# **Ox**idation **Red**uction Reactions

# (red-ox rxns)

## objectives:

(#4-3) How do chemicals undergo an oxidation reduction reaction?

(#4-3a) I can identify if a reaction is oxidation/reduction

(#4- 3b) I can identify which species in a reaction is being oxidized or reduced.

(#4- 3c) I can balance a "simple" redox reaction. Simple: Non- oxygen based.

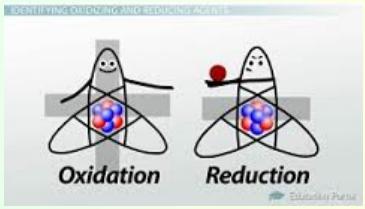
(#4-3d) I can determine the voltage of a redox reaction.

(#4-3e) I can determine the spontaneity based upon a chemical voltage.

also

I can write half reactions and model the reaction.

# Oxidation Reduction Reactions




(a.k.a. RedOx rxns)

Atoms/ions gain and lose charge in reaction

- $e^-$ are transfered from one species to another
- must occur simultaneously

First, must determine the oxidation state(charges)

**oxidation state**: the apparent charge on an atom

**Oxidation State Rules**

- 0 is alway $0^{-2}$ when bonded to other atom (except F)
- H is always $H^{+1}$ when bonded to other atom (usually)
- elements by self have 0 charge if → not bonded / diatomic (super 7)
- use ion sheet or periodic table

## Practice: write oxidation state

HF (+1 −1) Cu (0) Fe (0) $O_2$ (0) $FeCl_2$ (+2 −1)

Al (0) $AgNO_3$ (+1 −1) $NO_2$ ($+4 + 2(-2) = 0$) $Cl_2$ (0)

Ag +1, N +5, O −2, $NO_3^{-1}$ ($+5 + 3(-2) = -1$)

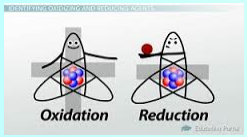
N +4, O −2

try these:

$SO_4^{-2}$ $NaHCO_3$

Nov 22-6:11 AM

# **Ox**idation **Red**uction Reactions




(**redox** rxns)

Atoms/ions gain and lose charge in reaction

**L**ose **E**lectrons **O**xidation

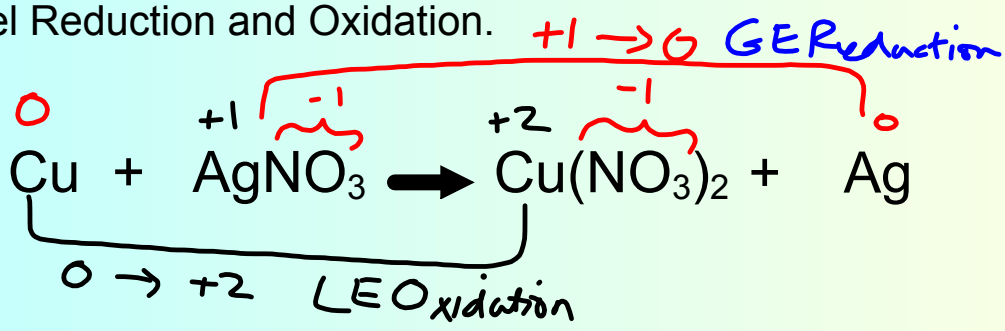
**G**ain **E**lectrons **R**eduction

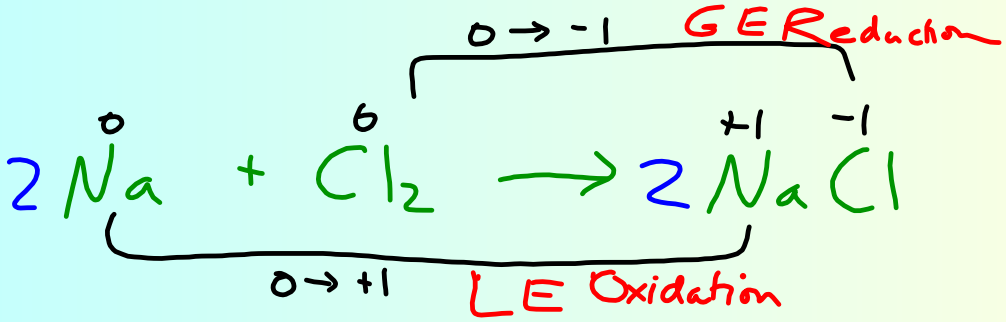

to help you remember

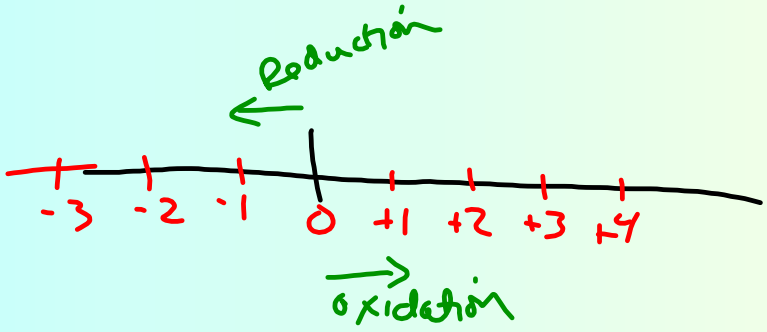
OIL RIG

Check for REDOX: write charges (oxidation state) above each to see what happens to the charge.

