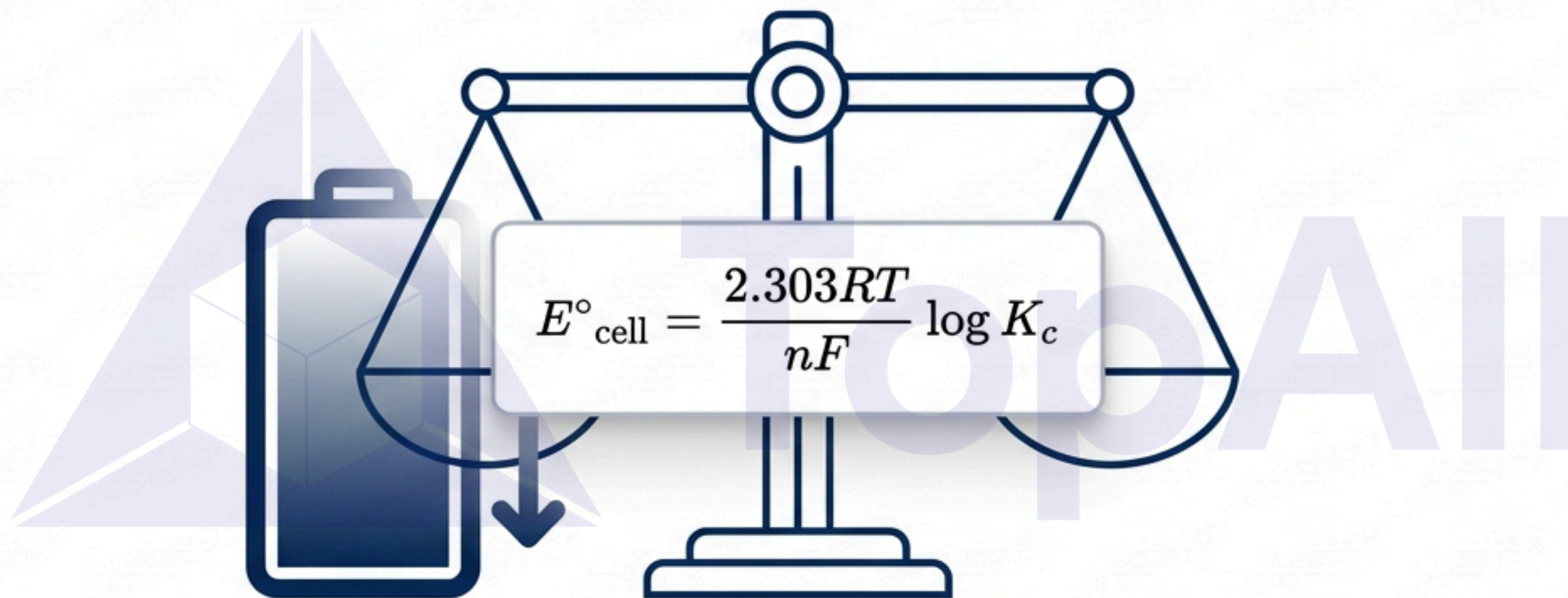


Equilibrium Constant from the Nernst Equation



Discover how the measurable voltage of a galvanic cell reveals the invisible equilibrium state of its chemical reaction.

The Path to Equilibrium

Active Cell

$[\text{Zn}^{2+}] \uparrow$

$[\text{Cu}^{2+}] \downarrow$

1.10 V

Time passes $\rightarrow$ Reaction proceeds $\rightarrow$ Voltage drops

Equilibrium Reached

$[\text{Zn}^{2+}] / [\text{Cu}^{2+}]$ frozen

0.00 V

0.00 V
Equilibrium Reached

At equilibrium, there is no net chemical reaction, no change in ion concentration, and zero electrical potential.

The Mathematical Pivot Point

$$E_{\text{cell}} = E^{\circ}_{\text{cell}} - \frac{2.303RT}{nF} \log \left(\frac{[\text{Zn}^{2+}]}{[\text{Cu}^{2+}]} \right)$$

$\downarrow$ 0 $\downarrow$ K_c

The Volt Drop

The cell can no longer do electrical work.

$$E_{\text{cell}} = 0$$

The Quotient Shift

The **reaction quotient** is no longer dynamic; it locks into a constant.

$$Q = K_c$$

Equilibrium provides the exact conditions needed to algebraically link the standard cell potential (E°_{cell}) directly to the equilibrium constant (K_c).



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$$E=mc^2$$



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Linking Potential to Equilibrium

Step 1

Set E_{cell} to zero and Q to K_c

$$0 = E^{\circ}_{\text{cell}} - \left(\frac{2.303RT}{nF} \right) \log K_c$$

Step 2

Move E°_{cell} to isolate the variables

$$E^{\circ}_{\text{cell}} = \left(\frac{2.303RT}{nF} \right) \log K_c$$

Step 3

Simplify using standard constants at 298K

$$E^{\circ}_{\text{cell}} = (0.059V / n) \log K_c$$

Constants Key

$$R = 8.314 \text{ J/K}\cdot\text{mol} \mid T = 298 \text{ K} \mid F = 96487 \text{ C/mol}$$

We can now calculate equilibrium constants—which are often impossible to measure directly—simply by measuring the standard voltage of a cell.

