Success 24/7 Chemistry Notes: Electrochemistry

Electrochemistry

- The interconversions of chemical and electrical energy that involve the transfer of electrons.
- This process occurs in a device called an electrochemical cell.

The Activity Series and Redox

- We will utilize the activity series of metals to determine reactivity in single replacement redox reactions.
- Electrons are lost by the more active metals and gained by the less active metals.
- The higher a metal is on the activity series, the easier it is oxidized.

Lithium
Potassium
Calcium
Sodium
Magnesium
Aluminum
Zinc
Chromium
Iron
Cadmium
Nickel
Tin
Lead
Hydrogen
Copper
Mercury
Silver
Platinum
Gold

The simplified order from most reactive to least reactive:

- Group I metals
- Group II metals
- Aluminum
- Transition metals
- Hydrogen
- “Jewelry metals”

Circle the metal of the pair that would be most likely to be oxidized.

Ca/Fe Ni/Zn Au/Na

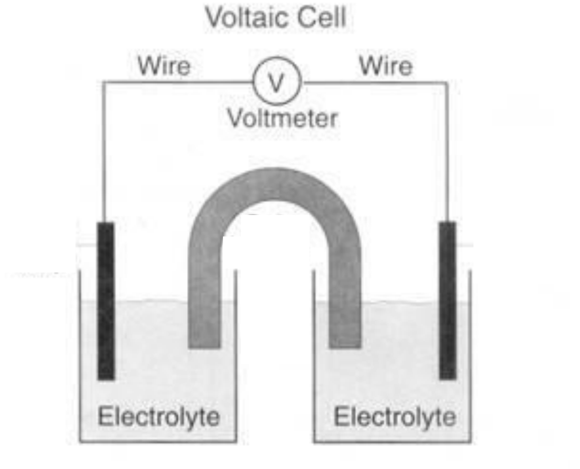
Batteries

- Electrochemical cells that convert chemical energy into electrical energy are called voltaic cells.
- The energy is produced by spontaneous redox reactions.
- Voltaic cells can be separated into two half cells.
- A half cell consists of a metal rod or strip immersed in a solution of its ions.

Half-Cells

- The half cells are connected by a salt bridge. A salt bridge is a tube containing a solution of ions.
- Ions pass through the salt bridge to keep the charges balanced.
- Electrons pass through an external wire.
- The metal rods in voltaic cells are called electrodes.
- Oxidation occurs at the anode and reduction occurs at the cathode. **(An Ox and Red Cat)**
- The direction of electron flow is from the anode to the cathode. **(FAT CAT)**

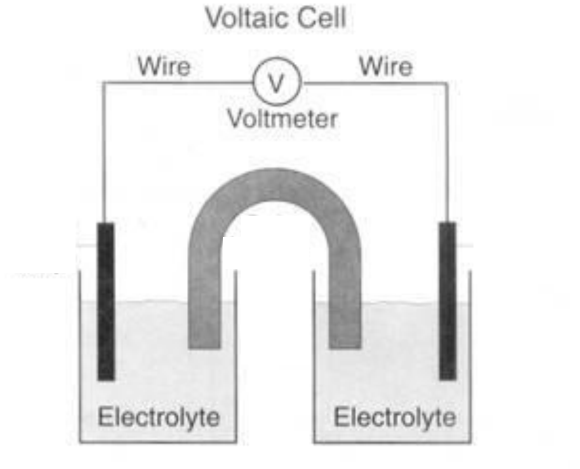
Example Diagram of Zn/Mg Voltaic Cell



Practice:

Label the Ag/Zn Voltaic Cell.

Include: anode, cathode, salt bridge, & the direction of the flow of electrons



Half-Reactions and Cell Potential

We write half reactions to show what happens in each part of the cell.

- Reduction: When electrons are gained, the electrons are placed in the reactants.
- Oxidation: When electrons are lost, the electrons are placed in the products.

Write the half reactions for the Ag/Zn cell you labeled above.

