Solubility #1

1. Write the net ionic equation(s) for the reaction(s) when equal volumes of 0.2 M $Sr(OH)_2$ and 0.2 M $Fe_2(SO_4)_3$ are mixed.

2. Describe the equilibrium that exists in a saturated solution of $BaSO_4$ in contact with some solid residue of $BaSO_4$.

3. In an experiment, 0.1 M $AgNO_3$ is added to 0.1 M NaCl, resulting in the formation of a white precipitate. When 0.1 M NaI is added to this mixture, the white precipitate dissolves and a yellow precipitate forms.
   (a) Write the formula and name for each of the following:
      (i) the white precipitate

      (ii) the yellow precipitate

   (b) Write the net ionic equation to represent the formation of the more soluble precipitate.

4. A solution of $Ba(NO_3)_2$ is added to a solution of Na_2CO_3, resulting in the formation of a white precipitate the reacts with HNO_3.
   (a) Write a net ionic equation to represent the formation of the white precipitate.

   (b) Explain why the precipitate reacts in HNO_3.

5. A student is given three beakers, each containing 100 mL of solution. The first beaker contains 0.20 M CaS; the second contains 0.20 M $CuSO_4$; the third contains 0.20 M $Sr(OH)_2$. The student is asked to select two solutions which, when combined, would result in the formation of a mixture containing a single precipitate.
   (a) Which two solutions should the student use?

   (b) Write the net ionic equation for the precipitation reaction.

6. If a solution of calcium nitrate is added to a saturated solution of calcium sulphate, a precipitate is observed to form. Explain why this occurs, including any relevant equation(s) and identify the precipitate.

7. Write an equation that describes a saturated solution of NaCl.

8. A solution containing Al^{3+}, NH_4^+ and Mg^{2+} ions is added to a solution containing S^{2-}, Cl^- and OH^- ions. Identify the ions that do **not** form a precipitate.

9. Write an equation that describes the equilibrium present in a saturated solution of $Cu_3(PO_4)_2$.

10. A 1.0 M solution of sodium sulphide is added to a 1.0 M solution of copper(II) chloride resulting in the formation of a precipitate.
    (a) Identify the precipitate.

    (b) Write the **complete** ionic equation for the reaction.

    (c) Identify **all** spectator ions.

11. Identify a salt that could be added to a saturated solution of $BaSO_4$ that would result in more solid barium sulphate forming.

12. Write an equation that describes a saturated solution of magnesium hydroxide.

13. When solid $Ca(NO_3)_2$ is added to a saturated solution of $MgCO_3$, more $MgCO_3$ dissolves. Explain.

14. A student mixes equal volumes of 0.20 M Na_2CO_3 and 0.20 M $Ba(NO_3)_2$, forming a white precipitate.
    (a) Write the net ionic equation for the precipitation reaction.

    (b) Explain why the precipitate dissolves when HCl is added.

15. Write an equation that represents the solubility equilibrium of a saturated solution of barium sulphate.

Solubility #2

1. A solution contains SO_4^{2-} and Cl^-. Outline an experimental procedure to remove each ion individually from the solution, and identify the reagents used in the procedure.

2. A solution is known to contain Cu^+, Be^{2+} and Sr^{2+} ions, each at a concentration of 0.20 M.

   (a) What compound could be used to precipitate the Sr^{2+} while leaving the other two cations in solution?

   (b) Write the net ionic equation for the reaction

3. A solution contains Pb^{2+}, Mg^{2+}, and Sr^{2+}. Outline a procedure to isolate the precipitate $SrSO_4$ from this solution.

4. Write the formula of two materials (other than water) that could be added to a saturated solution of Ag_2CO_3 to increase the amount of Ag_2CO_3 that will dissolve.

5. A solution contains Ca^{2+}, Sr^{2+} and Pb^{2+} ions that must be separated.

   (a) Identify an anion that could be used to remove only the lead ion by precipitation.

   (b) Identify an anion that could be used to separate Ca^{2+} from Sr^{2+}.

6. Use the table of solubilities to determine a scheme that allows the separation of Ba^{2+}, Cu^{2+}, and Br^- from each other.

7. Use the table of solubilities to describe how you would separate Mg^{2+}, Ba^{2+} and Ag^+ from each other.

8. Use the table of solubilities to outline a scheme to separate a mixture of Li^+, Ag^+, Sr^{2+} and Fe^{3+} from each other.

9. A beaker contains OH^- ions and S^{2-} ions in solution both at a concentration of 0.10 M. You are asked to precipitate the OH^- ions while leaving the S^{2-} ions in solution.
(a) Which reagent could you use?

