Name: _____________________________________________ CLID # ________________________________

LAST NAME, First
(Circle the alphabet segment of your LAST NAME): A-B   C-F   G-L   M-O   P-Z

Please answer the following questions:

**Part I: Multiple Choices (44 pts: 11 @ 4 pts each). Circle the **ONE** best answer:**

1. Solid gold(I), AuCl (K_sp = 2.0 x 10^{-13}) is dissolved when excess, CN^- is added to give a water soluble complex ion, Au(CN)_2^-. If K_f for Au(CN)_2^- from Au^+ and CN^- is 2.0 x 10^{38}. What is the value of K for the following reaction:
   \[ \text{AuCl (s) + 2 CN}^- (aq) \rightarrow \text{Au(CN)}_2^- (aq) + \text{Cl}^- (aq) \]
   a) 4.0 x 10^{25}                     b) 8.0 x 10^{12}                     c) 2.0 x 10^{38}  d) can’t be calculated from the given data.

2. Which of the following statements is FALSE:
   a) Reactions with negative \( \Delta H^\circ_{\text{rxn}} \) and positive \( \Delta S^\circ_{\text{rxn}} \) are *product-favored* at all temperatures.
   b) The entropy of a pure, perfect crystal is zero at 0 K.
   c) A sample of pure I_2 vapor has higher entropy than pure solid I_2 (both at room temperature).
   d) At the same temperature a gaseous CH_4 molecule has more entropy than a gaseous C_4H_{10} molecule.

3. The following reaction is endothermic: 3 O_2 (g) \rightarrow 2 O_3 (g). The reaction is:
   a) spontaneous at all temperatures
   b) non- spontaneous at all temperatures
   c) spontaneous at high temperatures
   d) spontaneous at low temperatures.

4. What is the standard cell potential, E^\circ, for the reaction?
   \[ \text{Br}_2 (l) + 2 \text{Ce}^{3+} (aq) \rightarrow 2 \text{Br}^- (aq) + 2 \text{Ce}^{4+} (aq) \]
   \[
   \begin{align*}
   \text{Given that} & \quad 2 \text{Ce}^{4+} (aq) + 2e^- \rightarrow 2 \text{Ce}^{3+} (aq) \quad E^\circ = +1.61 \text{ V} \\
   \text{and} & \quad \text{Br}_2 (l) + 2e^- \rightarrow 2 \text{Br}^- (aq) \quad E^\circ = +1.08 \text{ V} \\
   \end{align*}
   \]
   a) -2.69 V                          b) + 0.53 V                          c) - 0.53 V                          d) + 2.69 V

5. For which of the following processes is most likely to have the most positive change in entropy?
   a) Hg (l) \rightarrow Hg (s)
   b) 4 Fe (s) + 3 O_2 (g) \rightarrow 2 Fe_2O_3 (s)
   c) 2 SO_2 (g) + O_2 (g) \rightarrow 2 SO_3 (g)
   d) 2 NH_3 (g) \rightarrow N_2 (g) + 3 H_2 (g)
6. Which of the following sulfate salts is the least soluble in water?
   a) BaSO₄ (Ksp = 1.1 x 10⁻¹⁰)  b) SrSO₄ (Ksp = 2.8 x 10⁻⁷)
   c) PbSO₄ (Ksp = 1.8 x 10⁻⁸)  d) Ag₂SO₄ (Ksp = 1.7 x 10⁻⁵)

7. For Zn(OH)₂ (Ksp = 4.5 x 10⁻¹⁷), what is the maximum concentration of Zn²⁺ in a solution of pH = 10.0
   a) 4.5 x 10⁻⁹  b) 4.5 x 10⁻⁷  c) 4.5 x 10³  d) 4.5 x 10⁻¹³

8. For a certain reaction, the enthalpy change is -148.5 kJ, the entropy change is 256 J/K, and the free energy change is -250.1 kJ. At what temperature is the reaction occurring in ºC?
   a) 124  b) 102  c) 85  d) 210

