

THE ROTATORY POWER OF COMMERCIAL GLUCOSE AND GRAPE SUGAR. A METHOD OF DETERMINING THE AMOUNT OF REDUCING SUBSTANCE PRESENT BY THE POLARISCOPE. By H. W. WILEY, of Lafayette, Ind.

IN "the trade" the name "Grape Sugar" is applied only to the solid product obtained from corn starch. On the other hand, the term "Glucose" is given to the thick syrup made from the same material. I shall use these words in their commercial sense.

INSTRUMENTS EMPLOYED.

I used in the following investigations two polariscopes, made by Franz Schmidt and Hænsch, Berlin.

The readings of these instruments, after correction for displacement, agreed well together.

The one was the instrument ordinarily used, in which the purple ray is employed and the quartz half moons give blue and red tints.

The other was the Laurent "half shadow."

Both of these instruments are graduated to read 100 divisions each equal to 1 per cent. sugar with a solution containing 26.048 grams. pure cane sugar in 100 cc.

In addition to this scale the "half shadow" has another which gives the actual angular rotation. This is especially convenient when the specific rotatory power of a substance is to be determined.

The angular rotation however can be calculated for the former instrument.

For if we take the specific rotatory power of pure cane sugar at $73^{\circ}.8$ we have the following equation:

$$73^{\circ}.8 = \frac{a \times 100}{2 \times 26.048}, \text{ whence } a = 38^{\circ}.45$$

Each division on the cane sugar scale is therefore equal to $0^{\circ}.3845$ angular measure.

This quantity corresponds to the transition tint. It is different for the differently colored rays.

In the "half shadow" polariscope, an instrument particularly adapted to persons afflicted with any degree of color blindness, the mono-chromatic light, coming from the sodium-Bunsen lamp, passes through a crystal of acid potassium chromate.

The ray thus produced is less rotatable than the "transition tint." When the instrument gives 100 divisions on the sugar scale, it shows an angular rotation of only $34^{\circ} 42' = 34^{\circ}.7$.

One division therefore of the sugar scale is equal to $0^{\circ}.347$ angular measure.

To determine the specific rotatory power of cane sugar for the sodium-acid potassium chromate ray, we use the following equation.

$$\text{Sp. rot. pr.} = \frac{34^{\circ}.7 \times 100}{2 \times 26.048} = 66^{\circ}.6$$

To determine the specific rotatory power for any other substance which has been determined for the transition tint, we multiply by the factor .9024.

Thus, if we take the specific rotatory power of dextrin for the transition tint at 139° , for the "half shadow" tint it will be $139^{\circ} \times .9024 = 125^{\circ}.4$.

These data rest upon the accepted formulæ;

$$(1) \theta = \frac{a}{e \cdot \delta \cdot \lambda}$$

$$(2) \theta = \frac{a \times V}{\lambda \times \omega}$$

Here a = angular rotation.

" θ = specific rotatory power.

" e = amount of substance in one gramme of the solution.

" δ = specific gravity of solution.

" λ = length of observation tube.

" ω = weight of substance in grammes.

MATERIAL.

The glucoses studied in the following examinations were made by the Peoria Grape Sugar Company. I am under obligations to Mr. Wm. Allen, the superintendent, for many favors in connection with my work.

The grape sugars were made in Buffalo.

ROTATORY POWER.

The average value of θ for the "half shadow" ray is nearly 85° . For the purple ray it is nearly 94° . It however varies extremely in different samples.

The following table will show the range of these variations:—

Showing Variations of θ in different Specimens of Glucose and Grape Sugar, together with the Specific Gravities of the same.

TABLE I.

