Chapter 4 Solution Stoichiometry Problems

Key

1. A stock solution of sodium hydroxide is prepared by dissolving 120.0 g of NaOH in 500.0 mL of water. What is the molarity of the stock solution?

$$M = \frac{\text{moles}}{L} = \frac{120.0\,\cancel{g}\,NaOH}{500.0\,\cancel{mL}}\left(\frac{1000\,\cancel{mL}}{1\,L}\right)\left(\frac{1\,mole\,NaOH}{40.0\,\cancel{g}}\right) = \boxed{6.000\,M\ NaOH}$$

2. A stock solution of HCl is prepared by adding 30.00 mL (V_1) of a 12.00 M (M_1) HCl solution to water and diluting to a final volume of 250.0 mL (V_2). What is the molarity of the stock solution? ($M_2 = ?$)

$$M_1V_1 = M_2V_2$$

$$(12.00\,M)(30.00\,mL) = M_2(250.0\,mL)$$

$$\boxed{M_2 = 1.440\,M\ HCl}$$

3. A chemistry student wants to verify the molarity of the acid stock solution prepared in problem 2, so she titrates a 25.00 mL aliquot (measured sample) with the NaOH solution described in problem 1. If she wants to use 40.00 mL of the NaOH solution as the titrant, what molarity would her NaOH solution need to be? How would she prepare 100.0 mL of that solution?

$$M_AV_A = M_BV_B$$

$$(1.440\,M)(25.00\,mL) = M_B(40.0\,mL)$$

$$\boxed{M_B = 0.9000\,M\ NaOH}$$

$M_A = 1.440\,M$ HCl

$V_A = 25.00$ mL

$M_B = ?$

$V_B = 40.00$ mL

$$(6\,M\,NaOH)(V_1) = (.9000\,M)(100.0\,mL)$$

$V_1 = 15.00$ mL NaOH of 6M to make 100 mL of .9M NaOH

4. What is the concentration of the following in ppm?

a. 1.0×10^{-2} g Cu^{2+} in 2.0 L of solution.
b. The concentration of Pb^{2+} in 2.1×10^{-5} M $Pb(NO_3)_2$.

$$ppm = \frac{mg}{L}$$

a) $$\frac{1.0 \times 10^{-2}\,\cancel{g}\,Cu^{+2}}{2.0\,L}\left(\frac{1000\,mg}{1\,\cancel{g}}\right) = \boxed{5.0\ mg/L = 5.0\ ppm}$$

b) $$\frac{2.10 \times 10^{-5}\,\cancel{mol}\,Pb(NO_3)_2}{L}\left(\frac{1\,\cancel{mol\,Pb^{+2}}}{1\,mol\,Pb(NO_3)_2}\right)\left(\frac{207.2\,\cancel{g}}{1\,\cancel{mol\,Pb^{+2}}}\right)\left(\frac{1000\,mg}{1\,g}\right) = \boxed{4.35\ \frac{mg}{L} = 4.35\ ppm}$$

5. A solution contains Ag^{+}, Pb^{2+}, and Fe^{3+}. If you want to precipitate the Pb^{2+} selectively, what anion would you choose?

You could mix it in some sort of sulfate solution (Ex Na_2SO_4)

The sulfate ion is soluble in Ag^{+1} and Fe^{+3}, it is insoluble in Pb^{+2}, thus forming a $PbSO_4$ precipitate.

Write molecular, complete ionic, and net ionic equations for the following reactions:

6. a. aqueous sodium sulfide reacts with aqueous copper (II) nitrate
   b. aqueous hydrogen fluoride reacts with aqueous potassium hydroxide to give water and aqueous potassium fluoride

a) molecular: $Na_2S_{(aq)} + Cu(NO_3)_{2\,(aq)} \longrightarrow CuS_{(s)} + 2NaNO_{3\,(aq)}$

C.I.E: $2Na^{+}_{(aq)} + S^{-2}_{(aq)} + Cu^{+2}_{(aq)} + 2NO_3^{-}{}_{(aq)} \longrightarrow CuS_{(s)} + 2Na^{+}_{(aq)} + 2NO_3^{-}{}_{(aq)}$

NIE: $Cu^{+2}_{(aq)} + S^{-2}_{(aq)} \longrightarrow CuS_{(s)}$

b) Molecular: $HF_{(aq)} + KOH_{(aq)} \longrightarrow H_2O_{(l)} + KF_{(aq)}$

CIE: $H^{+}_{(aq)} + F^{-}_{(aq)} + K^{+}_{(aq)} + OH^{-}_{(aq)} \longrightarrow H_2O_{(l)} + K^{+}_{(aq)} + F^{-}_{(aq)}$

NIE: $H^{+}_{(aq)} + OH^{-}_{(aq)} \longrightarrow H_2O_{(l)}$

7. A titration is done using 0.1302 M NaOH to determine the molar mass of an acid. The acid contains one acidic hydrogen per molecule. If 1.863 g of the acid require 70.11 mL of the NaOH solution, what is the molar mass of the acid?

