ELECTRIC MOBILITY FORUM

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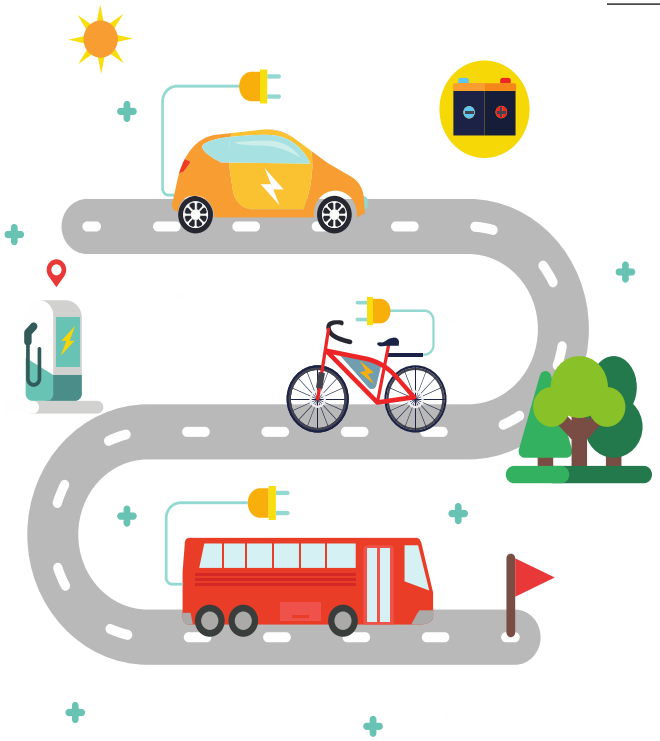


Lithium-ion Battery Hazards and Design Challenges for the Electric Vehicle Sector

May 25, 2020
7:00 PM - 8:00 PM (IST)
WRI India Delhi

Speaker:
Dr. Judy Jeevarajan
Research Director – Battery Safety, Underwriters Laboratories Inc.

Moderator:
Shravani Sharma
WRI India

WRI INDIA — ROSS CENTER

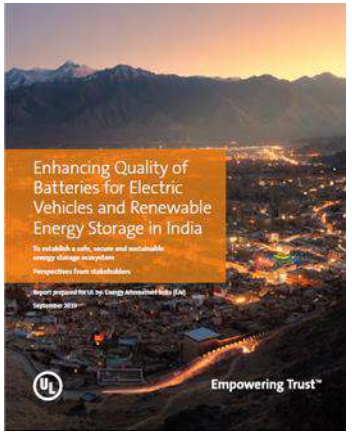
SHAKTI SUSTAINABLE ENERGY FOUNDATION

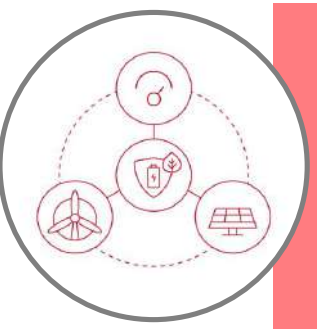
About UL

Working for a safer world

RESEARCH: We conduct research and **share scientific data-driven knowledge** to drive safe, reliable, innovative designs to meet the world's increasing energy demands.

Findings of the research are presented in conferences and other public forums, and also through journal and newsletter publications.





OUTREACH: We conduct the **Battery Safety Summits** and **Battery Safety Council forums.**
The **India Energy Storage Summit (IESS) held last year** is an example. It was a platform to catalyze the growth of electric mobility and renewable energy through emphasis on battery performance, safety and innovation.

In the US, we convene the Battery Safety Council (BSC) forums twice a year to deliberate the hazards and challenges associated with lithium-ion cells and batteries.

EDUCATION (awareness-building): We participate in **trainings,** and **webinars,** and share our **research findings** in different platforms like learning modules for students of different age groups.

