TAIWAN TECH
National Taiwan University of Science and Technology

NanoElectroChem. Lab.
Chemical Engineering

Electrochemical Engineering

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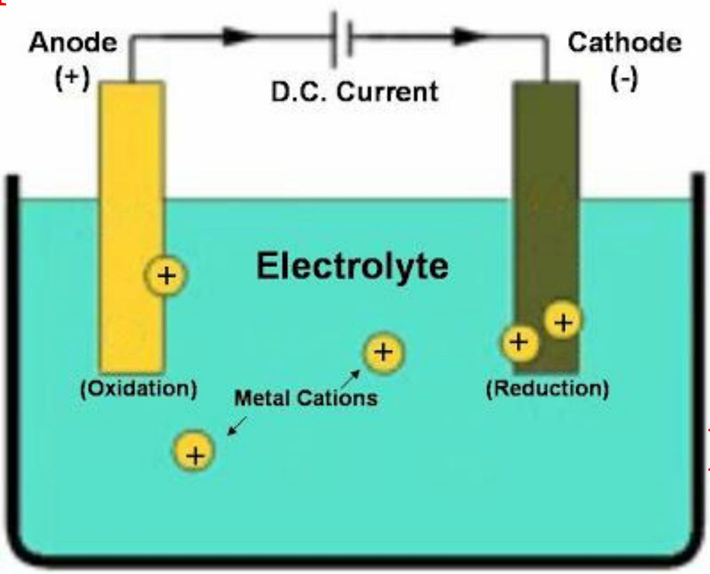
Contents

1. General Introduction
2. Thermodynamics in Electrochemistry
3. Kinetics in Electrochemistry
4. Transport in Electrochemistry
5. Electrochemical Methods
6. Applications

