KENT STATE UNIVERSITY

Conceptual Chemistry

Repurposed Materials for Low-cost Science Experiments

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Conceptual Chemistry

Conceptual Chemistry is a graduate course designed for grade school and middle school teachers to assist in their understanding of chemistry and to provide concrete ideas that they can take back to their classrooms to teach their students.

http://personal.kent.edu/~cfenk/Chemistry/Conceptual_Chemistry.html

Conceptual Chemistry

Participants in this course receive:

- Free tuition and five graduate credit hours from the College of Education of Kent State University. *($2,425 value)*
- Over $850 worth of materials and supplies to take back to the classroom.

Conceptual Chemistry

Support for ***Conceptual Chemistry*** and the development/production of this material was provided by a grant under the federally funded ***Improving Teacher Quality State Grants Program***, administered by the ***Ohio Department of Higher Education***.

Activity Objectives

Key Concepts

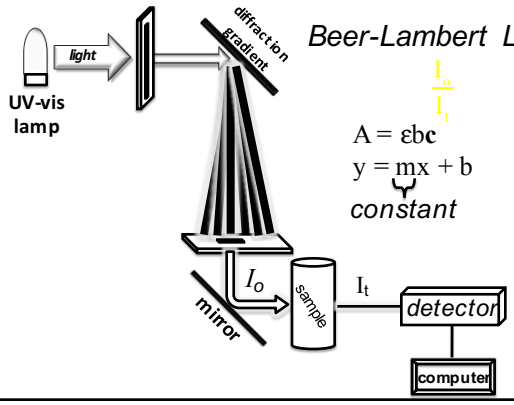
- Molecular Spectroscopy
- Electromagnetic Radiation
- Quantitative Analyses
- Forensic Science
- Having fun with science!

Spectroscopy

Spectroscopy
The investigation into the nature of matter using electromagnetic radiation.

Most Common Types
Infrared, ultraviolet, visible, NMR, X-ray and microwave.

UV-Vis Spectroscopy



Beer-Lambert Law

$$\frac{I_o}{I_t}$$

$$A = \varepsilon b c$$

$$y = mx + b$$

constant

UV-Vis Spectroscopy

Pro's

- Safe
- Accurate *~$2,100 each*
- Easy to use

Con's

- *$$$ Expensive $$$*
- Not generally available

Mobile-Phone Spectroscopy

Purpose

To determine the concentration food coloring in an unknown sample using quantitative visible light spectroscopy.

Mobile-Phone Spectroscopy

Materials

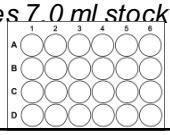
- 10 ml aqueous food coloring solution
- distilled water
- 24-well plate or ½" bubble wrap
- 5.8 ml plastic pipet
- 2 smart phones or similar devices
- 25 - 30 cm high box

Stock solution of food coloring is prepared by dissolving 1.00 mL (20 drops) of food coloring into a total of 1.00 L solution.

Mobile-Phone Spectroscopy

Procedure

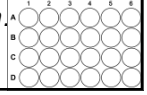
1. Obtain a 15 ml plastic conical tube containing *10.0 ml "stock" solution.*
2. Use a plastic pipette to withdraw exactly 3.0 ml of *"stock"* solution from the conical tube and place it into well number **A-1** of the 24-well plate. *(This leaves 7.0 ml stock solution in the plastic tube.)*



Mobile Phone Spectroscopy

Procedure (cont.)

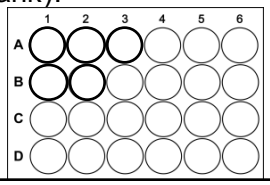
3. Add 3.0 ml water to the plastic conical tube, replace the cap and mix thoroughly. *(This gives 10.0 ml of solution again!)*
4. Withdraw 3.0 ml of the diluted stock solution from the conical tube and place it into well A-2 of the 24-well plate. *(This leaves 7.0 ml drink mix in the plastic tube again.)*



Mobile-Phone Spectroscopy

Procedure (cont.)

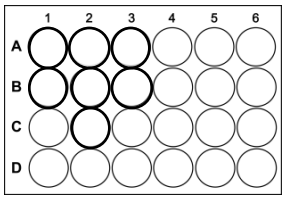
5. Continue this dilution process three more times until wells A-1, A-2, A-3, B-1 and B-2 are filled. Fill well B-3 with 3.0 mL water (blank).



Mobile-Phone Spectroscopy

Procedure (cont.)

6. Place 3.0 mL of the unknown solution in well **C-2**.



Mobile-Phone Spectroscopy

Procedure (cont.)

