vacuo. The dried material was sublimed at 0.005–0.02 mm. and 80–90°; yield 1.5 g. (44.1%), m. p. 96.5–96.7°.

Anal. Calcd. for $C_9H_9ON_3$: C, 61.70; H, 5.18; N, 23.98. Found: C, 61.45; H, 5.18; N, 24.07.

Diazotization of 7-Methoxy-5-aminoquinoxaline.—Twenty-three and one-tenth milligrams (0.132 millimole) of the amino compound was dissolved in dilute hydrochloric acid, and titrated at 5° with 0.1000 molar sodium nitrite. One-tenth molar sodium nitrite required 1.32 ml. (0.132 millimole).

7-Methoxy-5-acetaminoquinoxaline.—About 5 mg. of 7-methoxy-5-aminoquinoxaline was dissolved in several drops of acetic anhydride. After shaking for two minutes at room temperature, the mixture was diluted with several milliliters of water and shaken. The white needles which separated were filtered off, washed with water, and recrystallized from 30% alcohol; m. p. 173.7–174.5°.

7-Methoxy-5-aminoquinoxaline Dihydrochloride.—About one hundred milligrams of 7-methoxy-5-aminoquinoxaline was dissolved in 10 ml. of methanol. To this there was added a considerable excess of 10 *N* methanolic hydrogen chloride over that theoretically required for the trihydrochloride. On evaporation of the solvent at room temperature with the aid of a current of dry air, pinkish-white crystals separated out. The hydrochloride was dried *in vacuo;* m. p. 205–208°.

Anal. Calcd. for $C_9H_9ON_3 \cdot 2\ HCl \cdot (CH_3OH)$: Cl, 26.04. Found: Cl, 25.97.

About one hundred milligrams of 7-methoxy-5-aminoquinoxaline was dissolved in 10 ml. of methanol. To this there was added a considerable excess of 10 *N* methanolic hydrogen chloride over that theoretically required for the trihydrochloride. On evaporation of the solvent on a water-bath a maroon colored substance was obtained. This substance was dried *in vacuo;* m. p. 210.5–211°.

Anal. Calcd. for $C_9H_9ON_3 \cdot 2\ HCl$: Cl, 28.83. Found: Cl, 28.88.

Summary

1. 3,4-Diamino-5-nitroanisole was prepared by alkaline reduction of 3,5-dinitro-4-aminoanisole.

2. 7-Methoxy-5-nitroquinoxaline was synthesized by condensation of 3,4-diamino-5-nitroanisole with glyoxal-bisulfite.

3. 7-Methoxy-5-aminoquinoxaline was prepared by reduction of 7-methoxy-5-nitroquinoxaline.

4. 7-Methoxy-5-hydroxylaminoquinoxaline was synthesized by alkaline reduction of 7-methoxy-5-nitroquinoxaline.

5. A number of the properties of these four compounds are described.

BROOKLYN 2, N. Y. RECEIVED APRIL 6, 1945

The Action of Hydrogen Peroxide on Carbohydrates[1]

BY JOHN H. PAYNE[2] AND LUTHER FOSTER[3]

Simple carbohydrates, such as *d*-glucose, are known to be oxidized by hydrogen peroxide. Numerous investigators[4,5,6] have proposed reaction mechanisms based upon products isolated under various conditions of temperature, concentration, and catalysts. There have been few attempts to consider the reaction quantitatively, although Evans and co-workers[7] have made a thorough study of the quantitative oxidation of certain sugars with silver oxide.

