

[Class 11 Chemistry]

[Physical Chemistry]

Mastering Chemical Equilibrium



Exam Snapshot

- **High-Yield JEE Linkages**
 - **Connects directly** to Ionic Equilibrium & Thermodynamics.
 - **Real-World Hook:** Biological systems rely on equilibrium (e.g., Hemoglobin + O_2 / CO toxicity).

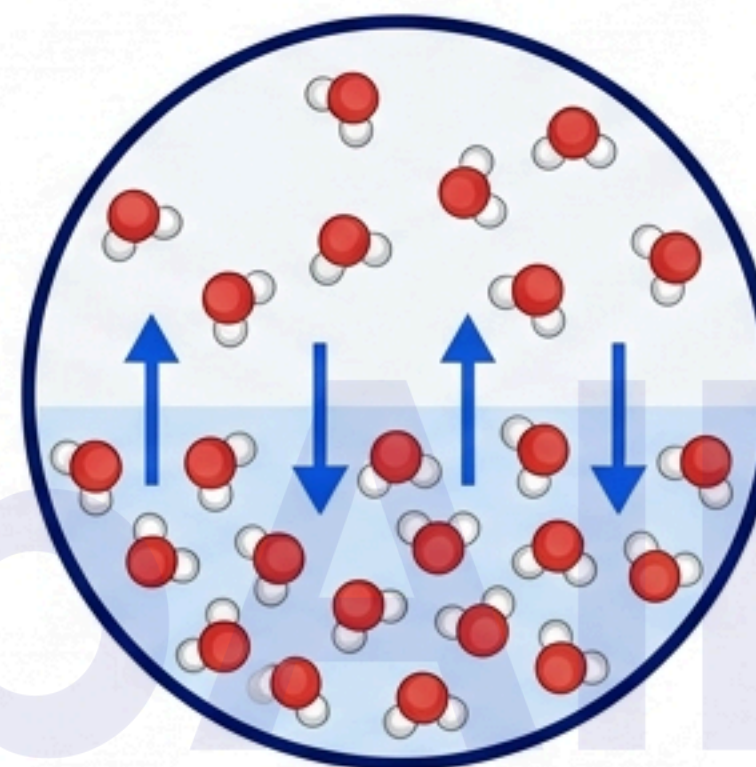
The Core Concept: Dynamic, Not Static

Macroscopic View



Macroscopic View: No observable change in measurable properties (mass, volume, pressure).

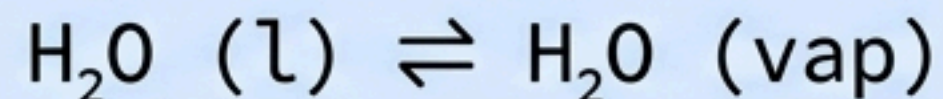
Microscopic View



Microscopic View: Intense, continuous activity at the boundary.

Explanation

Dynamic Equilibrium occurs when the rate of the forward process exactly equals the rate of the reverse process.



System Diagnostics: Physical Equilibria

Solid $\rightleftharpoons$ Liquid



Constant:
Melting point
(at fixed pressure)

Liquid $\rightleftharpoons$ Vapour



Constant:
Vapour pressure
(at given temp)

Solid $\rightleftharpoons$ Solution



Constant:
Solute concentration
(Proven via
radioactive sugar
exchange)