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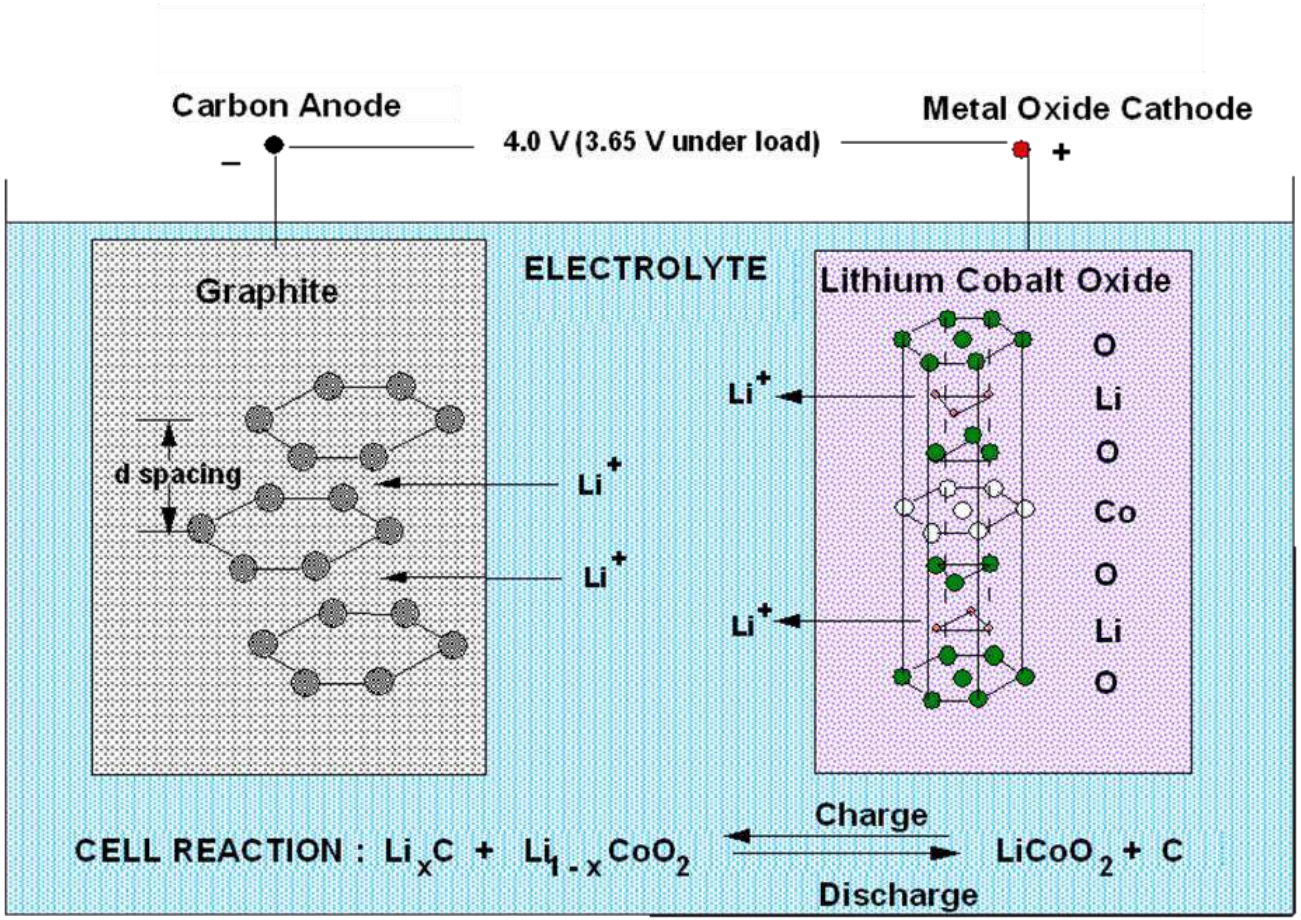
Introduction

- Lithium-ion battery chemistry was **first commercialized** in the **early 1990s**.
- Discoveries in the area of Li-ion chemistry started two decades before that.
- Lithium-ion battery chemistry has the **highest energy density** of rechargeable battery chemistries, has **no memory effect**, has **long cycle and calendar life** and **good rate capability**.
- It is used in a myriad of applications today from consumer electronics to electric vehicles and stationary grid energy storage as well as in sea and space applications.
- Associated with the high energy density is their **propensity to experience fire and thermal runaway if not designed or used correctly**.
- The chemistry is still being optimized as there is opportunity to make material improvements to get better performance.
- In addition to improvements for performance, **safety improvements** have also received a lot of attention for almost three decades and all component areas of a Li-ion cell and battery have been looked into for improved safety.

Charge and Discharge Process for a Lithium-ion Cell



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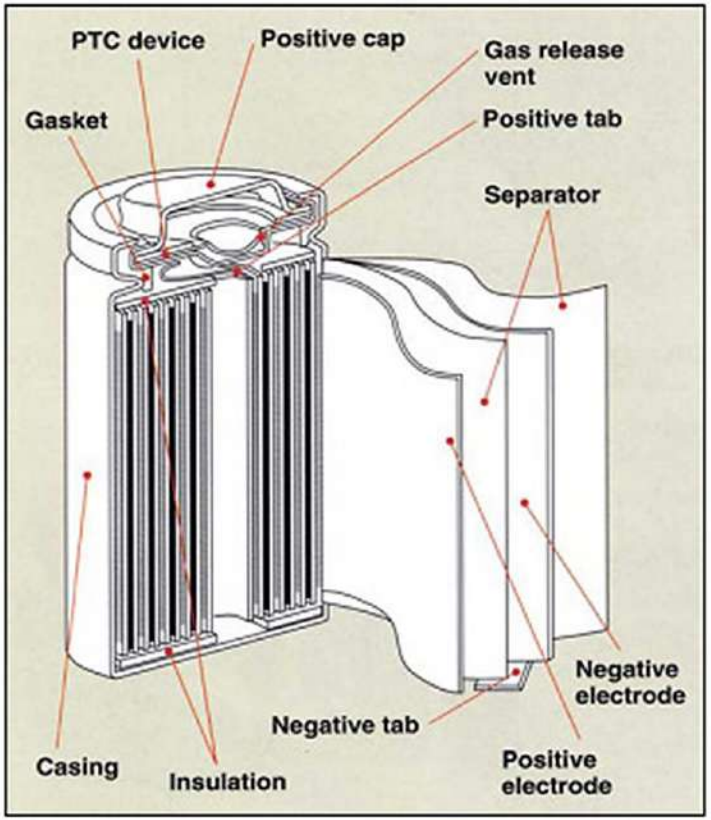
Factors to Consider in Choosing a Battery

