



PEEL

People for Energy and
Environmental Literacy

Electric Vehicle Batteries

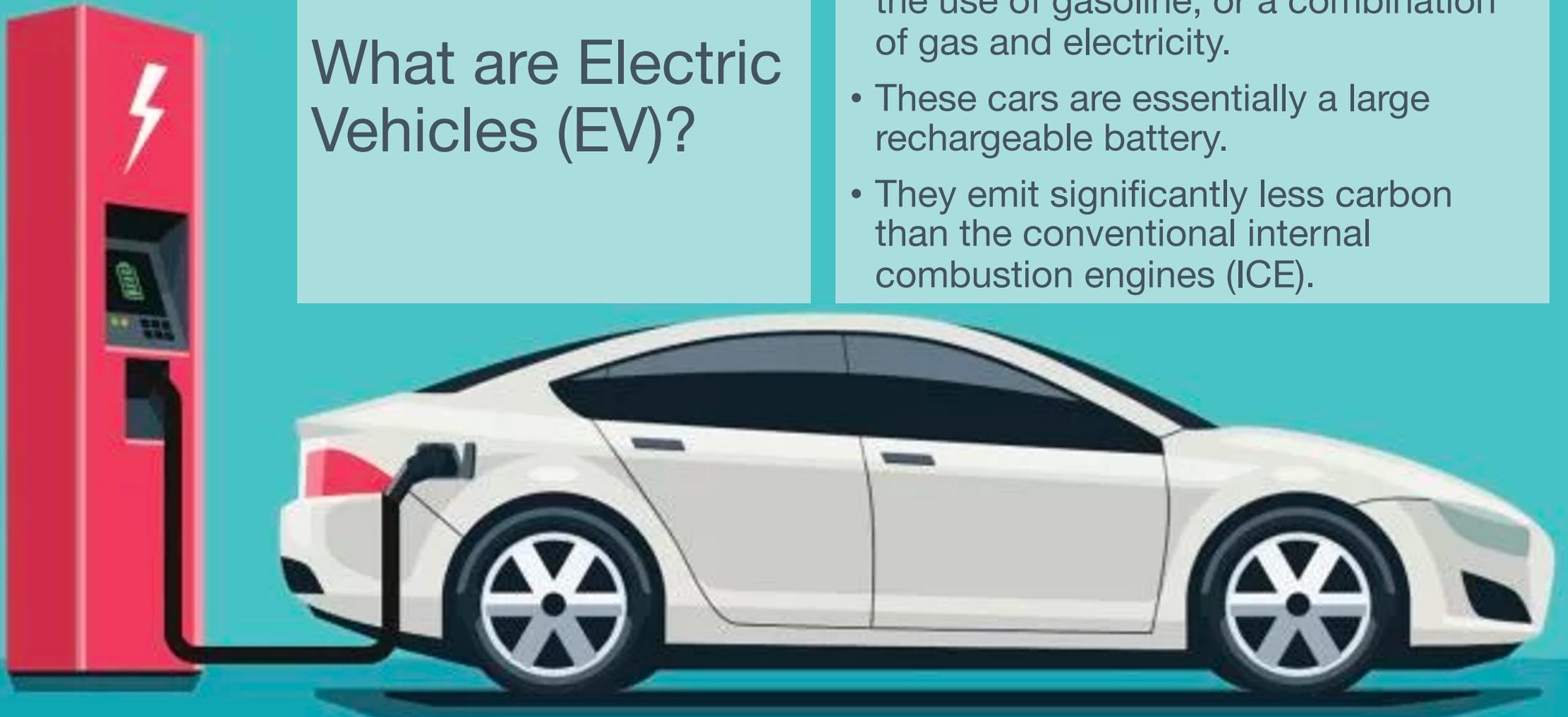
2022

An Introduction to Rechargeable Batteries

Recommended for High School

What are Electric Vehicles (EV)?

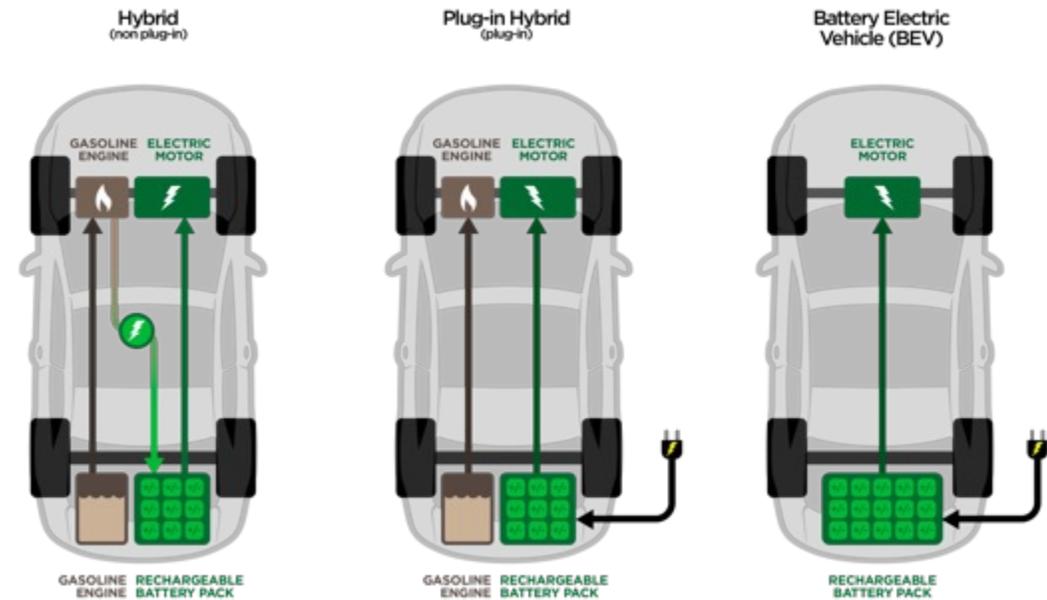
- An electric vehicle is a car that operates on an **electric motor** without the use of gasoline, or a combination of gas and electricity.
- These cars are essentially a large rechargeable battery.
- They emit significantly less carbon than the conventional internal combustion engines (ICE).



Source: www.greetechmedia.com

Types of electric vehicles

- **Hybrid:** Powered by gasoline and an electric motor. The battery is recharged while the vehicle is running on gas.
- **Plug-in hybrid Electric Vehicle (PHEV):** Similar to conventional hybrids, except they can be plugged in to recharge the battery.
- **Battery Electric Vehicle (BEV):** Powered 100% by an electric motor and battery. All-electric cars do not burn gasoline, have gears or a transmission, or require oil for the parts. On average, all-electric cars can travel 200 – 250 km on a single charge.



Source: www.nspower.ca

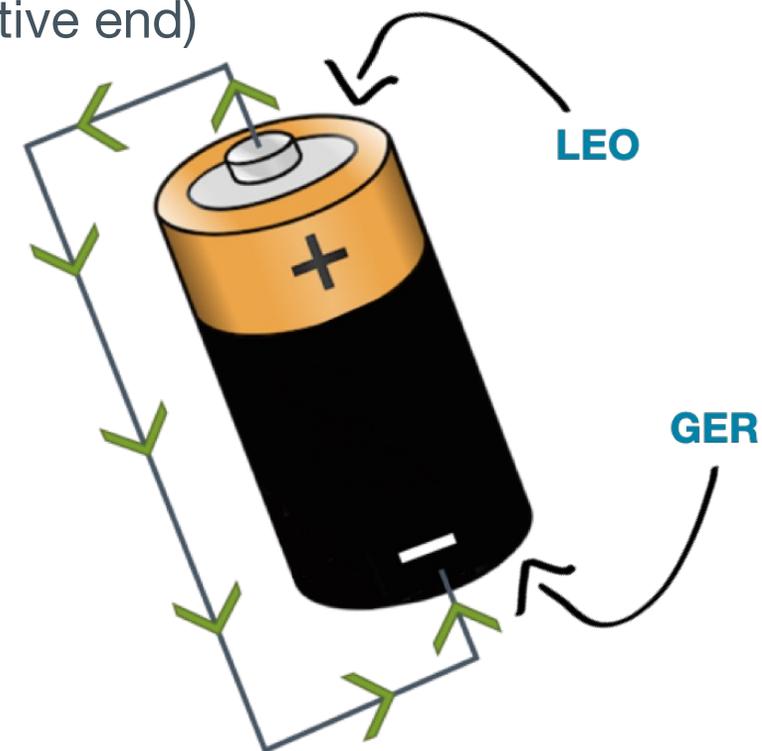
The First Battery

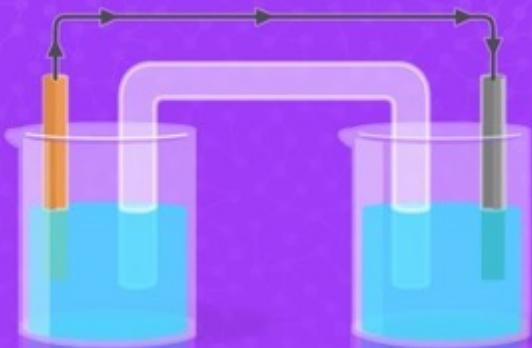
- The first battery was invented by Alessandro Volta in 1799, called the Voltaic Pile. 
- The electrodes used were **zinc** and **cooper**, and the electrolyte was brine-soaked paper.
- The first rechargeable battery – the lead acid battery – was invented in 1859 (more to come later).



