3-31-1974

An experimental study of parametric pump

Khalid Omar Ranginwala
New Jersey Institute of Technology

Recommended Citation

Ranginwala, Khalid Omar, "An experimental study of parametric pump" (1974). *Theses*. 2157.
https://digitalcommons.njit.edu/theses/2157

AN EXPERIMENTAL STUDY OF PARAMETRIC PUMP

BY

KHALID OMAR RANGINWALA

A PROJECT

PRESENTED IN PARTIAL FULFILMENT OF

THE REQUIREMENTS FOR THE DEGREE

OF

MASTER OF SCIENCE IN CHEMICAL ENGINEERING

AT

NEWARK COLLEGE OF ENGINEERING

Newark, New Jersey 1974

APPROVAL OF PROJECT

AN EXPERIMENTAL STUDY OF PARAMETRIC PUMPING

BY

KHALID OMAR RANGINWALA

FOR

DEPARTMENT OF CHEMICAL ENGINEERING

NEWARK COLLEGE OF ENGINEERING

BY

FACULTY

APPROVED :

NEWARK, NEW JERSEY

MARCH, 1974.

INDEX PAGE

Abstract

In this research for Master's Project, the possibility for separation of glucose and fructose by parametric pumping was investigated. In this research activated carbon was used as adsorbent. First Langmuir's isotherms for glucose and fructose were experimentally found. These results were utilized in the thermal parametric pumping. The pump was run semicontinuously. Parametric pumping was also carried out with KCl $+H_2O$ solution using a resin as adsorbent, and the 'b' value of KCl was found.

Introduction

Uptil now there are various methods for the separation of fructose and glucose. There is good possibility for the separation of these by parametric pumping technique.

Activated carbon used is of Calgon Corporation. Filtrasorb 400, Pittsburgh. Before using, activated carbon was heated to 110^{oc} for 30 hours to take out moisture from inside of its pores. There is a good hope that this physical method of separation for fructose and glucose will be an economical method in industries among other methods.

Previous Work

Some people (7, 9, 15, 19) have worked on the separation of glucose and fructose. Here briefly two methods are mentioned.

In this method sugar is used. 2000 grams of granulated sugar is dissolved in 600 c.c. of distilled water. The optical rotation of solution is measured. At room temperature add sufficient quantity of invertase in about 18 hours period. Then the solution is acidified with 2 c.c. of glacial acetic acid, as the activation of invertase become maximum in slite acidified solution. The solution is allowed to stand at 20 to 30°c until inversion is completed. For complete inversion the reading should be about 1/3 rd than before but negative instead of positive. Then the solution is deodourize and cleaned and concentrated under vaccume at low temperature and slow evaporation.

The thick sirup is then mixed with two volumes of hot glacial acetic acid. Then cool to room temperature and glucose is allowed to crystallize at about 15- 20^{oc} in 3 to 4 days. After this crystals are separated by Buchner funnels and washed with glacial acetic acid. The crystals of glucose is dried in vaccume oven at low temperature. The filterate contains a little bit of uncrystallized glucose, fructose and acetic acid. Now it is diluted with two parts of distilled water and concentrated in vaccume and low temperature to remove acetic acid. In the same way again diluted and concentrated to approximately 90 to 95% solid. Then allowed to crystallize at 15 - 20^{oc} for two to three days. Crystals are filtered and washed with glacial acetic acid. Then dried at low temperature in vaccume oven.

In other method sucrose is inverted with little amount of hydrochloric acid or sulfuric acid and the solution is cooled to about 0^{oc}, then milk of lime is added so it forms calcium fructosate. This salt is decomposed with CO_2, sulfuric or oxalic acid. Filterate is concentrated using vaccume distillation at low temperature. Then fructose can be crystallized by using alcohol.

Experimental Procedure For
Langmuir Adsorption Isotherms

For Langmuir's adsorption isotherm, the equation for solid - liquid system can be written as

$$X = \frac{N\ K\ Y}{1 + KY}$$

Where N is constant and independent of temperature, K is function of temperature, X is the gram mole adsorbed per gram of adsorbent and Y is equilibrium concentration in gram mole of solute per gram mole of solution. K the function of temperature is given by

$$K = K^{o}\ T^{-0.5}\ e^{-(\Delta H/\ RT)}$$

where ΔH is heat of adsorption.

For the experiment aqous solution of 5 % concentration of glucose by weight, was taken in eleven conical flasks. each flask contained 25 grams of solution. Then in each flask different amount of activated carbon was added. From 0.50 gram to 13 grams of activated carbon was used. Then put these flasks in mechanical shaker and the temperature was maintained constant at 25^{oc}. After about three and half hours of shaking in the shaker, the solution was poured in to marked test tubes and the solution was cleaned up of each test tube, first by centrifuging and then double filtering. First and last portion of filtrate was discarded to get accurate results. Then this clear solution was very carefully analsed by electronic automatic polarimeter. In the same way blank reading i.e. without activated carbon was done with various concentrations to estimate amount of adsorption took place.

The data is mentioned in the table (1) and (2). In the

Table: 1. Experimental Results of Glucose Adsorption

Initial Conc. $\frac{\text{gram}}{\text{gram solution}}$	Amount of Act. Carbon used in grams	Equilibrium Conc. $\frac{\text{gram}}{\text{gram soln.}}$	Grams Adsorbed
0.0125	2	0.0045	0.20
	5	0.0012	0.282
	8	0.0002	0.3075
0.025	3	0.0112	0.345
	6	0.0045	0.501
	8	0.0028	0.555
	10	0.0015	0.5875
	11	0.0010	0.60
0.050	0.5	0.0425	0.187
	1	0.038	0.30
	1.5	0.0356	0.36
	2.5	0.03	0.50
	3	0.0286	0.535
	6	0.0145	0.8875
	8	0.0095	1.01
	10	0.0060	1.10
	11	0.0050	1.125

Table:1. Continued:

Initial Conc.	Amount of Act. Carbon used	Equilibrium Conc.	Grams Adsorbed
0.050	12	0.0042	1.145
	13	0.0040	1.15
0.075	4	0.042	0.825
	6	0.03	1.125
	8	0.0215	1.3375
	10	0.015	1.50
	11	0.0125	1.5625
0.10	0.5	0.090	0.25
	1	0.0857	0.357
	1.5	0.082	0.45
	2.5	0.075	0.625
	3	0.071	0.725
	4	0.0637	0.907
	6	0.051	1.225
	8	0.039	1.525

Table: 1 Continued:

Initial Conc.	Amount of Act. Carbon used	Equilibrium Conc.	Grams Adsorbed
0.10	10	0.030	1.75
	11	0.0258	1.855
0.15	0.5	0.1432	0.17
	1	0.1385	0.287
	1.5	0.1351	0.372
	2.5	0.124	0.65
	3	0.120	0.75
	4	0.112	0.95

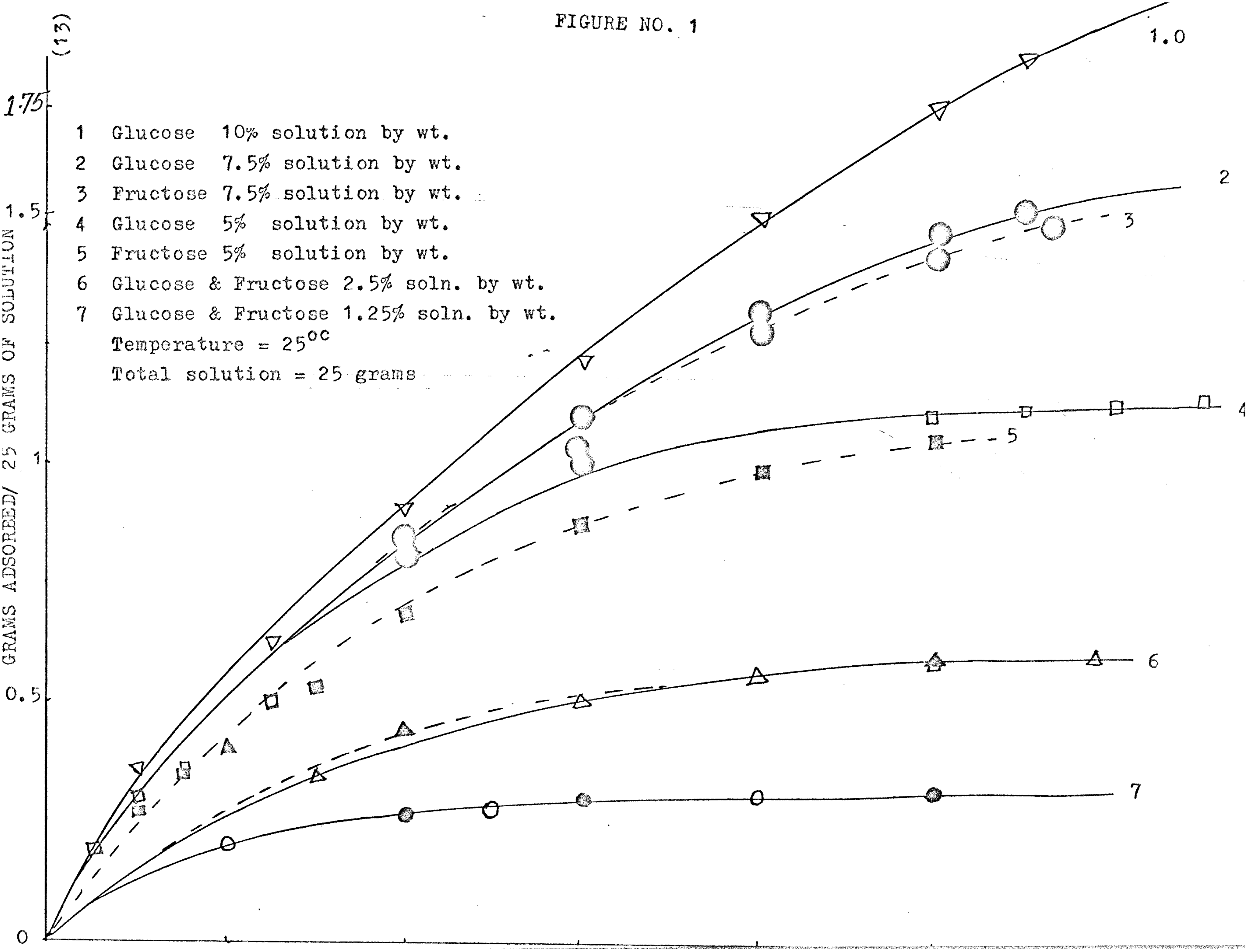
Table:2 . Experimental Results of Fructose Adsorption

Initial Conc. gram / gram solution	Amount of Act. Carbon used in grams	Equilibrium Conc. gram / gram soln.	Grams Adsorbed
00.0125	4	0.002	0.2625
	6	0.005	0.30
	8	0.0002	0.3075
	10	0.0001	0.31
0.025	2	0.0128	0.405
	4	0.0075	0.4375
	6	0.0040	0.525
	8	0.0023	0.5675
	10	0.0015	0.5875
0.050	0.5	0.043	0.175
	1	0.0396	0.26
	1.5	0.036	0.35
	4	0.0225	0.6875
	6	0.015	0.875
	8	0.010	1.00

Table:2 . Continued:

Initial Conc.	Amount of Act. Carbon used	Equilibrium Conc.	Grams Adsorbed
0.050	10	0.007	1.075
0.075	4	0.041	0.85
	6	0.0305	1.1125
	8	0.0225	1.3125
	10	0.0170	1.45
	11	0.0136	1.535
0.10	0.5	0.092	0.2
	1	0.088	0.3
	1.5	0.084	0.4
	4	0.0637	0.9
0.15	0.5	0.1432	0.17
	1	0.1385	0.287
	1.5	0.1351	0.372
	3	0.1198	0.755
	4	0.112	0.95

FIGURE NO. 1


1 Glucose 10% solution by wt.
2 Glucose 7.5% solution by wt.
3 Fructose 7.5% solution by wt.
4 Glucose 5% solution by wt.
5 Fructose 5% solution by wt.
6 Glucose & Fructose 2.5% soln. by wt.
7 Glucose & Fructose 1.25% soln. by wt.
Temperature = 25°C
Total solution = 25 grams
GRAMS ADSORBED/ 25 GRAMS OF SOLUTION
1.75
1.5
1
0.5
0
1.0
2
3
4
5
6
7

same way experiments were performed with 1.25%, 2.5%, 7.5%, 10%, and 15% concentrations by weight glucose and fructose. The purpose of this was to find out the optimum amount of activated carbon should be used. Table (1) and figure(1) shows that 10 grams of activated carbon can give the best equilibrium.

It is very difficult to get the solution at equilibrium if we take more quantity of activated carbon and higher concentration. So we decided to take upto 7.5% concentration by weight and 10 grams of activated carbon.

After this the solution of 1.25%, 2.5 %, 5% and 7.5% concentration by weight of glucose were prepared and 25 grams of each was taken into 125 ml. conical flask. Then 10 grams of activated carbon was added to each of them and put them in to mechanical shaker at constant temperature of 20^{oc}. After $3\frac{1}{2}$ hours the solution was taken out in to different marked test tubes. Then the solutions were cleaned by centrifuging and filtration and then analysed on polarometer for the amount adsorbed by the activated carbon. Same procedure was repeated at 40^{oc} and 60^{oc} with glucose solution and 20^{oc}, 40^{oc} and 60^{oc} with fructose solution. The experimental results are shown in table (4) & (5).

