Zumbdahl C-4

takes 20.46 mL of a sodium hydroxide solution to titrate a 0.1082-g sample of KHP. What is the molarity of the sodium hydroxide?

A 0.500-L sample of H_2SO_4 solution was analyzed by taking a 100.0-mL aliquot and adding 50.0 mL of 0.213 *M* NaOH. After the reaction occurred, an excess of OH^- ions remained in the solution. The excess base required 13.21 mL of 0.103 *M* HCl for neutralization. Calculate the molarity of the original sample of H_2SO_4.

Calcium metal will react with water as follows:

$$Ca(s) + 2H_2O(l) \rightarrow Ca(OH)_2(aq) + H_2(g)$$

What is the molarity of hydroxide ions in the solution formed when 4.25 g of calcium metal is dissolved in enough water to make a final volume of 225 mL?

48. A 10.00-mL sample of sulfuric acid from an automobile battery requires 35.08 mL of 2.12 *M* sodium hydroxide solution for complete neutralization. What is the molarity of the sulfuric acid? The reaction is

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

49. A 10.00-mL sample of vinegar, an aqueous solution of acetic acid ($HC_2H_3O_2$), is titrated with 0.5062 *M* NaOH, and 16.58 mL is required to reach the end point.
   a. What is the molarity of the acetic acid?
   b. If the density of the vinegar is 1.006 g/cm^3, what is the mass percent of acetic acid in the vinegar?

50. A 25.00-mL sample of hydrochloric acid solution takes 24.16 mL of 0.106 *M* sodium hydroxide for complete neutralization. What is the concentration of the hydrochloric acid solution?

51. A solution is prepared by dissolving 15 g of NaOH in 150 mL of 0.25 *M* nitric acid. Will the final solution be acidic, basic, or neutral? Calculate the concentrations of all of the ions present in the solution after the reaction has occurred.

52. A 50.00-mL sample of an ammonia solution is analyzed by titration with HCl. The reaction is

$$NH_3(aq) + H^+(aq) \rightarrow NH_4^+(aq)$$

It took 39.47 mL of 0.0984 *M* HCl to titrate (react completely with) the ammonia. What is the concentration of the original ammonia solution?

53. Hydrochloric acid (75 mL of 0.25 *M*) is added to 225 mL of 0.055 *M* $Ba(OH)_2$ solution. What is the concentration of the excess H^+ or OH^- left in this solution?

Oxidation-Reduction Reactions

54. Assign oxidation states to all atoms in each compound.

a. $KMnO_4$	c. $K_4Fe(CN)_6$ (Fe only)	
b. NiO_2	d. $(NH_4)_2HPO_4$	
e. P_4O_6	h. SF_4	
f. Fe_3O_4	i. CO	
g. $XeOF_4$	j. $Na_2C_2O_4$	

55. Assign an oxidation state to chlorine in each of the following anions: OCl^-, ClO_2^-, ClO_3^-, and ClO_4^-.

56. Assign an oxidation state to nitrogen in each of the following:

a. Li_3N	d. NO	g. NO_2^-
b. NH_3	e. N_2O	h. NO_3^-
c. N_2H_4	f. NO_2	i. N_2

57. Assign oxidation states to all atoms in each of the following:

a. UO_2^{2+}	d. As_4	g. $Na_2S_2O_3$
b. As_2O_3	e. $HAsO_2$	h. Hg_2Cl_2
c. $NaBiO_3$	f. $Mg_2P_2O_7$	i. $Ca(NO_3)_2$

58. Tell which of the following are oxidation-reduction reactions. For those that are, identify the oxidizing agent, the reducing agent, the substance being oxidized, and the substance being reduced.
   a. $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$
   b. $Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$
   c. $Cr_2O_7^{2-}(aq) + 2OH^-(aq) \rightarrow 2CrO_4^{2-}(aq) + H_2O(l)$
   d. $O_3(g) + NO(g) \rightarrow O_2(g) + NO_2(g)$
   e. $2H_2O_2(l) \rightarrow 2H_2O(l) + O_2(g)$
   f. $2CuCl(aq) \rightarrow CuCl_2(aq) + Cu(s)$
   g. $HCl(g) + NH_3(g) \rightarrow NH_4Cl(s)$
   h. $SiCl_4(l) + 2H_2O(l) \rightarrow 4HCl(aq) + SiO_2(s)$
   i. $SiCl_4(l) + 2Mg(s) \rightarrow 2MgCl_2(s) + Si(s)$

