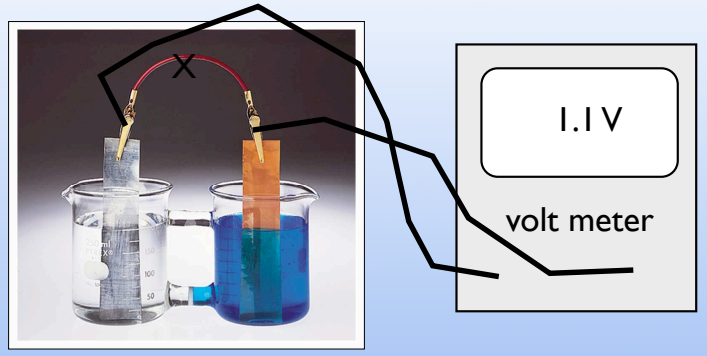
Today

Electrochemistry in the World
Batteries
Fuel Cells
Corrosion

This is the most impractical 1.1 V battery



How can we get rid of the beaker and salt bridge?

Can we use this to make a 1.5 V battery?

Yes. Change the concentrations

$$Zn(s) + Cu^{2+}(aq) \longleftrightarrow Zn^{2+}(aq) + Cu(s)$$

$$E = E^\circ - \frac{0.0591}{n}\log Q$$

$$Q = \frac{[Zn^{2+}]}{[Cu^{2+}]}$$

$$E = 1.1 - \frac{0.0591}{n}\log Q \qquad Q = \frac{[Zn^{2+}]}{[Cu^{2+}]}$$

To make a 1.5 V battery I will need

A. $[Zn^{2+}] = [Cu^{2+}]$

B. $[Zn^{2+}] < [Cu^{2+}]$ ← need $\log Q < 0$, $Q < 1$

C. $[Zn^{2+}] > [Cu^{2+}]$

I want the reaction to go to the product side (decrease P increase R)

D. the voltage is independent of the concentrations

$$E = 1.1 - \frac{0.0591}{n}\log Q \qquad Q = \frac{[Zn^{2+}]}{[Cu^{2+}]}$$

To make a 1.5 V battery I will need

$$1.5 = 1.1 - \frac{0.0591}{2}\log Q$$

$$\log Q = \frac{-2(1.5-1.1)}{0.0591} = -13.5$$

$$Q = 10^{-13.5} \ !$$

$$Q = 10^{-13.5} \ !$$

$$Q = \frac{[Zn^{2+}]}{[Cu^{2+}]}$$

$[Zn^{2+}] = 10^{-13.5}$ M $\qquad [Cu^{2+}] = 1$ M

Why is this hard to maintain?

Any reaction will dramatically increase $[Zn^{2+}]$ and drop the voltage

We really need a reaction for which E° is close to the voltage that we want

$$E = E° - \frac{0.0591}{n}\log Q$$

Current will flow until E = 0
Equilibrium

$$E° = + \frac{0.0591}{n}\log K \qquad \log K = \frac{nE°}{0.0591}$$

What do we have at equilibrium for our Zn/Cu battery?

$$\log K = \frac{nE°}{0.0591} = \frac{2(1.1)}{0.0591} = 37 \qquad K = 10^{37}$$

no more Cu^{2+}

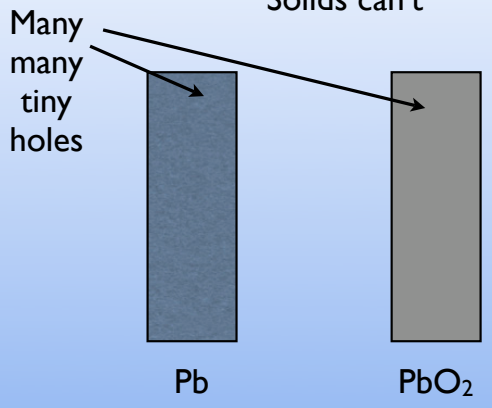
Issue to deal with

Beakers keep the oxidation and reduction reactions physically separated from one another

