SCWIBLES an NSF GK-12 Project | Santa Cruz-Watsonville Inquiry-Based Learning in Environmental Sciences

Vehicles Powered on Waste

Producing Biodiesel from Used Vegetable Oil

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Field-tested with: 10th-12th grade students in the Natural Resources and Green Careers courses, ESNR Academy, Watsonville High School, Watsonville, CA (Fall, 2010)

Concepts: Alternative fuel, biofuels, energy, titration, viscosity, catalyst, molecular structures, triglycerides, (transesterification)

Skills: Scientific investigation, laboratory techniques and safety (e.g., measurements, preparing of solutions), environmental problem solving

Module Type:
Presentation/discussion and lab activity

Duration: Two 100-minute class sessions

Key materials:

- New/waste vegetable oil
- Hot plates/microwave
- Thermometers
- Mixing bottles
- Potassium hydroxide
- Methanol
- Scale and scale boat
- Beakers
- Safety glasses and gloves

Science Education Standards:
National: Physical Science; Science in Personal and Social Perspectives
California: Chemistry: 2. Chemical Bonds, 5. Acids and Bases, 6. Solutions, 8. Reaction Rates; Investigation and Experimentation

Overview: In this 2-day module, students learn about the chemical reactions necessary to produce biodiesel from vegetable oil and gain hands-on experience in producing vehicle-ready fuel. Students experiment with different starting materials (waste versus new oil and different quantities of catalyst) to explore how this affects the catalytic reaction.

This project is an opportunity for students to learn:

- The catalytic transesterification reaction needed to produce biodiesel from vegetable oil
- Laboratory skills for producing vehicle-ready fuel from waste/new oil
- How to critically evaluate different solutions for addressing the environmental impacts of fuel consumption

SCWIBLES is an NSF-GK-12 project, #DGE-0947923, a partnership between the University of California, Santa Cruz, and the Pájaro Valley Unified School District. For more information, see: http://scwibles.ucsc.edu

Background for Teachers

Learning the Chemical Reaction for Making Biodiesel

Students develop skills in chemistry and scientific investigation while producing biodiesel. The students experiment with reacting different oils and quantities of a catalyst and observe the resulting effects on fuel quality. The hands-on laboratory allows students to generate a local solution to an environmental issue. This module also facilitates a discussion of the environmental and social impacts from different sources of fuel (petroleum fuels, crops grown for biofuels and biodiesel produced from waste oil).

Science Education Standards Addressed:

Science Content Standards for California Public Schools Grades 9-12

Chemistry

2. Chemical Bonds. Biological, chemical, and physical properties of matter result from the ability of atoms to form bonds from electrostatic forces between electrons and protons and between atoms and molecules. As a basis for understanding this concept:

a. Students know atoms combine to form molecules by sharing electrons to form covalent or metallic bonds or by exchanging electrons to form ionic bonds. (p46)

b. Students know chemical bonds between atoms in molecules such as H_2, CH_4, NH_3, H_2CCH_2, N_2, Cl_2, and many large biological molecules are covalent. (p46)

5. Acids and Bases. Acids, bases, and salts are three classes of compounds that form ions in water solutions. As a basis for understanding this concept:

a. Students know the observable properties of acids, bases, and salt solutions (p47).

b. Students know acids are hydrogen-ion-donating and bases are hydrogen-ion-accepting substances (47).

6. Solutions. Solutions are homogeneous mixtures of two or more substances. As a basis for understanding this concept:

a. Students know the definitions of solute and solvent.

8. Reaction Rates. Chemical reaction rates depend on factors that influence the frequency of collision of reactant molecules. As a basis for understanding this concept:

a. Students know the rate of reaction is the decrease in concentration of reactants or the increase in concentration of products with time. (p48)
b. Students know how reaction rates depend on such factors as concentration, temperature, and pressure. (p48)
c. Students know the role a catalyst plays in increasing the reaction rate. (p48)

For courses where the students do not have a background in chemistry, basic chemistry principles can be taught in this lab such as molecular structures, chemical equations and an overview of chemical bonds, properties of solutions and factors that affect the rate of reaction (the role of the catalyst and heating the oil).

