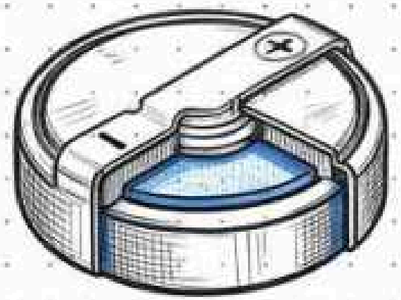
Lecture 6: Electrochemistry

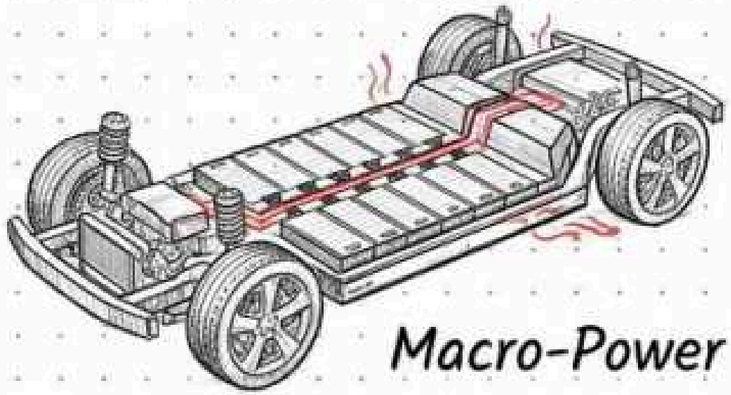
At a Glance

- [x] Oxidation numbers & half-reactions
- [x] Galvanic cells
- [x] Standard potentials
- [ ] Cell potential, Free Energy, and K
- [ ] The Nernst equation
- [ ] Batteries, electrolysis, and corrosion

¶ 6.2

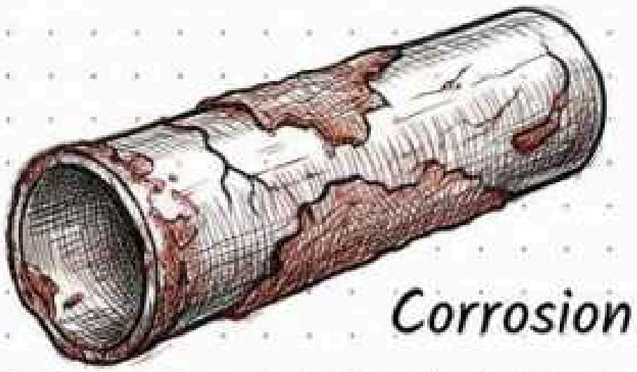


Micro-Power

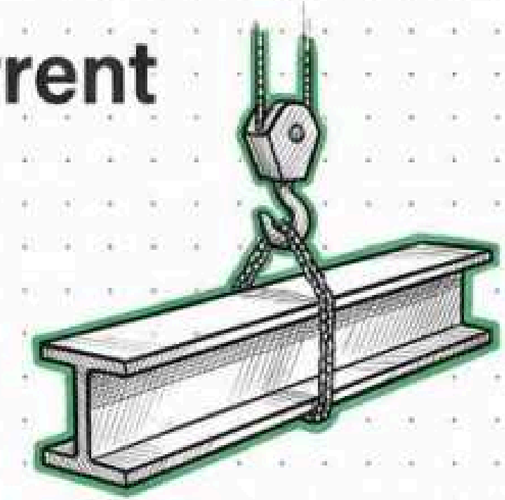


Macro-Power

Chemical Reaction ⇄ Electric Current



Corrosion



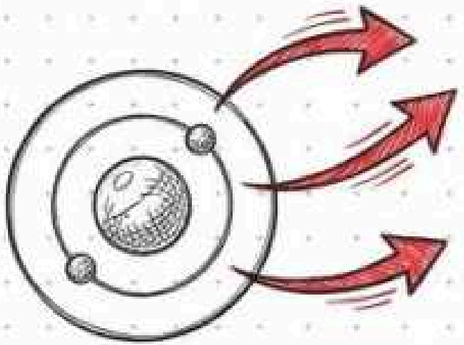
Electroplating & Production

The same ideas explain corrosion, and they run in reverse in electroplating and aluminum production. This connects free energy to voltage and ties the whole course together.

