# Unit III: Energy storage devices, Hydrogen storage & Sensors

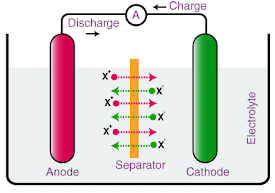
## Batteries

### Component

* Devices that store CE and convert to EE

|  |  |
| --- | --- |
| Anode | * Oxidation takes place * electroactive material: must oxidise readily * E.g.: Zn, Pb, Li |
| Cathode | * reduction takes place * electroactive material: must reduce readily * E.g.: PbO2, MnO2, O2 |
| Electrolyte | * substance with good ionic conductivity * E.g.: H2SO4, KOH |
| Separator | * Insulator which separates anode and cathode compartment * Role: to prevent internal short circuit * Transport ions from anode to cathode and vice-versa * E.g.: Polypropylene / (C3H6)­n |

Schematic diagram of battery:



### Working

|  |  |  |
| --- | --- | --- |
|  | While Charing | While discharging |
| Power draw | Consumers power | Delivers power |
| Cell  type | Electrolytic Cell (EE 🡪 CE) | Galvanic Cell (CE 🡪 EE) |
| Reactions | Anode: An- ⇌ A + ne-  Cathode: Mn+ + ne- ⇌ M  Overall: MA → M + A | Anode: M → Mn+ + ne-  Cathode: A + ne-→ An-  Overall: M + A → M |

|  |  |  |
| --- | --- | --- |
| Types of Cells | | |
|  | Primary (1o) | Secondary (2o) |
| Electro-active material | Does not re-generate | Does re-generate |
| Cell Type | Galvanic Cell (CE 🡪 EE) | Electrolytic + Galvanic |
| Uses | Single-use | Multi-use |
| Example | Dry Cell, Li-MnO2 | Li-ion, Pb-acid, Ni-Cd |

### Characteristics

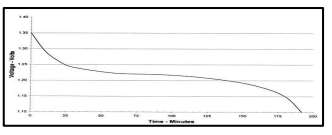
Voltage:

* + EMF of cell 🡪 Δ G 🡪 reaction 🡪 choice of electrodes
  + Factors affecting Voltage
    - ↑ = ↑ V
    - ↑ T = ↓ V
    - ↑Q = Δ V (marginal change)

Current:

* + measures rate at which battery discharges
  + A / mA
  + Factors affecting Current
    - Amt of electrolyte species
    - Conductivity of electrolyte
    - Inter-electrode distance

Capacity:

* + Charge or amount of electricity that may be obtained from battery
  + Ah (ampere-hr)
  + (Faradays relation)
    - W = mass of active material
    - F = faradays constant (96500)
    - M = molar mass of active material
    - N = no.of moles
  + C = It
  + Longer flat portion = better battery

Electricity storage density:

* + Amount of charge / electricity per unit weight which the battery can hold
  + Weight includes everything.
  + 7g of Li @ anode = 1F , 104g of Pb = 1F

Cycle life:

* + No.of charge/discharge cycles before possible failure
  + Reasons for limited cycle-life :
    - Corrosion at contact points
    - Shedding of active materials
    - Shorting between electrodes due to dendrite formation

Energy efficiency:

* + Depends on shelf-life

Tolerance to service conditions:

* + Tolerant to different service conditions:
    - Temp
    - Vibration
    - Shock

Energy Density:

* + Energy density = Energy available from the battery / mass of battery
    - I = current
    - T = time
    - W = mass of battery
  + Watt-hr/kg

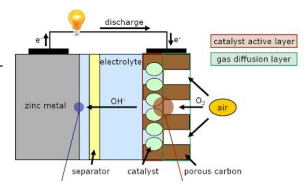
Power Density:

* + Power density = power available from battery / mass of battery

## Modern Batteries

### Zinc-Air battery

* + Metal-air battery



|  |  |
| --- | --- |
| Anode | Zn / Zinc |
| Cathode | O2 from atmosphere |
| Electrolyte | 30% KOH |
| Separator | Polypropylene (C3H6) n |

* + Anode: Zinc granules with gelling agent and small amt of electrolyte
  + Cathode: graphite blended with MnO2 with Ni wire mesh support and outer layer of Teflon than is air permeable. Air holes on cathode allow O2 to enter
  + Anode:
    - Zn 🡪 Zn2+ + 2e-
    - Zn2+ + 2OH- 🡪 ZnO + H­2O
    - ---------------------------------
    - Zn + 2OH-  🡪 ZnO + H­­­2O + 2e-
  + Cathode:
    - ½ O2 + H2O + 2e- 🡪 2OH-
  + Overall:
    - Zn + ½ O2 🡪 ZnO-
  + EMF = 1.4V
  + Advantages:
    - High energy density (cathode air is taken from atmosphere)
    - Very long shelf life (needs to be kept sealed)
    - Environmentally friendly
    - Low cost
  + Disadvantages:
    - Limited power output
    - If CO­2enters battery may damage / degrade it
    - CO2 + 2KOH 🡪 K2CO3 + H2O
  + Applications:
    - Used in power source for hearing aids (write in three sentences)

