Chemistry 30

Data Booklet 2017-18

Student First

Government of Saskatchewan

Formula Sheet – Chemistry

$$[\ ] = \text{mol/L or M}$$

$$\text{Molarity (M)} = \frac{\text{amount of solute (moles)}}{\text{volume of solution (litres)}}$$

$$C_1V_1 = C_2V_2 \quad \text{or} \quad M_1V_1 = M_2V_2$$

$$\text{number of moles} = \frac{\text{mass}}{\text{molar mass}} \quad \text{or} \quad n = \frac{m}{\text{molar mass}}$$

$$M_aV_a = M_bV_b \quad \text{or} \quad C_aV_a = C_bV_b$$

$$pH = -\log\left[H_3O^+\right] \quad \text{or} \quad pH = -\log\left[H^+\right]$$

$$\left[H^+\right]\left[OH^-\right] = 1\times10^{-14} \quad \text{or} \quad \left[H_3O^+\right]\left[OH^-\right] = 1\times10^{-14}$$

$$pH + pOH = 14$$

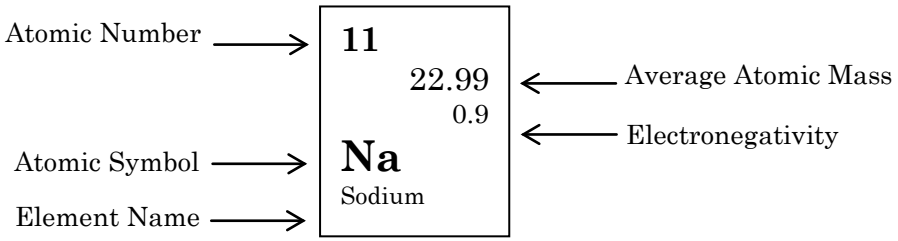
SI Prefixes

Value	Prefix	Organic Prefix
1	mono	meth
2	di	eth
3	tri	prop
4	tetra	but
5	penta	pent
6	hexa	hex
7	hepta	hept
8	octa	oct
9	nona	non
10	deca	dec

Notation

Symbol	Term	Unit
E°	standard electric potential	V or J/C
K_{eq}	equilibrium constant	___
K_a	acid ionization constant	___
K_b	base ionization constant	___
M	molar mass	g/mol
m	mass	g
n	amount of substance	mol
P	pressure	kPa
V	volume	L
C	concentration	mol/L

Periodic Table of Elements



( ) Indicates mass of the most stable isotope

1	2		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 1.01 2.2 **H** Hydrogen																		2 4.00 — **He** Helium
3 6.94 1.0 **Li** Lithium	4 9.01 1.6 **Be** Beryllium												5 10.81 2.0 **B** Boron	6 12.01 2.6 **C** Carbon	7 14.01 3.0 **N** Nitrogen	8 16.00 3.4 **O** Oxygen	9 19.00 4.0 **F** Fluorine	10 20.18 — **Ne** Neon
11 22.99 0.9 **Na** Sodium	12 24.31 1.3 **Mg** Magnesium												13 26.98 1.6 **Al** Aluminum	14 28.09 1.9 **Si** Silicon	15 30.97 2.2 **P** Phosphorus	16 32.07 2.6 **S** Sulfur	17 35.45 3.2 **Cl** Chlorine	18 39.95 — **Ar** Argon
19 39.10 0.8 **K** Potassium	20 40.08 1.0 **Ca** Calcium		21 44.96 1.4 **Sc** Scandium	22 47.87 1.5 **Ti** Titanium	23 50.94 1.6 **V** Vanadium	24 52.00 1.7 **Cr** Chromium	25 54.94 1.6 **Mn** Manganese	26 55.85 1.8 **Fe** Iron	27 58.93 1.9 **Co** Cobalt	28 58.69 1.9 **Ni** Nickel	29 63.55 1.9 **Cu** Copper	30 65.41 1.7 **Zn** Zinc	31 69.72 1.8 **Ga** Gallium	32 72.64 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
37 85.47 0.8 **Rb** Rubidium	38 87.62 1.0 **Sr** Strontium		39 88.91 1.2 **Y** Yttrium	40 91.22 1.3 **Zr** Zirconium	41 92.91 1.6 **Nb** Niobium	42 95.94 2.2 **Mo** Molybdenum	43 (98) 2.1 **Tc** Technetium	44 101.07 2.2 **Ru** Ruthenium	45 102.91 2.3 **Rh** Rhodium	46 106.42 2.2 **Pd** Palladium	47 107.87 1.9 **Ag** Silver	48 112.41 1.7 **Cd** Cadmium	49 114.82 1.8 **In** Indium	50 118.71 2.0 **Sn** Tin	51 121.76 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
55 132.91 0.8 **Cs** Cesium	56 137.33 0.9 **Ba** Barium	57-70 * La-Yb	71 174.97 1.0 **Lu** Lutetium	72 178.49 1.3 **Hf** Hafnium	73 180.95 1.5 **Ta** Tantalum	74 183.84 1.7 **W** Tungsten	75 186.21 1.9 **Re** Rhenium	76 190.23 2.2 **Os** Osmium	77 192.22 2.2 **Ir** Iridium	78 195.08 2.2 **Pt** Platinum	79 196.97 2.4 **Au** Gold	80 200.59 1.9 **Hg** Mercury	81 204.38 1.8 **Tl** Thallium	82 207.20 1.8 **Pb** Lead	83 208.98 1.9 **Bi** Bismuth	84 (208.98) 2.0 **Po** Polonium	85 (209.99) 2.2 **At** Astatine	86 (222.02) — **Rn** Radon
87 (223.02) 0.7 **Fr** Francium	88 (226.03) 0.9 **Ra** Radium	89-102 ** Ac-No	103 (262.11) — **Lr** Lawrencium	104 (265.12) — **Rf** Rutherfordium	105 (268.13) — **Db** Dubnium	106 (271.13) — **Sg** Seaborgium	107 (270) — **Bh** Bohrium	108 (277.15) — **Hs** Hassium	109 (276.15) — **Mt** Meitnerium	110 (281.16) — **Ds** Darmstadtium	111 (280.16) — **Rg** Roentgenium	112 (285.17) — **Cn** Copernicium	113 (284.18) — **Nh** Nihomium	114 (289.19) — **Fl** Flerovium	115 (288.19) — **Mc** Moscovium	116 (293) — **Lv** Livermorium	117 (294) — **Ts** Tennessine	118 (294) — **Og** Oganesson

