

MISCELLANEOUS CHEMICAL INFORMATION

1 Conversion	2 Quantum	3 Gas Laws	4 fpt/Bpt	5 VSEPR
6 Bond Energies	7 Solubility	8 Solution	9 Colligative	10 Equilibrium
11 Acid-base	12 Kinetics	13 Inorganic	14 Thermo/Electro	15 Organic
16 Periodic table	17 Ka acids	18 Electrochem	19 Thermodynamics	

1 Conversion information:

System	Pressure:	LENGTH:	VOLUME	MASS	Temperature
English:	760 mmHg = 14.7 psi 1 atm = 101.3 KPa	1 ft = 12 in 1 mile = 5280 ft	1 gal = 4 qt 1 qt = 57.75 in ³	1 lb = 16 oz 1 ton = 2000 lb	$T_{\circ F} = 1.8T_{\circ C} + 32$
SI-English:	1 atm = 760 torr 1 atm = 760 mmHg	1 in = 2.54 cm 1 mi = 1.609 km	1 L = 1.057 qt 1 qt = 0.946 L 1 fl oz = 20.57 ml	1 lb = 453.6 g 1 oz = 28.35 g	$T_{\circ C} = \frac{(T_{\circ F} - 32)}{1.8}$
Misc. info	1 J = 1 kg m ² / s ²	1 mole = 6.02 · 10 ²³	Density H ₂ O: 1.0 g/ml		

2 Quantum Equations

Electromagnetic Radiation	$E = h \cdot \nu = \frac{h c}{\lambda}$, $h = 6.63 \cdot 10^{-34} \text{ J} \cdot \text{s}$, $c = 3.0 \cdot 10^8 \text{ m/s}$		
Energy for H-like atom	$E = Z^2 R_H \left[\frac{1}{n^2} \right]$		
Rydberg Equation	$\Delta E = R_H \left[\frac{1}{n_i^2} - \frac{1}{n_f^2} \right]$	$\frac{1}{\lambda} = R_{H(\lambda)} \left[\frac{1}{n_i^2} - \frac{1}{n_f^2} \right]$	
	$R_{H(E)} = 2.18 \cdot 10^{-18} \text{ J}$	$R_{H(\lambda)} = 1.097 \cdot 10^7 \text{ m}^{-1}$	

3 Gas law equations:


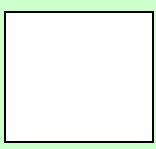

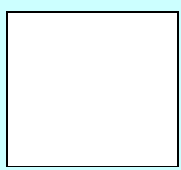
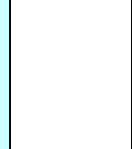
Ideal Gas Law	$PV = nRT$ Density(D) = $\frac{m \cdot P}{n R T}$, m = mass		$R = 0.08206 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}}$
Real Gas vander Waal Equation	$\left(P + \frac{a \cdot n^2}{V^2} \right) (V - n \cdot b) = nRT$		
STP	P = 1 atm, T = 0°C, 1mole = 22.4 L		
Dalton's Law of Partial Pressure	$P_T = P_a + P_b + P_c + \dots$		
	$P_a = \chi_a \cdot P_T$ $P_b = \chi_b \cdot P_T$	$\chi_a = n_a / n_T$ $\chi_b = n_b / n_T$	
Speed of Gas particles			
Graham's Law of effusion			
Calorimetry	$q_p = \Delta H = m C_s \Delta T$ where $\Delta T = T_f - T_i$, $C_s (\text{H}_2\text{O}) = 4.184 \text{ J/g} \cdot \text{K} = 1.00 \text{ cal/g} \cdot \text{K}$		

4 Boiling Points of Liquids

	Liquid	Boiling Point (°C)
1	Acetone	56.5
2	Carbon disulfide	46.3
3	Carbon tetrachloride	76.8
4	Chloroform	61.3

	Liquid	Boiling Point (°C)
5	Ethanol	78.5
6	Ether	34.6
7	Methanol	64.6
8	Water	100.0

Valence Shell Electron-Pair Repulsion Theory (VSEPR) :

# e- Domain or region	AE_n	Electronic Geometry	Bond Pr [Cord #]	non- bond	AE_nB_m	Molecular Geometry	Bond angle, Hybrid	Examples
2	AE_2	 Linear	2	0	AB_2	 Linear	180° sp	BeH_2 CO_2
3	AE_3	 Trigonal	3	0	AB_3	 Trigonal Planar	120° sp^2	BF_3 BCl_3
			2	1	AB_2E	 (Trigonal) Bent	$< 120^\circ$ sp^2	NO_2
4	AE_4	 Tetrahedral	4	0	AB_4	 Tetrahedra	109.5° sp^3	CH_4 NH_4^+
			3	1	AB_3E	 Trigonal Pyramidal	$< 109.5^\circ$ sp^3	NH_3 H_3O^+ PH_3
			2	2	AB_2E_2	 (Tetrahedral) Bent	$< 109.5^\circ$ sp^3	H_2O H_2S F_2O
5	AE_5	 Trigonal Bipyramidal	5	0	AB_5	 Trigonal Bipyramidal	180° 120° 90° sp^3d	$P I_5$
			4	1	AB_4E	 See-saw	180° 90° $< 120^\circ$ sp^3d	$S F_4$
			3	2	AB_3E_2	 T-shape	180° 90° sp^3d	$Cl F_3$
			2	3	AB_2E_3	 Linear	180° sp^3d	$Xe F_2$
6	AE_6	 Octahedral	6	0	AB_6	 Octahedral	90° sp^3d^2	$S F_6$
			5	1	AB_5E	 Square Pyramidal	90° $< 90^\circ$ sp^3d^2	$Br F_5$
			4	2	AB_4E_2	 Square planar	90° sp^3d^2	$Xe F_4$

Bond Energies:

Bond	Bond Energy (kJ/mol)	Bond	Bond Energy (kJ/mol)	Bond	Bond Energy (kJ/mol)
H—H	436	N—N	163	Br—F	237
H—C	414	N=N	418	Br—Cl	218
H—N	389	N≡N	946	Br—Br	193
H—O	464	N—O	222	I—Cl	208
H—S	368	N=O	590	I—Br	175
H—F	565	N—F	272	I—I	151
H—Cl	431	N—Cl	200	Si—H	323
H—Br	364	N—Br	243	Si—Si	226
H—I	297	N—I	159	Si—C	301
C—C	347	O—O	142	S—O	265
C=C	611	O=O	498	Si=O	368
C≡C	837	O—F	190	S—O	523
C—N	305	O—Cl	203	Si—Cl	464
C=N	615	O—I	234	S—S	418
C≡N	891	F—F	159	S—F	327
C—O	360	Cl—F	253	S—Cl	253
C=O	736*	Cl—Cl	243	S—Br	218
C≡O	1072			S—S	266
C—Cl	339				

*799 in CO₂

Solubility rules:

Soluble substances with -	Exceptions	Insoluble substances with -	Exceptions
(NO ₃ ⁻) (ClO ₃ ⁻) (ClO ₄ ⁻) (CH ₃ COO ⁻)	None	(S ²⁻), (CO ₃ ²⁻), (CrO ₄ ²⁻), (PO ₄ ³⁻)	Grp1A, NH ₄ ⁺
X ⁻ = Cl ⁻ , Br ⁻ , I ⁻	Ag, Hg, Pb	(OH ⁻)	Grp1A, NH ₄ ⁺ , Sr, Ba, Ca
(SO ₄ ²⁻)	Sr, Ca, Ba, Hg, Pb	Soluble - dissolve, no precipitate (aq -phase)	
Alkali & NH ₄ ⁺	None	insoluble (or slightly soluble) - does not dissolve, precipitate forms. (s-phase)	

Solubility Table

	C ₂ H ₃ O ₂ ⁻	AsO ₄ ³⁻	Br ⁻	CO ₃ ²⁻	Cl ⁻	CrO ₄ ²⁻	OH ⁻	I ⁻	NO ₃ ⁻	C ₂ O ₄ ²⁻	O ²⁻	PO ₄ ³⁻	SO ₄ ²⁻	S ²⁻	SO ₃ ²⁻
Al ³⁺	S	I	S	-	S	-	I	S	S	-	I	I	S	d	-
NH ₄ ⁺	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Ba ²⁺	S	I	S	I	S	I	s	S	S	I	s	S	S	S	S
Bi ³⁺	-	s	d	I	d	-	I	I	d	I	I	s	d	I	-
Ca ²⁺	S	I	S	I	S	S	I	S	S	I	I	I	I	d	I
Co ²⁺	S	I	S	I	S	I	I	S	S	I	I	I	S	I	I
Cu ²⁺	S	I	S	I	S	I	I	-	S	I	I	I	S	I	-
Fe ²⁺	S	I	S	s	S	-	I	S	S	I	I	I	S	I	s
Fe ³⁺	I	I	S	I	S	-	I	-	S	S	I	I	S	I	-
Pb ²⁺	S	I	I	I	I	I	I	I	S	I	I	I	I	I	I
Mg ²⁺	S	d	S	I	S	S	I	S	S	I	I	I	S	d	s
Hg ²⁺	S	I	I	I	S	s	I	I	S	I	I	I	d	I	-
K ⁺	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Ag ⁺	s	I	I	I	I	I	-	I	S	I	I	I	I	I	I
NH ₄ ⁺	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Zn ²⁺	S	I	S	I	S	I	I	S	S	I	I	I	S	I	I

S=Soluble in water

I=Insoluble in water (less than 1g/100g H₂O)

s=slightly soluble in water

d=Decomposes in water

8 Solution and Concentration equations:

Concentrations	M, molarity = moles solute / liter solution N, normality = eq solute / liter solution m, molality = moles solute / Kg solvent % m, percent by mass = (mass solute / mass solution)*100 χ , mole fraction = moles a / moles a + moles b ...
Solution Dilution	$C_1V_1 = C_2V_2$ (moles before dilution = moles after dilution)

9 Solubility and Colligative Properties

Pressure effects: Henry's Law	$P = c / k$ where c = solubility
Raoult's Law	$P_{solv} = \chi_{solvent} \cdot P^{\circ}_{solvent}$
	$\Delta P_{solv} = P^{\circ}_{solv} - P_{solv} = \chi_{solute} \cdot P^{\circ}_{solv}$
Boiling Point Elevation	$\Delta T_b = m K_b$
Freezing Point Depression	$\Delta T_f = m K_f$
Osmotic Pressure	$P = MRT$ (R = 0.08206 L·atm / mol·K)
Van't Hoff Factor	$i = \frac{\text{moles particles solution (expt)}}{\text{moles solute dissolved (calculated conc)}}$

10 Equilibrium

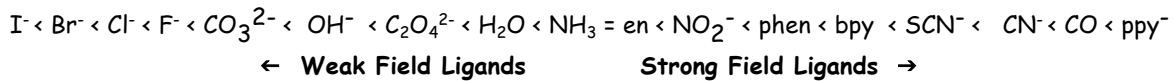
Equilibrium constant	K_p & K_c	$K_p = K_c(RT)^{\Delta n}$	$K_c = K_p(RT)^{-\Delta n}$
Quadratic Eqn $ax^2+bx+c=0$			

11 Acid Base:

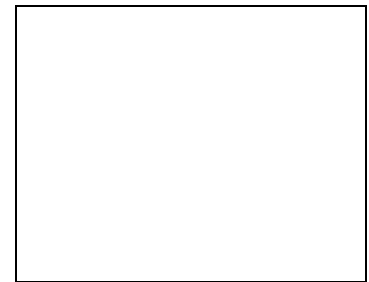
pX and [X] Relationship	$pH = -\log [H_3O^+]$ $[H_3O^+] = 10^{-pH}$	$pOH = -\log [OH^-]$ $[OH^-] = 10^{-pOH}$	$pK_a = -\log [K_a]$ $[K_a] = 10^{-pK_a}$
K_w	$K_w = 1 \cdot 10^{-14}$ @ 25°C	$K_w = K_a \cdot K_b$	$14 = pH + pOH$
Henderson - Hasselbach Equation	$pH = pK_a + \log [C_b/C_a]$	$pOH = pK_b + \log [C_a/C_b]$	
Quadratic Equation $ax^2+bx+c=0$			