For courses with an advanced chemistry background, this module can be adapted to include why the process used to produce biodiesel is referred to as **transesterification** (i.e., by teaching the structure of an ester and how the biodiesel reaction exchanges one kind of ester for another), properties of acids and bases, properties of an alcohol (the methanol), the deprotonation of the alcohol by the base (catalyst), the stoichiometry of biodiesel, chemical bonds and polarity, as well as include a more in depth treatment of the titration step.

Investigation & Experimentation

1. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other four strands, students should develop their own questions and perform investigations. Students will:

c. Identify possible reasons for inconsistent results, such as sources of error or uncontrolled conditions. (p 61)
d. Formulate explanations by using logic and evidence. (p 61)

Students will compare the quality of their biodiesel products and identify possible reasons for inconsistent results within similar treatments (e.g., oil source and quantity of catalyst). For example, for students for whom the reaction did not produce two separate liquid phases (biodiesel and glycerine), or forms an emulsion during the water wash, students might have neglected to fully dissolve the KOH in the methanol.

SCSCPS (http://www.cde.ca.gov/be/st/ss/documents/sciencestnd.pdf)

National Science Education Content Standards A-G: Grades 9-12

B. Physical Science (pp 176-181)

Structure and properties of matter (p 179)

- Carbon atoms can bond to one another in chains, rings, and branching networks to form a variety of structures, including synthetic polymers, oils, and the large molecules essential to life.

Chemical reactions (p 179)

- Chemical reactions occur all around us, for example in health care, cooking, cosmetics, and automobiles.
- Chemical reactions may release or consume energy. Some reactions such as the burning of fossil fuels release large amounts of energy by losing heat and by emitting light.
- Catalysts, such as metal surfaces, accelerate chemical reactions.

F. Science in Personal and Social Perspectives (pp 193-199)

Natural resources (p 198)

- The earth does not have infinite resources; increasing human consumption places severe stress on the natural processes that renew some resources, and it depletes those resources that cannot be renewed.

Environmental quality (p 198)

- Many factors influence environmental quality. Factors that students might investigate include population growth, resource use, population distribution, overconsumption, the capacity of technology to solve problems, poverty, the role of economic, political, and religious views, and different ways humans view the earth.

Science and technology in local, national, and global challenges (p 199)

- Individuals and society must decide on proposals involving new research and the introduction of new technologies into society. Decisions involve assessment of alternatives, risks, costs, and benefits and consideration of who benefits and who suffers, who pays and gains, and what the risks are and who bears them. Students should understand the appropriateness and value of basic questions—"What can happen?"—"What are the odds?"—and "How do scientists and engineers know what will happen?"
- Humans have a major effect on other species. For example, the influence of humans on other organisms occurs through land use—which decreases space available to other species—and pollution—which changes the chemical composition of air, soil, and water.

The presentation and discussion on biofuels prior to beginning the laboratory can address many of the standards in Science in Personal and Social Perspectives (see Biodiesel Module, Lecture 1). The presentation/discussion can begin with the potential benefits of biodiesel, which include mitigating the negative environmental impacts caused by the extraction and consumption of non-renewable petroleum fuels. The controversy over biofuels, however, can also be addressed. This includes the land use and pollution issues associated with growing crops for fuel, as well as potential indirect increases in the cost of food crops. Discussion can include the effects on other species and soil and water quality, as well as examining who bears the risks in a regional and global context. The discussion can also highlight that, in light of this controversy, science and technology researchers have been assessing alternative methods to produce biofuels (e.g., from algae). The students then discuss how they can produce biodiesel from a local waste product (i.e., used vegetable oil from nearby restaurants).

