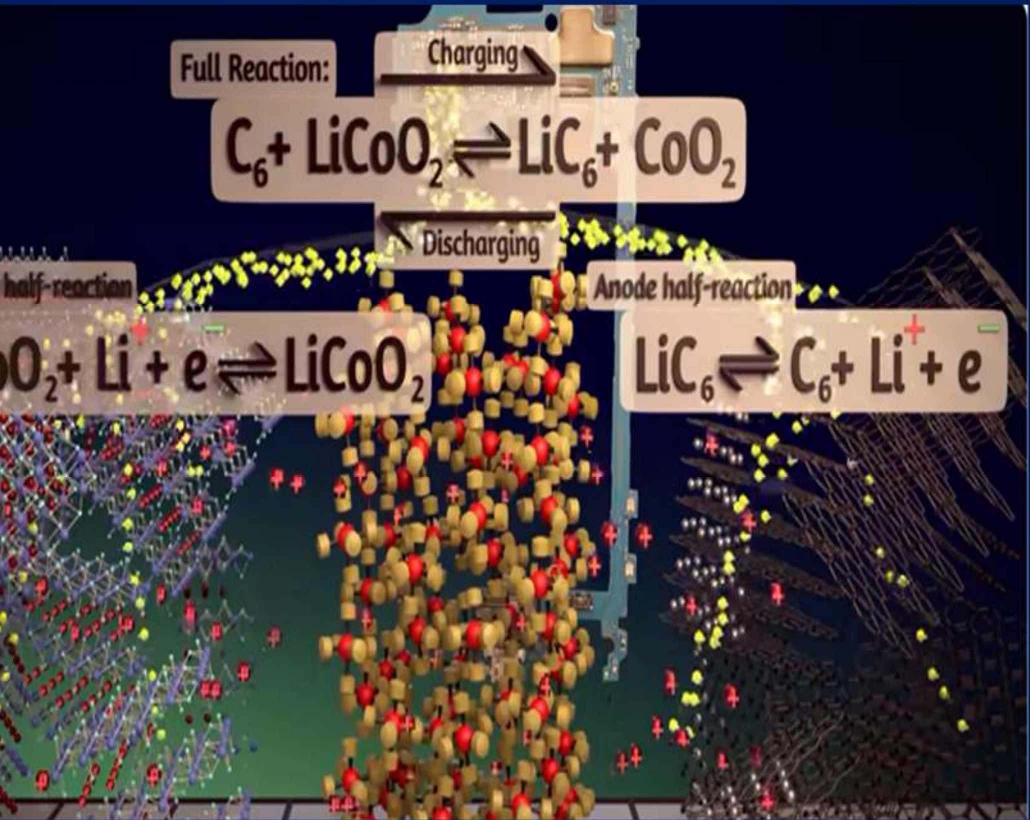
Li-ion Batteries



Li-ion Batteries - Principle

- Lithium ion batteries belong to the group of batteries that generate electric energy by converting chemical energy through redox reactions.
- Different types of lithium-ion batteries use different chemistry and ha different performance, cost, and safety characteristics.
- Li-ion battery is classified as primary Li-ion battrery and secondary Li-i battery based on whether or not they are rechargeable by applying current.
- In conventional Li-ion batteries, Li ions are shuttled between the positi electrode usually a layered transition metal oxide material and graphite bas negative elcetrode .
- The electrolyte usually contains additional Li^+ ions to ensure rapid transport ionic charge within the cell.

