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Covalent radius

The **covalent radius**, r_{cov}, is a measure of the size of an atom that forms part of one covalent bond. It is usually measured either in picometres (pm) or angstroms (Å), with 1 Å = 100 pm.

In principle, the sum of the two co equal the covalent bond length between two atoms, $R(AB) = r(A) + r(B)$. Moreover, different radii can be introduced for single, double and triple bonds (r_1, r_2 and r_3 below), in a purely operational sense. These relationships are certainly not exact because the size of an atom is not constant but depends on its chemical environment. For heteroatomic A–B bonds, ionic terms may enter. Often the polar covalent bonds are shorter than would be expected on the basis of the sum of covalent radii. Tabulated values of covalent radii are either average or idealized values, which nevertheless show a certain transferability between different situations, which makes them useful.

The bond lengths $R(AB)$ are measured by X-ray diffraction (more rarely, neutron diffraction on molecular crystals). Rotational spectroscopy can also give extremely accurate values of bond lengths. For homonuclear A–A bonds, Linus Pauling took the covalent radius to be half the single-bond length in the element, e.g. R(H–H, in H_2) = 74.14 pm so r_{cov}(H) = 37.07 pm: in practice, it is usual to obtain an average value from a variety of covalent compounds, although the difference is usually small. Sanderson has published a recent set of non-polar covalent radii for the main-group elements,[1] but the availability of large collections of bond lengths, which are more transferable, from the Cambridge Crystallographic Database[2][3] has rendered covalent radii obsolete in many situations.

Contents

Average radii

The values in the table below are based on a statistical analysis of more than 228,000 experimental bond lengths from the Cambridge Structural Database.[4] For carbon, values are given for the different hybridisations of the orbitals.

Covalent radii in pm from analysis of the Cambridge Structural Database, which contains about 1,030,000 crystal structures[4]

H 1 31(5)																	
Li 3 128(7)	Be 4 96(3)			Radius (standard deviation) / [pm](pm)								B 5 84(3)	C 6 sp³ 76(1) sp² 73(2) sp 69(1)	N 7 71(1)	O 8 66(2)	F 9 57(3)
Na 11 166(9)	Mg 12 141(7)											Al 13 121(4)	Si 14 111(2)	P 15 107(3)	S 16 105(3)	Cl 17 102(
K 19 203(12)	Ca 20 176(10)	Sc 21 170(7)	Ti 22 160(8)	V 23 153(8)	Cr 24 139(5)	Mn 25 l.s. 139(5) h.s. 161(8)	Fe 26 l.s. 132(3) h.s. 152(6)	Co 27 l.s. 126(3) h.s. 150(7)	Ni 28 124(4)	Cu 29 132(4)	Zn 30 122(4)	Ga 31 122(3)	Ge 32 120(4)	As 33 119(4)	Se 34 120(4)	Br 35 120(
Rb 37 220(9)	Sr 38 195(10)	Y 39 190(7)	Zr 40 175(7)	Nb 41 164(6)	Mo 42 154(5)	Tc 43 147(7)	Ru 44 146(7)	Rh 45 142(7)	Pd 46 139(6)	Ag 47 145(5)	Cd 48 144(9)	In 49 142(5)	Sn 50 139(4)	Sb 51 139(5)	Te 52 138(4)	I 53 139(
Cs 55 244(11)	Ba 56 215(11)	La Hf 72 187(8)	Ta 73 170(8)	W 74 162(7)	Re 75 151(7)	Os 76 144(4)	Ir 77 141(6)	Pt 78 136(5)	Au 79 136(6)	Hg 80 132(5)	Tl 81 145(7)	Pb 82 146(5)	Bi 83 148(4)	Po 84 140(4)	At 85 150	Rn 86 150
Fr 87 260	Ra 88 221(2)	Ac														

La 57 207(8)	Ce 58 204(9)	Pr 59 203(7)	Nd 60 201(6)	Pm 61 199	Sm 62 198(8)	Eu 63 198(6)	Gd 64 196(6)	Tb 65 194(5)	Dy 66 192(7)	Ho 67 192(7)	Er 68 189(6)	Tm 69 190(10)	Yb 70 187(
Ac 89 215	Th 90 206(6)	Pa 91 200	U 92 196(7)	Np 93 190(1)	Pu 94 187(1)	Am 95 180(6)	Cm 96 169(3)						

Radii for multiple bonds

A different approach is to make a self-consistent fit for all elements in a smaller set of molecules. This was done separately for single,[5] double,[6] and triple bonds[7] up to superheavy elements. Both experimental and computational data were used. The single-bond results are often similar to those of Cordero et al.[4] When they are different, the coordination numbers used can be different. This is notably the case for most (d and f) transition metals. Normally one expects that $r_1 > r_2 > r_3$. Deviations may occur for weak multiple bonds, if the differences of the ligand are larger than the differences of R in the data used.