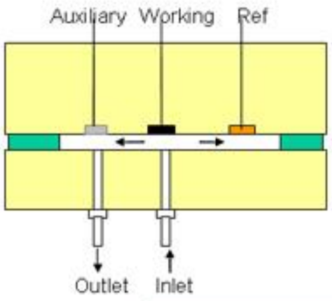
Electrochemical Cells

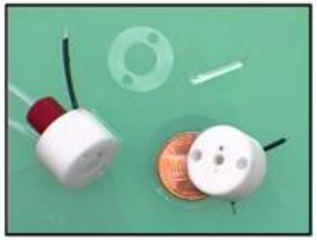
Honda Fuel Cell Car



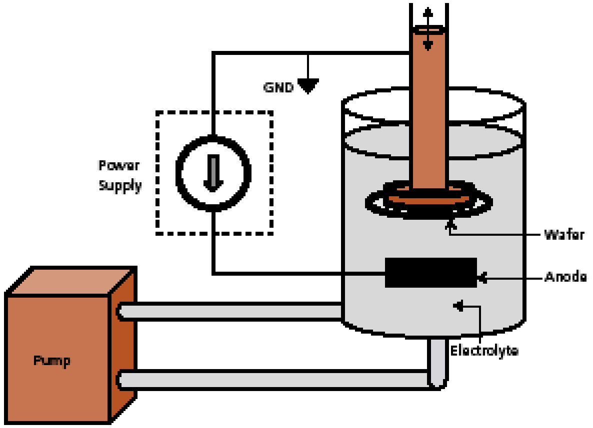
Tesla Electric Car

Electrochem. Sensors





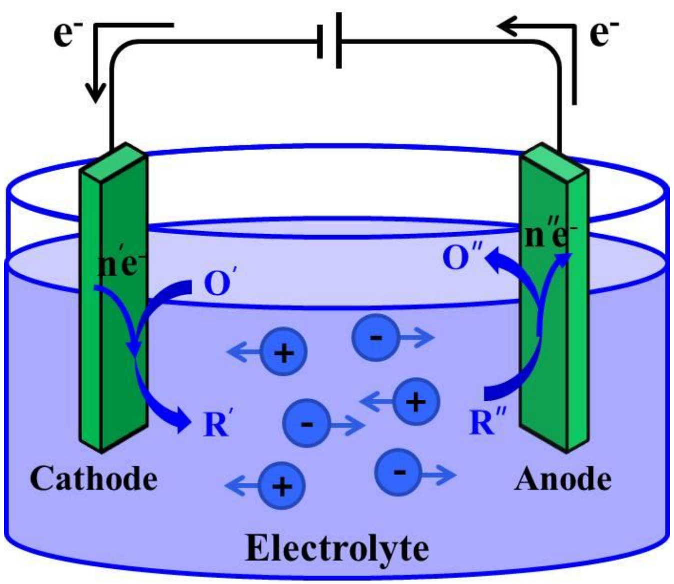
Electroplating

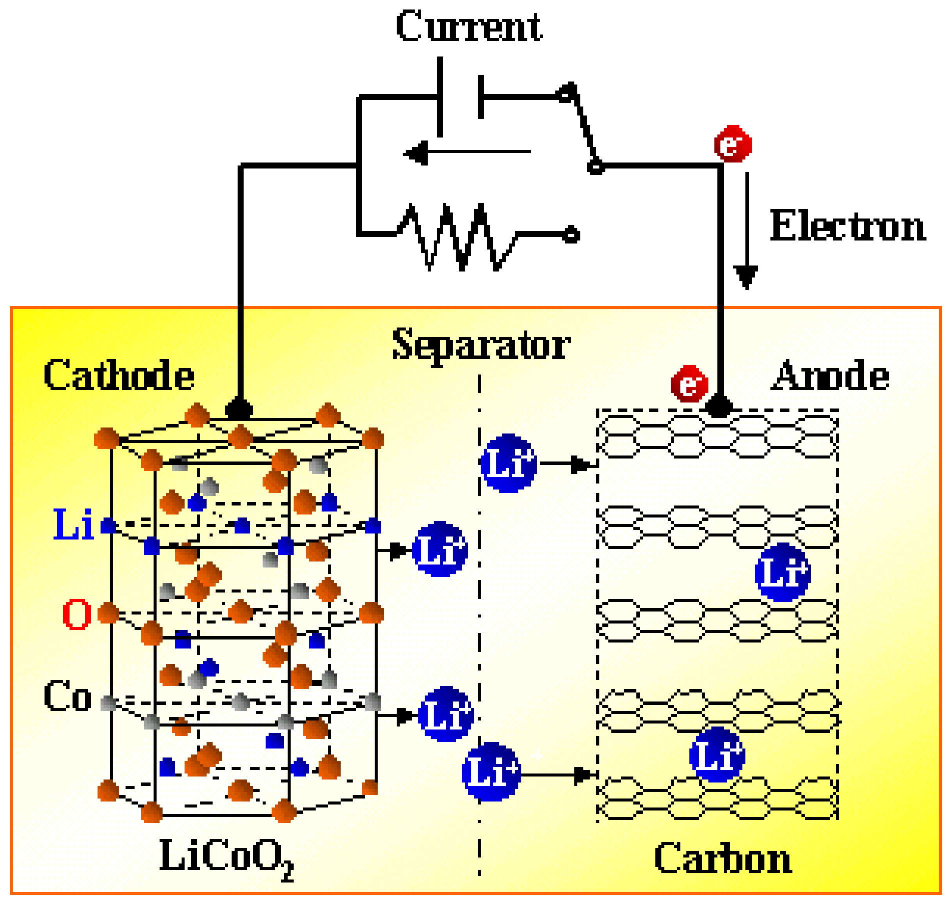


IC Cu plating

Electrochemical Cell

Chemical energy + thermal energy ↔ Electric energy + thermal energy





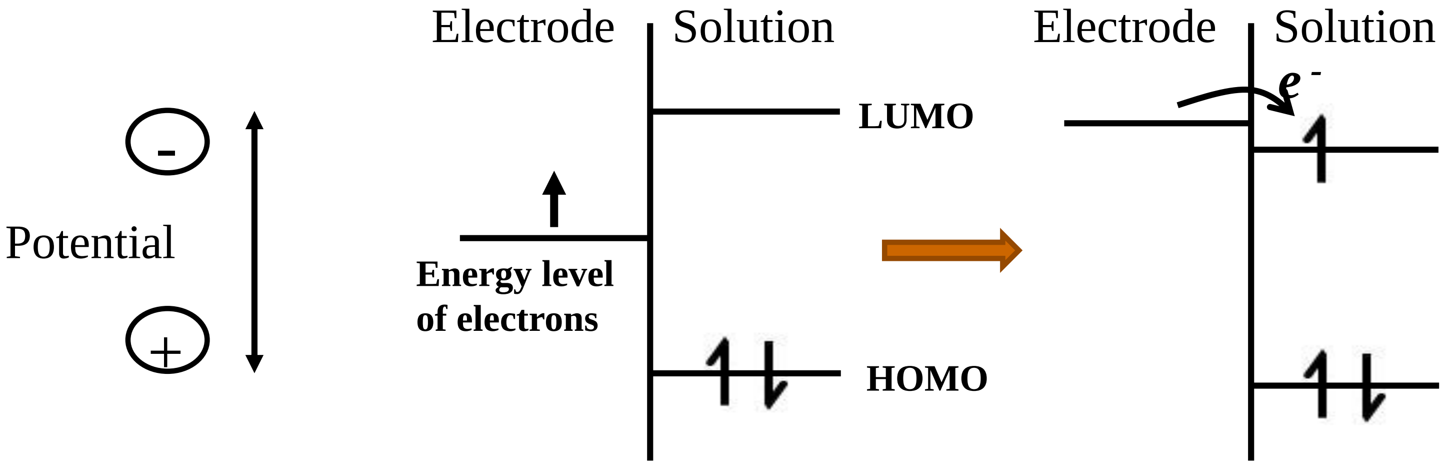
Types of cell

1. Galvanic cell ($\Delta G<0$)
   1) Batteries
   2) Fuel cells
   3) Corrosion
   4) Others
2. Electrolytic cell ($\Delta G>0$)
   1) Electro-synthesis
   2) Electro-deposition
   3) Electro-coating
   4) Electro-etching
   5) Others