- Performance (voltage and capacity) including any pulse requirements
- Volumetric and Gravimetric Energy Density
- Safety
- Toxicity
- Thermal Capability
- Cycle / Service life
- Calendar life
- Cost

Components of a Cell

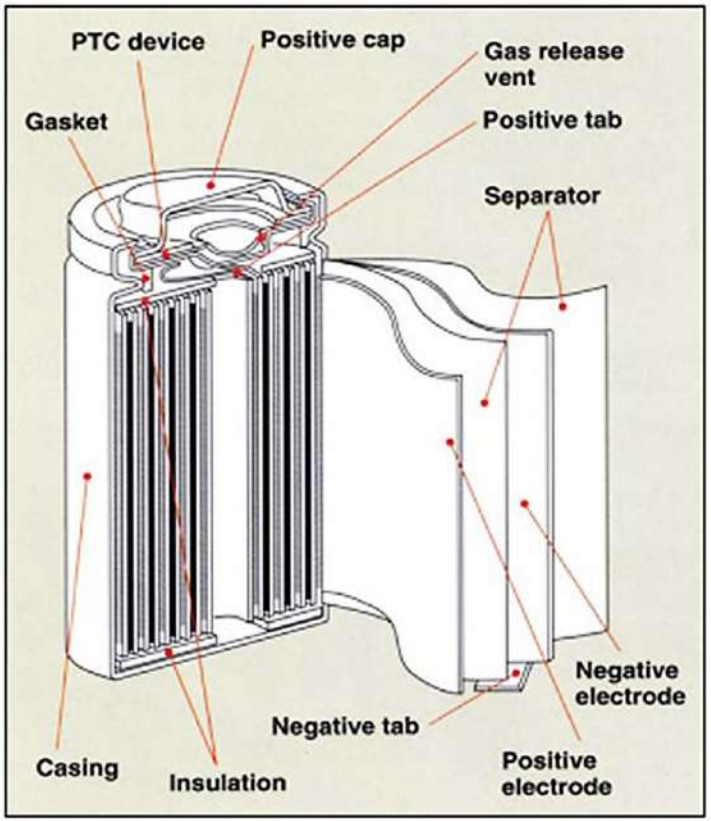
1. **Cathode:** The positive electrode of the cell (for discharge).
2. **Anode:** The negative electrode of the cell (for discharge).
3. **Electrolyte:** The medium that provides the ion transport mechanism between the positive and negative electrodes in a cell. (This can be aqueous or non-aqueous)
4. **Separator:** A microporous material that keeps the cathode and anode from touching each other.



Courtesy: ***Handbook of Batteries by Linden and Reddy***

Types of Cell Construction

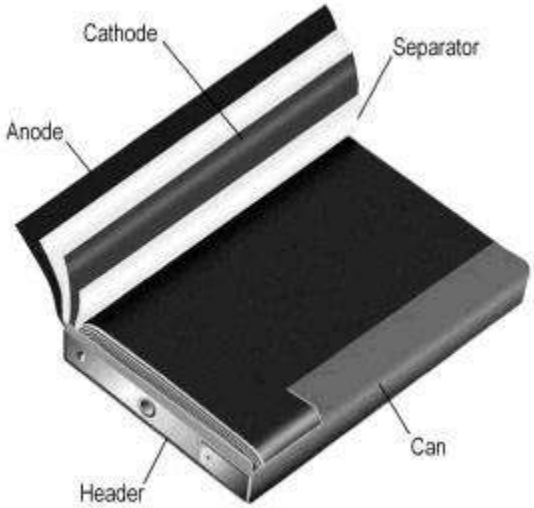
Cylindrical

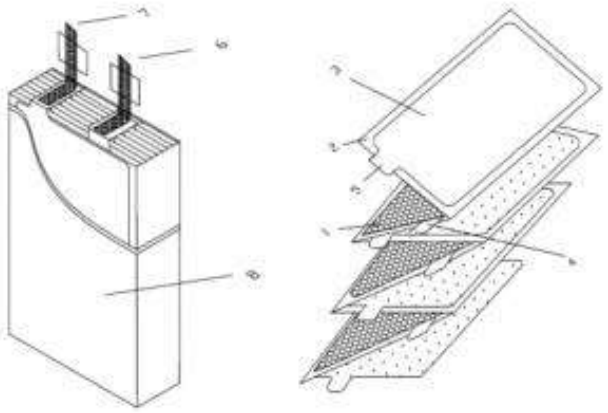


Courtesy: ***Handbook of Batteries by Linden and Reddy***

Prismatic Pouch

Prismatic Metal Can





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Lithium-ion Cell Model Designation

According to IEC61960 standard, identification of lithium battery cell as below:

a. Battery identification includes 3 letters & 5 numbers for cylindrical battery or 6 numbers for flat battery.

b. First letter shows battery anode material, “I” is battery with lithium ion; “L” is lithium metal electrode.

