FREE NOTES · NCERT + JEE/NEET LEVEL

Equilibrium

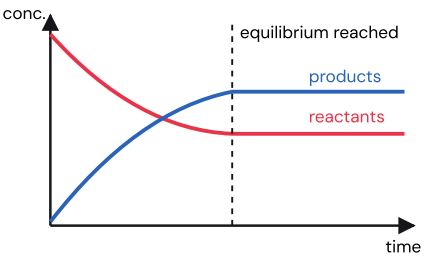
Physical aur chemical equilibrium, law of mass action, Kc aur Kp, reaction quotient, Le Chatelier's principle, acids aur bases, paani ka ionisation, pH, weak acids aur bases, common ion effect, salts ka hydrolysis, buffers aur solubility product.

01 Dynamic equilibrium
02 Equilibrium constants Kc, Kp & Q
03 Le Chatelier's principle
04 Acids & bases
05 Paani ka ionisation & pH
06 Weak acids & bases
07 Common ion effect, hydrolysis & buffers
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01 Dynamic equilibrium

Band system me reversible reaction aisi state pe pahunchta jahan **forward rate = backward rate**. Concentrations constant rehte par reactions rukte nahi (dynamic).

- **Physical:** 273 K pe barf ⇌ paani; paani ⇌ bhaap (vapour pressure); solid ⇌ solution (saturated); liquid me gas (Henry's law).
- **Chemical:** $N_2 + 3H_2 \rightleftharpoons 2NH_3$; $H_2 + I_2 \rightleftharpoons 2HI$.
- Kisi bhi taraf se pahunch sakte hain.



Equilibrium pe concentrations constant ho jaate

02 Equilibrium constants Kc, Kp & Q

$$aA + bB \rightleftharpoons cC + dD$$

$$K_c = [C]^c[D]^d / [A]^a[B]^b$$

$K_p = K_c\,(RT)^{\Delta n}$ (Δn = products − reactants ke gaseous moles; $R = 0.0831$ bar L/(mol K))

Pure solids aur liquids nahi likhte. K sirf temperature pe depend.

- Ulta reaction: K′ = 1/K. Equation ko n se guna: K′ = K^n. Equations jodo: Ks ka guna.
- K > 10^3 ⇒ zyada products; K < 10^{-3} ⇒ zyada reactants.
- **Reaction quotient Q** (same expression, kisi bhi pal): Q < K ⇒ aage; Q > K ⇒ peeche; Q = K ⇒ equilibrium pe.
- $\Delta G° = -RT \ln K$.

03 Le Chatelier's principle

Equilibrium wale system ko chhedo to wo badlav ko ulta karne ki taraf khisakta.

Badlav	Shift
Reactant daalo / product hatao	Aage
Pressure badhao (volume ghatao)	Kam gaseous moles ki taraf ($N_2 + 3H_2 \rightleftharpoons 2NH_3$ aage)
Temperature badhao	Endothermic disha (K badal jaata!)
Catalyst	Koi shift nahi; equilibrium jaldi
Constant volume pe inert gas	Koi asar nahi
Constant pressure pe inert gas	Zyada gaseous moles ki taraf

Haber process (exothermic, $\Delta n = -2$): high pressure (~200 atm), madhyam temperature (~700 K), Fe catalyst.

04 Acids & bases

Theory	Acid	Base
Arrhenius	Paani me H^+ (H_3O^+) deta	Paani me OH^- deta
Brønsted-Lowry	Proton deta	Proton leta
Lewis	Electron pair leta (BF_3, $AlCl_3$, H^+)	Electron pair deta (NH_3, OH^-)

Conjugate pairs me ek H^+ ka fark: HCl/Cl^-, NH_4^+/NH_3, H_2O/OH^-. Strong acid ka conjugate base weak. Paani amphoteric hai.

05 Paani ka ionisation & pH

$$K_w = [H^+][OH^-] = 298\ \text{K pe}\ 1.0 \times 10^{-14}$$

$$\text{pH} = -\log[H^+],\ \ \text{pH} + \text{pOH} = 14$$

Neutral pH 7 (298 K pe); acidic < 7; basic > 7. Temperature badhe to K_w badhta, neutral pH girta (par paani neutral hi rehta). Conjugate pair ke liye $pK_a + pK_b = 14$; $K_a \times K_b = K_w$.

06 Weak acids & bases

$HA \rightleftharpoons H^+ + A^-,\ K_a = c\alpha^2/(1-\alpha) \approx c\alpha^2$

$\alpha = \sqrt{(K_a/c)},\ [H^+] = c\alpha = \sqrt{(K_a c)}$

$pH = ½(pK_a - \log c)$

Weak bases ke liye K_b aur $[OH^-]$ ke saath same (Ostwald dilution law: dilution pe α badhta). Polyprotic acids: $K_{a1} >> K_{a2} >> K_{a3}$.

Acid strength: period me zyada electronegative A ⇒ strong HA (CH_4 < NH_3 < H_2O < HF); group me neeche bada A ⇒ kamzor H–A bond ⇒ strong acid (HF < HCl < HBr < HI).

07 Common ion effect, hydrolysis & buffers

- **Common ion effect:** pehle se maujood ion daalne se ionisation dab jaata (CH_3COONa, CH_3COOH ka dissociation ghatata).

