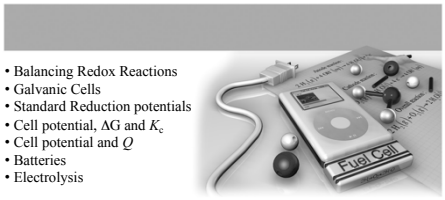
Tro Chapter 18 - Electrochemistry



- Balancing Redox Reactions
- Galvanic Cells
- Standard Reduction potentials
- Cell potential, ΔG and K_c
- Cell potential and Q
- Batteries
- Electrolysis

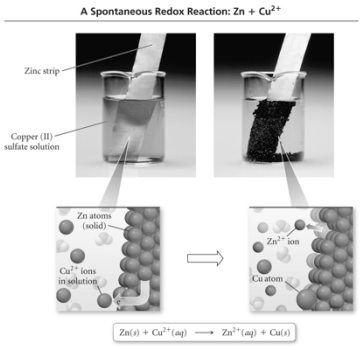
Next on-line HW due Thursday at 11:59 PM!

Balancing redox reactions using half-reactions

$Cu\ (s) + NO_3^-\ (aq) \longrightarrow Cu^{2+}\ (aq) + NO_2\ (g)$

$MnO_4^- + C_2O_4^{2-} \longrightarrow MnO_2\ (s) + CO_3^{2-}$ in basic solution

Spontaneous Redox Reactions



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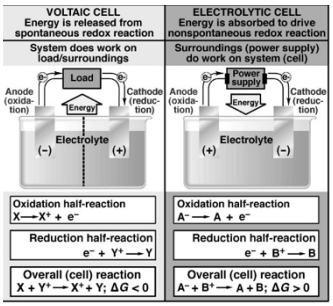
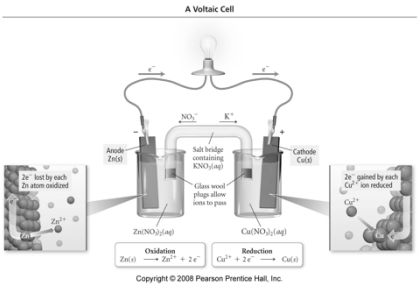


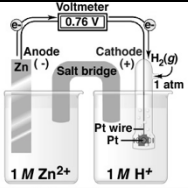
Generating Electricity from a Redox Reaction



Tro 18.4

Cell Potentials and Standard Reduction Potentials: E°

The Standard Hydrogen Electrode



Oxidation half-reaction
$Zn(s) \longrightarrow Zn^{2+}(aq) + 2e^-$
E° = -0.76 V

Reduction half-reaction
$2H^+(aq) + 2e^- \longrightarrow H_2(g)$
E° = 0.0 V

Overall (cell) reaction
$Zn(s) + 2H^+(aq) \longrightarrow Zn^{2+}(aq) + H_2(g)$

$$E^\circ_{cell} = E^\circ_{cath} - E^\circ_{anode}$$

Cell potentials and spontaneity

"Any half reaction will be spontaneous when paired with the reverse of a half-reaction below it in the table"

$Br_2 + Zn\ (s) \longrightarrow Zn^{2+} + 2Br^-$ $\quad E^\circ_{cell} = 1.85\ V$

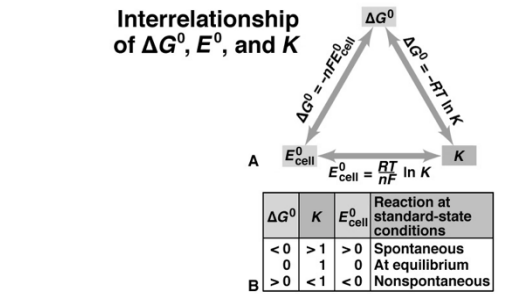
$E^\circ_{Zn/Zn2+} = -0.76\ V$ (reduction potential!)

Calculate $E^\circ(Br_2/Br^-)$

Will magnesium metal dissolve in HCl?

$Mg_{(s)} + 2\ HCl_{(aq)} \longrightarrow Mg^{2+}\ (aq) + H_{2\ (g)} + 2\ Cl^-_{(aq)}$

Tro 18.5 Cell Potential, Free Energy and *K*



	ΔG^0	K	E^0_{cell}	Reaction at standard-state conditions
	< 0	> 1	> 0	Spontaneous
	0	1	0	At equilibrium
B	> 0	< 1	< 0	Nonspontaneous

