Experiment 5

Identification of a Metal Carbonate

Pre-Lab Assignment

Before coming to lab:

- Read the lab thoroughly.
- Answer the pre-lab questions that appear at the end of this lab exercise.

Purpose

The chemical formula of an unknown metal carbonate or bicarbonate will be identified from a given list by its molar mass. The molar mass will be determined via stoichiometry after adding acid to produce and lose carbon dioxide gas.

Background

Carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) are polyatomic ions that pair with metals to form ionic compounds. When a metal carbonate or bicarbonate is reacted with hydrochloric acid, a water-soluble ionic compound, water, and carbon dioxide form. This is the "acid test" often used by geologists to identify carbonates in rocks and follows the balanced reaction in Eqn. 1 for a metal carbonate and Eqn. 2 for a metal bicarbonate. In these equations, M = Na or K.

$$M_2CO_3(s) + 2\ HCl(aq) \rightarrow 2\ MCl(aq) + H_2O(l) + CO_2(g) \qquad \text{Eqn. 1}$$

$$MHCO_3(s) + HCl(aq) \rightarrow MCl(aq) + H_2O(l) + CO_2(g) \qquad \text{Eqn. 2}$$

While carbon dioxide is fairly soluble in water under high pressures, as evidenced by canned soft drinks, it escapes at normal atmospheric pressures. This explains why when left open, containers of soda go flat rather quickly. Carbon dioxide is slightly more dense than atmospheric air so will sink.

Stoichiometry is the study of amounts. In chemistry, stoichiometry allows us to calculate the amount of a particular chemical required for a reaction and how it relates to the other reactants and products. For this experiment, the metal carbonate sample will be fully reacted with excess hydrochloric acid to produce the products seen in Eqn. 1 and 2. The metal carbonate will be the limiting the reactant.

By the Law of Conservation of Mass, the mass of the reactants before reaction should equal the mass of products after. However, since $CO_2(g)$ is a gas, the container will be left open and allowed to escape so that the amount of $CO_2(g)$ produced can be measured by subtraction. Using the stoichiometric relationships in Eqn. 1 and 2 we can calculate the amount of moles of the original metal carbonate that reacted from the amount of $CO_2(g)$ produced.

The molar mass of a substance is usually determined from the atomic masses on the periodic table. However, since the exact formula of the metal carbonate is unknown, the molar mass will be experimentally determined as the grams of metal carbonate reacted/moles of metal carbonate reacted and then compared to the options listed on Table 1 to identify its formula.

Table 1: Possible Metal Carbonate Unknowns

Chemical Name	Chemical Formula	Molar Mass
sodium bicarbonate	$NaHCO_3$	84.066 g/mol
potassium bicarbonate	$KHCO_3$	100.115 g/mol
sodium carbonate	Na_2CO_3	105.988 g/mol
sodium carbonate · ½ hydrate	$Na_2CO_3 \cdot \frac{1}{2} H_2O$	114.996 g/mol
potassium carbonate	K_2CO_3	138.206 g/mol
potassium carbonate · 1 ½ hydrate	$K_2CO_3 \cdot 1\frac{1}{2} H_2O$	165.229 g/mol

Example Problem: Determining the Molar Mass of an Unknown

An empty 125 mL Erlenmeyer flask weighs 85.0155 g. An unknown metal carbonate is added to the flask and weighed again at 86.0255 g. It and 15 mL of 6.0 M HCl in a Styrofoam weigh 101.1115 g. The HCl solution is added to the flask, allowed to react, and the $CO_2(g)$ escaped. The resulting mixture after the reaction weighed 100.7250 g. Find the molar mass of the unknown and identify it on Table 1.

Step 1: Find the mass of metal carbonate

86.0255 g – 85.0155 g = 1.0100 g

Step 2: Find the mass of $CO_2(g)$ that escaped

101.1115 g – 100.7250 g = 0.3865 g

Step 3: Find the moles of $CO_2(g)$

$$0.3865 \text{ g } CO_2 \times \frac{1 \text{ mol } CO_2}{44.0095 \text{ g } CO_2} = 0.008782 \text{ moles } CO_2$$

Step 4: Find the moles of metal carbonate

$$0.008782 \text{ mols } CO_2 \times \frac{1 \text{ mol metal carbonate}}{1 \text{ mol } CO_2} = 0.008782 \text{ mols metal carbonate}$$

Step 5: Find the molar mass of the metal carbonate

$$\frac{1.0100 \text{ g}}{0.008782 \text{ mols}} = 115.1 \frac{\text{g}}{\text{mol}} \text{ sodium carbonate}*\frac{1}{2}\text{hydrate}$$

Procedure

1. Weigh a clean, dry 125 mL Erlenmeyer flask. Record this mass in your data sheet.

2. Add 1.0-2.0 g of your metal carbonate to the Erlenmeyer flask and reweigh. Record this mass in your data sheet.

3. Collect a clean, dry Styrofoam cup. Measure approximately 20 mL of 6.0 M HCl(aq) and pour it carefully into the cup, being sure to not spill.

