Optical Rotation by Sugars

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Topic

Optical activity and chirality

Time

1½ hours

Safety

Please click on the safety icon to view the safety precautions. Care must be taken when using a 110-V light socket. Make sure it does not get wet. Do not drink the sugar solutions. Be careful handling the knife and scissors.

Materials

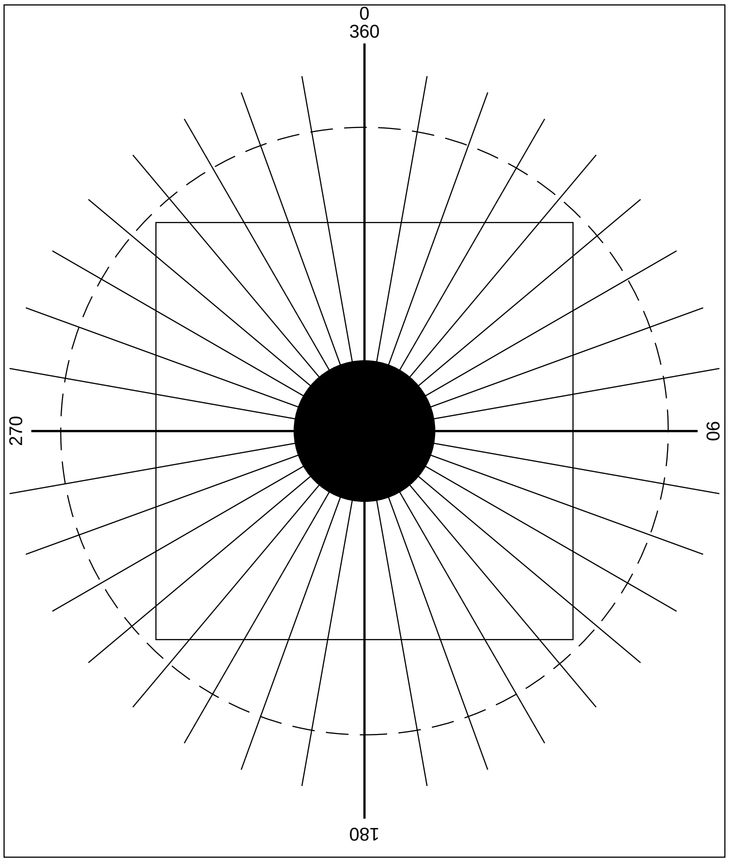
1 ring stand and ring
tape
porcelain lamp socket with 110-V plug
stiff cardboard
25-W bulb
distilled water
600-mL beaker
3 tbs glucose (lab grade)
250-mL beaker and mixing rod or 500-mL Florence flask
two pieces of plastic polarizing filter material (an old pair of polarized sunglasses cut in half will substitute)
100-mL beaker or a flat-bottomed test tube
three small water glasses
3 tbs fructose (lab grade)
graduated cylinder
3 tbs sucrose (table sugar)
scissors and/or X-Acto™ knife
100 mL light (clear) corn syrup

Procedure

Part A: Setting Up the Polarimeter

1. Make two photocopies of figure 1 and four copies of data tables 1 and 2.
2. Cut the large outside circle (broken line) out of one copy of figure 1. Using a red marker pen, highlight the vertical and horizontal axes. Then cut the small black circle out of the center of it. Tape the doughnut shape that results on top of one piece of polarizing filter material, so that the hole in the middle is covered by the filter. Trim any excess material that extends beyond the outside edge of the doughnut (see figure 2a).

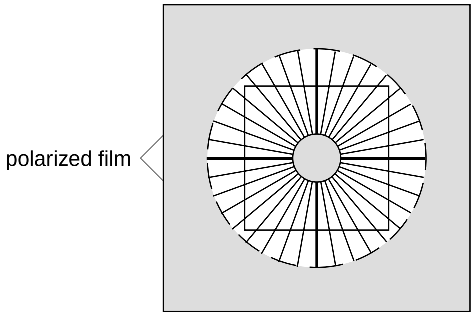
Figure 1



DATA TABLE 1		
Effect of amount of solution Identity of sugar ________		
Trial	Volume of solution (mL)	Optical rotation (degrees)

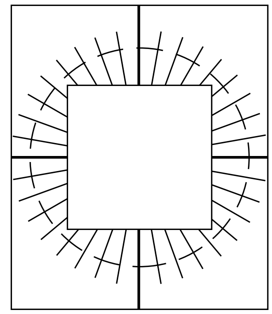
DATA TABLE 2			
Effect of concentration Identity of sugar ________			
Volume of sugar solution (mL)	Volume of sugar (mL)	Final concentration (%)	Optical rotation (degrees)

