chromatography and subsequent crystallization, gave **1b** as colorless needles: mp 90–92 °C; 17% yield (69 mg); UV (benzene) λ_{max} 313 nm (ϵ 2240), 277 (4700); ^{1}H NMR ($CDCl_3$) δ 2.36 (s, Me, 3 H), 7.18 and 7.72 (each d, J = 8.2 Hz, aromatic, 4 H). Anal. Calcd for $C_{19}H_7D_{10}NO_2S_3$: C, 57.39; H, 4.31; N, 3.52. Found: C, 57.53; H, 4.45; N, 3.36.

***N,N*-Bis(4-tolylthio)-4-toluenesulfonamide (1c).** On heating at 150 °C for ~20 min, the reaction mixture, after chromatography and subsequent crystallization, gave 120 mg (29%) of **1c**: mp 94.5–95.5 °C (lit.[7] mp 94.5 °C); UV (benzene) λ_{max} 316 nm (ϵ 2760), 277 (5810).

***N,N*-Bis[(4-methoxyphenyl)thio]-4-toluenesulfonamide (1d).** On heating at 120 °C for 10 min, the reaction mixture, after chromatography and subsequent crystallization, gave 61 mg (14%) of **1d**: mp 90–91 °C (lit.[7] mp 92.5 °C); UV (benzene) λ_{max} 315 nm (sh) (ϵ 3840), 277 (12 200).

***N,N*-Bis[(4-chlorophenyl)thio]-4-toluenesulfonamide (1e).** On heating at 165 °C for ~1 h, the reaction mixture, after chromatography and subsequent crystallization, gave 58 mg (13%) of **1e**: mp 111–112 °C (lit.[7] mp 111–112 °C); UV (benzene) λ_{max} 315 nm (ϵ 2800), 277 (6600).

N-(Arylthio)-4-toluenesulfonamides (**2**) were prepared by heating a solution of *S*-aryl-*S*-ethyl-*N*-(4-toluenesulfonyl)sulfilimines (0.65 mmol) in refluxing toluene (4 mL) for 1–2 h according to the reported procedure and were purified by repeated recrystallization from benzene–hexane.[12]

***N*-(Phenylthio)-4-toluenesulfonamide (2a)**: colorless needles; mp 97–99 °C (lit.[12] mp 113–115 °C); yield 97 mg (53%); IR (KBr) 3230 (NH), 1290 and 1160 cm^{-1} (SO_2); ^{1}H NMR ($CDCl_3$) δ 2.36 (s, Me, 3 H), 6.55 (s, NH, 1 H), 7.12–7.79 (m, aromatic, 9 H).

***N*-(4-Tolylthio)-4-toluenesulfonamide (2c)**:[36] colorless needles; mp 101–103 °C; yield 79 mg (41%); IR (KBr) 3210 (NH), 1290 and 1160 cm^{-1} (SO_2); ^{1}H NMR ($CDCl_3$) δ 2.25 (s, Me, 3 H), 2.33 (s, Me, 3 H), 6.74 (s, NH, 1 H), 6.93 –7.77 (m, aromatic, 8 H).

***N*-[(4-Chlorophenyl)thio]-4-toluenesulfonamide (2e)**: colorless prisms; mp 107–109 °C; yield 135 mg (65%); IR (KBr) 3200 (NH), 1320 and 1160 cm^{-1} (SO_2); ^{1}H NMR ($CDCl_3$) δ 2.35 (s, Me, 3 H), 6.96 (s, NH, 1 H), 7.06–7.76 (m, aromatic, 8 H). Anal. Calcd for $C_{13}H_{12}ClNO_2S_2$: C, 49.75; H, 3.85; N, 4.46. Found: C, 50.14; H, 3.79; N, 4.20.

***N*-[(4-Nitrophenyl)thio]-4-toluenesulfonamide (1f)**:[36] light brown prisms; mp 142–143 °C; yield 104 mg (49%); IR (KBr) 3200 (NH), 1340 and 1160 cm^{-1} (SO_2); ^{1}H NMR ($CDCl_3$) δ 2.38 (s, Me, 3 H), 6.62 (s, NH, 1 H), 7.18–8.09 (m, aromatic, 8 H).