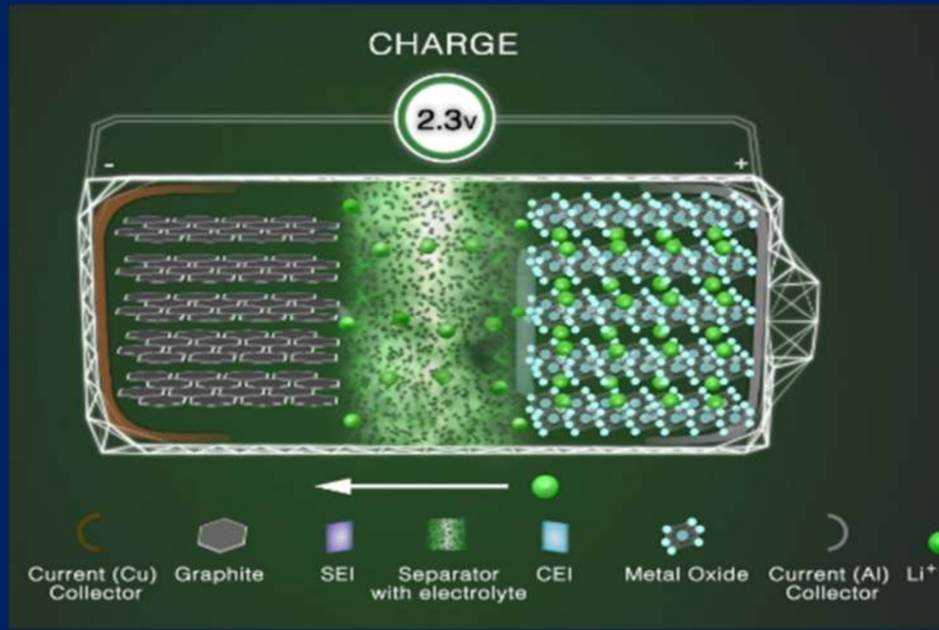
Components of Li-ion battery

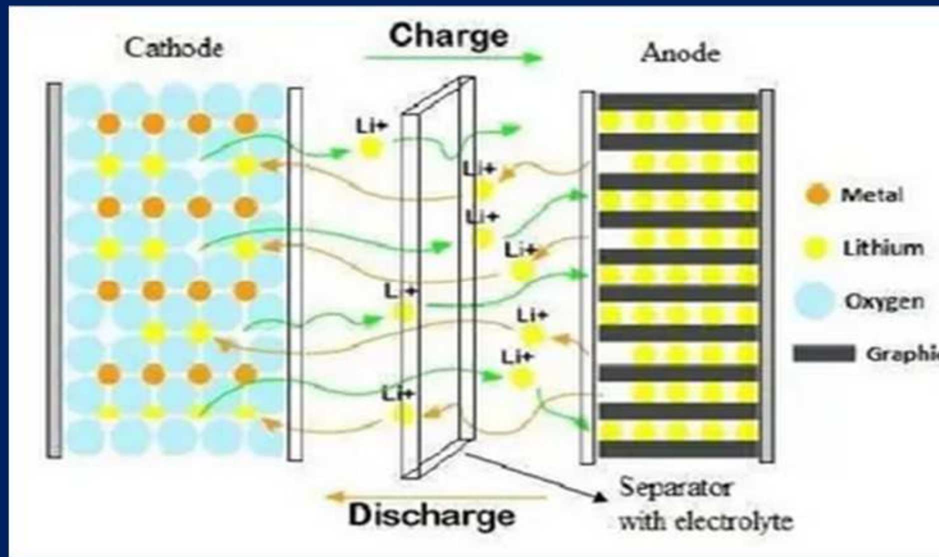
Anode – Graphite -C_6

Cathode – The positive electrode determines the voltage and capacity of the lithium-ion battery as well as the source of the lithium ions. Generally metal oxide of transition metals ex: $LiCoO_2$, $LiFePO_4$, $LiMn_2O_4$, $LiNiO_2$,

Electrolyte – Lithium salt in an organic solvent

Separator – Electrolyte carries the positively charged Li ions from cathode to anode and vice versa through separator. It also blocks the movement of electrons inside the battery.





ositive and negative current collectors – Positive rent collector on cathode is made up of thin minium foil and negative current collector of anode is de up of thin copper foil.

Working

During Charging:

- In the very first charging process, Li ions de-intercalate from the cathode and migrate throug the electrolyte to the anode.
- As a result of these reactions, boundary phases solid electrolyte interphase (SEI) and cathode electrolyte interphase (CEI) are formed at interfaces between electrolyte/anode surface and electrolyte/ cathode surface respectively.
- These interphases are built from insoluble decomposition products of electrolyte componen and Li ion originating from cathode and also enables the reversible cycling of battery.
- After the formation of these interphases, further Li ions deintercalate from cathode to anode

