CHEMISTRY

Data Booklet

Alberta
LEARNING

1	2	3	4	5	6	7	8	9

Table of Common Polyatomic Ions

acetate (ethanoate)	CH_3COO^-	chromate	CrO_4^{2-}	phosphate	PO_4^{3-}
ammonium	NH_4^+	dichromate	$Cr_2O_7^{2-}$	hydrogen phosphate	HPO_4^{2-}
benzoate	$C_6H_5COO^-$	cyanide	CN^-	dihydrogen phosphate	$H_2PO_4^-$
borate	BO_3^{3-}	hydroxide	OH^-	silicate	SiO_3^{2-}
carbide	C_2^{2-}	iodate	IO_3^-	sulfate	SO_4^{2-}
carbonate	CO_3^{2-}	nitrate	NO_3^-	hydrogen sulfate	HSO_4^-
hydrogen carbonate (bicarbonate)	HCO_3^-	nitrite	NO_2^-	sulfite	SO_3^{2-}
		oxalate	$OOCCOO^{2-}$	hydrogen sulfite	HSO_3^-
perchlorate	ClO_4^-	hydrogen oxalate	$HOOCCOO^-$	hydrogen sulfide	HS^-
chlorate	ClO_3^-	permanganate	MnO_4^-	thiocyanate	SCN^-
chlorite	ClO_2^-	peroxide	O_2^{2-}	thiosulfate	$S_2O_3^{2-}$
hypochlorite	ClO^- or OCl^-	persulfide	S_2^{2-}		

1 1.01 1+,1– 2.2 –253 –259 H hydrogen								
3 6.94 1+ 1.0 1342 181 Li lithium	**4** 9.01 2+ 1.6 2467 1287 Be beryllium							
11 22.99 1+ 0.9 883 98 Na sodium	**12** 24.31 2+ 1.3 1090 650 Mg magnesium							
19 39.10 1+ 0.8 759 64 K potassium	**20** 40.08 2+ 1.0 1484 842 Ca calcium	**21** 44.96 3+ 1.4 2836 1541 Sc scandium	**22** 47.87 4+, 3+ 1.5 3287 1668 Ti titanium	**23** 50.94 5+, 4+ 1.6 3407 1910 V vanadium	**24** 52.00 3+, 2+ 1.7 2671 1907 Cr chromium	**25** 54.94 2+, 4+ 1.6 2061 1246 Mn manganese	**26** 55.85 3+, 2+ 1.8 2861 1538 Fe iron	**27** 58.93 2+, 3+ 1.9 2927 1495 Co cobalt
37 85.47 1+ 0.8 688 39 Rb rubidium	**38** 87.62 2+ 1.0 1382 777 Sr strontium	**39** 88.91 3+ 1.2 3345 1522 Y yttrium	**40** 91.22 4+ 1.3 4409 1855 Zr zirconium	**41** 92.91 5+, 3+ 1.6 4744 2477 Nb niobium	**42** 95.94 6+ 2.2 4639 2623 Mo molybdenum	**43** (98) 7+ 2.1 4265 2157 Tc technetium	**44** 101.07 3+, 4+ 2.2 4150 2334 Ru ruthenium	**45** 102.91 3+ 2.3 3695 1964 Rh rhodium
55 132.91 1+ 0.8 671 29 Cs cesium	**56** 137.33 2+ 0.9 1897 727 Ba barium	**57-71**	**72** 178.49 4+ 1.3 4603 2233 Hf hafnium	**73** 180.95 5+ 1.5 5458 3017 Ta tantalum	**74** 183.84 6+ 1.7 5555 3422 W tungsten	**75** 186.21 7+ 1.9 5596 3186 Re rhenium	**76** 190.23 4+ 2.2 5012 3033 Os osmium	**77** 192.22 4+ 2.2 4428 2446 Ir iridium
87 (223) 1+ 0.7 — 27 Fr francium	**88** (226) 2+ 0.9 1737 700 Ra radium	**89-103**	**104** (261) Rf rutherfordium	**105** (262) Db dubnium	**106** (266) Sg seaborgium	**107** (264) Bh bohrium	**108** (277) Hs hassium	**109** (268) Mt meitnerium

57 138.91 3+ 1.1 3464 918 La lanthanum	**58** 140.12 3+ 1.1 3443 798 Ce cerium	**59** 140.91 3+ 1.1 3520 931 Pr praseodymium	**60** 144.24 3+ 1.1 3074 1021 Nd neodymium	**61** (145) 3+ — 3000 1042 Pm promethium	**62** 150.36 3+, 2+ 1.2 1794 1074 Sm samarium
89 (227) 3+ 1.1 3198 1051 Ac actinium	**90** 232.04 4+ 1.3 4788 1750 Th thorium	**91** 231.04 5+, 4+ 1.5 — 1572 Pa protactinium	**92** 238.03 6+, 4+ 1.7 4131 1135 U uranium	**93** (237) 5+ 1.3 — 644 Np neptunium	**94** (244) 4+, 6+ 1.3 3228 640 Pu plutonium

References

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Dean, John A. 1999. *Lange's Handbook of Chemistry*. 15th ed. New York: McGraw-Hill, Inc.

