

[CONTRIBUTION FROM THE SCHOOL OF CHEMISTRY OF THE UNIVERSITY OF MINNESOTA]

**THE OXIDATION OF THE TRIBROMO AND TRICHLORO  
DERIVATIVES OF PYROGALLOL-1,3-DIMETHYL ETHER<sup>1</sup>**

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It was recognized early in the work on the decompositions of halogenated phenol salts,<sup>2</sup> that the univalent oxygen radicals  $C_6H_2X_3O-$  (Type A) postulated as the first state of the reacting ring should also be obtained by dehydrogenation of the phenol hydroxyl, and that the doubly unsaturated radicals  $-C_2H_2X_2O-$  (Type B) postulated as formed spontaneously in the second stage, should result equally from the first stage, whether this was formed from the salt or by oxidation of the phenol. The appearance of the important work of Pummerer and others on the oxidation of phenols, prevented any investigation along this line, until it became evident that no work was being done on halogenated phenols such as ours.

The problem was then attacked in this Laboratory, as its solution promised information on the most striking phenomenon connected with the behavior of the halogenated phenol ring, namely, the loss of halogen from the *para* (or *ortho*) position, with formation of radicals of Type B. Now, the 1,3-dimethyl ether of pyrogallol is the best known example of the small class of phenols which on oxidation lose *para* hydrogen, with the formation of diphenoquinones.<sup>3</sup> Accordingly, one of the first phenols chosen for investigation was the tribromo derivative of this di-ether.

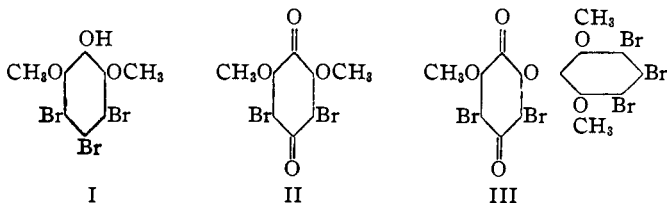
The investigation of its oxidation has resulted in the discovery of a new class of phenol oxidation products whose existence could not be predicted by any theory of a double attack on the ring and at the phenol hydroxyl. On the other hand, it is readily accounted for on the basis of the formation of radicals of Type A and Type B, as will be shown below. A further point of interest is that the replacement of the ring hydrogens by halogen atoms changed the character of the products entirely, no diphenyl derivatives analogous to cedriret being isolated.

Thus the tribromopyrogallol-1,3-dimethyl ether (I) yielded two main products: 3,5-dibromo-2,6-dimethoxy-*p*-benzoquinone (II) and 2-(2',6'-dimethoxy - 3',4',5' - tribromophenoxy) - 3,5 - dibromo - 6 - methoxy - *p* - benzoquinone (III).

<sup>1</sup> The work described in this paper formed part of a thesis submitted to the Graduate Faculty of the University of Minnesota by Arthur A. Levine in partial fulfillment of the requirements for the degree of Doctor of Philosophy, June, 1923.

<sup>2</sup> Hunter and others, *THIS JOURNAL*, **38**, 1761 (1916); **39**, 2640 (1917); **43**, 131, 135, 151 (1921). Woollett, *ibid.*, **38**, 2474 (1916).

<sup>3</sup> The formation of cedriret (coerulignone) by the oxidation of pyrogallol-1,3-dimethyl ether can be easily explained as a result of the union of two residues of Type B. This point will be discussed at a later time.



The trichloro derivative yielded exactly analogous products. In addition, chromium trioxide in warm 50% acetic acid yielded a small amount of a colorless material, which is now being studied in this Laboratory.

A variety of oxidizing agents was used, and the products formed in each case are indicated in Table I.

TABLE I  
USING PHENOL I

Oxidizing Agent	Product	Yield, % (approx.)
CrO <sub>3</sub> in glacial acetic acid	II	30
CrO <sub>3</sub> in 50% acetic acid	III	40
CrO <sub>3</sub> in 50% acetic acid (60°)	III (II tr.) <sup>a</sup>	40
PbO <sub>2</sub> in glacial acetic acid	III (II tr.)	60
NaNO <sub>2</sub> in glacial acetic acid	III	25
PbO <sub>2</sub> in dry benzene	III	70

<sup>a</sup> Colorless product in small amount.