In order to find the maximum time required by the adsorption to get in equilibrium position, we took solutionof 5% concentration by weight in 125 ml. conical flaskseach contained 25 grams of solution and 10 gramsof activated carbon, and put in the shaker at constant temperature of 25^{oc} for 15 minutes, 1hr., 2 hrs. and 3 hrs. Equilibrium concentrations were gotten by the polarometer in the same way as done before. Results are mentioned in table (3) and plotted

Table: 3., Experimental Result of Glucose and Fructose Adsorption

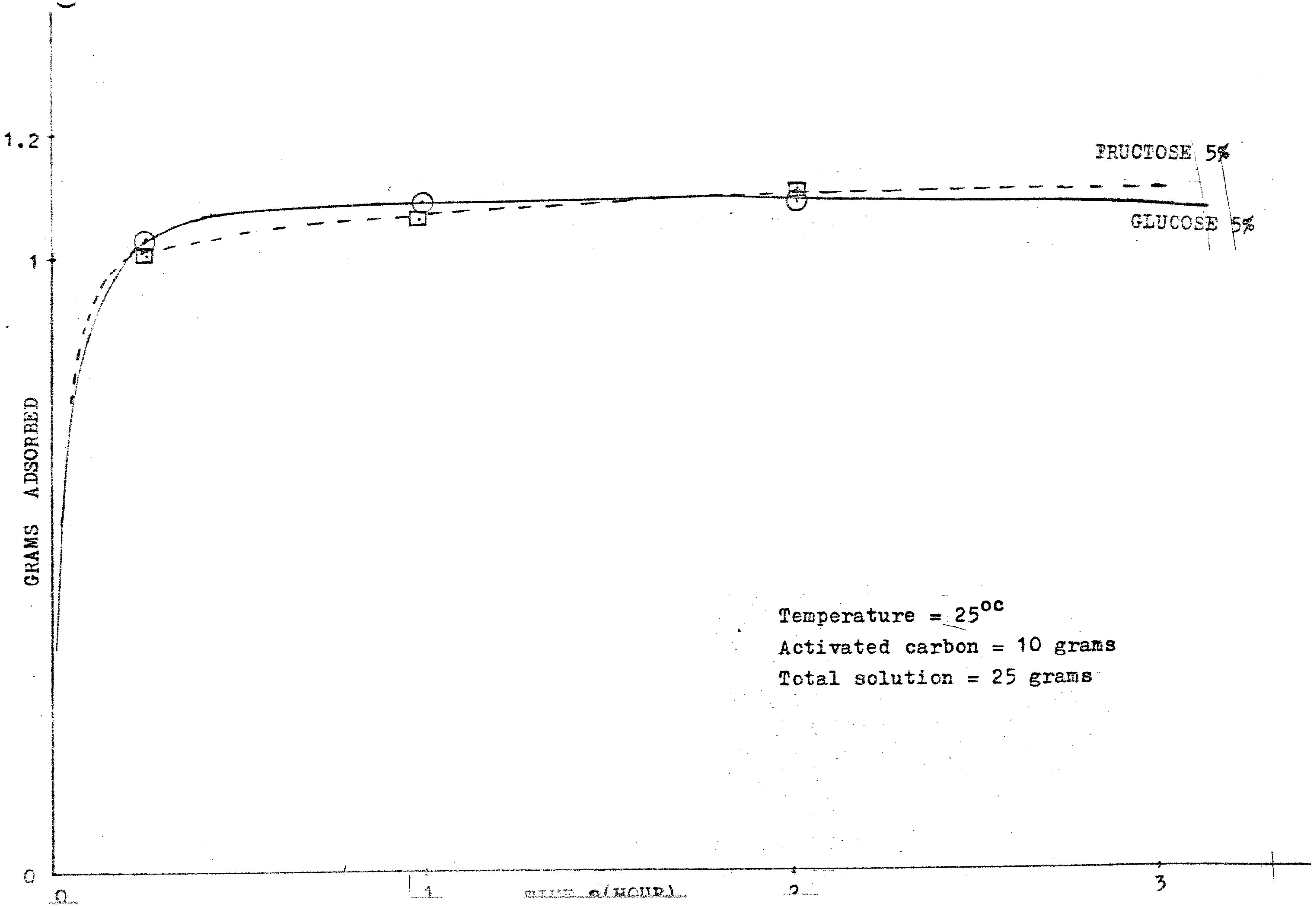
Glucose

Time in Hours	Equilibrium Conc.	Grams Adsorbed
0.25	0.0096	1.01
1	0.0070	1.075
2	0.0060	1.10
3	0.0057	1.1075

Fructose

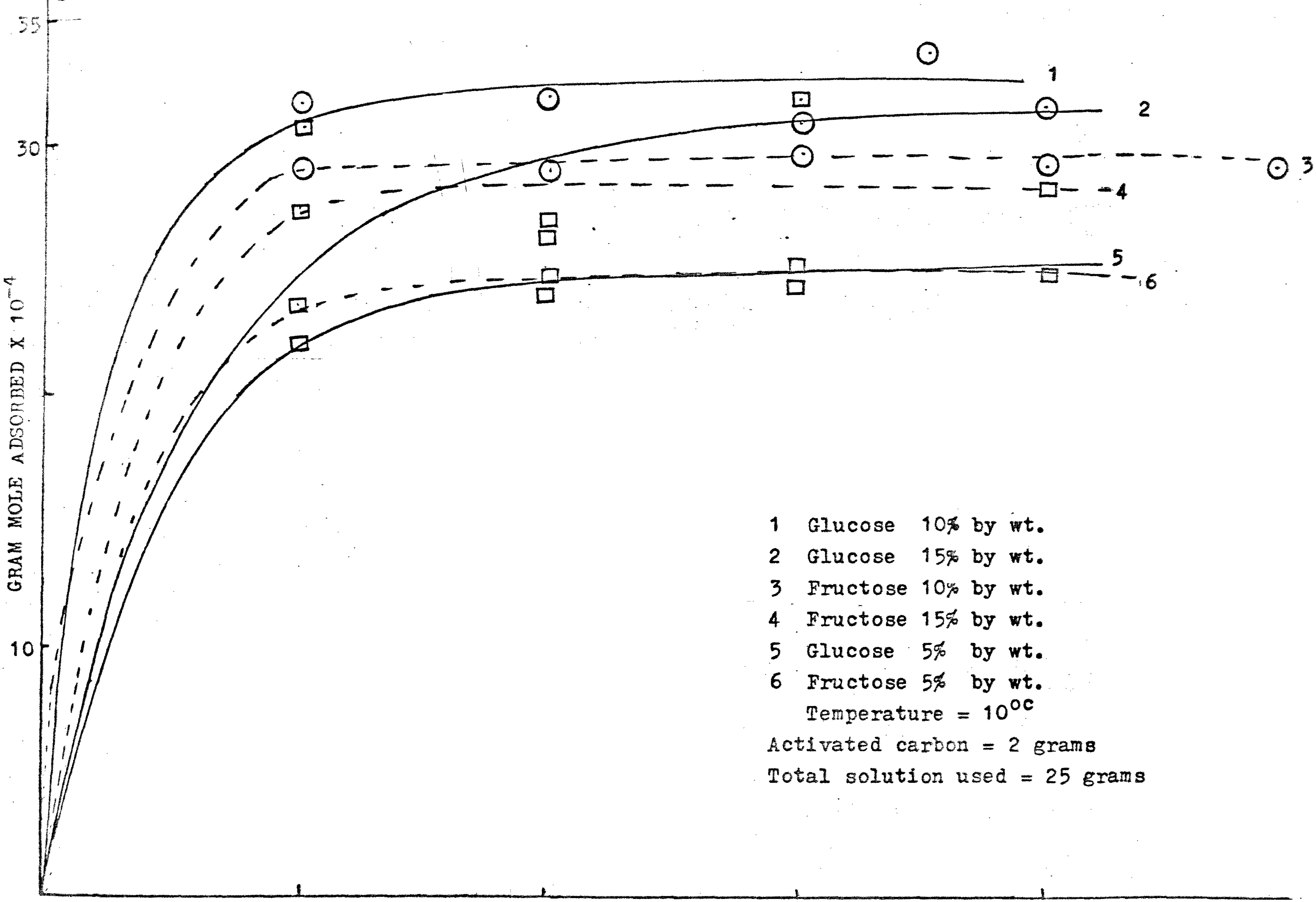
0.25	0.0089	1.027
1	0.0072	1.07
2	0.0070	1.075
3	0.0068	1.08

FIGURE NO. 2



GRAMS ADSORBED
1.2
1
0
0
1
2
3
TIME θ (HOUR)
FRUCTOSE 5%
GLUCOSE 5%
Temperature = 25°C
Activated carbon = 10 grams
Total solution = 25 grams

FIGURE NO. 3


35
30
10
GRAM MOLE ADSORBED X 10^-4
1
2
3
4
5
6
1 Glucose 10% by wt.
2 Glucose 15% by wt.
3 Fructose 10% by wt.
4 Fructose 15% by wt.
5 Glucose 5% by wt.
6 Fructose 5% by wt.
Temperature = 10°C
Activated carbon = 2 grams
Total solution used = 25 grams

in figure (2). Same procedure was also done by taking 2 grams of activated carbon with different solutions of concentration for different time. The resuls are plotted in figure (2)

For applying our experimental results in to Langmuir's Equation we have obtained, from the table (4 &5), the values for X, Y and Y/X for fructose and glucose.

$X = \frac{N\ K\ Y}{1 + KY}$ is the mathematical expression for the Langmuir's adsorption isotherm as shown in the theory. This can be more simplified in the form of

$$\frac{Y}{X} = \frac{1}{N\ K} + \frac{Y}{N}$$

This equation represent straight line if we plot $\frac{Y}{X}$ verses Y and the slope of the line is given by $\frac{1}{N}$.

So we plotted best possible line with our experimental data obtained (Table 4 & 5). The slope of this line (Figure4) gives us as $\frac{1}{N} = 10^3$ and the intercept i.e. at $Y = 0$ we get the value of $\frac{1}{NK}$ as we found the value of N so we can calculate the value of K using the value of N and intercept. (Table 6). K is expressed in Langmuir's adsorption isotherm as

$$K = K^o T^{-\frac{1}{2}} e^{-(H/RT)}$$

This can be simplified to

$$\ln K T^{-\frac{1}{2}} = \ln K^o + (-H/RT)$$

This equation expresses a straight line if we plot $\ln KT^{-\frac{1}{2}}$ against $\frac{1}{T}$ on semi log paper, and the slope will give us the value of $(-\frac{H}{R})$ and $\ln K^o$ will be the intercept. So the value of K^o and H were calculated from figure (6,7) and noted in the table (7).

For example let us take the experimental value of glucose at 293^{ok} in table (4). The values $\frac{Y}{X}$ verses Y are plotted in figure (4). This gives us approximately straight line, whose slope $(\frac{1}{N})$ equals 10^3 so we get N equals 10^{-3}. The intercept i.e. at $Y= 0$ we get $\frac{1}{NK}$

which is from graph equals to 2.83×10^{-1}

$$\therefore \frac{1}{NK} = 2.83 \times 10^{-1} \text{ and } N = 10^{-3}$$

$$\therefore K = \frac{1}{10^{-3} \times 2.83 \times 10^{-1}} = \frac{10^4}{2.83} = 3535$$

$$\therefore K = 3535$$

In the same way value of K was calculated for 313^{ok} and 333^{ok} and mentioned in table 6. Now using these values of K we plotted the graph $KT^{\frac{1}{2}}$ verses $\frac{1}{T}$ in figure 6. This gives us straight line. The slope of this line equals

$$\frac{\log 4.6 \times 10^4 - \log 2.3 \times 10^3}{1.95} = 667.5$$

Now from our equation slope $= \frac{-\Delta H}{R}$

$$\therefore \frac{-H}{R} = 667.5 \quad \therefore (-\ H) = 3062 \text{ cal/gm mole}$$

The intercept from equation is $Ln\ K^o$ and from our plot in figure 6 is $Ln \approx 3.1 \times 10^2$

$$\therefore K^o = 3.1 \times 10^2$$

In the same way we found the value of K^o and H for fructose and mentioned in table 7.

Table: 4. Experimental Results of Glucose Adsorption

Temp.	I	X $x10^{-4}$	Y $x10^{-4}$	$\frac{Y}{X}$ $x10^{-1}$	Slope
293^{ok}	1.25	1.694	0.6	3.54	10^3
	2.5	3.33	1.0	3.005	
	5	6.138	6.5	10.6	
	7.5	8.4027	16.2	19.28	
313^{ok}	1.25	1.652	0.7	4.23	10^3
	2.5	3.236	2.0	6.195	
	5	5.97	8.5	14.21	
	7.5	7.94	20.0	25.2	
333^{ok}	1.25	1.6736	0.8	4.78	10^3
	2.5	3.18	2.6	8.18	
	5	5.694	10.4	18.28	
	7.5	7.694	22.0	28.6	

I= Initial % concentration by weight

X= Gram mole adsorbed/gram of adsorbant

Y= Equilibrium concentration $\frac{\text{mole of solute}}{\text{mole of solution}}$

FIGURE NO. 4

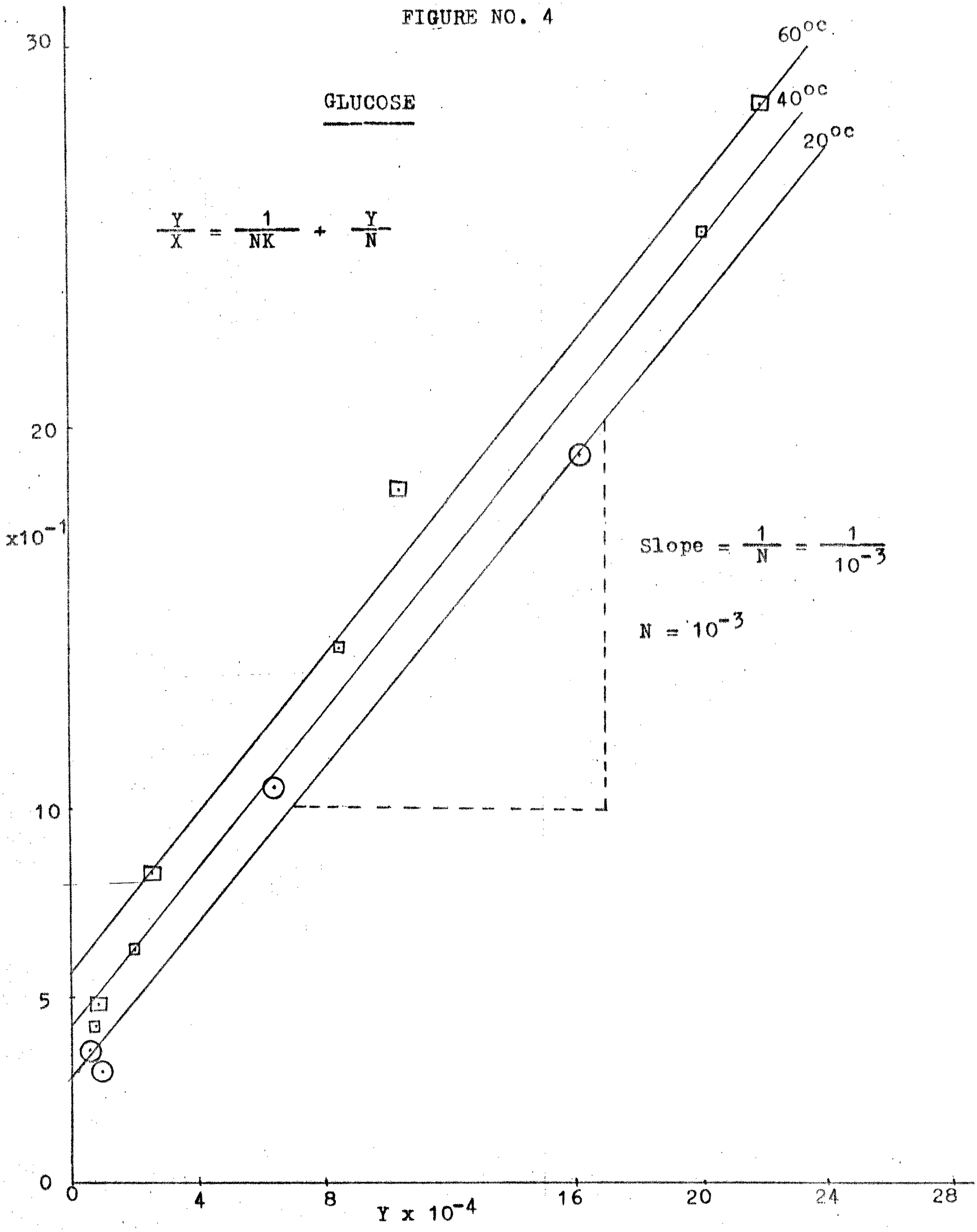

GLUCOSE
$\frac{Y}{X} = \frac{1}{NK} + \frac{Y}{N}$
60°c
40°c
20°c
Slope = $\frac{1}{N} = \frac{1}{10^{-3}}$
N = 10^{-3}
x10^{-1}
30
20
10
5
0
0
4
8
16
20
24
28
Y x 10^{-4}