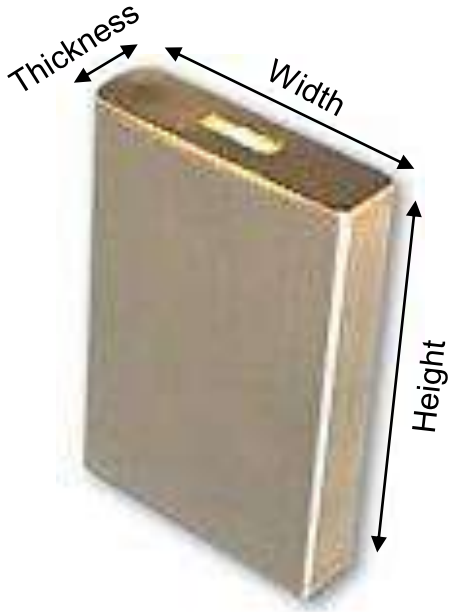
c. Second letter shows battery cathode material, “C” is cobalt; “N” is nickel, “M” is manganese, “V” is vanadium.

d. Third letter represents battery shape, “R” is cylindrical battery, and “P” is flat battery.

e. Number. Cylindrical battery, 5 numbers represent diameter (mm) and height (0.1mm), diameter or height any size (100mm, should add “/” between two sizes).

Flat battery, six numbers represent thickness, width and height, unit mm, any size (100mm, should add “/”; any size) 1mm, should add “t” before this size, unit 0.1mm.

- ICR18650 represents cylindrical lithium-ion battery, cobalt cathode, diameter 18mm, height 65mm;
- ICP103450 represents flat lithium ion battery, cobalt cathode, and thickness 10mm, width 34mm, height 50mm;
- ICP08/34/150 represents flat lithium ion battery, cobalt cathode, and thickness 8mm, width 34mm, height 150mm;
- ICPt73448 represents flat lithium ion battery, cobalt cathode, and thickness 0.7mm, width 34mm, height 48mm.



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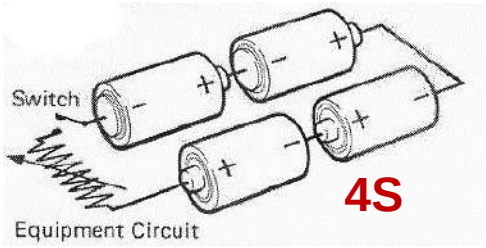
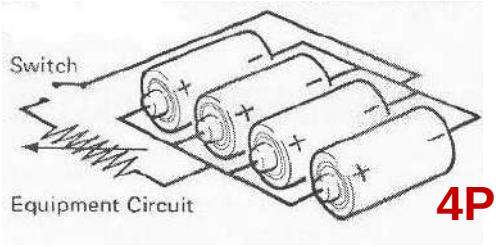
Battery Configuration



Voltage is additive, capacity is not and remains the same as for a single cell.

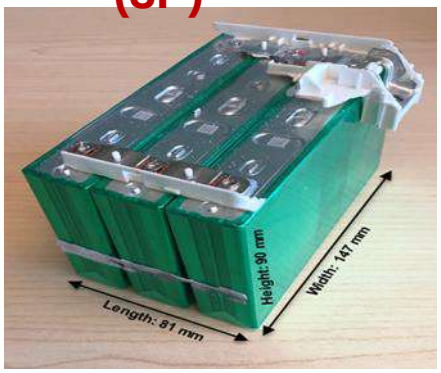
Series Configuration (string)



Capacity is additive, voltage is not and remains the same as for a single cell.

Parallel Configuration (bank)

Module (3P)



