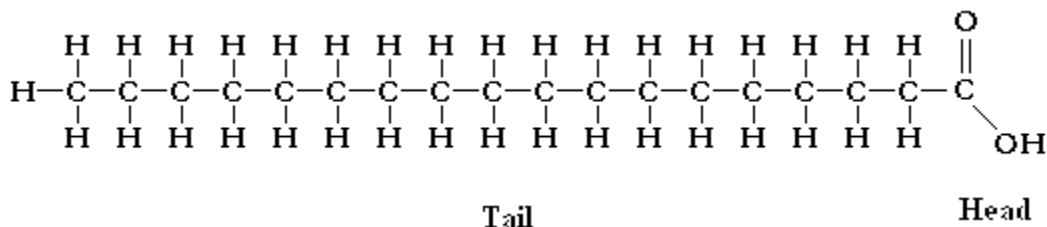


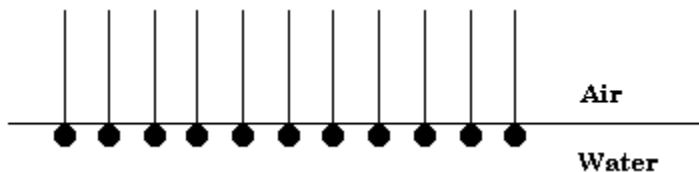
Laboratory Exercise: Diameter of a Carbon Atom

In this exercise, we will see how atomic level properties can be estimated using measurements of macroscopic properties. This will give us a sense of the "size" of these atomic properties in terms of macroscopic measuring devices. Specifically, we will measure the diameter of a Carbon atom. This will be done by measuring the diameter of a monolayer of molecules composed of Carbon atoms which forms on the surface of Water.

Fatty Acids are molecules that have a polar, water soluble, head and a long non-polar, water insoluble, tail. For example, Oleic Acid is a Fatty Acid composed of 18 Carbon atoms bound together in a roughly linear fashion; one Carbon is part of the head and seventeen are part of the tail.



When placed on the surface of water, a drop of an Oleic Acid solution spreads out until it forms a thin film one molecule thick across the surface; a monolayer. This is because the polar heads of the fatty acid dissolve in the water and the non-polar tails stick up into the air.



We can estimate the thickness of this monolayer by knowing the volume of the drop placed on the surface and the area of the monolayer, as determined by measuring its diameter:

$$\textit{Thickness} = \frac{\textit{drop volume}}{\textit{monolayer area}}$$

If we know the number of carbon atoms in the "tail" of the fatty acid, we can then estimate the diameter of an individual carbon atom:

$$\textit{Diameter of C Atom} = \frac{\textit{monolayer thickness}}{\textit{number C atoms in tail}}$$

We will carry-out this procedure in order to estimate the diameter of a carbon atom. Although the result so obtained will be relatively crude, this experiment provides us with a nice example of how atomic level information can be obtained from macroscopic measurements.

Procedure

All your measurements must be reported with the correct number of Significant Digits.

1. Obtain a pizza pan and clean it thoroughly with detergent.
2. Place the pan on a solid surface and fill it to near the top with deionized Water.
3. Sprinkle a very thin, even layer of lycopodium powder or chalk dust over the water's surface.
4. Obtain a 9" disposable Pasteur pipette and 1 mL pipette bulb. Practice using the pipette to deliver 1 drop of liquid. (If the bulb is securely seated on the pipette, then liquid drawn into the pipette will not leak out of the tip.)
5. Carefully deliver one drop of 0.5% Oleic Acid solution into the center of the Water's surface.
6. Reasonably quickly, measure the diameter of the film which forms with a meter stick. **(Make your measurement in centimeters.)**
7. Rinse the pan and repeat the measurement twice more.
8. Use a 10 mL graduated cylinder to estimate the volume of one drop of solution delivered from your pipette. (Think about the best way of doing this.) The cylinder is graduated in milliliters, mL, which are equivalent to cm^3 .

Data Sheet

Monolayer Dimensions:

Trial Diameter of Film [cm]

1 _____

2 _____

3 _____

Average = _____ cm

Method of Est. Vol. of One Drop:

Vol. of One Drop = _____ cm^3

Concentration of Oleic Acid Solution:

Conc. of Sol'n = _____ % (Will be reported on the sample bottle.)

Name: _____

Date: _____

Signature: _____

Data Analysis

All your calculate results must be reported in Scientific Notation with the correct number of Significant Digits. You must show all the steps in your calculation with the units of measurement noted.

For example, suppose we have made the following measurements in order to determine the density of a liquid:

$$\begin{aligned}\text{Mass Sample} &= 7.4332 \text{ g} \\ \text{Volume Sample} &= 9.9815 \text{ mL}\end{aligned}$$

Then, you should report your calculation as:

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} = \frac{7.4332 \text{ g}}{9.9815 \text{ mL}} = 0.7447 \text{ g/mL}$$

Since the oleic acid is only 0.5% of the total solution used, the volume oleic acid in a drop is 0.5% of the volume of the drop. Calculate the volume of Oleic Acid delivered in the drop.

$$\text{Vol. Oleic Acid} =$$

Calculate the area of the film.

$$\text{Area} =$$

Calculate the thickness of the film.

$$\text{Thickness} =$$

Assume the thickness of the film is evenly divided among the Carbon atoms in the non-polar tail of the Oleic Acid molecule. Calculate the diameter of a Carbon atom.

$$\text{Diameter of Carbon Atom} =$$

One source reports the Carbon atom's diameter at 1.54×10^{-8} cm. What is your percentage error when compared with this value?

$$\% \text{ Error} =$$

Post Lab Questions:

1. The mass of a Carbon atom is 1.99×10^{-23} g.

- a) Assume the Carbon atom is spherical. Estimate the Volume of the Carbon atom using your measured diameter.

$$Volume = \frac{4}{3} \pi \left(\frac{diameter}{2} \right)^3$$

- b) Now estimate the density of a Carbon atom.

$$Density = \frac{Mass}{Volume}$$

- c) Compare this result with that reported for solid Graphite. (Wiki sources are okay. Cite your source!)
2. Does it make sense to worry about the precision of our Carbon atom diameter result? Comment. (Recall how we measured the diameter of the monolayer film.)
3. What is the difference between Macroscopic and Microscopic properties of matter? (Internet sources are okay. Cite your sources!) Is the monolayer thickness a Macroscopic or Microscopic property? Is the diameter of the Carbon atom a Macroscopic or Microscopic property? Comment.
4. The Oleic Acid used in this experiment is dissolved in an Alcohol (Ethanol) solution. What happens to the Alcohol when a drop of the solution is placed on the Water's surface? (In other words, will the Alcohol interfere with our measurement?)
5. Suppose the powder/dust is sprinkled too thickly on the Water's surface. How would this impact our measurement? What type of error will this introduce? Explain.
6. How will variability in drop size affect our measurement? What type of error does this introduce?