59. Balance each of the following oxidation-reduction reactions using the oxidation states method:
   a. $C_2H_6(g) + O_2(g) \rightarrow CO_2(g) + H_2O(g)$
   b. $Mg(s) + HCl(aq) \rightarrow Mg^{2+}(aq) + 2Cl^-(aq) + H_2(g)$
   c. $Cu(s) + Ag^+(aq) \rightarrow Cu^{2+}(aq) + Ag(s)$
   d. $Cu(s) + HNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + NO(g)$
   e. $Zn(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2(g)$

60. Balance the following oxidation-reduction reactions, which occur in acidic solution, using the half-reaction method.
   a. $Cu(s) + HNO_3(aq) \rightarrow Cu^{2+}(aq) + NO(g)$
   b. $Cr_2O_7^{2-}(aq) + Cl^-(aq) \rightarrow Cr^{3+}(aq) + Cl_2(g)$
   c. $Pb(s) + PbO_2(s) + H_2SO_4(aq) \rightarrow PbSO_4(s)$
   d. $Mn^{2+}(aq) + NaBiO_3(s) \rightarrow Bi^{3+}(aq) + MnO_4^-(aq)$
   e. $H_3AsO_4(aq) + Zn(s) \rightarrow AsH_3(g) + Zn^{2+}(aq)$
   f. $As_2O_3(s) + NO_3^-(aq) \rightarrow H_3AsO_4(aq) + NO(g)$
   g. $Br^-(aq) + MnO_4^-(aq) \rightarrow Br_2(l) + Mn^{2+}(aq)$
   h. $CH_3OH(aq) + Cr_2O_7^{2-}(aq) \rightarrow CH_2O(aq) + Cr^{3+}(aq)$

61. Balance the following oxidation-reduction reactions, which occur in basic solution, using the half-reaction method.
   a. $Al(s) + MnO_4^-(aq) \rightarrow MnO_2(s) + Al(OH)_4^-(aq)$
   b. $Cl_2(g) \rightarrow Cl^-(aq) + ClO^-(aq)$
   c. $NO_2^-(aq) + Al(s) \rightarrow NH_3(g) + AlO_2^-(aq)$
   d. $MnO_4^-(aq) + S^{2-}(aq) \rightarrow MnS(s) + S(s)$
   e. $CN^-(aq) + MnO_4^-(aq) \rightarrow CNO^-(aq) + MnO_2(s)$

62. Balance the following equations by the half-reaction method:

a. $Fe(s) + HCl(aq) \rightarrow HFeCl_4(aq) + H_2(g)$

b. $IO_3^-(aq) + I^-(aq) \xrightarrow{(acid)} I_3^-(aq)$

c. $Cr(NCS)_6^{4-}(aq) + Ce^{4+}(aq) \xrightarrow{(acid)} Cr^{3+}(aq) + Ce^{3+}(aq) + NO_3^-(aq) + CO_2(g) + SO_4^{2-}(aq)$

d. $CrI_3(s) + Cl_2(g) \xrightarrow{(base)} CrO_4^{2-}(aq) + IO_4^-(aq) + Cl^-(aq)$

e. $Fe(CN)_6^{4-}(aq) + Ce^{4+}(aq) \xrightarrow{(base)} Ce(OH)_3(s) + Fe(OH)_3(s) + CO_3^{2-}(aq) + NO_3^-(aq)$

f. $Fe(OH)_2(s) + H_2O_2(aq) \xrightarrow{(base)} Fe(OH)_3(s)$

63. The Ostwald process for the commercial production of nitric acid involves the following three steps:

$$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$$
$$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$$
$$3NO_2(g) + H_2O(l) \rightarrow 2HNO_3(aq) + NO(g)$$

a. Which reactions in the Ostwald process are oxidation-reduction reactions?

b. Identify the oxidizing agent and the reducing agent in those that are.

c. How much nitric oxide, NO, can be produced from a mixture of

5.0×10^6 g of ammonia and 5.0×10^7 g of O_2?

64. Chlorine gas was first prepared in 1774 by C. W. Scheele by oxidizing hydrochloric acid with manganese(IV) oxide. The reaction is

$$NaCl(aq) + H_2SO_4(aq) + MnO_2(s) \rightarrow Na_2SO_4(aq) + MnCl_2(aq) + H_2O(l) + Cl_2(g)$$

Balance this reaction by the oxidation number method.

