

Which is the Anode??

GUILTY PARTIES



Michael Faraday

Anode is where current flows "into" an electrolytic cell. When the *internal* current goes in same direction as current loop providing Earth's magnetic field, anode is on the **east** side.¹

1. M. Faraday, "Experimental Researches in Electricity, Seventh Series." *Philosophical Transactions of the Royal Society* 1834 124 (1): 77. Note that the North Pole is the *south* pole of earth's magnet.

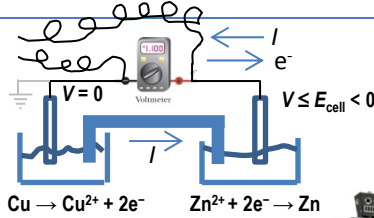
Benjamin Franklin

Silk on glass: "vitreous electricity" = positive
Fur on amber: "resinous electricity" = negative



WE WERE GOING TO USE THE TIME MACHINE TO PREVENT THE ROBOT APOCALYPSE, BUT THE GUY WHO BUILT IT WAS AN ELECTRICAL ENGINEER.

CHARGING BATTERY / ELECTROLYTIC CELL



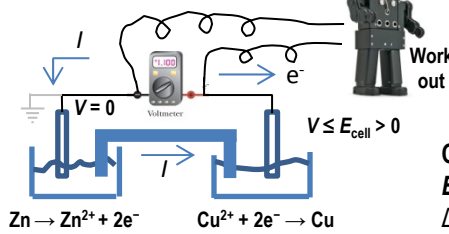
Anode: oxidation takes place
Current flows into cell



Cathode: reduction takes place on the right
 $E = E_{red(right)} - E_{red(left)} < 0$
 $\Delta G > 0$ for net reaction

DISCHARGING BATTERY

Anode: oxidation takes place
Current flows into cell



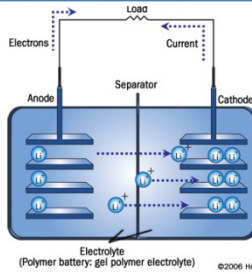
Anode marked "-" on battery package

$V = E_{cell}$ when no current flowing
Cathode: reduction takes place on the right
 $E = E_{red(right)} - E_{red(left)} > 0$
 $\Delta G < 0$ for net reaction

LI-ION BATTERIES

Electrodes named according to role in **discharge** cycle

Anode material hosts Li in charged state
Lithium batteries (primary): Li metal
Li-ion batteries (secondary = rechargeable): Li:C, Li:Si



Cathode material hosts Li in **discharged** state
 $Fe(PO_4):Li, Li_2S$, etc

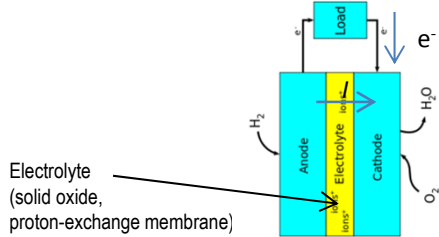
During discharge:
Li ions move from anode to cathode through separator
Electrons move from anode to cathode through circuit

http://en.wikipedia.org/wiki/Lithium-ion_battery

FUEL CELL

Anode: fuel is **oxidized**

e.g.: H_2 oxidized to H_2O
Pt catalyst on porous carbon



Cathode: oxygen is **reduced** (e.g. to H_2O)

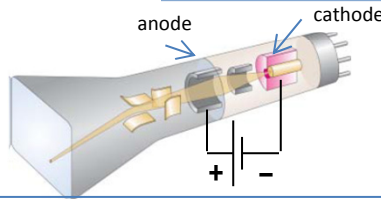
Oxygen reduction catalysts typically less efficient
 $E = E_{red(right)} - E_{red(left)} > 0$
 $\Delta G < 0$ for net reaction

http://en.wikipedia.org/wiki/Fuel_cell

CATHODE-RAY TUBE

Anode: current flows into device from external circuit

Anode is "positive" terminal



Cathode: current flows out of device ("negative" terminal)

Cathode ray (electron beam) is *emitted* from the cathode, typically a heated metal filament

<http://wps.aw.com/wps/media/objects/877/898586/topics/topic07.pdf>

SCHOTTKY DIODE (rectifying metal-semiconductor contact)

Anode: where current flows into device in "forward" (highly conducting) direction



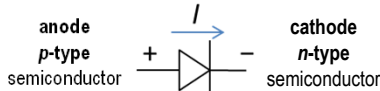
Typically anode is a high-workfunction metal like Pt, W, Cr and cathode is an n-type semiconductor crystal such as galena (PbS).

Cathode: where current flows out of device in "forward" direction – tip of the arrow in symbol

http://en.wikipedia.org/wiki/Schottky_diode

P-N JUNCTION DIODE

Anode: where current flows into device in "forward" (highly conducting) direction



Even when device is typically used with current flowing in "reverse" direction (PV, Zener).

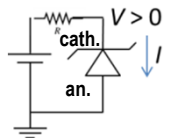
http://en.wikipedia.org/wiki/Zener_diode
http://photonicswiki.org/index.php?title=Physics_of_Solar_Cells

p-n junction photovoltaic (solar cell):

Forward voltage, but reverse current
p-type is still "anode"

Zener diode

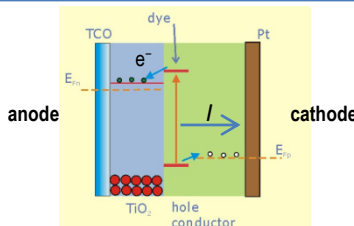
Current and voltage reversed; operates at breakdown



DYE-SENSITIZED SOLAR CELL

Anode: where current flows into device under illumination (opposite of p-n junction solar cell).

Anode typically TiO_2 ; collects electrons from photoexcited dye. Naming convention follows electrolytic cells because hole conductor is **oxidized**.



Cathode: where current flows out of device under illumination (electrons go in)

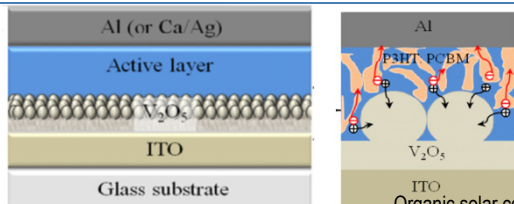
Cathode typically metal (e.g. Pt) electrode that *reduces* hole conductor.

1. M. Grätzel, "Photoelectrochemical cells." *Nature* 2001 v414 p338.
2. E. Bequerel. *C.R. Acad. Sci.* 1839 v9, p145.

THIN FILM SOLAR CELL

Follows p-n junction convention.

Anode: where current flows out of device under illumination. Collects "holes" from active layer.



Cathode: where current flows into device under illumination: collects electrons from active layer.