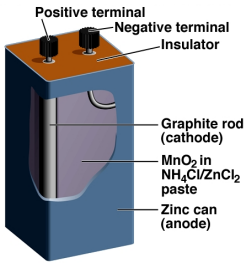
Dry Cell Battery



Chemistry of Batteries

Dry Cells

Anode (oxidation):

$Zn_{(s)} \longrightarrow Zn^{2+}_{(aq)} + 2\ e^-$

Cathode (reduction):

$2\ MnO_{2\ (s)} + 2\ NH_4^+{}_{(aq)} + 2\ e^- \longrightarrow Mn_2O_{3\ (aq)} + 2\ NH_{3\ (aq)} + H_2O_{(l)}$

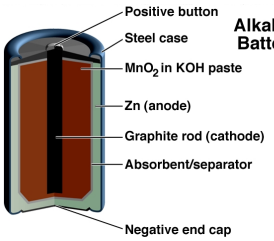
ammonia is tied up with Zn^{2+}

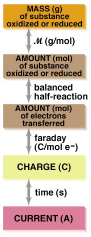
$Zn^{2+}_{(aq)} + 2\ NH_{3\ (aq)} + 2\ Cl^-_{(aq)} \longrightarrow Zn(NH_3)_2Cl_{2\ (s)}$

Overall (cell) reaction:

$2\ MnO_{2\ (s)} + 2NH_4Cl_{(aq)} + Zn_{(s)} \rightarrow Zn(NH_3)_2Cl_{2\ (s)} + H_2O_{(l)} + Mn_2O_{3\ (s)}$

Alkaline Battery





Current: C/s
A= ampere (amp)
mAh = Milliamp hour

Type	*Voltage (V)*	*Capacity (mAh)*
AA	1.5	2800
AAA	1.5	1200
C	1.5	8000
D	1.5	12000
PP3	9	565

Chemistry of Batteries

Alkaline Battery

Anode (oxidation):

$Zn_{(s)} + 2\ OH^-_{(aq)} \longrightarrow ZnO_{(s)} + H_2O_{(l)} + 2\ e^-$

Cathode (reduction):

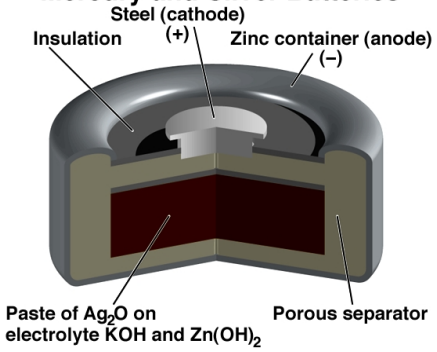
$MnO_{2\ (s)} + 2\ H_2O_{(l)} + 2\ e^- \longrightarrow Mn(OH)_{2\ (s)} + 2\ OH^-_{(aq)}$

Overall (cell) reaction:

$Zn_{(s)} + MnO_{2\ (s)} + H_2O_{(l)} \longrightarrow ZnO_{(s)} + Mn(OH)_{2\ (s)}$ $\quad E_{cell} = 1.5$ V

Leaking battery.

Mercury and Silver Batteries



Chemistry of Batteries

Mercury and Silver (Button) Batteries

Anode (oxidation):

$Zn_{(s)} + 2\ OH^-_{(aq)} \longrightarrow ZnO_{(s)} + H_2O_{(l)}$

Cathode (reduction) (mercury):

$HgO_{(s)} + H_2O_{(l)} + 2\ e^- \longrightarrow Hg_{(l)} + 2\ OH^-_{(aq)}$

Cathode (reduction) (silver):

$Ag_2O_{(s)} + H_2O_{(l)} + 2\ e^- \longrightarrow 2\ Ag_{(s)} + 2\ OH^-_{(aq)}$

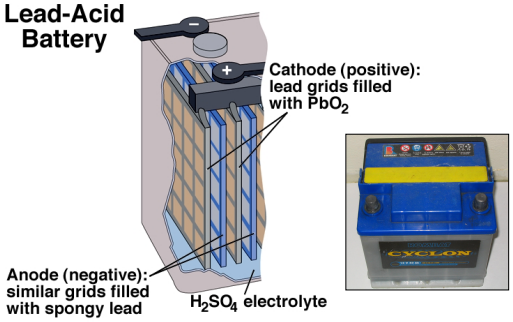
Overall (cell) reaction (mercury):

$Zn_{(s)} + HgO_{(s)} \longrightarrow ZnO_{(s)} + Hg_{(l)}$; $\quad E_{cell} = 1.3$ V

Overall (cell) reaction (silver):

$Zn_{(s)} + Ag_2O_{(s)} \longrightarrow ZnO_{(s)} + 2\ Ag_{(s)}$; $\quad E_{cell} = 1.6$ V

Lead-Acid Battery



Rechargeable Batteries

Lead-Acid Batteries

Anode (oxidation):

$Pb_{(s)} + SO_4^{2-}{}_{(aq)} \longrightarrow PbSO_{4\,(s)} + 2\,e^-$

Cathode (reduction):

