Making Chemistry Visible

Overview:

The objective is to explain and demonstrate the chemical process of turning woody biomass into biofuel.

Keywords:

lignin, cellulose, biofuel, biomass, pretreatment, isobutanol

Age/Grade Range:

10-12

Background:

Jet fuel is made out of essentially kerosene (Shell.com) which is incredibly harmful to our environment. The CO2 emissions are harmful to our atmosphere and is increasingly attributing to global warming. For each gallon of jet fuel used, 21.1 pounds are released into the atmosphere (EIA.org). Although this does not seem like much, but when thousands of flights are running on gallons and gallons of jet fuel all of the time the effect is grandiose. NARA is an association focused on turning woody **biomass** into jet fuel which is a lot less harmful to our planet and a new way to work with what would just be burned and wasted anyways (NARArenewables.org). Biomass is materials derived from organisms that are living or that were living.

The whole purpose of this project is convert what would already be "waste" (slash piles) and turn them into **biofuels**, more specifically jet fuel. Biofuels are considered to be any fuel derived from living matter. The overall process can be quite complex. The overall goal is to extract the simple sugars from woody biomass which are **cellulose** and **hemicellulose.** These sugars are pretty large polymers that are then broken down and converted into biofuel. This becomes very complicated because the woody biomass must be taken through a **pretreatment** to expose the sugars by breaking down the **lignin** surrounding the sugar. Pretreatment is when the biomass is either exposed to acids, or some sort of breakdown to break apart the lignin from the sugar. Lignin is a polymer in woody biomass that is essential for rigidity and to prevent the material to rot. *You could think of lignin as the stringy strands in celery when you break them apart.* These molecules are very large and although maybe a cartoon picture could help visualize it, building it out would be a lot more beneficial in the long run by seeing and walking through the NARA process.

MOSS
McCALL OUTDOOR SCIENCE SCHOOL

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NARA
Northwest Advanced Renewables Alliance

Isobutanol is an alcohol that would be used to make biofuel out of it with the right pretreatment, conversion, and fermentation. GEVO, an association affiliated with NARA, is working to find certain traces of yeast to ferment biomass sugars to isobutanol which eventually would be converted to biofuel (July 2014 NARA Newsletter). This is groundbreaking and potentially the best way to convert biomass into biofuel. By modeling isobutanol, a student could see the similarities in the organic material that makes up the majority of crucial living organisms.

In this lesson specifically, the students will focus on visualizing and understanding the pretreatment process.

Next Generation
Science Standards &
Common Core:

CCSS.ELA-LITERACY.RI.11-12.7 ***Integrate and evaluate multiple sources of information presented in different media or formats (e.g. visually, quantitatively) as well as in words in order to address a question or solve a problem.***

HS-ESS3.A Natural Resources
HS-ESS3.C Human Impacts on Earth Systems
HS-ESS3.D Global Climate Change

Goals:

- To have students improve their energy literacy skills
- For students to be able to engage and learn the chemistry in the pretreatment process
- For students to be able to explain the overall goal of NARA and how they are doing
- To provide students with enough information that they can apply their ideas and thoughts on deciding if the NARA project is a good idea environmentally, economically and socially.

Objectives:

Students will understand:

- The same components from a tree (woody biomass) are present when making biofuels. It is all made possible by chemistry.
- and be able to see the chemistry involved in turning woody biomass into isobutanol – more specifically the pretreatment process which is prepping the biomass for conversion.

- And comprehend technical writing by reading a NARA newsletter that involves the background knowledge of what is trying to be done.

Materials:

- Visuals that show where in the plant cell cellulose, lignin, and hemicellulose is located
- Gumdrops or mini marshmallows – with varied colors
- Toothpicks
- "Making Chemistry Visible" worksheet – one per group is sufficient
- "Cell Walls to Alcohol" MOSS lesson (to integrate with this lesson)
- NARA Newsletter
    - http://www.nararenewables.org/feature/newsletter-18#story2

Step up:

Have enough of the readings and worksheets assigned for this lesson printed out (stapled, if needed) ready to go for discussion.

If you do not already have colored marshmallows and/or gumdrops, then either color or label them ahead of time.

Classroom Time: 1.5 hours

Introduction (Engage):

Give the NARA Newsletter to students and allow them to read. Encourage active reading which involves highlighting, underlining or circling unknown words or concepts, and writing questions/comments on the margins. This level of reading could be difficult since it is more advanced, but encourage them to push through and really try to understand the newsletter.

Discuss the NARA Newsletter and allow students to critically think of what the newsletter is trying to communicate. If they are all completely lost, then break it down for them a paragraph at a time. Point out keywords, headings, and big ideas that are important to the main point of the newsletter.

Show the visual to students of the plant cell and especially the cross section of the cell wall where all the polymers are located at. Point out the three main components (cellulose, lignin, and hemicellulose) of the plant cell wall. Using the NARA Newsletter, ask students what part of the plant cell wall is being extracted and used for the production of biofuels.

