Single Displacement Reaction

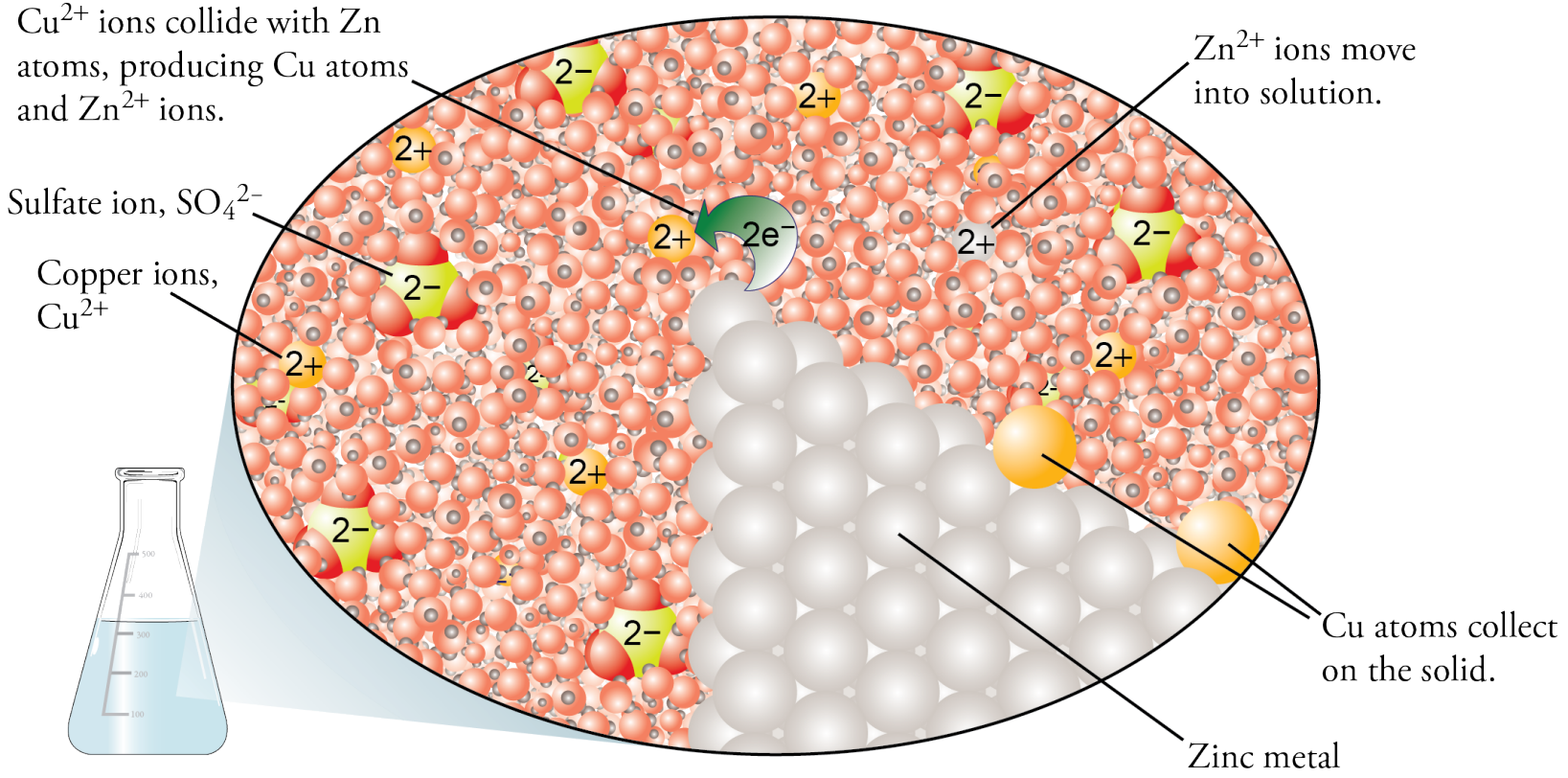
$$Zn(s) + CuSO_4(aq) \rightarrow ZnSO_4(aq) + Cu(s)$$

