

Electrochemistry for materials technology

Chapter 1 Introduction

Electrochemical reactions

Chemical reactions which take place at the interface between an electrode, usually a solid metal or a semiconductor, and an ionic conductor, the electrolyte.

These reactions involve electric charges moving between the electrodes and the electrolyte.

At those interfaces, transfer of charge and mass takes place. These translate to voltage loss (overvoltage).

Electrochemistry deals with the interaction between electrical energy and chemical change.

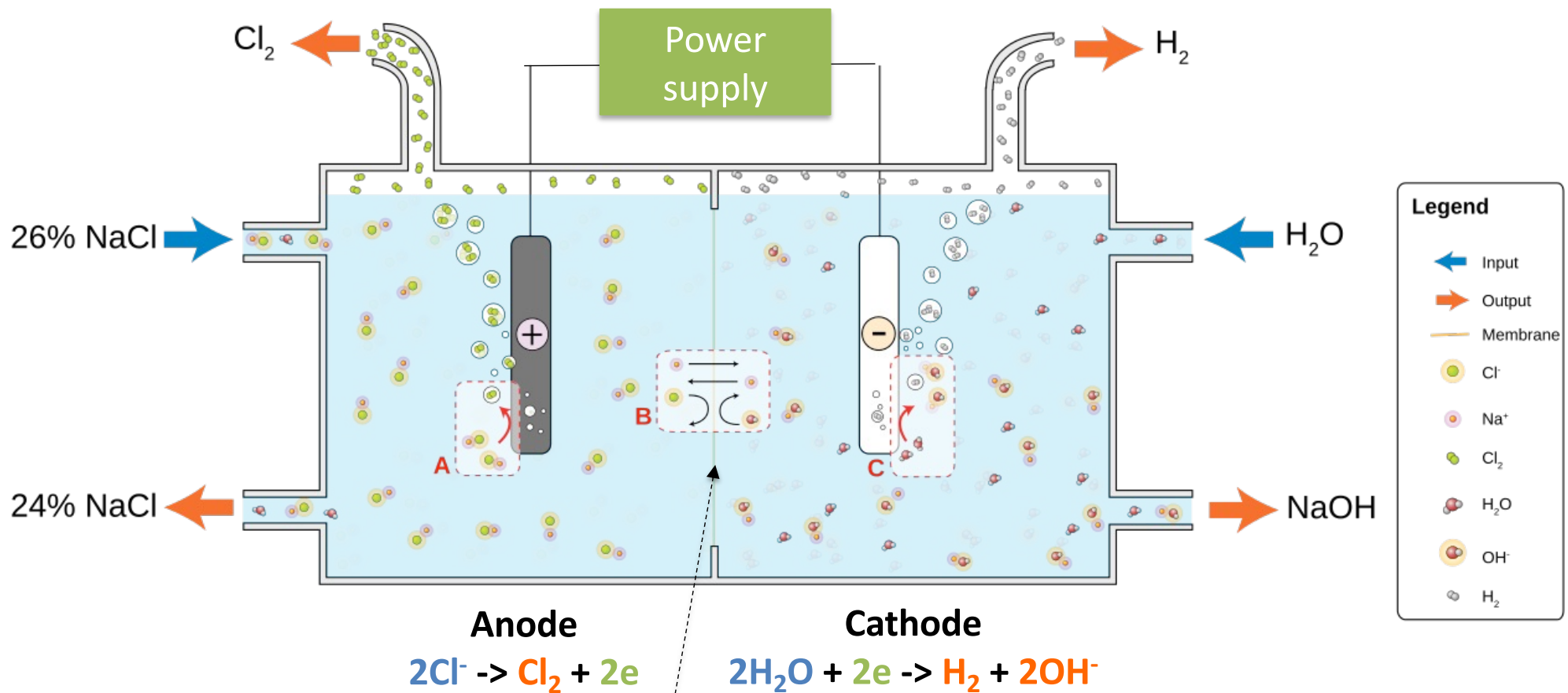
Some dates

- **1791:** L. Galvani linked electricity to chemical reactions (bioelectricity).
- **1800:** A. Volta discovered the first battery.
- **1800:** Discovery of water electrolysis as method to produce hydrogen and oxygen.
- **1805:** Electroplating as manufacturing technique
- **1832:** **Faraday**'s law formulated.
- **1839:** First fuel cell by W. Grove.
