IONIC EQUILIBRIUM-III

Exercise-1

✍ **Marked questions are recommended for Revision.**

PART - I : SUBJECTIVE QUESTIONS

Section (A) : Solubility, Solubility product and Simple solubility calculations

Commit to memory :
Solubility (s ; in mol/L) of a sparingly soluble salt A_xB_y : $K_{sp} = x^x.y^y.(s)^{x+y}$

A-1. If the solubility product of a salt MX is 3×10^{-10} at 0ºC, determine its solubility.

A-2. A saturated solution of $PbCl_2$ contains 2×10^{-3} mol of $PbCl_2$ per litre. What is the K_{sp} of $PbCl_2$?

A-3. K_{sp} at 25ºC of AgCl, AgBr and AgI are respectively 3×10^{-10}, 7.7×10^{-13}, 1.5×10^{-16}. Write decreasing order of solubility of these salts.

A-4.✍ Write solubility product expression for Hg_2SO_4.

Section (B) : Condition for precipitation, Common ion effect on solubility

Commit to memory :
Condition for precipitation of A_xB_y : Ionic product or $K_{IP} > K_{sp}$; $[A^{y+}]^x [B^{x-}]^y > K_{sp}$ of A_xB_y
Common ion effect on solubility : Solubility (s') of A_xB_y (sparingly soluble ; K_{sp}) in a solution of 'c' M A_pD_q/E_rB_p (both readily soluble) : $(pc)^x(ys')^y = K_{sp}$; s' = **.....**

B-1.✍ Determine solubility of PbI_2 in a 0.1 M solution of NaI. (K_{sp} of $PbI_2 = 8 \times 10^{-9}$)

B-2.✍ Determine solubility of PbI_2 in a 0.1 M solution of $Pb(NO_3)_2$. (K_{sp} of $PbI_2 = 8 \times 10^{-9}$)

B-3. At 25ºC, the solubility of Ag_2CO_3 ($K_{sp} = 4.3 \times 10^{-13}$) would be in what order in the following solutions ?
(a) 0.01 M $AgNO_3$ (b) 0.04 M K_2CO_3 (c) pure water (d) in a buffer (pH = 4)

PART - II : ONLY ONE OPTION CORRECT TYPE

Section (A) : Solubility, Solubility product and Simple solubility calculations

Commit to memory :
Solubility (s ; in mol/L) of a sparingly soluble salt A_xB_y : $K_{sp} = x^x.y^y.(s)^{x+y}$

A-1.✍ $M(OH)_x$ (producing M^{x+} and OH^- ions) has K_{sp} 4×10^{-12} and solubility 10^{-4} M. The value of x is :
(A) 1 (B) 2 (C) 3 (D) 4

A-2. If the solubility of Lithium sodium hexafluoridoaluminate, $Li_3Na_3[AlF_6]_2$ is 's' mol L^{-1}, its solubility product is: (Assume no ionisation of $[AlF_6]^{3-}$)
(A) 18 s^3 (B) 186624 s^8 (C) 1458 s^8 (D) 2916 s^8

A-3. Which of the following is most soluble in water ? Assume no reaction of cation/anion.
(A) MnS ($K_{sp} = 2.5 \times 10^{-13}$) (B) ZnS ($K_{sp} = 1.6 \times 10^{-24}$)
(C) Bi_2S_3 ($K_{sp} = 1.6 \times 10^{-72}$) (D) Ag_2S ($K_{sp} = 10^{-51}$)

A-4. When different types of salts have nearly same solubility product constants K_{sp}, but less than one, the most soluble salt is that :
(A) Which produces maximum number of ions per formula unit
(B) Which produces minimum number of ions per formula unit
(C) Which produces ions with maximum charge
(D) Which produces ions with miniumum charge

A-5. In a saturated solution of Ag_2SO_4, silver ion concentration is 3×10^{-2} M. Its solubility product is : Assume no reaction of cation/anion.
(A) 1.35×10^{-5} (B) 1.08×10^{-4} (C) 2.7×10^{-5} (D) 4.5×10^{-4}

A-6.✍ The minimum volume of the water needed to dissolve 1 g of $BaSO_4$ ($K_{sp} = 10^{-10}$) is about: Assume no reaction of cation/anion. [Mol. mass ($BaSO_4$) = 233 u]
(A) 10^5 litres (B) 430 litres (C) 43 litres (D) 4300 litres