NSES (http://www.nap.edu/catalog/4962.html)

Experimenting with Producing Biodiesel from Vegetable Oil

The goal of this module is to give students experience producing biodiesel from vegetable oil and to discuss the costs and benefits of different sources of energy. Through an introductory lecture and class discussion (see Biodiesel Module, Lecture 1), hands-on production of biodiesel in the laboratory (see Lab 1), and follow-up class discussion (see questions 1-7 in Lab 1), students learn about the chemical reactions that produce biodiesel and why these chemical reactions are needed to produce vehicle-ready fuel.

The students will produce vehicle-grade biodiesel by chemically reacting an alcohol, a base **catalyst** (see Glossary, attached), and vegetable oil. During biodiesel production, **triglycerides** (the constituents of the oil; see Glossary, attached) react chemically with the **alcohol** (usually methanol) with the help of a catalyst to produce methyl **ester** (biodiesel) molecules (see Lab, attached). Glycerine will be another byproduct of the reaction and will gradually settle to the bottom of the container. Students will then drain the glycerine off and wash the biodiesel.

Project Description

Materials:

- 1 liter of new vegetable oil per group for half of the class
  Canola oil, corn oil, or sunflower oil are recommended and can be purchased from any supermarket. Avoid peanut oil, palm oil, and olive oil as they contain a higher percentage of acids that can interfere with the biodiesel process. Also avoid oils with high melting points (e.g., palm oil and coconut oil).
- 1 liter of used vegetable oil per group for half of the class
  Used vegetable oil can be collected from a restaurant (bring your own container). Avoid oil that appears to have high food, fat, or water contamination and/or is very dark in color. Japanese restaurants are often good sources of used oil. After inquiring inside, the staff will typically direct you to a drum of oil outside. For collecting large quantities, you will need to purchase 5-gallon plastic barrels for storage and a pump.
- 1 liter beakers (or pots for heating oil)
- Heat source (hot plate or microwave)
- Empty 2 liter soda bottle
- Potassium hydroxide (7 grams, or amount derived from titration, per group)
  High-quality potassium hydroxide can be purchased from an online biodiesel supply store (e.g., DudaDiesel.com) for around $7 for 2 lbs. You can also try calling chemical supply stores (chemical section in the yellow pages).
- Scale and scale boat
  Can be purchased from an online lab or biodiesel supply store (e.g., DudaDiesel.com) for under $15. A scale that measures to 200g, with an accuracy of 0.01g, works well.
- 200 ml of methanol per group
  For test batches, methanol can be purchased in 355-mL bottle of HEET antifreeze (the yellow bottle) from a local automotive store for approximately $6. Methanol can also be purchased in bulk for $2-4 per gallon from automotive racing shops or chemical suppliers. The best place to find a local supplier is using the yellow pages and looking under the categories of performance, auto, racing, racetracks or chemicals.
- 250ml graduated cylinders
- 1 mason jar for mixing the methanol and KOH (enough for 200mL)

- Funnels
- Eye protection and safety gloves
- Biodiesel Lab workbooks (including introduction, methods and follow-up questions)

Preparation:

Planning for this laboratory should take place at least a few weeks in advance, as some supplies might have to be ordered online (see materials section for how to acquire supplies).

The teacher can also do a titration step before doing the lab with students to get a more accurate measurement of the amount of KOH that is needed (rather than just adding 7g). The procedure for titration can be found online. A good site for finding biodiesel recipes is Journey to Forever (http://journeytoforever.org/biodiesel_mike.html). The project below, and the lab handout, assumes that this titration will be done, and that there will be 4 different lab groups, comparing results based on controlling for amounts of catalyst and the source material—used or new vegetable oil.

