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What's The Difference Between Rechargeable Lithium And Nickel Batteries?

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Strictly speaking, in a battery, electrochemical cells are connected together to convert chemical energy to electrical energy. When most people talk about battery chemistry, they really mean cell chemistry. There are two types of commonly used rechargeable cell chemistries: those based on lithium and those based on nickel cathodes.

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Cathodes And Anodes

First, a caution about a terminology stumbling block: which end of the cell is the cathode? Engineers use the terms consistently. But to people who are somewhat familiar with electronic circuits, it may seem contrary that the positive (+) terminal of a battery is its "cathode."

In diodes (electronic devices that conduct only in one direction), the cathode is the negative (–) terminal. If one puts a light bulb in series with a diode and connects a battery across the pair, the bulb lights only when the battery's cathode (+) terminal is connected to the diode's anode (also +) terminal and the return path through the bulb runs from the diode's cathode (–) to the battery's anode.

That makes sense to chemists because, inside the battery, surplus cations (positively charged ions) are attracted to the cathode, and anions (negatively charged ions) are attracted to the anode. Inside and outside the battery, electron current flows in a consistent direction.

Recharging Batteries

Most battery cells can be recharged by applying a reverse voltage to their terminals. This reverses the chemical process in which anions and cations were separated in the cell electrolyte and attracted to the anode and cathode. For storing large amounts of charge, lead-acid (automotive type) batteries are good, but they're too bulky and heavy for portable applications. For (relatively) inexpensive portable applications, nickel chemistries were developed first, then lithium.

Although the first nickel-cadmium (NiCd) batteries were built in 1899, their practical application in consumer products did not begin until after World War II. Nickel-metal-hydride (NiMH) batteries weren't commercialized until 1989.

Sony introduced the first commercial lithium-ion (Li-ion) battery in 1991. Lithium-cathode batteries tend to be lighter than nickel batteries, with higher energy densities (more ampere-hours for a given volume). They also do not present the hazardous-materials disposal problems of NiCd batteries.

On the other hand, if they are overheated or overcharged, Li-ion batteries may undergo thermal runaway, generating oxygen and heat, creating a fire danger. Adding protection increases cost and does not guarantee 100% safety.

Lithium-polymer batteries are a newer type (introduced around 1995) of Li-ion battery, with lower energy densities, in which the electrolyte is held in a solid-polymer composite. Where the form-factor for Li-ion batteries is typically a rigid cylinder, Lithium-poly batteries are assembled from flexible plastic sacs and have a prismatic form factor.

Lithium-iron phosphate technology, which is widely used in power tools, also avoids the potential fire danger of Li-ion, but cannot match its power density.

Nickel Cadmium (NiCd)

The popular rechargeable NiCd batteries of the 1970s are rarely seen, since the European Union banned cadmium for most uses in 2004. (Exceptions include medical devices, alarm systems, and emergency lighting.) In the U.S., the battery price includes a surcharge to pay for proper disposal.

NiCd cells used a nickel-hydroxide cathode and a cadmium-hydroxide anode. The electrolyte consisted of potassium, sodium, and lithium hydroxides. NiCd cells were rechargeable and delivered a nominal 1.2 V.

According to urban legend, NiCd batteries had a "memory" defect that appeared after they were discharged and recharged to the same state of charge over and over. The battery was supposed to "remember" the point in its charge cycle where recharging began and, during discharge, would exhibit a sudden drop in voltage at that point.

The legend may be based on a real effect associated with certain automatic chargers that over-charge the battery. If the mistreated battery is subsequently undercharged, it may run out of charge rapidly, even though it appeared to be fully charged. Sometimes, the lost capacity can be recovered by a few deep-discharge cycles.

Nickel Metal Hydride (NiMH)

NiMH is a practical replacement for NiCd. In lieu of cadmium, rechargeable NiMH battery anodes use an alloy that can absorb and desorb hydrogen. The cathode is nickel hydroxide, and the electrolyte is a solution of potassium, sodium, and lithium hydroxides. Each cell delivers 1.2 V. NiMH cells are generally robust, but they require specialized chargers. Charge monitoring also helps minimize heating under charge to maximize capacity and service life.

There are sealed and open (vented) NiMH batteries. Cylindrical sealed units are used in more compact applications. Open, prismatic-packaged cells have been used for traction and backup power in public transport and industrial vehicles and in uninterruptable power systems. Toyota has used NiMH batteries through three generations of Prius vehicles.

Lithium-ion (Li-ion)

In Li-ion cells, the anode is graphite and the cathode is a compound of lithium and some other metal. Possibilities include lithium cobalt oxide (LCO), lithium nickel oxide, lithium aluminum oxide, lithium manganese oxide, and lithium iron phosphate ($LiFePO_4$). The electrolyte is a mixture of organic carbonates.

Fully charged, the output of a single Li-ion cell is approximately 4.2 V. The manufacturer can vary power and energy density. Saft cites large and medium-sized batteries in cylindrical and near-prismatic shapes with power densities from 150 W/kg.[1]

Li-ion batteries can be stored for more than 20 years at ambient temperature, with self-discharge at rates less than 5% per year. Operating temperatures can range from –30°C to 60°C.

Tesla Motors uses Li-ion batteries in both the original Roadster and the Model S sedan. The sedan's battery packs can be totally recharged in as little as an hour (using the Tesla Supercharger) or swapped in a few minutes.

Lithium Thionyl Chloride (Li-$SOCl_2$)

Li-$SOCl_2$ cells have an anode of lithium metal and a liquid cathode. The cathode structure is a porous carbon current-collector, filled with thionyl chloride ($SOCl_2$). They're packaged in a cylindrical form factor and deliver 3.6 V with a capacity of better than 18 Ah in a size that approximates a D-size cell, which helps them deliver high energy densities of as much as1220 Wh/L or 760 Wh/kg. Self-discharge is less than 1% per year, so they are popular for standby use.

Lithium Sulfur Dioxide (Li-SO_2)

Li-SO_2 cells are like Li-$SOCl_2$ cells, except the solution in the porous carbon current collector is sulfur dioxide (SO_2). They come in the same range of standard cylindrical battery sizes but deliver a lower voltage of 2.8 V, rather than 3.6 V, and thus somewhat lower energy density (250 Wh/kg).

Less Common Lithium Chemistries

Other lithium chemistry pairings include LCO and $LiFePO_4$. In fact, some blends of these chemistries have emerged. Alone, LCO is used for high-energy applications, and $LiFePO_4$ is used where high discharge rates are required.

Blending cathode materials let manufacturers tailor the performance of the cathode to the application. For example, Boston Power blends LCO and lithium manganese oxide in its Sonata and Swing cells and claims improved energy density, charge rate, calendar and cycle life, and operating-temperature range.

References

Saft

Boston Power

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