

acid) gave, by reduction in hydrogen, 48.26 per cent. iron, showing complete reduction of all the iron but the small amount present in a combination insoluble in hydrochloric acid. This method is not recommended for general use, but is given merely as an illustration of the widely various uses to which the crucible may be put.

It is, however, not adapted for those organic combustions in which condensable decomposition products are formed. These condense in the cooler upper part of the crucible where they are beyond reach of the temperature necessary to burn them. Probably by mixing such organic compounds with suitable oxidizing material, such combustions might be successfully made, but this is a field that has not yet been investigated.

My last combustion apparatus was made for me by the Baker and Adamson Chemical Co., of Easton, Pa., who also furnished me with a reliable quality of pure rubber bands.

[CONTRIBUTIONS FROM THE CHEMICAL LABORATORY OF THE U. S. DEPARTMENT OF AGRICULTURE, NO. 34.]

THE INFLUENCE OF TEMPERATURE ON THE SPECIFIC ROTATION OF SUCROSE AND METHOD OF CORRECTING READINGS OF COMPENSATING POLARISCOPEs THEREFOR.¹

BY HARVEY W. WILEY.

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THE influence of temperature on the specific rotation of sucrose has been mentioned by several authors. A partial résumé of the literature on the subject is given by von Lippmann.² A more detailed discussion of the subject is given by Sachs.³ A rather full abstract of previous papers on the subject is given by Sachs, who strangely, however, fails to mention the paper of Andrews on this subject. The early writers with the exception of Dubrunfaut⁴ seem to be unanimously of the opinion that the temperature exerts no notable influence on specific rotation. This is the doctrine announced by Tuchschnid⁵ and

¹ Read before the American Chemical Society and Section C, of the American Association for the Advancement of Science, at Boston Meeting, August, 1898, and before the Third International Congress of Applied Chemistry, Vienna, August, 1898.

² *Chemie der Zuckerarten*, Edition 1895, page 672.

³ *Ztschr. Rübenzuckerind.*, 46, 264.

⁴ *J. prakt. Chem.*, 28, 10.

⁵ *Ztschr. Rübenzuckerind.*, (1870), 649.

Mitscherlich.¹ Sachs also cites the experiments of Wachtel,² who explained the difference in polarization under the influence of temperature by ascribing it to the expansion of the quartz plates of the compensating polariscopes used. This explanation is evidently insufficient, and, as will appear further on, erroneous.

Petrucci and Sachs,³ in 1889, also observed differences in polarization, due to temperature, and these observations were corroborated by Wartze.⁴

The experiments of Sachs were conducted by making the sugar solution at a given temperature and then polarizing it at other temperatures, and also by making up the sugar solution at the same temperature at which it was polarized. As a result of his investigations, he concludes that a solution of practically pure sugar, made up at 17.5° , and polarized at 17.5° , will show a decreased polarization of 0.20° Ventzke, when made up at 25° and polarized at 25° .

The causes of variation in polarizations in the trade were considered in a convention of technical chemists held in Berlin in 1895.⁵

In the United States the first corrections which were employed for variations in polarizations due to temperature were those ascertained by the Office of Weights and Measures of the United States Coast and Geodetic Survey in 1890, and adopted by the commission appointed by the Secretary of the Treasury to prepare regulations for use in the Bureau of Internal Revenue of the Treasury Department. The total correction due to variations in temperature for each degree C., as prescribed by the regulations, was 0.0293° Ventzke for a sugar polarizing 100° Ventzke. This correction was uniformly employed in the Bureau of Internal Revenue, in polarizations for determining the amount of bounty to be paid on domestic sugar in the United States, during the whole time in which the act granting such bounty was in force. It appears, therefore, that the first practical application of a correction for variations in temperature in sugar polarizations was applied in the United States.

¹ *Berl. Acad. Ber.*, (1841), 150.

² *Organ des Central-Verein*, Wien 1878, 42.

³ *Bull. Assoc. Belge Chim.*, 15 Febr., 1889, 112.

⁴ *Deutsche Zuckerind.*, 20 April, 1889.

⁵ *Ztschr. des Vereins für Rübenzuckerind.*, (1895), 1, 73.

A painstaking study of the influence of temperature on the polarization of cane-sugar was made by Andrews.¹ As a result of the investigations he deduced the following formula to express the influence of temperature on specific rotation :

$$[a]_D^t = [a]_D^{20} - 0.0114 (t-20).^2$$

If 66.50 be taken as the mean value for $[a]_D^{20}$ the coefficient of change per degree C. is 0.000171,³ which is somewhat smaller than that obtained by Dubrunfaut ; namely, 0.000232.

The formula for calculation used by Andrews was

$$[a]_D^t = \frac{100a}{l \times p \times d}$$

in which a = angle observed, in degrees ;

l = length of tube, in decimeters ;

p = percentage of sugar, by weight *in vacuo*.

d = specific gravity of the solution at temperature of observation, water at 4° C. being unity.

Dividing the total difference in rotation for different temperatures by the number of degrees of difference in the two sets of experiments conducted by Andrews, we have the following as the variation in the rotation for each degree C. in the two sets of experiments :

Difference per degree in the first set	0.0106
“ “ “ “ second set	0.0122
Mean of the two.....	0.0114

Andrews in his second paper⁴ gives a table showing the factors for computing total variations in polarizations of solutions read at temperatures extending from 10° to 40°, both for direct and quartz compensation polariscopes. The mean factor for instruments without quartz compensation for each degree from 17.5° to 40° is 0.00018, and for quartz compensation instruments is 0.00030. These factors multiplied by 100 show the corrections for each degree of temperature for a pure sugar solution ; *viz.*, 0.018 due to change in specific rotating power alone and 0.030 for total correction for quartz compensation instruments. These

¹ *Technology Quarterly*, Mass. Inst. of Technology, 2, May, 1889, 367.

² In Andrews' article the coefficient 0.0114 is given as 0.00014, but the context shows that this displacement of the decimal point is evidently a typographical error.

³ This coefficient is obtained by dividing 0.0114 by 66.5.

⁴ *Technological Quarterly*, May, 1889, 2, 373.

figures are almost identical with those obtained in these investigations and given further on.

Schönrock¹ shows that temperature has a marked influence on the rotatory power of sucrose, which he expresses mathematically by the equation $\frac{d(\alpha)}{dt} = -0.0144$, which may be expressed as follows: $[\alpha]_D^t = [\alpha]_D^{20} - 0.0144(t - 20)$. By a solution of this equation he shows that the influence of temperature on rotation is one-fourth as great as that due to the change of volume of the liquid.

Landolt² elaborates the formula and shows that the change in polarization on the quartz wedge compensation polariscope, of a pure sugar solution, is equal to 0.065° V. for each degree of temperature. Of this 0.029° V. is due to the change of volume, leaving 0.036° V. due to the influence of temperature on polarization alone. These observations by Schönrock and Landolt were not seen by me until the work, on which this paper is based, was finished.

The recent changes in tariffs in the United States have resulted in a return to the polariscopic methods of ascertaining the percentage of sugar in imported sugars, with a view to levying duty in proportion thereto. I was designated by the Secretaries of the Treasury and Agriculture as chairman of a commission charged with preparing regulations for the control of the polarimetric work in the various ports of entry where sugars were received. It seemed advisable to make a new experimental study of the influence of temperature on the rotatory powers of sugars, especially in relation to the use of compensating polariscopes; *i. e.*, those instruments using a quartz wedge or wedges to restore the displacement of the plane of polarization produced by a sugar solution.

