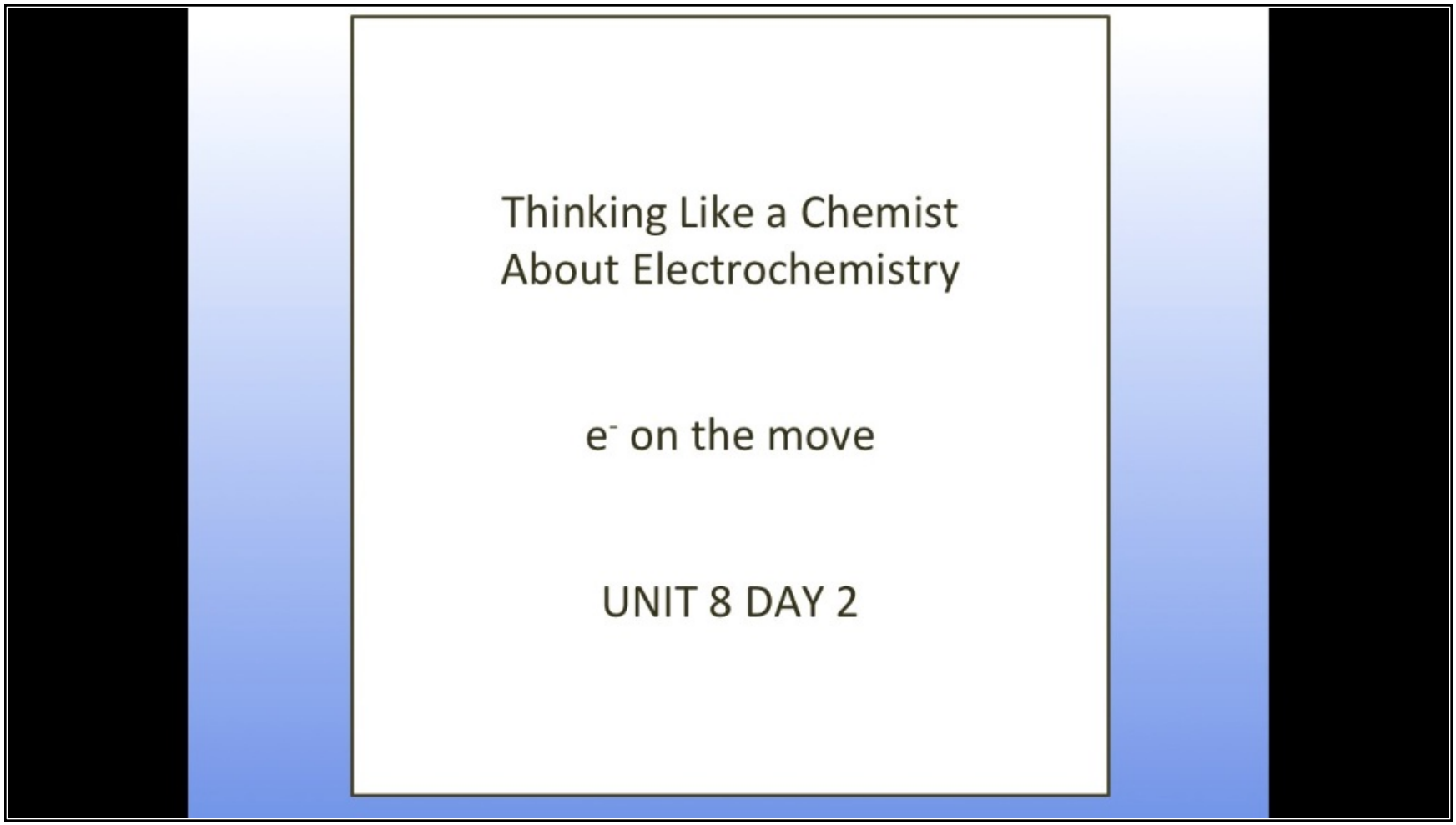
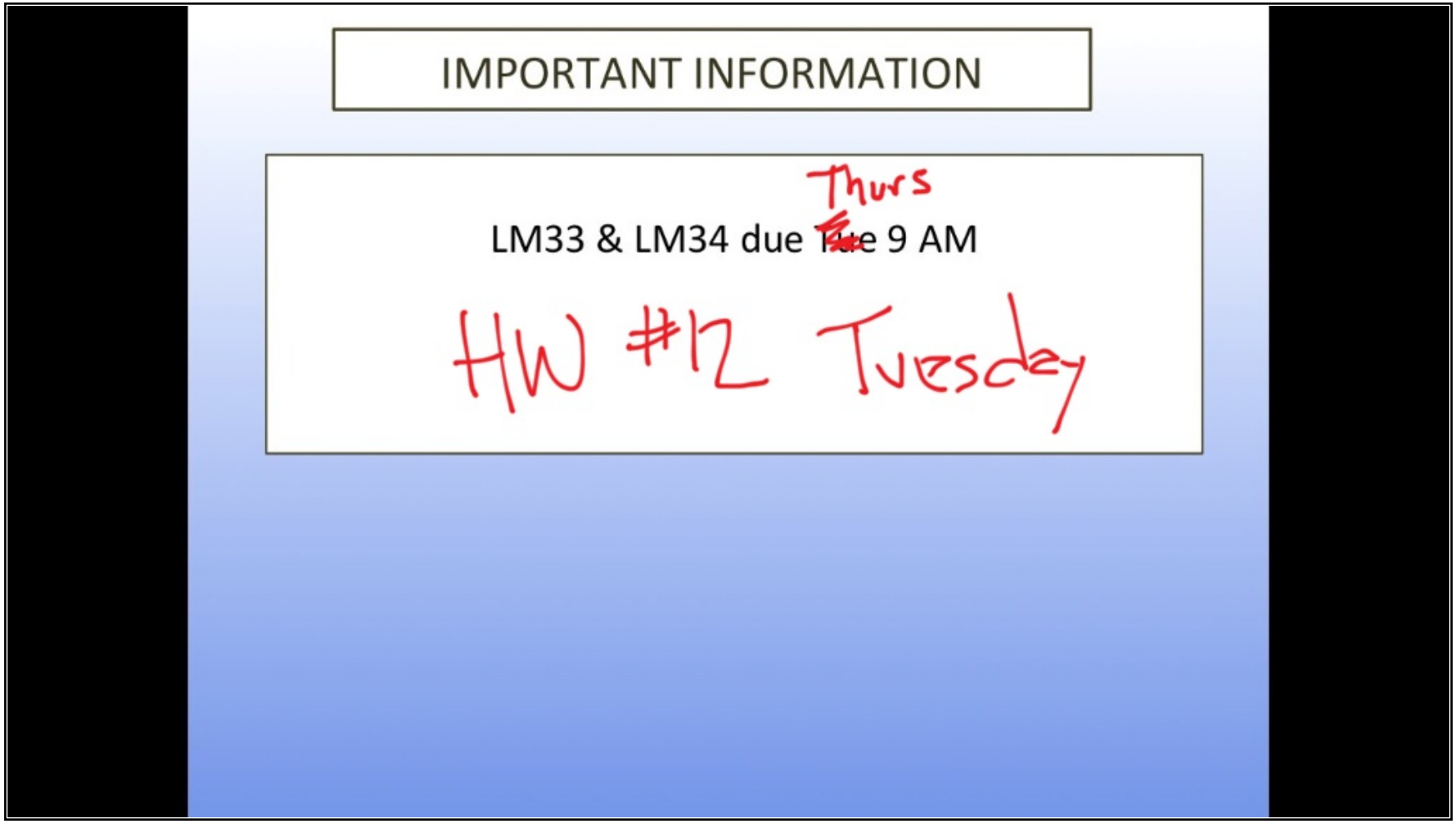
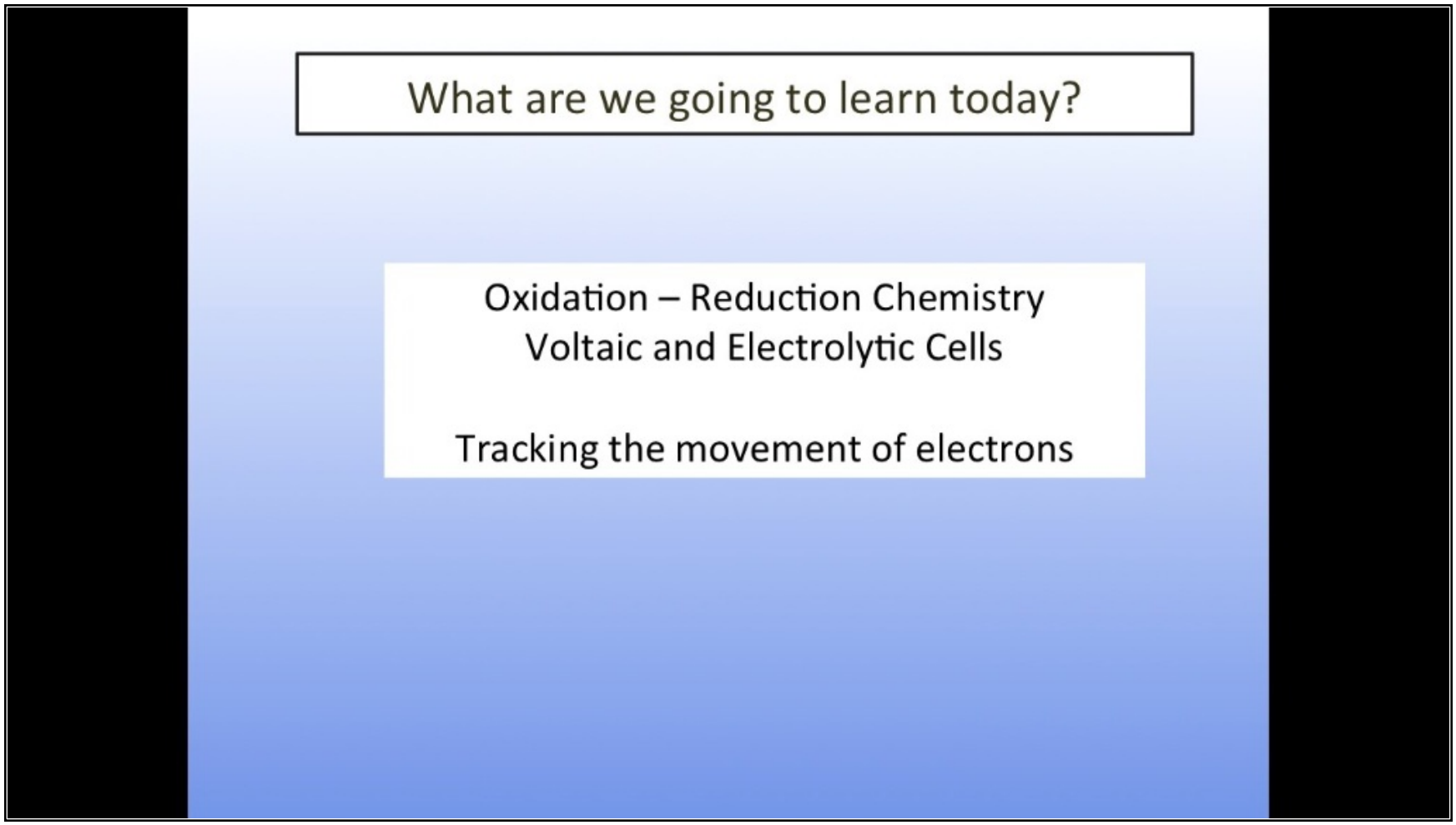