- **1868:** First patent related to the zinc-carbon cell, i.e. the first widely used battery.
- **1886:** Héroult-Hall electrolysis of molten alumina for aluminium production.
- **1889:** **Nernst** equation for the Gibbs free energy change in electrochemical reactions.
- **1902:** Foundation of the Electrochemical Society in the USA.
- **1905:** **Tafel** equation describing electrochemical kinetics

Engineering use of electrochemistry

- **Electrosynthesis**
 - Large scale production of Al, Cl₂, H₂, NaOH, organics, metals,...
- **Surface treatments**
 - Coatings, anodic films, polishing, electroforming, ...
- **Energy storage and conversion**
 - Batteries, fuel cells, water electrolysis
- **Corrosion**
 - Mechanisms, protection
- **Analysis and measurement**
 - Sensors for pH, glucose, pollutants
- ...

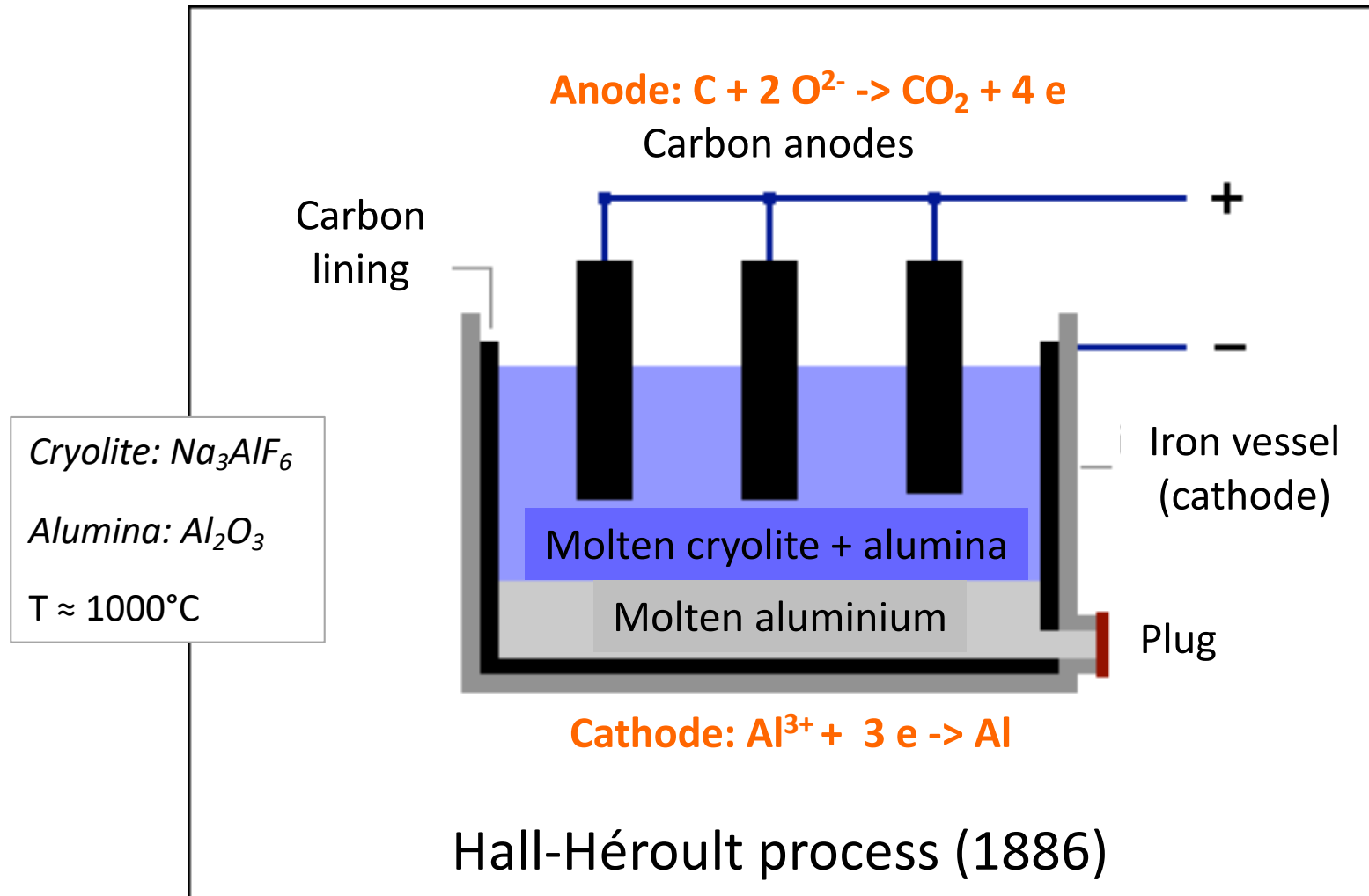
Electrosynthesis of Cl₂, H₂ and NaOH by electrolysis of NaCl solutions and water