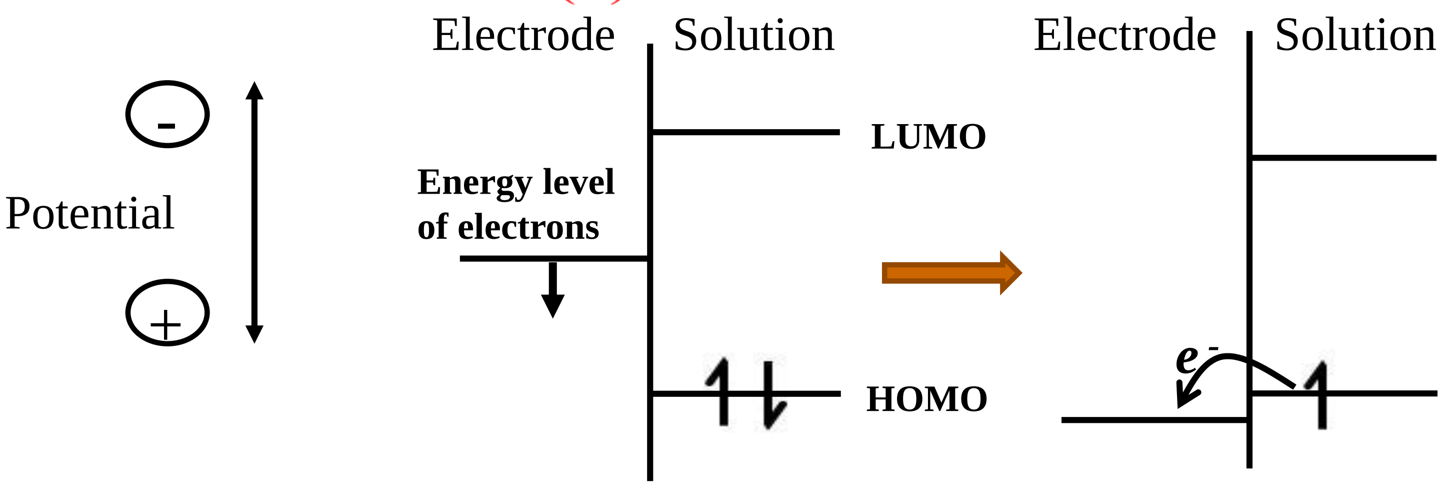
Definition of Electrochemistry

Electrochemistry: Reactions involve the charge transfer (electrons and ions) across an interface between two phases (*e.g.*, a ***solid*** and an adjacent ***solution***).

$$(1)\ A + e^- \rightarrow A^-$$



$$(2)\ A \rightarrow A^+ + e^-$$



Basic Electrical concept

Charge carried by a current

$$Q = It$$

where

I = strength of a current

t = time

Unit of Q is Coulomb, C.

1 C = 1 A.s

1 Faraday = 96,490 absolute Coulombs

Basic Electrical concept

The electrical work performed: Joule's law (Energy)

$$work = VIt = VQ = V^2t/R$$

The rate of electrical work (Power)

$$P = IV = QV/t = V^2/R$$

Electronic Conduction

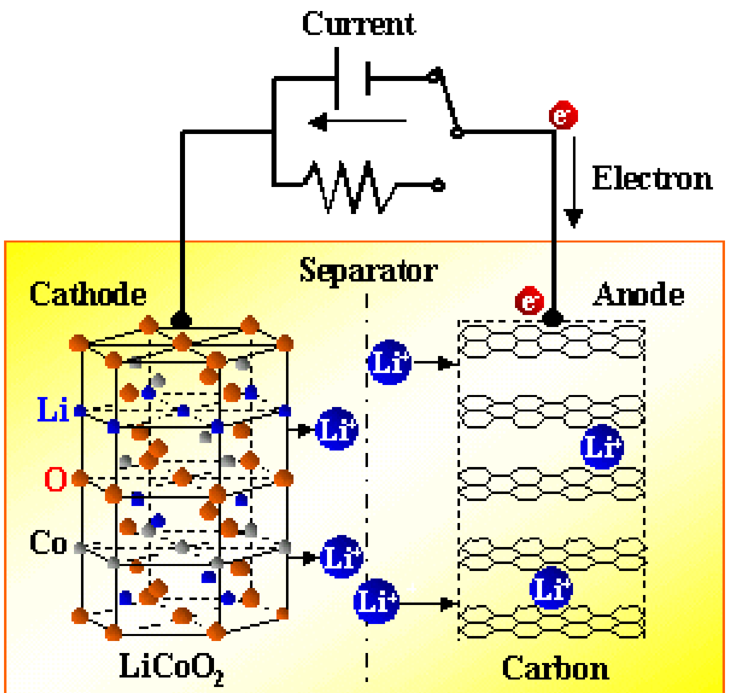
Conduction takes place by direct migration of electrons through the conductor under the influence of an applied potential.

"Atoms or ions composing the conductor are not involved in the process, and except for a vibration about their mean positions of equilibrium."

