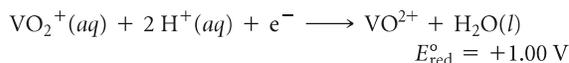
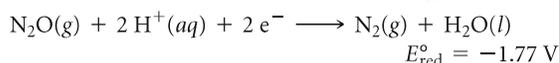
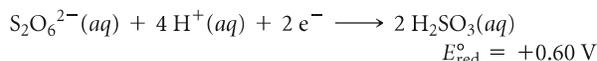
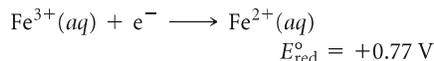


STRENGTHS OF OXIDIZING AND REDUCING AGENTS (section 20.4)

- 20.43 From each of the following pairs of substances, use data in Appendix E to choose the one that is the stronger reducing agent:
- Fe(s) or Mg(s)
 - Ca(s) or Al(s)
 - H₂(g, acidic solution) or H₂S(g)
 - BrO₃⁻(aq) or IO₃⁻(aq)
- 20.44 From each of the following pairs of substances, use data in Appendix E to choose the one that is the stronger oxidizing agent:
- Cl₂(g) or Br₂(l)
 - Zn²⁺(aq) or Cd²⁺(aq)
 - Cl⁻(aq) or ClO₃⁻(aq)
 - H₂O₂(aq) or O₃(g)
- 20.45 By using the data in Appendix E, determine whether each of the following substances is likely to serve as an oxidant or a reductant: (a) Cl₂(g), (b) MnO₄⁻(aq, acidic solution), (c) Ba(s), (d) Zn(s).
- 20.46 Is each of the following substances likely to serve as an oxidant or a reductant: (a) Ce³⁺(aq), (b) Ca(s), (c) ClO₃⁻(aq), (d) N₂O₅(g)?
- 20.47 (a) Assuming standard conditions, arrange the following in order of increasing strength as oxidizing agents in acidic solution: Cr₂O₇²⁻, H₂O₂, Cu²⁺, Cl₂, O₂. (b) Arrange the following in order of increasing strength as reducing agents in acidic solution: Zn, I⁻, Sn²⁺, H₂O₂, Al.
- 20.48 Based on the data in Appendix E, (a) which of the following is the strongest oxidizing agent and which is the weakest in acidic solution: Br₂, H₂O₂, Zn, Cr₂O₇²⁻? (b) Which of the following is the strongest reducing agent, and which is the weakest in acidic solution: F⁻, Zn, N₂H₅⁺, I₂, NO?
- 20.49 The standard reduction potential for the reduction of Eu³⁺(aq) to Eu²⁺(aq) is -0.43 V. Using Appendix E, which of the following substances is capable of reducing Eu³⁺(aq) to Eu²⁺(aq) under standard conditions: Al, Co, H₂O₂, N₂H₅⁺, H₂C₂O₄?
- 20.50 The standard reduction potential for the reduction of RuO₄⁻(aq) to RuO₄²⁻(aq) is +0.59 V. By using Appendix E, which of the following substances can oxidize RuO₄²⁻(aq) to RuO₄⁻(aq) under standard conditions: Br₂(l), BrO₃⁻(aq), Mn²⁺(aq), O₂(g), Sn²⁺(aq)?

FREE ENERGY AND REDOX REACTIONS (section 20.5)

- 20.51 Given the following reduction half-reactions:



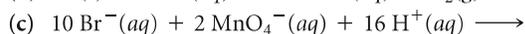
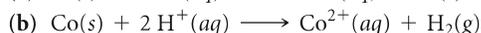
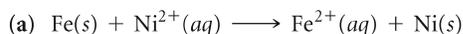
(a) Write balanced chemical equations for the oxidation of Fe²⁺(aq) by S₂O₆²⁻(aq), by N₂O(aq), and by VO₂⁺(aq). (b) Calculate ΔG° for each reaction at 298 K. (c) Calculate the equilibrium constant K for each reaction at 298 K.

- 20.52 For each of the following reactions, write a balanced equation, calculate the standard emf, calculate ΔG° at 298 K, and calculate the equilibrium constant K at 298 K. (a) Aqueous iodide ion is oxidized to I₂(s) by Hg₂²⁺(aq). (b) In acidic solution, copper(I) ion is oxidized to copper(II) ion by nitrate ion. (c) In basic solution, Cr(OH)₃(s) is oxidized to CrO₄²⁻(aq) by ClO⁻(aq).

