Chemistry 30 Resource Package

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Periodic Table of the Elements

11A																	8A
1 H Hydrogen 1.008	2 IIA 2A											13 IIIA 3A	14 IVA 4A	15 VA 5A	16 VIA 6A	17 VIIA 7A	2 He Helium 4.003
3 Li Lithium 6.941	4 Be Beryllium 9.012											5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180
11 Na Sodium 22.990	12 Mg Magnesium 24.305	3 IIIB 3B	4 IVB 4B	5 VB 5B	6 VIB 6B	7 VIIB 7B	8	9 VIII 8	10	11 IB 1B	12 IIB 2B	13 Al Aluminum 26.982	14 Si Silicon 28.086	15 P Phosphorus 30.974	16 S Sulfur 32.066	17 Cl Chlorine 35.453	18 Ar Argon 39.948
19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.88	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.933	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.39	31 Ga Gallium 69.732	32 Ge Germanium 72.61	33 As Arsenic 74.922	34 Se Selenium 78.09	35 Br Bromine 79.904	36 Kr Krypton 84.80
37 Rb Rubidium 84.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.94	43 Tc Technetium 98.907	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.906	46 Pd Palladium 106.42	47 Ag Silver 107.868	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.71	51 Sb Antimony 121.760	52 Te Tellurium 127.6	53 I Iodine 126.904	54 Xe Xenon 131.29
55 Cs Cesium 132.905	56 Ba Barium 137.327	57-71	72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	74 W Tungsten 183.85	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.967	80 Hg Mercury 200.59	81 Tl Thallium 204.383	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium [208.982]	85 At Astatine 209.987	86 Rn Radon 222.018
87 Fr Francium 223.020	88 Ra Radium 226.025	89-103	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [269]	109 Mt Meitnerium [268]	110 Ds Darmstadtium [269]	111 Rg Roentgenium [272]	112 Cn Copernicium [277]	113 Uut Ununtrium unknown	114 Fl Flerovium [289]	115 Uup Ununpentium unknown	116 Lv Livermorium [298]	117 Uus Ununseptium unknown	118 Uuo Ununoctium unknown

Lanthanide Series	57 La Lanthanum 138.906	58 Ce Cerium 140.115	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.24	61 Pm Promethium 144.913	62 Sm Samarium 150.36	63 Eu Europium 151.966	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925	66 Dy Dysprosium 162.50	67 Ho Holmium 164.930	68 Er Erbium 167.26	69 Tm Thulium 168.934	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.967
Actinide Series	89 Ac Actinium 227.028	90 Th Thorium 232.038	91 Pa Protactinium 231.036	92 U Uranium 238.029	93 Np Neptunium 237.048	94 Pu Plutonium 244.064	95 Am Americium 243.061	96 Cm Curium 247.070	97 Bk Berkelium 247.070	98 Cf Californium 251.080	99 Es Einsteinium [254]	100 Fm Fermium 257.095	101 Md Mendelevium 258.1	102 No Nobelium 259.101	103 Lr Lawrencium [262]

Table 2: Common Ion Chart

Names, Formulas, and Charges of Positive Ions (Cations)

actinium	Ac^{3+}	nickel II, nickelous	Ni^{2+}
aluminum	Al^{3+}	nickel III, nickelic	Ni^{3+}
ammonium	NH_4^+	osmium	Os^{4+}
barium	Ba^{2+}	palladium II	Pd^{2+}
beryllium	Be^{2+}	palladium IV	Pd^{4+}
bismuth III	Bi^{3+}	platinum II	Pt^{2+}
bismuth V	Bi^{5+}	platinum IV	Pt^{4+}
cadmium	Cd^{2+}	polonioum II	Po^{2+}
calcium	Ca^{2+}	polonium IV	Po^{4+}
cesium	Cs^+	potassium	K^+
chromium II, chromous	Cr^{2+}	radium	Ra^{2+}
chromium III, chromic	Cr^{3+}	rubidium	Rb^+
cobalt II, cobaltous	Co^{2+}	scandium	Sc^{3+}
cobalt III, colbaltic	Co^{3+}	silver	Ag^+
copper I, cuprous	Cu^+	sodium	Na^+
copper II, cupric	Cu^{2+}	strontium	Sr^{2+}
erbium	Er^{3+}	titanium III	Ti^{3+}
francium	Fr^+	titanium IV	Ti^{4+}
gallium	Ga^{3+}	tin II, stannous	Sn^{2+}
gold I, aurous	Au^+	tin IV, stannic	Sn^{4+}
gold III, auric	Au^{3+}	uranium IV	U^{4+}
hydrogen	H^+	uranium VI	U^{6+}
hydronium	H_3O^+	vanadium IV	V^{4+}
iron II, ferrous	Fe^{2+}	vanadium V	V^{5+}
iron III, ferric	Fe^{3+}	zinc	Zn^{2+}
lead II, plumbous	Pb^{2+}		
lead IV, plumbic	Pb^{4+}		
lithium	Li^+		
magnesium	Mg^{2+}		
manganese II, manganous	Mn^{2+}		
manganese IV, manganic	Mn^{4+}		
mercury I, mercurous	Hg^+		
mercury II, mercuric	Hg^{2+}		

NUMERIC PREFIXES

1 - mono	6 - hexa
2 - di	7 - hepta
3 - tri	8 - octa
4 - tetra	9 - non
5 - penta	10 - deca

Names, Formulas, and Charges for Negative Ions (Anions)

