

CHEMISTRY

Data Booklet *Updated 2010*

Government
of Alberta ■

Alberta ■
Freedom To Create. Spirit To Achieve.

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Table of Common Polyatomic Ions

acetate (ethanoate)	CH_3COO^-	chromate	CrO_4^{2-}	phosphate	PO_4^{3-}
ammonium	NH_4^+	dichromate	$\text{Cr}_2\text{O}_7^{2-}$	hydrogen phosphate	HPO_4^{2-}
benzoate	$\text{C}_6\text{H}_5\text{COO}^-$	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	HCO_3^-	nitrite	NO_2^-	sulfite	SO_3^{2-}
perchlorate	ClO_4^-	oxalate	$\text{OOC}\text{COO}^{2-}$	hydrogen sulfite	HSO_3^-
chlorate	ClO_3^-	hydrogen oxalate	HOOCCOO^-	hydrogen sulfide	HS^-
chlorite	ClO_2^-	permanganate	MnO_4^-	thiocyanate	SCN^-
hypochlorite	OCl^- or ClO^-	peroxide	O_2^{2-}	thiosulfate	$\text{S}_2\text{O}_3^{2-}$
		persulfide	S_2^{2-}		

1 1.01 1+, 1− 2.2 H hydrogen																																																																																			
3 6.94 1+ 1.0 Li lithium	4 9.01 2+ 1.6 Be beryllium																																																																																		
11 22.99 1+ 0.9 Na sodium	12 24.31 2+ 1.3 Mg magnesium																																																																																		
<table><tr><td>acetate (ethanoate)</td><td>CH₃COO[−]</td><td>chromate</td><td>CrO₄^{2−}</td><td>phosphate</td><td>PO₄^{3−}</td></tr><tr><td>ammonium</td><td>NH₄⁺</td><td>dichromate</td><td>Cr₂O₇^{2−}</td><td>hydrogen phosphate</td><td>HPO₄^{2−}</td></tr><tr><td>benzoate</td><td>C₆H₅COO[−]</td><td>cyanide</td><td>CN[−]</td><td>dihydrogen phosphate</td><td>H₂PO₄[−]</td></tr><tr><td>borate</td><td>BO₃^{3−}</td><td>hydroxide</td><td>OH[−]</td><td>silicate</td><td>SiO₃^{2−}</td></tr><tr><td>carbide</td><td>C₂^{2−}</td><td>iodate</td><td>IO₃[−]</td><td>sulfate</td><td>SO₄^{2−}</td></tr><tr><td>carbonate</td><td>CO₃^{2−}</td><td>nitrate</td><td>NO₃[−]</td><td>hydrogen sulfate</td><td>HSO₄[−]</td></tr><tr><td>hydrogen carbonate</td><td>HCO₃[−]</td><td>nitrite</td><td>NO₂[−]</td><td>sulfite</td><td>SO₃^{2−}</td></tr><tr><td>perchlorate</td><td>ClO₄[−]</td><td>oxalate</td><td>OOCCOO^{2−}</td><td>hydrogen sulfite</td><td>HSO₃[−]</td></tr><tr><td>chlorate</td><td>ClO₃[−]</td><td>hydrogen oxalate</td><td>HOCCOO[−]</td><td>hydrogen sulfide</td><td>HS[−]</td></tr><tr><td>chlorite</td><td>ClO₂[−]</td><td>permanganate</td><td>MnO₄[−]</td><td>thiocyanate</td><td>SCN[−]</td></tr><tr><td>hypochlorite</td><td>OCI[−] or ClO[−]</td><td>peroxide</td><td>O₂^{2−}</td><td>thiosulfate</td><td>S₂O₃^{2−}</td></tr><tr><td></td><td></td><td>persulfide</td><td>S₂^{2−}</td><td></td><td></td></tr></table>												acetate (ethanoate)	CH ₃ COO [−]	chromate	CrO ₄ ^{2−}	phosphate	PO ₄ ^{3−}	ammonium	NH ₄ ⁺	dichromate	Cr ₂ O ₇ ^{2−}	hydrogen phosphate	HPO ₄ ^{2−}	benzoate	C ₆ H ₅ COO [−]	cyanide	CN [−]	dihydrogen phosphate	H ₂ PO 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	HCO ₃ [−]	nitrite	NO ₂ [−]	sulfite	SO ₃ ^{2−}	perchlorate	ClO ₄ [−]	oxalate	OOCCOO ^{2−}	hydrogen sulfite	HSO ₃ [−]	chlorate	ClO ₃ [−]	hydrogen oxalate	HOCCOO [−]	hydrogen sulfide	HS [−]	chlorite	ClO ₂ [−]	permanganate	MnO ₄ [−]	thiocyanate	SCN [−]	hypochlorite	OCI [−] or ClO [−]	peroxide	O ₂ ^{2−}	thiosulfate	S ₂ O ₃ ^{2−}			persulfide	S ₂ ^{2−}		
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19 39.10 1+ 0.8 K potassium	20 40.08 2+ 1.0 Ca calcium	21 44.96 3+ 1.4 Sc scandium	22 47.87 4+, 3+ 1.5 Ti titanium	23 50.94 5+, 4+ 1.6 V vanadium	24 52.00 3+, 2+ 1.7 Cr chromium	25 54.94 2+, 4+ 1.6 Mn manganese	26 55.85 3+, 2+ 1.8 Fe iron	27 58.93 2+, 3+ 1.9 Co cobalt
37 85.47 1+ 0.8 Rb rubidium	38 87.62 2+ 1.0 Sr strontium	39 88.91 3+ 1.2 Y yttrium	40 91.22 4+ 1.3 Zr zirconium	41 92.91 5+, 3+ 1.6 Nb niobium	42 95.94 6+ 2.2 Mo molybdenum	43 (98) 7+ 2.1 Tc technetium	44 101.07 3+ 2.2 Ru ruthenium	45 102.91 3+ 2.3 Rh rhodium
55 132.91 1+ 0.8 Cs cesium	56 137.33 2+ 0.9 Ba barium	57 138.91 3+ 1.1 La lanthanum	72 178.49 4+ 1.3 Hf hafnium	73 180.95 5+ 1.5 Ta tantalum	74 183.84 6+ 1.7 W tungsten	75 186.21 7+ 1.9 Re rhenium	76 190.23 4+ 2.2 Os osmium	77 192.22 4+ 2.2 Ir iridium
87 (223) 1+ 0.7 Fr francium	88 (226) 2+ 0.9 Ra radium	89 (227) 3+ 1.1 Ac actinium	104 (261) 4+ Rf rutherfordium	105 (262) Db dubnium	106 (266) Sg seaborgium	107 (264) Bh bohrium	108 (277) Hs hassium	109 (268) Mt meitnerium

