Sample Problems

1. Redox reactions (look at the change in oxidation states)

   a. Na is oxidized ($Na^0 \rightarrow Na^+$), making it the reducing agent
   S is reduced ($S^0 \rightarrow S^{-2}$), making it the oxidizing agent

   b. Al is oxidized ($Al^0 \rightarrow Al^{+3}$), making it the reducing agent
   O is reduced ($O_2^0 \rightarrow 2O^{-2}$), making it the oxidizing agent

2. Redox reactions (look at the change in oxidation states)

   a. oxidization ($Li^0 \rightarrow Li^+$) … increase in oxidation state

   b. oxidation ($2I^- \rightarrow I_2^0$) … increase in oxidation state

   c. reduction ($Zn^{+2} \rightarrow Zn^0$) … decrease in oxidation state

   d. reduction ($Br_2^0 \rightarrow 2Br^-$) … decrease in oxidation state

Lesson Check Answers

3. Oxidation is the gain of oxygen. Reduction is the loss of oxygen.

4. Oxidation is the loss of electrons. Reduction is the gain of electrons.

5. Salts and acids produce conductive solutions that make electron transfer easier.

6. The species reduced is the oxidizing agent. The species oxidized is the reducing agent.

7. The oxidizing agent gets reduced (decreased oxidation state/gain e-); the reducing agent gets oxidized (increased oxidation state/lose e-)

   a. Cl_2^0 is likely to get reduced to $2Cl^{-1}$ by gaining e- $\rightarrow$ oxidizing agent

   b. K is likely to get oxidized to K^+ by losing e- $\rightarrow$ reducing agent

   c. Ag^+ is likely to get reduced to Ag^0 by gaining e- $\rightarrow$ oxidizing agent

8 & 9.

The oxidizing agent gets reduced (decreased oxidation state/gain e-); the reducing agent gets oxidized (increased oxidation state/lose e-)

a. Na is oxidized ($Na^0 \rightarrow Na^+$) by losing an e-; reducing agent
Br_2 is reduced ($Br_2^0 \rightarrow 2Br^-$) by gaining 2 e-; oxidizing agent

b. H_2 is oxidized ($H_2^0 \rightarrow 2H^+$) by losing 2 e-; reducing agent
Cl_2 is reduced ($Cl_2^0 \rightarrow 2Cl^-$) by gaining 2 e-; oxidizing agent

c. Li is oxidized ($Li^0 \rightarrow Li^+$) by losing an e-; reducing agent
F_2 is reduced ($F_2^0 \rightarrow 2F^-$) by gaining 2 e-; oxidizing agent

d. S is oxidized ($S^0 \rightarrow S^{+2}$) by losing 2 e-; reducing agent
Cl_2 is reduced ($Cl_2^0 \rightarrow 2Cl^-$) by gaining 2 e-; oxidizing agent

e. N_2 is oxidized ($N_2^0 \rightarrow N^{+4}$) by losing 4 e-; reducing agent
O_2 is reduced ($O_2^0 \rightarrow O^{-2}$) by gaining 2 e-; oxidizing agent

f. Mg is oxidized ($Mg^0 \rightarrow Mg^{+2}$) by losing an e-; reducing agent
Cu is reduced ($Cu^{+2} \rightarrow Cu^0$) by gaining 2 e-; oxidizing agent

Sample Problems

FIGURE 20.8 0, +6, +3

10. **a.** S, +3; O, −2
b. Na, +1; O, −1
c. P, +5; O, −2
d. N, +5; O, −2

11. **a.** +5 **b.** 0 **c.** +7 **d.** +1

12 & 13.

