	137.8
92.0	81000.	96000.	100000.	93000.	.	.	.	.	134.8
94.0	84000.	98000.	103000.	95000.	.	.	.	.	131.9
96.0	87000.	101000.	105000.	97000.	.	.	.	.	129.1
98.0	90000.	104000.	108000.	99000.	.	.	.	.	126.5
100.0	93000.	107000.	110000.	101000.	.	.	.	.	124.0
105.0	101000.	114000.	116000.	105000.	.	.	.	.	118.1
110.0	108000.	121000.	104000.	109000.	.	.	.	.	112.7
115.0	115000.	127000.	109000.	112000.	.	.	.	.	107.8
120.0	122000.	133000.	113000.	115000.	.	.	.	.	103.3
125.0	129000.	138000.	117000.	.	.	.	.	.	99.2
130.0	135000.	144000.	120000.	.	.	.	.	.	95.4
135.0	142000.	149000.	123000.	.	.	.	.	.	91.8
140.0	148000.	132000.	126000.	.	.	.	.	.	88.6
145.0	154000.	136000.	129000.	.	.	.	.	.	85.5
150.0	159000.	140000.	131000.	.	.	.	.	.	82.7
155.0	165000.	143000.	133000.	.	.	.	.	.	80.0
160.0	170000.	147000.	134000.	.	.	.	.	.	77.5
165.0	175000.	150000.	135000.	.	.	.	.	.	75.1
170.0	179000.	152000.	.	.	.	.	.	.	72.9
175.0	183000.	155000.	.	.	.	.	.	.	70.8
180.0	187000.	157000.	.	.	.	.	.	.	68.9
185.0	191000.	159000.	.	.	.	.	.	.	67.0
190.0	195000.	160000.	.	.	.	.	.	.	65.3
195.0	171000.	162000.	.	.	.	.	.	.	63.6
200.0	174000.	163000.	.	.	.	.	.	.	62.0

Henke et al (1967)

μ (cm²/gram) vs. E (ev.)

II

MASS ATTENUATION COEFFICIENTS BELOW L3 EDGE

ENERGY (EV)	HELIUM	LITHIUM	BERYLLIUM	BORON	CARBON	NITROGEN	OXYGEN	FLUORINE	NEON	ENERGY (EV)
30.	863000.	.	79000.	161000.	290000.	380000.	395000.	299000.	283000.	30.
35.	657000.	.	59000.	118000.	221000.	312000.	348000.	324000.	270000.	35.
40.	509000.	.	45000.	90000.	172000.	255000.	303000.	297000.	253000.	40.
45.	402000.	.	35800.	71000.	137000.	210000.	262000.	269000.	270000.	45.
50.	322000.	.	29100.	57000.	111000.	175000.	226000.	242000.	251000.	50.
55.	262000.	457000.	24100.	46800.	91000.	146000.	196000.	217000.	233000.	55.
60.	215000.	390000.	20300.	39100.	76000.	124000.	170000.	195000.	215000.	60.
65.	179000.	335000.	17200.	33100.	64000.	105000.	148000.	175000.	198000.	65.
70.	150000.	290000.	14800.	28400.	55000.	91000.	130000.	157000.	183000.	70.
75.	127000.	253000.	12800.	24600.	47100.	79000.	114000.	141000.	168000.	75.
80.	108000.	221000.	11100.	21500.	40900.	69000.	101000.	127000.	155000.	80.
85.	93000.	195000.	9700.	19000.	35900.	60000.	90000.	115000.	143000.	85.
90.	81000.	172000.	8500.	16800.	31700.	53000.	80000.	104000.	131000.	90.
95.	70000.	153000.	7500.	15000.	28200.	47300.	72000.	94000.	121000.	95.
100.	61000.	137000.	6600.	13500.	25200.	42200.	65000.	86000.	112000.	100.
105.	54000.	123000.	5800.	12200.	22600.	37900.	58000.	78000.	104000.	105.
110.	47700.	110000.	5100.	11000.	20400.	34100.	53000.	72000.	96000.	110.
115.	42300.	100000.	166000.	10000.	18500.	30900.	47900.	66000.	89000.	115.
120.	37700.	90000.	152000.	9100.	16800.	28000.	43600.	60000.	83000.	120.
125.	33700.	82000.	140000.	8300.	15400.	25600.	39800.	55000.	77000.	125.
130.	30300.	75000.	129000.	7600.	14100.	23400.	36500.	51000.	71000.	130.
135.	27300.	68000.	119000.	7000.	13000.	21400.	33500.	47100.	66000.	135.
140.	24700.	62000.	110000.	6400.	12000.	19700.	30900.	43600.	62000.	140.
145.	22300.	57000.	102000.	5900.	11000.	18200.	28500.	40400.	58000.	145.
150.	20300.	52000.	95000.	5500.	10200.	16800.	26400.	37500.	54000.	150.
155.	18500.	48300.	88000.	5100.	9500.	15600.	24400.	34900.	51000.	155.
160.	16900.	44600.	82000.	4690.	8800.	14500.	22700.	32500.	47500.	160.
165.	15500.	41300.	77000.	4350.	8200.	13500.	21100.	30300.	44600.	165.
170.	4200.	38200.	72000.	4040.	7700.	12600.	19700.	28300.	41900.	170.
175.	13100.	35500.	67000.	3760.	7200.	11700.	18400.	26500.	39400.	175.
180.	12000.	33000.	63000.	3500.	6700.	11000.	17200.	24800.	37100.	180.
185.	11100.	30700.	59000.	3260.	6300.	10300.	16100.	23300.	34900.	185.
190.	10300.	28700.	55000.	86000.	6000.	9700.	15100.	21900.	32900.	190.
195.	9500.	26800.	52000.	82000.	5600.	9100.	14200.	20600.	31100.	195.
200.	8900.	25000.	49100.	77000.	5300.	8600.	13400.	19400.	29400.	200.
210.	7700.	22000.	43700.	70000.	4700.	7600.	11900.	17300.	26300.	210.
220.	6700.	19400.	39100.	63000.	4210.	6800.	10600.	15400.	23600.	220.
230.	5800.	17200.	35100.	57000.	3780.	6100.	9500.	13900.	21300.	230.
240.	5100.	15300.	31600.	52000.	3400.	5500.	8600.	12500.	19300.	240.
250.	4550.	13700.	28600.	47000.	3080.	5000.	7800.	11300.	17500.	250.
260.	4040.	12300.	25900.	42900.	2790.	4560.	7100.	10200.	15900.	260.
270.	3610.	11100.	23500.	39300.	2530.	4160.	6400.	9300.	14500.	270.
280.	3230.	10000.	21400.	36100.	2310.	3800.	5900.	8500.	13200.	280.
290.	2900.	9100.	19600.	33200.	51000.	3490.	5400.	7800.	12100.	290.
300.	2610.	8200.	18000.	30600.	47500.	3210.	4950.	7200.	11100.	300.
310.	2360.	7500.	16500.	28300.	44100.	2960.	4560.	6600.	10300.	310.
320.	2140.	6900.	15200.	26200.	41000.	2730.	4210.	6100.	9500.	320.
330.	1950.	6300.	14000.	24300.	38200.	2530.	3900.	5600.	8800.	330.
340.	1780.	5800.	12900.	22600.	35700.	2350.	3610.	5200.	8100.	340.
350.	1620.	5300.	12000.	21000.	33300.	2180.	3360.	4820.	7500.	350.
360.	1490.	4890.	11100.	19600.	31200.	2030.	3130.	4490.	7000.	360.
370.	1370.	4510.	10300.	18300.	29200.	1900.	2920.	4180.	6500.	370.
380.	1260.	4180.	9600.	17100.	27400.	1770.	2730.	3900.	6100.	380.
390.	1160.	3870.	9000.	16000.	25800.	1660.	2560.	3650.	5700.	390.
400.	1070.	3590.	8400.	15100.	24300.	1550.	2400.	3420.	5300.	400.
420.	920.	3110.	7300.	13300.	21600.	29600.	2120.	3010.	4670.	420.
440.	790.	2720.	6400.	11800.	19200.	26500.	1880.	2670.	4130.	440.
460.	690.	2380.	5700.	10500.	17200.	23800.	1680.	2380.	3670.	460.
480.	600.	2100.	5100.	9400.	15500.	21500.	1510.	2130.	3280.	480.
500.	530.	1860.	4500.	8400.	14000.	19500.	1360.	1910.	2940.	500.
520.	469.	1650.	4030.	7600.	12700.	17700.	1230.	1730.	2650.	520.
540.	416.	1470.	3620.	6900.	11500.	16200.	21600.	1570.	2390.	540.
560.	371.	1320.	3270.	6200.	10500.	14800.	19800.	1430.	2170.	560.
580.	332.	1190.	2960.	5700.	9600.	13600.	18200.	1300.	1980.	580.
600.	298.	1070.	2680.	5200.	8800.	12500.	16800.	1190.	1810.	600.
650.	231.	840.	2130.	4150.	7100.	10200.	13800.	970.	1460.	650.
700.	182.	670.	1720.	3380.	5900.	8500.	11500.	14100.	1200.	700.
750.	146.	540.	1400.	2790.	4880.	7100.	9700.	11900.	1000.	750.
800.	119.	445.	1160.	2320.	4100.	6000.	8200.	10100.	850.	800.
850.	98.	369.	970.	1960.	3480.	5100.	7000.	8700.	720.	850.
900.	82.	309.	820.	1660.	2970.	4390.	6100.	7500.	10000.	900.
950.	69.	262.	700.	1420.	2560.	3800.	5300.	6600.	8700.	950.
1000.	59.	223.	600.	1230.	2220.	3310.	4620.	5800.	7700.	1000.
1100.	43.3	166.	447.	930.	1700.	2560.	3590.	4510.	6000.	1100.
1200.	32.9	127.	344.	720.	1330.	2020.	2850.	3590.	4810.	1200.
1300.	25.5	99.	269.	570.	1060.	1620.	2300.	2910.	3910.	1300.
1400.	20.2	78.	215.	458.	860.	1310.	1880.	2390.	3220.	1400.
1500.	16.3	63.	174.	373.	700.	1080.	1560.	1990.	2690.	1500.
1600.	13.3	52.	143.	307.	580.	900.	1300.	1670.	2270.	1600.
1700.	11.0	42.8	118.	256.	487.	760.	1100.	1420.	1930.	1700.
1800.	9.2	35.8	99.	216.	412.	640.	940.	1210.	1660.	1800.
1900.	7.8	30.3	84.	183.	351.	550.	810.	1050.	1430.	1900.
2000.	6.7	25.8	72.	157.	302.	476.	700.	910.	1250.	2000.
2500.	3.4	13.0	36.0	80.	155.	249.	370.	487.	680.	2500.
3000.	1.9	7.4	20.5	45.5	90.	145.	219.	291.	406.	3000.
3500.	1.2	4.6	12.7	28.4	56.	92.	139.	187.	263.	3500.
4000.	0.8	3.1	8.4	18.8	37.5	62.	94.	127.	180.	4000.
4500.	0.6	2.2	5.9	13.1	26.2	43.	66.	90.	128.	4500.
5000.	.	1.6	4.2	9.5	19.0	32.	49.	66.	95.	5000.
5500.	.	1.2	3.2	7.0	14.2	24.	37.	50.	72.	5500.
6000.	.	0.9	2.4	5.4	10.9	18.	28.	39.	56.	6000.

Henke et al (1967)

μ (cm^2/gram) vs. E (ev.)

II

MASS ATTENUATION COEFFICIENTS BELOW L3 EDGE

ENERGY (EV)	SODIUM	MAGNESIUM	ALUMINUM	SILICON	PHOSPHORUS	SULFUR	CHLORINE	ARGON	ENERGY (EV)
35.	190000.	.	.	.	.	.	.	.	35.
40.	197000.	.	.	.	.	.	.	.	40.
45.	198000.	.	.	.	.	.	.	.	45.
50.	194000.	.	.	.	.	.	.	.	50.
55.	187000.	166000.	.	.	.	.	.	.	55.
60.	178000.	164000.	.	.	.	.	.	.	60.
65.	195000.	161000.	.	.	.	.	.	.	65.
70.	185000.	156000.	.	.	.	.	.	.	70.
75.	175000.	150000.	135000.	.	.	.	.	.	75.
80.	165000.	143000.	133000.	.	.	.	.	.	80.
85.	155000.	137000.	129000.	.	.	.	.	.	85.
90.	145000.	151000.	125000.	.	.	.	.	.	90.
95.	136000.	144000.	121000.	.	.	.	.	.	95.
100.	128000.	137000.	116000.	118000.	.	.	.	.	100.
105.	119000.	131000.	111000.	114000.	.	.	.	.	105.
110.	112000.	124000.	106000.	111000.	.	.	.	.	110.
115.	105000.	118000.	102000.	107000.	.	.	.	.	115.
120.	98000.	112000.	114000.	104000.	.	.	.	.	120.
125.	92000.	106000.	109000.	100000.	.	.	.	.	125.
130.	86000.	100000.	105000.	96000.	.	.	.	.	130.
135.	81000.	95000.	100000.	93000.	.	.	.	.	135.
140.	76000.	90000.	96000.	89000.	90000.	.	.	.	140.
145.	72000.	86000.	92000.	85000.	87000.	.	.	.	145.
150.	67000.	81000.	88000.	82000.	84000.	.	.	.	150.
155.	64000.	77000.	84000.	92000.	81000.	.	.	.	155.
160.	60000.	73000.	80000.	89000.	78000.	.	.	.	160.
165.	56000.	70000.	77000.	86000.	76000.	83000.	.	.	165.
170.	53000.	66000.	73000.	82000.	73000.	81000.	.	.	170.
175.	50000.	63000.	70000.	79000.	70000.	78000.	.	.	175.
180.	47600.	60000.	67000.	76000.	68000.	76000.	.	.	180.
185.	45000.	57000.	64000.	73000.	65000.	73000.	.	.	185.
190.	42600.	54000.	61000.	71000.	63000.	71000.	.	.	190.
195.	40400.	52000.	59000.	68000.	72000.	69000.	.	.	195.
200.	38300.	49100.	56000.	65000.	69000.	66000.	.	.	200.
210.	34600.	44700.	52000.	61000.	65000.	62000.	65000.	.	210.
220.	31200.	40700.	47400.	56000.	60000.	58000.	61000.	.	220.
230.	28300.	37200.	43700.	52000.	56000.	54000.	58000.	.	230.
240.	25700.	34000.	40200.	48300.	53000.	60000.	54000.	.	240.
250.	23500.	31200.	37100.	44900.	49300.	57000.	51000.	53000.	250.
260.	21400.	28700.	34300.	41700.	46100.	53000.	47900.	50000.	260.
270.	19600.	26400.	31800.	38900.	43200.	50000.	45000.	47500.	270.
280.	18000.	24300.	29500.	36200.	40500.	47100.	50000.	44800.	280.
290.	16600.	22500.	27300.	33800.	37900.	44400.	47600.	42400.	290.
300.	15300.	20800.	25400.	31600.	35600.	41800.	45000.	40000.	300.
310.	14100.	19300.	23700.	29500.	33400.	39400.	42600.	37800.	310.
320.	13100.	17900.	22100.	27600.	31400.	37200.	40300.	35700.	320.
330.	12100.	16700.	20600.	25900.	29500.	35100.	38200.	40200.	330.
340.	11200.	15500.	19200.	24300.	27800.	33200.	36200.	38200.	340.
350.	10400.	14500.	18000.	22800.	26200.	31300.	34300.	36300.	350.
360.	9700.	13500.	16900.	21400.	24700.	29700.	32500.	34600.	360.
370.	9100.	12600.	15800.	20200.	23300.	28100.	30900.	32900.	370.
380.	8500.	11800.	14900.	19000.	22000.	26600.	29300.	31300.	380.
390.	7900.	11100.	14000.	17900.	20800.	25200.	27900.	29800.	390.
400.	7400.	10400.	13200.	16900.	19700.	23900.	26500.	28400.	400.
420.	6600.	9200.	11700.	15100.	17700.	21500.	24000.	25800.	420.
440.	5800.	8200.	10400.	13500.	15900.	19500.	21800.	23500.	440.
460.	5200.	7300.	9300.	12200.	14400.	17600.	19800.	21500.	460.
480.	4630.	6600.	8400.	11000.	13000.	16100.	18000.	19600.	480.
500.	4150.	5900.	7500.	9900.	11800.	14600.	16500.	18000.	500.
520.	3740.	5300.	6900.	9000.	10800.	13300.	15100.	16500.	520.
540.	3380.	4820.	6200.	8200.	9800.	12200.	13900.	15200.	540.
560.	3070.	4380.	5700.	7500.	9000.	11200.	12700.	14000.	560.
580.	2790.	3990.	5200.	6800.	8200.	10300.	11800.	12900.	580.
600.	2550.	3650.	4730.	6300.	7600.	9500.	10900.	11900.	600.
650.	2050.	2940.	3830.	5100.	6200.	7800.	8900.	9900.	650.
700.	1680.	2410.	3140.	4190.	5100.	6500.	7500.	8300.	700.
750.	1390.	2000.	2610.	3490.	4270.	5400.	6300.	7000.	750.
800.	1170.	1670.	2190.	2940.	3600.	4580.	5300.	6000.	800.
850.	990.	1420.	1860.	2500.	3060.	3900.	4550.	5100.	850.
900.	850.	1210.	1590.	2140.	2630.	3360.	3920.	4410.	900.
950.	730.	1050.	1370.	1850.	2270.	2910.	3400.	3830.	950.
1000.	630.	910.	1190.	1610.	1980.	2540.	2970.	3350.	1000.
1100.	7300.	700.	920.	1240.	1530.	1960.	2300.	2610.	1100.
1200.	5800.	550.	720.	980.	1210.	1550.	1820.	2070.	1200.
1300.	4760.	444.	580.	780.	970.	1250.	1470.	1670.	1300.
1400.	3930.	5000.	475.	640.	790.	1020.	1200.	1370.	1400.
1500.	3280.	4190.	394.	530.	660.	850.	1000.	1130.	1500.
1600.	2770.	3540.	4210.	446.	550.	710.	840.	950.	1600.
1700.	2370.	3020.	3600.	379.	468.	600.	710.	810.	1700.
1800.	2030.	2600.	3100.	325.	401.	520.	610.	690.	1800.
1900.	1760.	2260.	2690.	3350.	347.	447.	530.	600.	1900.
2000.	1540.	1970.	2350.	2930.	303.	390.	459.	520.	2000.
2500.	840.	1090.	1300.	1620.	1880.	2280.	255.	289.	2500.
3000.	510.	660.	800.	1000.	1150.	1400.	1570.	181.	3000.
3500.	332.	434.	520.	660.	760.	930.	1040.	1130.	3500.
4000.	228.	300.	363.	457.	530.	650.	720.	790.	4000.
4500.	164.	216.	263.	331.	386.	470.	530.	570.	4500.
5000.	121.	161.	196.	248.	289.	353.	396.	431.	5000.
5500.	92.	123.	150.	190.	223.	272.	306.	333.	5500.
6000.	72.	96.	118.	150.	175.	214.	241.	263.	6000.