lanthanide and actinide series begin

58 140.12 3+ 1.1 Ce cerium	59 140.91 3+ 1.1 Pr praseodymium	60 144.24 3+ 1.1 Nd neodymium	61 (145) 3+ — Pm promethium	62 150.36 3+, 2+ 1.2 Sm samarium
90 232.04 4+ 1.3 Th thorium	91 231.04 5+, 4+ 1.5 Pa protactinium	92 238.03 6+, 4+ 1.7 U uranium	93 (237) 5+ 1.3 Np neptunium	94 (244) 4+, 6+ 1.3 Pu plutonium

References

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Speight, James G. 2005. *Lange's Handbook of Chemistry*. 16th ed. New York: McGraw-Hill, Inc.

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Legend for Elements

	Metallic solids		Gases
	Non-metallic solids		Liquids

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

Key

Atomic number	→	26	55.85	← mass (g/mol)*
			3+, 2+	← Most stable ion charges
Electronegativity	→	1.8		
Symbol	→	Fe		
Name	→	iron		

* Based on $^{12}_6\text{C}$
() Indicates mass of the most stable isotope

28 58.69 2+, 3+ 1.9 Ni nickel	29 63.55 2+, 1+ 1.9 Cu copper	30 65.41 2+ 1.7 Zn zinc	31 69.72 3+ 1.8 Ga gallium	32 72.64 4+ 2.0 Ge germanium	33 74.92 — 2.2 As arsenic	34 78.96 — 2.6 Se selenium	35 79.90 — 3.0 Br bromine	36 83.80 — — Kr krypton
46 106.42 2+, 3+ 2.2 Pd palladium	47 107.87 1+ 1.9 Ag silver	48 112.41 2+ 1.7 Cd cadmium	49 114.82 3+ 1.8 In indium	50 118.71 4+, 2+ 2.0 Sn tin	51 121.76 3+, 5+ 2.1 Sb antimony	52 127.60 — 2.1 Te tellurium	53 126.90 — 2.7 I iodine	54 131.29 — 2.6 Xe xenon
78 195.08 4+, 2+ 2.2 Pt platinum	79 196.97 3+, 1+ 2.4 Au gold	80 200.59 2+, 1+ 1.9 Hg mercury	81 204.38 1+, 3+ 1.8 Tl thallium	82 207.2* 2+, 4+ 1.8 Pb lead	83 208.98 3+, 5+ 1.9 Bi bismuth	84 (209) 2+, 4+ 2.0 Po polonium	85 (210) — 2.2 At astatine	86 (222) — — Rn radon
110 (271) Ds darmstadtium	111 (272) Rg roentgenium	* The isotopic mix of naturally occurring lead is more variable than other elements, preventing precision to greater than tenths of a gram per mole						