(b) Write the net ionic equation for the precipitation reaction.

Solubility #3 - Assume that all solutions are at 25°C unless told otherwise.

1. Which one of the following solutions will contain the greatest silver ion concentration?

   saturated Ag_2CO_3 saturated AgCl

2. In which solution would you find the highest magnesium ion concentration: saturated $MgCO_3$ or saturated $Mg(OH)_2$?

3. The K_{sp} values for various silver salts are given below:

$AgBrO_3$	5.3×10^{-5}	Ag_2CO_3	8.5×10^{-12}
$Ag_2Cr_2O_7$	2.0×10^{-7}	AgSCN	1.2×10^{-12}
AgOH	1.5×10^{-10}	AgBr	5.4×10^{-13}
AgCl	1.8×10^{-10}	AgI	8.5×10^{-17}
Ag_2CrO_4	1.1×10^{-12}	$AgIO_3$	3.2×10^{-8}

   Determine which one of these compounds gives the highest silver ion concentration in a saturated solution and calculate this concentration.

4. Calculate the solubility of $BaSO_4$.

5. Calculate the mass of solid $PbSO_4$ that can be dissolved in 5.0 L of solution at 25°C.

6. Calculate the solubility of PbI_2 at 25°C.

7. What is the solubility of calcium oxalate at 25°C in g/L?

8. How many milligrams of $CaCO_3$ would be dissolved in 1.0 L of saturated solution at 25°C.

9. What mass of PbI_2 will dissolve in 250 mL of water?

10. a. What is the solubility of magnesium hydroxide?
    b. What is the $[OH^-]$ in a saturated solution of magnesium hydroxide?

Solubility #4

1. When excess Ag_2CO_3 solid is shaken with 1.00 L of 2.00 M K_2CO_3, it is determined that 6.00×10^{-6} mol Ag_2CO_3 solid dissolves. Calculate the solubility product for silver carbonate.

2. Calculate the K_{sp} for SrF_2 if the solubility is 0.122 g/L.

3. A saturated solution of calcium hydroxide is found to have $[OH^-]$ of 2.09×10^{-2} M. Calculate the K_{sp} for $Ca(OH)_2$.

4. The solubility of Ag_2SO_4 is 0.62 g/L at 6° C. What is the K_{sp} at this temperature?

5. Describe an analytical method which could be used to determine the K_{sp} of a saturated solution of silver sulphate other than drying the solid from a saturated solution.

6. At 20° C the solubility of PbF_2 is 64 mg per 100 mL of solution. Determine the K_{sp} for lead II fluoride.

7. The equilibrium in a saturated ZnI_2 solution is given by:

$$ZnI_{2(s)} <----> Zn^{2+}_{(aq)} + 2I^-_{(aq)}$$

Predict the effect on the solubility of ZnI_2 of adding some:

(a) solid NaI.
(b) solid $Zn(NO_3)_2$
(c) solid NaOH
(d) concentrated HCl
(e) solid NH_4NO_3

Solubility #5

1. What is the minimum mass of Na_2SO_4 crystal that must be dissolved in 5.0 L of 0.0010 M $Ca(NO_3)_2$ solution in order to initiate precipitation of calcium sulphate?

2. 750 mL of a $1.0x10^{-2}$ M lead II chloride solution was cooled resulting in the precipitation of 1.80 g of solid $PbCl_2$. What is the molarity of the cooled solution?

3. Determine the mass of silver chloride precipitated when 50 mL of 0.60 M $AgNO_3$ solution is mixed with 100 mL of 0.10 M $CaCl_2$ solution. Assume AgCl has negligible solubility.

4. A given sample of water with temporary hardness has a $[Ca^{2+}]$ of $1.0x10^{-3}$ M.
(a) If the K_{sp} of CaF_2 is $1.7x10^{-10}$, what is the maximum $[F^-]$ that can be attained in temporary hard water before CaF_2 would precipitate?

5. A solution is prepared by adding 1.5 mol $BaCrO_4$ to water to make 1.0 L of solution. Calculate the $[Ba^{2+}]$ and the $[CrO_4^{2-}]$ at equilibrium.

6. The $[Ag^+]$ of a solution is $4.0x10^{-3}$ M. Calculate the $[Cl^-]$ that must be exceeded before AgCl can precipitate.

7. Calculate the solubility of PbI_2.

8. 30 mL of 0.10 M $AgNO_3$ is added to 70 mL of 0.10 M $CaCl_2$. What is the concentration of each ion in the solution once precipitation stops and equilibrium is established?

