Properties of Liquids: Teacher Manual

Goals

- Students will differentiate between density and viscosity.
- Students will separate and identify liquids by density.
- Students will predict viscosity of biodiesel.

Background

Density and viscosity are essential properties in characterizing liquids, and the differences between the two are important. Density is the amount of matter in a given space (mass per unit volume), and viscosity is the resistance of a liquid to flow. Unfortunately, the terms "thick" and "thin" are frequently used as synonyms for both dense/not dense and viscous/not viscous.

Students confuse density and viscosity, or they simply do not possess a separate viscosity concept. They are inclined to think that oils are denser than water, because oils do not flow as easily as water. They need the idea of viscosity as a distinct property, and if the ideas of viscosity and density are introduced in close proximity with deliberate comparisons, long term confusion might be avoided. The table below gives the densities and viscosities of six liquids arranged in order of viscosity. Though the organic substances follow the same order for viscosity and density, the inorganic substances, water and mercury, do not.

Table of Liquid Viscosities and Densities

LIQUID	VISCOSITY (Pa·s)*** (at 20°C)	DENSITY (g/mL)** (at 20°C)
Methanol	5.9×10^{-4}	0.79
Water	1.003×10^{-3}	1.00
Mercury	1.55×10^{-3}	13.53
Biodiesel*	34×10^{-4} - 51×10^{-4}	0.86 - 0.90
Corn oil	3.1×10^{-2}	0.92
Glycerin	1.42	1.26

*Varies by source, e.g., corn or soy

**Densities are given in g/mL, because they are more intuitive for students than the SI kg/m3. They can be changed by multiplying by 1000, e.g., 0.79 g/mL becomes 790 kg/m^3.

***Viscosities of other common liquids: http://hypertextbook.com/physics/matter/viscosity/

Should students wish to explore other liquids, the website given as a footnote to the table provides common examples. It should be noted that in articles that deal with viscosity, in particular those concerned with biodiesel technology, two types of viscosity are usually mentioned: dynamic or absolute viscosity and kinematic viscosity. Dynamic or absolute viscosity is the number used here. (Kinematic viscosity is the ratio of dynamic viscosity to density.)

Materials

- Water (tap water works)
- Methanol (about 150 mL per student team)
- Corn oil (about 150 mL per student team)
- Biodiesel (about 150 mL/team; from previous lab?)
- Glycerin (about 150 mL/team; if from previous lab, this will be a glycerin/methanol mixture)
- 250 mL beakers (3/team)
- 100 mL graduated cylinders (1/team)
- Scales for finding mass
- Plastic balls, small enough to drop easily in the cylinder (5/team)
- Stopwatches (1/team)
- Printed lab sheets for Exploration and Experiment

Preparation

On Day 1 prepare a chart (chalkboard, overhead, or computer/projector) to record and share data on densities and ball drop times for water and methanol. On Day 2 a similar chart will be needed for corn oil, glycerin, and biodiesel. DATA FOR WATER AND METHANOL SHOULD BE INCLUDED ON THE DAY 2 CHART FOR COMPARISON.

This lab is meant to follow one in which students make biodiesel and glycerin from corn oil and methanol. If the products from this lab are used, the glycerin will really be a glycerin/methanol mixture. A sample of pure glycerin could be used for comparison. If this lab has not been completed, samples of biodiesel and glycerin will need to be obtained elsewhere, and students can skip the question about which product, biodiesel or glycerin, contains the waste methanol.

Procedure (See also student version)

Exploration (Day 1)

1) Students will find the densities of 2 liquids, water and methanol, by measuring 100 mL of each into graduated cylinders that have been massed. They find the mass of cylinder plus liquid and then the mass of the liquid by difference. They divide by 100 to find the density of each liquid in grams/milliliter. (This procedure is used to build an instinctive sense of liquid density, and it could be modified for students who are already very familiar with the density concept.)

2) Using the same cylinders with 100 mL of liquid, students will mark cylinders for each liquid by placing a piece of masking tape vertically on the cylinder. They will mark a starting point about 1 centimeter below the level of the liquid and a stopping point 10 centimeters below the starting point. They then use a stopwatch to find the time it takes a small ball to drop through the measured distance in the cylinder.