acetate	CH_3COO^-	iodide	I^-
benzoate	$C_6H_5COO^-$	periodate	IO_4^-
borate	BO_3^{3-}	iodate	IO_3^-
tetraborate	$B_4O_7^{2-}$	iodite	IO_2^-
bromide	Br^-	hypoiodite	IO^-
perbromate	BrO_4^-	nitride	N^{3-}
bromate	BrO_3^-	nitrate	NO_3^-
bromite	BrO_2^-	nitrite	NO_2^-
hypobromite	BrO^-	oxide	O^{2-}
carbonate	CO_3^{2-}	oxalate	$C_2O_4^{2-}$
hydrogen carbonate, bicarbonate	HCO_3^-	hydrogen oxalate, binoxalate	$HC_2O_4^-$
chloride	Cl^-	permanganate	MnO_4^-
perchlorate	ClO_4^-	phosphide	P^{3-}
chlorate	ClO_3^-	phosphate	PO_4^{3-}
chlorite	ClO_2^-	phosphite	HPO_3^{2-}
hypochlorite	ClO^-	monohydrogen phosphate	HPO_4^{2-}
chromate	CrO_4^{2-}	dihydrogen phosphate	$H_2PO_4^-$
dichromate	$Cr_2O_7^{2-}$	tripolyphosphate	$P_3O_{10}^{5-}$
cyanate	CNO^-	silicate	SiO_4^{4-}
cyanide	CN^-	selenide	Se^{2-}
thiocyanate	SCN^-	selenate	SeO_4^{2-}
ferricyanide	$Fe(CN)_6^{3-}$	sulfide	S^{2-}
ferrocyanide	$Fe(CN)_6^{4-}$	sulfate	SO_4^{2-}
fluoride	F^-	sulfite	SO_3^{2-}
perfluorate	FO_4^-	hydrogen sulfide, bisulfide	HS^-
fluorate	FO_3^-	hydrogen sulfire, bisulfite	HSO_3^-
fluorite	FO_2^-	hydrogen sulfate, bisulfate	HSO_4^-
hypofluorite	FO^-	stearate	$C_{17}H_{35}COO^-$
glutamate	$C_5H_8NO_4^-$	thiosulfate	$S_2O_3^{2-}$
hydroxide, (hydroxyl)	OH^-	telluride	Te^{2-}
hydride	H^-	uranate	UO_4^-

Table 3: Formulas

Solubility:

$$\text{ppm} = \frac{\text{grams of solute}}{1\times10^{6}\text{ grams of solvent}}$$

