Partial credit will be given for work shown. The answer by itself is not satisfactory for full credit.

**Academic Honesty Policy:** Intentionally using or attempting to use unauthorized materials, information or study aids in any academic exercise, OR intentionally or knowingly helping or attempting to help someone else to commit an act of academic dishonesty, such as knowingly allowing another to copy information during an examination or other academic exercise constitutes Academic Dishonesty and is **punishable with a possible grade of F** in this course!!!

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**INFORMATION THAT MAY BE OF USE TO YOU IN THE EXAM**

\[
E = E^\circ - \frac{0.059}{n} \log K \text{ (at } 25^\circ \text{C)}
\]

\[
\Delta G^\circ = -nF E^\circ
\]

\[
\Delta G^\circ = \Delta H^\circ - T \Delta S^\circ
\]

---

**Periodic Table**
10 pts  1. I have a theory that only cations that have the same charges and half the size of the sulfate anion will precipitate with the sulfate anion (radius = 244pm. Carefully choose three (and only three) of the following cations to help prove or disprove my theory and tell why they were selected.

\[
\begin{array}{ccccccccccc}
\text{Mn}^{2+} & \text{Al}^{3+} & \text{Ba}^{2+} & \text{Ce}^{4+} & \text{Cs}^+ & \text{Hg}^{2+} & \text{La}^{3+} & \text{K}^+ & \text{Mg}^{2+} & \text{Na}^+ \\
\text{radius} & 67 & 149 & 101 & 181 & 116 & 117 & 152 & 86 & 116
\end{array}
\]

15 pts  2. Diagram a Born Haber cycle for the formation of AgCl(s).

15 pts  3. HClO is a weak acid. Write a reaction showing this. Its \(K_a\) value is \(6.3 \times 10^{-8}\), or its \(pK_a\) value is 7.2. Is this \(pK_a\) value consistent with what you would expect for this oxo anion? (Show me!) Write a reaction and an equilibrium expression for the conjugate base of HClO. Prove, using the expressions for \(K_a \times K_b\), that this is in fact equal to \(K_w\). What is the \(pK_b\) value for the oxo anion hydrolysis reaction? Is the oxo anion a strong or weak base?

6 pts  4. Predict which way the following reactions proceed and explain why:

\[
\text{Cr(NCS)}_3 + \text{CuSCN} \rightleftharpoons \text{Cr(SCN)}_3 + \text{CuNCS}
\]

These are called linkage isomers and whichever atom is next to the metal, that is the atom attached to it.

\[
\text{NH}_3 + \text{CsI} \rightleftharpoons \text{HI} + \text{CsNH}_2
\]

9 pts  5. Given the following reactions and Latimer diagram (in an acidic solution), will any of the chromium species oxidize or reduce water, and if so, which ones? Will any of the species disproportionate?

\[
\begin{align*}
2 \text{H}^+ + 2\text{e}^- & \rightarrow \text{H}_2 & 0.00 \text{ V} \\
\text{H}_2\text{O} & \rightarrow \frac{1}{2} \text{O}_2 + 2 \text{H}^+ + 2\text{e}^- & -1.23 \text{ V}
\end{align*}
\]

\[
\begin{array}{cccccccccccc}
\text{Cr}_2\text{O}_7^{2-} & \rightarrow & \text{Cr}^{3+} & \rightarrow & \text{Cr}^{2+} & \rightarrow & \text{Cr} & \\
+1.36 \text{ V} & \rightarrow & -0.42 \text{ V} & \rightarrow & -0.89 \text{ V} & \\
\text{Cr}_2\text{O}_7^{2-} & \rightarrow & \text{Cr}^{3+} & \rightarrow & \text{Cr}^{2+} & \rightarrow & \text{Cr}
\end{array}
\]
6. The Ellingham Diagram shown below shows the free energy changes for oxides of mercury, carbon, magnesium, and aluminum. Explain how you arrived at each of your conclusions.
   a) Explain why most of the lines slope upwards from left to right.
   c) Will aluminum reduce water?
   d) At what temperature will carbon reduce magnesium oxide?
   e) Why is hydrogen gas rarely used for metal reduction?

   Ellingham Diagram

   ![Ellingham Diagram](image)

   2 Hg + O₂ → 2 HgO
   C + O₂ → CO₂
   2 H₂ + O₂ → 2 H₂O
   2 Mg + O₂ → 2 MgO
   2 C + O₂ → 2 CO
   \( \frac{4}{3} Al + O₂ \rightarrow \frac{2}{3} Al₂O₃ \)

7. Explain the importance of the reactants and products in the following three related equations:
   C + H₂O(g) \( \xrightarrow{1000°C} \) CO(g) + H₂(g)
   CO(g) + H₂O(g) \( \xrightarrow{450°C} \) Fe₂O₃ \( \xrightarrow{\text{K₂CO₃}} \) CO₂(g) + H₂(g)
   K₂CO₃ + CO₂ + H₂O → 2 KHCO₃

8. Show reactions between the alkali metals: Li, Na, and K with dioxygen and subsequently with water.

9. Complete 4 of the following 6 reactions (These do not need to be balanced). State which one should not be graded otherwise the first 4 will be counted.
   a) hydrogen gas and chlorine gas
   b) sodium and liquid ammonia – allow the liquid ammonia to eventually evaporate
   c) hydrogen gas and sodium metal
   d) deuterium oxide and CaC₂
   e) lithium metal and air (list two reactions here)

Bonus: (9 pts) The Down's cell is used to obtain pure sodium metal. Describe how this works.