Unit III – Assignment 1 – Solubility

1. Define *solubility*. **(2 marks)**

Answer:

The maximum amount of solute that will dissolve in a given amount of solvent.

or

The concentration of a saturated solution. **(2 marks)**

2. Write chemical equations to represent the equilibria for saturated solutions of the following chemicals: **(3 marks)**

   a. Syrup, $C_{12}H_{22}O_{11(s)}$

   b. Milk of magnesia, $Mg(OH)_{2(s)}$

   c. Washing soda, $Na_2CO_{3(s)}$

Answers:

a. $C_{12}H_{22}O_{11(s)} \rightarrow C_{12}H_{22}O_{11(aq)}$ **(1 mark)**

b. $Mg(OH)_{2(s)} \rightarrow Mg^{2+}_{(aq)} + 2OH^{-}_{(aq)}$ **(1 mark)**

c. $Na_2CO_{3(s)} \rightarrow 2Na^{+}_{(aq)} + CO_3^{2-}{}_{(aq)}$ **(1 mark)**

3. A $100.0\,mL$ sample of $0.600\,M\ Ca(NO_3)_2$ is diluted by adding $400.0\,mL$ of water. Calculate the concentration of ions in the resulting solution. **(2 marks)**

Answer:

$$\left[Ca(NO_3)_2\right] = 0.600\,M \times \frac{100.0\ mL}{500.0\ mL} = 0.120\,M \quad \leftarrow \textbf{1 mark}$$

$$\left[Ca^{2+}\right] = 0.120\,M$$

$$\left[NO_3^{-}\right] = 0.240\,M \quad \leftarrow \textbf{1 mark}$$

4. Determine the molar concentration of each ion from the solubility of the following saturated solutions:

   a. Rock phosphorus, $Ca_3(PO_4)_{2(s)}$ at 1.4×10^{-7} mol/L at 25°C **(3 marks)**

   b. Rock salt, $NaCl_{(s)}$ at 32.2 g/100 mL at 25°C **(4 marks)**

Answer:

a. $[Ca^{2+}] = 3(1.4 \times 10^{-4}\ M) = 4.2 \times 10^{-4}\ M$
$[PO_4^{-3}] = 2(1.4 \times 10^{-4}\ M) = 2.8 \times 10^{-4}\ M$

b. (32.2 g / 0.100 L) (1 mol / 58.5 g) = 5.50 M
$[Na^+] = [Cl^-] = 5.50\ M$

5. A 100 ml solution containing 0.2 M Al^{3+}, 0.2 M NH_4^+ and 0.2 M Mg^{2+} is added to a 100 ml solution containing 0.2 M S^{2-}, 0.2 M Cl^- and 0.2 M OH^-. Identify the ions that do **not** form a precipitate. **(2 marks)**

Answer: NH_4^+ and Cl^- ←**2 marks**

6. Write a balanced chemical equation for the equilibrium in a saturated solution of an ionic compound with low solubility. **(2 marks)**

Answer:

Any EQM equation as long as it has low solubility.

Example: $Ca_3(PO_4)_{2(s)} \rightleftharpoons 3\ Ca^{2+}_{(aq)} + 2\ PO_4^{3-}{}_{(aq)}$

7. Write an equation that describes the equilibrium present in a saturated solution of $Cu_3(PO_4)_2$. **(2 marks)**

Answer:

Example: $Ca_3(PO_4)_{2(s)} \rightleftharpoons 3\ Ca^{2+}_{(aq)} + 2\ PO_4^{3-}{}_{(aq)}$

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

   a) Identify the precipitate. **(1 mark)**
   b) Write the complete ionic equation for the reaction. **(1 mark)**
   c) Identify all spectator ions. **(1 mark)**

Answer:

Copper(II) sulphite or $CuSO_3$

b) $2Na^+_{(aq)} + SO_3^{2-}{}_{(aq)} Cu^{2+} + 2Cl^-_{(aq)} \rightarrow CuSO_{3(aq)} + 2Na^+ + 2Cl^-$
or
$Na^+_{(aq)} + SO_3^{2-}{}_{(aq)} + Cu^{2+}_{(aq)} + Cl^-_{(aq)} \rightarrow CuSO_{3(s)} + Na^+_{(aq)} + Cl^-_{(aq)}$

c) Na^+ , Cl^-

9. Write the net ionic equation representing the reaction that occurs when equal volumes of 0.20 M H_2SO_4 and 0.20 M $Ba(NO_3)_2$ are mixed together. **(2 marks)**

