4 Reactions in Aqueous Solution

4.1 $C_{12}H_{22}O_{11}$, 342.3; 355 mL = 0.355 L

$$43.0 \text{ g } C_{12}H_{22}O_{11} \times \frac{1 \text{ mol } C_{12}H_{22}O_{11}}{342.3 \text{ g } C_{12}H_{22}O_{11}} = 0.126 \text{ mol } C_6H_{12}O_6$$

$$\text{molarity} = \frac{0.126 \text{ mol}}{0.355 \text{ L}} = 0.355 \text{ M}$$

4.2 $C_6H_{12}O_6$, 180.2; NaCl, 58.4; 250.0 mL = 0.2500 L

$$13.252 \text{ g } C_6H_{12}O_6 \times \frac{1 \text{ mol } C_6H_{12}O_6}{180.2 \text{ g } C_6H_{12}O_6} = 0.073\ 54 \text{ mol } C_6H_{12}O_6$$

$$C_6H_{12}O_6 \text{ molarity} = \frac{0.073\ 54 \text{ mol}}{0.2500 \text{ L}} = 0.2942 \text{ M}$$

$$0.686 \text{ g NaCl} \times \frac{1 \text{ mol NaCl}}{58.4 \text{ g NaCl}} = 0.0117 \text{ mol NaCl}$$

$$\text{NaCl molarity} = \frac{0.0117 \text{ mol}}{0.2500 \text{ L}} = 0.0470 \text{ M}$$

4.3 (a) 125 mL = 0.125 L; (0.20 mol/L)(0.125 L) = 0.025 mol $NaHCO_3$

4.4 (a) $C_{27}H_{46}O$, 386.7; 750 mL = 0.750 L

$$\frac{0.0050 \text{ mol } C_{27}H_{46}O}{\text{L}} \times 0.750 \text{ L} \times \frac{386.7 \text{ g } C_{27}H_{46}O}{1 \text{ mol } C_{27}H_{46}O} = 1 \text{ g } C_{27}H_{46}O$$

(b) $$25 \text{ mg } C_{27}H_{46}O \times \frac{1 \times 10^{-3} \text{ g}}{1 \text{ mg}} \times \frac{1 \text{ mol } C_{27}H_{46}O}{386.7 \text{ g } C_{27}H_{46}O} \times \frac{1 \text{ L}}{0.005 \text{ mol } C_{27}H_{46}O} \times \frac{1 \text{ mL}}{1 \times 10^{-3} \text{ L}} = 13 \text{ mL blood}$$

4.5 $M_i \times V_i = M_f \times V_f$; $M_f = \dfrac{M_i \times V_i}{V_f} = \dfrac{3.50 \text{ M} \times 75.0 \text{ mL}}{400.0 \text{ mL}} = 0.656 \text{ M}$

4.6 $M_i \times V_i = M_f \times V_f$; $V_i = \dfrac{M_f \times V_f}{M_i} = \dfrac{0.500 \text{ M} \times 250.0 \text{ mL}}{18.0 \text{ M}} = 6.94 \text{ mL}$

4.7 $FeBr_3$ contains 3 Br^- ions. The molar concentration of Br^- ions = 3 x 0.225 M = 0.675 M.

4.8 (a) A_2Y is the strongest electrolyte because all the molecules have dissociated into ions. A_2X is the weakest because only 1 out of 5 molecules have dissociated into ions.
(b) In a 0.350 M solution of A_2Y, the molar concentration of A ions = 2 x 0.350 = 0.700 M. In a 0.350 M solution of A_2Y, the molar concentration of Y ions = 1 x 0.350 = 0.350 M.
(c) There are 5 A_2X molecules initially in the solution. Only one of them is ionized. The percent ionization = (1/5) x 100% = 20%

4.9 (a) Ionic equation:
$2\ Ag^+(aq) + 2\ NO_3^-(aq) + 2\ Na^+(aq) + CrO_4^{2-}(aq) \rightarrow Ag_2CrO_4(s) + 2\ Na^+(aq) + 2\ NO_3^-(aq)$
Delete spectator ions from the ionic equation to get the net ionic equation.
Net ionic equation: $2\ Ag^+(aq) + CrO_4^{2-}(aq) \rightarrow Ag_2CrO_4(s)$

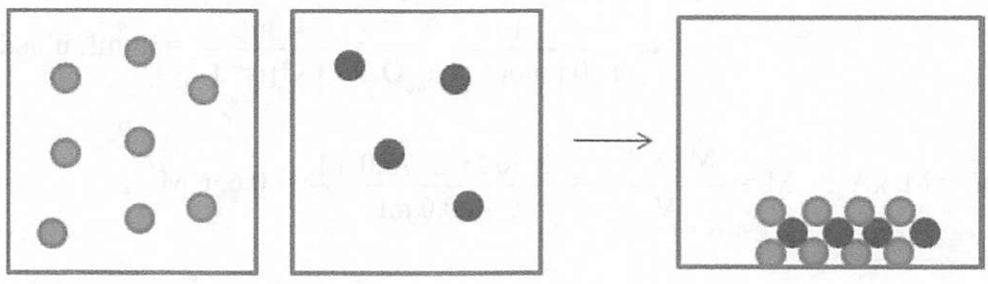
4.10 Spectator ions: Ca^{2+} and NO_3^-
Net ionic equation: $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$
Molecular equation: $2\ AgNO_3(aq) + CaCl_2(aq) \rightarrow 2\ AgCl(s) + Ca(NO_3)_2(aq)$

4.11 Ionic equation:
$2\ Ag^+(aq) + 2\ ClO_4^-(aq) + Ca^{2+}(aq) + 2\ Br^-(aq) \rightarrow 2\ AgBr(s) + Ca^{2+}(aq) + 2\ ClO_4^-(aq)$
Delete spectator ions from the ionic equation and reduce coefficients to get the net ionic equation.
Net ionic equation: $Ag^+(aq) + Br^-(aq) \rightarrow AgBr(s)$
A precipitation reaction occurs.

4.12 $3\ CaCl_2(aq) + 2\ Na_3PO_4(aq) \rightarrow Ca_3(PO_4)_2(s) + 6\ NaCl(aq)$
Ionic equation:
$3\ Ca^{2+}(aq) + 6\ Cl^-(aq) + 6\ Na^+(aq) + 2\ PO_4^{3-}(aq) \rightarrow Ca_3(PO_4)_2(s) + 6\ Na^+(aq) + 6\ Cl^-(aq)$
Delete spectator ions from the ionic equation to get the net ionic equation.
Net ionic equation: $3\ Ca^{2+}(aq) + 2\ PO_4^{3-}(aq) \rightarrow Ca_3(PO_4)_2(s)$

4.13 A precipitate results from the reaction. The precipitate contains cations and anions in a 3:2 ratio. The precipitate is $Mg_3(PO_4)_2$.

4.14 The precipitate is $PbBr_2$.



4.15 (a) HI, hydroiodic acid (b) $HBrO_2$, bromous acid

4.16 (a) H_3PO_3 (b) H_2Se

4.17 Ionic equation:
$Ca^{2+}(aq) + 2\ OH^-(aq) + 2\ CH_3CO_2H(aq) \rightarrow Ca^{2+}(aq) + 2\ CH_3CO_2^-(aq) + 2\ H_2O(l)$
Delete spectator ions from the ionic equation and reduce coefficients to get the net ionic equation.
Net ionic equation: $CH_3CO_2H(aq) + OH^-(aq) \rightarrow CH_3CO_2^-(aq) + H_2O(l)$

4.18 $Mg^{2+}(aq) + 2\ OH^-(aq) + 2\ H^+(aq) + 2\ Cl^-(aq) \rightarrow Mg^{2+}(aq) + 2\ Cl^-(aq) + H_2O(l)$
$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

4.19 50.0 mL = 0.0500 L
$(0.100\ mol/L)(0.0500\ L) = 5.00 \times 10^{-3}$ mol NaOH

$$5.00 \times 10^{-3}\ mol\ NaOH \times \frac{1\ mol\ H_2SO_4}{2\ mol\ NaOH} = 2.50 \times 10^{-3}\ mol\ H_2SO_4$$

$$2.50 \times 10^{-3}\ mol\ H_2SO_4 \times \frac{1\ L}{0.250\ mol\ H_2SO_4} \times \frac{1000\ mL}{1\ L} = 10.0\ mL$$

4.20 25.0 mL = 0.0250 L; 68.5 mL = 0.0685 L
From the reaction stoichiometry, moles KOH = moles HNO_3
$(0.150\ mol/L)(0.0250\ L) = 3.75 \times 10^{-3}$ mol KOH = 3.75×10^{-3} mol HNO_3

$$\text{molarity} = \frac{3.75 \times 10^{-3}\ mol}{0.0685\ L} = 0.0547\ M$$

4.21 25.0 mL = 0.0250 L; 94.7 mL = 0.0947 L
From the reaction stoichiometry, moles NaOH = moles CH_3CO_2H
$(0.200\ mol/L)(0.0947\ L) = 0.018\ 94$ mol NaOH = $0.018\ 94$ mol CH_3CO_2H

$$\text{molarity} = \frac{0.018\ 94\ mol}{0.0250\ L} = 0.758\ M$$

4.22 $$\text{vol } H^+ \text{ solution} = 8\ OH^- \times \frac{1\ H^+}{1\ OH^-} \times \frac{100\ mL}{12\ H^+} = 66.7\ mL$$

4.23
(a) $SnCl_4$: Cl –1, Sn +4
(b) CrO_3: O –2, Cr +6
(c) $VOCl_3$: O –2, Cl –1, V +5
(d) V_2O_3: O –2, V +3
(e) HNO_3: O –2, H +1, N +5
(f) $FeSO_4$: O –2, S +6, Fe +2

4.24 (a) +2, ClO, chlorine monoxide; +3, Cl_2O_3, dichlorine trioxide; +6, ClO_3, chlorine trioxide; +7, Cl_2O_7, dichlorine heptoxide
(b) Cl_2O_7 cannot react with O_2 because Cl has its maximum oxidation number, +7, and cannot be further oxidized.

4.25 $4\,NH_3(g) + 5\,O_2(g) \rightarrow 4\,NO(g) + 6\,H_2O(l)$
The N in NH_3 is oxidized (its oxidation number increases from –3 to +2). NH_3 is the reducing agent.
Each O in O_2 is reduced (its oxidation number decreases from 0 to –2). O_2 is the oxidizing agent.

4.26 (a) C in C_2H_5OH oxidized and Cr in $K_2Cr_2O_7$ gets reduced.
(b) $K_2Cr_2O_7$ is the oxidizing agent; C_2H_5OH is the reducing agent.

4.27 Mg is below Ca in the activity series; therefore NO REACTION.

4.28 "Any element higher in the activity series will react with the ion of any element lower in the activity series."
$A + D^+ \rightarrow A^+ + D$; therefore A is a stronger reducing agent than D.
$B^+ + D \rightarrow B + D^+$; therefore D is a stronger reducing agent than B.
$C^+ + D \rightarrow C + D^+$; therefore D is a stronger reducing agent than C.
$B + C^+ \rightarrow B^+ + C$; therefore B is a stronger reducing agent than C.
The net result is A(strongest) > D > B > C(weakest).

4.29 31.50 mL = 0.031 50 L; 10.00 mL = 0.010 00 L

$$0.031\,50\text{ L} \times \frac{0.105\text{ mol } BrO_3^-}{1\text{ L}} \times \frac{6\text{ mol } Fe^{2+}}{1\text{ mol } BrO_3^-} = 1.98 \times 10^{-2}\text{ mol } Fe^{2+}$$

$$\text{molarity} = \frac{1.98 \times 10^{-2}\text{ mol } Fe^{2+}}{0.010\,00\text{ L}} = 1.98\text{ M } Fe^{2+}\text{ solution}$$

4.30 14.92 mL = 0.014 92 L

$$0.014\,92\text{ L} \times \frac{0.100\text{ mol } Cr_2O_7^{-2}}{1\text{ L}} \times \frac{6\text{ mol } Fe^{2+}}{1\text{ mol } Cr_2O_7^{-2}} \times \frac{55.85\text{ g } Fe^{2+}}{1\text{ mol } Fe^{2+}} \times \frac{1000\text{ mg}}{1\text{ g}} = 50.0\text{ mg } Fe^{2+}$$

4.31 (a) Sodium chloride, sodium citrate, and potassium dihydrogen phosphate are strong electrolytes since they are soluble ionic compounds; citric acid and vitamin B3 are weak electrolytes due the presence of the carboxylic acid (CO_2H) group; and fructose is a nonelectrolyte. (b) Sodium chloride, potassium dihydrogen phosphate, and sodium citrate replenish electrolytes with important biological functions.

4.32 150 mg = 0.15 g; 35 mg = 0.035 g; 360 mL = 0.36 L

$$\text{molarity} = \frac{\left(0.15\text{ g } Na^+ \times \frac{1\text{ mol } Na^+}{23\text{ g } Na^+}\right)}{0.36\text{ L}} = 0.018\text{ M}$$

$$\text{molarity} = \frac{\left(0.35\text{ g } K^+ \times \frac{1\text{ mol } K^+}{39\text{ g } K^+}\right)}{0.36\text{ L}} = 0.0025\text{ M}$$

4.33 NaCl, 58.4; 0.500 L = 500 mL

$$0.416 \text{ mg } Na^+/\text{mL} \times \frac{1 \times 10^{-3} \text{ g}}{1 \text{ mg}} \times 500 \text{ mL} \times \frac{1 \text{ mol } Na^+}{23.0 \text{ g } Na^+} \times \frac{1 \text{ mol NaCl}}{1 \text{ mol } Na^+} \times \frac{58.4 \text{ g NaCl}}{1 \text{ mol NaCl}} = 0.528 \text{ g NaCl}$$

4.34 (a) Ba^{2+} (b) $3\ Ba^{2+}(aq) + 2\ PO_4^{3-}(aq) \rightarrow Ba_3(PO_4)_2(s)$

4.35 AgCl, 143.3; 172 mg = 0.172 g; 100.0 mL = 0.1000 L

$$0.172 \text{ g AgCl} \times \frac{1 \text{ mol AgCl}}{143.3 \text{ g AgCl}} \times \frac{1 \text{ mol } Cl^-}{1 \text{ mol AgCl}} = 0.001\ 20 \text{ mol } Cl^-$$

$$Cl^- \text{ molarity} = \frac{0.001\ 20 \text{ mol } Cl^-}{0.1000 \text{ L}} = 0.0120 \text{ M}$$

4.36 35.6 mL = 0.0356 L; 25.0 mL = 0.0250 L

(0.0356 L)(0.0400 mol/L) = 0.001 42 mol NaOH

$$0.001\ 42 \text{ mol NaOH} \times \frac{1 \text{ mol } H_3C_6H_5O_7}{3 \text{ mol NaOH}} = 4.75 \times 10^{-4} \text{ mol } H_3C_6H_5O_7$$

$$H_3C_6H_5O_7 \text{ molarity} = \frac{4.75 \times 10^{-4} \text{ mol}}{0.0250 \text{ L}} = 0.0190 \text{ M}$$

Conceptual Problems

4.37 The concentration of a solution is cut in half when the volume is doubled. This is best represented by box (b).

4.38 (a) $2\ Na^+(aq) + CO_3^{2-}(aq)$ does not form a precipitate. This is represented by box (1).
(b) $Ba^{2+}(aq) + CrO_4^{2-}(aq) \rightarrow BaCrO_4(s)$. This is represented by box (2).
(c) $2\ Ag^+(aq) + SO_4^{2-}(aq) \rightarrow Ag_2SO_4(s)$. This is represented by box (3).

