ELECTROCHEMISTRY – 3
PRACTICAL APPLICATION
BATTERIES AND ELECTROLYSIS

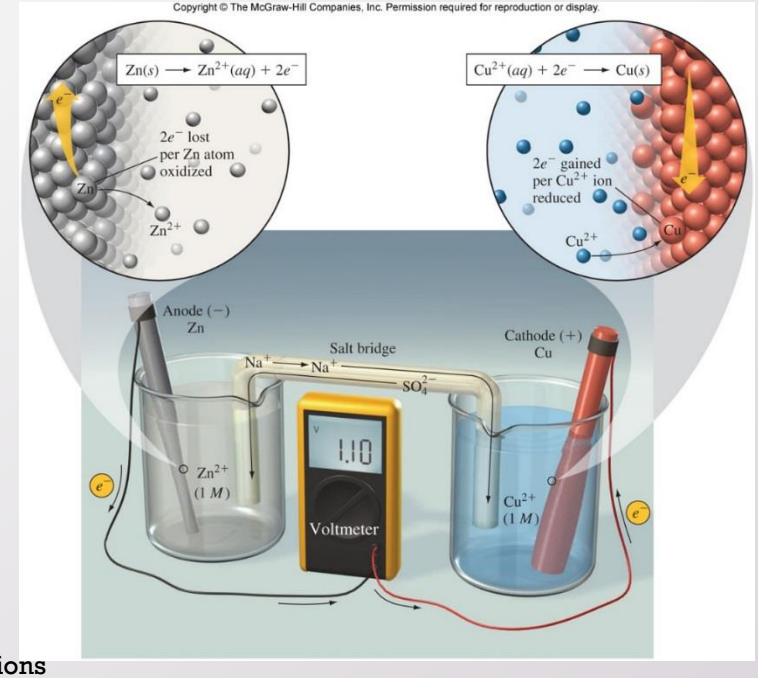
Dr. Sapna Gupta

ELECTROCHEMICAL CELLS

An **electrochemical cell** is a system consisting of electrodes that dip into an electrolyte and in which a chemical reaction either uses or generates an electric current.

A **voltaic** or **galvanic cell** is an electrochemical cell in which a spontaneous reaction generates an electric current.

An **electrolytic cell** is an electrochemical cell in which an electric current drives an otherwise nonspontaneous reaction.



GALVANIC CELLS

- **Galvanic cell** - the experimental apparatus for generating electricity through the use of a spontaneous reaction
- **Electrodes**
  - Anode (oxidation)
  - Cathode (reduction)
- **Half-cell** - combination of container, electrode and solution
- **Salt bridge** - conducting medium through which the cations and anions can move from one half-cell to the other.
- **Ion migration**
  - Cations – migrate toward the cathode
  - Anions – migrate toward the anode
- **Cell potential (E_{cell}) –** difference in electrical potential between the anode and cathode
  - Concentration dependent
  - Temperature dependent
  - Determined by nature of reactants

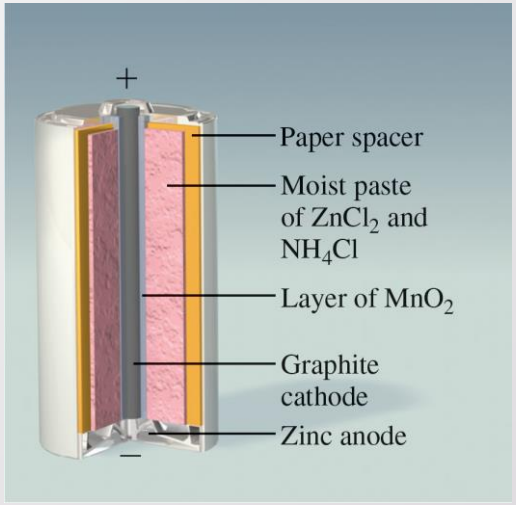
BATTERIES

- A battery is a **galvanic cell**, or a series of cells connected that can be used to deliver a self-contained source of direct electric current.
- Dry Cells and Alkaline Batteries
  - no fluid components
  - Zn container in contact with MnO_2 and an electrolyte

$$\textit{Anode:} \quad Zn(s) \longrightarrow Zn^{2+}(aq) + 2e^-$$

$$\textit{Cathode:} \quad 2NH_4^+(aq) + 2MnO_2(s) + 2e^- \longrightarrow Mn_2O_3(s) + 2NH_3(aq) + H_2O(l)$$

$$\textit{Overall:} \quad Zn(s) + 2NH_4^+(aq) + 2MnO_2(s) \longrightarrow Zn^{2+}(aq) + Mn_2O_3(s) + 2NH_3(aq) + H_2O(l)$$