Answer: $Ba^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)} \rightarrow BaSO_{4(s)}$ ← **2 marks**

10. Write the net ionic equation representing the reaction that occurs when 50.0 mL of 0.20 M $ZnSO_4$ and 50.0 mL of 0.20 M BaS are combined. **(2 marks)**

Answer: $Zn^{2+}{}_{(aq)} + SO_4^{2-}{}_{(aq)} + Ba^{2+}{}_{(aq)} + S^{2-}{}_{(aq)} \rightarrow ZnS_{(s)} + BaSO_{4(s)}$

11. Write the formula equation, complete ionic, and net ionic equations for the following double replacement reactions: **(6 marks)**

    a. $Na_2CO_{3(aq)}$ and $CaCl_{2(aq)}$

    b. $Fe(NO_3)_{3(aq)}$ and $NaOH_{(aq)}$

Answers:

a. **(1 mark for each)**

Formula: $Na_2CO_{3(aq)} + CaCl_{2(aq)} \rightarrow 2NaCl_{(aq)} + CaCO_{3(s)}$

Complete: $2Na^+_{(aq)} + CO_3^{2-}{}_{(aq)} + Ca^{2+}_{(aq)} + 2Cl^-_{(aq)} \rightarrow 2Na^+_{(aq)} + 2Cl^-_{(aq)} + CaCO_{3(s)}$

Net Ionic: $Ca^{2+}_{(aq)} + CO_3^{2-}{}_{(aq)} \rightarrow CaCO_{3(s)}$

b. **(1 mark for each)**

Formula: $Fe(NO_3)_{3(aq)} + 3NaOH_{(aq)} \rightarrow Fe(OH)_{3(s)} + 3NaNO_{3(aq)}$

Complete: $Fe^{3+}_{(aq)} + 3NO_3^-{}_{(aq)} + 3Na^+_{(aq)} + 3OH^-_{(aq)} \rightarrow Fe(OH)_{3(s)} + 3Na^+_{(aq)} + 3NO_3^-{}_{(aq)}$

Net Ionic: $Fe^{3+}_{(aq)} + 3OH^-_{(aq)} \rightarrow Fe(OH)_{3(s)}$

12. a) Identify a compound that could be used to precipitate both the $Mg^{2+}_{(aq)}$ and $Ca^{2+}_{(aq)}$ from "hard water". **(1 mark)**

    b) Write the net ionic equations for the reactions. **(2 marks)**

Answer: Add NaOH to precipitate Mg^{2+} and Ca^{2+}.

b) $Mg^{2+}_{(aq)} + 2OH^-_{(aq)} \rightarrow Mg(OH)_{2(s)}$ (1 mark)

$Ca^{2+}_{(aq)} + 2OH^-_{(aq)} \rightarrow Ca(OH)_{2(s)}$ (1 mark)

13. A solution contains 0.20 M Cl^- and 0.20 M SO_4^{2-}.

    a) Identify a cation that could be added to the solution to give a precipitate with only one of these anions. **(1 mark)**

    b) Write the net ionic equation for the precipitation reaction in part a). **(1 mark)**

Answer: For example: Ca^{+2} or Sr^{+2} or Ba^{+2}

b) $Ca^{+2}_{(aq)} + SO_4^{2-}{}_{(aq)} \rightarrow CaSO_{4(s)}$

$Sr^{+2}_{(aq)} + SO_4^{2-}{}_{(aq)} \rightarrow SrSO_{4(s)}$

$Ba^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)} \rightarrow BaSO_{4(s)}$

14. Write an experimental design to determine whether one or both of $Ag^{+}_{(aq)}$ or $Ba^{2+}_{(aq)}$ are present in a waste solution from a commercial establishment. **(4 marks)**

Answer:

Add NaCl, if a ppt forms, Ag^{+} ions are present. If no ppt, no Ag^{+} ions in the waste solution. Next add Na_2SO_4 to test for the presence of Ba^{2+}. If a ppt forms, Ba^{2+} is present.