Lesson 5

Biofuels

Time: 1 45 min. class period for the simple biofuel demonstration. Two 45 min class periods will be needed if making biodiesel. See link to complete lab instructions below.

HCPSIII benchmarks

SC.6.6.5 Explain how matter can change physical, chemical forms but total amount of matter remains constant
SC.6.6.6 Describe and compare the physical and chemical properties of different substances
SC.6.1.1 Formulate a testable hypothesis that can be answered through a controlled experiment
SC.6.1.2 Use appropriate tools, equipment, and techniques safely to collect, display, and analyze data
SC.6.2.1 Explain how technology has an impact on society and science
SC.6.2.2 Explain how needs of society have influenced development and use of technologies

NSES standards

Properties and changes of properties in matter
Transfer of energy
Form and function
Abilities of technological design
Understandings about science and technology
Science and technology in society
Science as a human endeavor

Nature of Science
History of science

Learning Objectives

1. Design and safely conduct a crude calorimeter to determine the amount of energy contained within a seed and/or nut
2. Formulate a hypothesis to which nut will contain the most energy per gram and test using the experimental design.
3. Use the Heat energy equation to calculate the amount of energy consumed in each respective nut.

Background

What are biofuels? Biofuels are energy sources that are made from renewable living materials such as plants. Crude oil and coal are considered non-renewable because they take millions of years to form and we have a limited supply of them. In contrast, biofuel sources, such as plant oils, may be produced in a single growing cycle. Kukui aka the candlenut was a source of fuel for the Hawaiians and other Polynesian cultures. Lamps were made from the oil and tiki torches were made from the dried kernels. The dried Kukui nut kernels contain around 50% oil, a high energy source, accounting for its use in lamps and torches. Current research at the College of Tropical Agriculture and Human Resources (CTAHR) at the University of Hawaii Manoa is focused on crops that grow locally as a source of biofuel, namely biodiesel.

The process of determining the energy content of a specific substance is known as calorimetry and can be measured in calories. One calorie is equivalent to the amount of energy required to raise 1 gram of water by 1 degree Celsius. You may have noticed on some food packaging labels that Calories with a capital "C" or kcal are listed under the nutrition facts. One Calorie or kilocalorie is actually 1000 calories. Another unit of heat energy is the joule. Adults need about 1,800 to 4,000 Calories per day depending on body size, activity level, health status, and other variables. One joule is equivalent to about 4.2 calories.

Let's compare the energy content of kukui compared to other local sources of oil. (suggest comparing to macadamia, dried coconut meat (copra), jatropha seed, soybean, and/or dried kamani kernel). Data can be extracted from observation logs after experiments have been performed. For an option you may compare the energy content (kcals) per gram of the edible (coconut, soybean, macadamia, and other edible nuts) fuels found in the USDA nutrient database at the following site http://www.nal.usda.gov/fnic/foodcomp/search by dividing the kcal content that you determined experimentally of your edible fuel by the kcal content found in the USDA nutrient database you can estimate the efficiency of the calorimeter that you have used.

Experiment

1. Gather your testing materials, dried kernels of kukui, macadamia, coconut, jatropha, and/or kamani. 2 paper clips for each setup, a small metal or glass dish, thermometer, O ring stand, safety glasses, grill lighter, aluminum can, and observation log. (Note this experiment works well with partners, one to start the stopwatch and to record while the other applies the flame and monitors the temperature).

2. Skewer the nut with an unfolded paper clip and tape opposite end to a dish with the nut pointing in the air. Weigh this setup and record.

3. Pour 50 ml of water into the empty aluminum can and record the temperature in the observation log. Suspend from the ring clamp using the second paperclip.

4. Hold a flame under the nut until it ignites. Start a stopwatch when you first begin to apply the flame.

5. Make sure the can is hanging directly over the burning nut/seed. Allow to burn completely. If the nut is not completely burned (there will be

parts not completely charred) ignite again.

6. Record the final temperature of the water when nut/seed is completely consumed by the fire, but do not allow the thermometer to touch the bottom of the can. Record the burning time and weigh the final product on the paper clip stand.

