Name ____ Date ______________

Lab #10 Avogadro's Number
Quantitative Chemistry

Purpose: ____

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Discussion: You have been introduced recently to a very important and useful concept in Chemistry -- that of the "average atomic weight" or "gram-atomic weight". In recent years it has become accepted practice in chemistry to use the term "mole" in reference to both of these. A "mol", then, is a quantity of material, equal in mass to the atomic weight of an element or the formula weight of a compound. Thus a mol of sulfur would be 32.1 grams of sulfur; a mol of NaOH would be 40.0 grams, etc. In this investigation we will examine the mol from another standpoint--that of a collection of particles. We will try to establish how many particles are in one mol of a substance. As we do so, we will also make some other measurements on the sizes and volumes of individual molecules. The compound used in this investigation is oleic acid, chemically $\mathbf{C_{17}H_{33}COOH}$. Oleic acid is one of a family of organic compounds known as "fatty" acids. This name stems from the fact that such acids are derived from fats, such as lard. Oleic acid lends itself nicely to a study of molecular measurements. In its structure it shows a long chain of carbon and hydrogen atoms (the "hydrocarbon" end of the molecule). This part of the oleic acid molecule will not dissolve in water, but will dissolve in organic solvents, such as alcohol. The other end of the molecule, -COOH, (called the acid end) is water soluble but will not dissolve appreciably in organic solvents. As a result of this difference in the solubilities of the two ends of the oleic acid molecule, we can perform the following: if a very dilute solution is placed (using a very small volume) of the acid on the surface of a fairly large expanse of water, all of the billions upon billions of oleic acid molecules will align themselves with the water-soluble end dissolved in the water and the alcohol-soluble end up out of the water. Thus a thin layer of oleic acid, literally "one-molecule thick" will be formed on the surface of the water. By making proper measurements and knowing some facts about the oleic acid solution one can then make some fairly accurate measurements of individual oleic acid molecules.

For the purposes of this investigation each individual oleic acid molecule will be assumed to be cylindrical in shape.

Procedures:

Obtain a metal or plastic pizza pan, a dusting sock, a dropping bottle with the oleic acid solution, a dropping bottle with the hydrochloric acid solution, a half-meter stick and a 10 mL graduated cylinder.

Part I. Calibration of the dropper SKIP THIS SECTION

Using the graduated cylinder and the oleic acid dropping bottle, carefully measuring the number of drops needed to make exactly 2.00 mL of oleic acid solution. Empty the contents of the graduated cylinder into the sink with plenty of water.

Number of drops needed for 2.00 mL:___ drops

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Part II. Determination of the height of a cylindrical acid molecule

Fill the pan completely with water. Be certain that the entire bottom of the pan is covered with water. Use one of the socks filled with the mixture of chalk dust and lycopodium powder to cover the entire surface of the water with a light covering of the dust. The dust coating must be neither too thick nor too thin. Now hold the dropper containing some of the oleic acid solution right above the surface of the water. Allow one drop of the solution to fall to the water surface. When the drop hits the surface, all of the oleic acid molecules will spread out in a film "one molecule thick". The film itself should be roughly circular. So what you have produced is a very large cylinder whose height is the height of an oleic acid molecule. Use the half-meter stick to measure to the nearest .1 cm the diameter of this circle through 5 different positions. Record these measurements. (Trial 1) Dump out the water, add fresh water, dust and repeat the process. (Trial 2)

Data:	Trial 1		Trial 2
	________________cm		________________cm
	________________cm		________________cm
	________________cm		________________cm
	________________cm		________________cm
	________________cm		________________cm
Average:	________________cm	Average:	________________cm

Average of Trials 1 and 2: ___________cm

Part III. Determination of the diameter of the circular base of an oleic acid molecule

Fill the pan with water. Now add 12 drops of the HCl solution from the small acid bottle. Use your stirring rod to thoroughly mix the acid with the water. Dust the pan. Add one drop of oleic acid solution as you did in part II. This time the acidic solution in the pan will tend to repel the acidic end of the water, much like trees might float on their sides in a lake or pond. The thickness of this film will be the same as the diameter of the circular base of the oleic acid molecules. As you did before, measure through the center of the circle in five positions. Dump out the water, replace with fresh water and repeat the process.

Data:	Trial 1		Trial 2
	______________cm		______________cm
	______________cm		______________cm
	______________cm		______________cm
	______________cm		______________cm
	______________cm		______________cm
Average:	______________cm	Average:	______________cm

Average of Trials 1 and 2: __________cm

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When finished, return the oleic acid dropping bottle, the ruler and the dusting bags to the storage area. Wipe out the pizza pan, dry it and place it in the rear of the lab for complete drying.

Calculations (<u>USE SCIENTIFIC NOTATION</u>):

1. Use the data from Part I to determine the volume of <u>one</u> drop of the oleic acid solution. (cm^3/drop) Hint: Take 2 mL (cm^3) and divide it by the number of drops from Part I.

2. The oleic acid solution is 0.50% oleic acid. Calculate the volume of <u>pure</u> oleic acid in one drop of the solution. (cm^3 oleic acid/drop)

3. Using your average film diameter from Part II, determine the area of the circular film.

$A=\pi r^2$ Use 3.14 for π

(Note: The data is the <u>diameter</u> of the film. You need to use the <u>radius</u> to find the area.)

4. Calculate the length of one oleic acid molecule. Since the film in Part II is “one molecule thick”, the thickness of this film <u>is</u> the length of one oleic acid molecule. In turn, the thickness of the film is the height of the cylinder formed when the drop is placed on the water.

Volume of a cylinder = $\pi r^2 h = Ah$

(where V is the volume of oleic acid (calculation #2) and πr^2 (A) is the area of the circular base (calculation #3)). Solve for h (cm).

5. Using your average film diameter from Part III, determine the area of the circular film when the oleic acid molecules are “lying down”.

$A=\pi r^2$

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6. Again use the formula for the volume of a cylinder to find the height of the film in Part III. This height will be the same as the diameter of one oleic acid molecule.

$$V = \pi r^2 h = Ah$$

(where V is the volume of oleic acid (calculation #2) and πr^2 (A) is the area of the circular base (calculation #5)). Solve for h (cm).

7. You now know two measurements of an oleic acid molecule: the height (from calculation #4) and the diameter of its circular base (from calculation #6). Use these two facts to determine the volume of one cylindrical oleic acid molecule:

$$V = \pi r^2 h$$

Note: The answer arrived at in calculation #6 is the diameter of the circular base of a molecule. You need to use the radius in the equation above.

8. The density of oleic acid itself is 0.887 grams/cm^3. Use this value to find the mass of one oleic acid molecule. (grams/molecule)

m = D x V (from calculation #7)

9. Calculate the formula weight (molar mass) of oleic acid, $C_{17}H_{33}COOH$. (grams/mol)

10. Using your answers for calculations #8 and 9, determine the number of molecules in one mol of oleic acid (molecules/mol). (Divide the molar mass (mass of one mol) by the mass of one molecule.)