AP Chemistry Homework Answers
Chapter 20 Principles of Reactivity: Electron Transfer Reactions (Kotz)
Problems: 3ab, 5ab, 9, 13, 17, 23, 25, 29, 31, 34, 41, 45, 49, 59

20.3 (a) $Ag(s) \rightarrow Ag^{+}(aq) + e^{-}$

$NO_3^{-}(aq) + 2\ H^{+}(aq) + e^{-} \rightarrow NO_2(g) + H_2O(\ell)$

$Ag(s) + NO_3^{-}(aq) + 2\ H^{+}(aq) \rightarrow Ag^{+}(aq) + NO_2(g) + H_2O(\ell)$

(b) $2[MnO_4^{-}(aq) + 8\ H^{+}(aq) + 5\ e^{-} \rightarrow Mn^{2+}(aq) + 4\ H_2O(\ell)]$

$5[HSO_3^{-}(aq) + H_2O(\ell) \rightarrow SO_4^{2-}(aq) + 3\ H^{+}(aq) + 2\ e^{-}]$

$2\ MnO_4^{-}(aq) + H^{+}(aq) + 5\ HSO_3^{-}(aq) \rightarrow 2\ Mn^{2+}(aq) + 3\ H_2O(\ell) + 5\ SO_4^{2-}(aq)$

20.5 (a) $2[Al(s) + 4\ OH^{-}(aq) \rightarrow 3\ e^{-} + Al(OH)_4^{-}(aq)]$

$3[2\ H_2O(\ell) + 2\ e^{-} \rightarrow 2\ OH^{-}(aq) + H_2(g)]$

$2\ Al(s) + 6\ H_2O(\ell) + 2\ OH^{-}(aq) \rightarrow 2\ Al(OH)_4^{-}(aq) + 3\ H_2(g)$

(b) $2[CrO_4^{-}(aq) + 4\ H_2O(\ell) + 3\ e^{-} \rightarrow Cr(OH)_3(s) + 5\ OH^{-}(aq)]$

$3[SO_3^{2-}(aq) + 2\ OH^{-}(aq) \rightarrow SO_4^{2-}(aq) + H_2O(\ell) + 2\ e^{-}]$

$2\ CrO_4^{-}(aq) + 5\ H_2O(\ell) + 3\ SO_3^{2-}(aq) \rightarrow 2\ Cr(OH)_3(s) + 4\ OH^{-}(aq) + 3\ SO_4^{2-}(aq)$

20.9 (a) Oxidation: $Fe(s) \rightarrow Fe^{2+}(aq) + 2\ e^{-}$

Reduction: $O_2(g) + 4\ H^{+}(aq) + 4\ e^{-} \rightarrow 2\ H_2O(\ell)$

Overall: $2\ Fe(s) + O_2(g) + 4\ H^{+}(aq) \rightarrow 2\ H_2O(\ell) + 2\ Fe^{2+}(aq)$

(b) Oxidation occurs in the anode compartment and reduction occurs in the cathode compartment.

(c) Electrons in the external circuit flow from the Fe electrode to the positive (site of O_2 reduction) electrode.

Negative ions move in the salt bridge from the O_2/H_2O half-cell to the Fe/Fe^{2+} half-cell.

20.13 (a) $E^{o}_{cell} = E^{o}_{cathode} - E^{o}_{anode} = (-0.763\ V) - (+0.535\ V) = -1.298\ V$ not product-favored

(b) $E^{o}_{cell} = E^{o}_{cathode} - E^{o}_{anode} = (-0.763\ V) - (-0.25\ V) = -0.51\ V$ not product-favored

(c) $E^{o}_{cell} = E^{o}_{cathode} - E^{o}_{anode} = (+0.337\ V) - (+1.360\ V) = -1.023\ V$ not product-favored

(d) $E^{o}_{cell} = E^{o}_{cathode} - E^{o}_{anode} = (+0.80\ V) - (+0.771\ V) = +0.03\ V$ product-favored

20.17 (a) Al(s)

(b) Zn(s) and Al(s)

(c) $Fe^{2+}(aq) + Sn(s) \rightarrow Fe(s) + Sn^{2+}(aq)$

$E^{o}_{cell} = E^{o}_{cathode} - E^{o}_{anode} = (-0.44\ V) - (-0.14\ V) = -0.30\ V$ reactant-favored

(d) $Zn^{2+}(aq) + Sn(s) \rightarrow Zn(s) + Sn^{2+}(aq)$

$E^{o}_{cell} = E^{o}_{cathode} - E^{o}_{anode} = (-0.76\ V) - (-0.14\ V) = -0.62\ V$ reactant-favored