The instrument employed in these researches was a large triple shadow polariscope, double wedge compensation, made with the greatest care for the Department of Agriculture of the United States by Schmidt and Haensch, of Berlin.

The instrument was accompanied by three right-handed unnormal quartz plates, standardized by the Imperial Technical

¹ *Ztschr. für Instrumentenkunde*, 17, June, 1897, 180.

² Das spezifische Drehungsvermögen, Edition of 1898, pp. 344 *et seq.*

Institute at Charlottenburg. These plates were independently standardized by myself and my assistant, Dr. G. L. Spencer, in a large Landolt-Lippich monochromatic polariscope made by the firm above mentioned. The values in all cases were either determined at 17.5° , the standard temperature, or calculated thereto by accepted formulas. The values obtained by the three sets of independent observers are given in the following table :

Plate number.	Thickness determined by the Imperial Technical Institute. mm.	Rotation at 17.5° , determined by the Imperial Technical Institute. Angular degrees.	Rotation at 17.5° , determined by H. W. Wiley. Angular degrees.	Rotation at 17.5° determined by G. L. Spencer. Angular degrees.	Value on the Ventzke scale, determined by Schmidt and Haensch. $^\circ$ V.
1	1.4927	32.420	32.408	32.418	93.59
2	1.6020	34.777	34.748	34.739	100.36
3	1.2042	26.150	26.105	26.119	75.45

From the data supplied by the Imperial Technical Institute of Charlottenburg, and from the markings of the Ventzke scale by Schmidt and Haensch, the following conclusions are drawn :

(1) The rotation of a quartz plate one mm. in thickness at a temperature of 17.5° C. is equal to 21.7148° .

(2) The angular rotation of a quartz plate one mm. thick corresponds to 62.641 divisions on the Ventzke scale.

(3) One degree circular rotation corresponds to 2.8847 Ventzke scale.

(4) One degree of the Ventzke scale corresponds to 0.3465° angular rotation.

The mean determinations of the three independent observers for the three plates are as follows :

	Angular degrees.
Plate No. 1	32.415°
Plate No. 2	34.755°
Plate No. 3	26.125°

Determining the sugar factors¹ by the marked values of the plates, we get the following relations for the two sets of determinations, the data obtained by Wiley and Spencer being combined and compared with the data obtained from the Imperial Technical Institute of Charlottenburg.

¹ These factors are obtained by dividing each of the mean angular readings of the two series of observations by the marked value of the plate with which the observation was made.

Plate number.	Im. Tech. Institute determination. Angular degrees.	Sugar factor. $r \cdot V =$ angular degrees.	Mean of Wiley and Spencer. Angular degrees.	Sugar factor. $r \cdot V =$ angular degrees.	Marked * V.
1	32.420	0.34640 ^o	32.413	0.34633 ^o	93.59
2	34.777	0.34652 ^o	34.744	0.34619 ^o	100.36
3	26.150	0.34659 ^o	26.112	0.34608 ^o	75.45
	Mean	0.34650 ^o	Mean	0.34620 ^o	

We have then as the mean of the three factors obtained by the German authorities for converting angular rotation into degrees Ventzke 0.3465. For the same plates we have for the mean determinations secured by Wiley and Spencer the factor 0.3462. The difference between the two sets of determinations is insignificant, being only 0.0003. If now we use these factors for computing the sugar values of the quartz plates we have the following results from the German standard and from the mean standard as determined by Wiley and Spencer.

Plate number.	German rotation. Angular degrees.	Wiley and Spencer rotation. Angular degrees.	Calculated value of plate (German). * V.	Calculated value of plate (Wiley and Spencer). * V.	Marked value of plate. * V.
1	32.420	32.413	93.564	93.625	93.59
2	34.777	34.744	100.367	100.358	100.36
3	26.150	26.112	75.469	75.425	75.45

It is noticed that the variation of the results calculated from the mean factor from the marked values is very slight.

Being assured thus of the practical accuracy of the instrument employed and the control plates by which it was regulated, it was possible to begin the investigations looking to the determination of the influence of temperature on the specific rotatory power. Advantage was taken of the natural changes in the temperature during the period of investigation, to secure working periods of constant temperatures varying from each other by about 5° from 10° to 20°. Lower temperatures were secured, on the one hand, by conducting the experiments in a cold storage room, and on the other, higher temperatures were secured by means of artificial heat, keeping the atmosphere of the room thoroughly stirred by means of electric fans. In all cases the polariscope was exposed to the temperature of observation long enough to permit the various parts thereof to acquire the ambient temperature; *viz.*, from two to five hours.

For the purpose of having an absolutely unvarying quality of sugar solution, the whole of the material to be used was dissolved at one time into a thick sirup having almost exactly fifty per cent. of pure sugar and fifty per cent. of water. This sirup was preserved by having added to the water before solution an appropriate quantity of mercuric chloride. Double the normal quantity by weight of this solution was used in each determination. One flask, graduated with the greatest accuracy to a true Mohr flask at 17.5° , was used for all the determinations. With these sugars the following recorded observations were made. In each case, unless otherwise noted, five solutions were used and each solution was read four times, or more if there were errant readings, and the mean of the four concordant readings taken as representing the true reading.

In order to secure a better check on the readings, each set of readings was made in triplicate, one set with the white light telescope, one with the yellow light telescope, and one by inserting in the instrument a left-handed quartz plate of known value. The value of the control plate was determined by each of these methods and the necessary corrections made to bring them all up to the same standard of comparison. By adopting this method of triple readings any possible error of observation was eliminated. These triple readings were made in all cases, except the readings at 4° in the cold storage room, where, on account of the low temperature, it was deemed advisable to shorten the work by leaving out one of the sets of readings; *viz.*, the one checked against the left-handed quartz plate.

READINGS AT 4° .

On the afternoon of the 15th of April, 1898, readings were made at 4° in the cold storage room of the Washington Central Market, one of the rooms of which was kindly placed at our disposal by the superintendent.

Five solutions were read with the yellow and white lights. The term "yellow light" hereinafter employed refers to the readings with a telescope carrying a crystal of potassium bichromate or yellow glass plate, or with a tube containing a solution of potassium bichromate. On account of the absence of gas, in

the cold storage rooms, a kerosene lamp was used as the source of light. In all cases the temperature of the instrument and solutions was determined by a delicate thermometer, standardized by the Office of Weights and Measures of the Coast and Geodetic Survey. The readings of the right-handed quartz plate were as follows:

With white light	°v. 100.20
With yellow light	100.24

The variations in the readings of the standard quartz plates, which will be noticed in the data here and following, aside from the nature of the light, are due to differences in setting the double quartz wedge compensation and not to changes in rotatory power. The readings of the sugar solutions with the yellow and white light were as follows:

Number.	Yellow light. °v.	White light. °v.
1	100.25	100.20
2	100.24	100.20
3	100.19	100.19
4	100.24	100.25
5	100.22	100.21
Means	100.23	100.21

Corrections: Add to the reading of the yellow light 0.12. Add to the reading of the white light 0.16.

These corrections here and following represent the differences between the observed reading of the unnormal quartz plate and its marked value; *viz.*, 100.36.

Corrected means: Yellow light	°v. 100.35
White light	100.37
Mean of the two means	100.36

READINGS AT 10°.

