Goal- The goal of the inquiry part of the lab is to find out who killed Toby Flenderson using spectroscopy and dilutions of a Gatorade solution.

Role- The role of the students is to help the company find out who killed their human resources employee.

Audience- The audience of the task is the jury, judge, and attorneys dealing with the murder case.

Product- The product of the task is a combination between a lab report and a presentation to the “jury, judge, and attorneys.”

Expectations- The expectations are explained clearly in the rubric at the end of the assignment. The students are familiar with the lab report sections, as this is the same rubric used for all lab reports.

Lab – Relationship between Solution Concentration and Transmitted Light

Purpose: To use spectroscopy and graphical analysis to determine the concentration of a colored beverage and hence solve a crime.

Pre-Lab Questions:

The visible absorption for the dyes Red 40, Blue 1 and Crystal Violet are show in the figure 1 below. The concentration of the blue dye was 6.0 µM (6.0 x 10^(-6) M)

1. What is the optimum wavelength for measuring the absorbance versus the concentration of the Blue 1 dye solution? Explain your answer. (This value will be used in the introductory activity)
2. What is the optimum wavelength for the red dye? (This value will be used in the grape soda lab).
3. In order to construct a calibration curve for the Beer’s Law lab, a series of known concentration solutions is prepared. Using the concentration of the Blue 1 stock solution, calculate the concentration of the following dilutions: (Recall: M_1V_1 = M_2V_2)

<table>
<thead>
<tr>
<th>Concentration (µM)</th>
<th>Dye Stock Solution (A)</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.0 µM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water (mL)</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>Stock (mL)</td>
<td>10</td>
<td>8</td>
<td>6</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

4. The Beer-Lambert Law is used to relate the concentration of a colored solution to the amount of visible light the solution will absorb. The amount of absorbance can be calculated using the formula: A = abc
A = absorbance; a = molar absorptivity (a constant for the material been tested); b = path length (length of the cuvette holding the sample); and c = concentration
For each solution A – H, predict the absorbance if Blue 1 has a molar absorptivity of 130,000 M⁻¹cm⁻¹ and the path length (b) is 1 cm.

Part 1 – Introductory Activity – Introduction to Colorimetry – Analysis of a Blue Solution

Objective: To predict the concentration of Blue 1 food coloring solution in a diluted solution.

Materials:
- Blue Solution (Add 10 drops blue food coloring diluted to 1.00 Liter in a 1 L volumetric flask)
- Standard Solutions (25.0%, 35.0%, 50.0%, 75.0%, 95.0%) Prepared with 10 mL serological buret.
- Colorimeter or Spectronic 20
- Unknown solution (want unknown concentration to be between 25.0 – 100.0%)

Safety:
Wear goggles and laboratory aprons. Students should wash hands after completing lab. Dispose of materials in the sink.

Creating the Calibration Curve:
1. Turn on the spectrophotometer and to warm up 15-20 minutes. Set the wavelength to the red wavelength (Q 1 in prelab). Set up the colorimeter at the closest settings.
2. Blank the spectrophotometer/colorimeter with distilled or deionized water in a sample cell. Be sure to clean the outside walls of the cuvette with Kimwipes. Fingers leave oily residues that interfere with light transmittance.
3. Collect absorbance readings for each of the known diluted solutions and create a calibration curve.
4. Labquest 2 and graphing calculator connected to colorimeter will automatically record the absorbance.

<table>
<thead>
<tr>
<th>Concentration</th>
<th>% T</th>
<th>Transmittance (T)</th>
<th>Absorbance (-log T)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25.0</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>35.0</td>
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<td>50.0</td>
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<td>75.0</td>
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<tr>
<td>95.0</td>
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</table>

Concentration of the diluted solution:
Measure the absorbance of your unknown solution. Use your calibration curve to determine the concentration of your unknown. The best fit line of the linear graph should be used to calculate the concentration (it will have a positive slope and go through zero). y = mx + b so A = m(concentration) + 0. See the graphing calculator handout for directions.