positive ion (Na⁺) exchange membrane

Adapted from Wikimedia Commons

Aluminium production through the electrolysis of aluminium molten salt



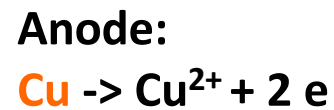
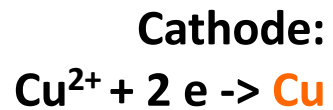
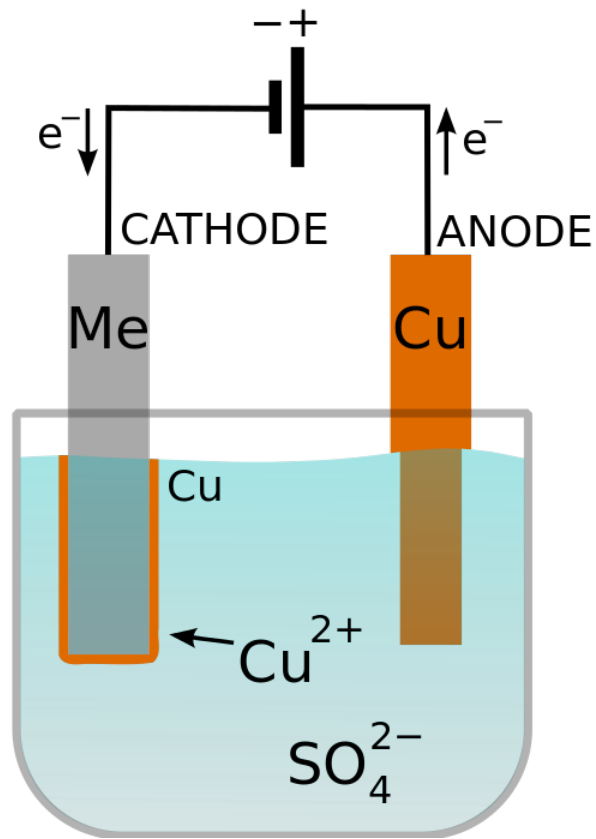
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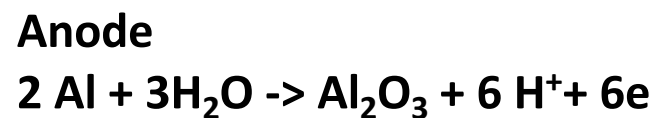