4.39 In the precipitate there are two cations (blue) for each anion (red). Looking at the ions in the list, the anion must have a –2 charge and the cation a +1 charge for charge neutrality of the precipitate. The cation must be Ag^+ because all Na^+ salts are soluble. Ag_2CrO_4 and Ag_2CO_3 are insoluble and consistent with the observed result.

4.40 HY is the strongest acid because it is completely dissociated.
HX is the weakest acid because it is the least dissociated.

4.41 One OH^- will react with each available H^+ on the acid forming H_2O. The acid is identified by how many of the 12 OH^- react with three molecules of each acid.
(a) Three HF's react with three OH^-, leaving nine OH^- unreacted (box 2).
(b) Three H_2SO_3's react with six OH^-, leaving six OH^- unreacted (box 3).
(c) Three H_3PO_4's react with nine OH^-, leaving three OH^- unreacted (box 1).

4.42 The concentration in the buret is three times that in the flask. The NaOCl concentration is 0.040 M. Because the I^- concentration in the buret is three times the OCl^- concentration in the flask and the reaction requires 2 I^- ions per OCl^- ion, 2/3 or 67% of the I^- solution from the buret must be added to the flask to react with all of the OCl^-.

4.43 (a) Ionic equation:
$K^+(aq) + Cl^-(aq) + Ag^+(aq) + NO_3^-(aq) \rightarrow AgCl(s) + K^+(aq) + NO_3^-(aq)$
(b) Ionic equation:
$HF(aq) + K^+(aq) + OH^-(aq) \rightarrow K^+(aq) + F^-(aq) + H_2O(l)$
(c) Ionic equation:
$Ba^{2+}(aq) + 2\ Cl^-(aq) + 2\ Na^+(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s) + 2\ Na^+(aq) + 2\ Cl^-(aq)$
Reaction (c) would have the highest initial conductivity because of the 3 net ions for each $BaCl_2$ (a strong electrolyte).
Reaction (b) would have the lowest (almost zero) initial conductivity because HF is a very weak acid/electrolyte.
Reaction (a) would have an intermediate initial conductivity between that for reactions (b) and (c).
Figure (1) is for reaction (a); figure (2) is for reaction (b); and figure (3) is for reaction (c).

4.44

(a) $Sr^+ + At \rightarrow Sr + At^+$	No reaction.
(b) $Si + At^+ \rightarrow Si^+ + At$	Reaction would occur.
(c) $Sr + Si^+ \rightarrow Sr^+ + Si$	Reaction would occur.

4.45 "Any element higher in the activity series will react with the ion of any element lower in the activity series."
$BLUE + RED^+ \rightarrow BLUE^+ + RED$; therefore BLUE is higher than RED.
$RED + GREEN^+ \rightarrow RED^+ + GREEN$; therefore RED is higher than GREEN.
The net result is BLUE > RED > GREEN. Because BLUE is above GREEN, the following reaction will occur: $BLUE + GREEN^+ \rightarrow BLUE^+ + GREEN$

Section Problems
Molarity (Section 4.1)

4.46 (a) $35.0\ mL = 0.0350\ L;\ \dfrac{1.200\ mol\ HNO_3}{L} \times 0.0350\ L = 0.0420\ mol\ HNO_3$

(b) $175\ mL = 0.175\ L;\ \dfrac{0.67\ mol\ C_6H_{12}O_6}{L} \times 0.175\ L = 0.12\ mol\ C_6H_{12}O_6$

4.47 (a) C_2H_6O, 46.07; $250.0\ mL = 0.2500\ L$

$$\frac{0.600\ mol\ C_2H_6O}{L} \times 0.2500\ L = 0.150\ mol\ C_2H_6O$$

$(0.150\ mol)(46.07\ g/mol) = 6.91\ g\ C_2H_6O$

(b) H_3BO_3, 61.83; $167\ mL = 0.167\ L$

$$\frac{0.200\ mol\ H_3BO_3}{L} \times 0.167\ L = 0.0334\ mol\ H_3BO_3$$

$(0.0334\ mol)(61.83\ g/mol) = 2.07\ g\ H_3BO_3$

4.48 $BaCl_2$, 208.2

$$15.0\text{ g } BaCl_2 \times \frac{1\text{ mol } BaCl_2}{208.2\text{ g } BaCl_2} = 0.0720\text{ mol } BaCl_2$$

$$0.0720\text{ mol} \times \frac{1.0\text{ L}}{0.45\text{ mol}} = 0.16\text{ L};\quad 0.16\text{ L} = 160\text{ mL}$$

4.49 $$0.0171\text{ mol KOH} \times \frac{1.00\text{ L}}{0.350\text{ mol KOH}} = 0.0489\text{ L};\ 0.0489\text{ L} = 48.9\text{ mL}$$

4.50 NaCl, 58.4; 400 mg = 0.400 g; 100 mL = 0.100 L

$$0.400\text{ g NaCl} \times \frac{1\text{ mol NaCl}}{58.4\text{ g NaCl}} = 0.006\,85\text{ mol NaCl}$$

$$\text{molarity} = \frac{0.006\,85\text{ mol}}{0.100\text{ L}} = 0.0685\text{ M}$$

4.51 $C_6H_{12}O_6$, 180.2; 90 mg = 0.090 g; 100 mL = 0.100 L

$$0.090\text{ g } C_6H_{12}O_6 \times \frac{1\text{ mol } C_6H_{12}O_6}{180.2\text{ g } C_6H_{12}O_6} = 0.000\,50\text{ mol } C_6H_{12}O_6$$

$$\text{molarity} = \frac{0.000\,50\text{ mol}}{0.100\text{ L}} = 0.0050\text{ M} = 5.0 \times 10^{-3}\text{ M}$$

4.52 $$3.045\text{ g Cu} \times \frac{1\text{ mol Cu}}{63.546\text{ g Cu}} = 0.047\,92\text{ mol Cu};\ 50.0\text{ mL} = 0.0500\text{ L}$$

$$Cu(NO_3)_2\text{ molarity} = \frac{0.047\,92\text{ mol}}{0.0500\text{ L}} = 0.958\text{ M}$$

4.53 (a) $$1.0 \times 10^{-11}\text{ g/mL} \times \frac{1\text{ mol Au}}{197.0\text{ g Au}} \times \frac{1\text{ mL}}{1 \times 10^{-3}\text{ L}} = 5.1 \times 10^{-11}\text{ mol/L}$$

(b) $$1.0 \times 10^{-11}\text{ g/mL} \times \frac{1\text{ mL}}{1 \times 10^{-3}\text{ L}} \times 1.3 \times 10^{21}\text{ L} = 1.3 \times 10^{13}\text{ g Au}$$

4.54 (a) NaOH, 40.0; 500.0 mL = 0.5000 L

$$\frac{1.25\text{ mol NaOH}}{\text{L}} \times 0.500\text{ L} \times \frac{40.0\text{ g NaOH}}{1\text{ mol NaOH}} = 25.0\text{ g NaOH}$$

(b) $C_6H_{12}O_6$, 180.2

$$\frac{0.250\text{ mol } C_6H_{12}O_6}{\text{L}} \times 1.50\text{ L} \times \frac{180.2\text{ g } C_6H_{12}O_6}{1\text{ mol } C_6H_{12}O_6} = 67.6\text{ g } C_6H_{12}O_6$$

4.55 $CaCl_2$, 111.0; 500 mL = 0.500 L

(0.500 L)(0.33 mol/L) = 0.165 mol $CaCl_2$

$$0.165 \text{ mol } CaCl_2 \times \frac{111.0 \text{ g } CaCl_2}{1 \text{ mol } CaCl_2} = 18.3 \text{ g } CaCl_2$$

Place 18.3 g of $CaCl_2$ in a 500 mL volumetric flask and fill it to the mark with water.

4.56 CaF_2, 78.07; 250 mL = 0.250 L

(0.250 L)(0.100 mol/L) = 0.0250 mol F^- ions

$$0.0250 \text{ mol } F^- \text{ ions} \times \frac{1 \text{ mol } CaF_2}{2 \text{ mol } F^-} \times \frac{78.07 \text{ g } CaF_2}{1 \text{ mol } CaF_2} = 0.976 \text{ g } CaF_2$$

Place 0.976 g of CaF_2 in a 250 mL volumetric flask and fill it to the mark with water.

Dilutions (Section 4.2)

4.57 250.0 mL = 0.2500 L

mass of Zn in penny = (2.482 g)(0.975) = 2.42 g Zn

$$2.42 \text{ g Zn} \times \frac{1 \text{ mol Zn}}{65.38 \text{ g Zn}} = 0.0370 \text{ mol Zn}$$

mol $Zn(NO_3)_2$ = mol Zn = 0.0370 mol

$$Zn(NO_3)_2 \text{ molarity} = \frac{0.0370 \text{ mol}}{0.2500 \text{ L}} = 0.148 \text{ M}$$

4.58 $M_f \times V_f = M_i \times V_i$; $\quad M_f = \dfrac{M_i \times V_i}{V_f} = \dfrac{12.0 \text{ M} \times 35.7 \text{ mL}}{250.0 \text{ mL}} = 1.71 \text{ M HCl}$

4.59 $M_f \times V_f = M_i \times V_i$; $\quad V_f = \dfrac{M_i \times V_i}{M_f} = \dfrac{0.0913 \text{ M} \times 70.00 \text{ mL}}{0.0150 \text{ M}} = 426 \text{ mL}$

4.60 250 mL = 0.250 L

(0.250 L)(0.100 mol/L) = 0.0250 mol Cl^- ions

$$Cl^- \text{ molarity} = 3.00 \text{ M } CaCl_2 \times \frac{2 \text{ mol } Cl^-}{1 \text{ mol } CaCl_2} = 6.00 \text{ M } Cl^-$$

$$M_f \times V_f = M_i \times V_i; \quad V_i = \frac{M_f \times V_f}{M_i} = \frac{0.100 \text{ M} \times 250 \text{ mL}}{6.00 \text{ M}} = 4.17 \text{ mL}$$

Using a 10 mL graduated cylinder, measure out 4.17 mL of 3.00 M $CaCl_2$ solution. Pour the 4.17 mL into a 250 mL volumetric flask and fill it to the mark with water.

4.61 $M_f \times V_f = M_i \times V_i$; $\quad V_i = \dfrac{M_f \times V_f}{M_i} = \dfrac{0.150 \text{ M} \times 250 \text{ mL}}{3.00 \text{ M}} = 12.5 \text{ mL}$

Using a 25 mL graduated cylinder, measure out 12.5 mL of 3.00 M $CaCl_2$ solution. Pour the 12.5 mL into a 250 mL volumetric flask and fill it to the mark with water.

Electrolytes (Section 4.3)

4.62 (a) strong electrolyte, bright (b) nonelectrolyte, dark (c) weak electrolyte, dim

4.63 (a) weak electrolyte, dim (b) strong electrolyte, bright (c) nonelectrolyte, dark

4.64 $Ba(OH)_2$ is soluble in aqueous solution, dissociates into $Ba^{2+}(aq)$ and 2 $OH^-(aq)$, and conducts electricity. In aqueous solution, H_2SO_4 dissociates into $H^+(aq)$ and $HSO_4^-(aq)$. H_2SO_4 solutions conduct electricity. When equal molar solutions of $Ba(OH)_2$ and H_2SO_4 are mixed, the insoluble $BaSO_4$ is formed along with two H_2O. In water, $BaSO_4$ does not produce any appreciable amount of ions and the mixture does not conduct electricity.

4.65 H_2O is polar and a good H^+ acceptor. It allows the polar HCl to dissociate into ions in aqueous solution: $HCl + H_2O \rightarrow H_3O^+ + Cl^-$.
$CHCl_3$ is not very polar and not a H^+ acceptor and so does not allow the polar HCl to dissociate into ions.

4.66 (a) HBr, strong electrolyte (b) HF, weak electrolyte
(c) $NaClO_4$, strong electrolyte (d) $(NH_4)_2CO_3$, strong electrolyte
(e) NH_3, weak electrolyte (f) C_2H_5OH, nonelectrolyte

4.67 It is possible for a molecular compound to be a strong electrolyte. For example, HCl is a molecular compound when pure, but dissociates completely to give H^+ and Cl^- ions when it dissolves in water.

4.68 (a) K_2CO_3 contains 3 ions (2 K^+ and 1 CO_3^{2-}).
The molar concentration of ions = 3 x 0.750 M = 2.25 M.
(b) $AlCl_3$ contains 4 ions (1 Al^{3+} and 3 Cl^-).
The molar concentration of ions = 4 x 0.355 M = 1.42 M.

4.69 (a) CH_3OH is a nonelectrolyte. The ion concentration from CH_3OH is zero.
(b) $HClO_4$ is a strong acid.
$HClO_4(aq) \rightarrow H^+(aq) + ClO_4^-(aq)$
In solution, there are 2 moles of ions per mole of $HClO_4$.
The molar concentration of ions = 2 × 0.225 M = 0.450 M.

4.70 NaCl, 58.4; KCl, 74.6; $CaCl_2$, 111.0; 500 mL = 0.500 L

$$4.30 \text{ g NaCl} \times \frac{1 \text{ mol NaCl}}{58.4 \text{ g NaCl}} = 0.0736 \text{ mol NaCl}$$

$$0.150 \text{ g KCl} \times \frac{1 \text{ mol KCl}}{74.6 \text{ g KCl}} = 0.002\,01 \text{ mol KCl}$$

$$0.165 \text{ g } CaCl_2 \times \frac{1 \text{ mol } CaCl_2}{111.0 \text{ g } CaCl_2} = 0.001\,49 \text{ mol } CaCl_2$$

0.0736 mol + 0.002 01 mol + 2(0.001 49 mol) = 0.0786 mol Cl^-

$$Na^+ \text{ molarity} = \frac{0.0736 \text{ mol}}{0.500 \text{ L}} = 0.147 \text{ M}$$

$$Ca^{2+} \text{ molarity} = \frac{0.001\ 49 \text{ mol}}{0.500 \text{ L}} = 0.002\ 98 \text{ M}$$

$$K^+ \text{ molarity} = \frac{0.002\ 01 \text{ mol}}{0.500 \text{ L}} = 0.004\ 02 \text{ M}$$

$$Cl^- \text{ molarity} = \frac{0.0786 \text{ mol}}{0.500 \text{ L}} = 0.157 \text{ M}$$

4.71 Na_2SO_4, 142.04; Na_3PO_4, 163.94; Li_2SO_4, 109.95; 100.00 mL = 0.100 00 L

$$0.550 \text{ g } Na_2SO_4 \times \frac{1 \text{ mol } Na_2SO_4}{142.04 \text{ g } Na_2SO_4} = 0.003\ 872 \text{ mol } Na_2SO_4$$

$$1.188 \text{ g } Na_3PO_4 \times \frac{1 \text{ mol } Na_3PO_4}{163.94 \text{ g } Na_3PO_4} = 0.007\ 247 \text{ mol } Na_3PO_4$$

$$0.223 \text{ g } Li_2SO_4 \times \frac{1 \text{ mol } Li_2SO_4}{109.95 \text{ g } Li_2SO_4} = 0.002\ 028 \text{ mol } Li_2SO_4$$

$$Na^+ \text{ molarity} = \frac{(2 \times 0.003\ 872 \text{ mol}) + (3 \times 0.007\ 247 \text{ mol})}{0.100\ 00 \text{ L}} = 0.295 \text{ M}$$

$$Li^+ \text{ molarity} = \frac{2 \times 0.002\ 028 \text{ mol}}{0.100\ 00 \text{ L}} = 0.0406 \text{ M}$$

$$SO_4^{2-} \text{ molarity} = \frac{(1 \times 0.003\ 872 \text{ mol}) + (1 \times 0.002\ 028 \text{ mol})}{0.100\ 00 \text{ L}} = 0.0590 \text{ M}$$

$$PO_4^{3-} \text{ molarity} = \frac{1 \times 0.007\ 247 \text{ mol}}{0.100\ 00 \text{ L}} = 0.0725 \text{ M}$$

