Bond energies in diatomic molecules

Homonuclear

Bond	Energy/kJ mol^{-1}
H—H	436
D—D	442
N≡N	944
O=O	496
F—F	158
Cl—Cl	244
Br—Br	193
I—I	151

Heteronuclear

Bond	Energy/kJ mol^{-1}
H—F	562
H—Cl	431
H—Br	366
H—I	299
C≡O	1077

Bond energies in polyatomic molecules

Homonuclear

Bond	Energy/kJ mol^{-1}
C—C	350
C=C	610
C≡C	840
C⎓C (benzene)	520
N—N	160
N=N	410
O—O	150
Si—Si	222
P—P	200
S—S	264

Heteronuclear

Bond	Energy/kJ mol^{-1}
C—H	410
C—F	485
C—Cl	340
C—Br	280
C—I	240
C—N	305
C=N	610
C≡N	890
C—O	360
C=O	740
C=O in CO_2	805
N—H	390
N—Cl	310
O—H	460
Si—Cl	359
Si—H	320
Si—O (in SiO_2(s))	460
Si=O (in SiO_2(g))	640
P—H	320
P—Cl	330
P—O	340
P=O	540
S—H	347
S—Cl	250
S—O	360
S=O	500

$E^{\ominus}$ in decreasing order of oxidising power

Electrode reaction	$E^{\ominus}$ / V
$F_2 + 2e^- = 2F^-$	+2.87
$S_2O_8^{2-} + 2e^- = 2SO_4^{2-}$	+2.01
$H_2O_2 + 2H^+ + 2e^- = 2H_2O$	+1.77
$MnO_4^- + 8H^+ + 5e^- = Mn^{2+} + 4H_2O$	+1.52
$PbO_2 + 4H^+ + 2e^- = Pb^{2+} + 2H_2O$	+1.47
$Cl_2 + 2e^- = 2Cl^-$	+1.36
$Cr_2O_7^{2-} + 14H^+ + 6e^- = 2Cr^{3+} + 7H_2O$	+1.33
$O_2 + 4H^+ + 4e^- = 2H_2O$	+1.23
$Br_2 + 2e^- = 2Br^-$	+1.07
$NO_3^- + 10H^+ + 8e^- = NH_4^+ + 3H_2O$	+0.87
$ClO^- + H_2O + 2e^- = Cl^- + 2OH^-$	+0.81
$NO_3^- + 2H^+ + e^- = NO_2 + H_2O$	+0.81
$Ag^+ + e^- = Ag$	+0.80
$Fe^{3+} + e^- = Fe^{2+}$	+0.77
$I_2 + 2e^- = 2I^-$	+0.54
$O_2 + 2H_2O + 4e^- = 4OH^-$	+0.40
$Cu^{2+} + 2e^- = Cu$	+0.34
$SO_4^{2-} + 4H^+ + 2e^- = SO_2 + 2H_2O$	+0.17
$Sn^{4+} + 2e^- = Sn^{2+}$	+0.15
$S_4O_6^{2-} + 2e^- = 2S_2O_3^{2-}$	+0.09
$2H^+ + 2e^- = H_2$	0.00
$Pb^{2+} + 2e^- = Pb$	−0.13
$Sn^{2+} + 2e^- = Sn$	−0.14

Electrode reaction	$E^{\ominus}$ / V
$O_2 + H_2O + 2e^- \rightleftharpoons HO_2^- + OH^-$	−0.08
$2H_2O + 2e^- \rightleftharpoons H_2 + 2OH^-$	−0.83
$Pb^{2+} + 2e^- \rightleftharpoons Pb$	−0.13
$Pb^{4+} + 2e^- \rightleftharpoons Pb^{2+}$	+1.69
$PbO_2 + 4H^+ + 2e^- \rightleftharpoons Pb^{2+} + 2H_2O$	+1.47
$SO_4^{2-} + 4H^+ + 2e^- \rightleftharpoons SO_2 + 2H_2O$	+0.17
$S_2O_8^{2-} + 2e^- \rightleftharpoons 2SO_4^{2-}$	+2.01
$S_4O_6^{2-} + 2e^- \rightleftharpoons 2S_2O_3^{2-}$	+0.09
$Sn^{2+} + 2e^- \rightleftharpoons Sn$	−0.14
$Sn^{4+} + 2e^- \rightleftharpoons Sn^{2+}$	+0.15
$V^{2+} + 2e^- \rightleftharpoons V$	−1.20
$V^{3+} + e^- \rightleftharpoons V^{2+}$	−0.26
$VO^{2+} + 2H^+ + e^- \rightleftharpoons V^{3+} + H_2O$	+0.34
$VO_2^+ + 2H^+ + e^- \rightleftharpoons VO^{2+} + H_2O$	+1.00
$VO_3^- + 4H^+ + e^- \rightleftharpoons VO^{2+} + 2H_2O$	+1.00
$Zn^{2+} + 2e^- \rightleftharpoons Zn$	−0.76

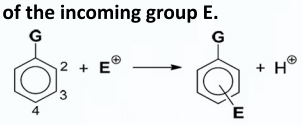
All ionic states refer to aqueous ions but other state symbols have been omitted.

