C1 Units, Symbols, and Prefixes

Throughout *Nelson Chemistry 12* and in this reference section, we have attempted to be consistent in the presentation and usage of quantities, units, and their symbols. As far as possible, the text uses the Système international d'unités (SI). However, some other units have been included because of their practical importance, wide usage, or use in specialized fields. In our interpretations and usage, *Nelson Chemistry 12* has followed the most recent *Canadian Metric Practice Guide* (CAN/CSA–Z234.1–89), published in 1989 and reaffirmed in 1995 by the Canadian Standards Association.

Numerical Prefixies

Prefix	Power	Symbol
deca-	10^{1}	da
hecto-	10^{2}	h
kilo-	10^{3}	k*
mega-	10^{6}	M*
giga-	10^{9}	G*
tera-	10^{12}	T
peta-	10^{15}	P
exa-	10^{18}	E
deci-	10^{-1}	d
centi-	10^{-2}	c*
milli-	10^{-3}	m*
micro-	10^{-6}	μ*
nano-	10^{-9}	n*
pico-	10^{-12}	p
femto-	10^{-15}	f
atto-	10^{-18}	a

* commonly used

Some Examples of Prefix Use

$0.0034 \text{ mol} = 3.4 \times 10^{-3} \text{ mol} =$ 3.4 **milli**moles or 3.4 mmol

$1530 \text{ L} = 1.53 \times 10^{3} \text{ L} =$ 1.53 **kilo**litres or 1.53 kL

SI Base Units

Quantity	Symbol	Unit name	Symbol
amount of substance	*n*	mole	mol
electric current	*I*	ampere	A
length	*L, l, h, d, w*	metre	m
luminous intensity	I_v	candela	cd
mass	*m*	kilogram	kg
temperature	*T*	kelvin	K
time	*t*	second	s

Defined (Exact) Quantities

1 mL	=	1 cm^3
1 kL	=	1 m^3
1000 kg	=	1 t
1 Mg	=	1 t
1 atm	=	101.325 kPa
0°C	=	273.15 K
STP	=	0°C and 101.325 kPa
SATP	=	25°C and 100 kPa

Common Multiples

Multiple	Prefix
1	mono–
2	bi–, di–
3	tri–
4	tetra–
5	penta
6	hexa
7	hepta–
8	octa
9	nona–
10	deca–

C2 Common Chemicals

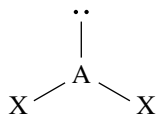
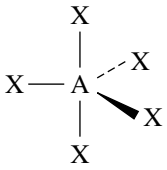
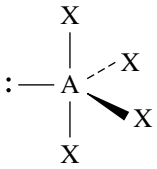
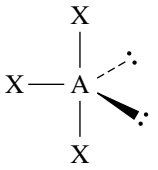
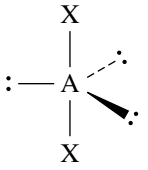
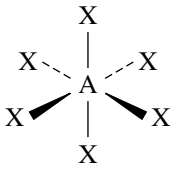
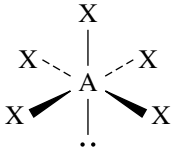
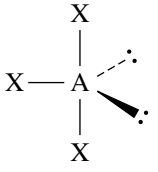
You live in a chemical world. As one bumper sticker asks, "What in the world isn't chemistry?" Every natural and technologically produced substance around you is composed of chemicals. Many of these chemicals are used to make your life easier or safer, and some of them have life-saving properties. Following is a list of selected common chemicals.