At Positive electrode

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

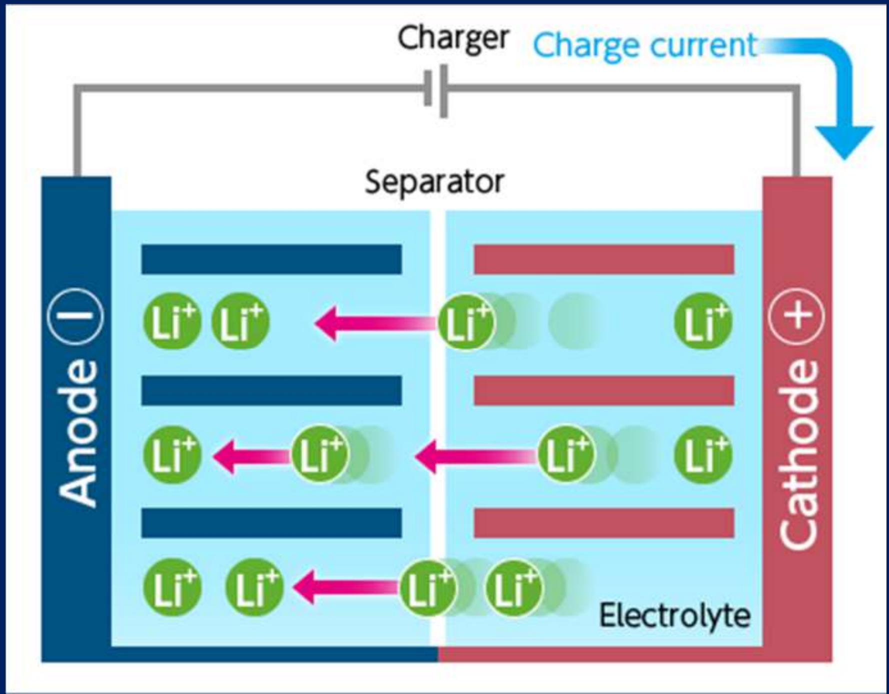
At Negative electrode

$$\boxed{C_6 + Li^+ + e^- \rightarrow LiC_6}$$

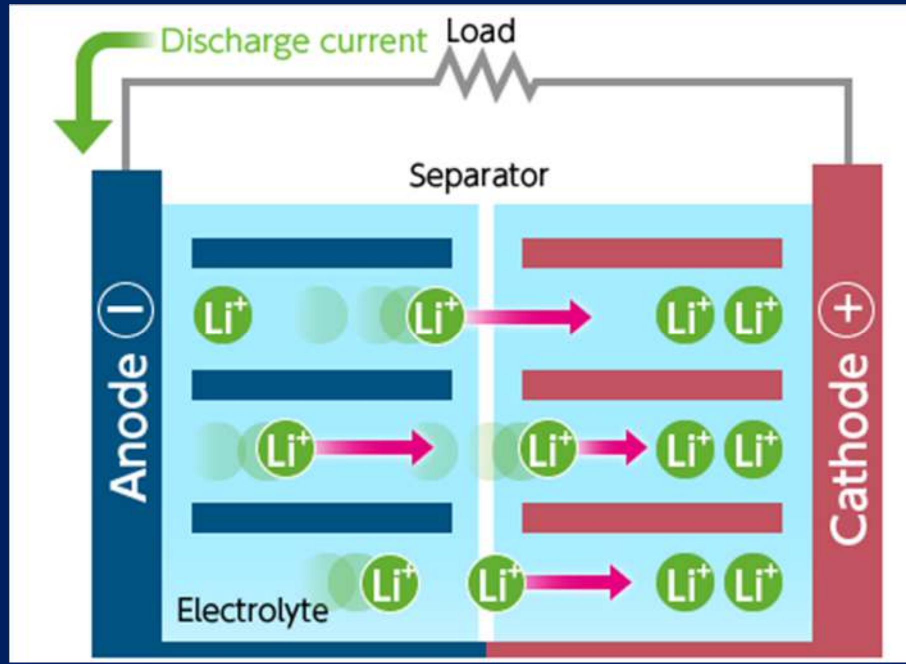
Overall reaction

$$\boxed{C_6 + LiCoO_2 \leftrightarrow LiC_6 + CoO_2}$$

During Charging



During Discharging



During discharging

- During discharge, the reverse reactions take place. Li ions are dissociated from the ano and migrate across the electrolyte towards the cathode. The e^- move from anode to cathode

