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Future Fuels from Forests Unit:
The Chemistry of Making Ethanol from Cellulose

Grade/Subject: Gr. 10-11 / Chemistry

Unit Overview

This unit is inquiry-based to encourage student thought and discovery. Students will have had prior experience with similar experiments as it will come near the end of the course after the study of thermodynamics and leading into the study of kinetics and catalysts. The major goal of this unit is to have students carry out a chemical experiment while seeing the relevance of the chemistry concepts they learn in class. This unit centers around a partially student-designed experiment investigating the effects of changing variables on the hydrolysis of cellulose. Students will then attempt to ferment and distill their product to obtain ethanol. This investigation will be set in the context of the current challenges faced by scientists in producing cellulosic ethanol. Students will learn some of the fascinating chemistry involved in this cutting-edge area of science and come to appreciate how chemistry might be used to help solve some of society's future fuel problems.

Sources

Shonnard, D.R., Jensen, J.R., Morinelly, J. 2008. "Biofuels from Forest Resources: Women in Engineering Program" (lab handout). Michigan Technological University. This is a lab protocol that provided some technical information for the lab experiment I developed for this unit.

Lab-Aids Kits. "Modeling and Comparing Fossil Fuel and Biofuel Combustion". Retrieved from www.sepup.com This is a lab kit using molecular models that is being utilized in this unit.

U.S. Department of Energy. 2006. *Breaking the Biological Barriers to Cellulosic Ethanol: A Joint research Agenda.* This is a pre-course reading on the chemical aspects of cellulosic ethanol production, and some of the material was incorporated into a class lecture.

Shonnard, D.R. "Technology for Processing Tree Biomass to Energy" (PowerPoint lecture given on 7/9/2008). Michigan Technological University. This material was incorporated into a class lecture.

Myers, R.T., Oldham, O.B., Tocci, S. 2004. Chemistry. This is the students' class textbook, and material on catalysts was used in class lecture.

Learning Objectives

Students will be able to:

1. Explain the significance of cellulosic ethanol technology.
2. Use previous knowledge of bond energy and stoichiometry to compare the combustion products of different fuels.
3. Identify some of the chemical processes and barriers involved in cellulosic ethanol production.
4. Design a single variable experiment in order to examine the effects of a catalyst under different conditions.
5. Interpret data and make conclusions, including constructing particle models, using experimental results.

Wisconsin Model Academic Standards Addressed:

Science Standards
Standard C: Science Inquiry
C.12.2 Identify issues from an area of science study, write questions that could be investigated, review previous research on these questions, and design and conduct responsible and safe investigations to help answer questions

C.12.4 During investigations, choose the best data-collection procedures and results, and materials available, use them competently, and calculate the degree of precision of the resulting data

C.12.5 Use the explanations and models found in the earth and space, life and environmental, and physical sciences to develop likely explanations for the results of their investigations

Standard G: Science Applications
G.12.2 Design, build, evaluate, and revise models and explanations related to the earth and space, life and environmental, and physical sciences

Math Standard
Standard F: The student understands and applies the basic concepts of analysis and distributions.
M-F1: Organizes and displays data using simple graphs, tables, complex graphs, tables, and plots.

Unit Timeline

Day 1

After a short introductory class discussion about concerning the reasons for developing alternative fuels, students will work on the activity, "Modeling and Comparing Fossil Fuel and Biofuel Combustion" that makes use of molecular models to examine the energy changes and carbon dioxide production during the combustion of different possible fuels. Students will use their prior knowledge of bond energy, molecular structures, and stoichiometry to consider some of the advantages and disadvantages of using each chemical for fuel. They will fill out the worksheet included in this kit.

Assignment: Students will be given two short reports on current developments in the development of alternatives to fossil fuels. There are great articles every week found at www.sciencedaily.com. Since this is a constantly evolving field, and I want students to appreciate this fact, articles will be chosen within a few weeks of this unit being used. Students will read the articles at home and fill out a response sheet. (See attached file.)

Day 2

Class will begin with a 15 minute discussion on the articles assigned and of the conclusions students made from the previous day's activity. (Answers for the calculations done will be provided and any student questions will be answered.)

A 30-35 minute PowerPoint presentation will serve as a lecture on the basic chemistry of producing ethanol from cellulose including how catalysts work. (See attached file).

Assignment: Students will receive the lab handout titled, “Making Ethanol from Cellulose”. (See attached file.) They will be expected to read it and have a plan to test the effects of different pH and on the activity of the cellulases.

