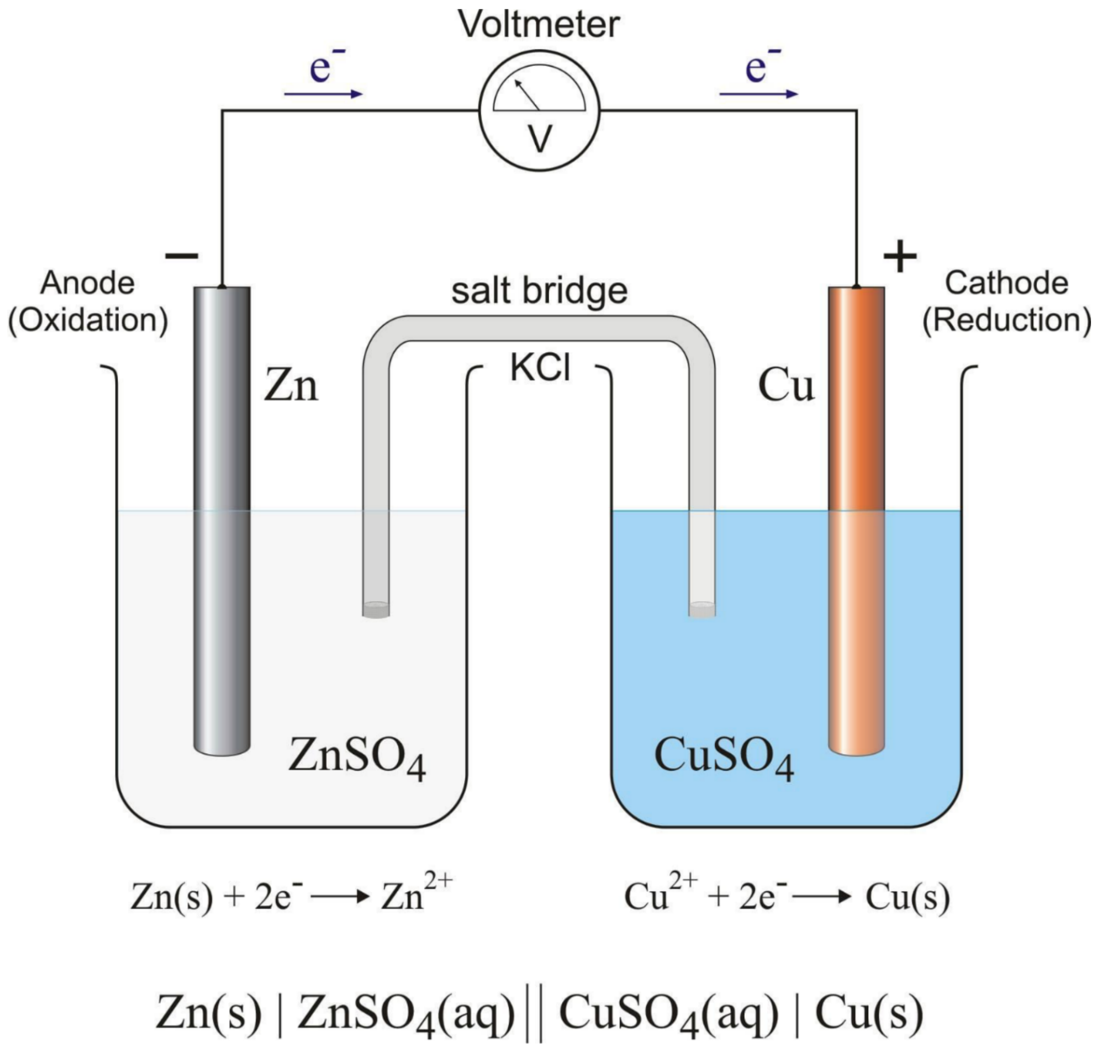
N44 - Electrochemistry

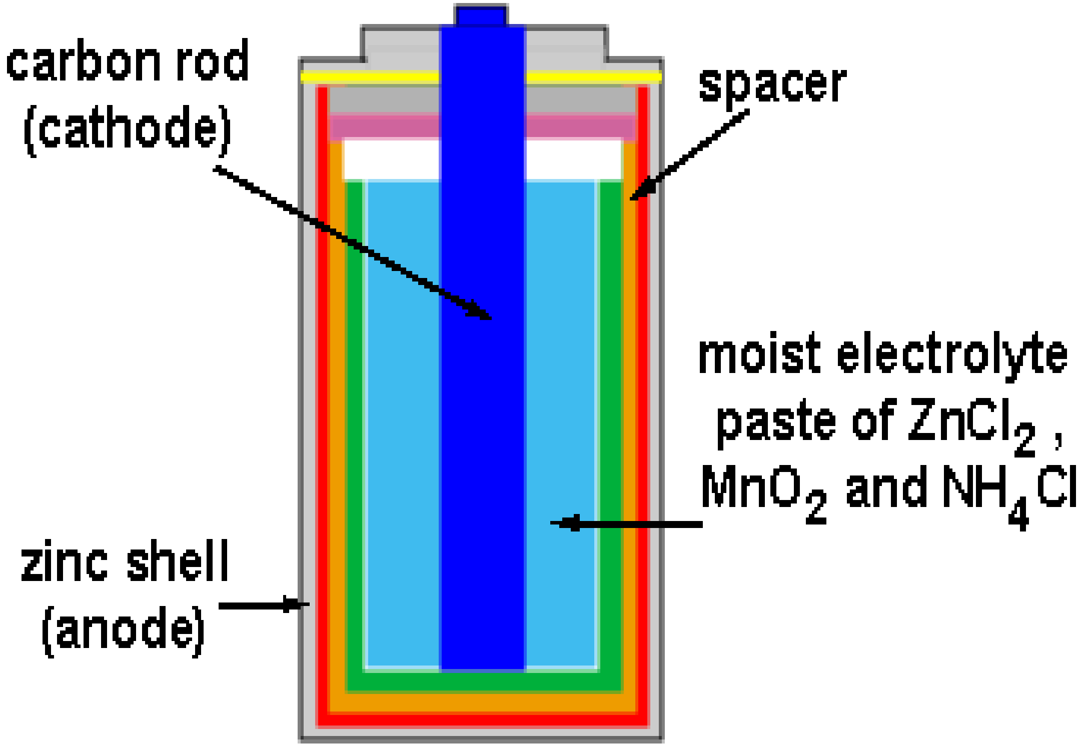
Intro to Cells

Target: I can label cells and perform calculations for both Galvanic and Electrolytic cells.

N44 - Electrochemistry

Intro to Cells


Voltmeter
e-
e-
V
Anode
(Oxidation)
salt bridge
Cathode
(Reduction)
Zn
KCl
Cu
ZnSO4
CuSO4
Zn(s) + 2e- ⟶ Zn2+
Cu2+ + 2e- ⟶ Cu(s)
Zn(s) | ZnSO4(aq) || CuSO4(aq) | Cu(s)


carbon rod
(cathode)
spacer
moist electrolyte
paste of ZnCl2 ,
MnO2 and NH4Cl
zinc shell
(anode)

