LEARNING GOALS: After the completion of this workshop, students will understand:

1. Biodiesel fuel is used in all types of combustible engines
2. Biodiesel fuel can be made out of any vegetable oil or animal fat, including used oils
3. Biodiesel is lower in sulfur and does not contribute extra Carbon Dioxide into the atmosphere

CONCEIVE – What do I wish to accomplish through this project?

This stage involves guiding students in defining the goals of the project, then helping them develop conceptual, technical and action plans to meet those goals while considering the technology, knowledge, and skills that apply. This guidance is provided in the form of Essential Questions that use student’s preconceptions, and misperceptions then move them toward a deeper and more realistic understanding of the process and skills needed to complete the project.

ESSENTIAL QUESTIONS:

1. Why is biodiesel a greener fuel?
2. How does the chemical process change with using a “dirty” oil vs. clean?
3. What is the transesterification process and the side reactions?
4. Why are we still exploring for and processing fossil fuels instead of focusing on using just biodiesel to power engines?
5. If used – How do Putt Putt boat engines work?

http://www.scientoymaker.org/boat/howBoatWorks1.html

NOTES: You can use the PowerPoint info and resources listed on the PowerPoint as a reference for the above questions. Also here are some sites that if time permits you can have the students research and present http://allaboutstuff.hubpages.com/hub/Is-biodiesel-green
http://www.dummies.com/how-to/content/biodiesel-is-a-greener-fuel.html

DESIGN - How will I accomplish the project?

This stage focuses on creating the plans, drawings and algorithms that describe the product, process or system that will be implemented.

Using the Carolina ChemKits : Production of Biodiesel kit :
http://www.carolina.com/product/physical+science/chemistry/carolina+chemkits/carolina+chemkits%26trade--+production+of+biodiesel+kit.do This kits includes materials for 30 students working in 10 groups of 3. It includes the instructions for 3 labs, 60 minutes for each lab.

Lab 1 : Titration of Feedstock – students learn how to determine the quality of a sample of a biodiesel feedstock, a potential raw material for producing biodiesel. Any type of triglyceride can be a feedstock, including vegetable oils and animal fats. Students use a simple titration to determine the pH of various feedstock, and then calculate the percentage of free fatty acids in each feedstock.

NOTE: When you have limited time, this first lab can be eliminated and just explained prior to starting the actual production of biodiesel fuel. This is also recommended for students grades 6-7.
**Lab 2: Batch production** – students make two small batches of biodiesel, one from virgin vegetable oil and the other from used cooking oil. Students use the data from the titration lab to calculate the amount of catalyst (KOH-Potassium hydroxide) needed to produce biodiesel.

**NOTE:** If you decide to not perform lab #1 – then these amounts can be given to the students and explained how they are calculated.

**Lab 3: Soap Titration** – students learn how to determine the soap content of a sample of biodiesel. Unwashed biodiesel contains a certain amount of soap (Glycerol) as a byproduct of production. Biodiesel is washed or processed to remove this soap. If too much soap remains after the wash, the fuel cannot be used safely without risk of engine damage or fuel filter clogging. This is one of many quality control specifications used to evaluate biodiesel to ensure that it meets the standards set out in ASTM D6751.

**IMPLEMENT - From an idea to a product!**
This stage refers to the transformation of the design into a product. It includes hardware, manufacturing, software coding, testing and validation.

**Lab 1:** Carolina has a short 2 minute video on titration calculations and setting up and performing a titration: [http://www.carolina.com/category/teacher+resources/educational+videos.do](http://www.carolina.com/category/teacher+resources/educational+videos.do)

**Prep:**
1. Gather a variety of used vegetable oil feedstock that can be tested. They can be collected from local restaurants, school cafeteria and home. Sample feedstock should include different types of oil, used vegetable oil, animal fat, lard, and grease. A total of 2 liters of each collected feedstock should be sufficient to cover all the activities of this workshop.
2. Prepare a 0.1M potassium hydroxide solution. Using a metal scoop, measure 5.61 grams of granular potassium hydroxide onto a weigh boat on a scale. Measure 1 liter of distilled water into a 1500-mL flask. Pour the potassium hydroxide into the water. Securely place the stopper in the flask, and shake vigorously until the potassium hydroxide is fully dissolved. Do not invert the flask while shaking it. All 10 groups will use this solution. Label this flask, "0.1 M Potassium Hydroxide (KOH) Solution. Do Not Drink."
3. Set up 10 lab stations, each with the following materials:
   - safety equipment for each student, including gloves, goggles, and lab aprons
   - buret setup with funnel
   - 125-mL Erlenmeyer flask
   - 100-mL beaker
4. Set up one central materials station with the following materials:
   - the 0.1 M potassium hydroxide solution
   - isopropyl alcohol
   - phenolphthalein
NOTE: If you have them, supply several additional 100-mL graduated cylinders so that groups can work concurrently.