Section (B) : Condition for precipitation, Common ion effect on solubility

Commit to memory :
Condition for precipitation of A_xB_y : Ionic product or $K_{IP} > K_{sp}$; $[A^{y+}]^x [B^{x-}]^y > K_{sp}$ of A_xB_y
Common ion effect on solubility : Solubility (s') of A_xB_y (sparingly soluble ; K_{sp}) in a solution of 'c' M A_pD_q/E_rB_p (both readily soluble) : $(pc)^x(ys')^y = K_{sp}$; s' = **.....**

B-1.✍ The solubility product of $BaCrO_4$ is 2.4×10^{-10} M^2. The maximum concentration of $Ba(NO_3)_2$ possible without precipitation in a 6×10^{-4} M K_2CrO_4 solution is :
(A) 4×10^{-7} M (B) 1.44×10^{-13} M (C) 2×10^{-7} M (D) 2.5×10^{6} M

B-2.✍ The solubility product of AgCl is 1.8×10^{-10}. Precipitation of AgCl will occur only when equal volumes of solutions of :
(A) 2×10^{-5} M Ag^+ and 2×10^{-5} M Cl^- are mixed.
(B) 10^{-7} M Ag^+ and 10^{-7} M Cl^- are mixed.
(C) 10^{-5} M Ag^+ and 10^{-5} M Cl^- are mixed.
(D) 10^{-4} M Ag^+ and 10^{-4} M Cl^- are mixe

B-3.✍ The solubility of CaF_2 ($K_{sp} = 5.3 \times 10^{-9}$) in 0.1 M solution of NaF would be : Assume no reaction of cation/anion.
(A) 5.3×10^{-10} M (B) 5.3×10^{-8} M (C) 5.3×10^{-7} M (D) 5.3×10^{-11} M

B-4.✍ Let the solubilities of AgCl in pure water, 0.01 M $CaCl_2$, 0.01 M NaCl & 0.05 M $AgNO_3$ be s_1, s_2, s_3 & s_4 respectively. What is the correct order of these quantities ? Neglect any complexation.
(A) $s_1 > s_4 > s_3 > s_2$ (B) $s_1 > s_2 = s_3 > s_4$ (C) $s_1 > s_3 > s_2 > s_4$ (D) $s_4 > s_2 > s_3 > s_1$

B-5. Solubility of BaF_2 in a solution of $Ba(NO_3)_2$ will be represented by which concentration term ? Assume no reaction of cation/anion.
(A) $[Ba^{2+}]$ (B) $[F^-]$ (C) $[F^-]/2$ (D) 2[]

PART - III : MATCH THE COLUMN

1. Match the correct K_{sp} expression in terms of solubility (s) for given salts :
(Dont assume hydrolysis of any ion)

	Column-I		Column-II
(A)	$Ca_3(PO_4)_2$	(p)	$4s^3$
(B)	Hg_2I_2	(q)	$27s^4$
(C)	$Cr(OH)_3$	(r)	$108s^5$
(D)	CaF_2	(s)	$16s^4$

Exercise-2

✍ **Marked questions are recommended for Revision.**

PART - I : ONLY ONE OPTION CORRECT TYPE

1.✍ Slaked lime, $Ca(OH)_2$ is used extensively in sewage treatment. What can be the maximum pH of $Ca(OH)_2$ (aq) ? (Take log11 = 1.04)
$Ca(OH)_2(s) \rightleftharpoons Ca^{2+}(aq) + 2OH^-(aq)$; $K_{sp} = 5.324 \times 10^{-6}$
(A) 12.04 (B) 12.34 (C) 10.68 (D) 14

2. The solubility of Ag_2CO_3 in water is 1.26×10^{-4} mole/litre. What is its solubility in 0.02 M Na_2CO_3 solution ? Assume no hydrolysis of CO_3^{2-} ion. (Take $\sqrt[3]{2} = 1.26$)
(A) 5×10^{-6} M (B) $\sqrt{50} \times 10^{-6}$ M (C) 10^{-5} M (D) 2×10^{-5} M

PART - II : SINGLE AND DOUBLE VALUE INTEGER TYPE

1. How many of the following relations are correct for the solubility product (K_{sp}) & solubility (s g/litre) of sparingly soluble salt A_3B_2 (producing A^{2+} & B^{3-} ions ; mol. wt. M) in water ? (Assume no hydrolysis of any ion).