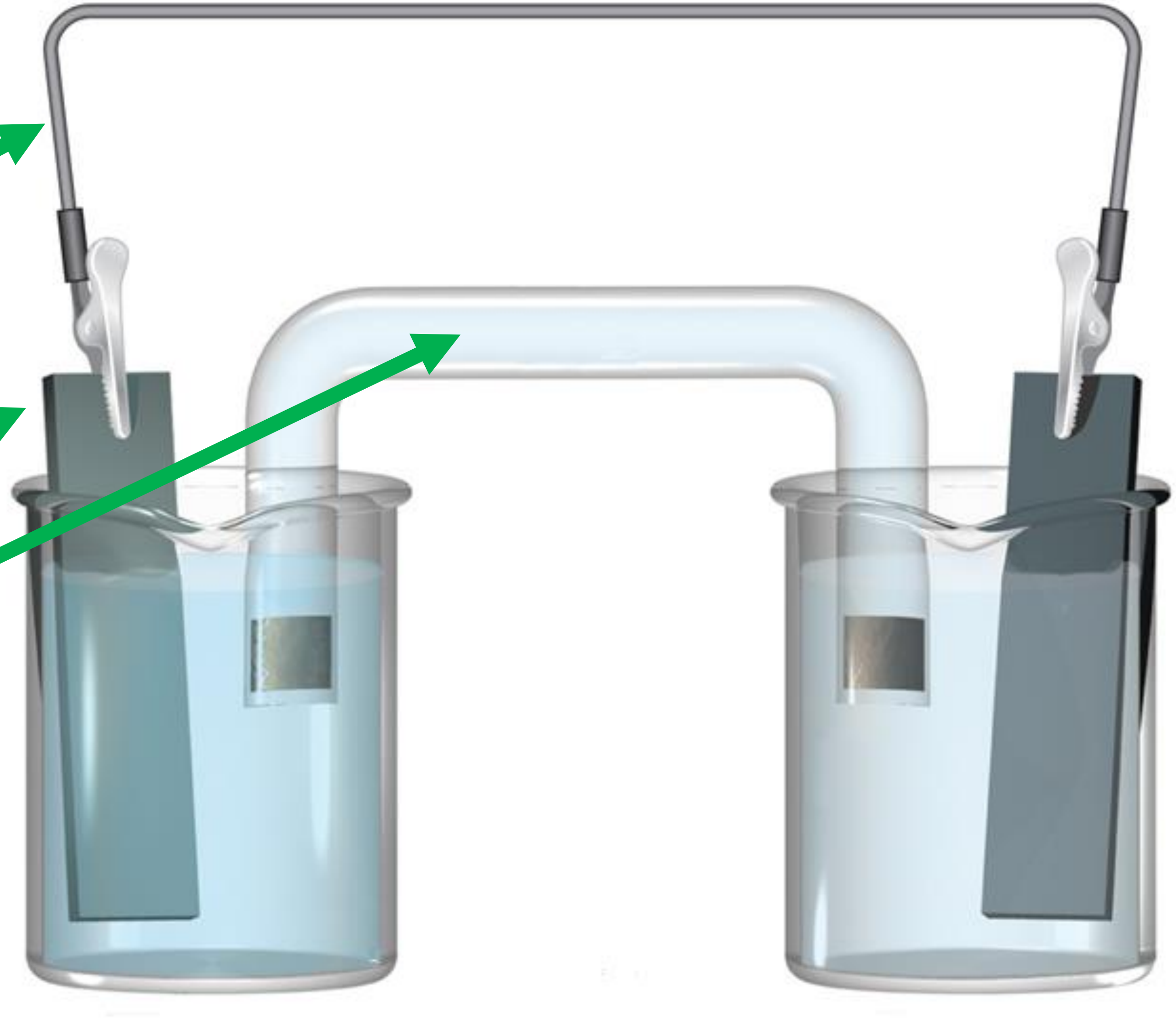
Galvanic/Voltaic Cells

- Thermodynamically favorable
- Reaction will take place spontaneously

Example: Mn and Ni

Start with basics

- ❑ Beakers
- ❑ Wire
- ❑ Electrodes
- ❑ Salt bridge



Identifying Oxidation and Reduction

Mn and Ni electrodes

Which will oxidize, which will reduce?

Look at reduction tables!

$Mn^{2+} + 2e^- \rightarrow Mn \quad E°_{red} = -1.18$ Oxidize! Lose e^-

$Ni^{2+} + 2e^- \rightarrow Ni \quad E°_{red} = -0.25$ Reduce! Gain e^-

Identifying Anode, Cathode, Electrodes

Anode

e- are being lost.

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

LEO

Oxidation

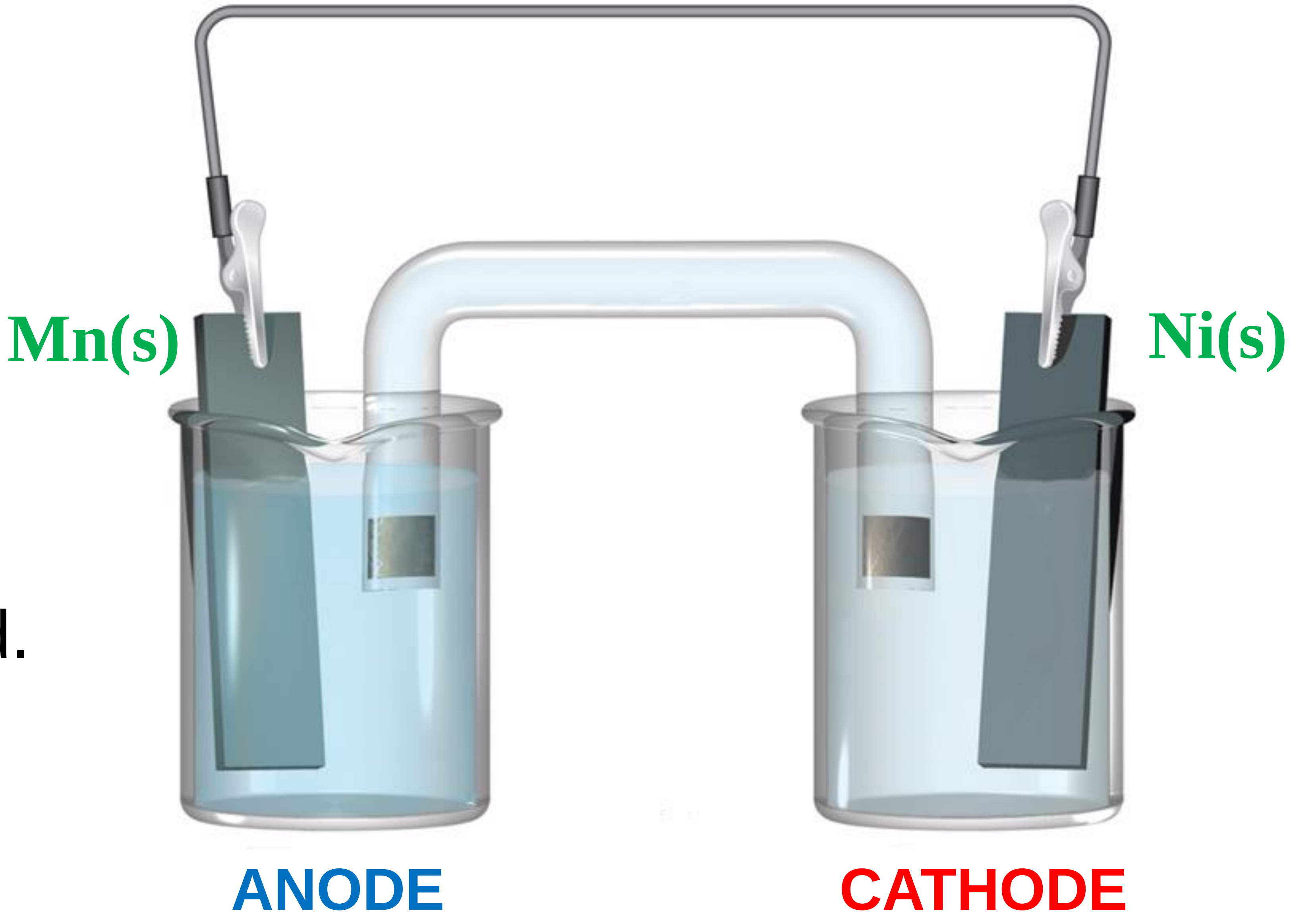
Cathode

e- are being gained.

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

GER

Reduction



Identifying Solutions

Anode

e- are being lost.

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

LEO

Oxidation

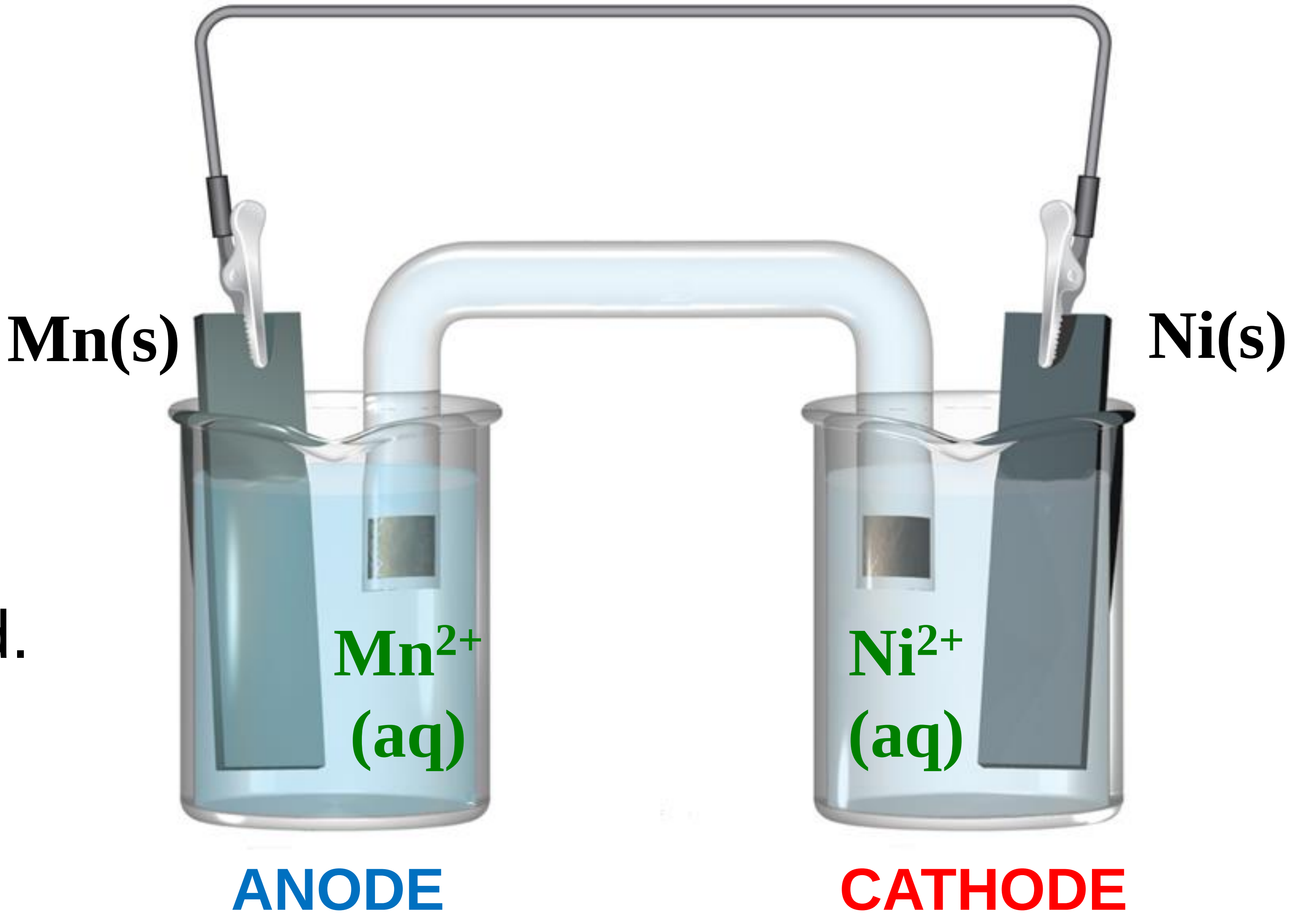
Cathode

e- are being gained.

