UNIT8-DAY2-LaB1230

Monday, April 15, 2013
3:52 PM

Thinking Like a Chemist
About Electrochemistry

e^- on the move

UNIT8 DAY2

CH302 Vanden Bout/LaBrake Spring 2013

IMPORTANT INFORMATION

LM34 & LM35 due ~~Tue~~ Thurs 9 AM

Exam Average ☺

Redox Worksheet Coming Soon
Balancing, etc

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What are we going to learn today?

Oxidation – Reduction Chemistry
Voltaic and Electrolytic Cells

Tracking the movement of electrons

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QUIZ: Clicker Question 1

The oxidation numbers on the C in the following oxides, CO, CO_2 and CO_3^{2-} are:

A) -2, -4, -6
B) +2, +4, +6
C) -2, +4, -8
D) +2, +4, +4
E) 0, 0, -2

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QUIZ : Clicker Question 2

In the following redox reaction, what is serving as the oxidizing agent?

gets reduced

$$2H_2S\,(g) + SO_2(g) \rightarrow 3S\,(s) + 2H_2O\,(l)$$

In the following redox reaction, what is serving as the oxidizing agent?

gets reduced

$$2H_2S\ (g) + SO_2(g) \rightarrow 3S\ (s) + 2H_2O\ (l)$$

H_2S: (-2) S: (+4) S: (0)

A) H_2S
B) SO_2 ← can pull this off a shelf to oxidize something
C) S
D) H_2O

Sometimes it is NOT EASY to make ½ reactions

$$\overset{0}{Na}(s) + \overset{+1}{H_2}\overset{-2}{O}\ (l) \rightarrow \overset{+1}{Na}\overset{-2}{O}\overset{+1}{H}\ (aq) + \overset{0}{H_2}\ (g)$$

Oxid ½ $2(Na \rightarrow Na^+ + 1e^-)$

Red $\cancel{2OH^-}$ $2H^+ + H_2O \rightarrow H_2 + H_2O + 2OH^-$

$2H_2O + \cancel{H_2O} \rightarrow H_2 + \cancel{H_2O} + 2OH^-$

For this you must remember/assign oxidation #'s

$2e^- + 2H_2O \rightarrow H_2 + 2OH^-$

Last class we noticed electrons will move from higher energy to lower energy

Electrons moved from Al to Cu^{2+}

Electrons moved from Cu to Ag^+

Metal	Oxidation Reaction
Lithium	$Li(s) \longrightarrow Li^+(aq) + e^-$
Potassium	$K(s) \longrightarrow K^+(aq) + e^-$
Barium	$Ba(s) \longrightarrow Ba^{2+}(aq) + 2e^-$
Calcium	$Ca(s) \longrightarrow Ca^{2+}(aq) + 2e^-$
Sodium	$Na(s) \longrightarrow Na^+(aq) + e^-$
Magnesium	$Mg(s) \longrightarrow Mg^{2+}(aq) + 2e^-$
Aluminum	$Al(s) \longrightarrow Al^{3+}(aq) + 3e^-$
Manganese	$Mn(s) \longrightarrow Mn^{2+}(aq) + 2e^-$
Zinc	$Zn(s) \longrightarrow Zn^{2+}(aq) + 2e^-$
Chromium	$Cr(s) \longrightarrow Cr^{3+}(aq) + 3e^-$
Iron	$Fe(s) \longrightarrow Fe^{2+}(aq) + 2e^-$
Cobalt	$Co(s) \longrightarrow Co^{2+}(aq) + 2e^-$
Nickel	$Ni(s) \longrightarrow Ni^{2+}(aq) + 2e^-$
Tin	$Sn(s) \longrightarrow Sn^{2+}(aq) + 2e^-$
Lead	$Pb(s) \longrightarrow Pb^{2+}(aq) + 2e^-$
Hydrogen	$H_2(g) \longrightarrow 2H^+(aq) + 2e^-$
Copper	$Cu(s) \longrightarrow Cu^{2+}(aq) + 2e^-$
Silver	$Ag(s) \longrightarrow Ag^+(aq) + e^-$
Mercury	$Hg(l) \longrightarrow Hg^{2+}(aq) + 2e^-$

