EXPERIMENT 8

Estimating Avogadro's Number

Purpose

To estimate the number of stearic acid molecules in a mole of stearic acid based on an assumption about a thin film of stearic acid on a water surface. A monolayer of stearic acid can be created in which we can estimate the number of molecules. To do this we make assumptions of the size and shape of the stearic acid molecule.

Introduction

In the International System (SI) of units, the fundamental measure of quantity is the mole. A mole of carbon is 12.0000 grams of carbon-12, and Avogadro's number, N_A, is the number of carbon atoms in this mass. A mole of any substance contains Avogadro's number of particles.

In this experiment you will estimate Avogadro's number by calculating the amount of stearic acid necessary to form a single layer on the surface of water. This single layer is called a monolayer. We will be making some assumptions about how stearic acid molecules arrange themselves to form the monolayer. From these assumptions we can determine the thickness of the layer, and from the thickness we can estimate the number of the stearic acid molecules. If we know the volume occupied by a mole of stearic acid molecules we can use the volume of one stearic acid molecule to estimate Avogadro's number. We simply divide the volume of a mole of stearic acid by the volume of one stearic acid molecule.

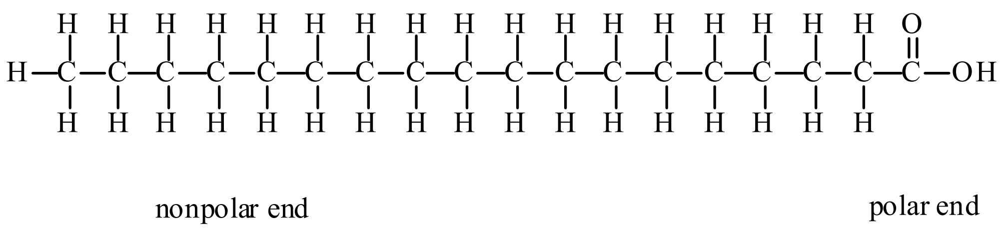
Note – the number calculated will not be accurate, but should be within a power of 10 of the accepted value of 6.02214×10^{23} particles/mol.

Theory and Basis of the Experiment

One of the properties displayed by water is its polarity. For covalent polar molecules, it is a partial charge separation denoted by a delta, δ. These polar ends are referred to as *dipole moments*. Polar molecules attract each other in much the same way magnets do. The negative end of the dipole moment of one polar molecule is attracted to the positive end of the dipole moment of another polar molecule. Because of this, acetic acid, CH_3COOH, will dissolve in water. Whereas, pentane, $CH_3CH_2CH_2CH_2CH_3$, a non-polar molecule is not water soluble. It stands to reason that a molecule that possesses both a nonpolar and polar end will have the polar end attracted to water and the non-polar end be repelled by water.

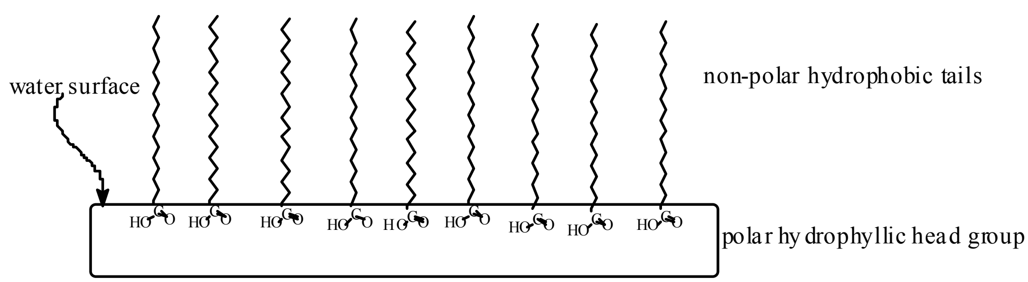
Stearic acid, $CH_3(CH_2)_{16}CO_2H$, has the structure shown below. The acid has a polar portion and a non-polar portion. The large non-polar, hydrophobic portion, of the molecule makes it immiscible with water.