Common name	Recommended name	Formula	Common use/source
acetic acid	ethanoic acid	$HC_2H_3O_{2(aq)}$; $CH_3COOH_{(aq)}$	vinegar
acetone	propanone	$(CH_3)_2CO_{(l)}$	nail polish remover
acetylene	ethyne	$C_2H_{2(g)}$	cutting/welding torch
ASA (Aspirin®)	acetylsalicylic acid	$HC_9H_7O_{4(s)}$; $C_6H_4COOCH_3COOH_{(s)}$	for pain-relief medication
baking soda	sodium hydrogen carbonate	$NaHCO_{3(s)}$	leavening agent
battery acid	sulfuric acid	$H_2SO_{4(aq)}$	car batteries
bleach	sodium hypochlorite	$NaClO_{(s)}$	bleach for clothing
bluestone	copper(II) sulfate pentahydrate	$CuSO_4 \cdot 5\ H_2O_{(s)}$	algicide, fungicide
brine	aqueous sodium chloride	$NaCl_{(aq)}$	water-softening agent
CFC	chlorofluorocarbon	$C_xCl_yF_{z(l)}$; e.g.,$C_2Cl_2F_{4(l)}$	refrigerant
charcoal/graphite	carbon	$C_{(s)}$	fuel, lead pencils
citric acid	2-hydroxy-1,2,3-propanetricarboxylic acid	$H_3C_8H_5O_{7(s)}C_3H_4OH(COOH)_{3(s)}$	in fruit and beverages
carbon dioxide	carbon dioxide	$CO_{2(g)}$	dry ice, carbonated beverages
ethylene	ethene	$C_2H_{4(g)}$	for polymerization
ethylene glycol	1,2-ethanediol	$C_2H_4(OH)_{2(l)}$	radiator antifreeze
freon-12	dichlorodifluoromethane	$CCl_2F_{2(l)}$	refrigerant
Glauber's salt	sodium sulfate decahydrate	$Na_2SO_4 \cdot 10\ H_2O_{(s)}$	solar heat storage
glucose	D-glucose; dextrose	$C_6H_{12}O_{6(s)}$	in plants and blood
grain alcohol	ethanol (ethyl alcohol)	$C_2H_5OH_{(l)}$	beverage alcohol
gypsum	calcium sulfate dihydrate	$CaSO_4 \cdot 2\ H_2O_{(s)}$	wallboard
lime (quicklime)	calcium oxide	$CaO_{(s)}$	masonry
limestone	calcium carbonate	$CaCO_{3(s)}$	chalk and building materials
lye (caustic soda)	sodium hydroxide	$NaOH_{(s)}$	oven/drain cleaner
malachite	copper(II) hydroxide carbonate	$Cu(OH)_2 \cdot CuCO_{3(s)}$	copper mineral
methyl hydrate	methanol (methyl alcohol)	$CH_3OH_{(l)}$	gas line antifreeze
milk of magnesia	magnesium hydroxide	$Mg(OH)_{2(s)}$	antacid (for indigestion)
MSG	monosodium glutamate	$NaC_5H_8NO_{4(s)}$	flavour enhancer
muriatic acid	hydrochloric acid	$HCl_{(aq)}$	concrete etching
natural gas	methane	$CH_{4(g)}$	fuel
PCBs	polychlorinated biphenyls	$(C_6H_xCl_y)_2$; e.g., $(C_6H_4Cl_2)_{2(l)}$	in transformers
potash	potassium chloride	$KCl_{(s)}$	fertilizer
road salt	calcium chloride or sodium chloride	$CaCl_{2(s)}$ or $NaCl_{(s)}$	melts ice
rotten-egg gas	hydrogen sulfide	$H_2S_{(g)}$	in natural gas
rubbing alcohol	2-propanol (also isopropanol)	$CH_3CHOHCH_{3(l)}$	for massage
sand (silica)	silicon dioxide	$SiO_{2(s)}$	in glassmaking
slaked lime	calcium hydroxide	$Ca(OH)_{2(s)}$	limewater
soda ash	sodium carbonate	$Na_2CO_{3(s)}$	in laundry detergents
sugar	sucrose	$C_{12}H_{22}O_{11(s)}$	sweetener
table salt	sodium chloride	$NaCl_{(s)}$	seasoning
vitamin C	ascorbic acid	$H_2C_6H_6O_{6(s)}$	vitamin supplement
washing soda	sodium carbonate decahydrate	$Na_2CO_3 \cdot 10\ H_2O_{(s)}$	water softener

C3 Using VSEPR Theory to Predict Molecular Shape

Note: This is an expansion of the table found on page 245 of the text.

Table 1 Using VSEPR Theory to Predict Molecular Shape

General formula*	Bond pairs	Lone pairs	Total pairs	Molecular shape		Examples
				Geometry**	Shape diagram	
AX_2E	2	1	3	V-shaped (trigonal planar)		$SnCl_2$
AX_5	5	0	5	trigonal bipyramidal (trigonal bipyramidal)		$SbCl_5$
AX_4E	4	1	5	seesaw (trigonal bipyramidal)		SF_4
AX_3E_2	3	2	5	T-shaped (trigonal bipyramidal)		BrF_3
AX_2E_3	2	3	5	linear (trigonal bipyramidal)		XeF_2
AX_6	6	0	6	octahedral (octahedral)		SF_6
AX_5E	5	1	6	square pyramidal (octahedral)		BrF_{25}
AX_4E_2	4	2	6	square planar (octahedral)		XeF_4

* A is the central atom; X is another atom; E is a lone pair of electrons.
** Electron-pair arrangement is in parentheses.

C4 Specific Heat Capacities

Specific Heat Capacities of Pure Substances

Substance	Specific Heat Capacity* (J/(g•°C))	Substance	Specific Heat Capacity* (J/(g•°C))
aluminum	0.900	nickel	0.444
calcium	0.653	potassium	0.753
copper	0.385	silver	0.237
gold	0.129	sodium	1.226
hydrogen	14.267	sulfur	0.732
iron	0.444	tin	0.213
lead	0.159	zinc	0.388
lithium	3.556	ice, $H_2O_{(s)}$	2.01
magnesium	1.017	water, $H_2O_{(l)}$	4.18
mercury	0.138	steam, $H_2O_{(g)}$	2.01

*Elements at SATP state

C5 Molar Enthalpies of Combustion

Substance	Molar Enthalpy of Combustion (kJ/mol)
Methanel	–890
Ethane	–1560
Propane	–2220
Butane	–2871
Hexane	–4163
Octane	–5450
Methanol	–727
Ethanol	–1367
Propanol	–2020
Butanol	–2676