On the night of April 14-15, between eleven and two o'clock, the external temperature sank to a little below 10°, and a series of readings was made at 10°. Preliminary readings were as follows:

Right-handed plate, white light	°v. 100.33
Right-handed plate, yellow light	100.33
Right and left plates, white light	8.45
Difference in plates	91.88

	Readings of the sugar solutions with		
	quartz plate. ¹ °v.	yellow light. °v.	white light. °v.
1	100.17	100.15	100.20
2	100.16	100.10	100.18
3	100.16	100.16	100.19
4	100.18	100.15	100.20
5	100.17	100.13	100.20
Means.....	100.17	100.14	100.19

Corrections: Add 0.03 to all mean readings. The corrected mean readings are:

Solutions, with quartz plate	°v.	100.20
“ “ yellow light		100.17
“ “ white light		100.22
Mean.....		100.20

READINGS AT 15°.

A northwestern rainstorm on the morning of April 14 made it easily possible to secure a temperature of 15° in the observation room. A series of readings was therefore made at this temperature. The preliminary readings were as follows:

Right-handed quartz plate, with white light.....	°v.	100.33
Right-handed quartz plate, with yellow light.....		100.29
Right-handed and left-handed quartz plates together, with white light.....		8.50
Difference between the two plates, $100.33 - 8.50 =$		91.83.

To facilitate observations and avoid changing the telescopes for white and yellow lights, a one-fourth per cent. solution of bichromate of potassium was prepared, with which a 100 mm. observation tube was filled and placed in the trough of the instrument, when it was desired to get a reading with yellow light. This gave a beautiful field, clearer than the yellow glass disk, and gave readings superior in every way to those made by means of the yellow light telescope.

	Readings of the solutions with		
	quartz plate. °v.	yellow light. °v.	white light. °v.
1	100.02	99.95	100.05
2	100.06	99.95	100.05
3	100.03	99.95	100.04
4	100.10	100.01	100.08
5	100.03	99.93	100.03
Means	100.05	99.96	100.05

¹ The readings entered here and following in column marked "quartz plate" are the observed readings of the solution with left-handed plate plus the difference between the reading of the right- and left-handed plates together. In this case the observed reading of solution No. 1, was 8.29. The reading of the solution is $8.29 + 91.88$, the difference between the two plates.

Corrections: Add 0.03 to the readings with the quartz plate and white light telescope, and 0.07 to the readings with the yellow light telescope.

	Corrected means. °v.
Solutions, with quartz plate.....	100.08
" " yellow light	100.03
" " white light.....	100.08
Mean of means.....	100.06

Variation from the mean reading at 20°, 0.18.

READINGS AT 20°.

On the morning of April 13, the temperature of the polariscope room being at 20°, four samples were polarized at the temperature mentioned. The reading of the right-handed plate by the plain telescope was 100.32; by the yellow eye-piece, 100.28. The reading of the two plates by the white light telescope was 8.46, showing the true value of the left-handed plate at the temperature mentioned to be 91.86.

The mean readings of the four samples were as follows :

	Readings of sugar solutions with		
	quartz plate. °v.	yellow light. °v.	white light. °v.
1	99.89	99.71	99.86
2	99.87	99.73	99.86
3	99.91	99.75	99.86
4	99.87	99.73	99.86
Means	99.89	99.73	99.86

Corrections: Add 0.04 to the mean reading with the quartz plate and the white telescope. Add 0.08 to the mean reading of the yellow light.

	Corrected means. °v.
Solutions, with quartz plate.....	99.93
" " yellow light.....	99.81
" " white light.....	99.90
Mean of the means	99.88

READINGS AT 25°.

Five solutions were examined on the afternoon of April 12, at a temperature of 25°. This temperature and those following were obtained by artificial heat, the air in the observation room being kept in constant motion by means of electric fans. Every part of the room was thus kept at the same temperature.

Mean reading of right-handed plate, white light.....	100.30
Mean reading of right-handed plate, yellow light	100.28
Mean reading of right-handed and left-handed quartz.	8.46
Difference to be added, 91.82.	

	Readings of solutions with		
	quartz plate. °V.	yellow light. °V.	white light. °V.
1	99.68	99.60	99.63
2	99.72	99.60	99.73
3	99.72	99.60	99.70
4	99.76	99.61	99.71
5	99.73	99.61	99.71
Means	99.72	99.60	99.70

Corrections: Add 0.06 to the reading with the quartz plate and the white light and 0.08 to the reading with the yellow light.

	Corrected means. °V.
Solutions, with quartz plate	99.78
“ “ yellow light	99.68
“ “ white light	99.76
Mean of the means	99.74

READINGS AT 30°.

On the afternoon of April 13, observations were made at 30°
The mean results of the readings were as follows :

Right-handed quartz plate, white light	100.33
Right-handed quartz plate, yellow light	100.30
Right-handed and left-handed quartz plate, white light	8.50
The value of left-handed plate in terms of right-handed plate	91.83

	Reading of sugar solutions.		Means of readings with °V.
	quartz plate. °V.	yellow light. °V.	
1	99.54	99.45	99.55
2	99.53	99.43	99.54
3	99.53	99.44	99.58
4	99.56	99.45	99.60
5	96.54	99.41	99.56
Means	99.54	99.44	99.57

Corrections: Add 0.03 to the readings of the quartz plate and white light, and 0.06 to the mean reading with yellow light.

	Corrected means. °V.
Solutions, with quartz plate	99.57
“ “ yellow light	99.50
“ “ white light	99.60
Mean of the means	99.56

Variation from the mean reading at 25°, 0.18.

READINGS AT 35°.

On the afternoon of April 14, a series of readings was made at 35°. The preliminary readings were as follows :

Right-handed quartz plate, white light	100.33
Right-handed plate, yellow light	100.30
Right and left plates, white light	8.50
Difference in plates	91.83

	Readings of sugar solutions with		
	quartz plates. ° V.	yellow light. ° V.	white light. ° V.
1	99.38	99.34	99.38
2	99.42	99.33	99.40
3	99.38	99.33	99.39
4	99.41	99.31	99.41
5	99.39	99.36	99.40
Means	99.40	99.33	99.40

Corrections: Add 0.03 to the mean reading with the quartz plate and that with the white light, and 0.06 to that with the yellow light.

	Corrected Means. ° V.
Solutions, with quartz plate	99.43
“ “ yellow light.....	99.39
“ “ white light.....	99.43
Mean of corrected means	99.42

READINGS AT 40.°

On April 15, a series of readings was made at 40° with the following results:

	° V.
Right-handed plate, white light	100.35
Right-handed plate, yellow light	100.31
Right and left plates, white light.....	8.55
Difference between the two plates.....	91.80

	Readings of sugar solutions with		
	quartz plate. ° V.	yellow light. ° V.	white light. ° V.
1	99.23	99.18	99.26
2	99.14	99.14	99.21
3	99.20	99.20	99.23
4	99.23	99.18	99.28
Means	99.20	99.18	99.25

Corrections: Add 0.01 to the readings with the quartz plate and white light, and 0.05 to the readings with yellow light.

	Corrected means. ° V.
Solutions, with quartz plate	99.21
“ “ yellow light.....	99.23
“ “ white light.....	99.26
Mean	99.23

SUMMARY OF MEAN POLARIZATIONS FROM 4° TO 40°.

