C 141 (Experiment No.___)

NAME : ________________________________ BATCH : _________

ROLL No. : ____________________________ SEM: _________

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STUDY OF THE KINETICS OF INVERSION OF CANE SUGAR, CATALYZED BY ACID, POLARIMETRICALLY

AIM

To study the kinetics of inversion of cane sugar, catalyzed by acid, polarimetrically.

THEORY

A solution of sucrose is optically active, that is, it has the ability to rotate the plane of polarization. It is dextro-rotatory, which means that it can rotate the plane of polarization of the plane polarized light in a clockwise manner.

Fructose is laevo-rotatory, which means that it can rotate the plane of polarization of the plane polarized light in an anti-clockwise manner. Glucose is dextro-rotatory, and the mixture of products has the resultant laevo-rotatory.

The angle of rotation depends on : (a) temperature ; (b) wavelength of light used; (c) length of the liquid column through which the light passes ; (d) nature of the substrate.

In order to indicate the rotatory power of the liquid or solution, we have to define a quantity known as **SPECIFIC ROTATION.**

The specific rotation of a substance (solute in solution) is given by :

$$[\ \alpha\ ]_{\lambda} = 100\ \alpha / c\ l \qquad (1)$$

where 'α' is the angle of rotation, 't' is the temperature, 'λ' is the wavelength of light used, 'l' is the length of the liquid column (in decimeters), 'c' is the concentration of the solution (i.e., 'c' gram of substance present in 100 ml of solution).

MATERIALS REQUIRED

Polarimeter with polarimeter tube ; sodium vapour lamp; hot water bath; standard volumetric flasks (100ml, 50 ml); 100 ml measuring cylinders; 250 ml stoppered reagent bottles; 250 ml stoppered conical flasks; Burette (50 ml); Pipette (10 ml, 20 ml); sucrose (20%); fructose (5%); 2N HCl solution.

PART – I
(Determination of Specific Rotation)

PROCEDURE

1. A stock solution of 5% fructose is prepared (5 g in 100 ml water).
2. The polarimeter is set up with the sodium vapour lamp.
3. The polarimeter tube is cleaned and filled with distilled water, taking care to exclude any air bubbles.
4. The "analyzer" of the polarimeter is rotated using the rough and fine adjustments, until the field of view is uniformly dark. This reading is taken. Readings in both the semi-circles of the scale are taken, and the mean of the readings are taken, after applying the correction. Let this reading be taken as 'a'.
5. The distilled water is removed from the polarimeter tube. The tube is rinsed and filled with 5 % fructose solution. Step (4) is repeated. Let this reading be taken as 'b'.
6. Step (5) is repeated with 1 %, 2 %, 3 % , 4% solutions, and for the unknown solution.
7. The angle of rotation (α) would correspond to (b – a). That is, α = (b – a).

OBSERVATIONS AND CALCULATIONS

Room Temperature = ……. ºC

Wavelength of light = 5893 Aº ; Length of Polarimeter Tube (l) = 2. 0 dm

Zero-reading with water, 'a' = ……..... deg ; Instrumental error = ... deg

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Table 1 : Determination of Specific Rotation of Fructose

Sl. No.	Fructose (%)	Polarimeter Readings Clockwise (MS)	(VS)	(T)	Anti-clockwise (MS)	(VS)	(T)	Mean Value (b)	Corrected Value $\alpha = (b-a)$	$[\alpha] = \frac{100\,\alpha}{c\,l}$
1	5									
2	4									
3	3									
4	2									
5	1									
6	Unk									

(MS = Main Scale ; VS = Vernier Scale ; T = Total Reading)
Average Specific rotation, [α] = __________________
Plot a graph of concentration (c) versus angle of rotation (α).

$$Slope = [\alpha]\, l / 100 \Rightarrow [\alpha] = (slope \times 100) / l$$

From the rotation of the unknown solution, the concentration of the unknown solution can be determined.

RESULTS

1. Specific Rotation of Fruit Sugar at …... ºC = …….....… degree
2. Concentration of Unknown Solution = ………… %

PART – II
(Determination of Specific Rate Constant)

AIM

To determine the specific rate constant for the hydrolysis of sucrose, in the presence of acid, using polarimetry.