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

GER

Reduction



Identifying Direction of Current (e^-) Flow

Anode

e- are being lost.

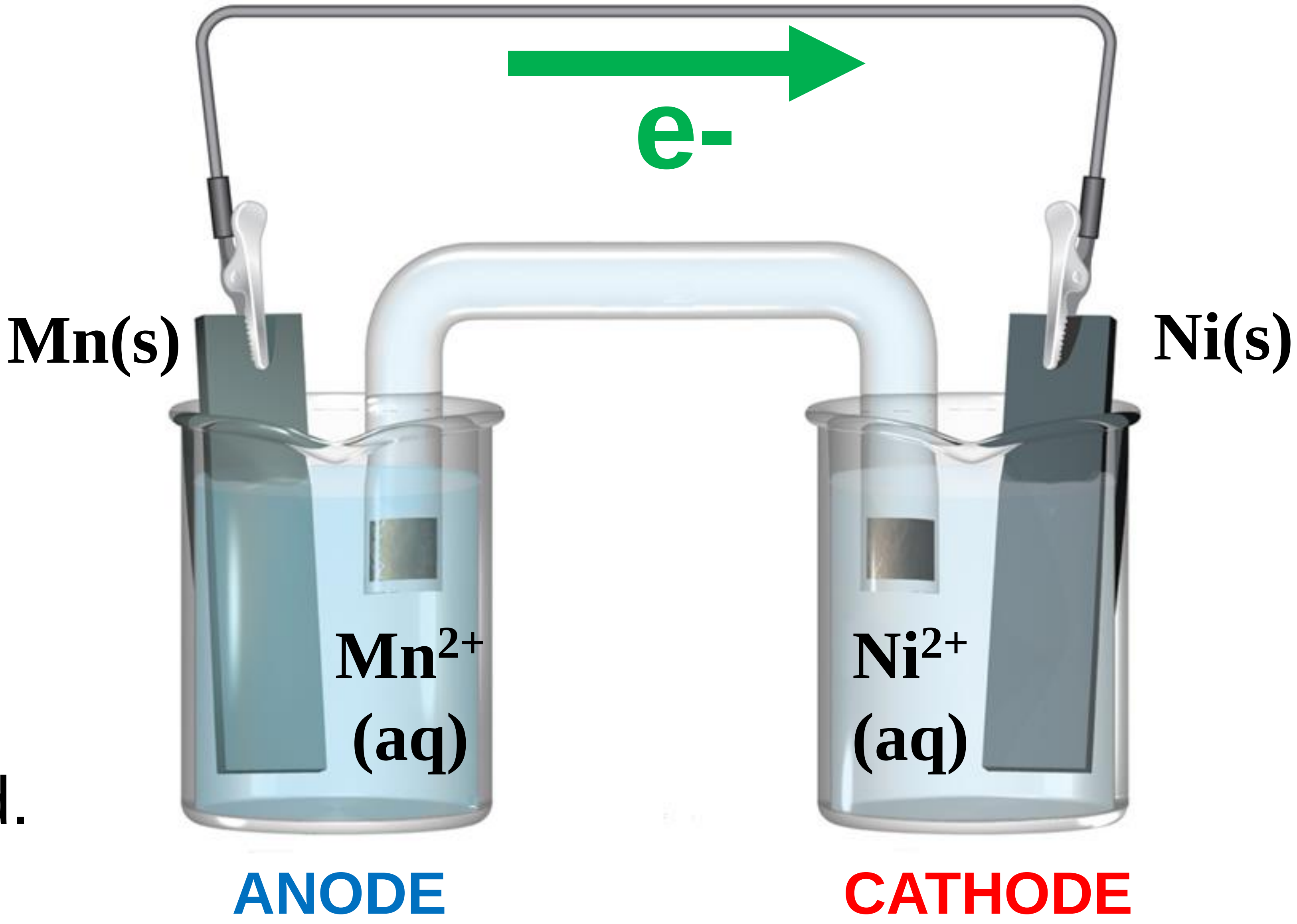
$Mn \rightarrow Mn^{2+} + 2e^-$

They leave anode and flow towards the Cathode.

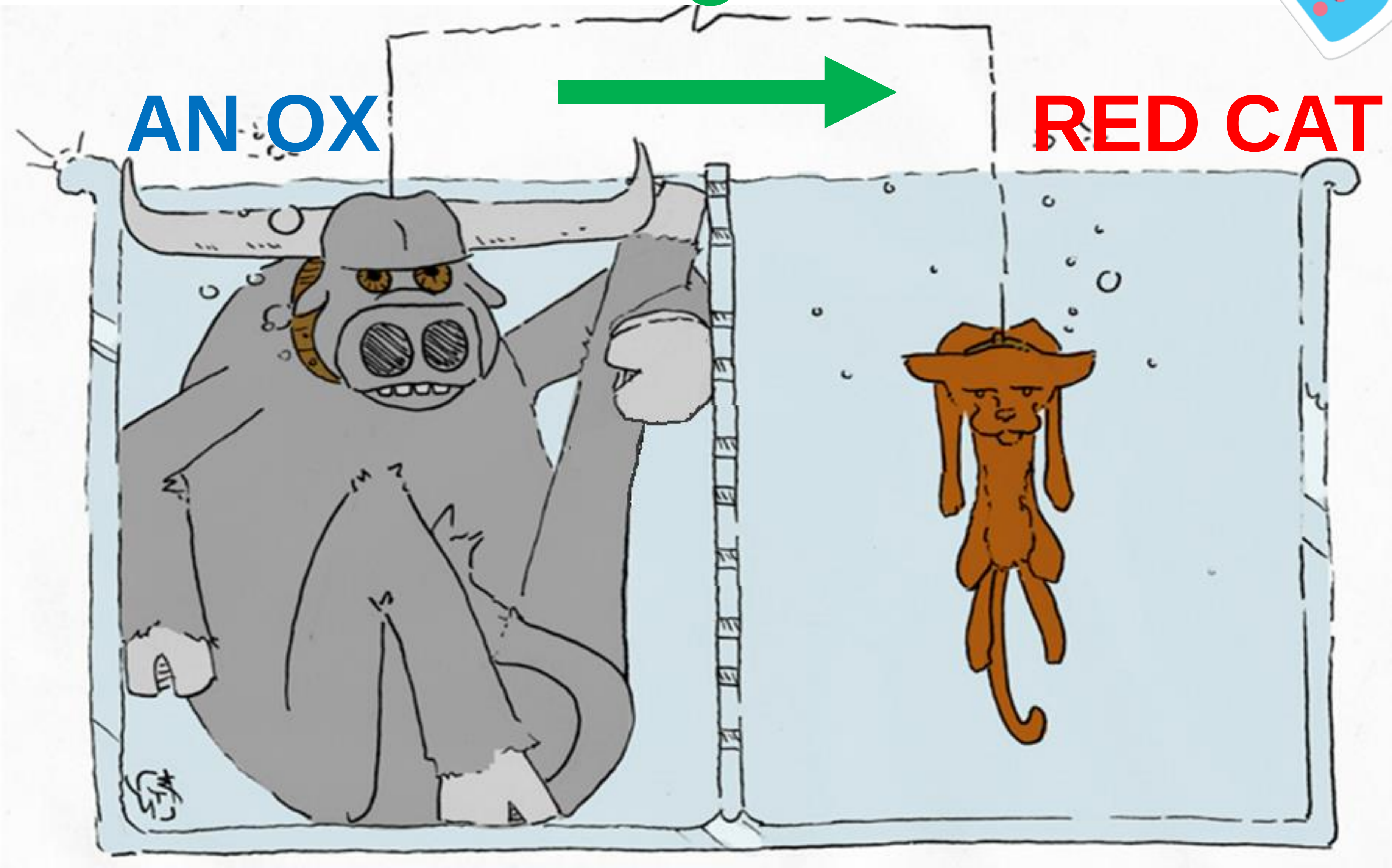
Cathode

e- are being gained.

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



a RED CAT gains, what AN OX loses



Identifying Signs on Electrodes

Anode

e- are being lost.