$$\text{ppb} = \frac{\text{grams of solute}}{1\times10^{9}\text{ grams of solvent}}$$

} for water, 1 mL = 1 g

$$[\ ] = \text{mol}\cdot\text{L}^{-1} \text{ or M}$$

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

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

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

Equilibrium:

$$K_{eq} = \frac{[C]^c[D]^d}{[A]^a[B]^b}$$

Acid-Base:

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

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

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

$$\text{pH} + \text{pOH} = 14$$

Table 6: Electronegativity Chart

H 2.1																	He ....
Li 1.0	Be 1.5											B 2.0	C 2.5	N 3.0	O 3.5	F 4.0	Ne ....
Na 0.9	Mg 1.2											Al 1.5	Si 1.8	P 2.1	S 2.5	Cl 3.0	Ar ....
K 0.8	Ca 1.0	Sc 1.3	Ti 1.5	V 1.6	Cr 1.6	Mn 1.5	Fe 1.8	Co 1.8	Ni 1.8	Cu 1.9	Zn 1.6	Ga 1.6	Ge 1.8	As 2.0	Se 2.4	Br 2.8	Kr ....
Rb 0.8	Sr 1.0	Y 1.2	Zr 1.4	Nb 1.6	Mo 1.8	Tc 1.9	Ru 2.2	Rh 2.2	Pd 2.2	Ag 1.9	Cd 1.7	In 1.7	Sn 1.8	Sb 1.9	Te 2.1	I 2.5	Xe ....
Cs 0.7	Ba 0.9	La-Lu 1.1-1.2	Hf 1.3	Ta 1.5	W 1.7	Re 1.9	Os 2.2	Ir 2.2	Pt 2.2	Au 2.4	Hg 1.9	Tl 1.8	Pb 1.8	Bi 1.9	Po 2.0	At 2.2	Rn ....
Fr 0.7	Ra 0.9	Ac-Lr 1.1-															

Table 7: Elemental Standard States

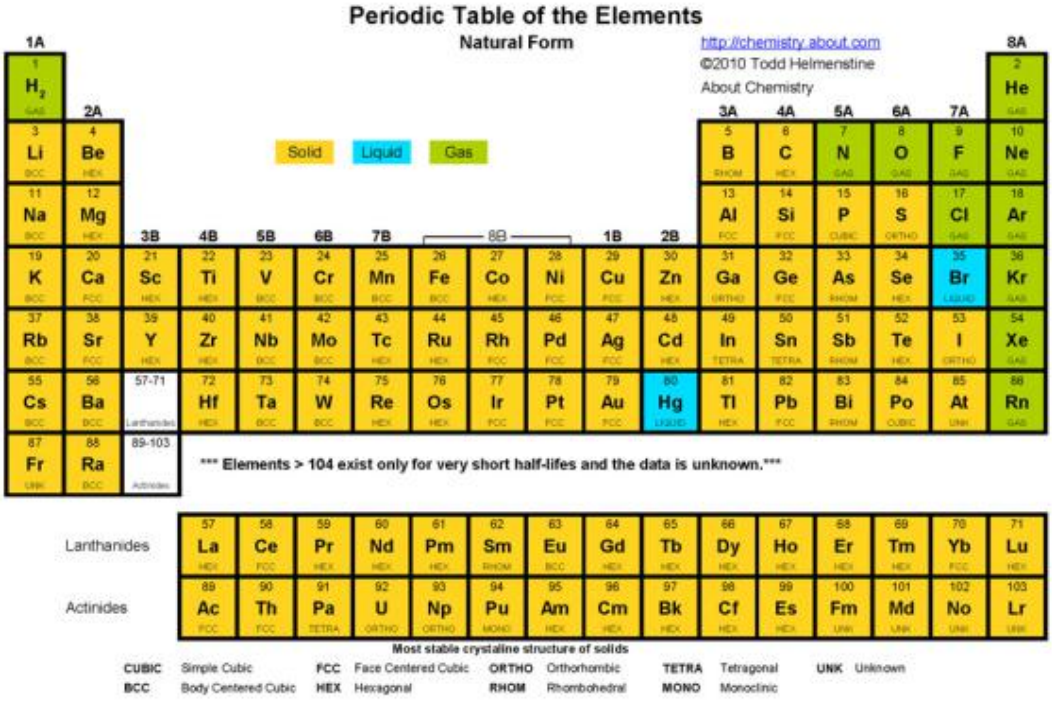
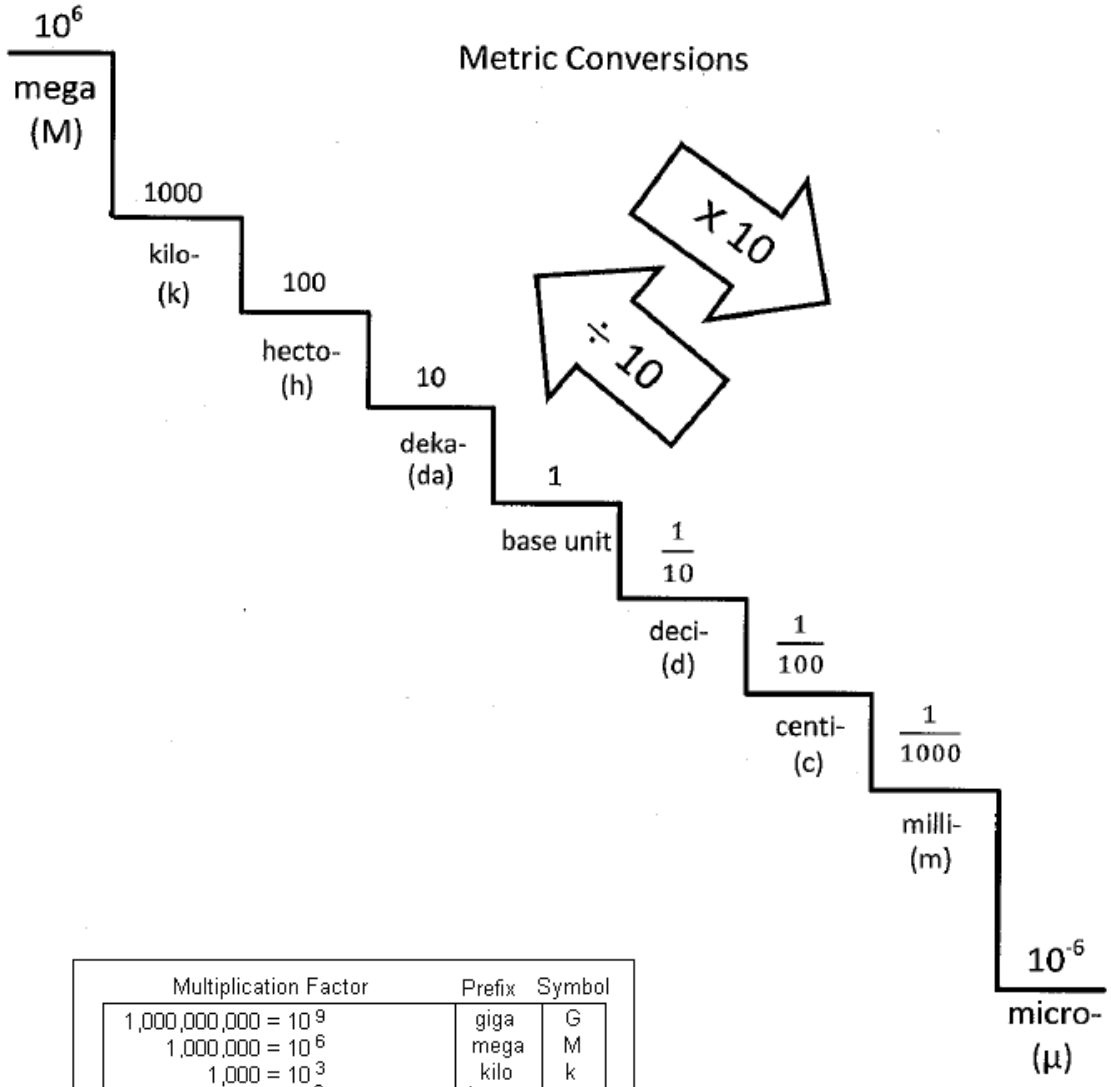


