PROPERTIES OF LIQUIDS & INTERMOLECULAR FORCES:
Testing Properties of Biodiesel

Georgia Performance Standards: SCSh1-9, SC1 b, SC6 a
National Science Standards: Content Standards A, B: structure and properties of matter, F: environmental quality

Objective: Students will test various properties of biodiesel in the lab. They will measure the viscosity, solvent properties and gel points of biodiesel. The students will compare biodiesel with petroleum diesel and the "feedstock oil". (They may also compare biodiesels made from different feedstocks or blends.)

Essential Questions:

- How do the properties of biodiesel compare to the properties of petroleum diesel?
- How do the properties of biodiesel compare to the properties of the "feedstock oil"?
- Which fuel is better for use in a vehicle or does it matter?
- What are the pros and cons of using biodiesel?

Background:

Part I: Solvent Properties

Biodiesel has many uses other than as a fuel for cars or heating. Biodiesel can be an excellent parts cleaner for greasy engine components (parts left in a bucket overnight are usually clean the next day). It can also be used as a lubricant for machinery, to clean up petroleum oil spills on land or water, and as a solvent for many paints and adhesives.

Solvents are substances that can dissolve other materials. Many commercial solvents are produced from crude petroleum oil. These solvents include: benzene, gasoline, ether, and mineral spirits. A good number of petroleum-derived solvents are very flammable, dangerous to handle, and some are even carcinogens (cancer-causing). Solvents that are derived from methyl esters (biodiesel) are becoming more common because they are more stable, less flammable and non-toxic.

Sometimes car-owners who run biodiesel in their engines have to occasionally check their fuel filters after using it for the first time. Often, since it is a good solvent, the biodiesel will clean out engine components of buildup and the filters will clog with the loosened debris. Also biodiesel users need to replace rubber fuel lines with synthetic hoses to avoid deterioration.

Part II: Viscosity
Viscosity is the resistance of a liquid to flow. The strength of the intermolecular forces between the liquid's molecules is what determines how viscous a liquid is. Stronger forces mean that the liquid is less likely to flow. In a diesel engine, viscosity of the fuel is a very important thing to worry about. The fuel injectors need to be able to spray a very fine mist of fuel into the cylinder so the hot compressed air can evenly ignite the fuel and ensure a complete combustion reaction. If the viscosity of the fuel is too high, the injectors will not spray evenly (and may even 'dribble') so some of the fuel may not combust due to the poor atomization. This results in poor fuel mileage and possible damage to the engine.

Part III: Cloud and Pour Points
Some diesel vehicles have difficulty operating in cold-weather situations. Due to the components in diesel fuel, it tends to solidify at a higher temperature than gasoline, therefore diesel fuel use becomes more of an issue in the winter. Diesel engines are equipped with glow plugs which are partially sitting in path of the fuel flow. These glow plugs heat up and keep the fuel from solidifying. Petroleum diesel will begin to cloud at 20˚F or -7˚C. The cloud point of diesel is when the fuel starts to appear hazy because wax crystals begin to form in the fuel. When the fuel clouds, the fuel filter can become clogged and therefore the vehicle won't run. At -10˚F or -23 ˚C, petroleum diesel #2 will no longer be usable. At this temperature the pour point of the fuel has been reached. This is when the fuel will no longer run through the fuel lines. Diesel #1 is less common but has characteristics closer to kerosene and can be used down to -20˚F (-29˚C). Sale-grade biodiesel must have a cloud point of at least 38˚F or 3˚C. Depending on what the biodiesel is made from, it can cloud between 60˚F (16˚C) and 25˚F (-4˚C). The more free fatty acids that are in the biodiesel, the higher the cloud point will be. Used cooking oil and animal fat have very high amounts of free fatty acids. Therefore biodiesel made from these feedstocks will not have good cold-weather properties.

Materials: *This may be a two or three period lab*

1. vials with caps OR test tubes with corks (not rubber stoppers)
   Each must hold approximately 50 mL
2. thermometers or temperature computer probes
3. Cargille Viscosity Tubes (Time-Test, 10.65mm (ASTM D 1545))
4. large test tubes with corks that have single holes

5. buckets of ice
6. 400 mL beaker
7. stop watch
8. Styrofoam (polystyrene) peanuts (not the cornstarch kind)
9. previously made biodiesel (from lesson #2)
10. diesel #2
11. “feedstock oil”
12. water

******Before starting the lab, state your hypothesis on the results you expect to see when you do these tests.***

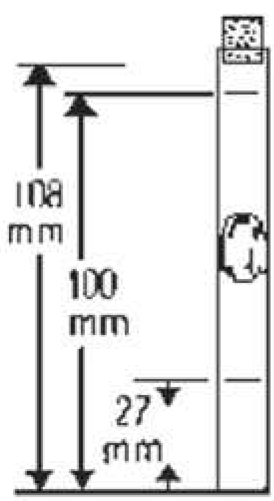
Procedure:

Part I: Solvent Properties (procedure modified-see notes)

1. Get three vials or large test tubes with corks
2. Pour 20 mL of biodiesel into one tube
3. Pour 20 mL of petroleum diesel into a second tube
4. Pour 20 mL of “feedstock oil” into the third tube
5. Place two styrofoam peanuts in each test tube
6. Put the lid or cork on and shake
7. Every 15 seconds stop to observe the peanuts. Record your observations.
8. When the peanuts in one of the tubes become completely dissolved, stop shaking and record your final observations.