Ionic Conduction

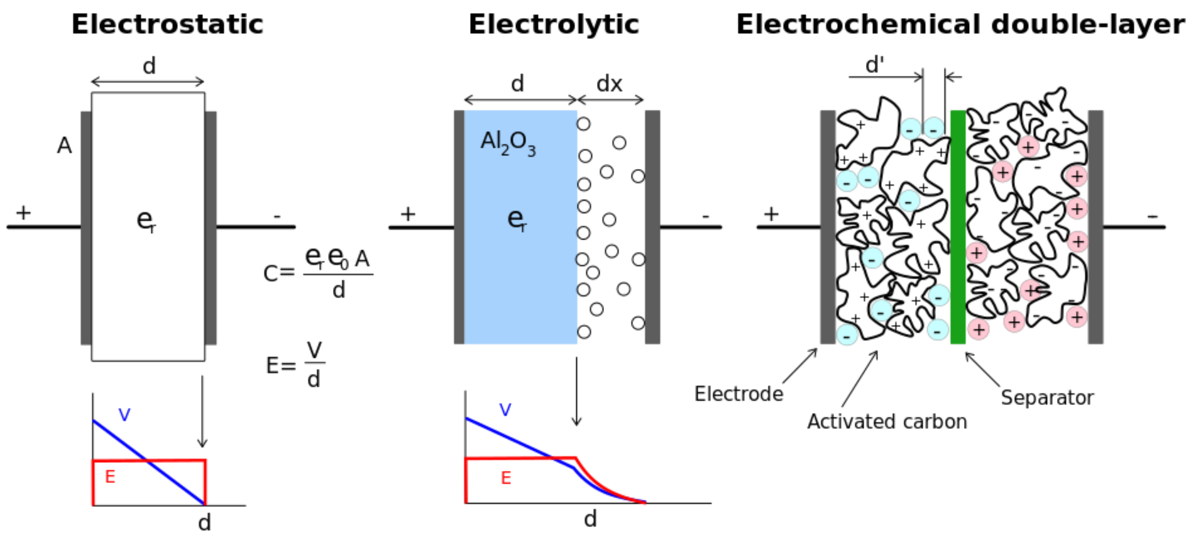
Charge transfer takes place via migration of ions, both positive and negative, toward the electrodes.

"Migration involves a transfer of electricity from one electrode to another as well as a transport of matter from one part of the conductor to another."



Nonfaradaic and Faradaic Processes

- Nonfaradaic processes: charge associated with movement of electrolyte ions, reorientation of solvent dipoles, adsorption/desorption, etc. at the electrode-electrolyte interface



- Faradaic processes: charge transferred across the electrified interface as a result of an electrochemical reaction

Faraday's Law

The mass of a substance involved in reaction at the electrodes is directly proportional to the quantity of electricity passed through the solution.

$$m = (Q/F)(M/z) \quad ; m = \xi(Q/F)(M/z)$$

where:

m: **the mass of the substance liberated at an electrode in grams**

Q: **the total electric charge passed through the substance**

F **(Faraday constant)*:*** **96485 C mol^{-1}**

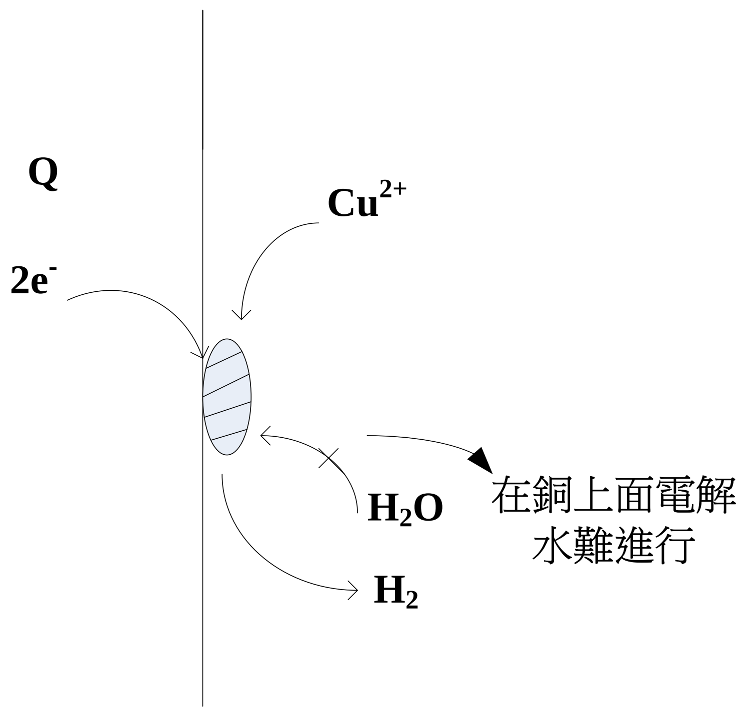
M: **the molar mass of the substance**

z: **electrons transferred per ion or species**

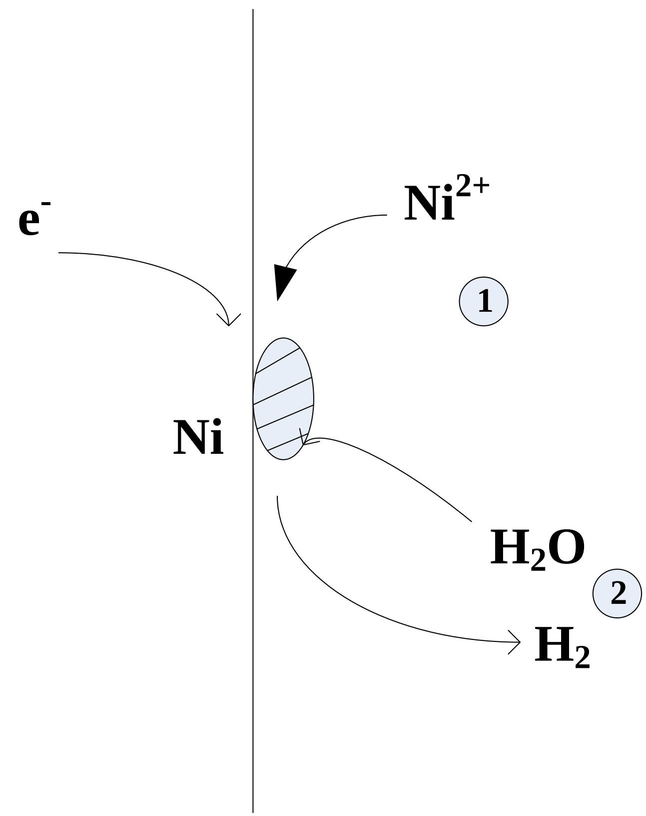
ξ: **Columbic efficiency** $= Q_j/\sum Q_i = Q_j/Q$

Faraday's Law

1. $W = (Q/nF)\,M_W$
2. $W = (Q\xi/nF)\,M_W$



反應 : $Cu^{2+} + 2e^{-} = Cu$



Applications of Faraday's Law (I)

Ni Electroplating

$$h = 0.205 \times \xi \times i \times t$$

where:

h - coating thickness, µm;

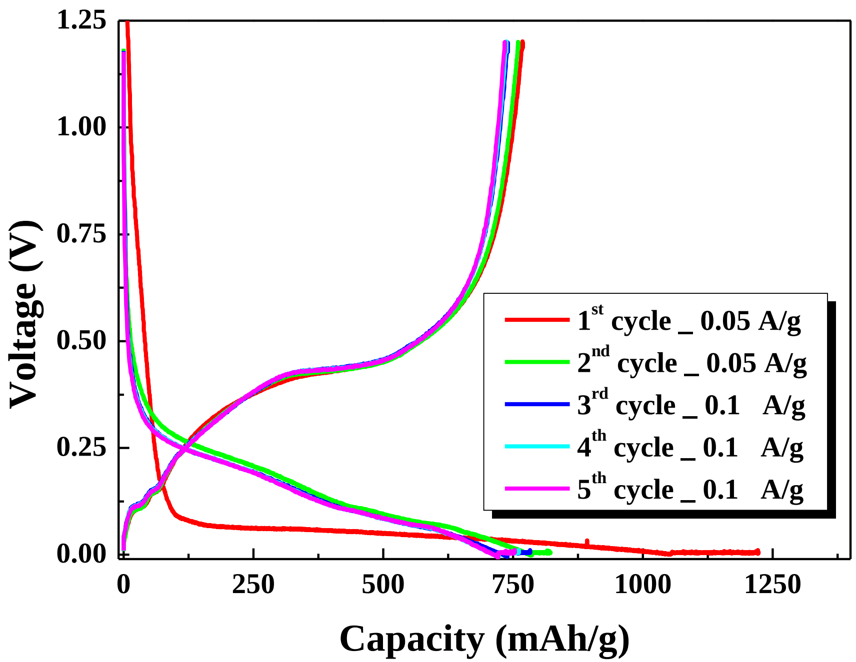
ξ - current efficiency ;

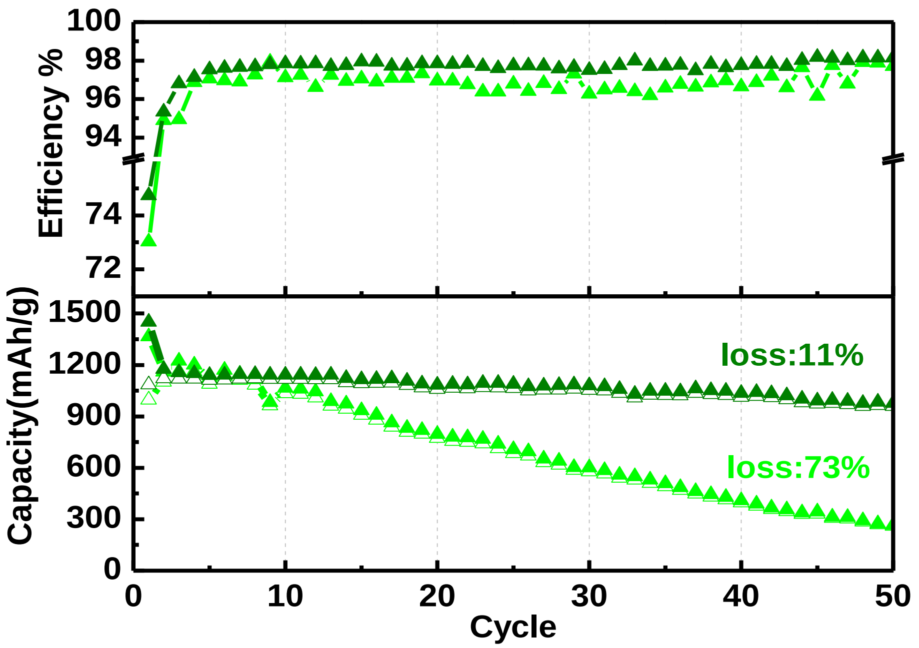
i - current density (I/A), A/dm²;

t - time, min.