Thermolysis of 5. In a glass tube were placed **5** (300 mg, 0.537 mmol) and benzene (10 mL), and the mixture was degassed by three freeze–pump–thaw cycles. After the tube was sealed off from the vacuum system, the mixture was heated to 60 °C for 8 h. After concentration, the residue was column chromatographed on silica gel (Wako gel C-200, column size 3 × 10 cm). Elution with 1:1 (v/v) benzene–hexane gave diphenyl disulfide, and subsequent elution with benzene gave **1a** (82 mg, 39%) containing small amounts of impurities that on crystallization from methanol, afforded colorless needles: mp 94–95 °C (lit.[7] mp 97.5–98 °C); 24% yield (50 mg, 0.13 mmol). The IR and ^{1}H NMR spectra were in complete agreement with those of an authentic sample.

Reaction of 5 with Azobis(diphenylmethane). In a glass tube were placed **5** (200 mg, 0.36 mmol), azobis(diphenylmethane) (390 mg, 1.1 mmol), and dichloromethane (10 mL). After the mixture was degassed as above, the tube was sealed off and the mixture was heated to 50 °C for 5 h. After concentration, the residue was column chromatographed on silica gel (Wako gel C-200, column size 3 × 20 cm) with benzene as eluant to give a semisolid mass (100 mg) that on crystallization from hexane, afforded colorless prisms: mp 121–123 °C; 12% yield (37 mg, 0.083 mmol); ^{1}H NMR ($CDCl_3$) δ 2.34 (s, Me, 3 H), 6.76 (s, Ph_2CH, 1 H), 6.70–7.63 (m, aromatic, 19 H); mass spectrum (35 eV), *m/e* 218 (21), 182 (71), 181 (23), 180 (27), 168 (63), 167 (100), 109 (44), 91 (39). Anal. Calcd for $C_{26}H_{23}NO_2S_2$: C, 70.08; H, 5.20; N, 3.14. Found: C, 70.31; H, 5.42; N, 3.01.

Generation of Radicals. Radicals **3** were generated in benzene by either or both of the following two methods: (a) photolysis of a solution of **1** with an 100-W high-pressure mercury or an 1-kW xenon lamp and (b) oxidation of a solution of **2** with PbO_2. All ESR samples were degassed by three freeze–pump–thaw cycles using a high-vacuum line.

Acknowledgment. The authors thank Professor T. Ohta and Dr. H. Tanaka of Tokushima University for the use of an ESR instrument and valuable suggestions on the ESR data. They also thank Professor N. Furukawa of Tsukuba University for valuable suggestions and discussion on the syntheses of sulfilimines and related compounds.

Registry No. **1a**, 37753-02-9; **1b**, 99397-59-8; **1c**, 37753-03-0; **1d**, 37753-04-1; **1e**, 37753-05-2; **1f**, 99376-69-9; **2a**, 29723-57-7; **2c**, 99376-70-2; **2e**, 99376-71-3; **3a**, 99376-73-5; **3b**, 99376-74-6; **3c**, 99376-75-7; **3d**, 99376-76-8; **3e**, 99376-77-9; **3f**, 99376-78-0; **5**, 28833-59-2; **6**, 99376-72-4; TsN=SPh_2, 13150-76-0; Ph_2S_2, 882-33-7; $(C_6D_5)_2S_2$, 99397-58-7; $(p\text{-}MeC_6H_4)_2S_2$, 103-19-5; $(p\text{-}MeOC_6H_4)_2S_2$, 5335-87-5; $(p\text{-}ClC_6H_4)_2S_2$, 1142-19-4; azobis(diphenylmethane), 34863-14-4.

(36) In spite of repeated recrystallizations, the results of the elemental analyses of these products did not coincide staisfactorily with the calculated values (1–2% deviations in carbon). This is probably due to the thermally labile properties of these compounds. However, the ^{1}H NMR spectra could be assigned satisfactorily to the proposed structures.

