

ELECTROCHEMISTRY

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PART I

- Definition

Electrochemistry learns about the chemical difference produced by the electricity current as well as the electricity current formation by chemical reactions. All electrochemical reactions involve electron transfer (oxidation-reduction reaction). Both oxidation and reduction reaction can be divided physically, thus, oxidation happens in the first place and reduction happens in another place.

Electrochemical process requires several ways to conduct electricity into reaction system. Reaction system happens in a “**cell**” and electric current enters and leaves through “**electrode**”.

Comparison Between Galvanic Cells and Electrolytic Cells

Galvanic Cell (or Voltaic Cell)	Electrolytic Cell
Converts chemical energy into electrical energy.	Converts electrical energy into chemical energy.
Contain negatively charged anodes and positively charged cathodes.	Contain positively charged anode and negatively charged cathode.
Feature spontaneous cell reactions.	Feature non-spontaneous cell reactions.

- Electric Conduction

The electric current causes charge transfer. The charge can be transferred through metal and through the pristine electric liquid (salt melt) or called the metal conduction. Meanwhile, ionic/electrolyte conduction is the electric current conduction with the ionic movement through the pristine solution or liquid. The positive ion will move to the negative electrode, while the negative ion will move to the positive electrode. This electric conduction happens inside the electrochemical's cell.

- Electrode

The electrode is the surface where half-oxidation or reduction reaction happens. Electrodes can be included or not into reactions. The electrode that is not reacted is called inert electrode. By neglecting electrolysis or volta cell type, the definition of electrode is:

- ✓ Katode = the electrode where the reduction happens (electrons produced)
- ✓ Anoda = the electrode where the oxidation happens (electrons gone)

- Electrolytic Cell

In several electrochemical cells, the non-spontan chemical reaction is forced to happen by infiltrating the electric energy inside. This process is called the electrolysis. An electrolysis cell consists of mediums for reaction materials with electrodes soaked inside and connected by a direct source. The inert electrode is often used so that it is not reacted.

- The electrolysis of sodium chloride melt (down cell)

The NaCl solid cannot conduct electric current. Vibrated ions on the steady position but it's not free in movement through crystal. Meanwhile, the NaCl melt is a good conductor because the ions move freely. On a cell where a direct source is connected by a wire on the soaked graphit electrode (figure 1) in a medium containing the NaCl melt.

1. The formed light-green gas is chlorine (Cl_2) on an electrode.
2. The white silver sodium (AgNO_3) metal, Na, is formed on another electrode and floats above the NaCl melt.

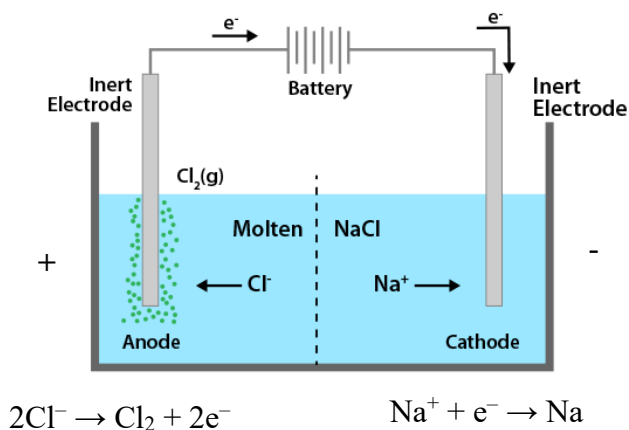


Figure 1. The Electrolysis Scheme

Reaction at Cathode: $[\text{Na}^+ + \text{e}^- \rightarrow \text{Na}] \times 2$

Reaction at Anode: $2\text{Cl}^- \rightarrow \text{Cl}_2 + 2\text{e}^-$

Cell Reaction: $2\text{NaCl} \rightarrow 2\text{Na} + \text{Cl}_2$

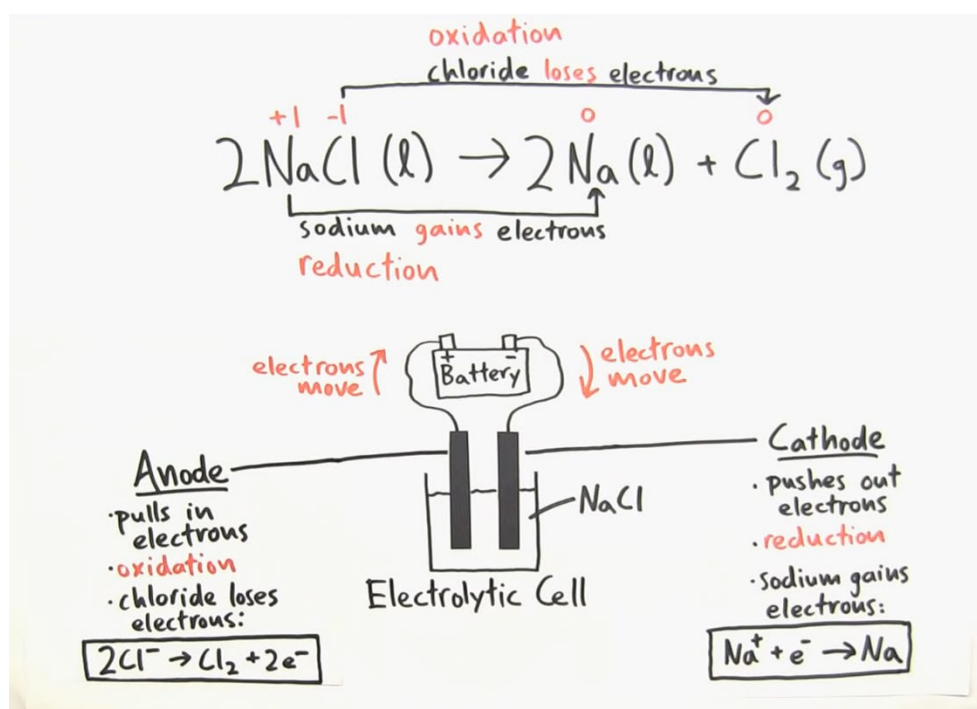
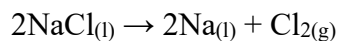
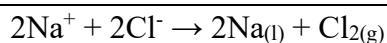
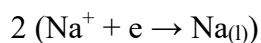
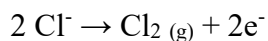