*§ Lanthanoid Series

57	58	59	60	61	62	63	64	65	66	67	68	69	70
138.91 1.1 **La** Lanthanum	140.12 1.1 **Ce** Cerium	140.91 1.1 **Pr** Praseodymium	144.24 1.1 **Nd** Neodymium	(145) — **Pm** Promethium	150.36 1.2 **Sm** Samarium	151.96 — **Eu** Europium	157.25 1.2 **Gd** Gadolinium	158.93 — **Tb** Terbium	162.50 1.2 **Dy** Dysprosium	164.93 1.2 **Ho** Holmium	167.26 1.2 **Er** Erbium	168.93 1.3 **Tm** Thulium	173.04 — **Yb** Ytterbium

**¥ Actinoid Series

89	90	91	92	93	94	95	96	97	98	99	100	101	102
(227.03) 1.1 **Ac** Actinium	232.04 1.3 **Th** Thorium	231.04 1.5 **Pa** Protactinium	238.03 1.7 **U** Uranium	(237.05) 1.3 **Np** Neptunium	(244.06) 1.3 **Pu** Plutonium	(243.06) — **Am** Americium	(247.07) — **Cm** Curium	(247.07) — **Bk** Berkelium	(251.08) — **Cf** Californium	(252.08) — **Es** Einsteinium	(257.10) — **Fm** Fermium	(258.10) — **Md** Mendelevium	(259.10) — **No** Nobelium

Polyatomic Ions

Name	Symbol
acetate	CH_3COO^-
ammonium	NH_4^+
carbonate	CO_3^{2-}
hydrogen carbonate	HCO_3^-
hypochlorite	ClO^-
chlorite	ClO_2^-
chlorate	ClO_3^-
perchlorate	ClO_4^-
chromate	CrO_4^{2-}
dichromate	$Cr_2O_7^{2-}$
cyanide	CN^-
hydronium	H_3O^+
hydroxide	OH^-
nitrate	NO_3^-
nitrite	NO_2^-
permanganate	MnO_4^-
phosphate	PO_4^{3-}
hydrogen sulfate	HSO_4^-
sulfate	SO_4^{2-}
sulfite	SO_3^{2-}

Solubility of Common Compounds in Water

Rule	Negative Ions	Positive Ions	Solubility
1	essentially all	Li^+, Na^+, K^+, Rb^+, Cs^+, Fr^+	soluble
2	essentially all	H^+	soluble
3	essentially all	NH_4^+	soluble
4	Chlorate, ClO_3^- nitrate, NO_3^- perchlorate, ClO_4^-	essentially all	soluble
5	acetate, CH_3COO^-	Ag^+	low solubility
		all others	soluble
6	fluoride, F^-	Mg^{2+}, Ca^{2+}, Ba^{2+}, Pb^{2+}	low solubility
		all others	soluble
7	bromide, Br^- chloride, Cl^- iodide, I^-	Ag^+, Pb^{2+}, Hg_2^{2+}, Cu^+, Tl^+	low solubility
		all others	soluble
8	sulfate, SO_4^{2-}	Ca^{2+}, Sr^{2+}, Ba^{2+}, Ra^{2+}, Pb^{2+}, Ag^+, Hg_2^{2+}	low solubility
		all others	soluble
9	sulfide, S^{2-}	Li^+, Na^+, K^+, Rb^+, Cs^+, Fr^+, H^+, NH_4^+, Be^{2+}, Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}, Ra^{2+}	soluble
		all others	low solubility
10	hydroxide, OH^-	Li^+, Na^+, K^+, Rb^+, Cs^+, Fr^+, H^+, NH_4^+, Sr^{2+}, Ba^{2+}, Ra^{2+}, Tl^+	soluble
		all others	low solubility
11	carbonate, CO_3^{2-} phosphate, PO_4^{3-} sulfite, SO_3^{2-}	Li^+, Na^+, K^+, Rb^+, Cs^+, Fr^+, H^+, NH_4^+	soluble
		all others	low solubility

*considered soluble if they give ion concentrations above 0.1 mol/L at room temperature

(Adapted from *Chemistry: Experimental Foundations*, by Parry, R. W.; Steiner, L. E.; Tellefsen, R. L.; Dietz, P. M.

Relative Strengths of Acids in Aqueous Solution at Room Temperature, 25°C

Acid	Reaction	K_a
perchloric acid	$HClO_4(aq) \rightarrow H^+(aq) + ClO_4^-(aq)$	very large
hydriodic acid	$HI(aq) \rightarrow H^+(aq) + I^-(aq)$	3.2×10^{9}
hydrobromic acid	$HBr(aq) \rightarrow H^+(aq) + Br^-(aq)$	1.0×10^{9}
hydrochloric acid	$HCl(aq) \rightarrow H^+(aq) + Cl^-(aq)$	1.3×10^{6}
sulfuric acid	$H_2SO_4(aq) \rightarrow H^+(aq) + HSO_4^-(aq)$	1.0×10^{3}
nitric acid	$HNO_3(aq) \rightarrow H^+(aq) + NO_3^-(aq)$	2.4×10^{1}
oxalic acid	$HOOCCOOH(aq) \Leftrightarrow H^+(aq) + HOOCCOO^-(aq)$	5.4×10^{-2}
sulfurous acid ($SO_2 + H_2O$)	$H_2SO_3(aq) \Leftrightarrow H^+(aq) + HSO_3^-(aq)$	1.7×10^{-2}
hydrogen sulfate ion	$HSO_4^-(aq) \Leftrightarrow H^+(aq) + SO_4^{2-}(aq)$	1.3×10^{-2}
phosphoric acid	$H_3PO_4(aq) \Leftrightarrow H^+(aq) + H_2PO_4^-(aq)$	7.1×10^{-3}
hydrofluoric acid	$HF(aq) \Leftrightarrow H^+(aq) + F^-(aq)$	6.7×10^{-4}
nitrous acid	$HNO_2(aq) \Leftrightarrow H^+(aq) + NO_2^-(aq)$	5.1×10^{-4}
benzoic acid	$C_6H_5COOH(aq) \Leftrightarrow H^+(aq) + C_6H_5COO^-(aq)$	6.6×10^{-5}
acetic acid	$CH_3COOH(aq) \Leftrightarrow H^+(aq) + CH_3COO^-(aq)$	1.8×10^{-5}
carbonic acid ($CO_2 + H_2O$)	$H_2CO_3(aq) \Leftrightarrow H^+(aq) + HCO_3^-(aq)$	4.4×10^{-7}
hydrogen sulfide	$H_2S(aq) \Leftrightarrow H^+(aq) + HS^-(aq)$	1.0×10^{-7}
dihydrogen phosphate ion	$H_2PO_4^-(aq) \Leftrightarrow H^+(aq) + HPO_4^{2-}(aq)$	6.3×10^{-8}
hydrogen sulfite ion	$HSO_3^-(aq) \Leftrightarrow H^+(aq) + SO_3^{2-}(aq)$	6.2×10^{-8}
hypochlorous acid	$HClO(aq) \Leftrightarrow H^+(aq) + ClO^-(aq)$	2.9×10^{-8}
ammonium ion	$NH_4^+(aq) \Leftrightarrow H^+(aq) + NH_3(aq)$	5.7×10^{-10}
hydrogen carbonate ion	$HCO_3^-(aq) \Leftrightarrow H^+(aq) + CO_3^{2-}(aq)$	4.7×10^{-11}
hydrogen peroxide	$H_2O_2(aq) \Leftrightarrow H^+(aq) + HO_2^-(aq)$	2.4×10^{-12}
monohydrogen phosphate ion	$HPO_4^{2-}(aq) \Leftrightarrow H^+(aq) + PO_4^{3-}(aq)$	4.4×10^{-13}
hydrogen sulfide ion	$HS^-(aq) \Leftrightarrow H^+(aq) + S^{2-}(aq)$	1.2×10^{-15}
ammonia	$NH_3(aq) \Leftrightarrow H^+(aq) + NH_2^-(aq)$	very small