No.	θ	Sp. gr.	No.	θ	Sp. gr.
1	91.50	1.406	11	89.36	1.416
2	91.50	1.407	12	87.73	1.422
3	98.10	1.440	13	89.77	1.417
4	79.93	1.414	14	70.84	1.463
5	75.47	1.414	15	69.40	1.463
6	83.97	1.417	16	87.67	1.412
7	82.75	1.416	17	109.00	1.427
8	86.41	1.415	18	93.17	1.431
9	84.11	1.416	19	89.75	1.409
10	87.10	1.417	20	91.31	1.421

From a study of this table it is seen that within small limits θ is independent of the specific gravity of the solution.

Nos. 14 and 15 were grape sugar and the specific gravity is much higher here than in the glucoses, while the value of θ is much less.

Where the increase in density however is considerable, as in 3 and 17, there is also a marked increase in the value of θ , although this increase is not proportional to the increment of specific gravity.

In masses of homogeneous nature and structure we should expect *a priori* that θ would always be proportional to the density of the body, *i. e.*, to the amount of optically active matter in a unit number of grammes.

It is thus seen without further argument that commercial glucoses are not optically homogeneous, even when made in the same factory and by processes which do not sensibly vary. A further study of these optical reactions convinced me that the rotatory power of commercial glucose increased, as the percentage of reducing substance diminished. The following table shows the value of θ and the corresponding percentage of reducing matter as obtained by Fehling's solution.

TABLE II.

No.	θ	Per cent. reducing matter.	No.	θ	Per cent. reducing matter.
1	91.50	53.20	11	89.36	53.50
2	91.50	52.36	12	87.73	56.49
3	98.10	54.60	13	89.77	52.36
4	79.93	61.73	14	70.84	69.93
5	75.47	62.50	15	69.40	69.30
6	83.97	59.35	16	87.67	56.34
7	82.75	61.40	17	109.99	39.22
8	80.41	58.80	18	93.17	57.14
9	84.11	58.55	19	89.75	54.37
10	87.19	55.60	20	91.31	56.81

It will be seen by the above table that, as the per cent. of reducing matter increases, the value of θ diminishes, and *vice versa*. Nos. 14 and 17 show extreme cases of this law.

Nos. 3, 18 and 20, because of their high specific gravities should not be included in the above generalization.

Having thus established the law that the per cent. of reducing matter is in general inversely as the value of θ , it is next proposed to investigate the relation between these two quantities and determine whether it is constant or variable. From Nos. 1 and 2 of table II, it is seen that for a value of $\theta = 91.50$, the percentage of reducing matter is 52.78. Let us say for convenience in calculation that $\theta = 91.50$ corresponds to reducing substance = 53 per centage. Let us consider next some of the cases in which the value of θ differs widely from 91.50. No. 17 of above table affords an example.

The difference is $109.99 - 91.50 = 18.49$. The difference in the percentage of reducing substance is $53 - 39.22 = 13.78$. Thus an excess of the value of θ of 18.49 corresponds to a deficit of 13.78 in the percentage of reducing matter.

Therefore a variation of each degree in the value of θ is equivalent to .745 in the percentage of reducing matter. By similar calculations with the other data furnished by the table I have found, not including Nos. 3, 18 and 20, marked by the high specific gravity, that this number lies between .75 and .78.

I will give the calculations for the first of these numbers and compare them with the numbers obtained by analysis.

TABLE III.

No.	Variation of θ .	Per cent. reducing matter by .75 factor.	Per cent. reducing matter by Fehling's solution.	No.	Variation of θ .	Per cent. reducing matter by .75 factor.	Per cent. reducing matter by Fehling's solution.
1	0	53.	53.20	11	- 3.77	55.82	56.40
2	0	53.	52.36	12	- 1.73	54.29	56.18
3	-12.08	62.06	61.73	13	-20.66	68.32	69.93
4	-16.03	65.03	62.50	14	-22.10	69.56	69.30
5	- 7.53	58.64	59.35	15	- 3.83	55.88	56.09
6	- 8.75	59.57	61.40	16	+18.49	39.14	39.22
7	- 5.07	56.81	58.80	17	- 1.75	54.32	54.05
8	- 7.44	58.58	58.55	18	- .19	53.14	56.81
9	- 4.80	56.21	56.60	19	+ 0.60	47.15	54.60
10	- 2.14	54.62	53.50	20	+ 1.66	51.75	57.14

In the above table, Nos. 18, 19 and 20 are the three specimens with high specific gravities; we will, therefore, exclude them from the discussion.