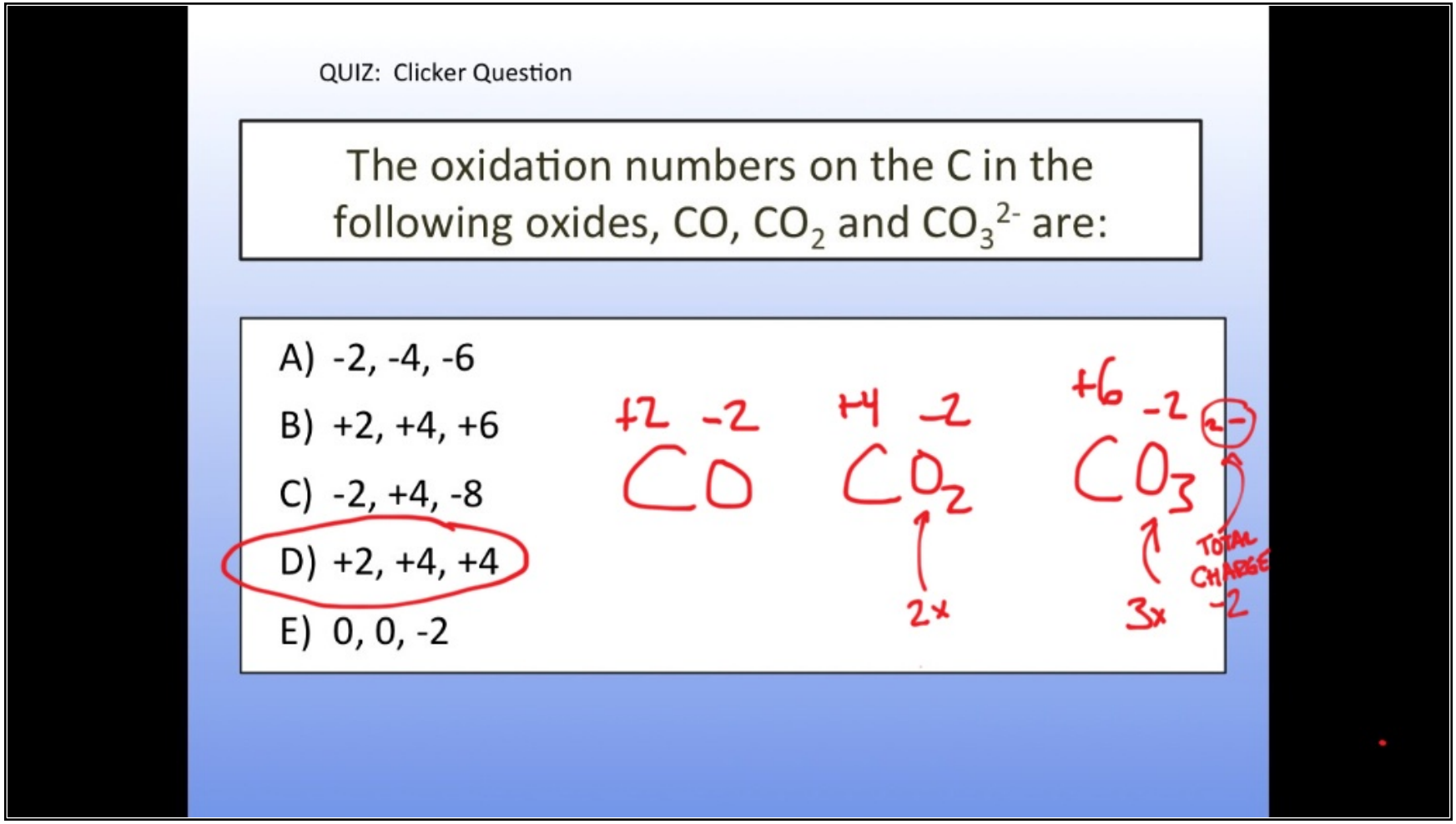
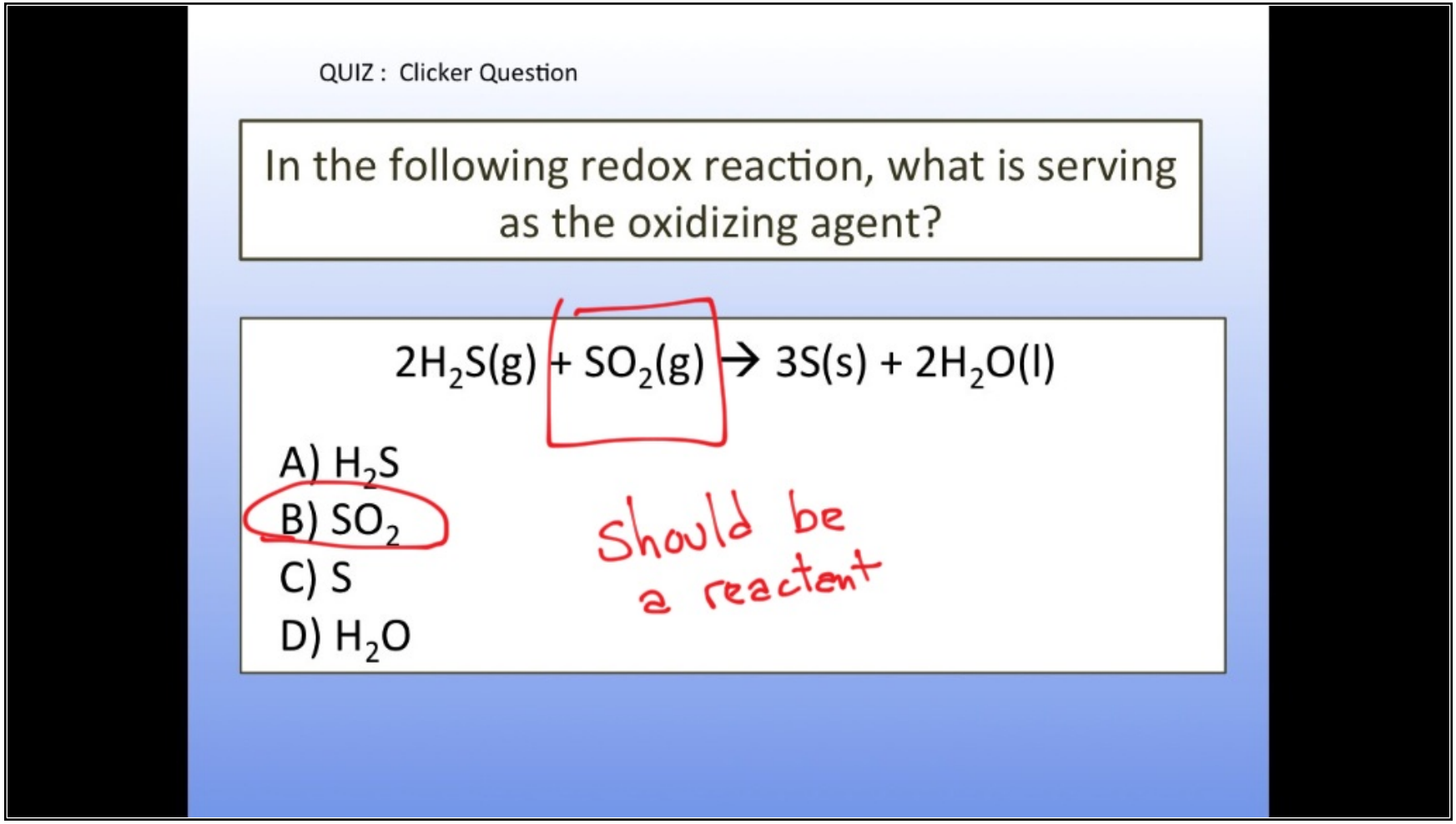
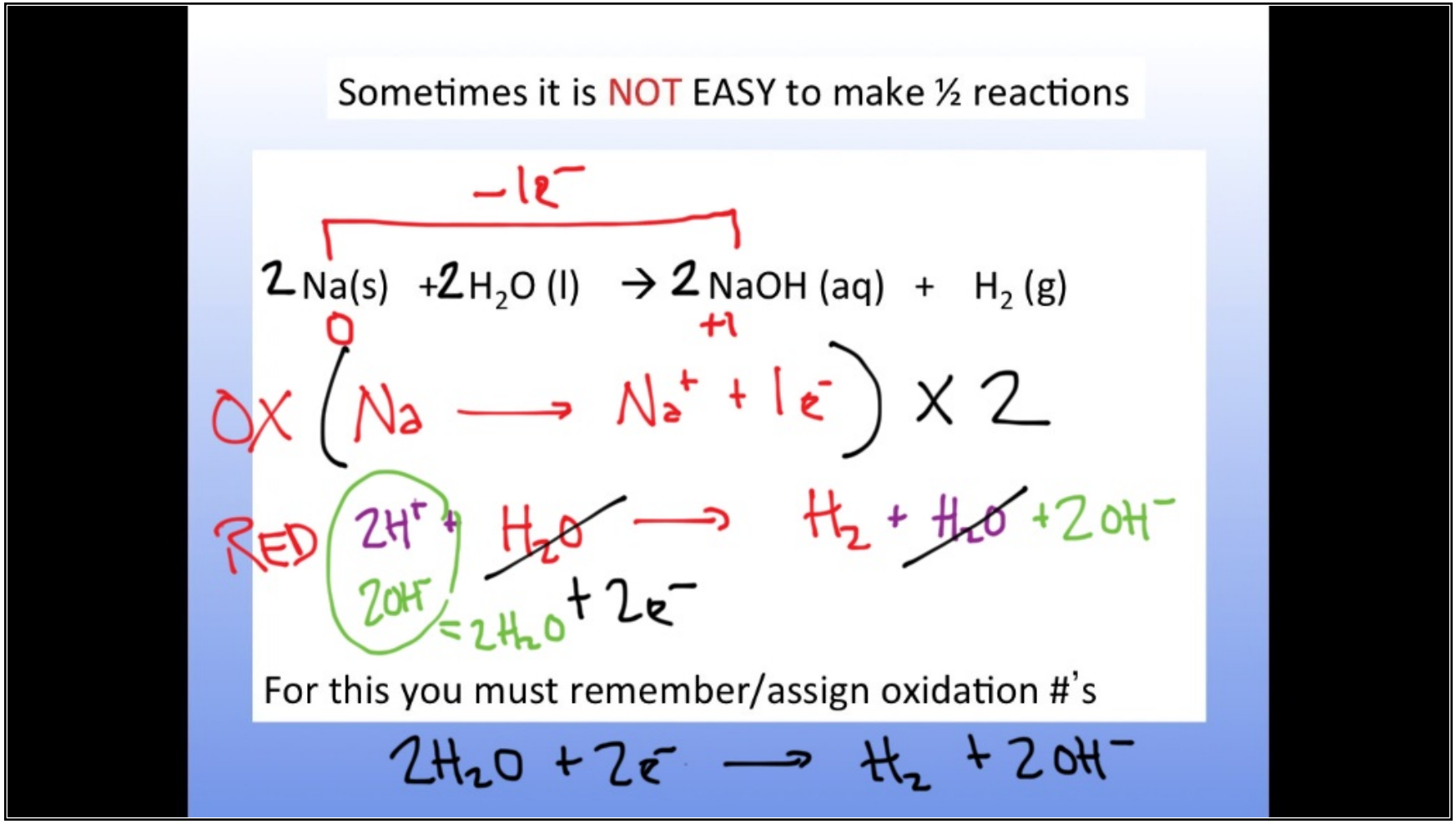

