Project 6: Nanostructured Catalytic Membranes as Optical Sensors

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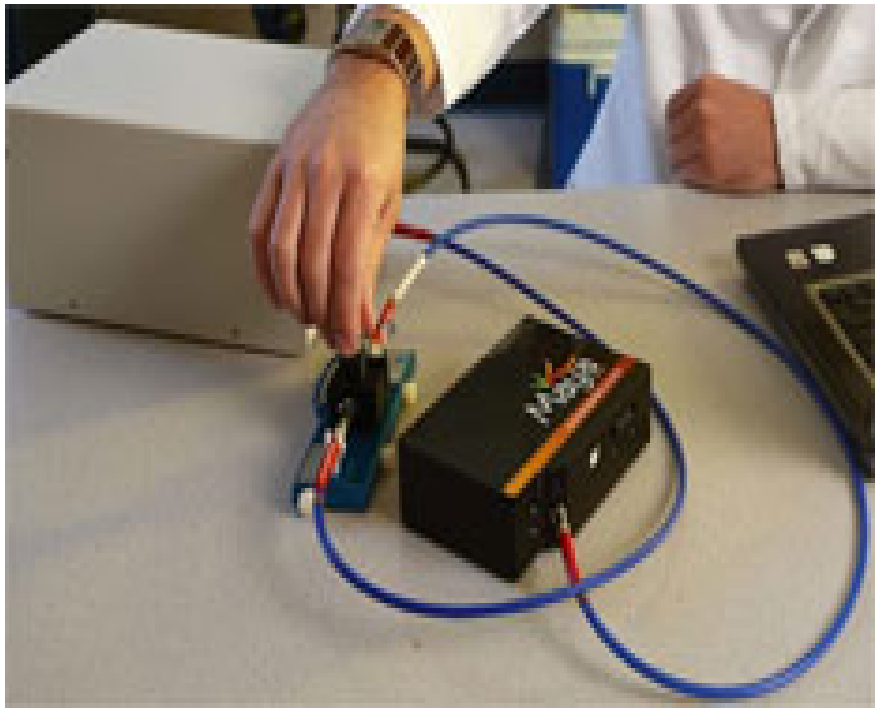
Project Overview

- The purpose of this project was to utilize nanostructured catalytic membranes as optical sensors to determine if a correlation could be found between exposure levels for a given chemical and the color it produced in the membrane.

UV/Vis Spectroscopy

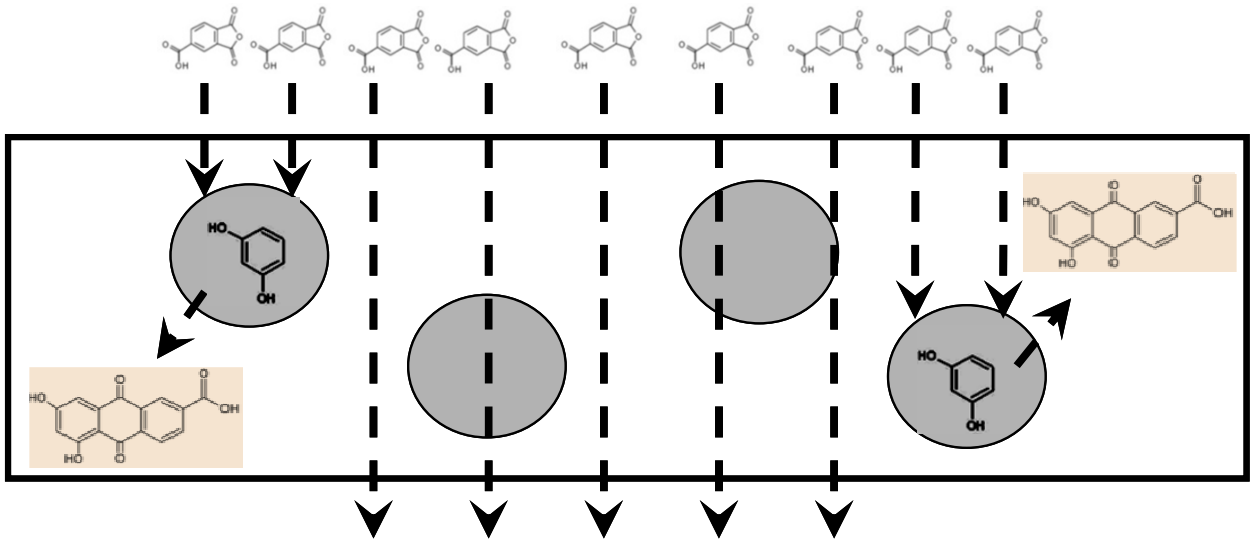


UV/Vis Spectroscopy – used to detect absorbance of a sample in the UV and visible light range.

