1. (3 pts) Which of the following would be non-spontaneous under standard conditions (1 atm and 298 K)? (Circle all that are.)
   A. freezing of water
   B. corrosion of iron metal
   C. solid sodium chloride dissolving in pure water
   D. sugar crystals forming in a cup of hot coffee that contains one packet of sugar
   E. a strong acid and strong base reacting when mixed
   F. an opened can of soda pop losing its carbonation

2. Consider the following gas phase reaction:

   ![Diagram of gas phase reaction]

   (a) (2 pts) Write the simplest balanced equation for the reaction, using A for О and B for ●.

   (b) (1 pt) Predict the sign for ΔS for the reaction.

   (c) (1 pt) If the reaction is exothermic, under what conditions of temperature will the reaction be spontaneous?
      A. Low temperatures only.
      B. High temperatures only.
      C. All temperatures
      D. It will never be spontaneous.

3. (2 pts) Provide the sign of ΔH and ΔS for the following phase changes.
   A. a gas condensing: ΔH < 0 or ΔH > 0
      ΔH < 0 or ΔH > 0
      ΔS < 0 or ΔS > 0
   B. a solid melting:
      ΔH < 0 or ΔH > 0
      ΔS < 0 or ΔS > 0

4. (3 pts) When alcohol burns, the reaction is:
   \[\text{C}_2\text{H}_5\text{OH}(l) + 3 \text{O}_2(g) \rightarrow 2 \text{CO}_2(g) + 3 \text{H}_2\text{O}(g)\]
   Provide the sign of ΔG, ΔH, and ΔS for the reaction.
   ΔG > 0 or ΔG < 0
   ΔH > 0 or ΔH < 0
   ΔS > 0 or ΔS < 0

5. Consider the reaction and data:
   \[4 \text{NH}_3 + 3 \text{O}_2 \rightarrow 2 \text{N}_2 + 6 \text{H}_2\text{O}\]

<table>
<thead>
<tr>
<th>Substance</th>
<th>ΔH°, kJ/mol</th>
<th>S°, J/mol K</th>
</tr>
</thead>
<tbody>
<tr>
<td>NH₃(g)</td>
<td>-46</td>
<td>192</td>
</tr>
<tr>
<td>O₂(g)</td>
<td>0</td>
<td>205</td>
</tr>
<tr>
<td>N₂(g)</td>
<td>0</td>
<td>192</td>
</tr>
<tr>
<td>H₂O(g)</td>
<td>-242</td>
<td>189</td>
</tr>
</tbody>
</table>

   (a) (2 pts) Determine ΔH° with correct units for the reaction:

   \[4 \text{NH}_3 + 3 \text{O}_2 \rightarrow 2 \text{N}_2 + 6 \text{H}_2\text{O}\]

   (b) (2 pts) Determine ΔS° with correct units for the reaction:

   \[4 \text{NH}_3 + 3 \text{O}_2 \rightarrow 2 \text{N}_2 + 6 \text{H}_2\text{O}\]

   (c) (2 pts) Use the values determined in (a) and (b) to determine ΔG° with correct units at 298 K.

   (d) (1 pt) Is this reaction endothermic? YES  NO
   (e) (1 pt) Is it entropy favored? YES  NO

6. (3 pts) Consider the following reaction:
   \[2 \text{HgO(s)} + 2 \text{S(s)} \rightleftharpoons 2 \text{HgS(s)} + \text{O}_2(g)\]
   ΔG° = +8.0 kJ

   (a) Determine the equilibrium constant, K_p, for this reaction at 298 K.
6 (b) (3 pts) continued... Under what circumstances would ΔG be positive for this reaction? Circle all that apply.
   A. High temperatures only.
   B. Low temperatures only.
   C. When Q_p > K_p
   D. When Q_p < K_p
   E. When P_o2 is zero or close to zero
   F. This reaction will never be spontaneous.
7. A Galvanic cell (ΔG < 0) is prepared using Pb|Pb^+2 and Cr|Cr^+3 half cells.
   (a) (3 pts) Determine E^0_rxn.
   (b) (3 pts) Write and balance the spontaneous reaction that takes place.
8. Given E^0_rxn = -0.06 v for the reaction:
   Co(s) + 2 Tl^+(aq) → Co^{2+}(aq) + 2 Tl(s)
   (a) (3 pts) What is the expected value for E if [Co^{2+}] = 0.0020 M and [Tl^+] = 1.20 M?
   (b) (3 pts) What is ΔG° for this reaction?
   (c) (3 pts) What is the equilibrium constant, K_c, for this reaction?
9. (2 pts) If you were to balance the following two half reactions, how many electrons would be transferred in the balanced equation? (You do not need to actually balance it.)
   MnO_4^- + 8 H^+ + 5 e^- → Mn^{2+} + 4 H_2O
   Br^- + 3 H_2O → BrO_2^- + 6 H^+ + 4 e^-
10. Consider the following information:
    A → A^{+2} + e^- E = -0.30 v
    B → B^{+2} + e^- E = -0.40 v
    C → C^{+2} + e^- E = -0.50 v
    D → D^{+2} + e^- E = -0.60 v
    E → E^{+2} + e^- E = -0.70 v
   (a) (1 pt) Which of these is the most easily reduced?
   (b) (1 pt) Which of these is most easily oxidized?
   (c) (1 pt) Will C react spontaneously with B^{+2}, D^{+2} or both?
11. (1 pt) The reducing agent in the following equation is
    IO_3^- + 3 SO_3^{2-} → I^- + 3 SO_4^{2-}
    (A) IO_3^-  (B) SO_3^{2-}  (C) I^-  (D) SO_4^{2-}
12. (3 pts) Balance the following redox reaction in acidic solution.
    Cr_2O_7^{2-} + Fe^{+2} → Cr^{3+} + Fe^{+3}
13. (BONUS 1 point) Print your name here:

Your exam score (50 possible): _______
PrenHall (0 – 5 max.): _______
Adjusted exam score (50 max.): _______

Determine your grade:
A ≥ 46.5; B+ ≥ 43.5; B ≥ 41.0; C+ ≥ 37.5; C ≥ 34.00; D ≥ 30.00
### Standard Reduction Potentials:

<table>
<thead>
<tr>
<th>Reaction</th>
<th>$E^o$ (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{Ag}^+ + e^- \rightarrow \text{Ag}$</td>
<td>+0.80</td>
</tr>
<tr>
<td>$\text{Fe}^{3+} + e^- \rightarrow \text{Fe}^{2+}$</td>
<td>+0.77</td>
</tr>
<tr>
<td>$\text{I}_2(s) + 2 e^- \rightarrow 2 \text{I}^-$</td>
<td>+0.54</td>
</tr>
<tr>
<td>$\text{Cu}^{2+} + 2 e^- \rightarrow \text{Cu}$</td>
<td>+0.34</td>
</tr>
<tr>
<td>$2 \text{H}^+ + 2 e^- \rightarrow \text{H}_2(g)$</td>
<td>0.00</td>
</tr>
<tr>
<td>$\text{Pb}^{2+} + 2 e^- \rightarrow \text{Pb}$</td>
<td>-0.13</td>
</tr>
<tr>
<td>$\text{Ni}^{2+} + 2 e^- \rightarrow \text{Ni}$</td>
<td>-0.26</td>
</tr>
<tr>
<td>$\text{Fe}^{3+} + 2 e^- \rightarrow \text{Fe}$</td>
<td>-0.44</td>
</tr>
<tr>
<td>$\text{Cr}^{3+} + 3 e^- \rightarrow \text{Cr}$</td>
<td>-0.73</td>
</tr>
<tr>
<td>$\text{Zn}^{2+} + 2 e^- \rightarrow \text{Zn}$</td>
<td>-0.76</td>
</tr>
<tr>
<td>$\text{Mg}^{2+} + 2 e^- \rightarrow \text{Mg}$</td>
<td>-1.66</td>
</tr>
</tbody>
</table>

**Useful equations**

\[ \Delta G = \Delta H - T\Delta S \]
\[ \Delta G^o = \Delta H^o - T\Delta S^o \]
\[ \Delta G = \Delta G^o + RT\ln Q \]
\[ \Delta G^o = -RT\ln K \]
\[ \Delta G = -nFE \]
\[ \Delta G^o = -nFE^o \]

$R = 8.314 \text{ J/mol K} = 0.0821 \text{ L atm/mol K}$

\[ E = E^o - \frac{0.0592}{n}\log Q \]

\[ E^o = \frac{0.0592}{n}\log K \]

Charge(coulombs) = Current(amps) x Time(s)

$F = 96500 \text{ J/mol e}^- \text{ V}$

$F = 1 \text{ mol e}^- = 96,500 \text{ coul}$
Answers:
1. A and D
2. (a) $A_2 + 2B \rightarrow 2AB$; (b) negative; (c) A
3. A. $\Delta H < 0$ and $\Delta S < 0$; B. $\Delta H > 0$ and $\Delta S > 0$
4. $\Delta G < 0$; $\Delta H < 0$ and $\Delta S > 0$
5. (a) $\Delta H^0 = -1268 \text{ kJ}$; (b) $\Delta S^0 = +135 \text{ J/K}$; (c) $\Delta G^0 = -1308 \text{ kJ}$; (d) NO; (e) YES
6. (a) $K_p = 0.04$; (b) B and C
7. (a) $E_{rxn}^0 = +0.60 \text{ v}$; (b) $2Cr + 3Pb^{2+} \rightarrow 2Cr^{3+} + 3Pb$
8. (a) $E_{rxn} = +0.025 \text{ v}$; (b) $\Delta G^0 = +11.6 \text{ kJ}$; $K_c = 0.0094$
9. twenty
10. $E^{+2}$; (b) A; (c) $D^{+2}$
11. B
12. $14H^+ + Cr_2O_7^{2-} + 6Fe^{2+} \rightarrow 2Cr^{3+} + 6Fe^{3+} + 7H_2O$