$E^{\ominus}$ IN ALPHABETICAL ORDER

Electrode reaction	$E^{\ominus}$ / V
$Ag^+ + e^- \rightleftharpoons Ag$	+0.80
$Al^{3+} + 3e^- \rightleftharpoons Al$	−1.66
$Ba^{2+} + 2e^- \rightleftharpoons Ba$	−2.90
$Br_2 + 2e^- \rightleftharpoons 2Br^-$	+1.07
$Ca^{2+} + 2e^- \rightleftharpoons Ca$	−2.87
$Cl_2 + 2e^- \rightleftharpoons 2Cl^-$	+1.36
$2HOCl + 2H^+ + 2e^- \rightleftharpoons Cl_2 + 2H_2O$	+1.64
$ClO^- + H_2O + 2e^- \rightleftharpoons Cl^- + 2OH^-$	+0.81
$Co^{2+} + 2e^- \rightleftharpoons Co$	−0.28
$Co^{3+} + e^- \rightleftharpoons Co^{2+}$	+1.89
$[Co(NH_3)_6]^{2+} + 2e^- \rightleftharpoons Co + 6NH_3$	−0.43
$Cr^{2+} + 2e^- \rightleftharpoons Cr$	−0.91
$Cr^{3+} + 3e^- \rightleftharpoons Cr$	−0.74
$Cr^{3+} + e^- \rightleftharpoons Cr^{2+}$	−0.41
$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightleftharpoons 2Cr^{3+} + 7H_2O$	+1.33
$Cu^+ + e^- \rightleftharpoons Cu$	+0.52
$Cu^{2+} + 2e^- \rightleftharpoons Cu$	+0.34
$Cu^{2+} + e^- \rightleftharpoons Cu^+$	+0.15
$[Cu(NH_3)_4]^{2+} + 2e^- \rightleftharpoons Cu + 4NH_3$	−0.05
$F_2 + 2e^- \rightleftharpoons 2F^-$	+2.87
$Fe^{2+} + 2e^- \rightleftharpoons Fe$	−0.44
$Fe^{3+} + 3e^- \rightleftharpoons Fe$	−0.04
$Fe^{3+} + e^- \rightleftharpoons Fe^{2+}$	+0.77
$[Fe(CN)_6]^{3-} + e^- \rightleftharpoons [Fe(CN)_6]^{4-}$	+0.36
$Fe(OH)_3 + e^- \rightleftharpoons Fe(OH)_2 + OH^-$	−0.56
$2H^+ + 2e^- \rightleftharpoons H_2$	0.00
$I_2 + 2e^- \rightleftharpoons 2I^-$	+0.54
$K^+ + e^- \rightleftharpoons K$	−2.92
$Li^+ + e^- \rightleftharpoons Li$	−3.04
$Mg^{2+} + 2e^- \rightleftharpoons Mg$	−2.38
$Mn^{2+} + 2e^- \rightleftharpoons Mn$	−1.18
$Mn^{3+} + e^- \rightleftharpoons Mn^{2+}$	+1.54
$MnO_2 + 4H^+ + 2e^- \rightleftharpoons Mn^{2+} + 2H_2O$	+1.23
$MnO_4^- + e^- \rightleftharpoons MnO_4^{2-}$	+0.56
$MnO_4^- + 4H^+ + 3e^- \rightleftharpoons MnO_2 + 2H_2O$	+1.67
$MnO_4^- + 8H^+ + 5e^- \rightleftharpoons Mn^{2+} + 4H_2O$	+1.52
$NO_3^- + 2H^+ + e^- \rightleftharpoons NO_2 + H_2O$	+0.81
$NO_3^- + 3H^+ + 2e^- \rightleftharpoons HNO_2 + H_2O$	+0.94
$NO_3^- + 10H^+ + 8e^- \rightleftharpoons NH_4^+ + 3H_2O$	+0.87
$Na^+ + e^- \rightleftharpoons Na$	−2.71
$Ni^{2+} + 2e^- \rightleftharpoons Ni$	−0.25
$[Ni(NH_3)_6]^{2+} + 2e^- \rightleftharpoons Ni + 6NH_3$	−0.51
$H_2O_2 + 2H^+ + 2e^- \rightleftharpoons 2H_2O$	+1.77
$HO_2^- + H_2O + 2e^- \rightleftharpoons 3OH^-$	+0.88
$O_2 + 4H^+ + 4e^- \rightleftharpoons 2H_2O$	+1.23
$O_2 + 2H_2O + 4e^- \rightleftharpoons 4OH^-$	+0.40
$O_2 + 2H^+ + 2e^- \rightleftharpoons H_2O_2$	+0.68

The orientating effect of groups in aromatic substitution reactions

The position of the incoming group, E, is determined by the nature of the group, G, already bonded to the ring, and not by the nature of the incoming group E.



G	–alkyl –OH or –OR –NH_2, –NHR or –NR_2 –NHCOR	–Cl, –Br, –I	–CHO, –COR –CO_2H, –CO_2R –NH_3^+ –NO_2, –CN
Reactivity of ring (compared to benzene)	Activated	Deactivated	Deactivated
Position of E (relative to position of G)	2- and/or 4-	2- and/or 4-	3-