- The absorbance for the catalytic membrane (PSA), the organic dye (Resorcinol) were studied previously.
- Our research was focused on a new chemical and what happens to its absorbance over time (Sample A)

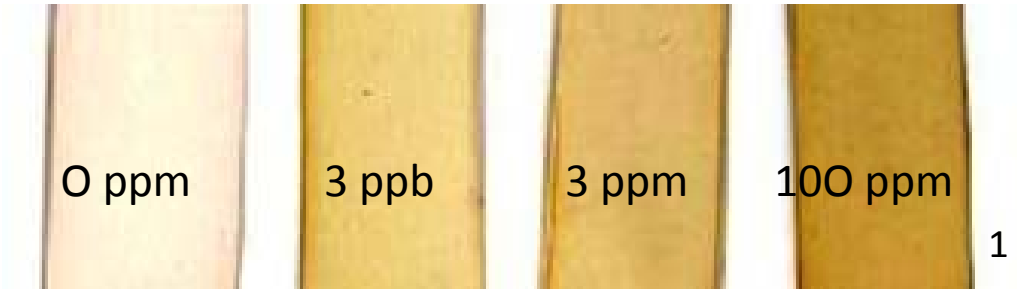
http://www.google.com/imgres

“Fabricated Sensor”



Schematic of Optical Sensing Mechanism

Source: Ayyadurai, S. *Perfluorosulfonic Acid Membrane Catalysts for Optical Sensing of Anhydrides in the Gas Phase; Anal. Chem.* 2010, 82, 6265–6272



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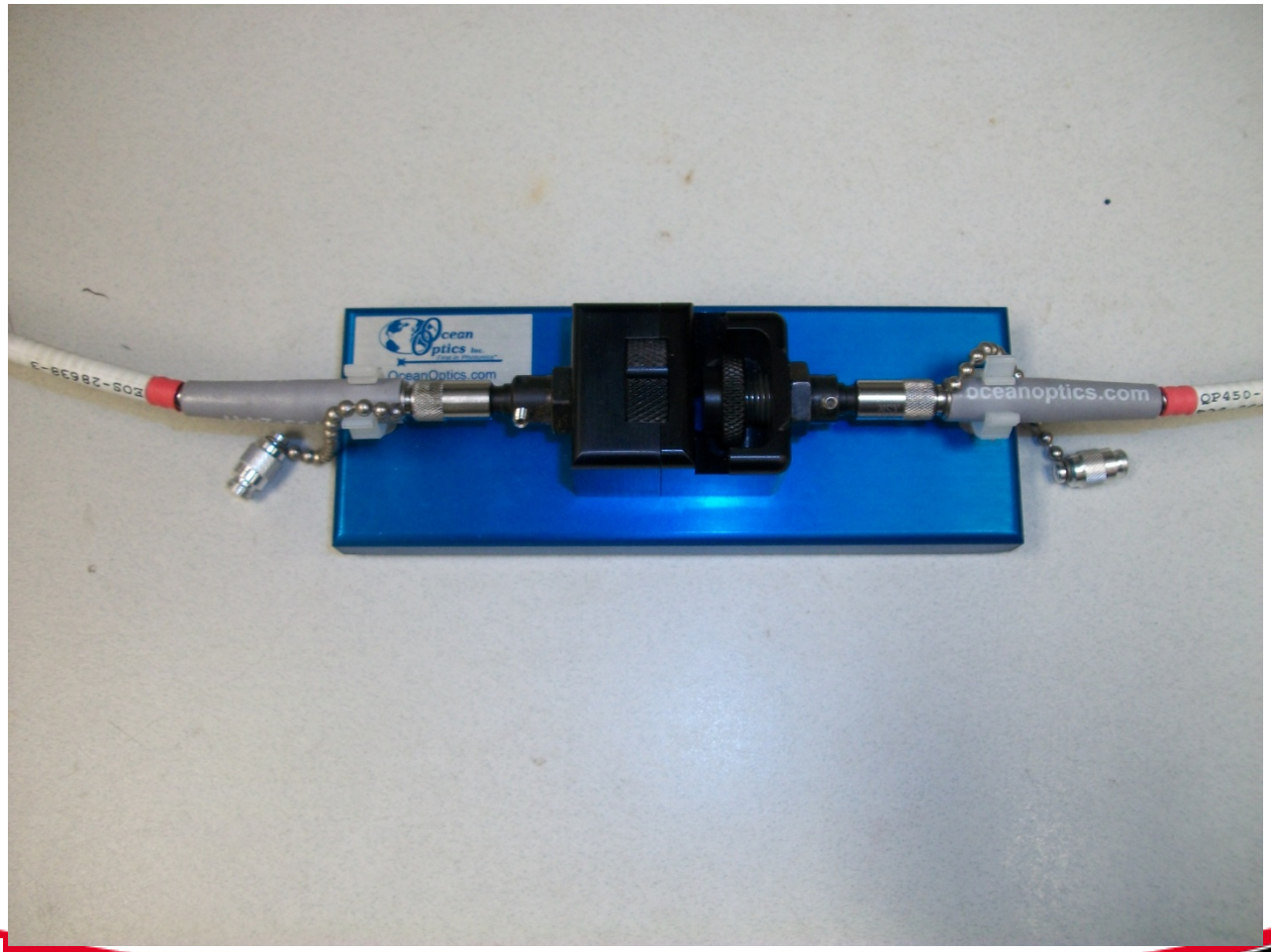
Catalytic Optodes After Exposure to Indicated TMA Concentrations

Ayyadurai, S. M., Worrall, A. D., Bernstein, j. A., and Angelopoulos, A. P**.** (2010). “Perfluorosulfonic Acid Membrane Catalysts for Optical Sensing of Anhydrides in the Gas Phase,” *Analytical Chemistry, Vol. 82, Issue 16,* June 18, pgs. 6265-6272