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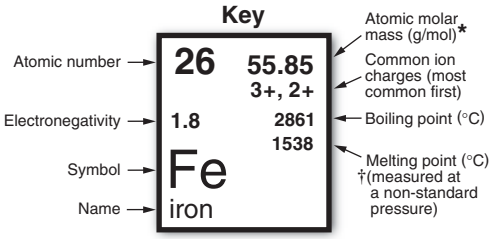
10	11	12	13	14	15	16	17	18

Legend for Elements

Solid	*Liquid*	Gas
Natural	**Synthetic**	

Note: The legend denotes the physical state of the elements at exactly 101.325 kPa and 298.15 K.

Key



* Based on $^{12}_{6}C$

( ) Indicates mass of the most stable isotope

								2 4.00 — — –269 –272† He helium
			5 10.81 — 2.0 4000 2075 B boron	6 12.01 — 2.6 — 4489 C carbon	7 14.01 3– 3.0 –196 –210 N nitrogen	8 16.00 2– 3.4 –183 –219 O oxygen	9 19.00 1– 4.0 –188 –220 F fluorine	10 20.18 — — –246 –249 Ne neon
			13 26.98 3+ 1.6 2519 660 Al aluminum	14 28.09 — 1.9 3265 1414 Si silicon	15 30.97 3– 2.2 281 44 P phosphorus	16 32.07 2– 2.6 445 115 S sulfur	17 35.45 1– 3.2 –34 –101 Cl chlorine	18 39.95 — — –186 –189 Ar argon
28 58.69 2+, 3+ 1.9 2913 1455 Ni nickel	29 63.55 2+, 1+ 1.9 2562 1085 Cu copper	30 65.39 2+ 1.7 907 420 Zn zinc	31 69.72 3+ 1.8 2204 30 Ga gallium	32 72.64 4+ 2.0 2833 938 Ge germanium	33 74.92 3– 2.2 — 817 As arsenic	34 78.96 2– 2.6 685 221 Se selenium	35 79.90 1– 3.0 59 –7 Br bromine	36 83.80 — — –153 –157† Kr krypton
46 106.42 2+, 4+ 2.2 2963 1555 Pd palladium	47 107.87 1+ 1.9 2162 962 Ag silver	48 112.41 2+ 1.7 767 321 Cd cadmium	49 114.82 3+ 1.8 2072 157 In indium	50 118.71 4+, 2+ 2.0 2602 232 Sn tin	51 121.76 3+, 5+ 2.1 1587 631 Sb antimony	52 127.60 2– 2.1 988 450 Te tellurium	53 126.90 1– 2.7 184 114 I iodine	54 131.29 — 2.6 –108 –112† Xe xenon
78 195.08 4+, 2+ 2.2 3825 1768 Pt platinum	79 196.97 3+, 1+ 2.4 2856 1064 Au gold	80 200.59 2+, 1+ 1.9 357 –39 Hg mercury	81 204.38 1+, 3+ 1.8 1473 304 Tl thallium	82 207.21 2+, 4+ 1.8 1749 327 Pb lead	83 208.98 3+, 5+ 1.9 1564 271 Bi bismuth	84 (209) 2+, 4+ 2.0 962 254 Po polonium	85 (210) 1– 2.2 — 302 At astatine	86 (222) — — –62 –71 Rn radon
110 (281) Uun ununnilium	111 (272) Uuu unununium	112 (285) Uub ununbium		114 (289) Uuq ununquadium				

63 151.96 3+, 2+ — 1529 822 Eu europium	64 157.25 3+ 1.2 3273 1313 Gd gadolinium	65 158.93 3+ — 3230 1356 Tb terbium	66 162.50 3+ 1.2 2567 1412 Dy dysprosium	67 164.93 3+ 1.2 2700 1474 Ho holmium	68 167.26 3+ 1.2 2868 1529 Er erbium	69 168.93 3+ 1.3 1950 1545 Tm thulium	70 173.04 3+, 2+ — 1196 819 Yb ytterbium	71 174.97 2+ 1.0 3402 1663 Lu lutetium
95 (243) 3+, 4+ — 2011 1176 Am americium	96 (247) 3+ — 3100 1345 Cm curium	97 (247) 3+, 4+ — — 1050 Bk berkelium	98 (251) 3+ — — 900 Cf californium	99 (252) 3+ — — 860 Es einsteinium	100 (257) 3+ — — 1527 Fm fermium	101 (258) 2+, 3+ — — 827 Md mendelevium	102 (259) 2+, 3+ — — 827 No nobelium	103 (262) 3+ — — 1627 Lr lawrencium

Chemistry Notation

Symbol	Term	Unit(s)
[ ]	molar concentration	mol/L
c	specific heat capacity	J/(g • °C) or J/(g • K)
C	heat capacity	J/°C or J/K
c	speed of light	m/s
E	electrical potential	V or J/C
E_k	kinetic energy	kJ
E_p	potential energy	kJ
ΔH, H	molar enthalpy (heat)	kJ/mol
ΔH_f°, H_f°	standard molar enthalpy of formation	kJ/mol
I	current	A or C/s
K_{eq}	equilibrium constant	—
K_a	acid ionization (dissociation) constant	—
K_b	base ionization (dissociation) constant	—
M	molar mass	g/mol
m	mass	g
n	amount	mol
P	pressure	kPa
Q	charge	C
T	temperature (absolute)	K
t	temperature (Celsius)	°C
t	time	s
V	volume	L

