

CALCULATING THE SIZE OF AN ATOM

Introduction:

The atom is so very small that only highly sophisticated instruments are able to measure its dimensions. In this experiment we attempt to obtain the diameter of a carbon atom by using solid BBs as a model. A known volume of BBs will be spread out in a single layer (or monolayer) bound by a piece of string, and the diameter of the monolayer will be measured. The area and thickness of the monolayer can then be calculated using a mathematical formula. The thickness of the monolayer corresponds to the average diameter of a single BB.

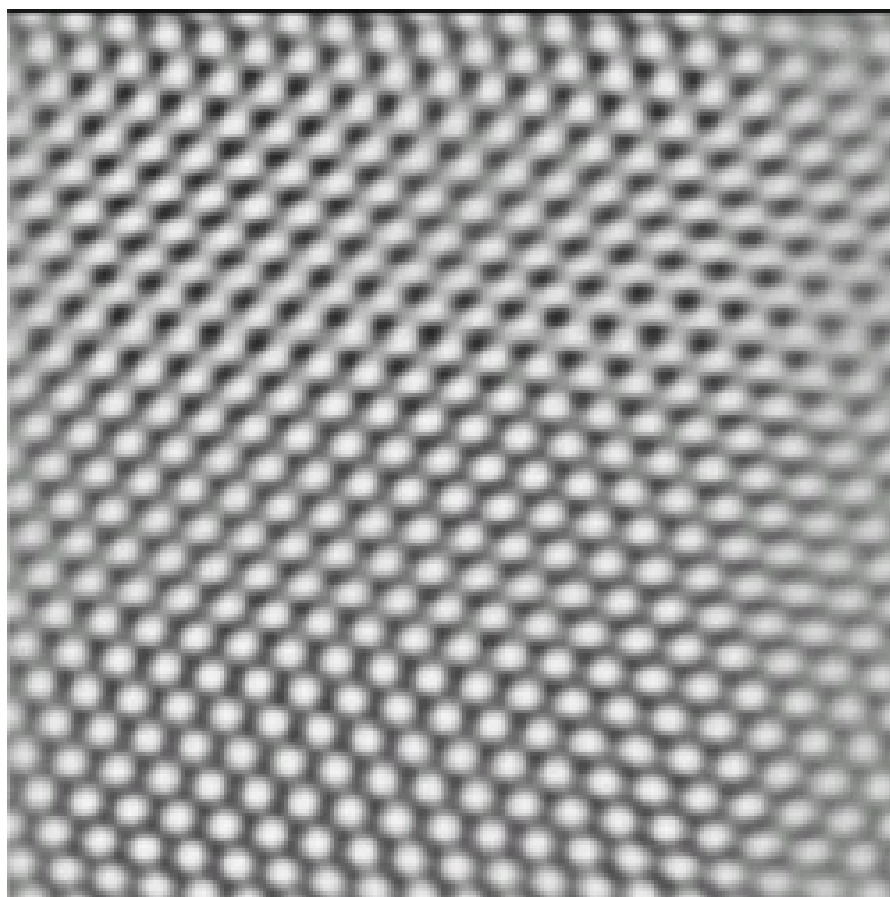


Figure 1. 5.0 nm x 5.0 nm Scanning Tunneling Microscope image of a carbon atom surface.

This procedure will next be applied to vegetable oil, which is made up of oleic acid. Oleic acid is a fatty acid molecule composed of carbon, hydrogen, and oxygen atoms. The molecules will spread out on the surface of the water like the BBs in the tray. Using lycopodium powder as our "string", we will drop a known volume of oleic acid solution onto water and determine the area of the monolayer the same as we did for the BBs. We will then be able to calculate the thickness of the oleic acid monolayer.

An oleic acid molecule (see Appendix) is slightly more complex than a single BB. It consists of a chain of eighteen carbon atoms. The molecule is hydrophobic and it will not dissolve in water. One end of the chain, however, is hydrophilic and buries itself in the surface of the water. The hydrophobic part stands upright, much like a forest of trees. The thickness of the monolayer actually corresponds to a film that is seventeen carbon atoms thick. Dividing the calculated thickness of the monolayer by 17 should give us the diameter of a single carbon atom.