UV-vis Apparatus to Hold Membrane



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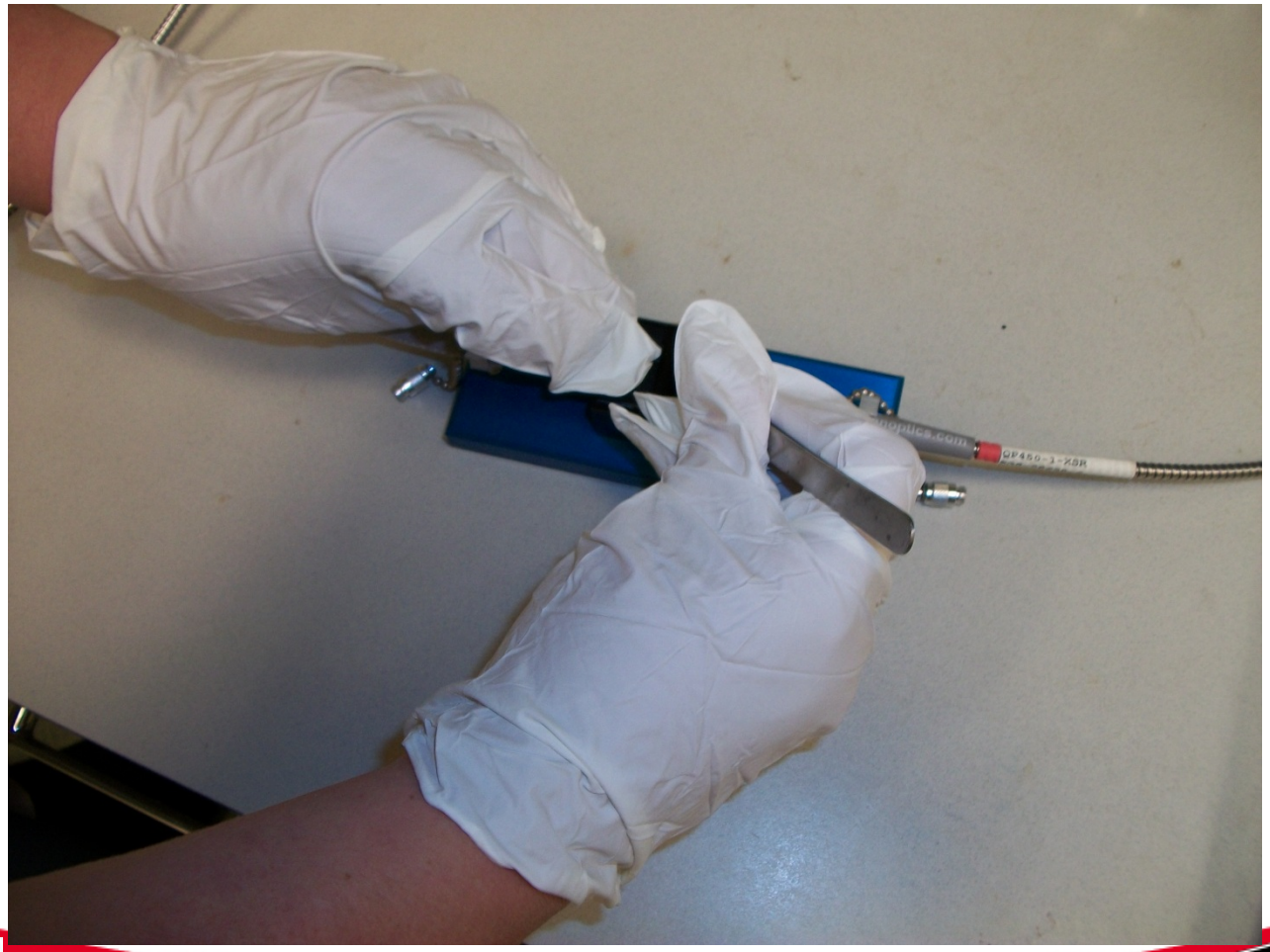
Learning the Technique to Insert Membranes