How do Electric Vehicles Work?

- An EV has a **large battery**. The battery energy storage system (BESS) stores chemical energy that is then converted into electrical energy. The BESS within an EV is also considered a form of energy storage
- Electrons flow from the cathode (positive end) to the anode (negative end)
 - Here's a saying to help you remember:
LEO the Lion says GER
Lose **G**ain
Electrons **E**lectrons
Oxidation **R**eduction
- Batteries operate through a process called **electrochemistry**





ELECTROCHEMISTRY

Source: Crash Course Chemistry #36

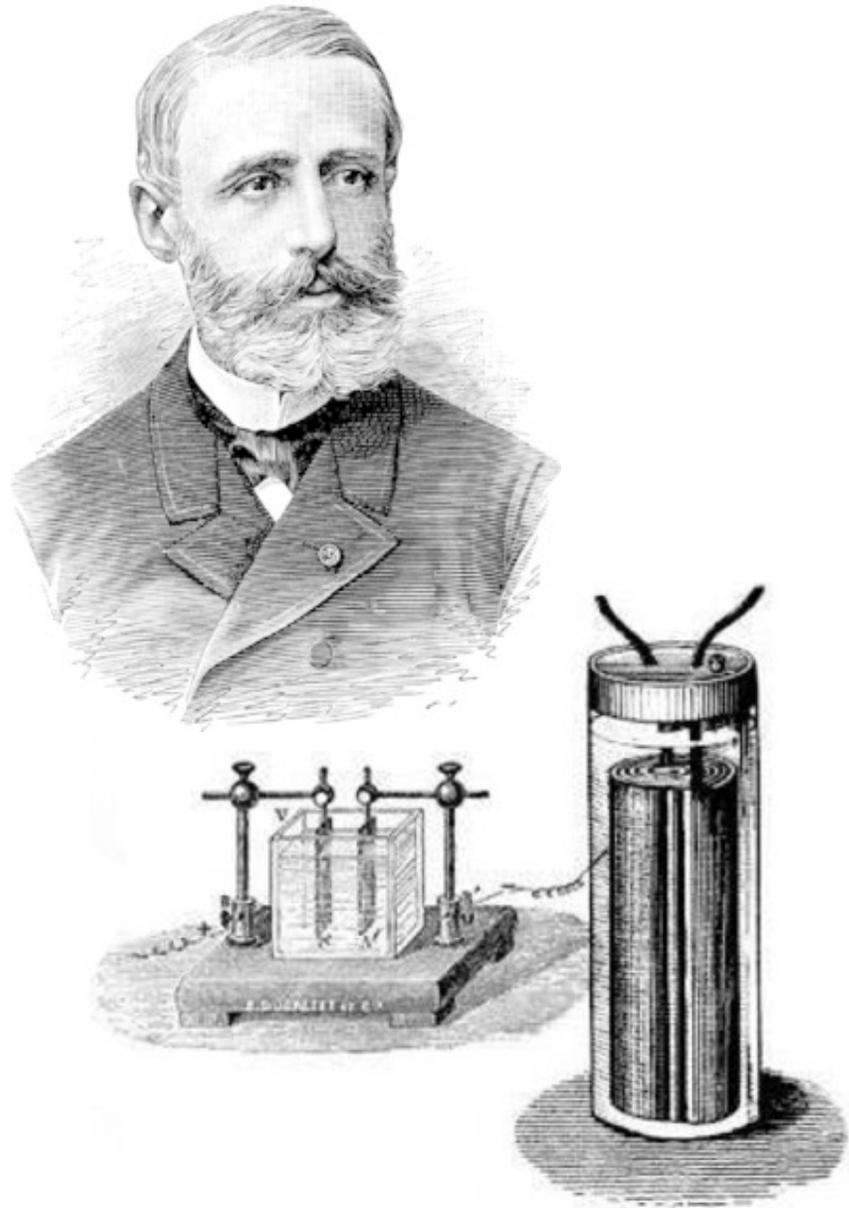
What is Electrochemistry?

- **Electrochemistry:** The study of chemical reactions that cause electrons to move and produce electricity.
- These reactions are called **redox reactions**, which is made of reduction and oxidation half reactions.

What Common Types of Batteries are used in Electric Vehicles?

- Lead-Acid Batteries
- Nickel Metal Hydride Battery
- Lithium-Ion Battery (Most common)

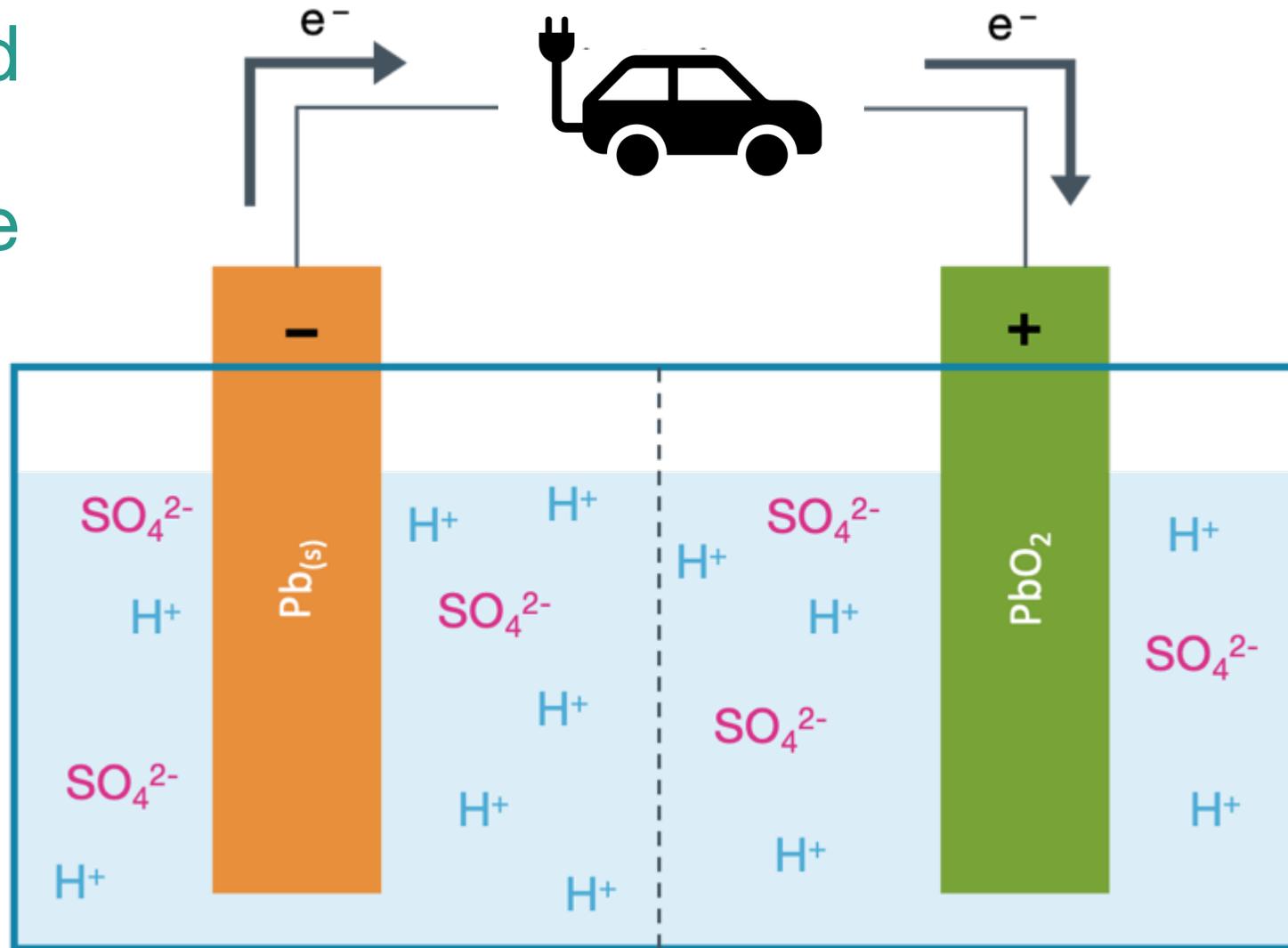




Lead-Acid Batteries

- Rechargeable battery invented in 1859 by Gaston Planté
- Found in ICE cars as a starter, and early electric vehicles
- Battery is prone to self-discharge
 - ~5% per month when left unused
- Positive and negative electrodes conduct charge

