

 High Weightage Chapter

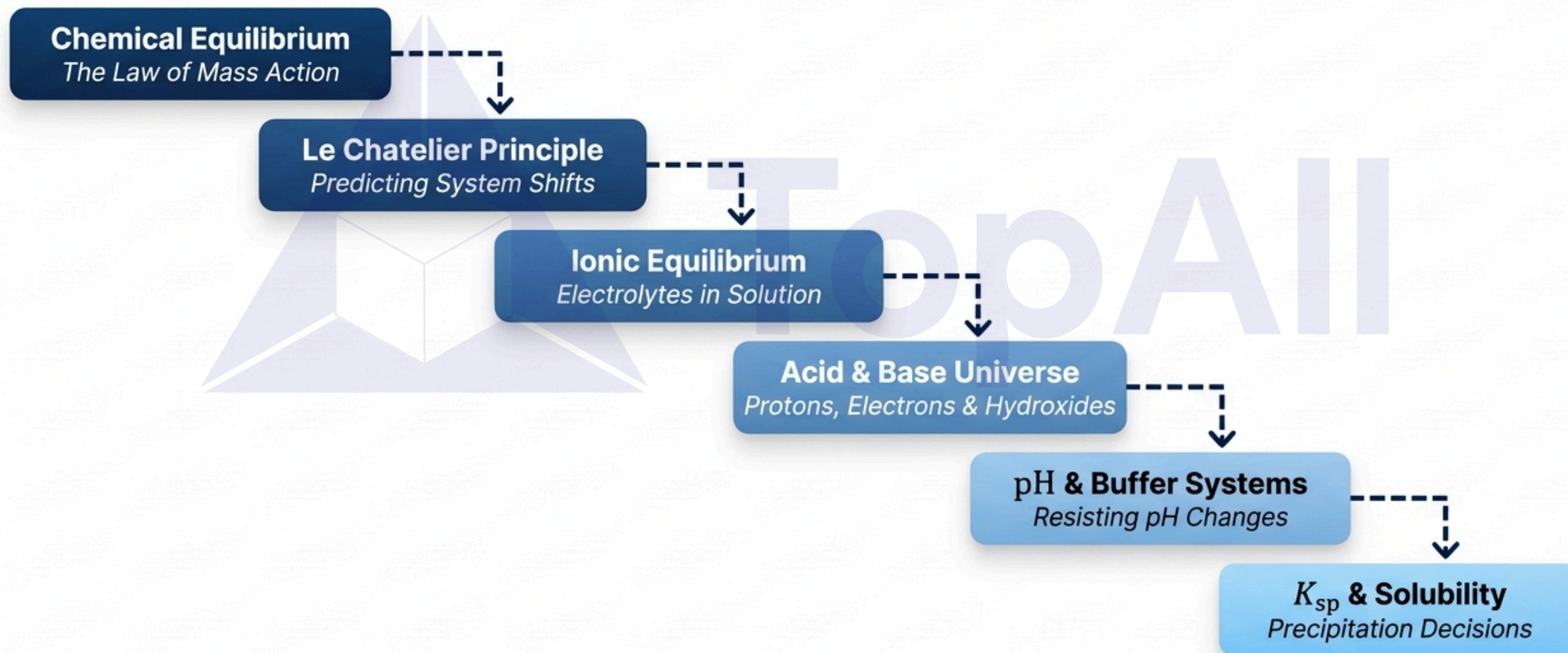
Equilibrium Mastery for JEE Main + Advanced