Figure 2. The Detail of The Electrolysis of NaCl

Based on the observation, we can conclude those processes that happened in cell. Chlorine is resulted in from the ion Cl^- oxidation, the electrode causes this happen is certainly the anode. The ion sodium is resulted in by the ion Na^+ reduction on cathode.



The metal sodium and gas Cl_2 formation from NaCl is non-spontaneous unless done in the temperature is higher than 801°C . The DC direct way source should provide electric energy to force the reaction happen. The electron is used on the half-cathode reaction (reduction) and resulted in half-anode reaction (oxidation). Thus, the electrons move through wires from anode to cathode. The DC current source pushes electrons to move unspontaneously from the positive to negative electrode.

In electrolytic cells: the anode is a positive electrode and the cathode is a negative electrode.

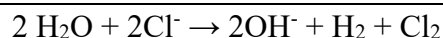
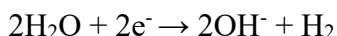
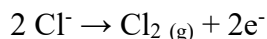
Sodium and chlorine are not allowed to contact one another because it can be reacted spontaneously fast and causing the explosion to form sodium chloride. The down process is used in industry to result in the metal sodium. The down cell is astonishingly expensive especially because of the NaCl construction, electricity, and heating cost. However, the NaCl molten electrolysis is the most efficient way to produce the metal Na , which is so reactive. After produced by the electrolysis, the Na liquid is separated, cooled, and printed in boxes. The metal Na should be stored in the inert environment (in example, inside the mineral oil) in order to avoid the reaction with O_2 or other components at atmosphere.

- The sodium chloride liquid electrolysis

In the NaCl liquid electrolysis that is a little bit denser, then it uses the inert electrode. The result observation of the experience that happens when used the quite high electrical voltage on the electrode is:

1. Gas H_2 is resulted in one electrode, and the solution turns base.
2. Gas Cl_2 is resulted in on another electrode.

In this cell, the chloride ion is oxidized to be Cl_2 , meanwhile on cathode, ion Na^+ is not reduced to be the metal Na . but, it produces gas H_2 and ion OH^- because of the molecules H_2O reduction. Water is easier to get reduced instead of ion Na^+ . This thing is primarily is caused by the ion Na^+ reduction that will result in H_2 and H_2O which are more stable. The active metals such as Li , K , and Na are substituted by H_2 from the watery liquid, hence, it doesn't form metal inside the watery liquid.



PART II

- Faraday law about the elektrolysis

In the year 1832-1833, Michael Faraday learnt the electrolysis process. He concluded into the Faraday law of electrolysis.

The number of substances that experience either the oxidation or reduction on electrodes respectively as long as the electrolysis equal with the total electric current that passes the cell.

One faraday is total electric that still connects $6,02 \times 10^{23}$ electrons or one mole electron.

To calculate total and electric energy that interacts with the material should learn related units:

1. Charge, C, is an electric current unit. The charge of 1.0 mole of electron is called 1 Faraday is 96.487 C or ≈ 96.500 C and the charge of 1 electron is 1.60×10^{-19} C.
2. Ampere, A, is an electric current unit. One ampere is current that goes through every point 1 coulomb per second: $1 \text{ A} = 1 \text{ C/s}$.
3. One joule of energy requires to place one coulomb of current goes through a potential 1 Volt. Volt, V is a potential that causes a charge flows: $1 \text{ J} = (1 \text{ V})(1 \text{ C}) = (1 \text{ V})(1 \text{ A})(1 \text{ s})$.

A common electric current unit used in chemistry, physics, and electronic is Coloumb (C). One coulomb is total charge that passes through certain points when 1 Ampere (A) of electric current flows for 1 second. An ampere current equals 1 coulomb per second. One faraday equals 96.485 coulombs.

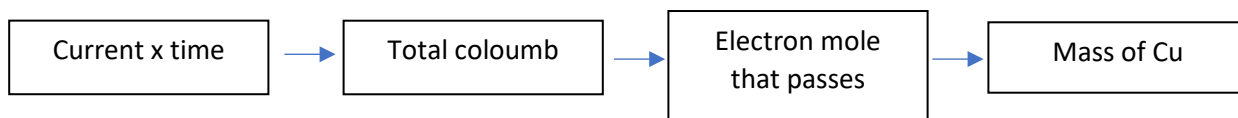
$$1 \text{ ampere} = 1 \frac{\text{coloumb}}{\text{second}} \quad 1 \text{ faraday} = 6,022 \times 10^{23} e^- = 96.485 \text{ C}$$

Example =

1. The electrolysis of copper (II) sulfate for 50 minutes!

The solution :

A half of reaction that depicts the reduction of ion Cu^{2+} shows total electron mole that is needed to produce one mole of the metal Cu. Each electrom mole connects 1 faraday, or 96.500 C. the current and time can be changed to be total coulomb.