Label Reduction and Oxidation.



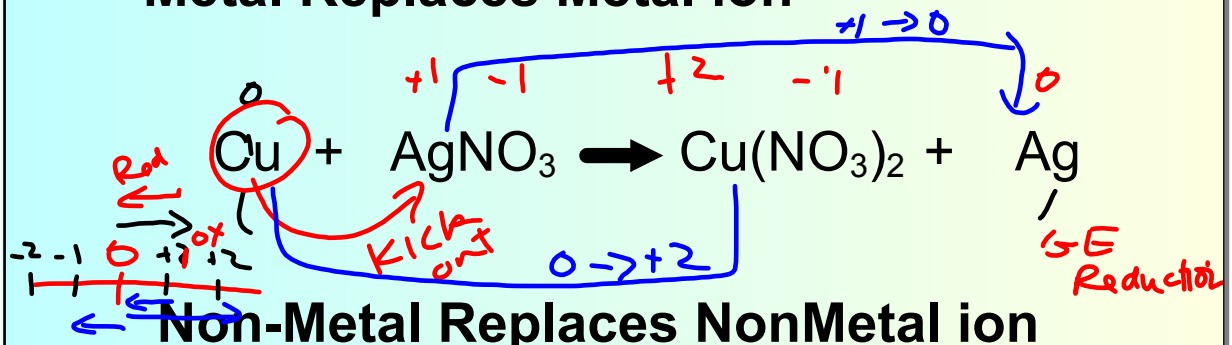



# **Ox**idation **Red**uction Reactions

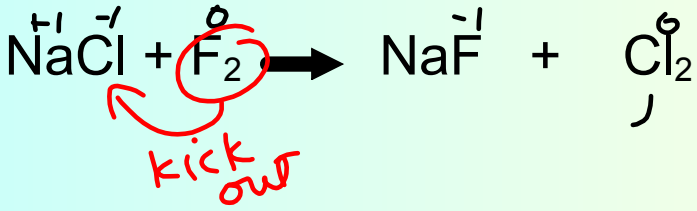
(**redox** rxns)

## Types: Determine oxidation and reduction

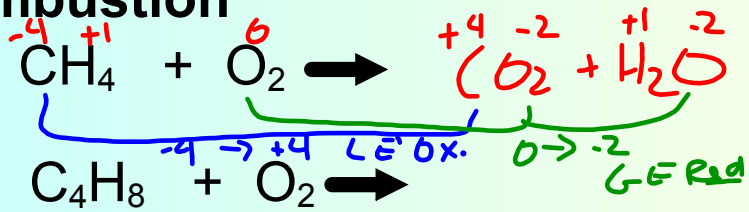
### Metal Replaces Metal ion



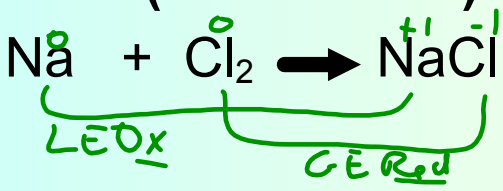

### Non-Metal Replaces NonMetal ion



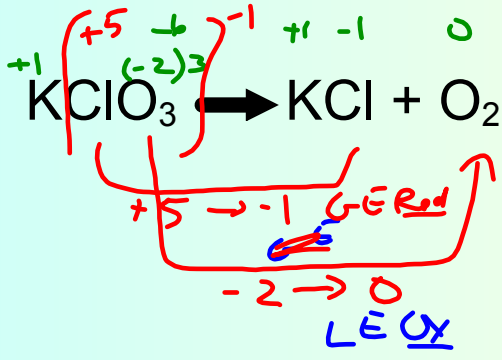

### Combustion




### Synthesis (often redox)




### Decompostion (often redox)

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# 3 equations to depict reaction:

molecular, ionic and net ionic

**molecular:** $Cu + 2AgNO_3 \longrightarrow Cu(NO_3)_2 + 2Ag$

**ionic:** $Cu^0 + 2Ag^{+1} + 2NO_3^{-1} \longrightarrow Cu^{+2} + 2NO_3^{-1} + 2Ag^0$

(show any ions dissociated)

spectator ion: ion that does not change on either side and is not part of the reaction

(remove spectator ions -- cross off $NO_3^{-1}$ -- same on both sides)

