the rotation from +123° to +14.9°.[1] This interesting difference we attribute to the presence of an enzyme in the invertase solution from bottom yeast which carried the hydrolysis of raffinose a step beyond that which invertase causes. Probably invertase and melibiase are in the solution which was prepared from bottom yeast, while melibiase is lacking in that made from top yeast. This view corresponds to the well known fact that top yeast ferments raffinose to alcohol and melibiose, and bottom yeast ferments it completely to alcohol. T. S. Harding and the writer have worked out an analytical method for estimating raffinose in solutions containing other sugars, by utilizing the difference in rotation which is observed when the solution is acted upon, first by invertase from top yeast, and then by invertase and melibiase from bottom yeast.

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THE INVERSION OF SUCROSE BY INVERTASE. IX. IS THE REACTION REVERSIBLE?[2]

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Received May 15, 1914.

The synthetic production of sucrose by various plants, ultimately from carbon dioxide and water, is a firmly founded fact, though it is not positively known what substances are the intermediate products in the synthesis. Many plants also synthesize an enzyme of unknown composition called invertase, which can accomplish the hydrolysis of sucrose to glucose and fructose. Thus the synthesis of sucrose may proceed in plants along with its decomposition by invertase. If the last stage in the synthesis should prove to be the uniting of glucose and fructose to yield sucrose, this change would represent the reverse reaction to the hydrolysis of sucrose by invertase. It has been suggested at various times that the enzyme invertase can accomplish such a synthesis of sucrose from glucose and fructose, and that therefore the inversion of sucrose by invertase is a balanced or reversible reaction. The present investigation was undertaken for the purpose of obtaining experimental evidence upon this question, partly because the subject is of some general interest and partly

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[1] The values 63.9° and 14.9° correspond almost exactly to those (64.1° and 14.9°) which have been calculated by C. A. Browne ("Handbook of Sugar Analysis," p. 737) for the two steps that are to be expected in the hydrolysis of raffinose, which may be represented as the reactions

$$\underset{\text{(raffinose)}}{C_{18}H_{32}O_{16}} + 2H_2O = \underset{\text{(melibiose)}}{C_{12}H_{22}O_{11}} + \underset{\text{(fructose)}}{C_6H_{12}O_6} + H_2O = \underset{\text{(glucose)}}{C_6H_{12}O_6} + \underset{\text{(galactose)}}{C_6H_{12}O_6} + \underset{\text{(fructose)}}{C_6H_{12}O_6}.$$

[2] Read at the Minneapolis meeting of the American Chemical Society in December, 1910.

[3] Contribution from the Division of Carbohydrate Investigations, Bureau of Chemistry.

because it became necessary to know whether invertase accomplishes a complete hydrolysis of sucrose in connection with an investigation on the possible use of this enzyme in the quantitative estimation of sucrose.[1]

Repetition of Osaka's Experiments.—In a recent article, Osaka[2] claims to have shown by accurate experiments that the well known hydrolysis of sucrose by acids, which has heretofore been regarded as an irreversible reaction, is really reversible, and indeed to the extent of an easily detectable amount, 1%, under certain favorable conditions. If this conclusion of Osaka is correct, it gives much ground, from a theoretical standpoint, for the view that the inversion of sucrose by invertase is also a reversible reaction, because both acid and enzyme are to be regarded as catalysts of the hydrolysis, and, since the equilibria of the better investigated reversible reactions are not changed by catalysts,[3] though the rate of reaction is, it might be expected that invertase will cause the synthesis of sucrose from glucose and fructose if the other catalysts, acids, do so. It is necessary to consider the details of the procedure in Osaka's experiments, although they are rather complicated. Osaka reasoned that, since the synthesis of sucrose from invert sugar is a combination of two substances (glucose and fructose) to produce one, it should proceed more favorably in concentrated than in dilute solutions. All of Osaka's experiments are similar and we have therefore selected for careful repetition the one in which he obtained the best indication of reversibility during acid hydrolysis. This experiment concerns the hydrolysis of sucrose by hydrochloric acid in an aqueous solution of about 61% sugar strength, which is the highest concentration that Osaka studied. He describes this experiment as follows:

"Twenty grams of cane sugar were introduced into a weighed measuring flask of 25 cc. capacity and dissolved in a small quantity of water by warming. When cold, 5 cc. of 2.5 *N* hydrochloric acid were added and the solution diluted to almost 25 cc. A small piece of camphor was then added to the solution[4] and the flask left in a thermostat at 25° over night. On the next day water, at 25°, was added to make exactly 25 cc. and the flask and contents were weighed. About 5 cc. of the solution were taken out from each of the duplicate solutions into two weighed measuring flasks of 25 cc. capacity and weighed. About 4 cc. of 2.5 *N* hydrochloric acid were added to each of them, and the solutions diluted to about 25 cc. The four diluted solutions thus prepared, together with the two original solutions, were again left in the thermostat over night.

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[1] *J. Ind. Eng. Chem.*, **2**, 143–6 (1910).

[2] *J. Col. Sci., Imp. Univ. Tokyo*, **25**, Art. 1 (1908).

[3] van't Hoff, "Die Chemische Dynamik," p. 210 (1898).

[4] This addition was presumably for the purpose of preventing the growth of microörganisms though the high acidity of the solution accomplishes this effectively, according to our experience. *H and P.*

"On the next day about 5 cc. of the two original solutions were taken out, each into two weighed measuring flasks of 25 cc. capacity, and weighed. In order to prevent its further inversion on dilution, 3.4 g. of sodium acetate were added to the solutions taken out, which were then diluted to the mark. The same amount of the salt was also introduced into each of the solutions diluted the day previous, to make them as nearly as possible similar to those newly prepared[1] and then the solutions were further diluted to the mark. It was ascertained by experiment that a small difference in the concentrations of hydrochloric acid exerts no perceptible influence on the optical rotations of the sugar solutions. The eight dilute solutions thus prepared were then subjected to polarimetric observations a polarization apparatus after Landolt being used with a Lippich polarizer. In order to obtain the mean value of the rotations of the solutions of the same treatment and to be able to compare those of solutions of different treatments with each other, it was assumed that, within narrow limits of concentration, as in the case in hand, the rotations are proportional to the concentrations of the solutions. The average amount of the solutions taken out in eight instances was 6.3776 g. The rotation of this weight of solution diluted to 25 cc. was calculated from the weights and respective rotations (when diluted to 25 cc. final volume) of the eight samples above to be *viz*:

	Inverted in orig. soln.		Inverted in dil. soln.
	—6.325		—6.587
	—6.307		—6.625
	—6.310		—6.586
	—6.311		—6.578
Mean,[2]	—6.313	Mean,	—6.594

"Twenty-five cc. of the original solution weighed 32.793 g. and contained 20 g. sugar, so that 6.3776 g. of the solution contained 3.8896 g. The same amount of sugar was dissolved in water with the addition of sodium acetate and hydrochloric acid so as to make the solution similar to those in the other cases, diluted to 25 cc. and polarized. The mean of the two polarizations was +20.099. Thus the degree of the inversion in the original solution in percentage is as follows:

$$\frac{20.099 + 6.313}{20.099 + 6.594} \times 100 = 98.9\%."$$

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[1] One observes that though the two sets of solutions were thus made similar in respect to salt content, they differed in that the set which represented inversion in concentrated solution had stood one day longer in a highly acid condition. This matter is discussed later, on page 1575, *et seq. H. and P.*

[2] These readings presumably refer to a tube length of 20 cm. and to circular degrees and sodium light. *H. and P.*

From these data Osaka concluded that 1.1% of sucrose was synthesized during the experiment.

