

Complete Equilibrium Chapter Connection Map

The Ultimate JEE Mastery Blueprint: From K_c/K_p to K_{sp}



EQUILIBRIUM

Branch 01: Chemical Equilibrium

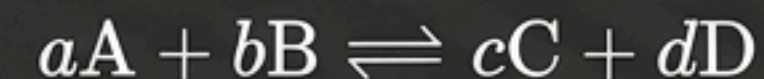
Dynamic Equilibrium

Forward Rate = Reverse Rate.



Macroscopic properties (pressure, concentration) remain constant, but molecular activity never stops.

Formula Bank



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

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

$\Delta n = (\text{gaseous product moles}) - (\text{gaseous reactant moles})$

! Pure Phases Ignored!

Pure solids and pure liquids are never included in K_c or K_p expressions. Their concentration remains constant (active mass = 1).

✓ Key Takeaway

Equilibrium can only be established in a closed system at a given temperature.

Branch 02: Le Chatelier's Principle

The Counteraction Principle

If a system at equilibrium is disturbed, it shifts in a direction that minimizes or counteracts the stress.

Stress & Shift		
Stress Factor	Disturbance	Direction of Shift
Concentration	Add Reactant	Shifts Forward (Consumes addition)
Pressure	Increase Pressure (Decrease Vol.)	Shifts toward fewer gaseous moles
Temperature	Increase Temperature	Favors Endothermic direction

The Catalyst Illusion.

A catalyst speeds up both forward and reverse reactions equally. It achieves equilibrium faster but does NOT change the equilibrium composition or the K value.

Key Takeaway

Adding an inert gas at constant volume has no effect on equilibrium.



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Branch 03: Ionic Equilibrium

Weak Acid/Base Ionization

Weak acids/bases only partially ionize in water. Their strength is measured by dissociation constants K_a and K_b . Larger K = stronger electrolyte.

Formula Bank

Ostwald's Dilution Law

$$K_a = \frac{c \alpha^2}{1 - \alpha}$$

(α = degree of ionization)

Ionic Product of Water (298K)

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

Conjugate Pair Relation

$$K_a \times K_b = K_w$$

Exam Snapshot

- Brönsted-Lowry Concept: An Acid is a proton (H^+) donor; a Base is a proton acceptor.
- Rule: A conjugate acid-base pair differs by exactly one H^+ (e.g., NH_4^+ and NH_3).

Branch 04: Acid/Base & Buffers

pH Scale

pH measures $[H^+]$ logarithmically. A change of 1 pH unit = 10x change in $[H^+]$.

$$\begin{aligned} \text{pH} &= -\log[H^+] \\ \text{pOH} &= -\log[OH^-] \\ \text{pH} + \text{pOH} &= 14 \end{aligned}$$

Buffers

Engineered solutions that resist pH changes upon adding small amounts of acid/alkali.

Henderson-Hasselbalch Equations

Acidic: $\text{pH} = \text{pKa} + \log\left(\frac{[\text{Salt}]}{[\text{Acid}]}\right)$

Basic: $\text{pOH} = \text{pKb} + \log\left(\frac{[\text{Conjugate Acid}]}{[\text{Base}]}\right)$

Key Takeaway

Maximum buffer capacity occurs when $[\text{Salt}] = [\text{Acid}]$. In this state, $\text{pH} = \text{pKa}$ (because $\log 1 = 0$).

Branch 05: Solubility Equilibrium

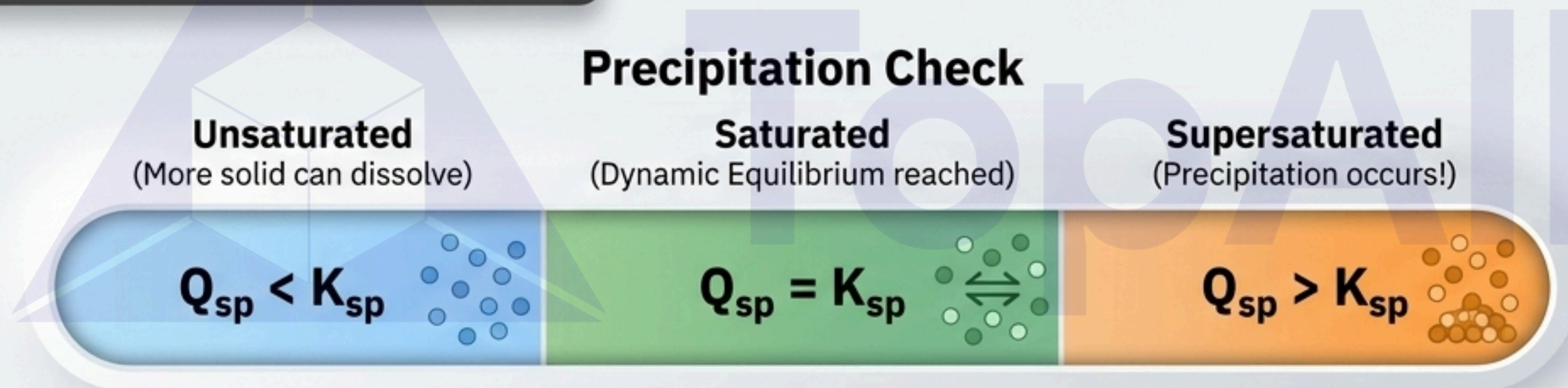


K_{sp} (Solubility Product) is the equilibrium constant for a sparingly soluble solid dissolving in an aqueous solution.