Salt bridge connect the circuits by allowing ions to flow between the two regions

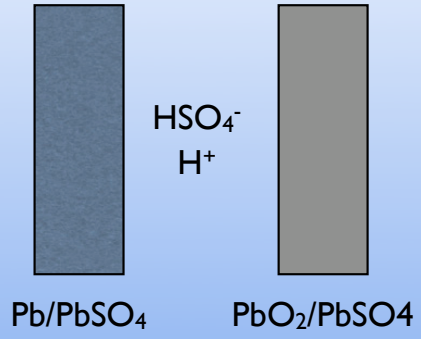
No Beakers is easy. Put chemical into a porous medium

Water and ions can flow in and out
Solids can't



How to connect them?

Use a common electrolyte
Same chemical is common to both the oxidation and reduction



Lead Acid Battery

Anode

reduction potential

$\mathrm{Pb}(s) + \mathrm{HSO_4^-}(aq) + \mathrm{H_2O}(l) \leftrightarrow \mathrm{PbSO_4}(s) + \mathrm{H_3O^+}(aq) + 2e^-$ E° = -0.356V

Cathode

$\mathrm{PbO_2}(s) + 3\mathrm{H_3O^+}(aq) + \mathrm{HSO_4^-}(aq) + 2e^- \leftrightarrow \mathrm{PbSO_4}(s) + 5\mathrm{H_2O}(l) \quad \epsilon^o = 1.685\ \mathrm{V}$

$E°_{cell}$ = 1.685 - (-.356) = 2.041 V

Total Reaction

$\mathrm{Pb(s) + PbO_2(s) + 2HSO_4^- + 2H_3O^+ \longleftrightarrow 2PbSO_4(s) + 4H_2O(l)}$

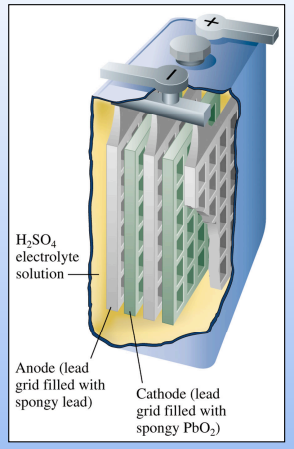
Imagine starting with 1M
HSO_4^- and H^+ (1 M H_2SO_4)

E = E° = 2.04 V

What is the voltage when 90% of the acid has reacted?

work out on doc cam

Lead Acid Battery was invented in 1859



Why is it still used in cars today?

A. It provides a lot of voltage
B. It provides a lot of current
C. Its fun to drive around with sulfuric acid in the car
D. It is infinitely rechargable

Current is Charge per time

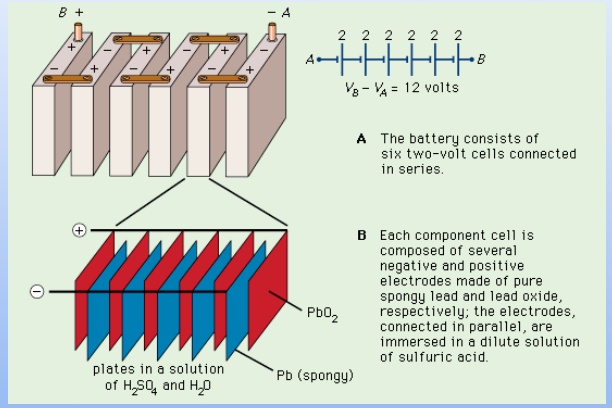
To get a lot of current you need a fast reaction.

