U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

ENERGY EDUCATION AND WORKFORCE DEVELOPMENT

Cell Wall Chemistry of Biofuel

Grades: 9-12

Topic: Biomass

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Owner: ACTS

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Education Module 2007

Cell Wall Chemistry of Biomass

A lesson on the use of biomass for fuel, focusing on cellulose as a source of fermentable sugar for ethanol. Included are reference materials and inquiry activities to give understanding of the chemistry of starch and glucose.

I. Contextual Analysis:
See Professional Development Plan for specific context details.

II. Learning Goals:
NATIONAL SCIENCE EDUCATION STANDARDS:

CONTENT STANDARD A: **Science as Inquiry**
As a result of activities in grades 9-12, all students should develop

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

CONTENT STANDARD B: **Physical Science**
As a result of their activities in grades 9-12, all students should develop an understanding of

- Structure of atoms
- Structures and of properties in matter
- Chemical reactions

CONTENT STANDARD C: **Life Science**

- Understanding of the cell

CONTENT STANDARD E: **Science and Technology**
As a result of their activities in grades 9-12, all students should develop

- Abilities of technological design
- Understandings about science and technology

CONTENT STANDARD F: **Science in Personal and Social Perspectives**
As a result of activities in grades 9-12, all students should develop understanding of

- Natural resources
- Environmental quality
- Science and technology in local, national, and global challenges

CONTENT STANDARD G: **History and Nature of Science**
As a result of their activities in grades 9-12, all students should develop understanding of

- Science as a human endeavor

III. Assessment Plan:

A. Pre-test: What do you know about biomass?
   This activity is designed to find out what knowledge the students already possess regarding biomass, its structure and usefulness as an energy source.
B. Formative Assessment: As the students research biomass and perform lab experiments, they are surveyed about what they understand about their objectives and processes.
C. Post-test: What have you learned about biomass that is essential to you as a consumer and as a life-long learner?

IV. Implementation Design:

A. Background information on Biomass: Days 1 and 2 (online resources)

   Learning Objectives: In small groups, students will research general applications involving biomass to energy. Each group will be assigned a topic, such as biomass sources, biomass components, biomass to ethanol process, or other biomass to energy applications. They will use the following web resources to investigate their subject, then give a short presentation (~5 minutes) to the class.

   a. "Biomass Energy From Plant Matter:" http://www.eia.doe.gov/kids/energyfacts/sources/renewable/biomass.html
   b. "Biomass Energy Basics" http://www.nrel.gov/learning/re_biomass.html
   c. "How Biomass Energy Works:" http://www.ucsusa.org/clean_energy/renewable_energy_basics/offmen-how-biomass-energy-works.html
   d. "Exploring Ways to use Biomass:" http://www.eere.energy.gov/consumer/renewable_energy/biomass/index.cfm/mytopic=50001

B. Specifics of Cell Wall chemistry: Day 3

   Learning objectives: Students will learn about the complexity of the cell wall through lecture, discussion, and diagrams demonstrating structural characteristics of the following cellular components .

   a. Starch: http://en.wikipedia.org/wiki/Starch
   b. Cellulose: 38%–50%
      Most abundant form of carbon in biosphere
      http://en.wikipedia.org/wiki/Cellulose
      Polymer of glucose, good biochemical feedstock
   c. Other Cell Wall components:
      i. Hemicellulose: 23%–32%
         Xylose is the second most abundant sugar in the biosphere

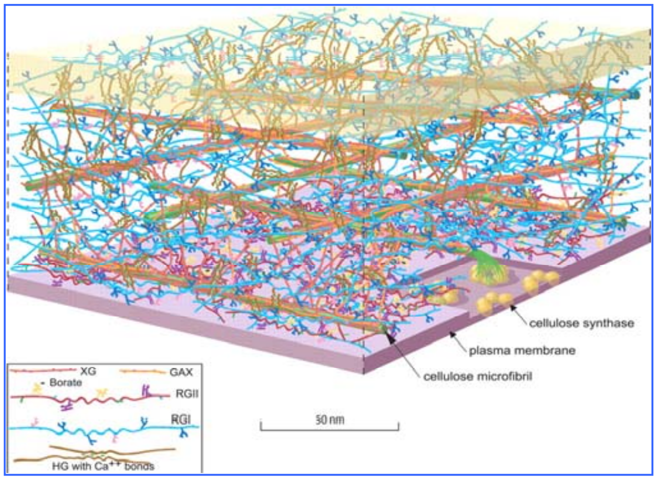
Polymer of 5- and 6-carbon sugars, marginal biochemical feed

ii. Lignin:15%–25%

High energy content

Resists biochemical conversion

iii. Polymers in living organisms



C. Chemistry Activities: Days 4 and 5

Learning objectives: Students will learn safe laboratory techniques as they observe the chemical changes in matter related to biomass. (See acivities a. and b. at the end of this module.)