Gas $\rightleftharpoons$ Solution

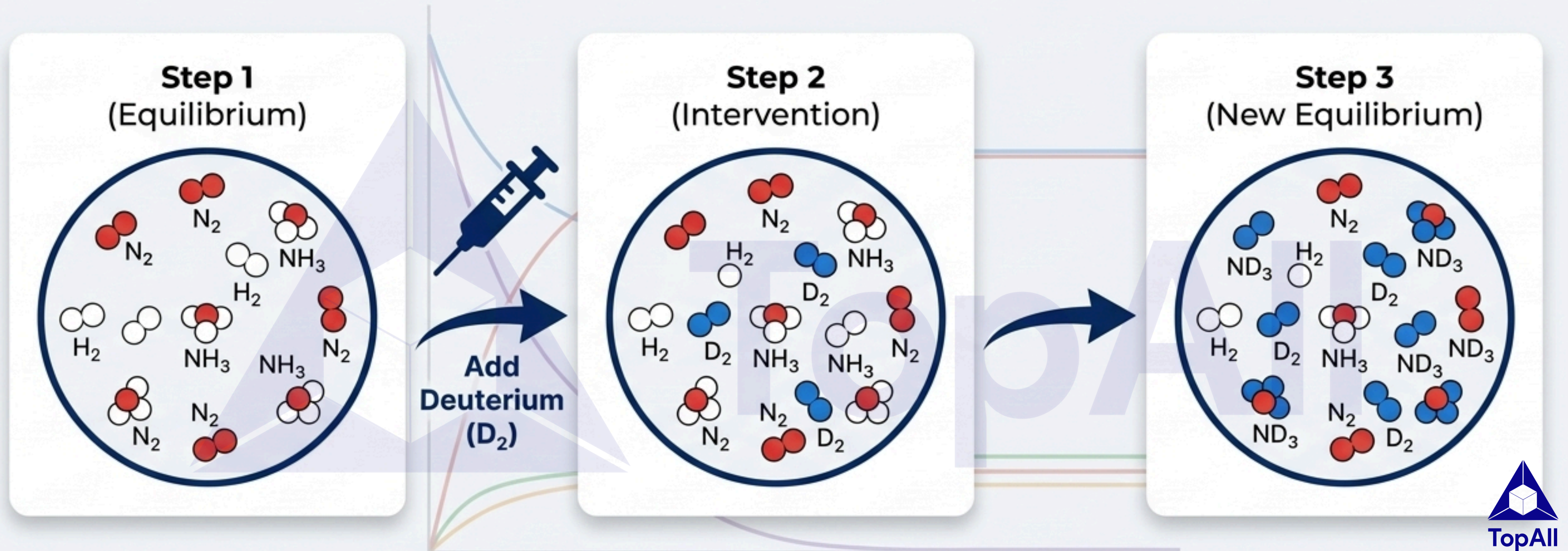


Constant:
Gas(aq) / Gas(g)
ratio

JEE Trap Alert

Henry's Law Trap: Mass of dissolved gas is proportional to pressure. However, solubility decreases as temperature increases (why warm soda goes flat)!

Proving the Dynamic Nature (The Isotope Experiment)



Key Takeaway:

If the system were static, D_2 would remain unreacted. The emergence of ND_3 proves that forward and reverse reactions continuously occur, maintaining a net zero composition change.



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$$E=mc^2$$



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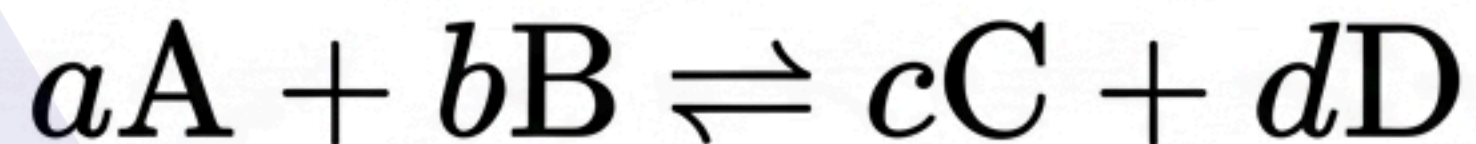
Key Highlights

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Quantifying the System: The Law of Chemical Equilibrium

Formula Bank




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

Explanation

Proposed by Guldberg and Waage. The product of product concentrations divided by reactant concentrations, each raised to their stoichiometric coefficient.

Key Takeaway

Square brackets [] strictly denote equilibrium molar concentrations (mol L^{-1}), not initial concentrations.