Source of e-

"e- rich"

- sign

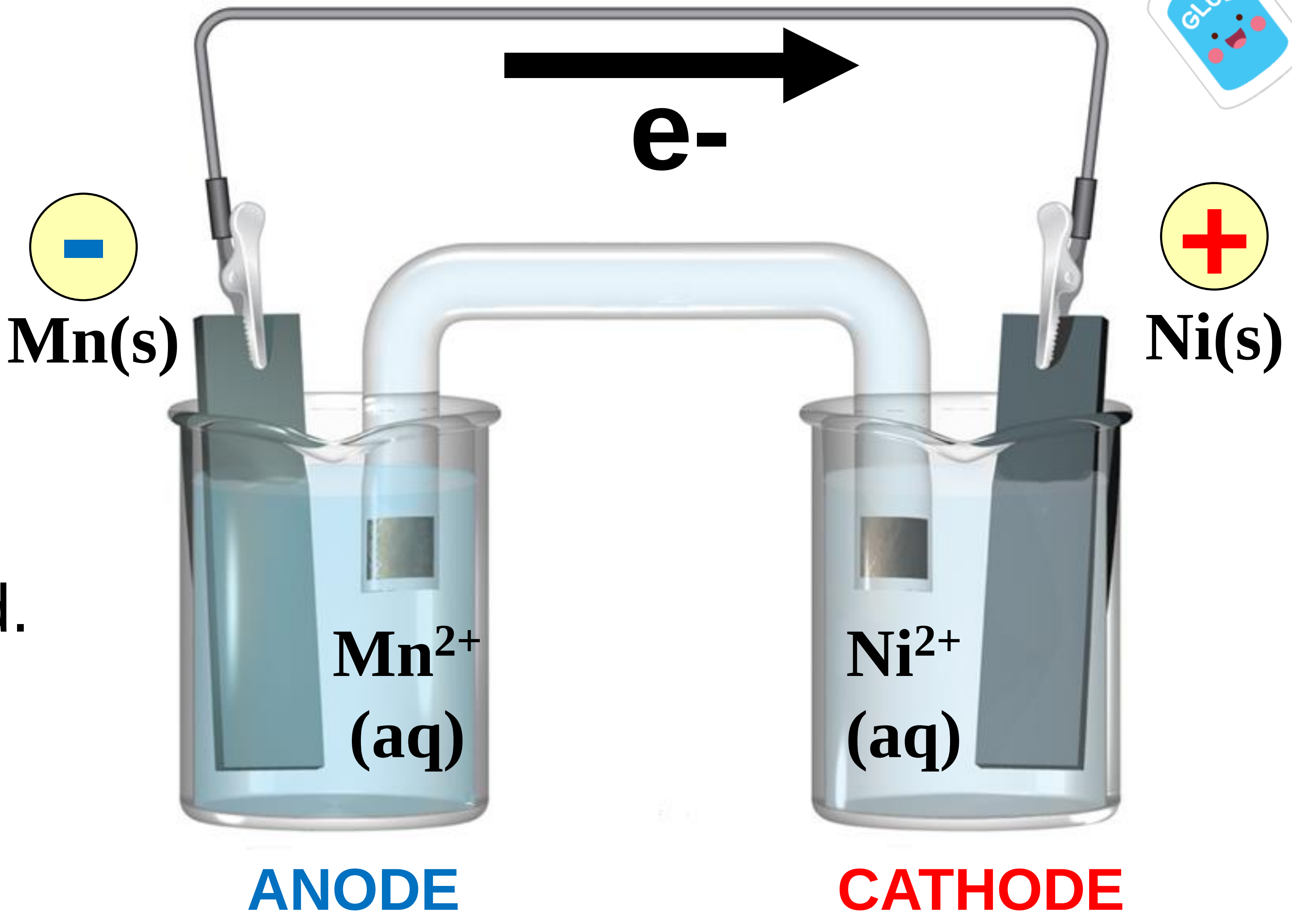
Cathode

e- are being gained.

Drawing e-

"e- deficient"

