basified strongly with aqueous alkali, and extracted with $CH_2Cl_2$. Drying (with $Na_2SO_4$) and evaporation of the organic phase affords the isoquinoline, characterized as in Table I.

**Wittig Reaction to 5 and Cyclization to 6 and 7.** To a solution of isolated phosphonate **3** (X = Y = OMe; Z = H; 2.05 g, 4.7 mmol) in 40 mL of dry tetrahydrofuran was added 2 mL of *n*-butyllithium (2.6 M in hexane) under nitrogen at −78 °C and stirred 15 min. To this was slowly added (−78 °C) a solution of 784 mg (4.6 mmol) of veratraldehyde in 10 mL of dry tetrahydrofuran. After half an hour at −78 °C the solution was allowed to come to room temperature and stirred for 3 h. Quenched with aqueous ammonium chloride and extracted with chloroform, the organic phase was washed with brine, dried over magnesium sulfate, filtered through Celite, and concentrated to an oil (2.07 g), which showed one spot on TLC and spectra consistent with **5**.

The oil (524 mg) was dissolved in 14 mL of dry methylene chloride and 0.75 mL of titanium tetrachloride was added at −78 °C under nitrogen. The solution was stirred at −78 °C for 15 min and warmed to room temperature and then stirred for 3 h and worked up as above to provide 64 mg of papaverine (**6**, X = Y = $OCH_3$; Z = H; R = 3,4-dimethoxyphenyl), identical with an authentic sample. Preparative TLC of the complex neutral fraction yielded 80 mg of the corresponding pyrrole **7** as an oil: NMR ($CDCl_3$) δ 1.15 (3 H, t), 3.55, 3.75, 3.80, 3.90 (12 H as four $OCH_3$ singlets), 4.15 (2 H, q), 6.4 (1 H, d, $J$ = 4.0 Hz), 6.6–6.8 (6 H, m), 7.4 (1 H, d, $J$ = 4.0 Hz).

**Acknowledgment.** We acknowledge with thanks partial support of this work by a grant from the National Institute of Drug Abuse (DA-02735).

**Registry No.** 1 (X = OMe; Y = Z = H), 123-11-5; 1 (X = Y = H; Z = OMe), 135-02-4; 1 (X = Y = OMe; Z = H), 120-14-9; 1 (X = Me; Y = Z = H), 104-87-0; 1 (X = OMe; Y = OH; Z = H), 621-59-0; 1 (X = OMe; Y = OH; Z = Br), 2973-58-2; 1 (X = Y = $OCH_2O$; Z = H), 120-57-0; 1 (X = Z = H; Y = OMe), 591-31-1; **3** (X = Y = OMe; Z = H), 86727-46-0; **4** (X = OMe; Y = Z = H) picrate, 86712-43-8; **4** (X = Y = H; Z = OMe) picrate, 1723-71-3; **4** (X = Y = OMe; Z = H), 15248-39-2; **4** (X = Me; Y = Z = H), 42398-73-2; **4** (X = OMe; Y = OH; Z = H), 1810-58-8; **4** (X = OMe; Y = OH; Z = Br), 86712-44-9; **4** (X = OMe; Y = OH; Z = Br) picrate, 86712-46-1; **4** (X = Y = $OCH_2O$; Z = H), 269-44-3; **4** (X = Z = H; Y = OMe) picrate, 86712-47-2; **5** (X = Y = OMe; Z = H; R = 3,4-dimethoxyphenyl), 86712-48-3; **6** (X = Y = OMe; Z = H; R = 3,4-dimethoxyphenyl), 58-74-2; **7** (X = Y = OMe; Z = H; R = 3,4-dimethoxyphenyl), 86712-49-4; $H_2NCH_2CH(OCH_3)_2$, 22483-09-6; ClCOOEt, 541-41-3; $P(OCH_3)_3$, 121-45-9; $TiCl_4$, 7550-45-0.

## Synthesis of 4-Methylene-1,3-dioxolan-2-one, a Bifunctional Cyclic Carbonate

Barry M. Trost* and Dominic M. T. Chan[1]

*McElvain Laboratories of Organic Chemistry, Department of Chemistry, University of Wisconsin, Madison, Wisconsin 53706*

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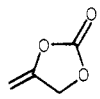
In the course of a study directed toward the development of conjunctive reagents, it was of interest to synthesize 4-methylene-1,3-dioxolan-2-one (**1**) to investigate



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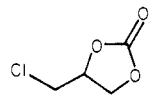
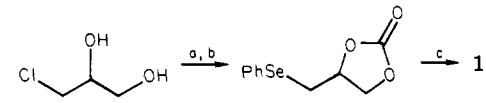


