

Changing Viscosity

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Grade level: Fifth

Discipline: Physical Science/Chemistry

Goal: To have students investigate the properties of flow and viscosity.

Specific objectives: To strengthen observational skills. To record observations in a science journal. To cooperate and share findings.

Background:

One of the most obvious differences between solids and liquids is that liquids, like gases, flow. Because both gases and liquids tend to flow, whereas solids do not, the gaseous state and the liquid state are referred to as fluid states. Thus the solid state is a condensed non fluid state, the liquid state is the condensed fluid state, and the gaseous state is the noncondensed fluid state. A measure of the tendency to flow is the viscosity. There is a wide range of viscosities among liquids. Water flows readily, glycerine is much slower, and a tar's pace is even more leisurely. Viscosity is one of a group of properties of fluids called transport properties, which are related to the flow of matter or energy.

Viscosity is the property of fluids responsible for their resistance to flow. A high viscosity is characteristic of a liquid that flows slowly, and a relatively low viscosity characterizes liquids that flow freely. The measurement of viscosity is made by a number of methods, including passing the liquid through a narrow tube or dropping a ball through the liquid. The measurements are usually made by measuring the time required for a flow process to be completed and comparing this with the time required for a standard liquid (often water). In the falling-ball method the liquid is placed in a tube and a ball is dropped into it. The viscosity is determined from the length of time required for the ball to sink through a calibrated distance on the tube.

Materials:

- glycerine
- water
- graduated cylinders (various sizes but at least two 25 mL, two 50 mL, and two 100 mL)
- assorted beads 6mm in diameter (glass, plastic, steel)
- stopwatch
- centimeter ruler
- funnels

Procedure:

With a magic marker mark a distance of 5 cm in the middle of the graduated cylinder. If you are using clear beads, mark them with a "sharpie" (permanent magic marker). This will help make them more visible. If you are using different types of clear beads, color code them.

Using a funnel, fill a graduated cylinder. Then fill the same size graduated cylinder with water. Drop a bead into each graduated cylinder and time the descent through the calibrated distance with a stopwatch. Calculate the cm/sec for each. Repeat this operation with different types of beads. Then try different sizes of graduated cylinders. Develop a chart to keep track of your results.

Now let's see if we can change the viscosity by mixing water and glycerine. Fill one graduated cylinder with 25% water and 75% glycerine, one with a 50-50 mix, and a third with 75% water and 25% glycerine. Again time the descent of the bead through the calibrated distance for each. Now develop a graph to show your results. Be sure to include your times for 100% glycerine and 100% water.

Discussion questions:

1. Did different types of beads fall at different speeds? Why or why not?
2. What kind of effect did different sizes of graduated cylinders have on the speed of the bead?
What might cause this?
3. Explain your graphed results for changing the viscosity of glycerine by adding water.

Extensions:

1. Design, conduct, and share another experiment using these materials.
2. Brighter math students can calculate viscosity and see that it stays the same.
3. Make predictions for using 10%, 20%, 30%,...90% glycerine. What would the graph look like?

Thixotropy and Dilatancy

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Discipline: Physical Science/Chemistry

Goal: To investigate thixotropy and dilatancy.

Specific objectives: To strengthen observational skills. To record observations in a science journal. To work together in cooperative groups. To share findings and insight.

Background:

Thixotropy is the ability of certain substances to liquefy when agitated and to return to a gel form when at rest. The term thixotropy is derived from the Greek words thixis, meaning "the act of handling," and trope, meaning "change." Thixotropic substances are colloidal gels when solid and sols when liquefied. Examples of thixotropic substances include catsup, some hand creams, certain paints and printer's inks, and suspensions of clay in water. The reversibility and essentially isothermal nature of the of the gel-sol-gel transformation distinguish thixotropic materials from those that liquefy upon heating--for example gelatin.

Thixotropic systems are quite diverse. Therefore, it is unlikely that a single descriptive theory can include them all. However, in general, the phenomenon is found only in colloidal suspensions.

Various mechanisms can cause thixotropic behavior. For a gel system, agitation disrupts the three-dimensional structure that binds the system into a gel. Agitation might also introduce order into the system. In a system containing long polymeric molecules, these molecules can be disordered in the gel. When the gel is agitated, the molecules can align in the direction of flow, reducing the resistance to flow.