$Na^{+} + OH^{-} + H^{+} + A^{-} \longrightarrow H_2O + HA$

$$70.11\text{ mL NaOH}\left(\frac{1\text{ L}}{1000\text{ mL}}\right)\left(\frac{.1302\text{ mol NaOH}}{\text{L}}\right)\left(\frac{1\text{ mol }OH^-}{1\text{ mol NaOH}}\right)\left(\frac{1\text{ mol }H^+}{1\text{ mol }OH^-}\right)\left(\frac{1\text{ mol Acid}}{1\text{ mol }H^+}\right) =$$

.009128 mol Acid

$$MM_{acid} = \frac{\text{g acid}}{\text{moles acid}} = \frac{1.863\text{ g}}{.009128\text{ mol}} = 204.1\text{ g/mol}$$

Precipitation Reactions and Solubility

8. Write the formulas of the following compounds and decide which are soluble in water.

   (a) aluminum chloride
   (b) ammonium carbonate
   (c) strontium sulfate
   (d) chromium(III) hydroxide

a) $AlCl_3$ soluble

b) $(NH_4)_2CO_3$ soluble

c) $SrSO_4$ insoluble

d) $Cr(OH)_3$ soluble

9. Write net ionic equations to explain the formation of
   (a) a red precipitate when solutions of iron(III) chloride and sodium hydroxide are mixed.
   (b) two different precipitates, one yellow and the other white, when solutions of cadmium(II) sulfate and strontium sulfide are mixed.

a) $Fe^{+3}_{(aq)} + 3OH^-_{(aq)} \longrightarrow Fe(OH)_{3\,(s)}$

b) $Cd^{+2}_{(aq)} + SO_{4\,(aq)}^{-2} + Sr^{+2}_{(aq)} + S^{-2}_{(aq)} \longrightarrow CdS_{(s)} + SrSO_{4\,(s)}$

10. Decide whether a precipitate will form when the following solutions are mixed. If a precipitate forms, write a net ionic equation for the reaction.

(a) copper(II) sulfate and sodium chloride.
(b) mercury(I) nitrate and hydrochloric acid.
(c) ammonium sulfide and potassium hydroxide.
(d) silver nitrate and lithium carbonate.
(e) aluminum sulfate and strontium hydroxide.

a) No PPT - both combos soluble

$$Cu^{+2}_{(aq)} + SO_4^{-2}{}_{(aq)} + 2Na^{+1}_{(aq)} + 2Cl^-_{(aq)} \longrightarrow Cu^{+2}_{(aq)} + 2Cl^-_{(aq)} + 2Na^+_{(aq)} + SO_4^{-2}{}_{(aq)}$$

b) $$Hg_2^{2+}{}_{(aq)} + \cancel{2NO_3^-{}_{(aq)}} + \cancel{2H^+_{(aq)}} + 2Cl^-_{(aq)} \longrightarrow Hg_2Cl_{2(s)} + \cancel{2H^+_{(aq)}} + \cancel{2NO_3^-{}_{(aq)}}$$

$$Hg_2^{2+}{}_{(aq)} + 2Cl^-_{(aq)} \longrightarrow Hg_2Cl_{2(s)}$$

c) $$\cancel{2NH_4^+{}_{(aq)}} + S^{-2}_{(aq)} + 2K^+_{(aq)} + \cancel{2OH^-_{(aq)}} \longrightarrow \cancel{2NH_4^+{}_{(aq)}} + \cancel{2OH^-_{(aq)}} + K_2S_{(s)}$$

$$2K^+_{(aq)} + S^{-2}_{(aq)} \longrightarrow K_2S_{(s)}$$

d) $$2Ag^+_{(aq)} + \cancel{2NO_3^-{}_{(aq)}} + \cancel{2Li^+_{(aq)}} + CO_3^{-2}{}_{(aq)} \longrightarrow Ag_2CO_{3(s)} + \cancel{2Li^+_{(aq)}} + \cancel{2NO_3^-{}_{(aq)}}$$

