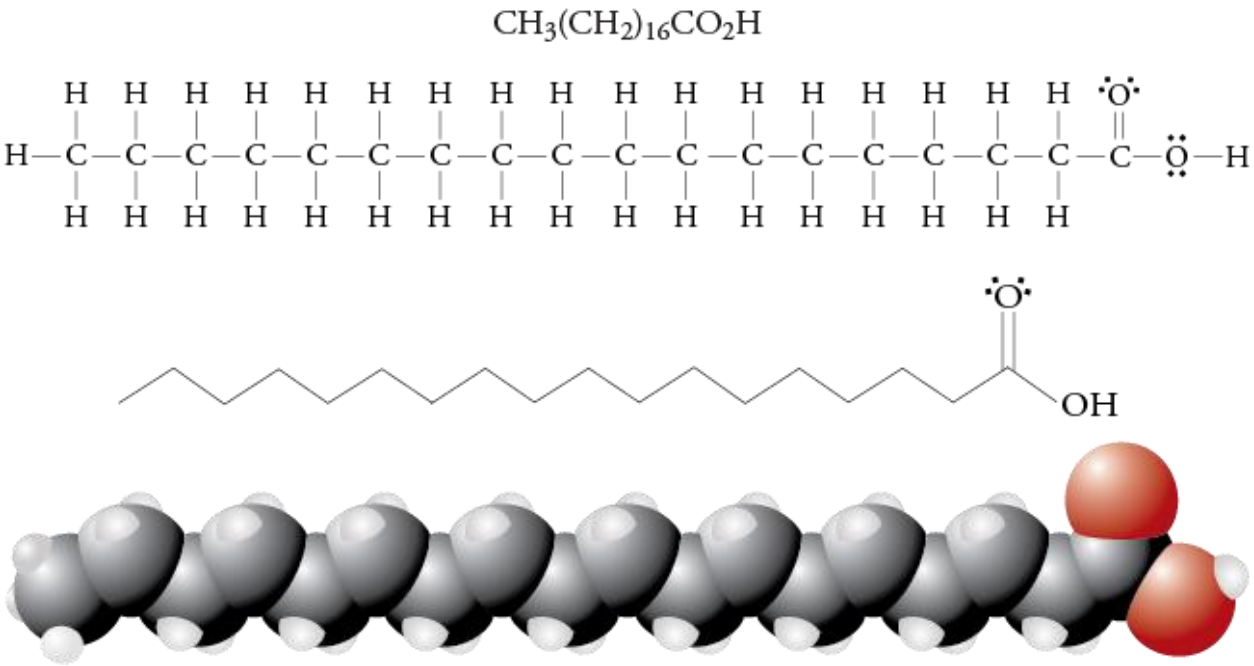
Experiment 12 – Stearic Acid Monolayer

Overview

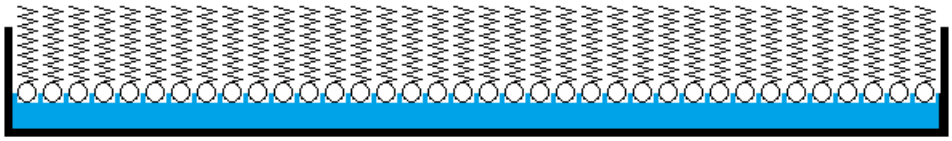
A **monolayer** of stearic acid on the surface of water of known surface area can be used to estimate the length of a stearic acid molecule. (Dimmensions of a Molecule, n.d.) A monolayer, as the name implies, is a layer of material that is one molecule thick. The nature of a stearic acid molecule, with one end that is **hydrophilic** and another that is **hydrophobic**, makes it a good candidate for the formation of such a monolayer on the surface of water.

Theory

Stearic acid molecules, like all long-chain carboxylic acids, have two chemically different parts. These can be characterized by the types of inter-molecular forces in which the parts will engage. One end, the carboxylate end, is very **polar**, and will interact very favorably with water. Such an interaction is called "hydrophilic". The other end, the long-chain hydrocarbon end, is **nonpolar**, and will interact unfavorably with water. This type of interaction is called "hydrophobic". Oftentimes, the polar end of the molecule is referred to as the **head** and the nonpolar part is known as the **tail**.



When a stearic acid molecule is placed on the surface of water, the head (the hydrophilic end) will interact with the water, while the tail (the hydrophobic end) will align so as to get as far from the surface as possible. The result looks as follows:



The thickness of such a layer will be given by the length of a single molecule.

Procedure

Part A – Calibration of a pipet

In the first part of the experiment, you will determine the number of drops from your pipet needed to deliver 1.0 mL of solution.

1. Obtain a dropper and 10 mL graduated cylinder.
2. Using water, count the number of drops needed to fill the graduated cylinder to a volume of 1.0 mL. Record this number of drops.
3. Repeat the procedure to fill the graduated cylinder to 2.0 and 3.0 mL by adding 1 mL each time.
4. Calculate the number of drops per mL using the average.

