APPENDIX B

ANSWERS TO PRACTICE EXERCISES AND SELECTED REVIEW PROBLEMS

CHAPTER 1

Practice Exercises

1.1 meter^3 or m^3. **1.2** $\text{kg}\left(\frac{\text{m}}{\text{s}^2}\right)$ or kg m s^{-2}. **1.3** 187 °C.

1.4 10 °C, 293 K. **1.5** (a) 42.0 g, (b) 0.857 g/mL, (c) 149 cm. **1.6** (a) 30.0 mL, (b) 54.155 g, (c) 11.3 g, (d) 3.62 ft, (e) 0.48 m^2. **1.7** 11.5 m^2. **1.8** (a) 108 in., (b) 1.25×10^5 cm, (c) 0.0107 ft, (d) 8.59 km L^{-1}. **1.9** $d = 16.5$ g cm^{-3}. The object is not composed of pure gold. **1.10** 647 lb. **1.11** 0.899 g/cm^3. **1.12** 0.0568 cm^3

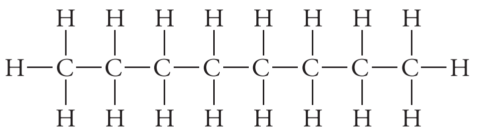
Review Problems

1.26 (a) 0.01 m, (b) 1000 m, (c) 10^{12} pm, (d) 0.1 m, (e) 0.001 kg, (f) 0.01 g. **1.28** (a)120 °F, (b) 50 °F, (c) −3.61 °C, (d) 9.4 °C, (e) 333 K, (f) 243 K. **1.30** At 39.7 °C, this dog has a fever; the temperature is out of normal canine range. **1.32** 1.0×10^7 K − 2.5×10^7 K, 1.0×10^7 °C − 2.5×10^7 °C, 1.8×10^7 °F − 4.5×10^7 °F. **1.34** −269 °C. **1.36** (a) 4 significant figures, (b) 5 significant figures, (c) 4 significant figures, (d) 2 significant figures, (e) 4 significant figures, (f) 2 significant figures. **1.38** (a) 0.72 m^2, (b) 84.24 kg, (c) 4.19 g/mL, (d) 19.42 g/mL, (e) 857.7 cm^2. **1.40** (a) 11.5 km/h, (b) 8.2×10^6 µg/L, (c) 7.53×10^{-5} kg, (d) 0.1375 L, (e) 25 mL, (f) 3.42×10^{-20} dm. **1.42** (a) 91 cm, (b) 2.3 kg, (c) 2800 mL, (d) 200 mL, (e) 88 km/hr, (f) 80.4 km. **1.44** (a) 7,800 cm^2, (b) 577 km^2, (c) 6.54×10^6 cm^3. **1.46** 4,000 pistachios. **1.48** 90 m/s. **1.50** 1520 mi/hr. **1.52** 5.1×10^{13} mi. **1.54** 11,034 m. **1.56** 0.798 g/mL. **1.58** 31.6 mL. **1.60** 276 g. **1.62** 11 g/mL. **1.64** 0.0709 g/mL

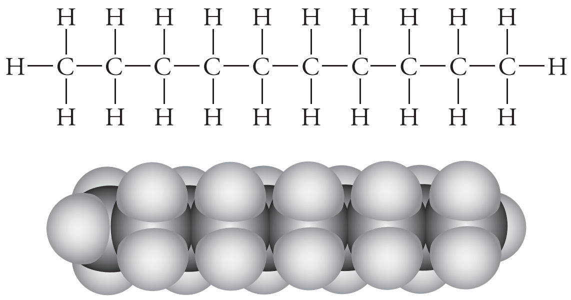
CHAPTER 2

Practice Exercises

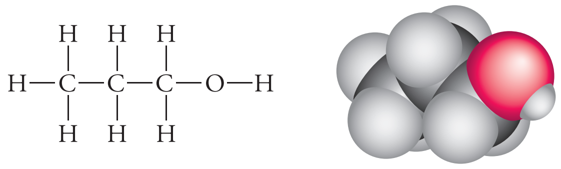
2.1 12.3 g Cd. **2.2** Compounds A and D are the same, as are compounds B and C. **2.3** $^{240}_{94}\text{Pu}$ 94 electrons. **2.4** $^{35}_{17}\text{Cl}$ 17 protons, 17 electrons, and 18 neutrons. **2.5** We can discard the 17 since the 17 tells the number of protons which is information that the symbol “Cl” also provides. In addition, the number of protons equals the number of electrons in a neutral atom, so the symbol “Cl” also indicates the number of electrons. The 35 is necessary to state which isotope of chlorine is in question and therefore the number of neutrons in the atom. **2.6** 26.9814 u. **2.7** 5.2955 times as heavy as carbon. **2.8** 10.8 u. **2.9** (a) 1 Ni, 2 Cl, (b) 1 Fe, 1 S, 4 O, (c) 3 Ca, 2 P, 8 O, (d) 1 Co, 2 N, 12 O, 12 H. **2.10** (a) 2 N nitrogen, 4 H hydrogen, 3 O oxygen, (b) 1 Fe iron, 1 N nitrogen, 4 H hydrogen, 2 S sulfur, 8 O oxygen, (c) 1 Mo molybdenum, 2 N nitrogen, 11 O oxygen, 10 H hydrogen, (d) 6 C carbon, 4 H hydrogen, 1 Cl chlorine, 1 N nitrogen, 2 O oxygen. **2.11** 1 Mg, 2 O, 4 H, and 2 Cl. **2.12** $\text{Mg(OH)}_2(s) + 2\text{HCl}(aq) \longrightarrow \text{MgCl}_2(aq) + 2\text{H}_2\text{O}$. **2.13** 6 N, 42 H, 2 P, 20 O, 3 Ba, and 12 C. **2.14** $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$



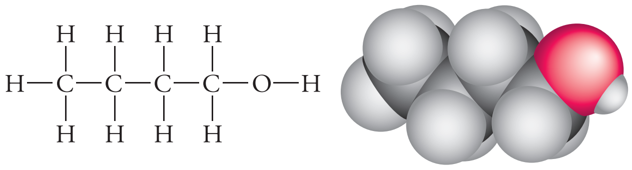
2.15 $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$



2.16 (a) $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$



(b) $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$



2.17 (a) 26 protons and 26 electrons, (b) 26 protons and 23 electrons, (c) 7 protons and 10 electrons, (d) 7 protons and 7 electrons. **2.18** (a) 8 protons and 8 electrons, (b) 8 protons and 10 electrons, (c) 13 protons and 10 electrons, (d) 13 protons and 13 electrons. **2.19** (a) NaF, (b) Na_2O, (c) MgF_2, (d) Al_4C_3. **2.20** (a) Ca_3N_2, (b) AlBr_3, (c) Na_3P, d) CsCl. **2.21** (a) CrCl_3 and CrCl_2, Cr_2O_3 and CrO, (b) CuCl, CuCl_2, Cu_2O and CuO. **2.22** (a) Au_2S and Au_2S_3, Au_3N and AuN, (b) SnS and SnS_2, Sn_3N_2 and Sn_3N_4. **2.23** (a) $\text{KC}_2\text{H}_3\text{O}_2$, (b) $\text{Sr(NO}_3)_2$, (c) $\text{Fe(C}_2\text{H}_3\text{O}_2)_3$. **2.24** (a) Na_2CO_3, (b) $(\text{NH}_4)_2\text{SO}_4$. **2.25** (a) phosphorous trichloride, (b) sulfur dioxide, (c) dichlorine heptaoxide. **2.26** (a) AsCl_5, (b) SCl_6, (c) S_2Cl_2. **2.27** (a) K_2O, (b) BaBr_2, (c) Na_3N, (d) Al_2S_3. **2.28** (a) aluminum chloride, (b) barium sulfide, (c) sodium bromide, (d) calcium fluoride. **2.29** (a) postassium sulfide, (b) magnesium phosphide, (c) nickel(II) chloride, (d) iron(III) oxide. **2.30** (a) Al_2S_3, (b) SrF_2, (c) TiO_2, (d) Au_2O_3. **2.31** (a) lithium carbonate, (b) iron(III) hydroxide. **2.32** (a) KClO_3, (b) $\text{Ni}_3(\text{PO}_4)_2$. **2.33** diiodine pentaoxide. **2.34** chromium(III) acetate

Review Problems

2.76 $x = 29.3$ g nitrogen. **2.78** 5.54 g ammonia. **2.80** 2.286 g of O. **2.82** 1.008 u. **2.84** 2.01588 u. **2.86** $(0.6917 \times 62.9396\ \text{u}) + (0.3083 \times 64.9278\ \text{u}) = 63.55\ \text{u}$.

2.88

	neutrons	*protons*	*electrons*
(a) Radium-226	138	88	88
(b) ^{206}Pb	124	82	82
(c) Carbon-14	8	6	6
(d) ^{23}Na	12	11	11

2.90 1 Cr, 6 C, 9 H, 6 O. **2.92** $MgSO_4$. **2.94** (a) 2 K, 2 C, 4 O, (b) 2 H, 1 S, 3 O, (c) 12 C, 26 H, (d) 4 H, 2 C, 2 O, (e) 9 H, 2 N, 1 P, 4 O. **2.96** (a) 1 Ni, 2 Cl, 8 O, (b) 1 Cu, 1 C, 3 O, (c) 2 K, 2 Cr, 7 O, (d) 2 C, 4 H, 2 O, (e) 2 N, 9 H, 1 P, 4 O. **2.98** (a) 6 N, 3 O, (b) 4 Na, 4 H, 4 C, 12 O, (c) 2 Cu, 2 S, 18 O, 20 H. **2.100** (a) 6, (b) 3, (c) 27. **2.102** (a) K^+, (b) Br^-, (c) Mg^{2+}, (d) S^{2-}, (e) Al^{3+}. **2.104** (a) NaBr, (b) KI, (c) BaO, (d) $MgBr_2$, (e) BaF_2. **2.106** (a) KNO_3, (b) $Ca(C_2H_3O_2)_2$, (c) NH_4Cl, (d) $Fe_2(CO_3)_3$, (e) $Mg_3(PO_4)_2$. **2.108** (a) PbO and PbO_2, (b) SnO and SnO_2, (c) MnO and Mn_2O_3, (d) FeO and Fe_2O_3, (e) Cu_2O and CuO. **2.110** (a) silicon dioxide, (b) xenon tetrafluoride, (c) tetraphosphorus decaoxide, (d) dichlorine heptaoxide. **2.112** (a) calcium sulfide, (b) aluminum bromide, (c) sodium phosphide, (d) barium arsenide, (e) rubidium sulfide. **2.114** (a) iron(II) sulfide, (b) copper(II) oxide, (c) tin(IV) oxide, (d) cobalt(II) chloride hexahydrate. **2.116** (a) sodium nitrite, (b) potassium permanganate, (c) magnesium sulfate heptahydrate, (d) potassium thiocyanate. **2.118** (a) ionic, chromium(II) chloride, (b) molecular, disulfur dichloride, (c) ionic, ammonium acetate, (d) molecular, sulfur trioxide, (e) ionic, potassium iodate, (f) molecular, tetraphosphorous hexaoxide, (g) ionic, calcium sulfite, (h) ionic, silver cyanide, (i) ionic, zinc(II) bromide, (j) molecular, hydrogen selenide. **2.120** (a) Na_2HPO_4, (b) Li_2Se, (c) $Cr(C_2H_3O_2)_3$, (d) S_2F_{10}, (e) $Ni(CN)_2$, (f) Fe_2O_3, (g) SbF_5. **2.122** (a) $(NH_4)_2S$, (b) $Cr_2(SO_4)_3{\cdot}6H_2O$, (c) SiF_4, (d) MoS_2, (e) $SnCl_4$, (f) H_2Se, (g) P_4S_7. **2.124** diselenium hexasulfide and diselenium tetrasulfide

CHAPTER 3

Practice Exercises

3.1 0.129 mol Al. **3.2** $\pm 7.12 \times 10^{-5}$ mol Si. **3.3** Yes. **3.4** 3.5×10^{18} molecules of sucrose. **3.5** 0.0516 mol Al^{3+}. **3.6** 3.44 mol N atoms. **3.7** 59.5 g Fe. **3.8** 10.5 g Fe. **3.9** 27.9 g Fe. **3.10** 13.04% H, 52.17% C. It is likely that the compound contains another element. **3.11** 36.84% N, 63.16% O, There are no other elements present. **3.12** 30.45% N, 69.55% O.

3.13

N_2O:	63.65% N	36.34% O
NO:	46.68% N	53.32% O
NO_2:	30.45% N	69.55% O
N_2O_3:	36.86% N	63.14% O
N_2O_4:	30.45% N	69.55% O
N_2O_5:	25.94% N	74.06% O

The compound N_2O_3 corresponds to the data in Practice Exercise 3.11. **3.14** NO. **3.15** SO_2. **3.16** Al_2O_3. **3.17** N_2O_5. **3.18** Na_2SO_4. **3.19** C_9H_8O. **3.20** CS_2. **3.21** CH_2O. **3.22** $C_2H_4Cl_2$ and $C_6H_6Cl_6$. **3.23** N_2H_4.

3.24 $AlCl_3(aq) + Na_3PO_4(aq) \longrightarrow AlPO_4(s) + 3NaCl(aq)$.

3.25 $3CaCl_2(aq) + 2K_3PO_4(aq) \longrightarrow Ca_3(PO_4)_2(s) + 6KCl(aq)$.

3.26 3.38 mol O_2. **3.27** 0.183 mol H_2SO_4. **3.28** 78.5 g Al_2O_3. **3.29** 1.18×10^2 g CO_2. **3.30** 55.0 g CO_2, 34 g HCl remaining. **3.31** 30.01 g NO. **3.32** 36.78 g $HOOCC_6H_4O_2C_2O_3$, 83.5%. **3.33** 30.9 g $HC_2H_3O_2$, 86.1%

Review Problems

3.25 1:2, 2 mol N to 4 mol O. **3.27** 2.59×10^{-3} mole Ta. **3.29** (a) 6 atom C:11 atom H, (b) 12 mole C:11 mole O, (c) 12 atom H:11 atom O, (d) 12 mole H:11 mole O. **3.31** 1.05 mol Bi. **3.33** 4.32 mol Cr.

3.35 (a) $\left(\dfrac{2\text{ mol Al}}{3\text{ mol S}}\right)$ or $\left(\dfrac{3\text{ mol S}}{2\text{ mol Al}}\right)$,

(b) $\left(\dfrac{3\text{ mol S}}{1\text{ mol } Al_2(SO_4)_3}\right)$ or $\left(\dfrac{1\text{ mol } Al_2(SO_4)_3}{3\text{ mol S}}\right)$,

(c) 0.600 mol Al, (d) 3.48 mol S. **3.37** 0.0725 mol N_2, 0.218 mole H_2. **3.39** 0.833 mol CF_4. **3.41** 9.33×10^{23} atoms C. **3.43** 3.76×10^{24} atoms. **3.45** 3.01×10^{23} atoms C–12. **3.47** (a) 75.4 g Fe, (b) 392 g O, (c) 35.1 g Ca. **3.49** 1.30×10^{-10} g K. **3.51** 0.302 mol Ni. **3.53** (a) $NaHCO_3$ 84.0066 g/mol, (b) $(NH_4)_2CO_3$ 96.0858 g/mol, (c) $CuSO_4{\cdot}5H_2O$ 249.685 g/mole, (d) $K_2Cr_2O_7$ 294.1846 g/mole, (e) $Al_2(SO_4)_3$ 342.151 g/mol. **3.55** (a) 388 g $Ca_3(PO_4)_2$, (b) 0.151 g $Fe(NO_3)_3$, (c) 34.9 g C_4H_{10}, (d) 1.39×10^{-4} g $(NH_4)_2CO_3$. **3.57** (a) 0.215 mol $CaCO_3$, (b) 9.16×10^{-11} mol NH_3, (c) 7.94×10^{-2} mol $Sr(NO_3)_2$, (d) 4.31×10^{-8} mol Na_2CrO_4. **3.59** 0.0750 mol Ca, 3.01 g Ca. **3.61** 1.30 mol N, 62.5 g $(NH_4)_2CO_3$. **3.63** 3.43 kg fertilizer. **3.65** Assume one mole total for each of the following.

(a) 19.2% Na	1.68% H	25.8% P	53.3% O
(b) 12.2% N	5.26% H	26.9% P	55.6% O
(c) 62.0% C	10.4% H	27.6% O	
(d) 23.3% Ca	18.6% S	55.7% O	2.34% H
(e) 23.3% Ca	18.6% S	55.7% O	2.34% H.

3.67 Heroin. **3.69** Freon 141b. **3.71** 22.9% P, 77.1% Cl. **3.73** These data are consistent with the experimental values cited in the problem. **3.75** 0.474 g O. **3.77** (a) SCl, (b) CH_2O (c) NH_3, (d) AsO_3, (e) HO. **3.79** $NaTcO_4$. **3.81** CCl_2. **3.83** $C_9H_8O_2$. **3.85** C_2H_6O. **3.87** $C_{19}H_{30}O_2$. **3.89** (a) $Na_2S_4O_6$, (b) $C_6H_4Cl_2$, (c) $C_6H_3Cl_3$. **3.91** $C_{19}H_{30}O_2$. **3.93** HgBr, Hg_2Br_2. **3.95** CHNO, $C_3H_3N_3O_3$. **3.97** 36 mol H. **3.99** $4Fe(s) + 3O_2(g) \longrightarrow 2Fe_2O_3(s)$.

3.101 (a) $Ca(OH)_2 + 2HCl \longrightarrow CaCl_2 + 2H_2O$,
(b) $2AgNO_3 + CaCl_2 \longrightarrow Ca(NO_3)_2 + 2AgCl$,
(c) $Pb(NO_3)_2 + Na_2SO_4 \longrightarrow PbSO_4 + 2NaNO_3$,
(d) $2Fe_2O_3 + 3C \longrightarrow 4Fe + 3CO_2$,
(e) $2C_4H_{10} + 13O_2 \longrightarrow 8CO_2 + 10H_2O$.

3.103 (a) $Mg(OH)_2 + 2HBr \longrightarrow MgBr_2 + 2H_2O$,
(b) $2HCl + Ca(OH)_2 \longrightarrow CaCl_2 + 2H_2O$,
(c) $Al_2O_3 + 3H_2SO_4 \longrightarrow Al_2(SO_4)_3 + 3H_2O$,
(d) $2KHCO_3 + H_3PO_4 \longrightarrow K_2HPO_4 + 2H_2O + 2CO_2$,
(e) $C_9H_{20} + 14O_2 \longrightarrow 9CO_2 + 10H_2O$.

3.105 $2FeCl_3 + SnCl_2 \longrightarrow 2FeCl_2 + SnCl_4$.

3.107 (a) 0.030 mol $Na_2S_2O_3$, (b) 0.24 mol HCl, (c) 0.15 mol H_2O, (d) 0.15 mol H_2O. **3.109** (a) 3.6 g Zn, (b) 22 g Au, (c) 55 g $Au(CN)_2^{\,-}$. **3.111** (a) $4P + 5O_2 \longrightarrow P_4O_{10}$, (b) 8.85 g O_2, (c) 14.2 g P_4O_{10}, (d) 3.26 g P. **3.113** 30.28 g HNO_3. **3.115** 0.47 kg O_2. **3.117** (a) Fe_2O_3, (b) 195 g Fe. **3.119** 26.7 g $FeCl_3$. **3.121** 0.913 mg HNO_3. **3.123** 66.98 g $BaSO_4$, 96.22%. **3.125** 88.72%. **3.127** 9.2 g C_7H_8

CHAPTER 4

Practice Exercises

4.1 (a) $FeCl_3(s) \longrightarrow Fe^{3+}(aq) + 3Cl^-(aq)$,
(b) $K_3PO_4(s) \longrightarrow 3K^+(aq) + PO_4^{\,3-}(aq)$.

4.2 (a) $MgCl_2(s) \longrightarrow Mg^{2+}(aq) + 2Cl^-(aq)$,
(b) $Al(NO_3)_3(s) \longrightarrow Al^{3+}(aq) + 3NO_3^{\,-}(aq)$,
(c) $Na_2CO_3(s) \longrightarrow 2Na^+(aq) + CO_3^{\,2-}(aq)$.

4.3 molecular: $(NH_4)_2SO_4(aq) + Ba(NO_3)_2(aq) \longrightarrow BaSO_4(s) + 2NH_4NO_3(aq)$,
ionic: $2NH_4^{\,+}(aq) + SO_4^{\,2-}(aq) + Ba^{2+}(aq) + 2NO_3^{\,-}(aq) \longrightarrow BaSO_4(s) + 2NH_4^{\,+}(aq) + 2NO_3^{\,-}(aq)$,
net ionic: $Ba^{2+}(aq) + SO_4^{\,2-}(aq) \longrightarrow BaSO_4(s)$.