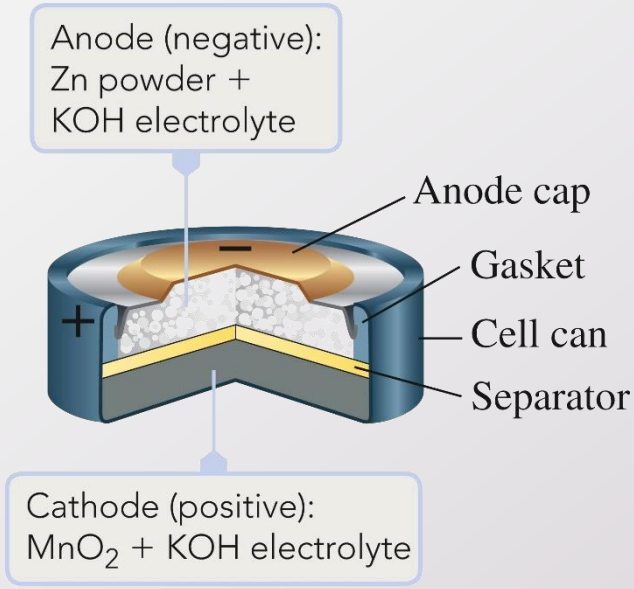
ALKALINE CELL

- Common watch batteries

Anode: $Zn(s) + 2OH^-(aq) \rightarrow Zn(OH)_2(s) + 2e^-$

Cathode: $2MnO_2(s) + H_2O(l) + 2e^- \rightarrow Mn_2O_3(s) + 2OH^-(aq)$

This cell performs better under current drain and in cold weather. It isn't truly "dry" but rather uses an aqueous paste.

