THE MOLECULAR CONDITION OF SUGAR AND THE SACCHARATES IN SOLUTIONS

by

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The Molecular Condition of Sugar and the Saccharates in Solutions.

In the year 1838 the eminent French chemist, Peligot, published his researches on the nature and properties of cane sugar and the saccharates. Although sugar had been known for a long time, the investigation of it had progressed but slowly, and beyond the analyses by Berzelius, Dumas, Brunner and Liebig, comparatively little was known of its physical and chemical properties. When, however, in 1830, organic chemistry received a new impulse, the attention of chemists was drawn towards the unexplored field of the hydrocarbons and their derivatives.

Five years after the appearance of Peligot's investigation, Soubeiran published his work. His results were closely followed by those of Brendecke, Benedikt, Pfeffer, Tollens, Berthollet, Pelonze and others. As a result of the analysis and further work of investigation of sugar and the saccharates, carried on by these men, definite conclusions were reached as to the nature, the formation and structure of the latter. Sugar itself is generally regarded as having the empirical formula $C_{12} H_{22} O_{11}$.

The saccharates that have been considered in this work are those of the alkalies and alkaline earths; besides this, it was investigated whether silicic acid unites with sugar. Eight solutions of sugar in solvents other than water were investigated in order to observe the action and behavior of sugar in pure solvents of an organic nature.

All the solutions containing hydroxides of the alkalies and alkaline earths plus sugar were aqueous. The object was to note the effect that the alkalies and alkaline earths have on the rotatory power of the solution, and on the freezing point of the latter with a view of ascertaining the molecular condition of the saccharates present in the solution.

The various aqueous solutions were prepared so that they contained a molecule of sugar to every molucule of the base. Solutions containing two molecules of base to one molecule of sugar were also investigated by means of the polariscope and freezing point apparatus.

The extent to which the molecules of the base unite with the sugar molecules can be ascertained by means of these methods.

Since the lowering of the freezing point ofas olution depends upon the number of dissolved molecules, the freezing point method is especially adapted to the investigation of the question as to the extent to which the sugar is in combination with the various bases in solution.

In the case of the solution containing colloidal silicic acid and sugar the question as to the influence of the molecules of the former upon those of the latter was also considered.

It is not generally known that there are but few solvents besides water that will dissolve sugar readily. In order to cause sugar to dissolve in some organic solvents the application of heat is necessary, and even under the most favorable conditions but small quantities will dissolve as a rule. Generally only the rotatory power of the sugar solutions in solvents other than water was tested. In the case of the solution in glacial acetic acid a molecular weight determination was also made by means of the freezing point method. That the various organic solvents would effect the rotatory power in different ways, according to their chemical nature was to be expected, but the modern theory of solutions does not permit one to foresee that different solvents will influence the rotatory power in different ways provided that the molecular weight of the sugar in solution remains normal.

The change of the rotatory power with the change of the volume of the solution was studied. The optical activity of the solutions was also determined at various times to ascertain whether any alterations of the same took place upon standing.

The following table gives the solutions that were investigated.

Unless otherwise indicated, the solutions contained the molecular weights of the substance whose formula is given in grams per liter.

Solution of $C_{12}H_{22}O_{11}$ in Water, (10 grams in 100cc.)

" " $C_{12}H_{22}O_{11}$ " "

" " $C_{12}H_{22}O_{11}$ + Na OH in Water.

" " $C_{12}H_{22}O_{11}$ + 2Na OH " "

" " $C_{12}H_{22}O_{11}$ + Ba $(OH)_2$ " "

" " $C_{12}H_{22}O_{11}$ + Ca $(OH)_2$ " "

" " $C_{12}H_{22}O_{11}$ + Mg $(OH)_2$ " "

" " $C_{12}H_{22}O_{11}$ + Sr $(OH)_2$ " "

" " $C_{12}H_{22}O_{11}$ in (163.4cc) Si O_2 solution.

