CHAPTER 3 Batteries

Expected Outcomes

- What is a battery?
- Performance of batteries
- Types of batteries
- Advantages & Disadvantages
- Electric vehicles

Batteries

Contents

- What is a battery?
- Performance of batteries
- Types of batteries
- Advantages & Disadvantages
- Electric vehicles

What is a battery?

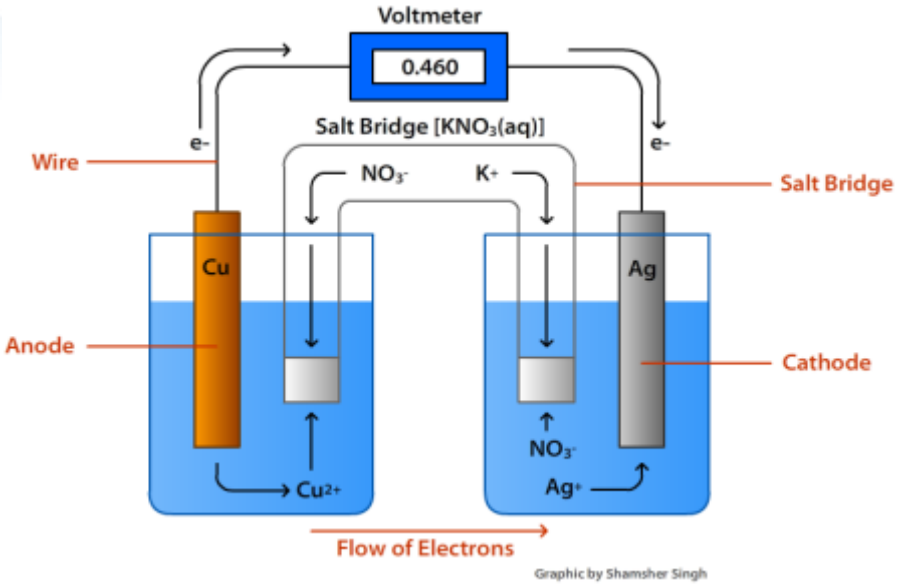
- **An electric battery is a device consisting of one or more electrochemical cells (battery cells) that convert stored chemical energy into electrical energy.**

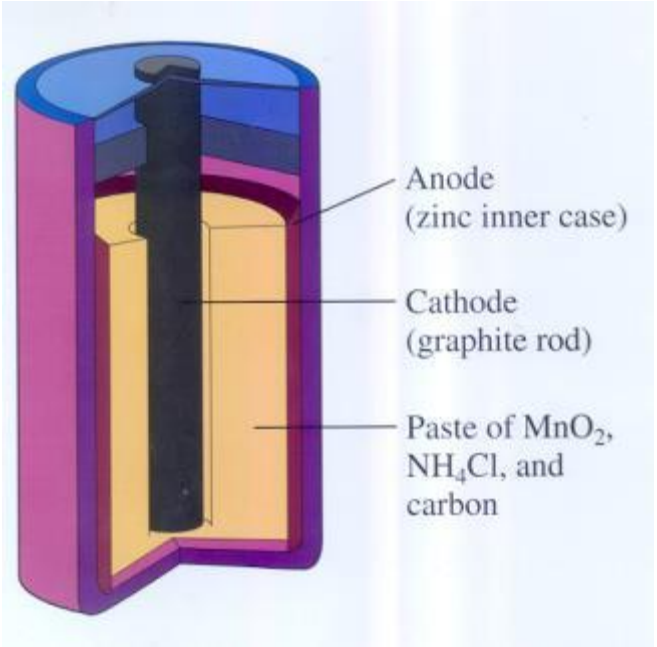
- **Each cell contains a positive terminal, or cathode, and a negative terminal, or anode. Electrolytes allow ions to move between the electrodes and terminals, which allows current to flow out of the battery to perform work.**

Types of battery cells

Wet cell- **A wet cell battery has a liquid electrolyte.**

e.g. , **Grove cell, Bunsen cell etc.**





http://www.upsbatterycenter.com/blog/what-is-a-dry-cell-battery/ 12/19/2015

A dry cell uses a paste electrolyte, with only enough moisture to allow current to flow.

e.g., Zinc–carbon battery or Leclanche cell.