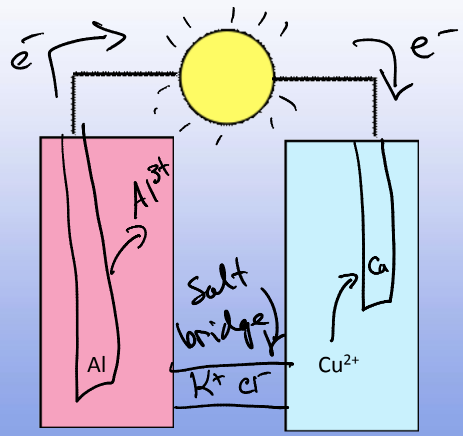
Ease of oxidation increases

Zinc	$Zn(s)$	$\longrightarrow$	$Zn^{2+}(aq) + 2e^-$
Chromium	$Cr(s)$	$\longrightarrow$	$Cr^{3+}(aq) + 3e^-$
Iron	$Fe(s)$	$\longrightarrow$	$Fe^{2+}(aq) + 2e^-$
Cobalt	$Co(s)$	$\longrightarrow$	$Co^{2+}(aq) + 2e^-$
Nickel	$Ni(s)$	$\longrightarrow$	$Ni^{2+}(aq) + 2e^-$
Tin	$Sn(s)$	$\longrightarrow$	$Sn^{2+}(aq) + 2e^-$
Lead	$Pb(s)$	$\longrightarrow$	$Pb^{2+}(aq) + 2e^-$
Hydrogen	$H_2(g)$	$\longrightarrow$	$2H^+(aq) + 2e^-$
Copper	$Cu(s)$	$\longrightarrow$	$Cu^{2+}(aq) + 2e^-$
Silver	$Ag(s)$	$\longrightarrow$	$Ag^+(aq) + e^-$
Mercury	$Hg(l)$	$\longrightarrow$	$Hg^{2+}(aq) + 2e^-$
Platinum	$Pt(s)$	$\longrightarrow$	$Pt^{2+}(aq) + 2e^-$
Gold	$Au(s)$	$\longrightarrow$	$Au^{3+}(aq) + 3e^-$

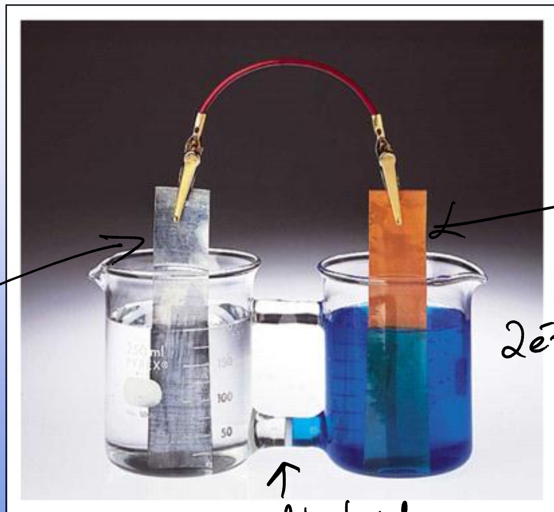
Ease of oxidation inc

Electrons moved from Cu to Ag^+

To make a battery or a fuel cell, you need the electrons to flow "externally".



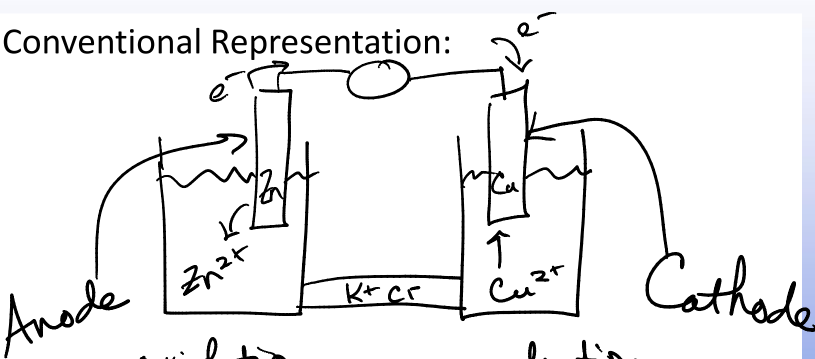
Separate
oxid'n
&
red'n



$Zn \Rightarrow Zn^{2+} + 2e^-$ salt bridge
Semi permeable membrane

Take a look at an electrochemical cell demo

Conventional Representation:



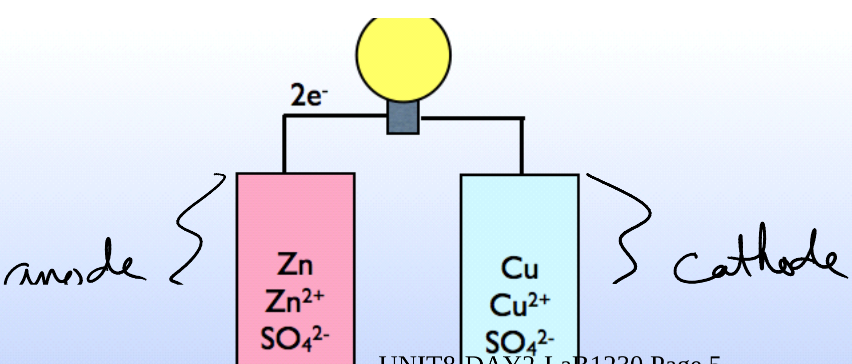
oxidation

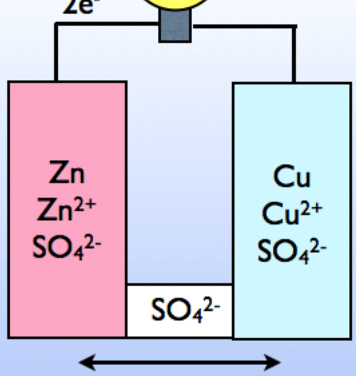
reduction

$Zn \rightarrow Zn^{2+} + 2e^-$

$Cu^{2+} + 2e^- \rightarrow Cu$

Anode compartment





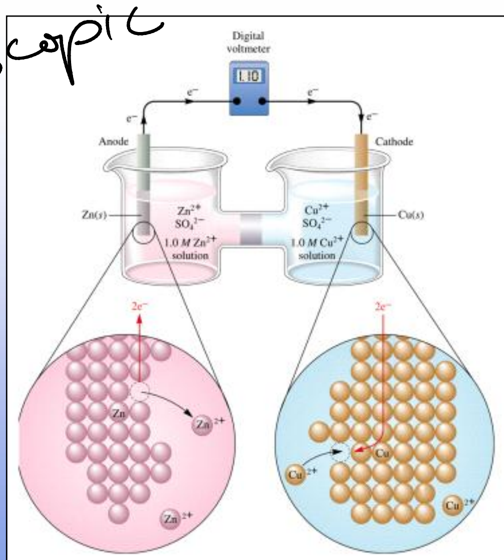
anode compartment

cathode compartment

Add a connection that let's a "counter" ion move between the two sides

As the reaction proceeds Zn is oxidized into Zn^{2+}
Cu^{2+} is reduced into Cu
note I have two solid pieces of metal (electrodes) connected to the wire

microscopic view



chemistry occurs at surface

electrode is the solid surface

Oxidation $Zn \rightarrow Zn^{2+} + 2e^-$ Reduction $Cu^{2+} + 2e^- \rightarrow Cu$

