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THE DETERMINATION OF REDUCING SUGARS IN TERMS OF CUPRIC OXIDE.

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IT is now approximately fifty years since alkaline metallic solutions were first used in determining quantitatively the various reducing sugars. During this period of time many investigators have worked on the subject, and much has been done towards perfecting the method of analysis, so that to-day there are several admirable processes in use for the exact estimation of these carbohydrates.

The quantitative methods of determining reducing sugars may be divided into two main classes: those based upon the volumetric plan, and those which depend on a gravimetric estimation of the precipitated cuprous oxide.

Of the first class many processes have been suggested which have met with more or less success. The volumetric methods are mainly used for factory control work, where the progress of some processes require a rapid and fairly accurate idea of the stage of manufacture. In expert hands the volumetric methods are capable of giving excellent and concordant results, and are, therefore, used in the laboratories of many consulting chemists, and even in scientific institutions.

The main objections to the use of the volumetric methods are that each freshly prepared quantity of Fehling solution requires accurate standardization against the same kind of pure sugar as that which is undergoing analysis. Different dilutions and the time of boiling affect the results materially. The exact determination of the "end point" also requires considerable practice and skill.

On the other hand, the Fehling liquor used in the gravimetric processes need not be made up as accurately as is required for volumetric work. The gravimetric methods, however, ordinarily require more time. A possible loss of cuprous oxide by filtration, and an incomplete oxidation to the higher oxide are also potent factors, though where the requisite degree of care is exercised these need not cause anxiety. The same statement regarding dilution and time of boiling holds true with as much force in gravimetric as in volumetric work.

The gravimetric methods are generally employed for scientific and accurate analytical work. Here the processes are comparatively few, all depending upon the oxidation of the total sugar present in an excess of the alkaline copper solution.

The tables in use for the determination of reducing sugars are mainly constructed in terms of metallic copper. As the amount of metal precipitated per gram of carbohydrate is not a constant for all dilutions of any sugar, specially constructed tables are generally employed. Several such tables have been prepared, as for instance Allihn's table of reduced copper for dextrose, Wein's table for maltose, and Soxhlet's table for lactose, etc.

Various modifications of the alkaline copper solutions are used for the determination of the different sugars, each requiring special treatment. Therefore a chemist in determining the amount of malt sugar in, say beer, must, if he uses Wein's table for maltose, follow exactly Wein's method for the estimation of that sugar.

Where a variety of work is carried on in a laboratory, it is therefore necessary to have several different Fehling solutions on hand for each special kind of determination. If all the tables for the estimation of the different carbohydrates could have been prepared for use under uniform conditions, the existing state of affairs would be much simplified.

In order to supply this need, I have constructed such tables, using a method which I have employed for some time, in determining reducing sugars. This method, proposed by O'Sullivan[1] in 1876, is used to some extent in England, but as it seems to be not generally known, I here give the procedure in detail :

To fifteen cc. of the copper sulphate solution, prepared as given below, are added fifteen cc. of the alkaline tartrate solution, in an Erlenmeyer flask having a capacity of from 250–300 cc. The mixture is diluted with fifty cc. of freshly boiled distilled water and placed in a boiling water bath for five minutes. Twenty to twenty-five cc. accurately measured from a calibrated burette of an approximately one-half per cent. solution of the sugar to be analyzed, are then run into the hot Fehling liquor and the whole kept in the boiling water bath for from twelve to fifteen minutes. The flask is then removed from the bath and the precipitated cuprous oxide is filtered as rapidly as possible, either through filter paper or asbestos in a Soxhlet's tube or porcelain Gooch crucible, and washed with boiling distilled water until the wash water no longer reacts alkaline. It is ignited and weighed as cupric oxide as described below. The corresponding amounts of dextrose, maltose or lactose are ascertained by reference to the tables at the end of this article. It should be noted that the above directions must be closely followed. The volume of the Fehling liquor and the added sugar solution should be from 100–105 cc.

The Fehling solution used is made up according to Soxhlet's formula, with a very slight modification. 69.278 grams of pure crystallized copper sulphate, pulverized and dried between filter paper, are dissolved in distilled water. It is advantageous to add one cc. of strong sulphuric acid to this, as recommended by Sutton.[2] The whole is then made up to one liter with distilled water and kept in a separate bottle. The alkaline tartrate solution is made by dissolving 356 grams of crystalline Rochelle salt and 100 grams of sodium hydroxide in distilled water and making up to one liter. This is also kept in a separate bottle.

Two methods of filtration of the precipitated cuprous oxide and further treatment are generally adopted. In the first double "washed" filter paper is used; in the other the precipitate is

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[1] *J. Chem. Soc.*, 2, 130, *1876*.

[2] Sutton : Fourth edition, (1882), 256.

retained by a layer of asbestos. After washing the precipitate on the filter paper as above described, it is dried in the usual manner and ignited in a previously weighed porcelain crucible, taking care to burn the filter paper cautiously, heating for fifteen minutes to a red heat, cooling the crucible over sulphuric acid in a desiccator and weighing as cupric oxide. Additional treatment with nitric acid has been found of no practical advantage, the results by direct ignition being very exact, providing the filter paper is slowly burned. The chief objection to the employment of filter paper to retain the precipitated cuprous oxide, is that some of the finely divided particles are liable to go through, thus causing low results.

