OBJECTIVE

The theoretical yield of the reaction product and the ratio of products to reactants will
be predicted using the Law of Conservation of Matter and the Law of Definite
Composition.

INTRODUCTION

The Laws of Conservation of Matter and Definite Composition were established only
after much controversy and careful quantitative experimentation. The universal
acceptance of these laws enables us to confidently predict percentage compositions of
specific compounds irrespective of the methods used to form them. Accordingly, one
can calculate the theoretical yields of products and the mass ratios between the
products and reactants. With the background of these proven principles, you can test
your ability to develop laboratory skills, and can learn to depend upon your predictions
as you discover that your calculations represent examples of real events in nature.

In this experiment, a sample of sodium carbonate is treated with hydrochloric acid in a
crucible. As the acid attacks the carbonate, carbon dioxide gas is generated and
sodium chloride (common table salt) and water are formed. No matter is destroyed; it
is merely converted from one type to another in accordance with the Law of
Conservation of Matter. The equation for this reaction is:

\[ \text{Na}_2\text{CO}_3 \text{(aq)} + 2 \text{HCl (aq)} \rightarrow 2 \text{NaCl (aq)} + \text{H}_2\text{O} + \text{CO}_2 \text{(gas)} \]

The carbon dioxide escapes into the atmosphere, and you will evaporate the water and
excess acid (to ensure complete reaction). The dry sodium chloride will remain behind
in the crucible. From the recorded masses of the Na_2CO_3 sample and the NaCl
residue, you will calculate the mass ratio. This ratio is a fixed value, because the Law
of Definite Composition assures that these two compounds always have the same
compositions regardless of their origins. Careful attention to the experimental
procedures, techniques, and precision weighing will be rewarded with the satisfaction
of correct results. An unknown carbonate will then be treated in the same manner as
the Na_2CO_3 to test the skills which you will have learned with the known sample.
Skills:
Quantitative Measurements
Handling of chemicals
Balancing chemical reactions
Careful experimental work
Calculations
Data recording and observations

Yields
Error calculations
Experimental Predictions & testing
Chemical mixing
Lab equipment: Scales, Burners

Pre Lab Problems (answer on separate paper, showing all appropriate work)
Refer to the chemical equation on the previous page as you solve the following problems.

1. Write the net ionic reaction for part I of this experiment.

2. Calculate the percent sodium (by mass) in sodium carbonate and in sodium chloride.

3. Calculate the mass of sodium chloride that could be obtained from 0.689 g of sodium carbonate.

4. Using the results of Problem 3, calculate the mass ratio of sodium chloride to sodium carbonate.

5. Would you expect the chloride to carbonate mass ratio calculated in the preceding problem to increase, decrease, or stay the same if more than 0.689 g of sodium carbonate were reacted? Explain.

Materials & Equipment

Na$_2$CO$_3$  
Crucible and cover

Hydrochloric acid, 6M  
Crucible tongs

Unknown carbonate or bicarbonate  
Ring stand

Dropper pipet  
Triangle

Spatula  
Ceramic tile

Bunsen burner  
20 mL beaker

Procedure

Record all weights in your laboratory notebook (as you perform the measurements). If the known and unknown carbonates are in bottles, be sure to use a clean, dry, stainless steel spatula each time you remove a sample to prevent contamination of the contents of the bottle.

Part I. Conversion of sodium carbonate to sodium chloride

1. Check your porcelain crucible for any hairline cracks, and replace if necessary. The sound when you tap it should be a “ping,” not a “thud.”

2. Clean and dry the crucible and cover. Place the empty crucible with its cover ajar on a triangle, as shown in the figures for the previous experiment. Gently heat for about
Carbonate to Halide

- one minute to remove any residual moisture, and then fully heat to a dull red glow. Turn off the burner and - with crucible tongs - place the cover on the crucible.

3. Cover and cool the crucible (to room temperature); when cooled, weigh the crucible and cover (to the nearest milligram, ± 0.001 g).

4. Weigh out between 0.5 and 0.6 g of Na₂CO₃ on a small piece of paper, or weighing boat (do not record this weight). Break up any lumps with a clean, dry spatula before taking your sample. With the crucible off the balance, carefully add this Na₂CO₃ to the crucible, replace the cover, and reweigh the crucible to the nearest milligram.

5. Add 20 drops (~ 1 mL) of distilled water to the sample in the crucible. Pour ~ 5 mL of 6M HCl into a small beaker (CAUTION: corrosive). Add HCl drop-wise down the side of the crucible to the sample.

After the addition of each drop, wait until effervescence stops before adding the next drop. The effervescence is due to the release of carbon dioxide gas. When there is sufficient liquid present to make a solution, gently swirl the crucible contents to thoroughly mix the ingredients after each acid addition and wait for fizzing to stop. Continue additions of HCl until no further gas bubbles are released, then add 5 additional drops. Save any excess acid in the beaker for subsequent experiments.

6. Replace the crucible with its cover ajar on the triangle as before, being sure not to tilt the crucible enough to allow the contents to come close to the top. Now gently heat the mixture to evaporate the water and excess HCl.