**net ionic:** $Cu^0 + 2Ag^{+1} \longrightarrow Cu^{+2} + 2Ag^0$

actual chemical reaction

## balancing 1/2 reactions

separate the species, add $e^-$ to balance

lose $e^-$ -- Ox. $Cu^0 \longrightarrow Cu^{+2} + 2e^-$

gain $e^-$ --Red. $2e^- + 2Ag^{+1} \longrightarrow 2Ag^0$

net ionic: $Cu^0 + 2Ag^{+1} \longrightarrow Cu^{+2} + 2Ag^0$

# 3 equations to depict reaction:

molecular, ionic and net ionic

$(AgNO_3 \rightarrow Ag^{+1} + NO_3^{-1})$

**molecular:** $Cu_{(s)} + 2AgNO_{3(aq)} \longrightarrow Cu(NO_3)_{2(aq)} + 2Ag_{(s)}$

**ionic:** $Cu^0 + 2Ag^{+1} + 2NO_3^{-1} \longrightarrow Cu^{+2} + 2NO_3^{-1} + 2Ag^0$

(show any ions dissociated)

spectator ion: ion that does not change on either side and is not part of the reaction

(remove spectator ions -- cross off $NO_3^{-1}$ -- same on both sides)

**net ionic:** $Cu^0 + 2Ag^{+1} \longrightarrow Cu^{+2} + 2Ag^0$

actual chemical reaction

LEO $0 \rightarrow +2$

GER $+1 \rightarrow 0$

## balancing 1/2 reactions

separate the species, add $e^-$ to balance

lose $e^-$ -- Ox. $Cu^0 \longrightarrow Cu^{+2} + 2e^-$

gain $e^-$ --Red. $2e^- + 2Ag^{+1} \longrightarrow 2Ag^0$ (+2)

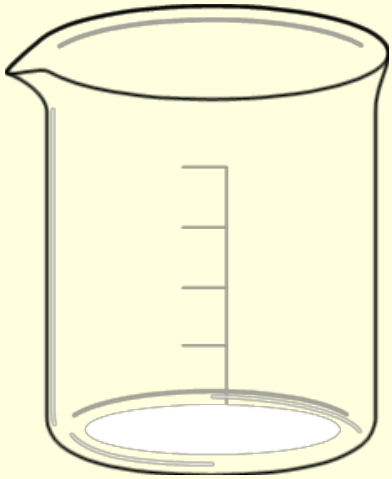
net ionic: $Cu^0 + 2Ag^{+1} \longrightarrow Cu^{+2} + 2Ag^0$

Write the molecular, ionic, and net ionic equation

Write the half reactions.

Determine the voltage and

if the reaction is spontaneous.



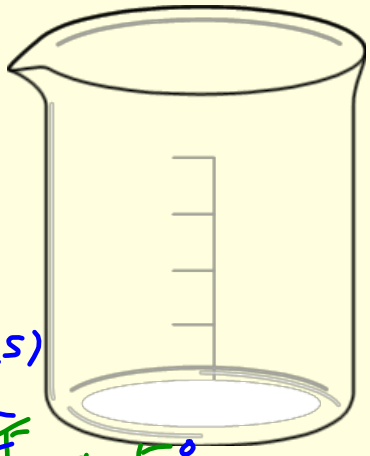
$$Na + FeCl_2 \longrightarrow$$

Write the molecular, ionic, and net ionic equation

Write the half reactions.

Determine the voltage and

if the reaction is spontaneous.



mol $2Na_{(s)} + FeCl_{2(aq)} \rightarrow 2NaCl_{(aq)} + Fe_{(s)}$

ionic eq: $2Na^{0}_{(s)} + Fe^{+2} + 2Cl^{-} \rightarrow 2Na^{+} + 2Cl^{-} + Fe^{0}_{(s)}$