Table:5 . Experimental Results of Fructose Adsorption

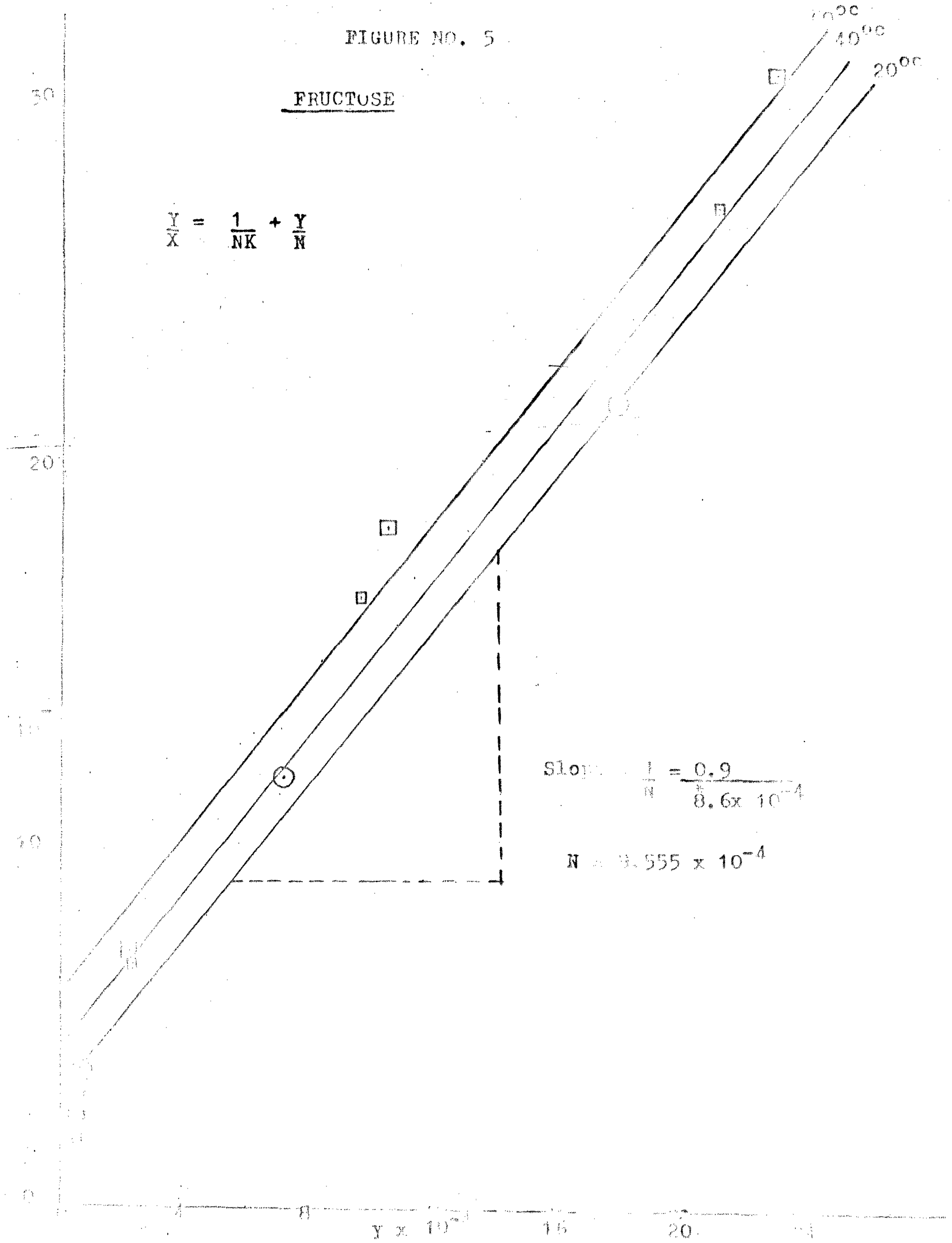
Temp.	I	X $\times10^{-4}$	Y $\times10^{-4}$	$\frac{Y}{X}\times10^{-1}$	Slope
293^{ok}	1.25	1.611	0.60	3.72	1047
	2.5	3.333	1.0	3.005	
	5	6.08	7.2	11.84	
	7.5	8.222	18.0	21.9	
313^{ok}	1.25	1.666	0.3	1.8	1047
	2.5	3.208	2.2	6.86	
	5	5.77	9.7	16.8	
	7.5	7.819	21.3	27.25	
333^{ok}	1.25	1.68	0.4	2.38	1047
	2.5	3.19	2.2	6.9	
	5	5.68	10.6	18.68	
	7.5	7.5	23.2	30.95	

I= Initial % concentration by weight

$X = \frac{\text{Gram mole solute adsorbed}}{\text{Gram of adsorbent}}$

Y= Equilibrium concentration $\frac{\text{gram mole of solute}}{\text{gram mole of solution}}$

FIGURE NO. 5



FRUCTOSE

$$\frac{Y}{X} = \frac{1}{NK} + \frac{Y}{N}$$

Slope $= \frac{1}{N} = \frac{0.9}{8.6 \times 10^{-4}}$

$N = 9.555 \times 10^{-4}$

Table: 6.

GLUCOSE

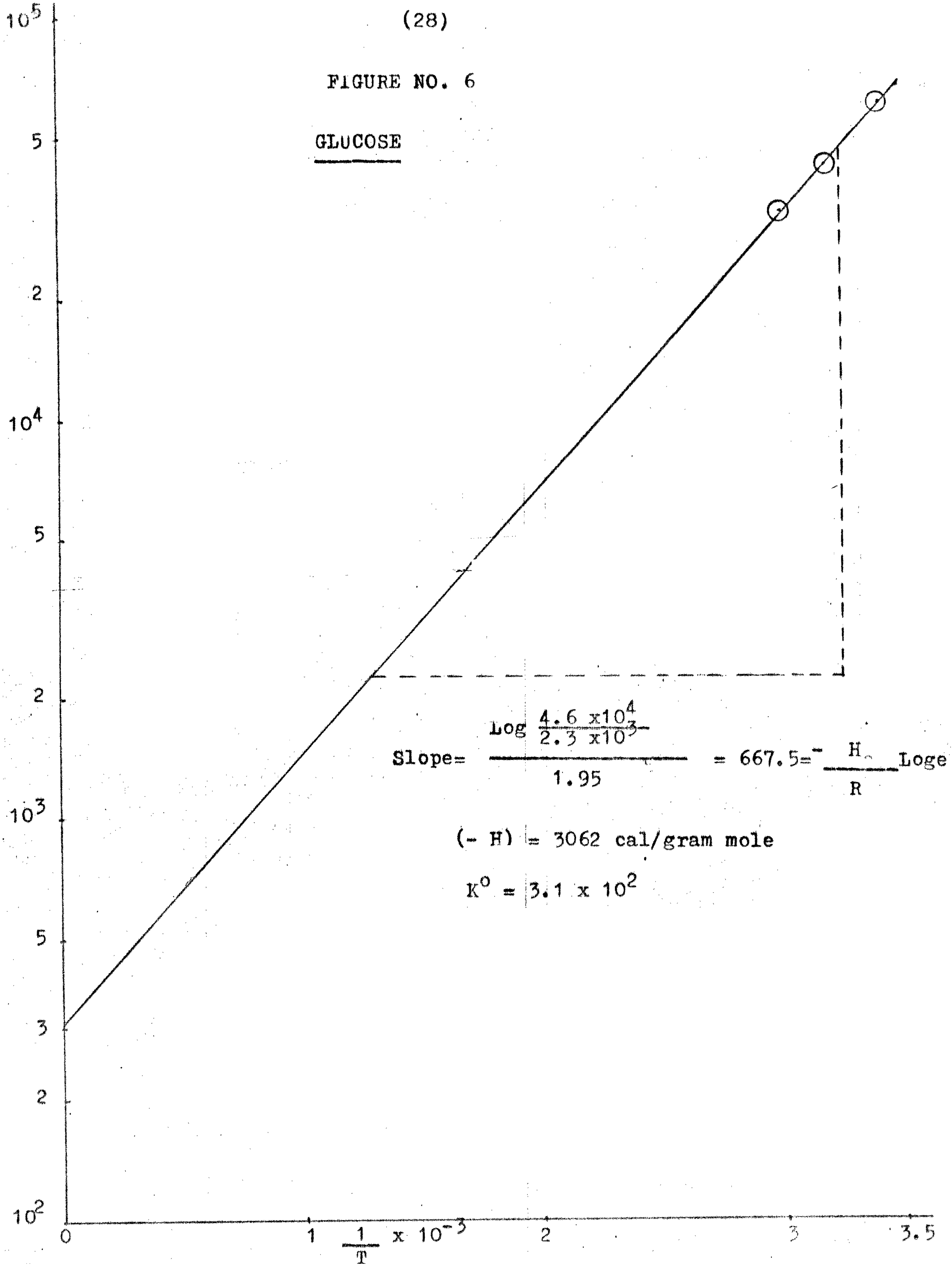
Temperature	K.	N
293^{ok}	3535	10^{-3}
313^{ok}	2355	10^{-3}
333^{ok}	1766	10^{-3}

FRUCTOSE

Temperature	K.	N
293^{ok}	3324	9.555×10^{-4}
313^{ok}	2324	9.555×10^{-4}
333^{ok}	1742	9.555×10^{-4}

FIGURE NO. 6

GLUCOSE



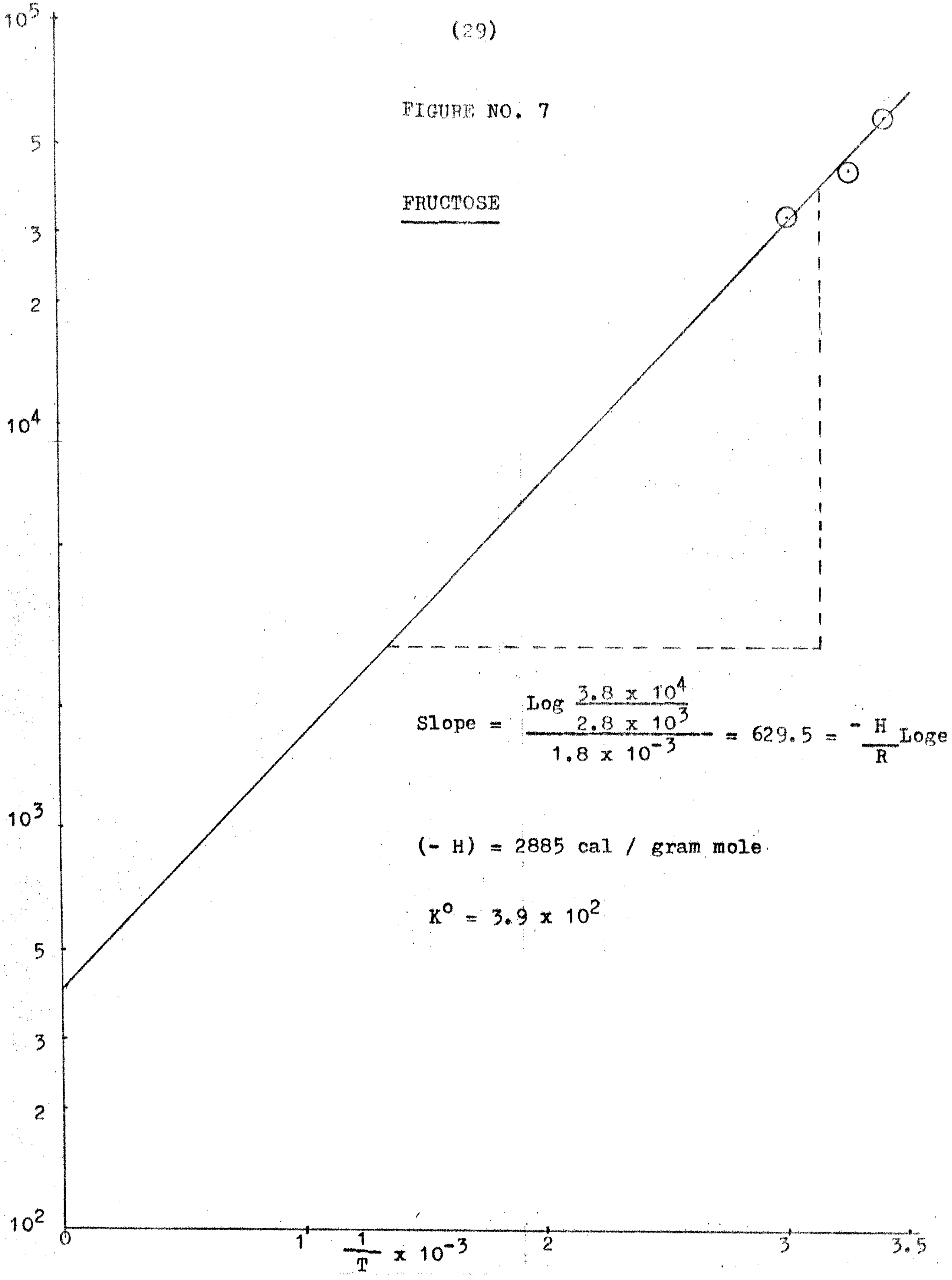
$$\text{Slope} = \frac{\text{Log}\,\frac{4.6 \times 10^4}{2.3 \times 10^3}}{1.95} = 667.5 = \frac{-H}{R}\,\text{Loge}$$

(- H) = 3062 cal/gram mole

$K^o = 3.1 \times 10^2$

FIGURE NO. 7

FRUCTOSE



$$\text{Slope} = \frac{\text{Log}\ \frac{3.8 \times 10^4}{2.8 \times 10^3}}{1.8 \times 10^{-3}} = 629.5 = \frac{-H}{R} \text{Loge}$$

$(-H) = 2885$ cal / gram mole

$K^o = 3.9 \times 10^2$

Table: 7.

