Battery University

BU-205: Types of Lithium-ion

Become familiar with the many different types of lithium-ion batteries.

Lithium-ion is named for its active materials; the words are either written in full or shortened by their chemical symbols. A series of letters and numbers strung together can be hard to remember and even harder to pronounce, and battery chemistries are also identified in abbreviated letters.

For example, lithium cobalt oxide, one of the most common Li-ions, has the chemical symbols $LiCoO_2$ and the abbreviation LCO. For reasons of simplicity, the short form Li-cobalt can also be used for this battery. Cobalt is the main active material that gives this battery character. Other Li-ion chemistries are given similar short-form names. This section lists six of the most common Li-ions. All readings are average estimates at time of writing.

Lithium Cobalt Oxide($LiCoO_2$)

Its high specific energy makes Li-cobalt the popular choice for mobile phones, laptops and digital cameras. The battery consists of a cobalt oxide cathode and a graphite carbon anode. The cathode has a layered structure and during discharge, lithium ions move from the anode to the cathode. The flow reverses on charge. The drawback of Li-cobalt is a relatively short life span, low thermal stability and limited load capabilities (specific power). Figure 1 illustrates the structure.

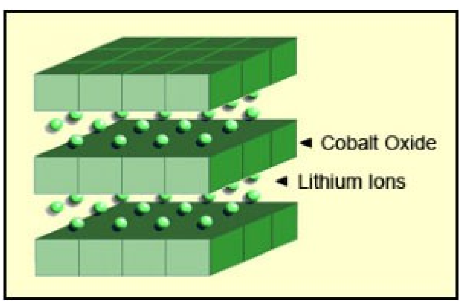

Figure 1: **Li-cobalt structure.**
The cathode has a layered structure. During discharge the lithium ions move from the anode to the cathode; on charge the flow is from cathode to anode.
Courtesy of Cadex

The drawback of Li-cobalt is a relatively short life span, low thermal stability and limited load capabilities (specific power). Like other cobalt-blended Li-ion, Li-cobalt has a graphite anode that limits the cycle life by a changing solid electrolyte interface (SEI), thickening on the anode and lithium plating while fast charging and charging at low temperature. Newer systems include nickel, manganese and/or aluminum to improve longevity, loading capabilities and cost.

Li-cobalt should not be charged and discharged at a current higher than its C-rating. This means that an 18650 cell with 2,400mAh can only be charged and discharged at 2,400mA. Forcing a fast charge or applying a load higher than 2,400mA causes overheating and undue stress. For optimal fast charge, the manufacturer recommends a C-rate of 0.8C or about 2,000mA. (See BU-402: What is C-rate). The mandatory battery protection circuit limits the charge and discharge rate to a safe level of about 1C for the Energy Cell.

The hexagonal spider graphic (Figure 2) summarizes the performance of Li-cobalt in terms of *specific energy* or capacity that relates to runtime; *specific power* or the ability to deliver high current; *safety; performance* at hot and cold temperatures; *life span* reflecting cycle life and longevity; and *cost*. Other characteristics of interest not shown in the spider webs are toxicity, fast-charge capabilities, self-discharge and shelf life. (See BU-104c: The Octagon Battery – What makes a Battery a Battery).

The Li-cobalt is losing favor to Li-manganese, but especially NMC and NCA because of the high cost of cobalt and improved performance by blending with other active cathode materials. (See description of the NMC and NCA below.)

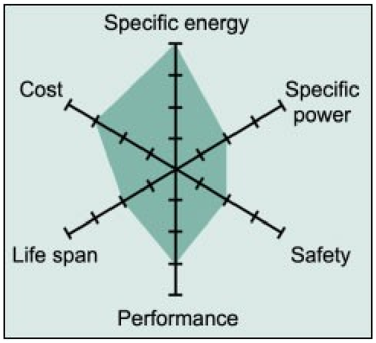

Figure 2: **Snapshot of an average Li-cobalt battery.**
Li-cobalt excels on high specific energy but offers only moderate performance specific power, safety and life span.
Courtesy of Cadex

Summary Table

Lithium Cobalt Oxide: $LiCoO_2$ cathode (~60% Co), graphite anode Short form: LCO or Li-cobalt. Since 1991	
Voltages	3.60V nominal; typical operating range 3.0–4.2V/cell
Specific energy (capacity)	150–200Wh/kg. Specialty cells provide up to 240Wh/kg.
Charge (C-rate)	0.7–1C, charges to 4.20V (most cells); 3h charge typical. Charge current above 1C shortens battery life.
Discharge (C-rate)	1C; 2.50V cut off. Discharge current above 1C shortens battery life.
Cycle life	500–1000, related to depth of discharge, load, temperature
Thermal runaway	150°C (302°F). Full charge promotes thermal runaway
Applications	Mobile phones, tablets, laptops, cameras
Comments	Very high specific energy, limited specific power. Cobalt is expensive. Serves as Energy Cell. Market share has stabilized.

Table 3: Characteristics of lithium cobalt oxide.

Lithium Manganese Oxide ($LiMn_2O_4$)

Li-ion with manganese spinel was first published in the *Materials Research Bulletin* in 1983. In 1996, Moli Energy commercialized a Li-ion cell with lithium manganese oxide as cathode material. The architecture forms a three-dimensional spinel structure that improves ion flow on the electrode, which results in lower internal resistance and improved current handling. A further advantage of spinel is high thermal stability and enhanced safety, but the cycle and calendar life are limited.

Low internal cell resistance enables fast charging and high-current discharging. In an 18650 package, Li-manganese can be discharged at currents of 20–30A with moderate heat buildup. It is also possible to apply one-second load pulses of up to 50A. A continuous high load at this current would cause heat buildup and the cell temperature cannot exceed 80°C (176°F). Li-manganese is used for power tools, medical instruments, as well as hybrid and electric vehicles.

Figure 4 illustrates the formation of a three-dimensional crystalline framework on the cathode of a Li-manganese battery. This spinel structure, which is usually composed of diamond shapes connected into a lattice, appears after initial formation.

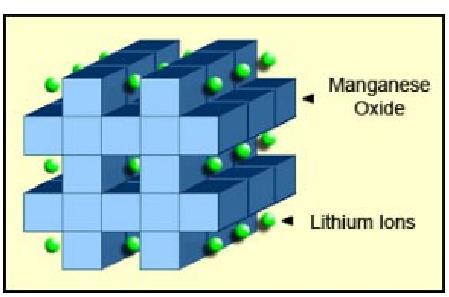

Figure 4: Li-manganese structure.
The cathode crystalline formation of lithium manganese oxide has a three-dimensional framework structure that appears after initial formation. Spinel provides low resistance but has a more moderate specific energy than cobalt.
Courtesy of Cadex

Li-manganese has a capacity that is roughly one-third lower than Li-cobalt. Design flexibility allows engineers to maximize the battery for either optimal longevity (life span), maximum load current (specific power) or high capacity (specific energy). For example, the long-life version in the 18650 cell has a moderate capacity of only 1,100mAh; the high-capacity version is 1,500mAh.

Figure 5 shows the spider web of a typical Li-manganese battery. The characteristics appear marginal but newer designs have improved in terms of specific power, safety and life span. Pure Li-manganese batteries are no longer common today; they may only be used for special applications.

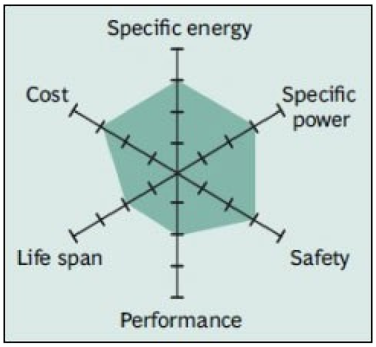

Figure 5: Snapshot of a pure Li-manganese battery.
Although moderate in overall performance, newer designs of Li-manganese offer improvements in specific power, safety and life span.
Source: Boston Consulting Group

Most Li-manganese batteries blend with lithium nickel manganese cobalt oxide (NMC) to improve the specific energy and prolong the life span. This combination brings out the best in each system, and the LMO (NMC) is chosen for most electric vehicles, such as the Nissan Leaf, Chevy Volt and BMW i3. The LMO part of the battery, which can be about 30 percent, provides high current boost on acceleration; the NMC part gives the long driving range.