Gaseous Systems: Moving from K_c to K_p

$$pV = nRT \text{ (Ideal Gas Law)}$$

$$p = (n/V)RT$$

$$p = cRT \text{ (where } c \text{ is molar concentration)}$$

Formula Bank

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

Explanation

For gaseous systems, partial pressures are more practical than molarity. Standard state pressure is exactly 1 bar.

The Master Equation: Linking K_p and K_c

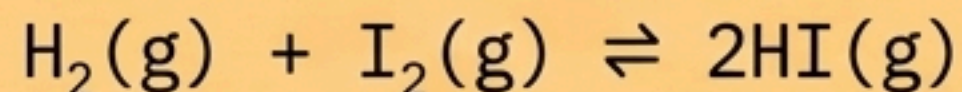
$$K_p = K_c(RT)^{\Delta n}$$

JEE Trap Alert

CRITICAL TRAP: Calculating Δn

ONLY count gaseous moles! Ignore solids and liquids.

$$\Delta n_g = n_{\text{gas}}(\text{products}) - n_{\text{gas}}(\text{reactants})$$



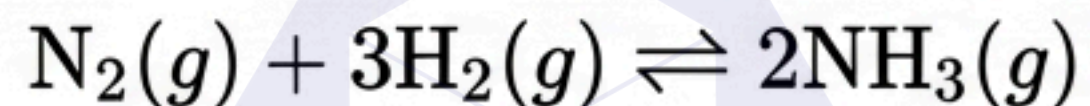
$$2 - (1+1) = 0. \text{ Therefore, } K_p = K_c$$

Heterogeneous Equilibria: The Active Mass Rule



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Homogeneous



All species appear in the K_p expression.

Heterogeneous



$$K_p = p\text{CO}_2$$

Key Takeaway

The concentration (or density) of pure solids and pure liquids is constant. Their active mass is taken as unity (1) and absorbed into the equilibrium constant.

Data Point: At 1100 K, for CaCO_3 ,
 $K_p = p\text{CO}_2 = 2.0 \times 10^5 \text{ Pa} / 10^5 \text{ Pa} = 2.00$

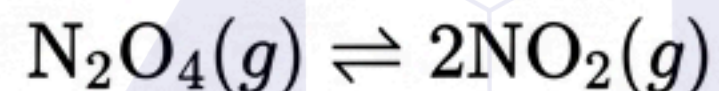
The Unit Paradox of Equilibrium Constants



Does K have units?

Traditional Calculation

Yes, units depend on Δn .



K_c units = mol/L

K_p units = bar

Standard State Calculation

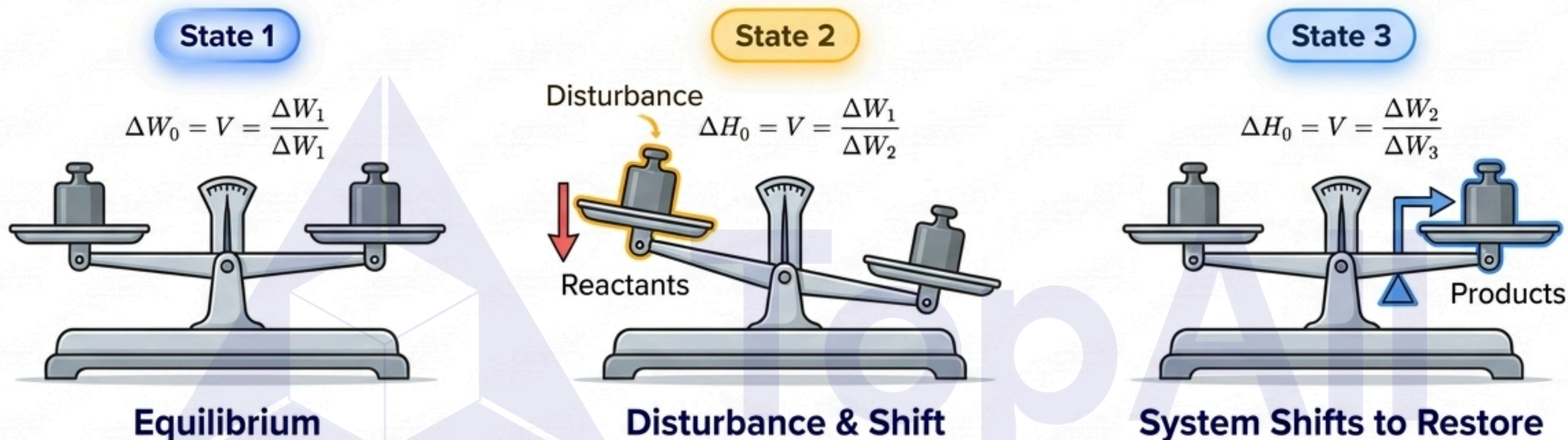
No, it is dimensionless.