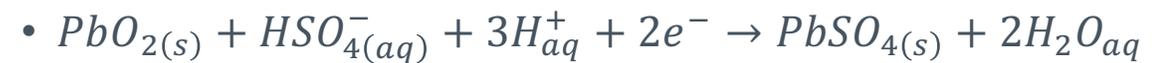
Lead Acid Battery - Discharge



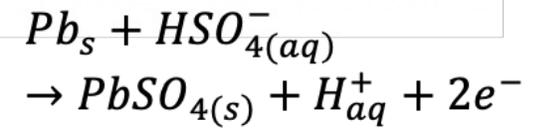
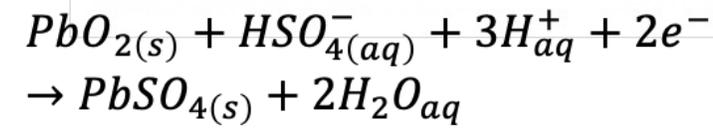
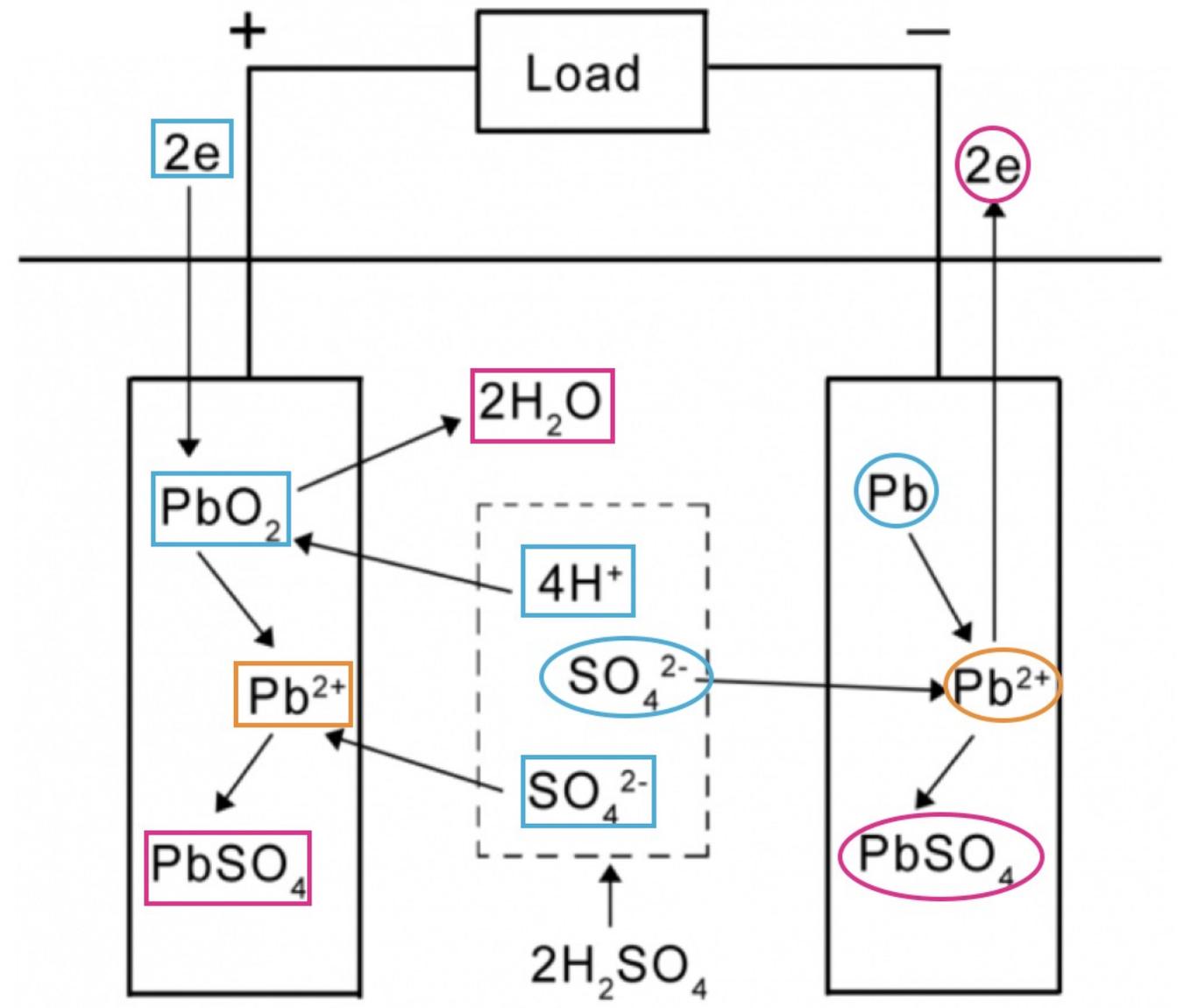
• Negative electrode chemical reaction:



• Positive electrode chemical reaction:

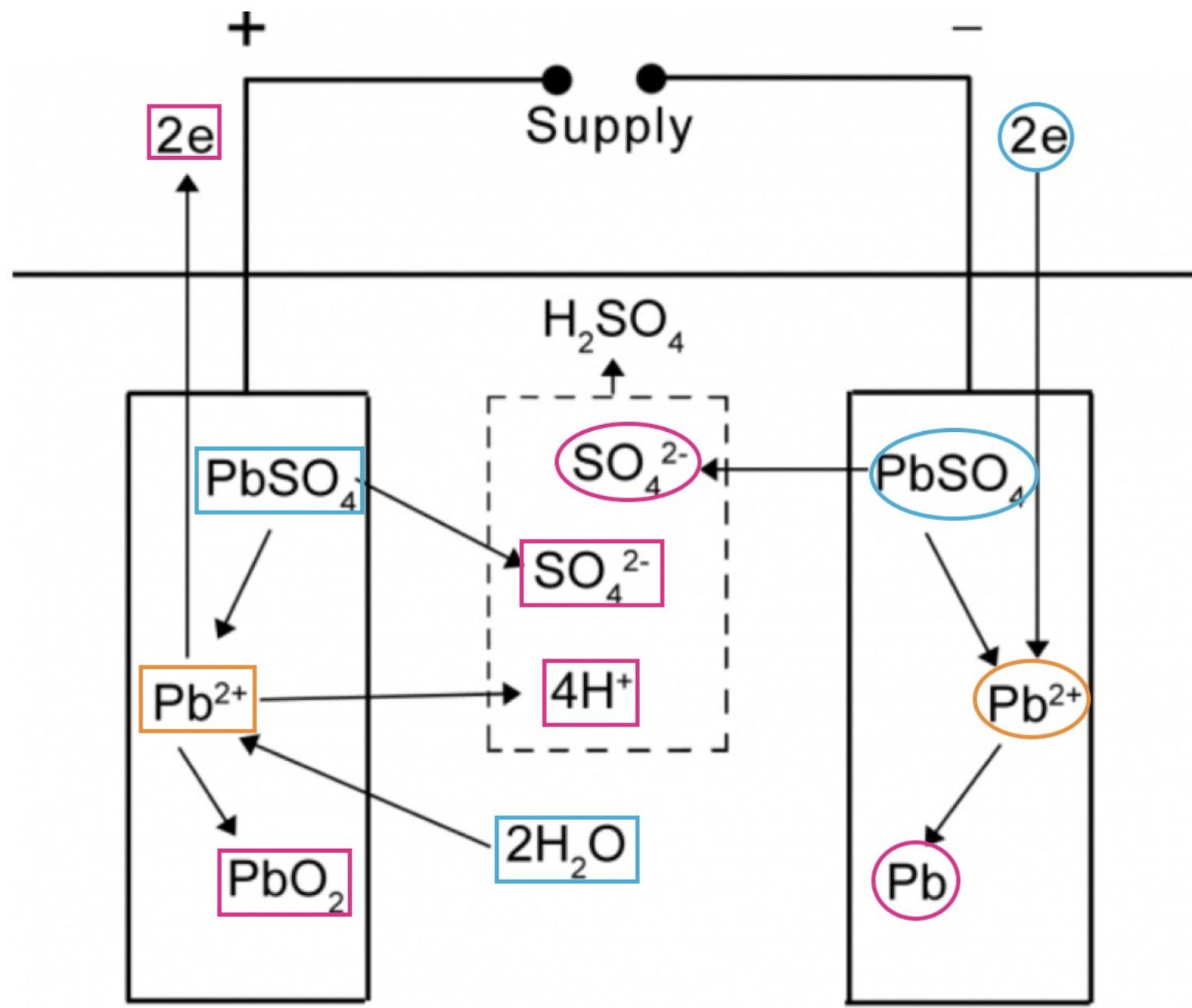


Lead Acid Battery - Discharging

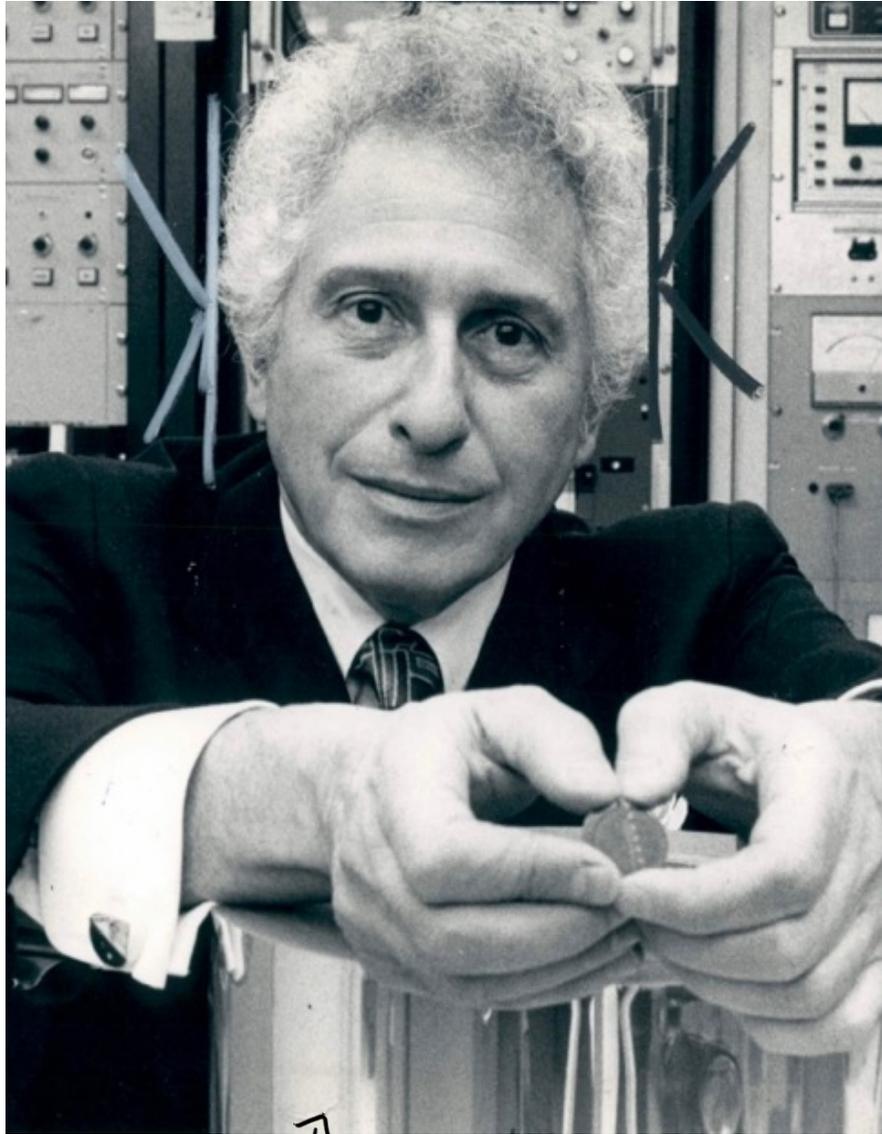


- Reactant
- Intermediate
- Product

Lead Acid Battery - Charging



- Reactant
- Intermediate
- Product



Stanford Ovshinsky

Nickel-Metal Hydride (NiMH) Batteries

- NiMH Batteries first emerged in 1967 (invented by Stanford Ovshinsky) to replace the Nickel Cadmium (NiCd) batteries.
- NiCd batteries had many advantages; however, the **toxicity** of the cadmium was one of a few major concerns.
 - The toxicity prevented easy disposal.
- NiCd is a mature battery and is often used as a comparison for new batteries
- NiMH batteries are commonly used in high energy consumption and demand devices
 - Digital cameras, flashlights, toys
 - NiMH is recommended over alkaline batteries (non-rechargeable) for these devices

Advantages and Disadvantages of NiMH Batteries

ADVANTAGES

- Low cost
- Not toxic like the prior NiCd battery (More environmentally friendly)
- 30—40% higher capacity than NiCd
- High energy density (amount of energy in system) than NiCd
- Less prone to **memory**



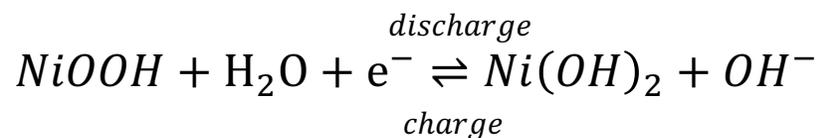
DISADVANTAGES

- Self discharges 20% in first 24 hours following charge, and 10% per month following
 - Not recommended for devices not frequently used
- Less recharge cycles than NiCd

