Chemistry Reference Tables

PHYSICAL CONSTANTS AND CONVERSION FACTORS

NAME	SYMBOL	VALUE (with units)
Length		
Meter	m	
Nanometer	nm	1×10^{-9} m
Angstrom	Å	1×10^{-10} m
Mass (m)		
Kilogram	kg	
Atomic Mass Units	amu or u	1.66×10^{-24} g
Volume (V)		
Liter	L	
	1 mL = 1 cm^3	
Pressure (P)		
Standard Pressure	1 atm	1 atm = 101.3 kPa = 760. Torr = 760. mmHg = 14.7 lb/in^2
Temperature (T)		
Standard Temperature	°C	32.0°F = 0.0°C = 273.15K
Energy		
Heat	Q	1 cal = 4.184 J 1 Cal = 4.184 kJ
Activation Energy	E_a	kJ/mol
Specific Heat of water (l)	C_p	4.18 J/g•°C
Specific Heat of water (g)	C_p	2.02 J/g•°C
Specific Heat of water (s)	C_p	2.05 J/g•°C
Heat of fusion of water	ΔH_{fus}	6.01 kJ/mol or 334 J/g
Heat of vaporization of water	ΔH_{vap}	40.7 kJ/mol or 2260 J/g
Constants		
Speed of light	c	3.00×10^8 m/s
Avogadro's number	N_A	6.022×10^{23} particles/mol
Charge of an electron	e	1.60×10^{-19} C
Equilibrium constant	K	
Rate constant	k	
Reaction quotient	Q	
Universal gas constant	R	0.08206 L-atm/mol K 62.4 L mmHg/mol K 8.314 J/K mol 8.314 L kPa/mol K 1.99 cal/K mol

NAME	SYMBOL	DENSITY	BOILING POINT (K)	MELTING POINT (K)
Ammonia	NH_3	0.771 g/L@STP	240	195.3
Carbon Dioxide	CO_2	1.98 g/L@STP	195 subl	216.4
Carbon Monoxide	CO	1.25 g/L@STP	82	74
Chlorine	Cl_2	3.21 g/L@STP	238	172.02
Ethanol	CH_3CH_2OH	0.7893 g/cm^3	351.5	155.7
Glucose	$C_6H_{12}O_6$	1.54 g/cm^3	decompose	359
Gold	Au	19.31 g/cm^3	3353	1337.43
Hexane	C_6H_{14}	0.6603 g/cm^3	342	178
Hydrogen	H_2	0.0899 g/L@STP	20	13.86
Hydrogen Chloride	HCl	1.64 g/L@STP	188	158.2
Hydrogen Sulfide	H_2S	1.54 g/L@STP	212	187.5
Iron	Fe	7.86 g/cm^3	3023	1808
Lead	Pb	11.3437 g/cm^3	2013	600.502
Magnesium	Mg	1.74 g/cm^3	1380	921.8
Methane	CH_4	0.716 g/cm^3	109	91
Methanol	CH_3OH	0.7914 g/cm^3	338	179.1
Nitrogen	N_2	1.25 g/L@STP	77	63.14
Nitrogen(II) Oxide	NO	1.34 g/L@STP	121	109.4
Oxygen	O_2	1.43 g/L@STP	90	54.6
Silver	Ag	10.5 g/cm^3	2485	1234.93
Sodium Bicarbonate	$NaHCO_3$	2.159 g/cm^3	decompose	543
Sodium Carbonate	Na_2CO_3	2.532 g/cm^3	decompose	1124
Sodium Chloride	NaCl	2.165 g/cm^3	1686	1074
Sucrose	$C_{12}H_{22}O_{11}$	1.27 g/cm^3	decompose	359
Sulfur Dioxide	SO_2	2.92 g/L@STP	263	200.3
Tin	Sn	5.75 g/cm^3	2543	504.96
Water	H_2O	1.00 g/cm^3	373	273

STANDARD UNITS

Symbol	Name	Quantity
m	meter	length
kg	kilogram	mass
Pa	pascal	pressure
K	Kelvin	temperature
mol	mole	amount of a substance
J	joule	energy, work, quantity of heat
s	second	time
C	coulomb	electric charge
V	volt	electric potential
L	liter	volume

WRITING CHEMICAL EQUATIONS

Writing correct chemical equations requires that you know how to predict products of reactions. Even with limited experience, one can use a few guidelines to accomplish this. Seven frequently used elements naturally occur as diatomic molecules: H_2, O_2, N_2, F_2, Cl_2, Br_2, I_2. This is how they should always be written in a chemical equation. States of matter should be indicated by (*s*), (*l*), or (*g*) and ions in aqueous solution as (*aq*).

