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\[ \Delta G = \Delta G^\circ + RT \ln Q \]

\[ \Delta G^\circ = -n \ F \ E' \]

\[ \text{pH} = \text{pK}_a + \log [\text{Base}]/[\text{Acid}] \]

\[ F = 96500 \text{ C mol}^{-1} \text{ mol}^{-1} \]

\[ 1 \ V = 1 \ J \text{ C}^{-1} \]

\[ R = 8.31451 \text{ J mol}^{-1} \text{ K}^{-1} \]

Multiple Choice Questions: Circle the single best answer. No penalty for guessing.

1. Calculate the pH of a buffer prepared from 0.20 moles of NaOH and 0.15 moles of HClO (Ka = 2.0x10^{-8}) in 1500.0 mL of water. (4 points)
   A) 1.000  B) 7.574  C) 7.699  D) 7.824  E) 13.125

2. What is the maximum completely soluble quantity of BaSO_4 (in mol/L) if K_{sp} = 1.10x10^{-10}. (4 points)
   A) 1.21x10^{-20} M  B) 1.10x10^{-10} M  C) 1.05x10^{-5} M  D) 7.42x10^{-5} M  E) no solubility limit

3. The molar entropies (S°) for H_2, N_2 and NH_3 are 130.6, 191.5 and 192.5 J mol^{-1} K^{-1} respectively. Calculate \( \Delta S^\circ \) for the reaction 3 H_2 + N_2 \rightarrow 2NH_3? (4 points)
   A) 517.6 J mol^{-1} K^{-1}  B) -129.5 J mol^{-1} K^{-1}  C) 390.8 J mol^{-1} K^{-1}
   D) -390.8 J mol^{-1} K^{-1}  E) -517.6 J mol^{-1} K^{-1}

4. Given that K_w = 1.0x10^{-14} for the autodissociation of water, what is \( \Delta G^\circ \) for this reaction at 298 K? (4 points)
   \[ \text{H}_2\text{O (l)} \rightarrow \text{H}^+ (aq) + \text{OH}^- (aq) \]
   A) -79.9 kJ mol^{-1}  B) -268 J mol^{-1}  C) +14 J mol^{-1}  D) +268 J mol^{-1}  E) +79.9 kJ mol^{-1}

5. In which of the following is Cl a reduced species from HClO_2. (4 points)
   A) Cl_2  B) HClO_3  C) HClO_4  D) all of these  E) none of these

6. Given a 3.00V Li battery, what is the maximum work extracted in a 1.00 A current over 30.0 s? (4 points)
   A) 90.0 J  B) 3.00 J  C) 0.100 J  D) -3.00 J  E) -90.0 J
7. Name the following ionic compounds or give the empirical formula as appropriate. (8 points)
   - B$_2$O$_3$
   - Fe(NO$_2$)$_2$
   - Magnesium phosphate
   - Potassium dichromate

8. Balance the following oxidation-reduction reaction in **acidic** solution. Indicate oxidation state of the O and Cl atoms in all compounds. (15 points)
   \[
   \text{H}_2\text{O} \ (l) \ + \ \text{CO}_2 \ (g) \ + \ \text{Cl}_2 \ (g) \ \rightarrow \ \text{H}_2\text{C}_2\text{O}_4 \ (aq) \ + \ \text{HClO} \ (aq)
   \]

9. Draw the titration curve for 15.0 mL of 0.10 M NH$_3$ with 0.0500 M HCl given that K$_b$ = 1.8x10$^{-5}$ for NH$_3$. Indicate initial pH, pH at half-way point and pH at equivalence point. (15 points)
10. What is the maximum solubility (in mol/L) of $\text{Ag}_2\text{CO}_3$ ($K_{sp} = 8.1 \times 10^{-12}$) in the presence of 0.50 M $\text{Na}_2\text{CO}_3$. (14 points)

11. Calculate the Gibbs free energy of reaction for the following reaction if the partial pressures of $\text{N}_2\text{O}$, $\text{NO}_2$ and $\text{NO}$ are 0.50, 0.25 and 0.75 atm respectively at 300K. (Note the $\Delta G^\circ$ for $\text{N}_2\text{O}$, $\text{NO}_2$ and $\text{NO}$ are 103.59, 51.84 and 86.71 kJ/mol respectively.) (14 points)

$$\text{N}_2\text{O} (g) + \text{NO}_2 (g) \rightarrow 2 \text{NO} (g)$$

12. Given the standard reduction potentials for $\text{Cd}^{2+}$ ($-0.403$ V), $\text{Cu}^+$ ($+0.521$ V), $\text{Zn}^{2+}$ ($-0.763$ V) and $\text{Hg}^{2+}$ ($+0.854$ V), calculate the cell potential for the highest voltage battery you can construct with these ions and their reduced metals. (10 points)