OPTICAL ACTIVITY

EXPERIMENT PROCEDURE

- **Measurement of the angle of rotation as a function of the length of the sample.**
- **Measurement of the angle of rotation as a function of the solution concentration.**
- **Determining the specific rotation for different light wavelengths.**
- **Comparing the directions of rotation and angles of rotation for fructose, glucose and saccharose.**
- **Measurement of the angle of rotation during the inversion of saccharose to give an equimolar mixture of glucose and fructose.**

OBJECTIVE

Investigate the rotation of the plane of polarisation by sugar solutions.

SUMMARY

Sugar solutions are optically active, in other words they rotate the plane of polarisation of any linearly polarised light that is passed through them. The direction of rotation depends on the molecular properties of the sugar. Thus, solutions of glucose and saccharose (sucrose) rotate the plane of polarisation to the right (clockwise), whereas fructose solutions rotate it to the left (anti-clockwise), as found when the angle of rotation is measured with a polarimeter. The experiment also includes measuring the angle of rotation to study the behaviour of a saccharose solution when hydrochloric acid is added. This causes a gradual reversal ("inversion") of the direction of rotation from clockwise to anti-clockwise, as the double-ring structure of the saccharose molecule is split into two, giving an equimolar mixture of glucose and fructose. The angle of rotation of the mixture is the sum of the angles of rotation of the dextro-rotatory glucose and the more strongly laevo-rotatory fructose.

REQUIRED APPARATUS

Quantity	Description	Number
1	Polarimeter with 4 LEDs (230 V, 50/60 Hz)	**1001057** or
	Polarimeter with 4 LEDs (115 V, 50/60 Hz)	**1001056**
1	Graduated Cylinder, 100 ml	**1002870**
1	Beaker	**1002872**
1	Electronic Scale Scout Pro 200 g (230 V, 50/60 Hz)	**1009772** or
	Electronic Scale Scout Pro 200 g (115 V, 50/60 Hz)	**1003426**

Additionally required:

	Fruit Sugar (Fructose), 500 g	***
	Grape Sugar (Glucose), 500 g	***
	Cane Sugar (Sucrose), 500 g	***

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BASIC PRINCIPLES

The term optical activity is used to describe the rotation of the plane of polarisation of linearly polarised light when it passes through certain substances. This rotation is observed in solutions of chiral molecules such as sugars and in certain solids such as quartz. Substances that rotate the plane of polarisation to the right (i.e., clockwise) as viewed against the direction of propagation of the light are described as dextro-rotatory, whereas substances with the opposite behaviour are described as laevo-rotatory. Glucose and saccharose solutions are dextro-rotatory, whereas fructose solutions are laevo-rotatory.

The angle α through which the plane of polarisation is rotated by a solution depends on the nature of the dissolved substance, and it is proportional to the concentration (mass per unit volume) c and to the length or thickness d of the sample. The relationship is expressed as:

(1) $$\alpha = [\alpha] \cdot c \cdot d$$

where $[\alpha]$ is called the specific rotation of the dissolved substance.The specific rotation depends on the wavelength λ of the light and the sample temperature T, and the relationship has the form:

(2) $$[\alpha] = \frac{k(T)}{\lambda^2}$$

Values of $[\alpha]$ in published tables are usually given for yellow sodium light at an ambient temperature of 25°C. If $[\alpha]$ is known, the concentration of a solution can be determined by measuring the angle of rotation in a polarimeter.

In the experiment, measurements are made on solutions of different sugars in a polarimeter under different conditions, and the angles of rotation are compared. The colour of the light can be changed by choosing between four LEDs. The effect of adding hydrochloric acid to a solution of ordinary cane sugar (saccharose) is also investigated. This causes a slow reaction whereby the double-ring structure is split to give an equimolar mixture of glucose and fructose. During this process the direction of rotation becomes "inverted" from clockwise to anti-clockwise, because the angle of rotation after completion of the reaction is the sum of the angles of rotation of the dextro-rotatory glucose and the more strongly laevo-rotatory fructose.