Table 4: Metric Staircase/Prefixes



Multiplication Factor	Prefix	Symbol
$1,000,000,000 = 10^9$	giga	G
$1,000,000 = 10^6$	mega	M
$1,000 = 10^3$	kilo	k
$100 = 10^2$	hecto	h
$1 = 1$		
$0.01 = 10^{-2}$	centi	c
$0.001 = 10^{-3}$	milli	m
$0.000001 = 10^{-6}$	micro	μ
$0.000000001 = 10^{-9}$	nano	n

Table 5: Mole Conversion Chart

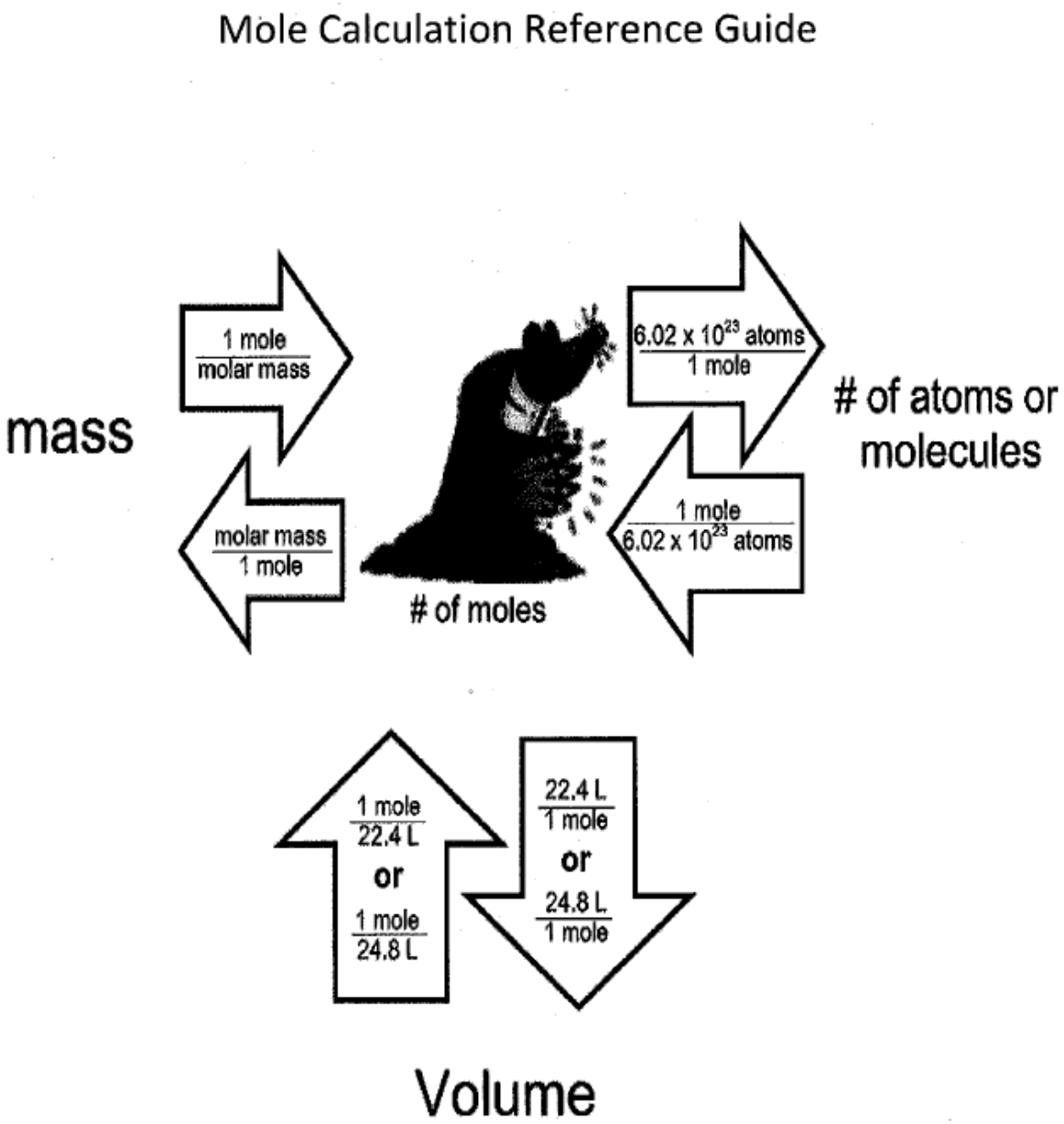


Table 8: VSEPR Shapes

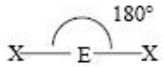
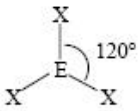
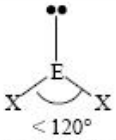
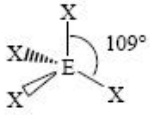
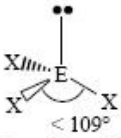
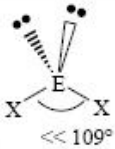
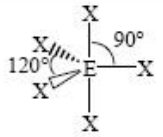
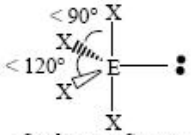
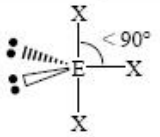
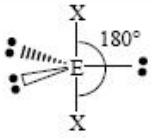
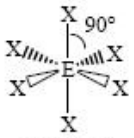
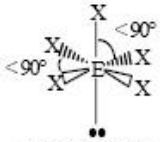
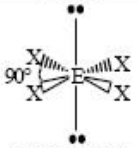
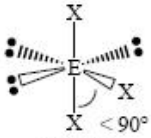
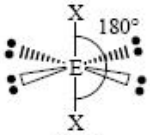
VSEPR Geometries					
Steric No.	Basic Geometry 0 lone pair	1 lone pair	2 lone pairs	3 lone pairs	4 lone pairs
2	 Linear				
3	 Trigonal Planar	 Bent or Angular			
4	 Tetrahedral	 Trigonal Pyramid	 Bent or Angular		
5	 Trigonal Bipyramid	 Sawhorse or Seesaw	 T-shape	 Linear	
6	 Octahedral	 Square Pyramid	 Square Planar	 T-shape	 Linear

Table 9: Organic Chem Functional Groups

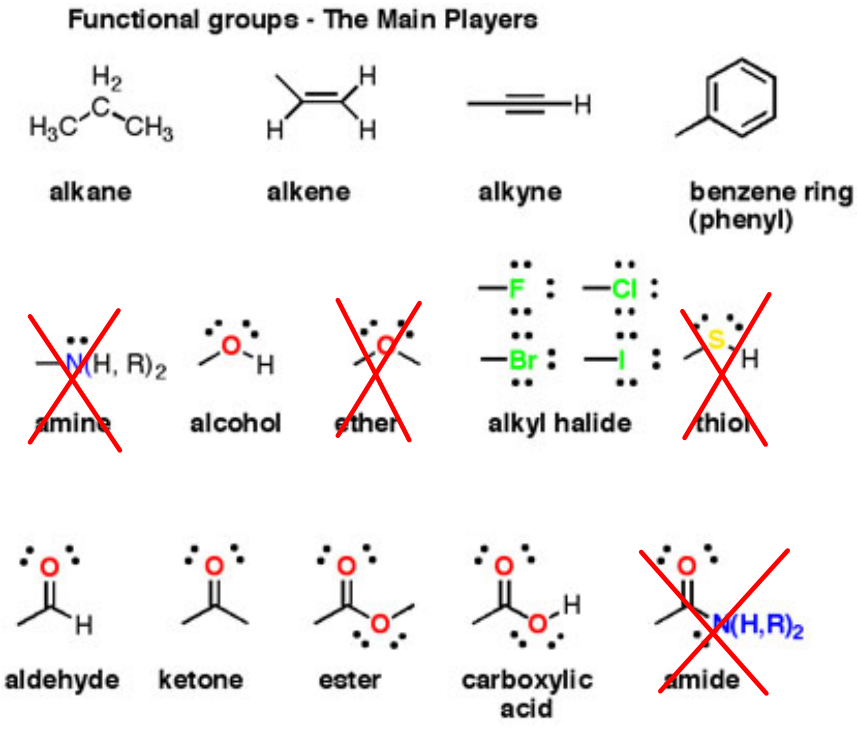


Table 10: Solubility of Common Ions

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	nitrate, NO_3^-	essentially all	soluble
5	acetate, CH_3COO^-	Ag^+	low solubility
		all others	soluble
6	bromide, Br^- chloride, Cl^- iodide, I^-	Ag^+, Pb^{+2}, Hg_2^{+2}, Cu^+, Tl^+	low solubility
		all others	soluble
7	sulfate, SO_4^{-2}	Ca^{+2}, Sr^{+2}, Ba^{+2}, Ra^{+2}, Pb^{+2}, Ag^+, Hg_2^{+2}	low solubility
		all others	soluble
8	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
9	hydroxide, OH^-	Li^+, Na^+, K^+, Rb^+, Cs^+, Fr^+, H^+, NH_4^+, Sr^{+2}, Ba^{+2}, Ra^{+2}, Tl^+	soluble
		all others	low solubility
10	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

Substances are considered soluble if they dissolve enough to give ion concentrations above 0.1 moles per litre at room temperature.

