At-Home Chemistry Experiment

Spectrophotometry Using *Gatorade*™

Objective

The objective of this at-home experiment is to observe the relationship between the absorbance and concentration of blue Gatorade powder using spectrophotometry. This relationship can then be used to estimate the sugar content in a liquid Gatorade drink.

Introduction

All molecules or ions absorb light. The quantity of light absorbed depends on both the wavelength of the incoming light and the concentration of the absorbing species.

In absorption spectrophotometry, light is directed through a sample and the fraction of light that passes through the sample is measured. Thus, the percent of transmittance, T, is

$$\mathrm{T} = \left(\frac{I}{I_0}\right) \cdot 100\% \tag{1}$$

where

T = transmittance (%)
I = intensity of light transmitted through the sample
I_0 = intensity of light transmitted through a blank (a reference solution)

The transmittance of a sample is related to its absorbance, A, as defined by

$$\mathrm{A} = \log\left(\frac{100}{\mathrm{T}}\right) \tag{2}$$

Absorbances are measured using a spectrophotometer. When solutions are dilute enough, there is a linear relationship between the absorbance and the concentration of the absorbing species as illustrated by the Beer-Lambert law (Beer's Law for short)

$$\mathrm{A} = \varepsilon bc \tag{3}$$

where

A = absorbance (unitless)
Ɛ = extinction coefficient or molar absorptivity ($M^{-1}\,cm^{-1}$)
b = pathlength or length of sample through which light travels
c = concentration (*M*)

In this at-home experiment, a powdered form of blue Gatorade will be used to prepare a stock solution. From the stock solution, dilute solutions will be prepared. The absorbances for each solution will be measured using a smartphone app as the spectrophotometer. The app has a RGB feature which provides a 'Red value', R, to represent the amount of light, reflecting off red construction paper, that passes through the Gatorade solutions. The amount of red light absorbed by the blue solution can be determined using

$$A = - \log \left(\frac{R}{R_o}\right) \quad (4)$$

where

A = absorbance (unitless)
R = red value from RGB reading; representing the intensity of red light transmitted through the blue solution
R_o = red value from RGB reading; representing the intensity of red light transmitted through only water (the 'blank')

A calibration curve of the absorbance vs the concentration of the blue Gatorade (from the powder form) will be prepared. The absorbance of the same flavoured, commercially prepared, bottled liquid drink (referred to as the Gatorade drink), will then be measured. Using the calibration curve, the concentration of the Gatorade drink will be determined. Based on the nutrition facts label on the can of Gatorade powder, the expected amount of sugar can be calculated. This value will be compared to the actual amount of sugar in the Gatorade drink.

Materials

- Water
- Blue Gatorade **powder** ('Frost Glacier Freeze flavour')
- Frost Glacier flavoured Gatorade **liquid** drink in a bottle
- Measuring cup (1 cup / 250 mL)
- Tablespoon (15 mL)
- Metal spoon
- Smartphone
- 2 Standard size (~10 oz) colorless drinking glass
- Stand for smartphone (can be a taller drinking glass, preferably colourless)
- 5 mL plastic syringe
- 10 mL plastic syringe
- Red construction paper

Procedure

<u>Part A – Preparation of the blue Gatorade stock solution</u>

1. In a glass container (such as a drinking glass), add 4 tablespoons of the blue Gatorade powder. The 4 tablespoons should be full and leveled with a knife (figure 1). If you have a kitchen scale, weigh out exactly 50 g of the powder rather than using the tablespoon measurements as this would be more accurate.

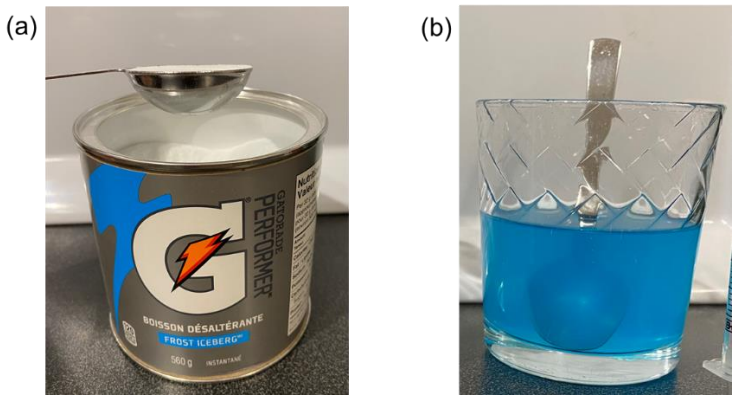

Figure 1: *(a) Tablespoon of powder should be full and leveled*
(b) Stock solution made from blue Gatorade powder

