Exercise 3: Carbohydrates and optical activity

Carbohydrates are biomolecules containing carbon, hydrogen and oxygen in a ratio of roughly 1:2:1, respectively. They are also chiral molecules (in other words, contain chiral carbons). You will be using two such molecules in this exercise: [D]-glucose (called “dextrose”) and [D]-fructose (called “levulose”), as well as an unknown containing one of these (Karo syrup).

You will need two pieces of Polaroid (plane polarizing) film, a light source from below, a bunch of clean 50 mL graduated cylinders, a transparency of polar graph paper and the various sugar solutions.

Place the polar graph paper transparency on the light source. Place one piece of Polaroid film on the center of the polar graph and place the graduated cylinder on top of that. Finally, place the other piece of Polaroid film on top of all that and switch on the light. Rotate the bottom piece of Polaroid film around and make sure you can see the lines on the polar graph paper. Note that some angles of the bottom Polaroid film will not allow any light. Congratulations; you have now constructed a crude polarimeter.

The direction in which you must turn the bottom Polaroid film in order to achieve full brightness determines whether you have a dextrorotatory (clockwise — symbolized “+”), levorotatory (counterclockwise — symbolized “−”) or racemic (no rotation — symbolized “±”) sugar.

The number of degrees the Polaroid film must be rotated in order to achieve full brightness (regardless of direction) is called the specific rotation of the sugar (actually, the measured rotation, but the specific rotation is for a particular set of standard conditions).

1. With nothing in the graduated cylinder, through how many degrees must the bottom Polaroid film be turned, in order to go from no light transmission to maximum light transmission?

2. Pour about 20 mL of 25% dextrose into the polarimeter graduated cylinder. Is the specific rotation for 25% dextrose positive, negative or zero?

3. Put a fresh graduated cylinder in the polarimeter. Pour about 20 mL of 25% levulose into the polarimeter graduated cylinder. Is the specific rotation for 25% dextrose positive, negative or zero?

4. Put a fresh graduated cylinder in the polarimeter. Pour about 10 mL of Karo syrup into the polarimeter graduated cylinder. Measure the specific rotation (in degrees) for Karo syrup. Don’t forget the sign of the rotation. Also, measure the height (in cm) of the Karo syrup in the graduated cylinder.
5. Add another 10 mL of Karo syrup into the graduated cylinder and remeasure the specific rotation for Karo syrup. Measure the height of the Karo syrup (it should be about double).

6. How did the specific rotation change (describe this numerically)? How did the height of the syrup change? What is the mathematical relationship between syrup height (also called “optical path length”) and the measured specific rotation? Did the sign of the specific rotation change?

7. With a neighboring group, dilute the Karo syrup in one of your graduated cylinders with an equal amount of hot water and stir the mixture thoroughly. Pour 20 mL of this mixture back into a polarimeter graduated cylinder and measure the specific rotation.

8. How did the specific rotation change (describe this numerically)? How did the concentration of the syrup change? What is the mathematical relationship between the sugar concentration and the measured specific rotation? Did the sign of the specific rotation change?

9. Write a mathematical equation that connects the specific rotation (call it \( \lambda \)), the concentration (call it \( c \)) and the optical path length (call it \( l \)). You will need a constant (called \( k \)) for the equation.

10. Based on your observations above, which sugar (dextrose or levulose) is Karo syrup more likely to made of?