a. Polymer synthesis: bouncy balls
   About.com
b. Food chemistry: testing for glucose and starch
   http://school.discovery.com/curriculumcenter/chemistry/pdf/activity2.pdf
c. The role of enzymes in converting starch to glucose
   http://en.wikipedia.org/wiki/Amylase

D. Review of concepts: Day 6

E. Post-Assessment: Day 7

See Analysis of Learning Results below

V. Analysis of Learning Results

Students will correctly communicate the following concepts:

1. What is biomass?
   a. How is biomass produced?
2. What are the differences between starch and glucose?
   a. What are their similarities?
3. What chemical processes used for converting biomass to liquid fuel?
   a. Hydrolysis

    b. Alcohol fermentation
4. What are the differences between starch based fermentation and cellulosic fermentation?
5. What role does cellulose play in the structure of plants?
6. What other structural plant materials are useful in producing ethanol?
7. What is a polymer?
8. Give examples of starchy foods.
9. Describe how starch is converted to glucose in the process of digestion.

Assessment of Specific Learning Objectives:

1. Formative assessment as students work on background research, complete the lab activity according to safe procedures, and complete post-lab objectives
2. Summative assessment in the form of formal written quest, test, or reporting according to concepts stated above

VI. Reflection on Teaching and Learning

To be completed after implementation

VII. Linkage to Scientific Learning Communities

A. Students generate questions at the completion of the unit to be asked of mentor scientist at NREL
B. Possible field trip to NREL or local research institution such as a state university

Activity a.

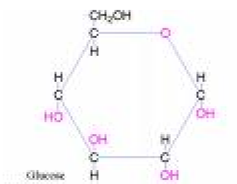
Polymer Synthesis: Bouncy Balls

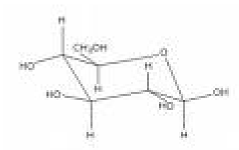
Objective:

- To gain a general understanding of what polymers are and what characteristics they possess.
- Student inquiry where students design their own experiment

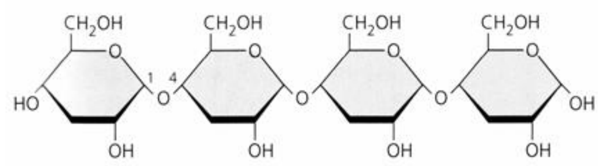
Introduction: Polymers are long chemical chains composed of repeating chemical units that are linked together. For example, starch is a polymer made from linked glucose molecules.

Glucose:



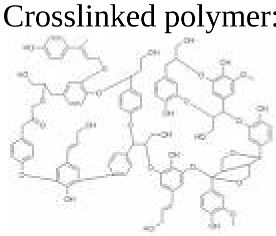


Starch:



Today, you will make two different bouncy balls, made of cross-linked polymers. You will combine glue, which contains the polymer polyvinyl acetate, or PVA, and borax. When borax and PVA combine they crosslink, creating a more complex polymer.

Crosslinked polymer:



Materials:

Item:	**Quantity:**
Petri dish	2
Borax	½ tsp, divided
White craft glue	2 tbsp
Gel craft glue	2 tbsp
Stirring rod	2
Ziploc bag	1
Marking pen	1
Food coloring (optional)	

Procedure:

As you proceed, be certain to take careful observations of reactants, reaction in progress, and products.

1. Label 2 petri dishes A and B.
2. Pour 1 tablespoon of white glue into the dish A and 1 tbsp gel glue into dish B.
3. Add ¼ tsp borax to each dish.
4. Wait 15 seconds to allow the ingredients to react.
5. Stir vigorously with a stir stick until the mixture becomes a gummy, solid mass.
6. Roll the ball(s) between the palms of your hands to mold it into a sphere.
7. Once the ball is no longer sticky, go ahead and bounce it!
8. You can store your plastic ball in a sealed zip loc bag when you are finished playing with it.
9. Don't eat the materials used to make the ball or the ball itself.
10. **CLEAN UP!**

Analysis:

1. What, if any, of your observations are indicative that a polymer was forming/ formed?
2. What conclusions can you draw about the properties of polymers?
3. Give an example of a common polymer not mentioned in this lab. Provide a diagram of a single polymer unit and the polymer chain.
4. Write a short discussion summarizing your learning. Please cite any additional resources used in answering questions.
5. Design an experiment to compare the properties of the two balls. (Examples: lifetime test, performance test) Check your experiment with your teacher before proceeding. Starting with fresh materials, redo the procedure and try your experiment.