Net Ionic Equations and Aqueous Reactions (Sections 4.4–4.5)

4.72 (a) precipitation (b) redox (c) acid-base neutralization

4.73 (a) redox (b) precipitation (c) acid-base neutralization

4.74 (a) Ionic equation:
$Hg^{2+}(aq) + 2\ NO_3^-(aq) + 2\ Na^+(aq) + 2\ I^-(aq) \rightarrow 2\ Na^+(aq) + 2\ NO_3^-(aq) + HgI_2(s)$
Delete spectator ions from the ionic equation to get the net ionic equation.
Net ionic equation: $Hg^{2+}(aq) + 2\ I^-(aq) \rightarrow HgI_2(s)$

(b) $2\ HgO(s) \xrightarrow{\text{Heat}} 2\ Hg(l) + O_2(g)$
(c) Ionic equation:
$H_3PO_4(aq) + 3\ K^+(aq) + 3\ OH^-(aq) \rightarrow 3\ K^+(aq) + PO_4^{3-}(aq) + 3\ H_2O(l)$
Delete spectator ions from the ionic equation to get the net ionic equation.
Net ionic equation: $H_3PO_4(aq) + 3\ OH^-(aq) \rightarrow PO_4^{3-}(aq) + 3\ H_2O(l)$

4.75 (a) $S_8(s) + 8\ O_2(g) \rightarrow 8\ SO_2(g)$
(b) Ionic equation:
$Ni^{2+}(aq) + 2\ Cl^-(aq) + 2\ Na^+(aq) + S^{2-}(aq) \rightarrow NiS(s) + 2\ Na^+(aq) + 2\ Cl^-(aq)$
Delete spectator ions from the ionic equation to get the net ionic equation.
Net ionic equation: $Ni^{2+}(aq) + S^{2-}(aq) \rightarrow NiS(s)$
(c) Ionic equation:
$2\ CH_3CO_2H(aq) + Ba^{2+}(aq) + 2\ OH^-(aq) \rightarrow 2\ CH_3CO_2^-(aq) + Ba^{2+}(aq) + 2\ H_2O(l)$
Delete spectator ions from the ionic equation to get the net ionic equation.
Net ionic equation: $CH_3CO_2H(aq) + OH^-(aq) \rightarrow CH_3CO_2^-(aq) + H_2O(l)$

Precipitation Reactions and Solubility Guidelines (Section 4.6)

4.76 (a) $PbSO_4$, insoluble (b) $Ba(NO_3)_2$, soluble
(c) $SnCO_3$, insoluble (d) $(NH_4)_3PO_4$, soluble

4.77 (a) ZnS, insoluble (b) $Au_2(CO_3)_3$, insoluble
(c) $PbCl_2$, insoluble (soluble in hot water) (d) Na_2S, soluble

4.78 (a) No precipitate will form. (b) $Fe^{2+}(aq) + 2\ OH^-(aq) \rightarrow Fe(OH)_2(s)$
(c) No precipitate will form. (d) No precipitate will form.

4.79 (a) $Mn^{2+}(aq) + S^{2-}(aq) \rightarrow MnS(s)$
(b) No precipitate will form.
(c) $3\ Hg^{2+}(aq) + 2\ PO_4^{3-}(aq) \rightarrow Hg_3(PO_4)_2(s)$
(d) $Ba^{2+}(aq) + 2\ OH^-(aq) \rightarrow Ba(OH)_2(s)$

4.80 (a) 0.10 M $LiNO_3$ will not form a precipitate.
(b) $BaSO_4(s)$ will precipitate. (c) AgCl(s) will precipitate.

4.81 (a) $Mg(OH)_2(s)$ will precipitate. (b) 0.10 M NH_4Br will not form a precipitate.
(c) $Fe(OH)_2(s)$ will precipitate.

4.82 (a) $Pb(NO_3)_2(aq) + Na_2SO_4(aq) \rightarrow PbSO_4(s) + 2\ NaNO_3(aq)$
(b) $3\ MgCl_2(aq) + 2\ K_3PO_4(aq) \rightarrow Mg_3(PO_4)_2(s) + 6\ KCl(aq)$
(c) $ZnSO_4(aq) + Na_2CrO_4(aq) \rightarrow ZnCrO_4(s) + Na_2SO_4(aq)$

4.83 (a) $AlCl_3(aq) + 3\ NaOH(aq) \rightarrow Al(OH)_3(s) + 3\ NaCl(aq)$
(b) $Fe(NO_3)_2(aq) + Na_2S(aq) \rightarrow FeS(s) + 2\ NaNO_3(aq)$
(c) $CoSO_4(aq) + K_2CO_3(aq) \rightarrow CoCO_3(s) + K_2SO_4(aq)$

4.84 $Ag^+(aq) + NO_3^-(aq) + H^+(aq) + Cl^-(aq) \rightarrow AgCl(s) + H^+(aq) + NO_3^-(aq)$

$$\text{mol } Cl^- = 30.0\text{ mL} \times \frac{1 \times 10^{-3}\text{ L}}{1\text{ mL}} \times 0.150\text{ mol/L} = 0.00450\text{ mol}$$

$$\text{mol } Ag^+ = 25.0\text{ mL} \times \frac{1 \times 10^{-3}\text{ L}}{1\text{ mL}} \times 0.200\text{ mol/L} = 0.00500\text{ mol}$$

Because the mole ratio between Ag^+ and Cl^- is 1 to 1, Cl^- is the limiting reactant because it is the smaller mol quantity. 0.00450 mol of AgCl is produced.

AgCl, 143.3; $\quad$ mass AgCl = 0.00450 mol AgCl x $\dfrac{143.3 \text{ g AgCl}}{1 \text{ mol AgCl}}$ = 0.645 g AgCl

4.85 $Ba^{2+}(aq) + 2\ Cl^-(aq) + 2\ Na^+(aq) + CO_3^{2-}(aq) \rightarrow BaCO_3(s) + 2\ Na^+(aq) + 2\ Cl^-(aq)$

mol CO_3^{2-} = 40.0 mL x $\dfrac{1 \times 10^{-3} \text{ L}}{1 \text{ mL}}$ x 0.150 mol/L = 0.00600 mol

mol Ba^{2+} = 55.0 mL x $\dfrac{1 \times 10^{-3} \text{ L}}{1 \text{ mL}}$ x 0.100 mol/L = 0.00550 mol

Because the mole ratio between Ba^{2+} and CO_3^{2-} is 1 to 1, Ba^{2+} is the limiting reactant because it is the smaller mol quantity. 0.00550 mol of $BaCO_3$ is produced.

$BaCO_3$, 197.3

mass $BaCO_3$ = 0.00550 mol $BaCO_3$ x $\dfrac{197.3 \text{ g } BaCO_3}{1 \text{ mol } BaCO_3}$ = 1.09 g $BaCO_3$

4.86 Add HCl(aq); it will selectively precipitate AgCl(s).

4.87 Add $Na_2SO_4(aq)$; it will selectively precipitate $BaSO_4(s)$.

4.88 Ag^+ is eliminated because it would have precipitated as AgCl(s); Ba^{2+} is eliminated because it would have precipitated as $BaSO_4(s)$. The solution might contain Cs^+ and/or NH_4^+. Neither of these will precipitate with OH^-, SO_4^{2-}, or Cl^-.

4.89 Cl^- is eliminated because it would have precipitated as AgCl(s). OH^- is eliminated because it would have precipitated as either AgOH(s) or $Cu(OH)_2(s)$. SO_4^{2-} is eliminated because it would have precipitated as $BaSO_4(s)$. The solution might contain NO_3^- because all nitrates are soluble.

4.90

(a) Add HCl to precipitate Hg_2Cl_2.	$Hg_2^{2+}(aq) + 2Cl^-(aq) \rightarrow Hg_2Cl_2(s)$
(b) Add H_2SO_4 to precipitate $PbSO_4$.	$Pb^{2+}(aq) + SO_4^{2-}(aq) \rightarrow PbSO_4(s)$
(c) Add Na_2CO_3 to precipitate $CaCO_3$.	$Ca^{2+}(aq) + CO_3^{2-}(aq) \rightarrow CaCO_3(s)$
(d) Add Na_2SO_4 to precipitate $BaSO_4$.	$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$

4.91

(a) Add $AgNO_3$ to precipitate AgCl.	$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$
(b) Add $NiCl_2$ to precipitate NiS.	$Ni^{2+}(aq) + S^{2-}(aq) \rightarrow NiS(s)$
(c) Add $CaCl_2$ to precipitate $CaCO_3$.	$Ca^{2+}(aq) + CO_3^{2-}(aq) \rightarrow CaCO_3(s)$
(d) Add $MgCl_2$ to precipitate $Mg(OH)_2$.	$Mg^{2+}(aq) + 2\ OH^-(aq) \rightarrow Mg(OH)_2(s)$

4.92 100.0 mL = 0.1000 L and 50.0 mL = 0.0500 L

mol Na_2SO_4 = (0.1000 L)(0.100 mol/L) = 0.0100 mol Na_2SO_4

mol SO_4^{2-} = mol Na_2SO_4 = 0.0100 mol SO_4^{2-}

mol Na^+ = 0.0100 mol Na_2SO_4 x $\dfrac{2 \text{ mol } Na^+}{1 \text{ mol } Na_2SO_4}$ = 0.0200 mol Na^+

mol $ZnCl_2$ = (0.0500 L)(0.300 mol/L) = 0.0150 mol $ZnCl_2$
mol Zn^{2+} = mol $ZnCl_2$ = 0.0150 mol Zn^{2+}

$$\text{mol } Cl^- = 0.0150 \text{ mol } ZnCl_2 \times \frac{2 \text{ mol } Cl^-}{1 \text{ mol } ZnCl_2} = 0.0300 \text{ mol } Cl^-$$

mol $Ba(CN)_2$ = (0.1000 L)(0.200 mol/L) = 0.0200 mol $Ba(CN)_2$
mol Ba^{2+} = mol $Ba(CN)_2$ = 0.0200 mol Ba^{2+}

$$\text{mol } CN^- = 0.0200 \text{ mol } Ba(CN)_2 \times \frac{2 \text{ mol } CN^-}{1 \text{ mol } Ba(CN)_2} = 0.0400 \text{ mol } CN^-$$

The following two reactions will take place to form precipitates.
$Zn^{2+}(aq) + 2\ CN^-(aq) \rightarrow Zn(CN)_2(s)$
$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$

$$\text{For } Zn^{2+}, \text{ mol } CN^- \text{ needed} = 0.0150 \text{ mol } Zn^{2+} \times \frac{2 \text{ mol } CN^-}{1 \text{ mol } Zn^{2+}} = 0.0300 \text{ mol } CN^- \text{ needed}$$

CN^- is in excess, so Zn^{2+} is the limiting reactant and is totally consumed.
mol CN^- remaining after reaction= 0.0400 mol – 0.0300 mol = 0.0100 mol CN^-
For Ba^{2+}, mol SO_4^{2-} needed = mol Ba^{2+} = 0.0200 mol SO_4^{2-} needed
Ba^{2+} is in excess, so SO_4^{2-} is the limiting reactant and is totally consumed.
mol Ba^{2+} remaining after reaction = 0.0200 mol – 0.0100 mol = 0.0100 mol Ba^{2+}
total volume = 0.1000 L + 0.0500 L + 0.1000 L = 0.2500 L
$[Zn^{2+}] = [SO_4^{2-}] = 0$

$$[Na^+] = \frac{0.0200 \text{ mol}}{0.2500 \text{ L}} = 0.0800 \text{ M}$$

$$[Cl^-] = \frac{0.0300 \text{ mol}}{0.2500 \text{ L}} = 0.120 \text{ M}$$

$$[CN^-] = \frac{0.0100 \text{ mol}}{0.2500 \text{ L}} = 0.0400 \text{ M}$$

$$[Ba^{2+}] = \frac{0.0100 \text{ mol}}{0.2500 \text{ L}} = 0.0400 \text{ M}$$

4.93 KNO_3, 101.10; $BaCl_2$, 208.24; NaCl, 58.44; $BaSO_4$, 233.40; AgCl, 143.32
(a) The two precipitates are $BaSO_4(s)$ and AgCl(s).
(b) H_2SO_4 only reacts with $BaCl_2$.
$H_2SO_4(aq) + BaCl_2(aq) \rightarrow BaSO_4(s) + 2\ HCl(aq)$
Calculate the number of moles of $BaCl_2$ in 100.0 g of the mixture.

$$\text{mol } BaCl_2 = 67.3 \text{ g } BaSO_4 \times \frac{1 \text{ mol } BaSO_4}{233.40 \text{ g } BaSO_4} \times \frac{1 \text{ mol } BaCl_2}{1 \text{ mol } BaSO_4} = 0.288 \text{ mol } BaCl_2$$

Calculate mass and moles of $BaCl_2$ in 250.0 g sample.

$$\text{mass } BaCl_2 = 0.288 \text{ mol } BaCl_2 \times \frac{208.24 \text{ g } BaCl_2}{1 \text{ mol } BaCl_2} \times \frac{250.0 \text{ g}}{100.0 \text{ g}} = 150. \text{ g } BaCl_2$$

$$\text{mol } BaCl_2 = 150. \text{ g } BaCl_2 \times \frac{1 \text{ mol } BaCl_2}{208.24 \text{ g } BaCl_2} = 0.720 \text{ mol } BaCl_2$$

$AgNO_3$ reacts with both NaCl and $BaCl_2$ in the remaining 150.0 g of the mixture.

$3\ AgNO_3(aq) + NaCl(aq) + BaCl_2(aq) \rightarrow 3\ AgCl(s) + NaNO_3(aq) + Ba(NO_3)_2(aq)$
Calculate the moles of AgCl that would have been produced from the 250.0 g mixture.

$$\text{mol AgCl} = 197.6\text{ g AgCl} \times \frac{1\text{ mol AgCl}}{143.32\text{ g AgCl}} \times \frac{250.0\text{ g}}{150.0\text{ g}} = 2.30\text{ mol AgCl}$$

mol AgCl = 2 x (mol $BaCl_2$) + mol NaCl
Calculate the moles and mass of NaCl in the 250.0 g mixture.
2.30 mol AgCl = 2 x 0.720 mol $BaCl_2$ + mol NaCl
mol NaCl = 2.30 mol – 2(0.720 mol) = 0.86 mol NaCl

$$\text{mass NaCl} = 0.86\text{ mol NaCl} \times \frac{58.44\text{ g NaCl}}{1\text{ mol NaCl}} = 50.\text{ g NaCl}$$

Calculate the mass of KNO_3 in the 250.0 g mixture.
total mass = mass $BaCl_2$ + mass NaCl + mass KNO_3
250.0 g = 150. g $BaCl_2$ + 50. g NaCl + mass KNO_3
mass KNO_3 = 250.0 g – 150. g $BaCl_2$ – 50. g NaCl = 50. g KNO_3

Acids, Bases, and Neutralization Reactions (Section 4.7)

4.94 Add the solution to an active metal, such as magnesium. Bubbles of H_2 gas indicate the presence of an acid.

4.95 We use a double arrow to show the dissociation of a weak acid or weak base in aqueous solution to indicate the equilibrium between reactants and products.

