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REDETERMINATION OF THE MUNSON-WALKER REDUCING-SUGAR VALUES

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ABSTRACT

The various methods for the gravimetric determination of reducing sugars by the alkaline copper tartrate reagent (Fehling's solution) were unified by L. S. Munson and Percy H. Walker in 1906. This method has gained widespread use because of its simplicity and reproducibility. Now that sugars of higher purity are available, a redetermination of the values of Munson and Walker has been made. To this have been added the values for levulose, as well as the values for an additional sugar mixture containing 0.3 g of total sugar. This latter mixture extends the adaptability of the method to include such products as simulated molasses, which contains such high percentages of invert sugar in the total sugar present that neither column of sugar-mixture values in the original table was directly applicable. The conditions of the Munson and Walker method were followed, except that the copper was determined electrolytically and the solution was heated by electricity. It was demonstrated that the substitution of electricity for gas-flame heating produces no change in the results. Also, the invert sugar was prepared by taking equal weights of crystalline dextrose and levulose. For a given weight of copper the new values are somewhat higher than the old values. An extensive table showing the reducing-sugar values for weights of copper from 10 mg to 435 mg in 1-mg intervals has been computed.

CONTENTS

I. INTRODUCTION

During the process of manufacturing or refining sugar, there occurs a certain amount of decomposition of the sucrose into simpler sugars, dextrose and levulose. Their quantitative estimation is of great importance in factory methods and in the United States customs laboratories, where a knowledge of the percentage of reducing sugars in a sugar product is necessary for the assessment of customs duties. In 1841, Trommer [1][1] reported a method of distinguishing between sucrose and dextrose by treating separate solutions of these sugars with an alkaline copper sulfate solution, in which the dextrose produced a dark-red precipitate of cuprous oxide, whereas the sucrose solution gave little or no such reaction. In 1844, Barreswil [2] made the important contribution that potassium tartrate increases the stability of the alkaline copper reagent; and in 1849, Fehling [3] published the details of the method essentially as it is now used.

[1] Figures in brackets indicate the literature references at the end of this paper.

In the years that have followed the publication of Fehling's work, many reducing-sugar methods have been proposed in which various modifications of the concentrations of the components of the Fehling reagent and of the period of boiling the solution of sugar and reagent were made. Jackson [4] has made an extensive study of this method in which he shows the results of determining the copper by volumetric and electrometric methods, while Erb and Zerban [5] have studied the total reducing sugar and the dextrose and levulose in cane molasses, determining the copper as cupric oxide. Smolenski [6] has recently summarized a graphical classification of 29 methods for the estimation of reducing sugars.

In 1906, Munson and Walker [7] surveyed the various methods and proposed one to unify all the others for the determination of dextrose, invert sugar, and two mixtures of invert sugar and sucrose totaling 0.4 g and 2.0 g, respectively. This method has gained widespread use because of its simplicity and extreme reproducibility of results. Their solutions and method of manipulation are as follows: The copper sulfate solution contains 34.639 g of $CuSO_4.5H_2O$ in 500 ml, and the alkaline tartrate solution contains 173 g of potassium sodium tartrate ($KNaC_4H_4O_6.4H_2O$) and 50 g of sodium hydroxide in 500 ml. Transfer 25 ml each of the copper and alkaline tartrate solutions to a 400-ml beaker and add 50 ml of reducing-sugar solution; or if a smaller volume of sugar solution is used, add water to make the final volume 100 ml. Heat the beaker upon an asbestos gauze over a bunsen burner; so regulate the flame that boiling begins in 4 minutes and continue the boiling for exactly 2 minutes. Keep the beaker covered with a watch glass throughout the entire time of heating. Without diluting, filter the cuprous oxide at once on an asbestos felt in a porcelain Gooch crucible, using suction. Wash the cuprous oxide thoroughly with water at 60° C, then with 10 ml of alcohol, and finally with 10 ml of ether. Dry for 30 minutes at 100° C, cool in a desiccator, and weigh as cuprous oxide.

Despite the wide utilization of the Munson and Walker method for scientific and commercial purposes, there has been neither a redetermination of their original values nor any needed additions to the scope of the tables since their publication. Now that purer sucrose and dextrose are readily available, it was decided to redetermine the reducing-sugar values from which the Munson and Walker table was computed, and also, since pure levulose is now available by methods developed at this Bureau [8], to determine the values for this sugar.

Within the past few years a new article of commerce has appeared. It is a simulated molasses manufactured directly from cane juice or raw sugar with or without the addition of molasses. It is now imported into the United States in large quantities and, because of its lack of accumulated impurities, is a product preferred for many purposes to ordinary molasses. The sucrose present is partially hydrolyzed with acid, neutralized, and concentrated to a thick sirup. Samples received at this Bureau have a composition varying between 70 and 82 percent of total sugar and a reducing-sugar content between 45 and 58 percent. When a sample of such a molasses is taken to give a total sugar content of 0.4 g in 50 ml, the concentration of reducing sugar is such that the limits of the Munson-Walker table are exceeded. In analyzing this new material, it is now necessary to use a smaller sample and to add sufficient pure sucrose to obtain 0.4 g of total sugar in the 50-ml aliquot. In order to be able to directly weigh out a sample, it was decided to determine data for a new column for 0.3 g of total sugar.

II. ANALYTICAL PROCEDURE

In redetermining these values, as well as in determining the new ones, the conditions of the Munson-Walker method were followed and the same concentration of alkaline copper tartrate reagent was used. However, certain changes in technique were soon found to be advisable. Munson and Walker brought the solution to boiling by heating over a gas flame, but this procedure was changed to the use of the more convenient electric heating. When the 400-ml beaker was placed in the electric heater, the 100 ml of solution it contained was entirely surrounded by a nest of the resistance wire. When gas is used to heat such a mixture, a yellow substance often forms on the side of the beaker which is more marked when low-grade sugar products, such as blackstrap molasses, are to be analyzed, but which has never been observed when the heating is done electrically. Also, the beaker can be handled more comfortably, which permits the filtering of the cuprous oxide to be started more rapidly than can be done when gas heating is used.

The current was controlled in the following manner: The line voltage was stabilized by means of a voltage regulator whose output voltage was constant within small limits, regardless of input variations caused by fluctuations in the line voltage. This constant output voltage was fed into the input of a continuously variable transformer whose output voltage was adjusted to give the correct current through the heater. The solution could readily be brought to boiling in the 4-minute interval used in the method within ± 5 seconds.

Munson and Walker transferred the precipitated cuprous oxide to Gooch crucibles and weighed the cuprous oxide. This procedure was abandoned, and the copper was determined electrolytically. The cuprous oxide was transferred to a Gooch crucible, washed, and then dissolved by the slow dropwise addition of 5 ml of 1:1 nitric acid. The copper nitrate was received in a 250-ml beaker, and 10 ml of 1:1 nitric acid added, as well as about 5 g of ammonium sulfate. Enough water to cover the cylindrical platinum-gauze electrodes was added, making the total volume of electrolyte about 180 ml. The electrolysis was conducted for about 36 hours [2] at a current density of approximately 0.10 amp/dm^2; and upon completion, as indicated by the ferrocyanide test, the electrolyte was displaced with distilled water before breaking the current. The copper deposit was washed with alcohol, dried for 15 minutes at 100° C, cooled in a desiccator, and weighed. All deposits were bright and showed no trace of "burning." [3]

Munson and Walker prepared the invert sugar by hydrolyzing a pure sucrose solution with 10 ml of 0.2 N HCl and, upon completion of the hydrolysis, neutralizing with 0.2 N sodium hydroxide. This procedure leaves in the invert solution an amount of sodium chloride equivalent to the acid used. Six experiments in determining dextrose with the addition of approximately 150 mg of sodium chloride

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[2] The electrolysis can be completed overnight by using a larger current. John A. Scherrer, Rosemond K. Bell, and William D. Mogerman, J. Research NBS 22, 697 (1939) RP1213.

[3] Electroanalysis of copper was selected on account of its extreme accuracy. In the routine analysis of sugar products, any method of determining copper which is suitable to the products may be used.

to the solution showed significantly larger amounts of cuprous oxide precipitated than in the absence of the salt. Consequently, the invert solution was made by taking equal weights of crystalline dextrose and levulose.