Temperature. Degrees.	Mean polarization. ° v.	Differences. ° v.
4	100.36	
10	100.20	0.16
15	100.06	0.14
20	99.88	0.18
25	99.74	0.14
30	99.56	0.18
35	99.42	0.14
40	99.23	0.18

The relations of the data given in this table are best shown by plotting them on cross-section paper. It is seen by this plot, which is appended hereto, that the line intersecting the different points determined by the instrument is practically a straight one. By plotting the line upon cross-section paper, therefore, it is easy to compute the variations for each degree or a fraction of a degree for a sugar polarizing practically 100° in the ordinary conditions secured in the use of the triple-shadow instrument with the Ventzke scale. For sugars of different content of sucrose the magnitude of the corrections to be employed is easily calculated and, for convenience, these corrections are given in the appended table for temperatures from 4° to 40° and for sugar content from 80 to 100 per cent. These data are computed from the points of intersection of the straight line showing the polarization of pure sugar measured by quartz wedges at temperatures from 0° to 40°. These data in extreme cases do not differ more than 0.03 from those determined from the direct observations made. While it is entirely probable that there are slight differences in the rates of change at different temperatures, as shown by the data of observation, for practical purposes, it is better to assume that the rate of change is uniform throughout and therefore is represented by a straight line.

Following is a table of corrections for polarizations made with quartz-wedge compensating polariscopes at temperatures other than the standard temperature of 17.5° C. To obtain the proper correction select the number found at the intersection of the horizontal column corresponding most nearly with the observed polarization, and the vertical column headed with the temperature at which the observation is made. This correction is to be subtracted from the observed polarization when the temperature is below 17.5° C., and added when the temperature of observation is above 17.5° C.

TEMPERATURE, DEGREES CENTIGRADE.

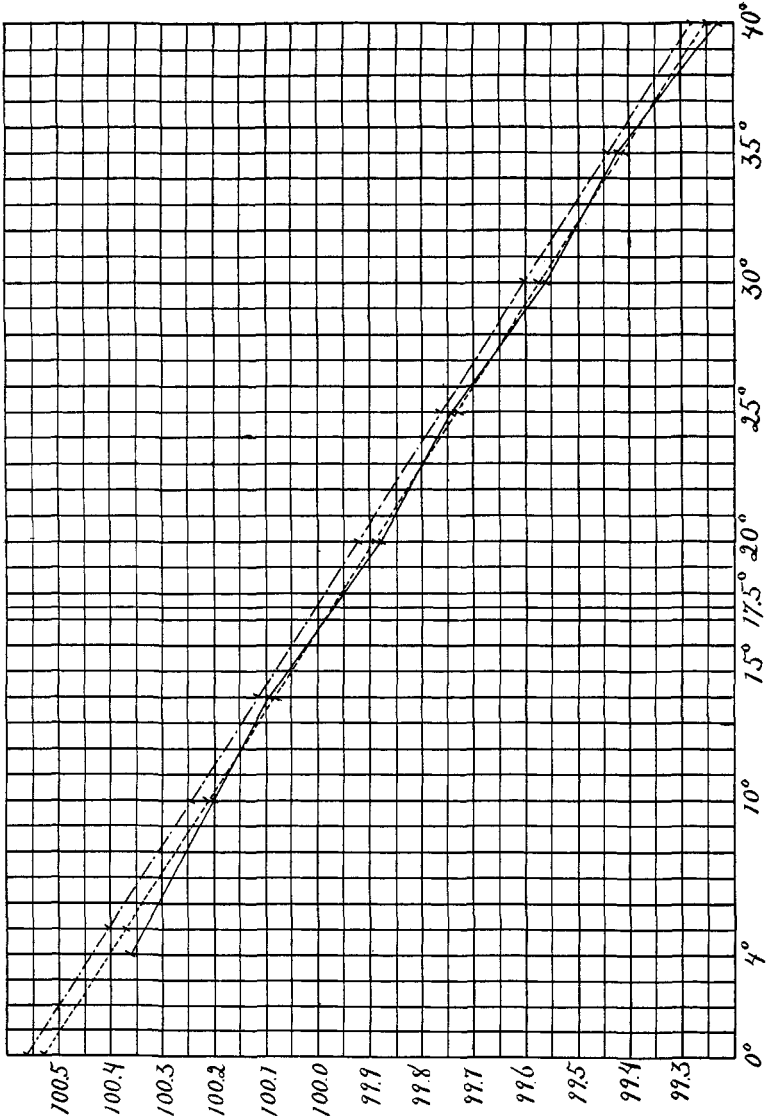
Degrees Ventzke.	4	5	6	7	8	9	10	11	12	13	14	15	16	17	17.5	18	19	20	21
100..	0.43	0.40	0.37	0.34	0.30	0.27	0.24	0.21	0.18	0.14	0.11	0.08	0.05	0.02	0.00	0.02	0.05	0.08	0.11
99..	0.43	0.40	0.37	0.34	0.30	0.27	0.24	0.21	0.18	0.14	0.11	0.08	0.05	0.02	0.00	0.02	0.05	0.08	0.11
98..	0.42	0.39	0.36	0.33	0.29	0.26	0.24	0.21	0.18	0.14	0.11	0.08	0.05	0.02	0.00	0.02	0.05	0.08	0.11
97..	0.42	0.39	0.36	0.33	0.29	0.26	0.23	0.20	0.17	0.14	0.11	0.08	0.05	0.02	0.00	0.02	0.05	0.08	0.11
96..	0.41	0.38	0.36	0.33	0.29	0.26	0.23	0.20	0.17	0.13	0.11	0.08	0.05	0.02	0.00	0.02	0.05	0.08	0.11
95..	0.41	0.38	0.35	0.32	0.29	0.26	0.23	0.20	0.17	0.13	0.10	0.08	0.05	0.02	0.00	0.02	0.05	0.08	0.10
94..	0.40	0.38	0.35	0.32	0.28	0.25	0.23	0.20	0.17	0.13	0.10	0.08	0.05	0.02	0.00	0.02	0.05	0.08	0.10
93..	0.40	0.37	0.34	0.32	0.28	0.25	0.22	0.20	0.17	0.13	0.10	0.07	0.05	0.01	0.00	0.01	0.05	0.07	0.10
92..	0.40	0.36	0.34	0.31	0.28	0.25	0.22	0.19	0.17	0.13	0.10	0.07	0.05	0.01	0.00	0.01	0.05	0.07	0.10
91..	0.39	0.36	0.34	0.31	0.27	0.25	0.22	0.19	0.16	0.13	0.10	0.07	0.05	0.01	0.00	0.01	0.05	0.07	0.10
90..	0.39	0.36	0.33	0.31	0.27	0.24	0.22	0.19	0.16	0.13	0.10	0.07	0.05	0.01	0.00	0.01	0.05	0.07	0.10
89..	0.38	0.36	0.33	0.30	0.27	0.24	0.21	0.19	0.16	0.12	0.10	0.07	0.05	0.01	0.00	0.01	0.05	0.07	0.10
88..	0.38	0.35	0.33	0.30	0.26	0.24	0.21	0.18	0.16	0.12	0.10	0.07	0.04	0.01	0.00	0.01	0.04	0.07	0.10
87..	0.37	0.35	0.32	0.30	0.26	0.23	0.21	0.18	0.16	0.12	0.10	0.07	0.04	0.01	0.00	0.01	0.04	0.07	0.10
86..	0.37	0.34	0.32	0.29	0.26	0.23	0.21	0.18	0.15	0.12	0.09	0.07	0.04	0.01	0.00	0.01	0.04	0.07	0.09
85..	0.37	0.34	0.31	0.29	0.26	0.23	0.20	0.18	0.15	0.12	0.09	0.07	0.04	0.01	0.00	0.01	0.04	0.07	0.09
84..	0.36	0.34	0.31	0.29	0.25	0.23	0.20	0.18	0.15	0.12	0.09	0.07	0.04	0.01	0.00	0.01	0.04	0.07	0.09
83..	0.36	0.33	0.31	0.28	0.25	0.22	0.20	0.17	0.15	0.12	0.09	0.07	0.04	0.01	0.00	0.01	0.04	0.07	0.09
82..	0.35	0.33	0.30	0.28	0.25	0.22	0.20	0.17	0.15	0.11	0.09	0.07	0.04	0.01	0.00	0.01	0.04	0.07	0.09
81..	0.35	0.32	0.30	0.28	0.24	0.22	0.19	0.17	0.15	0.11	0.09	0.06	0.04	0.01	0.00	0.01	0.04	0.06	0.09
80..	0.34	0.32	0.30	0.27	0.24	0.22	0.19	0.17	0.14	0.11	0.09	0.06	0.04	0.01	0.00	0.01	0.04	0.06	0.09
79..	0.34	0.32	0.29	0.27	0.24	0.21	0.19	0.17	0.14	0.11	0.09	0.06	0.04	0.01	0.00	0.01	0.04	0.06	0.09
78..	0.33	0.31	0.29	0.27	0.23	0.21	0.19	0.16	0.14	0.11	0.09	0.06	0.04	0.01	0.00	0.01	0.04	0.06	0.09
77..	0.33	0.31	0.28	0.26	0.23	0.21	0.18	0.16	0.14	0.11	0.09	0.06	0.04	0.01	0.00	0.01	0.04	0.06	0.09
76..	0.33	0.30	0.28	0.26	0.23	0.21	0.18	0.16	0.14	0.11	0.08	0.06	0.04	0.01	0.00	0.01	0.04	0.06	0.08
75..	0.32	0.30	0.28	0.26	0.23	0.20	0.18	0.16	0.14	0.11	0.08	0.06	0.04	0.01	0.00	0.01	0.04	0.06	0.08