Battery Pack 3P4S

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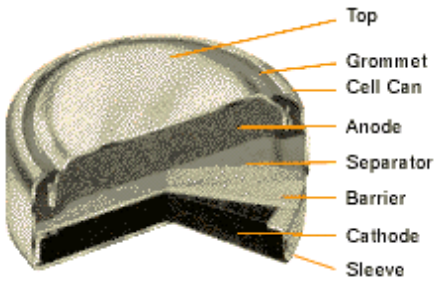
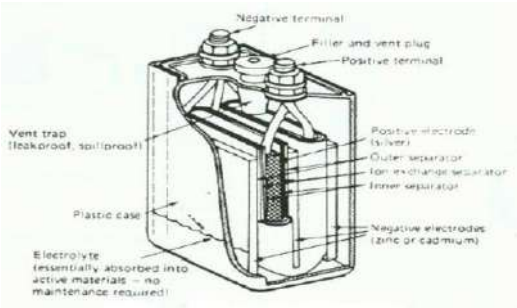
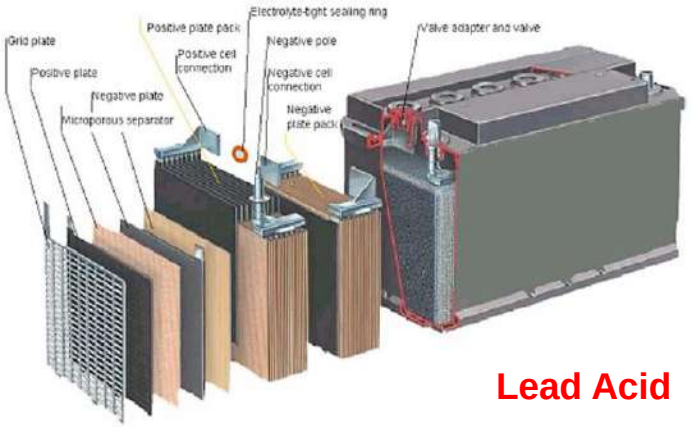
Rechargeable Battery Chemistries