Our repetition of Osaka's experiment was carried out in duplicate and the final measurements which were obtained by the same method of experimentation just quoted are as follows:

	Inverted in concentrated solution.		Inverted in dilute solution.
First experiment.......	—19.65	First experiment.......	—20.25
Second experiment.....	—19.70	Second experiment.....	—20.40
Mean,[1]	—19.67	Mean,	—20.32

These results fully confirm Osaka's values as to the direction of the rotation difference and its approximate magnitude. Having thus duplicated a typical one of his experiments, we wish to examine his interpretation of them. It is to be observed that in the quoted experiment of Osaka's, 4 cc. of 2.5 *N* hydrochloric acid were added to each of the flasks containing the solutions to be inverted in dilute solution; on dilution to 25 cc., the acidity was then the same as in the original solution when made to the volume mark. On the other hand, no acid was added to the solution which had been removed from the original solution and to which sodium acetate had been added to stop any further inversion. Its acidity was, therefore, only a fifth of the acidity of the solution which had been diluted without addition of sodium acetate. It is well known that hydrochloric acid increases the levo-rotation of invert sugar solutions,[2] the increase being approximately in proportion to the concentration of acid present, and it seemed possible, therefore, that the difference in rotation of the two sets of solutions might be due to such an influence. The following experiments were accordingly made.

Fifteen (15) cc. of a solution containing 13.445 g. each of pure glucose and fructose in 100 cc. were added to each of four 25 cc. flasks. After addition of hydrochloric acid and sodium acetate as indicated below, the volumes were completed to 25 cc. at 20° and the rotations read in a 200 mm. tube at that temperature in a saccharimeter. The concentration of invert sugar in these solutions was nearly the same as for the solutions employed in our repetition of Osaka's experiment.

(1) One cc. of 2.5 *N* hydrochloric acid, 3.4 g. sodium acetate. Rotation —19.0° V.

(2) Five cc. of 2.5 *N* hydrochloric acid, 3.4 g. sodium acetate. Rotation —19.0° V.

(3) One cc. of 2.5 *N* hydrochloric acid, no sodium acetate. Rotation —16.95° V.

(4) Five cc. of 2.5 *N* hydrochloric acid, no sodium acetate. Rotation —17.35° V.

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[1] These measurements refer to a tube length of 20 cm., and to Ventzke degrees, using white light. If expressed in circular degrees they agree fairly well with Osaka's quoted values, since 100 Ventzke degrees equal about 34.6 circular degrees.

[2] von Lippmann, *Chemie der Zuckerarten*, 1, 922 (1904).

These experiments (3 and 4) confirm the well known influence of the acid concentration on the rotation of invert sugar, but show further (1 and 2) that in the presence of sodium acetate, which neutralizes the acid, the variation in the strength of the latter does not affect the reading. Accordingly, the greater negative rotation, when the sucrose was inverted in dilute solution, cannot be due to the influence of the acid, which had been added in greater amount than when the sugar was inverted in higher concentration.

In Osaka's experiment the portion of original solution inverted in concentrated solution was not removed until the day following the removal of the portion intended for inversion in dilute solution;[1] it, therefore, stood in concentrated solution in the presence of 5 cc. of 2.5 *N* hydrochloric acid per 25 cc. for one day longer than did the portion intended for inversion in dilute solution. Any destruction of invert sugar (particularly of fructose) by the acid during this period might, therefore, have been different in degree in the portions inverted in concentrated and dilute solution, thus causing their rotations to be different. In order to test this possibility, the following experiments were carried out, the procedure being the same as Osaka's, with the exception that the 5 cc. for inversion in concentrated solution were removed at the same time as the 5 cc. intended for inversion in dilute solution. The procedure of making up the final volume of 25 cc. for the inversions in concentrated and dilute solutions is indicated below. The solutions were kept at 25° and were read in a saccharimeter at 20° as soon as the volumes were completed to 25 cc. For sodium acetate, a solution which contained 2.05 g. of the anhydrous salt in 7 cc. (which was found by trial to be sufficient to stop inversion) was employed.

	Concentrated solution. Cc.	Dilute solution. Cc.
Added on the first day:		
Original solution[2]	5	5
Sodium acetate solution	7	0
2.5 *N* hydrochloric acid	0	4
Water	5	8
	17	17
Added further on the second day:		
Sodium acetate solution	0	7
Water	8	1
	25	25

In addition to an original solution containing 80 g. of sucrose in 100 cc.,

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[1] See note 1 on page 1573.

