

The Chemistry of Tea

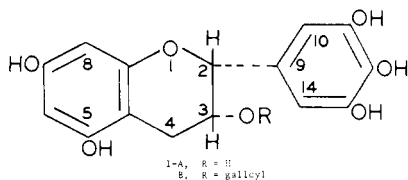
Structures of Compounds A and B of Roberts and Reactions of Some Model Compounds

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Nuclear magnetic resonance spectral evidence for the constitution of bisflavanols A and B of black tea is presented. Such evidence is in agreement with the structures originally proposed by Roberts (II-A and II-B, respectively). Results of a study of oxidation reactions of some 5-mono-, 4,5-di-, and 4,5,6-tri-substituted pyrogallols are reported;

in all cases compounds having a tricyclododecane structure result. 4,5-Dimethylpyrogallol by oxidation yields only one (III-D) of the three possible isomeric oxidation products. Reaction paths established for pyrogallols and variously substituted pyrogallols under a number of oxidizing conditions are also reported.

Understanding of the complex chemical reactions that occur during the conversion of tea leaves into the black tea of commerce is being sought via two distinct approaches. The first consists of the study of some end products of tea fermentation and has led to the structure of theaflavin (Brown *et al.*, 1966; Takino *et al.*, 1965, 1966), an important orange-red pigment of black tea. The second approach is based on an investigation of chemical and enzymatic oxidation reactions of simple model compounds, and may shed some light on reaction paths possible for (-)-epigallocatechin (I-A) and its gallate ester (I-B) as well as for some other polyphenols which are either present in unfermented tea leaves or formed during the fermentation step. The epigallocatechins are the most abundant polyphenolic constituents of unfermented tea leaves and relatively minor constituents of black tea (Roberts, 1962).

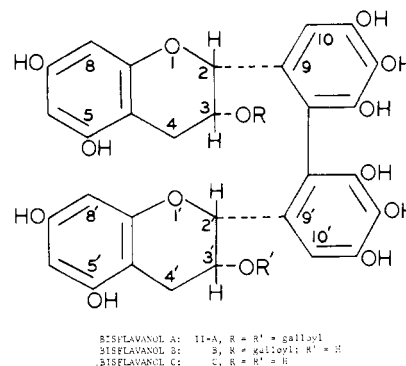


The purpose of this paper is to clarify the structure of two colorless polyphenols which have been postulated to be important intermediates in the formation of thearubigins (brown-red pigments of tea) (Roberts, 1961), as well

as to report the results of a study of oxidation reactions of some 5-mono-, 4,5-di-, and 4,5,6-tri-substituted pyrogallols. Recent work on the oxidation of pyrogallol itself and of simple 4- and 5-monosubstituted and 4,6-disubstituted pyrogallols has been reported from other laboratories (Critchlow *et al.*, 1967; Teuber *et al.*, 1966).

STRUCTURE OF COMPOUNDS A AND B OF ROBERTS

In the course of an extensive chromatographic investigation of the polyphenols of black tea (Vuataz and Brandenberger, 1961), the Nestlé group isolated three substances (compounds A, B, and C) for which Roberts had previously postulated structures II-A, B, and C, respectively (Roberts, 1958, 1961; Roberts and Myers, 1959). However, the question of whether these were the correct structures remained unsettled.



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A gift of milligram amounts of compounds A and B from the Nestlé group has now permitted us to obtain their nuclear magnetic resonance (NMR) spectra, and to show that they are consistent with the structures originally postulated by Roberts (1961) for these compounds. The pertinent NMR data of A and B, as well as of (-)-epigallocatechin (I-A) and (-)-epigallocatechin gallate (I-B),

Table I. NMR Spectral Data of Compounds A and B, (-)-Epigallocatechin, and (-)-Epigallocatechin Gallate^a

