Table 4.4.4.1. *Bound scattering lengths, b, in fm and cross sections, σ, in barns (1 barn = 100 fm²) of the elements and their isotopes*

Z: atomic number; A: mass number; $I(\pi)$: spin (parity) of the nuclear ground state; c: % natural abundance (for radioisotopes, the half-life is given instead in annums); b_c: bound coherent scattering length; b_i: bound incoherent scattering length; σ_c: bound coherent scattering cross section; σ_i: bound incoherent scattering cross section; σ_s: total bound scattering cross section; σ_a: absorption cross section for 2200 m s^{-1} neutrons (E = 25.30 meV, k = 3.494 Å^{-1}, λ = 1.798 Å); $i = \sqrt{-1}$.

Element	Z	A	$I(\pi)$	c	b_c	b_i	σ_c	σ_i	σ_s	σ_a
H	1				−3.7390(11)		1.7568(10)	80.26(6)	82.02(6)	0.3326(7)
		1	1/2(+)	99.985	−3.7406(11)	25.274(9)	1.7583(10)	80.27(6)	82.03(6)	0.3326(7)
		2	1(+)	0.015	6.671(4)	4.04(3)	5.592(7)	2.05(3)	7.64(3)	0.000519(7)
		3	1/2(+)	(12.32a)	4.792(27)	−1.04(17)	2.89(3)	0.14(4)	3.03(5)	0
He	2				3.26(3)		1.34(2)	0.00	1.34(2)	0.00747(1)
		3	1/2(+)	0.00014	5.74(7)	−2.5(6)	4.42(10)	1.6(4)	6.0(4)	5333.(7.)
					−1.483(2)i	+2.568(3)i				
		4	0(+)	99.99986	3.26(3)	0	1.34(2)	0	1.34(2)	0
Li	3				−1.90(2)		0.454(14)	0.92(3)	1.37(3)	70.5(3)
		6	1(+)	7.5	2.00(11)	−1.89(5)	0.51(5)	0.46(2)	0.97(7)	940.(4.)
					−0.261(1)i	0.257(11)i				
		7	3/2(−)	92.5	−2.22(2)	−2.49(5)	0.619(11)	0.78(3)	1.40(3)	0.0454(3)
Be	4	9	3/2(−)	100	7.79(1)	0.12(3)	7.63(2)	0.0018(9)	7.63(2)	0.0076(8)
B	5				5.30(4)		3.54(5)	1.70(12)	5.24(11)	767.(8.)
					0.213(2)i					
		10	3(+)	20.0	−0.1(3)	−4.7(3)	0.144(8)	3.0(4)	3.1(4)	3835.(9.)
					1.066(3)i	1.231(3)i				
		11	3/2(−)	80.0	6.65(4)	−1.3(2)	5.56(7)	0.22(6)	5.78(9)	0.0055(33)
C	6				6.6460(12)		5.550(2)	0.001(4)	5.551(3)	0.00350(7)
		12	0(+)	98.90	6.6511(16)	0	5.559(3)	0	5.559(3)	0.00353(7)
		13	1/2(−)	1.10	6.19(9)	−0.52(9)	4.81(14)	0.034(12)	4.84(14)	0.00137(4)
N	7				9.36(2)		11.01(5)	0.50(12)	11.51(11)	1.90(3)
		14	1(+)	99.63	9.37(2)	2.0(2)	11.03(5)	0.5(1)	11.53(11)	1.91(3)
		15	1/2(−)	0.37	6.44(3)	−0.02(2)	5.21(5)	0.00005(10)	5.21(5)	0.000024(8)
O	8				5.803(4)		4.232(6)	0.000(8)	4.232(6)	0.00019(2)
		16	0(+)	99.762	5.803(4)	0	4.232(6)	0	4.232(6)	0.00010(2)
		17	5/2(+)	0.038	5.78(12)	0.18(6)	4.20(22)	0.004(3)	4.20(22)	0.236(10)
		18	0(+)	0.200	5.84(7)	0	4.29(10)	0	4.29(10)	0.00016(1)
F	9	19	1/2(+)	100	5.654(10)	−0.082(9)	4.017(17)	0.0008(2)	4.018(14)	0.0096(5)
Ne	10				4.566(6)		2.620(7)	0.008(9)	2.628(6)	0.039(4)
		20	0(+)	90.51	4.631(6)	0	2.695(7)	0	2.695(7)	0.036(4)
		21	3/2(+)	0.27	6.66(19)	±0.6(1)	5.6(3)	0.05(2)	5.7(3)	0.67(11)
		22	0(+)	9.22	3.87(1)	0	1.88(1)	0	1.88(1)	0.046(6)
Na	11	23	3/2(+)	100	3.63(2)	3.59(3)	1.66(2)	1.62(3)	3.28(4)	0.530(5)
Mg	12				5.375(4)		3.631(5)	0.08(6)	3.71(4)	0.063(3)
		24	0(+)	78.99	5.66(3)	0	4.03(4)	0	4.03(4)	0.050(5)
		25	5/2(+)	10.00	3.62(14)	1.48(10)	1.65(13)	0.28(4)	1.93(14)	0.19(3)
		26	0(+)	11.01	4.89(15)	0	3.00(18)	0	3.00(18)	0.0382(8)
Al	13	27	5/2(+)	100	3.449(5)	0.256(10)	1.495(4)	0.0082(7)	1.503(4)	0.231(3)
Si	14				4.1491(10)		2.1633(10)	0.004(8)	2.167(8)	0.171(3)
		28	0(+)	92.23	4.107(6)	0	2.120(6)	0	2.120(6)	0.177(3)
		29	1/2(+)	4.67	4.70(10)	0.09(9)	2.78(12)	0.001(2)	2.78(12)	0.101(14)
		30	0(+)	3.10	4.58(8)	0	2.64(9)	0	2.64(9)	0.107(2)
P	15	31	1/2(+)	100	5.13(1)	0.2(2)	3.307(13)	0.005(10)	3.312(16)	0.172(6)
S	16				2.847(1)		1.0186(7)	0.007(5)	1.026(5)	0.53(1)
		32	0(+)	95.02	2.804(2)	0	0.9880(14)	0	0.9880(14)	0.54(4)
		33	3/2(+)	0.75	4.74(19)	1.5(1.5)	2.8(2)	0.3(6)	3.1(6)	0.54(4)
		34	0(+)	4.21	3.48(3)	0	1.52(3)	0	1.52(3)	0.227(5)
		36	0(+)	0.02	3.(1.) E	0	1.1(8)	0	1.1(8)	0.15(3)