1500-mL flask containing 0.1 M potassium hydroxide
2 graduated cylinders, 100 mL
2 disposable glass pipets isopropyl alcohol
1% phenolphthalein
2 plastic pipets
disposal container for titrated oils
hot plates (one for each feedstock type)
thermometers (one for each feedstock type)
250-mL beaker full of virgin oil feedstock
250-mL beakers containing student-collected feedstock samples
digital scale (accurate to 0.01 g or better)

6. Before class, at the central station, heat each of the biodiesel feedstocks to 100°F in a different, labeled 250 mL beaker.

Lab 2: Preparation

1. Set up a central station under a fume hood with the following materials. If you have them, supply several additional 100-mL graduated cylinders so that groups can work simultaneously:
   - Methanol
   - 2 graduated cylinders, 100-mL

2. At a central station, set up the following components. Divide the different feedstocks into smaller labeled containers so that multiple groups can access them. Be sure to keep the container of potassium hydroxide sealed to avoid contact with moisture.
   - vegetable oil feedstock
   - collected feedstock sample(s) from Lab 1
   - 250-mL graduated cylinder potassium hydroxide, granular
   - 1 or more digital scales (accurate to 0.01 g or better)

3. Set up the following materials under each group’s fume hood. If no fume hoods are available, be sure to that each group’s work area has plenty of air movement and ventilation.
   - safety equipment for each student, including gloves, goggles, and lab aprons weigh boat
   - metal scoop
   - 250-mL beaker
   - 2 half-pint glass jars with self-sealing lids

Lab 3: Preparation

1. Set up 10 lab stations, each with the following materials:
   - safety equipment for each student, including gloves, goggles, and lab aprons
• 250 mL beaker
• 125 mL Erlenmeyer flask
• buret setup with funnel

2. Set up one central station with the following materials. Isopropyl alcohol and bromophenol blue can be poured into several containers to allow multiple groups access to the chemicals simultaneously. If you have them, supply several additional 100-mL graduated cylinders so that groups can work simultaneously:

• samples of biodiesel
• 2 graduated cylinders, 100 mL
• isopropyl alcohol
• 0.01 M hydrochloric acid solution
• 1% bromophenol blue in water, 100 mL
• 2 plastic pipets
• disposal container for titrated oils

OPERATE – Does it work the way I planned?

This stage uses the built product, process or system to satisfy the intended goal.

Lab 1: Procedure:
Show Powerpoint: slide 11:

Feedstock samples are titrated to test their quality. During this titration lab, students will measure the percent free fatty acids present in the feedstock. **Review proper lab procedures and safety rules.**

1. Each group will perform a blank titration and then three titrations of a feedstock. Divide the feedstocks collected and the included vegetable oil so that each group will titrate a different feedstock.

2. For the calculations students find the percent free fatty acids in the feedstock. We know that 1 mole of potassium hydroxide = 1 mole fatty acid.

**Students will use a modified formula of \( M = \text{moles/liter} \) to calculate the percentage of free fatty acids.** The molecular weight of oleic acid is given, and can be used if the fatty acid present in the feedstock is unknown.

Each group of three should assign the following tasks:

**Lab partner # 1:** should go to the central lab station and use a graduated cylinder to measure 80 mL of 0.1 M potassium hydroxide solution into a 100-mL beaker. This will be your group's potassium hydroxide supply to fill the buret for each titration.
Lab partner # 2: Another lab partner should use a 125-mL Erlenmeyer flask to obtain 10 mL of isopropyl alcohol from the central lab station using a graduated cylinder. Next, with a plastic pipet, add two drops of phenolphthalein to the isopropyl alcohol, and return to the group’s workstation.

