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CHEMISTRY WORKSHEET

K_{sp} & MOLAR SOLUBILITY

Course: SCH4U Grade 12 Chemistry

50 Practice Problems with Answers and Detailed Solutions

FULL worksheet contains 50 representative problems on:

✓ K_{sp} expressions, ✓ molar solubility, ✓ common ion effect, ✓ Q_{sp}, ✓ precipitation prediction, ✓hydroxide precipitation, ✓ selective precipitation.

All problems are designed to reflect style and difficulty commonly seen on quizzes, tests, and final exams. Detailed solutions are included to help students understand the reasoning behind every step.

PART A - FUNDAMENTAL PROBLEMS
Problems 1-15. Simple calculations and basic applications

PART B - INTERMEDIATE PROBLEMS
Problems 16-30. Typical unit test questions involving multiple steps

PART C - ADVANCED PROBLEMS
Problems 31-40. More challenging calculations requiring deeper understanding

PART D - CHALLENGE PROBLEMS
Problems 41-50. Difficult exam-style questions combining multiple concepts

SUITABLE FOR:
quizzes, unit tests and final exam preparation

Section 1 - Essential Information

Salt hydrolysis happens when an ion from a salt reacts with water and changes $[H_3O^+]$ or $[OH^-]$. The main idea is to identify whether each ion comes from a strong acid, strong base, weak acid, or weak base.

Ion type	Hydrolysis behaviour	Main result
Cation from strong base	No important hydrolysis	Neutral effect
Anion from strong acid	No important hydrolysis	Neutral effect
Cation from weak base	$BH^+ + H_2O \rightleftharpoons B + H_3O^+$	Acidic solution
Anion from weak acid	$A^- + H_2O \rightleftharpoons HA + OH^-$	Basic solution
Weak acid + weak base salt	Both ions hydrolyze	Compare K_a (cation) and K_b (anion)

Key relationships

Weak acid model: HA reacts with water to form H_3O^+ and A^-.

$$HA_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + A^-_{(aq)}$$

$$K_a = \frac{[H_3O^+][A^-]}{[HA]}$$

Weak base model: B reacts with water to form BH^+ and OH^-.

$$B_{(aq)} + H_2O_{(l)} \rightleftharpoons BH^+_{(aq)} + OH^-_{(aq)}$$

$$K_b = \frac{[BH^+][OH^-]}{[B]}$$

pH relationships at 25 °C	Conjugate pairs: $K_a K_b = K_w$
$pH = -\log[H_3O^+]$, $[H_3O^+] = 10^{-pH}$ $pOH = -\log[OH^-]$, $[OH^-] = 10^{-pOH}$ $pH + pOH = 14.00$ $[H_3O^+][OH^-] = K_w = 1.0 \times 10^{-14}$	use $K_b = K_w/K_a$ for a conjugate base and $K_a = K_w/K_b$ for a conjugate acid

For weak acid + weak base salts: $pH = 7.00 + \frac{1}{2}\log\left(\frac{[\text{Weak cation}]}{[\text{Weak anion}]}\right)$

For amphiprotic ions such as HCO_3^-: $pH = \frac{pK_{a1} + pK_{a2}}{2}$

Common constants used in this worksheet

Acid or base	Constant	Acid or base	Constant
CH_3COOH	$K_a = 1.8 \times 10^{-5}$	NH_3	$K_b = 1.8 \times 10^{-5}$
HF	$K_a = 6.8 \times 10^{-4}$	CH_3NH_2	$K_b = 4.4 \times 10^{-4}$
HNO_2	$K_a = 4.5 \times 10^{-4}$	C_5H_5N	$K_b = 1.7 \times 10^{-9}$
HCN	$K_a = 3.5 \times 10^{-10}$	$HCOOH$	$K_a = 1.8 \times 10^{-4}$
HClO	$K_a = 3.2 \times 10^{-8}$	HCO_3^-	$K_{a2} = 4.7 \times 10^{-11}$

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Section 2 - Practice Problems

Part A - Fundamental Problems (Problems 1-15)

8. The K_{sp} of $Ag_2CrO_{4(s)}$ is 1.1×10^{-12}. Calculate its molar solubility in pure water

Part B - Intermediate Problems (Problems 16-30)

16. Calculate the molar solubility of CaF_2 in 0.010 M NaF. Use $K_{sp} = 3.9 \times 10^{-11}$

Part C - Advanced Problems (Problems 31-40)