Table 4.4.4.1. *Bound scattering lengths (cont.)*

Element	Z	A	$I(\pi)$	c	b_c	b_i	σ_c	σ_i	σ_s	σ_a
Cl	17				9.5770(8)		11.526(2)	5.3(5)	16.8(5)	33.5(3)
		35	3/2(+)	75.77	11.65(2)	6.1(4)	17.06(6)	4.7(6)	21.8(6)	44.1(4)
		37	3/2(+)	24.23	3.08(6)	0.1(1)	1.19(5)	0.001(3)	1.19(5)	0.433(6)
Ar	18				1.909(6)		0.458(3)	0.22(2)	0.683(4)	0.675(9)
		36	0(+)	0.337	24.90(7)	0	77.9(4)	0	77.9(4)	5.2(5)
		38	0(+)	0.063	3.5(3.5)	0	1.5(3.1)	0	1.5(3.1)	0.8(2)
		40	0(+)	99.600	1.830(6)	0	0.421(3)	0	0.421(3)	0.660(9)
K	19				3.67(2)		1.69(2)	0.27(11)	1.96(11)	2.1(1)
		39	3/2(+)	93.258	3.74(2)	1.4(3)	1.76(2)	0.25(11)	2.01(11)	2.1(1)
		40	4(−)	0.012	3.(1.) *E*		1.1(8)	0.5(5)	1.6(9)	35.(8.)
		41	3/2(+)	6.730	2.69(8)	1.5(1.5)	0.91(5)	0.3(6)	1.2(6)	1.46(3)
Ca	20				4.70(2)		2.78(2)	0.05(3)	2.83(2)	0.43(2)
		40	0(+)	96.941	4.80(2)	0	2.90(2)	0	2.90(2)	0.41(2)
		42	0(+)	0.647	3.36(10)	0	1.42(8)	0	1.42(8)	0.68(7)
		43	7/2(−)	0.135	−1.56(9)	0.31(4)	0.5(5) *E*		0.8(5)	6.2(6)
		44	0(+)	2.086	1.42(6)	0	0.25(2)	0	0.25(2)	0.88(5)
		46	0(+)	0.004	3.6(2)	0	1.6(2)	0	1.6(2)	0.74(7)
		48	0(+)	0.187	0.39(9)	0	0.019(9)	0	0.019(9)	1.09(14)
Sc	21	45	7/2(−)	100	12.29(11)	−6.0(3)	19.0(3)	4.5(5)	23.5(6)	27.5(2)
Ti	22				−3.370(13)		1.427(11)	2.63(3)	4.06(3)	6.43(6)
		46	0(+)	8.2	4.725(5)	0	2.80(6)	0	2.80(6)	0.59(18)
		47	5/2(−)	7.4	3.53(7)	−3.5(2)	1.57(6)	1.5(2)	3.1(2)	1.7(2)
		48	0(+)	73.8	−5.86(2)	0	4.32(3)	0	4.32(3)	8.30(9)
		49	7/2(−)	5.4	0.98(5)	5.1(2)	0.12(1)	3.3(3)	3.4(3)	2.2(3)
		50	0(+)	5.2	5.88(10)	0	4.34(15)	0	4.34(15)	0.179(3)
V	23				−0.3824(12)		0.01838(12)	5.08(6)	5.10(6)	5.08(2)
		50	6(+)	0.250	7.6(6)		7.3(1.1)	0.5(5) *E*	7.8(1.0)	60.(40.)
		51	7/2(−)	99.750	−0.402(2)	6.435(4)	0.0203(2)	5.07(6)	5.09(6)	4.9(1)
Cr	24				3.635(7)		1.660(6)	1.83(2)	3.49(2)	3.05(8)
		50	0(+)	4.35	−4.50(5)	0	2.54(6)	0	2.54(6)	15.8(2)
		52	0(+)	83.79	4.920(10)	0	3.042(12)	0	3.042(12)	0.76(6)
		53	3/2(−)	9.50	−4.20(3)	6.87(10)	2.22(3)	5.93(17)	8.15(17)	18.1(1.5)
		54	0(+)	2.36	4.55(10)	0	2.60(11)	0	2.60(11)	0.36(4)
Mn	25	55	5/2(−)	100	−3.750(18)	1.79(4)	1.77(2)	0.40(2)	2.17(3)	13.3(2)
Fe	26				9.45(2)		11.22(5)	0.40(11)	11.62(10)	2.56(3)
		54	0(+)	5.8	4.2(1)	0	2.2(1)	0	2.2(1)	2.25(18)
		56	0(+)	91.7	9.94(3)	0	12.42(7)	0	12.42(7)	2.59(14)
		57	1/2(−)	2.2	2.3(1)	0.66(6)		0.3(3) *E*	1.0(3)	2.48(30)
		58	0(+)	0.3	15.(7.)	0	28.(26.)	0	28.(26.)	1.28(5)
Co	27	59	7/2(−)	100	2.49(2)	−6.2(2)	0.779(13)	4.8(3)	5.6(3)	37.18(6)
Ni	28				10.3(1)		13.3(3)	5.2(4)	18.5(3)	4.49(16)
		58	0(+)	68.27	14.4(1)	0	26.1(4)	0	26.1(4)	4.6(3)
		60	0(+)	26.10	2.8(1)	0	0.99(7)	0	0.99(7)	2.9(2)
		61	3/2(−)	1.13	7.60(6)	±3.9(3)	7.26(11)	1.9(3)	9.2(3)	2.5(8)
		62	0(+)	3.59	−8.7(2)	0	9.5(4)	0	9.5(4)	14.5(3)
		64	0(+)	0.91	−0.37(7)	0	0.017(7)	0	0.017(7)	1.52(3)
Cu	29				7.718(4)		7.485(8)	0.55(3)	8.03(3)	3.78(2)
		63	3/2(−)	69.17	6.43(15)	0.22(2)	5.2(2)	0.006(1)	5.2(2)	4.50(2)
		65	3/2(−)	30.83	10.61(19)	1.79(10)	14.1(5)	0.40(4)	14.5(5)	2.17(3)
Zn	30				5.60(5)		4.054(7)	0.077(7)	4.131(10)	1.11(2)
		64	0(+)	48.6	5.22(4)	0	3.42(5)	0	3.42(5)	0.93(9)
		66	0(+)	27.9	5.97(5)	0	4.48(8)	0	4.48(8)	0.62(6)
		67	5/2(−)	4.1	7.56(8)	−1.50(7)	7.18(15)	0.28(3)	7.46(15)	6.8(8)
		68	0(+)	18.8	6.03(3)	0	4.57(5)	0	4.57(5)	1.1(1)
		70	0(+)	0.6	6.(1.) *E*	0	4.5(1.5)	0	4.5(1.5)	0.092(5)

