UNIVERSITY of SAN CARLOS
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Department of Chemical Engineering

Data Processing and Analysis Report

Laboratory Course	:	CHE2204L
Experiment Title	:	Inversion of Sucrose
Group Code	:	CHE2204L01WED
Students' Name & Signature	:	Cabo, Jae Michelle.
		Sumarago, Erwin
		Talandron, Rhoel
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Teacher	:	Engr. May V. Tampus
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Data Processing and Results	**Grade**
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Data Analysis and Interpretation (x 0.40)	
Grade	

Assessed and Graded By: Engr. May V. Tampus

(Signature over printed name)

Date and Time

Summary of Revisions

Comments	*Actions Taken*	*Status of Implementation*	*Teacher's Remarks*
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Inversion of Sucrose

Objectives of the Experiment

1. To determine the change in the angle of rotation with time using a polarimeter
2. To determine the reaction order of the acid-catalyzed inversion of sucrose using a polarimeter
3. To determine the reaction rate constant of the acid-catalyzed inversion of sucrose from the change in the angle of rotation

Results & Discussion

Objective 1:

Sucrose, commonly known as “table sugar” or “cane sugar”, is a carbohydrate formed from the combination of glucose and fructose. Sucrose is a disaccharide. A disaccharide is a molecule made of two monosaccharides. In the case of sucrose, the two monosaccharides are glucose and fructose. The structure of sucrose is shown below.

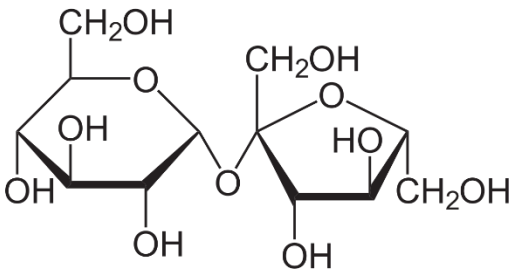

Figure 1. Structure of Sucrose

Glucose and fructose are connected by glycosidic linkages to form sucrose. As a combined molecule of two monosaccharides, sucrose has nine chirality centers. Chirality is a property that results from its structure. Chiral molecules are characterized by their property to rotate the plane of polarized light. Therefore, they are called optically active. The effect caused by this property is referred to **as** optical rotation. Sucrose is an optically active which in return, could rotate the plane of the polarized light to the clockwise direction (dextrorotatory) or to the counterclockwise direction (levorotatory).

Since sucrose is a disaccharide, it needs to undergo hydrolysis to break the whole molecule to two monosaccharides, glucose and fructose. In this experiment, sucrose was inverted to its

corresponding monosaccharides in the presence of an acid catalyst, hydrochloric acid (HCl). According to Ernest (2013), as the reaction proceeds, the optical rotation properties of sucrose and its corresponding components to change with respect to time.

To determine the change in angle of rotation with respect to time, a polarimeter was used. The polarimeter used was Atago POLAX-2L. The polarimeter was used to read the angle of rotation of the polarized light that passed through the sucrose solution. The sucrose solution contained optically active compounds: glucose and fructose. For substances that are optically active, a positive (+) angle of rotation would be observe if the substance of focus is dextrorotatory and a negative (-) angle of rotation would be observed for substances that are levorotatory. In contrast to optically active substances, optically inactive substances would have a zero-net angle of rotation. Consequently, no change of orientation would be observed.

Sucrose has a positive molar rotation and is dextrorotatory [+66.5^{o}]. On the other hand, fructose is levorotatory [-92.4^{o}] and glucose is dextrorotatory [+52.5^{o}]. Fructose has a greater molar rotation compared to that of glucose. Both fructose and glucose cause the overall mixture to be slightly levorotatory because of their respective optical properties. Consequently, as the products form, the rotation would be from right to left.

$$C = \frac{\alpha_{observed}}{[\alpha] \times L} \qquad \textbf{Eqn. 1}$$

Where

C= Amount of optically active substances

$\alpha_{observed}$ = Extent of rotation of light

α = Specific rotation

L =Length of polarized light

According to Daniels (1970), the extent of the rotation of polarized light in an optically active substance is proportional to the amount of optically active substances present in that solution. Moreover, the algebraic difference between the angle of rotation at any time, *t*, and the end reaction time, ∞, determines the concentration of sucrose.

