3,4,9-Trimethoxyphenalenone (6). The reaction was carried out under an argon atmosphere, and all of the glassware was flame dried. 3-Hydroxy-4,9-dimethoxyphenalenone (3) (1.0 g, 0.0039 mol) was dissolved in acetone (dried over alumina). Anhydrous potassium carbonate (2.0 g, 0.01 mol) was added to the flask while the solution was mechanically stirred. After 10 min, methyl *p*-toluenesulfonate (1.5 mL, 0.01 mol) was slowly added to the flask and the reaction mixture was taken to reflux. After 16 h the solution was filtered and the filtrate was evaporated down on a rotary evaporator to give a viscous pale yellow oil. The compound was purified by high-pressure liquid chromatography on a silica gel column (using methanol–methylenechloride (5:95) as eluant) to give 3,4,9-trimethoxyphenalenone (0.43 g, 41% yield) as a yellow solid: mp 166.0–166.2 °C); IR 9 Hz, CsI) 2940 (w), 2840 (w), 1650 (vs), 1578 (s), 1540 (m), 1508 (m), 1455 (m), 1392 (m), 1366 (w), 1306 (m), 1266 (s), 1220 (s), 1170 (s), 1090 (w), 1038 (s), 1000 (w), 958 (w), 835 (m), 804 (w), 785 (w), 662 (w), 510 (w), 430 (w); UV [λ_{max} nm (ϵ) (hexane)] 413 (3300, sh), 392 (6000, sh), 362 (14400), 323 (5500, sh), 250 (22200); ^{1}H NMR ($CDCl_3$, Me_4Si) δ 3.96 (s, 3 H), 4.08 (s, 3 H), 4.15 (s, 3 H), 6.26 (s, 1 H), two AB patterns δ_A 7.20, δ_A 7.28, δ_B 7.91, δ_B 7.98 (J_{AB} = 9 Hz, 4 H). Anal. Calcd for $C_{16}H_{14}O_4$: C, 71.10; H, 5.22. Found: C, 70.88; H, 5.50.

1,3,4,9-Tetramethoxyphenalenylium Tetrafluoroborate ($7^+,BF_4^-$). Trimethoxyphenalenone (6) (0.135 g, 0.5 mmol) was dissolved in 5 mL of dry 1,2-dichloroethane under nitrogen, and trimethyloxonium tetrafluoroborate (0.1 g, 0.7 mmol) was added with stirring. After 3 h the mixture was filtered and the precipitate isolated (0.135 g, 72%). Recrsytallization from acetonitrile gave yellow needles: mp >300 °C; IR (cm^{-1}, CsI) 3450 (w,br), 1615 (s), 1600 (s, sh), 1561 (s), 1500 (m), 1488 (m, sh), 1465 (w), 1393 (w), 1354 (w), 1285 (vs), 1247 (m), 1230 (m), 1182 (m), 1055 (s), 1020 (vs), 950 (w), 901 (w), 835 (m), 655 (vw), 515 (vw); UV [λ_{max} nm (ϵ) (acetonitrile)] 423 (24100), 399 (19900) 374 (19300), 267 (11000, sh), 236 (22000), 220 (23900); ^{1}H NMR (CD_3CN, Me_4Si) δ 4.32 (s, 6 H), 4.38 (s, 6 H), 7.05 (s, 1 H), AB pattern δ_A 7.67, δ_B 8.67 (J_{AB} = 9 Hz, 4 H). Anal. Calcd for $C_{17}H_{17}O_4BF_4$: C, 54.87; H, 4.60; B, 2.91; F, 20.41. Found: C, 54.77; H, 4.64, B, 3.01; F, 20.11.

Acknowledgment. We are grateful to M. L. Kaplan and R. G. Cooke for useful discussions.

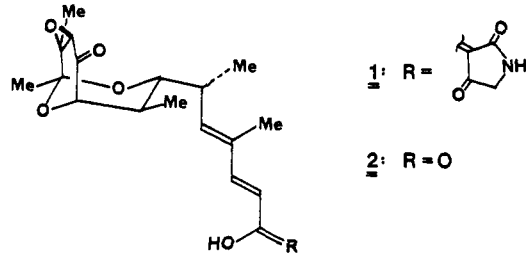
Registry No. 1, 3469-26-9; 2, 71094-90-1; 3, 52588-83-7; 5, 85736-07-8; 6, 85736-08-9; 7^+, 85736-09-0; $7^+BF_4^-$, 85736-10-3; ethyl malonyl chloride, 36239-09-5.

