ESSENTIAL EXPERIMENTS
for
CHEMISTRY

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Sample Experiment

Predicting and Measuring the Mass of NaCl Produced

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Predicting and Measuring the Mass of NaCl Produced

Making predictions of the outcomes of chemical reactions is an integral part of the scientific process. Not only is it important to be able to predict the identity of chemicals that will be produced but you must also be able to predict the quantities of those chemicals. For the latter we use stoichiometry which involves performing calculations on chemical reactions. We can find examples of its use in many industrial applications. Stoichiometry allows chemists to determine how much iron is in a barge of iron ore, how much sulfur dioxide is in polluted air, or whether a new batch of fertilizer contains all of the nitrogen, phosphorus, and potassium listed on the label.

In this experiment you will study two common reactions between acids and carbonates. In Reaction 1, hydrochloric acid (the acid present in stomach acid) and sodium hydrogen carbonate (sodium bicarbonate or baking soda) will be mixed. The reaction is immediate, impressive, and simple, yet it occurs in two steps. Two products initially result: table salt and carbonic acid, but the carbonic acid is quite unstable and instantly decomposes into water and carbon dioxide gas. It is the fizzing of the carbon dioxide gas that is most noticeable during the progress of this reaction. In the language of chemistry, this reaction can be best described as:

Reaction 1: $HCl(aq) + NaHCO_3(s) \rightarrow NaCl(aq) + H_2O(l) + CO_2(g)$

In Reaction 2, hydrochloric acid and sodium carbonate (washing soda) will be mixed. Reaction 2 should behave similarly to Reaction 1 but Reaction 2 is described by the following skeletal (unbalanced) equation:

Reaction 2: $HCl(aq) + Na_2CO_3(s) \rightarrow NaCl(aq) + H_2O(l) + CO_2(g)$

In both reactions, you will be using an excess of hydrochloric acid in order to ensure that the carbonates react completely. In each case, the excess hydrochloric acid solution can be easily boiled away, leaving only solid sodium chloride in the reaction vessel. At the end of the experiment, you will measure the final mass of the product. Boiling away the excess acid solution and obtaining the dry salt requires more time than is normally available in one lab period so this experiment will be typically carried out over two days.

It is interesting to note that Reaction 1 describes a way of neutralizing excess stomach acid (heartburn). Of course, this remedy should only be performed with the advice of a physician who would recommend proper substances and dosages. It is also interesting to note that such medically recommended dosages are determined through stoichiometry!

OBJECTIVES

1. to observe the reactions between hydrochloric acid and sodium hydrogen carbonate, then hydrochloric acid and sodium carbonate
2. to predict the mass of sodium chloride that should be produced in each reaction
3. to measure the actual mass of sodium chloride produced in each reaction
4. to determine the percent yield of sodium chloride in each reaction

SUPPLIES

Equipment
centigram balance
hot plates (for class use in fume hood)
2 Erlenmeyer flasks (250 mL)
beaker (250 mL)
plastic teaspoon
dropping pipet (1 – 3 mL)
safety goggles
lab apron

Chemical Reagents
1.0*M* hydrochloric acid, HCl
sodium hydrogen carbonate, $NaHCO_3$
sodium carbonate, Na_2CO_3

PROCEDURE

Part I: Reactions 1 and 2 (Day 1)

1. Put on your lab apron and safety goggles.
2. Obtain two clean, dry 250 mL Erlenmeyer flasks, identify them with your name, and then number them 1 and 2. Use the centigram balance to measure the empty flasks' masses. Record these values in your copy of Table 1 in your notebook.

Reaction 1: HCl and $NaHCO_3$

3. Place about half a level teaspoon of powdered sodium hydrogen carbonate in flask #1. Using too much powder will spoil your results. Find the combined mass of the flask and its contents and record this value.
4. Place about 150 mL of 1.0*M* hydrochloric acid in a 250 mL beaker. Using a dropping pipet, slowly add a pipette full of the acid to the flask containing the sodium hydrogen carbonate. Be careful to add the acid slowly so that the reaction bubbling does not force some the reactants out of the flask. Swirl the flask to ensure proper mixing. Do not add any more acid than is necessary since you will need to remove the excess acid solution later. Continue adding acid one pipet at a time until the bubbling stops and no white solid remains.

CAUTION

Hydrochloric acid is corrosive to skin and clothing. Wash spills off immediately using plenty of water. Notify your instructor.

Reaction 2: HCl and Na_2CO_3

5. Repeat Steps 3 and 4 but this time use flask #2 with sodium carbonate.

CAUTION

An operating fume hood must be used when evaporating the excess hydrochloric acid. The hydrogen chloride vapor that is produced during heating is extremely irritating and corrosive to skin, eyes and nasal passages.