Table 4.4.4.1. *Bound scattering lengths (cont.)*

Element	Z	A	$I(\pi)$	c	b_c	b_i	σ_c	σ_i	σ_s	σ_a
Ga	31				7.288(2)		6.675(4)	0.16(3)	6.83(3)	2.75(3)
		69	3/2(−)	60.1	7.88(2)	−0.85(5)	7.80(4)	0.091(11)	7.89(4)	2.18(5)
		71	3/2(−)	39.9	6.40(3)	−0.82(4)	5.15(5)	0.084(8)	5.23(5)	3.61(10)
Ge	32				8.185(20)		8.42(4)	0.18(7)	8.60(6)	2.20(4)
		70	0(+)	20.5	10.0(1)	0	12.6(3)	0	12.6(3)	3.0(2)
		72	0(+)	27.4	8.51(10)	0	9.1(2)	0	9.1(2)	0.8(2)
		73	9/2(+)	7.8	5.02(4)	3.4(3)	3.17(5)	1.5(3)	4.7(3)	15.1(4)
		74	0(+)	36.5	7.58(10)	0	7.2(2)	0	7.2(2)	0.4(2)
		76	0(+)	7.8	8.21(1.5)	0	8.(3.)	0	8.(3.)	0.16(2)
As	33	75	3/2(−)	100	6.58(1)	−0.69(5)	5.44(2)	0.060(10)	5.50(2)	4.5(1)
Se	34				7.970(9)		7.98(2)	0.33(6)	8.30(6)	11.7(2)
		74	0(+)	0.9	0.8(3.0)	0	0.1(6)	0	0.1(6)	51.8(1.2)
		76	0(+)	9.0	12.2(1)	0	18.7(3)	0	18.7(3)	85.(7.)
		77	1/2(−)	7.6	8.25(8)	±0.6(1.6)	8.6(2)	0.05(26)	8.65(16)	42.(4.)
		78	0(+)	23.5	8.24(9)	0	8.5(2)	0	8.5(2)	0.43(2)
		80	0(+)	49.6	7.48(3)	0	7.03(6)	0	7.03(6)	0.61(5)
		82	0(+)	9.4	6.34(8)	0	5.05(13)	0	5.05(13)	0.044(3)
Br	35				6.795(15)		5.80(3)	0.10(9)	5.90(9)	6.9(2)
		79	3/2(−)	50.69	6.80(7)	−1.1(2)	5.81(12)	0.15(6)	5.96(13)	11.0(7)
		81	3/2(−)	49.31	6.79(7)	0.6(1)	5.79(12)	0.05(2)	5.84(12)	2.7(2)
Kr	36				7.81(2)		7.67(4)	0.01(14)	7.68(13)	25.(1.)
		78	0(+)	0.35		0		0		6.4(9)
		80	0(+)	2.25		0		0		11.8(5)
		82	0(+)	11.6		0		0		29.(20.)
		83	9/2(+)	11.5		185(30.)				
		84	0(+)	57.0		0		0		0.113(15)
		86	0(+)	17.3	8.1(2)	0	8.2(4)	0	8.2(4)	0.003(2)
Rb	37				7.09(2)		6.32(4)	0.5(4)	6.8(4)	0.38(4)
		85	5/2(−)	72.17	7.03(10)	6.2(2)	0.5(5)	*E*	6.7(5)	0.48(1)
		87	3/2(−)	27.83	7.23(12)	6.6(2)	0.5(5)	*E*	7.1(5)	0.12(3)
Sr	38				7.02(2)		6.19(4)	0.06(11)	6.25(10)	1.28(6)
		84	0(+)	0.56	7.(1.) *E*	0	6.(2.)	0	6.(2.)	0.87(7)
		86	0(+)	9.86	5.67(5)	0	4.04(7)	0	4.04(7)	1.04(7)
		87	9/2(+)	7.00	7.40(7)	6.88(13)	0.5(5)	*E*	7.4(5)	16.(3.)
		88	0(+)	82.58	7.15(6)	0	6.42(11)	0	6.42(11)	0.058(4)
Y	39	89	1/2(−)	100	7.75(2)	1.1(3)	7.55(4)	0.15(8)	7.70(9)	1.28(2)
Zr	40				7.16(3)		6.44(5)	0.02(15)	6.46(14)	0.185(3)
		90	0(+)	51.45	6.4(1)	0	5.1(2)	0	5.1(2)	0.011(5)
		91	5/2(+)	11.32	8.7(1)	−1.08(15)	9.5(2)	0.15(4)	9.7(2)	1.17(10)
		92	0(+)	17.19	7.4(2)	0	6.9(4)	0	6.9(4)	0.22(6)
		94	0(+)	17.28	8.2(2)	0	8.4(4)	0	8.4(4)	0.0499(24)
		96	0(+)	2.76	5.5(1)	0	3.8(1)	0	3.8(1)	0.0229(10)
Nb	41	93	9/2(+)	100	7.054(3)	−0.139(10)	6.253(5)	0.0024(3)	6.255(5)	1.15(5)
Mo	42				6.715(2)		5.67(3)	0.04(5)	5.71(4)	2.48(4)
		92	0(+)	14.84	6.91(8)	0	6.00(14)	0	6.00(14)	0.019(2)
		94	0(+)	9.25	6.80(7)	0	5.81(12)	0	5.81(12)	0.015(2)
		95	5/2(+)	15.92	6.91(6)	6.00(10)	0.5(5)	*E*	6.5(5)	13.1(3)
		96	0(+)	16.68	6.20(6)	0	4.83(9)	0	4.83(9)	0.5(2)
		97	5/2(+)	9.55	7.24(8)	6.59(15)	0.5(5)	*E*	7.1(5)	2.5(2)
		98	0(+)	24.13	6.58(7)	0	5.44(12)	0	5.44(12)	0.127(6)
		100	0(+)	9.63	6.73(7)	0	5.69(12)	0	5.69(12)	0.4(2)
Tc	43									
		99	9/2(+)	$(2.13\times10^5$a)	6.8(3)	5.8(5)	0.5(5)	*E*	6.3(7)	20.(1.)