Henke et al (1967).

τ (Barns) vs. E (ev.)

III

ATOMIC CROSS SECTIONS BELOW L3 EDGE

ENERGY (EV)	HELIUM	LITHIUM	BERYLLIUM	BORON	CARBON	NITROGEN	OXYGEN	FLUORINE	NEON	ENERGY (EV)
30.	5740000.	.	1190000.	2880000.	5780000.	8850000.	10490000.	9440000.	9490000.	30.
35.	4360000.	.	880000.	2120000.	4420000.	7250000.	9250000.	10220000.	9060000.	35.
40.	3390000.	.	670000.	1620000.	3440000.	5930000.	8040000.	9370000.	8480000.	40.
45.	2670000.	.	540000.	1270000.	2730000.	4890000.	6950000.	8490000.	9040000.	45.
50.	2140000.	.	435000.	1020000.	2210000.	4060000.	6000000.	7640000.	8420000.	50.
55.	1740000.	5270000.	361000.	840000.	1810000.	3400000.	5200000.	6860000.	7800000.	55.
60.	1430000.	4490000.	303000.	700000.	1510000.	2880000.	4520000.	6150000.	7210000.	60.
65.	1190000.	3860000.	256000.	590000.	1280000.	2450000.	3940000.	5510000.	6650000.	65.
70.	1000000.	3340000.	221000.	510000.	1090000.	2110000.	3450000.	4950000.	6120000.	70.
75.	840000.	2910000.	191000.	442000.	940000.	1830000.	3040000.	4450000.	5630000.	75.
80.	720000.	2550000.	166000.	387000.	820000.	1590000.	2690000.	4010000.	5190000.	80.
85.	620000.	2250000.	145000.	341000.	720000.	1400000.	2390000.	3630000.	4780000.	85.
90.	540000.	1990000.	127000.	302000.	630000.	1240000.	2130000.	3280000.	4410000.	90.
95.	466000.	1770000.	112000.	270000.	560000.	1100000.	1910000.	2980000.	4070000.	95.
100.	408000.	1580000.	99000.	242000.	500000.	980000.	1710000.	2710000.	3760000.	100.
105.	358000.	1410000.	87000.	218000.	451000.	880000.	1550000.	2470000.	3470000.	105.
110.	317000.	1270000.	77000.	197000.	407000.	790000.	1400000.	2260000.	3220000.	110.
115.	281000.	1150000.	2480000.	179000.	369000.	720000.	1270000.	2070000.	2980000.	115.
120.	251000.	1040000.	2270000.	163000.	336000.	650000.	1160000.	1900000.	2770000.	120.
125.	224000.	940000.	2090000.	149000.	307000.	590000.	1060000.	1750000.	2570000.	125.
130.	201000.	860000.	1930000.	137000.	281000.	540000.	970000.	1610000.	2390000.	130.
135.	181000.	780000.	1780000.	126000.	259000.	498000.	890000.	1490000.	2230000.	135.
140.	164000.	720000.	1650000.	115000.	238000.	458000.	820000.	1370000.	2080000.	140.
145.	148000.	660000.	1530000.	106000.	220000.	423000.	760000.	1270000.	1940000.	145.
150.	135000.	600000.	1420000.	98000.	204000.	391000.	700000.	1180000.	1820000.	150.
155.	123000.	560000.	1320000.	91000.	190000.	362000.	650000.	1100000.	1700000.	155.
160.	112000.	510000.	1230000.	84000.	176000.	336000.	600000.	1020000.	1590000.	160.
165.	103000.	476000.	1150000.	78000.	164000.	313000.	560000.	960000.	1490000.	165.
170.	94000.	441000.	1070000.	73000.	154000.	292000.	520000.	890000.	1400000.	170.
175.	87000.	409000.	1000000.	68000.	144000.	273000.	488000.	840000.	1320000.	175.
180.	80000.	380000.	940000.	63000.	135000.	255000.	457000.	780000.	1240000.	180.
185.	74000.	354000.	880000.	59000.	126000.	239000.	428000.	740000.	1170000.	185.
190.	68000.	330000.	830000.	1550000.	119000.	225000.	402000.	690000.	1100000.	190.
195.	63000.	308000.	780000.	1470000.	112000.	211000.	377000.	650000.	1040000.	195.
200.	59000.	288000.	740000.	1390000.	105000.	199000.	355000.	610000.	980000.	200.
210.	51000.	253000.	650000.	1250000.	94000.	177000.	316000.	540000.	880000.	210.
220.	44400.	224000.	590000.	1130000.	84000.	159000.	282000.	487000.	790000.	220.
230.	38900.	198000.	530000.	1020000.	75000.	143000.	253000.	437000.	710000.	230.
240.	34200.	177000.	473000.	930000.	68000.	129000.	228000.	394000.	650000.	240.
250.	30300.	158000.	427000.	840000.	61000.	117000.	206000.	356000.	590000.	250.
260.	26900.	142000.	387000.	770000.	56000.	106000.	187000.	323000.	530000.	260.
270.	24000.	128000.	352000.	710000.	51000.	97000.	171000.	294000.	485000.	270.
280.	21400.	115000.	321000.	650000.	46000.	88000.	156000.	268000.	444000.	280.
290.	19300.	104000.	293000.	600000.	1020000.	81000.	143000.	246000.	407000.	290.
300.	17400.	95000.	269000.	550000.	950000.	75000.	131000.	226000.	374000.	300.
310.	15700.	86000.	247000.	510000.	880000.	69000.	121000.	208000.	344000.	310.
320.	14200.	79000.	227000.	471000.	820000.	64000.	112000.	191000.	317000.	320.
330.	12900.	72000.	209000.	437000.	760000.	59000.	104000.	177000.	293000.	330.
340.	11800.	66000.	194000.	406000.	710000.	55000.	96000.	164000.	272000.	340.
350.	10800.	61000.	179000.	378000.	660000.	51000.	89000.	152000.	252000.	350.
360.	9900.	56000.	166000.	352000.	620000.	47300.	83000.	142000.	234000.	360.
370.	9100.	52000.	154000.	329000.	580000.	44100.	78000.	132000.	218000.	370.
380.	8400.	48100.	144000.	308000.	550000.	41200.	73000.	123000.	204000.	380.
390.	7700.	44600.	134000.	288000.	510000.	38500.	68000.	115000.	190000.	390.
400.	7100.	41400.	125000.	270000.	484000.	36100.	64000.	108000.	178000.	400.
420.	6100.	35900.	109000.	238000.	430000.	690000.	56000.	95000.	157000.	420.
440.	5300.	31300.	96000.	212000.	384000.	620000.	50000.	84000.	138000.	440.
460.	4590.	27400.	85000.	188000.	344000.	550000.	44600.	75000.	123000.	460.
480.	4010.	24200.	76000.	169000.	309000.	500000.	40000.	67000.	110000.	480.
500.	3530.	21400.	67000.	151000.	279000.	454000.	36000.	60000.	99000.	500.
520.	3120.	19000.	60000.	136000.	253000.	413000.	32600.	55000.	89000.	520.
540.	2760.	17000.	54000.	123000.	230000.	376000.	570000.	49400.	80000.	540.
560.	2460.	15200.	48900.	112000.	210000.	344000.	530000.	45000.	73000.	560.
580.	2200.	13700.	44200.	102000.	191000.	316000.	483000.	41100.	66000.	580.
600.	1980.	12400.	40100.	93000.	175000.	290000.	445000.	37600.	61000.	600.
650.	1530.	9700.	31900.	74000.	142000.	237000.	366000.	30600.	48900.	650.
700.	1210.	7700.	25700.	61000.	117000.	197000.	305000.	444000.	40200.	700.
750.	970.	6300.	21000.	50000.	97000.	165000.	257000.	375000.	33500.	750.
800.	790.	5100.	17300.	41700.	82000.	139000.	218000.	319000.	28300.	800.
850.	650.	4250.	14500.	35100.	69000.	119000.	187000.	274000.	24200.	850.
900.	540.	3560.	12200.	29900.	59000.	102000.	161000.	238000.	334000.	900.
950.	458.	3010.	10400.	25600.	51000.	88000.	140000.	207000.	292000.	950.
1000.	390.	2570.	8900.	22100.	44300.	77000.	123000.	182000.	257000.	1000.
1100.	288.	1910.	6700.	16700.	33900.	59000.	95000.	142000.	202000.	1100.
1200.	219.	1460.	5100.	13000.	26500.	46900.	76000.	113000.	161000.	1200.
1300.	170.	1140.	4030.	10200.	21100.	37600.	61000.	92000.	131000.	1300.
1400.	135.	900.	3210.	8200.	17100.	30600.	49900.	75000.	108000.	1400.
1500.	109.	730.	2600.	6700.	14000.	25200.	41300.	63000.	90000.	1500.
1600.	89.	600.	2140.	5500.	11600.	21000.	34600.	53000.	76000.	1600.
1700.	74.	494.	1770.	4600.	9700.	17700.	29200.	44700.	65000.	1700.
1800.	62.	413.	1490.	3870.	8200.	15000.	24900.	38300.	55000.	1800.
1900.	52.	350.	1260.	3290.	7000.	12800.	21400.	33000.	48000.	1900.
2000.	44.7	298.	1070.	2820.	6000.	11100.	18500.	28600.	41700.	2000.
2500.	22.8	150.	540.	1430.	3100.	5800.	9800.	15400.	22600.	2500.
3000.	13.3	86.	307.	820.	1790.	3380.	5800.	9200.	13600.	3000.
3500.	8.5	54.	191.	510.	1120.	2140.	3700.	5900.	8800.	3500.
4000.	5.8	36.3	127.	338.	750.	1430.	2500.	4010.	6000.	4000.
4500.	4.2	25.6	89.	236.	520.	1010.	1770.	2840.	4300.	4500.
5000.	.	18.9	64.	171.	380.	730.	1290.	2090.	3180.	5000.
5500.	.	14.3	48.	128.	284.	550.	970.	1580.	2410.	5500.
6000.	.	11.2	37.	98.	218.	423.	750.	1220.	1870.	6000.

Henke et al (1967)

τ (Barns) vs. E (ev.)

III

ATOMIC CROSS SECTIONS BELOW L3 EDGE

ENERGY (EV)	SODIUM	MAGNESIUM	ALUMINUM	SILICON	PHOSPHORUS	SULFUR	CHLORINE	ARGON	ENERGY (EV)
35.	7240000.	.	.	.	.	.	.	.	35.
40.	7530000.	.	.	.	.	.	.	.	40.
45.	7560000.	.	.	.	.	.	.	.	45.
50.	7410000.	.	.	.	.	.	.	.	50.
55.	7140000.	6690000.	.	.	.	.	.	.	55.
60.	6810000.	6630000.	.	.	.	.	.	.	60.
65.	7450000.	6490000.	.	.	.	.	.	.	65.
70.	7070000.	6290000.	.	.	.	.	.	.	70.
75.	6680000.	6050000.	6070000.	.	.	.	.	.	75.
80.	6290000.	5790000.	5940000.	.	.	.	.	.	80.
85.	5910000.	5510000.	5790000.	.	.	.	.	.	85.
90.	5540000.	6100000.	5600000.	.	.	.	.	.	90.
95.	5200000.	5820000.	5400000.	.	.	.	.	.	95.
100.	4870000.	5540000.	5200000.	5480000.	.	.	.	.	100.
105.	4560000.	5270000.	4980000.	5330000.	.	.	.	.	105.
110.	4270000.	5010000.	4770000.	5180000.	.	.	.	.	110.
115.	4000000.	4750000.	4560000.	5010000.	.	.	.	.	115.
120.	3750000.	4510000.	5100000.	4840000.	.	.	.	.	120.
125.	3520000.	4280000.	4890000.	4660000.	.	.	.	.	125.
130.	3300000.	4060000.	4680000.	4490000.	.	.	.	.	130.
135.	3100000.	3850000.	4480000.	4310000.	.	.	.	.	135.
140.	2910000.	3650000.	4290000.	4140000.	4610000.	.	.	.	140.
145.	2740000.	3460000.	4100000.	3980000.	4470000.	.	.	.	145.
150.	2570000.	3280000.	3920000.	3810000.	4320000.	.	.	.	150.
155.	2420000.	3110000.	3750000.	4310000.	4170000.	.	.	.	155.
160.	2280000.	2960000.	3590000.	4150000.	4030000.	.	.	.	160.
165.	2160000.	2810000.	3430000.	4000000.	3880000.	4420000.	.	.	165.
170.	2030000.	2670000.	3280000.	3850000.	3750000.	4290000.	.	.	170.
175.	1920000.	2540000.	3140000.	3700000.	3610000.	4160000.	.	.	175.
180.	1820000.	2410000.	3000000.	3560000.	3480000.	4020000.	.	.	180.
185.	1720000.	2290000.	2870000.	3430000.	3350000.	3900000.	.	.	185.
190.	1630000.	2180000.	2750000.	3300000.	3230000.	3770000.	.	.	190.
195.	1540000.	2080000.	2630000.	3170000.	3680000.	3650000.	.	.	195.
200.	1460000.	1980000.	2520000.	3050000.	3560000.	3530000.	.	.	200.
210.	1320000.	1800000.	2310000.	2830000.	3330000.	3300000.	3830000.	.	210.
220.	1190000.	1640000.	2130000.	2620000.	3110000.	3080000.	3610000.	.	220.
230.	1080000.	1500000.	1960000.	2430000.	2900000.	2880000.	3390000.	.	230.
240.	980000.	1370000.	1800000.	2250000.	2710000.	3200000.	3190000.	.	240.
250.	900000.	1260000.	1660000.	2090000.	2540000.	3010000.	3000000.	3530000.	250.
260.	820000.	1160000.	1540000.	1950000.	2370000.	2830000.	2820000.	3330000.	260.
270.	750000.	1070000.	1420000.	1810000.	2220000.	2670000.	2650000.	3150000.	270.
280.	690000.	980000.	1320000.	1690000.	2080000.	2510000.	2960000.	2970000.	280.
290.	630000.	910000.	1230000.	1580000.	1950000.	2360000.	2800000.	2810000.	290.
300.	580000.	840000.	1140000.	1470000.	1830000.	2230000.	2650000.	2650000.	300.
310.	540000.	780000.	1060000.	1380000.	1720000.	2100000.	2510000.	2510000.	310.
320.	498000.	720000.	990000.	1290000.	1620000.	1980000.	2370000.	2370000.	320.
330.	462000.	670000.	920000.	1210000.	1520000.	1870000.	2250000.	2670000.	330.
340.	429000.	630000.	860000.	1130000.	1430000.	1770000.	2130000.	2540000.	340.
350.	399000.	580000.	810000.	1060000.	1350000.	1670000.	2020000.	2410000.	350.
360.	372000.	550000.	760000.	1000000.	1270000.	1580000.	1920000.	2290000.	360.
370.	347000.	510000.	710000.	940000.	1200000.	1490000.	1820000.	2180000.	370.
380.	324000.	478000.	670000.	890000.	1130000.	1420000.	1730000.	2080000.	380.
390.	303000.	448000.	630000.	830000.	1070000.	1340000.	1640000.	1980000.	390.
400.	284000.	421000.	590000.	790000.	1010000.	1270000.	1560000.	1880000.	400.
420.	251000.	373000.	520000.	700000.	910000.	1150000.	1410000.	1710000.	420.
440.	222000.	331000.	467000.	630000.	870000.	1040000.	1280000.	1560000.	440.
460.	198000.	296000.	419000.	570000.	740000.	940000.	1170000.	1420000.	460.
480.	177000.	265000.	376000.	510000.	670000.	850000.	1060000.	1300000.	480.
500.	159000.	238000.	339000.	463000.	610000.	780000.	970000.	1190000.	500.
520.	143000.	215000.	307000.	420000.	550000.	710000.	890000.	1090000.	520.
540.	129000.	195000.	279000.	382000.	500000.	650000.	820000.	1010000.	540.
560.	117000.	177000.	254000.	348000.	462000.	600000.	750000.	930000.	560.
580.	107000.	161000.	231000.	319000.	423000.	550000.	690000.	860000.	580.
600.	97000.	147000.	212000.	292000.	389000.	500000.	640000.	790000.	600.
650.	78000.	119000.	171000.	237000.	318000.	414000.	530000.	660000.	650.
700.	64000.	97000.	141000.	196000.	263000.	343000.	439000.	550000.	700.
750.	53000.	81000.	117000.	163000.	219000.	288000.	369000.	465000.	750.
800.	44500.	68000.	98500.	137000.	185000.	244000.	313000.	395000.	800.
850.	37700.	57000.	83000.	116000.	158000.	208000.	268000.	339000.	850.
900.	32300.	49000.	71000.	100000.	135000.	179000.	231000.	293000.	900.
950.	27900.	42200.	61000.	86000.	117000.	155000.	200000.	254000.	950.
1000.	24200.	36700.	53000.	75000.	102000.	135000.	175000.	222000.	1000.
1100.	278000.	28300.	41100.	58000.	79000.	104000.	136000.	173000.	1100.
1200.	223000.	22300.	32400.	45500.	62000.	83000.	107000.	137000.	1200.
1300.	182000.	17900.	26000.	36600.	49900.	66000.	87000.	111000.	1300.
1400.	150000.	202000.	21300.	29900.	40800.	54000.	71000.	91000.	1400.
1500.	125000.	169000.	17700.	24800.	33800.	45000.	59000.	75000.	1500.
1600.	106000.	143000.	189000.	20800.	28400.	37800.	49300.	63000.	1600.
1700.	90000.	122000.	161000.	17700.	24100.	32100.	41800.	54000.	1700.
1800.	78000.	105000.	139000.	15100.	20600.	27500.	35900.	45900.	1800.
1900.	67000.	91000.	120000.	156000.	17900.	23800.	31000.	39700.	1900.
2000.	59000.	80000.	105000.	136000.	15600.	20700.	27000.	34600.	2000.
2500.	32100.	43900.	58000.	76000.	96000.	121000.	15000.	19200.	2500.
3000.	19500.	26800.	35700.	46500.	59000.	75000.	93000.	12000.	3000.
3500.	12700.	17500.	23500.	30700.	39200.	49300.	61000.	75000.	3500.
4000.	8700.	12100.	16300.	21300.	27300.	34400.	42700.	52000.	4000.
4500.	6300.	8700.	11800.	15400.	19800.	25000.	31000.	38000.	4500.
5000.	4630.	6500.	8800.	11600.	14900.	18800.	23300.	28600.	5000.
5500.	3530.	4950.	6700.	8900.	11400.	14500.	18000.	22100.	5500.
6000.	2750.	3870.	5300.	7000.	9000.	11400.	14200.	17400.	6000.

