Carbohydrate Research, 36 (1974) C1–C4
© Elsevier Scientific Publishing Company, Amsterdam – Printed in Belgium

Preliminary communication

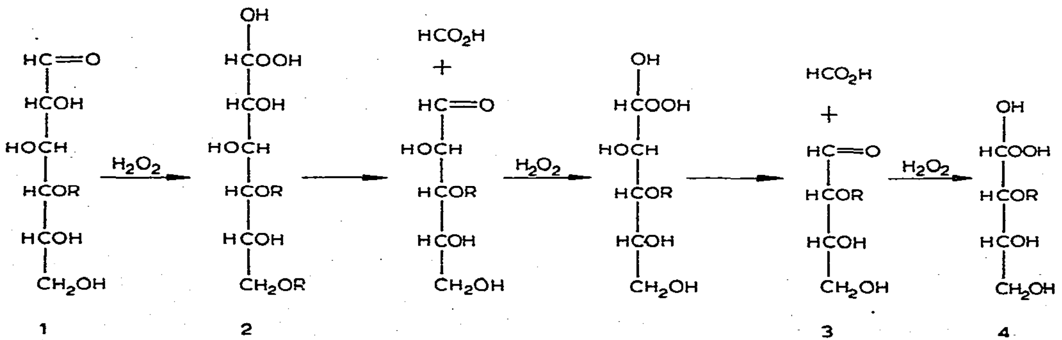
Degradation of reducing disaccharides by alkaline hydrogen peroxide*

HORACE S. ISBELL and RENEE G. NAVES

Department of Chemistry, The American University, Washington, D.C. 20016 (U. S. A.)

(Received May 13th, 1974; accepted May 25th, 1974)

Oxidative degradations of aldoses, ketoses, uronic acids, and keto acids by alkaline peroxides were discussed in prior papers of this series[1–4]. In view of the earlier results, it was expected that the degradation of a 4-*O*-aldohexosyl-aldohexose (**1**) (see Scheme 1) would begin with the addition of a hydroperoxide anion to the aldehydic carbon atom of the acyclic form of the aldohexose residue; this would be followed by decomposition of the adduct (**2**) to the next lower disaccharide and formic acid. The degradation process would then proceed stepwise, until interrupted by the glycosidic linkage. Presumably, the resulting 2-*O*-aldohexosyl-aldotetrose (**3**) would form a hydroperoxide adduct (**4**). However, this adduct, lacking a hydroxyl group on the carbon atom adjacent to the peroxide, would be unable to decompose by the process depicted in Scheme 1. Furthermore, it was expected that the degradation of a 6-*O*-aldohexosyl-aldohexose would be similar, but would proceed farther down the chain before interruption by the glycosyl group.



Scheme 1. Hydroperoxide degradation of a 4-*O*-aldohexosyl-aldohexose to a 2-*O*-aldohexosyl-aldotetrose (R represents an aldohexosyl group).

---

*Reactions of Carbohydrates with Hydroperoxides. Part IV. For Parts I, II, and III, see refs. 2, 3, and 4.

It now appears that, under certain conditions, the degradation proceeds farther than expected, and that disaccharides are almost completely converted into formic acid. Fig. 1 shows the changes in optical rotation of some reducing disaccharides on treatment with alkaline hydrogen peroxide. The initial, fairly rapid reaction is followed by a slow change. As indicated by the extension of the curves (shown by dotted lines), with prolonged reaction times, the optical rotations approach zero, indicating almost complete degradation.

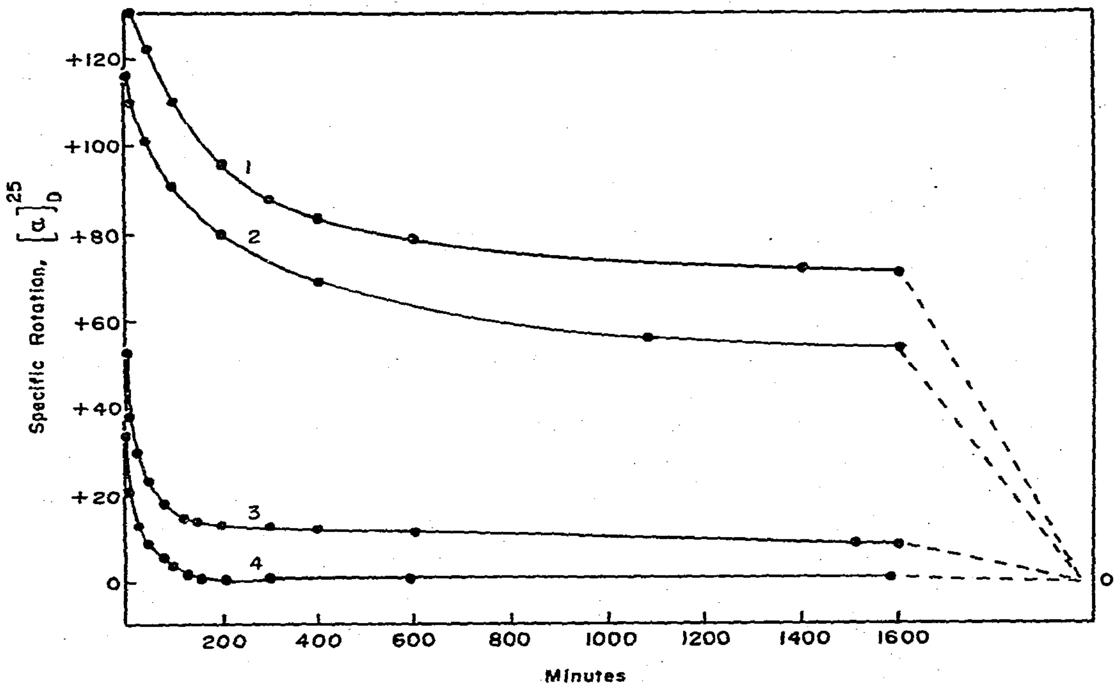


Fig. 1. Changes in optical rotation during the reaction of some disaccharides with alkaline hydrogen peroxide. The disaccharides are (1) melibiose, (2) maltose, (3) lactose, and (4) cellobiose. (The reaction mixture consisted of 1 millimole of the disaccharide in a solution containing 2 ml of 30% H_2O_2 and 8 ml of 2M KOH at 25°.)

