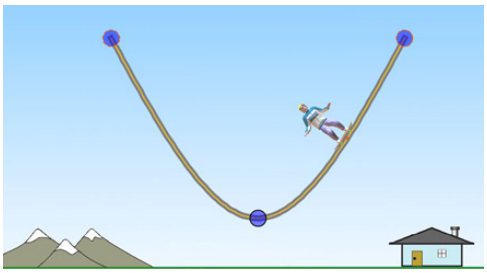
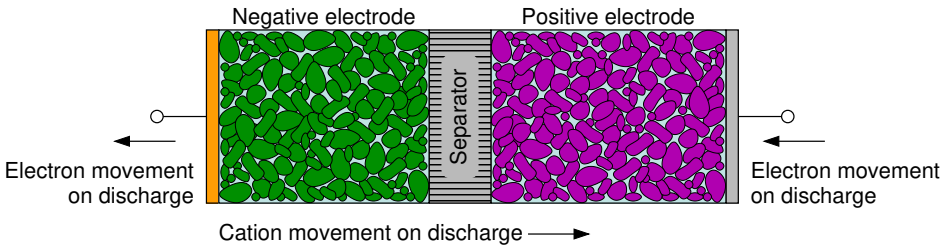
Potential energy

- To understand how electrochemical cells store and release energy, we need to understand the idea of potential energy
  - The skateboard picture illustrates storing and releasing gravitational potential energy—a process with which we are all very familiar
  - Electrochemical cells instead store electrochemical potential energy, which they can later release to do work

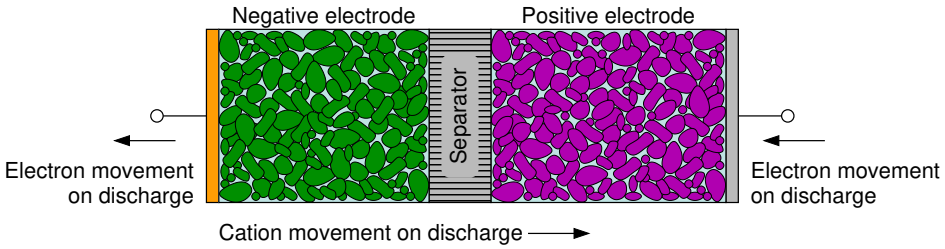


The discharge process: Potentials



- Electrochemical potential energy at negative electrode favors a chemical process that releases electrons into external circuit and cations into electrolyte
- Electrochemical potential at positive electrode favors a chemical process that accepts both electrons from external circuit and cations from electrolyte

The discharge process: Voltage and work

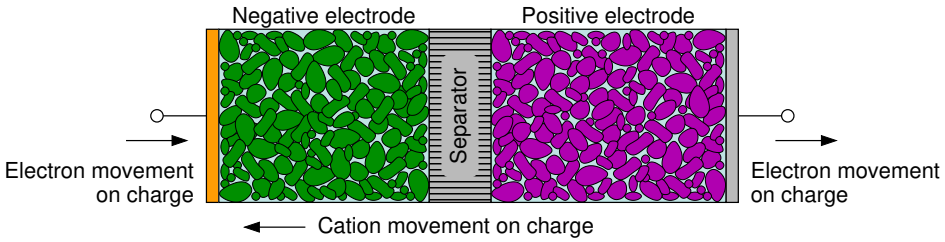


- Resulting electrical pressure (potential difference) between terminals is cell voltage
- Work is performed when external circuit is completed, converting stored electrochemical potential energy into electrical energy

Rechargeable cells

- In primary cells, this electrochemical reaction is not reversible
  - During discharge, the chemical compounds are changed permanently and electrical energy is released until the original compounds are completely exhausted
  - Primary cells can be used only once
- In secondary (rechargeable) cells, this electrochemical reaction is reversible
  - The original chemical compounds can be reconstituted by the application of an electrical potential between the electrodes, injecting energy into the cell
  - Such cells can be discharged and recharged many times
  - Life is limited by degradation processes, not by primary chemical reaction

The charge process



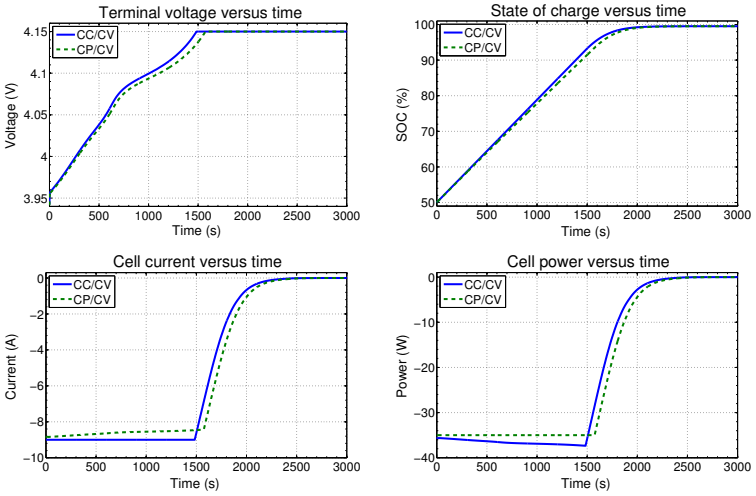
- During charge, cations move from positive to negative electrode through electrolyte; electrons move from positive to negative electrode through external circuit.
- The energy “pumped” into the cell transforms the active chemicals back to their original state.

Beware overcharge and undercharge!

- Manufacturers publish safe operating voltage limits for their cells
- Overcharging or overdischarging can cause irreversible damage, fire, or explosion!

Example: If a PbA battery is not maintained at a high state-of-charge, lead sulfate deposits on both electrodes will begin to form hard crystals, which cannot be reconverted by a standard fixed-voltage (13.6 V) battery charger.

CC/CV and CP/CV charging modes



- Cells are often first charged with either constant-current or constant-power
- When maximum permitted cell voltage is reached, the cell is held at that voltage until it is fully charged

Summary

- Battery cells store energy as electrochemical potential energy
- Whenever an external circuit is completed, the electrochemical potential energy is converted to electrical energy
  - The negative electrode supplies electrons to the circuit and the positive electrode sinks electrons, powering the load and discharging the battery cell
- Whenever a charger provides electrical energy to the cell, that energy is stored as electrochemical potential energy, to be used at a later date
- Manufacturer voltage limits must be carefully maintained to ensure safety, longevity
- Constant-current/constant-voltage and constant-power/constant-voltage are both commonly used charging methods

Credits

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- Phone battery on slide 6: By Mpt-matthew (own work) [CC BY-SA 3.0 (`http://creativecommons.org/licenses/by-sa/3.0`)], via Wikipedia, `https://en.wikipedia.org/wiki/File:Expanded_lithium-ion_polymer_battery_from_an_Apple_iPhone_3GS.jpg`