3. At your lab station, one partner, while wearing safety goggles and gloves, should carefully load the buret with the 0.1 M potassium hydroxide solution using the funnel. Then, place the potassium hydroxide beaker beneath the buret. Open the stopcock and allow the potassium hydroxide solution to fill the buret tip and drain until the liquid in the buret reaches the “0 mL graduation at the top of the buret.

4. Place the buret directly above the alcohol/indicator mixture in the Erlenmeyer flask for titration. Record the initial volume of potassium hydroxide solution in the buret in Table 1, located after Activity 2. Then, add potassium hydroxide solution one drop at a time from the buret to the alcohol. Swirl the solution in the flask constantly as the potassium hydroxide solution is added to ensure it mixes thoroughly. When the color changes from clear to pink and holds for 30 seconds, stop. Record the final volume of potassium hydroxide in the buret in Table 1. Find the difference between the two volumes, and record this volume as “Amount of KOH added” for the Blank Titration.

5. Discard the titrated alcohol solution into a designated container as directed by your teacher. Rinse the flask with isopropyl alcohol or wipe it with a clean paper towel.

6. Using an Erlenmeyer flask, another member of your group should measure 10 mL of isopropyl alcohol at the central lab station. With a plastic pipet, add two drops of phenolphthalein to the isopropyl alcohol. Place the flask with the alcohol and pH indicator on a scale and tare it to zero. Using a glass pipet, add 5 grams of biodiesel feedstock to the flask. Mix it thoroughly by carefully swirling by hand. Return to your workstation. Label this flask, "Feedstock/Alcohol Solution."

7. In Table 1, record the initial volume of potassium hydroxide solution in the buret. Then, add the potassium hydroxide solution one drop at a time from the buret to the feedstock/alcohol solution.

     Swirl the solution in the flask constantly as the potassium hydroxide solution is added to ensure it mixes thoroughly. Watch carefully for a color change; it will occur suddenly. Continue adding drops of potassium hydroxide solution until the pink color holds for 30 seconds. When it does, stop. Record the final buret volume in Table 1. Find the difference between the initial and final volumes, and record this value in Table 1 as 'Amount of KOH Added' for Titration #1.

8. Discard your feedstock/alcohol solution into the designated waste container. Rinse the flask with isopropyl alcohol or wipe it with a clean paper towel.

9. Using fresh alcohol, pH indicator, and biodiesel feedstock, repeat the titration two more times. Be sure to clean the equipment between titrations. As before, record the results of Titration #2 and Titration #3 in Table 1. Reload the buret with potassium hydroxide solution from the storage beaker as necessary.

10. Wash and dry all glassware.

After the groups have completed the titrations and determined the free fatty acid content and acid value of their feedstocks, have students share their results. Lead a class discussion wherein students discuss which feedstock would make the best biodiesel fuel, and why.
Sample Data for Com Oil:
Table 1

<table>
<thead>
<tr>
<th>Titration</th>
<th>Initial KOH Volume</th>
<th>Final KOH Volume</th>
<th>Amount of KOH Added</th>
<th>Percent Free Fatty Acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blank</td>
<td>0.00</td>
<td>0.70</td>
<td>0.70</td>
<td>0.73%</td>
</tr>
<tr>
<td>Titratio</td>
<td>0.70</td>
<td>2.70</td>
<td>2.00</td>
<td>0.68%</td>
</tr>
<tr>
<td>Titratio</td>
<td>2.70</td>
<td>4.60</td>
<td>1.90</td>
<td>0.90%</td>
</tr>
<tr>
<td>Titratio</td>
<td>4.60</td>
<td>6.90</td>
<td>2.30</td>
<td>X= 0.77%</td>
</tr>
<tr>
<td>Average Percent Free Fatty Acid of 3 Titrations</td>
<td>0.0077</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Acid Value of Biodiesel Feedstock: 1.53

Note: Remind students to convert milliliters to liters when calculating Percent Free Fatty Acid

Activity 2. Calculation of Free Fatty Acid Content

After completing the titrations, calculate the acid value of the feedstock sample.