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63151.96 3+, 2+ — Eu europium	64157.25 3+ 1.2 Gd gadolinium	65158.93 3+ — Tb terbium	66162.50 3+ 1.2 Dy dysprosium	67164.93 3+ 1.2 Ho holmium	68167.26 3+ 1.2 Er erbium	69168.93 3+ 1.3 Tm thulium	70173.04 3+, 2+ — Yb ytterbium	71174.97 3+ 1.0 Lu lutetium
95(243) 3+, 4+ — Am americium	96(247) 3+ — Cm curium	97(247) 3+, 4+ — Bk berkelium	98(251) 3+ — Cf californium	99(252) 3+ — Es einsteinium	100(257) 3+ — Fm fermium	101(258) 2+, 3+ — Md mendelevium	102(259) 2+, 3+ — No nobelium	103(262) 3+ — Lr lawrencium

Chemistry Notation

Symbol	Term	Unit(s)
c	specific heat capacity	J/(g·°C) or J/(g·K)
E°	standard electrical potential	V or J/C
E_k	kinetic energy	kJ
E_p	potential energy	kJ
ΔH	enthalpy (heat)	kJ
$\Delta_f H^\circ$	standard molar enthalpy of formation	kJ/mol
I	current	A or C/s
K_c	equilibrium constant	—
K_a	acid ionization (dissociation) constant	—
K_b	base ionization (dissociation) constant	—
M	molar mass	g/mol
m	mass	g
n	amount of substance	mol
P	pressure	kPa
Q	charge	C
T	temperature (absolute)	K
t	temperature (Celsius)	°C
t	time	s
V	volume	L
c	amount concentration	mol/L

Symbol	Term
Δ	delta (change in)
$^\circ$	standard
[]	amount concentration

Miscellaneous

25.00 °C is equivalent to 298.15 K

Specific Heat Capacities at 298.15 K and 100.000 kPa

$$c_{\text{air}} = 1.01 \text{ J/(g}\cdot\text{°C)}$$

$$c_{\text{polystyrene foam cup}} = 1.01 \text{ J/(g}\cdot\text{°C)}$$

$$c_{\text{copper}} = 0.385 \text{ J/(g}\cdot\text{°C)}$$

$$c_{\text{aluminium}} = 0.897 \text{ J/(g}\cdot\text{°C)}$$

$$c_{\text{iron}} = 0.449 \text{ J/(g}\cdot\text{°C)}$$

$$c_{\text{tin}} = 0.227 \text{ J/(g}\cdot\text{°C)}$$

$$c_{\text{water}} = 4.19 \text{ J/(g}\cdot\text{°C)}$$

Water Autoionization Constant (Dissociation Constant)

$$K_{\text{w}} = 1.0 \times 10^{-14} \text{ at } 298.15 \text{ K (for ion concentrations in mol/L)}$$