Li-ion research gravitates heavily towards combining Li-manganese with cobalt, nickel, manganese and/or aluminum as active cathode material. In some architecture, a small amount of silicon is added to the anode. This provides a 25 percent capacity boost; however, the gain is commonly connected with a shorter cycle life as silicon grows and shrinks with charge and discharge, causing mechanical stress.

These three active metals, as well as the silicon enhancement can conveniently be chosen to enhance the specific energy (capacity), specific power (load capability) or longevity. While consumer batteries go for high capacity, industrial applications require battery systems that have good loading capabilities, deliver a long life and provide safe and dependable service.

Summary Table

Lithium Manganese Oxide: $LiMn_2O_4$ cathode. graphite anode
Short form: LMO or Li-manganese (spinel structure) Since 1996

Voltages	3.70V (3.80V) nominal; typical operating range 3.0–4.2V/cell
Specific energy (capacity)	100–150Wh/kg
Charge (C-rate)	0.7–1C typical, 3C maximum, charges to 4.20V (most cells)
Discharge (C-rate)	1C; 10C possible with some cells, 30C pulse (5s), 2.50V cut-off
Cycle life	300–700 (related to depth of discharge, temperature)
Thermal runaway	250°C (482°F) typical. High charge promotes thermal runaway
Applications	Power tools, medical devices, electric powertrains
Comments	High power but less capacity; safer than Li-cobalt; commonly mixed with NMC to improve performance.

Table 6: Characteristics of Lithium Manganese Oxide.

Lithium Nickel Manganese Cobalt Oxide ($LiNiMnCoO_2$ or NMC)

One of the most successful Li-ion systems is a cathode combination of nickel-manganese-cobalt (NMC). Similar to Li-manganese, these systems can be tailored to serve as Energy Cells or Power Cells. For example, NMC in an 18650 cell for moderate load condition has a capacity of about 2,800mAh and can deliver 4A to 5A; NMC in the same cell optimized for specific power has a capacity of only about 2,000mAh but delivers a continuous discharge current of 20A. A silicon-based anode will go to 4,000mAh and higher but at reduced loading capability and shorter cycle life. Silicon added to graphite has the drawback that the anode grows and shrinks with charge and discharge, making the cell mechanically unstable.

The secret of NMC lies in combining nickel and manganese. An analogy of this is table salt in which the main ingredients, sodium and chloride, are toxic on their own but mixing them serves as seasoning salt and food preserver. Nickel is known for its high specific energy but poor stability; manganese has the benefit of forming a spinel structure to achieve low internal resistance but offers a low specific energy. Combining the metals enhances each other strengths.

NMC is the battery of choice for power tools, e-bikes and other electric powertrains. The cathode combination is typically one-third nickel, one-third manganese and one-third cobalt, also known as 1-1-1. This offers a unique blend that also lowers the raw material cost due to reduced cobalt content. Another successful combination is NCM with 5 parts nickel, 3 parts cobalt and 2 parts manganese (5-3-2). Other combinations using various amounts of cathode materials are possible.

Battery manufacturers move away from cobalt systems toward nickel cathodes because of the high cost of cobalt. Nickel-based systems have higher energy density, lower cost, and longer cycle life than the cobalt-based cells but they have a slightly lower voltage.

New electrolytes and additives enable charging to 4.4V/cell and higher to boost capacity. Figure 7 demonstrates the characteristics of the NMC.

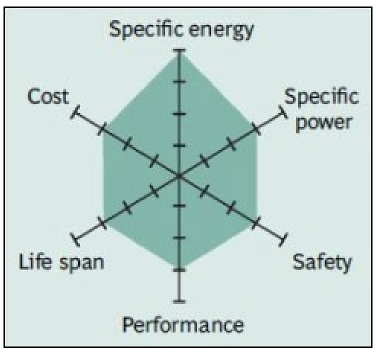

Figure 7: Snapshot of NMC.
NMC has good overall performance and excels on specific energy. This battery is the preferred candidate for the electric vehicle and has the lowest self-heating rate.
Source: Boston Consulting Group

There is a move towards NMC-blended Li-ion as the system can be built economically and it achieves a good performance. The three active materials of nickel, manganese and cobalt can easily be blended to suit a wide range of applications for automotive and energy storage systems (EES) that need frequent cycling. The NMC family is growing in its diversity.

Summary Table

Lithium Nickel Manganese Cobalt Oxide: $LiNiMnCoO_2$. cathode, graphite anode Short form: NMC (NCM, CMN, CNM, MNC, MCN similar with different metal combinations) Since 2008	
Voltages	3.60V, 3.70V nominal; typical operating range 3.0–4.2V/cell, or higher
Specific energy (capacity)	150–220Wh/kg
Charge (C-rate)	0.7–1C, charges to 4.20V, some go to 4.30V; 3h charge typical. Charge current above 1C shortens battery life.
Discharge (C-rate)	1C; 2C possible on some cells; 2.50V cut-off
Cycle life	1000–2000 (related to depth of discharge, temperature)
Thermal runaway	210°C (410°F) typical. High charge promotes thermal runaway
Cost	~$420 per kWh (Source: RWTH, Aachen)
Applications	E-bikes, medical devices, EVs, industrial

Comments	Provides high capacity and high power. Serves as Hybrid Cell. Favorite chemistry for many uses; market share is increasing.

Table 8: Characteristics of lithium nickel manganese cobalt oxide (NMC).

Lithium Iron Phosphate($LiFePO_4$)

In 1996, the University of Texas (and other contributors) discovered phosphate as cathode material for rechargeable lithium batteries. Li-phosphate offers good electrochemical performance with low resistance. This is made possible with nano-scale phosphate cathode material. The key benefits are high current rating and long cycle life, besides good thermal stability, enhanced safety and tolerance if abused.

Li-phosphate is more tolerant to full charge conditions and is less stressed than other lithium-ion systems if kept at high voltage for a prolonged time. (See BU-808: How to Prolong Lithium-based Batteries). As a trade-off, its lower nominal voltage of 3.2V/cell reduces the specific energy below that of cobalt-blended lithium-ion. With most batteries, cold temperature reduces performance and elevated storage temperature shortens the service life, and Li-phosphate is no exception. Li-phosphate has a higher self-discharge than other Li-ion batteries, which can cause balancing issues with aging. This can be mitigated by buying high quality cells and/or using sophisticated control electronics, both of which increase the cost of the pack. Cleanliness in manufacturing is of importance for longevity. There is no tolerance for moisture, lest the battery will only deliver 50 cycles. Figure 9 summarizes the attributes of Li-phosphate.

Li-phosphate is often used to replace the lead acid starter battery. Four cells in series produce 12.80V, a similar voltage to six 2V lead acid cells in series. Vehicles charge lead acid to 14.40V (2.40V/cell) and maintain a topping charge. Topping charge is applied to maintain full charge level and prevent sulfation on lead acid batteries.

With four Li-phosphate cells in series, each cell tops at 3.60V, which is the correct full-charge voltage. At this point, the charge should be disconnected but the topping charge continues while driving. Li-phosphate is tolerant to some overcharge; however, keeping the voltage at 14.40V for a prolonged time, as most vehicles do on a long road trip, could stress Li-phosphate. Time will tell how durable Li-Phosphate will be as a lead acid replacement with a regular vehicle charging system. Cold temperature also reduces performance of Li-ion and this could affect the cranking ability in extreme cases.

