TABLE III
SPECIFIC RESISTANCE VALUES FOR SOLUTIONS OF $(n\text{-Bu})_4NBF_4$

Electrolyte concn, *M*	Specific resistance at 25°, ohm cm DMF	HMP
0.5	73	555
0.25	110	608
0.05	382	1780
0.01	1450	5250

(2.8 *M*) to these solutions resulted in the appearance of a new reduction wave in the potential range −1.7 to −2.0 V (*vs.* sce) which we presume corresponds to the reduction of protons to hydrogen. However, the presence of small amounts of water in these solutions does not significantly change the limiting reduction potentials attainable.[25]

From the foregoing information we concluded that the optimum salts to use as supporting electrolytes in aprotic solvents are the tetra-*n*-butylammonium salts. Only in instances where obtaining the minimum resistance in an electrolyte solution is essential (as in salt bridges to reference electrodes) does there appear to be any advantage offered by the tetraethylammonium salt.

Either the tetrafluoroborate or the perchlorate salt of a particular quaternary ammonium cation offer about the same advantages in terms of solubility and solution resistance. However, except in certain oxidations where the choice of the anion may control the nature of the reaction product,[21e] there are at least two reasons why we believe use of the tetrafluoroborate salts is preferable. In the preparation and purification of these electrolytes we consistently found the tetrafluoroborates to be easier to purify and, especially, to dry than the corresponding perchlorates. Also, we have consistently felt concern about the potential explosive nature of perchlorate salts or of the mixtures of organic materials and perchloric acid which could be formed when these salts are stored or are used as supporting electrolytes. Thus, at least for preparative electrolytic reductions in aprotic solvents, we concluded that the properties and ready availability of tetra-*n*-butylammonium tetrafluoroborate make this salt the supporting electrolyte of choice.

Registry No.—Et_4NClO_4, 2567-83-1; $(n\text{-Pr})_4NClO_4$, 15780-02-6; $(n\text{-Bu})_4NClO_4$, 1923-70-2; Et_4NBF_4, 429-06-1; $(n\text{-Pr})_4NBF_4$, 15553-52-3; $(n\text{-Bu})_4NBF_4$, 429-42-5; Et_4NBr, 71-91-0; $(n\text{-Pr})_4NBr$, 1941-30-6; $(n\text{-Bu})_4NBr$, 1643-19-2; tetra-*n*-butylammonium acetate, 10534-59-5.

[25] However, small amounts of water may strikingly alter the lifetimes of anions or anion radicals formed as intermediates in electrochemical reductions. See K. W. Bowers, R. W. Giese, J. Grimshaw, H. O. House, N. H. Kolodny, K. Kronberger, and D. K. Roe, *J. Amer. Chem. Soc.*, **92**, 2783 (1970).

The Reaction of Dimethylsulfoxonium Methylide and Griseofulvin

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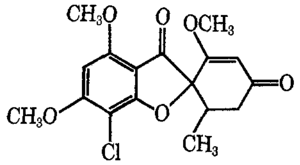
Our finding that the behavior of the β-methoxy-substituted enone system in griseofulvin (1) toward peroxide in base parallels that of enone systems generally in undergoing ready epoxidation[1] prompted us to attempt to introduce the cyclopropyl moiety at position 2′-3′ by allowing 1 to react with dimethylsulfoxonium methylide (2). The latter reagent was first shown by Corey[2] and then by others[3] to react readily with α,β-unsaturated ketones to give the corresponding cyclopropyl ketones.