12 Kinetics

Rates of Reaction	$rate = \Delta[A] / \Delta t = -\Delta [react] / \Delta t = \Delta [prod] / \Delta t$	
Rate laws (Order of reaction)	initial rate = $k [A]^x [B]^y [C]^z \dots$	Overall order = $x + y + z + \dots$
Conc. vs. Time dependence		
Zeroth Order rate = k	$[A] = [A]_0 - kt$	Conc. vs. Time β straight line. Half life; $t_{1/2} = [A]_0 / 2k$
First Order rate = k [A]	$[A] = [A]_0 \exp\{-kt\}$ $\ln[A] = \ln[A]_0 - kt$	$\ln[Conc.]$ vs. Time β straight line Half life; $t_{1/2} = 0.693 / k$
Second Order rate = $k [A]^2$ or $k [A][B]$	$1/[A] = 1/[A]_0 + kt$	$1/[Conc.]$ vs. Time β straight line Half life; $t_{1/2} = 1 / k [A]_0$
Temperature vs. Rate dependence	$k = A \exp \{-E_a / RT\}$ $\ln k = \ln A - (E_a/R) \cdot 1/T$	$\ln(k)$ vs. $1/T$ β straight line.

Spectrochemical Series:**Bidentate Ligands****Abbreviation**Ox²⁻ (oxalato), en (ethylenediamine), phen (1,10-phenathroline),ppy⁻ (2-phenylpyridine), bpy (2,2'-bipyridine),

EDTA (ethylenediaminetrisacetate)



Color Wheel

Thermodynamics

Standard Conditions: 1 atm, 25°C

Universe = surroundings + system

State Function (X) where X = E, H, S or G

$$\Delta X_{rxn} = \sum n \Delta X^{\circ}_{prod} - \sum n \Delta X^{\circ}_{react}$$

$$w = -P \Delta V$$

$$\Delta E = q + w$$

$$\Delta H = \Delta E + P \Delta V$$

$$\Delta H = qp$$

$$\Delta S^{\circ}_{univ} = \Delta S^{\circ}_{surr} + \Delta S^{\circ}_{sys}$$

$$\Delta S^{\circ}_{surr} = -\Delta H^{\circ}_{sys} / T$$

$$\Delta G = \Delta H - T\Delta S$$

$$\Delta G = \Delta G^{\circ} + RT \ln Q$$

$$\Delta G^{\circ} = -RT \ln K_{eq}$$

$$K_{eq} = \exp \{-\Delta G^{\circ} / RT\}$$

$$\ln K_{eq} = (\Delta S^{\circ} / R) - (\Delta H^{\circ} / RT)$$

Cell Potential, ΔG and Keq

$$\Delta G = -nFE$$

$$\Delta G^{\circ} = -nFE^{\circ}$$

$$E^{\circ} = (0.0591 / n) \log K_{eq}$$

$$E^{\circ}_{cell} = E^{\circ}_{red}(cathode) - E^{\circ}_{red}(anode)$$

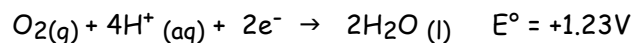
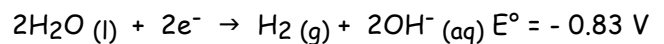
$$E^{\circ}_{cell} = E^{\circ}_{red} + E^{\circ}_{ox}$$

Cell concentration and the Nernst equation

$$E^{\circ} = (RT / nF) \ln K_{eq}$$

$$E^{\circ} = (0.0592 / n) \log K_{eq}$$

$$E = E^{\circ} - (0.0592 / n) \log Q$$

**Constants**

$$R = 8.314 J / mol \cdot K$$

$$F = 96,485 C / mol e^-$$

Group	Structural Feature	Suffix	#C	prefix	C _n H _{2n+2} Alkane	C _n H _{2n} Alkene	C _n H _{2n-2} Alkyne
Alkane	single bond	-ane	1	meth-	methane		
Alkene	double bond	-ene	2	eth-	ethane	ethene	ethyne
Alkyne	triple bond	-yne	3	prop-	propane	propene	propyne
Alcohol	-OH group	-ol	4	but-	butane	butene	butyne
Ether	R-O-R	ether	5	pent-	pentane	pentene	pentyne
Aldehyde	RCHO	-al	6	hex-	hexane	hexene	hexyne
Ketone	R-CO-R	-one	7	hept-	heptane	heptene	heptyne
carboxylic acid	R-COOH	-oic acid	8	oct-	octane	octene	octyne
ester	RCOOR'	-ate	9	non-	nonane	nonene	nonyne
amine	RR'R''N	-amine	10	dec-	decane	decene	decyne
amide	R-CONHR'	-amide					

Alkyl groups:				Reactivity			
Methyl	Ethyl	Propyl	Butyl	Alkene & Alkynes			
				1	Halogenation (+ X ₂)		
		n-propyl	n-butyl	2	Hydrogenation (+ H ₂)		
		iso-propyl	iso-butyl	3	Hydrohalogenation (+ HX)		
			sec-butyl	4	Polymerization		

← Electronegativity Values

18
VIII A

2
He
4.0026

13 14 15 16 17
III A IV A V A VI A VII A

5 6 7 8 9 10
B C N O F Ne
10.811 12.0112 14.0067 15.9994 18.9984 20.179

13 14 15 16 17 18
Al Si P S Cl Ar
26.9815 28.086 30.9738 32.064 35.453 39.948

31 32 33 34 35 36
Ga Ge As Se Br Kr
69.72 72.59 74.9216 78.96 79.909 83.80

49 50 51 52 53 54
In Sn Sb Te I Xe
114.82 118.69 121.75 127.60 126.904 131.30

81 82 83 84 85 86
Tl Pb Bi Po At Rn
204.37 207.19 208.980 [210] [210] [222]

114 116
[289] [292]