Number of drops for 1.0 mL	
Additional drops to reach 2.0 mL	
Additional drops to reach 3.0 mL	
Average number of drops per mL	

Part B – Formation of a monolayer

1. Obtain and clean a watch glass from your drawer. In order for the procedure to work, the watch glass must be completely free of any oil deposits. So you should wash the glass, with detergent, and rinse until the water drains from the surface in a continuous sheet (no beading).
2. Place the watch glass on a flat, horizontal surface with the concave side facing upward (like a bowl). Using a wash bottle, fill the glass with water, all the way to the edges.
3. Add stearic acid solution dropwise, counting the number of drops to form a monolayer.

a. When each drop is added to the surface, two things will happen. First, the hexane solvent will very quickly evaporate. Second, you will see evidence of the stearic acid molecules spreading across the surface. This will happen more slowly as you near single-molecule coverage of the surface.
b. As you near the monolayer coverage, each drop will create a "lens" on the surface. As this happens, wait until the lens dissipates before adding the next drop.
c. One the lens does not dissipate, you have exceeded the monolayer (and started to form a second layer.) That means you have added one too many drops. Record the number of drops you have added, less the one drop that exceeded the monolayer.

4. Repeat the process three times.
5. Measure the diameter of your watch glass. This will be used to calculate the base area of the cylinder comprising your monolayer.

Number of drops for monolayer: Trial 1	
Number of drops for monolayer: Trial 2	
Number of drops for monolayer: Trial 3	
Average number of drops for a monolayer	
Diameter of watch glass	

Example: Lucas adds 23 drops of solution, noting that it takes longer and longer for the "lens" to dissipate. On drop 24, the lens takes a very long time, but completely dissipates. On drop 25, the lens persists.

Result: Lucas records the number of drops needed to form a monolayer as 24.

Sample Calculation

Example: A theoretical organic acid, AMAF (Acidy McAcidFace), has a density of 1.27 g/cm^3. The following data is collected in the experiment to determine the length of an AMAF molecule using the methodology described in this experiment:

[AMAF] in hexane	0.11 g/L
Drops per mL	37
Drops to form monolayer	14
Diameter of water surface	13.54 cm

Solution: First, let's find the volume of the monolayer. This is determined from the amount of AMAF deposited on the surface. In order to do this, we need the volume of AMAF solution deposited, the concentration of the solution (to get g of AMAF), and the density of AMAF (to get the volume of the monolayer.

$$14\ drop \cdot \frac{mL}{37\ drop} \cdot \frac{L}{1000\ mL} \cdot \frac{0.11\ g}{L} \cdot \frac{cm^3}{1.27\ g} = 3.\underline{2}8 \cdot 10^{-5} cm^3$$

Now, we can determine the thickness of the monolayer (h) by assuming the monolayer forms a cylinder. The volume of a cylinder is given by

$$V = \pi \left(\frac{d}{2}\right)^2 h$$

So

$$3.\underline{2}8 \cdot 10^{-5} cm^3 = \pi \left(\frac{13.54\ cm}{2}\right)^2 h$$

$$h = 2.\underline{2}8 \cdot 10^{-7} cm$$

This value can be converted to Å (1 Å = 10^{-10} m) quite easily:

$$2.\underline{2}8 \cdot 10^{-7} cm \cdot \frac{m}{100\ cm} \cdot \frac{10^{10} Å}{m} = 2\underline{2}.8\ Å$$

Bibliography

Dimmensions of a Molecule. (n.d.). Retrieved from http://kennethmaloney.com/GenCenCtr/LearningCenter/LaboratoryExpt

Vocabulary

Pre-Laboratory Assignment – Stearic Acid Monolayer

Name _____ Section _____

1. A certain acid (molecule length = 11 Å) has a density of 0.92 g/cm^3. If a monolayer of the acid is formed on the surface of water on a 5.25 cm diameter watch glass, What is the mass of acid in the monolayer?

   Base area of monolayer (show work below) _____ cm

   Volume of monolayer (show work below) _____ cm^3

   Mass of acid in monolayer (show work below) _____ g

2. The above acid has a molar mass of approximately 170 g/mol. How many molecules are there in the monolayer described above?

Report Sheet – Stearic Acid Monolayer

Name _____ Date _____

Lab Partner(s) _____

Part A – Calibration of a Pipet

Number of drops for 1.0 mL	
Additional drops to reach 2.0 mL	
Additional drops to reach 3.0 mL	
Average number of drops per mL	

Standard deviation: $\sigma = \sqrt{\frac{\sum_{i=1}^{N}(x_i - \overline{x})^2}{N-1}}$

Part B – Formation of a Monolayer

Number of drops for monolayer: Trial 1	
Number of drops for monolayer: Trial 2	
Number of drops for monolayer: Trial 3	
Average number of drops for a monolayer	
Diameter of watch glass	

Part B – continued

Mass of monolayer (show work below) _____ g

Volume of monolayer (show work below) _____ mL

Area of base (show work below) _____ cm^3

Thickness of monolayer (show work below) _____ cm

Length of molecule _____ Å

Question: What would be the effect on your calculated molecule length if you added more drops of solution than needed to form a monolayer? Explain.