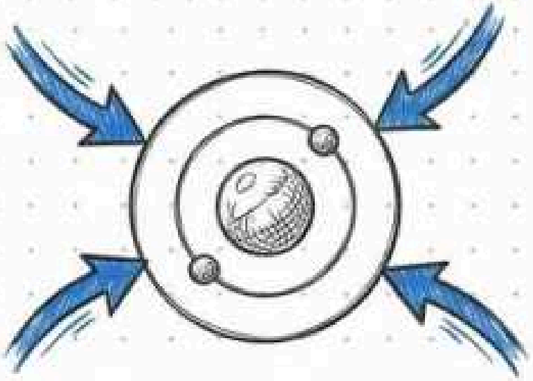
¶ 6.3

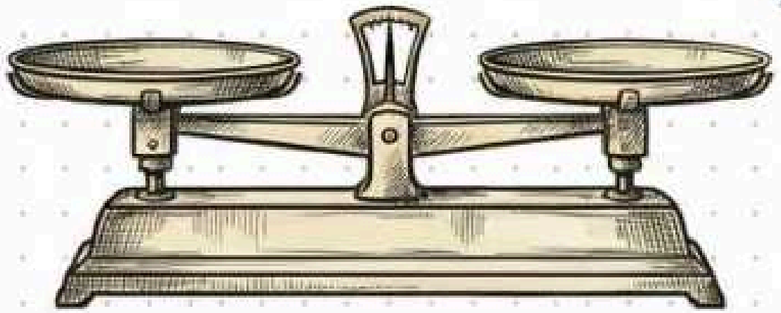
OIL RIG

Oxidation Is Loss



Reduction Is Gain



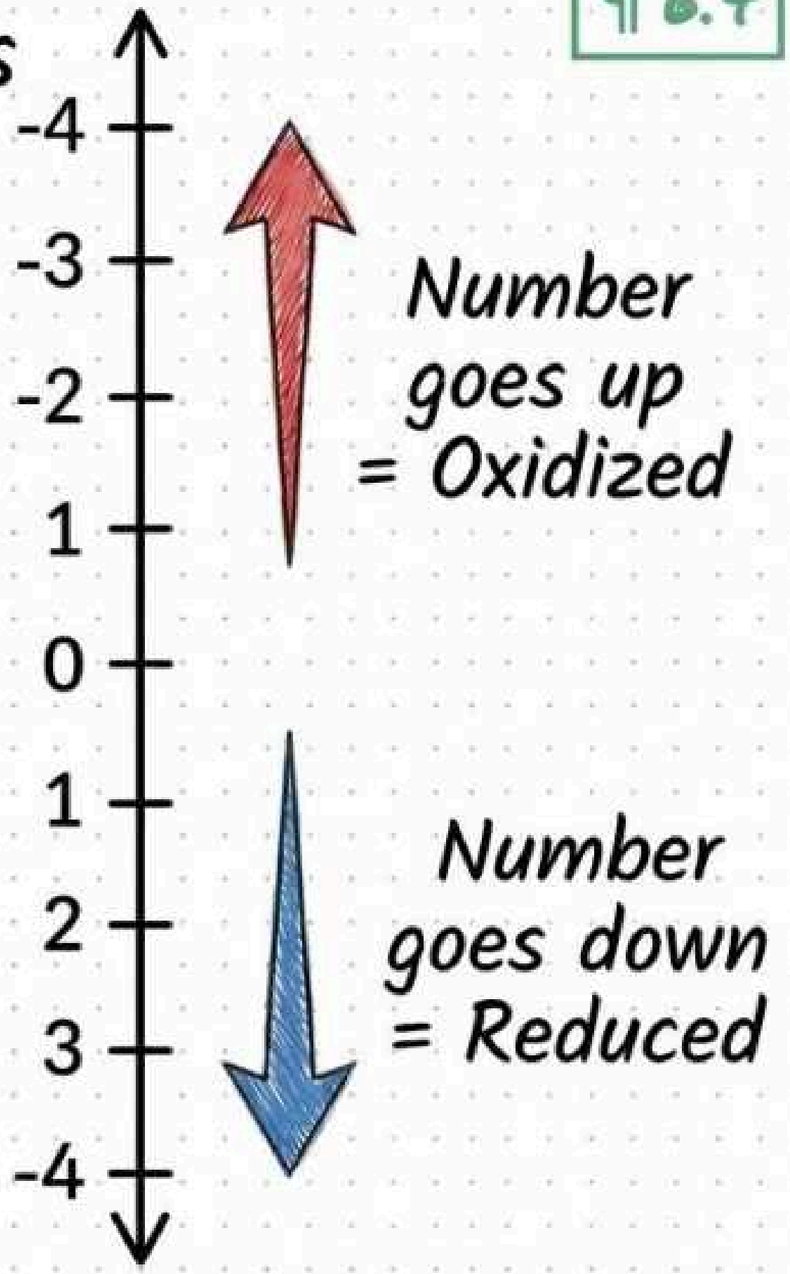


They always happen together.
Electrons lost = Electrons gained.