Solute	K^o	$(-\Delta H)$
Glucose	3.1×10^2	3062 $\frac{\text{calories}}{\text{gram mole}}$
Fructose	3.9×10^2	2885 $\frac{\text{calories}}{\text{gram mole}}$

Applications Of Adsorption Isotherms

The purpose of finding the adsorption isotherms was to decide the posssibility and the suitable operating conditions for thermal parametric pumping.

The graph x verses y was drawn where x is in gram mole of solute adsorbed per gram of activated carbon, and y is equilibrium concentration ~~in gram~~ mole of solute per c.c. of solution.

For finding the dimensionless parameter "b" the procedure of H. T. Chen et. al (2) was used. First find the average slopes M of the adsorption isotherm at 20^{oc} & 40^{oc} ; and 20^{oc} & 60^{oc} were determined for fructose and glucose. Then m was calculated by the equation

$$m = \frac{(1 - \epsilon) \rho_s \, M}{\rho_f \, \epsilon}$$

where ϵ = porosity = 0.561 ; $\rho_S = 1.35 \frac{\text{grams}}{\text{c.c.}}$

$\rho_f = 0.05555 \frac{\text{gram mole}}{\text{c.c.}}$ and M the slopeshould be

Table:8. Experimental Results of Glucose Adsorption

Temperature	I	E	A	C x10^{-4}
293^{ok}	0.0125	0.0003	0.305	0.05
	0.025	0.0010	0.60	0.10
	0.050	0.0058	1.105	0.37
	0.075	0.0145	1.5125	0.87
313^{ok}	0.0125	0.0006	0.2975	0.075
	0.025	0.0017	0.5825	0.15
	0.050	0.007	1.075	0.48
	0.075	0.0178	1.43	1.06
333^{ok}	0.0125	0.00045	0.30125	0.07
	0.025	0.0021	0.5725	0.17
	0.050	0.0090	1.025	0.57
	0.075	0.0196	1.385	1.15

I= Initial concentration in gram/gram solution

E= Equilibrium concentration in gram/gram solution

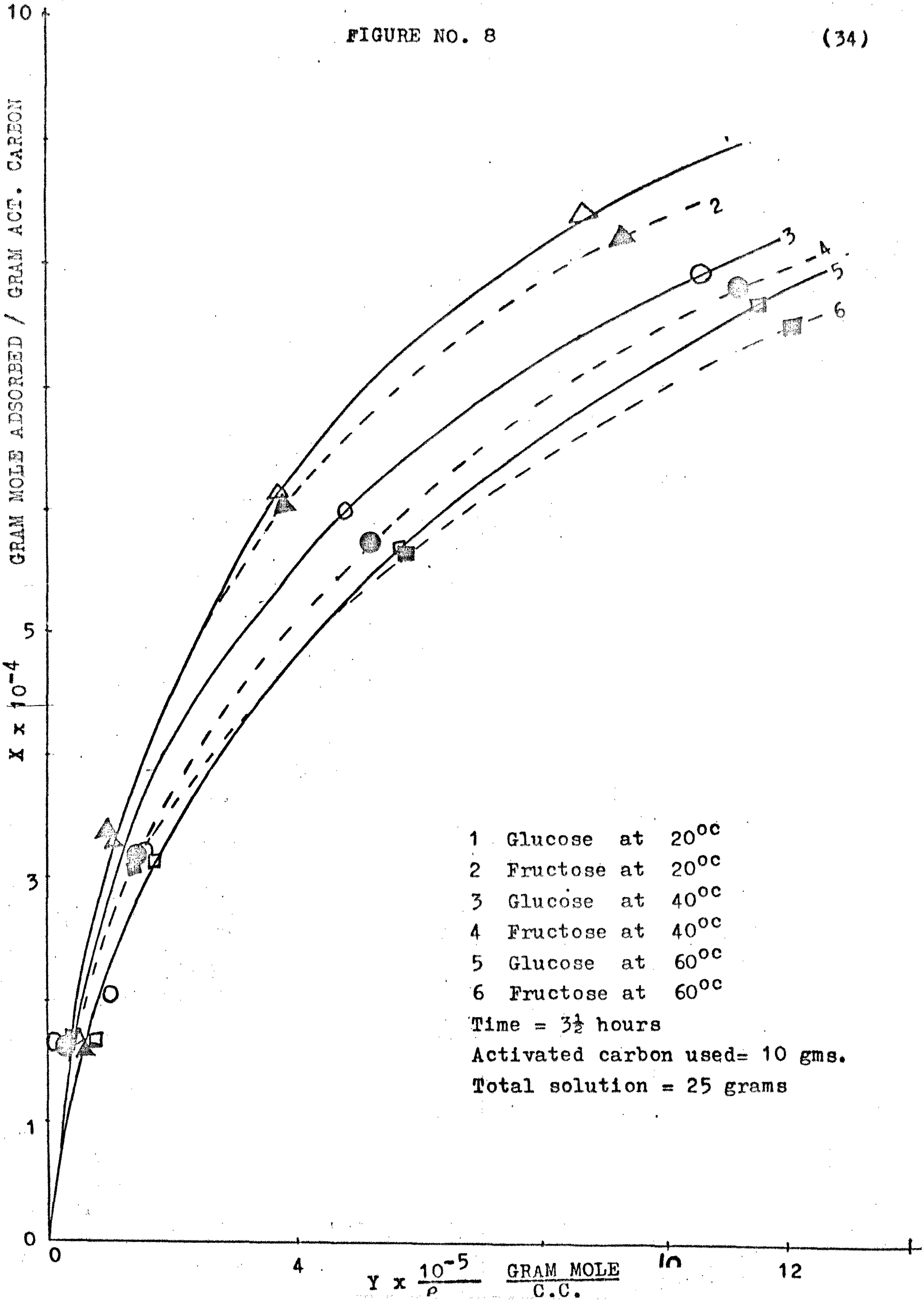
A= Grams of solute adsorbed

C= Equilibrium concentration in gram mole/cc of soln.

Table: 9. Experimental Results of Fructose Adsorption on

Temperature	I	E	A	$C \times 10^{-4}$
293^{ok}	0.0125	0.0009	0.29	0.06
	0.025	0.0010	0.60	0.09
	0.050	0.006	1.095	0.38
	0.075	0.0158	1.48	0.93
313^{ok}	0.0125	0.0005	0.30	0.03
	0.025	0.0019	0.5775	0.13
	0.050	0.0084	1.04	0.52
	0.075	0.0187	1.4075	1.12
333^{ok}	0.0125	0.0004	0.3025	0.03
	0.025	0.0020	0.575	0.13
	0.050	0.0091	1.0225	0.58
	0.075	0.021	1.35	1.21

FIGURE NO. 8


GRAM MOLE ADSORBED / GRAM ACT. CARBON
X x 10^-4
10
5
3
1
0
0
4
10
12
Y x 10^-5/ρ GRAM MOLE/C.C.
2
3
4
5
6
1 Glucose at 20°C
2 Fructose at 20°C
3 Glucose at 40°C
4 Fructose at 40°C
5 Glucose at 60°C
6 Fructose at 60°C
Time = 3½ hours
Activated carbon used= 10 gms.
Total solution = 25 grams

in mole fraction.

The value of m at mean temperature m_o between 20^{oc} & 40^{oc} was calculated, and same way m_o between 20^{oc} & 60^{oc} was calculated.

Then $a = m_{hot} - m_o$

and the dimensionless equilibrium parameter "b" was obtained by the equation

$$b = \frac{a}{1 + m_o}$$

Values of "b" for glucose and fructose are summerized in table (10).

The success of separation in parametric pump much depends on the value of "b". From the graph figure (Figure 8), the maximum time for reaching equilibrium is about 15 minutes when 10 grams of activated carbon was used, and about 1 hour when 2 grams of activated carbon was used. So the time for half cycle was selected as 20 minutes.

For finding the slope M from graph y vs x , Simpson's Rule was used to find the area under the curves For more accuracy, very small intervals were taken. The slope was checked out by least square method.

The values of M are as follows from figure 8

Slope of curve (1) Glucose 20^{oc} = M_{G20} = 0.745

Slope of curve (2) Fructose 20^{oc} = M_{F20} = 0.725

Slope of curve (3) Glucose 40^{oc} = M_{G40} = 0.657

Slope of curve (4) Fructose 40^{oc} = M_{F40} = 0.614

Slope of curve (5) Glucose 60^{oc} = M_{G60} = 0.582

Slope of curve (6) Fructose 60^{oc} = M_{F60} = 0.580

The value of m were calculated by the formula

$$m = \frac{\rho_s (1-\epsilon) M}{\rho_f \epsilon}$$

Where

ρ_s = Density of Activated Carbon = 1.35 gm/c.c

ϵ = Porosity = 0.561

ρ_f = 0.05555 gm mol /c.c

The values of m are as follows

$m_G 20^{oc}$ =14.15

$m_F 20^{oc}$ =13.76

$m_G 40^{oc}$ =12.47

$m_F 40^{oc}$ =11.65

$m_G 60^{oc}$ =11.02

$m_F 60^{oc}$ =11.01

So 'b' values were calculated by using equation

$$b = \frac{a}{1 + m_o}$$

where m_o = m at average temperature.

a = m at cold temperature - m_o

The values of b are mentioned in table (10)

Table: 10.

Solute	"b" Dimentionless Parameter	Temperature Range ok
Glucose	0.0594	293 - 313^{ok}
Glucose	0.114	293 - 333^{ok}
Fructose	0.0774	293 - 313^{ok}
Fructose	0.1055	293 - 333^{ok}

Experiment of Parametric Pumping For Binary Solution

The theory of parametric pumping can be found in the literature(3, 4, 16). The schematic diagram of thermal Parametric pumping is shown in figure (9). The activated carbon Filtrasorb 400 of Calgon Corporation, Pittsburgh, Pa., was heated to 110^{oc} for 30 hours to get rid of moisture. Then the cleaned column was packed by the activated carbon. Then the top and bottom connections were connected to top and bottom reservoir respectively. The syringes of top and bottom reservoir and feed were lubricated by thin film of grease. This also makes syringes air-tight. 5% by weight, the glucose solution was prepared for feed. The feed and bottom reservoir syringes were filled with feed solution upto 45 c.c. and the volume in top reservoir syringe was kept about 5c.c. as dead volume.

Then the column was filled at ambient temperature

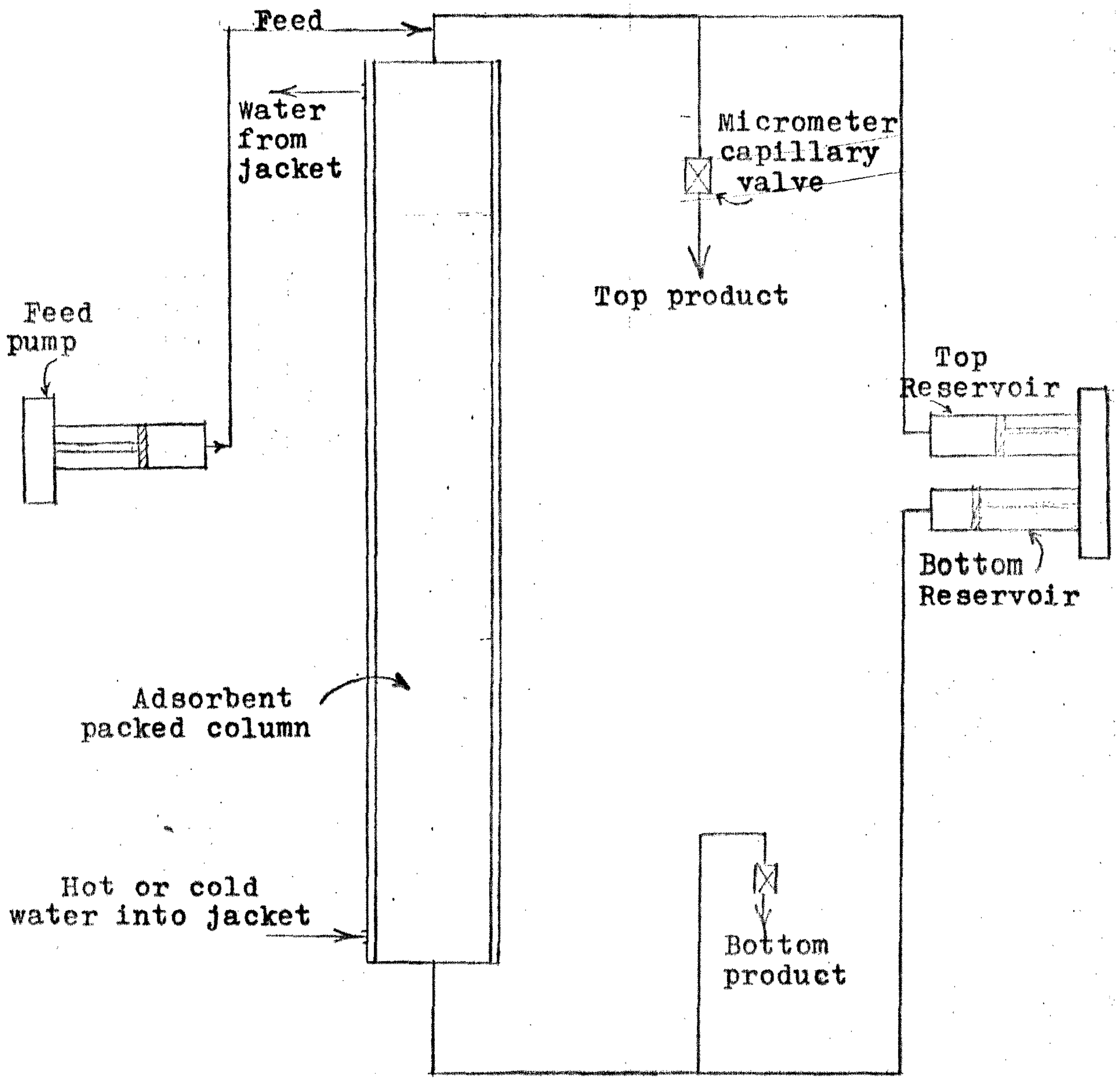

Feed
Water from jacket
Micrometer capillary valve
Top product
Feed pump
Top Reservoir
Bottom Reservoir
Adsorbent packed column
Hot or cold water into jacket
Bottom product

Figure No. 9

by allowing feed solution to flow from bottom reservoir to top reservoir. We can also fill up the column from top reservoir to bottom reservoir, in that case the volume of top reservoir at the beginning should be about 45 c.c. and bottom 5 c.c. First method seems to be better as it can take out air from the column more perfectly than the later method. Feed syringe does not operate at this time. After the column is filled up, the both lines of reservoirs were closed and the reservoir syringes were refilled by feed solution and the volumes of bottom reservoir was maintained to 45 c.c. and in top reservoir 5 c.c. which will act as dead volume of top reservoir. After this the column was kept overnight so that complete equilibrium adsorption should reach in the column. Next day the temperature in hot and cold bath were maintained to 60^{oc} and 20^{oc} respectively.