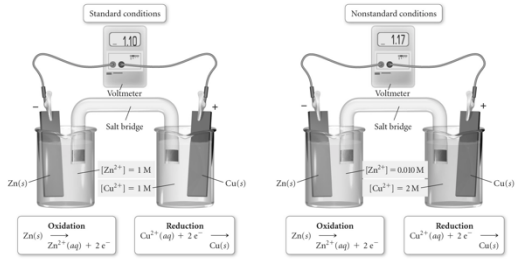
Calculating *K* and ΔG° from E°_{cell}

$Pb\ (s) + 2Ag^+ \longrightarrow Pb^{2+} + 2Ag\ (s)$

Recall $E^\circ_{cell} = E^\circ_{cathode} - E^\circ_{anode}$ and $E^\circ_{cell} = RT/nF\ (\ln K)$

- calculate *K* and ΔG°

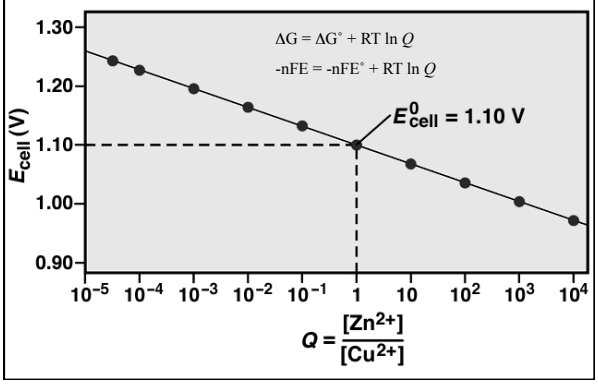
Tro 18.6 Cell Potential and Concentration



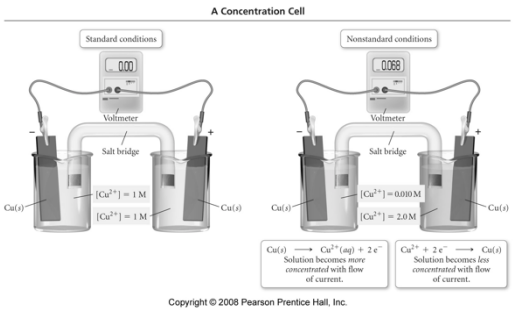
$$E_{cell} = E^\circ_{cell} - \frac{RT}{nF}\ln Q$$

$$E_{cell} = E^\circ_{cell} - \frac{0.05916V}{n}\log Q$$

Relation between E_{cell} and Log Q



The Nernst Equation and Concentration Cells



Calculating the cell potential of a concentration cell

An electrochemist builds a galvanic cell consisting of a Zn/Zn^{2+} half cell and an H_2/H^+ half cell under the following conditions:

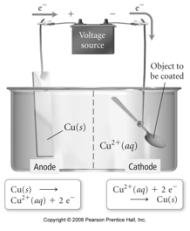
$[Zn^{2+}] = 0.010$ M $[H^+] = 2.5$ M $P_{H2} = 0.30$ atm

Calculate E_{cell} at 25°C…

Stoichiometry and electrolysis

1 A = 1 C/s

F = 96,485 C/mole e^-



Electrolytic cell for copper plating

What mass of Cu can be plated by the flow of 5 A of current for 30 minutes?

Tro 18.7

Putting galvanic cells to use: Batteries and their applications

Uses	Constraints
•Portable radios and CD players	cost, shelf life, safety
•Toys	size, rechargeable,
•Flashlights	constant output, low or
•Watches	zero maintenance
•Calculators	
•Automobiles	
•Computers	

http://www.alternative-energy-news.info/technology/battery-power/

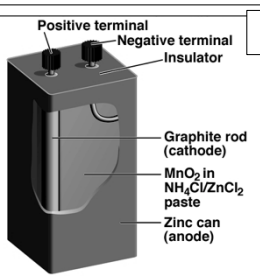
ACS.org

Tro 18.7

Dry Cell batteries

$Zn\ (s) \longrightarrow Zn^{2+} + 2e^-$

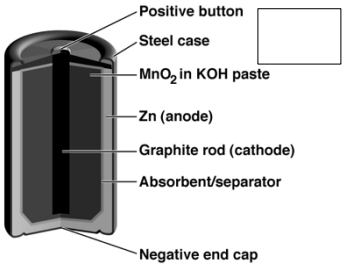
$2MnO_2 + 2NH_4^+ + 2e^- \rightarrow Mn_2O_3 + 2NH_3 + H_2O$



gas buildup at high current drains

$E^\circ_{cell} = 1.5$ V

Alkaline battery - an improved dry cell



$Zn + 2OH \longrightarrow + H_2O + 2e$

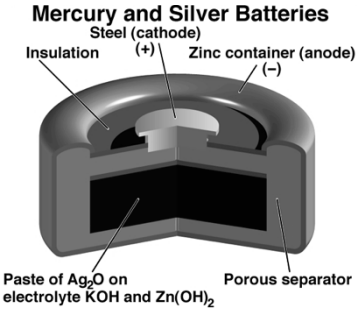
$MnO_2 + 2H_2O + 2e \longrightarrow Mn(OH)_2 + 2\ OH$

