The Care & Feeding of Lithium-Ion Batteries

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Who's Talking:
Rich Cregar

Over 50 years automotive experience, 24 years in automotive education, 22 years as a shop owner

Member, Vehicle Fire/Safety Committee, SAE

Past Co-Director, Code Green CIP, NCCCS

2011 White House Champion of Change

GSK Faculty Fellow, Institute for Emerging Issues, NCSU

Graduate, SAE Diesel Technology Academy
Graduate, SAE Hybrid/EV Engineering Academy

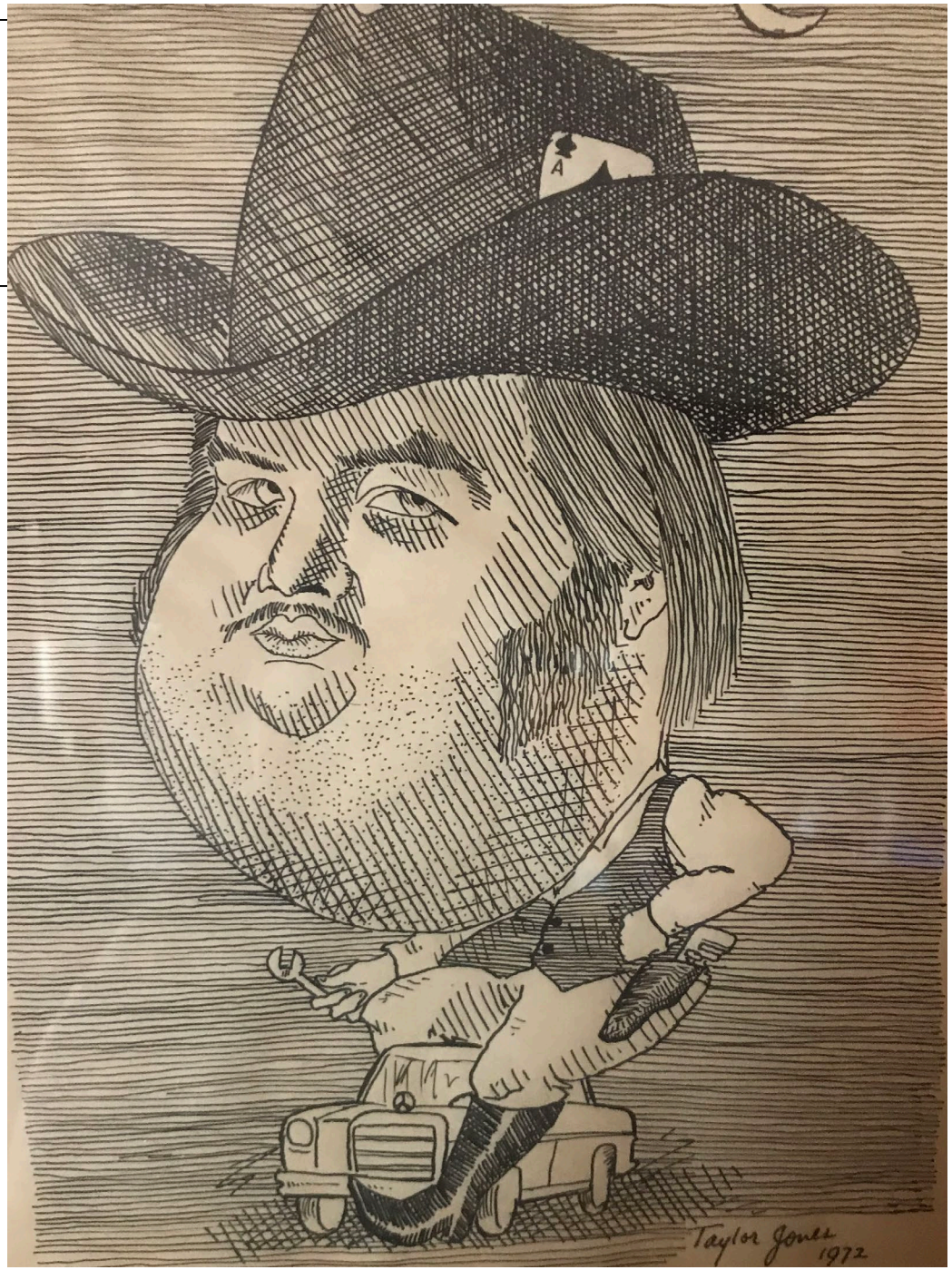
Past Member, President's Advisory Board for Sustainability, Shaw University

