Introductory Chemistry Lab: Stoichiometry

Outcomes

As a result of today's laboratory, you will have:

Reacted a measured amount of Na_2CO_3 with enough HCl to convert the Na_2CO_3 to NaCl and H_2O and CO_2
Isolated the NaCl product and measured its mass, the actual yield of NaCl.
Predicted the amount (theoretical yield) of NaCl that should be produced by the reaction
Calculated the % yield of NaCl
Calculated an experimental error

Prelab

Prepare a Title (can use the lab handout for this), Purpose (a concise statement) and a Procedure (short "to do" list … see "Writing a Procedure" in the lab handouts folder), and Data Table.

Purpose:

To measure the mass of sodium chloride that is produced when a sample of sodium carbonate completely reacts with dilute hydrochloric acid, to calculate the theoretical yield of sodium chloride, to calculate the % yield of sodium chloride, and the % error of the NaCl preparation.

Background Information

Chemical reactions communicate information about chemical changes. They indicate not only what substances react and what new materials are produced; they also show how much of the reactants and products are involved. The study of the quantities of reactants and products in chemical reactions is called *stoichiometry*. Stoichiometry is important to chemists because it is used to predict the amount of one reactant that is necessary to react with a given amount of another reactant to form product. Stoichiometry is also used to predict how much product can be formed when given quantities of reactants are mixed. It can also be used in the reverse sense to determine how much of the starting materials must be reacted to form a given amount of product.

A balanced chemical reaction shows the quantities of reactants and products on a number of levels. For example, consider the single replacement reaction between aluminum and hydrochloric acid to produce hydrogen gas and aqueous aluminum chloride:

$$2\ Al_{(s)} + 6\ HCl_{(aq)} \rightarrow 3\ H_{2\ (g)} + 2\ AlCl_{3\ (aq)}$$

The coefficients in the balanced equation can be interpreted on the molecular level as the number of formula units of reactants and products.

2 atoms of Al react with 6 formula units of HCl to form 3 molecules of H_2 and 2 formula units of $AlCl_3$.

The coefficients in the balanced equation can also be interpreted on the molar level as the number of moles of reactants and products.

2 moles of Al react with 6 moles of HCl to form 3 moles of H_2 and 2 moles of $AlCl_3$.

The coefficients of the balanced equation can be used to write "per expressions" relating the molar amounts of reactants and products to each other. The conversion factors that result are called *stoichiometric factors*.

The molar interpretation of the reaction can be used with the molar masses of the reactants and products to determine the number of grams of reactants and products involved in the reaction:

2 (26.98) g of Al react with 6 (36.46) *g f HCl to form 3 (2.016) g of H_2 and 2(133.33) g of $AlCl_3$.*

Notice that the total mass of all the reactants, 272.7 grams, is the same as the total mass of all the products. This is an example of the *Law of Conservation of Mass* that states that the total mass of substances does not change during a chemical reaction.

Chemists frequently use stoichiometry to calculate how much product should be formed during a reaction. This is called the **theoretical yield**. Once the reaction has been run the amount of product collected is the **actual yield**. The percent yield for the reaction can then be calculated using the equation below.

$$\% \text{ Yield} = \frac{\text{Actual Yield}}{\text{Theoretical Yield}} \times 100$$

Sometimes results are reported as a percentage error in the yield. This is defined as

$$\% \text{ Error} = \frac{\text{Experimental yield (g)} - \text{Theoretical Yield (g)}}{\text{Theoretical Yield (g)}} \times 100$$

Since experimental yield is supposed to be less than theoretical, the percent error value should be negative.

HCl is caustic to the skin and eyes!
Use caution. WEAR YOUR GOGGLES!!!

Procedure **Work in pairs**
Use the same balance for the entire procedure.

1. Measure the mass of an evaporating dish and a watch glass. Record the mass in Table 1.
2. Add 1.5 – 2.0 grams of sodium carbonate to the evaporating dish. Record the total mass of Na_2CO_3, watch glass and evaporating dish.
3. Place the evaporating dish in the small iron ring on the ring stand. Measure ~ 6.5 mL of 6 M HCl and gradually add the acid solution to the Na_2CO_3, a drop at a time, until CO_2 is no longer given off. (The calculation of the amount of HCl is shown on the calculation page).
4. When the reaction is complete (no solid Na_2CO_3 left or bubbles given off), carefully evaporate the solution to dryness using a laboratory burner. Use the watch glass as a cover to help prevent splattering.
5. Allow the evaporating dish and watch glass to cool completely (about 15 minutes), then weigh the evaporating dish, NaCl and watch glass. Record the mass in Table 1.

Clean Up

1. The NaCl product is drain disposable. Wash out the product and then clean the evaporating dish and watch glass with soap and water, rinse with tap water and then with de-ionized water. Dry the watch glass and evaporating dish and put them back into their proper storage drawers. Clean up all other glassware used.

2. Return all pieces of equipment, including Bunsen burners, to their proper storage drawer or cabinet.

Data

Table 1: Experimental Weights

Mass of evaporating dish and watch glass (g)	
Mass of evaporating dish, watch glass, and Na_2CO_3 (g)	
Mass of evaporating dish, watch glass and NaCl obtained (g)	

Calculations ***Show all of your work with properly labeled conversion factors***

For the balanced equation: $Na_2CO_{3\,(aq)} + 2\ HCl_{(aq)} \rightarrow 2\ NaCl_{(aq)} + H_2O_{(l)} + CO_{2\,(g)}$

Using your starting mass of Na_2CO_3, calculate the following; record the answers in Table 2.

a) The theoretical yield of NaCl
b) The actual yield of NaCl from today's experimental data
c) The % yield of NaCl
d) The % experimental error of your isolation of NaCl

Results

Table 2: Summary

Theoretical yield of NaCl (g NaCl predicted)	
Actual yield NaCl (g NaCl Collected)	
% Yield NaCl	
% Experimental Error	

Conclusion
Summarize your results by comparing your actual experimental yield to the theoretical yield.

Questions ***Show all work with units and correct number of significant figure***

1. What are two possible reasons why your % yield is different from 100%?

2. How would your value for the % yield be changed (increased, decreased, or remain the same) if:
   a. you did not heat the product long enough to remove all of the water?
   b. some of the product spattered out of the evaporating dish during heating?
   c. After heating, you recorded 98.207 g instead of the actual 98.507 g" as the mass of the evaporating dish + watch glass + NaCl?

3. a. Using the coefficients in the balanced chemical reaction, what is the theoretical ratio

   moles NaCl / moles Na_2CO_3?

   b. Use your experimental data (grams Na_2CO_3 reactant and grams NaCl product) to calculate:

   moles NaCl actually produced / moles Na_2CO_3 reacted

4. In the reaction below, how many grams of HCl are required to react with 2.000 g of Na_2CO_3?

$$Na_2CO_{3\,(aq)} + 2\ HCl_{(aq)} \rightarrow 2\ NaCl_{(aq)} + H_2O_{(l)} + CO_{2\,(g)}$$

5. What type of chemical reaction is this?

$$Na_2CO_{3\,(aq)} + 2\ HCl_{(aq)} \rightarrow 2\ NaCl_{(aq)} + H_2O_{(l)} + CO_{2\,(g)}$$