The experimental method of Fry and Payne[8] which makes possible the quantitative correlation of the extent of the occurrence of the likely reactions with the amounts of hydrogen peroxide used, has given insight to the reaction mechanism in the case of many simple organic compounds.[9] The outstanding characteristic of the reaction of hydrogen peroxide with many of the compounds is the liberation of relatively large quantities of hydrogen. Payne and Lemon[9] demonstrated that the hydrogen did not have its source in the aldehyde group. They proposed that any compound giving formaldehyde as an intermediate product might be expected to yield hydrogen when treated with hydrogen peroxide. The quantity of hydrogen produced would depend upon the quantity of formaldehyde formed, and, as found by Fry and Payne,[8] upon the concentration of the hydrogen peroxide. Higher concentrations of hydrogen peroxide might be expected to cause more extensive oxidation and hence produce more formaldehyde. Of the two concurrent reactions

$$2HCHO + H_2O_2 \longrightarrow 2HCOOH + H_2 \quad (1)$$
$$HCHO + H_2O_2 \longrightarrow HCOOH + H_2O \quad (2)$$

however, (2) predominates at higher peroxide concentrations, so that less hydrogen would result from the formaldehyde. Thus in the case of the carbohydrates where stepwise oxidation should result in the formation of formaldehyde at the last step, the total quantity liberated depends upon both the extent of the degradation and the concentration of hydrogen peroxide present when the formaldehyde step is reached. Of course the scission of formaldehyde, as found by Evans and co-workers,[7] may occur at initial or subsequent stages.

In order to determine the extent to which the liberation of hydrogen characterizes the reaction of hydrogen peroxide with carbohydrates, a quantitative investigation was conducted with glyceric aldehyde, erythritol, *d*-arabinose, and *d*-glucose in order to complete the one to six car-

(1) The experimental work was performed while the authors were at the University of Hawaii.

(2) Pacific Chemical and Fertilizer Company, Honolulu, Hawaii.

(3) Brown University, Providence, R. I.

(4) Bernhauer and Nistler, *Biochem. Z.*, **205**, 230 (1929).

(5) Kuen, *ibid.*, **215**, 12 (1929).

(6) Kuchlin, *Rec. trav. chim.*, **51**, 887 (1932).

(7) Bush, Clark, Genung, Schroeder and Evans, *J. Org. Chem.*, 1, 1 (1936).

(8) Fry and Payne, THIS JOURNAL, **53**, 1973 (1931).

(9) Payne and Lemon, *ibid.*, **63**, 226 (1941).

TABLE I

OXIDATION BY HYDROGEN PEROXIDE

	H_2O_2, moles	Time, hr.	Percentage of H_2O_2 going to reaction products: Unused	O_2	H_2	HCOOH	CO_2	CO	Other acids	Aldehyde	Total
Glyceric aldehyde, 0.050 mole	0.0086	4.5	0	10.90	3.00	0	13.90	1.17	114.80	...	143.8
	.0525	2.5	0	5.33	7.53	22.45	9.68	2.11	75.71	...	123.0
	.1050	4	2.95	1.43	8.44	5.62	18.02	1.31	74.52	...	112.2
	.2034	5	12.28	1.59	3.79	1.91	53.21	0.63	27.03	...	100.3
	.4024	6	33.33	8.08	1.72	−1.32	53.92	.11	4.57	...	100.4
Erythritol, 0.100 mole	.1970	12	16.90	2.60	1.41	4.04	7.51	.23	13.86	50.81	97.4
	.8000	7.75	4.57	17.64	1.03	0.03	49.55	.31	16.08	12.50	101.7
	.9980	7.25	6.67	19.20	0.71	0.70	51.74	.19	9.63	10.02	98.9
d-Arabinose, 0.050 mole	.1050	7	3.05	2.86	0.81	7.05	41.90	.70	42.85	...	99.2
	.2520	14	0	1.27	1.22	3.32	69.08	.43	25.74	...	101.7
	.4960	23	0	8.83	0.57	0.92	87.45	.29	2.76	...	100.8
d-Glucose, 0.100 mole	.1990	18	19.82	1.83	1.16	4.95	41.01	.26	28.92	...	98.8
	.5015	18	15.44	1.62	0.50	1.84	61.60	.21	17.18	...	98.9
	1.0030	22	16.50	3.66	.77	−0.27	72.00	.15	7.23	...	100.0
	1.5308	28	19.56	9.45	.63	− .82	68.35	.13	1.87	...	99.2
Sucrose, 0.050 mole	0.2500	16.25	4.80	2.14	4.30	.26	32.76	.35	50.60	...	95.2
	.5000	10.5	17.52	0.76	2.21	− .15	52.38	.20	23.38	...	96.3
	.7490	19.75	5.36	1.72	1.38	− .63	76.24	.12	13.84	...	98.0
	.8730	16.5	14.04	3.53	1.17	− .28	71.81	.15	7.80	...	98.2

bon series. The oxidation of sucrose as an example of a disaccharide was also studied.