Principle of operation

- **A battery consists of some number of voltaic cells. Each cell consists of two half-cells connected in series by a conductive electrolyte containing cathode and anode. The electrode to which anions (negatively charged ions) migrate; the other half-cell includes electrolyte and the positive electrode to which cations (positively charged ions) migrate.**
- **Cations are reduced (electrons are added) at the cathode during charging, while anions are oxidized (electrons are removed) at the anode during discharge.**

Major types of batteries

- ***Primary batteries*** **is a portable voltaic cell that is not rechargeable. When the supply of reactants is exhausted, energy cannot be readily restored to the battery.**
- ***Secondary batteries*** **can be recharged; that is, they can have their chemical reactions reversed by supplying electrical energy to the cell, approximately restoring their original composition.**

For example

In a zinc-silver oxide battery:

During Discharge

At anode: $Zn + 2OH^- \longrightarrow ZnO + H_2O + 2e^-$

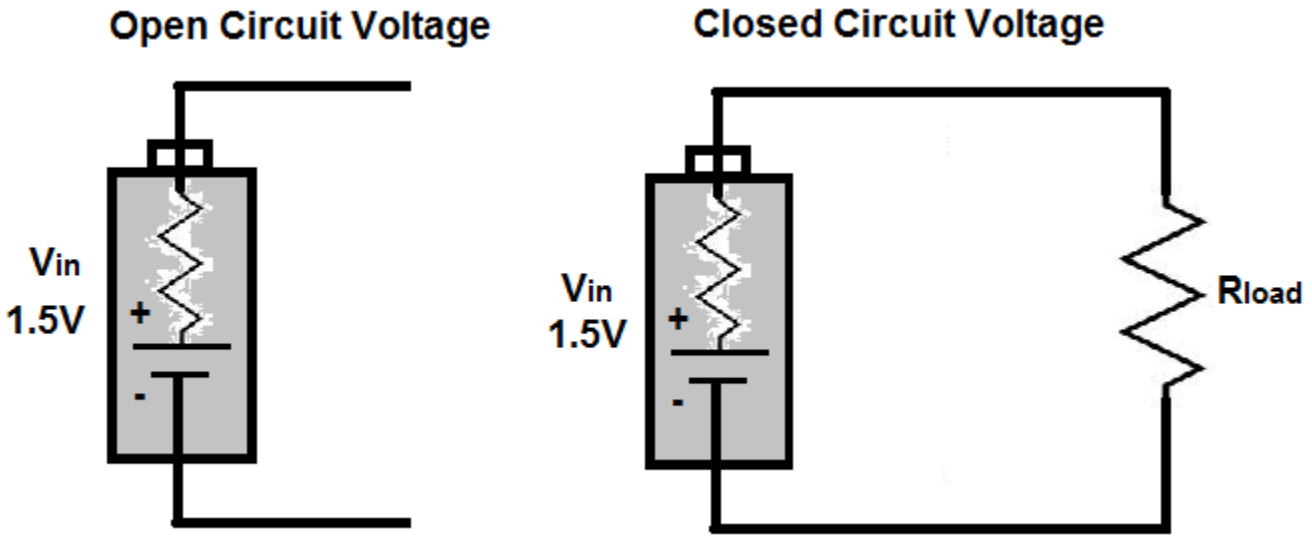
At cathode: $Ag_2O + H_2O + 2e^- \longrightarrow 2\,Ag + 2OH^-$

During charge

At anode: $ZnO + H_2O + 2e^- \longrightarrow Zn + 2OH^-$

At cathode: $2\,Ag + 2OH^- \longrightarrow Ag_2O + H_2O + 2e^-$

Open circuit voltage (V_o)



Source:http://www.learningaboutelectronics.com/Articles/What-is-open-circuit-voltage.php 12/19/2015

- **OCV is the difference of electrical potential between two terminals of a device when disconnected from any circuit.**
- **OCV is mainly affected by electrolyte concentration, degree of discharge, temperature.**

Discharge Voltage (V_d)

- **Discharge voltage is the prescribed lower-limit voltage at which battery discharge is considered complete.**
- **Because of electrode polarization and ohmic voltage drops, discharge voltage of a cell is lower than OCV and depends on the value of discharge current (I_d).**
- **Functional dependence of discharge voltage on discharge current is represented by**

$$V_d = V_o - I_d R_{int.}$$

Cell Capacity

- **The electric charge, $Q_{d,}$ that has passed through external circuit over a discharge period t, is given by**

$$Q_{d=} I_d \times t$$

This charge is expressed in Ampere-hours (Ah)