THEORY

Sucrose is dextro-rotatory. In the presence of acid (e.g. HCl), sucrose is hydrolysed to give an equimolar mixture of glucose (d-) and fructose (l-) :

$$C_{12} H_{22} O_{11} + H_2O \xrightarrow{H^+} C_6 H_{12} O_6 + C_6 H_{12} O_6 \qquad (2)$$

The course of the reaction (inversion of sucrose) is followed by observing the change in optical rotation of sucrose, as a function of time. Since water is taken in large excess, the active mass of water remains constant. Hence, the concentration of sucrose changes during the reaction.

Therefore, the reaction is a pseudo first order reaction.

$$dx / dt = k_1 [H_2O] [\text{ sucrose }] = k [\text{ sucrose }] \qquad (3)$$

If 'a' is initial concentration of sucrose, 'x' the amount decomposed, then (a – x) is the fraction of sucrose remaining after time t .Therefore, $dx / dt = k (a - x)$ (4)

Rearranging and integrating eq. (4), we get

$$k = \frac{2.303}{t} \log \frac{a}{(a - x)} \qquad (5)$$

If α_o : initial angle of rotation; α_t : angle of rotation at time t, α_∞ : angle of rotation after completion of the reaction, then

$$a \;\alpha\; (\alpha_o - \alpha_\infty) ; \; x \;\alpha\; (\alpha_o - \alpha_t) ; \text{ and } (a - x) \;\alpha\; (\alpha_t - \alpha_\infty)$$

$$k = \frac{2.303}{t} \log \frac{(\alpha_o - \alpha_\infty)}{(\alpha_t - \alpha_\infty)} \qquad (6)$$

PROCEDURE

The Specific Rotation of 20% sucrose is determined by using part – I.

1. 50 ml of 20 % sucrose solution is taken in a 250 ml stoppered reagent bottle.
2. 50 ml of 2N HCl solution is added. The mixture is shaken well.
3. The polarimeter tube is rinsed quickly with this solution, and then filled. The reading is taken which corresponds to α_o .
4. Readings are taken at regular intervals of time (2, 5, 10, 15, 25, 35, 45, 60 minutes). Each reading corresponds to α_t .
5. The remaining solution is taken in a stoppered conical flask, heated to 60ºC, for 5 min.
6. The solution is allowed to cool to room temperature for 5-10 min, and is taken into the polarimeter tube and the reading is taken. This reading corresponds to α_∞ .
7. Steps (5), (6) and (7) are repeated till concurrent values of α_∞ are obtained.

OBSERVATIONS AND CALCULATIONS

Room Temperature = …….ºC

Concentration of HCl = ...

Table 2 : Determination of Specific Rate Constant (k) for the hydrolysis of Sucrose

S.No.	Time (min)	Polarimeter Reading	$(\alpha_t - \alpha_\infty)$	$\frac{(\alpha_o - \alpha_\infty)}{(\alpha_t - \alpha_\infty)}$	$\log \frac{(\alpha_o - \alpha_\infty)}{(\alpha_t - \alpha_\infty)}$	$k = \frac{2.303}{t} \log \frac{(\alpha_o - \alpha_\infty)}{(\alpha_t - \alpha_\infty)}$ (min^{-1})
1	0	αo				
2	2	α_t				
3	5					
4	10					
5	15					
6	20					
7	25					
8	35					
9	45					
10	60					
11	∞	α_∞				

Then, α = (b-a) = ...

where 'a' is the zero reading for water and 'b' is the reading for 20 % sucrose solution.

Mean Value of 'k' = ...

Graphical Value of 'k' = ...

Specific Rotation of Sucrose solution, [α] = ...

Plot a graph of $\log \frac{(\alpha_o - \alpha_\infty)}{(\alpha_t - \alpha_\infty)}$ versus time (t).

From the graph, slope = k / 2.303

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NOTE

Show each and every calculation with proper formulas, units, scale & graph etc.,
Handle the instrument and apparatus with care.
Prepare the solutions with utmost care and take the readings without parallax error.

RESULTS

1. Specific Rotation of Sucrose at …….... °C = …….…... degrees.

2. Rate Constant (k) for the hydrolysis of Sucrose, in the presence of 2 N HCl, at ……. °C,

Theoretical value of k = ……………… min^{-1} .

Graphical value of k = ……………… min^{-1} .

3. Comment on the nature of the graph(s) and the result.

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