Combustion Comparisons of Fuel C. Kohn, Waterford WI  
*Based on Lab-Aids Kit 39S – Biofuels: Investigating Ethanol Production & Combustion*

Name: Hour Date:

Date Assignment is due:  Why late? Score: + ✓ -  
 Day of Week Date If your project was late, describe why

**Overview**: in this lab, you will be comparing the efficiency of the combustion of ethanol (E100), kerosene, and biodiesel. Additionally, you will compare how cleanly each fuel burns and will make a determination as to which fuel is the most effective as a whole.

On Day 1, you will test the combustion efficiency of each fuel by using a fuel burner lamp for each fuel. This lamp will be used to heat a soda can of water for 5 minutes. The change in the temperature of water will be an indication of the combustion efficiency of each fuel. By measuring the heat increase of the water, we can determine the amount of energy (in calories) in the amount of fuel consumed during the burning to obtain the amount of energy per unit of volume of fuel.

After you have completed the calorimetric test of fuel, you will then analyze the emissions of each fuel created as byproducts of combustion on Day 2. To do this, you will hold a small piece of aluminum foil 5 cm above the flame for 15 seconds and observe the changes that occur. After you have done this for each type of fuel, you will then test the CO2 emissions from each type of fuel using bromthymol blue (BTB), an acid-base indicator.

**Safety**: this is a potentially dangerous lab experiment! Each fuel is very flammable – keep away from sparks[[1]](#footnote-1) and avoid inhaling fumes. Kerosene can be hazardous and can be easily absorbed through the skin – avoid contact at all times and do not remove eyewear at any time while in the lab. Because of the presence of open flames, long hair should be tied back.

Be sure that ventilation is available at all times and that fresh air is continuously available to prevent the formation of carbon monoxide. If you feel faint or dizzy at any point, immediately leave the lab and return to the classroom or hallway.

Note where the fire extinguishers and fire blankets are located prior to this lab. Be prepared to use them in the event of an emergency. If you are unsure of how to use them, ask BEFORE the lab begins.

Gloves are not necessary for the first part of this lab. However, you should wash your hands after the lab is finished. Gloves and aprons will be necessary if you work with any caustic or corrosive chemicals. You instructor will inform you of if and when gloves and aprons are needed. Again, goggles will be needed at all times.

**Materials needed**: samples of pure ethanol (E100), kerosene, and biodiesel (produced earlier); safety goggles and disposable gloves/aprons; 3 glass fuel burners per group ([click here to purchase](http://www.enasco.com/product/SB34435M)); matches; one 100 ml graduated cylinder per group; 1 metric ruler per group; 1 aluminum soda can per group; 1 ring stand per group w/ clamp; paper clips; immersible thermometer; a clock; a balance; a sink with faucet; BTB; 0.05 M NaOH; tongs; aluminum foil; 180ml plastic bottle; 30 ml graduated cups; **calculator** (at least one per group)

# Day 1: Calorimetry of Fuel Combustion (safety goggles are needed)

1. To begin, we’ll revisit a concept we’ve covered earlier. In the space below, write a definition of combustion that includes what occurs at the molecular level when a substance is burned:
2. From earlier labs, you know that the more energy that is released by the formation of new molecular bonds in CO2 and H2O during combustion, the greater the value of that combusted substance as a fuel. We will be comparing kerosene (our petroleum product), pure ethanol (E100), and NVO biodiesel (B100) from our earlier labs. (We will leave the WVO biodiesel untested because of its variability).   
     