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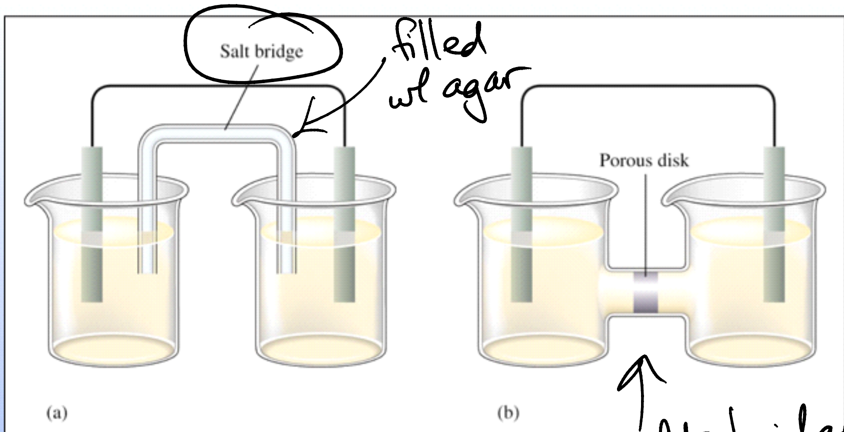


filled w/ agar

salt bridge

Salt Bridge or Porous Disk allow ions to flow back and forth between the two beakers

Salt bridge

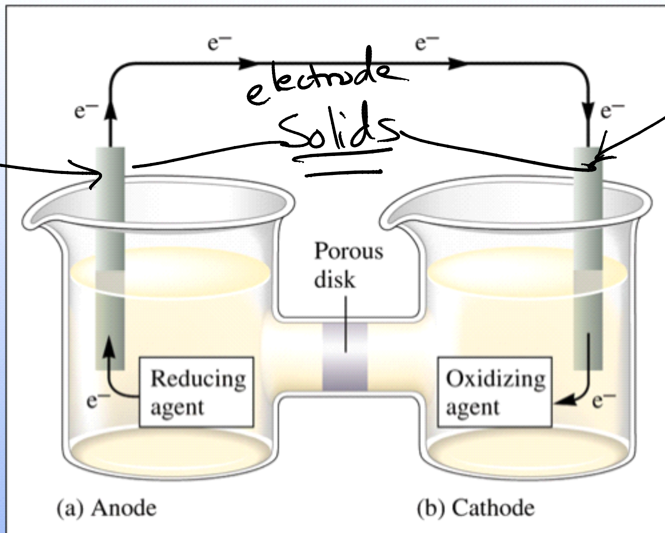
Salt Bridge or Porous Disk allow ions to flow back and forth between the two beakers.
As e^- move from one side to the other, counter anions move the opposite direction

Define by the chemistry we want to happen

the Anode

electrode
Solids

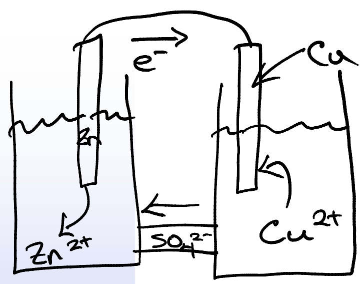
The cathode



Anode. Oxidation reaction

Cathode. Reduction Reaction

Poll: Clicker Question 3



Assuming sulfate is your counter ion, which way does it move in the salt bridge?

anode
oxidation
$Zn \rightarrow Zn^{2+}$

cathode
reduction
$Cu^{2+} \rightarrow Cu$

A. Moving into Cathode compartment
B. Moving into Anode compartment
C. Equal back and forth

anion goes toward anode

B. Moving into Anode compartment
C. Equal back and forth

anion goes toward anode

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Anode is Oxidation

An Ox

Reduction is Cathode

Red Cat

Dr VDB thinks this is an ox

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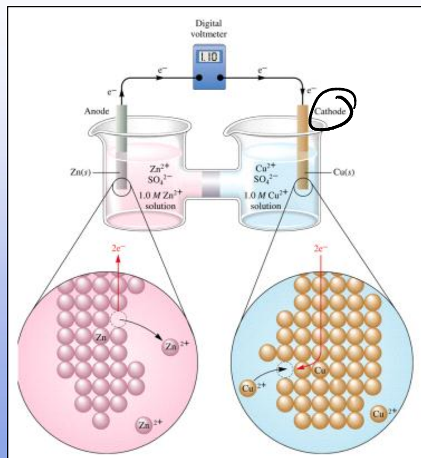
Poll: Clicker Question 4

In our demo cell - What is serving as the cathode?

