Chemistry 12

Solubility Equilibrium I

Ⅲ 1 - 4 (pg 73-87)

Name:
Date:
Block:

1. **Solutions Vocab & Calculations**
2. **Predicting Solubility**
3. **Writing Equations**

Solutions Vocab & Calculations

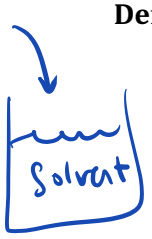
(aq)

What is a solution? → uniform composition & properties

- A homogenous mixture of 2 or more pure substances.
- Pure substances can be made of any state – gas & gas, solid & solid, solid & liquid, etc.

In this course, we will be focusing on solutions containing a solid (salt), mixed with a liquid (H_2O) → ions

Solute



Definitions:

- Solute: A substance that is dissolved in another substance (solid salt)
- Solvent: A substance that dissolves another substance (liquid H_2O)
- Soluble: The ability to dissolve
- Solution: The resulting mixture in which a solute has dissolved into a solvent

(aq)

- Saturated Solutions: A solution in which the maximum amount of solute is dissolved in solvent (ie. The dissolved substance is at equilibrium with the undissolved substance)

ex. $NaCl \rightleftharpoons Na^+ + Cl^-$

- Solubility: The [ ] of the ions in a saturated solution
- Precipitate: The solid that results [ions] exceeds solubility

Calculations:

solute

(1) Consider the addition of 2.3 g of $CaCl_2$ to water to produce 500. mL of solution.

$M = \frac{mol}{L}$

a) What is the concentration of the $CaCl_2$ solution?

$$\frac{2.3\,g}{0.500\,L} \times \frac{1\ mol}{111.1\,g} = \frac{0.041\ mol}{1\ L} \quad \text{or} \quad 0.041\ M$$

b) What is the dissociation equation?

$$CaCl_2 \rightarrow Ca^{2+} + 2Cl^-$$

c) What is the concentration of each ion in the solution?

0.041M $[CaCl_2]$ → 0.041M $[Ca^{2+}]$ (×2) → 0.082M $[Cl^-]$

(2) Calculate the concentration of each ion in a solution formed with 25 mL of 0.50 M $MgCl_2$ is mixed with 10. mL of 0.60 M $AlCl_3$.

- What is the final volume?

35 mL

- When one solution is added to another solution, both are diluted. What is the diluted concentration of each solution?

Dilute

$C_1V_1 = C_2V_2$

$[MgCl_2]$: $(0.50M)(25mL) = C_2(35mL)$, $C_2 = 0.36M$

$[AlCl_3]$: $(0.60M)(10mL) = C_2(35mL)$, $C_2 = 0.17M$

- What is the concentration of the ions in each solution? (You will need a dissociation equation).

$MgCl_2 \rightarrow Mg^{2+} + 2Cl^-$

0.36M → 0.36M, 0.72M (×2)

$AlCl_3 \rightarrow Al^{3+} + 3Cl^-$

0.17M → 0.17M, 0.51M (×3)

- What is the final concentration of each of the ions?

$[Mg^{2+}] = 0.36M$

$[Al^{3+}] = 0.17M$

$[Cl^-] = 0.72 + 0.51 = 1.23M$

Pb^{2+} SO_4^{2-}

$\frac{\text{Mol}}{1\,L} = M$ $PbSO_4$

(3) Calculate the molar solubility of lead (II) sulphate if 500. mL of saturated solution contains 0.0200 g of lead (II) sulphate.

$$\frac{0.0200\,g}{0.500\,L} \times \frac{1\,mol}{303.3\,g} = 1.32 \times 10^{-4}\,M$$

$$= 0.000132\,M$$

(4) The molar solubility of lead (II) chloride is 0.014 M at 25°C. What is the solubility in g/mL?

$$\frac{0.014\,mol}{1\,L} \times \frac{278.2\,g}{1\,mol} \times \frac{1\,L}{1000\,mL} = 3.9 \times 10^{-3}\,g/mL$$

$$= 0.0039\,g/mL$$

Pb^{2+} Cl^-

$PbCl_2$

(5) The solubility of lead (II) iodate is 4.5×10^{-5} M. What mass of lead (II) iodate is dissolved in 300. mL of saturated solution?

$$\frac{4.5 \times 10^{-5}\,mol}{1\,L} \times \frac{0.300\,L}{1} \times \frac{557.0\,g}{1\,mol} = 7.5 \times 10^{-3}\,g$$

Pb^{2+} IO_3^-

$Pb(IO_3)_2$

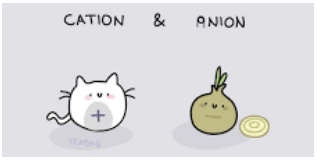
Worksheet

Predicting Solubility

SOLUBILITY OF COMMON COMPOUNDS IN WATER

The term soluble here means > 0.1 mol/L at 25°C.