7. Place the cover onto the 24-well plate and set aside.
8. Turn on an iPad and launch **AppBox Pro**. *(**AppBox Pro** is a free app available on the Apple App Store.)*
9. Select the ***"Flashlight"*** function and set the background to white light.

Mobile-Phone Spectroscopy

Procedure (cont.)

10. Place the lit iPad into a ~30 cm high cardboard box.
11. Carefully place the 24-well plate onto the iPad and close the box.
12. Position a mobile phone on top of the box so that the camera lens is aligned with the pre-cut hole on the box.

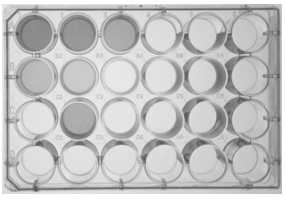
Mobile-Phone Spectroscopy

Procedure (cont.)

13. Focus the camera on the center of the sample wells and take a photo's.
14. Inspect the image to ensure that it is suitable.
15. Analyze the image using ***"ImageJ"*** available from the ***National Institute of Health***.

http://imagej.nih.gov/ij/

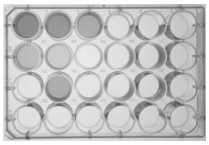
Mobile-Phone Spectroscopy



Dilution Math

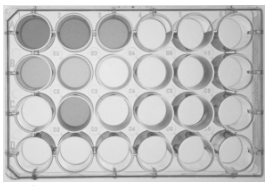
$$\frac{1.00\ \mu L}{mL} \times \frac{7.0\ mL}{10.0\ mL} = \frac{0.700\ \mu L}{mL}$$

Spectroscopic Analysis



Well A-1	Well A-2	Well A-3
1.0 μL/mL	0.70 μL/mL	0.49 μL/mL
Well B-1	**Well B-2**	**Well B-3**
0.34 μL/mL	0.24 μL/mL	*unknown*

Mobile-Phone Spectroscopy

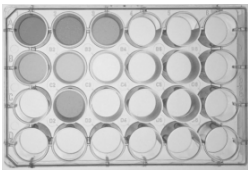


Dilution Math

$$\frac{20.0\ \text{drops}}{1.00\ \text{L}} \times \frac{1.00\ \text{L}}{1000\ \text{mL}} \times \frac{1000\ \text{millidrops}}{1.00\ \text{drop}} = \frac{20.0\ \text{mdrops}}{\text{mL}}$$

$$20.0\ {}^{\text{mdrops}}\!/_{\text{mL}} \times \frac{7.0\ \text{mL}}{10.0\ \text{mL}} = 14.0\ {}^{\text{mdrops}}\!/_{\text{mL}}$$

Spectroscopic Analysis



Well A-1	Well A-2	Well A-3
20.0 mdrops/mL	14.0 mdrops/mL	9.80 mdrops/mL
Well B-1	**Well B-2**	**Well B-3**
6.86 mdrops/mL	4.80 mdrops/mL	*unknown*

ImageJ

Procedure

1. Select the *Analyze* drop-down menu.
2. Select *Set Measurements…*
   - ✓ *check: mean value*
1. Select the oval shape in the shapes tool bar.
2. Select a representative part of the image in well A-1.
3. Use keyboard command, ⌘**M,** to analyze image and collect data.

ImageJ

Procedure (cont.)

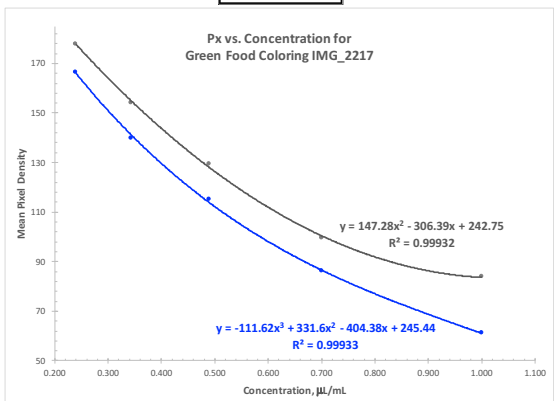
4. Move the oval shape to the next well and use keyboard command, ⌘**M**, to analyze image and collect data again. Repeat until all wells are analyzed.
5. Cut and paste the tabular data from the **Results** window into a graphing program for review.
6. Other color channels may be evaluated by selecting the *Analyze* drop-down menu and using the "histogram" command.