[2] It was found necessary for accuracy to weigh the quantity of original solution which was used; these weights are recorded in the second and third columns of the following tables.

three solutions were prepared and tested in the same manner: (*a*) A solution of equal parts of glucose and fructose corresponding to the above sucrose solution; (*b*) a fructose solution of one-half the concentration of the invert sugar solution; (*c*) a glucose solution of one-half the concentration of the invert sugar solution. The results of these experiments, in which portions of the original solutions intended for inversion in concentrated and dilute solution had been removed each day for a number of days in order to determine the effect of the prolonged action of hydrochloric acid on the original solutions, are shown in Tables I–IV.

All of the polarizations were checked by a standardized quartz plate and the rotations are corrected for any change of zero of the instrument during the period of the experiments. The data show that concentrated solutions of inverted sucrose, of invert sugar prepared by mixing pure glucose and fructose, and of fructose, decrease in levorotation progressively

TABLE I—SUCROSE.

Date.	Sample weight, dilute inversion. G.	Sample weight, concentrated inversion. G.	Rotation, dilute.	Rotation. concentrated.	Rotation, dilute (cor.).[2]	Rotation, concentrated (cor.).[1]
Jan. 9	6.2150	6.1050	—18.45	—18.20	—18.35	—18.45
10	6.2232	6.2355	—18.20	—18.20	—18.05	—18.05
11	6.2590	6.1890	—17.75	—17.65	—17.55	—17.60
12	6.1050	6.1165	—16.70	—16.80	—16.90	—17.00
13	6.1310	6.1475	—16.30	—16.40	—16.45	—16.50
14	6.1410	6.1550	—15.80	—15.90	—15.90	—15.95
16	6.2695	6.1655	—15.70	—15.35	—15.50	—15.40
17	6.1235	6.1355	—15.00	—15.00	—15.16	—15.10
18	6.2235	6.3440	—15.00	—15.30	—14.90	—14.90
Av..............		6.1808				

TABLE II—INVERT SUGAR.

Date.	Sample weight, dilute inversion. G.	Sample weight, concentrated inversion. G.	Rotation, dilute.	Rotation. concentrated.	Rotation, dilute (cor.).[2]	Rotation. concentrated (cor.).[2]
Jan. 9	6.1600	6.1350	—18.30	—18.35	—18.15	—18.25
10	6.2140	6.2020	—18.00	—18.05	—17.70	—17.75
11	6.0040	6.0065	—16.90	—17.00	—17.20	—17.30
12	6.0960	6.2650	—16.85	—17.40	—16.90	—16.95
13	6.1245	6.1240	—16.55	—16.60	—16.50	—16.55
14	5.9855	6.1165	—16.00	—16.35	—16.35	—16.35
16	6.0610	6.1240	—15.75	—16.00	—15.85	—15.95
17	5.9950	6.0780	—15.30	—15.45	—15.60	—15.55
18	6.0850	6.1620	—15.30	—15.50	—15.35	—15.35
Av..............		6.1077				

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[1] Corrected to a uniform sample weight of 6.1808 g. by direct proportion.

[2] Corrected to a uniform sample weight of 6.1077 g. by direct proportion.

TABLE III—GLUCOSE.

Date.	Sample weight, dilute inversion. G.	Sample weight, concentrated inversion. G.	Rotation. dilute.	Rotation, concentrated.	Rotation. dilute (cor.).[1]	Rotation, concentrated (cor.).[1]
Jan. 9	5.6650	5.6600	+23.15	+23.05	+23.10	+23.05
10	5.6470	5.6550	+23.10	+23.10	+23.15	+23.10
11	5.6640	5.6875	+23.10	+23.15	+23.05	+23.05
12	5.6285	5.6320	+23.00	+22.90	+23.10	+23.00
13	5.6460	5.6810	+23.05	+23.05	+23.10	+22.95
14	5.6630	5.6675	+23.10	+23.05	+23.10	+23.00
16	5.6725	5.6645	+23.10	+23.05	+23.05	+23.00
17	5.6530	5.6560	+23.05	+22.95	+23.05	+22.95
18	5.6395	5.6465	+23.00	+22.95	+23.05	+23.00
Av.		5.6571				

TABLE IV—FRUCTOSE.