Figure 2a



trim off excess polarized film

Figure 2b



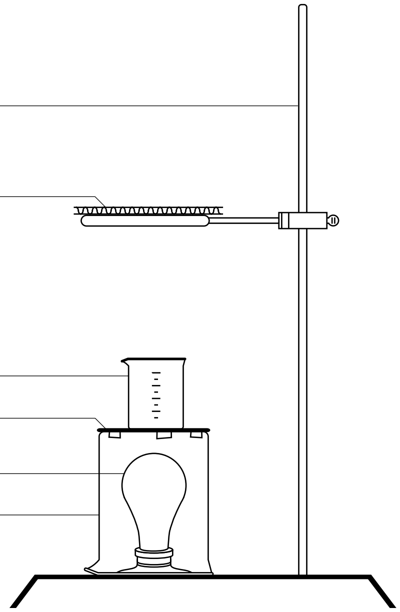
cut out rectangular hole

3. Tape the other copy to a piece of cardboard, and cut the cardboard to fit the outside edge of the whole rectangular figure. Take the red marker and again highlight the vertical and horizontal axes. Using the X-Acto™ knife, cut out the small rectangle in the middle, leaving a rectangular frame shape.
4. Place the lightbulb in the socket on the base of the ring stand. Make sure that it is steady and secure; tape it down if necessary.
5. Place the 600-mL beaker over the lightbulb, and place the other piece of polarizing filter on top of it.
6. Adjust the height of the ring so that you can fit the 100-mL beaker comfortably between it and the 600-mL beaker over the bulb. If you've used a polarizing filter, the 100-mL beaker should be able to rest securely on top of the 600-mL beaker. If you've used a pair of old sunglasses, this may not be possible, and you will have to carefully hold the 100-mL beaker between the 600-mL beaker and the ring when you do the procedures in Part B.
7. Tape the cardboard frame shape on top of the ring, making sure that its rectangular opening is centered with the front of the figure facing you and the axes square.
8. Place the doughnut shape with the polarized filter in the center on top of the frame, and line up the axes.
9. Plug in the lightbulb and rotate the piece of polarizing material on the 600-mL beaker clockwise while you look through the top polarizer. When you reach the point of *extinction* (when there is the least or no light coming through the top polarizer), stop and carefully tape the bottom polarizing filter to the bottom of the 600-mL beaker, making sure that you don't go past the point of extinction. Leave the top polarizer exactly where it is. The polarimeter is now complete and should look like figure 3.

Part B: Optical Rotation: Testing for Chirality

1. Using the 250-mL beaker and stirring rod or the 500-mL Florence flask, make saturated solutions of all three sugars, 100 mL each. This is done by mixing a sugar into 100 mL distilled water, adding more sugar as you mix, until no more of the sugar will dissolve. This may take a while, so be patient. Transfer each solution to a separate water glass, and label each according to which sugar it is. In the space for sugar identity on one copy of data table 1, label "glucose."
2. Fill your 100-mL beaker or flat-bottomed test tube with 25 mL glucose solution, and place this on top of the bottom beaker. Look through the top polarizer; you should see more light coming through it now. Rotate the top polarizer *clockwise*

Figure 3



(to the right) until you reach extinction again, and record the number of degrees that you rotated the disk on the labeled copy of data table 1 (each click on the disk is equal to 10 degrees). This is the optical rotation of the solution.

3. Add 25 mL of the same solution to the beaker, and repeat step 2. Repeat step 2 twice more, each time adding 25 mL more of the glucose solution. Record all your results on data table 1.
4. When you've finished with the glucose solution, pour it back into the glass it was stored in, and rinse out the 100-mL beaker.
5. Repeat steps 2 through 4 with the fructose and sucrose solutions. Record all your results on two more copies of data table 1.
6. Mix together 25 mL each of glucose and fructose solutions, and repeat steps 2 to 4. Record the results.
7. Using the graduated cylinder and water, make a series of dilutions of 50%, 25%, and 10% of each saturated sugar solution. This is done by adding a measured quantity of solution to a measured quantity of water to make a total of 100 mL. For example, a 10% glucose solution is made by filling the graduated cylinder with 90 mL water and adding 10 mL of the saturated glucose solution. This is based on the fact that a saturated solution is a 100% solution.
8. Repeat step 2 for each dilution of each sugar, and record the results on the copies of data table 2.
9. Fill the 100-mL beaker with light corn syrup. Place it in the polarimeter. Rotate the upper polarizer 360 degrees. Observe what happens. This is a demonstration of *interference* of *wave motion*.
10. Turning the upper polarizer clockwise (to the right) is considered dextro, and turning it counterclockwise (to the left) is considered levo. Readings from 0 degrees to 180 degrees are dextro readings; those from 181 degrees to 360 degrees are levo readings. Scientists refer to two of the three sugars tested by the more descriptive names, dextrose and levulose. Based on the data you collected using your polarimeter, which sugar is which? Why do you think this is so?

11. What effect did varying the volume of the saturated solutions and varying the concentrations of the solutions have?
12. What do the phenomena of greater concentration and greater volume have in common? What does this suggest about the reason that volume and concentration affect optical rotation?

What's Going On

Glucose is referred to as dextrose, and fructose as levulose. As the polarimeter tests show, this is because glucose rotates the plane of polarization to the right, and fructose rotates it to the left. Sucrose is not identified by its optical rotation, which you've seen is not as dramatic as the others. This is because it is actually a combination of both molecules. As you increased the volume of a saturated solution, the amount of optical rotation increased. Testing with varying concentrations, you observed the higher the concentration, the more optical rotation. The higher the concentration of a solution, the more molecules of the solute (sugar) are present. Increasing the volume of a solution also increases the number of solute molecules. The fact that an increase in volume or in concentration will increase the amount of rotation suggests that the amount of optical rotation is directly proportional to the number of sugar molecules encountered by the light.