General Classification of Reactions

(*A*, *B*, *C*, *D* represent elements and *M* represents a metal)

1. **Synthesis:** $A + B \rightarrow AB$

a. Reaction between hydrogen and a nonmetal
$H_2\ (g) + Cl_2\ (g) \rightarrow 2HCl\ (g)$

b. Metal-Nonmetal reactions
$2Na\ (s) + Cl_2\ (g) \rightarrow 2NaCl\ (s)$

c. Metal oxide-water reactions
$CaO\ (s) + H_2O\ (l) \rightarrow Ca(OH)_2\ (s)$

d. Nonmetal oxide-water reactions
$SO_2\ (g) + H_2O\ (l) \rightarrow H_2SO_3\ (aq)$

2. **Decomposition**

a. Binary compounds $AB\text{-heat/electricity} \rightarrow A + B$
$2HgO\ (s) + \text{heat} \rightarrow 2Hg\ (l) + O_2\ (g)$

b. Metallic carbonates $MCO_3 \rightarrow MO + CO_2$
$CaCO_3\ (s) + \text{heat} \rightarrow CaO\ (s) + CO_2\ (g)$

c. Metallic hydrogen carbonates $MHCO_3 \rightarrow MO + H_2O + CO_2$
$2NaHCO_3\ (s) + \text{heat} \rightarrow Na_2O\ (s) + H_2O\ (g) + 2CO_2\ (g)$

d. Metallic hydroxides $MOH \rightarrow MO + H_2O$
$2NaOH\ (s) + \text{heat} \rightarrow Na_2O\ (s) + H_2O\ (g)$

e. Metallic chlorates decompose $MClO_3 \rightarrow MCl + O_2$
$2KClO_3\ (s) + \text{heat} \rightarrow 2KCl\ (s) + 3O_2\ (g)$

f. Some acids decompose to nonmetal oxides and water
$H_2CO_3\ (aq) + \text{heat} \rightarrow H_2O\ (l) + CO_2\ (g)$

g. Hydrate decomposition $AB \cdot xH_2O \rightarrow AB + xH_2O$
$CuSO_4 \cdot 5H_2O\ (s) + \text{heat} \rightarrow CuSO_4\ (s) + 5H_2O\ (l)$

h. Peroxide
$2H_2O_2\ (l) + \text{heat or catalyst} \rightarrow 2H_2O\ (l) + O_2\ (g)$

3. **Single Replacement:** $A + BC \rightarrow AC + B$

a. Metal-metal replacement
$2Al\ (s) + 3Fe(NO_3)_2\ (aq) \rightarrow 2Al(NO_3)_3\ (aq) + 3Fe\ (s)$

b. Active metal + water reactions
$2Na\ (s) + 2H_2O\ (l) \rightarrow 2NaOH\ (aq) + H_2\ (g)$

c. Metal-Acid reactions
$2HCl\ (aq) + Mg\ (s) \rightarrow MgCl_2\ (aq) + H_2\ (g)$

d. Halide-Halide replacement
$Cl_2\ (g) + 2HBr\ (aq) \rightarrow 2HCl\ (aq) + Br_2\ (l)$