Henke et al (1967)

Table IV Comparison of Referenced Experimental Data with Values Predicted by the Weighted "Best Fit" Function Expressed in Tables I, II, and III

The following designations are used:

X	Experimental values, the letters referring to the sources as listed in the references presented at the end of Table IV.
A	An average, predicted value.
%D	The percentage deviation of the predicted value from the experimental value.
*	Values read from another author's graphical presentation of data.
**	Values corrected for impurities by authors of this paper.
-	Values that are not plotted in Figures 4 and 5.

λ	X		A	%D
HYDROGEN				
1.00	0.44	A		
1.23	0.45	A		
1.39	0.47	A		
1.54	0.48	A		
	0.55	B		
1.93	0.50	A		
	0.72	B		
2.29	0.86	B-		
2.50	0.55	A-		
2.75	1.17	B-		
3.60	2.15	B-		
4.15	2.63	B-		
31.68	241.	H		
44.60	1000.	M		
	729.	H		
67.90	2980.	M		
	2375.	H		
84.20	4610.	H		
113.80	11660.	H		
239.6	131000.	S		
283.5	236000.	S		
314.9	335000.	S		
345.1	450000.	S		
374.4	610000.	S		
452.2	1010000.	S		
HELIUM				
1.00	0.25	A		
1.54	0.28	B		
1.93	0.34	B		
2.29	0.49	B		
2.75	0.69	B	0.7	-9.9
3.60	1.33	B	1.4	0.3
4.15	2.	B	2.1	1.1
44.60	3600.	U	3300.	-8.4
	3960.	L		-16.7
	3320.	H		-0.6
51.20	6000.	T	5010.	-16.5
64.35	11700.	L	9880.	-15.6
67.90	11300.	H	11600.	2.3
72.20	15100.	L	13800.	-8.6
81.98	21300.	L	19800.	-6.8
84.20	21500.	H	21400.	-0.5
93.00	33000.	T	28200.	-14.4
108.70	46600.	L	43300.	-7.2
113.80	51000.	H	48900.	-4.1
139.50	89000.	L	83200.	-6.5
157.0	116000.	T	112000.	-3.5
164.6	128000.	L	126000.	-1.8
189.0	170000.	T	175000.	3.0
190.0	185000.	L	177000.	-4.2
239.0	280000.	T	298000.	6.3
250.0	354000.	L	328000.	-7.4
	240000.	S*		36.6
275.0	380000.	T	401000.	5.4
300.0	400000.	S*	478000.	19.4
325.0	540000.	T	560000.	3.4
350.0	580000.	S*	640000.	10.7
356.0	650000.	T	660000.	2.0
395.0	790000.	T	800000.	1.1
400.0	750000.	S*	820000.	8.8
443.0	990000.	T	970000.	-2.0
450.0	940000.	S*	1000000.	5.9
504.	1260000.	T	1190000.	-5.5
	1120000.	S*		6.3
LITHIUM				
1.00	0.43	A	0.2	-68.0
1.54	1.10	A	0.5	-61.2
1.94	2.10	A	0.9	-61.5
2.50	4.	A-	1.7	-58.2
83.3	58000.	T	53500.	-7.7
117.9	97000.	T	122000.	26.0
151.5	138000.	T	211000.	53.0
171.6	178000.	T	272000.	53.0
192.8	225000.	T	342000.	52.0
215.2	203000.	T-	420000.	107.0
231.2	119000.	T-	5450.	-95.4
272.2	139000.	T-	8290.	-94.0
BERYLLIUM				
1.00	0.55	A	0.4	-45.4
1.39	1.25	A	0.8	-38.5
1.54	1.60	A	1.1	-35.2
	1.06	B		-2.3
1.94	3.05	A	2.1	-32.7
	2.29	B		-10.4
2.29	3.70	B	3.4	-8.8
2.50	6.10	A	4.5	-27.8
2.75	6.25	B	5.9	-5.9
3.60	15.00	B	13.5	-10.6
4.16	22.80	B	21.0	-8.2
7.13	110.	C	111.	0.4
7.85	148.	C	149.	0.3
8.34	206.	U	179.	-13.2
	192.	U**		-6.9
8.60	189.	C	197.	3.9
9.45	252.	C	262.	3.9
9.89	340.	U	301.	-11.5
	318.	U**		-5.4
11.00	379.	C	416.	9.6
12.50	578.	C	611.	5.7
13.35	770.	U	744.	-3.4
	722.	U**		3.0
14.05	792.	C	867.	9.4
15.50	1050.	C	1160.	10.4
60.0	110000.	T*-	45500.	-58.7
105.0	140000.	T*	157000.	12.2
115.0	15000.	T*-	5430.	-63.8
200.0	80000.	T*-	19000.	-76.3

λ	X		A	%D
BORON				
1.00	0.76	A	0.7	-14.1
1.23	1.35	A	1.2	-15.9
1.39	1.87	A	1.7	-12.4
1.54	2.45	A	2.3	-9.0
1.94	4.70	A	4.5	-4.5
2.50	9.10	A	9.8	7.1
CARBON				
1.00	1.36	A	1.3	-11.7
1.04	1.39	G	1.4	-2.4
	1.43	WK		-5.1
1.10	1.70	WK	1.7	-5.5
1.17	1.90	G	2.0	1.8
	2.01	WK		-3.8
1.24	2.42	A	2.4	-4.7
1.25	2.40	WK	2.4	-1.6
1.33	2.93	WK	2.9	-2.7
1.39	3.35	A	3.3	-2.7
1.43	3.52	G	3.6	0.9
	3.53	WK		0.7
1.54	4.52	A	4.5	-1.5
	4.30	CU**		3.5
	4.33	B		2.8
1.65	5.57	G	5.5	-1.4
1.94	8.77	A	9.0	2.6
	8.83	CU**		1.9
	8.62	G		4.4
	8.79	B		2.3
2.29	15.20	B	15.0	-1.8
2.50	18.00	A	19.6	8.4
2.75	25.00	B	26.1	4.3
3.38	49.60	W**	48.9	-1.5
3.60	55.20	A	59.2	7.2
	59.70	W**		-0.9
	60.90	B		-2.9
3.93	77.40	W**	77.2	-0.4
4.15	92.00	W**	91.	-1.2
	85.00	B		7.0
4.36	97.80	A	106.	7.9
	106.40	W**		-0.8
5.17	160.	A	176.	9.9
	174.	W**		1.1
5.41	201.	W**	201.	0.2
	170.	B		18.5
6.97	390.	A	426.	9.3
	422.	W**		1.0
7.96	570.	B	628.	10.2
8.34	656.	A	719.	9.6
	711.	W**		1.2
	670.	B		7.4
	725.	U		-0.8
	720.	H		-0.1
9.89	1063.	A	1170.	10.4
	1156.	W**		1.6
	1090.	B		7.7
	1235.	U		-4.9
	1167.	H		0.6
12.25	2030.	B	2150.	5.8
13.35	2170.	A	2730.	25.6
	2550.	B		6.9
	2580.	U		5.7
	2740.	H		-0.5
14.55	3200.	B	3450.	7.9
16.00	4470.	H	4470.	-0.0
18.32	6400.	H	6420.	0.3
23.57	12200.	H	12300.	1.0
31.68	25400.	H	25600.	0.7
44.60	2300.	H**	2350.	2.3
	2280.	U		3.2
	2280.	H		3.2
67.90	6800.	H**	6530.	-4.0
	6550.	H		-0.3
84.20	10350.	H	10700.	3.1
113.80	21200.	H	20900.	-1.6
NITROGEN				
1.00	2.11	A	2.1	-4.7
1.24	3.95	A	3.9	-2.3
1.39	5.50	A	5.5	-0.8
1.54	7.40	A	7.5	0.6
	7.33	CU		1.6
	7.29	B		2.1
1.94	14.00	A	15.1	7.2
	15.00	B		0.0
2.29	25.10	B	24.8	-1.2
2.50	29.00	A	32.4	11.4
2.75	44.20	B	43.1	-2.6
3.38	79.50	W	80.0	0.6
3.60	96.30	W	96.6	0.2
	99.50	B		-3.0
3.93	120.70	W	125.	3.8
4.15	144.30	W	147.	2.0
	149.	B		-1.2
4.36	166.	W	170.	2.6
5.17	273.	W	281.	3.0
5.40	312.	W	319.	2.3
	320.	B		-0.3
6.97	645.	W	667.	3.4
7.96	980.	B	973.	-0.7
8.34	1109.	W	1110.	0.1
	1150.	B		-3.5
	1121.	H		-1.0
9.89	1796.	W	1790.	-0.5
	1825.	B		-2.1
	1800.	H		-0.7
12.25	3430.	B	3210.	-6.5
13.35	3836.	A	4040.	5.3
	4530.	B		-10.9
	4040.	H		-0.1
14.55	5300.	B	5070.	-4.3
16.00	6550.	H	6500.	-0.7
18.32	9100.	H	9210.	1.2
23.57	17200.	H	17300.	0.3
31.68	1730.	[illegible]	1640.	-5.1

λ	X		A	%D
44.60	3850.	U	3870.0	0.5
	3790.	M		2.1
	3880.	K		1.9
	3940.	M		-1.7
67.90	10900.	M	10600.0	-2.8
	10270.	M		3.3
84.20	17000.	M	17500.0	3.2
113.80	36500.	M	34900.0	-4.5
204.30	139000.	S	127000.0	-8.8
247.20	210000.	S	174000.0	-17.3
297.60	247000.	S	239000.0	-3.2
345.10	318000.	S	300000.0	-5.6
387.40	400000.	S	351000.0	-12.2
452.20	486000.	S	420000.0	-13.6
500.00	480000.	LE*	461000.0	-3.9
508.20	490000.	S	467000.0	-4.6
537.00	542000.	S	487000.0	-10.2
700.00	500000.	LE*	540000.0	8.1

OXYGEN

λ	X		A	%D
1.00	3.15	A	3.2	0.7
1.24	5.70	A	6.1	6.5
1.39	8.10	A	8.6	5.8
1.54	11.16	A	11.7	4.6
	11.6	SP		0.8
	11.5	GA		1.5
	11.1	CU		5.1
	11.8	B		-1.1
1.94	22.2	CU	23.4	5.2
	25.3	B		-7.7
2.29	36.4	W	38.4	5.4
	35.5	SP		8.0
	41.1	B		-6.7
2.50	45.5	A	49.9	9.5
2.75	69.1	B	66.1	-4.4
3.38	116.8	W	122.	4.0
3.60	150.0	A	146.	-2.6
	141.0	W		3.6
	156.0	B		-6.3
3.93	188.8	W	189.	-0.0
4.15	222.	W	221.	-0.4
	221.	SP		0.1
	220.	B		0.5
4.36	258.	W	255.	-1.1
5.17	413.	W	417.	0.9
5.40	476.	W	472.	-0.8
	420.	B		12.4
6.97	976.	W	970.	-0.6
	971.	SP		-0.1
7.96	1380.	B	1400.	1.6
8.34	1585.	W	1590.	0.6
	1615.	B		-1.3
	1540.	U		3.5
	1604.	M		-0.6
9.89	2540.	W	2530.	-0.2
	2520.	B		0.6
	2480.	U		2.2
	2540.	M		-0.2
12.25	4340.	B	4480.	3.1
13.35	5456.	A	5600.	2.6
	5500.	B		1.8
	5340.	U		4.8
	5560.	M		0.7
16.00	8850.	M	8900.	0.5
17.67	10000.	A	11400.	14.1
18.32	12620.	M	12500.	-1.1
23.57	1440.	M	1190.	-17.3
31.68	2550.	M	2530.	-0.6
44.60	5800.	A	5980.	3.1
	5765.	U		3.7
	5650.	M		5.8
	6000.	K		-0.4
	6150.	U		-2.8
	6250.	M		-4.4
67.90	16250.	M	16600.	2.3
	16500.	M		0.8
84.20	26500.	M	27500.	3.8
113.8[illegible]	[illegible]6000.	M	53800.	-3.9
225.2	200000.	S	195000.	-2.3
266.3	264000.	S	250000.	-5.3
314.9	309000.	S	308000.	-0.3
374.4	337000.	S	366000.	8.6
428.2	365000.	S	404000.	10.7
473.0	430000.	LE	426000.	-1.0
522.0	393000.	S	440000.	11.9
530.0	490000.	LE	367000.	-25.1
537.0	399000.	S	369000.	-7.6

FLUORINE

λ	X		A	%D
1.00	4.80	A	4.5	-7.3
1.04	4.94	WK	5.1	1.3
1.10	5.86	WK	6.0	1.1
1.17	7.06	WK	7.2	0.9
1.25	9.50	A	8.7	-8.6
	8.56	WK		1.5
1.33	10.22	WK	10.5	2.3
1.39	12.50	A	12.0	-4.6
1.43	12.59	WK	13.0	3.1
1.54	17.	A	16.2	-4.7
1.94	35.	A	32.2	-8.1
2.50	71.	A	67.9	-4.4
8.34	2035.	U	2040.	0.1
	2030.	M		0.5
9.89	3140.	U	3200.	2.1
	3140.	M		2.1
13.35	6850.	M	6960.	1.6
16.00	11000.	M	11000.	-0.4
18.32	860.	M	874.	1.6
23.57	1700.	M	1680.	-1.3
31.68	3700.	M	3620.	-2.2
44.60	8760.	M	8670.	-1.3
67.90	22500.	M	24000.	6.8
84.20	36600.	M	39100.	6.7
113.80	67000.	M	72900.	8.8

NEON

λ	X		A	%D
1.00	6.5	A	6.6	1.1
1.24	12.4	A	12.5	0.4
1.39	17.0	A	17.5	2.7
	16.0	CL		9.1
1.54	24.0	A	23.7	-1.6
	22.0	B		7.3
1.94	49.0	A	46.5	-5.2
	44.7	B		4.0
2.29	74.7	W	75.4	0.8
	75.5	CL		-0.2
	76.0	B		-0.9
	79.6	WU		-5.4
2.50	100.0	A	97.1	-2.9
	96.4	WU		0.7
2.75	130.	B	126.	-1.7
	127.	WU		0.8
3.38	231.	W	231.	-0.3
3.60	275.	A	276.	0.2
	270.	WU		2.0
	282.	B		-2.3
3.93	356.	W	353.	-0.9
4.15	416.	W	411.	-1.1
	421.	B		-2.3
	401.	WU		2.6
4.36	478.	W	472.	-1.2
	459.	WU		2.9
5.17	763.	W	758.	-0.7
5.41	865.	W	859.	-0.7
	831.	WU		3.3
	770.	B		11.5
6.97	1727.	W	1710	-1.1
7.96	2420.	B	2440.	0.6
8.34	2750.	W	2750.	0.2
	2760.	B		-0.2
	2780.	M		-0.9
9.89	4310.	W	4300.	-0.3
	4320.	B		-0.5
	4310.	M		-0.3
12.25	7700.	B	7430.	-3.5
13.35	8500.	A	9230.	8.5
	9800.	B		-5.9
	9770.	M		-5.6
14.45	750.	B	705.	-6.0
16.00	897.	M	919.	2.4
18.32	1310.	M	1310.	0.2
23.57	2600.	M	2570.	-1.2
31.68	5540.	M	5630.	1.6
44.60	13630.	M	13500.	-1.1
67.90	35900.	M	35900.	0.1
80.00	75000.	T*-	50700.	-32.4
84.20	56800.	M	56200.	-1.1
100.00	90000.	T*	77900.	-13.5
113.8	102000.	M	97500.	-4.4
150.0	167000.	T*-	148000.	-11.3
200.0	220000.	T*-	208000.	-5.3
	196000.	S*-		6.3
250.0	260000.	T*-	253000.	-2.8
	230000.	S*-		9.9
300.0	253000.	S*-	248000.	-1.9
	270000.	T*-		-8.1
350.0	266000.	S*	269000.	1.1
400.0	270000.	S*	281000.	4.1
	280000.	T*		0.4
450.0	258000.	S*	287000.	11.1
500.0	238000.	S*	287000.	20.8
	250000.	T*		15.0
550.0	206000.	S*	285000.	38.3
560.0	220000.	T*	284000.	29.1
576.0	188000.	S	283000.	50.3

