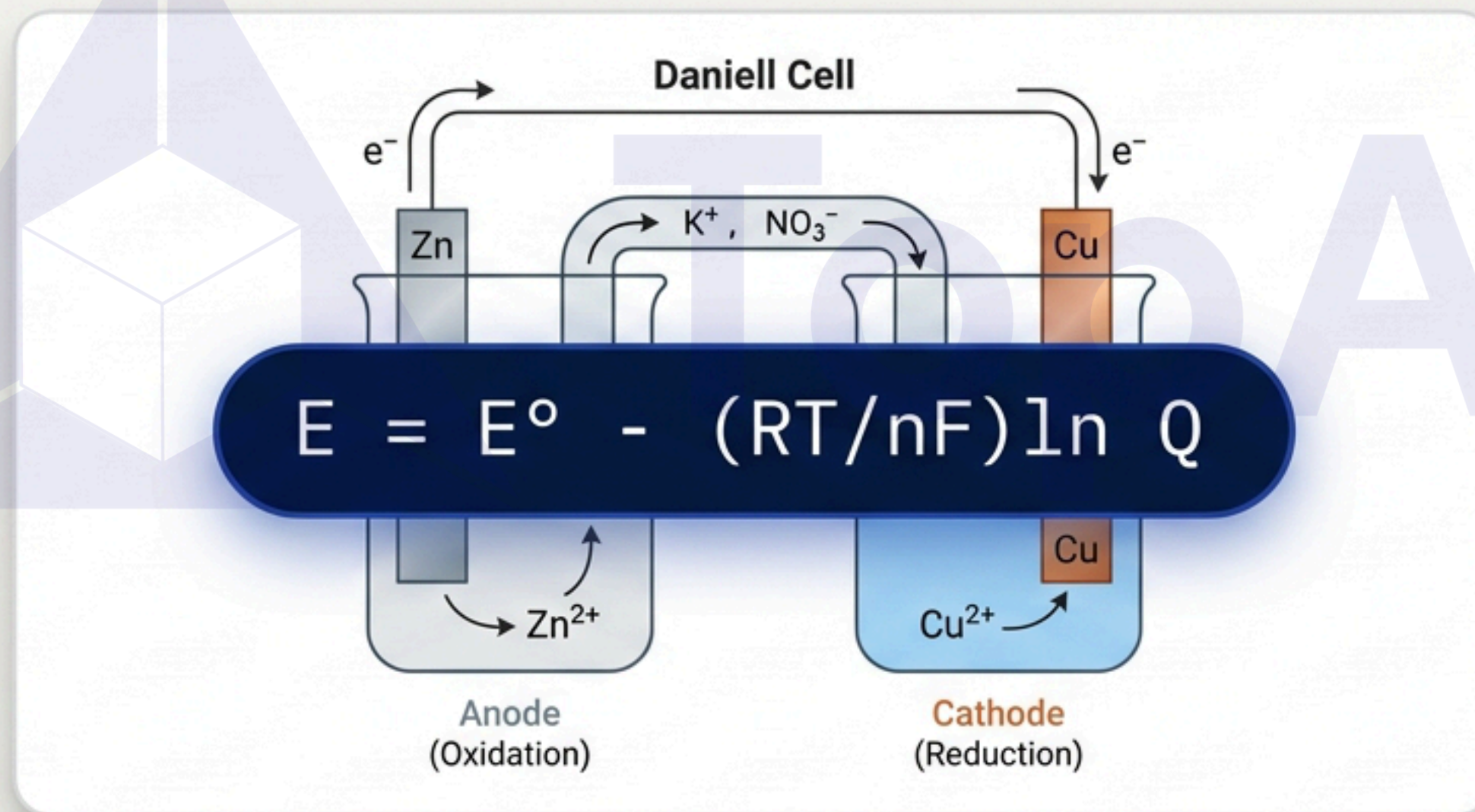


2.3 Nernst Equation

Moving Beyond Standard Conditions to Calculate Real Cell Potential.



The Limit of E° (Standard Potential)

The Ideal (Standard Conditions)



[Ion] = 1 M

T = 298 K

P = 1 bar

Standard Electrode Potential (E°) assumes all species remain strictly at unit concentration.

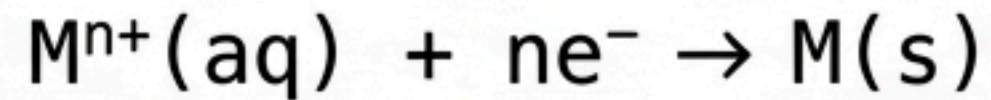
The Reality (Real Batteries)



In real galvanic cells, concentrations change constantly as the reaction proceeds. Reactants are consumed, and products build up. The voltage drops over time.

