Batteries (I)

From button cells to utility storage

- Primary batteries
- Secondary batteries (Rechargeable)

Batteries in general

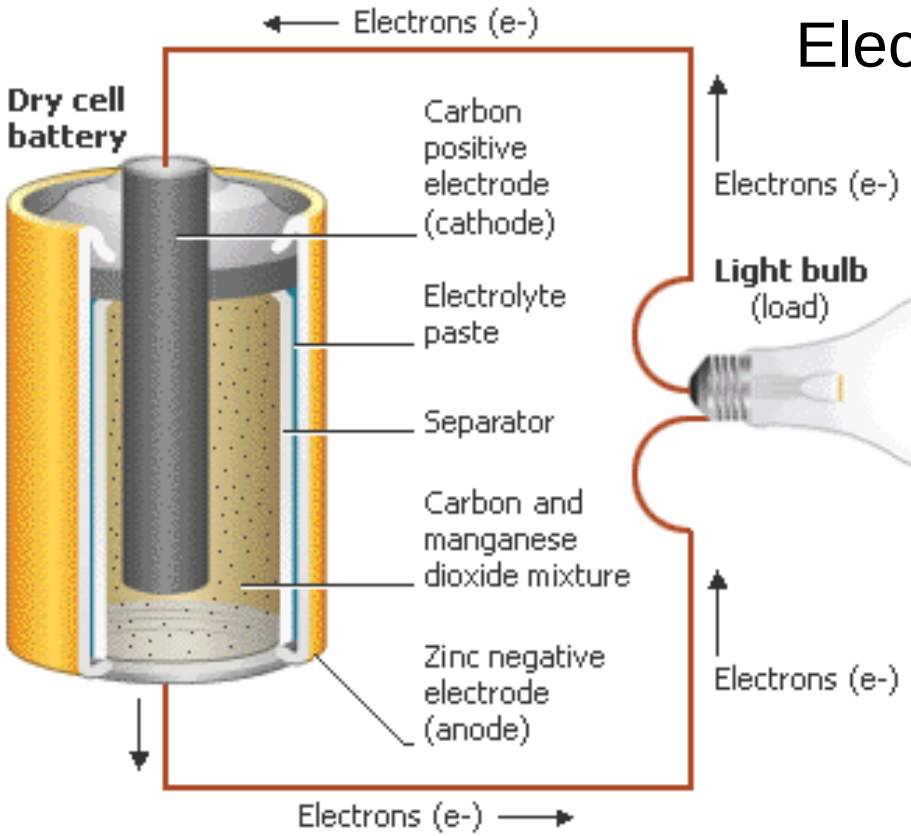
Electrochemical Redox Pair

- (Reducing Agent)/(Oxidizing Agent) or
- (Oxidizing Agent)-(Reducing Agent)
- Examples: Zn/MnO2 (dry cell)
- Examples: Ag-Zn: actually AgO-Zn

Ag-Zn Silver-Zinc button cell

Zn/MnO2 AA size

Battery: Archetypical structure



Electrolyte: ionic conductivity only

Electrodes (in the sense of discharge):
Anode (negative)
Cathode (positive)

Preferably with mixed <u>electronic</u> and <u>ionic</u> conductivity

Batteries: Common types

- Zn/MnO2 and the Alkaline type (primary)
- Ni-Cd, Ni-MH (metal hydride) (rechargeable)
- Lead acid (rechargeable): SLI, deep cycling, storage (usage)
  Flooded, VRLA (AGM, Gel), Spiral wound (structure)
- Li-ion (rechargeable): cylindrical, prismatic (shape)
  Li-polymer (LiPo)
  LiCoOx, LiNiOx, LiMnOx, LiFePO4 (chemistry)
- Li-primary: (Li/SOCl2, thionyl chloride, Li/MnO2 button cell)
- Silver-Zinc (Ag-Zn) button
- Mixed type:
  Example: OxyrideZn/NiOOH
- Zinc/Air (in fact a semi fuel cell)