The reduction of Cu^{2+} to be the metal Cu is:

$\text{Cu}^{2+} + 2e \rightarrow \text{Cu}$, total coulomb that is retrieved is current \times time:

$$C = 50 \text{ min} \times \frac{60 \text{ s}}{1 \text{ min}} \times \frac{2,50 \text{ C}}{\text{s}} = 7,5 \times 10^3 \text{ C}$$

Then, calculate the mass of Cu. The molecular weight of Cu is 63,5 g/mole. From the equation, 63,5 g Cu is deposited for every 2 electron moles or to every $2 \times 96500 \text{ C}$, so that the mass of Cu is obtained:

$$g \text{ Cu} = 7,50 \times 10^3 \text{ C} \times \frac{1 \text{ mole of } e^-}{9,65 \times 10^4 \text{ C}} \times \frac{63,5 \text{ g of Cu}}{2 \text{ mol of } e^-} = 2,47 \text{ g of Cu}$$

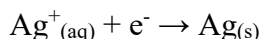
2. Calculate the mass of the metal copper that is produced from the solution CuSO_4 that passes the current of 3,00 A for 7.250 seconds!

The solution:

$$7250 \text{ s} \left(\frac{3,00 \text{ C}}{1 \text{ s}} \right) \left(\frac{1 \text{ mole of } e^-}{96.500 \text{ C}} \right) \left(\frac{1 \text{ mole of Cu}}{2 \text{ mole of } e^-} \right) \left(\frac{63,5 \text{ g of Cu}}{1 \text{ mole of Cu}} \right) = 7,16 \text{ g of Cu}$$

3. Calculate the required time to deposit 7,0 g of silver of the solution AgNO_3 with the current of 4,00 A!

The solution:



$$7,00 \text{ g of Ag} \left(\frac{1 \text{ mole of Ag}}{108 \text{ g of Ag}} \right) \left(\frac{1 \text{ mole of } e^-}{1 \text{ mole of Ag}} \right) \left(\frac{96.500 \text{ C}}{1 \text{ mole of } e^-} \right) \left(\frac{1 \text{ s}}{4,00 \text{ C}} \right) = 1560 \text{ s (26,1 mins)}$$

PART III

- Electrochemical Application

- ✓ Battery cell

A battery is a device that is able to produce Direct Current (DC) Voltage, which constitutes, by the way, changing the chemical energy that is contained in it to the electrical energy through electrochemical reactions.

The battery that is widely known so far has a shape of a solid cylinder and solid box. The can containing these chemical materials functions as the power source because it can produce the electron current once it is connected to various electronic devices. These flowing electrons constitute the result of the electrochemical reactions between various chemicals that are arranged in certain ways inside. The reaction is called electrochemistry because both reduction and oxidation reactions (redox) happening between chemical

compounds that create a battery are always included by releasing and absorbing electrons that cause electricity occurrence.

The electron release happens on the negative electrode (or called the negative pole) because there is a reaction with the liquid or electrolyte paste. The positive electrode (positive pole) constitutes the pole that needs electrons so much so that it always strives to catch electrons. The electrons are released on negative poles striving to look for ways to reach the positive pole. Inside the battery is the same utterly as the way connecting the positive and negative poles. Thus there is no current anymore.

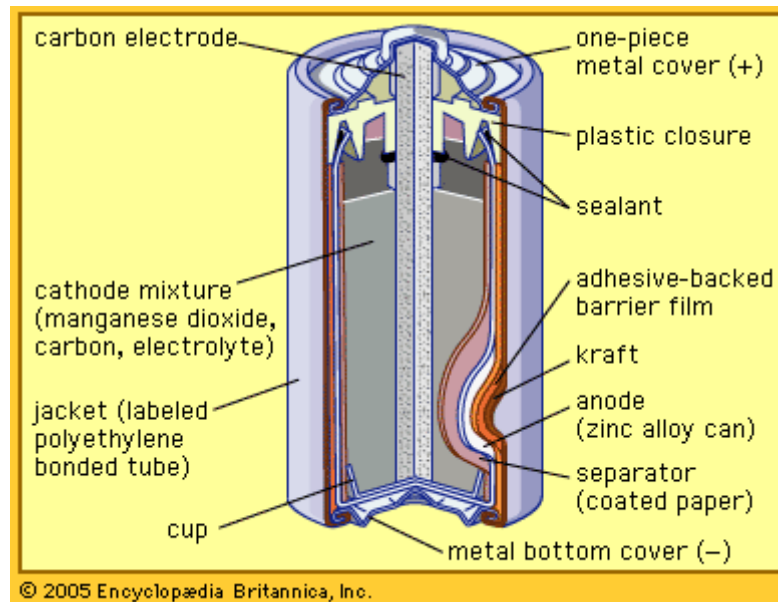


Figure 3. The Battery Composition

In Figure 3, it can be seen that the positive pole of battery is located in the upper end of battery, while the negative pole is located in the lower. The positive electrode of battery is really separated from the negative pole (called open circuit), so that inside the battery is not possible to conduct the electron current. Indeed, this is intended because if the negative pole meets directly the positive pole, the electrons are able to flow easily in the battery until it is empty and useless.

If it is installed a connecting wire or cable that connects the positive pole of battery to the negative pole, then electrons in the negative pole will find the way. These electrons flow through that wire or electric cable, so eventually it can reach the positive pole. Along the road, it can be put various electrical devices that require the electric current as their power, indeed. When the current passes a lamp, then the lamp will turn on until there's no electrons passing through (until there is no potential difference between both poles).

There are various both metals and electrolyte liquids or pastes that are used to arrange a battery. The materials sometimes have characteristics that are toxic for humans, then they should be wrapped inside a “can” to void the leakage.

