'Nano'tubes, Surface Area and NanoSolar Cells

Grades: 9-12

Topic: Solar

Owner: ACTS

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Instructional Activities in Details

NANO-"TUBES": Measuring the visible and understanding the invisible
Student Activity #1

Objectives: The student should be able to physically measure using a ruler; length, using a gram balance; mass, using a graduated beaker and cylinder; volume. They students should be able to apply these measurements graphically to determine to a constant that can be used to identify the degree of accuracy. In the end, the students should be able to apply measurement techniques to understand units of measure that are larger or smaller (the nanometer) than the one presented in this laboratory exercise.

Materials: Minimum of FOUR Beakers (Nano-"Tubes") of various sizes (10 ml – 600 ml), string, scissors, ruler, water, triple beam balance, 100 ml graduated cylinder

Part I – Measuring Length

1. Using a ruler, measure and record the diameter of each beaker in centimeters. The diameter is the width of the beaker.
2. Using the string, wrap it around the beaker and cut it so that the string length is equal to the circumference of the beaker. Measure and record the length of the string for each beaker.
3. Make a graph of this data with circumference on the y-axis and diameter on the x-axis. You can use graph paper, a computer, or a graphing calculator.

Data Table

Beaker Capacity	Diameter	Circumference

Calculations: The circumference of a circle is equal to the diameter times the constant "pi" or $C = \pi d$. If we divide the diameter to the left we get: $\frac{C}{d} = \pi, \quad slope = \frac{rise}{run}$. Based on this equation we see that Circumference is the rise, diameter is the run, and "pi" is the slope.

Find the slope of the graph that you made and show your work below.

The ACTUAL value for "pi" is 3.141592. Using the following error equation. Determine your % error. $\left|\frac{3.141592 - Experimental\ value}{3.141592}\right| x100 = \%\ error =$ ☐

Questions:

1) Looking on your % error, describe anything that might have increased your accuracy.

2) Looking at your graph, if you increased your diameter what would happen to your circumference?

3) A direct relationship is when variables do the same thing (both increase or both decrease). An inverse relationship is when one variable does the opposite of the other. Based on your answer to question two, what kind of relationship does the circumference and diameter have?

Graphing extension

4) Using your graph, what would the circumference be of a beaker that has a diameter of 20.0 cm. Explain how you came to this conclusion?

A typical diameter for a carbon nanotube is 1.4 nanometers or 1.4×10^{-9} meters. Using what you learned in the lab today, what would the circumference of the nanotube be in meters? In nanometers?

NANO-"TUBES": Measuring the visible and understanding the invisible
Student Activity #2

Part II – Measuring mass

1. Using the same beakers from part I, place then on the mass balance and measure and record the mass of each empty beaker in grams.
2. Using the graduated cylinder add a specific volume of water in milliliters to each beaker and record this value. Make sure you add <u>**DIFFERENT**</u> amounts to each beaker without over filling the beaker.
3. Measure and record the NEW mass of the beaker with the known volume of water added to it.
4. Measure and record the height of the column of water in centimeters inside the beaker.

Data Table

Mass of empty beaker (grams)	Volume of water added to beaker (ml)	Mass of water and beaker (grams)	Height of water column (cm)

Calculations

Subtract the mass of the empty beaker from the mass of water and beaker to get the MASS OF WATER that you added to each beaker. Show your work below and fill in the table appropriately.

Beaker Capacity	Mass of Water added (grams)

Part III- Measuring Volume

Volume is found by multiplying the height by the length by the width ($V = LxWxH$). The area is found by multiplying just the length times the width ($A = LxW$). If this is true, volume can be found by multiplying the area times the height ($V = AxH$). We know the height of our water column, but we still need the area. The tube has a circle on each end. Therefore we must use the area of circle to find the area that the water takes up inside the beaker. The area for a circle is given as $Area = \pi r^2$. The radius can be found by dividing the diameter that you measured in part one by two. Fill in the table below and show your work for at least ONE beaker below.

Beaker Capacity	Diameter From Part I (cm)	Radius of each beaker (cm)	Area of each beaker (cm^2)	Calculated volume of water beaker (cm^3)

Let's now compare the **calculated volume** of water to the **measured volume** of water to see if our calculations are accurate. To compare values in an experiment we find what is called a ***percent difference***. The formula is $\% \, difference = \left| \frac{Calculated - Measured}{Average} \right| x100$

This formula says you take the difference of the two values then divide by the AVERAGE of the two values. Keep in mind that you ARE NOT finding an error percentage. You are simply comparing the two numbers to see how close they are.