4.4 molecular: $CdCl_2(aq) + Na_2S(aq) \longrightarrow CdS(s) + 2NaCl(aq)$,

ionic: $Cd^{2+}(aq) + 2Cl^-(aq) + 2Na^+(aq) + S^{2-}(aq) \longrightarrow CdS(s) + 2Na^+(aq) + 2Cl^-(aq)$,
net ionic: $Cd^{2+}(aq) + S^{2-}(aq) \longrightarrow CdS(s)$.
4.5 $HCHO_2(aq) + H_2O \longrightarrow H_3O^+(aq) + CHO_2^-(aq)$.
4.6 $H_3C_6H_5O_7(s) + H_2O \longrightarrow H_3O^+(aq) + H_2C_6H_5O_7^-(aq)$,
$H_2C_6H_5O_7^-(aq) + H_2O \longrightarrow H_3O^+(aq) + HC_6H_5O_7^{2-}(aq)$,
$HC_6H_5O_7^{2-}(aq) + H_2O \longrightarrow H_3O^+(aq) + C_6H_5O_7^{3-}(aq)$.
4.7 $(C_2H_5)_3N(aq) + H_2O \longrightarrow (C_2H_5)_3NH^+(aq) + OH^-(aq)$.
4.8 $HONH_2(aq) + H_2O \longrightarrow HONH_3^+(aq) + OH^-(aq)$.
4.9 $CH_3NH_2(aq) + H_2O \rightleftharpoons CH_3NH_3^+(aq) + OH^-(aq)$.
4.10 $HNO_2(aq) + H_2O \rightleftharpoons H_3O^+(aq) + NO_2^-(aq)$.
4.11 Sodium arsenate. **4.12** Calcium formate. **4.13** HF: Hydrofluoric acid, sodium salt = sodium fluoride (NaF), HBr: Hydrobromic acid, sodium salt = sodium bromide (NaBr).
4.14 $NaHSO_3$, sodium hydrogen sulfite.
4.15 $H_3PO_4(aq) + NaOH(aq) \longrightarrow NaH_2PO_4(aq) + H_2O$
sodium dihydrogen phosphate,
$NaH_2PO_4(aq) + NaOH(aq) \longrightarrow Na_2HPO_4(aq) + H_2O$
sodium hydrogen phosphate,
$Na_2HPO_4(aq) + NaOH(aq) \longrightarrow Na_3PO_4(aq) + H_2O$
sodium phosphate.
4.16 molecular: $Zn(NO_3)_2(aq) + Ca(C_2H_3O_2)_2(aq) \longrightarrow Zn(C_2H_3O_2)_2(aq) + Ca(NO_3)_2(aq)$,
ionic: $Zn^{2+}(aq) + 2NO_3^-(aq) + Ca^{2+}(aq) + 2C_2H_3O_2^-(aq) \longrightarrow Zn^{2+}(aq) + 2C_2H_3O_2^-(aq) + Ca^{2+}(aq) + 2NO_3^-(aq)$,
net ionic: No reaction.
4.17 (a) molecular: $AgNO_3(aq) + NH_4Cl(aq) \longrightarrow AgCl(s) + NH_4NO_3(aq)$,
ionic: $Ag^+(aq) + NO_3^-(aq) + NH_4^+(aq) + Cl^-(aq) \longrightarrow AgCl(s) + NH_4^+(aq) + NO_3^-(aq)$,
net ionic: $Ag^+(aq) + Cl^-(aq) \longrightarrow AgCl(s)$,
(b) molecular: $Na_2S(aq) + Pb(C_2H_3O_2)_2(aq) \longrightarrow 2NaC_2H_3O_2(aq) + PbS(s)$,
ionic: $2Na^+(aq) + S^{2-}(aq) + Pb^{2+}(aq) + 2C_2H_3O_2^-(aq) \longrightarrow 2Na^+(aq) + 2C_2H_3O_2^-(aq) + PbS(s)$,
net ionic: $S^{2-}(aq) + Pb^{2+}(aq) \longrightarrow PbS(s)$.
4.18 molecular: $2HNO_3(aq) + Ca(OH)_2(aq) \longrightarrow Ca(NO_3)_2(aq) + 2H_2O$,
ionic: $2H^+(aq) + 2NO_3^-(aq) + Ca^{2+}(aq) + 2OH^-(aq) \longrightarrow Ca^{2+}(aq) + 2NO_3^-(aq) + 2H_2O$,
net ionic: $H^+(aq) + OH^-(aq) \longrightarrow H_2O$.
4.19 (a) molecular: $HCl(aq) + KOH(aq) \longrightarrow H_2O + KCl(aq)$,
ionic: $H^+(aq) + Cl^-(aq) + K^+(aq) + OH^-(aq) \longrightarrow H_2O + K^+(aq) + Cl^-(aq)$,
net ionic: $H^+(aq) + OH^-(aq) \longrightarrow H_2O$,
(b) molecular: $HCHO_2(aq) + LiOH(aq) \longrightarrow H_2O + LiCHO_2(aq)$,
ionic: $HCHO_2(aq) + Li^+(aq) + OH^-(aq) \longrightarrow H_2O + Li^+(aq) + CHO_2^-(aq)$,
net ionic: $HCHO_2(aq) + OH^-(aq) \longrightarrow H_2O + CHO_2^-(aq)$,
(c) molecular: $N_2H_4(aq) + HCl(aq) \longrightarrow N_2H_5Cl(aq)$,
ionic: $N_2H_4(aq) + H^+(aq) + Cl^-(aq) \longrightarrow N_2H_5^+(aq) + Cl^-(aq)$,
net ionic: $N_2H_4(aq) + H^+(aq) \longrightarrow N_2H_5^+(aq)$.
4.20 molecular: $CH_3NH_2(aq) + HCHO_2(aq) \longrightarrow CH_3NH_3CHO_2(aq)$,
ionic: $CH_3NH_2(aq) + HCHO_2(aq) \longrightarrow CH_3NH_3^+(aq) + CHO_2^-(aq)$,
net ionic: $CH_3NH_2(aq) + HCHO_2(aq) \longrightarrow CH_3NH_3^+(aq) + CHO_2^-(aq)$.
4.21 molecular: $2HCHO_2(aq) + Co(OH)_2(s) \longrightarrow Co(CHO_2)_2(aq) + 2H_2O$,
ionic: $2HCHO_2(aq) + Co(OH)_2(s) \longrightarrow 2CHO_2^-(aq) + Co^{2+}(aq) + 2H_2O$,
net ionic: $2HCHO_2(aq) + Co(OH)_2(s) \longrightarrow 2CHO_2^-(aq) + Co^{2+}(aq) + 2H_2O$,
4.22 (a) Formic acid, a weak acid will form. Molecular: $KCHO_2(aq) + HCl(aq) \longrightarrow KCl(aq) + HCHO_2(aq)$,
ionic: $K^+(aq) + CHO_2^-(aq) + H^+(aq) + Cl^-(aq) \longrightarrow K^+(aq) + Cl^-(aq) + HCHO_2(aq)$,
net ionic: $CHO_2^-(aq) + H^+(aq) \longrightarrow HCHO_2(aq)$,
(b) Carbonic acid will form and it will further dissociate to water and carbon dioxide:
$CuCO_3(s) + 2H^+(aq) \longrightarrow CO_2(g) + H_2O + Cu^{2+}(aq)$,
molecular: $CuCO_3(s) + 2HC_2H_3O_2(aq) \longrightarrow CO_2(g) + H_2O + Cu(C_2H_3O_2)_2(aq)$,
ionic: $CuCO_3(s) + 2HC_2H_3O_2(aq) \longrightarrow CO_2(g) + H_2O + Cu^{2+}(aq) + 2C_2H_3O_2^-(aq)$,
net ionic: $CuCO_3(s) + 2HC_2H_3O_2(aq) \longrightarrow CO_2(g) + H_2O + Cu^{2+}(aq) + 2C_2H_3O_2^-(aq)$,
c) NR, d) Insoluble nickel hydroxide will precipitate:
$Ni^{2+}(aq) + 2OH^-(aq) \longrightarrow Ni(OH)_2(s)$,
molecular: $NiCl_2(aq) + 2NaOH(aq) \longrightarrow Ni(OH)_2(s) + 2NaCl(aq)$,
ionic: $Ni^{2+}(aq) + 2Cl^-(aq) + 2Na^+(aq) + 2OH^-(aq) \longrightarrow Ni(OH)_2(s) + 2Na^+(aq) + 2Cl^-(aq)$,
net ionic: $Ni^{2+}(aq) + 2OH^-(aq) \longrightarrow Ni(OH)_2(s)$.
4.23 1.53 M HNO_3. **4.24** 0.1837 M NaCl.
4.25 0.0438 mol HCl. **4.26** 143 mL. **4.27** 2.11 g $Sr(NO_3)_2$.
4.28 0.531 g $AgNO_3$. **4.29** 250.0 mL. **4.30** 600 mL of water.
4.31 31.6 mL H_3PO_4. **4.32** 26.8 mL NaOH. **4.33** 0.40 M Fe^{3+}, 1.2 M Cl^-. **4.34** 0.750 M Na^+. **4.35** 0.0449 M $CaCl_2$.
4.36 60.0 mL KOH. **4.37** 0.605 g Na_2SO_4.
4.38 (a) 5.41×10^{-3} mol Ca^{2+}, (b) 5.41×10^{-3} moles Ca^{2+}, (c) 5.41×10^{-3} moles $CaCl_2$, (d) 0.600 g $CaCl_2$, (e) 30.0% $CaCl_2$.
4.39 0.178 M H_2SO_4. **4.40** 0.0220 M HCl, 0.0803%

Review Problems

4.49 (a) ionic:
$2NH_4^+(aq) + CO_3^{2-}(aq) + Mg^{2+}(aq) + 2Cl^-(aq) \longrightarrow 2NH_4^+(aq) + 2Cl^-(aq) + MgCO_3(s)$,
net: $Mg^{2+}(aq) + CO_3^{2-}(aq) \longrightarrow MgCO_3(s)$,
(b) ionic: $Cu^{2+}(aq) + 2Cl^-(aq) + 2Na^+(aq) + 2OH^-(aq) \longrightarrow Cu(OH)_2(s) + 2Na^+(aq) + 2Cl^-(aq)$,
net: $Cu^{2+}(aq) + 2OH^-(aq) \longrightarrow Cu(OH)_2(s)$,
(c) ionic: $3Fe^{2+}(aq) + 3SO_4^{2-}(aq) + 6Na^+(aq) + 2PO_4^{3-}(aq) \longrightarrow Fe_3(PO_4)_2(s) + 6Na^+(aq) + 3SO_4^{2-}(aq)$,
net: $3Fe^{2+}(aq) + 2PO_4^{3-}(aq) \longrightarrow Fe_3(PO_4)_2(s)$,
(d) ionic: $2Ag^+(aq) + 2C_2H_3O_2^-(aq) + Ni^{2+}(aq) + 2Cl^-(aq) \longrightarrow 2AgCl(s) + Ni^{2+}(aq) + 2C_2H_3O_2^-(aq)$,
net: $Ag^+(aq) + Cl^-(aq) \longrightarrow AgCl(s)$.
4.51 $HClO_4(l) + H_2O \longrightarrow H_3O^+(aq) + ClO_4^-(aq)$.
4.53 $N_2H_4(aq) + H_2O \rightleftharpoons N_2H_5^+(aq) + OH^-(aq)$.
4.55 $HNO_2(aq) + H_2O \rightleftharpoons H_3O^+(aq) + NO_2^-(aq)$.
4.57 $H_2CO_3(aq) + H_2O \rightleftharpoons H_3O^+(aq) + HCO_3^-(aq)$,
$HCO_3^-(aq) + H_2O \rightleftharpoons H_3O^+(aq) + CO_3^{2-}(aq)$
4.59 (a) ionic:
$3Fe^{2+}(aq) + 3SO_4^{2-}(aq) + 6K^+(aq) + 2PO_4^{3-}(aq) \longrightarrow Fe_3(PO_4)_2(s) + 6K^+(aq) + 3SO_4^{2-}(aq)$,
net: $3Fe^{2+}(aq) + 2PO_4^{3-}(aq) \longrightarrow Fe_3(PO_4)_2(s)$,
(b) ionic: $3Ag^+(aq) + 3C_2H_3O_2^-(aq) + Al^{3+}(aq) + 3Cl^-(aq) \longrightarrow 3AgCl(s) + Al^{3+}(aq) + 3C_2H_3O_2^-(aq)$,
net: $Ag^+(aq) + Cl^-(aq) \longrightarrow AgCl(s)$.
4.61 molecular: $Na_2S(aq) + Cu(NO_3)_2(aq) \longrightarrow CuS(s) + 2NaNO_3(aq)$,
ionic: $2Na^+(aq) + S^{2-}(aq) + Cu^{2+}(aq) + 2NO_3^-(aq) \longrightarrow CuS(s) + 2Na^+(aq) + 2NO_3^-(aq)$,
net: $Cu^{2+}(aq) + S^{2-}(aq) \longrightarrow CuS(s)$.
4.63 (a), (b), and (d).
4.65 (a) molecular: $Ca(OH)_2(aq) + 2HNO_3(aq) \longrightarrow Ca(NO_3)_2(aq) + 2H_2O$,
ionic: $Ca^{2+}(aq) + 2OH^-(aq) + 2H^+(aq) + 2NO_3^-(aq) \longrightarrow Ca^{2+}(aq) + 2NO_3^-(aq) + 2H_2O$,
net: $H^+(aq) + OH^-(aq) \longrightarrow H_2O$,

(b) molecular: $Al_2O_3(s) + 6HCl(aq) \longrightarrow 2AlCl_3(aq) + 3H_2O$,
ionic: $Al_2O_3(s) + 6H^+(aq) + 6Cl^-(aq) \longrightarrow 2Al^{3+}(aq) + 6Cl^-(aq) + 3H_2O$,
net: $Al_2O_3(s) + 6H^+(aq) \longrightarrow 2Al^{3+}(aq) + 3H_2O$,
(c) molecular: $Zn(OH)_2(s) + H_2SO_4(aq) \longrightarrow ZnSO_4(aq) + 2H_2O$,
ionic: $Zn(OH)_2(s) + 2H^+(aq) + SO_4^{2-}(aq) \longrightarrow Zn^{2+}(aq) + SO_4^{2-}(aq) + 2H_2O$,
net: $Zn(OH)_2(s) + 2H^+(aq) \longrightarrow Zn^{2+}(aq) + 2H_2O$.

4.67 The electrical conductivity would decrease gradually, until one solution had neutralized the other, forming a nonelectrolyte. Once the point of neutralization had been reached, the addition of excess sulfuric acid would cause the conductivity to increase, because sulfuric acid is a strong electrolyte itself.

4.69 (a) $2H^+(aq) + CO_3^{2-}(aq) \longrightarrow H_2O + CO_2(g)$,
(b) $NH_4^+(aq) + OH^-(aq) \longrightarrow NH_3(g) + H_2O$.

4.71 (a) formation of insoluble $Cr(OH)_3$, (b) formation of water, a weak electrolyte. **4.73** (a) molecular:
$3HNO_3(aq) + Cr(OH)_3(s) \longrightarrow Cr(NO_3)_3(aq) + 3H_2O$,
ionic: $3H^+(aq) + 3NO_3^-(aq) + Cr(OH)_3(s) \longrightarrow Cr^{3+}(aq) + 3NO_3^-(aq) + 3H_2O$,
net: $3H^+(aq) + Cr(OH)_3(s) \longrightarrow Cr^{3+}(aq) + 3H_2O$,
(b) molecular: $HClO_4(aq) + NaOH(aq) \longrightarrow NaClO_4(aq) + H_2O$,
ionic: $H^+(aq) + ClO_4^-(aq) + Na^+(aq) + OH^-(aq) \longrightarrow Na^+(aq) + ClO_4^-(aq) + H_2O$,
net: $H^+(aq) + OH^-(aq) \longrightarrow H_2O$,
(c) molecular: $Cu(OH)_2(s) + 2HC_2H_3O_2(aq) \longrightarrow Cu(C_2H_3O_2)_2(aq) + 2H_2O$,
ionic: $Cu(OH)_2(s) + 2HC_2H_3O_2(aq) \longrightarrow Cu^{2+}(aq) + 2C_2H_3O_2^-(aq) + 2H_2O$,
net: $Cu(OH)_2(s) + 2HC_2H_3O_2(aq) \longrightarrow Cu^{2+}(aq) + 2C_2H_3O_2^-(aq) + 2H_2O$,
(d) molecular: $ZnO(s) + H_2SO_4(aq) \longrightarrow ZnSO_4(aq) + H_2O$,
ionic: $ZnO(s) + 2H^+(aq) + SO_4^{2-}(aq) \longrightarrow Zn^{2+}(aq) + SO_4^{2-}(aq) + H_2O$,
net: $ZnO(s) + 2H^+(aq) \longrightarrow Zn^{2+}(aq) + H_2O$.

4.75 (a) molecular: $Na_2SO_3(aq) + Ba(NO_3)_2(aq) \longrightarrow BaSO_3(s) + 2NaNO_3(aq)$,
ionic: $2Na^+(aq) + SO_3^{2-}(aq) + Ba^{2+}(aq) + 2NO_3^-(aq) \longrightarrow BaSO_3(s) + 2Na^+(aq) + 2NO_3^-(aq)$,
net: $Ba^{2+}(aq) + SO_3^{2-}(aq) \longrightarrow BaSO_3(s)$,
(b) molecular: $2HCHO_2(aq) + K_2CO_3(aq) \longrightarrow CO_2(g) + H_2O + 2KCHO_2(aq)$,
ionic: $2HCHO_2(aq) + 2K^+(aq) + CO_3^{2-}(aq) \longrightarrow CO_2(g) + H_2O + 2K^+(aq) + 2CHO_2^-(aq)$,
net: $2HCHO_2(aq) + CO_3^{2-}(aq) \longrightarrow 2CHO_2^-(aq) + CO_2(g) + H_2O$,
(c) molecular: $2NH_4Br(aq) + Pb(C_2H_3O_2)_2(aq) \longrightarrow 2NH_4C_2H_3O_2(aq) + PbBr_2(s)$,
ionic: $2NH_4^+(aq) + 2Br^-(aq) + Pb^{2+}(aq) + 2C_2H_3O_2^-(aq) \longrightarrow 2NH_4^+(aq) + 2C_2H_3O_2^-(aq) + PbBr_2(s)$,
net: $Pb^{2+}(aq) + 2Br^-(aq) \longrightarrow PbBr_2(s)$,
(d) molecular: $2NH_4ClO_4(aq) + Cu(NO_3)_2(aq) \longrightarrow Cu(ClO_4)_2(aq) + 2NH_4NO_3(aq)$,
ionic: $2NH_4^+(aq) + 2ClO_4^-(aq) + Cu^{2+}(aq) + 2NO_3^-(aq) \longrightarrow Cu^{2+}(aq) + 2ClO_4^-(aq) + 2NO_3^-(aq) + 2NH_4^+(aq)$,
net: N.R.

4.77 There are numerous possible answers. One of many possible sets of answers would be,
(a) $NaHCO_3(aq) + HCl(aq) \longrightarrow NaCl(aq) + CO_2(g) + H_2O$,
(b) $FeCl_2(aq) + 2NaOH(aq) \longrightarrow Fe(OH)_2(s) + 2NaCl(aq)$,
(c) $Ba(NO_3)_2(aq) + K_2SO_3(aq) \longrightarrow BaSO_3(s) + 2KNO_3(aq)$,
(d) $2AgNO_3(aq) + Na_2S(aq) \longrightarrow Ag_2S(s) + 2NaNO_3(aq)$,
(e) $ZnO(s) + 2HCl(aq) \longrightarrow ZnCl_2(aq) + H_2O$.

4.79 (a) 1.00 *M* NaOH, (b) 0.577 *M* $CaCl_2$.
4.81 658 mL $NaC_2H_3O_2$. **4.83** (a) 1.46 g NaCl, (b) 16.2 g $C_6H_{12}O_6$, (c) 6.13 g H_2SO_4. **4.85** 0.11 *M* H_2SO_4.