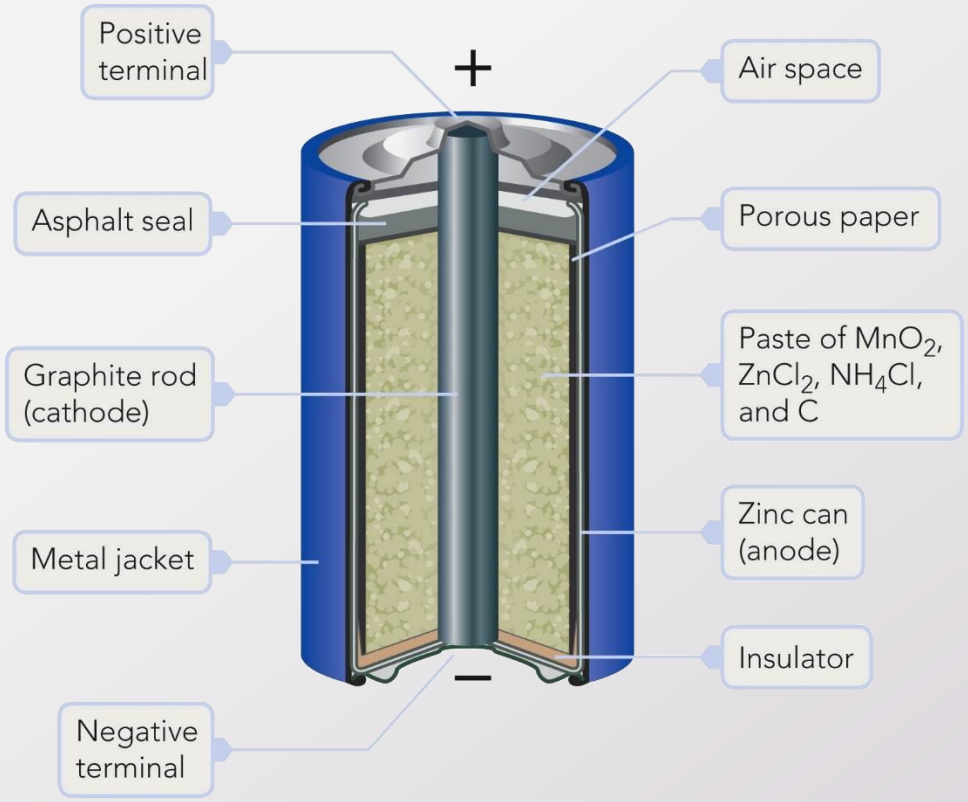


DRY CELLS – ZINC-CARBON

Anode: $Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$

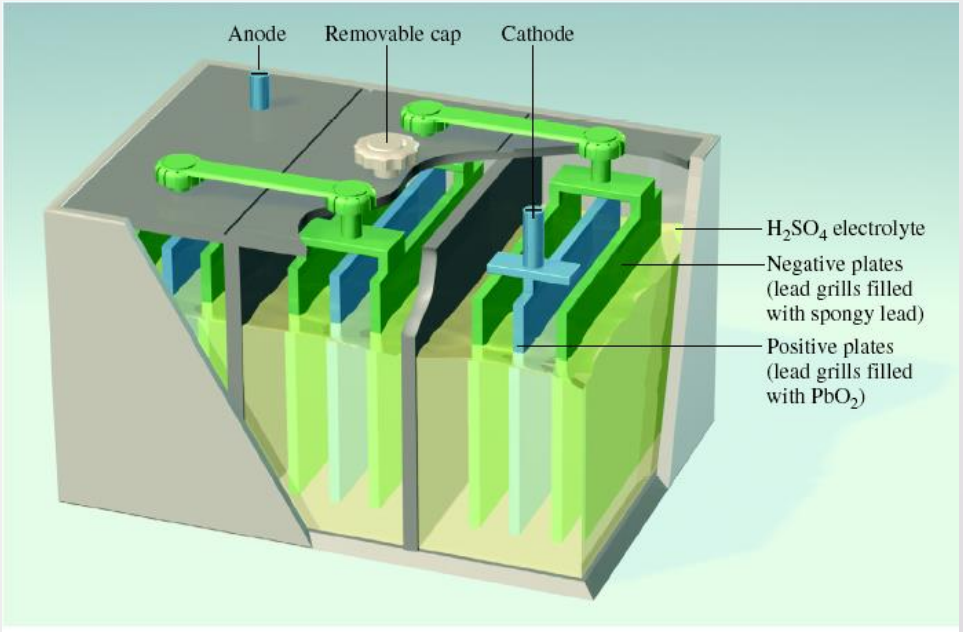
Cathode: $2NH_4^+(aq) + 2MnO_2(s) + 2e^- \rightarrow Mn_2O_3(s) + H_2O(l) + 2NH_3(aq)$

The initial voltage is about 1.5 V, but decreases and deteriorates rapidly in cold weather.



LEAD BATTERIES

- Six identical cells in series
- Lead anode and PbO_2 cathode
- Immersed in H_2SO_4
- Each cell delivers ~ 2 V
- Rechargeable



$$\textit{Anode:} \quad Pb(s) + SO_4^{2-}(aq) \longrightarrow PbSO_4(s) + 2e^-$$

$$\textit{Cathode:} \quad PbO_2(s) + 4H^+(aq) + SO_4^{2-}(aq) + 2e^- \longrightarrow PbSO_4(s) + 2H_2O(l)$$

$$\textit{Overall:} \quad Pb(s) + PbO_2(s) + 4H^+(aq) + 2SO_4^{2-}(aq) \longrightarrow 2PbSO_4(s) + 2H_2O(l)$$

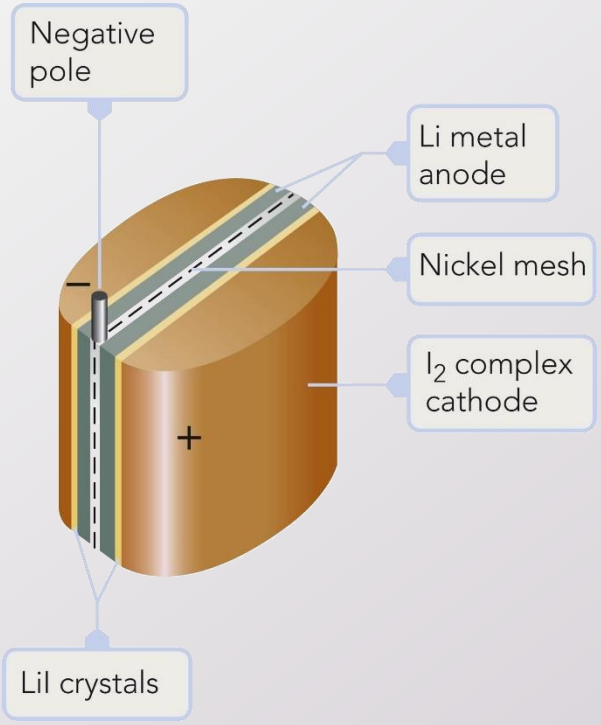
LITHIUM ION BATTERIES

- The overall cell potential is 3.4 V, which is a relatively large potential.
- Lithium is also the lightest metal—only 6.941 g of Li (its molar mass) are needed to produce 1 mole of electrons.
- Recharged hundreds of times.