Timeline:

Day 1

1. Starting Points for Inquiry: Introductory presentation and discussion (see Biodiesel Module, Lecture 1), **25 minutes**
2. Lab
    a. Overview: Read over introduction and safety sections in lab handout as a class, **15 minutes**
    b. Hands On: Methods for Part 1, **45 minutes**
    c. Clean up: **10 minutes**
    d. Worksheets: Answer questions 1-7 in lab, **15 minutes**

Day 2

1. Re-starting Inquiry: Recap from last class, demo and discussion of Part 2 of lab, **20 minutes**
2. Lab
    a. Overview: Read instructions as class, **10 minutes**
    b. Hands On: Methods for Part 2, **45 minutes**
    c. Clean up: **10 minutes**
3. Discussion: **15 minutes**

Procedure:

Day One

1. Starting Points For Inquiry: An introductory presentation with brainstorming **25 minutes**

Vegetable Power and Viscosity. The module starts off with an introductory presentation on biodiesel (see Biodiesel Module, Lecture 1). The teacher can describe how the energy stored in vegetable oil can be used to power a vehicle. Some people will convert their vehicle so it can run directly off of straight vegetable oil by having their vehicle heat the vegetable oil before internal combustion in the engine. No conversion is, however, necessary to run a vehicle off of biodiesel. This leads to a discussion on fuel **viscosity** (see Glossary, attached). The presentation then highlights the chemical reaction that produces biodiesel. It makes the point that the reaction results in a fluid with lower viscosity and challenges the students to **hypothesize why.**

Social Perspectives: The students are asked to **brainstorm potential positive and negative impacts of biofuels.** The teacher can scaffold this section by making reference to agriculture and encouraging the students to think about the impacts of land use and habitat conversion, as well as fertilizer and water additions. The presentation then highlights how biofuels have been both promoted and critiqued in the media and academia. While I have included some of the arguments within the accompanying notes in the PowerPoint presentation, the website Grist has a comprehensive series of short articles that highlight various aspects of the biofuels debate and are a good starting place for teachers to consult (see references).

Clarifying variables. The students are then told that they will experiment with making biodiesel from used oil collected from a local restaurant; in this instance they running a vehicle off of a waste product. They are then asked to **brainstorm** what might be the **differences** between new and used oil sources and **what effects** this might have on the chemical reaction. Students will often correctly guess that used oil might contain food particles/water and was exposed to heat.

Changing variables to improve outcomes. The teacher can tell the students that used oil will often be filtered beforehand to remove food particles. The teacher can then explain that heat degrades the chemical structure of a **triglyceride** (a glycerol molecule attached to three fatty acid tails) and will lead to free fatty acids being present in the oil (fatty acids that are unattached to a glycerol molecule). The **catalyst** (in this case potassium hydroxide) will react with the free fatty acids to produce soap rather than help catalyze the biodiesel reaction. The students will be asked **how they can experiment with making quality biodiesel**. The teacher can guide them to experimental designs that include both used and new oil and different quantities of catalyst. The teacher can let them know that making quality biodiesel is often easier when using new oil, but most people produce it using local waste oil and it is important to become skilled in producing biodiesel from this source.

The presentation concludes with highlighting news articles of other students, mainly at universities, that are producing biodiesel.

2. Lab

Procedural Advice: The teacher can set up two stations before the lab starts; one will be for measuring the methanol and another for weighing the KOH. This way the chemicals stay in one place and the teacher can more easily supervise these steps of the lab. All other lab materials are set up at the back of the room and students are encouraged to read through the methods in the lab on their own and acquire the appropriate supplies.

To ensure that students are reading through the steps in the lab, the teacher can require that the students put a checkmark next to each step after they complete it.

a. **Overview.** Read over introduction and safety sections in lab handout (see Lab 1) as a class **15 minutes**

   Be sure to ask students to repeat critical points. For example, make sure that they can answer correctly when you ask them if they should add the methanol to KOH or vice versa (it's the KOH to the methanol).

b. **Hands On.** Students carry out methods for Part 1 in the lab handout below. **45 minutes**

Students are divided into groups of 3-4 and assigned to one of the following four treatments prior to beginning the lab: a) New oil, 7g of KOH b) New oil, amount of KOH derived by titration (that teacher did beforehand) c) Used oil, 7g of KOH d) Used oil, amount of KOH derived by titration.