Faraday Constant

$$F = 9.65 \times 10^4 \text{ C/mol e}^{-}$$

Quadratic Formula

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Selected SI Prefixes

Prefix	Exponential Symbol	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}

Standard Molar Enthalpies of Formation at 298.15 K

Name	Formula	$\Delta_f H^\circ$ (kJ/mol)
aluminium oxide	$\text{Al}_2\text{O}_3(\text{s})$	-1 675.7
ammonia	$\text{NH}_3(\text{g})$	-45.9
ammonium chloride	$\text{NH}_4\text{Cl}(\text{s})$	-314.4
ammonium nitrate	$\text{NH}_4\text{NO}_3(\text{s})$	-365.6
barium carbonate	$\text{BaCO}_3(\text{s})$	-1 213.0
barium chloride	$\text{BaCl}_2(\text{s})$	-855.0
barium hydroxide	$\text{Ba}(\text{OH})_2(\text{s})$	-944.7
barium oxide	$\text{BaO}(\text{s})$	-548.0
barium sulfate	$\text{BaSO}_4(\text{s})$	-1 473.2
benzene	$\text{C}_6\text{H}_6(\text{l})$	+49.1
butane	$\text{C}_4\text{H}_{10}(\text{g})$	-125.7
calcium carbonate	$\text{CaCO}_3(\text{s})$	-1 207.6
calcium chloride	$\text{CaCl}_2(\text{s})$	-795.4
calcium hydroxide	$\text{Ca}(\text{OH})_2(\text{s})$	-985.2
calcium oxide	$\text{CaO}(\text{s})$	-634.9
calcium sulfate	$\text{CaSO}_4(\text{s})$	-1 434.5
carbon dioxide	$\text{CO}_2(\text{g})$	-393.5
carbon monoxide	$\text{CO}(\text{g})$	-110.5
chromium(III) oxide	$\text{Cr}_2\text{O}_3(\text{s})$	-1 139.7
copper(I) oxide	$\text{Cu}_2\text{O}(\text{s})$	-168.6
copper(II) oxide	$\text{CuO}(\text{s})$	-157.3
copper(II) sulfate	$\text{CuSO}_4(\text{s})$	-771.4
copper(I) sulfide	$\text{Cu}_2\text{S}(\text{s})$	-79.5
copper(II) sulfide	$\text{CuS}(\text{s})$	-53.1
dinitrogen tetroxide	$\text{N}_2\text{O}_4(\text{g})$	+11.1
ethane	$\text{C}_2\text{H}_6(\text{g})$	-84.0
ethanoic acid (acetic acid)	$\text{CH}_3\text{COOH}(\text{l})$	-484.3
ethanol	$\text{C}_2\text{H}_5\text{OH}(\text{l})$	-277.6
ethene (ethylene)	$\text{C}_2\text{H}_4(\text{g})$	+52.4
ethyne (acetylene)	$\text{C}_2\text{H}_2(\text{g})$	+227.4
glucose	$\text{C}_6\text{H}_{12}\text{O}_6(\text{s})$	-1 273.3
hydrogen bromide	$\text{HBr}(\text{g})$	-36.3
hydrogen chloride	$\text{HCl}(\text{g})$	-92.3
hydrogen fluoride	$\text{HF}(\text{g})$	-273.3
hydrogen iodide	$\text{HI}(\text{g})$	+26.5
hydrogen perchlorate	$\text{HClO}_4(\text{l})$	-40.6
hydrogen peroxide	$\text{H}_2\text{O}_2(\text{l})$	-187.8
hydrogen sulfide	$\text{H}_2\text{S}(\text{g})$	-20.6
iron(II) oxide	$\text{FeO}(\text{s})$	-272.0
iron(III) oxide	$\text{Fe}_2\text{O}_3(\text{s})$	-824.2
iron(II,III) oxide (magnetite)	$\text{Fe}_3\text{O}_4(\text{s})$	-1 118.4
lead(II) bromide	$\text{PbBr}_2(\text{s})$	-278.7
lead(II) chloride	$\text{PbCl}_2(\text{s})$	-359.4
lead(II) oxide (red)	$\text{PbO}(\text{s})$	-219.0
lead(IV) oxide	$\text{PbO}_2(\text{s})$	-277.4
magnesium carbonate	$\text{MgCO}_3(\text{s})$	-1 095.8
magnesium chloride	$\text{MgCl}_2(\text{s})$	-641.3

Standard Molar Enthalpies of Formation at 298.15 K cont'd

Name	Formula	$\Delta_f H^\circ$ (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 ₂ O(g)	– 108.6
methane	CH ₄ (g)	– 74.6
methanoic acid (formic acid)	HCOOH(l)	– 425.0
methanol	CH ₃ OH(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 ₈ H ₁₈ (l)	– 250.1
pentane	C ₅ H 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 ₃ H 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)	– 425.8
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 ₂ SO 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 ₂ O(l)	– 285.8
water (vapour)	H ₂ O(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 ions NH_4^+ NO_3^- ClO_3^- ClO_4^- CH_3COO^-	F^-	Cl^- Br^- I^-	SO_4^{2-}	CO_3^{2-} PO_4^{3-} SO_3^{2-}	IO_3^- $\text{OOC}\text{COO}^{2-}$	OH^-
Solubility greater than or equal to 0.1 mol/L (very soluble)	most	most	most	most	Group 1 ions NH_4^+	Group 1 ions NH_4^+ $\text{Co}(\text{IO}_3)_2$ $\text{Fe}_2(\text{OOC}\text{COO})_3$	Group 1 ions NH_4^+
Solubility less than 0.1 mol/L (slightly soluble)	RbClO_4 CsClO_4 AgCH_3COO $\text{Hg}_2(\text{CH}_3\text{COO})_2$	Li^+ Mg^{2+} Ca^{2+} Sr^{2+} Ba^{2+} Fe^{2+} Hg_2^{2+} Pb^{2+}	Cu^+ Ag^+ Hg_2^{2+} Pb^{2+} Tl^+	Ca^{2+} Sr^{2+} Ba^{2+} Ag^+ Hg_2^{2+} Pb^{2+} Ra^{2+}	most	most	most

