Salt Hydrolysis

$$\text{Salt} + \text{water} \rightleftharpoons \text{Acid} + \text{Base}$$

is called Salt Hydrolysis.

it is opposite to "Neutralisation" Reaction

$$\text{Acid} + \text{Base} \rightleftharpoons \text{Salt} + \text{water}$$

is called "Neutralisation" Reaction.

Salt has → Anion (−ve charge)
→ Cation (+ve charge)

Anion from Acid

Cation from Base

Example :- KCl is salt

$$\underset{\text{Base}}{KOH} + \underset{\text{acid}}{HCl} \rightarrow \underset{\text{Salt}}{KCl} + \underset{\text{water}}{H_2O}$$

Cation: K^+ → from Base
anion: Cl^- → From Acid
} KCl

Types of Salts

Salt of [Weak acid + Strong Base]	Salt of [Strong acid + weak base]	Salt of [Weak acid + weak Base]	Salt of [Strong acid + Strong Base]
CH_3COONa	NH_4Cl	CH_3COONH_4	$NaCl$
Na_2CO_3	$CuSO_4$	$Mg(CN)_2$	K_2SO_4
KCN	$Al(NO_3)_3$	$CaCO_3$	KNO_3
KNO_2	NH_4NO_3	$(NH_4)_3PO_4$	$KClO_4$
$HCOOK$	$(NH_4)_2SO_4$	$Ca_3(PO_4)_2$	KCl
NaF	$MgSO_4$		Na_2SO_4
Na_3PO_4	$CaCl_2$		KBr, NaI
K_2SO_3			

Salts Types

* Strong acids :- HCl, HNO_3, H_2SO_4, ~~H_3PO_4~~, HBr, $HClO_4$, HI etc
* Weak acids :- CH_3COOH, HCN, H_2CO_3, H_3PO_4 etc ($HCOOH$)

* Strong Base :- $NaOH$, KOH,
* Weak base :- $Mg(OH)_2$, $Ca(OH)_2$, NH_4OH, etc

Salt [anion (Acid) / cation (Base)]

Salt Hydrolysis (4 Types)

(I) Anionic Hydrolysis

(W.A + SB)

Salt + H_2O → Acid + Base

(CH_3COOH + NaOH)
↓
$\underbrace{CH_3COO}_{\text{anion}}\underbrace{Na}_{\text{cation}}$ Salt

$$CH_3COO^- + H_2O \rightleftharpoons CH_3COOH + OH^-$$

$$K_h = \frac{[CH_3COOH][OH^-]}{[CH_3COO^-]}$$

Kw

$$K_h = \frac{[CH_3COOH][OH^-][H^+]}{[CH_3COO^-][H^+]} = \frac{Kw}{Ka}$$

1/Ka

$\boxed{K_h = Kw/Ka}$

(II) Cationic Hydrolysis

(S.A + W.B)

Cation + H_2O → Base + H^+

$$NH_4^+ + H_2O \rightleftharpoons NH_4OH + H^+$$

solution is acidic

$$\boxed{K_h = \frac{Kw}{K_b}}$$

For both degree of hydrolysis

$$\boxed{h = \sqrt{\frac{K_h}{c}}}$$

(III) Cationic & Anionic Hydrolysis

(W.A + WB)

$$\boxed{K_h = \frac{Kw}{K_a \cdot K_b}}$$

$$\boxed{h = \sqrt{K_h}}$$

$$B^+ + A^- + H_2O \rightleftharpoons BOH + HA$$

(IV) both do not goes Hydrolysis

(SA + S.B)

$$\boxed{K_h = Kw}$$

('h' not possible)

No hydrolysis

Salt Hydrolysis p^H & p^{OH} Finding

Anionic	Cationic	both Cationic & Anionic	No hydrolysis
(Weak acid - Strong base)	(Strong acid + Weak Base)	(weak acid + weak Base)	(Strong acid + Strong Base)
$\boxed{A^- + H_2O \rightleftharpoons HA + OH^-}$	$\boxed{B^+ + H_2O \rightleftharpoons BOH + H^+}$	$\boxed{B^+ + A^- + H_2O \rightleftharpoons BOH + HA}$	No hydrolysis
$K_h = \frac{[HA][OH^-]}{[A^-]}$	$K_h = \frac{[BOH][H^+]}{[B^+]}$	$K_h = \frac{[BOH][HA]}{[B^+][A^-]}$	K_h not possible
$\boxed{K_h = \frac{K_w}{K_a}}$ hint (WA)	$\boxed{K_h = \frac{K_w}{K_b}}$ hint (WB)	$\boxed{K_h = \frac{K_w}{K_a \cdot K_b}}$ hint (WA, WB)	$\boxed{K_h = K_w}$
$p^H = \frac{1}{2}(p^{K_w} + p^{K_a} + \log c)$ (all ⊕)	$p^H = \frac{1}{2}(p^{K_w} - (p^{K_b} + \log c))$ (⊖)	$p^H = \frac{1}{2}(p^{K_w} + p^{K_a} - p^{K_b})$	$p^H = 7$