SODIUM

λ	X		A	%D
1.00	8.80	A	8.7	-1.3
1.54	32.10	A	30.8	-4.1
2.50	128.00	A	124.0	-2.9

MAGNESIUM

λ	X		A	%D
1.00	11.50	A	11.9	3.0
	10.65	DE		11.2
1.10	14.71	DE	15.7	6.3
1.25	21.40	A	22.7	5.9
	21.54	DE		5.2
1.39	30.00	A	30.9	2.7
	29.32	DE		5.1
1.54	40.80	A	41.4	1.5
	39.33	DE		5.2
1.93	77.2	A	79.	2.3
2.50	161.	A	164.	2.1
10.00	510.	C	506.	-0.9
11.50	767.	C	740.	-3.5
13.00	1100.	C	1040.	-5.9
14.05	1470.	C	1280.	-12.9
15.50	1830.	C	1680.	-8.5

ALUMINUM

λ	X		A	%D
1.00	14.12	A	14.9	5.3
	13.50	B		10.1
	13.64	DE		9.0
	14.70	MU		1.1
1.10	18.77	DE	19.6	4.2
1.12	20.07	DE	20.7	2.7
1.17	23.48	G	23.4	-0.5
1.24	26.30	A	27.6	4.5
	29.80	MU		-7.4
	29.90	B		-7.7
	27.12	DE		1.8
1.39	36.80	A	38.3	4.0
	37.12	DE		3.1
	36.40	HE		5.1
1.43	41.44	EH	41.5	0.1
1.45	45.6	MU	43.2	-5.3

λ	X		A	%D
1.54	49.00	A	51.3	4.6
	51.15	G		0.2
	50.70	EM		1.1
	50.28	DE		1.9
	52.00	B		-1.5
	49.10	ME		4.4
1.64	68.70	MU	61.3	-10.8
	62.25	EM		-1.6
1.77	76.34	G	76.1	-0.4
1.93	93.50	A	97.1	3.8
	97.12	EM		-0.0
	92.4	B		5.1
	92.1	ME		5.4
2.08	122.4	G	120.	-2.1
	123.0	EM		-2.6
2.27	152.3	BI	153.	0.5
	149.5	ME		2.4
	151.9	G		0.8
	149.1	EM		2.7
	149.0	B		2.8
2.50	193.0	A-	201.	3.8
	196.3	BI		2.1
2.73	255.0	BI	256.	0.4
	252.3	EM		1.4
	244.0	B		4.9
	251.5	ME		1.8
3.04	333.0	BI	345.	3.5
3.33	450.0	BI	443.	-1.7
	506.2	EM		-12.6
3.36	447.	ME	454.	1.5
3.57	500.	A-	535.	7.1
	541.	B		-1.0
	535.	ME		0.1
3.69	613.	BI	586.	-4.4
	581.	EM		0.8
3.74	595.	ME	608.	2.1
4.14	774.	B	801.	3.4
4.36	880.	A-	921.	4.6
4.71	1167.	BI	1130.	-2.9
	1142.	EM		-0.8
5.17	1370.	A-	1450.	6.1
5.36	1567.	BI	1600.	2.1
	1598.	EM		0.1
	1600.	B,WI		-0.0
6.13	2247.	BI	2280.	1.5
6.97	2800.	A-	3200.	14.1
7.13	3429.	BI	3390.	-1.1
	3370.	C		0.6
7.50	3890.	C	3870.	-0.5
7.95	3600.	A-	4500.	25.0
7.95	280.	A-	355.	26.7
8.34	330.	A-	404.	22.3
	396.	BI		1.9
	390.	B,WI		3.5
	396.	U		1.9
8.60	430.	C	439.	2.0
9.45	556.	C	567.	1.9
9.89	500.	A-	642.	28.3
	632.	BI		1.5
	632.	WI		1.5
	630.	U		1.9
	630.	B		1.9
11.00	862.	C	859.	-0.4
11.90	850.	A-	1070.	25.3
12.25	1150.	B,WI	1150.	0.3
12.50	1200.	C	1220.	1.6
13.35	1410.	U	1460.	3.5
	1440.	B,WI		1.3
14.05	1700.	C	1680.	-1.3
14.55	1830.	WI	1850.	0.8
	1840.	B		0.3
15.50	2200.	C	2190.	-0.4
17.00	2840.	C	2810.	-1.0
80.00	17500.	T*-	83800.	378.8
150.00	115000.	MU-	131000.	13.8
160.00	28000.	T*-	134000.	379.1
165.00	90000.	MU-	135000.	50.4

SILICON

λ	X		A	%D
1.00	17.	A	19.3	13.4
1.39	44.	A	49.2	11.7
1.94	111.	A	126.	13.0

PHOSPHORUS

λ	X		A	%D
1.00	21.2	A	23.0	8.4
1.39	54.	A	58.2	7.8
1.94	134.	A	147.	9.7

SULFUR

λ	X		A	%D
1.00	26.5	ST**	28.6	7.8
1.24	49.2	ST**	52.2	6.0
1.39	65.5	A	71.7	9.4
	69.2	ST**		3.6
1.54	90.	A	95.3	5.8
	93.	ST**		2.4
	88.	CU**		8.2
1.94	173.	A	180.	4.1
	179.	ST**		0.6
2.29	289.	W**	284.	-1.8
2.50	355.	A	361.	1.6
3.38	787.	W**	816.	3.7
3.60	900.	A	967.	7.5
	949.	W**		1.9
3.93	1139.	W**	1220.	7.4
4.15	1350.	W**	1420.	4.9
4.36	1562.	W**	1620.	3.4
5.01	2100.	A	2340.	11.4
5.01	210.	A	223.	6.0
5.17	221.	W**	241.	9.2
5.41	250.	W**	272.	8.7
6.97	500.	W**	533.	6.6
8.34	793.	W**	867.	9.3
	868.	W		-0.2
9.89	1270.	W**	1380.	8.4
	1390.	W		-0.9
11.90	2100.	A	2270.	8.1
13.35	3090.	W	3090.	-0.0
16.00	4940.	W	4970.	0.6
18.32	6990.	W	7020.	0.5
23.57	13000.	W	13000.	-0.1
31.68	25400.	W	25000.	-1.7
44.60	47500.	W	47600.	0.2
67.90	69000.	W	74100.	7.4

CHLORINE

λ	X		A	%D
1.00	30.5	A	32.6	6.8
1.39	76.9	CL	81.2	5.6
1.54	102.7	CL	108.	4.9
2.29	315.	CL	319.	1.3
2.50	400.	A	405.	1.3
3.57	1020.	A	1060.	4.0
3.93	1256.	W	1370.	9.3
4.15	1476.	W	1590.	7.7
4.36	1798.	W	1820.	0.9
4.38	1830.	A	1840.	0.3
4.38	178.	A	186.	4.2
5.17	277.	W	284.	2.6
5.41	311.	W	320.	2.9
6.97	610.	W	629.	3.1
8.34	960.	W	1020.	6.4
	1010.	W		1.1
9.89	1610.	W	1620.	0.7
	1570.	W		3.2
11.90	2500.	A	2660.	6.5
13.30	3300.	W	3570.	8.3

ARGON

λ	X		A	%D
1.00	35.0	A	35.9	2.5
1.39	85.7	CL	88.9	3.7
1.54	116.0	A	118.	1.5
	112.0	S		5.1
	114.0	CL		3.3
	112.5	CU		4.6
	119.6	GA		-1.6
	118.0	B		-0.2
1.94	235.0	A	221.	-5.9
	274.0	B		-19.3
2.08	282.0	W	268.	-5.2
2.29	344.0	SP	347.	1.0
	339.4	CL		2.4
	354.0	W		-1.9
	422.0	B		-17.7
	362.0	WU		-4.0
2.50	475.0	A	441.	-7.2
	478.0	WU		-7.8
2.75	667.0	B	571.	-14.5
	631.0	WU		-9.6
3.60	1210.0	W	1180.	-2.4
	1192.0	WU		-0.9
	1470.0	B		-19.7
3.72	1320.0	SP	1290.	-2.2
3.86	1465.0	SP	1430.	-2.7
	1490.0	WU		-4.3
3.87	147.0	SP	154.	4.6
	146.0	WU		5.3
3.93	152.7	W	160.	4.7
3.95	153.0	WU	162.	5.8
	151.0	SP		7.2
4.00	151.4	L	167.	10.3
	156.0	WU		7.1
4.15	171.0	SP	183.	7.1
	174.3	W		5.1
	174.0	B		5.3
	179.0	WU		2.4
4.36	202.0	W	208.	2.8
5.00	285.2	L	296.	3.7
	286.0	WU		3.4
5.17	324.0	W	323.	-0.4
5.41	360.0	W	364.	1.0
	320.0	WU		13.6
	315.0	B		15.4
6.97	762.0	SP	715.	-6.1
	748.0	W		-4.4
7.00	726.0	WU	724.	-0.3
	683.9	L		5.8
7.96	1030.	B	1020.	-0.6
8.34	1157.	W	1160.	0.4
	1150.	B		1.0
	1180.	W		-1.6
9.00	1318.	L	1430.	8.2
9.89	1865.	W	1840.	-1.4
	1770.	B		3.9
	1850.	W		-0.6
12.00	2724.	L	3080.	13.0
12.25	3200.	B	3250.	1.5
13.35	4040.	B	4070.	0.7
	4070.	W		-0.1
14.55	4600.	B	5080.	10.4
15.00	4732.	L	5490.	16.0
16.00	6390.	W	6460.	1.1
18.32	8940.	W	9020.	0.9
20.00	9886.	L	11100.	11.9
23.57	15900.	W	16100.	1.2
25.00	16220.	L	18300.	12.8
30.00	24800.	L	26700.	7.5
31.68	30200.	W	29600.	-1.9
35.00	36300.	L	35600.	-2.0
44.60	45700.	U	45400.	-0.7
	40740.	L		11.3
	45600.	W		-0.5
46.50	46800.	L	48400.	3.4
48.50	53090.	L	51500.	-2.9

REFERENCES TO SOURCES OF EXPERIMENTAL DATA LISTED IN TABLE IV

A S. J. M. Allen, reported Compton and Allison, X-RAYS IN THEORY AND EXPERIMENT, pp. 800-806

B A. J. Bearden, *J. Appl. Phys.* 37, 4, 1681 (1966)

Bi H. H. Biermann, *Ann. Physik* 26, 740 (1936)

C B. A. Cooke and E. A. Stewardson, *Brit. J. Appl. Phys.* 15, 1315 (1964)

Cl Colvert, *Phys. Rev.* 36, 1619 (1930)

Co Crowther and Orton, *Phil. Mag.* 13, 505 (1932)

D E. Dershem and M. Schein, *Phys. Rev.* 37, 1238 (1931)

De R. D. Deslattes, AFOSR TN-58-784 (1958)

Eh C. E. Ehrenfried and D. E. Dodds, AFSWC-TN-59-33 (1960)

G K. Grosskurth, *Ann. Physik* 20, 197 (1934)

H B. L. Henke, et al, this publication

He Heinrich, NBS (1962), private communication

Ho J. I. Hopkins, *J. Appl. Phys.* 30, 2, 185 (1959)

Hu W. R. Hunter and R. Tousey, *J. Physique* 25, 148 (1964)

K Kurtz, *Ann. Physik* 85, 529 (1928)

L A. P. Lukirskii, et al, *Akad. Nauk SSSR, Optics and Spectroscopy* 20, 203 (1966)

M Messner, *Z. Physik* 85, 727 (1933)

O W. T. Ogier, et al, *Appl. Phys. Letters* 5, 7, 146 (1964)

S J. A. R. Samson, et al, *J. Opt. Soc. Am.* 54, 7, 876 (1964); 54, 12, 1491 (1964); 54, 420 (1964); 54, 6, 842 (1964); 55, 1035 (1965); 55, 8, 935 (1965); 56, 526 (1966); *Applied Optics* 4, 8 (1965)

Sp Spencer, *Phys. Rev.* 38, 1932 (1931)

T D. H. Tomboulian, *Phys. Rev.* 83, 6, 1196 (1951); 94, 6, 1585 (1954); 124, 5, 1471 (1961); 128, 2, 677 (1962); 133, 6A, 1525 (1964)

W B. Woernle, *Ann. Physik* 5, 475 (1930)

Wi P. R. Wise, Johns Hopkins University Thesis NP-12661 (1961)

Wu F. Wuilleumier, *J. Phys. Radium* 26, 776 (1965)

Table V

ABSORPTION AND ABSORPTION-JUMP RATIOS (r) AT K-EDGES

Element	λ(A)	μ-	μ+	r
4 Be	112.	179000.	(5000)	(35)
5 B	66.0	88400.	3130.	28.3
6 C	43.7	53900.	2230.	24.2
7 N	30.9	32800.	1540.	21.4
8 O	23.3	22400.	1160.	19.3
9 F	18.1	14800.	846.	17.5
10 Ne	14.3	10950.	687.	15.94
11 Na	11.56	7760.	525.	14.78
12 Mg	9.50	6000.	440.	13.63
13 Al	7.95	4500.	355.	12.68
14 Si	6.74	3640.	307.	11.89
15 P	5.77	2800.	251.	11.18
16 S	5.01	2340.	222.	10.52
17 Cl	4.38	1840.	185.	9.92
18 Ar	3.87	1440.	154.	9.34
19 K	3.44	1300.	148.	8.79
20 Ca	3.07	1120.	135.	8.28

VI

MASS ATTENUATION COEFFICIENTS

WAVELENGTH	FORMVAR (C5H7O2)X	COLLODION (C12H11O22N6)X	POLYPROPYLENE (CH2)X	CELLULOSE ACETATE (C10H21O15)X	MYLAR (C10H8O4)X	TEFLON (CF2)X	ENERGY(EV)
2.0	14.	20.	8.	19.	14.	28.	6199.0
4.0	113.	156.	69.	150.	116.	220.	3099.5
6.0	372.	510.	234.	489.	384.	700.	2066.3
8.0	850.	1140.	550.	1100.	870.	1540.	1549.8
10.0	1580.	2110.	1040.	2020.	1630.	2800.	1239.8
12.0	2600.	3450.	1740.	3310.	2680.	4520.	1033.2
14.0	3920.	5200.	2660.	4950.	4040.	6700.	885.6
16.0	5600.	7300.	3830.	7000.	5800.	9400.	774.9
18.0	7500.	9800.	5200.	9400.	7800.	12600.	688.8
20.0	9900.	12800.	6900.	12300.	10200.	2780.	619.9
22.0	12500.	16200.	8800.	15500.	12900.	3540.	563.5
24.0	8200.	6400.	11000.	4850.	8500.	4430.	516.6
26.0	10100.	7900.	13500.	5900.	10400.	5400.	476.8
28.0	12000.	9400.	16200.	7100.	12400.	6500.	442.8
30.0	14300.	11100.	19200.	8400.	14700.	7800.	413.3
32.0	16700.	8200.	22400.	9900.	17200.	9100.	387.4
34.0	19300.	9500.	25900.	11400.	19900.	10600.	364.6
36.0	22100.	10800.	29600.	13100.	22800.	12100.	344.4
38.0	25000.	12300.	33600.	14900.	25800.	13800.	326.3
40.0	28200.	13900.	37800.	16800.	29100.	15600.	309.9
42.0	31500.	15500.	42200.	18700.	32500.	17500.	295.2
44.0	3250.	4540.	1940.	4370.	3350.	6900.	281.8
46.0	3640.	5100.	2180.	4900.	3760.	7800.	269.5
48.0	4050.	5600.	2430.	5400.	4170.	8600.	258.3
50.0	4450.	6200.	2690.	6000.	4590.	9500.	248.0
52.0	4910.	6800.	2960.	6600.	5100.	10500.	238.4
54.0	5400.	7500.	3240.	7200.	5600.	11500.	229.6
56.0	5900.	8200.	3540.	7900.	6100.	12500.	221.4
58.0	6400.	8900.	3860.	8600.	6600.	13600.	213.8
60.0	7000.	9700.	4190.	9300.	7200.	14800.	206.6
62.0	7500.	10500.	4540.	10100.	7800.	16000.	200.0
64.0	8100.	11300.	4880.	10900.	8400.	17300.	193.7
66.0	8700.	12100.	5200.	11700.	9000.	18600.	187.8
68.0	9400.	13100.	5700.	12600.	9700.	19900.	182.3
70.0	10000.	14000.	6000.	13500.	10300.	21300.	177.1
72.0	10700.	14900.	6400.	14400.	11100.	22700.	172.2
74.0	11400.	15900.	6800.	15400.	11800.	24200.	167.5
76.0	12200.	17000.	7300.	16300.	12500.	25700.	163.1
78.0	12900.	18000.	7700.	17300.	13300.	27200.	158.9
80.0	13600.	19100.	8100.	18400.	14100.	28800.	155.0
82.0	14500.	20200.	8600.	19500.	14900.	30500.	151.2
84.0	15300.	21400.	9100.	20600.	15800.	32100.	147.6
86.0	16100.	22600.	9600.	21700.	16600.	33800.	144.2
88.0	17000.	23700.	10100.	22900.	17500.	35500.	140.9
90.0	17800.	25000.	10600.	24100.	18400.	37300.	137.8
92.0	18800.	26300.	11100.	25300.	19400.	39100.	134.8
94.0	19700.	27600.	11700.	26500.	20300.	40900.	131.9
96.0	20600.	28900.	12200.	27800.	21300.	43000.	129.1
98.0	21600.	30300.	12800.	29200.	22300.	44600.	126.5
100.0	22600.	31700.	13400.	30500.	23300.	46300.	124.0
105.0	25200.	35300.	15000.	34000.	26000.	51000.	118.1
110.0	27900.	39100.	16600.	37600.	28800.	56000.	112.7
115.0	30700.	43000.	18200.	41300.	31600.	61000.	107.8
120.0	33600.	47000.	20000.	45100.	34600.	67000.	103.3
125.0	36800.	52000.	21900.	49600.	38000.	72000.	99.2
130.0	39800.	56000.	23900.	53000.	41100.	78000.	95.4
135.0	43200.	60000.	25900.	58000.	44600.	83000.	91.8
140.0	46700.	65000.	28100.	63000.	48200.	89000.	88.6
145.0	50000.	70000.	30300.	67000.	52000.	95000.	85.5
150.0	54000.	75000.	32600.	72000.	55000.	101000.	82.7
155.0	57000.	80000.	35000.	76000.	59000.	106000.	80.0
160.0	61000.	85000.	37600.	82000.	63000.	112000.	77.5
165.0	65000.	90000.	40200.	87000.	67000.	118000.	75.1
170.0	69000.	96000.	42800.	92000.	72000.	124000.	72.9
175.0	73000.	101000.	45400.	97000.	75000.	130000.	70.8
180.0	77000.	107000.	47900.	102000.	80000.	136000.	68.9
185.0	82000.	113000.	51000.	108000.	84000.	141000.	67.0
190.0	86000.	118000.	54000.	112000.	88000.	147000.	65.3
195.0	90000.	124000.	57000.	118000.	93000.	153000.	63.6
200.0	95000.	130000.	61000.	124000.	98000.	159000.	62.0

