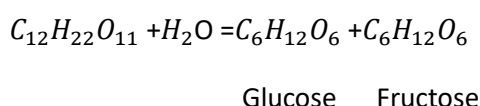


Using a polarimeter , determine the rate constant for the acid catalysed inversion of sucrose using the supplied catalyst solution at room temperature

Theory:- For the acid catalysed hydrolysis of sucrose( $C_{12}H_{22}O_{11}$ ) the following reaction is involved.



(1)The optical rotation for sucrose is  $+66.5^\circ$  but for glucose and fructose the values are  $+52.7^\circ$  and  $-92^\circ$  for glucose and fructose respectively so , basically after the hydrolysis of sucrose there will be a conversion from 'dextrorotatory' to laevorotatory and the change / inversion in the values for the optical rotation is termed as inversion. Theory(1)=1

(2)If we write the rate equation of the above reaction then it will be ,

$$\text{Rate} = -\frac{d}{dt}[\text{sucrose}] = k[\text{sucrose}]$$

[under experimental condition]

From the reaction, one may think that this reaction will be Second order i.e first order w.r.t sucrose and first order w.r.t water individually .Now, for this reaction water concentration is high enough (hence avoided)

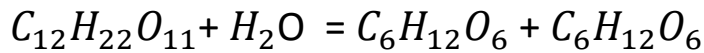
Now, this rate of the hydrolysis reaction is increased in presence of strong acid (i.e HCl say) but, as  $H^+$  ion is not involved in this reaction , hence, we can say , this is basically a pseudo-first order reaction .

Now, if we prepare two different solution where the acid  $conc^n$ s are different say  $[acid]_1$  and  $[acid]_2$  and the value

of the rate constant are  $K_1$  and  $K_2$  respectively then it is observed that ,

$$\frac{K_1}{K_2} = \frac{[acid]_1}{[acid]_2}$$

From the above relation, one may easily conclude that this reaction is linearly dependent on  $H^+$  ion  $conc^n$  .Hence, basically the catalyst which is used is nothing but a homogeneous catalyst in nature.



t=0	a	0	0
t =t	a-x	x	x
t =∞	0	a	a

where , a = amount of sucrose taken

x = amount of sucrose hydrolysed.

From the rate equation written before the following equation can be written,  $-\frac{d}{dt}(a - x) = k(a - x)$

$$\therefore \frac{dx}{dt} = k(a-x) \text{-----(1)}$$

On integrating the equation (1)

$$\log_{10} \left( \frac{a}{a-x} \right) = \frac{k}{2.303} (t_n - t_1) \text{-----(2)}$$

Where,  $t_n$  and  $t_1$  are the time of the  $n^{th}$  reading and first readings taken respectively.

If the amount of sucrose taken and hydrolysed at different time intervals  $t_1, t_2, t_3, \dots, t_n$  are  $(a - x_1), (a - x_2), (a - x_3), \dots, (a - x_n)$  and  $x_1, x_2, x_3, \dots, x_n$  then equation (2) transformed

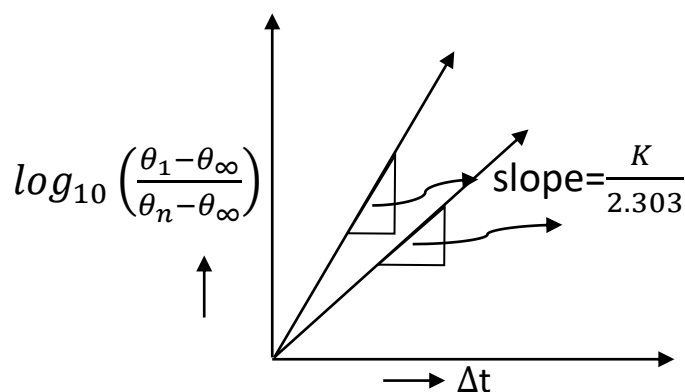
to the following eq<sup>n</sup>  $\log_{10} \left( \frac{a-x_1}{a-x_n} \right) = \frac{k}{2.303} (t_n - t_1) \text{-----(3)}$

