1-*p*-Bromophenyl-3-methyl-3-pyrroline (III).—At 0°, a solution of 7.5 g (0.07 mole) of nitrosobenzene in 40 ml of benzene and 40 ml of ether was combined with 6.8 g (0.10 mole) of isoprene in 20 ml of ether. After 64 hr at 0°, the solvent was removed and the product (2-phenyl-4- and/or -5-methyl-3,6-dihydro-1,2-oxazine) distilled at 95–110° (1.4 mm) [lit.[9] bp 126–130° (12 mm], yield 5.3 g (43%). The product (5.3 g) in 20 ml of glacial acetic acid was treated (cooling) with 6.5 g of powdered zinc. After the initial exothermic reaction had moderated, the mixture was refluxed for 4 hr. A solution of 17 g of sodium hydroxide in 40 ml of water was added to the cooled mixture and the resulting suspension filtered. The residue was washed with three 40-ml portions of boiling benzene and the aqueous and organic layers (filtrate) were separated. Evaporation of the solvent gave 5 g of tan solid which afforded 1.4 g (29%) of 3-methyl-1-phenyl-3-pyrroline after recrystallization from methanol, mp 88–90° (lit.[9] mp 89–90°).

The pyrroline was brominated in carbon tetrachloride by the method of Roberts and Ross.[10] Three recrystallizations from methanol gave the analytical sample, mp 120–121°.

Anal. Calcd for $C_{11}H_{12}BrN$: C, 55.48; H, 5.08; N, 5.88. Found: C, 55.36; H, 4.92; N, 5.84.

Registry No.—I, 13116-35-3; II, 13124-63-5; II picrate derivative, 13124-64-6; III, 13119-23-8; triazaline adduct, 13124-65-7.

(9) S. Kojima, *J. Chem. Soc. Japan Ind. Chem. Sect.*, **57**, 819 (1954).
(10) J. J. Roberts and W. C. J. Ross, *J. Chem. Soc.*, 4288 (1952).

2-(2′,6′-Dimethoxyphenyl)-1,3-dioxolenium Fluoroborate. A Stable Carboxonium Salt. Reactions as an Alkylating Agent[1]

F. MARSHALL BERINGER AND SUZANNE A. GALTON[2]

Department of Chemistry, Polytechnic Institute of Brooklyn, Brooklyn, New York 11201

Received May 17, 1966

We have in the past studied arylations by diaryliodonium salts,[3] and a recent publication reports an ethynylation and vinylation by iodonium salts.[4] While alkyliodonium salts are presently unknown, stable oxonium salts are known; they first were reported by Meerwein and co-workers in 1937.[5] The most useful reaction to date of trialkyloxonium salts[6–9] is the facile alkylation of nucleophiles.[7–9] The very stable triphenyloxonium fluoroborate, first prepared by Nesmeyanov,[10] is reported to be an arylating agent.

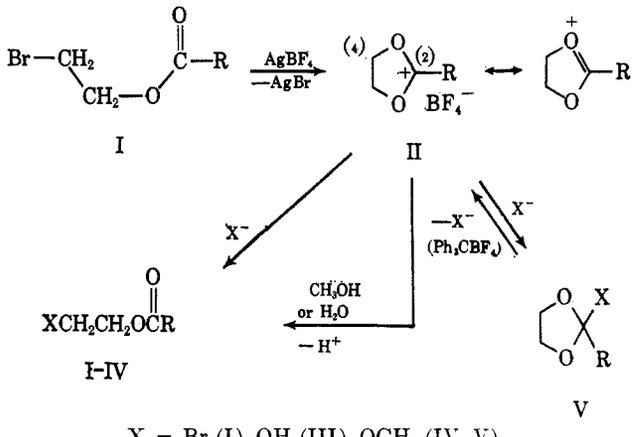
Numerous resonance-stabilized carboxonium salts have been prepared by Meerwein and co-workers[11,12] by alkylation of the carbonyl groups of aldehydes, ketones, esters, lactones, amides, and lactams with trialkyloxonium salts or with alkyl halides in the presence of silver fluoroborate.[7b,11]

The five-membered cyclic 1,3-dioxolenium ions have enhanced stability; indeed, some have been isolated as the hydrogen sulfates.[11] The 2-phenyl-1,3-dioxolenium fluoroborate has been prepared by Meerwein and co-workers,[11,12] who reported its reaction to be that of both carbonium and oxonium ions. Strong nucleophiles (CH_3O^-, CN^-) reacted at the 2 position without ring cleavage while others reacted with ring opening to give β-substituted ethyl esters.