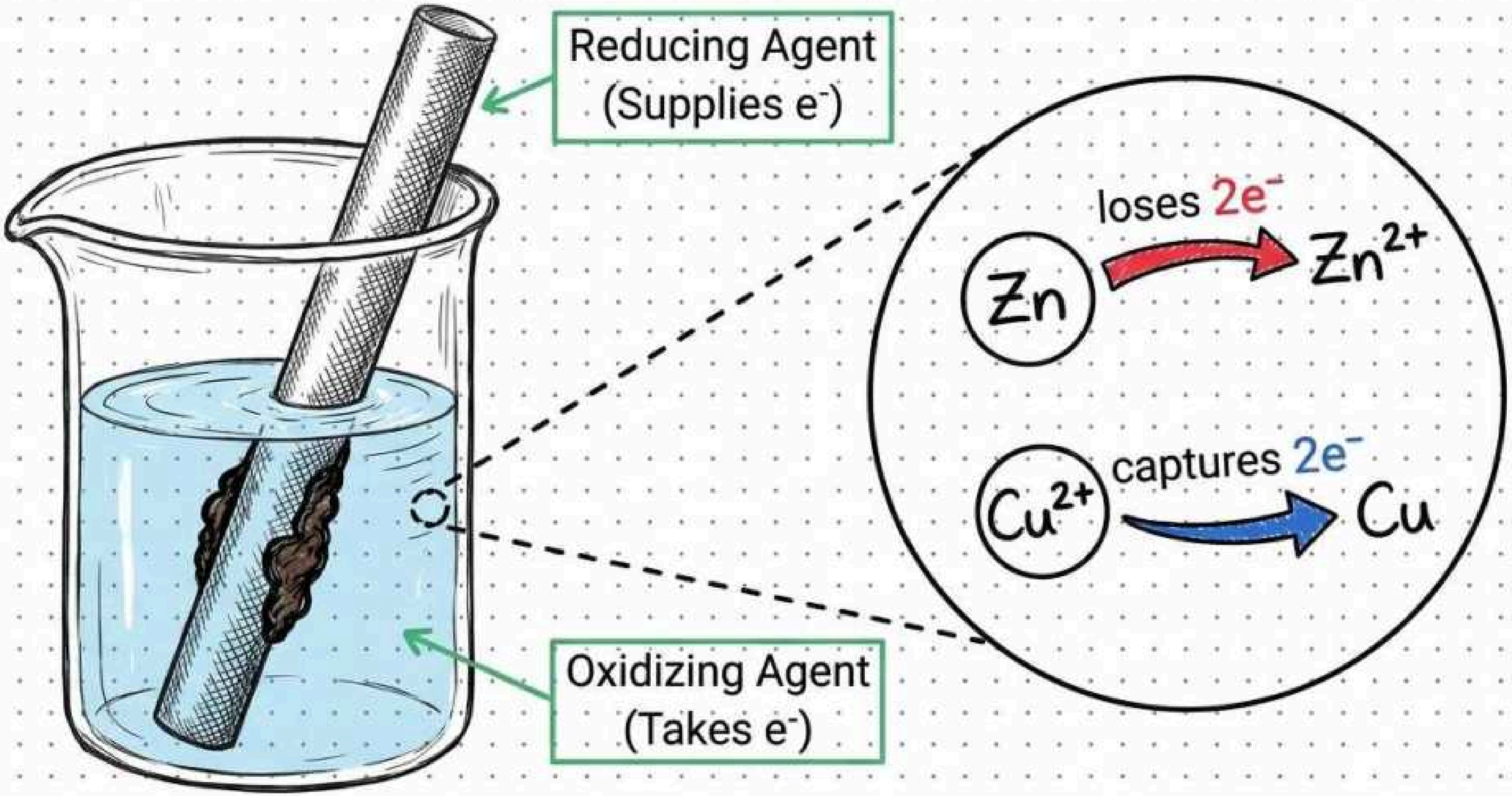
Tracking Electrons: Oxidation Numbers

¶ 6.4

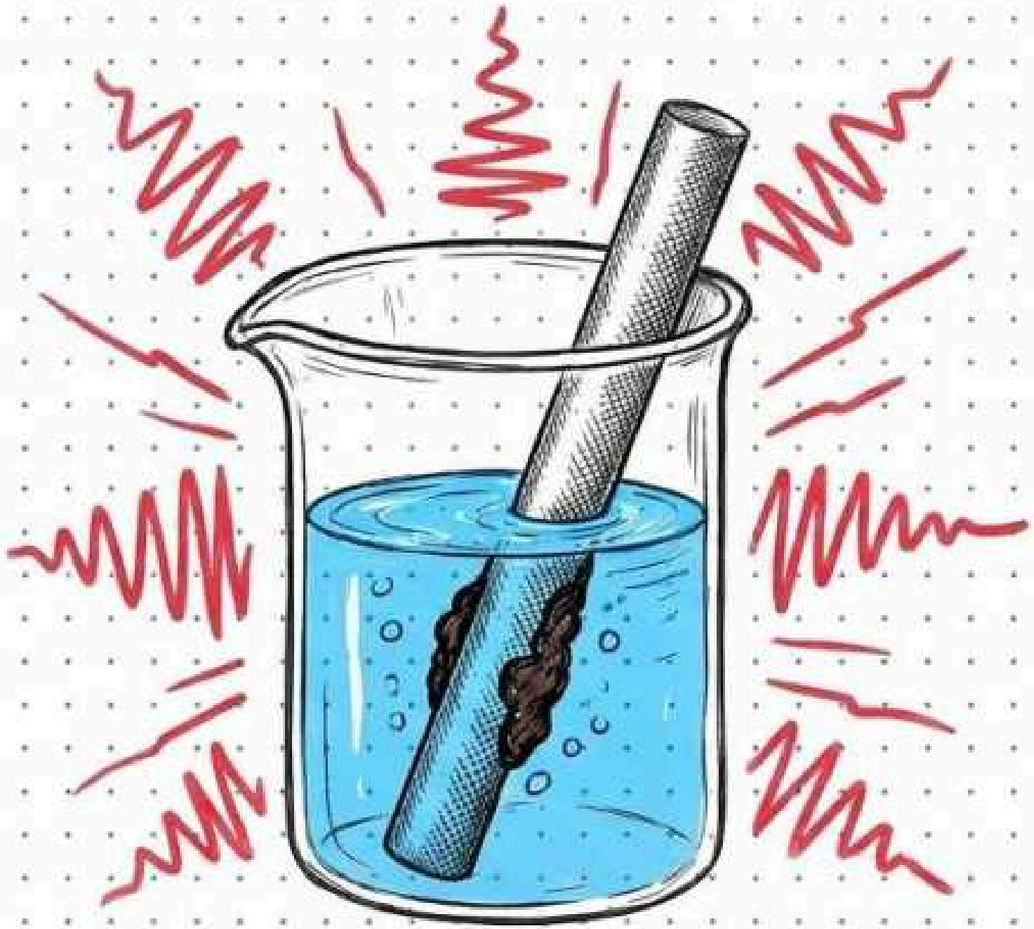
Atoms in an element = 0
Simple ion = Its charge
Oxygen = Usually -2
Hydrogen = Usually +1
Neutral compound = Sums to 0



¶ 6.5


Reducing Agent
(Supplies e⁻)
loses 2e⁻
Zn
Zn2+
captures 2e⁻
Cu2+
Cu
Oxidizing Agent
(Takes e⁻)

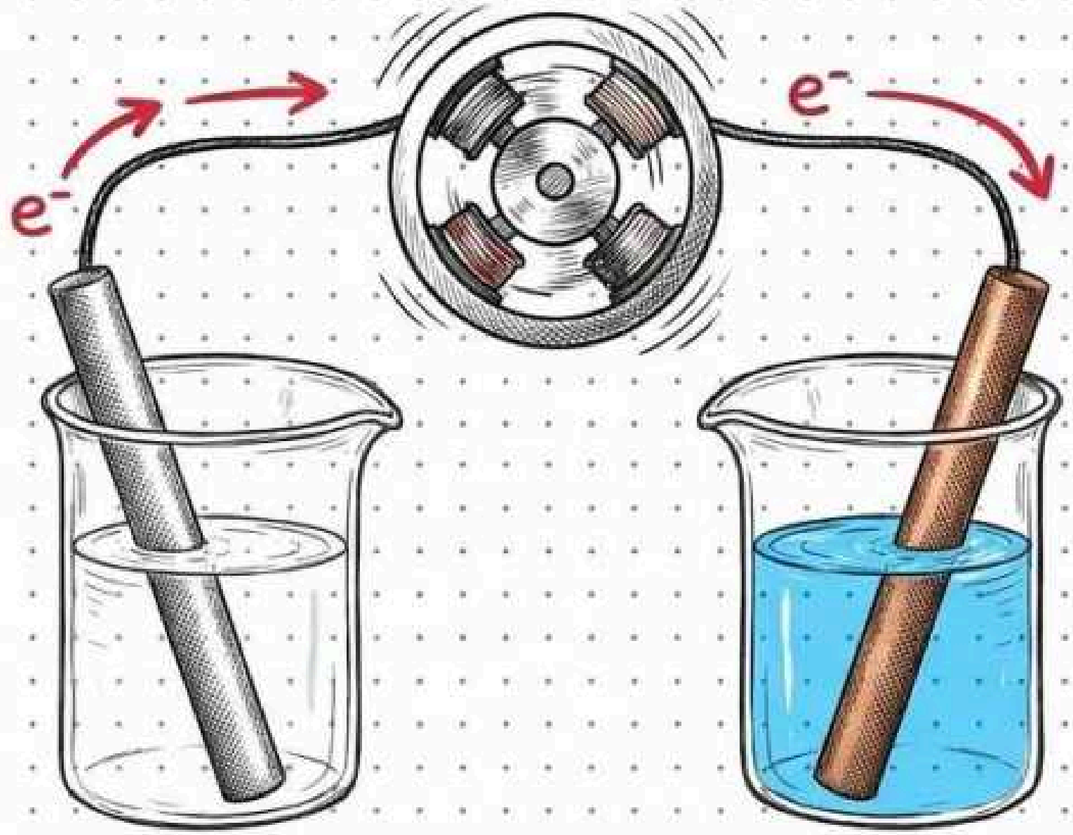
Direct Electron Transfer



Electrons pass directly.
Energy = Heat.