4.96 (a) $2\ H^+(aq) + 2\ ClO_4^-(aq) + Ca^{2+}(aq) + 2\ OH^-(aq) \rightarrow Ca^{2+}(aq) + 2\ ClO_4^-(aq) + 2\ H_2O(l)$
(b) $CH_3CO_2H(aq) + Na^+(aq) + OH^-(aq) \rightarrow CH_3CO_2^-(aq) + Na^+(aq) + H_2O(l)$

4.97 (a) $2\ H^+(aq) + 2\ Br^-(aq) + Ca^{2+}(aq) + 2\ OH^-(aq) \rightarrow Ca^{2+}(aq) + 2\ Br^-(aq) + 2\ H_2O(l)$
(b) $Ba^{2+}(aq) + 2\ OH^-(aq) + 2\ H^+(aq) + 2\ NO_3^-(aq) \rightarrow Ba^{2+}(aq) + 2\ NO_3^-(aq) + 2\ H_2O(l)$

4.98 (a) $LiOH(aq) + HI(aq) \rightarrow LiI(aq) + H_2O(l)$
Ionic equation: $Li^+(aq) + OH^-(aq) + H^+(aq) + I^-(aq) \rightarrow Li^+(aq) + I^-(aq) + H_2O(l)$
Delete spectator ions from the ionic equation to get the net ionic equation.
Net ionic equation: $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$
(b) $2\ HBr(aq) + Ca(OH)_2(aq) \rightarrow CaBr_2(aq) + 2\ H_2O(l)$
Ionic equation:
$2\ H^+(aq) + 2\ Br^-(aq) + Ca^{2+}(aq) + 2\ OH^-(aq) \rightarrow Ca^{2+}(aq) + 2\ Br^-(aq) + 2\ H_2O(l)$
Delete spectator ions from the ionic equation to get the net ionic equation.
Net ionic equation: $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

4.99 (a) $2\ Fe(OH)_3(s) + 3\ H_2SO_4(aq) \rightarrow Fe_2(SO_4)_3(aq) + 6\ H_2O(l)$
Ionic equation and net ionic equation are the same.
$2\ Fe(OH)_3(s) + 3\ H^+(aq) + 3\ HSO_4^-(aq) \rightarrow 2\ Fe^{3+}(aq) + 3\ SO_4^{2-}(aq) + 6\ H_2O(l)$
(b) $HClO_3(aq) + NaOH(aq) \rightarrow NaClO_3(aq) + H_2O(l)$
Ionic equation $H^+(aq) + ClO_3^-(aq) + Na^+(aq) + OH^-(aq) \rightarrow Na^+(aq) + ClO_3^-(aq) + H_2O(l)$
Delete spectator ions from the ionic equation to get the net ionic equation.
Net ionic equation: $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

Solution Stoichiometry and Titration (Sections 4.8–4.9)

4.100 $2\ HBr(aq) + K_2CO_3(aq) \rightarrow 2\ KBr(aq) + CO_2(g) + H_2O(l)$

K_2CO_3, 138.2; 450 mL = 0.450 L

$$\frac{0.500\ \text{mol HBr}}{\text{L}} \times 0.450\ \text{L} = 0.225\ \text{mol HBr}$$

$$0.225\ \text{mol HBr} \times \frac{1\ \text{mol } K_2CO_3}{2\ \text{mol HBr}} \times \frac{138.2\ \text{g } K_2CO_3}{1\ \text{mol } K_2CO_3} = 15.5\ \text{g } K_2CO_3$$

4.101 $2\ C_4H_{10}S + NaOCl \rightarrow C_8H_{18}S_2 + NaCl + H_2O$

$C_4H_{10}S$, 90.19; 5.00 mL = 0.005 00 L

$$\frac{0.0985\ \text{mol NaOCl}}{\text{L}} \times 0.005\ 00\ \text{L} = 4.925 \times 10^{-4}\ \text{mol NaOCl}$$

$$4.925 \times 10^{-4}\ \text{mol NaOCl} \times \frac{2\ \text{mol } C_4H_{10}S}{1\ \text{mol NaOCl}} \times \frac{90.19\ \text{g } C_4H_{10}S}{1\ \text{mol } C_4H_{10}S} = 0.0888\ \text{g } C_4H_{10}S$$

4.102 $H_2C_2O_4$, 90.0

$$3.225\ \text{g } H_2C_2O_4 \times \frac{1\ \text{mol } H_2C_2O_4}{90.0\ \text{g } H_2C_2O_4} \times \frac{2\ \text{mol } KMnO_4}{5\ \text{mol } H_2C_2O_4} = 0.0143\ \text{mol } KMnO_4$$

$$0.0143\ \text{mol} \times \frac{1\ \text{L}}{0.250\ \text{mol}} = 0.0572\ \text{L} = 57.2\ \text{mL}$$

4.103 $H_2C_2O_4$, 90.0; 400.0 mL = 0.4000 L; 25.0 mL = 0.0250 L

$$12.0\ \text{g } H_2C_2O_4 \times \frac{1\ \text{mol } H_2C_2O_4}{90.0\ \text{g } H_2C_2O_4} = 0.133\ \text{mol } H_2C_2O_4$$

$$\text{molarity} = \frac{0.133\ \text{mol}}{0.4000\ \text{L}} = 0.333\ \text{M } H_2C_2O_4$$

$H_2C_2O_4(aq) + 2\ KOH(aq) \rightarrow K_2C_2O_4(aq) + 2\ H_2O(l)$

$$\frac{0.333\ \text{mol } C_2H_2O_4}{\text{L}} \times 0.0250\ \text{L} = 0.008\ 32\ \text{mol } H_2C_2O_4$$

$$0.008\ 32\ \text{mol } H_2C_2O_4 \times \frac{2\ \text{mol KOH}}{1\ \text{mol } H_2C_2O_4} = 0.0166\ \text{mol KOH}$$

$$0.0166\ \text{mol} \times \frac{1\ \text{L}}{0.100\ \text{mol}} = 0.166\ \text{L};\ 0.166\ \text{L} = 166\ \text{mL}$$

4.104 (a) $LiOH(aq) + HBr(aq) \rightarrow LiBr(aq) + H_2O(l)$

25.0 mL = 0.0250 L and 75.0 mL = 0.0750 L

(0.240 mol/L LiOH)(0.0250 L) = 0.006 00 mol LiOH

(0.200 mol/L HBr)(0.0750 L) = 0.0150 mol HBr

HBr and LiOH react in a one to one mole ratio.

mol HBr left over = 0.0150 mol HBr – 0.006 00 mol LiOH = 0.0090 mol HBr

$KOH(aq) + HBr(aq) \rightarrow KBr(aq) + H_2O(l)$
HBr and KOH react in a one to one mole ratio.
0.0090 mol KOH will neutralize the solution.

$$\text{volume} = \frac{\text{mol}}{\text{M}} = \frac{0.0090 \text{ mol KOH}}{1.00 \text{ mol/L}} = 0.0090 \text{ L} = 9.0 \text{ mL KOH}$$

(b) $HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$
45.0 mL = 0.0450 L and 10.0 mL = 0.0100 L
(0.300 mol/L HCl)(0.0450 L) = 0.0135 mol HCl
(0.250 mol/L NaOH)(0.0100 L) = 0.002 50 mol NaOH
HCl and NaOH react in a one to one mole ratio.
mol HCl left over = 0.0135 mol HCl – 0.002 50 mol NaOH = 0.0110 mol HCl
$KOH(aq) + HCl(aq) \rightarrow KCl(aq) + H_2O(l)$
HCl and KOH react in a one to one mole ratio.
0.0110 mol KOH will neutralize the solution.

$$\text{volume} = \frac{\text{mol}}{\text{M}} = \frac{0.0110 \text{ mol KOH}}{1.00 \text{ mol/L}} = 0.0110 \text{ L} = 11.0 \text{ mL KOH}$$

4.105 (a) $HNO_3(aq) + KOH(aq) \rightarrow KNO_3(aq) + H_2O(l)$
100.0 mL = 0.1000 L and 400.0 mL = 0.4000 L
(0.160 mol/L HNO_3)(0.1000 L) = 0.0160 mol HNO_3
(0.100 mol/L KOH)(0.4000 L) = 0.0400 mol KOH
HNO_3 and KOH react in a one to one mole ratio.
mol KOH left over = 0.0400 mol KOH – 0.0160 mol HNO_3 = 0.0240 mol KOH
$HCl(aq) + KOH(aq) \rightarrow KCl(aq) + H_2O(l)$
HCl and KOH react in a one to one mole ratio.
0.0240 mol HCl will neutralize the solution.

$$\text{volume} = \frac{\text{mol}}{\text{M}} = \frac{0.0240 \text{ mol HCl}}{2.00 \text{ mol/L}} = 0.0120 \text{ L} = 12.0 \text{ mL HCl}$$

(b) $NaOH(aq) + HBr(aq) \rightarrow NaBr(aq) + H_2O(l)$
350.0 mL = 0.3500 L and 150.0 mL = 0.1500 L
(0.120 mol/L NaOH)(0.3500 L) = 0.0420 mol NaOH
(0.190 mol/L HBr)(0.1500 L) = 0.0285 mol HBr
NaOH and HBr react in a one to one mole ratio.
mol NaOH left over = 0.0420 mol NaOH – 0.0285 mol HBr = 0.0135 mol NaOH
$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$
HCl and NaOH react in a one to one mole ratio.
0.0135 mol HCl will neutralize the solution.

$$\text{volume} = \frac{\text{mol}}{\text{M}} = \frac{0.0135 \text{ mol HCl}}{2.00 \text{ mol/L}} = 0.006\,75 \text{ L} = 6.75 \text{ mL HCl}$$

4.106 (a) $HBr(aq) + KOH(aq) \rightarrow KBr(aq) + H_2O(l)$
50.0 mL = 0.0500 L and 30.0 mL = 0.0300 L
(0.100 mol/L HBr)(0.0500 L) = 0.005 00 mol HBr

(0.200 mol/L KOH)(0.0300 L) = 0.006 00 mol KOH
HBr and KOH react in a one to one mole ratio. The resulting solution is basic because there is an excess of KOH.

(b) $2\ HCl(aq) + Ba(OH)_2(aq) \rightarrow BaCl_2(aq) + 2\ H_2O(l)$)
100.0 mL = 0.1000 L and 75 mL = 0.0750 L
(0.0750 mol/L HCl)(0.1000 L) = 0.007 50 mol HCl
(0.100 mol/L $Ba(OH)_2$)(0.0750 L) = 0.007 50 mol $Ba(OH)_2$

$$0.007\ 50\ \text{mol HCl} \times \frac{1\ \text{mol Ba(OH)}_2}{2\ \text{mol HCl}} = 0.003\ 75\ \text{mol Ba(OH)}_2\ \text{needed}$$

The resulting solution is basic because there is an excess of $Ba(OH)_2$.

4.107 (a) $HClO_4(aq) + NaOH(aq) \rightarrow NaClO_4(aq) + H_2O(l)$
65.0 mL = 0.0650 L and 40.0 mL = 0.0400 L
(0.0500 mol/L $HClO_4$)(0.0650 L) = 0.003 25 mol $HClO_4$
(0.0750 mol/L NaOH)(0.0400 L) = 0.003 00 mol NaOH
$HClO_4$ and NaOH react in a one to one mole ratio. The resulting solution is acidic because there is an excess of $HClO_4$.

(b) $2\ HNO_3(aq) + Ca(OH)_2(aq) \rightarrow Ca(NO_3)_2(aq) + 2\ H_2O(l)$
125.0 mL = 0.1250 L and 90.0 mL = 0.0900 L
(0.100 mol/L HNO_3)(0.1250 L) = 0.0125 mol HNO_3
(0.0750 mol/L $Ca(OH)_2$)(0.0900 L) = 0.006 75 mol $Ca(OH)_2$

$$0.0125\ \text{mol HNO}_3 \times \frac{1\ \text{mol Ca(OH)}_2}{2\ \text{mol HNO}_3} = 0.006\ 25\ \text{mol Ca(OH)}_2\ \text{needed}$$

The resulting solution is basic because there is an excess of $Ca(OH)_2$.

Oxidation Numbers (Section 4.10)

4.108

(a) NO_2	O –2, N +4		(b) SO_3	O –2, S +6
(c) $COCl_2$	O –2, Cl –1, C +4		(d) CH_2Cl_2	Cl –1, H +1, C 0
(e) $KClO_3$	O –2, K +1, Cl +5		(f) HNO_3	O –2, H +1, N +5

4.109

(a) $VOCl_3$	O –2,	Cl –1,	V +5
(b) $CuSO_4$	O –2,	S +6,	Cu +2
(c) CH_2O	O –2,	H +1,	C 0
(d) Mn_2O_7	O –2,	Mn +7	
(e) OsO_4	O –2,	Os +8	
(f) H_2PtCl_6	Cl –1,	H +1,	Pt +4

4.110

(a) ClO_3^-	O –2, Cl +5	(b) SO_3^{2-}	O –2, S +4
(c) $C_2O_4^{2-}$	O –2, C +3	(d) NO_2^-	O –2, N +3
(e) BrO^-	O –2, Br +1	(f) AsO_4^{3-}	O –2, As +5

4.111 (a) $Cr(OH)_4^-$ O –2, H +1, Cr +3
(b) $S_2O_3^{2-}$ O –2, S +2
(c) NO_3^- O –2, N +5
(d) MnO_4^{2-} O –2, Mn +6
(e) HPO_4^{2-} O –2, H +1, P +5
(f) $V_2O_7^{4-}$ O –2, V +5

4.112 (a) +1, N_2O, nitrous oxide; +2, NO, nitric oxide; +4, N_2O_4, dinitrogen tetroxide; +5, N_2O_5, dinitrogen pentoxide
(b) N_2O_5 cannot react with O_2 because N has its maximum oxidation number, +5, and cannot be further oxidized.

4.113 (a) tetraphosphorus hexoxide, P_4O_6, P oxidation number = +12/4 = +3
tetraphosphorus decoxide, P_4O_{10}, P oxidation number = +20/4 = +5
(b) P_4O_6, because it has the lower P oxidation number.

Redox Reactions (Section 4.11)

4.114 The best reducing agents are at the bottom left of the periodic table. The best oxidizing agents are at the top right of the periodic table (excluding the noble gases).

4.115 The most easily reduced elements in the periodic table are in the top-right corner, excluding group 8A.
The most easily oxidized elements in the periodic table are in the bottom-left corner.

4.116 (a) An oxidizing agent gains electrons.
(b) A reducing agent loses electrons.
(c) A substance undergoing oxidation loses electrons.
(d) A substance undergoing reduction gains electrons.

4.117 (a) In a redox reaction, the oxidation number decreases for an oxidizing agent.
(b) In a redox reaction, the oxidation number increases for a reducing agent.
(c) In a redox reaction, the oxidation number increases for a substance undergoing oxidation.
(d) In a redox reaction, the oxidation number decreases for a substance undergoing reduction.

4.118 (a) $Ca(s) + Sn^{2+}(aq) \rightarrow Ca^{2+}(aq) + Sn(s)$
Ca(s) is oxidized (oxidation number increases from 0 to +2).
$Sn^{2+}(aq)$ is reduced (oxidation number decreases from +2 to 0).
(b) $ICl(s) + H_2O(l) \rightarrow HCl(aq) + HOI(aq)$
No oxidation numbers change. The reaction is not a redox reaction.

4.119 (a) $Si(s) + 2\ Cl_2(g) \rightarrow SiCl_4(l)$
Si(s) is oxidized (oxidation number increases from 0 to +4).
$Cl_2(g)$ is reduced (oxidation number decreases from 0 to –1).
(b) $Cl_2(g) + 2\ NaBr(aq) \rightarrow Br_2(aq) + 2\ NaCl(aq)$
$Br^-(aq)$ is oxidized (oxidation number increases from –1 to 0).
$Cl_2(g)$ is reduced (oxidation number decreases from 0 to –1).

