

CHEMISTRY CLASS 11

UNIT 6

Equilibrium Chapter Master Revision

The Ultimate JEE Edition Dashboard

Distilled concepts, critical formulas, and high-yield traps for rank-focused preparation.

Chapter Blueprint: What You Need to Know



Phase 1 Physical & Chemical Equilibrium

Dynamic nature, K_c , K_p , Reaction Quotient (Q_c), Thermodynamics (ΔG).



Phase 2 Le Chatelier's Principle

System stress, predictive shifts, parameter optimization.



Phase 3 Ionic Equilibrium

Acids/Bases frameworks, pH scale, Buffers, Solubility Product (K_{sp}).



Equilibrium is never static. It is a state of intense, balanced, dynamic activity at the boundary of phases and molecules.

The Dynamic State: Physical vs. Chemical

Physical Equilibrium

- 📈 **Nature:** Phase transformations.
- 🔬 **Example:** $\text{H}_2\text{O}_{(l)} \rightleftharpoons \text{H}_2\text{O}_{(vap)}$
- 📄 **Constants:** Vapour pressure, solubility.
- 🌡️ **Condition:** Requires a closed system at a given Temperature.



Chemical Equilibrium

- 📈 **Nature:** Forward rate = Reverse rate.
- 🔬 **Example:** $\text{N}_{2(g)} + 3\text{H}_{2(g)} \rightleftharpoons 2\text{NH}_{3(g)}$
- 📄 **Constants:** Reactant/Product concentrations.

Both opposing processes occur simultaneously and at the same rate.

Isotopic tracing (e.g., reacting with Deuterium to form ammonia) proves there is no net change in macroscopic composition, but constant molecular exchange.

⚠️ JEE Trap Alert

Assuming equilibrium means 'equal amounts' of reactants and products.

Reality: It only means 'constant amounts' because opposing rates are strictly equal.

The Law of Chemical Equilibrium

Formula Bank

General Reaction: $aA + bB \rightleftharpoons cC + dD$

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

$$K_p = \frac{(p_C)^c (p_D)^d}{(p_A)^a (p_B)^b}$$

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

Variable Breakdown

- Δn = (moles of gaseous products) - (moles of gaseous reactants)
- R = Gas constant, T = Temperature in Kelvin
- Reversibility Rule: Forward reaction = K_c . Reverse reaction = $1 / K_c$.

JEE Trap Alert

Standard state pressure is strictly 1 bar. For K_p , partial pressures must be in bar or atm.

CRITICAL: Pure solids and pure liquids are ignored in the expression (Standard state Activity = 1)!



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$$E=mc^2$$



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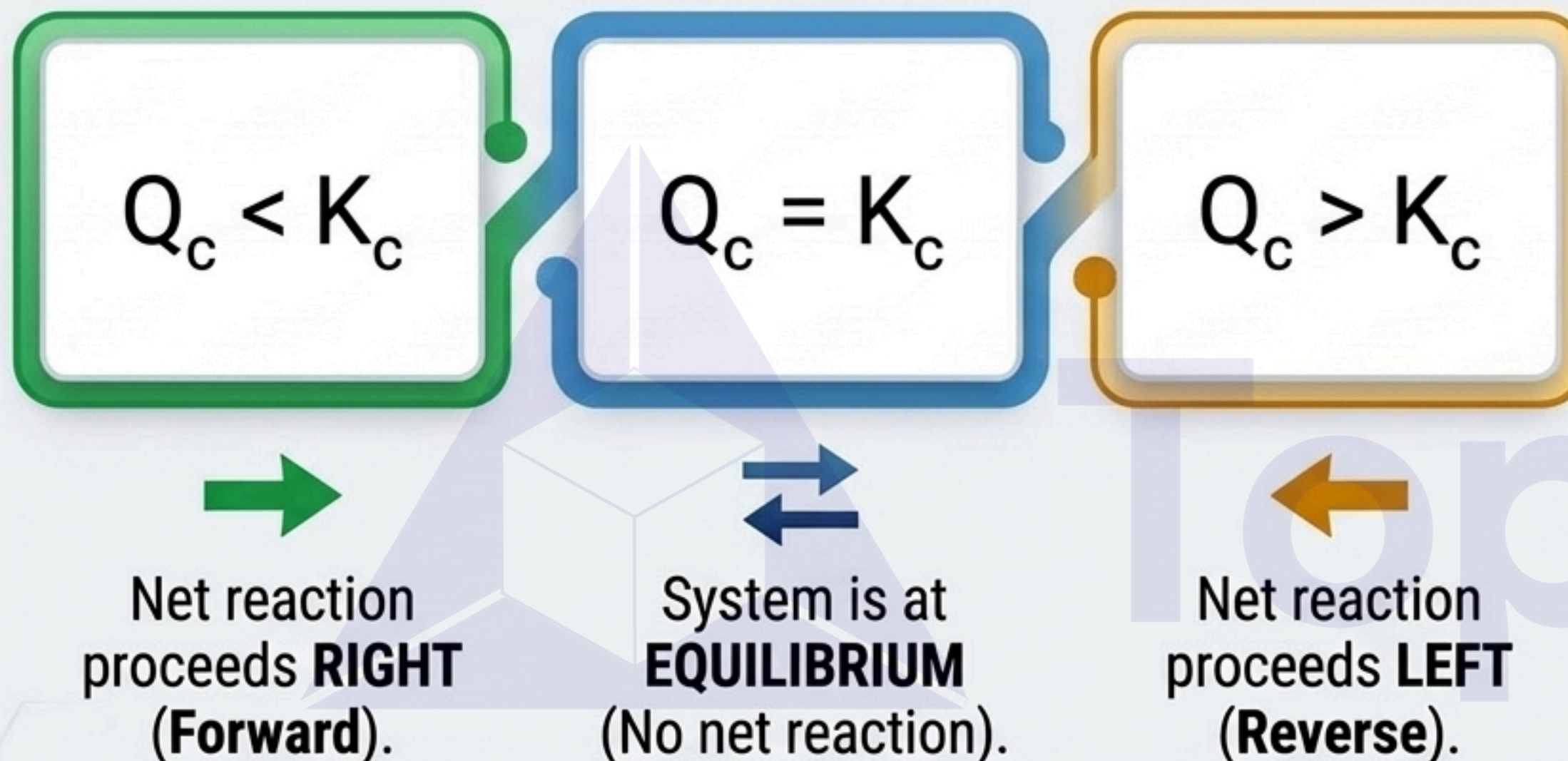
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Predicting Direction: The Reaction Quotient (Q_c)