Table 4.4.4.1. *Bound scattering lengths (cont.)*

Element	Z	A	$I(\pi)$	c	b_c	b_i	σ_c	σ_i	σ_s	σ_a
Ru	44				7.03(3)		6.21(5)	0.4(1)	6.6(1)	2.56(13)
		96	0(+)	5.5	0	0	0.28(2)			
		98	0(+)	1.9	0	0	<8.0			
		99	5/2(+)	12.7	6.9(1.0)					
		100	0(+)	12.6	0	0	4.8(6)			
		101	5/2(+)	17.0	3.3(9)					
		102	0(+)	31.6	0	0	1.17(7)			
		104	0(+)	18.7	0	0	0.31(2)			
Rh	45	103	1/2(−)	100	5.88(4)	4.34(6)	0.3(3)	*E*	4.6(3)	144.8(7)
Pd	46				5.91(6)		4.39(9)	0.093(9)	4.48(9)	6.9(4)
		102	0(+)	1.02	7.7(7) *E*	0	7.5(1.4)	0	7.5(1.4)	3.4(3)
		104	0(+)	11.14	7.7(7) *E*	0	7.5(1.4)	0	7.5(1.4)	0.6(3)
		105	5/2(+)	22.33	5.5(3)	−2.6(1.6)	3.8(4)	0.8(1.0)	4.6(1.1)	20.(3.)
		106	0(+)	27.33	6.4(4)	0	5.1(6)	0	5.1(6)	0.304(29)
		108	0(+)	26.46	4.1(3)	0	2.1(3)	0	2.1(3)	8.5(5)
		110	0(+)	11.72	7.7(7)*E*	0	7.5(1.4)	0	7.5(1.4)	0.226(31)
Ag	47				5.922(7)		4.407(10)	0.58(3)	4.99(3)	63.3(4)
		107	1/2(−)	51.839	7.555(11)	1.00(13)	7.17(2)	0.13(3)	7.30(4)	37.6(1.2)
		109	1/2(−)	48.161	4.165(11)	−1.60(13)	2.18(1)	0.32(5)	2.50(5)	91.0(1.0)
Cd	48				4.87(5)		3.04(6)	3.46(13)	6.50(12)	2520.(50.)
					−0.70(1)*i*					
		106	0(+)	1.25	5.(2.) *E*	0	3.1(2.5)	0	3.1(2.5)	1.
		108	0(+)	0.89	5.4(1)	0	3.7(1)	0	3.7(1)	1.1(3)
		110	0(+)	12.51	5.9(1)	0	4.4(1)	0	4.4(1)	11.(1.)
		111	1/2(+)	12.81	6.5(1)	5.3(2)	0.3(3)	*E*	5.6(4)	24(3.)
		112	0(+)	24.13	6.4(1)	0	5.1(2)	0	5.1(2)	2.2(5)
		*113	1/2(+)	12.22	−8.0(2)	12.1(4)	0.3(3) *E*	12.4(5)		20600(400.)
					−5.73(11)*i*					
		114	0(+)	28.72	7.5(1)	0	7.1(2)	0	7.1(2)	0.34(2)
		116	0(+)	7.47	6.3(1)	0	5.0(2)	0	5.0(2)	0.075(13)
In	49			4.065(20)	2.08(2)	0.54(11)	2.62(11)	193.8(1.5)		
					−0.0539(4)*i*					
		113	9/2(+)	43	5.39(6)	±0.017(1)	3.65(8)	0.000037(5)	3.65(8)	12.0(1.1)
		115	9/2(+)	957	4.01(2)	−2.1(2)	2.02(2)	0.55(11)	2.57(11)	202(2.)
					−0.0562(6)*i*					
Sn	50				6.225(2)		4.870(3)	0.022(5)	4.892(6)	0.626(9)
		112	0(+)	1.0	6.1(1.) *E*	0	4.5(1.5)	0	4.5(1.5)	1.01(11)
		114	0(+)	0.7	6.2(3)	0	4.8(5)	0	4.8(5)	0.114(30)
		115	1/2(+)	0.4	6.(1.) *E*	4.5(1.5)	0.3(3) *E*	4.8(1.5)	30(7.)	
		116	0(+)	14.7	5.93(5)	0	4.42(7)	0	4.42(7)	0.14(3)
		117	1/2(+)	7.7	6.48(5)	5.28(8)	0.3(3) *E*	5.6(3)	2.3(5)	
		118	0(+)	24.3	6.07(5)	0	4.63(8)	0	4.63(8)	0.22(5)
		119	1/2(+)	8.6	6.12(5)	4.71(8)	0.3(3) *E*	5.0(3)	2.2(5)	
		120	0(+)	32.4	6.49(5)	0	5.29(8)	0	5.29(8)	0.14(3)
		122	0(+)	4.6	5.74(5)	0	4.14(7)	0	4.14(7)	0.18(2)
		124	0(+)	5.6	5.97(5)	0	4.48(8)	0	4.48(8)	0.133(5)
Sb	51				5.57(3)		3.90(4)	0.00(7)	3.90(6)	4.91(5)
		121	7/2(+)	57.3	5.71(6)	−0.05(15)	4.10(9)	0.0003(19)	4.10(9)	5.75(12)
		123	5/2(+)	42.7	5.38(7)	−0.10(15)	3.64(9)	0.001(4)	3.64(9)	3.8(2)
Te	52				5.80(3)		4.23(4)	0.09(1)	4.32(4)	4.05(5)
		120	0(+)	0.096	5.3(5)	0	3.5(7)	0	3.4(7)	2.3(3)
		122	0(+)	2.60	3.8(2)	0	1.8(2)	0	1.8(2)	3.4(5)
		123	1/2(+)	0.908	−0.05(25)	−2.04(9)	0.002(3)	0.52(5)	0.52(5)	418(30.)
					−0.116(8)*i*					
		124	0(+)	4.816	7.96(10)	0	8.0(2)	0	8.0(2)	6.8(1.3)
		125	1/2(+)	7.14	5.02(8)	−0.26(13)	3.17(10)	0.008(8)	3.18(10)	1.55(16)
		126	0(+)	18.95	5.56(7)	0	3.88(10)	0	3.88(10)	1.04(15)
		128	0(+)	31.69	5.89(7)	0	4.36(10)	0	4.36(10)	0.215(8)
		130	0(+)	33.80	6.02(7)	0	4.55(11)	0	4.55(11)	0.29(6)

