Using Polarized Light

Background Information

Some substances change the direction in which polarized light waves vibrate. These substances are said to be optically active. Sucrose, or table sugar, is optically active. When polarized light passes through a solution of sucrose dissolved in water, the polarization of the light changes—the light waves begin to vibrate in a different direction.

To measure this change, a device called a polarimeter is used. A polarimeter contains two polarizing filters. A container between the two filters holds a sample to be tested for optical activity. If the filters are at right angles to each other, no light can pass through the polarimeter. However, if you place an optically active sample between the filters, it will change the polarization of the light. As a result, some light will pass through the second filter. To measure the optical activity of a sample, you would look through the polarimeter and rotate the second filter until no light is able to pass though the filter. The angle that you rotate the second filter depends on the sample's optical activity.

In this investigation, you will use a polarimeter to determine how the optical activity of a sugar solution is related to the concentration of the solution.

Problem

How is the concentration of a sugar solution related to its optical activity?

Pre-Lab Discussion

Read the entire investigation. Then, work with a partner to answer the following questions.

1. **Inferring** Explain how two polarizing filters can completely block a beam of light.

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2. **Designing Experiments** Why will you need to be able to change the angle between the polarizing filters in the polarimeter?

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3. Applying Concepts Could you determine the optical activity of a solution if the light passed through the sample before it passed through the two polarizing filters? Explain your answer.

4. Controlling Variables Identify the manipulated, responding, and controlled variables in this investigation.

a. Manipulated variable

b. Responding variable

c. Controlled variables

5. Controlling Variables Why will you need to measure the optical activity of water in Step 9?

Materials *(per group)*

2 cardboard tubes
scissors
transparent tape
metric ruler
glass vial with cap
2 square polarizing filters, approximately 2 cm × 2 cm
duct tape
graph paper with millimeter rulings
bright light source
red pencil
paper towels
10 mL 20% sugar solution
10 mL 30% sugar solution
10 mL 40% sugar solution
unknown sugar solution

Safety

Put on a lab apron. Be careful to avoid breakage when working with glassware. Be careful when handling sharp instruments. Never look directly at the sun. Note all safety alert symbols next to the steps in the Procedure and review the meaning of each symbol by referring to the Safety Symbols on page xiii.

Name ____________________ Class ______________ Date ___________

Procedure

Part A: Building a Polarimeter

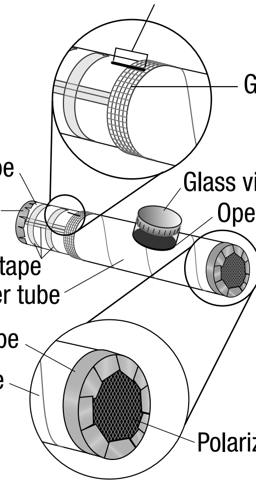

Figure 1

1. Use scissors to cut a cardboard tube open lengthwise. Then, overlap the cut edges to make a slightly smaller tube that just fits inside the second cardboard tube, as shown in Figure 1. Use transparent tape to hold the cut edges of the smaller tube together. **CAUTION:** *Be careful not to puncture or cut skin when using scissors.*
2. Using a metric ruler to measure, make a pencil mark on the side of the larger tube 4 cm from one end of the tube. Hold the glass vial with the center of its base on this mark. Use a pencil to trace the outline of the base of the vial on the tube.
3. Cut out the circle that you traced on the tube in Step 2. The resulting opening in the tube should be just large enough to allow the vial to fit snugly inside the tube, as shown in Figure 1.
4. Use small pieces of duct tape to carefully mount a polarizing filter over one end of the larger tube. Place tape only on the edges of the filter. To avoid getting any dirt or fingerprints on the polarizing filter, handle the filter only by its edges. If necessary, use small pieces of duct tape to cover any gaps between the edges of the filter and the tube. To hold the pieces of duct tape in place, wrap a piece of duct tape around the end of the tube, as shown in Figure 1.
5. Repeat Step 4 with the second polarizing filter and the smaller tube.
6. Cut a strip of graph paper that is 12 cm long and 1 cm wide. Wrap this strip around the open end of the larger tube, as shown in Figure 1. Use transparent tape to attach the strip of graph paper to the tube.
7. Insert the vial into the hole that you made in Step 3. Then, gently insert the smaller tube into the larger tube as far as the smaller tube will go.
8. Hold the polarimeter in one hand. Use your other hand to cover the vial to prevent it from falling out of the larger tube. Then, look at the bright light source through the polarimeter. As you look at the light through the polarimeter, rotate the smaller tube to make the light as dim as possible. Have a member of your group mark a short red pencil line on the strip of graph paper. Extend this line onto the smaller tube, as shown in Figure 1. **CAUTION:** *Do not aim the polarimeter at the sun.*

Part B: Measuring Optical Activity

9. Remove the vial from the polarimeter. Fill the vial with water and place the cap tightly on the vial. Use a paper towel to remove any water on the outside of the vial. Hold the polarimeter with the opening on top. Carefully put the vial back into the opening. Line up the red lines on both tubes. Look at the bright light source through the polarimeter. Rotate the smaller tube clockwise if necessary until the light is as dim as possible. **CAUTION:** *Immediately wipe up any spilled water. Make sure the vial does not slip out of the polarimeter.*
10. Observe the red pencil lines on the graph paper strip and on the smaller tube. Note that the rulings on the graph paper strip are 1 mm apart. In the data table, record the distance between the two red pencil lines. If the red pencil lines are precisely end to end, record this distance as zero.
11. Carefully remove the vial from the polarimeter. Discard the water in the sink. Rinse out the vial with water and use a paper towel to dry the vial.
12. Repeat Steps 9 through 11 with the 20%, 30%, and 40% sugar solutions. Then, repeat Steps 9 through 11 with the unknown sugar solutions.
13. Make a graph of the data from your observations of the water and the 20%, 30%, and 40% sugar solutions. Plot sugar concentration on the horizontal axis and optical activity on the vertical axis. Draw a straight line as close as possible to all four data points.
14. Find the point on the vertical axis of your graph that corresponds to the optical activity of the unknown sugar solution. Draw a horizontal dotted line from this point to the solid line. Then, draw a vertical dotted line from the point where the two lines meet down to the horizontal axis. The point where the vertical dotted line meets the horizontal axis marks the concentration of the unknown solution. Record this concentration in the data table.

Observations

DATA TABLE

Sugar Concentration (percent)	Optical Activity (mm)
0 (water)	
20	
30	
40	
Unknown ____________	

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Analysis and Conclusions

1. **Analyzing Data** What was the relationship between the concentration of the sugar solutions and their optical activities?

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2. **Using Graphs** Was it reasonable to use your graph to determine the concentration of sugar in the unknown solution? Explain your answer.

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3. **Evaluating and Revising** When would it be unreasonable to use your graph to determine the concentration of an unknown sugar solution? Explain your answer.

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4. **Predicting** How do you think the distance that light passes through the sample affects the observed optical activity?

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Go Further

Design an experiment to use your polarimeter to determine the concentration of sugar in liquids such as fruit juices or syrups. Write a detailed plan of your experiment. Your plan should state the hypothesis to be tested, identify the manipulated, responding, and controlled variables, and describe the procedures and safety precautions that you will use. If the liquids you choose to test contain sugar other than sucrose, you will need to make solutions of known concentrations. After your teacher approves your plan, carry out your experiment and report your results and conclusions.