SHOW ALL CALCULATIONS & USE PROPER SIGNIFICANT FIGURES AND UNITS

\[ \Delta G = \Delta G^\circ + RT \ln Q \quad \Delta G^\circ = -n F E^\circ \quad \text{pH} = pK_a + \text{Log [Base]/[Acid]} \]

\[ F = 96500 \ \text{C mol}^{-1} \quad 1 \ \text{V} = 1 \ \text{J C}^{-1} \quad R = 8.31451 \ \text{J mol}^{-1} \text{K}^{-1} \]

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

1. What is the pH of a buffer prepared by mixing 0.20 moles of NaNO\(_2\) with 0.10 moles of HNO\(_2\) in 1.0 L of water. The pK\(_a\) for HNO\(_2\) is 3.347. (4 points)
   A) 1.000  B) 3.046  C) 3.347  D) 3.648  E) 10.653

2. Given the K\(_{sp}\) for Mg(OH)\(_2\) is 1.8x10\(^{-11}\), calculate the maximum concentration of Mg\(^{2+}\) if the buffered pH of a solution is 11.00. (4 points)
   A) 5.6x10\(^{-12}\) M  B) 1.8x10\(^{-11}\) M  C) 1.8x10\(^{-5}\) M  D) 1.6x10\(^{-4}\) M  E) no solubility limit

3. If a solid (defined as the system) melts at its normal melting temperature, the entropy of the system does what? (4 points)
   A) increases  B) decreases  C) is unchanged  D) depends upon external pressure  E) may not be determined

4. Calculate \(\Delta G^\circ\) at 298K for the following reaction (as written in forward direction) given that the equilibrium constant is 8.09x10\(^4\). (4 points)
   \[ 2 \text{Eu}^{2+} (aq) + \text{Sn}^{2+} (aq) \rightarrow \text{Sn} (s) + 2 \text{Eu}^{3+} (aq) \]
   A) −28 kJ mol\(^{-1}\)  B) −56 kJ mol\(^{-1}\)  C) +14 kJ mol\(^{-1}\)  D) +28 kJ mol\(^{-1}\)  E) +56 kJ mol\(^{-1}\)

5. What is the oxidation state of iodine in the molecule H\(_2\)I\(_2\)O\(_4\). (4 points)
   A) +5  B) +3  C) +1  D) 0  E) −1

6. The chemical species which are most easily reduced are those with (4 points)
   A) standard reduction potential of 0.00 V
   B) small positive standard reduction potential.
   C) small negative standard reduction potential.
   D) large negative standard reduction potential.
   E) large positive standard reduction potential.
7. Name the following ionic compounds or give the empirical formula as appropriate. (8 points)
   - Li₂CO₃
   - NH₄C₂H₃O₂
   - Cobalt (II) hypobromite
   - Beryllium sulfate

8. Balance the following oxidation-reduction reaction in **basic** solution. Indicate oxidation state of the O and Cl atoms in all compounds. (15 points)
   \[ H₂O₂(\text{aq}) + Cl₂O₇(\text{aq}) \rightarrow ClO₂^-(\text{aq}) + O₂(g) \]

9. Calculate the pH of a solution prepared by mixing 0.331 moles of NH₄Cl with 0.126 moles of NH₃ in 1.0 L of water, given that \( K_b = 1.8 \times 10^{-5} \) for NH₃. (10 points)
10. Calculate the final concentration (after equilibrium formation of all precipitates) of Pb$^{2+}$, SO$_4^{2-}$ and Na$^+$ if 0.500 mol of Na$_2$SO$_4$ and 0.500 mol of PbSO$_4$ are mixed in 1.0 L of water. Indicate the quantity and variety of precipitates formed. The $K_{sp}$ for Na$_2$SO$_4$ is $1.5 \times 10^5$ and for PbSO$_4$ is $1.6 \times 10^{-8}$. (15 points)

11. Calculate the Gibbs free energy of reaction for the following reaction if the partial pressure of Cl$_2$ is 0.23 atm and of O$_2$ is 0.72 atm at 300K. (Note the $\Delta G_f^*$ for Cl$_2$, Fe$_2$O$_3$, FeCl$_3$ and O$_2$ are 0.0, –741.0, –334.0 and 0.0 kJ/mol respectively.) (14 points)

$$6 \text{Cl}_2 (g) + 2 \text{Fe}_2\text{O}_3 (s) \rightarrow 4 \text{FeCl}_3 (s) + 3 \text{O}_2 (g)$$

12. Given the standard reduction potentials below, calculate the free energy ($\Delta G$) released if 1.00 mole of CrO$_4^{2-}$ ($aq$) reacts with excess Fe ($s$) to produce Fe$^{2+}$ ($aq$) and Cr(OH)$_3$ ($s$). (14 points)

$$\text{CrO}_4^{2-} (aq) + 4 \text{H}_2\text{O} (l) + 3 \text{e}^- \rightarrow \text{Cr(OH)}_3 (s) + 5 \text{OH}^- (aq) \quad E^* = -0.130 \text{ V}$$
$$\text{Fe}^{2+} (aq) + 2 \text{e}^- \rightarrow \text{Fe} (s) \quad E^* = -0.440 \text{ V}$$