Stoichiometry – Decomposition of Baking Soda

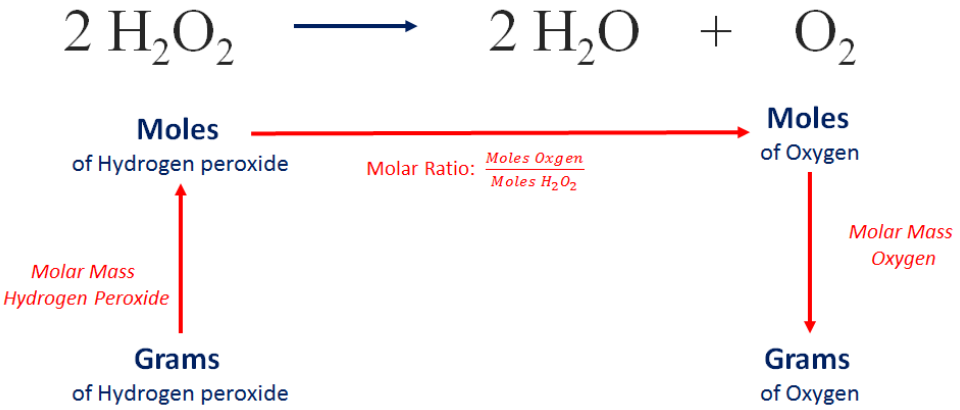
For our soul is humbled down to the dust. ***Psalms 43:25***

Introduction

A balanced chemical reaction shows products forming reactants such that the Law of Conservation of Matter is obeyed. The balanced chemical reaction may be used to answer mathematical questions such as "how much reactant" should be used for a given amount of product, or; "how much of Reactant A" is required to react with a given amount of Reactant B. ***Stoichiometry*** is using a balanced chemical reaction in a numerical relationship in order to calculate quantities of the reactant(s) and product(s) used in that chemical equation.

As an example, the balanced equation for the decomposition of hydrogen peroxide is: $2\ H_2O_2 \rightarrow 2\ H_2O + O_2$. The whole number coefficients are most commonly interpreted as molar ratios. In the decomposition of hydrogen peroxide, we may write several molar ratios (as well as their inverses of course): $\frac{2\ mol\ H_2O_2}{2\ mol\ H_2O}, \frac{2\ mol\ H_2O_2}{1\ mol\ O_2}\ and\ \frac{2\ mol\ H_2O}{1\ mol\ O_2}$.

In the laboratory, we weigh out grams, not moles. But the balanced chemical formula is coded in ***mole:to:mole*** ratios. Therefore, in order to perform mathematical stoichiometric calculations, one must first convert the grams of a substance to moles (using the molar mass as determined from the periodic table). For example, we are asked, ***"How many grams of hydrogen peroxide are required to produce 10-grams of oxygen?".*** The "roadmap" shows that there are three steps to the stoichiometric calculations, since there is no direct route between grams of hydrogen peroxide and grams of oxygen.



Learning Objectives:

- Use stoichiometric calculations to determine the decomposition of sodium bicarbonate

Materials Required:

From Chemistry Kit	Student Supplied
Scale	Baking soda ($NaHCO_3$)
	Aluminum foil*
	Timer, Stove and Oven Mitts

***Use the Aluminum foil to make a small crucible with loose-fitting lid (see figure)**

Safety

- Handle the contents from stove with care to prevent burns.

Pre-Lab Overview:

Have you ever baked? Baking soda (sodium bicarbonate, $NaHCO_3$) is used in bakery products to ensure that they rise during baking. Why? As the dough is heated, the baking soda decomposes, and carbon dioxide is released, causing the dough to rise so that it is light and fluffy. There are 3, theoretically-possible Baking Soda Decomposition Reactions. However, only one reaction actually occurs.

YOUR TASKS:

1. Perform the experiment below
2. Use Stoichiometry and your results to determine which of 3 reactions actually occurs
3. The three possible reactions – [Write and balanced them NOW in Question 1]:
   - **A. Sodium bicarbonate (s) → sodium oxide (s) + carbon dioxide (g) + water (g)**
   - **B. Sodium bicarbonate (s) → sodium hydroxide (s) + carbon dioxide (g)**
   - **C. Sodium bicarbonate (s) → sodium carbonate (s) + carbon dioxide (g) + water (g)**

Experiment

1. Preheat oven to 400°F

2. Prepare crucible with baking soda:
   - Make a small crucible (with sides) out of aluminum foil as shown above
   - Determine the mass of the crucible and record in Table 1; Line 1
   - Add approximately 2-g of baking soda to the pre-weighed crucible
     - Actual mass may vary between 1.75 and 2.25 grams
   - Record total mass of crucible + solid on Line 3 in Table 1
   - Determine the actual mass of baking soda and record in Table 1; Line 3
   - Calculate the number of moles of baking soda (Molar Mass = 84.007 g/mol) and record in Table 1: Line 4