4.87 300 mL. **4.89** 225 mL water. **4.91** (a) 0.0145 mol Ca^{2+}, 0.0290 mol Cl^-, (b) 0.020 mol Al^{3+}, 0.060 mol Cl^-.
4.93 (a) 0.25 *M* Cr^{2+}, 0.50 *M* NO_3^-, (b) 0.10 *M* Cu^{2+}, 0.10 *M* SO_4^{2-}, (c) 0.48 *M* Na^+, 0.16 *M* PO_4^{3-}, (d) 0.15 *M* Al^{3+}, 0.22 *M* SO_4^{2-}. **4.95** 1.0 g $Al_2(SO_4)_3$. **4.97** 12.0 mL $NiCl_2$ soln, 0.36 g $NiCO_3$. **4.99** 0.113 *M* KOH, $KOH(aq) + HCl(aq) \longrightarrow KCl(aq) + H_2O$. **4.101** 0.485 g $Al_2(SO_4)_3$.
4.103 2.00 mL $FeCl_3$ soln, 0.129 g AgCl. **4.105** 13.3 mL $AlCl_3$.
4.107 0.167 *M* Fe^{3+}, 3.67 g Fe_2O_3. **4.109** (a) 8.00×10^{-3} mol AgCl, (b) 0.160 *M* NO_3^-, 0.220 *M* Na^+, 0.060 *M* Cl^-. **4.111** 0.114 *M* HCl.
4.113 2.67×10^{-3} mol $HC_3H_5O_3$. **4.115** $MgSO_4 \cdot 7H_2O$.
4.117 48.40% Pb in the sample. **4.119** 58.6%

CHAPTER 5

Practice Exercises

5.1 Reduced. **5.2** Aluminum is oxidized and is the reducing agent, Chlorine is reduced and is the oxidizing agent. **5.3** +3.
5.4 (a) Ni +2; Cl −1, (b) Mg +2; Ti +4; O −2, (c) K +1; Cr +6; O −2, (d) H +1; P +5, O −2, (e) V +3; C 0; H +1; O −2.
5.5 +8/3. **5.6** $KClO_3$ is reduced and HNO_2 is oxidized.
5.7 Cl_2 is reduced and is the oxidizing agent. $NaClO_2$ is oxidized and is the reducing agent. **5.8** Water, since the oxidation number of oxygen drops from −1 to −2 in the formation of water.
5.9 $2Al(s) + 3Cu^{2+}(aq) \longrightarrow 2Al^{3+}(aq) + 3Cu(s)$.
5.10 $3Sn^{2+} + 16H^+ + 2TcO_4^- \longrightarrow 2Tc^{4+} + 8H_2O + 3Sn^{4+}$.
5.11 $4Cu + 2NO_3^- + 10H^+ \longrightarrow 4Cu^{2+} + N_2O + 5H_2O$.
5.12 $4OH^- + SO_2 \longrightarrow SO_4^{2-} + 2e^- + 2H_2O$.
5.13 $2MnO_4^- + 3C_2O_4^{2-} + 4OH^- \longrightarrow 2MnO_2 + 6CO_3^{2-} + 2H_2O$.
5.14 $Zn \longrightarrow Zn^{2+} + 2e^-$, $2H^+ + 2e^- \longrightarrow H_2$.
5.15 $HNO_3 + 9H^+ + 4Mg \longrightarrow NH_4^+ + 4Mg^{2+} + 3H_2O$.
5.16 (a) molecular: $Mg(s) + 2HCl(aq) \longrightarrow MgCl_2(aq) + H_2(g)$,
ionic: $Mg(s) + 2H^+(aq) + 2Cl^-(aq) \longrightarrow Mg^{2+}(aq) + 2Cl^-(aq) + H_2(g)$,
net ionic: $Mg(s) + 2H^+(aq) \longrightarrow Mg^{2+}(aq) + H_2(g)$,
(b) molecular: $2Al(s) + 6HCl(aq) \longrightarrow 2AlCl_3(aq) + 3H_2(g)$,
ionic: $2Al(s) + 6H^+(aq) + 6Cl^-(aq) \longrightarrow 2Al^{3+}(aq) + 6Cl^-(aq) + 3H_2(g)$,
net ionic: $2Al(s) + 6H^+(aq) \longrightarrow 2Al^{3+}(aq) + 3H_2(g)$.
5.17 $Cu^{2+}(aq) + Mg(s) \longrightarrow Cu(s) + Mg^{2+}(aq)$.
5.18 (a) $2Al(s) + 3Cu^{2+}(aq) \longrightarrow 2Al^{3+}(aq) + 3Cu(s)$,
(b) $Ag(s) + Mg^{2+}(aq) \longrightarrow$ No reaction.
5.19 $2C_{20}H_{42}(s) + 21O_2(g) \longrightarrow 40C(s) + 42H_2O(g)$.
5.20 $2C_4H_{10}(g) + 13O_2(g) \longrightarrow 8CO_2(g) + 10H_2O(g)$.
5.21 $C_2H_5OH(l) + 3O_2(g) \longrightarrow 2CO_2(g) + 3H_2O(g)$.
5.22 $2Sr(s) + O_2(g) \longrightarrow 2SrO(s)$.
5.23 $4Fe(s) + 3O_2(g) \longrightarrow 2Fe_2O_3(s)$.
5.24 0.06100 *M* $H_2C_2O_4$. **5.25** 2.37 g $Na_2S_2O_3$.
5.26 (a) $5Sn^{2+} + 2MnO_4^- + 16H^+ \longrightarrow 5Sn^{4+} + 2Mn^{2+} + 8H_2O$, (b) 0.120 g Sn, (c) 40.0% Sn, (d) 50.7% SnO_2

Review Problems

5.25 (a) S^{2-}: −2, (b) SO_2: S +4, O −2, (c) P_4: P 0, (d) PH_3: P −3, H +1. **5.27** (a) O: −2, Na: +1, Cl: +1, (b) O: −2, Na: +1, Cl: +3, (c) O: −2, Na: +1, Cl: +5, (d) O: −2, Na: +1, Cl: +7.
5.29 The sum of the oxidation numbers should be zero, (a) S: −2, Pb: +2, (b) Cl: −1, Ti: +4, (c) Cs +1, O −1/2, (d) F −1, O +1. **5.31** In the forward direction: Cl_2 is reduced and Cl_2 also oxidized. In the reverse direction: Cl^- is the reducing agent. HOCl must be the oxidizing agent. **5.33** (a) substance reduced (and oxidizing agent): HNO_3, substance oxidized (and reducing agent): H_3AsO_3, (b) substance reduced (and oxidizing agent): HOCl, substance oxidized (and reducing agent): NaI, (c) substance reduced (and oxidizing agent): $KMnO_4$, substance oxidized

(and reducing agent): $H_2C_2O_4$, (d) substance reduced (and oxidizing agent): H_2SO_4, substance oxidized (and reducing agent): Al.

5.35 (a) $OCl^- + 2S_2O_3^{2-} + 2H^+ \longrightarrow S_4O_6^{2-} + Cl^- + H_2O$, (b) $2NO_3^- + Cu + 4H^+ \longrightarrow 2NO_2 + Cu^{2+} + 2H_2O$, (c) $3AsO_3^{3-} + IO_3^- \longrightarrow I^- + 3AsO_4^{3-}$, (d) $Zn + SO_4^{2-} + 4H^+ \longrightarrow Zn^{2+} + SO_2 + 2H_2O$, (e) $NO_3^- + 4Zn + 10H^+ \longrightarrow 4Zn^{2+} + NH_4^+ + 3H_2O$, (f) $2Cr^{3+} + 3BiO_3^- + 4H^+ \longrightarrow Cr_2O_7^{2-} + 3Bi^{3+} + 2H_2O$, (g) $I_2 + 5OCl^- + H_2O \longrightarrow 2IO_3^- + 5Cl^- + 2H^+$, (h) $2Mn^{2+} + 5BiO_3^- + 14H^+ \longrightarrow 2MnO_4^- + 5Bi^{3+} + 7H_2O$, (i) $3H_3AsO_3 + Cr_2O_7^{2-} + 8H^+ \longrightarrow 3H_3AsO_4 + 2Cr^{3+} + 4H_2O$, (j) $2I^- + HSO_4^- + 3H^+ \longrightarrow I_2 + SO_2 + 2H_2O$.

5.37 (a) $2CrO_4^{2-} + 3S^{2-} + 4H_2O \longrightarrow 2CrO_2^- + 3S + 8OH^-$, (b) $3C_2O_4^{2-} + 2MnO_4^- + 4H_2O \longrightarrow 6CO_2 + 2MnO_2 + 8OH^-$, (c) $4ClO_3^- + 3N_2H_4 \longrightarrow 4Cl^- + 6NO + 6H_2O$, (d) $NiO_2 + 2Mn(OH)_2 \longrightarrow Ni(OH)_2 + Mn_2O_3 + H_2O$, (e) $3SO_3^{2-} + 2MnO_4^- + H_2O \longrightarrow 3SO_4^{2-} + 2MnO_2 + 2OH^-$.

5.39 $4OCl^- + S_2O_3^{2-} + H_2O \longrightarrow 4Cl^- + 2SO_4^{2-} + 2H^+$.

5.41 $O_3 + Br^- \longrightarrow BrO_3^-$.

5.43 (a) $Mn(s) + 2HCl(aq) \longrightarrow MnCl_2(aq) + H_2(g)$, $Mn(s) + 2H^+(aq) + 2Cl^-(aq) \longrightarrow Mn^{2+}(aq) + 2Cl^-(aq) + H_2(g)$, $Mn(s) + 2H^+(aq) \longrightarrow Mn^{2+}(aq) + H_2(g)$, (b) $Cd(s) + 2HCl(aq) \longrightarrow CdCl_2(aq) + H_2(g)$, $Cd(s) + 2H^+(aq) + 2Cl^-(aq) \longrightarrow Cd^{2+}(aq) + 2Cl^-(aq) + H_2(g)$, $Cd(s) + 2H^+(aq) \longrightarrow Cd^{2+}(aq) + H_2(g)$, (c) $Sn(s) + 2HCl(aq) \longrightarrow SnCl_2(aq) + H_2(g)$, $Sn(s) + 2H^+(aq) + 2Cl^-(aq) \longrightarrow Sn^{2+}(aq) + 2Cl^-(aq) + H_2(g)$, $Sn(s) + 2H^+(aq) \longrightarrow Sn^{2+}(aq) + H_2(g)$.

5.45 (a) $3Ag(s) + 4HNO_3(aq) \longrightarrow 3AgNO_3(aq) + 2H_2O + NO(g)$, (b) $Ag(s) + 2HNO_3(aq) \longrightarrow AgNO_3(aq) + H_2O + NO_2(aq)$.

5.47 (a) N.R., (b) $2Cr(s) + 3Pb^{2+}(aq) \longrightarrow 2Cr^{3+}(aq) + 3Pb(s)$, (c) $2Ag^+(aq) + Fe(s) \longrightarrow 2Ag(s) + Fe^{2+}(aq)$, (d) $3Ag(s) + Au^{3+}(aq) \longrightarrow Au(s) + 3Ag^+(aq)$.

5.49 Pt, Ru, Tl, Pu.

5.51 $Cd(s) + 2TlCl(aq) \longrightarrow CdCl_2(aq) + 2Tl(s)$.

5.53 (a) $2C_6H_6(l) + 15O_2(g) \longrightarrow 12CO_2(g) + 6H_2O(g)$, (b) $C_3H_8(g) + 5O_2(g) \longrightarrow 3CO_2(g) + 4H_2O(g)$, (c) $C_{21}H_{44}(s) + 32O_2(g) \longrightarrow 21CO_2(g) + 22H_2O(g)$.

5.55 (a) $2C_6H_6(l) + 9O_2(g) \longrightarrow 12CO(g) + 6H_2O(g)$, $2C_3H_8(g) + 7O_2(g) \longrightarrow 6CO(g) + 8H_2O(g)$, $2C_{21}H_{44}(s) + 43O_2(g) \longrightarrow 42CO(g) + 44H_2O(g)$, (b) $2C_6H_6(l) + 3O_2(g) \longrightarrow 12C(s) + 6H_2O(g)$, $C_3H_8(g) + 2O_2(g) \longrightarrow 3C(s) + 4H_2O(g)$, $C_{21}H_{44}(s) + 11O_2(g) \longrightarrow 21C(s) + 22H_2O(g)$.

5.57 $2CH_3OH(l) + 3O_2(g) \longrightarrow 2CO_2(g) + 4H_2O(g)$.

5.59 $2(CH_3)_2S(g) + 9O_2(g) \longrightarrow 4CO_2(g) + 6H_2O(g) + 2SO_2(g)$.

5.61 (a) $2Zn(s) + O_2(g) \longrightarrow 2ZnO(s)$, (b) $4Al(s) + 3O_2(g) \longrightarrow 2Al_2O_3(s)$, (c) $2Mg(s) + O_2(g) \longrightarrow 2MgO(s)$, (d) $4Fe(s) + 3O_2(g) \longrightarrow 2Fe_2O_3(s)$.

5.63 (a) $IO_3^- + 3SO_3^{2-} \longrightarrow I^- + 3SO_4^{2-}$, (b) 9.55 g Na_2SO_3.

5.65 3.53 g Cu.

5.67 (a) $2MnO_4^- + 5Sn^{2+} + 16H^+ \longrightarrow 2Mn^{2+} + 5Sn^{4+} + 8H_2O$, (b) 17.4 mL $KMnO_4$.

5.69 (a) 6.38×10^{-3} M I_3^-, (b) 1.01×10^{-3} g SO_2, (c) 2.10×10^{-3}%, (d) 21 ppm.

5.71 (a) 9.463%, (b) 18.40%.

5.73 (a) 0.02994 g H_2O_2, (b) 2.994% H_2O_2.

5.75 (a) $2CrO_4^{2-} + 3SO_3^{2-} + H_2O \longrightarrow 2CrO_2^- + 3SO_4^{2-} + 2OH^-$, (b) 0.875 g Cr in the original alloy., (c) 25.4% Cr.

5.77 (a) 5.405×10^{-3} mol $C_2O_4^{2-}$, (b) 0.5999 g $CaCl_2$, (c) 24.35% $CaCl_2$

CHAPTER 6

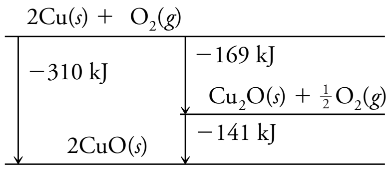
Practice Exercises

6.1 55.1 J/°C. **6.2** 5.23 kJ, 1250 cal, 1.25 kcal. **6.3** 12.4 kJ $°C^{-1}$. **6.4** 394 kJ/mol C. **6.5** −58 kJ mol^{-1}. **6.6** 3.7 kJ, 74 kJ/mol.

6.7 $\frac{1}{4}CH_4(g) + \frac{1}{2}O_2(g) \longrightarrow \frac{1}{4}CO_2(g) + \frac{1}{2}H_2O(l)$ $\Delta H = 222.6$ kJ

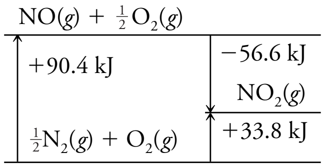
6.8 $2.500\,H_2(g) + \frac{2.500}{2}O_2(g) \longrightarrow 2.500\,H_2O(l)$ $\Delta H = -714.75$ kJ

6.9



The reaction is exothermic.

6.10



The reaction is endothermic.

6.11 $\Delta H = +857.7$ kJ. **6.12** $\Delta H = +99.2$ kJ. **6.13** $\Delta H° = -44.0$ kJ. **6.14** 385 kJ. **6.15** 2.62×10^6 kJ.

6.16 $\frac{1}{2}N_2(g) + 2H_2(g) + \frac{1}{2}Cl_2(g) \longrightarrow NH_4Cl(s)$ $\Delta H_f° = -315.4$ kJ

6.17 $Na(s) + \frac{1}{2}H_2(g) + C(s) + \frac{3}{2}O_2(g) \longrightarrow NaHCO_3(s)$ $\Delta H_f° = -947.7$ kJ/mol

6.18 +800.34 kJ.

6.19 $S(s) + \frac{3}{2}O_2(g) \longrightarrow SO_3(g)$ $\Delta H_f° = -395.2$ kJ/mol

$S(s) + O_2(g) \longrightarrow SO_2(g)$ $\Delta H_f° = -296.9$ kJ/mol

Reverse the first reaction and add the two reactions together to get

$SO_3(g) \longrightarrow SO_2(g) + \frac{1}{2}O_2(g)$ $\Delta H_f° = +98.3$ kJ

The answers for the enthalpy of reaction are the same using either method. **6.20** (a) −113.1 kJ, (b) −177.8 kJ

Review Problems

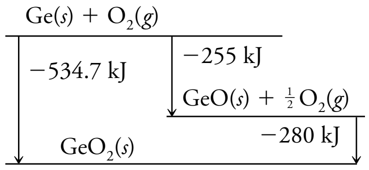
6.41 −17 J. **6.43** +100 J. **6.45** −1320 J, −315 cal. **6.47** (a) 1.67×10^3 J, (b) 1.67×10^3 J, (c) 23.2 J $°C^{-1}$, (d) 4.64 J g^{-1} $°C^{-1}$. **6.49** 25.12 J/mol °C. **6.51** −30.4 kJ.

6.53 $HNO_3(aq) + KOH(aq) \longrightarrow KNO_3(aq) + H_2O(l)$, 3.8×10^3 J, 53 kJ/mol.

6.55 (a) $C_3H_8(g) + 5O_2(g) \longrightarrow 3CO_2(g) + 4H_2O(l)$, (b) 2.22×10^5 J, (c) −222 kJ/mol.

6.57 (a) $2CO(g) + O_2(g) \longrightarrow 2CO_2(g)$, $\Delta H° = -566$ kJ, (b) −283 kJ/mol. **6.59** 162 kJ of heat are evolved.

6.61



$\Delta H° = -280$ kJ

6.63 $2NO_2(g) \longrightarrow N_2O_4(g)$, $\Delta H° = -57.93$ kJ, $2NO(g) + O_2(g) \longrightarrow 2NO_2(g)$, $\Delta H° = -113.14$ kJ, $2NO(g) + O_2(g) \longrightarrow N_2O_4(g)$, $\Delta H° = -171.07$ kJ.

6.65 $\frac{1}{2}Na_2O(s) + HCl(g) \longrightarrow \frac{1}{2}H_2O(l) + NaCl(s)$, $\Delta H° = -253.66$ kJ,

$NaNO_2(s) \longrightarrow \frac{1}{2}Na_2O(s) + \frac{1}{2}NO_2(g) + \frac{1}{2}NO(g)$, $\Delta H° = +213.57$ kJ,

$\frac{1}{2}NO(g) + \frac{1}{2}NO_2(g) \longrightarrow \frac{1}{2}N_2O(g) + \frac{1}{2}O_2(g)$, $\Delta H° = -21.34$ kJ,

$\frac{1}{2}\,H_2O(l) + \frac{1}{2}\,O_2(g) + \frac{1}{2}\,N_2O(g) \longrightarrow HNO_2(l),$
$\Delta H° = -17.18$ kJ,
$HCl(g) + NaNO_2(s) \longrightarrow HNO_2(l) + NaCl(s),$
$\Delta H° = -78.61$ kJ.

6.67 $\frac{1}{2}\,CaO(s) + \frac{1}{2}\,Cl_2(g) \longrightarrow \frac{1}{2}\,CaOCl_2(s)$
$\Delta H° = \frac{1}{2}\,(-110.9 \text{ kJ}).$
$\frac{1}{2}H_2O(l) + \frac{1}{2}CaOCl_2(s) + NaBr(s) \longrightarrow$
$NaCl(s) + \frac{1}{2}Ca(OH)_2(s) + \frac{1}{2}Br_2(l) \quad \Delta H° = \frac{1}{2}\,(-60.2 \text{ kJ}).$
$\frac{1}{2}Ca(OH)_2(s) \longrightarrow \frac{1}{2}CaO(s) + \frac{1}{2}H_2O(l) \quad \Delta H° = \frac{1}{2}\,(+65.1 \text{ kJ}).$
$\frac{1}{2}Cl_2(g) + NaBr(s) \longrightarrow NaCl(s) + \frac{1}{2}Br_2(l)$
$\Delta H° = \frac{1}{2}\,(-160.1 \text{ kJ}) = -53$ KJ.

6.69 $12NH_3(g) + 21O_2(g) \longrightarrow 12NO_2(g) + 18H_2O(g)$
$\Delta H° = 3(-1132 \text{ kJ}),$
$12NO_2(g) + 16NH_3(g) \longrightarrow 14N_2(g) + 24H_2O(g)$
$\Delta H° = 2(-2740 \text{ kJ}),$
$28NH_3(g) + 21O_2(g) \longrightarrow 14N_2(g) + 42H_2O(g)$
$\Delta H° = -8876$ kJ,
Now divide this equation by 7 to get
$4NH_3(g) + 3O_2(g) \longrightarrow 2N_2(g) + 6H_2O(g)$
$\Delta H° = 1/7(-8876 \text{ kJ}) = -1268$ kJ.