If divided by standard state ($c^\circ = 1 \text{ M}$ or $p^\circ = 1 \text{ bar}$), all terms become dimensionless numbers (e.g., $4 \text{ bar} / 1 \text{ bar} = 4$).

Explanation

JEE MCQs frequently test this. The numerical value of K depends entirely on the standard state chosen. Always check the problem's framing.

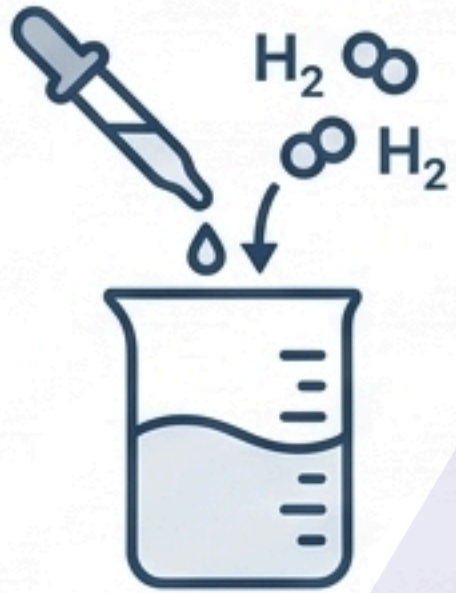
System Control: Le Chatelier's Principle



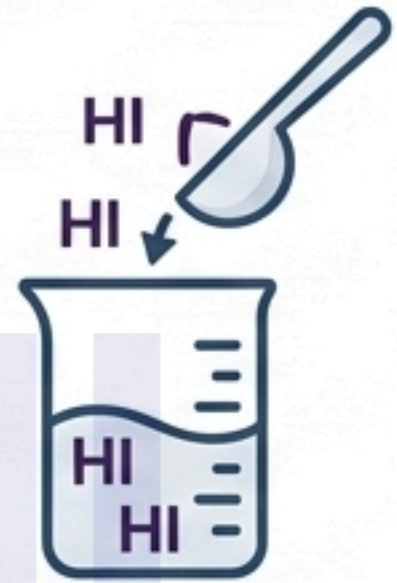
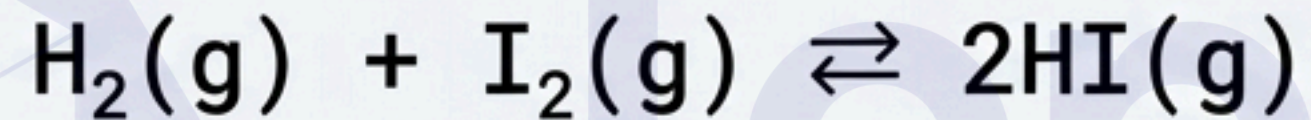
Core Quote

A change in any of the factors that determine the equilibrium conditions of a system will cause the system to change in such a manner so as to reduce or counteract the effect of the change.

Applying Le Chatelier: Concentration Shifts



→ System shifts **RIGHT** to consume excess H₂ and form more HI.