We need a mathematical model that adapts to dynamic concentrations. **Enter the Nernst Equation.**

Deriving the Half-Cell Equation



$$E_{(\text{M}^{n+}/\text{M})} = E^{\circ}_{(\text{M}^{n+}/\text{M})} - (RT/nF) * \ln(1/[\text{M}^{n+}])$$

R = Gas constant
(8.314 J/K·mol)

T = Temperature in
Kelvin

n = Number of
electrons transferred

F = Faraday constant
(96487 C/mol)



Solid State Rule: The concentration of a solid metal [M] is taken as **unity** (1). The general formula $\ln([M] / [\text{M}^{n+}])$ simplifies cleanly to: $\ln(1 / [\text{M}^{n+}])$.



You've Learned the Theory. Let's Test Them Now.

$$E=mc^2$$



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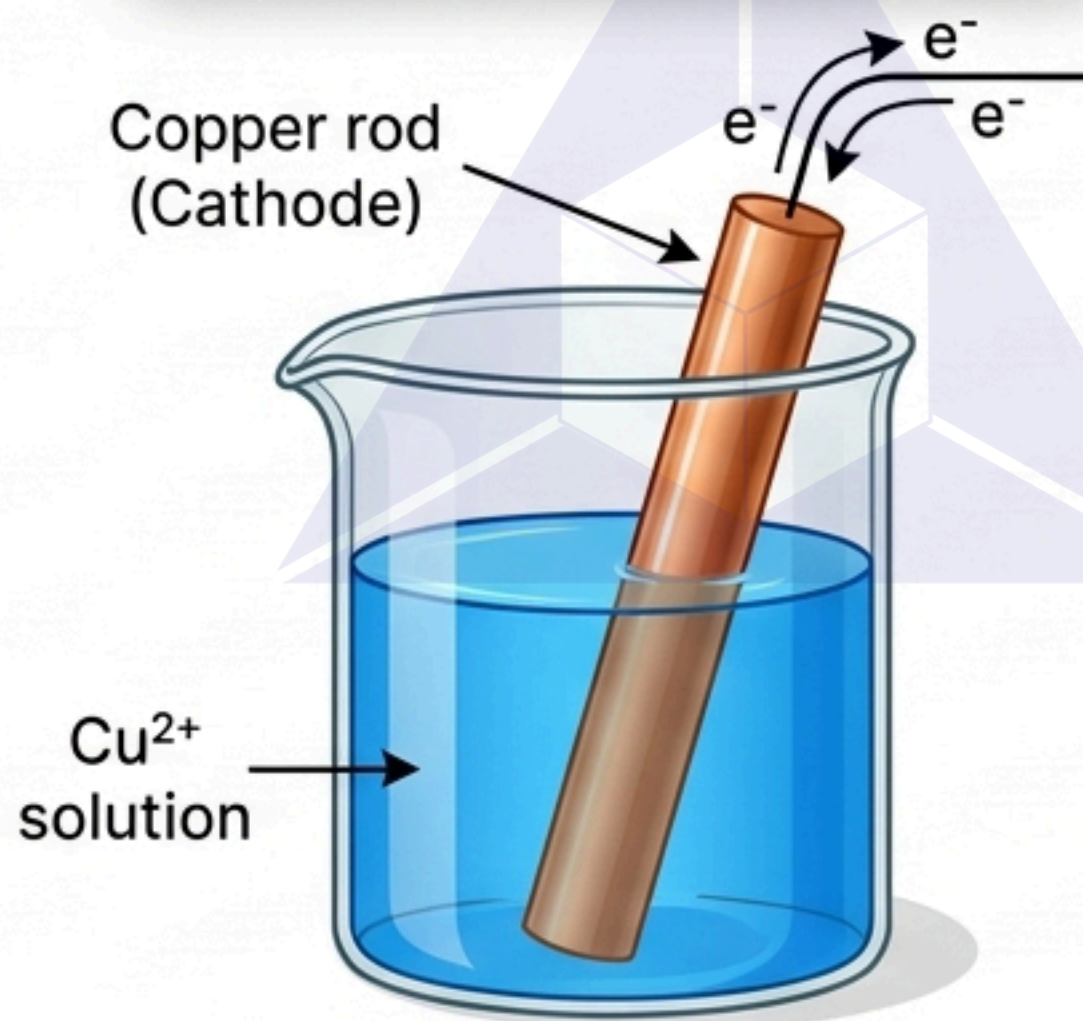
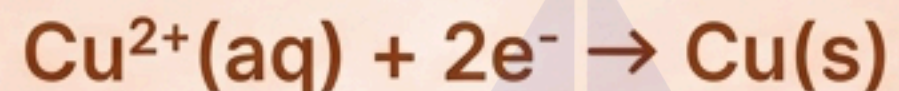
Key Highlights