2,2,5-Trimethyl-1,3-dioxolane-4-carboxaldehyde as a Chiral Synthon: Synthesis of the Two Enantiomers of Methyl 2,3,6-Trideoxy-α-L-*threo*-hex-2-enopyranoside, Key Intermediate in the Synthesis of Daunosamine, and of (+)- and (−)-Rhodinose

Stefano Servi

CNR Centro di Studio per le Sostanze Organiche Naturali, Dipartimento di Chimica, Politecnico di Milano, 20133 Milano, Italy

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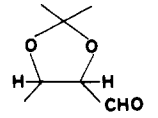
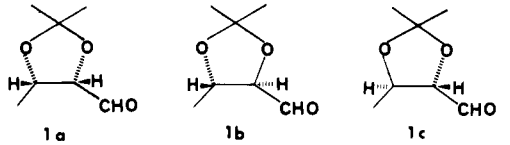
2,2,5-Trimethyl-1,3-dioxolane-4-carboxaldehyde (**1**) has proven to be a valuable chiral synthon in the preparation of optically active naturally occurring compounds.[1b] Thus,



1

chiron **1** has been used in synthetic methodologies as an alternative to tartaric, malic, and lactic acids and more often to carbohydrates. Moreover, aldehyde **1** is currently easily accessible in three of the possible stereoisomers,[2] i.e.,



[(4*S*)-cis] **1a** from the products obtained from cinnamaldehyde in fermenting bakers' yeast,[3] (4*R*-trans) **1b** from

(1) (a) This work has been financially supported by Piano Finalizzato CNR Chimica Fine e Secondaria. (b) See, for instance: Fuganti, C.; Servi, S.; Zirotti, C. *Tetrahedron Lett.* **1983**, 5285. Fuganti, C.; Grasselli, P.; Servi, S. *J. Chem. Soc., Chem. Commun.* **1982**, 1285. Servi, S. *Tetrahedron Lett.* **1983**, 2023.

(2) Although analytical data are elusive, the three aldehydes are relatively stable compounds and can be prepared in a reproducible way. Their absolute configuration and optical purity, has been proved by conversion into compounds of known absolute configuration (see ref 1–5).

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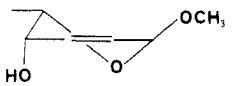
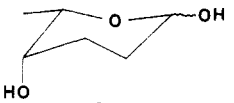
the epimerization of **1a** or from D-threonine,[4] (4S-trans) **1c** from L-threonine.[5]

It is often desirable that a chiral biologically active compound be accessible in the two enantiomeric forms both for determination of absolute configuration of the natural product and for biomedical evaluation of the unnatural enantiomer. The availability of **1b** and **1c** allows, with a single synthetic strategy, to prepare the two enantiomeric forms of a chiral product. As an example of this possibility, I wish to report that **1b** and **1c** can be transformed through a very short synthetic pathway into both enantiomeric forms of methyl 2,3,6-trideoxy-α-L-*threo*-hex-2-enopyranoside (**2**), key intermediate in the synthesis of daunosamine, and into (+)- and (−)-rhodinose (**3**).



2

2a = D-enantiomer



3

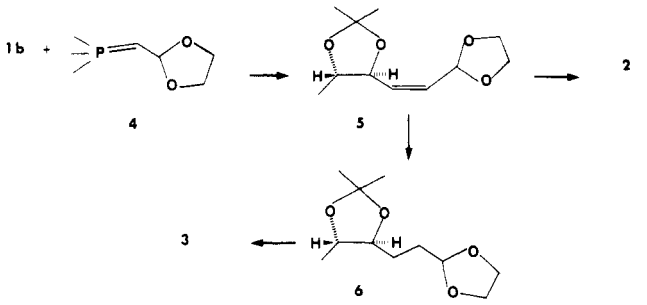
3a = D-enantiomer

Daunosamine is the amino sugar component of the important antitumor agents daunomycin and adriamycin, and its synthesis from compound **2** has been recently reported independently by two groups[6] starting from L-rhamnose. Natural rhodinose (**3**)[7] is the glycosidic part of biologically active molecules isolated from various stems of streptomyces, and it has been synthesized from L-rhamnose,[8] L-xylose,[9] and glutamic acid[10] through complex chemical modifications involving deoxygenation and invertion of configuration of the chiral centers through multistep procedures or nonstereoselective steps. Recently a rather direct approach to this sugar from natural lactic acid has been reported.[11] D-Rhodinose has been prepared from L-glucose.[12]

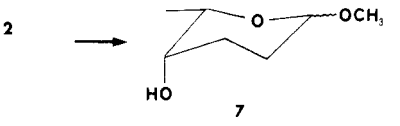
This synthesis of **2** and **3** and of their enantiomers, starts from **1b** or **1c**, requiring only chain elongation and cyclization, the two chiral centers being already present with the required absolute configurations in the starting materials.