C

C6 Standard Molar Entropies and Enthalpies of Formation

Chemical Name	Formula	ΔH_f° (kJ/mol)	S° (J/(mol·K))	Chemical Name	Formula	ΔH_f° (kJ/mol)	S° (J/(mol·K))
acetone	$(CH_3)_2CO_{(l)}$	–248.1	198.8	carbon disulfide	$CS_{2(l)}$	+89.0	–
aluminum oxide	$Al_2O_{3(s)}$	−1675.7	50.92	carbon monoxide	$CO_{(g)}$	−110.5	197.66
ammonia	$NH_{3(g)}$	−45.9	192.78	chloroethene	$C_2H_3Cl_{(g)}$	+37.3	263.9
ammonium chloride	$NH_4Cl_{(s)}$	−314.4	94.6	chromium(III) oxide	$Cr_2O_{3(s)}$	−1139.7	81.2
ammonium chloride	$NH_4Cl_{(aq)}$	−299.7	169.9	copper(I) oxide	$Cu_2O_{(s)}$	−168.6	93.1
ammonium nitrate	$NH_4NO_{3(s)}$	−365.6	151.08	copper(II) oxide	$CuO_{(s)}$	−157.3	42.6
barium carbonate	$BaCO_{3(s)}$	−1216.3	112.1	copper(I) sulfide	$Cu_2S_{(s)}$	−79.5	120.9
barium hydroxide	$Ba(OH)_{2(s)}$	−944.7	107	copper(II) sulfide	$CuS_{(s)}$	−53.1	66.5
barium oxide	$BaO_{(s)}$	−553.5	72.07	cyclopropane	$C_3H_{6(g)}$	+17.8	–
barium sulfate	$BaSO_{4(s)}$	−1473.2	132.2	1,2-dichloroethane	$C_2H_4Cl_{2(l)}$	−126.9	–
benzene	$C_6H_{6(l)}$	+49.0	173.4	ethane	$C_2H_{6(g)}$	−83.8	229.1
bromine (vapour)	$Br_{2(g)}$	+30.9	245.47	1,2-ethanediol	$C_2H_4(OH)_{2(l)}$	−454.8	163.2
butane	$C_4H_{10(g)}$	−125.6	310.1	ethanoic (acetic) acid	$CH_3COOH_{(l)}$	−432.8	159.9
calcium carbonate	$CaCO_{3(s)}$	−1206.9	91.7	ethanol	$C_2H_5OH_{(l)}$	−235.2	161.0
calcium chloride	$CaCl_{2(s)}$	−795.8	104.6	ethanol	$C_2H_5OH_{(g)}$	−235.2	282.70
calcium hydroxide	$Ca(OH)_{2(s)}$	−986.1	83.4	ethene (ethylene)	$C_2H_{4(g)}$	+52.5	219.3
calcium oxide	$CaO_{(s)}$	−634.9	38.1	ethyne (acetylene)	$C_2H_{2(g)}$	+228.2	201.0
calcium sulphate	$CaSO_{4(s)}$	−1434.1	108.4	glucose	$C_6H_{12}O_{6(s)}$	−1273.1	212.1
carbon dioxide	$CO_{2(g)}$	−393.5	213.78				