4. **Double Replacement:** $AB + CD \rightarrow AD + BC$

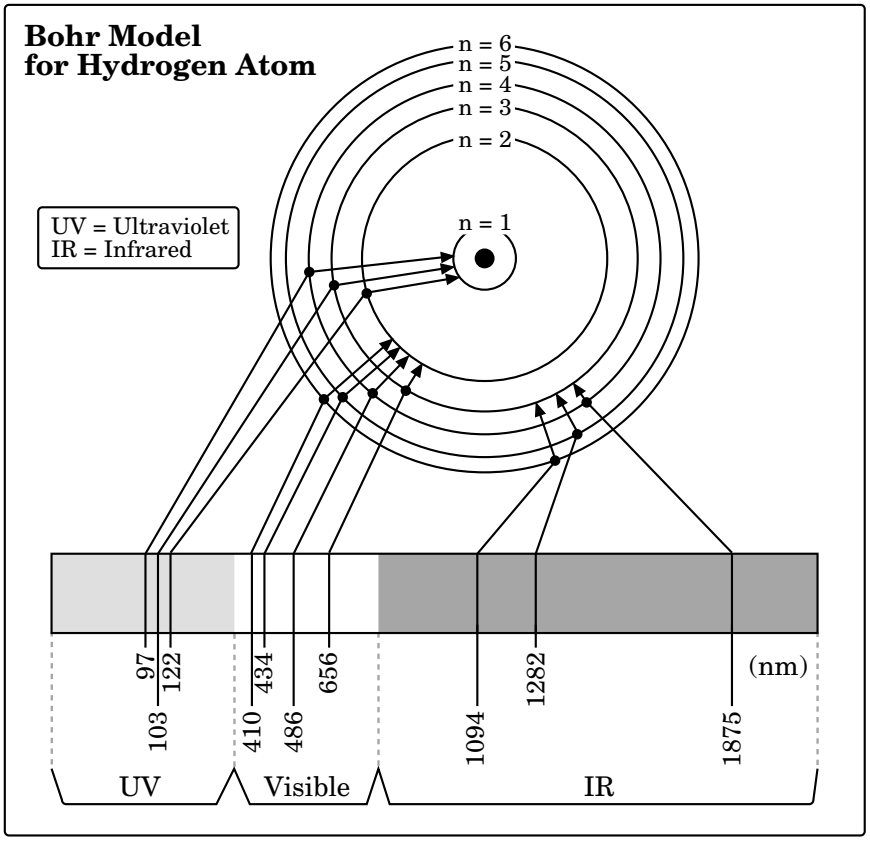
a. Formation of a precipitate from solution
$Pb(NO_3)_2\ (aq) + 2KI\ (aq) \rightarrow PbI_2\ (s) + 2KNO_3\ (aq)$

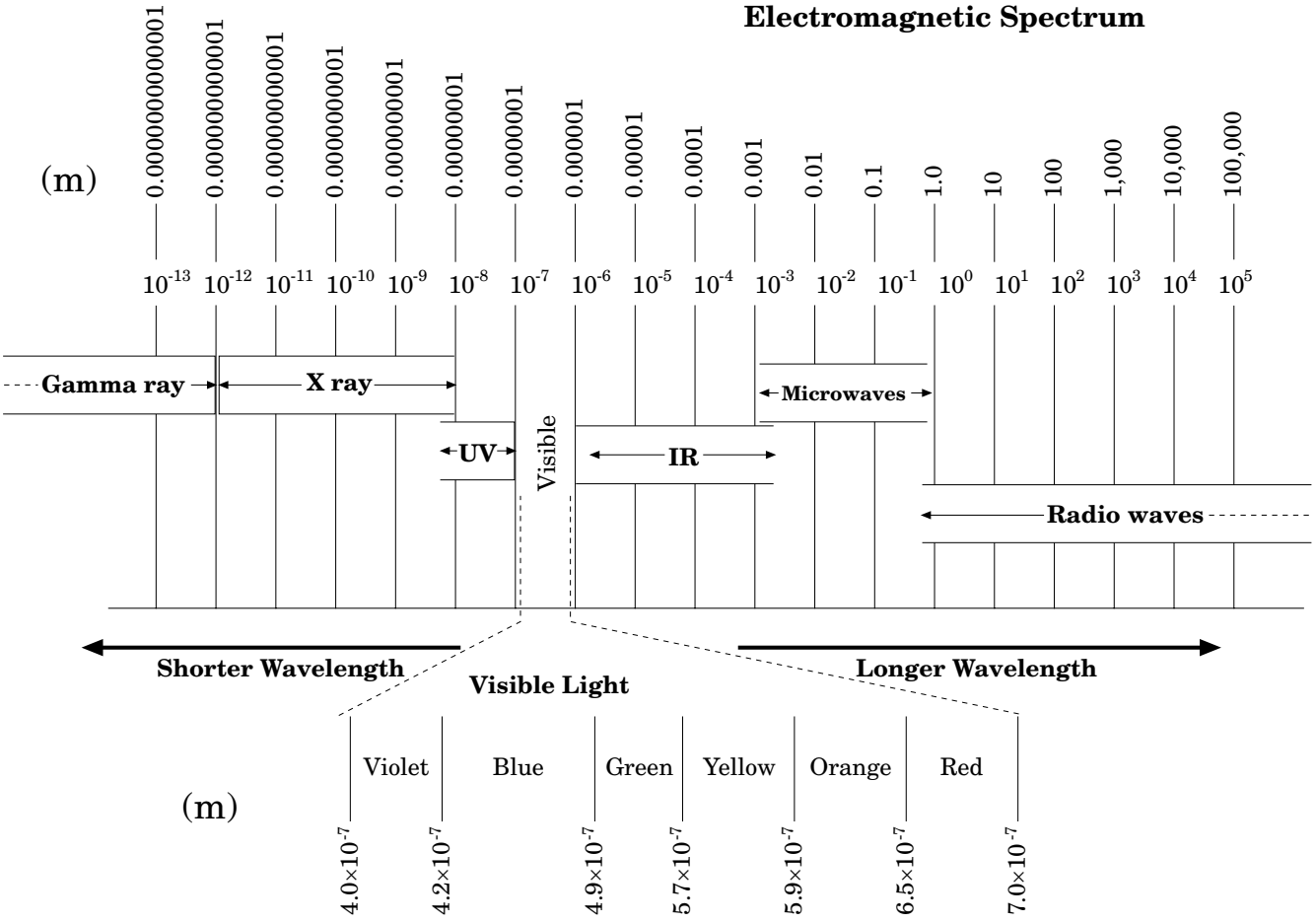
b. Formation of a gas
$CaCO_3\ (s) + 2HCl\ (aq) \rightarrow CaCl_2\ (aq) + H_2O\ (l) + CO_2\ (g)$