The levulose was prepared by taking a purified sample and dissolving it in water to make a 50-percent solution. Vegetable carbon was added and the solution heated. The filtered solution was evaporated in vacuo to a thick sirup, seeded with pure levulose, and crystallized in motion. The crystals were centrifuged and then washed with absolute alcohol. After drying in the air, the crystals were pulverized, dried for 2 hours at 50° C, and finally dried and stored in a vacuum desiccator. A polariscopic examination showed the levulose to be pure.

The sucrose and dextrose used in this work were Standard Samples 17 and 41, respectively, issued by this Bureau.

In general, the same intervals in the concentrations of the sugars employed by Munson and Walker were used, except that additional points were determined at higher concentrations to obtain data for a better least-squares adjustment in the high range of sugar concentrations. Fresh solutions were made for each determination by weighing the requisite amount of sugar into a sugar scoop, transferring to a 500-ml flask, and completing the volume at 20° C, at which temperature the solution was kept while the aliquots of 50 ml were taken. For the concentration 20 mg per 50 ml, the amount of sugar necessary for 1 liter of solution was taken.

The experimental data are shown in table 1. A single weight of sugar or sugar mixture was dissolved, and four 50-ml aliquots were taken for each determination. However, for dextrose another series of duplicate determinations was made from a different specimen of Standard Sample 41 in order to check the reproducibility of results.

TABLE 1.—*Tabulation of analytical data*

DEXTROSE[1]					
Reducing sugar	Copper	Copper	Copper	Copper	Average result
mg	*mg*	*mg*	*mg*	*mg*	*mg*
20	42.2	41.5	41.8	41.7	41.8
	41.8	41.9			
40	82.5	81.7	82.1	82.0	82.2
	82.4	82.2			
60	121.1	121.1	121.2	121.2	121.2
	121.1	121.2			
80	160.3	160.0	160.3	160.1	160.2
	160.1	160.1			
100	197.6	198.1	197.6	198.2	197.9
	198.0	198.0			
120	235.0	235.2	234.6	234.5	235.0
	235.5	235.3			
140	271.2	271.2	271.0	270.6	271.1
	271.2	271.4			
160	307.3	307.1	306.7	306.6	307.1
	307.4	307.4			

[1] For each reducing-sugar concentration the 4 values in the first line represent the results from 4 aliquots of the solution. A new solution was prepared and the 2 values in the second line represent the results from the 2 aliquots taken from that solution.

TABLE 1.—*Tabulation of analytical data*—Continued

Reducing sugar	Copper	Copper	Copper	Copper	Average result
DEXTROSE—Continued					
mg	*mg*	*mg*	*mg*	*mg*	*mg*
180	341.4	341.4	341.4	340.5	341.4
	341.8	341.8			
200	375.1	375.5	374.9	374.9	375.3
	375.8	375.7			
220	408.4	408.8	408.6	407.8	408.7
	409.1	409.3			
240	438.5	438.2	438.4	438.3	438.3
	438.1	438.5			
INVERT SUGAR					
20	39.7	39.6	39.6	39.7	39.7
40	78.2	78.0	78.3	78.0	78.1
60	115.9	115.5	115.4	116.0	115.7
80	153.4	152.8	153.3	153.4	153.2
100	190.3	190.1	190.0	190.2	190.2
120	226.6	226.4	225.9	226.1	226.3
140	262.2	261.1	260.9	261.1	261.3
160	296.7	297.0	296.6	296.7	296.8
180	330.5	330.2	330.6	330.2	330.4
200	363.8	363.6	363.5	364.1	363.8
220	396.1	396.1	396.3	396.0	396.1
240	427.7	427.7	427.6	428.0	427.8
250	438.4	438.6	438.2	438.4	438.4
INVERT SUGAR AND SUCROSE—0.3 g OF TOTAL SUGAR					
20	42.9	42.8	42.9	43.1	42.9
40	80.9	81.2	81.2	81.4	81.2
60	118.7	118.7	119.0	118.7	118.8
80	155.5	155.8	155.2	155.1	155.4
100	192.1	192.6	192.0	191.9	192.2
120	227.9	228.2	228.3	228.7	228.3
140	263.7	263.1	263.6	263.7	263.5
160	297.3	297.5	297.4	297.5	297.4
180	331.1	331.3	331.5	331.5	331.4
200	364.9	364.9	365.2	364.7	364.9
220	397.4	397.6	397.8	397.8	397.7
240	428.5	428.4	429.1	428.5	428.6
250	438.6	438.4	438.2	438.6	438.5
INVERT SUGAR AND SUCROSE—0.4 g OF TOTAL SUGAR					
20	43.8	44.1	43.9	43.8	43.9
40	81.5	81.9	81.8	81.7	81.7
60	119.7	119.6	119.5	120.1	119.7
80	156.5	156.4	156.4	156.7	156.5
100	193.5	193.6	193.4	193.5	193.5
120	229.2	228.8	229.2	228.7	229.0
140	263.9	264.1	263.9	264.2	264.0
160	298.2	298.5	298.2	298.2	298.3
180	332.1	331.5	332.0	332.0	331.9
200	364.5	364.5	364.8	364.9	364.7
220	397.9	397.6	397.7	397.7	397.7
240	428.7	428.5	429.1	428.9	428.8
250	438.4	438.6	438.5	438.5	438.5

TABLE 1.—*Tabulation of analytical data*—Continued

INVERT SUGAR AND SUCROSE—2.0 g OF TOTAL SUGAR					
Reducing sugar	Copper	Copper	Copper	Copper	Average result
mg	*mg*	*mg*	*mg*	*mg*	*mg*
20	55.1	54.9	55.2	55.2	55.1
40	93.8	93.9	94.3	94.2	94.1
60	130.2	131.0	131.2	130.9	130.8
80	166.9	166.7	166.8	167.3	166.9
100	202.9	203.7	204.1	204.2	203.7
120	238.5	238.6	238.6	238.7	238.6
140	273.5	273.4	273.0	273.3	273.3
160	308.0	307.2	307.1	307.3	307.4
180	339.8	339.9	340.1	340.3	340.0
200	373.0	373.4	373.4	373.3	373.3
220	404.7	404.7	404.6	404.7	404.7
240	434.7	434.3	434.6	434.6	434.6
LEVULOSE					
20	38.3	38.2	38.2	38.2	38.2
40	74.7	74.7	74.4	74.7	74.6
60	110.8	111.0	111.0	111.1	111.0
80	146.9	146.9	146.8	146.8	146.9
100	182.5	182.5	182.6	182.5	182.5
120	218.2	217.9	217.5	217.6	217.8
140	251.7	252.2	251.7	252.2	252.0
160	286.2	285.8	285.7	285.5	285.8
180	318.9	318.8	319.6	319.0	319.1
200	352.6	352.6	352.3	352.0	352.4
220	385.2	384.6	384.9	384.6	384.8
240	416.8	416.5	416.8	416.5	416.7
260	438.5	438.8	438.4	438.5	438.6

Critical examination of the experimental data shows that either the parabolic or the rectangular hyperbolic equation fits the data for the lower range of sugar concentrations but that neither equation can be made to fit the whole range. The following are the characteristics required of an equation fitting the data over the whole experimental range. For low concentrations of reducing sugar the amount of copper obtained is very nearly proportional to the concentration of reducing sugar, and the curve representing the equation is therefore very nearly linear in this range. With increasing sugar concentrations the slope of the curve decreases, since the change in the amount of copper obtained for a given increase in concentration of sugar decreases. The data show this decrease in slope to be uniform, and it becomes very rapid as the amount of unreduced copper becomes approximately 5 mg. As the amount of available copper is further diminished, the decrease in the slope of the curve becomes less rapid, approaching zero as the amount of available copper approaches zero. A curve having the above characteristics and possessing ease of application was found to be of the form

$$(a+x)\ (b-y)=c+d\ (y_1-y)^{-1}. \tag{1}$$

It is formed by adding the term $d(y_1-y)^{-1}$ to the equation for the rectangular hyperbola. It fits the data satisfactorily throughout and, in addition, is considerably easier to apply than an equation of the parabolic form. The added term causes the curve to approach the limiting value of copper, y_1=440.9 mg, asymptotically, as was indicated by additional data taken for sugar concentrations corresponding to values for reduced copper between 435 and 440.9 mg. In this range, the additional amounts of copper reduced during the reaction by equal increments of sugar become increasingly smaller, which is probably explained by the decreased amount of unreduced copper in the reagent as the reaction of the reagent and sugar proceeds