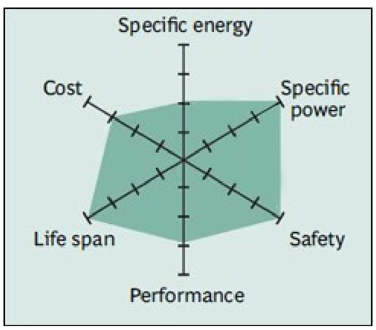

Figure 9: Snapshot of a typical Li-phosphate battery.
Li-phosphate has excellent safety and long life span but moderate specific energy and elevated self-discharge.
Courtesy of Cadex

Summary Table

Lithium Iron Phosphate: $LiFePO_4$ cathode, graphite anode
Short form: LFP or Li-phosphate Since 1996

Voltages	3.20, 3.30V nominal; typical operating range 2.5–3.65V/cell
Specific energy (capacity)	90–120Wh/kg
Charge (C-rate)	1C typical, charges to 3.65V; 3h charge time typical
Discharge (C-rate)	1C, 25C on some cells; 40A pulse (2s); 2.50V cut-off (lower that 2V causes damage)
Cycle life	1000–2000 (related to depth of discharge, temperature)
Thermal runaway	270°C (518°F) Very safe battery even if fully charged
Cost	~$580 per kWh (Source: RWTH, Aachen)
Applications	Portable and stationary needing high load currents and endurance

Comments	Very flat voltage discharge curve but low capacity. One of safest Li-ions. Used for special markets. Elevated self-discharge.

Table 10: Characteristics of lithium iron phosphate.

Lithium Nickel Cobalt Aluminum Oxide ($LiNiCoAlO_2$)

Lithium nickel cobalt aluminum oxide battery, or NCA, has been around since 1999 for special applications. It shares similarities with NMC by offering high specific energy, reasonably good specific power and a long life span. Less flattering are safety and cost. Figure 11 summarizes the six key characteristics. NCA is a further development of lithium nickel oxide; adding aluminum gives the chemistry greater stability.

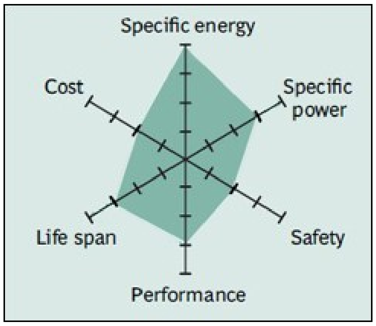

Figure 11: Snapshot of NCA.
High energy and power densities, as well as good life span, make NCA a candidate for EV powertrains. High cost and marginal safety are negatives.
Courtesy of Cadex

Summary Table

Lithium Nickel Cobalt Aluminum Oxide: $LiNiCoAlO_2$ cathode (~9% Co), graphite anode
Short form: NCA or Li-aluminum. Since 1999

Voltages	3.60V nominal; typical operating range 3.0–4.2V/cell
Specific energy (capacity)	200-260Wh/kg; 300Wh/kg predictable
Charge (C-rate)	0.7C, charges to 4.20V (most cells), 3h charge typical, fast charge possible with some cells
Discharge (C-rate)	1C typical; 3.00V cut-off; high discharge rate shortens battery life
Cycle life	500 (related to depth of discharge, temperature)
Thermal runaway	150°C (302°F) typical, High charge promotes thermal runaway
Cost	~$350 per kWh (Source: RWTH, Aachen)
Applications	Medical devices, industrial, electric powertrain (Tesla)
Comments	Shares similarities with Li-cobalt. Serves as Energy Cell.

Table 12: Characteristics of Lithium Nickel Cobalt Aluminum Oxide.

Lithium Titanate ($Li_4Ti_5O_{12}$)

Batteries with lithium titanate anodes have been known since the 1980s. Li-titanate replaces the graphite in the anode of a typical lithium-ion battery and the material forms into a spinel structure. The cathode can be lithium manganese oxide or NMC. Li-titanate has a nominal cell voltage of 2.40V, can be fast charged and delivers a high discharge current of 10C, or 10 times the rated capacity. The cycle count is said to be higher than that of a regular Li-ion. Li-titanate is safe, has excellent low-temperature discharge characteristics and obtains a capacity of 80 percent at –30°C (–22°F).

LTO (commonly $Li4Ti_5O_{12}$) has advantages over the conventional cobalt-blended Li-ion with graphite anode by attaining zero-strain property, no SEI film formation and no lithium plating when fast charging and charging at low temperature. Thermal stability under high temperature is also better than other Li-ion systems; however, the battery is expensive. At only 65Wh/kg, the specific energy is low, rivalling that of NiCd. Li-titanate charges to 2.80V/cell, and the end of discharge is 1.80V/cell. Figure 13 illustrates the characteristics of the Li-titanate battery. Typical uses are electric powertrains, UPS and solar-powered street lighting.

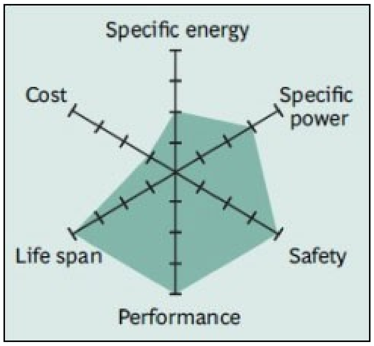

Figure 13: Snapshot of Li-titanate.
Li-titanate excels in safety, low-temperature performance and life span. Efforts are being made to improve the specific energy and lower cost.
Source: Boston Consulting Group

Summary Table

Lithium Titanate: Can be lithium manganese oxide or NMC; $Li_4Ti_5O_{12}$ (titanate) anode
Short form: LTO or Li-titanate Commercially available since about 2008.

Voltages	2.40V nominal; typical operating range 1.8–2.85V/cell
Specific energy (capacity)	50–80Wh/kg
Charge (C-rate)	1C typical; 5C maximum, charges to 2.85V
Discharge (C-rate)	10C possible, 30C 5s pulse; 1.80V cut-off on LCO/LTO
Cycle life	3,000–7,000
Thermal runaway	One of safest Li-ion batteries
Cost	~$1,005 per kWh (Source: RWTH, Aachen)
Applications	UPS, electric powertrain (Mitsubishi i-MiEV, Honda Fit EV), solar-powered street lighting
Comments	Long life, fast charge, wide temperature range but low specific energy and expensive. Among safest Li-ion batteries.

Table 14: Characteristics of lithium titanate.

Figure 15 compares the specific energy of lead-, nickel- and lithium-based systems. While Li-aluminum (NCA) is the clear winner by storing more capacity than other systems, this only applies to specific energy. In terms of specific power and thermal stability, Li-manganese (LMO) and Li-phosphate (LFP) are superior. Li-titanate (LTO) may have low capacity but this chemistry outlives most other batteries in terms of life span and also has the best cold temperature performance. Moving towards the electric powertrain, safety and cycle life will gain dominance over capacity. (LCO stands for Li-cobalt, the original Li-ion.)