CAUTION: If the crucible is heated too strongly while liquid is present, the contents will boil over or spatter. Until all the liquid is expelled, heat only enough to evaporate it slowly. Any popping sound is a signal that the temperature is too high, and that spattering (with resulting losses) is occurring. A good technique is to hold the burner at its base and to pass the flame back and forth under the crucible, being prepared to withdraw the flame at the first sign of excessive heating.

7. When the contents of the crucible are completely dry, and when no popping sound is heard while moderate heat is applied, place the crucible upright on the triangle and put its cover on. Heat strongly for five minutes. Allow the covered crucible to cool to room temperature on a ceramic tile.

8. Weigh the cooled crucible, contents, and cover to the nearest milligram, and record the weight. Repeat the heating, cooling, and weighing cycles until the weights agree to within ± 5 milligrams of one another. Consider the final weighing to be your best value.

Part II. Conversion of unknown carbonate to chloride salt

1. Obtain 0.5 – 0.6 grams of an assigned unknown carbonate. Record the code and repeat Steps 1 through 8 from Part I above.
Carbonate to Halide

Cleanup
Clean your lab area and crucible before being signed out. Excess HCl should be carefully diluted and flushed safely down the sink with plenty of water.

Calculations (show all appropriate work, and report to the correct number of significant figures)
1. Determine the masses of your Na₂CO₃ sample and residual NaCl in Part I, and use them to calculate the mass ratio:

\[
\text{Mass of chloride} \quad \text{Mass of carbonate}
\]

2. Calculate the percent error of your experimental mass ratio for Na₂CO₃ by comparing the mass ratio with the theoretical value from Pre Lab Problem 4:

\[
\text{Percent error} = \frac{\text{Experimental mass ratio} - \text{Theoretical mass ratio}}{\text{Theoretical mass ratio}} \times 100
\]

Note that the percent error will be positive if your experimental mass ratio is high, and negative if it is low. (A negative percent error will occur if the carbonate sample has absorbed moisture from the air. You will not be penalized if this happens because your results will be graded on the basis of the actual mass ratio of the sample.)

3. Repeat the mass ratio calculation for the unknown carbonate (but not the Percent error).

Post Lab Questions (answer on separate paper, again showing all appropriate work)
1. Why can’t you repeat the percent error calculation for the unknown carbonate?
2. Predict the effect on the mass ratio if a carbonate is reacted with insufficient HCl. Will the value from the experimental data be too large, too small, or correct? Explain (mathematical treatment will be beneficial).
3. A 0.622 g sample of sodium carbonate was treated with sulfuric acid (H₂SO₄) instead of hydrochloric acid. Calculate the mass of sodium sulfate (Na₂SO₄) expected.
4. If the halide/carbonate mass ratio is determined with precision and accuracy using highly purified reactants, the atomic weight of an element may be determined. A sample of carbonate, M₂CO₃, of a hypothetical unipositive metal, M, was converted to the chloride MCl. The mass ratio was found to be precisely 1.04660. From this value and the following atomic weights, calculate the atomic weight of M. (HINT: Begin by writing a balanced equation.)

<table>
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<tr>
<th>Atom</th>
<th>Atomic Weight</th>
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<tbody>
<tr>
<td>C</td>
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<tr>
<td>Cl</td>
<td>35.453</td>
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<tr>
<td>O</td>
<td>15.9994</td>
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Report: Carbonate to Halide Conversion

Name ________________  
Lab Partner(s) ________________  
Section ________________  
Date performed ________________

Data

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<tr>
<th></th>
<th>Na$_2$CO$_3$</th>
<th>Unknown</th>
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<tbody>
<tr>
<td>Mass of empty crucible and cover</td>
<td>__________ g</td>
<td>__________ g</td>
</tr>
<tr>
<td>Mass of crucible + carbonate + cover</td>
<td>__________ g</td>
<td>__________ g</td>
</tr>
<tr>
<td>Mass of crucible + chloride + cover</td>
<td>__________ g</td>
<td>__________ g</td>
</tr>
<tr>
<td>Mass of crucible + chloride + cover (second weighing)</td>
<td>__________ g</td>
<td>__________ g</td>
</tr>
<tr>
<td>Mass of crucible + chloride + cover (third weighing)</td>
<td>__________ g</td>
<td>__________ g</td>
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</tbody>
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Calculations (detailed calculations are attached)

<table>
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<tr>
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<th>Na$_2$CO$_3$</th>
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</thead>
<tbody>
<tr>
<td>Mass of carbonate</td>
<td>__________ g</td>
<td>__________ g</td>
</tr>
<tr>
<td>Mass of chloride</td>
<td>__________ g</td>
<td>__________ g</td>
</tr>
<tr>
<td>Mass ratio (chloride/carbonate)</td>
<td>__________</td>
<td>__________</td>
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<tr>
<td>Percent error (Na$_2$CO$_3$ only)</td>
<td>__________ %</td>
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