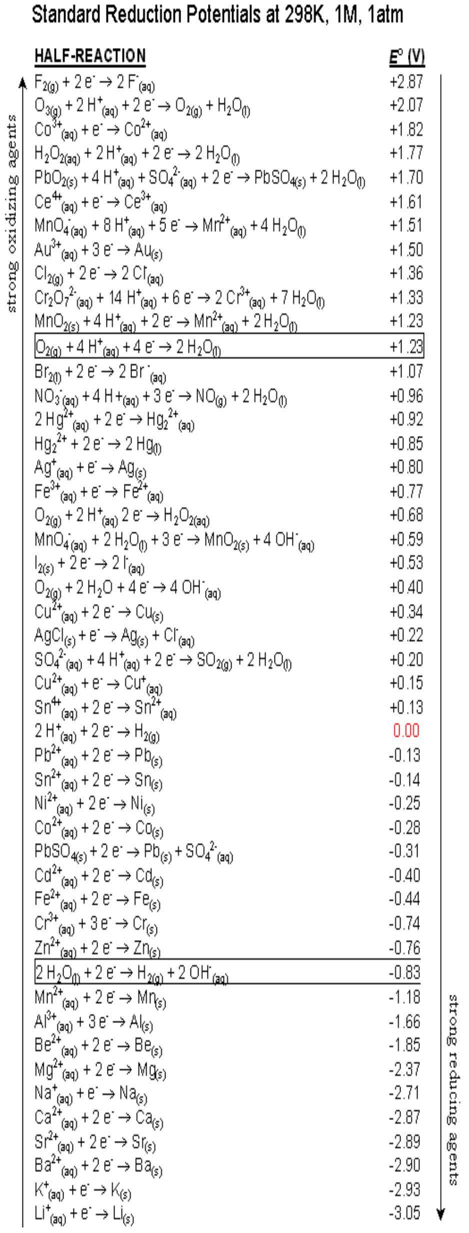
Calculating the Charge (Cell Potential) of a Battery

- The potential charge of a battery can be calculated with a set of values from a table of reduction potentials.
  - To do this, write the oxidation and reduction half reactions.
  - Look up the cell potentials from the data table.
  - Flip the sign of the cell potential for oxidation. (*The most negative value will be flipped.)*
  - Add the potentials together.

Ex: Calculate the cell potential of the Ag/Zn battery.

