Stoichiometry of the Decomposition of Potassium Bicarbonate

Introduction

Stoichiometry, at its most basic level, is the calculation of the amount of one compound in a chemical reaction based on the amount of another compound in the reaction. Such calculations require the correct molar ratios based on a balanced reaction and molar masses (or molecular weight) of compounds in the reaction. Chemists use stoichiometry whenever they are interested in doing a chemical reaction: taking the time to perform stoichiometric calculations before going into the lab saves time and money.

Stoichiometry also helps chemists identify the products obtained in a chemical reaction. The purpose of this experiment is for you to explore this use of stoichiometry. Potassium bicarbonate, a colorless solid, will be heated and undergo a decomposition reaction. Invisible gases will be released when the reactant is heated to a sufficiently high temperature and a new, colorless solid will be produced. Several decomposition reactions are proposed (see below), each with different potential products. These potential (unbalanced!) reactions are

Reaction 1: $KHCO_3$ (s) → K_2CO_3 (s) + H_2O (g) + CO_2 (g)

Reaction 2: $KHCO_3$ (s) → KOH (s) + CO_2 (g)

Reaction 3: $KHCO_3$ (s) → $KCHO_2$ (s) + O_2 (g)

Your task is to determine which of the three reactions is actually occurring and therefore the identity of the decomposition products. This approach will work best if the product masses measured experimentally are within a few percent of the theoretical amounts, so be sure to apply careful technique.

Procedure

Clean and dry a crucible and lid. Make sure that the lid fits! Assemble a ring stand with a clay triangle lying on top of the iron ring. Place a Bunsen burner directly beneath the clay triangle, and adjust the ring so that it is approximately 1½ inches above the burner.

Obtain the mass of the dry crucible and lid. Be sure to tare the balance before taking each measurement. Weigh out 1.2xx g of $KHCO_3$ (potassium bicarbonate, a.k.a. potassium hydrogen carbonate) on a piece of paper. Record all the decimal places displayed on the balance when you measure masses. Describe the appearance of the potassium bicarbonate in your lab notebook, then pour it into the crucible. Cover the crucible with the lid, and weigh again.

Seat the crucible, lid and its contents securely into the clay triangle. Light the Bunsen burner and adjust the flame height so that the hottest part of the flame (how will you identify this?) touches the bottom of the crucible. Heat the crucible for ten minutes. Turn off the flame and remove the crucible and lid to a cooling pad. Let it cool for ten minutes, then record the mass of the crucible, lid and its contents. Heat the crucible and lid for another five minutes, then cool again and record the mass of the crucible, lid and powder. If the masses are within 0.010 g of one another, then the reaction is complete. If not, heat again for five minutes, cool, and reweigh. Use the last measurement as your actual product yield.

When the reaction is finished (subsequent masses are within 0.010 g), describe the appearance of the decomposition product in your lab notebook. Dispose of your decomposition product by pouring it down the drain with plenty of water. Clean and dry the crucible and lid, and repeat the procedure.

Scientific Communication: The Notebook and the Experimental Procedure Section

The goal of the notebook and Experimental Procedure sections is to communicate your particular methods and observations to an audience who understands scientific vocabulary and concepts, but is not personally familiar with your methods. In other words, write for a person who has never seen this lab handout or performed this experiment.

The Lab Notebook: Your notebook is a narrative record of everything you did in the lab. Record all procedural steps in complete sentences as you perform them; do not come to lab with a pre-written procedure. If you make a mistake, cross it out using a single line and keep writing. Be sure to record all of your procedural steps, observations, and calculations (if performed in the lab) in your lab notebook.

