Rotation of the plane of polarisation with sugar solutions

Aims of the experiment

- Observe the rotation of the polarisation plane with the help of the penumbral method.
- Understand the difference between dextrorotatory and levorotatory substances.
- Become familiar with enantiomers and their stereodescriptors.
- Understand the determination of specific rotation values for optically active substances.

Principles

The optical activity describes the property of some substances that rotate the polarisation plane of linearly polarised light when passing through a substance. A so-called angle of rotation *α* can be determined from these substances. This then allows the specific rotation angle to be calculated for a substance as follows:

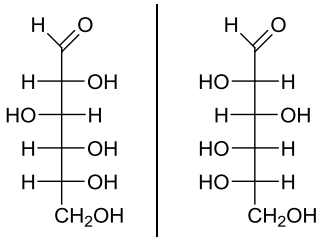
$$\alpha = \frac{\alpha}{l \cdot c}$$

Here *α* is the measured angle of rotation, *l* the length of the cuvette and *c* the concentration of the optically active substance. The specific angle of rotation *[α]* also depends on the wavelength of the polarised light (mostly Na radiation at 589.3 nm), the type and purity of the solvent and the measuring temperature. These parameters must therefore be indicated as well.

The question is now how this rotation of the polarisation plane comes about. The reason for this is mostly a carbon atom present in the molecule with four different substituents. Depending on how these substituents are arranged at this carbon atom, there are spatially non-identical, stereoisomeric forms of the molecule. These are differentiated into enantiomers, which behave in image and mirror image to each other, and diastereomers, which do not have this symmetry element.

In nature, however, a substance does not usually occur as a racemic mixture, i.e. with an enantiomer ratio of 1:1, but instead mostly as only one of the enantiomers.

The steric configuration of, above all, sugar can be described with the stereodescriptors D and L in the Fischer projection. The enantiomers D- and L-glucose are shown here as an example.



D-glucose L-glucose

Rather than providing any information on the optical properties, however, these descriptors only indicate the spatial arrangement.

The rotation of polarised light enables a further differentiation of enantiomers. Here the compounds that rotate linearly polarised light to the right are marked with (+) and compounds that rotate the plane to the left are marked with (-). This rotation is specific to every substance.

Fig. 1: Experimental apparatus for determining the rotation of the polarisation plane through sugar solution.

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Risk assessment

The chemicals used are not hazardous.

Equipment and chemicals

1	Polarimeter	657 591
1	Compact balance CS200E	OHC S-200E
1	Spoon-ended spatula, SS, 120 mm	666 963
3	Volumetric flask Boro 3.3, 100 ml	665 793
3	Funnel, PP. 75 mm diam.	665 009
3	Watch glass dish, 60 mm diam.	664 153
3	Beaker Boro 3.3, 100 ml	664 137
1	D(+) glucose, 100 g	672 1100
1	D(-) fructose, 50 g	672 0700
1	D(+) saccharose, 100 g	674 6050

Set-up and preparation of the experiment

Preparing the sugar solutions

10 g of a sugar (glucose, fructose or saccharose) is weighed out on a watchmaker glass using a spoon spatula. Then use the funnel to add the weighed sugar to a 100 ml volumetric flask and fill this with distilled water up to the 100 ml mark. Seal the volumetric flask with the associated stopper and shake well for a few minutes until the sugar has fully dissolved. In this way, three different sugar solutions with glucose, fructose or saccharose are prepared.

Set-up of the apparatus

Installing/Replacing the sodium lamp: Before inserting the sodium lamp in the polarimeter, make sure that the mains plug is not plugged in.

Note: Do not touch the lamp with your fingers but instead use a suitable cloth for this.

First remove the lamp cover (f, Fig.2) and then insert the sodium lamp in the base. The fit the lamp cover again so that the window points to the polariser.