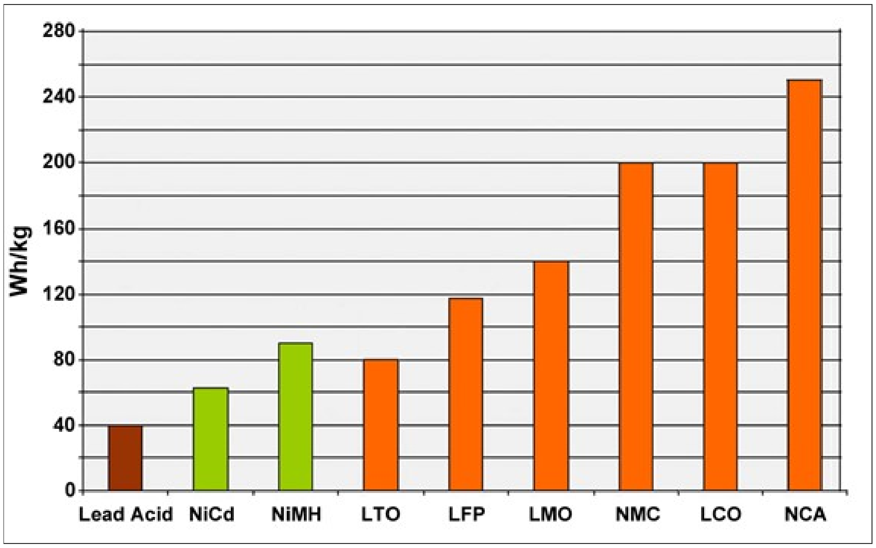

Figure 15: Typical specific energy of lead-, nickel- and lithium-based batteries.
NCA enjoys the highest specific energy; however, manganese and phosphate are superior in terms of specific power and thermal stability. Li-titanate has the best life span.
Courtesy of Cadex

Last updated: 2018-05-31

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If you have a suggestion or would like to report an error, please use the "contact us" form or email us at: BatteryU@cadex.com. We like to hear from you but we cannot answer all inquiries. We recommend posting your question in the comment sections for the Battery University Group (BUG) to share.

Or Jump To A Different Article

Basics You Should Know

Comments

On April 19, 2011 at 1:45pm

Mike wrote:

Not correct: "on charge the flow is from anode to cathode"

On charge, Li+ ion flow is from cathode to anode. On discharge, flow is from anode to cathode. This is easy to remember. The battery is assembled in a discharged state, where only the cathode contains lithium (e.g. $LiCoO_2$) and the anode is pure carbon containing no lithium. Thus on charging, the Li+ flow must be from cathode to anode.

On July 10, 2011 at 4:08am

Ken Neal wrote:

I just want decent battery life for my Mesmerise Phone.

On July 21, 2011 at 9:59am

karl wrote:

Danke für die vergleichende Darstellung der verschiedenen Li-Elemente.
Die Parameter.Grafiken geben einen raschen Überblick.
MFG karl!

On February 1, 2012 at 12:47am

Victor wrote:

Not Correct "Not correct: "on charge the flow is from anode to cathode" "

Lithium ion flow is ALWAYS from anode to cathode, both charge and discharge. You are confusing the negative and positive electrodes (which are the same on charge and discharge) with the sites of oxidation and reduction (which are respectively the anode and cathode and reverse on charge to discharge and vice / versa). Battery engineers (me included) use this mistaken nomenclature for the electrodes as a historical artifact of primary (non-rechargeable) batteries which operate only in the discharge mode.

On March 14, 2012 at 2:08pm

Tom Blakley wrote:

Victor's comments clear up the misunderstanding that Mike voiced concerning the phrase "on charge, the flow is from anode to cathode", which is found in the first paragraph of the section describing Lithium Cobalt Oxide.
Another (more wordy) way of stating what Victor is teaching is to say that: On Discharge, the negative electrode is called the anode and the positive electrode is called the cathode. However, on Charge, the negative electrode is now called the cathode, while the positive electrode is called the anode.
We swap the names (functions) of the physical negative and positive electrodes depending on whether discharging or charging is occuring.
Another point: The negative electode is always labeled as the negative terminal (-) and the positive electrode is always the positive terminal (+).

On March 20, 2012 at 2:01am

Shivbraham Singh Rajawat wrote:

Very Good Material on Batteries

On March 28, 2012 at 12:44pm

Robert Bernal wrote:

MORE info for the LiFePo4 (lithium iron phosphate) battery… please!
They should not be grouped with the other li-ion chemistries in the "safety" table.
Anyways, they (and I guess, all li-ion types) need to be charged constant current until reaching charged voltage, then constant voltage just for maintaining. I hear that CC/CV is how the li-ion smart chargers do it.
What I want to know, is if it is alright to simply put a low drop out voltage regulator on a 6v SOLAR panel, set to the 3.5 or 3.6v (not 4.2v as with li-ion), would it be Ok? I visualize such that "it can't get filled up past that point no matter how large the charging source is, as long as the input voltage remains below the recommended charge cut off". I tried to search this many times but nobody's doing it.
Bty, they do not have thermal issues and have about 4x the charge discharge cycles (about 2,000 complete) wheras li-ion is prone to thermal issues (catch fire) and only last a few hundred cycles.
For this reason, the LiFePO4 battery should be on the top of everybody's list and that we all should DEMAND robotic factories that mass produce them cheap enough to be used in solar and electric car applications. The ONLY trade off (other than current high costs) is that it is not quite as energy dense as li-ion. There are enough raw materials in this planet's crust to safely mine and base an entire global infrastructure on it, too!

On May 15, 2012 at 9:53am

ron davison wrote:

Robert,
Add a current limiting diode to your idea and whne the battery voltage is very low you will not draw more current than the battey will take without damage.

Caveat…at very very low voltages this current limit is very low and mAY NOT ALLOW FOR A FAST ENOUGH CHARGE if you protect current fore below cot-off chARGING.

a SERIES RESistor with a fet across it (in //) that closes when the battery voltage is above the cut-off voltage (without charge current). So the state of the switch needs to be set with the LDO off. So a timing circuit that turns off the LDo and checks voltage is needed this can be low duty cycle. Starting to not be a simple circuit…

On November 21, 2012 at 6:29am

krishna wrote:

great material ! I have a question though..for motor driven applications like power tools, is it okay to use Li-Cobalt batteries? Is there some precautions to take care of ?
would Li-Manganese be a good choice for tradeoff between power and energy capacity in such applications?

On January 11, 2013 at 9:52pm

John Paul wrote:

Is specific energy and specific capacity the same thing? If yes, are the units of specific energy (W-hr/kg) and specific capacity (mA-hr/kg) are equivalent?

On February 4, 2013 at 6:44am

Tushar Dobhal wrote:

I am involved in a project for making an electric vehicle for the Shell Eco Marathon Asia. I want to know which of the above Li ion batteries will be suitable if I need an energy output of 3 KWhr, and efficiency of the vehicle (Km / KWhr) is of prime importance.

On February 4, 2013 at 1:14pm

ron davison wrote:

LIFEPO4 is your best bet for energy density and power density at this time.
also does not have the level of safety issues, some brands claim they have solved the issue.

On February 4, 2013 at 4:11pm

Victor wrote:

For a (smallish) 3kWh battery in a normal sized EV, the km / kWh of the vehicle will be dominated by the vehicle's weight and aerodynamics. The battery type can simply be chosen on energy density considerations.

On March 11, 2013 at 7:46am

Josh wrote:

Request for clarity on the section on Lithium Manganese Oxide:

"An 18650 package can be discharged with currents of 20-30 amps."

Later:

"The long-life version in the 18650 cell has a moderate capacity of 1,100mAh; the high-capacity version is 1,500mAh but has a reduced service life."

Is this stating that this single 1,100 - 1,500mAh cell can take discharge currents of 20-30 amps, or is it saying that a package of cells in a string can take a such currents?

On May 22, 2013 at 5:09am

Ranjusha wrote:

Hi
I am currently working on manganese oxide based lithium ion battery. I am looking for the best electrolyte for this system. I went through the literature but there are plenty of lithium based electrolytes. Can anyone recommend the best composition for the electrolyte so that the best performance can be attained?

Thanks in advance

Ranjusha

On May 24, 2013 at 3:55am

John Hardy wrote:

This is excellent material. The only statement I would suggest you look at again is the "... Li-phosphate has a higher self-discharge than other Li-ion batteries, which can cause balancing issues with aging…"

I have done long term cycle testing on LiFePO4 battery packs and have seen no drift in cell voltages in almost 600 cycles in one test and almost 400 cycles in another. From my observations I see no benefit in balancing a battery of this kind unless there are parasitic loads such as a poorly designed voltage monitoring system. I have also seen no self discharge. I checked some of the cells from the earlier test after 7 - 8 months. The cell voltages were all within 10 mV and were approximately 10 - 20 mV HIGHER than the last recorded ones at the end of the test.