Thus Wittig reaction of **1b** with phosphonium ylide **4**[13] gives **5** as a 9:1 inseparable mixture of cis and trans isomers, in 65% yield (Scheme I). The deprotection and cyclization of **5** to **2** is a delicate step in that the unsaturated aldehydo diol formed is a very sensitive intermediate. The transformation can be accomplished in acceptable yields by low-temperature treatment of **5** with dilute methanolic HCl in inert atmosphere. Preparation of the valuable intermediate **2** is thus possible in only two steps from **1b** and in a total 35% yield. **5** is quantitatively reduced to **6** whose transformation into rhodinose (**3**) is

Scheme I



straightforward, requiring only acidic hydrolysis. Catalytic hydrogenation of **2** gives methyl 2,3,6-trideoxy-L-*threo*-hexopyranoside (**7**) as a mixture of α and β anomers.[14] Acidic hydrolysis eventually gives **3** identical with the compound obtained from **6**.



7a = D-enantiomer

When aldehyde **1c** was used as starting material, **2a** and **3a** were obtained through the same intermediates involved in the synthesis of **2** and **3**.

In conclusion, whereas most of the constitutents of the chiral pool are readily accessible in only one enantiomeric form, aldehyde **1**, which can be prepared in three of the possible stereoisomers, is a convenient chiron for the synthesis of the two enantiomeric forms of important chiral molecules like **2** and **3**, which have either been synthesized in only one enantiomeric form or from nonenantiomeric starting materials, requiring two distinct synthetic strategies.

Experimental Section

General Methods. ^{1}H NMR spectra were determined on a Varian EM-390 (90 MHz) and on a Bruker CXP (300 MHz) instrument. Chemical shifts are in ppm (δ) relative to internal Me_4Si. Mass spectra were obtained with VG Micromass ZAB 2F spectrometer. Optical rotations were recorded on a Jasco DIP-181 digital polarimeter. Purification of products was performed by flash chromatography on silica gel (Merck 60, 0.040–0.063 mm) with mixtures of hexane and ethyl acetate. Analytical samples were prepared by bulb-to-bulb distillation under reduced pressure. Melting points are uncorrected.

(4*R*)-*trans*-2,2,5-Trimethyl-1,3-dioxolane-4-carboxaldehyde (1b). (a) Epimerization of the Corresponding *erythro* Aldehyde (4*S*-*cis*) Prepared from the Products Obtained from Cinnamaldehyde in Fermenting Bakers' Yeast.[3] To 11 g of aldehyde **1a** (76 mmol) dissolved in 60 mL of absolute MeOH under nitrogen was added 10 g of potassium carbonate and the mixture stirred at room temperature. After 15 min, GC analysis showed a *threo* to *erythro* ratio of 98:2. The mixture was treated with brine and the clear solution extracted with methylene chloride. The crude material showed physicochemical properties consistent with a mixture of aldehyde and its hydrated form. This mixture was adequate for Wittig reaction. Dehydration to the aldehydic form was performed by refluxing a methylene chloride solution in a Soxhlet apparatus containing 4-Å molecular sieves, for 48 h (after this time IR spectra still showed some OH absorption at 3450 cm^{-1}): $[\alpha]^{20}_D$ +27.7° (*c* 1, $CHCl_3$) (+13.2° for the cyclohexylidene analogue); ^{1}H NMR

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(4) Fuganti, C.; Grasselli, P.; Pedrocchi-Fantoni, G. *Tetrahedron Lett.* **1981**, 4017.
(5) Fuganti, C.; Grasselli, P.; Servi, S.; Zirotti, C. *Tetrahedron Lett.* **1982**, 4269.
(6) (a) Pauls, H. W.; Fraser-Reid, B. *J. Chem. Soc., Chem. Commun.* **1983**, 1031. (b) Cardillo, G.; Orena, M.; Sandri, S.; Tomasini, C. *J. Org. Chem.* **1984**, *49*, 3951.
(7) Rhodinose is usually depicted in its pyranosidic form although it is an equilibrium mixture of pyranosidic and furanosidic forms.
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(12) Stevens, C. L.; Blumbergs, P.; Wood, D. L. *J. Am. Chem. Soc.* **1964**, *83*, 3592.
(13) Cresp, M. T.; Sargent, M. V.; Vogel, P. *J. Chem. Soc., Perkin Trans. 1* **1974**, 37.

