Key

Solubility Open-ended Review

1. Write an equation that describes the equilibrium present in a saturated solution of Cu_3PO_4.

$Cu_3PO_{4(s)} \longleftrightarrow 3Cu^+_{(aq)} + PO_4^{3-}{}_{(aq)}$

2. 53 g of Na_2CO_3 are dissolved in sufficient water to make 5.0 L of solution.

A. Write the equation for the dissolution of Na_2CO_3 into its aqueous ions.

$Na_2CO_{3(s)} \longrightarrow 2Na^+_{(aq)} + CO_3^{2-}{}_{(aq)}$

B. Calculate the concentration of each ion.

FW $Na_2CO_3 = 2(23.0) + 12.0 + 3(16.0) = 106$ g/mol

$53g \div 106$ g/mol $= 0.50$ mol

$[Na_2CO_3] = 0.50\text{mol}/5.0L = 0.10M$

$[Na^+] = 2(0.10M) = 0.20M$

$[CO_3^{2-}] = 0.10M$

C. Describe the changes in entropy and enthalpy as the Na_2CO_3 dissolves.

entropy increases as ions are formed.

enthalpy increases as the dissolving process is endothermic

D. When the solution was prepared, some doubt existed that Na_2SO_4 might have been used by mistake. Describe a suitable precipitation test that will confirm the presence of CO_3^{2-} ions in the solution.

Add any cation except: Alkali ions, H^+, NH_4^+ which put neither

or Ag^+, Ca^{2+}, Sr^{2+}, Ba^{2+}, Pb^{2+} which put both

possible answers include Al^{3+}, Fe^{2+}, Cu^{2+} etc.

3. Write an equilibrium expression and an equation that describes the equilibrium for only those salts that have low solubility:

A. Cu_2S $\quad Cu_2S \longleftrightarrow 2Cu^+ + S^{2-} \quad K_{sp} = [Cu^+]^2[S^{2-}]$

B. PbI_2 $\quad PbI_2 \longleftrightarrow Pb^{2+} + 2I^- \quad K_{sp} = [Pb^{2+}][I^-]^2$

C. $Al_2(SO_4)_3$ $\quad$ soluble

4. 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. Write the name and formula of the precipitate.

copper II sulphide $\quad CuS$

B. Write the full equation for the reaction.

$Na_2S_{(aq)} + CuCl_{2(aq)} \longleftrightarrow CuS_{(s)} + 2NaCl_{(aq)}$

C. Write the net ionic equation for the reaction.

$Cu^{2+}_{(aq)} + S^{2-}_{(aq)} \longleftrightarrow CuS_{(s)}$

5. Write balanced net ionic equations showing the formation of each precipitate formed when equal volumes of the following 0.50 M solutions are mixed:

A. $MgCl_2$ and $Pb(NO_3)_2$

$Pb^{2+}_{(aq)} + 2Cl^-_{(aq)} \longleftrightarrow PbCl_{2(s)}$

B. SrS and $CuSO_4$

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

$Cu^{2+}_{(aq)} + S^{2-}_{(aq)} \longleftrightarrow CuS_{(s)}$

C. $(NH_4)_3PO_4$ and $Mg(OH)_2$

$3Mg^{2+}_{(aq)} + 2PO_4^{3-}{}_{(aq)} \longleftrightarrow Mg_3(PO_4)_2$

6. Calculate the concentration of each ion in the following saturated solutions:

A. $Al(OH)_3$ $\quad K_{sp} = 3.0 \times 10^{-33}$

$Al(OH)_3 \longleftrightarrow Al^{3+} + 3OH^- \quad K_{sp} = [Al^{3+}][OH^-]^3$

Let x = solubility

then $[Al^{3+}] = x$

$[OH^-] = 3x$

$3.0\times10^{-33} = x(3x)^3$

$x = 3.25\times10^{-9}M$

$[Al^{3+}] = 3.3\times10^{-9}M$

$[OH^-] = 9.7\times10^{-9}M$

B. $Pb(IO_3)_2$

$Pb(IO_3)_2 \longleftrightarrow Pb^{2+} + 2IO_3^- \quad K_{sp} = [Pb^{2+}][IO_3^-]^2 = 3.7\times10^{-13}$

Let x = solubility

then $[Pb^{2+}] = x$

$[IO_3^-] = 2x$

$3.7\times10^{-13} = x(2x)^2$

$x = 4.52\times10^{-5}$

$[Pb^{2+}] = 4.5\times10^{-5}M$

$[IO_3^-] = 9.0\times10^{-5}M$

Key

7. A suspension of barium sulphate is used to improve the quality of X-rays in the digestive system. If the patient is required to drink 0.400 L of this suspension, calculate the actual mass in grams of the dissolved $BaSO_4$.