Evaporating the Excess Hydrochloric Acid

6. Several hot plates will be set up in the fume hood. Place both Erlenmeyer flasks on one of the hot plates (see Figure 6B-1) and leave them there. The hot plates will be shared with other students and the Erlenmeyer flasks will be monitored to dryness by your instructor. This activity will not be completed in this laboratory period.

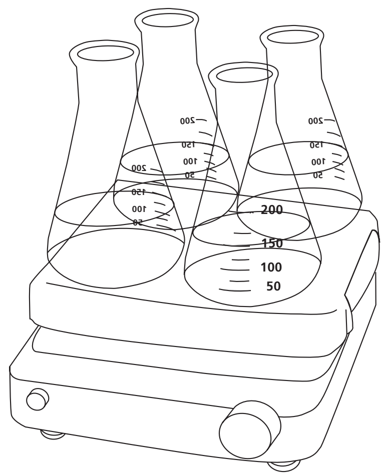

Figure 6B-1 *Evaporating solutions to dryness in a fume hood*

7. Clean up and put away all the other apparatus.
8. Before leaving the laboratory, wash your hands thoroughly with soap and water.

Part II: Measuring the Masses of NaCl Produced (Day 2)

1. Obtain your 2 Erlenmeyer flasks from your instructor and a centigram balance.
2. What remains in both Erlenmeyer flasks is now simply the dry NaCl(s) (table salt). Measure and record, in your copy of Table 2, the masses of both flasks containing the dry solid.
3. Wash out the flasks and put all equipment away.
4. Before leaving the laboratory, wash your hands thoroughly with soap and water.

REAGENT DISPOSAL

Rinse all solutions down the sink with copious amounts of water. Any solid waste should go into the designated waste container.

POST LAB CONSIDERATIONS

In each of the two reactions in this experiment, three products are formed: carbon dioxide, water, and sodium chloride. The only product that remains in the flask after heating is solid sodium chloride (table salt). Before attempting any stoichiometric calculations, you will need to determine the balanced equation for the reactions so that you can correctly predict the amounts of products that should have formed.

Chemists are often interested in how well they did in manufacturing a certain chemical. One way of measuring this is to calculate the percent yield of that particular chemical by using this formula:

$$\text{Percent yield} = \frac{\text{actual mass produced}}{\text{theoretical mass produced}} \times 100\%$$

EXPERIMENTAL RESULTS

Table 1

Part I, Reaction 1: HCl and $NaHCO_3$ (Day 1)		Part I, Reaction 2: HCl and Na_2CO_3 (Day 1)	
Mass of Erlenmeyer flask #1	COMPLETE IN YOUR NOTEBOOK	Mass of Erlenmeyer flask #2	COMPLETE IN YOUR NOTEBOOK
Mass of Erlenmeyer flask #1 + $NaHCO_3$		Mass of Erlenmeyer flask #2 + Na_2CO_3	

Table 2

Part II: Measuring the Masses of NaCl Produced (Day 2)		
Reaction 1	Mass of Erlenmeyer flask #1 + dry solid NaCl (after the reaction)	COMPLETE IN YOUR NOTEBOOK
Reaction 2	Mass of Erlenmeyer flask #2 + dry solid NaCl (after the reaction)	

ANALYSIS OF RESULTS

Reaction 1

1. Copy the chemical equation for Reaction 1 from the introduction and check to see if it is balanced.
2. On Day 2, only NaCl(s) remained. What happened to the other two products?
3. From Part I Results, determine the mass (in grams) of $NaHCO_3$ reacted.
4. Using the principles of stoichiometry you have learned in class, calculate the theoretical mass of NaCl that should have been produced from the mass of $NaHCO_3$ reacted.
5. From Part II Results determine the actual mass of NaCl that was produced.
6. Consult the Post Lab Considerations and calculate the percent yield of NaCl.

Reaction 2

7. Repeat Anaylisis 1 to 6 for Reaction 2.
8. What are some possible reasons for a yield that is not 100%?

FOLLOW-UP QUESTIONS

1. A similar reaction to those performed in this experiment occurs between hydrochloric acid solution (HCl) and solid limestone (calcium carbonate). Write a balanced equation for this reaction.
2. If 6.00 g of limestone reacted in Follow-up Question #1, what theoretical masses of the following would be produced?

   a. calcium chloride
   b. carbon dioxide
   c. water
3. In terms of stoichiometry, why was it important to have a balanced chemical equation for Follow-Up Question #2?

CONCLUSION

State the results of Objective 4.