$E^\circ_{cell} = 1.5$ V

Mercury and Silver Batteries

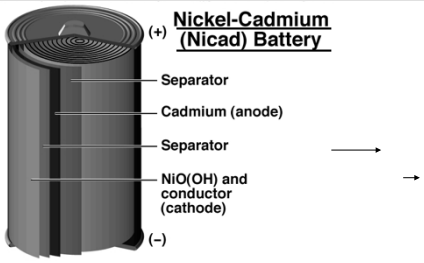
$E^\circ_{cell} = 1.3$ V w/Hg

$E^\circ_{cell} = 1.6$ V w/Ag



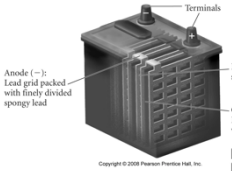
$Zn + 2OH \longrightarrow ZnO + H_2O + 2e$

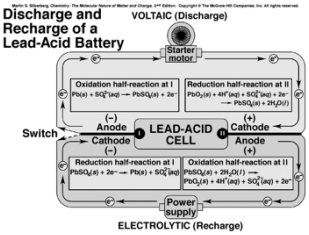
$Ag_2O + H_2O + 2e \rightarrow 2Ag + 2OH$



Nickel-Metal Hydride

Lead-Acid storage batteries

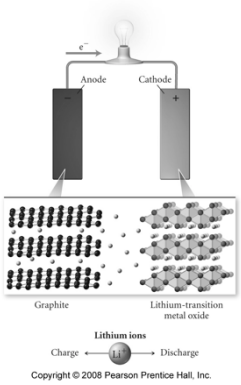




Lithium Ion Batteries

Li_x (gr) ⟶ $xLi^+ + e^-$

$Li_{1-x}Mn_2O_4 + xLi^+ + e^- \longrightarrow LiMn_2O_4$



Voltages of Some Voltaic Cells

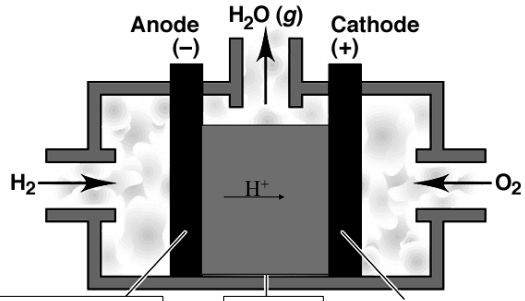
Table 21.1 Voltages of Some Voltaic Cells

Voltaic Cell	Voltage (V)
Common alkaline battery	1.5
Lead-acid car battery (6 cells = 12 V)	2.0
Calculator battery (mercury)	1.3
Electric eel (~5000 cells in 6-ft eel = 750 V)	0.15
Nerve of giant squid (across cell membrane)	0.070

TABLE 18.2 **Energy Density and Overcharge Tolerance of Several Rechargeable Batteries**

Battery Type	Energy Density (W · h/kg)	Overcharge Tolerance
NiCad	45–80	Moderate
NiMH	60–120	Low
Li ion	110–160	Low
Pb storage	30–50	High

Flow Batteries (Fuel Cells)

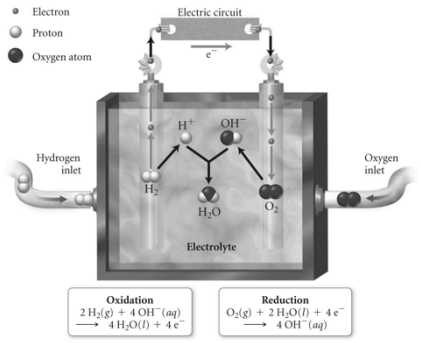


Pt catalyst surrounding graphite electrode

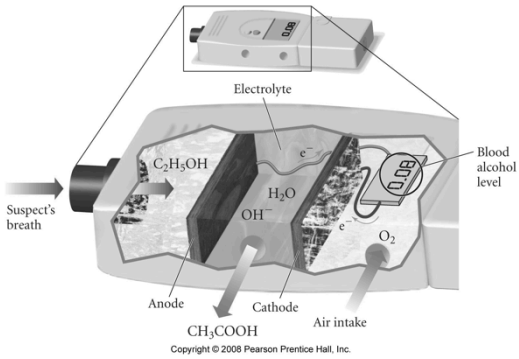
Electrolyte: perfluoropolymer

Pt catalyst surrounding graphite electrode

Hydrogen–Oxygen Fuel Cell



Fuel-cell based breathalyzer



Tro 18.8 Electrolysis - Driving nonspontaneous reactions