Show the work for at least one trial below. **Average all of the percent differences for each beaker to get an AVERAGE % DIFFERENCE.**

Average % difference

Part IV – Measuring Density

The **DENSITY** of a material is defined as the ratio of the mass to the volume. A ratio is simply a fraction. Therefore we can construct a formula for density that looks like this: $Density = \frac{Mass}{Volume}$. It just so happens that this formula ALSO resembles SLOPE = RISE/RUN

What does this mean? This means that we can find the DENSITY of water if we plot its MASS in the y-axis and it VOLUME on the x –axis. Construct a graph with the mass of water on the y-axis and the MEASURED volume of water on the y-axis.

Find the slope of the line and determine the density of water in the units of grams/cubic centimeter.

Slope = (density of water) = ____________

The ACTUAL value for the density of water is 1.0 g/cm³. Using the following error equation. Determine your % error. $\left|\frac{1.0 - Experimental\ value}{1.0}\right| x100 =$ ☐

NANO-"TUBES": Measuring the visible and understanding the invisible
Student Activity #3

Part V – Applying Measurement and Understanding the size of things

Materials: roll of 50 pennies, ruler

Procedure:

1) Stack the pennies vertically on a flat surface.
2) Measure and record the height of the stack in centimeters.

Height of stack in centimeters	

A centimeter is SMALLER than a meter. In fact the prefix "centi" means 100. Common words that represent this prefix are centipede (100 legs) and century (100 years). So that means that there are 100 centimeters in 1 meter. So ONE centimeter would be a small fraction in fact it is $1/100^{th}$ of a meter.

So now let's convert the height of our penny stack to meters. To do this we divide by 100.

Height of stack in meters	

Remember, the stack above had 50 pennies. So how many pennies would it take to make a tower 1 billion meters tall (1,000,000,000 m)? One billion meters is also known as 1 Gigameter. "Giga" means one billion and it is often used to describe how fast a computer can operate. Stores that sell computers advertise computers, which have an operating speed of 2 Gigahertz. This means that the computer can perform 2 billion different tasks every second. We also see that computer manufacturers express the hard drive of a computer in terms of Gigabytes. This is a measure of storage capacity. The hard drive, therefore, can hold 1 billion bytes of data.

# of pennies for a tower 1 billion meters tall	

How much money is the 1 billion meter tall tower? What could you buy with this amount of money? Show below how you determined your amount.

Understanding Surface Area in Chemical Reactions
Student Activity #4

Objectives: To understand the affect of reaction time based on changing surface area

Materials:
Magnesium Ribbon, scissors, 1 M HCL, beaker, stopwatch
(Alternatively Alka-Seltzer and Water can be used as substitutes for the chemicals)

Procedure:
1. Place 100 ml of 1.0 M HCL in 3 separate beakers.
2. Measure out three 5-cm pieces of magnesium ribbon.
3. Leave one piece of ribbon untouched, roll one of the pieces into a tight ball, and cut the other piece into very tiny fragments.
4. Place the tight ball into one of the beakers of acid.
5. Measure and record the time it takes for the reaction to complete.
6. Repeat for the other magnesium pieces. Remember that each piece is placed in a different beaker.

Data Table

Magnesium Ribbon	**Time in seconds**
Tight Ball	
Untouched Ribbon	
Ribbon Pieces	

Analysis:
Which of the following situations produced the fastest time?

What is the ratio of Tight Ball to Ribbon Pieces?

Write the balanced equation for HCL and Magnesium ribbon below.

Nanofabrication of Solar Cells:
Student Activity 5

A) Nanotitania synthesis (Preparation)
1. Add 100-ml of anhydrous isopropanol [$(CH_3)_2CHOH$] to 2-ml of 2,4 – Pentanedione ($C_5H_8O_2$) and stir covered for 20 minutes.
2. Add 6.04-ml of titanium isopropoxide ($Ti[(CH_3)_2CHO]_4$ to the solution and stir for 3 hours.
3. Add 2.88-ml of distilled water and stir for another 2 hours.
4. The solution must then age for 12 hours, as the powder will precipitate out of solution at room temperature.
5. The remaining liquid can be decanted and the precipitate allowed to dry.
6. If you have access to X-Ray diffraction, it might be a good idea to place some crystals on a slide. A Scanning Electron Microscope with and EDX device may also work. This is used simply to determine whether the product is titanium dioxide.

Nanocrystalline Solar Cells:

The Materials

1. (2) F-SnO_2 glass slides
2.Iodine and Potassium Iodide
3.Mortar/Pestle
4.Air Gun
5.Surfactant (Triton X 100 or Detergent)
6.Colloidal Titanium Dioxide Powder
7.Nitric Acid
8.Blackberries, raspberries, citrus leaves
9.Masking Tape
10.Tweezers
11.Filter paper
12.Binder Clips
13.Various glassware
14.Multi-meter

The photovoltaic cell has basically four main parts.