Deposit	Electrolyte	ξ Range, %
Ag	CN	100
Au	Acid Neutral CN	50 - 100
Cd	CN	85 - 95
Cr	CrO_3/H_2SO_4 CrO_3/SO_4-F	10 - 15 18 - 25
Cu	Acid SO_4 CN (low eff.) CN (high eff.) P_2O_7	97 - 100 30 - 45 90 - 95 ~100
Fe	Acid	90 - 98
In	Acid or CN	30 - 50
Ni	Acid	93 - 98
Pb	Acid	95 - 100
Rh	Acid	10 - 50
Sn	Acid Alkaline	90 - 95 70 - 95
Zn	Acid CN	~95 50 - 80

Lithium Ion Batteries

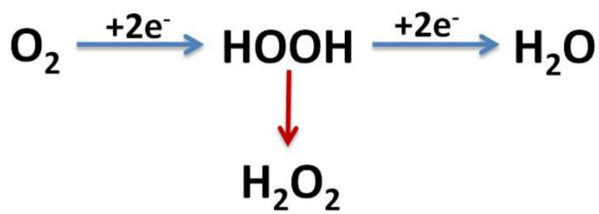




Applications of Faraday's Law (III)

Fuel Cell:

Oxygen Reduction Reaction (ORR)



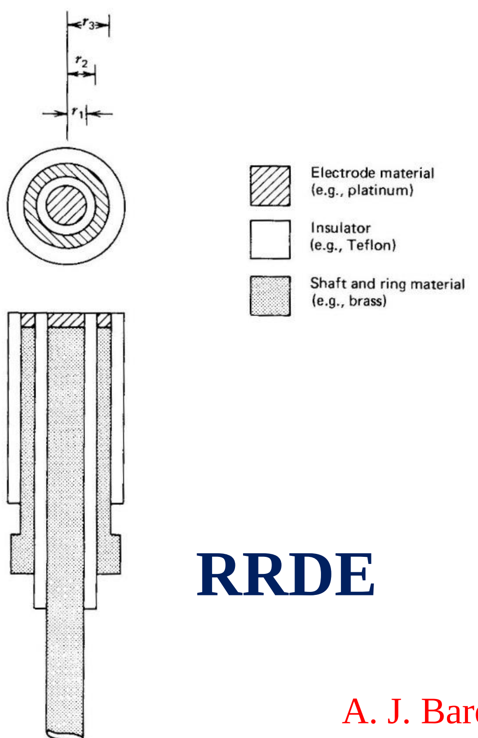
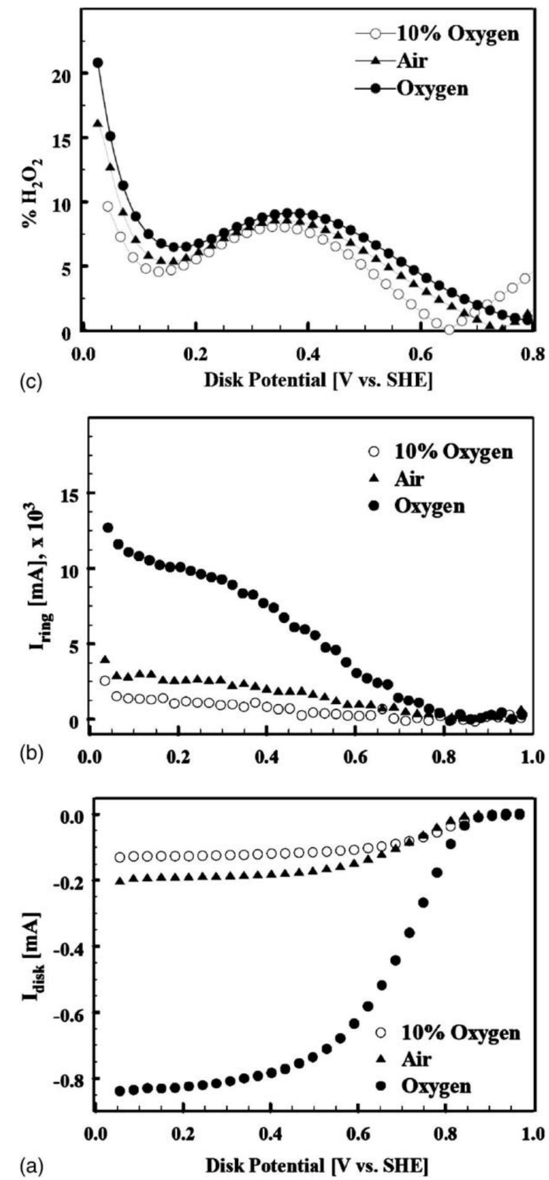


Figure 8.4.1 Ring-disk electrode.

