Please answer the following questions:

Part I: Multiple Choices (40 pts: 10 @ 4 pts each). Circle the **ONE** best answer:

1. In a saturated solution of Pb(OH)₂, the concentration of lead ions is 4.2 x 10⁻⁶ M and the concentration of hydroxide ions is 8.3 x 10⁻⁶ M. What is the predicted value of Ksp for Pb(OH)₂?
   a) 2.9 x 10⁻¹⁶  
   b) 5.8 x 10⁻¹⁶  
   c) 1.5 x 10⁻¹⁶  
   d) 3.5 x 10⁻¹³

2. Predict the sign of ΔH and ΔS for the evaporation of water from a glass:
   a) ΔH = 0 and ΔS > 0  
   b) ΔH > 0 and ΔS > 0  
   c) ΔH > 0 and ΔS = 0  
   d) ΔH < 0 and ΔS > 0

3. For the process  O₂ (g)  →  2 O (g), ΔH° = +498 kJ. What would be predicted for the sign of ΔS° rxn and the conditions under which this reaction would be spontaneous?
   ΔS° rxn  Spontaneous
   a) positive  at low temperature only  
   b) positive  at high temperature only  
   c) negative  at high temperature only  
   d) negative  at low temperature only

4. What is the standard cell potential, E°, for the reaction?
   Br₂ (l) + 2 Ce³⁺ (aq)  →  2 Br⁻ (aq) + 2 Ce⁴⁺ (aq)
   Given that  2 Ce⁴⁺ (aq) + 2e  →  2 Ce³⁺ (aq)  
   and  Br₂ (l) + 2e  →  2 Br⁻ (aq)
   a) -2.69 V  
   b) +0.53 V  
   c) -0.53 V  
   d) +2.69 V

5. Which of the following ions is the best reducing agent?
   Fe³⁺ (aq) + e  →  Fe²⁺ (aq)  
   Cu²⁺ (aq) + e  →  Cu⁺ (aq)
   a) Fe³⁺  
   b) Fe²⁺  
   c) Cu²⁺  
   d) Cu⁺

6. For the reaction: 2 NO₂ (g) → N₂O₄ (g), ΔG° = -4.7 kJ at 25°C. Calculate ΔG for this reaction if the partial pressures of NO₂ and N₂O₄ are both 0.50 atm (R = 8.31 x 10⁻³ kJ/mol.K).
   a) -3.0 kJ  
   b) -6.4 kJ  
   c) -4.6 kJ  
   d) -4.8 kJ
7. The more _______ E°_red is for a species, the stronger the oxidizing strength of the species.
   a) voltaic                    b) positive   c) concentrated  d) negative

8. Using Nernst equation, what is the E_cell, at 25 ºC for the reaction:
   Zn (s)   +   Cu^{2+} (aq)   \rightarrow   Zn^{2+} (aq)   +    Cu (s)
   Given that E°_cell = +1.100 V, [Cu^{2+}] = 1.0 M and [Zn^{2+}] = 0.10 M
   a) 1.13                                  b) 1.16       c) 1.10    d) 1.07

9. Which of the following reactions is most likely to have the most negative change in entropy?
   a) CaCO_3 (s)   \rightarrow   CaO (s)   +   CO_2 (g)
   b) 2 NH_3 (g)   \rightarrow   N_2 (g)   +   3 H_2 (g)
   c) O_2 (g)  +  N_2 (g)   \rightarrow   2 NO (g)
   d) NH_3 (g)  +  HCl (g)   \rightarrow   NH_4Cl (s)

10. The Ksp for AgCl is 1.8 x 10^{-10} and the Kf for Ag(NH_3)_{2}^+ is 1.7 x 10^7. What is the value of K for
    the reaction below?
    AgCl (s)   +  2 NH_3 (aq)   \rightarrow   Ag(NH_3)_{2}^+ (aq)  +  Cl^- (aq)
    a) 1.1 x 10^{-17} b) 3.1 x 10^{-3} c) 9.4 x 10^{16} d) 5.5 x 10^{-2}