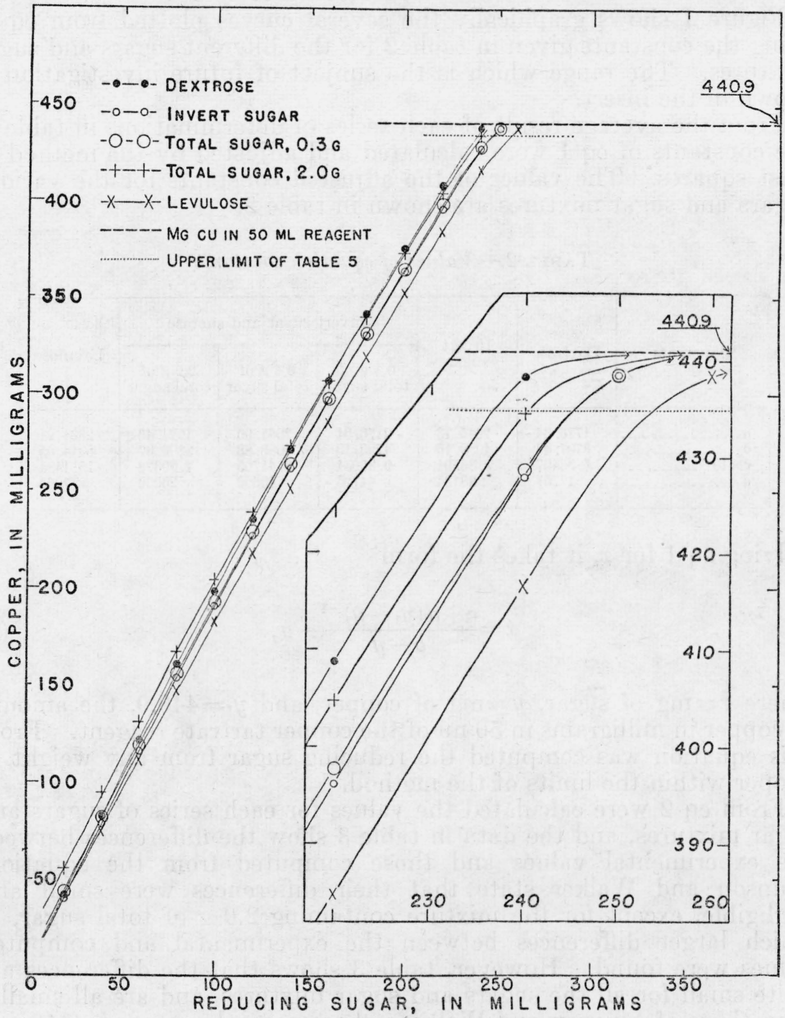

FIGURE 1.—*Graphic representation of data in table 1.*

in the range closely approaching 440.9 mg of reduced copper. In all of the sugars and sugar mixtures, the total amount of copper reduced approaches the ordinate 440.9 asymptotically. Therefore, it is obvious that the adaptability of the method is questionable for sugar concentrations corresponding to values of copper greater than approximately 435 mg. There is some evidence that the precision of the measurements for all concentrations greater than 220 mg of sugar is somewhat less than that for lower concentrations. Although this region is of lesser importance analytically, a further study of the reaction for it is contemplated and is justified from theoretical considerations alone. Also, additional data may be instrumental in even more definitely fixing the positions of the several curves in this range.

Figure 1 shows graphically the several curves plotted from eq 1, using the constants given in table 2 for the different sugars and sugar mixtures. The range which is the subject of future investigation is shown in the insert.

From the average result of each series of determinations in table 1, the constants of eq 1 were calculated and adjusted by the method of least squares. The values of the adjusted constants for the various sugars and sugar mixtures are shown in table 2.

TABLE 2.—*Values of equation constants*

Constants	Dextrose	Invert sugar	Invert sugar and sucrose			Levulose
			0.3 g of total sugar	0.4 g of total sugar	2.0 g of total sugar	
a	1776.34	2045.73	2176.94	2061.90	1924.46	2834.91
b	3707.48	4089.15	4299.10	4086.88	3806.37	5344.05
$c \times 10^{-6}$	6.58497	8.36591	9.35084	8.41765	7.29378	15.1484
d	17757	38134	44726	40666	26959	77065

Solving eq 1 for x, it takes the form

$$x=\frac{c+d(y_1-y)^{-1}}{b-y}-a, \tag{2}$$

where x=mg of sugar, y=mg of copper, and y_1=440.9, the amount of copper in milligrams in 50 ml of the copper tartrate reagent. From this equation was computed the reducing sugar from any weight of copper within the limits of the method.

From eq 2 were calculated the values for each series of sugars and sugar mixtures, and the data in table 3 show the differences between the experimental values and those computed from the equation. Munson and Walker state that their differences were small and negligible, except for the mixture containing 2.0 g of total sugar, in which larger differences between the experimental and computed values were found. However, table 3 shows that the differences are quite small for all the sugars and sugar mixtures, and are all smaller than those of Munson and Walker, whose general average is 0.48 mg.

TABLE 3.—*Differences between the computed and experimental values*

Reducing sugar	Dextrose	Invert sugar	Invert sugar and sucrose: 0.3 g of total sugar	Invert sugar and sucrose: 0.4 g of total sugar	Invert sugar and sucrose: 2.0 g of total sugar	Levulose
mg	*mg of* Cu	*mg of* Cu	*mg of* Cu	*mg of* Cu	*mg of* Cu	*mg of* Cu
20	−0.1	−0.4	0.2	−0.3	−0.2	0.3
40	−.1	0	.1	.3	.6	−.2
60	.3	.5	0	.1	−.1	−.2
80	0	.3	−.5	.3	−.6	−.2
100	.1	0	−.1	−.3	.2	0
120	0	−.1	.3	−.2	−.1	.4
140	.1	.2	.4	−.1	0	.1
160	−.4	−.6	−.2	0	.2	0
180	0	−.1	−.2	.1	−.4	−.2
200	.1	−.1	0	.4	.4	0
220	0	.3	.2	−.1	−.1	−.1
240	0	0	−.1	−.2	0	.1
250	--------	0	0	0	--------	--------
260	--------	--------	--------	--------	--------	0
Mean	0.1	0.2	0.1	0.2	0.2	0.1

In table 4 are given the differences between the copper values of the Munson and Walker table and the new values for concentrations of reducing sugar between 20 and 240 mg. In general, the differences between the two tables increase with increase of sugar concentration. It is to be noted that if a comparison is made between a given weight of copper and the corresponding sugar value, the new sugar value will be somewhat higher than that in the Munson and Walker table.

TABLE 4.—*Differences between the Munson and Walker table and the new table*

Concentration of reducing sugar	Dextrose			Invert sugar			Invert sugar and sucrose 0.4 g of total sugar			Invert sugar and sucrose 2.0 g of total sugar		
	Munson and Walker	Hammond	Difference	Munson and Walker	Hammond	Difference	Munson and Walker	Hammond	Difference	Munson and Walker	Hammond	Difference
mg	*mg of* Cu	*mg of* Cu	*mg of* Cu	*mg of* Cu	*mg of* Cu	*mg of* Cu	*mg of* Cu	*mg of* Cu	*mg of* Cu	*mg of* Cu	*mg of* Cu	*mg of* Cu
20	41.7	41.8	0.1	39.8	39.2	0.6	44.9	43.6	1.3	57.2	55.2	2.0
40	82.2	82.0	.2	79.1	78.0	1.1	83.5	82.0	1.5	95.2	93.4	1.8
60	121.7	121.6	.1	117.6	116.2	1.4	121.3	119.8	1.5	132.9	130.8	2.1
80	160.6	160.2	.4	155.3	153.5	1.8	158.5	156.8	1.7	169.7	167.5	2.2
100	198.3	198.0	.3	192.3	190.2	2.1	194.9	193.2	1.7	205.9	203.5	2.4
120	235.4	235.0	.4	228.5	226.2	2.3	230.8	228.8	2.0	241.6	238.7	2.9
140	271.4	271.2	.2	263.8	261.5	2.3	265.8	263.8	2.0	276.5	273.3	3.2
160	306.8	306.7	.1	298.6	296.2	2.4	300.2	298.2	2.0	310.8	307.2	3.6
180	341.1	341.5	.4	332.5	330.3	2.2	334.0	332.0	2.0	344.4	340.3	4.1
200	374.7	375.5	.8	365.6	363.7	1.9	367.0	365.2	1.8	377.5	373.0	4.5
220	407.4	408.7	1.3	397.9	396.3	1.6	399.3	397.6	1.7	409.9	404.8	5.1
240	--------	--------	--------	429.6	427.7	1.9	431.0	428.6	2.4	--------	--------	--------