Lab Notebook Points (up to 7)

- 1 pt for the requested heading information
- 1 pt for submitting the pages
- 1 pt for legibility
- 2 pts for providing an adequate summary of procedure and results
- 2 pts for agreement between your notebook and report sheet/formal report

The Experimental Procedure Section: This consists of several paragraphs that describe what you actually did in the lab. A good rule of thumb is that each major step in the procedure marks the beginning of a new paragraph. This section must provide enough detail so that a person who has never seen the lab handout before could take your Experimental Procedure section into the lab and do exactly what you did, just by reading what you wrote. Do not copy the procedure from the handout; rather, summarize what you recorded in your lab notebook.

The tense and voice of the Experimental Procedure section are different from the lab handout. Use **third person, past tense, passive voice**. Past tense and passive voice is the standard scientific writing style. Third person means that you never refer to yourself. Do not use "I," "we," or "you." Some common errors, along with explanation and correction, are:

- **INCORRECT:** "I heated the flask." Although this is past tense, it is in first person. **CORRECT:** "The flask was heated."
- **INCORRECT:** "Stir for 30 minutes." This sentence is an imperative (command). Instead, describe what you did. **CORRECT**: "The solution was stirred for 30 minutes."
- **INCORRECT:** "You should add 5.0 mL of 0.5 M sulfuric acid slowly." This is both imperative and in second person. **CORRECT**: "5.0 mL of 0.5 M sulfuric acid was added slowly."
- **INCORRECT:** "5 grams of sodium chloride was measured." This number was probably copied from the handout (no!) and does not properly reflect the precision of your instrument. Copy exact measurements from your lab notebook to your report. **CORRECT:** "5.026 grams of sodium chloride was measured using a milligram balance."

Experimental Procedure Points (up to 3)

- 3 – Each major step is described in well-constructed, separate paragraphs or sections using correct verb tense and voice; experimental details are in your own words and not copied from the handout; actual reagent amounts, times, and temperatures are reported.
- 2 – As in level 3, except missing separate sections or paragraphs; verb tense and voice are inconsistent or wrong; and/or paragraph and sentence structure are poor.
- 1 – As in level 2, as well as portions of procedure do not reflect what you did.
- 0 – Verb tense and voice are inconsistent; procedure was copied from text; amounts of reagents, times and temperatures are not mentioned.

Report Sheet #1 – Decomposition of Potassium Bicarbonate

Name: ____ **Due date:** _______________

Unless otherwise indicated, all non-numerical answers should be written as grammatically-correct sentences (not lists or phrases). All numerical answers, whether they are measured or calculated quantities, must be expressed to the appropriate number of significant figures.

Make sure that your lab pages clearly describe your observations and laboratory procedure. This means that any information present in your answers below should also be present in your notebook. Failure to do this will keep you from earning full credit on your lab pages.

Introduction (3 pts total)

1. (1 pt) In 1-2 grammatically-correct sentences, define a decomposition reaction.

2. (2 pts) According to your results, what was/were the product(s) of the decomposition of potassium bicarbonate? In 1-2 sentences, explain how your lab data supports this conclusion.

Experimental Procedure

3. (3 pts) Attach a typed and double-spaced description of your experimental procedure, written in third person passive voice, giving specific details so that someone else could reproduce the experiment without knowing about the lab handout. This should take no more than half a page. Be sure to include the exact amounts of potassium bicarbonate used in each trial, as well as the heating time that was necessary to complete the reaction.

Results (8 pts total)

4. (1 pt) Describe the visual change(s) observed in the solid reactant when it decomposed to a solid product.

5. (3pts) Fill in the table with your own data and calculations. Also, in the blank spaces in the first row of the table, provide the missing units for the indicated quantities. Report the entries in your table to the appropriate number of significant figures.

Reaction number	**Amount of reactant ($KHCO_3$)** **Units: _______**	**Actual yield*** **Units: ______**	**Expected solid product** **Units: ____**	**Theoretical yield of solid product** **Units: ____**	**Percent yield** **Units: ____**
Trial 1, Reaction 1			K_2CO_3		
Trial 1, Reaction 2			KOH		
Trial 1, Reaction 3			$KCHO_2$		
Trial 2, Reaction 1			K_2CO_3		
Trial 2, Reaction 2			KOH		
Trial 2, Reaction 3			$KCHO_2$		

*Your actual yield is the amount of solid product you obtained. Thus, it should not change between reactions within the same trial. This is why there are only two places to enter actual yield in the table.