SPECIFIC ROTATION OF SUCROSE, ETC.

TEMPERATURE, DEGREES CENTIGRADE—(Continued).

Degrees Ventzke.	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
100..	0.14	0.18	0.21	0.24	0.27	0.30	0.34	0.37	0.40	0.43	0.46	0.50	0.53	0.56	0.59	0.62	0.66	0.69	0.72
99..	0.14	0.18	0.21	0.24	0.27	0.30	0.34	0.37	0.40	0.43	0.46	0.50	0.52	0.55	0.58	0.61	0.65	0.68	0.71
98..	0.14	0.18	0.21	0.24	0.26	0.29	0.33	0.36	0.39	0.42	0.45	0.49	0.52	0.55	0.58	0.61	0.65	0.68	0.71
97..	0.14	0.17	0.20	0.23	0.26	0.29	0.33	0.36	0.39	0.42	0.45	0.49	0.51	0.54	0.57	0.60	0.64	0.67	0.70
96..	0.13	0.17	0.20	0.23	0.26	0.29	0.33	0.36	0.38	0.41	0.44	0.48	0.51	0.54	0.57	0.60	0.63	0.66	0.69
95..	0.13	0.17	0.20	0.23	0.26	0.29	0.32	0.35	0.38	0.41	0.44	0.48	0.50	0.53	0.56	0.59	0.63	0.66	0.68
94..	0.13	0.17	0.20	0.23	0.25	0.28	0.32	0.35	0.38	0.40	0.43	0.47	0.50	0.53	0.55	0.58	0.62	0.65	0.68
93..	0.13	0.17	0.20	0.22	0.25	0.28	0.32	0.34	0.37	0.40	0.43	0.47	0.49	0.52	0.55	0.58	0.61	0.64	0.67
92..	0.13	0.17	0.19	0.22	0.25	0.28	0.31	0.34	0.36	0.40	0.42	0.46	0.49	0.52	0.54	0.57	0.61	0.63	0.66
91..	0.13	0.16	0.19	0.22	0.25	0.27	0.31	0.34	0.36	0.39	0.42	0.46	0.48	0.51	0.54	0.56	0.60	0.63	0.66
90..	0.13	0.16	0.19	0.22	0.24	0.27	0.31	0.33	0.36	0.39	0.41	0.45	0.48	0.50	0.53	0.56	0.59	0.62	0.65
89..	0.12	0.16	0.19	0.21	0.24	0.27	0.30	0.33	0.36	0.38	0.41	0.45	0.47	0.50	0.53	0.55	0.59	0.61	0.64
88..	0.12	0.16	0.18	0.21	0.24	0.26	0.30	0.33	0.35	0.38	0.40	0.44	0.47	0.49	0.52	0.55	0.58	0.61	0.63
87..	0.12	0.16	0.18	0.21	0.23	0.26	0.30	0.32	0.35	0.37	0.40	0.44	0.46	0.48	0.51	0.54	0.57	0.60	0.63
86..	0.12	0.15	0.18	0.21	0.23	0.26	0.29	0.32	0.34	0.37	0.40	0.43	0.46	0.48	0.51	0.53	0.57	0.59	0.62
85..	0.12	0.15	0.18	0.20	0.23	0.26	0.29	0.31	0.34	0.37	0.39	0.43	0.45	0.48	0.50	0.53	0.56	0.59	0.61
84..	0.12	0.15	0.18	0.20	0.23	0.25	0.29	0.31	0.34	0.36	0.39	0.42	0.45	0.47	0.50	0.52	0.55	0.58	0.60
83..	0.12	0.15	0.17	0.20	0.22	0.25	0.28	0.31	0.33	0.36	0.38	0.42	0.44	0.46	0.49	0.51	0.55	0.57	0.60
82..	0.11	0.15	0.17	0.20	0.22	0.25	0.28	0.30	0.33	0.35	0.38	0.41	0.43	0.46	0.48	0.51	0.54	0.57	0.59
81..	0.11	0.15	0.17	0.19	0.22	0.24	0.28	0.30	0.32	0.35	0.37	0.41	0.43	0.45	0.48	0.50	0.53	0.56	0.58
80..	0.11	0.14	0.17	0.19	0.22	0.24	0.27	0.30	0.32	0.34	0.37	0.40	0.42	0.45	0.47	0.50	0.53	0.55	0.58
79..	0.11	0.14	0.17	0.19	0.21	0.24	0.27	0.29	0.32	0.34	0.36	0.40	0.42	0.44	0.47	0.49	0.52	0.55	0.57
78..	0.11	0.14	0.16	0.19	0.21	0.23	0.27	0.29	0.31	0.33	0.36	0.39	0.41	0.44	0.46	0.48	0.51	0.54	0.56
77..	0.11	0.14	0.16	0.18	0.21	0.23	0.26	0.28	0.31	0.33	0.35	0.39	0.41	0.43	0.45	0.48	0.51	0.53	0.55
76..	0.11	0.14	0.16	0.18	0.21	0.23	0.26	0.28	0.30	0.33	0.35	0.38	0.40	0.43	0.45	0.47	0.50	0.52	0.55
75..	0.11	0.14	0.16	0.18	0.20	0.23	0.26	0.28	0.30	0.32	0.34	0.38	0.40	0.42	0.44	0.47	0.50	0.52	0.54

GRAPHIC REPRESENTATION OF THE INFLUENCE OF TEMPERATURE ON THE ROTATION OF SUCROSE AS DETERMINED BY MEANS OF THE SCHMIDT AND HAENSCH TRIPLE-FIELD SACCHARIMETER.