### Lithium batteries

* + Properties:
    - Lithium
      * light weight
      * electrochemical equivalence is high (7g of Li = 1F)
      * high (-ve) standard reduction potential (-3.05 V)
      * cannot not be used with water-based electrolytes as it is reacting violently with w/ water (only organic / inorganic electrolytes used)
  + Components:
    - Anode: Lithium
    - Cathode: MnO2, SO2Cl2
    - Electrolyte: Li-salt in organic solvent (e.g.: propylene carbonate
  + Types
    - Primary: Li-MnO2
    - Secondary: Li-ion
  + Advantages
    - High EMF up to 4V
    - High ED
    - Lightest metal ever
    - High tolerance to service conditions (-40 0C to 70 0C)
    - Flat discharge characteristics
  + Disadvantages
    - Safety concerns due to high reactivity of Li metal
    - Poor life cycle (dendrite formation)
    - Transportation limit (flights)

### Lithium-ion batteries

* + Construction:  
    - Anode:
      * Lithiated graphite (carbon) coated on copper current collector
    - Cathode:
      * Lithiated transition metal oxide coated on Aluminium current collector (E.g.: LiCoO2)
    - Electrolyte:
      * Mixture of carbonate solvents e.g.: diethyl carbonate and contain lithium salts like LiClO4
    - Separator:
      * Thin sheet of micro-perforated polypropylene
  + Working:  
    - charging:
      * Anode:
      * Cathode:
      * Overall:
    - Discharging:
      * Anode:
      * Cathode:
      * Overall:
  + Pros:
    - Lighter than other batteries for given capacity
    - High EMF
    - Low self-discharge rate
    - Good life cycle (elimination of dendrite formation)
  + Cons:
    - Rising internal resistance with age and cycles
    - Safety concerns over-heating / charging

## Fuel Cells

### Intro

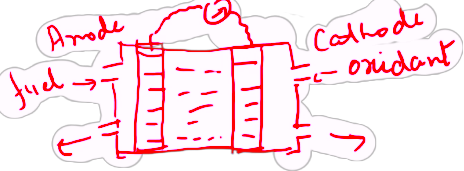
Fuel Cell



* + Fuel cell converts CE 🡪 EE directly with less loss of energy and efficiency (i.e., galvanic cell)
  + Does not store energy but converts CE 🡪 EE
  + needs continuous supply of fuel + oxidising agent to electrode
  + Advantages:
    - High power efficiency (50%-80%)
    - Eco-friendly
    - Silent
  + Disadvantages:
    - Cost of fuel cell is high (expensive electrode + catalyst)
    - Power output is mid
    - Fuel (gasses and O2) need to be stored @ high pressure
  + Applications:
    - H2-O2 fuel cells in newer hybrid cars

### Components

* + Fuel | Electrode | Electrolyte | Electrode | Oxidant



* + Anode 🡪 fuel gets oxidised (loss of e-)
  + Cathode 🡪 oxidant gets reduced (gain of e-)
  + Potential diff between anode & cathode due to redox 🡪 used as output

### Working

* + Anode:
    - Fuel → Oxidation product + ne
  + Cathode:
    - Oxidant + ne- → Reduction products
  + Fuels:
    - H2, CO, CH3OH, C2H5OH, HCHO, N2H4
  + Oxidants:
    - O2, H2O2, [X] (halogens)

### Efficiency

* + (∴ ΔG = -nFE)
    - η% = efficiency %
    - ΔG = electrical energy output
    - ΔH = heat energy output

### Types of fuel cells

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Alkaline | Phosphoric acid | Molten carbonate | Polymer electrolyte | Solid oxide |
| electrolyte | Aq. KOH | Conc Phosphoric acid | Molten carbonate (mixture of LiAlO2 + K2CO3 +Li2CO3) | ???  IDK | Ceramic oxide (capable of conducting oxide ions) (e.g.: ZrO2 doped w/ Y2O3) |
| Temp (OC) | Low  100 OC | Mid  160-220 OC | High  600-650 OC | ???  IDK | Very high  650-1000 OC |
| Catalyst | non-noble metal | Pt | Not required | Noble metal: Usually, Pt | Expensive catalyst not required (high temp) |
| Fuel & properties | Cannot use Carbon containing fuels as CO2 reacts w/ KOH to form K2CO3 which reduces efficiency | Only H2 used as fuel  H2 must be pure as Sulphur and CO compounds poison Pt catalyst | H2 or CO can be used | CO cannot be used (poisons Pt catalyst) | CO can be used |
| Extra Info | O2 reduction is more rapid in alkaline electrolyte v/s acid one | - | - | ???  IDK | Slow start-up |

## Alkaline Fuel cell

### Intro

### Construction

### Working

### Pros-Cons