RRDE

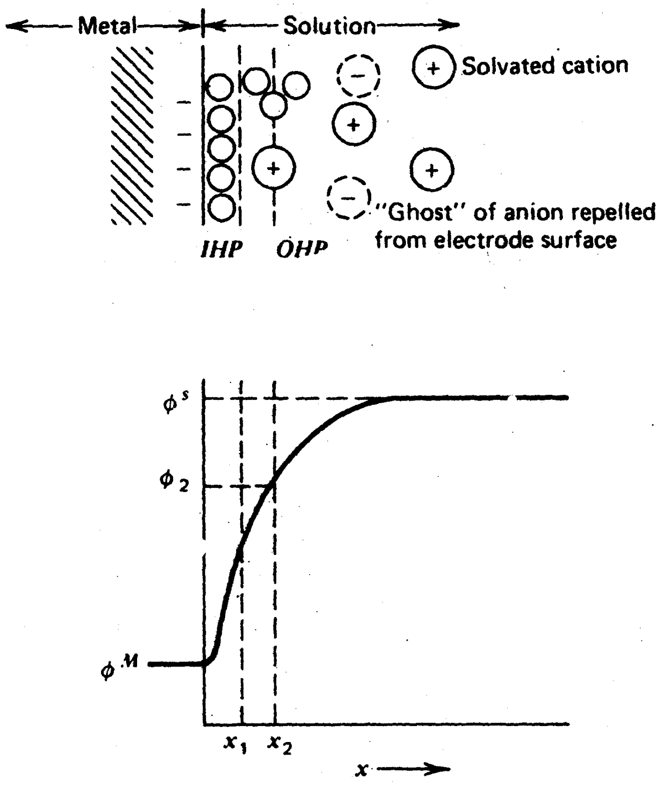
A. J. Bard and L. R. Faulkner, "Electrochemical Methods - Fundamentals and Applications"

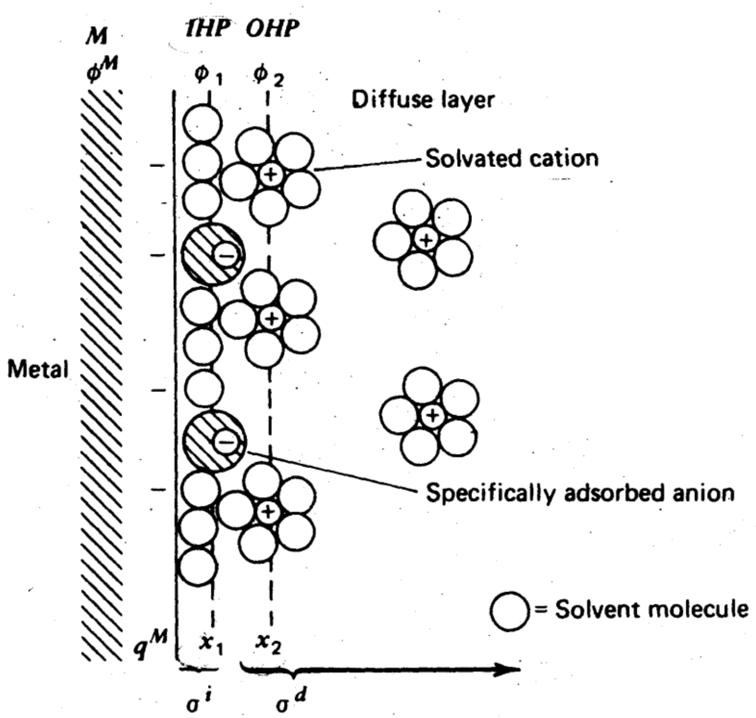
JES, 155, B50-57(2008)



Model of Electrode/Solution Interface

Electric Double Layer (EDL)