In the other numbers the percentage of reducing matter, as calculated from the readings of the polariscope, falls short of the amount obtained by the alkaline copper test ten times, and by an average of 1.018. It exceeds that amount seven times, with an average of .75.

We thus see that the polariscope will enable us to compute the reducing matter present in a glucose with a probable error of less than one per cent. This is quite accurate enough for practical purposes.

Perhaps a larger number of determinations should be made before constructing a formula for determining the amount of reducing substance in a "straight" glucose.

The following formulæ, however, are given provisionally, subject to some slight correction derived from more extended data.

We may have three cases:

1st. The value of $\theta = 91.50$.

2nd. " " " " < 91.50 .

3rd. " " " " > 91.50 .

In the first case, the percentage of reducing substance in a glucose of not far from 1.410 specific gravity will be nearly 53.

In the second case, the required percentage may be found by the following formula, in which a = difference between the value of θ and 91.50 and g = percentage reducing substance required.

$$g = 53 + .75a \text{ or } .78a$$

In the third case we have

$$g = 53 - .75a \text{ or } .78a$$

In order to make this principle of more general application, I have modified the calculations so as to apply the formulæ directly to the cane sugar scale of the instrument. To this end, for instruments using 26.048 grammes for 100 divisions, it is convenient to use only 10 grammes of the glucose. If 26.048 grammes are employed, the neutral point is thrown entirely beyond the limit of the scale. Ten grammes is the quantity which has been employed in the following table. The average reading of the sugar scale for ten grammes is about 50. In Table IV (p. 314), will be found the results of my experiments.

The calculations (Table IV, p. 214) were made from the following data.

Starting with Nos. 1 and 2 and discarding small fractions, we find that 53 divisions of the cane sugar scale correspond to 53 per cent. of reducing matter nearly.

By a method of calculation entirely similar to that employed in determining the reducing matter from the fluctuations of θ , I have found that a variation of one degree in the sugar scale corresponds to an inverse variation of nearly 1.25 per cent. of reducing substance.

We may have, as in the previous calculation, three cases.

$$\begin{array}{l} \text{1st. The reading of the scale} = 53 \\ \text{2nd. " " " " " } > 53 \\ \text{3rd. " " " " " } < 53 \end{array}$$

In the first case $53 = 53$ per cent. nearly.

In the second case placing a for the reading of the scale we have

$$g = 53 - (a - 53) 1.25$$

In the third case we have

$$g = 53 + (53 - a) 1.25$$

TABLE IV.

No.	Scale.	Per cent. reducing substance by calculation.	Per cent. same by copper test.	Difference.
1	52.65	53.43	53.20	+ .23
2	52.65	53.43	52.36	- 1.07
3	46.07	61.66	61.73	- .07
4	43.05	64.90	62.50	+ 2.40
5	48.04	58.75	59.35	- .60
6	47.70	59.63	61.40	- 1.77
7	49.80	57.00	58.80	- 1.80
8	48.45	58.56	58.55	+ .01
9	50.26	56.45	55.60	+ .85
10	51.50	54.88	53.50	+ 1.30
11	50.57	56.04	56.49	- .45
12	51.74	54.58	56.18	- 1.60
13	40.83	68.21	69.93	- 1.72
14	40.00	69.25	69.30	- .05
15	50.53	56.09	56.34	- .27
16	63.80	39.50	39.22	+ .28
17	51.73	54.37	54.05	+ .32
18	52.63	53.46	56.81	
19	56.53	48.59	54.00	
20	53.70	52.10	57.14	

In seven of the first seventeen cases the percentage of reducing substance, calculated by the above formulæ, exceeded that given by the copper test, and by a mean amount of .539.