Chemical Name	Formula	ΔH_f° (kJ/mol)	S° (J/(mol·K))	Chemical Name	Formula	ΔH_f° (kJ/mol)	S° (J/(mol·K))
hexane	$C_6H_{14(l)}$	−198.7	296.1	pentane	$C_5H_{12(l)}$	−173.5	262.7
hydrazine	$N_2H_{4(g)}$	+95.4	237.11	phenylethene (styrene)	$C_6H_5CHCH_{2(l)}$	+103.8	237.6
hydrazine	$N_2H_{4(l)}$	50.6	121.2	phosphorus pentachloride	$PCl_{5(g)}$	–443.5	364.6
hydrogen bromide	$HBr_{(g)}$	−36.3	198.70	phosphorus trichloride	$PCl_{3(l)}$	−319.7	217.2
hydrogen chloride	$HCl_{(g)}$	−92.3	186.90	phosphorus trichloride	$PCl_{3(g)}$	−287.0	311.8
hydrogen cyanide	$HCN_{(g)}$	+135.1	201.81	potassium	$K_{(s)}$	0.0	75.90
hydrogen iodide	$HI_{(g)}$	+26.5	206.59	potassium	$K_{(l)}$	2.3	71.46
hydrogen peroxide	$H_2O_{2(l)}$	−187.8	109.6	potassium chlorate	$KClO_{3(s)}$	−397.7	143.1
hydrogen sulfide	$H_2S_{(g)}$	−20.6	205.81	potassium chloride	$KCl_{(s)}$	−436.7	82.55
iodine (vapour)	$I_{2(g)}$	+62.4	180.79	potassium hydroxide	$KOH_{(s)}$	−424.8	78.9
iron(III) oxide	$Fe_2O_{3(s)}$	−824.2	87.40	propane	$C_3H_{8(g)}$	−104.7	270.2
iron(II, III) oxide	$Fe_3O_{4(s)}$	−1118.4	145.27	silicon dioxide	$SiO_{2(s)}$	−910.7	41.46
lead(II) oxide	$PbO_{(s)}$	−219.0	66.5	silver bromide	$AgBr_{(s)}$	−100.4	107.11
lead(IV) oxide	$PbO_{2(s)}$	−277.4	68.60	silver chloride	$AgCl_{(s)}$	−127.0	96.25
magnesium carbonate	$MgCO_{3(s)}$	−1095.8	65.7	silver iodide	$AgI_{(s)}$	−61.8	115.5
magnesium chloride	$MgCl_{2(s)}$	−641.3	89.63	sodium bromide	$NaBr_{(s)}$	−361.1	86.82
magnesium hydroxide	$Mg(OH)_{2(s)}$	−924.5	63.24	sodium chloride	$NaCl_{(s)}$	−411.2	115.5
magnesium oxide	$MgO_{(s)}$	−601.6	26.95	sodium hydroxide	$NaOH_{(s)}$	−425.6	64.4
manganese(II) oxide	$MnO_{(s)}$	−385.2	59.8	sodium iodide	$NaI_{(s)}$	−287.8	98.50
manganese(IV) oxide	$MnO_{2(s)}$	−520.0	53.1	sucrose	$C_{12}H_{22}O_{11(s)}$	−2225.5	360.2
mercury	$Hg_{(l)}$	0.0	75.90	sulfur dioxide	$SO_{2(g)}$	−296.8	248.22
mercury	$Hg_{(g)}$	61.4	174.97	sulfur trioxide (liquid)	$SO_{3(l)}$	−441.0	—
mercury(II) oxide	$HgO_{(s)}$	−90.8	70.25	sulfur trioxide (vapour)	$SO_{3(g)}$	−395.7	256.77
mercury(II) sulfide	$HgS_{(s)}$	−58.2	82.4	sulfuric acid	$H_2SO_{4(l)}$	−814.0	156.90
methanal (formaldehyde)	$CH_2O_{(g)}$	−108.6	218.8	tin(II) oxide	$SnO_{(s)}$	−280.7	57.17
methane	$CH_{4(g)}$	−74.4	186.3	tin(IV) oxide	$SnO_{2(s)}$	−577.6	49.04
methanoic (formic) acid	$HCOOH_{(l)}$	−425.1	129.0	2,2,4-trimethylpentane	$C_8H_{18(l)}$	−259.2	328.0
methanol	$CH_3OH_{(l)}$	−239.1	126.8	urea	$CO(NH_2)_{2(s)}$	−333.5	104.6
methylpropane	$C_4H_{10(g)}$	−134.2	294.6	water (liquid)	$H_2O_{(l)}$	−285.8	69.95
nickel(II) oxide	$NiO_{(s)}$	−239.7	38.00	water (vapour)	$H_2O_{(g)}$	−241.8	188.84
nitric acid	$HNO_{3(l)}$	−174.1	155.60	zinc oxide	$ZnO_{(s)}$	−350.5	43.65
nitrogen dioxide	$NO_{2(g)}$	+33.2	240.1	zinc sulfide	$ZnS_{(s)}$	−206.0	57.7
nitrogen monoxide	$NO_{(g)}$	+90.2	210.76				
nitromethane	$CH_3NO_{2(l)}$	−113.1	171.8				
octane	$C_8H_{18(l)}$	−250.1	—				
ozone	$O_{3(g)}$	+142.7	163.2				

- Standard molar enthalpies (heats) of formation are measured at SATP (25°C and 100 kPa). The values were obtained from *The CRC Handbook of Chemistry and Physics,* 71st Edition.
- The standard molar enthalpies of elements in their standard states are defined as zero.

C7 Cations and Anions

Common Cations

Ion	Name
H^+	hydrogen
Li^+	lithium
Na^+	sodium
K^+	potassium
Cs^+	cesium
Be^{2+}	beryllium
Mg^{2+}	magnesium
Ca^{2+}	calcium
Ba^{2+}	barium
Al^{3+}	aluminum
Ag^+	silver

Common Anions

Ion	Name
H^-	hydride
F^-	fluoride
Cl^-	chloride
Br^-	bromide
I^-	iodide
O^{2-}	oxide
S^{2-}	sulfide
N^{3-}	nitride
P^{3-}	phosphide

Ion Colours

Ion	Solution colour
Groups 1, 2, 17	colourless
$Cr^{2+}_{(aq)}$	blue
$Cr^{3+}_{(aq)}$	green
$Co^{2+}_{(aq)}$	pink
$Cu^{+}_{(aq)}$	green
$Cu^{2+}_{(aq)}$	blue
$Fe^{2+}_{(aq)}$	pale green
$Fe^{3+}_{(aq)}$	yellow-brown
$Mn^{2+}_{(aq)}$	pale pink
$Ni^{2+}_{(aq)}$	green
$CrO_{4(aq)}^{2-}$	yellow
$Cr_2O_{7(aq)}^{2-}$	orange
$MnO_{4(aq)}^{-}$	purple

Ion	Flame
Li^+	bright red
Na^+	yellow
K^+	violet
Ca^{2+}	yellow-red
Sr^{2+}	bright red
Ba^{2+}	yellow-green
Cu^{2+}	blue (halides) green (others)
Pb^{2+}	light blue-grey
Zn^{2+}	whitish green