Past Member, SAE green Standards Committee

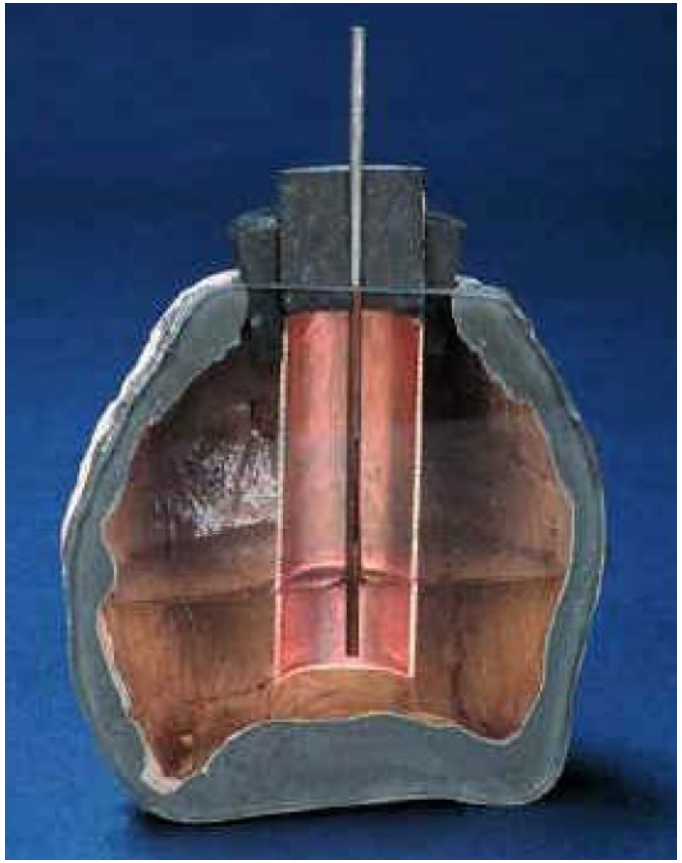
Former Technical Consultant to Miles Automotive Group, EV Manufacturer

Past Chair, Triangle J Clean Cities (NC)

Currently working as a consultant to DTS / Volt



Batteries & Related Systems



What Is A Battery?

"If an electric charge (q) is taken to a higher electric potential (V), then it is capable of releasing its potential energy given by:

"**E=q x V**"

This is Ohm's Power Law, or Watts=Volts X Amps

Cell voltage is dependent upon the composition & structure of the electrode materials. Research continues.