A. The Cu strip
B. The Zn strip
C. neither



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Poll: Clicker Question 5

What is your major?

A. Engineering
B. Biology
C. Chemistry
D. Other

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While setting up next demo

Watch this video snippet……

http://www.learner.org/resources/series26.html?pop=yes&pid=76

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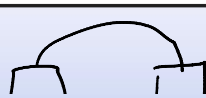
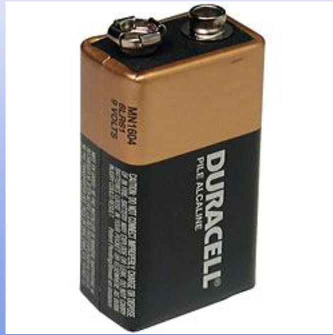
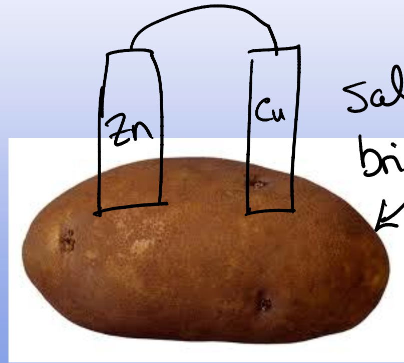
Macroscopic Look Conversion of Chemical Energy to Electrical Energy - Electrochemistry



Energy to Electrical Energy - Electrochemistry





Salt bridge?

Battery/Potato Clock/Electrochemical Cell

What do these things have in common?

Potato Clock

Competition

Biology vs Chemistry vs Engineering vs Others

1. get potato clock to work
2. explain why/how it works
   - where the energy comes from to power the clock?

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Potato Clock

EXPLANATION?

Oxidation ½ reaction

$$Zn \rightarrow Zn^{2+} + 2e^-$$

?

Reduction ½ reaction

$$\underset{(acid)}{2H^+} + 2e^- \rightarrow H_2(g)$$

2 potatoes vs. 1 potato?

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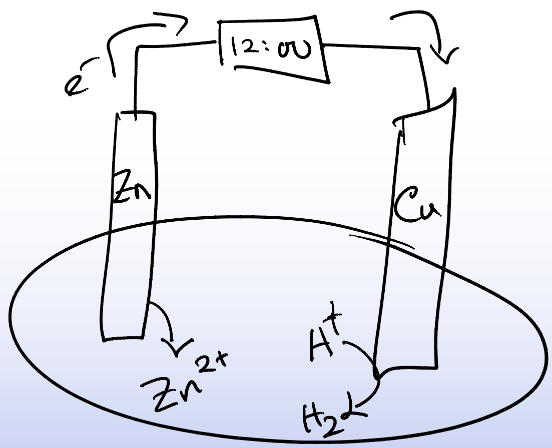
Use the chart to explain the Potato clock:

Movement of electrons and
What is acting as anode and
What is acting as a cathode.

