Part 1: Batteries

What is a battery?

A battery is an electrochemical energy storage device. There are many types of batteries since the conception in the 1800s and they fall into two categories; primary which are single use and secondary which can be recharged and used again and again. Today the most popular secondary battery is the lead-acid battery in every petrol/diesel automobile, however the popular shift is turning towards lithium-ion batteries which have proven to be useful in portable devices such as phones and laptops.

A typical lithium-ion battery looks like figure 1. The main components of the battery include the electrodes on either side known as the cathode and anode. During discharge, the cathode is known as the positive (+) electrode and is where electrons flow into. The anode is known as the negative (-) electrode and is where electrons flow out of. The electrolyte solution in the battery consists of cations which are positive ions (+) and anions which are negative ions (-). To stop the cathode and anode electrodes from touching but allowing the ions in the electrolyte to move freely, a porous separator is placed in the middle. Finally, the entire components are packaged up in a casing.

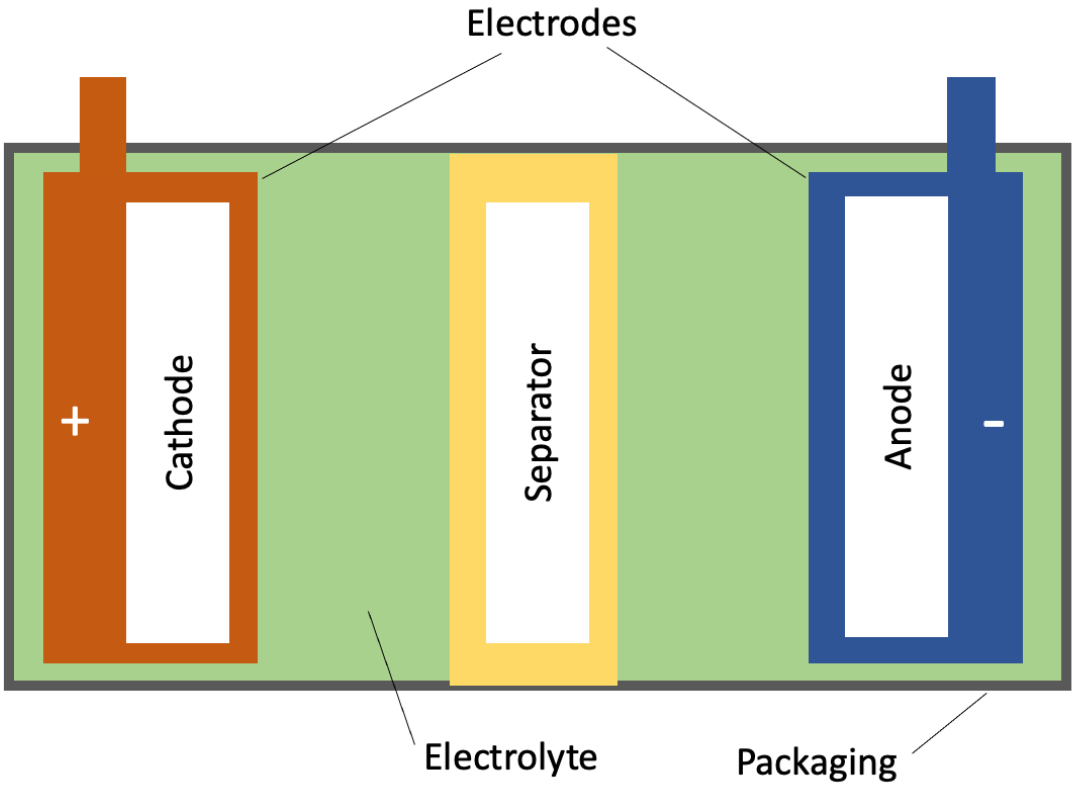

Figure 1. Schematic of a typical battery including the electrodes, electrolyte, separator and packaging.

Figure 1 is a schematic of the inside of a coin cell battery like figure 2a. However, you might be more familiar with an AA battery such as figure 2b. In this battery design one electrode will be in the centre and other electrode wrapped around the centre electrode. Batteries come in all shapes and sizes with varying designs. However, the electrochemistry is the same.

