Table III. Final Bond Lengths and Angles in 8

atoms	distance	atoms	distance
S(1)-S(2)	2.064 (9)	S(1)-C(1)	1.78 (2)
S(2)-C(2)	1.81 (2)	N(1)-C(3)	1.42 (3)
N(2)-C(6)	1.45 (3)	C(1)-C(2)	1.42 (3)
C(1)-C(6)	1.38 (3)	C(2)-C(3)	1.38 (3)
C(3)-C(4)	1.43 (3)	C(4)-C(5)	1.34 (3)
C(5)-C(6)	1.41 (3)		
atoms	**angle**	**atoms**	**angle**
S(2)'-S(1)-C(1)	105.3 (9)	S(1)'-S(2)-C(2)	102.5 (8)
S(1)-C(1)-C(2)	122 (2)	S(1)-C(1)-C(6)	119 (2)
C(2)-C(1)-C(6)	120 (2)	S(2)-C(2)-C(1)	121 (2)
S(2)-C(2)-C(3)	116 (2)	C(1)-C(2)-C(3)	123 (2)
N(1)-C(3)-C(2)	125 (2)	N(1)-C(3)-C(4)	120 (2)
C(2)-C(3)-C(4)	116 (2)	C(3)-C(4)-C(5)	121 (2)
C(4)-C(5)-C(6)	123 (2)	N(2)-C(6)-C(1)	123 (2)
N(2)-C(6)-C(5)	119 (2)	C(1)-C(6)-C(5)	117 (2)

sentially according to literature procedure.[9] The red material was conveniently recrystallized from DMF instead of boiling aniline–ethanol: mp >225 °C dec; IR (KBr) 3400, 3300, 1600, 1595, 1590, 1460, 1285, 1220, 1155, 918, 810 cm^{-1}; UV–visible (DMF) λ_{max} (log ϵ) 276 nm (4.14), 313 (3.58), 4.91 (4.02), (DMF/HCl) 267 (3.95), 410 (3.93); mass spectrum, *m/e* (rel intens, %) 340 (0.3), 276 (35), 243 (26), 202 (100), 169 (44).

1,4-Diaminobenzene-2,3-dithiol (9). Tetrathiocin 8 (100 mg) was heated cautiously with hypophosphorus acid (25%, 5 mL) for 20 min at 100 °C until a pale yellow solution resulted. The mixture was concentrated to half its volume in vacuo. Hydriodic acid (48%) was added dropwise until the HI salt precipitated (150 mg). This was recrystallized best from CH_2Cl_2–MeOH–Et_2O: mp >150 °C dec; mass spectrum; *m/e* (rel intens, %) 172 (M^+, 2.4%); IR, 2800 br, 1560, 1510, 1400, 1280, 830, 725 cm^{-1}. Anal. Calcd for $C_6H_{10}I_2N_2S_2$: C, 16.83; H, 2.12. Found: C, 16.79; H, 2.48.

2,3-Bis(methylthio)-1,4-benzenediamine (10). A suspension of tetrathiocin 8 (350 mg) in THF–water (3:17, 20 cm^3) containing aqueous sodium hydroxide (1 cm^3) was stirred under nitrogen after the addition of excess $NaBH_4$. After 3 days of stirring, a yellow solution resulted. Methyl iodide (excess, 1 cm^3) was added, and stirring was continued. The product was extracted into ether and after standard workup was obtained as a dark gum. Its solutions in organic solvents were highly fluorescent, and it turned rapidly blue in air and light. It was best isolated as the HI salt by treatment with ethanolic hydriodic acid: the white crystalline salt (340 mg) decomposed above 200 °C; mass spectrum, *m/e* (intens, %), 200 (M^+, 100), 185 (16.7), 184 (11.7), 152 (36.1), 139 (13.8), 121 (15.8); IR (KBr) 2850, 1490, 1450, 1110, 1035, 980, 965 cm^{-1}. Anal. Calcd for $C_8H_{14}I_2N_2S_2$: C, 21.07; H, 3.09. Found: C, 21.32; H, 3.16.

