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Let it Flow! Worksheet

Objective: To determine the effect of temperature on fluid viscosity.

Background: The viscosity of a liquid is its resistance to flow. Various liquids have different viscosities. For example, rubbing alcohol seems to pour very easily from its container, whereas liquids such as lotion or hand sanitizer seem to flow out more slowly. Liquids with higher viscosities tend to pour more slowly, due to strong molecular bonding.

There are several formulas or equations that can be used to calculate viscosity, but the most common is this equation derived from Stoke's Law:

$$\text{Viscosity} = \frac{2 * g * r^2 \text{ (ball density – liquid density)}}{9 * v}$$

where g = acceleration due to gravity = 9.81 m/s^2 (981cm/s^2), r = radius of ball bearing, and v = velocity of ball moving through a liquid. Although there are several factors that can affect a fluid's viscosity, today we will investigate how temperature is related to a liquid's viscosity.

Hypothesis: Do you think the temperature of a fluid has a significant effect on its ability to flow? Why or why not?

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Safety: YOU MUST WEAR GOGGLES AND AN APRON!

Materials

- scale
- weighing tray
- 100 ml graduated cylinder
- steel or marble ball (about 1-inch diameter)
- 500 ml or 600 ml beaker
- 1-3 150 ml beakers
- beaker tongs or heat mitt
- ruler
- electronic or glass thermometer
- hot plate
- ice/cold water bath
- dry-erase marker
- stopwatch app or device
- pen or pencil
- viscous or semi-viscous liquid (e.g., honey, oil, corn syrup, clear dish soap, etc.)

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Instructions:

Your stock solution: Using a 500 ml or 600 ml beaker, obtain 500 ml of the liquid assigned to you by your teacher. Write your liquid name here: ________________________.

Part 1: Calculate density of ball

1. With a ruler, measure the radius (halfway point) of the ball. Record your radius (r) in cm.
r_{bal} = _______ cm

2. Calculate the volume of the ball using this equation: $Vol_{bal} = \frac{4}{3}\pi r^3$. Record the volume of the ball in cubic centimeters (cm^3). Vol_{bal} = _______ cm^3

3. Weigh the weighing tray on a scale. Record the mass of the balanced tray.
Tray = _______ g

4. Place the ball on the weighing tray. Balance the mass of the ball + weighing tray and record.
Ball + tray = _______ g

5. Subtract the masses of Step 4 and 3 (4 - 3) to get the mass of the ball. M_{bal} =______ g

6. Calculate the density (D) of the ball by dividing its mass by its volume (Step 5 ÷ Step 2) .
$D_{bal} = \frac{Mass\ bal}{Vol\ bal}$ D_{bal}= ________ g/cm^3

Part 2: Calculate density of liquid

1. Weigh an empty 150 ml beaker. Record its mass. M_{bek} = ________ g

2. Pour **<u>100 ml of your liquid</u>** from your 500 ml or 600 ml beaker into the150 ml beaker.

3. Record the liquid volume of the 150 ml beaker in cm^3. Note: 1 ml = cm^3.
Vol_{liq} = _________ cm^3

4. Weigh the fluid-filled 150 ml beaker and record its mass. $M_{bek + liq}$ = _________ g.

5. Subtract the mass of the filled beaker from the mass of the empty beaker (Step 4 – Step 1) and record the mass of the liquid. M_{liq} = _________ g

6. Calculate the density of the liquid by dividing its mass over its volume (Step 5 ÷ Step 3).
$D_{liq} = \frac{Mass\ liq}{Vol\ liq}$ D_{liq}= ________ g/cm^3

Part 3: Calculate terminal velocity (speed) of the ball through liquid at "room" temperature

1. Place a thermometer in your liquid-filled 150 ml beaker and let it sit for five minutes. After five minutes, record the temperature of the liquid. Liq. $Temp._{room}$ = _______ °F

2. Pour and fill the 100 ml graduated cylinder to the 100 ml mark with the liquid from the 150 ml beaker. Observe the flow of your liquid and add observation to the data table.

3. With a dry-erase marker, draw a line at the 100 ml mark (top) and mark a measurement line near the bottom of the graduated cylinder.

4. With your stopwatch ready, drop the ball into the fluid-filled graduated cylinder. (Note: Be ready to IMMEDIATELY START the timer when the ball passes the top measurement line and to STOP it once it passes the lower measurement line.)