Thinking Like a Chemist
About Electrochemistry
e- on the move
UNIT 8 DAY 2

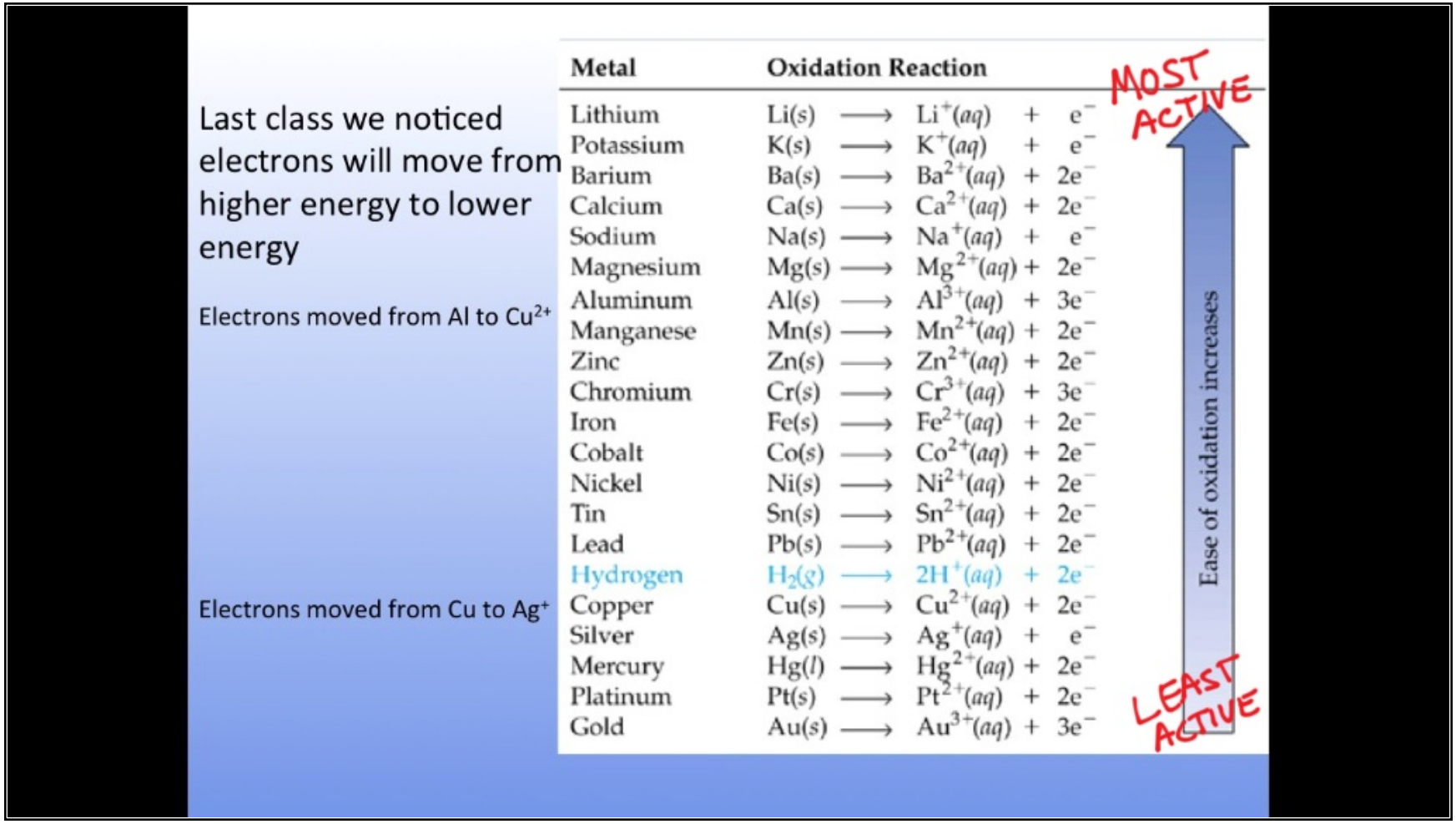

IMPORTANT INFORMATION
Thurs
LM33 & LM34 due Tue 9 AM
HW #12 Tuesday

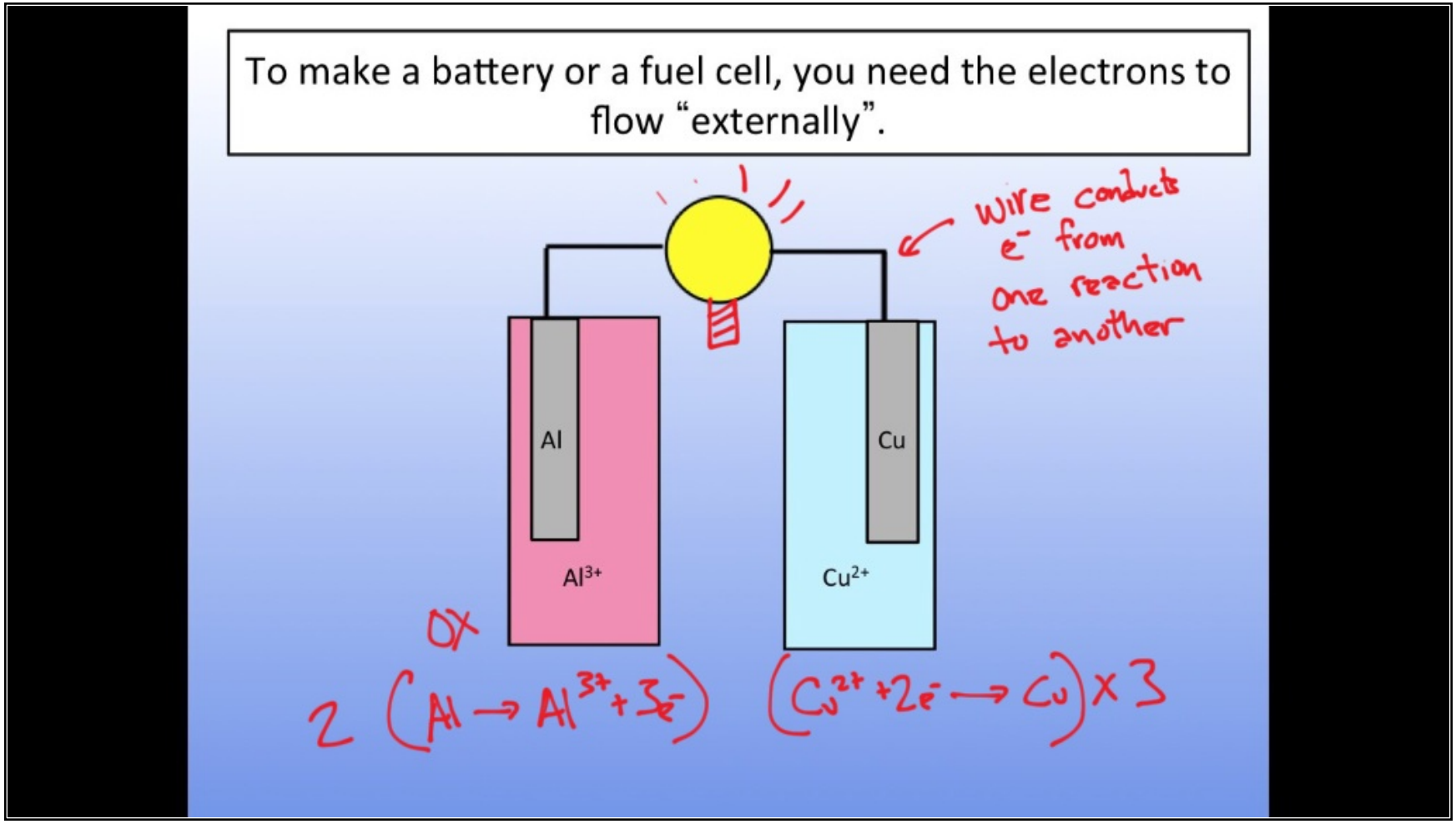

What are we going to learn today?
Oxidation – Reduction Chemistry
Voltaic and Electrolytic Cells
Tracking the movement of electrons

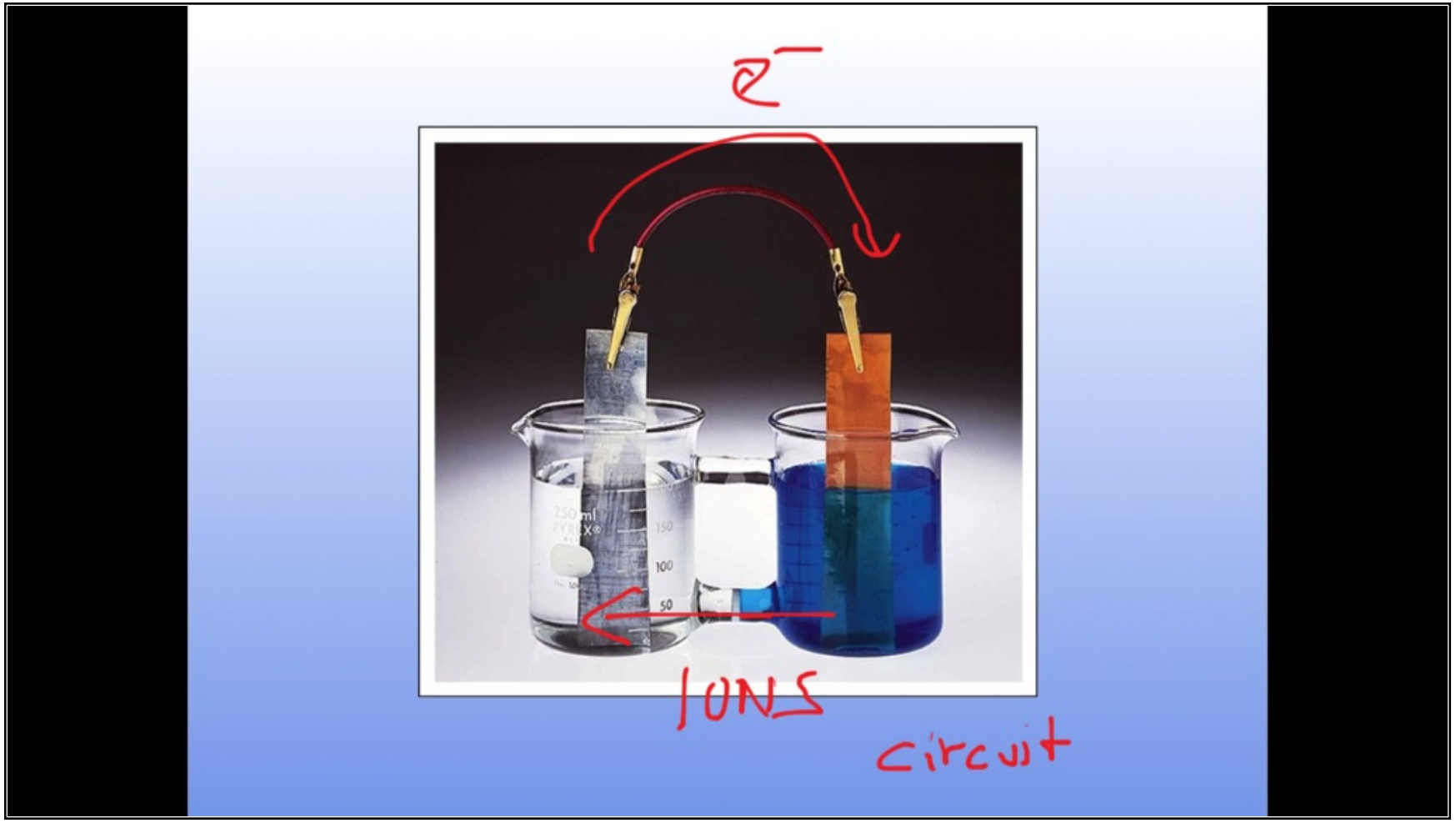

QUIZ: Clicker Question
The oxidation numbers on the C in the following oxides, CO, CO_2 and CO_3^{2-} are:
A) -2, -4, -6
B) +2, +4, +6
C) -2, +4, -8
D) +2, +4, +4
E) 0, 0, -2
+2 -2
CO
+4 -2
CO_2
2x
+6 -2
CO_3
3x
2-
TOTAL CHARGE
-2

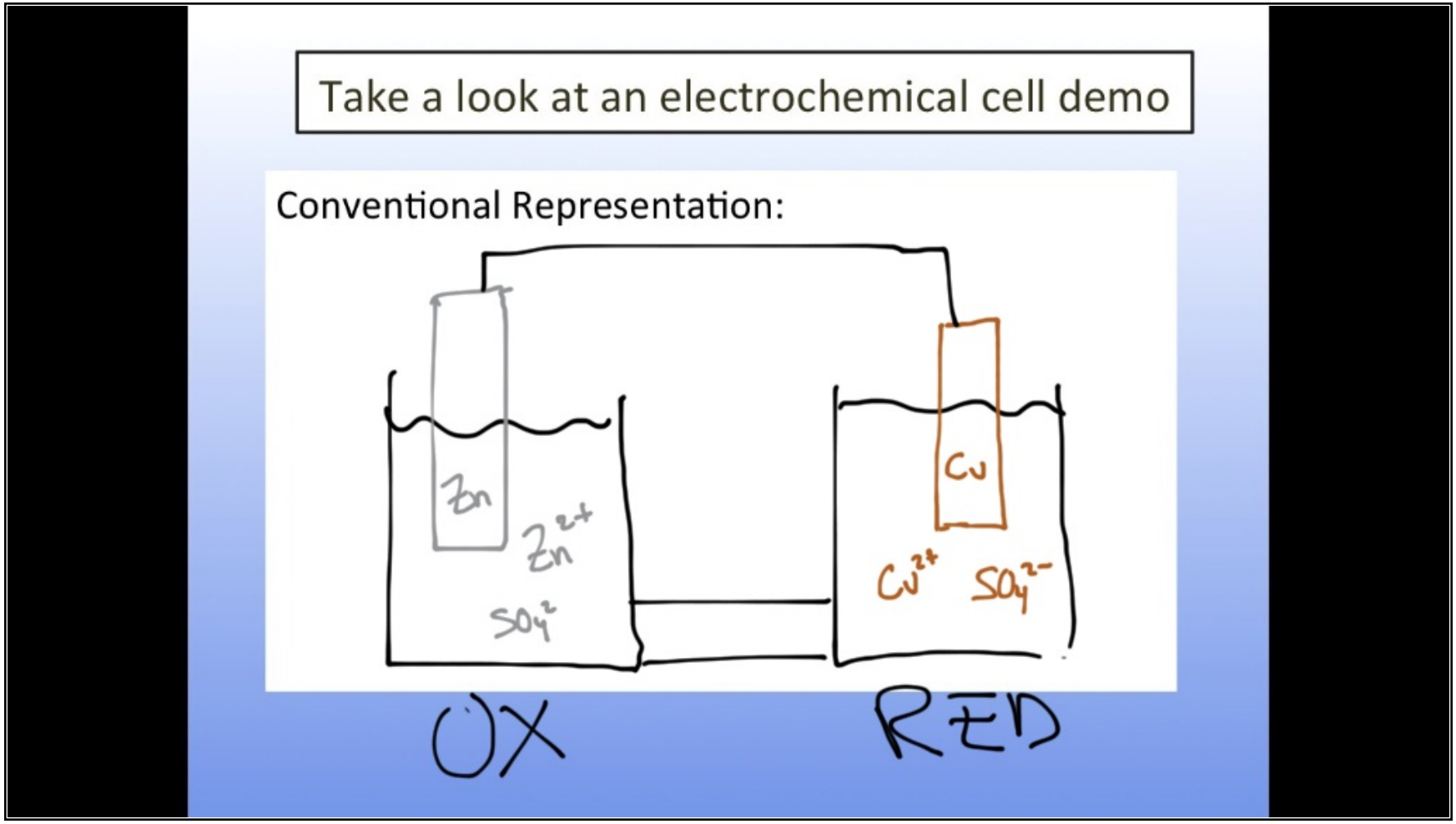

QUIZ : Clicker Question
In the following redox reaction, what is serving as the oxidizing agent?
$2H_2S(g) + SO_2(g) \rightarrow 3S(s) + 2H_2O(l)$
A) H_2S
B) SO_2
C) S
D) H_2O
Should be a reactant

