**Experiment #1: “Stoichiometric Determinations”**

**Chem1411.P01**

**General Chemistry I**

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**Objective**

Stoichiometric measurements are among the most important in chemistry, indicating the proportions by mass in which various substances react. In this experiment, the reaction of sodium carbonate, Na2CO3, with hydrochloric acid, HCl, was investigated.[[1]](#endnote-1)

**Introduction**

Stoichiometry is an essential calculation in chemistry. The knowledge of understanding the mole ratios of the reactants and products provides chemists with precise indicators for reacting chemical together. Without this knowledge, hazardous situations may exist with certain reactions where careful mole ratios for the reaction are needed.

**Materials & Methods**

The chemicals used for this experiment were sodium carbonate, 3 M HCl (aq), methyl red indicator, and DI water. The equipment used were crucible, ring stand, ring clamp, wire gauze, watch glass, disposable pipet, graduated cylinder, Bunsen burner, hot plate, and 250-mL beaker.1

A 50-60 mm diameter casserole dish was cleaned with warm soapy water and dried with a paper towel. The casserole was dried further using the Bunsen burner by placing the casserole on a wire gauze seated on top of ring clamp connected to a ring stand. The height of the ring clamp was situated such that the ring was about 1.5-2 in taller than the top of the Bunsen burner. The flame height was to just touch the wire gauze. After about 5 min of heating, the casserole was removed from heating and allowed to cool completely to room temperature. The mass of the casserole was recorded and place on the wire gauze to heat again. Again, after about 5 min, it was allowed to cool completely to room temperature and the mass measured again. The goal was to obtain two masses no different than 0.02 g. Sodium carbonate, 0.500 g – 1.000 g, was added to the casserole and dissolved in 5 mL of water and 2-3 drops of methyl red solution and covered with a watch glass. An amount of 3 M HCl (aq) was calculated. Of this amount, all but 1 mL was added to the sodium carbonate solution. The casserole was transferred to the wire gauze to heat the solution until it either became colorless or yellow. At this point, the remaining 1 mL of acid was added dropwise to the solution until it remained a pale pink color. The watch glass was removed and rinsed with DI water. The casserole was placed on top of a 250-mL beaker that had 200 mL of boiling water in it. The water was gently boiled away leaving a white solid. The casserole was placed on the wire gauze again, where it was heated gently for 5 min to confirm all water was removed. The flame was increased and the casserole was heated for another 2 min. The casserole was removed and allowed to cool completely to room temperature. The mass of sodium chloride produced was determined by measuring the casserole with the solid on a balance and subtracting the mass of the casserole.

**Discussion/Analysis**

The neutralization of a sodium carbonate, Na2CO3, with stoichiometric amounts of acid, 3 M HCl (aq), produces carbon dioxide (CO2), water, and sodium chloride (NaCl). As the reaction proceeds, the carbon dioxide is removed by heating the solution. Once the solution becomes slightly acidic, the water is boiled away leaving sodium chloride. A near quantitative yield is expected to be produced since no transfer of material occurs, which would cause loss of product. Several observations were made during the experiment.

During the preparation of the experimental setup, the casserole to be used was cleaned and dried with a paper towel. In order to remove all the water from the casserole, a small flame was applied to the casserole for several minutes. Water was noticeably evaporating from the casserole proving that the paper towel was not able to remove all the water from the casserole. When the acid was added to the sodium carbonate solution, the solution turned a rose color. This indicated that the solution was acidic. When the rose-colored solution was heated it became yellow-to-colorless. This result was caused by two things working together, the loss of CO2 from the solution made the solution more basic. The addition of the remaining acid caused the solution to become pale pink. This meant that the solution was acidic and all of the sodium carbonate had completely reacted. The complete reaction of sodium carbonate was the expected result as any unreacted sodium carbonate would have affected the final results of the experiment. The evaporation of the water provided a white solid. The solid was believed to be sodium chloride due to the fact that all the sodium carbonate was completely reacted away in a previous step. During the final heating with the Bunsen burner some spattering occurred causing some of the solid to pop out of the casserole. The spattering was caused by small amounts of water being trapped under the solid. As the liquid became a gas, pressure built up until the solid could not hold the gas any longer. The force of the gas release caused some solid the leave the casserole.

**Results**

The initial amount of sodium carbonate used was 0.693 g. Several calculations for the experiment were determined to obtain a proper amount of product. The first calculation that was required was the amount of 3 M HCl (aq) needed to completely react with the sodium carbonate:

Na2CO3 + 2 HCl → 2 NaCl +H2O + CO2

Calculation:

$$\left(\frac{0.693 g Na\_{2}CO\_{3}}{1}\right)\left(\frac{1 mol Na\_{2}CO\_{3}}{105.99 g Na\_{2}CO\_{3}}\right)\left(\frac{2 mol HCl}{1 mol Na\_{2}CO\_{3}}\right)\left(\frac{1L}{3 mol HCl}\right)\left(\frac{1000 mL}{1 L}\right)=4.36 mL 3 M HCl$$

Due to limitation of the graduated cylinder used, 4.4 mL of 3 M HCl was measured and used.

Two more calculations were needed at the end of the experiment, 1) determined of the theoretical yield of sodium chloride produced, and 2) the percent yield of the reaction.

Theoretical yield:

The theoretical yield was determined from the mass of the sodium carbonate only. This was due to the fact that the acid was in excess.

$$\left(\frac{0.693 g Na\_{2}CO\_{3}}{1}\right)\left(\frac{1 mol Na\_{2}CO\_{3}}{105.99 g Na\_{2}CO\_{3}}\right)\left(\frac{2 mol NaCl}{1 mol Na\_{2}CO\_{3}}\right)\left(\frac{58.44 g NaCl}{1 mol NaCl}\right)=0.764 g NaCl$$

Percent Yield:

The percent yield calculation is a relationship of the amount obtained versus the theoretical amount.

$$\left(\frac{Actual Yield}{Theoretical Yield}\right)x 100 \%=\left(\frac{0.651 g NaCl}{0.764 g NaCl}\right)x 100 \%=85.2 \% yield$$

**Conclusion**

The experiment investigated the stoichiometry involved in the reaction of sodium carbonate and hydrochloric acid to produce sodium chloride, water and carbon dioxide. The reaction of 0.693 g of sodium carbonate with an excess of acid produced 0.651 g NaCl, correlating to an 85.2 % yield. During the course of the reaction 4.4 mL of 3 M HCl (aq) was used to completely react with the sodium carbonate. The complete reaction was observed when the methyl red indicator stayed a pale red/pink color while heating during the addition of acid. Methyl red indicator is an indicator that turns red in the presence of excess acid. With this knowledge, it was assumed that all the sodium carbonate had completely reacted. The 85.2 % yield indicates a successful reaction but not a perfect reaction.

As in any experiment, errors do occur. One of the biggest sources of error for this experiment was the fact that some spattering occurred. The spattering caused product to be lost, thus, lowering the percent yield. To prevent this issue in the future, the evaporation of the water could occur with slightly lower heat to allow the water to evaporate slower and allow the solid to settle to the bottom of the casserole. Other sources of error would be the incomplete evaporation of water, causing the % yield to be higher than reported or the incorrect measurement of masses. To prevent these issues, greater care in confirming the evaporation and measurements would be made. The acid concentration could be a source of error. If the concentration was lower than indicated, it may cause some error in the complete neutralization of the base if care was not taken to observe the endpoint.

**References**

1. *Signature Labs Series, Custom Lab Manual for Chemistry at South Texas College*. 1st Ed. Wentworth/Hall. **2010**. [↑](#endnote-ref-1)