Compound	Absorption, δ	<i>J</i> , c./s.	Relative Intensity Found and (Calcd.)	Assignment of Proton
Bisflavanol A ^b (II-A)	2.50(d)	18	2(2)	C-4(ax) and C-4'(ax)
	2.86(d)	18	2(2)	C-4(eq) and C-4'(eq)
	4.73(s)	...	2(2)	C-2 and C-2'
	5.33(m)	...	2(2)	C-3 and C-3'
	5.90(d)	2.3} AB	2(2)	C-6 and C-6' or C-8 and C-8'
	5.99(d)	2.3} syst.	2(2)	C-6 and C-6' or C-8 and C-8'
	6.95(s)	...	2(2)	C-10 and C-10'
	7.02(s)	...	4(4)	Aromatic galloyl ^c
	7.10-8.60(broad) ^d	...	17(16)	Phenolic OHs
	1.10(t)	7	e	Et ₂ O methyl
3.40(q)	7	e	Et ₂ O methylene	
Bisflavanol B (II-B)	2.38(d)	15	2(2)	C-4(ax) and C-4'(ax)
	2.69(d)	15	2(2)	C-4(eq) and C-4'(eq)
	4.61(s)	...	1(1)	C-2 or C-2'
	4.78(s)	...	1(1)	C-2 or C-2'
	4.07(m)	...	1(1)	C-3'
	5.33(m)	...	1(1)	C-3
	5.85(d)	2.2	1(1)	C-6 and C-8 or C-6' and C-8' (AB system)
	5.96(d)	2.2	1(1)	
	5.94(d)	2.2	1(1)	C-6 and C-8 or C-6' and C-8'
	6.01(d)	2.2	1(1)	(AB system)
	6.82(s)	...	1(1)	C-10 or C-10'
	6.92(s)	...	1(1)	C-10 or C-10'
	6.97(s)	...	2(2)	Aromatic galloyl
7.10-8.60(broad)	...	13(13)	Phenolic OHs	
3.45(broad)	...	f	Alcoholic OH (at C-3')	
Bisflavanol B ^b (II-B)	2.37(d)	19	2(2)	C-4(ax) and C-4'(ax)
	2.68(d)	19	2(2)	C-4(eq) and C-4'(eq)
	4.57(s)	...	1(1)	C-2 or C-2'
	4.75(s)	...	1(1)	C-2 or C-2'
	5.32(m)	...	1(1)	C-3 ^g
	6.00(d)	2.3	1(1)	C-6 and C-8 or C-6' and C-8' (AB system)
	5.85(d)	2.3	1(1)	
	6.00(d)	2.3	1(1)	C-6 and C-8 or C-6' and C-8'
	5.92(d)	2.3	1(1)	(AB system)
	6.94(s)	...	1(1)	C-10 or C-10'
	6.96(s)	...	1(1)	C-10 or C-10'
7.04(s)	...	2(2)	Aromatic galloyl	
(-)-Epigallocatechin (I-A)	2.82(m)	...	2(2)	C-4
	4.22(m)	...	1(1)	C-3
	4.84(s)	...	1(1)	C-2
	5.93(d)	2.5} AB	1(1)	C-6 or C-8
	6.04(d)	2.5} syst.	1(1)	C-6 or C-8
	6.61(s)	...	2(2)	C-10 and C-14
	3.50	...	h	Alcoholic OH (at C-3)
7.50-8.80(broad)	...		Phenolic OHs	
(-)-Epigallocatechin gallate (I-B)	2.98(m)	...	2(2)	C-4
	5.08(s)	...	1(1)	C-2
	5.55(m)	...	1(1)	C-3
	6.05(s) ⁱ	...	2(2)	C-6 and C-8
	6.63(s)	...	2(2)	C-10 and C-14
	7.06(s)	...	2(2)	Aromatic galloyl
	7.60-8.60(broad)	...		Phenolic OHs

^a All spectra recorded in acetone-*d*₆ at 25°, and expressed as parts per million (δ) from tetramethylsilane (internal reference). Multiplicity in parenthesis: s = singlet, d = doublet, t = triplet, q = quadruplet, m = multiplet.

^b Spectrum determined after addition of D₂O.

^c Aromatic protons in ethyl gallate appear at 7.10 p.p.m. (Ferretti, 1967).

^d Determined before addition of D₂O.

^e Integral curve shows about 1/2 molecule of ether associated with one molecule of bisflavanol.

^f Partially overlapping H₂O signal.

^g Signal of proton at C-3', expected to be found around 4.1 p.p.m., is hidden by HDO broad band.

^h Signal partially overlaps H₂O band.

ⁱ Apparently, two protons at C-6 and C-8 show identical chemical shift.

which served as model compounds, are given in Table I.