Solving for K_c in a Daniell Cell



$$n = 2 \text{ electrons}$$

$$E^\circ_{\text{cell}} = 1.1 \text{ V}$$

$$1.1 \text{ V} = (0.059 \text{ V} / 2) \log K_c$$

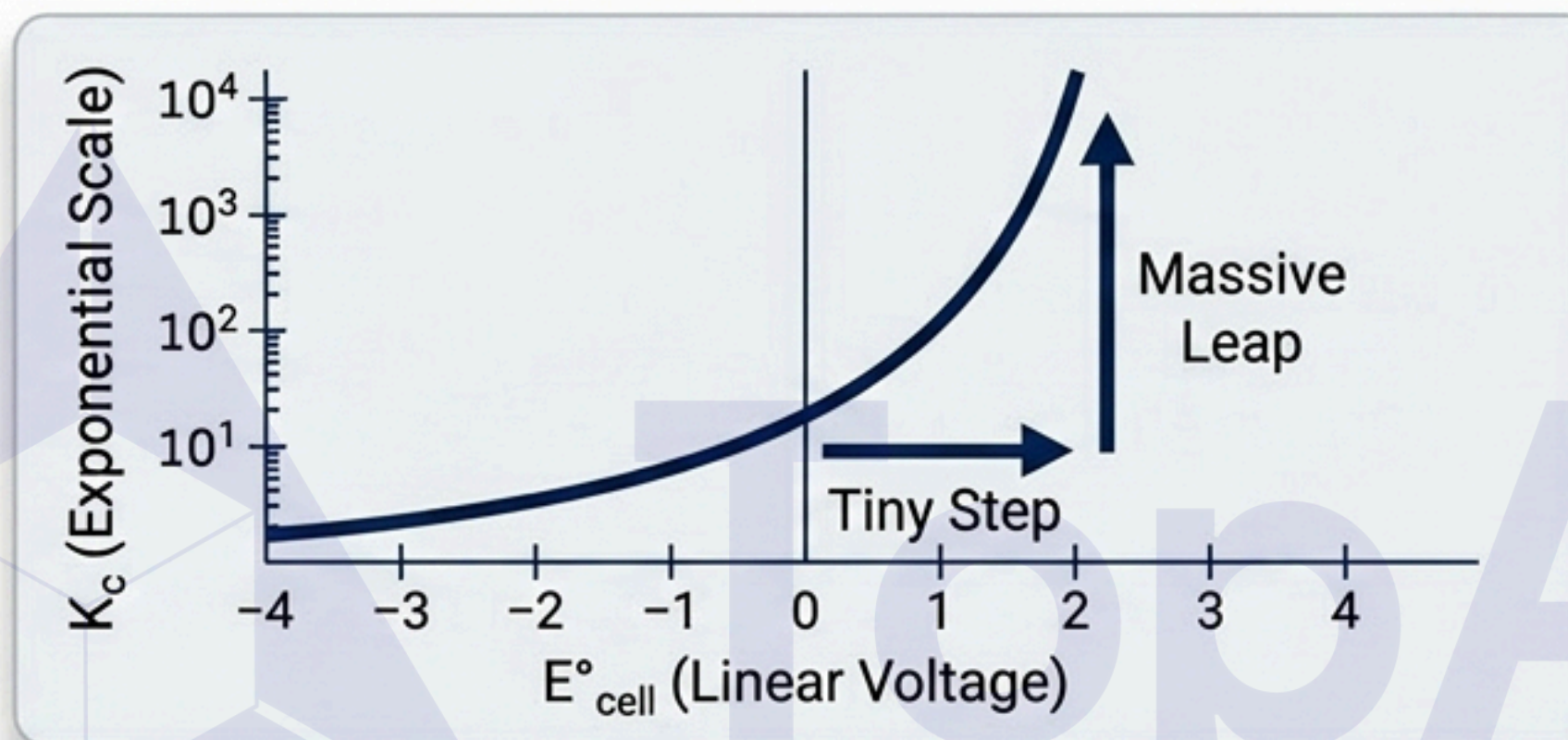
$$\log K_c = (1.1 \times 2) / 0.059$$

$$\log K_c = 37.288$$

$$K_c = 2 \times 10^{37}$$

The incredibly massive K_c value (2×10^{37}) indicates that the Daniell cell reaction goes almost entirely to completion before ever reaching equilibrium.

The Magnitude of Voltage



High Positive E°_{cell}

Massive $K_c \rightarrow$ Reaction goes nearly to completion.

Negative E°_{cell}

Tiny $K_c \rightarrow$ Reaction hardly proceeds forward.

E°_{cell} acts as a direct, measurable window into the extreme extremes of chemical equilibrium.
The higher the standard potential, the more heavily the equilibrium favors the products.



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