$$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$$

oxidation: $Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$

reduction: $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$

Single Displacement Reaction Example

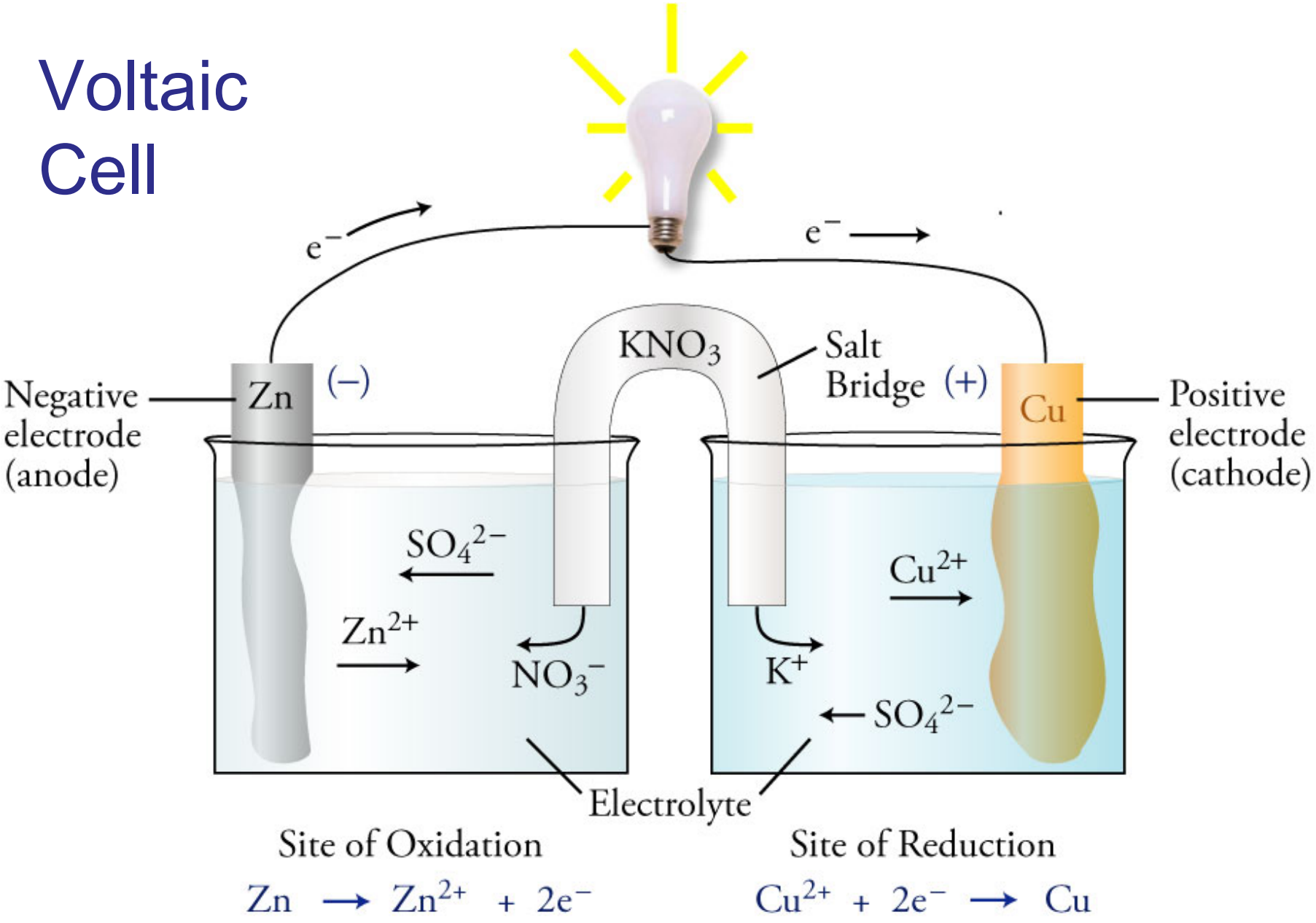


https://preparatorychemistry.com/Zn_CuSO4_Canvas.html

Voltaic Cell

- The system in which two half-reactions for a redox reaction are separated allowing the electrons transferred in the reaction to be passed between them through a wire is called ***voltaic cell.***

Voltaic Cell



Electrodes

- The electrical conductors placed in the half-cells are called ***electrodes***.
- They can be ***active electrodes***, which participate in the reaction, or ***passive electrodes***, which transfer the electrons into or out of a half-cell but do not participate in the reaction.

