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On the Inversion of Cane Sugar.

By

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HILL (Journ. Chem. Soc. 73, 634; 1898.) has shown that the hydrolysis of maltose by the catalytic action of an enzyme is incomplete and that the less the degree of hydrolysis, the more concentrated is the solution. As to the inversion of cane sugar by the catalytic action of an acid, it has been studied extensively from several points of view and it is well known that the hydrolysis is complete. It is not, however, improbable, that the hydrolysis of cane sugar may also be in some measure incomplete when the solution is highly concentrated. In this respect I have undertaken the investigation of the inversion of cane sugar and obtained the results expected, as shown in the following communication.

Pure commercial cane sugar was purified by precipitation from the cold saturated aqueous solution with absolute alcohol and washing it with ether. The experiments and the calculation of the results were carried out as follows:

I. *80 grams of cane sugar in 100 c.c. of the solution.*

20 grams of cane sugar were introduced into a weighed measuring flask of 25 c.c. capacity and dissolved in a small

quantity of water by warming. When it was cold, 5 c.c. of 2.5 normal hydrochloric acid were added and the solution was diluted nearly to the mark. A small piece of camphor was then added to the solution and the flask left in a thermostat at 25° over night. On the next day water at 25° was added to the mark and weighed. The two solutions thus prepared weighed:

(*a*) 32.787, (*b*) 32.799; mean: 32.793.

About 5 c.c. of the solution were taken out from each of the solution into two weighed measuring flasks of 25 c.c. capacity and weighed. About 4 c.c. of 2.5 norm. hydrochloric acid were added to each of them and the solutions were diluted to about 20 c.c. The four diluted solutions thus prepared, together with the two original solutions, were again left in the thermostat over night.

On the next day about 5 c.c. of the two original solutions were taken out, each into two weighed measuring flasks of 25 c.c. capacity, and weighed. In order to prevent its further inversion on dilution, 3.4 grams of sodium acetate were added to the solutions taken out, which were then diluted to the mark. The same amount of the salt was also introduced into each of the solutions diluted the day previous to make them as nearly as possible similar to those newly prepared and then the solutions were further diluted to the mark. It was ascertained by experiments that a small difference in the concentrations of hydrochloric acid exerts no remarkable influence on the optical rotation of sugar solutions.

The eight dilute solutions thus prepared were then subjected to polarimetric observations, a polarisation apparatus after LANDOLT being used with a LIPPICH's polariser.

		Solution taken out in grams.	Rotation of the solution diluted to 25 c.c.
		Inverted in the original solution.	
(*a*)	(1)	6.3341	−6.282°
	(2)	6.3398	−6.270°
(*b*)	(3)	6.3391	−6.272°
	(4)	6.3565	−6.290°
		Inverted in the dilute solution.	
(*a*)	(5)	6.4350	−6.646°
	(6)	6.3612	−6.608°
(*b*)	(7)	6.4488	−6.660°
	(8)	6.4067	−6.608°

In order to obtain the mean value of the rotations of the solutions of the same treatment and to be able to compare those of the solutions of different treatments with each other, it was assumed that within narrow limits of concentrations, as in the case in hand, the rotations are proportional to the concentrations of the solutions. The average amount of the solutions taken out in eight instances was 6.3776 grams and the rotation of it diluted to 25 c.c. was calculated from the above data as follows:

(*a*)	(1)	−6.325°	(*a*)	(5)	−6.587°
	(2)	−6.307°		(6)	−6.625°
(*b*)	(3)	−6.310°	(*b*)	(7)	−6.586°
	(4)	−6.311°		(8)	−6.578°
Mean:		−6.313°	Mean:		−6.594°

25 c.c. of the original solution weighed 32.793 grams and contained 20 grams of sugar, so that 6.3776 grams of the solution contained 3.8896 grams. The same amount of sugar was dissolved in water with the addition of sodium acetate and hydrochloric

acid so as to make the solution similar to those in the other cases, diluted to 25 c.c. and polarised:

(9) 20.094°, (10) 20.104°; mean: 20.099.°

Thus we find the degree of the inversion in the original solution in percentage as follows:

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

With solution of other concentrations, the experiments and calculation were carried out quite similarly, so that merely the results will be reported.

II. *70 grams of cane sugar in 100 c.c. of the solution.*

25 c.c. of the solution weighed:

(*a*) 31.872, (*b*) 31.872; mean: 31.872.