At Anode (Negative electrode): Lithiated graphite is oxidized to form Li ion and it mo towards the cathode.

$$LiC_6 \rightarrow C_6 + Li^+ + e^-$$

At Cathode (positive electrode): Cobalt oxide combines with lithium ions to form lithium cob oxide ($LiCoO_2$).

$$CoO_2 + Li^+ + e^- \rightarrow LiCoO_2$$

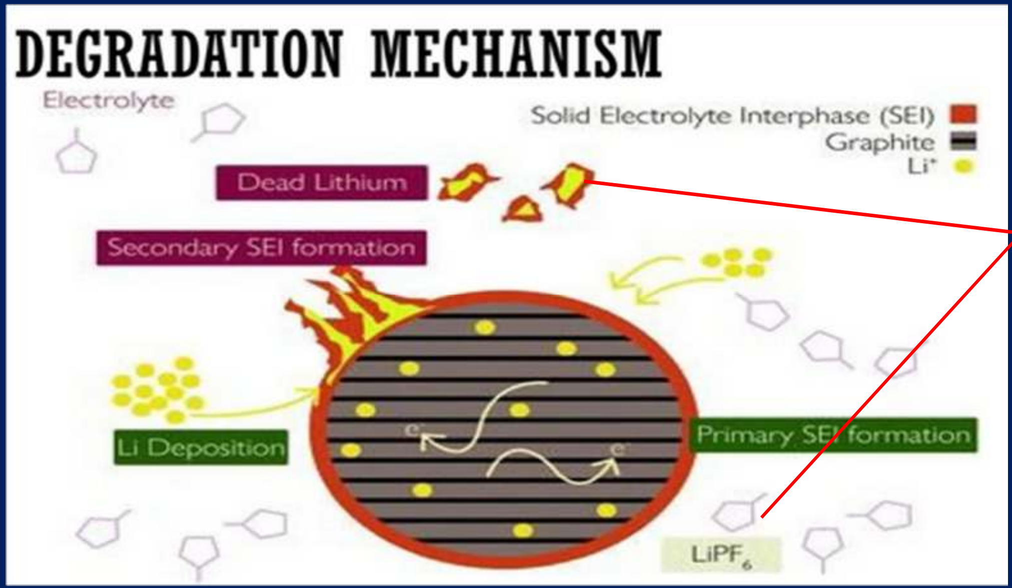
Net reaction

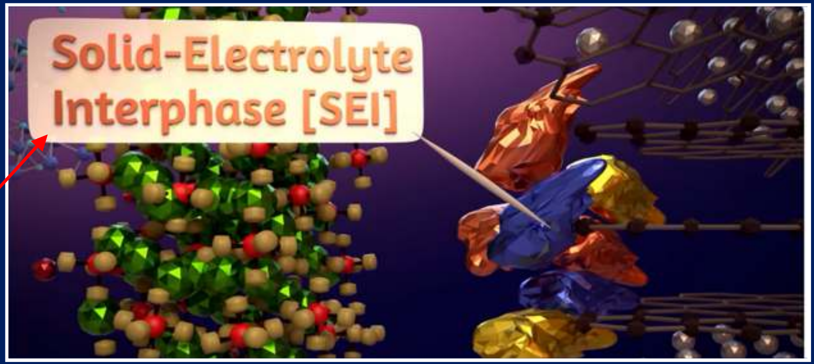
$$LiC_6 + CoO_2 \leftrightarrow C_6 + LiCoO_2$$

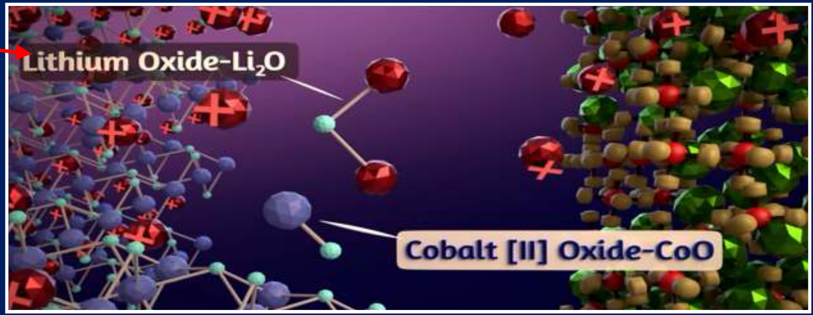
After discharge, the Li-ions are restored in the positive electrode (i.e) cathode from which th originally came.

why capacity of lithium battery decrease over time ?

