Fractional Precipitation

A solutions contains two of the following cations: Pb^{2+}, Fe^{3+}, Ca^{2+}. Based upon the following experiments, determine which two cations are present !

You add 1M HCl(aq) to the solution. **No precipitate forms**

No Pb^{2+} b/c Cl^- forms $PbCl_2$ precipitate

You add 1M NaOH(aq) to the solution.

$Fe(OH)_3$ precipitate

You add $(NH_4)_2HPO_4/NH_3$ to the solution **Precipitate forms**

$Ca_3(PO_4)_2$ precipitate

Solubility Rules for Ionic Compounds in Water

Compounds Containing the Following Ions Are Generally *Soluble*	Exceptions
Li^+, Na^+, K^+, and NH_4^+	None
NO_3^-, CH_3COO^-	None
Cl^-, Br^-, and I^-	When these ions pair with Ag^+, Hg_2^{2+}, or Pb^{2+} => insoluble compounds
SO_4^{2-}	When SO_4^{2-} pairs with Ca^{2+}, Sr^{2+}, Ba^{2+}, Pb^{2+}, or Ag^+ => insoluble

Compounds Containing the Following Ions Are Generally *Insoluble*	Exceptions
OH^- and S^{2-}	When these ions pair with Li^+, Na^+, K^+, or NH_4^+ => soluble
	When S^{2-} pairs with Ca^{2+}, Sr^{2+} or Ba^{2+} => soluble
	When OH^- pairs with Ca^{2+}, Sr^{2+} or Ba^{2+} => slightly soluble
CO_3^{2-} and PO_4^{3-}	When these ions pair with Li^+, Na^+, K^+, or NH_4^+ => soluble

Precipitation Calculations

What mass of mercury II sulfide can be produced when 50 mL of 0.0150 M mercury II nitrate is mixed with a solution containing excess of sodium sulfide

Given: $Hg(NO_3)_2$ 50 mL 0.0150 M
Na_2S excess

Complete Ionic Equation

$$Hg^{2+}(aq) + 2NO_3^-(aq) + 2Na^+(aq) + S^{2-}(aq) \rightarrow HgS(s) + 2Na^+(aq) + 2NO_3^-(aq)$$

Net Ionic

$$Hg^{2+}(aq) + S^{2-}(aq) \rightarrow HgS(s)$$

Calculation

$$\# moles(Hg^{2+}) = 0.0150 M \cdot 0.0500 L = 0.00075 mol$$

$$\# moles(HgS) = 0.00075 mol(Hg^{2+}) \cdot \frac{1 mol(HgS)}{1 mol(Hg^{2+})}$$

$$\# moles(HgS) = 0.00075 mol$$

$$mass(HgS) = 0.00075 mol \cdot \frac{232.7 g}{1 mol} = 0.175 g$$

When aqueous solutions of Na_2SO_4 and $Pb(NO_3)_2$ are mixed $PbSO_4$ precipitates. Calculate the mass of $PbSO_4$ formed when 1.25L of 0.0500M $Pb(NO_3)_2$ and 2.00L of 0.0250M Na_2SO_4 are mixed

Given:

1.25L of 0.0500M $Pb(NO_3)_2$

2.00L of 0.0250M Na_2SO_4

Complete Ionic

$$Pb^{2+}(aq) + 2NO_3^-(aq) + 2Na^+(aq) + SO_4^{2-}(aq) \rightarrow PbSO_4(s) + 2Na^+(aq) + 2NO_3^-$$

Net Ionic

$$Pb^{2+}(aq) + SO_4^{2-}(aq) \rightarrow PbSO_4(s)$$

What is the limiting reagent?

$$\text{moles}(Pb^{2+}) = 1.25L \cdot \frac{0.0500\,mol}{1L} = 0.0625\,mol$$

$$\text{moles}(PbSO_4) = 0.0625\,mol\,(Pb^{2+}) \cdot \frac{1\,mol\,(PbSO_4)}{1\,mol\,Pb^{2+}}$$

$$= 0.0625\,mol$$

$$\text{moles}(SO_4^{2-}) = 2.00L \cdot \frac{0.0250\,mol}{1L} = 0.0500\,mol$$

$$\text{moles}(PbSO_4) = 0.0500\,mol\,(SO_4^{2-}) \cdot \frac{1\,mol\,(PbSO_4)}{1\,mol\,(SO_4^{2-})}$$

$$= 0.0500\,mol$$

SO_4^{2-} is the limiting reagent

$$\text{mass}(PbSO_4) = 0.0500\,mol \cdot \frac{303.3\,g}{1\,mol} = 15.2\,g$$

Example 3: You mix 200 mL of 0.20 M $Fe_2(SO_4)_3$ solution with 250 mL of 0.20 M Na_3PO_4 solution. What is the precipitate that will form? What is its mass? What is the conc. of the ion that is in excess?

1. Net Ionic Equation

$$Fe^{3+}(aq) + PO_4^{3-}(aq) \rightarrow FePO_4(s)$$

2. Determine limiting reagent

$$\#\text{moles}(Fe^{3+}) = 200\,mL \cdot \frac{1\,L}{1000\,mL} \cdot 0.20\,M\,(Fe_2(SO_4)_3) \cdot \frac{2\,mol\ Fe^{3+}}{1\,mol\ Fe_2(SO_4)_3}$$

$$= 0.080\,mol$$

$$\#\text{moles}(PO_4^{3-}) = \ldots = 0.050\,mol$$

limiting reagent PO_4^{3-}

3. mass of $FePO_4$

$$\text{mass}(FePO_4) = 0.050\,mol \cdot \frac{150.82\,g}{1\,mol}$$

$$= 7.54\,g$$

4. What is the conc. of the ion in excess?

$$\#\text{moles}(Fe^{3+})_{\text{remaining}} = \underset{\text{(initial)}}{0.080\,mol} - \underset{\text{consumed}}{0.050\,mol}$$

$$= 0.030\,mol$$

total volume: $200\,mL + 250\,mL = 450\,mL$

$$= 0.45\,L$$

$$M(Fe^{3+}) = \frac{0.030\,mol}{0.45\,L} = 0.067\,M = 67\,mM$$