This is very hard to accomplish without a liquid battery

The lead battery is among the best at providing high current

You car needs 12V not 2V

How does it do this with a Lead/Acid Battery



Something everyone should know

Don't "overcharge" your car battery
Or use too high a voltage!

$$\begin{aligned} &\text{Anode (oxidation):} && 2H_2O\,(l) \rightarrow O_2\,(g) + 4H^+\,(aq) + 4e^- \\ &\text{Cathode (reduction):} && 2H_2O\,(l) + 2e^- \rightarrow H_2\,(g) + 2OH^-\,(aq) \end{aligned}$$

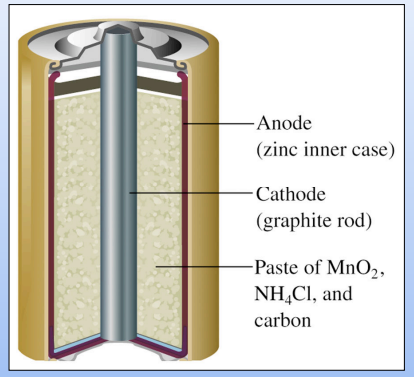
E°_{cell} = -2.06 V

This is very close to the reverse of what you need to charge the lead reaction.

So if you "over charge" you will generate H_2 and O_2 in your battery

Batteries without liquids

Dry Cell



$Zn(s) \rightarrow Zn^{2+}(aq) + 2\,e^-$

$2MnO_2(s) + 2\,H^+(aq) + 2\,e^- \rightarrow Mn_2O_3(s) + H_2O(l)$

The Key
Solid Electrolyte
Paste
NH_4^+, NH_3, H_2O

Carbon makes electrical connection

Very slow reaction. Constant V. Very low current

What is the difference between AAA, AA, C, D batteries?

A. the bigger batteries (D cell) have a higher voltage

B. the bigger batteries are faster

C. the bigger batteries have more material (more electrons)

D. the bigger batteries are the same only bulky

They are all the same materials
same reaction = same voltage

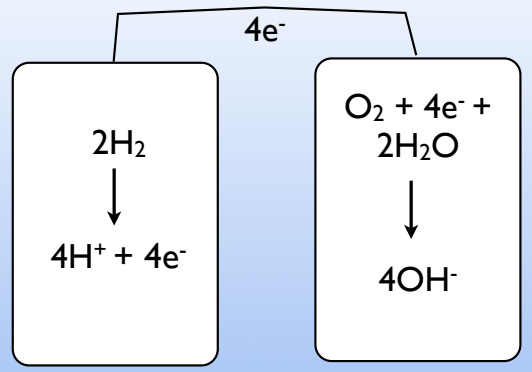
$$Zn(s) \longrightarrow Zn^{2+}(aq) + 2e^-$$
$$2MnO_2(s) + 2H^+(aq) + 2e^- \longrightarrow Mn_2O_3(s) + H_2O(l)$$

anode is straight forward
cathode reaction is a bit more complicated than presented

For given concentrations

E = 1.5 V

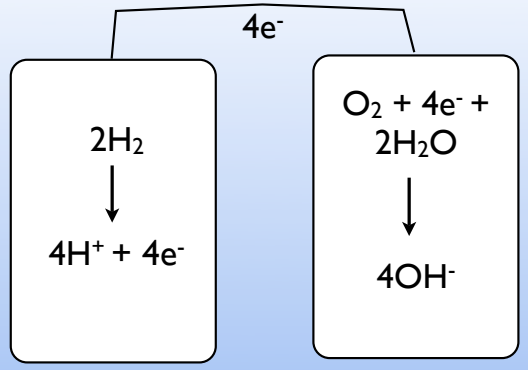
Fuel Cells



Anode
oxidation

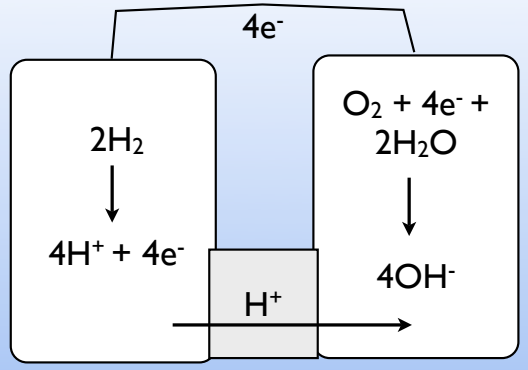
Cathode
reduction

Fuel Cells



We need a salt Bridge!

Fuel Cells



Proton Transport Membrane