Batteries and Fuel Cells

Section 20.7

Batteries Around Us

Batteries and Fuel Cells

Battery – A portable, self-contained power source that consists of one or more voltaic cells.

Primary Cell – A battery that cannot be recharged.

Secondary Cell – A battery that can be recharged from an external power source.

Fuel Cell – Fuel is supplied (not self contained) driving redox reactions that generate electricity.

Lead Acid Battery

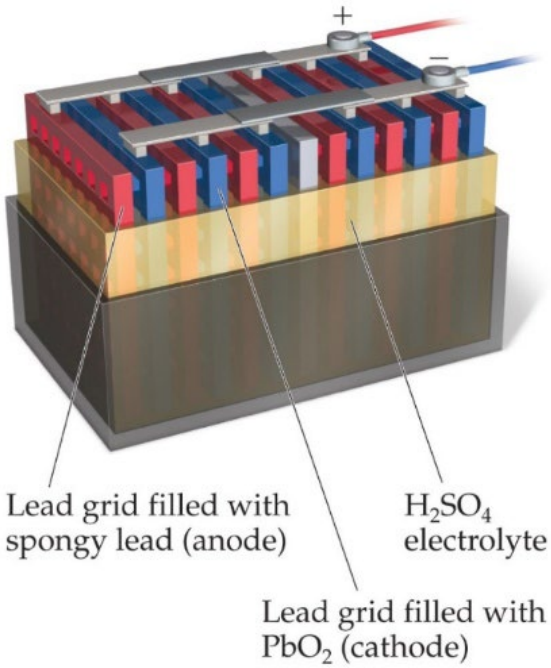
Electrolyte: $H_2SO_4(aq)$
Voltage: 2.05 V
Type: Secondary

Anode: $Pb(s) + HSO_4^-(aq) \rightarrow PbSO_4(s) + H^+(aq) + 2\ e^-$
$E° = -0.36\ V$

Cathode: $PbO_2(s) + HSO_4^-(aq) + 3\ H^+ + 2\ e^- \rightarrow PbSO_4(s) + 2\ H_2O(l)$
$E° = 1.69\ V$

$E° = E°_{red}(cathode) - E°_{red}(anode)$

$E° = 1.69\ V - (-0.36\ V) = 2.05\ V$

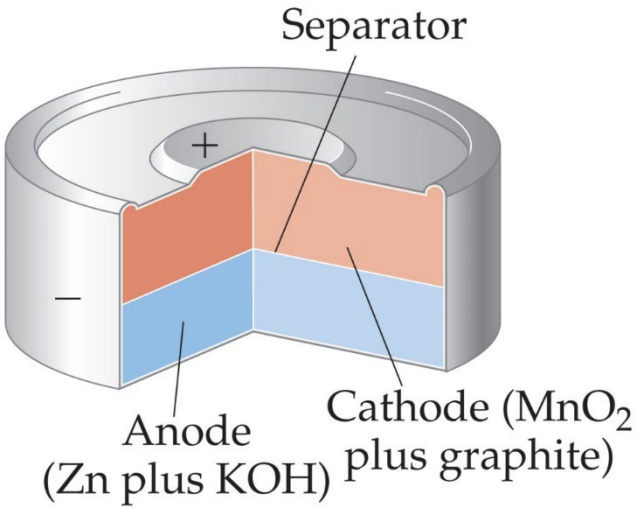


What element is being oxidized at the anode?

What species is being reduced at the cathode?

Alkaline Battery

Electrolyte: KOH(*aq*)
Voltage: 1.5 V
Type: Primary



Anode Rxn: $Zn(s) + 2\ OH^-(aq) \rightarrow Zn(OH)_2(s) + H_2O(l) + 2\ e^-$

Cathode Rxn: $2\ MnO_2(s) + 2\ H_2O(l) + 2\ e^- \rightarrow 2\ MnO(OH)(s) + 2\ OH^-(aq)$