Solubility #6

1. Show whether or not a precipitate would be expected to form when 0.0050 g $AgNO_3$ crystals are added to 2.00 L of 0.0010 M NaCl.

2. 2.0 mg of $Ca(NO_3)_2$ and 2.0 mg NaF are dissolved and made up to 500 mL of solution. If the K_{sp} for CaF_2 is $4.0x10^{-11}$, will a precipitate form?

3. Will a precipitate of AgCl form when 5.1 mg of $AgNO_3$ crystals are added to 3.0 L of $2.0x10^{-3}$ M NaCl?

4. Show whether or not a precipitate of silver acetate forms when 15 mL of 1.0 M $AgNO_3$ is added to 45 mL of acetic acid in which the $[CH_3COO^-]$ is $5.2x10^{-3}$ M. K_{sp} CH_3COOAg = $3.7x10^{-3}$

5. Determine whether or not a precipitate of $BaSO_4$ will form when 0.15 g of K_2SO_4 solid is added to 2.0 L of $1.7x10^{-5}$ M $BaCl_2$.

6. Explain why a precipitate of silver chloride will not be produced when 20 mL of $3.0x10^{-6}$ M $AgNO_3$ is mixed with 30 mL of $1.0x10^{-4}$ M NaCl.

7. When $AgNO_3$ crystals dissolve in a solution containing 0.010 M NaCl and 0.010 M Na_2CrO_4, AgCl precipitates before the Ag_2CrO_4. Explain this behavior.

8. A 0.010 M solution of $AgNO_3$ is added dropwise to a solution containing a mixture of carbonate and iodate ions, in which $[CO_3^{2-}]$ = $3.0x10^{-3}$ M and $[IO_3^-]$ = $5.0x10^{-3}$ M. Which substance precipitates first?

9. Will a precipitate of $Al(OH)_3$ form when 0.50 L of $2.0x10^{-3}$ M $AlCl_3$ and 0.50 L of $4.0x10^{-2}$ M NaOH are mixed and diluted to 1000 L with water? K_{sp} $Al(OH)_3$ = $3.7x10^{-15}$

10. Will a precipitate form when 400 mL of 0.0020 M $Ba(OH)_2$ are mixed with 200 mL of 0.0020 M H_2SO_4?

VI. Quantitative Aspects of Solubility

Low solubility compounds form an eq^{m} between the solid and its aqueous ions.

$$\text{Solid} \leftrightarrow n(\text{cations}) + m(\text{anions})$$

$$\text{Then: } K_{eq} = [\text{cation}]^n \times [\text{anion}]^m$$

If both [ion] are large, the K_{eq} is large; a large K_{eq} implies high solubility.

The K_{eq} is the product of the solubilities, so this constant is:

$$K_{sp} = \text{Solubility Product Constant}$$

(A) Calculating the solubility

Example 1: Find the solubility for CuI. $K_{sp} = 1.3\times10^{-12}$

Example 2: Find the solubility of $PbCl_2$. $K_{sp} = 1.2\times10^{-5}$

Example 3: Find the solubility of $Al(OH)_3$. $K_{sp} = 3.7\times10^{-15}$

Shortcuts

Compound	K_{sp}	Solubility
AB	X^2	$\sqrt{Ksp}$
A_2B or AB_2	$4X^3$	$\sqrt[3]{Ksp/4}$
A_3B or AB_3	$27X^4$	$\sqrt[4]{Ksp/27}$

(B) Calculating the K_{sp} of a compound

Example 1: A saturated solution of $PbSO_4$ has $[Pb^{2+}] = 1.05\times10^{-4}$ M. Find the K_{sp} for lead (II) sulphate.

The Pb^{2+} ion results from the dissociation of the salt. An equal number of both lead and sulphate ions would have formed. As this is a saturated sol^n, the [ion] would be eq^m concentrations.

Example 2: A saturated solution of $PbCl_2$ has $[Pb^{2+}] = 3.56\times10^{-2}$ M. Find the K_{sp} for lead (II) chloride.

For every Pb^{2+} ion there will be two Cl^- ions formed.

(C) Concentration of other ion

Example 1: A solution contains $[Pb^{2+}] = 1.0\times10^{-3}$ M. If the K_{sp} for $PbSO_4$ is 1.8×10^{-8}, what is the maximum possible $[SO_4^{2-}]$?

This is not a case of forming ions by dissociation of the salt, but rather mixing two solutions together. In this case, the [ions] must meet the K_{sp} value.

Example 2: A solution contains $[Pb^{2+}] = 2.0\times10^{-3}$ M. If the K_{sp} for $PbCl_2$ is 1.2×10^{-5}, what is the maximum possible $[Cl^-]$?