Formula Bank

Reaction: $A_xB_y(s) \rightleftharpoons xA^{(y+)} + yB^{(x-)}$

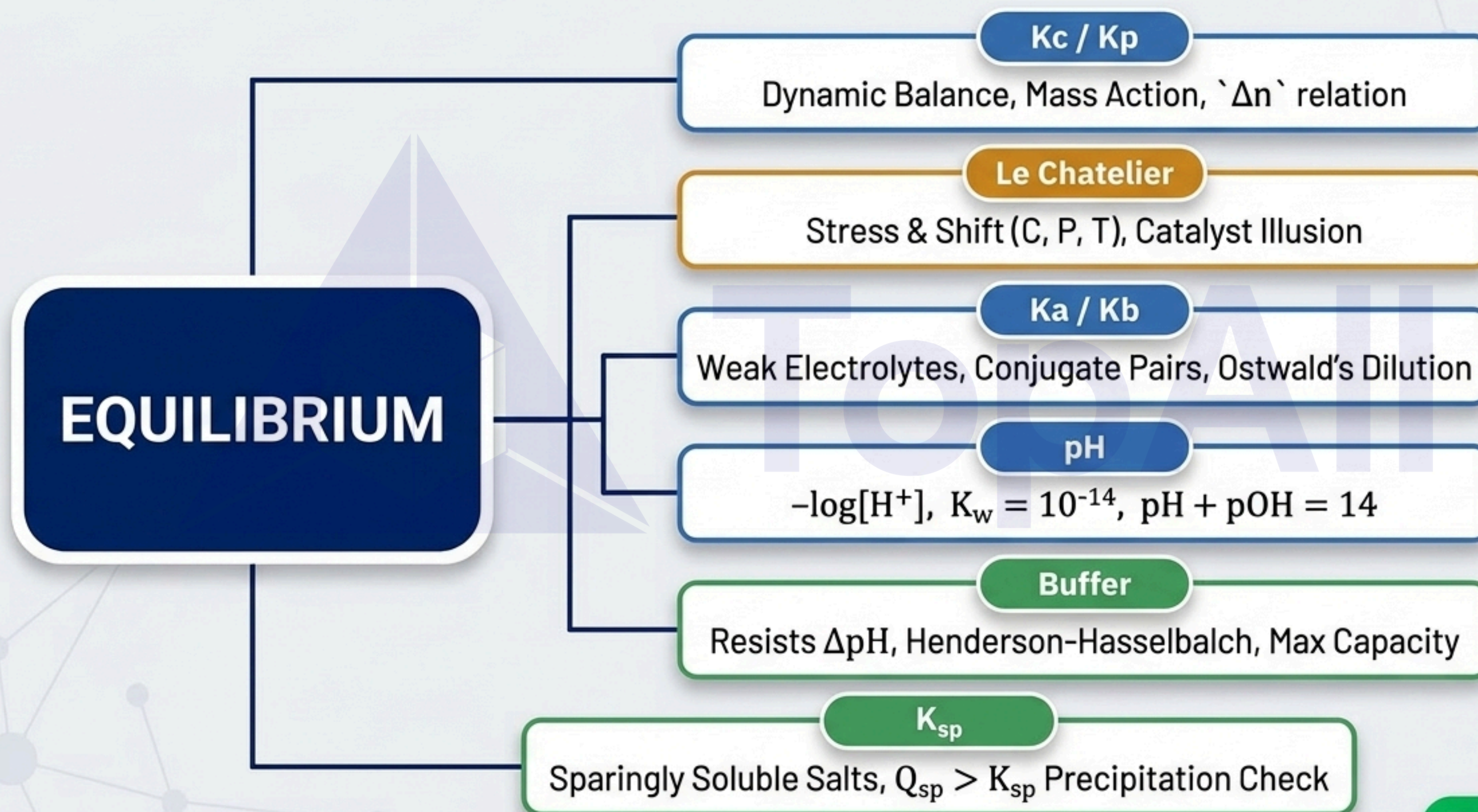
Formula: $K_{sp} = [A^{(y+)}]^x [B^{(x-)}]^y$



JEE Trap Alert: Coefficient Exponents!

Stoichiometric coefficients become exponents in the K_{sp} formula.
For $BaSO_4$, $K_{sp} = S^2$. For A_2X_3 , $K_{sp} = (2S)^2(3S)^3 = 108S^5$.

Final Synthesis: Complete Equilibrium Connection Map





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