

## Chapter 19 Electrochemistry Math Summary

### Relating Standard Cell Potential to Standard Half Cell Potentials

$$E^\circ_{\text{cell}} = E^\circ_{\text{oxidation}} + E^\circ_{\text{reduction}} \quad (\text{standard conditions assume } 1.0 \text{ M concentrations})$$

### Relating Half Cell Potentials when Written in Opposite Directions

$$E^\circ_{\text{ox}} = -E^\circ_{\text{red}} \quad \text{for half reactions written in opposite directions}$$

### Relating Standard Cell Potentials to $\Delta G$

$$\Delta G^\circ = -nFE^\circ_{\text{cell}} \quad (\text{to give answer in kJ, use } F = 96.485)$$

$$F = 96,500 \text{ C/mol}$$

n = number of electrons transferred

### Relating Actual Cell Potential to Standard Cell Potential when Concentrations aren't 1.0-M

$$E_{\text{cell}} = E^\circ_{\text{cell}} - [0.0592/n] \log Q \quad (Q = \text{ratio of actual concentrations})$$

### Relating Standard Cell Potential to Equilibrium Constant

$$\log K = nE^\circ/0.0592$$

### Relating Actual Cell Potential to Actual Concentrations in Concentration Cells

$$E_{\text{cell}} = -[0.0592/n] \log Q \quad \text{for concentration cells, where anode and cathode differ only in concentration, but otherwise have same ions}$$

### Relating # of Moles of Electrons Transferred as a Function of Time and Current in Electrolysis

$$1 \text{ mol } e^- = 96,500 \text{ C}$$

$$\text{moles of electrons} = [\text{current (A)} \cdot \text{time (sec)}] / 96,500 \quad \text{for electrolysis, moles, current, and time are related.}$$

$$\text{rearranged: time (sec)} = (\text{moles of electrons})(96500) / \text{current (in A)}$$

Note: 3600 sec/hour

$$\text{so time (hours)} = (\text{moles of electrons})(26.8) / \text{current (in A)}$$

### Electrochemistry-Related Units

C = Coulomb = quantity of electrical charge =  $6.24 \cdot 10^{18}$  electrons

• 1 mole of electrons = 96,500 C

A = amp = rate of charge flow per time = C/sec

V = volt = electrical power/force/strength = J/C

$$F = \text{Faraday} = \frac{96,500 \text{ C}}{\text{mole } e^-} = \frac{96.5 \text{ kJ}}{\text{mole } e^- \cdot \text{V}}$$

**Assigning Oxidation Numbers (See Section 5.4)**

This is a more complete set of rules than your textbook. It always works.

Use these rules in order.

The sum of all oxidation numbers of all elements = charge on substance.

		Oxidation Number:	Examples:
1.	Atoms in their elemental state	= 0	Fe, H <sub>2</sub> , O <sub>2</sub>
2.	Monatomic ions	= charge	F <sup>1-</sup> , Na <sup>1+</sup> , Fe <sup>3+</sup>

**IN COMPOUNDS**

3.	Group 1A	= +1	NaCl, KNO <sub>3</sub>
4.	Group 2A	= +2	MgO
5.	Fluorine	= -1	HF, ClF
6.	Hydrogen	= +1	H <sub>2</sub> O
7.	Oxygen	= -2	SO <sub>2</sub> , HClO <sub>4</sub>
8.	Group 7A (Halogen family)	= -1	HCl
9.	Group 6A (Oxygen family)	= -2	PbS <sub>2</sub>

The sum of all oxidation numbers of all elements = charge on substance.

Key: For anything else, (or for a group 7A or group 6A in the presence of higher priority atoms), set its oxidation number = "x", and solve for "x" such that the ox. #'s = actual charge.

**Find Ox #'s for**

1. H <sub>2</sub> OC      C:	2. PCl <sub>3</sub> P:
3. HSO <sub>4</sub> <sup>-</sup> S:	4. KMnO <sub>4</sub> Mn:
5. Mg <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> P:	6. HClO <sub>2</sub> Cl:

Balancing Redox: Simple Cases where all Reactants and Products are Provided

1. Identify oxidation numbers for redox actors
2. Set coefficients for them so that the **#e's released = #e's accepted**
  - focus completely on the atoms whose oxidation numbers change
3. Then balance any redox spectators
4. Check at the end to make sure:
  - Charges balance
  - Atoms balance

Note: Test problems will give you all of the species involved. Some OWL problems will be harder and will not include all of the chemicals

Some Harder OWL-Level Redox-Balancing Problems: When some necessary chemicals are omitted

- a. Sometimes  $\text{H}_2\text{O}$ ,  $\text{OH}^-$ ,  $\text{H}^+$  are omitted, and need to be added in order to balance oxygens and hydrogens
- b. In knowing how to do this, it is helpful to distinguish acid versus base conditions
- c. Under acid conditions, it's appropriate to have  $\text{H}^+$  but not  $\text{OH}^-$
- d. Under base conditions, it's appropriate to have  $\text{OH}^-$  but not  $\text{H}^+$