Nickel-Cadmium (Nicad) Battery

Electrolyte: KOH(aq)
Voltage: 1.2 V
Type: Secondary

PANASONIC NICAD

Anode: $Cd(s) + 2\ OH^-(aq) \rightarrow Cd(OH)_2(s) + 2e^-$

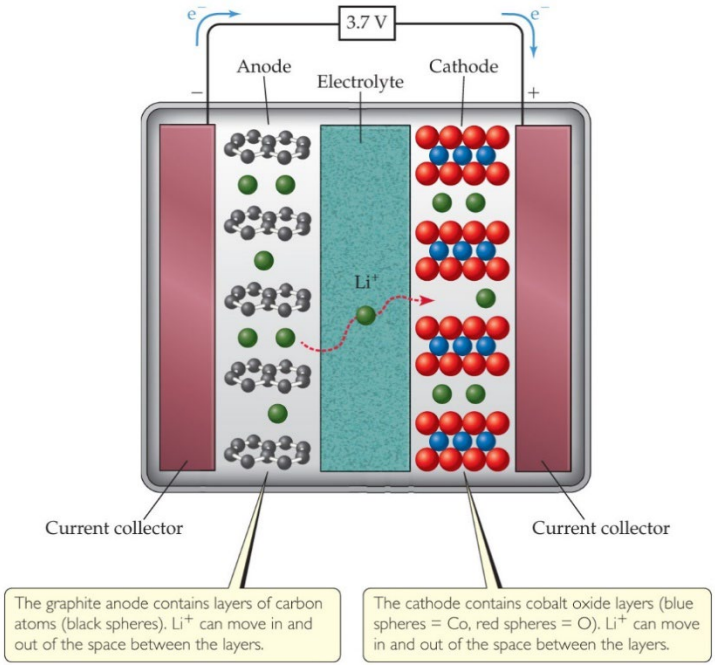
Cathode: $2\ NiO(OH)(s) + H_2O(l) + 2e^- \rightarrow 2\ Ni(OH)_2(s) + 2\ OH^-(aq)$

Table 20.1 Standard Reduction Potentials in Water at 25 °C

E°_{red}(V)	Reduction Half-Reaction
+2.87	$F_2(g) + 2\,e^- \longrightarrow 2\,F^-(aq)$
+1.51	$MnO_4^-(aq) + 8\,H^+(aq) + 5\,e^- \longrightarrow Mn^{2+}(aq) + 4\,H_2O(l)$
+1.36	$Cl_2(g) + 2\,e^- \longrightarrow 2\,Cl^-(aq)$
+1.33	$Cr_2O_7^{2-}(aq) + 14\,H^+(aq) + 6\,e^- \longrightarrow 2\,Cr^{3+}(aq) + 7\,H_2O(l)$
+1.23	$O_2(g) + 4\,H^+(aq) + 4\,e^- \longrightarrow 2\,H_2O(l)$
+1.06	$Br_2(l) + 2\,e^- \longrightarrow 2\,Br^-(aq)$
+0.96	$NO_3^-(aq) + 4\,H^+(aq) + 3\,e^- \longrightarrow NO(g) + 2\,H_2O(l)$
+0.80	$Ag^+(aq) + e^- \longrightarrow Ag(s)$
+0.77	$Fe^{3+}(aq) + e^- \longrightarrow Fe^{2+}(aq)$
+0.68	$O_2(g) + 2\,H^+(aq) + 2\,e^- \longrightarrow H_2O_2(aq)$
+0.59	$MnO_4^-(aq) + 2\,H_2O(l) + 3\,e^- \longrightarrow MnO_2(s) + 4\,OH^-(aq)$
+0.54	$I_2(s) + 2\,e^- \longrightarrow 2\,I^-(aq)$
+0.40	$O_2(g) + 2\,H_2O(l) + 4\,e^- \longrightarrow 4\,OH^-(aq)$
+0.34	$Cu^{2+}(aq) + 2\,e^- \longrightarrow Cu(s)$
0 [defined]	$2\,H^+(aq) + 2\,e^- \longrightarrow H_2(g)$
−0.28	$Ni^{2+}(aq) + 2\,e^- \longrightarrow Ni(s)$
−0.44	$Fe^{2+}(aq) + 2\,e^- \longrightarrow Fe(s)$
−0.76	$Zn^{2+}(aq) + 2\,e^- \longrightarrow Zn(s)$
−0.83	$2\,H_2O(l) + 2\,e^- \longrightarrow H_2(g) + 2\,OH^-(aq)$
−1.66	$Al^{3+}(aq) + 3\,e^- \longrightarrow Al(s)$
−2.71	$Na^+(aq) + e^- \longrightarrow Na(s)$
−3.05	$Li^+(aq) + e^- \longrightarrow Li(s)$

Li-ion Battery

Electrolyte: Lithium salt (e.g. $LiPF_6$) in an organic solvent
Voltage: 3.7 V
Type: Secondary



