Essential Question

What does voltage tell us about a reaction?

The Sign of $E°_{cell}$

- $E°_{cell}$ = cell voltage at standard conditions
- Its sign tells us if the reaction is favored

$E°_{cell} > 0$
thermodynamically favored
(galvanic cell)

$E°_{cell} < 0$
unfavored, needs applied voltage
(electrolytic cell)

Standard Reduction Potentials

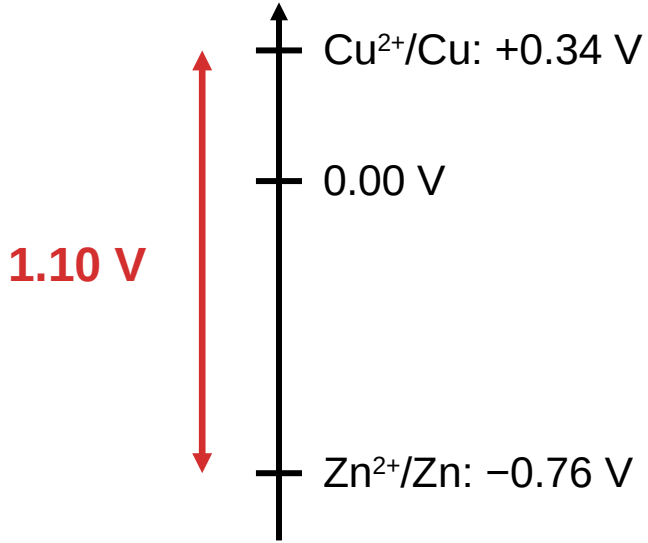
- Every half-reaction is written as a reduction
- Higher $E°$ → easier to reduce

Half-reaction	$E°$ (V)
$Ag^+(aq) + e^- \rightarrow Ag(s)$	+0.80
$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	+0.34
$2H^+(aq) + 2e^- \rightarrow H_2(g)$	0.00
$Ni^{2+}(aq) + 2e^- \rightarrow Ni(s)$	−0.25
$Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$	−0.76
$Al^{3+}(aq) + 3e^- \rightarrow Al(s)$	−1.66
$Mg^{2+}(aq) + 2e^- \rightarrow Mg(s)$	−2.37

Calculating $E°_{cell}$

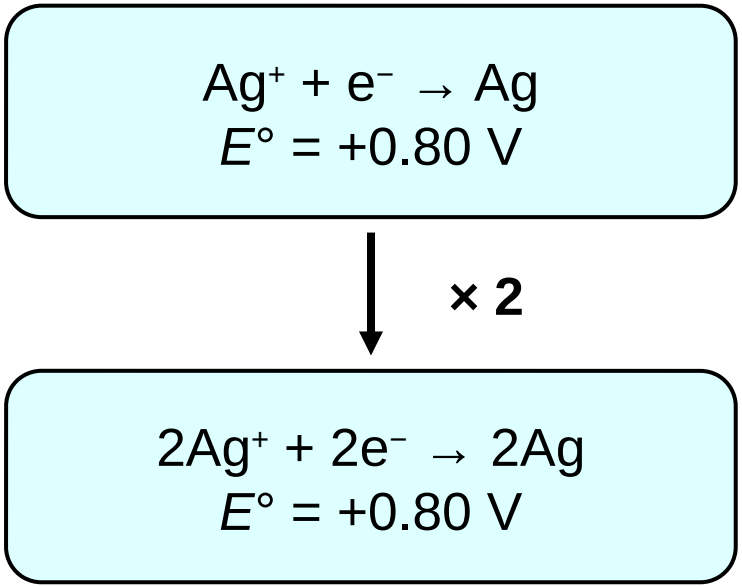
$$E°_{cell} = E°_{cathode} - E°_{anode}$$

- Use both reduction potentials as listed
- The minus sign takes care of the oxidation



Never Multiply *E*°

- *E*° is in volts: 1 V = 1 J/C
- Double the reaction: double the J and the C
- J/C stays the same, so *E*° stays the same



Not 1.60 V!

Writing the Overall Reaction

- Multiply so e^- lost = e^- gained
- *n* = moles of e^- transferred

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

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

***n* = 2 mol e^-**

Free Energy from $E°$

$$\Delta G° = -nFE°$$

n = mol e^- transferred	F = 96,485 C/mol e^-	$E°$ in volts 1 V = 1 J/C

C × J/C = J, then divide by 1000 for kJ

Opposite Signs

$E°_{cell}$	$\Delta G°$	Thermodynamically favored?
+ (positive)	− (negative)	Yes (galvanic)
− (negative)	+ (positive)	No, needs applied voltage

$\Delta G°$ and $E°_{cell}$ always have opposite signs

Example: Calculating $E°_{cell}$

Calculate $E°_{cell}$ for a galvanic cell that runs this reaction.

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

Half-reaction	$E°$ (V)
$Ag^{+}(aq) + e^{-} \rightarrow Ag(s)$	+0.80
$Cu^{2+}(aq) + 2e^{-} \rightarrow Cu(s)$	+0.34

Example: Finding *n*

How many moles of electrons (*n*) are transferred in this reaction?

$$2MnO_4^- + 16H^+ + 10Cl^- \rightarrow 2Mn^{2+} + 5Cl_2 + 8H_2O$$

Example: Calculating $\Delta G°$

This cell has $E°_{cell}$ = +1.41 V. Calculate $\Delta G°$ in kJ/mol_{rxn}.

$$2Al(s) + 3Ni^{2+}(aq) \rightarrow 2Al^{3+}(aq) + 3Ni(s)$$

F = 96,485 C/mol e^-

Example: Is It Favored?

Is this reaction thermodynamically favored under standard conditions? Justify your answer.

$$Ni(s) + Mg^{2+}(aq) \rightarrow Ni^{2+}(aq) + Mg(s)$$

Half-reaction	$E°$ (V)
$Ni^{2+}(aq) + 2e^- \rightarrow Ni(s)$	−0.25
$Mg^{2+}(aq) + 2e^- \rightarrow Mg(s)$	−2.37

Cell Potential and Free Energy

Big Ideas

- $E°_{cell} = E°_{cathode} - E°_{anode}$
- Never multiply $E°$ by coefficients
- $\Delta G° = -nFE°$, then J → kJ
- $E°_{cell} > 0$ → favored

$E° > 0, \Delta G° < 0$
favored

$E° < 0, \Delta G° > 0$
unfavored