Measuring the Length of an Oleic Acid Molecule

Introduction

Langmuir received the Nobel Prize in chemistry in 1932 for his work on monomolecular films, which are films that are assumed to have a thickness of one molecule. By using a method similar to his, it is possible to determine the approximate length of an oleic acid molecule.

Concepts

- Atomic Structure
- Chemical Bonding
- Organic Chemistry

Materials

Ethyl alcohol, CH_3CH_2OH, 140 mL
Lycopodium powder or fine talcum powder
Oleic acid, $C_{18}H_{34}O_2$, 5 mL
Water, tap
Beral-type pipet
Cafeteria style tray or other large, shallow container (at least 30 × 40 cm)
Detergent
Graduated cylinder, 10-mL
Meter stick or ruler
Salt shaker

Safety Precautions

Ethyl alcohol is flammable and a dangerous fire risk. Lycopodium is a highly flammable powder and a possible allergen. Wear chemical splash goggles, a chemical-resistant apron, and chemical-resistant gloves. Please review current Material Safety Data Sheets for additional safety, handling, and disposal information.

Preparation

1. Clean all equipment thoroughly with detergent and water, rinse well, and allow it to dry completely. Clean, dry equipment is a must!
2. Dissolve 5 mL of oleic acid in 95 mL of ethyl alcohol. Now take 5 mL of this solution and dissolve it in 45 mL of ethyl alcohol. This second solution will contain 0.005 mL of oleic acid per mL of solution and will be used in the demonstration.
3. Use some of the second oleic acid/ethyl alcohol solution to calibrate the pipet by counting the number of drops needed to produce a volume change of 1 mL in a graduated cylinder. You may want to show this technique to your students.
4. Calculate the volume of oleic acid in one drop by dividing the number of milliliters of oleic acid in one milliliter of oleic acid/ethyl alcohol solution by the number of drops per milliliter. For example, if it takes 25 drops of solution to produce a volume change of 1 mL, then the volume of oleic acid per drop of solution is 0.0002 mL.

$$\text{Volume of oleic acid in one drop} = \frac{0.005 \text{ mL oleic acid/mL of solution}}{25 \text{ drops/mL of solution}} = \frac{0.0002 \text{ mL oleic acid}}{\text{drop of solution}}$$

Procedure

1. Add enough cold tap water to the tray to cover it to a depth of 0.5 cm. Allow it to stand for a minute or two so that any motion caused by the pouring has subsided.
2. Put a light dusting of lycopodium or talcum powder on the surface of the water. A salt shaker works well for this.
3. Carefully add one drop of the oleic acid/ethyl alcohol solution to the center of the tray. Gently tap the tray so that the oleic acid is spread out over the largest possible area without being broken. This area should be roughly circular.

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4. Measure the diameter of this circle, taking at least three measurements, and calculate the average diameter, then the average radius. The average radius should be about 14 cm.
5. Using the formula for the volume of a cylinder, solve for h, the height of the cylinder. In the formula for the volume of a cylinder, $V = \pi r^2 h$, V is the volume of oleic acid per drop of solution (calculated in Step 4 of the *Preparation* section) and r is the average radius of the circle (determined in Step 4 of the *Procedure* section). The height of the cylinder is equal to the length of an oleic acid molecule, or the thickness of the monolayer. The length should turn out to be in the neighborhood of 10^{-7} cm.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. Flush the oleic acid/ethyl alcohol/water mixture in the tray down the drain according to Flinn Suggested Disposal Method #26b.

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
Evidence, models, and explanation
Constancy, change, and measurement
Content Standards: Grades 5–8
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, properties and changes of properties in matter
Content Standard G: History and Nature of Science, history of science
Content Standards: Grades 9–12
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, structure of atoms, structure and properties of matter
Content Standard G: History and Nature of Science, history of science

Tips

- You can compare the layer of oleic acid to a piece of filter paper (a very short cylinder).
- Make sure the tray used is large (at least 30 × 40 cm). If not, the layer of oleic acid will fill the entire tray instead of forming a circular shape.
- Have students calculate the theoretical length of an oleic acid molecule and compare the theoretical value to the experimental value determined in this demonstration.

Discussion

Oleic acid, $C_{18}H_{34}O_2$, is a fatty acid molecule that has two distinct parts. One end is a nonpolar, hydrophobic (water-fearing) carbon chain, resembling a "tail". The other end is a polar, hydrophilic (water-loving) "head". Fatty acid molecules are commonly simplified using "head" and "tail" drawings, such as the one in Figure 1.

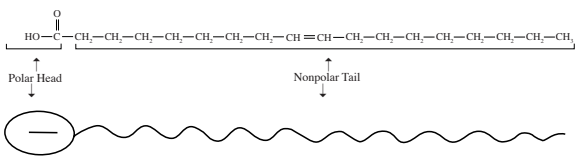

Figure 1. Oleic acid

Oleic acid is soluble in many organic solvents, such as ethyl alcohol, but not in water. When placed in water, it tends to form a monolayer with the polar "head" sticking down towards the surface of the water and the nonpolar "tail" sticking straight up away from the surface of the water. See Figure 2.

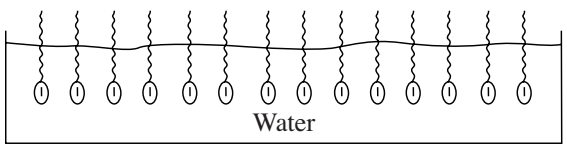

Figure 2. A monolayer of oleic acid in water.

If a small amount of oleic acid is placed onto the surface of water, it will spread out to form a layer that is roughly circular in shape. The

length of the molecule is calculated by assuming that this "circle" is actually a cylinder with a very small height. The height of the cylinder is equal to the length of the oleic acid molecule.

Reference

Bilash, B; Gross, G.; Koob, J. *A Demo A Day™, Volume 2—Another Year of Chemical Demonstrations;* Flinn Scientific Inc.: Batavia, IL, 1996; p 5.

Materials for *Measuring the Length of an Oleic Acid Molecule* are available from Flinn Scientific Inc.

Catalog No.	Description
Q0025	Oleic acid, 100 mL
E0009	Ethyl alcohol, 95%, 500 mL
L0059	Lycopodium powder, 25 g

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.