The operation of pump was started by first half hot cycle. The fluid was flowing from bottom reservoir to top reservoir through the column. No feed was fed in hot half cycle. Timer and solinoid were used to change the hot and cold water flow through jacket after each 20 minutes of half cycle. The speed of reservoir pumps was maintained to supply 2 c.c. per minute, and the speed of feed pump was 0.80 c.c. per minute.

In first half hot cycle after 20 minutes when the timer changes from hot water flow to cold water flow through the jacket, the reservoir switch should be off immediately and change the direction of reservoir pump. At this point the volume of solution in top and bottom reservoir must be 45 c.c. and 5 c.c. respectively. Immediately after changing the direction of reservoir pump the switches of reservoir and feed were on. Feed is always fed in half cold cycle. In this cold half cycle the bottom product is first collected then top product is collected as it is easier to take out top product than bottom product. Total feed of 16 c.c. was fed in each half cold cycle. During this cold half cycle 0.80 c.c. of bottom product and 15.2 c.c. of top product was collected. As it is very difficult to analyse 0.80c.c. So the products from 1 to 5 cyclesare combined to gether and considered as average for 3rd cycle product. In the same way average of 6 to 10 cycles is cosidered as 8th cycle, average of 11 to 15 cycles as 13th cycle product and average of 16 to 20 cycles products as 18 th cycle product.

After 20 minutes the timer change the solinoid valve and hot water start flowing through the jacket. At this point the volume of solution in top and bottom reservoir should be 5 c.c. and 45 c.c. respectively as to be sure that.

displacement should be around 40 c.c. After changing the direction the switch of reservoir pump should be on. Now the solution will flow from bottom reservoir to top reservoir in this half hot cycle. After every two cycles the feed syringe was refilled. During the refilling the feed syringe, slight amount of feed solution was lost as feed line is always in some pressure. So there might be slight error in the volume of product. The column was run uptil 20 cycles completed. After every half cycle, the position of the reservoir pumps, feed pump and the volume of product collected, were recorded.

After this the top and bottom product was analysed in polarimeter. The results are shown in tables (11 t020)

Same procedure was done in the experiment of binary solution of fructose i.e. fructose + water.

Then the results of the experiments have plotted on semilog paper as Log $\frac{\langle Y_B \rangle n}{Y_o}$ versus n and Log $\frac{\langle Y_T \rangle n}{Y_o}$ versus n for glucose + water system and fructose + water system in graph (Fig. 10 to 14)

In binary solution of fructose, the system was in slightly more pressure than glucose & water system.

Table:11. FRUCTOSE + H_2O

PARAMETRIC PUMP RUN NO. 1

TOP PRODUCT NO.	POLARIMETER READING	CORRECTED READING	(Y_T/Y_O)
T5	3.439	3.739	0.750
T6	4.027	4.327	0.869
T7	4.567	4.867	0.976
T8	4.917	5.217	1.048
T9	4.972	5.272	1.059
T10	5.554	5.854	1.177
T11	5.447	5.747	1.150
T12	5.402	5.702	1.146
T13	5.949	6.249	1.252
T14	5.774	6.074	1.220
T15	5.934	6.234	1.250

INSTRUMENTAL ERROR= 0.30

Table:12

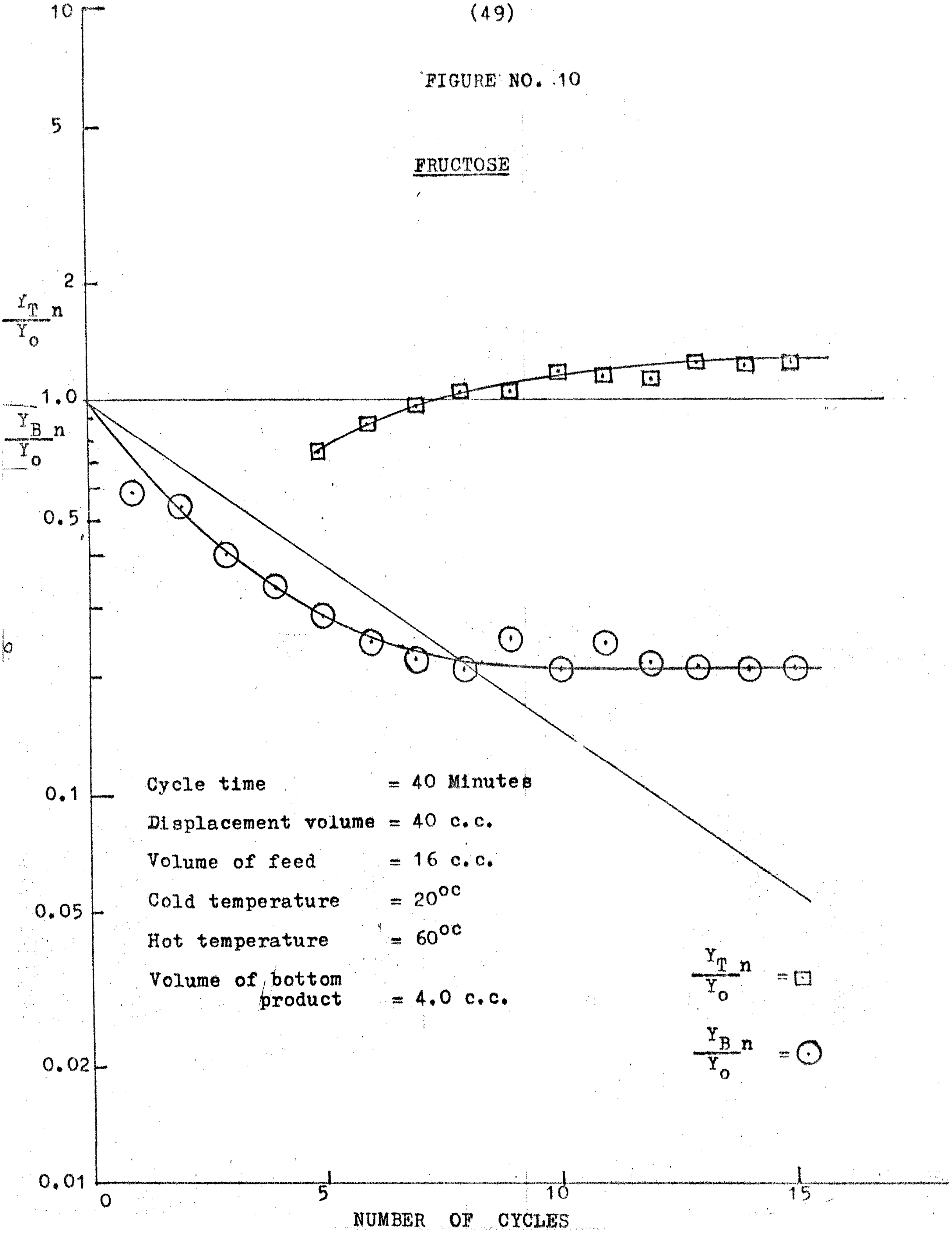
FRUCTOSE + H_2O
PARAMETRIC PUMP RUN NO.1

BOTTOM PRODUCT NO.	POLARIMETER READING	CORRECTED READING	$\frac{\langle Y_B \rangle n}{Y_o}$
B1	2.654	2.954	0.592
B2	2.386	2.686	0.540
B3	1.750	2.050	0.411
B4	1.391	1.691	0.340
B5	1.144	1.444	0.289
B6	0.942	1.242	0.2495
B7	0.821	1.121	0.225
B8	0.746	1.046	0.210
B9	0.969	1.269	0.2545
B10	0.802	1.102	0.2115
B11	0.943	1.243	0.2497
B12	0.791	1.091	0.2190
B13	0.762	1.062	0.2130
B14	0.745	1.045	0.210
B15	0.750	1.050	0.211
FEED	4.687	4.987	

INSTRUMENTAL ERROR = 0.30

FIGURE NO. 10

FRUCTOSE



Cycle time = 40 Minutes
Displacement volume = 40 c.c.
Volume of feed = 16 c.c.
Cold temperature = 20^{oc}
Hot temperature = 60^{oc}
Volume of bottom product = 4.0 c.c.

$$\text{Slope} = \alpha = -\frac{\log 0.68 - \log 0.15}{10 - 2}$$

$$\alpha = -\frac{\bar{1}.832 - \bar{1}.176}{8} = -\frac{0.656}{8} = -0.082$$

$$\therefore 10^{\alpha} = 0.827$$

'b' value can be calculated by the equation

$$b = \frac{(1 - 10^{\alpha}) + C_2\,(1 - 10^{\alpha})}{(1 + 10^{\alpha}) - C_2\,(1 - 10^{\alpha})}$$

$$C_2 = \frac{\text{Dead volume of bottom reservoir}}{\text{Volume of displacement}} = \frac{5.2}{40.27}$$

$$C_2 = 0.129$$

$$\therefore b = \frac{(1 - 0.827) + 0.129\,(1 - 0.827)}{(1 + 0.827) - 0.129\,(1 - 0.827)}$$

$$\therefore b = 0.1085$$

Table:13 FRUCTOSE + H_2O

PARAMETRIC PUMP RUN NO.2.

TOP PRODUCT NO.	POLARIMETER READING	CORRECTED READING	(Y_T / Y_O)
T1	4.145	4.235	0.885
T11	4.936	5.026	1.050
T111	5.360	5.450	1.111
T1V	5.304	5.394	1.090
FEED	4.828	4.918	1.00

INSTRUMENTAL ERROR = 0.090 .

Table:14 FRUCTOSE + H_2O

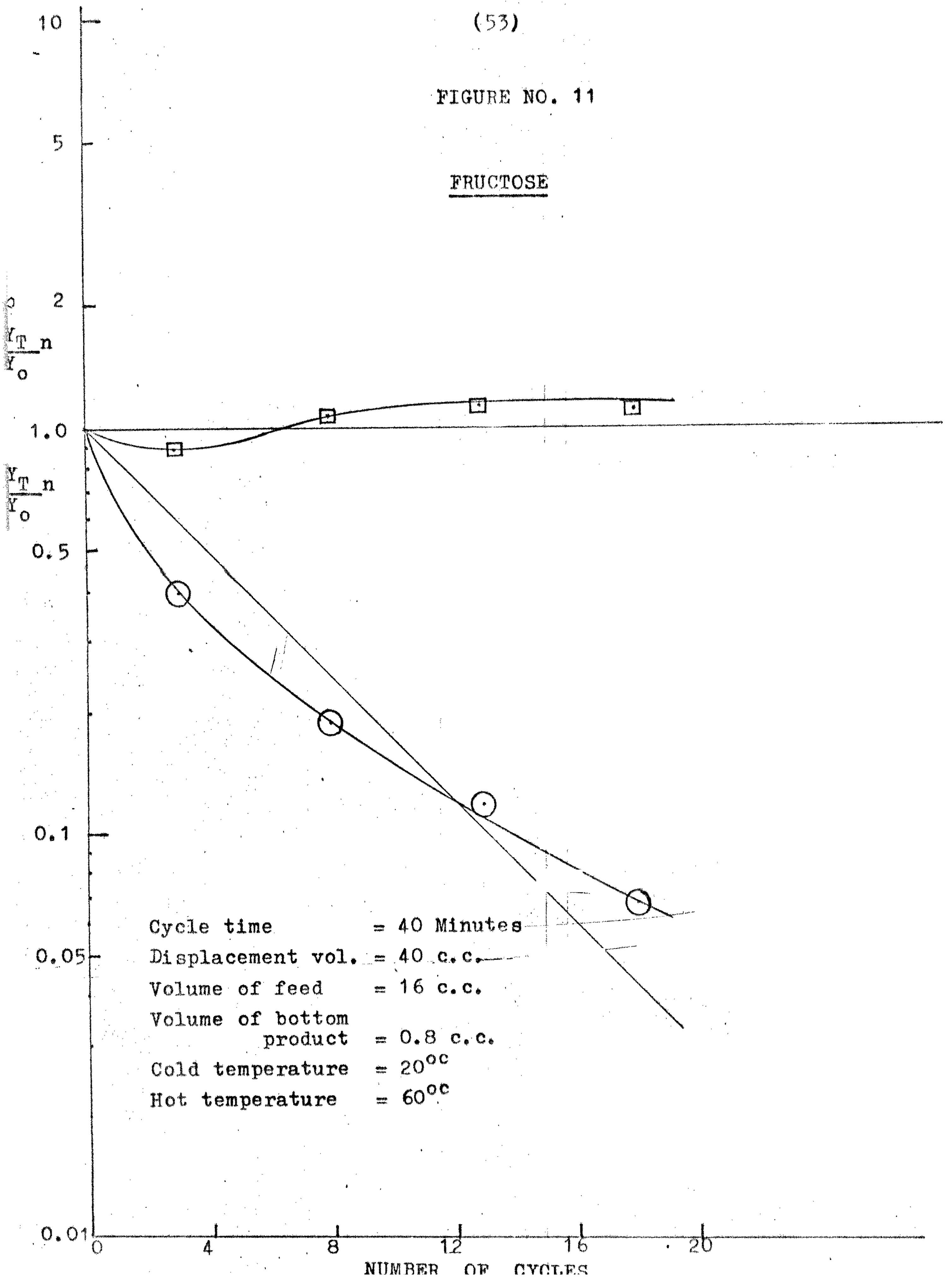
PARAMETRIC PUMP RUN NO. 2

BOTTOM PRODUCT NO.	POLARIMETER READING	CORRECTED READING	Y_B / Y_0
B1	1.820	1.910	0.399
B11	0.840	0.930	0.1942
B111	0.410	0.500	0.118
B1V	0.246	0.336	0.0682