Solution of $C_{12}H_{22}O_{11}$ in Glycerine ($C_3H_5(OH)_3$) (10 grams in 100cc.)

" " $C_{12}H_{22}O_{11}$ " Acetic acid (CH_3COOH) (" " ")

" " $C_{12}H_{22}O_{11}$ " Formic acid (H C OOH) (" " ")

" " $C_{12}H_{22}O_{11}$ " Ethylene glycol $C_2H_4(OH)_2$ (" " ")

" " $C_{12}H_{22}O_{11}$ " Phenol (C_6H_5OH) (" " ")

" " $C_{12}H_{22}O_{11}$ " Pyridine (C_5H_5N) (3.95 grams in 50cc)

" " $C_{12}H_{22}O_{11}$ " " " (5. grams in 75cc.)

" " $C_{12}H_{22}O_{11}$ " n Butyric acid(C_3H_7COOH)(10 " " 100cc.)

The pycnometer was used for all specific gravity determinations. Its weight was 14.521 grams, and the volume of water it contained weighed 50.0512 grams at 20 degrees centigrade. The weights of equal volumes of all the solutions were found at the same temperature, and the specific gravity was then calculated in each case.

The polariscope used for the determination of the rotatory power, was of the triple-field type, manufactured by Schmidt & Haensch of Berlin. For the light a gas flame was used into which a platinum wire, supporting a bead of fused sodium cholride, was suspended. An iron hood, surrounding the flame, threw the light in the desired direction. The tube containing the solution during the period of determination was (unless otherwise stated) 200 mm. in length. The tube was surrounded by a jacket, through which a constant flow of water was maintained during the time of operation. The scale of the instrument was graduated to hundredths of a degree. The specific rotation was calculated by means of the following formula:

$$[\alpha]_D = \frac{\alpha}{l.Xp.Xd.}$$

$[\alpha]_D$ = specific rotation for (D) sodium light.

α = degrees read off on the scale.

l = length of the tube in mm.

p = percentage strength.

d = density.

For the molecular weight determinations the Beckmann freezing-point apparatus was used. It consists of a large test tube fitted with a cork, perforated by two holes, through one of which is passed a Beckmann's differential thermometer, and through the other a glass stirring rod. The solution whose freezing point is to be determined is put into this test tube, which is then set into a cooling mixture, and the solution agitated by means of the stirring rod. After the solution has been cooled down beyond its freezing point, the mercury suddenly rises rapidly, the apparatus is then taken out of the freezing mixture, rapidly wiped off, and set into an air chamber. The agitation of the solution is continued. The thermometer rises more slowly and finally remains stationary at a certain point. This point is read off, and the freezing point of the pure solvent subtracted from it, the difference is the number of degrees of lowering of the freezing point of the solution. The molecular weight is calculated from the formula:

$$100\,K \frac{S}{\Delta\,L} = \text{Molecular Weight.}$$

K = Constant for the solvent.

S = Substance in solution in grams.

Δ = Observed lowering in degrees.

L = Solvent in grams.

Solution (10 grams in 100cc.) of $C_{12}H_{22}O_{11}$ in Water.

The solution was prepared by dissolving 10 grams of cane sugar (cut loaf variety ground up to a fine powder) in water[1] to make 100 cc. at 20°C[2].

Specific gravity = 1.0399.

Solution of $C_{12}H_{22}O_{11}$ in Water.

68.4 grams of sugar were dissolved in water to make 200 cc. Thus the solution contained one gram molecule per liter.

Specific gravity = 1.1557.

Solution of Sodium Hydroxide.

The substance used was a jar of Natrium Caustic, puriss (Na OH) of 250 grams manufactured by E. Merck of Darmstadt. This was dissolved in water, and an excess of barium hydroxide was added in order to precipitate any carbonate that might be present. The solution was now diluted with water up to about two liters and set aside for a day, when all the suspended matter had subsided. It was now rapidly filtered through glass wool by means of a force filter, put in a suitable bottle and protected from the air. This solution was tested by comparing it with a newly

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[1] All aqueous solutions were prepared with distilled water.