FIGURE 8.1



We will create a layer of stearic acid <u>one molecule thick</u> on the surface of a watch glass filled with water. The polar head group will stay near the water and the non-polar tail will orient themselves away from the water.

FIGURE 8.2



We will create our monolayer by using a solution of the stearic acid in hexane. Hexane is also hydrophobic and will not mix with water. The hexane will evaporate leaving just the thin layer of stearic acid.

If we know the area of the monolayer and we know the volume of the monolayer, we can measure the thickness, *t*, of the monolayer. This thickness will correspond to the length of the stearic acid molecule. If we make the assumption that the stearic acid molecule is a rectangular solid, with a width and length equal to 1/5.44 of the height, where the height equals the thickness of the mono-layer, we can calculate the volume of one stearic acid molecule. Knowing the volume of the mono-layer and the volume of one molecule we can calculate the number of molecules in the monolayer. By using the density of stearic acid we can determine the number of moles in the monolayer. Finally, we can use the molar volume of stearic acid and divide by the volume of the stearic acid molecule to get Avogadro's number, N_A!

There are two parts to this experiment. In part 1, we will calibrate a dropping pipet so that we can determine the number of drops in 1 mL. This will require a Pasteur pipet for optimum results. In part 2, we will slowly add the stearic acid/hexane solution to a watch glass of water. We will allow the hexane to evaporate leaving just the stearic acid on the water.

Any impurities will ruin this experiment so be very careful not to put soap, water or dust where it does not belong. **Do not use dirty glassware!**

Procedure

Part 1: Calibration of the Pipet

1. Obtain a Pasteur pipet from your instructor
2. Obtain a 10 mL beaker from the stock room. Wash it well. Wash the inside 3 times with approximately 1 mL of aqueous ammonia. Rinse the beaker 3 times with distilled water. Rinse the beaker 1 time with acetone and then dry the beaker thoroughly with a paper towel. Rinse the beaker three times with approximately 1/2-mL of hexane and then add 3 mL of hexane to the beaker.

> **NOTE: ALL WASTE HEXANE MUST BE DISPOSED OF INTO THE ORGANIC WASTE CONTAINERS. DO NOT DUMP HEXANE IN THE SINK.**

3. Obtain a clean dry 10 mL graduated cylinder from your drawer. If your graduated cylinder is not clean and dry, clean it and then dry it with acetone and a tissue. Add hexane drop-wise to a volume of 1 mL. Record the number of drops.
4. Repeat this procedure.
5. If the two values are relatively close (within 10% of each other), then find the average. If not, repeat step 3 again.
6. Dispose of excess hexane in the appropriate waste container and save the beaker for part 2.

Part 2: The Monolayer

1. Obtain a watch glass from your drawer. Measure the diameter. Thoroughly clean the watch glass by scrubbing with soap for 2 minutes. Rinse well with tap water and then scrub with aqueous ammonia. Rinse 3 times with tap water and then three times with distilled water. Hold the glass by the edges to avoid putting fingerprints on it.
2. Place the watch glass on a beaker; making sure that the watch glass is parallel to the floor. Fill the watch glass to the brim with **distilled** water.
3. Take your clean 10 mL beaker and pour into it the stearic acid/hexane solution from under the hood.
4. Draw some of the stearic acid/hexane solution into your Pasteur pipet, hold the dropper perpendicular to the surface of the water in the watch glass, and add one drop of the stearic acid solution.
    a. The solution should spread out rapidly across the surface of the water and disappear within a few seconds.
    b. If the watch glass is not properly cleaned then an oily residue may appear after only a few drops of solution. In this case it will be necessary to clean the watch glass again.

c. If the first few drops disappear rapidly, continue adding the solution drop-wise, counting the drops.

d. As the monolayer nears completion, the drop of solution forms a circular pattern rather than flowering out.

e. The circular film of solution contracts as it evaporates and disappears in a relatively short time.

f. This pattern will be observed for a few drops until finally, one drop strikes the surface and remains as a lens or globule that requires a prolonged period of time to disappear.