Buffer solutions (Solution p^H is almost constant when a small amount of acid (or) bases are added)

Acidic Buffer

(Weak Acid + Salt of Strong Base)

$CH_3COOH + CH_3COONa$

$HCN + KCN$

p^H :- Henderson's equation :-

$$p^H = p^{Ka} + \log \frac{[Salt]}{[acid]}$$

$$p^H = p^{Ka} + \log \frac{[\overset{A^-}{anion}]}{[acid]}$$

$$\boxed{p^{OH} = 14 - p^H}$$

Basic Buffer

(Weak Base + Salt of Strong acid)

$NH_4OH + NH_4Cl$

$Ca(OH)_2 + CaCl_2$

p^H

$$p^{OH} = p^{Kb} + \log \frac{[Salt]}{[base]}$$

$$p^{OH} = p^{Kb} + \log \frac{[\overset{B^+}{Cation}]}{[Base]}$$

$$\boxed{14 - p^{OH} = p^H}$$

Compounds

Soluble

NaCl
KCl

NaCl Soluble in H_2O

Like dissolves in Like

Unlike dissolves in unlike

Polar " Polar Solvent

nonpolar " nonpolar solvent

Solubility :-

The Maximum amount of Salt that Can dissolve in 100g (or) 1000g of solvent at Room Temperature.

Solubility $> 0.1m$

Insoluble

Salt / compound does not dissolves

$0.01m < \text{solubility} < 0.1m$

Sparingly Soluble

" compound some Portion soluble"

$$\underset{\text{undissolved}}{AB} \rightleftharpoons \underset{\text{dissolved}}{AB} \rightleftharpoons \underset{\text{ions}}{A^+ + B^-}$$

- → AgCl
- → $BaSO_4$
- → $PbSO_4$ etc

Solubility product :-

(2)

$$\underset{\substack{\text{solid} \\ \text{(undissolved)}}}{AB} \rightleftharpoons \underset{\text{Soluble}}{AB} \rightleftharpoons \underset{\text{ions}}{A^+ + B^-}$$

$$K_{sp} = [A^+][B^-]$$

"product of cation & Anion concentration is called solubility product"

Types of Salts

- → AB Type
- → A_2B (or) AB_2 Type
- → AB_3 Type
- → A_2B_3 Type

Type-I : AB Type

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$$\underset{s}{AB} \rightleftharpoons \underset{s}{A^+} + \underset{s}{B^-} \longrightarrow \text{Solubility}$$

$$K_{sp} = [A^+][B^-]$$

$$K_{sp} = s.s = s^2$$

$$\boxed{K_{sp} = s^2}$$

$$\boxed{s = \sqrt{K_{sp}}}$$

Type : 2

A_2B (or) AB_2 Type :-

$$A_2B \rightleftharpoons 2A^+ + B^-$$

$$K_{sp} = [2A^+]^2 [B^-]$$

$$K_{sp} = (2s)^2 (s)$$

$$K_{sp} = 4s^3$$

$$s = \sqrt[3]{\frac{K_{sp}}{4}}$$

Type : 3

A_3B (or) AB_3 Type :-

$$A_3B \rightleftharpoons 3A^+ + B^-$$

$$K_{sp} = [3A^+]^3 [B^-]$$

$$K_{sp} = (3s)^3 (s)$$

$$K_{sp} = 27s^4$$

$$s = \left(\frac{K_{sp}}{27}\right)^{1/4}$$

④ A_2B_3 Type

$$A_2B_3 \rightleftharpoons 2A^+ + 3B^-$$

$$K_{sp} = (2A^+]^2 [3B^-]^3$$

$$K_{sp} = (2s)^2 (3s)^3$$

$$K_{sp} = 2^2 \cdot 3^3 \cdot s^2 \cdot s^3$$

$$K_{sp} = 108\, s^5$$

$$s = \left(\frac{K_{sp}}{108}\right)^{1/5}$$

⑤

Trick.

