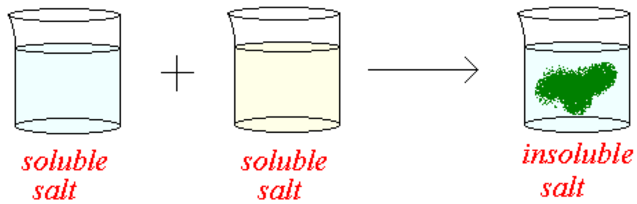
Precipitation Reactions

1. What occurs in a precipitation reaction?

An insoluble solid forms after mixing solutions together that contained soluble aqueous salts.



2. Consider:

$$Na_2SO_{4\,(aq)} + Pb(NO_3)_{2\,(aq)} \rightarrow$$

for these reactions switch the cation and anion partners to determine if a product forms.

a. What are the three types of reaction equations that can be used to describe this reaction?

i. Molecular Equation

$$Na_2SO_{4\,(aq)} + Pb(NO_3)_{2\,(aq)} \rightarrow 2NaNO_{3\,(aq)} + PbSO_{4\,(s)}$$

use rules of solubility to determine the states of matter of the products.

soluble salts are (aq) insoluble salts are (s)

In these equations you treat the solutes in solution as though they remained whole.

ii. Total Ionic Equation

$$2Na^{+}{}_{(aq)} + SO_4^{2-}{}_{(aq)} + Pb^{2+}{}_{(aq)} + 2NO_3^{-}{}_{(aq)} \rightarrow 2Na^{+}{}_{(aq)} + 2NO_3^{-}{}_{(aq)} + PbSO_{4\,(s)}$$

In these equations you indicate how solutes are actually found in solution. Soluble salts are completely dissociated (meaning cation and anion are not bound together) and insoluble salts remain whole, as they are solid.

iii. <u>Net Ionic Equation</u>

spectator ions

$$\cancel{2Na^{+}}_{(aq)} + SO_4^{2-}{}_{(aq)} + Pb^{2+}{}_{(aq)} + \cancel{2NO_3^{-}}_{(aq)} \rightarrow \cancel{2Na^{+}}_{(aq)} + \cancel{2NO_3^{-}}_{(aq)} + PbSO_{4(s)}$$

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

In these equations you eliminate species that are found, unchanged, on both side of the reaction arrow – also known as spectator ions. This equation shows only those species that actually participated in the reaction.

In an equation in which all species remained aqueous, there would be no net ionic equation (as everything would cancel out) and thus, no reaction actually took place.

b. What products, if any, form?

$PbSO_{4\,(s)}$ formed – once again this is determined by looking at the rules of solubility.

3. Consider the reaction between silver nitrate and calcium chloride

a. How many grams of silver chloride can be prepared by the reaction of 100.0 mL of 0.20M silver nitrate with 100.0 mL of 0.15 M calcium chloride?

These problems follow the system established in the introduction to stoichiometry

Step1 – Set up and balance reaction equation

$2AgNO_{3\,(aq)} + CaCl_{2\,(aq)} \rightarrow 2AgCl_{(s)} + Ca(NO_3)_{2\,(aq)}$

As a matter of course, it is a good idea to keep the net ionic equation in mind. That way it reminds you what species did and did not participate in actual reaction. This is really important when you solve for the second part pf this question (ion concentrations).

$Ag^{+}_{(aq)} + Cl^{-}_{(aq)} \rightarrow AgCl_{(s)}$

Step 2 – Using stoichiometry, determine the limiting reagent

$$0.1000L\ of\ sol'n\ \frac{0.20\ mol\ AgNO_3}{L\ of\ sol'n}\ \frac{2\ mol\ AgCl}{2\ mol\ AgNO_3} = \boxed{0.020\ mol\ AgCl}\quad limiting\ reactant.$$

$$0.1000L\ of\ sol'n\ \frac{0.15\ mol\ CaCl_2}{L\ of\ sol'n}\ \frac{2\ mol\ AgCl}{1\ mol\ CaCl_2} = 0.030\ mol\ AgCl$$

Step 3 – Convert to units needed to answer question

$$0.020\ mol\ AgCl\ \frac{143.35g\ AgCl}{1\ mol\ AgCl} = \boxed{2.9g\ AgCl}$$

b. Calculate the concentration, in M, for each of the ions remaining in sol'n after reaction has gone to completion.

In the previous problem we solved for the limiting reagent. Because we used the molecular equation it appears that $AgNO_3$, as a whole, is the limiting reactant. But remember from the net ionic reaction that NO_3^- is a spectator ion. This means that Ag^+ is the only limiting reactant! This is really important to establish before solving the problem. Once you have identified all the species you can use the following equations to solve…

$$[limiting\ ion] = 0$$

$$[spectator\ ions] = \frac{M_1 V_1}{V_2}$$

$$[excess\ reacting\ ion] = \frac{moles_{\ initial} - moles_{\ used}}{total\ volume}$$

Step 1 – Identify each ion

$$[limiting\ ion] = [Ag^+]$$

$$[spectator\ ions] = \begin{matrix}[NO_3^-] \\ [Ca^{2+}]\end{matrix}$$

$$[excess\ reacting\ ion] = [Cl^-]$$

Step 2 – Solve

$$[Ag^+] = \boxed{0}$$

$$[NO_3^-] = \frac{(0.20\ M\ NO_3^-)\ (100.0\ mL)}{200.0\ mL} = \boxed{0.10\ M\ NO_3^-}$$

$$[Ca^{2+}] = \frac{(0.15\ M\ Ca^{2+})\ (100.0\ mL)}{200.0\ mL} = \boxed{0.075M\ Ca^{2+}}$$

$$Initial\ moles\ of\ Cl^- = \frac{0.1000\ L\ of\ sol'n}{} \frac{0.15\ mol\ CaCl_2}{L\ of\ sol'n} \frac{2\ mol\ Cl^-}{1\ mol\ CaCl_2} = 0.30\ mol\ Cl^-$$

$$Moles\ of\ Cl^-\ used = \frac{0.020\ mol\ Ag^+}{} \frac{1\ mol\ Cl^-}{1\ mol\ Ag^+} = 0.020\ mol\ Cl^-\ required\ to\ react\ with\ Ag^+$$

$$[Cl^-] = \frac{(0.30\ mol\ Cl^- - 0.020\ mol)}{0.2000L\ of\ sol'n} = \boxed{0.050\ M\ Cl^-}$$

4. What volume of 0.900M Na_3PO_4 is required to precipitate all the lead (II) ions from 160.0 mL of 0.650M $Pb(NO_3)_2$?

$$2Na_3PO_{4\,(aq)} + 3\,Pb(NO_3)_{2\,(aq)} \rightarrow Pb_3(PO_4)_{2\,(s)} + 6\,NaNO_{3\,(aq)}$$

$$0.1600\text{ L of sol'n}\;\frac{0.650\text{ mol }Pb(NO_3)_2}{\text{L of sol'n}}\;\frac{2\text{ mol }Na_3PO_4}{3\text{ mol }Pb(NO_3)_2}\;\frac{\text{L of sol'n}}{0.900\text{ mol }Na_3PO_4}\;\frac{1000\text{ mL}}{\text{L}} = \boxed{77.0\text{ mL }Na_3PO_4}$$