5. Record the number of drops. At this point, the surface of the water is covered with a monolayer of stearic acid and one more drop placed at a different point on the water surface forms a second "lens".

6. Fill out the following table. You must show your calculations for all starred rows. Clearly show these calculations using dimensional analysis.

Prelaboratory Exercise

Estimating Avogadro's Number

Name: ____________________

Section:___________________

Lab Grade

Prelab Questions		20
General Format (Signature, ink, no obliterations, etc.)		10
Data and Analysis (observations, questions, units, significant figures, sample calculations, etc.)		20
Accuracy		30
Post Lab Questions		20
Total		100

1. What substance will you use to make a monolayer? ___ ___ ___ ___ ___ ___ ___

2. How close should your experimental value be to the actual value of Avogadro's number?
   a. Within 1% of actual value
   b. Within 5% of actual value
   c. Within a factor of 10 of the actual value
   d. Within a factor of 100 of the actual value

3. What do polar molecules behave like? ___ ___ ___ ___ ___ ___ ___.

4. Where do you dispose of the waste hexane?

5. What is the procedure for cleaning the watch glass?

6. How do you know when the stearic acid has formed a monolayer covering the entire surface of the water?

Use the data below to answer the following questions

Drops of hexane/mL 75 drops

Number of drops hexane used for monolayer 27 drops

Diameter of water surface 5.2 cm

1. Calculate the mass of stearic acid in the monolayer.

2. Calculate the volume of stearic acid in the monolayer in mL

3. Calculate the thickness of the monolayer in cm.

4. Calculate the volume of a stearic acid molecule in the monolayer.

5. Calculate the number of stearic acid molecules in the surface layer.

6. Calculate the number of moles of stearic acid in the surface layer.

7. Calculate the value of Avogadro's number.

Data Sheet: Estimating Avogadro's Number

Part 1: Calibration

TABLE 8.1

	Trial 1	**Trial 2**	**Trial 3** (if needed)
Drops of hexane/mL			
Number of drops of solution used for monolayer			
Diameter of water surface (cm)			

Sample Calculations:

Why is it important to do the calibration of the dropper quickly?

Describe the appearance of the monolayer as you add the final drops of stearic acid.

Part 2: Estimating Avogadro's Number

TABLE 8.2 Calculations

	Trial 1	Trial 2	Sample Calculations
Drops of hexane/ mL			
Number of drops of solution used for monolayer			
*Volume of solution used (mL)			
Concentration of stearic acid-hexane solution (g/L)	0.10g/L	0.10g/L	
*Mass stearic acid in monolayer on water surface (g)			
Density of stearic acid (g/mL)	0.870	0.870	
*Volume of stearic acid in monolayer (mL)			
Diameter of water surface (cm)			
*Area of water surface (of monolayer) ($A=\pi d^2/4$)			
*Thickness of monolayer			
*Volume of stearic acid molecule assuming it is a rectangular solid with a width and length equal to 1/5.44 of the height where the height equals the thickness of the monolayer.			

TABLE 8.3 Calculations continued

	Trial 1	Trial 2	Sample Calculations
Mass stearic acid in monolayer on water surface (g)			From previous page
Volume of stearic acid in monolayer (mL)			From previous page
*Number of stearic acid molecules in the surface layer			
Molecular mass of stearic acid (g/mole)	284	284	
*Number of moles of stearic acid in surface layer			
*Value of Avogadro's number (molecules per mole of stearic acid)			

Post Lab Questions

1. What is the mass of 5.47 mole of stearic acid? (MW = 284 g/mole)

2. The density of stearic acid is 0.870g/mL. What is the volume of 7.8×10^{-6} mole of stearic acid?

3. What assumptions were made in this experiment to arrive at a value for Avogadro's number?

4. What is the mass, in grams, of 1 molecule of stearic acid have?