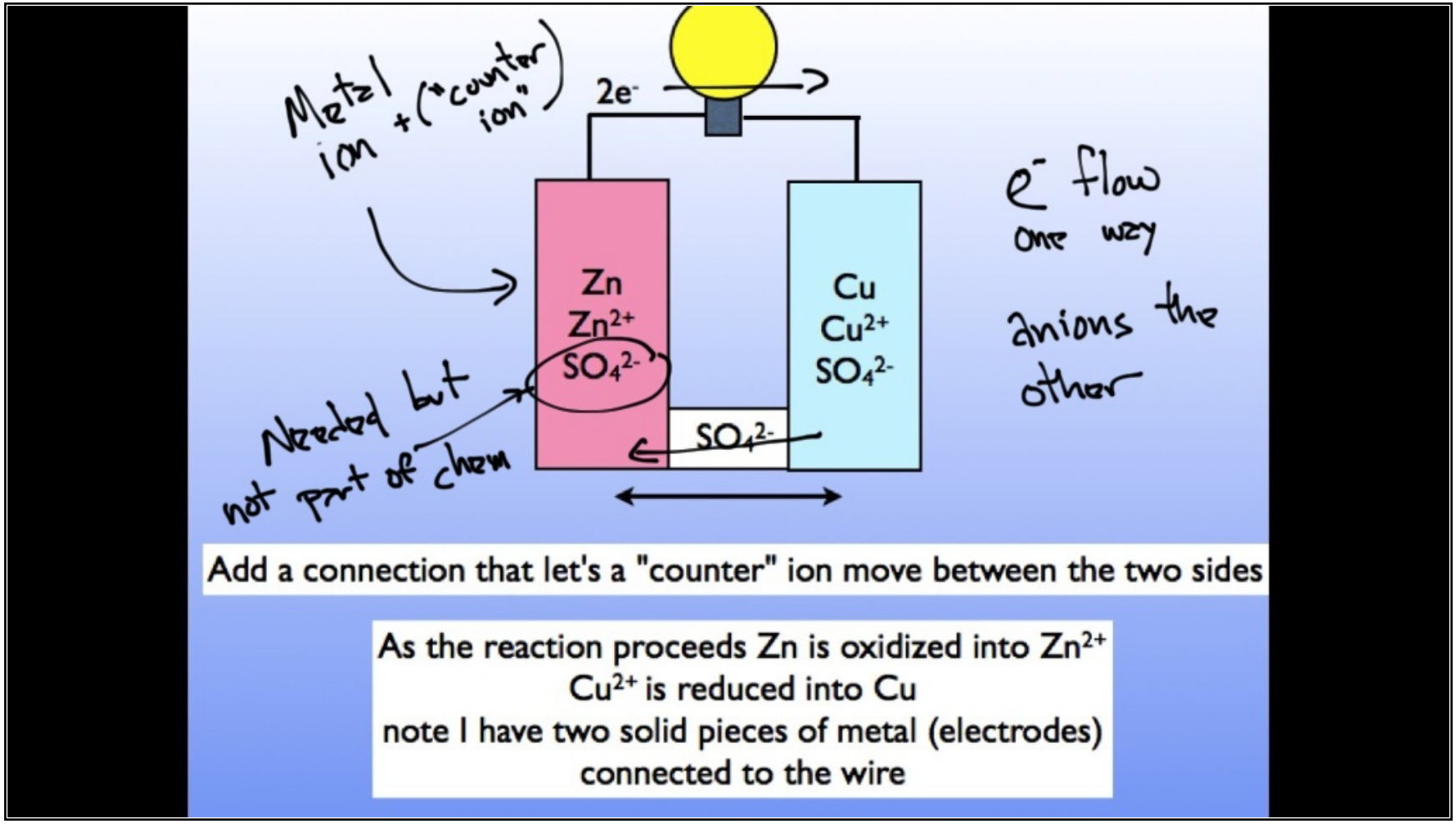

Sometimes it is NOT EASY to make ½ reactions
−1e⁻
2 Na(s) + 2 H2O (l) → 2 NaOH (aq) + H2 (g)
0
+1
OX (Na → Na+ + 1e-) x 2
RED 2H+ + 2OH- = 2H2O + H2O → H2 + H2O + 2OH- + 2e-
For this you must remember/assign oxidation #'s
2H2O + 2e- → H2 + 2OH-

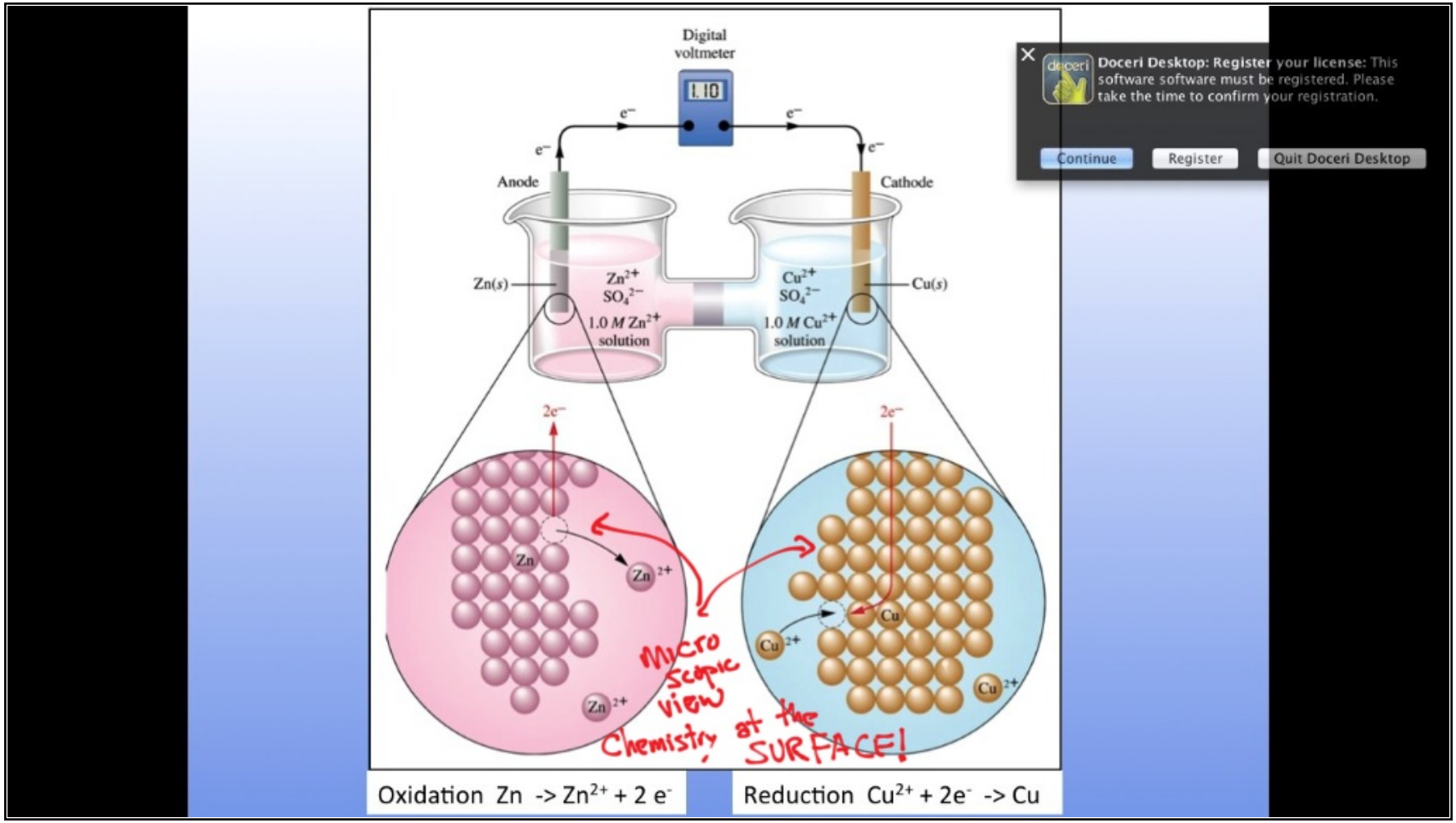

Last class we noticed electrons will move from higher energy to lower energy
Electrons moved from Al to Cu^{2+}
Electrons moved from Cu to Ag^{+}
Metal
Oxidation Reaction
Lithium $Li(s) \longrightarrow Li^{+}(aq) + e^{-}$
Potassium $K(s) \longrightarrow K^{+}(aq) + e^{-}$
Barium $Ba(s) \longrightarrow Ba^{2+}(aq) + 2e^{-}$
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 $Hg(l) \longrightarrow Hg^{2+}(aq) + 2e^{-}$
Platinum $Pt(s) \longrightarrow Pt^{2+}(aq) + 2e^{-}$
Gold $Au(s) \longrightarrow Au^{3+}(aq) + 3e^{-}$
MOST ACTIVE
Ease of oxidation increases
LEAST ACTIVE


To make a battery or a fuel cell, you need the electrons to flow "externally".
Wire conducts e⁻ from one reaction to another
Al
Cu
Al^{3+}
Cu^{2+}
OX
$2\left(Al \rightarrow Al^{3+} + 3e^-\right)$
$\left(Cu^{2+} + 2e^- \rightarrow Cu\right) \times 3$


e⁻
IONS
circuit


Take a look at an electrochemical cell demo
Conventional Representation:
Zn
Zn^{2+}
SO_4^{2-}
Cu
Cu^{2+}
SO_4^{2-}
OX
RED


Metal ion + ("counter ion")
2e⁻
e⁻ flow one way
Zn
Zn^{2+}
SO_4^{2-}
Cu
Cu^{2+}
SO_4^{2-}
anions the other
Needed but not part of chem
SO_4^{2-}
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


Digital voltmeter
1.10
e⁻
e⁻
e⁻
e⁻
Anode
Cathode
Zn(s)
Cu(s)
Zn²⁺
SO₄²⁻
1.0 M Zn²⁺ solution
Cu²⁺
SO₄²⁻
1.0 M Cu²⁺ solution
2e⁻
2e⁻
Zn
Zn²⁺
Zn²⁺
Cu
Cu²⁺
Cu²⁺
Micro scopic view
Chemistry at the SURFACE!
Oxidation Zn -> Zn²⁺ + 2 e⁻
Reduction Cu²⁺ + 2e⁻ -> Cu
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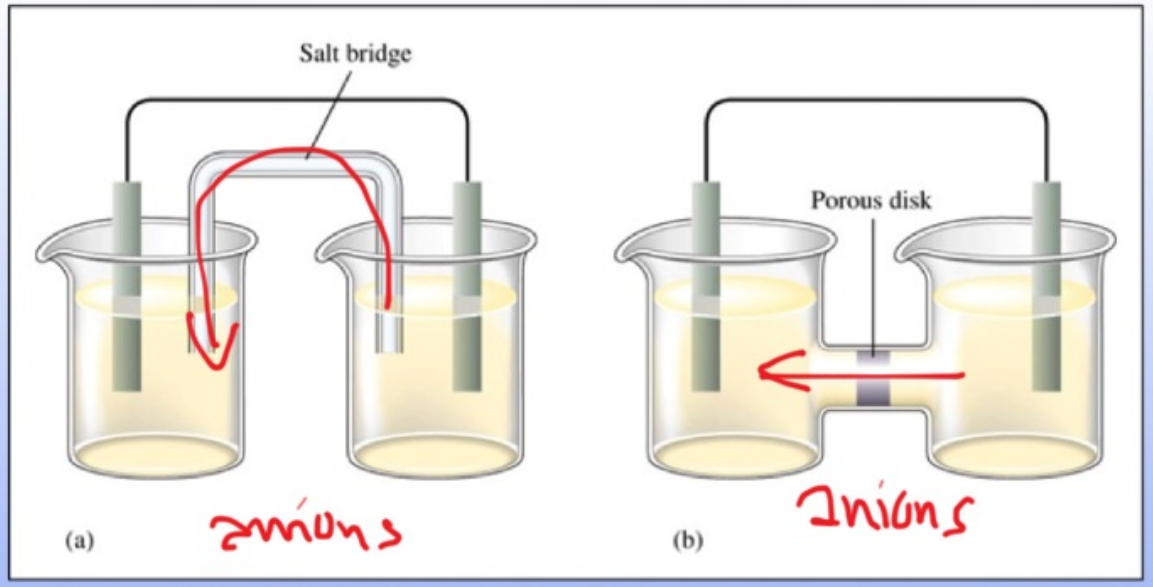
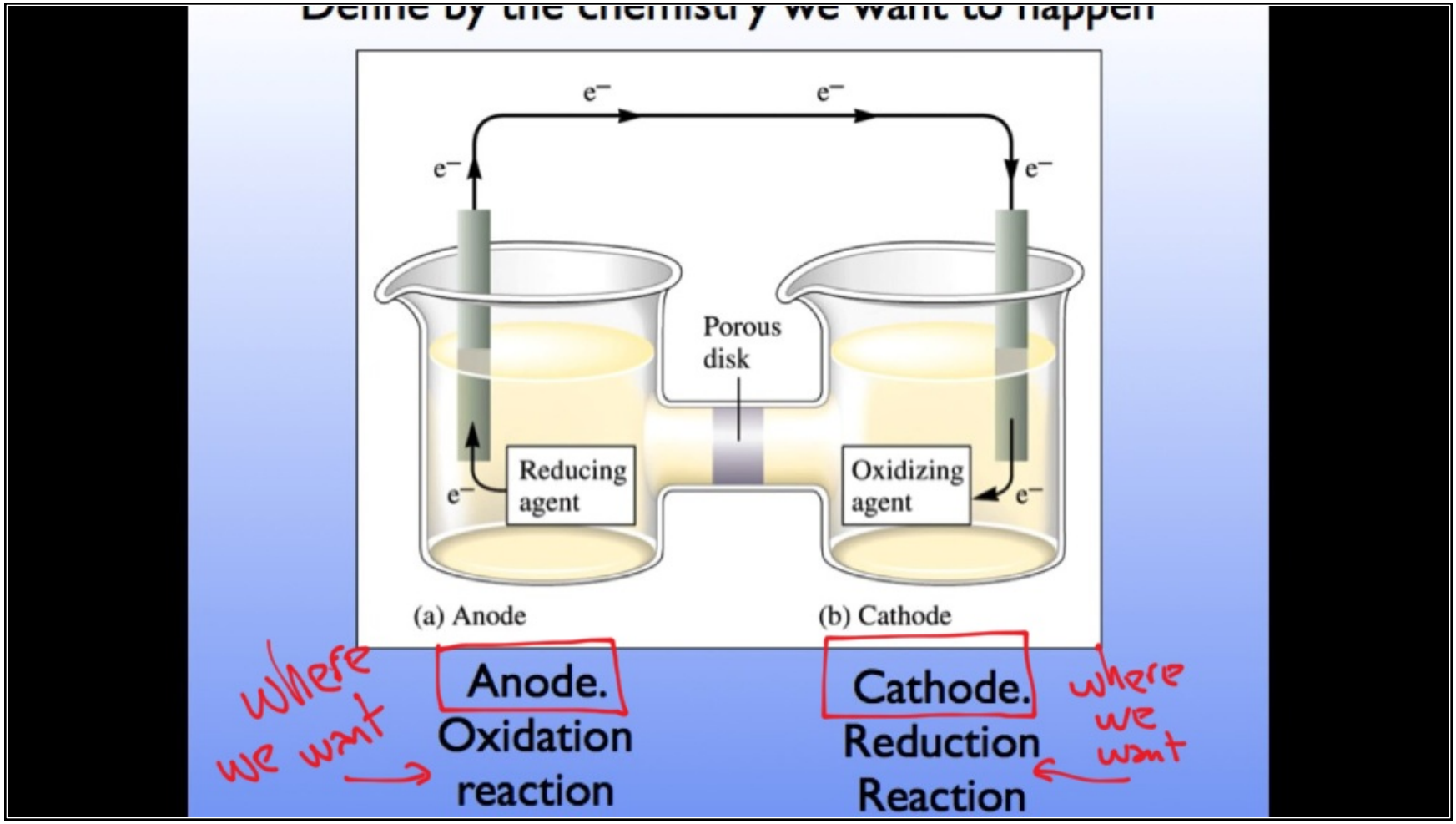
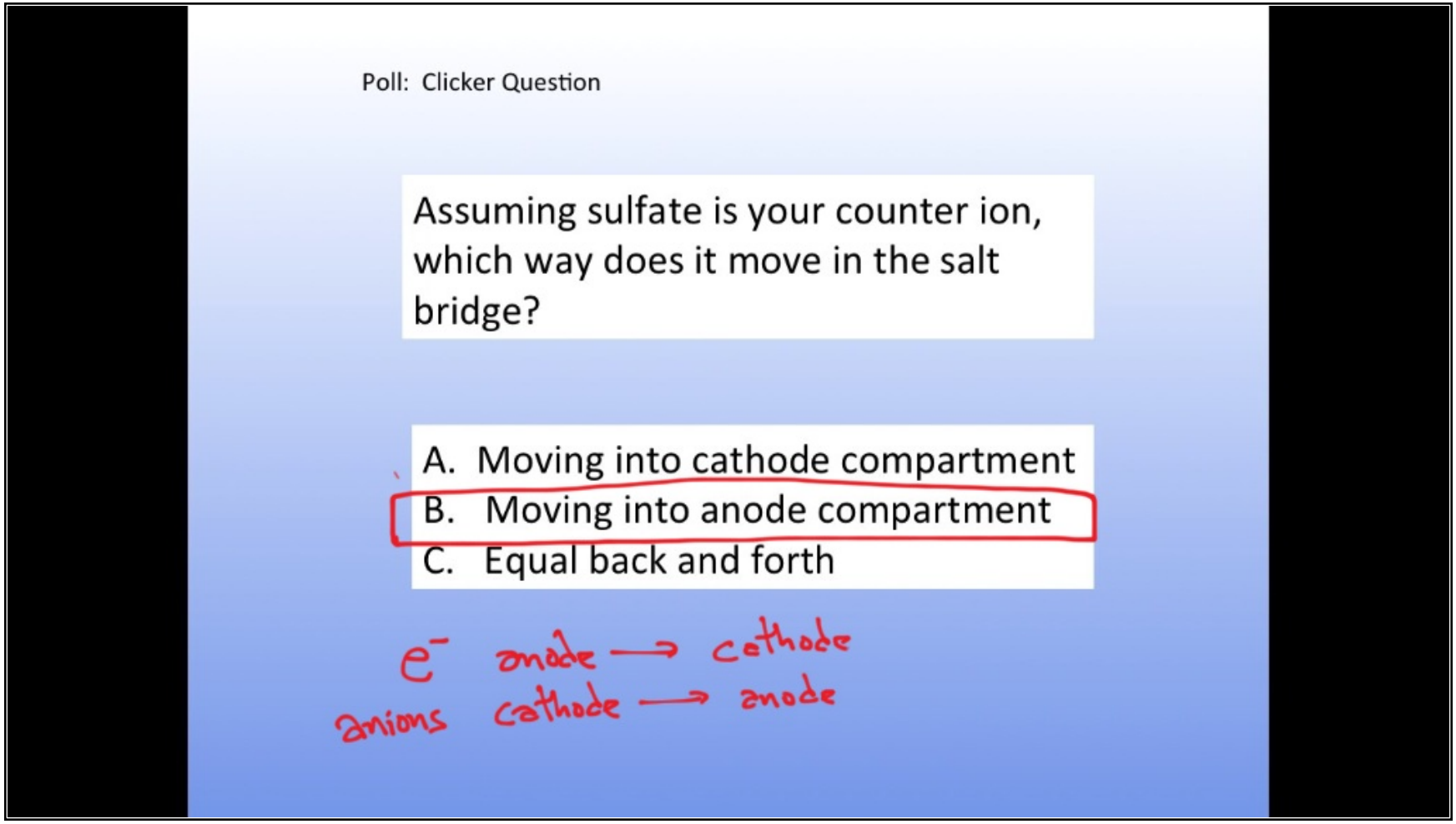