If the teacher does not have time to do the titration step prior to running the lab, then the groups can all just use 7g of KOH and be divided between new and used oil.

c. **Clean up. 10 minutes**

d. **Worksheets.** Answer questions 1-7 in lab handout **15 minutes**

If there is time left over during the two days, the teacher can use questions 1-7 to facilitate a class discussion on biodiesel.

Day Two

1. Re-Starting Inquiry and Demo: Recap from last class; demonstration and discussion of Part 2 of lab **20 minutes**

At the beginning of class the students are encouraged to recall Part 1 of the lab. For example, the students are asked what starting materials they had last class (What was the catalyst? What was the alcohol?). The soda bottle in which they made the biodiesel is held up and they are asked to distinguish between the two products in the bottle (i.e., which is the glycerine and which is the biodiesel).

The teacher then demonstrates how they will drain the glycerine from the biodiesel (see Lab handout).

Finally, the students are told that there is likely still glycerine in the biodiesel layer, as well excess KOH and unwanted byproducts such as soap (see Lab and Lecture 1 presentation). To make better quality fuel, they will then also include another step in which they wash the biodiesel with water.

2. Lab

a. **Overview.** The students read the introductory text in part 2 of the lab handout to further explain the washing process. **10 minutes.**

b. **Hands On.** Students carry out methods for part 2 in the lab handout **45 minutes**

c. **Clean Up. 10 minutes.**

d. **Discussion. 15 minutes.**

Assessment Methods

1. A teacher should assess learning by asking questions of groups and individuals while they carry out each step of the lab. For example,
   a. "Why are you heating up the oil?"
   b. "Why would heating up the oil increase the rate of the chemical reaction?"
   c. "If it makes the reaction go faster, why don't you heat the oil to an even higher temperature?" (because we do not want the methanol to boil)
   d. "Why are you adding the catalyst?" "What is the name of this catalyst?"
   e. "Which is the base in this reaction?"
   f. "Why do the biodiesel and glycerine separate?"
   g. "Why do you wash the biodiesel with water?"
2. Class discussion on questions 1-7 at the end of the laboratory.
3. Grading of written answers to questions 1-7 at the end of the laboratory.

Appendices

Glossary

Alcohol- A substance containing hydroxyl (-OH) components.

Catalyst- A substance that facilitates or enables a reaction between other substances but is not consumed in the reaction.

Ester- An acid (e.g., fatty acid) bonded to an alcohol

Titration- a lab method used to calculate of the unknown concentration of a substance by reacting it with a solution of known concentration. In biodiesel production, titration is a method that determines how much KOH is required to neutralize the free fatty acids in the vegetable oil.

Triglyceride- the main constituent of vegetable oil and animal fats. An ester derived from glycerol and three fatty fatty acids.

Viscosity- a measure of the resistance of a fluid to shear forces (hence flow). For fluids, viscosity refers to "thickness". The less viscous the fluid is, the greater its ease of movement. Thus water has a lower viscosity, whereas a "thicker" fluid (e.g., honey) has a higher viscosity.

Lecture

See powerpoint on SCWIBLES website (http://www2.ucsc.edu/scwibles/).

Lab Handout

LAB: POWERING VEHICLES FROM WASTE
BIODIESEL PRODUCTION

INTRODUCTION

Biodiesel is a fuel made from any plant oil. Vegetable oil is stored energy and, through combustion with oxygen, that energy is made available to power vehicles. Since vegetable oil itself is also a fuel, why do we need to convert the vegetable oil to biodiesel before we use it in a vehicle? The **viscosity** (or "thickness") of vegetable oil prevents it from flowing easily through the fuel pump systems of an engine. Special modifications can be made to a vehicle to heat the vegetable oil before it flows through the fuel system of an engine. Biodiesel, on that other hand, is less viscous and can be used in any diesel vehicle with no modifications required to the engine, tank, or fuel lines.