Ask students what types of challenges or difficulty could arise when using cellulose in the production of biofuel. What polymer intersects cellulose and hemicellulose which in results makes this process difficult? (Answer: lignin)

Activity (Explore):

This activity is focused on allowing students to visibly see the chemistry behind the pretreatment process so they can better understand the conversion from woody biomass to isobutanol and how it all applies to the NARA project.

Split the class into 4 groups (each will make and present a different molecule) and give them the "Making Chemistry Visible" worksheet. One group will make cellulose, the other will have lignin, another will have hemicellulose, and the last would have calcium bisulfite. Isobutanol is not included because that is well after the pretreatment process.

The molecular formula will be given to the students and also simplistic drawings of the molecules on a worksheet. Their job is to construct these out of the materials given – gumdrops and toothpicks. On all the worksheets, they have questions regarding the polymers they are making. This way, they stay focused on the reason they are "playing" with candy and the importance of what they are building.

To tie with the activity that MOSS had already created (provided with this lesson), have students come up as a class (each group had different molecules to make) with the molecules that they formed and have them act out how these polymers interact within a cell wall. They are to present and explain as a whole what is happening and why this process that NARA is doing poses difficulties.

Explanation:

Pretreatment

- Different pretreatment options that are being conducted in NARA research
- Main one that they chose to be used in created the 1000 gallons of biofuel is called mild bisulfite (NARA June 3, 2014 blog post)

Monomers vs. Polymers: Explain to students the difference between the two. Have them discuss why this becomes a big deal during the conversion process. Big example is how glucose (monomer) is linked up several times to make cellulose (polymer). The goal in the conversion process is to turn complex sugars into simple sugars. On their worksheets it will say if the molecule is a polymer or not and there will be ways to simplify building molecules (like cellulose) that would be just way too complicated to build.

- Monomers: two identical molecules that can be bonded together to make a polymer
- Polymers: made up of multiple monomers

Elaboration:

Reiterate to students as to why they are building large polymers. Also, tie back to the reading assigned before the activity and discuss what is going on in the steps.

Have students identify the monomers that make up the large polymers. (Ex: glucose monomers make up one cellulose polymer)

Have students identify what chemical is used in the pretreatment process that NARA overall adopted (Answer: calcium bisulfite).

Evaluation:

- So why were we playing with these models? What was the purpose?
- Why is converting woody biomass into biofuel a challenge? What steps do scientists take when separating polymers?
- What basic elements are found in the compounds? Found any similarities?
- Lignin is mentioned as a co-product, can you brainstorm of anything that can be made up of this polymer? **Hint:** lignin provides support.
- Do you overall think that the NARA project is a good idea in the long run? Think in terms of economy, environment, and social.

Bibliography:

World-wide Civil Jet Fuel Grades [Internet]. [Updated N/A]. Shell.; [cited 2015 June 10]. Available from: **http://www.shell.com/global/products-services/solutions-for-businesses/aviation/shell-aviation-fuels/fuels/types/civil-jet-fuel-grades.html**

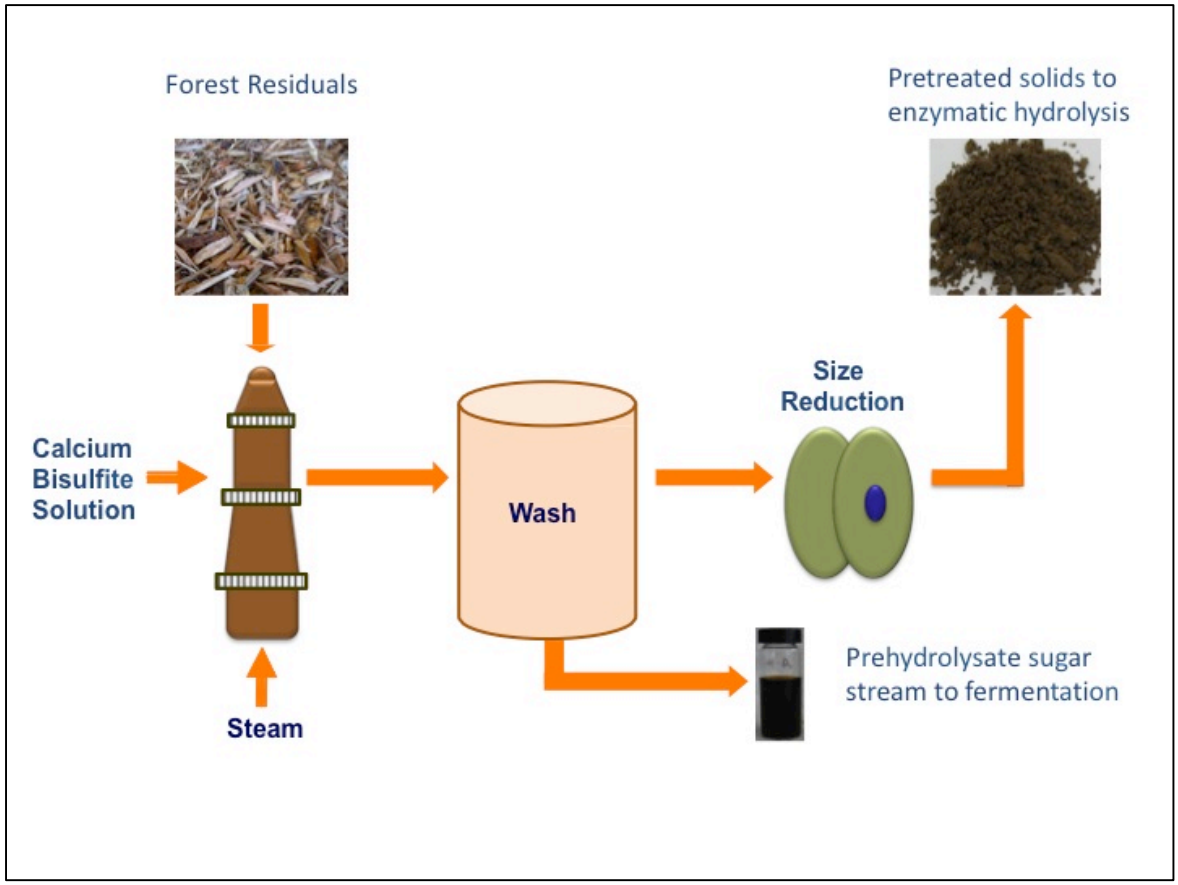
Carbon Dioxide Emissions Coefficients [Internet]. [Updated 2013 February 14]. U.S. Energy Information Administration.; [cited 2015 July 1]. Available from: **http://www.eia.gov/environment/emissions/co2_vol_mass.cfm**