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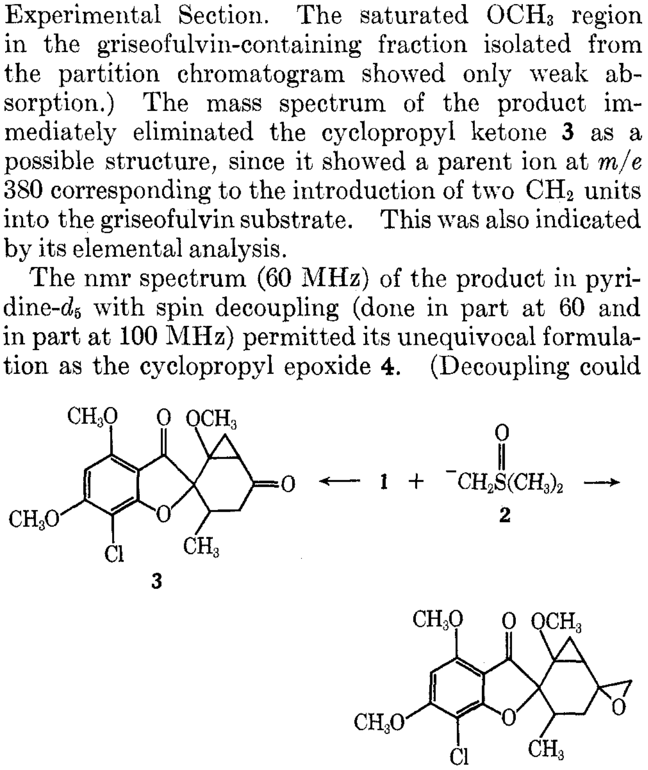
We have found that allowing griseofulvin (1) to react with approximately 1 molar equiv of 2 in dimethyl sulfoxide (DMSO) at room temperature for 20 hr gave a product mixture which could be resolved by partition chromatography into a fraction containing considerable amounts of starting griseofulvin and a new crystalline product. This product melted at 165–175°, showed a band at 5.9 μ in the carbonyl region of the infrared, and an nmr spectrum in chloroform which had as its outstanding feature a new sharp 3-proton singlet at δ 3.13 shifted δ 0.5 upfield from the vinyl OCH_3 signal in griseofulvin. This latter result we attributed to a new OCH_3 group located on a saturated carbon. (The remainder of the chloroform spectrum is given in the Experimental Section. The saturated OCH_3 region in the griseofulvin-containing fraction isolated from the partition chromatogram showed only weak absorption.) The mass spectrum of the product immediately eliminated the cyclopropyl ketone 3 as a possible structure, since it showed a parent ion at *m/e* 380 corresponding to the introduction of two CH_2 units into the griseofulvin substrate. This was also indicated by its elemental analysis.

The nmr spectrum (60 MHz) of the product in pyridine-d_5 with spin decoupling (done in part at 60 and in part at 100 MHz) permitted its unequivocal formulation as the cyclopropyl epoxide 4. (Decoupling could not be done in deuterated chloroform because the sample was further transformed during the time required



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[1] H. Newman, *J. Org. Chem.*, **35**, 3990 (1970).

[2] (a) E. J. Corey and M. Chaykovsky, *J. Amer. Chem. Soc.*, **84**, 867 (1962); (b) *ibid.*, **87**, 1353 (1965).

[3] (a) H. R. Lehmann, H. Muller, and R. Wiechert, *Chem. Ber.*, **98**, 1470 (1965); (b) G. W. Krakower and H. A. VanDine, *J. Org. Chem.*, **31**, 3467 (1966); (c) N. H. Dyson, J. A. Edwards, and J. H. Fried, *Tetrahedron Lett.*, 1841 (1966).

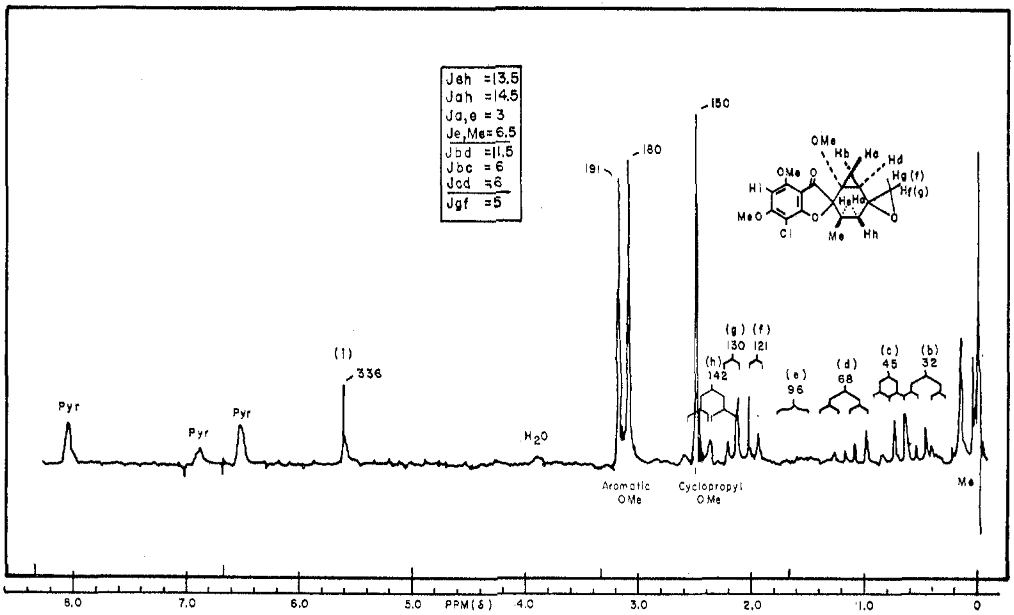


Figure 1.—Nmr spectrum of **4** in pyridine-d_5. The various chemical shift and coupling constant assignments are derived from spin decoupling experiments. Since the data does not permit a delineation of the stereochemical relationship of any of the protons on C-5′ or C-6′ with that at C-2′ or those on the cyclopropyl group, the heavy and dotted lines are meant to show stereochemistry *only within* each of the two groups.