Batteries: Form factors

- Zn/MnO2 and the Alkaline type, Ni-Cd, Ni-MH:

  AA, AAA, C, D, SC, SD
- Ag-Zn button type: AG0 – AG13
- Li-primary:

  CR927, CR1216, CR1220, CR1616, CR1620,CR2016,CR2025,CR2032
- Li-ion:

  18650 (diameter: 18mm, length 65mm)

C size

D size

18650

SC size

Batteries: Common specs

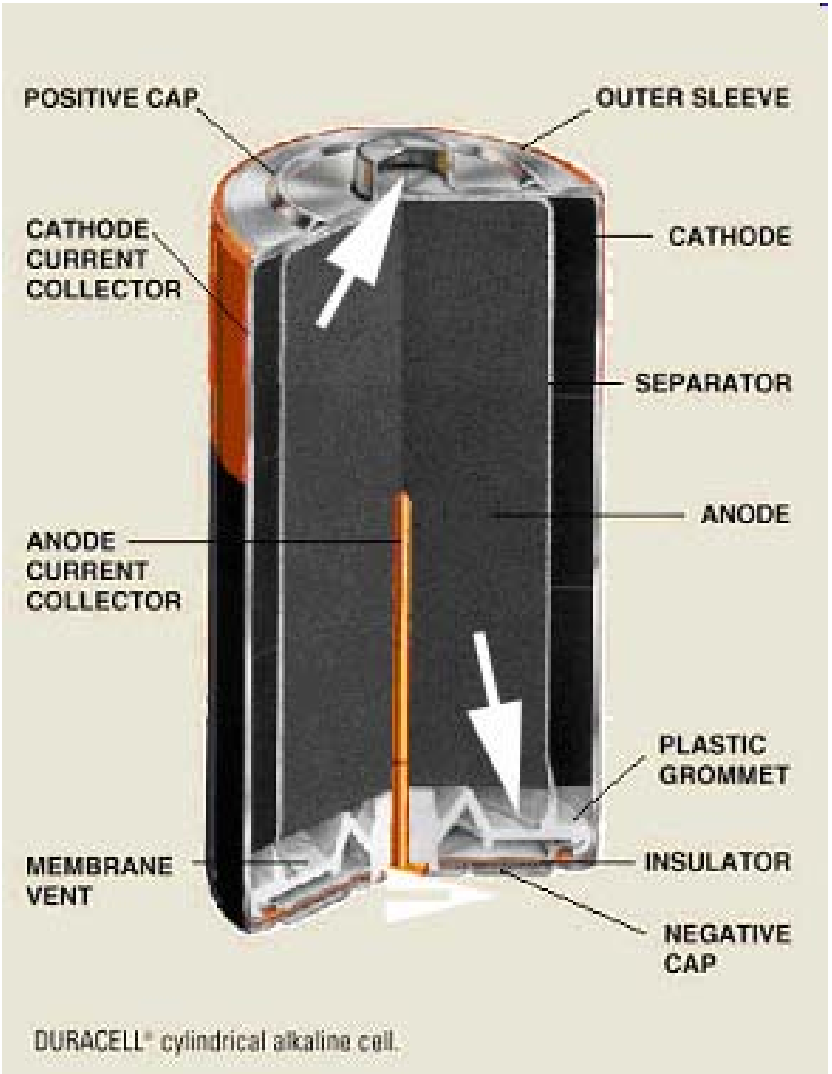
Example: 18650 3.7V 2200 mAh

3.7V: Nominal Voltage
2200 mAh: the nominal capacity:
discharge at 1C (2220mA) it can last 1 hour
Note:
1. Recharge: typically between 0.1 and 0.2C so it takes 5 to 10 hours to recharge full.
2. The capacity depends on discharge rate:
10C discharge will leave a much smaller capacity

