Modern Electro chemistry- Introduction

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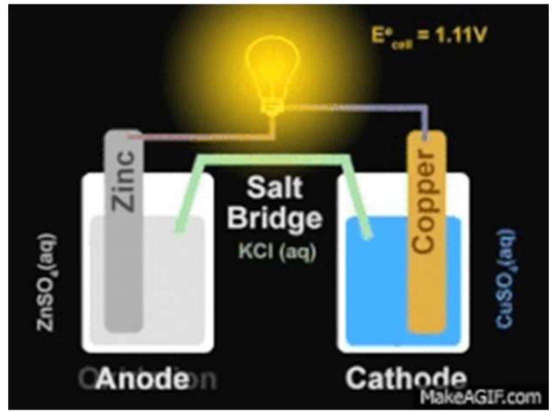
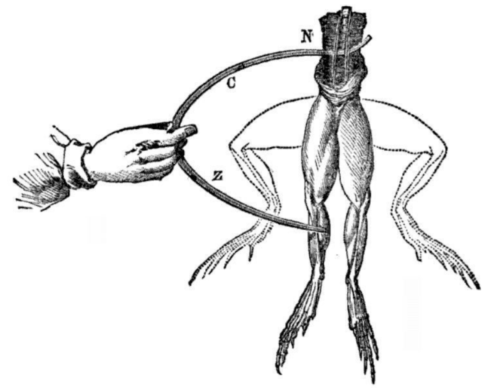


Galvanic Cell



Animal Electricity!!!

Battery

Duracell batteries

9v battery

6v dry cell

Battery Chemistry

The ideal battery does not yet exist

Unit -5

Advanced energy systems

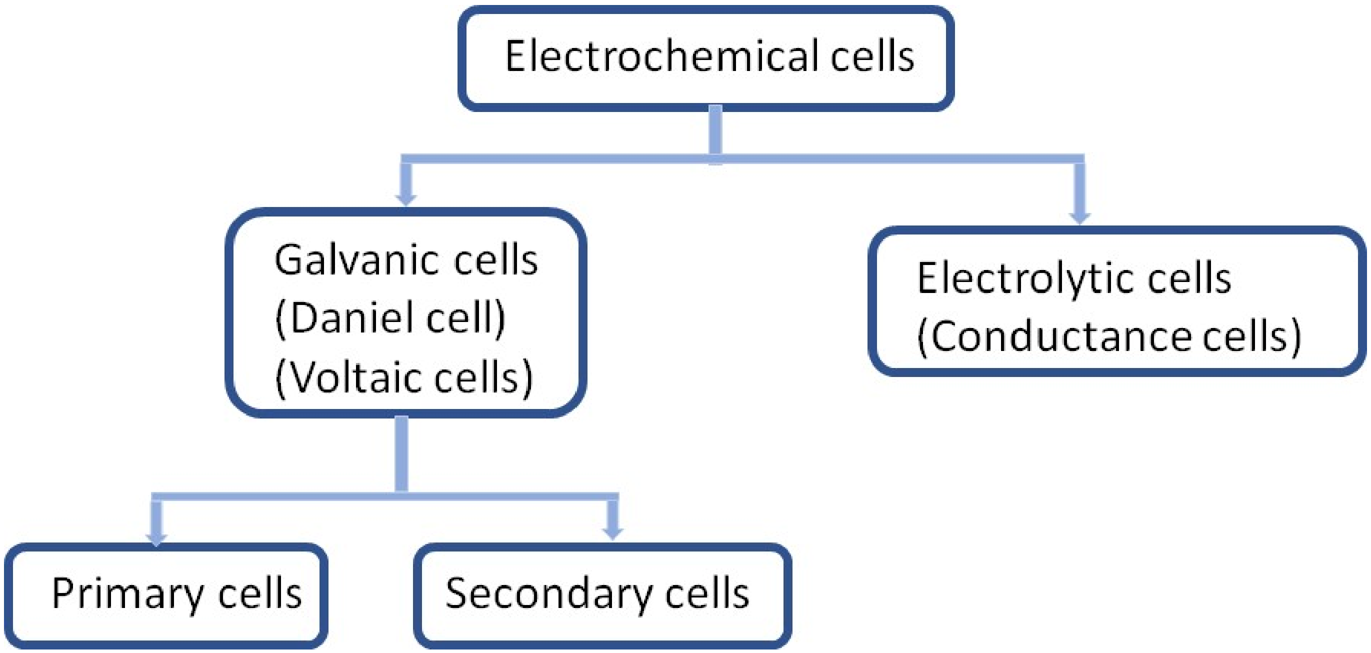
Syllabus

Battery technology: Introduction to Electrochemistry, characteristics of battery, Lithium-Ion battery, metal air battery. Battery technology for e-mobility.