$$2Ag^+_{(aq)} + CO_3^{-2}{}_{(aq)} \longrightarrow Ag_2CO_{3(s)}$$

e) $$\cancel{2Al^{+3}_{(aq)}} + 3SO_4^{-2}{}_{(aq)} + 3Sr^{+2}_{(aq)} + \cancel{6OH^-_{(aq)}} \longrightarrow 3SrSO_{4(s)} + \cancel{2Al^{+3}_{(aq)}} + \cancel{6OH^-_{(aq)}}$$

$$3Sr^{+2}_{(aq)} + 3SO_4^{-2}{}_{(aq)} \longrightarrow 3SrSO_{4(s)}$$

11. Write a balanced net ionic equation for each of the following acid-base reactions in water.

(a) nitrous acid and sodium hydroxide.
(b) cesium hydroxide and sulfuric acid.
(c) aniline ($C_6H_5NH_2$) and nitric acid.

a) $HNO_2 + NaOH \rightarrow NaNO_2 + H_2O$

$H^+ + \cancel{NO_2^-} + \cancel{Na^+} + OH^- \rightarrow \cancel{Na^+} + \cancel{NO_2^-} + H_2O$

$\boxed{H^+ + OH^- \rightarrow H_2O}$

b) $2CsOH + H_2SO_4 \rightarrow 2H_2O + Cs_2SO_4$

$\cancel{2Cs^+} + 2OH^- + 2H^+ + \cancel{SO_4^{2-}} \rightarrow 2H_2O + \cancel{2Cs^+} + \cancel{SO_4^{2-}}$

$\boxed{H^+ + OH^- \rightarrow H_2O}$

c) $C_6H_5NH_2 + HOH \rightleftharpoons C_6H_5NH_3^+ + OH^-$

12. Consider the equation $H^+(aq) + OH^-(aq) \longrightarrow H_2O$. For which of the following pairs would this be the correct equation for the acid-base reaction in solution? If it is not correct, write the proper equation for the acid-base reaction between the pair.

(a) nitric acid and $C_2H_5NH_2$
(b) perchloric acid and cesium hydroxide
(c) $HC_2H_3O_2$ and LiOH
(d) sulfuric acid and calcium hydroxide
(e) barium hydroxide and hydriodic acid

$H^+ + OH^- \rightarrow H_2O$

S/A / S/B Combo

13. Assign oxidation numbers to each element in

(a) nitrate ion NO_3^-
(b) sulfate ion SO_4^{-2}
(c) sodium peroxide (Na_2O_2)
(d) oxalate ion ($C_2O_4^{2-}$)

a) NO_3^- (+5)

$x + 3(-2) = -1$

$x - 6 = -1$

$x = +5$

b) SO_4^{-2} (+6)

$x + 4(-2) = -2$

$x - 8 = -2$

$x = +6$

c) Na_2O_2 (+1)

$2(x) + 2(-1) = 0$

$x = +1$

d) $C_2O_4^{-2}$ (+3)

$2(x) + 4(-2) = -2$

$2x - 8 = -2$

$x = +3$

14. Assign oxidation numbers to each element in
(a) HIO_2 **(b)** Na_2MoO_4 **(c)** Fe_2O_3
(d) NOF **(e)** KO_2

a) HIO_2

+1 x $2(-2)$

$1 + x - 4 = 0$

$x = 3$

b) Na_2MoO_4

$2(1)$ x $4(-2)$

$2 + x - 8 = 0$

$x = +6$

c) Fe_2O_3

$2(x) + 3(-2) = 0$

$x = +3$

d) NOF

x -2 $+1$

$x = +3$

e) KO_2

x $2(-2)$

$x - 4 = 0$

$x = 4$

15. Classify each of the following half-equations as oxidation or reduction and balance.

(a) (basic) $ClO^-(aq) \longrightarrow Cl^-(aq)$
(b) (acidic) $NO_3^-(aq) \longrightarrow NO(g)$
(c) (basic) $Ni(OH)_2(s) \longrightarrow Ni_2O_3(s)$
(d) (acidic) $Mn^{2+}(aq) \longrightarrow MnO_2(s)$

a) $2e^- + 2H^+ + ClO^- \rightarrow Cl^- + H_2O$

Cl $+1 \rightarrow -1$

Gain $2e^-$ red

$2e^- + 2H^+ + ClO^- \rightarrow Cl^- + H_2O + 2OH^-$
$+2OH^-$

$2e^- + \cancel{2}H_2O + ClO^- \rightarrow Cl^- + \cancel{H_2O} + 2OH^-$

$2e^- + H_2O + ClO^- \rightarrow Cl^- + 2OH$

reduction ($2e^-$ on reactant side)