1.Nanolayer (nanotitinia suspension)
2.Dye
3.Electrolyte
4.2 electrodes

The nanolayer is the nanotatinia. The dye can be juice extracted from raspberries, blackberries, or citrus leaves. The electrolyte is a solution of Iodine/Iodide. The two electrodes are conductive glass slides, which have been coated with fluorine doped tin oxide.

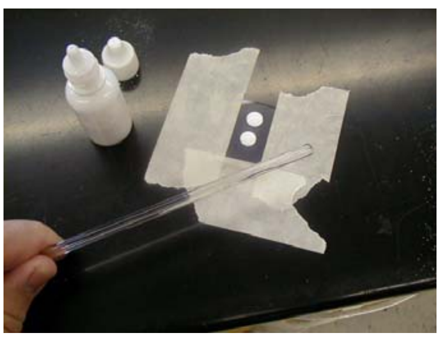
Preparation of the Electrolyte
1.Measure out 10-ml of ethylene glycol
2.Weigh out 0.127-g of I_2 and add it to the ethylene glycol and stir.
3.Weigh out 0.83 g of KI and add it to the same ethylene glycol.
4.Stir and sore in a container with a tight lid. This container should be dark as well so as to not allow too much light to enter.

Preparation of the Dye

1. Crush 5-6 berries in a mortar and pestle with 2-ml of deionized water.
2. Filter the solution with a coffee filter or any type of tissue.

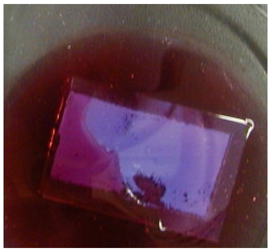
Preparation of the Nanotitania Suspension

1. Add 9 ml (in 1 ml increments) of nitric or acetic acid (ph3-4) to six grams of titanium dioxide in a mortar and pestle.
2. Grinding for 30 minutes will produce a lump free paste.
3. 1 drop of a surfactant is then added (triton X 100 or dish washing detergent).
4. The suspension is then stored and allowed to equilibrate for 15 minutes.

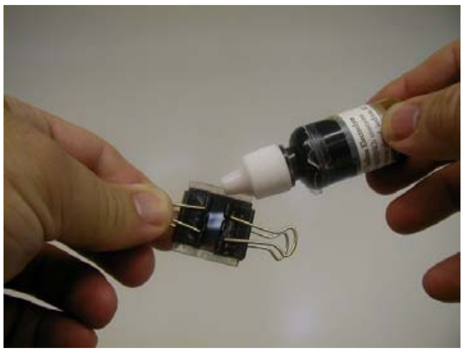


Cell Fabrication Procedure

1. After testing with a multimeter to determine which side is conductive, one of the glass slides is then masked off 1-2 mm on THREE sides with masking tape. This is to form a mold.
2. A couple of drops if the titanium dioxide suspension is then added and distributed across the area of the mold with a glass rod.
3. The slide is then set aside to dry for one minute.
4. After the first slide has dried the tape can be removed.
5. The titanium dioxide layer need to be heat sintered using a hot air gun that can reach a temperature of at least 450 degrees Celsius.
6. This heating process should last 30 minutes.
7. Allow the heat sintered slide to cool to room temperature.



8. Once the slide has cooled, place the slide face down in the filtered dye and allow the dye to be absorbed for 5 or more minutes.
9. After the first slide had absorbed the dye, it is quickly rinsed with ethanol to remove any water. It is then blotted dry with tissue paper.
10. The two slides are then placed quickly in an offset manner together to that the layers are touching. ***A picture showing this is at the beginning of this section on page 27.***



11. Binder clips can be used to keep the two slides together.
12. One drop of a liquid iodide/iodine solution is then added. Capillary action will stain the entire inside of the slides

Activities that can be done the Fabricated Solar Cell:

1. The cell can be placed in series with a voltmeter and ammeter. Its power can then be calculated.
2. The cell can be placed in series with a potentiometer. Voltage vs. Current data can then be obtained.
3. The area of the cell can be determined which could then be used to calculate current and power density.
4. Multiple Cells could be made and attached in various configurations to measure total voltage output and verify Kirchhoff's Voltage Law.
5. The cell can be placed in an RC circuit of which the time constant can be measured.