Activity b.

It All Comes Down to Glucose

Objectives:

- Students perform controlled comparison of chemical properties of food and biomass items
- Students learn the relationship between cellulose, starch, sugar, and enzymes
- Students develop inquiry experiments

Introduction: Testing for chemicals in food can be simple. In part one of this laboratory experiment, we will test a variety of foods to see if they contain glucose (sugar) and starch. In part two, we will see that starch can easily be hydrolyzed, or broken down, into sugar using the enzyme amylase. In a more laborious process, cellulose from biomass (corn stalks or grass) can also be broken down into simple sugars. This is important because these sugars are easily fermented into ethanol that can be used as fuel.

Materials:

- dropper bottles of water
- iodine (0.1 percent)
- 8 TesTape strips (2-inch [5-cm] strips)
- 8 brown-paper squares (paper sack, cut into 2-inch [5-cm] squares)
- 4 wooden tasting spoons
- 4 forceps
- 4 small plastic cups (2-ounce nut cups)
- small plate with 2 oyster crackers
- 2 miniature marshmallows
- small amount of smooth peanut butter
- small amount of unsweetened applesauce
- a few corn kernels
- about .1 g ground biomass (cornstalks and/or grass)
- paper towels
- goggles
- clear tape

Procedure to be performed with a partner: *Part I:* Testing foods for glucose (sugar) and starch:

1. Label 6 cups with the numbers 1-6 with a sharpie.
    a. Use one of the wooden tasting spoons to crush one of the oyster crackers on the plate. With the spoon, transfer the cracker crumbs to cup 1 Add a few drops of water to create a liquid mixture.
    b. Place a marshmallow in cup 2, and use a clean tasting spoon to tear it into small pieces. Add a few drops of water to create a liquid mixture.
    c. Place half the peanut butter in a cup 3.

d. Place half the applesauce in cup 4.
e. Grind your corn kernels with a spoon on a plate. Transfer to cup 5 and add a few drops of water.
f. Add your ground biomass to cup 6. Add a few drops of water.

2. Label six of the brown-paper squares with the names of the foods. Use forceps to rub the second sample of each food against a brown-paper square. Place these on a paper towel.

3. Label TesTape strips with the name of each food, and then dip it into that food's cup. Place each strip on a paper towel to dry.

4. Place two drops of iodine on the food remaining in each cup.

5. Observe the reactions in each test, recording them on the attached worksheet.

    a. If a stain is observed on the brown paper, the sample tests positive for fat.

    b. If a color change is observed on the glucose test strip, the sample tests positive for glucose. Record color.

    c. If a color change is observed when iodine is added, the sample tests positive for starch. Record color.

6. Compare your group's results with those of another group.

7. What other foods would you like to test? Develop a list of 10 additional foods with your group, and arrange to bring them in for testing. Test them using iodine, TesTape strips, and brown-paper squares. Be sure to add your results to the worksheet table.

Procedure: *Part II:* Hydrolysis of starch and cellulose to create glucose

1. Use one of the wooden tasting spoons to crush one of the oyster crackers on the plate. With the spoon, transfer the cracker crumbs to cup 1. Add a few drops of saliva (containing the amylase enzyme) to create a liquid mixture. Repeat steps 2-6 from Part I.

2. a. Your teacher will demonstrate this step for you in a fume hood: Add about .1 g biomass to a large test tube. Cover with 1 mL 12 M sulfuric acid and allow to sit for one hour at or just above room temperature. Dilute the solution to 30 mL with water. Heat strongly. Allow to cool.

    b. Repeat steps 2-6 from Part I.

Food source	**Observations**	**Glucose? (+/-)**	**Starch (+/-)**	**Fat (+/-)**
Crackers				

Marshmallows				
Peanut Butter				
Applesauce				
Corn				
Biomass				
Corn after enzyme treatment				
Biomass after acid treatment				

Write a conclusion summarizing what you learned and discussing any experimental errors you notice.