

CBL Laboratory to Determine The Concentration of Yellow 5 in Yellow Food Color

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Revision 0

[NOTE! In this document I have included explanatory information in italic type. You should omit the italic text to produce a procedure for your students. If you find any mistakes in the procedure or calculations, please email me].

INTRODUCTION

To prepare commercial products, companies often buy a solid raw material, dilute it, package it, and sell it to the public. This is how food color solutions are prepared.

What compound is used is listed on the bottle. A common colorant used in yellow food colors (also called food dyes) is FD&C Yellow 5 which is also known as Tartrazine. The concentration may or may not be listed on the container. If you want to determine or verify the concentration, you must perform a quantitative analysis of the product.

Spectrophotometry [*for an explanation of spectrophotometry you can access standard analytical chemistry texts or go to <http://www.chem.ubc.ca/courseware/121/tutorials/exp3A/colorimetry> or <http://www.biology.ucsc.edu/classes/bio20L/content/basics/dyes.pdf> or <http://dl.clackamas.cc.or.us/ch105-05/colorime.htm>*] is a quantitative analytical technique based upon Beer's Law: $A=abC$, where A=absorbance, a=absorptivity, b=path length of the cuvette, and C=concentration. When the apparatus is designed to measure only electromagnetic radiation in the visible range, the apparatus is known as a colorimeter and the technique is called colorimetry.

There are several experimental designs that might be applied to this type of analysis. In this lab you will prepare a three point calibration curve (also known as a working curve), and using this curve, determine the concentration in grams/liter of the yellow food color.

OBJECTIVE

Using the analytical technique of colorimetry, the objective of the lab is to determine the concentration, in g/L, of Tartrazine in commercial food color. You will construct a calibration curve by making multiple dilutions of a working solution of known concentration provided by your teacher. [*Add exactly 2.00g of Tartrazine (Aldrich Product Number 20195-2, Aldrich's website is <http://www.sigmaaldrich.com>) to a 500mL volumetric flask (or 600mL beaker or Erlenmeyer flask) and then dilute to the 500mL mark with water. Pipet (or used a graduated cylinder) to transfer 25mL of this solution by pipet to a 500mL volumetric flask (or beaker or Erlenmeyer flask) and dilute to the 500mL mark with distilled water. This working solution is 0.2g/L. It should be noted that the Tartrazine obtained from Aldrich (or any other source) is not 100% pure. Information from the manufacturer described the Tartrazine used to develop this lab procedure to be 89% colorant. I do not know what technique was used to determine the % colorant. I have not used the purity in the calculations below. You should consider whether this factor should be included in the calculations. Modifying the equations to include the % purity might be an extension or extra credit problem for your students.]*

SAFETY

Wear goggles. It is advisable to wear latex gloves and a lab apron to protect your hands and clothes from stains.

MATERIALS

- Colorimeter
- Cuvette
- TI 83Plus calculator
- CBL
- 100mL graduated cylinder
- Wash bottle
- Pipet bulb
- 10mL serological pipet
- 1 dropper [or Beral pipet]
- Distilled water
- Working solution of FD&C Yellow 5
- Durkee yellow food color
- Five 16mmX150mm test tubes [You can use inexpensive and reusable plastic cups available at any grocery store if you do not have enough test tubes.]
- 1 #6 rubber stopper

[You can use yellow food color from other manufacturers if the Durkee product is not available in your area. Check the label to ensure that only the Yellow 5 was used. Alternatively, to save time and money, you can prepare a 4% solution from the Aldrich product and label it as yellow food color. Commercial yellow food colors are prepared at about 4% Tartrazine. Volumetric flasks would produce more accurate results but the graduated cylinder will suffice. Consider discussing the issue of which glassware would produce the most accurate and precise results.

[If you have other calculators or the CBL2 or LabPro, you will have to make some modifications in the procedure.]

PROCEDURE

[If you have the time, see if the students can devise their own experimental design. It is assumed that the students are already familiar with dilution and concentrations calculations.]

Part 1-Dilution of the Yellow Food Color

Read the procedure and then prepare a table to record your data.*[The table should have columns and rows for recording the absorbance of the three concentrations of the Tartrazine and the absorbance of the diluted yellow food color.]*

Your teacher will supply you with a test tube containing undiluted yellow food color. It is necessary to dilute the food color to obtain a solution that exhibits an absorbance within the working range of the colorimeter, that is, about 0.1-0.6 with a target about 0.1-.3. Using the apparatus available, it will be necessary to perform two consecutive dilutions.