Table 11: Solubility Chart

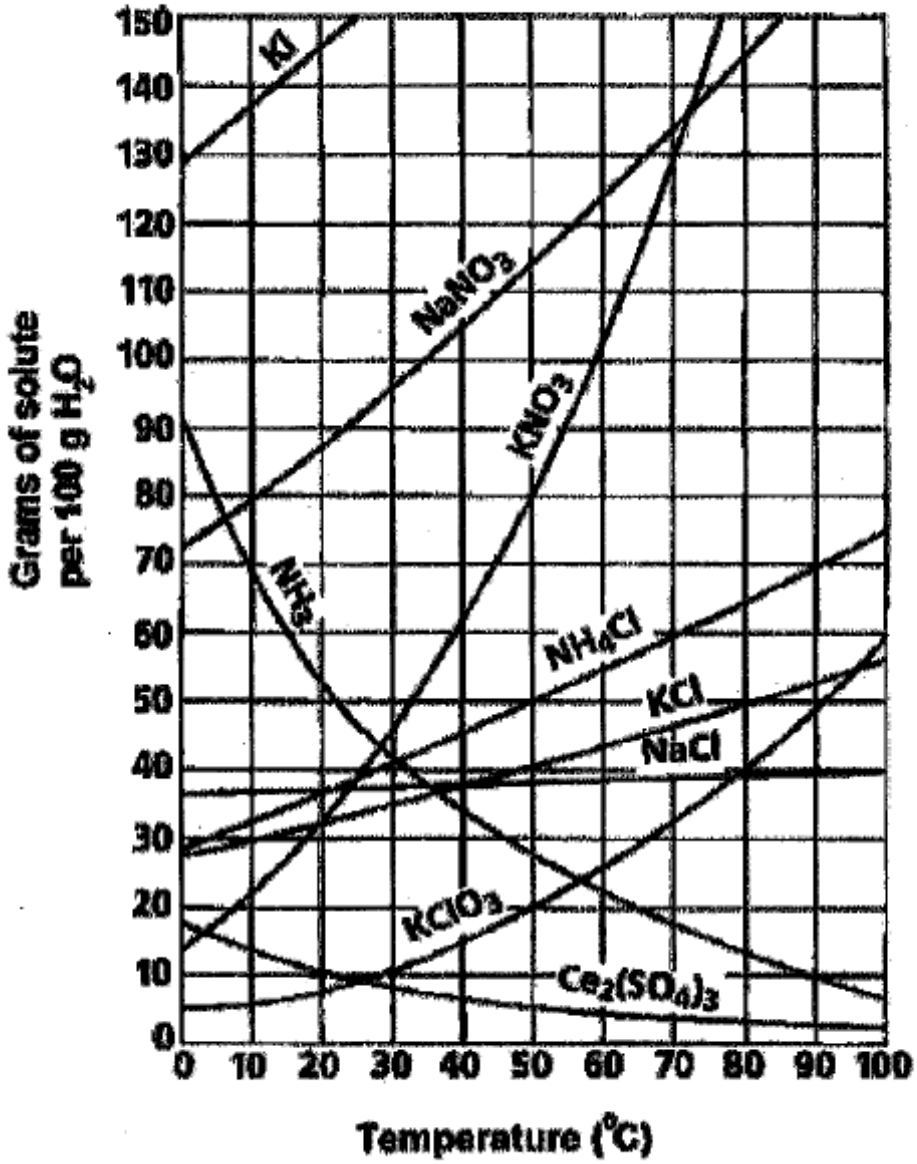


Table 12: Solubility Chart

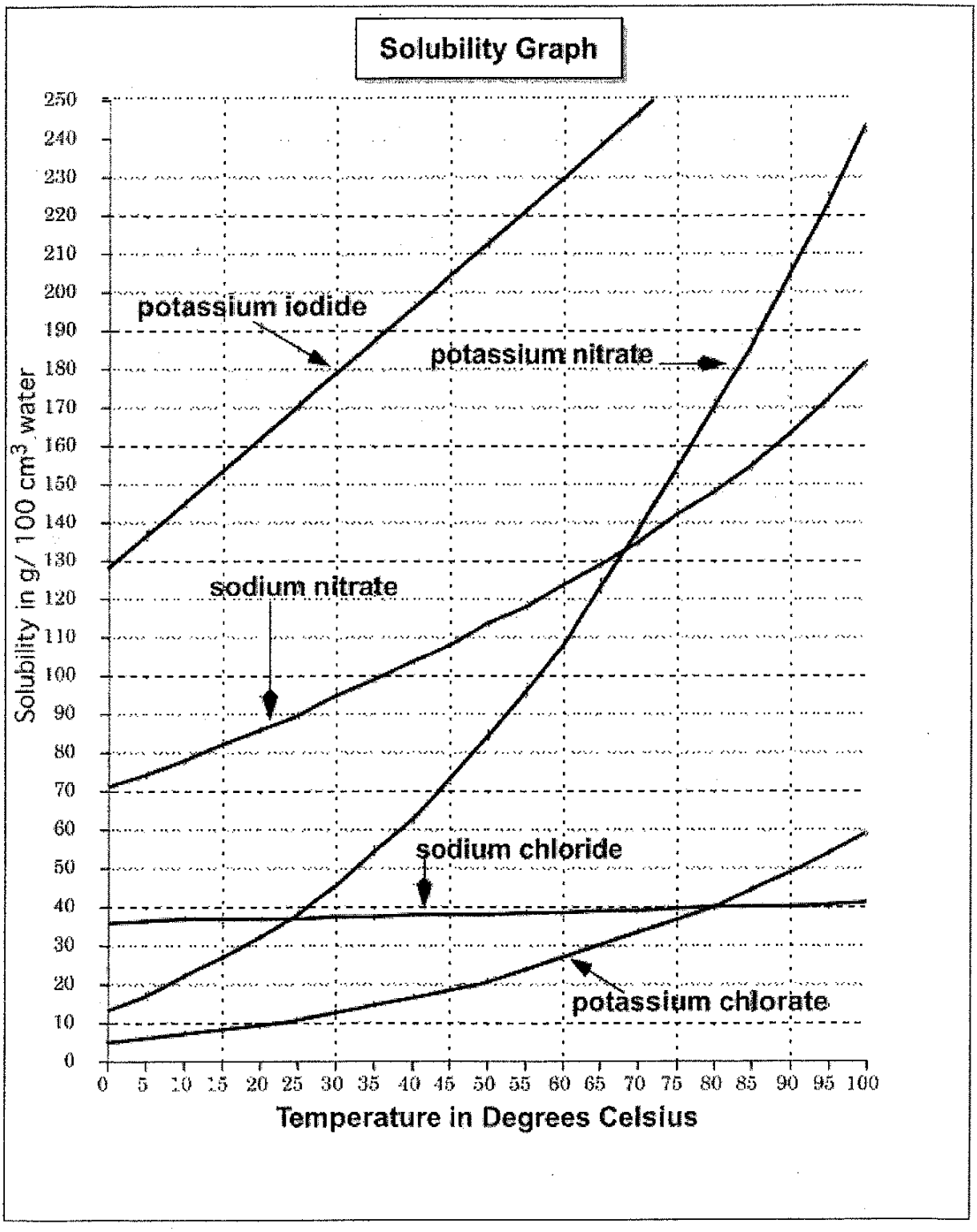


Table 13: Solubility Product Constants (Ksp)