Thermodynamic Link

$$\Delta G = \Delta G^\circ + RT \ln Q$$

At equilibrium: $\Delta G = 0$,
leading to standard state
master equation:

$$\Delta G^\circ = -RT \ln K$$

💡 Key Takeaway

Q_c is calculated exactly like K_c , but using current concentrations at any given moment t , not necessarily at equilibrium.

Le Chatelier's Principle: The System Fights Back

Concept Panel: A change in any factor determining equilibrium conditions causes the system to shift in a **direction that reduces or counteracts** the effect of the change.

Action		Reaction
Exam Snapshot Matrix	→	Reaction
Increase Reactants	→	Shifts Forward (Consumes excess)
Increase Pressure	→	Shifts to side with fewer gaseous moles
Increase Temperature	→	Favors endothermic direction
Add Catalyst	→	<u>NO shift</u> (only reaches equilibrium faster by lowering activation energy)

 **Amber JEE Trap Alert:** Adding an inert gas has **NO** effect on equilibrium. Only adding it at constant pressure causes a shift (towards more moles to compensate for expanded volume).

Ionic Equilibrium: Acid-Base Frameworks

Arrhenius

Definition:

Acids produce H^+ in water.
Bases produce OH^- in water.

Scope:

Strictly aqueous focus.

Brønsted-Lowry

Definition:

Acids are proton (H^+) donors.
Bases are proton (H^+) acceptors.

Scope:

Introduces Conjugate acid-base pairs.

Lewis

Definition:

Acids are electron-pair acceptors.
Bases are electron-pair donors.

Scope:

Broader chemical scope (e.g., BF_3).

Strength & Ionization:

Strong electrolytes ionize completely.
Weak electrolytes exist in dynamic equilibrium (e.g., $\text{HX} \rightleftharpoons \text{H}^+ + \text{X}^-$).



Key Takeaway

The degree of ionization of a weak electrolyte depends heavily on its initial concentration and the presence of any common ions in the solution.

Solubility Equilibrium & The pH Effect

Exam Snapshot (Solubility Product): For a sparingly soluble salt, a dynamic equilibrium exists between the solid and its dissolved ions. The constant is K_{sp} .

The Advanced Hacker Tool

Solubility of salt of a weak acid (HX) at a given pH.

$$K_a = [H^+][X^-]/[HX]$$

$$\text{Fraction of unbound ion } f = K_a / (K_a + [H^+])$$

$$S = \{ K_{sp} * ([H^+] + K_a) / K_a \}^{1/2}$$

Explanation Panel

As $[H^+]$ increases (pH decreases), the equilibrium shifts to consume X^- to form the weak acid HX.

Key Takeaway

$\uparrow [H^+]$ (More acidic) $\rightarrow \uparrow S$

The solubility (S) of the salt of a weak acid strictly increases with a decrease in pH.

Equilibrium: Master Formula Board

Constants

Law of Mass Action

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

Pressure

Pressure Constant

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

Manipulation

Reverse Reaction

$$K'_c = \frac{1}{K_c}$$

Thermodynamics

Gibbs Energy

$$\Delta G = \Delta G^\circ + RT \ln Q_c$$

Standard State

Standard Gibbs

$$\Delta G^\circ = -RT \ln K_c$$

Ionic

Solubility (pH dependent)

$$S = \sqrt{K_{sp} \frac{[H^+] + K_a}{K_a}}$$

Final JEE Checklist: Equilibrium



Concept

I understand that physical and chemical equilibria are dynamic, with opposing rates equalizing, not concentrations.



Formula

I have memorized the relationships between K_p , K_c , Q_c , ΔG , and K_{sp} .



Condition

I know that K only changes with temperature. It is strictly independent of initial concentrations.



Trap

I will not include pure solids or pure liquids in my K_c or K_p expressions.



Practice

I am ready to apply Le Chatelier's principle to predict shifts based on pressure, temperature, and volume changes.



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