Solution Limiting Reactant Problems

1. When 70.0 mL of 0.200 M $Pb(NO_3)_2$ are mixed with 80.0 mL 0.400 M KI, PbI_2 is precipitated. Determine the number of moles of PbI_2 that will be precipitated and the concentration of each ion remaining in solution when the reaction has gone to completion.

2. When 50.0 mL of 0.400 M $AgNO_3$ are mixed with 20.0 mL of 0.800 M Na_2CrO_4, Ag_2CrO_4 is precipitated. Determine the number of moles of Ag_2CrO_4 that will be precipitated and the concentration of each ion remaining in solution when the reaction has gone to completion.

3. When 30.0 mL of 0.200 M $Fe_2(SO_4)_3$ are mixed with 30.0 mL of 0.700 M NaOH, $Fe(OH)_3$ is precipitated. Determine the number of moles of $Fe(OH)_3$ that will be precipitated and the concentration of each ion remaining in solution when the reaction has gone to completion.

4. When 60.0 mL of 0.300 M $MgCl_2$ are mixed with 40.0 mL of 0.400 M Na_3PO_4, $Mg_3(PO_4)_2$ is precipitated. Determine the number of moles of $Mg_3(PO_4)_2$ that will be precipitated and the concentration of each ion remaining in solution when the reaction has gone to completion.

Answers

1. 14.0 mmol = 0.014 mol of PbI_2 $[Pb^{2+}] \approx 0$ $[I^-]$ = 4 mmol/150 mL = 0.027 M

$[K^+]$ = .400 M x 80 mL/ 150 mL = 0.213 M $[NO_3^-]$ = 2 x .2 M x 70 mL/ 150 ml = 0.187 M

2. 10.0 mmol = 0.010 mol of Ag_2CrO_4 $[Ag^+] \approx 0$ $[CrO_4^{2-}]$ = 6 mmol/70 mL = 0.086 M

$[NO_3^-]$ = .4 M x 50 ml/ 70 mL = 0.286 M $[Na^+]$ = 2 x .8 M x 20 mL / 70 mL = 0.457 M

3. 7.0 mmol = 0.0070 mol of $Fe(OH)_3$ $[OH^-] \approx 0$ $[Fe^{3+}]$ = 5 mmol / 60 mL = 0.083 M

$[Na^+]$ = 0.7 M x 30 mL / 60 mL = 0.35 M $[SO_4^{2-}]$ = 3 x .2 M x 30 mL / 60 mL = 0.30 M

4. 6.0 mmol = 0.006 mol $Mg_3(PO_4)_2$ $[Mg^{2+}] \approx 0$ $[PO_4^{3-}]$ = 4 mmol / 100 mL = 0.040 M

$[Cl^-]$ = 2 x .3 M x 60 mL / 100 mL = 0.36 M $[Na^+]$ = 3 x .4 M x 40 mL / 100 mL = 0.48 M

Solutions and Notes

1. 70.0 mL 0.200 M $Pb(NO_3)_2$ = 70.0×0.200 = 14.0 mmol Pb^{2+}
and 70.0×0.200×2 = 28.0 mmol NO_3^-

80.0 mL 0.400 M KI = 80.0×0.400 = 32.0 mmol K and 32.0 mmol I^-

The reaction is $Pb(NO_3)_2(aq) + 2\ KI(aq) \longrightarrow PbI_2(s) + 2\ KNO_3(aq)$

but the spectator ions will not be used up in the precipitation. The ionic equation is more useful.

$$Pb^{2+} + 2\ NO_3^- + 2\ K^+ + 2\ I^- \longrightarrow PbI_2(s) + 2\ NO_3^- + 2\ K^+$$

the net ionic equation:	Pb^{2+} +	$2\ I^-$ $\longrightarrow$	$PbI_2(s)$	indicates the ions used up
	14.0	16.0		= mmoles of reaction (Pb^{2+}) is limiting
starting quantities (mmol)	14.0	32.0	0	= starting / coefficient, 32/2 = 16
change line	–14.0	–28.0	+14.0	
final values	0.0	4.0	14.0	so 14.0 mmol PbI_2 produced or 0.0140 mol PbI_2

Ions in solution:

Pb^{2+} is essentially used up so $[Pb^{2+}] = \dfrac{0 \text{ mmol } Pb^{2+}}{150.0 \text{ mL soln}}$ (= 70.0 mL + 80.0 mL) ≈ 0 M Pb^{2+}

Unprecipitated I^- = 4.0 mmol so $[I^-] = \dfrac{4.0 \text{ mmol } I^-}{150 \text{ mL}}$ = 0.0267 M I^-

All K^+ (32.0 mmol) is still in solution so $[K^+] = \dfrac{32.0 \text{ mmol } K^+}{150.0 \text{ mL}}$ = 0.213 M K^+

All NO_3^- (28.0 mmol) is still in solution so $[NO_3^-] = \dfrac{28.0 \text{ mmol } NO_3^-}{150.0 \text{ mL}}$ = 0.187 M NO_3^-

2. 50.0 mL×0.400 M = 20.0 mmol $AgNO_3$ 20.0 mL×0.800 M Na_2CrO_4

	$2\ Ag^+$ +	CrO_4^{2-} $\longrightarrow$	$Ag_2CrO_4(s)$	
	10.0	16.0		mmols rxn
init	20.0	16.0	0	
change	–20.0	–10.0	+10.0	
final	0.0	6.0	10.0	so 10.0 mmol = 0.0100 mol Ag_2CrO_4 precipitated

$[Ag^+] \approx 0$ $[CrO_4^{2-}] = \dfrac{6.0 \text{ mmol } CrO_4^{2-}}{70.0 \text{ mL}} = 0.086 \text{ M } CrO_4^{2-}$

$[NO_3^-] = \dfrac{20.0 \text{ mmol } NO_3^{1-}}{70.0 \text{ mL}} = 0.286 \text{ M } NO_3^-$ $[Na^{2+}] = \dfrac{32.0 \text{ mmol } Na^+}{70.0 \text{ mL}} = 0.457 \text{ M } Na^+$

3. 30.0 mL×0.200 M = 6.0 mmol $Fe_2(SO_4)_3$ = 12.0 mmol Fe^{3+} + 18.0 mmol SO_4^{2-}

30.0 mL×0.700 M = 21.0 mmol NaOH

$Fe^{3+} + 3\ OH^- \longrightarrow Fe(OH)_3(s)$

	Fe^{3+}	$3\ OH^-$	$Fe(OH)_3(s)$	
	12.0	7.0		mmol rxn
init	12.0	21.0	0	
change	–7.0	-21.0	+7.0	
final	5.0	0.0	7.0	mmol = 0.0070 mol $Fe(OH)_3$ ppt

$[Fe^{3+}] = \dfrac{5.0 \text{ mmol } Fe^{3+}}{60.0 \text{ mL}} = 0.083 \text{ M } Fe^{3+}$ $[OH^-] \approx 0$

$[SO_4^{2-}] = \dfrac{18.0 \text{ mmol } SO_4^{2-}}{60.0 \text{ mL}} = 0.300 \text{ M } SO_4^{2-}$ $[Na^+] = \dfrac{21.0 \text{ mmol } Na^+}{60.0 \text{ mL}} = 0.350 \text{ M } Na^+$

4. 60.0 mL×0.300 M = 18.0 mmol $MgCl_2$ 40.0 mL×0.400 M = 16.0 mmol Na_3PO_4

$3\ Mg^{2+} + 2\ PO_4^{3-} \longrightarrow Mg_2(PO_4)_2$

	$3\ Mg^{2+}$	$2\ PO_4^{3-}$	$Mg_2(PO_4)_2$	
	6.0	8.0		mmol rxn
init	18.0	16.0	0	
change	–18.0	–12.0	+6.0	
final	0.0	4.0	6.0	mmol = 0.0060 mol $Mg_2(PO_4)_2$

$[Mg^{2+}] \approx 0$ $[PO_4^{3-}] = \dfrac{4.0 \text{ mmol } PO_4^{3-}}{100 \text{ mL}} = 0.040 \text{ M } PO_4^{3-}$

$[Cl^-] = \dfrac{36.0 \text{ mmol } Cl^-}{100 \text{ mL}} = 0.360 \text{ M } Cl^-$ $[Na^+] = \dfrac{48.0 \text{ mmol } Na^+}{100 \text{ mL}} = 0.480 \text{ M } Na^+$