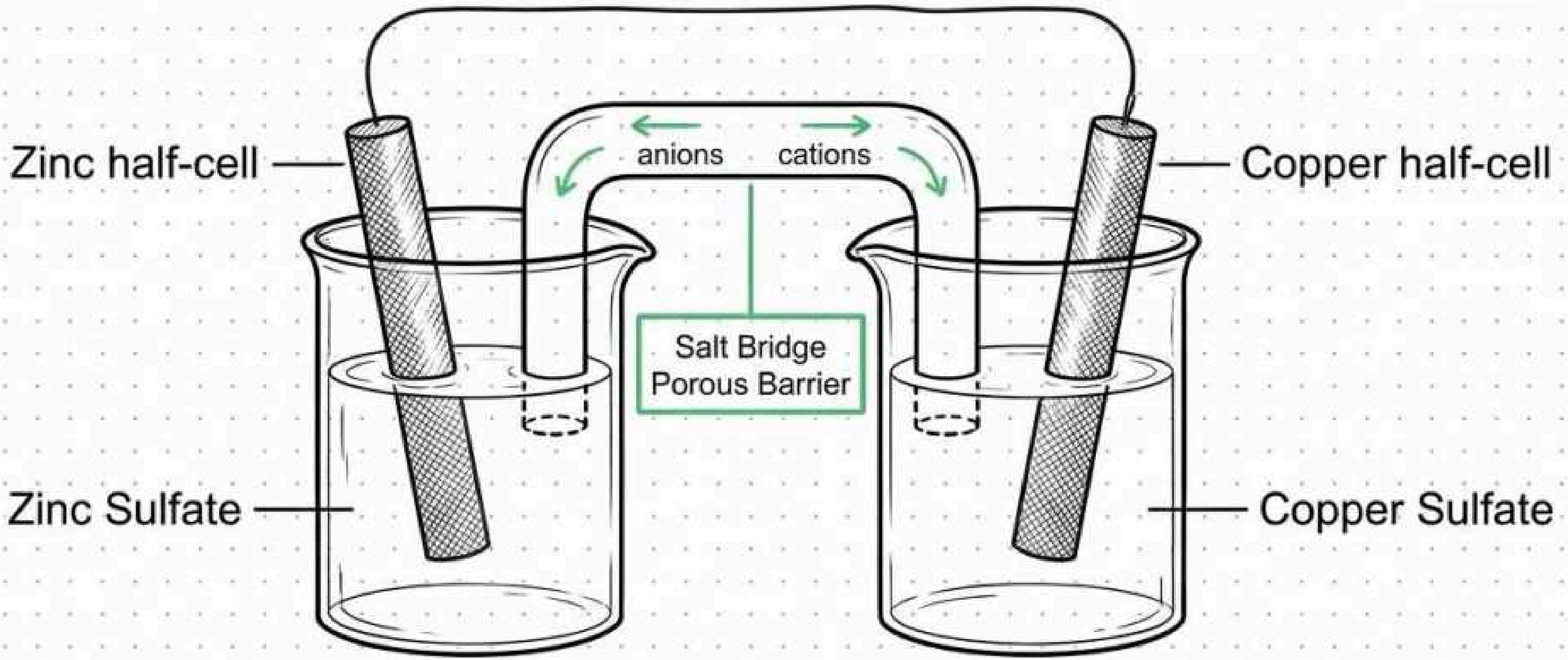
Galvanic (Voltaic) Cell

¶ 6.6



Galvanic (Voltaic) Cell.
Electrons travel outside wire.
Energy = Useful Work.

¶ 6.7



Keeps each side neutral. Without this, charge builds up and current stops.

¶6.8

Vowels { Anode Oxidation } { Cathode Reduction } Consonants



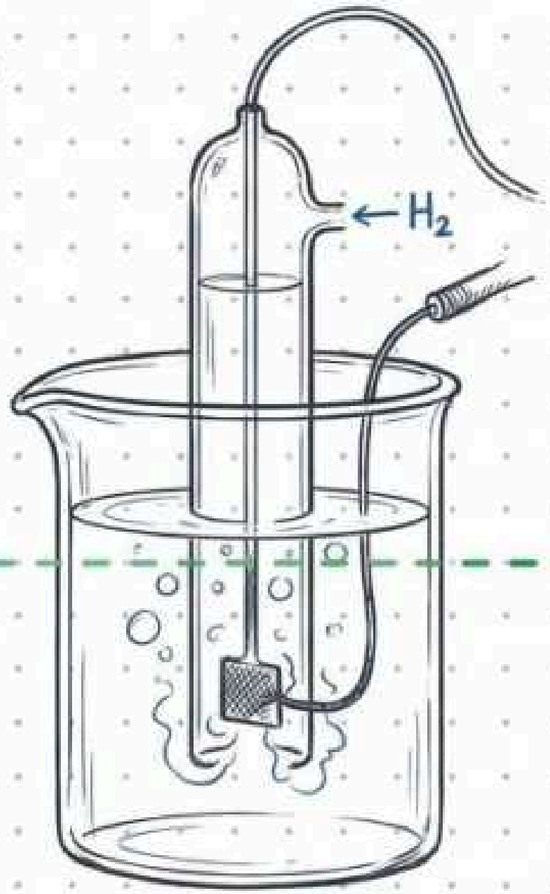
Electrons flow from Anode to Cathode.

In our cell: Zinc = Anode, Copper = Cathode.