7. Calculate the change in time, temperature, and mass and record the results in the observation log.

8. Repeat steps 1-7 with any nuts/seeds you wish to compare with. Note that nuts seeds with higher oil contents will work best.

9. Calculate the total heat energy (calories) with the following formula and compare

Heat energy = Mass of Water (g) x Change of Temperature (Celsius) x specific heat of water (1 cal/g C)

*For advanced students lab instructions on how to make crude biodiesel in the lab

Biodiesel Lab

Learning Objectives

1. Students will make biodiesel from vegetable oil
2. Students will record lab procedures, calculations, and observations in lab notebook
3. Students will write safety precautions in dealing with sodium hydroxide in lab manual

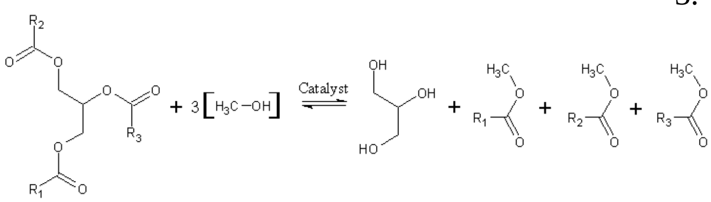
Activity

Materials

250 ml pyrex separation flask
Glass funnel
Pipette
Ring stand with 2 burette clamps
20 ml 99% methanol
100 ml vegetable oil
500 mg potassium hydroxide reagent grade pellets
2 x 250 ml or 500 ml glass beaker with top
Paraffin film
Lab coat
Eye kit
Neoprene or nitrile exam gloves
Digital scale
Filter paper

Background

Biodiesel is a fuel that is cleaner burning than regular diesel and comes from renewable sources such as vegetable oil or animal fats, both of which are triglycerides. A triglyceride is named as such because it has three fatty acids attached to a glycerol molecule. Biodiesel can be burned in an unmodified diesel engine and is also mixable with regular diesel fuel as seen in the popular 80/20 mix of diesel to biodiesel. Biodiesel is made from triglycerides through a process known as transesterification, or the changing from one ester to another. In the reaction below you can see that the triglyceride plus methanol in the presence of a catalyst, in this case potassium hydroxide (KOH), yields glycerol plus methyl esters (biodiesel). In this lab we will separate the glycerol from the biodiesel using a separation flask that relies on gravity. Glycerol separates to the bottom and can be drained off from the bottom of the separation flask with the valve.



Triglyceride Methanol (3) Glycerol Methyl Esters

Laboratory safety

Caution: The methanol you will be working with is highly flammable and toxic. Do not inhale fumes and do not make contact with skin. Potassium hydroxide (KOH), the base catalyst, is extremely caustic. Do not make contact with skin. Everyone should wear safety goggles and gloves when working with either of these chemicals. Check that you are wearing long pants and closed-toed shoes. Measuring the methanol and dissolving the KOH in the methanol should be done under ventilated hood and with supervision or by your chemistry teacher.

Laboratory Procedure

1. Measure out 20 ml of methanol under hood with a volumetric pipette set to deliver 20ml, place in a pyrex beaker with top, and cover with top.
2. Carefully weigh out 500 mg of KOH reagent grade pellets on to a tared digital scale with filter paper under the KOH. Return the top to the KOH container quickly. KOH is hygroscopic and will absorb water from the atmosphere and thus change its mass.
3. Under the hood, remove top from methanol jar and add KOH. Stir with a glass rod until dissolved while still under the hood. When the KOH is completely dissolved cover with top and leave under the hood. This is your potassium methoxide
4. Measure out 100 ml of vegetable oil in the second glass beaker
5. Add the potassium methoxide to the vegetable oil and cover with top.
6. Seal beaker with the paraffin film around the top. You may now remove the sealed beaker from the hood.
7. While holding the top of the beaker securely, shake the mixture vigorously for 10 min. You may take turns with your lab partner. The mixture should thicken and turn a bit cloudy, the transesterification is taking place.
8. After 10 minutes you may remove the paraffin film and beaker top.
9. Set up your pyrex separation flask on the ring stand with two burette clamps. Make sure the valve is closed.

