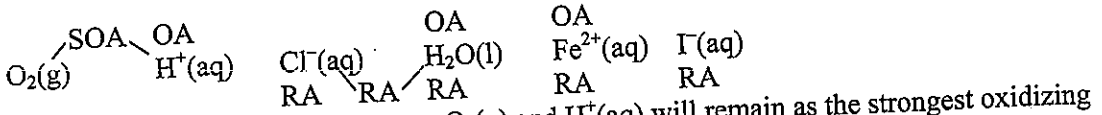
30. 

Because an excess of acid is present, $O_2(g)$ and $H^+(aq)$ will remain as the strongest oxidizing agent throughout all of the reactions.

$O_2(g) + 4\ H^+(aq) + 4\ e^- \rightarrow 2\ H_2O(l)$

Oxygen in an acidic solution will spontaneously oxidize (in order) iodide ions, iron(II) ions, and lastly iodine (a product of the iodide oxidation).

$2\ I^-(aq) \rightarrow I_2(s) + 2\ e^-$

$Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e^-$

$I_2(s) + 6\ H_2O(l) \rightarrow 2\ IO_3^-(aq) + 12\ H^+(aq) + 10\ e^-$

The spontaneous reactions are:

$O_2(g) + 4\ H^+(aq) + 4\ I^-(aq) \rightarrow 2\ H_2O(l) + 2\ I_2(s)$

$O_2(g) + 4\ H^+(aq) + 4\ Fe^{2+}(aq) \rightarrow 2\ H_2O(l) + 4\ Fe^{3+}(aq)$

$5\ O_2(g) + 2\ I_2(s) + 2\ H_2O(l) \rightarrow 4\ IO_3^-(aq) + 4\ H^+(aq)$

Practice

(Page 581)

31. (a)
$$\begin{array}{r} 4\ [Zn(s) \rightarrow Zn^{2+}(aq) + 2\ e^-] \\ NO_3^-(aq) + 10\ H^+(aq) + 8\ e^- \rightarrow NH_4^+(aq) + 3\ H_2O(l) \\ \hline 4\ Zn(s) + NO_3^-(aq) + 10\ H^+(aq) \rightarrow 4\ Zn^{2+}(aq) + NH_4^+(aq) + 3\ H_2O(l) \end{array}$$

(b)
$$\begin{array}{r} Cl_2(aq) + 2\ e^- \rightarrow 2\ Cl^-(aq) \\ SO_2(g) + 2\ H_2O(l) \rightarrow SO_4^{2-}(aq) + 4\ H^+(aq) + 2\ e^- \\ \hline Cl_2(aq) + SO_2(g) + 2\ H_2O(l) \rightarrow 2\ Cl^-(aq) + SO_4^{2-}(aq) + 4\ H^+(aq) \end{array}$$

32. (a)
$$\begin{array}{r} 2\ [MnO_4^-(aq) + 2\ H_2O(l) + 3\ e^- \rightarrow MnO_2(s) + 4\ OH^-(aq)] \\ 3\ [2\ I^-(aq) \rightarrow I_2(s) + 2\ e^-] \\ \hline 2\ MnO_4^-(aq) + 4\ H_2O(l) + 6\ I^-(aq) \rightarrow 2\ MnO_2(s) + 8\ OH^-(aq) + 3\ I_2(s) \end{array}$$

(b)
$$\begin{array}{r} 3\ [CN^-(aq) + 2\ OH^-(aq) \rightarrow CNO^-(aq) + H_2O(l) + 2\ e^-] \\ IO_3^-(aq) + 3\ H_2O(l) + 6\ e^- \rightarrow I^-(aq) + 6\ OH^-(aq) \\ \hline 3\ CN^-(aq) + IO_3^-(aq) \rightarrow 3\ CNO^-(aq) + I^-(aq) \end{array}$$