The mononuclear quinones were easily identified, as the bromine derivative (II) had previously been made by Will,<sup>4</sup> and its chlorine analog had been made by Graebe and Hess.<sup>5</sup>

The phenoxyquinone III represents the new type of phenol oxidation product, the chlorine analog of which was also obtained. From the elementary analyses, and determination of methoxyl and quinoid oxygen, it was evident that the constitution must be either that of Formula III or that of the *o*-quinonoid isomer, with the phenoxy group in the *para* position. Since it has been shown by Jackson<sup>6</sup> and his students that halogenated *o*-quinones react with alcohols and with water, these reagents were used on our materials, but without effect. Accordingly, it was decided that the *p*-quinoid formula best represented the facts.

### Mechanism of the Reaction

If it is assumed, in accordance with the evidence presented by Pummerer,<sup>7</sup> that the first effect of oxidizing agents on a phenol is the de-

<sup>4</sup> Will, *Ber.*, **21**, 608 (1888).

<sup>5</sup> Graebe and Hess, *Ann.*, **340**, 232 (1905).

<sup>6</sup> Jackson and Porter, *Am. Chem. J.*, **31**, 89 (1903). Jackson and Carlton, *ibid.*, **34**, 422 (1905). Jackson and MacLaurin, *ibid.*, **38**, 127 (1907). Jackson and Flint, *ibid.*, **39**, 80 (1908).

<sup>7</sup> Pummerer and others, *Ber.*, **47**, 1472, 2957 (1914); *Ber.*, **52**, 1404, 1411 (1919); *Ber.*, **55B**, 3116 (1922).

hydrogenation of the hydroxyl, then the first product obtained from the brominated ether should be this univalent oxygen radical designated below as Radical A.

Now, according to the views developed during the work on the decompositions of halogenated phenol salts, such a radical should decompose spontaneously to the new radicals designated as Radical B, *para*, and Radical B, *ortho*. The *para* radical would have a free valence on the oxygen and on the *para* carbon; the *ortho* radical, on the oxygen and on the *ortho* carbon.

In the absence of oxidizing agents, these radicals of the B type would proceed to saturate each other, giving the polyphenylene oxides of the general formula  $(C_6H_2X_2O)_n$ .<sup>2</sup> In the presence of oxidizing agents, it would be expected that unsaturated radicals of this type would take up oxygen at the trivalent carbon atom. Unless one of these two actions was very much more rapid than the other, they should appear as concurrent reactions, but the stronger the oxidizing conditions, the greater would be the amount of B radical oxidized to mononuclear products, before addition occurred.

In the light of our experimental results, such seems indeed to be the case. A reference to the table shows that the strongest oxidizing agent used, chromium trioxide in glacial acetic acid, gave as the only obtainable product, a 30% yield of the mononuclear *p*-quinone from the brominated ether. It also gave a 40% yield of the analogous *p*-quinone, from the chlorinated ether. This must have resulted on our hypothesis, from a direct oxidation of the *para* radical B. The low yield, and the entire failure to obtain *o*-quinones in any experiment, lead to the supposition that the *ortho* radical is more active, and is broken down by chromic acid into smaller fragments. This idea is borne out by the fact that in the presence of weaker oxidizing agents, the *ortho* radical seems to appear as the phenoxyquinone III. This should be the case, if addition occurs before destruction by oxidation can take place.

### Experimental Part

**Syringic Acid.**—This was made by a modification of the method of Graebe and Martz.<sup>8</sup> Fifty g. of 3,4,5-trimethoxybenzoic acid, made according to the directions of the authors cited above, was heated for two hours on the steam-bath with 150 cc. of 48% hydrobromic acid. On cooling, the contents of the flask solidified.

At this point Graebe and Martz recommend extraction of the syringic acid by means of chloroform. Instead, in our procedure water was added to the reaction product until the concentrated acid was diluted sufficiently to allow easy filtration, and the syringic acid obtained was recrystallized

<sup>8</sup> Graebe and Martz, *Ann.*, **340**, 219 (1905).

from water. In this way was obtained an average yield of 75% of pure syringic acid melting at 204°.

**Pyrogallol-1,3-dimethyl Ether.**—The syringic acid in convenient amount was heated in a distilling flask to 240° until the evolution of carbon dioxide had ceased, as directed by Graebe and Hess.<sup>5</sup> At this point the temperature was raised to 256°, whereupon the ether distilled. After a second distillation, a yield of 70% of solid ether was obtained, sufficiently pure for bromination.

**4,5,6-Tribromopyrogallol-1,3-dimethyl Ether.**—Forty-six g. of the 1,3-dimethyl ether was dissolved in 250 cc. of carbon disulfide and the solution cooled with ice and salt. It was then treated little by little with 48 cc. of bromine previously dried over sulfuric acid.