The Blue Polymer.[9] A filtered solution of diamino tetrathiosulfonate **12** (0.96 g) in hot water (30 mL) was treated with concentrated HCl (30 mL), and the dark mixture was boiled until no more SO_2 evolved. The resulting red precipitate of hydrochloride was filtered, washed with concentrated HCl and ether successively, and dried. Trituration of the foregoing hydrochloride with dilute sodium hydroxide solution yielded the blue polymer which was filtered, washed with water, alcohol, and ether, and dried: 0.3 g (94.6%); IR (KBr) 3450, 3350, 1600, 1400, 1250, 1020 cm^{-1}.

2,3,5,6-Tetrakis(methylthio)-*p*-phenylenediamine (13). Reduction of the above polymer (0.12 g) in THF–water–NaOH suspension with excess sodium borohydride (300 mg) at 45 °C over a period of 48 h followed by methylation with Me_2SO_4 (0.8 mL) under nitrogen yielded a light yellow precipitate (0.08 g) that is extremely susceptible to oxidation in air and light leading to soluble blue polar material. A pure sample of **13** (30 mg) was isolated by careful chromatography on alumina under inert atmosphere and crystallization from ether–hexane. It formed light yellow fluorescent prisms: mp 115 °C (30 mg); mass spectrum, *m/e* 292 (M^+, 100%); IR (KBr) 3400, 3300, 3000, 2900, 1570, 1400, 1250, 1160, 985 cm^{-1}. Anal. Calcd for $C_{10}H_{16}N_2S_4$: C, 41.10; H, 5.50. Found: C, 41.11; H, 5.60.

Acknowledgment. This work was supported by a grant from the National Science Foundation (85-14876).

Registry No. 8, 107474-48-6; 9·2HI, 107474-49-7; 10·2HI, 107474-50-0; 12, 107474-51-1; 12 (hydrochloride), 107474-52-2; 12 (hydrochloride homopolymer), 107474-54-4; 13, 107474-53-3.

Supplementary Material Available: Listings of anisotropic thermal parameters (1 page); listings of observed and calculated structure factors (2 pages). Ordering information is given on any current masthead page.

Stereochemistry of the Ring Opening of Chiral Epoxides Derived from Allylic Alcohols Having Two Substituted-Phenyl Groups

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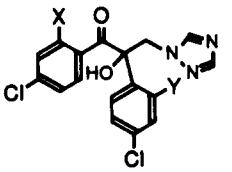
The antifungal activity of imidazole- and triazole-containing compounds has led us to study their synthesis over the past few years.[1] We have found that 2,3-diphenyl-3-oxo-1-(1*H*-1,2,4-triazol-1-yl)propan-2-ol derivatives such as **1** are orally active against fungi.[2,3] As generally ob-



1a X=Y=H
1b X=H, Y=Cl
1c X=Y=Cl

served with biologically active compounds, only one of the two enantiomers of the imidazole-containing compounds is active against fungi.[3,4] We were interested in synthesizing optically active isomers of **1** by using the Sharpless asymmetric epoxidation to introduce chirality.[5] The asymmetric epoxidation of allylic alcohols has been extensively studied and widely applied[6] to syntheses of optically active compounds. However, few examples of the epoxidation of allylic alcohols having two substituted-phenyl groups have been reported.[7] Moreover, although there are many reports of ring-opening epoxides that have aliphatic side chains, there are few examples of ring-opening epoxides with two aromatic substituents.[8-10] We

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(2) In formula **a**, **b**, and **c**, X = Y = H,X = H,Y = Cl, and X = Y = Cl, respectively, throughout this paper.

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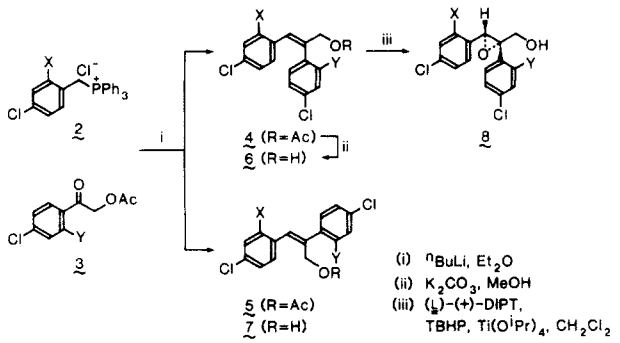
Scheme I



have synthesized optically active ketols (+)-(*S*)-**1** using asymmetric epoxidation of α-phenylcinnamyl alcohol derivatives **6a–c** followed by ring opening the epoxide, condensation with triazole, cleavage of the methoxy group, and oxidation. We discovered that the reactivity and stereochemistry of ring opening are very different among **8a–c**. We here report the stereochemistry of their ring opening.