(c)
$$\begin{array}{r} 2\ [OCl^-(aq) + H_2O(l) + 2\ e^- \rightarrow Cl^-(aq) + 2\ OH^-(aq)] \\ OCl^-(aq) + 4\ OH^-(aq) \rightarrow ClO_3^-(aq) + 2\ H_2O(l) + 4\ e^- \\ \hline 3\ OCl^-(aq) \rightarrow 2\ Cl^-(aq) + ClO_3^-(aq) \end{array}$$

33. *[Note that MnO_4^- changes to Mn^{2+}, H_2S changes to S, and the rest are spectator ions.]*
$$\begin{array}{r} 2\ [MnO_4^-(aq) + 8\ H^+(aq) + 5\ e^- \rightarrow Mn^{2+}(aq) + 4\ H_2O(l))] \\ 5\ [H_2S(aq) \rightarrow S(s) + 2\ H^+(aq) + 2\ e^-] \\ \hline 2\ MnO_4^-(aq) + 6\ H^+(aq) + 5\ H_2S(aq) \rightarrow 2\ Mn^{2+}(aq) + 5\ S(s) + 8\ H_2O(l)) \end{array}$$

Adding spectator ions:

$2\ KMnO_4(aq) + 5\ H_2S(aq) + 3\ H_2SO_4(aq) \rightarrow K_2SO_4(aq) + 2\ MnSO_4(aq) + 5\ S(s) + 8\ H_2O(l)$

Section 13.2 Questions

(Page 582)

1. The key idea used to explain a redox reaction is the transfer of electrons between chemical entities.

2. According to modern theory, oxidation refers to the process of losing electrons, while oxidizing agent refers to the chemical entity that causes the oxidation of another entity by removing electrons from it.
3. According to modern theory, reduction refers to the process of gaining electrons, while reducing agent refers to the chemical entity that causes the reduction of another entity by donating electrons to it.
4. (a) $Cu^{2+}(aq) + 2\ e^- \rightarrow Cu(s)$ (reduction)
   $Co(s) \rightarrow Co^{2+}(aq) + 2\ e^-$ (oxidation)
   (b) $Zn^{2+}(aq) + 2\ e^- \rightarrow Zn(s)$ (reduction)
   $Cd(s) \rightarrow Cd^{2+}(aq) + 2\ e^-$ (oxidation)
   (c) $Br_2(l) + 2\ e^- \rightarrow 2\ Br^-(aq)$ (reduction)
   $2\ I^-(aq) \rightarrow I_2(s) + 2\ e^-$ (oxidation)
5. (a) spontaneous
   (b) nonspontaneous
   (c) spontaneous
6. SOA $Tl^+(aq) + e^- \leftrightarrows Tl(s)$ ↑
   ↓ $In^{3+}(aq) + 3\ e^- \leftrightarrows In(s)$
   $Ga^{3+}(aq) + 3\ e^- \leftrightarrows Ga(s)$
   $Al^{3+}(aq) + 3\ e^- \leftrightarrows Al(s)$ SRA
7. $Pt^{4+}(aq) + 4\ e^- \leftrightarrows Pt(s)$
   $2\ H^+(aq) + 2\ e^- \leftrightarrows H_2(g)$
   $Ni^{2+}(aq) + 2\ e^- \leftrightarrows Ni(s)$
   $Ce^{3+}(aq) + 3\ e^- \leftrightarrows Ce(s)$
   $Sr^{2+}(aq) + 2\ e^- \leftrightarrows Sr(s)$
8. Design: Each of the three metals is placed separately in solutions of the other three metal ions. The reaction is allowed to proceed, and observations are made. While zinc ions can be safely disposed of down the drain with copious amounts of water, cadmium (in solid as well as ionic form) and mercury (solid and ionic form) must be deposited in appropriate containers for safe disposal.
9. (a)

SOA		**OA**		**OA**
$Ni^{2+}(aq)$,	$NO_3^-(aq)$,	$Fe^{2+}(aq)$,	$Cl^-(aq)$,	$H_2O(l)$
		SRA	**RA** **RA**	**RA**

$$Ni^{2+}(aq) + 2\ e^- \rightarrow Ni(s)$$
$$2\ [Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e^-]$$
$$2\ Fe^{2+}(aq) + Ni^{2+}(aq) \xrightarrow{\text{nonspont.}} 2\ Fe^{3+}(aq) + Ni(s)$$

If the solutions are mixed, and the colour does not change from blue-green to a pale yellowish, and no solid forms, then the reaction is nonspontaneous.