$Ag^+ + e^- \rightarrow Ag$ E° = +0.80V

$Zn^{2+} + 2\ e^- \rightarrow Zn$ E° = -0.76 V



Standard Reduction Potentials at 298K, 1M, 1atm

strong oxidizing agents

HALF-REACTION	***E*° (V)**
$F_{2(g)} + 2\,e^- \rightarrow 2\,F^-_{(aq)}$	+2.87
$O_{3(g)} + 2\,H^+_{(aq)} + 2\,e^- \rightarrow O_{2(g)} + H_2O_{(l)}$	+2.07
$Co^{3+}_{(aq)} + e^- \rightarrow Co^{2+}_{(aq)}$	+1.82
$H_2O_{2(aq)} + 2\,H^+_{(aq)} + 2\,e^- \rightarrow 2\,H_2O_{(l)}$	+1.77
$PbO_{2(s)} + 4\,H^+_{(aq)} + SO_4^{2-}{}_{(aq)} + 2\,e^- \rightarrow PbSO_{4(s)} + 2\,H_2O_{(l)}$	+1.70
$Ce^{4+}_{(aq)} + e^- \rightarrow Ce^{3+}_{(aq)}$	+1.61
$MnO_4^-{}_{(aq)} + 8\,H^+_{(aq)} + 5\,e^- \rightarrow Mn^{2+}_{(aq)} + 4\,H_2O_{(l)}$	+1.51
$Au^{3+}_{(aq)} + 3\,e^- \rightarrow Au_{(s)}$	+1.50
$Cl_{2(g)} + 2\,e^- \rightarrow 2\,Cl^-_{(aq)}$	+1.36
$Cr_2O_7^{2-}{}_{(aq)} + 14\,H^+_{(aq)} + 6\,e^- \rightarrow 2\,Cr^{3+}_{(aq)} + 7\,H_2O_{(l)}$	+1.33
$MnO_{2(s)} + 4\,H^+_{(aq)} + 2\,e^- \rightarrow Mn^{2+}_{(aq)} + 2\,H_2O_{(l)}$	+1.23
$O_{2(g)} + 4\,H^+_{(aq)} + 4\,e^- \rightarrow 2\,H_2O_{(l)}$	+1.23
$Br_{2(l)} + 2\,e^- \rightarrow 2\,Br^-_{(aq)}$	+1.07
$NO_3^-{}_{(aq)} + 4\,H+_{(aq)} + 3\,e^- \rightarrow NO_{(g)} + 2\,H_2O_{(l)}$	+0.96
$2\,Hg^{2+}_{(aq)} + 2\,e^- \rightarrow Hg_2^{2+}{}_{(aq)}$	+0.92
$Hg_2^{2+} + 2\,e^- \rightarrow 2\,Hg_{(l)}$	+0.85
$Ag^+_{(aq)} + e^- \rightarrow Ag_{(s)}$	+0.80
$Fe^{3+}_{(aq)} + e^- \rightarrow Fe^{2+}_{(aq)}$	+0.77
$O_{2(g)} + 2\,H^+_{(aq)}\ 2\,e^- \rightarrow H_2O_{2(aq)}$	+0.68
$MnO_4^-{}_{(aq)} + 2\,H_2O_{(l)} + 3\,e^- \rightarrow MnO_{2(s)} + 4\,OH^-_{(aq)}$	+0.59
$I_{2(s)} + 2\,e^- \rightarrow 2\,I^-_{(aq)}$	+0.53
$O_{2(g)} + 2\,H_2O + 4\,e^- \rightarrow 4\,OH^-_{(aq)}$	+0.40
$Cu^{2+}_{(aq)} + 2\,e^- \rightarrow Cu_{(s)}$	+0.34
$AgCl_{(s)} + e^- \rightarrow Ag_{(s)} + Cl^-_{(aq)}$	+0.22
$SO_4^{2-}{}_{(aq)} + 4\,H^+_{(aq)} + 2\,e^- \rightarrow SO_{2(g)} + 2\,H_2O_{(l)}$	+0.20
$Cu^{2+}_{(aq)} + e^- \rightarrow Cu^+_{(aq)}$	+0.15
$Sn^{4+}_{(aq)} + 2\,e^- \rightarrow Sn^{2+}_{(aq)}$	+0.13
$2\,H^+_{(aq)} + 2\,e^- \rightarrow H_{2(g)}$	0.00
$Pb^{2+}_{(aq)} + 2\,e^- \rightarrow Pb_{(s)}$	-0.13
$Sn^{2+}_{(aq)} + 2\,e^- \rightarrow Sn_{(s)}$	-0.14
$Ni^{2+}_{(aq)} + 2\,e^- \rightarrow Ni_{(s)}$	-0.25
$Co^{2+}_{(aq)} + 2\,e^- \rightarrow Co_{(s)}$	-0.28
$PbSO_{4(s)} + 2\,e^- \rightarrow Pb_{(s)} + SO_4^{2-}{}_{(aq)}$	-0.31
$Cd^{2+}_{(aq)} + 2\,e^- \rightarrow Cd_{(s)}$	-0.40
$Fe^{2+}_{(aq)} + 2\,e^- \rightarrow Fe_{(s)}$	-0.44
$Cr^{3+}_{(aq)} + 3\,e^- \rightarrow Cr_{(s)}$	-0.74
$Zn^{2+}_{(aq)} + 2\,e^- \rightarrow Zn_{(s)}$	-0.76
$2\,H_2O_{(l)} + 2\,e^- \rightarrow H_{2(g)} + 2\,OH^-_{(aq)}$	-0.83
$Mn^{2+}_{(aq)} + 2\,e^- \rightarrow Mn_{(s)}$	-1.18
$Al^{3+}_{(aq)} + 3\,e^- \rightarrow Al_{(s)}$	-1.66
$Be^{2+}_{(aq)} + 2\,e^- \rightarrow Be_{(s)}$	-1.85
$Mg^{2+}_{(aq)} + 2\,e^- \rightarrow Mg_{(s)}$	-2.37
$Na^+_{(aq)} + e^- \rightarrow Na_{(s)}$	-2.71
$Ca^{2+}_{(aq)} + 2\,e^- \rightarrow Ca_{(s)}$	-2.87
$Sr^{2+}_{(aq)} + 2\,e^- \rightarrow Sr_{(s)}$	-2.89
$Ba^{2+}_{(aq)} + 2\,e^- \rightarrow Ba_{(s)}$	-2.90
$K^+_{(aq)} + e^- \rightarrow K_{(s)}$	-2.93
$Li^+_{(aq)} + e^- \rightarrow Li_{(s)}$	-3.05