SOLUBILITY PRODUCT CONSTANTS OF VARIOUS IONIC COMPOUNDS AT 25°C

COMPOUND		K_{sp}
barium carbonate	$BaCO_3$	8.1×10^{-9}
barium chromate	$BaCrO_4$	8.5×10^{-11}
barium sulfate	$BaSO_4$	1.1×10^{-10}
calcium carbonate	$CaCO_3$	8.7×10^{-9}
calcium fluoride	CaF_2	3.9×10^{-11}
calcium sulfate	$CaSO_4$	2.0×10^{-4}
lead carbonate	$PbCO_3$	3.3×10^{-14}
lead chromate	$PbCrO_4$	2.0×10^{-16}
lead fluoride	PbF_2	3.7×10^{-8}
lead iodide	PbI_2	1.4×10^{-8}
lead sulfate	$PbSO_4$	1.3×10^{-8}
magnesium carbonate	$MgCO_3$	2.6×10^{-5}
magnesium fluoride	MgF_2	6.4×10^{-9}
magnesium hydroxide	$Mg(OH)_2$	1.2×10^{-11}
silver bromide	$AgBr$	6.5×10^{-13}
silver carbonate	Ag_2CO_3	6.2×10^{-12}
silver chloride	$AgCl$	1.6×10^{-10}
silver chromate	Ag_2CrO_4	1.9×10^{-12}
silver iodide	AgI	1.5×10^{-16}
strontium carbonate	$SrCO_3$	1.6×10^{-9}
strontium fluoride	SrF_2	7.9×10^{-10}
strontium sulfate	$SrSO_4$	7.6×10^{-7}

Aluminum Hydroxide	$Al(OH)_2$	.....	3.7×10^{-15}
Barium Fluoride	BaF_2	.....	1.7×10^{-6}
Calcium Oxalate	CaC_2O_4	.....	2.3×10^{-9}
Copper (I) Iodide	CuI	.....	1.3×10^{-12}
Copper (I) Iodate	$Cu(IO_3)_2$	.....	6.9×10^{-3}
Copper (II) Oxalate	CuC_2O_4	.....	2.9×10^{-9}
Copper (I) Sulfide	CuS	.....	1.0×10^{-44}
Iron (II) Hydroxide	$Fe(OH)_2$	.....	4.9×10^{-17}
Iron (III) Hydroxide	$Fe(OH)_3$	.....	2.6×10^{-39}
Iron (II) Sulfide	FeS	.....at 18°C.....	3.7×10^{-36}
Lead (II) Bromide	$PbBr_2$	.....	6.6×10^{-5}
Lead (II) Chloride	$PbCl_2$	.....	1.2×10^{-5}
Lithium Carbonate	$LiCO_3$	.....	1.7×10^{-3}
Mercury (II) Sulfide	HgS	.....	3.0×10^{-54}
Silver Sulfate	Ag_2SO_4	.....	1.2×10^{-5}
Silver Sulfide	Ag_2S	.....	1.8×10^{-50}
Zinc Sulfide	ZnS	.....	2.0×10^{-25}

Table 14: Relative Strengths of Acids and Bases

Strength of Acid

Strong

Tendency to lose protons increases

Weak

Strength of Base

Weak

Tendency to gain protons increases

Strong

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}
hydrogen telluride	$H_2Te(aq) \Leftrightarrow H^+(aq) + HTe^-(aq)$	2.3×10^{-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}
hydrogen selenide	$H_2Se(aq) \Leftrightarrow H^+(aq) + HSe^-(aq)$	1.7×10^{-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 telluride ion	$HTe^-(aq) \Leftrightarrow H^+(aq) + Te^{2-}(aq)$	1.0×10^{-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

Table 15: pH Ranges of Common 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

Table 16: Oxidation Number Rules

Oxidation Number Rules

1. The oxidation number of a pure element (by itself, and not an ion) is zero.

Element	Oxidation Number
Na	0
H_2	0
O_2	0
P_4	0

2. The oxidation number of a monatomic ion (by itself or as part of an ionic compound) is equal to its charge.

Alkali metals - elements in the first column of the periodic table - will always have an oxidation number of +1; Alkali metals (column 2) are almost always +2

Ionic Compound	Ions	Charge	Oxidation Number
NaCl	Na^+	+1	+1
	Cl^-	-1	-1
Mg_3N_2	Mg^{+2}	+2	+2
	N^{-3}	-3	-3

3. The oxidation number of hydrogen is almost always +1 when it is in a compound.

It is -1 in **metallic hydrides** like NaH and BaH_2.

Compound	element	Oxidation Number
HCl	H	+1
	Cl	-1
H_2S	H	+1
	S	-2

4. The oxidation number of oxygen is almost always -2 when it is in a compound

The exceptions:

- peroxides, such as hydrogen peroxide. In peroxides oxygen has an oxidation number of -1.
- when oxygen is combined with fluorine it's oxidation number is +2

Compound	element	Oxidation Number
MgO	Mg	+2
magnesium oxide	O	-2
Na_2O	Na	+1
sodium oxide	O	-2
Na_2O_2	Na	+1
sodium peroxide	O	-1

Oxidation Number Rules Cont.

5. The sum of the oxidation numbers in a compound is zero.

To determine the oxidation number of Mn in Mn_2O_7 we must work backwards:

- We know each oxygen is -2 (Rule 4)
- 7 oxygen gives a total of:

-2×7 atoms $= -14$ total

Since the sum of oxidation numbers must be zero, the total oxidation number of Mn must be +14 to cancel out oxygen's -14, but since there are 2 Mn atoms, each **individual atom** will have an oxidation number of +7:

$$\frac{+14 \text{ total}}{2 \text{ Mn atoms}} = +7$$

Compound	element	Oxidation Number	Number atoms	Total
Mg_3N_2	Mg	+2	3	+6
	N	-3	2	-6
			SUM	0
Mn_2O_7	Mn	+7	2	+14
	O	-2	7	-14
			SUM	**0**
Cl_2O_3	Cl	+3	2	+6
	O	-2	3	-6
			SUM	**0**

6. The sum of the oxidation numbers in a polyatomic ion is equal to the charge on that ion.

Again, work backwards to determine the oxidation number of any non-oxygen or non-hydrogen atom.