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MASS ATTENUATION COEFFICIENTS

WAVELENGTH	POLYSTYRENE (CH2)X	NYLON (C12H22O3N2)X	VYNS (C22H33O2CL9)X	SARAN (C2H2CL2)X	ALUMINUM OXIDE AL2O3	QUARTZ (SIO2)X	ENERGY(EV)
2.0	9.	12.	114.	164.	68.	77.	6199.0
4.0	74.	96.	750.	1070.	480.	530.	3099.5
6.0	252.	318.	350.	375.	1440.	1600.	2066.3
8.0	590.	730.	780.	820.	860.	980.	1549.8
10.0	1120.	1370.	1440.	1520.	1580.	1810.	1239.8
12.0	1870.	2270.	2370.	2490.	2570.	2950.	1033.2
14.0	2870.	3440.	3590.	3760.	3840.	4400.	885.6
16.0	4120.	4910.	5100.	5400.	5500.	6200.	774.9
18.0	5600.	6700.	6900.	7200.	7300.	8400.	688.8
20.0	7500.	8800.	9000.	9300.	9600.	11000.	619.9
22.0	9500.	11100.	11400.	11800.	12100.	13800.	563.5
24.0	11900.	10600.	12800.	14400.	4290.	4920.	516.6
26.0	14600.	13000.	15500.	17300.	5200.	6000.	476.8
28.0	17400.	15500.	18400.	20400.	6300.	7200.	442.8
30.0	20700.	18400.	21400.	23700.	7500.	8500.	413.3
32.0	24200.	17300.	24700.	27100.	8700.	9900.	387.4
34.0	28000.	20000.	28100.	30800.	10100.	11300.	364.6
36.0	31900.	22800.	31600.	34400.	11500.	12900.	344.4
38.0	36200.	25800.	35400.	38200.	13100.	14500.	326.3
40.0	40700.	29100.	39100.	42100.	14700.	16200.	309.9
42.0	45500.	32500.	43100.	46000.	16300.	18000.	295.2
44.0	2090.	2730.	25700.	37000.	18100.	19800.	281.8
46.0	2350.	3060.	23600.	33600.	19900.	21700.	269.5
48.0	2620.	3400.	25300.	36100.	21800.	23600.	258.3
50.0	2900.	3750.	27300.	38800.	23700.	25500.	248.0
52.0	3190.	4130.	28900.	41100.	25700.	27500.	238.4
54.0	3500.	4540.	30600.	43400.	27700.	29400.	229.6
56.0	3820.	4950.	32200.	45700.	29800.	31800.	221.4
58.0	4160.	5400.	33900.	47900.	31800.	33700.	213.8
60.0	4510.	5800.	35100.	49500.	33900.	35600.	206.6
62.0	4890.	6300.	.	.	35900.	37500.	200.0
64.0	5300.	6800.	.	.	38000.	39900.	193.7
66.0	5600.	7300.	.	.	40600.	41900.	187.8
68.0	6100.	7900.	.	.	42800.	44000.	182.3
70.0	6500.	8400.	.	.	44900.	46000.	177.1
72.0	6900.	9000.	.	.	47100.	48000.	172.2
74.0	7400.	9600.	.	.	49300.	50000.	167.5
76.0	7800.	10200.	.	.	51000.	52000.	163.1
78.0	8300.	10800.	.	.	54000.	54000.	158.9
80.0	8800.	11400.	.	.	56000.	56000.	155.0
82.0	9300.	12100.	.	.	58000.	52000.	151.2
84.0	9800.	12800.	.	.	61000.	53000.	147.6
86.0	10300.	13500.	.	.	62000.	56000.	144.2
88.0	10900.	14200.	.	.	65000.	57000.	140.9
90.0	11400.	15000.	.	.	67000.	59000.	137.8
92.0	12000.	15700.	.	.	69000.	61000.	134.8
94.0	12600.	16500.	.	.	71000.	63000.	131.9
96.0	13200.	17300.	.	.	73000.	65000.	129.1
98.0	13800.	18100.	.	.	75000.	67000.	126.5
100.0	14500.	19000.	.	.	77000.	69000.	124.0
105.0	16100.	21100.	.	.	83000.	73000.	118.1
110.0	17900.	23400.	.	.	79000.	78000.	112.7
115.0	19600.	25800.	.	.	84000.	82000.	107.8
120.0	21600.	28300.	.	.	88000.	86000.	103.3
125.0	23600.	31000.	.	.	93000.	.	99.2
130.0	25700.	33600.	.	.	97000.	.	95.4
135.0	28000.	36500.	.	.	101000.	.	91.8
140.0	30300.	39400.	.	.	106000.	.	88.6
145.0	32700.	42400.	.	.	110000.	.	85.5
150.0	35100.	45600.	.	.	114000.	.	82.7
155.0	37700.	48900.	.	.	118000.	.	80.0
160.0	40500.	52000.	.	.	122000.	.	77.5
165.0	43300.	56000.	.	.	125000.	.	75.1
170.0	46100.	59000.	.	.	.	.	72.9
175.0	48900.	63000.	.	.	.	.	70.8
180.0	52000.	66000.	.	.	.	.	68.9
185.0	55000.	70000.	.	.	.	.	67.0
190.0	58000.	74000.	.	.	.	.	65.3
195.0	62000.	78000.	.	.	.	.	63.6
200.0	65000.	82000.	.	.	.	.	62.0

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MASS ATTENUATION COEFFICIENTS

WAVELENGTH	STEARATE CH3(CH2)16COO	ANIMAL PROTEINS C52.5%,H7%,S1.5% O22.5%,N16.5%	AIR O21%,N78% AR1%	P 10 (CH4)10% AR90%	METHANE CH4	Q GAS (C4H10)1.3% HE98.7%	ENERGY(EV)
2.0	10.	16.	21.	230.	7.	1.	6199.0
4.0	84.	126.	148.	162.	60.	12.	3099.5
6.0	281.	361.	481.	467.	205.	41.	2066.3
8.0	650.	820.	1090.	1020.	479.	97.	1549.8
10.0	1220.	1530.	2020.	1850.	910.	185.	1239.8
12.0	2030.	2530.	3310.	3010.	1520.	313.	1033.2
14.0	3080.	3830.	4980.	4500.	2330.	484.	885.6
16.0	4410.	5500.	7100.	6400.	3350.	700.	774.9
18.0	6000.	7400.	9500.	8400.	4570.	970.	688.8
20.0	7900.	9700.	12400.	10900.	6100.	1300.	619.9
22.0	10100.	12300.	15700.	13500.	7700.	1670.	563.5
24.0	10000.	10300.	14100.	16400.	9700.	2110.	516.6
26.0	12200.	12600.	17100.	19600.	11800.	2620.	476.8
28.0	14600.	15100.	20400.	22800.	14100.	3160.	442.8
30.0	17300.	17800.	24000.	26300.	16800.	3780.	413.3
32.0	20300.	15500.	2290.	29700.	19600.	4460.	387.4
34.0	23400.	17900.	2650.	33300.	22700.	5200.	364.6
36.0	26800.	20400.	3040.	36900.	25900.	6000.	344.4
38.0	30300.	23100.	3460.	40500.	29300.	6900.	326.3
40.0	34100.	26000.	3810.	37600.	33000.	7800.	309.9
42.0	38200.	29100.	4270.	40900.	36900.	8800.	295.2
44.0	2390.	3750.	4780.	42600.	1700.	2960.	281.8
46.0	2680.	4180.	5300.	45600.	1910.	3380.	269.5
48.0	2980.	4610.	5900.	48900.	2130.	3840.	258.3
50.0	3290.	5000.	6400.	52000.	2350.	4340.	248.0
52.0	3620.	5500.	6300.	.	2590.	4910.	238.4
54.0	3970.	5900.	7000.	.	2840.	5500.	229.6
56.0	4340.	6400.	7600.	.	3100.	6100.	221.4
58.0	4730.	6900.	8200.	.	3380.	6700.	213.8
60.0	5100.	7500.	8900.	.	3660.	7400.	206.6
62.0	5600.	8100.	9700.	.	3970.	8200.	200.0
64.0	6000.	8700.	10400.	.	4270.	8900.	193.7
66.0	6400.	9300.	11200.	.	4570.	9700.	187.8
68.0	6900.	10000.	12100.	.	4940.	10600.	182.3
70.0	7400.	10600.	12900.	.	5200.	11500.	177.1
72.0	7900.	11300.	13800.	.	5600.	12500.	172.2
74.0	8400.	12000.	14700.	.	6000.	13500.	167.5
76.0	8900.	11600.	15600.	.	6400.	14600.	163.1
78.0	9500.	12300.	16600.	.	6700.	15600.	158.9
80.0	10000.	13000.	17600.	.	7100.	16800.	155.0
82.0	10600.	13800.	18600.	.	7600.	18000.	151.2
84.0	11200.	14600.	19700.	.	7900.	19300.	147.6
86.0	11800.	15400.	20800.	.	8400.	20500.	144.2
88.0	12400.	16200.	21900.	.	8800.	21900.	140.9
90.0	13100.	17000.	23100.	.	9300.	23300.	137.8
92.0	13700.	17900.	24200.	.	9700.	24700.	134.8
94.0	14400.	18800.	25400.	.	10300.	26200.	131.9
96.0	15100.	19700.	26700.	.	10700.	27800.	129.1
98.0	15800.	20700.	28000.	.	11200.	29400.	126.5
100.0	16600.	21600.	29200.	.	11800.	31000.	124.0
105.0	18400.	24100.	32700.	.	13100.	35400.	118.1
110.0	20400.	26700.	36200.	.	14500.	40100.	112.7
115.0	22500.	29300.	39900.	.	15900.	44800.	107.8
120.0	24600.	32200.	43800.	.	17500.	50000.	103.3
125.0	27000.	35300.	48000.	.	19200.	56000.	99.2
130.0	29300.	38200.	52000.	.	20900.	62000.	95.4
135.0	31800.	41500.	57000.	.	22700.	68000.	91.8
140.0	34400.	44800.	61000.	.	24600.	75000.	88.6
145.0	37000.	48200.	65000.	.	26500.	82000.	85.5
150.0	39800.	52000.	71000.	.	28500.	89000.	82.7
155.0	42600.	55000.	76000.	.	30600.	96000.	80.0
160.0	45700.	59000.	80000.	.	32900.	104000.	77.5
165.0	48600.	63000.	86000.	.	35100.	112000.	75.1
170.0	52000.	67000.	91000.	.	37400.	121000.	72.9
175.0	55000.	71000.	96000.	.	39700.	130000.	70.8
180.0	58000.	75000.	102000.	.	41900.	138000.	68.9
185.0	62000.	79000.	108000.	.	44900.	147000.	67.0
190.0	65000.	83000.	114000.	.	47200.	157000.	65.3
195.0	68000.	88000.	119000.	.	50000.	167000.	63.6
200.0	72000.	92000.	125000.	.	53000.	177000.	62.0

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Table VII

MASS ABSORPTION COEFFICIENTS MEASURED FROM GAS STATE

WAVELENGTH	HELIUM	C_2H_6	*CARBON*	NITROGEN (N_2)	OXYGEN (O_2)	C_2F_6	*FLUORINE*	NEON
8.34		575	*720*	1121	1604	1800	*2030*	2780
9.89		933	*1167*	1800	2540	2800	*3140*	4310
13.35		2190	*2740*	4040	5560	6140	*6850*	9770
16.00		3570	*4470*	6550	8850	9800	*11000*	897
18.32		5100	*6400*	9100	12620	1830	*860*	1310
23.57		9700	*12200*	17200	1440	3520	*1700*	2600
31.68		20300	*25400*	1730	2550	7500	*3700*	5540
44.6	3320	1830	*2280*	3940	6250	7650	*8780*	13630
67.9	11300	5230	*6550*	10270	16500	19700	*22500*	35900
84.2	21500	8300	*10350*	17000	26500	32000	*36600*	56800
113.8	51000	17000	*21200*	36500	56000	59000	*67000*	102000

Table VII (continued)

MASS ABSORPTION COEFFICIENTS MEASURED FROM GAS STATE

WAVELENGTH	H_2S	*SULFUR*	CCl_4	*CHLORINE*	ARGON	KRYPTON	XENON
8.34	820	*868*	984	*1010*	1180	1090	4500
9.89	1320	*1390*	1580	*1610*	1850	1710	6200
13.35	2920	*3090*	3250	*3300*	4070	3550	8800
16.00	4670	*4940*			6390	5450	10900
18.32	6600	*6990*			8940	7270	3580
23.57	12200	*13000*			15900	12300	4250
31.68	24000	*25400*			30200	21500	6200
44.6	45000	*47500*			45600	31400	7130
67.9	65000	*69000*			9170	35800	4000
84.2	8000	*8400*			12700	32400	10200
113.8	14000	*15000*			19500	13000	87000

II. METHODS ADOPTED FOR THE MEASUREMENT AND THE EXTENSION BY INTERPOLATION OF ULTRASOFT X-RAY ABSORPTION DATA

1. Measurement

Because of the relatively high absorption of the radiations in the 10 - 100 A region, very small absorber mass thicknesses must be used ($\sim 10^{-4}$ grams/cm^2). For such, it is generally not possible to obtain thin films of material of the necessary uniformity to allow precise measurement of mass attenuation coefficients. In the work reported here, all measurements have been made upon the gas state for which the mass thickness values could be determined accurately from a knowledge of the absorption cell length, the gas temperature and pressure.

In Figures 1 and 2 are shown a photograph and a schematic of the measurement system.[1,2,3] Here a specially designed, high intensity source of low energy x-radiations is utilized to efficiently excite eleven fluorescent radiations from the following solid radiators: Aluminum Al-K (8.34 A), magnesium Mg-K (9.89 A), copper Cu-L (13.35 A), cobalt Co-L (16.0 A), Teflon F-K (18.32 A), quartz O-K (23.57 A), boron nitride N-K (31.68 A), graphite C-K (44.6 A), boron nitride B-K (67.9 A), sulfur S-L (84.2 A), and beryllium Be-K (113.8 A). These radiations were isolated by Bragg reflection from Langmuir-Blodgett type multilayer analyzers of lead stearate and lead lignocerate which have been made in this laboratory and which are typically of 2d-spacings 100 A and 130 A respectively. The wavelength values used here are effective, mean wavelengths as passed by these analyzers and determined from the Bragg equation. Second-order reflected radiation background was effectively eliminated by pulse height discrimination in flow proportional counter intensity measurement. Methane counting gas was employed at pressures just sufficient to insure nearly complete absorption of the measured radiation within the total gas path of the counter.

The pressure of the sample gas within the absorption cell was measured with either a mercury or a di-butyl phthalate oil manometer for which calibrations were corrected for changes in ambient temperature. The absorption cell temperature was measured by a precision thermometer placed on the spectrograph exterior near the position of the cell and by a sensitive thermocouple measuring between this thermometer and the absorption cell.

