Rotation of the polarization plane in sugar solution

Task and equipment

Information for teachers

Additional Information

Optically active substances such as sugar solution and quartz rotate the polarization plane of the light passing through them. The optical activity is brought about by the form of the sugar molecules in the sugar solution, or by the grid structure of the quartz.
The angle α, by which the polarization plane of light is rotated in a sugar solution, depends on the wavelength λ of the light, the concentration c of the solution and on the layer thickness d (path travelled by the light source in the solution).
This phenomenon is called rotational dispersion and we use it, for instance, to determine the concentration of optically active substances in solutions. The device used to determine in particular the concentration of sugar solutiones is known as the saccharimeter.
There are dextrorotatory (right-handed) and laevo-rotatory (left-handed) optically active substances. In this experiment the students should become familiar with the phenomenon of rotational dispersion, its dependence on λ, c and d, and the basic design of a saccharimeter.

Suggestions for Set-up and Performance

The experiment must be performed in a darkened room.
The teacher should prepare in advance sufficient quantities of concentrated sugar solution - dextrorotatory with household sugar, laevo-rotatory with frucotse - (100 ml per group of students).

Remark

The high concentration of the sugar solution (0.5 g/ml) in the experiment was selected to minimize the relative measuring error for the angles of rotation which can only be read off to the nearest degree.
The measured values must be regarded as examples, as they will always depend on the type of sugar used.
To save time, we recommend letting only the fastest group of students carry out the last stage of the experiment with the laevo-rotatory sugar solution. They can inform the others about their results.
The figure below will be useful for your explanation of the term "dextrorotatory".

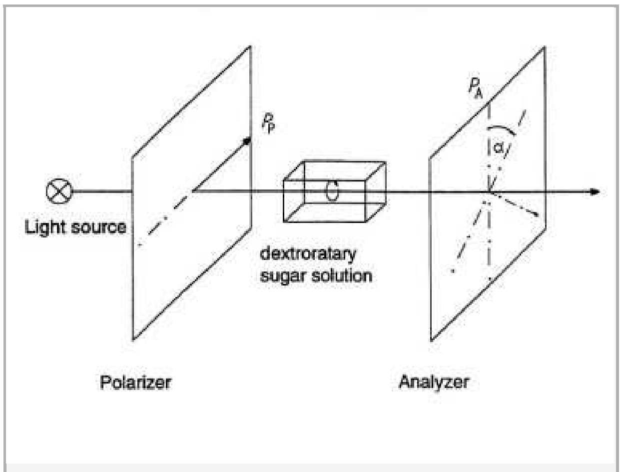

Fig. L1

Fig. L1:

P_P - transmission axis of the polarizer

P_A - transmission axis of the analyzer

α - Angle of rotation bringing about extinction

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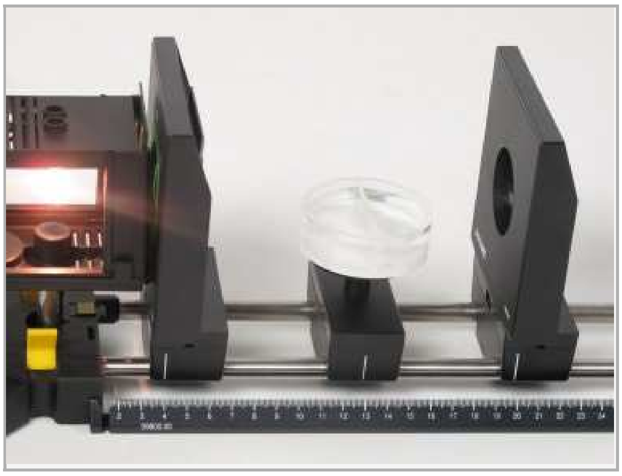
Task

How does a saccharimeter work?

Set up a model of a saccharimeter and investigate what happens to a sugar solution when polarized light of various wavelengths passes through it. Find out also, whether and to what extent the observed phenomenon is dependent on the layer thickness and concentration of the sugar solution.