The capacity of a lithium battery decreases over time due to the formation of the **solid electrolyte interphase (SEI) layer** on the anode, which consumes lithium ions, and lithium plating, where metallic lithium deposits on the anode. Other factors include the loss of active material and the structural breakdown of electrodes from repeated charging and discharging and exposure to high temperatures







https://www.youtube.com/watch?v=G5McJw4KkG8

Advantages

- Low self discharge
- High energy density than other rechargeable batteries
- Less in weight
- Produce high voltage of about 4V as compared with other batteries
- More resistant to overcharging-(i.e) improved safety
- Fast charge and discharge rate
- Low internal resistance and long shelf life

Limitations

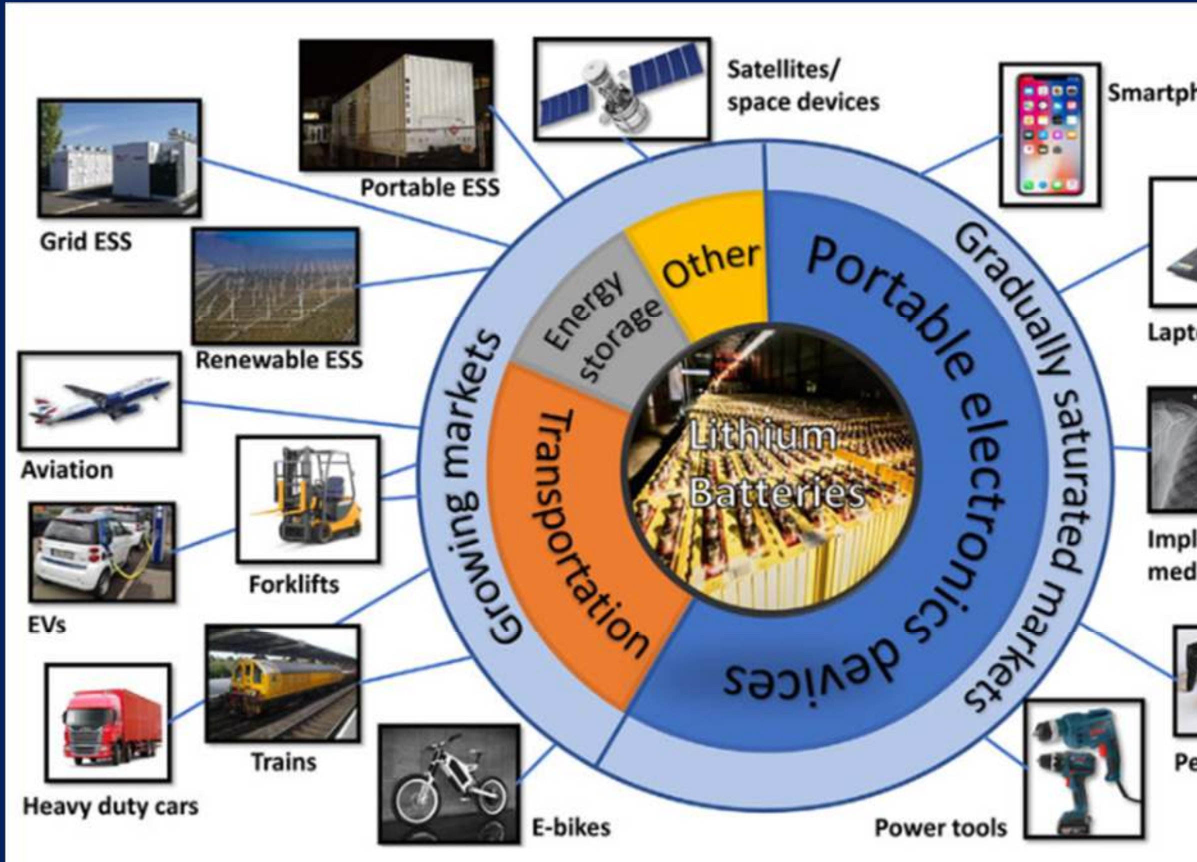
- Expensive
- Degrades at high temperature
- Transportation regulations required when shipping in larger quantities
- Requires protection circuit to prevent thermal runaway if stressed

Applications

Used in many products such as electronics, toys, wireless headphones, handheld power tools, small and large appliances, electric vehicles and electrical energy storage systems.