Operational characteristics

1. Temperature

- **At lower temperatures reactant utilization coefficients and discharge voltage are lower .**
- **Higher temperatures are favorable to side reactions like corrosion, thus reduces the efficiency of battery.**

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2. Lifetime parameters

- **Rate of self discharge is important factor in all batteries.**

Shelf life- maximum interval between utilization and manufacturing in discharge

Service life- charge-discharge cycles

Types of batteries

Primary Batteries

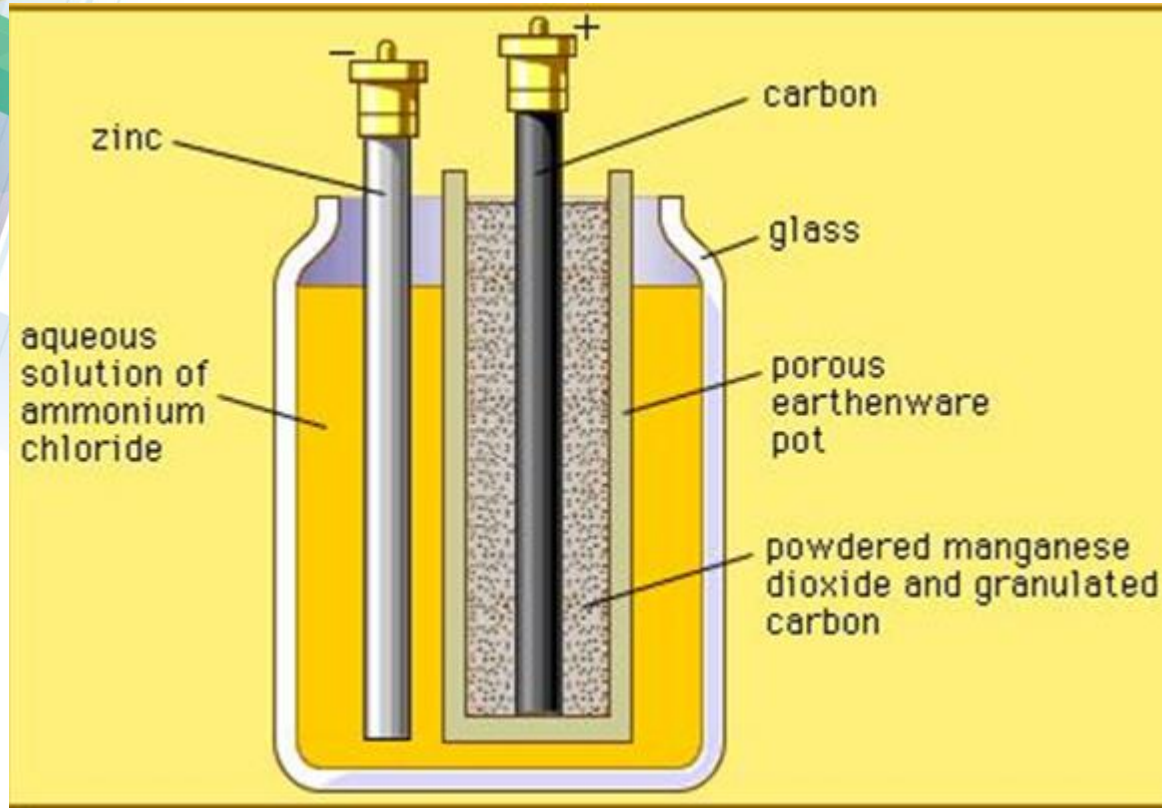
- Leclanche (Zinc-carbon) batteries
- Alkaline Manganese Dioxide batteries

Storage Batteries

- Lead-acid batteries
- Nickel-cadmium batteries
- Lithium-ion Batteries

Leclanche (Zinc-carbon) batteries

- **Invented and patented by the French scientist Georges Leclanche in 1866.**
- **The battery contained a cathode of carbon, a depolarizer of manganese dioxide, and an anode of zinc and a conducting solution of ammonium chloride.**



http://kids.britannica.com/comptons/art-106623/In-1866-Georges-Leclanche-invented-a-dry-cell-that-uses. 12/19/2015

- **At cathode: $2NH_4(aq)+2MnO_2(s)+2e- \rightarrow 2MnO(OH)+2NH_3$**
- **At anode: $Zn \rightarrow Zn^{2+} + 2e-$**
- **OCV of freshly manufactured zinc-carbon cells with salt electrolyte varies between 1.55-1.85V**