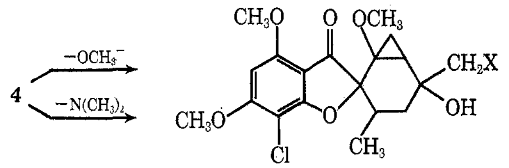
for the experiment, presumably owing to the sensitivity of **4** to traces of acid present in this solvent.)

Thus, in the spectrum of **4** shown in Figure 1, which incidentally indicates a single isomer, the H_b and H_d signals were considerably simplified on irradiation of H_c, the H_b multiplet went to an approximate doublet on irradiating H_d, irradiating H_g and H_f, sequentially, collapsed first one then the other to approximately a singlet, irradiating H_a collapsed H_h to a doublet, and irradiation of the C-6′ CH_3 collapsed H_e to a double doublet. A rather interesting feature of the spectrum is the relatively low-field signal of the cyclopropyl protons H_b and H_c. The signal for this proton type usually appears considerably further upfield in the $\delta \leq 0.5$ region.[4a] The magnitude of the gem coupling constant of these protons is, on the other hand, on the order expected for this proton type[4b] which is considerably less (*ca.* 5 Hz) than that observed for gem protons on a carbon with tetrahedral geometry (*ca.* 15 Hz).

With regard to the stereochemistry of the epoxy and cyclopropyl groups in **4**, the CH_2 of the former is tentatively assumed to be cis (equatorial) to the C-6′ CH_3 by analogy with the results of Corey[2b] with substituted cyclohexanones, while the orientation of the latter is at present unknown.

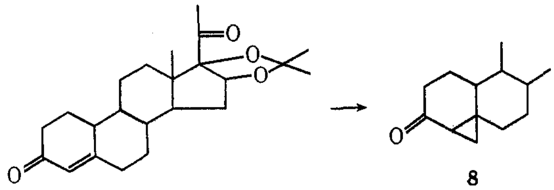
In agreement with structure **4**, the product reacted with methoxide ion in refluxing methanol to give the ether–alcohol **5** and with methanolic dimethylamine to give the amino alcohol **6**.

Our failure to isolate any of the cyclopropyl ketone **3** indicates that any **3** initially formed reacts competitively with griseofulvin toward dimethylsulfoxonium methylide. This contrasts with the observations of Corey[2] and others[3] for α,β-unsaturated ketones which, they found, are readily converted to the corresponding cyclopropyl ketones indicating a considerably faster reaction rate for the former compared to the latter.



5, X = $-OCH_3$
6, X = $-N(CH_3)_2$

Our results and theirs are not inconsistent, since one would expect our enone system to be rendered less reactive toward nucleophilic attack by the electron-releasing β-methoxy substituent present, thus allowing the initially formed cyclopropyl ketone **3** to compete effectively for the methylide. The fact that no **3** was isolated would seem to indicate that **3** is actually more reactive than griseofulvin since it effectively competes with the latter even at initially low concentrations. This observation would appear to be in conflict with that of Krakower, *et al.*[3b] who report that, even in the presence of a 5 molar excess of methylide, the steroidal α,β-unsaturated ketone **7** was converted to the corresponding cyclopropyl ketone **8** in 40% yield, with ostensibly no further reaction of the latter.



7 **8**

By doubling the amount of methylide **2** used in the reaction, we found we could significantly increase the yield of **4**. We were also able to isolate **4** by a fractional crystallization from ethyl acetate thereby avoiding the partition chromatography. The recovery, however, was not so good.

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[4] (a) N. S. Bhacca and D. H. Williams, "Applications of Nmr Spectroscopy in Organic Chemistry," Holden-Day, San Francisco, Calif., 1964, p 190; (b) p 56.