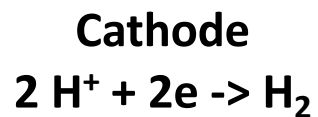
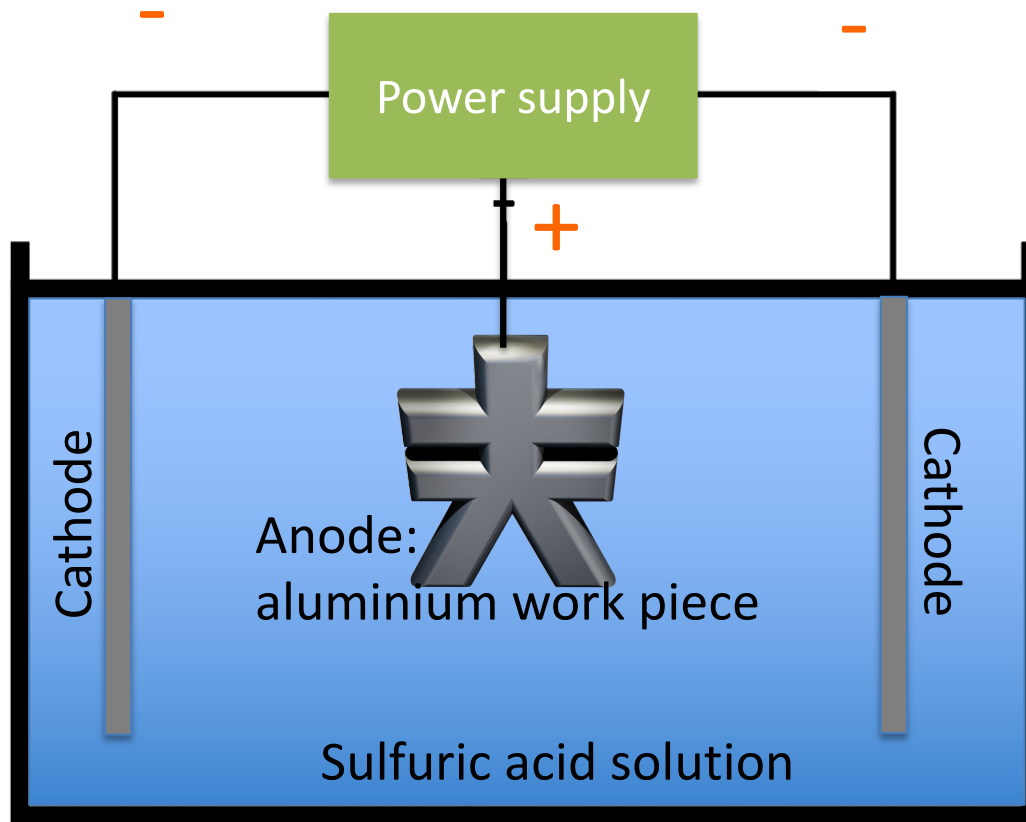
Surface treatments by metal electrodeposition

Principle of electrodeposition

Examples of electrodeposition



Surface treatments by metal anodizing (formation of a metal oxide surface film)