Communications

Total Synthesis of Tirandamycin. A Short, Efficient Synthesis of the Ireland Alcohol

Summary: Alcohol 3, comprising the bicyclic portion of the antibiotic tirandamycin, has been synthesized in seven steps from 2,3-dimethylfuran and aldehyde 5. The key transformation in this scheme is conversion of furan alcohol 4 into pyranone 11.

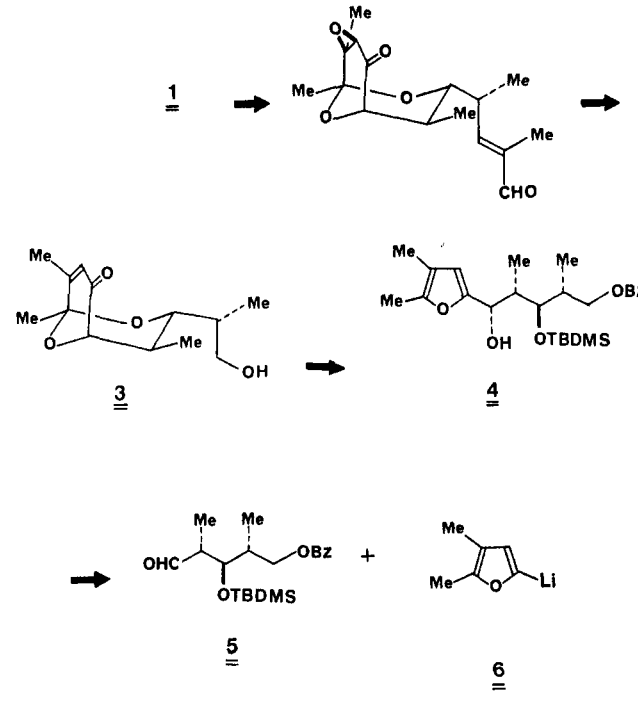
Sir: Tirandamycin (1)[1,2] is a member of the 3-dienoyltetramic acid family of antibiotics. Several groups have



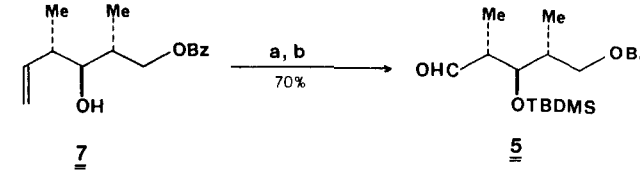
been involved in the development of methodology for the total synthesis of this molecule.[3-6] These efforts have recently culminated in the synthesis of (+)-tirandamycic acid (2), a degradation product of tirandamycin, by Ireland and his co-workers, beginning with D-glucose.[4] In this communication, we report a short, efficient synthesis of alcohol 3 (the Ireland alcohol) in racemic form.

Alcohol 3 was prepared previously in the Ireland synthesis of tirandamycin acid and was chosen as a key intermediate in our strategy for the synthesis of tiran-

Scheme I



Scheme II[a]



[a] *t*-$BuMe_2SiCl$, imidazole, DMF, room temperature; (b) O_3, CH_2Cl_2, −20 °C; HOAc, Zn, room temperature.

(1) Duchamp, D. J.; Branfman, A. R.; Button, A. C.; Rinehart, K. L., Jr. *J. Am. Chem. Soc.* **1973**, *95*, 4077, and references cited therein.
(2) MacKellar, F. A.; Grostic, M. F.; Olson, E. C.; Wuuk, R. J.; Branfman, A. R.; Rinehart, K. L., Jr. *J. Am. Chem. Soc.* **1971**, *93*, 4943.
(3) Lee, V. J.; Branfman, A. R.; Herrin, T. R.; Rinehart, K. R., Jr. *J. Am. Chem. Soc.* **1978**, *100*, 4225. Cartwright, D.; Lee, V. J.; Rinehart, K. R., Jr. *Ibid.* **1978**, *100*, 4237.
(4) Ireland, R. E.; Wuts, P. G. M.; Ernst, B. *J. Am. Chem. Soc.* **1981**, *103*, 3205.
(5) DeShong, P.; Ramesh, S.; Perez, J. J.; Bodish, C. *Tetrahedron Lett.* **1982**, *23*, 2243.
(6) Ziegler, F. E.; Thottathil, J. K. *Tetrahedron Lett.* **1981**, *22*, 4883.