c. Acid-Base Neutralization Reaction
$HCl\ (aq) + NaOH\ (aq) \rightarrow NaCl\ (aq) + H_2O\ (l)$

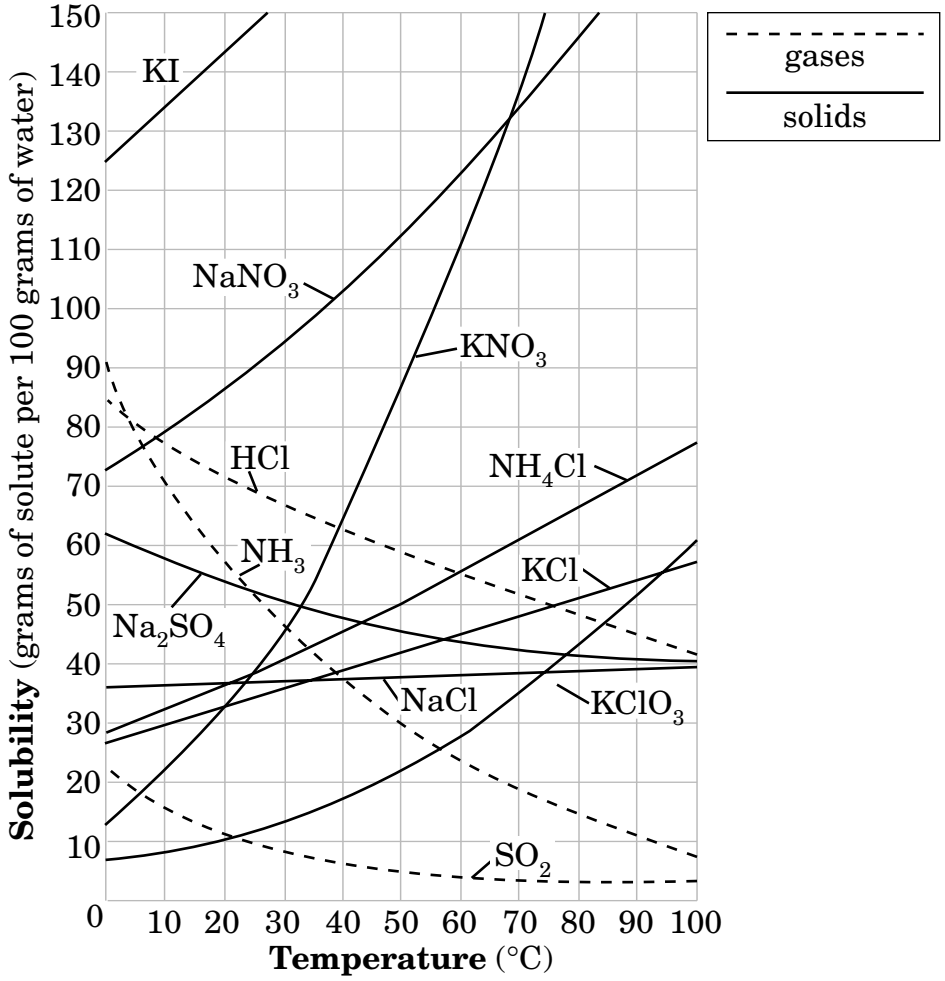
5. **Combustion Reaction**

Hydrocarbon + oxygen → Carbon dioxide and water
$CH_4\ (g) + 2O_2\ (g) \rightarrow CO_2\ (g) + 2H_2O\ (l)$