$$\textit{Anode:} \quad \mathrm{Li}(s) \longrightarrow \mathrm{Li}^+ + e^-$$

$$\textit{Cathode:} \quad \mathrm{Li}^+ + \mathrm{CoO_2} + e^- \longrightarrow \mathrm{LiCoO_2}(s)$$

$$\textit{Overall:} \quad \mathrm{Li}(s) + \mathrm{CoO_2} \longrightarrow \mathrm{LiCoO_2}(s)$$



FUEL CELLS

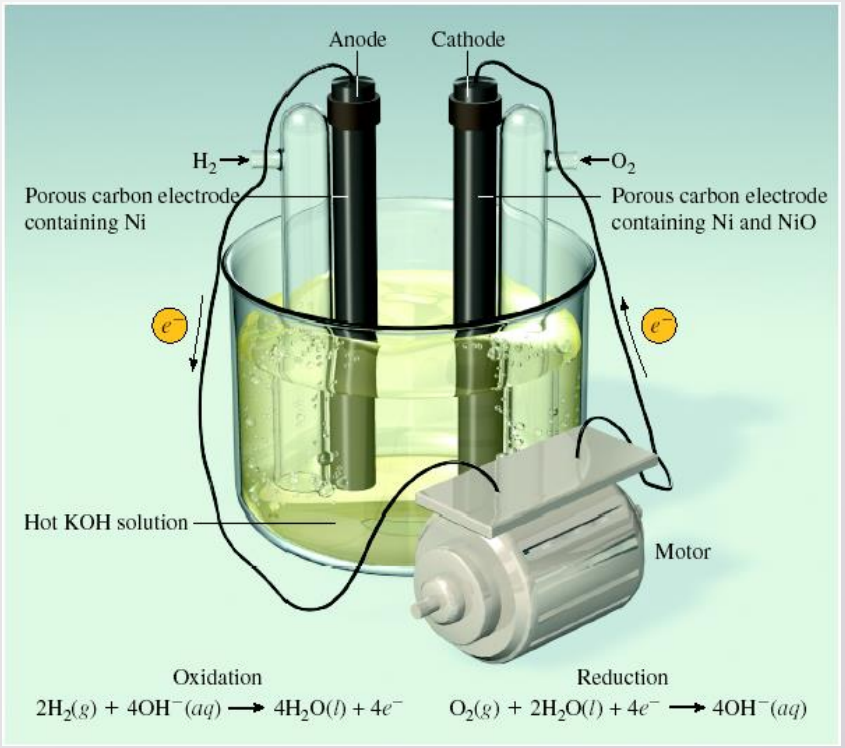
- Direct production of electricity by electrochemical means
- Increased efficiency of power production

Anode: $2H_2(g) + 4OH^-(aq) \longrightarrow 4H_2O(l) + 4e^-$

Cathode: $O_2(g) + 2H_2O(l) + 4e^- \longrightarrow 4OH^-(aq)$

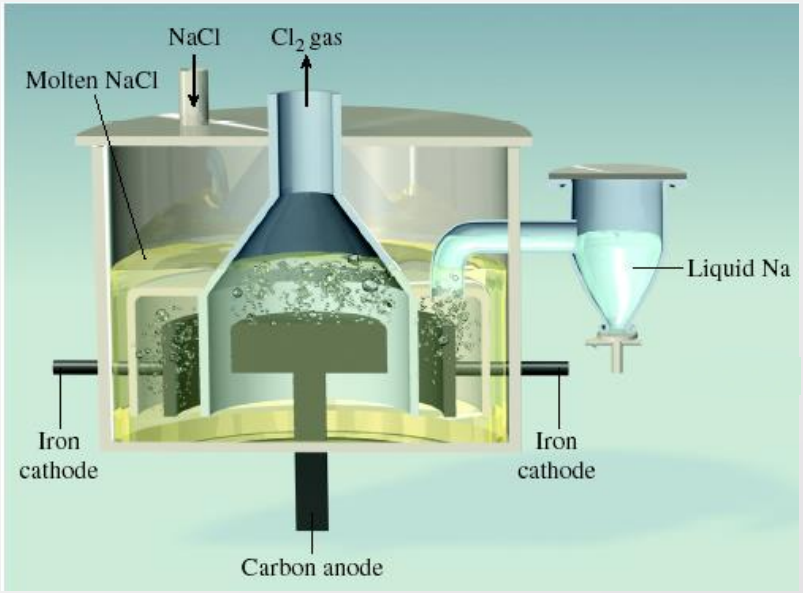
Overall: $2H_2(g) + O_2(g) \longrightarrow 2H_2O(l)$