HP: Helmholtz Plane

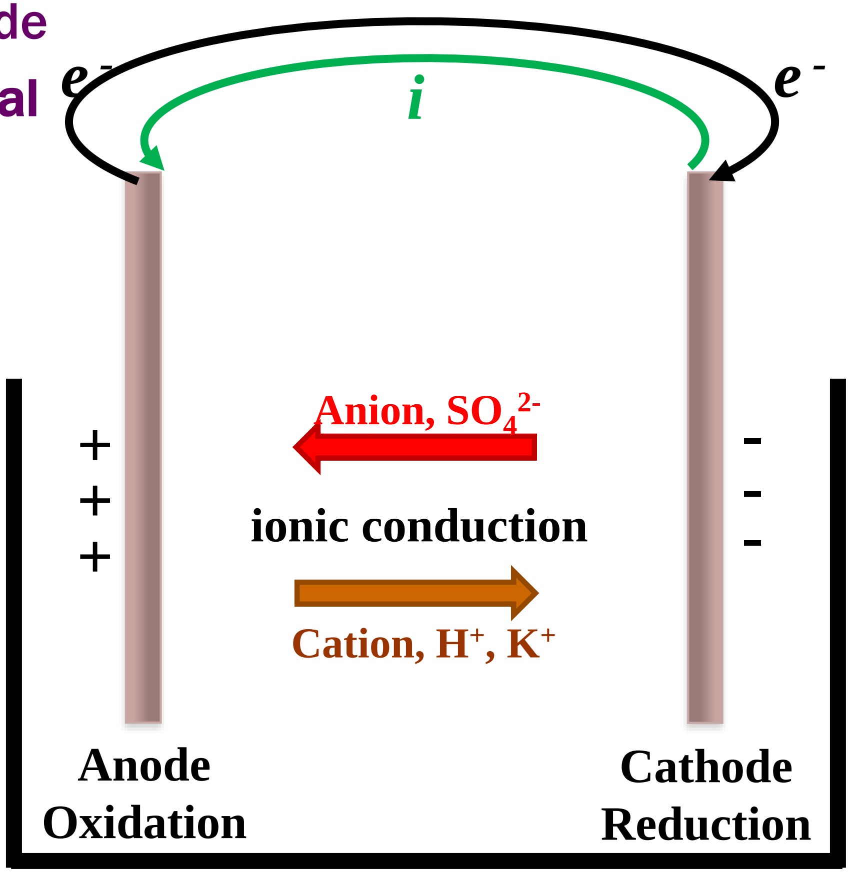
Compact layer

Diffuse layer

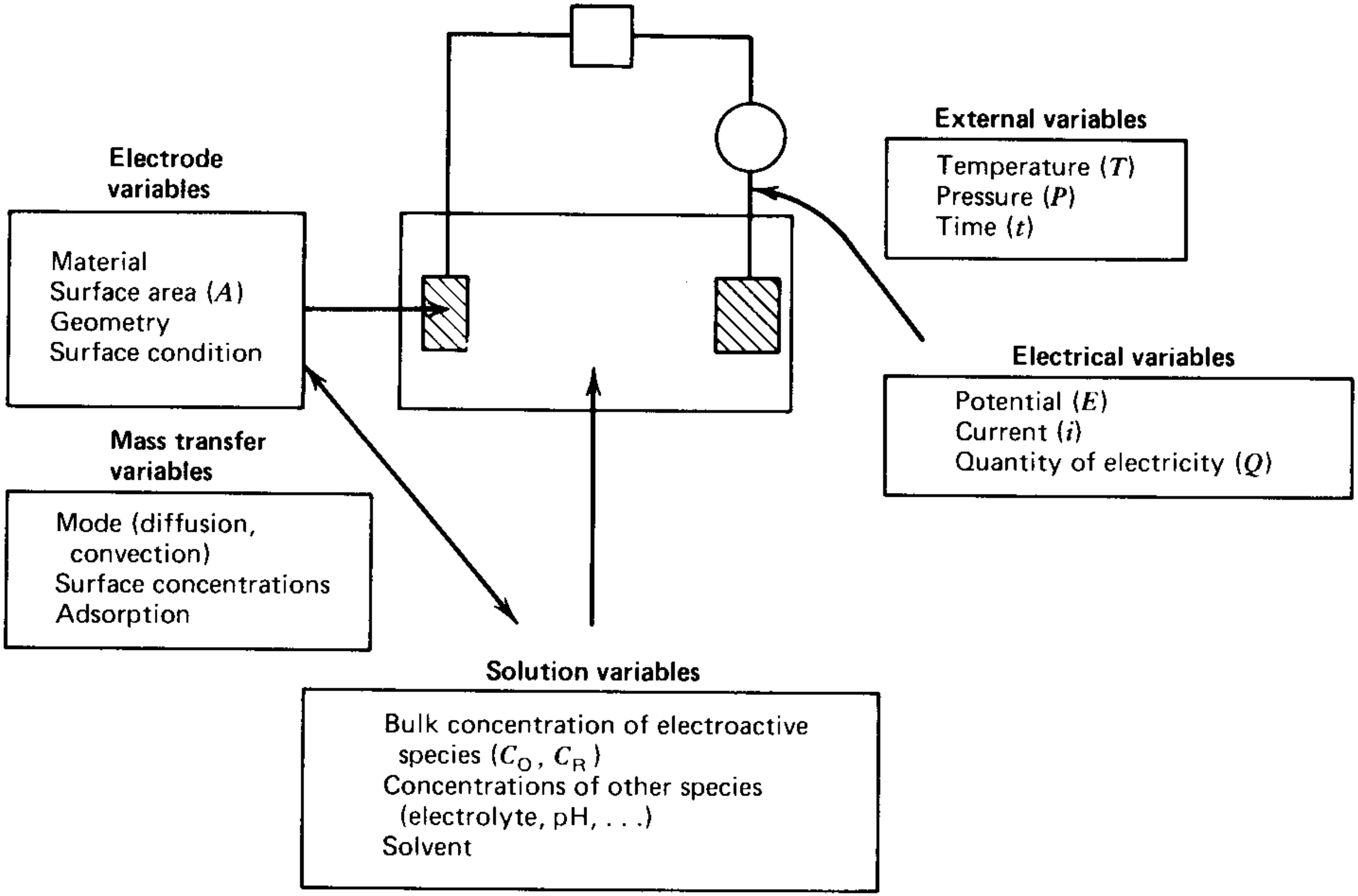
A. J. Bard and L. R. Faulkner, "Electrochemical Methods - Fundamentals and Applications"

Basic Terminology (I)

1. **Electrode:** electronic conductor or Ionic conductor or mixed conductor
2. **Electrolytes: Ionic conductors**
3. **Anode, Anion, Anolyte :**
4. **Cathode, Cation, Catholyte :**
5. **Cell Potential (Voltage):** potential difference of electrons between cathode and anode
6. **Electrode potential**



Variables affecting the rate of an electrode reaction



A. J. Bard and L. R. Faulkner, "Electrochemical Methods - Fundamentals and Applications"

Recap!