1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8	9 VIII B	10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIII A
1 H 1.00797	2 He 4.0026											5 B 10.811	6 C 12.0112	7 N 14.0067	8 O 15.9994	9 F 18.9984	10 Ne 20.179
3 Li 6.939	4 Be 9.0122											13 Al 26.9815	14 Si 28.086	15 P 30.9738	16 S 32.064	17 Cl 35.453	18 Ar 39.948
11 Na 22.9898	12 Mg 24.305	21 Sc 44.956	22 Ti 47.90	23 V 50.942	24 Cr 51.996	25 Mn 54.9380	26 Fe 55.847	27 Co 58.9332	28 Ni 58.71	29 Cu 63.54	30 Zn 65.37	31 Ga 69.72	32 Ge 72.59	33 As 74.9216	34 Se 78.96	35 Br 79.909	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.905	40 Zr 91.22	41 Nb 92.906	42 Mo 95.94	43 Tc [99]	44 Ru 101.07	45 Rh 102.905	46 Pd 106.4	47 Ag 107.870	48 Cd 112.40	49 In 114.82	50 Sn 118.69	51 Sb 121.75	52 Te 127.60	53 I 126.904	54 Xe 131.30
55 Cs 132.905	56 Ba 137.34	71* Lu 174.967	72 Hf 178.49	73 Ta 180.948	74 W 183.85	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.09	79 Au 197.0	80 Hg 200.59	81 Tl 204.37	82 Pb 207.19	83 Bi 208.980	84 Po [210]	85 At [210]	86 Rn [222]
87 Fr [223.02]	88 Ra [226.03]	103† Lr [260]	104 Rf [261.11]	105 Db [262.11]	106 Sg [266.12]	107 Bh [264.12]	108 Hs [269.13]	109 Mt [268.14]	110 Ds [271]	111 Rg [272]	112 [277]		114 [289]		116 [292]		

*
Lanthanide Series

†
Actinide Series

57 La 138.91	58 Ce 140.115	59 Pr 140.9077	60 Nd 144.24	61 Pm (145)	62 Sm 150.368	63 Eu 151.965	64 Gd 157.25	65 Tb 158.9254	66 Dy 162.50	67 Ho 164.9303	68 Er 167.26	69 Tm 168.9342	70 Yb 173.04
89 Ac [227.03]	90 Th 232.0381	91 Pa 231.0359	92 U 238.0289	93 Np 237.048	94 Pu [244]	95 Am [260]	96 Cm [247]	97 Bk [247]	98 Cf [251]	99 Es [252]	100 Fm [257]	101 Md [258]	102 No [259]

Acid	Formula	K_{a1}	K_{a2}	K_{a3}
Acetic	CH_3COOH	1.75×10^{-5}		
Ammonium Ion	NH_4^+	5.70×10^{-10}		
Anilinium Ion	$C_6H_5NH_3^+$	2.51×10^{-5}		
Arsenic	H_3AsO_4	5.8×10^{-3}	1.1×10^{-7}	3.2×10^{-12}
Arsenous	H_3AsO_3	5.1×10^{-10}		
Benzoic	C_6H_5COOH	6.28×10^{-5}		
Boric	H_3BO_3	5.81×10^{-10}		
1-Butanoic (butric acid)	$CH_3CH_2CH_2COOH$	1.52×10^{-5}		
Carbonic	H_2CO_3	4.45×10^{-7}	4.69×10^{-11}	
Chloroacetic	$ClCH_2COOH$	1.36×10^{-3}		
Citric	$HOOC(OH)C(CH_2COOH)_2$	7.45×10^{-4}	1.73×10^{-5}	4.02×10^{-7}
Crotonic acid (cis)	$HC_4H_5O_2$	3.89×10^{-5}		
Crotonic acid (trans)	$HC_4H_5O_2$	2.04×10^{-5}		
Formic	$HCOOH$	1.80×10^{-4}		
Fumaric	<i>trans</i> - $HOOCCH:CHCOOH$	8.85×10^{-4}	3.21×10^{-5}	
Glycolic	$HOCH_2COOH$	1.47×10^{-4}		
Hydrazinium Ion	$H_2NNH_3^+$	1.05×10^{-8}		
Hydrazoic	HN_3	2.2×10^{-5}		
Hydrogen Cyanide	HCN	6.2×10^{-10}		
Hydrofluoric	HF	3.2×10^{-4}		
Hydrogen Peroxide	H_2O_2	2.2×10^{-12}		
Hydrogen Sulfide	H_2S	9.6×10^{-8}	1.3×10^{-14}	
Hydroxyl Ammonium Ion	$HONH_3^+$	1.10×10^{-6}		
Hypochlorous	$HOCl$	3.0×10^{-8}		
Iodic	HIO_3	1.7×10^{-1}		
Lactic	$CH_3CHOHCOOH$	1.38×10^{-4}		
Maleic	<i>cis</i> - $HOOCCH:CHCOOH$	1.3×10^{-2}	5.9×10^{-7}	
Malic	$HOOCCHOHCH_2COOH$	3.48×10^{-4}	8.00×10^{-6}	
Malonic	$HOOCCH_2COOH$	1.42×10^{-3}	2.01×10^{-6}	
Mandelic	$C_6H_5CHOHCOOH$	4.0×10^{-4}		
Methyl Ammonium Ion	$CH_3NH_3^+$	2.3×10^{-11}		
Nitric	HNO_3	Strong		
Nitrous	HNO_2	4.6×10^{-4}		
Oxalic	$HOOC-COOH$	5.60×10^{-2}	5.42×10^{-5}	
Periodic	H_5IO_6	2×10^{-2}	5×10^{-9}	
Phenol	C_6H_5OH	1.00×10^{-10}		
Phosphoric	H_3PO_4	7.11×10^{-3}	6.32×10^{-8}	4.5×10^{-13}
Phosphorous	H_3PO_3	3×10^{-2}	1.62×10^{-7}	
o-Phthalic	$C_6H_4(COOH)_2$	1.12×10^{-3}	3.91×10^{-6}	
Picric	$(NO_2)_3C_6H_2OH$	4.3×10^{-1}		
Piperidinium	$C_5H_{11}NH^+$	7.50×10^{-12}		
Propanoic	CH_3CH_2COOH	1.34×10^{-5}		
Pyridinium	$C_5H_5NH^+$	5.90×10^{-6}		
Salicylic	$C_6H_4(OH)COOH$	1.06×10^{-3}		
Sulfamic	H_2NSO_3H	1.03×10^{-1}		
Succinic	$HOOCCH_2CH_2COOH$	6.21×10^{-5}	2.31×10^{-6}	
Sulfuric	H_2SO_4	Strong	1.02×10^{-2}	
Sulfurous	H_2SO_3	1.23×10^{-2}	6.16×10^{-8}	
Tartaric	$HOOC(CHOH)_2COOH$	9.20×10^{-4}	4.31×10^{-5}	
Thiocyanic	$HSCN$	0.13		
Thiosulfuric	$H_2S_2O_3$	0.3	2.5×10^{-2}	
Trichloroacetic	Cl_3CCOOH	3		
Trimethyl Ammonium Ion	$(CH_3)_3NH^+$	1.58×10^{-10}		