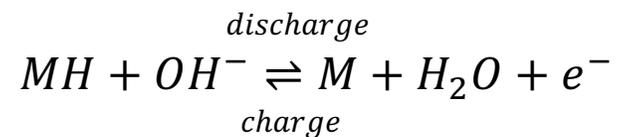


NiMH Charge and Discharge

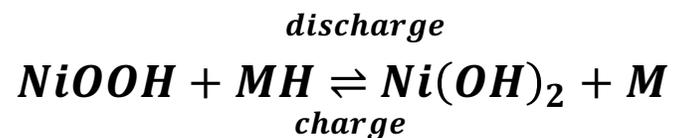
Positive Electrode



Negative Electrode

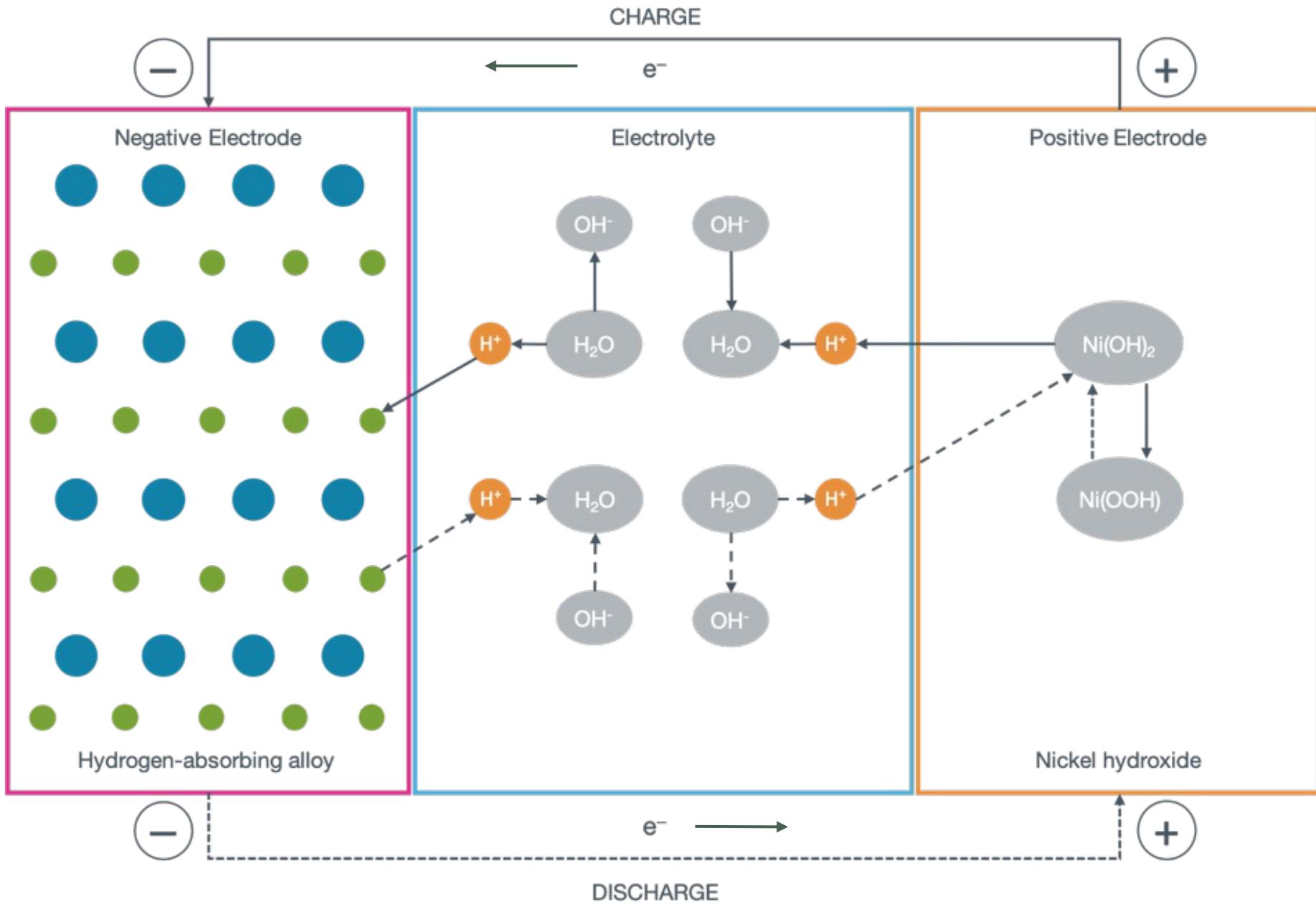


Overall Reaction



- Metal Hydride
- Hydrogen

NiMH Batteries



Lithium-Ion Batteries

- A rechargeable battery commonly used for portable devices and electric vehicles.
- Developed by John Goodenough, Richard Yazami and Akira Yoshino in 1980.
 - Akira Yoshino is known as the Father of Lithium-Ion Batteries
- Became available to the public in 1991 by Sony and Asahi Kasei.
- Advantages: high energy density, low self-discharge and light weight.



Akira Yoshino



John Goodenough



Richard Yazami

Advantages and Disadvantages of Lithium-Ion Batteries

ADVANTAGES

- High energy density
- Little self-discharge
- Low maintenance
- No priming required
 - A conditioning cycle to improve performance
- Many different types to meet needs



DISADVANTAGES

- Fire hazard*
- Overcharge protection required
- Ageing
 - The older the battery is, the lower the capacity is
- Higher cost than NiCd
- Technology not as advanced as alternatives



* See next slide for more

Short circuits are when an unintentional circuit forms due to the contact of two components

Lithium-Ion Fire Hazard



- Malfunctions are rare, but not impossible.
- There is a small risk of microscopic particles coming into contact with other parts of the battery. This can cause what is called a **short-circuit** in the cell.
- Short-circuits can cause fires
- The failure rate of Li-ion batteries is **less than one in a million**
- Controls are in place to minimize this effect.

- In 2013, when the the Boeing 787 Dreamliner was first released, aircrafts had fires on board due to the Li-ion batteries electrical issues.
 - What happened? Overheating due to a short circuit from a manufacturing defect
 - Issues were promptly resolved by Boeing and the Federal Aviation Administration

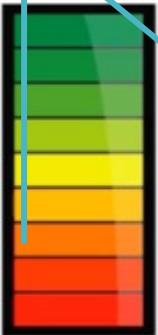
Lithium-Ion Charge/Discharge Cycle



Electrolyte:
A liquid that acts as a transporter of Li ions.

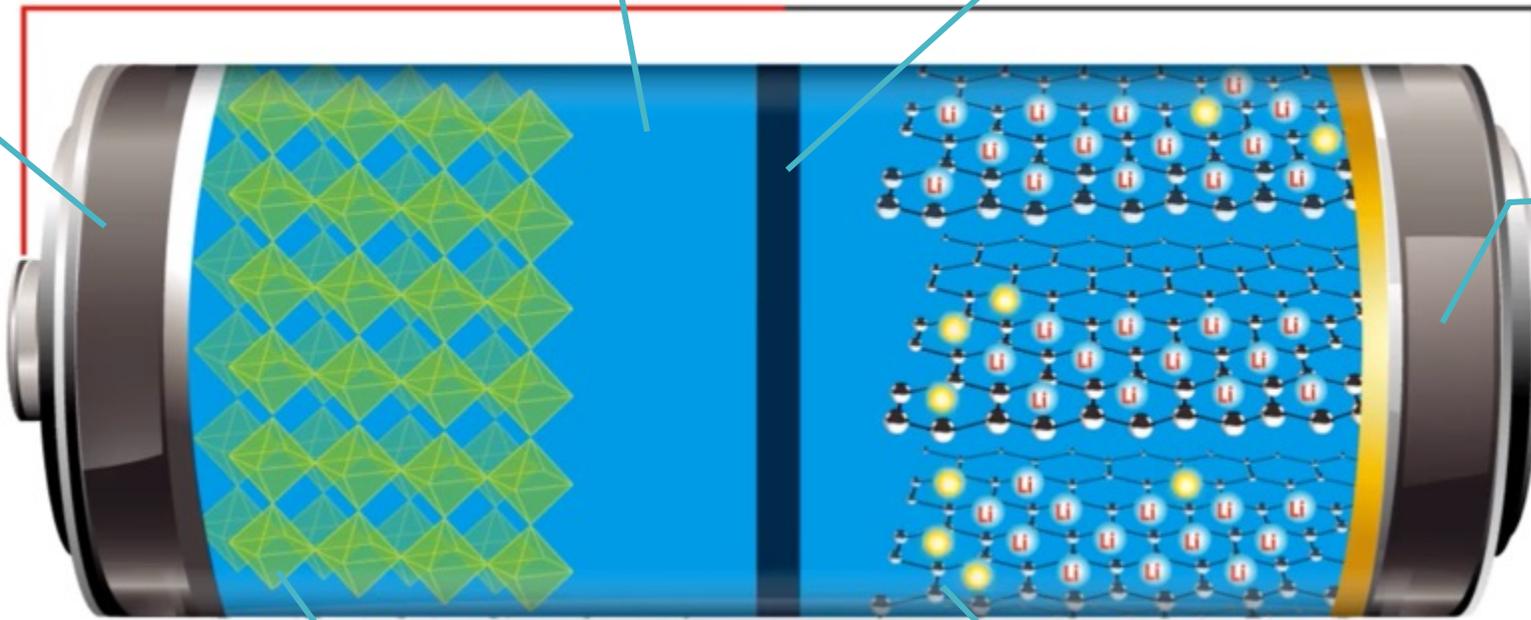
Separator/membrane:
Allows for Li ions to flow freely from the anode to the cathode and vice versa. It also prohibits the flow of electrons inside the battery structure.

Positive Electrode:
Receives electrons from the external circuit during **discharging** of the battery from the negative electrode.



Charge Meter

Negative Electrode:
Receives electrons from the external circuit during **charging** of the battery from the positive electrode.



Cathode:
Stores Li and releases Li ions when the battery is **charging**.

Anode:
Stores Li and releases Li ions when the battery is **discharging**.