Date.	Sample weight, dilute inversion. G.	Sample weight, concentrated inversion. G.	Rotation, dilute.	Rotation, concentrated.	Rotation, dilute (cor.).[1]	Rotation, concentrated (cor.).[2]
Jan. 9	5.7000	5.6950	—42.35	—42.25	—42.15	—42.10
10	5.6510	5.6730	—41.60	—41.65	—41.80	—41.65
11	5.6715	5.6600	—41.65	—41.45	—41.65	—41.55
12	5.6595	5.6890	—41.30	—41.50	—41.40	—41.40
13	5.6695	5.6750	—41.00	—41.00	—41.05	—41.00
14	5.6955	5.7020	—40.85	—40.95	—40.70	—40.75
16	5.6700	5.6810	—40.50	—40.65	—40.55	—40.60
17	5.6560	5.6135	—40.25	—40.05	—40.40	—40.50
18	5.6870	5.6980	—40.40	—40.55	—40.30	—40.40
Av.		5.6748				

with age when hydrochloric acid is present. It is evident that the decomposition of fructose by the acid is responsible for the change of rotation, since the solution of glucose in acid retains a constant rotation. It will be recalled that in Osaka's experiment the reading of the solution which was removed on the *first* day and allowed to stand in dilute solution (in which the destruction of fructose is arrested) was —6.594 circular degrees, while that of the solution which was removed on the *second* day and immediately diluted and read was only —6.313. The difference of 0.281°, corresponding to 0.81° Ventzke, is of the same order of magnitude as the average daily loss in rotation recorded in Tables I, II, IV, that is, about 0.35° Ventzke. The somewhat higher value of Osaka's experiment may be due to his working at 25°, whereas our experiments were made at 20°. Our experiments show no certain difference in rotation between sucrose solutions which are inverted in dilute and in concentrated solution, provided the inversions are carried out under comparable conditions. We

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[1] Corrected to a uniform sample weight of 5.6571 g. by direct proportion.

[2] Corrected to a uniform sample weight of 5.6748 g. by direct proportion.

are forced to discard Osaka's experiments because the inversions in dilute and concentrated solutions were not carried out under comparable conditions. The conclusion from our experiments is that the hydrolysis of sucrose by hydrochloric acid is not to any detectable degree a reversible reaction in aqueous solution.

Repetition of Visser's Experiments.—Visser[1] states that the inversion of sucrose by invertase is not complete as compared with its inversion by acids; a 0.25 *N* sucrose solution gave, after inversion by invertase, a rotation of —3.26°, while the rotation of a similar solution inverted by a 0.25 *N* hydrochloric acid was —3.42°. He therefore assumes the existence of an equilibrium in the hydrolysis of sucrose by invertase, which would afford a basis for the belief that this reaction is reversible. In our repetition of Visser's experiments (the rotations of the solutions were read in a saccharimeter and with a tube of different length from that used by Visser), —20.7° and —19.5°, respectively, were obtained for the solutions inverted by hydrochloric acid and invertase; after exactly neutralizing the former with sodium carbonate, to make it really comparable with the latter, which was very slightly acid with acetic, the rotation became —19.6. The difference observed by Visser was, therefore, due to the well known influence of hydrochloric acid on the optical rotation of invert sugar, and does not indicate the existence of an equilibrium in the inversion of sucrose by invertase. Visser also stated that a solution containing equal parts of glucose and fructose, in an amount equivalent to a 0.25 *N* sucrose solution, gave a rotation of —3.42°, that is, the same as a 0.25 *N* sucrose solution inverted by hydrochloric acid. As this statement is, however, in full disagreement with the well known influence by hydrochloric acid on the rotation of invert sugar solutions, the experimental data cannot be accepted. A synthesis of sucrose from invert sugar which Visser supposedly obtained is described by him in the following words: "A solution, which contained equal amounts of fructose and glucose, showed an initial rotation of —12.46°; after being subjected to the action of invertase for two months, the rotation was —12.29°." No further details in regard to this experiment are given. The possibility of this supposed reversion was tested by diluting a solution, containing equal amounts of glucose and fructose with a solution of invertase,[2] so that the rotation after dilution was approximately the same as that of a certain quartz plate; the latter was used to control the constancy on the saccharimeter scale of the initial rotation of the solution. After addition of toluene to prevent the growth of microörganisms, the solution was kept in a 200 mm. tube and

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[1] *Z. physik. Chem.*, **52**, 275 (1905).