INSTRUMENTAL ERROR = 0.090

FIGURE NO. 11

FRUCTOSE



$$\text{Slope} = \alpha = -\frac{\log 0.70 - \log 0.050}{17 - 2}$$

$$\alpha = -0.0764$$

$$10^{\alpha} = 0.84$$

$$C_2 = \frac{\text{Dead volume of bottom reservoir}}{\text{Displacement volume}} = \frac{2.25}{35.5}$$

$$C_2 = 0.0634$$

$$b = \frac{(1 - 10^{\alpha}) + C_2 (1 - 10^{\alpha})}{(1 + 10^{\alpha}) - C_2 (1 - 10^{\alpha})}$$

$$\therefore b = \frac{(1 - 0.84) + 0.0634 (1 - 0.84)}{(1 + 0.84) - 0.0634 (1 - 0.84)}$$

$$\therefore b = 0.093$$

Table:15. GLUCOSE + H_2O
PARAMETRIC PUMP RUN NO1

TOP PRODUCT NO	INITIAL READING	FINAL READING	NET READING	($<Y_T>/Y_0$)
1	0.073	0.500	0.427	0.178
2	0.069	0.702	0.633	0.224
3	0.071	1.354	1.283	0.448
4	0.072	2.096	2.024	0.7069
5	0.073	2.370	2.297	0.8023
6	0.069	2.527	2.458	0.8585
7	0.070	2.796	2.726	0.9520
8	0.075	2.864	2.789	0.9741
9	0.071	3.065	2.994	1.0457
10	0.065	3.122	3.057	1.06776
11	0.060	2.888	2.828	0.9877
12	0.065	3.327	3.262	1.1393
13	0.071	3.233	3.162	1.1044
14	0.069	3.307	3.238	1.1309
15	0.069	3.280	3.211	1.1215
16	0.059	3.051	2.992	1.045
17	0.065	3.233	3.168	1.1065
18	0.072	3.426	3.354	1.1715
19	0.071	3.200	3.129	1.0929
20	0.069	3.180	3.111	1.0866
21	0.067	3.382	3.315	1.1578
FEED	0.070	2.933	2.863	

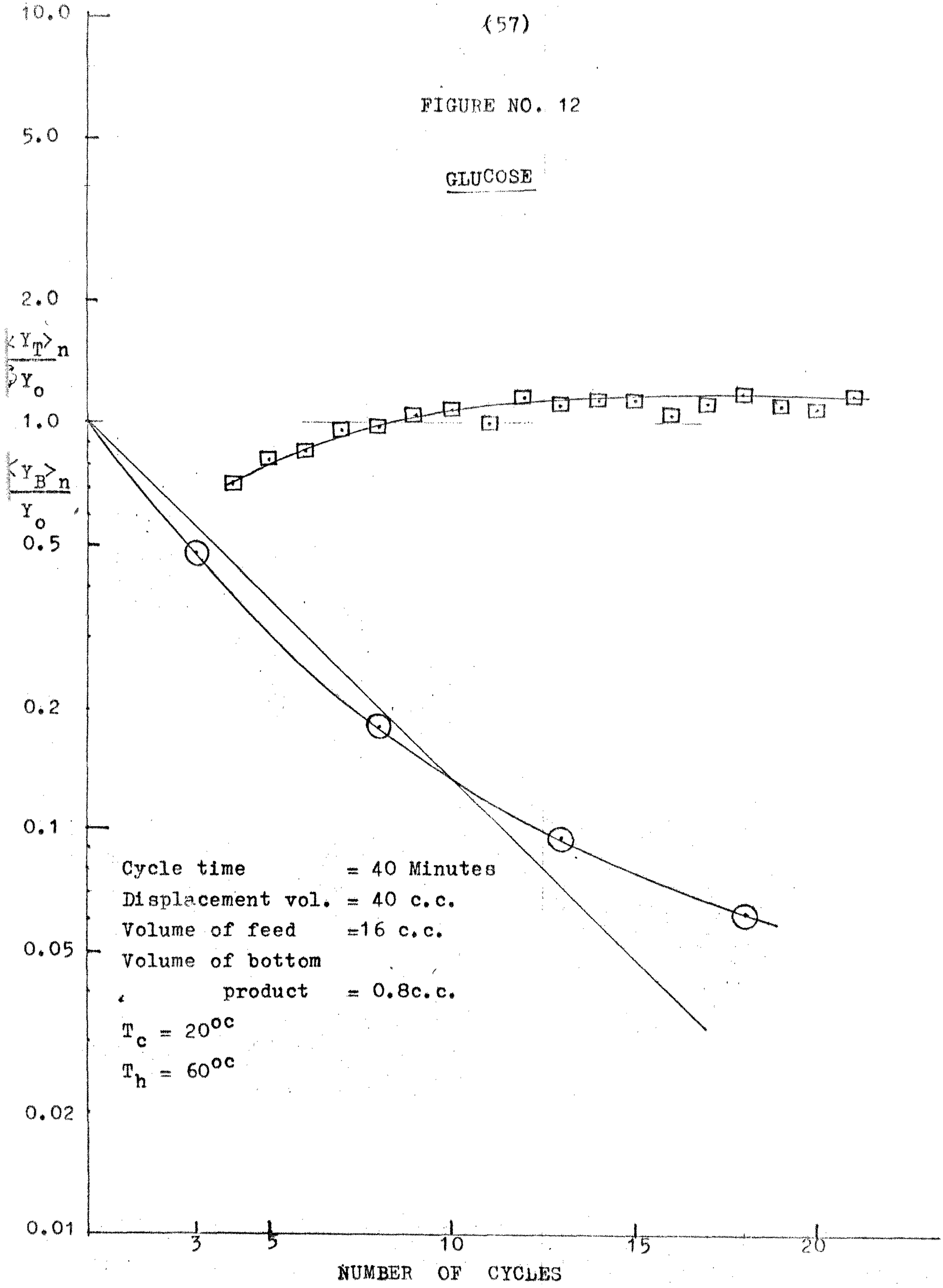
Table:16 GLUCOSE + H_2O

PARAMETRIC PUMP RUN NO 1.

BOTTOM PRODUCT NO.	INITIAL READING	FINAL READING	NET	$\frac{\langle Y_B \rangle_n}{Y_0}$
B1	0.072	1.405	1.333	0.471
B2	0.068	0.580	0.512	0.181
B3	0.063	0.330	0.267	0.0945
B4	0.044	0.221	0.177	0.0627
FEED	0.066	2.890	2.824	1

FIGURE NO. 12

GLUCOSE



$$\text{Slope} = \alpha = -\frac{\log 0.67 - \log 0.032}{17 - 2}$$

$$\alpha = -\frac{\bar{1}.826 - \bar{2}.505}{15} = -0.088$$

$$10^{\alpha} = 0.816$$

$$C_2 = \frac{\text{Dead volume of bottom reservoir}}{\text{Displacement}} = \frac{5.3}{40.65}$$

$$C_2 = 0.1306$$

$$b = \frac{(1 - 10^{\alpha}) + C_2\,(1 - 10^{\alpha})}{(1 + 10^{\alpha}) - C_2\,(1 - 10^{\alpha})}$$

$$\therefore b = \frac{(1 - 0.816) + 0.1306\,(1 - 0.816)}{(1 + 0.816) - 0.1306\,(1 - 0.816)}$$

$$b = 0.116$$

Table:17. GLUCOSE + H_2O

PARAMETRIC PUMP RUN NO2

NO OF CYCLES	INITIAL READING	FINAL READING	NET	$<Y_T>/ Y_0$
T1	0.040	0.047	0.007	0.00247
T2	0.031	0.592	0.561	0.19858
T3	0.037	1.365	1.328	0.47000
T4	0.036	1.974	1.938	0.68600
T5	0.053	2.415	2.362	0.83600
T6	0.031	2.754	2.723	0.96390
T7	0.039	2.822	2.783	0.98510
T8	0.047	3.036	2.989	1.0580
T9	0.023	2.973	2.950	1.0440
T10	0.042	3.289	3.247	1.1493
T11	0.033	3.140	3.107	1.0998
T12	0.044	3.378	3.334	1.1801
T13	0.035	3.340	3.305	1.1699
T14	0.025	3.313	3.288	1.1639

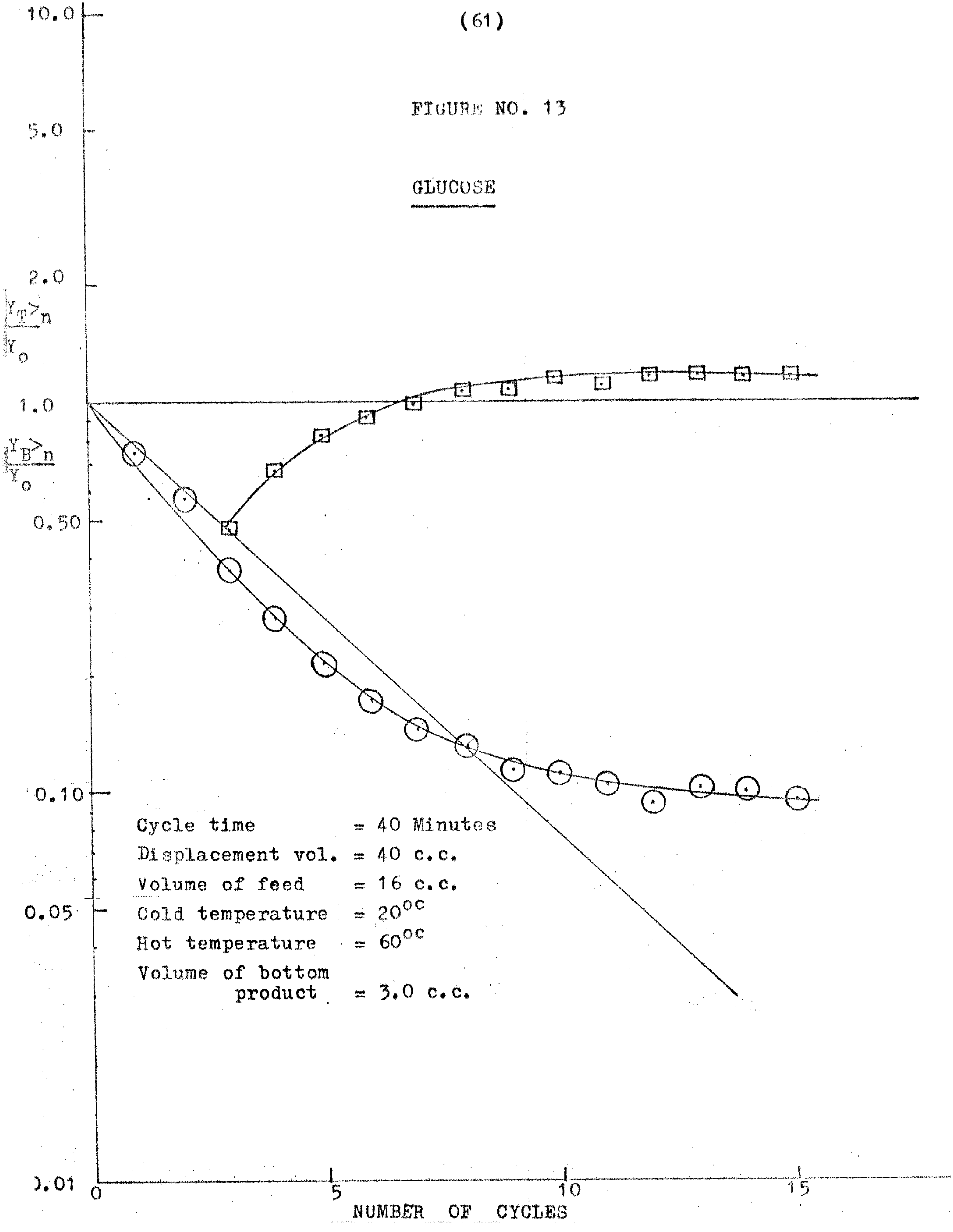
Table: 18 GLUCOSE + H_2O

PARAMETRIC PUMP RUN NO 2

NO OF CYCLES N	INITIAL READING	FINAL READING	NET	$\langle Y_B \rangle_N / Y_O$
B1	0.039	2.155	2.116	0.749
B2	0.045	1.667	1.622	0.5741
B3	0.052	1.109	1.057	0.3740
B4	0.044	0.845	0.801	0.2835
B5	0.062	0.671	0.609	0.21557
B6	0.040	0.536	0.496	0.17557
B7	0.044	0.459	0.415	0.14690
B8	0.042	0.414	0.372	0.13168
B9	0.046	0.375	0.329	0.11646
B10	0.041	0.369	0.328	0.11610
B11	0.052	0.358	0.306	0.10831
B12	0.041	0.310	0.269	0.09522
B13	0.035	0.332	0.297	0.10513
B14	0.045	0.330	0.285	0.10100
B15	0.046	0.319	0.273	0.09664

FIGURE NO. 13

GLUCOSE



Cycle time = 40 Minutes
Displacement vol. = 40 c.c.
Volume of feed = 16 c.c.
Cold temperature = 20°C
Hot temperature = 60°C
Volume of bottom product = 3.0 c.c.

$$\text{Slope} = \alpha = - \frac{\log 0.60 - \log 0.078}{10 - 2}$$

$$\alpha = - 0.1107$$

$$10^{\alpha} = 0.775$$

$$C_2 = \frac{\text{Dead volume of bottom reservoir}}{\text{Displacement}} = \frac{5.2}{40.2}$$

$$\therefore C_2 = 0.129$$

$$b = \frac{(1 - 10^{\alpha}) + C_2 (1 - 10^{\alpha})}{(1 + 10^{\alpha}) - C_2 (1 - 10^{\alpha})}$$

$$\therefore b = \frac{(1 - 0.775) + 0.129 (1 - 0.775)}{(1 + 0.775) - 0.129 (1 - 0.775)}$$

$$b = 0.146$$

Table:19. GLUCOSE + H_2O

PARAMETRIC PUMP RUN NO.3.

