Objective 14. Apply oxidation-reduction reaction principles to electrolytic cells.

1. Electroplating and thermodynamics.
a. You have Cr metal, Cr^{3+} (aq), Fe metal, and Fe^{2+} (aq).
(i) You place Cr metal into the Fe^{2+} (aq). This reaction will occur. Look up the reduction half reaction and reduction potential in the Standard Reduction Potential Table. Look up the oxidation half reaction and reduction potential in the Standard Reduction Potential Table. Add the two half reactions to give an overall reaction. Calculate E for the overall reaction (should be a positive E). Then, calculate ΔG for this reaction (should be less than 0).
(ii) You place Fe metal ino the Cr^{3+} (aq). Will a reaction occur? Calculate E and ΔG for this reaction.
b. You want to chrome plate a steel car part, e.g., wheels. In other words, you want to plate a more active metal (Cr) onto a a less active metal (Fe).
(i) This electroplating reaction uses a ____ (voltaic or electrolytic) cell. The electroplating reaction is _____ and has a ΔG __ 0.
(ii) The anode is the electrode at which oxidation occurs. Should the anode be the steel car part or chromium?
The cathode is the electrode at which reduction occurs. Should the cathode be the steel car part or chromium?
(iii) What would you use as the electrolyte?
What is the minimum voltage required to plate chrome onto the car part?
(iv) 100 mA of current is passed through the cell for 30 min. Calculate the mass of Cr that is plated onto the car part.
Formulas to use: I = Q/t and Q = n F

2. Use an electrolytic cell to gold plate an iron ring. Draw a cell diagram to show how to plate the ring with gold. Label the anode and cathode. Write the half reaction that occurs at each electrode. Specify an electrolyte. Calculate the minimum voltage for this cell to work.

3. Hydrogen may be the fuel of the next generation. One way to produce hydrogen is by the electrolysis of water.
a. Draw an electrochemical cell that can be used for the electrolysis of water. Use an inert material such as C or Pt for each electrode. Label the anode and cathode. Write the reactions that occur at each electrode. You have the following choices for half reactions (some of which may <u>not</u> be balanced):

H^+ (aq) + e^- ---> H_2 (g)
2 H_2O (l) + 2 e^- ---> H_2 (g) + OH^- (aq)
O_2 (g) + 4 H^+ (aq) + 2e^- ---> 2 H_2O (l)
O_2 (g) + 4 H_2O (l) + 4 e^- ---> 2 OH^- (aq)

Write the net (overall) reaction. State what you will use as the electrolyte (choose prudently; more than one reaction may occur at each electrode). Calculate E^o_{cell}. At which electrode will H_2 be produced?
b. How can you make the electrolysis of water reaction go faster?

4. Hydrogen is thought to be the fuel of the 21^{st} century. It will be used in a fuel cell rather than combusted in a car engine. You need hydrogen for a hydrogen fuel cell. You have two carbon rods, one 1 V and one 1.5 V battery, NaOH pellets, water, some wire, and a 250 ml beaker.
a. Draw an electrochemical cell that can be used to split water. Label the anode and cathode. Write the half reaction that occurs at each electrode and the overall reaction.
b. Which battery would you use to split water? Give reasons.
c. You are impatient and want your cell to split water faster. What variable do you change?
d. How much energy in V is produced by a hydrogen fuel cell? Then, use E = QV to convert your energy from V to kJ/mole. What is K_{eq} for this reaction?
e. Hydrogen undergoes combustion in a heat engine. What is ΔG for the combustion of H_2? At what T will this reaction not occur?
f. Explain why H_2 is used in fuel cells and not in car engines. Hint: see work in a hydrogen combustion reaction.
What is the function of a proton exchange membrane (PEM) in a fuel cell?