Appendix 11 Standard Reduction Potentials in Aqueous Solution at 25° C

Acidic Solution	Std Red Potential E _o (volts)
$S_2O_8^{2-} + 2e^- \rightarrow 2SO_4^{2-}$	2.0
$Co^{3+} + e^- \rightarrow Co^{2+}$	1.82
$Pb^{4+} + 2e^- \rightarrow Pb^{2+}$	1.8
$H_2O_2 + 2H^+ + 2e^- \rightarrow 2H_2O$	1.77
$NiO_2 + 4H^+ + 2e^- \rightarrow Ni^{2+} + 2H_2O$	1.7
$PbO_2 + HSO_4^- + 3H^+ + 2e^- \rightarrow PbSO_4 + 2H_2O$	1.685
$Au^+ + e^- \rightarrow Au$	1.68
$2HClO + 2H^+ + 2e^- \rightarrow Cl_2(g) + 2H_2O$	1.63
$Ce^{4+} + e^- \rightarrow Ce^{3+}$	1.61
$NaBiO_3 + 6H^+ + 2e^- \rightarrow Bi^{3+} + Na^+ + 3H_2O$	1.6
$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$	1.51
$Au^{3+} + 3e^- \rightarrow Au$	1.50
$HO_2 + H^+ + e^- \rightarrow H_2O_2$	1.495
$ClO_3^- + 6H^+ + 5e^- \rightarrow Cl_2 + 3H_2O$	1.47
$BrO_3^- + 6H^+ + 6e^- \rightarrow Br^- + 3H_2O$	1.44
$Cl_2 + 2e^- \rightarrow 2Cl^-$	1.358
$Cl_2O_2 + 14H^+ + 6e^- \rightarrow 2ClO_3^- + 7H_2O$	1.33
$N_2H_5^+ + 3H^+ + 2e^- \rightarrow 2NH_4^+$	1.24
$MnO_2 + 4H^+ + 2e^- \rightarrow Mn^{2+} + 2H_2O$	1.23
$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$	1.229
$Pt^{2+} + 2e^- \rightarrow Pt$	1.2
$IO_3^- + 6H^+ + 5e^- \rightarrow I_2 + 3H_2O$	1.195
$Br_2 + 2e^- \rightarrow 2Br^-$	1.19
$AuCl_4^- + 3e^- \rightarrow Au + 4Cl^-$	1.066
$Pd^{2+} + 2e^- \rightarrow Pd$	1.00
$NO_3^- + 4H^+ + 3e^- \rightarrow NO + 2H_2O$	0.987
$ClO_4^- + 2H^+ + 2e^- \rightarrow ClO_3^- + H_2O$	0.96
$NO_3^- + 3H^+ + 2e^- \rightarrow HNO_2 + H_2O$	0.94
$2Hg^{2+} + 2e^- \rightarrow Hg_2^{2+}$	0.920
$Hg^{2+} + 2e^- \rightarrow Hg$	0.855
$Ag^+ + e^- \rightarrow Ag$	0.7994
$Hg_2^{2+} + 2e^- \rightarrow 2Hg$	0.789
$Fe^{3+} + e^- \rightarrow Fe^{2+}$	0.771
$SbCl_6^- + 2e^- \rightarrow SbCl_4^- + 2Cl^-$	0.75
$[PtCl_4]^{2-} + 2e^- \rightarrow Pt + 4Cl^-$	0.73
$O_2 + 2H^+ + 2e^- \rightarrow H_2O_2$	0.682
$[PtCl_6]^{2-} + 2e^- \rightarrow [PtCl_4]^{2-} + 2Cl^-$	0.68
$S_2O_8^{2-} + 4H^+ + 2e^- \rightarrow 2H_2SO_4$	0.6
$H_3AsO_4 + 2H^+ + 2e^- \rightarrow H_3AsO_3 + H_2O$	0.58
$I_3^- + 2e^- \rightarrow 3I^-$	0.536
$I_2 + 2e^- \rightarrow 2I^-$	0.5355
$TeO_2 + 4H^+ + 4e^- \rightarrow Te + 2H_2O$	0.529
$Cu^+ + e^- \rightarrow Cu$	0.521
$[RhCl_6]^{3-} + 3e^- \rightarrow Rh + 6Cl^-$	0.44