2. Add 1 cup of water (250 mL).

3. Stir the solution with a spoon until the powder is completely dissolved.

Part B – Obtaining the absorbance measurement for the blank

4. Place the standard size drinking glass that is colorless in the middle of the red construction paper. If red construction paper is unavailable, other red objects can be used (ex. a red shirt or cloth). Draw a circle around the glass, as well as a mark on the glass in line with a mark on the construction paper (figure 2). This will allow you to always put the glass in the same position in order to keep the pathlength of the red light readings consistent.

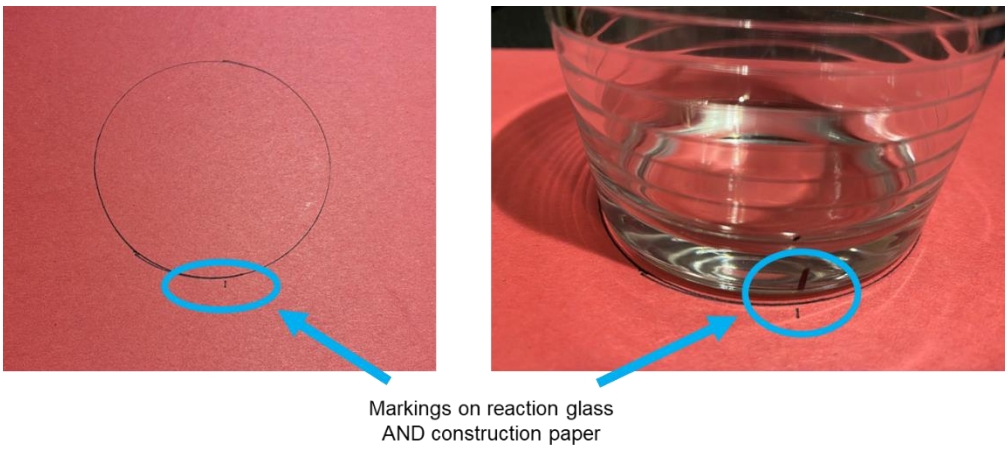

Figure 2*: Mark the construction paper as well as a glass, and trace out a circle on the red construction paper, to align the glass in the same position for each absorbance reading.*

5. Download the free app called '*Color Name*' onto your smartphone. Alternatively, you can use any other app that detects color and is able to give an RGB reading.

6. Set up your smartphone and a stand to hold your smartphone. The stand can be a taller drinking glass (figure 3). Make sure the bottom of the glass is centered in the camera view (figure 4).