Kiska salt	Solution	pH
Strong acid + strong base (NaCl)	Hydrolysis nahi	7
Weak acid + strong base (CH_3COONa)	Basic	$7 + ½(pK_a + \log c)$
Strong acid + weak base (NH_4Cl)	Acidic	$7 - ½(pK_b + \log c)$
Weak acid + weak base (CH_3COONH_4)	Depend karta	$7 + ½(pK_a - pK_b)$

BUFFER SOLUTIONS

pH badalne nahi dete. Acidic buffer: weak acid + uska salt (CH_3COOH + CH_3COONa). Basic buffer: weak base + uska salt (NH_4OH + NH_4Cl). **Henderson equation:** pH = pK_a + log([salt]/[acid]); pOH = pK_b + log([salt]/[base]). Blood ~7.4 pe buffered.

08 Solubility product (K_{sp})

$$A_xB_y(s) \rightleftharpoons xA^{y+} + yB^{x-},\ K_{sp} = [A]^x[B]^y$$

$$K_{sp} = x^x\, y^y\, S^{x+y}\ \ (S = \text{molar solubility})$$

AB: $K_{sp} = S^2$. AB_2: $4S^3$. A_2B_3: $108S^5$.

- Ionic product > K_{sp} ⇒ **precipitate**; < K_{sp} ⇒ aur ghulta.
- Common ion solubility ghatata (NaCl solution me AgCl kam ghulta). HCl gas pass karke NaCl shuddh karte.

09 JEE Extra + Tricks

JEE LEVEL

- $K_p = K_c(RT)^{\Delta n}$; ulti reaction $K' = 1/K$; reaction × n ⇒ K^n; reactions jodne pe K guna.
- Vapour density se degree of dissociation: $\alpha = (D - d)/((n - 1)d)$.
- Salt ka pH: weak acid + strong base $pH = 7 + \frac{1}{2}(pK_a + \log C)$; strong acid + weak base $pH = 7 - \frac{1}{2}(pK_b + \log C)$; weak–weak $pH = 7 + \frac{1}{2}(pK_a - pK_b)$.
- Buffer (Henderson): $pH = pK_a + \log([salt]/[acid])$; $pH = pK_a$ pe max buffer capacity.
- Solubility product: AB_2 ⇒ $K_{sp} = 4s^3$; A_2B_3 ⇒ $108s^5$; ionic product > K_{sp} ⇒ precipitate.
- Bahut patla strong acid (10^{-8} M HCl): paani ka H^+ bhi jodo ⇒ pH ≈ 6.98, 8 nahi.

10 Solved numericals

Q1. 0.001 M HCl ka pH?

$[H^+] = 10^{-3}$ ⇒ **pH = 3**.

Q2. 0.1 M acetic acid ($K_a = 1.8 \times 10^{-5}$) ka pH?

$[H^+] = \sqrt{(1.8 \times 10^{-6})} = 1.34 \times 10^{-3}$ ⇒ **pH ≈ 2.87**.

Q3. AgCl ka $K_{sp} = 1.8 \times 10^{-10}$. Solubility?

$S = \sqrt{K_{sp}}$ = **1.34×10^{-5} mol/L**.

Q4. $N_2 + 3H_2 \rightleftharpoons 2NH_3$ me K_p aur K_c ka rishta?

$\Delta n = -2$ ⇒ $K_p = K_c(RT)^{-2}$.

Q5. 0.1 M CH_3COOH + 0.1 M CH_3COONa ka buffer (pK_a 4.74). pH?

pH = 4.74 + log 1 = **4.74**.

11 Mistakes & practice

- K expression me solids ya pure liquids daal dena.
- Kehna ki catalyst K badalta ya equilibrium shift karta.
- Sochna ki pressure se K badalta (sirf T se).
- Weak acid ke liye pH = -log c lagana.

1. Exothermic equilibrium pe T badhane ka asar?
2. $AlCl_3 + Cl^- \rightarrow AlCl_4^-$ me Lewis acid?
3. Aqueous NH_4Cl ka nature?
4. $Ca_3(PO_4)_2$ ka K_{sp} S me?
5. HSO_4^- ka conjugate base?

ANSWERS

1) Peeche shift, K ghatta · 2) $AlCl_3$ · 3) Acidic · 4) $108S^5$ · 5) SO_4^{2-}

12 Quick revision: exam se 5 minute pehle

CHEMICAL EQUILIBRIUM

- $K_p = K_c(RT)^{\Delta n}$.
- $Q < K \Rightarrow$ aage.
- Sirf T se K badalta.

LE CHATELIER

- ↑p ⇒ kam gas moles.
- ↑T ⇒ endothermic side.
- Catalyst: shift nahi.

IONIC

- pH + pOH = 14; $K_w = 10^{-14}$.
- Weak: $[H^+] = \sqrt{(K_a c)}$.
- Buffer: $pH = pK_a + \log(\text{salt/acid})$.

K_{SP}

- AB: S^2, AB_2: $4S^3$.
- IP > $K_{sp} \Rightarrow$ ppt.
- Common ion ↓ solubility.

Koi doubt? padhaiadda.netlify.app pe AI Doubt Solver se poocho, ya is chapter ka mock test do.