- » Free Study Material, Videos & Infographics
- » Push Your Limits with Level-Based Challenges
- » Climb the Leaderboard Among Fellow Aspirants
- » Practice Unlimited MCQs for NEET & JEE
- » Get Clear Explanations, Not Just Marks
- » Track Your Performance Smarter



Step 1: Reduction

The Copper Half-Cell (Cathode)



$$E_{(\text{Cu}^{2+}/\text{Cu})} = E^{\circ}_{(\text{Cu}^{2+}/\text{Cu})} - \frac{RT}{2F} \ln \left(\frac{1}{[\text{Cu}^{2+}]} \right)$$

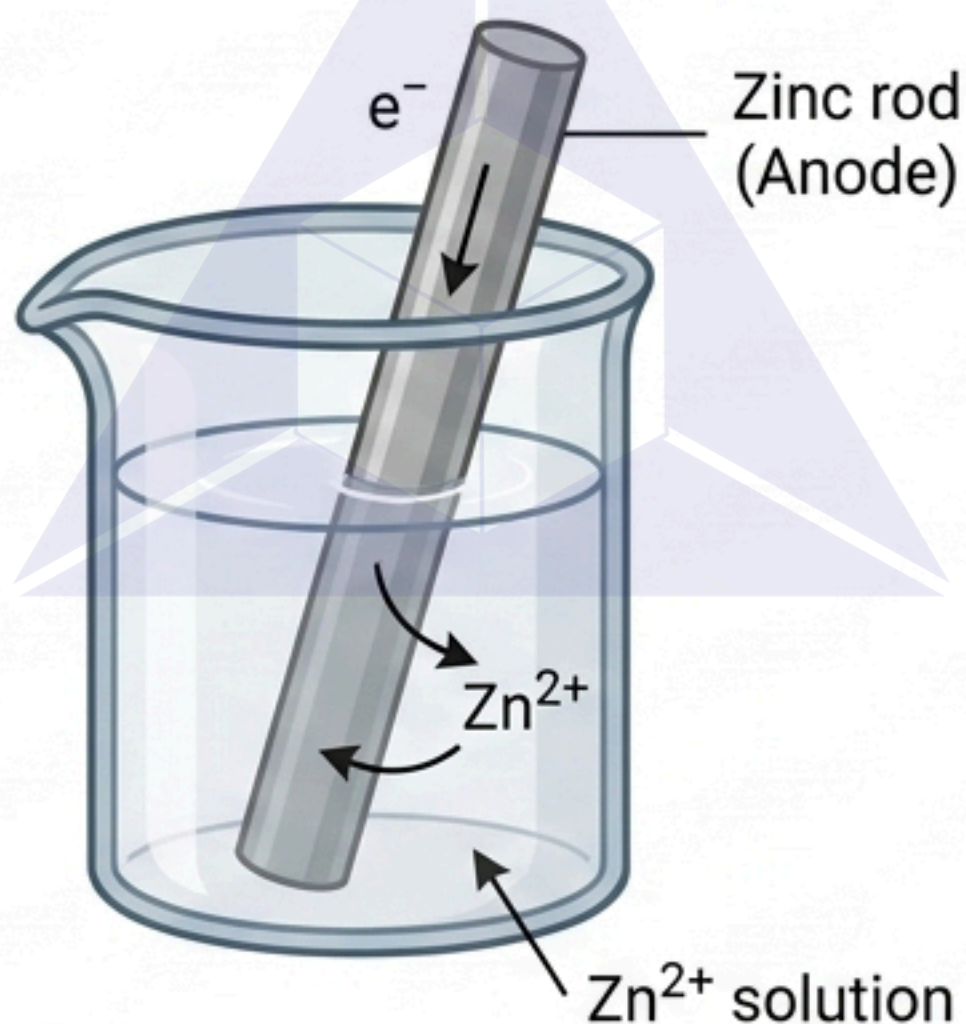
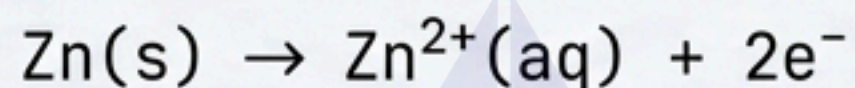
- Why $n = 2$? Because exactly 2 electrons are gained by each Copper ion. e^{-}

Cu^{2+}

- The Concentration Relationship: As $[\text{Cu}^{2+}]$ decreases during the reaction, the actual reduction potential $E_{(\text{Cu}^{2+}/\text{Cu})}$ decreases.