Cell Potential (The Push)

¶ 6.9

$$1\ \text{Volt} = \frac{1\ \text{Joule of energy}}{1\ \text{Coulomb of charge}}$$

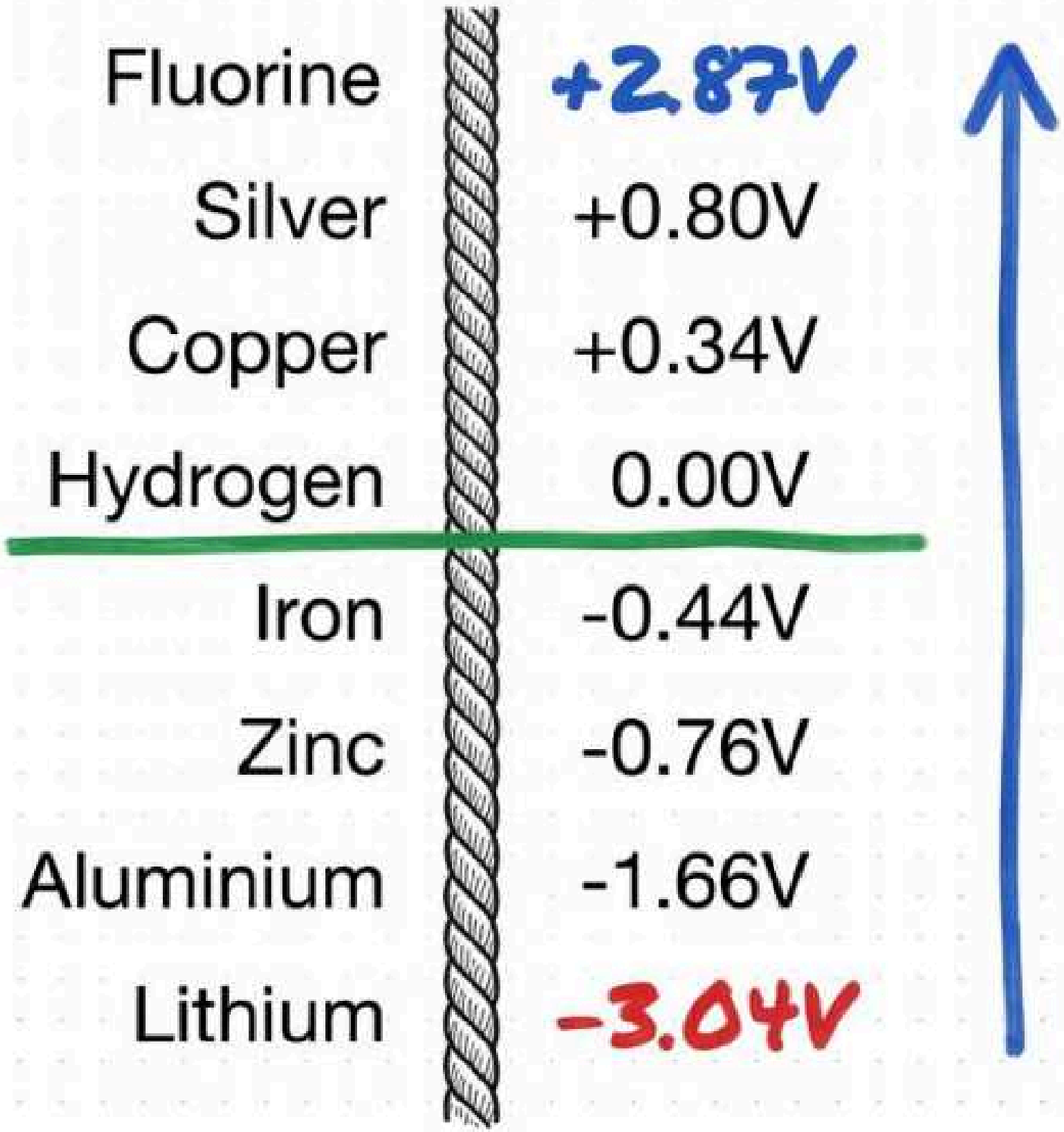


0.00V

The standard baseline. All other half-reactions are measured against this.

Standard Reduction Potentials

¶ 6.10



The more positive the value, the stronger the pull on electrons.

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

Worked Example (Zn/Cu cell):

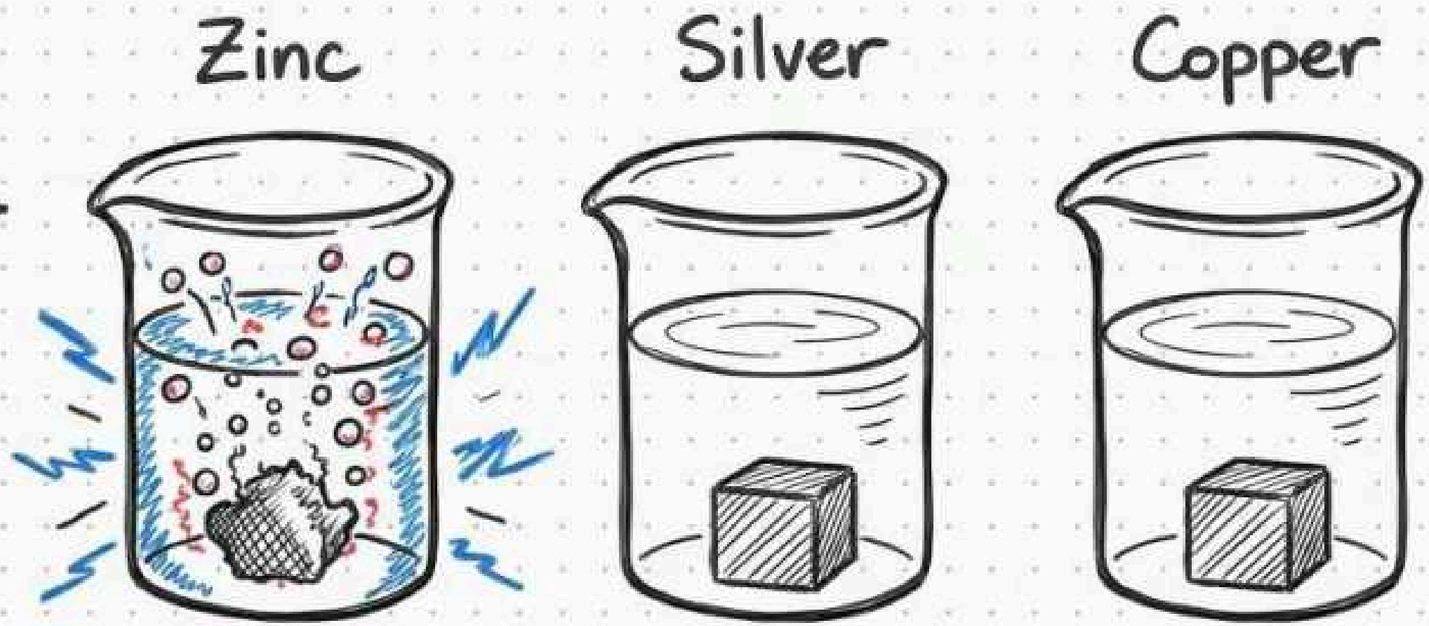
Cathode (Cu): +0.34V

Anode (Zn): -0.76V

Math: (+0.34) - (-0.76) = **1.10 Volts**

Do **NOT multiply** by the number of **electrons.**
The voltage is per **charge.**

Positive E°_{cell}	Spontaneous as written.
Negative E°_{cell}	Runs in reverse.