1. $K_{sp} = 108s^5$
2. $K_{sp} = \left[\frac{3s}{M}\right]^3 \left[\frac{2s}{M}\right]^2$
3. $K_{sp} = (3[A^{2+}])^3 (2[B^{3-}])^2$
4. $[B^{3-}] = \frac{2s}{M}$
5. $\frac{[B^{3-}]}{K_{sp}} = \frac{1}{54}\frac{M^4}{s^4}$
6. $[A^{2+}] = \left(\frac{K_{sp}}{[B^{3-}]^3}\right)^{1/2}$
7. $[A^{2+}]^3 M^5 = \frac{108s^5}{[B^{3-}]^2}$
8. $\frac{K_{sp}}{[A^{2+}]} = 36s^4$
9. $K_{sp} = [A^{2+}]^2 [B^{3-}]^3$

2. 8×10^{-6} M $AgNO_3$ solution is gradually added in 1 L of 10^{-4} M KCl solution. Upto what volume of $AgNO_3$ solution being added (in L), precipitation of AgCl will not take place? (K_{sp} of AgCl = 2×10^{-10})

PART - III : ONE OR MORE THAN ONE OPTIONS CORRECT TYPE

1. The solubility of a sparingly soluble salt A_xB_y in water is 1.4×10^{-4} M. The solubility product is 1.1×10^{-11}. The possibilities are :
(A) x = 1, y = 2 (B) x = 2, y = 1 (C) x = 1, y = 3 (D) x = 3, y = 1

Exercise-3

JEE (MAIN) / AIEEE PROBLEMS (PREVIOUS YEARS)

1. The solubility of $Mg(OH)_2$ is s moles/litre. The solubility product under the same condition is : **[AIEEE-2002, 3/225]**
(1) $4s^3$ (2) $3s^4$ (3) $4s^2$ (4) s^3

2. The solubility in water of a sparingly soluble salt AB_2 is 1.0×10^{-5} mol L^{-1}. Its solubility product will be : **[AIEEE-2003, 3/225]**
(1) 4×10^{-15} (2) 4×10^{-10} (3) 1×10^{-15} (4) 1×10^{-10}

3. The molar solubility (in mol L^{-1}) of a sparingly soluble salt MX_4 is s. The corresponding solubility product is K_{sp}.. s is given in terms of K_{sp} by the relation : **[AIEEE-2004, 3/225]**
(1) $s = (K_{sp}/128)^{1/4}$ (2) $s = (128K_{sp})^{1/4}$ (3) $s = (256K_{sp})^{1/5}$ (4) $s = (K_{sp}/256)^{1/5}$

4. The solubility product of a salt having general formula MX_2, in water is : 4×10^{-12}. The concentration of M^{2+} ions in the saturated aqueous solution of the salt is : **[AIEEE-2005, 3/225]**
(1) 2.0×10^{-6} M (2) 1.0×10^{-4} M (3) 1.6×10^{-4} M (4) 4.0×10^{-10} M

5. In a saturated solution of the sparingly soluble strong electrolyte $AgIO_3$ (Molecular mass = 283), the equilibrium which sets in is :
$$AgIO_3(s) \rightleftharpoons Ag^+(aq) + IO_3^-(aq)$$
If the solubility product constant K_{sp} of $AgIO_3$ at a given temperature is 1.0×10^{-8}, what is the mass of $AgIO_3$ contained in 100 mL of its saturated solution? **[AIEEE-2007, 3/120]**
(1) 1.0×10^{-7} g (2) 1.0×10^{-4} g (3) 28.3×10^{-2} g (4) 2.83×10^{-3} g

6. Solid $Ba(NO_3)_2$ is gradually dissolved in 1.0×10^{-4} M Na_2CO_3 solution. At what concentration of Ba^{2+} will a precipitate begin to form ? (K_{sp} for $BaCO_3$ = 5.1×10^{-9}) **[AIEEE-2009, 4/144]**
(1) 5.1×10^{-5} M (2) 8.1×10^{-8} M (3) 8.1×10^{-7} M (4) 4.1×10^{-5} M

7. Solubility product of silver bromide is 5.0×10^{-13} . The quantity of potassium bromide (molar mass taken as 120 g mol^{-1}) to be added to 1 litre of 0.05 M solution of silver nitrate to start the precipitation of AgBr is : **[AIEEE-2010, 4/144]**
(1) 1.2×10^{-10} g (2) 1.2×10^{-9} g (3) 6.2×10^{-5} g (4) 5.0×10^{-8} g