Table 4.4.4.1. *Bound scattering lengths (cont.)*

Element	Z	A	$I(\pi)$	c	b_c	b_i	σ_c	σ_i	σ_s	σ_a
I	53	127	5/2(+)	100	5.28(2)	1.58(15)	3.50(3)	0.31(6)	3.81(7)	6.15(6)
Xe	54				4.92(3)		3.04(4)			23.9(1.2)
		124	0(+)	0.10		0		0		165.(20.)
		126	0(+)	0.09		0		0		3.5(8)
		128	0(+)	1.91		0		0		< 8.
		129	1/2(+)	26.4						21.(5.)
		130	0(+)	4.1		0		0		< 26.
		131	3/2(+)	21.2						85.(10.)
		132	0(+)	26.9		0		0		0.45(6)
		134	0(+)	10.4		0		0		0.265(20)
		136	0(+)	8.9		0		0		0.26(2)
Cs	55	133	7/2(+)	100	5.42(2)	1.29(15)	3.69(3)	0.21(5)	3.90(6)	29.0(1.5)
Ba	56				5.07(3)		3.23(4)	0.15(11)	3.38(10)	1.1(1)
		130	0(+)	0.11	−3.6(6)	0	1.6(5)	0	1.6(5)	30(5.)
		132	0(+)	0.10	7.8(3)	0	7.6(6)	0	7.6(6)	7.0(8)
		134	0(+)	2.42	5.7(1)	0	4.08(14)	0	4.08(14)	2.0(1.6)
		135	3/2(+)	6.59	4.67(10)		2.74(12)	0.5(5) *E*	3.2(5)	5.8(9)
		136	0(+)	7.85	4.91(8)	0	3.03(10)	0	3.03(10)	0.68(17)
		137	3/2(+)	11.23	6.83(10)		5.86(17)	0.5(5) *E*	6.4(5)	3.6(2)
		138	0(+)	71.70	4.84(8)	0	2.94(10)	0	2.94(10)	0.27(14)
La	57				8.24(4)		8.53(8)	1.13(19)	9.66(17)	8.97(5)
		138	5(+)	0.09	8.(2.) *E*	8.(4.)	0.5(5) *E*	8.5(4.0)	57.(6.)	
		139	7/2(+)	99.91	8.24(4)	3.0(2)	8.53(8)	1.13(15)	9.66(17)	8.93(4)
Ce	58				4.84(2)		2.94(2)	0.00(10)	2.94(10)	0.63(4)
		136	0(+)	0.19	5.80(9)	0	4.23(13)	0	4.23(13)	7.3(1.5)
		138	0(+)	0.25	6.70(9)	0	5.64(15)	0	5.64(15)	1.1(3)
		140	0(+)	88.48	4.84(9)	0	2.94(11)	0	2.94(11)	0.57(4)
		142	0(+)	11.08	4.75(9)	0	2.84(11)	0	2.84(11)	0.95(5)
Pr	59	141	5/2(+)	100	4.58(5)	−0.35(3)	2.64(6)	0.015(3)	2.66(6)	11.5(3)
Nd	60				7.69(5)		7.43(10)	9.2(8)	16.6(8)	50.5(1.2)
		142	0(+)	27.16	7.7(3)	0	7.5(6)	0	7.5(6)	18.7(7)
		143	7/2(−)	12.18	14.2(5) *E*	±21.1(6)	25.(7.)	55.(7.)	80.(2.)	334.(10.)
		144	0(+)	23.80	2.8(3)	0	1.0(2)	0	1.0(2)	3.6(3)
		145	7/2(−)	8.29	14.2(5)	*E*	25.(7.)	5.(5.) *E*	30.(9.)	42.(2.)
		146	0(+)	17.19	8.7(2)	0	9.5(4)	0	9.5(4)	1.4(1)
		148	0(+)	5.75	5.7(3)	0	4.1(4)	0	4.1(4)	2.5(2)
		150	0(+)	5.63	5.3(2)	0	3.5(3)	0	3.5(3)	1.2(2)
Pm	61									
		147	7/2(+)	(2.62a)	12.6(4)	±3.2(2.5)	20.0(1.3)	1.3(2.0)	21.3(1.5)	168.4(3.5)
Sm	62				0.80(2) −1.65(2)*i*		0.422(9)	39.(3.)	39.(3.)	5922.(56.)
		144	0(+)	3.1	−3.(4.) *E*	0	1.(3.)	0	1.(3.)	0.7(3)
		147	7/2(−)	15.1	14(3.)	±11.(7.)	25.(11.)	14.(19.)	39(16.)	57(3.)
		148	0(+)	11.3	−3.(4.) *E*	0	1.(3.)	0	1.(3.)	2.4(6)
		*149	7/2(−)	13.9	−19.2(1) −11.7(1)*i*	±31.4(6) −10.3(1)*i*	63.5(6)	137.(5.)	200.(5.)	42080.(400.)
		150	0(+)	7.4	14(3.)	0	25(11.)	0	25(11.)	104(4.)
		152	0(+)	26.6	−5.0(6)	0	3.1(8)	0	3.1(8)	206.(6.)
		154	0(+)	22.6	9.3(1.0)	0	11.(2.)	0	11.(2.)	8.4(5)
Eu	63				7.22(2) −1.26(1)*i*		6.75(4)	2.5(4)	9.2(4)	4530.(40.)
		*151	5/2(+)	47.8	6.13(14) −2.53(3)*i*	±4.5(4) −2.14(2)*i*	5.5(2)	3.1(4)	8.4(4)	9100(100.)
		153	5/2(+)	52.2	8.22(12)	±3.2(9)	8.5(2)	1.3(7)	9.8(7)	312.(7.)