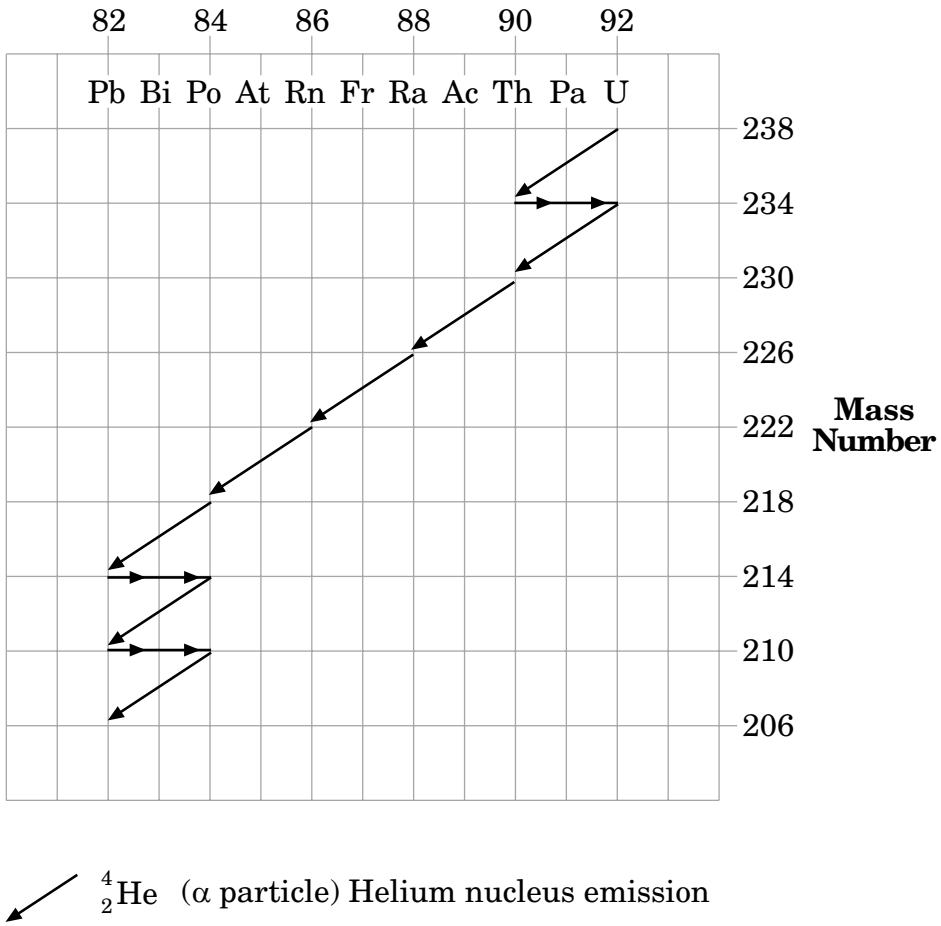

Bohr Model
for Hydrogen Atom
n = 6
n = 5
n = 4
n = 3
n = 2
n = 1
UV = Ultraviolet
IR = Infrared
97
103
122
410
434
486
656
1094
1282
1875
(nm)
UV
Visible
IR


Electromagnetic Spectrum
(m)
0.000000000001
0.00000000001
0.0000000001
0.000000001
0.00000001
0.0000001
0.000001
0.00001
0.0001
0.001
0.01
0.1
1.0
10
100
1,000
10,000
100,000
10^{-13} 10^{-12} 10^{-11} 10^{-10} 10^{-9} 10^{-8} 10^{-7} 10^{-6} 10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1} 10^{0} 10^{1} 10^{2} 10^{3} 10^{4} 10^{5}
Gamma ray
X ray
UV
Visible
IR
Microwaves
Radio waves
Shorter Wavelength
Longer Wavelength
Visible Light
(m)
Violet
Blue
Green
Yellow
Orange
Red
4.0×10^{-7}
4.2×10^{-7}
4.9×10^{-7}
5.7×10^{-7}
5.9×10^{-7}
6.5×10^{-7}
7.0×10^{-7}

