Name: ____

Chemistry 117 Laboratory

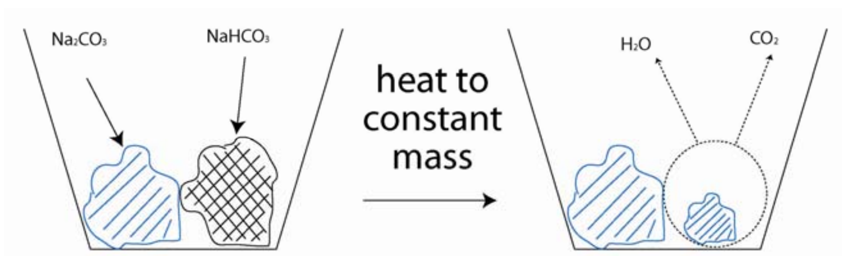
University of Massachusetts Boston

DETERMINATION OF THE COMPOSITION OF A MIXTURE

PRELAB ASSIGNMENT

The following problems are similar to calculations you will do and questions you will answer based on your own experimental data once you complete this experiment. After reading the Introduction on pages 3-5, answer questions 1-4 and bring them to lab with you. Show your work.

A mixture of sodium carbonate and sodium bicarbonate is heated. Sodium carbonate does not undergo a chemical reaction.



The sodium bicarbonate decomposes into sodium carbonate, carbon dioxide and water. Note that while in the cartoon the sodium carbonate and sodium bicarbonate are separated, in reality they will be mixed together.

1. Write a balanced chemical equation for the reaction that occurs. Remember that only one of the substances reacts (see cartoon above)!

2. What is the theoretical atom economy of this reaction? Sodium carbonate is the desired product and water and carbon dioxide are the undesirable wastes.

3. A student heats 5.128 g of the sodium carbonate/sodium bicarbonate mixture to a constant mass of 4.256 g. Determine the mass of sodium bicarbonate present in the mixture.

4. What is the percent by mass of sodium bicarbonate in the mixture, based on your answer to #3 above?

Answers: 1) coefficients of the correctly balanced reaction are 2-1-1-1 2) 63.08 3) 2.362 g, 4) 46.05%

Introduction

Green chemistry is a relatively new approach to chemical production and research in chemistry. The principles of green chemistry emphasize the reduction of hazards to human health and the larger environment as well as the conservation of nonrenewable natural resources, like petroleum. Green chemists achieve these goals through informed design of chemicals and chemical processes. They use their extensive knowledge of chemistry to create substances that serve a current need in industry or society and are safe to produce, can be produced without creating excess waste, and do not harm people or other organisms once they are no longer in use. Green chemistry has the power to transform all areas of chemistry into a far safer enterprise, while simultaneously challenging widely held perceptions that chemistry on the large scale is a polluting, "dirty" industry and a drain on limited natural resources. This approach to chemistry is exciting, modern, and ethically conscious.

Many experiments used in student laboratory courses are not "green." Some use toxic materials, others create excess waste, and still others use unnecessary amounts of natural resources. Some might do all three or may violate other tenets of green chemistry. A green chemistry approach to teaching laboratory chemistry meets the same goals as a more traditional approach. Students still do experiments that teach the same concepts, techniques, and skills, but the experiments use green materials and processes.

In this experiment, you will learn about the mass and mole relationships of reactants and products in a chemical reaction, and you will practice communicating with other students in the laboratory both orally and in writing in the way that scientists do. The experiment has been designed in accordance with green chemistry principles. All solid wastes produced in this experiment will be collected and used again next semester for the same experiment. The only gaseous wastes generated by the reaction in the experiment are carbon dioxide and water, which are not harmful.