net eq: $2Na^{0}_{(s)} + Fe^{+2} \rightarrow 2Na^{+} + Fe^{0}_{(s)}$

$0 \rightarrow +1$ LEOx

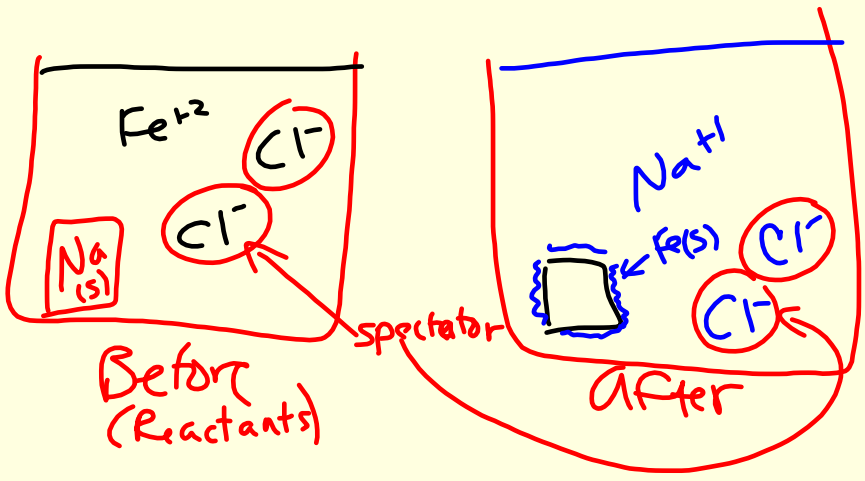
$+2 \rightarrow 0$ GERed

½ rxns $2Na^{0} \rightarrow 2Na^{+} + 2e^{-}$ Oxidation

$2e^{-} + Fe^{+2} \rightarrow Fe^{0}$

Net $2Na^{0} + Fe^{+2} \rightarrow 2Na^{+} + Fe^{0}$

$FeCl_2 \rightarrow Fe^{+2} + 2Cl^{-1}$



# Does this reaction happen?

look at potential to lose or gain e⁻

$Cu^0 \rightarrow Cu^{+2} + 2e^-$

$2e^- + 2Ag^{+1} \rightarrow 2Ag^0$

$Cu^0 + 2Ag^{+1} \rightarrow Cu^{+2} + 2Ag^0$

**reduction potential chart:** ability to gain e⁻ in E⁰(Volts)

GER

(based off $H_2$ at 0 V)

**Standard Reduction Potentials**
in Aqueous Solution at 25°C

| Half-reaction | | | $E°$(V) |
|---|---|---|---|
| $F_2(g) + 2e^-$ | → | $2F^-$ | 2.87 |
| $Co^{3+} + e^-$ | → | $Co^{2+}$ | 1.82 |
| $Au^{3+} + 3e^-$ | → | $Au(s)$ | 1.50 |
| $Cl_2(g) + 2e^-$ | → | $2Cl^-$ | 1.36 |
| $O_2(g) + 4H^+ + 4e^-$ | → | $2H_2O(l)$ | 1.23 |
| $Br_2(l) + 2e^-$ | → | $2Br^-$ | 1.07 |
| $2Hg^{2+} + 2e^-$ | → | $Hg_2^{2+}$ | 0.92 |
| $Hg^{2+} + 2e^-$ | → | $Hg(l)$ | 0.85 |
| $Ag^+ + e^-$ | → | $Ag(s)$ | 0.80 |
| $Hg_2^{2+} + 2e^-$ | → | $2Hg(l)$ | 0.79 |
| $Fe^{3+} + e^-$ | → | $Fe^{2+}$ | 0.77 |
| $I_2(s) + 2e^-$ | → | $2I^-$ | 0.53 |
| $Cu^+ + e^-$ | → | $Cu(s)$ | 0.52 |
| $Cu^{2+} + 2e^-$ | → | $Cu(s)$ | 0.34 |
| $Cu^{2+} + e^-$ | → | $Cu^+$ | 0.15 |
| $Sn^{4+} + 2e^-$ | → | $Sn^{2+}$ | 0.15 |
| $S(s) + 2H^+ + 2e^-$ | → | $H_2S(g)$ | 0.14 |
| $2H^+ + 2e^-$ | → | $H_2(g)$ | 0.00 |
| $Pb^{2+} + 2e^-$ | → | $Pb(s)$ | −0.13 |
| $Sn^{2+} + 2e^-$ | → | $Sn(s)$ | −0.14 |
| $Ni^{2+} + 2e^-$ | → | $Ni(s)$ | −0.25 |
| $Co^{2+} + 2e^-$ | → | $Co(s)$ | −0.28 |
| $Cd^{2+} + 2e^-$ | → | $Cd(s)$ | −0.40 |
| $Cr^{3+} + e^-$ | → | $Cr^{2+}$ | −0.41 |
| $Fe^{2+} + 2e^-$ | → | $Fe(s)$ | −0.44 |
| $Cr^{3+} + 3e^-$ | → | $Cr(s)$ | −0.74 |
| | | $Zn(s)$ | −0.76 |
| | | $H_2(g) + 2OH^-$ | −0.83 |
| | | $Mn(s)$ | −1.18 |
| | | $Al(s)$ | −1.66 |
| | | $Be(s)$ | −1.70 |
| | | $Mg(s)$ | −2.37 |
| | | $Na(s)$ | −2.71 |
| | | $Ca(s)$ | −2.87 |
| | | $Sr(s)$ | −2.89 |
| | | $Ba(s)$ | −2.90 |
| | | $Rb(s)$ | −2.92 |
| | | $K(s)$ | −2.92 |
| | | $Cs(s)$ | −2.92 |
| | | $Li(s)$ | −3.05 |