+ sign



Identifying ∆ Mass of Electrodes

Anode

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

Solid Mn turning into $Mn^{2+}(aq)$

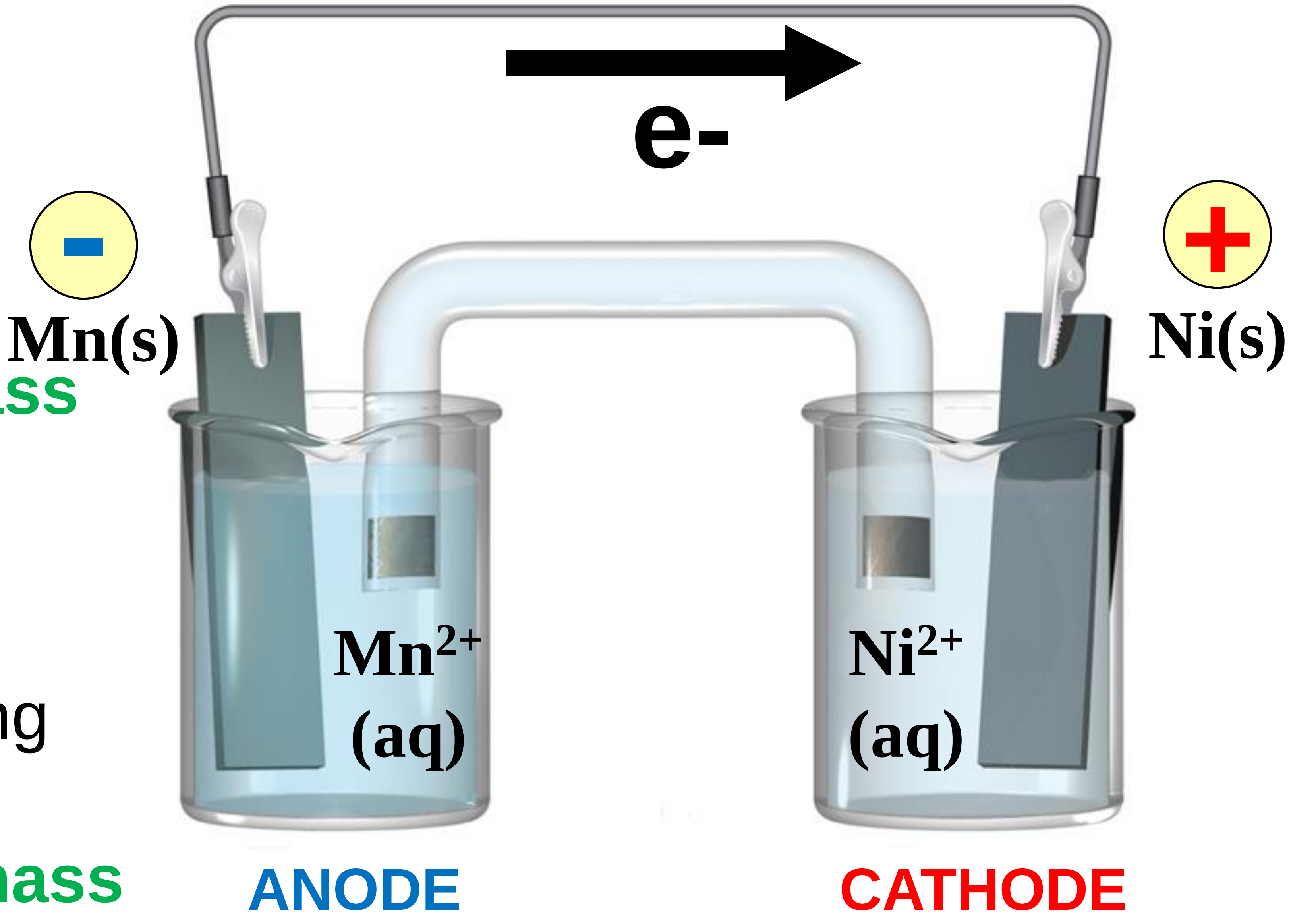
Anode LOSES mass

Cathode

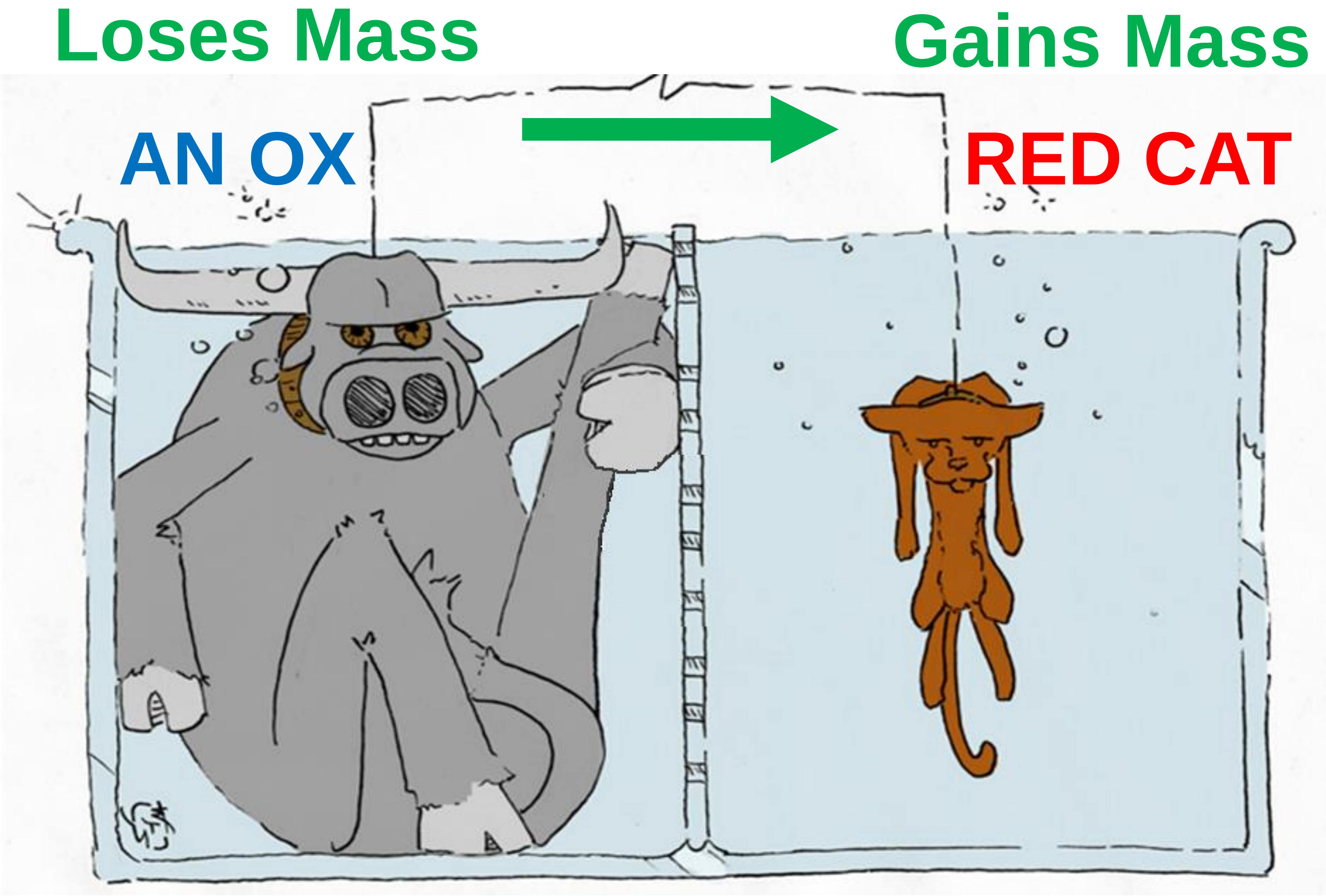
$Ni^{2+} + 2e^- \rightarrow Ni$

Aqueous Ni^{2+} turning into solid Ni metal

Cathode GAINS mass



a RED CAT gains, what AN OX loses



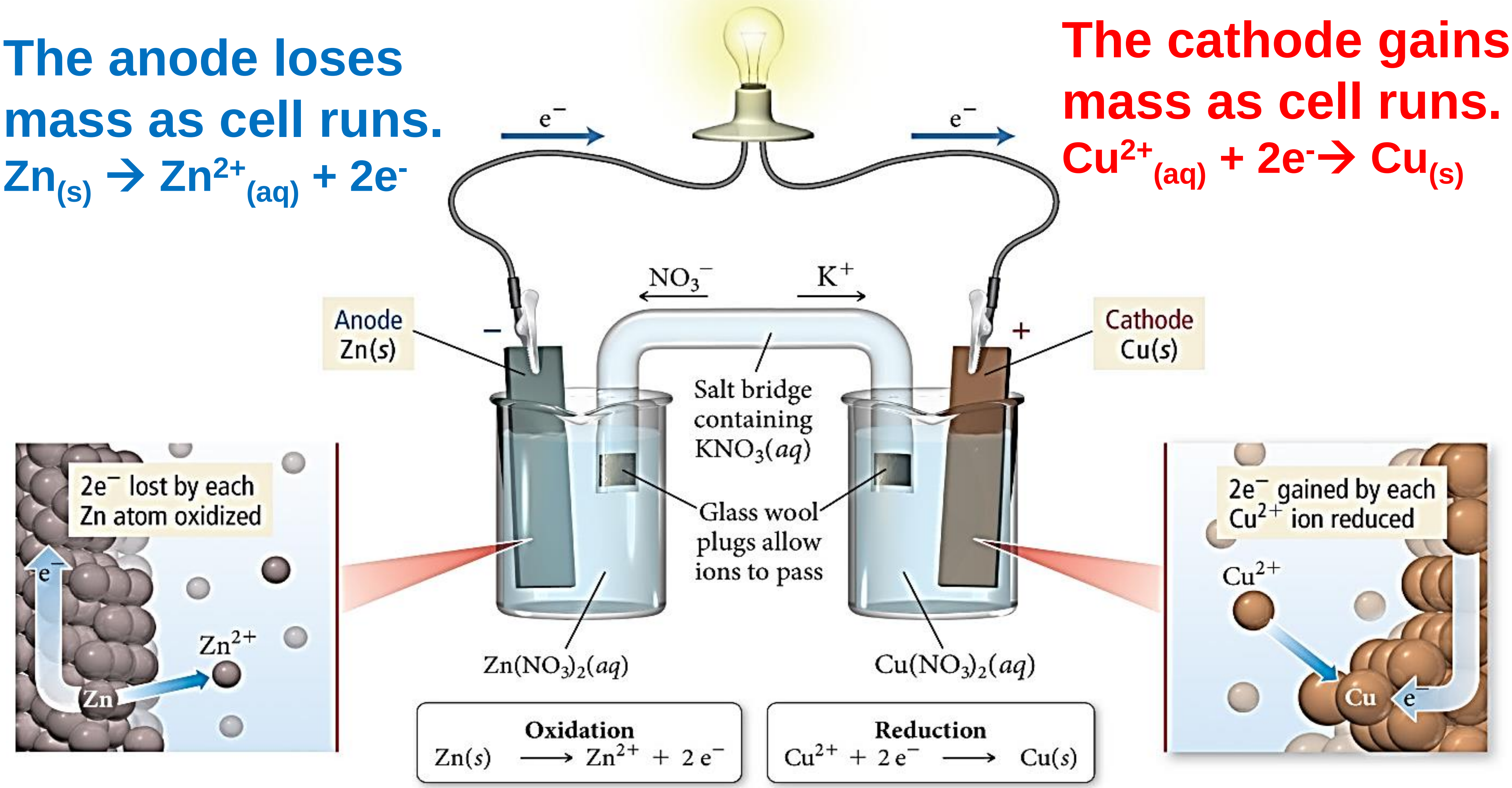
Atomic View (different electrodes)

The anode loses mass as cell runs.

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

The cathode gains mass as cell runs.