Activity Series (Section 4.12)

4.120 (a) Zn is below Na^+; therefore no reaction.
(b) Pt is below H^+; therefore no reaction.
(c) Au is below Ag^+; therefore no reaction.
(d) Ag is above Au^{3+}; the reaction is $Au^{3+}(aq) + 3\ Ag(s) \rightarrow 3\ Ag^+(aq) + Au(s)$.

4.121 Sr is more metallic than Sb because it is in the same period and to the left of Sb on the periodic table. Sr is the better reducing agent.
$2\ Sb^{3+}(aq) + 3\ Sr(s) \rightarrow 2\ Sb(s) + 3\ Sr^{2+}(aq)$ will occur, the reverse will not.

4.122 (a) "Any element higher in the activity series will react with the ion of any element lower in the activity series."
$A + B^+ \rightarrow A^+ + B$; therefore A is higher than B.
$C^+ + D \rightarrow$ no reaction; therefore C is higher than D.
$B + D^+ \rightarrow B^+ + D$; therefore B is higher than D.
$B + C^+ \rightarrow B^+ + C$; therefore B is higher than C.
The net result is A > B > C > D.
(b) (1) C is below A^+; therefore no reaction.
(2) D is below A^+; therefore no reaction.

4.123 (a) "Any element higher in the activity series will react with the ion of any element lower in the activity series."
$2\ A + B^{2+} \rightarrow 2\ A^+ + B$; therefore A is higher than B.
$B + D^{2+} \rightarrow B^{2+} + D$; therefore B is higher than D.
$A^+ + C \rightarrow$ no reaction; therefore A is higher than C.
$2\ C + B^{2+} \rightarrow 2\ C^+ + B$; therefore C is higher than B.
The net result is A > C > B > D.
(b) (1) D is below A^+; therefore no reaction.
(2) C is above D^{2+}; therefore the reaction will occur.

Redox Titrations (Section 4.13)

4.124 $I_2(aq) + 2\ S_2O_3^{2-}(aq) \rightarrow S_4O_6^{2-}(aq) + 2\ I^-(aq)$; 35.20 mL = 0.032 50 L

$$0.035\ 20\ L \times \frac{0.150\ mol\ S_2O_3^{2-}}{L} \times \frac{1\ mol\ I_2}{2\ mol\ S_2O_3^{2-}} \times \frac{253.8\ g\ I_2}{1\ mol\ I_2} = 0.670\ g\ I_2$$

4.125 $$2.486\ g\ I_2 \times \frac{1\ mol\ I_2}{253.8\ g\ I_2} \times \frac{2\ mol\ S_2O_3^{2-}}{1\ mol\ I_2} = 1.959 \times 10^{-2}\ mol\ S_2O_3^{2-}$$

$$1.959 \times 10^{-2}\ mol \times \frac{1\ L}{0.250\ mol} \times \frac{1\ mL}{1 \times 10^{-3}\ L} = 78.4\ mL$$

4.126 46.99 mL = 0.046 99 L; 50.00 mL = 0.050 00 L
$(0.2004\ mol/L\ Cr_2O_7^{2-})(0.046\ 99\ L) = 0.009\ 417\ mol\ Cr_2O_7^{2-}$

$$0.009\,417 \text{ mol } Cr_2O_7^{2-} \times \frac{6 \text{ mol } Fe^{2+}}{1 \text{ mol } Cr_2O_7^{2-}} = 0.056\,50 \text{ mol } Fe^{2+}$$

$$[Fe^{2+}] = \frac{0.056\,50 \text{ mol}}{0.050\,00 \text{ L}} = 1.130 \text{ M}$$

4.127 $FeSO_4$, 151.9; 18.72 mL = 0.018 72 L

$(0.1500 \text{ mol/L } Cr_2O_7^{2-})(0.018\,72 \text{ L}) = 0.002\,808 \text{ mol } Cr_2O_7^{2-}$

$$0.002\,808 \text{ mol } Cr_2O_7^{2-} \times \frac{6 \text{ mol } Fe^{2+}}{1 \text{ mol } Cr_2O_7^{2-}} \times \frac{1 \text{ mol } FeSO_4}{1 \text{ mol } Fe^{2+}} \times \frac{151.9 \text{ g } FeSO_4}{1 \text{ mol } FeSO_4} = 2.559 \text{ g } FeSO_4$$

4.128 $3\,H_3AsO_3(aq) + BrO_3^-(aq) \rightarrow Br^-(aq) + 3\,H_3AsO_4(aq)$

22.35 mL = 0.022 35 L and 50.00 mL = 0.050 00 L

$$0.022\,35 \text{ L} \times \frac{0.100 \text{ mol } BrO_3^-}{\text{L}} \times \frac{3 \text{ mol } H_3AsO_3}{1 \text{ mol } BrO_3^-} = 6.70 \times 10^{-3} \text{ mol } H_3AsO_3$$

$$\text{molarity} = \frac{6.70 \times 10^{-3} \text{ mol}}{0.050\,00 \text{ L}} = 0.134 \text{ M As(III)}$$

4.129 As_2O_3, 197.8; 28.55 mL = 0.028 55 L

$$1.550 \text{ g } As_2O_3 \times \frac{1 \text{ mol } As_2O_3}{197.84 \text{ g } As_2O_3} \times \frac{2 \text{ mol } H_3AsO_3}{1 \text{ mol } As_2O_3} \times \frac{1 \text{ mol } BrO_3^-}{3 \text{ mol } H_3AsO_3}$$

$$= 5.223 \times 10^{-3} \text{ mol } BrO_3^-; \quad KBrO_3 \text{ molarity} = \frac{5.223 \times 10^{-3} \text{ mol}}{0.028\,55 \text{ L}} = 0.1829 \text{ M}$$

4.130 $2\,Fe^{3+}(aq) + Sn^{2+}(aq) \rightarrow 2\,Fe^{2+}(aq) + Sn^{4+}(aq)$; 13.28 mL = 0.013 28 L

$$0.013\,28 \text{ L} \times \frac{0.1015 \text{ mol } Sn^{2+}}{\text{L}} \times \frac{2 \text{ mol } Fe^{3+}}{1 \text{ mol } Sn^{2+}} \times \frac{55.845 \text{ g } Fe^{3+}}{1 \text{ mol } Fe^{3+}} = 0.1506 \text{ g } Fe^{3+}$$

$$\text{mass \% Fe} = \frac{0.1506 \text{ g}}{0.1875 \text{ g}} \times 100\% = 80.32\%$$

4.131 Fe_2O_3, 159.69; 23.84 mL = 0.023 84 L

$$1.4855 \text{ g } Fe_2O_3 \times \frac{1 \text{ mol } Fe_2O_3}{159.69 \text{ g } Fe_2O_3} \times \frac{2 \text{ mol } Fe^{3+}}{1 \text{ mol } Fe_2O_3} \times \frac{1 \text{ mol } Sn^{2+}}{2 \text{ mol } Fe^{3+}} = 0.009\,302 \text{ mol } Sn^{2+}$$

$$Sn^{2+} \text{ molarity} = \frac{0.009\,302 \text{ mol}}{0.023\,84 \text{ L}} = 0.3902 \text{ M}$$

4.132 $C_2H_5OH(aq) + 2\,Cr_2O_7^{2-}(aq) + 16\,H^+(aq) \rightarrow 2\,CO_2(g) + 4\,Cr^{3+}(aq) + 11\,H_2O(l)$

C_2H_5OH, 46.1; 8.76 mL = 0.008 76 L

$$0.008\ 76\ \text{L} \times \frac{0.049\ 88\ \text{mol}\ Cr_2O_7^{2-}}{\text{L}} \times \frac{1\ \text{mol}\ C_2H_5OH}{2\ \text{mol}\ Cr_2O_7^{2-}} \times \frac{46.1\ \text{g}\ C_2H_5OH}{1\ \text{mol}\ C_2H_5OH}$$

$$= 0.0101\ \text{g}\ C_2H_5OH$$

$$\text{mass \%}\ C_2H_5OH = \frac{0.0101\ \text{g}}{10.002\ \text{g}} \times 100\% = 0.101\%$$

4.133 $21.08\ \text{mL} = 0.021\ 08\ \text{L}$

$$0.021\ 08\ \text{L} \times \frac{9.88 \times 10^{-4}\ \text{mol}\ MnO_4^-}{\text{L}} \times \frac{5\ \text{mol}\ H_2C_2O_4}{2\ \text{mol}\ MnO_4^-} \times \frac{1\ \text{mol}\ Ca^{2+}}{1\ \text{mol}\ H_2C_2O_4} \times \frac{40.08\ \text{g}\ Ca^{2+}}{1\ \text{mol}\ Ca^{2+}}$$

$$= 0.002\ 09\ \text{g} = 2.09\ \text{mg}$$

Multiconcept Problems

4.134 Let X equal the mass of benzoic acid and Y the mass of gallic acid in the 1.00 g mixture. Therefore, $X + Y = 1.00\ \text{g}$.

Because both acids contain only one acidic hydrogen, there is a 1 to 1 mol ratio between each acid and NaOH in the acid-base titration.

In the titration, mol benzoic acid + mol gallic acid = mol NaOH.

$$\text{Therefore, } X \times \frac{1\ \text{mol BA}}{122\ \text{g BA}} + Y \times \frac{1\ \text{mol GA}}{170\ \text{g GA}} = \text{mol NaOH}$$

$$\text{mol NaOH} = 14.7\ \text{mL} \times \frac{1 \times 10^{-3}\ \text{L}}{1\ \text{mL}} \times \frac{0.500\ \text{mol NaOH}}{1\ \text{L}} = 0.00735\ \text{mol NaOH}$$

We have two unknowns, X and Y, and two equations.

$X + Y = 1.00\ \text{g}$

$$X \times \frac{1\ \text{mol BA}}{122\ \text{g BA}} + Y \times \frac{1\ \text{mol GA}}{170\ \text{g GA}} = 0.00735\ \text{mol NaOH}$$

Rearrange to get $X = 1.00\ \text{g} - Y$ and then substitute it into the equation above to solve for Y.

$$(1.00\ \text{g} - Y) \times \frac{1\ \text{mol BA}}{122\ \text{g BA}} + Y \times \frac{1\ \text{mol GA}}{170\ \text{g GA}} = 0.00735\ \text{mol NaOH}$$

$$\frac{1\ \text{mol}}{122} - \frac{Y\ \text{mol}}{122\ \text{g}} + \frac{Y\ \text{mol}}{170\ \text{g}} = 0.00735\ \text{mol}$$

$$-\frac{Y\ \text{mol}}{122\ \text{g}} + \frac{Y\ \text{mol}}{170\ \text{g}} = 0.00735\ \text{mol} - \frac{1\ \text{mol}}{122} = -8.47 \times 10^{-4}\ \text{mol}$$

$$\frac{(-Y\ \text{mol})(170\ \text{g}) + (Y\ \text{mol})(122\ \text{g})}{(170\ \text{g})(122\ \text{g})} = -8.47 \times 10^{-4}\ \text{mol}$$

$$\frac{-48\ Y\ \text{mol}}{20740\ \text{g}} = -8.47 \times 10^{-4}\ \text{mol}; \quad \frac{48\ Y}{20740\ \text{g}} = 8.47 \times 10^{-4}$$

$$Y = \frac{(20740\ \text{g})(8.47 \times 10^{-4})}{48} = 0.366\ \text{g}$$

$X = 1.00\ \text{g} - 0.366\ \text{g} = 0.634\ \text{g}$

In the 1.00 g mixture there is 0.63 g of benzoic acid and 0.37 g of gallic acid.

4.135 (a) $XOCl_2 + 2\,H_2O \rightarrow 2\,HCl + H_2XO_3$
(b) 96.1 mL = 0.0961 L
mol NaOH = (0.1225 mol/L)(0.0961 L) = 0.01177 mol NaOH

$$\text{mol } H^+ = 0.01177 \text{ mol NaOH x } \frac{1 \text{ mol } H^+}{1 \text{ mol NaOH}} = 0.01177 \text{ mol } H^+$$

Of the total H^+ concentration, half comes from HCl and half comes from H_2XO_3.

$$\text{mol } H_2XO_3 = \frac{0.01177 \text{ mol } H^+}{2} \text{ x } \frac{1 \text{ mol } H_2XO_3}{2 \text{ mol } H^+} = 2.943 \text{ x } 10^{-3} \text{ mol } H_2XO_3$$

$$\text{mol } XOCl_2 = 2.943 \text{ x } 10^{-3} \text{ mol } H_2XO_3 \text{ x } \frac{1 \text{ mol } XOCl_2}{1 \text{ mol } H_2XO_3} = 2.943 \text{ x } 10^{-3} \text{ mol } XOCl_2$$

$$\text{molar mass } XOCl_2 = \frac{0.350 \text{ g } XOCl_2}{2.943 \text{ x } 10^{-3} \text{ mol } XOCl_2} = 118.9 \text{ g/mol}$$

molecular mass of $XOCl_2$ = 118.9
atomic weight of X = 118.9 – 16.0 – 2(35.45) = 32.0: X = S

4.136 54.91 mL = 0.054 91 L

$$0.054\,91 \text{ L x } \frac{0.1018 \text{ mol } Ce^{4+}}{L} \text{ x } \frac{1 \text{ mol } Fe^{2+}}{1 \text{ mol } Ce^{4+}} \text{ x } \frac{55.85 \text{ g } Fe^{2+}}{1 \text{ mol } Fe^{2+}} = 0.3122 \text{ g } Fe^{2+}$$

$$\text{mass \% Fe} = \frac{0.3122 \text{ g}}{1.2284 \text{ g}} \text{ x } 100\% = 25.41\%$$

4.137 (a) platinum (b) silver (c) chromium

4.138 10.49 mL = 0.010 49 L
(0.100 mol/L $S_2O_3^{2-}$)(0.010 49 L) = 0.001 049 mol $S_2O_3^{2-}$

$$0.001\,049 \text{ mol } S_2O_3^{2-} \text{ x } \frac{1 \text{ mol } I_3^-}{2 \text{ mol } S_2O_3^{2-}} \text{ x } \frac{2 \text{ mol } Cu^{2+}}{1 \text{ mol } I_3^-} = 0.001\,049 \text{ mol } Cu^{2-}$$

$$0.001\,049 \text{ mol } Cu^{2-} \text{ x } \frac{63.55 \text{ g Cu}}{1 \text{ mol } Cu^{2+}} = 0.066\,66 \text{ g Cu}$$

$$\text{mass \% Cu} = \frac{0.066\,66 \text{ g Cu}}{14.98 \text{ g sample}} \text{ x } 100\% = 0.4450 \text{ \% Cu}$$

4.139 (a) $K_{sp} = [Ag^+]^2[CrO_4^{2-}]$
(b) $Ag_2CrO_4(s) \rightleftarrows 2\,Ag^+(aq) + CrO_4^{2-}(aq)$
2x x
In a saturated solution 2x = $[Ag^+]$ and x = $[CrO_4^{2-}]$.
$K_{sp} = [Ag^+]^2[CrO_4^{2-}] = 1.1 \text{ x } 10^{-12} = (2x)^2(x) = 4x^3$; Solve for x; x = $6.5 \text{ x } 10^{-5}$ M
$[Ag^+] = 2x = 2(6.5 \text{ x } 10^{-5} \text{ M}) = 1.3 \text{ x } 10^{-4}$ M; $[CrO_4^{2-}] = x = 6.5 \text{ x } 10^{-5}$ M

4.140 $MgF_2(s) \rightleftarrows Mg^{2+}(aq) + 2\,F^-(aq)$

$$\ x \qquad\qquad 2x$$

$[Mg^{2+}] = x = 2.6 \times 10^{-4}$ M and $[F^-] = 2x = 2(2.6 \times 10^{-4}\text{ M}) = 5.2 \times 10^{-4}$ M in a saturated solution.