If you would like any of the test data (available as CSVs) give me a shout

John

On June 10, 2013 at 1:01pm

Rob wrote:

Hi,

The battery of my ebike is composed of ncr18650b cells.
It will not be used for 3 weeks.
Is it ok to store it loaded at 40% in the fridge (about 6 degrees celcius) ?
Thanks
Rob

On July 10, 2013 at 5:27am

Mark McElroy wrote:

I am not a battery engineer but, as a chemist, find battery technology fascinating. However, my question is about the PV system I have on my roof. Would it be possible to use a Toyota Prius battery (one that has been replaced because it`s capacity has become too low for efficient use) to store energy generated from my roof PV panels for use at night?

On August 24, 2013 at 9:17am

Mark McElroy wrote:

I am not sure ow this applies to my query

On October 13, 2013 at 8:19pm

Justin wrote:

Could a Prius cell/cells be used to store energy from a PV, sure but a cell that is already reaching considerable drift won't be much use as designing both a circuit to compensate for the ESR of the cell and the degrading performance will be tad of a waste of expensive components. A Prius individual cell is not extremely expensive if Ni-Mh is your goal. Li-MN in SP arrangement would be far better albeit more complicated to charge.

On November 22, 2013 at 3:54pm

Peter Hasek wrote:

Which of the above-mentioned Lithium battery formulas is closest to the typical Lithium Polymer formulas that are widely used in RC aircraft?

On December 2, 2013 at 9:40pm

Md. Asadur Rahman Dolon wrote:

hi,
i need the equipment list and process of lithium ferrous phosphate battery manufacturing.

thanking you

On December 3, 2013 at 2:50am

Mark McElroy wrote:

Thanks Justin, I get your point, although I was thinking of the whole battery from a prius and not an individual cell. I understand that the whole battery has to be replaced when its capacity has reduced to, 40% (not too sure of this figure). So my thought is that at 40% of original capacity it might just do as a storage unit for PV generated energy.

On February 15, 2014 at 10:27am

Nisei wrote:

As I understand, the maximum/minimum charge/discharge voltages for these different Lithium-ion batteries aren't the same. Would it be possible to add these to the article or can someone point me to a page where I can find them?
Thanks in advance.

On March 18, 2014 at 8:45am

Martyn Adams wrote:

I have the quintessential simple Lithium installation.
Boat, 40ah LiFePO4 "12V" battery,75W solar panel, MPPT controller.
Location NW WA.
Battery seems to maintain a 14.8-15.1V charge after a period of no use which may be temperature dependent.
Anyone see any problems?

Cheers,Martyn

On April 10, 2014 at 2:44am

Robert W Best wrote:

Are LFP batteries always conditioned in the factory? Or should I condition new batteries before use?

On May 29, 2014 at 5:43am

Vijay wrote:

Very well explained for better understanding of Li batteries and it's function for various application.

On July 1, 2014 at 12:59am

John wrote:

needed for my research. Thanks a lot. hope to see more

On July 7, 2014 at 2:15pm

Mohammad wrote:

Does any body know what is the chemistry of LG chem 18650 MG1 2900 Ah battery? What does MG1 stands for?
Thanks

On August 3, 2014 at 9:40am

Edward wrote:

Here many commented but no one concluded what is the best Lithium battery ?

Can anyone suggest me best battery based on over all performance. High power, Long duration, high cycles, normal charging time,

Thanks

On August 9, 2014 at 2:29am

Kam wrote:

Is there any easy and non-destructive way to determine the chemistry of an unknown 18650 cell? And for charging and discharging purposes, does it matter?

I have obtained a number of cells made by EPT out of a computer battery, and I would like to learn how they are best charged and maintained. By the way, I'm using an imax B6AC charger.

On February 13, 2015 at 5:43am

Tesfamariam wrote:

It is so nice material but it lucks some clear descriptions about the stages of charging and discharging process with in the different oxidation states of Cobalt

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On April 5, 2015 at 4:01pm

Antonio wrote:

Done long term testing of LFP batteries both 26650 and prismatic.
My data doesn't match your information on high self discharge. Get around 1-2 percent a month in prismatic cells.
The only umbalance happened with a set of second-grade 26650 cells in a single occurrence. If your testing indicates unbalance, check the source of your batteries. LFP can replace lead-acid -if so is decided from maret, provided that defective cells are not sniked into production.

On April 13, 2015 at 8:59am

jess vote wrote:

good god anode and cathode, capacitance, farads and such. why can't people make a usage of the power generated by our planet. e.g. what tesla worked on. free power transmitted? heck if it relates to lightning and our own ionosphere, why not use it? storage banks that we use to harness the power of lightning strikes, but some crazy bastard will use it to get rich. nature is rich in the evolution of man. and all i have to say is kiss, an acronym.. nuff said. just my thought. tesla was the stuff.

On April 14, 2015 at 2:31pm

Antonio wrote:

Dear Friend.
don't you like batteries?
Portable electric power, solid state electronics and the IP protocol are the three most important achievements of Mankind. The poetry of our Genre, which Tesla represented genially, by fusing the practical aspects of electricity, with the invisible (at the time) potentiality of alternating current.

He didn't harnessed Earth energy directly, as you propose. Think. It is possible to harness the power of a lightning, but not very practical. We all hope for better batteries and nuclear fusion. The alternative, and there is no point to it, we will be back to a cave all together. Fancy that?

On April 22, 2015 at 9:59pm

Theo Veeren wrote:

Dear Sir,
I am an elevator mechanic by trade since the last 30 years and soon I will be retiring I wonder if you can recomend a basic book with instructions which a simple mechanic can understand (I still remember Ohms law)on how to build a battery, and charger for electric bikes according to Australian standards as a pensioner I like to produce battery which delivers enough power to drive the Tricycle or bike 30 /40 km distance with a speed of 20km/hr. could you please supply the info about which type of batteries, charger and battery monitors you would use and preferable a wiring diagram for the serial and paralel and monitoring wiring connections. I know it is a big ask but I be willing to pay for your advice if it is not too expensive, I be grateful. sincerely, Theo Veeren

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On June 4, 2015 at 4:39am

NILESH RAO wrote:

i want more information about LiNiCoAlO2(lithium nickel cobalt aluminium oxide). plss . send a reply..

On June 15, 2015 at 1:24am

Larry Becque wrote:

What about the new LimPO4 batteries?

On June 15, 2015 at 10:03am

Antonio wrote:

LiNiCoAlO2 are the Panasonic NCR18650B, they give 2C max current and 3450 mAh capacity. They have a graphite anode. Shortly we should see the same battery with a silicone anode, as they reached max half capacity. Next gen with silicone anode will start at 3900 mAh.
LiMnPo4 batteries are an evolution of LiFePO4, giving higher terminal voltage. From what I know production of those haven't ramped up. Manganese is not allowing the same 2000 cycles of correspondent iron-based structure.

On June 15, 2015 at 4:14pm

Larry Becque wrote:

I became aware of LimPO4 batteries when I saw the following listing on eBay for a BMS:
http://www.ebay.com/itm/12V-14-6V-4S-90A-LiFePO4-LFP-LimPO4-Car-Battery-Starting-BMS-/121632554497?&_trksid=p2056016.l4276
Apparently, in China, they are starting to replace Lead Acid car starting batteries with these. Interesting idea; less weight, less environmental problems. Just wonder how practical it is in real use compared to the brute durability of Lead Acid.