***Figure 3**: Materials needed for the experiment.*

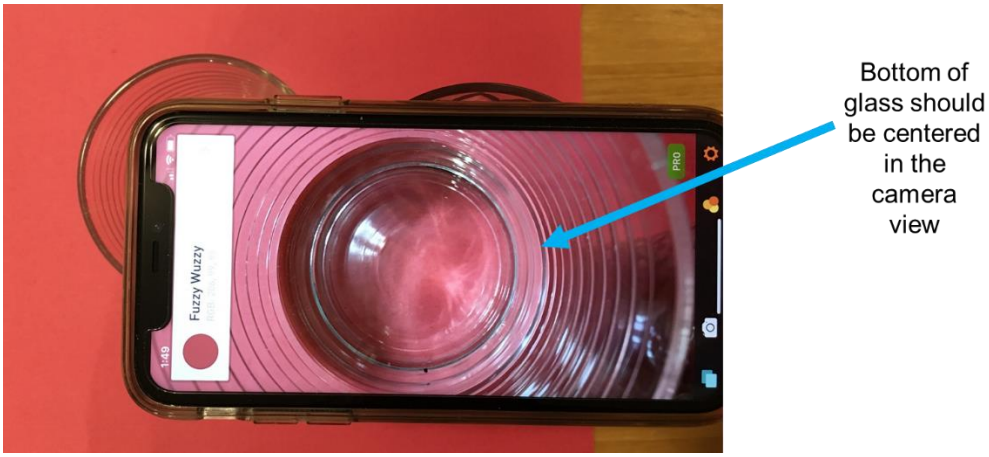

***Figure 4**: Positioning of the smartphone camera centered over the glass*

7. Take the glass off the red construction paper. Using the 10 mL plastic syringe, add 60 mL of water to the glass, ensure there are no air bubbles in the syringe. Make sure to remove any excess water hanging from the sides or end of the syringe by dragging the syringe along the edge of the glass. *Do not use the 5 mL plastic syringe as it will be used for the blue Gatorade stock solution*.

8. Make sure the outside of the glass is dry. Then line it up with the circle on the construction paper, with the marking on the glass in line with the marking on the construction paper. The glass should be centered in the camera view. If not, make adjustments by moving the smartphone and/or stand.

9. Ensure there are ***no shadows*** casted onto the glass during the entire time of the experiment, and the glass is not directly in any sunlight.

10. Open the '*Color Name'* app on your smartphone. Select 'Live view' and after a few seconds, tap the color identifier box (the white box), and record the first number of the RGB value in the data section. This corresponds to the initial Red value (R_o) which serves as the blank. It is the maximum amount of red light that is passing through the glass and water, and the smartphone camera is detecting it. See figures 5 and 6.