[2] The solutions were all made up to the indicated volume at 20° C.

prepared standard oxalic acid solution.[1] 25 cc. of standard oxalic acid solution required for the complete neutralization of 13.58 cc. of the sodium hydroxide, phenolphthalien having been used as indicator. The result is the average of three readings. One and eighty-four hundredths cubic centimeters of $^{n}/_{1}$ oxalic acid solution then is the equivalent of one cubic centimeter of the sodium hydroxide solution.

Solution of $C_{12}H_{22}O_{11}$+ Na OH in Water.

For a solution of 200 cc. of sugar and sodium hydroxide in water, 68.4 grams of sugar and 8. grams of sodium hydroxide are required. 8. grams of sodium hydroxide required 108.8 cc. of sodium hydroxide solution. Accordingly 68.4 grams sugar was dissolved in 108.8 cc. Na OH and the resulting solution was diluted to 200 cc. Specific gravity = 1.1598.

Solution of $C_{12}H_{22}O_{11}$+ 2Na OH in Water.

This solution contained 68.4 grams of sugar to 16 grams (217.6 cc. solution) of Na OH in 200 cc. In this case the 217.6 cc Na OH solution had to be evaporated slightly so that when added to the sugar the solution measured the required volume. Specific gravity = 1.549.

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[1] This solution was prepared by dissolving 31.5 grams of pure oxalic acid in water, and diluting to 500 cc.

Solution (saturated) of Barium Hydroxide.

Barium hydroxide $Ba(OH)_2 + 7H_2O$ manufactured by C. A. F. Kahlbaum of Berlin was used. 175 grams were dissolved in about 1200 cc. of water and the solution boiled for about two hours; it was then allowed to stand in a moderately warm place for some days. Finally it was filtered rapidly with a force filter and kept in a bottle well protected from air. In estimating the strength it was found that 28.71 cc. of the $Ba(OH)_2$ solution was required to neutralize 10 cc. of the $n/1$ oxalic acid. Phenolphthalein was used as indicator. Three tests were made in this estimation. One cubic centimeter of $n/1$ oxalic acid is the equivalent of 2.87 cc. of the $Ba(OH)_2$ solution.

Solution of $C_{12}H_{22}O_{11}+Ba(OH)_2$ in Water.

For a 500 cc. solution, 171. grams of sugar are required and 42.5 grams of barium hydroxide. To obtain 42.5 grams, 868.72cc. are required which were evaporated down so as to come within the required volume when the sugar is added. Specific gravity = 1.1201. Upon estimation with $n/1$ hydrochloric acid it was found that 16.55 cc. of acid were required to neutralize 25 cc. of the alkaline solution. The result is the average of the readings. Phenolphthalein was used as indicator.

Solution of $C_{12}H_{22}O_{11}$ + $Ca(OH)_2$ in Water.

In 500 cc. of solution, 171. grams of sugar and 14. grams of calcium hydroxide were contained. Specific gravity = 1.1532. 25 cc. of the solution required 18.15 cc. of $^n/_1$ hydrochloric acid to neutralize. Therefore 0.02024 grams of CaO were present in every cubic centimeter of solution.

Solution of $C_{12}H_{22}O_{11}$ + $Mg(OH)_2$ in Water.

Magnesium oxide, from E. B. Benjamin, New York. For 500 cc. solution, 10 grams of the magnesium oxide were boiled for two hours with water, the 171. grams of sugar were dissolved in the solution, and the boiling continued for another hour. Finally the solution was filtered. Specific gravity = 1.1601. To neutralize 25 cc. of solution required 0.15 cc. of $^n/_1$ hydrochloric acid. Therefore, 0.0000731 grams of MgO were present in one cubic centimeter of solution.