The differences between the old and new tables become greater, in general, with the increase in sugar concentration, and it was thought they might be caused by differences in the heating characteristics when electric heating was substituted for gas-flame heating. To test this, a series of experiments, using solutions containing 220 mg of reducing sugars in 50-ml aliquots, was carried out. New solutions were prepared, and from a given solution two 50-ml aliquots were analyzed by heating with a gas flame and two 50-ml aliquots by heating electrically. The results showed differences too small to be considered significant. The averages of the results are given in table 5 and show that the differences between the two tables are not caused by substituting electricity for gas-flame heating in the method of procedure. In addition, reducing-sugar determinations on two samples of blackstrap molasses were made in which one aliquot from each sample was heated by a gas flame and one aliquot of each sample was heated electrically, but again there were no significant differences in the amounts of copper formed.

TABLE 5.—*Comparison of gas and electric heating*

Taken for analysis	Milligrams of copper	
	Gas	Electric
220 mg of dextrose	407.9	408.2
220 mg of invert sugar	396.2	396.5
0.4 g of total sugar 220 mg of invert sugar	396.8	397.2
2.0 g of total sugar 220 mg of invert sugar	404.1	404.5
220 mg of levulose	384.7	384.7
Blackstrap molasses:		
Sample 1	322.5	322.5
Sample 2	409.4	409.3

III. CALCULATION OF TABLE

In table 6 are shown the reducing-sugar values for each sugar and sugar mixture for weights of copper from 10 to 435 mg at intervals of 1 mg. For each sugar and sugar mixture the value for each tenth point from 10 to 420 mg of copper was computed from eq 2 and all intermediate points were determined by linear interpolation. Above 420 mg the differences between successive points change with increasing rapidity, so that smaller intervals were necessary in order for linear interpolation to give sufficiently accurate values. In this range, points 425, 430, 433, and 436 were computed from the equation. The values for cuprous oxide were computed by multiplying the corresponding value for copper by the factor 1.12585.

Attention is called to the fact that the columns for 0.3 g and 0.4 g of total sugar are practically identical beyond the concentration 220 mg of reducing sugar. It is believed that this is due to the slowing of the reaction beyond 220 mg, as explained above, and that the effect of the slight differences in concentration of the two mixtures is of a magnitude approximating the experimental error of the determination.

In 1907, Walker [9] published his determination of the reducing-sugar values of lactose and maltose. Subsequently an error in the calculation of the table for lactose was discovered and a corrected table was published [10]. Later, Given stated that a question had arisen as to the composition of the lactose used by Walker, and that M. N. Straughn, of the Sugar Laboratory, Bureau of Chemistry, United States Department of Agriculture, had prepared a sample of lactose of known composition and had determined values for a new lactose table. Straughn and Given then determined values for two mixtures of lactose and sucrose which, with the new lactose values, were published in 1912 [11]. However, none of the analytical data from which they constructed the tables now in use were given. Work is now in progress on the redetermination of the reducing-sugar values of lactose, two mixtures of lactose and sucrose, and of maltose.

Acknowledgment is made to James B. Saunders for the mathematical treatment of the data and the computation of the reducing-sugar table.

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TABLE 6.—*Table for calculating dextrose, invert sugar alone, invert sugar in the presence of sucrose (0.3, 0.4, and 2.0 g of total sugar), and levulose* [1]

Copper	Cuprous oxide	Dextrose	Invert sugar	Invert sugar and sucrose: 0.3 g of total sugar	Invert sugar and sucrose: 0.4 g of total sugar	Invert sugar and sucrose: 2.0 g of total sugar	Levulose	Copper
mg	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*
10	11.3	4.6	5.2	3.2	2.9	----------	5.1	10
11	12.4	5.1	5.7	3.7	3.4	----------	5.6	11
12	13.5	5.6	6.2	4.2	3.9	----------	6.1	12
13	14.6	6.0	6.7	4.8	4.4	----------	6.7	13
14	15.8	6.5	7.2	5.3	4.9	----------	7.2	14
15	16.9	7.0	7.7	5.8	5.4	----------	7.7	15
16	18.0	7.5	8.2	6.3	5.9	----------	8.3	16
17	19.1	8.0	8.7	6.8	6.4	----------	8.8	17
18	20.3	8.5	9.2	7.3	6.9	----------	9.3	18
19	21.4	8.9	9.7	7.8	7.4	----------	9.9	19
20	22.5	9.4	10.2	8.3	7.9	1.9	10.4	20
21	23.6	9.9	10.7	8.8	8.4	2.4	10.9	21
22	24.8	10.4	11.2	9.3	8.9	2.9	11.5	22
23	25.9	10.9	11.7	9.9	9.5	3.4	12.0	23
24	27.0	11.4	12.3	10.4	10.0	3.9	12.5	24
25	28.1	11.9	12.8	10.9	10.5	4.4	13.1	25
26	29.3	12.3	13.3	11.4	11.0	4.9	13.6	26
27	30.4	12.8	13.8	11.9	11.5	5.5	14.2	27
28	31.5	13.3	14.3	12.4	12.0	6.0	14.7	28
29	32.6	13.8	14.8	12.9	12.5	6.5	15.2	29
30	33.8	14.3	15.3	13.4	13.0	7.0	15.8	30
31	34.9	14.8	15.8	14.0	13.5	7.5	16.3	31
32	36.0	15.3	16.3	14.5	14.1	8.0	16.8	32
33	37.2	15.7	16.8	15.0	14.6	8.5	17.4	33
34	38.3	16.2	17.3	15.5	15.1	9.0	17.9	34

[1] The values in the table for concentrations of reducing sugar less than 20 mg are extrapolated and should be used with caution and only for approximate determinations.

TABLE 6.—*Table for calculating dextrose, invert sugar alone, invert sugar in the presence of sucrose (0.3, 0.4, and 2.0 g of total sugar), and levulose*—Continued

