Chemical and Ionic Equilibrium Formula Sheet (JEE Main & Advanced)

1. Chemical Equilibrium Basic Formulas

Equilibrium Constant

- For reaction: $aA + bB \rightleftharpoons cC + dD$

$Kc = [C]^c[D]^d/[A]^a[B]^b$
$Kp = (PC)^c(PD)^d/(PA)^a(PB)^b$

Kp-Kc Relationship

$Kp = Kc(RT)\Delta n$
where $\Delta n = (c + d) - (a + b)$

Reaction Quotient (Q)

$Q = [C]^c[D]^d/[A]^a[B]^b$ (at any instant)

Free Energy Relationships

$\Delta G = \Delta G^\circ + RT \ln Q$
$\Delta G^\circ = -RT \ln Kc = -2.303RT \log Kc$
At equilibrium: $\Delta G = 0, Q = Kc$

Temperature Effect (van't Hoff Equation)

$\log(K_2/K_1) = [\Delta H^\circ/2.303R][T_2-T_1/T_1T_2]$

2. Modified Equilibrium Constants

For Reversed Reaction

$K' = 1/K$

For Divided Equation

$K' = \sqrt[n]{K}$ (when divided by n)

For Multiplied Equation

$K' = K^n$ (when multiplied by n)

For Multi-step Reactions

$K = K_1 \times K_2 \times K_3 \times ... \times K_n$

3. Ionic Equilibrium Formulas

Ionization Constants

$Ka = [H^+][A^-]/[HA]$
$Kb = [OH^-][BH^+]/[B]$
$Kw = [H^+][OH^-] = 10^{-14}$ at 298K

pH Related

$\mathrm{pH} = -\log[\mathrm{H}^+]$
$\mathrm{pOH} = -\log[\mathrm{OH}^-]$
$\mathrm{pH} + \mathrm{pOH} = 14$ (at 298K)
$\mathrm{p}K_a = -\log K_a$
$\mathrm{p}K_b = -\log K_b$

4. Salt Hydrolysis

Hydrolysis Constants

For weak acid + strong base salt:
$K_h = K_w/K_a$
$\mathrm{pH} = \frac{1}{2}[\mathrm{p}K_w + \mathrm{p}K_a + \log C]$

For strong acid + weak base salt:
$K_h = K_w/K_b$
$\mathrm{pH} = -\frac{1}{2}[\mathrm{p}K_w - \mathrm{p}K_b + \log C]$

For weak acid + weak base salt:
$K_h = K_w/(K_a \times K_b)$
$\mathrm{pH} = \frac{1}{2}[\mathrm{p}K_a + \mathrm{p}K_w - \mathrm{p}K_b]$

5. Solubility Product (K_{sp})

General Formula

$K_{sp} = [\text{Cation}]^a[\text{Anion}]^b$

For Different Types

Binary (1:1): $K_{sp} = s^2$
Ternary (1:2 or 2:1): $K_{sp} = 4s^3$
Quaternary (1:3): $K_{sp} = 27s^4$
Complex (3:2): $K_{sp} = 108s^5$

6. Buffer Solutions

Henderson-Hasselbalch Equations

For acidic buffer:
$pH = pK_a + \log([\text{Salt}]/[\text{Acid}])$

For basic buffer:
$pOH = pK_b + \log([\text{Base}]/[\text{Salt}])$

Buffer Capacity (β)

$\beta = \Delta n/\Delta pH$

7. Degree of Dissociation (α)

For Weak Electrolyte

$\alpha = \sqrt{(Ka/C)}$ [for dilute solutions]
$\alpha = [\text{ionized}]/[\text{initial}]$

Ostwald's Dilution Law

$Ka = C\alpha^2/(1-\alpha)$
For very weak electrolytes ($\alpha \ll 1$):
$Ka = C\alpha^2$

8. Common Ion Effect

$[H^+] = Ka \times [HA]/[A^-]$
$[OH^-] = Kb \times [B]/[BH^+]$

9. Temperature Dependence

$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$
$d(\ln K)/dT = \Delta H^\circ/RT^2$

Important Notes:

1. All concentrations must be in mol/L for Kc
2. All pressures must be in atm for Kp
3. Temperature must be in Kelvin
4. For dilute solutions, molarity ≈ molality
5. Activity coefficients are assumed to be 1 for dilute solutions