(14) Catalytic hydrogenation in MeOH of **2** surprisingly gives **7** as a mixture of α and β anomers as deduced from the two methyl singlets and the two H_5 signals in the ^{1}H NMR spectra. This observation is confirmed by other authors (Cardillo, G., personal communication). The α configuration of **2** was assigned on the basis of identity with the analytical data described in the literature for the same compound.[6b]

($CDCl_3$) δ 1.4 (d, 3 H, J = 3 Hz), 1.48 (s, 3 H), 1.50 (s, 3 H), 3.75–4.35 (m, 2 H), 9.75 (d, 1 H); MS, m/z 162 (M^+), 159, 129, 115, 99, 85, 73, 59; IR (liquid film) 1730, 1760, 3450 cm^{-1}.

(b) From D-Threonine (See Preparation of the 4*S*-Trans Enantiomer from L-Threonine).

(4*S*)-*trans*-2,2,5-Trimethyl-1,3-dioxolane-4-carboxaldehyde (1c). L-Threonine (220 g, 1.85 mol) suspended in 500 mL of water at −5 °C was treated simultaneously while stirring with a solution of 138 g of $NaNO_2$ (2 mol) in 200 mL of water and 55.7 mL of concentrated H_2SO_4 (1 mol) in 150 mL of water. The two solutions were added at such a rate that the temperature remained between 0 and 5 °C. The solution was then stirred at room temperature overnight. The water was evaporated under vacuum and the remaining mixture treated with 300 mL of EtOH. The salts were then filtered and the solution evaporated to dryness again. Absolute MeOH (200 mL) was then added and the solution saturated with gaseous HCl and refluxed for 6 h. Evaporation of the solvent gave a crude dihydroxy ester which was directly transformed into the 1,3-dioxolane derivative by treatment with 200 mL of acetone, 200 mL of 2,2-dimethoxypropane, and 1 g of *p*-toluenesulfonic acid. After 2 h at room temperature the solution was evaporated. Partition between water and ethyl acetate and conventional treatment of the organic phase gave a crude product, which after distillation [70–75 °C (1 mm)] gave 177 g (55%) of (4*S*)-*trans*-2,2,5-trimethyl-4-(methoxycarbonyl)-1,3-dioxolane: $[\alpha]^{20}_D$ −16.4° (*c* 1, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 1.4 (d, 3 H), 1.48 (s, 6 H), 3.8 (s, 3 H), 4–4.4 (m, 2 H); MS, m/z 174 (M^+), 173, 159, 131, 115, 99, 97, 85; IR (liquid film) 1850 cm^{-1}. Anal. Calcd for $C_8H_{14}O_4$: C, 55.16; H, 8.10. Found: C, 54.91; H, 7.96.

The ester (25 g, 0.143 mol) in 200 mL of anhydrous ethyl ether was treated under nitrogen with 145 mL of a 1 M solution of DIBAH in hexane at −78 °C. The solution was stirred 1 h at −40 °C, cooled again at −78 °C, and 75 mL of water added dropwise. The mixture was allowed to come to room temperature. The solid part separated by filtration and washed with ether. Evaporation of the solvent and bulb-to-bulb distillation gave 18.2 g (88%) of the aldehyde **1c** mainly in its hydrated form, $[\alpha]^{20}_D$ −28.2° (*c* 1, $CHCl_3$) (−10.8° for the cyclohexylidene analogue).