   **In the space below, 1) rank the fuels from most energy per unit of volume to least. Then 2) provide a rationale to justify your rankings. Finally 3) note which fuel you think will be cleanest-burning.**
3. Fill an empty soda can with exactly 100 ml of water (be sure that there was no water in the empty can before adding). 100 ml of water will equal 100 g of water (water has a density of 1 g per ml). We will measure the change in temperature of 100 ml of water after heating with each fuel to the energy in each unit of volume of fuel.
4. Suspend the soda can with 100 ml of water 3-4 inches above the capped burner using your ring stand and a paperclip. Place the thermometer into the can.
5. Fill each of your three jars half full of a different fuel; you should have one glass fuel burner jar for ethanol, one for kerosene, and one for biodiesel. Mark each with a wax pencil and replace the lid with the wick on top.
6. Adjust each wick so that it is just above the top of the lid. Your wick should be less than 1-2 mm from the top of the burner.
7. Weigh each jar and record the weight below. It is ok if their weights are different.   
   1. *Weight of Ethanol glass fuel burner prior to burning: g*
   2. *Weight of Kerosene glass fuel burner prior to burning: g*
   3. *Weight of Biodiesel glass fuel burner prior to burning: g*
8. Begin with the Ethanol Glass fuel burner. **Ask your instructor to light the wick** and measure the flame. If necessary, adjust the wick so that the flame is between 2-3 cm tall. Extinguish the wick by replacing the cap until you are ready to move to Step 9.
9. Place the glass fuel burner directly underneath the soda can. Light your Ethanol glass fuel burner. Note the time. Record the time when the wick is lit and the initial temperature of the water in the can.   
     
   *Start Time for Ethanol glass fuel burner: : End time (5 min later): :   
     
   Initial Temperature of the Water: Co*
10. After exactly 5 minutes has passed, safely extinguish your wick. Record the Final Temperature of the Water:  
      
    *Final Temperature of the Water: Co*
11. Weigh the Ethanol glass fuel burner and record the new mass below:  
      
    *Weight of Ethanol glass fuel burner after burning: g*
12. Repeat Steps 8-11 above for Kerosene and Biodiesel. Use new water each time; ensure that all water samples begin at the same temperature for each kind of fuel. Record the data in the table below:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Fuel | Initial Weight (g) | Final Weight (g) | Change in Weight (g) | Initial Temp (C) | Final Temp (C) | Change in Temp (C) |
| Ethanol |  |  |  |  |  |  |
| Kerosene |  |  |  |  |  |  |
| Biodiesel |  |  |  |  |  |  |

1. For each of the following, calculate **Average Energy Absorbed** by multiplying the change in temperature (in C) x the mass of water (100 g) x the specific heat of water (1 cal/g x Co = 4.2 J/ g x Co)   
     
   *Ethanol: Temp change x mass 100 ml x specific heat 1 cal /g C = cal   
     
   Kerosene: Temp change x mass 100 ml x specific heat 1 cal /g C = cal   
     
   Biodiesel: Temp change x mass 100 ml x specific heat 1 cal /g C = cal*
2. For each of the following, determine the **Average Energy Content** per gram.   
     
   *Ethanol: Avg E Absorbed: ÷ Mass of fuel consumed (g) = cal/g  
     
   Kerosene : Avg E Absorbed: ÷ Mass of fuel consumed (g) = cal/g  
     
   Biodiesel: Avg E Absorbed: ÷ Mass of fuel consumed (g) = cal/g*
3. Multiply your **Average Energy Content** per gram by the **density** of each fluid to determine the **Energy by Volume**:  
     
   *Ethanol: Avg E Content cal/g x 0.78 g/ml = calories/ml   
     
   Kerosene: Avg E Content cal/g x 0.82 g/ml = calories/ml   
     
   Biodiesel: Avg E Content cal/g x 0.88 g/ml = calories/ml*
4. Obtain the **Class Average Energy Content** **by Volume** for each fuel by averaging your calculations with the calculations from the other groups in class.   
     
   ***Class Average Energy Content by Volume of Ethanol = calories/ml   
     
   Class Average Energy Content by Volume of Kerosene = calories/ml   
     
   Class Average Energy Content by Volume of Biodiesel = calories/ml***
5. Which fuel appears to be the best in regards to the amount of energy in every gallon? Rank the fuels and explain in the space below:
6. Based on the data above and your own knowledge of each fuel, which fuel do you think is the most appropriate as a source of transportation energy (use kerosene as a substitute for octane gasoline). Explain.
7. Set aside your fuel glass fuel burners for later use . Clean up your lab station and wash labware if needed.