Negative Ions (Anions)	Positive Ions (Cations)	Solubility of Compounds
All	Alkali ions: Li^+, Na^+, K^+, Rb^+, Cs^+, Fr^+	Soluble
All	Hydrogen ion: H^+	Soluble
All	Ammonium ion: NH_4^+	Soluble
Nitrate, NO_3^-	All	Soluble
Chloride, Cl^- or Bromide, Br^- or Iodide, I^-	All others	Soluble
	Ag^+, Pb^{2+}, Cu^+	Low Solubility
Sulphate, SO_4^{2-}	All others	Soluble
	Ag^+, Ca^{2+}, Sr^{2+}, Ba^{2+}, Pb^{2+}	Low Solubility
Sulphide, S^{2-}	Alkali ions, H^+, NH_4^+, Be^{2+}, Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}	Soluble
	All others	Low Solubility
Hydroxide, OH^-	Alkali ions, H^+, NH_4^+, Sr^{2+}	Soluble
	All others	Low Solubility
Phosphate, PO_4^{3-} or Carbonate, CO_3^{2-} or Sulphite, SO_3^{2-}	Alkali ions, H^+, NH_4^+	Soluble
	All others	Low Solubility



Remember…

Soluble = dissolves
- Aqueous
- Cation and anion DO NOT form a precipitate

Low Solubility = does not dissolve
- Solid
- Cation and anion DO form a precipitate

How to read the table:
- ⇒ *Identify ANION*
- ⇒ *Identify CATION*
- ⇒ *Soluble (aq) or Low Soluble (s)*

Practice:

1. Classify the following salts as being soluble or having low solubility in water:

a. Copper (II) chloride — Cu^{2+} Cl^- — soluble → (aq) dissolved

b. Aluminum hydroxide — Al^{3+} OH^- — low solubility → (s) precipitates

c. Sodium phosphate — Na^+ PO_4^{3-} — soluble

d. Calcium sulphate — low solubility

e. Iron (II) sulphide — low solubility

f. Strontium hydroxide — soluble

g. Zinc bromide — soluble

h. Cesium sulphite — soluble

i. Potassium chromate — soluble

2. Write the formula for the following: CO_3^{2-}

   a. A salt containing carbonate that is soluble

ionic compound H_2CO_3, $(NH_4)_2CO_3$, Na_2CO_3, etc.

   b. A salt containing sulphate with low solubility

Ag_2SO_4, $CaSO_4$, $SrSO_4$, $BaSO_4$, $PbSO_4$

   c. A cation that forms a salt with low solubility with both chloride and sulphate ions

Ag^+, Pb^{2+}

   d. An anion that forms soluble salts with all cations.

NO_3^-

3. A student is given a sample of either magnesium nitrate or strontium nitrate. When a few drops of a solution of sodium hydroxide is added to the sample, no precipitate forms. Does the sample contain magnesium nitrate or strontium nitrate? Explain your reasoning.

soluble

$Mg(NO_3)_2$ → Mg^{2+} NO_3^- → ~~$Mg(OH)_{2(s)}$~~

or

$Sr(NO_3)_2$ → Sr^{2+} NO_3^-

Na^+ + OH^-

all soluble

↳ The solution was $Sr(NO_3)_2$

Types of chemical equations:

Formula Equation: shows the chemical formulas of the compounds and their states

$$2\ KI_{(aq)} + Pb(NO_3)_{2\ (aq)} \rightleftharpoons 2\ KNO_{3\ (aq)} + PbI_{2\ (s)}$$

← low solubility

Solid ppt doesn't dissociate!

Complete Ionic Equation: shows the soluble salts represented in their dissociated form.