1. To calculate the percentage of free fatty acids in your sample, use the following equation. Calculate a percent free fatty acid value for each of the three trials, and record the results in your table. Be sure to convert milliliters to liters.

\[
\frac{((T-B) \times M \times 282/W) \times 100}{\% FFA}
\]

- \( T \) = total volume, in liters, of potassium hydroxide solution in the titration
- \( B \) = volume, in liters, of potassium hydroxide solution used in the blank titration
- \( M \) = molarity of the potassium hydroxide solution (in this procedure, 0.1)
- \( 282 \) = value corresponding to the molecular weight of oleic acid in grams
- \( W \) = weight of a feedstock sample in grams (This lab uses 5.0 grams of feedstock for each titration.)
- \( \% FFA \) = percent free fatty acids in the sample

2. Find the average of the three "Percent Free Fatty Acid" values, and record this value as \( X \) in Table 1. You will need this value to complete an equation in Lab 2, Activity 2.

3. To convert the percent free fatty acids to acid value, multiply by 1.99. The higher the acid value number, the lower the quality of the biodiesel feedstock. Record this value in the blank provided below Table 1.
Table 1

<table>
<thead>
<tr>
<th>Titration Result</th>
<th>Initial KOH Volume (mL)</th>
<th>Final KOH Volume (mL)</th>
<th>Amount of KOH Added (mL)</th>
<th>Percent Free Fatty Acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blank Titration</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Titration #1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Titration #2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Titration #3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average Percent Free Fatty Acid of 3 Titrations</td>
<td></td>
<td></td>
<td></td>
<td>x=</td>
</tr>
</tbody>
</table>

Acid Value of Biodiesel Feedstock: ________________________________

Note: These are from the Student Guide included with the Carolina kit. You can use them to guide a discussion after the lab is completed.

Answers to Questions in the Student Guide

1. What is the important property of the potassium hydroxide (KOH) solution we use as the titrant?
   Potassium hydroxide solution is alkaline, or basic, which allows it to alter the pH of the acidic feedstock samples and eventually neutralize the samples.

2. Why are some of the feedstock samples solid at room temperature? What effect might this have on biodiesel made from these feedstocks?
   The reason that some of the feedstock samples are solid at room temperature is because they are composed primarily of saturated fats. This is in contrast to feedstocks composed of unsaturated fats, which typically are liquid at room temperature. Biodiesel made from feedstocks that are high in saturated fats tend to share the qualities of the original feedstock. The fuel will become cloudy and solidify at much higher temperatures than biodiesel made from feedstocks composed of unsaturated fats, such as soy or canola oil.

3. What could you infer about the history of a sample of oil that has a very high acid value?
   A high acid value generally reflects that a sample has aged or been exposed to excessive heat or water, or some combination of these. The oil could be months old, could have been stored in a warm location, could have been used heavily in a fryer, or could have encountered condensation (or even rain) in a storage bin.

Lab 2: Procedure
Students will work in 10 groups of three. Each group will create two batches of biodiesel.
Powerpoint slide #12 and 13: **Before the lab, review proper lab procedures and safety rules.** Every student should wear safety goggles, gloves, and a lab apron during this activity. Some of the chemicals used are caustic and should be handled with care. Using a central station to distribute chemicals may assist you in overseeing the proper handling of these chemicals.

Assign each group a different feedstock to use to create the batch of biodiesel. Groups will create two batches, one with the vegetable oil and the other with their assigned feedstock. When they have finished, have the groups compare the batches and review the process of transesterification.

**NOTE:** The following are the instructions to have at each groups lab station:

**Activity 1. Making a 15 mL Batch of Biodiesel From Virgin Oil**

1. Each member of your group is responsible for acquiring a component needed to create a batch of biodiesel and returning with it to the lab station.

**Use extreme caution when working with these chemicals. Avoid direct contact to the skin, and do not inhale the fumes.**

2. Using one glass jar and lid, one lab partner should acquire 30 mL of methanol from the central lab station. Be careful not to breathe the fumes while pouring the methanol.

3. Another lab partner should take the weigh boat and metal scoop to the central station and weigh out 1.05 grams of potassium hydroxide. Be sure to tare the scale to zero after placing the weigh boat on the pan but before adding the potassium hydroxide. Because potassium hydroxide will rapidly absorb moisture from the air, making it more difficult to handle, try to complete this step as quickly as possible. Keep the container of potassium hydroxide sealed when not in use.