Super capacitors: Storage principle, types (EDLC, pseudo and hybrid) with examples and applications.

Photovoltaics: organic/inorganic solar cells, quantum dot sensitized (QDSSC's). Photo catalytic water splitting

Types



Electrochemical cells
Galvanic cells
(Daniel cell)
(Voltaic cells)
Electrolytic cells
(Conductance cells)
Primary cells
Secondary cells

Types of Electrodes

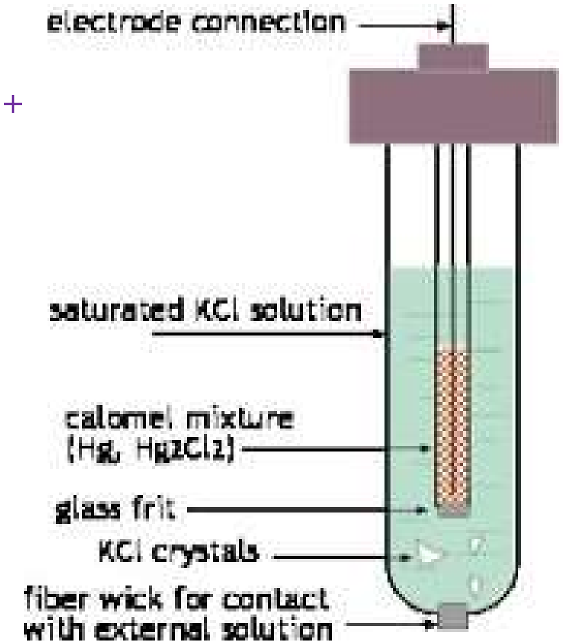
1. Metal-Metal Ion electrode
Example: $Zn/Zn^{2+}//Cu/Cu^{2+}$

2. Metal-Metal salt ion electrodes
Example: Calomel electrode $Hg/Hg_2Cl_2/Cl^-$
Silver- Silver chloride electrode $Ag/AgCl(s)/Cl^-$

3. Gas electrode:
Example: Standard hydrogen electrode Pt/H_2 (g) (1atm)/ H^+

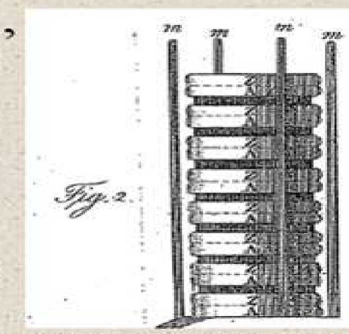
4. Oxidation –Reduction electrodes:
Example: Pt/Fe^{2+}; Fe^{3+}, Pt/Sn^{2+}; Sn^{4+}

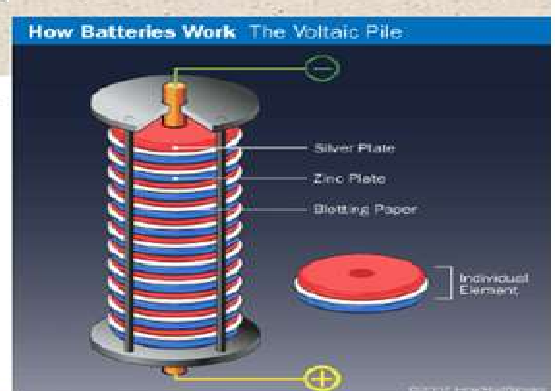
5. Ion selective electrode:
Ex: Glass electrode



Battery History

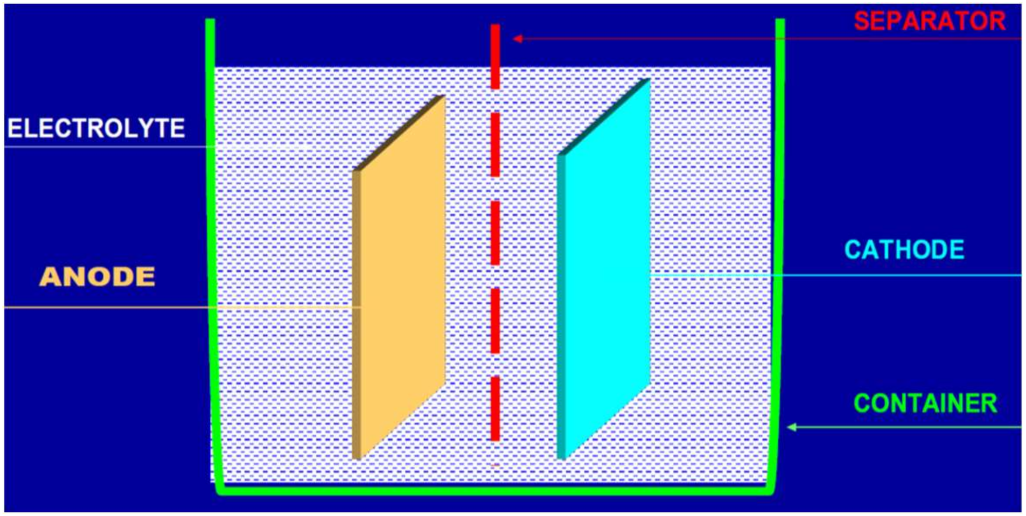
- The modern battery was developed by Alessandro Volta in 1800.
  - ✓ Ingredients: Zinc, Saltwater paper, and Silver
  - ✓ An electrochemical reaction.
  - ✓ The "Voltaic Pile"