Examples: Lead acid cell 2.1V

Ni-MH cell 3.2V

Li-Ion cell 4.3V and rising

Goal: 5.0V

Lithium Ion Basic Reaction

- Lithium ion

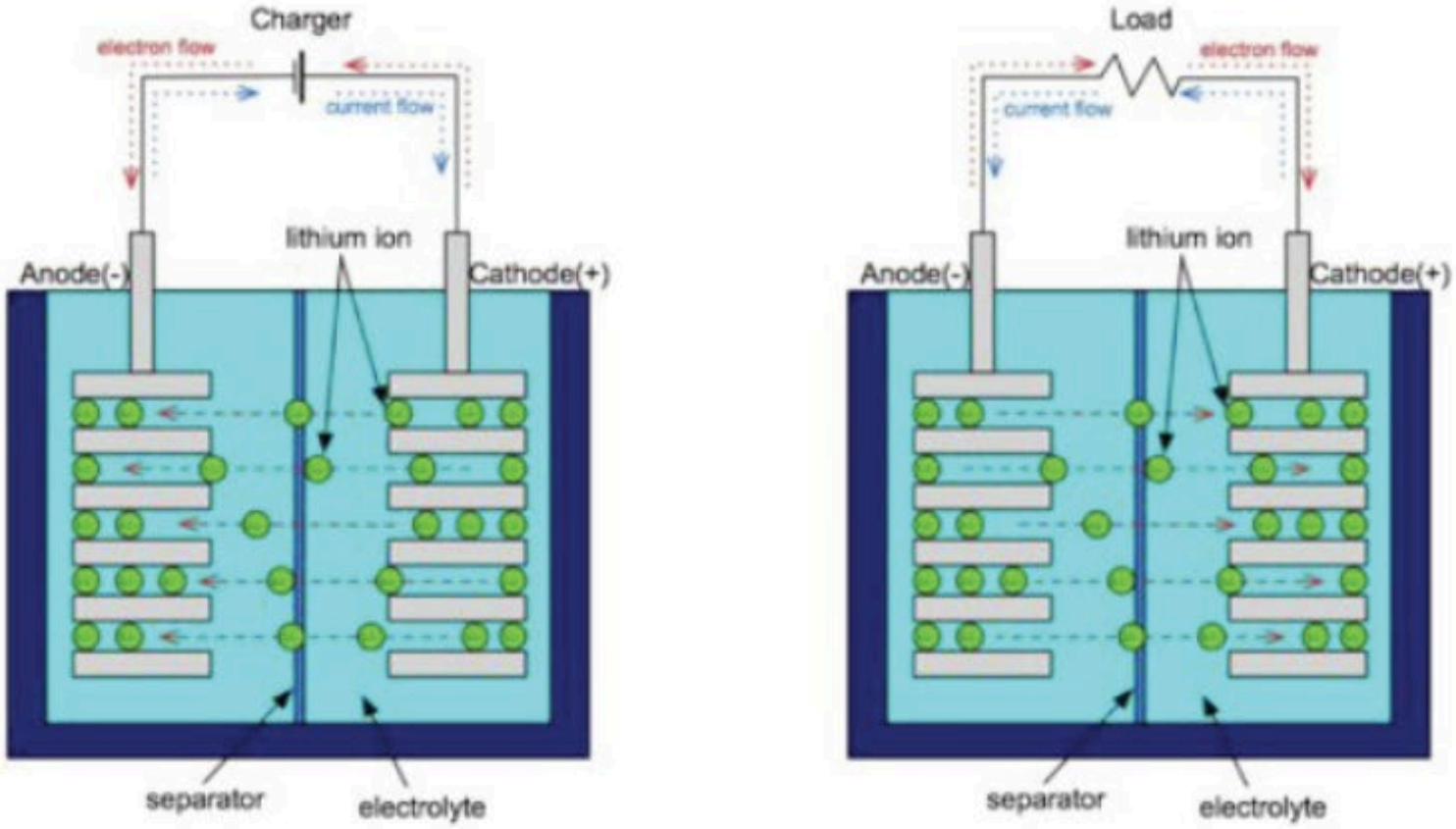
discharge LiC + Li ion (-) e + CoO2

charge LiCoO2 + Li ion (+) → LiC + Li ion (-)

  - Electrolyte Varied, consists of a salt such as Lithium Hexafluorophosphate ($LiPF_6$) dissolved in a blend of organic carbonates
    - Typical Freezing point - 40° C
    - Typical Boiling point is above 189° C
    - Electrolyte composition and reactivity changes dramatically with temperature

    - Nickel Manganese Cobalt Aluminum used in GM's Ultium cell
    - 12 modules in a Cadillac Lyriq, 24 in a Hummer