Solubility Curve



URANIUM DISINTEGRATION SERIES



$D = \frac{m}{V}$

D = density
m = mass
V = volume

$K = °C + 273$

K = Kelvin

$\frac{V_1P_1}{T_1} = \frac{V_2P_2}{T_2}$

$P_t = P_1 + P_2 + P_3 + \ldots$

$PV = nRT$

$\frac{v_1}{v_2} = \frac{\sqrt{mw_2}}{\sqrt{mw_1}}$

T = temperature
P = pressure
V = volume
R = universal gas constant
v = rate of effusion
mw = molecular mass

$M = \frac{\text{moles of solute}}{\text{liters of solution}}$

$nM_1V_1 = nM_2V_2$

M = molarity
n = number of moles of ions

$Q = mC_p\Delta T$

$Q = mH_f$

$Q = mH_v$

Q = quantity of heat
ΔT = change in temperature
C_p = specific heat
H_f = heat of fusion
H_v = heat of vaporization
m = mass

$c = \lambda\upsilon$

$E = h\upsilon$

c = speed of light
λ = wavelength
υ = frequency
E = energy
h = Planck's constant

$pH = -\log[H^+]$

$pOH = -\log[OH^-]$

$K_w = [H^+][OH^-] = 1 \times 10^{-14}$

K_w = equilibrium constant for the ionization of water

$\%$ Error $= \frac{\text{Accepted value} - \text{Experimental value}}{\text{Accepted value}} \times 100$

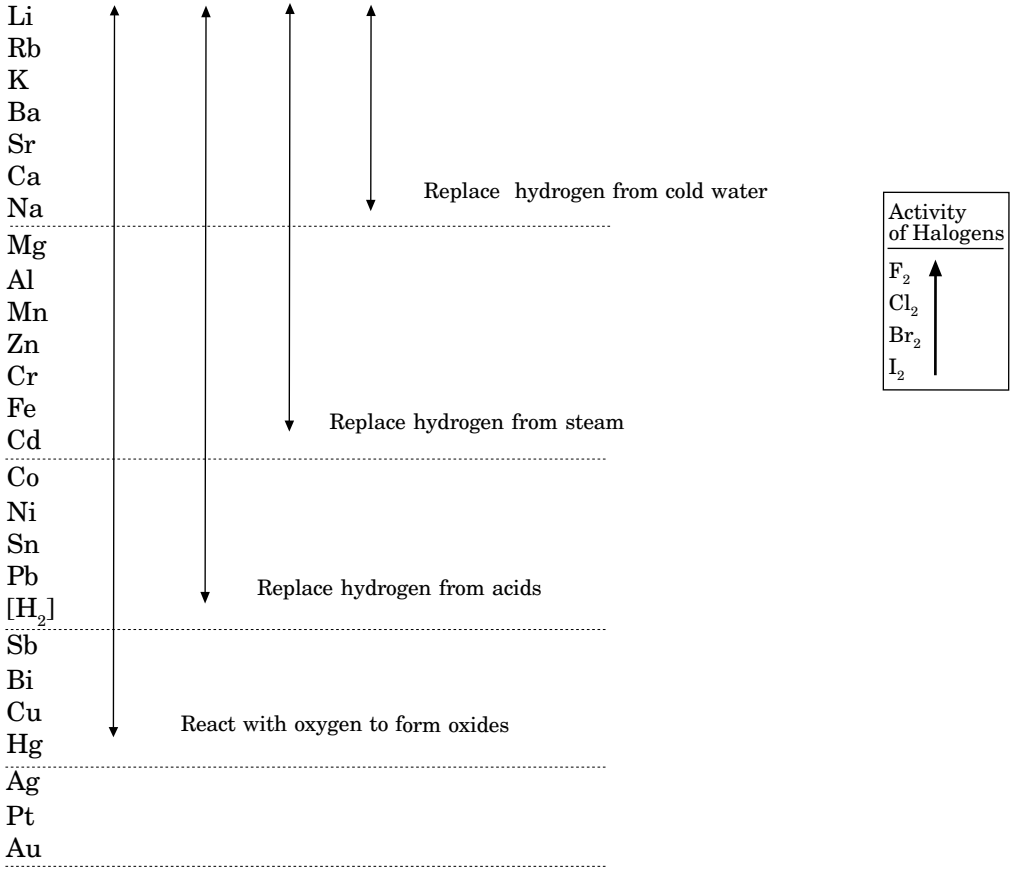
SOLUBILITY RULES:

SOLUBLE:
All Nitrates, Acetates, Ammonium and Group I salts
All Chlorides, Bromides, and Iodides, except Silver, Lead, and Mercury(I)
All Fluorides except Group II, Lead(II), and Iron(III)
All Sulfates except Calcium, Strontium, Barium, Mercury, Lead(II), and Silver

INSOLUBLE:
All Carbonates and Phosphates except Group I and Ammonium
All Hydroxides except Group I, Strontium, and Barium
All Sulfides except Group I, II, and Ammonium
All Oxides except Group I

INSOLUBLE means a precipitate forms when equal volumes of 0.10 M solutions or greater are mixed

ACTIVITY SERIES of METALS:



1. Any metal higher in the activity series will displace another metal in a single displacement reaction.
2. Metals above water may react with water rather than a metal compound.

Standard Reduction Table
25°C

Half-Reaction	E° (V)
$H_2O_2+2H^++2e^- \rightarrow 2H_2O$	1.78
$PbO_2+4H^++SO_4^{2-}+2e^- \rightarrow PbSO_4+2H_2O$	1.69
$MnO_4^-+4H^++3e^- \rightarrow MnO_2+2H_2O$	1.68
$MnO_4^-+8H^++5e^- \rightarrow Mn^{2+}+4H_2O$	1.51
$PbO_2+4H^++2e^- \rightarrow Pb^{2+}+2H_2O$	1.46
$Cl_2+2e^- \rightarrow 2Cl^-$	1.36
$O_2+4H^++4e^- \rightarrow 2H_2O$	1.23
$Br_2+2e^- \rightarrow 2Br^-$	1.09
$NO_3^-+4H^++3e^- \rightarrow NO+2H_2O$	0.96
$Ag^++e^- \rightarrow Ag$	0.80
$I_2+2e^- \rightarrow 2I^-$	0.54
$Cu^++e^- \rightarrow Cu$	0.52
$O_2+2H_2O+4e^- \rightarrow 4OH^-$	0.40
$Hg_2Cl_2+2e^- \rightarrow 2Hg+2Cl^-$	0.34
$Cu^{2+}+2e^- \rightarrow Cu$	0.34
$SO_4^{2-}+4H^++2e^- \rightarrow H_2SO_3+H_2O$	0.20
$Cu^{2+}+e^- \rightarrow Cu^+$	0.16
$2H^++2e^- \rightarrow H_2$	0.00
$Fe^{3+}+3e^- \rightarrow Fe$	–0.036
$Pb^{2+}+2e^- \rightarrow Pb$	–0.13
$Sn^{2+}+2e^- \rightarrow Sn$	–0.14
$Ni^{2+}+2e^- \rightarrow Ni$	–0.23
$PbSO_4+2e^- \rightarrow Pb+SO_4^{2-}$	–0.35
$Cd^{2+}+2e^- \rightarrow Cd$	–0.40
$Fe^{2+}+2e^- \rightarrow Fe$	–0.44
$Cr^{3+}+3e^- \rightarrow Cr$	–0.73
$Zn^{2+}+2e^- \rightarrow Zn$	–0.76
$2H_2O+2e^- \rightarrow H_2+2OH^-$	–0.83
$Mn^{2+}+2e^- \rightarrow Mn$	–1.18
$Al^{3+}+3e^- \rightarrow Al$	–1.66
$Mg^{2+}+2e^- \rightarrow Mg$	–2.37
$Na^++e^- \rightarrow Na$	–2.71
$Ca^{2+}+2e^- \rightarrow Ca$	–2.76
$K^++e^- \rightarrow K$	–2.92
$Li^++e^- \rightarrow Li$	–3.05