NO. OF CYCLES	INITIAL READING	FINAL READING	NET	$\langle Y_T \rangle / Y_0$
T1	0.040	0.047	0.007	0.0248
T2	0.031	0.592	0.561	0.1985
T3	0.037	1.396	1.359	0.481
T4	0.036	1.974	1.938	0.685
T5	0.053	2.415	2.362	0.836
T6	0.031	2.754	2.723	0.915
T7	0.039	2.822	2.783	0.987
T8	0.047	3.036	2.989	1.059
T9	0.023	2.973	2.950	1.043
T10	0.042	3.289	3.247	1.150
T11	0.033	3.140	3.107	1.100
T12	0.044	3.378	3.334	1.179
T13	0.035	3.340	3.305	1.170
T14	0.025	3.313	3.288	1.163
T15	0.032	3.281	3.249	1.150
FEED	0.040	2.865	2.825	1

Table:20. GLUCOSE + H_2O

PARAMETRIC PUMP RUN NO 3

NO. OF CYCLES N	INITIAL READING	FINAL READING	NET	$<Y_{BN}>/Y_0$
B1	0.039	2.155	2.116	0.748
B2	0.045	1.667	1.622	0.574
B3	0.052	1.109	1.057	0.374
B4	0.044	0.845	0.801	0.284
B5	0.062	0.671	0.609	0.2158
B6	0.040	0.536	0.496	0.1758
B7	0.044	0.459	0.415	0.147
B8	0.042	0.414	0.372	0.1317
B9	0.046	0.375	0.329	0.1164
B10	0.041	0.369	0.328	0.1160
B11	0.052	0.358	0.306	0.1083
B12	0.041	0.310	0.269	0.0952
B13	0.035	0.332	0.297	0.1050
B14	0.045	0.330	0.285	0.1019
B15	0.046	0.319	0.273	0.0965
FEED	0.040	2.865	2.825	1.00

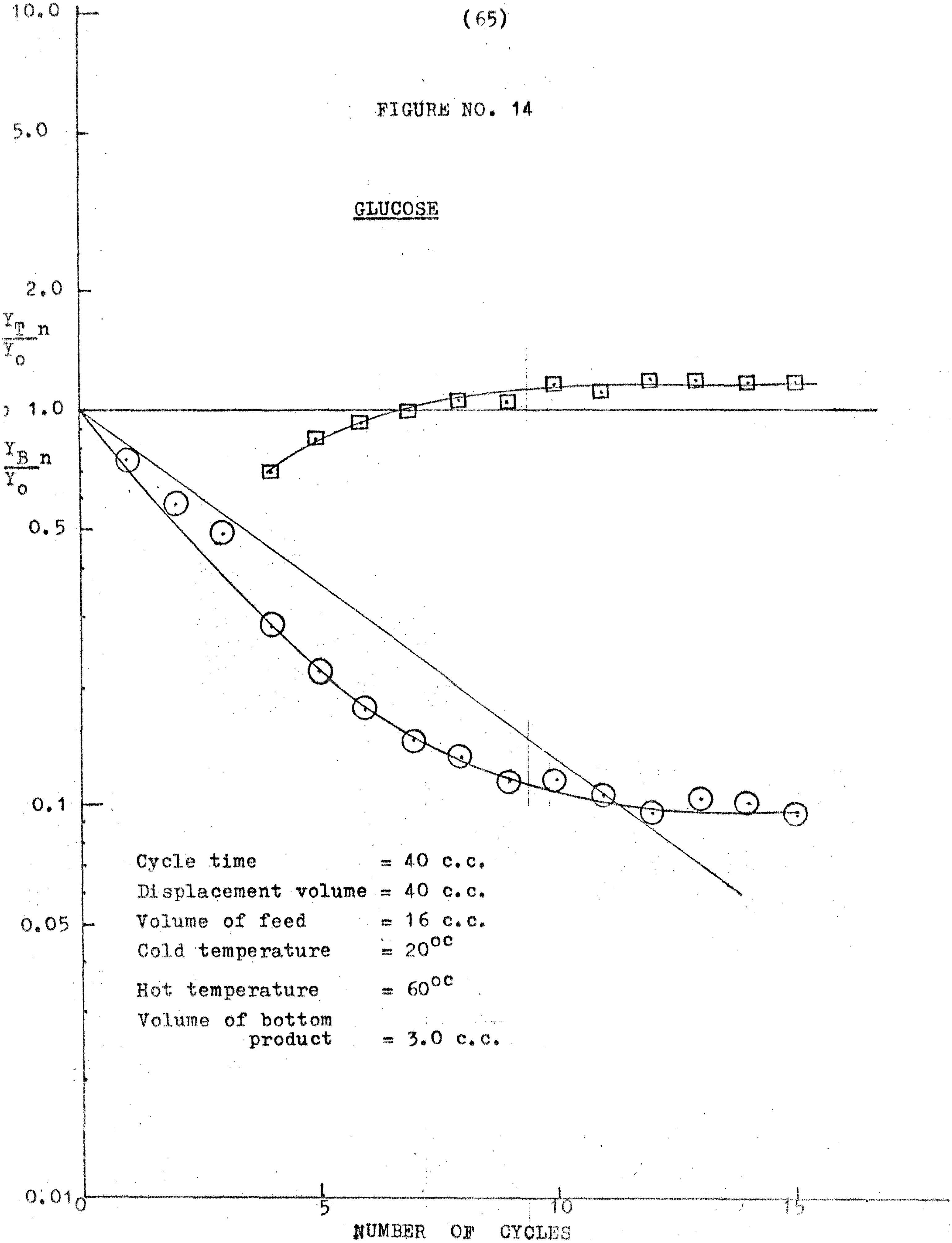


FIGURE NO. 14

GLUCOSE

Cycle time = 40 c.c.
Displacement volume = 40 c.c.
Volume of feed = 16 c.c.
Cold temperature = 20^{oc}
Hot temperature = 60^{oc}
Volume of bottom product = 3.0 c.c.

$$\text{Slope} = \alpha = - \frac{\log 0.66 - \log 0.032}{17 - 2}$$

$$\alpha = - 0.0876$$

$$10^{\alpha} = 0.818$$

$$C_2 = \frac{\text{Dead volume of bottom reservoir}}{\text{Volume of displacement}} = 0.131$$

$$b = \frac{(1 - 10^{\alpha}) + C_2 (1 - 10^{\alpha})}{(1 + 10^{\alpha}) - C_2 (1 - 10^{\alpha})}$$

$$\therefore b = \frac{(1 - 0.818) + 0.131 (1 - 0.818)}{(1 + 0.818) - 0.131 (1 - 0.818)}$$

$$\therefore b = 0.1086$$

COMPARISON OF 'b' VALUE

	GLUCOSE	FRUCTOSE
'b' VALUE FROM PARAMETRIC PUMP $\Phi_B = 0.02$ $Tc = 293^{ok}$ $T_H = 333^{ok}$	0.116	0.095
'b' VALUE FROM ADSORPTION ISOTHERM	0.0594 $Tc = 293^{ok}$ $T_H = 313^{ok}$	0.0774 $Tc = 293^{ok}$ $T_H = 313^{ok}$
	0.114 $Tc = 293^{ok}$ $T_H = 333^{ok}$	0.1055 $Tc = 293^{ok}$ $T_H = 333^{ok}$

DISCUSSION ON RESULT

(A) GLUCOSE + H_2O SYSTEM:

By observing the figure (12) (13) and (14) we can conclude that after ten cycles the separation per cycle $\frac{Y_B}{Y_0}/n$ decreases. From the graph we can say after some cycles the bottom concentration might become constant . Regarding the top product concentration if we observe the concentration is less than feed concentration upto few cycles i.e. $\frac{Y_T}{Y_0} < 1$. The reason for this can be this that initially activated carbon had not adsorbed to its maximum capacity of adsorption . After couple of cycles when activated carbon adsorbs its maximum amount then we see the concentration of top product increasing.

The concentration of top product does not increase too much as we take out large amount of top product and as to have material balanced .

If we have $\Phi_B = \frac{\text{volume of Bottom Product}}{\text{Volume of Displacement}}$ is less we get very good separation for example looking into the graph FIGURE NO. 12 the separation i.e. $\frac{Y_B}{Y_O}$ at eighteenth cycle is 0.062, which in FIGURE No. 13 and 14 is around 0.09. in first run which was plotted in FIGURE NO. 12 we took 0.8c.c of bottom product and 15.2c.c top product while in other two experiments of Glucose run , volume of bottom product was around 3c.c and top product 13c.c So in this way we can say lesser the Φ_B taken, more separation we get and hence greater the (b) value. There might be some good separation if we take higher concentration of feed and difference in cold and hot half cycle temperature more.

The (b) value got from adsorbent isotherm and from parametric pump resembles very closely. From adsorbent isotherm (b) value of glucose was 0.114 and from parametric pump-ing it came out 0.116

(B) FRUCTOSE + H_2O SYSTEM

The behaviour of experimental result of fructose and water system resembles very closely.to glucose. Two parametric pump runs were done. In one total bottom product was about 3c.c and in other 0.8c.c of bottom product was taken. Other parameters were same as glucose. Here also we observe that lesser the Φ_B we choose we get better separation. For example in FIGURE 11 the separation is 0.068 in 18th cycle but in FIGURE 10 the separation is around 0.2 the value of Φ_B in FIGURE 11 is $\frac{0.8}{40} = 0.02$ and in FIGURE 10 $\Phi_B = \frac{4}{40} = 0.1$.

This experiment shows that the separation in Fructose + H_2O System is slightly less than Glucose+ H_2O System. In Glucose + Water System we had got maximum separation of 0.062 in eighteenth cycle at

Φ_B = 0.02 while in Fructose + Water System is 0.068 So therefore the ,b, value of Fructose + WAter System is also slightly less than ,b, value of Glucose+ Water System. According to this experiment the separation in Fructose+ Water System can be more after eighteenth cycle i.e. less than 0.068 . The behaviour of top product concentration is the same i.e. initially less than feed then gradually when system attains equilibrium it started rising and maintain slightly higher concentration than feed.

CONCLUSION

It is a great success in the separation of Glucose and Water System and Fructose and Water System, by using parametric pumping. The adsorbent used for this came out to be of good properties for separation by parametric pumping.

By observing the graph of separation i.e. $\frac{Y_B}{Y_o}$ vs Number of cycles and $\frac{Y_T}{Y_o}$ vs Number of cycles we can predict that after twenty cycles the separation will be more than 0.06 in the bottom product in both glucose and fructose system.

The system can be of great advantageous to industries specially pharmaceutical industries for separating glucose and fructose from the water solution and can economically extract maximum amount of glucose and fructose from their waste solution and make their extraction more economical.

Possibilities for separating glucose and fructose from ternary mixture (glucose + fructose + water) as the b value of glucose + Water system and b value of fructose + water system are very close, so according to chen's theory there is very small possibility of separation from ternery mixture. there might be possibility of possibility of separation of glucose and fructose from ternery mixture if we use two different type of adsorbents. If the difference between b value of glucose + water system with one adsorbent and b value of fructose + water system with other system, is more, than we might have good chances of success in separating glucose and fructose from ternery mixture which will be of great success, although it need more more research in this field.

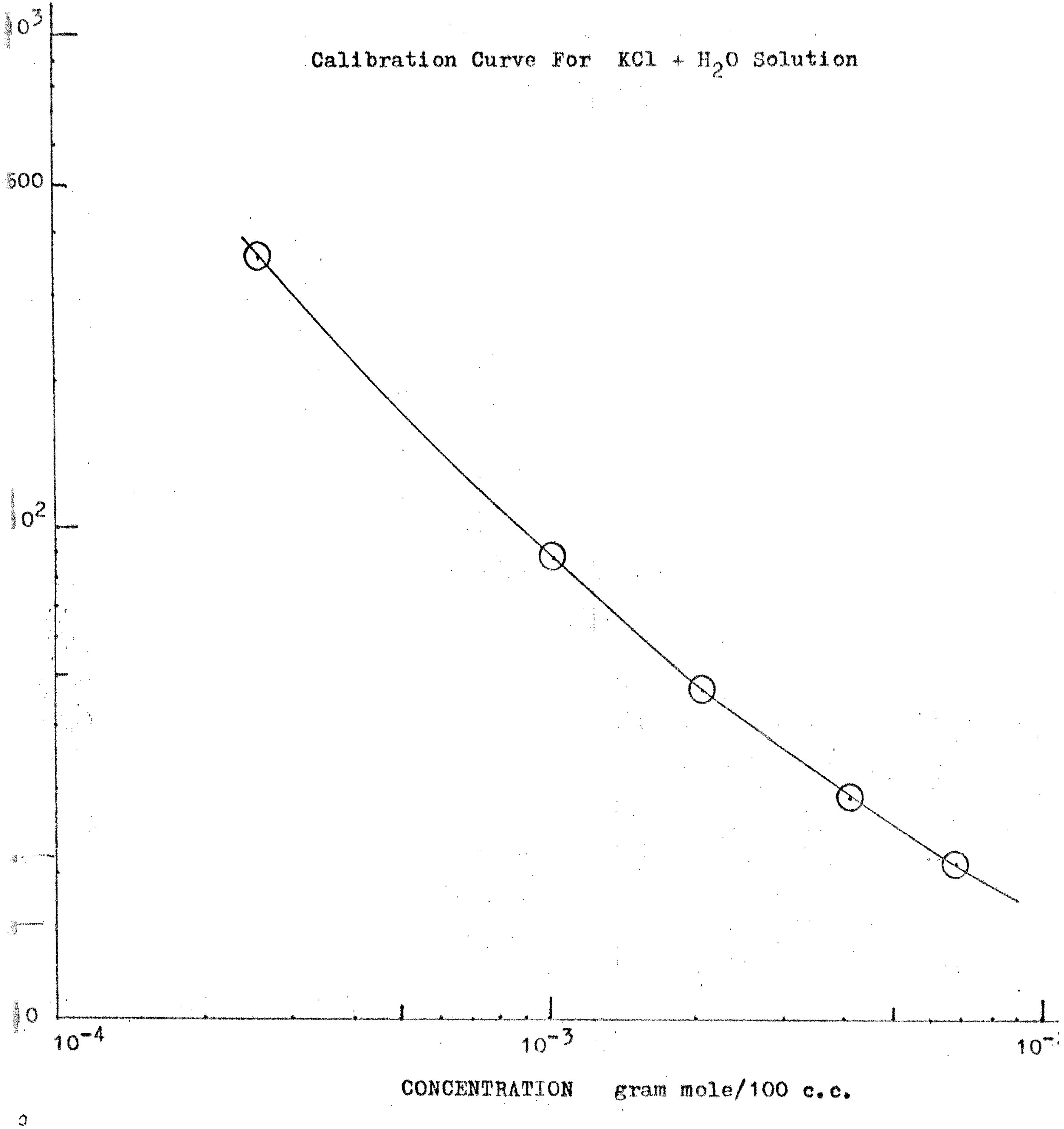
Experiment Of Parametric Pumping For Binary Solution OF KCl.

This experiment was carried out more or less the same way as glucose and fructose parametric run. In this case we used Ion Retardation Resin (AG11A8) manufactured by Bio-Rad. Cold temperature of 15°C and hot temperature of 65°C was selected. This temperature was selected on the basis of the previous experiences. The feed solution of 5% KCl solution by weight was used. The resin was filled into column very carefully as there is too much chance of air bubbles, and it is very hard to remove them afterwards. After filling up column with resin and KCl solution, flushed the lines with feed solution and filled the top and bottom reservoir syringes upto 5c.c and 25c.c respectively. This was kept for overnight for getting better equilibrium.

