I. Multiple Choice (for those with an asterisk, you must show work)

1. Which one of the following cannot act as a reducing agent because it has the highest oxidation number?
   - (A) S²⁻  
   - (B) SO₃²⁻  
   - (C) SO₄²⁻  
   - (D) S₂O₈²⁻  

*2. Permanganate ion oxidizes hydrogen peroxide in acidic solution according to the following equation:

   \[2 \text{MnO}_4^- (aq) + 5 \text{H}_2\text{O}_2 (aq) + 6 \text{H}^+(aq) \rightarrow 2 \text{Mn}^{2+}(aq) + 5 \text{O}_2(g) + 8 \text{H}_2\text{O}(l)\]

   If 35.0 mL of an acidic 0.150 M KMnO₄ solution is required to consume all the H₂O₂ in 50.0 mL of a disinfectant solution, what is the concentration of H₂O₂ in the disinfectant?
   - (A) 0.0420 M  
   - (B) 0.105 M  
   - (C) 0.263 M  
   - (D) 0.368 M  

3. A sample of 0.040 mol hypochlorite ion is treated with varying amounts of 1.0 M aqueous H₂O₂. Which graph represents the amount of O₂(g) that is evolved according to the chemical reaction shown?

   \[\text{OCl}^- (aq) + \text{H}_2\text{O}_2 (aq) \rightarrow \text{Cl}^- (aq) + \text{H}_2\text{O}(l) + \text{O}_2(g)\]

   ![Graph A](image1.png)  
   ![Graph B](image2.png)  
   ![Graph C](image3.png)  
   ![Graph D](image4.png)

4. A student has 10 mL of a solution that might contain any or all of the following cations at 0.01 M concentrations: Mn²⁺, Ba²⁺, Ag⁺, and Cu²⁺. Addition of 10 mL of 1 M HCl causes a precipitate to form. After the precipitate is filtered off, 1 M H₂SO₄ is added to the filtrate and another precipitate forms. What is the second precipitate?
   - (A) MnSO₄  
   - (B) BaSO₄  
   - (C) Ag₂SO₄  
   - (D) A mixture of BaSO₄ and Ag₂SO₄  

*5. A solution is prepared by mixing 25.0 mL of 6.0 M HCl with 45.0 mL of 3.0 M HNO₃. What is [H⁺] in the resulting solution?
   - (A) 1.9 M  
   - (B) 2.1 M  
   - (C) 4.1 M  
   - (D) 4.5 M  

6. Potassium carbonate, K₂CO₃, sodium iodide, NaI, ammonium perchlorate, NH₄ClO₄, methanol, CH₃OH, and ammonium chloride, NH₄Cl, are soluble in water. Which produces the largest number of dissolved particles per mole of dissolved solute?
   - A. K₂CO₃  
   - B. NaI  
   - C. NH₄ClO₄  
   - D. CH₃OH  
   - E. NH₄Cl  

7. In the following reaction, what ions, if any, are spectator ions?

   \[\text{Pb(NO}_3\text{)_2(aq) + 2NaCl(aq) \rightarrow PbCl}_2(s) + 2\text{NaNO}_3(aq)\]
   - A. Pb²⁺(aq), Cl⁻(aq)  
   - B. Na⁺(aq), NO₃⁻(aq)  
   - C. Pb²⁺(aq), NO₃⁻(aq)  
   - D. Na⁺(aq), Cl⁻(aq)  
   - E. There are no spectator ions.
8. Which of the following is true?
   A. The oxidation number of iodine in IO$_3^-$ is -1.
   B. The best oxidizing agents are good electron donors.
   C. The transformation of glucose (C$_6$H$_{12}$O$_6$) into CO$_2$ is a reduction process.
   D. The process SO$_4^{2-}$(aq) → SO$_2$(g) would require a reducing agent.
   E. More than one of the above.

9. One gram of each of the following compounds is mixed with 100mL of water. List the compounds that will conduct electricity when mixed with water because they are strong electrolytes (more than one answer possible- circle all that are correct).
   A. acetic acid
   B. octane
   C. calcium acetate
   D. sulfuric acid
   E. iron (II) hydroxide
   F. sulfur hexafluoride

10. Consider the following characteristics of aqueous acidic solutions. Which of these do not describe strong acids?
   A. Examples include HCl, HNO$_3$, and H$_2$SO$_4$.
   B. Are all completely soluble in water.
   C. All completely ionize into hydrogen ions and stable anions in dilute aqueous solution.
   D. Their solutions contain acid molecules.
   E. All the above describe strong acids.

11. Which one of the following salts is insoluble in water?
   A. FeCl$_2$
   B. KCH$_3$COO
   C. Pb(NO$_3$)$_2$
   D. PbS
   E. NH$_4$Cl

II. Short Answer (for those with an asterisk, you must show work)
*1. Hydrochloric acid dissolves calcium carbonate to produce calcium chloride and carbon dioxide gas and another product.
   A. Write the balanced reaction for this process. Be sure to include phases for all species. Be sure to balance the reaction.