(4*S*,5*S*)-[2-(1,3-Dioxolan-2-yl)ethenyl]-2,2,5-trimethyl-1,3-dioxolane (5). To a stirred mixture of 34 g of (1,3-dioxolan-2-ylmethyl)triphenylphosphonium bromide (85.6 mmol) in dry THF (70 mL) was added 171 mL of a 0.5 M solution of potassium *tert*-butoxide in anhydrous THF (85.6 mmol) dropwise at room temperature. The mixture was stirred for an additional 30 min, and the aldehyde **1b** (7 g, 4.3 mmol) was added in 10 mL of THF. The mixture was stirred at room temperature for 24 h. After conventional treatment (evaporation of the solvent, partition between water and methylene chloride) the crude extract was purified by flash chromatography, yielding **5** (6.2 g, 67%) as a 9:1 mixture of cis and trans isomers: $[\alpha]^{20}_D$ −16.2° (*c* 1, EtOH); ^1H NMR (300 MHz, $CDCl_3$) δ 1.29 (d, 3 H), 1.41 (s, 3 H), 1.42 (s, 3 H), 3.79 (m, 1 H), 3.90 and 4.01 (2 m, 5 H), 4.38 (m, 1 H), 5.53–5.58 (m, 1 H), 5.66–5.71 (m, 1 H); MS, m/e 199 (M^+ − 15), 183, 152, 139, 107, 87, 73. Anal. Calcd for $C_{11}H_{18}O_4$: C, 61.66; H, 8.47. Found: C, 61.57; H, 8.38. 4*R*,5*R* enantiomer of **5**: $[\alpha]^{20}_D$ +15.6° (*c* 1, EtOH).

Methyl 2,3,6-Trideoxy-α-L-*threo*-hex-2-enopyranoside (2). **5** (1.6 g, 7.5 mmol) was dissolved at −78 °C in 90 mL of a cooled 0.1% HCl solution in anhydrous MeOH under nitrogen and kept at −78 °C for 72 h. The solution was then left at room temperature for 1 h. Sodium hydrogen carbonate was then added and the solvent evaporated in vacuum. Flash chromatography of the residue gave **2** as an oil (560 mg, 52%). The oily product was sublimed under reduced pressure to give white needles: mp 62–62.5 °C; $[\alpha]^{20}_D$ +130° (*c* 2, MeOH) [lit.[6b] $[\alpha]^{20}_D$ +139° (*c* 2, MeOH)]; ^1H NMR ($CDCl_3$) δ 1.3 (d, 3 H, J = 6 Hz), 1.9 (br s, 1 H, OH), 3.4 (s, 3 H), 3.3–3.8 (m, 1 H), 3.9–4.5 (dq, 1 H), 4.85 (d, 1 H, J = 3 Hz), 5.7–6.3 (m, 2 H); MS, m/z 144 (M^+), 127, 125, 113, 100, 95, 85, 83. Anal. Calcd for $C_7H_{12}O_3$: C, 58.31; H, 8.39 Found: C, 58.16; H, 8.31. **2a**: $[\alpha]^{20}_D$ −132° (*c* 2, MeOH).

(4*S*,5*S*)-4-[2-(1,3-Dioxolan-2-yl)ethyl]-2,2,5-trimethyl-1,3-dioxolane (6). **5** (850 mg, 3.97 mmol) in 15 mL of MeOH was hydrogenated in a Parr apparatus in the presence of 200 mg of 10% Pd/C during 20 min. Filtration and evaporation of the solvent gave crude **6** in nearly quantitative yield (845 mg): $[\alpha]^{20}_D$ −9.3° (*c* 2, MeOH); ^1H NMR ($CDCl_3$) δ 1.22 (d, 3 H), 1.35 (s, 3 H), 1.5–1.9 (m, 4 H), 3.5–4.0 (m, 6 H), 4.8 (m, 1 H); MS, m/z 216 (M^+), 201, 157, 141, 129, 115, 113, 99, 87, 73. Anal. Calcd for $C_{11}H_{20}O_4$: C, 61.09; H, 9.32. Found: C, 61.25; H, 9.16. 4*R*,5*R* enantiomer of **6**: $[\alpha]^{20}_D$ +8.1° (*c* 2, MeOH).