Part II: Viscosity

1. Obtain one viscosity tube with a cork from your teacher.
2. Fill the tube up with biodiesel to the mark that is second from the top.
3. Insert the cork so the bottom of the cork is exactly at the top line. This will ensure that your bubble of air is an exact volume.
4. Turn the test tube upside down so that the bubble is at the bottom of the test tube.
5. Turn the test tube right-side-up and hit the stop watch the instance the bubble touches the first line and stop it when the bubble hits the second line.
6. Record how many seconds it took for the bubble to travel between the lines (exactly 73mm). The units on that number will be “bubble seconds” or “Stokes.”
7. Do two more readings of the biodiesel and average the three trials together. Show the



calculation of the average.
8. Thoroughly clean and dry the viscosity tube.
9. Repeat steps 2-7 using petroleum diesel.
10. Thoroughly clean and dry the viscosity tube.
11. Repeat steps 2-7 using "feedstock oil".
12. Thoroughly clean and dry the viscosity tube.
13. Repeat steps 2-7 with water for comparison.
14. Thoroughly clean and dry the viscosity tube and return it to your teacher.

Part III: Cloud and Pour Points

1. Obtain two large test tubes and two corks (with holes)
2. Place 20 mL of petroleum diesel in one test tube and cork it.
3. Place 20 mL of biodiesel in the other test tube and cork it.
4. Fill a 400 mL beaker with ice and a little water.
5. Put the temperature probe into the test tube with the petroleum diesel through the hole in the cork.
6. On the Logger Pro software on the computer, go to 'experiment' at the top and click on 'data collection.'
7. Make sure it says Mode: 'Time Based' Length: '30 minutes' and '2 samples/minute'
8. Click 'Done'
9. Place the petroleum diesel tube into the ice bath and click 'collect' at the top
10. Every minute or two, stir the diesel around. Periodically look at the sample.
11. Record the time (in seconds) when the first instance of "haze" or cloudiness appears. Also note the time when the diesel no longer able to pour or flow (if it happens).
12. Repeat steps 9-11 with the biodiesel.
13. Make a chart and collect the cloud points and pour points of your classmates' samples.

Questions: Part I: Solvent Properties

1. What affect did the biodiesel have on the peanuts? The petroleum diesel? The "feedstock oil"?
2. Which was a better solvent? If the peanuts dissolved, how many seconds did it take?
3. What is a possible use for this type of solvent property?
4. Why would we not want to use gasoline or another volatile solvent derived from petroleum?
5. Why do you think the straight "feedstock oil" might differ in solvent properties from the biodiesel?

6. How do you think the solvent properties of biodiesel could be an issue in an engine? If you ran an engine on straight vegetable oil, would you have any problems?

Part II: Viscosity

1. Of the two diesels, which one had a greater viscosity (in which one did the bubble take longer to move)? Was there a significant difference in the two diesels? Is this what you expected?
2. How did the viscosity of the diesels compare to the viscosity of water? Is this what you expected?
3. Based on the background information, is biodiesel suitable to run in your engine? Is crude vegetable oil suitable for your engine?
4. How do you expect the viscosities to change with the heat of the engine? Explain why on a molecular level.

Part III: Cloud and Pour Points

1. What were the cloud points of the two diesels? Pour points? How does the biodiesel compare to petroleum diesel?
2. Would you consider using B100 if you lived in Michigan?
3. Sometimes you hear about the gel point of diesel. Can you describe what you think the physical properties of diesel in that state might be?
4. Can you think of the physical or chemical ways that people try to accommodate for the high cloud/pour points of diesel? Will these ways work for biodiesel?
5. Look at your temperature vs. time graphs. Label on the graph where the cloud point and pour points are. Do you notice anything happening to the graphs at those times? Describe what happens in the Analysis section of your lab notebook.

Assessment: Lab rubric

Lab Data Sheet – Properties of Liquids (Page 1)

Hypothesis (include a statement about each of the three parts):

Solvent Properties:

Seconds Observations

Viscosity:

Seconds	Biodiesel	Petrodiesel	Feedstock Oil
Trial 1			
Trial 2			
Trial 3			
average			

Lab Data Sheet – Properties of Liquids (page 2)

Cloud and Pour Points:

Attach your temperature vs. time graphs.

Time (in seconds) of the first appearance of haze: ________________

Time (in seconds) where the fluid no longer flows: ________________

Classmates' data:

Time of Haze   Time No Longer Flows

Averages of each column:

PROPERTIES OF LIQUIDS & INTERMOLECULAR FORCES: Instructor Notes

Solvent properties procedure was modified from the Soy Biodiesel Education Kit from Purdue University and the National Biodiesel Board. The kit can be purchased at www.biodiesel.org .

For the cloud and pour point procedure: if you do not have access to computer temperature probes and graphing software, you may have the students manually record the temperature every 30 seconds and then use Microsoft Excel to make a plot of time vs. temperature. The lab was written for use with the Vernier Lab Pro software and probes. These items can be purchased at http://www.vernier.com

Viscosity tubes that are used are "bubble method" tubes purchased from Cargille Labs http://www.cargille.com/vistube.shtml .