It was our aim to prepare an even more stable 1,3-dioxolenium salt having the electron-releasing 2,6-dimethoxyphenyl substituent at the 2 position. It was believed that such stabilization of the cation would increase its selectivity toward nucleophiles, resulting in alkylation by displacement at the 4 position. It seemed likely that reaction at the 2 position would be reversible and rate controlled, while reaction of the 4 position would be irreversible and thermodynamically controlled. The preparation of such a salt is now reported as are its reactions as an alkylating agent toward carbon, nitrogen, oxygen, and sulfur atoms in nucleophilic molecules; several of these reactions are previously unreported.

The cyclization of β-bromoethyl 2,6-dimethoxybenzoate (I) in the presence of anhydrous silver fluoroborate in ether gave 2-(2′,6′-dimethoxyphenyl)-1,3-dioxolenium fluoroborate (II) (Scheme I); compounds I and II are previously unreported.

SCHEME I



X = Br (I), OH (III), OCH_3 (IV, V)
R = 2,6-dimethoxyphenyl (I–V)

We now report the first nmr spectrum of a dioxolenium salt, that of II in trifluoroacetic acid: a triplet centered around τ 2.27 for the *para* hydrogens, a doublet at 3.39 for the *meta* hydrogens (J = 8.6 cps), a singlet at 4.77 for the methylene protons of the five-membered ring, indicating strong deshielding by the positive charge, and a singlet at 6.06 for the methoxyl hydrogens. The ultraviolet spectra of carboxonium

(1) This research was supported by a fellowship from the National Cancer Institute, Public Health Service, National Institutes of Health, No. 1 F2 CA-19,690-02.
(2) National Institutes of Health Postdoctoral Fellow, 1963–1965.
(3) (a) F. M. Beringer, A. Brierly, M. Drexler, E. M. Gindler, and C. C. Lumpkin, *J. Am. Chem. Soc.*, **75**, 2705 (1953); (b) F. M. Beringer and R. A. Falk, *J. Chem. Soc.*, 4442 (1964); (c) F. M. Beringer, P. S. Forgione, and M. D. Yudis, *Tetrahedron*, **8**, 49 (1960); (d) F. M. Beringer, S. A. Galton, and S. J. Huang, *J. Am. Chem. Soc.*, **84**, 2819 (1962); (e) F. M. Beringer and P. S. Forgione, *Tetrahedron*, **19**, 739 (1963); *J. Org. Chem.*, **28**, 3417 (1963).
(4) F. M. Beringer and S. A. Galton, *ibid.*, **30**, 1930 (1965).
(5) H. Meerwein, G. Hinz, D. Hoffman, E. Konig, and E. Pfeil, *J. Prakt. Chem.*, **147**, 257 (1937); **154**, 83 (1939).
(6) F. Klages, H. Meuresch, and W. Steppich, *Ann.*, **592**, 81 (1955).
(7) (a) F. Klages and H. Meuresch, *Chem. Ber.*, **85**, 863 (1952); (b) H. Meerwein, V. Hederich, and K. Wunderlich, *Arch. Pharm.* **291**, 541 (1958); *Chem. Abstr.*, **54**, 5427 (1960).
(8) (a) G. Higetag and H. Teichmann, *Ber.*, **96**, 1446 (1963); (b) F. Klages, K. Hoheisel, E. Muehlnauer, and F. Malecki, *ibid.*, **96**, 2057 (1963).
(9) D. J. Pettitt and G. K. Helmkamp, *J. Org. Chem.*, **28**, 2932 (1963).
(10) A. N. Nesmeyanov and T. P. Tolstaya, *Dokl. Akad. Nauk. SSSR*, **117**, 626 (1957); *Chem. Abstr.*, **52**, 9005 (1958).
(11) H. Meerwein, K. Bodenbenner, P. Borner, F. Kunert, and K. Wunderlich, *Ann.*, **632**, 38 (1960).
(12) H. Meerwein, V. Hederich, H. Morschel, and K. Wunderlich, *ibid.*, **635**, 1 (1960).