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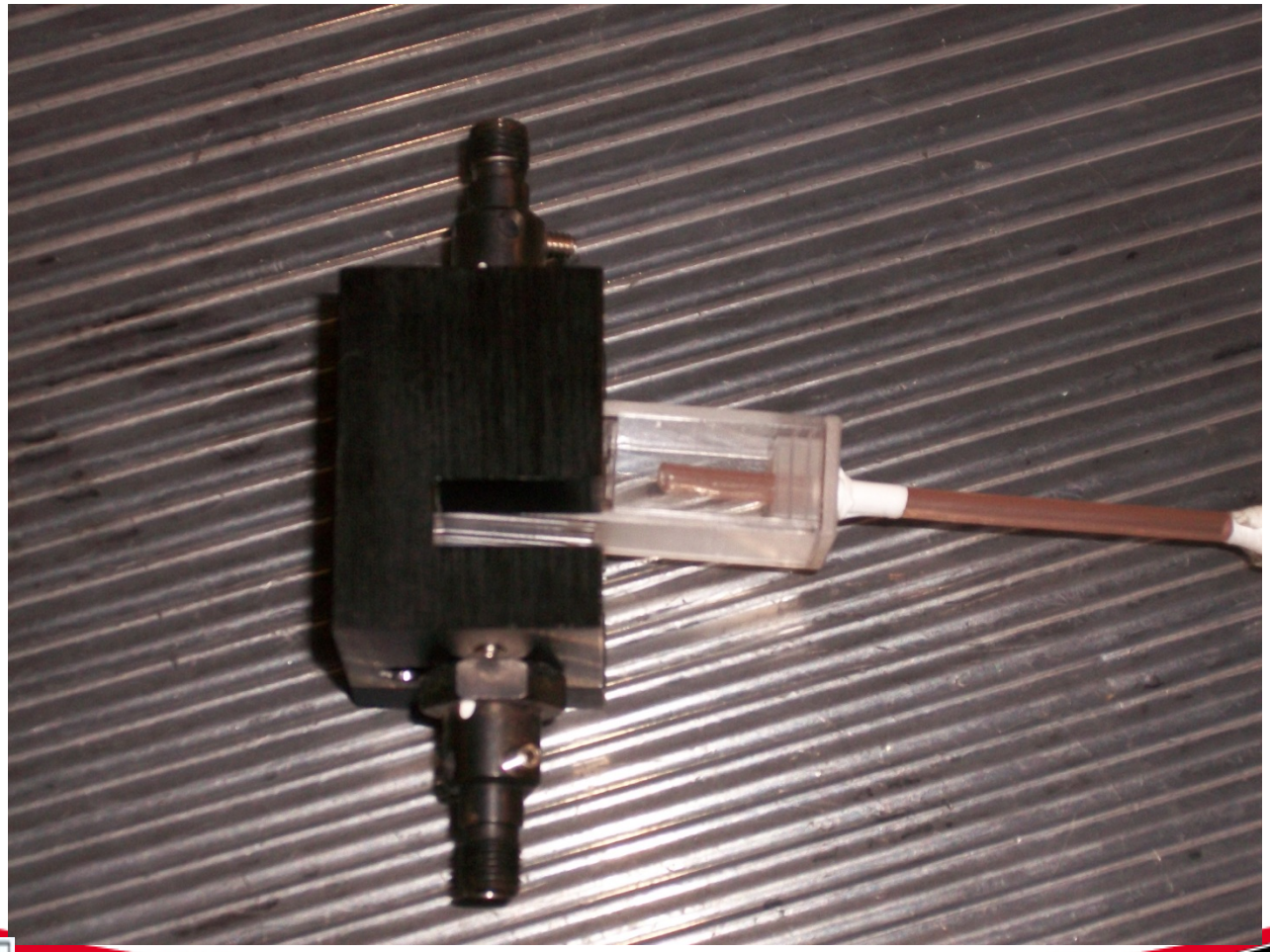
Experimental Setup

UV-vis Apparatus to Hold Sample for Expose to a Gas



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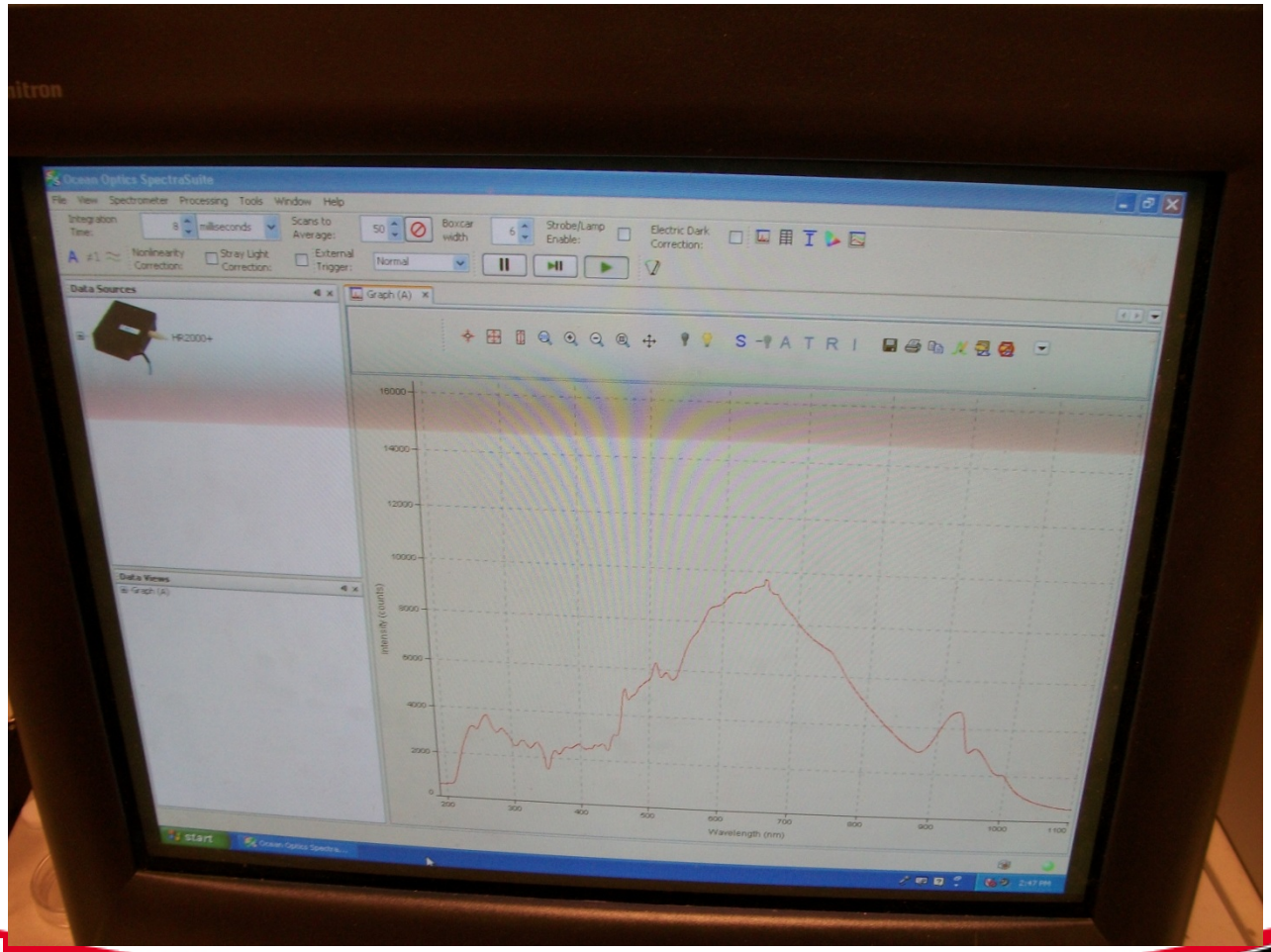
Computer Collected Data