Figure 2 shows how the angle of rotation changes with respect to time. The angle of rotation transitions from positive to negative since in the extent of the inversion reaction, the sucrose is consumed to form its monosaccharide counterparts, glucose and fructose. Consequently, the observed angle of rotation should remain constant as time passes and this indicates that the sucrose was already consumed forming the glucose-fructose mixture. The shifting of the angle was from dextrorotatory to levorotatory.

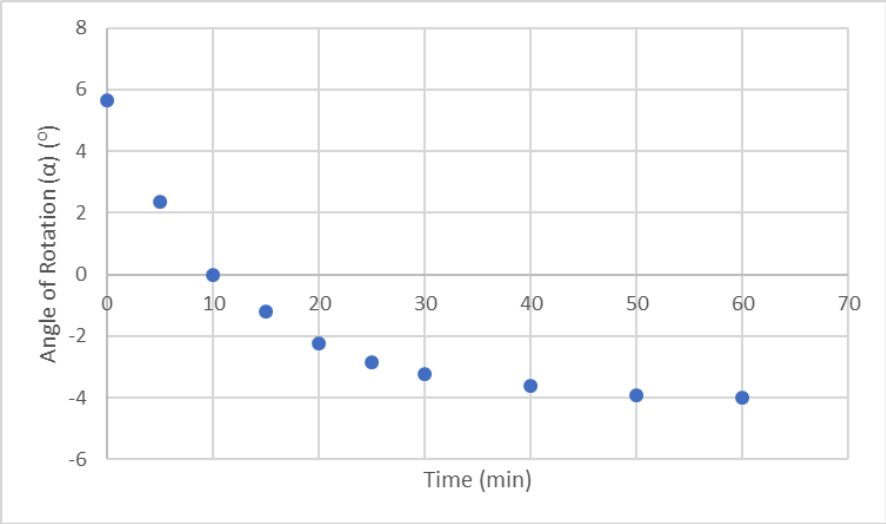

Figure 2. Angle of Rotation (α) (°) vs Time Graph

Objective 2:

For a hypothetical reaction shown below, the reaction speed is dependent on the concentrations of the reactants A and B.

$$aA + bB \rightarrow cC + dD \qquad \textbf{Eqn. 2}$$

This dependency could be expressed in a differential rate law. For the reaction above, the rate law would be:

$$\frac{dC}{dt} = k[A]^m[B]^n \qquad \textbf{Eqn. 3}$$

where *k* is the rate constant and the exponents *m* and *n* are the corresponding order for each reactant. Moreover, [A] and [B] corresponds to the concentrations of the reactants.

In this experiment, sucrose and water serves as the reactants which is then catalyzed by the hydrochloric acid (HCl). Supposedly, the inversion reaction would follow a second order reaction however, the concentration of water throughout the reaction changes negligibly. Moreover, the H^+ ions, from HCl, served as a catalyst only and is not consumed in the reaction. The rate law equation for the inversion of sucrose is shown below. This implies that the inversion of sucrose follows a First-Order Reaction and the speed of the inversion of sucrose depends only on the concentration of sucrose.

$$\frac{dC}{dt} = k[sucrose] \qquad \textbf{Eqn. 4}$$

The order of any reaction could be determined experimentally by graphing the gathered concentration data with respect to time. The reaction could follow a zeroth, first, or second order reactions. To identify the order of the reaction, logarithmic and squared values of the concentrations were computed and was plotted against time. The coefficient of determination (R) for each graph would determine how strong and related the gathered data are.