compare rxn to find $E^0$

do not matter

$2e^- + 2Ag^{+1} \rightarrow 2Ag^0$ **+0.80 V**

same rxn: use $E^0$
2x's $e^-$, but **do not** 2x's $E^0$

$Cu^0 \rightarrow Cu^{+2} + 2e^-$ **-0.34 V**

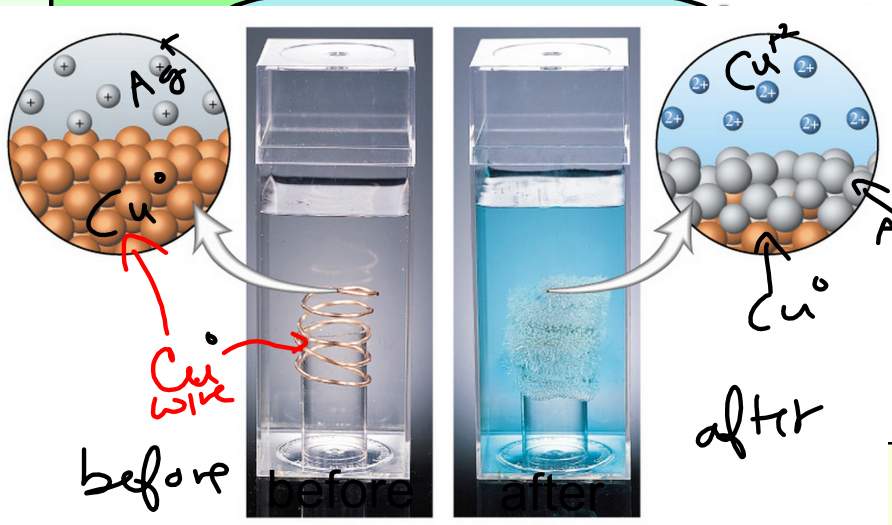
reverse rxn:
use $E^0$ with opposite sign

**+0.46 V**

spontaneous rxn

+ V = rxn will occur

if - V = rxn will not occur




Nov 22-6:48 AM

Determine if Red-Ox, write ionic and net ionic eq.

remember to balance these

**mol.** $NaF_{(aq)} + Cl_{2(g)} \longrightarrow NaCl_{(aq)} + F_2$

**ionic:** $Na^{+1} + F^{-1} + Cl_2^0 \longrightarrow Na^{+1} + Cl^{-1} + F_2^0$

**net ionic:** $F^{-1} + Cl_2^0 \longrightarrow Cl^{-1} + F_2^0$

GER

**half reactions** and $E^0$ (reduction potential)

$2F^{-1} \longrightarrow F_2 + 2e^-$ -2.87

$2e^- + Cl_2 \longrightarrow 2Cl^{-1}$ +1.36

---

$2F^{-1} + Cl_2 \longrightarrow 2Cl^{-1} + F_2$ -1.51 V

$E^0$ (-) is non-spontaneous

does not occur without electric current

# Predict products:

$Zn^{0} + Cu^{+2}(SO_4)^{-1}{}_2 \rightarrow ?$

**Zn** usually becomes $Zn^{+2}$

$Zn^0 \rightarrow Zn^{+2} + 2e^-$

**Cu** --either +1 or +2

$Cu^{+2} + 1e^- \rightarrow Cu^{+1}$

$Cu^{+2} + 2e^- \rightarrow Cu^0$

**$SO_4^{-1}$** spectator ion

general rule:
metals exchange with metals
non-metals exchange with non-metals

$Zn^0 + Cu^{+2} \rightarrow Zn^{+2} + Cu^0$

Does this happen?

Check reduction potential chart

$Cu^{+2} + 2e^- \rightarrow Cu^0$ +0.34 V

$Zn \rightarrow Zn^{+2} + 2e^-$ +0.76V

+1.00 V

V is (+) so spontaneous rxn

**Standard Reduction Potentials**
in Aqueous Solution at 25°C

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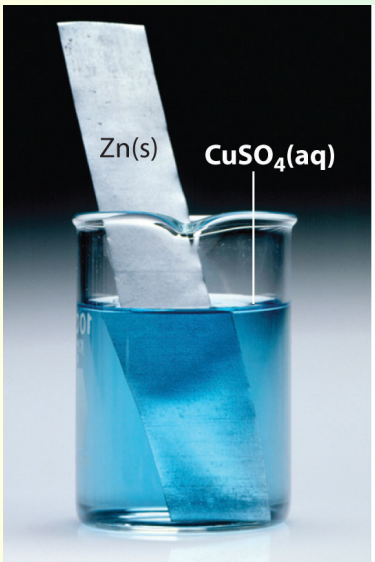
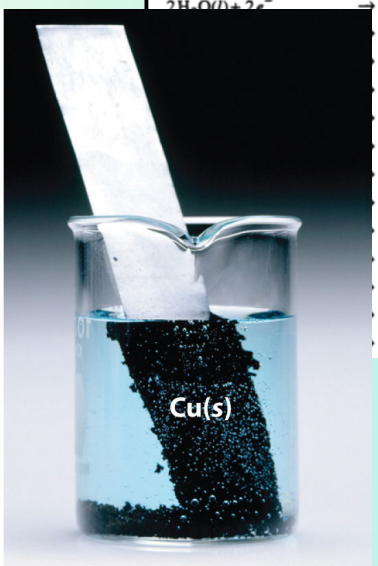