6.71 (a) $2C(\textit{graphite}) + 2H_2(g) + O_2(g) \longrightarrow HC_2H_3O_2(l)$
$\Delta H_f° = -487.0$ kJ,
(b) $2C(\textit{graphite}) + \frac{1}{2}\,O_2(g) + 3H_2(g) \longrightarrow C_2H_5OH(l)$
$\Delta H_f° = -277.63$ kJ,
(c) $Ca(s) + \frac{1}{8}\,S_8(s) + 3O_2(g) + 2H_2(g) \longrightarrow CaSO_4{\cdot}2H_2O(s)$
$\Delta H_f° = -2021.1$ kJ.

6.73 (a) −196.6 kJ, (b) −177.8 kJ.
6.75 $C_{12}H_{22}O_{11}(s) + 12O_2(g) \longrightarrow 12CO_2(g) + 11H_2O(l)$
$\Delta H_f° = -2021.1 \text{ kJ mol}^{-1} \quad \Delta H°_{\text{combustion}} = -5.65 \times 10^3$ kJ/mol.

CHAPTER 7

Practice Exercises

7.1 5.10×10^{14} Hz. **7.2** 3.00×10^{13} Hz. **7.3** 2.874 m.
7.4 2.63 μm. **7.5** 656.6 nm, red. **7.6** Shell 1 has 1 subshell, shell 2 has 2 subshells, shell 3 has 3 subshells, shell 4 has 4 subshells, shell 5 has 5 subshells, shell 6 has 6 subshells.
7.7 $n = 3$: *s*, *p* and *d* subshells, $n = 4$: *s*, *p*, *d* and *f* subshells.
7.8 (a) Mg: $1s^22s^22p^63s^2$,
(b) Ge: $1s^22s^22p^63s^23p^63d^{10}4s^24p^2$,
(c) Cd: $1s^22s^22p^63s^23p^63d^{10}4s^24p^64d^{10}5s^2$,
(d) Gd: $1s^22s^22p^63s^23p^63d^{10}4s^24p^64d^{10}4f^75s^25p^65d^16s^2$.
7.9 The electron configuration of an element follows the periodic table. The electrons are filled in the order of the periodic table and the energy levels are determined by the row the element is in and the subshell is given by the column, the first two columns are the *s*-block, the last six columns are the *p*-block, the *d*-block has ten columns, and the *f*-block has 14 columns.
7.10 (a) O: $1s^22s^22p^4$, S: $1s^22s^22p^63s^23p^4$,
Se: $1s^22s^22p^63s^23p^63d^{10}4s^24p^4$,
(b) P: $1s^22s^22p^63s^23p^3$, N: $1s^22s^22p^3$,
Sb: $1s^22s^22p^63s^23p^63d^{10}4s^24p^64d^{10}5s^25p^3$.
The elements have the same number of electrons in the valence shell, and the only differences between the valence shells are the energy levels.

7.11 (a) Na: ⇅ ⇅ ⇅⇅⇅ ↑ ○○○ ○ ○○○○○
1*s* 2*s* 2*p* 3*s* 3*p* 4*s* 3*d*

(b) S: ⇅ ⇅ ⇅⇅⇅ ⇅ ⇅↑↑ ○ ○○○○○
1*s* 2*s* 2*p* 3*s* 3*p* 4*s* 3*d*

(c) Fe: ⇅ ⇅ ⇅⇅⇅ ⇅ ⇅⇅⇅ ⇅ ⇅↑↑↑↑
1*s* 2*s* 2*p* 3*s* 3*p* 4*s* 3*d*

7.12 (a)
Mg: ⇅ ⇅ ⇅⇅⇅ ⇅ ○○○ ○ ○○○○○ ○○○
1*s* 2*s* 2*p* 3*s* 3*p* 4*s* 3*d* 4*p*
0 unpaired electrons
(b)
Ge: ⇅ ⇅ ⇅⇅⇅ ⇅ ⇅⇅⇅ ⇅ ⇅⇅⇅⇅⇅ ↑↑○
1*s* 2*s* 2*p* 3*s* 3*p* 4*s* 3*d* 4*p*
2 unpaired electrons
(c)
Cd: ⇅ ⇅ ⇅⇅⇅ ⇅ ⇅⇅⇅ ⇅ ⇅⇅⇅⇅⇅ ⇅⇅⇅
1*s* 2*s* 2*p* 3*s* 3*p* 4*s* 3*d* 4*p*

⇅ ⇅⇅⇅⇅⇅
5*s* 4*d*
0 unpaired electrons
(d)
Gd: ⇅ ⇅ ⇅⇅⇅ ⇅ ⇅⇅⇅ ⇅ ⇅⇅⇅⇅⇅ ⇅⇅⇅
1*s* 2*s* 2*p* 3*s* 3*p* 4*s* 3*d* 4*p*

⇅ ⇅⇅⇅⇅⇅ ⇅⇅⇅ ⇅ ↑○○○○ ↑↑↑↑↑↑↑
5*s* 4*d* 5*p* 6*s* 5*d* 4*f*
8 unpaired electrons

7.13 Yes, Ti, Cr, Fe, Ni and the elements in their groups have even numbers of electrons and are paramagnetic. Additionally, oxygen has eight electrons, but it is paramagnetic since it has two unpaired electrons in the 2*p* orbitals.

7.14 (a) P: [Ne]$3s^23p^3$
[Ne] ⇅ ↑↑↑
3*s* 3*p* (3 unpaired electrons),

(b) Sn: [Kr]$4d^{10}5s^25p^2$
[Kr] ⇅⇅⇅⇅⇅ ⇅ ↑↑○
4*d* 5*s* 5*p* (2 unpaired electrons)

7.15 For representative elements the valence shell is defined as the occupied shell with the highest value of *n*. In a ground state atom, only *s* and *p* electrons fit that definition.
7.16 (a) Se: $4s^24p^4$, (b) Sn: $5s^25p^2$, (c) I: $5s^25p^5$.
7.17 (a) Sn, (b) Ga, (c) Cr, (d) S^{2-}.
7.18 (a) P, (b) Fe^{3+}, (c) Fe, (d) Cl^-.
7.19 (a) Be, (b) C. **7.20** (a) Na^+, (b) Mg^{2+}

Review Problems

7.73 6.98×10^{14} Hz. **7.75** 4.38×10^{13} Hz.
7.77 1.02×10^{15} Hz. **7.79** 2.97 m.
7.81 5.0×10^6 m, 5.0×10^3 km.
7.83 2.7×10^{-19} J, 1.6×10^5 J mol^{-1}.
7.85 (a) violet, (b) 7.307×10^{14} Hz, (c) 4.842×10^{-19} J.
7.87 1094 nm, We would not expect to see the light since it is not in the visible region.
7.89 1.737×10^{-6} m, infrared region. **7.91** (a) *p*, (b) *f*.
7.93 (a) $n = 3$, $\ell = 0$, (b) $n = 5$, $\ell = 2$.
7.95 0, 1, 2, 3, 4, 5. **7.97** (a) $m_\ell = 1, 0,$ or -1, (b) $m_\ell = 3, 2, 1, 0, -1, -2,$ or -3.
7.99 $\ell = 4 \quad n = 5$.

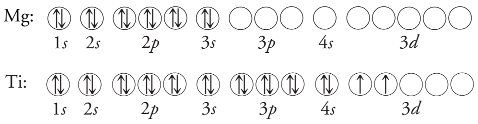
7.101

n	ℓ	m_ℓ	m_s
2	1	−1	+1/2
2	1	−1	−1/2
2	1	0	+1/2
2	1	0	−1/2
2	1	+1	+1/2
2	1	+1	−1/2

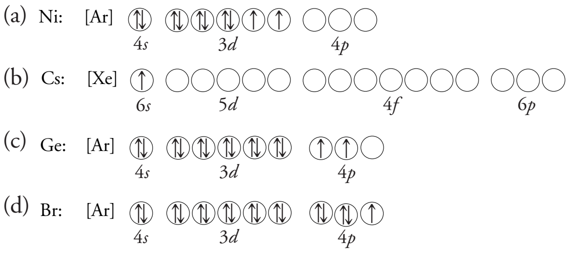
7.103 21 electrons have $\ell = 1$, 20 electrons have $\ell = 2$.

7.105 (a) S $1s^22s^22p^63s^23p^4$, (b) K $1s^22s^22p^63s^23p^64s^1$, (c) Ti $1s^22s^22p^63s^23p^63d^24s^2$, (d) Sn $1s^22s^22p^63s^23p^63d^{10}4s^24p^64d^{10}5s^25p^2$.
7.107 (a) Mn paramagnetic, (b) As paramagnetic, (c) S paramagnetic, (d) Sr not paramagnetic, (b) Ar not paramagnetic.
7.109 (a) Mg zero unpaired electrons, (b) P three unpaired electrons, (c) V three unpaired electrons.
7.111 (a) Ni $[Ar]3d^84s^2$, (b) Cs $[Xe]6s^1$, (c) Ge $[Ar]3d^{10}4s^24p^2$, (d) Br $[Ar]3d^{10}4s^24p^5$, (e) Bi $[Xe]4f^{14}5d^{10}6s^26p^3$.

7.113 (a) (b)

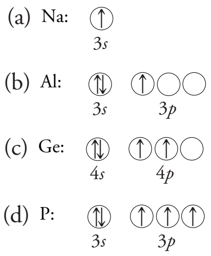


7.115



7.117 (a) 5, (b) 4, (c) 4, (d) 6.
7.119 (a) $3s^1$, (b) $3s^23p^1$, (c) $4s^24p^2$, (d) $3s^23p^3$.

7.121



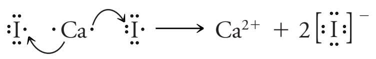
7.123 (a) 1, (b) 6, (c) 7. **7.125** (a) Mg, (b) Bi. **7.127** Sb. **7.129** (a) Na, (b) Co^{2+}, (c) Cl^-. **7.131** (a) N, (b) S, (c) Cl. **7.133** (a) Br, (b) As. **7.135** Mg

CHAPTER 8

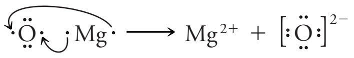
Practice Exercises

8.1 There is one electron missing, and it should go into the 5*s* orbital, and the 5*p* orbital should be empty, $1s^12s^22p^63s^23p^63d^{10}4s^24p^64d^{10}5s^2$.
8.2 (a) Cr^{2+}: $[Ar]3d^4$ The 4*s* electron and one 3*d* electron are lost, (b) Cr^{3+}: $[Ar]3d^3$ The 4*s* electron and two 3*d* electrons are lost, (c) Cr^{6+}: [Ar] The 4*s* electron and all of the 3*d* electrons are lost.
8.3 The electron configurations are identical.

8.4



8.5



8.6 1.24 D. **8.7** 0.795 e^-, on Na: +0.795 e^-, on Cl: −0.795 e^-, 57.6% positive charge on the Na, 57.6% negative charge on the Cl.
8.8 The bond is polar and the Cl carries the negative charge.
8.9 (a) Br, (b) Cl, (c) Cl.
8.10

O
H O P O H
O

32 valence electrons.

8.11

O S O

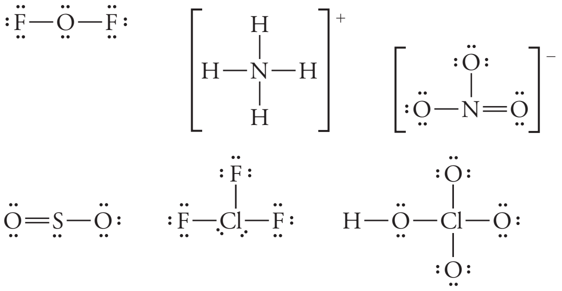
O
O N O

O
O Br O H

H
O
H O As O H
O

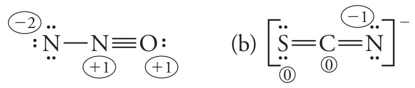
8.12 18 valence electrons, 32 valence electrons, 10 valence electrons.

8.13

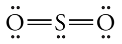


8.14 The negative sign should be on the oxygen, so two of the oxygen atoms should have a single bond and three lone pairs and the sulfur should have one double bond, two single bonds, and a lone pair.

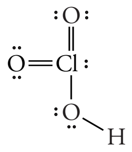
8.15 (a) (b)



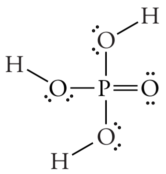
8.16 (a)



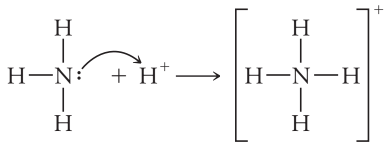
(b)



(c)

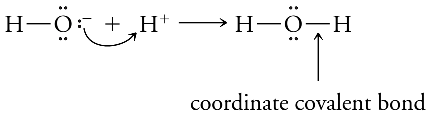


8.17

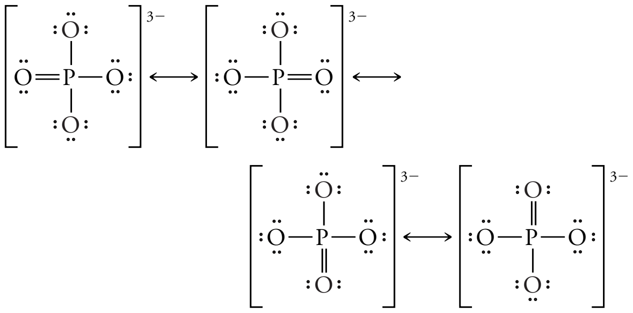


There is no difference between the coordinate covalent bond and the other covalent bonds.

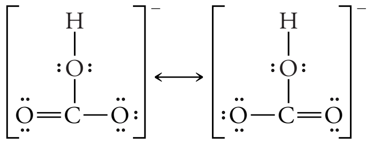
8.18



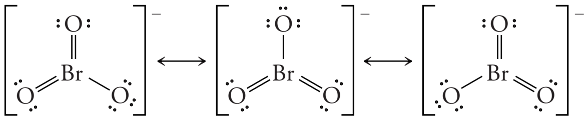
8.19



8.20

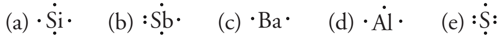


8.21

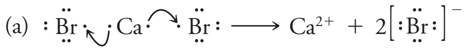


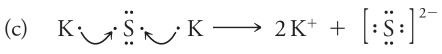
Review Problems

8.55 Magnesium loses two electrons, Bromine gains an electron: To keep the overall change of the formula unit neutral, two Br^- ions combine with one Mg^{2+} ion to form $MgBr_2$.
8.57 $[Xe]4f^{14}5d^{10}6s^2$, $[Xe]4f^{14}5d^{10}$.
8.59 $[Ar]3d^4$ 4 unpaired electrons.
8.61

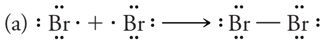


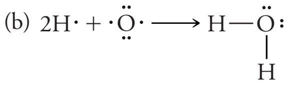
8.63

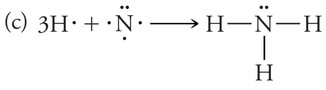




8.65 0.029 e^-, The nitrogen atom is positive. **8.67** 0.42 e^-.
8.69 1.4×10^3 g. **8.71** 344 nm, Ultraviolet region.
8.73





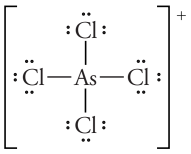


8.75 (a) H_2Se, (b) H_3As, (c) SiH_4. **8.77** (a) S, (b) Si, (c) Br, (d) C. **8.79** N—S.
8.81 (a)
Cl
Cl Si Cl
Cl

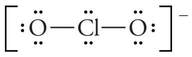
(b)
F
F P F

(c)
H
H P H

(d) Cl S Cl
8.83 (a) 32, (b) 26, (c) 8, (d) 20.
8.85 (a)



(b)



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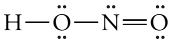
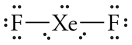
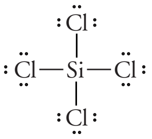


(d)



8.87 (a)



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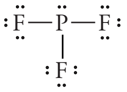

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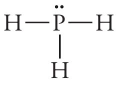

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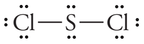
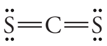
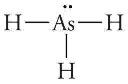


8.89 (a)



(b)

8.91 (a)



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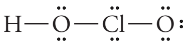

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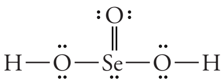

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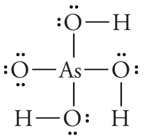
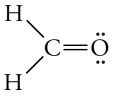
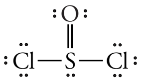


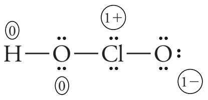
8.93 (a)



(b)



8.95 (a)



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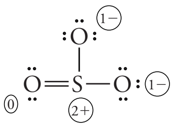
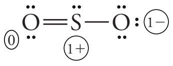
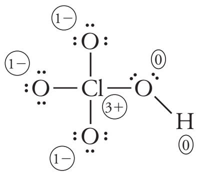
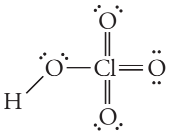


(c)

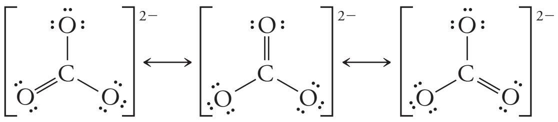


8.97





8.99 The formal charges on all of the atoms of the left structure are zero, therefore, the potential energy of this molecule is lower and it is more stable.
8.101 The average bond order is 4/3

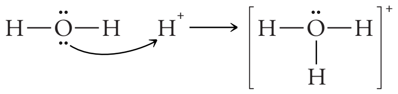


8.103 The N—O bond in NO_2^- should be shorter than that in NO_3^-.

8.105. $:\!O\equiv C-\underset{\cdot\cdot}{\ddot{O}}\!: \longleftrightarrow :\!\underset{\cdot\cdot}{\ddot{O}}-C\equiv O\!:$

These are not preferred structures, because in each Lewis diagram, one oxygen atom bears a formal charge of +1 whereas the other bears a formal charge of −1. The structure with the formal charges of zero has a lower potential energy and is more stable.

8.107

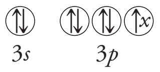


CHAPTER 9

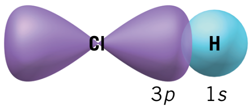
Practice Exercises

9.1 Octahedral shape. **9.2** Trigonal bipyramidal. **9.3** Linear. **9.4** Linear. **9.5** Square planar. **9.6** SO_3^{2-} trigonal pyramidal, CO_3^{2-} planar triangular, XeO_4 tetrahedral, OF_2 bent. **9.7** Polar. **9.8** (a) SF_6 Not polar, (b) SO_2 Polar, (c) BrCl Polar, (d) AsH_3, Polar, (e) CF_2Cl_2 Polar. **9.9** The H—Cl bond is formed by the overlap of the half–filled 1*s* atomic orbital of a H atom with the half–filled 3*p* valence orbital of a Cl atom,

Cl atom in HCl (x = H electron):

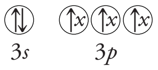


The overlap that gives rise to the H—Cl bond is that of a 1*s* orbital of H with a 3*p* orbital of Cl.

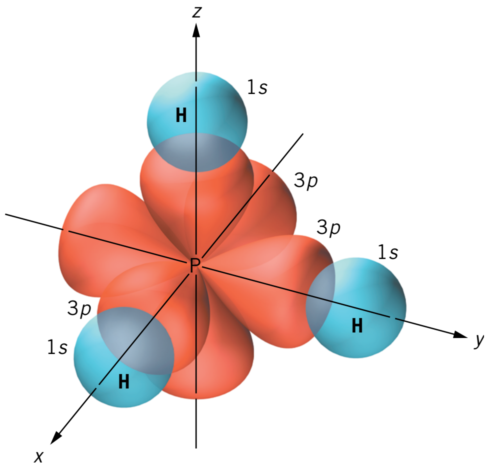


9.10 The half–filled 1*s* atomic orbital of each H atom overlaps with a half–filled 3*p* atomic orbital of the P atom, to give three P–H bonds. This should give a bond angle of 90°,

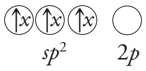
P atom in PH_3 (x = H electron):



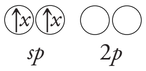
The orbital overlap that forms the P—H bond combines a 1*s* orbital of hydrogen with a 3*p* orbital of phosphorus:



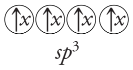
9.11 sp^2, The sp^2 hybrid orbitals on the B, x = Cl electron.



9.12 *sp*, The *sp* hybrid orbitals on the Be; x = F electron.