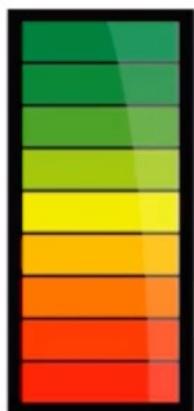
How Lithium-ion Batteries Work

Discharge

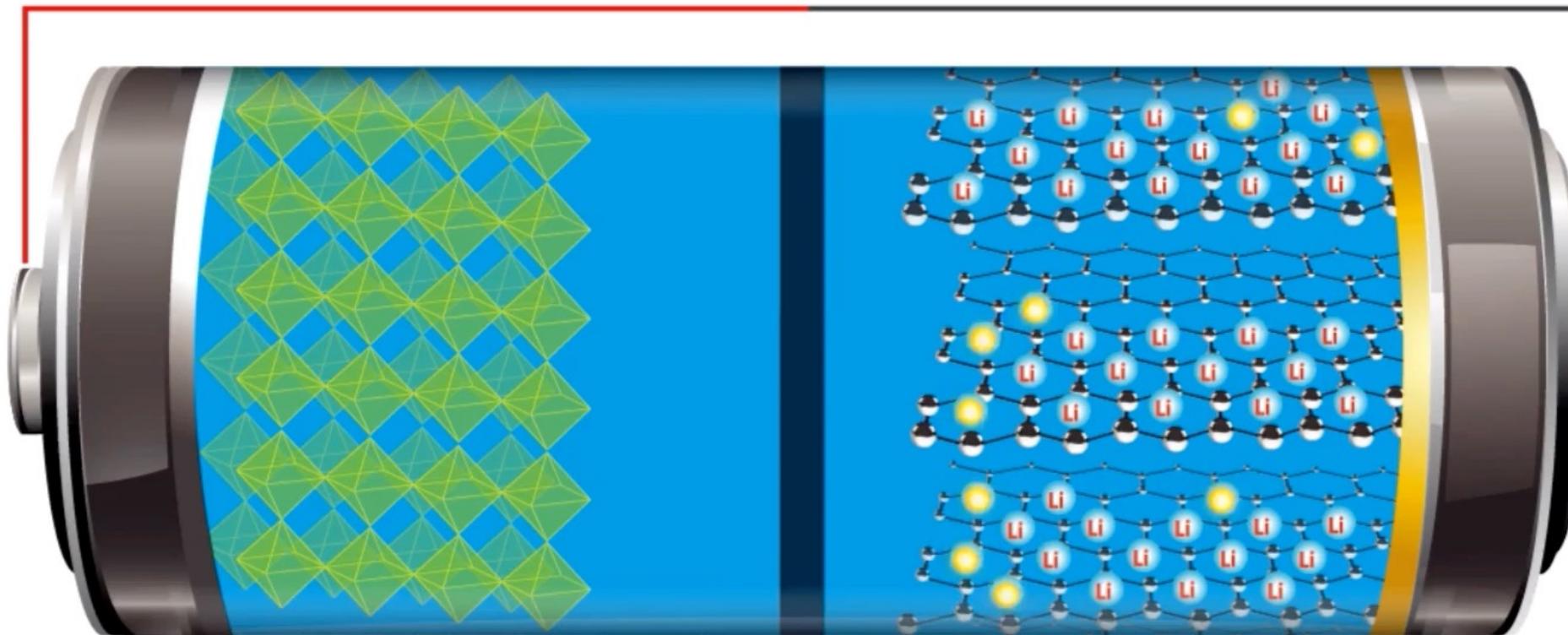
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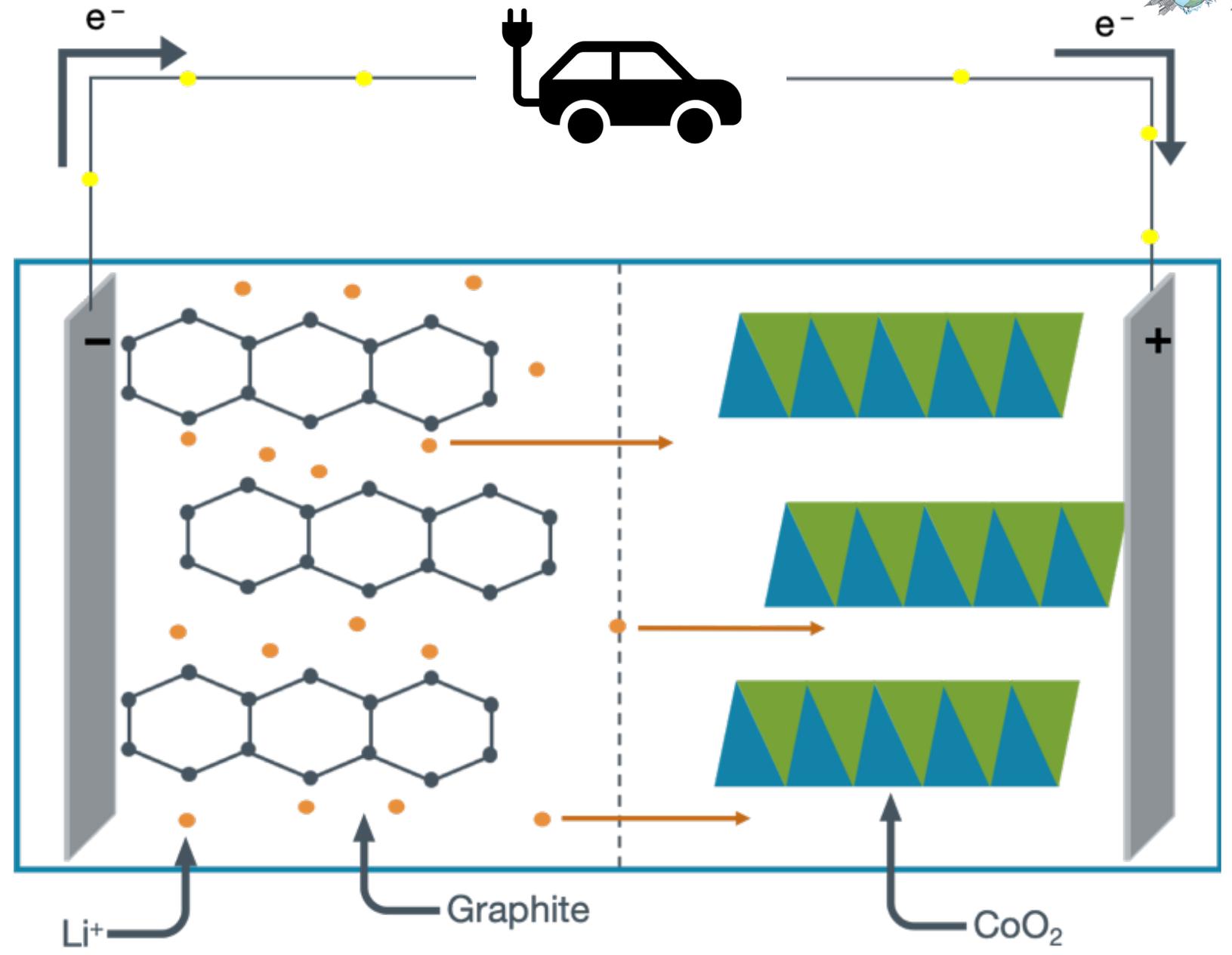