$Cu^{2+} + 2e^- \rightarrow Cu$	0.337
$HgCl_2 + 2e^- \rightarrow 2Hg + 2Cl^-$	0.27
$AgCl + e^- \rightarrow Ag + Cl^-$	0.222
$SO_4^{2-} + 4H^+ + 2e^- \rightarrow SO_2 + 2H_2O$	0.20
$SO_4^{2-} + 4H^+ + 2e^- \rightarrow H_2SO_3 + H_2O$	0.17
$Cu^{2+} + e^- \rightarrow Cu^+$	0.153
$S + 2H^+ + 2e^- \rightarrow Sn^{2+}$	0.15
$Sn^{4+} + 2e^- \rightarrow Sn^{2+}$	0.14
$AgBr + e^- \rightarrow Ag + Br^-$	0.0713
$2H^+ + 2e^- \rightarrow H_2$ (reference electrode)	0.0000
$N_2O + 6H^+ + 2e^- \rightarrow 2NH_4OH$	-0.05
$Pb^{2+} + 2e^- \rightarrow Pb$	-0.126
$Sn^{2+} + 2e^- \rightarrow Sn$	-0.14
$AgI + e^- \rightarrow Ag + I^-$	-0.15
$[SnF_6]^{2-} + 4e^- \rightarrow Sn + 6F^-$	-0.25
$Ni_2^{2+} + 2e^- \rightarrow Ni$	-0.25
$Co^{2+} + 2e^- \rightarrow Co$	-0.28
$Tl^+ + e^- \rightarrow Tl$	-0.34
$PbSO_4 + H^+ + 2e^- \rightarrow Pb + HSO_4^-$	-0.356
$PbI_2 + 2e^- \rightarrow Pb + 2I^-$	-0.365
$Se + 2H^+ + 2e^- \rightarrow H_2Se$	-0.40
$Cd^{2+} + 2e^- \rightarrow Cd$	-0.403
$Cr^{3+} + e^- \rightarrow Cr^{2+}$	-0.41
$Fe^{2+} + 2e^- \rightarrow Fe$	-0.44
$2CO_2 + 2H^+ + 2e^- \rightarrow (COOH)_2$	-0.49
$Ga^{3+} + 3e^- \rightarrow Ga$	-0.53
$HgS + 2H^+ + 2e^- \rightarrow Hg + H_2S$	-0.72
$Cr^{3+} + 3e^- \rightarrow Cr$	-0.74
$Zn^{2+} + 2e^- \rightarrow Zn$	-0.763
$Cr^{2+} + 2e^- \rightarrow Cr$	-0.91
$FeS + 2e^- \rightarrow Fe + S^{2-}$	-1.01
$Mn^{2+} + 2e^- \rightarrow Mn$	-1.18
$V^{2+} + 2e^- \rightarrow V$	-1.18
$CdS + 2e^- \rightarrow Cd + S^{2-}$	-1.21
$ZnS + 2e^- \rightarrow Zn + S^{2-}$	-1.44
$Zr^{4+} + 4e^- \rightarrow Zr$	-1.53
$Al^{3+} + 3e^- \rightarrow Al$	-1.66
$H_2 + 2e^- \rightarrow 2H^-$	-2.25
$La^{3+} + 3e^- \rightarrow La$	-2.37
$Mg^{2+} + 2e^- \rightarrow Mg$	-2.375
$Na^+ + e^- \rightarrow Na$	-2.714
$Ca^{2+} + 2e^- \rightarrow Ca$	-2.87
$Sr^{2+} + 2e^- \rightarrow Sr$	-2.89
$Ba^{2+} + 2e^- \rightarrow Ba$	-2.90
$Rb^+ + e^- \rightarrow Rb$	-2.925
$K^+ + e^- \rightarrow K$	-2.925
$Li^+ + e^- \rightarrow Li$	-3.045

Basic Solution	Std Red Potential E _o (volts)
$ClO^- + H_2O + 2e^- \rightarrow Cl^- + 2OH^-$	0.89
$OOH^- + H_2O + 2e^- \rightarrow 3OH^-$	0.88
$2NH_2OH + 2e^- \rightarrow N_2H_4 + 2OH^-$	0.74
$ClO_3^- + 3H_2O + 6e^- \rightarrow Cl^- + 6OH^-$	0.62
$MnO_4^- + 2H_2O + 3e^- \rightarrow MnO_2 + 4OH^-$	0.588
$MnO_4^- + e^- \rightarrow MnO_4^{2-}$	0.564
$NiO_2 + 2H_2O + 2e^- \rightarrow Ni(OH)_2 + 2OH^-$	0.49
$Ag_2CrO_4 + 2e^- \rightarrow 2Ag + CrO_4^{2-}$	0.446
$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$	0.40
$ClO_4^- + H_2O + 2e^- \rightarrow ClO_3^- + 2OH^-$	0.36
$Ag_2O + H_2O + 2e^- \rightarrow 2Ag + 2OH^-$	0.34
$2NO_2 + 3H_2O + 4e^- \rightarrow N_2O + 6OH^-$	0.15
$N_2H_4 + 2H_2O + 2e^- \rightarrow 2NH_3 + 2OH^-$	0.10
$[Co(NH_3)_6]^{3+} + e^- \rightarrow [Co(NH_3)_6]^{2+}$	0.10
$HgO + H_2O + 2e^- \rightarrow Hg + 2OH^-$	0.0984
$O_2 + H_2O + 2e^- \rightarrow OOH^- + OH^-$	0.076
$NO_3^- + H_2O + 2e^- \rightarrow NO_2^- + 2OH^-$	0.01
$MnO_2 + 2H_2O + 2e^- \rightarrow Mn(OH)_2 + 2OH^-$	-0.05
$CrO_4^{2-} + 4H_2O + 3e^- \rightarrow Cr(OH)_3 + 5OH^-$	-0.12
$Cu(OH)_2 + 2e^- \rightarrow Cu + 2OH^-$	-0.36
$S + 2e^- \rightarrow S^{2-}$	-0.48
$Fe(OH)_3 + e^- \rightarrow Fe(OH)_2 + OH^-$	-0.56
$2H_2O + 2e^- \rightarrow H_2 + 2OH^-$	-0.8277
$2NO_3^- + 2H_2O + 2e^- \rightarrow N_2O + 4OH^-$	-0.85
$Fe(OH)_2 + 2e^- \rightarrow Fe + 2OH^-$	-0.877
$SO_4^{2-} + H_2O + 2e^- \rightarrow SO_3^{2-} + 2OH^-$	-0.93
$N_2 + 4H_2O + 4e^- \rightarrow N_2H_4 + 4OH^-$	-1.15
$[Zn(OH)_4]^{2-} + 2e^- \rightarrow Zn + 4OH^-$	-1.22
$[Zn(OH)_2] + 2e^- \rightarrow Zn + 2OH^-$	-1.245
$[Zn(CN)_4]^{2-} + 2e^- \rightarrow Zn + 4CN^-$	-1.26
$Cr(OH)_3 + 3e^- \rightarrow Cr + 3OH^-$	-1.30
$SiO_3^{2-} + 3H_2O + 4e^- \rightarrow Si + 6OH^-$	-1.70

