

Name: _____ Period: _____ Seat #: _____

Stoichiometry of the Reaction of Sodium Carbonate with Hydrochloric Acid

Purpose:

- To calculate the theoretical (expected) yield of product in a reaction.
- To weigh the actual (experimental) mass of product collected in a reaction.
- To calculate the % yield of the chemical reaction.
- To practice making conversions and taking accurate measurements.

Background information:

Stoichiometry will be used to investigate the amounts of reactants and products that are involved. The word stoichiometry is derived from two Greek words: stoicheion (meaning “element”) and metron (meaning “measure”). Stoichiometry is an important field of chemistry that uses calculations to determine the quantities (masses, volumes) of reactants and products involved in chemical reactions. It is a very mathematical part of chemistry.

In real-life situations the number of moles of reactants available for a chemical reaction is not always exactly the same as the ratio of moles in the balanced equation. One of the reactants will run out before the other reactant. For instance, when a candle burns in an open room, the wax in the candle will run out long before all the oxygen in the air will be used up. On the other hand, put the candle in a closed jar, and the oxygen will be used up quickly, leaving the wax left over. When one of the reactants is used up in a situation like this, the reaction will stop, and no more product will be made. The reactant that gets used up first, and therefore limits the amount of product that can be made, is called the **limiting reactant**. The reactant that is left over is called the **excess reactant**.

It is often difficult as well as impractical to combine just the right amount of each reactant that is required for a particular reaction to occur. In the lab as well as in industrial processes, reactions are rarely carried out with exactly the required amount of each reactant. In most reactions, one or more reactants are in excess. Given this fact, this experiment is designed so that only one of the reactants will be completely used up. This is called the limiting reactant because it limits the amount of products formed. Since the other reactant will have a quantity remaining, it is called the excess reactant. One of your tasks will be to determine which of your reactants is limiting and which is in excess.

For a chemical reaction to happen the reactant molecules must collide with one another. All collisions do not lead to a chemical reaction. Only those collisions with proper orientation (angle of collision) and force of collision can cause the existing bonds to break and allow new bonds to form.

Many reactions stop or slow down when the concentration of reactants is low. Increasing the concentration of one reactant (usually the less expensive) drives the reaction to completion faster.

Theoretical yield is the maximum amount of product that can be produced from a given amount of reactant. (stoichiometry)

Actual yield is the amount of product actually produced when the reaction is carried out. (experimental)

Percent yield is the ratio of the actual yield to the theoretical yield as a percent.

$$\text{percent yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100$$

Percent yield is the percent of the theoretical yield that is obtained through laboratory procedures. Percent yield is done to determine how efficient a laboratory process is in producing the desired product. Percent yield is an important calculation in manufacturing situations, since a high percent yield (close to 100%) means more product and therefore more profit for the manufacturer. In reality, percent yield rarely is 100%. There always seems to be something that causes some product to be lost, if nothing more than some of it sticking to the inside of the container. If a percent yield over 100% is obtained, it is likely that some error in measurement was made.

Percent yield calculations are made to determine the success of a chemical reaction because most reactions do not succeed in producing the predicted amount of product. Reactions fail to go to completion because liquid adheres to containers or evaporates. Solids get stuck in filter paper or lost in the purification process.

In this mini-lab, sodium carbonate reacts with hydrochloric acid to produce sodium chloride, water and carbon dioxide. The "bubbles" are an indication of the carbon dioxide gas that is being released. Boiling it off then separates the water. As a result, we are able to isolate the NaCl as a solid product.

The reaction takes place in two stages:

In the first stage, sodium carbonate is reacted with hydrochloric acid to produce sodium bicarbonate. Write the reaction below:

In the second stage, sodium bicarbonate reacts with hydrochloric acid to produce sodium chloride, water, and carbon dioxide gas:

The balanced overall chemical equation for this process is:

Pre-lab questions:

- 1) If you have 50 bicycle frames and 80 bicycle wheels, how many bicycles can be made. What limits the number of bicycles?