$Cu^{2+}_{(aq)} + 2e^- \rightarrow Cu_{(s)}$



Identifying Charge Balance – Salt Bridge

Anode

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

Making more Mn^{2+}

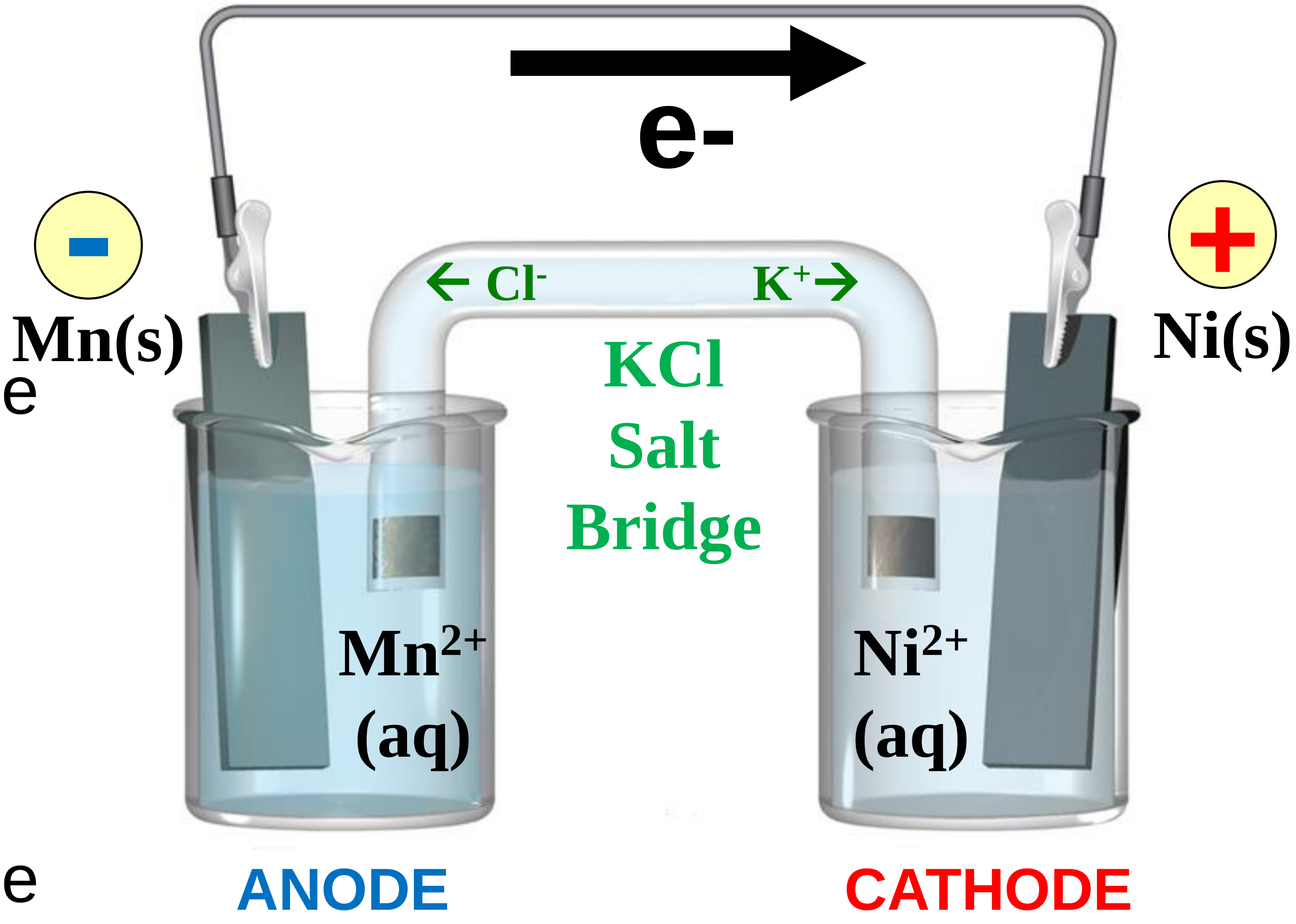
Need anions to balance new charge

Cathode

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

Using up Ni^{2+}

Need cations to balance new charge

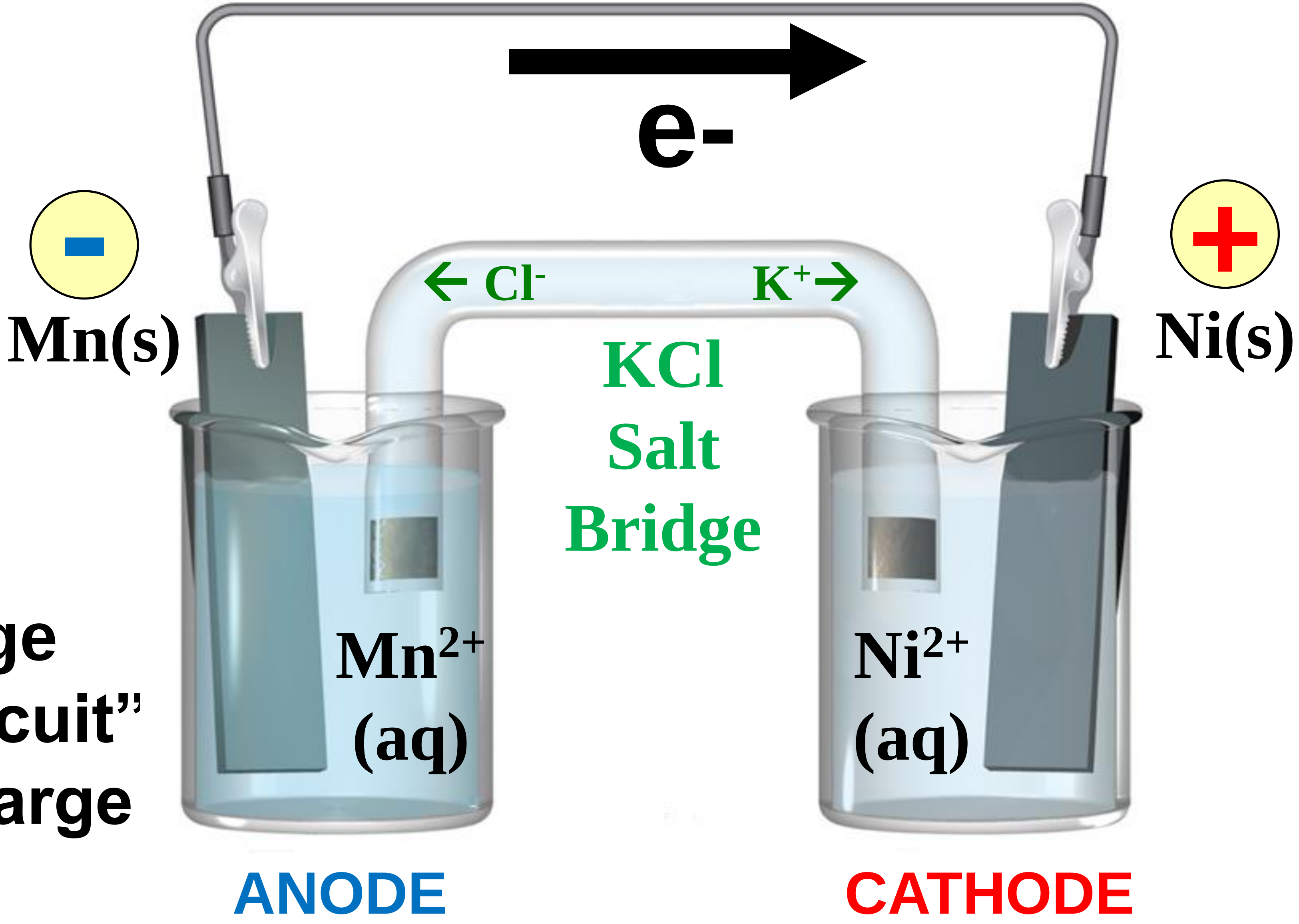


Identifying Charge Balance – Salt Bridge

No salt bridge? Charge becomes imbalanced after some time...

Cell dies!!!! ☹

Required salt bridge "completes the circuit" and "maintains charge balance"

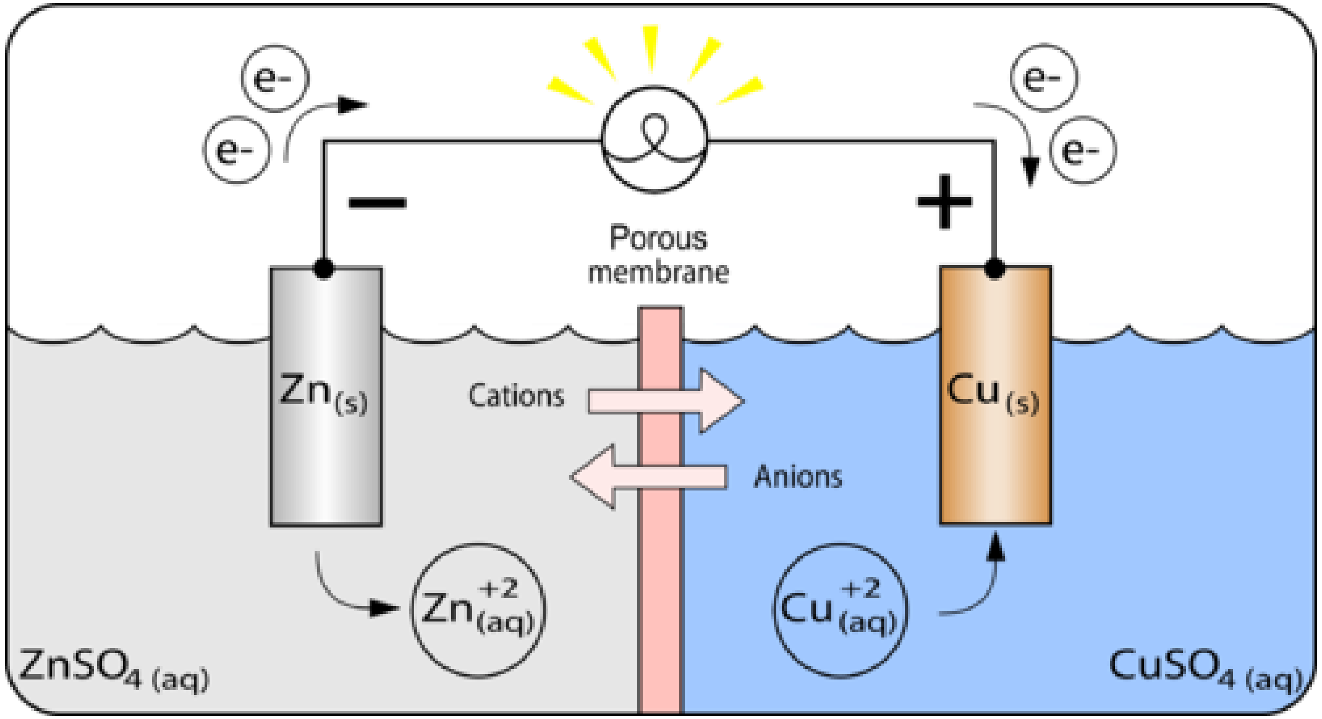


Identifying Charge Balance – Membranes

Sometimes you have a porous membrane partition instead of a salt bridge

Allows select ions to flow between sections

Still allows charge balance and complete circuit



Summary of Electrodes

Anode

- Electrode where oxidation occurs (loss of e^-)
- Anions from salt bridge attracted to it because cations being made.
- Loses weight

Cathode

- Electrode where reduction occurs (gain of e-)
- Cations from salt bridge attracted to it because losing cations.
- Gains weight
  - Electrode where “plating” takes place in electroplating

Electrolytic Cells

- NOT Thermodynamically favorable
- Reaction will NOT take place spontaneously
- Requires an outside electrical source to force it to happen!

What would you predict for Red and Ox?

Zn and Cu

$Zn^{2+} + 2e^{-} \rightarrow Zn \quad E°_{red} = -0.76$ Oxidize! Lose e^{-}

$Cu^{2+} + 2e^{-} \rightarrow Cu \quad E°_{red} = 0.34$ Reduce! Gain e^{-}

BUT!

What if you WANT to do the opposite???

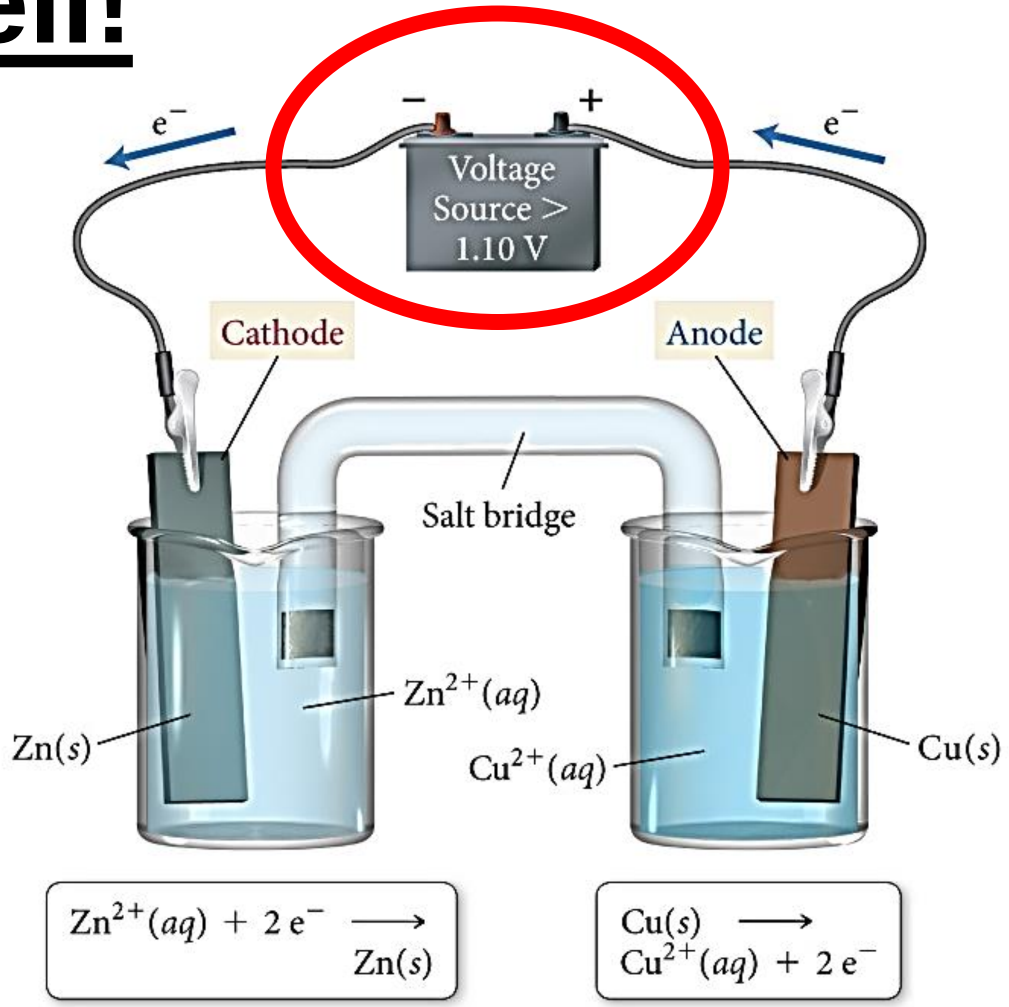
What if you want to make Zn(s) not Cu(s)???