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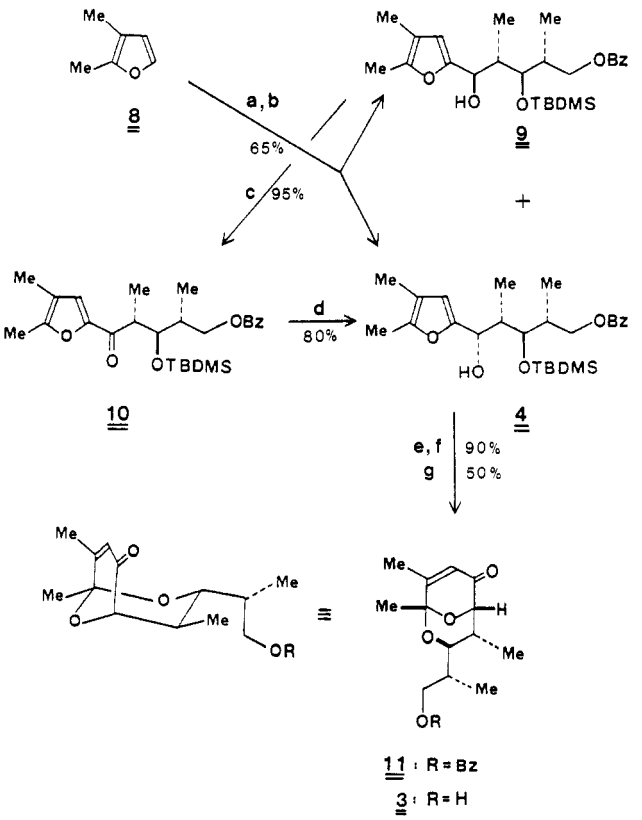
Scheme III[a]



[a] (a) *t*-BuLi, ether, 0 °C; (b) **5**, ether, −78 °C; (c) $BaMnO_4$, CH_2Cl_2, room temperature; (d) $Zn(BH_4)_2$, ether, room temperature; (e) mCPBA, CH_2Cl_2, 0 °C; (f) 5% aqueous HF, CH_3CN, room temperature; (g) Me_3SiCl, NaI, CH_3CN, room temperature.

damycin (Scheme I). In this strategy, the four contiguous asymmetric centers, C-5, C-4, C-3, and C-10, in **3** are established early in the sequence by utilizing aldehyde **5**[7] The key transformation in this strategy is the oxidation of furan–alcohol **4** to produce the bicyclic ring system found in **3**. We[5] and others[6,10] had earlier shown that oxidation of furan–alcohols could be used to prepare pyranones similar to **3**.

Synthesis of racemic **5** is outlined in Scheme II. Readily available homoallylic alcohol **7**[11] was converted to the TBDMS ether under standard conditions[14] and oxidized with ozone to give the unstable aldehyde **5** in 70% overall yield.

Metalation of 2,3-dimethylfuran (**8**)[15] followed by addition to aldehyde **5** gave a ~1:1 mixture of diastereomeric alcohols **4** and **9** (Scheme III).[16] The alcohols were separated by column chromatography, and **9** was oxidized to ketone **10** with $BaMnO_4$ (95%).[17] Reduction of **10** with $Zn(BH_4)_2$[18] resulted in selective formation of diastereomer **4** by "chelation-controlled" reduction.[19]

With **4** in hand, the critical step of the strategy could be investigated (vide supra). Oxidation of **4** with *m*-chloroperbenzoic acid[20] followed by cleavage of the silyl ether with HF in acetonitrile gave the bicyclic enone **11** in 90% yield.[21] Removal of the benzyl ether protecting group with MeSiI[22] gave **3** (50%), which was identical by IR and ^1H NMR with the Ireland alcohol. Alcohol **3** has been converted into tirandamycic acid (**2**) in four additional steps, and thus this synthesis constitutes a formal total synthesis of **2**.

The sequence outlined above for the synthesis of **3** is short (seven steps), stereospecific, and allows us to rapidly assemble the complex functionality of the bicyclic system of tirandamycin. We are currently attempting to employ this methodology for the total synthesis of tirandamycin and related antibiotics.

Acknowledgment. We acknowledge the Research Corp. for financial support. We acknowledge helpful discussions with Professors D. A. Evans and Y. Kishi concerning the preparation of **7**. We also thank Professor Ireland for IR and ^1H NMR spectra of **3**.