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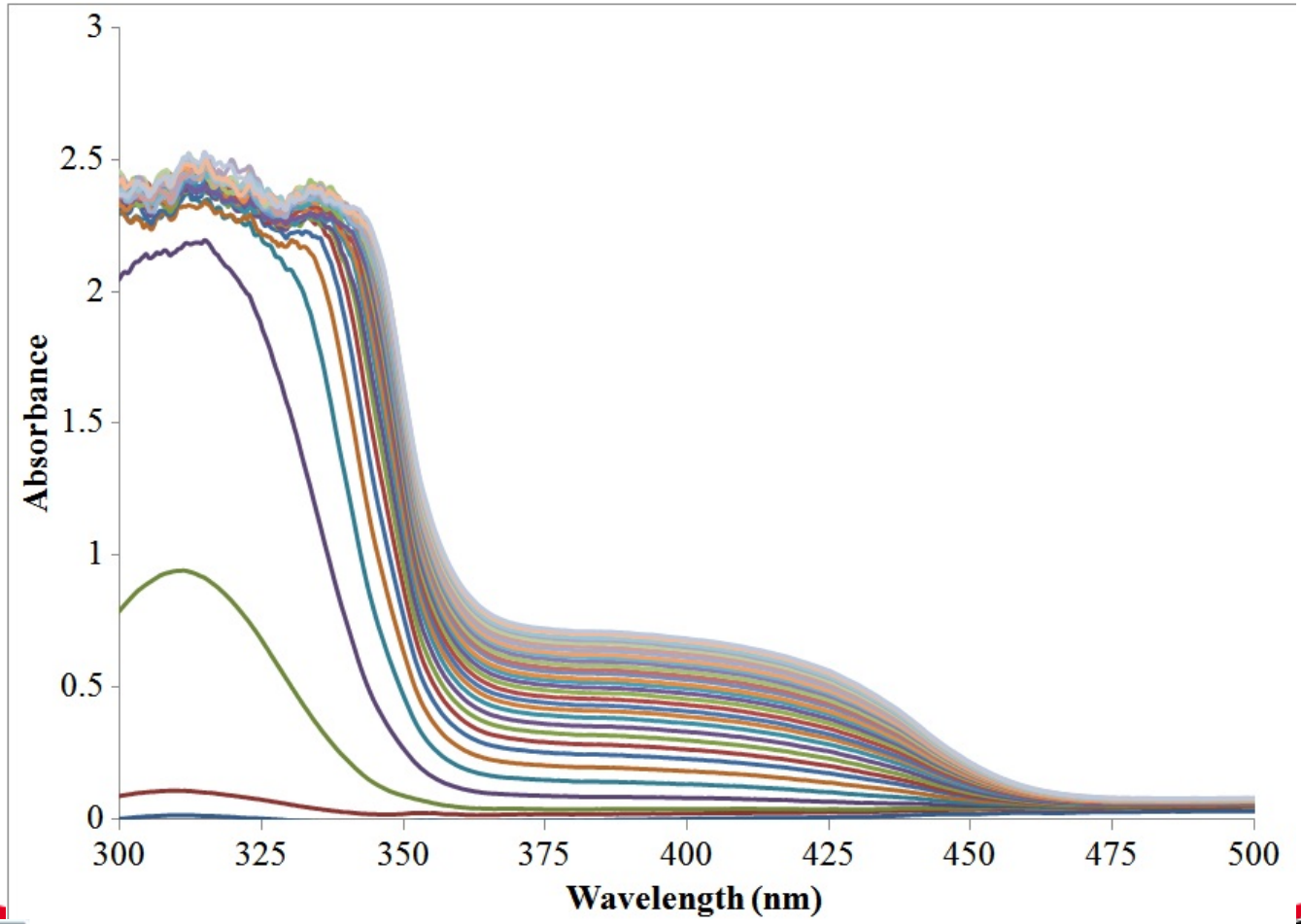
Time Elapsed Raw Data for 0.6 ppm For Test Sample A



