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The Lithium-Ion battery: The electrochemistry behind the world's most popular rechargeable battery

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Electrochemistry Basics

Redox reaction - a reaction in which a transfer of electrons takes place.
Reduction Reaction - The process in which electrons are gained.
Oxidation Reaction - The process in which electrons are donated.
Oxidizing agent - Species causing the oxidation to occur.
Reducing agent - Species causing the reduction to occur.

Mnemonic Devices

OIL RIG: Oxidation is loss. Reduction is gain
LEO the lion says GER.
 Loss of electrons is oxidation. Gain of electrons is reduction
 CATIONS are PAWssive

The Lithium-Ion Battery:

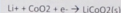


The electrochemical reaction:

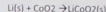
Negative Electrode:



Positive Electrode:



Overall:



The electrochemistry behind the world's most popular rechargeable battery.

Lithium-Ion Physical Components:

Non Rechargeable Lithium Batteries:

Why Lithium?

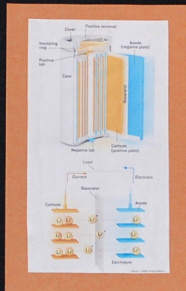
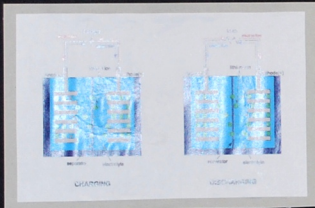
Lithium metal has the **lowest reduction potential** of all metals so it can easily undergo oxidation. Lithium is a **strong reducing agent**. Lithium is the **lightest metal**.

Li-Ion Advantages:

- High energy density and electrochemical potential for its weight.
- No memory effect.
- Maintenance free.
- Very low self-discharge.

Li-Ion Disadvantages:

- Subject to aging.
- High temperature sensitivity.
- Needs protection circuit. Ruined if completely depleted.
- Expensive.



Cathode – Positive electrode: Lithium material

Anode – Negative electrode: Carbon

Electrolyte – Ionic conductor or medium for transferring charge

Separator – Positive/Negative separator

Porous membrane that allows ions to flow but no electrical contact between the internal electrodes

Container

Model No.	Standard Reduction Potential vs. Pt (at 25°C)
Li/Li ⁺	-3.04
Li ⁺ /Li	3.04
Li ⁺ /Li ₂ O	1.85
Li ⁺ /Li ₂ CO ₃	1.85
Li ⁺ /Li ₂ SO ₄	1.85
Li ⁺ /Li ₂ SiO ₄	1.85
Li ⁺ /Li ₂ SiO ₃	1.85
Li ⁺ /Li ₂ SiO ₂	1.85
Li ⁺ /Li ₂ SiO	1.85
Li ⁺ /Li ₂ Si	1.85
Li ⁺ /Li ₂ Si ₂ O ₇	1.85
Li ⁺ /Li ₂ Si ₂ O ₆	1.85
Li ⁺ /Li ₂ Si ₂ O ₅	1.85
Li ⁺ /Li ₂ Si ₂ O ₄	1.85
Li ⁺ /Li ₂ Si ₂ O ₃	1.85
Li ⁺ /Li ₂ Si ₂ O ₂	1.85
Li ⁺ /Li ₂ Si ₂ O	1.85
Li ⁺ /Li ₂ Si ₂	1.85
Li ⁺ /Li ₂ Si	1.85
Li ⁺ /Li ₂ Si ₃ O ₈	1.85
Li ⁺ /Li ₂ Si ₃ O ₇	1.85
Li ⁺ /Li ₂ Si ₃ O ₆	1.85
Li ⁺ /Li ₂ Si ₃ O ₅	1.85
Li ⁺ /Li ₂ Si ₃ O ₄	1.85
Li ⁺ /Li ₂ Si ₃ O ₃	1.85
Li ⁺ /Li ₂ Si ₃ O ₂	1.85
Li ⁺ /Li ₂ Si ₃ O	1.85
Li ⁺ /Li ₂ Si ₃	1.85
Li ⁺ /Li ₂ Si ₄ O ₁₀	1.85
Li ⁺ /Li ₂ Si ₄ O ₉	1.85
Li ⁺ /Li ₂ Si ₄ O ₈	1.85
Li ⁺ /Li ₂ Si ₄ O ₇	1.85
Li ⁺ /Li ₂ Si ₄ O ₆	1.85
Li ⁺ /Li ₂ Si ₄ O ₅	1.85
Li ⁺ /Li ₂ Si ₄ O ₄	1.85
Li ⁺ /Li ₂ Si ₄ O ₃	1.85
Li ⁺ /Li ₂ Si ₄ O ₂	1.85
Li ⁺ /Li ₂ Si ₄ O	1.85
Li ⁺ /Li ₂ Si ₄	1.85
Li ⁺ /Li ₂ Si ₅ O ₁₅	1.85
Li ⁺ /Li ₂ Si ₅ O ₁₄	1.85
Li ⁺ /Li ₂ Si ₅ O ₁₃	1.85
Li ⁺ /Li ₂ Si ₅ O ₁₂	1.85
Li ⁺ /Li ₂ Si ₅ O ₁₁	1.85
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Li ⁺ /Li ₂ Si ₅	1.85
Li ⁺ /Li ₂ Si ₆ O ₁₈	1.85
Li ⁺ /Li ₂ Si ₆ O ₁₇	1.85
Li ⁺ /Li ₂ Si ₆ O ₁₆	1.85
Li ⁺ /Li ₂ Si ₆ O ₁₅	1.85
Li ⁺ /Li ₂ Si ₆ O ₁₄	1.85
Li ⁺ /Li ₂ Si ₆ O ₁₃	1.85
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Li ⁺ /Li ₂ Si ₆ O ₁₁	1.85
Li ⁺ /Li ₂ Si ₆ O ₁₀	1.85
Li ⁺ /Li ₂ Si ₆ O ₉	1.85
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Li ⁺ /Li ₂ Si ₆ O ₃	1.85
Li ⁺ /Li ₂ Si ₆ O ₂	1.85
Li ⁺ /Li ₂ Si ₆ O	1.85
Li ⁺ /Li ₂ Si ₆	1.85



Because lithium is a powerful reducing agent, it is used in high quality disposable batteries as an anode. Modern rechargeable lithium-ion batteries use lithium as a cathode.

Electrolyte:

Lithium violently reacts with water so a *nonaqueous electrolyte* had to be developed.

Lithium salts (mainly Lithium hexafluorophosphate, LiPF₄) are dissolved into an aprotic solvent (propylene carbonate or ethylene carbonate) to make electrolyte.

Liquid or gel electrolyte to acts as intermediate between phases.

Cathode

LiCoO₂
 LiNiO₂
 LiMn₂O₄

Layered cathode active material

- Increased electrode surface area
- Increased volumetric capacity
- Improved cell capacity

The Future of Batteries... The Fuel Cell

- Electrochemical cell where reactants are supplied continuously.
- Can operate without limit.
- No electrode material to replace.
- Fuel can be fed to continuously make power.

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