strong reducing agents

Practice:

Write the half reactions and calculate the cell potential of a Mg/Cu battery.

$Mg^{2+} + 2e^- \rightarrow Mg$ E°= -2.37V

$Cu^{2+} + 2e^- \rightarrow Cu$ E°= 0.34 V

Write the half reactions and calculate the cell

potential of a Zn/Mg battery.

$Mg^{2+} + 2e^- \rightarrow Mg$ E°= -2.37V

$Zn^{2+} + 2\ e^- \rightarrow Zn$ E° = -0.76 V

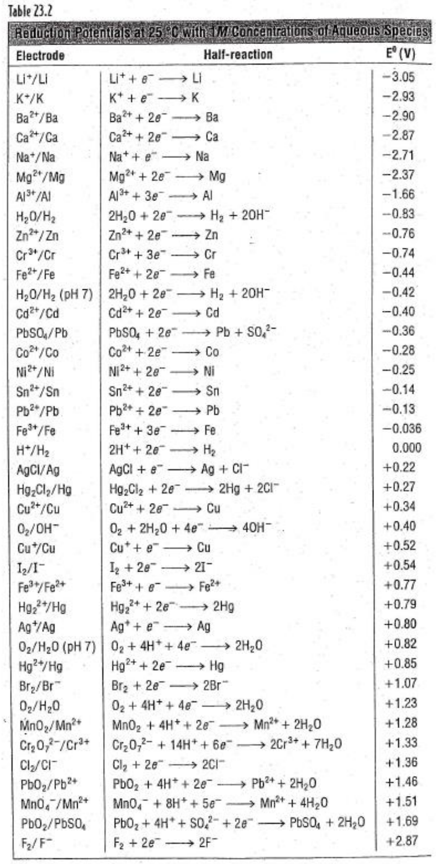


Table 23.2

Reduction Potentials at 25 °C with 1*M* Concentrations of Aqueous Species

Electrode	Half-reaction	E° (V)
Li^+/Li	$Li^+ + e^- \longrightarrow Li$	−3.05
K^+/K	$K^+ + e^- \longrightarrow K$	−2.93
Ba^{2+}/Ba	$Ba^{2+} + 2e^- \longrightarrow Ba$	−2.90
Ca^{2+}/Ca	$Ca^{2+} + 2e^- \longrightarrow Ca$	−2.87
Na^+/Na	$Na^+ + e^- \longrightarrow Na$	−2.71
Mg^{2+}/Mg	$Mg^{2+} + 2e^- \longrightarrow Mg$	−2.37
Al^{3+}/Al	$Al^{3+} + 3e^- \longrightarrow Al$	−1.66
H_2O/H_2	$2H_2O + 2e^- \longrightarrow H_2 + 2OH^-$	−0.83
Zn^{2+}/Zn	$Zn^{2+} + 2e^- \longrightarrow Zn$	−0.76
Cr^{3+}/Cr	$Cr^{3+} + 3e^- \longrightarrow Cr$	−0.74
Fe^{2+}/Fe	$Fe^{2+} + 2e^- \longrightarrow Fe$	−0.44
H_2O/H_2 (pH 7)	$2H_2O + 2e^- \longrightarrow H_2 + 2OH^-$	−0.42
Cd^{2+}/Cd	$Cd^{2+} + 2e^- \longrightarrow Cd$	−0.40
$PbSO_4/Pb$	$PbSO_4 + 2e^- \longrightarrow Pb + SO_4^{2-}$	−0.36
Co^{2+}/Co	$Co^{2+} + 2e^- \longrightarrow Co$	−0.28
Ni^{2+}/Ni	$Ni^{2+} + 2e^- \longrightarrow Ni$	−0.25