Metals with negative potentials dissolve in acid. Copper and Silver do not. (Ag/Cu cell = 0.46V with Cu as anode).

Link to Lecture 5: Free Energy

¶ 6.13

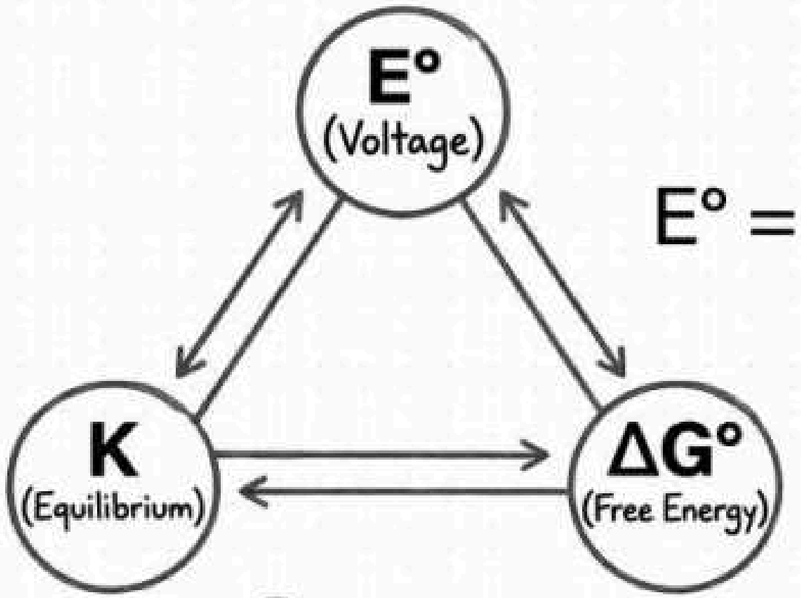
$$\Delta G^\circ = -nFE^\circ$$

n = moles of electrons transferred (2 for Zn/Cu)

F = Faraday constant (96,485 Coulombs per mole)

$$\Delta G^\circ = -(2) \times (96{,}485) \times (1.10) = \textbf{–212 kilojoules}$$

The Grand Synthesis Triangle



$$E^\circ = \frac{RT}{nF} \ln K$$



$$K \approx 10^{37}$$

The reaction goes essentially to completion. A voltmeter reading is a direct way to measure an equilibrium constant.

Non-Standard Conditions: The Nernst Equation

¶ 6.15

Constant at 25°C.

$$E = E° - \frac{0.0592}{n} \log_{10} Q$$

Reaction Quotient (from Lecture 2).

Cells do not stay at standard conditions. As reactants are used up, voltage falls.