Increasing strength as reducing agent ↓

PERIODIC TABLE OF THE ELEMENTS

1 1A																	18 8A
1 **H** Hydrogen 1.008	2 2A											13 3A	14 4A	15 5A	16 6A	17 7A	2 **He** Helium 4.003
3 **Li** Lithium 6.941	4 **Be** Beryllium 9.012											5 **B** Boron 10.81	6 **C** Carbon 12.01	7 **N** Nitrogen 14.01	8 **O** Oxygen 16.00	9 **F** Fluorine 19.00	10 **Ne** Neon 20.18
11 **Na** Sodium 22.99	12 **Mg** Magnesium 24.31	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B	10 8B	11 1B	12 2B	13 **Al** Aluminum 26.98	14 **Si** Silicon 28.09	15 **P** Phosphorus 30.97	16 **S** Sulfur 32.07	17 **Cl** Chlorine 35.45	18 **Ar** Argon 39.95
19 **K** Potassium 39.10	20 **Ca** Calcium 40.08	21 **Sc** Scandium 44.96	22 **Ti** Titanium 47.88	23 **V** Vanadium 50.94	24 **Cr** Chromium 52.00	25 **Mn** Manganese 54.94	26 **Fe** Iron 55.85	27 **Co** Cobalt 58.93	28 **Ni** Nickel 58.69	29 **Cu** Copper 63.55	30 **Zn** Zinc 65.39	31 **Ga** Gallium 69.72	32 **Ge** Germanium 72.61	33 **As** Arsenic 74.92	34 **Se** Selenium 78.96	35 **Br** Bromine 79.90	36 **Kr** Krypton 83.80
37 **Rb** Rubidium 85.47	38 **Sr** Strontium 87.62	39 **Y** Yttrium 88.91	40 **Zr** Zirconium 91.22	41 **Nb** Niobium 92.91	42 **Mo** Molybdenum 95.94	43 **Tc** Technetium (98)	44 **Ru** Ruthenium 101.1	45 **Rh** Rhodium 102.9	46 **Pd** Palladium 106.4	47 **Ag** Silver 107.9	48 **Cd** Cadmium 112.4	49 **In** Indium 114.8	50 **Sn** Tin 118.7	51 **Sb** Antimony 121.8	52 **Te** Tellurium 127.6	53 **I** Iodine 126.9	54 **Xe** Xenon 131.3
55 **Cs** Cesium 132.	56 **Ba** Barium 137.	57 **La** Lanthanum 138.	72 **Hf** Hafnium 178.	73 **Ta** Tantalum 181.0	74 **W** Tungsten 183.8	75 **Re** Rhenium 186.	76 **Os** Osmium 190.2	77 **Ir** Iridium 192.22	78 **Pt** Platinum 195.08	79 **Au** Gold 196.96	80 **Hg** Mercury 200.59	81 **Tl** Thallium 204.38	82 **Pb** Lead 207.2	83 **Bi** Bismuth 208.98	84 **Po** Polonium (209)	85 **At** Astatine (210)	86 **Rn** Radon (222)
87 **Fr** Francium (223)	88 **Ra** Radium 226.0	89 **Ac** Actinium 227.0	104 **Rf** Rutherfordium (261)	105 **Db** Dubnium (262)	106 **Sg** Seaborgium (263)	107 **Bh** Bohrium (262)	108 **Hs** Hassium (265)	109 **Mt** Meitnerium (266)	110 **Uun** Ununnilium (269)	111 **Uuu** Unununium (272)	112 **Uub** Ununbium (277)						

58 **Ce** Cerium 140.1	59 **Pr** Praseodymium 140.9	60 **Nd** Neodymium 144.2	61 **Pm** Promethium (145)	62 **Sm** Samarium 150.4	63 **Eu** Europium 152.0	64 **Gd** Gadolinium 157.3	65 **Tb** Terbium 158.9	66 **Dy** Dysprosium 162.5	67 **Ho** Holmium 164.9	68 **Er** Erbium 167.3	69 **Tm** Thulium 168.9	70 **Yb** Ytterbium 173.0	71 **Lu** Lutetium 175.0
90 **Th** Thorium 232.0	91 **Pa** Protactnium 231.0	92 **U** Uranium 238.0	93 **Np** Neptunium 237.0	94 **Pu** Plutonium (244)	95 **Am** Americium (243)	96 **Cm** Curium (247)	97 **Bk** Berkelium (247)	98 **Cf** Californium (251)	99 **Es** Einsteinium (252)	100 **Fm** Fermium (257)	101 **Md** Mendelevium (258)	102 **No** Nobelium (259)	103 **Lr** Lawrencium (262)

Stock No. 7952