Stoichiometry of a Gas Evolution/Neutralization Reaction

Introduction:
Several common anions, when acidified, evolve gases. The net ionic reactions of the carbonate, hydrogen carbonate, and sulfite ions are examples of this:

$$CO_3^{2-} + 2H^+ \rightarrow H_2CO_3 \rightarrow H_2O + CO_2(g)$$
$$HCO_3^- + H^+ \rightarrow H_2CO_3 \rightarrow H_2O + CO_2(g)$$
$$SO_3^{2-} + 2H^+ \rightarrow H_2SO_3 \rightarrow H_2O + SO_2(g)$$

Now consider the reactions

$$Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2(g)$$
$$NaHCO_3 + HCl \rightarrow NaCl + H_2O + CO_2(g)$$

These reactions are basically those given in the first two of the preceding net ionic reactions. Since one of the products of the reaction is a gas (CO_2), and a second of the products can be conveniently vaporized by heating (H_2O), the stoichiometry of the reaction can be studied by collecting and weighing the third product of the reaction (NaCl). A similar study could be made of the sulfite ion, but since the product gas SO_2 is toxic and noxious, this will not be done in this experiment.

In this experiment, you will treat weighed samples of sodium carbonate dropwise with dilute hydrochloric acid until the reactions are complete. You will then evaporate the water from the samples. The quantity of sodium chloride produced in each reaction will be determined and compared to the theoretical amount of NaCl that should have been produced from the stoichiometric ratios of the balanced chemical equations for the reactions.

Materials:
Porcelain evaporating dish or casserole
Sodium carbonate
Analytical balance
3.0 M Hydrochloric acid
Watch glass
Transfer pipet
Methyl red indicator

Procedure:

Goggles and aprons must be worn at all times in the lab!

A) Preparation of equipment and reactants
1) Clean your evaporation dish or casserole with soap and water. If any solid material in the dish cannot be removed with simple washing, consult with the instructor about other methods for cleaning. Rinse the casserole with distilled water and wipe dry with a towel.
2) On a wire gauze on a ringstand, heat the dish on a low flame for 5 minutes to dry it. Move the flame occasionally during the heating so that all portions of the casserole are heated. Allow the casserole/evaporating dish to cool to room temperature.
3) Weigh the casserole on the analytical scale, and record the mass.
4) Add 2.000 g of sodium carbonate, Na_2CO_3, to the casserole and record the combined mass.
5) Moisten the sodium carbonate with 4-5 mL of distilled water and add 2 drops of methyl red indicator (the mixture will be yellow). Cover the dish with a watch glass to catch any material that may spatter.
6) Based on the mass of sodium carbonate taken, calculate the volume (in mL) of 3.0 M hydrochloric acid that should be required to react with the sodium carbonate. <u>THIS CALCULATION SHOULD BE COMPLETED BEFORE COMING TO THE LAB!!!</u>
7) Use a CLEAN graduated cylinder to measure out the amount of 3.0 M HCl that you will need for the lab. You may transfer the HCl to a CLEAN beaker for use at your lab station.

B) Performing the Neutralization

1) When adding HCl to the sample in the casserole, use a transfer pipet and add the HCl down the pouring spout of the dish without removing the watch glass. The sodium carbonate will froth and fizz as carbon dioxide is generated, and the watch glass will prevent loss of solid. Begin adding 3.0 M hydrochloric acid dropwise to the casserole from the portion in the beaker
2) Continue adding HCl with the dropper from the beaker until there is approximately 1 mL remaining. During initial addition of the HCl, the indicator may change to red. This ***may not*** signal completion of the reaction, however, because some carbon dioxide may remain in solution at this point, thereby affecting the pH of the mixture.
3) Transfer the dish to the wire gauze/ringstand and heat with a low flame until the mixture just begins to boil. This heating is only to drive off carbon dioxide: ***do not*** attempt to boil off the water from the mixture at this point. As carbon dioxide is evolved on heating, the mixture should turn yellow again.
4) Add additional HCI dropwise from the beaker until the mixture in the casserole turns a permanent pale red.
5) Use a stream of distilled water from a plastic wash bottle to rinse any solids that may have collected on the bottom of the watch glass into the casserole.

C) Evaporation of Water

1) Place your evaporating dish on the wire gauze. Use a VERY gentle flame to begin heating the mixture. Overheating will result in "bumping" during which the mixture will spatter. This will reduce your yield of NaCl. More importantly, spattering of hot solids is dangerous. Use a stir rod if necessary to keep the moisture content of the mixture uniform. Be careful not to lose any of the mixture that might adhere to the stir rod.
2) When it appears that nearly all of the water is evaporated, turn the flame up and continue heating for five more minutes to remove the last traces of moisture.
3) Let the dish cool to room temperature and then reweigh it, recording the mass.

D) Calculations

1) Based on the mass of sodium carbonate taken originally, calculate the mass of sodium chloride that should in theory be produced by the reaction.
2) Based on the actual yield of NaCl and the calculated theoretical yield, calculate the percent yield for your experiment.