$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$

Nov 22-8:44 AM

$2KI + Br_2 \rightarrow 2KBr + I_2$

ionic $2K^{+1} + 2I^{-1} + Br_2^0 \rightarrow 2K^{+1} + 2Br^{-1} + I_2^0$

net $2I^{-1} + Br_2^0 \rightarrow 2Br^{-1} + I_2^0$

same rxn: use $E^0$
reverse rxn:
use $E^0$ with opposite sign

Red

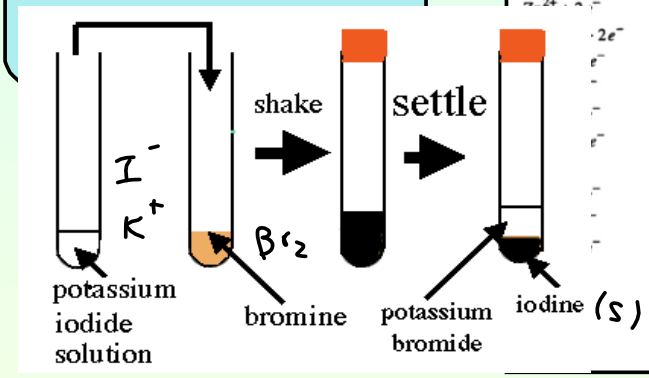
$2e^- + Br_2^0 \rightarrow 2Br^{-1}$ **+1.07**

ox

$2I^{-1} \rightarrow I_2^0 + 2e^-$ **-0.53**

$2I^{-1} + Br_2^0 \rightarrow 2Br^{-1} + I_2^0$ **+0.54 V**

+ V = rxn will occur spontaneous

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| $Hg^{2+} + 2e^-$ | → | $Hg(l)$ | 0.85 |
| $Ag^+ + e^-$ | → | $Ag(s)$ | 0.80 |
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| $Fe^{3+} + e^-$ | → | $Fe^{2+}$ | 0.77 |
| $I_2(s) + 2e^-$ | → | $2I^-$ | 0.53 |
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| $Cu^{2+} + e^-$ | → | $Cu^+$ | 0.15 |
| $Sn^{4+} + 2e^-$ | → | $Sn^{2+}$ | 0.15 |
| $S(s) + 2H^+ + 2e^-$ | → | $H_2S(g)$ | 0.14 |
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| $Cd^{2+} + 2e^-$ | → | $Cd(s)$ | −0.40 |
| $Cr^{3+} + e^-$ | → | $Cr^{2+}$ | −0.41 |
| $Fe^{2+} + 2e^-$ | → | $Fe(s)$ | −0.44 |
| $Cr^{3+} + 3e^-$ | → | $Cr(s)$ | −0.74 |
| $Zn^{2+} + 2e^-$ | → | $Zn(s)$ | −0.76 |
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| $Mn^{2+} + 2e^-$ | → | $Mn(s)$ | −1.18 |
| $Al^{3+} + 3e^-$ | → | $Al(s)$ | −1.66 |
| $Be^{2+} + 2e^-$ | → | $Be(s)$ | −1.70 |
| $Mg^{2+} + 2e^-$ | → | $Mg(s)$ | −2.37 |
| $Na^+ + e^-$ | → | $Na(s)$ | −2.71 |
| $Ca^{2+} + 2e^-$ | → | $Ca(s)$ | −2.87 |
| $Sr^{2+} + 2e^-$ | → | $Sr(s)$ | −2.89 |
| $Ba^{2+} + 2e^-$ | → | $Ba(s)$ | −2.90 |
| $Rb^+ + e^-$ | → | $Rb(s)$ | −2.92 |
| $K^+ + e^-$ | → | $K(s)$ | −2.92 |
| $Cs^+ + e^-$ | → | $Cs(s)$ | −2.92 |
| $Li^+ + e^-$ | → | $Li(s)$ | −3.05 |

Will the reverse (opposite) reaction occur?

$KBr + I_2 \rightarrow KI + Br_2$

$2Br^{-1} \rightarrow Br_2 + 2e^-$ −1.07

$2e^- + I_2 \rightarrow 2I^{-1}$ 0.53

- V so nonspontaneous − 0.54V

(reaction will not occur)

Nov 22-6:48 AM

p. 72 (2.)

$Pb_{(s)} + 2AgNO_{3(aq)} \rightarrow Pb(NO_3)_{2(aq)} + 2Ag_{(s)}$

(+1, −1; +2, −1; solution (dissolved); (aq); (s))

ionic: $Pb^0_{(s)} + 2Ag^{+1} + 2NO_3^{-1} \rightarrow Pb^{+2} + 2NO_3^{-1} + 2Ag^0_{(s)}$

net ionic: $Pb^0 + 2Ag^{+1} \rightarrow Pb^{+2} + 2Ag^0$

$Pb^0 \rightarrow Pb^{+2} + 2e^-$

$2e^- + 2Ag^{+2} \rightarrow 2Ag^0$ +0.93

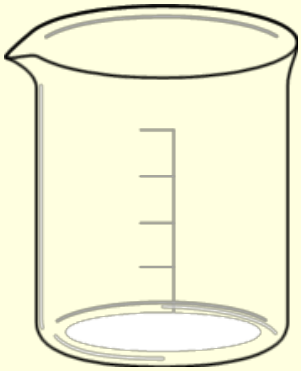
Write the molecular, ionic, and net ionic equation

Write the half reactions.

Determine the voltage and

if the reaction is spontaneous.