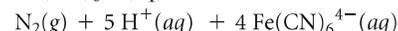
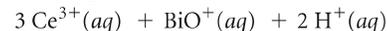
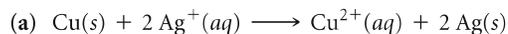
20.53 If the equilibrium constant for a two-electron redox reaction at 298 K is 1.5 × 10⁻⁴, calculate the corresponding ΔG° and E_{red}^o.

20.54 If the equilibrium constant for a one-electron redox reaction at 298 K is 8.7 × 10⁴, calculate the corresponding ΔG° and E_{red}^o.

- 20.55 Using the standard reduction potentials listed in Appendix E, calculate the equilibrium constant for each of the following reactions at 298 K:



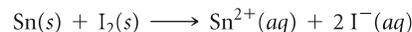
- 20.56 Using the standard reduction potentials listed in Appendix E, calculate the equilibrium constant for each of the following reactions at 298 K:



- 20.57 A cell has a standard cell potential of +0.177 V at 298 K. What is the value of the equilibrium constant for the reaction (a) if n = 1? (b) if n = 2? (c) if n = 3?

- 20.58 At 298 K a cell reaction has a standard cell potential of +0.17 V. The equilibrium constant for the reaction is 5.5 × 10⁵. What is the value of n for the reaction?

- 20.59 A voltaic cell is based on the reaction



Under standard conditions, what is the maximum electrical work, in joules, that the cell can accomplish if 75.0 g of Sn is consumed?

- 20.60 Consider the voltaic cell illustrated in Figure 20.5, which is based on the cell reaction



Under standard conditions, what is the maximum electrical work, in joules, that the cell can accomplish if 50.0 g of copper is formed?

CELL EMF UNDER NONSTANDARD CONDITIONS (section 20.6)

20.61 (a) Under what circumstances is the Nernst equation applicable? (b) What is the numerical value of the reaction quotient, Q , under standard conditions? (c) What happens to the emf of a cell if the concentrations of the reactants are increased?

20.62 (a) A voltaic cell is constructed with all reactants and products in their standard states. Will this condition hold as the cell operates? Explain. (b) Can the Nernst equation be used at temperatures other than room temperature? Explain. (c) What happens to the emf of a cell if the concentrations of the products are increased?

20.63 What is the effect on the emf of the cell shown in Figure 20.9, which has the overall reaction $\text{Zn}(s) + 2\text{H}^+(aq) \longrightarrow \text{Zn}^{2+}(aq) + \text{H}_2(g)$, for each of the following changes? (a) The pressure of the H_2 gas is increased in the cathode half-cell. (b) Zinc nitrate is added to the anode half-cell. (c) Sodium hydroxide is added to the cathode half-cell, decreasing $[\text{H}^+]$. (d) The surface area of the anode is doubled.

20.64 A voltaic cell utilizes the following reaction:



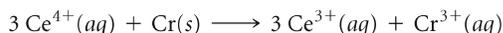
What is the effect on the cell emf of each of the following changes? (a) Water is added to the anode half-cell, diluting the solution. (b) The size of the aluminum electrode is increased. (c) A solution of AgNO_3 is added to the cathode half-cell, increasing the quantity of Ag^+ but not changing its concentration. (d) HCl is added to the AgNO_3 solution, precipitating some of the Ag^+ as AgCl .

20.65 A voltaic cell is constructed that uses the following reaction and operates at 298 K:



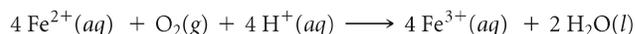
(a) What is the emf of this cell under standard conditions? (b) What is the emf of this cell when $[\text{Ni}^{2+}] = 3.00\text{ M}$ and $[\text{Zn}^{2+}] = 0.100\text{ M}$? (c) What is the emf of the cell when $[\text{Ni}^{2+}] = 0.200\text{ M}$ and $[\text{Zn}^{2+}] = 0.900\text{ M}$?