As a substitute for paper carefully selected asbestos is often used for filtering purposes. To insure a layer of asbestos which shall be kept at constant weight under the action of hot Fehling liquor, it is advantageous to boil the mineral with nitric acid (1.05–1.10 sp. gr.) for a short time, washing the acid out with hot water, and then boiling with a twenty-five per cent. solution of sodium hydroxide. This is also washed out with hot water. Reboiling with the above reagents as before diminishes the liability of leaving any soluble portions. As thus prepared the filtering material may be kept indefinitely under water in a wide-mouthed bottle ready for use.

The objections of some chemists[1] to the employment of asbestos on the ground that it loses weight on using, does not seem to hold, when it is prepared as above. A sample boiled as stated with acid and alkali three times, lost only two-tenths milligram when two "blanks" of hot dilute Fehling solution, as used in the process above described, were passed through the mineral in a porcelain Gooch crucible.

For use, a layer of asbestos, about one centimeter in thickness, is placed in a porcelain Gooch crucible, to retain the finely divided precipitate, which is filtered by means of suction, in the usual manner. The crucible containing the cuprous oxide is then dropped into a triangular frame, made of platinum wire, suspended within an iron radiator, or shell, heated to redness. This quickly and thoroughly dries the asbestos without cracking

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[1] Killing: *Ztschr. angew. Chem.*, 431, *1894*; Praeger: *Ztschr. angew. Chem.*, 520, *1894*.

the crucible. After about five minutes the crucible is transferred by means of a pair of nippers to a red hot platinum crucible and heated for about fifteen minutes. It is then quickly transferred to a desiccator near at hand to prevent cracking, allowed to cool and weighed. As cupric oxide is somewhat hygroscopic, it is advantageous to weigh quickly and to keep the balance case as dry as possible. Prolonged heating in the iron radiator would have changed the cuprous oxide to the cupric state. The advantage of transferring the porcelain crucible to a red-hot platinum crucible, is that the oxidation is quickly completed, as a much higher temperature is available.

If pressed for time, another determination can be made in the same crucible without cleaning it. As a rule, it is, however, advisable to wash out the cupric oxide by means of hot nitric acid (1.05–1.10 sp. gr.) and then with hot water. The crucible is then heated, cooled and weighed as before. It must necessarily be weighed, because this treatment with hot nitric acid dissolves some of the asbestos.

If preferred, a Soxhlet's tube may be used to retain the precipitated cuprous oxide. As a porcelain Gooch crucible possessed obvious advantages over this apparatus, I have used it in all my determinations with success.

The cupric reducing powers of dextrose, maltose aud lactose were determined by the method given above. A table for invert sugar was not constructed because most invert sugar determinations are made by double polarization in a saccharimeter.

DEXTROSE.

The "cupric reducing power" of dextrose was first determined. This is defined as "the amount of cupric oxide which 100 parts reduce."[1] This may be represented by $\frac{100\ W}{D}$, in which W is the weight of cupric oxide obtained by the given weight of any sugar, and D the weight of cupric oxide formed by an equal weight of dextrose.[2] Hence, if the amount of cupric oxide formed by one gram of dextrose be known, the amount of cupric oxide reduced by one gram of any other substance, calculated

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[1] *J. Chem. Soc.*, **2**, 130, *1876*.

[2] *J. Chem. Soc.*, *Trans.*, 606, *1879*.

upon this number as a percentage, will represent the cupric oxide reducing power of the substance, which we denote by the symbol *K*.

The amount of cupric oxide has been determined by O'Sullivan[1] to be 2.205 grams per gram dextrose. The factor for dextrose in terms of cupric oxide is, therefore, the reciprocal of 2.205 or 0.4535. This value, 0.4535, was assumed to be a constant for all amounts of dextrose when used with Fehling's solution in the manner indicated. As such it was a very convenient quantity, it being only necessary to obtain the weight of cupric oxide formed by the action of a dextrose solution, multiply this by 0.4535, and the amount of dextrose corresponding was obtained. No tables are needed if this assumption be true. Consequently the determination of dextrose was indeed a very simple one.

On an extended investigation of this subject, using various amounts of dextrose on the same volume of Fehling liquor in each determination, I find that the value 2.205, above given as representing the quantity of cupric oxide obtained by the action of one gram of dextrose, is not as was heretofore assumed, a constant for all weights of dextrose taken, the amount varying from 2.27 grams cupric oxide per gram dextrose for small quantities of sugar, to 2.22 grams cupric oxide for the largest amount of dextrose permissible. Allihn,[2] boiling his sugar solutions with the Fehling liquor and reducing the cuprous oxide to copper, obtained analogous varying results.

The purity of the dextrose used was first determined, dextrose anhydride being employed. 10.008 grams of anhydrous dextrose were disssolved in distilled water and the solution boiled to prevent birotation. It was then transferred to a flask, the capacity of which at 15.5° C. was 100.08 cc., thus giving a solution which contained 0.100 gram dextrose anhydride per cc.

The specific gravity of the above solution at 15.5° was determined in the usual manner by means of a picnometer with thermometer attached.

Capacity picnometer (at 15.5°) = 55.2055 cc.
Dextrose solution (at 15.5°) = 57.3083 grams.

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[1] *Loc. cit.*

[2] *J. prakt. Chem.*, (2), 22, 63.