In the spectrum of compound A, equivalence of the C-2 with the C-2' proton, of the C-3 with the C-3' proton, and of the C-10 with the C-10' proton is in agreement with the postulated symmetry of the molecule. The C-2 and C-2' protons' resonance is a singlet: Coupling with the vicinal proton is small, consistent (Bhacca and Williams, 1964) with the expected dihedral angle near 60° (cis stereochemistry) (Clark-Lewis and Jackman, 1961; Clark-Lewis *et al.*, 1964). The two pairs of aromatic protons at C-6, C-8 and C-6', C-8' form two coincident AB patterns at 5.90 and 5.99 p.p.m. ($J_{AB} = 2.3$ c./s.). The C-4 protons appear together with the C-4' ones as a pair of doublets ($J_{gem} = 18$ c./s., four protons) centered at 2.50 and 2.86 p.p.m. The downfield signal is assigned to the equatorial protons; the signal of the axial protons at 2.50 δ shows a second-order splitting due to an axial-equatorial interaction with the C-3 (or C-3') proton. The phenolic protons give a broad irregular band between 7.10 and 8.60 p.p.m. The signals due to ether of crystallization are observed at 1.10 δ and 3.4 δ ; the integral indicates that each molecule of bisflavanol A is associated with only a half molecule of ether of crystallization.

The NMR spectrum of bisflavanol B clearly shows that this molecule is not symmetric. Specifically, the equivalence of the three pairs of protons at C-2 and C-2', C-3 and C-3', and C-10 and C-10' has disappeared, each proton giving a separate and distinct signal. Furthermore, the two pairs of aromatic protons at C-6, C-8 and C-6', C-8' give a total of seven lines recognizable as two partially overlapping AB patterns; after addition of D₂O only six distinct lines are observable because of a slight variation of the chemical shifts. Cis stereochemistry of the pyran ring is confirmed along the lines indicated above. The expected upfield shift of the C-3' proton is also observed (from 5.33 to 4.07 p.p.m.), and the alcoholic proton at C-3' shows up as a broad signal at 3.45 δ . The phenolic OH protons absorb exactly in the same frequency range as those of bisflavanol A (7.10 to 8.60 p.p.m.), and integrate exactly for 13 protons. The two aromatic protons of the galloyl moiety show up at 6.97 δ .

Attempts to obtain direct confirmation of the molecular weights of A and B via the mass spectra of their trimethylsilyl (TMS) derivatives have failed. In fact, the derivative of compound A (calculated molecular weight 2066) could

not be volatilized in the spectrometer and, even though the spectrum of the TMS derivative of B showed its highest *m/e* peaks in the area corresponding to the calculated molecular weight (1770), unequivocal reading of the exact mass of the parent peak was not possible for lack of an appropriate standard. However, the NMR evidence puts the structures of compounds A and B on a rather firm basis. The reason that A and B are present in black tea only in small amounts is unexplained. In particular, it must be determined whether the reaction leading from (–)-epigallocatechin (I-A) and its gallate ester (I-B) to A and B is only of minor significance, or whether A and B (or the corresponding quinones) (Roberts and Myers, 1959; Vuataz and Brandenberger, 1961) are transient intermediates in a reaction sequence leading from the epigallocatechins to the abundant thearubigins or to other constituents of black tea.

OXIDATION OF SIMPLE PYROGALLOLS

In a recent publication from this laboratory, Takino *et al.* (1967) reported that oxidation of 5-methylpyrogallol with either potassium ferricyanide or hydrogen peroxide–horseradish peroxidase results in high yields of a colorless carbonylic compound of empirical formula C₁₄H₁₂O₆ and of very low solubility in water and organic solvents. This contrasts with the fact that Murakami and Suzuki (1956) have postulated a noncarbonylic diphenyl structure for a supposed C₁₈H₂₂O₆ product of potassium iodate oxidation of 5-*n*-propylpyrogallol.