20.23 (a) F_2

(b) Cl_2 and F_2

20.25 $Zn(s) + 4\ OH^-(aq) \rightarrow Zn(OH)_4^{2-}(aq) + 2\ e^-$

$2\ H_2O(\ell) + 2\ e^- \rightarrow H_2(g) + 2\ OH^-(aq)$

$E^o_{cell} = E^o_{cathode} - E^o_{anode} = (-0.8277\ V) - (-1.22\ V) = +0.39\ V$

$$E_{cell} = E^o_{cell} - \frac{0.0257}{n} \ln \frac{[Zn(OH)_4^{2-}]P_{H_2}}{[OH^-]^2} = +0.39\ V - \frac{0.0257}{2} \ln \frac{(0.025)(1.0)}{(0.025)^2} = 0.34\ V$$

20.29 $Zn(s) + 2\ Ag^+(aq) \rightarrow Zn^{2+}(aq) + 2\ Ag(s)$

$E^o_{cell} = E^o_{cathode} - E^o_{anode} = (0.80\ V) - (-0.763\ V) = +1.56\ V$

$$E_{cell} = 1.48\ V = 1.56\ V - \frac{0.0257}{2} \ln \frac{1.0}{[Ag^+]^2}$$

$[Ag^+] = 0.040\ M$

20.31 (a) $2[Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)]$

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

$E^o_{cell} = E^o_{cathode} - E^o_{anode} = (0.771\ V) - (0.535\ V) = +0.236\ V$

$\Delta G^o = -nFE^o = -(2\ mol\ e^-)(96{,}500\ C/mol\ e^-)(0.236\ V)(1\ J/1\ C{\cdot}V)(1\ kJ/10^3\ J) = -45.5\ kJ$

$$\ln K = \frac{nE^o}{0.0257\ V} = \frac{(2)(0.236\ V)}{0.0257\ V} = 18.4$$

$K = 9 \times 10^7$

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

$2\ Br^-(aq) \rightarrow Br_2(\ell) + 2\ e^-$

$E^o_{cell} = E^o_{cathode} - E^o_{anode} = (0.535\ V) - (1.08\ V) = -0.55\ V$

$\Delta G^o = -nFE^o = -(2\ mol\ e^-)(96{,}500\ C/mol\ e^-)(-0.55\ V)(1\ J/1\ C{\cdot}V)(1\ kJ/10^3\ J) = 110\ kJ$

$$\ln K = \frac{nE^o}{0.0257\ V} = \frac{(2)(-0.55\ V)}{0.0257\ V} = -42$$

$K = 4 \times 10^{-19}$

20.34 $Hg_2Cl_2(s) + 2\ e^- \rightarrow 2\ Hg(\ell) + 2\ Cl^-(aq)$

$2\ Hg(\ell) \rightarrow Hg_2^{2+}(aq) + 2\ e^-$

$Hg_2Cl_2(s) \rightarrow Hg_2^{2+}(aq) + 2\ Cl^-(aq)$

$E^o_{cell} = E^o_{cathode} - E^o_{anode} = (0.27\ V) - (0.789\ V) = -0.52\ V$

$$\ln K = \frac{nE^o}{0.0257\ V} = \frac{(2)(-0.52\ V)}{0.0257\ V} = -40.$$

$K = 3 \times 10^{-18}$

20.41 F^- is much more difficult to oxidize than water, so O_2 is more likely to be formed at the anode.

20.45 Charge = current × time = (0.150 A)(12.2 min)(60.0 s/min) = 110. C

$$\text{mol e}^- = (110.\ \text{C})\left(\frac{1\ \text{mol e}^-}{96{,}500\ \text{C}}\right) = 0.00114\ \text{mol e}^-$$

$$\text{mass of Ni} = (0.00114\ \text{mol e}^-)\left(\frac{1\ \text{mol Ni}}{2\ \text{mol e}^-}\right)\left(\frac{58.69\ \text{g}}{1\ \text{mol Ni}}\right) = 0.0334\ \text{g Ni}$$

20.49 $Al(s) \rightarrow Al^{3+}(aq) + 3\ e^-$

$$(84\ \text{g Al})\left(\frac{1\ \text{mol Al}}{27.0\ \text{g}}\right)\left(\frac{3\ \text{mol e}^-}{1\ \text{mol Al}}\right)\left(\frac{96{,}500\ \text{C}}{1\ \text{mol e}^-}\right) = 9.0 \times 10^5\ \text{C}$$

$(9.0 \times 10^5$ C/1.0 A)(1 min/60.0 s)(1 h/60.0 min) = 250 h

20.59 (a) The combination of a negative E°_{anode} half-cell with a SHE cathode (0 V) will result in a positive E°_{cell}

$Cr^{3+}(aq) + 3\ e^- \rightarrow Cr(s)$ $\quad E^\circ_{anode} = –0.74$ V

$Fe^{2+}(aq) + 2\ e^- \rightarrow Fe(s)$ $\quad E^\circ_{anode} = –0.44$ V

$Mg^{2+}(aq) + 2\ e^- \rightarrow Mg(s)$ $\quad E^\circ_{anode} = –2.37$ V

(b) Highest voltage (Mg): E°_{cell} = (0.00 V) – (–2.37 V) = 2.37 V

Lowest voltage (Cu): E°_{cell} = (0.337 V) – (0.00 V) = 0.337 V