Copper	Cuprous oxide	Dextrose	Invert sugar	Invert sugar and sucrose			Levulose	Copper
				0.3 g of total sugar	0.4 g of total sugar	2.0 g of total sugar		
mg	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*
35	39.4	16.7	17.8	16.0	15.6	9.5	18.4	35
36	40.5	17.2	18.3	16.5	16.1	10.1	19.0	36
37	41.7	17.7	18.9	17.0	16.6	10.6	19.5	37
38	42.8	18.2	19.4	17.6	17.1	11.1	20.1	38
39	43.9	18.7	19.9	18.1	17.6	11.6	20.6	39
40	45.0	19.2	20.4	18.6	18.2	12.1	21.1	40
41	46.2	19.7	20.9	19.1	18.7	12.6	21.7	41
42	47.3	20.1	21.4	19.6	19.2	13.1	22.2	42
43	48.4	20.6	21.9	20.1	19.7	13.7	22.8	43
44	49.5	21.1	22.4	20.7	20.2	14.2	23.3	44
45	50.7	21.6	22.9	21.2	20.7	14.7	23.8	45
46	51.8	22.1	23.5	21.7	21.3	15.2	24.4	46
47	52.9	22.6	24.0	22.2	21.8	15.7	24.9	47
48	54.0	23.1	24.5	22.7	22.3	16.2	25.4	48
49	55.2	23.6	25.0	23.2	22.8	16.8	26.0	49
50	56.3	24.1	25.5	23.8	23.3	17.3	26.5	50
51	57.4	24.6	26.0	24.3	23.8	17.8	27.1	51
52	58.5	25.1	26.5	24.8	24.3	18.3	27.6	52
53	59.7	25.6	27.0	25.3	24.9	18.8	28.2	53
54	60.8	26.1	27.6	25.8	25.4	19.3	28.7	54
55	61.9	26.5	28.1	26.3	25.9	19.9	29.2	55
56	63.0	27.0	28.6	26.9	26.4	20.4	29.8	56
57	64.2	27.5	29.1	27.4	26.9	20.9	30.3	57
58	65.3	28.0	29.6	27.9	27.5	21.4	30.9	58
59	66.4	28.5	30.1	28.4	28.0	21.9	31.4	59
60	67.6	29.0	30.6	28.9	28.5	22.5	31.9	60
61	68.7	29.5	31.2	29.5	29.0	23.0	32.5	61
62	69.8	30.0	31.7	30.0	29.5	23.5	33.0	62
63	70.9	30.5	32.2	30.5	30.1	24.0	33.6	63
64	72.1	31.0	32.7	31.0	30.6	24.5	34.1	64
65	73.2	31.5	33.2	31.6	31.1	25.1	34.7	65
66	74.3	32.0	33.7	32.1	31.6	25.6	35.2	66
67	75.4	32.5	34.3	32.6	32.1	26.1	35.8	67
68	76.6	33.0	34.8	33.1	32.7	26.6	36.3	68
69	77.7	33.5	35.3	33.6	33.2	27.1	36.8	69
70	78.8	34.0	35.8	34.2	33.7	27.7	37.4	70
71	79.9	34.5	36.3	34.7	34.2	28.2	37.9	71
72	81.1	35.0	36.8	35.2	34.7	28.7	38.5	72
73	82.2	35.5	37.4	35.7	35.3	29.2	39.0	73
74	83.3	36.0	37.9	36.3	35.8	29.8	39.6	74
75	84.4	36.5	38.4	36.8	36.3	30.3	40.1	75
76	85.6	37.0	38.9	37.3	36.8	30.8	40.7	76
77	86.7	37.5	39.4	37.8	37.4	31.3	41.2	77
78	87.8	38.0	40.0	38.4	37.9	31.9	41.7	78
79	88.9	38.5	40.5	38.9	38.4	32.4	42.3	79
80	90.1	39.0	41.0	39.4	38.9	32.9	42.8	80
81	91.2	39.5	41.5	39.9	39.5	33.4	43.4	81
82	92.3	40.0	42.0	40.5	40.0	34.0	43.9	82
83	93.4	40.5	42.6	41.0	40.5	34.5	44.5	83
84	94.6	41.0	43.1	41.5	41.0	35.0	45.0	84
85	95.7	41.5	43.6	42.0	41.6	35.5	45.6	85
86	96.8	42.0	44.1	42.6	42.1	36.1	46.1	86
87	97.9	42.5	44.7	43.1	42.6	36.6	46.7	87
88	99.1	43.0	45.2	43.6	43.1	37.1	47.2	88
89	100.2	43.5	45.7	44.1	43.7	37.6	47.8	89
90	101.3	44.0	46.2	44.7	44.2	38.2	48.3	90
91	102.5	44.5	46.7	45.2	44.7	38.7	48.9	91
92	103.6	45.0	47.3	45.7	45.2	39.2	49.4	92
93	104.7	45.5	47.8	46.3	45.8	39.8	50.0	93
94	105.8	46.0	48.3	46.8	46.3	40.3	50.5	94
95	107.0	46.5	48.8	47.3	46.8	40.8	51.1	95
96	108.1	47.0	49.4	47.8	47.4	41.3	51.6	96
97	109.2	47.5	49.9	48.4	47.9	41.9	52.2	97
98	110.3	48.0	50.4	48.9	48.4	42.4	52.7	98
99	111.5	48.5	50.9	49.4	48.9	42.9	53.3	99

TABLE 6.—*Table for calculating dextrose, invert sugar alone, invert sugar in the presence of sucrose (0.3, 0.4, and 2.0 g of total sugar), and levulose*—Continued

Copper	Cuprous oxide	Dextrose	Invert sugar	Invert sugar and sucrose: 0.3 g of total sugar	Invert sugar and sucrose: 0.4 g of total sugar	Invert sugar and sucrose: 2.0 g of total sugar	Levulose	Copper
mg	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*
100	112.6	49.0	51.5	50.0	49.5	43.5	53.8	100
101	113.7	49.5	52.0	50.5	50.0	44.0	54.4	101
102	114.8	50.0	52.5	51.0	50.5	44.5	54.9	102
103	116.0	50.6	53.0	51.6	51.1	45.1	55.5	103
104	117.1	51.1	53.6	52.1	51.6	45.6	56.0	104
105	118.2	51.6	54.1	52.6	52.1	46.1	56.6	105
106	119.3	52.1	54.6	53.1	52.7	46.7	57.1	106
107	120.5	52.6	55.2	53.7	53.2	47.2	57.7	107
108	121.6	53.1	55.7	54.2	53.7	47.7	58.2	108
109	122.7	53.6	56.2	54.7	54.2	48.3	58.8	109
110	123.8	54.1	56.7	55.3	54.8	48.8	59.3	110
111	125.0	54.6	57.3	55.8	55.3	49.3	59.9	111
112	126.1	55.1	57.8	56.3	55.8	49.9	60.4	112
113	127.2	55.6	58.3	56.9	56.4	50.4	61.0	113
114	128.3	56.1	58.9	57.4	56.9	50.9	61.6	114
115	129.5	56.7	59.4	57.9	57.4	51.5	62.1	115
116	130.6	57.2	59.9	58.5	58.0	52.0	62.7	116
117	131.7	57.7	60.4	59.0	58.5	52.5	63.2	117
118	132.8	58.2	61.0	59.5	59.0	53.1	63.8	118
119	134.0	58.7	61.5	60.1	59.6	53.6	64.3	119
120	135.1	59.2	62.0	60.6	60.1	54.1	64.9	120
121	136.2	59.7	62.6	61.2	60.7	54.7	65.4	121
122	137.4	60.2	63.1	61.7	61.2	55.2	66.0	122
123	138.5	60.7	63.6	62.2	61.7	55.8	66.5	123
124	139.6	61.3	64.2	62.8	62.3	56.3	67.1	124
125	140.7	61.8	64.7	63.3	62.8	56.8	67.7	125
126	141.9	62.3	65.2	63.8	63.3	57.4	68.2	126
127	143.0	62.8	65.8	64.4	63.9	57.9	68.8	127
128	144.1	63.3	66.3	64.9	64.4	58.4	69.3	128
129	145.2	63.8	66.8	65.4	64.9	59.0	69.9	129
130	146.4	64.3	67.4	66.0	65.5	59.5	70.4	130
131	147.5	64.9	67.9	66.5	66.0	60.1	71.0	131
132	148.6	65.4	68.4	67.1	66.6	60.6	71.6	132
133	149.7	65.9	69.0	67.6	67.1	61.1	72.1	133
134	150.9	66.4	69.5	68.1	67.6	61.7	72.7	134
135	152.0	66.9	70.0	68.7	68.2	62.2	73.2	135
136	153.1	67.4	70.6	69.2	68.7	62.8	73.8	136
137	154.2	68.0	71.1	69.8	69.3	63.3	74.3	137
138	155.4	68.5	71.6	70.3	69.8	63.9	74.9	138
139	156.5	69.0	72.2	70.8	70.3	64.4	75.5	139
140	157.6	69.5	72.7	71.4	70.9	64.9	76.0	140
141	158.7	70.0	73.2	71.9	71.4	65.5	76.6	141
142	159.9	70.5	73.8	72.5	72.0	66.0	77.1	142
143	161.0	71.1	74.3	73.0	72.5	66.6	77.7	143
144	162.1	71.6	74.9	73.5	73.0	67.1	78.3	144
145	163.2	72.1	75.4	74.1	73.6	67.7	78.8	145
146	164.4	72.6	75.9	74.6	74.1	68.2	79.4	146
147	165.5	73.1	76.5	75.2	74.7	68.7	80.0	147
148	166.6	73.7	77.0	75.7	75.2	69.3	80.5	148
149	167.8	74.2	77.6	76.3	75.7	69.8	81.1	149
150	168.9	74.7	78.1	76.8	76.3	70.4	81.6	150
151	170.0	75.2	78.6	77.3	76.8	70.9	82.2	151
152	171.1	75.7	79.2	77.9	77.4	71.5	82.8	152
153	172.3	76.3	79.7	78.4	77.9	72.0	83.3	153
154	173.4	76.8	80.3	79.0	78.5	72.6	83.9	154
155	174.5	77.3	80.8	79.5	79.0	73.1	84.4	155
156	175.6	77.8	81.3	80.1	79.6	73.7	85.0	156
157	176.8	78.3	81.9	80.6	80.1	74.2	85.6	157
158	177.9	78.9	82.4	81.2	80.6	74.8	86.1	158
159	179.0	79.4	83.0	81.7	81.2	75.3	86.7	159
160	180.1	79.9	83.5	82.2	81.7	75.9	87.3	160
161	181.3	80.4	84.0	82.8	82.3	76.4	87.8	161
162	182.4	81.0	84.6	83.3	82.8	77.0	88.4	162
163	183.5	81.5	85.1	83.9	83.4	77.5	89.0	163
164	184.6	82.0	85.7	84.4	83.9	78.1	89.5	164