Sn^{2+}/Sn	$Sn^{2+} + 2e^- \longrightarrow Sn$	−0.14
Pb^{2+}/Pb	$Pb^{2+} + 2e^- \longrightarrow Pb$	−0.13
Fe^{3+}/Fe	$Fe^{3+} + 3e^- \longrightarrow Fe$	−0.036
H^+/H_2	$2H^+ + 2e^- \longrightarrow H_2$	0.000
$AgCl/Ag$	$AgCl + e^- \longrightarrow Ag + Cl^-$	+0.22
Hg_2Cl_2/Hg	$Hg_2Cl_2 + 2e^- \longrightarrow 2Hg + 2Cl^-$	+0.27
Cu^{2+}/Cu	$Cu^{2+} + 2e^- \longrightarrow Cu$	+0.34
O_2/OH^-	$O_2 + 2H_2O + 4e^- \longrightarrow 4OH^-$	+0.40
Cu^+/Cu	$Cu^+ + e^- \longrightarrow Cu$	+0.52
I_2/I^-	$I_2 + 2e^- \longrightarrow 2I^-$	+0.54
Fe^{3+}/Fe^{2+}	$Fe^{3+} + e^- \longrightarrow Fe^{2+}$	+0.77
Hg_2^{2+}/Hg	$Hg_2^{2+} + 2e^- \longrightarrow 2Hg$	+0.79
Ag^+/Ag	$Ag^+ + e^- \longrightarrow Ag$	+0.80
O_2/H_2O (pH 7)	$O_2 + 4H^+ + 4e^- \longrightarrow 2H_2O$	+0.82
Hg^{2+}/Hg	$Hg^{2+} + 2e^- \longrightarrow Hg$	+0.85
Br_2/Br^-	$Br_2 + 2e^- \longrightarrow 2Br^-$	+1.07
O_2/H_2O	$O_2 + 4H^+ + 4e^- \longrightarrow 2H_2O$	+1.23
MnO_2/Mn^{2+}	$MnO_2 + 4H^+ + 2e^- \longrightarrow Mn^{2+} + 2H_2O$	+1.28
$Cr_2O_7^{2-}/Cr^{3+}$	$Cr_2O_7^{2-} + 14H^+ + 6e^- \longrightarrow 2Cr^{3+} + 7H_2O$	+1.33
Cl_2/Cl^-	$Cl_2 + 2e^- \longrightarrow 2Cl^-$	+1.36
PbO_2/Pb^{2+}	$PbO_2 + 4H^+ + 2e^- \longrightarrow Pb^{2+} + 2H_2O$	+1.46
MnO_4^-/Mn^{2+}	$MnO_4^- + 8H^+ + 5e^- \longrightarrow Mn^{2+} + 4H_2O$	+1.51
$PbO_2/PbSO_4$	$PbO_2 + 4H^+ + SO_4^{2-} + 2e^- \longrightarrow PbSO_4 + 2H_2O$	+1.69
F_2/F^-	$F_2 + 2e^- \longrightarrow 2F^-$	+2.87