Vit C
ascorbic
acid

Metal	Oxidation Reaction
Lithium	$Li(s) \longrightarrow Li^{+}(aq) + e^{-}$
Potassium	$K(s) \longrightarrow K^{+}(aq) + e^{-}$
Barium	$Ba(s) \longrightarrow Ba^{2+}(aq) + 2e^{-}$
Calcium	$Ca(s) \longrightarrow Ca^{2+}(aq) + 2e^{-}$
Sodium	$Na(s) \longrightarrow Na^{+}(aq) + e^{-}$
Magnesium	$Mg(s) \longrightarrow Mg^{2+}(aq) + 2e^{-}$
Aluminum	$Al(s) \longrightarrow Al^{3+}(aq) + 3e^{-}$
Manganese	$Mn(s) \longrightarrow Mn^{2+}(aq) + 2e^{-}$
Zinc	$Zn(s) \longrightarrow Zn^{2+}(aq) + 2e^{-}$
Chromium	$Cr(s) \longrightarrow Cr^{3+}(aq) + 3e^{-}$
Iron	$Fe(s) \longrightarrow Fe^{2+}(aq) + 2e^{-}$
Cobalt	$Co(s) \longrightarrow Co^{2+}(aq) + 2e^{-}$
Nickel	$Ni(s) \longrightarrow Ni^{2+}(aq) + 2e^{-}$
Tin	$Sn(s) \longrightarrow Sn^{2+}(aq) + 2e^{-}$
Lead	$Pb(s) \longrightarrow Pb^{2+}(aq) + 2e^{-}$
Hydrogen	$H_2(g) \longrightarrow 2H^{+}(aq) + 2e^{-}$
Copper	$Cu(s) \longrightarrow Cu^{2+}(aq) + 2e^{-}$
Silver	$Ag(s) \longrightarrow Ag^{+}(aq) + e^{-}$
Mercury	$Hg(l) \longrightarrow Hg^{2+}(aq) + 2e^{-}$
Platinum	$Pt(s) \longrightarrow Pt^{2+}(aq) + 2e^{-}$
Gold	$Au(s) \longrightarrow Au^{3+}(aq) + 3e^{-}$

Ease of oxidation increases



Variety of Electrochemical Cells
pair different oxidation/reduction reactions for different reasons

rather than draw a picture – short hand notation
convention: oxidation ½ reaction is always written on left

|| = "salt bridge" this divides the cell into to halves
| = show the different compounds of each 1/2 reaction

oxidation reduction

anode <Zn|Zn^{2+}||Cu^{2+}|Cu> cathode

$Zn \rightarrow Zn^{2+}$ $Cu^{2+} \rightarrow Cu$

if we knew the concentrations of the ions
<Zn|Zn^{2+}(1 M) ||Cu^{2+}(10^{-3} M) |Cu>

ANOTHER EXAMPLE: Electrochemical Cell in which:
Ag goes to Ag+
Fe^{3+} goes to Fe^{2+}

$Ag \rightarrow Ag^{+}$ $Fe^{3+}(aq) \rightarrow Fe^{2+}(aq)$

< Ag | Ag^{+} || Fe^{3+} | Fe^{2+} >

but we would like this to represent the actual cell
I cannot hook a wire up to Fe^{2+}. I need an electrode in the solution. Let's say I use a Pt electrode

anode < Ag | Ag^{+} || Fe^{3+} | Fe^{2+} | Pt > cathode

Shorthand is NOT balanced

ANOTHER EXAMPLE: Potato Clock Cell?

< Zn | Zn^{2+} || H^{+} | H_2 | Cu >

What goes in the blanks?

ANOTHER EXAMPLE: Potato Clock Cell?

balanced

$$< Zn \mid Zn^{2+} \parallel H^+ \mid H_2 \mid Cu >$$

anode (metal) — oxidation — reduction — cathode (metal)

What goes in the blanks?

A) Zn, Zn^{2+}, Cu^{2+}, Cu, extra needs to be deleted
B) Zn^{2+}, Zn, Cu, Cu^{2+}, extra needs to be deleted
C) Zn, Zn^{2+}, H^+, H_2, Cu
D) Zn, Zn^{2+}, Cu^{2+}, Cu, H^+, H_2
E) Zn, Zn^{2+}, H_2, H^+, Cu