Lithium Ion Technology

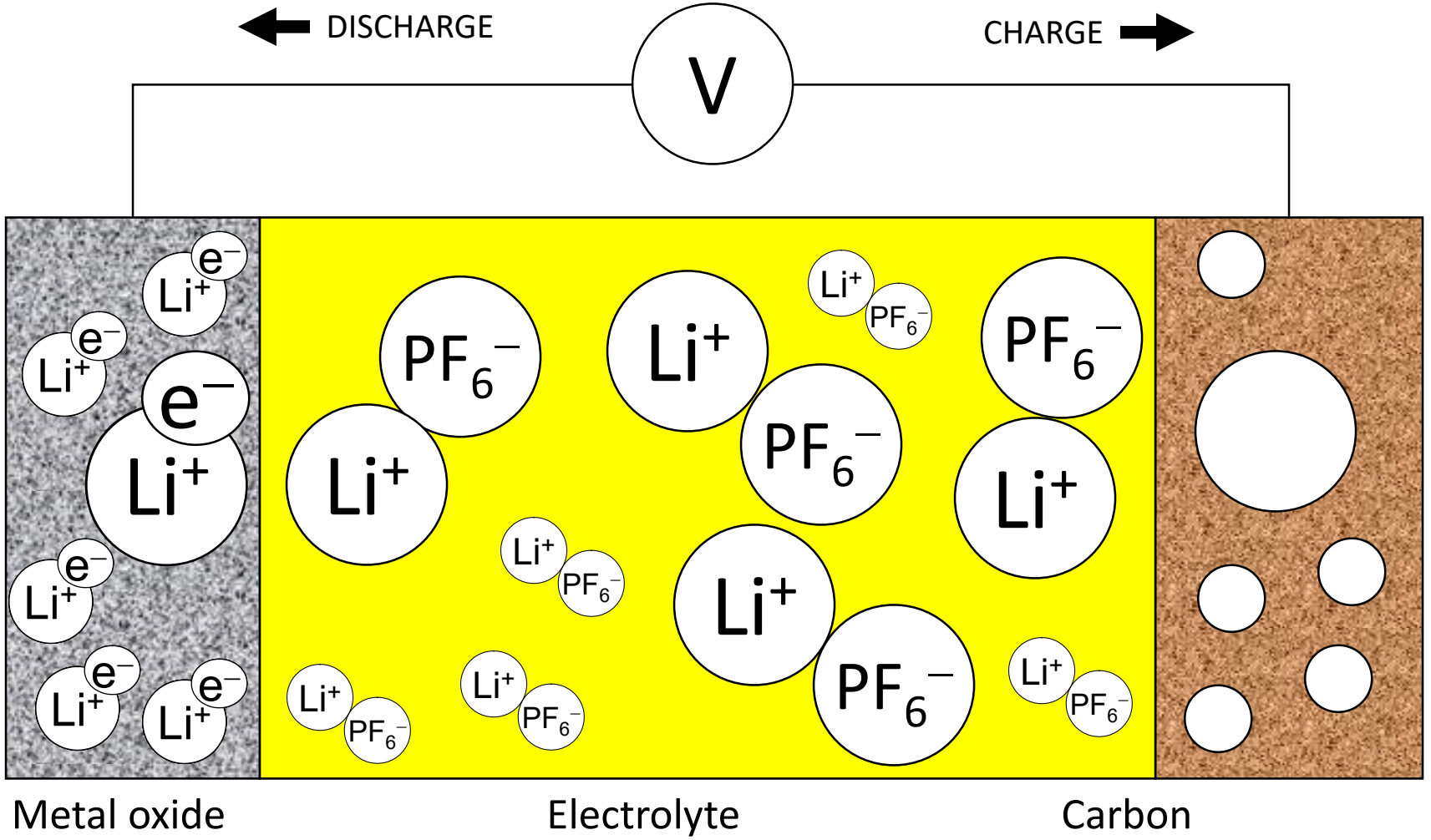


CHARGING **DISCHARGING**

Charging: Electrons are pumped from the cathode to the anode. Positively charged lithium ions move from the cathode through the separator via the electrolyte to the anode.

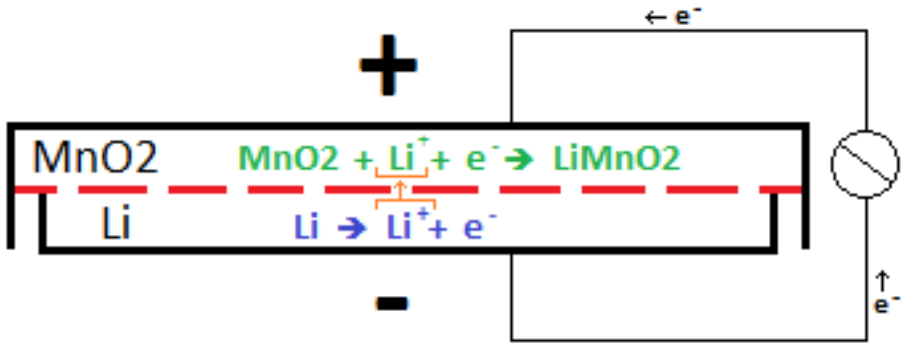
Discharging: Positively charged lithium ions move from the anode through the separator via the electrolyte to the cathode. Electrons move through the external load from the anode to the cathode, resulting in a current that provides power to the load.