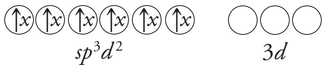


9.13 Since there are five bonding pairs of electrons on the central phosphorus atom, we choose sp^3d hybridization for the P atom. Each of phosphorus' five sp^3d hybrid orbitals overlaps with a 3*p* atomic orbital of a chlorine atom to form a total of five P—Cl single bonds. Four of the 3*d* atomic orbitals of P remain unhybridized.
9.14 sp^3

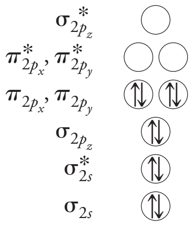


9.15 Trigonal bipyramidal, sp^3d—*p* bonds. **9.16** sp^3d^2. **9.17** (a)sp^3, (b) sp^3d. **9.18** NH_3 is sp^3 hybridized. Three of the electron pairs are use for bonding with the three hydrogens. The fourth pair of electrons is a lone pair of electrons. This pair of electrons is used for the formation of the bond between the nitrogen of NH_3 and the hydrogen ion, H^+.
9.19 Octahedral. sp^3d^2,

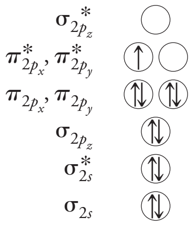
P atom in PCl_6 (x = Cl electron):



9.20 atom 1: sp^2, atom 2: sp^3, atom 3: sp^2, 10 σ bonds and 2 π bonds. **9.21** atom 1: *sp*, atom 2: sp^2, atom 3: sp^3, 9 σ bonds and 3 π bonds. **9.22** Bond order: 3 and this does agree with the Lewis structure.



9.23

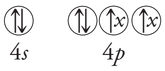


Bond order: 5/2:

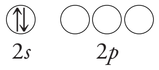
Review Problems

9.50 (a) Bent, (b) Planar triangular, (c) T-shaped, (d) Linear, (e) Planar triangular. **9.52** (a) Nonlinear, (b) Trigonal bipyramidal, (c) Trigonal pyramidal, (d) Trigonal pyramidal, (e) Nonlinear. **9.54** (a) Tetrahedral, (b) Square planar, (c) Octahedral, (d) Tetrahedral, (e) Linear. **9.56** BrF_4^-. **9.58** 180°. **9.60** (a) 109.5°, (b) 109.5°, (c) 120°, (d) 180°, (e) 109.5°. **9.62** (a), (b), and (c). **9.64** All are polar. **9.66** In SF_6, although the individual bonds in this substance are polar bonds, the geometry of the bonds is symmetrical which serves to cause the individual dipole moments of the various bonds to cancel one another. In SF_5Br, one of the six bonds has a different polarity so the individual dipole moments of the various bonds do not cancel one another. **9.68** The 1*s* atomic orbitals of the hydrogen atoms overlap with the mutually perpendicular *p* atomic orbitals of the selenium atom.

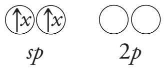
Se atom in H_2Se (x = H electron):



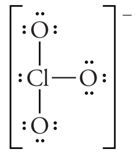
9.70



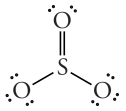
Hybridized Be: (x = a Cl electron)



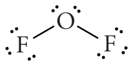
9.72 (a) sp^3



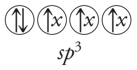
(b) sp^2



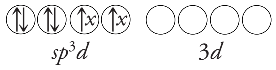
(c) sp^3



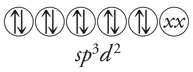
9.74 (a) sp^3,
The hybrid orbital diagram for As: (x = a Cl electron).



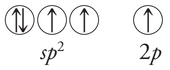
(b) sp^3d,
The hybrid orbital diagram for Cl: (x = a F electron).

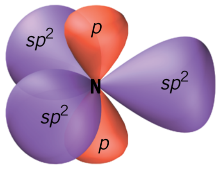


9.76 Sb in SbF_6^-: (xx = an electron pair from the donor F^-).

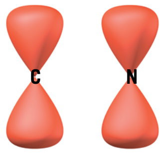


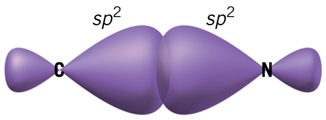
9.78 (a) N in the C═N system,





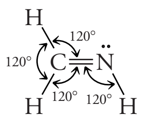
(b) pi bond,





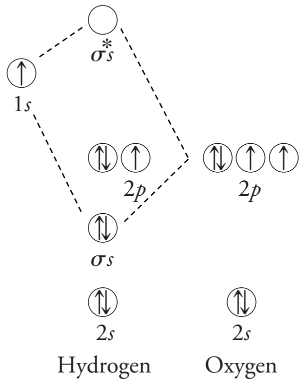
sigma bond

(c)



9.80 Each carbon atom is sp^2 hybridized, and each C—Cl bond is formed by the overlap of an sp^2 hybrid of carbon with a *p* atomic orbital of a chlorine atom. The C═C double bond consists first of a C—C σ bond formed by "head on" overlap of sp^2 hybrids from each C atom. Secondly, the C═C double bond consists of a side–to–side overlap of unhybridized *p* orbitals of each C atom, to give one π bond. The molecule is planar, and the expected bond angles are all 120°. **9.82** 1. sp^3, 2. sp, 3. sp^2, 4. sp^2. **9.84** (a) O_2^+, (b) O_2, (c) N_2. **9.86** (a) N_2^+, (b) NO, (c) O_2^-.

9.88



2 electrons in bonding MOs and 3 electrons in nonbonding MOs, Bond order: 1

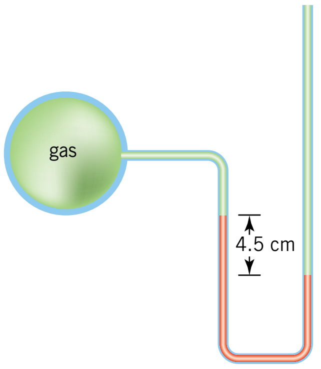
CHAPTER 10

Practice Exercises

10.1 14.1 psi, 28.7 in. Hg. **10.2** 88,800 Pascal, 666 torr. **10.3** 1270 mm Hg, 270 mm Hg. **10.4** 663 mm Hg. **10.5** 2/3. **10.6** 750 torr. **10.7** 688 torr. **10.8** 9.00 L O_2. **10.9** 64.3 L air. **10.10** 495 mL O_2. **10.11** 15,000 g solid CO_2. **10.12** 1,130 g Ar. **10.13** 26.0 g/mol. **10.14** 132 g mol^{-1}, Xenon. **10.15** Radon is almost eight times denser than air, the sensor should be in the basement. **10.16** 2.94 g L^{-1}. **10.17** P_2F_4. **10.18** 114 g mol^{-1}, 9 C and 6 H, 8 C and 18 H, 7 C and 30 H, 6 C and 42 H, 5 C and 54 H, 4 C and 66 H, 3 C and 78 H, 2 C and 90 H, 1 C and 102 H, 8 C and 18 H is the most likely combination. **10.19** 2.80 L CO_2, 5.60 L SO_2, Total volume = 8.40 L. **10.20** 1.00 g $CaCO_3$. **10.21** P_{Ar} = 6.01 atm, P_{N_2} = 8.59 atm, P_{O_2} = 7.53 atm, P_{total} = 22.13 atm. **10.22** 2713 g O_2. **10.23** 743.18 torr, 0.0983 mol CH_4. **10.24** 732 torr 283 mL. **10.25** 1.125 atm when just added, 0.750 atm when reaction is complete. **10.26** P_{H_2} = 0.996 atm, P_{NO} = 1.05 atm. **10.27** 0.153, 15.3%. **10.28** 0.988. **10.29** HI

Review Problems

10.25 (a) 958 torr, (b) 0.974 atm, (c) 738 mm Hg, (d) 10.9 torr.
10.27 (a) 250 torr, (b) 350 torr.
10.29 4.5 cm Hg,



10.31 813 torr. **10.33** 125 torr. **10.35** 507 mL. **10.37** 4.28 L. **10.39** 843 °C. **10.41** 796 torr. **10.43** 5.73 L. **10.45** −53.4 °C. **10.47** 6.24×10^4 mL torr mol^{-1} K^{-1}. **10.49** 0.104 L. **10.51** 2340 torr. **10.53** 0.0398 g. **10.55** (a) 1.34 g L^{-1}, (b) 1.25 g L^{-1}, (c) 3.17 g L^{-1}, (d) 1.78 g L^{-1}. **10.57** 1.28 g/L. **10.59** 88.2 g/mol. **10.61** 27.6 g/mol. **10.63** 1.14×10^3 mL. **10.65** 10.7 L H_2. **10.67** 36.3 mL O_2.

10.69 217 mL. **10.71** 650 torr. **10.73** $P_{N_2} = 228$ torr, $P_{O_2} = 152$ torr, $P_{He} = 304$ torr, $P_{CO_2} = 76$ torr. **10.75** 736 torr, 260 mL. **10.77** 250 mL. **10.79** N_2, 1.25. **10.81** $^{235}UF_6$ 1.0043

CHAPTER 11

Practice Exercises

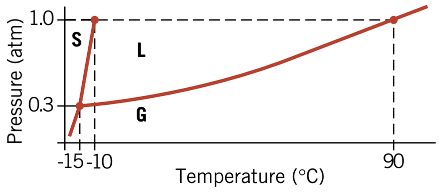
11.1 (a) $CH_3CH_2CH_2CH_2CH_3 < CH_3CH_2OH < Ca(OH)_2$, (b) $CH_3—O—CH_3 < CH_3CH_2NH_2 < HOCH_2CH_2CH_2CH_2OH$. **11.2** Propylamine, because of its ability to form hydrogen bonds. **11.3** Pushed in. **11.4** The total number of molecules remains the same. **11.5** (a) less than 10 °C. **11.6** 75 °C. **11.7** The equilibriumwill shift to the right, producing more vapor. **11.8**

Boiling,	Endothermic,
Melting,	Endothermic,
Condensing,	Exothermic,
Subliming,	Endothermic,
Freezing,	Exothermic,

No, each physical change is always exothermic, or always endothermic as shown. **11.9** 4 Ca^{2+} and 8 F^-. **11.10** 1 to 1. **11.11** Molecular crystal. **11.12** Covalent or network solid. **11.13** Molecular solid. **11.14** Vapor pressure curve, see Fig. 11.21. **11.15** Solid to gas. **11.16** Liquid.

Review Problems

11.78 Diethyl ether. **11.80** (a) London forces, dipole- dipole and hydrogen bonding, (b) London forces and dipole- dipole, (c) London forces, (d) London forces and dipole- dipole. **11.82** Chloroform would be expected to display larger dipole-dipole attractions because it has a larger dipole moment than bromoform. On the other hand, bromoform would be expected to show stronger London forces due to having larger electron clouds which are more polarizable than those of chlorine. Since bromoform in fact has a higher boiling point that chloroform, we must conclude that it experiences stronger intermolecular attractions than chloroform, which can only be due to London forces. Therefore, London forces are more important in determining the boiling points of these two compounds. **11.84** Ethanol. **11.86** ether < acetone < benzene < water < acetic acid. **11.88** 305 kJ. **11.90** (a) 0 °C, (b) 47.9 g. **11.92** 4 Zn^{2+}, 4 S^{2-}. **11.94** 3.51 Å., 351 pm. **11.96** 656 pm. **11.98** (a) 6.57°, (b) 27.3°. **11.100** 176 pm. **11.102** Molecular solid. **11.104** Metallic solid. **11.106** (a)molecular, (b) ionic, (c) ionic, (d) metallic, (e) covalent, (f) molecular, (g) ionic. **11.108**



11.110 (a) solid, (b) gas, (c) liquid, (d) solid, liquid, and gas

CHAPTER 12

Practice Exercises

12.1 3.4 g L^{-1} atm^{-1}. Hydrogen sulfide is more soluble in water than nitrogen and oxygen. Hydrogen sulfide reacts with the water to form hydronium ions and $HS^-(aq)$ ions. **12.2** 0.899 mg of O_2, 1.48 mg of N_2. **12.3** 405.7 mL water. **12.4** 2.50 g NaBr, 248 g H_2O, 251 mL H_2O. **12.5** 2.0×10^1 g solution. **12.6** 1.239 *m*, Smaller. **12.7** 16.0 g CH_3OH. **12.8** (a) 28.3 g solution, (b) 70.7 g solution, (c) 1.41 g solution. **12.9** 25 *m* NaOH. **12.10** 16.1 *m*. **12.11** 6.82 M. **12.12** 0.00469 *M* $Al(NO_3)_3$, 0.00470 *m* $Al(NO_3)_3$. **12.13** 9.02 torr. **12.14** 61.2 g stearic acid. **12.15** 55.4 torr. **12.16** 45.0 torr. **12.17** 100.16 °C. **12.18** 209 g glucose. **12.19** 157 g/mol. **12.20** 125 g mol^{-1}. **12.21** 3.75 mm Hg, 51.1 mm H_2O. **12.22** 0.051 g. **12.23** 4.99×10^4 g mol^{-1}. **12.24** 5.38×10^2 g mol^{-1}. **12.25** −0.882 °C, −0.441 °C. **12.26** (a) 0.372 °C, (b) 0.0372 °C, (c) 0.00372 °C, The first freezing point depression could be measured using a laboratory thermometer that can measure 0.1 °C increments.

Review Problems

12.38

$$\begin{array}{ll}
\text{(a) } KCl(s) \longrightarrow K^+(g) + Cl^-(g), & \Delta H° = +690 \text{ kJ mol}^{-1} \\
\text{(b) } K^+(g) + Cl^-(g) \longrightarrow K^+(aq) + Cl^-(aq), & \underline{\Delta H° = -686 \text{ kJ mol}^{-1}} \\
\quad KCl(s) \longrightarrow K^+(aq) + Cl^-(aq), & \Delta H° = +4 \text{ kJ mol}^{-1}
\end{array}$$

12.40 0.038 g/L. **12.42** 0.020 g L^{-1}. **12.44** 3.35 *m*. **12.46** 0.133 molal, 2.39×10^{-3}, 2.34%. **12.48** = 5.45%. **12.50** 7.89%, 4.76 *m*. **12.52** 0.359 *M* $NaNO_3$, 3.00%, 6.49×10^{-3}. **12.54** 22.8 torr. **12.56** 52.7 torr. **12.58** 70 mol % toluene and 30 mol % benzene. **12.60** (a) 0.029, (b) 2.99×10^{-2} mol soute, (c) 278 g/mol. **12.62** 55.1 g. **12.64** 152 g/mol. **12.66** 127 g/mol, $C_8H_4N_2$.

12.68 (a) $\dfrac{(g) \times (L\ atm\ mol^{-1}K^{-1}) \times (K)}{L \times atm} = \dfrac{g}{mol}$, (b) 1.8×10^6 g/mol. **12.70** 15.3 torr. **12.72** 1.3×10^4 torr. **12.74** −1.1 °C. **12.76** 2. **12.78** 1.89

CHAPTER 13

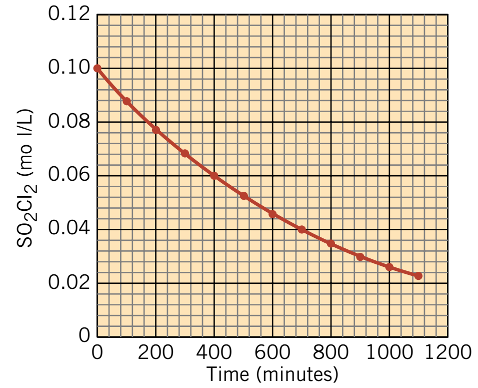
Practice Exercises

13.1 Rate of production of $I^- = 8.0 \times 10^{-5}$ mol L^{-1} s^{-1}, Rate of production of $SO_4^{2-} = 2.4 \times 10^{-4}$ mol L^{-1} s^{-1}. **13.2** Rate of disappearance of $O_2 = 0.45$ mol L^{-1} s^{-1}. Rate of disappearance of $H_2S = 0.30$ mol L^{-1} s^{-1}. **13.3** -2.1×10^{-4} mol L^{-1} s^{-1}. **13.4** 1×10^{-4} mol L^{-1} s^{-1} is correct. **13.5** (a) 9.8×10^{14} L^2 mol^{-2} s^{-1}, (b) L^2 mol^{-2} s^{-1}. **13.6** (a) 8.0×10^{-2} L mol^{-1} s^{-1}, (b) L mol^{-1} s^{-1}. **13.7** order of the reaction with respect to $[BrO_3^-] = 1$, order of the reaction with respect to $[SO_3^{2-}] = 1$, overall order of the reaction $= 1 + 1 = 2$. **13.8** Rate $= k[Cl_2]^2[NO]$. **13.9** $k = 2.0 \times 10^2$ L^2 mol^{-2} s^{-1}. Each of the other data sets also gives the same value. **13.10** (a) The rate will increase nine–fold, (b) The rate will increase three–fold, (c) The rate will decrease by three fourths. **13.11** rate $= k[NO]^n [H_2]^m$, (a) rate $= k[NO]^2 [H_2]^1$, (b) $k = 2.1 \times 10^5$ mol^{-2} L^2 s^{-1}, (c) mol^{-2} L^2 s^{-1}. **13.12** (a) First order with respect to sucrose. (b) 6.17×10^{-4} s^{-1}. **13.13** (a) Rate $= k[A]^2[B]^2$, (b) $k = 6.9 \times 10^{-3}$ L^3 mol^{-3} s^{-1}, (c) L^3 mol^{-3} s^{-1}, (d) 4. **13.14** $k = 2.56 \times 10^{-2}$ yr^{-1}. **13.15** (a) 0.26 *M*, (b) 77 min. **13.16** 18.7 min, 37.4 min. **13.17** 27.0 yr. **13.18** 1.72×10^4 yrs. **13.19** 24,800 years BP, 424 years BP. **13.20** 63 min. **13.21** 4.0×10^{-4} *M*. **13.22** 1.03 L mol^{-1} s^{-1}, $t_{1/2} = 1.48 \times 10^3$ s. **13.23** The reaction is first–order. **13.24** 45 °C. **13.25** a) 1.4×10^2 kJ/mol, b) 0.30 L mol^{-1} s^{-1}. **13.26** (a), (b), and (e) may be elementary processes. Equations (c), (d), and (f) are not elementary processes because they have more than two molecules colliding at one time, and this is very unlikely. **13.27** Rate $= k[NO][O_3]$.

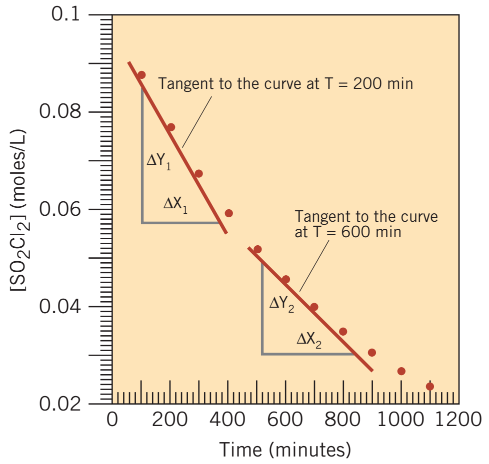
13.28 Rate $= \dfrac{k[NO_2Cl]^2}{[NO_2]}$

Review Problems

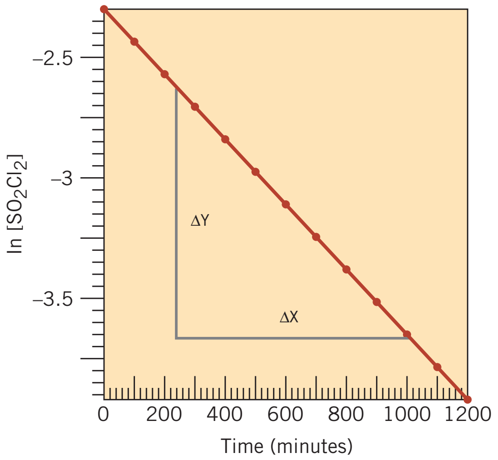
13.47



At 200 min: 1×10^{-4} *M*/s At 600 minutes: 7×10^{-5} *M*/s.