Green chemistry is based on twelve overarching principles. Three of these principles are addressed in this experiment. **Prevention** is an extremely important part of the green chemistry philosophy. One of the main things that distinguishes green chemistry from the environmental chemistry of the past is the latter's focus on treatment and cleanup of waste after it is created. Very often, current (non-green) cleanup efforts involve merely placing hazardous waste in containers for indefinite storage or simply diluting them with water or other safe substances and then releasing them into the environment. Frequently these policies of containment and dilution fail because of spills, long-term build-up of toxic materials in the environment, and other problems. By contrast, green chemistry emphasizes the crucial role of prevention as an easier, cheaper and ultimately safer way of avoiding harm from chemical waste. After all, if hazardous waste is never created, then it never has to be stored, treated, or otherwise dealt with. There are often many different ways of creating a chemical to serve a particular purpose. Green chemists consider all the alternatives available, and the long-term effects of each alternative, before selecting a chemical reaction to carry out.

Atom economy is a very important measure used in assessing how "green" a chemical process is. Although the atom economy calculation is usually applied to organic synthesis processes, it can be calculated for any chemical reaction. All chemical reactions have the form

$$\text{Reactants} \rightarrow \text{Products}$$

The products of the reaction can either be desired products or undesirable waste. Green chemistry seeks to minimize undesirable waste (or not generate it in the first place, if possible). You can think of a reaction instead as

$$\text{Reactants} \rightarrow \text{(Desirable Products)} + \text{(Undesirable Waste)}$$

The atom economy calculation measures what part of the original input is converted to desirable products. In essence, atom economy measures how well the process conserves input.

$$\text{Atom economy} = \frac{\text{Mass of all desired products}}{\text{Mass of all reactants}} \times 100\%$$

Atom economy can be calculated from actual laboratory data or it can be a theoretical prediction. The theoretical atom economy for a reaction can be calculated using molar masses instead of actual masses measured in the laboratory. For example, for the reaction

$$Fe_2O_3 + 3\ CO \rightarrow 2\ Fe + 3CO_2$$

the desired product is iron metal, and the undesirable waste is carbon dioxide.

The theoretical sum of the molar masses of the reactants is:

$$\begin{aligned}
&\text{Mass of all reactants}\\
&\quad = \text{mass of } 1\,mol \text{ of } \mathrm{Fe_2O_3} + \text{mass of } 3\,mol \text{ of CO}\\
&\quad = \left(1\,mol\ \mathrm{Fe_2O_3} \times \frac{159.7\ g}{mol}\right) + \left(3\,mol\ \mathrm{CO} \times \frac{28.02\ g}{mol}\right)\\
&\quad = 243.8\ g
\end{aligned}$$

The theoretical mass of the desired product is:

$$\begin{aligned}
&\text{Mass of desired product}\\
&\quad = \text{mass of } 2\ mol \text{ of Fe}\\
&\quad = 2\ mol\ \mathrm{Fe} \times \frac{55.85\ g}{mol}\\
&\quad = 111.7\ g
\end{aligned}$$

Therefore, the theoretical atom economy is:

$$\begin{aligned}
\text{Atom economy} &= \frac{\text{Mass of all desired products}}{\text{Mass of all reactants}} \times 100\%\\
&= \frac{111.7\ g}{243.8\ g} \times 100\% \quad = 45.82\%
\end{aligned}$$

In principle, a reaction with higher atom economy is preferable to one with lower atom economy, because higher atom economy means less waste produced for a given amount of product produced. However, it is important to realize that atom economy is only one measure of a reaction's greenness. Atom economy tells what fraction of the original materials ends up in the desired product, but says nothing about what the original materials or desired product are and whether they are green or not. A reaction that uses highly toxic materials can have high atom economy, and that reaction still would not be green.

