NS J6 (pg 1 of 3) Solution Stoichiometry − Precipitation Reactions

Name_____Per___

Now that you know plenty of stoichiometry, now we can consider solution stoichiometry. The process is the same, we just have to consider the concentration and volumes of the solutions − use that information to get at moles of each reactant. Further we must consider which ions form precipitates, and which ions are the spectator ions and remain in solution.

Consider the reaction between sodium iodide and lead(II) nitrate. $Pb(NO_3)_2$ + 2 NaI → 2 $NaNO_3$ + PbI_2

The simplest type of problem you might be asked would be to determine the amount of one solution that would need to be put into the other solution to precipitate all of the ions. Further, you might be asked what mass of precipitate would be formed.

In a more challenging problem, you might be asked a limiting reactant type problem. Given quantities of two solutions, and after the precipitation is complete (assuming the reaction will form the maximum amount of solid possible) you may be asked how much precipitate is on the bottom, and what is the concentration of the ions still in the solution. There will be lead(II) iodide precipitate on the bottom, and ions left in solution. The spectator ions will *always* be left in solution, as they are *never* part of the precipitate, and then only one of the two precipitating ions will be left in solution, as one of the two precipitate ions will be in excess.

Sample Problem: One reactant *(Two reactants on page 2 and sample problem from class on page 3.)*

1. What volume of 0.50 M sodium iodide would be required to precipitate all of the lead ions from 250 ml of 0.35 M lead(II) nitrate? (Assume that the precipitation reaction goes to completion.)
   What mass of precipitate would be formed?
   What would be the concentration of the nitrate ions in the solution after the reaction?
   What would be the concentration of sodium ions in the solution after the reaction?

Molar Masses g/mol
$Pb(NO_3)_2$ = 331.22
NaI = 149.89
$NaNO_3$ = 85
PbI_2 = 461

   A. Balance the equation: $Pb(NO_3)_2$ + 2 NaI → 2 $NaNO_3$ + PbI_2

   B. Determine the millimole or mole of lead(II) nitrate
   - $M \times V = moles \quad 0.35M \times 250ml = 87.5millimol\ Pb(NO_3)_2$

   C. Use the stoichiometric link to determine the millimole or mole of sodium iodide required.
   - $87.5millimol\ Pb(NO_3)_2 \times \frac{2NaI}{1Pb(NO_3)_2} = 175NaI\ millimol\ required$

   D. Convert millimole required to volume using the known molarity of the sodium iodide.
   - $Molarity = \frac{mol}{Liter} or \frac{millimol}{milliLiter}$ thus $\frac{millimol}{Molarity} = milliLiter$ calculate: $\frac{175NaI\ millimol}{0.50M} = 350ml$

   E. Use the stoichiometric link to determine the mole, and then mass of lead(II) iodide formed.
   - $87.5millimol\ Pb(NO_3)_2 \times \frac{1PbI_2}{1Pb(NO_3)_2} \times \frac{1mol}{1000millimol} \times \frac{461g}{1mol} = 40.gPbI_2$

   F. ALL of the nitrate ions are in solution (remember lead(II) nitrate is a "buy one get two"), and none of the nitrates precipitate, but remember, the nitrates are "swimming" in a larger volume of total solution after the 350 ml of NaI is added to the 250 ml of $Pb(NO_3)_2$.
   - $87.5millimol\ Pb(NO_3)_2 \times \frac{2NO_3^-}{1Pb(NO_3)_2} = 175mmillimol\ NO_3^- \quad \frac{175mmillimol\ NO_3^-}{600ml\ total} = 0.29M\ NO_3^-\ ions$

   G. ALL of the sodium ions are also in solution and none of the sodium ions precipitate, but remember, the sodium ions are "swimming" in a larger volume of total solution after the 350 ml of NaI is added to the 250 ml of $Pb(NO_3)_2$.
   - $175millimol\ NaI \times \frac{1Na^+}{1NaI} = 175mmillimol\ Na^+ \quad \frac{175mmillimol\ NO_3^-}{600ml\ total} = 0.29M\ Na^+\ ions$

   Beware….do NOT think that the spectator ions will always be the same concentration as each other.

Another Sample Problem on the next page

Sample Problem: Two reactants.

Molar Masses g/mol
$Pb(NO_3)_2$ = 331.22
NaI = 149.89
$NaNO_3$ = 85
PbI_2 = 461

2. Suppose 20. ml of 0.50 M sodium iodide was mixed with 18 of 0.35 M lead(II) nitrate?
   What mass of precipitate would be formed? (Assume that the precipitation reaction goes to completion.)
   What is the concentration of each remaining ion in solution?