$K_{sp} = [Mg^{2+}][F^-]^2 = (2.6 \times 10^{-4}\text{ M})(5.2 \times 10^{-4}\text{ M})^2 = 7.0 \times 10^{-11}$

4.141 100.0 mL = 0.1000 L; 47.14 mL = 0.047 14 L

$$\text{mol HCl and HBr} = \text{mol H}^+ = 0.1235\ \frac{\text{mol NaOH}}{1\text{ L}} \times 0.047\,14\text{ L} = 5.8218 \times 10^{-3}\text{ mol}$$

mass of AgCl and AgBr = 0.9974 g; mol Ag = mol H^+ = 5.8218×10^{-3} mol

$$\text{mass of Ag} = 5.8218 \times 10^{-3}\text{ mol Ag} \times \frac{107.87\text{ g Ag}}{1\text{ mol Ag}} = 0.6280\text{ g Ag}$$

mass of Cl and Br = 0.9974 g – 0.6280 g = 0.3694 g of Cl and Br

Let Y = moles Cl and Z = moles Br in 0.3694 g of Cl and Br.

Let (Y + Z) = moles Ag in 0.6280 g Ag.

For Ag: 0.6280 g = (Y + Z) x 107.87 g

For Cl and Br: 0.3694 g = (Y x 35.453 g) + (Z x 79.904 g)

Solve the simultaneous equations for Y and Z.

$$\text{Rearrange the Ag equation: } \left(\frac{0.6280\text{ g}}{107.87\text{ g}} - Z\right) = Y$$

Substitute for Y in the Cl and Br equation above and solve for Z.

$$0.3694\text{ g} = \left[\left(\frac{0.6280\text{ g}}{107.87\text{ g}} - Z\right) \times 35.453\text{ g}\right] + (Z \times 79.904\text{ g}); \qquad Z = \frac{0.1630}{44.451} = 3.667 \times 10^{-3}$$

$$Y = \left(\frac{0.6280\text{ g}}{107.87\text{ g}} - Z\right) = \left(\frac{0.6280\text{ g}}{107.87\text{ g}} - 3.667 \times 10^{-3}\right) = 2.155 \times 10^{-3}$$

$$\text{HCl molarity} = \frac{2.155 \times 10^{-3}\text{ mol}}{0.1000\text{ L}} = 0.021\,55\text{ M}$$

$$\text{HBr molarity} = \frac{3.667 \times 10^{-3}\text{ mol}}{0.1000\text{ L}} = 0.036\,67\text{ M}$$

4.142 CuO, 79.55; Cu_2O, 143.09

Let X equal the mass of CuO and Y the mass of Cu_2O in the 10.50 g mixture. Therefore, X + Y = 10.50 g.

$$\text{mol Cu} = 8.66\text{ g} \times \frac{1\text{ mol Cu}}{63.546\text{ g Cu}} = 0.1363\text{ mol Cu}$$

mol CuO + 2 x mol Cu_2O = 0.1363 mol Cu

$$X \times \frac{1\text{ mol CuO}}{79.55\text{ g CuO}} + 2 \times \left(Y \times \frac{1\text{ mol Cu}_2\text{O}}{143.09\text{ g Cu}_2\text{O}}\right) = 0.1363\text{ mol Cu}$$

Rearrange to get X = 10.50 g – Y and then substitute it into the equation above to solve for Y.

$$(10.50\text{ g} - \text{Y})\text{ x }\frac{1\text{ mol CuO}}{79.55\text{ g CuO}} + 2\text{ x}\left(\text{Y x }\frac{1\text{ mol Cu}_2\text{O}}{143.09\text{ g Cu}_2\text{O}}\right) = 0.1363\text{ mol Cu}$$

$$\frac{10.50\text{ mol}}{79.55} - \frac{\text{Y mol}}{79.55\text{ g}} + \frac{2\text{ Y mol}}{143.09\text{ g}} = 0.1363\text{ mol}$$

$$-\frac{\text{Y mol}}{79.55\text{ g}} + \frac{2\text{ Y mol}}{143.09\text{ g}} = 0.1363\text{ mol} - \frac{10.50\text{ mol}}{79.55} = 0.0043\text{ mol}$$

$$\frac{(-\text{Y mol})(143.09\text{ g}) + (2\text{ Y mol})(79.55\text{ g})}{(79.55\text{ g})(143.09\text{ g})} = 0.0043\text{ mol}$$

$$\frac{16.01\text{ Y mol}}{11383\text{ g}} = 0.0043\text{ mol};\quad \frac{16.01\text{ Y}}{11383\text{ g}} = 0.0043$$

$\text{Y} = (0.0043)(11383\text{ g})/16.01 = 3.06\text{ g Cu}_2\text{O}$

$\text{X} = 10.50\text{ g} - \text{Y} = 10.50\text{ g} - 3.06\text{ g} = 7.44\text{ g CuO}$

4.143 Mass O in $M_2O_3 = 1.890\text{ g }M_2O_3 - 1.000\text{ g M} = 0.890\text{ g O}$

$$0.890\text{ g O x }\frac{1\text{ mol O}}{16.00\text{ g O}} = 0.0556\text{ mol O}$$

$$0.0556\text{ mol O x }\frac{2\text{ mol M}}{3\text{ mol O}} = 0.0371\text{ mol M}$$

$$\text{molar mass M} = \frac{1.000\text{ g M}}{0.0371\text{ mol M}} = 26.97\text{ g/mol; M is Al}$$

4.144 Mass S in $MS = 1.504\text{ g MS} - 1.000\text{ g M} = 0.504\text{ g S}$

$$0.504\text{ g S x }\frac{1\text{ mol S}}{32.06\text{ g S}} = 0.0157\text{ mol S}$$

$$0.0157\text{ mol S x }\frac{1\text{ mol M}}{1\text{ mol S}} = 0.0157\text{ mol M}$$

$$\text{molar mass M} = \frac{1.000\text{ g M}}{0.0157\text{ mol M}} = 63.69\text{ g/mol; M is Cu}$$

4.145 CH_3CO_2H, 60.05; $H_2C_2O_4$, 90.03

27.15 mL = 0.027 15 L and 15.05 mL = 0.015 05 L

$(0.0247\text{ mol/L }KMnO_4)(0.015\ 05\text{ L}) = 3.72 \times 10^{-4}\text{ mol }KMnO_4$

$$3.72 \times 10^{-4}\text{ mol }KMnO_4\text{ x }\frac{5\text{ mol }H_2C_2O_4}{2\text{ mol }K_2MnO_4} = 9.30 \times 10^{-4}\text{ mol }H_2C_2O_4$$

$2\text{ NaOH(aq)} + H_2C_2O_4\text{(aq)} \rightarrow Na_2C_2O_4\text{(aq)} + 2\text{ }H_2O\text{(l)}$

$$9.30 \times 10^{-4}\text{ mol }H_2C_2O_4\text{ x }\frac{2\text{ mol NaOH}}{1\text{ mol }H_2C_2O_4} = 1.86 \times 10^{-3}\text{ mol NaOH}$$

$$\text{volume} = \frac{\text{mol}}{\text{M}} = \frac{1.86 \times 10^{-3}\text{ mol NaOH}}{0.100\text{ mol/L}} = 0.0186\text{ L} = 18.6\text{ mL NaOH reacted with }H_2C_2O_4$$

remaining NaOH = 27.15 mL – 18.6 mL = 8.5 mL = 0.0085 L

$(0.100\text{ mol/L NaOH})(0.0085\text{ L}) = 8.5 \times 10^{-4}\text{ mol NaOH reacted with }CH_3CO_2H$

$NaOH(aq) + CH_3CO_2H(aq) \rightarrow NaCH_3CO_2(aq) + H_2O(l)$

$$8.5 \times 10^{-4} \text{ mol NaOH} \times \frac{1 \text{ mol } CH_3CO_2H}{1 \text{ mol NaOH}} = 8.5 \times 10^{-4} \text{ mol } CH_3CO_2H$$

$$8.5 \times 10^{-4} \text{ mol } CH_3CO_2H \times \frac{60.05 \text{ g } CH_3CO_2H}{1 \text{ mol } CH_3CO_2H} = 0.051 \text{ g } CH_3CO_2H$$

$$9.30 \times 10^{-4} \text{ mol } H_2C_2O_4 \times \frac{90.03 \text{ g } H_2C_2O_4}{1 \text{ mol } H_2C_2O_4} = 0.0837 \text{ g } H_2C_2O_4$$

mass of sample = 0.051 g CH_3CO_2H + 0.0837 g $H_2C_2O_4$ = 0.135 g

$$\text{mass \% } CH_3CO_2H = \frac{0.051 \text{ g } CH_3CO_2H}{0.135 \text{ g}} \times 100\% = 38\%$$

$$\text{mass \% } H_2C_2O_4 = \frac{0.0837 \text{ g } H_2C_2O_4}{0.135 \text{ g}} \times 100\% = 62.0\%$$

4.146 48.39 mL = 0.048 39 L

$(0.1116 \text{ mol/L } MnO_4^-)(0.048\ 39 \text{ L}) = 5.400 \times 10^{-3} \text{ mol } MnO_4^-$

$$5.400 \times 10^{-3} \text{ mol } MnO_4^- \times \frac{5 \text{ mol } Fe^{2+}}{1 \text{ mol } MnO_4^-} \times \frac{55.84 \text{ g } Fe^{2+}}{1 \text{ mol } Fe^{2+}} = 1.508 \text{ g } Fe^{2+}$$

$$\text{mass \% Fe} = \frac{1.508 \text{ g } Fe^{2+}}{2.368 \text{ g}} \times 100\% = 63.68\%$$

4.147 $FeCl_2$, 126.8; NaCl, 58.44; AgCl, 143.3; 14.28 mL = 0.014 28 L

$(0.198 \text{ mol/L } MnO_4^-)(0.014\ 28 \text{ L}) = 0.002\ 83 \text{ mol } MnO_4^-$

$$0.002\ 83 \text{ mol } MnO_4^- \times \frac{5 \text{ mol } Fe^{2+}}{1 \text{ mol } MnO_4^-} = 0.0141 \text{ mol } Fe^{2+}$$

$AgNO_3(aq)$ reacts with a solution of $FeCl_2(aq)$ and NaCl(aq) to precipitate AgCl(s).

$$7.0149 \text{ g AgCl} \times \frac{1 \text{ mol AgCl}}{143.3 \text{ g AgCl}} = 0.048\ 95 \text{ mol AgCl}$$

$$0.048\ 95 \text{ mol AgCl} \times \frac{1 \text{ mol } Cl^-}{1 \text{ mol AgCl}} = 0.048\ 95 \text{ mol } Cl^-$$

$$0.0141 \text{ mol } Fe^{2+} \times \frac{2 \text{ mol } Cl^-}{1 \text{ mol } Fe^{2+}} = 0.0282 \text{ mol } Cl^- \text{ from } FeCl_2$$

mol Cl^- from NaCl = 0.048 95 mol Cl^- – 0.0282 mol Cl^- from $FeCl_2$ = 0.0207 mol Cl^-

mol NaCl = mol Cl^- from NaCl = 0.0207 mol NaCl

mol $FeCl_2$ = mol Fe^{2+} = 0.0141 mol $FeCl_2$

$$0.0207 \text{ mol NaCl} \times \frac{58.44 \text{ g NaCl}}{1 \text{ mol NaCl}} = 1.21 \text{ g NaCl}$$

$$0.0141 \text{ mol } FeCl_2 \times \frac{126.8 \text{ g } FeCl_2}{1 \text{ mol } FeCl_2} = 1.79 \text{ g } FeCl_2$$

total mass = 1.21 g + 1.79 g = 3.00 g

$$\text{mass \% NaCl} = \frac{1.21\ \text{g NaCl}}{3.00\ \text{g}} \times 100\% = 40.3\%$$

$$\text{mass \% } FeCl_2 = \frac{1.79\ \text{g } FeCl_2}{3.00\ \text{g}} \times 100\% = 59.7\%$$

4.148 Let SA stand for salicylic acid.

$$\text{mol C in 1.00 g of SA} = 2.23\ \text{g } CO_2 \times \frac{1\ \text{mol } CO_2}{44.01\ \text{g } CO_2} \times \frac{1\ \text{mol C}}{1\ \text{mol } CO_2} = 0.0507\ \text{mol C}$$

$$\text{mass C} = 0.0507\ \text{mol C} \times \frac{12.011\ \text{g C}}{1\ \text{mol C}} = 0.609\ \text{g C}$$

$$\text{mol H in 1.00 g of SA} = 0.39\ \text{g } H_2O \times \frac{1\ \text{mol } H_2O}{18.02\ \text{g } H_2O} \times \frac{2\ \text{mol H}}{1\ \text{mol } H_2O} = 0.043\ \text{mol H}$$

$$\text{mass H} = 0.043\ \text{mol H} \times \frac{1.008\ \text{g H}}{1\ \text{mol H}} = 0.043\ \text{g H}$$

mass O = 1.00 g – mass C – mass H = 1.00 – 0.609 g – 0.043 g = 0.35 g O

$$\text{mol O in 1.00 g of} = 0.35\ \text{g N} \times \frac{1\ \text{mol O}}{16.00\ \text{g O}} = 0.022\ \text{mol O}$$

Determine empirical formula.

$C_{0.0507}H_{0.043}O_{0.022}$; divide each subscript by the smallest, 0.022.

$C_{0.0507\,/\,0.022}H_{0.043\,/\,0.022}O_{0.022\,/\,0.022}$

$C_{2.3}H_2O$, multiply each subscript by 3 to get integers.

The empirical formula is $C_7H_6O_3$. The empirical formula mass = 138.12 g/mol.

Because salicylic acid has only one acidic hydrogen, there is a 1 to 1 mol ratio between salicylic acid and NaOH in the acid-base titration.

$$\text{mol SA in 1.00 g SA} = 72.4\ \text{mL} \times \frac{1 \times 10^{-3}\ \text{L}}{1\ \text{mL}} \times \frac{0.100\ \text{mol NaOH}}{1\ \text{L}} \times \frac{1\ \text{mol SA}}{1\ \text{mol NaOH}} = 0.00724\ \text{mol SA}$$

$$\text{SA molar mass} = \frac{1.00\ \text{g}}{0.00724\ \text{mol}} = 138\ \text{g/mol}$$

Because the empirical formula mass and the molar mass are the same, the empirical formula is the molecular formula for salicylic acid.

4.149 (a) $$\text{mol C} = 4.83\ \text{g } CO_2 \times \frac{1\ \text{mol } CO_2}{44.01\ \text{g } CO_2} \times \frac{1\ \text{mol C}}{1\ \text{mol } CO_2} = 0.110\ \text{mol C}$$

$$\text{mass C} = 0.110\ \text{mol C} \times \frac{12.011\ \text{g C}}{1\ \text{mol C}} = 1.32\ \text{g C}$$

$$\text{mol H} = 1.48\ \text{g } H_2O \times \frac{1\ \text{mol } H_2O}{18.02\ \text{g } H_2O} \times \frac{2\ \text{mol H}}{1\ \text{mol } H_2O} = 0.164\ \text{mol H}$$

$$\text{mass H} = 0.164\ \text{mol H} \times \frac{1.008\ \text{g H}}{1\ \text{mol H}} = 0.165\ \text{g H}$$

109.8 mL = 0.1098 L

mol NaOH = (0.1098 L)(1.00 mol/L) = 0.110 mol NaOH

$H_2SO_4(aq) + 2\ NaOH(aq) \rightarrow Na_2SO_4(aq) + 2\ H_2O(l)$

$$\text{mol } H_2SO_4 = 0.110 \text{ mol NaOH} \times \frac{1 \text{ mol } H_2SO_4}{2 \text{ mol NaOH}} = 0.0550 \text{ mol } H_2SO_4$$

$$\text{mol S} = 0.0550 \text{ mol } H_2SO_4 \times \frac{1 \text{ mol S}}{1 \text{ mol } H_2SO_4} = 0.0550 \text{ mol S}$$

$$\text{mass S} = 0.0550 \text{ mol S} \times \frac{32.06 \text{ g S}}{1 \text{ mol S}} = 1.76 \text{ g S}$$

mass O = 5.00 g – mass C – mass H – mass S = 5.00 g –1.32 g – 0.165 g – 1.76 g = 1.75 g O

$$\text{mol O} = 1.75 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 0.109 \text{ mol O}$$

$C_{0.110}H_{0.164}O_{0.109}S_{0.0550}$; divide each subscript by the smallest, 0.0550.