To clarify this point, the oxidation of 5-*n*-propylpyrogallol has been reinvestigated; with either potassium iodate or hydrogen peroxide–horseradish peroxidase, the reaction results in good yields of a nonaromatic carbonylic product. Mass spectrometry showed that its molecular weight is 332 and that its empirical formula is C₁₈H₂₀O₆, rather than C₁₈H₂₂O₆ as proposed by the Japanese authors. Furthermore, all the spectral evidence obtained clearly points to the fact that the structural skeletons of these oxidation products of 5-methylpyrogallol and 5-*n*-propylpyrogallol are identical. This is shown, in particular, by the following: Their infrared spectra are identical in the ν OH, ν C=O, and ν C=C regions with maxima at 2.90, 5.72, 5.90, and 6.19 microns; with the obvious exceptions resulting from the presence of two different alkyl substituents, their NMR spectra are identical (Table II);

Table II. NMR Spectral Data of Alkyl Hydroxybenzoquinone Dimers^a

Compound	OH	CH ₃ CO	R'	R''	R'''
III-A ^b	5.25(broad)		6.15(m)	2.22(d, $J = 2$ c./s.)	3.46(s)
III-B ^c	2.78(s)		6.15(m)	0.92(t, $J = 7$ c./s.)(CH ₃) 1.50(m)(β CH ₂) 2.65(m)(α CH ₂)	3.55(s)
III-B diacetate ^d		2.20(s)	6.23(m)	0.97(t, $J = 7$ c./s.)(CH ₃) 1.57(m)(β CH ₂) 2.53(m)(α CH ₂)	3.70(s)
III-D ^e	6.75(broad)		1.77(s)	2.17(s)	3.47(s)
III-C ^e	3.20(broad)		1.72(s)	2.00(s)	1.20(s)

^a Data expressed in parts per million (δ) from tetramethylsilane (internal reference). Multiplicity in parentheses: s = singlet, d = doublet, t = triplet, m = multiplet.

^b Spectrum determined at 100° C. in DMSO-*d*₆.

^c Determined in acetone-*d*₆.

^d Determined in CDCl₃.

^e Determined with JNM-4H-100 instrument (Japan Electron Optics Laboratory Co.) (III-C at 70° C.) in DMSO-*d*₆.

the products show an identical ultraviolet spectrum—namely, absorption at 268 and 223 $m\mu$. Finally, both products yield a diacetate, and the relationships between the spectra of the diacetates parallel those of the parent substances.

With the skeletal identity of the two products thus established, further chemical and spectroscopic studies were carried out almost exclusively with the more readily soluble oxidation product of 5-*n*-propylpyrogallol.

Interpretation of the data led us to structures III-A and III-B for the methyl and *n*-propyl compounds, respectively, in agreement with the formulations of 3-hydroxy-*o*-quinone dimer and 3-hydroxy-5-methyl-*o*-quinone dimer recently advanced by Teuber *et al.* (1966) and Critchlow *et al.* (1967), respectively. Our structural assignment was based on the following:

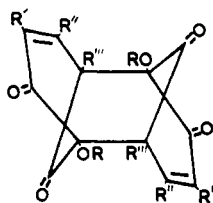
The NMR spectrum (determined at 60 Mc.) of the propyl derivative shows the presence of two chemically equivalent *n*-propyl groups, two equivalent and exchangeable OH protons, two equivalent vinylic protons, and two equivalent methine protons; the molecule must be symmetrical because the apparent equivalence of the above four groups of protons is still observed after acetylation, or after changing the solvent from dimethyl sulfoxide- d_6 (DMSO- d_6) to acetone- d_6 , and in the spectrum determined at 100 Mc. Furthermore, in the spectrum of the acetyl derivative only one signal is observed for the two acetyl methyl groups; the compound does not react with diazomethane, and by catalytic hydrogenation is readily converted into the starting pyrogallol; the two alcoholic groups must be tertiary because no α -splitting of their NMR signals is observed in DMSO (Chapman and King, 1964), and also because no downfield shift is observed of the signals (tentatively) assigned to two equivalent methines; the two vinylic protons must be attached to a trisubstituted alkene moiety because no olefinic coupling is observed; spin decoupling experiments clearly show that

$$\begin{array}{c} \text{R} \\ | \\ \text{Pr}-\text{C}=\text{C}-\text{H} \\ | \\ \text{R} \end{array}$$

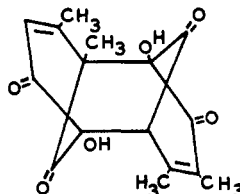
there are two equivalent Pr-C=C-H groupings;

the empirical formula ($\text{C}_{13}\text{H}_{20}\text{O}_6$) indicates that there are nine sites of unsaturation. Since there are two nonenolic hydroxyl groups and six oxygens, there must be four carbonyls. (The alternative of five cycles and two carbonyls, with two oxygens engaged in cycle formation, is not compatible with molecular symmetry.) Two of the four carbonyls are conjugated (infrared). With two double bonds (NMR) the compound must be tricyclic; the compound does not react with *o*-phenylenediamine, and its diacetyl derivative is not cleaved by periodic acid; therefore there are no α -dicarbonyl moieties in the molecule. However, since the starting material was a pyrogallol, it seems reasonable to expect that the three oxygen-containing functions, in both halves of the molecule, are consecutive. All the above experimental evidence can be accommodated only by structure III-B for the propyl and, consequently, by structure III-A for the methyl derivative.