Symbol	Term
Δ	delta (change in)
°	standard

Miscellaneous

25°C	equivalent to 298.15 K
Specific heat capacity..... (at 298.15 K and 100.000 kPa)	c_{air} = 1.01 J/(g • °C) c_{wood} = 1.26 J/(g • °C) c_{glass} = 0.84 J/(g • °C) $c_{Styrofoam}$ = 0.30 J/(g • °C)
Speed of light	$c = 3.00 \times 10^8$ m/s
Mass of 1.00 mol of dry air.....	m_{air} = 29.18 g (at 273.15 K and 100.000 kPa)
Avogadro constant	$N_A = 6.02 \times 10^{23}$ particles/mol
Water autoionization constant..... (Dissociation constant)	$K_w = 1.00 \times 10^{-14}$ at 298.15 K (for ion concentrations in mol/L)
Faraday constant.....	$F = 9.65 \times 10^4$ C/mol
1 volt (V).....	= 1 joule/coulomb (1 J/C)
1 ampere (A)	= 1 coulomb/second (1 C/s)
Quadratic formula	$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$
Gas constant	R = 8.314 (L • kPa)/(K • mol) **or** R = 8.314 J/(K • mol)
Ideal gas law.....	$PV = nRT$
Commonly accepted standards.....	STP = 273.15 K and 101.325 kPa (1 atm) SATP = 298.15 K and 100.000 kPa

Nuclear Radiation

Radiation	Symbol
Alpha-particle	${}^4_2\text{He}$ or α
Beta-particle	${}^0_{-1}\text{e}$ or β
Gamma-ray	γ

Selected SI Prefixes

Prefix	Symbol	Exponential Value
tera	T	10^{12}
giga	G	10^9
mega	M	10^6
kilo	k	10^3
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}

Thermodynamic Properties of Selected Elements

Name	Formula	ΔH_{fusion}* (kJ/mol)	$\Delta H_{vaporization}$* (kJ/mol)	Specific Heat Capacity† (J/(g • °C))
aluminum	Al	10.79	294	0.897
argon	Ar	1.18	6.43	0.520
beryllium	Be	7.90	297	1.825
boron	B	50.2	480	1.026
bromine	Br_2	10.57	29.96	0.474
carbon (graphite)	C	117	—	0.709
chlorine	Cl_2	6.40	20.41	0.479
chromium	Cr	21.0	339.5	0.449
cobalt	Co	16.06	377	0.421
copper	Cu	12.93	300.4	0.385
fluorine	F_2	0.51	6.62	0.824
gallium	Ga	5.58	254	0.371
germanium	Ge	36.94	334	0.320
gold	Au	12.72	324	0.129
helium	He	0.014	0.08	5.193
hydrogen	H_2	0.12	0.90	14.304
iodine	I_2	15.52	41.57	0.214
iron	Fe	13.81	340	0.449
krypton	Kr	1.64	9.08	0.248
lead	Pb	4.78	179.5	0.129
magnesium	Mg	8.48	128	1.023
manganese	Mn	12.91	221	0.479
mercury	Hg	2.29	59.1	0.140
neon	Ne	0.33	1.71	1.030
nickel	Ni	17.04	377.5	0.444
nitrogen	N_2	0.71	5.57	1.040
oxygen	O_2	0.44	6.82	0.918
phosphorus	P_4	0.66	12.4	0.769
platinum	Pt	22.17	469	0.133
radon	Rn	3.25	18.10	0.094
scandium	Sc	14.1	332.7	0.568
selenium	Se	6.69	95.48	0.321
silicon	Si	50.21	359	0.705
silver	Ag	11.28	258	0.235
sulfur	S_8	1.72	45	0.710
tin	Sn	7.17	296.1	0.228
titanium	Ti	14.15	425	0.523
tungsten	W	52.31	806.7	0.132
uranium	U	9.14	417.1	0.116
vanadium	V	21.5	459	0.489
xenon	Xe	2.27	12.57	0.158
zinc	Zn	7.07	123.6	0.388

* at 101.325 kPa

† for the standard state of the element at 298.15 K

Thermodynamic Properties of Selected Compounds

Name	Formula	ΔH_{fusion}* (kJ/mol)	$\Delta H_{vaporization}$* (kJ/mol)	Specific Heat Capacity† (J/(g • °C))
ice	$H_2O_{(s)}$	6.01	—	2.00
water	$H_2O_{(l)}$	—	40.65	4.19
steam	$H_2O_{(g)}$	—	—	2.02
ammonia	$NH_{3(g)}$	5.66	23.33	2.06
methanol	$CH_3OH_{(l)}$	3.22	35.21	2.53
ethanol	$C_2H_5OH_{(l)}$	4.93	38.56	2.44
dichlorodifluoromethane (Freon-12)	$CCl_2F_{2(g)}$	4.14	20.1	0.60