Note: This solubility table is only a guideline that is established using the K_{sp} values. A concentration of 0.1 mol/L corresponds to approximately 10 g/L to 30 g/L depending on molar mass. Hg_2^{2+} is a polyatomic ion of mercury.

Flame Colour of Elements

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

Note: The flame test can be used to determine the identity of a metal or a metal ion. Blue to green indicates a range of colours that might appear.

Table of Selected Standard Electrode Potentials*

Reduction Half-Reaction	Electrical Potential E° (V)
$\text{F}_2(\text{g}) + 2 \text{e}^- \rightleftharpoons 2 \text{F}^-(\text{aq})$	+2.87
$\text{PbO}_2(\text{s}) + \text{SO}_4^{2-}(\text{aq}) + 4 \text{H}^+(\text{aq}) + 2 \text{e}^- \rightleftharpoons \text{PbSO}_4(\text{s}) + 2 \text{H}_2\text{O}(\text{l})$	+1.69
$\text{MnO}_4^-(\text{aq}) + 8 \text{H}^+(\text{aq}) + 5 \text{e}^- \rightleftharpoons \text{Mn}^{2+}(\text{aq}) + 4 \text{H}_2\text{O}(\text{l})$	+1.51
$\text{Au}^{3+}(\text{aq}) + 3 \text{e}^- \rightleftharpoons \text{Au}(\text{s})$	+1.50
$\text{ClO}_4^-(\text{aq}) + 8 \text{H}^+(\text{aq}) + 8 \text{e}^- \rightleftharpoons \text{Cl}^-(\text{aq}) + 4 \text{H}_2\text{O}(\text{l})$	+1.39
$\text{Cl}_2(\text{g}) + 2 \text{e}^- \rightleftharpoons 2 \text{Cl}^-(\text{aq})$	+1.36
$2 \text{HNO}_2(\text{aq}) + 4 \text{H}^+(\text{aq}) + 4 \text{e}^- \rightleftharpoons \text{N}_2\text{O}(\text{g}) + 3 \text{H}_2\text{O}(\text{l})$	+1.30
$\text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 14 \text{H}^+(\text{aq}) + 6 \text{e}^- \rightleftharpoons 2 \text{Cr}^{3+}(\text{aq}) + 7 \text{H}_2\text{O}(\text{l})$	+1.23
$\text{O}_2(\text{g}) + 4 \text{H}^+(\text{aq}) + 4 \text{e}^- \rightleftharpoons 2 \text{H}_2\text{O}(\text{l})$	+1.23
$\text{MnO}_2(\text{s}) + 4 \text{H}^+(\text{aq}) + 2 \text{e}^- \rightleftharpoons \text{Mn}^{2+}(\text{aq}) + 2 \text{H}_2\text{O}(\text{l})$	+1.22
$\text{Br}_2(\text{l}) + 2 \text{e}^- \rightleftharpoons 2 \text{Br}^-(\text{aq})$	+1.07
$\text{Hg}^{2+}(\text{aq}) + 2 \text{e}^- \rightleftharpoons \text{Hg}(\text{l})$	+0.85
$\text{OCl}^-(\text{aq}) + \text{H}_2\text{O}(\text{l}) + 2 \text{e}^- \rightleftharpoons \text{Cl}^-(\text{aq}) + 2 \text{OH}^-(\text{aq})$	+0.84
$2 \text{NO}_3^-(\text{aq}) + 4 \text{H}^+(\text{aq}) + 2 \text{e}^- \rightleftharpoons \text{N}_2\text{O}_4(\text{g}) + 2 \text{H}_2\text{O}(\text{l})$	+0.80
$\text{Ag}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{Ag}(\text{s})$	+0.80
$\text{Fe}^{3+}(\text{aq}) + \text{e}^- \rightleftharpoons \text{Fe}^{2+}(\text{aq})$	+0.77
$\text{O}_2(\text{g}) + 2 \text{H}^+(\text{aq}) + 2 \text{e}^- \rightleftharpoons \text{H}_2\text{O}_2(\text{l})$	+0.70
$\text{I}_2(\text{s}) + 2 \text{e}^- \rightleftharpoons 2 \text{I}^-(\text{aq})$	+0.54
$\text{O}_2(\text{g}) + 2 \text{H}_2\text{O}(\text{l}) + 4 \text{e}^- \rightleftharpoons 4 \text{OH}^-(\text{aq})$	+0.40
$\text{Cu}^{2+}(\text{aq}) + 2 \text{e}^- \rightleftharpoons \text{Cu}(\text{s})$	+0.34