13.49 The rate of disappearance of hydrogen is three times the rate of disappearance of nitrogen. NH_3 appears twice as fast as N_2 disappears. **13.51** (a) rate for $O_2 = 11.4$ mol L^{-1} s^{-1}, (b) rate for $CO_2 = 7.20$ mol L^{-1} s^{-1}, (c) rate for $H_2O = 8.40$ mol L^{-1} s^{-1}.
13.53 rate $= 8.0 \times 10^{-11}$ mol L^{-1} s^{-1}.
13.55 rate $= 2.4 \times 10^{2}$ mol L^{-1} s^{-1}.
13.57 rate $= k \times [M][N]^2$, $k = 2.5 \times 10^{3}$ L^2 mol^{-2} s^{-1}.
13.59 rate $= k[OCl^-][I^-]$, $k = 6.1 \times 10^{9}$ L mol^{-1} s^{-1}.
13.61 rate $= k[ICl][H_2]$, $k = 1.5 \times 10^{-1}$ L mol^{-1} s^{-1}.
13.63



$k = 1.32 \times 10^{-3}$ min^{-1}.
13.65 (a) $x = 3.7 \times 10^{-3}$ *M*, (b) $x = 6.0 \times 10^{-4}$ *M*.
13.67 4.26×10^{-3} min^{-1}. **13.69** 1.3×10^{4} min.
13.71 1/256. **13.73** Approximately 500 min, The reaction is first–order in SO_2Cl_2. **13.75** 1.3×10^{9} years old.
13.77 2.7×10^{4} years ago.
13.79 $E_a = 7.93 \times 10^{4}$ J/mol = 79.3 kJ/mol.
13.81 $E_a = 99$ kJ mol^{-1} and $A = 6.6 \times 10^{9}$ L mol^{-1} s^{-1}.
13.83 Use equation 13.10: (a) 1.9×10^{-5} s^{-1}, (b) 1.6×10^{-1} s^{-1}

CHAPTER 14

Practice Exercises

14.1 $2N_2O_3 + O_2 \rightleftharpoons 4NO_2$.

14.2 (a) $\frac{[H_2O]^2}{[H_2]^2[O_2]} = K_c$, (b) $\frac{[CO_2][H_2O]^2}{[CH_4][O_2]^2} = K_c$.

14.3 $K_c = 1.2 \times 10^{-13}$. **14.4** $K_c = 1.9 \times 10^{5}$.

14.5 $K_P = \frac{(P_{N_2O})^2}{(P_{N_2})^2(P_{O_2})}$. **14.6** $K_P = \frac{(P_{HI})^2}{(P_{H_2})(P_{I_2})}$.

14.7 $K_P = 1.8 \times 10^{36}$. **14.8** Smaller $K_c = 57$.

14.9 $K_c = \frac{1}{[NH_3(g)][HCl(g)]}$.

14.10 (a) $K_c = \frac{1}{[Cl_2(g)]}$,
(b) $K_c = [Na^+ (aq)][OH^- (aq)][H_2 (g)]$,
(c) $K_c = [Ag^+]^2[CrO_4^{\ 2-}]$,
(d) $K_c = \frac{[Ca^{+2}(aq)][HCO_3^-(aq)]^2}{[CO_2(aq)]}$.

14.11 Reaction will proceed to the left. **14.12** Reaction (b).
14.13 There will be no change in the amount of H_3PO_4.
14.14 (a) Decreasing the concentration of Cl_2 at equilibrium, the value of K_P will be unchanged. (b) Increasing the amount of Cl_2 at equilibrium. The value of K_P will be unchanged, (c) Increasing the amount of Cl_2 at equilibrium. Decreasing the value of K_P. (d) Decreasing the concentration of Cl_2 at equilibrium, The value of K_P will be unchanged.
14.15 [CO] decreases by 0.060 mol/L and $[CO_2]$ increases by 0.060 mol/L. **14.16** $K_c = 4.06$.
14.17 (a) $[PCl_3] = 0.200$ *M*, $[Cl_2] = 0.100$ *M*, $[PCl_5] = 0.000$ *M*, (b) PCl_3 and Cl_2 have decreased by 0.080 *M* and PCl_5 has increased by 0.080 *M*. (c) $[PCl_3] = 0.120$ *M*. $[PCl_5] = 0.080$ *M* $[Cl_2] = 0.020$ *M*. (d) $K_c = 33$.
14.18 $[NO_2] = 1.04 \times 10^{-2}$ *M*.
14.19 $[C_2H_5OH] = 8.98 \times 10^{-3}$ *M*.
14.20 $[H_2] = [I_2] = 0.044$ *M*, $[HI] = 2(0.156) = 0.312$ *M*.
14.21 $[H_2] = 0.200 - 0.0934 = 0.107$ *M*, $[I_2] = 0.100 - 0.0934 = 0.0066$ *M*, $[HI] = 2(0.0934) = 0.1868$ *M*.
14.22 $[N_2] = 6.2 \times 10^{-4}$ *M*, $[H_2] = 1.9 \times 10^{-3}$ *M*.
14.23 $[NO] = 1.1 \times 10^{-17}$ *M*.

Review Problems

14.19 (a) $K_c = \frac{[POCl_3]^2}{[PCl_3]^2[O_2]}$, (b) $K_c = \frac{[SO_2]^2[O_2]}{[SO_3]^2}$,

(c) $K_c = \frac{[NO]^2[H_2O]^2}{[N_2H_4][O_2]^2}$, (d) $K_c = \frac{[NO_2]^2[H_2O]^8}{[N_2H_4][H_2O_2]^6}$,

(e) $K_c = \frac{[SO_2][HCl]^2}{[SOCl_2][H_2O]}$.

14.21 (a) $K_P = \frac{(P_{POCl_3})^2}{(P_{PCl_3})^2(P_{O_2})}$, (b) $K_P = \frac{(P_{SO_2})^2(P_{O_2})}{(P_{SO_3})^2}$,

(c) $K_P = \dfrac{(P_{NO})^2(P_{H_2O})^2}{(P_{N_2H_4})(P_{O_2})^2}$, (d) $K_P = \dfrac{(P_{NO_2})^2(P_{H_2O})^8}{(P_{N_2H_4})(P_{H_2O_2})^6}$,

(e) $K_P = \dfrac{(P_{SO_2})(P_{HCl})^2}{(P_{SOCl_2})(P_{H_2O})}$.

14.23 (a) $K_c = \dfrac{[Ag(NH_3)_2{}^+]}{[Ag^+][NH_3]^2}$, (b) $K_c = \dfrac{[Cd(SCN)_4{}^{2-}]}{[Cd^{2+}][SCN^-]^4}$.

14.25 $K = 1 \times 10^{85}$.

14.27 (a) $K_c = \dfrac{[HCl]^2}{[H_2][Cl_2]}$, (b) $K_c = \dfrac{[HCl]}{[H_2]^{1/2}[Cl_2]^{1/2}}$,

K_c for reaction (b) is the square root of K_c for reaction (a). **14.29** 0.0375 *M*. **14.31** b. **14.33** $K_c = 11$. **14.35** $K_P = 2.7 \times 10^{-2}$. **14.37** $K_P = 5.4 \times 10^{-5}$. **14.39** (a) 55.5 *M*, (b) 55.5 *M*, (c) 55.5 *M*.

14.41 (a) $K_c = \dfrac{[CO]^2}{[O_2]}$, (b) $K_c = [H_2O][SO_2]$,

(c) $K_c = \dfrac{[CH_4][CO_2]}{[H_2O]^2}$, (d) $K_c = \dfrac{[H_2O][CO_2]}{[HF]^2}$,

(e) $K_c = [H_2O]^5$.

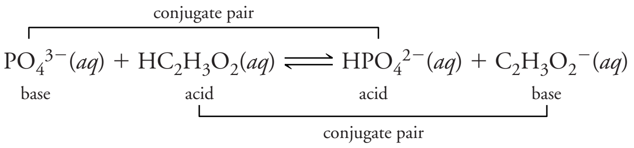
14.43 $[HI] = 1.47 \times 10^{-12}$ *M*, $[Cl_2] = 7.37 \times 10^{-13}$ *M*. **14.45** (a) The system shifts to the right to consume some of the added methane. (b) The system shifts to the left to consume some of the added hydrogen. (c) The system shifts to the right to make some more carbon disulfide. (d) The system shifts to the left to decrease the amount of gaseous moles. (e) The system shifts to the right to absorb some of the added heat. **14.47** (a) right, (b) left, (c) left, (d) right, (e) no effect, (f) left. **14.49** (a) No, (b) To the left. **14.51** $[CH_3OH] = 4.36 \times 10^{-3}$ *M*. **14.53** $K_c = 0.398$. **14.55** $K_c = 0.0955$. **14.57** $K_c = 0.915$. **14.59** $[Br_2] = [Cl_2] = 0.011$ *M*. **14.61** $[NO_2] = [SO_2] = 0.0497$ mol/L, $[NO] = [SO_3] = 0.0703$ mol/L. **14.63** $[H_2] = [CO_2] = 7.7 \times 10^{-3}$ *M*, $[CO] = [H_2O] = 0.0123$ *M*. **14.65** $[H_2] = [Cl_2] = 8.9 \times 10^{-19}$ *M*. **14.67** $[CO] = 5.0 \times 10^{-4}$ *M*. **14.69** $[PCl_5] = 3.0 \times 10^{-5}$ *M*. **14.71** $[NO_2] = [SO_2] = 0.0281$ *M*. **14.73** $[CO] = [H_2O] = 0.200$ *M*.

CHAPTER 15

Practice Exercises

15.1 Conjugate acid base pairs (a), (c), and (f). (b) The conjugate base of HI is I^-. (d) The conjugate base of HNO_2 is NO_2^- and the conjugate base of NH_4^+ is NH_3. (e) The conjugate acid of CO_3^{2-} is HCO_3^- and the conjugate acid of CN^- is HCN. **15.2** (a) OH^-, (b) I^-, (c) NO_2^- (d) $H_2PO_4^-$, (e) HPO_4^{2-}, (f) PO_4^{3-}, (g) HS^- (h) NH_3. **15.3** (a) H_2O_2, (b) HSO_4^-, (c) HCO_3^-, (d) HCN, (e) NH_3 (f) NH_4^+, (g) H_3PO_4 (h) $H_2PO_4^-$. **15.4** HCN and CN^-, HCl and Cl^-. **15.5** Brønsted acids: $H_2PO_4^-(aq)$ and $H_2CO_3(aq)$, Brønsted bases: $HCO_3^-(aq)$ and $HPO_4^{2-}(aq)$.

15.6

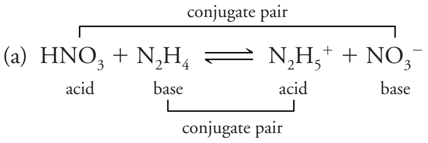


$$\underset{\text{base}}{PO_4^{3-}(aq)} + \underset{\text{acid}}{HC_2H_3O_2(aq)} \rightleftharpoons \underset{\text{acid}}{HPO_4^{2-}(aq)} + \underset{\text{base}}{C_2H_3O_2^-(aq)}$$

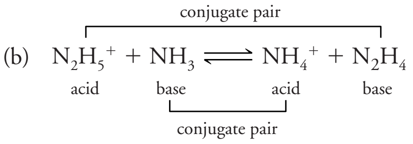
15.7 (a) $H_2PO_4^-$ amphoteric since it can both accept and donate a proton, (b) HPO_4^{2-} amphoteric since it can both accept and donate a proton, (c) H_2S amphoteric since it can both accept and donate a proton, (d) H_3PO_4 not amphoteric: it can only donate protons, (e) NH_4^+ not amphoteric: it can only donate protons, (f) H_2O amphoteric since it can both accept and donate a proton, (g) HI not amphoteric: it can only donate protons, (h) HNO_2 not amphoteric: it can only donate protons.
15.8 $HPO_4^{2-}(aq) + OH^-(aq) \longrightarrow PO_4^{3-}(aq) + H_2O$; $HPO_4^{2-}(aq) + H_3O^+(aq) \longrightarrow H_2PO_4^- + H_2O$.
15.9 $HSO_4^-(aq) + HPO_4^{2-}(aq) \longrightarrow SO_4^{-2}(aq) + H_2PO_4^-(aq)$.
15.10 The substances on the right because they are the weaker acid and base. **15.11** (a) HF < HBr < HI, (b) $PH_3 < H_2S <$ HCl, (c) $H_2O < H_2Se < H_2Te$, (d) $AsH_3 < H_2Se <$ HBr, (e) $PH_3 < H_2Se <$ HI. **15.12** (a) HBr, (b) H_2Te, (c) H_2S. **15.13** (a) $HClO_3$, (b) H_2SO_4. **15.14** (a) H_3AsO_4, (b) H_2TeO_4. **15.15** (a) HIO_4, (b) H_2TeO_4, (c) H_3AsO_4. **15.16** (a) H_2SO_4, (b) H_3AsO_4. **15.17** (a) NH_3 Lewis base, H^+ Lewis acid, (b) CN^- Lewis base, H_2O Lewis acid, (c) Ag^+ Lewis acid, NH_3 Lewis base. **15.18** (a) Fluoride ions have a filled octet of electrons and are likely to behave as Lewis bases, i.e., electron pair donors. (b) $BeCl_2$ is a likely Lewis acid since it has an incomplete shell. The Be atom has only two valence electrons and it can easily accept a pair of electrons. (c) It could reasonably be considered a potential Lewis base since it contains three oxygens, each with lone pairs and partial negative charges. However, it is more effective as a Lewis acid, since the central sulfur bears a significant positive charge. **15.19** 8.3×10^{-16} *M*. **15.20** 1.3×10^{-9} *M*, Basic. **15.21** pOH = 9.75, $[H^+] = 5.62 \times 10^{-5}$ *M*, $[OH^-] = 1.78 \times 10^{-10}$ *M*. **15.22** pH = 3.44, pOH = 10.56, Basic. **15.23** 5.17. **15.24** CaO. **15.25** pH = 1.1, pOH = 15.1. **15.26** (a) $[H^+] = 1.3 \times 10^{-3}$ *M*, $[OH^-] = 7.7 \times 10^{-12}$ *M*, Acidic. (b) $[H^+] = 1.4 \times 10^{-4}$ *M*, $[OH^-] = 7.1 \times 10^{-11}$ *M*, Acidic. (c) $[H^+] = 1.5 \times 10^{-11}$ *M*, $[OH^-] = 6.7 \times 10^{-4}$ *M*, Basic. (d) $[H^+] = 7.8 \times 10^{-5}$ *M*, $[OH^-] = 1.3 \times 10^{-10}$ *M*, Acidic. (e) $[H^+] = 2.5 \times 10^{-12}$ *M*, $[OH^-] = 4.0 \times 10^{-3}$ *M*, Basic.
15.27 $[H^+] = 0.005$ *M*, pH = 2.30, pOH = 11.70.
15.28 pOH = 1.068, pH = 12.932, $[H^+] = 1.17 \times 10^{-13}$ *M*.
15.29 $[H^+] = 3.2 \times 10^{-6}$ *M*.

Review Problems

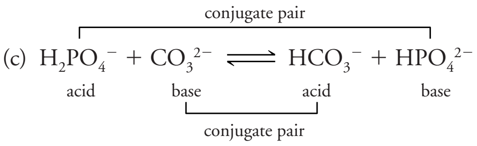
15.41 (a) HF, (b) $N_2H_5^+$, (c) $C_5H_5NH^+$, (d) HO_2^-, (e) H_2CrO_4.
15.43



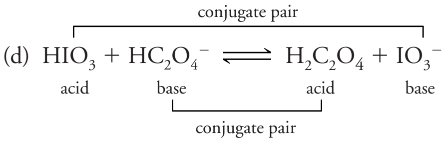
$$\text{(a)}\ \underset{\text{acid}}{HNO_3} + \underset{\text{base}}{N_2H_4} \rightleftharpoons \underset{\text{acid}}{N_2H_5^+} + \underset{\text{base}}{NO_3^-}$$



$$\text{(b)}\ \underset{\text{acid}}{N_2H_5^+} + \underset{\text{base}}{NH_3} \rightleftharpoons \underset{\text{acid}}{NH_4^+} + \underset{\text{base}}{N_2H_4}$$

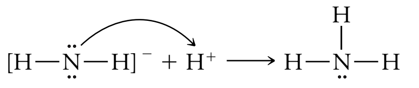


$$\text{(c)}\ \underset{\text{acid}}{H_2PO_4^-} + \underset{\text{base}}{CO_3^{2-}} \rightleftharpoons \underset{\text{acid}}{HCO_3^-} + \underset{\text{base}}{HPO_4^{2-}}$$



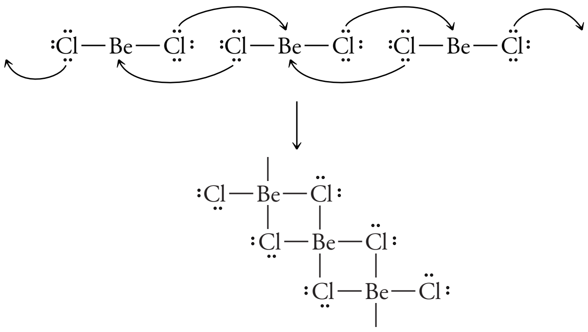
$$\text{(d)}\ \underset{\text{acid}}{HIO_3} + \underset{\text{base}}{HC_2O_4^-} \rightleftharpoons \underset{\text{acid}}{H_2C_2O_4} + \underset{\text{base}}{IO_3^-}$$

15.45 (a) HBr, HBr bond is weaker, (b) HF, more electronegative F polarizes and weakens the bond, (c) HBr, larger Br forms a weaker bond with H. **15.47** (a) $HClO_2$, because it has more oxygen atoms, (b) H_2SeO_4, because it has more lone oxygen atoms. **15.49** (a) $HClO_3$, because Cl is more electronegative, (b) $HClO_3$, because the charge is more evenly distributed, (c) $HBrO_4$, because the negative charge is more evenly distributed.
15.51

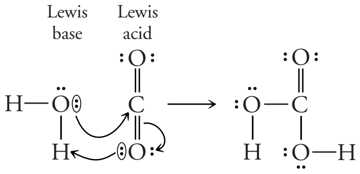


Lewis bases: NH_2^- Lewis acid: H^+

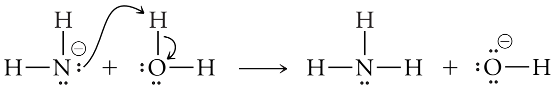
15.53



15.55



15.57



Lewis bases: NH_2^- and OH^-; Lewis acid: H^+

15.59 $[D^+] = [OD^-] = 3.0 \times 10^{-8}$ *M*, pD = 7.52, pOD = 7.52.
15.61 (a) $[H^+] = 1.5 \times 10^{-12}$ *M*, pH = 11.83, pOH = 2.17, (b) $[H^+] = 1.6 \times 10^{-10}$ *M*, pH = 9.81, pOH = 4.19, (c) $[H^+] = 6.3 \times 10^{-7}$ *M*, pH = 6.20, pOH = 7.80, (d) $[H^+] = 1.2 \times 10^{-3}$ *M*, pH = 2.91, pOH = 11.09.
15.63 4.72. **15.65** (a) $[H^+] = 7.2 \times 10^{-9}$ *M*, $[OH^-] = 1.4 \times 10^{-6}$ *M*, (b) $[H^+] = 2.7 \times 10^{-3}$ *M*, $[OH^-] = 3.6 \times 10^{-12}$ *M*, (c) $[H^+] = 5.6 \times 10^{-12}$ *M*, $[OH^-] = 1.8 \times 10^{-3}$ *M*, (d) $[H^+] = 5.3 \times 10^{-14}$ *M*, $[OH^-] = 1.9 \times 10^{-1}$ *M*, (e) $[H^+] = 2.0 \times 10^{-7}$ *M*, $[OH^-] = 5.0 \times 10^{-8}$ *M*. **15.67** $[H^+] = 2.0 \times 10^{-6}$ *M*, $[OH^-] = 5.0 \times 10^{-9}$ *M*. **15.69** pH = 3.19, $[OH^-] = 1.55 \times 10^{-11}$ *M*. **15.71** 0.15 *M* OH^-, pOH = 0.82, pH = 13.18, $[H^+] = 6.61 \times 10^{-14}$ *M*.
15.73 2.0×10^{-3} *M* $Ca(OH)_2$, 2.0×10^{-4} *M* $Ca(OH)_2$.
15.75 168 mL 0.0100 *M* KOH. **15.77** 5×10^{-12} *M*.

