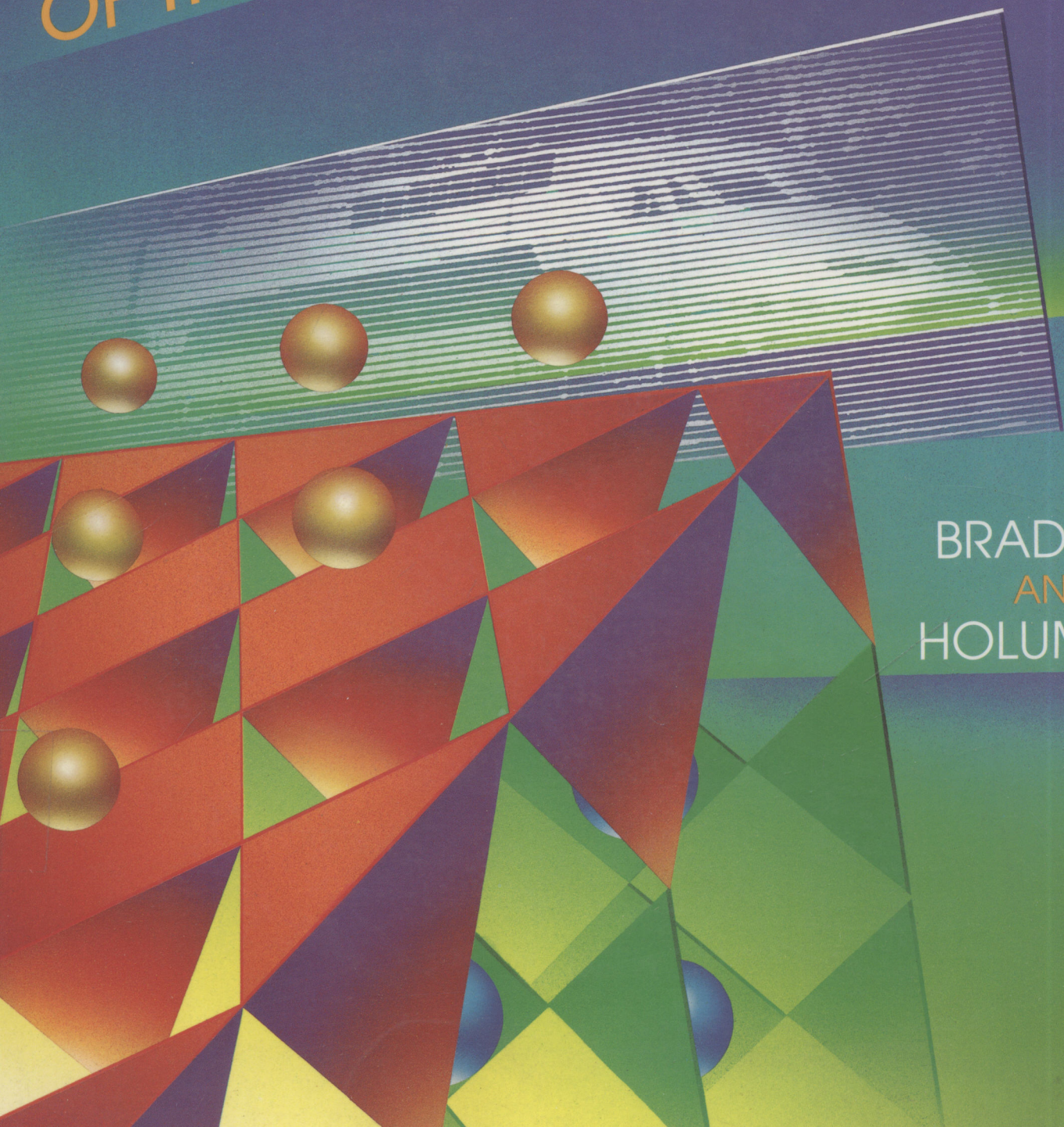


DESCRIPTIVE CHEMISTRY OF THE ELEMENTS



BRADY
AND
HOLUM

Descriptive Chemistry of the Elements



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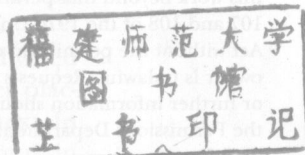
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Appendix A