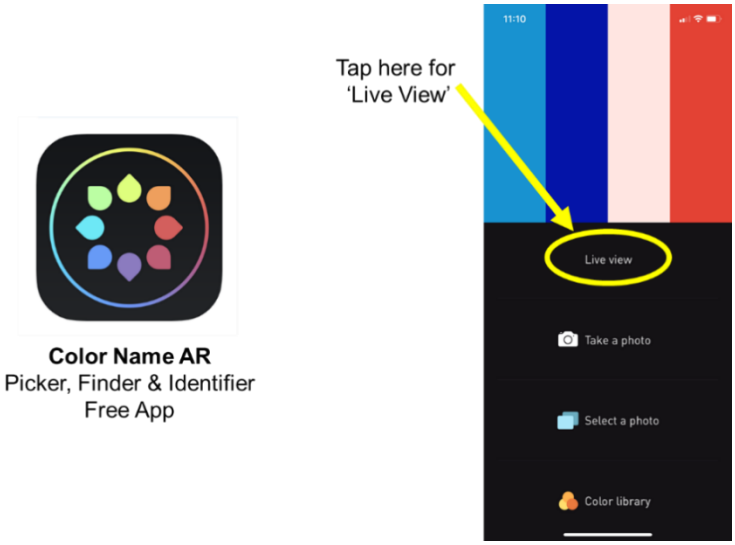

Figure 5*: Select the 'Live View' within the 'Color Name AR' app*

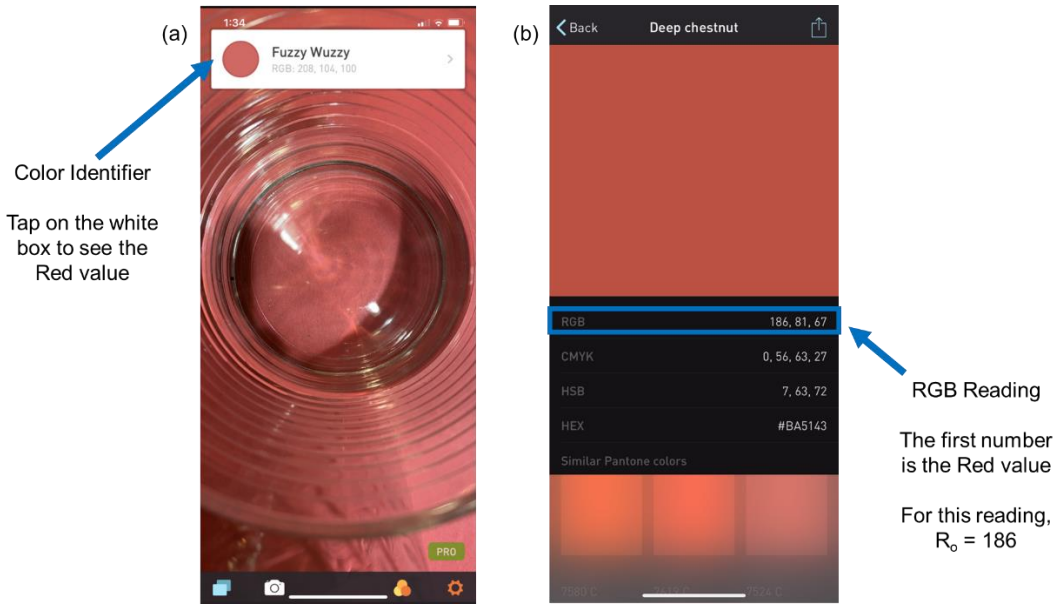

Figure 6*: The R values are obtained by (a) tapping on the color identifier box and (b) recording the first value from the RGB reading*

11. From this point on, ***do not*** move the smartphone, and do not cast any shadows onto the glass as you observe and record the data. (*Test your hand movements to be sure the smartphone does not move.)*

12. Go back to the live view on the app by tapping on 'back'.

13. Slide the glass away from the smartphone, pour the water out and dry the glass.

<u>Part C – Preparation and the absorbance of the diluted solutions of blue Gatorade</u>

14. Prepare the first dilution by adding 5 mL of the blue Gatorade stock solution directly into the glass using the 5 mL plastic syringe. Then add 55 mL of water using the 10 mL plastic syringe. From here on in, do not switch the syringes (figure 7). Make sure to remove any excess liquid hanging from the sides or end of the syringe by dragging the syringe along the edge of the glass.

Figure 7*: The 10 mL plastic syringe will be used to measure the water and the 5 mL plastic syringe will be used to measure the stock solution of Gatorade*

15. Slide the glass back into the circle, lining up the marking on the glass with the marking on the construction paper. Tap the color identifier box and record the red value on your data sheet in Table A as dilution 1. Then return back to the live view.

16. Empty out the contents in the glass, rinse the glass with water, and then dry it.

17. Repeat steps 14-16 for the remaining 5 dilutions (2 to 6) using the volumes of Gatorade stock solution and water as shown in Table 1. The total volume should always be 60 mL.

Dilution	Volume of blue Gatorade stock solution (mL)	Volume of water (mL)
Blank	0	60
1	5	55
2	10	50
3	15	45
4	20	40
5	25	35
6	30	30

Table 1*: Volume of blue Gatorade stock solution and water required for each dilution*

Part D – Absorbance of the Gatorade drink

18. To the clean and dried glass, add 60 mL (4 tablespoons) of the bottled blue liquid Gatorade drink.

19. Slide the glass back into the circle, lining up the marking on the glass with the marking on the construction paper. Tap the color identifier box and record the red value on your data sheet in Table B.

20. Take a picture of your experimental set up and include it in your lab report.

Calculations and Data Analysis

1. Calculate the concentration of the blue Gatorade stock solution in grams per mL (g/mL) using equation 4. If you did not use a kitchen scale to weigh out the powder, assume 4 tablespoons is equivalent to 50 g.

$$C = \frac{Mass\ of\ blue\ Gatorade\ powder\ (g)}{Volume\ of\ water\ (mL)} \quad (5)$$

2. Calculate the concentration of the blue Gatorade for each dilution (g/mL). Fill in Table A in the data section.

$$C_1V_1 = C_2V_2 \quad (6)$$

3. Calculate the absorbance of red light for each dilution using equation 4. Fill in Table A in the data section.

4. Prepare a calibration curve of A (absorbance) vs C (concentration, g/mL) and add a linear trendline. Include the graph in your lab report. Be sure to provide an appropriate title and include labels for the axes.

5. Using the equation of the line and the absorbance of the bottled blue liquid Gatorade drink, determine the concentration of the Gatorade (C_{bottle}).