Lithium ion Operation

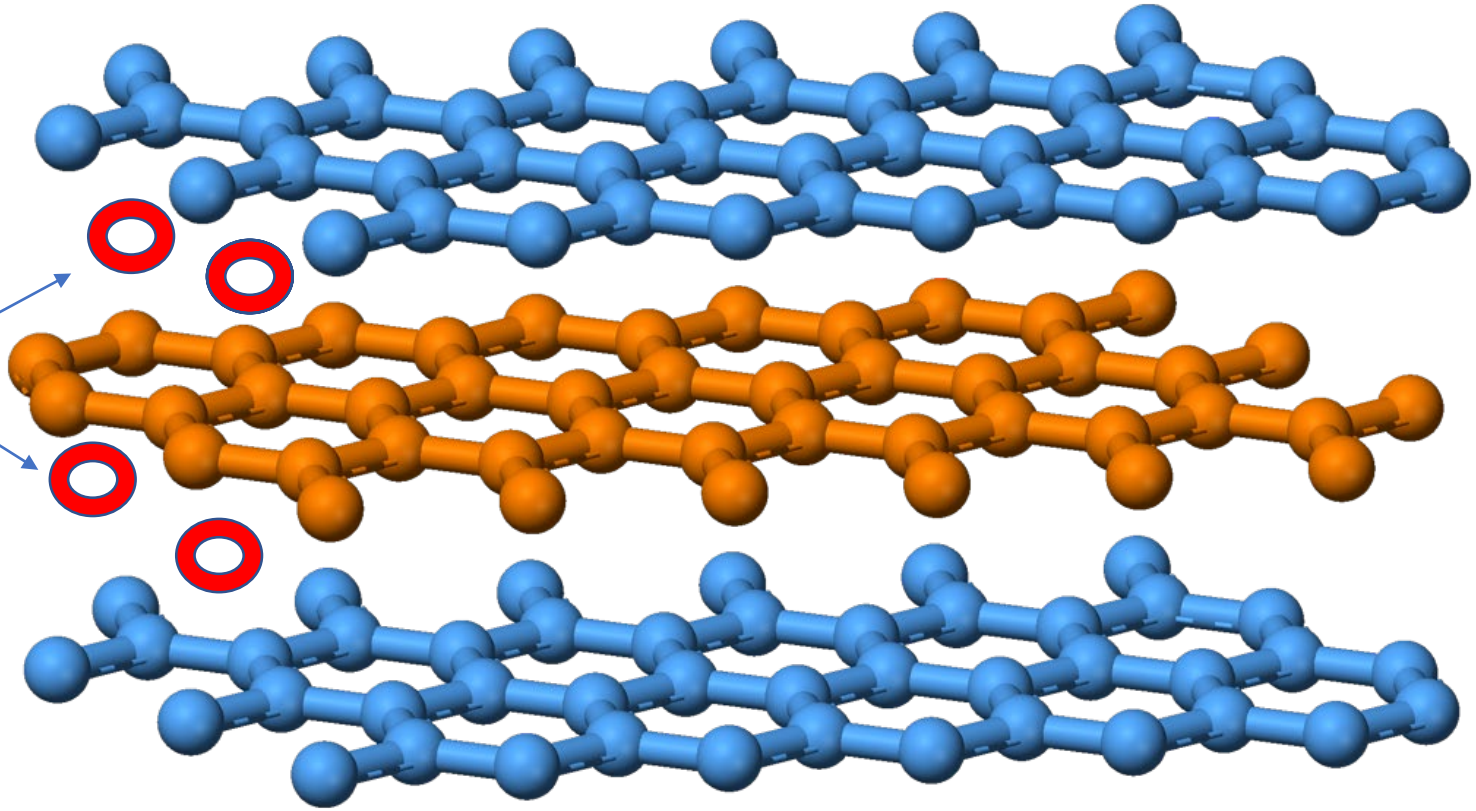


The Anode

Why can I only fast charge to 80% SOC?



Lithium Ions (Neg)



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Formation of Dendrites at the anode accelerated by fast charging, rapid discharging.