Step 2: Oxidation

The Zinc Half-Cell (Anode)



$$E_{(\text{Zn}^{2+}/\text{Zn})} = E^{\circ}_{(\text{Zn}^{2+}/\text{Zn})} - \frac{RT}{2F} \ln \left(\frac{1}{[\text{Zn}^{2+}]} \right)$$

- Consistency Check: Per IUPAC convention, notice we still write the Nernst equation using the reduction potential format, even for the anode.
- The Concentration Relationship: As $[\text{Zn}^{2+}]$ increases during the reaction, the reduction potential $E_{(\text{Zn}^{2+}/\text{Zn})}$ decreases.

Merging into the Full Cell Potential

$$E_{\text{cell}} = E_{\text{cathode}} - E_{\text{anode}}$$



$$\ln(1)/[\text{Cu}^{2+}] - \ln(1)/[\text{Zn}^{2+}] = \ln([\text{Zn}^{2+}]/[\text{Cu}^{2+}])$$



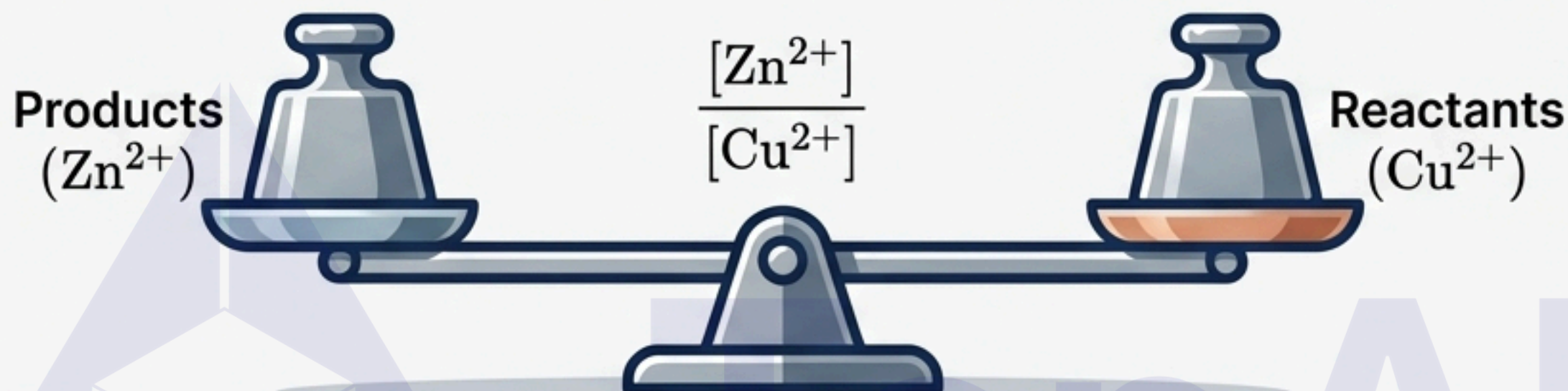
$$E_{\text{cell}} = E^{\circ}_{\text{cell}} - (RT/2F) * \ln([\text{Zn}^{2+}] / [\text{Cu}^{2+}])$$



At 298 K (25°C), substituting R, T, and F, and converting from natural log (ln) to base-10 log (log₁₀) yields the magic constant 0.059.

$$E_{\text{cell}} = E^{\circ}_{\text{cell}} - (0.059/2) * \log([\text{Zn}^{2+}] / [\text{Cu}^{2+}])$$

How Concentration Drives the Voltage



A Fresh Battery

When **Reactants** > **Products**:
 $[\text{Cu}^{2+}]$ is high. The log term becomes negative.

E_{cell} becomes greater than E_{cell}° .

(Represents a fresh battery).

A Dying Battery

When **Products** > **Reactants**:
 $[\text{Zn}^{2+}]$ is high. The log term becomes positive.

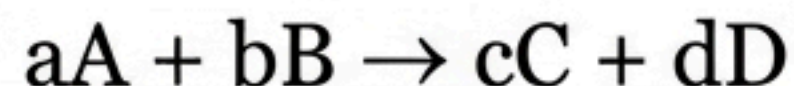
E_{cell} drops below E_{cell}° .

(Represents a dying battery).

E_{cell} increases with a higher concentration of cathode ions, and decreases with a higher concentration of anode ions.

The Universal Nernst Equation

Extending the logic to any general electrochemical reaction:



$$E_{\text{cell}} = E^{\circ}_{\text{cell}} - (RT/nF) * \ln Q \quad Q = ([C]^c [D]^d) / ([A]^a [B]^b)$$



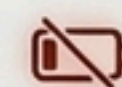
The Constants

E°_{cell} is a fixed constant.
 E_{cell} is a dynamic reality.



The Electrons

Always use the same number of electrons (n) to balance both electrodes before calculating.



The End State

When the battery dies (reaches equilibrium), $E_{\text{cell}} = 0$, and the reaction quotient Q becomes the equilibrium constant K_c .



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