* at 101.325 kPa

† at 101.325 kPa for the phase stated in the formula column

Calculated Molar Enthalpies of Combustion of Selected Organic Compounds at 298.15 K*

Compound	Formula	ΔH_c° (kJ/mol)
methane	$CH_{4(g)}$	– 890.5
ethane	$C_2H_{6(g)}$	– 1 560.4
propane	$C_3H_{8(g)}$	– 2 219.9
butane	$C_4H_{10(g)}$	– 2 877.3
pentane	$C_5H_{12(l)}$	– 3 508.8
hexane	$C_6H_{14(l)}$	– 4 162.9
heptane	$C_7H_{16(l)}$	– 4 816.7
octane	$C_8H_{18(l)}$	– 5 470.1
nonane	$C_9H_{20(l)}$	– 6 124.8
decane	$C_{10}H_{22(l)}$	– 6 777.9
benzoic acid	$C_6H_5COOH_{(s)}$	– 3 226.7
methanol	$CH_3OH_{(l)}$	– 725.9
ethanol	$C_2H_5OH_{(l)}$	– 1 366.8

* products are $H_2O_{(l)}$ and $CO_{2(g)}$

Standard Molar Enthalpies of Formation at 298.15 K

Name	Formula	ΔH_f° (kJ/mol)
aluminum oxide	$Al_2O_{3(s)}$	–1 675.7
ammonia	$NH_{3(g)}$	– 45.9
ammonium chloride	$NH_4Cl_{(s)}$	–314.4
ammonium nitrate	$NH_4NO_{3(s)}$	–365.6
barium carbonate	$BaCO_{3(s)}$	–1 213.0
barium chloride	$BaCl_{2(s)}$	–855.0
barium hydroxide	$Ba(OH)_{2(s)}$	–944.7
barium oxide	$BaO_{(s)}$	–548.0
barium sulfate	$BaSO_{4(s)}$	–1 473.2
benzene	$C_6H_{6(l)}$	+49.1
butane	$C_4H_{10(g)}$	–125.7
calcium carbonate	$CaCO_{3(s)}$	–1 207.6
calcium chloride	$CaCl_{2(s)}$	–795.4
calcium hydroxide	$Ca(OH)_{2(s)}$	–985.2
calcium oxide	$CaO_{(s)}$	–634.9
calcium sulfate	$CaSO_{4(s)}$	–1 434.5
carbon dioxide	$CO_{2(g)}$	–393.5
carbon monoxide	$CO_{(g)}$	–110.5
chromium(III) oxide	$Cr_2O_{3(s)}$	–1 139.7
copper(I) oxide	$Cu_2O_{(s)}$	–168.6
copper(II) oxide	$CuO_{(s)}$	–157.3
copper(II) sulfate	$CuSO_{4(s)}$	–771.4
copper(I) sulfide	$Cu_2S_{(s)}$	–79.5
copper(II) sulfide	$CuS_{(s)}$	–53.1
dinitrogen tetroxide	$N_2O_{4(g)}$	+11.1
ethane	$C_2H_{6(g)}$	–84.0
ethanoic acid (acetic acid)	$CH_3COOH_{(l)}$	– 484.3
ethanol	$C_2H_5OH_{(l)}$	–277.6
ethene (ethylene)	$C_2H_{4(g)}$	+52.4
ethyne (acetylene)	$C_2H_{2(g)}$	+227.4
glucose	$C_6H_{12}O_{6(s)}$	–1 273.3
hydrogen bromide	$HBr_{(g)}$	–36.3
hydrogen chloride	$HCl_{(g)}$	–92.3
hydrogen fluoride	$HF_{(g)}$	–273.3
hydrogen iodide	$HI_{(g)}$	+26.5
hydrogen perchlorate	$HClO_{4(l)}$	– 40.6
hydrogen peroxide	$H_2O_{2(l)}$	–187.8
hydrogen sulfide	$H_2S_{(g)}$	–20.6
iron(II) oxide	$FeO_{(s)}$	–272.0
iron(III) oxide	$Fe_2O_{3(s)}$	–824.2
iron(II,III) oxide (magnetite)	$Fe_3O_{4(s)}$	–1 118.4
lead(II) bromide	$PbBr_{2(s)}$	–278.7
lead(II) chloride	$PbCl_{2(s)}$	–359.4
lead(II) oxide (red)	$PbO_{(s)}$	–219.0
lead(IV) oxide	$PbO_{2(s)}$	–277.4
magnesium carbonate	$MgCO_{3(s)}$	–1 095.8
magnesium chloride	$MgCl_{2(s)}$	–641.3

Standard Molar Enthalpies of Formation at 298.15 K, con't.