$Cu + AgNO_3$



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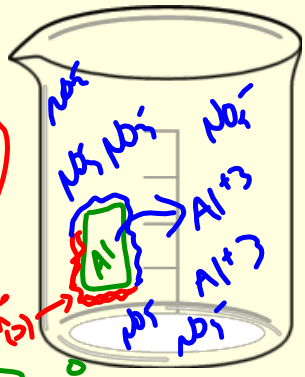
Write the molecular, ionic, and net ionic equation

Write the half reactions.

Determine the voltage and

if the reaction is spontaneous.



$3Zn(NO_3)_2 \rightarrow 3Zn^{+2} + 6NO_3^{-1}$

$+3 \quad -3 = 0$

$+2 \quad -1 \qquad +3 \quad (-1)3$

$2Al^0 + 3Zn(NO_3)_2 \rightarrow 2Al(NO_3)_3 + 3Zn^0$

ionic

$2Al^0 + 3Zn^{+2} + 6NO_3^{-1} \rightarrow 2Al^{+3} + 6NO_3^{-1} + 3Zn^0$

net $2Al^0 + 3Zn^{+2} \rightarrow 2Al^{+3} + 3Zn^0$

$+6$

½ rxns

$2Al^0 \rightarrow 2Al^{+3} + 6e^-$ LEOx $+1.66$

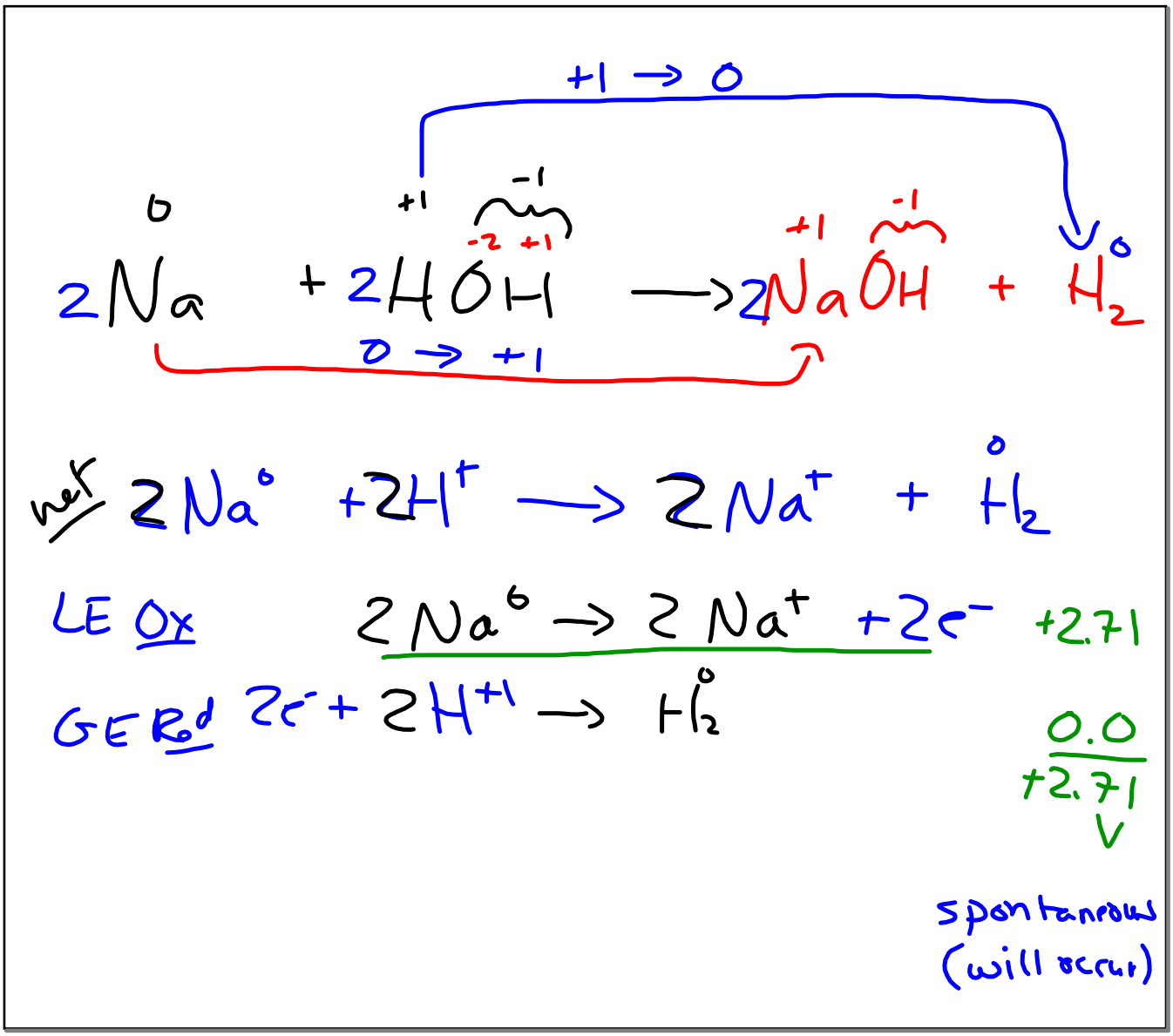
$6e^- + 3Zn^{+2} \rightarrow 3Zn^0$ (s) $-0.76$