$\text{SO}_4^{2-}(\text{aq}) + 4 \text{H}^+(\text{aq}) + 2 \text{e}^- \rightleftharpoons \text{H}_2\text{SO}_3(\text{aq}) + \text{H}_2\text{O}(\text{l})$	+0.17
$\text{Sn}^{4+}(\text{aq}) + 2 \text{e}^- \rightleftharpoons \text{Sn}^{2+}(\text{aq})$	+0.15
$\text{S}(\text{s}) + 2 \text{H}^+(\text{aq}) + 2 \text{e}^- \rightleftharpoons \text{H}_2\text{S}(\text{aq})$	+0.14
$\text{AgBr}(\text{s}) + \text{e}^- \rightleftharpoons \text{Ag}(\text{s}) + \text{Br}^-(\text{aq})$	+0.07
$2 \text{H}^+(\text{aq}) + 2 \text{e}^- \rightleftharpoons \text{H}_2(\text{g})$	0.00
$\text{Pb}^{2+}(\text{aq}) + 2 \text{e}^- \rightleftharpoons \text{Pb}(\text{s})$	-0.13
$\text{Sn}^{2+}(\text{aq}) + 2 \text{e}^- \rightleftharpoons \text{Sn}(\text{s})$	-0.14
$\text{AgI}(\text{s}) + \text{e}^- \rightleftharpoons \text{Ag}(\text{s}) + \text{I}^-(\text{aq})$	-0.15
$\text{Ni}^{2+}(\text{aq}) + 2 \text{e}^- \rightleftharpoons \text{Ni}(\text{s})$	-0.26
$\text{Co}^{2+}(\text{aq}) + 2 \text{e}^- \rightleftharpoons \text{Co}(\text{s})$	-0.28
$\text{PbSO}_4(\text{s}) + 2 \text{e}^- \rightleftharpoons \text{Pb}(\text{s}) + \text{SO}_4^{2-}(\text{aq})$	-0.36
$\text{Se}(\text{s}) + 2 \text{H}^+(\text{aq}) + 2 \text{e}^- \rightleftharpoons \text{H}_2\text{Se}(\text{aq})$	-0.40
$\text{Cd}^{2+}(\text{aq}) + 2 \text{e}^- \rightleftharpoons \text{Cd}(\text{s})$	-0.40
$\text{Cr}^{3+}(\text{aq}) + \text{e}^- \rightleftharpoons \text{Cr}^{2+}(\text{aq})$	-0.41
$\text{Fe}^{2+}(\text{aq}) + 2 \text{e}^- \rightleftharpoons \text{Fe}(\text{s})$	-0.45
$\text{NO}_2^-(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{e}^- \rightleftharpoons \text{NO}(\text{g}) + 2 \text{OH}^-(\text{aq})$	-0.46
$\text{Ag}_2\text{S}(\text{s}) + 2 \text{e}^- \rightleftharpoons 2 \text{Ag}(\text{s}) + \text{S}^{2-}(\text{aq})$	-0.69
$\text{Zn}^{2+}(\text{aq}) + 2 \text{e}^- \rightleftharpoons \text{Zn}(\text{s})$	-0.76
$2 \text{H}_2\text{O}(\text{l}) + 2 \text{e}^- \rightleftharpoons \text{H}_2(\text{g}) + 2 \text{OH}^-(\text{aq})$	-0.83
$\text{Cr}^{2+}(\text{aq}) + 2 \text{e}^- \rightleftharpoons \text{Cr}(\text{s})$	-0.91
$\text{Se}(\text{s}) + 2 \text{e}^- \rightleftharpoons \text{Se}^{2-}(\text{aq})$	-0.92
$\text{SO}_4^{2-}(\text{aq}) + \text{H}_2\text{O}(\text{l}) + 2 \text{e}^- \rightleftharpoons \text{SO}_3^{2-}(\text{aq}) + 2 \text{OH}^-(\text{aq})$	-0.93
$\text{Al}^{3+}(\text{aq}) + 3 \text{e}^- \rightleftharpoons \text{Al}(\text{s})$	-1.66
$\text{Mg}^{2+}(\text{aq}) + 2 \text{e}^- \rightleftharpoons \text{Mg}(\text{s})$	-2.37
$\text{Na}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{Na}(\text{s})$	-2.71
$\text{Ca}^{2+}(\text{aq}) + 2 \text{e}^- \rightleftharpoons \text{Ca}(\text{s})$	-2.87
$\text{Ba}^{2+}(\text{aq}) + 2 \text{e}^- \rightleftharpoons \text{Ba}(\text{s})$	-2.91
$\text{K}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{K}(\text{s})$	-2.93
$\text{Li}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{Li}(\text{s})$	-3.04