[2] The invertase solution which was used in these and the other experiments recorded in this article was prepared from yeast by rapid autolysis according to the method described by one of us in the accompanying article.

the rotation at 20° observed at various times during a period of three and a half months. All of the readings lay between the values —50.65 and —50.70, as compared with the reading of the quartz plate, which was —50.15. There was accordingly no change in rotation beyond the limits of experimental error and no synthesis of sucrose was detected.

As an indication of the activity of the invertase present in this solution, it may be stated that a sucrose solution of equivalent concentration and containing the same amount of invertase was half inverted in one and one-half days at 20°. This experiment was better controlled, we believe, than was Visser's and no indication of a synthesis of sucrose by the action of invertase was found.

Kohl's Experiment.—F. G. Kohl[1] has stated that "yeast extracts with a high inverting power, when acting on sucrose solutions of known concentration in the absence of light and at different temperatures, produced glucose and fructose up to certain limits and then remained stationary or brought about a reversion." This supposed reversion was tested as follows, the degree of acidity being varied by adding acetic acid and sodium phosphate to the solutions in view of the possibility that the acidity may play an important part in reversion. Five 200 mm. observation tubes were prepared so that each one contained a synthetic invert sugar solution (equal amounts of glucose and fructose) of the same strength and a small amount of potassium fluoride to prevent the growth of microorganisms; the concentration of these invert sugar solutions was 10 g. per 100 cc. The hydrogen ion concentrations were 10^{-5}, 10^{-6}, 10^{-7}, 10^{-8}, and 10^{-9}, respectively,[2] or, in other words, the first two solutions were slightly acid, the third was approximately neutral, and the last two were slightly alkaline. The invertase used was quite active; when diluted 1 to 11, it inverted a 0.5% sucrose solution to the extent of 50% in 5 minutes at 30°. The dilution of this invertase in the above sugar solutions was 3 to 40. All the solutions were kept in the dark during the experiment. The data, as indicated in Table V, do not give evidence of any reversion of invert sugar to sucrose.

TABLE V.—TEMPERATURE 20°.

Date.	$10^{-5}H^+$.	10^{-6}.	10^{-7}.	10^{-8}.	10^{-9}.	Quartz plate.
Dec. 15	—12.35	—12.40	—12.35	—12.35	—12.35	—50.15
19	—12.35	—12.40	—12.35	—12.35	—12.35	—50.15
22	—12.35	—12.35	—12.35	—12.30	—12.35	—50.15
Jan. 4	—12.35	—12.40	—12.30	—12.35	—12.35	—50.15
10	—12.40	—12.45	—12.35	—12.40	—12.40	—50.15
28	—12.35	—12.35	—12.30	—12.35	—12.40	—50.15
Mar. 23	—12.40	—12.35	—12.35	—12.35	—12.40	—50.15

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[1] *Bot. Centrbl., Beihefte, Abt. I,* **23,** 64*f*–64*o*, Jan. 10, 1908.

[2] Cf. A. A. Noyes, THIS JOURNAL, **32,** 823 (1910), for the preparation of solutions with these hydrogen ion concentrations.