Silver Zinc

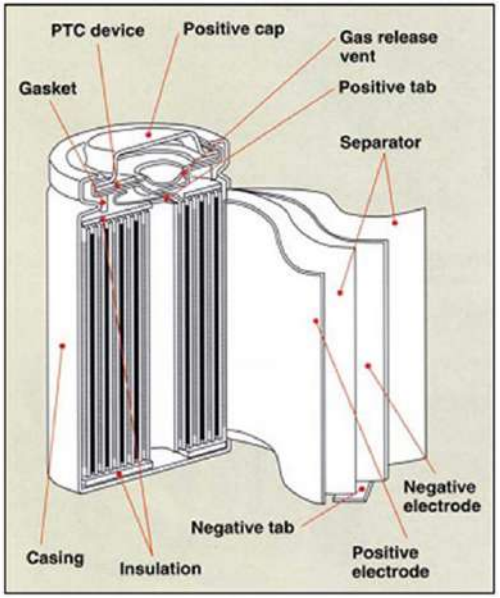




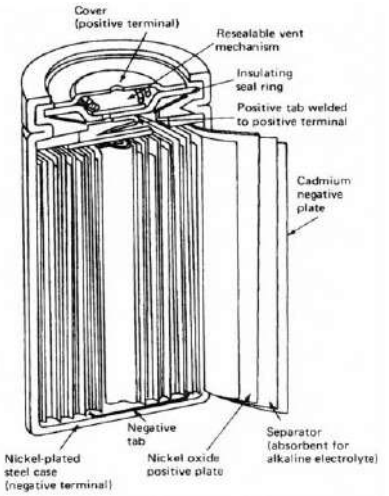
Lead Acid



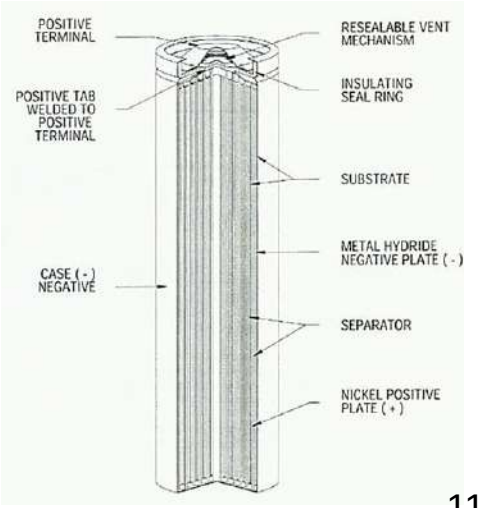
Lithium-ion



NiCd



NiMH



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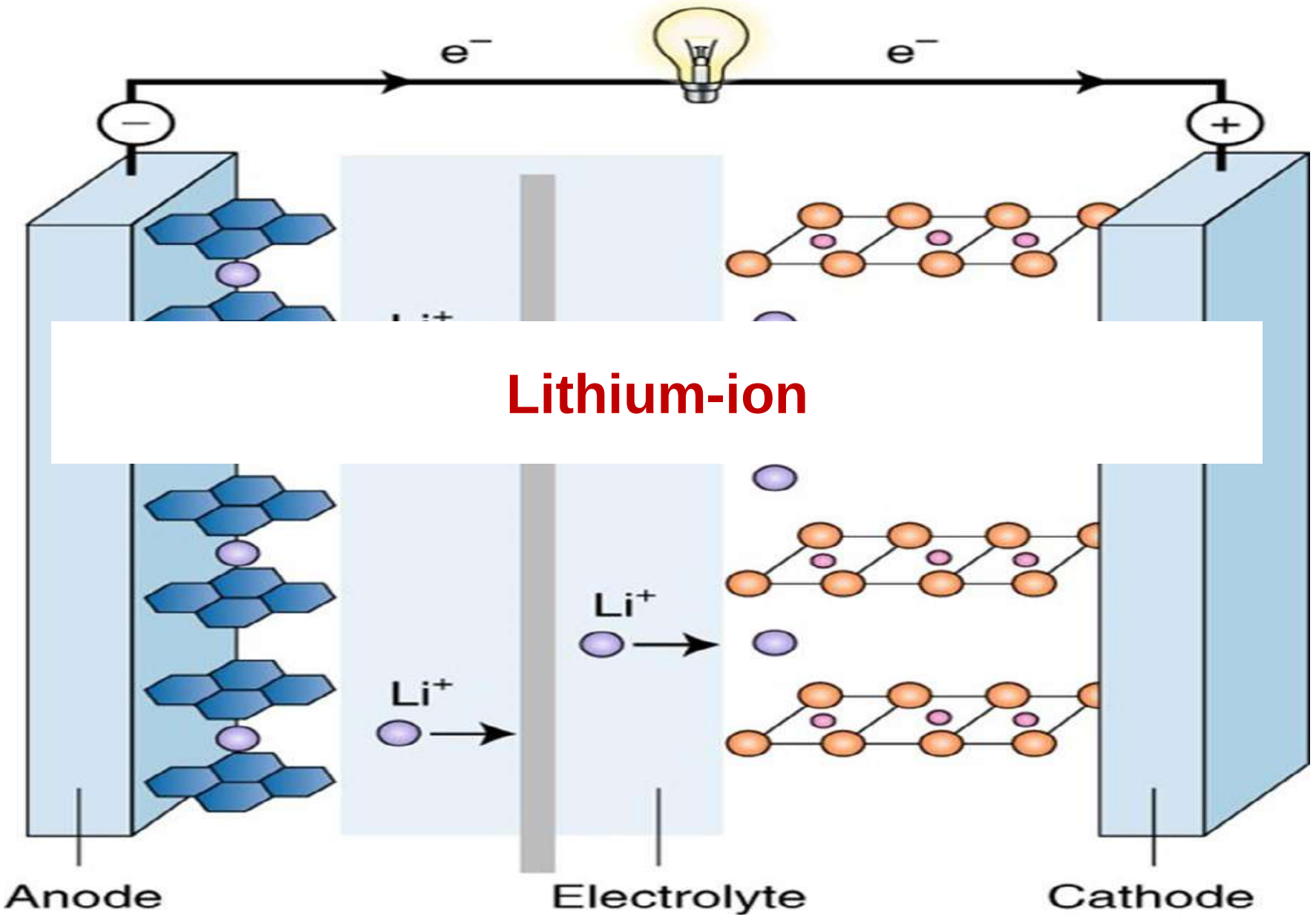

Lithium-ion

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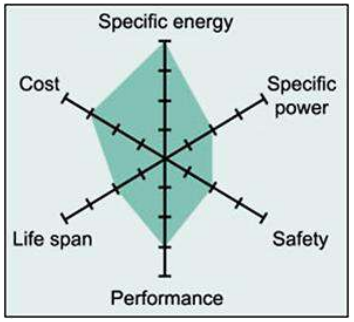
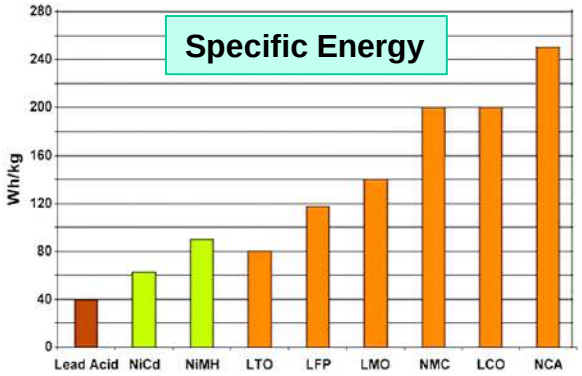
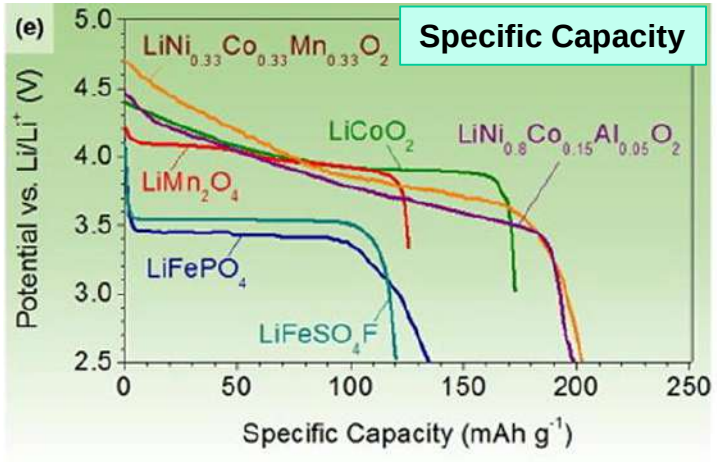
Trends for Cathode Materials