TABLE I

PROTON MAGNETIC RESONANCE SPECTRA (τ, PARTS PER MILLION)[a]

	Ring protons							
	para		*meta*		CH_2			
Compd	τ	J	τ	J	τ	J	OCH_3, τ	CCH_3, τ
I	2.88 t	8	3.61 d	8	5.58 t[b]	6	6.26 s	
					6.53 t	6		
II	2.27 s	8.6	3.39 d	8.6	4.77 s	...	6.06 s[c]	
IV	2.89 t	8	3.59 d	8	5.72 sextet	...	6.24 s	
V	3.01 t	8.8	3.62 d	8.8	6.10 d	2.6	6.31 s[d]	
							6.89 s	
IX	2.70 t	10	3.46 d	8	6.22 to		6.22	8.64[e]
			3.70 d	2[f]	6.30			8.93
X			2.39 s[f]					8.66 s
2,6-Di-*t*-butylphenol	2.92 d	3	3.23 s					
	3.03 s		3.37 d	3				8.53 s[g]

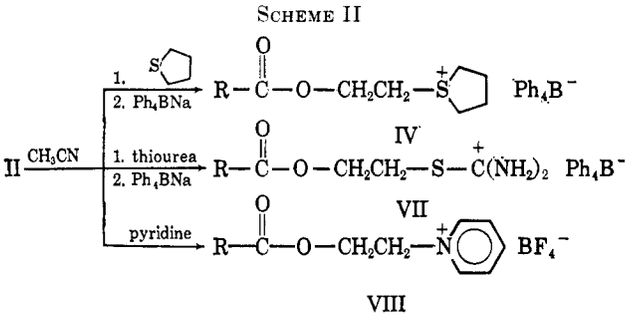
[a] The notations s, d, and t refer to singlet, doublet, and triplet, respectively. J is given in cycles per second (cps). Spectra were taken in CCl_4. [b] CH_2Br = 5.58; CO_2CH_2 = 6.53. [c] Spectrum run in trifluoroacetic acid. [d] Aromatic OCH_3 = 6.31; aliphatic OCH_3 = 6.89, in the ratio 2:1. [e] A peak at τ 6.45 might be assigned to the OH proton. [f] This peak is assigned to the vinyl protons. [g] A peak at τ 5.05 is assigned to the OH proton.

salt II and the starting β-bromoethyl ester in acetonitrile were found to be identical; there was no shift in the wavelength of the absorption maxima. These results suggest that the positive charge is restricted to the dioxolane ring and that there is little resonance interaction with the aromatic ring in the 2 position. Details of the ultraviolet spectra are given in the Experimental Section; nmr data are summarized in Table I.

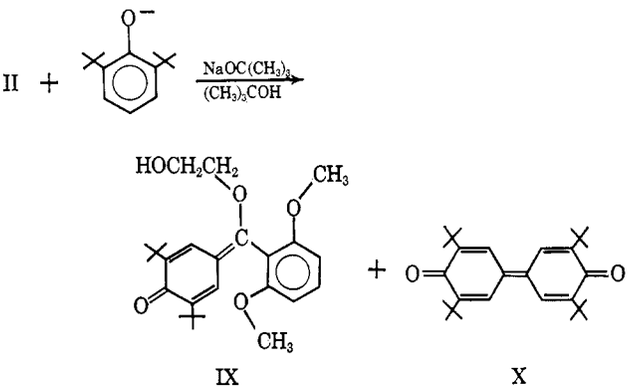
Compound II on reaction with sodium methoxide gave V. Alkylation with ring opening occurred in the presence of water, methanol, or bromide ion giving β-hydroxy- (III), β-methoxy- (IV), and β-bromoethyl (I) esters of 2,6-dimethoxybenzoic acid. The last reaction confirmed that the β-bromoethyl ester was thermodynamically favored over the dioxolenium bromide. The reactivity of the cation toward water and methanol limits the usefulness of these solvents and shows that the methoxyl substituents do not substantially enhance the reported selectivity of this dioxolenium cation.[11,12]

As for new reactions of II, while attempts to alkylate diphenyl sulfide and benzyl mercaptan were unsuccessful, tetrahydrothiophene, thiourea, and pyridine reacted with ring opening to give new sulfonium (VI), thiuronium (VII), and pyridinium (VIII) salts, respectively (Scheme II).