Salt Bridge or Porous Disk allow ions to flow back and forth between the two beakers.
As e^- move from one side to the other, counter anions move the opposite direction


Define by the chemistry we want to happen
e⁻
e⁻
e⁻
e⁻
Porous disk
Reducing agent
Oxidizing agent
e⁻
e⁻
(a) Anode
(b) Cathode
where we want
Anode.
Oxidation reaction
Cathode.
Reduction Reaction
where we want


Poll: Clicker Question
Assuming sulfate is your counter ion, which way does it move in the salt bridge?
A. Moving into cathode compartment
B. Moving into anode compartment
C. Equal back and forth
e⁻ anode → cathode
anions cathode → anode

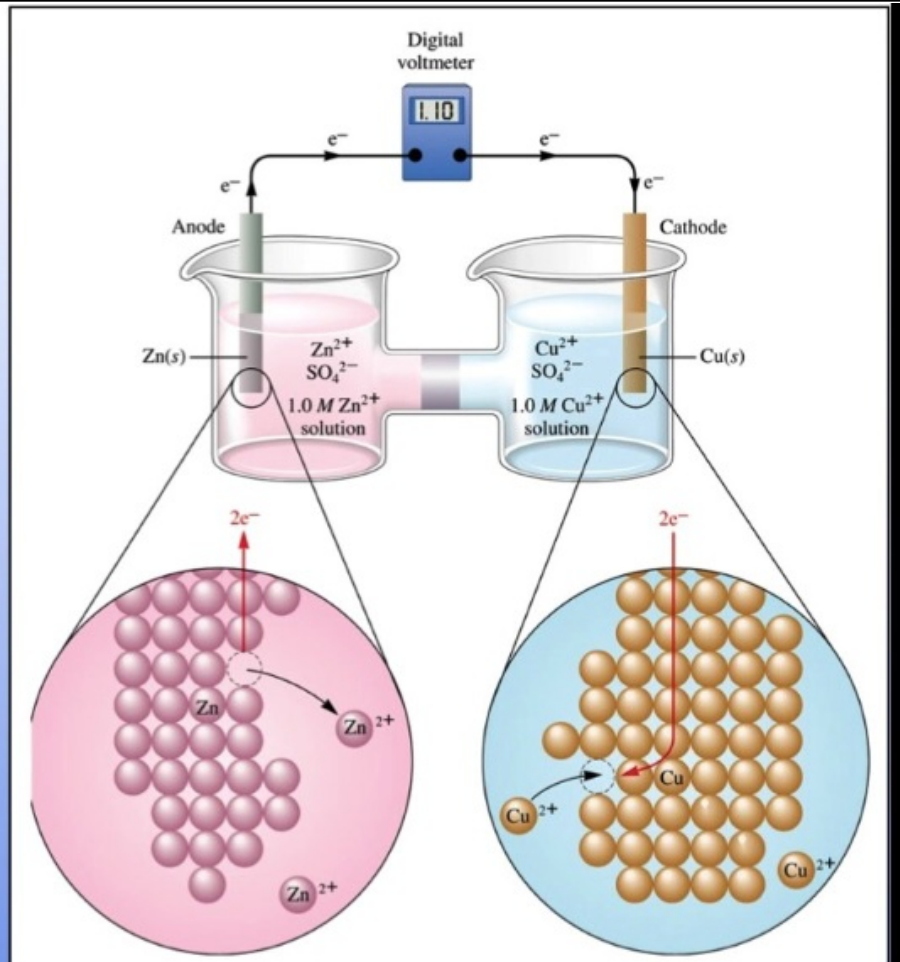

ANode
OXidation
OR
YAK
REDuction
CAThode