CHAPTER 16

Practice Exercises

16.1 (a) $HC_2H_3O_2 + H_2O \rightleftharpoons H_3O^+ + C_2H_3O_2^-$,

$$K_a = \frac{[H_3O^+][C_2H_3O_2^-]}{[HC_2H_3O_2]},$$

(b) $(CH_3)_3NH^+ + H_2O \rightleftharpoons H_3O^+ + (CH_3)_3N$,

$$K_a = \frac{[H_3O^+][(CH_3)_3N]}{[(CH_3)_3NH^+]},$$

(c) $H_3PO_4 + H_2O \rightleftharpoons H_3O^+ + H_2PO_4^-$,

$$K_a = \frac{[H_3O^+][H_2PO_4^-]}{[H_3PO_4]}.$$

16.2 (a) $HCHO_2 + H_2O \rightleftharpoons H_3O^+ + CHO_2^-$,

$$K_a = \frac{[H_3O^+][CHO_2^-]}{[HCHO_2]},$$

(b) $(CH_3)_2NH_2^+ + H_2O \rightleftharpoons H_3O^+ + (CH_3)_2NH$,

$$K_a = \frac{[H_3O^+][CH_3NH]}{[(CH_3)_2NH_2^+]},$$

(c) $H_2PO_4^- + H_2O \rightleftharpoons H_3O^+ + HPO_4^{2-}$,

$$K_a = \frac{[H_3O^+][HPO_4^{2-}]}{[H_2PO_4^-]}.$$

16.3 Barbituric acid. **16.4** *HA* is the strongest acid, For HA: $K_a = 6.9 \times 10^{-4}$, For HB: $K_a = 7.2 \times 10^{-5}$.
16.5 (a) $(CH_3)_3N + H_2O \rightleftharpoons (CH_3)_3NH^+ + OH^-$,

$$K_b = \frac{[(CH_3)_3NH^+][OH^-]}{[(CH_3)_3N]},$$

(b) $SO_3^{2-} + H_2O \rightleftharpoons HSO_3^- + OH^-$,

$$K_b = \frac{[HSO_3^-][OH^-]}{[SO_3^{2-}]},$$

(c) $NH_2OH + H_2O \rightleftharpoons NH_3OH^+ + OH^-$,

$$K_b = \frac{[NH_3OH^+][OH^-]}{[NH_2OH]}.$$

16.6 (a) $HSO_4^- + H_2O \rightleftharpoons H_2SO_4 + OH^-$,

$$K_b = \frac{[H_2SO_4][OH^-]}{[HSO_4^-]},$$

(b) $H_2PO_4^- + H_2O \rightleftharpoons H_3PO_4 + OH^-$,

$$K_b = \frac{[H_3PO_4][OH^-]}{[H_2PO_4^-]},$$

(c) $HPO_4^{2-} + H_2O \rightleftharpoons H_2PO_4^- + OH^-$,

$$K_b = \frac{[H_2PO_4^-][OH^-]}{[HPO_4^{2-}]},$$

(d) $HCO_3^- + H_2O \rightleftharpoons H_2CO_3 + OH^-$,

$$K_b = \frac{[H_2CO_3][OH^-]}{[HCO_3^-]},$$

(e) $HSO_3^- + H_2O \rightleftharpoons H_2SO_3 + OH^-$,

$$K_b = \frac{[H_2SO_3][OH^-]}{[HSO_3^-]}.$$

16.7 $K_b = 4.3 \times 10^{-4}$. **16.8** $K_b = 5.6 \times 10^{-11}$.
16.9 $K_a = 1.15 \times 10^{-3}$, $pK_a = 2.938$.
16.10 $K_a = 1.7 \times 10^{-5}$, $pK_a = 4.78$.
16.11 $K_b = 1.6 \times 10^{-6}$, $pK_b = 5.79$.
16.12 $[H^+] = 5.4 \times 10^{-6}$ *M*, pH = 5.27.
16.13 $[H^+] = 8.4 \times 10^{-4}$ *M*, pH = 3.08.
16.14 pOH = 5.48. **16.15** pH = 8.59. **16.16** pH = 5.36.
16.17 (a) basic, (b) neutral, (c) acidic. **16.18** (a) neutral, (b) basic, (c) acidic. **16.19** pH = 5.39. **16.20** pH = 8.07.
16.21 pH = 5.13. **16.22** basic. **16.23** neutral.

16.24 pH = 10.79. **16.25** Solving using the quadratic formula: pH = 2.38. Solving by simplification pH = 2.35. The difference is a difference of 0.03 pH units. **16.26** pH = 10.68. **16.27** Upon addition of a strong acid, the concentration of $HC_2H_3O_2$ will increase. When a strong base is added, it reacts with the acid to form more of the acetate ion, therefore the concentration of the acetic acid will decrease. **16.28** (a) $H^+ + NH_3 \longrightarrow NH_4^+$, (b) $OH^- + NH_4^+ \longrightarrow H_2O + NH_3$. **16.29** 4.84, the difference is due to rounding errors. **16.30** 4.61. **16.31** Acetic acid buffer, 26.2 g $NaC_2H_3O_2$, or hydrazoic acid buffer, 21.0 g NaN_3, or butanoic acid buffer, 29.6 g $NaC_4H_7O_2$, or propanoic acid buffer, 22.9 g $NaC_3H_5O_2$. **16.32** Yes, 0.692 mol $HCHO_2$ for 1 mol CHO_2^-, 4.7 g $NaCHO_2$. **16.33** 0.13 pH units. **16.34** pH = 9.76, pH = 9.67.

16.35 $H_3PO_4 \rightleftharpoons H^+ + H_2PO_4^- \quad K_a = \dfrac{[H^+][H_2PO_4^-]}{[H_3PO_4]}$,

$$H_2PO_4^- \rightleftharpoons H^+ + HPO_4^{2-} \quad K_a = \frac{[H^+][HPO_4^{2-}]}{[H_2PO_4^-]},$$

$$HPO_4^{2-} \rightleftharpoons H^+ + PO_4^{3-} \quad K_a = \frac{[H^+][PO_4^{3-}]}{[HPO_4^{2-}]}.$$

16.36 $[H^+] = 2.6 \times 10^{-3}$ *M*, pH = 2.58, $[HC_6H_6O_6^-] = 2.7 \times 10^{-12}$.
16.37 pH = 11.66, It is not a substitute for $NaHCO_3$.
16.38 pH = 10.24. **16.39** $[H_2SO_3] = K_{b2}$ for SO_3^{2-}.
16.40 (a) H_2O, K^+, $HC_2H_3O_2$, H^+, $C_2H_3O_2^-$, and OH^-, $[H_2O] > [K^+] > [C_2H_3O_2^-] > [OH^-] > [HC_2H_3O_2] > [H^+]$, (b) H_2O, $HC_2H_3O_2$, H^+, $C_2H_3O_2^-$, and OH^-, $[H_2O] > [HC_2H_3O_2] > [H^+] > [C_2H_3O_2^-] > [OH^-]$, (c) H_2O, K^+, $HC_2H_3O_2$, H^+, $C_2H_3O_2^-$, and OH^-, $[H_2O] > [K^+] > [OH^-] > [C_2H_3O_2^-] > [HC_2H_3O_2] > [H^+]$, (d) H_2O, K^+, $HC_2H_3O_2$, H^+, $C_2H_3O_2^-$, and OH^-, $[H_2O] > [HC_2H_3O_2] > [K^+] > [C_2H_3O_2^-] > [OH^-] > [H^+]$.
16.41 (a) 2.37, (b) 3.74, (c) 4.22, (d) 8.22. **16.42** pH = 3.66

Review Problems

16.32 1.5×10^{-11}. **16.34** 7.1×10^{-11}. **16.36** 0.30%, $K_a = 1.82 \times 10^{-6}$. **16.38** $K_a = 2.3 \times 10^{-2}$, pK_a = 1.6.
16.40 $K_b = 5.6 \times 10^{-4}$ pK_b = 3.25, 7.2%.
16.42 $[HC_3H_5O_2] = 0.145$, $[H^+] = 4.5 \times 10^{-3}$, $[C_3H_5O_2^-] = 4.5 \times 10^{-3}$, pH = 2.34. **16.44** 10.26.
16.46 $[HC_2H_3O_2] = 0.47$ *M*. **16.48** pH = 10.44.
16.50 $[H^+] = 6.0 \times 10^{-4}$ *M*, pH = 3.22.
16.52 pH = 11.26, $[HCN] = 1.8 \times 10^{-3}$ *M*.
16.54 pH = 5.72. **16.56** $K_a = 1.4 \times 10^{-5}$.
16.58 pH = 10.67. **16.60** pH = 4.97. **16.62** pH = 9.00.
16.64 $\Delta[NH_4^+] = -0.01$ *M*, $\Delta[NH_3] = -0.03$ *M*.
16.66 −0.12 pH units. **16.68** −0.11 pH units.
16.70 2.2 g $NaCHO_2$. **16.72** $pH_{initial} = 4.788$, $pH_{final} = 4.761$, pH = 1.63. **16.74** $[H_2C_6H_6O_6] \cong 0.15$ *M*, $[H_3O^+] = [HC_6H_6O_6^-] = 3.2 \times 10^{-3}$ *M*, $[C_6H_6O_6^{2-}] = 2.7 \times 10^{-12}$ *M*, $[OH^-] = 3.2 \times 10^{-12}$ *M*, pH = 2.5. **16.76** $[H^+] = [H_2PO_4^-] = 0.12$ *M*, $[H_3PO_4] = 2.0 - 0.12 = 1.9$ *M*, pH = 0.92, $[HPO_4^{2-}] = 6.3 \times 10^{-8}$, $[PO_4^{3-}] = 2.4 \times 10^{-19}$.
16.78 $[H^+] = [H_2PO_3^-] = 0.16$ *M*, $[HPO_3^{2-}] = 1.6 \times 10^{-7}$ *M*, pH = 0.80. **16.80** pH = 10.28, $[HSO_3^-] = 1.9 \times 10^{-4}$, $[H_2SO_3] = 8.3 \times 10^{-13}$. **16.82** pH = 9.10. **16.84** pH = 12.97, $[HPO_4^{2-}] = 9.4 \times 10^{-2}$ *M*, $[H_2PO_4^-] = 1.6 \times 10^{-7}$, $[H_3PO_4^-] = 2.4 \times 10^{-18}$. **16.86** pH = 8.07, Cresol red.
16.88 pH = 12.93. **16.90** (a) 2.8724, (b) 4.444, (c) 4.7447, (d) 8.7236

CHAPTER 17

Practice Exercises

17.1 $Ba_3(PO_4)_2(s) \rightleftharpoons 3Ba^{2+}(aq) + 2PO_4^{3-}(aq)$, $K_{sp} = [Ba^{2+}]^3[PO_4^{3-}]^2$.
17.2 (a) $K_{sp} = [Ba^{2+}][C_2O_4^{2-}]$, (b) $K_{sp} = [Ag^+]^2[SO_4^{2-}]$.
17.3 3.2×10^{-10}. **17.4** 3.98×10^{-8}. **17.5** 1.5×10^{-5}.
17.6 1.0×10^{-10}. **17.7** 3.9×10^{-8}. **17.8** 1.8×10^{-5} *M* Ag_3PO_4.
17.9 (a) 7.1×10^{-7} *M* AgBr, (b) 1.3×10^{-4} *M* Ag_2CO_3.
17.10 2.1×10^{-16} *M* of AgI will dissolve in a 0.20 *M* CaI_2 solution. In pure water, the solubility is 9.1×10^{-9} *M*.
17.11 1.3×10^{-35} *M* of $Fe(OH)_3$. **17.12** A precipitate will form. **17.13** No precipitate will form. **17.14** We expect $PbSO_4(s)$ since nitrates are soluble. A precipitate of $PbSO_4$ is not expected. **17.15** We expect a precipitate of $PbCl_2$ since nitrates are soluble. A precipitate of $PbCl_2$ is not expected.
17.16 No. **17.17** 2.9. **17.18** 0.35 *M* H^+.
17.19 5.40 to 6.13. **17.20** 4.9×10^{-3} *M* in 0.10 *M* NH_3; 1.3×10^{-5} *M* in pure water. **17.21** 4.1 mol NH_3

Review Problems

17.16 (a) $K_{sp} = [Ca^{2+}][F^-]^2$, (b) $K_{sp} = [Ag^+]^2[CO_3^{2-}]$, (c) $K_{sp} = [Pb^{2+}][SO_4^{2-}]$, (d) $K_{sp} = [Fe^{3+}][OH^-]^3$, (e) $K_{sp} = [Pb^{2+}][I^-]^2$, (f) $K_{sp} = [Cu^{2+}][OH^-]^2$.
17.18 1.6×10^{-5}. **17.20** 1.10×10^{-10}. **17.22** 8.0×10^{-7}.
17.24 2.8×10^{-18}. **17.26** 8.1×10^{-3} *M*. **17.28** 1.3×10^{-4} *M*.
17.30 4.1×10^{-2} *M* LiF, 7.5×10^{-3} *M* BaF_2, LiF is more soluble.
17.32 2.8×10^{-18}. **17.34** 4.9×10^{-3} *M*.
17.36 (a) 4.4×10^{-4} *M*, (b) 9.5×10^{-6} *M*, (c) 9.5×10^{-7} *M*, (d) 6.3×10^{-7} *M*. **17.38** 6.9×10^{-9} *M*. **17.40** 1.7×10^{-3} *M*.
17.42 (a) 3.0×10^{-11} mol/L, (b) 1.2×10^{-6} mol/L.
17.44 1.3 %, +1.8 pH units. **17.46** 2.2 g $Fe(OH)_2$, 2.0×10^{-12} *M*. **17.48** 7.9×10^{-7} *M*. **17.50** No precipitate will form. **17.52** (a) No precipitate will form, (b) A precipitate will form. **17.54** 2.3×10^{-8} *M*. **17.56** No precipitate forms.
17.58 $[H^+] = 0.045$ *M*, pH = 1.35. **17.60** pH = 4.8–8.1, $Mn(OH)_2$ will be soluble, but some $Cu(OH)_2$ will precipitate out of solution.

17.62 (a) $Cu^{2+}(aq) + 4Cl^-(aq) \rightleftharpoons CuCl_4^{2-}(aq)$

$$K_{form} = \frac{[CuCl_4^{2-}]}{[Cu^{2+}][Cl^-]^4},$$

(b) $Ag^+(aq) + 2I^-(aq) \rightleftharpoons AgI_2^-(aq) \quad K_{form} = \dfrac{[AgI_2^-]}{[Ag^+][I^-]^2}$,

(c) $Cr^{3+}(aq) + 6NH_3(aq) \rightleftharpoons Cr(NH_3)_6^{3+}(aq)$

$$K_{form} = \frac{[Cr(NH_3)_6^{3+}]}{[Cr^{3+}][NH_3]^6}.$$

17.64 (a) $Co^{3+}(aq) + 6NH_3(aq) \rightleftharpoons Co(NH_3)_6^{3+}(aq)$

$$K_{form} = \frac{[Co(NH_3)_6^{3+}]}{[Co^{3+}][NH_3]^6},$$

(b) $Hg^{2+}(aq) + 4I^-(aq) \rightleftharpoons HgI_4^{2-}(aq)$

$$K_{form} = \frac{[HgI_4^{2-}]}{[Hg^{2+}][I^-]^4},$$

(c) $Fe^{2+}(aq) + 6CN^-(aq) \rightleftharpoons Fe(CN)_6^{4-}(aq)$

$$K_{form} = \frac{[Fe(CN)_6^{4-}]}{[Fe^{2+}][CN^-]^6}.$$

17.66 4.3×10^{-4}. **17.68** 450 g NaCN are required.
17.70 1.9×10^{-4} g AgI. **17.72** 9.5×10^{-3} *M*.
17.74 $K_{inst} = 3.7 \times 10^{-10}$

CHAPTER 18

Practice Exercises

18.1 +154 L atm. **18.2** Energy is added to the system in the form of work. **18.3** −2.64 kJ, ΔE is more exothermic.

18.4 −214.6 kJ, 1.14 %. **18.5** negative.

18.6 (a) negative, (b) positive.

18.7 (a) negative, (b) negative.

18.8 (a) negative, (b) negative, (c) positive.

18.9 $-99.1\ \mathrm{J\ K^{-1}}$.

18.10 (a) −229 J/K, (b) −120.9 J/K.

18.11 +98.3 kJ/mol. **18.12** 1482 kJ.

18.13 −30.3 kJ/mol.

18.14 (a) −69.7 kJ/mol, (b) −120.1 kJ/mol.

18.15 2820 kJ work for $C_2H_5OH(l)$, 4650 kJ work for $C_8H_{18}(l)$, C_8H_{18} is a better fuel on a gram basis.

18.16 788 kJ. **18.17** $+90.5\ \mathrm{J\ mol^{-1}\ K^{-1}}$.

18.18 614 K (341 °C).

18.19 The reaction should be spontaneous.

18.20 We do not expect to see products formed from reactants.

18.21 −4.3 kJ. **18.22** +32.8 kJ, −29.1 kJ. The equilibrium shifts to products. **18.23** $\Delta G = 0$. The reaction is at equilibrium.

18.24 The reaction will proceed to the right. **18.25** −33 kJ.

18.16 0.26

Review Problems

18.46 +1000 J, Endothermic. **18.48** 121 J.

18.50 (a) $\Delta H° = +\ 24.58$ kJ, $\Delta E° = 19.6$ kJ,
(b) $\Delta H° = -178$ kJ, $\Delta E° = -175$ kJ,
(c) $\Delta H° = 847.6$ kJ, $\Delta E° = \Delta H°$,
(d) $\Delta H° = 65.029$ kJ $\Delta E° = \Delta H°$.

18.52 $\Delta E = -677$ kJ, $\Delta E_{200\ °C} = -683$ kJ.

18.54 (a) −178 kJ spontaneous, (b) −311 kJ spontaneous, (c) +1084.3 kJ not spontaneous. **18.56** number of moles of reactants and products, state of the reactants and products, and complexity of the molecules. **18.58** (a) negative, (b) negative, (c) negative, (d) positive. **18.60** (a) −198.3 J/K not spontaneous, (b) −332.3 J/K not spontaneous, (c) +92.6 J/K spontaneous, (d) +14 J/K spontaneous, (e) +159 J/K spontaneous.

18.62 (a) $-52.8\ \mathrm{J\ mol^{-1}\ K^{-1}}$, (b) $-868.9\ \mathrm{J\ mol^{-1}\ K^{-1}}$, (c) $-318\ \mathrm{J\ mol^{-1}\ K^{-1}}$.

18.64 −269.7 J/K.

18.66 −209 kJ/mol.

18.68 (a) −82.3 kJ, (b) −8.8 kJ, (c) +70.7 kJ.

18.70 +0.16 kJ. **18.72** 1299.8 kJ. **18.74** 333 K.

18.76 $101\ \mathrm{J\ mol^{-1}\ K^{-1}}$.

18.78 spontaneous.

18.80 (a) $K_P = 10^{263}$, (b) $K_P = 2.90 \times 10^{-25}$.

18.82 The system is not at equilibrium and must shift to the right to reach equilibrium.

18.84 $K_P = 8.000 \times 10^8$. This is a favorable reaction, since the equilibrium lies far to the side favoring products and is worth studying as a method for methane production.

18.86 If $\Delta G° = 0$, $K_c = 1$. If we start with pure products, the value of Q will be infinite (there are zero reactants) and, since $Q > K_c$, the reaction will proceed towards the reactants, i.e., the pure products will decompose to their elements.

18.88 1.16×10^3 kJ/mol. **18.90** 354 kJ/mol.

18.92 577.7 kJ/mol. **18.94** 308.0 kJ/mol.

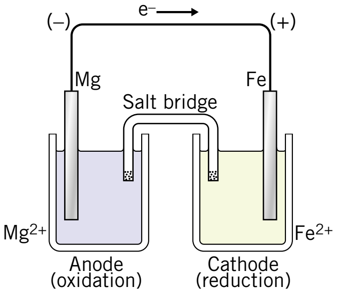
18.96 85 kJ/mol.

18.98 The heat of formation of CF_4 should be more exothermic than that of CCl_4 because more energy is released on formation of a C—F bond than on formation of a C—Cl bond. Also, less energy is needed to form gaseous F atoms than to form gaseous Cl atoms.

CHAPTER 19

Practice Exercises

19.1 anode: $Mg(s) \longrightarrow Mg^{2+}(aq) + 2e^-$,
cathode: $Fe^{2+}(aq) + 2e^- \longrightarrow Fe(s)$,
cell notation: $Mg(s)\,|\,Mg^{2+}(aq)\,\|\,Fe^{2+}(aq)\,|\,Fe(s)$,



19.2 anode: $Al(s) \longrightarrow Al^{3+}(aq) + 3e^-$,
cathode: $Ni^{2+}(aq) + 2e^- \longrightarrow Ni(s)$,
overall: $3Ni^{2+}(aq) + 2Al(s) \longrightarrow 2Al^{3+}(aq) + 3Ni(s)$.

19.3 Zinc. **19.4** −0.44 V.

19.5 (a) $2I^-(aq) + 2Fe^{3+}(aq) \longrightarrow I_2(s) + 2Fe^{2+}(aq)$
(b) $3Mg(s) + 2Cr^{3+}(aq) \longrightarrow 2Cr(s) + 3Mg^{2+}(aq)$
(c) $Co(s) + 4H^+(aq) + 2SO_4{}^{2-}(aq) \longrightarrow H_2SO_3(aq) + H_2O + Co^{2+}(aq)$.

19.6 $Br_2\,(aq) + H_2SO_3(aq) + H_2O \longrightarrow 2Br^-(aq) + SO_4{}^{2-}(aq) + 4H^+(aq)$.