The oxidizing agent gets reduced (decreased oxidation state/gain e-); the reducing agent gets oxidized (increased oxidation state/lose e-)

a. H_2 is oxidized ($H_2^0 \rightarrow 2H^+$) by losing 2 e-; reducing agent
O_2 is reduced ($O_2^0 \rightarrow O^{-2}$) by gaining 2 e-; oxidizing agent

b. O_2 is oxidized ($O^{-2} \rightarrow O_2^{0}$) by losing 2 e-; reducing agent
N is reduced ($N^{+5} \rightarrow N^{+\$}$) by gaining 2e-; oxidizing agent

FIGURE 20.9 The oxidation number of silver changes from +1 to 0; the oxidation number of copper changes from 0 to +2.

14. **a.** N in NH_4^+ is oxidized (−3 to 0); H is unchanged; N in NO_2^- is reduced (+3 to 0); O is unchanged.
b. Pb is reduced (+4 to +2); O is unchanged; H is unchanged; I is oxidized (−1 in HI to 0 in I_2).

15. **a.** N in NH_4^+ is the reducing agent; N in NO_2^- is the oxidizing agent.
b. Pb is the oxidizing agent; I is the reducing agent.

FIGURE 20.11 The oxidation number of potassium changes from 0 to +1, so this is a redox reaction. The oxidation number of zinc changes from 0 to +2, so this is a redox reaction.

Lesson Check Answers

16. The oxidation number is the charge a bonded atom would have if the electrons in the bond were assigned to the more electronegative element.

17. An increase in oxidation number indicates oxidation; a decrease in oxidation number indicates reduction.

18. For a polyatomic ion, the sum of the oxidation numbers must equal the ionic charge of the ion.

19. **a.** Na, oxidized; Cl_2, reduced
b. I, oxidized; N, reduced
c. S, oxidized; N, reduced
d. Pb, oxidized and reduced

20. **a.** Na reducing agent, Cl_2 oxidizing agent
b. N in HNO_3 oxidizing agent, I in HI reducing agent
c. N in HNO_3, oxidizing agent; S in H_2S, reducing agent
d. Pb in $PbSO_4$, oxidizing-reducing agent

19 & 20.

The oxidizing agent gets reduced (decreased oxidation state/gain e-); the reducing agent gets oxidized (increased oxidation state/lose e-)

a. Na is oxidized ($Na^0 \rightarrow Na^+$) by losing an e-; reducing agent
   Cl_2 is reduced ($Cl_2^0 \rightarrow 2Cl^-$) by gaining 2 e-; oxidizing agent

b. I is oxidized ($2I^- \rightarrow I_2^0$) by losing an 2 e-; reducing agent
   N is reduced ($N^{+5} \rightarrow N^{+2}$) by gaining 3e-; oxidizing agent

c. S is oxidized ($S^- \rightarrow S^0$) by losing an 2 e-; reducing agent
   N is reduced ($N^{+5} \rightarrow N^{+2}$) by gaining 3e-; oxidizing agent

d. $\mathbf{Pb^{+2}}SO_4$ is oxidized and reduced
   Pb is oxidized ($Pb^{+2} \rightarrow Pb^{+4}$) by losing an e-; reducing agent
   Pb is reduced ($Pb^{+2} \rightarrow Pb^0$) by gaining 2 e-; oxidizing agent

Sample Problems

21a. This is a redox reaction.
Mg is oxidized ($Mg^0 \rightarrow Mg^{+2}$) by losing 2 e-; reducing agent
Br_2 is reduced ($Br_2^0 \rightarrow 2Br^-$) by gaining 2 e-; oxidizing agent

21b. This is NOT a redox reaction. No element changes oxidation state.

22a. This is NOT a redox reaction. No element changes oxidation state.

22b. This is a redox reaction.
H_2 is oxidized ($H_2^0 \rightarrow 2H^+$) by losing 2 e-; reducing agent
Cu is reduced ($Cu^{+2} \rightarrow Cu^0$) by gaining 2 e-; oxidizing agent

23 – 26. You may balance using either the oxidation-number method or the half reaction method.