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**Part II (32 pts)***

1. (12 pts) The following figure depicts the electrochemical cell for the reaction.
   Cl_2 (g) + 2 Br^- (aq)   \rightarrow   2 Cl^- (aq)   +    Br_2 (l)
   a) Label the components of the cell (anode, cathode, flow of electrons and direction of anions)
      and sketch the reaction (oxidation & reduction) at each electrode

   b) (8 pts) Using the standard electrode potentials given in the data sheet, calculate ∆E°_cell and ∆G°_cell.

   \[ \Delta E°_\text{cell} = +0.283 \text{ V} \]  
   \[ \Delta G°_\text{cell} = -54.6 \text{ kJ} \]
2. (12 pts: 4 @ 3 pts): Fill the blanks in each of the following sentences (positive, negative, zero, oxidation, reduction, spontaneous, non-spontaneous, anode, cathode, electrolysis):

   a)  In an electrolytic cell, a --------------- redox reaction is made to occur by pumping electrical energy into the system.

   a) In electrochemical cells, oxidation takes place at the ---------------

   b) In voltaic cells, \( \Delta G \) is always ---------------.

   c) Standard molar entropies of pure substances are always ---------------.

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Part III (32 pts) Calculations: Show all work for full credit. Please express all answers with proper units and correct number of significant figures.

1. (12 pts) In electroplating a decorative bathroom fixture how many minutes does it take to deposit 1.48 g of chromium from \( \text{Cr(NO}_3\text{)}_3 \) solution \( \text{Cr}^{3+} \text{(aq)} + 3 \text{ e} \rightarrow \text{Cr(s)} \) with a current of 2.5 A?

   54.9 min
2. (20 pts) For the following reaction at 298 K:

\[
\text{Al}_2\text{O}_3 (s) + 2 \text{H}_2 (g) \rightarrow 2 \text{Al} (s) + 3 \text{H}_2\text{O} (g)
\]

<table>
<thead>
<tr>
<th></th>
<th>Al(_2)O(_3) (s)</th>
<th>H(_2) (g)</th>
<th>Al (s)</th>
<th>H(_2)O (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\Delta H^\circ) (kJ/mol)</td>
<td>-1669.8</td>
<td>0</td>
<td>0</td>
<td>-241.8</td>
</tr>
<tr>
<td>(S^\circ) (J/K.mol)</td>
<td>51.0</td>
<td>130.6</td>
<td>28.3</td>
<td>188.8</td>
</tr>
</tbody>
</table>

a) Calculate \(\Delta G^\circ\) in kilojoules

\[
\Delta G^\circ_{\text{rxn}} \text{ (kJ)}
\]

b) Is the calculated entropy change consistent with what you expected? Why?

Yes because:

No because:

c) Calculate the equilibrium constant for the reaction at 298 K.

\[
K = \text{ }
\]
When you are told to do so, tear off the Periodic Table cover sheet and use as required during exam.

Useful Information:
Gas Constant: \( R = 8.3145 \text{ J/K.mol} = 8.3145 \times 10^{-3} \text{ kJ/K.mol} = 0.0821 \text{ L atm/mol.K} \)
\( K = 273 + ^\circ \text{C} \quad 1 \text{ atm} = 760 \text{ torr} = 760 \text{ mmHg} \quad \text{Standard temperature} = 298.15 \text{ K} \)
Faraday’s constant, \( F = 9.65 \times 10^4 \text{ C/mol} = 9.65 \times 10^4 \text{ J/K.mol} \quad 1 \text{ V} = 1 \text{ J.C}^{-1} \)
\[
\text{Cl}_2 (g) + 2e^- \rightarrow 2 \text{Cl}^- (aq) \quad E^\circ = +1.360 \text{ V}
\]
\[
\text{Br}_2 (l) + 2e^- \rightarrow 2 \text{Br}^- (aq) \quad E^\circ = +1.077 \text{ V}
\]

Useful Equations:
Nernst equations: \( E_{\text{Net}} = E^\circ_{\text{Net}} - (0.0257 \text{ V/n}) \ln Q \) (at 25 \(^\circ \text{C}\)) & \( \Delta G_{\text{rxn}} = \Delta G^\circ_{\text{rxn}} + RT \ln K \)
\( E^\circ = (0.0257 \text{ V/n}) \ln K \) (at 25 \(^\circ \text{C}\))
\( \Delta G^\circ_{\text{rxn}} = -nF E^\circ = -RT \ln K \)
Charge (coulombs, C) = current (A) x time (s)