Name	Formula	ΔH_f° (kJ/mol)
magnesium hydroxide	$Mg(OH)_{2(s)}$	–924.5
magnesium oxide	$MgO_{(s)}$	–601.6
magnesium sulfate	$MgSO_{4(s)}$	–1 284.9
manganese(II) oxide	$MnO_{(s)}$	–385.2
manganese(IV) oxide	$MnO_{2(s)}$	–520.0
mercury(II) oxide (red)	$HgO_{(s)}$	–90.8
mercury(II) sulfide (red)	$HgS_{(s)}$	–58.2
methanal (formaldehyde)	$CH_2O_{(g)}$	–108.6
methane	$CH_{4(g)}$	–74.6
methanoic acid (formic acid)	$HCOOH_{(l)}$	–425.0
methanol	$CH_3OH_{(l)}$	–239.2
nickel(II) oxide	$NiO_{(s)}$	–240.6
nitric acid	$HNO_{3(l)}$	–174.1
nitrogen dioxide	$NO_{2(g)}$	+33.2
nitrogen monoxide	$NO_{(g)}$	+91.3
octane	$C_8H_{18(l)}$	–250.1
pentane	$C_5H_{12(l)}$	–173.5
phosphorus pentachloride	$PCl_{5(s)}$	–443.5
phosphorus trichloride (liquid)	$PCl_{3(l)}$	–319.7
phosphorus trichloride (vapour)	$PCl_{3(g)}$	–287.0
potassium bromide	$KBr_{(s)}$	–393.8
potassium chlorate	$KClO_{3(s)}$	–397.7
potassium chloride	$KCl_{(s)}$	–436.5
potassium hydroxide	$KOH_{(s)}$	–424.6
propane	$C_3H_{8(g)}$	–103.8
silicon dioxide (α-quartz)	$SiO_{2(s)}$	–910.7
silver bromide	$AgBr_{(s)}$	–100.4
silver chloride	$AgCl_{(s)}$	–127.0
silver iodide	$AgI_{(s)}$	–61.8
sodium bromide	$NaBr_{(s)}$	–361.1
sodium chloride	$NaCl_{(s)}$	–411.2
sodium hydroxide	$NaOH_{(s)}$	–425.6
sodium iodide	$NaI_{(s)}$	–287.8
sucrose	$C_{12}H_{22}O_{11(s)}$	–2 226.1
sulfur dioxide	$SO_{2(g)}$	–296.8
sulfuric acid	$H_2SO_{4(l)}$	–814.0
sulfur trioxide (liquid)	$SO_{3(l)}$	–441.0
sulfur trioxide (vapour)	$SO_{3(g)}$	–395.7
tin(II) chloride	$SnCl_{2(s)}$	–325.1
tin(IV) chloride	$SnCl_{4(l)}$	–511.3
tin(II) oxide	$SnO_{(s)}$	–280.7
tin(IV) oxide	$SnO_{2(s)}$	–577.6
water (liquid)	$H_2O_{(l)}$	–285.8
water (vapour)	$H_2O_{(g)}$	–241.8
zinc oxide	$ZnO_{(s)}$	–350.5
zinc sulfide (sphalerite)	$ZnS_{(s)}$	–206.0

Solubility of Some Common Ionic Compounds in Water at 298.15 K

Ion	Group 1 NH_4^+ H_3O^+ (H^+)	ClO_3^- NO_3^- ClO_4^-	CH_3COO^-	Cl^- Br^- I^-	SO_4^{2-}	S^{2-}	OH^-	PO_4^{3-} SO_3^{2-} CO_3^{2-}
Solubility greater than or equal to 0.1 mol/L (very soluble)	all	all	most	most	most	Group 1 Group 2 NH_4^+	Group 1 NH_4^+ Sr^{2+} Ba^{2+} Tl^+	Group 1 NH_4^+
Solubility less than 0.1 mol/L (slightly soluble)	none	none	Ag^+ Hg^+	Ag^+ Pb^{2+} Hg^+ Cu^+ Tl^+	Ca^{2+} Sr^{2+} Ba^{2+} Ra^{2+} Pb^{2+} Ag^+	most	most	most

Flame Colours of Elements

Element	Symbol	Colour
lithium	Li	red
sodium	Na	yellow
potassium	K	violet
rubidium	Rb	violet
cesium	Cs	violet
calcium	Ca	red
strontium	Sr	red
barium	Ba	yellow-green
copper	Cu	blue-green
boron	B	green
lead	Pb	blue-white