There are 2 ways happening in a battery

	Charging Process	Using Process
Type of Cell	Electrolysis	Volataic
Scheme	Electric energy → chemical energy	Chemical energy → electric energy

✓ Types of battery

Battery can be classified into 2:

1. The primary battery (unrechargeable battery), which is a battery that is only used once, and after the content is empty or after the components already reached the equilibrium concentration, the the battery is useless.
2. The secondary battery, which is the battery that can be used several times by recharging the charge, if the energy is used empty, then it can be recharged by giving the electric energy in order to make a reversible reaction, and it forms the reactans again. So, in this kind of battery, the voltaic cell is periodically converted to the electrolysis cell.

This is the table of battery types

TABLE 1 COMMON BATTERY TYPES					
Battery	Anode (-)	Cathode (+)	Nominal voltage (V)	Approximate energy density (MJ/kg)	Special characteristics
Alkaline	Zinc	Manganese dioxide	1.5	0.5	Long shelf life, supports high-to medium-drain applications
Zinc-carbon	Zinc	Manganese dioxide	1.5	0.13	Economical in cost per hour for low current consumption
Lithium (BR)	Lithium	Carbon monofluoride	3	1.3	Wide temperature operation, high internal impedance, low pulse current
Lithium (CR)	Lithium	Manganese dioxide	3	1	Good pulse capability, stable voltage during discharge
Lithium-thionyl chloride	Lithium	Sulfur-oxygen chlorine	3.6	1.04	Low self-discharge rate, can support 20-year battery
Zinc-air	Zinc	Oxygen	1.4	1.69	High energy density, battery life of weeks to months

✓ Dry cell

The dry cell is sort of battery that has been widely used since decades ago. A battery cell has the capacity of 1,5 volt. The positve pole (anode) uses Zn in a can shape, while the negative pole (catode) uses MnO₂, the used electrolyte is a paste that contains HH₄Cl,

ZnCl₂, H₂O, and starch. The powder grafit is used to increase the conductivity because MnO₂ is a weak electric conductor.

The benefits of this kind of battery is inexpensive, secured, available in various sizes. Meanwhile, the drawback is it will form NH₃ gas that causes the voltage drop in the high electric current decrease. In the high temperature, the capacity of leclanche cell will drop drastically. In that so, this battery storage should be placed in the lower temperature.

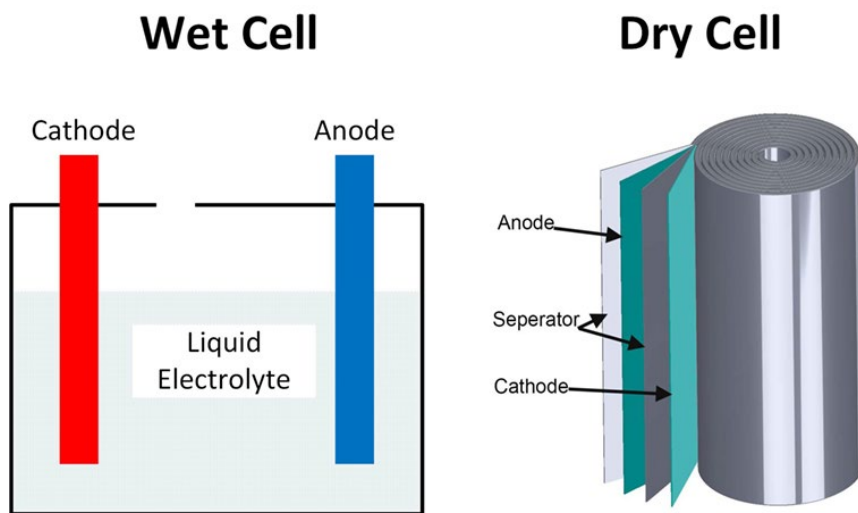
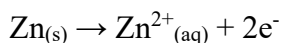


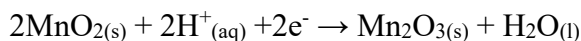
Figure 4. The Wet and Dry Cell

The occurred reaction is:

Inside the dry cell, zinc is anode (-). The zinc is oxidized based on a half-reaction:



The graphite rod that is surrounded by the powder of mangan (IV) oxide is cathode (+). Mangan oxide is mixed by the carbon powder to enhance the cathode mixture conductivity. The reaction that happens on cathode is:



The ion H⁺ is sourced from NH₄⁺_(aq):

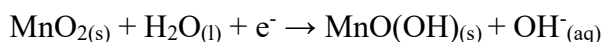


Next, NH_3 is combined with the Zn^{2+} . At this half-reaction, mangan is reduced from the oxidation number (+4) to (+3). At this cell, it also contains side reactions. However, the zinc-carbon cell overall is:

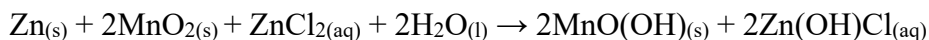


A battery has e.m.f that is worth 1,5 V. Because there are a side reaction and activation drop of chemicals increasing the resistance in battery. Hence, it causes the e.m.f drop. When the dry cell is already used for certain times, the zink medium will be thin because the metal Zn is oxidized to the ion Zn^{2+} , which causes the possible leakage of the zinc chloride out of battery.

The “heavy duty” zink-chloride cell is the development from the original one using more pristine chemicals and giving more long-lasting life time as well as the output is much stable. The mixture of electrolyte contains much NH_4Cl , which is substituted by the paste ZnCl_2 only. The reaction that occurs on the cathode is:



The rest of reaction is going to be:



PART IV

✓ Alkaline battery

The alkaline battery is an improvement of the dry cell. The half reaction is still same. Yet, the electrolyte that is used is KOH paste. The base electrolyte decrease the gas formation. The benefits if we compare with the dry cell are the density is higher, there is no voltage drop in the alkaline cell, more long-lasting life time.