The mean readings at the various temperatures of a commercial sugar, polarizing 99.97° Ventzke at 17.5° C., are shown by

The straight line from which the observations, made at temperatures from 10° C. to 40° C., inclusive, differ by only 0.01° Ventzke is shown by

The parallel straight line, representing the polarization of pure sucrose at temperatures from 0° to 40° C. is shown by

The total variation in polarization observed in this series of experiments for the 36° between 4° and 40° was $100.36-99.23$, or 1.13° Ventzke, an average difference of 0.0314 for each degree of temperature. A comparison of this result with those of other observers is given in the following table :

Observer.	Variations in the polarization of a pure sugar for each degree centigrade. Degree Ventzke.
Andrews	0.0300
U. S. Coast and Geodetic Survey.....	0.0293
Schönrock and Landolt.....	0.0360
Wiley	0.0314
Mean	0.0317

DETERMINATION OF THE CHANGE IN POLARIZATION DUE TO THE INFLUENCE OF TEMPERATURE ON THE SPECIFIC ROTATION, OTHER TEMPERATURE INFLUENCES HAVING BEEN ELIMINATED.

Having thus determined with the greatest exactitude the total variations in polarizations under the influence of temperature, it remains to determine the magnitude of the deviation produced by temperature as a result of change of specific rotatory power of the sugar alone. It is evident that the temperature affects the polarization of a sugar solution in a compensating instrument in the following ways :

(1) By producing variations in the capacity of the flask ; (2) by producing variations in the length of the observation tube ; (3) by producing variations in the degree of concentration ; (4) by changes produced in the rotating power of the compensating quartz wedges ; and (5) by changes produced in the specific rotatory power of the sugar solution itself. It is understood that

the changes due to change of volume of the solution, are not considered here, because the readings are made at the same temperature as those at which the solutions are made.

It is evident, therefore, that if the magnitude of the first four of these factors can be determined, and the total variation in polarization corrected accordingly, the residual quantity of variation must be due to the influence of the temperature upon the specific rotatory power, and an effort will now be made to determine the magnitude of these various factors and to correct the total deviation from the polarization at 17.5° therefor.

(1) *Variations in the Size of the Flask.*—The flask employed in these investigations was most carefully graduated, both in this laboratory and by the Office of Weights and Measures of the Coast and Geodetic Survey, and was found to contain 100.23 cc. at a temperature of 17.5° . It was, therefore, a true Mohr flask, within 0.004 of a cubic centimeter. The variations in the size of the flask due to changes in temperature, calculated by the formula given in the tables of Landolt and Boernstein, are as follows:

Temperatures. C.	Capacities. cc.	Capacities. Mohr cc.
4	100.196	99.966
10	100.211	99.981
15	100.224	99.994
17.5	100.230	100.000
20	100.236	100.006
25	100.249	100.019
30	100.261	100.031
35	100.274	100.044
40	100.286	100.056

(2) *Variations in the Length of the Tube.*—The glass observation tube employed in the investigations had a length of 200 mm. at a temperature of 17.5° . Its length at the other temperatures of observation is shown by the following table:

Temperature. C.	Length. mm.
4	199.976
10	199.987
15	199.996
17.5	200.000
20	200.004
25	200.013
30	200.022
35	200.031
40	200.040

It is evident that the changes in the capacity of the flask and in the length of the tube are, to a certain extent, compensatory. As the flask increases in size, thus diminishing the proportion of the sugar to the volume, the tube increases in length, producing a partial compensation. The rate of increase in the capacity of the flask is, however, slightly greater than in the length of the tube, so that at temperatures varying considerably from 17.5° an appreciable correction is necessary. The amount of this correction is shown in the following table, which gives the variation in the first column of the length of the tube, in the capacity of the flask for each 5° in the second column.

Temperature. °C.	Variation in the length of tube. mm.	Variation in the capacity of flask. cc.
4	0.024	0.034
10	0.013	0.019
15	0.004	0.006
17.5
20	0.004	0.006
25	0.013	0.019
30	0.022	0.031
35	0.031	0.044
40	0.040	0.056

In the comparison of the variations in the capacity of the flask and the length of the tube due to temperature, it should be remembered that 100 cc. are compared with 200 mm. The percentage of variation, therefore, referred to units, is only half as great in the tube as in the flask. In other words, assuming that the capacity of the flask remains constant, it is seen that a variation of one-tenth mm. in the length of the tube produces a variation of only 0.05° in the polarization of the sugar. The variation in the length of the tube, therefore, expressed in millimeters, must be doubled in order to make a direct comparison. When this rule is applied it is seen that the correction for polarization, due to the volume of the flask, is directly proportional to the change in capacity. In other words, at 40° it is seen that the flask has increased 0.056 cc. in capacity. The polarization, therefore, as directly read on the instrument, should be increased by 0.056 to compensate for this increase in volume. On the other hand, we see that at the same temperature the length of the tube is increased by 0.040, and therefore the polarization

must be diminished by just half that amount to reduce it to the proper scale; namely, 0.020. Thus the total correction for the polarization at 40° for changes in the volume of the flask and length of the tube is made in the following way:

Example: Let the polarization at 40° be 99.24; add 0.056 to compensate for change in the volume of the flask and the polarization becomes 99.296. Subtract 0.020 to allow for the increase in the length of the tube, and the polarization becomes 99.276. Applying this principle to the correction of the polarizations obtained upon the standard samples of sugar at the different temperatures, we have the following for the polarizations of sugars for the temperatures named, after correction for changes induced by temperature in the volume of the flask and the length of the tube.

Temperature. °C.	Corrected polarizations. °V.
4	100.338
10	100.188
15	100.056
20	99.884
25	99.753
30	99.580
35	99.449
40	99.266

DERIVATION OF A FORMULA FOR COMPUTING THE CORRECTION FOR THE INCREASE IN THE CAPACITY OF THE FLASK AND FOR THE INCREASE IN THE LENGTH OF THE TUBE WHEN THE OBSERVATION IS MADE AT ANY TEMPERATURE OTHER THAN THE STANDARD TEMPERATURE OF 17.5°.

Let the observed polarization at this temperature be 99.23° V; the capacity of the flask 100.056 Mohr cc. (1 Mohr cc. = 1.00234 true cc.); and the length of the tube 200.040 mm.

The number of grams of sugar per 100 cc. (Mohr) of the solution is

$$100.056 : 100 :: 26.048 : x$$

$$x = \frac{100 \times 26.048}{100.056} = 26.0334.$$

The true polarization of a solution containing x grams of sugar per 100 cc. (Mohr) and giving a reading of 99.23 is

$$x : 26.048 :: 99.23 : y.$$

Then the polarization corrected for the expansion of the flask,

$$y = \frac{26.048 \times 99.23 \times 100.056}{100 \times 26.048} = 99.286.$$

This value must now be corrected for the increased length of the tube, by the following ratios:

$$200.040 : 200 :: 99.286 : z.$$

Then the polarization corrected for the expansion of the flask and the tube is,

$$z = \frac{200 \times 99.286}{200.040} = 99.266.$$

Substituting the unreduced fractional value of y in the last proportion, we have:

$$200.040 : 200 :: \frac{26.048 \times 99.23 \times 100.056}{100 \times 26.048} : z.$$

$$z = \frac{200 \times 26.048 \times 99.23 \times 100.056}{200.040 \times 100 \times 26.048},$$

or dropping out the common factor 26.048, which occurs in both numerator and denominator, the expression becomes

$$z = \frac{200 \times 99.23 \times 100.056}{200.040 \times 100}.$$

If we let the capacity of the flask at 17.5° be represented by C ; the capacity of the same flask at t degrees by C' ; the length of the tube at 17.5° by l ; the length of the same tube at t degrees by l' ; and the polarization at t degrees by P' ; we have the following general formula:

P' , the polarization corrected for expansion of the flask and observation tube = $\frac{lP'C'}{l'C}$.