Table of Selected Standard Electrode Potentials*

Reduction Half-Reaction	Electrical Potential (V) $E°$
$F_{2(g)} + 2\,e^- \rightleftharpoons 2\,F^-_{(aq)}$	+2.87
$PbO_{2(s)} + SO_4^{2-}{}_{(aq)} + 4\,H^+_{(aq)} + 2\,e^- \rightleftharpoons PbSO_{4(s)} + 2\,H_2O_{(l)}$	+1.69
$MnO_4^-{}_{(aq)} + 8\,H^+_{(aq)} + 5\,e^- \rightleftharpoons Mn^{2+}_{(aq)} + 4\,H_2O_{(l)}$	+1.51
$Au^{3+}_{(aq)} + 3\,e^- \rightleftharpoons Au_{(s)}$	+1.50
$ClO_4^-{}_{(aq)} + 8\,H^+_{(aq)} + 8\,e^- \rightleftharpoons Cl^-_{(aq)} + 4\,H_2O_{(l)}$	+1.39
$Cl_{2(g)} + 2\,e^- \rightleftharpoons 2\,Cl^-_{(aq)}$	+1.36
$2\,HNO_{2(aq)} + 4\,H^+_{(aq)} + 4\,e^- \rightleftharpoons N_2O_{(g)} + 3\,H_2O_{(l)}$	+1.30
$Cr_2O_7^{2-}{}_{(aq)} + 14\,H^+_{(aq)} + 6\,e^- \rightleftharpoons 2\,Cr^{3+}_{(aq)} + 7\,H_2O_{(l)}$	+1.23
$O_{2(g)} + 4\,H^+_{(aq)} + 4\,e^- \rightleftharpoons 2\,H_2O_{(l)}$	+1.23
$MnO_{2(aq)} + 4\,H^+_{(aq)} + 2\,e^- \rightleftharpoons Mn^{2+}_{(aq)} + 2\,H_2O_{(l)}$	+1.22
$Br_{2(l)} + 2\,e^- \rightleftharpoons 2\,Br^-_{(aq)}$	+1.07
$Hg^{2+}_{(aq)} + 2\,e^- \rightleftharpoons Hg_{(l)}$	+0.85
$OCl^-_{(aq)} + H_2O_{(l)} + 2\,e^- \rightleftharpoons Cl^-_{(aq)} + 2\,OH^-_{(aq)}$	+0.84
$2\,NO_3^-{}_{(aq)} + 4\,H^+_{(aq)} + 2\,e^- \rightleftharpoons N_2O_{4(g)} + 2\,H_2O_{(l)}$	+0.80
$Ag^+_{(aq)} + e^- \rightleftharpoons Ag_{(s)}$	+0.80
$Fe^{3+}_{(aq)} + e^- \rightleftharpoons Fe^{2+}_{(aq)}$	+0.77
$O_{2(g)} + 2\,H^+_{(aq)} + 2\,e^- \rightleftharpoons H_2O_{2(l)}$	+0.70
$I_{2(s)} + 2\,e^- \rightleftharpoons 2\,I^-_{(aq)}$	+0.54
$O_{2(g)} + 2\,H_2O_{(l)} + 4\,e^- \rightleftharpoons 4\,OH^-_{(aq)}$	+0.40
$Cu^{2+}_{(aq)} + 2\,e^- \rightleftharpoons Cu_{(s)}$	+0.34
$SO_4^{2-}{}_{(aq)} + 4\,H^+_{(aq)} + 2\,e^- \rightleftharpoons H_2SO_{3(aq)} + H_2O_{(l)}$	+0.17
$Sn^{4+}_{(aq)} + 2\,e^- \rightleftharpoons Sn^{2+}_{(aq)}$	+0.15
$S_{(s)} + 2\,H^+_{(aq)} + 2\,e^- \rightleftharpoons H_2S_{(aq)}$	+0.14
$AgBr_{(s)} + e^- \rightleftharpoons Ag_{(s)} + Br^-_{(aq)}$	+0.07
$2\,H^+_{(aq)} + 2\,e^- \rightleftharpoons H_{2(g)}$	0.00
$Pb^{2+}_{(aq)} + 2\,e^- \rightleftharpoons Pb_{(s)}$	−0.13
$Sn^{2+}_{(aq)} + 2\,e^- \rightleftharpoons Sn_{(s)}$	−0.14
$AgI_{(s)} + e^- \rightleftharpoons Ag_{(s)} + I^-_{(aq)}$	−0.15
$Ni^{2+}_{(aq)} + 2\,e^- \rightleftharpoons Ni_{(s)}$	−0.26
$Co^{2+}_{(aq)} + 2\,e^- \rightleftharpoons Co_{(s)}$	−0.28
$PbSO_{4(s)} + 2\,e^- \rightleftharpoons Pb_{(s)} + SO_4^{2-}{}_{(aq)}$	−0.36
$Se_{(s)} + 2\,H^+_{(aq)} + 2\,e^- \rightleftharpoons H_2Se_{(aq)}$	−0.40
$Cd^{2+}_{(aq)} + 2\,e^- \rightleftharpoons Cd_{(s)}$	−0.40
$Cr^{3+}_{(aq)} + e^- \rightleftharpoons Cr^{2+}_{(aq)}$	−0.41
$Fe^{2+}_{(aq)} + 2\,e^- \rightleftharpoons Fe_{(s)}$	−0.45
$NO_2^-{}_{(aq)} + H_2O_{(l)} + e^- \rightleftharpoons NO_{(g)} + 2\,OH^-_{(aq)}$	−0.46
$Ag_2S_{(s)} + 2\,e^- \rightleftharpoons 2\,Ag_{(s)} + S^{2-}_{(aq)}$	−0.69
$Zn^{2+}_{(aq)} + 2\,e^- \rightleftharpoons Zn_{(s)}$	−0.76
$2\,H_2O_{(l)} + 2\,e^- \rightleftharpoons H_{2(g)} + 2\,OH^-_{(aq)}$	−0.83
$Cr^{2+}_{(aq)} + 2\,e^- \rightleftharpoons Cr_{(s)}$	−0.91
$Se_{(s)} + 2\,e^- \rightleftharpoons Se^{2-}_{(aq)}$	−0.92
$SO_4^{2-}{}_{(aq)} + H_2O_{(l)} + 2\,e^- \rightleftharpoons SO_3^{2-}{}_{(aq)} + 2\,OH^-_{(aq)}$	−0.93
$Al^{3+}_{(aq)} + 3\,e^- \rightleftharpoons Al_{(s)}$	−1.66
$Mg^{2+}_{(aq)} + 2\,e^- \rightleftharpoons Mg_{(s)}$	−2.37
$Na^+_{(aq)} + e^- \rightleftharpoons Na_{(s)}$	−2.71
$Ca^{2+}_{(aq)} + 2\,e^- \rightleftharpoons Ca_{(s)}$	−2.87
$Ba^{2+}_{(aq)} + 2\,e^- \rightleftharpoons Ba_{(s)}$	−2.91
$K^+_{(aq)} + e^- \rightleftharpoons K_{(s)}$	−2.93
$Li^+_{(aq)} + e^- \rightleftharpoons Li_{(s)}$	−3.04

