1. Chemical kinetics

1.a. Measurement of sucrose inversion in acidic solution

The decomposition of sucrose into glucose and fructose in water (so-called inversion of sucrose) is a reaction that can be accelerated by acidic catalysis:

$$C_{12}H_{22}O_{11} + H_2O \xrightarrow{H^+} C_6H_{12}O_6 + C_6H_{12}O_6 \qquad (1.1.)$$

In excess of water, it is a pseudo-first order reaction and the rate equation is given by the expression:

$$v = -\frac{dc}{dt} = k \cdot c \qquad (1.2.)$$

where c is the sucrose concentration, t means time, and k is the velocity constant of the acid catalysed reaction. With respect to the catalyst concentration, the following applies:

$$k = k_0 + k_1\left[H^+\right] \qquad (1.3.)$$

where k_0 is the rate constant in pure solvent (*H_2O*) that is practically negligible, k_1 is the rate constant of the reaction that is homogeneously catalysed by hydrogen ions of concentration $[\mathrm{H}^+]$.

The first-order rate constant is given by the relationship:

$$k = \frac{1}{t}\ln\frac{c_0}{c} \qquad (1.4.)$$

where c is sucrose concentration at time t from the reaction beginning (ie from acidification of the solution), c_0 is the initial sucrose concentration.

The sucrose solution turns the plane of polarized light clockwise while the equimolar mixture of the fructose and glucose turns the light counter-clockwise after complete reaction. We can detect a shift from initial angle α_0 of polarized light to final angle α_∞.

The fraction c_0/c in relation (1.4.) can be replaced by a fraction, which depends on the angle rotation of the plane of light α_t at time t:

We obtain relationship:

$$k = \frac{1}{t}\ln\frac{\alpha_0 - \alpha_\infty}{\alpha_t - \alpha_\infty} \qquad (1.5.)$$

where α_∞ can be determined either after a few days when the reaction is completed, or by computing using empirical equation:

$$\alpha_\infty = -[0.20695 + 0.00004 \cdot c_0 - 0{,}0032(\tau - 20)] \cdot c_0 \cdot l \qquad (1.6.)$$

where c_0 is given in unit *g/dm^3*, τ is the solution temperature in °C and l is the polarimetric tube length in meters.

The rearranging of eqn (1.5.) gives:

$$t = \frac{1}{k}\ln\left(\alpha_0 - \alpha_\infty\right) - \frac{1}{k}\ln\left(\alpha_t - \alpha_\infty\right) \qquad (1.7.)$$

which is a linear dependence t on $ln(\alpha_0 - a_\infty)$ that allows to determine the rate constant k from the slope of the regression line.

? **TASK:** Measure the turning of the polarized light during the inversion reaction of sucrose and evaluate the rate constant at two different concentrations of the catalyst.

LABORATORY AIDS AND CHEMICALS: polarimeter, *2* polarimetric cells, weighting boat, stopwatch, *2* volume pipettes (*20 cm³*), volumetric flask (*100 cm³*), *3* Erlenmeyer flasks (*100 cm³*), sucrose, *4 M HCl* and *2 M HCl*.

INSTRUCTIONS: Switch polarimeter on and get to know with instrument operating manual.

Prepare $100ml$ of stock solution by dissolving *20 g* (accurate to *0.05g*) of sucrose in water (use *100 cm³* volumetric flask).

Take in Erlenmeyer flask and mix *20 cm³* of sucrose stock solution with *20 cm³* of water and mix thoroughly. Fill the polarimetric cuvette with the solution. Insert the cuvette into the polarimeter (see scheme in **FIGURE 1**) and measure the starting angle of the plane of polarized light for the sucrose solution. Empty the polarimetric cuvette and rinse it with distilled water.

Prepare the reaction solution in Erlenmeyer flask by mixing $20\ cm^3$ of stock solution of sucrose and $20\ cm^3$ of $4\ M\ HCl$. Mix the solutions quickly and intensively. Start the stopwatch immediately. Rinse out the polarimetric cell with small amount of reaction solution. Finally, pour the reaction solution up to cuvette marking and do measuring the plane of the polarised plane of light in *5* minute intervals within one hour. Measure the angle also at time *80*, *100* and *120* minutes.

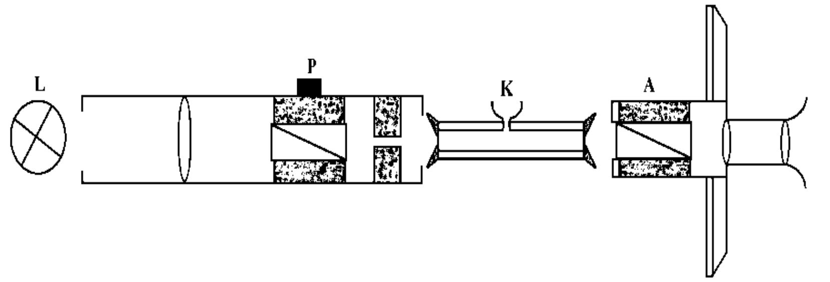

FIGURE 1: Scheme of polarimetric measurement. L-sodium lamp, P-polarizer, A-analyser, K-cuvette with sucrose solution.

Similarly prepare a reaction solution applying $2\ M\ HCl$ and use same procedure as before. The rotation changes of both reaction mixtures can be measured simultaneously at shifted times.

REPORT: weight of sucrose, value α_∞ and temperature τ used for evaluation of it. **Table 1a** and **1b**: for both experiments at different $[H^+]$ concentration: time *t*, angle α_t , $ln(\alpha_t - \alpha_\infty)$. **Common graph 1:** for both $[H^+]$ concentrations: time dependency of angle α_t. **Common graph 2:** for both $[H^+]$ concentrations: dependency t on $ln(\alpha_t - \alpha_\infty)$. **Next:** Evaluation of rate constants k at variable $[H^+]$ and their confidence intervals. Evaluation of rate constants k_0 and k_1 by solution of two equations with two unknowns (use eqn (1.3.)).