NARA selects a single pretreatment method [Internet]. [Updated 2014 June 3]. NARA: Northwest Advanced Renewables Alliance.; [cited 2015 July 15]. Available from: **https://nararenewables.org/blog/?p=523**

Making Chemistry Visible (Student worksheet)

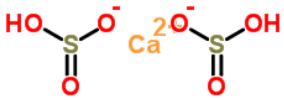
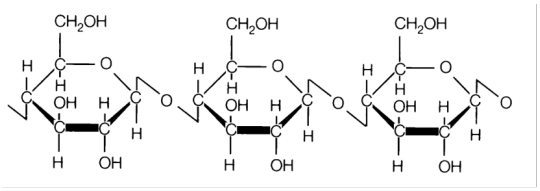
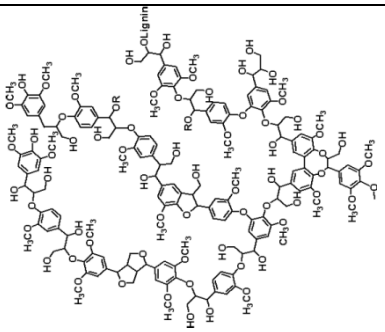
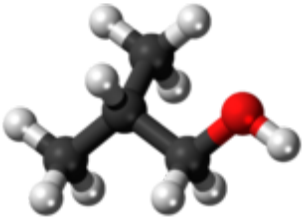
Name: _____

NARA (Northwest Advanced Renewables Alliance) is a project that is specifically focused on turning woody biomass into biofuel – more specifically jet fuel. Traditional jet fuel is primarily made up of kerosene and it creates problems for the environment with an increase of CO2 in the atmosphere. Woody biomass cannot be easily converted into biofuel. The biomass must first go through a **pretreatment** process to then be able to convert it into biofuel. NARA chose that the best way to do pretreatment was by using the method called mild bisulfite (illustrated below).



Source: www.nararenewables.org

Directions: Look through the chemical structures given. Construct the molecules that were assigned to your group using the materials given and answer the questions at the end.

Calcium Bisulfite **Formula:** Ca(HSO3)2 ***FOR Ca, USE A MARSHMALLOW**	 Source: www.chemspider.com	**What is this compound? How is it important in the pretreatment process?**
Cellulose **Formula:** (C6H10O5)n	 Source: technologyinscience.blogspot.com ***ONE GUMDROP = GLUCOSE (MONOMER)**	**What is this compound? How is it important in the pretreatment process?**
Lignin **Formula:** C9H10O2,C10H12O3, C11H14O4 ***PICK ONE**	 Source: lignoworks.ca	**What is this compound? How is it important in the pretreatment process?**
Isobutanol **Formula:** C4H10O	 Source:Wikipedia.org	**What is this compound? How is this important to NARA? To the world?**

Follow Up Questions:

1. **What part of the NARA project do you think is the most complicated?**

2. **What part of the cell wall makes biofuel?**

3. **What is the pretreatment option that is being used to make all 1000 gallons of biofuel?**

4. **Do you agree or disagree with what NARA is trying to accomplish?**