Complete Chemical & Ionic Equilibrium Ecosystem



Masterclass Roadmap

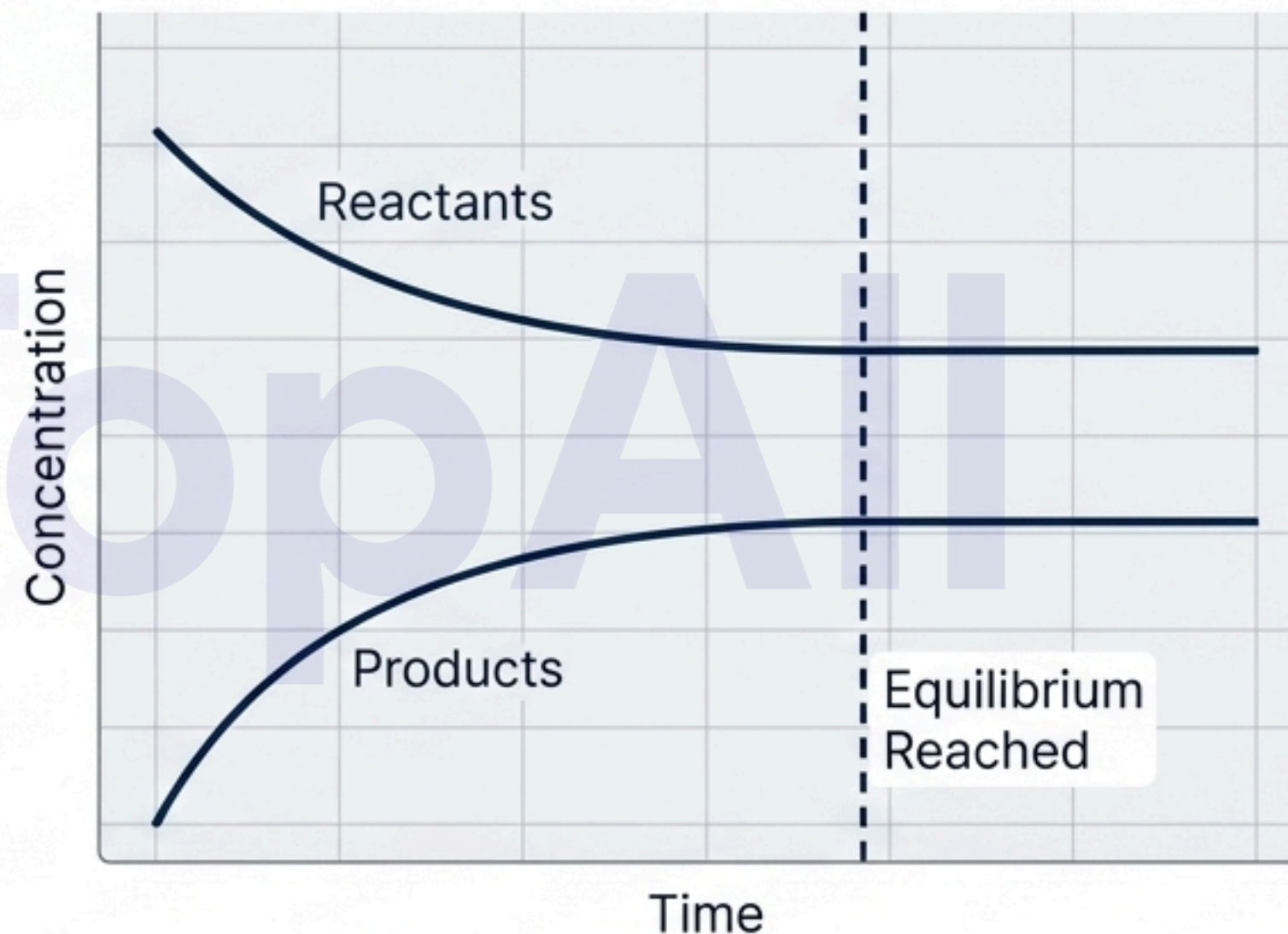
The step-by-step architecture of Equilibrium.



The Dynamic Foundation

Equilibrium is active, not static.

- **Forward Reaction:** Reactants convert to products. Rate decreases as concentration drops.
- **Reverse Reaction:** Products convert back. Rate increases as products accumulate.
- **Dynamic Balance:** The precise moment when $\text{Rate}_{\text{forward}} = \text{Rate}_{\text{reverse}}$.
- **The Isotope Proof:** Haber's synthesis using D_2 instead of H_2 proves molecules continue reacting even after macroscopic concentrations stabilize.



No Net Change: At equilibrium, macroscopic properties (concentration, pressure, color) remain perfectly constant, even though molecular collisions continue endlessly.

The Equilibrium Constants

The quantitative law of mass action.

Concentration Constant

$$K_c = \frac{[C]^c [D]^d}{[A]^a [B]^b}$$

- For reaction: $aA + bB \rightleftharpoons cC + dD$
- Uses molar concentrations (mol/L)
- Solids and pure liquids excluded (value = 1)

Pressure Constant

$$K_p = \frac{(P_C)^c (P_D)^d}{(P_A)^a (P_B)^b}$$

- Used for gaseous systems
- Uses partial pressures (bar or atm)

The JEE Master Relation

$$K_p = K_c (RT)^{\Delta n}$$

- R = Universal Gas Constant | T = Temperature (Kelvin)
- Δn = (moles of gaseous products) - (moles of gaseous reactants)

Le Chatelier Master Map

How a system counteracts external stress.