Common Polyatomic Ions

Ion	Name	Ion	Name
$C_2H_3O_2^-$	acetate	CO_3^{2-}	carbonate
ClO_3^-	chlorate*	CrO_4^{2-}	chromate
ClO_2^-	chlorite*	$Cr_2O_7^{2-}$	dichromate
CN^-	cyanide	HPO_4^{2-}	hydrogen phosphate
$H_2PO_4^-$	dihydrogen phosphate	$C_2O_4^{2-}$	oxalate
HCO_3^-	hydrogen carbonate (bicarbonate)	O_2^{2-}	peroxide
HSO_4^-	hydrogen sulfate (bisulfate)	SiO_3^{2-}	silicate
HS^-	hydrogen sulfide (bisulfide)	SO_4^{2-}	sulfate
HSO_3^-	hydrogen sulfite (bisulfite)	SO_3^{2-}	sulfite
ClO^-, OCl^-	hypochlorite*	$S_2O_3^{2-}$	thiosulfate
OH^-	hydroxide	BO_3^{3-}	borate
NO_2^-	nitrite	PO_4^{3-}	phosphate
NO_3^-	nitrate	$P_3O_{10}^{5-}$	tripolyphosphate
ClO_4^-	perchlorate*	NH_4^+	ammonium
MnO_4^-	permanganate	H_3O^+	hydronium
SCN^-	thiocyanate	Hg_2^{2+}	mercury(I)

*There are also corresponding ions containing Br and I instead of Cl.

Solubility of Ionic Compounds at SATP

		Anions						
		Cl^-, Br^-, I^-	S^{2-}	OH^-	SO_4^{2-}	CO_3^{2-}, PO_4^{3-}, SO_3^{2-}	$C_2H_3O_2^-$	NO_3^-
Cations	High solubility (aq) ≥0.1 mol/L (at SATP)	most	Group 1, NH_4^+ Group 2	Group 1, NH_4^+ Sr^{2+}, Ba^{2+}, Tl^+	most	Group 1, NH_4^+	most	all
		All Group 1 compounds, including acids, and all ammonium compounds are assumed to have high solubility in water.						
	Low Solubility (s) <0.1 mol/L (at SATP)	Ag^+, Pb^{2+}, Tl^+, Hg_2^{2+} (Hg^+), Cu^+	most	most	Ag^+, Pb^{2+}, Ca^{2+}, Ba^{2+}, Sr^{2+}, Ra^{2+}	most	Ag^+	none

C8 Solubility Product Constants (K_{sp})

Solubility Product Constants at 25°C

Name	Formula	K_{sp}
barium carbonate	$BaCO_{3(s)}$	2.6×10^{-9}
barium chromate	$BaCrO_{4(s)}$	1.2×10^{-10}
barium sulfate	$BaSO_{4(s)}$	1.1×10^{-10}
calcium carbonate	$CaCO_{3(s)}$	5.0×10^{-9}
calcium oxalate	$CaC_2O_{4(s)}$; $CaOOCCOO_{(s)}$	2.3×10^{-9}
calcium phosphate	$Ca_3(PO_4)_{2(s)}$	2.1×10^{-33}
calcium sulfate	$CaSO_{4(s)}$	7.1×10^{-5}
copper(I) chloride	$CuCl_{(s)}$	1.7×10^{-7}
copper(I) iodide	$CuI_{(s)}$	1.3×10^{-12}
copper(II) iodate	$Cu(IO_3)_{2(s)}$	6.9×10^{-8}
copper(II) sulfide	$CuS_{(s)}$	6.0×10^{-37}
iron(II) hydroxide	$Fe(OH)_{2(s)}$	4.9×10^{-17}
iron(II) sulfide	$FeS_{(s)}$	6.0×10^{-19}
iron(III) hydroxide	$Fe(OH)_{3(s)}$	2.6×10^{-39}
lead(II) bromide	$PbBr_{2(s)}$	6.6×10^{-6}
lead(II) chloride	$PbCl_{2(s)}$	1.2×10^{-5}
lead(II) iodate	$Pb(IO_3)_{2(s)}$	3.7×10^{-13}
lead(II) iodide	$PbI_{2(s)}$	8.5×10^{-9}
lead(II) sulfate	$PbSO_{4(s)}$	1.8×10^{-8}
magnesium carbonate	$MgCO_{3(s)}$	6.8×10^{-6}
magnesium fluoride	$MgF_{2(s)}$	6.4×10^{-9}
magnesium hydroxide	$Mg(OH)_{2(s)}$	5.6×10^{-12}
mercury(I) chloride	$Hg_2Cl_{2(s)}$	1.5×10^{-18}
silver bromate	$AgBrO_{3(s)}$	5.3×10^{-5}
silver bromide	$AgBr_{(s)}$	5.4×10^{-13}
silver carbonate	$Ag_2CO_{3(s)}$	8.5×10^{-12}
silver chloride	$AgCl_{(s)}$	1.8×10^{-10}
silver chromate	$Ag_2CrO_{4(s)}$	1.1×10^{-12}
silver iodate	$AgIO_{3(s)}$	3.2×10^{-8}
silver iodide	$AgI_{(s)}$	8.5×10^{-17}
strontium carbonate	$SrCO_{3(s)}$	5.6×10^{-10}
strontium fluoride	$SrF_{2(s)}$	4.3×10^{-9}
strontium sulfate	$SrSO_{4(s)}$	3.4×10^{-7}
zinc hydroxide	$Zn(OH)_{2(s)}$	7.7×10^{-17}
zinc sulfide	$ZnS_{(s)}$	2.0×10^{-25}

- Values in this table are taken from *The CRC Handbook of Chemistry and Physics,* 76th Edition.