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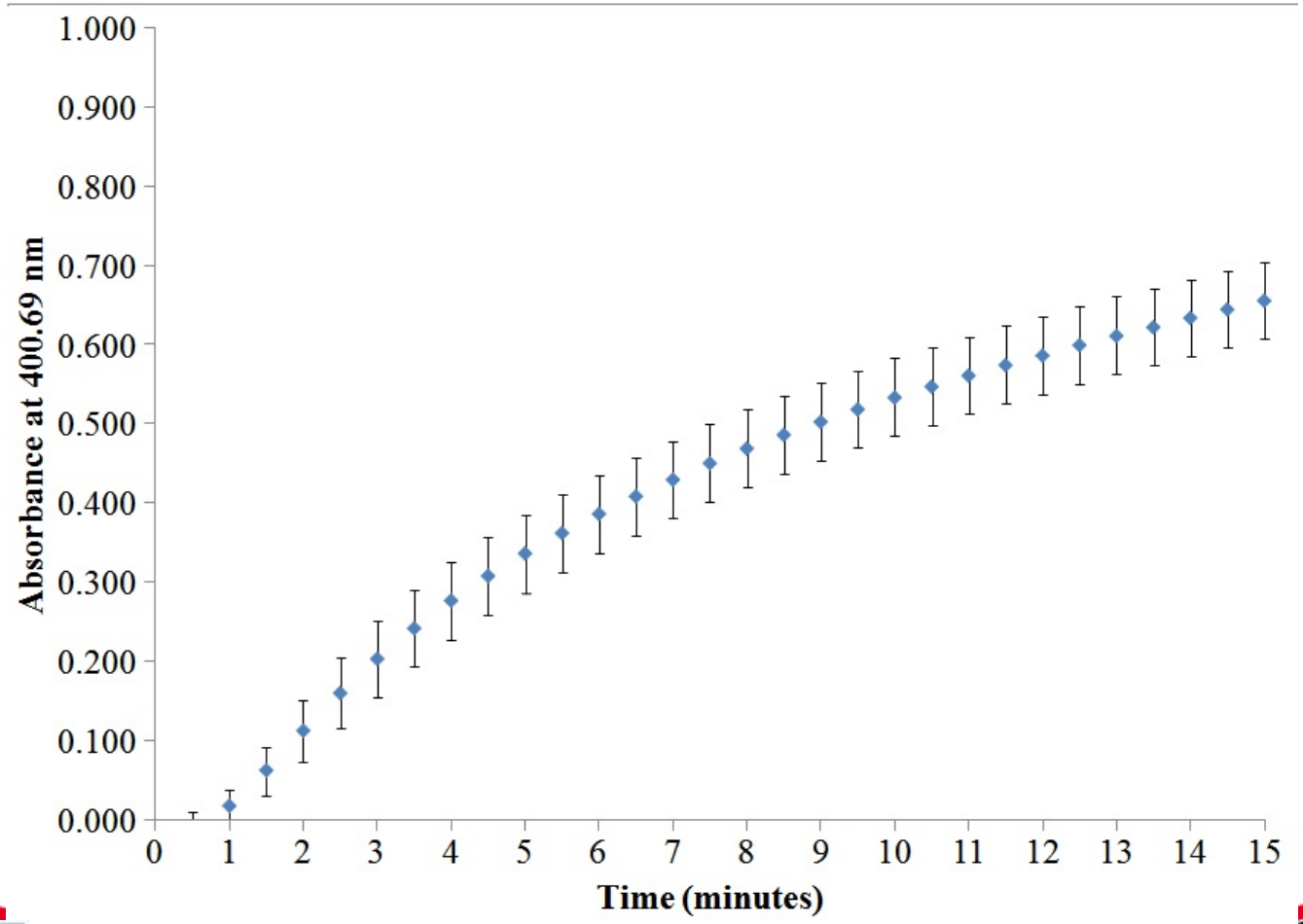
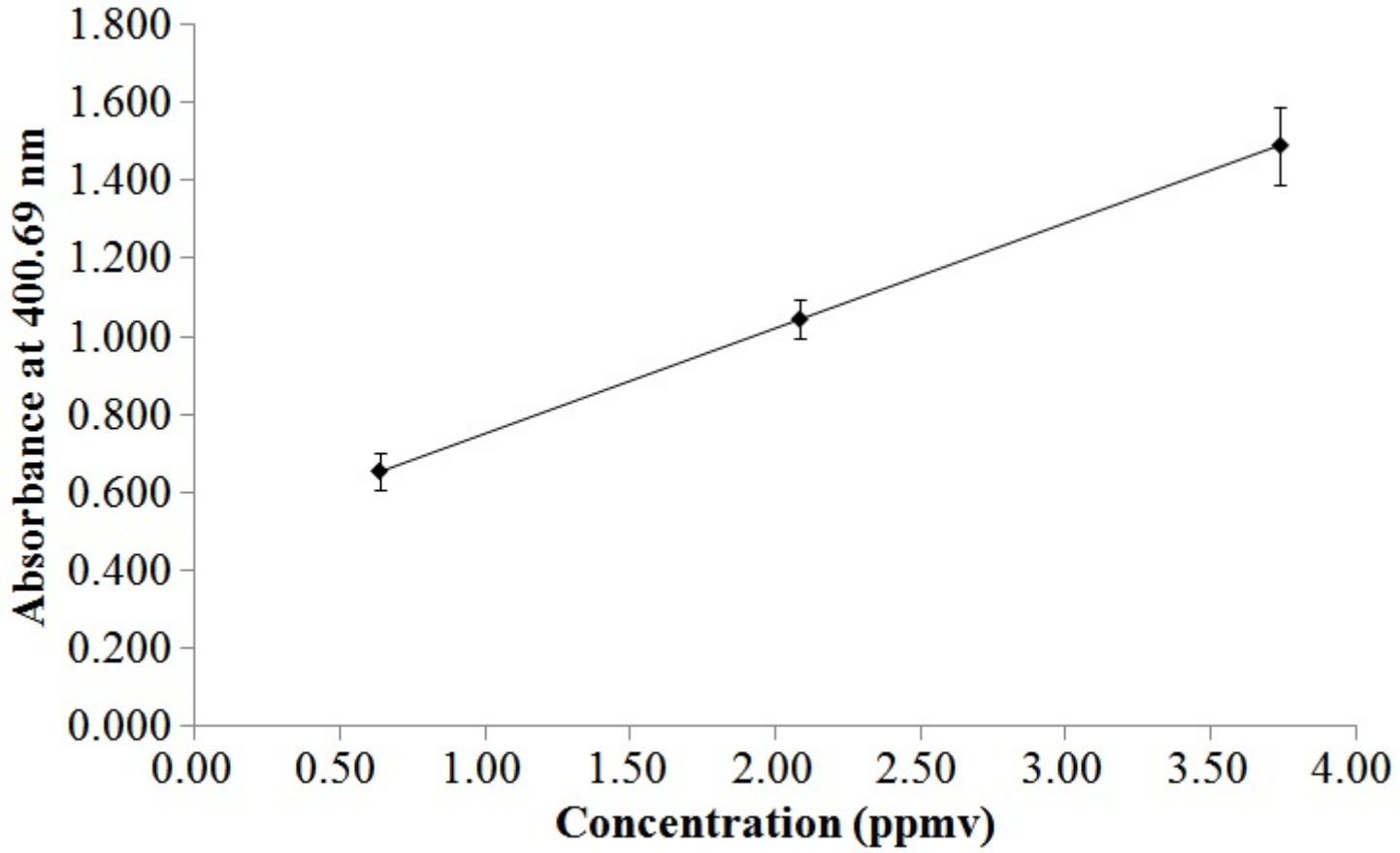
Average Absorbance Data For 0.60 ppm Run for Sample A