   A. Balance the equation: $Pb(NO_3)_2 + 2\ NaI \rightarrow 2\ NaNO_3 + PbI_2$

   B. Determine the millimoles (hereafter represented as mmol) of lead(II) nitrate and sodium iodide.

   - $0.50M \times 20ml = 10mmol\ NaI \quad 0.35M \times 18ml = 6.3mmol\ Pb(NO_3)_2$

   C. Use the "trick" to determine which reactant limits

   - $\frac{10millimol\ NaI}{2} = 5 \ < \ \frac{6.3millimol\ Pb(NO_3)_2}{1} = 6.3 \qquad Thus\ NaI\ limits$

   D. Determine the mass of precipitate that can be produced (be sure and base you calculations on the limiting reactant).

   - $10millimol\ NaI \times \frac{1PbI_2}{2NaI} \times \frac{1mol}{1000millimol} \times \frac{461g}{1mol} = 2.3gPbI_2$

   E. Because the NaI limits, but only the I^- ions are part of the precipitate, lead ions must be the excess ion in the precipitate.

   $10mmol\ I^- \times \frac{1Pb^{2+}}{2I^-} = 5mmolPb^{2+}required$ thus $6.3mmolPb^{2+}provided - 5mmolPb^{2+}required = 1.3mmolPb^{2+}remaining$

   - $\frac{1.3mmolPb^{2+}remaining}{40ml\ total\ solution} = 0.032M\ Pb^{2+}$

   F. Remember ALL the spectator ions are still in solution, since none of them precipitate

   - $\frac{10mmolNaI \times \frac{1Na^+}{1NaI}}{40ml\ total\ solution} = 0.25M\ Na^+$ and $\frac{6.3mmolPb(NO_3)_2 \times \frac{2NO_3^-}{1Pb(NO_3)_2}}{40ml\ total\ solution} = 0.31M\ NO_3^-$

Solution Stoichiometry – Precipitation Reactions

Opener: Solution Stoichiometry

$2\ K_3PO_4 + 3\ CuCl_2 \rightarrow 6\ KCl + Cu_3(PO_4)_2$

$2PO_4^{3-} + 3Cu^{2+} \rightarrow Cu_3(PO_4)_2$ Net Ionic Eq.

MM g/mole
K_3PO_4 = 212.27
$CuCl_2$ = 134.45
KCl = 74.55
$Cu_3(PO_4)_2$ = 380.58

You poured 60.0 ml of 0.500 M potassium phosphate with 75.0 ml of 0.500 M copper(II) chloride and allowed a precipitate to form.

1. What mass of precipitate would be produced?
2. What is the concentration of the potassium ions after the two solutions are mixed and the precipitate forms?
3. What is the concentration of chloride ions after the two solutions are mixed and the precipitate forms?
4. What is the concentration of phosphate ions after the two solutions are mixed and the precipitate forms?
5. What is the concentration of copper(II) ions after the two solutions are mixed and the precipitate forms?

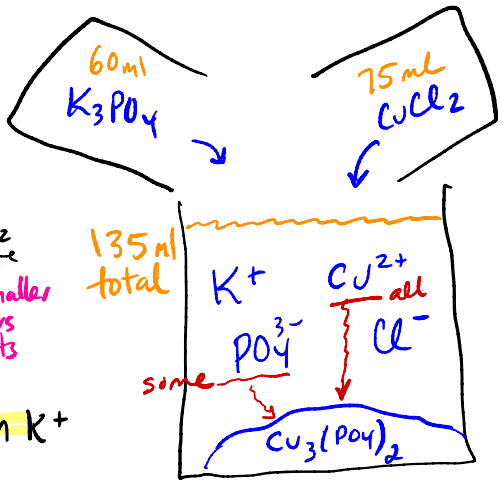
spectator ions – ALL still in Sol'n

$0.5M \times 60ml = 30\ mmol\ K_3PO_4$ / 2 = 15

Limit normalize trick

$0.5M \times 75ml = 37.5\ mmol\ CuCl_2$ / 3 = 12.5

compare – smaller value tells us $CuCl_2$ limits



① $37.5\ mmol\ CuCl_2 \times \frac{1\ Cu_3(PO_4)_2}{3\ CuCl_2} \times \frac{380.58g}{1mol} = 4760mg$ → 4.76g $Cu_3(PO_4)_2$ precipitate

OR $30\ mmol\ K_3PO_4 \times \frac{1\ Cu_3(PO_4)_2}{2\ K_3PO_4} \times \frac{380.58g}{1mol} = 5709mg$

compare, smaller value tells us $CuCl_2$ limits

② $30mmol\ K_3PO_4 \times \frac{3\ K^+}{1\ K_3PO_4} = \frac{90\ mmol\ K^+}{135\ ml\ total\ vol} = 0.667M\ K^+$

③ $37.5\ mmol\ CuCl_2 \times \frac{2\ Cl^-}{1\ CuCl_2} = \frac{75\ mmol\ Cl^-}{135\ ml\ total\ vol} = 0.556M\ Cl^-$

④ How much PO_4^{3-} reacts with Cu^{2+}

$37.5\ mmol\ Cu^{2+} \times \frac{2\ PO_4^{3-}}{3\ Cu^{2+}} = 25\ mmol\ PO_4^{3-}$ reacts

30 mmol PO_4^{3-} Given

5 mmol PO_4^{3-} left in sol'n (not in ppt)

$\frac{5\ mmol\ PO_4^{3-}}{135ml\ total} = 0.0370M\ PO_4^{3-}$

⑤ No Cu^{2+} left, all in ppt

thus 0 M