Cell pressure and temperature measurements were with accuracies which were probably better than 0.25%.

By operating the x-ray excitation source with a clean, high vacuum in order to eliminate any contamination build-up and by regulating both tube voltage and current, such source stability was gained to permit easily the collection of sufficient counts to reduce the counting statistical errors to well below 0.5% for most measurements. Minimum statistical error was obtained by adjusting the sample pressure to effect optimum transmission as shown in Figure 3 to be in the 2% to 20% range and according to a straightforward error analysis. Here the error in an absorption measurement due to counting statistics is plotted as a function of sample transmission for the optimum conditions of negligible background counts and the ratio of counting times with sample-in to that for sample-out, t/t_o, equal to 3.6. In a few measurements for which background was not sufficiently small, other optimal ratios of counting times had to be used.[4]

A source of systematic error that could become of the same order of size as that fixed by the counting statistics was determined to be that due to sample contamination within the system. The samples were of reagent grade and of purities typically better than 99.9%. Because the effect on the measured attenuation coefficient of a possible contamination should increase as the sample pressure is decreased, measurements were routinely carried out by systematically reducing the sample pressure through a series of absorption measurements and within the 2% to 20% transmission range. If a systematic variation in the attenuation coefficient was evidenced, the data would be thrown out and the system would be checked for leaks and thoroughly flushed with the gas under measurement. Each set of measurements, on an optimal range of sample pressures, was immediately entered into a laboratory digital computer (Bendix G-15) which was programmed to calculate an average coefficient based upon a statistical weighting, the standard deviation to be expected according to the counting statistics and the experimental standard deviation. That data would be thrown out for which there was a significant difference between the two standard deviation values. In Table VIII are listed the formulae which have been used in the computer program for this data reduction.

2. Interpolation

An objective of this work has been to obtain a "state of the art" table for the photoelectric cross sections in the 10 to 100 A region and for the light elements as can be interpolated from experimental data on elements obtainable in the gas state. Among the high purity gases which were available commercially, the following were chosen: Helium, ethane, nitrogen, oxygen, freon, neon, hydrogen sulfide, carbon tetrachloride, argon, krypton, and xenon. The mass attenuation coefficients for these gases and for the eleven ultrasoft wavelengths cited above have been listed in Table VII.

For this wavelength region and for the elements involved, coherent as well as incoherent scattering has a negligible effect on the measured attenuation, and the calculated cross sections can be considered to be essentially photoelectric. Because many of the photoelectric absorptions which are measured here are involved with the valence electron levels, it might well be expected that the particular molecular state will change somewhat the total photoelectric cross section from simply the sum value of atomic or "free atom" cross sections. As a preliminary test for the magnitude for such an effect the atomic cross sections-vs-wavelength were deduced for carbon by simple subtraction from measurements on methane, carbon monoxide, carbon dioxide as well as for ethane. Internal consistency upon neglecting possible chemical effects on such data was within a few percent. Large effects would not be expected because the photon energies which are involved here are still large as compared to the first ionization energies. In Table VII, atomic cross sections have been deduced from measurements on the molecular gas states completely neglecting possible chemical effects. An investigation is now underway on the detection and evaluation of such effects as an extension of the present work.

In order to determine the "best fit" as have been presented in Tables I, II, and III, the following procedure was adopted: In all regions for which data was measured in this laboratory that data alone was used. For the remaining regions all data that could be found was plotted on large sheets and graphically averaged. The averaged values were then read at approximately 30% wavelength intervals (e.g. 10, 13, 17, 22, ...) between 2 and 400 angstroms. This laboratory's data was given statistical weights

between .7 and 2% or roughly two standard deviations of all internal errors. Other data was weighted from 2 to 4% depending upon the amount and consistency of the data available. In total there were 168 points with weights corresponding to 3% or less and approximately 75% of the weight was for points measured in this laboratory.

Many attempts were made to utilize the available theories for predicting the photoelectric cross sections to assist in the interpolation procedures.[5] It was found, however, that the quality and extent of the experimental data which are now available does permit prediction of cross sections for the 2 to 200 A region with considerably more precision than that which can be obtained with present theory. For wavelengths below the K edge, theory typically predicts values which vary within 10% of measured values. For wavelengths above the L edges, theory is typically only within 50% to 100% of measured values. Nevertheless, in establishing the polynomial fits expressed here, it was found useful to work with the experimental data as expressed in ratios to corresponding values calculated by the unmodified Stobbe theory[6] (based upon hydrogen-like wave functions). Because of the relatively large range in both variables, wavelength and atomic number, the logarithms of these values were used in the fitting programs. The most efficient fitting was typically obtained with polynomials of third degree in the logarithm of wavelength and of second degree in the logarithm of the atomic number. Separate fits (least square by an IBM 360/40 computer) were determined for the regions below the K edge, above the K edge, for inner electron shell absorption, and for valence electron shell absorption. The absorption jump ratios at the L_I edge were taken as predicted by Stobbe theory.

It is to be emphasized that the tables thus determined must simply reflect the present "state of the art" and for certain elements, particularly among the lightest group, these could be in error by an amount greater than 10%. Nevertheless, in many regions the predicted values could be appreciably more accurate than certain individual experimental values. In order to suggest the precision of these interpolations, all of the available experimental data that could be found for this wavelength region of interest here have been tabulated along with reference to their sources, and with the corresponding predicted values by these "best fit" functions. The percentage deviation of the predicted values from the individual experimental values are

also presented.

Because of the strong possibility of enhanced chemical effects or other anomalous effects being present for the absorption of wavelengths near an absorption edge wavelength, such data were not used in the polynomial fitting, but are listed in Table IV. By simple polynomial extrapolation, the values for the predicted cross sections at the K absorption edge were determined along with their associated absorption jump ratios. These have been presented in Table V.

Ignoring possible chemical combination effects, the mass attenuation coefficients for many compound samples which are often encountered in the application of ultrasoft x-ray analysis have been tabulated in Table VI. Here the percentage composition values for the gases are given, as conventional, in percentage by volume.

III. ATMOSPHERIC ABSORPTION OF EXTRA TERRESTRIAL RADIATIONS IN THE 2 TO 200 A REGION

For the wavelengths of interest here, the effective atmospheric composition with respect to x-ray absorption is nearly constant below 150 km altitude where most of the absorption takes place. Above 150 km, the relative numbers of nitrogen, oxygen, and argon atoms begin to change because of diffusion and the mean molecular weight decreases. Because the measurements reported here were directly on the gas state of N_2, O_2, and Ar, it is particularly appropriate to apply these data to the prediction of atmospheric absorption. In Table IX is presented the transmission of x-radiations from a source directly above the effective absorption region of the atmosphere as a function of wavelength, of the mass per unit area thickness above the given position, and of the associated altitude. The relation between the mass thickness, m, and altitude, h, is that deduced from the U. S. Standard Atmosphere Tables.[7] The assumed, effective composition, by volume, is 78% N_2, 21% O_2, and 1% Ar, and with negligible water vapor.

The number of photons absorbed within an atmospheric layer thickness, dh, is given by:

$$dI = \mu\rho I_o e^{-\mu m(h)} dh$$

where I_o is the number of photons incident from above the earth, μ is the mass attenuation coefficient and ρ is the atmospheric density at a given altitude. Thus the fractional loss of photons or energy can be calculated from

$$(dI/I_o)/dh = \mu\rho t$$

where $\exp[-\mu m(h)]$ or transmission, t, is given in Table IX.

The fractional loss per centimeter has been tabulated in Table X as a function of wavelength and altitude, and of the atmospheric density which has been taken from the U. S. Standard Atmosphere Tables for its dependence upon altitude.

Tables IX and X should be considered as very approximate for altitudes above 150 km, where the assumption of sea level atmospheric composition no longer obtains and the actual composition is not known with sufficient accuracy at this time.

REFERENCES

[1] B. L. Henke, "X-Ray Fluorescence Analysis for Sodium, Fluorine, Oxygen, Nitrogen, Carbon, and Boron", *Advances in X-Ray Analysis, Vol. 7* (Plenum Press, New York, 1963)

[2] B. L. Henke, "Some Notes on Ultrasoft X-Ray Fluorescence Analysis - 10 to 100 Angstrom Region", *Advances in X-Ray Analysis, Vol. 8* (Plenum Press, New York, 1964)

[3] B. L. Henke, "Spectroscopy in the 15 to 150 Angstrom Ultrasoft X-Ray Region", 4th International Symposium on X-Ray Microscopy and X-Ray Microanalysis, Orsay, France, *Optique des Rayons X et Microanalyze*, R. Castaing, P. Deschamps, and J. Philibert, Editors (Editions Scientifiques Hermann, Paris, 1966)

[4] B. Nordfors, "The Statistical Error in X-Ray Absorption Measurements", Arkiv Fysik 18, 37 (1960)

[5] B. L. Henke, "Semiempirical Determination of Mass Absorption Coefficients for the 5 to 50 Angstrom X-Ray Region", J. Appl. Phys. 28, 98 (1957)

[6] A. J. Bearden, "X-Ray Photoeffect Cross Sections in Low and Medium Z Absorbers for the Energy Range 852 eV to 40 KeV", J. Appl. Phys. 37, 4 (1966) p. 1681

[7] United States Committee on Extension to the Standard Atmosphere, *U. S. Standard Atmosphere, 1962*, Superintendent of Documents, U. S. Government Printing Office, Washington, D. C.

Table VIII DATA REDUCTION FORMULAE

$I = I_o \exp(-\mu m)$

$I_o = X_o/t_o - b_o/t_{bo}$

$I = X/t - b/t_o$

$P = .78154(S_2 - S_1)/(1 + .0008T_m)$ for oil

$P = 10(S_2 - S_1 - .02)/(1 + .000182T_m)$ for mercury (with .26 cm of oil protecting open end)

$m = MP/(273.15 + T_s)6228$

where $6228 = R/g\rho\ell$; $R = 8.3143 \times 10^7$; $g = 979.52$; $\rho = 13.595$; and ℓ = length of cell = 10.025 cm

therefore

$\mu_i = (1/m)\ell n(I_o/I)$

$$\sigma_c = (1/m) \times \left(\frac{X_o + (t_o/t_{bo})^2 b_o}{[X_o - (t_o/t_{bo})b_o]^2} + \frac{X + (t/t_b)^2 b}{[X - (t/t_b)b]^2}\right)^{\frac{1}{2}}$$

$W = (\mu/\sigma_c)^2$

$\mu = (\Sigma W\mu_i)/(\Sigma W)$

$d_i = [(\mu - \mu_i)^2]^{\frac{1}{2}}$

$\sigma^2 = (\Sigma Wd^2)/(n - 1)\Sigma W$

$\sigma_c^2 = \mu^2/\Sigma W$

DEFINITIONS

μ - absorption coefficient in cm^2/gm

m - mass per unit area of sample

With no gas in cell:

I_o - effective x-ray intensity in counts/sec

t_o - time of count

X_o - total count including background

t_{bo} - time of background count

b_o - total background count

With gas in cell use:

I, t, X, t_b, & b respectively

S_2 - high reading on manometer in cm

S_1 - low reading on manometer

P - gas pressure of sample in mm of Hg at 0° C

T_s - temperature of manometers

M - molecular weight of gas sample

λ - wavelength of radiation in Angstroms

σ_c - standard deviation as computed from counting rates

σ - experimental standard deviation of mean

W - data weight or effective number of counts

τ - atomic absorption coefficient in $cm^2/atom$

T - transmission in percent

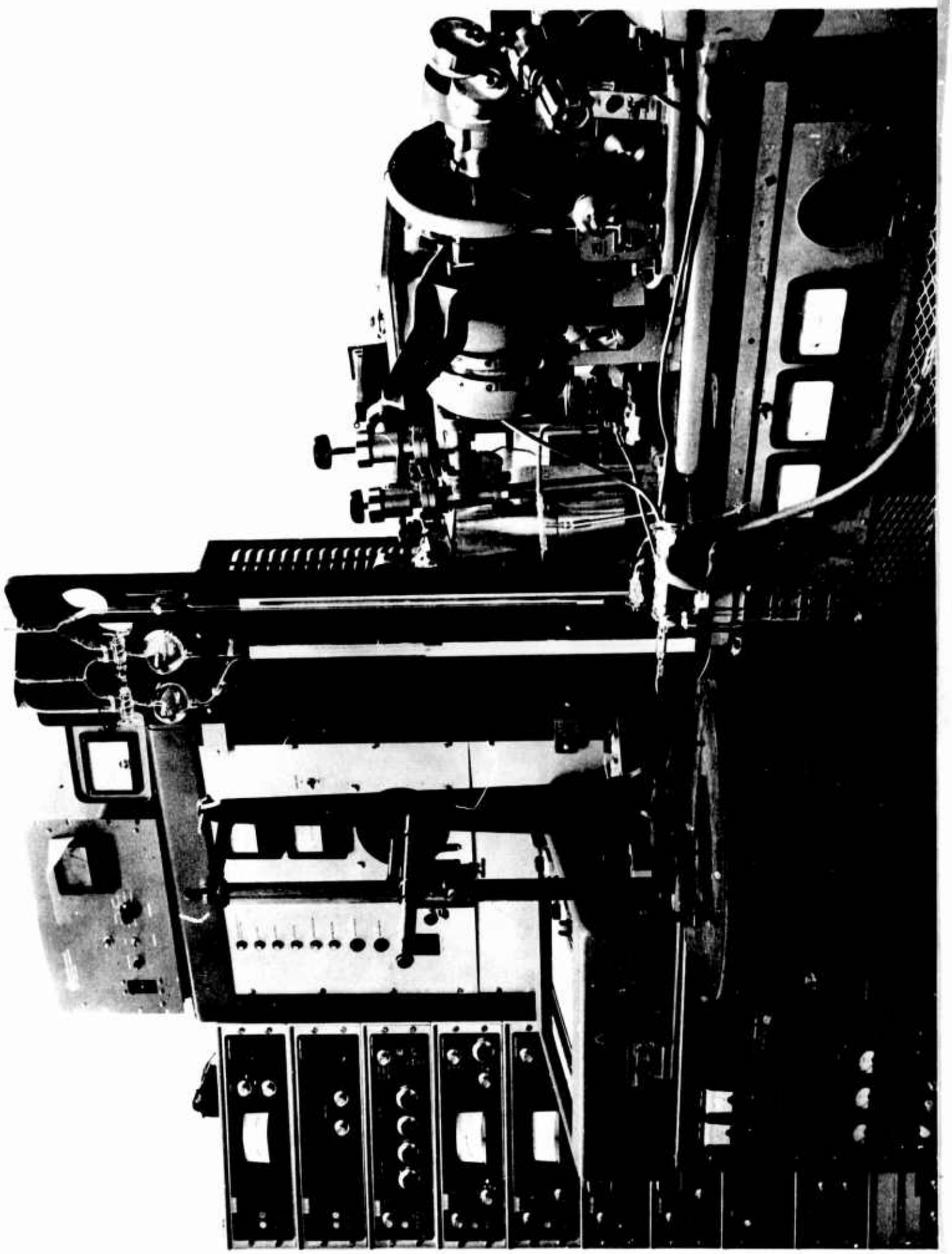
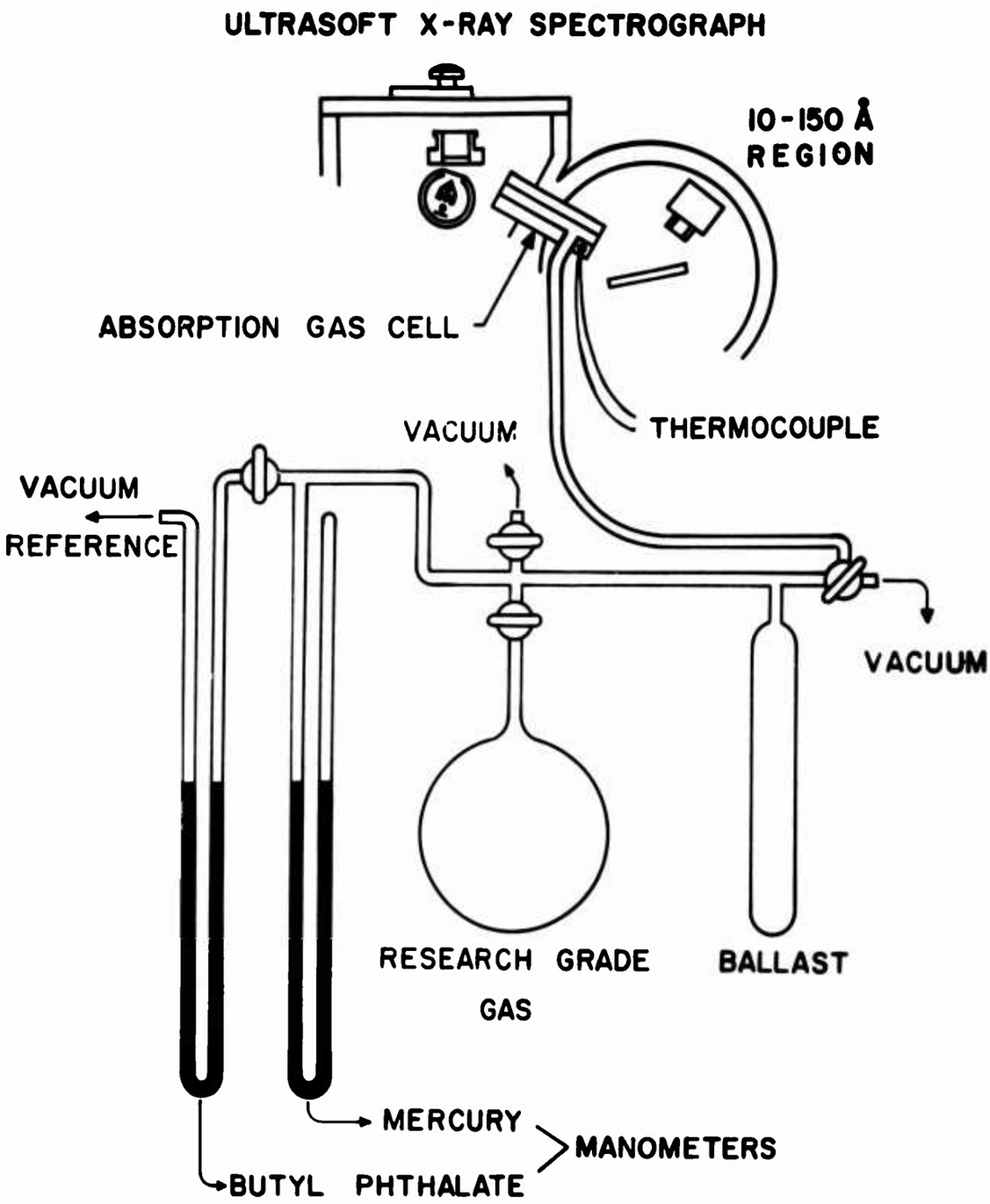


