Unit 1: Optics – Spectrophotometry
Project 5

Save Yourself From a Sunburn: A scientific Way to Determine the Most Effective Suntan Lotion

Do you want to know whether the suntan lotion you are using to protect you from sunburns is the most effective in blocking the sun radiation that causes them? Do you want to know if you are using the right protection factor? Follow this experiment and see how an effective sunscreen (one that completely blocked the radiation in the vicinity of the wavelength that causes sunburns) can be identified spectrophotometrically. Despite the fact that the term might sound complex, for the purpose of this experiment the process you will follow is very simple. Spectrophotometry involves the photometric (the measurement of the interaction of radiant energy with matter) comparison between parts of the spectra (ultraviolet and visible). The experiment is separated in two parts. The first part aims to familiarize you with the operation of the Spectrometer. The second part describes a simple method you can follow in order to identify the suntan lotion that will better protect you from getting sunburned.

Degree of Difficulty

Experimental: Moderate
Conceptual: Moderate to Difficult

Objectives

Completion of the activities should enable you:

- to understand the function of the spectrometer 20D.
- to set the spectrometer to a specific wavelength.
- to determine the most effective suntan lotion through spectrophotometric analysis.

Materials for Part A: Spectrophotometer 20D, 2 cuvettes, Chalk, Water, Kimwipes. The Educational Absorption Spectra Kit is available from: Milton Roy Company, 820 Linden Avenue, Rochester, NY 14625, Phone: 800-654-9955 (Catalog # 333135, List Price: $62.00)

Materials for Part B: "PABA free" suntan lotions (they can be dissolved with *n*-propanol), cuvettes, spectrophotometer, *n*-propanol, waterproof and not waterproof lotions, deionized water.

.

Part A: Procedure

The digital spectrometer 20D

1. Turn on the Spectrometer (turn the left front knob clockwise).

2. Turn the large knob (wavelength control knob) on the top slowly. What do you observe on the display? What does the number represent?

3. Adjust the wavelength to 450 nm (nm corresponds to *nanometers, which is* wavelength's unit of measurement – 1 nanometer = 1 x 10^{-9} meters). Place a cuvette with white chalk (or a white piece of plastic/rubber) into the *sample compartment* (if you have difficulty finding it, ask your teacher or use the manual). Look into the sample compartment and describe what you see. What do you observe as you increase the wavelength? How about when you decrease the wavelength?

4. Without removing the chalk, slowly turn the front right knob (Transmittance control knob) both towards right and towards left. What do you observe?

5. Set the wavelength to the lowest possible setting without removing the chalk in your cuvette. Increase the wavelength until you see light appearing on the chalk. This is the *lowest visible wavelength.* What light's wavelength is immediately beneath the lowest visible wave length?

6. Remove the chalk cuvette and close the lid on the sample compartment. Turn the left front knob (Zero control knob) until the data value is 0.0. (The minus sign may flash on and off this is normal.)

7. Pour deionized water in a cuvette with to within 2 cm of the top (the water is called a *blank* because it does not have anything dissolved in it). Make sure that the bottom of the cuvette is clean. Why is it important to keep the cuvette clean? [The manufacturer, Milton Roy, suggests to handle cuvettes by touching them near the top by the mark – this mark should line up with the raised ridge on the front of the sample compartment, (Harris, 1993)]. Insert the blank (cuvette with deionized water) into the *sample compartment.* Make sure that the lid is closed.

8. Adjust the transmittance control until the right number reads 100.00. Press the mode button once. The data should read 0.00 (the spectrophotometer should now be set on absorbance). Remove your cuvette and set the mode to transmittance. Set the wavelength to 450 nm. Insert a blank and set transmittance to 100%. Adjust the wavelength to 550 nm. What has happened to the percent transmittance? [According to the manufacturer, Milton Roy, because the instrument is not equally sensitive to all wavelengths, it must be adjusted *every time you change wavelengths* – The transmittance control should be adjusted so that the instrument reads 100.00 transmittance or 0.00 absorbance when a blank is placed in the sample holder, (Harris, 1993)].

Note: *The structure and procedure of introducing the Spectrophotometer 20D was based upon the description that was provided by the manufacturer's manual (Harris, 1993).*

Activities

1. Repeat steps 1 to 5. Looking at the chalk, determine the range of wavelengths for each color of light and record your data in the following table:

Table 1

Color of Light	Wavelength-Lowest Value	Wavelength-Highest Value
Red		
Orange		
Yellow		
Green		
Blue		
Indigo		
Violet		

Using your data, describe the relationship between color and wavelength. Have you seen colors appear in this order before?

2. In addition to the markings, is there anything that has to be more carefully made on a cuvette than on test tubes? Explain.