3) Class Discussion: Compare data posted by each group. It should be clear that water has a density greater than methanol (about 1 g/mL for water compared to about 0.8 g/mL for methanol) . It should also be clear that the ball sinks faster in the methanol than in water. Students should

form a hypothesis for Day 2, remembering that a hypothesis has reason and a prediction. A good initial "reason" for the differences in time for the ball to sink is density. Students should be able to predict accordingly that denser liquids will have times greater than less dense liquids. A good hypothesis statement would be, "If denser liquids cause the ball to drop more slowly, then times for the ball to drop should be greater as density increases. (The density reason is NOT correct, but students should discover that for themselves on Day 2.)

Experiment (Day 2)

1) Students will find the densities of corn oil, biodiesel, and glycerin using the same procedure as Day 1.
2) Ball dropping is timed as in Day 1.
3) Students arrange data in a table according to ball drop times. It should become clear that the densities do not go in the same order.
4) Each group adds densities and times to the class chart for comparison.
5) The hypothesis has been disproven, because water is not in order. Students might need to be reminded that it only takes one piece of data to disprove a hypothesis.
6) Introduce the term viscosity: resistance to flow.

Questions

1. You found that density was not a dependable way to predict the time a ball takes to drop through a liquid. Instead, you found that there was another property of liquids called viscosity. In your own words, what is viscosity? (Answers may vary, but will probably include resistance to flow or stickiness.)
2. The liquids in the table below are arranged from lowest viscosity to greatest viscosity. How would the time for a ball to drop through mercury compare to that for water? How would it compare to corn oil? How does the density of mercury compare to water and corn oil? (Mercury is more viscous than water, so the ball would drop more slowly. Mercury is less viscous than corn oil, the ball would drop more quickly through mercury. Mercury is much more dense than either water or corn oil.)

LIQUID	VISCOSITY (Pa·s)*** (at 20°C)	DENSITY (g/mL)** (at 20°C)
Methanol	5.9×10^{-4}	0.79
Water	10.03×10^{-4}	1.00
Mercury	15.5×10^{-4}	13.53
Biodiesel*	?	0.86-0.90
Corn oil	310×10^{-4}	0.92
Glycerin	1420×10^{-4}	1.26

3. Do you think heating a liquid would change the viscosity? Give a reason for your answer. (Heating will lower the viscosity. A possible reason for the answer is experience heating syrup; syrup flows more easily when it's heated.)
4. When you made biodiesel and glycerin by mixing corn oil and methanol, you added more methanol than needed. Some methanol did not react, and it was left in one of the products. Based on the densities in the table and the densities you found for your biodiesel and glycerin samples, do you think the extra methanol was mixed with the biodiesel or the glycerin? Explain. (Answers may vary, but logically methanol will reduce the density of the product with which it mixes, so if students found a density lower than the density in the table, they should guess that that product contains the methanol. In fact, the methanol is found mixed in the glycerin.)

Properties of Liquids: Student Lab Day 1

EXPLORATION (DAY 1)

Question: How is density related to movement in liquid?

Materials/Equipment:

Your team will need

- 250 mL beakers, 2
- Tap water - a little more than 100 milliliters
- Methanol - a little more than 100 milliliters
- 100 mL graduated cylinder
- Nylon balls, 5
- Stopwatch

You will also be using a balance scale.

Procedure

1. *Find the density of water by the following method:*
   a. Use a 250 mL beaker to obtain a sample of tap water, slightly more than 100 mL.
   b. Find the mass of a dry 100 mL graduated cylinder. (Record below.)
   c. Pour exactly 100 mL of the water into the 100 mL graduated cylinder.
   d. Find the mass of the graduated cylinder with water. (Record below.)
   e. Subtract to find the mass of water alone.
   f. Find the density of water in g/mL (grams per milliliter).
   g. Pour the water back into its beaker for later use.
2. *Find the density of methanol by the same method used for water. Complete the table below.* ***Save the methanol in its beaker.***

	WATER	METHANOL
Mass of cylinder with 100 mL liquid		
Mass of dry cylinder		
Mass of 100 mL liquid		
Density of liquid (g/mL) *Note: You know the mass of liquid in 100 grams. This will be the mass of liquid in 1 gram.*		