Experimental

The experimental method has been described by Payne and Lemon.[9] The hydrogen peroxide was from the same batch as described by them.

Glyceric Aldehyde.—The glyceric aldehyde was "reinst" grade obtained from Dr. Fraenkel and Dr. Landau in Berlin.

Erythritol.—The erythritol was recrystallized Eastman Kodak Co. White Label, m.p. 117–118°. This was used instead of the corresponding but unavailable 4-carbon sugar.

***d*-Arabinose.**—The *d*-arabinose was Eastman White Label.

***d*-Glucose.**—The *d*-glucose was Eastman White Label anhydrous dextrose.

Sucrose.—The sucrose sample was prepared from Hawaiian small cube cane sugar. It had an ash content of less than 0.001%, and a polarization of 99.95.

Results and Discussion

The average data from duplicate runs at varying molecular ratios of hydrogen peroxide to carbohydrate are shown in tabular form above. In this table the percentage of the total hydrogen peroxide going to the various reaction products is based upon the formaldehyde mechanism for the liberation of hydrogen. In cases where the total hydrogen peroxide going to formic acid, column 6, has a negative value, it means that formic acid has been oxidized to carbon dioxide and hence appears in column 7.

All of these compounds show the same reaction products, namely, hydrogen, carbon dioxide, formic acid, and small amounts of carbon monoxide. Other acids included in every case glycolic acid, and glyoxalic acid was found qualitatively in all runs except those with erythritol. In no instance was oxalic, lactic, or tartaric acid present. Formaldehyde was present always in small quantities, and pentoses were found in the *d*-arabinose, *d*-glucose, and sucrose reaction mixtures.

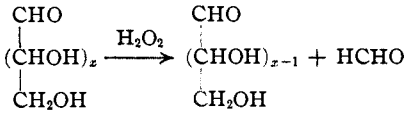
The amount of hydrogen produced increases with the concentration of hydrogen peroxide at first, and then decreases in the same manner for each compound. This would be expected, as stated previously, as higher concentrations of hydrogen peroxide favor reaction (2). The formaldehyde mechanism calculations account for close to 100% of the hydrogen peroxide used in the case of all compounds except glyceric aldehyde. Here there is the surprising apparent total of 143.8% of the hydrogen peroxide accounted for at the lowest concentration. More moles of acid were formed than there were moles of hydrogen peroxide present. The runs were repeated several times with the same results. There was no acid in the original glyceric aldehyde, and no air was in the system. In a check experiment no acid was produced by heating the glyceric aldehyde in water solution in the absence of air for four hours. A possible explanation is that a dismutation reaction is taking place under conditions of low concentration of hydrogen peroxide. Attempts to isolate a reduction product such as glycerol failed however, as did attempts to bring about a similar dismutation with other aldehydes. Significant however is the fact that at higher concentrations of hydrogen peroxide the total accounted for is no more than 100%. If dismutation has occurred the reduction product is oxidized under the conditions of higher concentration.

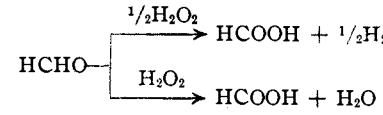
Erythritol behaved quite normally. In the calculations it was assumed that all of the erythritol was first oxidized to erythrose. *d*-Arabinose was much more slowly oxidized than the lower

compounds. The liberation of hydrogen is characteristic, although the quantities formed were relatively small. *d*-Glucose is likewise only slowly oxidized by the hydrogen peroxide. There is some indication that the hydrogen peroxide is stabilized by the glucose.