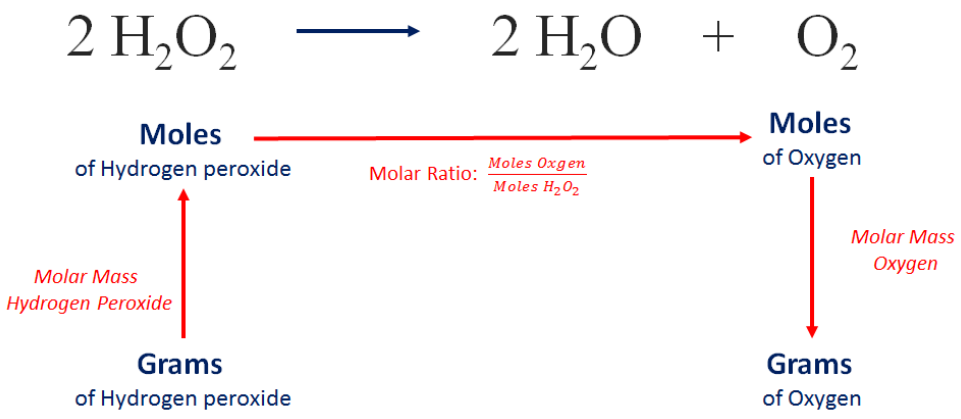
3. Heat :
   - Place the lid on the crucible so that is about ½ covered
   - Place the crucible containing baking soda on a pie pan or cookie sheet
   - Place in the oven at 400°F for 15 minutes
   - If you have not done so already, write and balance the 3 equations in Question 1 of Data Analysis
   - Remove carefully with oven mitts and allow to cool completely
   - Remove the lid once the crucible has cooled

4. Determine mass of residual solid:
   - Determine the mass of the crucible + remaining solid crucible and record on Line 5
   - Determine the mass of the solid alone and record on Line 6
     - This solid is the "***unknown***" solid that you are going to identify by stoichiometry
     - Given the 3 possible decomposition reactions for sodium bicarbonate, you know that this residual solid could be one of the following compounds:
       - Sodium oxide
       - Sodium hydroxide
       - Sodium carbonate

5. Determine mass of gas – or gases – released during heating:
   - Determine change in mass of the solid material from before heating to after heating
     - This mass is the mass of the starting material that was lost as gas
     - Review the possible decomposition reactions and you will find that gas could have been released in one of two ways:
       - CO_2 *(g)* only
       - CO_2 *(g)* and H_2O *(g)*

6. Use Stoichiometry to determine Theoretical Yield:
   - Review the 3 possible balanced equations for baking soda decomposition in Question 1
   - Use the "roadmap" below to calculate the Theoretical Yield of the solid product
     - Results should be answered in grams
     - Place calculations and results in Table 2
     - There should be a Theoretical Yield for Reaction A, Reaction B, and Reaction C
   - Record the Actual Yield (in grams) that you obtained in the experiment heating
     - From Table 1: Line 6

7. Perform remaining Data Analyses and Conclusions



Lab Report for: _____

TABLE 1 – Data Collection Table

1	Mass of empty crucible	
2	Mass of crucible + baking soda	
3	Mass of baking soda BEFORE heating **(Line 2 – Line 1 = Line 3)**	
4	MOLES of baking soda BEFORE heating	
5	Mass of solid and crucible AFTER heating	
6	Mass of **solid** remaining in crucible **(Line 5 – Line 1 = Line 6)**	
7	Change in mass by heating (gas/gases) **(Line 3 – Line 6 = Line 7)**	

NOTE to STUDENT: Often students do not review their data with respect to the chemical reaction they have just performed. Take a moment to review Table 1 and Question 1 before proceeding. Notice that there are 3 highlighted lines corresponding to either the Reactant or the Products of interest. You will use these in your stoichiometric calculations.

- **Line 3:** Reactant – Baking Soda or Sodium Bicarbonate
- **Line 6:** Remaining solid. You will determine if it is sodium oxide, sodium hydroxide, or sodium carbonate
- **Line 7:** Gas or Gases – You will determine if it is carbon dioxide alone, or carbon dioxide and water.

This is the type of initial analysis that you should make in each experiment that you encounter.

TABLE 1 – Using Stoichiometry

Theoretical and Actual Yield of Solid Product

REACTION	STOICHIOMETRIC CALCULATIONS	THEORETICAL YIELD OF SOLID PRODUCT (g)	ACTUAL YIELD (g)
Reaction A			
Reaction B			
Reaction C			

Data Analysis

1. There are 3 possible decomposition reactions for sodium bicarbonate (baking soda). Write a balanced chemical equation for each.
   Reaction A:

Sodium bicarbonate (s) → sodium oxide (s) + carbon dioxide (g) + water (g)

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Reaction B:
Sodium bicarbonate (s) → sodium hydroxide (s) + carbon dioxide (g)

_____

Reaction C:
Sodium bicarbonate (s) → sodium carbonate (s) + carbon dioxide (g) + water (g)

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2. Based on the Theoretical Yield and the Actual Yield (Table 2), determine which of the three reactions occurred in the decomposition of sodium bicarbonate. Explain your answer.

3. What was the solid product remaining in the crucible after heating?

4. What gas – or gases were released from sodium bicarbonate upon heating?

5. Discuss three experimental sources of error with this procedure.

6. In the "Introduction" we discussed the decomposition of hydrogen peroxide:

$$2\ H_2O_2 \rightarrow 2\ H_2O + O_2$$

- Why is it necessary to relate the quantities in a chemical reaction to **moles** rather than **grams**?
- What is the mole ratio between hydrogen peroxide and oxygen in the balanced equation?
- How many grams of H_2O_2 are required to produce 10.00 g of O_2? Show your work.