Table 4.4.4.1.*Bound scattering lengths (cont.)*

Element	Z	A	$I(\pi)$	c	b_c	b_i	σ_c	σ_i	σ_s	σ_a
Gd	64				6.5(5) −13.82(3)*i*		29.3(8)	151.(2.)	180.(2.)	49700.(125.)
		152	0(+)	0.2	10.(3.) *E*	0	13.(8.)	0	13.(8.)	735.(20.)
		154	0(+)	2.1	10.(3.) *E*	0	13.(8.)	0	13.(8.)	85.(12.)
		*155	3/2(−)	14.8	6.0(1) −17.0(1)*i*	±5.(5.) *E* −13.16(9)*i*	40.8(4.)	25.(6.)	66.(6.)	61100.(400.)
		156	0(+)	20.6	6.3(4)	0	5.0(6)	0	5.0(6)	1.5(1.2)
		*157	3/2(−)	15.7	−1.14(2) −71.9(2)*i*	±5.(5.) *E* −55.8(2)*i*	650(4.)	394.(7.)	1044.(8.)	259000.(700.)
		158	0(+)	24.8	9.(2.)	0	10.(5.)	0	10.(5.)	2.2(2)
		160	0(+)	21.8	9.15(5)	0	10.52(11)	0	10.52(11)	0.77(2)
Tb	65	159	3/2(+)	100	7.38(3)	−0.17(7)	6.84(6)	0.004(3)	6.84(6)	23.4(4)
Dy	66				16.9(2) −0.276(4)*i*		35.9(8)	54.4(1.2)	90.3(9)	994.(13.)
		156	0(+)	0.06	6.1(5)	0	4.7(8)	0	4.7(8)	33.(3.)
		158	0(+)	0.10	6.(4.) *E*	0	5.(6.)	0	5.(6.)	43.(6.)
		160	0(+)	2.34	6.7(4)	0	5.6(7)	0	5.6(7)	56.(5.)
		161	5/2(+)	19.0	10.3(4)	±4.9(8)	13.3(1.0)	3.(1.)	16.(1.)	600.(25.)
		162	0(+)	25.5	−1.4(5)	0	0.25(18)	0	0.25(18)	194.(10.)
		163	5/2(−)	24.9	5.0(4)	1.3(3)	3.1(5)	0.21(10)	3.3(5)	124.(7.)
		164	0(+)	28.1	49.4(5) −0.79(1)*i*	0	307.(3.)	0	307.(3.)	2840.(40.)
Ho	67	165	7/2(−)	100	8.01(8)	−1.70(8)	8.06(16)	0.36(3)	8.42(16)	64.7(1.2)
Er	68				7.79(2)		7.63(4)	1.1(3)	8.7(3)	159.(4.)
		162	0(+)	0.14	8.8(2)	0	9.7(4)	0	9.7(4)	19.(2.)
		164	0(+)	1.56	8.2(2)	0	8.4(4)	0	8.4(4)	13.(2.)
		166	0(+)	33.4	10.6(2)	0	14.1(5)	0	14.1(5)	19.6(1.5)
		167	7/2(+)	22.9	3.0(3)	1.0(3)	1.1(2)	0.13(8)	1.2(2)	659.(16.)
		168	0(+)	27.1	7.4(4)	0	6.8(7)	0	6.9(7)	2.74(8)
		170	0(+)	14.9	9.6(5)	0	11.6(1.2)	0	11.6(1.2)	5.8(3)
Tm	69	169	1/2(+)	100	7.07(3)	0.9(3)	6.28(5)	0.10(7)	6.38(9)	100.(2.)
Yb	70				12.43(3)		19.42(9)	4.0(2)	23.05(18)	34.8(8)
		168	0(+)	0.14	−4.07(2) −0.62(1)*i*	0	2.13(2)	0	2.13(2)	2230.(40.)
		170	0(+)	3.06	6.77(10)	0	5.8(2)	0	5.8(2)	11.4(1.0)
		171	1/2(−)	143	9.66(10)	−5.59(17)	11.7(2)	3.9(2)	15.6(3)	48.6(2.5)
		172	0(+)	21.9	9.43(10)	0	11.2(2)	0	11.2(2)	0.8(4)
		173	5/2(−)	16.1	9.56(7)	−5.3(2)	11.5(2)	3.5(3)	15.0(4)	17.1(1.3)
		174	0(+)	31.8	19.3(1)	0	46.8(5)	0	46.8(5)	69.4(5.0)
		176	0(+)	12.7	8.72(10)	0	9.6(2)	0	9.6(2)	2.85(5)
Lu	71				7.21(3)		6.53(5)	0.7(4)	7.2(4)	74.(2.)
		175	7/2(+)	97.39	7.24(3)	±2.2(7)	6.59(5)	0.6(4)	7.2(4)	21.(3.)
		*176	7(−)	2.61	6.1(1) −0.57(1)*i*	±3.0(4) +0.61(1)*i*	4.7(2)	1.2(3)	5.9(4)	2065.(35.)
Hf	72				7.77(14)		7.6(3)	2.6(5)	10.2(4)	104.1(0.5)
		174	0(+)	0.2	10.9(1.1)	0	15.(3.)	0	15.(3.)	561.(35.)
		176	0(+)	5.2	6.61(18)	0	5.5(3)	0	5.5(3)	23.5(3.1)
		177	7/2(−)	18.6	0.8(1.0) *E*	±0.9(1.3)	0.1(2)	0.1(3)	0.2(2)	373.(10.)
		178	0(+)	27.1	5.9(2)	0	4.4(3)	0	4.4(3)	84.(4.)
		179	9/2(+)	13.7	7.46(16)	±1.06(8)	7.0(3)	0.14(2)	7.1(3)	41.(3.)
		180	0(+)	35.2	13.2(3)	0	21.9(1.0)	0	21.9(1.0)	13.04(7)
Ta	73				6.91(7)		6.00(12)	0.01(17)	6.01(12)	20.6(5)
		*180	9(−)	0.012	7.(2.) *E*	6.2(3.5)	0.5(5)	*E*	7.(4.)	563.(60.)
		181	7/2(+)	99.988	6.91(7)	−0.29(3)	6.00(12)	0.011(2)	6.01(12)	20.5(5)