ImageJ

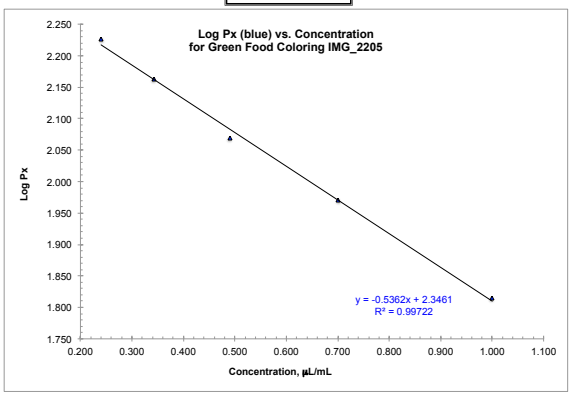
Procedure (cont.)

7. The histogram may be used to evaluate **RGB** and gray scale values. This data must be collected individually.
8. Plot P_x vs. Concentration. Also try to plot $1/P_x$ vs. Concentration or log P_x vs. Concentration. Determine the best fit calibration curve.
9. Determine unknown concentration using equations derived above.

ImageJ



ImageJ



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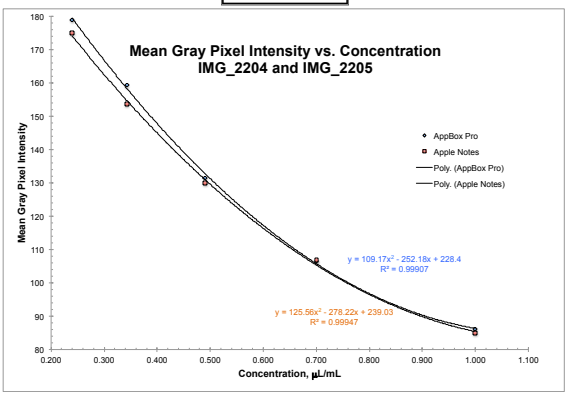


ImageJ

y = 147.28x2 - 306.39x + 242.75

y = 130.394

http://www.wolframalpha.com

~~**x = 1.61 µL/mL**~~

or

x = 0.48 µL/mL

Compare to: **0.49 µL/mL**

Mobile-Phone Spectroscopy

Procedure (Bubble Wrap)

1. Obtain a 15 ml plastic conical tube containing *12.0 ml "stock" solution.*
2. Place a small hole along the edge of 7 bubbles forming a "daisy" pattern.
3. Use a plastic pipet to *fill* the first bubble with ~3.5 mL stock solution. Dispose of 0.5 mL so that the conical tube contains 8.0 mL.

Mobile-Phone Spectroscopy

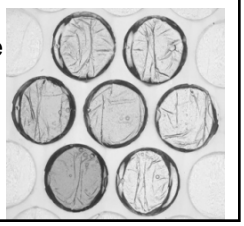
Procedure

4. Dilute the stock solution by adding 4.0 mL water to the conical tube giving 12.0 mL dilute solution.
5. Use a plastic pipette to *fill* a second bubble with solution (~3.5 mL). Dispose of ~0.5 mL solution so that 8.0 mL remains.
6. Continue with the serial dilution until 6 bubbles are filled.

Mobile-Phone Spectroscopy

Procedure

7. Add a water blank to the bubble daisy.
8. Use a plastic pipette to ***fill*** the center bubble of the daisy with unknown solution.
9. Photograph and analyze as before.



Conclusions

- A new colorimetric method incorporating bubble wrap as a storage medium was presented.
- Colorimetric results are readily obtained with mobile phone cameras.
- Free, open source software (***ImageJ***) allows for the easy preparation of standard curves.
- ***Wolfram Alpha*** readily solves polynomial functions that requiring evaluative cognitive reasoning skills for interpretation.

References

1. D. Kealey *Talanta,* **1972***, 19, 1563-1571.*
2. P. R. Teasdale, S. Hayward, and W. Davison *Anal. Chem.* **1999,** *71*, 2186-2191.
3. A. W. Martinez, S. T. Phillips, E. Carrilho, S. W. Thomas III, H. Sindi, and G. M. Whitesides *Anal. Chem.* **2008**, *80* (10), 3699–3707. DOI: 10.1021/ac800112r
4. A. W. Martinez, S. T. Phillips, and G. M. Whitesides *Anal. Chem.* **2010**, *82,* 3–10. DOI: 10.1021/ac9013989
5. D. K. Bwambok, D. C. Christodouleas, S. A. Morin, H. Lange, S. T. Phillips, and G. M. Whitesides *Anal. Chem.* **2014**, *86*, 7478−7485. DOI: 10.1021/ac501206m