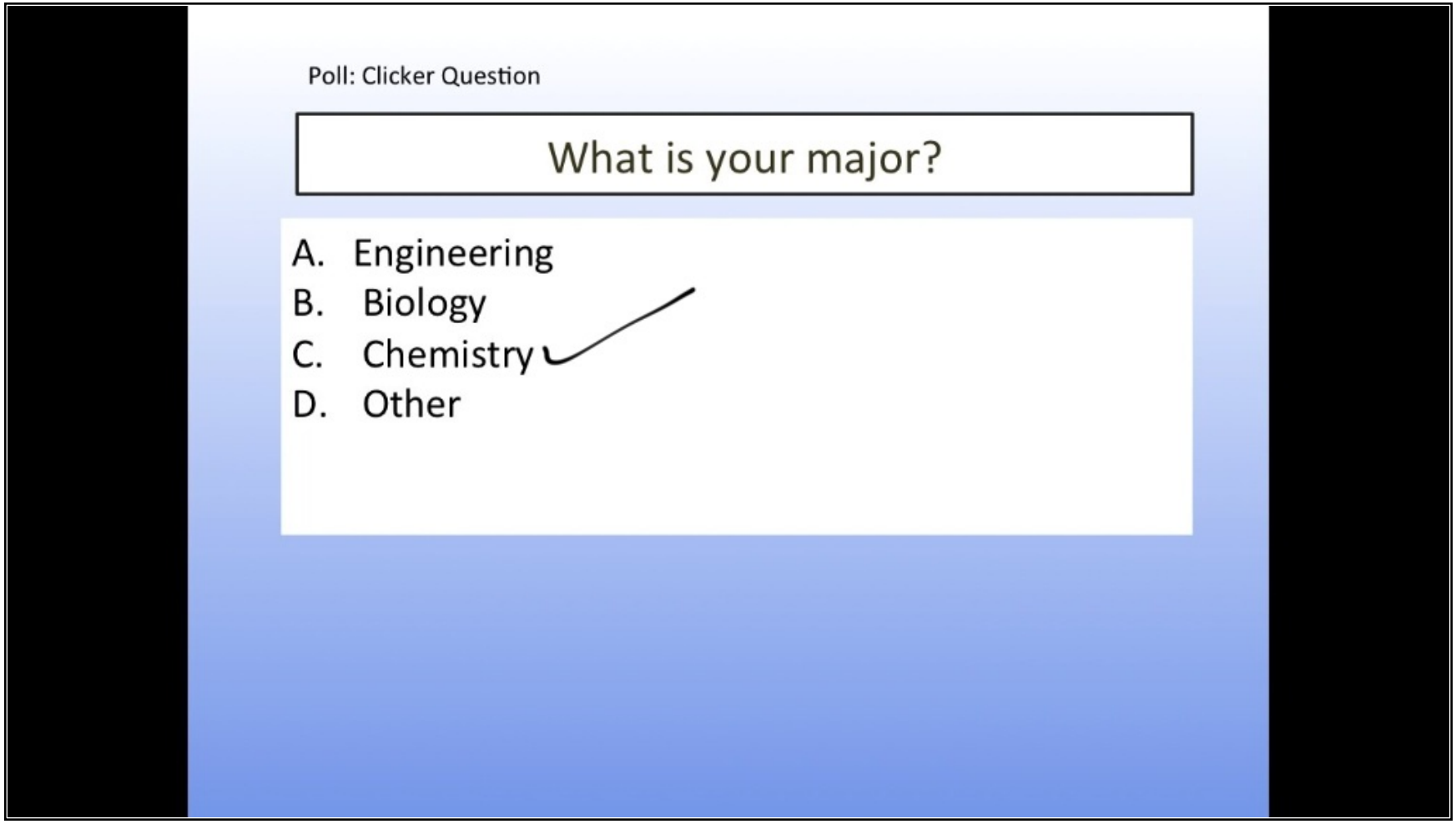
Poll: Clicker Question

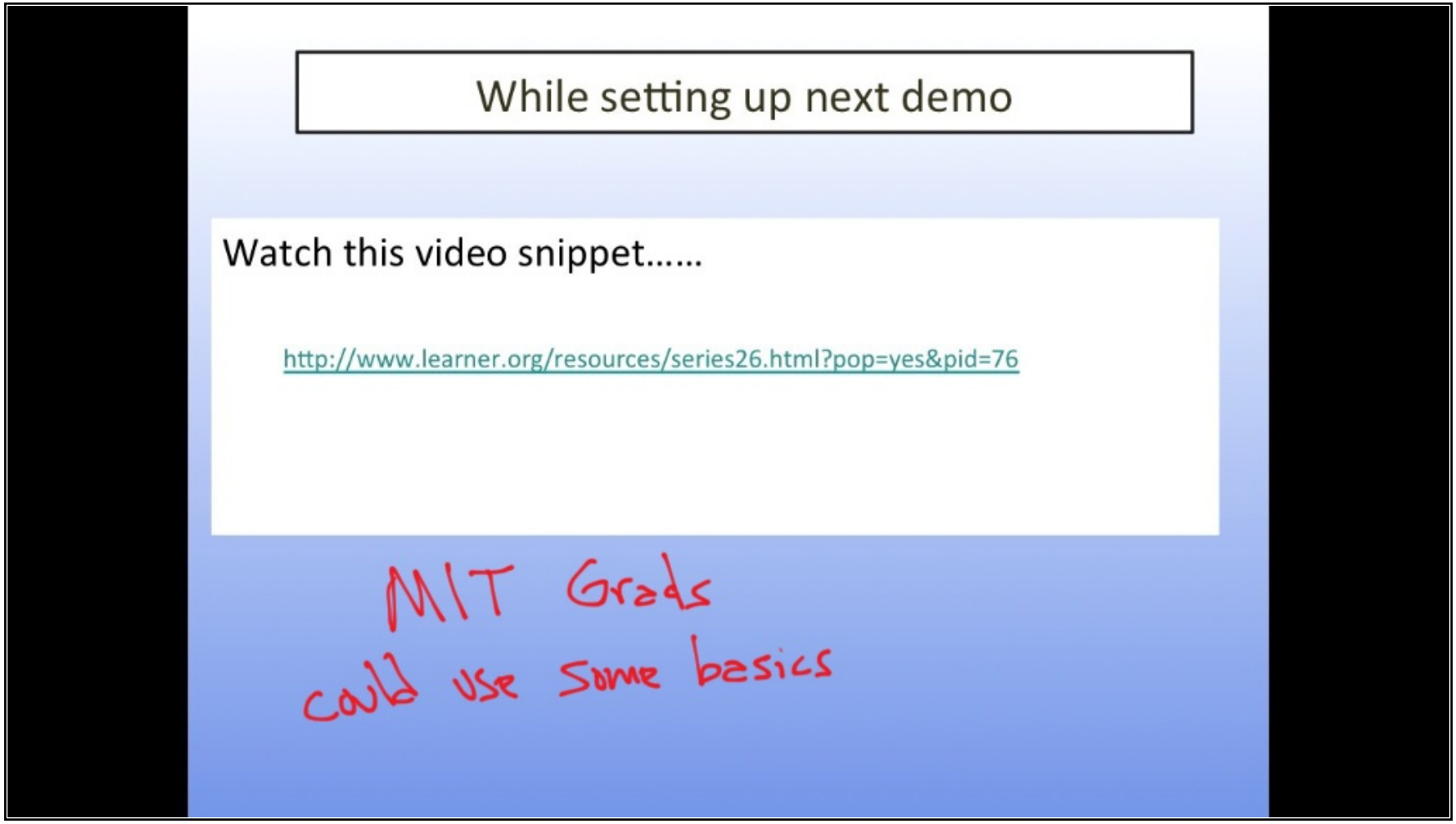
In our demo cell - What is serving as the cathode?

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

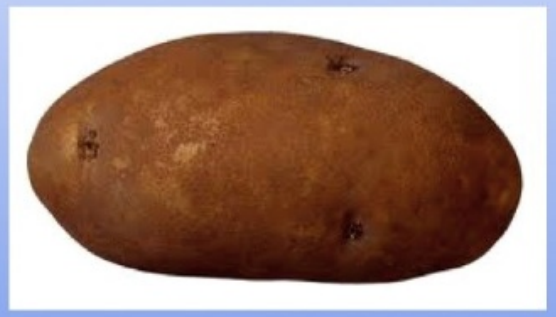
It the SOLID!



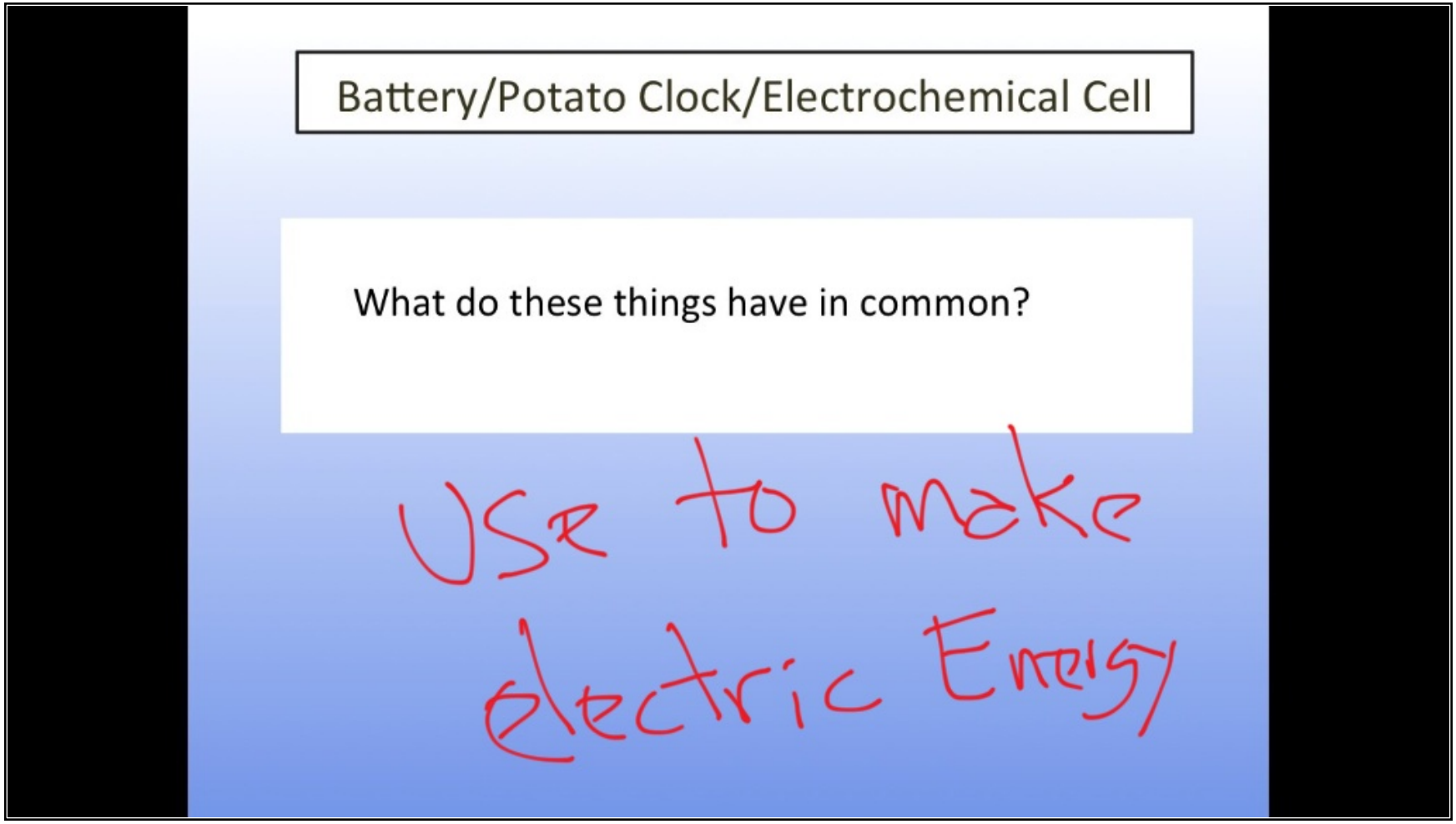

Poll: Clicker Question
What is your major?
A. Engineering
B. Biology
C. Chemistry
D. Other

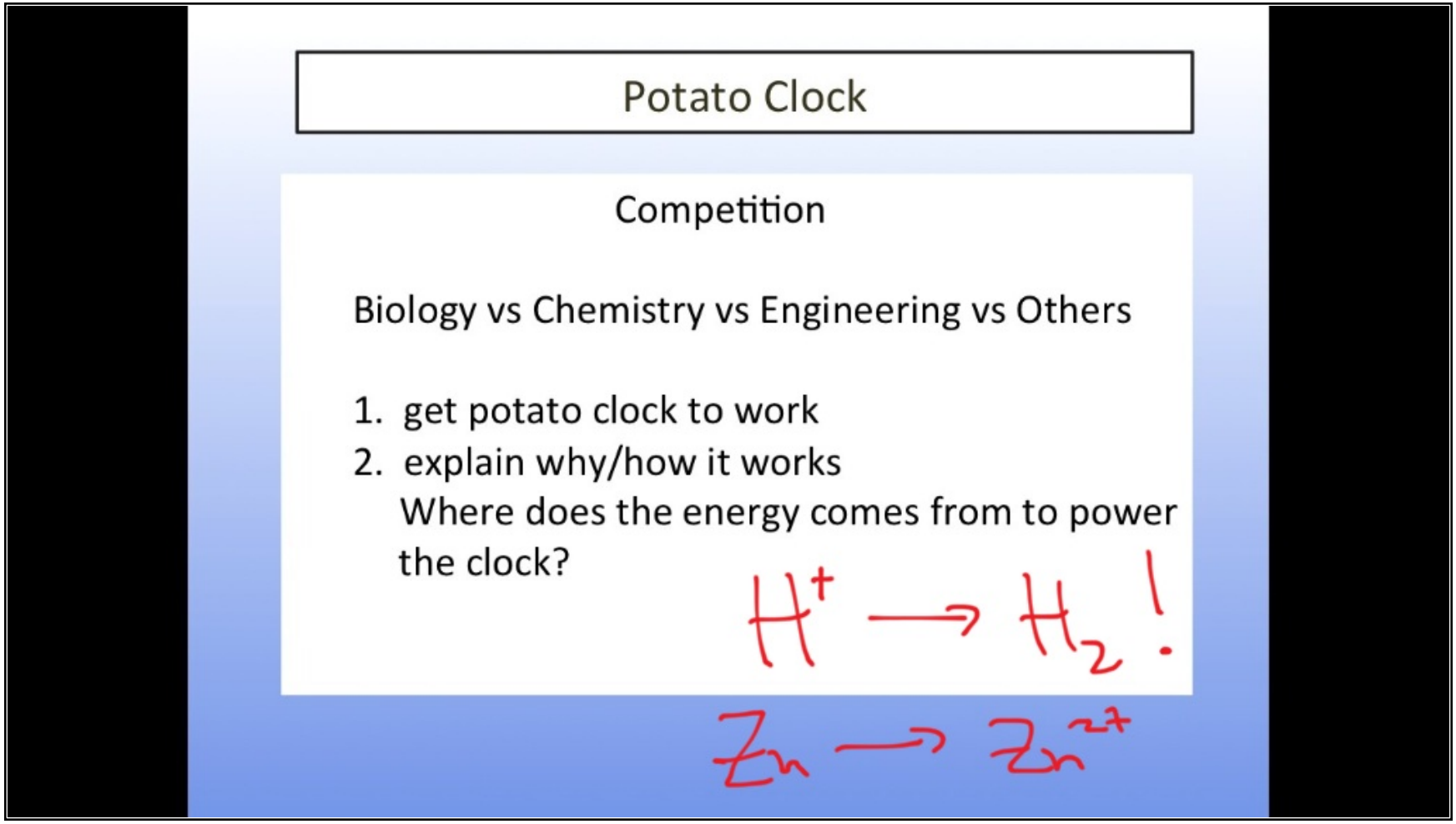

While setting up next demo
Watch this video snippet……
http://www.learner.org/resources/series26.html?pop=yes&pid=76
MIT Grads
could use some basics

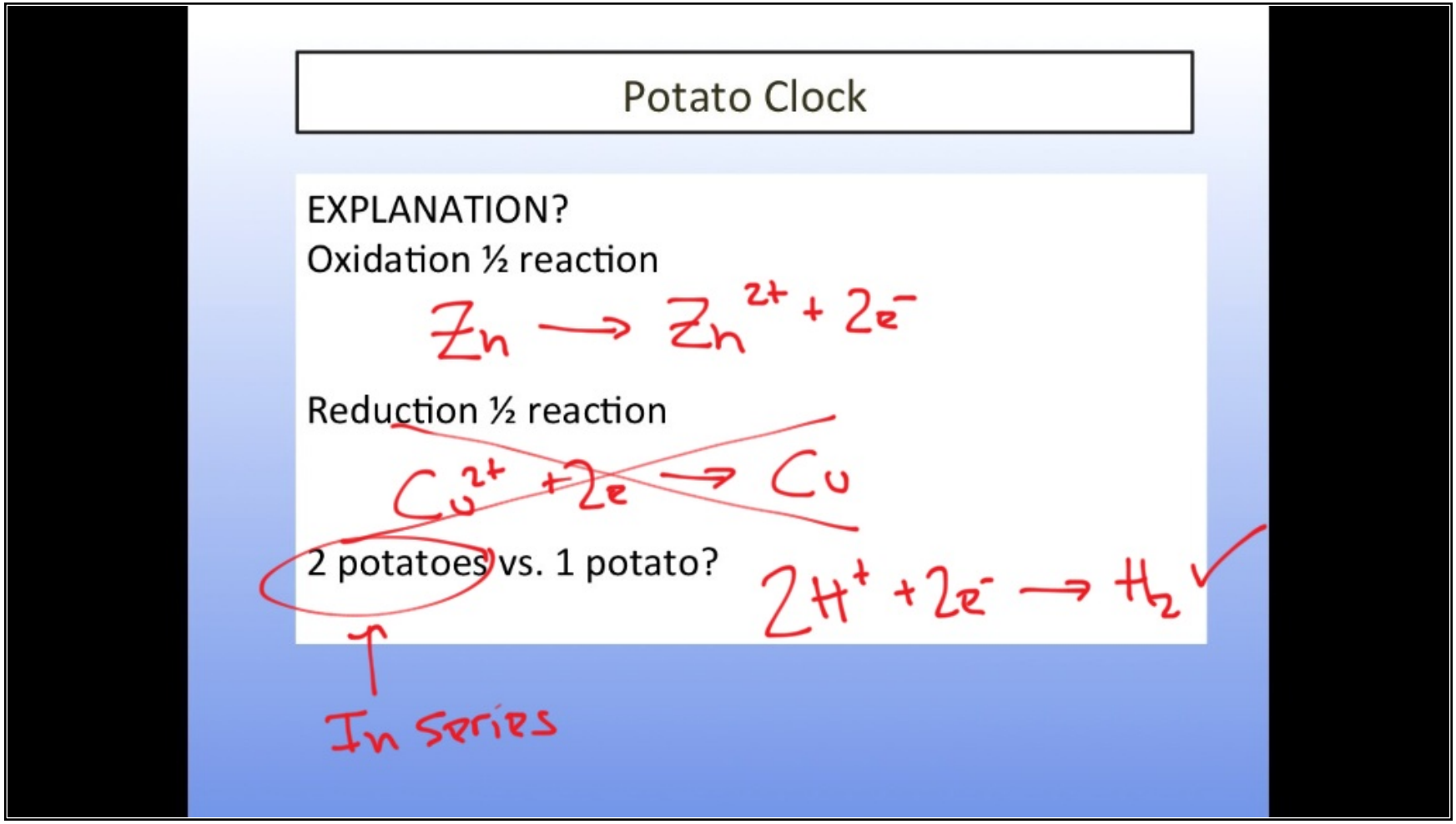
Macroscopic Look Conversion of Chemical Energy to Electrical Energy - Electrochemistry