The semi continuous run started with hot half cycle at 65°C and the displacement of reservoir was kept 20c.c in 20 minutes. $\phi_B < 0.050$, $\phi_T \cong .450$ total feed of Of 10c.c was used. The feed was fed at cold half cycle at 15°C . The top and bottom products were collected about 9.1c.c and 0.9c.c and very accurately diluted to 25c.c and concentration obtained by using bridge conductivity meter.

The results are noted in table 21, 22 and plotted in graph FIGURE NO. 16.

FIGURE NO. 15



Calibration Curve For KCl + H_2O Solution

Table:21.

POTASSIUM CHLORIDE
PARAMETRIC PUMP RUN NO1

Cycle No.	Reading Of Bottom Product Con.	Concentration Of Bottom Product Gram Mole / 100c.c	$\langle Y_b \rangle / Y_o$
1	42	$2.375 \times 10^{-3} \times 27.8 = 0.0658$	0.984
2	49	$1.98 \times 10^{-3} \times 27.8 = 0.055$	0.821
3	55	$1.75 \times 10^{-3} \times 27.8 = 0.0486$	0.726
4	57	$1.67 \times 10^{-3} \times 27,8 = 0.0464$	0.692
5	63	$1.48 \times 10^{-3} \times 27.8 = 0.0411$	0.614
6	67	$1.375 \times 10^{-3} \times 27.8 = 0.0382$	0.570
7	70	$1.3 \times 10^{-3} \times 27.8 = 0.0361$	0.539
8	69	$1.325 \times 10 \times 27.8 = 0.0367$	0.548
9	71	$1.28 \times 10^{-3} \times 27.8 = 0.356$	0.532
10	73	$1.25 \times 10^{-3} \times 27.8 = 0.0348$	0.519
11	76	$1.18 \times 10^{-3} \times 27.8 = 0.0328$	0.489
12	80	$1.125 \times 10^{-3} \times 27.8 = 0.0313$	0.467

Table:21. POTASSIUM CHLORIDE

PARAMETRIC PUMP RUN NO1

Cycle No.	ReadingOf Bottom Product Con.	Concentration Of Bottom Product Gram Mole/100c.c	$\langle Y_b \rangle / Y_o$
13	83	$1.075 \times 10^{-3} \times 27.8 = 0.0298$	0.445
14	95	$9.3 \times 10^{-4} \times 27.8 = 0.0258$	0.386
15	92	$9.6 \times 10^{-4} \times 27.8 = 0.0267$	0.398
16	96	$9.2 \times 10^{-4} \times 27.8 = 0.0256$	0.382
17	100	$8.8 \times 10^{-4} \times 27.8 = 0.0245$	0.366
18	103	$8.2 \times 10^{-4} \times 27.8 = 0.0228$	0.341
19	105	$8.4 \times 10^{-4} \times 27.8 = 0.0235$	0.349
20	125	$6.9 \times 10^{-4} \times 27.8 = 0.0192$	0.287
21	123	$7.1 \times 10^{-4} \times 27.8 = 0.0197$	0.295
22	134	$6.21 \times 10^{-4} \times 27.8 = 0.01725$	0.257
23	151	$5.55 \times 10^{-4} \times 27.8 = 0.01672$	0.250
Feed	79	0.067	

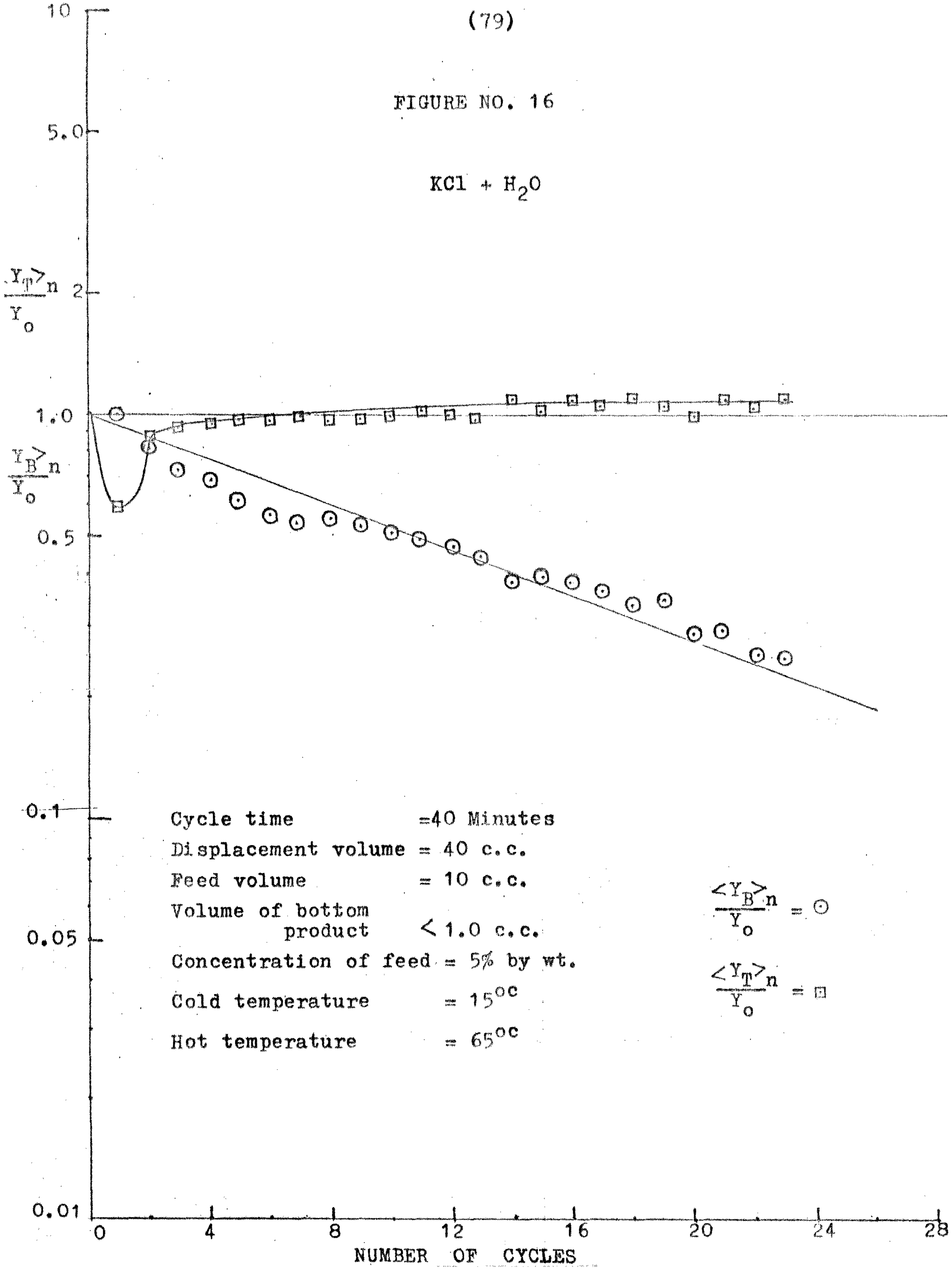


FIGURE NO. 16

$KCl + H_2O$

Cycle time = 40 Minutes

Displacement volume = 40 c.c.

Feed volume = 10 c.c.

Volume of bottom product < 1.0 c.c.

Concentration of feed = 5% by wt.

Cold temperature = 15°C

Hot temperature = 65°C

$\frac{\langle Y_B \rangle n}{Y_o}$ = ⊙

$\frac{\langle Y_T \rangle n}{Y_o}$ = ⊡

Table:22. POTASSIUM CHLORIDE

PARAMETRIC PUMP RUN NO 1

Cycle No.	Reading Of top Product Con.	Concentration Of Bottom Product Gram Mole /100c.c	$<Y_T>/Y_o$
1	13.6	$1.4\times 10^{-2}\times 2.8 = 0.0392$	0.585
2	11.5	$2.1\times 10^{-2}\times 2.8 = 0.0588$	0.878
3	11.4	$2.2\times 10^{-2}\times 2.8 = 0.0616$	0.920
4	11.3	$2.25\times 10^{-2}\times 2.8 = 0.063$	0.940
5	11.1	$2.3\times 10^{-2}\times 2.8 = 0.0644$	0.963
6	11.0	$2.3\times 10^{-2}\times 2.8 = 0.0644$	0.963
7	10.9	$2.35\times 10^{-2}\times 2.8 = 0.0658$	0.982
8	10.7	$2.3\times 10^{-2}\times 2.8 = 0.0644$	0.961
9	11.0	$2.3\times 10^{-2}\times 2.8 = 0.0644$	0.961
10	10.9	$2.35\times 10^{-2}\times 2.8 = 0.0658$	0.982
11	10.8	$2.4\times 10^{-2}\times 2.8 = 0.0672$	1.001
12	10.9	$2.35\times 10^{-2}\times 2.8 = 0.0658$	0.982

Table:22. POTASSIUM CHLORIDE

PARAMETRIC PUMP RUN NO 1

Cycle No.	Reading Of toptop Product Con.	Concentration Of Bottom Product Gram Mole /100c.c	$\langle Y_T \rangle / Y_o$
13	11	$2.3 \times 10^{-2} \times 2.8 = 0.0644$	0.961
14	10.55	$2.6 \times 10^{-2} \times 2.8 = 0.0728$	1.088
15	10.8	$2.4 \times 10^{-2} \times 2.8 = 0.0672$	1.001
16	10.5	$2.6 \times 10^{-2} \times 2.8 = 0.0728$	1.088
17	10.65	$2.5 \times 10^{-2} \times 2.8 = 0.070$	1.045
18	10.5	$2.6 \times 10^{-2} \times 2.8 = 0.0728$	1.088
19	10.6	$2.5 \times 10^{-2} \times 2.8 = 0.070$	1.045
20	10.7	$2.45 \times 10^{-2} \times 2.8 = 0.0658$	0.982
21	10.55	$2.6 \times 10^{-2} \times 2.8 = 0.0728$	1.088
22	10.6	$2.5 \times 10^{-2} \times 2.8 = 0.070$	1.045
23	10.5	$2.6 \times 10^{-2} 2.8 = 0.0728$	1.088
FEED	79.0	0.067	1.00

$$\text{Slope} = \alpha = -\frac{\log 0.930 - \log 0.245}{22 - 1}$$

$$\alpha = -\frac{\bar{1}.968 - \bar{1}.389}{21} = -0.0276$$

$$10^{\alpha} = 0.92$$

$$C_2 = \frac{\text{Dead vol. of bottom reservoir}}{\text{Displacement}} = \frac{5.0}{20} = 0.25$$

$$b = \frac{(1 - 10^{\alpha}) + C_2\,(1 - 10^{\alpha})}{(1 + 10^{\alpha}) - C_2\,(1 - 10^{\alpha})}$$

$$\therefore b = \frac{(1 - 0.92) + 0.25\,(1 - 0.92)}{(1 + 0.92) - 0.25\,(1 - 0.92)}$$

$$\therefore b = 0.0516$$

Discussion On Result - Of KCl Separation From KCl + H_2O System

By observing the figure 16 we can see that the separation in this case is slower than glucose and fructose system. We can get better separation than 0.2 after twenty five cycles. There are far more chances that after infinite cycles the concentration of KCl in bottom product becomes considerably low. b value of this system is calculated by Chen's method and comes out to be 0.0516. Φ_B for this system was chosen equals less than $\frac{1}{20} = 0.05$. Bottom product was less than 1c.c and displacement volume was 20c.c. If Φ_B is taken still less i.e. if we take displacement volume there might be better separation and b value might increase.

The behavior of top product concentration again very much resembles to that of glucose and fructose system. Initially top product concentration decreases and gradually becomes more and more until it becomes slightly more than feed concentration. At this time the system has acquired its complete equilibrium, and there is no more accumulation of salt in the column. So whatever KCl fed in, comes out ofthe system in bottom and top product. As bottom product has low concentration so obviously top product must have more than feed concentration.

This might be very helpful separation process in industries where it needed to reduce the concentration of KCl in the solution which might be required by certain processes. as KCl is present in sea water . It might be also helpful in cleaning waste water treatment and disposal.

Parametric pumping has created a vast field for research and development in separation science and Engineering . This can be proved as most economical method for the separation of various solutes using different adsorbents. The separation can be attained in some cases to considerably large factor. The time has come now that this process might be utilized by industries and great research can be done on this line.

References

(1) Aris, R. Ind. Engg. Chem. Fundamental <u>8</u> 603 (1969)

(2) Chen, H.T.; et, al. AIChE J. <u>18</u>, 2, 356 (1972)

(3) Chen, H. T. and Hill, F. B., Separation Science <u>6</u> (3) 411, 1971.

(4) Chen, H. T. and Hill, F. B., Atomic Energy Commision Report BNL 13976 September 1969.

(5) Dubrunfaut, A.P.C.R.. Acad. Science, Paris <u>69</u> 1366 (1864),<u>42</u>, 901 (1856)

(6) Gyani, B. P., J. Indian Chem. Soc., <u>21</u>, 79 (1944)

(7) Harding, T.S., J. Am. Chem. Soc. <u>44</u> 1765, (1922)

(8) Harding, T. S., Sugar Chicago <u>25</u>,406, (1923)

(9) Hatt, H. H., and Triffett, C. K., J. App. Chem. <u>14</u> 195 (1964)

(10) Jones, J. K. N., and Wall, R. A., Canad. J. Technol. <u>29</u> 243 (1951)

(11) Kniaseff, Valsily, J. Phy. Chem. <u>36</u> 1191 (1932)

(12) Langmuir, I., J. Am. Chem. Soc. <u>38</u> 221, (1916)

(13) Langmuir, I., J. Am. Chem. Soc. 40 1361, (1918)

(14) Lefre, L.J., U.S.P. 3.044, 904

(15) Movery, D.F., J.Am. Chem. Soc. 73 5049,(1951)

(16) Pigford, R.L.,Baker , B. and Blum, D.E., Ind.Eng Chem., Fundam. 8 144 (1969)

(17) Swead, N,H,, Ph.D. Dissertation, Princeton Univ. (1969)

(18) Smith, F., and Priesterbach, D.R., J. Am. Chem. Soc. 76 4191 (1954)

(19) Tink, R.R., and Neish, A.C., Canad. J. Technol., 29 , 243, (1951)

(20) Whistler R.L. Durso, D.F. J. Am. Chem. Soc. 72, 677, (1968)

(21) Wilhelm, R.H, and Sweed, N.H., Science 159,522, (1968)

(22) Wilhelm, R.H., Rice, A.W,, Rolke, R.W. and Sweed, N.H.; Ind. Eng. Chem.,Fundam. 7, 337, (1968)

(23) Wolfrom, M.L., J.Am. Chem. Soc. 72 4778 (1950)

(24) Wolfrom, M.L., J.A.C.S., 68 1449 (1946)

(25) Chen, H.T., and Jaferi, J.A. Unpublished work