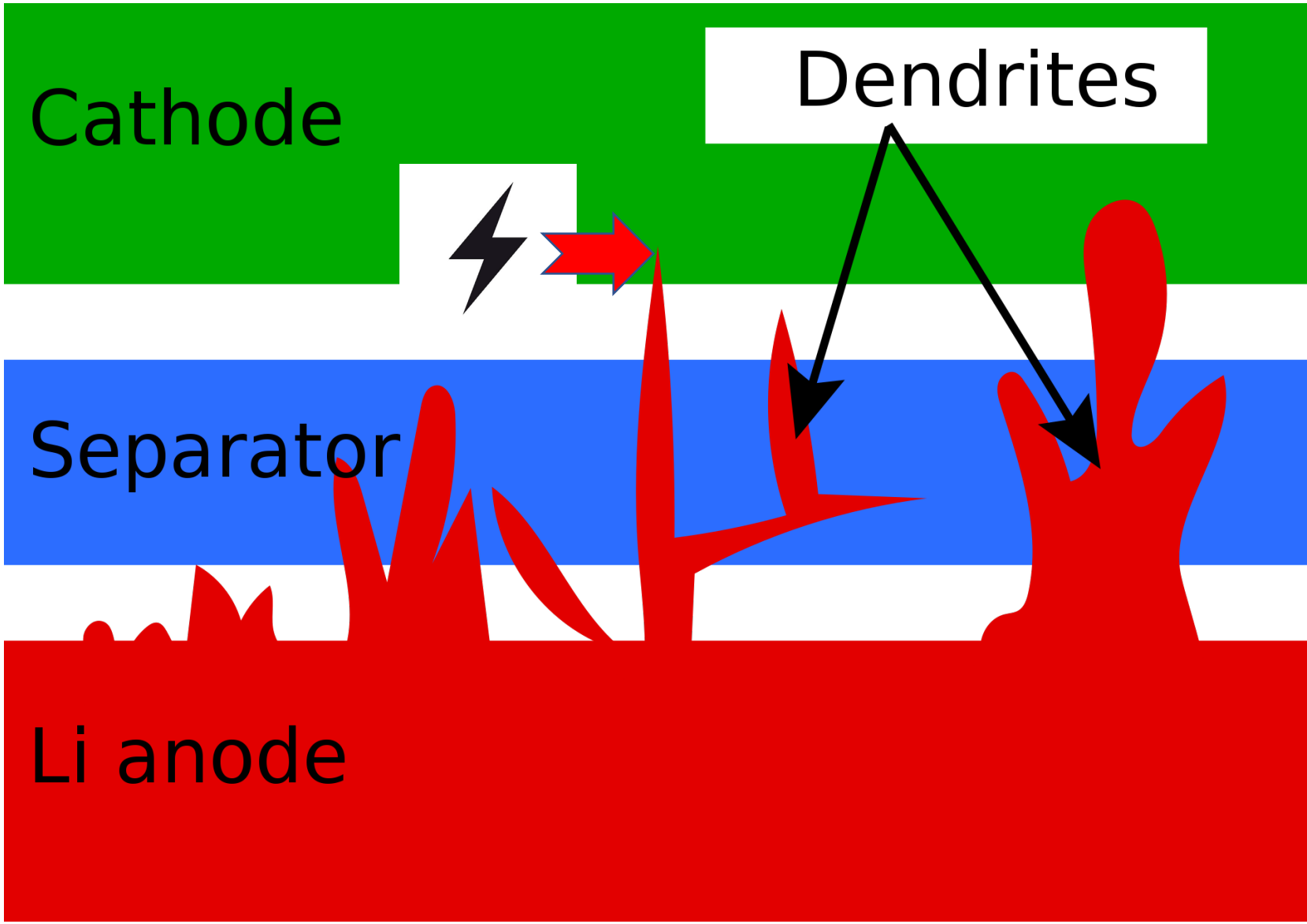
Thermal runaway can result (Fire).

Cyclic aging due to:

Cathode & Anode damage, Lithium plating.

Calendar aging due to:

Electrolyte oxidation & Passivation Layering (SEI Solid Electrolyte Interface).