Now, the optical rotation of sucrose is proportional to the amount of sucrose taken and if the optical rotation values at different time intervals be  $\theta_0, \theta_1, \theta_2, \dots, \theta_n$  then we can substitute the (3) to the following mathematical form,

$$\log_{10} \left( \frac{\theta_1 - \theta_\infty}{\theta_n - \theta_\infty} \right) = \frac{K}{2.303} (t_n - t_1)$$

$$\left[ \begin{array}{l} A_\infty, (\theta_0 - \theta_\infty) \text{ is proportional to } a, (\theta_1 - \theta_\infty) \\ \text{is proportional to } (a - x_1) \text{ and} \\ \text{similarly } (\theta_n - \theta_\infty) \text{ is proportional to } (a - x_n) \end{array} \right]$$

equation (4) is the basic fundamental working eq<sup>n</sup> of this experiment.



Now, if we plot  $\log_{10} \left( \frac{\theta_1 - \theta_\infty}{\theta_n - \theta_\infty} \right)$  vs  $\Delta t$  then a straight line will be observed starting from origin and the slope will be  $\frac{K}{2.303}$  for the st. Line multiplying slope of the st. line with 2.303 we can evaluate the rate constant of the rx<sup>n</sup>.  $\text{slope} = \frac{K}{2.303} \therefore k = 2.303 \times \text{slope}$ .

## B. Experimental data:-

### 1. Room temperature:-

Temp. Before exp(°C)	Temp. After exp(°C)	During exp. mean temp(°C)
31°C	31°C	31°C

## 2. Preparation of a 100 ml 30 %(w/v) sucrose solution

~30 gm sucrose was measured on a rough balance in a 250 ml beaker and then 100ml distilled water was added in portions to the 250 ml beaker and the mixture was stirred till a homogenous solution of ~30% (w/v) sucrose solution was prepared.

3. Reading for water:- Water was filled in the polarimeter tube and the optical rotation value was recorded. The recorded value was used for future correction of all rotation values.

Optical rotation value for water =  $0^\circ$

Therefore, for all the other readings there will be no correction in the optical rotation values for different solutions.

## 4. preparation of experimental solution (set-A):-

25 ml of sucrose solution was pipette out in a dry 100ml conical flask. Then 25 ml of the supplied catalyst (PA-) was added to it by using another 25 ml pipette and the stopwatch was started at the time of half discharge.

## 5. Optical rotation values for set- A solution at different time interval:-

The optical rotation for water  $\equiv 0^\circ \equiv \theta_{H_2O}$

Time (min)	Time (sec)	Angle of optical (degree)( $^\circ$ )	Corrected angle of optical (degree)( $^\circ$ )
1 min37 sec	97	$19.52^\circ$	$19.52^\circ$
4 min40 sec	280	$17.16^\circ$	$17.16^\circ$
7 min35 sec	455	$14.48^\circ$	$14.48^\circ$
15 min9 sec	909	$8.44^\circ$	$8.44^\circ$
18 min32sec	1112	$6.12^\circ$	$6.12^\circ$
22 min 27 sec	1347	$4.10^\circ$	$4.10^\circ$

26 min58 sec	1618	3.1°	3.1°
29 min25 sec	1765	1.69°	1.69°
32 min 04 sec	1924	0.64°	0.64°

6. Reading for the  $\theta_{\infty}$  for the set –A solution :-

The remaining part of the reaction mixture (set-A solution) was refluxed by fitting the conical with an air condenser in water bath for about 45 minutes (such that the temperature never rises above 60°C)

Corrected  $\theta_{\infty}$  for set-A solution  $\equiv 354.71^{\circ} \equiv (354.71^{\circ} - 360^{\circ}) \equiv -5.29^{\circ}$