Answers to Selected Exercises

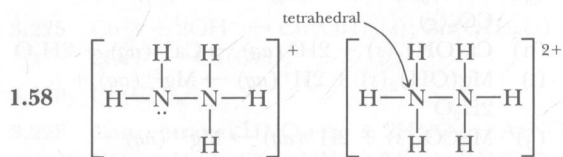
CHAPTER 1

Review Exercises

- 1.9 (a) $\text{NaH}(s) + \text{H}_2\text{O} \rightarrow \text{H}_2(g) + \text{NaOH}(aq)$
 (b) $\text{CaH}_2(s) + 2\text{H}_2\text{O} \rightarrow 2\text{H}_2(g) + \text{Ca}(\text{OH})_2(aq)$
 (c) $\text{HCl}(g) + \text{H}_2\text{O} \rightarrow \text{H}_3\text{O}^+(aq) + \text{Cl}^-(aq)$
 (d) $2\text{Na}(s) + 2\text{H}_2\text{O} \rightarrow \text{H}_2(g) + 2\text{NaOH}(aq)$
 (e) $\text{Mg}(s) + \text{H}_2(g) \rightarrow \text{MgH}_2(s)$
- 1.11 Ionic: MgH_2 , KH , CaH_2 Molecular: H_2Se , HI , PH_3
- 1.20 (a) alkali metals (b) alkali metals (c) Group IIIA (d) Group VIIA
- 1.23 Covalent. Ionic oxides are basic and react with acids.
- 1.26 It must have an oxygen–oxygen bond.
- 1.28 –1
- 1.31 (a) $\text{H}_2\text{O}_2 + \text{H}_2\text{SO}_3 \rightarrow \text{H}_2\text{O} + \text{SO}_4^{2-} + 2\text{H}^+$
 (b) $E^\circ_{\text{cell}} = 1.60 \text{ V}$ (c) 1.42 g H_2O_2
- 1.34 (a) $2\text{NaH}(s) + \text{O}_2(g) \rightarrow \text{Na}_2\text{O}(s) + \text{H}_2\text{O}$
 (b) $\text{H}^-(s) + \text{H}_2\text{O} \rightarrow \text{H}_2(g) + \text{OH}^-(aq)$
 (c) $2\text{HgO}(s) \xrightarrow{\text{heat}} 2\text{Hg}(l) + \text{O}_2(g)$
 (d) $2\text{KClO}_3(s) \xrightarrow{\text{heat}} 2\text{KCl}(s) + 3\text{O}_2(g)$
 (e) $\text{Na}_2\text{O}_2(s) + 2\text{H}_2\text{O} \rightarrow 2\text{NaOH}(aq) + \text{H}_2\text{O}_2(aq)$
 (f) $4\text{Li}(s) + \text{O}_2(g) \rightarrow 2\text{Li}_2\text{O}(s)$
 (g) $2\text{H}_2\text{O}_2(l) \rightarrow 2\text{H}_2\text{O} + \text{O}_2(g)$
- 1.40 More difficult, because the NH_3 would vaporize more rapidly.
- 1.41 (a) $\text{NH}_3(aq) + \text{H}_2\text{O} \rightleftharpoons \text{NH}_4^+(aq) + \text{OH}^-(aq)$
 (b) $\text{NH}_3(aq) + \text{H}_3\text{O}^+(aq) \rightarrow \text{NH}_4^+(aq) + \text{H}_2\text{O}$
 (c) $4\text{NH}_3(aq) + 3\text{O}_2(g) \rightarrow 2\text{N}_2(g) + 6\text{H}_2\text{O}$
- 1.42 (a) $\text{NH}_3(aq) + \text{HCl}(aq) \rightarrow \text{NH}_4\text{Cl}(aq)$
 (b) $\text{NH}_3(aq) + \text{HBr}(aq) \rightarrow \text{NH}_4\text{Br}(aq)$
 (c) $\text{NH}_3(aq) + \text{HI}(aq) \rightarrow \text{NH}_4\text{I}(aq)$
 (d) $2\text{NH}_3(aq) + \text{H}_2\text{SO}_4(aq) \rightarrow (\text{NH}_4)_2\text{SO}_4(aq)$
 (e) $\text{NH}_3(aq) + \text{HNO}_3(aq) \rightarrow \text{NH}_4\text{NO}_3(aq)$
- 1.47 $\text{KNH}_2(s) + \text{H}_2\text{O} \rightarrow \text{KOH}(aq) + \text{NH}_3(aq)$
 $\text{NH}_2^-(s) + \text{H}_2\text{O} \rightarrow \text{OH}^-(aq) + \text{NH}_3(aq)$
- 1.49 $\text{NH}_4^+(aq) + \text{H}_2\text{O} \rightleftharpoons \text{NH}_3(aq) + \text{H}_3\text{O}^+(aq)$