3. Record the densities in the class data table.
4. *Use the following method to find how long it takes a nylon ball to fall 10 centimeters through water:*

a. Place a piece of masking tape vertically on the graduated cylinder.
b. Mark a starting point about 1 centimeter below the 100 mL mark.
c. Mark a stopping point 10 centimeters below the starting point.
d. Put 100 mL of water in the cylinder.
e. Drop a ball in the water. Start the stopwatch (or other timer) when the ball reaches the starting point on the masking tape. Stop the stopwatch when the ball reaches stopping point on the masking tape.
f. Record the time below.
g. Repeat 2 more times and average the 3 times for water.

5. *Use the same method to find how long it takes the ball to fall through methanol.* ***You may discard the water, but DO NOT discard the methanol.***

TIME FOR BALL TO FALL 10 CENTIMETERS	WATER	METHANOL
Trial #1		
Trial #2		
Trial #3		
Average time		

6. Record the average times in the class data table.

Class Discussion

1. Based on data from the whole class, how do the densities of water and methanol compare?

2. Based on data from the whole class, how do the ball drop times for water and methanol compare?

3. How might you predict ball drop times for other liquids? Write this in the form of a hypothesis, remembering that the hypothesis gives *reasoning* for believing the prediction might be true, and it is *testable*.

Properties of Liquids: Student Lab Day 2

EXPERIMENT (DAY 2)

Question: How is density related to movement in liquid?

Materials/Equipment:

Your team will need	250 mL beakers, 3
	Corn oil - a little more than 100 milliliters
	Biodiesel - a little more than 100 milliliters
	Glycerin - a little more than 100 milliliters
	100 mL graduated cylinder
	Nylon balls, 5
	Stopwatch

You will also be using a balance scale.

Hypothesis (Use the hypothesis you developed on Day 1, or change it if you wish.)

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Procedure

1. Use the same method you used in the Exploration to find the time it takes for a nylon ball to fall 10 centimeters through each of the following liquids: corn oil, glycerin, and biodiesel. Put your data in **Table 1**.
2. Use these times and the times for water and methanol found in the Exploration (Day 1). Arrange the liquids in **Table 3** from least time to greatest time.
3. Use the same method you used in the Exploration to find the densities of each liquid. Use **Table 2** for your raw data, and then put the densities in **Table 3**.
4. Add your times and densities to the class data table.

Results

Table 1: Ball drop times.

TIME FOR BALL TO FALL 10 CENTIMETERS	CORN OIL	GLYCERIN	BIODIESEL
Trial #1			
Trial #2			
Trial #3			
Average time			

Table 2: Densities.

	CORN OIL	GLYCERIN	BIODIESEL
Mass of cylinder with 100 mL liquid			
Mass of dry cylinder			
Mass of 100 mL liquid			
Density of liquid (g/mL)			

Table 3: Liquids from least to greatest ball drop time.

LIQUID	BALL DROP TIME	DENSITY

Conclusion: Explain whether the data in Table 3 supports your hypothesis or not. Then answer the beginning question.

Properties of Liquids: Post Lab

Post Lab Questions

1. You found that density was not a dependable way to predict the time a ball takes to drop through a liquid. Instead, you found that there was another property of liquids called viscosity. In your own words, what is viscosity?

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2. The liquids in the table below are arranged from lowest viscosity to greatest viscosity. How would the time for a ball to drop through mercury compare to that for water?

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How would it compare to corn oil? How does the density of mercury compare to water and corn oil?

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LIQUID	VISCOSITY (Pa·s) (at 20°C)	DENSITY (g/mL) (at 20°C)
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*Varies by source, for instance, corn or soy

3. Do you think heating a liquid would change the viscosity? Give a reason for your answer.

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4. When you made biodiesel and glycerin by mixing corn oil and methanol, you added more methanol than needed. Some methanol did not react, and it was left in one of the products. Based on the densities in the table and the densities you found for your biodiesel and glycerin samples, do you think the extra methanol was mixed with the biodiesel or the glycerin? Explain.

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