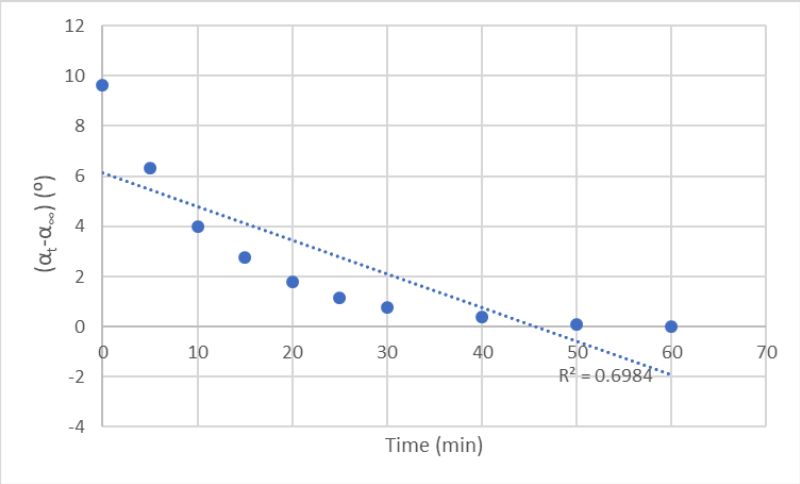

Figure 2. *(α_t-α_∞) vs. time graph*

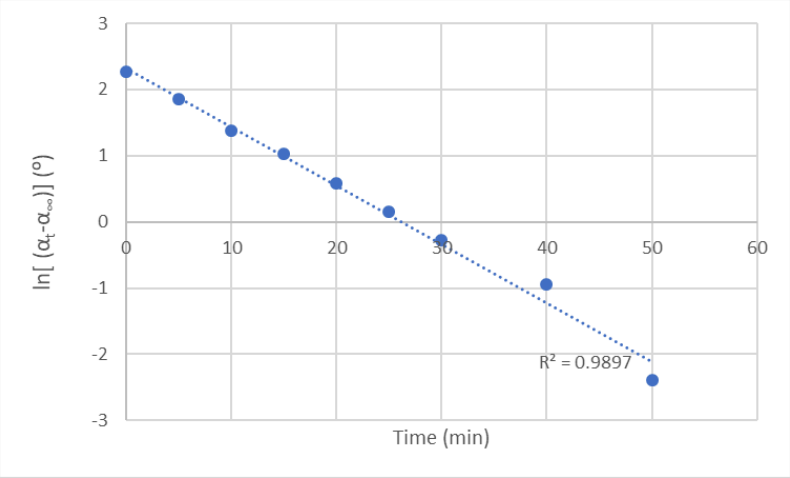

Figure 3. ln(α_t-α_∞) vs time graph

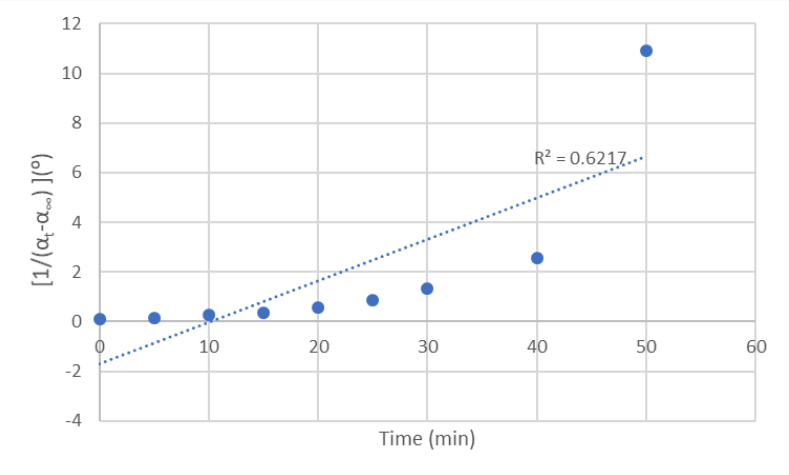

Figure 4. (α_t-α_∞)$^{-1}$ vs. time graph

Among the three graphs, Figure 3 has the strongest relationship among the gathered data with R^2=0.9897. This implies that the experiment data followed a first-order reaction which confirms the theoretical assumption that the inversion of sucrose is a first-order reaction.