Experimental Section[5]

Reaction of Dimethylsulfoxonium Methylide (2) with Griseofulvin. Formation of 7-Chloro-1′,4,6-trimethoxy-3′-methyldispirobenzofuran-2(3*H*)-2′-norcarane-5′-2″-oxirane. (4).—A solution of 0.005 mol of dimethylsulfoxonium methylide in 10 ml of dry dimethyl sulfoxide (DMSO) (the solvent was stored over molecular sieves and used directly) was prepared by adding 225 mg (0.005 mol) of a 54% NaH dispersion in mineral oil (Foote Mineral Co., Exton, Pa.) to 1.1 g (0.005 mol) of trimethylsulfoxonium iodide (Aldrich) in the solvent at room temperature under nitrogen with stirring. The vigorous gas evolution which accompanied the addition of the sodium hydride ceased after *ca.* 15 min. After *ca.* an additional 30 min another 10 ml of DMSO was added followed by 1.4 g (0.004 mol) of griseofulvin and the resulting light yellow solution was stirred at room temperature under nitrogen for 20 hr and then poured into ice–water. The solid which separated was collected, washed well with water, and air-dried to give a 1.2-g yield of crude product (contaminated with mineral oil), 0.5 g of which was further purified by partition chromatography on Celite 545 using heptane–chloroform–methanol–water 50:8:16:1. One major peak appeared in the chromatogram at *ca.* 8 holdback volumes. Evaporation of the corresponding eluate left 72 mg (5%) of an ivory colored solid: mp 165–175°; $\lambda_{\max}^{\text{KBr}}$ 5.90 μ; $\lambda_{\max}^{\text{MeOH}}$ 324 nm (ε 5200), 290 (23,000), 233 (infl) (14,500), and 212 (27,000); $\delta_{\text{TMS}}^{\text{CDCl}_3}$ 6.15 (1-proton singlet, aromatic H), 4.03 and 4.00 (two 3-proton singlets, aromatic OCH_3's), 3.13 (3-proton singlet, OCH_3 on C-2′ in **4**, 2.83 (represents the center of a 3-proton multiplet due to the epoxy CH_2 protons and H_h at C-5′), 2.00–1.55 (1-proton multiplet due to H_d), 1.33–1.10 (2-proton multiplet due to H_b and H_c), and 0.75 (3-proton doublet, J = 6 Hz, C-6′ CH_3). H_c and H_a in **4** appear as multiplets in the δ 2.7–2.08 and 1.0 region, respectively. The major high mass peak in the mass spectrum of the compound was at *m/e* 380 with the expected *m/e* 382 peak $^1/_3$ as intense due to the chlorine isotope, mol wt 37. (Very minor contamination by a still higher molecular weight product was indicated by a weak *m/e* 394 peak.)

The compound showed essentially a single spot on tlc (C_6H_6–EtOAc 1:1), R_f *ca.* 0.38 (R_f griseofulvin under these conditions is 0.42).

Anal. Calcd for $C_{19}H_{21}O_6Cl$ (380.82): C, 59.90; H, 5.56; Cl, 9.31. Found: C, 59.34; H, 5.60; Cl, 9.08.

The remainder of the chromatographed product was isolated from the methanol wash of the column (yield 318 mg) and was shown by nmr to be a mixture containing 50% or more of griseofulvin. The saturated OCH_3 region (3.5–3.08) in the nmr spectrum of this mixture did not show any significant absorptions.

A significantly improved yield of **4** was obtained by running the reaction in the presence of a 2 molar equiv of the dimethylsulfoxonium methylide and reducing the reaction time to 1 hr and 5 min. Work-up essentially as above except that the mineral oil contaminant was removed before partition chromatography by washing the crude solid with petroleum ether (bp 30–60°) gave 0.91 g (16%) of **4** [from 4.2 g (0.015 mol) of griseofulvin], melting at 170–180° after triturating with methanol.

Anal. Found: C, 59.60; H, 5.62; Cl, 9.65.

The product showed ir, nmr, and mass spectra identical with those of the product above. The pyridine-d_5 spectrum and the decoupling experiments were run on a sample of this product.

The reaction was also run using 3 molar equiv of the methylide and the reduced reaction time (1.25 hr) (2.4 g of griseofulvin was used). A comparison of the yield from this experiment with the other two is, however, precluded because of a change in the work-up in an attempt to eliminate the chromatography step. Thus, after removing the mineral oil with petroleum ether (bp 30–60°), the product was triturated with methanol then recrystallized from EtOAc to give the desired **4** in analytically pure form (yield *ca.* 200 mg, mp 173–179°).

[The rather broad melting point observed for the various preparations of "analytically pure" **4** is more probably due to minor contamination by trace amounts of higher molecular weight material as indicated by the various mass spectra than to its being an isomeric mixture. The latter possibility appears to be precluded by its nmr spectra (see Discussion)].