In ten of them it fell short and by a mean amount of .938. This method, therefore, can be relied upon to give results which vary from the copper test only by a small amount.

Not much more in the way of accuracy can be claimed for the copper test itself.

In Nos. 18, 19 and 20 we have again the cases where the high specific gravities vitiate the results of the calculation.

CORRECTION FOR SPECIFIC GRAVITY.

I next proceeded to investigate a method for correcting the reading of the polariscope for variations caused by changes in the

specific gravity of the specimens. First, I determined the percentage of water in glucoses of different specific gravities.

Following are the results:—

I.

Specific gravity = 1.440
 Weight taken = 5.515
 Loss = .350 at 170°, 2 hours.
 Per cent. H₂O = $.85 \div 5.515 = 6.37$

II.

Specific gravity = 1.431
 Weight taken = 5.86
 Loss = .53, 170°, 2 hours.
 Per cent. H₂O = $.53 \div 5.86 = 9.03$

III.

Specific gravity = 1.409
 Weight taken = 4.038
 Loss = .622, 170°, 3 hours.
 Per cent. H₂O = 15.40

IV.

Specific gravity = 1.416
 Weight taken = 4.425
 Loss = .525, 170°, 2 hours.
 Per cent. H₂O = 11.93

V.

Specific gravity = 1.417
 Weight taken = 8.639
 Loss = 1.091, 170°, 3 hours.
 Per cent. H₂O = 12.70

VI.

Solid Grape Sugar.

Specific gravity = 1.463
 Weight taken = 7.215
 Loss = .61, 170°, 3 hours.
 Per cent. H₂O = 9.29

These data are scarcely sufficient to establish a rule for correction for variations in specific gravity; but it appears from them that the formulæ will not vary much from the following.

The rule, 53 divisions = 53 percentage, seems applicable to samples in which the percentage of H₂O is 12 to 14 and of which the specific gravity is from 1.409 to 1.414.

For each variation of .001 in the specific gravity, the percentage of H₂O varies about .3.

Thus, if we take the two extreme cases, viz., 6.37 and 15.40 percentage of H₂O, we find the corresponding specific gravities to be 1.440 and 1.409, a difference of .031.

The difference in the percentage of water is 9.03. The quotient of $.0903 \div .031 = 3$ nearly.

Let us apply these data to the correction of Nos. 18, 19 and 20 in table IV.

I give below these numbers and also their corrections.

TABLE V.

No.	Scale.	Reducing substance by calculation.	Same corrected.	Same by copper solution.
18	52.63	53.46	55.83	56.81
19	56.53	48.59	55.17	54.60
20	53.70	52.10	56.55	57.14

The above corrections were based on the supposition that 53 divisions of the scale correspond to 53 percentage reducing matter when the specific gravity = 1.409 and the percentage water 15.

We may therefore construct the following provisional formulæ, for estimating the correction to be applied to the reading of the scale when the specific gravity of the specimen varies much from 1.409.

Let a = reading of scale;

“ a' = corrected reading;

“ ϵ = sp. gr. of the sample.

Then $a' = a - 3 a (\epsilon - 1.409)$ when the specific gravity is greater than 1.409; and $a' = a + 3 a (1.409 - \epsilon)$ when ϵ is less than 1.409.

I next propose to undertake some investigations to show the nature and number of the optically active principles present in glucose.

THE EFFECT OF HEATING WITH DILUTE ACIDS, AND TREATING WITH ANIMAL CHARCOAL ON THE ROTATORY POWER OF GLUCOSE; WITH NOTES ON THE ESTIMATION OF CANE SUGAR AND GLUCOSE IN MIXTURES. By H. W. WILEY, of Lafayette, Ind.

SHAKING dilute solutions of glucose or grape sugar with animal charcoal produces a slimy precipitate.