3. Design and perform experiments to answer the following questions. Your experiment's lab report must include: Title, Purpose, Equipment, Procedure and Data Collection, Data Analysis, Results and Conclusion. The Data Collection is the most critical part of a laboratory experiment. You must follow a *systematic research method* to secure valid answers to your questions. In a systematic research method you define, (a) your independent variable (the variable that is controlled by the researcher and is being changed, increased or decreased, in order to measure any changes regarding the variable we are interested in – It is suggested to change the independent variable by equal increments), (b) your dependent variable (the variable that is under investigation and depends upon the changes of the independent variable), (c) control variables (other variables that you assume that their presence might affect your experiment and therefore, you keep them constant throughout the whole experiment).

   - Do different solutions absorb light of different colors or wavelengths?
   - Does the wavelength of light that a solution absorbs best depend on the color of the solution?
   - Does the amount of light absorbed depend on concentration?
   - What would be an approximation for the wavelength of the infrared or ultraviolet light? Is it possible to approximate wavelengths smaller than the

wavelength of the ultraviolet light or bigger than the wavelength of the infrared light?

- What is the wavelength of maximum absorbance of a colored solution? (Help: Start with 350 nm. Set to 0% transmittance, place the blank into the *sample compartment* and set to zero absorbance. Remove the blank and place the colored solution into the unit. Record the absorbance in a table. Repeat the same process in increments of 25nm. Locate the 50nm region in which the absorbance is highest and repeat the process in increments of 10nm. By plotting absorbance versus wavelength, it will be easier for you to find the maximum absorbance – it's the point where your graph peaks. If you do not have a graphing program, such as, Cricket Graph, use Microsoft Excel.)

Part B: Procedure

Sunburn is caused most severely within the range of 285-315 nm. An effective sunscreen would be one that completely blocked the radiation of these wavelengths (Harris, 1993). In order to be effective, active ingredients of the suntan lotion must exhibit an intense absorption maximum centered around 300 nm while transmitting the longer wavelength tanning radiation (It could also block the tanning wavelengths. There's no requirement that you end up tanned).

Your experience with the spectrophotometer from Part A, can be used to find the absorbance of sun lotions at various wavelengths. Despite the fact that absorption below 320 nm can not be obtained by using spectrophotometer 20D, general trends in absorption can be observed graphically and decisions can be made about the lotions' effectiveness (Harris, 1993).

Determining effective sunscreen

1. Prepare a solution of the suntan lotion. To make the solution, n-propanol must be used as a solvent. Pour some suntan lotion in a test tube with n-propanol and shake gently (Precision isn't important, but it shouldn't be too dilute for the 20D to detect it, or so concentrated that there's no transmission). After the solution is ready pour 5mL in a cuvette.

2. Turn on the spectrophotometer. The manufacturer suggests allowing 15 minutes before use for warming up. Using n-propanol as a blank, set the wavelength to 420 nm and zero the instrument.

3. Replace the blank with the cuvette containing the sample and record the absorbance.

4. Continue to take readings at 10 nm intervals to the lowest wavelength your spectrophotometer is giving you. Remember to zero the instrument using the blank at every wavelength. Record your data in the following table:

Table 2

Wavelength (nm)	Absorbance
420	
410	
400	
390	
380	
370	
360	
…	

5. Use the data you collected in step 4 and graph absorbance versus wavelength.

Activities

1. "Despite the fact that absorption below 320 nm can not be obtained by using spectrophotometer 20D, general trends in absorption can be observed graphically and decisions can be made about the lotions' effectiveness." Explain why this is a good assumption. I.e., why it's not likely that the sunscreen you buy isn't a notch filter that blocks only the burning wavelengths?

2. Repeat steps 1 to 5 for different brands of suntan lotion. Use as many as possible.

3. Why did we use n-propanol for blank and not water?

4. Repeat steps 1 to 5 for different brands of non-waterproof suntan lotions. What solvent shall we use in this case?

5. Explain why was it necessary to scan the blank solution at step 2? If we skip this step how would our experiment be affected?

6. Design and perform experiments to answer the following questions. Your experiment's lab report must include: Title, Purpose, Equipment, Procedure and Data Collection, Data Analysis, Results and Conclusion. The Data Collection is the most critical part of a laboratory experiment. You must follow a *systematic research method* to secure valid answers to your questions.

    - Do the suntan lotions of a particular brand, but of different protection factor, have the same sunscreen effectiveness? Check various brands (at least five).
    - Do suntan lotions of different brands, but of the same protection factor, have the same sunscreen effectiveness? Compare all possible combinations (i.e. compare all the brands you have with protection factor 10 and then compare all the brands you have with protection factor 20, 30 etc.)

Final Project/Report

Your have been asked by the Consumer's Union to compare 5-10 different brands of suntan lotions and report which of them are the most effective for each particular protection factor and at the most affordable price. You have the freedom to make your own suntan lotion selections. Remember to summarize all the experiments and the activities you have performed in this project. Have in mind the report must be descriptive and understandable by people that have never done this experiment. Use of tables, diagrams or pictures is strongly suggested. The first part of your project report must summarize how suntan lotions are made, which are the active ingredients of the suntan lotion that exhibit an intense absorption maximum centered around 300nm, how do we obtain different protection factors, and why do we need different protection factors.

Reference

Harris, E. and Anderson, M. (1993). *Spectrometry Made Simple.* Miltor Roy