6. (1 pt) Using your Trial 1 data, show the calculation for the actual yield of solid product. Report your answer to the correct number of significant figures. Indicate how many significant figures are in each piece of data used in your calculation and state how you decided how many significant figures there are in your final answer.

7. Using the amount of $KHCO_3$ measured in the first trial, determine the theoretical yield of solid product for each of the three potential decomposition reactions (K_2CO_3, KOH, or $KCHO_2$). Report your answer to the correct number of significant figures. Indicate how many significant figures are in each piece of data or stoichiometric ratio used in your calculation and state how you decided how many significant figures there are in your final answer.

(0.5 pt) Theoretical yield calculation for K_2CO_3:

(0.5 pt) Theoretical yield calculation for KOH:

(0.5 pt) Theoretical yield calculation for $KCHO_2$:

8. Using the actual yield from question 6 and the theoretical yield from question 6, determine the percent yield for each of the potential products in Trial 1, Reaction 1. Report your answer to the appropriate number of significant figures. Indicate how many significant figures are in each piece of data used in your calculation and state how you decided how many significant figures there are in your final answer.

   (0.5 pt) Percent yield calculation if the product were K_2CO_3:

   (0.5 pt) Percent yield calculation if the product were KOH:

   (0.5 pt) Percent yield calculation if the product were $KCHO_2$:

Discussion (9 pts total)

9. (2 pts) Use your observations from the Results section to explain how you know that a chemical reaction occurred. Then, use your results to explain how you know that the decomposition reaction was finished.

10. (2 pts) In a well-written paragraph, explain exactly how you used your calculations of theoretical yield and percent yield to determine which of the proposed reactions is correct. You can type this and attach it to this sheet, if desired.

11. (2 pts) What was your percent yield for the reaction you chose as the correct decomposition reaction? (Note: an acceptable choice should have a percent yield of greater than 90%). Propose one **experimental** reason why you did not achieve a 100% yield.

12. The next several questions are intended to help you evaluate your experimental precision.

    a. (1 pt) What measurement(s) did you make to achieve your experimental goal, and what tool(s) did you use to make that/those measurement(s)?

    b. (1 pt) List your measured data, and state how many significant figures are in each of them. (Note the difference between measured and calculated data here – you should only list measured quantities.)

    c. (1 pt) Another scientist performed this experiment using a centigram balance, which is accurate to the nearest 0.1 g. This means that this person could report a mass of 1.15 g or 1.25 g, but not 1.200 g. Whose data is more precise: yours, or the other scientist's? Explain how you came to your decision.

Chemistry 111L

Name ___________________________

Prelab Worksheet

Stoichiometry of $KHCO_3$ Decomposition

T8:00 T12:30 T6:30 W3:00 R8:00 R12:30 R6:30 circle your regular lab time

Davis Klein Osborne circle your **lecture** instructor

1. Balance the following three chemical equations by filling in the blanks:

   Reaction 1: ___$KHCO_3$ (s) → ___K_2CO_3 (s) + ___H_2O (g) + ___CO_2 (g)

   Reaction 2: ___$KHCO_3$ (s) → ___KOH (s) + ___CO_2 (g)

   Reaction 3: ___$KHCO_3$ (s) → ___$KCHO_2$ (s) + ___O_2 (g)

2. Calculate the molar mass of $KHCO_3$ using the periodic table.

3. For Reaction 3, if you start with 1.000 g of potassium bicarbonate, what is the theoretical yield (in grams) of potassium formate, $KCHO_2$? Show your calculations.

4. For Reaction 2, what substance is being released during the reaction (heating time)?

5. What does it mean to tare a balance?