TABLE 6.—*Table for calculating dextrose, invert sugar alone, invert sugar in the presence of sucrose (0.3, 0.4, and 2.0 g of tatal sugar), and levulose*—Continued

Copper	Cuprous oxide	Dextrose	Invert sugar	Invert sugar and sucrose: 0.3 g of total sugar	Invert sugar and sucrose: 0.4 g of total sugar	Invert sugar and sucrose: 2.0 g of total sugar	Levulose	Copper
mg	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*
165	185.8	82.5	86.2	85.0	84.5	78.6	90.1	165
166	186.9	83.1	86.8	85.5	85.0	79.2	90.6	166
167	188.0	83.6	87.3	86.1	85.6	79.7	91.2	167
168	189.1	84.1	87.8	86.6	86.1	80.3	91.8	168
169	190.3	84.6	88.4	87.2	86.7	80.8	92.3	169
170	191.4	85.2	88.9	87.7	87.2	81.4	92.9	170
171	192.5	85.7	89.5	88.3	87.8	81.9	93.5	171
172	193.6	86.2	90.0	88.8	88.3	82.5	94.0	172
173	194.8	86.7	90.6	89.4	88.9	83.0	94.6	173
174	195.9	87.3	91.1	89.9	89.4	83.6	95.2	174
175	197.0	87.8	91.7	90.5	90.0	84.1	95.7	175
176	198.1	88.3	92.2	91.0	90.5	84.7	96.3	176
177	199.3	88.9	92.8	91.6	91.1	85.2	96.9	177
178	200.4	89.4	93.3	92.1	91.6	85.8	97.4	178
179	201.5	89.9	93.8	92.7	92.2	86.3	98.0	179
180	202.7	90.4	94.4	93.2	92.7	86.9	98.6	180
181	203.8	91.0	94.9	93.8	93.3	87.4	99.2	181
182	204.9	91.5	95.5	94.3	93.8	88.0	99.7	182
183	206.0	92.0	96.0	94.9	94.4	88.6	100.3	183
184	207.2	92.6	96.6	95.4	94.9	89.1	100.9	184
185	208.3	93.1	97.1	96.0	95.5	89.7	101.4	185
186	209.4	93.6	97.7	96.5	96.0	90.2	102.0	186
187	210.5	94.2	98.2	97.1	96.6	90.8	102.6	187
188	211.7	94.7	98.8	97.6	97.1	91.3	103.1	188
189	212.8	95.2	99.3	98.2	97.7	91.9	103.7	189
190	213.9	95.7	99.9	98.7	98.2	92.4	104.3	190
191	215.0	96.3	100.4	99.3	98.8	93.0	104.8	191
192	216.2	96.8	101.0	99.9	99.4	93.6	105.4	192
193	217.3	97.3	101.5	100.4	99.9	94.1	106.0	193
194	218.4	97.9	102.1	101.0	100.5	94.7	106.6	194
195	219.5	98.4	102.6	101.5	101.0	95.2	107.1	195
196	220.7	98.9	103.2	102.1	101.6	95.8	107.7	196
197	221.8	99.5	103.7	102.6	102.1	96.4	108.3	197
198	222.9	100.0	104.3	103.2	102.7	96.9	108.8	198
199	224.0	100.5	104.8	103.7	103.2	97.5	109.4	199
200	225.2	101.1	105.4	104.3	103.8	98.0	110.0	200
201	226.3	101.6	106.0	104.9	104.4	98.6	110.6	201
202	227.4	102.2	106.5	105.4	104.9	99.2	111.1	202
203	228.5	102.7	107.1	106.0	105.5	99.7	111.7	203
204	229.7	103.2	107.6	106.5	106.0	100.3	112.3	204
205	230.8	103.8	108.2	107.1	106.6	100.9	112.9	205
206	231.9	104.3	108.7	107.6	107.2	101.4	113.4	206
207	233.1	104.8	109.3	108.2	107.7	102.0	114.0	207
208	234.2	105.4	109.8	108.8	108.3	102.5	114.6	208
209	235.3	105.9	110.4	109.3	108.8	103.1	115.2	209
210	236.4	106.5	110.9	109.9	109.4	103.7	115.7	210
211	237.6	107.0	111.5	110.4	110.0	104.2	116.3	211
212	238.7	107.5	112.1	111.0	110.5	104.8	116.9	212
213	239.8	108.1	112.6	111.6	111.1	105.4	117.5	213
214	240.9	108.6	113.2	112.1	111.6	105.9	118.0	214
215	242.1	109.2	113.7	112.7	112.2	106.5	118.6	215
216	243.1	109.7	114.3	113.2	112.8	107.1	119.2	216
217	244.3	110.2	114.9	113.8	113.3	107.6	119.8	217
218	245.4	110.8	115.4	114.4	113.9	108.2	120.3	218
219	246.6	111.3	116.0	114.9	114.4	108.8	120.9	219
220	247.7	111.9	116.5	115.5	115.0	109.3	121.5	220
221	248.8	112.4	117.1	116.1	115.6	109.9	122.1	221
222	249.9	112.9	117.6	116.6	116.1	110.5	122.6	222
223	251.1	113.5	118.2	117.2	116.7	111.0	123.2	223
224	252.2	114.0	118.8	117.7	117.3	111.6	123.8	224
225	253.3	114.6	119.3	118.3	117.8	112.2	124.4	225
226	254.4	115.1	119.9	118.9	118.4	112.7	125.0	226
227	255.6	115.7	120.4	119.4	119.0	113.3	125.5	227
228	256.7	116.2	121.0	120.0	119.5	113.9	126.1	228
229	257.8	116.7	121.6	120.6	120.1	114.4	126.7	229

TABLE 6.—*Table for calculating dextrose, invert sugar alone, invert sugar in the presence of sucrose (0.3, 0.4, and 2.0 g of total sugar), and levulose*—Continued