4. The third lab partner should take a 250-mL beaker to the central lab station and obtain 150 mL of virgin oil.

5. At your lab station, open the lid of the jar containing the methanol. Carefully add the 1.05 grams of potassium hydroxide catalyst to the jar of methanol.

6. Seal the jar and carefully shake it vigorously until the flakes of potassium hydroxide are fully dissolved and invisible. Do not invert the jar. Be aware that the jar may get hot from this exothermic reaction.

7. After all the flakes of potassium hydroxide have been dissolved, add the 150 mL of virgin oil to the jar containing the potassium hydroxide and methanol solution.

8. Seal the jar and carefully shake it vigorously for 10 minutes. Do not invert the jar. Take turns and pass the jar to your lab partners as necessary. After 10 minutes, allow the solution to settle. You should begin to see the separation of glycerin from the biodiesel in 20-30 minutes.

9. While waiting for the glycerin to separate from the biodiesel, wash and dry all your labware, and prepare for Activity 2.

**Activity 2. Making a 150mL Batch of Biodiesel From Used Vegetable Oil**

1. If a feedstock contains free fatty acids, they will react with the potassium hydroxide and reduce the amount of potassium hydroxide catalyst available for the transesterification reaction. Therefore, you need to calculate how much additional potassium hydroxide is needed based on the percent free fatty acid content that was calculated from the titrations in Lab 1, Activity 2.

2. Each member of your group is responsible for acquiring a component needed to create a batch of biodiesel and returning with it to the lab station. **Use extreme caution when working with these chemicals. Avoid direct contact with skin, and do not inhale the fumes.**
3. Using one glass jar and lid, one lab partner should acquire 30 mL of methanol from the central lab station. **Be careful not to breathe the fumes while pouring the methanol.**

4. Another lab partner should take the weigh boat and metal scoop to the central station and weigh out the calculated amount of potassium hydroxide. Be sure to tare the scale to zero after placing the weigh boat but before adding the potassium hydroxide. Because potassium hydroxide will rapidly absorb moisture from the air, making it more difficult to handle, try to complete this step as quickly as possible. Keep the container of potassium hydroxide sealed when not in use.

5. The third lab partner should take a 250-mL beaker to the central lab station and obtain 150 mL of used vegetable oil.

6. At your lab station, open the lid of the jar containing the methanol. Carefully add the calculated number of grams of potassium hydroxide catalyst.

7. Seal the jar and carefully shake it vigorously until the flakes of potassium hydroxide are fully dissolved and invisible. Do not invert the jar.

**Sample Calculation**

1.05 g KOH + (0.0077 x 1.05 g KOH) = 1.06 g KOH

**Note:** These are from the Student Guide included with the Carolina kit. You can use them to guide a discussion after the lab is completed.

**Answers to Questions in the Student Guide**

1. What is transesterification? Is it an exothermic reaction?

   **Transesterification is the process of exchanging the alcohol group of an ester compound with another alcohol. These reactions are often catalyzed by the addition of an acid or base. Yes, it is an exothermic reaction.**

2. What is an ester?

   **An ester is a chemical compound derived formally from carboxylic acid and an alcohol.**

3. What is a free fatty acid?

   **A free fatty acid is an uncombined fatty acid. A free fatty acid may result from the breakdown of a triglyceride into its components (fatty acids and glycerol). For vegetable oil, free fatty acids result from exposure to heat and moisture.**

4. Is biodiesel more viscous or less viscous than vegetable oil?

   **Biodiesel is less viscous (thinner) than vegetable oil due to the transesterification processes the oil went through.**

**Lab 3: Procedure**

A soap titration on a sample of biodiesel is done to assess the quality of the fuel. The amount of free fatty acids in a feedstock sample will vary the amount of soap (potassium or sodium oleate) that may be produced as a side reaction. Free fatty acids can combine with the potassium hydroxide to form a soap molecule. Students will perform the titration and then calculate the amount of soap present in parts per million. **Each group consists of three students**

Each group will perform a blank titration and then three titrations on a sample of biodiesel. Assign a biodiesel sample to each group; include the batch produced from the vegetable oil feedstock as a comparison. After each group has completed the titrations, have students share the results and discuss which is the highest quality biodiesel and why.
NOTE: The following are the instructions to have at each group's lab station:

Activity 1. Soap Titration

1. Make sure that everyone in your group is wearing proper safety equipment, including gloves, goggles, and a lab apron. Use extreme caution when working with these chemicals. Avoid direct contact to the skin, and do not inhale the fumes.