   B. Blackboard chalk contains a certain percentage of calcium carbonate. If a 1.51 g piece of chalk produces 0.665 g of carbon dioxide, what percentage of calcium carbonate is chalk?

4. To be an electrolyte, whether strong, weak, or inert, a substance must __________________________.

5. Place the following lists of compounds into as many categories (boxes) as appropriate:
NaCl, HCl, AgCl, CH$_3$CH$_2$OH, AgNO$_3$, CH$_3$COOH, Fe(CH$_3$COO)$_3$, C$_6$H$_5$O$_6$, NaOH, Fe(OH)$_3$, H$_2$S, CaCO$_3$, NH$_4$NO$_3$, Li$_3$PO$_4$, H$_2$CO$_3$, H$_2$SO$_4$, HCOOH, LiOH, NH$_3$

<table>
<thead>
<tr>
<th>Strong acids.</th>
<th>Strong electrolytes.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weak acids.</td>
<td>Weak electrolytes.</td>
</tr>
<tr>
<td>Strong bases.</td>
<td>Nonelectrolytes.</td>
</tr>
</tbody>
</table>

Insoluble.
6. Write (i) the balanced overall reaction for each of the following reactions. Write (ii) the total ionic equation (TIE), and (iii) the net ionic equation (NIE) for each of the reactions that will occur when the following solutions are mixed.

A. aqueous solutions of silver nitrate and potassium chloride

B. aqueous solutions of acetic acid and potassium hydroxide

C. H₂SO₄(aq) and Na₂CO₃(aq)

D. aqueous solutions of potassium sulfate and calcium iodide
7. A chemist dissolves 0.00153 g of sodium hydroxide in water and dilutes the solution to the mark in a 500.00 mL volumetric flask. A 1.00 mL sample of this solution is then transferred to a 100.00 mL volumetric flask and diluted to the mark.

A. Draw pictures showing the process of creating the first solution and then diluting the first solution to make the second solution.

B. What is the molarity of the sodium hydroxide in the final solution?

C. What is the pH of the final solution?

8. Assign oxidation numbers to each of the elements in the following compounds:

A. P2O5  
B. N2O4  
C. SO2

D. Fe(NO3)2  
E. NH4Cl  
F. CH3CH2OH

G. C2H5COOH  
H. CH3COCH3  
I. CH3CH2CH3
9. Assign an oxidation number to each of the elements in the following reaction. Identify the element oxidized and the element reduced. Also identify the element that is the oxidizing agent and the reducing agent.

I\textsubscript{3}\^-(aq) + 2 S\textsubscript{2}O\textsubscript{3}\textsuperscript{2-}(aq) → 3 I\^-(aq) + S\textsubscript{4}O\textsubscript{6}\textsuperscript{2-}

10. List the 7 strong acids.

11. ________ acids are (essentially) 100% ionized.

_________ acids are approximately ________% ionized.

_________ bases are soluble in water, have the ________ ion in their formulas, and dissociate ________% into ions.

_________ bases are approximately ________% ionized. They are called amines and have nitrogen bonded to three other atoms and a lone pair of electrons.

12. Fill in the gaps in the following table:

<table>
<thead>
<tr>
<th>pH</th>
<th>[H\textsuperscript{+}] (mol/L)</th>
<th>[OH\textsuperscript{-}] (mol/L)</th>
<th>Acid/Base Sol'n?</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.90</td>
<td>1.9 \times 10\textsuperscript{-11}</td>
<td>8.4 \times 10\textsuperscript{-7}</td>
<td></td>
</tr>
<tr>
<td>12.25</td>
<td>5.9 \times 10\textsuperscript{-2}</td>
<td>2.2 \times 10\textsuperscript{-10}</td>
<td></td>
</tr>
</tbody>
</table>

pH: always 2 decimal places
[H\textsuperscript{+}], [OH\textsuperscript{-}]: always 2 sig figs
13. A chemical analysis shows that a sample contains .00500 grams of Copper in $2.50 \times 10^5$ grams of water. Convert the measurement to parts per billion (ppb).

14. A 250.0 mL sample of aqueous solution contains an unknown amount of dissolved NaCl. Analysis of the solution can be accomplished through use of a precipitation reaction such as the one that would result from adding an aqueous solution of Pb(NO$_3$)$_2$.
   A. What is the chemical formula of the precipitate?
   
   B. Write the net ionic equation for this precipitation reaction.

   *C. The precipitate can be recovered by filtration and then weighed. If the mass of precipitate recovered was 5.428 grams, what was the concentration of Cl$^-$ ions in the original solution?