The **use and production of non-toxic materials** whenever possible is another vital principle in green chemistry. The toxicity of a material is a measure of both the potential harmful effects of that material on people or other organisms, and the amount of the material required to produce harm. A small amount of a highly toxic material can severely harm or kill a person, while a non-toxic material causes no harm to people even in fairly large doses. Different substances range over a continuum from extremely toxic to entirely non-toxic. The toxicity of many thousands of substances has been studied. Green chemists use this information to select the reactants and products that are lowest in toxicity while still allowing them to achieve their goals. In the past, chemists frequently considered many factors when developing a process, such as availability and cost of materials, but they often ignored toxicity. By contrast, green chemists are mindful of toxicity at each step of any process.

Putting green chemistry into practice is more complex than just understanding these three principles, as well as the nine other fundamental principles not discussed here. Often, one of the alternative chemical reactants and pathways to a particular goal is not obviously preferable to other options in terms of greenness. For example, one choice may be better in terms of atom economy, while another is preferable regarding the toxicity of wastes. In such cases, green chemists carefully analyze the relative merits and drawbacks of each choice before making decisions.

References

Anastas, P.T. and Warner, J.C. (1998). Green Chemistry: Theory and Practice. New York: Oxford University Press.

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Kirchhoff, M., and Ryan, M.A. (Eds). (2002) Greener Approaches to Undergraduate Chemistry Experiments. Washington DC: American Chemical Society.

Lancaster, M. (2002). Green Chemistry: An Introductory Text. Cambridge, UK: Royal Society of Chemistry.

Parent, K. and Kirchoff, M. (Eds). (2004) Going Green: Integrating Green Chemistry into the Curriculum. Washington DC: American Chemical Society.

LABORATORY TASK

Your task during the laboratory period is to attempt to replicate the work of a student who did this experiment in this class last year, ***using the same unknown sample as you will use***. That student's lab report will be provided on the day of the lab for you to use as you plan and carry out your experiment. Other students in your class will receive the lab reports of different students, and thus they may have different information than you do. In order to have a better understanding of the experiment, you and your classmates may discuss information with each other during the lab period, but you may not read each other's lab reports.

Communicating science is a critical part of doing science. Scientists engage in communication when they discuss their experiments informally at meetings or over the phone or email, present their research formally at conferences, and publish their work in peer-reviewed journals. Lab reports that students write in science courses are intended to help students learn how to communicate science in writing. Questions 1-3 below ask you to evaluate some aspects of scientific communication that you engaged in as part of this laboratory exercise. There is a standard format for scientific articles in journals. Ordinarily, the format includes the following sections:

- Introduction – includes a justification for why the work is important, and a review of relevant prior work by others
- Materials and Methods
- Results – includes data and calculations
- Discussion – possible errors are analyzed, implications of the results are explained, and future directions for the work are projected
- Conclusion

Question 4 is a typical component of a Results section. Question 5 asks you to provide the kinds of explanations typical in Discussion sections of articles. Answer the following questions and turn them in by the end of the laboratory period, along with your data and calculations.

IMPORTANT SAFETY NOTE: Do not ever heat a closed container!

Questions to Answer

1) How could the student whose report you received have improved his or her lab report?

2) Why do scientists, and science students like yourself, write lab reports?

3) What did you learn from talking with other groups during the lab that you would not have been able to learn if you weren't able to talk with other groups?

4) Use your data to calculate the following quantities. Show calculations to support and explain your answers:
   a) The total **mass of water and carbon dioxide** lost in each trial.
   b) The **mass of water** lost in each trial.
   c) The **moles of water** lost in each trial.
   d) The **mass of sodium bicarbonate** originally present in the sample in each trial.
   e) The **percent composition by mass** of the original sample in each trial.

5) How does this experiment illustrate the Green Chemistry principles of *prevention* and *use and production of non-toxic materials*?

Each student must turn in his or her own lab report by the end of the laboratory period.

Don't forget to ***turn in pages 7-10 and your pre-lab*** as your lab report before you leave the laboratory.

Name: ____

Lab Partner(s): ____

Number of Lab Report Provided (in upper right hand corner): 1 2 3 (circle one)

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Use this space to present your data.

Name: ____

Lab Partner(s): ____

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