Anode

- The ***anode*** half-cell is the site of oxidation.
- Because oxidation involves loss of electrons, the anode electrode is the source of electrons. For this reason, it is described as the negative electrode.
- Because electrons are lost, forming more positive (or less negative) species at the anode electrode, the surroundings tend to become more positive. Thus anions are attracted to the anode electrode.

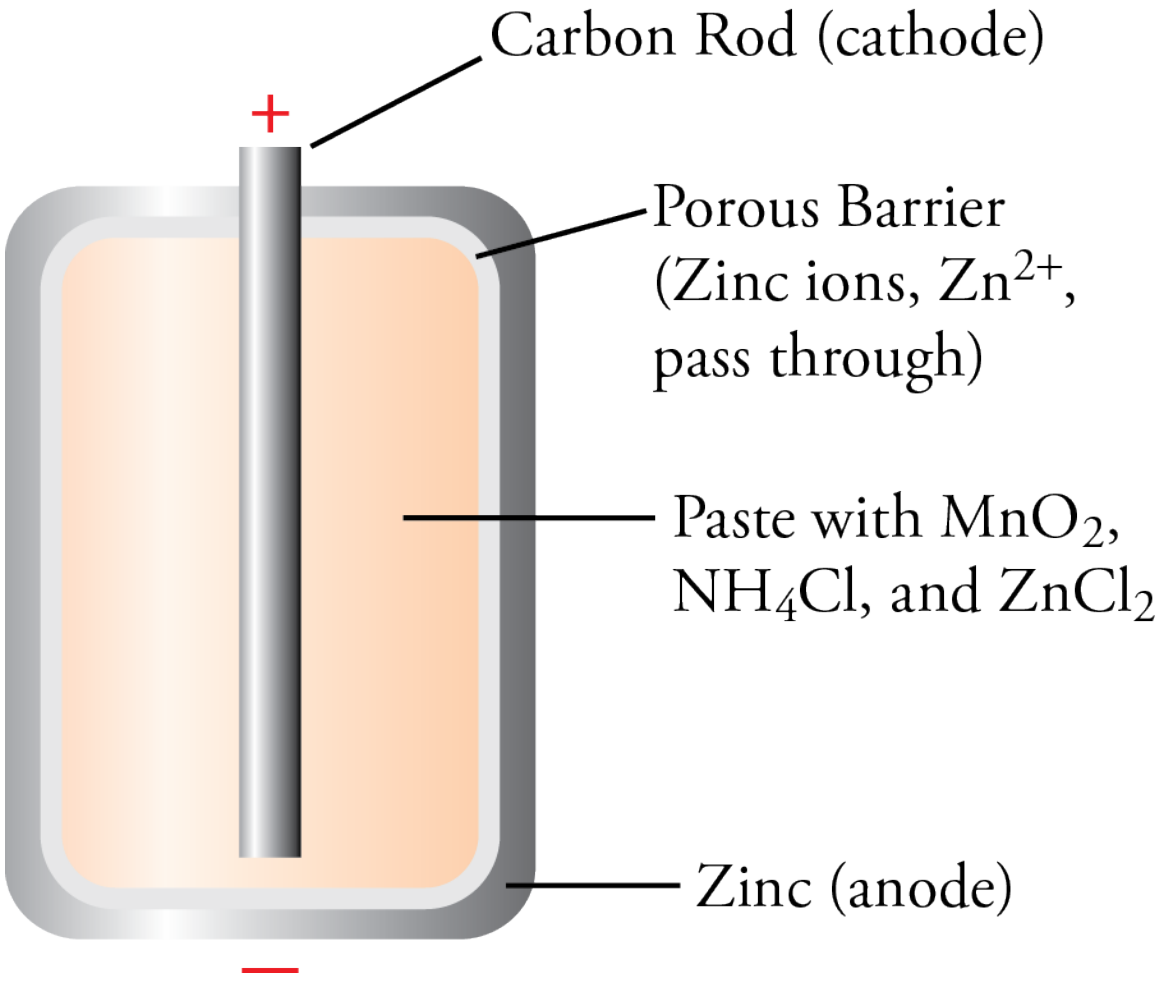
Cathode

- The ***cathode*** half-cell is the site of reduction.
- By convention, the cathode electrode is the positive electrode.
- Because electrons come to the cathode electrode and substances gain these electrons to become more negative (or less positive), the surroundings tend to become more negative. Thus cations are attracted to the cathode electrode.

Other Cell Components

- A device called a ***salt bridge*** can be used to keep the charges balanced.
- The portion of the electrochemical cell that allows ions to flow is called the ***electrolyte***.

Dry Cell Image



Leclanché Cell or Dry Cell

Anode oxidation:

$$Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$$

Cathode reduction:

$$2MnO_2(s) + 2NH_4^+(aq) + 2e^- \rightarrow Mn_2O_3(s) + 2NH_3(aq) + H_2O(l)$$

Overall reaction:

$$Zn(s) + 2MnO_2(s) + 2NH_4^+(aq) \rightarrow Zn^{2+}(aq) + Mn_2O_3(s) + 2NH_3(aq) + H_2O(l)$$

Alkaline Batteries

Anode oxidation:

$$Zn(s) + 2OH^-(aq) \rightarrow ZnO(s) + H_2O(l) + 2e^-$$