Equipment

Position No.	Material	Order No.	Quantity
1	Light box, halogen 12V/20 W	09801-00	1
2	Bottom with stem for light box	09802-10	1
3	Support base, variable	02001-00	1
4	Support rod, stainless steel, l = 600 mm, d = 10 mm	02037-00	2
5	Meter scale for optical bench	09800-00	1
6	Colour filter set, additive (red, blue, green)	09807-00	1
7	Diaphragms, d 1, 2, 3, 5 mm	09815-00	1
8	Lens on slide mount, f=+50mm	09820-01	1
9	Lens on slide mount, f=+100mm	09820-02	1
10	Slide mount for optical bench	09822-00	2
11	Mount with scale on slide mount	09823-00	1
12	Table with stem	09824-00	1
13	Cuvette, double semicircular	09810-06	1
14	Screen, white, 150x150mm	09826-00	1
15	Polarising filter, 50 mm x 50mm	08613-00	2
16	Diaphragm holder, attachable	11604-09	2
17	Glass beaker DURAN®, short, 250 ml	36013-00	1
18	PHYWE power supply DC: 0...12 V, 2 A / AC: 6 V, 12 V, 5 A	13506-93	1
Additional material			
19	Fructose, 250 g	30128-10	50 g
20	Ruler		1
21	Absorbent paper or cloth		

Set-up and procedure

Set up the optic bench with the two support rods and the support base and place the scale in position (Fig. 1 and Fig. 2).


Fig. 1


Fig. 2

- Assemble the light box according to Figures 3 and 4 and clamp it into the left part of the support base with the lens end pointing away from the optic bench (Fig. 5). Insert the light-tight diaphragm into the well in front of the lens (Fig. 6). Clamp the screen into the right part of the support base (Fig. 7).

Fig. 3

Fig. 4

Fig. 5

Fig. 6

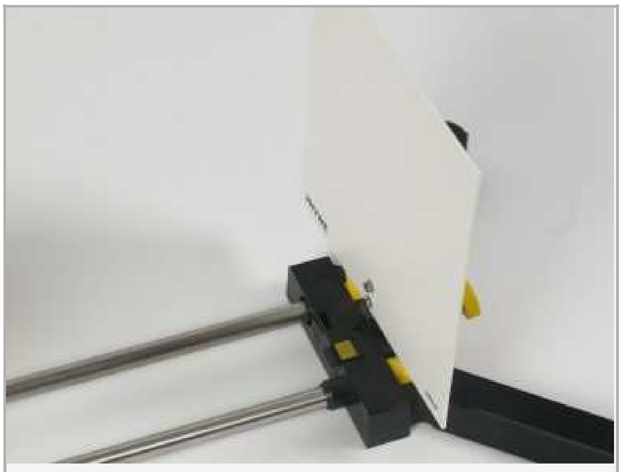


Fig. 7

- Position the lens with *f* = +50 mm directly next to the light on the optic bench (Fig. 8).

Fig. 8

- Insert a hole diaphragm and one polarization filter (polarizer) into a diaphragm holder and attach this to the mount of the lens with *f* = 50 mm (hole diaphragm facing the lens; Fig. 9).

Fig. 9

- Connect the light to the power supply (12 V~) and swith on the power supply (Fig. 10).

Fig. 10

- Position the lens with *f* = +100 mm at approx. 39 cm and focus the diaphragm hole by moving the lens back and forth (Fig. 11).

Fig. 11

- Insert the second polarization filter (analyzer) into the other diaphragm holder and attach this to the scale mount with its marking located over the zero point of the scale (Fig. 12).

Fig. 12

- Set up the scale mount at approx. 20 cm (Fig. 13); if the screen is not quite dark, rotate the polarizer until the light spot vanishes, i.e. the filters are crossed.