Flow Cell Absorbance Calibration Plot for Sample A



Potential Use For This Research

- Used in medical diagnostics and nanoimaging.

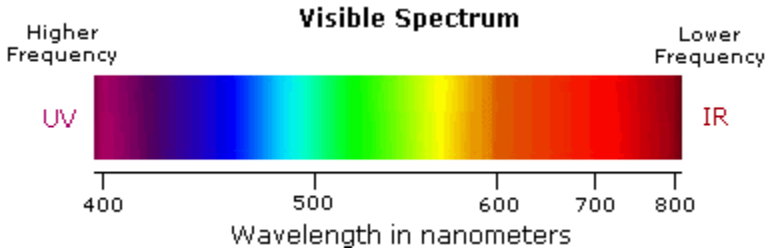
Lesson Plan Implementation

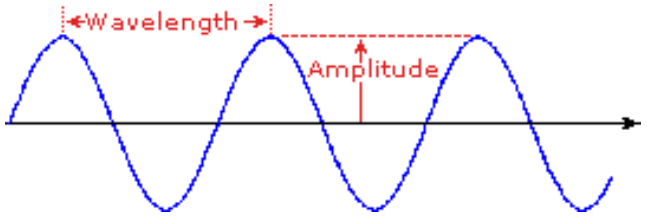
Advance Placement Biology

Advanced Placement Statistics

- 100% collaborative lesson
- Interdisciplinary
- Open ended
- Investigative

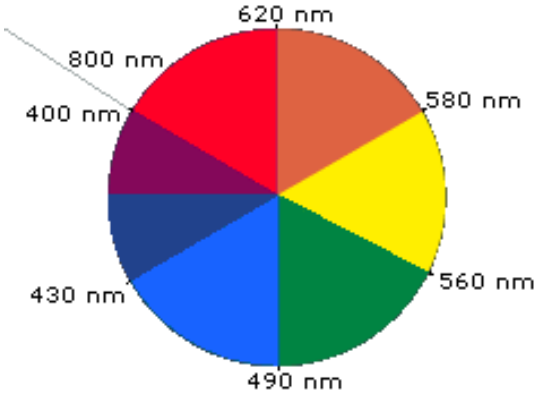
Color Science!





Light is a WAVE!! The distance between two successive peaks is called the wavelength. Different wavelengths of light appear to our eyes as different colors. Shorter wavelengths appear blue or violet, and longer wavelengths appear red.

Violet: 400 - 420 nm
Indigo: 420 - 440 nm
Blue: 440 - 490 nm
Green: 490 - 570 nm
Yellow: 570 - 585 nm
Orange: 585 - 620 nm
Red: 620 - 780 nm



http://www2.chemistry.msu.edu/faculty/reusch/VirtTxtJml/Spectrpy/UV-Vis/spectrum.htm

Student Misconceptions

Students are likely to confuse Transmittance and Absorbance. If they are trying to record absorbance data for red food dye, then their colorimeter must be set to blue and vise versa.

So, is grass **green**???

Another misconception is that linear regression can ALWAYS be performed.

Beer-Lambert Law

Students will use the Beer Lambert Law to explain the relationship between absorbance and concentration and then use their model to determine the concentration of an unknown sample.

$$A = \varepsilon * \ell * c$$

Where A = light absorption by the material

ε = proportionality constant known as the 'extinction coefficient'

ℓ = path length

c = concentration of the substance

The slope of the linear regression model is the extinction coefficient.