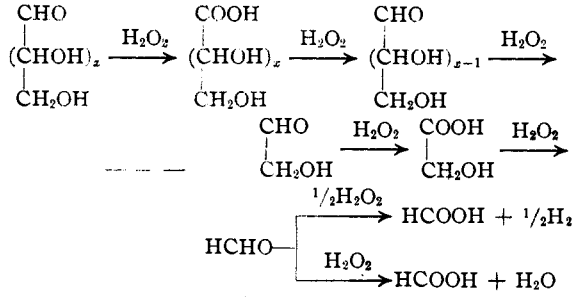
The reaction with sucrose is characterized by a much greater speed than with *d*-arabinose, or *d*-glucose. Hydrogen is evolved likewise in much greater quantities. A darkening of the reaction mixture occurred when low concentrations of hydrogen peroxide were used. This was not true at higher concentrations. No doubt the fructose portion of the molecule is more susceptible to attack than the glucose portion.

The evidence presented here indicates that the liberation of hydrogen is characteristic of the action of hydrogen peroxide on carbohydrates. The origin of the hydrogen in the formaldehyde produced by scission or in the last step of the degradation offers a satisfactory mechanism based on previous evidence that hydrogen is not set free from the peroxide itself, from the aldehyde group, or from carbon atoms in the alpha position to the aldehyde group. The scission reaction would proceed according to the general scheme





Stepwise degradation giving formaldehyde in the final step would be as follows



Summary

A quantitative investigation of the action of hydrogen peroxide on glyceric aldehyde, erythritol, *d*-arabinose, *d*-glucose, and sucrose, shows that hydrogen is a characteristic reaction product in every case. A satisfactory reaction mechanism places the origin of the hydrogen in formaldehyde produced in the oxidative degradation of the compounds.

Glyceric aldehyde apparently undergoes a dismutation reaction in the presence of low concentrations of hydrogen peroxide.

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[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY OF WESTERN KENTUCKY STATE TEACHERS COLLEGE]

A Study of Certain Brominated Derivatives of Oxindole

BY WARD C. SUMPTER, MARION MILLER AND LAURA NELL HENDRICK

The bromination of certain N-substituted oxindoles has been investigated by Stollé and co-workers.[1] These investigators found that the bromination of N-substituted oxindoles in aqueous solution yielded derivatives with bromine substituted in position 5 when one molecular proportion of bromine was employed and in positions 5 and 7 when two molecular proportions of bromine were used. On the other hand, the bromination of the N-substituted oxindoles in anhydrous carbon tetrachloride gave the 3,3-dibromo derivatives of the oxindole employed.

No similar study of the bromination of oxindole itself has been reported. Baeyer and Knop[2] reported the preparation of a monobromoöxindole through the action of bromine water on an aqueous solution of oxindole and a tribromoöxindole through the action of excess bromine on an aqueous solution of oxindole. Baeyer and Knop reported the m. p. of their monobromoöxindole as 176°. The preparation was repeated by Henze and Blair,[3] who found the m. p. to be 220–221° but did not determine the structure of the compound. Baeyer and Knop reported that their tribromoöxindole did not melt but decomposed on heating without melting. That this observation was also in error will appear in the Experimental Part.

This investigation was undertaken with the end in view of determining the structure of the two derivatives prepared by Baeyer and Knop and of determining whether the bromine atoms could be directed to the benzene or to the pyrrole ring by choice of solvent in the manner accomplished by Stollé and his co-workers in the case of the N-substituted oxindoles.

To this end a solution of oxindole (I) in water was treated with a solution of one molecular proportion of bromine in aqueous potassium bromide. The product was the monobromoöxindole, m. p. 220–221°, described by Henze and Blair. That this compound is 5-bromoöxindole (II) was shown

(1) Stollé, Bergdoll, Luther, Auerhahn and Wacker, *J. prakt. Chem.*, **128**, 1 (1930).

(2) Baeyer and Knop, *Ann.*, **140**, 1 (1866).

(3) Henze and Blair, THIS JOURNAL, **55**, 4621 (1933).