19.7 Non spontaneous.
$Ni(s) + 2Fe^{3+}(aq) \longrightarrow Ni^{2+}(aq) + 2Fe^{2+}(aq)$.

19.8 $NiO_2(s) + Fe(s) + 2H_2O \longrightarrow Ni(OH)_2(s) + Fe(OH)_2(s)$ $E°_{cell} = 1.37$ V.

19.9 $2Cr(s) + 3Cu^{2+}(aq) \longrightarrow 2Cr^{3+}(aq) + 3Cu(s)$ $E°_{cell} = 1.08$ V.

19.10 $3MnO_4{}^-\,(aq) + 24H^+\,(aq) + 5Cr(s) \longrightarrow 5Cr^{3+}\,(aq) + 3Mn^{2+}\,(aq) + 12H_2O$ $E°_{cell} = 2.25$ V.

19.11 (a) Spontaneous, (b) Spontaneous.

19.12 (a) Nonspontaneous, (b) Spontaneous. **19.13** 3 electrons.

19.14 $\Delta G° = -102$ kJ, −343 kJ, +108 kJ and −11.6 kJ, respectively. **19.15** $K_c = 2.7 \times 10^{-16}$, $K = 5.6 \times 10^{16}$.

19.16 $Ag^+(aq) + Br^-(aq) \longrightarrow AgBr(s)$,

$K = \dfrac{1}{[Ag^+][Br^-]}$, 2.2×10^{12}.

19.17 $Cu^{2+}(aq) + Mg(s) \longrightarrow Mg^{2+}(aq) + Cu(s)$, 2.82 V.

19.18 1.04 V. **19.19** $2.9 \times 10^{-5}\ M\ Mg^{2+}$.

19.20 $1.9 \times 10^{-4}\ M$, $6.6 \times 10^{-13}\ M$. **19.21** $6.6 \times 10^{-4}\ M$.

19.22 I_2. **19.23** Tin. **19.24** 8.29×10^{-3} mol OH^-.

19.25 7.33 min. **19.26** 3.67 A. **19.27** + 0.0187 M.

Review Problems

19.50 (a) anode: $Cd(s) \longrightarrow Cd^{2+}(aq) + 2e^-$,
cathode: $Au^{3+}(aq) + 3e^- \longrightarrow Au(s)$,
cell: $3Cd(s) + 2Au^{3+}(aq) \longrightarrow 3Cd^{2+}(aq) + 2Au(s)$,
(b) anode: $Fe(s) \longrightarrow Fe^{2+}(aq) + 2e^-$,
cathode: $Br_2(aq) + 2e^- \longrightarrow 2Br^-(aq)$,
cell: $Fe(s) + Br_2(aq) \longrightarrow Fe^{2+}(aq) + 2Br^-(aq)$,
(c) anode: $Cr(s) \longrightarrow Cr^{3+}(aq) + 3e^-$,
cathode: $Cu^{2+}(aq) + 2e^- \longrightarrow Cu(s)$,
cell: $2Cr(s) + 3Cu^{2+}(aq) \longrightarrow 2Cr^{3+}(aq) + 3Cu(s)$.

19.52 (a) $Pt(s)\,|\,Fe^{2+}(aq), Fe^{3+}(aq)\,\|\,NO_3{}^-(aq), H^+(aq)\,|\,NO(g)\,|\,Pt(s)$,
(b) $Pt(s)\,|\,Cl^-(aq), Cl_2(g)\,\|\,Br_2(aq), Br^-(aq)\,|\,Pt(s)$,
(c) $Ag(s)\,|\,Ag^+(aq)\,|\,Au^{3+}(aq)\,|\,Au(s)$.

19.54 (a) $Sn(s)$, (b) $Br^-(aq)$, (c) $Zn(s)$, (d) $I^-(aq)$.

19.56 (a) 0.19 V, (b) −0.29 V, (c) 0.62 V.

19.58 (a) Spontaneous. (b) Spontaneous. (c) Spontaneous.

19.60 $BrO_3^-(aq) + 6I^-(aq) + 6H^+(aq) \longrightarrow 3I_2(s) + Br^-(aq) + 3H_2O$, net reaction. $E^\circ_{cell} = 0.90V$.
19.62 $4HOCl(aq) + 2H^+(aq) + S_2O_3^{2-} \longrightarrow 2Cl_2(g) + H_2O + 2H_2SO_3(aq)$
19.64 Not spontaneous. **19.66** 1.0×10^2 kJ.
19.68 (a) $E^\circ_{cell} = 0.54V$, (b) -5.2×10^2 kJ, (c) 2.1×10^{91}.
19.70 0.31. **19.72** 2.38 V. **19.74** $[Cd^{2+}] = 2.86 \times 10^{-15}\ M$.
19.76 $K_{sp} = 1.96 \times 10^{-15}$. **19.78** 0.09 V.
19.80 (a) 0.40 mol e^-, (b) 0.70 mol e^-, (c) 4.50 mol e^-, (d) 5.0×10^{-2} mol e^-. **19.82** 2.68 g Fe(OH).
19.84 51.5 hr. **19.86** 66.2 amp. **19.88** 40.1 mL.
19.90 298 mL Cl_2.
19.92 $2H_2O \rightleftharpoons 2H_2(g) + O_2(g)$, $E^\circ = -2.06$ V.
19.94 Br_2 and Cu, $Cu^{2+} + 2Br^- \rightleftharpoons Br_2 + Cu(s)$

CHAPTER 20

Practice Exercises

20.1 ${}^{226}_{88}Ra \longrightarrow {}^{222}_{86}Rn + {}^{4}_{2}He + {}^{0}_{0}\gamma$.
20.2 ${}^{90}_{38}Sr \longrightarrow {}^{90}_{39}Y + {}^{0}_{-1}e$. **20.3** 50.0%.
20.4 1.10×10^5 atoms Rn-222. **20.5** 20 m. **20.6** 100 units

Review Problems

20.45 1.11×10^{-11} g. **20.47** -3.18 ng, 1.09×10^{-5}%.
20.49 1.8×10^{-13} J/nucleon.
20.51 (a) ${}^{211}_{83}Bi$, (b) ${}^{177}_{72}Hf$, (c) ${}^{216}_{84}Po$, (d) ${}^{19}_{9}F$.
20.53 (a) ${}^{242}_{94}Pu \longrightarrow {}^{4}_{2}He + {}^{238}_{92}U$, (b) ${}^{28}_{12}Mg \longrightarrow {}^{0}_{-1}e + {}^{28}_{13}Al$, (c) ${}^{26}_{14}Si \longrightarrow {}^{0}_{1}e + {}^{26}_{13}Al$, (d) ${}^{37}_{18}Ar + {}^{0}_{-1}e \longrightarrow {}^{37}_{17}Cl$.
20.55 (a) ${}^{261}_{102}No$, (b) ${}^{211}_{82}Pb$, (c) ${}^{141}_{61}Pm$, (d) ${}^{179}_{74}W$.
20.57 ${}^{87}_{36}Kr \longrightarrow {}^{86}_{36}Kr + {}^{1}_{0}n$. **20.59** The more likely process is positron emission. ${}^{38}_{19}K \longrightarrow {}^{0}_{1}e + {}^{38}_{18}Ar$. **20.61** 0.0469 mg.
20.63 ${}^{53}_{24}Cr^*$; ${}^{51}_{23}V + {}^{2}_{1}H \longrightarrow {}^{53}_{24}Cr^* \longrightarrow {}^{1}_{1}p + {}^{52}_{23}V$.
20.65 ${}^{80}_{35}Br$. **20.67** ${}^{55}_{26}Fe$; ${}^{55}_{25}Mn + {}^{1}_{1}p \longrightarrow {}^{1}_{0}n + {}^{55}_{26}Fe$.
20.69 ${}^{70}_{30}Zn + {}^{208}_{82}Pb \longrightarrow {}^{278}_{112}Uub \longrightarrow {}^{1}_{0}n + {}^{277}_{112}Uub$.
20.71 6.3 m. **20.73** 6.6 m.
20.75 2.4×10^7 Bq, 6.5×10^2 μCi.
20.77 $k = 1.0 \times 10^{-6}\ s^{-1}$, $t_{1/2} = 6.9 \times 10^5$ s.
20.79 3.1% The chemical product is $BaCl_2$.
20.81 2.84×10^{-3} Ci/g.
20.83 1.3×10^9 years old.
20.85 2.7×10^4 years ago.
20.87 ${}^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{94}_{38}Sr + {}^{140}_{54}Xe + 2{}^{1}_{0}n$.

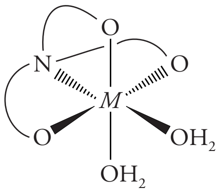
CHAPTER 21

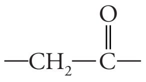
Practice Exercises

21.1 At any temperature. **21.2** 5570 K.
21.3 $[Ag(S_2O_3)_2]^{3-}$, $(NH_4)_3[Ag(S_2O_3)_2]$.
21.4 $AlCl_3{\cdot}6H_2O$, $[Al(H_2O)_6]^{3+}$.
21.5 (a) $[SnCl_6]^{2-}$, (b) $(NH_4)_2[Fe(CN)_4(H_2O)_2]$.
21.6 (a) potassium hexacyanoferrate(III), (b) dichlorobis(ethylenediamine)chromium(III) sulfate.
21.7 Six. **21.8** (a) Six, (b) Six, (c) Six.

Review Problems

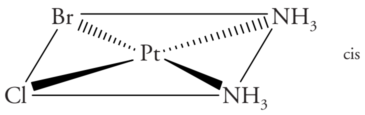
21.102 734 K.
21.104 The net charge is -3, and the formula is $[Fe(CN)_6]^{3-}$, hexacyanoferrate(III) ion. **21.106** $[CoCl_2(en)_2]^+$.
21.108 (a) oxalato, (b) sulfido or thio, (c) chloro, (d) dimethylamine. **21.110** (a) hexaamminenickel(II) ion, (b) triamminetrichlorochromate(II) ion, (c) hexanitrocobaltate(III) ion, (d) diamminetetracyanomanganate(II) ion, (e) trioxalatoferrate(III) ion or trisoxalatoferrate(III) ion.
21.112 (a) $[Fe(CN)_2(H_2O)_4]^+$, (b) $[Ni(C_2O_4)(NH_3)_4]$, (c) $[Fe(CN)_4(H_2O)_2]^-$, (d) $K_3[Mn(SCN)_6]$, (e) $[CuCl_4]^{2-}$.
21.114 Six.
21.116

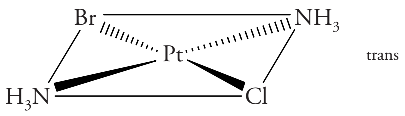


The curved lines represent  groups.

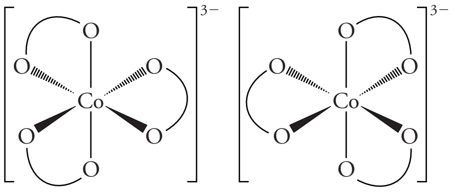
$$-CH_2-\overset{\displaystyle O}{\overset{\|}{C}}-$$

21.118 Since both are the *cis* isomer, they are identical.
21.120





21.122

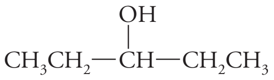


21.124 (a) $[Cr(H_2O)_6]^{3+}$, (b) $[Cr(en)_3]^{3+}$.
21.126 $[Cr(CN)_6]^{3-}$.
21.128 (a) $[RuCl(NH_3)_5]^{3+}$. The value of Δ increases down a group., (b) $[Ru(NH_3)_6]^{3+}$. The value of Δ increases with oxidation state of the metal.
21.130 This is the one with the strongest field ligand, since Co^{2+} is a d^7 ion: CoA_6^{3+}.
21.132 This is a weak field complex of Co^{2+}, and it should be a high–spin d^7 case. It cannot be diamagnetic.

CHAPTER 22

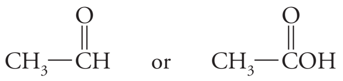
Practice Exercises

22.1 2,2-dimethylpropane.
22.2 (a) 3-methylhexane, (b) 4-ethyl-2,3-dimethylheptane, (c) 5-ethyl-2,4,6-trimethyloctane.
22.3



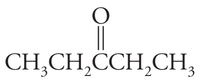
$$CH_3CH_2-\overset{\displaystyle OH}{\overset{|}{CH}}-CH_2CH_3$$

22.4 (a)



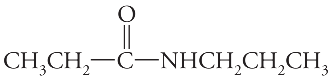
$$CH_3-\overset{\displaystyle O}{\overset{\|}{C}}H \quad \text{or} \quad CH_3-\overset{\displaystyle O}{\overset{\|}{C}}OH$$

(b)



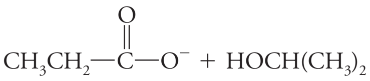
$$CH_3CH_2\overset{\displaystyle O}{\overset{\|}{C}}CH_2CH_3$$

22.5



$CH_3CH_2-\overset{\overset{O}{\|}}{C}-NHCH_2CH_2CH_3$

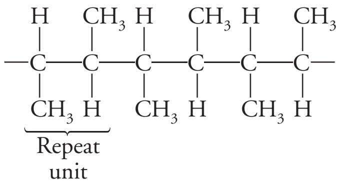
22.6 (a)



$CH_3CH_2-\overset{\overset{O}{\|}}{C}-O^- + HOCH(CH_3)_2$

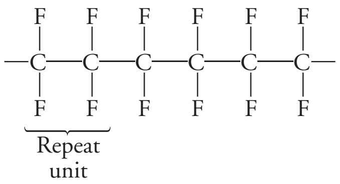
(b) $CH_3CH{=}CH_2$

22.7



$$-\underbrace{\underset{CH_3}{\overset{H}{C}}-\underset{H}{\overset{CH_3}{C}}}_{\text{Repeat unit}}-\underset{CH_3}{\overset{H}{C}}-\underset{H}{\overset{CH_3}{C}}-\underset{CH_3}{\overset{H}{C}}-\underset{H}{\overset{CH_3}{C}}-$$

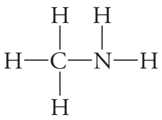
22.8



$$-\underbrace{\underset{F}{\overset{F}{C}}-\underset{F}{\overset{F}{C}}}_{\text{Repeat unit}}-\underset{F}{\overset{F}{C}}-\underset{F}{\overset{F}{C}}-\underset{F}{\overset{F}{C}}-\underset{F}{\overset{F}{C}}-$$

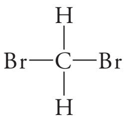
Review Problems

22.97 (a)



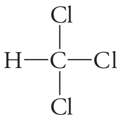
$H-\underset{H}{\overset{H}{C}}-\overset{H}{N}-H$

(b)



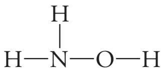
$Br-\underset{H}{\overset{H}{C}}-Br$

(c)



$H-\underset{Cl}{\overset{Cl}{C}}-Cl$

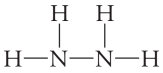
(d)



$H-\overset{H}{N}-O-H$

(e) $H-C\equiv C-H$

(f)



$H-\overset{H}{N}-\overset{H}{N}-H$

22.99 (a) alkene
(b) alcohol
(c) ester
(d) carboxylic acid
(e) amine
(f) alcohol.

22.101 b, e, and f.

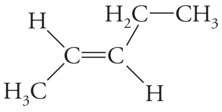
22.103 (a) amine, (b) amine, (c) amide, (d) amine, ketone.

22.105 (a) identical, (b) identical, (c) unrelated, (d) isomers, (e) identical, (f) identical, (g) isomers.

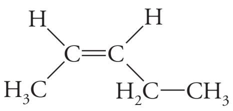
22.107 (a) pentane, (b) 2-methylpentane, (c) 2,4-dimethylhexane.

22.109 (a) No isomers,

(b)

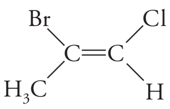


trans

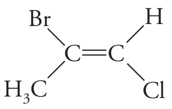


cis

(c)



cis

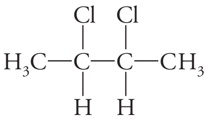


trans

22.111 (a) CH_3CH_3, (b) $ClCH_2CH_2Cl$, (c) $BrCH_2CH_2Br$, (d) CH_3CH_2Cl, (e) CH_3CH_2Br, (f) CH_3CH_2OH.

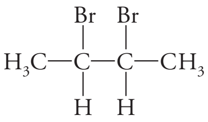
22.113 (a) $CH_3CH_2CH_2CH_3$,

(b)



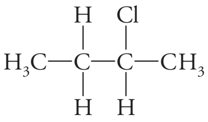
$H_3C-\underset{H}{\overset{Cl}{C}}-\underset{H}{\overset{Cl}{C}}-CH_3$

(c)



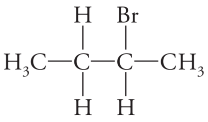
$H_3C-\underset{H}{\overset{Br}{C}}-\underset{H}{\overset{Br}{C}}-CH_3$

(d)



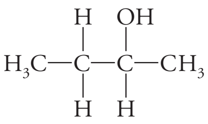
$H_3C-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{Cl}{C}}-CH_3$

(e)



$H_3C-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{Br}{C}}-CH_3$

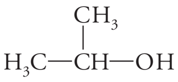
(f)



$H_3C-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{OH}{C}}-CH_3$

22.115 This sort of reaction would disrupt the π delocalization of the benzene ring. The subsequent loss of resonance energy would not be favorable.

22.117 CH_3OH:
IUPAC name = methanol; common name = methyl alcohol.
CH_3CH_2OH:
IUPAC name = ethanol; common name = ethyl alcohol.
$CH_3CH_2CH_2OH$:
IUPAC name = 1-propanol; common name = propyl alcohol.

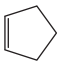


$H_3C-\overset{CH_3}{CH}-OH$

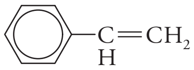
IUPAC name = 2-propanol; common name = isopropyl alcohol.

22.119 $CH_3CH_2CH_2-O-CH_3$ methyl propyl ether
$CH_3CH_2-O-CH_2CH_3$ diethyl ether
$(CH_3)_2CH-O-CH_3$ methyl 2-propyl ether

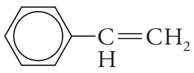
22.121 (a)



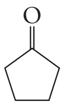
(b)



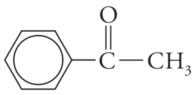
(c)



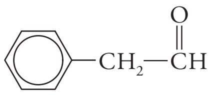
22.123 (a)



(b)



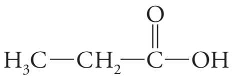
(c)



22.125 The elimination of water can result in a C=C double bond in two locations:

$CH_2{=}CHCH_2CH_3$ 1-butene
$CH_3CH{=}CHCH_3$ 2-butene

22.127 The aldehyde is more easily oxidized. The product is:

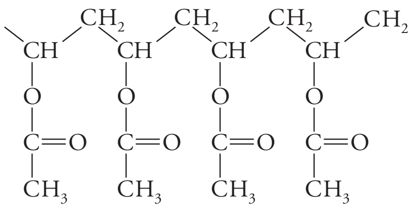


$H_3C-CH_2-\overset{\overset{O}{\|}}{C}-OH$

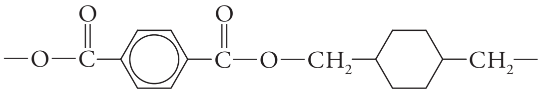
22.129 (a) $CH_3CH_2CO_2H$, (b) $CH_3CH_2CO_2H + CH_3OH$, (c) $Na^+ + CH_3CH_2CH_2CO_2{}^- + H_2O$

22.131 $CH_3CO_2H + CH_3CH_2NHCH_2CH_3$

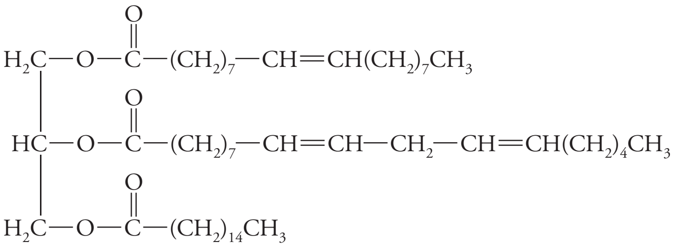
22.133



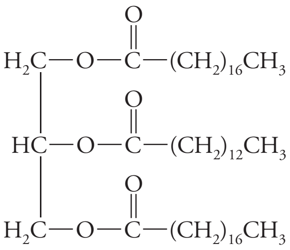
22.135



22.137

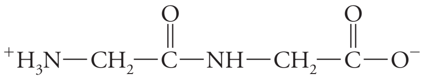


22.139



22.141 Hydrophobic sites are composed of fatty acid units. Hydrophilic sites are composed of charged units.

22.143



$^{+}H_3N-CH_2-\overset{O}{\overset{\Vert}{C}}-NH-CH_2-\overset{O}{\overset{\Vert}{C}}-O^{-}$

22.145