- 1.52 (a) $\text{Mg}_3\text{N}_2(s) + 6\text{H}_2\text{O} \rightarrow 2\text{NH}_3(g) + 3\text{Mg}(\text{OH})_2(s)$
 (b) magnesium oxide; $2\text{Mg}(s) + \text{O}_2(g) \rightarrow 2\text{MgO}(s)$

1.55 Poisonous hydrazine can be formed.



- 1.60 ammonia
- 1.63 basic; $\text{N}_3^-(aq) + \text{H}_2\text{O} \rightleftharpoons \text{HN}_3(aq) + \text{OH}^-(aq)$
- 1.73 Decomposition into N_2 and O_2 supplies expanding gases.
- 1.74 NO_2 has an unpaired electron on N; N_2O_4 has no unpaired electrons.
- 1.76 (a) 4.5×10^{-4} (b) $\text{HNO}_2(aq) + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+(aq) + \text{NO}_2^-(aq)$
- 1.77 Raise the pH; $\text{NO}_2^-(aq) + \text{H}_2\text{O} \rightleftharpoons \text{HNO}_2(aq) + \text{OH}^-(aq)$
- 1.95 $\text{CN}^-(aq) + \text{H}_2\text{O} \rightleftharpoons \text{HCN}(aq) + \text{OH}^-(aq)$
- 1.104 (a) $\text{N}_2(g) + 2\text{H}_2(g) \rightarrow \text{N}_2\text{H}_4(l)$, $\Delta H_f^\circ = +50.6 \text{ kJ mol}^{-1}$
 (b) Thermodynamically unstable, because ΔH_f° is positive and ΔS_f° would be negative.
 (c) Its decomposition is so slow that the compound is able to exist.
 (d) $\Delta S_f^\circ = -331 \text{ J mol}^{-1} \text{ K}^{-1}$. ΔS_f° is negative because molecules are becoming more complex (of lower entropy).
- 1.106 (a) $\text{NO}_3^-(aq) + 2\text{H}^+(aq) + e^- \rightarrow \text{NO}_2(g) + \text{H}_2\text{O}$ (reduction)
 $\text{NO}(g) + \text{H}_2\text{O} \rightarrow \text{NO}_2(g) + 2\text{H}^+(aq) + 2e^-$ (oxidation)
 (b) $2\text{NO}_3^-(aq) + \text{NO}(g) + 2\text{H}^+(aq) \rightarrow 3\text{NO}_2(g) + \text{H}_2\text{O}$
 (c) $E^\circ_{\text{cell}} = -0.04 \text{ V}$, not spontaneous. The negative value of E°_{cell} corresponds to a positive

value of ΔG° and so to a nonspontaneous event.

$$(d) E_{\text{cell}} = E_{\text{cell}}^\circ - \frac{0.0592}{2} \log \frac{P_{\text{NO}_2}^2}{[\text{NO}_3^-]^2 [\text{H}^+]^2 P_{\text{NO}}};$$

as $[\text{NO}_3^-]$ becomes larger, the second term on the right becomes smaller, so E_{cell} becomes, overall, less negative. This makes ΔG° less positive and so tends to favor the forward reaction.