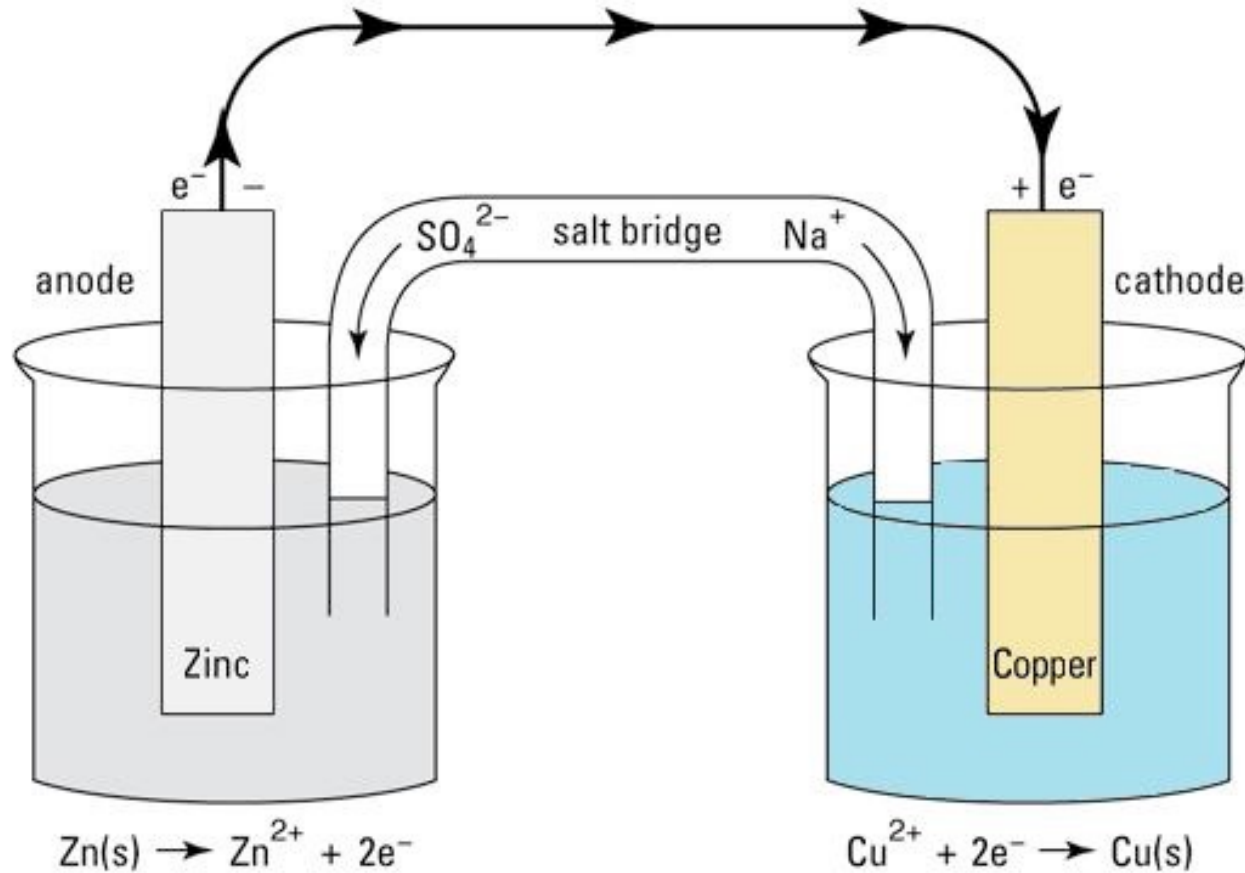
*Car fitting component:
color anodized aluminum*



Engineering use of electrochemistry

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Chemical to electrical energy conversion: the Daniell cell