Source:http://www.kentlaw.iit.edu/faculty/fbosselman/classes/Spring2008/PowerPoints/BryanLamble.ppt

Cell construction and cell reaction



ANODE REACTION: is an oxidation reaction which releases electrons (Anode is the –ve electrode in EC cell)

CATHODE REACTION: is a reduction reaction which consumes electrons (Cathode is the +ve electrode in EC cell)

ELECTROLYTE is an ion-conducting medium which conducts ions between the electrodes so that the above reactions can take place

CLASSIFICATIIION OF BATTERIES

PRIMARY BATTERY

Non-rechargeable (cell reactions are irreversible) - Self-discharges whether used or not

LECLANCHE CELLS (Zn/C) - Popular low-cost system, Applications: Torch light, portable radios, toys, novelties, etc.

Mg/MnO_2 CELLS - High capacity system: Applications: Military communication equipment, voting machines, etc.

SECONDARY BATTERY

Rechargeable (cell reactions are reversible),

Lead-Acid Battery (Pb/H^+), Nickel-Cadmium Battery (Ni-Cd), Nickel-Iron Battery (Ni-Fe), Nickel-Metal hydride Battery (Ni-MH)

Lithium battery (Li-LiM_xO_y), lithium-Ion battery (C-LiM_xO_y),Lithium-Ion Polymer Battery (C-LiM_xO_y)

RESERVE BATTERY

one of the cell components, usually the electrolyte, is kept isolated from the rest and is added at the time of need

Mg/Cu_2Cl_2, Mg/AgCl (sea water activated battery), Applications: Torpedoes, Sea beacons (Mainly in Meteorology and Defense fields)

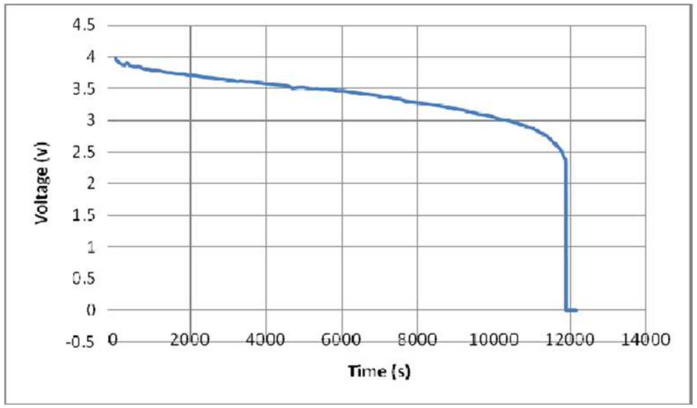
Li/FeS2 (Thermally activated battery) Applications: In Missiles

Voltage: The voltage of a battery mainly depends upon the emf of the cells which constitute the battery system. The emf of the cell depends on the free energy changes in the overall cell reaction. As given by Nernst equation,

$$E = E^0 - \frac{2.303RT}{nF}\log Q$$

$$where\ E^0{}_{cell} = E^0{}_{cathode} - E^0{}_{anode}\ \text{and}\ Q\ \text{is the reaction quotient}\ Q = \frac{[\text{product}]}{[\text{reactant}]}$$

Where $E_{cell} = E_{cathode} - E_{anode}$, and Q is the reaction quotient



Battery Characteristics Contd..

Current: Current is a measure of the rate at which the battery is discharging.

- Higher the rate of spontaneous reaction, higher is the current.
- Higher the surface area of the electrodes, higher is the rate of reaction.
- Current is measured in A.

Capacity: Capacity is a measure of the amount of electricity that may be obtained from the battery. It is expressed in Ah (ampere hours). It is proportional to the amount of charge in Coulombs that may be transported from anode to cathode through the external circuit. The charge (C) in Coulombs is given by the Faraday's relation: $\mathbf{C = WnF/M}$

Where, C is Capacity of battery (in Ah)
W is Weight of the active material
n is number of electrons involved in discharge reaction
F is Faradays constant, 96500 C/mol
M is Molar mass.