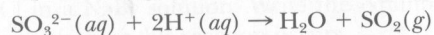
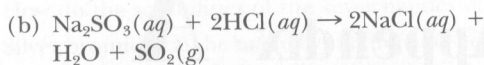
1.108 Net ionic equations are as follows:

- (a) $\text{H}^+(aq) + \text{OH}^-(aq) \rightarrow \text{H}_2\text{O}$
- (b) $\text{H}^+(aq) + \text{HCO}_3^-(aq) \rightarrow \text{H}_2\text{O} + \text{CO}_2(g)$
- (c) $2\text{H}^+(aq) + \text{CO}_3^{2-}(aq) \rightarrow \text{H}_2\text{O} + \text{CO}_2(g)$
- (d) same as (a)
- (e) same as (c)
- (f) same as (b)
- (g) $\text{CaCO}_3(s) + 2\text{H}^+(aq) \rightarrow \text{Ca}^{2+}(aq) + \text{H}_2\text{O} + \text{CO}_2(g)$
- (h) $\text{Ca}(\text{OH})_2(s) + 2\text{H}^+(aq) \rightarrow \text{Ca}^{2+}(aq) + 2\text{H}_2\text{O}$
- (i) $\text{Mg}(\text{OH})_2(s) + 2\text{H}^+(aq) \rightarrow \text{Mg}^{2+}(aq) + 2\text{H}_2\text{O}$
- (j) $\text{MgCO}_3(s) + 2\text{H}^+(aq) \rightarrow \text{Mg}^{2+}(aq) + \text{H}_2\text{O} + \text{CO}_2(g)$
- (k) $\text{S}^{2-}(aq) + 2\text{H}^+(aq) \rightarrow \text{H}_2\text{S}(g)$
- (l) $\text{SO}_3^{2-}(aq) + 2\text{H}^+(aq) \rightarrow \text{SO}_2(g) + \text{H}_2\text{O}$
- (m) no reaction
- (n) no reaction
- (o) $\text{CN}^-(aq) + \text{H}^+(aq) \rightarrow \text{HCN}(g)$
- (p) $\text{Pb}^{2+}(aq) + 2\text{Cl}^-(aq) \rightarrow \text{PbCl}_2(s)$
- (q) $\text{Ag}^+(aq) + \text{Cl}^-(aq) \rightarrow \text{AgCl}(s)$
- (r) $\text{Ca}(s) + 2\text{H}^+(aq) \rightarrow \text{Ca}^{2+}(aq) + \text{H}_2(g)$
- (s) $\text{NO}_2^-(aq) + \text{H}^+(aq) \rightarrow \text{HNO}_2(aq)$
- (t) no reaction
- (u) $\text{Mg}(s) + 2\text{H}^+(aq) \rightarrow \text{Mg}^{2+}(aq) + \text{H}_2(g)$
- (v) $\text{C}_2\text{H}_3\text{O}_2^-(aq) + \text{H}^+(aq) \rightarrow \text{HC}_2\text{H}_3\text{O}_2(aq)$
- (w) $\text{NaNH}_2(s) + 2\text{H}^+(aq) \rightarrow \text{Na}^+(aq) + \text{NH}_4^+(aq)$
- (x) $\text{N}_3^-(s) + \text{H}^+(aq) \rightarrow \text{HN}_3(aq)$
- (y) $\text{NH}_3(aq) + \text{H}^+(aq) \rightarrow \text{NH}_4^+(aq)$
- (z) no reaction