I use the words *glucose* and *grape sugar* in their commercial sense. By *glucose* I mean the thick syrup made from corn starch, and by *grape sugar*, the solid product made from the same substance.

By *pure glucose* I mean the substances present capable of reducing the alkaline copper solution. I will not take time here to discuss the propriety of these names, nor the exact nature of the substances present.

I have made some experiments to determine the effect of animal charcoal on the rotatory power of the glucose of commerce. The following are some of the results obtained.

In each case 10 grammes of the substance were taken and made up to 100 cc. The observation tube was 200 mm. in length.

EXPERIMENTS.

I.

Reading before addition of coal.....	52°
After shaking with 20 grammes coal.....	47.20
Loss.....	<u>4.80</u>

II.

Reading before.....	52°.63
After addition 10 grammes coal.....	50.28
Loss.....	<u>2.35</u>

III.

Reading before.....	52°.63
After addition 4 grammes ivory black.....	52.38
Loss.....	<u>.25</u>

IV.

Reading before.....	52°.20
After addition 4 grammes ivory black.....	51.13
Loss.....	<u>1.07</u>

V.

Reading before.....	52°.20
After addition 10 grammes ivory black.....	48.13
Loss.....	<u>4.07</u>

From these figures it is seen that a glucose may lose nearly 10 per cent. of its rotating power when shaken with animal charcoal.

This is a matter of great importance when attempts are made to examine commercial syrups with the polariscope.

These syrups are usually highly colored, and require a great deal of bone black and lead acetate to make them fit for polariscopic examination. I have not yet tried the action of lead acetate on the rotatory power of glucose.

HEATING WITH DILUTE ACIDS.

The following readings as well as those in the preceding part of this paper are divisions on the cane sugar scale.

I.	
A glucose gave direct reading.....	58° 7
Heated to 68° with 10 per cent. of its volume of strong sulphuric acid. Reading.....	52.96
Loss.....	.74
II.	
Heated same glucose for 50 minutes at 68°. Reading.....	50° 70
Loss.....	2.94
III.	
Direct reading another glucose.....	48° 86
Heated for 10 min. at 68° with 10 per cent. of its volume strong HCl. Reading.....	48° 02
Loss.....	.84
IV.	
Heated same glucose 20 min. at 68°. Reading.....	42° 86
Loss.....	1.00
V.	
Heated same for 30 min. at 68°. Reading.....	40° 16
Loss.....	3.20
VI.	
Heated same for one hour at 68°. Reading.....	39° 26
Loss.....	4.10
The per cent. of reducing substance in the above sample before heating with the acid was.....	62° 50
After.....	65.58
Increase.....	3.08

Thus a loss of 4.10 on the cane sugar scale corresponded to a gain of 3.08 per cent. in reducing power.

VII.

A grape sugar gave direct reading.....	40°.83
Heated with $\frac{1}{2}$ its volume strong HCl for 20 min. at 68°. Reading	31.70
Loss.....	9.13

VIII.

A grape sugar gave direct reading.....	40°.00
After heating with $\frac{1}{2}$ vol. HCl. for 15 min. at 68°. Reading.....	32.52
Loss.....	7.48
The per cent. of reducing substance in the above was, before heating	69°.30
After heating.....	71°.50
Gain.....	2.20

Thus a loss of 7.48 divisions in rotating power corresponded only to an increase of 2.20 per cent. in reducing power.

It will be seen, by inspection of the foregoing numbers, that glucose and grape sugar undergo quite a degree of change when subjected to the process of inversion as it is practised on cane sugar.

This change is sufficiently great to introduce an appreciable error into the process of estimating cane sugar and glucose in mixtures.

CONVERSION OF THE WHOLE OF THE OPTICALLY ACTIVE SUBSTANCES IN GLUCOSE INTO PURE MONO-ROTATORY GLUCOSE.

I next made an attempt to convert the whole of the optically active substances, present in glucose, into pure glucose, by prolonged heating with dilute sulphuric acid.