$$A_xB_y \rightleftharpoons \underline{x}A^{+y} + \underline{y}B^{-x}$$

$$K_{sp} = x^x \cdot y^y\, s^{x+y}$$

① $AB \rightleftharpoons A^+ + B^-$; $x = 1$; $y = 1$

$$K_{sp} = 1^1 \cdot 1^1 \cdot s^{1+1} = s^2$$

$$\boxed{K_{sp} = s^2}$$

② A_2B (or) AB_2 : $x = 2$; $y = 1$

$$K_{sp} = 2^2 \cdot 1^1\, s^{2+1} = 4s^3$$

$$K_{sp} = 4s^3$$

③ A_2B_3 Type :- $x = 2$; $y = 3$

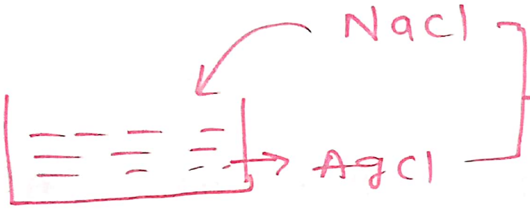
$$K_{sp} = 2^2 \cdot 3^3 \cdot s^{2+3} = (4 \times 27)\, s^5$$

$$K_{sp} = 108\, s^5$$

Find out K_{sp} & S Relations :-

1. Ag_2CrO_4
2. $Mg(OH)_2$
3. $Ca_3(PO_4)_2$
4. Iron (III) hydroxide
5. CdS
6. Na_2SO_4
7. $Zn_3(PO_4)_2$
8. PbS
9. AgI
10. $Cr(OH)_3$

Common ion Effect



adding NaCl to AgCl $Cl^{\ominus}$ concentration increases.

Generally in problems

NaCl concentration = ___ m (given)

$\Rightarrow NaCl \rightleftharpoons Na^+ + Cl^-$

$\quad 0.1m \qquad 0.1m \qquad 0.1m$

They ask Ksp of AgCl

$$AgCl \rightleftharpoons Ag^+ + Cl^{\ominus}$$
$$S \qquad\quad S \qquad (S + \underbrace{0.1m}_{\text{from NaCl}})$$

$$K_{sp} = [Ag^+][Cl^{\ominus}] = S(S+0.1)$$

$$K_{sp} = S^2 + 0.1S \Rightarrow \boxed{K_{sp} = 0.1 \times S}$$

S^2 negligible

(9)

Problem :-

Solubility product of magnesium hydroxide at 25°C is 3.2×10^{-11}. What is its solubility?

Magnesium Hydroxide $= Mg(OH)_2$ (AB_2 Type)

$$Mg(OH)_2 \rightleftharpoons Mg^{+2} + 2OH^-$$

$$K_{sp} = (S)(2S)^2 = 4S^3$$

$$S = \left(\frac{K_{sp}}{4}\right)^{1/3}$$

$$S = \left(\frac{3.2 \times 10^{-11}}{4}\right)^{1/3} = \left(\frac{\cancel{32}^{\,8} \times 10^{-12}}{\cancel{4}_{\,1}}\right)^{1/3} = (2^3 \times 10^{-12})^{1/3}$$

$$S = (2^3)^{1/3} (10^{-12 \times 1/3}) = \underline{\underline{2 \times 10^{-3}}} \text{ mol L}^{-1}$$

(9)

The Solubility product of pbs at 25°c is 9×10^{-28}. what is its solubility in pure water and in 2×10^{-12} M of Na_2S solution.

Common Ion effect

(a) $PbS \rightleftharpoons Pb^{+2} + S^{-2}$

$K_{sp} = s^2$

in water $s = \sqrt{K_{sp}}$.

$s = \sqrt{9 \times 10^{-28}} = (3^2 \times 10^{-28})^{1/2}$

$s = 3 \times 10^{-14}$ mol L^{-1}

(b) $Na_2S \rightleftharpoons 2Na^+ + S^{-2}$

2×10^{-12} m $\quad$ 2×10^{-12} m

$PbS \rightleftharpoons Pb^{+2} + S^{-2}$

$s \quad s \quad (s + (2 \times 10^{-12}))$

$K_{sp} = s(s + (2 \times 10^{-12}))$

$K_{sp} = s^2 + s(2 \times 10^{-12})$

s^2 value negligable

$K_{sp} = s(2 \times 10^{-12})$

$s = 4.5 \times 10^{-16}$ ML^{-1} $\Leftarrow$ $s = K_{sp} / 2 \times 10^{-12} = \dfrac{9 \times 10^{-28}}{2 \times 10^{-12}}$