2

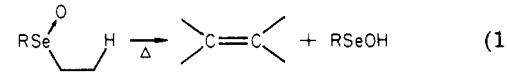
the interaction of such a bifunctional substrate with palladium(0) complexes in the hope of generating oxatrimethylenemethane intermediates. Our initial attempt involved dehydrochlorination of the known chloromethyl carbonate **2**.[2] However, treatment of **2** with DBU (1,5-diazabicyclo[5.4.0]undec-5-ene), potassium *tert*-butoxide, or basic alumina led only to destruction of starting material. The failure of this approach was not unexpected because of the predicted sensitivity of **1** toward basic conditions. The facile thermal elimination of selenenic acid from a selenoxide to produce an olefin[3,4] (eq 1) seemed an

Scheme I[a]



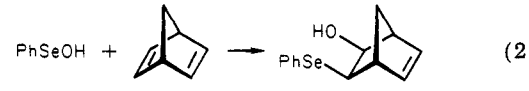
3 4

[a] (a) PhSeNa, MeOH, reflux, 99% yield; (b) $(CH_3O)_2C{=}O$, catalyst $NaHCO_3$, reflux, 92% yield, (c) $O_3$, $CH_2Cl_2$, −78 °C and then norbornadiene, $ClCH_2CH_2Cl$, and reflux, 57% yield.



(1)

attractive solution. We now report the first synthesis of **1** as depicted in Scheme I based on such a methodology. The starting material was the commercially available 3-chloro-1,2-propanediol (**3**). Reaction of the chloro diol with sodium phenylselenide[5] (generated in situ from diphenyl diselenide and sodium borohydride) followed by treatment with dimethyl carbonate gave the phenylselenenyl carbonate **4** in 91% yield. Oxidation of **4** with ozone at −78 °C produced the corresponding selenoxide.[3] The same product can also be prepared by reacting **4** with MCPBA. However, the yield was lower due to the high water solubility of the selenoxide during the aqueous workup. Thermolysis of the crude ozone-oxidation product at 100 °C under vacuum gave a low yield of the desired product **1** and a substantial amount of selenide **4**. Apparently, benzeneselenenic acid, the byproduct of the pyrolysis, effected the reduction of the starting material. Despite the success in the literature,[3] the use of amines such as diethylamine, piperidine, or diisopropylamine for the removal of PhSeOH proved unsatisfactory. To circumvent this problem, we were able to employ an activated olefin, e.g., norbornadiene, as a neutral trap. Presumably, the benzeneselenenic acid was removed as the innocuous and nonvolatile adduct **5** (eq 2). Thus, when the selenoxide



(2)

5

of **4** was added slowly to a refluxing solution of dichloroethane and 25 equiv of norbornadiene, the desired vinyl carbonate **1** was isolated in 57% yield after distillation of the crude reaction mixture.

The title compound was therefore obtained in 52% overall yield from **3** in a simple three-step operation. The

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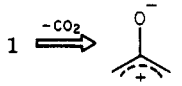
cyclic carbonate was thermally stable and showed no particular tendency toward olefin isomerization on silica gel. It can serve as a potential precursor for the oxyallyl synthon 6.



6 (3)

## Experimental Section

Melting points were taken with a Thomas-Hoover capillary melting point apparatus and are uncorrected. Proton NMR spectra were determined in chloroform-*d* on a Bruker WH-270 (270 MHz) spectrometer. Chemical shifts are reported in δ units, parts per million (ppm) downfield from tetramethylsilane, which was used as the internal standard. Splitting patterns are designated as: s, singlet; d, doublet; t, triplet; q, quartet; m, multiplet. Coupling constants are reported in hertz (Hz). Carbon ($^{13}C$) NMR spectra were determined on a JEOLCO FX-60 (15.4 MHz) spectrometer in chloroform-*d*. Infrared spectra (IR) were determined on a Perkin-Elmer 267 instrument and are reported in reciprocal centimeters. Mass spectra were obtained on an AEI-902 instrument.

**4-[(Phenylselenenyl)methyl]-1,3-dioxolan-2-one (4).** To a solution of diphenyl diselenide (20.0 g, 64 mmol) in 300 mL of absolute ethanol was added sodium borohydride (7.5 g, 197 mmol) in small portions (to prevent excessive evolution of hydrogen). The sodium phenylselenide solution was then added to 3-chloro-1,2-propanediol (13.6 g, 123 mmol) in a 500-mL flask. The resulting yellowish orange solution was refluxed for 50 h. The excess selenide anion was quenched with 0.8 mL of dichloroacetic acid, and the reaction mixture was filtered to remove sodium chloride. The bulk of the ethanol was removed by rotatory evaporation, and the residue was partitioned between ethyl acetate (500 mL) and saturated sodium bicarbonate solution (100 mL). The aqueous phase was extracted with ethyl acetate (100 mL). The combined organic layers were washed with saturated aqueous bicarbonate (2 × 100 mL) followed by brine (100 mL) and then dried over anhydrous potassium carbonate. After removal of the solvent, 28.2 g (99%) of 3-(phenylselenyl)-1,2-propanediol was obtained as a yellow solid. This was not purified but carried on to the next step.