32. Calculate the molar solubility of CaF_2 in 0.0010 M $Ca(NO_3)_2$. Use $K_{sp} = 3.9 \times 10^{-11}$

Part D - Challenge Problems (Problems 41-50)

45. Calculate $[Al^{3+}]$ in equilibrium with $Al(OH)_3$ at pH = 4.00. Use $K_{sp} = 3.0 \times 10^{-34}$

Solutions

Problem 8 Solution

Given: $K_{sp}(Ag_2CrO_4) = 1.1 \times 10^{-12}$

Find: Molar solubility, s, in pure water

$Ag_2CrO_{4(s)} \rightleftharpoons 2Ag^+_{(aq)} + CrO_4^{2-}{}_{(aq)}$

Dissolving s mol/L produces 2s mol/L Ag^+ and s mol/L CrO_4^{2-}.

Stage	Ag^+	CrO_4^{2-}
Initial	0	0
Change	+2s	+s
Equilibrium	2s	s

$K_{sp} = [Ag^+]^2[CrO_4^{2-}]$

$1.1 \times 10^{-12} = (2s)^2(s) = 4s^3$

$s = (1.1 \times 10^{-12}/4)^{1/3} = 6.50 \times 10^{-5}$ M

Final answer: Molar solubility = 6.50×10^{-5} M

Problem 16 Solution

Given: CaF_2 in 0.010 M NaF; $K_{sp} = 3.9 \times 10^{-11}$

Find: Molar solubility, s

NaF dissociates completely, so the solution initially contains 0.010 M F^-. Dissolving CaF_2 adds s mol/L Ca^{2+} and 2s mol/L F^-.

$$CaF_{2(s)} \rightleftharpoons Ca^{2+}_{(aq)} + 2F^-_{(aq)}$$

Stage	Ca^{2+}	F^-
Initial	0	0.010
Change	+s	+2s
Equilibrium	s	0.010 + 2s

$$K_{sp} = s(0.010 + 2s)^2$$

Because the common-ion concentration is much larger than the added 2s, first use $0.010 + 2s \approx 0.010$.

$$s \approx (3.9 \times 10^{-11})/(0.010)^2 = 3.9 \times 10^{-7}\ M$$

Check: $2s/(0.010) \times 100\% = 0.0078\%$, so the approximation is excellent.

Final answer: Molar solubility = 3.9×10^{-7} M

Problem 32 Solution

Given: CaF_2 in 0.0010 M $Ca(NO_3)_2$; $K_{sp} = 3.9 \times 10^{-11}$

Find: Molar solubility, s

$CaF_{2(s)} \rightleftharpoons Ca^{2+}_{(aq)} + 2F^-_{(aq)}$

Stage	Ca^{2+}	F^-
Initial	0.0010	0
Change	+s	+2s
Equilibrium	0.0010 + s	2s

$K_{sp} = (0.0010 + s)(2s)^2$

An initial approximation treats 0.0010 + s as 0.0010.

$s \approx \sqrt{((3.9 \times 10 - 11)/(4 \times 0.0010))} = 9.87 \times 10^{-5}$ M

This estimate is about 9.9% of 0.0010 M, so the approximation is borderline and the full equation should be solved.

$(0.0010 + s)(2s)^2 = 3.9 \times 10^{-11}$

Solving the cubic equation numerically gives $s = 9.44 \times 10^{-5}$ M.

Final answer: Molar solubility = 9.44×10^{-5} M

Problem 45 Solution

Given: pH = 4.00; $K_{sp}(Al(OH)_3) = 3.0 \times 10^{-34}$

Find: Equilibrium $[Al^{3+}]$

pOH = 14.00 - 4.00 = 10.00

$[OH^-] = 10^{-10.00} = 1.0 \times 10^{-10}$ M

$K_{sp} = [Al^{3+}][OH^-]^3$

$[Al^{3+}] = K_{sp}/[OH^-]^3$

$[Al^{3+}] = (3.0 \times 10^{-34})/(1.0 \times 10^{-10})^3 = 3.0 \times 10^{-4}$ M

Final answer: $[Al^{3+}] = 3.0 \times 10^{-4}$ M

Section 4 - Answer Key

Problem	Answer
8	6.50×10^{-5} M
16	3.9×10^{-7} M
32	9.44×10^{-5} M
45	$[Al^{3+}] = 3.0 \times 10^{-4}$ M