Electricity storage density: It is the amount of electricity stored in the battery per unit weight of the battery.

- i.e. it is the capacity per unit weight.
- It can be expressed in Coulombs/kg or in Ah/kg. The weight includes the weight of all components of the battery (i.e. total weight of active material, electrolyte, terminals etc.)

Energy efficiency: The energy efficiency of a rechargeable battery is given by

$$\%\ \text{Energy efficiency} = \frac{\text{Energy released during discharging} \times 100}{\text{Energy consumed during charging}}$$

Battery Characteristics Contd..

•**Cycle Life**: Primary batteries are designed for single discharge and secondary batteries can be chargeable again and again. **The number of charge and discharge cycles that are possible in secondary batteries, before failure occurs is called cycle life**. The cycle life of batteries must be high for secondary batteries.

• **Shelf life:** The duration of storage under specified conditions at the end of which a cell or a battery retains its ability to work or to produce energy is called shelf life. A good battery should have more shelf life.

Problems on Battery Characteristics

$$E = E^0 - \frac{2.303RT}{nF}\log Q$$

$$where\ E^0{}_{cell} = E^0{}_{cathode} - E^0{}_{anode}\ \text{and}\ Q\ \text{is the reaction quotient}\ Q = \frac{[\text{product}]}{[\text{reactant}]}$$

$$C = \frac{w \times n \times F}{M}$$

$$Energy\ (Wh) = Capacity(Ah) \cdot Voltage(V)$$

$$\%\ \text{Energy efficiency} = \frac{\text{Energy released during discharging} \times 100}{\text{Energy consumed during charging}}$$

1. A Lithium ion battery constructedusing lithium as anode and $LiCoO_2$ as cathode. Calculate the EMF (voltage) of a battery 298 K.

Given E0 Li = -3.04 V, E0$LiCoO_2$ = +3.9 V, R = 8.314Jmol^{-1} K^{-1}, [product] = 10.28M, [Reactant] = 0.29M and F = 96500C

$$E = E^0 - \frac{2.303RT}{nF}\log Q$$

$$where\ E^0{}_{cell} = E^0{}_{cathode} - E^0{}_{anode} \text{ and } Q \text{ is the reaction quotient } \mathrm{Q} = \frac{[\text{product}]}{[\text{reactant}]}$$

E^0_{cell} = 3.9 –(-3.04) = 6.94 V

Substitute in E formula

E_{cell} = 6.94 – ((2.303*8.314*298)/(1*96500)) *log (10.28/0.29)
=6.94 – (0.05912*1.5494)
=6.94 -0.916

E_{cell} = 6.8942 V

2. A battery comprised of Lithium and Copper produced an EMF of 3.38V. Calculate the standard reduction potential of cathode Copper electrode if SRP value of Lithium is -3.04 V and concentration of product and reactants are 1M.

$E_{cell} = E^0_{cell} – (2.303RT/nF) \log [Q]$

Where $E^0_{cell} = E^0_{cathode} - E^0_{anode}$

Where Q = [Product]/[Reactant] = [1]/[1] = 1, Log [1] = 0,

Copper cathode, Li Anode

$E_{cell} = E^0_{cell}$ & $E_{cell} = 3.38$ V

$E_{cell} = E^0_{cathode} - E^0_{anode}$

$E^0_{cathode} = E_{cell} + E^0_{anode}$

$E^0_{cell} = 3.38 + (-3.04)$

$E^0_{cell} = 0.34$ V

3. A battery comprised of Lithium as anode and $LiCoO_2$ as cathode employed in a vehicle. Calculate the capacity of battery if weight of electroactive material in the battery is 20 kg and molar mass of the active material is 198. given F = 96500 C

$$C = \frac{wnF}{M}$$

W = 20 kg

N = 1 because lithium is involved [$Li \rightarrow Li^{+} + e$]

F = 96500 C

M = 198

C =((20*1*96500)/198) Ah

C = 9747.47 Ah

4. Calculate the percentage efficiency of a rechargeable aluminum ion battery, if energy required during charging is 180J and energy released during discharge is 164 J.

$$\% \text{ energy efficiency} = \frac{Energy\ released\ during\ discharge}{Energy\ required\ during\ charging} * 100$$

$$= (164/180)*100$$

Energy efficiency = 91.11 %

Problem 5 Calculate the energy of the following battery

The formula to calculate the cell energy is

$$Energy\ (Wh) = Capacity(Ah) \cdot Voltage(V)$$

Where Q is the capacity of the battery (Ah) and V is the nominal voltage of the battery (V).

The energy for the battery in the picture is

$$E = 5.2\ Ah\ \cdot 3.7V = 19.24\ Wh$$

Thank you