On calculating from these values we find the specific gravity of a dextrose solution containing ten grams dextrose in 100 cc. to be 1.03809 at 15.5°.

The specific rotatory power was determined by the usual method, a Schmidt and Haensch saccharimeter being used in polarizing the dextrose solution. The polarizations were carried out in a 200 millimeter tube at 20°. To change from the readings of a saccharimeter to the rotary degrees, it is necessary to multiply the reading observed by 0.344, as shown by Reinbach.[1] I have verified this value with concordant results, a Laurent polariscope being used for comparison. The rotation of the above solution was 30.7 divisions. This gives by means of the usual formula — $[\alpha]_D^{20} = \frac{\alpha v}{lw}$ — a specific rotatory power of 52.8°, which is in accordance with that obtained by other observers.[2] The dextrose used was consequently pure.

For the determination with Fehling liquor, twenty-five cc. of the dextrose solution at 15.5° were accurately measured from a calibrated burette and made up to 500 cc. with distilled water at the same temperature. This consequently gave a solution, each cubic centimeter of which contained five milligrams dextrose. Various quantities of this were then taken to ascertain the cupric reducing power of dextrose. The results in detail are given below. In each case the combined volumes of the Fehling liquor and the sugar solution were made up to 105 cc. as described above.

Milligrams dextrose.	Cupric oxide obtained.	Cupric oxide per gram dextrose.	Dextrose equivalent.	Mean dextrose equivalent.
12½	0.0283	2.264	0.4416	0.4401
12½	0.0285	2.280	0.4386	
25	0.0569	2.276	0.4393	0.4419
25	0.0565	2.260	0.4425	
50	0.1129	2.258	0.4429	0.4440
50	0.1123	2.246	0.4452	
62½	0.1407	2.251	0.4443	0.4449
62½	0.1403	2.245	0.4454	
75	0.1683	2.244	0.4457	0.4462
75	0.1679	2.239	0.4467	

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[1] *Ber. d. chem. Ges.*, **27**, 2282.

[2] Pribram: *Monat. f. Chem.*, **9**, 399; Landolt: *Ber. d. chem. Ges.*, **21**, 191.

Milligrams dextrose.	Cupric oxide obtained.	Cupric oxide per gram dextrose.	Dextrose equivalent.	Mean dextrose equivalent.
100	0.2233	2.233	0.4478	0.4483
100	0.2227	2.227	0.4489	
125	0.2776	2.221	0.4503	0.4503
125	0.2782	2.225	0.4493	
125	0.2770	2.216	0.4512	
125	0.2774	2.219	0.4506	
125	0.2777	2.222	0.4500	
140	0.3105	2.218	0.4508	0.4511
140	0.3100	2.215	0.4515	

The foregoing values of the amounts of cupric oxide per gram dextrose are given graphically in curve *A*, Plot I, and the dextrose equivalents of this in *A*, Plot II.

From this we get the amount of dextrose corresponding to a given weight of copper oxide by means of the formula:

$$D = (0.4400 + 0.000037\ W)\ W,$$

in which D is the amount of dextrose, and W the weight of cupric oxide.

The dextrose table given in this article is based on this formula, the values of W varying from 30 to 320.

MALTOSE.

The cupric reducing power of dextrose is given as 100. Using this as a basis, the reducing force of maltose, as given by O'Sullivan,[1] is 65. Brown and Heron[2] place the value somewhat lower, claiming that 61 is more exact. The results which I have obtained agree very well with this latter number.

In the case of maltose, as with dextrose, it was found that the amount of cupric oxide obtained per gram of sugar was not a constant. The cupric reducing power of various amounts of maltose was, however, found to be almost exactly a constant when referred to the cupric oxide from equal weights of dextrose. That is, calling the reducing power of dextrose 100 for different aliquot parts of that sugar, the cupric reducing power of maltose referred to this standard was always 61.

The specific gravity of maltose was determined in the usual manner. 9.7558 grams maltose anhydride were dissolved in distilled water to 100.08 cc. at 15.5°.