Charge
Meter

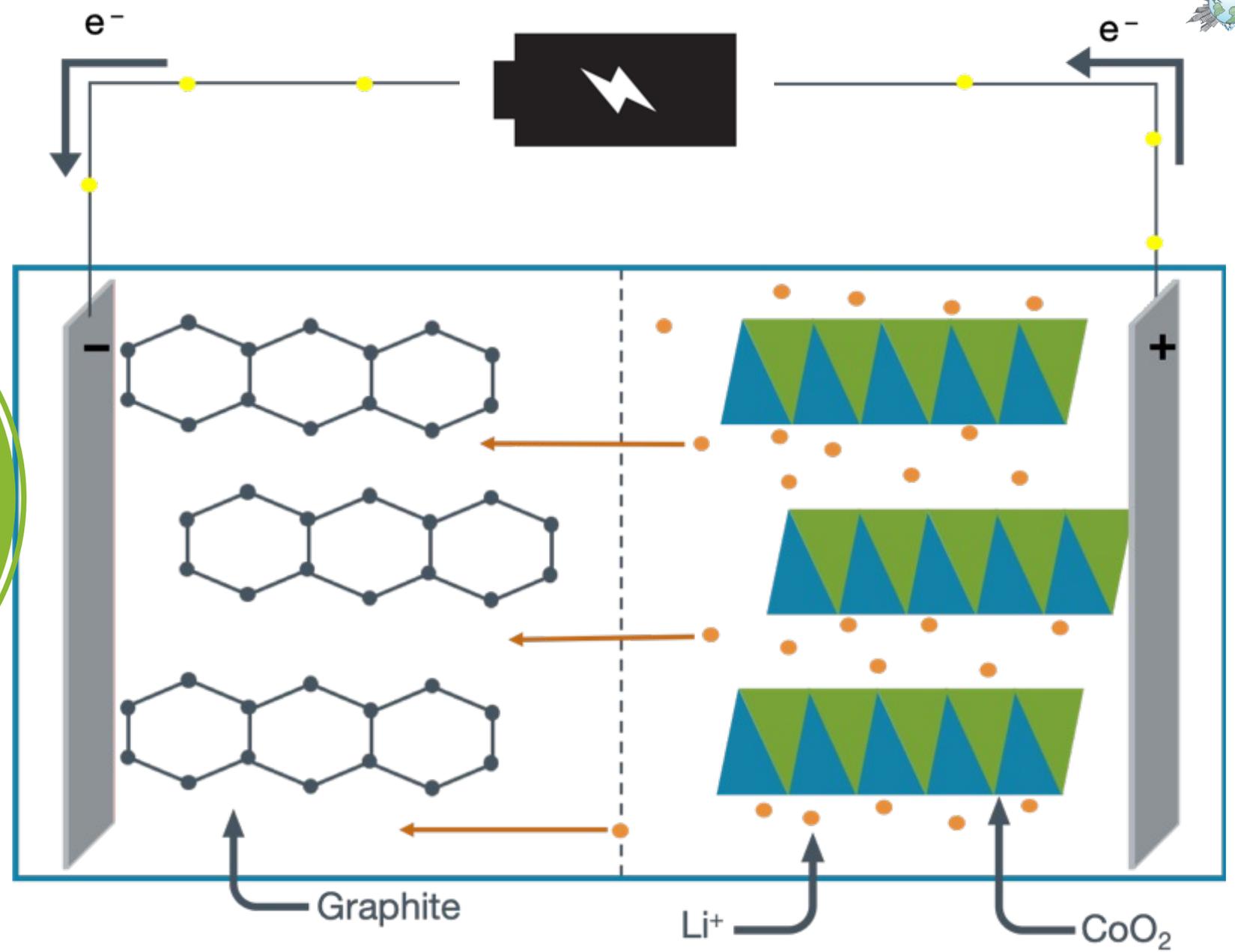


CLICK
PLAY
HERE

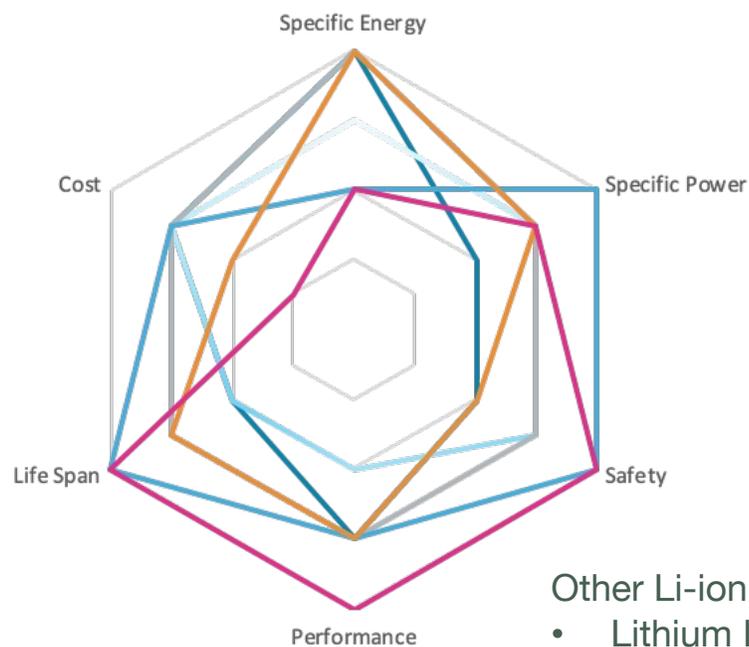
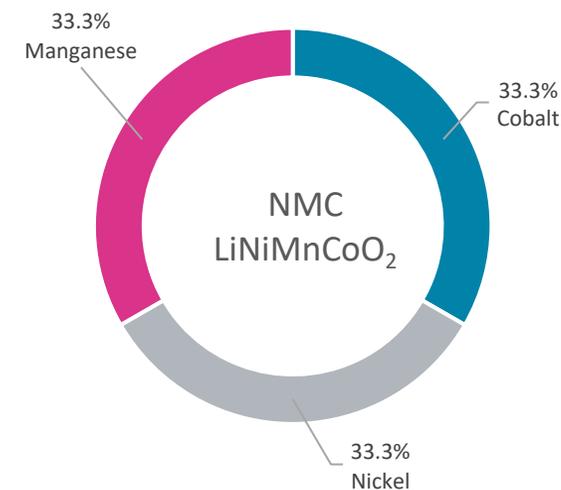
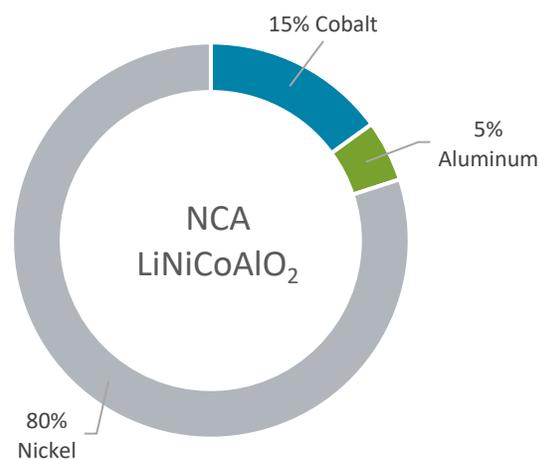
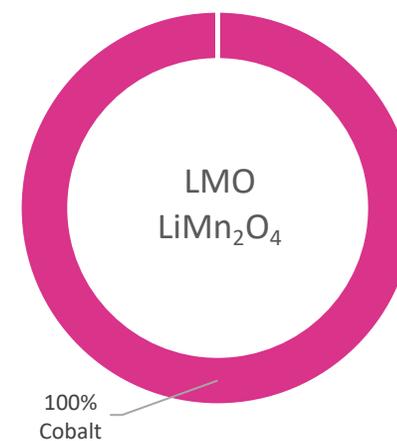
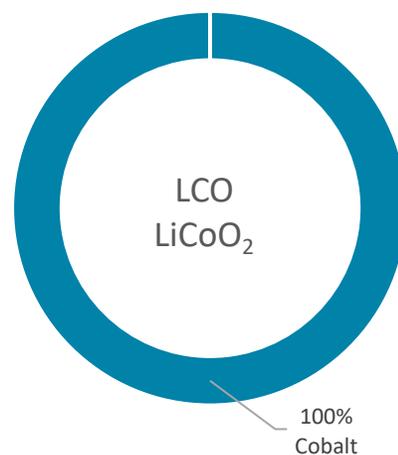
Lithium-Ion Battery - Discharging