5. Measure how fast the ball falls to the bottom. Record the distance (measure the marks with the ruler), and the time.

Distance = __________ cm Time = ____________ s

6. Calculate the velocity (V) of the ball, which is the distance divided by the time.

$$V_{bal} = \frac{distance\ (cm)}{time\ (s)} \qquad V_{bal} = \_\_\_\_\_\_\_\_ \text{ cm/s}$$

7. Retain the ball by pouring the liquid back into the 150 ml beaker. Proceed to the next part.

Part 4: Calculate terminal velocity (speed) of the ball through liquid at "cold" temperature

1a. Obtain a clean 150 ml beaker and fill it with your liquid from your larger stock beaker to the 100 ml mark. (Note: *If you do not have another 150 ml beaker, reuse the liquid you have and add more, if needed, to reach 100 ml).*

1b. Place your 150 ml beaker in an ice-water bath. Place the thermometer in the beaker and let it sit for five minutes.

1c. After five minutes, record the temperature of the liquid. Liq. $Temp._{cold}$ = _______ °F

Repeat Steps 2-7 from Part 3 and record your data below for Part 4.*

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<u>*Make sure to observe the flow of your *cold* liquid as you pour it into the graduated cylinder and add your observation to the data table.</u>

Distance = ___________ cm Time = _____________ s

$V_{bal} = \frac{distance\ (cm)}{time\ (s)}$ V_{bal}= _________ cm/s

Part 5: Calculate terminal velocity (speed) of the ball through liquid at "warm" temperature

1a. Obtain a clean 150 ml beaker and fill it with your liquid from your larger stock beaker to the 100 ml mark. (Note: *If you do not have another 150 ml beaker, reuse the liquid you have and add more, if needed, to reach 100 ml).*

1b. Place the 150 ml beaker on a hot plate and turn the heat to warm (but not hot!). Place the thermometer in the beaker and let it sit for five minutes.

Caution!!!: hot plates, heated glassware, and liquids can cause burns if not handled properly. Please remember to wear safety equipment and use heat mitts or beaker tongs when handling.

1c. After five minutes, record the temperature of the liquid.
Liq. Temp. $_{warm}$ = ________ °F

Repeat Steps 2-7 from Part 3 and record your data below for Part 5.*

<u>*Make sure to observe the flow of your *warm* liquid as you pour it into the graduated cylinder and add your observation to the data table.</u>

Distance = ___________ cm Time = _____________ s

$V_{bal} = \frac{distance\ (cm)}{time\ (s)}$ V_{bal}= _________ cm/s

Part 6: Calculating the viscosity of your liquid at different temperatures

Part 1 (Step 1) Part 1 (Step 6) Part 2 (Step 5)

$$\text{Viscosity } (\mu) = \frac{2 * g * r^2 (\text{ball density} - \text{liquid density})}{9 * v}$$

981 cm/s^2 Ball velocity - Part 3 (Step 6)

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1. **Plug in the values you recorded for these parts into the Stokes Viscosity Equation** in order to calculate the viscosity of your liquid at "room" temperature (Part 3).

   Place your calculated viscosity in the data table for "Room Temperature" under the "Viscosity Column."

2. To find the viscosities of your liquid at "cold" and "warm" temperatures, repeat this calculation by substituting your ball velocity values for Part 4 and Part 5 for "v" in the equation. Record these values in the correct viscosity columns in the table.

3. Make sure to also record the values you have for your liquid at "cold," "room," and "warm" temperatures in the chart.

Data Chart: Your Data
Fill in the information with your data and calculations from the previous parts.

Liquid Name:			
	Flow Observation	**Temperature (°F)**	**Viscosity (g/cm*s)**
Cold			
Room			
Warm			

Data Chart: "Guest" Data
Coordinate with a group that has a different liquid. Fill in their information on your chart.

Liquid Name:			
	Flow Observation	**Temperature (°F)**	**Viscosity (g/cm*s)**
Cold			
Room			
Warm			

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Conclusion Questions

1. Looking at the data you have, what trend do you see concerning the relationship between temperature and viscosity? Does this match your hypothesis?

Students should notice that as the temperature of the fluid increases, the viscosity value of the liquid decreases. They should also be able to make qualitative observations that as the viscosity decreases, the liquid pours faster from their beaker into their graduated cylinder.

Whether their answer matches their hypothesis is dependent on their initial answer.

2. Are there similarities between your results and those of a group with a different liquid? Explain your answer.

Yes - students should notice that as they compare their results with a group that used another liquid, there is an overall trend that shows that higher temperature produces lower viscosity.

3. Suppose you were a chemical engineer working at the company Chemical X. Your company produces a sandwich spread named 'Gloopy-Glop' that is used on sandwiches for lunch in high school. Your company is attempting to pump it through its piping system to fill jars.

However, the spread is very thick, and it is not pumping through the pipes very well. What could be done to fix this problem?

By heating the liquid spread, the viscosity can be decreased to allow it to flow more easily, thus causing it to better flow through the piping system.