Make it an Electrolytic Cell!

Force it to go the other way, the non-thermodynamically favorable way!

Hook it up to an outside electrical source.

Will DRIVE the electrons the other direction, against their normal flow.



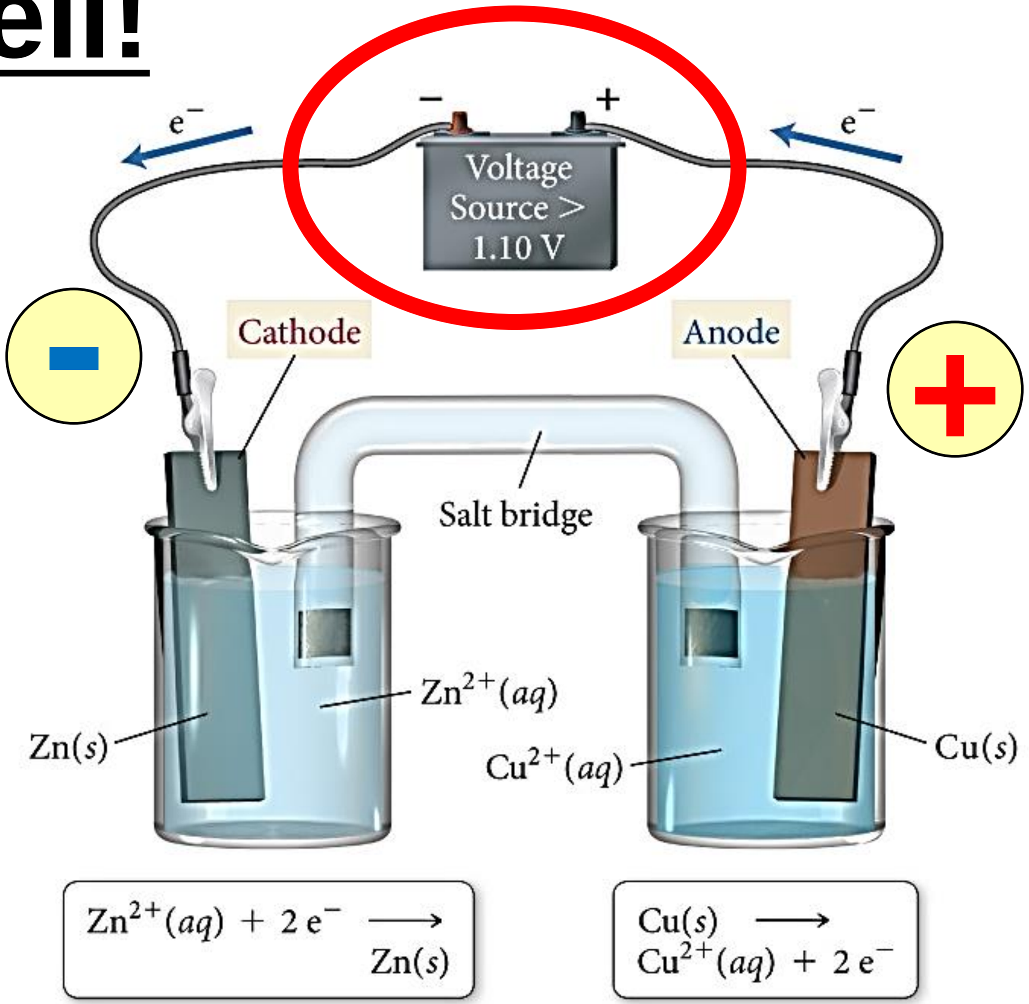
Make it an Electrolytic Cell!

STILL label loss of e- as anode
STILL label gain of e- as cathode
STILL show e- flow to cathode
STILL use salt bridge the same
anions towards anode
cations towards cathode

BUT...

Anode +   Cathode –

e^- coming off anode need to go to the + end of the voltage source, and they leave – end of voltage source



Galvanic versus Electrolytic Cells

Galvanic

- Converts chemical energy into electrical energy.
- Positive cell potential, $E°_{cell} = +$
- Spontaneous, $\Delta G = -$
- Anode = - and Cathode = +
- Electrons supplied by the chemical being oxidized.
- Electrons flow from anode to cathode.

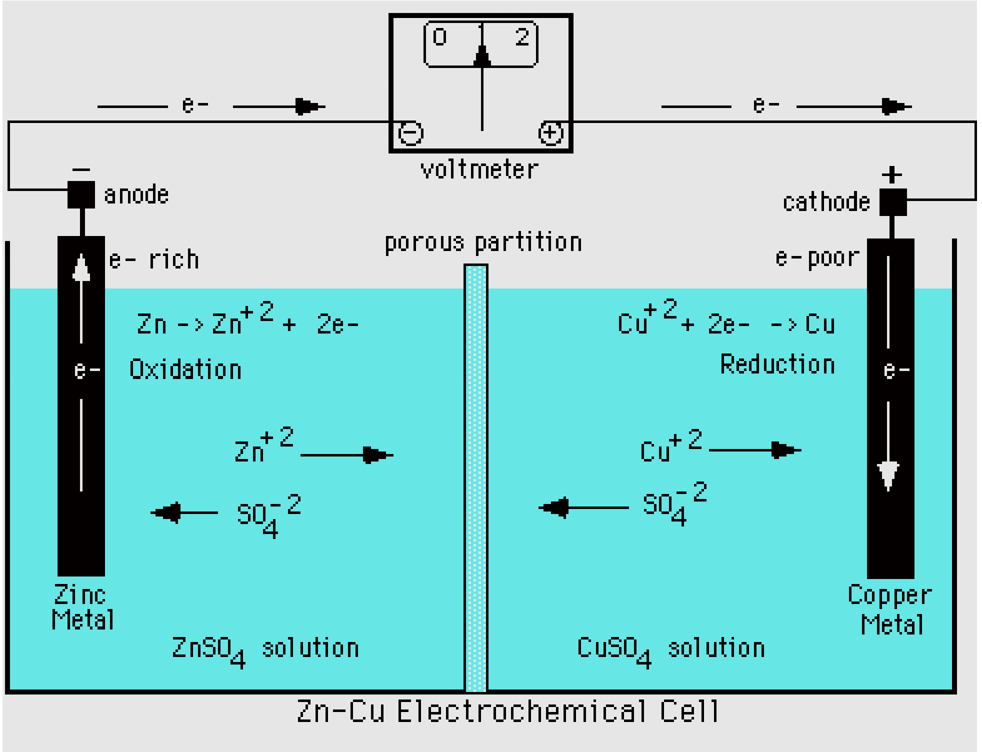
Electrolytic

- Converts electrical energy into chemical energy
- Negative cell potential, $E°_{cell} = -$
- NOT spontaneous, $\Delta G = +$
- Anode = + and Cathode = -
- Electrons supplied by an external source
- Electrons enter from the cathode and come out at the anode.

Galvanic or Electrolytic?

Zn - Cu

From a table of reduction potentials:



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

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

Cu more positive = reduced

Zn more negative = oxidized

flip eq and sign on E for Zn

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

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

E = (+0.76) + (+0.34) = +1.10 V

E = + so galvanic, spontaneous, ΔG = -

Galvanic or Electrolytic?

A cell is undergoing this rxn:

$2NaCl \rightarrow 2Na + Cl_2$

Careful!

Equation is telling you **that Na is going from $Na^+ \rightarrow Na$**
It is being reduced even though the table shows it would rather be oxidized!!!!

And $2Cl^- \rightarrow Cl_2$ so it is being oxidized even though it would rather be reduced!

$Na^+ + e^- \rightarrow Na$ E = -2.71V

$Cl_2 + 2e^- \rightarrow 2Cl^-$ E = 1.36V

Told that Na^+ = reduced

Told that Cl- = oxidized

flip eq and sign on E for Cl^-

$Na^+ + e^- \rightarrow Na$ E = -2.71V

$2Cl^- \rightarrow Cl_2 + 2e^-$ E = -1.36V

E = (-2.71) + (-1.36) = -4.07 V

E = - so electrolytic, NON-spontaneous, ΔG = +

Galvanic or Electrolytic?