Advantages

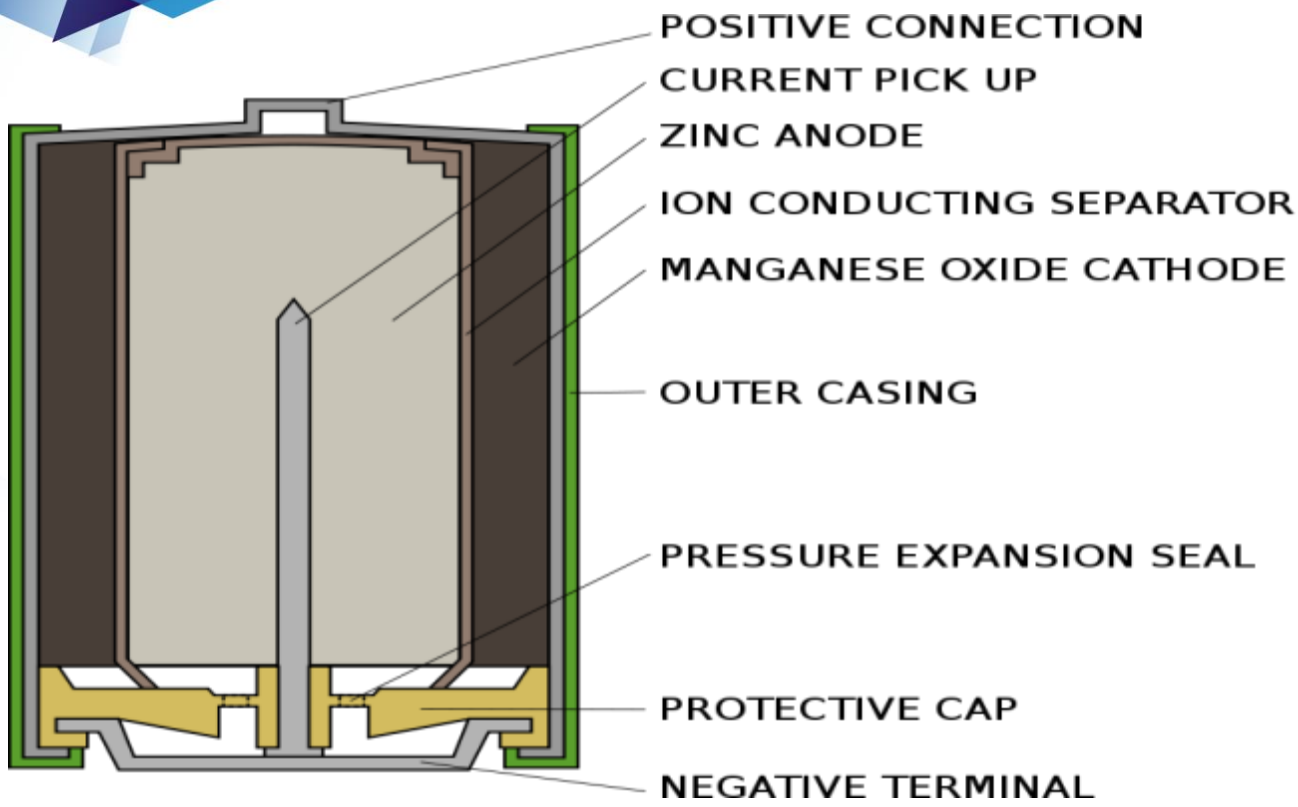
- They have appropriate storage life and offer suitable utilization.
- Reasonable electrical parameters.

Disadvantages

- Strong voltage decrease during progressive discharge.
- Depending on the load, the final voltage is just 50-70% of the initial value.

Alkaline Manganese Dioxide batteries

- **Alkaline batteries are dependent upon the reaction between zinc and manganese dioxide (Zn/MnO_2).**
- **First invented by Waldemar Jungner in 1899.**
- **It has an alkaline electrolyte of KOH**
- **In an alkaline battery, the positive electrode manganese dioxide and negative electrode is zinc .**