# Day 2: Emissions of Fuel Combustion (safety goggles are needed; gloves and aprons may be needed).

1. To begin, explain why a particular fuel might have more pollutants and unwanted particulates in its emission than another fuel by explaining how the breakdown of that fuel during combustion affects the production of pollutants.
2. Light all three wicks on your glass fuel burners. Observe the flames and smoke from all three types of fuel. Record your observations of each fuels’ flame and smoke below:  
     
   *Ethanol Combustion Observations:   
     
      
     
    Kerosene Combustion Observations:   
     
      
     
   Biodiesel Combustion Observations:*
3. While keeping the glass fuel burners lit, use tongs or tweezers to hold a small piece of aluminum foil 5 cm over the flame (one piece per flame) for 15 seconds. Describe any and all changes to the foil as a result of this below:   
     
   *Ethanol Foil Observations:   
     
      
     
    Kerosene Foil Observations:   
     
      
     
   Biodiesel Foil Observations:*
4. Which fuel appears to be the cleanest burning? The least clean?
5. Is this consistent with all of the other groups?
6. Put 10 ml of distilled water into your graduated cup (or cylinder if a cup is not available). Add 2 drops of bromthymol blue (BTB) and swirl to thoroughly mix each together. The solution should be blue. See you instructor if it is not.
   1. *The color blue is an indication of a base, while yellow indicates an acid. Because our water is affected by limestone, it should be slightly above neutral. The addition of NaOH, drop by drop, may be necessary to adjust the pH of your water.*
7. **Ask you instructor to light your wick.** Carefully place the open mouth of your group’s glass bottle over the lit wick of the ethanol glass fuel burner at an angle so that the lower edge of the mouth is resting just above the metal lid. As the flame extinguishes, keep the bottle upside down and over the wick. Lift it just enough to screw on the cap or insert a stopper.
8. [](http://www.google.com/imgres?um=1&hl=en&rls=com.microsoft:en-us:IE-Address&rlz=1I7ADRA_en&biw=1619&bih=772&tbm=isch&tbnid=7uzKIHshOLdmWM:&imgrefurl=http://www.enasco.com/c/science/Lab+Supplies/Alcohol+%26+Butane+Lamps/&docid=AO9pKkophrSkWM&imgurl=http://www.enasco.com/prod/images/products/9C/AC008241l.jpg&w=400&h=463&ei=Nw5iT6zXENL4ggfm1pC1CQ&zoom=1)As quickly as you can, turn the bottle right-side up, uncap it, and pour your water/BTB solution into the bottle.
9. Shake vigorously 20 times.
10. Pour the BTB solution back into its cup and note the appearance of the cup.   
    Record in the table below.
11. Add 0.05 M NaOH, drop by drop, to the cup until the original blue color returns. Record the number of drops needed below.
    1. *The more NaOH needed, the more acidic your water became as a result of your flame’s emissions. The more acidic your sample, the more CO2 that was emitted by the flame. CO2 causes the formation of acid when it reacts with water vapor in the air to produce carbonic acid (H2CO3).*
12. Repeat Steps 6-11 for kerosene and then biodiesel. Record the results of each below.

|  |  |  |
| --- | --- | --- |
| Fuel | Appearance of BTB Solution | Drops NaOH needed. |
| Ethanol |  |  |
| Kerosene |  |  |
| Biodiesel |  |  |

1. According to your observations and data, which fuel produced the most CO2?
2. Which fuel produced the least CO2 emissions?
3. Is this consistent with the class’s results? Explain:

# Class Data Summary

1. **Class Average Energy Content** by Volume for each fuel (average of your calculations with the calculations from the other groups in class).   
     
   *Class Average Energy Content by Volume of Ethanol = calories/ml   
     
   Class Average Energy Content by Volume of Kerosene = calories/ml   
     
   Class Average Energy Content by Volume of Biodiesel = calories/ml*
2. **Particulate emissions observations** and **foil data from combustion**:   
     
   *Ethanol Foil Observations:   
     
      
     
    Kerosene Foil Observations:   
     
      
     
   Biodiesel Foil Observations:*
3. **Carbon Dioxide Production**: Rank your fuels from greatest CO2 production to least based on your BTB and NaOH data:
4. Imagine you pull up to a gas station. At pump one is pure octane gasoline. At pump two is a blend of ethanol and gasoline. If both were identical in price, which would you choose?  
     
   *I would choose because*
5. Were your hypotheses correct? Explain:

1. *Except, of course, when intentionally lighting for the experiment.*  [↑](#footnote-ref-1)