Biodiesel can be produced at small scales from waste vegetable oil collected for free from restaurants and cafeterias. Of the billions of gallons of waste cooking oil produced in U.S. restaurants each year, many gallons inevitably end up in landfills and sewage systems, and the production of biodiesel from waste oil can potentially reduce environmental impacts. Biodiesel burns cleaner than petroleum diesel fuel by reducing the emission of pollutants such as unburned hydrocarbons, carbon monoxide, and sulphur dioxide.

Vegetable oil is composed of **triglycerides**. Triglycerides have a basic structure of a glycerol (or glycerine) bonded to three (tri) fatty acids.

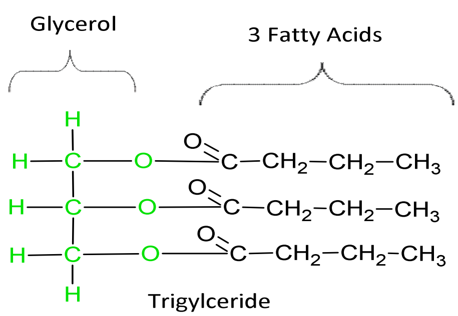

Figure 1. The chemical structure of a Triglyceride

To produce biodiesel, we need vegetable oil, a **catalyst**, and an **alcohol**. During biodiesel production, **triglycerides** (the molecules that make up the vegetable oil) react chemically with an alcohol (usually methanol) with the help of a catalyst (potassium hydroxide, KOH). The catalyst speeds up the reaction by breaking the fatty acids from the glycerol. If a methanol molecule then contacts a single fatty acid chain they will bond and form a methyl **ester** (biodiesel). One triglyceride molecule reacts with three methanol molecules and is converted into three methyl ester (biodiesel) molecules. The chemical reaction therefore has two products: biodiesel (the methyl ester) and glycerine.

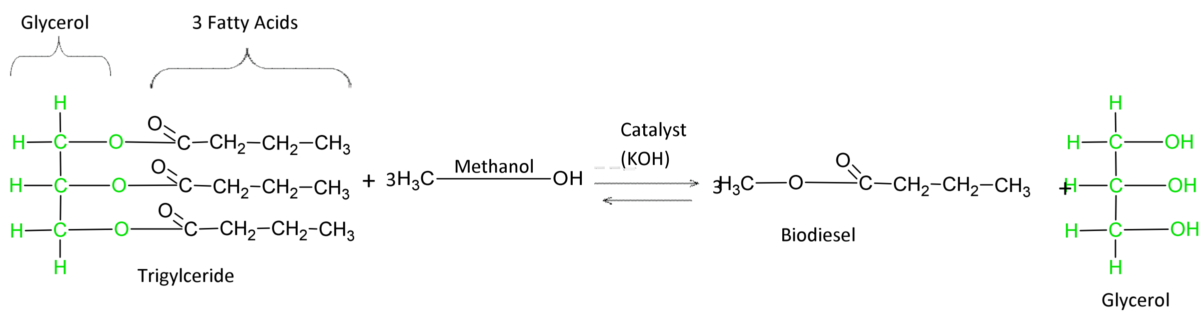

Figure 2. The reaction of a Triglyceride to Biodiesel and Glycerol

Since the glycerine is denser than biodiesel, it gradually settles to the bottom of the container and can then be drained off, leaving just the biodiesel. The glycerine layer will also contain KOH and excess methanol. The biodiesel can then be washed with water to remove any residual methanol or unwanted products from the finished fuel.