Solution of $C_{12}H_{22}O_{11}$+ $Sr(OH)_2$ in Water.

25.8 grams of strontium oxide were boiled with water for two hours, then 171. grams of sugar were added and the boiling was continued another hour. After filtration the filtrate was made up to 500 cc. Specific gravity = 1.1571. This solution gave no indication of the presence of SrO when tested with phenolphthalein.

Solution of $C_{12}H_{22}O_{11}$ in (163.4 cc.) SiO_2 Solution.

The sodium silicate used was from Dr. Schuchardt, of Görlitz. 100 cc. of sodium silicate were dialized from an acidulated solution in water, and evaporated to near the point of gelatinization. When analysed it was found to contain 0.05036 grams of SiO_2 per cubic centimeter of solution. 68.4 grams of sugar were dissolved in 163.4 cubic centimeters of this solution and the volume made up to 200 cubic centimeters. Specific gravity = 1.15349.

Solution (10 grams in 100cc.) of $C_{12}H_{22}O_{11}$ in Acetic acid(CH_3COOH).

Acetic acid, glacial, manufactured by C. A. F. Kahlbaum, of Berlin, was employed. 10. grams of sugar were dissolved in acetic acid, and made up to 100 cubic centimeters with more acetic acid. Specific gravity = 1.09291.

Solution (10 grams in 100cc.) of $C_{12}H_{22}O_{11}$ in Formic acid (H COOH).

The formic acid used was manufactured by Dr. Schuchardt. 10. grams of sugar were dissolved in the formic acid, and then made up to 100 cubic centimeters. Specific gravity = 1.23262.

Solution (10 grams in 100cc.) of $C_{12}H_{22}O_{11}$ in Glycerine ($C_3H_5(OH)_3$).

The glycerine was from C. A. F. Kahlbaum. 10 grams of sugar were dissolved in glycerine and then made up to 100 cubic centimeters. Specific gravity = 1.28744.

Solution (10 grams in 100cc.) of $C_{12}H_{22}O_{11}$ in Ethylene glycol ($C_2H_4(OH)_2$).

The Ethylene glycol was of Dr. Schuchardt's manufacture. 5. grams of sugar were dissolved in the glycol, and the volume made up to 50 cubic centimeters. Specific gravity = 1.12300

Solution (10 grams in 100 cc.) of $C_{12}H_{22}O_{11}$ in Phenol (C_6H_5OH).

Phenol puriss, from Schuchardt was used. 10 grams of sugar were put into a volume of 100 cubic centimeters of the melted phenol and heated, but when cooled down the sugar was thrown out of solution. At 40° C. the phenol gave no rotation when examined with the polariscope.

Solution (10 grams in 100 cc.) of $C_{12}H_{22}O_{11}$ in Butyric Acid (C_3H_7COOH).

The Butyric acid used was manufactured by Dr. König. 10 grams of sugar were put into 100 cubic centimeters of the acid and heated, on cooling the sugar was thrown out of solution. When examined with the polariscope the solution gave no rotation. Specific gravity = 0.9593.

Solution (3.95 grams in 50cc.) of $C_{12}H_{22}O_{11}$ in Pyridine(C_5H_5N).

The pyridine was purchased from Eimer and Amend, New York. 3.95 grams of sugar were dissolved in pyridine and the solution made up to 50cc. Specific gravity = 1.01138.

Another solution, containing 5 grams of sugar in 75. cubic centimeters of pyridine was prepared. Specific gravity = 1.01633.

Solution (3.95 grams in 50cc.) of $C_{12}H_{22}O_{11}$ in Water.

In this solution 3.95 grams of sugar were dissolved in water, and the solution made up to 50 cubic centimeters.

Solution of $C_{12}H_{22}O_{11}$ in Pyridine and Water.

Of the foregoing two solutions of sugar in pyridine and sugar in water, containing 3.95 grams of sugar each per 50 cubic centimeters, three other solutions were prepared.