7. Preparation of the experimental solution (set-B):-

25 ml of the sucrose solution was taken in a dry 100ml conical flask. Then 25 ml of the supplied catalyst (PB-)was added to it by using another 25 ml pipette and the stopwatch was started at the time of half discharge .°

8. Optical rotation values for set-B solution at different time interval:

The optical rotation value for  $H_2O = \theta_{H_2O} = 0^{\circ}$

Time (min)	Time (sec)	Angle of optical (degree)(°)	Corrected angle of optical (degree)(°)
1 min50 sec	110	19.24°	19.24°
4 min57 sec	297	16.3°	16.3°
7 min44 sec	464	14.18°	14.18°
11 min38sec	698	11.38°	11.38°
17 min 54 sec	1074	8.08°	8.08°
21min18 sec	1278	6.32°	6.32°
24 min11 sec	1451	4.24°	4.24°
29min 02 sec	1742	3.12°	3.12°

∴ Corrected  $\theta_{\infty}$  value for set- B solution  $\equiv - 5.29^{\circ}$

Set-A solution		Set-B solution	
$\text{Log}\left(\frac{\theta_1 - \theta_\infty}{\theta_n - \theta_\infty}\right)$	$\Delta t(\text{sec})$	$\text{Log}\left(\frac{\theta_1 - \theta_\infty}{\theta_n - \theta_\infty}\right)$	$\Delta t(\text{sec})$
0	0	0	0
0.0434	183	0.0554	187
0.0986	358	0.1003	354
0.2569	812	0.1677	588
0.3373	1015	0.2635	964
0.4219	1250	0.3248	1168
0.4708	1521	0.4106	1341
0.5507	1668	0.4649	1632
0.6215	1827		

### 11. Calculation:-

From the graph for set A solution,

$$\text{slop} = \frac{\Delta y}{\Delta x} = \frac{AB}{BC} = \frac{39 \times 0.004}{59 \times 8 \text{ sec}} = 3.305 \times 10^{-4} \text{ sec}^{-1}$$

rate const(k) for set –A solution= slope  $\times 2.303$

$$\therefore K_1 = 3.305 \times 10^{-4} \times 2.303 \text{ sec}^{-1}$$

$$= 7.6116 \times 10^{-4} \text{ s}^{-1}$$

$$=7.6116 \times 10^{-4} \times 60 \text{ min}$$

$$=0.04566 \text{ min}^{-1} \text{ (at } 31^\circ\text{C)}$$

from the graph for set-B solution,

$$\text{slope} = \frac{\Delta y'}{\Delta x'} = \frac{A'B'}{B'C'} = \frac{36 \times 0.004}{64 \times 8 \text{ sec}} = 2.8125 \times 10^{-4} \text{ s}^{-1}$$

rate constant (k) for set-B solution = slope  $\times 2.303$

$$\therefore k_2 = 2.8125 \times 10^{-4} \times 2.303 \text{ sec}^{-1}$$

$$= 6.477 \times 10^{-4} \text{ sec}^{-1}$$

$$= 6.477 \times 10^{-4} \times 60 \text{ min}^{-1}$$

$$= 0.038 \text{ min}^{-1} \text{ (at } 31^\circ\text{C)}$$

$$\therefore \text{Ratio of the two sets of different solution} = \frac{k_1}{k_2}$$

$$= \frac{0.04566 \text{ min}^{-1}}{0.038 \text{ min}^{-1}}$$

$$= 1.2018 \text{ (at } 31^\circ\text{C)}$$

12 result :-

(1) The rate constant for set-A solution =  $0.04566 \text{ min}^{-1}$  (at  $31^\circ\text{C}$ )

(2) the rate constant for set-B solution =  $0.038 \text{ min}^{-1}$  (at  $31^\circ\text{C}$ )

$$= 6.477 \times 10^{-4} \text{ s}^{-1} \text{ (at } 31^\circ\text{C)}$$