Modified 05/10

19 Thermodynamic Quantities for Selected Substances at 298.15 K (25°C)

Substance	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	ΔS° (J/mol-K)	Substance	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	ΔS° (J/mol-K)
Aluminum				Chlorine			
Al (s)	0	0	28.32	Cl (g)	121.7	105.7	165.2
AlCl ₃ (s)	-705.6	-630.0	109.3	Cl ⁻ (aq)	-167.2	-131.2	56.5
Al ₂ O ₃ (s)	-1669.8	1576.5	51.00	Cl ₂ (g)	0	0	222.96
Barium				HCl (aq)	-167.2	-131.2	56.5
Ba(s)	0	0	63.2	HCl (g)	-92.30	-95.27	186.69
BaCO ₃ (s)	-1216.3	-1137.6	112.1	Chromium			
BaO(s)	-553.5	-525.1	70.42	Cr (g)	397.5	352.6	174.2
Beryllium				Cr (s)	0	0	23.6
Be(s)	0	0	9.44	Cr ₂ O ₃ (s)	-1139.7	-1058.1	81.2
BeO(s)	-608.4	-579.1	13.77	Cobalt			
Be(OH) ₂ (s)	-905.8	-817.9	50.21	Co (g)	439	393	179
Bromine				Copper			
Br(g)	111.8	82.38	174.9	Cu (s)	0	0	33.30
Br ⁻ (aq)	-120.9	-102.8	80.71	CuCl ₂ (s)	-205.9	-167.7	108.1
Br ₂ (g)	30.71	3.14	245.3	CuO (s)	-156.1	-128.3	42.59
Br ₂ (l)	0	0	152.3	Cu ₂ O (s)	-170.7	-147.9	92.36
HBr(g)	-36.23	-53.22	198.49	Fluorine			
Calcium				F (g)	80.0	61.9	158.7
Ca(g)	179.3	145.5	154.8	F ⁻ (aq)	-332.6	-278.8	-13.8
Ca(s)	0	0	41.4	F ₂ (g)	0	0	202.7
CaCO ₃ (s, calcite)	-1207.1	-1128.76	92.88	HF (g)	-268.61	-270.70	173.51
CaCl ₂ (s)	-795.8	-7484	104.6	Hydrogen			
CaF ₂ (s)	-1219.6	-1167.3	68.87	H (g)	217.94	203.26	114.60
CaO(s)	-635.5	-604.17	39.75	H ⁺ (aq)	0	0	0
Ca(OH) ₂ (s)	-986.2	-898.5	83.4	H ⁺ (g)	1536.2	1517.0	108.9
CaSO ₄ (s)	-1434.0	-1321.8	106.7	H ₂ (g)	0	0	130.58
Carbon				Iodine			
C(g)	718.4	672.9	158.0	I (g)	106.60	70.16	180.66
C(s, diamond)	1.88	2.84	2.43	I ⁻ (aq)	-55.19	-51.57	111.3
C(s, graphite)	0	0	5.69	I ₂ (g)	62.25	19.37	260.57
CCl ₄ (g)	-106.7	-64.0	309.4	I ₂ (s)	0	0	116.73
CCl ₄ (l)	-139.3	-68.6	214.4	HI (g)	25.94	1.30	206.3
CF ₄ (g)	-679.9	-635.1	262.3	Iron			
CH ₄ (g)	-74.8	-50.8	186.3	Fe (g)	415.5	369.8	180.5
C ₂ H ₂ (g)	226.7	209.2	200.8	Fe (s)	0	0	27.15
C ₂ H ₄ (g)	52.30	68.11	219.4	Fe ²⁺ (aq)	-87.86	-84.93	113.4
C ₂ H ₆ (g)	-84.68	-32.89	229.5	Fe ³⁺ (aq)	-47.69	-10.54	293.3
C ₂ H ₅ (g)	-103.85	-23.47	269.9	FeCl ₂ (s)	-341.8	-302.3	1179
C ₄ H ₁₀ (g)	-124.73	-15.0	310.0	FeCl ₃ (s)	-400	-334	142.3
C ₄ H ₁₀ (l)	-147.6	-15.0	231.0	FeO (s)	-271.9	-255.2	60.75
C ₆ H ₆ (g)	82.9	129.7	269.2	Fe ₂ O ₃ (s)	-822.16	-740.98	89.96
C ₆ H ₆ (l)	49.0	124.5	172.8	Fe ₃ O ₄ (s)	-1117.1	-1014.2	146.4
CH ₃ OH (g)	-201.2	-161.9	237.6	FeS ₂ (s)	-171.5	-160.1	52.92
CH ₃ OH (l)	-238.6	-166.23	126.8	Lead			
C ₂ H ₅ OH (g)	-235.1	-168.5	282.7	Pb (s)	0	0	68.85
C ₅ H ₅ OH (l)	-277.7	-174.76	160.7	PbBr ₂ (s)	-277.4	-260.7	161
C ₆ H ₁₂ O ₆ (s)	-1273.02	-910.4	212.1	PbCO ₃ (s)	-6994	-625.5	131.0
CO (g)	-110.5	-137.2	197.9	Pb(NO ₃) ₂ (aq)	-421.3	-246.9	303.3
CO ₂ (g)	-393.5	-394.4	213.6	Pb(NO ₃) ₂ (s)	-451.9	-	-
HC ₂ H ₃ O ₂ (l)	-487.0	-392.4	159.8	PbO (s)	-217.3	-187.9	68.70
H ₂ CO (g)	-116.	-110	219	Lithium			
H ₃ CCHO (g)	-166	-133.7	266	Li (g)	159.3	126.6	138.8
Cesium				Li (s)	0	0	29.09
Cs (g)	76.50	49.53	175.6	Li ⁺ (g)	685.7	648.5	133.0
Cs (s)	0	0	85.15	LiCl (s)	-408.3	-384.0	59.30
CsCl (s)	-442.8	-414.4	101.2				