Registry No. (±)-**1**, 85880-71-3; (±)-**3**, 85880-72-4; (±)-**4**, 85828-13-3; (±)-**5**, 85828-12-2; (±)-**7**, 85880-73-5; **8**, 14920-89-9; (±)-**9**, 85880-74-6; (±)-**10**, 85828-14-4; (±)-**11**, 85828-15-5.

Supplementary Material Available: IR and NMR spectral data for compounds discussed and MS data for selected compounds (10 pages). Ordering information is given on any current masthead page.

(7) Aldehyde **5** is also a key synthon in the synthesis of the tirandamycin-related antibiotics streptolydigin[1,8] and nocamycin[9] since these compounds have the identical stereochemical relationship at the four asymmetric centers corresponding to C-5, C-4, C-3, C-10 in **1**.

(8) Rinehart, K. R., Jr.; Buk, J. R.; Bonders, D. B.; Kinstle, T. H.; Krauss, D. *J. Am. Chem. Soc.* **1963**, *85*, 4028.

(9) Horvath, G.; Brazhnikova, M. G.; Konstantinova, N. V.; Tolstykh, I. V.; Potapora, N. P. *J. Antibiot.* **1979**, *32*, 555. Nakagawa, S. Naito, Y.; Kawaguthi, H. *Heterocycles* **1979**, *12*, 477.

(10) Piancatelli, G.; Scettri, A.; D'Auria, M. *Tetrahedron* **1980**, *36*, 661. Hendrickson, J. B.; Farina, J. S. *J. Org. Chem.* **1980**, *45*, 3359.

(11) Racemic **7** was used in these experiments; however, both enantiomers of **7** can be prepared by either the "chiral auxiliary" methodology of Evans[12] or the Kishi methodology beginning from the "Roche alcohol".[13]

(12) Evans, D. A.; Ennis, M. D.; Mathre, D. J. *J. Am. Chem. Soc.* **1982**, *104*, 1737 and references cited therein. D. A. Evans and R. Dow, unpublished results.

(13) Lewis, M. D.; Kishi, Y. *Tetrahedron Lett.* **1982**, *23*, 2343 and references cited therein.

(14) Corey, E. J.; Venkateswarlu, A. *J. Am. Chem. Soc.* **1972**, *94*, 6190.

(15) Rice, K. C.; Dyer, J. R., Jr. *J. Heterocycl. Chem.* **1975**, *12*, 1325.

(16) Changing a variety of reaction parameters did not lead to a significant alteration in the ratio of diastereomers produced.

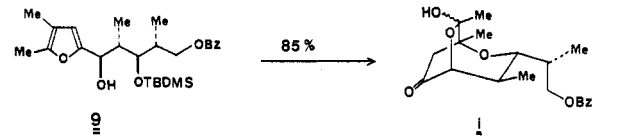
(17) Firouzabadi, H.; Ghaderi, E. *Tetrahedron Lett.* **1978**, 839.

(18) Nakata, T.; Oishi, T. *Tetrahedron Lett.* **1980**, *21*, 1641 and references cited therein.

(19) Still, W. C.; Schneider, J. A. *Tetrahedron Lett.* **1980**, *21*, 1035 and references cited therein.

(20) Williams, P. D.; LeGoff, E. *J. Org. Chem.* **1981**, *46*, 4143.

(21) Oxidation (MCPBA) of the diastereomeric alcohol **9** followed by acid treatment did not give a bicyclo[3.3.1]nonane system in analogy with **4**. Instead **i** was produced by Michael-like addition of the alcohol to the enone moiety.



(22) Olah, G. A.; Narang, S. C. *Tetrahedron* **1982**, *38*, 2225 and references cited therein. Jung, M. E.; Lyster, M. A. *J. Org. Chem.* **1977**, *42*, 3761.

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Received March 14, 1983

Catalysis of Nitration of Naphthalene by Lower Oxides of Nitrogen[1]

Summary: Nitrous acid catalyzed nitration of naphthalene does not proceed through nitrosation, and the mechanism

(1) Part 4 of the series Studies in Aromatic Nitration. Part 3: Ross, D. S.; Malhotra, R.; Ogier, W. C. *J. Chem. Soc., Chem. Commun.* **1982**, 1353.

0022-3263/83/1948-2118$01.50/0