I. (40 points)
A. (24 points) Identify the type of aqueous reaction on the blanks to the left using the symbols
   - **PPT** for precipitation
   - **SA/SA** for strong acid/strong base
   - **SA/WB** for strong acid/weak base
   - **WA/SB** for weak acid/strong base
   - **NR** for no reaction
Write all the products of the reaction or NR on the blanks to the right. Do not include spectator ions.

<table>
<thead>
<tr>
<th>Blank</th>
<th>Reaction</th>
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<tbody>
<tr>
<td>______________</td>
<td>CH$_3$CH$_2$NH$_2$ + HCl</td>
<td>______________</td>
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<tr>
<td>______________</td>
<td>Ca(OH)$_2$ + HF</td>
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<tr>
<td>______________</td>
<td>Ca(OH)$_2$ + Na$_3$PO$_4$</td>
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<td>______________</td>
<td>Ag$_2$SO$_4$ + BaCl$_2$</td>
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<tr>
<td>______________</td>
<td>Mg(NO$_3$)$_2$ + NaCl</td>
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</table>

B. (16 points) Show all work. Write your final answers in the blanks provided. Use correct units and significant figures throughout.
1. How many moles of ions are present in 215 mL of 0.732 M sodium hydroxide?
2. What volume of 0.732 M sodium hydroxide is required to react completely with 25 mL of 0.385 M HF?

3. How many moles of OH\(^-\) ions are present in 67.3 mL of a 1.45 M solution of barium hydroxide?

4. How many grams of barium carbonate (\(M = 197.3 \text{ g/mol}\)) are theoretically obtained when an excess of barium hydroxide reacts completely with 35 mL of 0.105 M Na\(_2\)CO\(_3\)?
II. (30 points) Fill in the blanks with the appropriate answers. *Read the instructions for each part.*

A. (14 points)

1. Assign oxidation numbers to each element in

   a. KMnO₄: K _____ Mn _____ O _____
   
   b. NOF: N _____ O _____ F _____

2. Classify the following half-reaction as oxidation or reduction.

   \[ \text{IO}_4^- (aq) \rightarrow \text{I}_2 (s) \]

   __________________________

3. Balance the following half-equation in acid and answer the following questions. (You may balance this equation at the bottom of the page.)

   \[ \text{Cr}_2\text{O}_7^{2-} (aq) \rightarrow \text{Cr}^{3+} (aq) \]

   __________________________ a. On which side of the equation do the electrons appear?

   __________________________ b. How many electrons appear in the balanced half-equation?

   __________________________ c. How many H⁺ ions appear in the balanced half-equation?
B. (16 points) Consider the following balanced redox equation.

\[ 2 \text{MnO}_4^- (aq) + 3 \text{BrO}_3^- (aq) + \text{H}_2\text{O} \rightarrow 2 \text{MnO}_2 (s) + 3 \text{BrO}_4^- (aq) + 2 \text{OH}^- (aq) \]

1. What is the element oxidized?
2. What is the element reduced?
3. What species is the oxidizing agent?
4. What species is the reducing agent?

5. What is the molarity of a Mg(MnO_4)_2 solution if 27.50 mL is required to react completely with 25.00 mL of 0.350 M NaBrO_3?
III. (55 points)

A. (15 points) Determine whether the statements given below are true or false. Write your answers in the blanks provided. If the statement is true, write Y. If the statement is false, write N. If more information is required write MI. Do not use T or F.

Consider 2 flasks with the same volume, temperature and pressure. One flask contains nitrogen gas, the other flask has helium gas.

_____ 1. Both flasks have the same number of moles.

_____ 2. The nitrogen gas in one flask has a lower density than the helium gas in the other flask.

_____ 3. If a pinhole is created in both flasks, nitrogen gas would effuse faster than the hydrogen gas.

_____ 4. The average translational energy of the gases in both flasks is the same.

_____ 5. One mole of CO\textsubscript{2} gas is introduced to each flask. In the resulting mixture of gases, the mole fraction of nitrogen is equal to the mole fraction of helium.

B. (6 points) A sealed tube is filled with 1.25 mol of gas at 25\textdegree C. The pressure in the tube is measured to be 12 atm. What is the volume of the tube?
C. (6 points) A sealed tube with He gas at 27°C and 1.5 atm is put into an oven where the temperature is 197°C. What is the pressure of the helium gas at this temperature?

D. (8 points) What is the density, in g/L, of CF₄ (M = 88.00 g/mol) at 752 mm Hg and 303 K?

E. (10 points) Aluminum reacts in aqueous base according to the following reaction.

\[
2 \text{Al}(s) + 6 \text{H}_2\text{O} \rightarrow 2 \text{Al}^{3+}(aq) + 6 \text{OH}^-(aq) + 3 \text{H}_2(g)
\]

How many L of hydrogen gas at 298 K and 1.00 atm can be theoretically obtained when excess base is added to 32 g of Al?
F. (12 points) In another experiment, hydrogen gas is collected over water in a 6.0 L flask at 25°C and 1.02 atm pressure. The vapor pressure of water is 23.8 mm Hg at 25°C.

1. How many moles of wet gas are collected?

2. What is the partial pressure of hydrogen in atmospheres?

3. How many moles of hydrogen are collected?

4. What is the mole fraction of hydrogen?
IV. (25 points)

A. (10 points) A student titrates 25.00 mL of an unknown chloride (delivered by pipet) with a solution of AgNO₃ of known molarity. The silver nitrate solution is delivered by a buret.

The following are descriptions of a student's activity during the experiment described above. Fill in the blanks on the left, using

– **LT** if the activity results in a calculated value being less than the true value
– **GT** if the activity results in a calculated value being larger than the true value
– **NE** if the activity has no effect on the calculated value.

1. A student read the molarity of AgNO₃ to be 0.1131 M instead of 0.1113 M.

2. A student went past the endpoint when doing the titration.

3. A student filled the buret and rinsed the tip to clear the air. The student begins titrating with the volume of AgNO₃ above the 0.00 mL mark.

4. A student did not dry the inside of the flask thoroughly before adding (by pipet) the solution containing the unknown chloride.

5. A student cleaned the buret with water and forgets to rinse the wet buret with a small amount of the AgNO₃ solution before filling the buret with the standardized AgNO₃ solution.

B. (6 points) A hydrate of CuSO₄ weighs 6.792 grams. The sample is heated until it is completely dehydrated. The anhydrous sample has a mass of 3.192 g.

1. How many moles of water did the sample of hydrate have?

2. Write the formula of the hydrate.
C. (9 points) Consider a chloride sample made up of Zr (zirconium) ions and chloride ions, with the formula ZrClₙ. The sample is weighed and found to have a mass of 2.330 g. The sample is treated with a reducing agent until all the Zr ions are converted to the metal zirconium. The metal is isolated, weighed, and found to have a mass of 0.9122 g. The molar mass of the metal Zr is 91.22 g/mol.

1. How many moles of the metal Zr are present in the compound?

____________________

2. How many moles of chloride are present in the compound?

____________________

3. What is n?
BONUS (15 points) All or nothing.
The bonus should be done only after you have completed the main part of this exam and checked your work for errors. The time allotted for this exam does not include time for the bonus. (SHOW ALL WORK! Lucky guesses will not be considered. A logical method must be shown.)

An ideal gas occupied a glass bulb of unknown volume at a pressure of 0.941 atm. A sample of the gas was withdrawn from the bulb (without loss) and was found to occupy 1.52 mL at 1.00 atm pressure. The pressure of the gas remaining in the bulb was 0.861 atm. All measurements were made at the same temperature. Calculate the volume of the bulb.