SCHEME II



The anion of the hindered 2,6-di-*t*-butylphenol reacted with compound II to give IX, a quinomethane resulting from substitution of the phenol in the *para* position. Also there was isolated X, a known oxidation product of the starting phenol. The infrared spectrum of IX shows a hydroxyl band at 3400, but no ester carbonyl band at 1730 cm^{-1} such as seen in the compounds obtained by ring opening. Bands at 1630 and 1590 cm^{-1} are assigned to quinone carbonyl and double bonds, respectively. These bands are identical with those seen in compound X. Compound II shows bands at 1585 and 1600, while the dioxolane V shows a broad band at 1580 cm^{-1}. These bands are assigned to the aromatic ring.



The ultraviolet absorption spectrum of IX shows maxima at 246, 259, 271, and 369 mμ. The quinone X has similar maxima at 248, 259, 269, and about 400 mμ. The nmr data are included in Table I. Based on the analysis, color, and the above spectra it is believed that C alkylation occurred with quinone formation and ring opening to give compound IX with the above-proposed structure.

The importance of steric hindrance in determining the site of alkylation of ambident anions, *e.g.*, carbanions from nitriles,[13] phenoxides,[14] and hindered phenoxides,[15,16] has been studied by several investigators. Kornblum and co-workers, studying the alkylation of potassium 2,6-di-*t*-butylphenoxide,[16] found 88% O alkylation with methyl iodide, in contrast to 100% *para*-C alkylation with isopropyl iodide. The observed *para* alkylation of the same phenoxide ion with carboxonium salt II in our study is in accord with previous

(13) (a) M. Prober, *J. Am. Chem. Soc.*, **78**, 2274 (1956); (b) M. S. Newman, T. Fukunaga, and T. Miwa, *ibid.*, **82**, 873 (1960); (c) N. Rabjohn and P. R. Stapp, *J. Org. Chem.*, **26**, 45 (1961).

(14) N. Kornblum and A. P. Lurie, *J. Am. Chem. Soc.*, **81**, 2705 (1959).

(15) T. H. Coffield, A. H. Filbey, G. G. Ecke, and A. J. Kolka, *ibid.*, **79**, 5019 (1957).

(16) N. Kornblum and R. Seltzer, *ibid.*, **83**, 3668 (1961).

findings though not clearly predictable in view of the cation's intermediate steric requirements and higher reactivity. It is perhaps surprising that such a bulky nucleophile was able to add to the 2 position of the dioxolenium ring, which is an α,α-disubstituted benzylic carbon flanked by the two *o*-methoxyl groups.

Experimental Section

β-Bromoethyl 2,6-Dimethoxybenzoate (I).—To a suspension of 36.4 g (0.2 mole) of 2,6-dimethoxybenzoic acid in 100 ml of benzene there was added 35 ml (0.45 mole) of thionyl chloride and the reaction was heated gently for about 0.5 hr, when gas evolution had largely stopped. The reaction mixture was heated for 2 hr, then diluted with another 200 ml of benzene. Most of the benzene was removed by distillation. This distillation procedure was repeated twice more in order to remove most of the excess thionyl chloride. A solution of 27 g (0.25 mole) of β-bromoethanol in 50 ml of benzene was added, and the solution was heated under reflux for another 2 hr. The cooled solution was extracted with saturated aqueous sodium bicarbonate and with water. After the organic phase had been dried with anhydrous magnesium sulfate, solvent was removed on a rotating evaporator. The thick, syrupy residue solidified on standing at room temperature to give 49.3 g (0.17 mole, 85%) of **β-bromoethyl 2,6-dimethoxybenzoate (I)**. This low-melting solid was distilled twice at 200° (0.05 mm) to give white crystals, mp 62–63°.

Anal. Calcd for $C_{11}H_{13}BrO_4$: C, 45.69; H, 4.53; Br, 27.64. Found: C, 45.89; H, 4.70; Br, 27.88.

The ultraviolet absorption spectrum showed two maxima: $\lambda_{max}^{CH_3CN}$ 217 and 281 mμ (ϵ_{max} 8770 and 2370, respectively).