Extension of these studies in our laboratory has shown that oxidation of 4,5,6-trimethylpyrogallol with hydrogen peroxide-horseradish peroxidase, potassium nitrosodi-



- III-A, R = R' = R''' = H; R'' = CH₃
 B, R = R' = R''' = H; R'' = *n*-C₃H₇
 C, R = H; R' = R'' = R''' = CH₃
 D, R = R''' = H; R' = R'' = CH₃
 E, R = R' = H; R'' = R''' = CH₃



III-F

sulfonate (Fremy's salt), and potassium iodate, and of 4,5-dimethylpyrogallol with the same oxidants as well as with *o*-chloranil results in products III-C and III-D, respectively, which are completely analogous to those obtained from the 5-monoalkyl-substituted pyrogallols. In the case of the 4,5-dimethyl derivative, choice among structures III-D, III-E, and III-F was possible because the NMR spectrum of the product does not show presence of vinylic protons.

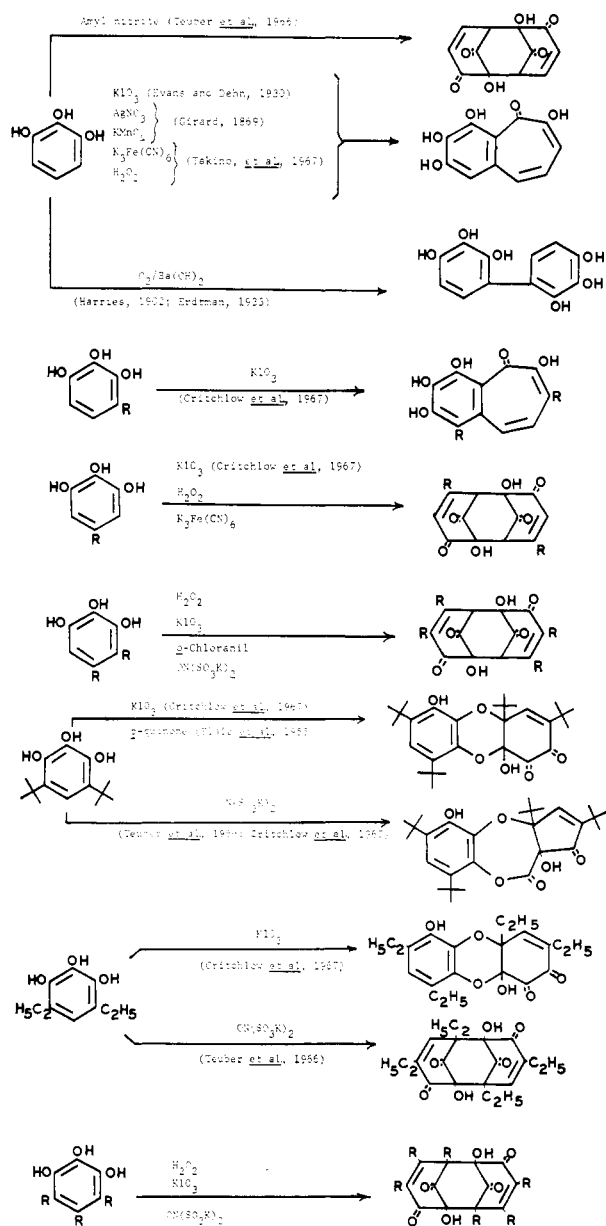
Some of the reaction paths established for pyrogallol and various alkyl substituted pyrogallols under various oxidizing conditions are summarized in Table III.