b) $3e^- + 4H^+ + NO_3^- \rightarrow NO + 2H_2O$

N: $+5 \rightarrow +2$ Gain $3e^-$ red

$3e^- + 4H^+ + NO_3^- \rightarrow NO + 2H_2O$

reduction ($3e^-$ on reactant side)

c) $2OH^- + 2Ni(OH)_2 \rightarrow Ni_2O_3 + H_2O + 2H^+ + 2OH^- + 2e^-$

$2OH^- + 2Ni(OH)_2 \rightarrow Ni_2O_3 + 3H_2O + 2e^-$ oxidation ($2e^-$ on product side)

Ni: $+2 \rightarrow +3$ lose e^- ox.

d) $2H_2O + Mn^{+2} \rightarrow MnO_2 + 4H^+ + 2e^-$ Oxidation ($2e^-$ on product side)

Mn: $+2 \rightarrow +4$ lose $2e^-$ ox.

$3\,Hg_2(NO_3)_2 + 2\,ScCl_3 \rightarrow 3\,Hg_2Cl_{2(s)} + 2\,Sc(NO_3)_3$

$3Hg_2^{+2} + \cancel{6NO_3^-} + \cancel{2Sc^{+3}} + 6Cl^- \rightarrow 3Hg_2Cl_{2(s)} + \cancel{2Sc^{+3}} + \cancel{6NO_3^-}$

$3Hg_{2(aq)}^{+2} + 6Cl^-_{(aq)} \rightarrow 3Hg_2Cl_{2(s)}$

Chemistry-II/AP

Chapter 4: Section 4.5

Solution Stoichiometry

16. A 50.00-mL sample of 0.0250 *M* mercury(I) nitrate, $Hg_2(NO_3)_2$, is mixed with 0.0500 *M* scandium chloride.

(**a**) What is the minimum volume of scandium chloride required to completely precipitate mercury(I) chloride (also known as calomel)?

(**b**) How many grams of calomel are produced from (a)? Hg_2Cl_2

(a) 1. Compute the moles of $Hg_2(NO_3)_2$ used.

$$\left(\frac{.0250 \text{ mol } Hg_2(NO_3)_2}{\cancel{L}}\right)\left(\frac{1\,\cancel{L}}{1000\,\cancel{mL}}\right)\left(50.00\,\cancel{mL}\right) = .00125 \text{ mol } Hg_2(NO_3)_2$$

2. How many moles of Hg_2^{+2} were present?

$$.00125 \text{ mol } Hg_2(NO_3)_2\left(\frac{1 \text{ mol } Hg_2^{+2}}{1 \text{ mol } Hg_2(NO_3)_2}\right) = .00125 \text{ mol } Hg_2^{2+}$$

3. How many moles of Cl^{-1} were used?

$$.00125\,\cancel{\text{mol } Hg_2^{2+}}\left(\frac{6 \text{ mol } Cl^-}{3\,\cancel{\text{mol } Hg_2^{2+}}}\right) = .0025 \text{ mol } Cl^-$$

4. Compute the moles of $ScCl_3$ required to furnish the moles of Cl^{-1}.

$$.0025\,\cancel{\text{mol } Cl^-}\left(\frac{1 \text{ mol } ScCl_3}{3\,\cancel{\text{mol } Cl^-}}\right) = .000833 \text{ mol } ScCl_3$$

5. Compute the volume of $ScCl_3$ required for the precipitation.

$$M = \frac{\text{moles}}{L} \qquad L = \frac{\text{moles}}{M} = \frac{.000833 \text{ mol } ScCl_3}{.0500 \frac{\text{mol } ScCl_3}{L}} =$$

$$L = .0167\,L = \boxed{16.67\,mL}$$

(b)

$$.0250 \frac{\text{mol}}{\cancel{L}} Hg_2(NO_3)_2 \times .05000\,\cancel{L}$$

$$.00125 \text{ mol } Hg_2(NO_3)_2\left(\frac{3 \text{ mol } Hg_2Cl_2}{3 \text{ mol } Hg_2(NO_3)_2}\right)\left(\frac{427.1\,g}{1 \text{ mol } Hg_2Cl_2}\right) = \boxed{0.534\,g}$$

Chemistry-II/AP

Chapter 4: Section 4.5

Solution Stoichiometry: Precipitation and Acid-Base Reactions

17. Aluminum (Al^{+3}) ions react with carbonate (CO_3^{-2}) ions to form an insoluble compound, aluminum carbonate. $Al_2(CO_3)_3$

(a) Write the net ionic equation for this reaction.