Fig. 13

- Set up a slide mount with the table at approx. 13 cm (Fig. 14); place the beaker containing 100 ml concentrated sugar solution (50 g sugar in 100 ml solution, i.e. concentration c = 0.5 g/ml) on the table so that the light beam travels along the diameter of the beaker (Fig. 15); now watch the screen.

Fig. 14

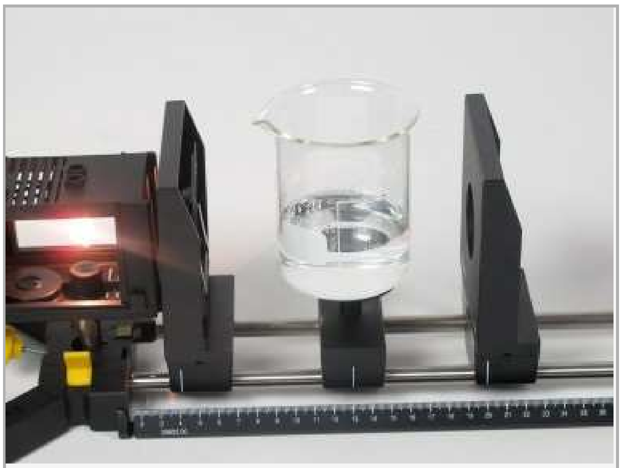


Fig. 15

- Slowly rotate the analyzer from 0° thru 90° to the right and then back to 0°, watching the screen all the time; note your observations in the report (1).
- Insert the red filter into the light well (Fig. 16) and rotate the analyzer to the right until the screen is completely dark; read off the angle of rotation α required for extinction, and then enter in table 1 in the report.

Fig. 16

- One after another, replace the red filter by the green and the blue filters, measure the respective angles of rotation required for extinction and enter them in table 1.
- *Hint:* The light transmitted by the coloured filters is not absolutely monochrome. Therefore, complete darkness will never be achieved on the screen. When taking your measurements, set the angle of rotation to the point where maximum extinction occurs. You will find that particularly the blue filter transmits a considerable proportion of red; in this case the analyzer should be rotated until the light sport appears red.
- Insert the green filter and use the green light only for the rest of the experiment.
- Measure the clear radius of the double semicircular cuvette and instead of the beaker place the cuvette on the table with its partition vertical to the optical axis (Fig. 17); if necessary, adjust the height of the table so that the whole of the light beam passes through the cuvettte just above the bottom.

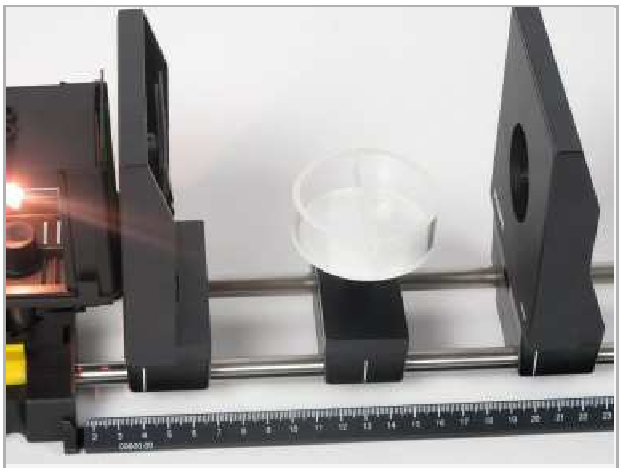


Fig. 17

- First of all, pour just enough sugar solution into one half of the cuvette to enable the whole of the light beam to pass through the solution (Fig. 18); measure the angle of rotation, then record the clear radius (layer thickness *d*) and angle of rotation α in table 2.