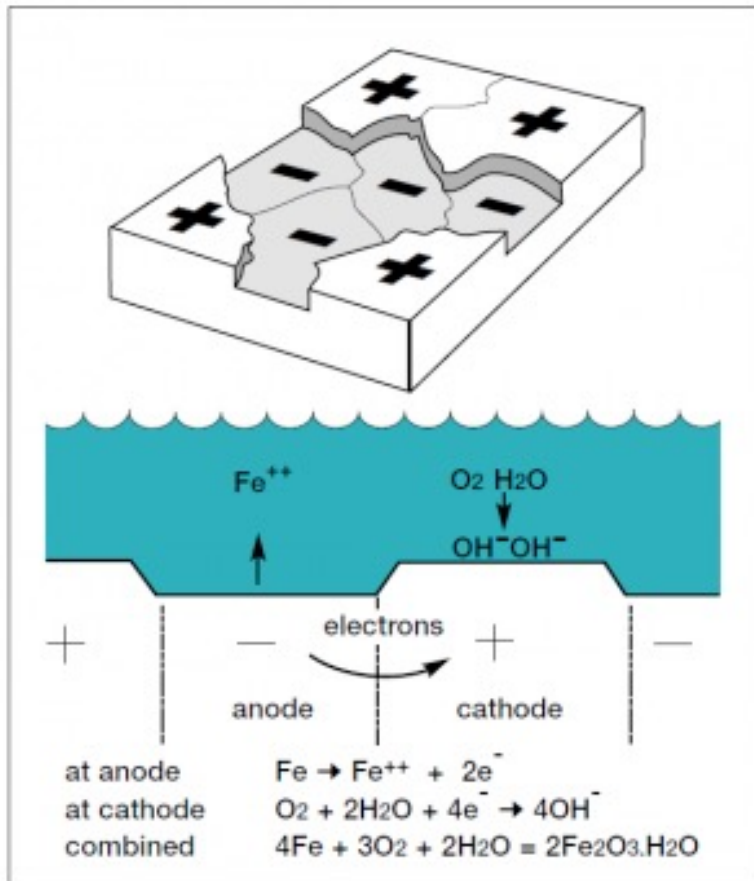


Engineering use of electrochemistry

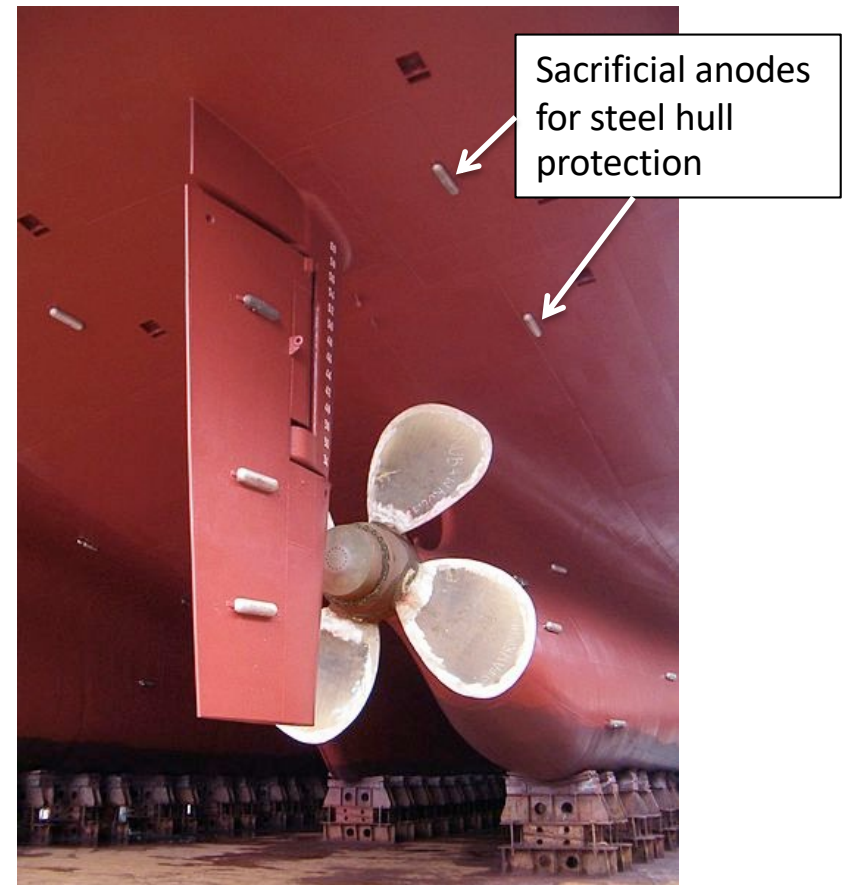
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Corrosion