Lithium-Ion
Battery -
Charging



Lithium Ion Cathode Chemistry Types



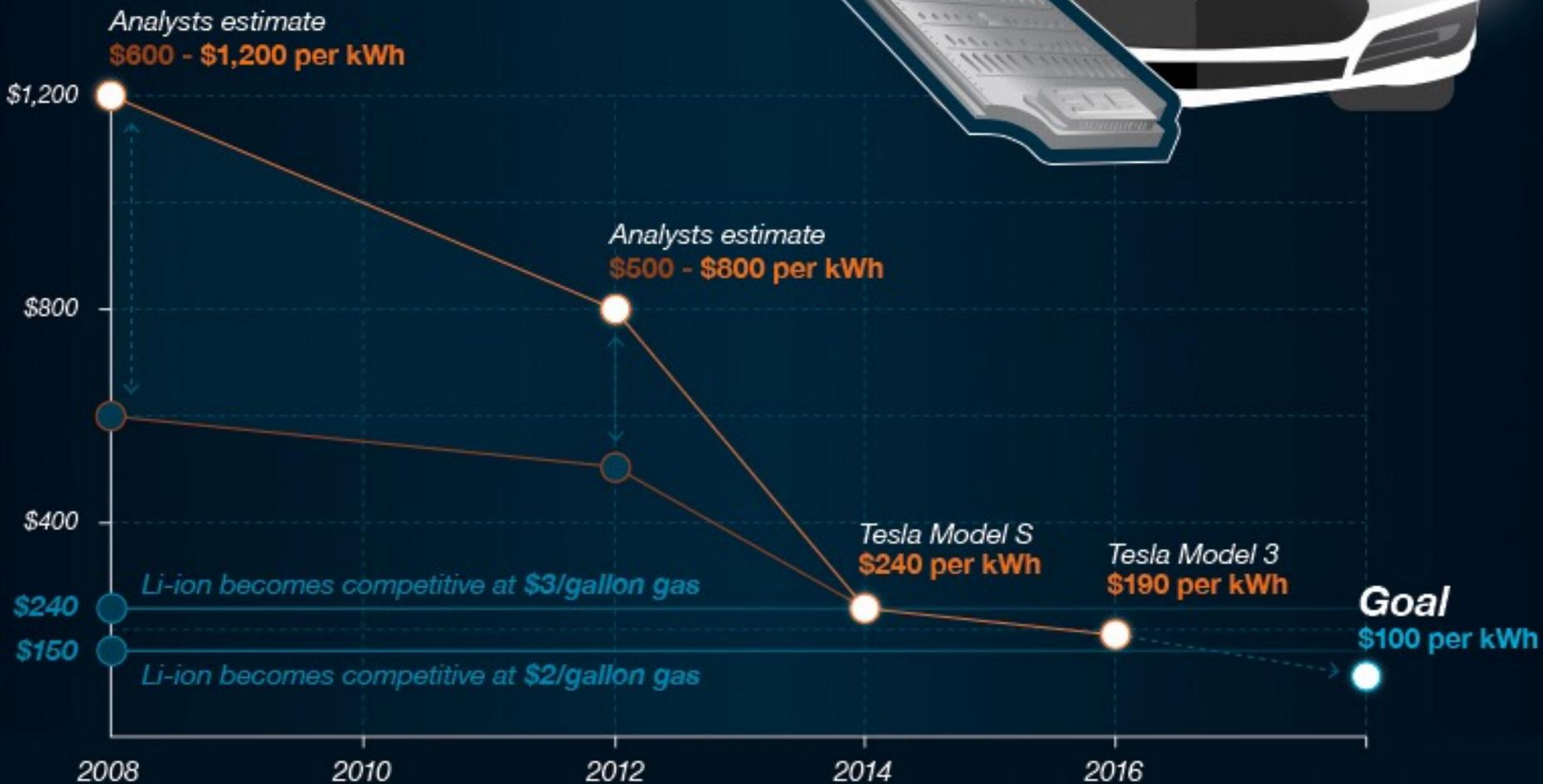
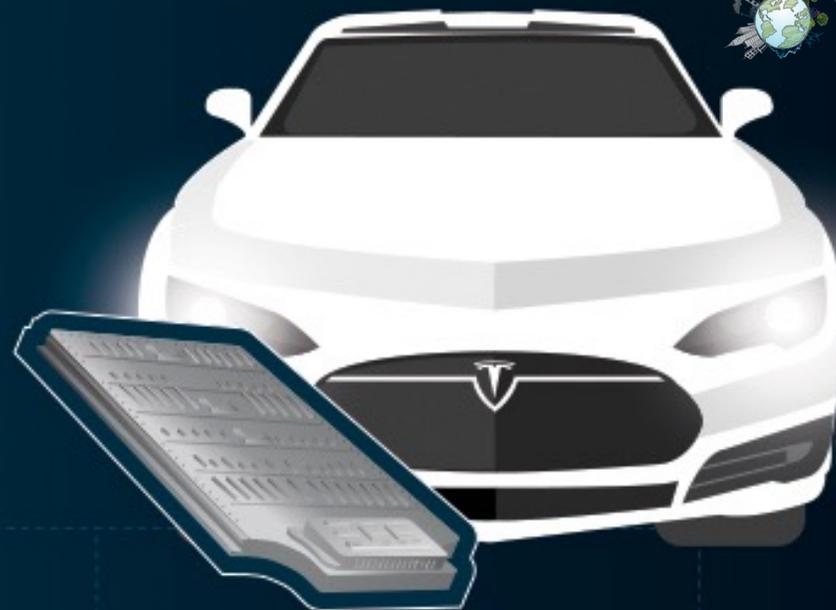
Other Li-ion batteries:

- Lithium Iron Phosphate (LFP) – LiFePO_4
- Lithium Titanate (LTO) – Li_2TiO_3

Cost of Lithium-Ion Batteries - 2018

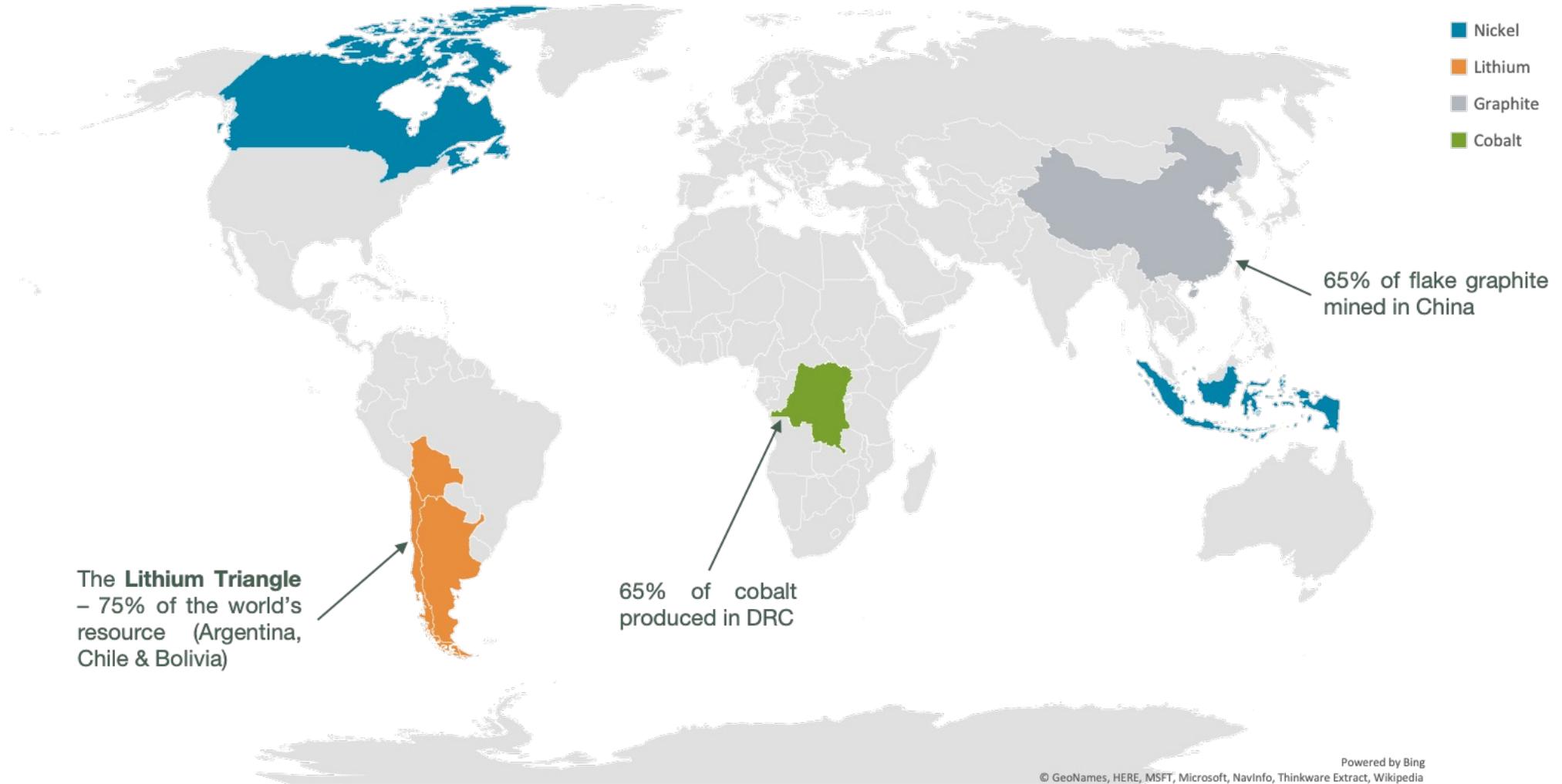
THE COST OF LITHIUM-ION AUTOMOTIVE BATTERIES

Recently, scientists have made even more progress, opening the lithium-ion to many more applications, namely in electric vehicles:



Chemical sources for batteries

Li-ion Material Resources



How are the EV batteries manufactured?

- There are several battery manufacturers in the market
- Battery production is all over the world. USA, Belgium, Poland, and China to name a few.
- Some of the major manufacturers are shown below



Panasonic



TOSHIBA

SAMSUNG



Hitachi Chemical
Working On Wonders

Where Could the Future of Batteries Go?

With more technology advancements, batteries could:

01

Remove the barriers associated to electric cars

02

Lower the cost and raise the efficiency of energy storage

03

Remove the variable nature of renewable energy, and increase integration

Innovation is happening with multiple types of technology and the rate of commercialization is faster than ever.



Thank you!

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