Peukert's Law

Developed by Wilhelm Peukert in 1897

$$t = H\left(\frac{C}{IH}\right)^{k}$$

T = actual time to discharge battery
H = rated discharge time
C = "C rate" or rated capacity at that rate of discharge
I = current flow from battery
K = Peukert's constant

"there are two ways of looking at this effect. We could say that discharging at higher currents reduces the total available power that can be got out of a battery. So a 100 amp hour battery might become say an 80 amp hour battery at higher discharge rates. This is technically the correct way of looking at it. However it is easier to assume that the total available power in the battery remains identical whatever the discharge rate. But that discharging at higher rates removes more amp hours. "---Wikipedia

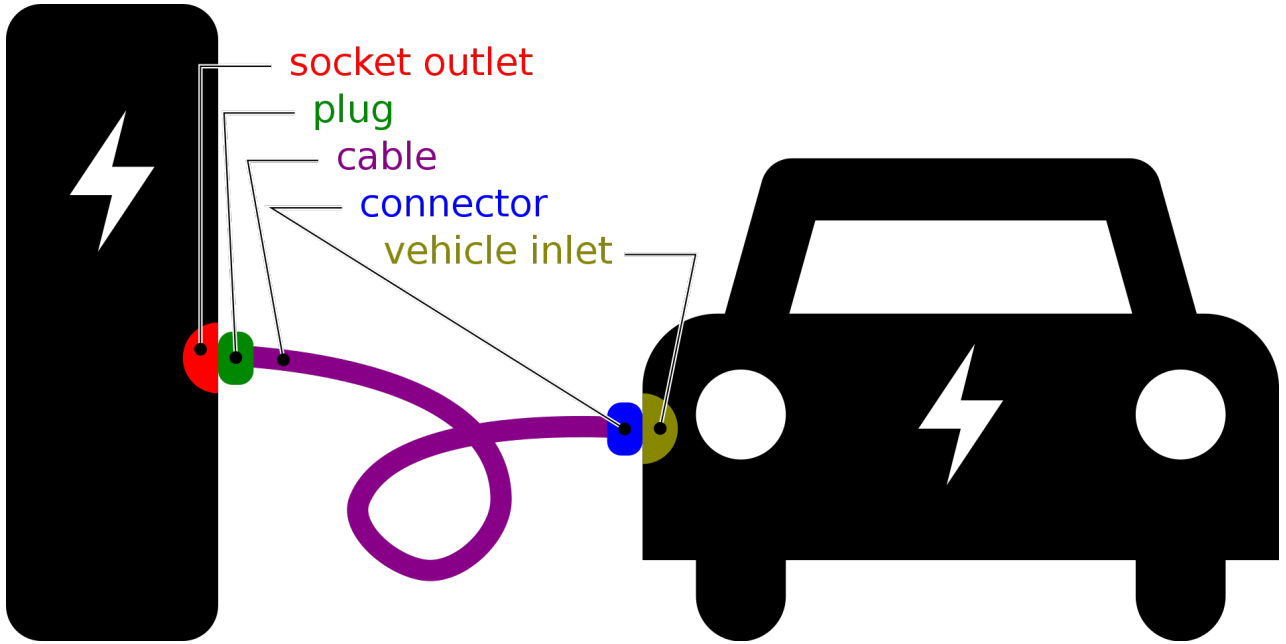
Degradation also impacted by temperatures. Losses in excess of 10% capacity likely at 110'F, more as this temperature is exceeded. (See "Leaf")

Summary:

- Level 1 or 2 charging is best for battery life. Frequent use of superchargers will reduce battery life/capacity
- Current 400V standard likely to be superseded by 800 Volt standard.
- Level 2 charger require 45-48 amps of excess capacity at the entry panel.
- Utilities typically require a home's wiring meet code before a level 2 charger can be installed.
- The Ford Charge Station Pro can charge at 30 mi/hr but requires 80 amps of panel capacity.
- Time of day electrical rates will create price fluctuations. As utilities install more charge stations, prices likely to increase.
- Development of new building codes may not be friendly to home charging.

Environmental Issues

- Li-Ion can NOT fast charge when cells colder than 32’F.
- An EV low on charge may need to be connected to a level 2 charger to pre condition (heat) the batteries before attempting a fast charge.
- When on a charger in cold weather, current will be used to keep the battery coolant warm (PTC Heating or heat pump) This is the recommended mode for cold weather parking/storage.



Credit: Wikipedia

Questions?

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THANK YOU!