C9 K_a and K_b for Common Acids and Weak Bases

Monoprotic Acids

Name	Formula of Acid	Formula of Conjugate Base	Equilibrium Constant, 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
nitric acid	$HNO_{3(aq)}$	$NO_{3(aq)}^-$	very large
hydronium ion	$H_3O^+_{(aq)}$	$H_20_{(l)}$	1.0
iron(III) ion	$Fe(H_2O)_6^{3+}_{(aq)}$	$Fe(H_2O)_5(OH)^{2+}_{(aq)}$	1.5×10^{-3}
citric acid	$H_3C_6H_5O_{7(aq)}$	$H_2C_6H_5O_{7(aq)}^-$	7.4×10^{-4}
nitrous acid	$HNO_{2(aq)}$	$NO_{2(aq)}^-$	7.2×10^{-4}
hydrofluoric acid	$HF_{(aq)}$	$F_{(aq)}^-$	6.6×10^{-4}
hydrogen cyanate	HOCN	$OCN_{(aq)}^-$	3.5×10^{-4}
methanoic acid	$HCHO_2$; $HCOOH_{(aq)}$	$CHO_{2(aq)}^-$	1.8×10^{-4}
chromium(III) ion	$Cr(H_2O)_6^{3+}_{(aq)}$	$Cr(H_2O)_5(OH)^{2+}_{(aq)}$	1.0×10^{-4}
methyl orange	$HMo_{(aq)}$	$Mo_{(aq)}^-$	$\sim 10^{-4}$
benzoic acid	$HC_7H_5O_{2(aq)}$; $C_6H_5COOH_{(aq)}$	$C_6H_5O_{2(aq)}^-$	6.3×10^{-5}
ethanoic (acetic) acid	$HC_2H_3O_{2(aq)}$; $CH_3COOH_{(aq)}$	$C_2H_3O_{2(aq)}^-$	1.8×10^{-5}
aluminum ion	$Al(H_2O)_6^{3+}_{(aq)}$	$Al(H_2O)_5(OH)^{2+}_{(aq)}$	9.8×10^{-6}
bromothymol blue	$HBb_{(aq)}$	$Bb_{(aq)}^-$	$\sim 10^{-7}$
hypochlorous acid	$HClO_{(aq)}$	$ClO_{(aq)}^-$	2.9×10^{-8}
phenolphthalein	$HPh_{(aq)}$	$Ph_{(aq)}^-$	$\sim 10^{-10}$
hydrocyanic acid	$HCN_{(aq)}$	$CN_{(aq)}^-$	6.2×10^{-10}
ammonium ion	$NH_4^+_{(aq)}$	$NH_{3(aq)}$	5.8×10^{-10}
boric acid	$H_3BO_{3(aq)}$	$H_2BO_{3(aq)}^-$	5.8×10^{-10}
phenol	$C_6H_5OH_{(aq)}$	$C_6H_5O_{(aq)}^-$	1.0×10^{-10}
hydrogen peroxide	$H_2O_{2(aq)}$	$HO_{2(aq)}^-$	2.2×10^{-12}
water	$H_2O_{(l)}$	$OH_{(aq)}^-$	1.0×10^{-14}
hydroxide ion	$OH_{(aq)}^-$	$O^{2-}_{(aq)}$	very small

• Values in this table are taken from *Lange's Handbook of Chemistry*, 13th Edition for 25°C.

Weak Bases

Name	Formula	Equilibrium Constant, K_b
dimethylamine	CH_3CH_3NH	9.6×10^{-4}
methylamine	CH_3NH_2	4.4×10^{-4}
ethylamine	$CH_3CH_2NH_2$	4.3×10^{-4}
trimethylamine	$CH_3CH_3CH_3N$	7.4×10^{-5}
ammonia	NH_3	1.8×10^{-5}
hydrazine	N_2H_4	9.6×10^{-7}
hydroxylamine	NH_2OH	6.6×10^{-9}
pyridine	C_5H_5N	1.5×10^{-9}
aniline	$C_5H_5NH_2$	4.1×10^{-10}

Polyprotic Acids

Name	Formula of Acid	Formula of Conjugate Base	Equilibrium Constant K_{a_1}	K_{a_2}	K_{a_3}
sulfuric acid	$H_2SO_{4(aq)}$	$HSO_{4(aq)}^-$	very large	1.0×10^{-2}	
oxalic acid	$H_2C_2O_{4(aq)}$; $HOOCCOOH_{(aq)}$	$HC_2O_{4(aq)}^-$	5.4×10^{-2}	5.4×10^{-5}	
sulfurous acid ($SO_2 + H_2O$)	$H_2SO_{3(aq)}$	$HSO_{3(aq)}^-$	1.3×10^{-2}	6.2×10^{-8}	
phosphoric acid	$H_3PO_{4(aq)}$	$H_2PO_{4(aq)}^-$	7.1×10^{-3}	6.3×10^{-8}	4.2×10^{-13}
carbonic acid ($CO_2 + H_2O$)	$H_2CO_{3(aq)}$	$HCO_{3(aq)}^-$	4.4×10^{-7}	4.7×10^{-11}	
hydrosulfuric acid	$H_2S_{(aq)}$	$HS_{(aq)}^-$	1.1×10^{-7}	1.3×10^{-13}	

• Values in this table are taken from *Lange's Handbook of Chemistry*, 13th Edition for 25°C.