2-(2′,6′-Dimethoxyphenyl)-1,3-dioxolenium Fluoroborate (II).—To a solution of 17.34 g (60 mmoles) of I in 150 ml of ether there was added with stirring and cooling 14.64 g (75 mmoles) of anhydrous silver fluoroborate. After the mixture had been stirred for 5 min, the yellow solid was collected and washed with ether. This solid was then suspended in 200 ml of acetonitrile and stirred for 10 min. The insoluble material was collected to give 10.58 g (56 mmoles, 94%) of silver bromide. The yellow acetonitrile filtrate was diluted to 1500 ml with ether, and the resulting white precipitate was collected to yield 9.55 g (32 mmoles, 53%) of **2-(2′,6′-dimethoxyphenyl)-1,3-dioxolenium fluoroborate (II)**, mp 202–203° dec. When this crude product was recrystallized from acetonitrile–ether, the fluffy precipitate that first formed became granular after stirring for about 1 hr, mp 203–204° dec.

Anal. Calcd for $C_{11}H_{13}BF_4O_4$: C, 44.63; H, 4.43; B, 3.65; F, 25.67. Found: C, 44.41; H, 4.42; B, 3.83; F, 25.41.

The ultraviolet absorption spectrum of II is identical with that of I: $\lambda_{max}^{CH_3CN}$ 217 and 281 mμ (ϵ_{max} 8600 and 2510, respectively).

Hydrolysis of II.—On stirring 500 mg (1.68 mmoles) of II into 10 ml of water a colorless oil formed which crystallized on standing. The crystals were collected and washed with water to give 225 mg (1.0 mmole, 60%) of **β-hydroxyethyl 2,6-dimethoxybenzoate (III)**, mp 66–67°. This low-melting solid was distilled at 180° (0.05 mm) and recrystallized from ether–hexane with no change in melting point.

Anal. Calcd for $C_{11}H_{14}O_5$: C, 58.40; H, 6.24. Found: C, 58.57; H, 6.30.

Methanolysis of II.—A mixture of 500 mg (1.68 mmoles) of II was stirred for 10 min in 8 ml of anhydrous methanol. The colorless solution was evaporated to dryness at room temperature, the residue was dissolved in ether and extracted three times with water until the aqueous phase was neutral. The ether layer was dried over anhydrous magnesium sulfate and evaporated to dryness. The residue was distilled twice at 140° (0.3 mm). The distillate solidified on cooling to yield 200 mg (0.83 mmole, 50%) of **β-methoxyethyl 2,6-dimethoxybenzoate (IV)**, mp 55°.

Anal. Calcd for $C_{12}H_{16}O_5$: C, 59.99; H, 6.71. Found: C, 60.17; H. 6.50.

Reaction of II with Sodium Bromide.—A mixture of 500 mg (1.68 mmoles) of II in 5 ml of acetonitrile and 173 mg (1.68 mmoles) of sodium bromide was stirred overnight. After dilution with ether to 25 ml the inorganic salts were collected, and the filtrate was concentrated to a yellow oil. Trituration with hexane gave 455 mg (1.57 mmoles, 94%) of a white solid whose melting point and infrared spectrum were identical with those of I.

Reaction of II with Sodium Methoxide.—To a solution of 88 mg (3.83 mg-atoms) of sodium in 5 ml of anhydrous methanol there was added with stirring 500 mg (1.68 mmoles) of II. The solution became homogeneous immediately and was concentrated to dryness. The residue was stirred with ether, and the insoluble inorganic salts were removed. The filtrate was concentrated to dryness, and the colorless oil was distilled three times at 135° (0.05 mm). The distillate solidified on cooling to give 200 mg (0.83 mmole, 50%) of white crystals of **2-(2′,6′-dimethoxyphenyl)-2-methoxy-1,3-dioxolane (V)**, mp 44–45°.

Anal. Calcd for $C_{12}H_{16}O_5$: C,59.99; H, 6.71. Found: C, 59.97; H, 6.62.