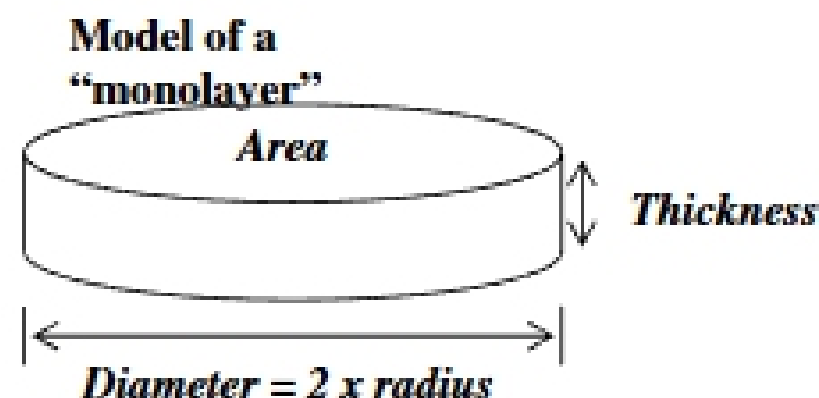
Purpose:

1. To make physical measurements using the metric system (& to practice unit conversion).
2. To perform calculations involving length, area, and volume.
3. To observe the physical characteristics of BBs and use this knowledge as a basis for calculating the size of an atom.
4. To compare experimental results with an authoritative source.

Theory:

In this exercise, the BB (and oleic acid) monolayer will be modeled as a cylindrical "pancake". The thickness, area and volume of the monolayer are related by the following equations:

$$\begin{aligned}\text{Area (of a circle)} &= \pi * (\text{radius})^2 \\ \text{Volume (of a cylinder)} &= \text{Area} * \text{Thickness} \\ \text{Thickness} &= \text{Volume} / \text{Area}\end{aligned}$$



Materials:

- 50 mL graduated cylinder
- 10 mL graduated cylinder
- circular Petri dish
- metric ruler
- eye dropper pipette
- cafeteria (or pizza) tray
- other items as indicated in lab

Part One: Diameter of a sphere

1. Pour a sample of BB's into a small Petri dish. There should be enough to completely cover the bottom of the dish without stacking, the BBs should form a tight monolayer. Measure the diameter of the monolayer of BBs in cm. Note that the ruler scale says "mm," but that the numbers on the scale actually show cm. Record the diameter. Notice that if you have a true monolayer, the calculated thickness of the monolayer will correspond to the diameter of one BB. (Later, in the analysis, you will use this data to perform the calculation, but for now the idea is just to obtain the measurements.)

Diameter of the BB monolayer = _____ cm

Observations:

2. Transfer the BB's from the dish to a 50 mL graduated cylinder. Record your exact volume, to the nearest 0.1 mL. Are there any problems associated with attaining this precision using the equipment available? Look at the BBs. Are they round? Are they the same size? What color are they? Record your observations.

Volume of BBs = _____ mL

Observations:

3. Measure the length of a "chain" of 17 BBs in cm and record the length. How did you accomplish this? You will use this measurement to verify the calculated thickness as mentioned in the previous step.

Length of chain = _____ cm

Observations :

Part Two: Thickness of an Oleic Acid Film

1. Pour enough water into a tray to completely cover the bottom, at least halfway up the side. Obtain a canister of lycopodium powder, and a bottle of oleic acid solution from the community area. Shake out a thin "patch" of lycopodium powder about 20 cm in diameter in the center of the tray. *Describe the lycopodium powder.* How does it behave on the water?
2. Holding the pipette close to the surface of the water, carefully dispense one drop of oleic acid solution in the center of the powder. What does the solution look like? What happens when the solution hits the water? When the oleic acid stabilizes, measure the diameter. Is your monolayer circular? If not, how do you determine an accurate diameter?

% concentration of Oleic Acid solution = _____ %

Diameter of the Oleic Acid monolayer = _____

Observations:

3. Using the same style of pipette and a stock of pure ethanol, count the number of drops it takes to reach the 1.0 mL mark in a small graduated cylinder. Be sure to measure from the bottom of the meniscus. Repeat the count for the number of drops to go from 1.0 to 2.0 mL. *Why does the surface of the liquid in the graduated cylinder curve the way it does?*

of drops to 1.0 mL = _____

of drops from 1.0 to 2.0 mL = _____

Observations:

Analysis:

Use the data you have recorded above to perform the following calculations. Record the calculations in the space provided, and show all work clearly. Use proper units and report answers to the correct number of significant figures. Do "scratch work" on a separate paper.

Part One: BB's

1. Calculate the radius, and then the area of the BB monolayer by substituting your measurement of the diameter into the appropriate equation.

Radius = diameter/2

Area = $\pi \times (\text{radius})^2$

Radius = _____

Area = _____

2. Calculate the thickness of the BB monolayer by substituting your values for area and volume into the appropriate equation. (**Note:** the thickness of the layer is equivalent to the diameter of one BB. Watch your units here so that they cancel out properly)

Thickness = Volume/Area

Thickness = _____

3. Calculate the diameter of one BB by dividing the measured length of the BB chain by the number of BBs in the chain.

Diameter of BB = _____

4. Summarize your data in the Data Table below.