Cathode reduction:

$$2MnO_2(s) + H_2O(l) + 2e^- \rightarrow Mn_2O_3(s) + 2OH^-(aq)$$

Overall reaction:

$$Zn(s) + 2MnO_2(s) \rightarrow ZnO(s) + Mn_2O_3(s)$$

Electrolysis

- ***Voltage***, a measure of the strength of an electric current, represents the force that moves electrons from the anode to the cathode in a voltaic cell.
- When a greater force (voltage) is applied in the opposite direction, electrons can be pushed from what would normally be the cathode toward the voltaic cell's anode. This process is called ***electrolysis***.
- In a broader sense, electrolysis is the process by which a redox reaction is made to occur in the nonspontaneous direction.

$$2NaCl(l) \rightarrow 2Na(l) + Cl_2(g)$$

Primary and Secondary Batteries

- Batteries that are not rechargeable are called ***primary batteries***.
- A rechargeable battery is often called a ***secondary battery*** or a ***storage battery***.

Nickel-Cadmium Battery

Anode reaction:

$$Cd(s) + 2OH^-(aq) \rightleftharpoons Cd(OH)_2(s) + 2e^-$$

Cathode reaction:

$$NiO(OH)(s) + H_2O(l) + e^- \rightleftharpoons Ni(OH)_2(s) + OH^-(aq)$$

Net Reaction:

$$Cd(s) + 2NiO(OH)(s) + 2H_2O(l) \rightleftharpoons Cd(OH)_2(s) + 2Ni(OH)_2(s)$$

Lead Acid Battery

$$Pb(s) + HSO_4^-(aq) + H_2O(l) \rightleftharpoons PbSO_4(s) + H_3O^+(aq) + 2e^-$$

Cathode reaction:

$$PbO_2(s) + HSO_4^-(aq) + 3H_3O^+(aq) + 2e^- \rightleftharpoons PbSO_4(s) + 5H_2O(l)$$