Note that elements up to atomic number 118 (oganesson) have now been experimentally produced and that there are chemical studies on an increasing number of them. The same, self-consistent approach was used to fit tetrahedral covalent radii for 30 elements in 48 crystals with subpicometer accuracy.[8]

Single-,[5] double-,[6] and triple-bond[7] covalent radii, determined using typically 400 experimental or calculated primary distances, R, per set.

Radius / pm: single-bond, double-bond, triple-bond.

Element	Z	single	double	triple
H	1	32	-	-
Li	3	133	124	-
Be	4	102	90	85
B	5	85	78	73
C	6	75	67	60
N	7	71	60	54
O	8	63	57	53
F	9	64	59	53
Na	11	155	160	-
Mg	12	139	132	127
Al	13	126	113	111
Si	14	116	107	102
P	15	111	102	94
S	16	103	94	95
Cl	17	99	95	93
K	19	196	193	-
Ca	20	171	147	133
Sc	21	148	116	114
Ti	22	136	117	108
V	23	134	112	106
Cr	24	122	111	103
Mn	25	119	105	103
Fe	26	116	109	102
Co	27	111	103	96
Ni	28	110	101	101
Cu	29	112	115	120
Zn	30	118	120	-
Ga	31	124	117	121
Ge	32	121	111	114
As	33	121	114	106
Se	34	116	107	107
Br	35	114	109	110
Rb	37	210	202	-
Sr	38	185	157	139
Y	39	163	130	124
Zr	40	154	127	121
Nb	41	147	125	116
Mo	42	138	121	113
Tc	43	128	120	110
Ru	44	125	114	103
Rh	45	125	110	106
Pd	46	120	117	112
Ag	47	128	139	137
Cd	48	136	144	-
In	49	142	136	146
Sn	50	140	130	132
Sb	51	140	133	127
Te	52	136	128	121
I	53	133	129	125
Cs	55	232	209	-
Ba	56	196	161	149
La-Lu				
Hf	72	152	128	122
Ta	73	146	126	119
W	74	137	120	115
Re	75	131	119	110
Os	76	129	116	109
Ir	77	122	115	107
Pt	78	123	112	110
Au	79	124	121	123
Hg	80	133	142	-
Tl	81	144	142	150
Pb	82	144	135	137
Bi	83	151	141	135
Po	84	145	135	129
At	85	147	138	138
Fr	87	223	218	-
Ra	88	201	173	159
Ac-Lr				
Rf	104	157	140	131
Db	105	149	136	126
Sg	106	143	128	121
Bh	107	141	128	119
Hs	108	134	125	118
Mt	109	129	125	113
Ds	110	128	116	112
Rg	111	121	116	118
Cn	112	122	137	130
Nh	113	136	-	-
Fl	114	143	-	-
Mc	115	162	-	-
Lv	116	175	-	-
Ts	117	165	-	-
La	57	180	139	139
Ce	58	163	137	131
Pr	59	176	138	128
Nd	60	174	137	
Pm	61	173	135	
Sm	62	172	134	
Eu	63	168	134	
Gd	64	169	135	132
Tb	65	168	135	
Dy	66	167	133	
Ho	67	166	133	
Er	68	165	133	
Tm	69	164	131	
Yb	70	170	129	
Ac	89	186	153	140
Th	90	175	143	136
Pa	91	169	138	129
U	92	170	134	118
Np	93	171	136	116
Pu	94	172	135	
Am	95	166	135	
Cm	96	166	136	
Bk	97	168	139	
Cf	98	168	140	
Es	99	165	140	
Fm	100	167		
Md	101	173	139	
No	102	176		

See also

- Atomic radii of the elements (data page)

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