A 33 Specific rotation of sucrose in solution – inversion of sucrose

Task:

1. Determine the angle of rotation α of sucrose for the following concentrations of sucrose β = 0.05 g/ml, 0.10 g/ml, 0.15 g/ml, and 0.20 g/ml in aqueous solution.
2. Determine the rate constant k of the sucrose inversion in s^{-1}.

Basics:

a) Specific rotation of sucrose in solution:

For linearly polarized light the vector of the electric field $\vec{E}$ oscillates in one plane. Optically active compounds rotate the plane of oscillation of linearly polarized light. The angle of rotation α where the plane of oscillation is rotated around can be measured with a polarimeter. The optically active compound is placed between polarizer and analyzer. The intensity of the light behind the analyzer is thereby proportional to the concentration of the optically active compound in solution, i.e.

$$\alpha = \alpha^* \cdot l \cdot \beta \qquad (1)$$

l: penetrated path length (l = 20 cm in this experiment)

β: mass concentration of the optically active compound

α^*: specific rotation

As α depends on the frequency of light, monochromatic light will be used in this experiment at a wavelength of 589 nm.

b) Inversion of sucrose:

Sucrose hydrolyses in acid solution as a first order reaction into glucose and fructose (so-called invert sugar).

$$C_{12}H_{22}O_{11} + H_2O \xrightarrow{H^+} C_6H_{12}O_6 + C_6H_{12}O_6$$

Saccharose D-glucose D-fructose

In a first order reaction the change of the concentration c of the reactant reads

$$\frac{dc}{dt} = -kc \tag{2}$$

After separation of variables integration leads to

$$c = c_0 e^{-kt} \tag{3}$$

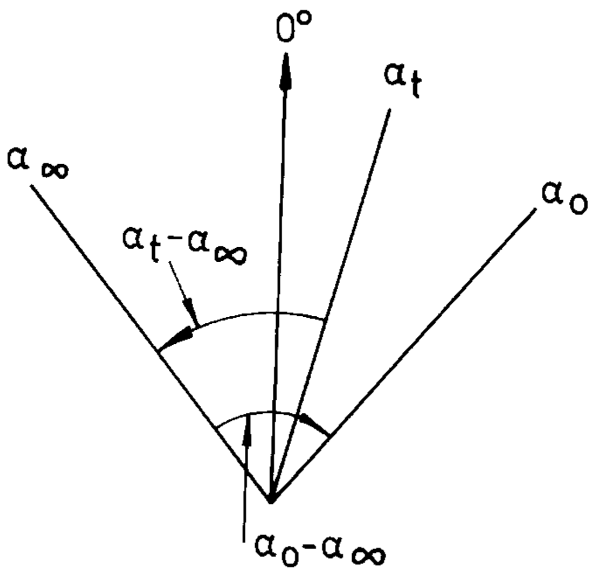
$$ln\left(\frac{c}{c_0}\right) = -kt \tag{4}$$

k: rate constant

c: concentration at time t

c_0: concentration at time t = 0

Sucrose rotates the plane of oscillation of linearly polarized light to the right, invert sugar to the left. The time-dependent change of the optical rotation is used to follow the chemical reaction.



α_0: angle of rotation at time t = 0

α_t: angle of rotation at time t

α_∞: angle of rotation after complete inversion at time t = ∞

The total change of the angle of rotation $(\alpha_0 - \alpha_\infty)$ is proportional to the total concentration of sucrose. The change of the angle of rotation $(\alpha_t - \alpha_\infty)$ up to time t results in a measure of the converted amount of sucrose

$$c_0 \sim (\alpha_0 - \alpha_\infty) \tag{5}$$
$$c_t \sim (\alpha_t - \alpha_\infty) \tag{6}$$

After insertion equation (5) and (6) into equation (3) one obtains

$$ln\left(\frac{\alpha_t - \alpha_\infty}{\alpha_0 - \alpha_\infty}\right) = -kt \tag{7}$$

By plotting $ln\left(\frac{\alpha_t - \alpha_\infty}{\alpha_0 - \alpha_\infty}\right)$ vs. time t one can determine the rate constant k from the linear slope.

<u>Experimental procedure:</u>

Please find a more detailed instruction in the tutorial supplied locally at the experiment. The operation of the device will be discussed with the supervisor. In order to determine the angle of rotation the tube will be filled with the respective solutions. After closing, the tube will be placed inside the measurement setup. Please pay attention that unavoidable air bubbles completely remain in the spherical thickening of the tube.

The polarimetric control panel will be focused with the eye's lens. The fractional shadows of the observation panel are to be aligned to the same shadiness using the control knobs for coarse and fine operation.

ad task 1:

Start by preparing two solutions with β = 0.20 g/ml and 0.15 g/ml in a 100 ml flask each. The other two solutions are quickly obtained via dilution with a corresponding amount of H_2O. Determine the temperature of the corresponding solutions.

ad task 2:

Use the remaining solution of task 1 for β = 0.15 g/ml and pipette 25 ml into an Erlenmeyer flask. Pipette another 25 ml of a 2 M hydrochlorid acid solution in a second Erlenmeyer flask. Join both solutions, mix them and return them into flask 1 for purging. Determine the temperature and fill the measuring cuvette without bubbles and free from reams. The measurement starts after infilling into the measuring cuvette and determination of the first value (α_0; do not forget to trigger a stop watch). Observe the angle of rotation α_t for roughly 1 hour (first shorter, later longer time intervals).

In order to determine the angle of rotation α_∞ for complete inversion heat up the remaining part of the sugar-HCl solution in a third flask under closed conditions ca. 30 minutes to 60 °C in a water bath (no overheating!). Let the solution cool down to room temperature (put the flask in cold water), fill in the cuvette and determine the angle of rotation.

<u>Data analysis:</u>

ad task 1:

1. Plot the angle of rotation α vs. β in a graph and calculate the specific rotation α^* from the linear slope.
2. Perform an error calculation and compare your results with literature data.

ad task 2:

3. Draw the following graph: $ln\left(\frac{\alpha_t-\alpha_\infty}{\alpha_0-\alpha_\infty}\right) = -kt$

   Determine the rate constant k in s^{-1} of the sucrose decomposition from the linear slope.
4. Discuss the measurement errors and the influence of temperature.

<u>What one should know:</u>

Linear, circular and elliptical polarized light, Nicol prism, optical activity, rotational dispersion, operating mode of a polarimeter, rate laws, order of reaction, application of polarized light in practice.