Less than Zero Lab

Background
The objective in this lab is to cool an aqueous solution to less than 0 °C. You will first run a scripted reaction. Each group will then change variables and do subsequent trials to make the temperature drop further below 0 °C. Everyone will turn in an official note page at the end of the investigation.

Procedure (scripted reaction)
1. Mass a 250-mL beaker. Record its mass.
2. Obtain a computer-interfaced thermometer (including USB link) and plug it into a computer. When prompted, choose Launch Data Studio. You should see a graph appear that has temperature on the y-axis and time on the x-axis.
3. Double click the Digits option on the lower left of the Data Studio screen to provide a box that easily allows you to read the temperature (with one or two decimal places).
4. Click the Run button to verify that your thermometer is working properly. Then click Stop to terminate this experiment.
5. Mass between 2.80 and 3.20 grams of baking soda (NaHCO₃) on weighing paper. Record the exact mass of the sample.
6. Pour 25 mL of 2-M HCl into the beaker. Click Run to measure the initial temperature of the acid (make sure the temperature probe is in the acid).
7. With the thermometer recording data on the computer screen, carefully add the baking soda to the beaker (Warning: fizzing will occur). Gently stir the reaction with the thermometer and record data until the reaction is complete.
8. Right-click on the computer graph and choose Statistics to display the minimum temperature the reaction reached.
9. Record the mass of the beaker and its contents.

Data

<table>
<thead>
<tr>
<th>Mass of beaker</th>
<th>Mass of baking soda</th>
<th>Volume and molarity of acid</th>
<th>Lowest Temperature</th>
<th>Mass of beaker and contents</th>
</tr>
</thead>
</table>

Calculations
The reaction that occurred is:
NaHCO₃ (s) + HCl (aq) → NaCl (aq) + H₂O (l) + CO₂ (g)  \( \Delta H = +28 \text{ kJ/mol} \)

1. Calculate the number of kJ absorbed by the reaction assuming the baking soda was the limiting reactant.
2. Convert the kJ into calories.
3. Divide the calories by the number of grams of solution you have in your beaker. This will give you a theoretical value for how much your temperature should have dropped during the reaction.
4. Compare your theoretical temperature drop from with the experimental temperature drop you recorded. Ponder why these numbers are not the same.
5. Calculate the moles of HCl present in the experiment. Was it correct to assume that the baking soda was the limiting reactant?

**Analysis (further trials)**

Now you will modify the experiment to achieve an even colder temperature than you did in Part I. You have two attempts to get the temperature to drop as low as possible.

The questions below are designed to help you consider possible modifications. These are NOT the only things that you could change. The best strategy will be to discuss the parameters you would like to change (and why) prior to performing actual experiments with your lab group members.

Some things to consider:

- Does the container affect the results of the experiment? *Ceramic, metal and Styrofoam vessels are available.*
- Are the amounts of baking soda and acid that you used in the first reaction the "right" amount?
- Would there be an advantage to adding some extra water to the reaction?
- Is there an advantage to scaling up or scaling down the reaction?
- Is the volume of acid important? If so, do you want more or less volume in your reaction?
- Would there be an advantage to using a different molarity of acid? *1 M, 2 M, 3 M, and 6 M HCl are available*

Once you’ve decided what variables to change, complete the reaction. Depending on your results from that trial, you may want to consider again what modifications to make for your final trial.

**Trial #1:**
Type of reaction vessel used: ______________________________

<table>
<thead>
<tr>
<th>Mass of baking soda</th>
<th>Moles of baking soda</th>
<th>Volume and molarity of acid</th>
<th>Moles of acid</th>
<th>Lowest Temperature</th>
<th>Theoretical ΔT</th>
</tr>
</thead>
</table>

What changes did you make to the original procedure? Why??

**Trial #2:**
Type of reaction vessel used: ______________________________

<table>
<thead>
<tr>
<th>Mass of baking soda</th>
<th>Moles of baking soda</th>
<th>Volume and molarity of acid</th>
<th>Moles of acid</th>
<th>Lowest Temperature</th>
<th>Theoretical ΔT</th>
</tr>
</thead>
</table>

Describe the reasoning behind the modifications you made in this trial.