$$E^\circ_{cell} = E^\circ_{cathode} - E^\circ_{anode}$$
$$= 0.40\ V - (-0.83\ V)$$
$$= 1.23\ V$$



ELECTROLYSIS

- ***Electrolysis*** **-** the use of electric energy to drive a nonspontaneous chemical reaction
- ***Electrolytic cell*** **–** the cell used to carry out electrolysis
  - same principles apply to both galvanic and electrolytic cells
  - in aqueous solutions you must also consider the oxidation or reduction of water
- Molten Sodium Chloride



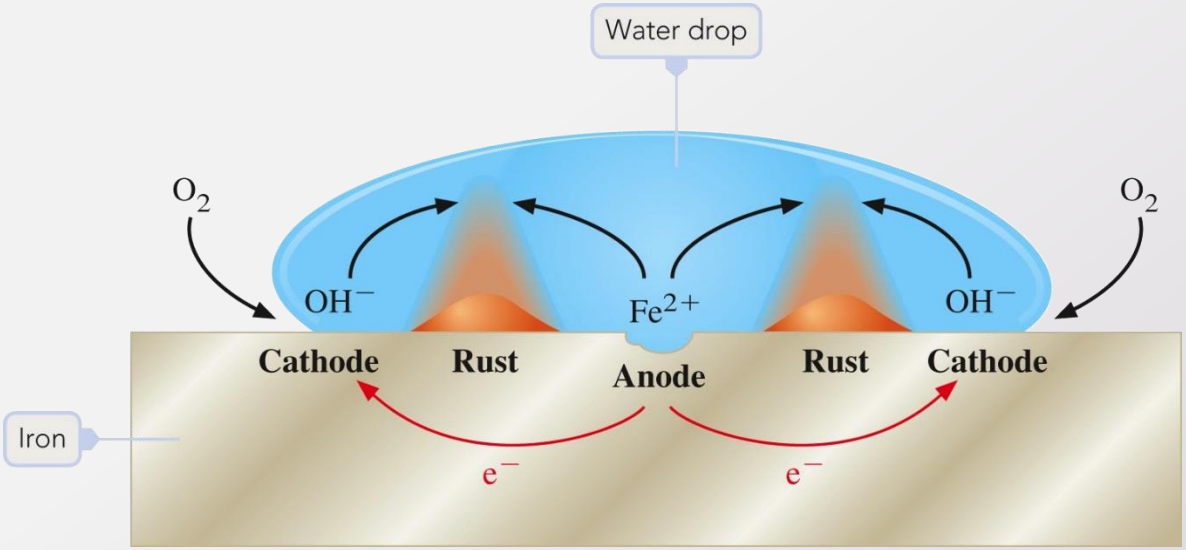
Anode (oxidation): $2Cl^-(l) \longrightarrow Cl_2(g) + 2e^-$

Cathode (reduction): $2Na^+(l) + 2e^- \longrightarrow 2Na(l)$

Overall: $2Na^+(l) + 2Cl^-(l) \longrightarrow 2Na(l) + Cl_2(g)$

CORROSION

- ***Corrosion*** **-** generally refers to the deterioration of a metal by an electrochemical process.
- Many metals undergo corrosion e.g. corrosion of Fe, oxidation of Al
- Can be enhanced by atmospheric conditions (e.g. acidic medium)



PREVENTING CORROSION

- Electrochemical processes can be used to prevent corrosion
  - **Passivation** – formation of a thin oxide layer by treating with an oxidizing agent
  - Formation of an alloy
  - Coating with a layer of a less active metal
  - Tin cans
  - **Galvanization** (zinc-plating)
  - Zinc oxide coating constitutes the protective coating

KEY CONCEPTS

- Batteries
  - Dry cell and alkaline batteries
  - Lead storage battery
  - Lithium-ion batteries
  - Fuel cells
- Electrolysis
  - Molten salts
  - Aqueous solutions
- Corrosion
  - Metal deterioration
  - Prevention