Objective 3:

The reaction rate constant, *k*, describes how fast or slow the rate of the reaction is. When the value of *k* is large, the faster the rate of reaction is. On the other hand, if the value of *k* is small, the rate of reaction is slow. Moreover, the reaction rate constant does not only depend on the concentration of the species involved. Temperature affects the rate of reaction (Fogler, 2006). According to the Arrhenius collision theory, the activation energy for a certain reaction could be used to determine the temperature dependence of the whole reaction. Additionally, the theory stated that when a catalyst is incorporated in the reaction, the activation energy is lowered thus making the reaction insensitive to temperature change. In the experiment, the catalyst was HCl which in return, lowers the activation energy of the inversion process.

The inversion of sucrose follows the first order reaction where C is the sucrose concentration. Therefore, if we integrate the first-order rate law we get:

$$ln\frac{C}{C_0} = \quad - \ kt \qquad \textbf{Eqn. 5}$$

In the experiment, the angle of rotation was measured instead of the direct concentration of sucrose at any time t. The concentration of sucrose, C, could be expressed in terms of angle of rotation

$$C = \alpha_t - \alpha_\infty \qquad \textbf{Eqn. 6}$$

$$C_0 = \alpha_0 - \alpha_\infty \qquad \textbf{Eqn. 7}$$

If we substitute the above equations to the integrated law, the rate law would then be expressed in terms of angles of rotation.

$$ln\frac{\left(\alpha_o - \alpha_\infty\right)}{\left(\alpha_t - \alpha_\infty\right)} = - \ kt \qquad \textbf{Eqn. 8}$$

$$ln\left(\alpha_o - \alpha_\infty\right) = \quad - \ kt \ + \ln ln\left(\alpha_t - \alpha_\infty\right) \qquad \textbf{Eqn. 9}$$

Where

$$\alpha_0 = initial\ angle\ of\ rotation$$

$$\alpha_\infty = angle\ of\ rotation\ at\ the\ end\ of\ the\ reacion$$

$$\alpha_t = angle\ of\ rotation\ at\ time\ t$$

Applying the laws of logarithm, the integrated rate law would be arranged to create a linear equation, y=mx+b, where m is the reaction rate constant, *k*. The value of m, which is -0.0886 is the slope of the line in the figure below.

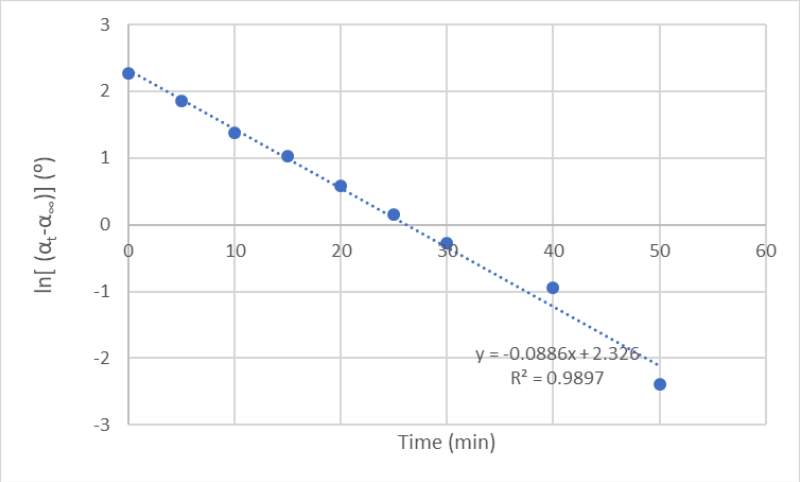

Figure 5. $\ln(\alpha_t-\alpha_\infty)$ vs time graph with Equation of the Line

[redacted]

In the process of inversion of sucrose, the angle of rotation is directly proportional to the concentration of sucrose. The angle of rotation transitions from a positive value towards a negative value as the reaction proceeds to completion. Moreover, the concentration of sucrose decreases as time increases. The inversion of sucrose is a first-order since the rate of reaction solely depends on the concentration of sucrose. The value of the reaction rate constant, *k*, was -0.0886.