Connections

Light travels in *transverse* waves. This means that its vibrations occur in planes *perpendicular* to the direction of the light's travel. When light is *polarized*, only those vibrations that occur in a single perpendicular plane pass through the polarizing filter. This is called the *plane of polarization*. Certain chemical compounds exhibit the property of *optical rotation*; that is, when polarized light passes through them, the plane of polarization is altered. This is due to the *chirality* of these substances. Chirality is the property of "handedness"; optically active compounds occur as asymmetrical molecules, existing in either right-handed (*dextro*) or left-handed (*levo*) forms. In this experiment, you constructed a simple version of a scientific instrument called a *polarimeter*, and you used it to see how the optical activity of a substance can help to identify it.

Safety Precautions

READ AND COPY BEFORE STARTING ANY EXPERIMENT

Experimental science can be dangerous. Events can happen very quickly while you are performing an experiment. Things can spill, break, even catch fire. Basic safety procedures help prevent serious accidents. Be sure to follow additional safety precautions and adult supervision requirements for each experiment. If you are working in a lab or in the field, do not work alone.

This book assumes that you will read the safety precautions that follow, as well as those at the start of each experiment you perform, and that you will *remember* them. These precautions will not always be repeated in the instructions for the procedures. It is up to you to use good judgment and pay attention when performing potentially dangerous procedures. Just because the book does not always say "be careful with hot liquids" or "don't cut yourself with the knife" does not mean that you should be careless when simmering water or stripping an electrical wire. It *does* mean that when you see a special note to be careful, it is extremely important that you pay attention to it. If you ever have a question about whether a procedure or material is dangerous, stop to find out for sure that it is safe before continuing the experiment. To avoid accidents, always pay close attention to your work, take your time, and practice the general safety procedures listed below.

PREPARE

- Clear all surfaces before beginning work.
- Read through the whole experiment before you start.
- Identify hazardous procedures and anticipate dangers.

PROTECT YOURSELF

- Follow all directions step by step; do only one procedure at a time.
- Locate exits, fire blanket and extinguisher, master gas and electricity shut-offs, eyewash, and first-aid kit.
- Make sure that there is adequate ventilation.
- Do not horseplay.
- Wear an apron and goggles.
- Do not wear contact lenses, open shoes, and loose clothing; do not wear your hair loose.
- Keep floor and work space neat, clean, and dry.
- Clean up spills immediately.
- Never eat, drink, or smoke in the laboratory or near the work space.
- Do not taste any substances tested unless expressly permitted to do so by a science teacher in charge.

USE EQUIPMENT WITH CARE

- Set up apparatus far from the edge of the desk.
- Use knives and other sharp or pointed instruments with caution; always cut away from yourself and others.
- Pull plugs, not cords, when inserting and removing electrical plugs.
- Don't use your mouth to pipette; use a suction bulb.
- Clean glassware before and after use.
- Check glassware for scratches, cracks, and sharp edges.
- Clean up broken glassware immediately.

- Do not use reflected sunlight to illuminate your microscope.
- Do not touch metal conductors.
- Use only low-voltage and low-current materials.
- Be careful when using stepstools, chairs, and ladders.

USING CHEMICALS

- Never taste or inhale chemicals.
- Label all bottles and apparatus containing chemicals.
- Read all labels carefully.
- Avoid chemical contact with skin and eyes (wear goggles, apron, and gloves).
- Do not touch chemical solutions.
- Wash hands before and after using solutions.
- Wipe up spills thoroughly.

HEATING INSTRUCTIONS

- Use goggles, apron, and gloves when boiling liquids.
- Keep your face away from test tubes and beakers.
- Never leave heating apparatus unattended.
- Use safety tongs and heat-resistant mittens.
- Turn off hot plates, bunsen burners, and gas when you are done.
- Keep flammable substances away from heat.
- Have a fire extinguisher on hand.

WORKING WITH MICROORGANISMS

- Assume that all microorganisms are infectious; handle them with care.
- Sterilize all equipment being used to handle microorganisms.

GOING ON FIELD TRIPS

- Do not go on a field trip by yourself.
- Tell a responsible adult where you are going, and maintain that route.
- Know the area and its potential hazards, such as poisonous plants, deep water, and rapids.
- Dress for terrain and weather conditions (prepare for exposure to sun as well as to cold).
- Bring along a first-aid kit.
- Do not drink water or eat plants found in the wild.
- Use the buddy system; do not experiment outdoors alone.

FINISHING UP

- Thoroughly clean your work area and glassware.
- Be careful not to return chemicals or contaminated reagents to the wrong containers.
- Don't dispose of materials in the sink unless instructed to do so.
- Wash your hands thoroughly.
- Clean up all residue, and containerize it for proper disposal.
- Dispose of all chemicals according to local, state, and federal laws.

BE SAFETY-CONSCIOUS AT ALL TIMES