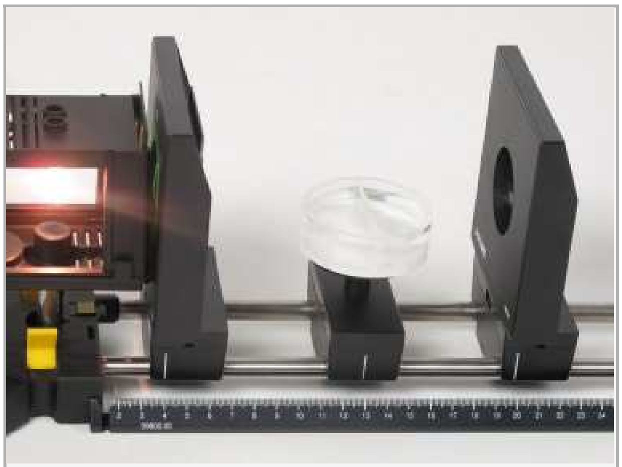


Fig. 18

- Now fill the other half of the cuvette with the sugar solution (double layer thickness); measure the angle of rotation and record together with the layer thickness in table 2.
- Measure the inner diameter of the beaker and transfer the angle of rotation for green light from table 1 to tables 2 and 3.
- Pour sugar solution from the cuvette back into the beaker; add 100 ml of water, thus halving the concentration. Stir the solution and place the beaker on the table es for the first measurement. Measure the angle of rotation and enter it in table 3.
- Pour 100 ml solution out of the beaker and again add 100 ml water, thus reducing the concentration to one quarter. Stir the solution, measure the angle of rotation and enter it in table 3.
- Empty the beaker and fill it with 100 ml concentrated fructose solution. Again determine the angle of rotation α for the green light. Note the angle and direction of rotation in the report.
- Switch off the power supply and clean the apparatus.

Report: Rotation of the polarization plane in sugar solution

Result – Observations 1

Note down your observations during the rotation of the analyzer.

Result – Table 1

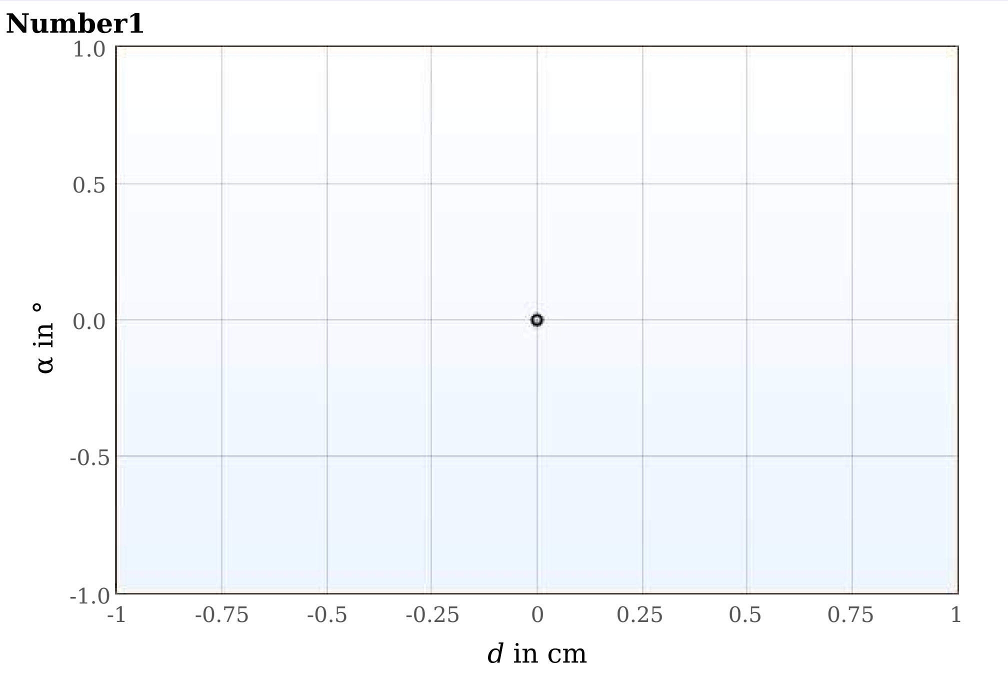
Record all the measured values in table 1:

Colour	Red	Green	Blue
Angle of rotation in °	1 ±0	1 ±0	1 ±0

Result – Table 2

Record all measured values in table 2.