The zink has a shape of powder to increase the anode large surface, ease the particle interaction. This thing can decrease the internal resistance, and increase the power density. The yield of the MnO_2 cathode should be high. The graphite is also used to increase the conductivity. KOH as electrolyte is a very good conductor. Zinc oxide is often added to slow down the Zn anode corrosion. The selulose derivation is added as the gel maker. These materials cause the alkaline to be more expensive than zinc-carbon.

The reaction that occurs:

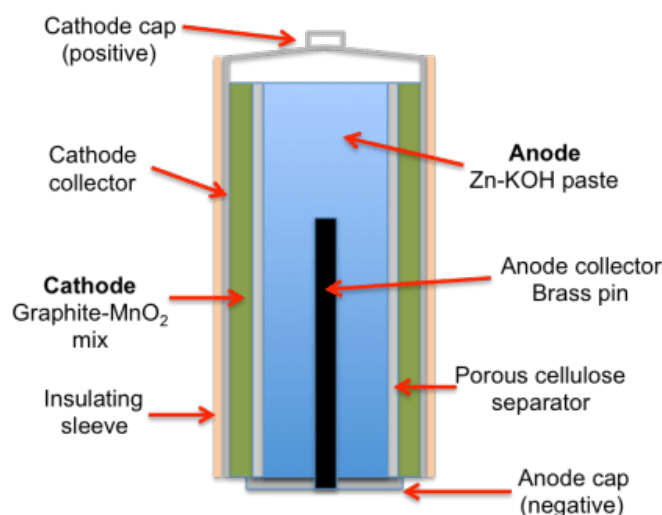
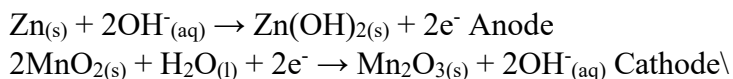


Figure 5. The Composition of Alkaline Battery

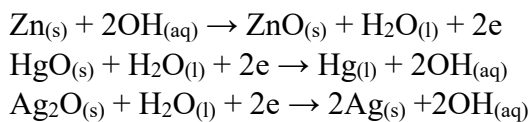
There are other cells that are designed such as the alkaline cell, among others are the mercury oxide and silver oxide.

✓ Mercury oxide and silver oxide cell

Both mercury and silver look quite similar. Both use the Zn anode (reductor) in a basic medium. One of them is HgO and AgO as oxidator and both use the steel cathode. The solid reactant is solidified apart with KOH with wet paper as a salt bridge.

This kind of battery is widely used for watch and calculator, the silver cell is used for camera, heart pace maker, and hearing aid. Both are small and have the high voltage. The silver cell has a stable output and non-toxic. Meanwhile, mercury releases the toxic metal. In addition, the silver cell is more expensive.

The reaction:



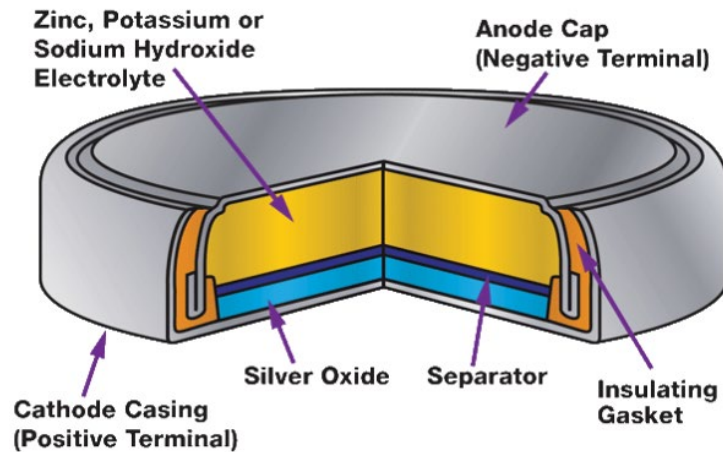


Figure 6. The Composition of Silver Oxide Battery (Button Cell Battery)

✓ Lithium battery

Lithium battery is sort of new for a primary cell, which has the high voltage in output, longer lifetime, light, and small. Therefore, this battery is used for a special purpose. The no-load output voltage can reach 2,9 volt or 3,7 volt, depending on electrolyte used. The lithium usage is so limited, it is usually used for the military scope, because if we do not take care for use, it will blow up.

✓ Lead-acid battery

The most known secondary a lead-acid cell, which is created by Gaston Plante' in the year 1859. The reaction that flows to the right for discharge, and to the right for charging. The total number of charges can be calculated by measuring the sulfate acid electrolyte density. Sulfate acid has higher density than water. Hence when the cell is discharged, the electrolyte density is reduced.

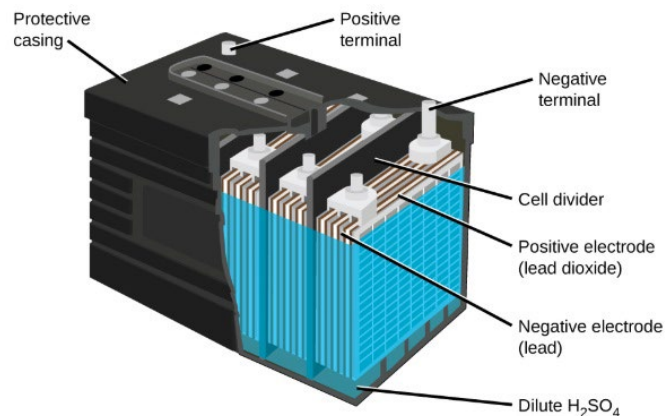


Figure 7.The Lead-Acid Storage Cell and Plate Construction

The sulfate acid electrolyte is prone to be denser when the temperature drops, hindering ion rates between plates and can cause the flowing current drop. This thing causes the difficulty when turning vehicle on in cold day

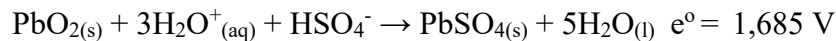
Each cell contains the metal electrode Pb and tin(IV) oxide PbO_2 in electrolyte liquid (33.5%) v/v (6 molar) H_2SO_4 . When both electrodes are discharged forming PbSO_4

Reaction:

❖ Anode (oxidation)



❖ Cathode (reduction)



Because open cell with the liquid electrolyte, overcharging with the excessive voltage will produce oxygen and hydrogen gas forming a mixture that is able to blow up. The acid electrolyte is also corrosive.