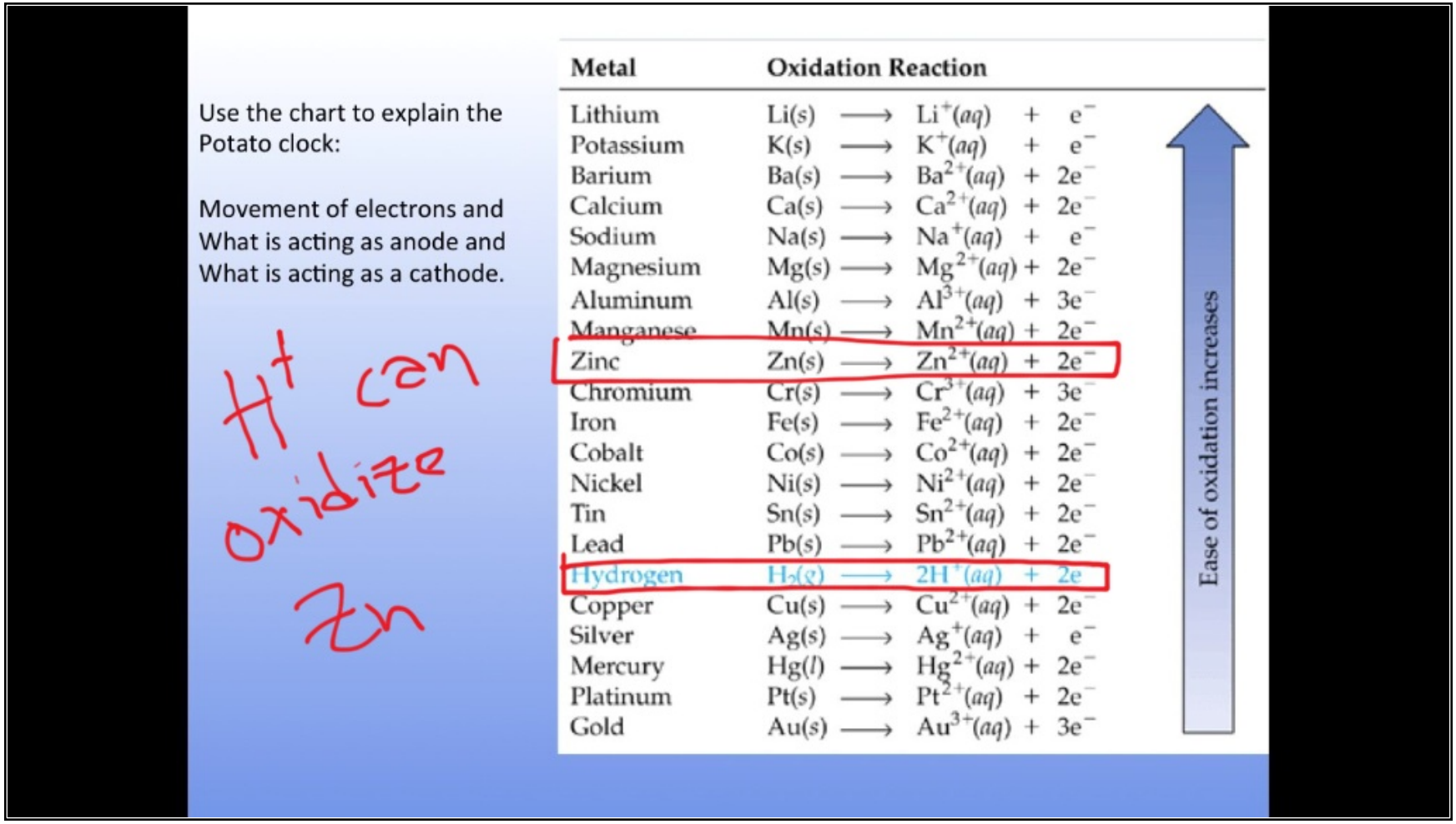


chemical E → electrical E

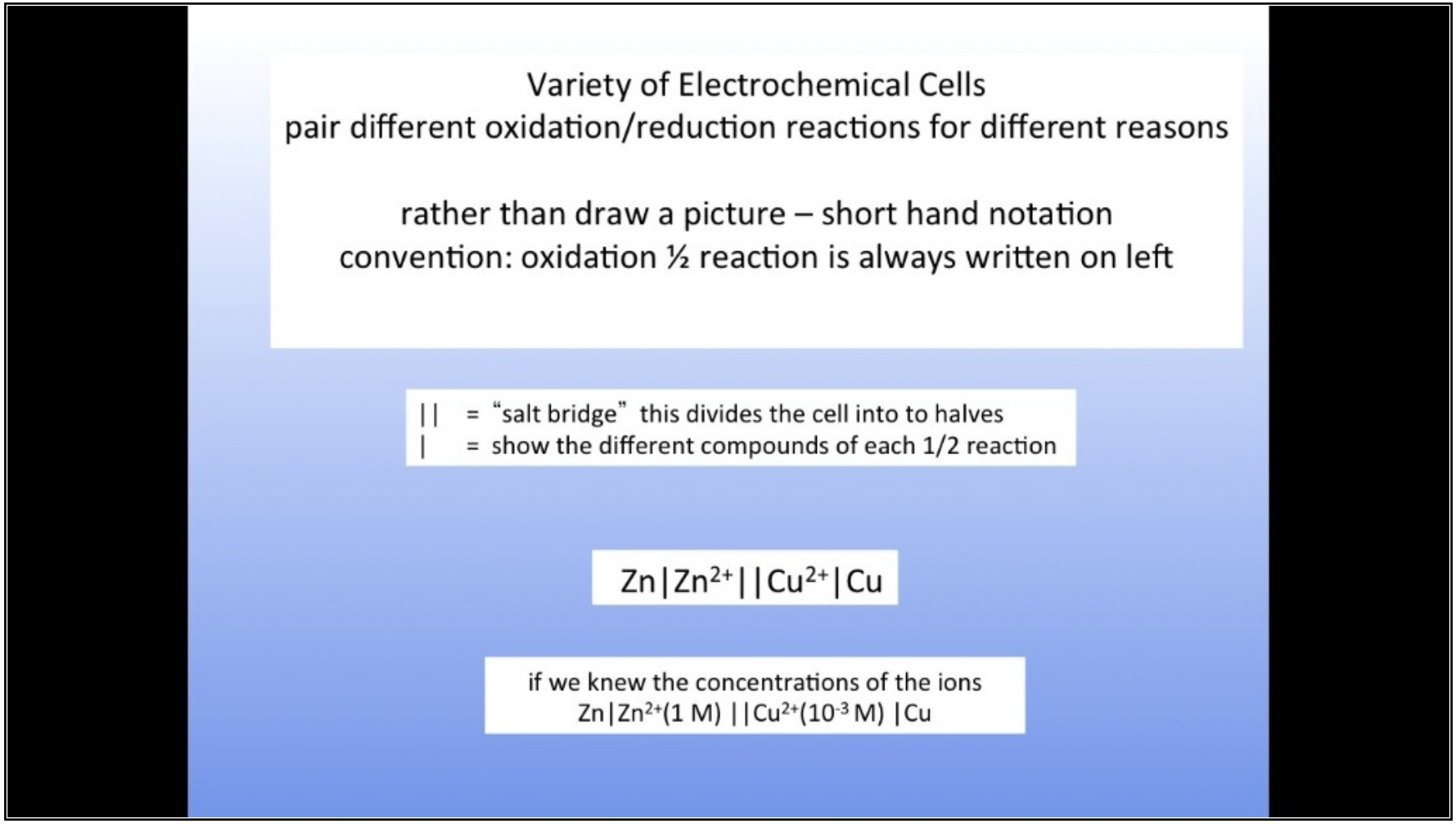

Battery/Potato Clock/Electrochemical Cell
What do these things have in common?
USE to make electric Energy

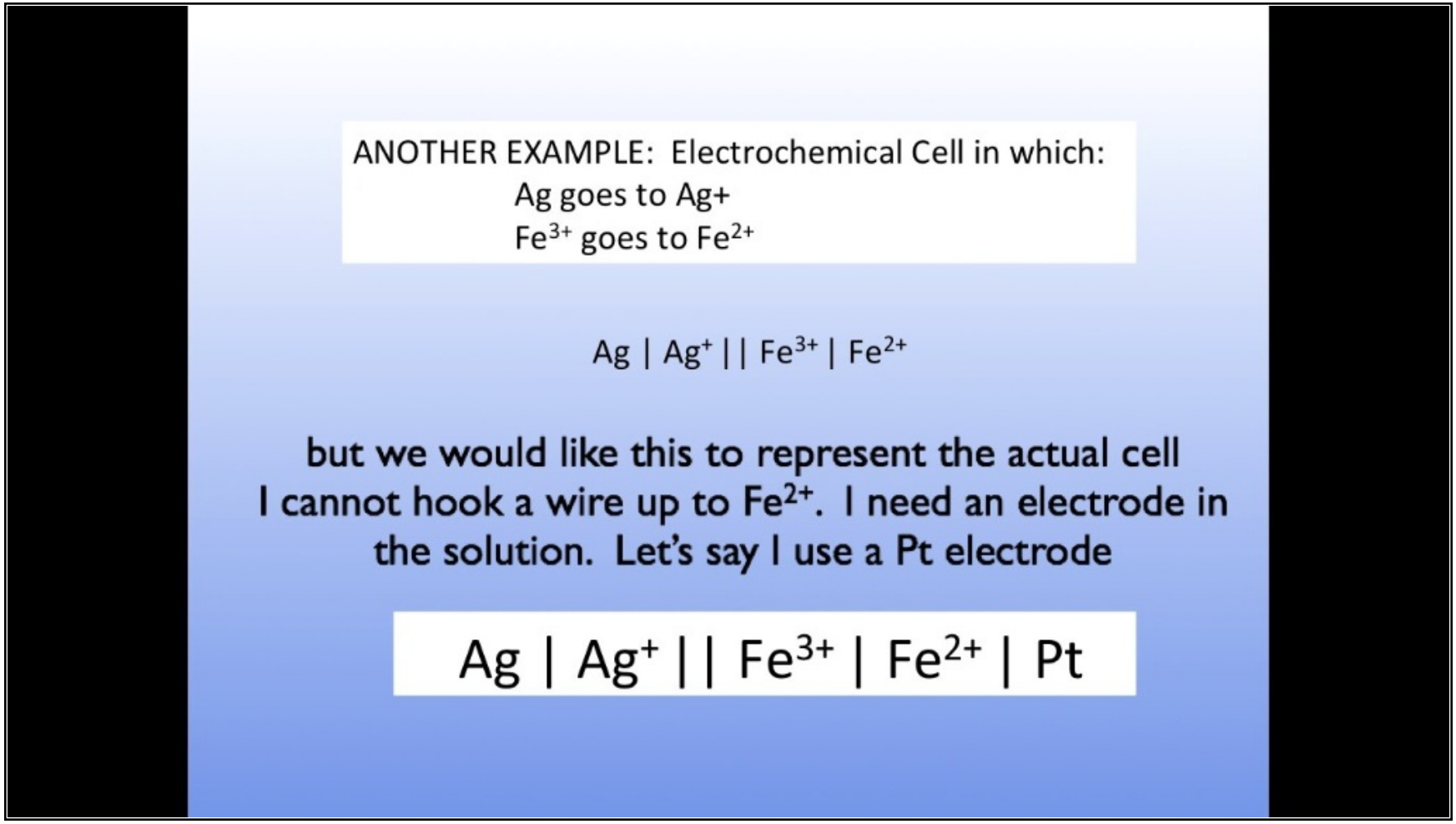

Potato Clock
Competition
Biology vs Chemistry vs Engineering vs Others
1. get potato clock to work
2. explain why/how it works
Where does the energy comes from to power the clock?
$H^+ \rightarrow H_2$!
$Zn \rightarrow Zn^{2+}$