FIGURE I

FIGURE 2

PHOTOELECTRIC CROSS SECTION MEASUREMENT



STATISTICAL ERROR vs TRANSMISSION

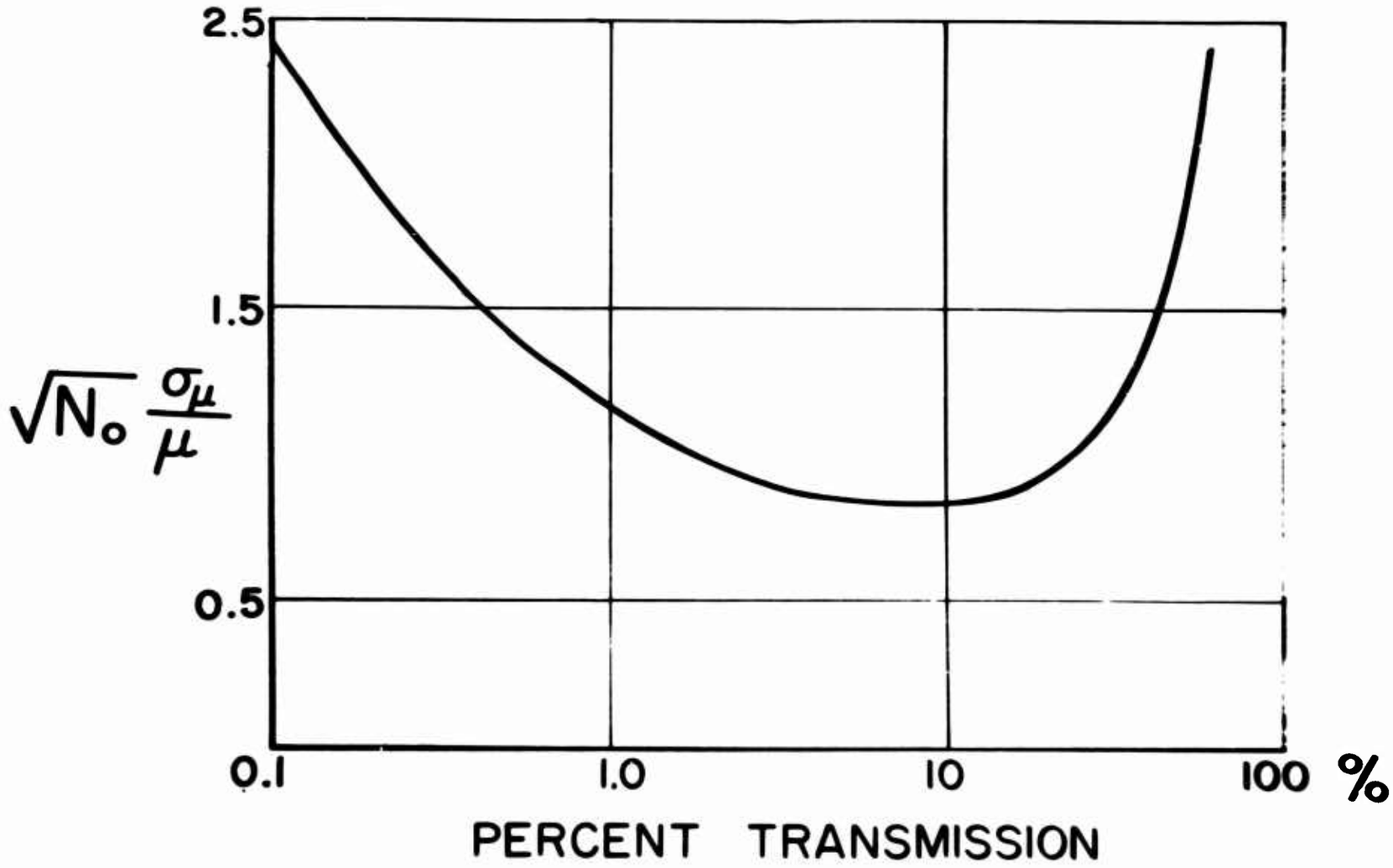


FIGURE 3

FIGURE 4

ATOMIC CROSS SECTION, τ, BELOW K-EDGE

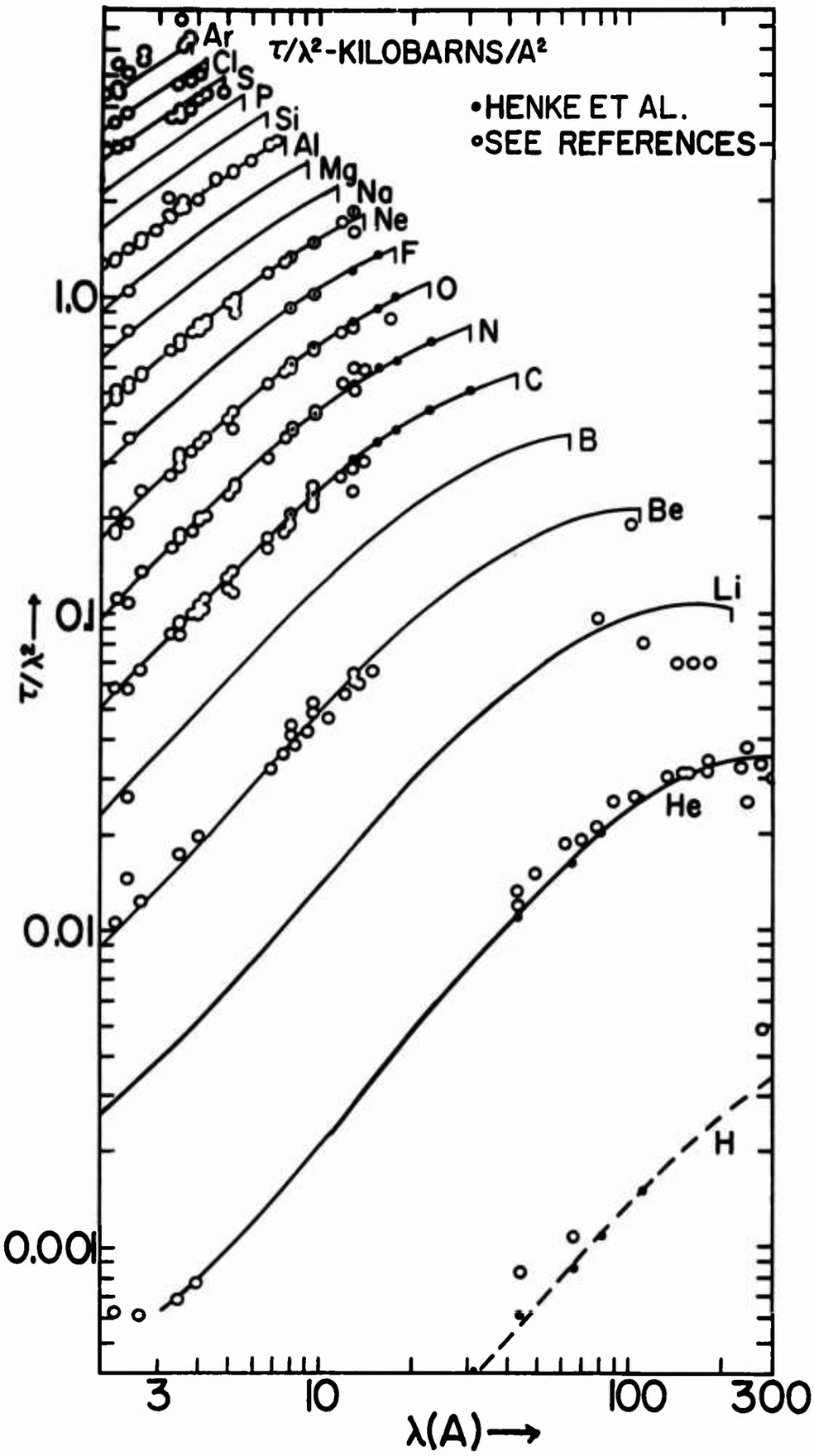
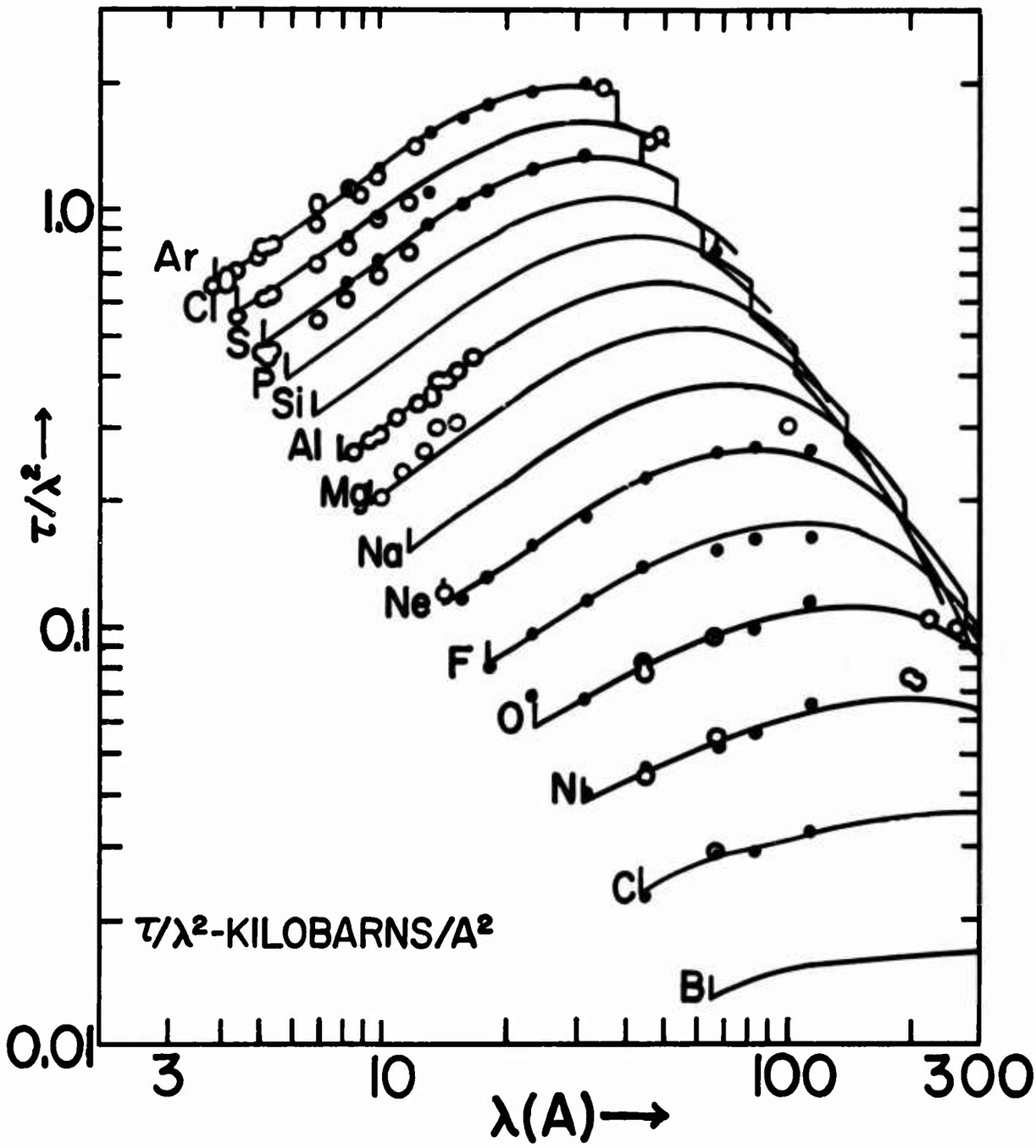