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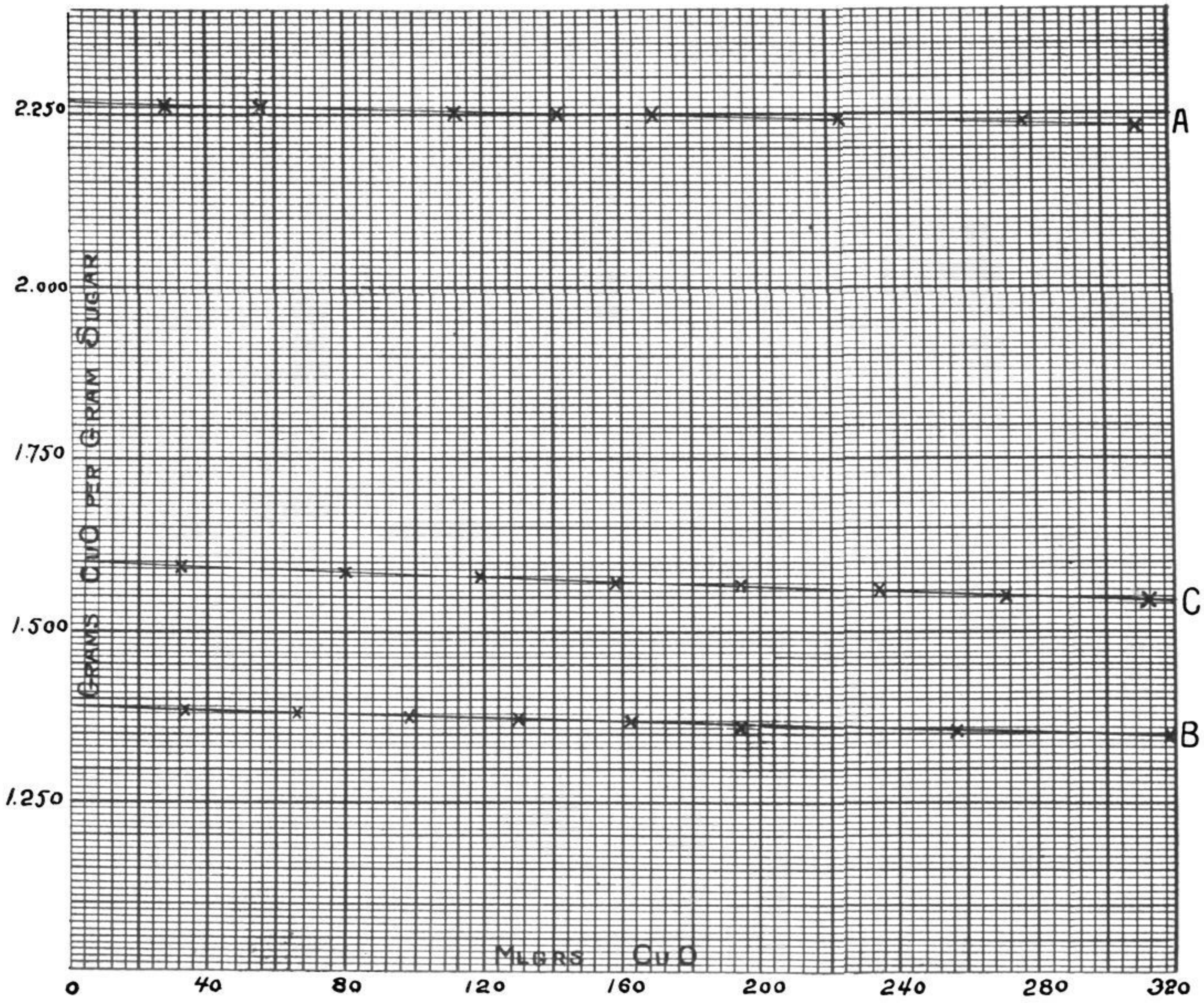
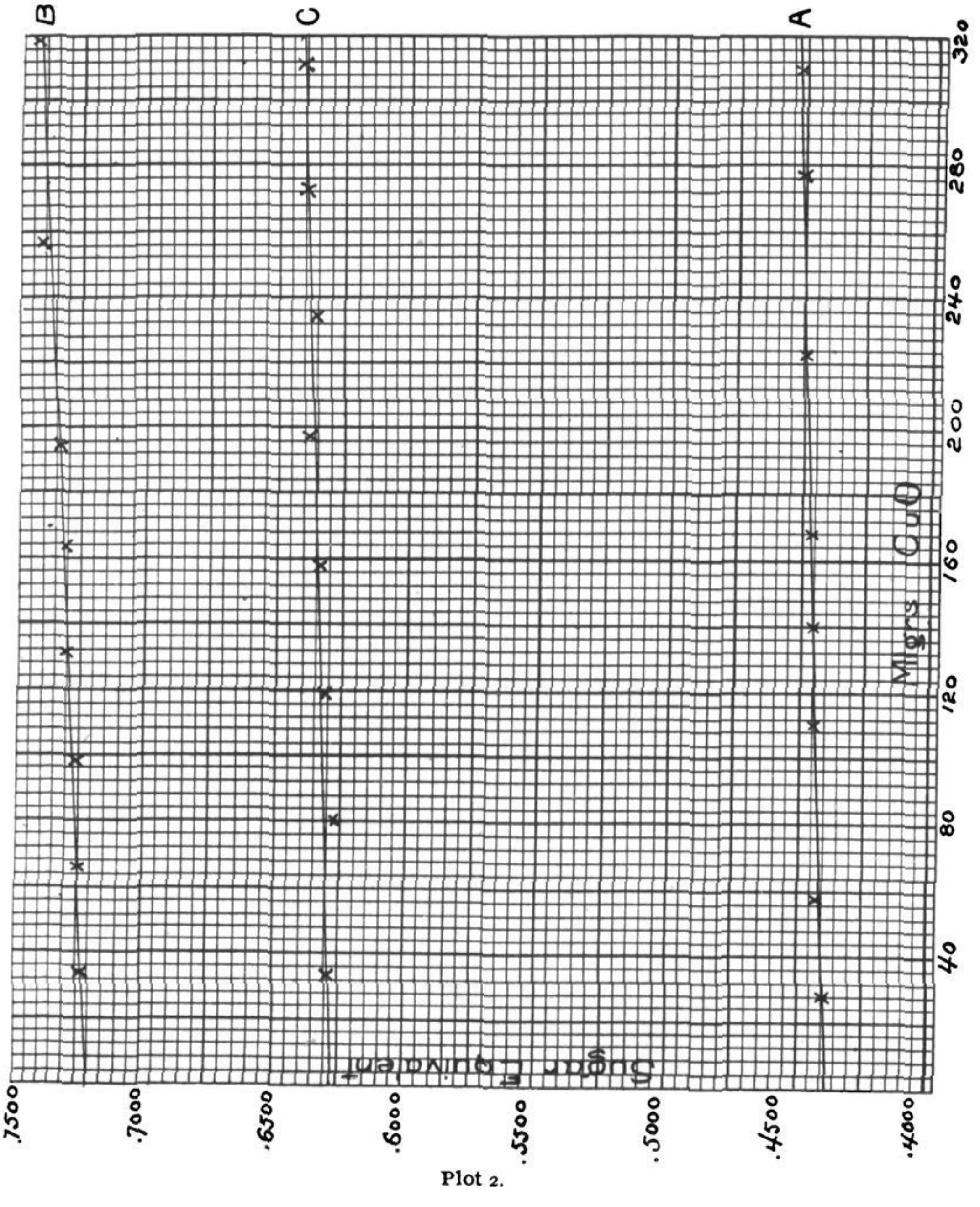
[1] *Loc. cit.*