2,3,6-Trideoxy-L-*threo*-hexose (L-Rhodinose) (3). **6** (750 mg, 4.6 mmol) was dissolved in 8 mL of 50% acqueous acetic acid and heated at 60 °C for 2 h. The solvent was evaporated in vacuum and the residue purified by flash chromatography, yielding 322 mg of **3** (73%) as a mixture of four isomers as already observed by other authors:[9,10] $[\alpha]^{20}_D$ −13.6° (*c* 1, acetone); ^1H NMR (300 MHz, $CDCl_3$) δ 1.17, 1.19, 1.21, 1.26 (4 d, 2 H), 1.5–2.1 (m, 2 H), 3.49, 3.68, 3.95, 4.03 (m, 4 H), 4.77, 4.85, 5.52, 5.59 (m, 1 H); MS, m/z 132 (M^+), 115, 114, 99, 88, 87, 70, 69. Anal. Calcd for $C_6H_{12}O_3$: C, 54.55; H, 9.15. Found: C, 54.44; H, 9.07. D-Rhodinose: $[\alpha]^{20}_D$ +14.2° (*c* 1, acetone).

Methyl 2,3,6-Trideoxy-L-*threo*-hexopyranoside (7). **2** (820 mg, 5.7 mmol) in 15 mL of anhydrous MeOH in the presence of 200 mg of 10% Pd/C was shaken with hydrogen in a Parr apparatus during 30 min. The solution was filtered and the residue purified by flash chromatography to give 710 mg of **7** (87%) as a mixture of α and β anomers: $[\alpha]^{20}_D$ −32° (*c* 1, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 1.29 (d, 3 H, J = 6 Hz), 1.7–2.0 (m, 4 H), 2.1 (m, 1 H, OH), 3.4 and 3.5 (2 s, 3 H), 2.55 (m, 1 H), 3.95 (q, 1 H), 4.53 and 4.62 (2 d, 1 H, J = 3 Hz); MS, m/z 146 (M^+), 145, 144, 119, 118, 113, 101, 87, 75, 71, 59, 55. Anal. Calcd for $C_7H_{14}O_3$: C, 57.51; H, 9.65. Found: C, 57.63; H, 9.49. **7a**: $[\alpha]^{20}_D$ +36.4° (*c* 1, $CHCl_3$).

Elemental Analysis of the Products of the D Series. Anal. Calcd for the 4*R*,5*R* enantiomer of **5**, $C_{11}H_{18}O_4$: C, 61.66; H, 8.47. Found: C, 61.44; H, 8.52. Anal. Calcd for **2a**, $C_7H_{12}O_3$: C, 58.31; H, 8.39. Found: C, 58.46; H, 8.41. Anal. Calcd for the 4*R*,5*R* enantiomer of **6**, $C_{11}H_{20}O_4$: C, 61.09; H, 9.32. Found: C, 60.98; H, 9.23. Anal. Calcd for D-rhodinose, $C_6H_{12}O_3$: C, 54.55; H, 9.15. Found: C, 54.48; H, 9.08. Anal. Calcd for **7a**, $C_7H_{14}O_3$: C, 57.51; H, 9.65. Found: C, 57.48; H, 9.73.

A New Synthesis of Azulene-5-carboxylic Acid

V. T. Ravi Kumar, S. Swaminathan, and K. Rajagopalan*

Department of Organic Chemistry, University of Madras, Guindy Campus, Madras 600 025, India

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In connection with our studies on the base-catalyzed rearrangement of oxy-Cope system,[1] we were interested in synthesizing a five-carbon fragment. Recently, we reported[2] the synthesis and Michael acceptor properties of ethyl α-propargylacrylate and its use in cycloheptenone annulation leading to the synthesis of a homo-Wieland–Mieschler ketone.[3] However, our initial attempts to synthesize the title compound utilizing the above synthon were hampered by several poor-yielding reactions. We report herein a modified route in which several of the above difficulties are alleviated. This paper deals with the synthesis of a modified synthon and its utility toward the first synthesis of the title compound via a cycloheptenone annulation.

Alkylation of triethyl phosphonoacetate with the ethylene ketal of bromoacetone[4] with sodium hydride in THF at room temperature for 6 h and then at reflux for 3 h gave the alkylated compound **3** as a colorless liquid in 76% yield. The Wittig–Horner reaction of compound **3** with 30% formalin in the presence of saturated aqueous

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