To determine the oxidation number of Cr in $Cr_2O_7^{2-}$:

- Oxygen will be -2 (Rule 4), for a total of:
  $-2 \times 7 = -14$
- Since the sum of the oxidation numbers will be -2 (the charge on the entire ion), the total for all Cr must be +12 because:
  +12 + (-14) = -2
- Since there is are two Cr, each Cr will have an oxidation number of +6

$$\frac{+12}{2} = +6 = +7$$

Compound	element	Oxidation Number	Number atoms	Total
NO_3^-	N	+5	1	+5
	O	-2	3	-6
			SUM	-1
$Cr_2O_7^{2-}$	Cr	+6	2	+12
	O	-2	7	-14
			SUM	**-2**
SO_4^{2-}	S	+6	1	+6
	O	-2	4	-8
			SUM	**-2**

Table 17: Common Oxidation States

I	II											III	IV	V	VI	VII
H +1																
Li +1	Be +2											B +3	C +4 +2 -4	N +5 +4 +3 +2 +1 -3	O -2	F -1
Na +1	Mg +2											Al +3	Si +4	P +5 +3 -3	S +6 +4 -2	Cl +7 +5 +3 +1 -1
K +1	Ca +2	Sc +3	Ti +4 +3	V +5 +4 +3 +2	Cr +6 +3 +2	Mn +7 +4 +3 +2	Fe +3 +2	Co +3 +2	Ni +2	Cu +2 +1	Zn +2	Ga +3 +1	Ge +4 +2	As +5 +3 -3	Se +6 +4 -2	Br +7 +5 +3 +1 -1
Rb +1	Sr +2									Ag +1	Cd +2	In +3 +1	Sn +4 +2	Sb +5 +3	Te +6 +4 -2	I +7 +5 +3 +1 -1
Rb +1	Sr +2									Au +3 +1	Hg +2 +1	Tl +3 +1	Pb +4 +2	Bi +5 +3	Po +6 +4	At

Table 18: Standard Reduction Potentials of Half Cells

Very Strong Oxidizing Agent

Very Weak Reducing Agent

Standard Electrode Potentials for Half-Reactions

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

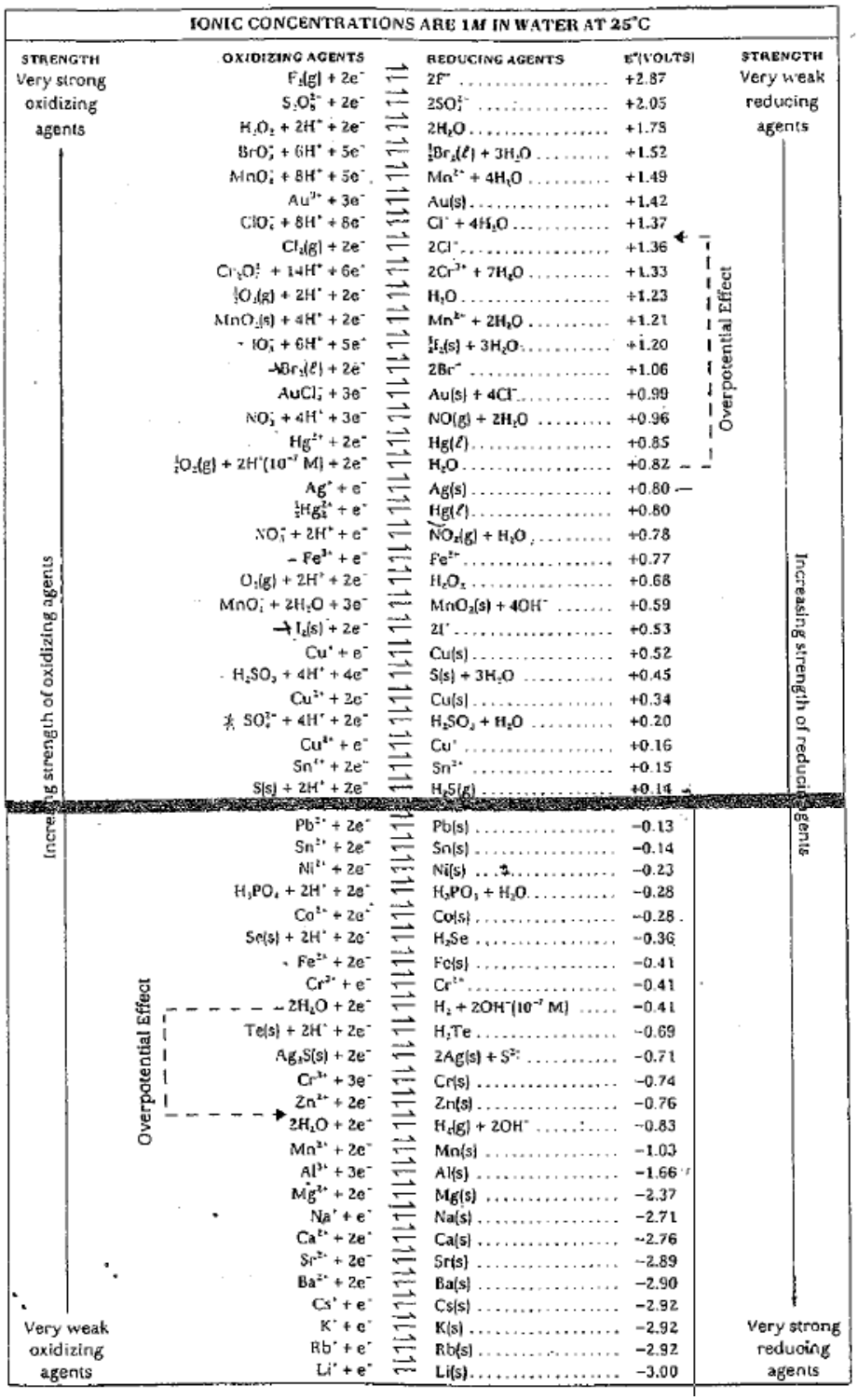
Half-reaction	E° (volts)
$F_2(g) + 2e^- \Leftrightarrow 2F^-$	+ 2.87
$MnO_4^- + 8H^+ + 5e^- \Leftrightarrow Mn^{2+} + 4H_2O$	+ 1.52
$Au^{3+} + 3e^- \Leftrightarrow Au(s)$	+ 1.50
$Cl_2(g) + 2e^- \Leftrightarrow 2Cl^-$	+ 1.36
$Cr_2O_7^{2-} + 14H^+ + 6e^- \Leftrightarrow 2Cr^{3+} + 7H_2O$	+ 1.33
$MnO_2(s) + 4H^+ + 2e^- \Leftrightarrow Mn^{2+} + 2H_2O$	+ 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