[2] *J. Chem. Soc.*, *1879*, Trans., 619.


2.250
2.000
1.750
1.500
1.250
GRAMS CuO PER GRAM SUGAR
MLGRS CuO
0
40
80
120
160
200
240
280
320
A
C
B

Plot I.


B
C
A
320
280
240
200
160
120
80
40
Mlgrs CuO
Sugar Equivalent
.7500
.7000
.6500
.6000
.5500
.5000
.4500
.4000

Plot 2.

Maltose solution at 15.5° = 57.3049 grams.

On calculating this we find the specific gravity of the above solution to be 1.03803. For a solution containing ten grams maltose anhydride in 100 cc. it would consequently be 1.03900 at 15.5°.

The specific rotatory power was determined as usual. The rotation of the above solution at 20°, in a 200 millimeter tube, was 74.4 divisions on the saccharimeter scale. This gives $[\alpha]_D^{20} =$ 136.6°.

As maltose anhydride is somewhat difficult to prepare, the solutions used to determine the cupric reducing powers were made up to approximately ten per cent. from the maltose hydrate. The specific gravity of the solutions was then determined. Subtracting from this value 1.00000—the specific gravity of water—and dividing the remainder by 0.00390, we get the amount of maltose anhydride in 100 cc. of solution.

Maltose solution at 15.5° = 57.2511 grams,

which gives a specific gravity of 1.03754, or 9.501 grams maltose anhydride in 100 cc.

The solution for Fehling determinations was made in the same manner as the dextrose solutions above. Each cubic centimeter of the diluted maltose solution therefore contained 4.75 milligrams maltose anhydride.

Milligrams maltose.	Cupric oxide obtained.	Cupric oxide per gram maltose.	Maltose equivalent.	Mean maltose equivalent.
23.75	0.0329	1.386	0.7218	0.7240
23.75	0.0327	1.377	0.7263	
47.5	0.0656	1.381	0.7243	0.7253
47.5	0.0654	1.377	0.7263	
71.25	0.0983	1.380	0.7247	0.7263
71.25	0.0979	1.374	0.7278	
95.0	0.1304	1.373	0.7286	0.7297
95.0	0.1300	1.369	0.7308	
118.75	0.1623	1.370	0.7302	0.7319
118.75	0.1619	1.367	0.7336	
142.5	0.1940	1.361	0.7345	0.7354
142.5	0.1934	1.357	0.7369	
190.0	0.2572	1.353	0.7284	0.7395
190.0	0.2566	1.350	0.7406	
237.5	0.3198	1.347	0.7429	0.7433
237.5	0.3193	1.345	0.7437	

The maltose equivalent in terms of copper oxide is shown in *B*, Plot II. From this we get the amount of maltose corresponding to a given weight of cupric oxide by the formula :

$$M = (0.7215 + 0.000061\ W)\,W,$$

in which M is the weight of maltose, and W the amount of cupric oxide obtained. It will be seen that these values make the cupric reducing power of maltose 0.61 that of dextrose.

LACTOSE.

Lactose was investigated in the same manner as the preceding. 10.008 grams lactose anhydride were dissolved in distilled water, boiled, and made up to 100.08 cc. at 15.5°.

The above solution, polarized in a 200 millimeter tube at 20°, gave a rotation of 30.7 divisions. This gives the specific rotary power of lactose of 52.8°.

The amounts of cupric oxide found by the reduction of known weights of lactose were determined as in the previous cases with the following results :

Milligrams lactose.	Cupric oxide obtained.	Cupric oxide per gram lactose.	Lactose equivalents.	Mean lactose equivalents.
20	0.0319	1.595	0.6269	0.6289
20	0.0317	1.585	0.6308	
50	0.0798	1.596	0.6266	0.6274
50	0.0796	1.592	0.6282	
75	0.1188	1.584	0.6313	0.6323
75	0.1184	1.579	0.6334	
100	0.1577	1.577	0.6340	0.6355
100	0.1570	1.570	0.6369	
125	0.1955	1.564	0.6395	0.6379
125	0.1964	1.561	0.6363	
150	0.2345	1.563	0.6397	0.6404
150	0.2340	1.560	0.6410	
175	0.2729	1.560	0.6412	0.6418
175	0.2724	1.557	0.6424	
200	0.3112	1.556	0.6425	0.6430
200	0.3107	1.553	0.6436	

The cupric oxide values per gram lactose are presented graphically in curve *C*, Plot I, while the reciprocals of these quantities are shown in *C*, Plot II. For this latter the amount of lactose corresponding to the weight of cupric oxide obtained is determined by the following :

$$L = (0.6270 + 0.000053\, W)\, W,$$

in which L is the lactose, and W the amount of copper oxide. The acompanying table for lactose is constructed on this basis.

