What is in the Tang?
Liquid Spectroscopy Lab
Teacher's Notes
Mr. Barry, Chemistry

Student Objectives:

- Determine "λ max" (wavelength of maximum absorbance)
- Create a calibration curve using standard molar concentrations of Yellow #5 Dye
- Determine an unknown concentration of Yellow #5 Dye in Tang using a calibration curve

Prerequisite Knowledge:

Students should know the basics of quantum mechanics before attempting this lab: which includes, but is not limited to: the Bohr model of the atom, diagram of a wave, relationships between wavelength/frequency/energy of electromagnetic radiation, the electromagnetic spectrum, mathematical relationships in equation form, the nature of light, how to determine basic molar concentrations, molarity, general lab safety, lab write-up skills, Excel computer skills, and Algebra II skills with plugging in variables to an equation.

Context of Lab:

This lab can be done shortly after completing a High School chemistry chapter on Quantum Mechanics and the nature of light as it relates to electrons (see pre-requisite knowledge below). Another alternative could be to present the lab shortly after working with molar concentrations of solutions.

Introduction:

Tang has many different flavors and many different colors. Once mixed with sugar, it can provide a delicious treat. However, there is more going on with the color of Tang than meets the eye. Color can been seen with the human eye, but its intensity can also be detected. We have already learned that different colors emit different wavelengths. If one changes the wavelength, you change the color. Tang is emitting certain wavelengths and absorbing others, depending on the flavor and color. A spectrophotometer is an instrument that can be used to detect what wavelengths of light are being absorbed and what wavelengths are being emitted in a liquid solution.

In this lab students will determine what are the maximum wavelengths are being absorbed by a particular Tang solution. Students will also create a calibration curve using standard molar concentrations of Yellow #5. Finally, using the calibration curve, <u>you will determine the unknown molar concentration of the Yellow #5 in Tang</u>.

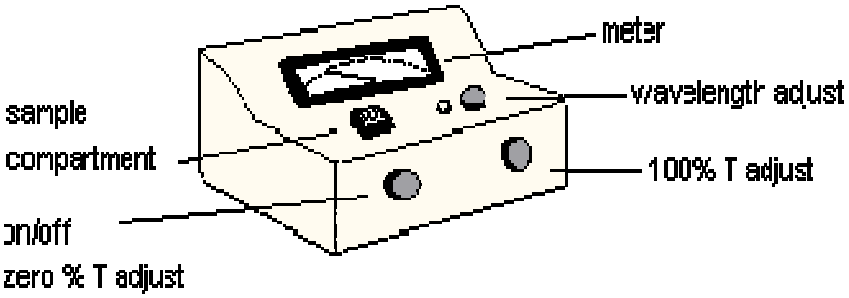
Background Section:

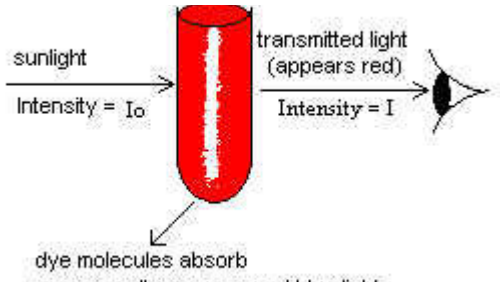
The purpose of this lab is to have students exposed to how the interaction of light with substances can help determine how light is absorbed and transmitted through solutions. In addition, according to Beer's Law, the concentration of a solution affects its absorbance. The greater the concentration of a solution the greater its absorbance of light. By using simple spectroscopic techniques, students can determine the maximum wavelength absorbed for a particular solution and relate the information to what was learned in the quantum mechanics section of the chemistry year. Students can also relate the molar concentrations to the absorbance of solutions.

Comparing an unknown concentration to standards is also a valuable skill, which ties in mathematical connections with chemistry. Students will be exposed to graphing on Excel and determining the linear regression of a line. Introduction to the Spectrophotometer 20 is also

beneficial given the general use of such equipment in general chemistry labs in college (although it might be a more modern version).