Table 4.4.4.1. *Bound scattering lengths (cont.)*

Element	Z	A	$I(\pi)$	c	b_c	b_i	σ_c	σ_i	σ_s	σ_a
W	74				4.86(2)		2.97(2)	1.63(6)	4.60(6)	18.3(2)
		180	0(+)	0.1	5.(3.) *E*	0	3.(4.)	0	3.(4.)	30.(20.)
		182	0(+)	26.3	6.97(14)	0	6.10(7)	0	6.10(7)	20.7(5)
		183	1/2(−)	14.3	6.53(4)		5.36(7)	0.3(3) *E*	5.7(3)	10.1(3)
		184	0(+)	30.7	7.48(6)	0	7.03(11)	0	7.03(11)	1.7(1)
		186	0(+)	28.6	−0.72(4)	0	0.065(7)	0	0.065(7)	37.9(0.6)
Re	75				9.2(2)		10.6(5)	0.9(6)	11.5(3)	89.7(1.0)
		185	5/2(+)	37.40	9.0(3)	±2.0(1.8)	10.2(7)	0.5(9)	10.7(6)	112.(2.)
		187	5/2(+)	62.60	9.3(3)	±2.8(1.1)	10.9(7)	1.0(8)	11.9(4)	76.4(1.0)
Os	76				10.7(2)		14.4(5)	0.3(8)	14.7(6)	16.0(4)
		184	0(+)	0.02	10.(2.) *E*	0	13.(5.)	0	13.(5.)	3000.(150.)
		186	0(+)	1.58	11.6(1.7)	0	17.(5.)	0	17.(5.)	80.(13.)
		187	1/2(−)	1.6	10.(2.) *E*	13.(5.)	0.3(3)	*E*	13.(5.)	320(10.)
		188	0(+)	13.3	7.6(3)	0	7.3(6)	0	7.3(6)	4.7(5)
		189	3/2(−)	16.1	10.7(3)		14.4(8)	0.5(5) *E*	14.9(9)	25(4.)
		190	0(+)	26.4	11.0(3)	0	15.2(9)	0	15.2(8)	13.1(3)
		192	0(+)	41.0	11.5(4)	0	16.6(1.2)	0	16.6(1.2)	2.0(1)
Ir	77				10.6(3)		14.1(8)	0.(3.)	14.(3.)	425.3(2.4)
		191	3/2(+)	37.3						954.(10.)
		193	3/2(+)	62.7						111.(5.)
Pt	78				9.60(1)		11.58(2)	0.13(11)	11.71(11)	10.3(3)
		190	0(+)	0.01	9.0(1.0)	0	10.(2.)	0	10.(2.)	152.(4.)
		192	0(+)	0.79	9.9(5)	0	12.3(1.2)	0	12.3(1.2)	10.0(2.5)
		194	0(+)	32.9	10.55(8)	0	14.0(2)	0	14.0(2)	1.44(19)
		195	1/2(−)	33.8	8.83(9)	−1.00(17)	9.8(2)	0.13(4)	9.9(2)	27.5(1.2)
		196	0(+)	25.3	9.89(8)	0	12.3(2)	0	12.3(2)	0.72(4)
		198	0(+)	7.2	7.8(1)	0	7.7(2)	0	7.6(2)	3.66(19)
Au	79	197	3/2(+)	100	7.63(6)	−1.84(10)	7.32(12)	0.43(5)	7.75(13)	98.65(9)
Hg	80				12.692(15)		20.24(5)	6.6(1)	26.8(1)	372.3(4.0)
		196	0(+)	0.2	30.3(1.0)	0	115(8.)	0	115(8.)	3080(180.)
		198	0(+)	10.1		0		0		2.0(3)
		199	1/2(−)	17.0	16.9(4)	±15.5(8)	36.(2.)	30.(3.)	66.(2.)	2150.(48.)
		200	0(+)	23.1		0		0		<60.
		201	3/2(−)	13.2			7.8(2.0)			
		202	0(+)	29.6		0		0		4.89(5)
		204	0(+)	6.8		0		0		0.43(10)
Tl	81				8.776(5)		9.678(11)	0.21(15)	9.89(15)	3.43(6)
		203	1/2(+)	29.524	6.99(16)	1.06(14)	6.14(28)	0.14(4)	6.28(28)	11.4(2)
		205	1/2(+)	70.476	9.52(7)	−0.242(17)	11.39(17)	0.007(1)	11.40(17)	0.104(17)
Pb	82				9.405(3)		11.115(7)	0.0030(7)	11.118(7)	0.171(2)
		204	0(+)	1.4	9.90(10)	0	12.3(2)	0	12.3(2)	0.65(7)
		206	0(+)	24.1	9.22(5)	0	10.68(12)	0	10.68(12)	0.0300(8)
		207	1/2(−)	22.1	9.28(4)	0.14(6)	10.82(9)	0.002(2)	10.82(9)	0.699(10)
		208	0(+)	52.4	9.50(2)	0	11.34(5)	0	11.34(5)	0.00048(3)
Bi	83	209	9/2(−)	100	8.532(2)	0.259(15)	9.148(4)	0.0084(10)	9.156(4)	0.0338(7)
Po	84									
At	85									
Rn	86									
Fr	87									
Ra	88									
		226	0(+)	$(1.60\times10^3$a)	10.0(1.0)	0	13.(3.)	0	13.(3.)	12.8(1.5)