Part 2: Who killed Toby Flenderson?

Background to the Murder:
An Atlanta-based company, Dundar-Mifflin, has contacted the Westlake AP Chemistry class to elicit their help in solving a terrible crime against one of their valued employees, Mr. Toby Flenderson. Toby is their human resources representative at one of their branches in Scranton, Ohio. At 3:00 pm on Friday, he was found dead in his office. The time of death is difficult to pinpoint because the office air-conditioning unit was turned up to high presumably by the murderer, to confuse the time of death. The body was found at 4:00 pm and the coroner has said that Mr. Flenderson was dead for at least three hours prior to this time thus narrowing the time of the murder to between 9:00 am and 2:00 pm. Closer analysis of the crime scene revealed a piece of evidence that could narrow down the time of death and determine which of the five identified suspects might have committed the murder. Mr. Flenderson had been drinking from a glass of Gatorade on his desk. Turning up the air temperature created condensation from an overhead duct so water dripped slowly into the glass at a rate of 1.0 mL every 6 minutes. When the glass was found at 3:00pm, it had 100 mL of diluted Gatorade. If you can determine the dilution of the Gatorade, then we can determine the time of the murder and narrow down our suspect list. Good luck!

Your Goal:
AP Chemistry Performance Task

Your help is needed in determining the dilution of the Gatorade, so the murderer can be apprehended. As the Gatorade was diluted, the color of the solution changed and color is determined by the wavelength of light. You can pinpoint the murderer by measuring the wavelength absorbance of various standard dilutions and comparing them to the wavelength absorbance of the Gatorade found at the crime scene. Once you have this information, you will present a case to a jury for conviction of your supposed suspect. A successful case will include: an opening statement, data necessary to show evidence beyond reasonable doubt (including charts and/or graphs), a closing statement, and a well-written lab report to submit to the judge, jury, and attorneys.

List of Suspects:
1. **Creed Bratton**: With a notorious history of frequent incarceration and drug abuse, it seems that it wouldn't take any personal motive to send Creed over the edge. Meredith has reportedly heard Creed muttering throughout the office about “Taking out the system.” It’s also common knowledge in the office that Toby disapproves of Creed’s inappropriate references to marijuana and heroine. Creed was the last seen with Toby, at a 8:00 am meeting concerning what exactly Creed’s job in the office is. Creed has no alibi from 9:00-10:00 am.

2. **Michael Scott**: With an honest disdain for Toby, Michael Scott is an obvious suspect. He’s also gone on record, actually admitting he would kill Toby, saying “If I had a gun with two bullets and I was in a room with Hitler, Bin Laden, and Toby, I would shoot Toby twice.” As the boss of the office, Michael does see opposition and challenge in Toby, but employees say it’s really more of an innocent rivalry. He had an argument with Toby on Thursday regarding an inappropriate email he had sent to the staff from Toby’s computer. Michael has no alibi from 12:00 pm to 1:00 pm.

3. **Dwight Schrute**: As an underling to Michael Scott, Dwight is affectionately in service to Michael’s many whims and demands. He is ambitious, and undertaking the murder of Toby Fleming for Michael Scott would mean a huge promotion for Dwight. Dwight is also very comfortable with murder. He killed Angela’s cat, and has made many a threat to the men of the office. He was not seen in the office for the entire day of Toby’s murder, but other workers say he is a skilled camouflager, and that this is common. He does not have an alibi for the timeframe 11:00 am – 12:00 pm.

4. **Jim Halpert**: Jim is considered an easygoing guy and, thus, an unlikely suspect. Everyone in the office, though, knows of his secret romance with Pam Beesly, the receptionist. For quite some time, the secret was well kept by the staff of the office. Unfortunately for Jim and Pam, an anonymous email was sent to Toby, head of human resources, detailing the relationship between co-workers. Toby was in the process of an office investigation of their relationship. Jim arrived at work late that day and has no alibi from 10:00 – 11:00 am.