*For 1.0 mol/L solutions at 298.15 K (25.00 °C) and a pressure of 101.325 kPa

Relative Strengths of Acids and Bases at 298.15 K

Common Name IUPAC / Systematic Name	Acid Formula	Conjugate Base Formula	K_a
perchloric acid aqueous hydrogen perchlorate	$\text{HClO}_4(\text{aq})$	$\text{ClO}_4^-(\text{aq})$	very large
hydroiodic acid aqueous hydrogen iodide	$\text{HI}(\text{aq})$	$\text{I}^-(\text{aq})$	very large
hydrobromic acid aqueous hydrogen bromide	$\text{HBr}(\text{aq})$	$\text{Br}^-(\text{aq})$	very large
hydrochloric acid aqueous hydrogen chloride	$\text{HCl}(\text{aq})$	$\text{Cl}^-(\text{aq})$	very large
sulfuric acid aqueous hydrogen sulfate	$\text{H}_2\text{SO}_4(\text{aq})$	$\text{HSO}_4^-(\text{aq})$	very large
nitric acid aqueous hydrogen nitrate	$\text{HNO}_3(\text{aq})$	$\text{NO}_3^-(\text{aq})$	very large
hydronium ion	$\text{H}_3\text{O}^+(\text{aq})$	$\text{H}_2\text{O}(\text{l})$	1
oxalic acid	$\text{HOOC}\text{COOH}(\text{aq})$	$\text{HOOC}\text{COO}^-(\text{aq})$	5.6×10^{-2}
sulfurous acid aqueous hydrogen sulfite	$\text{H}_2\text{SO}_3(\text{aq})$	$\text{HSO}_3^-(\text{aq})$	1.4×10^{-2}
hydrogen sulfate ion	$\text{HSO}_4^-(\text{aq})$	$\text{SO}_4^{2-}(\text{aq})$	1.0×10^{-2}
phosphoric acid aqueous hydrogen phosphate	$\text{H}_3\text{PO}_4(\text{aq})$	$\text{H}_2\text{PO}_4^-(\text{aq})$	6.9×10^{-3}
citric acid 2-hydroxy-1,2,3-propanetricarboxylic acid	$\text{C}_3\text{H}_5\text{O}(\text{COOH})_3(\text{aq})$	$\text{C}_3\text{H}_5\text{O}(\text{COOH})_2\text{COO}^-(\text{aq})$	7.4×10^{-4}
hydrofluoric acid aqueous hydrogen fluoride	$\text{HF}(\text{aq})$	$\text{F}^-(\text{aq})$	6.3×10^{-4}
nitrous acid aqueous hydrogen nitrite	$\text{HNO}_2(\text{aq})$	$\text{NO}_2^-(\text{aq})$	5.6×10^{-4}
formic acid methanoic acid	$\text{HCOOH}(\text{aq})$	$\text{HCOO}^-(\text{aq})$	1.8×10^{-4}
hydrogen oxalate ion	$\text{HOOC}\text{COO}^-(\text{aq})$	$\text{OOC}\text{COO}^{2-}(\text{aq})$	1.5×10^{-4}
lactic acid 2-hydroxypropanoic acid	$\text{C}_2\text{H}_5\text{O}\text{COOH}(\text{aq})$	$\text{C}_2\text{H}_5\text{O}\text{COO}^-(\text{aq})$	1.4×10^{-4}
ascorbic acid 2(1,2-dihydroxyethyl)-4,5-dihydroxy-furan-3-one	$\text{H}_2\text{C}_6\text{H}_6\text{O}_6(\text{aq})$	$\text{HC}_6\text{H}_6\text{O}_6^-(\text{aq})$	9.1×10^{-5}