*For 1.0 mol/L solutions at 298.15 K (25°C) and a pressure of 101.325 kPa

Acid–Base Indicators at 298.15 K

Indicator	Suggested Abbreviation(s)	pH Range	Colour Change As pH Increases	K_a
methyl violet	$HMv_{(aq)}$ / $Mv^-_{(aq)}$	0.0 – 1.6	yellow to blue	$\sim 10^{-1}$
cresol red	$H_2Cr_{(aq)}$ / $HCr^-_{(aq)}$	0.0 – 1.0	red to yellow	$\sim 10^{-1}$
	$HCr_{(aq)}$ / $Cr^{2-}_{(aq)}$	7.0 – 8.8	yellow to red	3.5×10^{-9}
thymol blue	$H_2Tb_{(aq)}$ / $HTb^-_{(aq)}$	1.2 – 2.8	red to yellow	2.2×10^{-2}
	$HTb^-_{(aq)}$ / $Tb^{2-}_{(aq)}$	8.0 – 9.6	yellow to blue	6.3×10^{-10}
orange IV	$HOr_{(aq)}$ / $Or^-_{(aq)}$	1.4 – 2.8	red to yellow	$\sim 10^{-2}$
methyl orange	$HMo_{(aq)}$ / $Mo^-_{(aq)}$	3.2 – 4.4	red to yellow	3.5×10^{-4}
bromocresol green	$HBg_{(aq)}$ / $Bg^-_{(aq)}$	3.8 – 5.4	yellow to blue	1.3×10^{-5}
methyl red	$HMr_{(aq)}$ / $Mr^-_{(aq)}$	4.8 – 6.0	red to yellow	1.0×10^{-5}
chlorophenol red	$HCh_{(aq)}$ / $Ch^-_{(aq)}$	5.2 – 6.8	yellow to red	5.6×10^{-7}
bromothymol blue	$HBb_{(aq)}$ / $Bb^-_{(aq)}$	6.0 – 7.6	yellow to blue	5.0×10^{-8}
phenol red	$HPr_{(aq)}$ / $Pr^-_{(aq)}$	6.6 – 8.0	yellow to red	1.0×10^{-8}
phenolphthalein	$HPh_{(aq)}$ / $Ph^-_{(aq)}$	8.2 – 10.0	colourless to pink	3.2×10^{-10}
thymolphthalein	$HTh_{(aq)}$ / $Th^-_{(aq)}$	9.4 – 10.6	colourless to blue	1.0×10^{-10}
alizarin yellow R	$HAy_{(aq)}$ / $Ay^-_{(aq)}$	10.1 – 12.0	yellow to red	6.9×10^{-12}
indigo carmine	$HIc_{(aq)}$ / $Ic^-_{(aq)}$	11.4 – 13.0	blue to yellow	$\sim 10^{-12}$
1,3,5–trinitrobenzene	$HNb_{(aq)}$ / $Nb^-_{(aq)}$	12.0 – 14.0	colourless to orange	$\sim 10^{-13}$