5. **Meredith Palmer**: In regards to Toby, Meredith is somewhat of a jilted lover. For weeks before the murder, Meredith has been making crude remarks to Toby. As the head of human resources and also an uncomfortable target of her overbearing affections, Toby threatened to contact the division head if she persisted. Meredith has sulked around the office and kept to her desk, but prior to Toby’s death, she was seen sprinkling his sandwich in the break room with an unknown substance. Meredith has no alibi between the times of 1:00 pm and 2:00 pm.

Chemistry Background:

The proportion of light absorbed by a colored solution depends on how many molecules it interacts with. Suppose you have a concentrated solution of a colored dye then it will have a very high absorbance because there are lots of molecules to interact with the light. However, in a very dilute solution, it is difficult to see that it is colored at all and so the absorbance is going to be very low. The **path length** that the light travels through also affects the absorbance. Suppose you have a very dilute solution of dye in a 1 cm cube-shaped container - the absorbance will not be very high. However, if you pass the light through the same concentration of solution in a 100 cm tube, more light would be absorbed because it interacts with more molecules. This relationship between absorbance, concentration and path length is summarized in the Beer-Lambert Law: A = abc (See prelab Q 4)

Purple Gatorade absorbs in the red region, so refer to the graph in the prelab Q2 to determine the optimum absorption.

Guided Inquiry Procedure:

- Your materials include the following:
  - Gatorade found at the crime scene (unknown concentration)
  - Unopened sample of the Gatorade (considered a 100% solution)

- Prepare 5 standard solutions. Decide on an appropriate range of concentrations. Get teacher approval before you start.
- Make standard solutions in a test tube. (Ex. 8 mL of 100% Gatorade to 2 mL of water makes 80% standard solution.)

Using the Spectrophotometer:

- Set the wavelength to optimum wavelength.
- Using the zero adjust knob set the zero transmittance (nothing should be in the sample compartment).
Fill one cuvette with distilled water and insert it in the sample compartment. Close the top.
Use the 100% adjust knob to set the 100% transmittance with the water-containing cuvette in the holder. Remove the cuvette and set it aside without emptying it.
Fill the other cuvettes (5 known samples) with your standardized solutions and the evidence solution.
Insert the cuvettes in the instrument and close the cover. Read the absorbance of each sample.
Graph your standard solutions (concentration vs. absorbance) and determine the concentration of the evidence solution.
Perform a regression analysis to determine the line of best fit and use this to calculate the unknown concentration.

Using the colorimeter
Refer to separate handout for the use of the colorimeter.

Lab Report:
Your lab report should follow the AP Chemistry lab rubric
- Since this is guided inquiry, you are developing your own procedure, data table and graph.
- Calculations should include determining concentrations of sample solutions and calculating the time of death

AP Review Questions
1. Who killed Toby Flenderson? Explain your conclusion.
2. Calculate the value of % T for an absorbance value A = 0.80.
3. The student handles the cuvette and leaves fingerprints in the path of the light beam. How will this affect the calculated concentration of the unknown? Explain your answer.
4. Transition metals form a wide selection of colored compounds. The complex ion tetraamminecopper (II) contains four ammonia molecules covalently bonded to a copper (II) ion. In aqueous solutions, Cu²⁺ ions will bond to four water molecules. The solution is light blue in color. The water molecules can be displaced by ammonia molecules, which form more stable complex bases than water. The appearance of the intense dark blue-violet color of the [Cu(NH₃)₄]²⁺ ion is often used as a positive test to verify the presence of Cu²⁺ ions.
   a. Write a balanced chemical equation for the reaction of copper (II) sulfate and concentrated ammonia to produce a tetraamminecopper (II) sulfate.
   b. [Cu(NH₃)₄]²⁺ solutions exhibit a deep blue-violet color. How can you use spectrophotometry to confirm that this reaction has occurred and that the product formed is tetraamminecopper (II) sulfate? Would you expect the wavelength of maximum absorbance for [Cu(NH₃)₄]²⁺ to be greater than or less than the wavelength of maximum absorbance for Cu(H₂O)₆²⁺? Explain