Results and Discussion

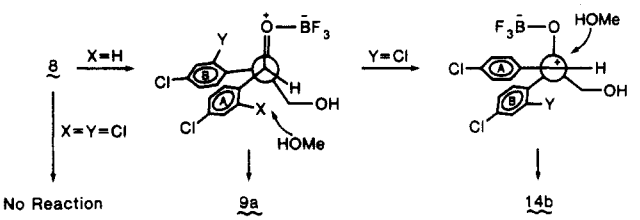
The acetate of allylic alcohol **4a** was prepared by the Wittig reaction of phosphonium salt **2a** and ketone **3a**, easily obtainable from 4-chlorophenacyl bromide and sodium acetate. The major product is (*E*)-**4a**, with a UV spectrum (230 nm, ε 19 800; 268 nm, ε 14 800) typical of *cis*-α-phenylcinnamyl alcohol (222 nm, ε 15 900; 257 nm, ε 12 500).[11] The minor one is (*Z*)-**5a**, which has a UV spectrum (283 nm, ε 22 000) also typical of that of *trans*-cinnamyl alcohol (273 nm, ε 19 800).[11] Four other acetates, **4b,c** and **5b,c** were prepared in a similar way (Scheme I). The major products **4a–c** were hydrolyzed to α-phenylcinnamyl alcohol derivatives **6a–c**, which were treated with *tert*-butyl hydroperoxide (TBHP), titanium isopropoxide [Ti(O-*i*-Pr)$_4$], and (+)-diisopropyl L-tartrate [(+)-L-DIPT] in dichloromethane to give epoxides **8a–c** in >80% yields. The enantiomeric excesses[12] of **8a** and **8b** were >90%, but that of **8c** was only 70%, probably because of the steric bulk of the two 2,4-dichlorophenyl groups.[13]

Attempts to open the ring of epoxide **8a** with NaOAc or NaOMe afforded a complex mixture, but the ring could be opened under acidic conditions. Treatment of **8a** with BF_3 etherate or perfluorinated ion-exchange powder (Nafion)[14] in methanol at 0 °C gave a single isomer of the ring-opened compound **9a** in 82% yield (Scheme II). Attempts to determine the regio- and stereochemistry of this diol by cis hydroxylation of allylic compounds **4a** or **6a** with $KMnO_4$ or OsO_4 did not succeed, but its structure was determined by X-ray analysis.[3e]

The ring opening of epoxide **8b** did not proceed at low temperature, but yielded **14b** on refluxing in MeOH for 6 h. The ring-opened compound, the only isolable product, was first assumed to have the same configuration as **9a**, but it turned out to be the opposite when **14b** was converted into the triazole-containing compound **17b**. Thus both **9a** and **14b** were tosylated with tosyl chloride and pyridine to **10a** and **15b**, respectively. Treatment of each tosylate with triazole yielded **11a** and **16b**. The methyl ether groups were cleaved with aluminum chloride and sodium iodide in acetonitrile.[15] The diol thus obtained from **8a** was identical with **12a**, the major product from the sodium borohydride reduction of the ketol **1a**, while the diol from **8b** was identical with **17b**, the minor reduction product from the ketol **1b**. The stereochemistry of the reduction products was confirmed by X-ray analysis[3e] of carbonate **13b**, prepared from diol **12b**. The major reduction products of ketol 1 had the 2*S*,3*R* configuration, and the minor ones were 2*S*,3*S*.[16] Diols 12a and 17b were oxidized with dimethyl sulfoxide–oxalyl chloride–triethylamine[17] to optically active ketols (*S*)-(+)-**1a** and (*S*)-(+)-**1b**, respectively.

Attempts to open the ring of **8c** with BF_3 etherate, H_2SO_4, $HClO_4$, or Nafion in refluxing MeOH, BF_3 etherate in refluxing AcOH, or NaOMe in MeOH did not succeed.