(b) What is the molarity of a solution of aluminum chloride if 25.0 mL is required to react with 35.5 mL of 0.155 *M* sodium carbonate?

(c) How many grams of aluminum carbonate are formed?

a) $2Al^{+3}_{(aq)} + 3CO^{-2}_{3(aq)} \longrightarrow Al_2(CO_3)_{3(s)}$

b) $35.5\,\cancel{mL}\,Na_2CO_3 \left(\frac{1\,\cancel{L}}{1000\,\cancel{mL}}\right)\left(\frac{.155\,\cancel{mol\,Na_2CO_3}}{1\,\cancel{L}}\right)\left(\frac{1\,\cancel{mol\,CO_3^{-2}}}{1\,\cancel{mol\,Na_2CO_3}}\right)\left(\frac{2\,\cancel{mol\,Al^{+3}}}{3\,\cancel{mol\,CO_3^{-2}}}\right)\left(\frac{1\,mol\,AlCl_3}{1\,\cancel{mol\,Al^{+3}}}\right) = 3.67\times10^{-3}\,mol\,AlCl_3$

$M = \frac{moles\,AlCl_3}{L\,AlCl_3} = \frac{3.67\times10^{-3}\,mol\,AlCl_3}{.025\,L\,AlCl_3} = \boxed{.147\,M\,AlCl_3}$

c) $35.5\,\cancel{mL}\,Na_2CO_3 \left(\frac{1\,\cancel{L}}{1000\,\cancel{mL}}\right)\left(\frac{.155\,mol\,\cancel{Na_2CO_3}}{\cancel{L}}\right)\left(\frac{1\,\cancel{mol\,CO_3^{-2}}}{1\,mol\,\cancel{Na_2CO_3}}\right)\left(\frac{1\,mol\,\cancel{Al_2(CO_3)_3}}{3\,mol\,\cancel{CO_3^{-2}}}\right)\left(\frac{234\,g}{1\,mol\,\cancel{Al_2(CO_3)_3}}\right) =$

$\boxed{.429\,g\,Al_2(CO_3)_3}$

18. What is the molarity of a solution of nitric acid (HNO_3) if 0.216 g of barium hydroxide ($Ba(OH)_2$) is required to neutralize 20.00 mL of nitric acid?

$$2H^+ + \cancel{2NO_3^-} + \cancel{Ba^{+2}} + 2OH^- \longrightarrow 2H_2O + \cancel{Ba^{+2}} + \cancel{2NO_3^-}$$

$$2H^+ + 2OH^- \longrightarrow 2H_2O$$

$$H^+ + OH^- \longrightarrow H_2O$$

$$.216\,\cancel{g\,Ba(OH)_2}\left(\frac{1\,\cancel{mol\,Ba(OH)_2}}{171.34\,\cancel{g}}\right)\left(\frac{2\,\cancel{mol\,OH^-}}{1\,\cancel{mol\,Ba(OH)_2}}\right)\left(\frac{1\,\cancel{mol\,H^+}}{1\,\cancel{mol\,OH^-}}\right)\left(\frac{1\,mol\,HNO_3}{1\,\cancel{mol\,H^+}}\right) = .00252\ mol\ HNO_3$$

$$M = \frac{moles}{L} = \frac{.00252\ mol\ HNO_3}{.02000\ L} = \boxed{.126\,M}\ HNO_3$$

19 Pennies made after 1982 contain about 97% zinc by mass. A student wants to prove this by filing the copper outside of a penny until he sees zinc and then putting the penny in a 1.00 M HCl solution. The zinc will be oxidized and the H^+ (from HCl) will be reduced:

$$Zn + 2H^+ \rightarrow Zn^{2+} + H_2$$

If the entire penny has a mass of 2.80 grams, how many mL of 1.00 M HCl are required to just react with all the zinc? (You would, in reality, add much more to completely surround the penny.)

$$2.80\,\cancel{g\ penny}\left(\frac{97\,\cancel{g}\,Zn}{100\,\cancel{g\ penny}}\right)\left(\frac{1\,\cancel{mole\,Zn}}{65.4\,\cancel{g}}\right)\left(\frac{2\,\cancel{mol\,H^+}}{1\,\cancel{mole\,Zn}}\right)\left(\frac{1\,\cancel{mol\,HCl}}{1\,\cancel{mol\,H^+}}\right)\left(\frac{1\,\cancel{L}}{1\,\cancel{mol\,HCl}}\right)\left(\frac{1000\,mL}{1\,\cancel{L}}\right) =$$