C10 Acids and Bases

Oxyacids

Acid	Name
$HNO_{3(aq)}$	nitric acid
$HNO_{2(aq)}$	nitrous acid
$H_2SO_{4(aq)}$	sulfuric acid
$H_2SO_{3(aq)}$	sulfurous acid
$H_3PO_{4(aq)}$	phosphoric acid
$HC_2H_3O_{2(aq)}$	acetic acid
$HClO_{4(aq)}$	perchloric acid
$HBrO_{4(aq)}$	perbromic acid
$HIO_{4(aq)}$	periodic acid
$HClO_{3(aq)}$	chloric acid
$HBrO_{3(aq)}$	bromic acid
$HIO_{3(aq)}$	iodic acid
$HClO_{2(aq)}$	chlorous acid
$HClO_{(aq)}$	hypochlorous acid
$HBrO_{(aq)}$	hypobromous acid
$HIO_{(aq)}$	hypoiodous acid
HFO(aq)	hypofluorous acid

Concentrated Reagents•

Reagent	Formula	Molar mass (g/mol)	Concentration (mol/L)	Concentration (mass %)
acetic acid	$HC_2H_3O_{2(aq)}$	60.05	17.45	99.8
carbonic acid	$H_2CO_{3(aq)}$	62.03	0.039	0.17
formic acid	$HCOOH_{(aq)}$	46.03	23.6	90.5
hydrobromic acid	$HBr_{(aq)}$	80.91	8.84	48.0
hydrochloric acid	$HCl_{(aq)}$	36.46	12.1	37.2
hydrofluoric acid	$HFl_{(aq)}$	20.01	28.9	49.0
nitric acid	$HNO_{3(aq)}$	63.02	15.9	70.4
perchloric acid	$HClO_{4(aq)}$	100.46	11.7	70.5
phosphoric acid	$H_3PO_{4(aq)}$	98.00	14.8	85.5
sulfurous acid	$H_2SO_{3(aq)}$	82.08	0.73	6.0
sulfuric acid	$H_2SO_{4(aq)}$	98.08	18.0	96.0
ammonia	$NH_{3(aq)}$	17.04	14.8	28.0
potassium hydroxide	$KOH_{(aq)}$	56.11	11.7	45.0
sodium hydroxide	$NaOH_{(aq)}$	40.00	19.4	50.5

• Typical concentrations of commercial concentrated reagents

Acid–Base Indicators

Common Name	Colour of $HIn_{(aq)}$	pH range	Colour of $In^-_{(aq)}$	Common name	Colour of $HIn_{(aq)}$	pH range	Colour of $In^-_{(aq)}$
methyl violet	yellow	0.0 — 1.6	blue	*p*-nitrophenol	colourless	5.3 – 7.6	yellow
cresol red (acid range)	red	0.2 — 1.8	yellow	litmus	red	6.0 – 8.0	blue
cresol purple (acid range)	red	1.2 – 2.8	yellow	bromothymol blue	yellow	6.2 – 7.6	blue
thymol blue (acid range)	red	1.2 — 2.8	yellow	neutral red	red	6.8 – 8.0	yellow
tropeolin oo	red	1.3 — 3.2	yellow	phenol red	yellow	6.4 – 8.0	red
orange iv	red	1.4 — 2.8	yellow	*m*-nitrophenol	colourless	6.4 – 8.8	yellow
benzopurpurine-4B	violet	2.2 — 4.2	red	cresol red	yellow	7.2 – 8.8	red
2,6-dinotrophenol	colourless	2.4 — 4.0	yellow	*m*-cresol purple	yellow	7.6 – 9.2	purple
2,4-dinotrophenol	colourless	2.5 — 4.3	yellow	thymol blue	yellow	8.0 – 9.6	blue
methyl yellow	red	2.9 — 4.0	yellow	phenolphthalein	colourless	8.0 – 10.0	red
congo red	blue	3.0 — 5.0	red	α-naphtholbenzein	yellow	9.0 – 11.0	blue
methyl orange	red	3.1 — 4.4	yellow	thymolphthalein	colourless	9.4 – 10.6	blue
bromophenol blue	yellow	3.0 — 4.6	blue-violet	alizarin yellow r	yellow	10.0 – 12.0	violet
bromocresol green	yellow	4.0 — 5.6	blue	tropeolin o	yellow	11.0 – 13.0	orange-brown
methyl red	red	4.4 — 6.2	yellow	nitramine	colourless	10.8 – 13.0	orange-brown
chlorophenol red	yellow	5.4 — 6.8	red	indigo carmine	blue	11.4 – 13.0	yellow
bromocresol purple	yellow	5.2 — 6.8	purple	1,3,5-trinitrobenzene	colourless	12.0 – 14.0	orange
bromophenol red	yellow	5.2 — 6.8	red				