A mixture of the crude diol (13.1 g, 57 mmol), dimethyl carbonate (35 mL, 415 mmol), and sodium bicarbonate (0.3 g, 3.5 mmol) was refluxed for 2 h. The reaction mixture was then heated to 120 °C to distill the volatile components. The pot residue was dissolved in ether (300 mL), washed successively with water (2 × 50 mL) and brine (50 mL), and then dried over anhydrous magnesium sulfate. After removal of solvent in vacuo, 13.5 g (92%) of the title compound was obtained as an orange oil. An analytical sample was obtained by flash chromatography[6] (25% ethyl acetate in hexane): $^1H$ NMR δ 7.54 (m, 2 H), 7.30 (m, 3 H), 4.78 (d of d of d of d, $J$ = 8.8, 8.1, 6.6, 4.6 Hz, 1 H), 4.50 (d of d, $J$ = 8.6, 8.1 Hz, 1 H), 4.14 (d of d, $J$ = 8.6, 6.6 Hz, 1 H), 3.28 (d of d, $J$ = 13.2, 4.6 Hz, 1 H), 3.00 (d of d, $J$ = 13.2, 8.8 Hz, 1 H); IR (neat) 3070, 3000, 1801, 1582, 1480, 1440, 1392, 1162, 1062, 772, 740, 690 $cm^{-1}$. Mass spectrum, $m/e$ (relative intensity) $M^+$ – 258 (2), 171 (3), 91 (3), 87 (10), 77 (3), 57 (100), 56 (5), 55 (3), 45 – (16), 44 (6), 43 (14), 41 (23), 40 (3), 39 (4); calcd for $C_{10}H_{10}O_3Se$ $m/e$ 257.9792, found $m/e$ 257.9794.

**4-Methylene-1,3-dioxolan-2-one (1).** Ozone was bubbled into a solution of 4-[(phenylselenenyl)methyl]-1,3-dioxolan-2-one (4; 3.0 g, 11.6 mmol) in 36 mL methylene chloride at −78 °C until a blue color persisted. After being purged with nitrogen, the reaction mixture was allowed to warm to room temperature. The solvent was removed in vacuo to give 3.0 g of the crude selenoxide as a white solid which was dissolved in 18 mL of 1,2-dichloroethane and added dropwise at a rate of 15 mL/h (via a syringe pump) to a refluxing solution (pot temperature 110–115 °C) of 25 mL of 1,2-dichloroethane and 2,5-norbornadiene (30 mL, 300 mmol). After the addition, refluxing was continued for 10 min, and the volatile components were removed by distillation. The orange residue (4.0 g) was then Kugelrohr distilled (50 °C, 0.25 mmHg) to give 650 mg (57%) of the methylene carbonate 1 as a low-melting waxy solid: mp 28–29.5 °C; $^1H$ NMR δ 5.04 (d of d, $J$ = 2.6, 2.2 Hz, 2 H), 4.91 (d of t, $J$ = 4.0, 2.6 Hz, 1 H), 4.47 (d of t, $J$ = 4.0, 2.2 Hz, 1 H); $^{13}C$ NMR 152.8, 149.1, 87.1, 67.8; IR ($CDCl_3$) 1838, 1698, 1353, 1283, 1137, 1079, 972, 845 $cm^{-1}$; mass spectrum, $m/e$ (relative intensity $M^+$ – 100 (12), 69 (1), 56 (4), 44 (16), 42 (1), 40 (10), 32 (100), 30 (1); calcd for $C_4H_4O_3$ $m/e$ 100.0159, found $m/e$ 100.0163.

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**Registry No.** 1, 4362-24-7; 3, 96-24-2; 4, 86728-47-4; 5, 86728-48-5; 3-(phenylselenyl)-1,2-proipoanediol, 65349-59-9; diphenyl diselenide, 1666-13-3.

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# Silica Gel Assisted Reductive Cyclization of Alkoxy-2,β-dinitrostyrenes to Alkoxyindoles[1]

Achintya K. Sinhababu and Ronald T. Borchardt*

*Department of Medicinal Chemistry, Smissman Research Laboratories, University of Kansas, Lawrence, Kansas 66045*

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The biochemical and pharmacological importance of numerous indole derivatives[2,3] have served to maintain a continuing interest in the development of new and improved methods for the synthesis of the indole nucleus.[2,4,5] We became interested in this area in connection with our synthesis of analogues of pharmacologically important serotonin neurotoxins 5,6- and 5,7-dihydroxytryptamines.[3,6] For the synthesis of these analogues we needed access to 5,6- and 5,7-dihydroxyindoles as their methyl and benzyl ethers with various other substituents on the indole ring. The most suitable method for the synthesis of these indoles appeared to be the reductive cyclization of appropriate 2,β-dinitrostyrenes using Fe in HOAc. This method is widely used[4] and is the most convenient one for the synthesis of N-unsubstituted alkoxyindoles. Although this method of constructing the indole nucleus is of broad

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