6. Determine the amount of sugar that is expected in the bottled Gatorade drink.

    a. Based on the concentration of the Gatorade drink (C_{bottle}) and the volume of the bottled Gatorade drink (V_{bottle}), calculate how much Gatorade powder is in the bottled drink (m_{powder}).

$$C_{bottle} = \frac{m_{powder}\ (g)}{V_{bottle}\ (mL)} \quad (7)$$

b. Using the nutrition facts label on the can of blue Gatorade powder, calculate the amount of sugar expected in the bottled drink. For example, in 32 g of the Gatorade powder, there is 29 g of sugar.

7. Compare the expected amount of sugar with the actual amount of sugar in the bottled drink by calculating the percent difference. The actual amount of sugar is indicated on the nutrition facts label on the bottle.

$$\% \text{ Difference} = \left(\frac{|\, expected\ amount\ of\ sugar - actual\ amount\ of\ sugar \,|}{expected\ amount\ of\ sugar} \right) * 100\% \qquad (8)$$

8. Fill in Table B in the data section.

Name _____ Section _____

Date _____

Spectrophotometry Using Gatorade™

Data

Mass of blue Gatorade powder (g) _____

Concentration of blue Gatorade stock solution (g/mL) _____

Red value of the blank, Ro _____

Table A – Data for the calibration curve

Sample	Red Value (R)	Absorbance (A)	Volume of blue Gatorade stock solution (mL)	Volume of water (mL)	Concentration of the blue Gatorade (g/mL)
Dilution 1					
Dilution 2					
Dilution 3					
Dilution 4					
Dilution 5					
Dilution 6					

Sample Calculations

For one of the dilution solutions, show a sample calculation for the absorbance and concentration of the blue Gatorade.

Table B – Summary of the data

Red value of the bottled blue Gatorade liquid drink, R	
Absorbance of the bottled blue Gatorade liquid drink, A	
Concentration of Gatorade in the bottled drink, C_{bottle} (g/mL)	
Volume of Gatorade in the bottled drink, V_{bottle} (mL)	
Mass of Gatorade powder in the bottle, m_{powder} (g)	
Ratio of sugar (g) to mass of Gatorade powder (g) as specified on the nutrition facts label (mass of sugar (g) / mass of Gatorade powder (g))	/
Expected amount of sugar in the bottled blue Gatorade liquid drink (g)	
Actual amount of sugar in the bottled blue Gatorade liquid drink (g)	
% Difference	

Sample Calculations

Show your calculations for the following:

(a) Concentration of the Gatorade in the bottled drink using the equation of the line from the calibration curve.
(b) Mass of Gatorade powder in the bottle
(c) Expected amount of sugar in the bottled blue liquid Gatorade drink
(d) % Difference

References

Department of Chemistry. (2019, Fall). 'Spectrophotometry', *Chemistry of Solutions 202-NYB-05 Laboratory Experiments*. Montreal, QC: Dawson College.

Kuntzleman, Thomas S., and Erik C. Jacobson. "Teaching Beer's Law and Absorption Spectrophotometry with a Smart Phone: A Substantially Simplified Protocol." *Journal of Chemical Education*, vol. 93, no. 7, 2016, pp. 1249–1252., doi:10.1021/acs.jchemed.5b00844.

Kuntzleman, Tom. "Chemical Kinetics with a Smartphone." *Chemical Education Xchange*, 27 Nov. 2019, www.chemedx.org/blog/chemical-kinetics-smartphone.

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Gatorade Jello Squares (Optional)

Gatorade Jello Squares are the perfect half-time or end-of-game treat! Use any flavour or mix and match, and create your own favorite flavour!

Ingredients:

- 2 1/2 cups Gatorade (any flavour)
- 4 (3 oz) pkgs Jello (any flavour)

Instructions

1. Heat Gatorade to just boiling in a medium pot.
2. Remove from heat.
3. Stir in Jello packages, and continue stirring for 3 minutes. Pour mixture into a 9×13 rectangular baking dish.
4. Chill for at least 3 hours.
5. Cut into squares and remove from pan using a spatula.
6. You can also place dish in warm water to help release the Jello from pan.

Notes:

Store airtight in refrigerator for up to a week.
Recipe lightly adapted from Jello

Reference: Cups, Author: Cookies &, and Cookies & Cups. “Gatorade Jello Squares: Easy No Bake Dessert/Snack.” *Cookies and Cups*, 4 June 2020, https://cookiesandcups.com/gatorade-jello-squares/.