Theory:
We already know that when electrons receive energy they get excited and move up on energy levels. Once they relax, they fall back down to their ground state and emit energy. If light passes through a sample of Tang, the electrons will absorb some of this light energy. Therefore some of the light is not fully transmitted through the sample. A spectrophotometer is a device that records the light that is transmitted (passes through) after being absorbed by a solution. (see pictures below)





Pictures From: http://wwwchem.csustan.edu/CHEM1102H/koolaid.htm

The amount of light that is absorbed by the Tang is expressed in terms of the absorbance, A, where

$$A = \log I_o/I$$

$\mathbf{I_o}$ is the amount of light entering the sample and **I** is the amount of light that actually traveled through the sample. (**I** would be less than $\mathbf{I_o}$ because some of the light was most likely absorbed by Tang)

The absorbance of the sample can change for the various reasons:

- ***Wavelengths***-Depending upon the color of the Tang solution, the part of the visible spectrum that will absorb light will vary. We will determine what the maximum absorbance ("λ max") before starting our calibration curve.
- ***Solution thickness***-The longer the sample, the more the solution can absorb. To eliminate this variable, we will be using the sample size cuvettes (smaller test tubes) in the spectrophotometer.

- ***Concentration***-The absorbance will increase with increased concentration. In order to determine the molar concentration of the unknown sample, you will first determine the absorbance of three known sample concentrations.

Beer's Law

Typically, % transmittance is recorded by a spectrophotometer. Because of its linear relationship to the wavelength of a solution, absorbance is better suited. Therefore to convert % Transmittance to absorbance, one must use the formula,

$$\text{Absorbance} = 2 - \log(\%T)$$

Now that the absorbance of a particular solution is obtained, this value will be much more useful in calculations that follow below.

Since light is absorbed when it is shone through a sample, the amount of light energy absorbed depends on the wavelength of the given light. The wavelength that absorbs the most is often called "λ max". At this wavelength, the absorbance can be calculated using "Beer's Law", which states:

$$\mathbf{A=\varepsilon bc}$$

Where A is absorbance

ε is the molar absorbtivity with units of L mol^{-1} cm^{-1}

b is the path length of the sample - that is, the path length of the cuvette in which the sample is contained.

c is the concentration of the compound in solution, expressed in mol L^{-1}

Assessment:

The teacher can asses the students abilities in this lab in multiple ways:

- Students can complete the Pre-Lab Questions to asses previous knowledge and that the background of the lab was read.
- Students can complete a Pre-Lab before coming to lab, which can include a unique introduction, materials list, and a brief procedure. (see rubric for more specific ideas)
- The lab can be split up into two days to asses the maximum wavelength for the standard solution (**if Yellow Dye #5 is used, it is around 427 nm**) and determining the standard curve in Excel. Questions at the end of each section can be graded for understanding.
- Students completing the lab can be assessed informally for proper laboratory techniques.
- A complete written or typed lab write up can be collected from the students with proper work shown for any calculations. Data tables should also be included. A rubric is provided for the teacher and the student to clarify expectations.

Equipment/Materials:

- "Spectrophotometer 20"
- 2 small cuvettes per student
- Solutions

    - 3-4 Standard solutions of Yellow Dye #5 (Concentrations can be made at teacher's discretion)
    - 1 Tang solution of unknown molar concentration 40 (Concentrations can be made at teacher's discretion)
- Distilled water for the "blank"
- Goggles
- Distilled water wash bottle
- Kim wipes

Time Requirements:

It is recommended that this lab is completed in two days (40-60 minute periods). This amount of time will vary greatly depending upon how many "Spec 20's" are available and how many computers are available. (to complete their Excel graphs). The lab is conveniently set up in two parts so that the teacher can have the students complete each part on a separate day. If a 90 minute block period is available, the entire lab might be completed fully.

Safety, handling and Disposal:

All solutions that are made can be disposed of down the drain. Yellow Dye #5 can be an irritant if in contact with eyes. Some students might be allergic to artificial dyes if swallowed.

Procedural Tips and Suggestions:

Be sure Spec 20 is warmed up properly before its use. Be sure to have students use the same cuvette each time a sample is tested for the absorbance.

ADDITIONAL STUDENT HANDOUT IF NECESSARY:

Data for Part I:

Food Color analyzed: _____

Molar Concentration of Stock Solution Tested _____

Guess of what color it will absorb: _____

Guess of what color it will transmit: _____

Wavelength (nm)	***% Transmittance***	***Absorbance***
400		
420		
440		
460		
480		
500		
520		
540		
560		
580		
600		
620		
640		
660		
680		
700		
720		
740		
760		
780		
800		

"λ max" from graph _____

Data for Part II:

Maximum Absorbance ("λ max") from Part I:_____(nanometers)

Standard Sample	***Concentration of Yellow #5 (Molarity)***	***% Transmittance at λ Max***	***Absorbance at λ Max***
Standard 1			
Standard 2			
Standard 3			
Standard 4			

Standard Sample	***Concentration (Molarity)***	***% Transmittance at λ Max***	***Absorbance at λ Max***
Unknown	**(from graph)**		