A cell is undergoing this rxn:

$2NaCl \rightarrow 2Na + Cl_2$

$Na^+ + e^- \rightarrow Na$ E = -2.71V

$Cl_2 + 2e^- \rightarrow 2Cl^-$ E = 1.36V

Told that Na^+ = reduced

Told that Cl- = oxidized

flip eq and sign on E for Cl^-

This cell won't run by itself! You need to hook it up to an outside electrical supply!

$Na^+ + e^- \rightarrow Na$ E = -2.71V

$2Cl^- \rightarrow Cl_2 + 2e^-$ E = -1.36V

E = (-2.71) + (-1.36) = -4.07 V

E = - so electrolytic, NON-spontaneous, ΔG = +

Cell (Line) Notation

Shorthand description of a voltaic cell

Electrode | electrolyte || electrolyte | electrode

Oxidation half cell side ***Reduction half cell side***

- Single | = phase barrier

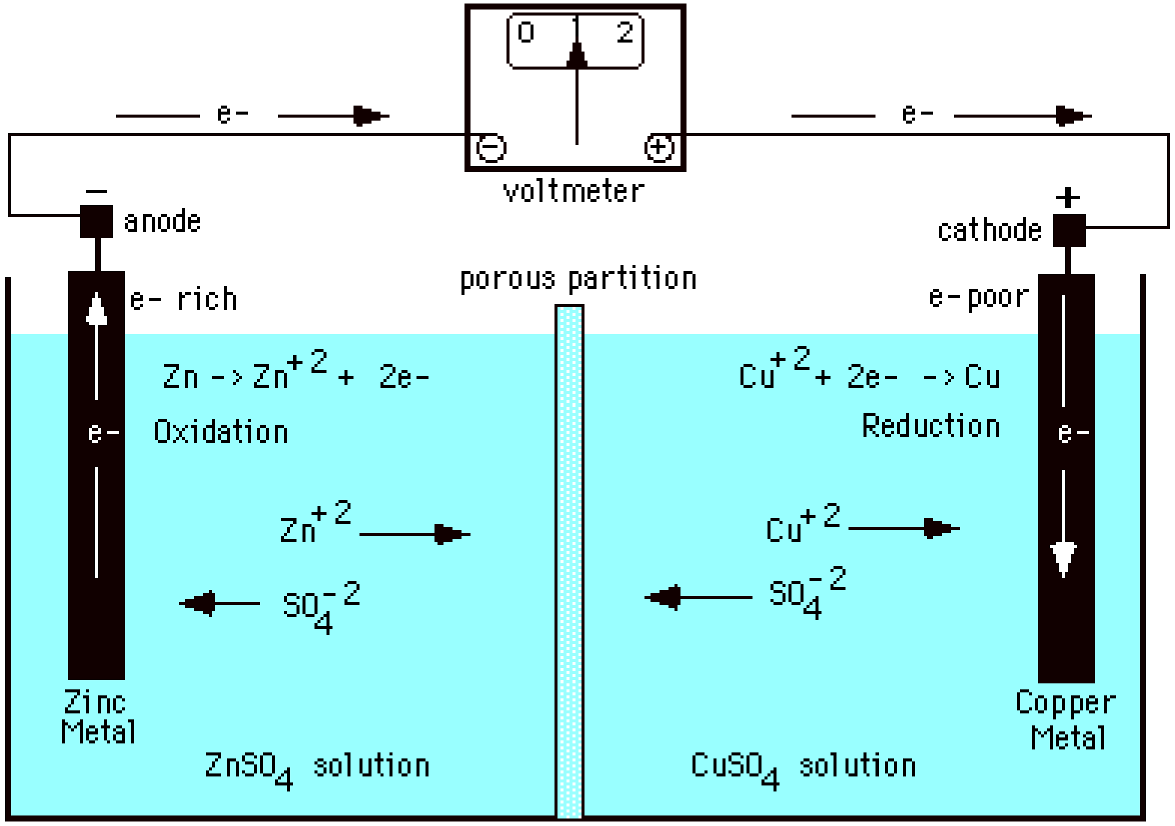
  If multiple electrolytes in same phase, a comma is used rather than **|**

  – Often use an **inert electrode**

  – Sometimes they put the concentrations in also

- Double line || = salt bridge

Line Notation



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

Anode material | Anode solution || Cathode solution | Cathode material

Requirements for Drawing/Labeling a Cell

- ❑ Determine what is reduced vs. oxidized (E°_{cell} values, OR told which rxn to do)
- ❑ Beaker/container for anode and cathode AND liquid line drawn for each beaker
- ❑ Anode/cathode metal strips drawn submerged in liquid
- ❑ Label which solution/ions are in each beaker
- ❑ Label which beaker is anode and cathode
- ❑ Label anode/cathode strips with which solid metal each is
- ❑ Label anode and cathode with correct -/+ depending on if it is a galvanic cell (A-/C+) or electrolytic cell (A+/C-).
- ❑ Write the half reactions for each beaker
- ❑ Wire connecting anode/cathode strips together
- ❑ Label direction of e- flow along wire at top of drawing (anode → cathode always)
- ❑ Salt bridge submerged in liquid on both sides
- ❑ Label direction of ion flow inside salt bridge (anions flowing to anode, cations flowing to cathode)

Practice! Zn and Cu electrodes, $ZnSO_4$, $CuSO_4$

- ❑ Determine what is reduced vs. oxidized ($E°_{cell}$ values, OR told which rxn to do)
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KCl salt bridge, Galvanic

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

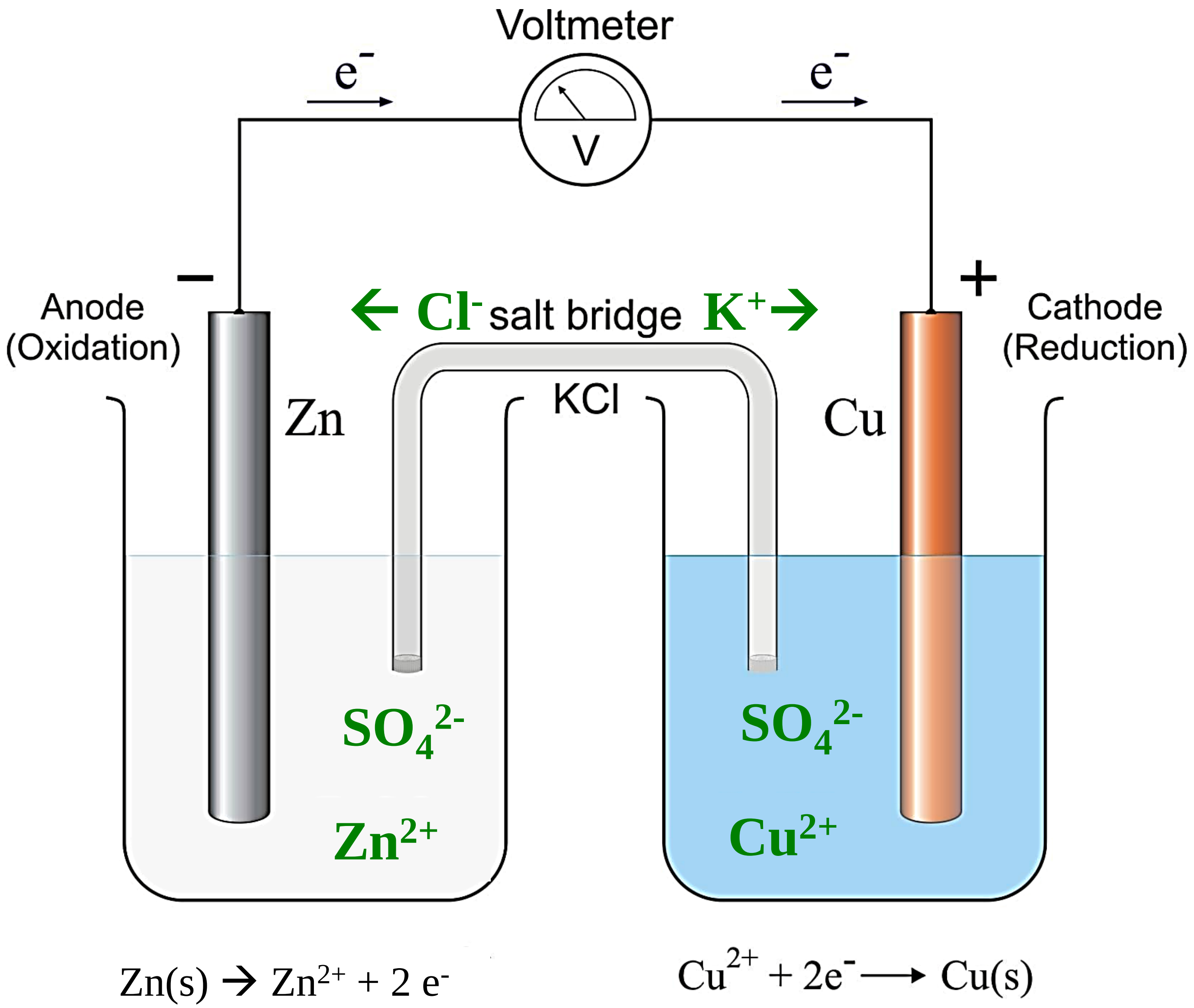
$E°_{cell} = -0.76$

Oxidized - Anode

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

$E°_{cell} = 0.34$

Reduced - Cathode



$Zn(s) \mid ZnSO_4(aq) \parallel CuSO_4(aq) \mid Cu(s)$

YouTube Link to Presentation

https://youtu.be/RRnWnKfYVDc