In order to follow the course of the reactions, we determined the amount of formic acid produced under three sets of conditions (see Table I). To ensure mild conditions, we used aqueous barium peroxide, with crystalline barium peroxide in suspension; as the reaction proceeded, the crystalline salt dissolved and maintained a constant (small) content of peroxide. From time to time, samples of the reaction mixture were taken, the excess of peroxide was filtered off, and formic acid was determined in the usual way. The reactions were slow, and even after several days, the amount of formic acid produced was less than that expected for the first stage of the degradation.

With 1M sodium peroxide, the amount of formic acid expected for the first stage of the degradation was obtained in 3 or 4 days. In the course of many days, the formic acid

TABLE I

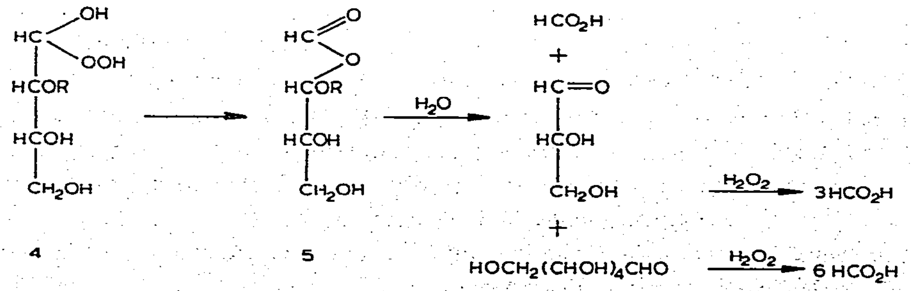
REACTIONS OF DISACCHARIDES WITH ALKALINE HYDROGEN PEROXIDE

Reaction mixture per millimole of disaccharide	*Reaction temp. (degrees)*	*Reaction time (days)*	*Millimoles of HCO_2H per millimole of disaccharide*			
			Melibiose	*Maltose*	*Lactose*	*Cellobiose*
50 ml sat'd. BaO_2 solution	25	1	1.0	0.4	0.8	
		3	1.9	0.6	1.4	
		7	3.6	1.3	2.5	
5 ml H_2O, 45 ml 1M Na_2O_2	4	1	2.3	1.0	0.8	0.9
		2	4.8	1.0	1.5	1.8
		3	6.2	1.3	1.8	1.9
		7	8.0	2.8	3.7	3.3
		10	8.2	3.4	4.8	4.8
4 ml H_2O, 12 ml 2M KOH, 4 ml 30% H_2O_2	4	1	10.9	10.8	11.1	10.8
		2	11.2	11.0	11.5	11.1
		6	11.2	11.0	11.5	11.1

increased, but did not reach the amount expected for rupture of the glycosidic bond and complete degradation of the fragments.

With an *excess of hydrogen peroxide* under alkaline conditions, the reaction was strikingly different; it was accompanied by evolution of oxygen, and over 90% of the disaccharide was converted into formic acid in one day. Thus, under these conditions, the glycosidic bond is ruptured, and the reaction proceeds more rapidly than with alkaline hydroperoxide in the absence of an excess of hydrogen peroxide.

A plausible mechanism (see Scheme 2) for the second (slow) stage of the degradation involves a shift of the carbohydrate entity of **4** to the peroxide oxygen atom, giving formic ester **5**. On hydrolysis, compound **5** would give formic acid and the D-glucose hemiacetal of D-glyceraldehyde; by alkaline hydrolysis, the latter would give D-glucose and D-glyceraldehyde, and, by further reaction, these compounds would be converted into formic acid. This mechanism is similar to that accepted for rearrangement of a ketone to an ester by a peroxy acid[5].



Scheme 2. Hydroperoxide cleavage and degradation of a 2-*O*-aldohexosyl-aldotetrose (R represents an aldohexosyl group).

The degradation process described here for disaccharides is also applicable to similar degradation of reducing oligosaccharides and polysaccharides.

ACKNOWLEDGMENTS

This investigation was supported by National Science Foundation grant GP 28941. The authors express their gratitude to Harriet L. Frush for counsel and to Martin Bondy, Zlata Orhanovic, and Pat Compagnone for laboratory assistance.

REFERENCES

1 H. S. Isbell, "Enolization and Oxidation Reactions of Reducing Sugars", in "Carbohydrates in Solution", *Advan. Chem. Ser.*, 117 (1973) 70–87.
2 H. S. Isbell, H. L. Frush, and E. T. Martin, *Carbohyd. Res.*, 26 (1973) 287–295.
3 H. S. Isbell and H. L. Frush, *Carbohyd. Res*,, 28 (1973) 295–301.
4 H. S. Isbell, H. L. Frush, and Z. Orhanovic, *Carbohyd. Res.*, in press.
5 E. S. Gould, *Mechanism and Structure in Organic Chemistry*, Holt, New York, 1959, pp. 629–634.