8. At 25°C, the solubility product of $Mg(OH)_2$ is 1.0×10^{-11}. At what pH, will Mg^{2+} ions start precipitating in the form of $Mg(OH)_2$ from a solution of 0.001 M Mg^{2+} ions ? **[AIEEE-2010, 4/144]**
(1) 9 (2) 10 (3) 11 (4) 8

9. An aqueous solution contains an unknown concentration of Ba^{2+}. When 50 mL of a 1M solution of Na_2SO_4 is added, $BaSO_4$ just begins to precipitate. The final volume is 500 mL. The solubility product of $BaSO_4$ is 1×10^{-10}. What is the original concentration of Ba^{2+}. **[JEE(Main) 2018, 4/120]**
(1) 1.1×10^{-9} M (2) 1.0×10^{-10} M (3) 5×10^{-9} M (4) 2×10^{-9} M

JEE(MAIN) ONLINE PROBLEMS

1. Zirconium phosphate $[Zr_3(PO_4)_4]$ dissociates into three zirconium cations of charge +4 and four phosphate anions of charge –3. If molar solubility of zirconium phosphate is denoted by S and its solubility product by K_{sp} then which of the following relationship between S and K_{sp} is correct ?
[JEE(Main) 2014 Online (19-04-14), 4/120]
(1) $S = \{K_{sp} /(6912)^{1/7}\}$ (2) $S = \{K_{sp} /144\}^{1/7}$ (3) $S = (K_{sp} /6912)^{1/7}$ (4) $S = \{K_{sp} /6912\}^{7}$

2. The minimum volume of water required to dissolve 0.1 g lead(II) chloride to get a saturated solution (K_{sp} of $PbCl_2 = 3.2 \times 10^{-8}$; atomic mass of Pb = 207 u) is : **[JEE(Main) 2018 Online (15-04-18), 4/120]**
(1) 1.798 L (2) 0.36 L (3) 17.98 L (4) 0.18 L

3. A mixture of 100 m mol of $Ca(OH)_2$ and 2 g of sodium sulphate was dissolved in water and the volume was made up to 100 mL. The mass of calcium sulphate formed and the concentration of OH^- in resulting solution, respectively, are : (Molar mass of $Ca(OH)_2$, Na_2SO_4 and $CaSO_4$ are 74, 143 and 136 g mol^{-1}, respectively; K_{sp} of $Ca(OH)_2$ is 5.5×10^{-6}) **[JEE(Main) 2019 Online (10-01-19), 4/120]**
(1) 13.6 g, 0.14 mol L^{-1} (2) 13.6 g, 0.28 mol L^{-1}
(3) 1.9 g, 0.28 mol L^{-1} (4) 1.9 g, 0.14 mol L^{-1}

4. If K_{sp} of Ag_2CO_3 is 8×10^{-12}, the molar solubility of Ag_2CO_3 in 0.1 M $AgNO_3$ is :
[JEE(Main) 2019 Online (12-01-19), 4/120]
(1) 8×10^{-10} M (2) 8×10^{-12} M (3) 8×10^{-13} M (4) 8×10^{-11} M

Answers

EXERCISE - 1

PART – I

A-1. 1.73×10^{-5} mol/L **A-2.** 3.2×10^{-8} **A-3.** AgCl > AgBr > AgI

A-4. $[Hg_2^{2+}][SO_4^{2-}]$ **B-1.** 8×10^{-7} M **B-2.** 1.414×10^{-4} M

B-3. (d) > (c) > (b) > (a)

PART - II

A-1.	(B)	**A-2.**	(D)	**A-3.**	(A)	**A-4.**	(A)	**A-5.**	(A)
A-6.	(B)	**B-1.**	(A)	**B-2.**	(D)	**B-3.**	(C)	**B-4.**	(C)
B-5.	(C)								

PART - III

1. (A $\rightarrow$ r) ; (B $\rightarrow$ p) ; (C $\rightarrow$ q) ; (D $\rightarrow$ p)

EXERCISE - 2

PART - I

1. (B) **2.** (C)

PART - II

1. 4 (2, 4, 5 and 7) **2.** 1

PART - III

1. (A) B)

EXERCISE – 3

JEE(MAIN) OFFLINE PROBLEMS

1.	(1)	**2.**	(1)	**3.**	(4)	**4.**	(2)	**5.**	(4)
6.	(1)	**7.**	(2)	**8.**	(2)	**9.**	(1)		

JEE(MAIN) ONLINE PROBLEMS

1.	(3)	**2.**	(4)	**3.**	(3)	**4.**	(1)