(b)

SOA **OA**		**OA**		
$O_2(g)$, $H_2O(l)$	$Ag(s)$,	$Na^+(aq)$,	$I^-(aq)$,	
RA	**RA**	**SRA**	**RA**	

$$O_2(g) + 2\ H_2O(l) + 4\ e^- \rightarrow 4\ OH^-(aq)$$
$$4\ [Ag(s) + I^-(aq) \rightarrow AgI(s) + e^-]$$
$$4\ Ag(s) + 4\ I^-(aq) + O_2(g) + 2\ H_2O(l) \xrightarrow{\text{spont.}} 4\ AgI(s) + 4\ OH^-(aq)$$

If the final solution is tested with litmus paper, and the litmus paper turns blue, then the solution is basic and hydroxide ions have formed.

(c) **OA** **SOA** **OA** **OA** **OA**
$K^+(aq)$, $Cr_2O_7^{2-}(aq)$, $H^+(aq)$, $Na^+(aq)$, $I^-(aq)$, $H_2O(l)$
SRA **RA**

$$Cr_2O_7^{2-}(aq) + 14\ H^+(aq) + 6\ e^- \rightarrow 2\ Cr^{3+}(aq) + 7\ H_2O(l)$$
$$3\ [2\ I^-(aq) \rightarrow I_2(s) + 2\ e^-]$$
$$Cr_2O_7^{2-}(aq) + 14\ H^+(aq) + 6\ I^-(aq) \xrightarrow{\text{spont.}} 2\ Cr^{3+}(aq) + 7\ H_2O(l) + 3\ I_2(s)$$

If a few millilitres of hexane are added to the final solution, and the colour of the solvent layer after shaking appears purple, then iodine is likely present.

10. (a) The solution will be stable because no spontaneous reaction occurs according to the table of relative strengths of oxidizing and reducing agents and the spontaneity rule.

SOA	**OA**		**OA**
$H^+(aq)$	$Sn^{2+}(aq)$	$Cl^-(aq)$	$H_2O(l)$
	SRA	**RA** **RA**	**RA**

(b) The solution will not be stable because a spontaneous reaction occurs according to the table of relative strengths of oxidizing and reducing agents and the spontaneity rule.

SOA		**OA**	
$Cu^{2+}(aq)$	$NO_3^-(aq)$	$H_2O(l)$	$Sn(s)$
		RA	**SRA**

11. **SOA** **OA**
$Cl_2(g)$ $I^-(aq)$ $H_2O(l)$
SRA **RA**

$$Cl_2(g) + 2\ e^- \rightarrow 2\ Cl^-(aq)$$
$$2\ I^-(aq) \rightarrow I_2(s) + 2\ e^-$$
$$Cl_2(g) + 2\ I^-(aq) \xrightarrow{\text{spont.}} 2\ Cl^-(aq) + I_2(s)$$

12. **OA** **SOA** **OA**
$Fe(s)$ $H^+(aq)$ $O_2(g)$ $H_2O(l)$
SRA **RA**

$$O_2(g) + 4\ H^+(aq) + 4\ e^- \rightarrow 2\ H_2O(l)$$
$$2\ [Fe(s) \rightarrow Fe^{2+}(aq) + 2\ e^-]$$
$$O_2(g) + 4\ H^+(aq) + 2\ Fe(s) \xrightarrow{\text{spont.}} 2\ H_2O(l) + 2\ Fe^{2+}(aq)$$

13. Disproportionation occurs when an entity is simultaneously oxidized and reduced.
$$Sn^{2+}(aq) + 2\ e^- \rightarrow Sn(s)$$
$$Sn^{2+}(aq) \rightarrow Sn^{4+}(aq) + 2\ e^-$$

14.