Copper	Cuprous oxide	Dextrose	Invert sugar	Invert sugar and sucrose			Levulose	Copper
				0.3 g of total sugar	0.4 g of total sugar	2.0 g of total sugar		
mg	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*
230	258.9	117.3	122.1	121.1	120.7	115.0	127.3	230
231	260.1	117.8	122.7	121.7	121.2	115.6	127.9	231
232	261.2	118.4	123.3	122.3	121.8	116.2	128.4	232
233	262.3	118.9	123.8	122.8	122.4	116.7	129.0	233
234	263.4	119.5	124.4	123.4	122.9	117.3	129.6	234
235	264.6	120.0	124.9	124.0	123.5	117.9	130.2	235
236	265.7	120.6	125.5	124.5	124.1	118.4	130.8	236
237	266.8	121.1	126.1	125.1	124.6	119.0	131.3	237
238	268.0	121.7	126.6	125.7	125.2	119.6	131.9	238
239	269.1	122.2	127.2	126.2	125.8	120.2	132.5	239
240	270.2	122.7	127.8	126.8	126.3	120.7	133.1	240
241	271.3	123.3	128.3	127.4	126.9	121.3	133.7	241
242	272.5	123.8	128.9	127.9	127.5	121.9	134.2	242
243	273.6	124.4	129.5	128.5	128.0	122.5	134.8	243
244	274.7	124.9	130.0	129.1	128.6	123.0	135.4	244
245	275.8	125.5	130.6	129.6	129.2	123.6	136.0	245
246	277.0	126.0	131.2	130.2	129.8	124.2	136.6	246
247	278.1	126.6	131.7	130.8	130.3	124.8	137.2	247
248	279.2	127.1	132.3	131.3	130.9	125.3	137.7	248
249	280.3	127.7	132.9	131.9	131.5	125.9	138.3	249
250	281.5	128.2	133.4	132.5	132.0	126.5	138.9	250
251	282.6	128.8	134.0	133.1	132.6	127.1	139.5	251
252	283.7	129.3	134.6	133.6	133.2	127.6	140.1	252
253	284.8	129.9	135.1	134.2	133.8	128.2	140.7	253
254	286.0	130.4	135.7	134.8	134.3	128.8	141.3	254
255	287.1	131.0	136.3	135.3	134.9	129.4	141.8	255
256	288.2	131.6	136.8	135.9	135.5	130.0	142.4	256
257	289.3	132.1	137.4	136.5	136.0	130.5	143.0	257
258	290.5	132.7	138.0	137.1	136.6	131.1	143.6	258
259	291.6	133.2	138.6	137.6	137.2	131.7	144.2	259
260	292.7	133.8	139.1	138.2	137.8	132.3	144.8	260
261	293.8	134.3	139.7	138.8	138.3	132.9	145.4	261
262	295.0	134.9	140.3	139.4	138.9	133.4	145.9	262
263	296.1	135.4	140.8	139.9	139.5	134.0	146.5	263
264	297.2	136.0	141.4	140.5	140.1	134.6	147.1	264
265	298.3	136.5	142.0	141.1	140.7	135.2	147.7	265
266	299.5	137.1	142.6	141.7	141.2	135.8	148.3	266
267	300.6	137.7	143.1	142.2	141.8	136.3	148.9	267
268	301.7	138.2	143.7	142.8	142.4	136.9	149.5	268
269	302.9	138.8	144.3	143.4	143.0	137.5	150.1	269
270	304.0	139.3	144.8	144.0	143.5	138.1	150.6	270
271	305.1	139.9	145.4	144.5	144.1	138.7	151.2	271
272	306.2	140.4	146.0	145.1	144.7	139.3	151.8	272
273	307.4	141.0	146.6	145.7	145.3	139.8	152.4	273
274	308.5	141.6	147.1	146.3	145.9	140.4	153.0	274
275	309.6	142.1	147.7	146.8	146.4	141.0	153.6	275
276	310.7	142.7	148.3	147.4	147.0	141.6	154.2	276
277	311.9	143.2	148.9	148.0	147.6	142.2	154.8	277
278	313.0	143.8	149.4	148.6	148.2	142.8	155.4	278
279	314.1	144.4	150.0	149.2	148.8	143.4	156.0	279
280	315.2	144.9	150.6	149.7	149.3	143.9	156.5	280
281	316.4	145.5	151.2	150.3	149.9	144.5	157.1	281
282	317.5	146.0	151.8	150.9	150.5	145.1	157.7	282
283	318.6	146.6	152.3	151.5	151.1	145.7	158.3	283
284	319.7	147.2	152.9	152.1	151.7	146.3	158.9	284
285	320.9	147.7	153.5	152.6	152.2	146.9	159.5	285
286	322.0	148.3	154.1	153.2	152.8	147.5	160.1	286
287	323.1	148.8	154.6	153.8	153.4	148.1	160.7	287
288	324.2	149.4	155.2	154.4	154.0	148.6	161.3	288
289	325.4	150.0	155.8	155.0	154.6	149.2	161.9	289
290	326.5	150.5	156.4	155.5	155.2	149.8	162.5	290
291	327.6	151.1	157.0	156.1	155.7	150.4	163.1	291
292	328.7	151.7	157.5	156.7	156.3	151.0	163.7	292
293	329.9	152.2	158.1	157.3	156.9	151.6	164.3	293
294	331.0	152.8	158.7	157.9	157.5	152.2	164.9	294

TABLE 6.—*Table for calculating dextrose, invert sugar alone, invert sugar in the presence of sucrose (0.3, 0.4, and 2.0 g of total sugar), and levulose*—Continued

Copper	Cuprous oxide	Dextrose	Invert sugar	Invert sugar and sucrose			Levulose	Copper
				0.3 g of total sugar	0.4 g of total sugar	2.0 g of total sugar		
mg	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*
295	332.1	153.4	159.3	158.5	158.1	152.8	165.4	295
296	333.3	153.9	159.9	159.0	158.7	153.4	166.0	296
297	334.4	154.5	160.5	159.6	159.3	154.0	166.6	297
298	335.5	155.1	161.0	160.2	159.9	154.6	167.2	298
299	336.6	155.6	161.6	160.8	160.4	155.2	167.8	299
300	337.8	156.2	162.2	161.4	161.0	155.7	168.4	300
301	338.9	156.8	162.8	162.0	161.6	156.3	169.0	301
302	340.0	157.3	163.4	162.5	162.2	156.9	169.6	302
303	341.1	157.9	164.0	163.1	162.8	157.5	170.2	303
304	342.3	158.5	164.5	163.7	163.4	158.1	170.8	304
305	343.4	159.0	165.1	164.3	164.0	158.7	171.4	305
306	344.5	159.6	165.7	164.9	164.6	159.3	172.0	306
307	345.6	160.2	166.3	165.5	165.1	159.9	172.6	307
308	346.8	160.7	166.9	166.1	165.7	160.5	173.2	308
309	347.9	161.3	167.5	166.7	166.3	161.1	173.8	309
310	349.0	161.9	168.0	167.2	166.9	161.7	174.4	310
311	350.1	162.5	168.6	167.8	167.5	162.3	175.0	311
312	351.3	163.0	169.2	168.4	168.1	162.9	175.6	312
313	352.4	163.6	169.8	169.0	168.7	163.5	176.2	313
314	353.5	164.2	170.4	169.6	169.3	164.1	176.8	314
315	354.6	164.7	171.0	170.2	169.9	164.7	177.4	315
316	355.8	165.3	171.6	170.8	170.5	165.3	178.0	316
317	356.9	165.9	172.2	171.4	171.1	165.9	178.6	317
318	358.0	166.5	172.8	172.0	171.7	166.5	179.2	318
319	359.1	167.0	173.3	172.6	172.2	167.1	179.8	319
320	360.3	167.6	173.9	173.1	172.8	167.7	180.4	320
321	361.4	168.2	174.5	173.7	173.4	168.3	181.0	321
322	362.5	168.8	175.1	174.3	174.0	168.9	181.6	322
323	363.6	169.3	175.7	174.9	174.6	169.5	182.2	323
324	364.8	169.9	176.3	175.5	175.2	170.1	182.8	324
325	365.9	170.5	176.9	176.1	175.8	170.7	183.4	325
326	367.0	171.1	177.5	176.7	176.4	171.3	184.0	326
327	368.2	171.6	178.1	177.3	177.0	171.9	184.6	327
328	369.3	172.2	178.7	177.9	177.6	172.5	185.2	328
329	370.4	172.8	179.2	178.5	178.2	173.1	185.8	329
330	371.5	173.4	179.8	179.1	178.8	173.7	186.4	330
331	372.7	173.9	180.4	179.7	179.4	174.3	187.0	331
332	373.8	174.5	181.0	180.3	180.0	174.9	187.6	332
333	374.9	175.1	181.6	180.9	180.6	175.5	188.2	333
334	376.0	175.7	182.2	181.5	181.2	176.1	188.8	334
335	377.2	176.3	182.8	182.1	181.8	176.7	189.4	335
336	378.3	176.8	183.4	182.6	182.4	177.3	190.1	336
337	379.4	177.4	184.0	183.2	183.0	178.0	190.7	337
338	380.5	178.0	184.6	183.8	183.6	178.6	191.3	338
339	381.7	178.6	185.2	184.4	184.2	179.2	191.9	339
340	382.8	179.2	185.8	185.0	184.8	179.8	192.5	340
341	383.9	179.7	186.4	185.6	185.4	180.4	193.1	341
342	385.0	180.3	187.0	186.2	186.0	181.0	193.7	342
343	386.2	180.9	187.6	186.8	186.6	181.6	194.3	343
344	387.3	181.5	188.2	187.4	187.2	182.2	194.9	344
345	388.4	182.1	188.8	188.0	187.8	182.8	195.5	345
346	389.5	182.7	189.4	188.6	188.4	183.4	196.1	346
347	390.7	183.2	190.0	189.2	189.0	184.0	196.7	347
348	391.8	183.8	190.6	189.8	189.6	184.6	197.3	348
349	392.9	184.4	191.2	190.4	190.2	185.3	197.9	349
350	394.0	185.0	191.8	191.0	190.8	185.9	198.5	350
351	395.2	185.6	192.4	191.6	191.4	186.5	199.2	351
352	396.3	186.2	193.0	192.2	192.0	187.1	199.8	352
353	397.4	186.8	193.6	192.8	192.6	187.7	200.4	353
354	398.5	187.3	194.2	193.4	193.2	188.3	201.0	354
355	399.7	187.9	194.8	194.0	193.8	188.9	201.6	355
356	400.8	188.5	195.4	194.6	194.4	189.5	202.2	356
357	401.9	189.1	196.0	195.2	195.0	190.2	202.8	357
358	403.1	189.7	196.6	195.8	195.7	190.8	203.4	358
359	404.2	190.3	197.2	196.4	196.3	191.4	204.0	359