9. Using Nernst equation, what is the Ecell, at 25 ºC for the reaction:
   Zn (s)   +   Cu²⁺ (aq)                       Zn²⁺ (aq)   +    Cu (s)
   Given that Eºcell = +1.100 V, [Cu²⁺] = 1.0 M and [Zn²⁺] = 0.10 M
   a) 1.13 V  b) 1.16 V  c) 1.10 V  d) 1.07 V

10. Given the following data, calculate ∆G, in kJ, for the following reaction at 25ºC:
    2 NH₃ (g)                       N₂ (aq)   +    3 H₂ (g)
    ∆Gf (kJ/mol)     -16.48
    a) 32.96  b) -32.96  c) -16.48  d) 16.48

11. Calculate the molar solubility of PbI₂ (Ksp = 7.1 x 10⁻⁹).
    a) 1.2 x 10⁻³  b) 1.9 x 10⁻³  c) 8.4 x 10⁻⁵

**Part II.** (12 pts: 3 @ 4 pts): Fill the blanks in each of the following sentences (positive, negative, zero, oxidation, reduction, spontaneous, non-spontaneous, < 1, > 1, anode, cathode, electrolysis):
   a) The solubility product expression for Mg₃(PO₄)₂ is evaluated by the expression:
      Ksp = ---------------------------
   b) In voltaic cells, reduction takes place at the ------------------ , and ∆G is always -----------------.
   c) The conditions that would apply to a reaction that is spontaneous at room temperature:
      ∆Gº = ------------------------ and K ----------------

**Part III (48 pts) Calculations**: Show all work for full credit. Please express all answers with proper units and correct number of significant figures.
1. **(10 pts)** Will a precipitate form when 150. mL of 1.5 x 10^{-3} M Pb(NO_3)_2 is mixed with 100. mL of 0.025 M NaCl? (K_{sp} for PbCl_2 = 1.6 x 10^{-5}). Explain your answer.

\[
P (9 \times 10^{-8}) < K_{sp}
\]

2. **(10 pts)** Using the standard electrode potentials given in the data sheet, calculate \( \Delta E^\circ_{\text{cell}} \) and \( \Delta G^\circ_{\text{cell}} \) for the following reaction:

\[
\text{Cl}_2 (g) + 2 \text{Br}^- (aq) \rightleftharpoons 2 \text{Cl}^- (aq) + \text{Br}_2 (l)
\]

\[
\Delta E^\circ_{\text{cell}} = +0.283 \text{ V} \quad \Delta G^\circ_{\text{cell}} = -54.6 \text{ kJ}
\]

3. **(12 pts)** For the following reaction at 298 K:

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

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<th>( S^\circ ) (J/K.mol)</th>
<th>( \Delta G^\circ_{\text{rxn}} ) (kJ)</th>
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a) Calculate \( \Delta G^\circ \) in kilojoules
b) Calculate the equilibrium constant for the reaction at 298 K.
4. (16 pts) In the titration of 25.0 mL of 0.120 M formic acid, HCO₂H (Ka = 1.8 x 10⁻⁴) with 0.100 M NaOH solution:
   
a) What is the pH of HCO₂H solution before the titration begins?

   pH =

b) What is the pH at the mid point of the titration?

   pH =

c) What is the pH at the equivalence point?

   pH =

d) What is the pH of the solution when 31.0 mL of NaOH was added?

   pH =
Useful Equations:

\[ \text{Cl}_2 (g) + 2e^- \rightarrow 2 \text{Cl}^- (aq) \quad E^0 = +1.360 \text{ V} \]

\[ \text{Br}_2 (l) + 2e^- \rightarrow 2 \text{Br}^- (aq) \quad E^0 = +1.077 \text{ V} \]

Useful Information:

- Faraday’s constant, \( F = 9.65 \times 10^4 \text{ C/mol} = 9.65 \times 10^4 \text{ J/K.mol} \)
- 1 V = 1 J.C\(^{-1}\)
- Standard temperature = 298.15 K
- 1 atm = 760 torr = 760 mmHg
- \( K = 273 + °C \)

Periodic Table of the Elements

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