2. One member of your group should go to the central lab station and use a graduated cylinder to measure 80 mL of 0.01 M hydrochloric acid solution into a 250-mL beaker. This will be your group's hydrochloric acid supply to fill the buret for each titration.

3. Another lab partner should pour approximately 30 mL of isopropyl alcohol into an Erlenmeyer flask at the central lab station. Next, with a plastic pipet, add four drops of bromophenol blue to the isopropyl alcohol, and return to the group's workstation.

4. At your lab station, one partner, while wearing safety goggles and gloves, should carefully load the buret with 0.01 M hydrochloric acid using the funnel. Then, place the beaker of hydrochloric acid beneath the buret. Open the stopcock and allow the hydrochloric acid solution to fill the buret tip and drain until the liquid in the buret reaches the "0 mi..." graduation at the top of the buret.

5. Place the buret directly above the alcohol/indicator solution in position for titration. Record the initial volume of hydrochloric acid solution in the buret in Table 2, located after Activity 2. Then, add hydrochloric acid solution one drop at a time from the buret to the alcohol. Swirl the solution in the flask constantly as the hydrochloric acid solution is added to ensure it mixes thoroughly. When the color changes from blue-green to yellow and holds for 30 seconds, Stop. Record the final volume of hydrochloric acid in the buret in Table 2. Find the difference between the two volumes, and record this volume as "Amount of KOH Added" for the Blank Titration.

6. Discard the titrated alcohol solution into a designated container as directed by your teacher. Rinse the flask with isopropyl alcohol or wipe it with a clean paper towel.

7. Using the flask, another member of your group should measure 30 mL of isopropyl alcohol at the central lab station. With a plastic pipet, add four drops of bromophenol blue to the isopropyl alcohol. Using a graduated cylinder, measure 5 mL of biodiesel. Pour the biodiesel sample into the flask containing the isopropyl alcohol and bromophenol blue. Mix it thoroughly by carefully swirling it by hand. Return to your workstation. Label this flask, "Feedstock/Alcohol Solution."

8. Place the flask under the buret for titration. In Table 2, record the initial volume of hydrochloric acid solution in the buret. Then, add hydrochloric acid one drop at a time from the buret to the alcohol. Swirl the solution in the flask constantly as the hydrochloric acid solution is added to ensure it mixes thoroughly. When the color changes from blue to yellow and holds for 30 seconds, stop. Record the final volume of hydrochloric acid in the buret in Table 2. Find the difference between the initial and final volumes, and record this value as "Amount of HCl Added" for Titration #1.

9. Discard your feedstock/alcohol solution into the designated waste container. Rinse the flask with isopropyl alcohol or wipe it with a clean paper towel.

10. Using fresh alcohol, pH indicator, and biodiesel, repeat the titration two more times. Be sure to clean the equipment between titrations. Record the results of Titration #2 and Titration #3 in Table 2. Reload the buret with hydrochloric acid solution from the storage beaker as necessary.

11. Discard the titrated alcohol solution into the designated container as directed by your teacher. Wash and dry all glassware. Activity 2. Calculation of Soap Concentration

After completing the blank titration and the three soap titrations, calculate the soap content of the sample of biodiesel. To calculate the parts per million (ppm) of soap in your sample, use the following equation.

\[
(T - B) \times M \times 320560N = \text{soap content in ppm}
\]

\[T = \text{total volume of hydrochloric acid solution in the titration, in mL}\]
B = volume of hydrochloric acid solution used in the blank titration, in mL M = molarity of hydrochloric acid solution (in this procedure, 0.01) 
320560 = value corresponding to the molecular weight of potassium oleate (i.e., soap), in mg 
V = volume of a biodiesel sample in mL (This lab uses 5.0 mL of biodiesel for each titration.)

1. Calculate the soap content in parts per million for each of your three titrations.
2. Average the three results to come up with a final soap content result. This is the soap content of your sample.