FIGURE 5

ATOMIC CROSS SECTION, τ, IN K-L_{III} REGION



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○ SEE REFERENCES

TRANSMISSION THROUGH ATMOSPHERE

IX

VERSUS

WAVELENGTH λ-Å ALTITUDE h-METERS

MASS THICKNESS - M(h) - GRAMS/CM^2

ALTITUDE / WAVELENGTH	50,000	60,000	80,000	100,000	120,000	140,000	160,000	180,000	200,000	220,000
2.0	.	.	7.925E-01	9.933E-01	9.994E-01	9.998E-01	9.999E-01	1.000E 00	1.000E 00	1.000E 00
4.0	.	.	1.942E-01	9.534E-01	9.960E-01	9.988E-01	9.994E-01	9.997E-01	9.998E-01	9.999E-01
6.0	.	.	4.859E-03	8.564E-01	9.870E-01	9.962E-01	9.981E-01	9.989E-01	9.993E-01	9.995E-01
8.0	.	.	.	7.038E-01	9.709E-01	9.913E-01	9.957E-01	9.975E-01	9.984E-01	9.990E-01
10.0	.	.	.	5.215E-01	9.467E-01	9.840E-01	9.920E-01	9.953E-01	9.971E-01	9.981E-01
12.0	.	.	.	3.441E-01	9.142E-01	9.739E-01	9.869E-01	9.923E-01	9.952E-01	9.969E-01
14.0	.	.	.	2.009E-01	8.737E-01	9.610E-01	9.803E-01	9.884E-01	9.928E-01	9.953E-01
16.0	.	.	.	1.014E-01	8.249E-01	9.448E-01	9.720E-01	9.835E-01	9.897E-01	9.934E-01
18.0	.	.	.	4.680E-02	7.730E-01	9.269E-01	9.628E-01	9.780E-01	9.863E-01	9.911E-01
20.0	.	.	.	1.838E-02	7.145E-01	9.057E-01	9.517E-01	9.714E-01	9.822E-01	9.885E-01
22.0	.	.	.	6.344E-03	6.534E-01	8.821E-01	9.392E-01	9.640E-01	9.775E-01	9.854E-01
24.0	.	.	.	1.062E-02	6.823E-01	8.934E-01	9.452E-01	9.676E-01	9.797E-01	9.869E-01
26.0	.	.	.	4.040E-03	6.290E-01	8.723E-01	9.340E-01	9.608E-01	9.755E-01	9.841E-01
28.0	.	.	.	1.395E-03	5.752E-01	8.496E-01	9.217E-01	9.535E-01	9.708E-01	9.811E-01
30.0	.	.	.	4.370E-04	5.217E-01	8.255E-01	9.086E-01	9.455E-01	9.658E-01	9.778E-01
32.0	.	.	.	4.780E-01	9.398E-01	9.819E-01	9.909E-01	9.947E-01	9.967E-01	9.979E-01
34.0	.	.	.	4.257E-01	9.307E-01	9.790E-01	9.895E-01	9.938E-01	9.962E-01	9.975E-01
36.0	.	.	.	3.754E-01	9.209E-01	9.760E-01	9.879E-01	9.929E-01	9.956E-01	9.972E-01
38.0	.	.	.	3.278E-01	9.105E-01	9.727E-01	9.863E-01	9.919E-01	9.950E-01	9.968E-01
40.0	.	.	.	2.929E-01	9.019E-01	9.700E-01	9.849E-01	9.911E-01	9.945E-01	9.964E-01
42.0	.	.	.	2.525E-01	8.907E-01	9.665E-01	9.831E-01	9.901E-01	9.938E-01	9.960E-01
44.0	.	.	.	2.142E-01	8.785E-01	9.625E-01	9.811E-01	9.889E-01	9.931E-01	9.955E-01
46.0	.	.	.	1.812E-01	8.662E-01	9.585E-01	9.790E-01	9.877E-01	9.923E-01	9.950E-01
48.0	.	.	.	1.493E-01	8.522E-01	9.539E-01	9.767E-01	9.863E-01	9.915E-01	9.945E-01
50.0	.	.	.	1.271E-01	8.407E-01	9.501E-01	9.748E-01	9.852E-01	9.908E-01	9.940E-01
52.0	.	.	.	1.313E-01	8.430E-01	9.509E-01	9.751E-01	9.854E-01	9.909E-01	9.941E-01
54.0	.	.	.	1.047E-01	8.272E-01	9.456E-01	9.724E-01	9.838E-01	9.899E-01	9.935E-01
56.0	.	.	.	8.633E-02	8.138E-01	9.411E-01	9.701E-01	9.824E-01	9.890E-01	9.929E-01
58.0	.	.	.	7.115E-02	8.007E-01	9.366E-01	9.678E-01	9.810E-01	9.882E-01	9.924E-01
60.0	.	.	.	5.678E-02	7.856E-01	9.314E-01	9.651E-01	9.794E-01	9.872E-01	9.917E-01
62.0	.	.	.	4.387E-02	7.688E-01	9.254E-01	9.620E-01	9.776E-01	9.860E-01	9.910E-01
64.0	.	.	.	3.501E-02	7.543E-01	9.203E-01	9.593E-01	9.760E-01	9.850E-01	9.903E-01
66.0	.	.	.	2.705E-02	7.381E-01	9.144E-01	9.562E-01	9.742E-01	9.839E-01	9.896E-01
68.0	.	.	.	2.024E-02	7.203E-01	9.078E-01	9.528E-01	9.721E-01	9.826E-01	9.887E-01
70.0	.	.	.	1.564E-02	7.049E-01	9.021E-01	9.498E-01	9.703E-01	9.814E-01	9.880E-01
72.0	.	.	.	1.170E-02	6.879E-01	8.956E-01	9.464E-01	9.683E-01	9.802E-01	9.872E-01
74.0	.	.	.	8.756E-03	6.713E-01	8.892E-01	9.430E-01	9.662E-01	9.789E-01	9.863E-01
76.0	.	.	.	6.551E-03	6.551E-01	8.828E-01	9.396E-01	9.642E-01	9.776E-01	9.855E-01
78.0	.	.	.	4.746E-03	6.376E-01	8.758E-01	9.358E-01	9.620E-01	9.762E-01	9.846E-01
80.0	.	.	.	3.439E-03	6.206E-01	8.688E-01	9.321E-01	9.597E-01	9.748E-01	9.837E-01
82.0	.	.	.	2.491E-03	6.040E-01	8.619E-01	9.284E-01	9.575E-01	9.734E-01	9.827E-01
84.0	.	.	.	1.748E-03	5.862E-01	8.544E-01	9.243E-01	9.550E-01	9.718E-01	9.817E-01
86.0	.	.	.	1.226E-03	5.690E-01	8.469E-01	9.203E-01	9.526E-01	9.703E-01	9.807E-01
88.0	.	.	.	8.599E-04	5.523E-01	8.395E-01	9.162E-01	9.501E-01	9.687E-01	9.797E-01
90.0	.	.	.	5.841E-04	5.346E-01	8.315E-01	9.118E-01	9.475E-01	9.670E-01	9.786E-01
92.0	.	.	.	4.097E-04	5.189E-01	8.242E-01	9.078E-01	9.450E-01	9.655E-01	9.776E-01
94.0	.	.	.	2.783E-04	5.023E-01	8.163E-01	9.035E-01	9.424E-01	9.638E-01	9.765E-01
96.0	.	.	.	1.831E-04	4.849E-01	8.079E-01	8.988E-01	9.395E-01	9.620E-01	9.753E-01
98.0	.	.	.	1.204E-04	4.681E-01	7.995E-01	8.942E-01	9.367E-01	9.602E-01	9.741E-01
100.0	.	.	.	.	4.531E-01	7.919E-01	8.899E-01	9.340E-01	9.585E-01	9.730E-01
105.0	.	.	.	.	4.121E-01	7.701E-01	8.775E-01	9.264E-01	9.536E-01	9.698E-01
110.0	.	.	.	.	3.748E-01	7.488E-01	8.653E-01	9.189E-01	9.488E-01	9.667E-01
115.0	.	.	.	.	3.390E-01	7.270E-01	8.526E-01	9.110E-01	9.437E-01	9.633E-01
120.0	.	.	.	.	3.050E-01	7.047E-01	8.395E-01	9.027E-01	9.384E-01	9.598E-01
125.0	.	.	.	.	2.722E-01	6.814E-01	8.255E-01	8.939E-01	9.327E-01	9.561E-01
130.0	.	.	.	.	2.442E-01	6.600E-01	8.124E-01	8.856E-01	9.273E-01	9.525E-01
135.0	.	.	.	.	2.133E-01	6.342E-01	7.963E-01	8.753E-01	9.206E-01	9.480E-01
140.0	.	.	.	.	1.913E-01	6.142E-01	7.837E-01	8.672E-01	9.153E-01	9.445E-01
145.0	.	.	.	.	1.717E-01	5.949E-01	7.713E-01	8.591E-01	9.100E-01	9.410E-01
150.0	.	.	.	.	1.459E-01	5.670E-01	7.530E-01	8.471E-01	9.021E-01	9.357E-01
155.0	.	.	.	.	1.274E-01	5.448E-01	7.381E-01	8.373E-01	8.955E-01	9.313E-01
160.0	.	.	.	.	1.143E-01	5.277E-01	7.264E-01	8.295E-01	8.904E-01	9.278E-01
165.0	.	.	.	.	9.716E-02	5.030E-01	7.092E-01	8.180E-01	8.826E-01	9.226E-01
170.0	.	.	.	.	8.484E-02	4.833E-01	6.952E-01	8.085E-01	8.763E-01	9.183E-01
175.0	.	.	.	.	7.409E-02	4.644E-01	6.814E-01	7.991E-01	8.699E-01	9.140E-01
180.0	.	.	.	.	6.297E-02	4.426E-01	6.653E-01	7.879E-01	8.624E-01	9.089E-01
185.0	.	.	.	.	5.351E-02	4.219E-01	6.495E-01	7.770E-01	8.549E-01	9.038E-01
190.0	.	.	.	.	4.548E-02	4.022E-01	6.341E-01	7.662E-01	8.475E-01	8.988E-01
195.0	.	.	.	.	3.972E-02	3.864E-01	6.216E-01	7.573E-01	8.414E-01	8.946E-01
200.0	.	.	.	.	3.375E-02	3.683E-01	6.069E-01	7.467E-01	8.341E-01	8.896E-01
MASS	8.472E-01	2.393E-01	1.107E-02	3.223E-04	2.711E-05	7.991E-06	3.996E-06	2.337E-06	1.452E-06	9.363E-07

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X

FRACTIONAL ENERGY LOSS PER CM.

VERSUS

WAVELENGTH λ - Å ALTITUDE h - METERS
DENSITY ρ - GRAMS / CC

ALTITUDE / WAVELENGTH	50,000	60,000	80,000	100,000	120,000	140,000	160,000	180,000	200,000	220,000
2.0	4.049E-10	4.225E-05	3.327E-04	1.037E-05	4.924E-07	7.126E-08	2.434E-08	1.230E-08	6.968E-09	4.181E-09
4.0	.	1.896E-17	5.744E-04	7.019E-05	3.458E-06	5.017E-07	1.714E-07	8.667E-08	4.910E-08	2.946E-08
6.0	.	.	4.672E-05	2.049E-04	1.114E-05	1.626E-06	5.564E-07	2.815E-07	1.595E-07	9.572E-08
8.0	.	.	1.246E-07	3.816E-04	2.483E-05	3.667E-06	1.258E-06	6.369E-07	3.611E-07	2.168E-07
10.0	.	.	7.772E-12	5.240E-04	4.486E-05	6.746E-06	2.322E-06	1.178E-06	6.683E-07	4.014E-07
12.0	.	.	7.957E-18	5.665E-04	7.099E-05	1.094E-05	3.786E-06	1.924E-06	1.093E-06	6.570E-07
14.0	.	.	.	4.976E-04	1.021E-04	1.624E-05	5.658E-06	2.884E-06	1.640E-06	9.869E-07
16.0	.	.	.	3.582E-04	1.374E-04	2.277E-05	7.999E-06	4.091E-06	2.332E-06	1.404E-06
18.0	.	.	.	2.211E-04	1.723E-04	2.989E-05	1.060E-05	5.443E-06	3.109E-06	1.875E-06
20.0	.	.	.	1.133E-04	2.079E-04	3.812E-05	1.368E-05	7.056E-06	4.041E-06	2.440E-06
22.0	.	.	.	4.954E-05	2.406E-04	4.700E-05	1.709E-05	8.866E-06	5.092E-06	3.080E-06
24.0	.	.	.	7.451E-05	2.257E-04	4.276E-05	1.545E-05	7.992E-06	4.584E-06	2.770E-06
26.0	.	.	.	3.436E-05	2.523E-04	5.063E-05	1.851E-05	9.625E-06	5.535E-06	3.351E-06
28.0	.	.	.	1.415E-05	2.753E-04	5.882E-05	2.179E-05	1.139E-05	6.571E-06	3.985E-06
30.0	.	.	.	5.217E-06	2.938E-04	6.724E-05	2.527E-05	1.329E-05	7.691E-06	4.672E-06
32.0	.	.	.	5.445E-04	5.049E-05	7.631E-06	2.630E-06	1.334E-06	7.573E-07	4.550E-07
34.0	.	.	9.513E-15	5.611E-04	5.786E-05	8.806E-06	3.039E-06	1.543E-06	8.759E-07	5.263E-07
36.0	.	.	1.453E-16	5.676E-04	6.568E-05	1.007E-05	3.481E-06	1.768E-06	1.004E-06	6.035E-07
38.0	.	.	1.579E-18	5.642E-04	7.390E-05	1.142E-05	3.955E-06	2.011E-06	1.142E-06	6.867E-07
40.0	.	.	3.604E-20	5.550E-04	8.061E-05	1.254E-05	4.349E-06	2.212E-06	1.257E-06	7.559E-07
42.0	.	.	.	5.363E-04	8.922E-05	1.401E-05	4.865E-06	2.477E-06	1.408E-06	8.468E-07
44.0	.	.	.	5.094E-04	9.851E-05	1.562E-05	5.435E-06	2.769E-06	1.575E-06	9.474E-07
46.0	.	.	.	4.776E-04	1.077E-04	1.724E-05	6.014E-06	3.067E-06	1.745E-06	1.050E-06
48.0	.	.	.	4.382E-04	1.180E-04	1.910E-05	6.679E-06	3.409E-06	1.941E-06	1.168E-06
50.0	.	.	.	4.046E-04	1.262E-04	2.064E-05	7.230E-06	3.693E-06	2.104E-06	1.267E-06
52.0	.	.	.	4.113E-04	1.246E-04	2.033E-05	7.120E-06	3.637E-06	2.071E-06	1.247E-06
54.0	.	.	.	3.647E-04	1.358E-04	2.247E-05	7.889E-06	4.034E-06	2.299E-06	1.385E-06
56.0	.	.	.	3.263E-04	1.451E-04	2.427E-05	8.545E-06	4.374E-06	2.494E-06	1.502E-06
58.0	.	.	.	2.902E-04	1.540E-04	2.607E-05	9.197E-06	4.712E-06	2.689E-06	1.620E-06
60.0	.	.	.	2.514E-04	1.640E-04	2.813E-05	9.955E-06	5.106E-06	2.915E-06	1.757E-06
62.0	.	.	.	2.117E-04	1.749E-04	3.047E-05	1.081E-05	5.555E-06	3.173E-06	1.914E-06
64.0	.	.	.	1.811E-04	1.840E-04	3.248E-05	1.156E-05	5.946E-06	3.399E-06	2.051E-06
66.0	.	.	.	1.507E-04	1.939E-04	3.476E-05	1.241E-05	6.391E-06	3.656E-06	2.207E-06
68.0	.	.	.	1.218E-04	2.045E-04	3.728E-05	1.336E-05	6.891E-06	3.945E-06	2.382E-06
70.0	.	.	.	1.004E-04	2.133E-04	3.949E-05	1.420E-05	7.332E-06	4.201E-06	2.538E-06
72.0	.	.	.	8.033E-05	2.227E-04	4.195E-05	1.514E-05	7.828E-06	4.488E-06	2.712E-06
74.0	.	.	.	6.402E-05	2.315E-04	4.436E-05	1.607E-05	8.321E-06	4.774E-06	2.887E-06
76.0	.	.	.	5.084E-05	2.398E-04	4.674E-05	1.699E-05	8.811E-06	5.060E-06	3.061E-06
78.0	.	.	.	3.919E-05	2.483E-04	4.934E-05	1.800E-05	9.354E-06	5.377E-06	3.254E-06
80.0	.	.	.	3.010E-05	2.562E-04	5.190E-05	1.901E-05	9.895E-06	5.692E-06	3.447E-06
82.0	.	.	.	2.305E-05	2.635E-04	5.441E-05	2.001E-05	1.043E-05	6.007E-06	3.639E-06
84.0	.	.	.	1.712E-05	2.709E-04	5.712E-05	2.110E-05	1.102E-05	6.352E-06	3.851E-06
86.0	.	.	.	1.268E-05	2.777E-04	5.979E-05	2.218E-05	1.161E-05	6.696E-06	4.061E-06
88.0	.	.	.	9.367E-06	2.837E-04	6.240E-05	2.326E-05	1.219E-05	7.039E-06	4.272E-06
90.0	.	.	.	6.711E-06	2.897E-04	6.519E-05	2.441E-05	1.282E-05	7.412E-06	4.501E-06
92.0	.	.	.	4.932E-06	2.946E-04	6.769E-05	2.546E-05	1.340E-05	7.752E-06	4.710E-06
94.0	.	.	.	3.516E-06	2.993E-04	7.037E-05	2.660E-05	1.402E-05	8.123E-06	4.938E-06
96.0	.	.	.	2.431E-06	3.037E-04	7.321E-05	2.781E-05	1.469E-05	8.522E-06	5.185E-06
98.0	.	.	.	1.677E-06	3.075E-04	7.598E-05	2.902E-05	1.536E-05	8.920E-06	5.431E-06
100.0	.	.	.	1.188E-06	3.104E-04	7.848E-05	3.012E-05	1.598E-05	9.286E-06	5.657E-06
105.0	.	.	.	4.305E-07	3.161E-04	8.546E-05	3.326E-05	1.775E-05	1.035E-05	6.314E-06
110.0	.	.	.	1.542E-07	3.183E-04	9.200E-05	3.631E-05	1.949E-05	1.140E-05	6.967E-06
115.0	.	.	.	5.159E-08	3.174E-04	9.845E-05	3.943E-05	2.129E-05	1.249E-05	7.653E-06
120.0	.	.	.	1.611E-08	3.134E-04	1.048E-04	4.261E-05	2.316E-05	1.364E-05	8.370E-06
125.0	.	.	.	4.560E-09	3.065E-04	1.110E-04	4.592E-05	2.514E-05	1.485E-05	9.137E-06
130.0	.	.	.	1.361E-09	2.979E-04	1.165E-04	4.896E-05	2.698E-05	1.600E-05	9.861E-06
135.0	.	.	.	2.977E-10	2.852E-04	1.227E-04	5.261E-05	2.923E-05	1.741E-05	1.076E-05
140.0	.	.	.	8.777E-11	2.738E-04	1.272E-04	5.541E-05	3.099E-05	1.852E-05	1.147E-05
145.0	.	.	.	2.576E-11	2.618E-04	1.312E-04	5.810E-05	3.271E-05	1.963E-05	1.218E-05
150.0	.	.	.	4.069E-12	2.430E-04	1.366E-04	6.196E-05	3.523E-05	2.125E-05	1.323E-05
155.0	.	.	.	8.693E-13	2.272E-04	1.405E-04	6.502E-05	3.728E-05	2.258E-05	1.409E-05
160.0	.	.	.	2.521E-13	2.146E-04	1.433E-04	6.735E-05	3.887E-05	2.363E-05	1.478E-05
165.0	.	.	.	3.918E-14	1.960E-04	1.468E-04	7.069E-05	4.121E-05	2.519E-05	1.580E-05
170.0	.	.	.	8.274E-15	1.811E-04	1.493E-04	7.332E-05	4.310E-05	2.646E-05	1.664E-05
175.0	.	.	.	1.742E-15	1.669E-04	1.513E-04	7.582E-05	4.494E-05	2.771E-05	1.747E-05
180.0	.	.	.	2.676E-16	1.507E-04	1.532E-04	7.865E-05	4.708E-05	2.919E-05	1.846E-05
185.0	.	.	.	4.097E-17	1.356E-04	1.547E-04	8.130E-05	4.916E-05	3.063E-05	1.943E-05
190.0	.	.	.	6.253E-18	1.216E-04	1.556E-04	8.379E-05	5.116E-05	3.206E-05	2.040E-05
195.0	.	.	.	1.303E-18	1.109E-04	1.561E-04	8.573E-05	5.279E-05	3.322E-05	2.119E-05
200.0	.	.	.	1.978E-19	9.898E-05	1.563E-04	8.792E-05	5.468E-05	3.459E-05	2.214E-05
DENSITY	1.027E-03	3.059E-04	1.999E-05	4.974E-07	2.346E-08	3.394E-09	1.159E-09	5.858E-10	3.318E-10	1.991E-10

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13. ABSTRACT

Physical and chemical analysis, x-ray astronomy and high temperature plasma diagnostics which utilize the ultrasoft x-radiations have made evident a strong need for filling the gap in measured absorption coefficient data for the radiations between the conventional x-rays and the extreme ultraviolet. More than one hundred new coefficients have been recently measured in this laboratory on the gas state, atomic or molecular, containing He, C, N, O, F, Ne, S, Cl, Ar, Kr, and Xe using eleven fluorescent, characteristic wavelengths Al-K (8.34 A) through Be-K (113.8 A). The radiations were isolated by Bragg reflection from multilayer analyzers of the Langmuir-Blodgett type and by pulse height discriminating proportional counter intensity measurements. Using these data and data previously published, a complete table has been determined for He through Ar and for wavelengths below the L_{III} edges and in the region 2-to-200 A. Absorption cross sections have been calculated for many compound materials which are commonly encountered in low energy x-ray analysis. The transmission of x-rays from a source above the earth has been tabulated as a function of altitude and wavelength.

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14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
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