benzoic acid benzenecarboxylic acid	$\text{C}_6\text{H}_5\text{COOH}(\text{aq})$	$\text{C}_6\text{H}_5\text{COO}^-(\text{aq})$	6.3×10^{-5}
acetic acid ethanoic acid	$\text{CH}_3\text{COOH}(\text{aq})$	$\text{CH}_3\text{COO}^-(\text{aq})$	1.8×10^{-5}
dihydrogen citrate ion	$\text{C}_3\text{H}_5\text{O}(\text{COOH})_2\text{COO}^-(\text{aq})$	$\text{C}_3\text{H}_5\text{OCOOH}(\text{COO})_2^{2-}(\text{aq})$	1.7×10^{-5}
butanoic acid	$\text{C}_3\text{H}_7\text{COOH}(\text{aq})$	$\text{C}_3\text{H}_7\text{COO}^-(\text{aq})$	1.5×10^{-5}
propanoic acid	$\text{C}_2\text{H}_5\text{COOH}(\text{aq})$	$\text{C}_2\text{H}_5\text{COO}^-(\text{aq})$	1.3×10^{-5}
carbonic acid ($\text{CO}_2 + \text{H}_2\text{O}$) aqueous hydrogen carbonate	$\text{H}_2\text{CO}_3(\text{aq})$	$\text{HCO}_3^-(\text{aq})$	4.5×10^{-7}
hydrogen citrate ion	$\text{C}_3\text{H}_5\text{OCOOH}(\text{COO})_2^{2-}(\text{aq})$	$\text{C}_3\text{H}_5\text{O}(\text{COO})_3^{3-}(\text{aq})$	4.0×10^{-7}
hydrosulfuric acid aqueous hydrogen sulfide	$\text{H}_2\text{S}(\text{aq})$	$\text{HS}^-(\text{aq})$	8.9×10^{-8}
hydrogen sulfite ion	$\text{HSO}_3^-(\text{aq})$	$\text{SO}_3^{2-}(\text{aq})$	6.3×10^{-8}
dihydrogen phosphate ion	$\text{H}_2\text{PO}_4^-(\text{aq})$	$\text{HPO}_4^{2-}(\text{aq})$	6.2×10^{-8}
hypochlorous acid aqueous hydrogen hypochlorite	$\text{HOCl}(\text{aq})$	$\text{OCl}^-(\text{aq})$	4.0×10^{-8}
hydrocyanic acid aqueous hydrogen cyanide	$\text{HCN}(\text{aq})$	$\text{CN}^-(\text{aq})$	6.2×10^{-10}
ammonium ion	$\text{NH}_4^+(\text{aq})$	$\text{NH}_3(\text{aq})$	5.6×10^{-10}
hydrogen carbonate ion	$\text{HCO}_3^-(\text{aq})$	$\text{CO}_3^{2-}(\text{aq})$	4.7×10^{-11}
hydrogen ascorbate ion	$\text{HC}_6\text{H}_6\text{O}_6^-(\text{aq})$	$\text{C}_6\text{H}_6\text{O}_6^{2-}(\text{aq})$	2.0×10^{-12}
hydrogen phosphate ion	$\text{HPO}_4^{2-}(\text{aq})$	$\text{PO}_4^{3-}(\text{aq})$	4.8×10^{-13}
water	$\text{H}_2\text{O}(\text{l})$	$\text{OH}^-(\text{aq})$	1.0×10^{-14}

Note: An approximation may be used instead of the quadratic formula when the concentration of H_3O^+ produced is less than 5% of the original acid concentration (or the concentration of the acid is 1 000 times greater than the K_a). An approximation can also be used for weak bases. The formulas of the carboxylic acids have been written so that the COOH group can be easily recognized. Either the common or IUPAC name is acceptable.

Acid–Base Indicators at 298.15 K

Indicator	Suggested Abbreviations	pH Range	Colour Change as pH Increases	K_a
methyl violet	HMv(aq) / Mv [−] (aq)	0.0 – 1.6	yellow to blue	$\sim 2 \times 10^{-1}$
cresol red	H ₂ Cr(aq) / HCr [−] (aq)	0.0 – 1.0	red to yellow	$\sim 3 \times 10^{-1}$
	HCr [−] (aq) / Cr ^{2−} (aq)	7.0 – 8.8	yellow to red	3.5×10^{-9}
thymol blue	H ₂ Tb(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	$\sim 1 \times 10^{-2}$
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	$\sim 6 \times 10^{-12}$
1,3,5–trinitrobenzene	HNb(aq) / Nb [−] (aq)	12.0 – 14.0	colourless to orange	$\sim 1 \times 10^{-13}$

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:

