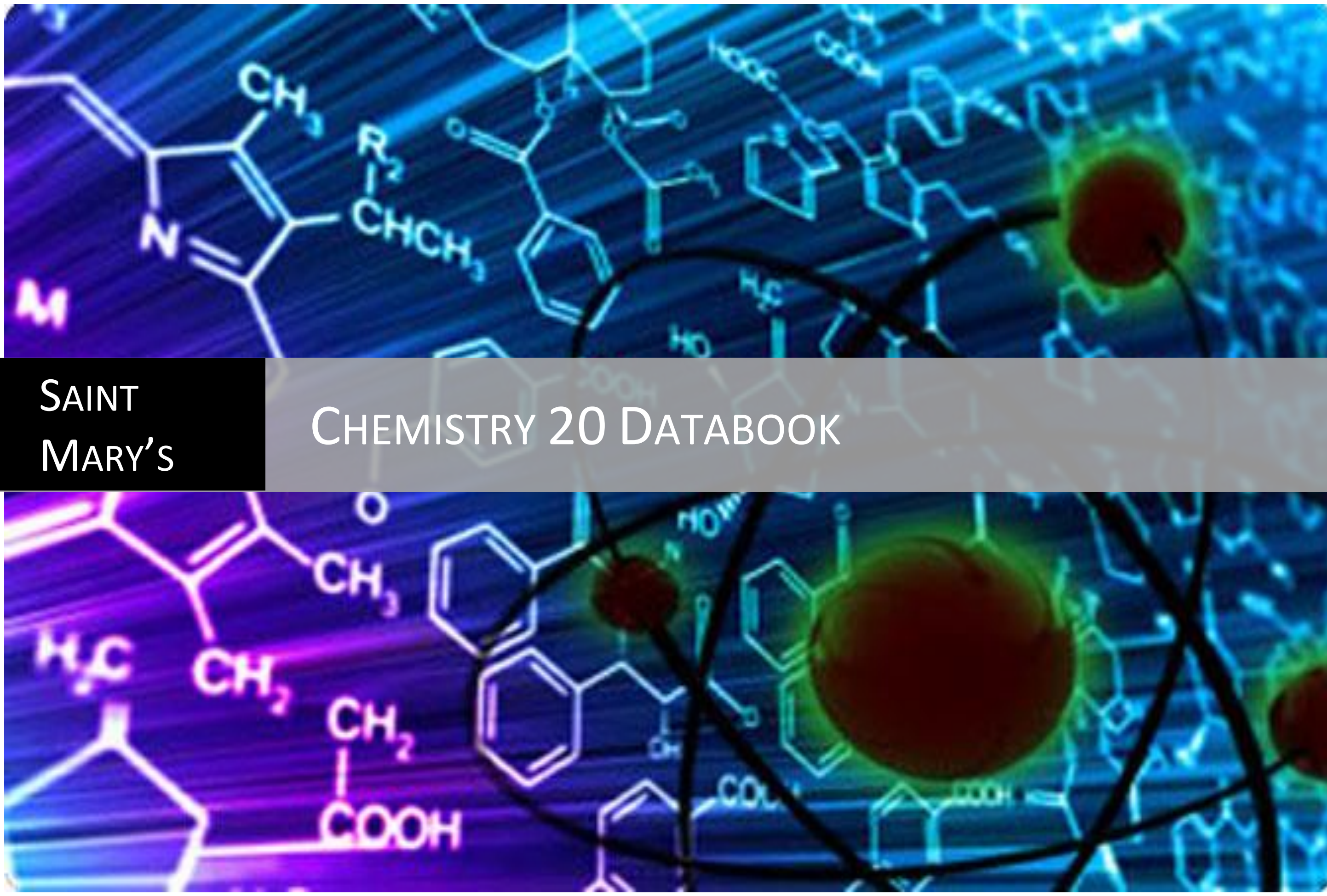
SAINT MARY'S

CHEMISTRY 20 DATABOOK



| Mr. Standring

1	2	3	4	5	6	7	8	9

Table of Common Polyatomic Ions

acetate (ethanoate)	CH_3COO^-	chromate	CrO_4^{2-}	phosphate	PO_4^{3-}
ammonium	NH_4^+	dichromate	$Cr_2O_7^{2-}$	hydrogen phosphate	HPO_4^{2-}
benzoate	$C_6H_5COO^-$	cyanide	CN^-	dihydrogen phosphate	$H_2PO_4^-$
borate	BO_3^{3-}	hydroxide	OH^-	silicate	SiO_3^{2-}
carbide	C_2^{2-}	iodate	IO_3^-	sulfate	SO_4^{2-}
carbonate	CO_3^{2-}	nitrate	NO_3^-	hydrogen sulfate	HSO_4^-
hydrogen carbonate	HCO_3^-	nitrite	NO_2^-	sulfite	SO_3^{2-}
perchlorate	ClO_4^-	oxalate	$OOCCOO^{2-}$	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	$S_2O_3^{2-}$
		persulfide	S_2^{2-}		

1	2	3	4	5	6	7	8	9
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							
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

Lide, D.R. 2005. *CRC Handbook of Chemistry and Physics*. 86th ed. Boca Raton: CRC Press.

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

IUPAC *commission on atomic weights and isotopic abundances.* 2002. http://www.chem.qmw.ac.uk/iupac/AtWt/index.html.

Period	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
1									2 4.00 — — He helium
2				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
3				13 26.98 3+ 1.6 Al aluminium	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
4	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
5	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
6	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
7	110 (271) Ds darmstadtium	111 (272) Rg roentgenium							

Legend for Elements

- Metallic solids
- Non-metallic solids
- Gases
- Liquids

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

Key

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

* Based on $^{12}_{6}C$
( ) Indicates mass of the most stable isotope

* The isotopic mix of naturally occurring lead is more variable than other elements, preventing precision to greater than tenths of a gram per mole.

63 151.96 3+, 2+ — Eu europium	64 157.25 3+ 1.2 Gd gadolinium	65 158.93 3+ — Tb terbium	66 162.50 3+ 1.2 Dy dysprosium	67 164.93 3+ 1.2 Ho holmium	68 167.26 3+ 1.2 Er erbium	69 168.93 3+ 1.3 Tm thulium	70 173.04 3+, 2+ — Yb ytterbium	71 174.97 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
$\Delta_{\mathrm{f}}H°$	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)
°	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_{air} = 1.01 J/(g·°C)

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

c_{copper} = 0.385 J/(g·°C)

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

c_{iron} = 0.449 J/(g·°C)

c_{tin} = 0.227 J/(g·°C)

c_{water} = 4.19 J/(g·°C)

Water Autoionization Constant (Dissociation Constant)

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

Faraday Constant

$F = 9.65 \times 10^4$ 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}

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^- $OOCCOO^{2-}$	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^+ $Co(IO_3)_2$ $Fe_2(OOCCOO)_3$	Group 1 ions NH_4^+
Solubility less than 0.1 mol/L **(slightly soluble)**	$RbClO_4$ $CsClO_4$ $AgCH_3COO$ $Hg_2(CH_3COO)_2$	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.

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	$HClO_4$(aq)	ClO_4^-(aq)	very large
hydroiodic acid aqueous hydrogen iodide	HI(aq)	I^-(aq)	very large
hydrobromic acid aqueous hydrogen bromide	HBr(aq)	Br^-(aq)	very large
hydrochloric acid aqueous hydrogen chloride	HCl(aq)	Cl^-(aq)	very large
sulfuric acid aqueous hydrogen sulfate	H_2SO_4(aq)	HSO_4^-(aq)	very large
nitric acid aqueous hydrogen nitrate	HNO_3(aq)	NO_3^-(aq)	very large
hydronium ion	H_3O^+(aq)	H_2O(l)	1
oxalic acid	HOOCCOOH(aq)	$HOOCCOO^-$(aq)	5.6×10^{-2}
sulfurous acid aqueous hydrogen sulfite	H_2SO_3(aq)	HSO_3^-(aq)	1.4×10^{-2}
hydrogen sulfate ion	HSO_4^-(aq)	SO_4^{2-}(aq)	1.0×10^{-2}
phosphoric acid aqueous hydrogen phosphate	H_3PO_4(aq)	$H_2PO_4^-$(aq)	6.9×10^{-3}
citric acid 2-hydroxy-1,2,3-propanetricarboxylic acid	$C_3H_5O(COOH)_3$(aq)	$C_3H_5O(COOH)_2COO^-$(aq)	7.4×10^{-4}
hydrofluoric acid aqueous hydrogen fluoride	HF(aq)	F^-(aq)	6.3×10^{-4}
nitrous acid aqueous hydrogen nitrite	HNO_2(aq)	NO_2^-(aq)	5.6×10^{-4}
formic acid methanoic acid	HCOOH(aq)	$HCOO^-$(aq)	1.8×10^{-4}
hydrogen oxalate ion	$HOOCCOO^-$(aq)	$OOCCOO^{2-}$(aq)	1.5×10^{-4}
lactic acid 2-hydroxypropanoic acid	C_2H_5OCOOH(aq)	$C_2H_5OCOO^-$(aq)	1.4×10^{-4}
ascorbic acid 2(1,2-dihydroxyethyl)-4,5-dihydroxy-furan-3-one	$H_2C_6H_6O_6$(aq)	$HC_6H_6O_6^-$(aq)	9.1×10^{-5}

benzoic acid benzenecarboxylic acid	$C_6H_5COOH(aq)$	$C_6H_5COO^-(aq)$	6.3×10^{-5}
acetic acid ethanoic acid	$CH_3COOH(aq)$	$CH_3COO^-(aq)$	1.8×10^{-5}
dihydrogen citrate ion	$C_3H_5O(COOH)_2COO^-(aq)$	$C_3H_5OCOOH(COO)_2^{2-}(aq)$	1.7×10^{-5}
butanoic acid	$C_3H_7COOH(aq)$	$C_3H_7COO^-(aq)$	1.5×10^{-5}
propanoic acid	$C_2H_5COOH(aq)$	$C_2H_5COO^-(aq)$	1.3×10^{-5}
carbonic acid ($CO_2 + H_2O$) aqueous hydrogen carbonate	$H_2CO_3(aq)$	$HCO_3^-(aq)$	4.5×10^{-7}
hydrogen citrate ion	$C_3H_5OCOOH(COO)_2^{2-}(aq)$	$C_3H_5O(COO)_3^{3-}(aq)$	4.0×10^{-7}
hydrosulfuric acid aqueous hydrogen sulfide	$H_2S(aq)$	$HS^-(aq)$	8.9×10^{-8}
hydrogen sulfite ion	$HSO_3^-(aq)$	$SO_3^{2-}(aq)$	6.3×10^{-8}
dihydrogen phosphate ion	$H_2PO_4^-(aq)$	$HPO_4^{2-}(aq)$	6.2×10^{-8}
hypochlorous acid aqueous hydrogen hypochlorite	$HOCl(aq)$	$OCl^-(aq)$	4.0×10^{-8}
hydrocyanic acid aqueous hydrogen cyanide	$HCN(aq)$	$CN^-(aq)$	6.2×10^{-10}
ammonium ion	$NH_4^+(aq)$	$NH_3(aq)$	5.6×10^{-10}
hydrogen carbonate ion	$HCO_3^-(aq)$	$CO_3^{2-}(aq)$	4.7×10^{-11}
hydrogen ascorbate ion	$HC_6H_6O_6^-(aq)$	$C_6H_6O_6^{2-}(aq)$	2.0×10^{-12}
hydrogen phosphate ion	$HPO_4^{2-}(aq)$	$PO_4^{3-}(aq)$	4.8×10^{-13}
water	$H_2O(l)$	$OH^-(aq)$	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.

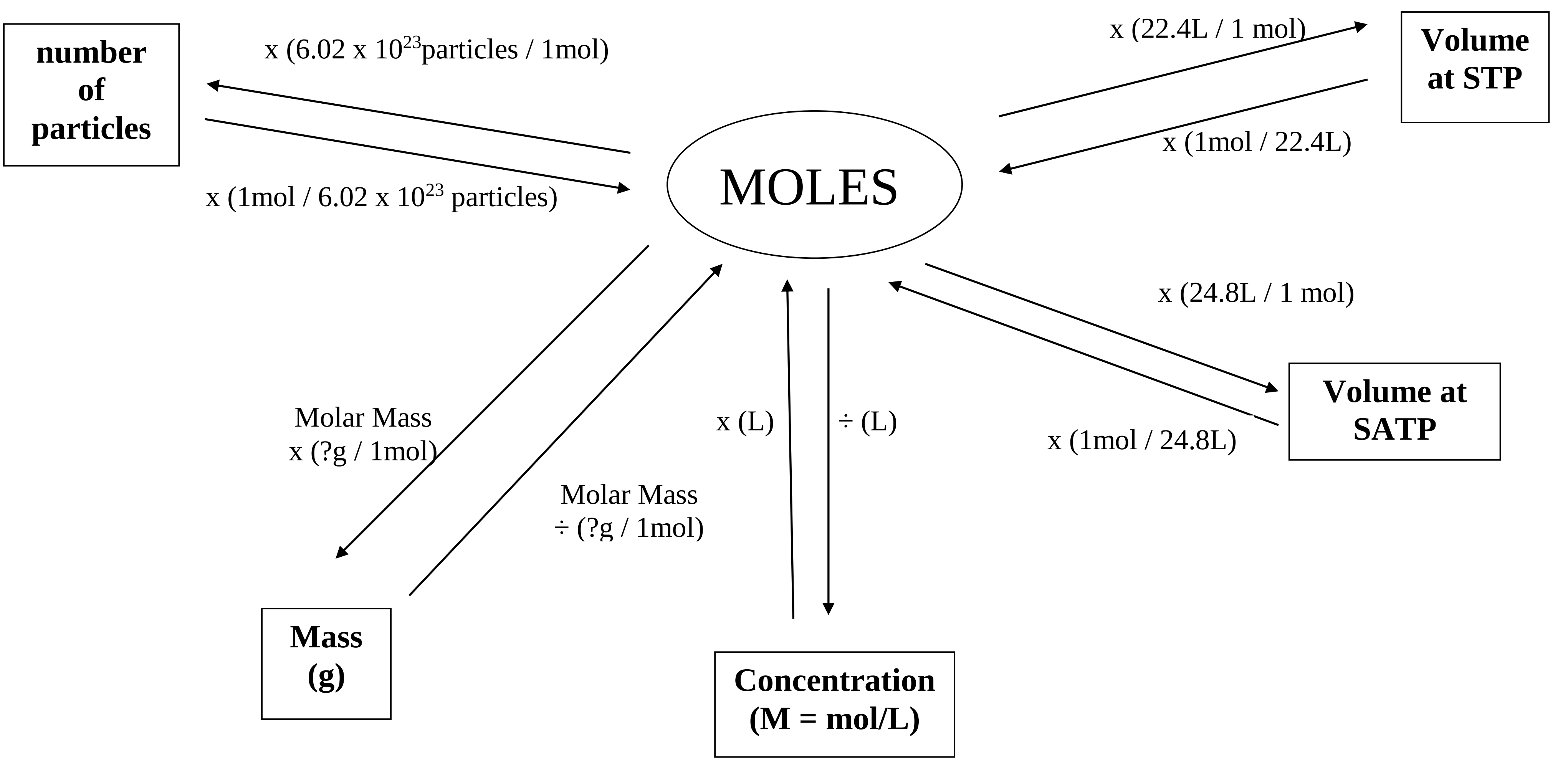
Acid–Base Indicators at 298.15 K

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	$H_2Cr(aq)$ / $HCr^-(aq)$ $HCr^-(aq)$ / $Cr^{2-}(aq)$	0.0 – 1.0 7.0 – 8.8	red to yellow yellow to red	$\sim 3 \times 10^{-1}$ 3.5×10^{-9}
thymol blue	$H_2Tb(aq)$ / $HTb^-(aq)$ $HTb^-(aq)$ / $Tb^{2-}(aq)$	1.2 – 2.8 8.0 – 9.6	red to yellow yellow to blue	2.2×10^{-2} 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

The Ultimate Mole Conversion Picture



- **Boyle's Law** $P_iV_i = P_fV_f$
- **Charles's Law** $V_i/T_i = V_f/T_f$
- **Avogadro's Law** $V_i/n_i = V_f/n_f$
- **Molar Volume** **22.4 L @ 1atm and 273 K (STP)**
  24.8 L @ 100 kPa & 298K (SATP)

$$R = 8.314 \frac{L \circ kPa}{mol \circ K} = 0.0821 \frac{L \circ atm}{mol \circ K}$$

- Combined Gas Law $\frac{P_1V_1}{n_1T_1} = \frac{P_2V_2}{n_2T_2}$
- **Ideal Gas Law** **PV = nRT**
- **1 atm = 760.0 mm Hg = 101.3 kPa**
- **°C = K - 273**

- **d**ensity = **m**ass / **V**olume
  - d = m/V
  - Substitute into ideal gas law:

    PV=nRT

$$d = \frac{PM}{RT}$$

- **M**olecular Weight = **m**ass / moles (**n**)
  - M = m/n
  - Substitute into ideal gas law:

    PV=nRT

$$PV = \frac{m}{MRT}$$

SUMMARY Concentration of a Solution

Type	Definition	Units	
percentage			
by volume	$c = \frac{V_{solute}}{V_{solution}} \times 100\%$	% V/V	(or mL/100 mL)
mass by volume	$c = \frac{m_{solute}}{V_{solution}} \times 100\%$	% W/V	(or g/100 mL)
by mass	$c = \frac{m_{solute}}{m_{solution}} \times 100\%$	% W/W	(or g/100 g)
parts per million	$c = \frac{m_{solute}}{m_{solution}}$	ppm	(or mg/kg)
amount	$c = \frac{n_{solute}}{V_{solution}}$	mol/L	

For dilution or reduction (*removal of solvent by evaporation*) → $c_iV_i = c_fV_f$

- $pH = -\log[H^+]$
- $[H^+] = 10^{-pH}$
- $pOH = -\log[OH^-]$
- $pH + pOH = 14$
- Assume that $[H^+] = [H_3O^+]$

*Rounding: $[H_3O^+]$ significant digits convert to pH decimal places.