Daniels, F., Williams, J., Becker, P., Alberty, R., Cornwell, C., & Harriman, J. (1970). *Experimental Physical Chemistry.* New York: McGraw-Hill.

Ernest, O. (2013). *INVERSION OF SUCROSE.* Ashanti: KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY.

Fogler, S. (2006). *Elements of Chemical Reaction Engineering.* USA: Pearson Education Inc.

APPENDIX 1: Raw Data

(Please See Attached)

APPENDIX 2: Processing of Data and Sample Calculations

Time, t (min)	Time, t (s)	Angle of Rotation (^{o})			α_o	α_∞	$(\alpha_t - \alpha_\infty)$ (^{o})	$\ln(\alpha_t - \alpha_\infty)$ (^{o})	$(\alpha_t - \alpha_\infty)^{-1}$ (^{o})
		Trial 1	Trial 2	Average (α_t)	(^{o})	(^{o})			
0	0	5.3	6	5.65	5.65	-4	9.65	2.266957915	0.103627
5	300	1.967	2.7167	2.34185	5.65	-4	6.34185	1.847170524	0.157683
10	600	0.05	-0.0667	-0.00835	5.65	-4	3.99165	1.384204679	0.250523
15	900	-1.3	-1.133	-1.2165	5.65	-4	2.7835	1.023709129	0.35926
20	1200	-2.167	-2.267	-2.217	5.65	-4	1.783	0.578297339	0.560852
25	1500	-2.767	-2.9	-2.8335	5.65	-4	1.1665	0.154007812	0.857265
30	1800	-3.2167	-3.267	-3.24185	5.65	-4	0.75815	-0.276874024	1.319
40	2400	-3.5	-3.7167	-3.60835	5.65	-4	0.39165	-0.937386695	2.5533
50	3000	-3.967	-3.85	-3.9085	5.65	-4	0.0915	-2.391416307	10.92896
60	3600	-4.05	-3.95	-4	5.65	-4	0	-∞	-∞

Table 1. Summary of Results and Calculated Data

Time, t (s)	TRIAL 1 Temp (^{o}C)	TRIAL 2 Temp (^{o}C)
0	30.1	31.7
300	30.4	31.8
600	30.5	31.8
900	30.7	31.9
1200	30.8	32
1500	31	32
1800	31.1	32.1
2400	31.2	32.3
3000	31.3	32.5
3600	31.5	32.6
AVERAGE	**30.86**	**32.07**

Table 1. Summary of Temperature Data

Table 3. Descriptive Statistics for Trial 1 Temperature Data	
Mean	30.86
Standard Error	0.139204087
Median	30.9
Mode	#N/A
Standard Deviation	0.440201974
Sample Variance	0.193777778
Kurtosis	-0.746191586
Skewness	-0.299721676
Range	1.4
Minimum	30.1
Maximum	31.5
Sum	308.6
Count	10
	0

Table 4. Descriptive Statistics for Trial 2 Temperature Data	
Mean	32.07
Standard Error	0.096667
Median	32
Mode	31.8
Standard Deviation	0.305687
Sample Variance	0.093444
Kurtosis	-0.68636
Skewness	0.704832
Range	0.9
Minimum	31.7
Maximum	32.6
Sum	320.7
Count	10
	0

Table 3 and 4 shows the descriptive statistics computed for each trial. Table 5 shows that the pearson correlation coefficient is 0.9396, thus implying that both trials are not significantly different with each other.

Table 5. t-Test: Paired Two Sample for Means

	Trial 1	*Trial 2*
Mean	30.86	32.07
	0.19377777	0.09344444
Variance	8	4
Observations	10	10
	0.93966061	
Pearson Correlation	4	
Hypothesized Mean Difference	0	
df	9	
t Stat	-20.6503485	
P(T<=t) one-tail	3.42281E-09	
	1.83311293	
t Critical one-tail	3	