$PbO_{2\,(s)} + 4\,H^+_{(aq)} + SO_4^{2-}{}_{(aq)} + 2\,e^- \longrightarrow PbSO_{4\,(s)} + 2\,H_2O_{(l)}$

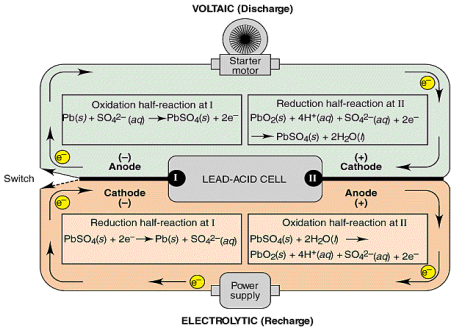
Overall (cell) reaction (discharge):

$PbO_{2\,(s)} + Pb_{(s)} + 2\,H_2SO_{4\,(aq)} \longrightarrow 2\,PbSO_{4\,(s)} + 2\,H_2O_{(l)}$; $E_{cell} = 2$ V

Overall cell) reaction (recharge):

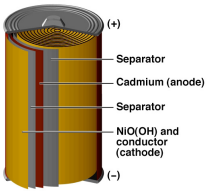
$2\,PbSO_{4\,(s)} + 2\,H_2O_{(l)} \longrightarrow PbO_{2\,(s)} + Pb_{(s)} + 2\,H_2SO_{4\,(aq)}$

Automotive Application: the Discharge and Recharging of a Lead-Acid Battery



Nickel-Cadmium (Nicad) Battery

Used in photovoltaic low voltage lighting



Anode (oxidation):

$Cd_{(s)} + 2\,OH^-_{(aq)} \longrightarrow Cd(OH)_{2\,(s)} + 2\,e^-$

Cathode (reduction):

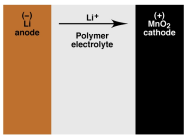
$2\,NiO(OH)_{(s)} + 2\,H_2O_{(l)} + 2\,e^- \longrightarrow 2\,Ni(OH)_{2\,(s)} + 2\,OH^-_{(aq)}$

Overall (cell) reaction:

$Cd_{(s)} + 2\,NiO(OH)_{(s)} + 2\,H_2O_{(l)} \longrightarrow 2\,Ni(OH)_{2\,(s)} + Cd(OH)_{2\,(s)}$

$E_{cell} = 1.4$ V

Solid Lithium Battery



Anode (oxidation): $Li_{(s)} \longrightarrow Li^+(s) + e^-$

Cathode (reduction): $MnO_{2\,(s)} + Li^+ + e^- \longrightarrow LiMnO_{2\,(s)}$

Overall (cell) reaction: $Li_{(s)} + MnO_{2\,(s)} \longrightarrow LiMnO_{2\,(s)}$; $E_{cell} = 3$ V

Lithium Ion Battery

Most Common Rechargeable Cell Phone Battery

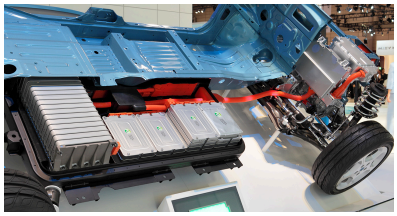
Anode (oxidation): $LiCoO_2 \leftrightarrows Li_{1-x}CoO_2 + xLi^+ + xe^-$

Cathode (reduction): $xLi^+ + xe^- + 6C \leftrightarrows Li_xC_6$

$E_{cell} = 3.6$ V

Lithium Ion Battery

Rechargeable Car Battery



Nissan Leaf

Lithium Ion Batteries

Positive Electrodes

Electrode material	Average potential difference	Specific capacity	Specific energy
$LiCoO_2$	3.7 V	140 mA·h/g	0.518 kW·h/kg
$LiMn_2O_4$	4.0 V	100 mA·h/g	0.400 kW·h/kg
$LiNiO_2$	3.5 V	180 mA·h/g	0.630 kW·h/kg
$LiFePO_4$	3.3 V	150 mA·h/g	0.495 kW·h/kg
Li_2FePO_4F	3.6 V	115 mA·h/g	0.414 kW·h/kg
$LiCo_{1/3}Ni_{1/3}Mn_{1/3}O_2$	3.6 V	160 mA·h/g	0.576 kW·h/kg
$Li(Li_aNi_xMn_yCo_z)O_2$	4.2 V	220 mA·h/g	0.920 kW·h/kg

Negative electrodes

Electrode material	Average potential difference	Specific capacity	Specific energy Graphite
(LiC_6)	0.1-0.2 V	372 mA·h/g	0.0372-0.0744 kW·h/kg
Hard Carbon (LiC_6)	? V	? mA·h/g	? kW·h/kg
Titanate ($Li_4Ti_5O_{12}$)	1-2 V	160 mA·h/g	0.16-0.32 kW·h/kg
Si ($Li_{4.4}Si$)[7][8]	0.5-1 V	4212 mA·h/g	2.106-4.212 kW·h/kg
Ge ($Li_{4.4}Ge$)[7][8]	0.7-1.2 V	1624 mA·h/g	1.137-1.949 kW·h/kg