1. For the first dilution of the food color, FC_{d1} , pipet exactly 1mL of the yellow food color into the 100mL graduated cylinder and then dilute to the 100mL mark with distilled water. Stopper the graduated cylinder and agitate the contents until the mixture is homogeneous. Transfer this solution to one of the clean and dry test tube and label the test tube FC_{d1} . The concentration of this solution is C_{FCd1} . Rinse the 100mL graduated cylinder with distilled water.
2. For the second dilution of the food color, FC_{d2} , pipet exactly 2mL of the FC_{d1} into the 100mL graduated cylinder and fill to the 100mL mark with distilled water. Stopper the graduated cylinder and agitate until the mixture is homogeneous. Transfer the solution to a clean and dry test tube and label the test tube FC_{d2} . The concentration of this solution is C_{FCd2} . Rinse the graduated cylinder with distilled water.

Part 2-Preparation of the Working Curve Solutions

You will prepare three “standards” by diluting a working solution of known concentration provided by your instructor. Since you know how the standards were prepared, you will be able to calculate the concentration of the standards. After measuring the absorbance of these standards, you will construct a “working curve”, that is, a graph of absorbance vs. concentration. Using the data and/or curve to determine the concentration of the yellow food color will be described in the “Calculations” section. Your teacher will supply you with a test tube containing 20mL of Tartrazine at a concentration of 0.20g/L [If you use volumetric flasks to prepare your working solution, your precision will be better than 2 significant figures] .

3. Transfer by pipet exactly 2mL of the working solution to the 100mL graduated cylinder and fill to the mark with distilled water. Stopper and agitate to produce a homogeneous solution. Transfer this solution to a test tube and label the test tube WS₁. The concentration of this solution is 0.0040g/L. The symbol for this concentration is C_{WS1}. [Consider having the students perform the concentration calculation instead of supplying them with the value]
4. Transfer by pipet exactly 4mL of the working solution to the 100mL graduated cylinder and fill to the mark with distilled water. Stopper and agitate to produce a homogeneous solution. Transfer this solution to a test tube and label the test tube WS₂. The concentration of this solution is 0.0080g/L. The symbol for this concentration is C_{WS2}.
5. Transfer by pipet exactly 6mL of the working solution to the 100mL graduated cylinder and fill to the mark with distilled water. Stopper and agitate to produce a homogeneous solution. Transfer this solution to a test tube and label the test tube WS₃. The concentration of this solution is 0.012g/L. The symbol for this concentration is C_{WS3}.

Part 3-Set Up of CBL

6. Plug the colorimeter into CH1 and connect the CBL to the calculator.
7. Turn on both the calculator and the CBL.
8. Press APPS on the calculator and start the ChemBio application.
9. Press ENTER when you see the “VERNIER SOFTWARE” screen.
10. Select #1, “SET UP PROBES”.
11. Type 1 for “ENTER NUMBER OF PROBES:” and then press ENTER.
12. Select #4 for the colorimeter sensor.
13. Type 1 for the “ENTER CHANNEL NUMBER:” and then press ENTER
14. Use the arrows on the colorimeter to select the 430nm wavelength and press ENTER on the calculator. [This set up assumes you have the second generation colorimeters. If you have the original colorimeters, you must modify the set up.]
15. Rinse the cuvette and fill $\frac{3}{4}$ full with distilled water. Insert cuvette into the colorimeter and press ENTER.
16. Press CAL on the colorimeter and wait for the red light to stop blinking. Press ENTER.
17. Select #2 for “COLLECT DATA”.
18. Select #1 for “MONITOR INPUT”. The absorbance of the water should be 0.000 or 0.001

Part 4-Absorbances of Working Curve and Diluted Food Color Samples

19. Empty the cuvette and using the dropper, rinse several times with WS₁. Fill the cuvette $\frac{3}{4}$ full with WS₁. Place the cuvette into the colorimeter and record the absorbance, A_{WS1}.
20. Empty the cuvette and using the dropper, rinse several times with WS₂. Fill the cuvette $\frac{3}{4}$ full with WS₂. Place the cuvette into the colorimeter and record the absorbance, A_{WS2}.

21. Empty the cuvette and using the dropper, rinse several times with WS₃. Fill the cuvette $\frac{3}{4}$ full with WS₃. Place the cuvette into the colorimeter and record the absorbance, A_{WS3}
22. Empty the cuvette and using the dropper, rinse several times with FC_{d2}. Fill the cuvette $\frac{3}{4}$ full with FC_{d2}. Place the cuvette into the colorimeter and record the absorbance, A_{FCd2}.
23. Press the “+” key on the calculator to stop the data collection and then select #7 to quit the program. Turn off the CBL and calculator.