No.I, consisted of 5. cubic centimeters of the aqueous solution plus 15. cubic centimeters of the pyridine solution.

No. II, contained 10 cubic centimeters each of the aqueous and puridene solutions.

No. III, contained 15. cubic centimeters of the aqueous solution and 5. cubic centimeters of the pyridine solution.

Unless otherwise specified the length of the polariscope tube, containing the solution, was 200 mm. The results given are the average of five readings, during the time of which the temperature was constant at 20°C

Solution (10grams in 100cc.) of $C_{12}H_{22}O_{11}$ in Water.

Degree of rotation		13.874.
" " "	after 20 weeks	13.861.

Solution of $C_{12}H_{22}O_{11}$ in Water.

Concentration		Readings in degrees.
n/1	Solution,	45. 40
n/2	"	22.70
n/4	"	11.44
n/8	"	5.72
n/16	"	2.81
n/32	"	1.37
n/64	"	0.73
[illegible]	"	0.38

Readings after 20 weeks standing.

[illegible]	Solution	45.38
n/2	"	22.71
n/4	"	11.38
[illegible]	"	5.70
n/16	"	2.82
[illegible]2	"	1.34

Solution of $C_{12}H_{22}O_{11}$ + NaOH in Water.

Concentration		Readings in degrees.
$n/_{1}$	Solution	40.78
$n/_{2}$	"	26.36
$n/_{4}$	"	10.16
$n/_{8}$	"	5.11
$n/_{16}$	"	2.57
$n/_{32}$	"	1.21
$n/_{64}$	"	0.63
$n/_{128}$	"	0.33.

Readings after 20 weeks standing.

$n/_{1}$	Solution	40.84
$n/_{2}$	"	20.41
$n/_{4}$	"	10.19
$n/_{8}$	"	5.08
$n/_{16}$	"	2.59
$n/_{32}$	"	1.21

Solution of $C_{12}H_{22}O_{11}$+ 2NaOH in Water.

Concentration		Readings in degrees.
n/1	Solution	24.68
n/2	"	12.51
n/4	"	6.40
n/8	"	3.20
n/16	"	1.55
n/32	"	0.77
n/64	"	[illegible]
n/128	"	0.17

Readings after 20 weeks standing.

n/1	Solution	24.65
n/2	"	1[illegible]
n/4	"	[illegible]
n/8	"	[illegible]
n/16	"	[illegible]
n/32	"	0.74

Solution of $C_{12}H_{22}O_{11}$ + $Ba(OH)_2$ in Water.

Concentration		Readings in
$^n/_1$	Solution	24.79
$^n/_2$	"	12.42
$^n/_4$	"	6.21
$^n/_8$	"	3.10
$^n/_{16}$	"	1.57
$^n/_{32}$	"	0.77
$^n/_{64}$	"	0.37
$^n/_{128}$	"	0.19

Readings after 20 weeks standing.

$^n/_1$	Solution	24.57
$^n/_2$	"	12.29
$^n/_4$	"	6.17
$^n/_8$	"	3.01
$^n/_{16}$	"	1.59
$^n/_{32}$	"	0.76

Solution of $C_{12}H_{22}O_{11} + Ca(OH)_2$ in Water.

Concentration		Readings in degrees.
$n/_{1}$	Solution	40.93
$n/_{2}$	"	20.51
$n/_{4}$	"	10.25
$n/_{8}$	"	5.14
$n/_{16}$	"	2.54
$n/_{32}$	"	1.26
$n/_{64}$	"	0.65
$n/_{128}$	"	0.31

Readings after 20 weeks standing.

$n/_{1}$	Solution	
$n/_{2}$	"	
$n/_{4}$	"	10.17
$n/_{8}$	"	5.18
$n/_{16}$	"	2.52
$n/_{32}$	"	1.28

Solution of $C_{12}H_{22}O_{11}$+ $Mg(OH)_2$ in Water.