Example: A solution polarizes 100.360 under the following conditions:

$$\begin{aligned} t &= 4^\circ \text{ C.} \\ l &= 200. \\ l' &= 199.976. \\ C &= 100. \\ C' &= 99.966. \end{aligned}$$

Then

$$P' = \frac{200 \times 100.36 \times 99.966}{199.976 \times 100} = 100.338.$$

VARIATION IN CONCENTRATION.

Perhaps there is no point connected with the polarization of sugars in which scientific literature contains more contradictory statements than that which relates to the influence of concentration on the specific rotatory power. It is not possible here to enter into a discussion of this subject, a matter which will be reserved later on for a separate investigation. It is sufficient here to call attention to the latest summary of our knowledge on this subject contained in Dr. Landolt's work entitled "Das optische Drehungsvermoegeu, etc.," second edition, page 419. The conclusion which Landolt reaches from a study of the data at hand is as follows: "The specific rotatory power of sucrose for sodium light for all degrees of concentration below 30° may be taken as $[\alpha]_D^{17.5^\circ} = 65.5$." It is evident that the sugar with which the analytical data contained in this paper were obtained was practically pure, since under all the necessary conditions of polarization at 17.5° it gave a reading of 99.97. It is certain that the degree of concentration of the solutions changed with each degree at which the polarizations were made. For instance, in filling the flask at 4°, the quantity of water used was considerably greater by weight than when the flask was filled at 40°. The weight of sugar in all cases having remained the same, it is evident that the degree of concentration of the solution at 4° was considerably less than at 40°. Since, however, as we have just seen, there is practically no correction to be made for variations in concentration under 30 per cent., the influence of this slight difference in concentration may be absolutely eliminated from the calculation. It is established, therefore, that none of the variation noticed in polarization was due to differences in concentration.

CHANGES IN COMPENSATING POWERS OF THE QUARTZ WEDGES.

It is well known that the power of quartz, of a given thickness, of rotating a plane of polarized light, varies with the temperature. As the temperature rises the rotating power of the quartz increases. The rate of increase has been calculated by physicists, and the formula of Joubert is one which is

usually accepted for the purpose of determining the rotating values at different temperatures. This formula is

$$A_t = A_0 (1 + 0.000149t),$$

in which A_0 represents the rotating power of the quartz plate at a temperature of 0° , and A_t represents the rotatory power at any desired temperature. In this formula A may either represent degrees Ventske or degrees of angular rotation.

E. Gumlich¹ has made careful determinations of the temperature coefficient of quartz for rays of different wave-lengths. He concludes that the influence of temperature on the rotatory power of quartz does not vary materially for light having wave-lengths varying from $656 \mu\mu$ to $436 \mu\mu$. For temperatures from 0° to 100° he expresses the influence of temperature on the specific rotatory power of quartz by the following equation $\phi' = \phi^\circ (1 + 0.000131t + 0.000000195t^2)$.

Using this formula for calculating the value at 40° of a thickness of quartz which rotates 1° V. at 17.5° the value 1.00319 is obtained instead of 1.00335 as given in the table.

Substituting this value in the calculation of the mean corrected polarization obtained at 40° and in the calculation of the specific rotatory power of sucrose at 40° , the numbers 99.582 and 66.288 are obtained, respectively. The former number differs by 0.016° V. from the one given in the table, while the value for $[\alpha]_D^{40}$ is 0.011 less than the result previously noted. It is therefore evident that the use of the formula of Gumlich would not materially change the results reported in this paper.

Applying Joubert's formula to the investigation in question, we have the following data:

A thickness of quartz, which gives a rotation of 1° V. at 17.5° , produces at other temperatures the amount of rotation shown in the following table:

Temperature. °C.	Rotation. ° V.	Difference from 17.5°
4	0.99799	0.00201
10	0.99888	0.00112
15	0.99963	0.00037
17.5	1.00000	0.00000
20	1.00037	0.00037
25	1.00112	0.00112
30	1.00186	0.00186
35	1.00261	0.00261
40	1.00335	0.00335

¹ Wiedemann's *Ann. phys. Chem.*, 59, 333; *Ztschr. des Vereins der deutschen Zuckerind.*, (1898), II, 971-992.

If the compensating system of a polariscope be warmed to 40° C., the quartz wedge used in its construction rotates 1.00335 times the number of degrees Ventzke shown by a quartz of equal thickness at 17.5°.

The true polarization of a sugar solution which reads 99.266° V. at 40° C. (correction having been made for the change in the volume of the flask and in the length of the observation tube, due to change of temperature), is 99.266 × 1.00335, or 99.598° V.

Correcting all the results given on page 587, we have :

POLARIZATION OF THE SUGAR UNDER EXAMINATION AT TEMPERATURES FROM 4° TO 40° C.

(Corrections having been made for the changes caused by temperature in the volume of the flask, in the length of the observation tube and in the rotatory power of the quartz used in the construction of the instrument.)

Temperature. C.	Polarization. V.
4	100.136
10	100.075
15	100.019
17.5	99.970
20	99.921
25	99.864
30	99.765
35	99.708
40	99.598

If the polarization at *t* degrees of a thickness of quartz which reads 1° V. at 17.5°, be designated by *Q'*, we may extend the formula for *P'* given above, as follows :

P', the polarization in degrees Ventzke, corrected for changes due to temperature in the volume of the flask, in the length of the observation tube and in the rotatory power of the quartz of the compensating system of the instrument,

$$= \frac{lP'C'Q'}{l'C} ; \text{ in which}$$

l = length of the observation tube at 17.5° C.

l' = " " " " " " the temperature of observation.

C = capacity of the flask at the temperature of observation.

Q' = polarization at *t*° of a thickness of quartz reading 1° V. at 17.5°.

P' = observed polarization, degrees Ventzke.

C = capacity of the flask at 17.5° C.

Example :

$$\text{Let } t = 40^\circ.$$

$$P' = 99.24.$$

$$l' = 200.040.$$

$$C' = 100.056.$$

$$Q' = 1.00335.$$

$$l = 200.$$

$$C = 100.$$

$$P'' = \frac{200 \times 99.23 \times 100.056 \times 1.00335}{200.040 \times 100} = 99.598.$$

It is evident, from an inspection of the above data, that a less thickness of the quartz wedge is required to compensate for the rotation produced in the plane of polarized light by a sugar solution at a higher than at a lower temperature. The result of this is that the apparent reading of the solution is lower than the true reading as the temperature of the quartz wedge and its rotating power increase.

CHANGES DUE TO PRESSURE ON THE QUARTZ PLATES AND WEDGES.

It is well known that any strain or pressure exerted on a piece of quartz will change its rotating power. Hence the operator must assure himself that he is using an instrument in which the rotating power of the quartz wedges and quartz plates is not changed by pressure due to changes in temperature. In the double compensating polariscope, used in these investigations, there are four quartz wedges, with independent settings. Theoretically the reading of a quartz plate mounted in such a way as to undergo no pressure, due to changes of temperature, by four quartz wedges, all independently mounted in the same way, should be practically the same at all temperatures. The permissible variations are due only to displacement of the zero mark, which is very common in double compensating instruments, to the personal errors of reading, which may amount to 0.10° V. and to changes in the nature or intensity of light.

The doctrine of probabilities would practically preclude the occurrence of a state of affairs in which the pressure exerted on a mounted quartz plate would be exactly compensated for by the sum of the pressures exerted on four independently mounted quartz wedges.

If in these conditions the readings of a quartz plate at widely varying temperatures in a double compensating instrument, agree within the limits of error above pointed out, it is a convincing proof, that neither the plate nor the wedges have suffered any change in rotating power due to pressure.