C11 Relative Strengths of Oxidizing and Reducing Agents

SOA
Strongest Oxidizing Agent

Decreasing Strength of Oxidizing Agents

Oxidizing Agents		Reducing Agents	E°_r (V)
$F_{2(g)}$	$+ 2e^- \rightleftharpoons$	$2F^-_{(aq)}$	+2.87
$PbO_{2(s)} + SO^{2-}_{4(aq)} + 4H^+_{(aq)}$	$+ 2e^- \rightleftharpoons$	$PbSO_{4(s)} + 2H_2O_{(l)}$	+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
$Cr_2O^{2-}_{7(aq)} + 14H^+_{(aq)}$	$+ 6e^- \rightleftharpoons$	$2Cr^{3+}_{(aq)} + 7H_2O_{(l)}$	+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
$2IO^-_{3(aq)} + 12H^+_{(aq)}$	$+ 10e^- \rightleftharpoons$	$I_{2(s)} + 6H_2O_{(l)}$	+1.20
$Br_{2(l)}$	$+ 2e^- \rightleftharpoons$	$2Br^-_{(aq)}$	+1.07
$Hg^{2+}_{(aq)}$	$+ 2e^- \rightleftharpoons$	$Hg_{(l)}$	+0.85
$ClO^-_{(aq)} + H_2O_{(l)}$	$+ 2e^- \rightleftharpoons$	$Cl^-_{(aq)} + 2OH^-_{(aq)}$	+0.84
$Ag^+_{(aq)}$	$+ e^- \rightleftharpoons$	$Ag_{(s)}$	+0.80
$NO^-_{3(aq)} + 2H^+_{(aq)}$	$+ e^- \rightleftharpoons$	$NO_{2(g)} + H_2O_{(l)}$	+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
$MnO^-_{4(aq)} + 2H_2O_{(l)}$	$+ 3e^- \rightleftharpoons$	$MnO_{2(s)} + 4OH^-_{(aq)}$	+0.60
$I_{2(s)}$	$+ 2e^- \rightleftharpoons$	$2I^-_{(aq)}$	+0.54
$Cu^+_{(aq)}$	$+ e^- \rightleftharpoons$	$Cu_{(s)}$	+0.52
$O_{2(g)} + 2H_2O_{(l)}$	$+ 4e^- \rightleftharpoons$	$4OH^-_{(aq)}$	+0.40
$Cu^{2+}_{(aq)}$	$+ 2e^- \rightleftharpoons$	$Cu_{(s)}$	+0.34
$SO^{2-}_{4(aq)} + 4H^+_{(aq)}$	$+ 2e^- \rightleftharpoons$	$H_2SO_{3(aq)} + H_2O_{(l)}$	+0.17
$Sn^{4+}_{(aq)}$	$+ 2e^- \rightleftharpoons$	$Sn^{2+}_{(aq)}$	+0.15
$Cu^{2+}_{(aq)}$	$+ e^- \rightleftharpoons$	$Cu^+_{(aq)}$	+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
$H_3PO_{4(aq)} + 2H^+_{(l)}$	$+ 2e^- \rightleftharpoons$	$H_3PO_{3(aq)} + H_2O_{(l)}$	−0.28
$PbSO_{4(s)}$	$+ 2e^- \rightleftharpoons$	$Pb_{(s)} + SO^{2-}_{4(aq)}$	−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
$Fe^{2+}_{(aq)}$	$+ 2e^- \rightleftharpoons$	$Fe_{(s)}$	−0.44
$Ag_2S_{(s)}$	$+ 2e^- \rightleftharpoons$	$2Ag_{(s)} + S^{2-}_{(aq)}$	−0.69
$Zn^{2+}_{(aq)}$	$+ 2e^- \rightleftharpoons$	$Zn_{(s)}$	−0.76
$Te_{(s)} + 2H^+_{(aq)}$	$+ 2e^- \rightleftharpoons$	$H_2Te_{(aq)}$	−0.79
$2H_2O_{(l)}$	$+ 2e^- \rightleftharpoons$	$H_{2(g)} + 2OH^-_{(aq)}$	−0.83
$Cr^{2+}_{(aq)}$	$+ 2e^- \rightleftharpoons$	$Cr_{(s)}$	−0.91
$SO^{2-}_{4(aq)} + H_2O_{(l)}$	$+ 2e^- \rightleftharpoons$	$SO^{2-}_{3(aq)} + 2OH^-_{(aq)}$	−0.93
$Al^{3+}_{(aq)}$	$+ 3e^- \rightleftharpoons$	$Al_{(s)}$	−1.66
$Mg^{2+}_{(aq)}$	$+ 2e^- \rightleftharpoons$	$Mg_{(s)}$	−2.37
$Na^+_{(aq)}$	$+ e^- \rightleftharpoons$	$Na_{(s)}$	−2.71
$Ca^{2+}_{(aq)}$	$+ 2e^- \rightleftharpoons$	$Ca_{(s)}$	−2.87
$Ba^{2+}_{(aq)}$	$+ 2e^- \rightleftharpoons$	$Ba_{(s)}$	−2.91
$K^+_{(aq)}$	$+ e^- \rightleftharpoons$	$K_{(s)}$	−2.93
$Li^+_{(aq)}$	$+ e^- \rightleftharpoons$	$Li_{(s)}$	−3.04

Decreasing Strength of Reducing Agents

SRA
Strongest Reducing Agent

- All E° values are reduction potentials measured relative to the standard hydrogen electrode. E° values are measured using standard half-cells with both the oxidizing and reducing agents present at SATP using 1.0 mol/L solutions.
- Values in this table are taken from *The CRC Handbook of Chemistry and Physics*, 71st Edition.