After all of the bromine had been added the red solution was concentrated to one-half its volume. A first crop of colorless crystals separated and on further concentration a second crop was obtained, which was pure enough to mix with the first. On recrystallization from hot alcohol by adding water, long needle-like crystals resulted, soluble in the usual solvents, except water and ligroin; m. p., pure, 133.5°.

*Anal.* Calcd. for  $C_8Br_3(OCH_3)_2OH$ : Br, 61.35. Found: 61.22, 61.15.

**SODIUM SALT.**—Ten g. of the tribromo ether was dissolved in 20 cc. of 10% sodium hydroxide solution, with the aid of heat. On cooling, colorless scale-like crystals separated, which were recrystallized from water, washed with dil. alcohol, and dried in the air. It proved to contain four molecules of water of crystallization; it was very soluble in water, and very slightly so in alcohol and ether.

*Anal.* Calcd. for  $C_8Br_3(OCH_3)_2ONa \cdot 4H_2O$ :  $H_2O$ , 15.48. Found: (loss at 150°) 15.32.

Anhydrous salt. Calcd. for  $C_8Br_3(OCH_3)_2ONa$ : Br, 58.08. Found: 57.47.

**Benzoate of 4,5,6-Tribromopyrogallol-1,3-dimethyl Ether.**—Three g. of the sodium salt, 4 cc. of benzoyl chloride and 20 cc. of 10% sodium hydroxide solution were digested on the steam-bath until no odor of benzoyl chloride remained. On filtering off the precipitate, washing and recrystallizing it from dil. alcohol, colorless scale-like crystals were obtained, melting at 129–130°; it was soluble in the ordinary solvents, except water and ligroin.

*Anal.* Calcd. for  $C_{18}H_{11}O_4Br_3$ : Br, 48.45. Found: 48.66.

**ACETATE.**—The ether was acetylated by an excess of acetyl chloride, with the addition of a drop of concd. sulfuric acid; scale-like crystals were obtained from dil. alcohol, melting at 113–114°, and insoluble in water but soluble in the ordinary organic solvents.

*Anal.* Calcd. for  $C_{10}H_9O_4Br_3$ : Br, 55.39. Found: 55.66.

**4,5,6-Trichloropyrogallol-1,3-dimethyl Ether.**—Ten g. of the pyrogallol-dimethyl ether was dissolved in 75 cc. of carbon disulfide, and dried chlorine was passed into the solution until it had gained the calculated amount, 6.9 g. At this time the evolution of hydrogen chloride had almost ceased. The chlorinated phenol was then isolated in the same way as its brominated analog. It crystallizes in long, colorless needles from dil. alcohol; m. p., 121.5°. It is soluble in the usual solvents except water.

*Anal.* Calcd. for  $C_8H_7O_3Cl_3$ : Cl, 41.31. Found: 41.23.

Its benzoate and acetate were made as were those of the tribromo derivative.

**BENZOATE.**—This formed colorless scales from dil. alcohol; m. p., 103–104°.

*Anal.* Calcd. for  $C_{18}H_{11}O_4Cl_3$ : Cl, 29.44. Found: 29.60.

**ACETATE.**—This was obtained as colorless plates from dil. alcohol; m. p., 102–103°.

*Anal.* Calcd. for  $C_{10}H_9O_4Cl_2$ : Cl, 35.54. Found: 35.57.

### Oxidation Experiments

**A. Oxidation of the Tribromopyrogallol-1,3-dimethyl Ether.** 1. **By Chromium Trioxide in Glacial Acetic Acid.**—Two g. of the ether was dissolved in 100 cc. of glacial acetic acid, and the solution was treated with 1.5 g. of chromic trioxide. After two hours the deep red solution was filtered from a precipitate, apparently of chromic oxide, and poured into 400 cc. of water. A reddish-yellow solid precipitated, which was filtered off when its amount no longer increased; yield, 0.6 g. of crude material, or 40%. On crystallization from glacial acetic acid, it appeared as beautiful red scales; m. p., 175°. This was identified as 2,6-dimethoxy-3,5-dibromo-*p*-benzoquinone. (II. See below.) No other products could be isolated.

2. **By Chromic Trioxide in 50% Acetic Acid.**—Five g. of the ether was dissolved in 200 cc. of 50% acetic acid, and treated with 3 g. of chromic oxide. In a few minutes a red, flocculent precipitate appeared, which was filtered off and recrystallized several times from glacial acetic acid. It then appeared as fine, red needles, melting at 214°. The yield of crude product was 40%. It was identified as (2',6'-dimethoxy-3',4',5'-tribromophenoxy)3,5-dibromo-6-methoxy-*p*-benzoquinone. (III. See below.)

