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CHEMISTRY WORKSHEET

PREDICTING PRECIPITATION

Course: SCH4U Grade 12 Chemistry

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50 Practice Problems with Answers and Detailed Solutions

FULL worksheet contains 50 representative problems on:

✓ Solubility-rule predictions, ✓ net ionic equations, ✓ Qsp vs Ksp precipitation calculations, ✓precipitation threshold calculations, ✓ selective precipitation, ✓ limiting-ion precipitate mass calculations.

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

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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: $K_a \times K_b$
$pH = -\log[H_3O^+]$; $[H_3O^+] = 10^{-pH}$ $pOH = -\log[OH^-]$; $[OH^-] = 10^{-pOH}$ $pH + pOH = 14.00$ $[H_3O^+][OH^-] = K_w = 1.0 \times 10^{-14}$	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: $pH \approx 7.00 + \frac{1}{2}\log\left(\frac{[\text{BH}^+\text{ cancels}]}{[\text{A}^-\text{ cancels}]}\right)$

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

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	$K_b = 1.7 \times 10^{-9}$
$HCHO$	$K_a = 1.8 \times 10^{-4}$	$HCOOH$	$K_a = 1.8 \times 10^{-4}$
HCN	$K_a = 6.2 \times 10^{-10}$	HCO_3^-	$K_{a2} = 4.7 \times 10^{-11}$

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Section 2 - Practice Problems

Part A - Solubility Rules and Simple Predictions

8. Predict whether a precipitate forms when aqueous copper(II) sulfate and aqueous sodium carbonate are mixed. If a precipitate forms, identify it and write the net ionic equation.

$$CuSO_{4(aq)} + Na_2CO_{3(aq)} \rightarrow CuCO_{3(s)} + Na_2SO_{4(aq)}$$

Part B - Net Ionic Equations and Mixed Ions

16. Aqueous lithium hydroxide is mixed with aqueous copper(II) nitrate. Predict the precipitate and write the balanced net ionic equation.

$$2\ LiOH_{(aq)} + Cu(NO_3)_{2(aq)} \rightarrow Cu(OH)_{2(s)} + 2\ LiNO_{3(aq)}$$

Part C - Q_{sp} versus K_{sp} Calculations

32. 10.0 mL of 0.0100 M $Pb(NO_3)_2$ is mixed with 40.0 mL of 0.0100 M KI. Use $K_{sp}(PbI_2) = 7.9 \times 10^{-9}$ to predict whether PbI_2 precipitates.

Part D - Threshold and Challenge Problems

45. 100.0 mL of 0.0100 M $Pb(NO_3)_2$ is mixed with 100.0 mL of 0.0200 M KI. Predict whether PbI_2 precipitates, then calculate the maximum mass of PbI_2 that can form if precipitation goes essentially to completion.

Section 3 - Solutions

Problem 8 Solution

Given: After the aqueous substances dissociate, the solution contains Cu^{2+}, SO_4^{2-}, Na^+, and CO_3^{2-}.

Find: Whether an insoluble product forms and, if it does, the balanced net ionic equation.

The possible new solid is $CuCO_3$. Most carbonates are insoluble except Group 1 and ammonium carbonates.

The ions Na^+ and SO_4^{2-} do not form the solid and remain dissolved as spectator ions. Removing them from the complete ionic equation leaves:

$$Cu^{2+}(aq) + CO_3^{2-}(aq) \rightarrow CuCO_3(s)$$

The equation is balanced for both atoms and total electrical charge.

Final answer: Yes - $CuCO_3$ precipitates; $Cu^{2+} + CO_3^{2-} \rightarrow CuCO_3(s)$.

Problem 16 Solution

Given: After the aqueous substances dissociate, the solution contains Li^+, OH^-, Cu^{2+}, and NO_3^-.

Find: Whether an insoluble product forms and, if it does, the balanced net ionic equation.

The possible new solid is $Cu(OH)_2$. Most transition-metal hydroxides are insoluble, including $Cu(OH)_2$.

The ions Li^+ and NO_3^- do not form the solid and remain dissolved as spectator ions. Removing them from the complete ionic equation leaves:

$$Cu^{2+}(aq) + 2\ OH^-(aq) \rightarrow Cu(OH)_2(s)$$

The equation is balanced for both atoms and total electrical charge.

Final answer: $Cu(OH)_2$ precipitates; $Cu^{2+} + 2\ OH^- \rightarrow Cu(OH)_2(s)$.

Problem 32 Solution

Given: Two ionic solutions are mixed. The total volume is 50.0 mL, so each ion must first be diluted into this combined volume.

Find: Whether PbI_2 precipitates.

Calculate the amount and concentration of each precipitating ion immediately after mixing, before any precipitation occurs:

Ion	Initial amount calculation	Amount	Concentration after mixing
Pb^{2+}	(0.0100 M)(10.0 mL)	1.00×10^{-4} mol	2.00×10^{-3} M
I^-	(0.0100 M)(40.0 mL)	4.00×10^{-4} mol	8.00×10^{-3} M

Use the solubility-product expression for the possible solid:

$$Q_{sp} = [Pb^{2+}][I^-]^2$$

$$Q_{sp} = (2.00 \times 10^{-3})(8.00 \times 10^{-3})^2 = 1.28 \times 10^{-7}$$

$K_{sp} = 7.9 \times 10^{-9}$

Q_{sp} exceeds K_{sp} by more than an order of magnitude, so $PbI_2(s)$ forms.

Final answer: Yes - PbI_2 precipitates; $Q_{sp} = 1.28 \times 10^{-7} > K_{sp}$.

Problem 45 Solution

Given: 100.0 mL of 0.0100 M $Pb(NO_3)_2$ is mixed with 100.0 mL of 0.0200 M KI. $K_{sp}(PbI_2) = 7.9 \times 10^{-9}$.

Find: Whether PbI_2 precipitates and the maximum mass that can form.

After mixing, $[Pb^{2+}] = 0.00500$ M and $[I^-] = 0.0100$ M.

$$Q_{sp} = [Pb^{2+}][I^-]^2 = (0.00500)(0.0100)^2 = 5.00 \times 10^{-7}$$

Because $Q_{sp} > K_{sp}$, PbI_2 precipitates. Use the net ionic equation and a stoichiometric table to calculate the maximum amount of solid.

$$Pb^{2+}(aq) + 2\ I^-(aq) \rightarrow PbI_2(s)$$

Substance	Initial amount	Change	Amount after reaction
Pb^{2+}	0.0100 M × 0.1000 L = 0.00100 mol	−0.00100 mol	0 mol
I^-	0.0200 M × 0.1000 L = 0.00200 mol	−0.00200 mol	0 mol
PbI_2	0 mol	+0.00100 mol	0.00100 mol

The reactants are present in the exact 1:2 stoichiometric ratio, so 0.00100 mol PbI_2 is the maximum theoretical amount.

$$m = nM = (0.00100\ mol)(461.0\ g/mol) = 0.461\ g$$

Final answer: Yes; PbI_2 precipitates. Maximum mass = 0.461 g PbI_2.

Section 4 - Answer Key

Final answers only.

Problem	Final answer
8	Yes - $CuCO_3$ precipitates; $Cu^{2+} + CO_3^{2-} \rightarrow CuCO_3(s)$.
16	$Cu(OH)_2$ precipitates; $Cu^{2+} + 2\ OH^- \rightarrow Cu(OH)_2(s)$.
32	Yes - PbI_2 precipitates; $Q_{sp} = 1.28 \times 10^{-7} > K_{sp}$.
45	Yes; PbI_2 precipitates. Maximum mass = 0.461 g PbI_2.