Some substances possess a property which is nearly the opposite of thixotropy. This property is called dilatancy. A dilatant substance is one that develops increasing resistance to flow as the rate of shear increases. A household example of a dilatant material is a thick dispersion of cornstarch in water. This appears to be a free-flowing liquid when poured, but when it is stirred, it becomes very firm. Another familiar example of dilatancy is the phenomenon of wet sand appearing to dry and become firm when it is walked on.

A very versatile commercial product that can perform multiple functions simultaneously in colloidal formulations is CAB-O-SIL. This is a submicroscopic, fire dried fumed silica.

Because fumed silica is inert, up to 2% by weight is allowed in foods. CAB-O-SIL is used as an emulsifier in salad dressings. The great efficiency in the application allows incorporation of more water in the product, resulting in "light" dressings. CAB-O-SIL can be added to catsup to make it thixotropic. It serves as an anticaking agent in cocoa, non dairy creamers, malted milk powder, baking soda, and so on. In fact, vinegar can be changed to a powder by adding 33% CAB-O-SIL. The powder can be added, for example, to dry sweet-sour mix; the acid is released, and the CAB-O-SIL amount drops to the 2% level when the mix is used. CAB-O-SIL acts as a thickener in heat-resistant margarine.

Lubricating oil is a nonpolar hydrocarbon liquid. The viscosity is increased by orders of magnitude with the addition of CAB-O-SIL. This allows the grease formed to be used at elevated temperatures without chemical degradation and loss of viscosity. The change of viscosity with temperature in bearing lubricants can be stabilized by adding a few percent of CAB-O-SIL, allowing higher speeds, temperatures, and pressures without oozing out. Paints can be stabilized in the same manner, permitting applications at room temperature and drying out at higher temperatures without runs. Also thicker films can be applied. Combined control of thixotropy and viscosity can be achieved.

Gelling of liquid cleaners by adding CAB-O-SIL allows the product to remain where it is applied so chemical action can take place where intended.

Materials: For each group of 4-6 students or have students rotate in small groups to each procedure.

Procedure A

- 500 mL catsup
- 600 mL beaker
- stand with ring small enough to support beaker
- mirror, ca. 20 cm in diameter
- 10 (or more) small steel balls, ca. 6mm in diameter (eg. bicycle ball bearings)
- stopwatch
- stirring rod

Procedure B

- 125 mL cornstarch
- 50 mL water
- 2 600 mL beakers
- stirring rod
- spoon

Procedure C

- 150 mL distilled water
- 23 g fumed silica (eg., CAB-O-SIL)
- Erlenmeyer flask
- rubber stopper for flask

Procedure A

Pour 500 mL of catsup into the 600 mL beaker. Set the beaker on the ring stand and place a mirror under the beaker so the bottom of the beaker can be seen. Allow the catsup to rest for at least 5 minutes.

From about 3 cm above the surface of the catsup, drop one of the steel balls into the beaker of catsup and time how long it takes for the ball to reach the bottom of the beaker. Repeat this with four more balls, and compute the average of the times. Do not drop more than one ball at any one point at the surface of the catsup, because each ball leaves a track through the catsup that another ball may follow. A significant variation in the times is to be expected.

Stir the catsup for one minute. Drop another ball and time its travel. It will sink much more quickly than the previous balls. Time the falls of several more balls dropped at one-minute intervals. The time required for the ball to sink to the bottom increases with each ball.

Procedure B

Place 125 mL (about half a cup) of cornstarch in a 600 mL beaker. While stirring the corn starch, slowly add about 50 mL of water. Stir the mixture with the stirring rod until it is homogeneous. The mixture will be very stiff and difficult to stir. Pour the mixture into the other beaker. It pours freely, although slowly. Stir the mixture again, and again it will be difficult to stir. Pour some of the mixture into the palm of your hand. Strike the mixture in your hand with the spoon. It will not splatter.