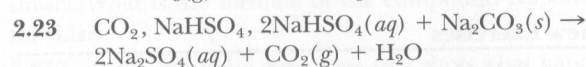
CHAPTER 2

Review Exercises

- 2.10 Sulfurous acid; sulfur dioxide, $\text{SO}_2 \cdot n\text{H}_2\text{O}$, bisulfite ion, $\text{HSO}_3^-(aq)$, and sulfite ion, $\text{SO}_3^{2-}(aq)$.
- 2.11 (a) $\text{NaOH}(aq) + \text{SO}_2(g) \rightarrow \text{NaHSO}_3(aq)$
(b) $\text{NaHCO}_3(aq) + \text{SO}_2(g) \rightarrow \text{NaHSO}_3(aq) + \text{CO}_2(g)$
- 2.16 (a) $\text{NaHSO}_3(aq) + \text{HCl}(aq) \rightarrow \text{NaCl}(aq) + \text{H}_2\text{O} + \text{SO}_2(g)$
 $\text{HSO}_3^-(aq) + \text{H}^+(aq) \rightarrow \text{H}_2\text{O} + \text{SO}_2(g)$

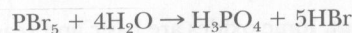
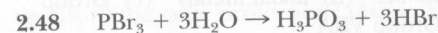
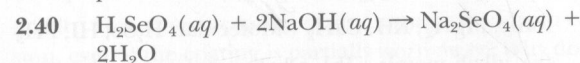


- 2.18 (a) $\text{SO}_3(g) + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_4(aq)$
(b) $\text{SO}_3(g) + \text{NaHCO}_3(aq) \rightarrow \text{NaHSO}_4(aq) + \text{CO}_2(g)$
 $\text{SO}_3(g) + 2\text{NaHCO}_3(aq) \rightarrow \text{Na}_2\text{SO}_4(aq) + \text{H}_2\text{O} + 2\text{CO}_2(g)$
(c) $\text{SO}_3(g) + \text{Na}_2\text{CO}_3(aq) \rightarrow \text{Na}_2\text{SO}_4(aq) + \text{CO}_2(g)$
(d) $\text{SO}_3(g) + \text{NaOH}(aq) \rightarrow \text{NaHSO}_4(aq)$
 $\text{SO}_3(g) + 2\text{NaOH}(aq) \rightarrow \text{Na}_2\text{SO}_4(aq) + \text{H}_2\text{O}$

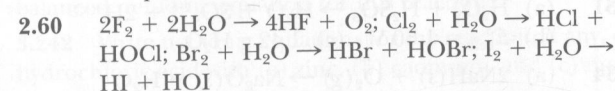


- 2.30 (a) $\text{S}_2\text{O}_3^{2-}(aq) + 4\text{Cl}_2(g) + 5\text{H}_2\text{O} \rightarrow 2\text{HSO}_4^-(aq) + 8\text{H}^+(aq) + 8\text{Cl}^-(aq)$
(b) $2\text{S}_2\text{O}_3^{2-}(aq) + \text{I}_2(aq) \rightarrow 2\text{I}^-(aq) + \text{S}_4\text{O}_6^{2-}(aq)$

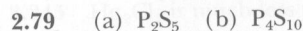
$$2.34 \text{pH} = 6.96$$



- 2.57 (a) arsenic acid (b) sodium arsenate (c) arsenous acid (d) sodium dihydrogen arsenate (e) arsenic trichloride (f) antimony pentachloride



- 2.68 (a) Y (actually, Y^-) (b) X (actually, X_2)
(c) No, Br_2 is a weaker oxidizing agent than Cl_2 . (d) Yes, Cl_2 is a stronger oxidizing agent than Br_2 . (e) Yes, Br_2 is a stronger oxidizing agent than I_2 .