Concentration		Readings in degrees.
$^n/_1$	Solution	45.12
$^n/_2$	"	22.51
$^n/_4$	"	11.27
$^n/_8$	"	5.59
$^n/_{16}$	"	2.24
$^n/_{32}$	"	1.09

Readings after 16 weeks standing.

$^n/_1$	Solution	45.02
$^n/_2$	"	22.47
$^n/_4$	"	11.21
$^n/_8$	"	5.61
$^n/_{16}$	"	2.21
$^n/_{32}$	"	1.11

Solution of $C_{12}H_{22}O_{11}$ + SrO in Water.

Concentration	Readings in
n/1	45.27
n/2	22.59
n/4	11.31
n/8	5.60

Readings after 16 weeks standing.

n/1	Solution	45.13
n/2	"	22.51
n/4	"	11.28
n/8	"	5.58

Solution of $C_{12}H_{22}O_{11}$ in (163.44 cc.) SiO_2 Solution.

Concentration		Readings in
n/1	Solution	45.16
n/2	"	22.56
n/4	"	11.27
n/8	"	5.67

Readings after 6 weeks standing.

n/1	Solution	45.13
n/2	"	22.52
n/4	"	11.30
n/8	"	5.63

Solution (10grams in 100cc.) of $C_{12}H_{22}O_{11}$ in Glycerine

100 mm. tube.	6.44
200 " "	12.95

Readings after 4 weeks standing.

100 mm. tube	6.45
200 " "	12.93

Solution (10grams in 100cc.) of $C_{12}H_{22}O_{11}$ in Ethylene glycol ($C_2H_4(OH)_2$).

100 mm. tube	6.28
200 " "	12.61

Readings after 4 weeks standing.

100 mm. tube	6.30
200 " "	12.60

Solution (10grams in 100 cc.) of $C_{12}H_{22}O_{11}$ in acetic acid(

100 mm. tube	0.84
200 " "	1.67

Readings after 4 weeks standing.

100 mm. tube	0.77
200 " "	1.60

Solution (10 grams in 100cc.) of $C_{12}H_{22}O_{11}$ in Formic acid (H COOH).

100 mm. tube	0.43
200 " "	0.92

Readings after 4 weeks standing.

100 mm. tube	0.30
200 " "	0.76

Solution (3.95 grams in 50cc.) of $C_{12}H_{22}O_{11}$ in Pyridine (C_5H_5N).

100 mm. tube	6.22
200 " "	12.46

Readings after 4 weeks standing.

100 mm. tube	6.22
200 " "	12.48

Solution (5 grams in 75 cc.) of $C_{12}H_{22}O_{11}$ in Pyridine

100 mm. tube	5.59
200 " "	11.18

Readings after 4 weeks standing.

100 mm. tube	5.63
200 " "	11.20

(1) Solution (3.95 grams in 50cc.) of $C_{12}H_{22}O_{11}$ in Water.

100 mm. tube 5.97

(2) Solution (3.95 grams in 50cc.) of $C_{12}H_{22}O_{11}$ in

100 mm. tube 6.22

Solution of 20cc., consisting of 5cc. of 1, and 15cc. of 2.

100 mm. tube 5.88

Solution of 20cc., consisting of 10cc. each of 1 and 2.

100 mm. tube 5.69

Solution of 20cc. consisting of 15cc. of 1 and

100 mm. tube 5.93

Specific Rotations.

