Name: ______________________________

**Acid/Base Stoichiometry**

**Background**
Chemistry is like baking. Correct proportions are essential to obtain the desired product. Imagine a cake baked with too much flour, it turns out dry. And if you omit baking powder, the cake becomes hard or rubbery. Knowing how much of one material will react with a given amount of another is extremely important. This activity will give you the opportunity to both visually and quantitatively observe the phenomenon of a limiting reactant. From the quantitative data obtained, you will be able to determine the amount of the active ingredient in a sample of vinegar.

**Acid/Base Reactions**
If an acid and base react, hydronium and hydroxide react to create water:

\[
\text{H}_3\text{O}^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow 2 \text{H}_2\text{O}(\text{l})
\]

This is called a neutralization reaction. This is a favorable reaction that releases a lot of energy, so if a strong acid and strong base react, the reaction can be quite dangerous.

You will explore the results of a neutralization reaction between a weak acid and base, using vinegar (acetic acid, HC\(_2\)H\(_3\)O\(_2\)) and baking soda (sodium bicarbonate, Na\(\text{HCO}_3\), which dissociates into Na\(^+\) and H\(\text{CO}_3^-\) in water). When these two compounds react, they produce acetate and carbonic acid. The production of carbonic acid leads to the formation of carbon dioxide gas in a second reaction:

\[
\text{HCO}_3^-(\text{aq}) + \text{HC}_2\text{H}_3\text{O}_2(\text{aq}) \rightarrow \text{C}_2\text{H}_3\text{O}_2^- + \text{H}_2\text{CO}_3 (\text{aq})
\]

... and then \(\text{H}_2\text{CO}_3 (\text{aq}) \rightarrow \text{CO}_2 (\text{g}) + \text{H}_2\text{O} (\text{l})\)

You will explore how the pH and the products of this reaction are affected if you react different amounts of vinegar and baking soda by trapping the final product carbon dioxide in a balloon over the flask. You will also use a universal indicator, which has already been dissolved in your solutions of vinegar, to monitor the pH of the solutions before and after the reaction.

**Universal indicator key**

<table>
<thead>
<tr>
<th>pH Range</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–3</td>
<td>red</td>
</tr>
<tr>
<td>3–6</td>
<td>orange-yellow</td>
</tr>
<tr>
<td>6–7</td>
<td>yellow-green</td>
</tr>
<tr>
<td>8–11</td>
<td>blue</td>
</tr>
<tr>
<td>11–14</td>
<td>purple</td>
</tr>
</tbody>
</table>

**Safety**
Wear safety goggles and apron for this experiment.

**Procedure**

**PART I**

1. Measure 10 mL, 20 mL, 30 mL, 40 mL, 50 mL, 60 mL, and 70 mL of the vinegar + indicator solution and pour it into seven 250-mL flasks.
2. Record the color and approximate pH of each solution based on the universal indicator key you created.
3. Measure 3.0 g of baking soda into seven different balloons.
4. Carefully fasten the balloon on the top of the flask without inverting it to avoid emptying the baking soda into the flask. Take the mass of this unreacted system.
5. Once secure, empty the contents of the balloons into the flasks. Hold the balloon to prevent it from coming off. Make sure all of the baking soda drops into the flask.
6. After the reactions are complete, record the color and approximate pH of each...
solution, based on the universal indicator key.

7. Remeasure the mass of each reacted system.

8. Carefully allow the gas to escape from the balloon. Reattach the balloon to the top of each flask. Remeasure the mass for each reacted system with the now-empty balloon.

PART II

1. Pour 50 mL of the vinegar + indicator solution into seven 250-mL flasks.

2. Record the color and approximate pH of each solution based on the universal indicator key.

3. Measure 1.0 g 2.0 g, 3.0 g, 4.0 g, 5.0 g, 6.0 g, and 7.0 g of baking soda into seven balloons.

4. Carefully fasten the balloon on the top of the flask without inverting it to avoid emptying the baking soda into the flask. Take the mass of this unreacted system.

5. Once secure, empty the contents of the balloons into the flasks. Hold the balloon to prevent it from coming off. Make sure all of the baking soda drops into the flask.

6. After the reactions are complete, record the color and approximate pH of each solution, based on the universal indicator key.

7. Remeasure the mass of each reacted system.

8. Carefully allow the gas to escape from the balloon. Reattach the balloon to the top of each flask. Remeasure the mass for each reacted system with the now-empty balloon.

Results/Observations

1. For each part, create a table for the seven trials to record color and pH before and after mixing.

2. For each part, create a table to record your before and after mass measurements.

Calculations

Show all work for at least one set of data for each part.

1. What was the mass difference of the reaction?

2. What was the mass difference when you released the gas in the balloon?

3. How many moles of baking soda were added to the reaction?

4. The vinegar solution has a concentration of 0.83 mol/L. How many moles of acetic acid were in each reaction?

5. How many moles of carbon dioxide were evolved in each reaction?

6. The limiting reagent is the one that runs out first and thus prevents the reaction from going any further. What is the limiting reagent in each reaction?

7. Describe the amount of carbon dioxide evolved as you increased the volume of vinegar from 10 to 70 mL and the mass of baking soda from 1.0 g to 7.0 g. How does your answer support your answer to question six?

8. Construct a graph of moles of vinegar vs. moles of carbon dioxide produced.

9. Compare the moles of baking soda used and the moles of carbon dioxide evolved. For each reaction, how do they compare? Does this comparison match with the limiting reagent answers you found in question six?

10. How do the moles of vinegar used compare to the number of moles of carbon dioxide evolved for each reaction? Does this comparison match with the limiting reagent answers you found in question six?

Analysis

1. What did you see when the baking soda was dropped into the vinegar? Why did
the balloon inflate?

2. What must be leftover (in excess) when the pH is <7? What must be leftover (in excess) when pH is >7? Why is the pH different in each flask?

3. If you have 1.0 g of baking soda and 10 mL of vinegar, how many moles of each do you have? Which would be the limiting reagent?

**Conclusion**

Answer these in paragraph form.

- What did you learn about stoichiometry from this lab? What did you learn about limiting reagents?
- Did you have any problems or difficulties making measurements? If so, how were these resolved? What were some sources of error and how did you minimize the error in your measurements?
- How does this lab apply to the real world?