Disturbance: Concentration

- **Add Reactant:** System consumes it.
- **Remove Product:** System replenishes it.



Equilibrium Response:
Shift FORWARD (to the right).

Disturbance: Pressure

- **Increase Pressure (Decrease Volume):** System seeks lower pressure.
- **Decrease Pressure (Increase Volume):** System seeks higher pressure.



Equilibrium Response:
Shift toward the side with FEWER gaseous moles.

Disturbance: Temperature

- **Increase T (Exothermic):** Shifts Backward.
- **Increase T (Endothermic):** Shifts Forward.

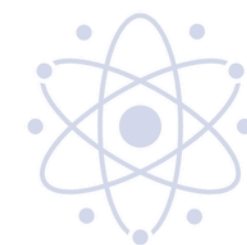


Equilibrium Response: K_c value changes exclusively with temperature.



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

$$E=mc^2$$



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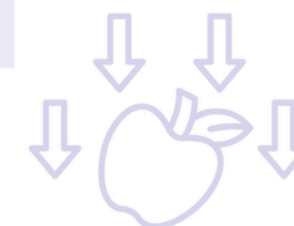
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Key Highlights

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



Ionic Equilibrium Foundation

When molecules break into charged species.



Where HA is an acid, ionizing into a proton and a conjugate base.

Strong Electrolyte

- **Behavior:** Ionizes almost 100%.
- **Equation:** Uses a single arrow ($\rightarrow$).
- **Examples:** HCl, HNO₃, NaOH, NaCl.
- **Equilibrium:** Practically non-existent.

Weak Electrolyte

- **Behavior:** Ionizes partially (typically < 5%).
- **Equation:** Uses double arrows ($\rightleftharpoons$).
- **Examples:** CH₃COOH, NH₄OH, HCN.
- **Equilibrium:** True dynamic equilibrium governed by K_a or K_b .

The Acid-Base Universe

Three frameworks to define chemical behavior.

Arrhenius Concept

The Water-Based Model

- **Acid:** Produces H^+ ions in aqueous solution.
- **Base:** Produces OH^- ions in aqueous solution.
- **Limitation:** Only applies to aqueous systems.

Bronsted-Lowry Concept

The Proton Transfer Model

- **Acid:** Proton (H^+) Donor.
- **Base:** Proton (H^+) Acceptor.
- **Feature:** Introduces Conjugate Acid-Base pairs.

Lewis Concept

The Electron Transfer Model

- **Acid:** **Electron-pair Acceptor** (e.g., BF_3).
- **Base:** **Electron-pair Donor** (e.g., NH_3).
- **Feature:** Most comprehensive; independent of protons.

pH and Buffer Systems

Measuring and protecting acidity.

The pH Scale

$$\text{pH} = -\log[\text{H}^+]$$

$$\text{pOH} = -\log[\text{OH}^-]$$

$$\text{pH} + \text{pOH} = 14 \text{ (at 298K)}$$

- **Logarithmic scale.** A change of 1 pH unit = 10x change in $[\text{H}^+]$.
- **Neutral water** at 298K has a **pH of 7**.

Buffer Action (Henderson-Hasselbalch)

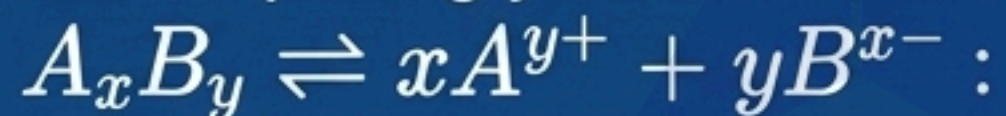
$$\text{pH} = \text{p}K_a + \log\left(\frac{[\text{Salt}]}{[\text{Acid}]}\right)$$

- **Definition:** A solution that **resists changes** in pH when **small amounts** of strong acid/base are added.
- **Composition:** Weak acid + its conjugate base (or weak base + conjugate acid).
- **Maximum Capacity:** Achieved when **pH = pK_a**.

Solubility Equilibrium (K_{sp})

The boundary between dissolved and solid.