Weekend Practice Session

- Collect data
- Perform regression
- Check assumptions and residual plot
- Determine concentration of an unknown

Technology Used

http://chariot.vernier.com/mbl/images/labquest.jpg

http://www.oppictures.com/SINGLEIMAGES/240/TEXTI84PLUSSE_3_1.JPG

http://chariot.vernier.com/caliper/spring03/images/COLBTA.jpg

Practice Lesson

L1	L2	L3 3
100.00	.33200	
80.000	.30100	
60.000	.26200	
40.000	.22500	
20.000	.16800	
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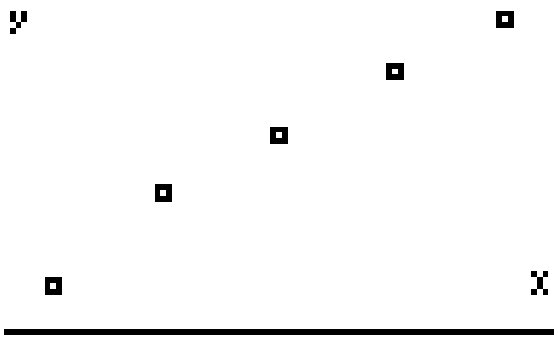
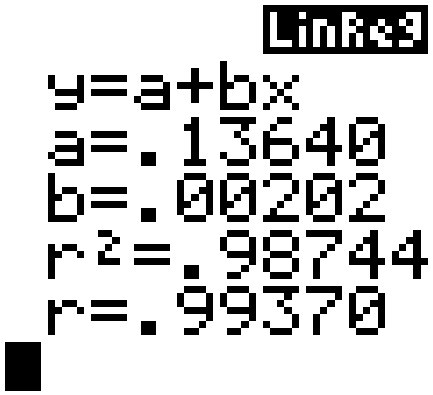
L3(1)=

Blue Absorbance Data



Scatterplot Concentration vs Absorbance

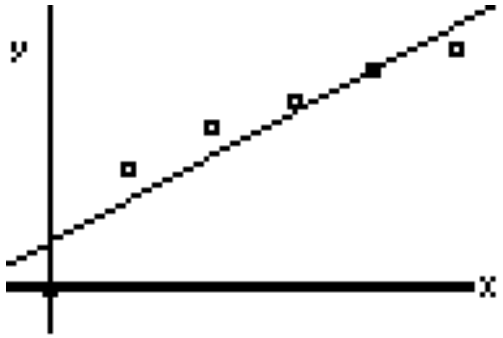
The plot thickens!!!



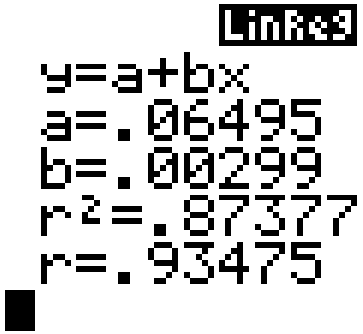
- Strong Coefficient of Determination
- Strong Correlation Coefficient

BUT we know that the Beer-Lambert Law is DIRECT VARIANCE!

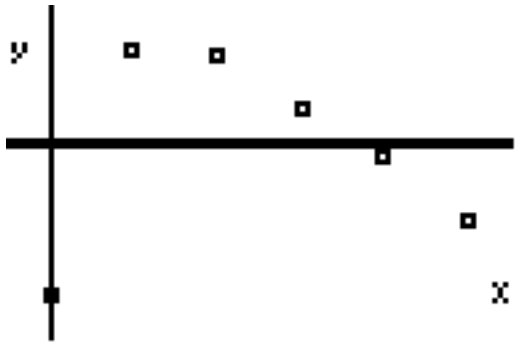
Forcing Direct Variance



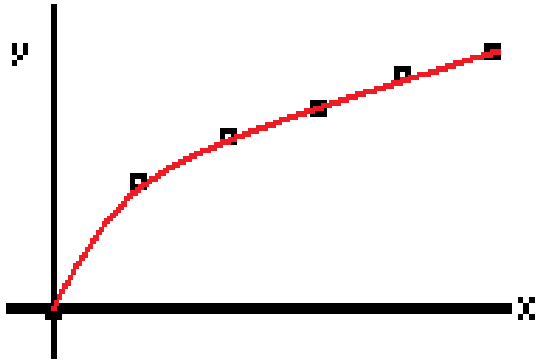
Forced linear model



Regression equation including (0,0)



Residual Plot



Does this look linear??

Data Analysis

Check assumptions
Create Scatterplot
Perform least squares regression line
Check residual plot
Check for outliers
Hypothesis test for slope

Determine the concentration of an unknown sample. Determine if it is within a certain interval.

Extensions

- Combine entire class data and create confidence intervals for each concentration.
- Use new model to determine concentration of the unknown.
- As a class, go through a stock solution that saturates the colorimeter.

AP Statistics Standards

Exploring bivariate data

1. Analyzing patterns in scatterplots
2. Correlation and linearity
3. Least-squares regression line
4. Residual plots, outliers, and influential points

Tests of significance

•Test for the slope of a least-squares regression line

National Science Standards

E.B.3 Light, heat, electricity, and magnetism

•a. Light travels in a straight line until it strikes an object. Light can be reflected by a mirror, refracted by a lens, or absorbed by the object.

Kentucky Science Academic Expectations

•**2.1** Students understand scientific ways of thinking and working and use those methods to solve real-life problems.

•**2.2** Students identify, analyze, and use patterns such as cycles and trends to understand past and present events and predict possible future events.

•**2.4** Students use the concept of scale and scientific models to explain the organization and functioning of living and nonliving things and predict other characteristics that might be observed.

•**2.5** Students understand that under certain conditions nature tends to remain the same or move toward a balance.

Special Thanks!

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