1. (5 pts) Which of the following substances is the best reducing agent?
   a) F⁻  b) Mg  c) Li⁺  d) Ag⁺  e) Zn

2. (5 pts) Which of the following substances is the best oxidizing agent?
   a) F⁻  b) Mg²⁺  c) O₃  d) Ag⁺  e) Cu

3. (10 pts) Balance the following reaction in acidic solution.
   \[2 \text{S}_2\text{O}_3^{2-} + \text{OCl}^- \rightarrow \text{S}_4\text{O}_6^{2-} + \text{Cl}^- + \text{H}_2\text{O}\]
   Use the half-cell method. Write out the oxidation and reduction half cells and balance based on # of electrons:
   - Oxidation half cell: \(2\text{S}_2\text{O}_3^{2-} \rightarrow \text{S}_4\text{O}_6^{2-} + 2\text{e}^-\)
   - Reduction half cell: \(\text{OCl}^- + 2\text{e}^- \rightarrow \text{Cl}^-\)

4. (10 pts) Balance the following reaction in basic solution.
   \[3\text{BiO}_3^- + 2\text{Cr}^{3+} \rightarrow 3\text{Bi}^{3+} + 2\text{CrO}_4^{2-} + \text{H}_2\text{O}\]
   Write out the oxidation and reduction half cells and balance based on # of electrons:
   - Oxidation half cell: \(\text{Cr}^{3+} \rightarrow \text{CrO}_4^{2-} + 3\text{e}^-\)
   - Reduction half cell: \(\text{BiO}_3^- + 2\text{e}^- \rightarrow \text{Bi}^{3+}\)

5. (5 pts) Write the oxidation state for the underlined element in the box following each compound.
   a) LiAlH₄  b) Ba₃(AsO₄)₂  c) Na₂NiCl₄
   d) CaSO₃  e) H₂O₂
6. (15 pts) Calculate the redox potentials for the following reactions. Show the two half cell reactions, written in the proper direction and their potentials used to calculate your answer.

   a) \( \text{H}_2(g) + 2\text{Li}(s) \rightleftharpoons 2\text{H}^-(\text{soln}) + 2\text{Li}^+(\text{soln}) \)

   \[
   \begin{align*}
   \text{H}_2 & \rightarrow 2\text{H}^- & E^\circ = -2.25 \text{ V} \\
   2\text{Li} & \rightarrow 2\text{Li}^+ + 2e^- & E^\circ = +3.05 \text{ V}
   \end{align*}
   \]

   \( \text{E}^\circ = +0.80 \text{ V} \)

   b) \( 4\text{H}^+(aq) + \text{O}_2(g) + 2\text{Cu}(s) \rightleftharpoons 2\text{H}_2\text{O} + 2\text{Cu}^{2+}(aq) \)

   \[
   \begin{align*}
   4\text{H}^+ & + \text{O}_2 + 4e^- & 2\text{H}_2\text{O} & E^\circ = +1.23 \text{ V} \\
   2\text{Cu} & \rightarrow 2\text{Cu}^{2+} + 4e^- & E^\circ = -0.34 \text{ V}
   \end{align*}
   \]

   \( \text{E}^\circ = +0.89 \text{ V} \)

   c) \( \text{F}_2(g) + 2\text{Cl}^-(aq) \rightleftharpoons 2\text{F}^-(aq) + \text{Cl}_2(g) \)

   \[
   \begin{align*}
   \text{F}_2 & + 2e^- & 2\text{F}^- & E^\circ = +2.87 \text{ V} \\
   2\text{Cl}^- & \rightarrow \text{Cl}_2 + 2e^- & E^\circ = -1.36 \text{ V}
   \end{align*}
   \]

   \( \text{E}^\circ = +1.51 \text{ V} \)

   d) \( \text{Cu}(s) + 2\text{Ag}^+(aq) \rightleftharpoons \text{Cu}^{2+}(aq) + 2\text{Ag}(s) \)

   \[
   \begin{align*}
   2\text{Ag}^+ & + 2e^- & 2\text{Ag} & E^\circ = +0.80 \text{ V} \\
   \text{Cu} & \rightarrow \text{Cu}^{2+} + 2e^- & E^\circ = -0.34 \text{ V}
   \end{align*}
   \]

   \( \text{E}^\circ = +0.46 \text{ V} \)

   e) \( 3\text{Pb}^{2+}(aq) + 2\text{Al}(s) \rightleftharpoons 3\text{Pb}(s) + 2\text{Al}^{3+}(aq) \)

   \[
   \begin{align*}
   3\text{Pb}^{2+} & + 6e^- & 3\text{Pb} & E^\circ = -0.13 \text{ V} \\
   2\text{Al} & \rightarrow 2\text{Al}^{3+} + 6e^- & E^\circ = +1.66 \text{ V}
   \end{align*}
   \]

   \( \text{E}^\circ = +1.53 \text{ V} \)

7. (10 pts) Library/web research topic: Describe in your own words the chemistry (with formulas) involved in a lithium-ion battery. Is lithium metal used? What is the voltage of this electrochemical reaction? List two main advantages and two main disadvantages of lithium-ion batteries with BRIEF explanations. DO NOT COPY DIRECTLY FROM ANY REFERENCE (except for chemical formulas). List your primary reference used at the end.

Lithium ion rechargeable batteries have anodes composed of carbon/graphite (represented by C₆ in the formula below) while the cathode is composed of Li⁺[CoO₂]⁻ (Co³⁺ oxidation state) or LiMn₂O₄ (mixed Mn³⁺/Mn⁴⁺). When the battery is charged some of the carbon anode is reduced to [C₆]ₓ⁻ (where x = # of electrons transferred) and some of the the Co³⁺ in the cathode is oxidized to a +4 oxidation state. Enough Li⁺ cations migrate to the anode to balance the negative charge build-up. This forms a mixture of [Li⁺]ₓ[C₆]ₓ⁻ at the anode (electron source) and oxidized CoO₂ at the cathode (electron acceptor). **Li metal is NOT formed unless something goes wrong during the charging process!** When the battery discharges (produces electricity) the electrons flow from the reduced anode to the oxidized cathode through the external circuit (wire) reducing the CoO₂ to [CoO₂]⁺. The Li⁺ cations migrate back from the carbon anode to the cathode to reform LiCoO₂. There is an electrolyte typically composed of either a polar organic gel and a lithium salt or a nano-porous polymer (Li-polymer-ion). This makes the Li⁺ cation migration possible between the anode and cathode.

\[
\text{Reaction: } [\text{Li}^+]_x[\text{C}_6]_x^{x^-} + x\text{CoO}_2 \rightleftharpoons \text{C}_6 + x\text{LiCoO}_2
\]

The voltage produced is about 3.6 V.

**Advantages:** light weight & high power density (voltage & amps; very good for small electronic devices); no memory effect (doesn't matter how often you charge or discharge, charging after light use does not reduce the battery capacity); low self-discharge (built-in computer chip for monitoring battery stats does slowly drain battery).

**Disadvantages:** limited lifetime (aging will gradually deactivate regardless of level of use, typically 3 years); heat sensitive (faster deactivation at higher temps); not good for high power drain devices; built-in computer chip and protection circuit to monitor charging and discharging, temp, etc. (adds to cost); internal short-circuit can cause fire due to high power density (recent fires and recalls for notebook computer batteries).

Refs:  http://electronics.howstuffworks.com/lithium-ion-battery1.htm  
http://www.buchmann.ca/Article5-Page1.asp  
http://en.wikipedia.org/wiki/Lithium_ion_battery