Comparison of some batteries

	Ag-Zn	Ni-Cd	Ni-H_2	Ni-MH	Li-ion
Anode	Zn	Cd	H_2	LaNi5	Li intercalated C
Cathode	AgO	NiOOH	NiOOH	NiOOH	$LiCoO_2$
Electrolyte	KOH	KOH	KOH	KOH	Li salt in PC EC
Aquatic?	yes	yes	yes	yes	no
Active ions in electrolyte	OH^-	OH^-	OH^-	OH^-	Li^+
Ion diffusion rate in electrolyte	fast	fast	fast	fast	slow
Need solid-state diffusion in electrode?	no	no	no	yes	yes
Corrosive Electrolyte?	yes	yes	yes	yes	no
Catalytic Anode?	no	no	yes	no	no
Catalytic Cathode?	no	no	no	no	no
Energy density (W·Hr/kg)	90-100	40~50	50-60	60-80	100-150
Cycle life (CL)	<30	>2000	>10000	~500	~500
CL@DOD 20%	100	>10000	>130000	~3000	~4000
CL @DOD 90%	30	>1000	>20000	500	500
Charge Time	2	1	1.5	3~4	4

Zn/MnO2 Alkaline



Why it's so good?

1. Alkaline electrolyte
2. Steel can construction
3. Electrolytic MnO2

Performance 2~3 times better than the old dry cell

Zn/MnO2: Electrochemistry

Anode (-): $Zn + 2\ OH^- \rightarrow ZnO + H_2O + 2e^-$

Cathode (+): $2\ MnO_2 + H_2O + 2e^- \rightarrow Mn_2O_3 + 2\ OH^-$

Lead Acid Battery

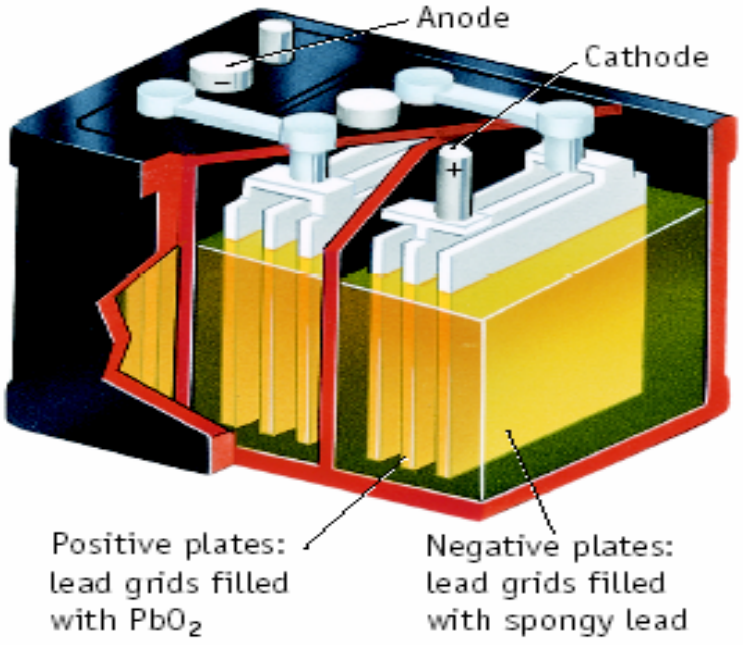
Anode (-) $E^o = +0.36$ V

$Pb + HSO_4^- \rightarrow PbSO_4 + H^+ + 2e^-$

Cathode (+) $E^o = +1.68$ V

$PbO_2 + HSO_4^- + 3\,H^+ + 2e^-$

$\rightarrow PbSO_4 + 2\,H_2O$



Ni-Cd

Anode (-)

$$Cd + 2\,OH^- \rightarrow Cd(OH)_2 + 2e^-$$

Cathode (+)

$$NiO(OH) + H_2O + e^- \rightarrow Ni(OH)_2 + OH^-$$