$LiCoO_2$

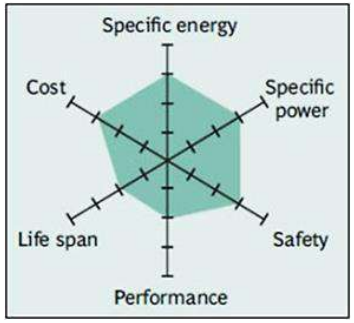




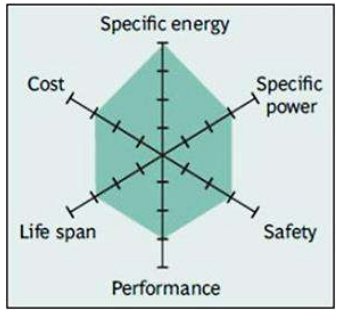


Courtesy: ***Battery University***

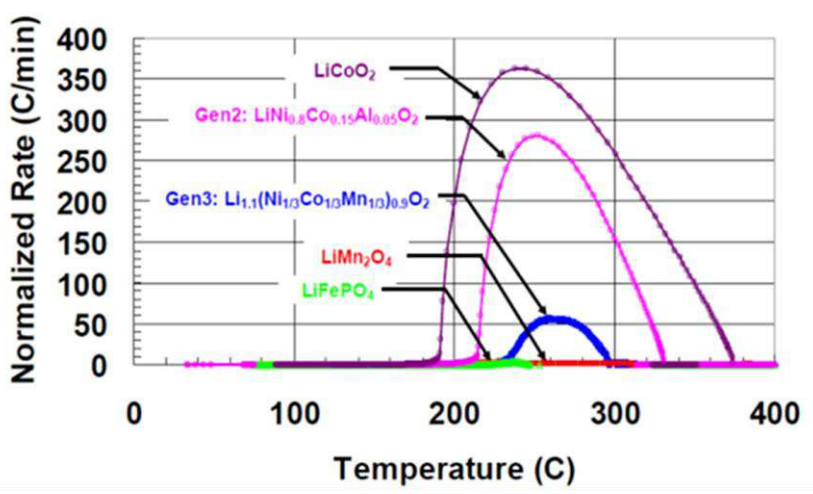
$LiMn_2O_4$



$LiNMCO_2$

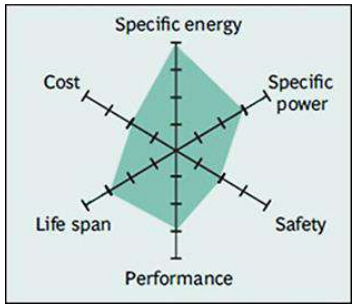


Accelerated Rate Calorimetry Self Heating Trends for 18650 Li-ion cells with Different Cathode Chemistries

