

Solution Limiting Reactant Problems

1. When 70.0 mL of 0.200 M $\text{Pb}(\text{NO}_3)_2$ 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 $\text{Fe}_2(\text{SO}_4)_3$ are mixed with 30.0 mL of 0.700 M NaOH, $\text{Fe}(\text{OH})_3$ is precipitated. Determine the number of moles of $\text{Fe}(\text{OH})_3$ 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 , $\text{Mg}_3(\text{PO}_4)_2$ is precipitated. Determine the number of moles of $\text{Mg}_3(\text{PO}_4)_2$ 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 $[\text{Pb}^{2+}] \approx 0$ $[\text{I}^-] = 4 \text{ mmol} / 150 \text{ mL} = 0.027 \text{ M}$
 $[\text{K}^+] = .400 \text{ M} \times 80 \text{ mL} / 150 \text{ mL} = 0.213 \text{ M}$ $[\text{NO}_3^-] = 2 \times .2 \text{ M} \times 70 \text{ mL} / 150 \text{ mL} = 0.187 \text{ M}$
2. 10.0 mmol = 0.010 mol of Ag_2CrO_4 $[\text{Ag}^+] \approx 0$ $[\text{CrO}_4^{2-}] = 6 \text{ mmol} / 70 \text{ mL} = 0.086 \text{ M}$
 $[\text{NO}_3^-] = .4 \text{ M} \times 50 \text{ mL} / 70 \text{ mL} = 0.286 \text{ M}$ $[\text{Na}^+] = 2 \times .8 \text{ M} \times 20 \text{ mL} / 70 \text{ mL} = 0.457 \text{ M}$
3. 7.0 mmol = 0.0070 mol of $\text{Fe}(\text{OH})_3$ $[\text{OH}^-] \approx 0$ $[\text{Fe}^{3+}] = 5 \text{ mmol} / 60 \text{ mL} = 0.083 \text{ M}$
 $[\text{Na}^+] = 0.7 \text{ M} \times 30 \text{ mL} / 60 \text{ mL} = 0.35 \text{ M}$ $[\text{SO}_4^{2-}] = 3 \times .2 \text{ M} \times 30 \text{ mL} / 60 \text{ mL} = 0.30 \text{ M}$
4. 6.0 mmol = 0.006 mol $\text{Mg}_3(\text{PO}_4)_2$ $[\text{Mg}^{2+}] \approx 0$ $[\text{PO}_4^{3-}] = 4 \text{ mmol} / 100 \text{ mL} = 0.040 \text{ M}$
 $[\text{Cl}^-] = 2 \times .3 \text{ M} \times 60 \text{ mL} / 100 \text{ mL} = 0.36 \text{ M}$ $[\text{Na}^+] = 3 \times .4 \text{ M} \times 40 \text{ mL} / 100 \text{ mL} = 0.48 \text{ M}$

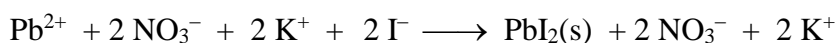
Solutions and Notes

1. $70.0 \text{ mL } 0.200 \text{ M Pb(NO}_3)_2 = 70.0 \times 0.200 = 14.0 \text{ mmol Pb}^{2+}$
 and $70.0 \times 0.200 \times 2 = 28.0 \text{ mmol NO}_3^-$

$80.0 \text{ mL } 0.400 \text{ M KI} = 80.0 \times 0.400 = 32.0 \text{ mmol K}$ and 32.0 mmol I^-



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



the net ionic equation:	$\text{Pb}^{2+} + 2 \text{I}^- \longrightarrow \text{PbI}_2(\text{s})$	indicates the ions used up
	<small>14.0 16.0</small>	= mmols of reaction (Pb^{2+}) is limiting
starting quantities (mmol)	14.0 32.0 0	= starting / coefficient, $32/2 = 16$
change line	<small>-14.0 -28.0 +14.0</small>	
final values	<hr/> 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 $[\text{Pb}^{2+}] = \frac{0 \text{ mmol Pb}^{2+}}{150.0 \text{ mL soln } (= 70.0 \text{ mL} + 80.0 \text{ mL})} \approx 0 \text{ M Pb}^{2+}$