Reaction of 4 with Methanolic Sodium Methoxide. Formation of 7-Chloro-5′-hydroxy-1′,4,6-trimethoxy-5′-(methoxymethyl)-3′-methylspiro[benzofuran-2(3*H*)-2′-norcaran]-3-one (**5**).—A suspension of 240 mg (0.63 mmol) of **4** in 4 ml of *ca.* 1 *M* methanolic sodium methoxide (4 mmol) was stirred and heated under reflux for 1 hr. The reaction mixture became homogeneous during this time (orange solution). The mixture was poured into ice–water and the organic product extracted with CH_2Cl_2–ether. Drying and evaporating the organic extract left a 210-mg solid residue which showed a major new spot on tlc (C_6H_6–EtOAc 1:1), R_f *ca.* 0.3 along with a somewhat faster running minor spot corresponding in R_f to starting **4**. The minor contaminant was removed by partition chromatography on Celite 545 using heptane–ethylene chloride–methanol–water 50:8:16:1 giving 137 mg of essentially pure **5** which melted at 217–220° after heating suspended in boiling ethyl acetate (partial solution): $\lambda_{\max}^{\text{KBr}}$ 2.9 (m) (OH) and 5.89 (s) (ring B C=O); $\lambda_{\max}^{\text{MeOH}}$ 324 nm (ε 5100), 290 (24,000), 232 (infl) (16,000), and 212 (29,000); $\delta_{\text{TMS}}^{\text{CDCl}}$ 6.15 (aromatic H), 4.05 and 4.02 (aromatic OCH_3's), 3.58 (singlet, $\mathbf{CH_2}OCH_3$), 3.50 (singlet, $CH_2O\mathbf{CH_3}$), 3.14 (singlet, cyclopropyl OCH_3), and 0.8 (doublet, J = 6 Hz, C-6′ CH_3). The signals for the remaining protons appeared between δ 2.4 and 1.0. (Unlike **4**, **5** was stable in $CDCl_3$.) The mass spectrum of **5** showed a parent ion at *m/e* 412 and a very strong M − 45 peak (base peak) corresponding to the loss of $-CH_2OCH_3$.

Anal. Calcd for $C_{20}H_{25}O_7Cl$ (412.86): C, 58.18; H, 6.10; Cl, 8.59. Found: C, 58.01; H, 6.15; Cl, 8.55.

Reaction of 4 with Dimethylamine. Formation of the Dimethylamino Adduct 6.—A suspension of 10 mg of **1** in *ca.* 0.5 ml of saturated methanolic dimethylamine was stirred at room temperature for 1 hr, the excess solvent removed in a stream of nitrogen, and the residue triturated with ether to give a colorless solid which melted partially at 180–184° and gave a completely clear melt at 211°: $\lambda_{\max}^{\text{KBr}}$ 2.9 μ (m) (OH), 5.90 (s) (ring B >C=O). The mass spectrum of the product showed a parent ion at *m/e* 425 and a major fragment at M − 58 and at *m/e* 58 (base peak) corresponding to the loss of $-CH_2N(Me)_2$ from **6** and the fragment $-CH_2N(Me)_2$, respectively.

Anal. Calcd for $C_{21}H_{28}ClO_6N \cdot H_2O$ (443.9): C, 56.81; H, 6.81; N, 3.16. Found: C, 57.23; H, 6.50; N, 2.90.

Registry No.—**1**, 126-07-8; **2**, 5367-24-8; **4**, 30256-33-8; **5**, 30256-34-9; **6**, 30256-35-0; methanolic sodium methoxide, 124-41-4.

Acknowledgments.—We are most grateful to Dr. J. E. Lancaster and Mr. G. Morton for the nmr spectra and the spin decoupling experiments. We thank Dr. G. VanLear for the mass spectra, Mr. C. Pidacks and staff for the partition chromatography, and Mr. L. Brancone and staff for the microanalyses.

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[5] Melting points are uncorrected. Mass spectra were determined on an AEI MS-9 spectrometer. Magnesium sulfate was used for drying. Thin layer chromatograms were run on phosphor-containing silica gel plates (Anal. Tech., Wilmington, Del.).

The Debromination of Stilbene Dibromides and Other Vicinal Dibromides by Tricovalent Phosphorus[1]

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Recent reports on the debromination of stilbene dibromide **1** by triethyl phosphite (TEP)[3] and by various

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[3] J. P. Schroeder, L. B. Tew, and V. M. Peters, *J. Org. Chem.*, **35**, 3181 (1970).