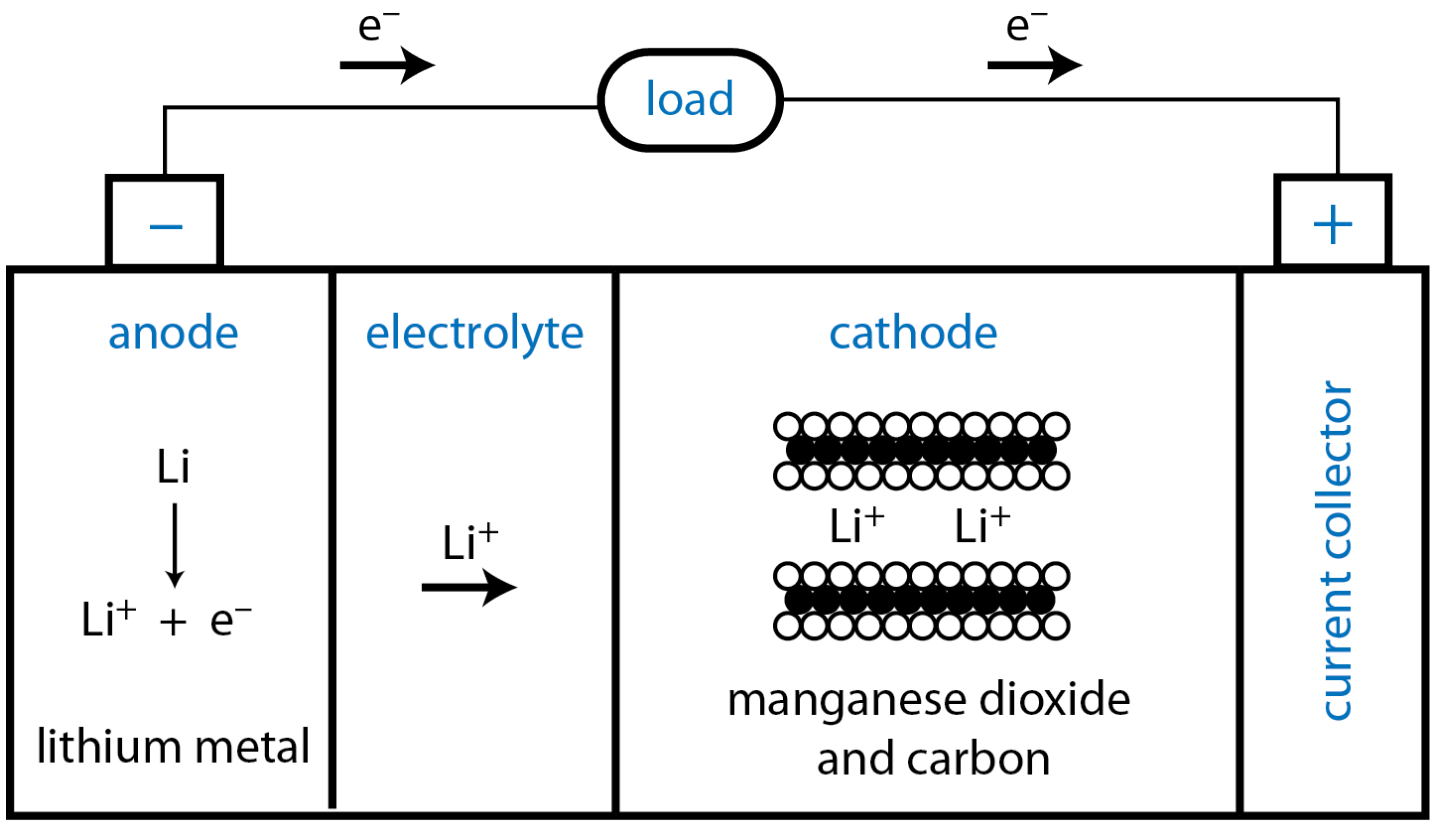
Net reaction:

$$Pb(s) + PbO_2(s) + 2HSO_4^-(aq) + 2H_3O^+(aq) \rightleftharpoons 2PbSO_4(s) + 4H_2O(l)$$

Lithium Batteries

- Because lithium metal has a very low density, and because lithium can yield high voltages in batteries, lithium batteries have very high voltage to mass ratios, making them ideal for powering electronic devices.
- The original lithium batteries used metallic lithium. The following slide shows a typical lithium-metal battery.