$<Zn|Zn^{2+}||Cu^{2+}|Cu>$

ONE CELL

~1.1 V

$[Zn^{2+}] \uparrow$

$[Cu^{2+}] \downarrow$

TWO CELLS

~1.6 V now

~2.2 @ 9:45 am

Batteries die

Assume 1M

$$E^\circ = E^\circ_{Red} - E^\circ_{Ox}$$

$$E^\circ = 0.34 - (-0.76) = \sim 1.1\,V$$

Standard Reduction Potentials

Reduces easist

Half-reaction	$\mathscr{E}^\circ$ (V)	Half-reaction	$\mathscr{E}^\circ$ (V)
$F_2 + 2e^- \rightarrow 2F^-$	2.87	$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$	0.40
$Ag^{2+} + e^- \rightarrow Ag^+$	1.99	$Cu^{2+} + 2e^- \rightarrow Cu$	0.34
$Co^{3+} + e^- \rightarrow Co^{2+}$	1.82	$Hg_2Cl_2 + 2e^- \rightarrow 2Hg + 2Cl^-$	0.27
$H_2O_2 + 2H^+ + 2e^- \rightarrow 2H_2O$	1.78	$AgCl + e^- \rightarrow Ag + Cl^-$	0.22
$Ce^{4+} + e^- \rightarrow Ce^{3+}$	1.70	$SO_4^{2-} + 4H^+ + 2e^- \rightarrow H_2SO_3 + H_2O$	0.20
$PbO_2 + 4H^+ + SO_4^{2-} + 2e^- \rightarrow PbSO_4 + 2H_2O$	1.69	$Cu^{2+} + e^- \rightarrow Cu^+$	0.16
$MnO_4^- + 4H^+ + 3e^- \rightarrow MnO_2 + 2H_2O$	1.68	$2H^+ + 2e^- \rightarrow H_2$	0.00
$IO_4^- + 2H^+ + 2e^- \rightarrow IO_3^- + H_2O$	1.60	$Fe^{3+} + 3e^- \rightarrow Fe$	−0.036
$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$	1.51	$Pb^{2+} + 2e^- \rightarrow Pb$	−0.13
$Au^{3+} + 3e^- \rightarrow Au$	1.50	$Sn^{2+} + 2e^- \rightarrow Sn$	−0.14
$PbO_2 + 4H^+ + 2e^- \rightarrow Pb^{2+} + 2H_2O$	1.46	$Ni^{2+} + 2e^- \rightarrow Ni$	−0.23
$Cl_2 + 2e^- \rightarrow 2Cl^-$	1.36	$PbSO_4 + 2e^- \rightarrow Pb + SO_4^{2-}$	−0.35
$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$	1.33	$Cd^{2+} + 2e^- \rightarrow Cd$	−0.40
$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$	1.23	$Fe^{2+} + 2e^- \rightarrow Fe$	−0.44
$MnO_2 + 4H^+ + 2e^- \rightarrow Mn^{2+} + 2H_2O$	1.21	$Cr^{3+} + e^- \rightarrow Cr^{2+}$	−0.50
$IO_3^- + 6H^+ + 5e^- \rightarrow \frac{1}{2}I_2 + 3H_2O$	1.20	$Cr^{3+} + 3e^- \rightarrow Cr$	−0.73
$Br_2 + 2e^- \rightarrow 2Br^-$	1.09	$Zn^{2+} + 2e^- \rightarrow Zn$	−0.76
$VO_2^+ + 2H^+ + e^- \rightarrow VO^{2+} + H_2O$	1.00	$2H_2O + 2e^- \rightarrow H_2 + 2OH^-$	−0.83
$AuCl_4^- + 3e^- \rightarrow Au + 4Cl^-$	0.99	$Mn^{2+} + 2e^- \rightarrow Mn$	−1.18
$NO_3^- + 4H^+ + 3e^- \rightarrow NO + 2H_2O$	0.96	$Al^{3+} + 3e^- \rightarrow Al$	−1.66
$ClO_2 + e^- \rightarrow ClO_2^-$	0.954	$H_2 + 2e^- \rightarrow 2H^-$	−2.23
$2Hg^{2+} + 2e^- \rightarrow Hg_2^{2+}$	0.91	$Mg^{2+} + 2e^- \rightarrow Mg$	−2.37
$Ag^+ + e^- \rightarrow Ag$	0.80	$La^{3+} + 3e^- \rightarrow La$	−2.37
$Hg_2^{2+} + 2e^- \rightarrow 2Hg$	0.80	$Na^+ + e^- \rightarrow Na$	−2.71
$Fe^{3+} + e^- \rightarrow Fe^{2+}$	0.77	$Ca^{2+} + 2e^- \rightarrow Ca$	−2.76
$O_2 + 2H^+ + 2e^- \rightarrow H_2O_2$	0.68	$Ba^{2+} + 2e^- \rightarrow Ba$	−2.90
$MnO_4^- + e^- \rightarrow MnO_4^{2-}$	[illegible]	[illegible]	−2.92