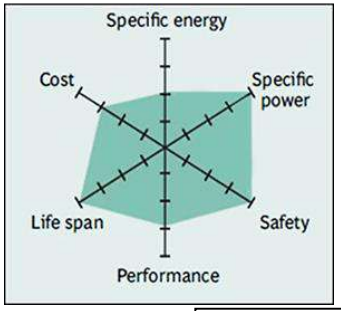


E. P. Roth et al., Proceedings of AABC 15-19 May, 2006

$LiNiCoAlO_2$



$LiFePO_4$



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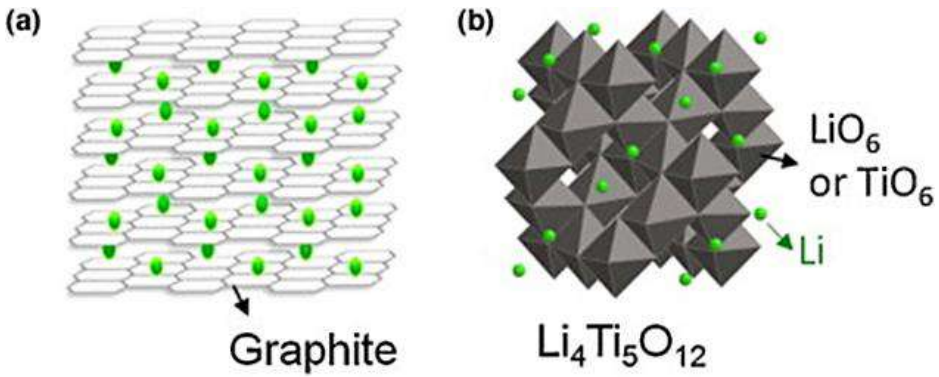
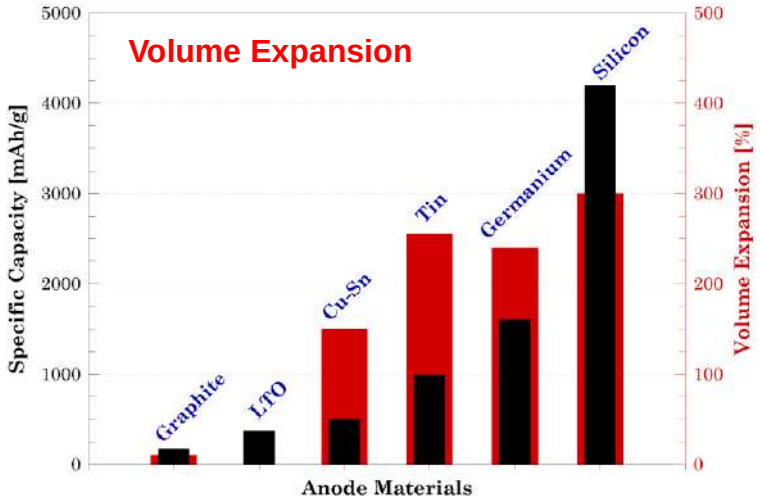
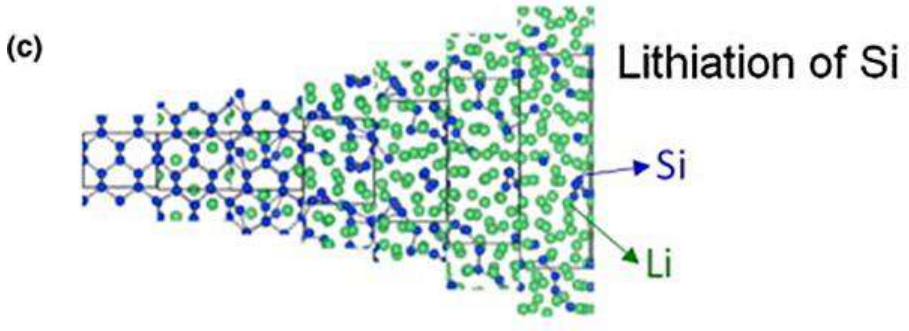
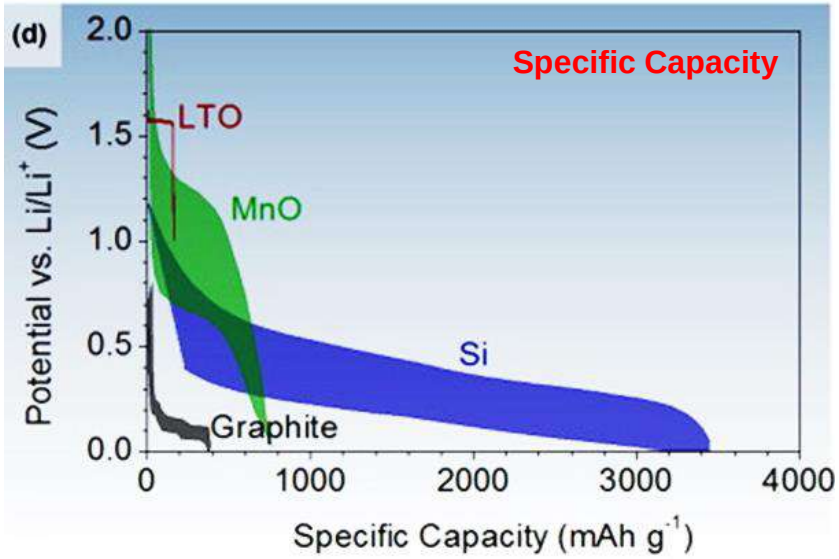
Anode Materials







Nitta et al., Materials Today, 18 (5), 2015, 252-264



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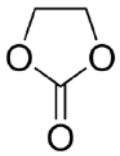
Electrolytes Used in Lithium-ion Cells

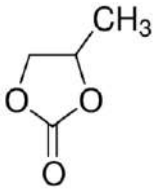
Electrolytes are composed of a combination of solvents with an electrolyte salt.

Typical salt used in Li-ion cells is $LiPF_6$ (Lithium hexafluorophosphate).

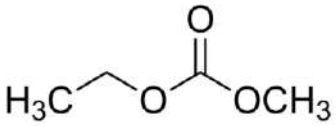
Solvent	FW	d, g cm^{-3} (25 °C)	ε_r (25 °C)	η, mPa s (25 °C)	E_{homo}, eV	E_{lumo}, eV	mp, °C	bp, °C	fp, °C
Ethylene carbonate (EC)	88	1.32 (40 °C)	90 (40 °C)	1.9 (40 °C)	−12.86	1.51	36	238	143
Propylene carbonate (PC)	102	1.2	65	2.5	−12.72	1.52	−49	242	138
Dimethyl carbonate (DMC)	90	1.06	3.1	0.59	−12.85	1.88	5	90	17
Ethyl methyl carbonate (EMC)	104	1.01	3	0.65	−12.71	1.91	−53	108	23
Diethyl carbonate (DEC)	118	0.97	2.8	0.75	−12.59	1.93	−74	127	25



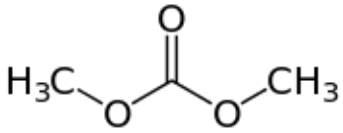
EC



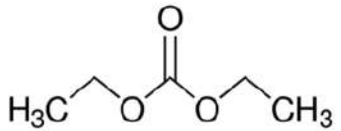
PC



EMC



DMC



DEC

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