Lithium-Metal Battery



$nLi \longrightarrow nLi^+ + ne^-$

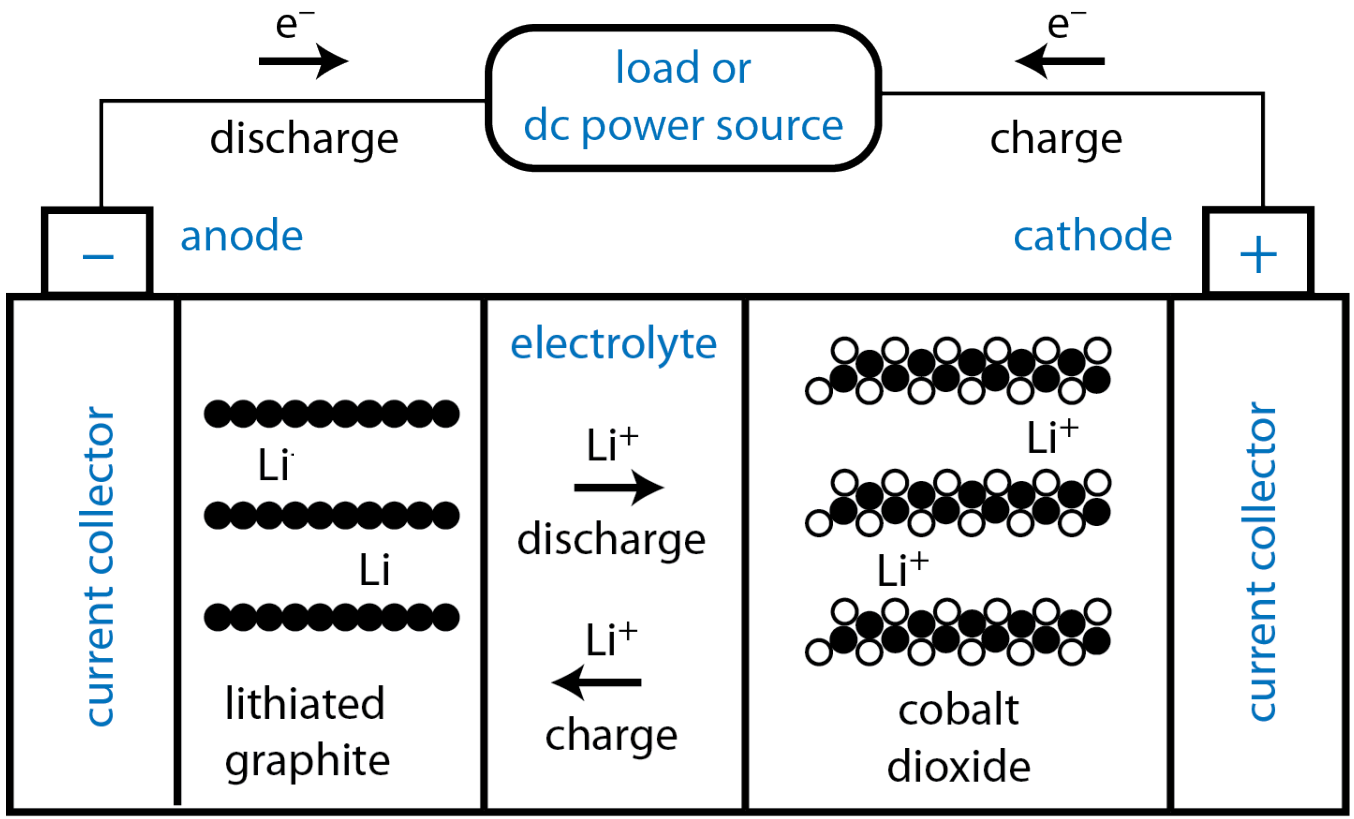
$MnO_2 + nLi^+ + ne^- \longrightarrow Li_nMnO_2$

$Li + MnO_2 \longrightarrow Li_nMnO_2$

Differences in Lithium-Ion Batteries

- The technology for lithium-ion batteries is constantly evolving, leading to changes in the cathode, anode, and electrolyte.
- One example of a lithium-ion battery is shown on the next slide.

Lithium-Ion Battery



$$Li_nC_6 \longrightarrow nLi^+ + 6C + ne^- \qquad CoO_2 + nLi^+ + ne^- \longrightarrow Li_nCoO_2$$

$$Li_nC_6 + CoO_2 \longrightarrow 6C + Li_nCoO_2$$