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It will be seen from the above results that the amount of cupric oxide produced by the action of one gram of reducing carbohydrate on Fehling liquor, in the manner described, is not a constant for all dilutions.

The cupric reducing power of maltose is 0.61 that of dextrose.

The following tables for the determination of the reducing sugars in terms of cupric oxide are based on the analytical results presented above, and can be used in the process outlined in the same manner as any other table for the same purpose:

Parts copper oxide.	Parts dextrose.	Parts maltose.	Parts lactose.	Parts copper oxide.	Parts dextrose.	Parts maltose.	Parts lactose.
30	13.2	21.7	18.8	57	25.1	41.3	35.9
31	13.7	22.4	19.5	58	25.5	42.1	36.5
32	14.1	23.1	20.1	59	26.0	42.8	37.1
33	14.6	23.9	20.7	60	26.4	43.5	37.8
34	15.0	24.6	21.4	61	26.9	44.3	38.4
35	15.4	25.3	22.0	62	27.3	45.0	39.0
36	15.9	26.1	22.6	63	27.8	45.7	39.7
37	16.3	26.8	23.3	64	28.2	46.5	40.3
38	16.8	27.5	23.9	65	28.7	47.2	40.9
39	17.2	28.3	24.5	66	29.1	47.9	41.6
40	17.6	29.0	25.2	67	29.5	48.6	42.2
41	18.1	29.7	25.8	68	30.0	49.4	42.8
42	18.5	30.5	26.4	69	30.4	50.1	43.5
43	19.0	31.2	27.1	70	30.9	50.8	44.1
44	19.4	31.9	27.7	71	31.3	51.6	44.7
45	19.9	32.7	28.3	72	31.8	52.3	45.4
46	20.3	33.4	29.0	73	32.2	53.0	46.0
47	20.7	34.1	29.6	74	32.6	53.8	46.6
48	21.2	34.8	30.2	75	33.1	54.5	47.3
49	21.6	35.5	30.8	76	33.5	55.2	47.9
50	22.1	36.2	31.5	77	34.0	56.0	48.5
51	22.5	37.0	32.1	78	34.4	56.7	49.2
52	23.0	37.7	32.7	79	34.9	57.4	49.8
53	23.4	38.4	33.3	80	35.4	58.1	50.5
54	23.8	39.2	34.0	81	35.9	58.9	51.1
55	24.2	39.9	34.6	82	36.3	59.6	51.7
56	24.7	40.5	35.2	83	36.8	60.3	52.4

Parts copper oxide.	Parts dextrose.	Parts maltose.	Parts lactose.	Parts copper oxide.	Parts dextrose.	Parts maltose.	Parts lactose.
84	37.2	61.1	53.0	127	56.5	92.5	80.4
85	37.7	61.8	53.6	128	56.9	93.3	81.1
86	38.1	62.5	54.3	129	57.3	94.0	81.7
87	38.5	63.3	54.9	130	57.8	94.8	82.4
88	39.0	64.0	55.5	131	58.2	95.5	83.0
89	39.4	64.7	56.2	132	58.7	96.2	83.6
90	39.9	65.5	56.8	133	59.1	97.0	84.2
91	40.3	66.2	57.4	134	59.6	97.7	84.9
92	40.8	66.9	58.1	135	60.0	98.4	85.5
93	41.2	67.7	58.7	136	60.5	99.2	86.1
94	41.7	68.4	59.3	137	60.9	99.9	86.8
95	42.1	69.1	60.0	138	61.3	100.7	87.4
96	42.5	69.9	60 6	139	61.8	101.4	88.1
97	43.0	70.6	61.2	140	62.2	102.1	88.7
98	43.4	71.3	61.9	141	62.7	102.8	89.3
99	43.9	72.1	62.5	142	63.1	103.5	90.0
100	44.4	72.8	63.2	143	63.6	104.3	90.6
101	44.8	73.5	63.8	144	64.0	105.0	91.3
102	45.3	74.3	64.4	145	64.5	105.8	91.9
103	45.7	75.0	65.1	146	64.9	106.5	92.6
104	46.2	75.7	65.7	147	65.4	107.2	93.2
105	46.6	76.5	66.3	148	65.8	108.0	93.9
106	47.0	77.2	67.0	149	66.3	108.7	94.5
107	47.5	77.9	67.6	150	66.8	109.5	95.2
108	48.0	78.7	68.2	151	67.3	110.2	95.8
109	48.4	79.4	68.9	152	67.7	111.0	96.5
110	48.9	80.1	69.5	153	68.3	111.7	97.1
111	49.3	80.9	70.1	154	68.7	112.4	97.8
112	49.8	81.6	70.8	155	69.2	113.2	98.4
113	50.2	82.3	71.4	156	69.6	113.9	99.1
114	50.7	83.1	72.0	157	70.0	114.7	99.7
115	51.1	83.8	72.7	158	70.5	115.4	100.4
116	51.6	84.5	73.3	159	70.9	116.1	101.0
117	52.0	85.2	74.0	160	71.3	116.9	101.7
118	52.4	85.9	74.6	161	71.8	117.6	102.3
119	52.9	86.6	75.2	162	72.3	118.4	103.0
120	53.3	87.4	75.9	163	72.7	119.1	103.6
121	53.8	88.1	76.6	164	73.2	119.9	104.3
122	54.2	88.9	77.2	165	73.6	120.6	104.9
123	54.7	89.6	77.9	166	74.1	121.4	105.6
124	55.1	90.3	78.5	167	74.5	122.1	106.2
125	55.6	91.1	79.1	168	74.9	122.9	106.9
126	56.0	91.8	79.8	169	75.4	123.6	107.5