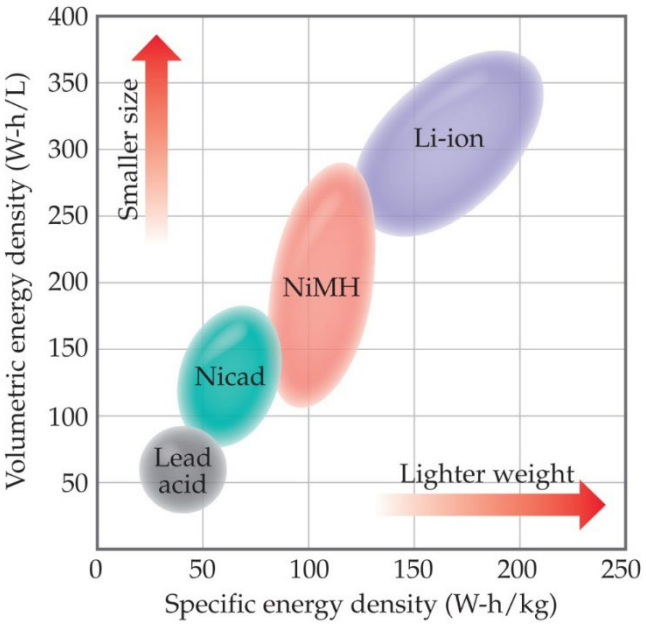
Anode: $Li_xC(s) \rightarrow C(s) + x\ Li^+(aq) + x\ e^-$

Cathode: $Li_{1-x}CoO_2(s) + x\ Li^+(aq) + x\ e^- \rightarrow LiCoO_2(s)$

https://www.youtube.com/watch?v=G5McJw4KkG8

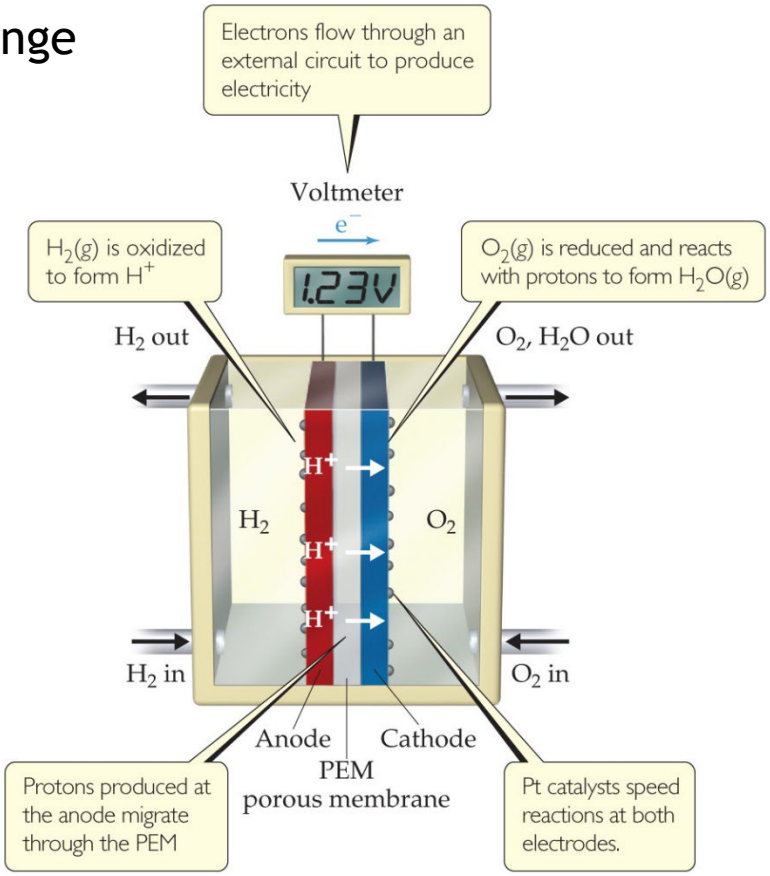
Batteries and Electric Vehicles

Tesla Roadster



Hydrogen Fuel Cell

Electrolyte: Proton exchange membrane (PEM)
Voltage: 1.2 V



Anode: $2\ H_2(g) \rightarrow 4\ H^+ + 4\ e^-$

Cathode: $O_2(g) + 4\ H^+ + 4\ e^- \rightarrow H_2O(l)$