For a sparingly soluble salt



$$K_{sp} = [A^{y+}]^x [B^{x-}]^y$$

- K_{sp} represents the maximum possible product of ionic concentrations in a saturated solution.

Compare Ionic Product (Q_{sp}) to Solubility Product (K_{sp}):

$$Q_{sp} < K_{sp}$$



Solution is unsaturated. More salt can dissolve.

$$Q_{sp} = K_{sp}$$



Solution is perfectly saturated. Dynamic equilibrium.

$$Q_{sp} > K_{sp}$$



PRECIPITATE FORMS. Excess ions crash out as solid.

JEE Formula Bank: Equilibrium

The ultimate reference wall.



Concentration Constant

$$K_c = [\text{Products}] / [\text{Reactants}]$$

Pressure Constant

$$K_p = K_c(RT)^{\Delta n}$$

Ionization of Water

$$K_w = [\text{H}^+][\text{OH}^-] = 10^{-14}$$

Acid Dissociation

$$K_a = ([\text{H}^+][\text{A}^-]) / [\text{HA}]$$

Base Dissociation

$$K_b = ([\text{B}^+][\text{OH}^-]) / [\text{BOH}]$$

Degree of Dissociation (α)

$$\alpha = \sqrt{K_a / C} \quad (\text{Ostwald's Law})$$

JEE Trap Collection

Don't lose negative marks here.

⚠ Catalyst Illusion

Trap: Thinking a catalyst increases product yield.

Truth: Catalyst DOES NOT shift equilibrium. It only speeds up reaching equilibrium by lowering activation energy for both directions equally.

⚠ Solid State Ignorance

Trap: Including solids or pure liquids in the K_c expression.

Truth: Solids and pure liquids have constant active mass. They are ALWAYS excluded (value = 1) in K expressions.

⚠ Neutrality Misconception

Trap: Assuming a neutral solution has no ions.

Truth: Neutral DOES NOT mean no ions. It means $[H^+] = [OH^-]$. Pure water at 90°C has a pH of ~6 (not 7) because K_w increases with temperature.

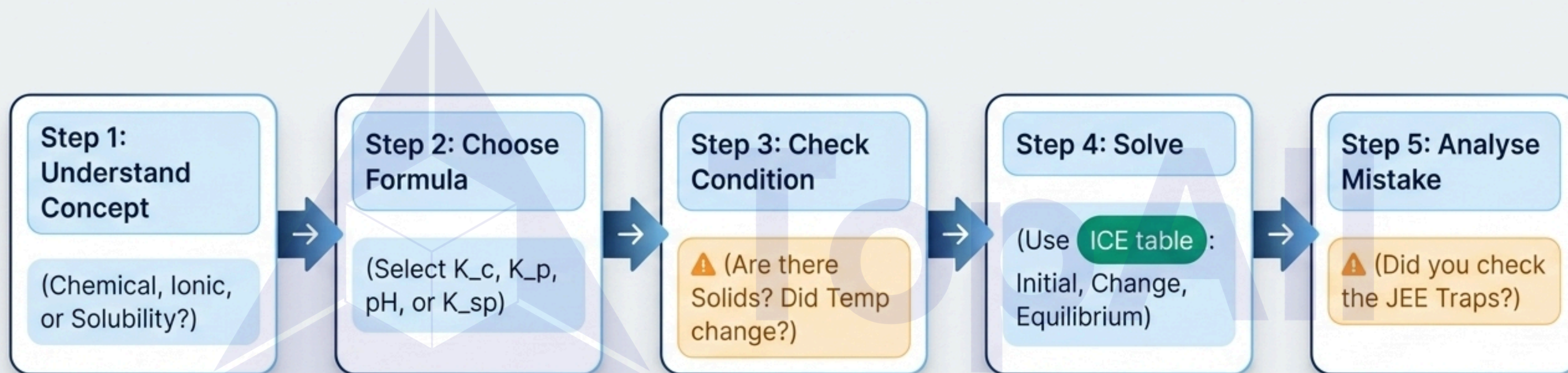
⚠ Buffer Invincibility

Trap: Believing a buffer completely stops any pH change.

Truth: Buffer DOES NOT completely stop pH change; it only resists it. Adding too much strong acid/base will eventually break the buffer capacity.

The Topper's Execution Algorithm

Your mental map for every JEE Equilibrium question.



Master Equilibrium. Master JEE Chemistry.



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