Nowadays, cells that are used are not created by pure lead, but they are added in a small quantity of antimony, tin, calcium, or selenium as a filler in the plate material. Because electrolyte has a role in the charge-discharge reaction. Then it is quite to determine the charges by calculating the specific gravity (sp gr) of the electrolyte solution. Sp gr will drop when a battery is discharged, several designs of battery allow to have the hydrometer, which is installed using a colored ball that floats.

Here is the process of the discharged and charged in a Pb-acid cell:

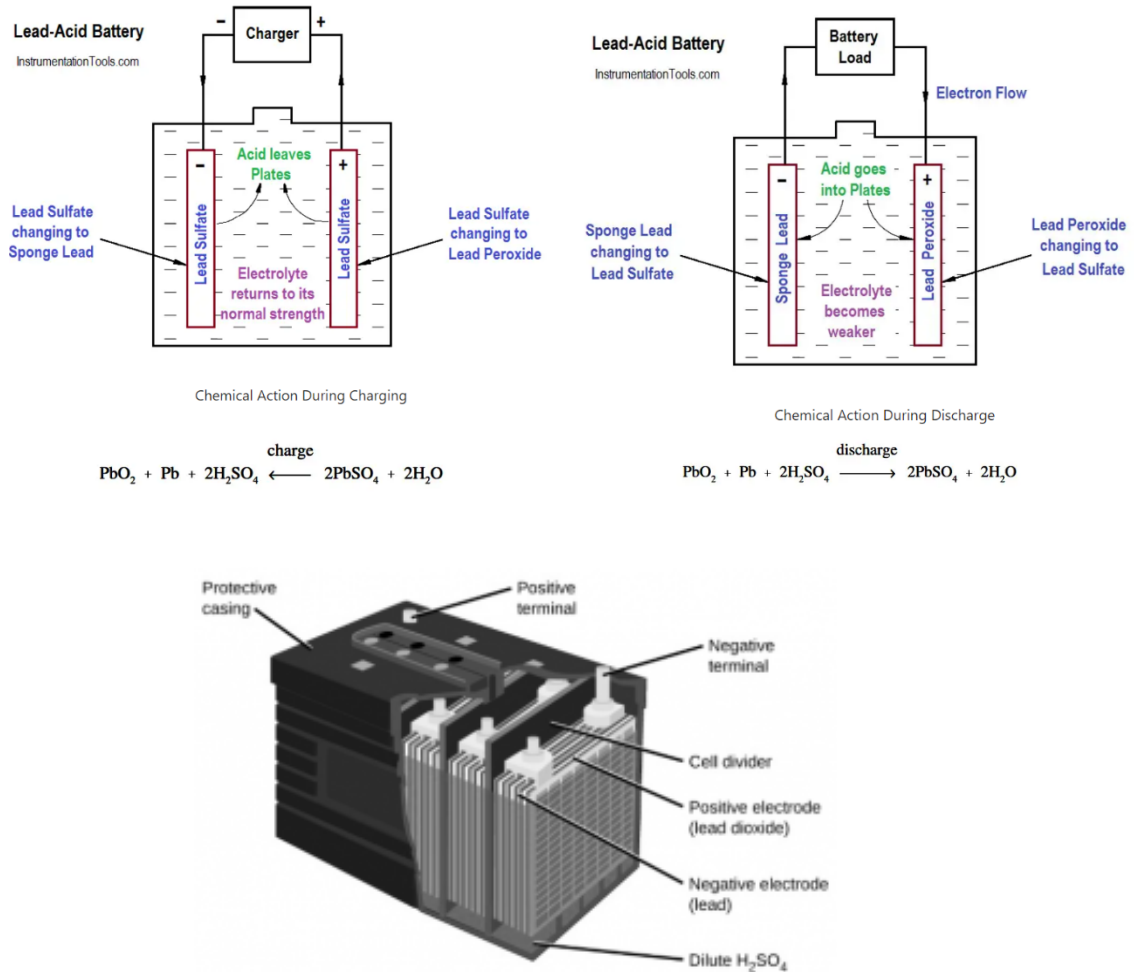


Figure 8. The Charge and Discharge of Lead-Acid Battery

✓ Recharger battery of NiCd, NiMH, and Lithium (Li-ion)

This type of rechargeable battery is divided into 3 common categories: nickel cadmium (NiCd), nickel metal-hydride (NiMH), and lithium-ion (Li-ion). In addition, there is also lithium polymer (Li-poly) type that is extremely thin. But it is so expensive, and rarely can it be available in the market.

❖ NiCd battery

NiCd battery has a half reaction that oxidizes cadmium in the base electrolyte (NaOH or KOH) while nickel (III) as $\text{NiO}(\text{OH})$ reduced on cathode.

This NiCd battery is infamously used in cutting tools, camera, etc.

The benefits of this battery are light, however, the drawbacks are to produce cadmium toxic compound.