¶ 6.16

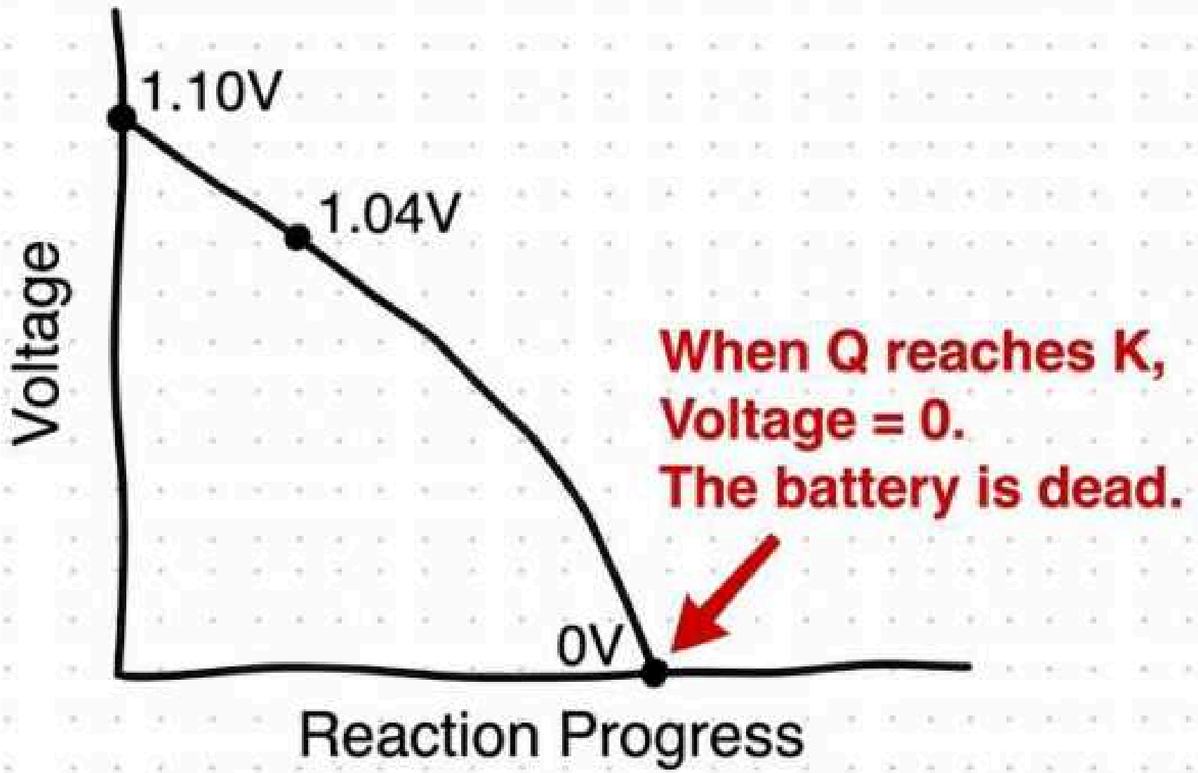
Math

Zn 1M, Cu 0.01M

$$\rightarrow Q = \frac{1}{0.01} = 100$$

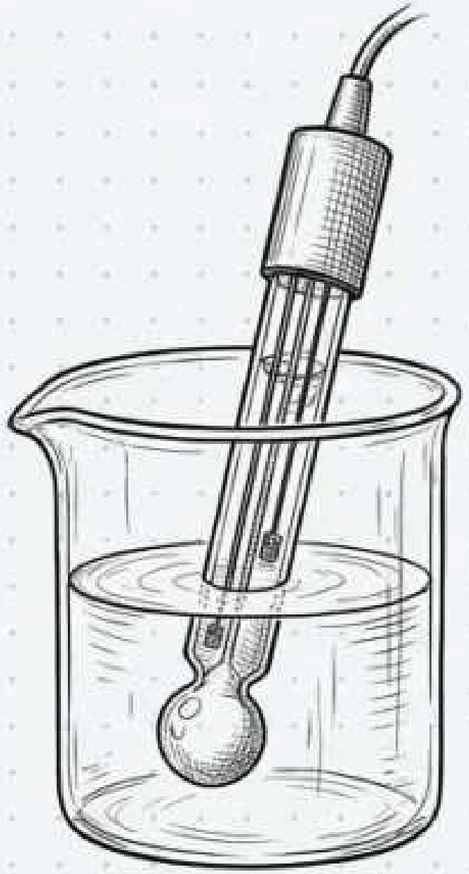
Potential = 1.10 - 0.0296 × 2 = **1.04V**

Graph

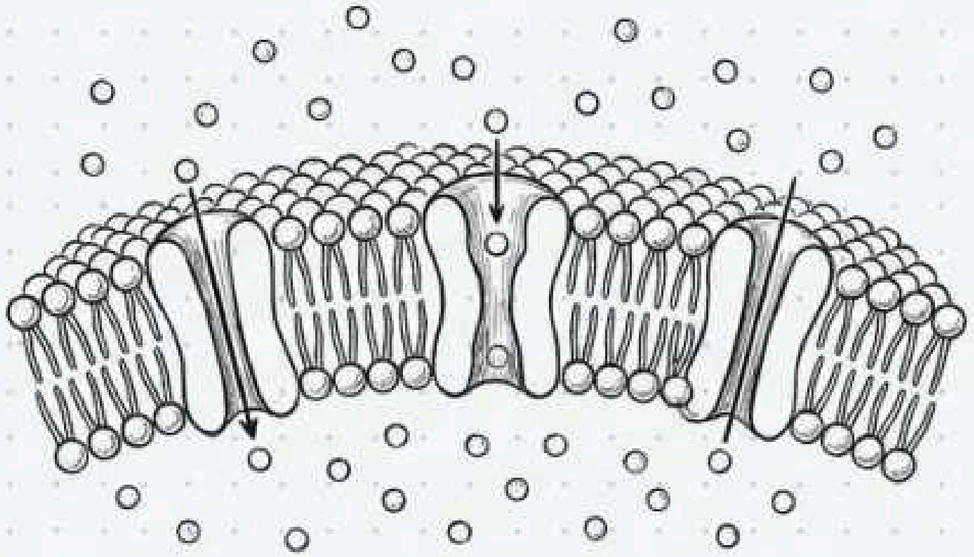


Nernst in the Wild

¶ 6.17



Produces a voltage that changes by ~59 millivolts for each pH unit.



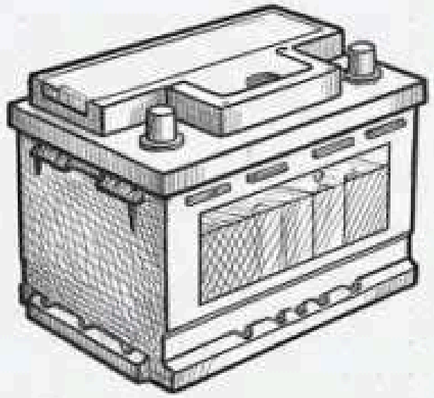
Voltage is set by the ratio of ion concentrations inside vs. outside the membrane.

Alkaline/Dry Cell



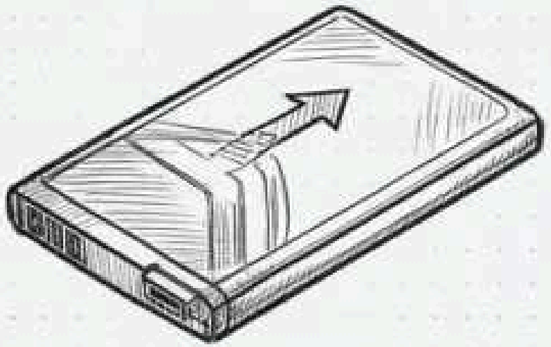
- Zinc & Manganese Dioxide
- Disposable

Lead-Acid



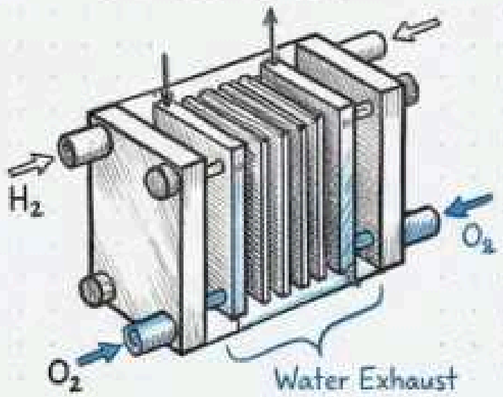
- Rechargeable
- Automotive use

Lithium-ion



- Moves Li ions between electrodes
- ~3.7 Volts (highly prized)