Day 3

Students will begin working on the lab, “Making Cellulose from Ethanol”. They will finish Part 1 and leave their test tube in incubators overnight.

Assignment: Students will think of data to be collected and create data tables to use on Day 4.

Day 4
Students will continue working on the lab, “Making Cellulose from Ethanol”. They will finish Part 2 and leave their test tube in incubators overnight.

Assignment: Students will think of data to be collected and create data tables to use on Day 5.

Day 5
Students will finish the lab, “Making Cellulose from Ethanol”. They will begin work on a lab report. They will follow the format listed on the file,

Day 6
Students will be given computer access to work on lab reports. They will be encouraged to share data as long as this data is cited. Reports will be due the following week and students will finish them away fro class.

Unit Assessment

The main assessment tool for this unit will be the attached rubric used to evaluate the lab report done for the investigation of producing cellulosic ethanol. Full credit will be given for both the activity worksheet and the reading response sheet from Day 1 if done completely and with satisfactory effort.

Making Ethanol from Cellulose
Lab

Introduction:

In this lab investigation, you will be attempting to turn cellulose into ethanol to simulate part of the process of turning plant material into fuel. Since plant material contains lignin bound to cellulose which is difficult to separate, you will be using a cellulase mixture that will hydrolyze pure cellulose. This mixture of enzymes contains endogluconase, cellobiohydrolase, and glucosidase. These enzymes act together to break down cellulose and convert it into glucose molecules. Part of your goal will be to investigate how different pH affects the ability of these enzymes. You will design an experiment and collect data that will help you answer this question. You will then take you product and ferment it into ethanol using yeast. Finally, you will distill the fermentation product in order to maximize the ethanol concentration of your end product. You will also have to figure someway of directly or indirectly estimating the amount of ethanol you produced.

Materials Available:

cellulose	cellulases
distilled water	1.0M HCl
rubber stoppers	large test tubes
Buchner funnel	side arm flask
rubber tubing	aspirator
filter paper	pH paper
pH probe	glucose test strips
pipettes	1.0M NaOH
incubator	analytical balance
matches	hydrometer
25 mL graduated cylinder	yeast

Procedure:

Day 1: **Hydrolysis of Cellulose**

1. Measure 25 mL of distilled water and pour into a large test tube.
2. Add 1.0M HCl drop-wise to achieve a pH of approximately 4.5. Use a pH probe or pH paper to determine as precisely as possible what the actual pH is. This is your control.
3. Set up two other test tubes to test the effects of varying pH. Precisely record their pH. Label these with your name and assign them a number.
4. Add 0.1g of cellulases to each test tube and stir to dissolve.
5. Add 2.0g of cellulose to each test tube. Cover with a stopper and shake for 5 minutes.
6. Incubate at 50˚ C for 24 hrs.
7. Set up a data table to enter the amount of glucose produced for each tube. This will be measured in tomorrow's lab.

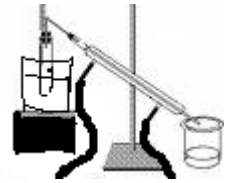
Day 2: **Fermentation of Glucose**

1. Remove test tubes from incubator.
2. Filter contents of test tube using vacuum filtration.

3. Pour your filtrate from into a clean test tube.
4. Repeat steps #3 and #4 with your other test tubes.
5. Test filtrate for glucose concentration using glucose test strips and record your results.
6. Add 1.0M NaOH drop-wise to test tubes until the pH of the mixture is 6.
7. Add 0.1g of yeast powder to test tubes, cover each with a balloon, and shake/swirl for 5 minutes.
8. Incubate at 30˚C for 24 hours.
9. Plan data collection for tomorrow that will give you at least two methods of testing for the amount of ethanol production. These might be direct methods or indirect methods using stoichiometry. Set up data tables to record this data tomorrow. Remember this fermentation is a decomposition of glucose into ethanol and carbon dioxide.

Day 3: **Distillation**

1. Gather any data at this time which could be used to help you calculate how much ethanol was produced.
2. Distill contents of your test tube tubes. Place a two-holed stopper in your test tube. Insert a thermometer into one hole so that it extends into your liquid. Insert a piece of Tygon tubing into the other hole so that it has a good seal. Insert the other end of this tubing into a one-holed stopper that fits a condensing tube. Connect your condensing tube to the cold water faucet using some rubber tubing. Angle your condenser so the distillate will drip into a small beaker. Secure everything in place using a ring stand. Place your test tube in a hot water bath. The boiling point of ethanol is 78.3˚C. (See set-up below.)
3. Test for the presence of ethanol by taking a drop of your distillate and seeing if it floats in small test tube filled with mineral oil. If there is any leftover distillate, test it for flammability.
4. Use your data to determine how much ethanol was produced in each trail. In your lab report, include graphs that clearly show your results form both the hydrolysis step and the distillation and a visual model that represents any ideas you develop explaining why pH had the effect on hydrolysis that it did. You are encouraged to collect other groups' data as long as you cite your sources in your report.