10. Place funnel on top opening of the separation flask and carefully pour the mixture in.
11. The transesterification process is now complete however you will need to let the mixture sit for 24 hours in order to let the glycerin settle to the bottom.
12. After 24 hours you should notice 2 distinct layers. The glycerin portion is on the bottom and the biodiesel, aka methyl ester, is on the top. Slowly turn the valve open with a pyrex beaker underneath to drain the glycerin off. When all of the glycerin is drained off you will be left with a crude biodiesel. Close the valve.
13. Place a second beaker underneath and open the nozzle to drain off the remaining liquid.

You now have crude biodiesel. You may be wondering what you can do with this now. You may construct a lamp with a simple wick and measure the amount of energy that it contains using the calorimeter in the burn a nut lab above. How does the energy density (calories) compare to that of the nut?

Option: To make biodiesel from waste oil you will want to follow lab instructions in the following resource: http://www.luc.edu/biodiesel/pdfs/Biodiesel_Curricula_-_Version1.0.pdf

Suggested Vocabulary

Transesterification- a chemical process of changing one ester into another

Ester- a chemical having the general structure of R'COOR"

Reagent - a substance or compound that is added to a system in order to bring about a chemical reaction or is added to see if a reaction occurs

Reactant - a substance that is consumed in the course of a chemical reaction

Catalyst- a substance that increase the rate of a reaction

Base- a substance that accepts H^+ ions or has a pH of >7

Triglyceride- major component of either plant oil or animal fat, three fatty acids attached to a glycerol

For lab instructions on how to make crude biodiesel in the lab from waste cooking oil.
http://www.luc.edu/biodiesel/pdfs/Biodiesel_Curricula_-_Version1.0.pdf

Recommended for class viewing Revolution Green dvd on biodiesel in Maui
http://www.revolutiongreen.com/thedvd.html

Further reading on biodiesel research in Hawaii
http://www.oceanicinstitute.org/pdfs/new-biodiesel-frontier.pdf

http://www.heco.com/portal/site/heco/menuitem.508576f78baa14340b4c0610c510b1ca/?vgnextoid=9fbfb7ba04ecd210VgnVCM1000005c011bacRCRD&vgnextfmt=default&cpsextcurrchannel=1
www.biodiesel.com

References:

IUPAC, *Compendium of Chemical Terminology*, 2nd ed. (the "Gold Book") (1997).

Matter and Energy in the Biosphere: Fast 2 Foundational Approaches in Science Teaching 2nd ed. Pottenger III, Francis M., Young, Donald B., and Klemm, E. Barbara. Curriculum Research & Development Group, Honolulu, HI, 2001.

Loyola University of Chicago Center for Urban Environmental Research and Policy. (Sep. 1, 2010). Biodiesel Program: Labs and Lessons. Retrieved June 5, 2011, from http://www.luc.edu/biodiesel/pdfs/Biodiesel_Curricula_-_Version1.0.pdf

Name ____________
Date ____________

Biofuels Observation Log

Kukui Nut	**Initial**	**Final**	**Change**
Initial temperature (°C) of water			
Mass of fuel, holder, dish (g)			
Time minutes			
Coconut	**Initial**	**Final**	**Change**
Initial temperature (°C) of water			
Mass of fuel, holder, dish (g)			
Time minutes			
Fuel : Other	**Initial**	**Final**	**Change**
Initial temperature (°C) of water			
Mass of fuel, holder, dish (g)			
Time minutes			

Heat Energy = Mass of Water (g) x Δ Temperature (°C) x Specific Heat (1 cal/g°C)

Fuel Source	**Δ Temperature (°C)**	**Heat(cal) captured**	**ΔTemp/ΔMass**
Kukui Nut			
Coconut			

1. Which is the most efficient fuel source?

2. Which do you think is the best fuel source? Why?