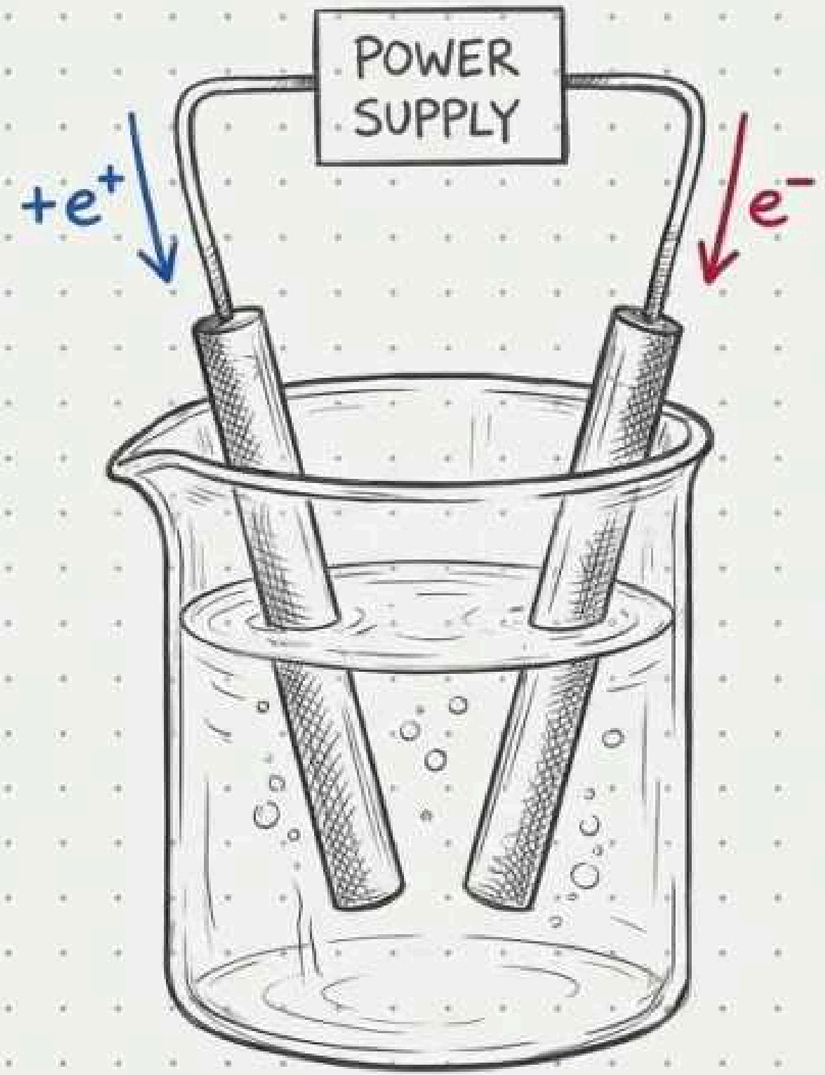
Fuel Cell



- Burns Hydrogen with Oxygen
- Byproduct is only Water

Electrolysis: Running Backwards

¶ 6.19



Faraday's Law: Moles of $e^- = \frac{\text{Current} \times \text{Time}}{F}$

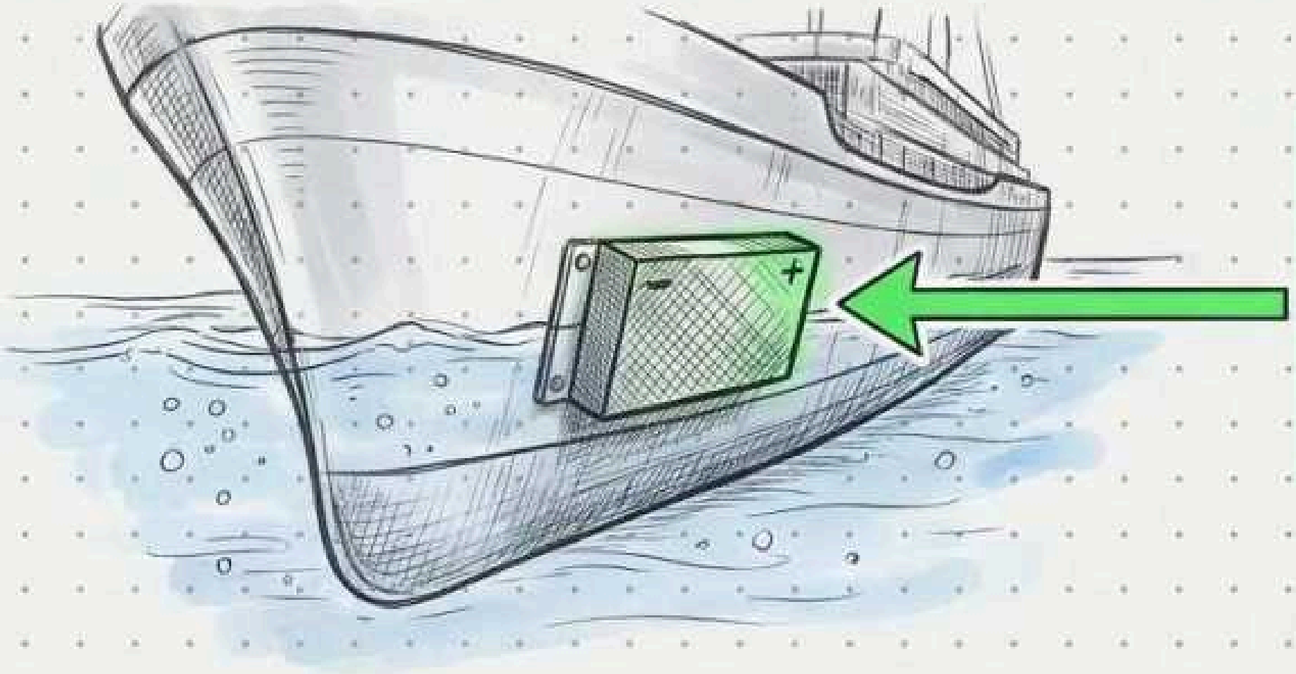
Worked Example: 2 Amperes passed for 1 Hour.

- $2A \times 3600s = 7{,}200$ Coulombs.
- $\frac{7{,}200}{96{,}485} = 0.0746$ moles e^-.

Yields: **2.37 grams of Copper.**



Corrosion: A galvanic cell nobody designed. Iron acts as an anode.



Sacrificial Anode.
Zinc has a **lower potential**, so it **corrodes** instead, protecting the ship.

Course Synthesis: General Chemistry 2

¶ 6.21

Rates
(Explains *How fast*)

Equilibrium
(Explains *How far*)

Acids, Bases & Buffers
(Applies equilibrium to water)

Free Energy
(Explains *Whether*)

Electrochemistry
(Turns Free Energy into *Voltage*)

Final Assignment: Pick a device you use every day and explain it with these ideas. Write it down, and keep it.