The differences in the reactivity and stereochemistry of methanolysis[18–20] among these three epoxides can be explained by the steric effect of their chlorine atoms. With **8a**, the MeOH nucleophile can be easily approach the back side of the epoxide oxygen, which is coordinated with BF_3. With **8b**, MeOH cannot attack from the back side of the epoxide; after the epoxide ring opens up to give carbonium ion, MeOH would come from the opposite side of the 2,4-dichlorophenyl group to give **14b**. With **8c**, coordination with BF_3 or ring opening of the epoxide would be blocked by the chlorine atom at the 2-position of the A phenyl ring.



In conclusion, asymmetric epoxidation of allylic alcohols that have two substituted phenyl groups, and ring opening of the resulting epoxide, can be used to synthesize chiral compounds, but the success depends on the substituents on the phenyl rings. In our compounds, the stereochemistry was controlled by the chlorine atoms on the phenyl rings.

Experimental Section

Melting points were determined on a Yanagimoto microapparatus or a Büchi apparatus and are uncorrected. A Hitachi 260-10 spectrophotometer was used to obtain IR spectra. UV spectra were recorded on a Hitachi 320 spectrophotometer. NMR spectra were obtained with a Varian T-60 or a Varian EM-390 spectrometer in $CDCl_3$ with Me_4Si as the internal reference unless otherwise mentioned. Optical rotations were determined by using a Perkin-Elmer Model 241 polarimeter. Elemental analyses were performed by the analytical department of these laboratories. Chromatography was done on Merck silica gel 60 (230–400 mesh). TLC plates were purchased from E. Merck. The enantiomeric

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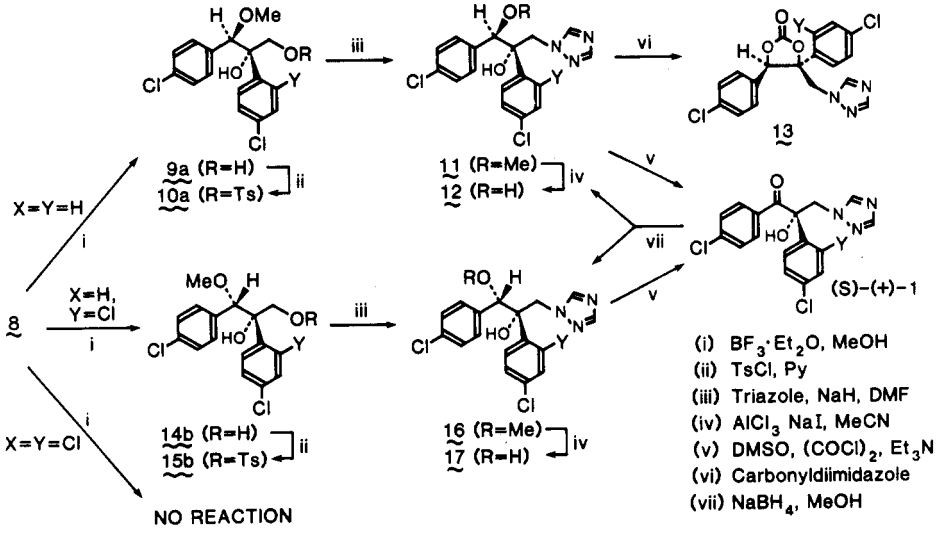
Scheme II



excess was determined by ^1H NMR of the corresponding MTPA ester.[12]

(*E*)-2,3-Bis(4-chlorophenyl)prop-2-en-1-yl Acetate (4a) and *Z* Isomer 5a. *n*-BuLi (15% in hexane, 21 mL) was added dropwise to a stirred suspension of phosphonium salt **2a** (13.8 g, 32.6 mmol) in Et_2O (100 mL) at 0 °C. After stirring for 30 min at 0 °C, the ketone **3a** (6.93 g, 32.6 mmol) in Et_2O (50 mL) was added dropwise at 0–5 °C. Then the mixture was stirred at room temperature for 1 h and filtered, and the filter cake was washed with Et_2O. The combined filtrate was evaporated and chromatographed. Elution with hexane/AcOEt (95/5) afforded **5a** (1.81 g, 17%): mp 111–113 °C (AcOEt/hexane); IR ($CHCl_3$) 1740 cm^{-1}; UV (MeOH) 283 nm (ϵ 22 000); NMR δ 7.50–7.20 (8 H, m, ArH × 8), 6.92 (1 H, s, vinyl H), 5.04 (2 H, s, OCH_2), and 2.00 (3 H, s, Ac). Anal. Calcd for $C_{17}H_{14}O_2Cl_2$: C, 63.56; H, 4.39; Cl, 22.08. Found: C, 63.34; H, 4.45; Cl, 21.84. Further elution gave **4a** (3.46 g, 33%): mp 81–82 °C (AcOEt/hexane); IR ($CHCl_3$) 1740 cm^{-1}; UV (MeOH) 230 nm (ϵ 19 800) and 268 (14 800); NMR δ 7.60–7.20 (8 H, m, ArH × 8), 6.62 (1 H, s, vinyl H), 5.04 (2 H, s, OCH_2), and 2.00 (3 H, s, Ac). Anal. Calcd for $C_{17}H_{14}O_2Cl_2$: C, 63.56; H, 4.39; Cl, 22.08. Found: C, 63.73; H, 4.31; Cl, 22.46.