Article Response	**Name:** _____ **Hour:** _____
Title:	**Summary:**
Author:	

Significance:	**Personal Reaction:**

Chemistry
Lab Report Format

The lab write-up should be written using **complete sentences** and use a **paragraph format**. Correct grammar usage is evaluated. The following sections should be included in the report:

TITLE

(Title needs to be centered)

- Title should be relevant to the experiment you conducted.
- Place group member's names (first and last) under the title.
- Include the date written and class period.

INTRODUCTION

(Section title needs to be labeled and centered)

Should include:

1. Main objective (purpose) of the lab
2. Background information
3. A clearly stated hypothesis

MATERIALS AND METHODS

(Section title needs to be labeled and centered)

This is a description of what you did. It is **NOT** a word for word restatement of a lab hand out. You will need to include important aspects of your lab procedure such as: type and amount of each chemical used, any special equipment used, duration of steps, and a summary of your steps in paragraph form. **DO NOT USE LISTS.**

RESULTS

(Section title needs to be labeled and centered)

Include:

1. Data/Observations
   - Usually presented in **TITLED** data tables. Notes of observations and descriptions of any mistakes should also be included.

2. Data calculations
   - Include all calculations, any formulas used, correct units used, and graphs (if useful/appropriate).
   - Significant figures rules should be observed

3. Analysis of product(s)
   - Any products produced are analyzed and identified.
   - Analysis/Identification procedure should be identified.

DISCUSSION/CONCLUSION

(Section title needs to be labeled and centered)

A complete discussion of what you found. You usually restate your hypothesis and whether or not it was supported. You need to discuss why you were able to come to your conclusions. Mention any possible errors, their sources and their effects on your work as well as ways to eliminate them (if possible). If your hypothesis needs to be changed, state a modified/new hypothesis. You will need to include a model of some aspect of your lab (this may be assigned). It will usually be at the molecular/atomic level. Make sure your model shows something that you believe to have occurred, but you were unable to directly see. Make sure you appropriately title the model.

Lab Report : Making Ethanol from Cellulose

Teacher Name: **Mr. Gritt**

Student Name: _____

CATEGORY	4	3	2	1
Question/Purpose	The purpose of the lab or the question to be answered during the lab is clearly identified and stated.	The purpose of the lab or the question to be answered during the lab is identified, but is stated in a somewhat unclear manner.	The purpose of the lab or the question to be answered during the lab is partially identified, and is stated in a somewhat unclear manner.	The purpose of the lab or the question to be answered during the lab is erroneous or irrelevant.
Experimental Design	Experimental design is a well-constructed test of the stated hypothesis.	Experimental design is adequate to test the hypothesis, but leaves some unanswered questions.	Experimental design is relevant to the hypothesis, but is not a complete test.	Experimental design is not relevant to the hypothesis.
Scientific Concepts	Report illustrates an accurate and thorough understanding of scientific concepts underlying the lab.	Report illustrates an accurate understanding of most scientific concepts underlying the lab.	Report illustrates a limited understanding of scientific concepts underlying the lab.	Report illustrates inaccurate understanding of scientific concepts underlying the lab.
Data	Professional looking and accurate representation of the data in tables and/or graphs. Graphs and tables are labeled and titled.	Accurate representation of the data in tables and/or graphs. Graphs and tables are labeled and titled.	Accurate representation of the data in written form, but no graphs or tables are presented.	Data are not shown OR are inaccurate.
Analysis	The relationship between the variables is discussed and trends/patterns logically analyzed. Predictions are made about what might happen if part of the lab were changed or how the experimental design could be changed.	The relationship between the variables is discussed and trends/patterns logically analyzed.	The relationship between the variables is discussed but no patterns, trends or predictions are made based on the data.	The relationship between the variables is not discussed.

Conclusion	Conclusion includes whether the findings supported the hypothesis, possible sources of error, and what was learned from the experiment.	Conclusion includes whether the findings supported the hypothesis and what was learned from the experiment.	Conclusion includes what was learned from the experiment.	No conclusion was included in the report OR shows little effort and reflection.