net $2Al^0 + 3Zn^{+2} \rightarrow 2Al^{+3} + 3Zn^0$ $+0.9V$

pos. $\Rightarrow$ rxn will occur spontaneous

① $Zn^0 + Ni(NO_3)_2 \rightarrow Zn(NO_3)_2 + Ni^0$

$+2 \quad -1 \qquad 0$


+1 → 0
0
+1
-1
-2 +1
+1
-1
2Na + 2HOH → 2NaOH + H2
0 → +1
0
net 2Na° + 2H+ → 2Na+ + H2
LE Ox 2Na° → 2Na+ + 2e- +2.71
GE Red 2e- + 2H+1 → H2°
0.0
+2.71
V
spontaneous
(will occur)

Predict the products and balance

Write the net ionic equation.

Write the half reactions.

Determine the voltage and

if the reaction is spontaneous.

Draw it!

$3\,Ag + Au(NO_3)_3 \rightarrow Au + 3AgNO_3$

(ionic) (ionic)

net ionic $3Ag + Au^{+3} \rightarrow Au + 3Ag^{+1}$

Both reactions

$3Ag^{0} \rightarrow 3Ag^{+1} + 3e^{-}$ $-0.8\,V$

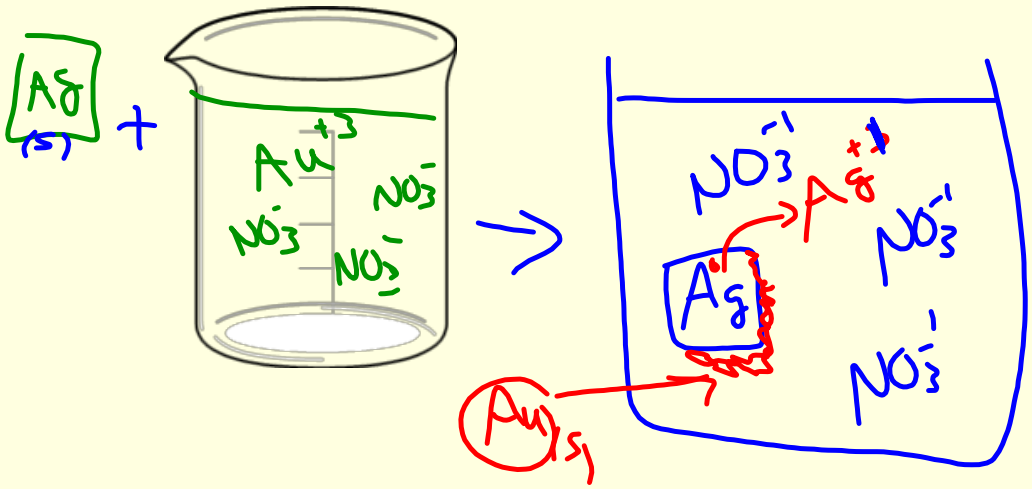
$3e^{-} + Au^{+3} \rightarrow Au^{0}$ $+1.50\,V$

$+0.70\,V$

spontaneous (will occur)

$Ag^{+} + e^{-} \rightarrow Ag$

$Au(NO_3)_3 \rightarrow Au^{+3} + 3NO_3^{-1}$



## Which will occur?

$2Al^0 + 3Na_2SO_4 \longrightarrow Al_2(SO_4)_3 + 6Na$

Net $2Al^0 + 6Na^{+1} \rightarrow 2Al^{+3} + 6Na^0$

$2Al^0 \rightarrow 2Al^{+3} + 6e^-$ $+1.66$

$6e^- + 6Na^{+1} \rightarrow 6Na^0$ $-2.71$

$-1.05V$

nonspont.

$Al_2(SO_4)_3 + 6\,Na \longrightarrow 2Al + 3\,Na_2SO_4$

$2Al^{+3} \rightarrow 2Al^0$

$6Na^0 \rightarrow 6Na^{+1} + 6e^-$ $Al_2(SO_4)_3 + Na$

molecular

$2Al^0 + 3Zn(NO_3)_2 \rightarrow 3Zn^0 + 2Al(NO_3)_3$

(aq) (aq)

ionic

$2Al^0 + 3Zn^{+2} + 6NO_3^{-1} \rightarrow 3Zn^0 + 2Al^{+3} + 6NO_3^{-1}$

net ionic

$2Al^0 + 3Zn^{+2} \rightarrow 3Zn^0 + 2Al^{+3}$

½ Rxns

Ox $2Al^0 \rightarrow 2Al^{+3} + 6e^-$ +1.66

Red $6e^- + 3Zn^{+2} \rightarrow 3Zn^0$ −0.76

$2Al^0 + 3Zn^{+2} \rightarrow 2Al^{+3} + 3Zn^0$

0.90V

$2Al^0 \rightarrow 2Al^{+3} + 6e^-$