- 2) 18.1 g of ammonia and 90.4 g of copper (II) oxide are used in the reaction $2 \text{NH}_3 + 3 \text{CuO} \rightarrow \text{N}_2 + 3 \text{Cu} + 3 \text{H}_2\text{O}$.
 - a) Which is the limiting reactant? How many grams of nitrogen will be formed?

 - b) If 9.87 grams of nitrogen were obtained when the reaction was done in the lab, what is the percent yield?

- 3) The reaction between solid white phosphorus (P_4) and oxygen (O_2) produces solid tetraphosphorus decoxide.
 - a) Write a balanced equation for the reaction.

 - b) Determine the mass of tetraphosphorus decoxide formed if 25.0 g of phosphorus (P_4) and 50.0 g of oxygen (O_2) are combined. How much of the excess reactant remains after the reaction?

 - c) When the reaction was conducted in the lab, 52.5 g of product was collected. What is the percent yield in this reaction?

- 4) Aluminum reacts with aqueous copper (II) chloride to produce copper plus aluminum chloride.
 - a) Write a balanced equation for this reaction.

 - b) Starting with 2.70 g copper chloride and 0.300 g aluminum, what is the theoretical yield of copper?

 - c) You ran this reaction and collected 0.290 g copper. What was your percent yield?

- 5) Why is an excess reactant used in many reactions?

- 6) Why do many reactions slow down when the concentration of the reactants gets low?

- 7) Classify the reaction of sodium carbonate with hydrochloric acid as a single replacement, double replacement, combustion, synthesis, or decomposition.

Procedure:

#	✓	Procedure
1		Weigh a beaker and record its mass below.
2		Add approximately 1.0 gram of sodium carbonate into the beaker and record the mass of the beaker and sodium carbonate.
3		Add 1M HCl (1 mole HCl per liter of solution) drop wise while stirring until the bubbling stops. Keep the beaker partially covered with watch glass. Then add a little more HCl to make sure the reaction has gone to completion. All of the sodium carbonate should be dissolved.
4		Feel the temperature of the beaker by touching on the sides of beaker on the outside with your fingers while the reaction is occurring.
5		Place the beaker without the watch glass on the hot plate. Heat gently and boil the liquid to dryness. Wear goggles & don't let the liquid splatter!
6		Let the beaker cool, and then record the mass of the beaker and the dried NaCl.

Data:**Qualitative Data**

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Quantitative Data

Mass of beaker	
Mass of beaker and Na ₂ CO ₃	
Mass of Na ₂ CO ₃	
Mass of beaker and NaCl	
Mass of NaCl (Actual yield)	

Calculations:

Calculate the moles of sodium carbonate that react.

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Use the balanced equation to calculate the moles of NaCl that should be produced.

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Convert theoretical moles of NaCl to grams of NaCl (Theoretical Yield).

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Calculate the %-Yield: % Yield = [Actual Yield / Theoretical Yield] * 100

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Conclusion:

The experimental yield of sodium chloride was found to be _____ g.

The theoretical yield (calculated yield) of sodium chloride was found to be _____ g.

The percent yield in the lab was found to be _____ %

Post laboratory questions:

- 1) What is the purpose of covering the beaker with a watch glass?
- 2) Why should the beaker only be partially open when adding the acid?
- 3) How did you know that the reaction was complete?
- 4) Why do you think scientist add excess of one or more chemicals when performing a reaction rather than combine the exact stoichiometric ratio?
- 5) What happened to the excess reactant after the reaction was complete?
- 6) What happened to the excess reactant after the evaporation was done?
- 7) Why did not we measure exactly the amount of hydrochloric acid added during the reaction?
- 8) Which starting material in the reaction is the limiting reactant and which material is present in excess? How do you know?
- 9) What physical evidence in the lab could be used to indicate the limiting reactant?
- 10) What does percent yield tell you?
- 11) Why do most reactions produce less than 100 % yield?
- 12) Discuss potential reasons why the percent yield of recovered products may be greater than 100%.
- 13) Was this reaction exothermic or endothermic? Explain with evidence.
- 14) Discuss at least 2 reasons that could explain your % yield and suggest improvements based on your error.
- 15) What chemistry concepts were demonstrated by the lab?
- 16) Explain at least one real life application where the concepts explored in the lab would be used.