On dilution of the filtrate, about 20% of the original ether was recovered unchanged. It was identified by its melting point after recrystallization from dil. alcohol, and by an analysis for bromine.

No further materials could be isolated, in the cold reaction, but if the reaction was run at 50–60°, a colorless substance was obtained from the filtrate by dilution, which on recrystallization from dil. alcohol weighed 0.5 g.; m. p., 198–199°. It will be further investigated in this Laboratory, as its structure is still uncertain.

Extraction of the filtrate from this substance in turn yielded a few centigrams of the 2,6-dimethoxy-dibromoquinone II melting at 175°.

3. **By Lead Dioxide in Glacial Acetic Acid.**—Four g. of the dimethyl ether was dissolved in 100 cc. of glacial acetic acid. To this solution was added little by little, during shaking, 5 g. of powdered lead dioxide. Lead bromide immediately precipitated, and a red color appeared. The solution was allowed to stand for 30 minutes and filtered.

The filtrate continued to yield precipitated lead bromide, but without waiting for this action to cease, 100 cc. of water was added. A very light colored precipitate formed, which was recovered and dried in an oven at 60°. It then appeared as a deep red, gummy material which was crystallized from glacial acetic acid. It proved to be the phenoxyquinone III.

A small amount of the mononuclear quinone II was obtained from the filtrate.

4. **By Sodium Nitrite in Glacial Acetic Acid.**—One g. of the ether was dissolved in 25 cc. of glacial acetic acid, and 0.4 g. of sodium nitrite was then added, little by little. Oxides of nitrogen were evolved. The mixture was allowed to stand for 20 minutes. On the addition of 100 cc. of water, a 26% yield of the phenoxyquinone III appeared, which required only a single crystallization for its complete purification.

This procedure is the best for the preparation of small amounts of the phenoxyquinone, as no other products can be isolated, and the material is very nearly pure on precipitation. The proportions given and the time must be closely adhered to, as a longer time or a larger amount of nitrite diminishes the yield. For instance, the use of 1.4 g. of nitrite, other materials being constant, prevented the isolation of any phenoxyquinone whatsoever.

5. **By Lead Dioxide in Benzene.**—Seven g. of the dimethyl ether was dissolved in 250 cc. of dry benzene. To this solution were added 10 g. of anhydrous sodium sulfate and

12 g. of lead peroxide. The mixture was allowed to stand for four hours and frequently shaken. It was then filtered, and the deep red filtrate was concentrated to about 40 cc. On the addition of ligroin about 5 g. of crystalline phenoxyquinone III was obtained.

**B. Oxidation of 4,5,6-Trichloropyrogallol-1,3-dimethyl Ether. 1. By Chromium Trioxide in Glacial Acetic Acid.**—One g. of the trichlorodimethyl ether was dissolved in 50 cc. of glacial acetic acid, and the solution treated with 0.6 g. of chromium trioxide. By the method outlined, 0.4 g. of 3,5-dichloro-2,6-dimethoxy-*p*-benzoquinone was obtained as red scales; m. p., 155.5°.

**2. By Chromium Trioxide in 50% Acetic Acid at 50–60°.**—One g. of the trichlorodimethyl ether was dissolved in 150 cc. of 50% acetic acid, and warmed to 60°; 0.6 g. of chromium trioxide was then added, whereupon about 0.5 g. of the 2-(trichlorophenoxy)-3,5-dichloro-6-methoxyquinone precipitated. On crystallization from glacial acetic acid, it formed minute, deep red needles; m. p., 211°.

A white substance was obtained in small amount, on diluting the filtrate, apparently analogous to that obtained from the bromine analog.

**C. Investigation of the Oxidation Products. II. 2,6-Dimethoxy-3,5-dibromoparabenzquinone.**—This material crystallized from glacial acetic acid in fine, red plates, melting at 174°. On analysis, it proved to be identical with the substance of this melting point obtained by Will<sup>4</sup> by the direct bromination of 2,6-dimethoxyquinone.

*Anal.* Calcd. for  $C_8H_6O_4Br_2$ : Br, 49.05. Found: 49.23, 49.27.

It was further identified by reduction with sulfur dioxide in acetone and water to the hydroquinone, which melted at 158°, as described by Will.

**DIACETATE.**—This formed pearly plates from dil. alcohol; m. p., 100–101°.

*Anal.* Calcd.: Br, 38.84. Found: 39.20.

**III. 2-(2',6'-Dimethoxy-3',4',5'-tribromophenoxy)-3,5-dibromo-6-methoxyparabenzquinone.**—This substance is most easily obtained by oxidizing the tribromo-ether in dry benzene with lead dioxide, as described above.