EXPERIMENTAL

Melting points were determined with a Kofler microscopic hot stage; correction was by calibration. Ultraviolet (MeOH), infrared (KBr), and mass spectra were determined with Beckman DK-2, Beckman IR-4, and CEC 21-110B instruments, respectively. Infrared data were obtained from spectra calibrated with polystyrene. Ultraviolet data were reported as obtained. The NMR spectra of compounds A and B (Table I) were run in acetone- d_6 , before and after addition of D_2O , with a Varian HA-100 spectrometer. The NMR spectra of the oxidation products of substituted pyrogallols (Table II) were determined at room temperature with a Varian A-60 spectrometer, unless otherwise specified. The ν OH, ν C=O, and ν C=C absorption frequencies in the infrared are reported for the synthetic products. Molecular weights and empirical formulas were determined by mass spectrometry.

Oxidation of 5-Methylpyrogallol. $\text{K}_3\text{Fe}(\text{CN})_6$ AS OXIDANT. A cold solution of 195 mg. of 5-methyl-pyrogallol in 15 ml. of water was treated with 4 ml. of oxidant solution prepared by dissolving 3.08 grams of $\text{K}_3\text{Fe}(\text{CN})_6$ and 0.78 gram of NaHCO_3 in 20 ml. of water. A white precipitate started to separate shortly after addition of oxidant, which was completed in 3 minutes. The crude material (77 mg.) was recrystallized from hot DMSO (quantitative recovery); [m.p. 215° C. (dec.); molecular weight found 276.0628 (calculated for $\text{C}_{14}\text{H}_{12}\text{O}_6$ 276.0634); ultraviolet: λ_{max} 268 $m\mu$ (ϵ 4500) and λ_{max} 222 $m\mu$ (ϵ 14,000); infrared: 3450, 1745, 1690, and 1615 cm^{-1}]. The aqueous mother

Table III. Modes of Oxidation of Alkyl-Substituted Pyrogallols and Pyrogallol



liquors, extracted with ethyl acetate, yielded 75 mg. of starting material contaminated with the quinone dimer.

HYDROGEN PEROXIDE-PEROXIDASE AS OXIDANT. Two hundred milligrams of 5-methylpyrogallol in 20 ml. of water was oxidized with 5 ml. of 1.2% H_2O_2 in the presence of horseradish peroxidase. The white precipitate weighed 190 mg. after recrystallization from DMSO, and had the same physical and spectral characteristics as the sample obtained using $K_3Fe(CN)_6$ as oxidant.

Oxidation of 5-n-Propylpyrogallol. HYDROGEN PEROXIDE-PEROXIDASE AS OXIDANT. One gram of 5-n-propylpyrogallol in 100 ml. of water was oxidized as above with 25 ml. of 1.2% H_2O_2 . Yield was 523 mg. after recrystal-

lization from benzene; at the Kofler hot stage it starts to decompose at $59^\circ C$. Murakami and Suzuki (1956) report melting point 178° . However, the identity of the two products has been firmly established [molecular weight found 332.1261 (calculated for $C_{18}H_{20}O_6$ 332.1260); ultraviolet: λ_{max} 268 $m\mu$ (ϵ 5900) and λ_{max} 223 $m\mu$ (ϵ 20,000); infrared: 3425, 1755, 1695, and 1615 cm^{-1}].

Identical material was obtained when the oxidation was carried out with KIO_3 essentially as previously described (Murakami and Suzuki, 1956).

Acetylation of 3-Hydroxy-5-n-propyl-o-benzoquinone Dimer. Acetylation of III-B was carried out with Ac_2O in pyridine at room temperature. The pure material, after recrystallization from ethanol, had a melting point of $210^\circ C$. (dec.) with a tendency to sublime around 195° at normal pressure [molecular weight found 416.1477 (calculated for $C_{22}H_{24}O_8$ 416.1471); infrared: 1765, 1710, and 1630 cm^{-1}].