On June 16, 2015 at 10:15pm

peter mare wrote:

Based on our patent-pending supercapacitor technology that uses a novel conductive polymer material, we are developing a high capacity Super Cathode for use by battery manufacturers to create the ultimate high capacity, low cost lithium-ion battery.

Our novel high capacity cathode is engineered from a polymer, similar to that of low-cost plastics used in the household. Through a smart chemical design, we are able to make the polymer hold an enormous amount of electrons. Instead of conventional cathodes that use lithium-ion intercalation chemistry, which is inherently slow, we exploit the fast redox-reaction properties of our polymer to enable rapid charge and discharge.

Most lithium-ion batteries cannot retain more than 80% of its storage capacity after 1,000 charge-discharge cycles. The stable redox chemistry of our cathode material can enable much longer life. Our laboratory experiments have shown that our cathode can easily cycle over 50,000 times without degradation in supercapacitors, and we believe that it can be very effective in batteries as well.

By enabling higher charge-discharge cycles, we can extend the life of lithium-ion batteries and further reduce the total cost of ownership. In certain applications such as off-grid solar energy storage where the batteries are fully charged and discharged daily, it is not cost-effective to use current lithium-ion batteries due to short replacement life.

We believe that by integrating our Super Cathode with conventional anodes, a complete lithium-ion battery can be built that is lower cost, higher capacity, faster charging and longer life.

[...]

http://www.biosolar.com/super_battery.php?PHPSESSID=5f75e8a836e96fa4ad9f5dea8baa3421

On August 14, 2015 at 8:44am

Gerald Biccum wrote:

Gerald this is awesome

On September 25, 2015 at 1:59am

sunil jaiswal wrote:

nice literature on li battary

On September 30, 2015 at 12:45pm

Larry Becque wrote:

Here is more information I found on WIkipedia regarding LimP04 batteries that clears this up for me:
LiFePO4 is a member of the olivine group, which has a general chemical formula of LiMPO4, where M refers to any metal, including Fe, Co, Mn and Ti. The first commercial LiMPO4 was C/LiFePO4 and therefore, people refer to the whole group of LiMPO4 as lithium iron phosphate, LiFePO4. However, more than one olivine compound may be used as a battery's cathode material. Olivine compounds such as AyMPO4, Li1-xMFePO4, and LiFePO4-zM have the same crystal structures as LiMPO4 and may replace in a cathode. All may be referred to as "LFP".

So the M in LiMPO4 stands for any metal, not necessarily Mn. Apparently, LFP batteries aren't necessarily Fe based and could be one of several metals. A bit of a misnomer has started since the first batteries where indeed Fe based. It would be better to start calling these LMP batteries but the misnomer has already been done.

On September 30, 2015 at 9:35pm

Andy Frederickson wrote:

Valuable site.
Thanks.

On October 17, 2015 at 12:56pm

hrncirik wrote:

Charging anode is reduction. Li+ +e = Li metal anode;
or Li+ + C + e = Li+ + C- graphite (carbide) anion anode; simply C + e = C-

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On November 2, 2015 at 11:45pm

Dr Weathers wrote:

I LIKE THAT !

On November 27, 2015 at 9:57am

Jonathan M wrote:

Great site!
What's about Lithium Polymer?

Thanks.

On January 30, 2016 at 9:36am

Tron wrote:

Could you please include Li-ion Polymer in this article?

On February 18, 2016 at 10:00pm

Rolfh R. wrote:

Good day. May I know what kind of li-ion EB535163LU of Samsung is? Thank you for your response.

On March 17, 2016 at 6:35pm

Susan wrote:

Which batteries out of those listed provide the best value (long life & low cost)? Does anyone know? I have batteries in my hand vacuum. They die very quickly. For the next one I would like to make sure that I have much better batteries but I do not know what to look for. Thanks.

On March 24, 2016 at 10:39am

Rvs wrote:

This is excellent stuff from Battery university they have put the complex subject in such a simple manner even a child can understand it

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On May 12, 2016 at 3:54am

RNMentropy wrote:

Hello Battery University,

I think you have a mistake regarding the Lithium Cobalt Oxide battery.

You've writeen:
"Li-cobalt cannot be charged and discharged at a current higher than its C-rating"

But, apparently, the vast majority of RC batteries are li-cobalt ,which peak at very high C.

Some MSDS and links:
https://system.netsuite.com/core/media/media.nl?id=1760869&c=1327152&h=dd21074dd6e7416e6499&_xt=.pdf

http://www.precisionhawk.com/MSDS-for-TP-BATTERIES.pdf

http://www.nrel.gov/education/pdfs/lithium-ion_battery_materials_safety_data_sheet.pdf

130C peak
"Utilising an advanced LiCo nano-technology substrate"
http://www.hobbyking.com/hobbyking/store/__19158__Turnigy_nano_tech_5000mah_8S_65_130C_Lipo_Pack.html

What do you guys think?

On May 26, 2016 at 4:28pm

Alex wrote:

I believe that LTO voltage is 1.55V vs. Lithium. Also, graphite has a nominal voltage of about 0.2V vs lithium. Thus I see a problem with the stated operating voltage. Also, due to the higher operating voltage, LTO when used as anode, decreases the amount of side reactions with the electrolyte.

On June 2, 2016 at 11:17am

GB wrote:

Great Summary - Thanks!

It's NMC for my e-bike.

On June 15, 2016 at 3:44am

Niels Van Brandt wrote:

Hello Battery University,

I'm doing an internship at a Belgian company called nLab.be . One of the projects for my thesis is building a battery pack for one of the first EV's build in Belgium as a production car. We are looking around to different 18650 cells and this kind of information (BU205) is very useful but it's limited to a few different kind of cell's. Currently we bought the Panasonic NCR1650PF cell's and i have a hard time finding more data on them other than the simple data sheet.

Do you have any recommendations on where to find more information on these and other battery? Our supplier doesn't know anything about the cells and apparently Panasonic isn't very responsive to our questions. I'm a big fan of those hexagonal spider graphs, so it would be great if i could find one for the NCR18650PF .

Thanks in advance,

Niels Van Brandt
nLab.be

On June 15, 2016 at 4:20pm

Rondoc wrote:

Please include a chart showing lifetime of the cells when stored. Our experience is that the cells deteriorate even when unused. This has occurred with LIPO4 cells and also in Li CO cells (used in the Leaf Nissan car).
The storage life can be more important than the cycle life for applications with few cycles.
Our experience with the LiPO4 has been a 50% loss of capacity in 4 years wit ideal storage. The Leaf cells seem to have about a 30% loss in the same time frame. The storage lifetime is difficult to obtain from manufacturers.

On June 17, 2016 at 12:52am

RNMentropy wrote:

Nissan Leaf are NOT LiCO cells, they are LMO/LNO mix
http://www.eco-aesc-lb.com/en/product/liion_ev/

On June 17, 2016 at 9:59pm

Rondoc wrote:

Thanks for correction. My comments re storage are still valid. I have a 2011 Leaf and range is now only 45 miles. Only has 20,000 miles , this makes the cost per mile , assuming that i can buy a new pack for $6000 from Nissan, very expensive and sadly far higher than a gas car.

On June 17, 2016 at 10:01pm

Rondoc wrote:

Where can i buy NCA CELLS?

On June 23, 2016 at 6:34am

Joe Sabatini wrote:

Who would be the most likely buyer of Manganese dioxide for EVs? Would it be Panasonic or Tesla? Remember the model 3 has lower cost basis?

On July 6, 2016 at 10:48pm

Purav Soni wrote:

Hello,

I have few questions for you which i need to clarify with you, i am currently working on a project where i need to select a battery the battery rating i need is 60V 60Ah.

so my concern to you is that what other combinations i use to that i get the above ratings?

so my question is, suppose for example i am not able to find 60V 60Ah battery in market so can i use other rating battery such as 12V 25Ah to get the rated energy or power whichever we calculate ?

If yes how do i calculate the ratings for this kind of this ?