I will now compare the readings of the urnormal quartz plate used for control in these investigations, at the various temperatures employed, excluding those made at 4° , in which a different light was used.

READING OF URNORMAL QUARTZ PLATE AT DIFFERENT TEMPERATURES.

Temperature. C.	Reading. V.	Difference.
10	100.33	...
15	100.33	0.00
20	100.32	0.01
25	100.30	0.02
30	100.33	0.03
35	100.33	0.00
40	100.35	0.02

The remarkable uniformity of the readings of the urnormal plate, at such widely varying temperatures, proves beyond any reasonable doubt that none of the data obtained was influenced in any way by pressure exerted either on the quartz plate or wedges.

We find, therefore, the total difference due alone to change in specific rotatory power for 36° equal to 0.538° V., and for 1° 0.01494° V. It therefore appears that for each change of one degree in the temperature the polarization of a pure sugar on an instrument with a Ventzke scale suffers a change of 0.01494° , due exclusively to the change in the specific rotatory power of the sugar solution. Converting this into angular degrees by multiplying by the factor 0.3462, we get the magnitude of the change in specific rotatory power in angular measure due to each degree of change of temperature = 0.005172 . It is now possible to convert the readings obtained on the Ventzke scale into angular measurement and to compute the specific rotatory power for each of the temperatures at which the observations were made. These calculations have been made and the results are found in the following table :

SPECIFIC ROTATORY POWER OF SUCROSE AT TEMPERATURES RANGING
FROM 4° TO 40° C.¹

Temperature of observation. °C.	Readings on Ventzke Scale. ² °V.	Equivalent angular degrees with sodium light.	$[\alpha]_D'$	Differences.		
				Range of temperature. °C.	For whole range.	For 1° C.
4	100.136	34.667	66.657	4 to 10	0.040	0.00667
10	100.075	34.646	66.617	10 " 15	0.038	0.00760
15	100.019	34.627	66.579
17.5	99.970	34.610	66.547	15 " 20	0.065	0.01300
20	99.921	34.593	66.514	20 " 25	0.038	0.00760
25	99.864	34.573	66.476	25 " 30	0.066	0.01320
30	99.765	34.539	66.410	30 " 35	0.038	0.00760
35	99.708	34.519	66.372	35 " 40	0.073	0.01460
40	99.598	34.481	66.299

This weight of sugar in 100.23 true cc. is equivalent to 26.004 grams (weighed *in vacuo*) in 100 true cc.

The formula for specific rotatory power is

$$[\alpha]_D' = \frac{100 a}{lc}$$

$$[\alpha]_D' = \frac{100 a}{2 \times 26.004} = aC, \text{ when } C = \text{the constant, } \frac{100}{2 \times 26.004}.$$

The specific rotatory power for a given temperature may be calculated directly from the reading of the saccharimeter at the given temperature by the use of the following formula:

$$[\alpha]_D' = \frac{0.3462 P' V' Q'}{26.0639 l'}$$

0.3462 = the value in angular degrees of 1° V.

P' = the observed polarization, degrees Ventzke.

V' = the capacity of the flask at the temperature of the observation, expressed in true cc.

Q' = the value in degrees Ventzke at t° of the thickness of quartz which gives a rotation of 1° V. at 17.5° C.

l' = the length of the observation tube in decimeters at the temperature of the observation.

26.0639 = the weight in grams (weighed *in vacuo*) of sugar contained in the quantity of the solution prepared.

¹ The observations were made with a triple-field saccharimeter, the readings being converted to angular degrees by use of the factor 0.3462. The concentration was 26.004 grams (weighed *in vacuo*) sugar in 100 true cc. (26.048 grams weighed in air in 100 Mohr cc).

² Corrected for all variations except in specific rotation.

Example : A solution of 26.048 grams of sugar (weighed in air) prepared at 40° C. in a flask that holds 100.23 true cc. at 17.5° C., polarizes 99.23° V. at 40° C.

This solution contains 26.0639 grams of sugar (weighed in vacuo).

$$\begin{array}{rcl}
 & \log & 0.3462 = 9.5393271 \\
 \log P' = & \log & 99.23 = 1.9966430 \\
 \log V' = & \log & 100.286 = 2.0012403 \\
 \log Q' = & \log & 1.00335 = 0.0014525 \\
 & \text{colog} & 26.0639 = 8.5839606 \\
 \text{colog } l' = & \text{colog} & 2.0004 = 9.6988832 \\
 \hline
 & \log [\alpha]_{17.5}^{\circ} & = 1.8215067 \\
 & [\alpha]_{17.5}^{\circ} & = 66.299^{\circ}
 \end{array}$$

From the foregoing data it is seen that the temperature has a marked effect upon the specific rotatory power of sucrose. After having obtained a large number of readings on a most delicate polariscope in which the conditions of temperature were most carefully controlled, it has been possible to estimate the magnitude of this change in rotatory power. It is seen that the specific rotatory power of the sugar employed at 17.5° is 66.547, and at the extreme ranges of temperature which were reached in the investigation, we find that the specific rotatory power at 4° of the same sugar is 66.657, and at 40°, 66.299. It is thus seen that the specific rotatory power of the sucrose solution increases as the temperature falls, and decreases as the temperature rises, and the mean magnitude of the variation for each degree is 0.00994.

A comparison of this result with those of other observers is given in the following table :

Observer.	Mean changes in the specific rotatory power of su- crose per °C.
Andrews	0.01140
Schönrock	0.01440
Wiley	0.00994
Mean	<u>0.01191</u>

It appears from the results of the investigation that the mean rate of increase is not the same at every temperature, as for instance, it appears to be greater from 15° to 17.5°, from 20°

to 25° , and from 30° to 35° than it is at the other points at which the observations were made. Numerous series of observations, however, would be necessary, on account of the small magnitudes involved, to definitely determine this question.

My thanks are due to Mr. W. H. Krug, who assisted me in obtaining all the experimental data given in this paper, and who cheerfully endured the fatigue and discomfort of working for several nights at very low temperatures; to Mr. E. E. Ewell, who assisted in calculating the data and in constructing the graphical charts and tables of correction; and to Mr. G. L. Spencer, who independently determined the values of the unnormal quartz plates used in controlling the polarizations.

THE DETERMINATION OF CARBON AND HYDROGEN IN ORGANIC SUBSTANCES CONTAINING NITROGEN.

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IN determining carbon and hydrogen in substances containing nitrogen, use is commonly made of a metallic copper spiral at the exit end of the combustion tube to reduce oxides of nitrogen. Liebig was the first to observe that such oxides might be formed, and he showed that the amount of nitric oxide formed, when determining nitrogen by heating with copper oxide, was sufficient to vitiate the results.¹ He further showed that no appreciable quantities of other oxides of nitrogen could be formed, for when the quantity of nitrogen collected was increased by the amount of nitrogen in the nitric oxide produced, the correct percentage of nitrogen in the substance was obtained. Later Klingemann² determined the amount of nitric oxide formed from a variety of complex nitrogen-containing substances, when nitrogen is determined by burning with copper oxide according to the method of Frankland and Armstrong. His results show that the quantity of nitric oxide produced is usually very small, from 0.00 to 0.28 cc., occasionally it is more, and in the case of picric acid 0.90 cc. was found. This last equals only 0.0011 gram. The amount of the substance burned was commonly about 0.1 gram. His results show further that the amount of

¹ *Pogg. Ann.*, 18, 357.

² *Ber. d. chem. Ges.*, 22, 3064.