Case/Lab Report Rubric

<table>
<thead>
<tr>
<th>Case Presentation</th>
<th>Below Expectations 2 to 3 points</th>
<th>Meets or Exceeds Expectations 4 to 5 points</th>
<th>Points Earned</th>
</tr>
</thead>
<tbody>
<tr>
<td>Far Below Expectations 0 to 1 point</td>
<td>The case presentation fails to meet two or more of the expectations that are to be met.</td>
<td>1. Opening statement leads into data. 2. Data is arranged in a neat chart/graph. 3. Closing statement concludes data.</td>
<td>/5</td>
</tr>
<tr>
<td>Title and Date, Neatness, and Organization.</td>
<td>The lab report fails to meet two or more of the expectations for neatness, organization, and/or title and date.</td>
<td>1. The lab report is typed. 2. The sections are in correct order, clearly labeled, and presented in a professional manner. 3. There are no spelling/grammatical errors in the report. 4. Title and date are present AND appropriate to the lab/</td>
<td>/5</td>
</tr>
<tr>
<td><strong>Purpose</strong></td>
<td>The purpose is missing, or is only loosely related to the lab being performed.</td>
<td>The purpose addresses the procedural aspects of the lab, but does not accurately summarize the theoretical foundation of the experiment.</td>
<td>The purpose accurately describes the theory that is intended to be reinforced by performing the lab.</td>
</tr>
<tr>
<td><strong>Procedure</strong></td>
<td>The procedure is missing altogether, missing important steps, or is wrong.</td>
<td>The procedure is a mostly copied directly from the lab description, with little attempt at brevity, or the procedure lacks sufficient content.</td>
<td>The procedure is a brief summary of each of the steps taken in completing the lab. It is NOT an exhaustive description containing minute details.</td>
</tr>
</tbody>
</table>
| **Experimental Data** | The student has copies or makes up data after the lab. The data section is missing, or fails to meet 2 or 3 of the expectations. | The lab report fails to meet one or two of the expectations of the data section. | 1. All data from experiments are included.  
2. Data are neatly organized (in tables if appropriate), and are easy to interpret.  
3. All data are correct with regard to significant figures, labels, and units. | /5 |
| **Analysis of Data** | The student omits graphs or calculations, or makes significant errors, making the graphs/calculations incomprehensible | The student makes 3 to 5 errors in graphing, labeling, calculations, and significant figures. | The report includes all of the required graphs and all calculations (with correct labels, descriptions, significant figures, etc…) | /5 |
| **Conclusion** | Conclusion is missing, or does not adequately address both of the expectations for this section. | Conclusion is present, but fails to correctly address one of the two expectations of this section. | 1. **Addresses the theory demonstrated** by the lab.  
2. **Explains how the calculations** do/do not support the theory and fulfill the purpose of the lab. | /5 |
| **Error Analysis** | The report fails to meet multiple expectations for error analysis. Or the error analysis section is omitted. | The report fails to meet all the expectations for error analysis. The error is given as *personal observation rather than quantitative values*. | 1. Relative error, if appropriate, has been calculated.  
2. Specific sources of experimental error are addressed.  
3. Write-up analyzes the effect of errors on the magnitude of calculated quantities. | /5 |
| **Post-Lab Questions** | The post-lab answers contain 3 or more errors, or are not attempted at all. | The post-lab questions contain some errors, or the post-lab questions are not written in complete sentences. | The post-lab questions contain no errors and are written in complete sentences. | /5 |

**Total:** /45