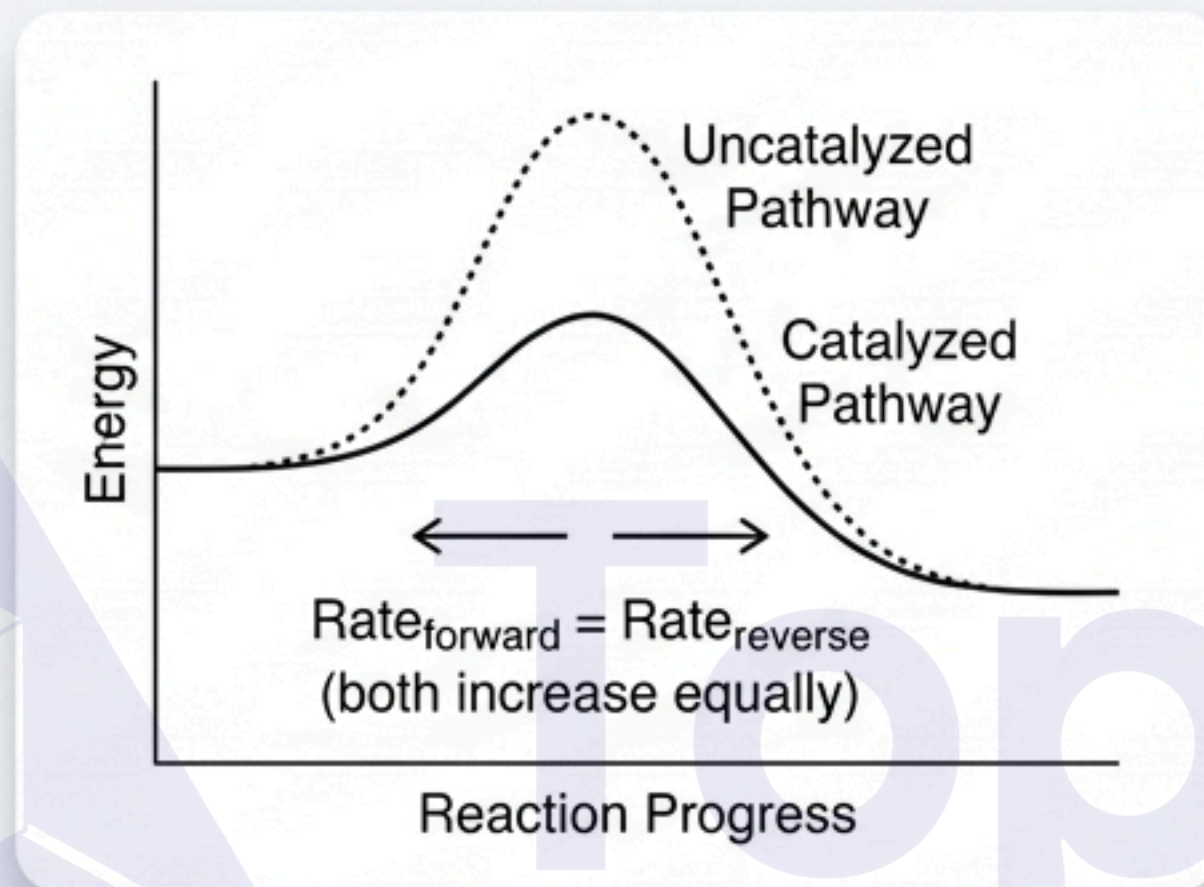


→ System shifts **RIGHT** to **replace** the lost HI.

Explanation

The system always acts to minimize the effect. If you add something, it shifts to consume it. If you remove something, it shifts to replace it.

Applying Le Chatelier: The Catalyst Illusion



JEE Trap Alert

TRAP

TRAP: Catalysts do **NOT** shift the equilibrium or change the value of K !

Key Takeaway

GREEN

A catalyst only allows the system to reach equilibrium faster by lowering the activation energy pathway. It does not alter the final composition.

Chapter Synthesis & Final Exam Checklist

Core Mathematics

- K_c and K_p expressions.

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



The Edge Cases

- Δn_g only counts gases.
- Pure solids/liquids = 1.
- Standard state makes K dimensionless.

System Shifts

- Le Chatelier: Add reactant = Shift Right.
- Add Catalyst = No Shift, just faster.

[Ready for Revision]

[Module Complete]



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