Answers to Exercise 9.2
Balancing Redox Reactions

1.

(a)

Oxidation:	$Te + 4\,H_2O \longrightarrow TeO_4^{2-} + 8\,H^+ + 6\,e^-$	
Reduction:	$UO_2^{2+} + 4\,H^+ + 2\,e^- \longrightarrow U^{4+} + 2\,H_2O$	multiply by 3
Overall:	$Te + 3\,UO_2^{2+} + 4\,H^+ \longrightarrow TeO_4^{2-} + 3\,U^{4+} + 2\,H_2O$	

(b)

Oxidation:	$PbSO_4 + 2\,H_2O \longrightarrow PbO_2 + SO_4^{2-} + 4\,H^+ + 2\,e^-$	
Reduction:	$PbSO_4 + 2\,e^- \longrightarrow Pb + SO_4^{2-}$	
Overall:	$2\,PbSO_4 + 2\,H_2O \longrightarrow PbO_2 + 4\,H^+ + 2\,Pb + 2\,SO_4^{2-}$	

(c)

Oxidation:	$4\,AsH_3 + 6\,H_2O \longrightarrow As_4O_6 + 24\,H^+ + 24\,e^-$	
Reduction:	$Ag^+ + e^- \longrightarrow Ag$	multiply by 24
Overall:	$4\,AsH_3 + 6\,H_2O + 24\,Ag^+ \longrightarrow As_4O_6 + 24\,H^+ + 24\,Ag$	

(d)

Oxidation:	$HCN + I^- \longrightarrow ICN + H^+ + 2\,e^-$	multiply by 5
Reduction:	$MnO_4^- + 8\,H^+ + 5\,e^- \longrightarrow Mn^{2+} + 4\,H_2O$	multiply by 2
Overall:	$5\,HCN + 5\,I^- + 2\,MnO_4^- + 11\,H^+ \longrightarrow 5\,ICN + 2\,Mn^{2+} + 8\,H_2O$	

(e)

Oxidation:	$2\,I^- \longrightarrow I_2 + 2\,e^-$	multiply by 7
Reduction:	$2\,H_5IO_6 + 14\,H^+ + 14\,e^- \longrightarrow I_2 + 12\,H_2O$	
Overall:	$14\,I^- + 2\,H_5IO_6 + 14\,H^+ \longrightarrow 8\,I_2 + 12\,H_2O$	
Simplifies to:	$7\,I^- + H_5IO_6 + 7\,H^+ \longrightarrow 4\,I_2 + 6\,H_2O$	

This is an example of a comproportionation reaction, a reaction in which the same species (I_2) *is produced by both the oxidation and reduction half reactions.*

(f)

Oxidation:	$UO^{2+} + H_2O \longrightarrow UO_2^{2+} + 2\,H^+ + 2\,e^-$	multiply by 3
Reduction:	$Cr_2O_7^{2-} + 14\,H^+ + 6\,e^- \longrightarrow 2\,Cr^{3+} + 7\,H_2O$	
Overall:	$3\,UO^{2+} + Cr_2O_7^{2-} + 8\,H^+ \longrightarrow 3\,UO_2^{2+} + 2\,Cr^{3+} + 4\,H_2O$	

2.

(a)

Oxidation: $I^- + 6\,OH^- \longrightarrow IO_3^- + 3\,H_2O + 6\,e^-$

Reduction: $OCl^- + H_2O + 2\,e^- \longrightarrow Cl^- + 2\,OH^-$ multiply by 3

Overall: $I^- + 3\,OCl^- \longrightarrow IO_3^- + 3\,Cl^-$

(b)

Oxidation: $P_4 + 20\,OH^- \longrightarrow 4\,HPO_3^{2-} + 8\,H_2O + 12\,e^-$

Reduction: $P_4 + 12\,H_2O + 12\,e^- \longrightarrow 4\,PH_3 + 12\,OH^-$

Overall: $2\,P_4 + 4\,H_2O + 8\,OH^- \longrightarrow 4\,HPO_3^{2-} + 4\,PH_3$

Simplifies to: $P_4 + 2\,H_2O + 4\,OH^- \longrightarrow 2\,HPO_3^{2-} + 2\,PH_3$

This is an example of a disproportionation reaction, a reaction in which the same species (P_4) *is consumed by both the oxidation and reduction half reactions.*

(c)

Oxidation: $Co + 3\,OH^- \longrightarrow Co(OH)_3 + 3\,e^-$ multiply by 2

Reduction: $OCl^- + H_2O + 2\,e^- \longrightarrow Cl^- + 2\,OH^-$ multiply by 3

Overall: $2\,Co + 3\,OCl^- + 3\,H_2O \longrightarrow 2\,Co(OH)_3 + 3\,Cl^-$

(d)

Oxidation: $As + 6\,OH^- \longrightarrow AsO_3^{3-} + 3\,H_2O + 3\,e^-$ multiply by 2

Reduction: $2\,H_2O + 2\,e^- \longrightarrow H_2 + 2\,OH^-$ multiply by 3

Overall: $2\,As + 6\,OH^- \longrightarrow 2\,AsO_3^{3-} + 3\,H_2$

(e)

Oxidation: $Au + 2\,CN^- \longrightarrow [Au(CN)_2]^- + e^-$ multiply by 4

Reduction: $O_2 + 2\,H_2O + 4\,e^- \longrightarrow 4\,OH^-$

Overall: $4\,Au + 8\,CN^- + O_2 + 2\,H_2O \longrightarrow 4\,[Au(CN)_2]^- + 4\,OH^-$

While gold is not oxidized by oxygen in aqueous solution, addition of cyanide makes this possible. This reaction is heavily used in gold mining operations, especially if the gold concentration of the ores is low. The "cyanide ponds" that are used for this extraction process are serious environmental hazards given the huge quantities of such a toxic substance!