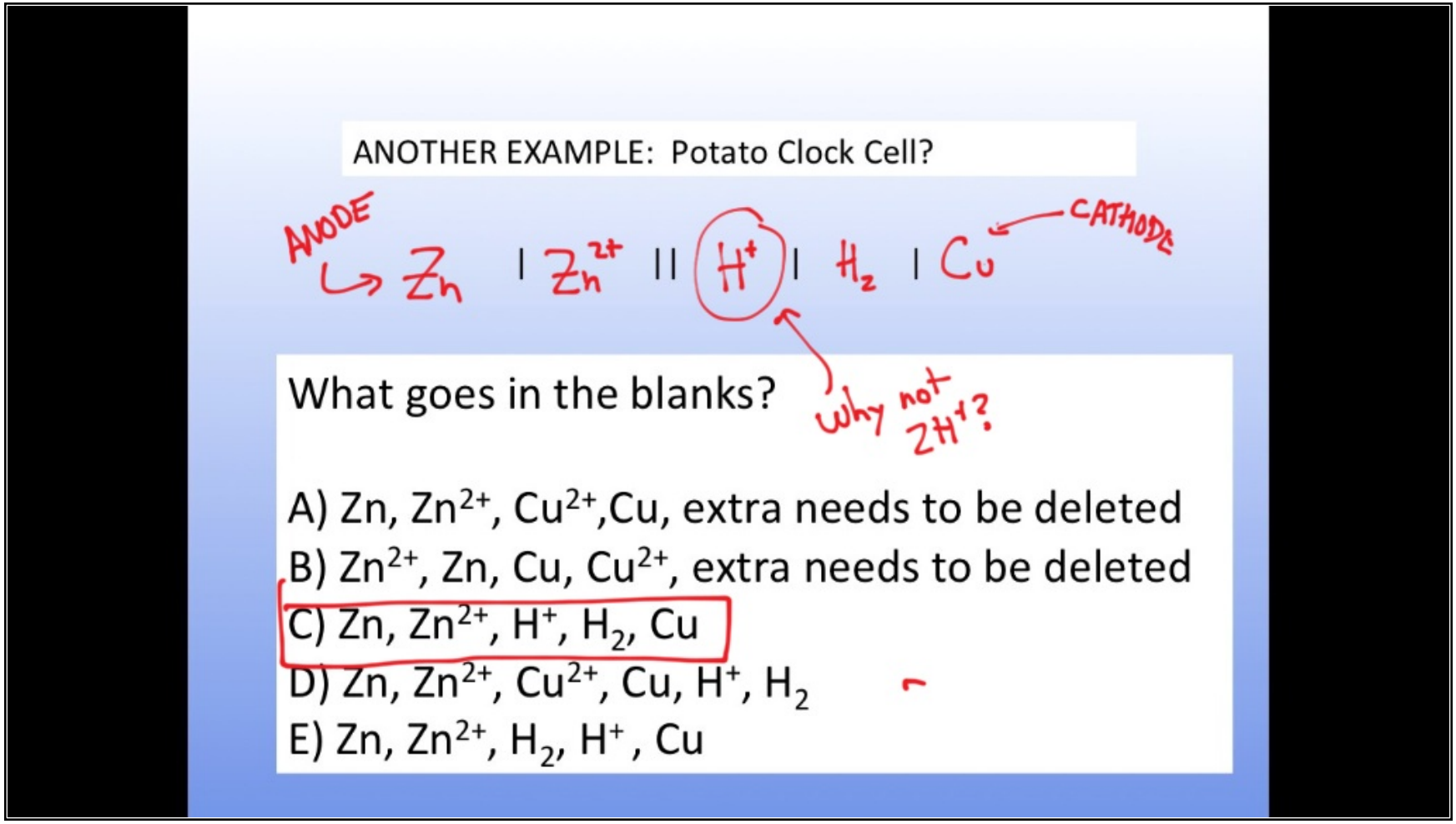

Potato Clock
EXPLANATION?
Oxidation ½ reaction
$Zn \rightarrow Zn^{2+} + 2e^-$
Reduction ½ reaction
$Cu^{2+} + 2e \rightarrow Cu$
2 potatoes vs. 1 potato?
$2H^+ + 2e^- \rightarrow H_2$
In series

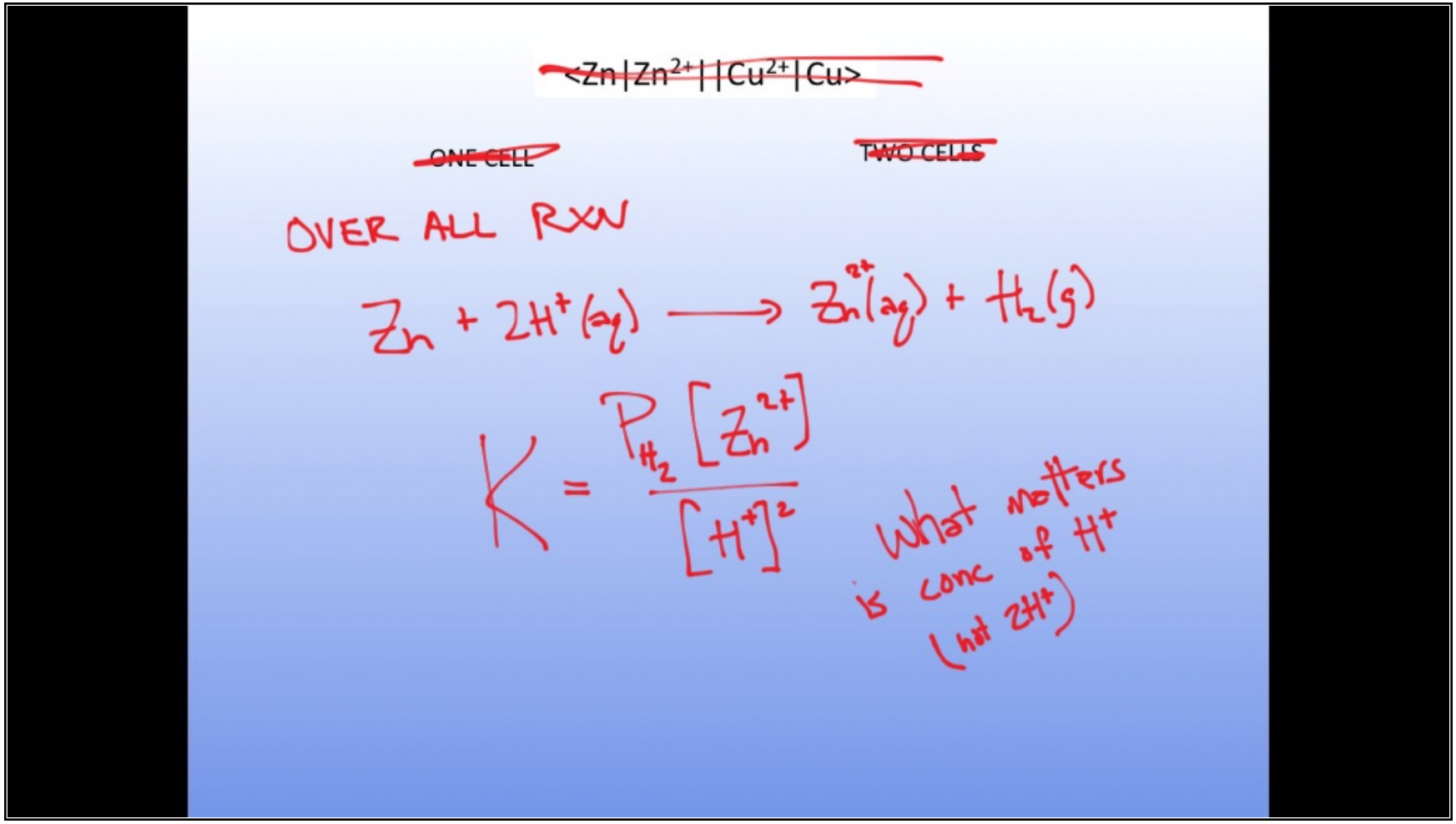


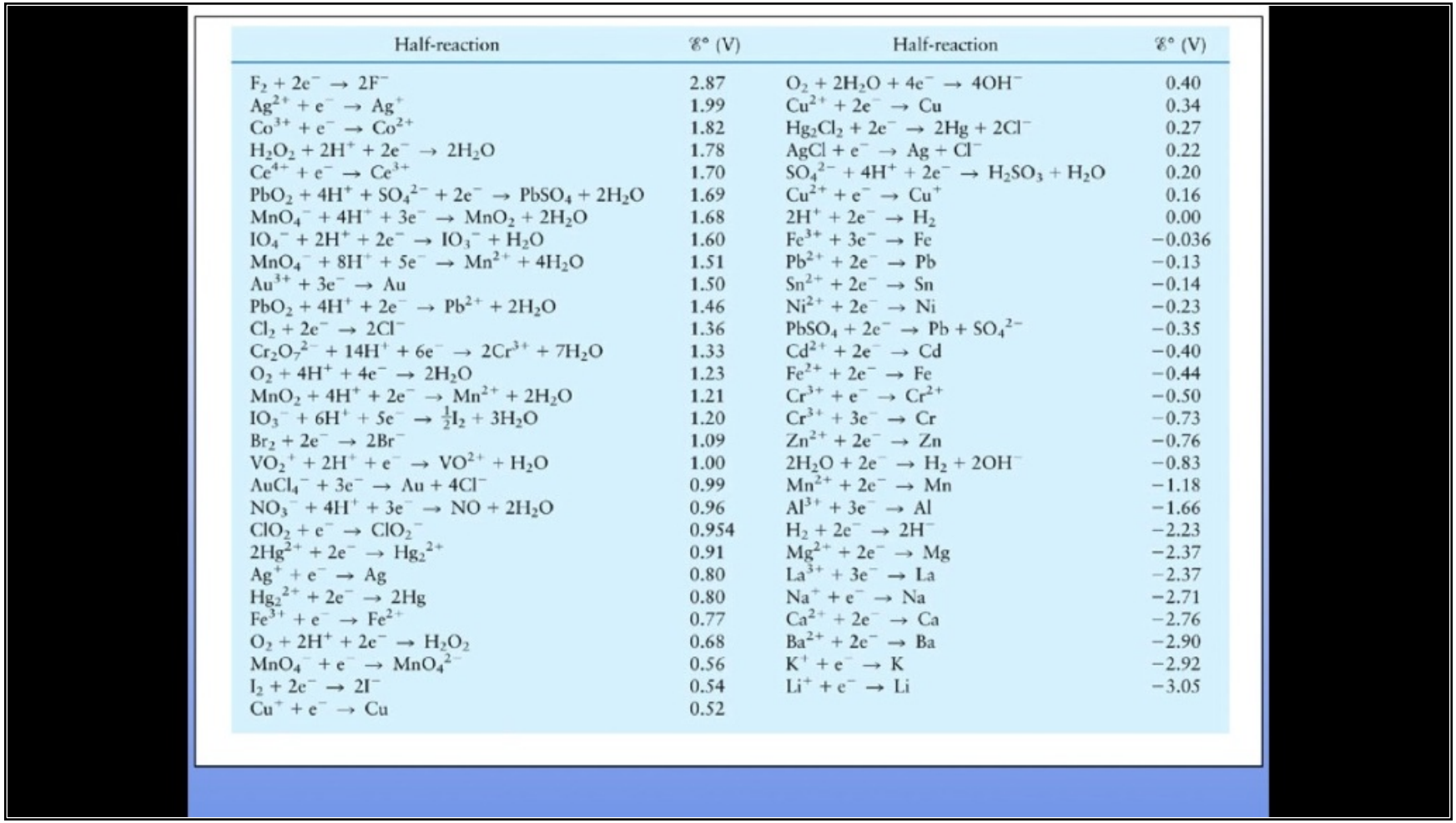
Metal	Oxidation Reaction
Lithium	$Li(s) \longrightarrow Li^+(aq) + e^-$
Potassium	$K(s) \longrightarrow K^+(aq) + e^-$
Barium	$Ba(s) \longrightarrow Ba^{2+}(aq) + 2e^-$
Calcium	$Ca(s) \longrightarrow Ca^{2+}(aq) + 2e^-$
Sodium	$Na(s) \longrightarrow Na^+(aq) + e^-$
Magnesium	$Mg(s) \longrightarrow Mg^{2+}(aq) + 2e^-$
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	$Au(s) \longrightarrow Au^{3+}(aq) + 3e^-$


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
Zn|Zn2+||Cu2+|Cu
if we knew the concentrations of the ions
Zn|Zn2+(1 M) ||Cu2+(10-3 M) |Cu


ANOTHER EXAMPLE: Electrochemical Cell in which:
Ag goes to Ag+
Fe3+ goes to Fe2+
Ag | Ag+ || Fe3+ | Fe2+
but we would like this to represent the actual cell
I cannot hook a wire up to Fe2+. I need an electrode in
the solution. Let's say I use a Pt electrode
Ag | Ag+ || Fe3+ | Fe2+ | Pt


ANOTHER EXAMPLE: Potato Clock Cell?
ANODE
CATHODE
Zn | Zn2+ || H+ | H2 | Cu
What goes in the blanks?
why not 2H+?
A) Zn, Zn2+, Cu2+,Cu, extra needs to be deleted
B) Zn2+, Zn, Cu, Cu2+, extra needs to be deleted
C) Zn, Zn2+, H+, H2, Cu
D) Zn, Zn2+, Cu2+, Cu, H+, H2
E) Zn, Zn2+, H2, H+, Cu


<Zn|Zn2+||Cu2+|Cu>
ONE CELL
TWO CELLS
OVER ALL RXN
Zn + 2H+(aq) → Zn2+(aq) + H2(g)
K = PH2 [Zn2+] / [H+]2
What matters is conc of H+ (not 2H+)



Half-reaction	$\mathscr{E}°$ (V)	Half-reaction	$\mathscr{E}°$ (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
$MnO_4^- + e^- \rightarrow MnO_4^{2-}$	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		