Please enlighten me on this i an stuck at this !!!

Thanking you in advance!

On August 10, 2016 at 1:38pm

Alessandro wrote:

Hello,

Can you please tell me which is the safest (and with less or zero hazardous materials in it) type of battery for laptops? If you are anle to, please make some examples of brands or models that use it,

Thanks a lot, regards,

Alessandro

On August 15, 2016 at 4:41pm

Donna Vnuk wrote:

what would happen if I took a 12volt lithium ion battery with a capacity of 25 a hrs and used a transformer and stepped up the voltage to 48 volts? Iam powering a 1000 watt e bike motor with a peak draw of 1300 watts?

On August 24, 2016 at 2:38pm

john kidd wrote:

HI we all asking each other..its down to needs and wants.what is good what is bad.
i owned a triumph.motorbike 2 years ago.battery died.slowly .cost for the correct battery
£200.? yes. bought a new battery cost £39. not cheep if you think about.3900 pence.
market value.in stocks….manerfactoris build a battery for you and batterys for the induresreal companyis ..so a low out put battery is good for my wiles .a high out put battery is good for my toys. the writer of this page as it all set out for you….i ask you all to think of this its worth millions.you build a small motor you power it up.it will drive and power its self.
and give you what power you need. A SELF POWERED BATTERY AS A INVERTER PROGRAM IT WILL RUN A SMALL TOOL AT 19000 REVS PERMITS.FOR 20 MINS.SO IN TIME YOU HAVE WHAT YOU WANT….WE WILL SOLVE THE UNISVERS IT AS BEEN SAID WE NO ABOUT 4 ELLEMENT .THEY SAY THEY HAVE FOUND A 5.. IDINE BE HIND THE 4 ELEMENTS. WILL SOLVE THE BATTERY LIFE.
THANK YOU ALL.

On September 15, 2016 at 8:07pm

Marcus wrote:

Wow the page is so useful. All people involved with LIB shoud read this so they can understand this very fundamental but truly useful information.

On September 27, 2016 at 10:11pm

bhuwan wrote:

Is it possible to use Li-cobalt batteries in telecom power plant, since the load is not greater than ~50A?
But the atmospheric temperature is about 52 degreee celcius in summer time.

On September 29, 2016 at 3:10am

Andrew Xenakis wrote:

Hi i am interestd in a Li-NMC Battery of minimum 15.6 Ah and 11 V to be charged by a solar panel and support 3 led lights x 4 Watt and charge 3 smartphones at the same time . May i have a guidance as i am working on a project and i am not so adept to battery types and where i could find them , the reliable ones . Very useful article of course. Thanks in advance .

On September 29, 2016 at 3:13pm

Max wrote:

Section with Lithium Titanate (Li4Ti5O12) is wrong!

Lithium Titanate (Li4Ti5O12) battery do NOT use Graphite cathode. It even not physically possible to use Graphite as cathod here. LTO chemistry usually include Lithium Manganese Oxide(LiMn2O4) as cathode resulting in ~2.5 V nominal voltage (LMO+LTO).
Or Lithium Iron Phosphate(LiFePO4) as cathode resulting ~ 1.9 V nominal voltage (LFP+LTO).

On October 18, 2016 at 10:41am

Saurabh wrote:

Have two questions:

I want to buy LFP power cell (3.2 v) either 1.1 ah or 2.2 ah. Can anyone recommend some good quality suppliers in low cost countries such as China etc.

My second question is, can we use NMC or LMO chemistry cell (nominal voltage of 3.6-3.7 v) for12 volt application. If yes, how do we charge them to full potential. Instead, can 3s2p kind of config be acceotable?

On October 31, 2016 at 5:23pm

Armin wrote:

Donna Vnuk wrote:

what would happen if I took a 12volt lithium ion battery with a capacity of 25 a hrs and used a transformer and stepped up the voltage to 48 volts? Iam powering a 1000 watt e bike motor with a peak draw of 1300 watts?

This is not a god Idea! With 12V the battery must deliver more than 110A on full throttle. If you need low throttle the motor will be driven with lower voltage than 48V.
On a 48V Battery the Current will draw only about 27A so hat you can use smaller cables an electronics.

regards

On November 7, 2016 at 7:57am

Rob wrote:

For a ‘University’, you put a relatively small number of references to actual battery datasheets in your articles (zero).

Would be helpful if you reference at least some of the performance related metrics in your summary tables (such as cycle life, etc).

On November 27, 2016 at 4:20am

Edward wrote:

Hi everyone! Has anyone tried building NCM packs with cells from www.szwestart.com?

On December 20, 2016 at 9:10am

Fran wrote:

Hi, I have some questions that I hope you can answer:
- What happens if you use LiFePO4 batteries in a Vcell of 3,3V in stead of 3,2V? Would the life cycles be lower?
- How do you calculate the life cycles of each type of battery? What SOC do you use to define de EOL of the battery? What DOC is taken for each cycle?
- Many manufacturers claim to have batteries of LiFePO4 and LTO with much higher life cycles. Is this possible?

Thank you very much!

On January 11, 2017 at 6:36am

Christiaan wrote:

Anyone knows which chemistry is used in the new Tesla 2170 cell ?

On February 22, 2017 at 1:13pm

Po Huang wrote:

Hi Battery University,

I have a question regarding the charging process of the Lithium-Ion battery, and was hoping you can help me with answering it.

1. when charging an empty battery, how do you determine the initial voltage on the charger? When you plug in your constant current source, what should be the voltage?

Thanks, great content
Po

On March 3, 2017 at 3:04pm

john wrote:

good to no some one as given some info on just about all up to date batters.but no one as given the life ending.hand lots of stores that sell battery s do not give much away about there battery s .i bought two motorbike battery s cost 30 each after five years i still use one to run my bike.they other one went last year on a bike i sold. what i no and remember the battery s wear labeled the day i bought i never said any thing.but the battery was one kilo
heaver than what i used in the past. the company bought in around 50.at 10 a shot.
two month later went back to buy some more the doors were closed.the shop empty.
i contact another shop but could not obtain any of the battery s.the battery is sealed
no bulges still charging to this day. so what element and plating one wonders.i use to cut battery s up for scrap. and theirs not much plastic and card or webbing. to dispose of.
just asking dose any one no what the army us.some one on YouTube used a battery and burnt out the selonod starter .in a short spin .battery was dead .using the army one it spoon the engine over and over.. a v twin was used but they would no give any one any info.as the army told them do not disclose any thing about the battery.that was about two years ago. do any one no. i have sander it can run 19.000rvs for 20 mints.then it will cut out start cut out.its like telling you i need charged .i took it to bits in side i found a small centerboard just like a computer board. now was there a invert er on the board. some thing are never talk about. Tesla did he no much more then any one
if some one can make a motor drive its self after you start it.it can then drive a motor. for power. you no electric is free. sorry for long out span.thank.

On March 31, 2017 at 1:38am

Kassim wrote:

Lithium-ion battery is a more dangerous than lfp battery.

On April 20, 2017 at 9:34pm

Melvin Mathew wrote:

Sir,

Pls let me know whether l lithium titanate is expensive.
In the description it is specified that it is expensive. However in graph , it is plotted at comparatively cheap.

On April 28, 2017 at 5:39am

Matthias wrote:

@Melvin Mathew:
Since this point confused me as well at first:
A big number in the graph is better than a small number;—> LTO = bad in the cost aspect.—> small number

Hope I could help 🙄

On May 3, 2017 at 3:55pm

Kassim wrote:

I use LFP now for 6 yrs and is still good, but the discharge depth never went below 6o%

On May 3, 2017 at 10:19pm

Shyam P.Sen wrote:

LiNiMnCoO2 (NMC) cell is suitable for e-Rickshaw OR e- Bikes… Please suggest what is the Life cycle for e- bikes.