Oxidation of 4,5-Dimethylpyrogallol. POTASSIUM NITROSODISULFONATE AS OXIDANT. An ice-cold solution of 4.72 grams of $NO(SO_3K)_2$ and 2 grams of $NaH_2PO_4 \cdot H_2O$ in 200 ml. of water was added to a vigorously stirred solution of 1.232 grams of 3,4-dimethylpyrogallol in 20 ml. of ether. After $1/2$ hour the reaction mixture was extracted with $CHCl_3$, and the combined organic extracts were dried and evaporated to dryness. The crude residue, after two crystallizations from acetone, yielded 160 mg. of pure product (III-D) [m.p. $203^\circ C$. (dec.); molecular weight found 304.0932 (calculated for $C_{16}H_{16}O_8$ 304.0947); ultraviolet: λ_{max} 271 $m\mu$ (ϵ 7800) and λ_{max} 228 $m\mu$ (ϵ 15,600); infrared: 3450, 1748, 1681, and 1620 cm^{-1}].

o-CHLORANIL AS OXIDANT. A solution of 1.082 grams of o-chloranil in 35 ml. of ether was added to 0.616 gram of 4,5-dimethylpyrogallol at room temperature with stirring. After $1/2$ hour the ether phase (containing tetrachlorocatechol) was eliminated, and the aqueous phase extracted with chloroform. On evaporation of the solvent the crude quinone dimer (III-D) was obtained, which was recrystallized from acetone. Yield was 152 mg. This is identical in all respects with the product obtained using potassium nitrosodisulfonate as oxidant.

POTASSIUM IODATE AND HYDROGEN PEROXIDE AS OXIDANTS. An identical product was obtained using these oxidants; 154 mg. of 4,5-dimethylpyrogallol by oxidation with 1.3 ml. of 6% aqueous KIO_3 yielded 57 mg. of pure quinone dimer (III-D); 200 mg. of substrate, by oxidation with 2 ml. of 3% H_2O_2 , yielded 73 mg. of pure quinone (III-D).

Acetylation of 3-Hydroxy-5,6-dimethyl-o-benzoquinone Dimer. The quinone (400 mg.) was heated under reflux for 15 minutes in Ac_2O (6 ml.) in the presence of one drop of concentrated H_2SO_4 . After cooling, the precipitate (453 mg.) was collected, washed with Ac_2O , and recrystallized from Ac_2O [m.p. $300^\circ C$. (dec.); molecular weight found 388.1154 (calculated for $C_{20}H_{20}O_8$ 388.1158); infrared 1765, 1695, and 1622 cm^{-1}].

Oxidation of 3,4,5-Trimethylpyrogallol. POTASSIUM IODATE AS OXIDANT. Trimethylpyrogallol (168 mg.) in 5 ml. of H_2O and 1.25 ml. of acetone was oxidized with 1.3 ml. of 6% aqueous KIO_3 . The precipitate was recrystallized from acetone to give 115 mg. of pure quinone dimer III-C [m.p. ca. $250^\circ C$. (dec.); molecular weight

found 332.1261 (calculated for $C_{18}H_{20}O_6$ 332.1260); ultra-violet λ_{\max} 266 $m\mu$ (ϵ 7100) and λ_{\max} 233 $m\mu$ (ϵ 12,000); infrared: 3450, 1748, 1666, 1654, and 1594 cm^{-1}].

POTASSIUM NITROSODISULFONATE AND HYDROGEN PEROXIDE AS OXIDANTS. A solution of 2.36 grams of $NO(SO_3K)_2$ and 1.0 grams of $NaH_2PO_4 \cdot H_2O$ in 100 ml. of iced water was added to a solution of 672 mg. of trimethylpyrogallol in 10 ml. of ether with vigorous stirring. The first crop of crude quinone dimer (III-C, 200 mg.), was filtered off after $1/2$ hour. The mother liquor by treatment with 2.36 grams more of oxidant yielded another 68 mg. of III-C. The filtered solution was then shaken four times with $CHCl_3$. By evaporation of the solvent a third crop (103 mg.) of crude product resulted. The crude products were combined and recrystallized from acetone.

When 218 mg. of the substrate was oxidized with 2 ml. of 3% hydrogen peroxide as previously described, the yield of quinone dimer (III-C) was 157 mg.

TMS Derivatives of Compounds A and B. In a typical experiment, 10 mg. of bisflavanol B was dissolved in 0.3 ml. of anhydrous pyridine and treated with 0.3 ml. of hexamethyldisilazane and 0.1 ml. of trimethylchlorosilane. The mixture was shaken for 5 minutes, then heated at 70° for 5 minutes more. The reaction mixture was evaporated to dryness; the residue was dissolved in 0.5 ml. of CCl_4 and brought again to dryness. The treatment with CCl_4 was repeated to remove any residual pyridine. The amorphous residue resulting after thorough drying was analyzed with the mass spectrometer. An analogous procedure was used for bisflavanol A.

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