20.66 A voltaic cell utilizes the following reaction and operates at 298 K:



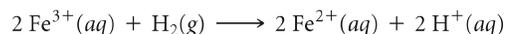
(a) What is the emf of this cell under standard conditions? (b) What is the emf of this cell when $[\text{Ce}^{4+}] = 3.0\text{ M}$, $[\text{Ce}^{3+}] = 0.10\text{ M}$, and $[\text{Cr}^{3+}] = 0.010\text{ M}$? (c) What is the emf of the cell when $[\text{Ce}^{4+}] = 0.010\text{ M}$, $[\text{Ce}^{3+}] = 2.0\text{ M}$, and $[\text{Cr}^{3+}] = 1.5\text{ M}$?

20.67 A voltaic cell utilizes the following reaction:



(a) What is the emf of this cell under standard conditions? (b) What is the emf of this cell when $[\text{Fe}^{2+}] = 1.3\text{ M}$, $[\text{Fe}^{3+}] = 0.010\text{ M}$, $P_{\text{O}_2} = 0.50\text{ atm}$, and the pH of the solution in the cathode half-cell is 3.50?

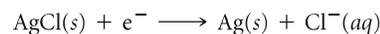
20.68 A voltaic cell utilizes the following reaction:



(a) What is the emf of this cell under standard conditions? (b) What is the emf for this cell when $[\text{Fe}^{3+}] = 3.50\text{ M}$, $P_{\text{H}_2} = 0.95\text{ atm}$, $[\text{Fe}^{2+}] = 0.0010\text{ M}$, and the pH in both half-cells is 4.00?

20.69 A voltaic cell is constructed with two Zn^{2+} -Zn electrodes. The two half-cells have $[\text{Zn}^{2+}] = 1.8\text{ M}$ and $[\text{Zn}^{2+}] = 1.00 \times 10^{-2}\text{ M}$, respectively. (a) Which electrode is the anode of the cell? (b) What is the standard emf of the cell? (c) What is the cell emf for the concentrations given? (d) For each electrode, predict whether $[\text{Zn}^{2+}]$ will increase, decrease, or stay the same as the cell operates.

20.70 A voltaic cell is constructed with two silver-silver chloride electrodes, each of which is based on the following half-reaction:



The two half-cells have $[\text{Cl}^-] = 0.0150\text{ M}$ and $[\text{Cl}^-] = 2.55\text{ M}$, respectively. (a) Which electrode is the cathode of the cell? (b) What is the standard emf of the cell? (c) What is the cell emf for the concentrations given? (d) For each electrode, predict whether $[\text{Cl}^-]$ will increase, decrease, or stay the same as the cell operates.

20.71 The cell in Figure 20.9 could be used to provide a measure of the pH in the cathode half-cell. Calculate the pH of the cathode half-cell solution if the cell emf at 298 K is measured to be $+0.684\text{ V}$ when $[\text{Zn}^{2+}] = 0.30\text{ M}$ and $P_{\text{H}_2} = 0.90\text{ atm}$.

20.72 A voltaic cell is constructed that is based on the following reaction:



(a) If the concentration of Sn^{2+} in the cathode half-cell is 1.00 M and the cell generates an emf of $+0.22\text{ V}$, what is the concentration of Pb^{2+} in the anode half-cell? (b) If the anode half-cell contains $[\text{SO}_4^{2-}] = 1.00\text{ M}$ in equilibrium with $\text{PbSO}_4(s)$, what is the K_{sp} of PbSO_4 ?

BATTERIES AND FUEL CELLS (section 20.7)

20.73 (a) What happens to the emf of a battery as it is used? Why does this happen? (b) The AA-size and D-size alkaline batteries are both 1.5-V batteries that are based on the same electrode reactions. What is the major difference between the two batteries? What performance feature is most affected by this difference?

20.74 (a) Suggest an explanation for why liquid water is needed in an alkaline battery. (b) What is the advantage of using highly concentrated or solid reactants in a voltaic cell?

20.75 During a period of discharge of a lead-acid battery, 402 g of Pb from the anode is converted into $\text{PbSO}_4(s)$. (a) What mass of

$\text{PbO}_2(s)$ is reduced at the cathode during this same period? (b) How many coulombs of electrical charge are transferred from Pb to PbO_2 ?

20.76 During the discharge of an alkaline battery, 4.50 g of Zn is consumed at the anode of the battery. (a) What mass of MnO_2 is reduced at the cathode during this discharge? (b) How many coulombs of electrical charge are transferred from Zn to MnO_2 ?

20.77 Heart pacemakers are often powered by lithium-silver chromate "button" batteries. The overall cell reaction is