The reaction:

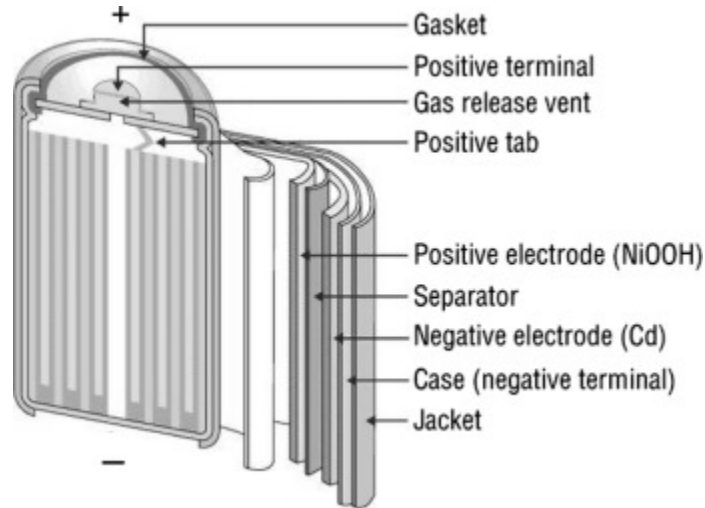
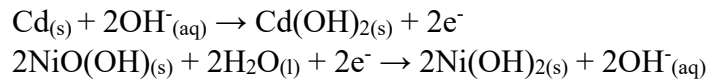


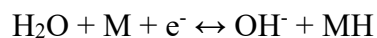
Figure 9. The NiCd Battery Components

The NiCd battery is the oldest, the most durable, yet it is heavy, and the biggest in volume size. This sort of battery is no longer used massively in camera due to be assumed not practical. The NiCd battery is prone to have memory effect. That means the battery is only recharged in the level where the last battery is discharged because of gas accumulation trapped inside the battery plate cell. In example, if the battery is discharged up to 30% and recharged, then the battery will be only recharged in energy up to 30%, and followed by the depreciation of “gas” volume that is trapped.

❖ Nickel-metal hydride battery (NiMH)

The NiMH is a secondary battery, which is similar to a NiCd battery unless it uses alloy that absorbs hydrogen as negative electrode instead of cadmium. It's similar with a NiCd battery, the positive electrode is nickel oxyhydroxide (NiOOH). The NiMH battery can have 2 capacities until 3 times the size of NiCd.

The reaction that occurs in the negative electrode:



The reaction is equilibrium. The electrode is charged to the right and discharged to the left. In the positive electrode, formed nickel oxyhydroxide,



The symbol “metal” M in the battery negative electrode NiMH is actually an intermetallic compound. Many different compounds were already developed for this application, but it can be divided into two classes. The most common is AB₅, where A is the mixture of lanthanum, cerium, neodymium, praseodymium and B is nickel, cobalt, manganese, and/or aluminum.

Ni-MH can resist 40% longer compared to Ni-Cd with the same size and has lifetime into 60 cycles, so that it is so useful for high energy tools or devices such as laptop, cell phone, and camcorder.

NiMH is the development of NiCd, compared NiCd with the same volume, the capacity is much more huge. Yet, as it goes for NiCd, NiMH is prone to memory effect, although it is not as massive as NiCd. Some battery producers even state the NiMH battery is free of memory effect. This phenomenon appears once the battery hasn't been empty completely yet but already recharged. If it is done several times, then the battery will lose its capacity and it will be able to hold little power before it'll be empty soon. The memory effect can be removed by burning the battery until empty before being recharged.

❖ Lithium-ion battery

The Li-ion battery one of secondary battery types that is massively used for electronic portables especially for laptop, PDA, cell phone, and iPod. The Li-ion battery is often used because it has many benefits such as:

1. Commonly it is lighter than other rechargeable batteries with same size. Electrodes used are light materials such as lithium and carbon. Lithium is the heavily reactive substance, so that much energy is stored in atomic bonds (having huge energy density).
Examples: the Li-ion battery can store 150 watt-hours of electricity in 1 kg of battery. Meanwhile, the lead-acid battery can store 25 watt-hours in 1 kg. That means it requires 6 kg of the lead-acid battery to store a number of the same energy as 1 kg of Li-ion battery.
2. There are just fewer charges that will be lost when they are not used. The Li-ion battery just loses 5% of its electric charge per month compared to Ni-MH, which loses 20% of its electric charge per month.
3. It doesn't have memory effect. That means we unnecessarily burn the whole battery before it is recharged as other batteries'.

The drawbacks of Li-ion are:

1. The Li-ion battery will start degraded once it leave the production plant, and it just survives about 2 years after the production date.

2. Too sensitive upon the high temperature. Heat causes the battery degraded faster than in normal condition.
3. There is a chance if the packaging of the battery is broken causing explosion.

Inside the Li-ion battery:

The Li-ion battery has various sizes, but the interior is the same. Here is the figure of the Li-ion battery interior.