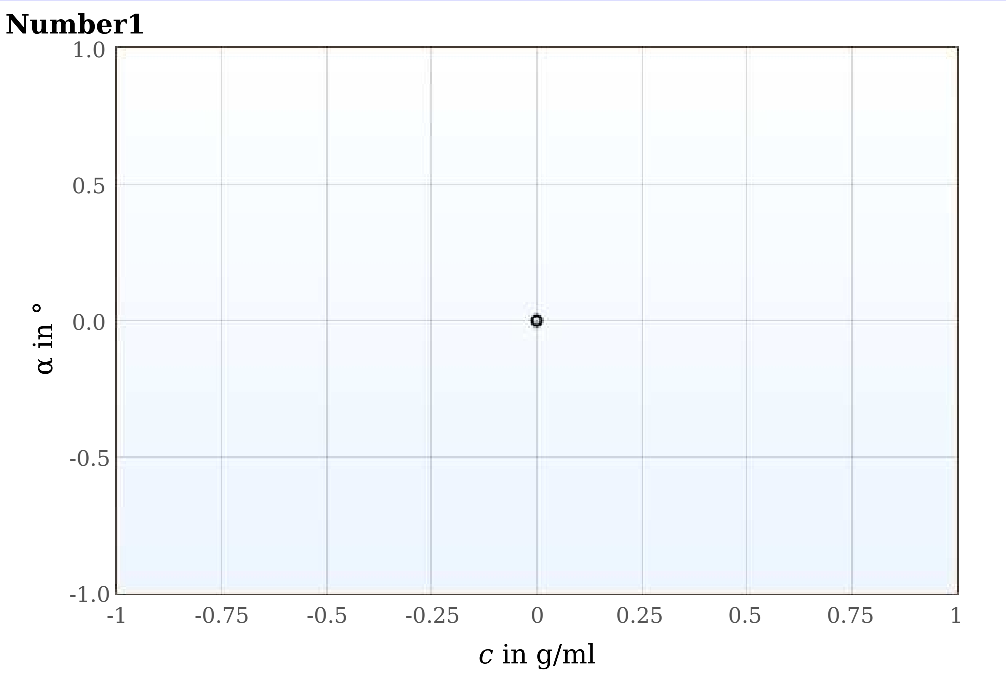
Receptacle for solution	Layer thickness *d* in mm	Angle of rotation α in °
-	0	0
one half of cuvette	1 ±0	1 ±0
two halfs of cuvette	1 ±0	1 ±0
Glass beaker	1 ±0	1 ±0



Result – Table 3

Enter your measurements in the table.

Concentration *c* in g/ml	Angle of rotation α in °
	1 ±0
	1 ±0
	1 ±0
0	0



Result – Observations 2

Determine the angle of rotation α for the green light with concentrated fructose solution.

Evaluation – Question 1

The sugar solution is optically active, i.e., it rotates the polarization plane (oscillation plane of the electrical vector) of plane-polarized light passing through it.

Now attempt to explain your observations noted under "Result - Observations 1" (Hint: the light passing through the solution is white.). Include in your explanation the conclusions to be drawn from table 1.

Evaluation – Question 2

What correlation exists between the angle α of rotation as a function of the layer thickness *d*, as seen in the graph below?

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Evaluation – Question 3

Now a graph is drawn of α as a function of the concentration *c* (table 3). What correlation is evident?

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Evaluation – Question 4

Express the relationship between α, *c* and *d* as an equation. The proportionality factor is know as specific rotation α_S.
Calculate from the rise of the straight lines in the graphs drawn above the specific α_S for green light.

Evaluation – Question 5

What conclusion can be drawn from the facts noted under Result - Observations 2?

Evaluation – Question 6

How is a saccharimeter basically designed and what can we use it for?

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