$2K^+_{(aq)} + 2I^-_{(aq)} + Pb^{2+}_{(aq)} + 2NO_3^-{}_{(aq)} \rightleftharpoons 2K^+_{(aq)} + 2NO_3^-{}_{(aq)} + PbI_{2\ (s)}$

Net Ionic Equation: shows only the ions that take part in the reaction. Ions that are the same on both sides of the equation are called **spectator ions.**

$$Pb^{2+}_{(aq)} + 2I^-_{(aq)} \rightleftharpoons PbI_{2\ (s)}$$

spectator ions: K^+, NO_3^-

Practice:

low solubility

1. Write the formula for the precipitate that forms when the following solutions are mixed:
   a. BaS and $MgSO_4$

   $BaSO_4\ (s)$

   b. NH_4OH and $FeBr_2$

   $Fe(OH)_2\ (s)$

   c. H_3PO_4 and $ZnCl_2$

   $Zn_3(PO_4)_2\ (s)$

   d. K_2CO_3 and $CrSO_4$

   $CrCO_3\ (s)$

   e. MnI_2 and $Sr(OH)_2$

   $Mn(OH)_2\ (s)$

Keep together - don't dissociate!

2. Write a formula equation, complete ionic equation and net ionic equation for the following reactions:
   a. Strontium hydroxide and silver nitrate

   $Sr(OH)_{2(aq)} + 2AgNO_{3(aq)} \rightleftharpoons Sr(NO_3)_{2(aq)} + 2AgOH_{(s)}$

   $Sr^{2+}_{(aq)} + 2OH^-_{(aq)} + 2Ag^+_{(aq)} + 2NO_3^-_{(aq)} \rightleftharpoons Sr^{2+}_{(aq)} + 2NO_3^-_{(aq)} + 2AgOH_{(s)}$

   $2Ag^+_{(aq)} + 2OH^-_{(aq)} \rightleftharpoons 2AgOH_{(s)}$

   b. Magnesium sulphide and zinc chloride

   $MgS_{(aq)} + ZnCl_{2\,(aq)} \rightleftharpoons MgCl_{2\,(aq)} + ZnS_{(s)}$

   $Mg^{2+}_{(aq)} + S^{2-}_{(aq)} + Zn^{2+}_{(aq)} + 2Cl^-_{(aq)} \rightleftharpoons Mg^{2+}_{(aq)} + 2Cl^-_{(aq)} + ZnS_{(s)}$

   $Zn^{2+}_{(aq)} + S^{2-}_{(aq)} \rightleftharpoons ZnS_{(s)}$

   c. Sodium carbonate and barium sulphide

   $Na_2CO_{3\,(aq)} + BaS_{(aq)} \rightleftharpoons Na_2S_{(aq)} + BaCO_{3\,(s)}$

   $2Na^+_{(aq)} + CO_3^{2-}_{(aq)} + Ba^{2+}_{(aq)} + S^{2-}_{(aq)} \rightleftharpoons 2Na^+_{(aq)} + S^{2-}_{(aq)} + BaCO_{3(s)}$

   $Ba^{2+}_{(aq)} + CO_3^{2-}_{(aq)} \rightleftharpoons BaCO_{3\,(s)}$

d. $(NH_4)_2S_{(aq)} + FeSO_{4\,(aq)} \rightarrow$ $(NH_4)_2SO_{4\,(aq)} + FeS_{(s)}$

$2NH_4^+{}_{(aq)} + S^{2-}{}_{(aq)} + Fe^{2+}{}_{(aq)} + SO_4^{2-}{}_{(aq)} \rightarrow 2NH_4^+{}_{(aq)} + SO_4^{2-}{}_{(aq)} + FeS_{(s)}$

$Fe^{2+}{}_{(aq)} + S^{2-}{}_{(aq)} \rightarrow FeS_{(s)}$

e. $H_2SO_{3\,(aq)} + CaCl_{2\,(aq)} \rightarrow$ $2HCl_{(aq)} + CaSO_{3\,(s)}$

$2H^+{}_{(aq)} + SO_3^{2-}{}_{(aq)} + Ca^{2+}{}_{(aq)} + 2Cl^-{}_{(aq)} \rightarrow 2H^+{}_{(aq)} + 2Cl^-{}_{(aq)} + CaSO_{3(s)}$

$Ca^{2+}{}_{(aq)} + SO_3^{2-}{}_{(aq)} \rightarrow CaSO_{3\,(s)}$

f. Copper (II) sulphate + calcium sulphide →

$CuSO_{4\,(aq)} + CaS_{(aq)} \rightarrow CaSO_{4(s)} + CuS_{(s)}$

$Cu^{2+}{}_{(aq)} + SO_4^{2-}{}_{(aq)} + Ca^{2+}{}_{(aq)} + S^{2-}{}_{(aq)} \rightarrow CaSO_{4\,(s)} + CuS_{(s)}$

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

Hebden Workbook Pg. 81 #18-20, Pg. 87 # 25