*Anal.* Calcd. for  $C_{18}H_{14}O_6Br_8$ : C, 26.39; H, 1.32; Br, 58.36. Found: C, 26.43, 26.25; H, 1.49, 1.74; Br, 58.08, 58.25.

Its molecular weight was determined cryoscopically in benzene ( $K = 5000$ ), and in ethylene dibromide ( $K = 11,800$ ) but its low solubility prevented a satisfactory depression.

*Mol. wt.* Solvent: ethylene dibromide, 55.1; benzene 27.9. Subs., 0.0755; 0.0650.  $\Delta t$ , 0.026°, 0.020°. Calcd. for  $C_{18}H_{14}O_6Br_8$ : 685. Found: 481, 585.

*Quinoid oxygen* was determined by titration with titanous chloride, and by the hydrazine method of Hunter and Woollett.<sup>9</sup>

Calcd. for  $C_{18}H_{14}O_6Br_8$ : quinoid O: 4.67. Found: 4.61, 4.77, 4.40, 4.58.

*Methoxyl.*—The Zeisel method, as modified by Hewitt and Moore, was used.<sup>10</sup>

Calcd. for  $C_{18}O_8Br_8(OCH_3)_3$ :  $OCH_3$ , 13.60. Found: 13.42.

*Properties.*—The substance formed minute, red needles, melting at 214°, slightly soluble in organic solvents except ligroin. It is not affected by methyl alcohol or ethyl alcohol, but is decomposed by concd. sulfuric acid. It crystallizes from glacial acetic acid, but separates from benzene as a varnish.

**HYDROQUINONE OF III.**—Ten g. of the phenoxyquinone was suspended in 200 cc. of acetone containing 10 cc. of water. Sulfur dioxide was passed in until the solution was decolorized and all of the solid had disappeared. On concentrating to about 50 cc., an oil separated, which could not be brought to crystallization. It was readily recon-

<sup>9</sup> Hunter and Woollett, *THIS JOURNAL*, **43**, 147 (1921).

<sup>10</sup> Hewitt and Moore, *J. Chem. Soc.*, **81**, 318 (1902).

verted to the quinone by chromium trioxide, lead dioxide, or sodium nitrite in acetic acid. It was easily converted into a crystalline diacetate

**ACETATE OF THE HYDROQUINONE.**—An excess of acetyl chloride was added to the oil, together with a drop of concd. sulfuric acid. The mixture was warmed on the steam-bath until the reaction was complete, when the excess of acetyl chloride was distilled. The residue crystallized from dil. acetic acid as microscopic, white plates; m. p., 150.5–151.5°.

*Anal.* Calcd. for  $C_{18}H_{18}O_8Br_6$ : Br, 51.84. Found: 51.37, 51.47.

**IV. 3,5-Dichloro-2,6-dimethoxy-*p*-benzoquinone.**—This substance had been prepared by Graebe and Hess<sup>8</sup> by direct chlorination of the 2,6-dimethoxyquinone. It was identified by its melting point, 155.5°, by reduction to the hydroquinone, also prepared by Graebe and Hess, m. p. 157–158°, and by analysis.

*Anal.* Calcd. for  $C_8H_6O_4Cl_2$ : Cl, 29.92. Found: 30.05.

**DIACETATE OF THE HYDROQUINONE.**—This formed pearly plates from dil. alcohol; m. p., 75°.

*Anal.* Calcd.: Cl, 21.96. Found: 21.87.

**V. 2 - (2',6' - Dimethoxy - 3',4',5' - trichlorophenoxy) - 3,5 - dichloro - 6 - methoxy-*p*-benzoquinone.**—This substance, the chlorine analog of III, crystallizes from glacial acetic acid in small, deep red needles; m. p., 211°. Its properties are very similar to those of the bromine compound. It is readily reduced by sulfur dioxide in moist acetone.

*Anal.* Calcd. for  $C_{18}H_8O_8Cl_6$ : Cl, 39.34. Found: 38.06.

### Summary

1. The oxidation of the tribromo derivative of the 1,3-dimethyl ether of pyrogallol yields no diphenyl derivatives corresponding to cediret.

2. Instead, there are formed a mononuclear *p*-benzoquinone, and a dinuclear substance, in which there appears a phenoxy group corresponding to the phenol.

3. The oxidation is explained as occurring in three stages: first, the dehydrogenation of the phenol hydroxyl; second, the spontaneous formation of the free radicals of the types indicated by previous work; third, these are oxidized to the final products.

4. The trichloro derivative behaves in an entirely analogous manner.

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