	OA	**OA**	**OA**	**OA**
$Co(s)$	$Ag^+(aq)$	$Fe^{3+}(aq)$	$Cu^{2+}(aq)$	$H_2O(l)$
SRA				**RA**

Because cobalt metal is in excess and it is the strongest reducing agent present, it will be the reducing agent in all reactions.
$$Co(s) \rightarrow Co^{2+}(aq) + 2\ e^-$$
The oxidizing agents that will spontaneously react, in order of decreasing strength, are:
$Ag^+(aq)$, $Fe^{3+}(aq)$, $Cu^{2+}(aq)$.
$$Ag^+(aq) + e^- \rightarrow Ag(s)$$
$$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$$
$$Cu^{2+}(aq) + 2\ e^- \rightarrow Cu(s)$$
The balanced redox chemical equations that are spontaneous are as follows:
$$Co(s) + 2\ Ag^+(aq) \rightarrow Co^{2+}(aq) + 2\ Ag(s)$$
$$Co(s) + 2\ Fe^{3+}(aq) \rightarrow Co^{2+}(aq) + 2\ Fe^{2+}(aq)$$

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

15.
$$2\,[Mn^{2+}(aq) + 4\,H_2O(aq) \rightarrow MnO_4^-(aq) + 8\,H^+(aq) + 5\,e^-]$$
$$5\,[HBiO_3(aq) + 5\,H^+(aq) + 2\,e^- \rightarrow Bi^{3+}(aq) + 3\,H_2O(l)]$$
$$2\,Mn^{2+}(aq) + 5\,HBiO_3(aq) + 9\,H^+(aq) \rightarrow 5\,Bi^{3+}(aq) + 2\,MnO4^-(aq) + 7\,H_2O(l)$$

16. (a)
$$2\,[Cr(OH)_3(s) + 5\,OH^-(aq) \rightarrow CrO_4^{2-}(aq) + 4\,H_2O(l) + 3\,e^-]$$
$$IO_3^-(aq) + 3\,H_2O(l) + 6\,e^- \rightarrow I^-(aq) + 6\,OH^-(aq)$$
$$2\,Cr(OH)_3(s) + 4\,OH^-(aq) + IO_3^-(aq) \rightarrow 2\,CrO_4^{2-}(aq) + 5\,H_2O(l) + I^-(aq)$$

(b)
$$Ag_2O(s) + H_2O(l) + 2\,e^- \rightarrow 2\,Ag(s) + 2\,OH^-(aq)$$
$$CH_2O(aq) + 3\,OH^-(aq) \rightarrow CHO_2^-(aq) + 2\,H_2O(l) + 2\,e^-$$
$$Ag_2O(s) + OH^-(aq) + CH_2O(aq) \rightarrow 2\,Ag(s) + CHO_2^-(aq) + H_2O(l)$$

17. (a)
$$2\,[Al(s) + 4\,OH^-(aq) \rightarrow Al(OH)_4^-(aq) + 3\,e^-]$$
$$3\,[2\,H_2O(l) + 2\,e^- \rightarrow H_2(g) + 2\,OH^-(aq)]$$
$$2\,Al(s) + 2\,OH^-(aq) + 6\,H_2O(l) \rightarrow 2\,Al(OH)_4^-(aq) + 3\,H_2(g)$$

(b) This technology provides heat and force (of the gas produced) to help displace blockages in drains. Therefore it is an inexpensive, efficient, effective and simple solution to a common problem.

(c) Sodium hydroxide is very caustic and should be handled with gloves and eye protection. Flushing aluminium compounds down the drain has an impact on the environment because aluminium ions are toxic to fish and other aquatic organisms.

18. WHMIS Symbol Household Symbol



or


Extension

19. The term *antioxidant* suggests preventing oxidation. Antioxidants deactivate free radicals, which usually come in the form of oxygen molecules. Often, the products of oxidation can be carcinogenic. Examples of antioxidants are vitamins (A, C, and E), selenium, and carotenoids. The ability of antioxidants to prevent cancer and other diseases has not been established empirically, yet they continue to be marketed under this guise. Some synthetic antioxidant supplements have been found to increase free radical formation.