Source: en.wikipedia.org 12/19/2015

Advantages

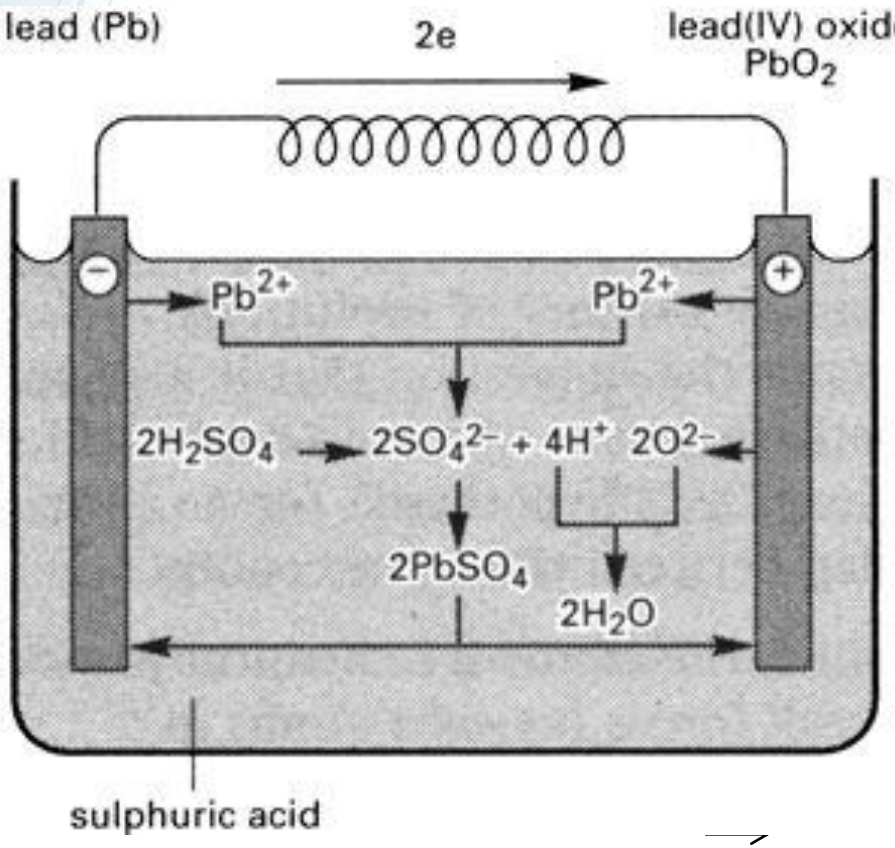
- It provide better performance at lower temperatures and high discharge currents as compared to Leclanche cells.
- Capacity of an alkaline battery is greater than an equal size Leclanche.

Disadvantages

- They are more expensive the Leclanche cells, but their cost per unit of energy is competitive and resources of raw materials are sufficient for mass production of these batteries.

Lead-acid batteries

- **The lead–acid battery is the oldest type of rechargeable battery and was discovered in 1859 by French physicist Gaston Planté.**
- **Large-format lead-acid designs are widely used for storage in backup power supplies in cell phone towers, high-availability settings like hospitals, and stand-alone power systems.**



Source: hyperphysics.phy-astr.gsu.edu. 12/19/2015

At anode: $Pb(s) + HSO_4^-(aq) \rightarrow PbSO_4(s) + H^+(aq) + 2e^-$

At cathode: $PbO_2(s) + HSO_4^-(aq) + 3H^+(aq) + 2e^- \rightarrow PbSO_4(s) + 2H_2O(l)$

Overall reaction: $Pb(s) + PbO_2(s) + 2H_2SO_4(aq) \rightarrow 2PbSO_4(s) + 2H_2O(l)$

Advantages

- **Simple to manufacture and inexpensive — in terms of cost per watt hours.**
- **Low self-discharge.**

Disadvantages

- **Low energy density**
- **Environmentally unfriendly —lead content and electrolyte can cause environmental problems .**

Nickel-cadmium batteries

- **The nickel–cadmium battery is a type of rechargeable battery and metallic Cd as negative electrode and nickel oxide hydroxide (positive plate), and an alkaline electrolyte KOH.**
- **The first Ni–Cd battery was produced by Waldemar Jungner.**
- **They can supply high surge currents. This makes them a favourable choice for remote-controlled electric model airplanes, cars, telephones, emergency lighting, as well as camera flash**
- **Low internal resistance**

- At cathode: $2NiO(OH) + 2H_2O + 2e^- \longrightarrow 2NiO(OH)_2 + 2OH^-$
- At anode: $Cd + 2OH^- \longrightarrow Cd(OH)_2 + 2e^-$
- Overall reaction:
- $2NiO(OH) + Cd + 2H_2O \longrightarrow 2NiO(OH)_2 + Cd(OH)_2$

Advantages

- Simple and fast charge — even after long time storage.
- High number of charge/discharge cycles — if properly maintained, the NiCd provides over 1000 charge/discharge cycles.
- Good load performance.