Increasing strength of oxidizing agent

Very Weak Oxidizing Agent

Very Strong Reducing Agent

Table 19: Standard Reduction Potentials of Half Cells



IONIC CONCENTRATIONS ARE 1M IN WATER AT 25°C

STRENGTH	OXIDIZING AGENTS	REDUCING AGENTS	E°(VOLTS)	STRENGTH
Very strong oxidizing agents	$F_2(g) + 2e^-$	$2F^-$	+2.87	Very weak reducing agents
	$S_2O_8^{2-} + 2e^-$	$2SO_4^{2-}$	+2.05	
	$H_2O_2 + 2H^+ + 2e^-$	$2H_2O$	+1.78	
	$BrO_3^- + 6H^+ + 5e^-$	$\frac{1}{2}Br_2(\ell) + 3H_2O$	+1.52	
	$MnO_4^- + 8H^+ + 5e^-$	$Mn^{2+} + 4H_2O$	+1.49	
	$Au^{3+} + 3e^-$	$Au(s)$	+1.42	
	$ClO_3^- + 6H^+ + 6e^-$	$Cl^- + 4H_2O$	+1.37	
	$Cl_2(g) + 2e^-$	$2Cl^-$	+1.36	
	$Cr_2O_7^{2-} + 14H^+ + 6e^-$	$2Cr^{3+} + 7H_2O$	+1.33	
	$\frac{1}{2}O_2(g) + 2H^+ + 2e^-$	H_2O	+1.23	
	$MnO_2(s) + 4H^+ + 2e^-$	$Mn^{2+} + 2H_2O$	+1.21	
	$IO_3^- + 6H^+ + 5e^-$	$\frac{1}{2}I_2(s) + 3H_2O$	+1.20	
	$\frac{1}{2}Br_2(\ell) + 2e^-$	$2Br^-$	+1.06	
	$AuCl_4^- + 3e^-$	$Au(s) + 4Cl^-$	+0.99	
	$NO_3^- + 4H^+ + 3e^-$	$NO(g) + 2H_2O$	+0.96	
	$Hg^{2+} + 2e^-$	$Hg(\ell)$	+0.85	
	$\frac{1}{2}O_2(g) + 2H^+(10^{-7}\ M) + 2e^-$	H_2O	+0.82	
	$Ag^+ + e^-$	$Ag(s)$	+0.80	
	$\frac{1}{2}Hg_2^{2+} + e^-$	$Hg(\ell)$	+0.80	
	$NO_3^- + 2H^+ + e^-$	$NO_2(g) + H_2O$	+0.78	
	$Fe^{3+} + e^-$	Fe^{2+}	+0.77	
	$O_2(g) + 2H^+ + 2e^-$	H_2O_2	+0.68	
	$MnO_4^- + 2H_2O + 3e^-$	$MnO_2(s) + 4OH^-$	+0.59	
	$I_2(s) + 2e^-$	$2I^-$	+0.53	
	$Cu^+ + e^-$	$Cu(s)$	+0.52	
	$H_2SO_3 + 4H^+ + 4e^-$	$S(s) + 3H_2O$	+0.45	
	$Cu^{2+} + 2e^-$	$Cu(s)$	+0.34	
	$SO_4^{2-} + 4H^+ + 2e^-$	$H_2SO_3 + H_2O$	+0.20	
	$Cu^{2+} + e^-$	Cu^+	+0.16	
	$Sn^{4+} + 2e^-$	Sn^{2+}	+0.15	
	$S(s) + 2H^+ + 2e^-$	$H_2S(g)$	+0.14	
	$Pb^{2+} + 2e^-$	$Pb(s)$	−0.13	
	$Sn^{2+} + 2e^-$	$Sn(s)$	−0.14	
	$Ni^{2+} + 2e^-$	$Ni(s)$	−0.23	
	$H_3PO_4 + 2H^+ + 2e^-$	$H_3PO_3 + H_2O$	−0.28	
	$Co^{2+} + 2e^-$	$Co(s)$	−0.28	
	$Se(s) + 2H^+ + 2e^-$	H_2Se	−0.36	
	$Fe^{2+} + 2e^-$	$Fe(s)$	−0.41	
	$Cr^{3+} + e^-$	Cr^{2+}	−0.41	
	$2H_2O + 2e^-$	$H_2 + 2OH^-(10^{-7}\ M)$	−0.41	
	$Te(s) + 2H^+ + 2e^-$	H_2Te	−0.69	
	$Ag_2S(s) + 2e^-$	$2Ag(s) + S^{2-}$	−0.71	
	$Cr^{3+} + 3e^-$	$Cr(s)$	−0.74	
	$Zn^{2+} + 2e^-$	$Zn(s)$	−0.76	
	$2H_2O + 2e^-$	$H_2(g) + 2OH^-$	−0.83	
	$Mn^{2+} + 2e^-$	$Mn(s)$	−1.03	
	$Al^{3+} + 3e^-$	$Al(s)$	−1.66	
	$Mg^{2+} + 2e^-$	$Mg(s)$	−2.37	
	$Na^+ + e^-$	$Na(s)$	−2.71	
	$Ca^{2+} + 2e^-$	$Ca(s)$	−2.76	
	$Sr^{2+} + 2e^-$	$Sr(s)$	−2.89	
	$Ba^{2+} + 2e^-$	$Ba(s)$	−2.90	
	$Cs^+ + e^-$	$Cs(s)$	−2.92	
	$K^+ + e^-$	$K(s)$	−2.92	
	$Rb^+ + e^-$	$Rb(s)$	−2.92	
Very weak oxidizing agents	$Li^+ + e^-$	$Li(s)$	−3.00	Very strong reducing agents

Increasing strength of oxidizing agents

Increasing strength of reducing agents

Overpotential Effect

Overpotential Effect

Table 20: Metal Activity Series

Metal	Metal Ion	Reactivity
Lithium	Li+	Most Reactive
Potassium	K+	-
Calcium	Ca2+	-
Sodium	Na+	-
Magnesium	Mg2+	-
Aluminum	Al3+	-
Manganese	Mn2+	-
Zinc	Zn2+	-
Chromium	Cr2+, Cr3+	-
Iron	Fe2+, Fe3+	-
Lead	Pb2+	-
Copper	Cu2+	-
Mercury	Hg2+	-
Silver	Ag+	-
Platinum	Pt2+	-
Gold	Au+, Au3+	Least Reactive