Procedure C

Pour 150 mL of distilled water into a 500 mL Erlenmeyer flask. Sprinkle about 5 grams of fumed silica onto the water, stopper the flask, and shake it until the silica is dispersed in the water. Repeat this process until all 23 g of the fumed silica have been added to the water. After the last addition, allow the flask to rest for several minutes, and the liquid in the flask will form a gel. After the liquid has gelled, tip the flask to show that its contents do not flow. Shake the flask vigorously, and the contents will become a viscous liquid. Allow the flask to rest for several minutes, and its contents will again solidify.

Discussion questions:

- A. How can thickness of catsup be misleading in advertising?
- B. How might cornstarch be used in products? Can you design a product that would need these characteristics?
- C. CAB-O-SIL is used in many products. Contrast the positive and the negative sides of its use.

Extensions:

Procedure A: Compare different brands of catsup. Make sure to include one with no additives or preservatives.

Procedure B: Design another experiment using cornstarch. You might want to observe it dry.

- Procedure C:**
1. Check labels on products for emulsifiers like CAB-O-SIL. Report on your findings.
 2. What are the advantages of being able to turn vinegar into a powder with CAB-O-SIL? Design some products that would use this powdered vinegar.

References:

Shakhashiri, Bazzam. *Chemical Demonstrations: A Handbook for Teachers of Chemistry*, Vol. 3, The University of Wisconsin Press, Madison, 1989.

CAB-O-SIL is manufactured by and available from the Cabot Corporation, 125 High Street, Boston, Massachusetts 02110

Viscosity of Some Petroleum-based Materials

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Discipline: Physical Science

Goal: To have the students investigate the properties of flow and viscosity.

Specific objectives: To strengthen observational skills. To record observations in a science journal. To strengthen the connection between math and science.
To work cooperatively and communicate findings.

Background:

Viscosity is one of a group of properties of fluids called transport properties, which are related to the flow of matter or energy. A material with a high viscosity flows slowly and with difficulty, like honey. A material with a low viscosity flows readily, like water. You will determine relative viscosities, which means ranking materials on a range from the most to the least viscous.

The viscosity of a liquid is an important design parameter in numerous practical applications. The pipe dimensions and size and number of pumping stations on the Alaskan pipeline are determined to a large extent by the viscosity of crude oil. The oil is heated to reduce the viscosity. The viscosity of blood affects the throughput in artificial heart-lung machines. When honey is packaged in a plastic dispenser bottle, its high viscosity requires an increase in pressure, by squeezing, to force the honey through the small nozzle

Materials: (for each group)

- water
- mineral oil
- kerosene
- motor oil
- household lubricating oil
- 5 test tubes
- 5 tube caps
- plastic beads (6mm)

Procedure: Copy this data table in your science journal:

Data Table--Viscosity Measurements

<i>Material</i>	<i>carbon atoms per molecule</i>	<i>average time for bead to fall (s)</i>	<i>relative viscosity</i>
water	--		
mineral oil	12-20		
kerosene	12-16		
motor oil	15-18		
household lubricating oil	14-18		

1. Determine the average time for a bead to fall from top to bottom within the capped tube containing water. Follow this procedure:
 - a. Hold the capped tube upright until the ball is at the bottom.
 - b. Gently turn the tube horizontally. (The bead will stay at one end.)
 - c. Quickly turn the tube upright so the bead is at the top.
 - d. Determine the number of seconds required for the bead to fall to the bottom of the tube.
 - e. Repeat this procedure three more times. Calculate the average time required for the bead to fall.
2. Repeat this procedure for each petroleum-based sample.
3. Rank your samples in order of relative viscosity, assigning the number 1 to the least viscous material (the one in which the ball fell fastest).

Discussion questions:

1. Propose a rule based on observations made in this activity regarding the relative number of carbon atoms per molecule and the resulting viscosity of the material.

2. Petroleum refiners and distributors must consider the viscosity of their products when shipping diesel/fuels and motor oils to different parts of the country. Explain why the diesel/fuel shipped to a northern state (say Alaska) in winter must be different from that shipped to southern state (say Florida) in summer. How would you adjust the products?

Extensions:

- Use different sizes of test tubes.
- Graph results
- Find out: Is viscosity a major factor both in oil spills and oil fires? How does it effect treatment and/or outcome?
- Have each group design their own experiment to share with other groups.

References:

Chem Com: Chemistry in the Community, ACS Kendall/Hunt Publishing Co. Iowa 1988.