$(1)(-6) = -6$

23. **a.** $\overset{+1+5-2}{KClO_3}(s) \longrightarrow \overset{+1\ -1}{KCl}(s) + \overset{0}{O_2}(g)$

$(3)(+2) = +6$

One K atom must be reduced for every 3 oxygen atoms oxidized.

$KClO_3(s) \longrightarrow KCl(s) + O_2(g)$

Balance by inspection; put the coefficient 3 in front of O_2, and the coefficient 2 in front of $KClO_3$ and KCl:

$2KClO_3(s) \longrightarrow 2KCl(s) + 3O_2(g)$

Cl^{+5} was reduced to Cl^{-1} … that is an overall -6 drop.

O^{-2} was oxidized to O_2^{0} … that is an overall +2 increase.

To account for the oxidation difference, use a common multiple.

b. $HN^{+3}O_2(aq) + HI^{-}(aq) \rightarrow I_2^{0}(s) + N^{+2}O(g) + H_2O(l)$

Oxid ½ rxn: $2HI^{-}(aq) \rightarrow I_2^{0}(aq) + 2e-$

Red ½ rxn: $2[HN^{+3}O_2(aq) + e- \rightarrow N^{+2}O(g)]$

Rewrite the red ½ rxn to account for 2 e-: $2HN^{+3}O_2(aq) + 2\ e- \rightarrow 2N^{+2}O(g)]$

Add to equation: $2HN^{+3}O_2(aq) + 2HI^{-}(aq) \rightarrow I_2^{0}(aq) + 2N^{+2}O(g) + H_2O(l)$

Balance overall equation (spectator ions) involving O, H.

$2HN^{+3}O_2(aq) + 2HI^{-}(aq) \rightarrow I_2^{0}(aq) + 2N^{+2}O(g) + 2H_2O(l)$

24. **a.** $(2)(-3) = -6$

$\overset{+3\,-2}{Bi_2S_3}(s) + \overset{+1\,+5\,-2}{HNO_3}(aq) \longrightarrow \overset{+3\,+5\,-2}{Bi(NO_3)_3}(aq) + \overset{+2\,-2}{NO}(g) + \overset{0}{S}(s) + \overset{+1\,-2}{H_2O}(l)$

$(3)(+2) = +6$

2 N atoms must be reduced for every 3 sulfur atoms oxidized.

$Bi_2S_3(s) + 2HNO_3(aq) \longrightarrow Bi(NO_3)_3(aq) + 2NO(g) + 3S(s) + H_2O(l)$

Balance by inspection; put the coefficient 2 in front of $Bi(NO_3)_3$, the coefficient 8 in front of HNO_3, and the coefficient 4 in front of H_2O:

$Bi_2S_3(s) + 8HNO_3(aq) \longrightarrow 2Bi(NO_3)_3(aq) + 2NO(g) + 3S(s) + 4H_2O(l)$

N^{+5} was reduced to N^{+2} … that is an overall -3 drop.

S^{-2} was oxidized to S^0 … that is an overall +2 increase.

To account for the oxidation difference, use a common multiple.

b. $SbCl_5(aq) + KI(aq) \rightarrow SbCl_3(aq) + KCl(aq) + I_2(s)$

Oxid ½ rxn: $2I^-(aq) \rightarrow I_2^0(aq) + 2e-$

Red ½ rxn: $Sb^{+5} + 2e- \rightarrow Sb^{+3}$

Both ½ rxns involve 2 e- without changing coefficients

Add to equation: $SbCl_5(aq) + 2KI(aq) \rightarrow SbCl_3(aq) + KCl(aq) + I_2(s)$

Balance overall equation (spectator ions) involving K, Cl.