Corrosion mechanisms



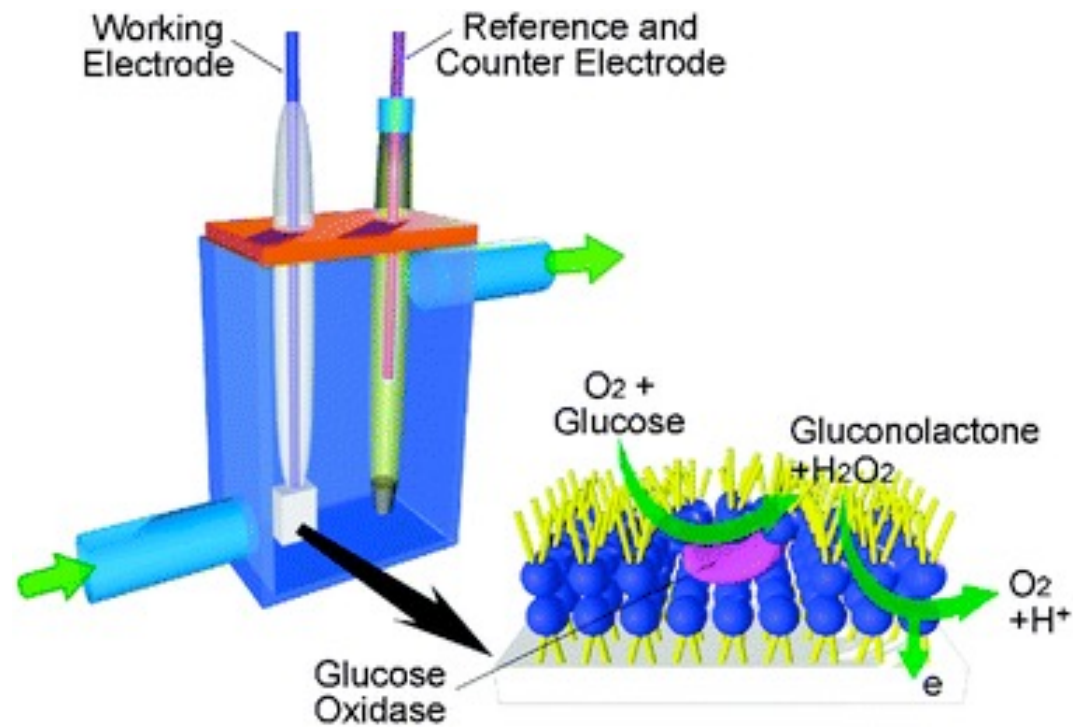
Corrosion protection



Engineering use of electrochemistry

- Electrosynthesis
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- Surface treatments
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 - Sensors for pH, glucose, pollutants (e.g. NO_x)
- ...

Glucose sensor based on electrochemical oxidation of hydrogen peroxide



Follow up : other courses

- Electrosynthesis (CHE407)
- **Surface treatments**
- **Energy storage and conversion**
- Analysis and measurement (CHE407)
- Environment (CHE407)
- Corrosion (MX Bachelor)

Take home message

- Electrochemistry and its applications are a vast and highly relevant field, with massive impact
 - electrical energy is (partly) replacing combustion
 - electrolytic industries (metal extraction)
- Very interdisciplinary
- **Voltage** and **current** are the (precise) tuning handles, instead of heat (thermal processing), to control the chemical reactions of interest

Follow up : in practice (lab)

- To apply your knowledge:
 - **Semester projects** at GEM lab (EPFL-Sion), see gem.epfl.ch (J Van herle)
 - **Master project** at GEM lab or elsewhere
 - with or without industry partner
 - Semester job (1-2 days/week), summer internship (possible to be full time) etc.
 - employed at GEM lab

Course contents:

- Introduction
- Basics of electrochemistry
 - Electrode reactions and potential, kinetics, experimental methods.
- Electrodeposition and micro-fabrication
 - Coatings, surface patterning, MEMS, nanowires.
- Electrochemistry for energy generation and conversion
 - Batteries, fuel cells, electrolysis, electrochemical synthesis; electric vehicles.