Relative Strengths of Bases in Aqueous Solution at Room Temperature, 25°C

Base	Reaction	K_b
sodium hydroxide	$NaOH(s) \rightarrow Na^+(aq) + OH^-(aq)$	very large
hydride ion	$H^-(aq) + H_2O \rightarrow H_2(aq) + OH^-(aq)$	very large
amide ion	$NH_2^-(aq) + H_2O \rightarrow NH_3(aq) + OH^-(aq)$	very large
phosphate ion	$PO_4^{3-}(aq) + H_2O \Leftrightarrow HPO_4^{2-}(aq) + OH^-(aq)$	5.9×10^{-3}
carbonate ion	$CO_3^{2-}(aq) + H_2O \Leftrightarrow HCO_3^-(aq) + OH^-(aq)$	2.1×10^{-4}
ammonia	$NH_3(aq) + H_2O \Leftrightarrow NH_4^+(aq) + OH^-(aq)$	1.8×10^{-5}
hydrazine	$N_2H_4(aq) + H_2O \Leftrightarrow N_2H_5^+(aq) + OH^-(aq)$	9.5×10^{-7}
aniline	$C_6H_5NH_2(aq) \Leftrightarrow C_6H_5NH_3^+(aq) + OH^-(aq)$	4.2×10^{-10}

Ksp Values for Selected Substances at Room Temperature, 25°C

Compound	Ksp	Compound	Ksp	Compound	Ksp
Carbonates		**Halides**		**Hydroxides**	
$BaCO_3$	2.6×10^{-9}	CaF_2	3.5×10^{-11}	$Al(OH)_3$	4.6×10^{-33}
$CaCO_3$	3.4×10^{-9}	$PbBr_2$	6.6×10^{-6}	$Ca(OH)_2$	5.0×10^{-6}
$CuCO_3$	2.5×10^{-10}	$PbCl_2$	1.7×10^{-5}	$Cu(OH)_2$	2.2×10^{-20}
$PbCO_3$	7.4×10^{-14}	PbF_2	3.3×10^{-8}	$Fe(OH)_2$	4.9×10^{-17}
$MgCO_3$	6.8×10^{-6}	PbI_2	9.8×10^{-9}	$Fe(OH)_3$	2.8×10^{-39}
Ag_2CO_3	8.5×10^{-12}	$AgCl$	1.8×10^{-10}	$Mg(OH)_2$	5.6×10^{-12}
$ZnCO_3$	1.5×10^{-10}	$AgBr$	5.4×10^{-13}	$Zn(OH)_2$	3.0×10^{-17}
Hg_2CO_3	3.6×10^{-17}	AgI	8.5×10^{-17}	**Sulfates**	
Chromates		**Phosphates**		$BaSO_4$	1.1×10^{-10}
$BaCrO_4$	1.2×10^{-10}	$Pb_3(PO_4)_2$	9.8×10^{-21}	$CaSO_4$	4.9×10^{-5}
$PbCrO_4$	2.3×10^{-13}	$Ca_3(PO_4)_2$	2.1×10^{-33}	$PbSO_4$	2.5×10^{-8}
Ag_2CrO_4	1.1×10^{-12}	$Mg_3(PO_4)_2$	1.0×10^{-24}	Ag_2SO_4	1.2×10^{-5}
Iodates		$FePO_4 \cdot 2H_2O$	9.91×10^{-16}	**Arsenates**	
$Cd(IO_3)_2$	2.3×10^{-8}	$Ni_3(PO_4)_2$	4.7×10^{-32}	$Pb_3(AsO_4)_2$	4.0×10^{-36}