$SbCl_5(aq) + 2KI(aq) \rightarrow SbCl_3(aq) + 2KCl(aq) + I_2(s)$

25. Balance: $Sn^{+2}(aq) + Cr_2O_7^{-2}(aq) \rightarrow Sn^{+4}(aq) + Cr^{+3}(aq)$

Oxid ½ rxn: $3[Sn^{+2}(aq) \rightarrow Sn^{+4}(aq) + 2\ e-]$

Red ½ rxn: $Cr_2^{+6}O_7^{-2}(aq) + 6\ e- \rightarrow 2Cr^{+3}(aq)$

Rewrite the oxid ½ rxn to account for 6 e-: $3Sn^{+2}(aq) \rightarrow 3Sn^{+4}(aq) + 6\ e-]$

Add to equation: $3Sn^{+2}(aq) + Cr_2O_7^{-2}(aq) \rightarrow 3Sn^{+4}(aq) + 2Cr^{+3}(aq)$

Balance overall equation (spectator ions) involving O, H. Since the reaction is acidic (H^+ ions) and aqueous (H_2O), we add those elements in.

$3Sn^{+2}(aq) + Cr_2O_7^{-2}(aq) + 14H^+ \rightarrow 3Sn^{+4}(aq) + 2Cr^{+3}(aq) + 7H_2O$

26. Balance: $Zn^0(s) + NO_3^-(aq) \rightarrow NH_3(aq) + Zn(OH)_4^{-2}(aq)$ [basic solution]

Oxid ½ rxn: $4[Zn^0(s) \rightarrow Zn^{+2}(s) + 2\ e^-]$

Red ½ rxn: $N^{+5}O_3^-(aq) + 8\ e^- \rightarrow N^{-3}H_3(aq)$

Rewrite the oxid ½ rxn to account for 8 e-: $4Zn^0(s) \rightarrow 4Zn^{+2}(s) + 8\ e^-$

Add to equation: $4Zn^0(s) + NO_3^-(aq) \rightarrow NH_3(aq) + 4Zn(OH)_4^{-2}(aq)$

Balance overall equation (spectator ions) involving O, H. Since the reaction is basic (OH^- ions) and aqueous (H_2O), we add those elements in.

$4Zn^0(s) + NO_3^-(aq) + 6H_2O + 7OH^- \rightarrow NH_3(aq) + 4Zn(OH)_4^{-2}(aq)$

Lesson Check Answers

27. Reactions in which electrons are transferred from one reacting species to another (redox reactions) and reactions that do not involve a transfer of electrons.

28. The oxidation-number-change method and the half-reaction method.

29 – 30. You may balance using either the oxidation-number method or the half reaction method.

29a. $ClO_3^-(aq) + I^-(aq) \rightarrow Cl^-(aq) + I_2(s)$ [acidic solution]

Oxid ½ rxn: $3[2I^-(aq) \rightarrow I_2^0(aq) + 2e^-]$

Red ½ rxn: $Cl^{+5} + 6e^- \rightarrow Cl^-$

Rewrite the oxid ½ rxn to account for 6 e-: $6I^-(aq) \rightarrow 3I_2^0(aq)$

Add to equation: $ClO_3^-(aq) + 6I^-(aq) \rightarrow Cl^-(aq) + 3I_2(s)$

Balance overall equation (spectator ions) involving O, H. Since the reaction is acidic (H^+ ions) and aqueous (H_2O), we add those elements in.

$ClO_3^-(aq) + 6I^-(aq) + 6H^+(aq) \rightarrow Cl^-(aq) + 3I_2(s) + 3H_2O(l)$

The acid (H^+ ions) are with I^- ions on the reactant side.

29b. $C_2O_4^{-2}(aq) + MnO_4^-(aq) \rightarrow Mn^{+2}(aq) + CO_2(g)$ [acidic solution]

Oxid ½ rxn: $5[C^{+3}(aq) \rightarrow C^{+4}(aq) + e^-]$

Red ½ rxn: $Mn^{+7} + 5e^- \rightarrow Mn^{+2}$

Rewrite the oxid ½ rxn to account for 5 e-: $5C^{+3}(aq) \rightarrow 5C^{+4}(aq) + 5e-$

Add to equation: $5C_2O_4^{-2}(aq) + 2MnO_4^{-}(aq) \rightarrow 2Mn^{+2}(aq) + 10CO_2(g)$ … *note that we had to double the amount of Carbons based on the equation. Therefore, we have to double the amount of manganese as well → 10 e-*

Balance overall equation (spectator ions) involving O, H. Since the reaction is acidic (H^+ ions) and aqueous (H_2O), we add those elements in.