CALCULATIONS

- [1 *Methods III below assumes that there is a linear relationship between absorbance and concentration. It should be noted that the TI83Plus has sophisticated statistical functionality that allows a student to obtain accurate results from non-linear data. Depending upon the time available and the interest or prior knowledge of your students, you might consider discussing how to investigate the linearity of data and how to address non-linear relationships.*
- 2 *There are several ways to determine the concentration of the “unknown”. You might construct a graph using a piece of graph paper (Method II), you might construct a graph on a calculator or computer (Method I), you might select the working curve concentration closest to the unknown (Method I), you can use a statistical method (Method III), or you can probably find several alternative approaches I have not mentioned. Select the one you think is best.]*

Method I-The Single Standard Method

In this method, it is assumed that if the standard solution and the unknown solution exhibit absorbances that are numerically close. You are to select the standard that exhibits an absorbance closest to the absorbance of FC_{d2}.

[If the “standard” solution and the “unknown” solution exhibit absorbances that are numerically close, it is possible to determine an accurate value for the concentration of the unknown even if the absorbance vs. concentration data is non-linear. Care must be taken in the decision as to the limits placed on what is considered “numerically close”]

1. If $A_1=abC_1$ and $A_2=abC_2$ and ab is constant, then $\frac{A_1}{C_1} = \frac{A_2}{C_2}$ rearranging $C_2 = A_2 \cdot \frac{C_1}{A_1}$

If A_{FCd2} is the absorbance of FC_{d2} and if it happens that WS₂ exhibits an absorbance, A_{WS2}, closest to A_{FCd2}, then the concentration of FC_{d2} is given by:

$$C_{FCd2} = A_{FCd2} \cdot \frac{C_{WS2}}{A_{WS2}}$$

- After calculating the concentration of the diluted food color, C_{FCd2} , it is necessary to determine the concentration of the undiluted food color, C_{FC} . This calculation can be done in either one or two steps. Presented below is the two step procedure.

However many steps you take, the calculation is based upon the concept that the number of grams of analyte before dilution is equal to the number of grams after dilution.

Step 1. First determine the concentration of FC_{d1} by using the value for the concentration of FC_{d2} found above.

$$C_{FCd1} \cdot \text{volume of } FC_{d1} = C_{FCd2} \cdot \text{volume of } FC_{d2}$$

$$\text{thus, } C_{FCd1} = \frac{C_{FCd2} \cdot \text{volume } FC_{d2}}{\text{volume } FC_{d1}}$$

Step 2. To determine the concentration of the yellow food color, C_{FC} , apply the same reasoning:

$$C_{FC} \cdot \text{volume of } FC = C_{FCd1} \cdot \text{volume of } FC_{d1}$$

$$\text{thus, } C_{FC} = \frac{C_{FCd1} \cdot \text{volume } FC_{d1}}{\text{volume } FC}$$

Method II-The Graphical Method

- Either on a piece of graph paper or a calculator or a computer, plot the concentration-absorbance data pairs, C_{WS1}, A_{WS1} ; C_{WS2}, A_{WS2} ; C_{WS3}, A_{WS3} , and draw a straight line through the points.
- Using the absorbance of the FC_{d2} solution, A_{FCd2} , draw a horizontal line from the y-axis (absorbance) to the straight line and then drop a perpendicular to the concentration axis. Read the concentration value at the point the perpendicular crosses the concentration axis. This is C_{FCd2} .
- To determine the concentration of the food color, C_{FC} , refer #2 under Method I above.

Method III-The Statistical Method

- Press the STAT key on the calculator and select EDIT. Key in the absorbance values in L1 and the concentration values in L2.
- Press the STAT key, cursor right to CALC, cursor down to LinReg and press ENTER twice.
- Press the Y= key and press CLEAR.
- Press the VARS key, cursor down to Statistics, press ENTER, cursor right to EQ and press ENTER.

5. Press TBLSET key (that is 2nd and then the WINDOW key), and then key in the absorbance of the FC_{d2} solution to the right of TblStart=.
6. Key in .001 to the right of ΔTbl=, and then press the TABLE (that is, 2nd GRAPH) key.
7. Cursor down until you find the absorbance in the “X” column and then record the concentration, C_{FCd2}, of the FC_{d2} solution in the Y₁ column.
9. To determine the concentration of the food color, C_{FC}, refer #2 under Method I above.

RESULTS and CONCLUSIONS

[Included below are some suggestions as to thought provoking items for discussion. You must decide which are appropriate for your students or you might devise your own questions.]

1. What is the concentration of the yellow food color?
2. How would you determine if your results are correct? *[Answers such as “compare results with other students” or “contact the food color company and ask” are possible answers.]*
3. Which calculation method yields the most accurate results? How do you know?
[Examples: The efficacy of Method III can be evaluated by reference to the R or R² values. The experimental values can be compared with the “true” values provided by the food color company.]
4. It was found that dilute solution of yellow food color faded when tap water was used for dilution rather than distilled water. Suggest an explanation for this phenomenon. *[The chlorine in the water is probably the cause but the salt content of tap water might be the cause.]*