<u>Acid Conditions</u>	<u>Base Conditions</u>
<ol style="list-style-type: none"> <li>1. Identify oxidation numbers for redox actors</li> <li>2. Set coefficients for them so that the <b>#e's released = #e's accepted</b> <ul style="list-style-type: none"> <li>• focus completely on the atoms whose oxidation numbers change Add <math>\text{H}_2\text{O}</math>'s to balance oxygen</li> </ul> </li> <li>3. Add <math>\text{H}_2\text{O}</math>'s as needed to balance <u>oxygens</u></li> <li>4. Add <math>\text{H}^+</math>'s as needed to balance <u>hydrogens</u> and charge</li> <li>5. Check at the end to make sure:               <ol style="list-style-type: none"> <li>a. Charges balance</li> <li>b. Atoms balance</li> </ol> </li> </ol>	<ol style="list-style-type: none"> <li>1. Identify oxidation numbers for redox actors</li> <li>2. Set coefficients for them so that the <b>#e's released = #e's accepted</b> <ul style="list-style-type: none"> <li>• focus completely on the atoms whose oxidation numbers change Add <math>\text{OH}^-</math>'s to balance charge</li> </ul> </li> <li>3. Add <math>\text{OH}^-</math>'s as needed to balance <u>charge</u></li> <li>4. Add <math>\text{H}_2\text{O}</math>'s to balance hydrogens</li> <li>5. Check at the end to make sure:               <ol style="list-style-type: none"> <li>a. Charges balance</li> <li>b. Atoms balance</li> </ol> </li> </ol>

## Standard Reduction (Electrode) Potentials at 25° C (OWL)

Half-cell reaction	$E_o$ (volts)
$F_2 + 2e \rightarrow 2F^-$	2.87
$Ce^{4+} + e \rightarrow Ce^{3+}$	1.61
$MnO_4^- + 8 H^+ + 5e \rightarrow Mn^{2+} + 4H_2O$	1.51
$Cl_2 + 2e \rightarrow 2Cl^-$	1.36
$Cr_2O_7^{2-} + 14 H^+ + 6e \rightarrow 2Cr^{3+} + 7H_2O$	1.33
$O_2 + 4H^+ + 4e \rightarrow 2H_2O$	1.229
$Br_2 + 2e \rightarrow 2Br^-$	1.08
$NO_3^- + 4H^+ + 3e \rightarrow NO + 2H_2O$	0.96
$2Hg^{2+} + 2e \rightarrow Hg_2^{2+}$	0.920
$Hg^{2+} + 2e \rightarrow Hg$	0.855
$O_2 + 4 H^+ (10^{-7} M) + 4e \rightarrow 2H_2O$	0.82
$Ag^+ + e \rightarrow Ag$	0.799
$Hg_2^{2+} + 2e \rightarrow 2Hg$	0.789
$Fe^{3+} + e \rightarrow Fe^{2+}$	0.771
$I_2 + 2e \rightarrow 2I^-$	0.535
$Fe(CN)_6^{3-} + e \rightarrow Fe(CN)_6^{4-}$	0.48
$Cu^{2+} + 2e \rightarrow Cu$	0.337
$Cu^{2+} + e \rightarrow Cu^+$	0.153
$S + 2H^+ + 2e \rightarrow H_2S$	0.14
$2H^+ + 2e \rightarrow H_2$	0.0000
$Pb^{2+} + 2e \rightarrow Pb$	-0.126
$Sn^{2+} + 2e \rightarrow Sn$	-0.14
$Ni^{2+} + 2e \rightarrow Ni$	-0.25
$Co^{2+} + 2e \rightarrow Co$	-0.28
$Cd^{2+} + 2e \rightarrow Cd$	-0.403
$Cr^{3+} + e \rightarrow Cr^{2+}$	-0.41
$2H_2O + 2e \rightarrow H_2 + 2OH^- (10^{-7} M)$	-0.41
$Fe^{2+} + 2e \rightarrow Fe$	-0.44
$Cr^{3+} + 3e \rightarrow Cr$	-0.74
$Zn^{2+} + 2e \rightarrow Zn$	-0.763
$2H_2O + 2e \rightarrow H_2 + 2OH^-$	-0.83
$Mn^{2+} + 2e \rightarrow Mn$	-1.18
$Al^{3+} + 3e \rightarrow Al$	-1.66
$Mg^{2+} + 2e \rightarrow Mg$	-2.37
$Na^+ + e \rightarrow Na$	-2.714
$K^+ + e \rightarrow K$	-2.925
$Li^+ + e \rightarrow Li$	-3.045