The conversions were made in a flask fitted with a glass tube about one metre in length.

By this device, vapors arising are condensed and flow back into the flask. Thus no loss of volume takes place.

The flask was at first heated in a water bath at 100°.

The conversion, however, took place so slowly by this method, that I afterwards added enough salt to the bath to raise the temperature to 104°.

The sulphuric acid employed was of 1.25 sp. gr., and was used in the proportion of 10 per cent. of the volume of the glucose solution. The readings were made in a tube longer by one-tenth than half of the length of the 200 mm., and the results multiplied by 2.

The following table contains the results of my work.
 Nos. 1, 2, and 3 were heated at 100°. No. 1 for six hours,
 No. 2 for four hours, and No. 3 for three hours.
 Nos. 4, 5, and 6 were heated for three hours at 102°.
 Nos. 7, 8, 9, 10, 11, and 12 were heated for three hours at 104°.

TABLE I.

No.	Reading before heating.	Per cent. reducing matter before heating.	Reading after heating.	Per cent. reducing matter after heating.
1	52.65	53.20	25.92	81.30
2	48.40	59.85	27.14	80.00
3	48.45	58.55	26.10	80.00
4	43.50	62.50	24.72	79.00
5	50.26	55.60	24.18	82.00
6	51.50	53.50	25.38	81.14
7	52.65	52.36	25.89	83.33
8	56.53	54.00	27.30	90.10
9	51.74	52.33	26.19	82.00
10	47.70	61.40	25.36	82.64
11	49.80	58.80	26.02	84.00
12	40.83	60.93	26.07	84.80

In all cases the samples assumed a decidedly yellowish tint before the completion of the operation; interfering somewhat with the delicacy of the final readings.

No. 8 was a sample of glucose made for confectioners' use. If we exclude it, we get the following general results.

1st. The per cent. of reducing substance obtained is nearly 82.00.

2nd. The average reading of the cane sugar scale is nearly 25.5 divisions.

3d. If the pure glucose present is mono-rotatory, the specific rotatory power θ would be $\theta = \frac{8^{\circ}.85 \times 100}{2 \times 8.2} = 54$ nearly. $8^{\circ}.85$ is the angular rotation (half shadow) corresponding to 25.5 divisions of the scale. But the specific rotatory power of pure glucose for the half shadow in the polariscope is supposed to be nearly 50. We have then here an excess of θ equal to 4.

4th. This excess is due to the presence of optically active matter of a higher specific rotatory power than pure glucose, which has not been changed even by prolonged boiling with dilute acid.

I conclude, therefore, that it is quite difficult to convert the whole of the optically active matter into pure mono-rotatory glucose.

EXAMINATION OF MIXTURES.

In the examination of mixtures of cane sugar and grape sugar, it is necessary, first, to obtain the direct reading. Afterwards, the cane sugar is to be inverted, using at the most not more than ten minutes for this, and keeping the temperature at 68° . It is simply necessary to heat to 68° and then quickly cool.

After inversion, the temperature is carefully noted and another reading taken. Then, by Clerget's table, the per cent. of cane sugar is calculated. This, however, will only be approximately correct. We next calculate the whole amount of rotation produced by the approximate amount of grape sugar present. Having determined this, the reading after inversion is to be corrected, for the effect of inversion on the rotatory power of the grape sugar present. The average correction, when the heating has been carried just to 68° , will be about two per cent. of the whole rotation due to the grape sugar. If the process of inversion is carried on for an hour, as is the practice with some, this correction may amount to 10 per cent.

If the amount of glucose present is very small, this correction can be neglected. But if the amount is large, a failure to correct will introduce an appreciable error into the result. If animal charcoal has been used, a correction must be made also for it, depending, as has been shown, upon the amount employed, and also upon some other conditions which are not yet clearly made out.