Calibration of the polarimeter: After plugging in the mains plug, switch on the sodium lamp and wait a short warm-up phase. Now set the analyser to about 90° using the adjusting screws (b). Then set the ocular (a) so that a sharp light circu-

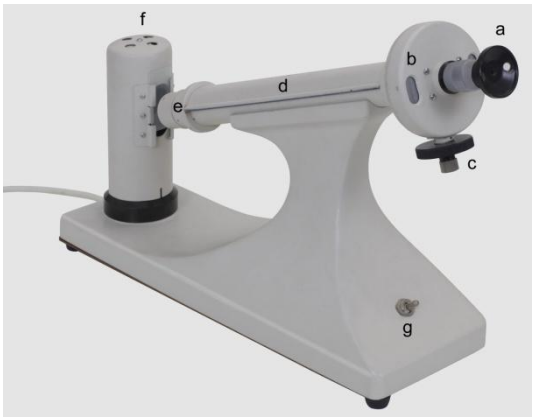

Fig. 2: Set-up of the polarimeter.

lator area is illuminated. Turn the analyser to 0°. The circular area should now be uniformly dark and the centre strip is no longer observable. If the analyser is now turned in the area of the zero point, the centre strips are alternately light or dark with the two edge areas (penumbral method). In this way, deviations from the zero position can be easily observed. If a deviation is determined, the analyser should be set exactly to 0° and the screws on the polariser (e) loosened. The polariser can now be positioned so that the circular areas are uniformly lit and the centre strips cannot be observed. Then screw the screws of the polariser tight again.

Performing the experiment

1. To fill the round cuvette, first transfer part of the sugar solution to a beaker. Hold the round cuvette vertically with the thickening at the top and screw on. Now remove both the inner cap, the sealing ring as well as a small glass disc. Now shake pour the sugar solution inside at the edge of the cuvette via the beaker's spout so that the solution is as free of bubbles as possible. Then close the cuvette again with the glass disc, sealing ring and screw ring.

2. The round cuvette is placed in the polarimeter with the solution to be examined. The thickening should occur at the top here.

Note: If it was not possible to fill the cuvette without bubbles, the bubbles can be collected in the area of the thickening. The light path is not disturbed by the air bubbles in this area.

3. The analyser is now turned until the observed circular area has darkened.

Note: The circular areas should not be equally light but equally dark, as the measured values should be determined with the penumbral method. The measurement should also be carried out very quickly as the rotation angle α is temperature dependent. After 10 minutes, the cuvette has heated so intensely that the analyser has to be reset and the measurement is falsified.

Observation

Measured values for three different sugar solutions were determined. Here the rotation value α_1 is measured at the beginning of the measurement and rotation value α_2 after 10 minutes. An angle over 90° is determined for the fructose solution. As a result, the rotation angle α still has to be calculated as follows:

Measured value - 180° = α

Thus the following values can be determined for the three different sugar solutions:

Tab. 1: Determined rotational angle of three different sugar solutions.

Sugar	α_1 [°]	α_2 [°]
D(+)glucose	10.70	11.15
D(-)fructose	-17.90	-17.50
D(+)saccharose	13.35	13.40

Evaluation

The following formula is used to calculate the specific rotation value of a sugar solution:

$$\alpha = \frac{\alpha}{l \cdot c}$$

Here *α* is the measured rotation angle [°], *l* the length of the cuvette [dm] and *c* the concentration of the solution $\frac{g}{100\,ml}$.

In this example the cuvette length is 2 dm long and the concentration is 10 $\frac{g}{100\,ml}$.

The following specific rotation values [α] could therefore be determined for the sugar solutions used:

Tab. 2: Representation of the rotation values for three different sugar solutions.

Sugar	$[\alpha_1]$ [°]	$[\alpha_2]$ [°]
D(+)glucose	53.50	55.75
D(-)fructose	-89.50	-87.50
D(+)saccharose	66.75	67.00

Result

The measurement confirms that D-glucose and D-saccharose represent dextrorotatory substances, as the measurements yield positive rotation values. D-fructose, on the other hand, is a levorotatory substance.

Comparison of the two determined specific rotation values α_1 and α_2 for the sugar solution shows minimal differences. This confirms the temperature relation of the specific rotation value already mentioned.

The determined rotation values can be compared with values from the literature for the evaluation.

Tab. 3: Representation of the rotation values of various sugar solutions from the literature.

Sugar	$[\alpha]$ [°]
D(+)glucose	52.70
D(-)fructose	-89.50
D(+)saccharose	66.40

The literature values also involve measured values, which were measured with sugar solutions at a concentration of $10\,\frac{g}{100\,ml}$ with a sodium lamp (589.3 nm). These measurements were conducted at a room temperature of 20°C.

In comparison, the measured values were very close to the literature values. With the D(-)fructose, the literature value could even be determined during the first measurement. The minor deviations primarily result from temperature fluctuations. This is also discernible from the fact that the second measured values, which were determined 10 minutes after the first measurement, deviate further from the literature values.

Cleaning and disposal

The solutions can be disposed of in the laboratory drain.