$5C_2O_4^{-2}(aq) + 2MnO_4^{-}(aq) + 16H^+(aq) \rightarrow 2Mn^{+2}(aq) + 10CO_2(g) + 8H_2O(l)$

The acid (H^+ ions) are with MnO_4^- *ions on the reactant side.*

29c. $Br_2(l) + SO_2(g) \rightarrow Br^-(aq) + SO_4^{-4}(aq)$ [acidic solution]

Oxid ½ rxn: $S^{+4}(aq) \rightarrow S^{+6}(aq) + 2e-$

Red ½ rxn: $Br_2^0 + 2e- \rightarrow 2Br^-$

Both ½ rxn involve 2 e- without changing coefficients

Balance overall equation (spectator ions) involving O, H. Since the reaction is acidic (H^+ ions) and aqueous (H_2O), we add those elements in.

$Br_2(l) + SO_2(g) + 2H_2O(l) \rightarrow 2Br^-(aq) + SO_4^{-4}(aq) + 4H^+(aq)$

The acid (H^+ ions) are with Br^- ions on the product side.

30a. You do NOT have to answer 30a.

30b. Balance: $NiO_2(s) + S_2O_3^{-2}(aq) \rightarrow Ni(OH)_2(s) + SO_3^{-2}(aq)$ [basic solution]

Oxid ½ rxn: $S^{+2} \rightarrow S^{+4} + 2e-$

Red ½ rxn: $Ni^{+4} + 2\ e- \rightarrow Ni^{+2}$

Both ½ rxn involve 2 e- without changing coefficients

Note that we had to double the amount of Sulfur based on the equation. Therefore, we have to double the amount of Nickel as well → 4 e-

Add to equation: $2NiO_2(s) + S_2O_3(aq) \rightarrow 2Ni(OH)_2(s) + SO_3^{-2}(aq)$

Balance overall equation (spectator ions) involving O, H. Since the reaction is basic (OH^- ions) and aqueous (H_2O), we add those elements in.

$2NiO_2(s) + S_2O_3^{-2}(aq) + H_2O(l) + 2OH^-(aq) \rightarrow 2Ni(OH)_2(s) + 2SO_3^{-2}(aq)$

The base (OH^- ions) are with the H^+ ions of water on the reactant side.

31. Production of sodium: $2NaCl(l) \longrightarrow 2Na(l) + Cl_2(g)$

Cl_2 is oxidized ($2Cl^- \rightarrow Cl_2^0$) by losing 2 e-; reducing agent
Na is reduced ($Na^+ \rightarrow Na^0$) by gaining an e-; oxidizing agent

Production of bromine: $2NaBr(aq) + Cl_2(g) \longrightarrow 2NaCl(aq) + Br_2(l)$

Br^- is oxidized ($2Br^- \rightarrow Br_2^0$) by losing 2 e-; reducing agent
Cl_2 is reduced ($Cl_2^0 \rightarrow 2Cl^-$) by gaining 2 e-; oxidizing agent

Production of Iodine: $2NaIO_3(aq) + 5NaHSO_3(aq) \longrightarrow I_2(g) + 2Na_2SO_4(aq) + 3NaHSO_4(aq) + H_2O(l)$

S^{+4} is oxidized ($S^{+4} \rightarrow S^{+6}$) by losing 2 e-; reducing agent
I^{+5} is reduced ($2I^{+5} \rightarrow I_2^0$) by gaining10 e-; oxidizing agent