		Solution taken out in grams.	Rotation of the solution diluted to 25 c.c.	Rotation calculated for the mean dilute solution.
			Inverted in the original solution.	
(*a*)	(1)	6.1883	−5.659°	−5.663°
	(2)	6.2090	−5.662°	−5.647°
(*b*)	(3)	6.1627	−5.628°	−5.656°
	(4)	6.1826	−5.638°	−5.647°
			Mean:	−5.653°
			Inverted in the dilute solution.	
(*a*)	(5)	6.2103	−5.798°	−5.782°
	(6)	6.2014	−5.778°	−5.771°
(*b*)	(7)	6.1988	−5.770°	−5.764°
	(8)	6.1884	−5.756°	−5.760°
			Mean:	−5.769°

The optical rotation of the sugar solution, not inverted, corresponding to the mean dilute solution was:

(9) 17.592°, (10) 17.572°; mean: 17.582°

Thus the degree of the inversion in the original solution in percentage is as follows:

$$\frac{17.582+5.653}{17.582+5.769}\times 100=99.5.$$

III. *60 grams of cane sugar in 100 c.c. of the solution.*

25 c.c. of the solution weighed:

(*a*) 30.967, (*b*) 30.963; mean: 30.965.

		Solution taken out in grams.	Rotation of the solution diluted to 25 c.c.	Rotation calculated for the mean dilute solution.
			Inverted in the original solution.	
(*a*)	(1)	6.0483	−4.916°	−4.917°
	(2)	6.0710	−4.950°	−4.933°
(*b*)	(3)	6.0287	−4.896°	−4.913°
	(4)	6.0503	−4.944°	−4.943°
			Mean:	−4.926°
			Inverted in the dilute solution.	
(*a*)	(5)	6.0255	−4.976°	−4.996°
	(6)	6.0683	−5.014°	−4.999°
(*b*)	(7)	6.0342	−5.006°	−5.019°
	(8)	6.0721	−4.994°	−4.976°
			Mean:	−4.998°

The optical rotation of the sugar solution, not inverted, corresponding to the mean dilute solution was:

(9) 15.126°, (10) 15.138°; mean: 15.132.°

Thus the degree of the inversion in the original solution in percentage is as follows:

$$\frac{15.132+4.926}{15.132+4.998}\times 100=99.6.$$

IV. *50 grams of cane sugar in 100 c.c. of the solution.*

25 c.c. of the solution weighed:

(*a*) 30.016, (*b*) 30.020; mean: 30.018.

		Solution taken out in grams.	Rotation of the solution diluted to 25 c.c.	Rotation calculated for the mean dilute solution.
			Inverted in the original solution.	
(*a*)	(1)	5.8721	−4.140°	−4.142°
	(2)	5.8818	−4.140°	−4.136°
(*b*)	(3)	5.8721	−4.132°	−4.135°
	(4)	5.8674	−4.141°	−4.147°
			Mean:	−4.140°
			Inverted in the dilute solution.	
(*a*)	(5)	5.8767	−4.180°	−4.179°
	(6)	5.8770	−4.183°	−4.182°
(*b*)	(7)	5.8803	−4.170°	−4.167°
	(8)	5.8764	−4.178°	−4.177°
			Mean:	−4.176°

The optical rotation of the sugar solution, not inverted, corresponding to the mean dilute solution was:

(9) 12.682°, (10) 12.669°; mean: 12.675°

Thus the degree of the inversion in the original solution in percentage is as follows:

$$\frac{12.675+4.140}{12.675+4.176}\times 100=99.8.$$

V. The *reverse reaction* was next studied. The experiments were carried out as follows:

About 20 grams of cane sugar were dissolved in a flask of 50 c.c. capacity and hydrochloric acid was added to a concentration of 0.5 normal, when the solution was diluted to 50 c.c.

When the inversion was complete, about 5 c.c. of the solution were taken out into a weighed flask of 25 c.c. capacity and weighed. After the addition of sodium acetate, it was diluted to 25 c.c. and polarised.

Solution taken out in grams.	Rotation of the solution diluted to 25 c.c.
5.7507	−3.83°
5.7478	−3.82°

About 5 c.c. of the same original solution were taken out into a weighed flask of 25 c.c. capacity and weighed. Air was passed over its surface by means of a powerful water pump and when the volume of the solution was reduced to about one-half, the flask was weighed again. Sodium acetate was then added, diluted to the mark and polarised.

Solution taken out in grams.	Solution after evaporation.	Loss by evaporation.	Rotation of the solution diluted to 25 c.c.
5.7505	3.0629	2.6876	−3.30°
5.7582	3.3187	2.4395	−3.36°
5.7576	3.4573	2.3003	−3.43°
5.7582	3.5686	2.1896	−3.53°

From these results it is very probable that in a concentrated solution a reversion of cane sugar from its hydrolytic products takes place. The reversion product may not be maltose or isomaltose; as I have found it, the reversion of maltose (or isomaltose) from d-glucose in a concentrated solution by the catalytic action of an acid did not take place in any remarkable degree at a temperature of 25° during a period of two months.

Thus the inversion of cane sugar by an acid seems to be a reversible reaction. In dilute solution the inversion may be regarded as practically complete and its incompleteness becomes remarkable first when the concentrations are very high; and the more incomplete, the more concentrated the solutions are, as expected from the theory.

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