IMPLEMENTATION DESIGN

DESIGN FOR INSTRUCTIONAL TABLE				
Instructional Activity	Learning Objectives	Resources	Timeframe	Assessment
A. Measurement and Data Analysis	Measurement	Beakers, Rulers, Food Coloring	1 class period	
B. NANO-"TUBES": Measuring the visible and understanding the invisible Measuring the visible and understanding the invisible	Understand nanoparticles	pennies, ruler	1 class period	
C. Understanding Surface Area in Chemical Reactions		Magnesium Ribbon Scissors, 1 M HCL, beaker, stopwatch	2 class period	
D. The photovoltaic capabilities of nanotitania. (Solar Cells)		(nanotitinia suspension) Dye Electrolyte Electrodes Vernier Pro Logger Voltage/Current Probe	3 class periods	Lab Energy quiz

- **Learning Goals:**
- The student selects and uses appropriate units and instruments for measurement
- to achieve the degree of precision and accuracy required in real-world situations.
- The student understands and uses the tools of data analysis for managing information.
- The student describes, analyzes, and generalizes a wide variety of patterns, relations, and functions.
- The student uses the scientific processes and habits of mind to solve problems.
- The student understands that all matter has observable, measurable properties.
- Matter is made of minute particles called atoms, and atoms are composed of even smaller components. These components have measurable properties, such as mass and electrical charge. Each atom has a positively charged nucleus surrounded by negatively charged electrons. The electric force between the nucleus and electrons holds the atom together.
- . Atoms interact with one another by transferring or sharing electrons that are furthest from the nucleus. These outer electrons govern the chemical properties of the element.
- Chemical reactions may release or consume energy. Some reactions such as the burning of fossil fuels release large amounts of energy by losing heat and by emitting light. Light can initiate many chemical reactions such as photosynthesis and the evolution of urban smog.
- Reactions involve electron transfer. A large number of important reactions
- involve the transfer of either electrons (oxidation/reduction reactions) or hydrogen ions (acid/base reactions) between reacting ions, molecules, or atoms. In other reactions, chemical bonds are broken by heat or light to form very reactive radicals with electrons ready to form new bonds. Radical reactions control many processes such as the presence of ozone and greenhouse gases in the atmosphere, burning and processing of fossil fuels, the formation of polymers, and explosions.

- Catalysts accelerate chemical reactions. Catalysts, such as metal surfaces, accelerate chemical reactions. Chemical reactions in living systems are catalyzed by protein molecules called enzymes.

Experiments and determines that the rates of reaction among atoms and molecules depend on the concentration, pressure, and temperature of the reactants and the presence of catalysts.

- *Student understands that the t*otal energy in universe is constant. The total energy of the universe is constant. Energy can be transferred by collisions in chemical and nuclear reactions, by light waves and other radiations, and in many other ways. However, it can never be destroyed. As these transfers occur, the matter involved becomes steadily less ordered.

- All energy is either kinetic or potential. All energy can be considered to be either kinetic energy, which is the energy of motion; potential energy, which depends on relative position; or energy contained by a field, such as Electromagnetic waves.
- Energy is quantized. Each kind of atom or molecule can gain or lose energy only in particular discrete amounts and thus can absorb and emit light only at wavelengths corresponding to these amounts. These wavelengths can be used to identify the substance.
- Electron flow in materials in some materials, such as metals, electrons flow easily, whereas in insulating materials such as glass they can hardly flow at all.
- Semiconducting materials have intermediate behavior. At low temperatures some materials become superconductors and offer no resistance to the flow of electrons.

State/ District Standards

Nanotechnology Idea	Standard it can address
The idea of "Nano" – being small	Structure of Atoms
Nanomaterials have a high surface area (nanosensors for toxins)	Structure and properties of matter, Personal and Community Health
Synthesis of nanomaterials and support chemistry (ie. Titanium Dioxide)	Chemical Reactions
Shape Memory Alloys and Smart Materials	Motion and Forces, Abilities of technological design, Understanding about science and technology
Nanocrystalline Solar Cells	Conservation of Energy and increase in disorder (entropy), Interactions of energy and matter, Natural Resources
Nanocoatings resistive to bacteria and pollution	Personal and Community Health, Population Growth, Environmental Quality, Natural and human-induced hazards
Nanomaterials, such as MR (magneto-resistive) fluids in security	Science and technology in local, national, and global challenges
Richard P. Feynman's talk, "There is plenty of room at the bottom". Feynman had a vision.	Science as a human endeavor, Nature of scientific knowledge, Historical perspective
Nanocosmetics and nanoclothing	Science as a human endeavor, Science and technology in local, national, and global challenges
Nanotechnology and Science Ethics	Science and technology in local, national, and global challenges, Science as a human endeavor, Historical perspective, Natural and human-induced hazards, Population Growth, Personal and Community Health

ASSESSMENT PLAN

ASSESSMENT PLAN TABLE			
Type of Assessment	Learning Objectives	Format of Assessment	Modification
Pre-Assessment	Student will show how to measure and analyze small objects	Nanotechnology Measurement	
Formative Assessment	To understand the affect of reaction time based on changing surface area	Show the effect of surface area on chemical reactions	
Formative Assessment	Student will demonstrate the conservation of energy	Show the design of solar cell with titanium oxide	
Post Assessment		Student will report all Laboratory activities	

This material was developed by Gilbert Amadi through participation in the DOE ACTS program at Lawrence Berkeley National Lab.