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

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

All NO_3^- (28.0 mmol) is still in solution so $[\text{NO}_3^-] = \frac{28.0 \text{ mmol NO}_3^-}{150.0 \text{ mL}} = 0.187 \text{ M NO}_3^-$

2. $50.0 \text{ mL} \times 0.400 \text{ M} = 20.0 \text{ mmol AgNO}_3$ $20.0 \text{ mL} \times 0.800 \text{ M Na}_2\text{CrO}_4$

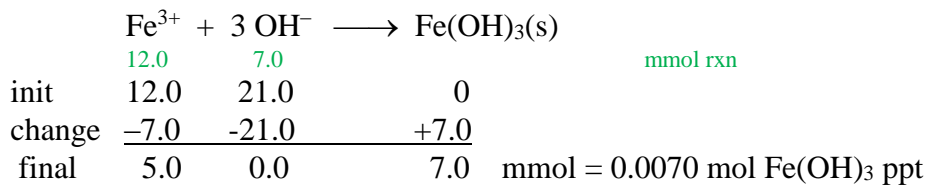
	$2 \text{Ag}^+ + \text{CrO}_4^{2-} \longrightarrow \text{Ag}_2\text{CrO}_4(\text{s})$	
	<small>10.0 16.0</small>	<small>mmols rxn</small>
init	20.0 16.0 0	
change	<u>-20.0 -10.0 +10.0</u>	
final	0.0 6.0 10.0	so 10.0 mmol = 0.0100 mol Ag_2CrO_4 precipitated

$$[\text{Ag}^+] \approx 0 \quad [\text{CrO}_4^{2-}] = \frac{6.0 \text{ mmol CrO}_4^{2-}}{70.0 \text{ mL}} = 0.086 \text{ M CrO}_4^{2-}$$

$$[\text{NO}_3^-] = \frac{20.0 \text{ mmol NO}_3^-}{70.0 \text{ mL}} = 0.286 \text{ M NO}_3^- \quad [\text{Na}^+] = \frac{32.0 \text{ mmol Na}^+}{70.0 \text{ mL}} = 0.457 \text{ M Na}^+$$

3. $30.0 \text{ mL} \times 0.200 \text{ M} = 6.0 \text{ mmol Fe}_2(\text{SO}_4)_3 = 12.0 \text{ mmol Fe}^{3+} + 18.0 \text{ mmol SO}_4^{2-}$

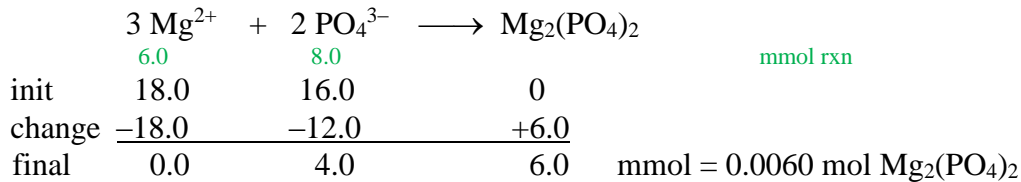
$$30.0 \text{ mL} \times 0.700 \text{ M} = 21.0 \text{ mmol NaOH}$$



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

$$[\text{SO}_4^{2-}] = \frac{18.0 \text{ mmol SO}_4^{2-}}{60.0 \text{ mL}} = 0.300 \text{ M SO}_4^{2-} \quad [\text{Na}^+] = \frac{21.0 \text{ mmol Na}^+}{60.0 \text{ mL}} = 0.350 \text{ M Na}^+$$

4. $60.0 \text{ mL} \times 0.300 \text{ M} = 18.0 \text{ mmol MgCl}_2 \quad 40.0 \text{ mL} \times 0.400 \text{ M} = 16.0 \text{ mmol Na}_3\text{PO}_4$



$$[\text{Mg}^{2+}] \approx 0 \quad [\text{PO}_4^{3-}] = \frac{4.0 \text{ mmol PO}_4^{3-}}{100 \text{ mL}} = 0.040 \text{ M PO}_4^{3-}$$

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