With waste vegetable oil, a method called **titration** is used to determine the correct amount of KOH (the catalyst) that is needed to be added to a particular batch of oil. The amount of KOH needed depends on the concentration of free fatty acids present in each batch of waste oil.

When oils break down or are degraded they can form free fatty acids. Oil is often degraded when it is exposed to heat and therefore used vegetable oil might have a higher percentage of free fatty acids. These free fatty acids cannot be easily converted into biodiesel; even worse, they react with the KOH to produce soap, which interferes with the reaction needed to produce biodiesel. Therefore oil suspected to have a high percentage of free fatty acids requires additional KOH to have enough to both produce soap from the free fatty acids as well as produce the biodiesel (oil that has a very high percentage of free fatty acids should be avoided altogether). Some of you today will be using new vegetable oil samples, and some of you will be using used vegetable oil that we have gathered from restaurants.

By using titration to determine oil quality, we can determine how much excess KOH is necessary to convert the free fatty acids into soap. Some of you will be adding the exact amount of catalyst needed, derived from titration on these samples, which we have already done, and some of you will be adding an estimated amount, so we can see what difference it makes.

The soap then settles out of the biodiesel or can be removed by washing the biodiesel (we will do this in Part II of the lab).

SAFETY

- Wear safety glasses and gloves
- Handle materials carefully
- Potassium Hydroxide (KOH) is corrosive (can cause severe burns) and is an eye, skin and lung irritant.
- Methanol is toxic when ingested, inhaled, or absorbed through the skin and can result in very serious, irreversible damage. Exposure to methanol may cause kidney, heart and liver damage. Prolonged or severe short-term exposure may cause eye damage. **Always wear gloves and safety glasses when handling (remember it can be absorbed through the skin) and do not leave the alcohol (methanol) bottle open**. It is also highly flammable and must be kept away from sparks and heat sources. In case of methanol contact with skin, wash with soap and water for 15 minutes and seek medical attention if irritation occurs. If methanol comes into contact with eyes, immediately flush eyes with tepid water for at least 15 minutes. In case of prolonged inhalation of methanol vapors, remove the individual to fresh air. If any methanol spills on your workspace, clean the spill with a wet paper towel immediately. Exercise precaution and you will be fine.
- The combination of KOH and methanol can burn you without you feeling it. If you come in contact with any of these chemicals, immediately wash the exposed area thoroughly with lots of cold water for at least 15 minutes.
- **NEVER add methanol directly to KOH. Transfer the methanol to the bottle first and then add the KOH to the methanol.**

- Biodiesel itself, when properly produced, is safe. It is non-toxic and has a higher flash point (temperature at which it ignites) than regular petrodiesel.

METHODS Part I.
Required items
- 1 liter of new or used vegetable oil (depends on assigned group)
- Heat source and thermometer
- KOH (either 7g or amount derived from titration)
- 200 ml of methanol
- 1 mason jar for mixing the methanol and KOH
- Empty 2 liter soda bottle

1. Heat 1 liter of oil to around 120º Fahrenheit/ 50º Celsius on a hot plate. Continually stir the oil and check temperature.

2. Pour the warm oil into the 2 liter soda bottle.

3. Using a beaker measure out 200 ml of methanol and pour into an empty mason jar. Use your gloves and goggles while pouring the methanol and cap the bottle containing the methanol tightly afterwards to avoid inhaling fumes.

4. With the scale boat on the scale **(don't forget to tare, or zero, the scale with the scale boat on the scale for accurate measurement**) measure out the needed the grams of KOH (either 7 grams or the amount determined by the titration test). Wear your gloves and goggles.

5. Pour the potassium hydroxide (KOH) into the mason jar containing the methanol. ***Never add methanol to KOH as it can boil. Only add KOH to methanol.** Close bottle top and shake; stop shaking every 20 seconds or so to momentarily loosen the top and release pressure. Tighten the top and continue shaking until the KOH is fully dissolved. The mixture is now called potassium methoxide. It is a strong caustic, so be careful handling it.