- 2.80 (a) $\text{IO}_3^- + 3\text{HSO}_3^- \rightarrow \text{I}^- + 3\text{SO}_4^{2-} + 3\text{H}^+$
(b) $5\text{I}^- + \text{IO}_3^- + 6\text{H}^+ \rightarrow 3\text{I}_2 + 3\text{H}_2\text{O}$
(c) 3.79 g NaHSO_3 (d) 7.98 g brine

$$2.81 K_{\text{eq}} = \frac{[\text{H}^+][\text{Cl}^-][\text{HOCl}]}{[\text{Cl}_2]} = 0.015$$

CHAPTER 3

Review Exercises

- 3.3 (a) Tl (b) Ba (c) K
- 3.5 MgO
- 3.9 It is not economically feasible to extract aluminum from aluminosilicates.
- 3.43 (a) $2\text{Li} + 2\text{H}_2\text{O} \rightarrow 2\text{LiOH} + \text{H}_2(g)$

- (b) $2\text{K} + 2\text{H}_2\text{O} \rightarrow 2\text{KOH} + \text{H}_2(g)$
 (c) $2\text{Rb} + 2\text{H}_2\text{O} \rightarrow 2\text{RbOH} + \text{H}_2(g)$
- 3.45** (a) $\text{Na}_2\text{O}_2 + 2\text{H}_2\text{O} \rightarrow 2\text{NaOH} + \text{H}_2\text{O}_2$
 (b) $\text{Na}_2\text{O} + \text{H}_2\text{O} \rightarrow 2\text{NaOH}$
 (c) $2\text{KO}_2 + 2\text{H}_2\text{O} \rightarrow 2\text{KOH} + \text{O}_2 + \text{H}_2\text{O}_2$
- 3.53** $\text{CO}_3^{2-} + \text{H}_2\text{O} \rightleftharpoons \text{HCO}_3^- + \text{OH}^-$, pH = 12.16
- 3.54** (a) NaClO_4 (b) $\text{KC}_2\text{H}_3\text{O}_2$ (c) $\text{KC}_2\text{H}_3\text{O}_2$
- 3.57** $1.41 \times 10^5 \text{ lb}$
- 3.77** $\text{Mg}(\text{OH})_2$. $\text{Mg}(\text{OH})_2 + 2\text{HCl} \rightarrow \text{MgCl}_2 + 2\text{H}_2\text{O}$
- 3.80** $2\text{Mg} + \text{O}_2 \rightarrow 2\text{MgO}$; $\text{MgCO}_3 \xrightarrow{\text{heat}} \text{MgO} + \text{CO}_2$;
 $\text{Mg}(\text{OH})_2 \xrightarrow{\text{heat}} \text{MgO} + \text{H}_2\text{O}$
- 3.116** PbO_2
- 3.121** $\text{Pb}(\text{OH})_4^{2-} + \text{OCl}^- \rightarrow \text{PbO}_2(s) + \text{Cl}^- + 2\text{OH}^- + \text{H}_2\text{O}$
- 3.122** $\text{PbO}_2(s) + 4\text{Cl}^-(aq) + 4\text{H}^+(aq) \rightarrow \text{PbCl}_2(s) + \text{Cl}_2(g) + 2\text{H}_2\text{O}$
- 3.126** (a) $1.6 \times 10^{-2} M$ (b) $8.1 \times 10^{-3} M$ (c) $1.3 \times 10^{-3} M$
- 3.128** The halide ion is oxidized by Pb^{IV} .
 $\text{PbBr}_4 \rightarrow \text{PbBr}_2 + \text{Br}_2$
- 3.142** 16.7 g/cm^3
- 3.147** Magnetic domains within the solid shift to align with Earth's magnetic field.
- 3.154** $\text{Bi}^{3+} + \text{H}_2\text{O} \rightarrow [\text{Bi}-\text{OH}_2]^{3+} \rightarrow \text{BiO}^+ + 2\text{H}^+$
- 3.162** $\text{Cr}(\text{H}_2\text{O})_6^{3+} + \text{H}_2\text{O} \rightleftharpoons \text{Cr}(\text{H}_2\text{O})_5\text{OH}^{2+} + \text{H}_3\text{O}^+$
- 3.166** $\text{H}_2\text{CrO}_4 \rightleftharpoons \text{H}^+ + \text{HCrO}_4^-$; $\text{HCrO}_4^- \rightleftharpoons \text{H}^+ + \text{CrO}_4^{2-}$