Table 2

<table>
<thead>
<tr>
<th>Titration Result</th>
<th>Initial HCl Volume</th>
<th>Final HCl Volume</th>
<th>Amount of HCl Added</th>
<th>Soap Content (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blank Titration</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Titration #1</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Titration #2</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Titration #3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average Soap Content (ppm) of 3 Titrations</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Sample Data for Biodiesel from Com Oil:

Table 2

<table>
<thead>
<tr>
<th>Titration</th>
<th>Initial HCl</th>
<th>Final HCl</th>
<th>Amount of HCl</th>
<th>Soap Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blank</td>
<td>0.3</td>
<td>0.4</td>
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<td></td>
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<tr>
<td>Titration</td>
<td>0.4</td>
<td>2.0</td>
<td>1.6</td>
<td>962</td>
</tr>
<tr>
<td>Titration</td>
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<tr>
<td>Average Soap Content (ppm) of 3 Titrations</td>
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<td></td>
<td>941</td>
</tr>
</tbody>
</table>

Note: These are from the Student Guide included with the Carolina kit. You can use them to guide a discussion after the lab is completed.
Answers to Questions in the Student Guide

1. What is the important property of the hydrochloric acid solution used as the titrant?
   *Hydrochloric acid solution is acidic, allowing it to alter the pH of the alkaline or basic biodiesel samples and eventually neutralize them.*

2. Why is it unimportant to measure exactly the amount of isopropyl alcohol used in the titration?
   *The alcohol does not react with the acid, and has no effect on the results of the titration.*

3. Based on your results of the "blank" titration, what do you think the purpose of this step might be?
   *This step is a control, designed to assure that the isopropyl alcohol solution is indeed uncontaminated and pH neutral.*

4. The average mass of 5 mL of biodiesel is 4.4 grams. Calculate the specific gravity of biodiesel, and determine whether it will float or sink in a sample of water.
   \[
   \text{specific gravity} = \frac{\text{density of a substance}}{\text{density of water}} = \frac{\text{mass}}{\text{volume}}
   \]
   The density of biodiesel is 4.4 g/5 mL, or 0.88. The density of water is 1.00. Anything having a specific gravity less than 1.00 is less dense than water and will float. Biodiesel will float in a sample of water.

5. Compare the biodiesel carbon cycle with the fossil fuel carbon cycle.
   *Plants absorb carbon dioxide from the air during their growth and development. The seeds are harvested and pressed for oil, then made into fuel. When the biofuel is burned, the emissions return carbon that was already in the air back to the atmosphere. When petroleum is burned, carbon that was fixed or 'sequestered' underground is released into the atmosphere, driving up the total global atmospheric concentration of carbon dioxide.*

Lab 4: Procedure

Have students use the Putt Putt boats (information attached in Appendix 1) to test their fuels that they created. Include a picture

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**RESOURCES NEEDED – What equipment and supplies do I need?**

**Included in the kit:**
vegetable oil feedstock
potassium hydroxide, granular methanol
isopropyl alcohol, 99%
0.01 M hydrochloric acid
1% phenolphthalein in 95% ethanol, 100 mL
1% bromophenol blue in water, 100 mL
4 plastic pipets
20 half-pint jars with sealing lids
4 disposable glass pipets

*Needed, but not supplied:*
safety equipment for each student including gloves, goggles, and lab aprons (nitrile gloves recommended)
10 buret setups with funnels
12 or more beakers, 250 mL
10 beakers, 100 mL
10 Erlenmeyer flasks, 125 mL
1 L of distilled water
1500 mL flask with stopper
2 graduated cylinders, 250 mL
2 (or more) graduated cylinders, 100 mL
10 weigh boats
10 metal scoops
2 or more hot plates (one for each feedstock type)
thermometers (one for each hot plate)
1 or more digital scales (accurate to 0.01 g or better)
fume hood(s) and/or ventilated work areas (one per station if possible; can be shared)
collected feedstock samples (used cooking oil; see Lab 1 Preparation)
paper towels
disposal containers for titrated solutions

Optional:
Large tank of water
Putt Putt boats (see Appendix 1)

**SET-UP**

**Lab 1:** at each group location in lab:
set out goggles, gloves and aprons for the number of groups needed
set up buret station with funnel
125 mL Erlenmeyer flask
100 mL beaker