Solution of $C_{12}H_{22}O_{11}$	in Water (10grams in 100cc.)	66.71°
" " $C_{12}H_{22}O_{11}$	" "	66.83
" " $C_{12}H_{22}O_{11}$	+ NaOH in water	60.13
" " $C_{12}H_{22}O_{11}$	+ 2NaOH " "	36.46
" " $C_{12}H_{22}O_{11}$	+ $Ba(OH)_2$ in water	30.27
" " $C_{12}H_{22}O_{11}$	+ $Ca(OH)_2$ " "	60.30
" " $C_{12}H_{22}O_{11}$	+ $Mg(OH)_2$ " "	66.54
" " $C_{12}H_{22}O_{11}$	+ $Sr(OH)_2$ " "	66.78
" " $C_{12}H_{22}O_{11}$	in(163.4cc) SiO_2 Solution	66.88

Solution of $C_{12}H_{22}O_{11}$	in Glycerine ($C_3H_5(OH)_3$)	0.50
" " $C_{12}H_{22}O_{11}$	" Ethyle glycol ($C_2H_4(OH)_2$	0.56
" " $C_{12}H_{22}O_{11}$	" Acetic acid (CH_3COOH)	0.07
" " $C_{12}H_{22}O_{11}$	" Formic acid (H COOH)	0.03
" " $C_{12}H_{22}O_{11}$	" Phenol (C_6H_5OH)	0.—
" " $C_{12}H_{22}O_{11}$	" Pyridine (C_3H_5N)(3.95grams in 50cc.)	0.78
" " $C_{12}H_{22}O_{11}$	" " " (5.grams in 75cc.)	0.82
" " $C_{12}H_{22}O_{11}$	" n Butyric acid(C_3H_7COOH)	0.—

Freezing-point Determinations.

	Lowering.	Apparent Mol. Wt. of the sugar.	$\frac{\text{Lowering.}}{2.979}$
$C_{12}H_{22}O_{11}$ in Water	2.979	346.67	1.
$C_{12}H_{22}O_{11}$ + NaOH in Water	3.439	309.58	1.16
$C_{12}H_{22}O_{11}$ + 2NaOH " "	4.139	247.59	1.36
$C_{12}H_{22}O_{11}$ + $Ba(OH)_2$ " "	3.112	228.77	1.05
$C_{12}H_{22}O_{11}$ + $Ca(OH)_2$ " "	3.22-	307.70	1.09
$C_{12}H_{22}O_{11}$ + $Mg(OH)_2$ " "	3.245	330.70	1.09
$C_{12}H_{22}O_{11}$ + $Sr(OH)_2$ " "	3.088	338.46	1.04
$C_{12}H_{22}O_{11}$ in (163.4cc.) SiO_2 Solution	3.048	336.86	1.04
$C_{12}H_{22}O_{11}$ in Acetic acid (10grams in 100 cc.)	1.555	278.74	——

The foregoing results clearly indicate the molecular condition of the sugar and the saccharates in the various solutions. In the aqueous solution of sugar and sodium hydroxide, where the molecular weight in grams of each is present, the molecules of sugar and sodium hydroxide unite to some extent, but when twice the molecular weight in grams of sodium hydroxide is present to only one of sugar then a considerably greater number of molecules unite with each other. In the case of the barium hydroxide even more saccharate is formed than in the case of the sodium hydroxide and sugar. The calcium hydroxide molecules unite with those of sugar to about the same extent as the soxium hydroxide does when an equal number of sugar and sodium hydroxide molecules are present. The magnesium hydroxide molecules unite with those of sugar to only a very small fraction of a per cent, and those of strontium hydroxide do not unite at all with those of sugar. It is strange that these hydroxides, otherwise so similar to that of calcium. should behave in such an entirely different way from the latter when in solution with sugar. The colloidal silicic acid molecules practically do not unite at all with those of sugar. When the sugar is in solution in organic solvents it is found that the specific rotation is greatly reduced. There is a striking similarity between the two lower acids of the fatty series, while their higher homologne would not even dissolve sugar. The two alkahols also yield results indicating close relationship. In pyridine sugar behaves more as though it were dissolved in water, although its rotation is slightly higher than in water when equal amounts are dissolved in the same amount of the different solvents. When the same amount of sugar is dissolved in the same volume of water and pyridine mixed in different proportions the rotation is lower than in the aqueous solution.

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