Parts copper oxide.	Parts dextrose.	Parts maltose.	Parts lactose.	Parts copper oxide.	Parts dextrose.	Parts maltose.	Parts lactose.
170	75.8	124.4	108.2	213	95.3	156.3	136.0
171	76.3	125.1	108.8	214	95.8	157.1	136.7
172	76.8	125.8	109.5	215	96.3	157.8	137.3
173	77.3	126.6	110.1	216	96.7	158.6	138.0
174	77.7	127.3	110.8	217	97.2	159.3	138.6
175	78.2	128.1	111.4	218	97.6	160.0	139.3
176	78.6	128.8	112.0	219	98.1	160.8	139.9
177	79.1	129.5	112.6	220	98.6	161.5	140.6
178	79.5	130.3	113.3	221	99.0	162.3	141.2
179	80.0	131.0	113.9	222	99.5	163.0	141.9
180	80.4	131.8	114.6	223	99.9	163.7	142.5
181	80.8	132.5	115.2	224	100.4	164.5	143.2
182	81.3	133.2	115.8	225	100.9	165.3	143.8
183	81.8	134.0	116.5	226	101.3	166.0	144.5
184	82.2	134.7	117.1	227	101.8	166.8	145.1
185	82.7	135.5	117.8	228	102.2	167.5	145.8
186	83.1	136.2	118.4	229	102.7	168.3	146.4
187	83.5	136.9	119.1	230	103.1	169.1	147.0
188	84.0	137.7	119.7	231	103.6	169.8	147.7
189	84.4	138.4	120.4	232	104.0	170.6	148.3
190	84.9	139.1	121.0	233	104.5	171.3	149.0
191	85.4	139.9	121.7	234	105.0	172.1	149.6
192	85.9	140.6	122.3	235	105.4	172.8	150.3
193	86.3	141.4	123.0	236	105.9	173.6	150.9
194	86.8	142.1	123.6	237	106.3	174.3	151.6
195	87.2	142.8	124.3	238	106.8	175.1	152.2
196	87.7	143.6	124.9	239	107.2	175.8	152.9
197	88.1	144.3	125.6	240	107.7	176.6	153.5
198	88.6	145.1	126.2	241	108.1	177.3	154.2
199	89.0	145.8	126.9	242	108.6	178.1	154.8
200	89.5	146.6	127.5	243	109.0	178.8	155.5
201	89.9	147.3	128.2	244	109.5	179.6	156.1
202	90.4	148.1	128.8	245	109.9	180.3	156.8
203	90.8	148.8	129.5	246	110.4	181.1	157.4
204	91.3	149.6	130.1	247	110.9	181.8	158.1
205	91.7	150.3	130.8	248	111.3	182.6	158.7
206	92.2	151.1	131.5	249	111.8	183.3	159.4
207	92.6	151.8	132.1	250	112.3	184.1	160.0
208	93.1	152.5	132.8	251	112.7	184.8	160.7
209	93.5	153.3	133.4	252	113.2	185.5	161.3
210	94.0	154.1	134.1	253	113.7	186.3	162.0
211	94.4	154.8	134.7	254	114.1	187.1	162.6
212	94.9	155.6	135.4	255	114.6	187.8	163.3

Parts. copper oxide.	Parts dextrose.	Parts maltose.	Parts lactose.	Parts. copper oxide.	Parts dextrose.	Parts maltose.	Parts lactose
256	115.0	188.6	163.9	289	130.2	213.6	185.6
257	115.5	189.3	164.6	290	130.6	214.3	186.2
258	116.0	190.1	165.2	291	131.1	215.1	186.9
259	116.4	190.8	165.9	292	131.5	215.9	187.6
260	116.9	191.6	166.5	293	132.0	216.6	188.2
261	117.3	192.4	167.2	294	132.5	217.4	188.9
262	117.8	193.1	167.8	295	133.0	218.2	189.5
263	118.3	193.9	168.5	296	133.4	218.9	190.2
264	118.7	194.6	169.1	297	133.9	219.7	190.8
265	119.2	195.4	169.8	298	134.3	220.4	191.5
266	119.6	196.1	170.4	299	134.8	221.2	192.1
267	120.1	196.9	171.1	300	135.3	221.9	192.8
268	120.6	197.7	171.7	301	135.7	222.7	193.4
269	121.0	198.4	172.4	302	136.2	223.5	194.1
270	121.4	199.2	173.0	303	136.6	224.2	194.7
271	121.9	199.9	173.7	304	137.1	225.0	195.3
272	122.4	200.7	174.4	305	137.6	225.8	196.0
273	122.8	201.5	175.0	306	138.0	226.5	196.6
274	123.3	202.2	175.7	307	138.5	227.3	197.3
275	123.7	203.0	176.3	308	138.9	228.1	197.9
276	124.2	203.7	177.0	309	139.4	228.8	198.6
277	124.6	204.5	177.6	310	139.9	229.6	199.3
278	125.1	205.2	178.3	311	140.3	230.4	199.9
279	125.6	206.0	178.9	312	140.8	231.1	200.6
280	126.1	206.8	179.6	313	141.2	231.9	201.3
281	126.5	207.5	180.2	314	141.7	232.7	202.0
282	127.0	208.3	180.9	315	142.2	233.4	202.6
283	127.4	209.0	181.5	316	142.6	234.2	203.3
284	127.9	209.8	182.2	317	143.1	234.9	203.9
285	128.3	210.5	182.9	318	143.6	235.7	204.6
286	128.8	211.3	183.6	319	144.0	236.5	205.3
287	129.3	212.1	184.2	320	144.5	237.2	205.9
288	129.7	212.8	184.9				

