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LITHIUM ION BATTERIES

A Lithium Ion battery is a chemical machine. In the periodic table, the simplest and lightest atom would be Hydrogen, with one proton (positive charge) and one orbiting electron. Hydrogen is highly reactive and is able to share its electron easily, due to its electro positivity.

Lithium, like Hydrogen is very reactive, and will readily share its electron but Lithium can release its electron with 3 volts more force than Hydrogen, which leads to its preference to be used in battery chemistry.

Batteries are composed of a cathode, an anode, a separator and electrolyte. The concept is simple, when the battery is charging or discharging, an electron and ion leave one electrode and arrive at the other electrode at the same time. However, electrons conduct at near speed of light while ions drift slowly from one electrode to the other.

So, to understand what is really happening, let's look at the cathode. Cathodes can be composed of different chemistries of metal oxides. Nickel Oxide for example: The Nickel and Oxygen are strongly bonded together and borrow an electron from Lithium, because Nickel has a strong potential to borrow electrons and lithium has an electron readily available.

When the battery is connected to a charger, positive lithium ions are liberated from the lithium nickel oxide crystal into the electrolyte solution wandering to the anode due to diffusion. At the same moment that ions are liberated, electrons are liberated from the cathode and conduct to the anode.

The electrolyte solution is made of solvents (ethylene carbonate mostly) and a salt of lithium. The solvent doesn't react with the positive lithium ion but instead forms a shell around it. Whenever a salt is dissolved in a solvent, the solvents pulls the salt apart to form a soup of positive and negative ions with solvation shells. That soup of positive and negative ions will always try to maintain a neutral charge. If positive ion is added, then somewhere else in the solution a positive ion must be removed.

The electrolyte conduct the lithium ions through diffusion but it won't conduct electrons due to the separator present in the electrolyte solution. The separator is made of a polymer material (polyolefin) and keeps the cathode and anode from touching. The electrolyte also contains an additive such as vinylene carbonate. The Anode is composed of graphite.

Lithium, the solvent and the additive are reacting with the shell of the graphite particles to create a protective film on the graphite particles. The vinylene carbonate additive helps this layer form a stable surface that extends battery life to thousands of cycles. The layer is called a solid electrolyte interphase. (SEI)

THERMAL RUNAWAY

The battery can experience over voltage, under voltage, mechanical failure, and lead the cells to enter in what is called thermal runaway.

When one or several cells get damage due to physical penetration, crushing, overheating due to current excess, or extreme ambient temperature, initially the SEI Layer starts disintegrating. This occurs at very low temperature (around 167 deg. F). As the temperature keeps building up, the anode reaction keeps generating heat exponentially which then causes the organic solvent used in the electrolyte to breakdown generating hydrocarbon flammable gases. This stage happens when the temperature reaches about 230 deg F.

The generated gases creates an accumulation of pressure inside the battery cell. While temperature keeps climbing, at about 275 degree F, the polymer separator starts melting and the batterie enters in short circuit between the anode and the cathode.

During this phase the metal oxide cathode starts to decompose, releasing oxygen gases, triggering the burning down of the electrolyte and other flammable gases in the cell. Temperature keeps climbing and thermal runaway start destroying the other cells.

SOLUTION

When fighting thermal runaway, we need to look at the batteries like we would look at a biological cell in their complexity because they juggle energy and matter in a dynamic system. Cooling the battery is not enough. We also need to stop the chemical reaction inside the cells, and neutralize the electrolyte solution, to stabilize the system and stop thermal propagation, thus Thermal runaway. Our solution cools the battery almost instantly but also, once penetrating the affected battery, neutralizes the chemical reaction within the electrolyte solution, and forms a porous barrier, condensing the toxic gases within the suppressing solution.

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