$\boxed{\text{83.1 mL of 1.00 M HCl}}$

$Sr(OH)_2$

19. What volume of 0.185 *M* strontium hydroxide is required to neutralize 35.00 mL of 0.175 *M* hydrogen fluoride?

HF

$$\cancel{Sr^{+2}} + 2OH^- + 2H^+ \cancel{2F^-} \rightarrow 2H_2O + \cancel{Sr^{+2}} + \cancel{2F^-}$$

$$H^+ + OH^- \rightarrow H_2O$$

$$35.00\,\cancel{mL}\,HF \left(\frac{1\,\cancel{L}}{1000\,\cancel{mL}}\right)\left(\frac{.175\,\cancel{mol\,HF}}{\cancel{L}}\right)\left(\frac{1\,\cancel{mol\,H^+}}{1\,\cancel{mol\,HF}}\right)\left(\frac{1\,\cancel{mol\,OH^-}}{1\,\cancel{mol\,H^+}}\right)\left(\frac{1\,\cancel{mol\,Sr(OH)_2}}{2\,\cancel{mol\,OH^-}}\right)\left(\frac{1\,\cancel{L}}{.185\,\cancel{mol\,Sr(OH)_2}}\right)\left(\frac{1000\,mL}{1\,\cancel{L}}\right) =$$

16.56 mL of .185 M $Sr(OH)_2$

20. A vitamin C capsule is analyzed by titrating it with 0.250 *M* sodium hydroxide. It is found that 10.3 mL of base is required to react with a capsule weighing 0.518 g. What is the percentage of vitamin C ($C_6H_8O_6$) in the capsule? (One mole of vitamin C reacts with one mole of hydroxide ion.)

$$10.3\,\cancel{mL}\,NaOH \left(\frac{1\,L}{1000\,\cancel{mL}}\right)\left(\frac{.250\,\cancel{mol\,NaOH}}{\cancel{L}}\right)\left(\frac{1\,\cancel{mol\,OH}}{1\,\cancel{mol\,NaOH}}\right)\left(\frac{1\,\cancel{mol\,VitC}}{1\,\cancel{mol\,OH^-}}\right)\left(\frac{176\,g}{1\,\cancel{mol\,VitC}}\right) =$$

.4532 g Vitamin C

$$\%\,VitC = \frac{\text{mass VitC}}{\text{mass capsule}} \times 100 \qquad \frac{.4532\,g}{.518\,g} \times 100 = \boxed{87.5\%\ \text{Vitamin C}}$$

Chemistry-II/AP

Chapter 4: Section 4.6

Solution Reactions in Quantitative Analysis

21 Potassium permanganate reacts with oxalic acid, $H_2C_2O_4$, to form carbon dioxide and solid manganese(IV) oxide (MnO_2).

$MnO_4^- + H_2C_2O_4 \rightarrow MnO_2 + CO_2$

(a) Write a balanced net ionic equation for the reaction.

(b) If 25.0 mL of 0.500 *M* potassium permanganate is required to react with 15.0 mL of oxalic acid, what is the molarity of the oxalic acid?

(c) What is the mass of manganese(IV) oxide formed?

a) $(3e^- + 4H^+ + MnO_4^- \rightarrow MnO_2 + 2H_2O) \times 2$

LCM 6

$(H_2C_2O_4 \rightarrow 2CO_2 + 2H^+ + 2e^-) \times 3$

$\cancel{8}\,2H^+ + 2MnO_4^- + 3H_2C_2O_4 \rightarrow 2MnO_2 + 4H_2O + 6CO_2 + \cancel{6H^+}$

$2H^+ + 2MnO_4^- + 3H_2C_2O_4 \rightarrow 2MnO_2 + 4H_2O + 6CO_2$

b) $25.0\,\cancel{mL}\,KMnO_4\left(\frac{1\cancel{L}}{1000\,\cancel{mL}}\right)\left(\frac{.500\,mol\,\cancel{KMnO_4}}{1\,L}\right)\left(\frac{1\,mol\,\cancel{MnO_4^-}}{1\,mol\,\cancel{KMnO_4}}\right)\left(\frac{3\,mol\,H_2C_2O_4}{2\,mol\,\cancel{MnO_4^-}}\right) = .01875\,mol\,H_2C_2O_4$