Table 4.4.4.1. *Bound scattering lengths (cont.)*

Element	Z	A	$I(\pi)$	c	b_c	b_i	σ_c	σ_i	σ_s	σ_a
Ac	89									
Th	90	232	0(+)	100	10.31(3)	0	13.36(8)	0	13.36(8)	7.37(6)
Pa	91									
		231	3/2(−)	(3.28×10^4a)	9.1(3)	1	0.4(7)	0.1(3.3)	10.5(3.2)	200.6(2.3)
U	92				8.417(5)		8.903(11)	0.005(16)	8.908(11)	7.57(2)
		233	5/2(+)	(1.59×10^5a)	10.1(2)	±1.(3.)	12.8(5)	0.1(6)	12.9(3)	574.7(1.0)
		234	0(+)	0.005	12.4(3)	0	19.3(9)	0	19.3(9)	100.1(1.3)
		235	7/2(−)	0.720	10.47(3)	±1.3(6)	13.78(11)	0.2(2)	14.0(2)	680.9(1.1)
		238	0(+)	99.275	8.402(5)	0	8.871(11)	0	8.871(11)	2.68(2)
Np	93									
		237	5/2(+)	(2.14×10^6a)	10.55(10)		14.0(3)	0.5(5)*E*	14.5(6)	175.9(2.9)
Pu	94									
		238	0(+)	(87.74a)	14.1(5)	0	25.0(1.8)	0	25.0(1.8)	558.(7.)
		239	1/2(+)	(2.41×10^4a)	7.7(1)	±1.3(1.9)	7.5(2)	0.2(6)	7.7(6)	1017.3(2.1)
		240	0(+)	(6.56×10^3a)	3.5(1)	0	1.54(9)	0	1.54(9)	289.6(1.4)
		242	0(+)	(3.76×10^5a)	8.1(1)	0	8.2(2)	0	8.2(2)	18.5(5)
Am	95									
		243	5/2(−)	(7.37×10^3a)	8.3(2)	±2.(7.)	8.7(4)	0.3(2.6)	9.0(2.6)	75.3(1.8)
Cm	96									
		244	0(+)	(18.10a)	9.5(3)	0	11.3(7)	0	11.3(7)	16.2(1.2)
		246	0(+)	(4.7×10^3a)	9.3(2)	0	10.9(5)	0	10.9(5)	1.36(17)
		248	0(+)	(3.5×10^5a)	7.7(2)	0	7.5(4)	0	7.5(4)	3.00(26)

4.4.4.2. *Scattering and absorption cross sections*

When a thermal neutron collides with a nucleus, it may be either scattered or absorbed. By absorption, we mean reactions such as (n,γ), (n,p), or (n,α), in which there is no neutron in the final state. The effect of absorption can be included by allowing the bound scattering length to be complex,

$$b = b' - ib''. \tag{4.4.4.3}$$

The total bound scattering cross section is then given by

$$\sigma_s = 4\pi\langle|b|^2\rangle, \tag{4.4.4.4}$$

in which $\langle\,\rangle$ denotes a statistical average over the neutron and nuclear spins and the absorption cross section is given by

$$\sigma_a = \frac{4\pi}{k}\langle b''\rangle, \tag{4.4.4.5}$$

where $k = 2\pi/\lambda$ is the wavevector of the incident neutron and λ is the wavelength.

If the neutron and/or the nucleus is unpolarized, then the total bound scattering cross section is of the form

$$\sigma_s = \sigma_c + \sigma_i, \tag{4.4.4.6}$$

in which σ_c and σ_i are called the bound coherent and incoherent scattering cross sections and are given by

$$\sigma_c = 4\pi|b_c|^2, \quad \sigma_i = 4\pi|b_i|^2. \tag{4.4.4.7}$$

Also,

$$b_c = \langle b\rangle, \tag{4.4.4.8}$$

so that the absorption cross section is given by

$$\sigma_a = \frac{4\pi}{k}\, b_c''. \tag{4.4.4.9}$$

The absorption cross section is therefore uniquely determined by the imaginary part of the bound coherent scattering length. It is only when the neutron and the nucleus are both polarized that the imaginary part of the bound incoherent scattering length contributes to the value of σ_a.

For most nuclides, the scattering lengths and, hence, the scattering cross sections are constant in the thermal-neutron region, and the absorption cross sections are inversely proportional to k. Since k is proportional to the neutron velocity v, the absorption is said to obey a $1/v$ law. By convention, absorption cross sections are tabulated for a velocity $v = 2200\ \mathrm{m\,s^{-1}}$, which corresponds to a wavevector $k = 3.494\ \mathrm{\AA^{-1}}$, a wavelength $\lambda = 1.798$ Å, or an energy $E = 25.30$ meV.

The only major deviations from the $1/v$ law are for a few heavy nuclides (specifically, ^{113}Cd, ^{149}Sm, ^{151}Eu, ^{155}Gd, ^{157}Gd, ^{176}Lu, and ^{180}Ta), which have an (n,γ) resonance at thermal-neutron energies. For these nuclides (which are indicated by the symbol * in Table 4.4.4.1), the scattering lengths and cross sections are strongly energy dependent. The scattering lengths of the resonant rare-earth nuclides have been tabulated as a function of energy by Lynn & Seeger (1990).

4.4.4.3. *Isotope effects*

The coefficients b_c and b_i in (4.4.4.2) for the bound scattering length depend on the particular isotope under consideration, and this provides an additional source of incoherence in the scattering of neutrons by a mixture of isotopes. If $\langle\,\rangle$ is now taken to denote an average over both the spin and isotope distributions, then the expressions (4.4.4.8) for b_c, (4.4.4.4) for σ_s, and (4.4.4.5) for

references