TABLE 6.—*Table for calculating dextrose, invert sugar alone, invert sugar in the presence of sucrose (0.3, 0.4, and 2.0 g of total sugar), and levulose*—Continued

Copper	Cuprous oxide	Dextrose	Invert sugar	Invert sugar and sucrose			Levulose	Copper
				0.3 g of total sugar	0.4 g of total sugar	2.0 g of total sugar		
mg	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*
360	405.3	190.9	197.8	197.1	196.9	192.0	204.7	360
361	406.4	191.5	198.4	197.7	197.5	192.6	205.3	361
362	407.6	192.0	199.0	198.3	198.1	193.2	205.9	362
363	408.7	192.6	199.6	198.9	198.7	193.9	206.5	363
364	409.8	193.2	200.2	199.5	199.3	194.5	207.1	364
365	410.9	193.8	200.8	200.1	199.9	195.1	207.7	365
366	412.1	194.4	201.4	200.7	200.5	195.7	208.3	366
367	413.2	195.0	202.0	201.3	201.1	196.3	209.0	367
368	414.3	195.6	202.6	201.9	201.7	196.9	209.6	368
369	415.4	196.2	203.2	202.5	202.4	197.6	210.2	369
370	416.6	196.8	203.8	203.1	203.0	198.2	210.8	370
371	417.7	197.4	204.4	203.7	203.6	198.8	211.4	371
372	418.8	198.0	205.0	204.3	204.2	199.4	212.0	372
373	419.9	198.5	205.7	204.9	204.8	200.0	212.6	373
374	421.1	199.1	206.3	205.6	205.4	200.7	213.3	374
375	422.2	199.7	206.9	206.2	206.0	201.3	213.9	375
376	423.3	200.3	207.5	206.8	206.6	201.9	214.5	376
377	424.4	200.9	208.1	207.4	207.3	202.5	215.1	377
378	425.6	201.5	208.7	208.0	207.9	203.1	215.7	378
379	426.7	202.1	209.3	208.6	208.5	203.8	216.3	379
380	427.8	202.7	209.9	209.2	209.1	204.4	217.0	380
381	428.9	203.3	210.5	209.8	209.7	205.0	217.6	381
382	430.1	203.9	211.1	210.4	210.3	205.6	218.2	382
383	431.2	204.5	211.8	211.1	211.0	206.3	218.8	383
384	432.3	205.1	212.4	211.7	211.6	206.9	219.5	384
385	433.5	205.7	213.0	212.3	212.2	207.5	220.1	385
386	434.6	206.3	213.6	212.9	212.8	208.1	220.7	386
387	435.7	206.9	214.2	213.5	213.4	208.8	221.3	387
388	436.8	207.5	214.8	214.1	214.0	209.4	221.9	388
389	438.0	208.1	215.4	214.7	214.7	210.0	222.6	389
390	439.1	208.7	216.0	215.4	215.3	210.6	223.2	390
391	440.2	209.3	216.7	216.0	215.9	211.3	223.8	391
392	441.3	209.9	217.3	216.6	216.5	211.9	224.4	392
393	442.5	210.5	217.9	217.2	217.1	212.5	225.1	393
394	443.6	211.1	218.5	217.8	217.8	213.2	225.7	394
395	444.7	211.7	219.1	218.5	218.4	213.8	226.3	395
396	445.8	212.3	219.8	219.1	219.0	214.4	226.9	396
397	447.0	212.9	220.4	219.7	219.6	215.1	227.6	397
398	448.1	213.5	221.0	220.3	220.3	215.7	228.2	398
399	449.2	214.1	221.6	220.9	220.9	216.3	228.8	399
400	450.3	214.7	222.2	221.5	221.5	217.0	229.4	400
401	451.5	215.3	222.9	222.2	222.1	217.6	230.1	401
402	452.6	215.9	223.5	222.8	222.8	218.2	230.7	402
403	453.7	216.5	224.1	223.4	223.4	218.9	231.3	403
404	454.8	217.1	224.7	224.0	224.0	219.5	232.0	404
405	456.0	217.8	225.4	224.7	224.7	220.1	232.6	405
406	457.1	218.4	226.0	225.3	225.3	220.8	233.2	406
407	458.2	219.0	226.6	225.9	225.9	221.4	233.9	407
408	459.3	219.6	227.2	226.6	226.5	222.0	234.5	408
409	460.5	220.2	227.9	227.2	227.2	222.7	235.1	409
410	461.6	220.8	228.5	227.8	227.8	223.3	235.8	410
411	462.7	221.4	229.1	228.4	228.4	224.0	236.4	411
412	463.8	222.0	229.7	229.1	229.1	224.6	237.1	412
413	465.0	222.6	230.4	229.7	229.7	225.3	237.7	413
414	466.1	223.3	231.0	230.4	230.4	225.9	238.4	414
415	467.2	223.9	231.7	231.0	231.0	226.6	239.0	415
416	468.4	224.5	232.3	231.6	231.7	227.2	239.7	416
417	469.5	225.1	232.9	232.3	232.3	227.8	240.3	417
418	470.6	225.7	233.6	232.9	232.9	228.5	241.0	418
419	471.7	226.3	234.2	233.5	233.6	229.1	241.6	419

TABLE 6.—*Table for calculating dextrose, invert sugar alone, invert sugar in the presence of sucrose (0.3, 0.4, and 2.0 g of total sugar), and levulose*—Continued

Copper	Cuprous oxide	Dextrose	Invert sugar	Invert sugar and sucrose			Levulose	Copper
				0.3 g of total sugar	0.4 g of total sugar	2.0 g of total sugar		
mg	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*
420	472.9	227.0	234.8	234.2	234.2	229.8	242.2	420
421	474.0	227.6	235.5	234.8	234.9	230.4	242.9	421
422	475.1	228.2	236.1	235.5	235.5	231.1	243.6	422
423	476.2	228.8	236.8	236.2	236.2	231.8	244.3	423
424	477.4	229.5	237.5	236.8	236.9	232.4	244.9	424
425	478.5	230.1	238.1	237.5	237.5	233.1	245.6	425
426	479.6	230.7	238.8	238.2	238.2	233.8	246.3	426
427	480.7	231.4	239.5	238.8	238.9	234.5	247.0	427
428	481.9	232.0	240.2	239.5	239.6	235.1	247.8	428
429	483.0	232.7	240.8	240.2	240.3	235.8	248.5	429
430	484.1	233.3	241.5	240.9	241.0	236.5	249.2	430
431	485.2	234.0	242.3	241.7	241.7	237.2	250.0	431
432	486.4	234.7	243.0	242.4	242.5	238.0	250.8	432
433	487.5	235.3	243.8	243.2	243.3	238.7	251.6	433
434	488.6	236.1	244.7	244.1	244.2	239.6	252.7	434
435	489.7	236.9	245.6	245.1	245.1	240.4	253.7	435

WASHINGTON, March 20, 1940.

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