(*E*)-3-(4-Chlorophenyl)-2-(2,4-dichlorophenyl)prop-2-en-1-yl Acetate (4b) and *Z* Isomer 5b. Wittig reaction of **2b** (21.15 g, 50 mmol) and the ketone **3b** (12.35 g, 50 mmol) yielded **5b** (2.71 g, 15%): mp 73–75 °C (Et_2O–hexane); NMR δ 7.45–7.15 (7 H, m, ArH × 7), 6.62 (1 H, s, vinyl H), 5.04 (2 H, brs, CH_2O), and 1.88 (3 H, s, Ac). Anal. Calcd for $C_{17}H_{13}O_2Cl_3$: C, 57.41; H, 3.68; Cl, 29.91. Found: C, 57.25; H, 3.80; Cl, 30.13. Further elution gave **4b** (6.17 g, 35%): mp 61–63 °C (Et_2O–hexane); NMR δ 7.55–6.85 (8 H, m, ArH × 7 and vinyl H), 4.88 (2 H, brs, CH_2O), and 2.00 (3 H, s, Ac). Anal. Calcd for $C_{17}H_{13}O_2Cl_3$: C, 57.41; H, 3.68; Cl, 29.91. Found: C, 57.26; H, 3.81; Cl, 30.18.

(*E*)-2,3-Bis(2,4-dichlorophenyl)prop-2-en-1-yl Acetate (4c) and *Z* Isomer 5c. Wittig reaction of **2c** (4.75 g, 10 mmol) and **3c** (2.47 g, 10 mmol) gave **5c** (0.37 g, 10%) as an oil: NMR δ 7.40–7.16 (6 H, m, ArH × 6), 6.60 (1 H, s, vinyl H), 4.88 (2 H, s, CH_2O), and 1.82 (3 H, s, Ac). Further elution afforded **4c** (1.50 g, 39%) as an oil: NMR δ 7.50–6.50 (7 H, m, ArH × 6 and vinyl H), 4.90 (2 H, brs, CH_2O), and 2.00 (3 H, s, Ac). These compounds were used in the next step without further purification.

(*E*)-2,3-Bis(4-chlorophenyl)prop-2-en-1-ol (6a). A mixture of the acetate **4a** (3.40 g, 10.6 mmol), K_2CO_3 (1.76 g, 12.7 mmol), and MeOH (30 mL) was stirred at room temperature for 1 h. The mixture was extracted with CH_2Cl_2 and washed with brine. The organic layer was dried (Na_2SO_4) and evaporated to give **6a** (2.08 g, 69%): mp 126–127 °C (AcOEt–hexane); NMR δ 7.45–6.80 (8 H, m, ArH × 8), 6.64 (1 H, s, vinyl H), 4.38 (2 H, d, J = 6 Hz, CH_2O), and 1.80 (1 H, t, J = 6 Hz, OH). Anal. Calcd for $C_{15}H_{12}OCl_2$: C, 64.53; H, 4.33; Cl, 25.40. Found: C, 64.19; H, 4.35; Cl, 25.47.

(*E*)-3-(4-Chlorophenyl)-2-(2,4-dichlorophenyl)prop-2-en-1-ol (6b). Hydrolysis of the acetate **4b** (1.70 g, 4.78 mmol) as above gave **6b** (1.41 g, 94%) as an oil: NMR δ 7.50–6.86 (8H, m, ArH × 7 and vinyl H), 4.36 (2 H, brs, CH_2O), and 2.00 (1 H, brs, OH). Anal. Calcd for $C_{15}H_{11}OCl_3$: C, 57.46; H, 3.51; Cl, 33.93. Found: C, 57.63; H, 3.73; Cl 33.54.