65. One of the classical methods for the determination of the manganese content in steel is to convert all the manganese to the deeply colored permanganate ion and then to measure the absorption of light. The steel is dissolved in nitric acid, producing the manganese(II) ion and nitrogen dioxide gas. This solution is then reacted with an acidic solution containing periodate ion; the products are the permanganate and iodate ions. Write balanced chemical equations for both of these steps.

66. Gold metal will not dissolve in either concentrated nitric acid or concentrated hydrochloric acid. It will dissolve, however, in *aqua regia*, a mixture of the two concentrated acids. The products of the reaction are the $AuCl_4^-$ ion and gaseous NO. Write a balanced equation for the dissolution of gold in aqua regia.

67. A solution of permanganate is standardized by titration with oxalic acid ($H_2C_2O_4$). It required 28.97 mL of the permanganate solution to react completely with 0.1058 g of oxalic acid. The unbalanced equation for the reaction is

$$MnO_4^-(aq) + H_2C_2O_4(aq) \xrightarrow{Acid} Mn^{2+}(aq) + CO_2(g)$$

What is the molarity of the permanganate solution?

68. A 50.00-mL sample of solution containing Fe^{2+} ions is titrated with a 0.0216 *M* $KMnO_4$ solution. It required 20.62 mL of the $KMnO_4$ solution to oxidize all of the Fe^{2+} ions to Fe^{3+} ions by the reaction:

$$MnO_4^-(aq) + Fe^{2+}(aq) \xrightarrow{Acid} Mn^{2+}(aq) + Fe^{3+}(aq) \quad \text{(Unbalanced)}$$

a. What was the concentration of Fe^{2+} ions in the sample solution?

b. What volume of 0.0150 *M* $K_2Cr_2O_7$ solution would it take to do the same titration? The reaction is

$$Cr_2O_7^{2-}(aq) + Fe^{2+}(aq) \xrightarrow{Acid} Cr^{3+}(aq) + Fe^{3+}(aq) \quad \text{(Unbalanced)}$$

69. The iron content of iron ore can be determined by titration with standard $KMnO_4$ solution. The iron ore is dissolved in HCl, and all of the iron is reduced to Fe^{2+} ions. This solution is then titrated with $KMnO_4$ solution, producing Fe^{3+} and Mn^{2+} ions in acidic solution. If it required 41.95 mL of 0.0205 *M* $KMnO_4$ to titrate a solution made from 0.6128 g of iron ore, what is the mass percent of iron in the iron ore?

70. The legal definition of intoxication in some states is a blood alcohol (C_2H_5OH) level of 0.1% by mass or higher. It required 35.48 mL of 0.05182 *M* $K_2Cr_2O_7$ to titrate a 50.02-g sample of blood.

a. Assuming only C_2H_5OH reacts with $K_2Cr_2O_7$, was the person from whom this blood was taken legally intoxicated? (See Sample Exercise 4.23.)

b. What would be your answer to part a if instead it required 48.02 mL of the same $K_2Cr_2O_7$ dichromate solution to titrate 48.91 g of blood?

71. Stibnite (Sb_2S_3) is the most important ore containing antimony. A 0.506 g sample of ore was chemically treated to produce antimony(III) ions in solution. The antimony(III) was oxidized to antimony(V) by adding 25.00 mL of 0.0233 *M* $KMnO_4$ solution. The excess $KMnO_4$ was titrated with 0.0843 *M* Fe^{2+}; 2.58 mL was required, producing $Fe^{3+}(aq)$ and $Mn^{2+}(aq)$. All reactions were carried out in acidic solutions. Calculate the mass percent of Sb_2S_3 in the sample.

72. What mass of CO_2 is produced from the reaction of 0.500 g of $Na_2C_2O_4$ with 50.00 mL of 0.0200 *M* $KMnO_4$ solution in the presence of acid? (See Exercise 67.)

73. A piece of copper metal (1.50 g) is placed in 250 mL of a 0.20 *M* $AgNO_3$ solution. Will all of the copper dissolve in this solution? The net ionic equation is

$$Cu(s) + 2Ag^+(aq) \rightarrow 2Ag(s) + Cu^{2+}(aq)$$