$M = \frac{.01875\,mol\,H_2C_2O_4}{.015\,L} = \boxed{1.25\,M\,H_2C_2O_4}$

c) $25.0\,\cancel{mL}\,KMnO_4\left(\frac{1\cancel{L}}{1000\,\cancel{mL}}\right)\left(\frac{.500\,mol\,\cancel{KMnO_4}}{\cancel{L}}\right)\left(\frac{1\,mol\,\cancel{MnO_4^-}}{1\,mol\,\cancel{KMnO_4}}\right)\left(\frac{2\,\cancel{mol\,MnO_2}}{2\,mol\,\cancel{MnO_4^-}}\right)\left(\frac{86.94\,g}{1\,mol\,\cancel{MnO_2}}\right) = \boxed{1.09\,g\,MnO_2}$

22. Consider the reaction between silver and nitric acid for which the unbalanced equation is

$$Ag(s) + H^+(aq) + NO_3^-(aq) \longrightarrow Ag^+(aq) + NO_2(g) + H_2O$$

(a) Balance the equation.
(b) If 35.00 mL of 12.0 *M* nitric acid furnishes enough H^+ to react with silver, how many grams of silver react?

a) $Ag_{(s)} \longrightarrow Ag^{+1} + \cancel{e^-}$ LCM: 1

$\cancel{e^-} + 2H^+ + NO_3^- \longrightarrow NO_2 + H_2O$

$$\boxed{2H^+ + Ag + NO_3^- \longrightarrow Ag^{+1} + NO_2 + H_2O}$$

b) $35.00\,\text{mL}\ HNO_3 \left(\frac{1\,L}{1000\,\text{mL}}\right)\left(\frac{12\,\text{mol}\ HNO_3}{1\,L}\right)\left(\frac{2\,\text{mol}\ H^+}{1\,\text{mol}\ HNO_3}\right)\left(\frac{1\,\text{mol}\ Ag}{2\,\text{mol}\ H^+}\right)\left(\frac{108\,g}{1\,\text{mol}\ Ag}\right) =$

$$\boxed{22.68\ g\ Ag}$$

23. Zinc metal reacts with nitrate ion in basic solution. The unbalanced equation for the reaction is

$$OH^-(aq) + Zn(s) + H_2O + NO_3^-(aq) \longrightarrow NH_3(aq) + Zn(OH)_4^{2-}(aq)$$

(a) Balance the equation.

(b) What volume of 0.250 *M* barium hydroxide is required to react completely with 2.50 g of zinc?

$Ba(OH)_2$

$$\left(4H_2O + Zn \longrightarrow Zn(OH)_4^{-2} + 4H^+ + 2e^-\right) \times 4$$

LCM = 8

$$8e^- \; 9H^+ + NO_3^- \longrightarrow NH_3 + 3H_2O$$

$$\overset{6}{\cancel{16}}H_2O + 4Zn + \cancel{9H^+} + NO_3^- \longrightarrow 4Zn(OH)_4^{-2} + \underset{7OH^-}{\cancel{16H^+}} + \cancel{3H_2O} + NH_3$$

$7OH^-$ +

$\cancel{7H_2O}$

$$\boxed{7OH^- + 6H_2O + 4Zn + NO_3^- \longrightarrow 4Zn(OH)_4^{-2} + NH_3}$$

b) $$2.50\,\cancel{g}\,Zn \left(\frac{1\ mole\ Zn}{65.4\,g\,Zn}\right)\left(\frac{7\ mol\ OH^-}{4\ mol\ Zn}\right)\left(\frac{1\ mol\ Ba(OH)_2}{2\ mol\ OH^-}\right)\left(\frac{1\,L}{.250\ mol\ Ba(OH)_2}\right)\left(\frac{1000\,mL}{1\,L}\right) =$$

133.8 mL of .250 M $Ba(OH)_2$

Chem-II/AP

Chapter 4 Section 4.6

Solution Reactions in Chemical Analysis: Redox Reactions

24. Hair bleaching solutions contain hydrogen peroxide, H_2O_2. The hydrogen peroxide content can be determined by reacting H_2O_2 with a potassium dichromate acidic solution. The unbalanced equation for the reaction is

$$H_2O_2(aq) + Cr_2O_7^{2-}(aq) + H^+(aq) \longrightarrow O_2(g) + Cr^{3+}(aq) + H_2O$$

A 15.0-g bleach solution needed 75.8 mL of 0.388 *M* $K_2Cr_2O_7$ to react completely with the H_2O_2 in the hair bleach. What is the mass % of H_2O_2 in the bleach?