EVALUATION

According to Equation (1), the angle of rotation of a solution of a given substance at a fixed concentration is proportional to the length of the sample, whereas for a fixed sample length it is proportional to the concentration. From the gradients of the straight lines through the origin in Figure 1, the specific rotation for each of the four wavelengths provided by the polarimeter can be calculated.

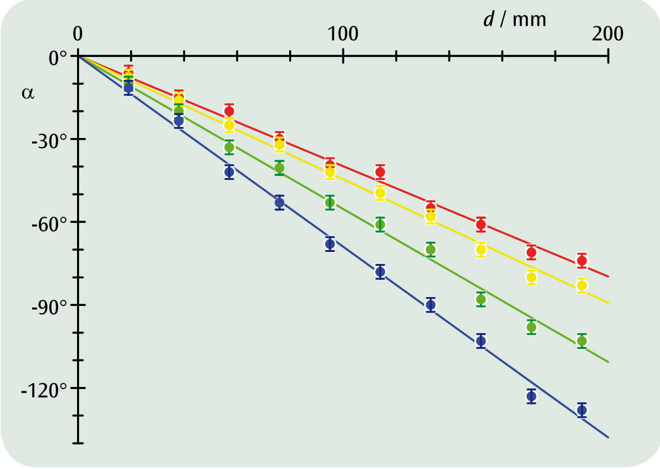

Fig. 1: Angle of rotation of a fructose solution (c = 0.5 g/cm³) as a function of sample length for four different light wavelengths.

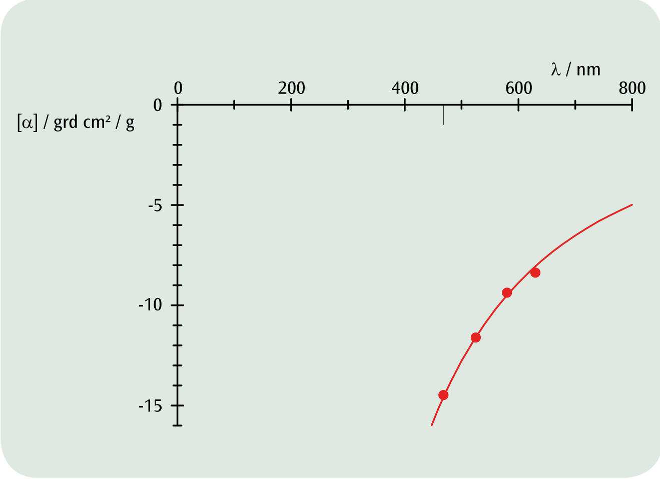

Fig. 2: Dependence of specific rotation on wavelength.

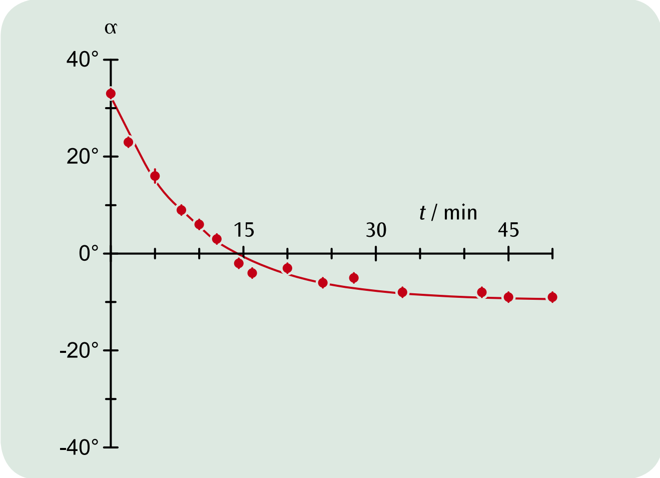

Fig. 3: Angle of rotation of a saccharose solution (c = 0.3 g/cm³, d = 190 mm) during the inversion process as a function of time.