$BaSO_{4(s)} \longleftrightarrow Ba^{2+} + SO_4^{2-}$

$K_{sp} = [Ba^{2+}][SO_4^{2-}] = 1.1 \times 10^{-10}$

Let x = solubility of $BaSO_4$

then $[Ba^{2+}] = [SO_4^{2-}] = x$

$1.1 \times 10^{-10} = x^2$

$x = 1.05 \times 10^{-5}\ M$

mols $BaSO_4 = 1.05 \times 10^{-5}\ M \times 0.400\ L = 4.20 \times 10^{-6}$ mols

FW $BaSO_4 = 137.3 + 32.1 + 4(16.0) = 233.4\ g/mol$

mass $= 4.20 \times 10^{-6}\ mol \times 233.4\ g/mol = 9.8 \times 10^{-4}\ g.$

8. Calculate the K_{sp} for $Mg(OH)_2$ if the solubility of magnesium hydroxide is 7.6 mg/L.

$Mg(OH)_2 \longleftrightarrow Mg^{2+} + 2OH^-$

$K_{sp} = [Mg^{2+}][OH^-]^2$

FW $Mg(OH)_2 = 24.3 + 2(16.0) + 2(1.0) = 58.3\ g/mol$

$[Mg^{2+}] = 7.6\ mg/L \div 58.3\ g/mol \div 1000\ mg/g = 1.30 \times 10^{-4}\ M$

$[OH^-] = 2(1.30 \times 10^{-4}\ M) = 2.61 \times 10^{-4}\ M$

$K_{sp} = (1.30 \times 10^{-4})(2.61 \times 10^{-4})^2$

$= 8.8 \times 10^{-12}$

9. What maximum $[F^-]$ exists in a solution in which the $[Sr^{2+}] = 4.4 \times 10^{-3}M$?

$SrF_2 \longleftrightarrow Sr^{2+} + 2F^-$

$K_{sp} = [Sr^{2+}][F^-]^2 = 4.3 \times 10^{-9}$

$[F^-]^2 = \dfrac{4.3 \times 10^{-9}}{4.4 \times 10^{-3}} = 9.77 \times 10^{-7}$

$[F^-] = 9.9 \times 10^{-4}\ M$

10. Show by calculation if a precipitate forms when 10.0 mL of 0.010 M $AgNO_3$ are mixed with an equal volume of 0.10 M Na_2CO_3.

$Ag_2CO_3 \longleftrightarrow 2Ag^+ + CO_3^{2-}$

$K_{sp} = [Ag^+]^2[CO_3^{2-}] = 8.5 \times 10^{-12}$

$[Ag^+] = \dfrac{10.0\ mL \times 0.010\ M}{20.0\ mL} = 0.0050\ M$

$[CO_3^{2-}] = \dfrac{10.0\ mL \times 0.10\ M}{20.0\ mL} = 0.050\ M$

$TIP = (0.0050)^2(0.050) = 1.25 \times 10^{-6}$

$TIP > K_{sp}$ ∴ a ppt forms.

11. A solution may contain Ba^{2+} and/or Al^{3+}. Describe a procedure to confirm the presence or absence of these ions.

① Add K_2SO_4 to ppt Ba^{2+}

② Add K_2SO_3 to ppt Al^{3+}

12. How many moles of PbI_2 would dissolve in water in which the $[Pb^{2+}] = 5.0 \times 10^{-6}M$?

– no volume given omit question.

13. A 25.0 mL sample of saturated $PbCl_2$ solution is titrated to the endpoint with 48.1 mL of 0.015 M $AgNO_3$ solution. Calculate the K_{sp} of $PbCl_2$.

mols $Ag^+ = 48.1\ mL \times 0.015\ M = 0.722\ mmol$

mols Ag^+ = mols Cl^-

$[Cl^-] = \dfrac{0.722\ mmol}{25.0\ mL} = 2.89 \times 10^{-2}\ M$

$[Pb^{2+}] = \frac{1}{2}(2.89 \times 10^{-2}\ M) = 1.44 \times 10^{-2}\ M$

$PbCl_2 \longleftrightarrow Pb^{2+} + 2Cl^-$

$K_{sp} = [Pb^{2+}][Cl^-]^2$

$K_{sp} = (1.44 \times 10^{-2})(2.89 \times 10^{-2})^2$

$= 1.2 \times 10^{-5}$