It is also used in cardiac pace makers and other implantable devices

Used in power tools such as cordless drills, saws…



Lithium battery sample applications.

LEAD-ACID BATTERY	VS	LITHIUM-ION BATTERY
500–1,000 cycles @ 50% DoD	LIFESPAN	2,000–5,000+ cycles @ 80% DoD
Heavy	WEIGHT	Lightweight
~50%	USEABLE CAPACITY	80–90%
Slow	CHARGING SPEED	Fast
Low	UPFRONT COST	High
Regular (especially flooded types)	MAINTENANCE	None
Drops during use	VOLTAGE STABILITY	Consistent
Basic	SAFETY FEATURES	Integrated BMS

Calculate the number of lithium-ion batteries 12v and 100AH , dod of 0.8 and efficiency of 0.9

The home daily consumption of 1000WH.

1: Calculate Total Required Energy Capacity

determine the total energy capacity required from the battery bank to account for **epth of discharge** (DOD) and system **efficiency**. The required energy (E_{req}) is ated by dividing the daily load (E_{load}) by the product of the DOD and efficiency (η):

$$E_{req} = \frac{E_{load}}{\text{DOD} \times \eta}$$

ituting the given values:

$$E_{req} = \frac{1000\text{ Wh}}{0.8 \times 0.9} = \frac{1000\text{ Wh}}{0.72} \approx 1388.89\text{ Wh}$$

2: Calculate Single Battery Energy Capacity

alculate the total energy stored in a single **lithium-ion battery** in watt-hours (Wh) tiplying its **voltage** (V_{batt}) by its **amp-hour** capacity (C_{batt}): [1]

$$E_{batt} = V_{batt} \times C_{batt}$$

tuting the given values:

$$E_{batt} = 12\text{ V} \times 100\text{ AH} = 1200\text{ Wh}$$

3: Determine the Number of Batteries Needed

Step 3: Determine the Number of Batteries Needed

Finally, divide the total required energy capacity (E_{req}) by the capacity of a single batte (E_{batt}) to find the number of batteries (N_{batt}) required. You must always round up to the nearest whole number to meet the **energy demand**:

$$N_{batt} = \frac{E_{req}}{E_{batt}}$$

Substituting the calculated values:

$$N_{batt} = \frac{1388.89\text{ Wh}}{1200\text{ Wh}} \approx 1.157$$

Rounding up to the nearest whole number gives 2 batteries.

ulate the number of lead-acid batteries 12v
100AH and efficiency of 0.75.

The home daily
consumption of 1000

Step 1: Calculate the total required energy from the battery bank

The total required energy from the battery bank must account for the system's efficiency, ensuring that the 1000 Wh required by the home is delivered after any power conversion losses.

The required energy $\mathrm{E_{required}}$ is calculated as:

$$\mathrm{E_{required}} = \frac{\text{Energy Usage}}{\text{Efficiency}} = \frac{1000\ \text{Wh}}{0.75} \approx 1333.33\ \text{Wh}$$

Step 2: Calculate the usable capacity of a single battery

A standard 12V, 100Ah lead-acid battery has a nominal capacity of $12\ \text{V} \times 100\ \text{Ah} = 1200\ \text{Wh}$. To maximize the battery's lifespan, lead-acid batteries should typically only be discharged to a maximum of 50% Depth of Discharge (DoD).

The usable energy per battery $\mathrm{E_{usable}}$ is:

$$\mathrm{E_{usable}} = \text{Nominal Capacity} \times \text{DoD} = 1200\ \text{Wh} \times 0.50 = 600\ \text{Wh}$$

Step 3: Determine the number of batteries needed

The number of batteries needed is the total required energy divided by the usable energy per battery, rounded up to the nearest whole number.

$$\text{Number of Batteries} = \frac{\mathrm{E_{required}}}{\mathrm{E_{usable}}} = \frac{1333.33\ \text{Wh}}{600\ \text{Wh}} \approx 2.22\ \text{batteries}$$

Since partial batteries cannot be used, the requirement is rounded up to 3 batteries.