SUPPLEMENTARY TABLE FOR GLUCOSE ANALYSIS.

The amounts of cupric oxide given above are those obtained by the use of absolute weights of sugar. The tables are constructed on this basis. In the case of a mixed product, like commercial glucose, which may be considered made up of the simple bodies, dextrin, maltose, and dextrose. it is far more convenient to determine the total carbohydrates present in solution by means of the specific gravity than by drying the glucose and obtaining in this way the total solids. For this purpose an arbitrary value is taken which shall represent the influence of one gram of a mixture of the three substances above mentioned on the specific gravity if dissolved to 100 cc. in distilled water. Brown and Heron[1] claim that this influence on the specific gravity of one gram starch conversion product in 100 cc. is 0.00386. This value has been determined to be correct for solutions of cane sugar, and is much used for glucose work.

As above mentioned the specific gravity of a dextrose solution containing ten grams dextrose anhydride in 100 cc. is 1.03809 at 15.5°. To determine the cupric reducing power of a substance using the value 3.86 as a divisor, it therefore becomes necessary to change the figures given in the tables to conform to this new factor, that is, the dextrose equivalents must be multiplied by $\frac{386}{381}$, which has been done for convenience of reference in the following table:

Copper oxide obtained.	Dextrose equivalent.	Copper oxide obtained.	Dextrose equivalent.	Copper oxide obtained.	Dextrose equivalent.
5	0·4461	110	0·4500	215	0·4540
10	0·4463	115	0·4502	220	0·4542
15	0·4465	120	0·4504	225	0·4543
20	0·4467	125	0·4506	230	0·4545
25	0·4468	130	0·4508	235	0·4547
30	0·4470	135	0·4510	240	0·4549
35	0·4472	140	0·4512	245	0·4551
40	0·4474	145	0·4513	250	0·4553
45	0·4476	150	0·4515	255	0·4555
50	0·4478	155	0·4517	260	0·4557
55	0·4480	160	0·4519	265	0·4558
60	0·4482	165	0·4521	270	0·4560
65	0·4484	170	0·4523	275	0·4562
70	0·4485	175	0·4525	280	0·4564
75	0·4487	180	0·4527	285	0·4566
80	0·4489	185	0·4528	290	0·4568
85	0·4491	190	0·4530	295	0·4570
90	0·4493	195	0·4532	300	0·4572
95	0·4495	200	0·4534	305	0·4574
100	0·4497	205	0·4536	310	0.4576
105	0·4498	210	0·4538	315	0·4578
				320	0·4580

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[1] *Loc. cit.*

Thus a solution containing 100 milligrams of mixed carbohydrates, using the factor 0.00386, if it formed 200 milligrams cupric oxide by reduction of the Fehling solution in the manner above described, would have a cupric reducing power, or $K_{3.86}$ of 90.68.

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ALUMINUM ANALYSIS.

BY JAMES OTIS HANDY.

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ALTHOUGH the aluminum industry is not a large one in the sense that the iron industry is, it is growing very rapidly. The output of the United States in 1894 was 550,000 pounds, and in 1895 it was about 850,000 pounds. The Pittsburg Reduction Company, with works at New Kensington, near Pittsburg, Pa., and at Niagara Falls, N. Y., is the only American producer of aluminum. The material is made by the electrolysis, in carbon-lined pots, of alumina dissolved in a fused bath of fluorides. The product of each pot is ladled out at intervals and is graded according to the analyses of the Pittsburgh Testing Laboratory, Limited. Some of the aluminum is sold as it is made and some is alloyed to modify its physical properties. Alloys of aluminum with three per cent. nickel, or with three to seven per cent. copper, or similar amounts of zinc are very useful on account of increased strength with only slightly increased specific gravity. The aluminum at present produced with the best ores available contains from

99 to 99.9 per cent. of aluminum.
0.3 to 0.05 per cent. of silicon (combined and graphitic).
0.50 to 0.0 per cent. of copper.
0.20 to 0.0 per cent. of iron.
Carbon is sometimes present in aluminum.

Second grade aluminum contains ninety-six to ninety-eight per cent. aluminum, silicon and iron making up the remainder. Aside from analyses of metallic aluminum, there are required in the pursuit of the aluminum industry, analyses of alloys of copper, nickel, manganese, chromium, tungsten, zinc, and tita-