ELECTROCHEMISTRY – 3
PRACTICAL APPLICATION
BATTERIES AND ELECTROLYSIS

Dr. Sapna Gupta
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 MnO₂ and an electrolyte

\[
\begin{align*}
\text{Anode:} & \quad \text{Zn}(s) & \rightarrow & \text{Zn}^{2+}(aq) + 2e^- \\
\text{Cathode:} & \quad 2\text{NH}_4^+(aq) + 2\text{MnO}_2(s) + 2e^- & \rightarrow & \text{Mn}_2\text{O}_3(s) + 2\text{NH}_3(aq) + \text{H}_2\text{O}(l) \\
\text{Overall:} & \quad \text{Zn}(s) + 2\text{NH}_4^+(aq) + 2\text{MnO}_2(s) & \rightarrow & \text{Zn}^{2+}(aq) + \text{Mn}_2\text{O}_3(s) + 2\text{NH}_3(aq) + \text{H}_2\text{O}(l)
\end{align*}
\]

Dr. Sapna Gupta/Electrochemistry - Applications
ALKALINE CELL

- Common watch batteries

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

Cathode: \( 2\text{MnO}_2(s) + \text{H}_2\text{O}(l) + 2e^- \rightarrow \text{Mn}_2\text{O}_3(s) + 2\text{OH}^- (aq) \)

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

Dr. Sapna Gupta/Electrochemistry - Applications
DRY CELLS – ZINC-CARBON

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

Cathode:  \( 2\text{NH}_4^+(aq) + 2\text{MnO}_2(s) + 2e^- \rightarrow \text{Mn}_2\text{O}_3(s) + \text{H}_2\text{O}(l) + 2\text{NH}_3(aq) \)

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 PbO₂ cathode
- Immersed in H₂SO₄
- Each cell delivers ~ 2 V
- Rechargeable

\[
\text{Anode: } \quad \text{Pb}(s) + \text{SO}_4^{2-}(aq) \quad \rightarrow \quad \text{PbSO}_4(s) + 2e^- \\
\text{Cathode: } \quad \text{PbO}_2(s) + 4\text{H}^+(aq) + \text{SO}_4^{2-}(aq) + 2e^- \quad \rightarrow \quad \text{PbSO}_4(s) + 2\text{H}_2\text{O}(l) \\
\text{Overall: } \quad \text{Pb}(s) + \text{PbO}_2(s) + 4\text{H}^+(aq) + 2\text{SO}_4^{2-}(aq) \quad \rightarrow \quad 2\text{PbSO}_4(s) + 2\text{H}_2\text{O}(l)
\]
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.

\[
\begin{align*}
\text{Anode:} & \quad \text{Li}(s) & \rightarrow & \text{Li}^+ + e^- \\
\text{Cathode:} & \quad \text{Li}^+ + \text{CoO}_2 + e^- & \rightarrow & \text{LiCoO}_2(s) \\
\text{Overall:} & \quad \text{Li}(s) + \text{CoO}_2 & \rightarrow & \text{LiCoO}_2(s)
\end{align*}
\]
FUEL CELLS

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

**Anode:** \[ 2\text{H}_2(g) + 4\text{OH}^- (aq) \rightarrow 4\text{H}_2\text{O}(l) + 4e^- \]

**Cathode:** \[ \text{O}_2(g) + 2\text{H}_2\text{O}(l) + 4e^- \rightarrow 4\text{OH}^- (aq) \]

**Overall:** \[ 2\text{H}_2(g) + \text{O}_2(g) \rightarrow 2\text{H}_2\text{O}(l) \]

\[ E_{\text{cell}}^\circ = E_{\text{cathode}}^\circ - E_{\text{anode}}^\circ \]
\[ = 0.40 \text{ V} - (-0.83 \text{ V}) \]
\[ = 1.23 \text{ V} \]
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

  \[
  \text{Anode (oxidation):}\quad 2\text{Cl}^- (l) \rightarrow \text{Cl}_2 (g) + 2e^-
  \]

  \[
  \text{Cathode (reduction):}\quad 2\text{Na}^+ (l) + 2e^- \rightarrow 2\text{Na}(l)
  \]

  \[
  \text{Overall:}\quad 2\text{Na}^+ (l) + 2\text{Cl}^- (l) \rightarrow 2\text{Na}(l) + \text{Cl}_2 (g)
  \]
• **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