$C_{0.110\,/\,0.0550}H_{0.164\,/\,0.0550}O_{0.109\,/\,0.0550}S_{0.0550\,/\,0.0550}$

The empirical formula is $C_2H_3O_2S$.

The empirical formula mass = 91.1 g/mol.

(b) 54.9 mL = 0.0549 L

mol NaOH = (0.0549 L)(1.00 mol/L) = 0.0549 mol NaOH

Because X has two acidic hydrogens, two mol of NaOH are required to titrate 1 mol of X.

$$\text{mol X} = 0.0549 \text{ mol NaOH} \times \frac{1 \text{ mol X}}{2 \text{ mol NaOH}} = 0.0274 \text{ mol X}$$

$$\text{X molar mass} = \frac{5.00 \text{ g}}{0.0274 \text{ mol}} = 182 \text{ g/mol}$$

Because the molar mass is twice the empirical formula mass, the molecular formula is twice the empirical formula.

The molecular formula is $C_{(2\times2)}H_{(2\times3)}O_{(2\times2)}S_{(2\times1)} = C_4H_6O_4S_2$.

4.150 100.00 mL = 0.100 00 L; 71.02 mL = 0.071 02 L

$$\text{mol } H_2SO_4 = \frac{0.1083 \text{ mol } H_2SO_4}{\text{L}} \times 0.100\,00 \text{ L} = 0.010\,83 \text{ mol } H_2SO_4$$

$$\text{mol NaOH} = \frac{0.1241 \text{ mol NaOH}}{\text{L}} \times 0.071\,02 \text{ L} = 0.008\,814 \text{ mol NaOH}$$

$H_2SO_4 + 2\ NaOH \rightarrow Na_2SO_4 + 2\ H_2O$

$$\text{mol } H_2SO_4 \text{ reacted with NaOH} = 0.008\,814 \text{ mol NaOH} \times \frac{1 \text{ mol } H_2SO_4}{2 \text{ mol NaOH}} = 0.004\,407 \text{ mol } H_2SO_4$$

mol H_2SO_4 reacted with MCO_3 = 0.010 83 mol – 0.004 407 mol = 0.006 423 mol H_2SO_4

mol H_2SO_4 reacted with MCO_3 = mol CO_3^{2-} in MCO_3 = mol CO_2 produced = 0.006 423 mol CO_2

(a) CO_3^{2-}, 60.01;

$$0.006\,423 \text{ mol } CO_3^{2-} \times \frac{60.01 \text{ g } CO_3^{2-}}{1 \text{ mol } CO_3^{2-}} = 0.3854 \text{ g } CO_3^{2-}$$

mass of M = 1.268 g – 0.3854 g = 0.8826 g M

$$\text{molar mass of M} = \frac{0.8826\ \text{g}}{0.006\,423\ \text{mol}} = 137.4\ \text{g/mol};\quad \text{M is Ba}$$

$$\text{(b)}\ 0.006\ 423\ \text{mol}\ CO_2 \times \frac{44.01\ \text{g}\ CO_2}{1\ \text{mol}\ CO_2} \times \frac{1\ \text{L}}{1.799\ \text{g}} = 0.1571\ \text{L}\ CO_2$$

4.151 (a) (i) $M_2O_3(s) + 3\ C(s) + 3\ Cl_2(g) \rightarrow 2\ MCl_3(l) + 3\ CO(g)$

(ii) $2\ MCl_3(l) + 3\ H_2(g) \rightarrow 2\ M(s) + 6\ HCl(g)$

(b) $HCl(aq) + NaOH(aq) \rightarrow H_2O(l) + NaCl(aq)$

144.2 mL = 0.1442 L

mol NaOH = (0.511 mol/L)(0.1442 L) = 0.07369 mol NaOH

$$\text{mol HCl} = 0.07369\ \text{mol NaOH} \times \frac{1\ \text{mol HCl}}{1\ \text{mol NaOH}} = 0.07369\ \text{mol HCl}$$

$$\text{mol M} = 0.07369\ \text{mol HCl} \times \frac{2\ \text{mol M}}{6\ \text{mol HCl}} = 0.02456\ \text{mol M}$$

$$\text{mol}\ M_2O_3 = 0.02456\ \text{mol M} \times \frac{2\ \text{mol}\ MCl_3}{2\ \text{mol M}} \times \frac{1\ \text{mol}\ M_2O_3}{2\ \text{mol}\ MCl_3} = 0.01228\ \text{mol}\ M_2O_3$$

$$\text{molar mass}\ M_2O_3 = \frac{0.855\ \text{g}}{0.01228\ \text{mol}} = 69.6\ \text{g/mol};\ \text{molecular mass}\ M_2O_3 = 69.6$$

$$\text{atomic weight of M} = \frac{69.6\ \text{amu} - (3 \times 16.0\ \text{amu})}{2} = 10.8;\quad \text{M} = \text{B}$$

$$\text{(c) mass of M} = 0.02456\ \text{mol M} \times \frac{10.81\ \text{g M}}{1\ \text{mol M}} = 0.265\ \text{g M}$$

4.152 NaOH, 40.00; $Ba(OH)_2$, 171.34

Let X equal the mass of NaOH and Y the mass of $Ba(OH)_2$ in the 10.0 g mixture.

Therefore, X + Y = 10.0 g.

$$\text{mol HCl} = 108.9\ \text{mL} \times \frac{1 \times 10^{-3}\ \text{L}}{1\ \text{mL}} \times \frac{1.50\ \text{mol HCl}}{1\ \text{L}} = 0.163\ \text{mol HCl}$$

$$\text{mol NaOH} + 2 \times \text{mol}\ Ba(OH)_2 = 0.163\ \text{mol HCl}$$

$$X \times \frac{1\ \text{mol NaOH}}{40.00\ \text{g NaOH}} + 2 \times \left(Y \times \frac{1\ \text{mol}\ Ba(OH)_2}{171.34\ \text{g}\ Ba(OH)_2} \right) = 0.163\ \text{mol HCl}$$

Rearrange to get X = 10.0 g – Y and then substitute it into the equation above to solve for Y.

$$(10.0\ \text{g} - Y) \times \frac{1\ \text{mol NaOH}}{40.00\ \text{g NaOH}} + 2 \times \left(Y \times \frac{1\ \text{mol}\ Ba(OH)_2}{171.34\ \text{g}\ Ba(OH)_2} \right) = 0.163\ \text{mol HCl}$$

$$\frac{10.00\ \text{mol}}{40.00} - \frac{Y\ \text{mol}}{40.00\ \text{g}} + \frac{2\ Y\ \text{mol}}{171.34\ \text{g}} = 0.163\ \text{mol}$$

$$-\frac{Y\ \text{mol}}{40.00\ \text{g}} + \frac{2\ Y\ \text{mol}}{171.34\ \text{g}} = 0.163\ \text{mol} - \frac{10.00\ \text{mol}}{40.00} = -0.087\ \text{mol}$$

$$\frac{(-Y\ \text{mol})(171.34\ \text{g}) + (2\ Y\ \text{mol})(40.00\ \text{g})}{(40.00\ \text{g})(171.34\ \text{g})} = -0.087\ \text{mol}$$

$$\frac{-91.34\ Y\ \text{mol}}{6853.6\ \text{g}} = -0.087\ \text{mol};\quad \frac{91.34\ Y}{6853.6\ \text{g}} = 0.087$$

$Y = (0.087)(6853.6\ \text{g})/91.34 = 6.5\ \text{g}\ Ba(OH)_2$

$X = 10.0\ \text{g} - Y = 10.0\ \text{g} - 6.5\ \text{g} = 3.5\ \text{g NaOH}$

4.153 100.0 mL = 0.1000 L; 50.0 mL = 0.0500 L; 250.0 mL = 0.2500 L

After step (2): $BaCl_2(aq) + 2\ AgNO_3(aq) \rightarrow AgCl(s) + Ba(NO_3)_2(aq)$

mol $BaCl_2$ = (0.1000 L)(0.100 mol/L) = 0.0100 mol $BaCl_2$

mol Ba^{2+} = mol $BaCl_2$ = 0.0100 mol Ba^{2+}

$$\text{mol } Cl^- = 0.0100\ \text{mol } BaCl_2 \times \frac{2\ \text{mol } Cl^-}{1\ \text{mol } BaCl_2} = 0.0200\ \text{mol } Cl^-$$

mol $AgNO_3$ = (0.0500 L)(0.100 mol/L) = 0.00500 mol $AgNO_3$

mol Ag^+ = mol $AgNO_3$ = 0.00500 mol Ag^+

mol NO_3^- = mol $AgNO_3$ = 0.00500 mol NO_3^-

0.00500 mol Ag^+ requires only 0.00500 mol Cl^-, so Ag^+ is the limiting reactant and totally consumed.

mol Cl^- remaining after reaction = 0.0200 mol – 0.00500 mol = 0.0150 mol Cl^-

After step (3): $Ba^{2+}(aq) + H_2SO_4(aq) \rightarrow BaSO_4(s) + 2\ H^+(aq)$

mol H_2SO_4 = (0.0500 L)(0.100 mol/L) = 0.00500 mol H_2SO_4

mol SO_4^{2-} = mol H_2SO_4 = 0.00500 mol SO_4^{2-}

$$\text{mol } H^+ = 0.00500\ \text{mol } H_2SO_4 \times \frac{2\ \text{mol } H^+}{1\ \text{mol } H_2SO_4} = 0.0100\ \text{mol } H^+$$

0.0100 mol Ba^{2+} requires 0.0100 mol SO_4^{2-}, so SO_4^{2-} is the limiting reactant and is totally consumed.

mol Ba^{2+} remaining after reaction = 0.0100 mol – 0.00500 mol = 0.00500 mol Ba^{2+}

After step (4): $NH_3(aq) + H^+(aq) \rightarrow NH_4^+(aq)$

mol NH_3 = (0.2500 L)(0.100 mol/L) = 0.0250 mol NH_3

0.0250 mol NH_3 requires 0.0250 mol H^+, so H^+ is the limiting reactant and is totally consumed.

mol NH_3 remaining after reaction = 0.0250 mol – 0.0100 mol = 0.0150 mol NH_3

mol NH_4^+ = mol H^+ before reaction = 0.0100 mol NH_4^+

total volume = 0.1000 L + 0.0500 L + 0.0500 L + 0.2500 L = 0.4500 L

$$[Ba^{2+}] = \frac{0.00500\ \text{mol}}{0.4500\ \text{L}} = 0.0111\ \text{M}$$

$$[Cl^-] = \frac{0.0150\ \text{mol}}{0.4500\ \text{L}} = 0.0333\ \text{M}$$

$$[NO_3^-] = \frac{0.00500\ \text{mol}}{0.4500\ \text{L}} = 0.0111\ \text{M}$$

$$[NH_3] = \frac{0.0150\ \text{mol}}{0.4500\ \text{L}} = 0.0333\ \text{M}$$

$$[NH_4^+] = \frac{0.0100\ \text{mol}}{0.4500\ \text{L}} = 0.0222\ \text{M}$$

4.154 (a) $Cr^{2+}(aq) + Cr_2O_7^{2-}(aq) \rightarrow Cr^{3+}(aq)$
$[Cr^{2+}(aq) \rightarrow Cr^{3+}(aq) + e^-] \times 6$ (oxidation half reaction)

$Cr_2O_7^{2-}(aq) \rightarrow Cr^{3+}(aq)$
$Cr_2O_7^{2-}(aq) \rightarrow 2\ Cr^{3+}(aq)$
$Cr_2O_7^{2-}(aq) \rightarrow 2\ Cr^{3+}(aq) + 7\ H_2O(l)$
$14\ H^+(aq) + Cr_2O_7^{2-}(aq) \rightarrow 2\ Cr^{3+}(aq) + 7\ H_2O(l)$
$6\ e^- + 14\ H^+(aq) + Cr_2O_7^{2-}(aq) \rightarrow 2\ Cr^{3+}(aq) + 7\ H_2O(l)$ (reduction half reaction)

Combine the two half reactions.
$14\ H^+(aq) + Cr_2O_7^{2-}(aq) + 6\ Cr^{2+}(aq) \rightarrow 8\ Cr^{3+}(aq) + 7\ H_2O(l)$

(b) total volume = 100.0 ml + 20.0 mL = 120.0 mL = 0.1200 L
Initial moles:

$$0.120\ \frac{\text{mol } Cr(NO_3)_2}{1\ \text{L}} \times 0.1000\ \text{L} = 0.0120\ \text{mol } Cr(NO_3)_2$$

$$0.500\ \frac{\text{mol } HNO_3}{1\ \text{L}} \times 0.1000\ \text{L} = 0.0500\ \text{mol } HNO_3$$

$$0.250\ \frac{\text{mol } K_2Cr_2O_7}{1\ \text{L}} \times 0.0200\ \text{L} = 0.005\ 00\ \text{mol } K_2Cr_2O_7$$

Check for the limiting reactant. 0.0120 mol of Cr^{2+} requires (0.0120)/6 = 0.00200 mol $Cr_2O_7^{2-}$ and (14/6)(0.0120) = 0.0280 mol H^+. Both are in excess of the required amounts, so Cr^{2+} is the limiting reactant.

	$14\ H^+(aq)$	+ $Cr_2O_7^{2-}(aq)$	+ $6\ Cr^{2+}(aq)$	→ $8\ Cr^{3+}(aq)$	+ $7\ H_2O(l)$
Initial moles	0.0500	0.00500	0.0120	0	
Change	−14x	−x	−6x	+8x	

Because Cr^{2+} is the limiting reactant, 6x = 0.0120 and x = 0.00200

Final moles	0.0220	0.00300	0	0.0160

$$\text{mol } K^+ = 0.00500\ \text{mol } K_2Cr_2O_7 \times \frac{2\ \text{mol } K^+}{1\ \text{mol } K_2Cr_2O_7} = 0.0100\ \text{mol } K^+$$

$$\text{mol } NO_3^- = 0.0120\ \text{mol } Cr(NO_3)_2 \times \frac{2\ \text{mol } NO_3^-}{1\ \text{mol } Cr(NO_3)_2}$$

$$+ 0.0500\ \text{mol } HNO_3 \times \frac{1\ \text{mol } NO_3^-}{1\ \text{mol } HNO_3} = 0.0740\ \text{mol } NO_3^-$$

mol H^+ = 0.0220 mol; mol $Cr_2O_7^{2-}$ = 0.00300 mol; mol Cr^{3+} = 0.01600 mol

Check for charge neutrality.
Total moles of +charge = 0.0100 + 0.0220 + 3 x (0.01600) = 0.0800 mol +charge
Total moles of –charge = 0.0740 + 2 x (0.00300) = 0.0800 mol –charge
The charges balance and there is electrical neutrality in the solution after the reaction.

$$K^+ \text{ molarity} = \frac{0.0100 \text{ mol } K^+}{0.1200 \text{ L}} = 0.0833 \text{ M}$$

$$NO_3^- \text{ molarity} = \frac{0.0740 \text{ mol } NO_3^-}{0.1200 \text{ L}} = 0.617 \text{ M}$$

$$H^+ \text{ molarity} = \frac{0.0220 \text{ mol } H^+}{0.1200 \text{ L}} = 0.183 \text{ M}$$

$$Cr_2O_7^{2-} \text{ molarity} = \frac{0.00300 \text{ mol } Cr_2O_7^{2-}}{0.1200 \text{ L}} = 0.0250 \text{ M}$$

$$Cr^{3+} \text{ molarity} = \frac{0.0160 \text{ mol } Cr^{3+}}{0.1200 \text{ L}} = 0.133 \text{ M}$$

4.155 (a) (1) $I^-(aq) \rightarrow I_3^-(aq)$

$3\ I^-(aq) \rightarrow I_3^-(aq)$

$3\ I^-(aq) \rightarrow I_3^-(aq) + 2\ e^-$ (oxidation half reaction)

$HNO_2(aq) \rightarrow NO(g)$

$HNO_2(aq) \rightarrow NO(g) + H_2O(l)$

$H^+(aq) + HNO_2(aq) \rightarrow NO(g) + H_2O(l)$

$[e^- + H^+(aq) + HNO_2(aq) \rightarrow NO(g) + H_2O(l)] \times 2$ (reduction half reaction)

Combine the two half reactions.