Figure 2. 2a(left) is a coin cell. 2b(right) is an AA battery. Both batteries are lithium-ion.

How do batteries work?

Secondary (rechargeable) batteries work based on an ion storage and release process. This process can be achieved through:

- surface adsorption/desorption
- Intercalation/deintercalation
- Chemical redox reactions
- Or a combination of above.

The electrolyte in a battery contains lithium ions which are free to move from the cathode to the anode, through the separator. During discharge, when you are using your phone for example, the lithium ions are released and move away from the anode (-) through the electrolyte, and simultaneously the electrons move away from the anode (-) outside the battery. The lithium ions and the electrons recombine at the cathode (+) to complete the circuit. The opposite process occurs during charging, where the lithium ions move away from the cathode (+) towards the anode (-) and combine with the electrons.

The movement of the ions in the electrolyte and the electron flow outside the battery produces the current. (Conventional current is known to move in the opposite direction the electron flow.) Batteries are a fundamental example of electrochemistry and the process of converting chemical energy to electrical energy is very efficient and reliable.

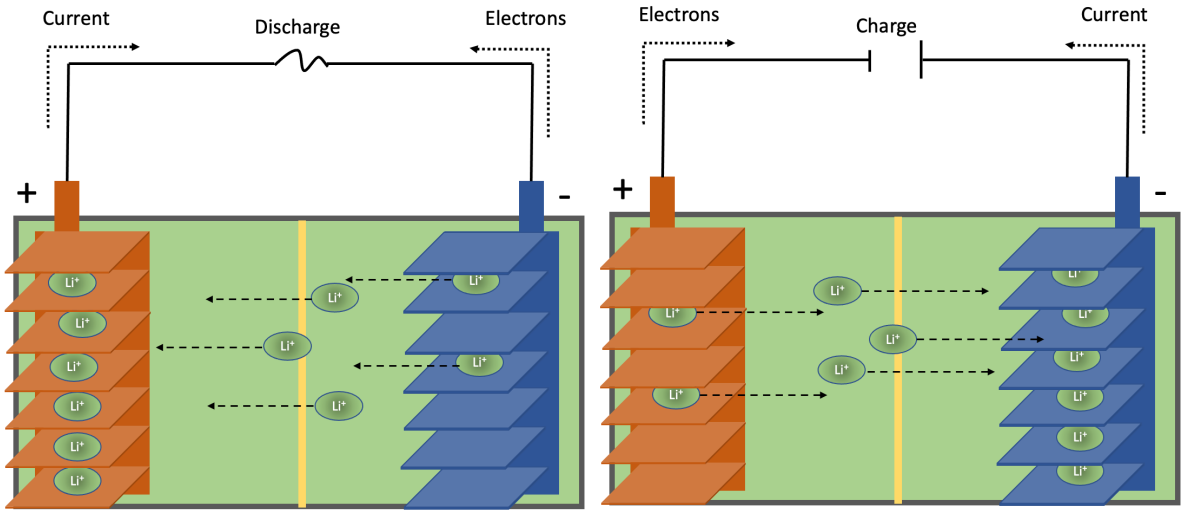

Figure 3. Schematic of battery discharging(left) and charging(right).

Key performance parameters

Under the new green plan by the UK government, there will be a ban on new petrol and diesel cars in the UK from 2030. The electrification of transport means we need cheaper, safer and longer lasting batteries for widespread adoption. When buying a new electric car the price and performance will be directly dependant on the battery inside it.

Figure 4. An electric vehicle charging point in the UK.

Some key questions you might ask are how far can you drive the car? How fast can I drive it? What is the lifetime of the car? Can I drive the car anywhere in whatever weather conditions? And how much does it cost?

These questions translate directly to key performance parameter of batteries. How far you can drive a car depends on the energy stored. How fast is determined by the power. The lifetime is shown by the cycling stability. How adaptable is through the working temperature of the battery. And finally, the cost will come from the components of the battery like the electrodes and especially the amount of electrolyte.