1. Balance the overall equation in acidic solution.

$$(H_2O_2 \longrightarrow O_2 + 2H^+ + 2e^-) \times 3$$

LCM: 6

$$6e^- + 14H^+ + Cr_2O_7^{-2} \longrightarrow 2Cr^{+3} + 7H_2O$$

$$\cancel{14H^+}\ 8 + Cr_2O_7^{-2} + 3H_2O_2 \longrightarrow 3O_2 + \cancel{6H^+} + 2Cr^{+3} + 7H_2O$$

2. Compute moles of $Cr_2O_7^{-2}{}_{(aq)}$ used in the titration.

$$75.8\ mL\ K_2Cr_2O_7\left(\frac{1\ L}{1000\ mL}\right)\left(\frac{.388\ mol\ K_2Cr_2O_7}{1\ L}\right)\left(\frac{1\ mol\ Cr_2O_7^{-2}}{1\ mol\ K_2Cr_2O_7}\right) = .0294\ mol\ Cr_2O_7^{-2}$$

3. From the balanced equation, compute the moles of $H_2O_{2(aq)}$ titrated.

$$.0294\ mol\ Cr_2O_7^{-2}\left(\frac{3\ mol\ H_2O_2}{1\ mol\ Cr_2O_7^{-2}}\right) = .0882\ mol\ H_2O_2$$

4. Compute the mass of $H_2O_{2(aq)}$ titrated.

$$.0882\ mol\ H_2O_2\left(\frac{34.0\ g}{1\ mol}\right) = 2.9999\ g = 3.00\ g\ H_2O_2$$

5 Compute the mass percent H_2O_2 in the sample.

$$\%H_2O_2 = \frac{\text{Mass } H_2O_2}{\text{Mass bleach}} \times 100 \qquad \frac{3.00}{15.0} \times 100 = \boxed{20.0\%\ H_2O_2}$$

5. Laws passed in some states define a drunk driver as one who drives with a blood alcohol level of 0.10% by mass or higher. The level of alcohol can be determined by titrating blood plasma with potassium dichromate according to the unbalanced equation

$$H^+(aq) + Cr_2O_7^{2-}(aq) + C_2H_5OH(aq) \longrightarrow Cr^{3+}(aq) + CO_2(g) + H_2O$$

Assuming that the only substance that reacts with dichromate in blood plasma is alcohol, is a person legally drunk if 45.02 mL of 0.05000 *M* potassium dichromate is required to titrate a 50.00 g sample of blood plasma?

1. Balance the overall equation in acidic solution.

$$(6e^- + 14H^+ + Cr_2O_7^{-2} \longrightarrow 2Cr^{+3} + 7H_2O) \times 2$$

LCM = 12

$$3H_2O + C_2H_5OH \longrightarrow 2CO_2 + 12H^+ + 12e^-$$

$$\underset{16}{\cancel{28}}H^+ + 2Cr_2O_7^{-2} + \cancel{3H_2O} + C_2H_5OH \longrightarrow 4Cr^{+3} + \underset{11}{\cancel{14}}H_2O + 2CO_2 + \cancel{12H^+}$$

$$\boxed{16H^+ + 2Cr_2O_7^{-2} + C_2H_5OH \longrightarrow 4Cr^{+3} + 11H_2O + 2CO_2}$$

2. Compute moles of $Cr_2O_7^{-2}{}_{(aq)}$ used in the titration.

$$45.02\,mL\ K_2Cr_2O_7\left(\frac{1\,L}{1000\,mL}\right)\left(\frac{.05000\ mol\ K_2Cr_2O_7}{1\,L}\right)\left(\frac{1\ mol\ Cr_2O_7^{-2}}{1\ mol\ K_2Cr_2O_7}\right) = .002251\ mol\ Cr_2O_7^{-2}$$

3. From the balanced equation, compute the moles of $C_2H_5OH_{(aq))}$ titrated.

$$.002251\ mol\ Cr_2O_7^{-2}\left(\frac{1\ mol\ C_2H_5OH}{2\ mol\ Cr_2O_7^{-2}}\right) = .0011255\ mol\ C_2H_5OH$$

4. Compute the mass of $C_2H_5OH_{(aq)}$ titrated.

$$.0011255\ mol\ C_2H_5OH\left(\frac{46\,g}{1\ mol}\right) = \boxed{.05177\,g\ C_2H_5OH}$$

5 Compute the mass percent C_2H_5OH in the sample. Compare to 0.100% ← Limit

$$\%\ alcohol = \frac{mass\ alcohol}{mass\ sample} \times 100 \qquad \frac{.05177\,g\ C_2H_5OH}{50.0\,g\ sample} \times 100 = .1035\%$$

DRUNK!