On June 23, 2017 at 1:23am

Hao wrote:

A type error:

first paragrah of NMC section, “2,000mWh” should be “2,000mAh”.

On July 25, 2017 at 5:12pm

ET wrote:

It’s frustrating, even on your site, that it’s difficult to find specific credible comparable self-discharge information on different battery chemistries. You say in multiple places that LifePO4, for example, has higher self discharge but there are no rates, references, etc. specified. There are many references on the web that state LifePO4 and conventional Li-Ion (cobalt) BOTH have typical self discharge rates of 5% or less per month.

In my own testing of A123 18650 LifePO4 cells charged to 80+% and stored for 1 years they only lost about 25% of their charge (2%/month). Compared to high quality Li-Ion (cobalt) 18650 cells charged to 50% and stored alongside them for the same year, the Li-Ion cells also lost about 25% of their charge. I also tested the capacity of the cells after 1 year and the LifePO4 cells retained more of their original capacity despite being stored at 80% charge. So, from my admittedly limited testing, they’re similar and LifePO4 has the advantage of (apparently) being more tolerant of being stored at higher charge levels as well as being significantly safer.

Do you have any credible references on the self discharge rates of LifePO4 vs Li-Ion chemistry? The higher self-discharge you mention might be more myth than fact and there’s a lot of conflicting information. Some sites claim LifePO4 has LOWER self discharge than Li-Ion. I think you should review your claims as, for long term storage, LifePO4 might be the better option.

On August 6, 2017 at 3:22am

bgt wrote:

How come batteries for mobile phones can be charged to 4.4V like in the new S8?
Does not that pose a high risk of explosion? I know they make cells being able to 4.4V but at what risk?

On September 1, 2017 at 4:00am

Alan wrote:

Comment to ET’s Comment about self discharge rates

I was wondering about this also.
I suspect the issue is that there isn’t a standard way about how to measure self-discharge, or even charge.

The only way to get a reliable self-discharge value is to discharge the batter over a given range. And then the rate you get, is path dependent: depending on where you measure from in the discharge process.

Perhaps a more reliable metric would be shelf life to self-discharge the battery to a given SOC. Say to 50%, 80% and 90% SOC. At a given temperature.

On September 11, 2017 at 12:38am

muhammad khan wrote:

what is deference between CR lithium cell ER lithium cell

On September 13, 2017 at 3:53pm

Marco wrote:

Hello, Do you know which type is safer in water? I need to buy 18650 batteries for a scuba torch. I would like to avoid fire underwater in case of infiltration and water damage. On youtube I saw a LiNiCoAlO2 not catching fire, is it true? Thanks

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On October 8, 2017 at 7:46am

Ed Metcalfe wrote:

You mentioned cost several times with the last battery, LTO.
However, this doesn’t match with the spider graph presented, which indicates, by comparison with all others, that LTO is the cheapest battery.
What gives?

On October 15, 2017 at 9:05pm

Matimba Khoza wrote:

The Li titanate type seems to be advance and safe. How easily available are the raw materials of Li titanate Batteries. What could be the cost of such raw materials on average. One think about this because our Global village is switching to li ion Batteries enmasse and on fast pace. So security of supply is critical.

On November 6, 2017 at 10:06am

k.shree kesavan wrote:

how to calculate C rate in lithium ion batteries?

On November 9, 2017 at 2:28am

George wrote:

Why are you not giving data on cell capacity in mA for lithium type cells? While there might be difficulties in coming up with this, THE REAL WORLD OF CELL USERS OUT THERE TALK ABOUT MILLIAMPERES CAPACITY. I do not know how you should call them. But your are the BATTERY UNIVERSITY As university, you are not just a REPORTER of what's going on in the world of batteries…but you also COIN WORDS, IDEAS, TRENDS, ETC. Give your readers an idea of the cell capacity of, say, 1 cell of NMC type, etc. If there are fine prints that will go with what you provide, for heaven's sake, just jot down those fine prints, but provide an idea of cell capacity

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On November 9, 2017 at 4:31pm

Niall Darwin wrote:

Great foundational information. Thank you.

On November 22, 2017 at 3:42pm

Solo Ning wrote:

I was wondering what the lattice structure of NCA or NMC look like as there wasnt a diagram provided, unlike Lithium Manganese Oxide ($LiMn_2O_4$) which has a photo

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On January 14, 2018 at 11:21pm

Peter McMahon wrote:

There seems to be a bit of confusion about cathode & anode, & about constant current & constant voltage charging. Firstly, except during charging, electrons go into the cathode & out of the anode. If it is NOT a battery, the electrons are pushed into the cathode from the outside, making it negative. With a battery, they are pulled in, making it positive, & pushing out the anode, making it negative. When charging, the same polarity is applied, but higher voltage. The battery is still trying to push them out, but the charger is pushing them in harder.
The charger is a constant voltage source with current limiting, making it ACT as a constant current source until the battery voltage rises to the set value, then it becomes a constant voltage source. As the battery is topped up, it draws less & less current from the charger. I hope this clears the confusion.

On January 27, 2018 at 6:06am

Christian wrote:

Can I use 1 18650 and 2 16340 batteries instead of just 2 18650 in a laser?

On January 27, 2018 at 6:37pm

urban sanchez wrote:

all this is new to me and I want to learn

On February 16, 2018 at 3:10am

ashar wrote:

can you give contact or email manufacture of battery type cell Lithium NMC Prismatic with spec. Voltage range 44.8 to 58.1V, Cell balancing Active Battery Optimizer (ABO), energy 33.6kWh, efficiency (battery) 98%, Current Charging 900A, Current Discharge 900A, operating Temp. -10 to 50 C?
Thank you for your information

On February 26, 2018 at 1:33am

sheik wrote:

can you say which battery technology is currently used in fastcharging elelctrical vehicles.and also say its spec.
thankyou

On March 3, 2018 at 3:05am

Orlando wrote:

Thanks for the knowledge writed un this web.

Knowledge maleta US a bit more free.

Orlando

On March 28, 2018 at 3:58pm

Azim wrote:

I wonder if I can use LiFePO4 charger for other Lithium ion Batteries?

On April 23, 2018 at 9:45pm

Akash thute wrote:

remember, oxidation always takes place at anode and reduction at cathode irrespective to the '+ve' or '-ve' terminal notation.

On May 25, 2018 at 5:39am

Abhinay Singh wrote:

Everything is fine but nomination of Anode and Cathode at different places are different and it is bit confusing, even few comments screwed me more.
rest I appreciate this article. Thank You

On July 10, 2018 at 7:32am

phang giap seng wrote:

which type of lithium ion batteries suitable for Garmin and tritium GPS receiver
and can tell me why suitable the chemical and physical properties. * i only want lithium ion batteries such as liFePo4 . request for answer thx

On August 2, 2018 at 8:32am

Roy Allen wrote:

A company in San Jose CA installed a commercial 3-ph BESS systems been advised by the local fire dept that the building site where the system is located must display a NFPA 704 Hazmat placard due to the large quantity of Li+ batteries.

FYI, the 704 placard is diamond shaped with four smaller diamond shaped quadrants and can be seen here: https://www.compliancesigns.com/NFPA_PRINTED_1200.shtml?gs=11.00&utm_source=GoDataFeed&utm_medium=GoogleShopping&gclid=CjwKCAjwtIXbBRBhEiwAWV-5nuO48ZlJRlb5Y2W7QYVuEEe5X4QFFlQnx9muFM2n5UcqNNgtc1k1RhoCRGwQAvD_BwE

Each colored quadrant (red, blue, yellow and white) represents an aspect of fire hazard. The three primary color diamonds have numbers (0 to 4) associated with increasing fire hazard levels,and the white one is for special assignments.
I think the numbers for LION should be:
Red:0, Blue:1, Yellow:0 and White: blank - however this is a SWAG…
Any help would be greatly appreciated