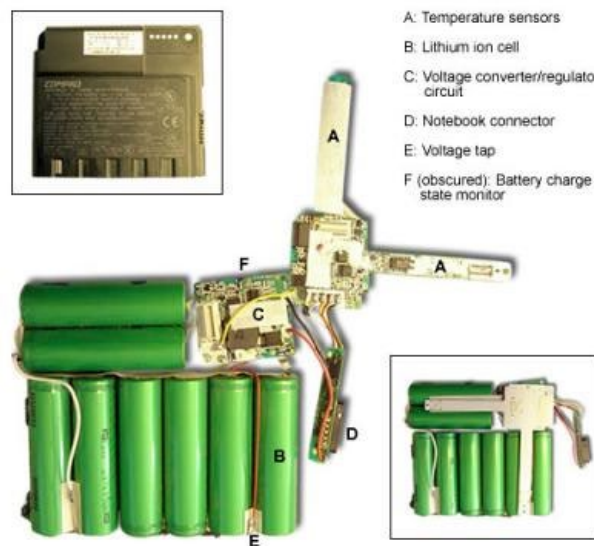


Figure 10. The Li-ion Battery Interior

The Li-ion cell also can be cylinder, prism, or square in shape

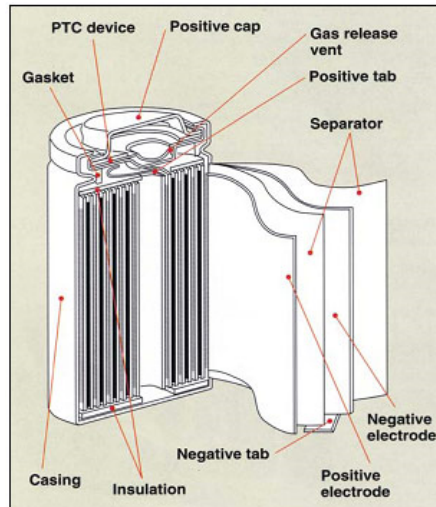


Figure 11. The Li-ion Cell Cylinder

The metal application is important because of pressure in a battery. In the metal, there is a ventilation hole. If the battery is too hot, it risks the explosion due to the excessive pressure, this ventilation will release the excessive pressure. Same as the switch PTC (Positive Temperature Coefficient), which is a tool to keep the battery safe from the excessive heat.

This cylinder metal functions to hold the spiral consisting of three thin layers that are pressured together, they are the positive electrode, negative electrode, and separator.

In a battery, these three thin layers are soaked by an organic solvent that functions as an electrolyte. The common solvent used is ether. The separator is a sheet of plastic that is so thin, which separates the positive electrode and the negative electrode by going through them with ions.

The positive electrode is made by LiCoO_2 , and the negative electrode is carbon

The lithium ion moves from anode to cathode. The lithium ion moves from anode to cathode for discharging and from cathode to anode for charging.

Three primary Li-ion battery components are anode, cathode, and electrolyte that are many material types used. The anode that is widely used in commercial is graphite. The common cathode is a sheet of oxide such as lithium-cobalt oxide. The polyanion base such as lithium ferro phosphate, or spinel such as lithium mangan oxide. It depends on the material selection for anode, cathode, and electrolyte, capacity, lifetime, and the Li-ion battery's security that can change dramatically.

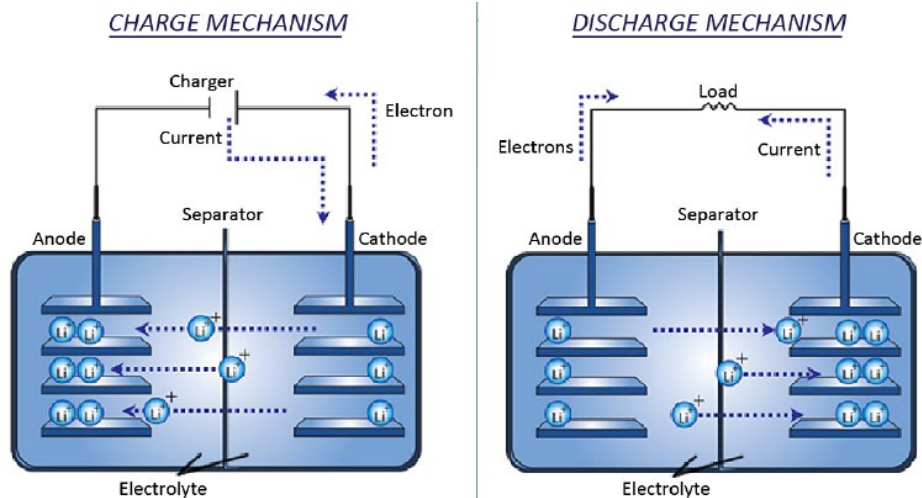


Figure 12. The Li-ion Battery Charge and Discharge Mechanism

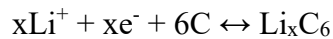
The lithium ions that happen in the high voltage, each cell produces 3,7 volts.

The reaction equation is stated in mole unit, which uses the coefisien x.

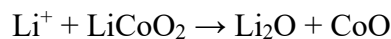
The half reaction on cathode (by charging) is:



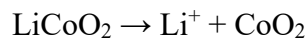
The half reaction of anode is:



The overall reaction has limit. The overdischarge can make lithium cobalt oxide to be oversaturated, it causes the lithium oxide formation, by having possibility to turn the irreversible reaction:



The overcharge beyond 5,2 V causes the occurance of the cobalt (IV) oxide synthesis, which is proven by x-ray fractionated:



It should be known the lithium ion itself is not oxidized in the Li-ion battery, the lithium ion moves to and from cathode or anode, with the transision metal Co, in Li_xCoO_2 oxidized from Co^{3+} to Co^{4+} as long as the charging and redacted from Co^{4+} to Co^{3+} for discharge.

- Electrolyte

In the Li-ion cell, it uses unwatery solution because the upper cell voltage is bigger than the potential in ionized watery liquid. The electrolyte solution inside the Li-ion battery consists of lithium salts such as LiPF_6 , LiBF_4 , or LiClO_4 , in an organic solvent such as ether. The electrolyte solution conducts Li ion that has a role as a carrier between cathode and anode when it goes through the electric current passing the external circuit.

This the example of the battery's specification and design



Remarks:

A lithium-ion battery from a mobile phone.

- Specific energy density : 150 to 200 Wh/kg (540 to 720 kJ/kg)
- Volumetric energy density : 250 to 530 Wh/l (900 to 1900 J/cm³)
- Specific power density : 300 to 1500 W/kg (@ 20 seconds and 285 Wh/l)

REFERENCES

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Wikipedia