Substance	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	ΔS° (J/mol-K)	Substance	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	ΔS° (J/mol-K)
Magnesium				K ₂ O (s)	-363.2	-322.1	94.14
Mg (g)	147.1	112.5	148.6	KO ₂ (s)	-284.5	-240.6	122.5
Mg (s)	0	0	32.51	K ₂ O ₂ (s)	-495.8	-429.8	113.0
MgCl ₂ (s)	-641.6	-592.4	89.6	KOH (s)	-424.7	-378.9	78.91
MgO (s)	-601.8	-569.6	26.8	KOH (aq)	-482.4	-440.5	91.6
Mg(OH) ₂ (s)	-924.7	-833.7	63.24	Rubidium			
Manganese				Rb (g)	85.8	55.8	170.0
Mn (g)	280.7	238.5	173.6	Rb (s)	0	0	76.78
Mn (s)	0	0	32.0	RbCl (s)	-430.5	-412.0	92
MnO (s)	-385.2	-362.9	59.7	RbClO ₃ (s)	-392.4	-292.0	152
MnO ₂ (s)	-519.6	-464.8	53.14	Scandium			
MnO ₄ ⁻ (aq)	-541.4	-447.2	191.2	Sc(g)	377.8	336.1	174.7
Mercury				Sc(s)	0	0	34.6
Hg (g)	60.83	31.76	174.89	Selenium			
Hg (l)	0	0	77.40	H ₂ Se(g)	29.7	15.9	219.0
HgCl ₂ (s)	-230.4	-184.0	144.5	Silicon			
Hg ₂ Cl ₂ (s)	-264.9	-210.5	192.5	Si (g)	368.2	323.9	167.8
Nickel				Si (s)	0	0	18.7
Ni (g)	429.7	384.5	182.1	SiC (s)	-73.22	-70.85	16.61
Ni (s)	0	0	29.9	SiCl ₄ (l)	-640.1	-572.8	239.3
NiCl ₂ (s)	-305.3	-259.0	97.65	SiO ₂ (s, quartz)	-910.9	-856.5	41.84
NiO (s)	-239.7	-211.7	37.99	Silver			
Nitrogen				Ag (s)	0	0	42.55
N (g)	472.7	455.5	153.3	Ag + (aq)	105.90	77.11	73.93
N ₂ (g)	0	0	191.50	AgCl (s)	-127.0	-109.70	96.11
NH ₃ (aq)	-80.29	-26.50	111.3	Ag ₂ O (s)	-31.05	-11.20	121.3
NH ₃ (g)	-46.19	-16.66	192.5	AgNO ₃ (s)	-124.4	-33.41	140.9
NH ₄ ⁺ (aq)	-132.5	-79.31	113.4	Sodium			
N ₂ H ₄ (g)	95.40	159.4	238.5	Na (g)	107.7	77.3	153.7
NH ₄ CN (s)	0.0	-	-	Na (s)	0	0	51.45
NH ₄ Cl (s)	-314.4	-203.0	94.6	Na+ (aq)	-240.1	-261.9	59.0
NH ₄ NO ₃ (s)	-365.6	-184.0	151	Na+ (g)	609.3	574.3	148.0
NO (g)	90.37	86.71	210.62	NaBr (aq)	-360.6	-364.7	141
NO ₂ (g)	33.84	51.84	240.45	NaBr (s)	-361.4	-349.3	86.82
N ₂ O (g)	81.6	103.59	220.0	Na ₂ CO ₃ (s)	-1130.9	-1047.7	136.0
N ₂ O ₄ (g)	9.66	98.28	304.3	NaCl (aq)	-407.1	-393.0	115.5
NOCl (g)	52.6	66.3	264	NaCl (g)	-181.4	-201.3	229.8
HNO ₃ (aq)	-206.6	-110.5	146	NaCl (s)	-410.9	-384.0	72.33
HNO ₃ (g)	-134.3	-73.94	266.4	NaHCO ₃ (s)	-947.7	-851.8	102.1
Oxygen				NaNO ₃ (aq)	-446.2	-372.4	207
O (g)	247.5	230.1	161.0	NaNO ₃ (s)	-467.9	-367.0	116.5
O ₂ (g)	0	0	205.0	NaOH (aq)	-469.6	-419.2	49.8
O ₃ (g)	142.3	163.4	237.6	NaOH (s)	-425.6	-379.5	64.46
OH ⁻ (aq)	-230.0	-157.3	-10.7	Strontium			
H ₂ O (g)	-241.82	-228.57	188.83	SrO (s)	-592.0	-561.9	54.9
H ₂ O (l)	-285.83	-237.13	69.91	Sr (g)	164.4	110.0	164.6
H ₂ O ₂ (g)	-136.40	-105.48	232.9	Sulfur			
H ₂ O ₂ (l)	-187.8	-120.4	109.6	S (s, rhombic)	0	0	31.88
Phosphorus				SO ₂ (g)	-296.9	-300.4	248.5
P (g)	316.4	280.0	163.2	SO ₃ (g)	-395.2	-370.4	256.2
P ₂ (g)	144.3	103.7	218.1	SO ₄ ²⁻ (aq)	-909.3	-744.5	20.1
P ₄ (g)	58.9	24.4	280	SOCl ₂ (l)	-245.6	-	-
P ₄ (s, red)	-17.46	-12.03	22.85	H ₂ S (g)	-20.17	-33.01	205.6
P ₄ (s, white)	0	0	41.08	H ₂ SO ₄ (aq)	-909.3	-744.5	20.1
PCl ₃ (g)	-288.07	-269.6	311.7	H ₂ SO ₄ (l)	-814.0	-689.9	156.1
PCl ₃ (l)	-319.6	-272.4	217	Titanium			
PF ₅ (g)	-1594.4	-1520.7	300.8	Ti (g)	468	422	180.3
PH ₃ (g)	5.4	13.4	210.2	Ti (s)	0	0	30.76
P ₄ O ₆ (s)	-1640.1	-	-	TiCl ₄ (g)	-763.2	-726.8	354.9
P ₄ O ₁₀ (s)	-2940.1	-2675.2	228.9	TiCl ₄ (l)	-804.2	-728.1	221.9
POCl ₃ (g)	-542.2	-502.5	325	TiO ₂ (s)	-944.7	-889.4	50.29
POCl ₃ (l)	-597.0	-520.9	222	Vanadium			
H ₃ PO ₄ (aq)	-1288.3	-1142.6	158.2	V (g)	514.2	453.1	182.2
Potassium				V (s)	0	0	28.9
K (g)	89.99	61.17	160.2	Zinc			
K (s)	0	0	64.67	Zn (g)	130.7	95.2	160.9
KCl (s)	-435.9	-408.3	82.7	Zn (s)	0	0	41.63
KClO ₃ (s)	-391.2	-289.9	143.0	ZnCl ₂ (s)	-415.1	-369.4	111.5
KClO ₃ (aq)	-349.5	-284.9	265.7	ZnO (s)	-348.0	-318.2	43.9
KNO ₃ (s)	-492.70	-393.13	288.1				