$3\ I^-(aq) + 2\ H^+(aq) + 2\ HNO_2(aq) \rightarrow I_3^-(aq) + 2\ NO(g) + 2\ H_2O(l)$

(2) $S_2O_3^{2-}(aq) \rightarrow S_4O_6^{2-}(aq)$

$2\ S_2O_3^{2-}(aq) \rightarrow S_4O_6^{2-}(aq)$

$2\ S_2O_3^{2-}(aq) \rightarrow S_4O_6^{2-}(aq) + 2\ e^-$ (oxidation half reaction)

$I_3^-(aq) \rightarrow I^-(aq)$

$I_3^-(aq) \rightarrow 3\ I^-(aq)$

$2\ e^- + I_3^-(aq) \rightarrow 3\ I^-(aq)$ (reduction half reaction)

Combine the two half reactions.

$2\ S_2O_3^{2-}(aq) + I_3^-(aq) \rightarrow S_4O_6^{2-}(aq) + 3\ I^-(aq)$

(b) 18.77 mL = 0.018 77 L; NO_2^-, 46.01

$$0.1500 \frac{\text{mol } S_2O_3^{2-}}{1 \text{ L}} \times 0.018\ 77 \text{ L} = 0.002\ 815\ 5 \text{ mol } S_2O_3^{2-}$$

$$\text{mass } NO_2^- = 0.002\ 815\ 5 \text{ mol } S_2O_3^{2-} \times \frac{1 \text{ mol } I_3^-}{2 \text{ mol } S_2O_3^{2-}} \times \frac{2 \text{ mol } NO_2^-}{1 \text{ mol } I_3^-} \times \frac{46.01 \text{ g } NO_2^-}{1 \text{ mol } NO_2^-} = 0.1295 \text{ g } NO_2^-$$

$$\text{mass \% } NO_2^- = \frac{0.1295 \text{ g}}{2.935 \text{ g}} \times 100\% = 4.412\%$$

4.156 (a) (1) $Cu(s) \rightarrow Cu^{2+}(aq)$
$[Cu(s) \rightarrow Cu^{2+}(aq) + 2\ e^-] \times 3$ (oxidation half reaction)

$NO_3^-(aq) \rightarrow NO(g)$
$NO_3^-(aq) \rightarrow NO(g) + 2\ H_2O(l)$
$4\ H^+(aq) + NO_3^-(aq) \rightarrow NO(g) + 2\ H_2O(l)$
$[3\ e^- + 4\ H^+(aq) + NO_3^-(aq) \rightarrow NO(g) + 2\ H_2O(l)] \times 2$ (reduction half reaction)

Combine the two half reactions.
$3\ Cu(s) + 8\ H^+(aq) + 2\ NO_3^-(aq) \rightarrow 3\ Cu^{2+}(aq) + 2\ NO(g) + 4\ H_2O(l)$

(2) $Cu^{2+}(aq) + SCN^-(aq) \rightarrow CuSCN(s)$
$[e^- + Cu^{2+}(aq) + SCN^-(aq) \rightarrow CuSCN(s)] \times 2$ (reduction half reaction)

$HSO_3^-(aq) \rightarrow HSO_4^-(aq)$
$H_2O(l) + HSO_3^-(aq) \rightarrow HSO_4^-(aq)$
$H_2O(l) + HSO_3^-(aq) \rightarrow HSO_4^-(aq) + 2\ H^+(aq)$
$H_2O(l) + HSO_3^-(aq) \rightarrow HSO_4^-(aq) + 2\ H^+(aq) + 2\ e^-$
(oxidation half reaction)

Combine the two half reactions.
$2\ Cu^{2+}(aq) + 2\ SCN^-(aq) + H_2O(l) + HSO_3^-(aq) \rightarrow$
$2\ CuSCN(s) + HSO_4^-(aq) + 2\ H^+(aq)$

(3) $Cu^+(aq) \rightarrow Cu^{2+}(aq)$
$[Cu^+(aq) \rightarrow Cu^{2+}(aq) + e^-] \times 10$ (oxidation half reaction)

$IO_3^-(aq) \rightarrow I_2(aq)$
$2\ IO_3^-(aq) \rightarrow I_2(aq)$
$2\ IO_3^-(aq) \rightarrow I_2(aq) + 6\ H_2O(l)$
$12\ H^+(aq) + 2\ IO_3^-(aq) \rightarrow I_2(aq) + 6\ H_2O(l)$
$10\ e^- + 12\ H^+(aq) + 2\ IO_3^-(aq) \rightarrow I_2(aq) + 6\ H_2O(l)$ (reduction half reaction)
Combine the two half reactions.
$10\ Cu^+(aq) + 12\ H^+(aq) + 2\ IO_3^-(aq) \rightarrow 10\ Cu^{2+}(aq) + I_2(aq) + 6\ H_2O(l)$

(4) $I_2(aq) \rightarrow I^-(aq)$
$I_2(aq) \rightarrow 2\ I^-(aq)$
$2\ e^- + I_2(aq) \rightarrow 2\ I^-(aq)$ (reduction half reaction)

$S_2O_3^{2-}(aq) \rightarrow S_4O_6^{2-}(aq)$
$2\ S_2O_3^{2-}(aq) \rightarrow S_4O_6^{2-}(aq)$
$2\ S_2O_3^{2-}(aq) \rightarrow S_4O_6^{2-}(aq) + 2\ e^-$ (oxidation half reaction)

Combine the two half reactions.
$I_2(aq) + 2\ S_2O_3^{2-}(aq) \rightarrow 2\ I^-(aq) + S_4O_6^{2-}(aq)$

(5) $2\ ZnNH_4PO_4 \rightarrow Zn_2P_2O_7 + H_2O + 2\ NH_3$

(b) 10.82 mL = 0.01082 L

mol $S_2O_3^{2-}$ = (0.1220 mol/L)(0.01082 L) = 0.00132 mol $S_2O_3^{2-}$

$$\text{mol } I_2 = 0.00132 \text{ mol } S_2O_3^{2-} \times \frac{1 \text{ mol } I_2}{2 \text{ mol } S_2O_3^{2-}} = 6.60 \times 10^{-4} \text{ mol } I_2$$

$$\text{mol } Cu^+ = 6.60 \times 10^{-4} \text{ mol } I_2 \times \frac{10 \text{ mol } Cu^+}{1 \text{ mol } I_2} = 6.60 \times 10^{-3} \text{ mol } Cu^+ \text{ (Cu)}$$

g Cu = $(6.60 \times 10^{-3}$ mol)(63.546 g/mol) = 0.419 g Cu

$$\text{mass \% Cu in brass} = \frac{0.419 \text{ g Cu}}{0.544 \text{ g brass}} \times 100\% = 77.1\% \text{ Cu}$$

(c) $Zn_2P_2O_7$, 304.72

$$\text{mass \% Zn in } Zn_2P_2O_7 = \frac{2 \times 65.39 \text{ g}}{304.72 \text{ g}} \times 100\% = 42.92\%$$

mass of Zn in $Zn_2P_2O_7$ = (0.4292)(0.246 g) = 0.106 g Zn

$$\text{mass \% Zn in brass} = \frac{0.106 \text{ g Zn}}{0.544 \text{ g brass}} \times 100\% = 19.5\% \text{ Zn}$$

4.157 (a) $BaSO_4$, 233.38

$$\text{mol S} = 7.19 \text{ g } BaSO_4 \times \frac{1 \text{ mol } BaSO_4}{233.38 \text{ g } BaSO_4} \times \frac{1 \text{ mol S}}{1 \text{ mol } BaSO_4} = 0.0308 \text{ mol S}$$

$$\text{theoretical mol S} = \frac{0.0308 \text{ mol S}}{0.913} = 0.0337 \text{ mol S}$$

(b) Assume n = 1:

$$\text{mol Cl in } MCl_5 = 0.0337 \text{ mol S} \times \frac{5 \text{ mol Cl}}{1 \text{ mol S}} = 0.168 \text{ mol Cl}$$

$$\text{mass Cl} = 0.168 \text{ mol Cl} \times \frac{35.453 \text{ g Cl}}{1 \text{ mol Cl}} = 5.97 \text{ g Cl}$$

This is impossible because the initial mass of MCl_5 was only 4.61 g.

Assume n = 2:

$$\text{mol Cl in } MCl_5 = 0.0337 \text{ mol S} \times \frac{5 \text{ mol Cl}}{2 \text{ mol S}} = 0.0842 \text{ mol Cl}$$

$$\text{mass Cl} = 0.0842 \text{ mol Cl} \times \frac{35.453 \text{ g Cl}}{1 \text{ mol Cl}} = 2.99 \text{ g Cl}$$

mass M = 4.61g – 2.99 g = 1.62 g M

$$\text{mol M} = 0.0337 \text{ mol S} \times \frac{1 \text{ mol M}}{2 \text{ mol S}} = 0.0168 \text{ mol}$$

$$\text{M molar mass} = \frac{1.62 \text{ g}}{0.0168 \text{ mol}} = 96.4 \text{ g/mol; M atomic weight} = 96.4$$

96.4 is reasonable and suggests that M is Mo.

Assume n = 3:

$$\text{mol Cl in } MCl_5 = 0.0337 \text{ mol S} \times \frac{5 \text{ mol Cl}}{3 \text{ mol S}} = 0.0562 \text{ mol Cl}$$

$$\text{mass Cl} = 0.0562 \text{ mol Cl} \times \frac{35.453 \text{ g Cl}}{1 \text{ mol Cl}} = 1.99 \text{ g Cl}$$

mass M = 4.61g – 1.99 g = 2.62 g M

$$\text{mol M} = 0.0337 \text{ mol S} \times \frac{1 \text{ mol M}}{3 \text{ mol S}} = 0.0112 \text{ mol}$$

$$\text{M molar mass} = \frac{2.62 \text{ g}}{0.0112 \text{ mol}} = 234 \text{ g/mol}; \quad \text{M atomic weight} = 234$$

234 is between Pa and U, which is highly unlikely for a lubricant.

Assume n = 4:

$$\text{mol Cl in } MCl_5 = 0.0337 \text{ mol S} \times \frac{5 \text{ mol Cl}}{4 \text{ mol S}} = 0.0421 \text{ mol Cl}$$

$$\text{mass Cl} = 0.0421 \text{ mol Cl} \times \frac{35.453 \text{ g Cl}}{1 \text{ mol Cl}} = 1.49 \text{ g Cl}$$

mass M = 4.61g – 1.49 g = 3.12 g M

$$\text{mol M} = 0.0337 \text{ mol S} \times \frac{1 \text{ mol M}}{4 \text{ mol S}} = 0.00842 \text{ mol}$$

$$\text{M molar mass} = \frac{3.12 \text{ g}}{0.008\,42 \text{ mol}} = 371 \text{ g/mol}; \quad \text{M atomic weight} = 371$$

No known elements have a mass as great as 371.

(c) M is most likely Mo and the metal sulfide is MoS_2.

(d) (1) $2\ MoCl_5(s) + 5\ Na_2S(s) \rightarrow 2\ MoS_2(s) + S(l) + 10\ NaCl(s)$

(2) $2\ MoS_2(s) + 7\ O_2(g) \rightarrow 2\ MoO_3(s) + 4\ SO_2(g)$

(3) $SO_2(g) + 2\ Fe^{3+}(aq) + 2\ H_2O(l) \rightarrow 2\ Fe^{2+}(aq) + SO_4^{2-}(aq) + 4\ H^+(aq)$

(4) $SO_4^{2-}(aq) + Ba^{2+}(aq) \rightarrow BaSO_4(s)$

4.158 (a) $H_3MO_3(aq) \rightarrow H_3MO_4(aq)$

$H_3MO_3(aq) + H_2O(l) \rightarrow H_3MO_4(aq)$

$H_3MO_3(aq) + H_2O(l) \rightarrow H_3MO_4(aq) + 2\ H^+(aq)$

$[H_3MO_3(aq) + H_2O(l) \rightarrow H_3MO_4(aq) + 2\ H^+(aq) + 2\ e^-] \times 5$ (oxidation half reaction)

$MnO_4^-(aq) \rightarrow Mn^{2+}(aq)$

$MnO_4^-(aq) \rightarrow Mn^{2+}(aq) + 4\ H_2O(l)$

$MnO_4^-(aq) + 8\ H^+(aq) \rightarrow Mn^{2+}(aq) + 4\ H_2O(l)$

$[MnO_4^-(aq) + 8\ H^+(aq) + 5\ e^- \rightarrow Mn^{2+}(aq) + 4\ H_2O(l)] \times 2$ (reduction half reaction)

Combine the two half reactions.

$5\ H_3MO_3(aq) + 5\ H_2O(l) + 2\ MnO_4^-(aq) + 16\ H^+(aq) \rightarrow$
$5\ H_3MO_4(aq) + 10\ H^+(aq) + 2\ Mn^{2+}(aq) + 8\ H_2O(l)$

$5\ H_3MO_3(aq) + 2\ MnO_4^-(aq) + 6\ H^+(aq) \rightarrow 5\ H_3MO_4(aq) + 2\ Mn^{2+}(aq) + 3\ H_2O(l)$

(b) 10.7 mL = 0.0107 L

mol MnO_4^- = (0.0107 L)(0.100 mol/L) = 1.07×10^{-3} mol MnO_4^-

$$\text{mol } H_3MO_3 = 1.07 \times 10^{-3} \text{ mol } MnO_4^- \times \frac{5 \text{ mol } H_3MO_3}{2 \text{ mol } MnO_4^-} = 2.67 \times 10^{-3} \text{ mol } H_3MO_3$$

$$\text{mol } M_2O_3 = 2.67 \times 10^{-3} \text{ mol } H_3MO_3 \times \frac{1 \text{ mol } M_2O_3}{2 \text{ mol } H_3MO_3} = 1.34 \times 10^{-3} \text{ mol } M_2O_3$$

$$\text{mol M in } M_2O_3 = 1.34 \times 10^{-3} \text{ mol } M_2O_3 \times \frac{2 \text{ mol M}}{1 \text{ mol } M_2O_3} = 2.68 \times 10^{-3} \text{ mol M}$$

(c) M molar mass = $\dfrac{0.200 \text{ g}}{2.68 \times 10^{-3} \text{ mol}}$ = 74.6 g/mol; M atomic weight = 74.6

M is As.