4. Place the Erlenmeyer flask from Step 2 on the balance. Carefully set the cup from Step 3 on the top. You may need to open the top door on the balance. Do not let the cup or flask rest on any of the balance's doors. Record the mass in your data sheet.

5. At your bench, slowly pour the HCl into the Erlenmeyer flask. If you pour too quickly, the reaction might foam over the top of the flask. Do not spill.

> Be careful! The reaction will bubble and fizz. Go slowly and do not allow your flask's contents to foam over!

6. After the bubbling subsides, swirl the flask to mix the contents. The reaction is complete when the mixture stops fizzing and you have a clear solution. Gently blow into the flask to push the $CO_2(g)$ out the top. Do not inhale over the flask. Continue to blow into the flask for about one minute to make sure all the CO_2 has been pushed out of the flask.

> HCl releases corrosive fumes that should not be inhaled.

7. Place the Erlenmeyer flask and contents on the balance. Carefully set the empty cup on top and record the weight in your data sheet.

8. Use baking soda to neutralize the excess HCl that remains in the flask. Slowly add small scoops of baking soda to the flask. Swirl the contents of the flask to mix. Be careful: the mixture will foam up as it reacts. Continue until the mixture stops fizzing when more baking soda is added.

9. Dispose of the neutralized solution in the sink with running water. Rinse out the flask with deionized water. Dry the outside of the flask. You do not need to dry the inside of the flask.

10. Repeat Steps 1-9 for a second trial. Wash and dry all equipment used. Your two trials should have an average molar mass near one of the values shown in Table 1.

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Experiment 5—Data Sheet

Name: ____

Unknown #: ___________________________________

Data

	Trial 1	Trial 2
1. Mass Erlenmeyer flask (g)	________________	________________
2. Mass Erlenmeyer flask and unknown (g)	________________	________________
3. Mass flask, unknown, cup, and HCl before reaction (g)	________________	________________
4. Mass flask, unknown, cup, and HCl after reaction (g)	________________	________________

Calculations

	Trial 1	Trial 2
5. Mass unknown (g)	________________	________________

Show calculation:

	Trial 1	Trial 2
6. Mass CO_2(g) lost (g)	________________	________________

Show calculation:

	Trial 1	Trial 2
7. Moles CO_2(g) (mols)	________________	________________

Show calculation:

	Trial 1	Trial 2
8. Moles unknown (mols) *Show calculation:*	________	________
9. Molar Mass unknown (g/mol) *Show calculation:*	________	________

10. Average Molar Mass of unknown (g/mol) ________
    Show calculation:

11. Identity of unknown (choose from Table 1) ________

12. True value for the molar mass of the unknown (g/mol) ________
    (This value will be given to you by your instructor.)

13. Percent error for molar mass of the unknown (%) ________
    Show calculation:

Experiment 5—Post-Lab Assignment

Name: ______________________________________

1. Give three experimental reasons why your average molar mass may differ from the true value.

2. A student performed the identical experiment as described to determine the identity of an unknown metal carbonate. They completed every step perfectly *except* they did not blow out the dense CO_2(g) after the reaction. Would this change the recorded mass of the flask, sample, cup, and HCl after reaction? If so, would the new value be higher or lower? Explain.

3. How would the error described in the previous question change (too high, too low, no effect) the calculated molar mass of the unknown? Explain.

4. A student performed the identical experiment as described to determine the identity of an unknown metal carbonate. They completed every step perfectly *except* they had a small piece of glass in the Erlenmeyer flask that remained in the flask from the beginning and through the entire experiment. Would this error make the calculated molar mass of the unknown inaccurate? If so, would the incorrect value be higher or lower than the correct one? Explain.

Experiment 5—Pre-Lab Assignment

Name: ____

For all calculations, show all work and draw a box around the final answers.

1. Why are you instructed to use no less than 1.0 g and no more than 2.0 g of sample?

2. A student obtained the following data from this experiment:

Mass flask (g)	75.0235 g
Mass flask + unknown (g)	76.8912 g
Mass flask, unknown, cup, and HCl before reaction	102.3649 g
Mass flask, unknown, cup, and HCl after reaction	101.5894 g

a. Calculate the molar mass in g/mol of the student's unknown.

b. According to Table 1, which metal carbonate is the unknown?

c. Write the balanced chemical equation for the reaction between the student's unknown and HCl.

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