Standard

$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$	1.23	$Fe^{2+} + 2e^- \rightarrow Fe$	−0.44
$MnO_2 + 4H^+ + 2e^- \rightarrow Mn^{2+} + 2H_2O$	1.21	$Cr^{3+} + e^- \rightarrow Cr^{2+}$	−0.50
$IO_3^- + 6H^+ + 5e^- \rightarrow \frac{1}{2}I_2 + 3H_2O$	1.20	$Cr^{3+} + 3e^- \rightarrow Cr$	−0.73
$Br_2 + 2e^- \rightarrow 2Br^-$	1.09	$Zn^{2+} + 2e^- \rightarrow Zn$	−0.76
$VO_2^+ + 2H^+ + e^- \rightarrow VO^{2+} + H_2O$	1.00	$2H_2O + 2e^- \rightarrow H_2 + 2OH^-$	−0.83
$AuCl_4^- + 3e^- \rightarrow Au + 4Cl^-$	0.99	$Mn^{2+} + 2e^- \rightarrow Mn$	−1.18
$NO_3^- + 4H^+ + 3e^- \rightarrow NO + 2H_2O$	0.96	$Al^{3+} + 3e^- \rightarrow Al$	−1.66
$ClO_2 + e^- \rightarrow ClO_2^-$	0.954	$H_2 + 2e^- \rightarrow 2H^-$	−2.23
$2Hg^{2+} + 2e^- \rightarrow Hg_2^{2+}$	0.91	$Mg^{2+} + 2e^- \rightarrow Mg$	−2.37
$Ag^+ + e^- \rightarrow Ag$	0.80	$La^{3+} + 3e^- \rightarrow La$	−2.37
$Hg_2^{2+} + 2e^- \rightarrow 2Hg$	0.80	$Na^+ + e^- \rightarrow Na$	−2.71
$Fe^{3+} + e^- \rightarrow Fe^{2+}$	0.77	$Ca^{2+} + 2e^- \rightarrow Ca$	−2.76
$O_2 + 2H^+ + 2e^- \rightarrow H_2O_2$	0.68	$Ba^{2+} + 2e^- \rightarrow Ba$	−2.90
$MnO_4^- + e^- \rightarrow MnO_4^{2-}$	0.56	$K^+ + e^- \rightarrow K$	−2.92
$I_2 + 2e^- \rightarrow 2I^-$	0.54	$Li^+ + e^- \rightarrow Li$	−3.05
$Cu^+ + e^- \rightarrow Cu$	0.52		

(reduces worst) oxidized easiest

Electromotive force : emf's : voltage:

What's pushing what's pulling ?

measure with voltage

"Activity Series" – easier or harder to oxidize?

"Reduction Potential" – easier or harder to reduce?

Standardized – Reduction Potentials

Difference b/w potentials is the EMF

Can Calculate!!!

Write a cell reaction for a cell diagram

1. Write the equation for the electrode on the right of the cell as a reduction ½-reaction.
2. Write the equation for the electrode on the left of the cell diagram as an oxidation ½-reaction.
3. Multiply one or both equations by a factor if necessary to balance the electron transfer then add the two ½-reactions together.

Write the chemical equation for the reaction corresponding to the cell:

Pt(s)|

$H_2(g)|H^+(aq)||Co^{3+}(aq),Co^{2+}(aq)|Pt(s)$

Then, referring to table, calculate the standard cell potential, E.

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Learning Outcomes

Recognize degrees of reactivity based on an activity series table or a standard reduction potential table.

Apply standard reduction potential data to determine the relative strength of oxidizing/reducing agents.

Construct an electrochemical cell diagram, including identifying the anode, cathode, direction of electron flow, sign of the electrodes, direction of ion flow in salt bridge, from a redox reaction or from short hand cell notation.