6. Take the funnel and pour the methaoxide into the 2 liter soda bottle.

7. Close top and shake, stopping every 20 seconds or so to loosen top and release pressure. Continue shaking for 5 minutes.

8. Observe the bottle. It will start to settle into two different layers in a process called separation. The top will be biodiesel and the bottom will be glycerin. About 75% of the separation will take place within the first hour, but the minimum settle time is 12 hours. The longer you wait between steps though, the more excess methanol and glycerine will be forced into the byproduct layer. Better quality biodiesel will need a settle time of 24-48 hours.

Part II.

In this second part, you will learn how to drain off the glycerin and wash the biodiesel. Some people will run their vehicles off of unwashed (or raw) biodiesel, although washing the fuel ensures that it is better quality.

There are several ways to wash biodiesel and we will be doing a water wash. Impurities, such as excess methanol, soap, and glycerine that are suspended in the biodiesel layer, dissolve more readily in water than in biodiesel. When a water droplet touches methanol or glycerine, it will dissolve the compounds and quickly settle out of the biodiesel layer. Since we are waiting a long time between Part I and Part II, more of the methanol, soaps and glycerine will have settled into the byproduct layer, making washing easier.

1. Draining off the glycerine is done by removing the top and using your thumb as a valve. Slowly and carefully turn the bottle upside down wearing gloves and drain the glycerine off into a container. The glycerine can later be mixed with dry materials such as hay, all natural kitty litter, or leaf litter and added to a compost pile or green bin.

2. Gently pour about 500 ml of warm water into the bottle and tightly secure the top.

3. Gently rotate bottle end to end for about 30 seconds.

4. If you did the previous steps carefully, the water will separate immediately. If the water does not, you might have mixed too fast. Let the bottle sit for 10 minutes and it should separate.

5. Drain the water off just like the glycerin (in the first few washes, the water will be milky looking).

6. Repeat steps 1-5 for a total of five (5) washes, with more vigorous shaking per wash on subsequent steps. On the last wash, vigorously shake and drain off water. Washed biodiesel will be very cloudy and lighter in color. Let the biodiesel sit out and be exposed to the air to allow the water to evaporate. Once the biodiesel is dry it should have a very clear appearance.

You have now completed your first biodiesel batch!

QUESTIONS

1. What are some of the benefits of biodiesel?

2. What are some drawbacks of biodiesel?

3. Why do you need to do conversions to a vehicle for it to run off of vegetable oil?

   Why can you put biodiesel into a regular diesel tank without any conversions?

4. Why did we heat the oil as one of the first steps in the lab?

5. Why do we use potassium hydroxide (KOH) when processing biodiesel?

6. Most people who produce biodiesel at home, use waste vegetable oil (e.g., oil that was already used by a restaurant to cook food). It is recommended that you use new vegetable oil when doing your first few test batches. In our lab, a group experimented with new vegetable oil and another group experimented with used vegetable oil. Why might it be easier in the beginning to produce quality biodiesel using new vegetable oil?

Bonus Question:

7. When making biodiesel, a titration step is often included to determines how much KOH is needed to be added to the reaction to produce biodiesel. Better quality oil typically requires less KOH. Why might this be?

GLOSSARY

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Catalyst- A substance that facilitates or enables a reaction between other substances but is not consumed in the reaction.

Ester- An acid (e.g., fatty acid) bonded to an alcohol

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Viscosity- a measure of the resistance of a fluid to shear forces (hence flow). For fluids, viscosity refers to "thickness". The less viscous the fluid is, the greater its ease of movement. Thus water has a lower viscosity, whereas a “thicker” fluid (e.g., honey) has a higher viscosity.

Assessment Materials

See questions 1-7 at end of lab.

Resources

Berkeley Biodiesel Collective
http://www.berkeleybiodiesel.org/

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