pH Ranges Of Common Acid-base Indicators

Indicator	pH range	Colour at low end of range	Colour at middle of range	Colour at high end of range
methyl violet	0.0–1.6	yellow	green	blue
orange IV	1.4–2.8	red	orange	yellow
methyl yellow	2.9–4.0	red	orange	yellow
bromophenol blue	3.0–4.6	yellow	green	blue
methyl orange	3.2–4.4	red	orange	yellow
bromocresol green	3.8–5.4	yellow	green	blue
methyl red	4.8–6.0	red	orange	yellow
chlorophenol red	5.2–6.8	yellow	orange	red
litmus	5.5–8.0	red	purple	blue
bromothymol blue	6.0–7.6	yellow	green	blue
phenol red	6.6–8.0	yellow	orange	red
phenolphthalein	8.2–10.0	colourless	pink	red
thymolphthalein	9.4–10.6	colourless	light blue	blue
alizarin yellow	10.1–12.0	yellow	orange	red
indigo carmine	11.4–13.0	blue	green	yellow

(Lide, David R., ed. *CRC Handbook of Chemistry and Physics: A Ready-Reference of Chemical and Physical Data.* 87th ed. Boca Raton: Taylor & Francis Group, 2006.)

Standard Electrode Potentials for Half-Reactions

Ionic concentrations of 1.0 mol/L in water at 25 °C. All ions are aqueous.

Half-reaction	E° (volts)
$F_2(g) + 2e^- \Leftrightarrow 2F^-$	+2.87
$MnO_4^- + 8H^+ + 5e^- \Leftrightarrow Mn^{2+} + 4H_2O$	+1.52
$Au^{3+} + 3e^- \Leftrightarrow Au(s)$	+1.50
$Cl_2(g) + 2e^- \Leftrightarrow 2Cl^-$	+1.36
$Cr_2O_7^{2-} + 14H^+ + 6e^- \Leftrightarrow 2Cr^{3+} + 7H_2O$	+1.33
$MnO_2(s) + 4H^+ + 2e^- \Leftrightarrow Mn^{2+} + 2H_2O$	+1.28
$\frac{1}{2}O_2(g) + 2H^+ + 2e^- \Leftrightarrow H_2O$	+1.23
$Br_2(\ell) + 2e^- \Leftrightarrow 2Br^-$	+1.06
$NO_3^- + 4H^+ + 3e^- \Leftrightarrow NO(g) + 2H_2O$	+0.96
$Ag^+ + e^- \Leftrightarrow Ag(s)$	+0.80
$NO_3^- + 2H^+ + e^- \Leftrightarrow NO_2(g) + H_2O$	+0.78
$Fe^{3+} + e^- \Leftrightarrow Fe^{2+}$	+0.77
$I_2(s) + 2e^- \Leftrightarrow 2I^-$	+0.53
$Cu^{2+} + 2e^- \Leftrightarrow Cu(s)$	+0.34
$SO_4^{2-} + 4H^+ + 2e^- \Leftrightarrow SO_2(g) + 2H_2O$	+0.17
$Sn^{4+} + 2e^- \Leftrightarrow Sn^{2+}$	+0.15
$S(s) + 2H^+ + 2e^- \Leftrightarrow H_2S(g)$	+0.14
$2H^+ + 2e^- \Leftrightarrow H_2(g)$	0.00
$Fe^{3+} + 3e^- \Leftrightarrow Fe(s)$	− 0.04
$Pb^{2+} + 2e^- \Leftrightarrow Pb(s)$	− 0.13
$Sn^{2+} + 2e^- \Leftrightarrow Sn(s)$	− 0.14
$Ni^{2+} + 2e^- \Leftrightarrow Ni(s)$	− 0.25
$Cd^{2+} + 2e^- \Leftrightarrow Cd(s)$	− 0.40
$Fe^{2+} + 2e^- \Leftrightarrow Fe(s)$	− 0.44
$Cr^{3+} + 3e^- \Leftrightarrow Cr(s)$	− 0.74
$Zn^{2+} + 2e^- \Leftrightarrow Zn(s)$	− 0.76
$Mn^{2+} + 2e^- \Leftrightarrow Mn(s)$	−1.18
$Al^{3+} + 3e^- \Leftrightarrow Al(s)$	−1.66
$Mg^{2+} + 2e^- \Leftrightarrow Mg(s)$	−2.37
$Na^+ + e^- \Leftrightarrow Na(s)$	−2.71
$Ca^{2+} + 2e^- \Leftrightarrow Ca(s)$	−2.87
$Ba^{2+} + 2e^- \Leftrightarrow Ba(s)$	−2.90
$Cs^+ + e^- \Leftrightarrow Cs(s)$	−2.92
$K^+ + e^- \Leftrightarrow K(s)$	−2.92
$Li^+ + e^- \Leftrightarrow Li(s)$	−3.00