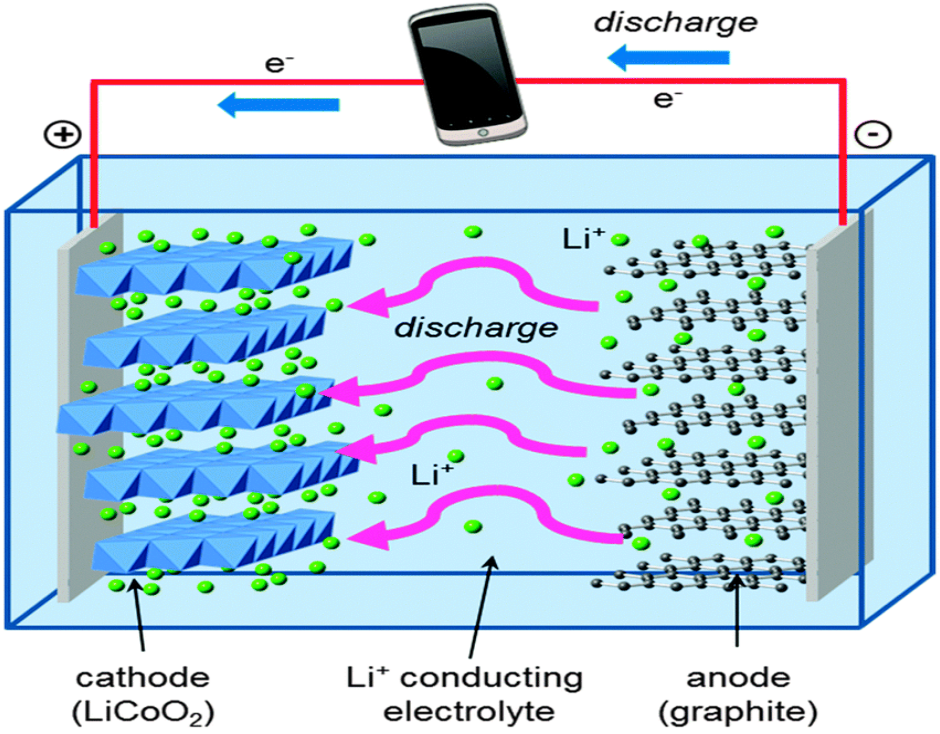
Disadvantages

- Relatively low energy density.
- Environmentally unfriendly.

Lithium-ion Batteries

- . The positive electrode is a metal oxide and negative electrode is made from carbon and the electrolyte is a lithium salt in an organic solvent.
- Lithium batteries were first proposed by M. S. Whittingham, at Binghamton University.

- **The electrolyte is typically a mixture of organic carbonates such as diethyl carbonate or ethylene carbonate containing complexes of Li ions. These non-aqueous electrolytes generally use non-coordinating anion salts such as lithium tetrafluoroborate (LiBF4) lithium perchlorate (LiClO4), lithium hexafluoroarsenate monohydrate (LiAsF6), etc.**
- **It reacts vigorously with water to form lithium hydroxide and hydrogen gas.**



At anode:

$$x\mathrm{Li}^+ + x\mathrm{e}^- + x\mathrm{C}_6 \leftrightarrows x\mathrm{LiC}_6$$

At cathode:

$$\mathrm{LiCoO_2} \leftrightarrows \mathrm{Li}_{1-x}\mathrm{CoO_2} + x\mathrm{Li}^+ + x\mathrm{e}^-$$

The overall reaction has its limits. Overdischarge supersaturates lithium cobalt oxide, leading to the production of lithium oxide, possibly by the following irreversible reaction

www.androidheadlines.com 12/19/2015

$$\mathrm{Li}^+ + \mathrm{e}^- + \mathrm{LiCoO_2} \rightarrow \mathrm{Li_2O} + \mathrm{CoO}$$

- **Overcharge up to 5.2 volts leads to the synthesis of cobalt (IV) oxide**

$$\mathrm{LiCoO_2} \rightarrow \mathrm{Li}^+ + \mathrm{CoO_2} + \mathrm{e}^-$$

Advantages

- High energy density — potential for yet higher capacities.
- Relatively low self-discharge.
- Low Maintenance.

Disadvantages

- Expensive to manufacture .
- Better manufacturing techniques and replacement of rare metals with lower cost.

TGV trains at Paris Gare de l'Est

Source: en.wikipedia.org 12/19/2015

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