It is easy to see into how grave an error we might fall, should we attempt to estimate directly the per cent. of reducing substance present in such mixtures from its rotatory power. I have shown in a previous paper, that the per cent. of such reducing substance is not *directly* but *inversely* as its rotatory power.

The error would be equally as grave, if the amount of the grape sugar present should be computed by using a factor supposed to represent the amount of such substance for each division of the scale. Such a method is based upon the assumption that

the rotatory power of grape sugar is constant and proportional to the reducing substance present. My paper, already mentioned, shows that this assumption is false.

SYRUPS.

When we come to the syrups of commerce, the case becomes still more difficult. These syrups are glucose adulterated with so called cane syrups, *i. e.*, with the drippings and refuse of the sugar refineries.

Among these syrups which are commonly used, I may mention the Revere and the Continental.

A Revere syrup, which I examined, had a specific gravity of 1.425, and contained 34.5 per cent. cane sugar.

A Continental syrup had a specific gravity of 1.415, and 35.7 per cent. cane sugar. It also contained 32.64 per cent. of inverted sugar.

It is easy to see how the admixture of such syrups with glucose tends to demoralize the results of the alkaline copper test, and mystify the readings of the polariscope.

No wonder that, heretofore, such egregious blunders have been committed in these examinations. It is only when examinations are made with a full knowledge of the optical peculiarities of the commercial glucose itself, and of the composition of the cane syrups employed, while at the same time attention is paid to the changes produced by inversion and clarification, that they can be relied upon as correct.

OBSERVATION TUBES.

In the polariscopic observation of inverted sugars, I use a copper tube, silver plated inside and out. I find the most convenient length to be 110 mm. This tube enables the readings to be made without the trouble of neutralizing the acid.

The silver plating of the tube is not necessary, but it makes the working with it a little cleaner. Pure copper can be used without any danger whatever of the acid acting on it.

I use a tube of thin copper and of small diameter. A few cc. will fill one of these tubes. Such a tube, when filled, quickly takes the temperature of the surrounding air. I have found by experiments, that when such a tube is filled with a liquid several degrees above or below the temperature of the air, in twenty minutes it will differ by less than half a degree from that temperature.

If an ordinary glass tube is employed, it is quite difficult to say how much time will be required to restore the equilibrium of temperature. My experiments show that it will require, at least, from two to three times as long.

I also provide this tube with a metallic jacket, very conveniently made of a piece of zinc tubing. This jacket is a little less in diameter than the metallic caps of the tube, and is of such a length that when the caps are screwed on, the jacket fits against a shoulder turned on them. The joint is made water-tight by using a rubber packing.

This jacket is furnished with three openings, fitted with short tubes. One in the centre carries a thermometer. One at each end serves as a supply or exit tube for any liquid, which we may wish to pass through the jacket.

By simply drilling a hole in the trough of the polariscope for the exit tube, the whole apparatus can be placed at once in position.

If now you wish to make a reading at a temperature, say of 88° , it is done in the following way :

In a large flask or tank, placed at one side and above the polariscope, and holding several litres, water is heated to a temperature of about 92° . By a rubber tube, this is connected on the principle of a siphon with the observation tube and its jacket. By means of a pinch cock attached to the exit tube, the hot water is allowed to flow through the jacket until the thermometer shows the temperature desired. It is hardly necessary to say that the observation tube must be filled at a temperature near that at which the reading is to be made to prevent expansion.

If we desire to make a reading at 0° corresponding to 44° to the left Clerget, we replace the water by alcohol, which is cooled by a salt and ice bath to -3° or -4° . The apparatus is then used as before.

We have thus a means of making readings at any desired temperature without having to mutilate the polariscope, as is done by fitting it with a water bath. I will say, however, that a judicious use of Clerget's principle renders readings at a given temperature unnecessary. They are, however, useful in certain complex mixtures by making certain calculations unnecessary.

I propose next to extend my investigations to candies and other confections in which glucose enters as an ingredient.