Reaction of II with Pyridine.—To a solution of 500 mg (1.68 mmoles) of II in 5 ml of acetonitrile there was added 0.5 ml (6.2 mmoles) of anhydrous pyridine, and the solution was allowed to stand overnight. After removal of the solvent the colorless, oily residue was triturated with ethanol. The resulting solid was collected and washed with ether to yield 525 mg (1.4 mmoles, 83%) of white, crystalline **N-[β-(2,6-dimethoxybenzoyloxy)ethyl]-pyridinium fluoroborate (VIII)**, mp 122°. Two recrystallizations from ethanol raised the melting point to 126–127°.

Anal. Calcd for $C_{16}H_{18}BF_4NO$: C, 51.23; H, 4.84; N, 3.79. Found: C, 51.49; H, 5.01; N, 3.79.

Reaction of II with Tetrahydrothiophene.—To a solution of 1 g (3.37 mmoles) of II in 10 ml of acetonitrile there was added 0.4 ml (6.92 mmoles) of tetrahydrothiophene. A clear, colorless solution was obtained in about 0.5 hr. After removal of the solvent the thick colorless, oily residue was dissolved in 15 ml of water. To this solution there was added a solution of sodium tetraphenylborate. The white precipitate was cooled, washed with water, and dried to give 979 mg (1.6 mmoles, 47%) of **S-[β-(2,6-dimethoxybenzoyloxy)ethyl]-tetramethylenesulfonium tetraphenylborate (VI)**; after recrystallization from acetone–ether the melting point was 180–181°.

Anal. Calcd for $C_{39}H_{41}BO_4S$: C, 75.97; H, 6.70; S, 5.20. Found: C, 76.24; H, 6.91; S, 5.05.

Reaction of II with Thiourea.—The above procedure, with substitution of 257 mg (3.37 mmoles) of thiourea for tetrahydrothiophene, gave 1.25 g (2.06 mmoles, 61%) of **S-[β-(2,6-dimethoxybenzoyloxy)ethyl]thiuronium tetraphenylborate (VII)**, mp 138–140° dec. Recrystallization from acetone–ether raised the melting point to 143–144° dec.

Anal. Calcd for $C_{36}H_{37}BN_2O_4S$: C, 71.52; H, 6.17; N, 4.63; S, 5.30. Found: C, 71.27; H, 5.92; N, 4.77; S, 5.47.

Reaction of II with the Anion of 2,6-Di-*t*-butylphenol.—To a solution of 156 mg (6.72 mg-atoms) of sodium in 20 ml of dry *t*-butyl alcohol (distilled from calcium hydride) there was added 1.39 g (6.72 mmoles) of 2.6-di-*t*-butylphenol. To this yellow solution there was added 1 g (3.37 mmoles) of II, and the resulting, green mixture was stirred at room temperature overnight. After removal of the solvent at room temperature, the residue was suspended in methylene chloride, and the mixture was extracted three times with water, The green organic phase turned orange during extraction. The solvent was then evaporated from the dried organic phase, and the residue was chromatographed on a 200-g Florisil column prepared in hexane. From the benzene eluate on evaporation of the solvent, 0.67 g (1.64 mmoles, 49% based on phenol used) of purple needles of **3,3′,5,5′-tetra-*t*-butyldiphenoquinone (X)**, mp 246–247°, was isolated. Recrystallization from ethanol raised the melting point to 249–250° (lit.[17] mp 247–248°).

Anal. Calcd for $C_{28}H_{40}O_2$: C, 82.30; H, 9.87. Found: C, 82.50; H, 10.07.

From the ether eluate on removal of the solvent and trituration of the residue with ether–hexane 0.83 g (2.0 mmoles, 59%) of compound (IX) was isolated, mp 194–195°. The yellow solid was recrystallized from methanol, mp 196–197°.

Anal. Calcd for $C_{25}H_{34}O_5$: C, 72.43; H, 8.27. Found: C, 72.33; H, 8.20.

The ultraviolet spectrum showed the following maxima: λ_{max}^{MeOH} 369, 271, 259, and 249 mμ (ε 30,500, 3500, 3950, and 4400, respectively).

Registry No.—I, 13094-91-2; III, 13084-23-6; IV, 13100-48-6; V, 13084-10-1; IX, 13084-11-2; X, 2455-14-3; 2,6-di-*t*-butylphenol, 128-39-2.

(17) T. J. Barnes and W. J. Hickinbottom, *J. Chem. Soc.*, 2615 (1961).