**Lab 2:** at each group location in lab:
set out goggles, gloves and lab aprons
weigh boat
metal scoop
250 mL beaker
2 half-pint glass jars with self-sealing lids

**Lab 3:** at each group location in lab:
set out goggles, gloves and lab aprons
buret setup with funnel
125 mL Erlenmeyer flask
250 mL beaker

**Lab 4: at one or more locations:**
Set up tank of water
Set out Putt Putt boats

**Lab 5: Optional**
See Instructions on page S-13 of Carolina booklet

<table>
<thead>
<tr>
<th>Colorado State Standards - High School</th>
<th>21st Century Skills</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Physical Science</strong></td>
<td><strong>Concepts and skills students master:</strong></td>
</tr>
<tr>
<td></td>
<td>6. When energy changes form, it is neither created nor destroyed; however, because some is necessarily lost as heat, the amount of energy available to do work decreases</td>
</tr>
<tr>
<td></td>
<td><strong>Relevance and Application:</strong></td>
</tr>
<tr>
<td></td>
<td>1. Incremental strides have been made in improving the efficiency of different forms of energy production and consumption. For example, today’s engines are much more efficient than those from 50 years ago, and batteries are more powerful and last longer than those from just a few years ago.</td>
</tr>
</tbody>
</table>

| 3. Earth Systems Science               | **Concepts and skills students master:** |
|                                       | 5. There are costs, benefits, and consequences of exploration, development, and consumption of renewable and nonrenewable resources |
|                                       | **Evidence Outcomes** |
|                                       | Students can: |
|                                       | a. Develop, communicate, and justify an evidence-based scientific explanation regarding the costs and benefits of exploration, development, and consumption of renewable and nonrenewable resources |
|                                       | b. Evaluate positive and negative impacts on the geosphere, atmosphere, hydrosphere, and biosphere in regards to resource use |
|                                       | **Inquiry Questions:** |
|                                       | 1. How do humans use resources? |
|                                       | 2. How can humans reduce the impact of resource use? |
|                                       | **Relevance and Application:** |
|                                       | 1. Technologies have had a variety of impacts on how resources are located, extracted, and consumed. |
|                                       | 2. Technology development has reduced the pollution, waste, and ecosystem degradation caused by extraction and use. |

<table>
<thead>
<tr>
<th>Colorado State Standards – Eighth Grade</th>
<th>21st Century Skills</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Physical Science</strong></td>
<td><strong>Concepts and skills students master:</strong></td>
</tr>
<tr>
<td></td>
<td>2. There are different forms of energy,</td>
</tr>
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<td></td>
<td><strong>Relevance and Application:</strong></td>
</tr>
<tr>
<td></td>
<td>4. There are ways of producing</td>
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</tbody>
</table>
and those forms of energy can be changed from one form to another – but total energy is conserved. electricity using both nonrenewable resources such as such as coal or natural gas and renewable sources such as hydroelectricity or solar, wind, and nuclear power.

**Nature of Science:**
3. Use tools to gather, view, analyze, and report results for scientific investigations designed to answer questions about energy transformations.

<table>
<thead>
<tr>
<th>Colorado State Standards – 6th Grade</th>
<th>21st Century Skills</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>3. Earth Systems Science</strong></td>
<td><strong>Inquiry Questions:</strong></td>
</tr>
<tr>
<td><strong>Concepts and skills students master:</strong></td>
<td>1. What resources are found and used in our community?</td>
</tr>
<tr>
<td>3. Earth’s natural resources provide the foundation for human society’s physical needs. Many natural resources are nonrenewable on human timescales, while others can be renewed or recycled</td>
<td></td>
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</tbody>
</table>

**Supply**

| Non-borrowed supplies listed on page 12-13 | $30.00 |
| Carolina kit for Production of Biodiesel [http://www.carolina.com/product/physical+science/chemistry/carolina+chemkits/carolina+chemkits%26trade--+production+of+biodiesel+kit.do](http://www.carolina.com/product/physical+science/chemistry/carolina+chemkits/carolina+chemkits%26trade--+production+of+biodiesel+kit.do) | $88.25 for 30 students working in groups of 3 |
| **Total** | **$118.25** |

*Based on 30 students - $3.94 cost per student  * 2 staff recommended