- 3.173** (a) $\text{Mn}(s) + 2\text{HCl}(aq) \rightarrow \text{MnCl}_2(aq) + \text{H}_2(g)$
 (b) $\text{MnCl}_2(aq) + 2\text{NaOH}(aq) \rightarrow \text{Mn}(\text{OH})_2(s) + 2\text{NaCl}(aq)$
- 3.187** $\text{Fe}(s) + 2\text{H}^+(aq) \rightarrow \text{Fe}^{2+}(aq) + \text{H}_2(g)$
- 3.193** $\text{Cr}(\text{H}_2\text{O})_3(\text{OH})_3$ is able to dissolve in base, but $\text{Fe}(\text{H}_2\text{O})_3(\text{OH})_3$ is not.
- 3.194** The Fe^{3+} ion has more of a polarizing effect on a neighboring water molecule than does the larger and less highly charged Fe^{2+} ion.
- 3.198** Add Fe^{2+} to the solution suspected to contain CN^- . If CN^- is present it will form $\text{Fe}(\text{CN})_6^{4-}$. Then add Fe^{3+} ion. A blue precipitate of Prussian blue confirms the presence of CN^- .
- 3.203** $4\text{Co}^{3+}(aq) + 2\text{H}_2\text{O} \rightarrow 4\text{Co}^{2+}(aq) + \text{O}_2(g) + 4\text{H}^+(aq)$
- 3.216** Very thin gold foil; $9.09 \times 10^{-5} \text{ mm}$, $3.58 \times 10^{-6} \text{ in.}$
- 3.220** (a) N.R.
 (b) $\text{Cu} + 2\text{H}_2\text{SO}_4 \rightarrow \text{CuSO}_4 + \text{SO}_2 + 2\text{H}_2\text{O}$
 (c) $3\text{Cu} + 8\text{HNO}_3 \rightarrow 3\text{Cu}(\text{NO}_3)_2 + 2\text{NO} + 4\text{H}_2\text{O}$
 (d) $\text{Cu} + 4\text{HNO}_4 \rightarrow \text{Cu}(\text{NO}_3)_2 + 2\text{NO}_2 + 2\text{H}_2\text{O}$
- 3.225** $\text{Cu}^{2+} + 2\text{OH}^- \rightarrow \text{Cu}(\text{OH})_2(s)$; $\text{Cu}(\text{OH})_2(s) + 2\text{OH}^- \rightarrow \text{Cu}(\text{OH})_4^{2-}$
- 3.226** $\text{Cu}(\text{CN})_4^{2-}$
- 3.228** Concentrated HNO_3 : $\text{Ag} + 2\text{HNO}_3 \rightarrow \text{AgNO}_3 + \text{NO}_2 + \text{H}_2\text{O}$; dilute HNO_3 : $3\text{Ag} + 4\text{HNO}_3 \rightarrow 3\text{AgNO}_3 + \text{NO} + 2\text{H}_2\text{O}$
- 3.233** Because gold is so easily reduced.
- 3.238** $\text{Zn}^{2+}(aq) + 2\text{OH}^-(aq) \rightarrow \text{Zn}(\text{OH})_2(s)$
 $\text{Zn}(\text{OH})_2(s) + 2\text{OH}^-(aq) \rightarrow \text{Zn}(\text{OH})_4^{2-}(aq)$
- 3.241** $4\text{Zn}(s) + \text{NO}_3^-(aq) + 10\text{H}^+(aq) \rightarrow 4\text{Zn}^{2+}(aq) + \text{NH}_4^+(aq) + 3\text{H}_2\text{O}$
- 3.243** $\text{Hg}(l) + 2\text{NO}_3^-(aq) + 4\text{H}^+(aq) \rightarrow \text{Hg}^{2+}(aq) + 2\text{NO}_2(g) + 2\text{H}_2\text{O}$

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CHAPTER 1

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CHAPTER 2

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CHAPTER 3

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