Relative Strengths of Acids And Bases at 298.15 K

Acid Name	Acid Formula	Conjugate Base Formula	K_a
perchloric acid	$HClO_{4(aq)}$	$ClO_4^-{}_{(aq)}$	very large
hydroiodic acid	$HI_{(aq)}$	$I^-{}_{(aq)}$	very large
hydrobromic acid	$HBr_{(aq)}$	$Br^-{}_{(aq)}$	very large
hydrochloric acid	$HCl_{(aq)}$	$Cl^-{}_{(aq)}$	very large
sulfuric acid	$H_2SO_{4(aq)}$	$HSO_4^-{}_{(aq)}$	very large
nitric acid	$HNO_{3(aq)}$	$NO_3^-{}_{(aq)}$	very large
hydronium ion	$H_3O^+{}_{(aq)}$	$H_2O_{(l)}$	1
oxalic acid	$HOOCCOOH_{(aq)}$	$HOOCCOO^-{}_{(aq)}$	5.6×10^{-2}
sulfurous acid ($SO_2 + H_2O$)	$H_2SO_{3(aq)}$	$HSO_3^-{}_{(aq)}$	1.4×10^{-2}
hydrogen sulfate ion	$HSO_4^-{}_{(aq)}$	$SO_4^{2-}{}_{(aq)}$	1.0×10^{-2}
orange IV	$HOr_{(aq)}$	$Or^-{}_{(aq)}$	$\sim \times 10^{-2}$
phosphoric acid	$H_3PO_{4(aq)}$	$H_2PO_4^-{}_{(aq)}$	6.9×10^{-3}
nitrous acid	$HNO_{2(aq)}$	$NO_2^-{}_{(aq)}$	5.6×10^{-3}
citric acid	$H_3C_6H_5O_{7(aq)}$	$H_2C_6H_5O_7^-{}_{(aq)}$	7.4×10^{-4}
hydrofluoric acid	$HF_{(aq)}$	$F^-{}_{(aq)}$	6.3×10^{-4}
methanoic acid	$HCOOH_{(aq)}$	$HCOO^-{}_{(aq)}$	1.8×10^{-4}
methyl orange	$HMo_{(aq)}$	$Mo^-{}_{(aq)}$	$\sim \times 10^{-4}$
hydrogen oxalate ion	$HOOCCOO^-{}_{(aq)}$	$OOCCOO^{2-}{}_{(aq)}$	1.5×10^{-4}
ascorbic acid	$C_6H_8O_{6(aq)}$	$C_6H_7O_6^-{}_{(aq)}$	9.1×10^{-5}
benzoic acid	$C_6H_5COOH_{(aq)}$	$C_6H_5COO^-{}_{(aq)}$	6.3×10^{-5}
ethanoic (acetic) acid	$CH_3COOH_{(aq)}$	$CH_3COO^-{}_{(aq)}$	1.8×10^{-5}
dihydrogen citrate ion	$H_2C_6H_5O_7^-{}_{(aq)}$	$HC_6H_5O_7^{2-}{}_{(aq)}$	1.7×10^{-5}
carbonic acid ($CO_2 + H_2O$)	$H_2CO_{3(aq)}$	$HCO_3^-{}_{(aq)}$	4.5×10^{-7}
hydrogen citrate ion	$HC_6H_5O_7^{2-}{}_{(aq)}$	$C_6H_5O_7^{3-}{}_{(aq)}$	4.0×10^{-7}
bromothymol blue	$HBb_{(aq)}$	$Bb^-{}_{(aq)}$	$\sim \times 10^{-7}$
hydrosulfuric acid	$H_2S_{(aq)}$	$HS^-{}_{(aq)}$	8.9×10^{-8}
hydrogen sulfite ion	$HSO_3^-{}_{(aq)}$	$SO_3^{2-}{}_{(aq)}$	6.3×10^{-8}
dihydrogen phosphate ion	$H_2PO_4^-{}_{(aq)}$	$HPO_4^{2-}{}_{(aq)}$	6.2×10^{-8}
hypochlorous acid	$HOCl_{(aq)}$	$OCl^-{}_{(aq)}$	4.0×10^{-8}
phenolphthalein	$HPh_{(aq)}$	$Ph^-{}_{(aq)}$	$\sim \times 10^{-10}$
hydrocyanic acid	$HCN_{(aq)}$	$CN^-{}_{(aq)}$	6.2×10^{-10}
ammonium ion	$NH_4^+{}_{(aq)}$	$NH_{3(aq)}$	5.6×10^{-10}
hydrogen carbonate ion	$HCO_3^-{}_{(aq)}$	$CO_3^{2-}{}_{(aq)}$	4.7×10^{-11}
hydrogen ascorbate ion	$C_6H_7O_6^-{}_{(aq)}$	$C_6H_6O_6^{2-}{}_{(aq)}$	2.0×10^{-12}
indigo carmine	$HIc_{(aq)}$	$Ic^-{}_{(aq)}$	$\sim \times 10^{-12}$
hydrogen phosphate ion	$HPO_4^{2-}{}_{(aq)}$	$PO_4^{3-}{}_{(aq)}$	4.8×10^{-13}
water (55.5 mol/L)	$H_2O_{(l)}$	$OH^-{}_{(aq)}$	1.0×10^{-14}

Note: An approximation may be used when the concentration of the acid is 1000 times greater than the K_a.

Colours of Common Aqueous Ions

Ionic Species	Solution Concentration	
	1.0 mol/L	0.010 mol/L
chromate	yellow	pale yellow
chromium(III)	blue-green	green
chromium(II)	dark blue	pale blue
cobalt(II)	red	pink
copper(I)	blue-green	pale blue-green
copper(II)	blue	pale blue
dichromate	orange	pale orange
iron(II)	lime green	colourless
iron(III)	orange-yellow	pale yellow
manganese(II)	pale pink	colourless
nickel(II)	blue-green	pale blue-green
permanganate	deep purple	purple-pink

Notes: