

Chemistry

DATA BOOKLET

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Introduction

Chemistry is part of the science curriculum from primary to grade 12. This chemistry data booklet is intended for student use for class work and assessments. This booklet is helpful for Science 9, Science 10, all chemistry classes, and Food Science 12.

Periodic Table of The Elements

1	H	hydrogen	2	He	helium
2	Li	lithium	3	Be	beryllium
3	Na	sodium	4	Mg	magnesium
4	K	potassium	5	Ca	calcium
5	Rb	rubidium	6	Sr	strontium
6	Cs	cesium	7	Ba	barium
7	Fr	francium	8	Ac	actinium
11	Na	lithium	12	Mg	magnesium
19	K	potassium	20	Ca	calcium
37	Rb	rubidium	38	Sr	strontium
55	Cs	cesium	87	Fr	francium
11	Al	aluminum	12	Si	silicon
13	Al	aluminum	14	Si	silicon
19	Cl	chlorine	20	P	phosphorus
28	Ar	argon	30	O	oxygen
31	Se	selenium	32	N	nitrogen
33	Br	bromine	34	F	fluorine
35	Kr	krypton	36	Ne	neon
53	Xe	xenon	54	Rn	radon
85	At	astatine	86	Rn	radon
132	Tl	thallium	133	Po	polonium
134	Bi	bismuth	135	At	astatine
136	Te	tellurium	137	I	iodine
138	Sb	stibnite	139	Te	tellurium
140	Ge	germanium	141	As	arsenic
142	Zn	zinc	143	Ge	germanium
144	Cu	copper	145	Ge	germanium
146	Ni	nickel	147	Ge	germanium
148	Fe	iron	149	Ge	germanium
149	Mn	manganese	150	Ge	germanium
151	Cr	chromium	152	Ge	germanium
152	V	vanadium	153	Ge	germanium
153	Ti	titanium	154	Ge	germanium
154	Sc	scandium	155	Ge	germanium
155	Y	yttrium	156	Ge	germanium
156	Zr	zirconium	157	Ge	germanium
157	Nb	niobium	158	Ge	germanium
158	Tc	technetium	159	Ge	germanium
159	Ru	rhodium	160	Ge	germanium
160	Pd	palladium	161	Ge	germanium
161	Ag	silver	162	Ge	germanium
162	Rh	rhodium	163	Ge	germanium
163	Pt	palladium	164	Ge	germanium
164	Ir	iridium	165	Ge	germanium
165	Os	osmium	166	Ge	germanium
166	W	tungsten	167	Ge	germanium
167	Ta	tantalum	168	Ge	germanium
168	Hf	hafnium	169	Ge	germanium
169	La	lanthanum	170	Ge	germanium
170	Bh	bohrium	171	Ge	germanium
171	Hs	hassium	172	Ge	germanium
172	Ds	darmstadtium	173	Ge	germanium
173	Rg	roentgenium	174	Ge	germanium
174	Mt	meitnerium	175	Ge	germanium
175	Cn	copernicium	176	Ge	germanium
176	Uut	ununtrium	177	Ge	germanium
177	Fl	fermium	178	Ge	germanium
178	Uup	ununpentium	179	Ge	germanium
179	Lv	livermoreum	180	Ge	germanium
180	He	helium	181	Ge	germanium
181	Ne	neon	182	Ge	germanium
182	Ar	argon	183	Ge	germanium
183	Xe	xenon	184	Ge	germanium
184	Rn	radon	185	Ge	germanium
185	At	astatine	186	Ge	germanium
186	Rn	radon	187	Ge	germanium
187	Fr	francium	188	Ge	germanium
188	Ac	actinium	189	Ge	germanium
189	Th	thorium	190	Ge	germanium
190	Pa	protactinium	191	Ge	germanium
191	U	uranium	192	Ge	germanium
192	Np	neptunium	193	Ge	germanium
193	Pu	plutonium	194	Ge	germanium
194	Am	americium	195	Ge	germanium
195	Cm	curium	196	Ge	germanium
196	Bk	berkelium	197	Ge	germanium
197	Cf	californium	198	Ge	germanium
198	Es	einsteinium	199	Ge	germanium
199	Fm	fermium	200	Ge	germanium
200	Md	mendelevium	201	Ge	germanium
201	No	nobelium	202	Ge	germanium
202	Lr	lawrencium	203	Ge	germanium

elements 113 and 115 have not yet been officially named

*Average atomic mass values in parenthesis represent the mass of the most stable isotope.

Table of Common Polyatomic Ions

acetate (ethanoate)	CH_3COO^-
ammonium	NH_4^+
benzoate	$\text{C}_6\text{H}_5\text{COO}^-$
borate	BO_3^{3-}
carbide	C_2^{2-}
carbonate	CO_3^{2-}
hydrogen carbonate	HCO_3^-
perchlorate	ClO_4^-
chlorate	ClO_3^-
chlorite	ClO_2^-
hypochlorite	OCl^- or ClO^-
chromate	CrO_4^{2-}
dichromate	$\text{Cr}_2\text{O}_7^{2-}$
cyanide	CN^-
hydroxide	OH^-
iodate	IO_3^-
nitrate	NO_3^-
nitrite	NO_2^-
oxalate	OOCOO^{2-}
hydrogen oxalate	HOOCOO^-
permanganate	MnO_4^-
peroxide	O_2^{2-}
persulfide	S_2^{2-}
phosphate	PO_4^{3-}
hydrogen phosphate	HPO_4^{2-}
dihydrogen phosphate	H_2PO_4^-
silicate	SiO_3^{2-}
sulfate	SO_4^{2-}
hydrogen sulfate	HSO_4^-
sulfite	SO_3^{2-}
hydrogen sulfite	HSO_3^-
hydrogen sulfide	HS^-
thiocyanate	SCN^-
thiosulfate	$\text{S}_2\text{O}_3^{2-}$

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
ΔH	enthalpy (heat)	kJ
ΔH_f°	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
Q	charge	C
T	temperature (absolute)	K
t	temperature (Celsius)	°C
t	time	s
V	volume	L
c	amount concentration	mol/L

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^- OOCOO^{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^+ $\text{Co}(\text{IO}_3)_2$ $\text{Fe}_2(\text{OOCOO})_3$	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
barium	Ba	yellowish green
boron	B	yellowish green
calcium	Ca	yellowish red
cesium	Cs	violet
copper	Cu	blue to green
lead	Pb	blue-white
lithium	Li	red
potassium	K	violet
rubidium	Rb	violet
sodium	Na	yellow
strontium	Sr	scarlet red

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.

Selected SI (Système International) Prefixes

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

Table of Selected Standard Electrode Potentials

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

Reduction: Half-Reactions		Electrical Potential E° (V)
$F_2(g) + 2e^- \rightleftharpoons 2F^-(aq)$	+2.87	
$PbO_2(s) + SO_4^{2-}(aq) + 4H^+(aq) + 2e^- \rightleftharpoons PbSO_4(s) + 2H_2O(l)$	+1.69	
$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightleftharpoons Mn^{2+}(aq) + 4H_2O(l)$	+1.51	
$Au^{3+}(aq) + 3e^- \rightleftharpoons Au(s)$	+1.50	
$ClO_4^-(aq) + 8H^+(aq) + 8e^- \rightleftharpoons Cl^-(aq) + 4H_2O(l)$	+1.39	
$Cl_2(g) + 2e^- \rightleftharpoons 2Cl^-(aq)$	+1.36	
$2HNO_2(aq) + 4H^+(aq) + 4e^- \rightleftharpoons N_2O(g) + 3H_2O(l)$	+1.30	
$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightleftharpoons 2Cr^{3+}(aq) + 7H_2O(l)$	+1.23	
$O_2(g) + 4H^+(aq) + 4e^- \rightleftharpoons 2H_2O(l)$	+1.23	
$MnO_2(s) + 4H^+(aq) + 2e^- \rightleftharpoons Mn^{2+}(aq) + 2H_2O(l)$	+1.22	
$Br_2(l) + 2e^- \rightleftharpoons 2Br^-(aq)$	+1.07	
$Hg^{2+}(aq) + 2e^- \rightleftharpoons Hg(l)$	+0.85	
$OCl^-(aq) + H_2O(l) + 2e^- \rightleftharpoons Cl^-(aq) + 2OH^-(aq)$	+0.84	
$2NO_3^-(aq) + 4H^+(aq) + 2e^- \rightleftharpoons N_2O_4(g) + 2H_2O(l)$	+0.80	
$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$	+0.80	
$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$	+0.77	
$O_2(g) + 2H^+(aq) + 2e^- \rightleftharpoons H_2O_2(l)$	+0.70	
$I_2(s) + 2e^- \rightleftharpoons 2I^-(aq)$	+0.54	
$O_2(g) + 2H_2O(l) + 4e^- \rightleftharpoons 4OH^-(aq)$	+0.40	
$Cu^{2+}(aq) + 2e^- \rightleftharpoons Cu(s)$	+0.34	
$SO_4^{2-}(aq) + 4H^+(aq) + 2e^- \rightleftharpoons H_2SO_3(aq) + H_2O(l)$	+0.17	
$Sn^{4+}(aq) + 2e^- \rightleftharpoons Sn^{2+}(aq)$	+0.15	
$S(s) + 2H^+(aq) + 2e^- \rightleftharpoons H_2S(aq)$	+0.14	
$AgBr(s) + e^- \rightleftharpoons Ag(s) + Br^-(aq)$	+0.07	
$2H^+(aq) + 2e^- \rightleftharpoons H_2(g)$	0.00	
$Pb^{2+}(aq) + 2e^- \rightleftharpoons Pb(s)$	-0.13	
$Sn^{2+}(aq) + 2e^- \rightleftharpoons Sn(s)$	-0.14	
$AgI(s) + e^- \rightleftharpoons Ag(s) + I^-(aq)$	-0.15	
$Ni^{2+}(aq) + 2e^- \rightleftharpoons Ni(s)$	-0.26	
$Co^{2+}(aq) + 2e^- \rightleftharpoons Co(s)$	-0.28	
$PbSO_4(s) + 2e^- \rightleftharpoons Pb(s) + SO_4^{2-}(aq)$	-0.36	
$Se(s) + 2H^+(aq) + 2e^- \rightleftharpoons H_2Se(aq)$	-0.40	
$Cd^{2+}(aq) + 2e^- \rightleftharpoons Cd(s)$	-0.40	
$Cr^{3+}(aq) + e^- \rightleftharpoons Cr^{2+}(aq)$	-0.41	
$Fe^{2+}(aq) + 2e^- \rightleftharpoons Fe(s)$	-0.45	
$NO_2^-(aq) + H_2O(l) + e^- \rightleftharpoons NO(g) + 2OH^-(aq)$	-0.46	
$Ag_2S(s) + 2e^- \rightleftharpoons 2Ag(s) + S^{2-}(aq)$	-0.69	
$Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s)$	-0.76	
$2H_2O(l) + 2e^- \rightleftharpoons H_2(g) + 2OH^-(aq)$	-0.83	
$Cr^{2+}(aq) + 2e^- \rightleftharpoons Cr(s)$	-0.91	
$Se(s) + 2e^- \rightleftharpoons Se^{2-}(aq)$	-0.92	
$SO_4^{2-}(aq) + H_2O(l) + 2e^- \rightleftharpoons SO_3^{2-}(aq) + 2OH^-(aq)$	-0.93	

Table Continued
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Reduction: Half-Reactions		Electrical Potential E° (V)
$\text{Al}^{3+}(\text{aq}) + 3\text{e}^- \rightleftharpoons \text{Al(s)}$		-1.66
$\text{Mg}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Mg(s)}$		-2.37
$\text{Na}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{Na(s)}$		-2.71
$\text{Ca}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Ca(s)}$		-2.87
$\text{Ba}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Ba(s)}$		-2.91
$\text{K}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{K(s)}$		-2.93
$\text{Li}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{Li(s)}$		-3.04

Acid–Base Indicators at 298.15 °K

Indicator	Suggested Abbreviations	pH Range	Colour Change as pH Increases	K_a
1,3,5-trinitrobenzene	$\text{HNb}(\text{aq}) / \text{Nb}^-(\text{aq})$	12.0–14.0	colourless to orange	$\sim 1 \times 10^{-13}$
alizarin yellow R	$\text{HAy}(\text{aq}) / \text{Ay}^-(\text{aq})$	10.1–12.0	yellow to red	6.9×10^{-12}
bromocresol green	$\text{HBg}(\text{aq}) / \text{Bg}^-(\text{aq})$	3.8–5.4	yellow to blue	1.3×10^{-5}
bromothymol blue	$\text{HBb}(\text{aq}) / \text{Bb}^-(\text{aq})$	6.0–7.6	yellow to blue	5.0×10^{-8}
chlorophenol red	$\text{HCh}(\text{aq}) / \text{Ch}^-(\text{aq})$	5.2–6.8	yellow to red	5.6×10^{-7}
cresol red	$\text{H}_2\text{Cr}(\text{aq}) / \text{HCr}^-(\text{aq})$ $\text{HCr}^-(\text{aq}) / \text{Cr}^{2-}(\text{aq})$	0.0–1.0 7.0–8.8	red to yellow yellow to red	$\sim 3 \times 10^{-1}$ 3.5×10^{-9}
indigo carmine	$\text{HIc}(\text{aq}) / \text{Ic}^-(\text{aq})$	11.4–13.0	blue to yellow	$\sim 6 \times 10^{-12}$
methyl orange	$\text{HMo}(\text{aq}) / \text{Mo}(\text{aq})$	3.2–4.4	red to yellow	3.5×10^{-4}
methyl red	$\text{HMr}(\text{aq}) / \text{Mr}(\text{aq})$	4.8–6.0	red to yellow	1.0×10^{-5}
methyl violet	$\text{HMv}(\text{aq}) / \text{Mv}(\text{aq})$	0.0–1.6	yellow to blue	$\sim 2 \times 10^{-1}$
orange IV	$\text{HOr}(\text{aq}) / \text{Or}(\text{aq})$	1.4–2.8	red to yellow	$\sim 1 \times 10^{-2}$
phenol red	$\text{HPr}(\text{aq}) / \text{Pr}(\text{aq})$	6.6–8.0	yellow to red	1.0×10^{-8}
phenolphthalein	$\text{HPh}(\text{aq}) / \text{Ph}(\text{aq})$	8.2–10.0	colourless to pink	3.2×10^{-10}
thymol blue	$\text{H}_2\text{Tb}(\text{aq}) / \text{HTb}^-(\text{aq})$ $\text{HTb}^-(\text{aq}) / \text{Tb}^{2-}(\text{aq})$	1.2–2.8 8.0–9.6	red to yellow yellow to blue	2.2×10^{-2} 6.3×10^{-10}
thymolphthalein	$\text{HTh}(\text{aq}) / \text{Th}^-(\text{aq})$	9.4–10.6	colourless to blue	1.0×10^{-10}

Colours of Common Aqueous Ions

Ionic Species	Solution Concentration	
	1.0 mol/L	0.010 mol/L
chromate	yellow	pale yellow
chromium(II)	dark blue	pale blue
chromium(III)	blue-green	green
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

Names of the Elements

Element	Symbol	Atomic No.
actinium	Ac	89
aluminium	Al	13
americium	Am	95
antimony	Sb	51
argon	Ar	18
arsenic	As	33
astatine	At	85
barium	Ba	56
berkelium	Bk	97
beryllium	Be	4
bismuth	Bi	83
bohrium	Bh	107
boron	B	5
bromine	Br	35
cadmium	Cd	48
caesium	Cs	55
calcium	Ca	20
californium	Cf	98
carbon	C	6
cerium	Ce	58
chlorine	Cl	17
chromium	Cr	24
cobalt	Co	27
copper	Cu	29
curium	Cm	96
dubnium	Db	105
dysprosium	Dy	66
einsteinium	Es	99
erbium	Er	68
europium	Eu	63
fermium	Fm	100
fluorine	F	9
francium	Fr	87
gadolinium	Gd	64
gallium	Ga	31
germanium	Ge	32
gold	Au	79
hafnium	Hf	72
hassium	Hs	108
helium	He	2
holmium	Ho	67
hydrogen	H	1
indium	In	49
iodine	I	53
iridium	Ir	77
iron	Fe	26
krypton	Kr	36
lanthanum	La	57
lawrencium	Lr	103
lead	Pb	82
lithium	Li	3
lutetium	Lu	71
magnesium	Mg	12
manganese	Mn	25
meitnerium	Mt	109

Element	Symbol	Atomic No.
mendelevium	101	
mercury	Hg	80
molybdenum	Mo	42
neodymium	Nd	60
neon	Ne	10
neptunium	Np	93
nickel	Ni	28
niobium	Nb	41
nitrogen	N	7
nobelium	No	102
osmium	Os	76
oxygen	O	8
palladium	Pd	46
phosphorus	P	15
platinum	Pt	78
plutonium	Pu	94
polonium	Po	84
potassium	K	19
praseodymium	Pr	59
promethium	Pm	61
protactinium	Pa	91
radium	Ra	88
radon	Rn	86
rhenium	Re	75
rhodium	Rh	45
rubidium	Rb	37
ruthenium	Ru	44
rutherfordium	Rf	104
samarium	Sm	62
scandium	Sc	21
seaborgium	Sg	106
selenium	Se	34
silicon	Si	14
silver	Ag	47
sodium	Na	11
strontium	Sr	38
sulfur	S	16
tantalum	Ta	73
technetium	Tc	43
tellurium	Te	52
terbium	Tb	65
thallium	Tl	81
thorium	Th	90
thulium	Tm	69
tin	Sn	50
titanium	Ti	22
tungsten	W	74
uranium	U	92
vanadium	V	23
xenon	Xe	54
ytterbium	Yb	70
yttrium	Y	39
zinc	Zn	30
zirconium	Zr	40

First Ionization Energy, Electron Affinity, and Electronegativity of the Elements

Element	First ionization energy (kJ mol ⁻¹)	Electron affinity (kJ mol ⁻¹) 2nd EA (kJ mol ⁻¹)	Electronegativity
Ac	499	-34	1.1
Ag	731	-126	1.9
Al	578	-42	1.6
Ar	1521		
As	947	-79	2.2
At		-270	2.2
Au	890	-223	2.4
B	801	-27	2.0
Ba	503	-14	0.9
Be	900		1.6
Bi	703	-91	1.9
Br	1140	-325	3.0
C	1086	-122	2.6
Ca	590	-2	1.0
Cd	868		1.7
Cl	1251	-349	3.2
Co	758	-64	1.9
Cr	653	-64	1.7
Cs	376	-46	0.8
Cu	746	-119	1.9
F	1681	-328	4.0
Fe	759	-15	1.8
Fr	393	-44	0.7
Ga	579	-41	1.8
Ge	762	-119	2.0
H	1312	-73	2.2
He	2372		
Hf	680		1.3
Hg	1007		1.9
I	1008	-295	2.7
In	558	-29	1.8
Ir	880	-151	2.2
K	419	-48	0.8
Kr	1351		
La	538	-45	1.1
Li	520	-60	1.0
Mg	738		1.3
Mn	717		1.6
Mo	685	-72	2.2
N	1402		3.0

Table Continued
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Element	First ionization energy (kJ mol ⁻¹)	Electron affinity (kJ mol ⁻¹) 2nd EA (kJ mol ⁻¹)	Electronegativity
Na	496	-53	0.9
Nb	664	-86	1.6
Ne	2081		
Ni	737	-112	1.9
O	1314	-141 / +798	3.4
Os	840	-106	2.2
P	1012	-72	2.2
Pb	716	-35	1.8
Pd	805	-54	2.2
Po	812	-183	2.0
Pt	870	-205	2.2
Ra	509	-10	0.9
Rb	403	47	0.8
Re	760	-14	1.9
Rh	720	-110	2.3
Rn	1037		
Ru	711	-101	2.2
S	1000	-200 / +640	2.6
Sb	834	-101	2.1
Sc	631	-18	1.4
Se	941	-195	2.6
Si	789	-134	1.9
Sn	709	-107	2.0
Sr	550	-5	1.0
Ta	761	-31	1.5
Tc	702	-53	2.1
Te	869	-190	2.1
Ti	658	-8	1.5
Tl	589	-19	1.8
V	650	-51	1.6
W	770	-79	1.7
Xe	1170		
Y	616	-30	1.2
Zn	906		1.7
Zr	660	-41	1.3

Covalent Bond Lengths and Bond Enthalpies

Bond	Bond length (nm)	ΔH (kJ mol ⁻¹ at 298 °K)
H–H	0.074	436
C–C	0.154	347
C=C	0.134	612
C≡C	0.120	838
Si–Si	0.235	226
N–N	0.145	158
N=N	0.120	410
N≡N	0.110	945
P–P	0.221	198
O–O	0.148	144
O=O	0.121	498
S–S	0.205	266
S=S	0.189	
F–F	0.142	158
Cl–Cl	0.199	243
Br–Br	0.228	193
I–I	0.267	151
C–H	0.108	413
Si–H	0.148	318
N–H	0.101	391
P–H	0.144	321
O–H	0.096	464
S–H	0.134	364
F–H	0.092	568
Cl–H	0.127	432
Br–H	0.141	366
I–H	0.161	298
C–O	0.143	358
C=O	0.120	746
C–N	0.147	286
C=N	0.130	615
C≡N	0.116	887
C–F	0.138	467
C–Cl	0.177	346
C–Br	0.194	290
C–I	0.214	228
Si–O	0.161	466

Thermodynamic Data of Organic Compounds

Substance	Formula	State	ΔH_f^\ominus (kJ mol $^{-1}$)	ΔG_f^\ominus (kJ mol $^{-1}$)	S^\ominus (J K $^{-1}$ mol $^{-1}$)
benzene	C ₆ H ₆	l	49	125	173
benzoic acid	C ₆ H ₅ COOH	s	-385	-245	
bromoethane	C ₂ H ₅ Br	l	-91		
bromomethane	CH ₃ Br	g	-37	-26	246
but-1-ene	C ₄ H ₈	g	0*	72	306
buta-1,3-diene	C ₄ H ₆	g	110	152	279
butane	C ₄ H ₁₀	g	-127	-16	310
chlorobenzene	C ₆ H ₅ Cl	l	11	94	
chloroethane	C ₂ H ₅ Cl	g	-137	-53	
chloromethane	CH ₃ Cl	g	-82	-57	235
cis-but-2-ene	C ₄ H ₈	g	-8	66	301
cyclohexane	C ₆ H ₁₂	l	-156	27	204
dichloromethane	CH ₂ Cl ₂	l	-124	-63	178
ethanal	CH ₃ CHO	g	-191	-128	160
ethane	C ₂ H ₆	g	-85	-33	230
ethanoic acid	CH ₃ COOH	l	-485	-390	160
ethanol	C ₂ H ₅ OH	l	-277	-175	161
ethene	C ₂ H ₄	g	52	68	220
ethylbenzene	C ₆ H ₅ CH ₂ CH ₃	l	-13	120	255
ethyne	C ₂ H ₂	g	228	209	201
hexane	C ₆ H ₁₄	l	-199	-4	296
iodomethane	CH ₃ I	l	-16	13	163
methanal	HCHO	g	-109	-113	219
methane	CH ₄	g	-75	-51	186
methanoic acid	HCOOH	l	-425	-361	129
methanol	CH ₃ OH	l	-239	-166	240
methylamine	CH ₃ NH ₂	g	-23	32	243
methylbenzene	C ₆ H ₅ CH ₃	l	12	111	320
pentane	C ₅ H ₁₂	l	-173	-9	261
phenol	C ₆ H ₅ OH	s	-165	-48	
phenylethene	C ₆ H ₅ CHCH ₂	l	104	203	345
propane	C ₃ H ₈	g	-105	-23	270
propanone	(CH ₃) ₂ CO	l	-248	-155	
propene	C ₃ H ₆	g	20	75	267
propyne	C ₃ H ₄	g	187	194	248
trans-but-2-ene	C ₄ H ₈	g	-12	63	296
trichloromethane	CHCl ₃	l	-135	-71	202

*(-0.4)

Enthalpies of Combustion

The values of the molar enthalpy of combustion (ΔH_c^\ominus) in the following table refer to a temperature of 298 °K and a pressure of 1.01×10^5 Pa (1 atm).

Substance	Formula	State	ΔH_c^\ominus (kJ mol ⁻¹)
(chloromethyl)benzene	C ₆ H ₅ CH ₂ Cl	l	-3709
benzaldehyde	C ₆ H ₅ CHO	l	-3525
benzene	C ₆ H ₆	l	-3267
benzoic acid	C ₆ H ₅ COOH	s	-3227
bromoethane	C ₂ H ₅ Br	l	-1425
buta-1,3-diene	C ₄ H ₆	g	-2541
butan-1-ol	C ₄ H ₉ OH	l	-2676
butane	C ₄ H ₁₀	g	-2877
carbon (graphite)	C	s	-394
carbon monoxide	CO	g	-283
chloroethane	C ₂ H ₅ Cl	g	-1413
cyclohexane	C ₆ H ₁₂	l	-3920
cyclohexanol	C ₆ H ₁₁ OH	s	-3727
ethanal	CH ₃ CHO	g	-1167
ethanamide	CH ₃ CONH ₂	s	-1185
ethane	C ₂ H ₆	g	-1560
ethanedioic acid	(COOH) ₂	s	-243
ethanoic acid	CH ₃ COOH	l	-874
ethanol	C ₂ H ₅ OH	l	-1367
ethene	C ₂ H ₄	g	-1411
ethoxyethane	(C ₂ H ₅) ₂ O	l	-2724
ethyl ethanoate	CH ₃ COOC ₂ H ₅	l	-2238
ethylamine	C ₂ H ₅ NH ₂	g	-1740
ethyne	C ₂ H ₂	g	-1301
glucose	C ₆ H ₁₂ O ₆	s	-2803
hexane	C ₆ H ₁₄	l	-4163
hydrogen	H ₂	g	-286
iodoethane	C ₂ H ₅ I	l	-1467
methanal	HCHO	g	-571
methane	CH ₄	g	-890
methanoic acid	HCOOH	l	-254
methanol	CH ₃ OH	l	-726
methylamine	CH ₃ NH ₂	g	-1085
methylbenzene	C ₆ H ₅ CH ₃	l	-3910
naphthalene	C ₁₀ H ₈	s	-5156
nitrobenzene	C ₆ H ₅ NO ₂	l	-3088
octane	C ₈ H ₁₈	l	-5470
pentan-3-one	(C ₂ H ₅) ₂ CO	l	-3100
pentane	C ₅ H ₁₂	l	-3509

Table Continued
On Next Page

Substance	Formula	State	$\Delta H_c^\circ \text{ (kJ mol}^{-1}\text{)}$
phenol	C ₆ H ₅ OH	s	-3053
phenylamine	C ₆ H ₅ NH ₂	l	-3393
phenylethanone	CH ₃ COC ₆ H ₅	l	-4149
propan-1-ol	C ₃ H ₇ OH	l	-2021
propane	C ₃ H ₈	g	-2219
propanone	(CH ₃) ₂ CO	l	-1817
sucrose	C ₁₂ H ₂₂ O ₁₁	s	-5640
sulfur	S	s	-297
trichloromethane	CHCl ₃	l	-474
urea	CO(NH ₂) ₂	s	-632

Standard Electrode Potentials

Oxidized species	\rightleftharpoons	Reduced species	E^o (V)
Li ⁺ (aq) + e ⁻	\rightleftharpoons	Li(s)	-3.04
K ⁺ (aq) + e ⁻	\rightleftharpoons	K(s)	-2.93
Ca ²⁺ (aq) + 2e ⁻	\rightleftharpoons	Ca(s)	-2.87
Na ⁺ (aq) + e ⁻	\rightleftharpoons	Na(s)	-2.71
Mg ²⁺ (aq) + 2e ⁻	\rightleftharpoons	Mg(s)	-2.37
Al ³⁺ (aq) + 3e ⁻	\rightleftharpoons	Al(s)	-1.66
Mn ²⁺ (aq) + 2e ⁻	\rightleftharpoons	Mn(s)	-1.19
H ₂ O(l) + e ⁻	\rightleftharpoons	½H ₂ (g) + OH ⁻ (aq)	-0.83
Zn ²⁺ (aq) + 2e ⁻	\rightleftharpoons	Zn(s)	-0.76
Fe ²⁺ (aq) + 2e ⁻	\rightleftharpoons	Fe(s)	-0.45
Ni ²⁺ (aq) + 2e ⁻	\rightleftharpoons	Ni(s)	-0.26
Sn ²⁺ (aq) + 2e ⁻	\rightleftharpoons	Sn(s)	-0.14
Pb ²⁺ (aq) + 2e ⁻	\rightleftharpoons	Pb(s)	-0.13
H ⁺ (aq) + e ⁻	\rightleftharpoons	½H ₂ (g)	0.00
Cu ²⁺ (aq) + e ⁻	\rightleftharpoons	Cu ⁺ (aq)	+0.15
SO ₄ ²⁻ (aq) + 4H ⁺ (aq) + 2e ⁻	\rightleftharpoons	H ₂ SO ₃ (aq) + H ₂ O(l)	+0.17
Cu ²⁺ (aq) + 2e ⁻	\rightleftharpoons	Cu(s)	+0.34
½O ₂ (g) + H ₂ O(l) + 2e ⁻	\rightleftharpoons	2OH ⁻ (aq)	+0.40
Cu ⁺ (aq) + e ⁻	\rightleftharpoons	Cu(s)	+0.52
½I ₂ (s) + e ⁻	\rightleftharpoons	I ⁻ (aq)	+0.54
Fe ³⁺ (aq) + e ⁻	\rightleftharpoons	Fe ²⁺ (aq)	+0.77
Ag ⁺ (aq) + e ⁻	\rightleftharpoons	Ag(s)	+0.80
½Br ₂ (l) + e ⁻	\rightleftharpoons	Br ⁻ (aq)	+1.07
½O ₂ (g) + 2H ⁺ (aq) + 2e ⁻	\rightleftharpoons	H ₂ O(l)	+1.23
Cr ₂ O ₇ ²⁻ (aq) + 14H ⁺ (aq) + 6e ⁻	\rightleftharpoons	2Cr ³⁺ (aq) + 7H ₂ O(l)	+1.33
½Cl ₂ (g) + e ⁻	\rightleftharpoons	Cl ⁻ (aq)	+1.36
MnO ₄ ⁻ (aq) + 8H ⁺ (aq) + 5e ⁻	\rightleftharpoons	Mn ²⁺ (aq) + 4H ₂ O(l)	+1.51
½F ₂ (g) + 2e ⁻	\rightleftharpoons	F ⁻ (aq)	+2.87

Strengths of Organics

The acid strengths in the following tables are given in terms of pK_a values, where $pK_a = -\log_{10} K_a$.

The dissociation constant K_a values are for aqueous solutions at 298 °K.

Carboxylic acids

Name	Formula	pK_a
methanoic	HCOOH	3.75
ethanoic	CH ₃ COOH	4.76
propanoic	CH ₃ CH ₂ COOH	4.87
butanoic	CH ₃ (CH ₂) ₂ COOH	4.83
2-methylpropanoic	(CH ₃) ₂ CHCOOH	4.84
pentanoic	CH ₃ (CH ₂) ₃ COOH	4.83
2,2-dimethylpropanoic	(CH ₃) ₃ CCOOH	5.03
benzoic	C ₆ H ₅ COOH	4.20
phenylethanoic	C ₆ H ₅ CH ₂ COOH	4.31

Halogenated carboxylic acids

Name	Formula	pK_a
chloroethanoic	CH ₂ ClCOOH	2.87
dichloroethanoic	CHCl ₂ COOH	1.35
trichloroethanoic	CCl ₃ COOH	0.66
fluoroethanoic	CH ₂ FCOOH	2.59
bromoethanoic	CH ₂ BrCOOH	2.90
iodoethanoic	CH ₂ I ⁻ COO ⁻	3.18

Phenols

Name	Formula	pK_a
phenol	C ₆ H ₅ OH	9.99
2-nitrophenol	O ₂ NC ₆ H ₄ OH	7.23
3-nitrophenol	O ₂ NC ₆ H ₃ OH	8.36
4-nitrophenol	O ₂ NC ₆ H ₂ OH	7.15
2,4-dinitrophenol	(O ₂ N) ₂ C ₆ H ₃ OH	4.07
2,4,6-trinitrophenol	(O ₂ N) ₃ C ₆ H ₂ OH	0.42

Alcohols

Name	Formula	pK_a
ethanol	C ₂ H ₅ OH	15.5
methanol	CH ₃ OH	15.5

Amines

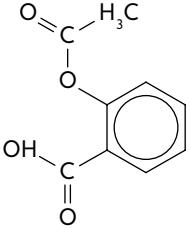
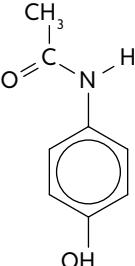
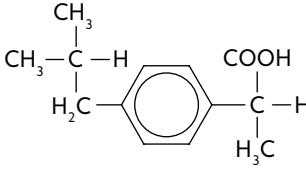
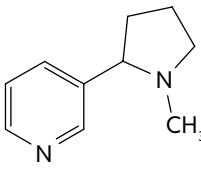
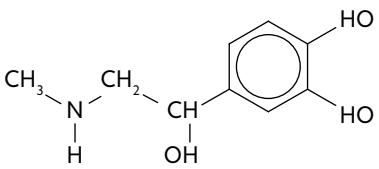
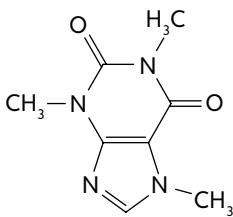
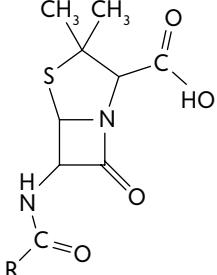
Name	Formula	pK _a
ammonia	NH ₃	4.75
methylamine	CH ₃ NH ₂	3.34
ethylamine	CH ₃ CH ₂ NH ₂	3.35
dimethylamine	(CH ₃) ₂ NH	3.27
trimethylamine	(CH ₃) ₃ N	4.20
diethylamine	(C ₂ H ₅) ₂ NH	3.16
triethylamine	(C ₂ H ₅) ₃ N	3.25
phenylamine	C ₆ H ₅ NH ₂	9.13

Acid–Base Indicators

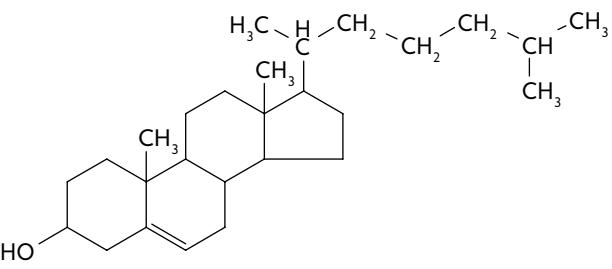
Indicator	pK _a	pH range	Colour change	
			Acid	Alkali
bromocresol green	4.90	3.8–5.4	yellow	blue
bromophenol blue	4.10	3.0–4.6	yellow	blue
bromothymol blue	7.30	6.0–7.6	yellow	blue
methyl orange	3.46	3.2–4.4	red	yellow
methyl red	5.00	4.8–6.0	red	yellow
phenol red	8.00	6.6–8.0	yellow	red
phenolphthalein	9.50	8.2–10.0	colourless	pink

Examples of Structural Formulas

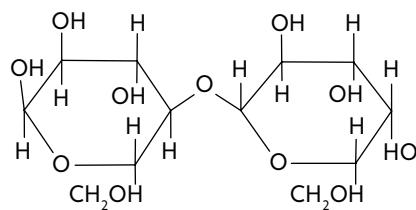
Medicines and Drugs

 aspirin	 paracetamol (acetaminophen)	 ibuprofen
 nicotine	 epinephrine (adrenaline)	 caffeine
 penicillin (general structure)		

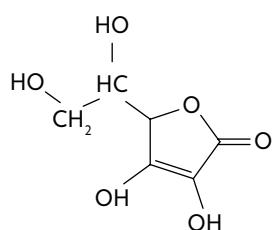
Biological Molecules



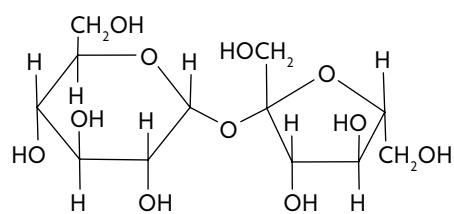
cholesterol



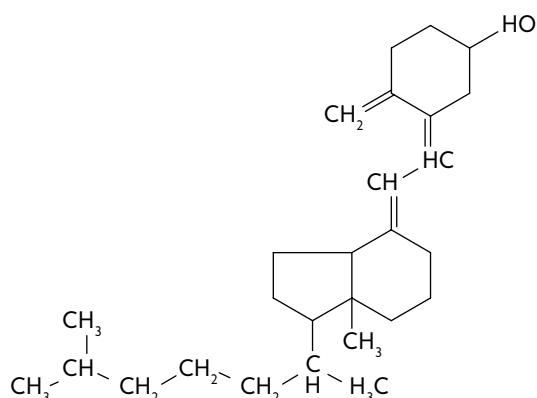
lactose



ascorbic acid (vitamin C)



sucrose



vitamin D

Examples of Common Ion Names, Formulas, and Charges

Positive Ions (Cations)		Negative Ions (Anions)	
Name	Formula/Charge	Name	Formula/Charge
Aluminum	Al^{3+}	Bromide	Br^-
Ammonium	NH_4^+	Carbonate	CO_3^{2-}
Barium	Ba^{2+}	Chlorate	ClO_3^-
Calcium	Ca^{2+}	Chloride	Cl^-
Chromium(II), chromous	Cr^{2+}	Chlorite	ClO_2^-
Chromium(III), chromic	Cr^{3+}	Chromate	CrO_4^{2-}
Copper(I)*, cuprous	Cu^+	Cyanide	CN^-
Copper(II), cupric	Cu^{2+}	Dichromate	$\text{Cr}_2\text{O}_7^{2-}$
Hydrogen	H^+	Dihydrogen phosphate	H_2PO_4^-
Hydronium	H_3O^+	Ethanoate, acetate	CH_3COO^-
Iron(II)*, ferrous	Fe^{2+}	Fluoride	F^-
Iron(III), ferric	Fe^{3+}	Hydrogen carbonate, bicarbonate	HCO_3^-
Lead(II), plumbous	Pb^{2+}	Hydrogen oxalate, binoxalate	HC_2O_4^-
Lead(IV), plumbic	Pb^{4+}	Hydrogen sulphate, bisulphate	HSO_4^-
Lithium	Li^+	Hydrogen sulphide, bisulphide	HS^-
Magnesium	Mg^{2+}	Hydrogen sulphite, bisulphite	HSO_3^-
Manganese(II), manganous	Mn^{2+}	Hydroxide	OH^-
Manganese(IV)	Mn^{4+}	Hypochlorite	ClO^-
Mercury(I)*, mercurous	Hg_2^{2+}	Iodide	I^-
Mercury(II), mercuric	Hg^{2+}	Monohydrogen phosphate	HPO_4^{2-}
Potassium	K^+	Nitrate	NO_3^-
Silver	Ag^+	Nitrite	NO_2^-
Sodium	Na^+	Oxalate	$\text{C}_2\text{O}_4^{2-}$
Tin(II)*, stannous	Sn^{2+}	Oxide**	O^{2-}
Tin(IV), stannic	Sn^{4+}	Perchlorate	ClO_4^-
Zinc	Zn^{2+}	Permanganate	MnO_4^-

* Aqueous solutions are readily oxidized by air.

** This ion is not stable in aqueous solutions.

Solubility of Common Compounds in Water

Soluble here means $> 0.1 \text{ mol/L}$ at 25°C .

Negative Ions (Anions)	Positive Ions (Cations)	Solubility of Compounds	
All	Alkali ions: Li^+ , Na^+ , K^+ , Rb^+ , Cs^+ , Fr^+	Soluble	
All	Hydrogen ion: H^+	Soluble	
All	Ammonium ion: NH_4^+	Soluble	
Nitrate, NO_3^-	All	Soluble	
Chloride, Cl^- or Bromide, Br^- or Iodide, I^-	All others	Soluble	
	Ag^+ , Pb^{2+} , Cu^+		Low Solubility
Sulphate, SO_4^{2-}	All others	Soluble	
	Ag^+ , Ca^{2+} , Sr^{2+} , Ba^{2+} , Pb^{2+}		Low Solubility
Sulphide, S^{2-}	Alkali ions, H^+ , NH_4^+ , Be^{2+} , Mg^{2+} , Ca^{2+} , Sr^{2+} , Ba^{2+}	Soluble	
	All others		Low Solubility
Hydroxide, OH^-	Alkali ions, H^+ , NH_4^+ , Sr^{2+}	Soluble	
	All others		Low Solubility
Phosphate, PO_4^{3-} or Carbonate, CO_3^{2-} or Sulphite, SO_3^{2-}	Alkali ions, H^+ , NH_4^+	Soluble	
	All others		Low Solubility

Solubility Product Constants at 25°C

Name	Formula	K_{sp}
Barium carbonate	BaCO_3	2.6×10^{-9}
Barium chromate	BaCrO_4	1.2×10^{-10}
Barium sulphate	BaSO_4	1.1×10^{-10}
Calcium carbonate	CaCO_3	5.0×10^{-9}
Calcium oxalate	CaC_2O_4	2.3×10^{-9}
Calcium sulphate	CaSO_4	7.1×10^{-5}
Copper(I) iodide	CuI	1.3×10^{-12}
Copper(II) iodate	$\text{Cu}(\text{IO}_3)_2$	6.9×10^{-8}
Copper(II) sulphide	CuS	6.0×10^{-37}
Iron(II) hydroxide	Fe(OH)_2	4.9×10^{-17}
Iron(II) sulphide	FeS	6.0×10^{-19}
Iron(III) hydroxide	Fe(OH)_3	2.6×10^{-39}
Lead(II) bromide	PbBr_2	6.6×10^{-6}
Lead(II) chloride	PbCl_2	1.2×10^{-5}
Lead(II) iodate	$\text{Pb}(\text{IO}_3)_2$	3.7×10^{-13}
Lead(II) iodide	PbI_2	8.5×10^{-9}
Lead(II) sulphate	PbSO_4	1.8×10^{-8}
Magnesium carbonate	MgCO_3	6.8×10^{-6}
Magnesium hydroxide	Mg(OH)_2	5.6×10^{-12}
Silver bromate	AgBrO_3	5.3×10^{-5}
Silver bromide	AgBr	5.4×10^{-13}
Silver carbonate	Ag_2CO_3	8.5×10^{-12}
Silver chloride	AgCl	1.8×10^{-10}
Silver chromate	Ag_2CrO_4	1.1×10^{-12}
Silver iodate	AgIO_3	3.2×10^{-8}
Silver iodide	AgI	8.5×10^{-17}
Strontium carbonate	SrCO_3	5.6×10^{-10}
Strontium fluoride	SrF_2	4.3×10^{-9}
Strontium sulphate	SrSO_4	3.4×10^{-7}
Zinc sulphide	ZnS	2.0×10^{-25}

Brønsted-Lowry Acids and Bases

The following table shows the relative strengths of acids and bases in aqueous solution at room temperature.

	Name of Acid	Acid	Base	K_a
Strong	Perchloric	$\text{HClO}_4 \rightarrow \text{H}^+ + \text{ClO}_4^-$		very large
	Hydriodic	$\text{HI} \rightarrow \text{H}^+ + \text{I}^-$		very large
	Hydrobromic	$\text{HBr} \rightarrow \text{H}^+ + \text{Br}^-$		very large
	Hydrochloric	$\text{HCl} \rightarrow \text{H}^+ + \text{Cl}^-$		very large
	Nitric	$\text{HNO}_3 \rightarrow \text{H}^+ + \text{NO}_3^-$		very large
	Sulphuric	$\text{H}_2\text{SO}_4 \rightarrow \text{H}^+ + \text{HSO}_4^-$		very large
	Hydronium Ion	$\text{H}_3\text{O}^+ \rightleftharpoons \text{H}^+ + \text{H}_2\text{O}$		1.0
	Iodic	$\text{HIO}_3 \rightleftharpoons \text{H}^+ + \text{IO}_3^-$		1.7×10^{-1}
	Oxalic	$\text{H}_2\text{C}_2\text{O}_4 \rightleftharpoons \text{H}^+ + \text{HC}_2\text{O}_4^-$		5.9×10^{-2}
	Hydrogen sulphate ion	$\text{HSO}_4^- \rightleftharpoons \text{H}^+ + \text{SO}_4^{2-}$		1.2×10^{-2}
	Phosphoric	$\text{H}_3\text{PO}_4 \rightleftharpoons \text{H}^+ + \text{H}_2\text{PO}_4^-$		7.5×10^{-3}
	Iron(III) ion	$\text{Fe}(\text{H}_2\text{O})_6^{3+} \rightleftharpoons \text{H}^+ + \text{Fe}(\text{H}_2\text{O})_5(\text{OH})^{2+}$		6.0×10^{-3}
	Citric	$\text{H}_3\text{C}_6\text{H}_5\text{O}_7 \rightleftharpoons \text{H}^+ + \text{H}_2\text{C}_6\text{H}_5\text{O}_7^-$		7.1×10^{-4}
	Nitrous	$\text{HNO}_2 \rightleftharpoons \text{H}^+ + \text{NO}_2^-$		4.6×10^{-4}
	Hydrofluoric	$\text{HF} \rightleftharpoons \text{H}^+ + \text{F}^-$		3.5×10^{-4}
	Methanoic formic	$\text{HCOOH} \rightleftharpoons \text{H}^+ + \text{HCOO}^-$		1.8×10^{-4}
	Ethanoic (acetic)	$\text{CH}_3\text{COOH} \rightleftharpoons \text{H}^+ + \text{CH}_3\text{COO}^-$		1.8×10^{-5}
	Carbonic ($\text{CO}_2 + \text{H}_2\text{O}$)	$\text{H}_2\text{CO}_3 \rightleftharpoons \text{H}^+ + \text{HCO}_3^-$		4.3×10^{-7}
	Hydrogen sulphite ion	$\text{HSO}_3^- \rightleftharpoons \text{H}^+ + \text{SO}_3^{2-}$		1.0×10^{-7}
	Hydrogen sulphide	$\text{H}_2\text{S} \rightleftharpoons \text{H}^+ + \text{HS}^-$		9.1×10^{-8}
	Dihydrogen phosphate ion	$\text{H}_2\text{PO}_4^- \rightleftharpoons \text{H}^+ + \text{HPO}_4^{2-}$		6.2×10^{-8}
	Boric	$\text{H}_3\text{BO}_3 \rightleftharpoons \text{H}^+ + \text{H}_2\text{BO}_3^-$		7.3×10^{-10}
	Ammonium ion	$\text{NH}_4^+ \rightleftharpoons \text{H}^+ + \text{NH}_3$		5.6×10^{-10}
	Hydrocyanic	$\text{HCN} \rightleftharpoons \text{H}^+ + \text{CN}^-$		4.9×10^{-10}
	Hydrogen carbonate ion	$\text{HCO}_3^- \rightleftharpoons \text{H}^+ + \text{CO}_3^{2-}$		5.6×10^{-11}
	Hydrogen peroxide	$\text{H}_2\text{O}_2 \rightleftharpoons \text{H}^+ + \text{HO}_2^-$		2.4×10^{-12}
	Monohydrogen phosphate ion	$\text{HPO}_4^{2-} \rightleftharpoons \text{H}^+ + \text{PO}_4^{3-}$		2.2×10^{-13}
	Water	$\text{H}_2\text{O} \rightleftharpoons \text{H}^+ + \text{OH}^-$		1.0×10^{-14}
Weak	Hydroxide ion	$\text{OH}^- \leftarrow \text{H}^+ + \text{O}^{2-}$		very small
	Ammonia	$\text{NH}_3 \leftarrow \text{H}^+ + \text{NH}_2^-$		very small

Standard Reduction Potentials of Half-Cells

Ionic concentrations are at 1 M (mol/L) in water at 25°C.

Oxidizing Agents		Reducing Agents	E° (Volts)
$F_{2(g)} + 2e^-$	\rightleftharpoons	$2F^-$	+2.87
$S_2O_8^{2-} + 2e^-$	\rightleftharpoons	$2SO_4^{2-}$	+2.01
$H_2O_2 + 2H^+ + 2e^-$	\rightleftharpoons	$2H_2O$	+1.78
$MnO_4^- + 8H^+ + 5e^-$	\rightleftharpoons	$Mn^{2+} + 4H_2O$	+1.51
$Au^{3+} + 3e^-$	\rightleftharpoons	$Au_{(s)}$	+1.50
$BrO_3^- + 6H^+ + 5e^-$	\rightleftharpoons	$Br_{2(l)} + 3H_2O$	+1.48
$ClO_4^- + 8H^+ + 8e^-$	\rightleftharpoons	$Cl^- + 4H_2O$	+1.39
$Cl_{2(g)} + 2e^-$	\rightleftharpoons	$2Cl^-$	+1.36
$Cr_2O_7^{2-} + 14H^+ + 2e^-$	\rightleftharpoons	$2Cr^{3+} + 7H_2O$	+1.23
$O_{2(g)} + 2H^+ + 2e^-$	\rightleftharpoons	H_2O	+1.23
$MnO_{2(s)} + 4H^+ + 2e^-$	\rightleftharpoons	$Mn^{2+} + 2H_2O$	+1.22
$IO_3^- + 6H^+ + 5e^-$	\rightleftharpoons	$I_{2(s)} + 3H_2O$	+1.20
$Br_{2(l)} + 2e^-$	\rightleftharpoons	$2Br^-$	+1.09
$AuCl_4^- + 3e^-$	\rightleftharpoons	$Au_{(s)} + 4Cl^-$	+1.00
$NO_3^- + 4H^+ + 3e^-$	\rightleftharpoons	$NO_{(g)} + 2H_2O$	+0.96
$Hg^{2+} + 2e^-$	\rightleftharpoons	$Hg_{(l)}$	+0.85
$O_{2(g)} + 2H^+(10^{-7}M) + 2e^-$	\rightleftharpoons	H_2O	+0.82
$2NO_3^- + 4H^+ + 2e^-$	\rightleftharpoons	$N_2O_4 + 2H_2O$	+0.80
$Ag^+ + e^-$	\rightleftharpoons	$Ag_{(s)}$	+0.80
$Hg_2^{2+} + e^-$	\rightleftharpoons	$Hg_{(l)}$	+0.80
$Fe^{3+} + e^-$	\rightleftharpoons	Fe^{2+}	+0.77
$O_{2(g)} + 2H^+ + 2e^-$	\rightleftharpoons	H_2O_2	+0.70
$MnO_4^- + 2H_2O + 3e^-$	\rightleftharpoons	$MnO_{2(s)} + 4OH^-$	+0.60
$I_{2(s)} + 2e^-$	\rightleftharpoons	$2I^-$	+0.54
$Cu^+ + e^-$	\rightleftharpoons	$Cu_{(s)}$	+0.52
$H_2SO_3 + 4H^+ + 4e^-$	\rightleftharpoons	$S_{(s)} + 3H_2O$	+0.45
$Cu_2 + 2e^-$	\rightleftharpoons	$Cu_{(s)}$	+0.34
$SO_4^{2-} + 4H^+ + 2e^-$	\rightleftharpoons	$H_2SO_3 + H_2O$	+0.17
$Cu^{2+} + e^-$	\rightleftharpoons	Cu^+	+0.15
$Sn^{4+} + 2e^-$	\rightleftharpoons	Sn^{2+}	+0.15
$S_{(s)} + 2H^+ + 2e^-$	\rightleftharpoons	$H_2S_{(g)}$	+0.14
$2H^+ + 2e^-$	\rightleftharpoons	$H_{2(g)}$	+0.00
$Pb^{2+} + 2e^-$	\rightleftharpoons	$PB_{(s)}$	-0.13
$Sn^{2+} + 2e^-$	\rightleftharpoons	$Sn_{(s)}$	-0.14
$Ni^{2+} + 2e^-$	\rightleftharpoons	$Ni_{(s)}$	-0.26
$H_3PO_4 + 2H^+ + 2e^-$	\rightleftharpoons	$H_3PO_3 + H_2O$	-0.28
$Co^{2+} + 2e^-$	\rightleftharpoons	$Co_{(s)}$	-0.28
$Se_{(s)} + 2H^+ + 2e^-$	\rightleftharpoons	H_2Se	-0.40
$Cr^{3+} + e^-$	\rightleftharpoons	Cr^{2+}	-0.41

Table Continued
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Strength of Oxidizing Agent	Oxidizing Agents	Reducing Agents	E° (Volts)	Strength of Oxidizing Agent
Strong	$2\text{H}_2\text{O} + 2\text{e}^-$	$\uparrow\!\!\!\uparrow$	$\text{H}_2 + 2\text{OH}^-(10^{-7} \text{ M})$	-0.41
	$\text{Fe}^{2+} + 2\text{e}^-$	$\uparrow\!\!\!\uparrow$	$\text{Fe}_{(s)}$	-0.45
	$\text{Ag}_2\text{S}_{(s)} + 2\text{e}^-$	$\uparrow\!\!\!\uparrow$	$2\text{Ag}_{(s)} + \text{S}^{2-}$	-0.69
	$\text{Cr}^{3+} + 3\text{e}^-$	$\uparrow\!\!\!\uparrow$	$\text{Cr}_{(s)}$	-0.74
	$\text{Zn}^{2+} + 2\text{e}^-$	$\uparrow\!\!\!\uparrow$	$\text{Zn}_{(s)}$	-0.76
	$\text{Te}_{(s)} + 2\text{H}^+ + 2\text{e}^-$	$\uparrow\!\!\!\uparrow$	H_2Te	-0.79
	$2\text{H}_2\text{O} + 2\text{e}^-$	$\uparrow\!\!\!\uparrow$	$\text{H}_{2(g)} + 2\text{OH}^-$	-0.83
	$\text{Mn}^{2+} + 2\text{e}^-$	$\uparrow\!\!\!\uparrow$	$\text{Mn}_{(s)}$	-1.19
	$\text{Al}^{3+} + 3\text{e}^-$	$\uparrow\!\!\!\uparrow$	$\text{Al}_{(s)}$	-1.66
	$\text{Mg}^{2+} + 2\text{e}^-$	$\uparrow\!\!\!\uparrow$	$\text{Mg}_{(s)}$	-2.37
	$\text{Na}^+ + 2\text{e}^-$	$\uparrow\!\!\!\uparrow$	$\text{Ma}_{(s)}$	-2.71
	$\text{Ca}^{2+} + 2\text{e}^-$	$\uparrow\!\!\!\uparrow$	$\text{Ca}_{(s)}$	-2.87
	$\text{Sr}^{2+} + 2\text{e}^-$	$\uparrow\!\!\!\uparrow$	$\text{Sr}_{(s)}$	-2.89
	$\text{Ba}^{2+} + 2\text{e}^-$	$\uparrow\!\!\!\uparrow$	$\text{Ba}_{(s)}$	-2.91
Weak	$\text{K}^+ + \text{e}^-$	$\uparrow\!\!\!\uparrow$	$\text{K}_{(s)}$	-2.93
	$\text{Rb}^+ + \text{e}^-$	$\uparrow\!\!\!\uparrow$	$\text{Rb}_{(s)}$	-2.98
	$\text{Cs}^+ + \text{e}^-$	$\uparrow\!\!\!\uparrow$	$\text{Cs}_{(s)}$	-3.03
	$\text{Li}^+ + \text{e}^-$	$\uparrow\!\!\!\uparrow$	$\text{Li}_{(s)}$	-3.04

Acid to Base Indicators

Indicator	pH Range in Which Colour Change Occurs	Colour Change as pH Increases
Methyl violet	0.0 to 1.6	yellow to blue
Thymol blue	1.2 to 2.8	red to yellow
Orange IV	1.4 to 2.8	red to yellow
Methyl orange	3.2 to 4.4	red to yellow
Brom cresol green	3.8 to 5.4	yellow to blue
Methyl red	4.8 to 6.0	red to yellow
Chlorophenol red	5.2 to 6.8	yellow to red
Brom thymol blue	6.0 to 7.6	yellow to blue
Phenol red	6.6 to 8.0	yellow to red
Neutral red	6.8 to 8.0	red to amber
Thymol blue	8.0 to 9.6	yellow to blue
Phenolphthalein	8.2 to 10.0	colourless to pink
Thymolphthalein	9.4 to 10.6	colourless to blue
Alizarin yellow	10.1 to 12.0	yellow to red
Indigo carmine	11.4 to 13.0	blue to yellow

Solubility Table

	F^-	Cl^-	Br^-	I^-	NO_3^-	ClO_3^-	CH_3COO^-	OH^-	S^{2-}	SO_4^{2-}	CO_3^{2-}	PO_4^{3-}
NH_4^+	S	S	S	S	S	S	S	S	S	S	S	S
Na^+	S	S	S	S	S	S	S	S	S	S	S	S
K^+	S	S	S	S	S	S	S	S	S	S	S	S
Mg^{2+}	i	S	S	S	S	S	S	i	-	S	i	i
Ca^{2+}	i	S	S	S	S	S	S	*	i	*	i	i
Sr^{2+}	i	S	S	S	S	S	S	*	*	i	i	i
Ba^{2+}	*	S	S	S	S	S	S	S	*	i	i	i
Cr^{3+}	i	S	S	-	S	-	S	-	i	S	-	-
Mn^{2+}	*	S	S	S	S	-	S	i	i	S	i	-
Fe^{2+}	*	S	S	S	S	-	S	i	i	*	i	i
Fe^{3+}	*	S	S	-	S	-	-	-	i	*	-	i
Co^{2+}	S	S	S	S	S	S	S	i	i	S	i	i
Ni^{2+}	S	S	S	S	S	S	-	i	i	S	i	i
Cu^{2+}	S	S	S	-	S	S	S	i	i	S	-	i
Ag^+	S	i	i	i	S	S	S	-	i	*	i	i
Zn^{2+}	S	S	S	S	S	S	S	i	i	S	i	i
Cd^{2+}	S	S	S	S	S	S	S	i	i	S	i	i
Hg_2^{2+}	-	i	i	i	-	S	*	-	i	i	i	-
Hg^{2+}	-	S	*	i	S	S	S	-	i	-	-	-
Al^{3+}	*	S	S	S	S	S	-	i	-	S	-	i
Sn^{2+}	S	S	S	S	-	-	-	-	i	S	-	i
Sn^{4+}	S	S	S	S	-	-	-	-	i	S	-	-
Pb^{2+}	i	*	*	i	S	S	S	i	i	i	i	i

s = soluble * = slightly soluble i = insoluble - = solubility data unavailable

Standard Heats of Formation at 298.15 K (25°C)

Name	Formula	ΔH_f° (kJ/mol)
aluminum oxide	$\text{Al}_2\text{O}_3(\text{s})$	-1675.7
ammonia	$\text{NH}_3(\text{g})$	-46.1
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	$\text{BaCO}_3(\text{s})$	-1216.3
barium chloride	$\text{BaCl}_2(\text{s})$	-858.6
barium hydroxide	$\text{Ba(OH)}_2(\text{s})$	-944.7
barium oxide	$\text{BaO}(\text{s})$	-553.5
barium sulphate	$\text{BaSO}_4(\text{s})$	-1473.2
benzene	$\text{C}_6\text{H}_6(\text{l})$	+49.0
butane	$\text{C}_4\text{H}_{10}(\text{g})$	-126.5
calcium carbonate	$\text{CaCO}_3(\text{s})$	-1206.9
calcium chloride	$\text{CaCl}_2(\text{s})$	-795.8
calcium hydroxide	$\text{Ca(OH)}_2(\text{s})$	-986.1
calcium oxide	$\text{CaO}(\text{s})$	-635.1
calcium sulphate	$\text{CaSO}_4(\text{s})$	-1434.1
carbon dioxide	$\text{CO}_2(\text{g})$	-393.5
carbon monoxide	$\text{CO}(\text{g})$	-110.5
chromium(III) oxide	$\text{Cr}_2\text{O}_3(\text{s})$	-1139.7
copper(I) oxide	$\text{Cu}_2\text{O}(\text{s})$	-168.6
copper(II) oxide	$\text{CuO}(\text{s})$	-157.3
copper(II) sulphate	$\text{CuSO}_4(\text{s})$	-771.4
copper(I) sulphide	$\text{Cu}_2\text{S}(\text{s})$	-79.5
copper(II) sulphide	$\text{CuS}(\text{s})$	-53.1
ethane	$\text{C}_2\text{H}_6(\text{g})$	-84.7
ethanoic acid (acetic acid)	$\text{CH}_3\text{COOH}(\text{l})$	-484.5
ethanol	$\text{C}_2\text{H}_5\text{OH}(\text{l})$	-277.1
ethane (ethylene)	$\text{C}_2\text{H}_4(\text{g})$	+52.3
ethyne (acetylene)	$\text{C}_2\text{H}_2(\text{g})$	+226.7
glucose	$\text{C}_6\text{H}_{12}\text{O}_6(\text{s})$	-1273.1
hydrogen bromide	$\text{HBr}(\text{g})$	-36.4
hydrogen chloride	$\text{HCl}(\text{g})$	-92.3
hydrogen fluoride	$\text{HF}(\text{g})$	-271.1
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 sulphide	$\text{H}_2\text{S}(\text{g})$	-20.6
iron(III) oxide	$\text{Fe}_2\text{O}_3(\text{s})$	-824.2
iron(II,III) oxide (magnetite)	$\text{Fe}_3\text{O}_4(\text{s})$	-1118.4
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	$\text{MgCO}_3(\text{s})$	-1095.8

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Name	Formula	ΔH_f° (kJ/mol)
magnesium chloride	MgCl ₂ (s)	-641.3
magnesium hydroxide	Mg(OH) ₂ (s)	-924.5
magnesium oxide	MgO(s)	-601.7
magnesium sulphate	MgSO ₄ (s)	-1284.9
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) sulphide (red)	HgS(s)	-58.2
methanol (formaldehyde)	CH ₂ O(g)	-115.9
methane	CH ₄ (g)	-74.8
methanoic acid (formic acid)	HCOOH(l)	-424.7
methanol	CH ₃ OH(l)	-239.0
nickel(II) oxide	NiO(s)	-239.7
nitric acid	HNO ₃ (l)	-174.1
nitrogen dioxide	N ₂ O ₂ (g)	+33.2
nitrogen monoxide	N ₂ O(g)	+90.2
octane	C ₈ H ₁₈ (l)	-250.0
pentane	C ₅ H ₁₂ (l)	-146.4
phosphorus pentachloride	PCl ₅ (s)	-443.5
phosphorus trichloride (liquid)	PCl ₃ (l)	-319.7
phosphorus trichloride (vapor)	PCl ₃ (g)	-287.0
potassium bromide	KBr(s)	-393.8
potassium chlorate	KClO ₃ (s)	-397.7
potassium chloride	KCl(s)	-436.7
potassium hydroxide	KOH(s)	-424.8
propane	C ₃ H ₈ (g)	-103.8
silicon dioxide	SiO ₂ (s)	-910.9
silver bromide	AgBr(s)	-100.4
silver chloride	AgCl(s)	-127.1
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)	-2225.5
sulphur dioxide	SO ₂ (g)	-296.8
sulphuric acid	H ₂ SO ₄ (l)	-814.0
sulphur trioxide (liquid)	SO ₃ (l)	-441.0
sulphur trioxide (vapor)	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)	-285.8
tin(IV) oxide	SnO ₂ (s)	-580.7
water (liquid)	H ₂ O(l)	-285.8
water (vapor)	H ₂ O(g)	-241.8
zinc oxide	ZnO(s)	-348.3
zinc sulphide	ZnS(s)	-206.0

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