Pantanelli's Experiments.—In 1906, Pantanelli[1] published a number of experiments on the inversion of sucrose by aqueous extracts of the mold *Mucor mucedo.* Among them are three instances in which the power of an invert sugar solution to reduce alkaline copper solutions decreased when the solution was mixed with the extract of the mold. Without making thorough inquiry into the cause of these decreases, Pantanelli drew the conclusion that they indicate a reversion of the invert sugar, the extent of the reversion being as high as 24% in one of the experiments. The evidence from this work for a synthesis of sucrose from invert sugar is slight, because the experiments were not checked by polarimetric data or the other usual ways for detecting the presence of sucrose, nor were the various possible sources of uncertainty controlled. No confirmation of this reversion has been subsequently published, although it should not be difficult to crystallize sucrose from the solutions if such an extensive synthesis as Pantanelli's experiments indicate were really to be obtained. We have not tried to duplicate Pantanelli's rather doubtful observations upon the action of invertase which may be prepared from *Mucor mucedo,* as our work has been limited to the invertase which is obtained from yeast.

Summary.

A solution of the enzyme invertase which was prepared by the rapid autolysis of yeast under the influence of toluene, and purified by clarification with neutral lead acetate and hydrogen sulfide, and by subsequent dialysis, was allowed to act upon aqueous invert sugar solutions, which were maintained at various degrees of slight alkalinity and acidity, in an attempt to detect a possible synthesis of sucrose by the enzyme.

Although numerous experiments under various conditions were tried, not one showed any indication of such a synthesis. A repetition of Osaka's experiments, which indicate the synthesis of sucrose from invert sugar in concentrated solution, in the presence of hydrochloric acid, shows that the change of polariscopic rotation which he observed is not due to synthesis, but is caused by the decomposing action of the acid upon fructose.

A repetition of similar experiments by Visser shows that his supposed synthesis of sucrose was only a change in rotation which is caused by the well known influence of hydrochloric acid upon the rotatory power of fructose.

An examination of the experiments of Kohl and of Pantanelli on the synthesis of sucrose by the action of invertase upon invert sugar solutions, shows the experimental evidence to be very doubtful.

Our conclusion, from a consideration of the experiments of others and from our own data is that invertase from yeast accomplishes a complete hydrolysis of sucrose to yield invert sugar and that the reaction does not

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[1] *Atti della R. Accad. dei Lincei,* **15,** first semester, 587–94 (1906).

establish a mobile equilibrium, and is not a reversible or balanced reaction, within our limits of detection.

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NEW BOOKS.

The Progress of Scientific Chemistry. By SIR WILLIAM A. TILDEN. Second Edition. 360 pp. Longmans, Green & Co. 1913. $2.25.

The merited success of the first edition of this work, published in 1899, has justified the present revised edition in which several new subjects, such as radiochemistry, are included. The majority of the chapters are written from a somewhat old-fashioned standpoint, but are readable and stimulating. The biographical notes and references appended to the several chapters add to the value of the work. GILBERT N. LEWIS.

Chemistry and Its Borderland. By ALFRED W. STEWART. Longmans, Green & Company. 314 pp. Price, $1.50, net.

This is a very readable and instructive general description of a number of selected topics of recent physical and chemical research. It includes chapters on such topics as the Relations between Chemists and Industry, Chemical problems of the Present and Future. Organization of Chemical Research (in England), The Methods of Chemical Research, etc. Separate chapters are devoted to the discoveries by means of the spectroscope, stereochemistry, colloids, the inert gases of the atmosphere, radium, niton, transmutation of the elements, the nature of the elements, etc. The author is evidently following closely the work of the English school of chemists, and does not hesitate to accept for niton all the properties ever ascribed to it. He does not doubt the transmutation of copper into lithium, as published by Ramsay and Cameron. Madam Curie's described inability to repeat this transmutation is "negative evidence that can hardly outweigh the positive." A bold author makes better reading than an apologetic one, and we do not refer to these facts in critical mood. This kind of book is greatly needed to help keep a very large class of chemists up-to-date and to inspire the aspiring younger generation. It is also very readable to the "near scientist." The author's treatment of his subject reminds one of R. K. Duncan's very interesting and instructive publications.

The author has occasionally fallen into a common didactic error. In this way he has given some impressions which, while they may represent desirable conditions of research, give too much credit to the foresight of chemists and not enough to the utility of their powers of observation. Bacon credited Herodotus with the statement that the Egyptians who deified discoverers, worshipped more animals than men, because the former made most of the discoveries. So also it is still true that many discoveries