(*E*)-2,3-Bis(2,4-dichlorophenyl)prop-2-en-1-ol (6c). Hydrolysis of the acetate **4c** (4.20 g, 10.77 mmol) as above yielded **6c** (3.60 g, 96%): mp 55–57 °C (Et_2O–hexane); NMR δ 7.50–6.55 (7 H, m, ArH × 6 and vinyl H), 4.40 (2 H, d, J = 7 Hz, CH_2O), and 2.90 (1 H, t, J = 7 Hz, OH). Anal. Calcd for $C_{15}H_{10}OCl_4$: C, 51.76; H, 2.90; Cl, 40.75. Found: C, 52.13; H, 3.00; Cl, 41.04.

(2*S*,3*S*)-2,3-Bis(4-chlorophenyl)-2,3-epoxypropan-1-ol (8a). (+)-L-DIPT (0.85 mL, 4 mmol) was added to a stirred solution of Ti(O-*i*-Pr)$_4$ (1.19 mL, 4 mmol) in CH_2Cl_2 (20 mL) at −20 °C. After 5 min **6a** (1.12 g, 4 mmol) in CH_2Cl_2 (10 mL) was added, then TBHP (3.3 M in toluene 1.13 mL) was added, and the solution was kept at − 20 °C for 15 h. Tartaric acid (10% in H_2O, 10 mL) was added, and the solution was stirred at room temperature for 1 h. Layers were separated and the organic layer was dried (Na_2SO_4) and evaporated. The residue was chromatographed with AcOEt/hexane (5/95) to give **8a** (965 mg, 81%) as an oil: NMR δ 7.35–6.80 (8 H, m, ArH × 8), 4.50 (1 H, s, C_3-H), 4.00 (2 H, d, J = 6 Hz, CH_2O), and 3.35 (1 H, t, J = 7 Hz, OH); $[\alpha]^{23}_D$ +60.9° (*c* 1.05, EtOH), >90% ee. Anal. Calcd for $C_{15}H_{12}O_2Cl_2$: C, 61.03; H, 4.10; Cl, 24.03. Found: C, 61.31; H, 4.19; Cl, 23.99.

(2*S*,3*S*)-3-(4-Chlorophenyl)-2-(2,4-dichlorophenyl)-2,3-epoxypropan-1-ol (8b). The alcohol **6b** (1.40 g, 4.47 mmol) was treated as above yielding **8b** (1.20 g, 81%) as an oil: NMR δ 7.70–6.85 (7 H, m, ArH × 7), 4.52 (1 H, s, C_3-H), 4.10 (2 H, d, J = 7 Hz, CH_2O), and 2.92 (1 H, t, J = 7 Hz, OH); $[\alpha]^{23}_D$ +39.7° (*c* 1.14, $CHCl_3$), >90% ee. Anal. Calcd for $C_{15}H_{11}O_2Cl_3$: C, 54.66; H, 3.36; Cl, 32.27. Found: C, 54.68; H, 3.43; Cl, 32.07.

(2*S*,3*S*)-2,3-Bis(2,4-dichlorophenyl)-2,3-epoxypropan-1-ol (8c). The alcohol **6c** (1.39 g, 4.0 mmol) was treated as above to give **8c** (1.17 g, 80%): mp 111–113 °C (Et_2O–hexane); NMR δ 7.50–6.50 (6 H, m, ArH × 6), 4.76 (1 H, s, C_3-H), 4.05 (2 H, d, J = 7 Hz, CH_2O), and 3.00 (1 H, t, J = 7 Hz, OH); $[\alpha]^{25}_D$ +148.2° (*c* 1.02, $CHCl_3$), 70% ee. Anal. Calcd for $C_{15}H_{10}O_2Cl_4$: C, 49.48; H, 2.77; Cl, 38.96. Found: C, 49.61; H, 2.91; Cl, 38.90.

(2*S*,3*R*)-2,3-Bis(4-chlorophenyl)-3-methoxypropane-1,2-diol (9a). (a) A mixture of the epoxide **8a** (1.50 g, 5.08 mmol) and $BF_3 \cdot Et_2O$ (1.0 g, 7.04 mmol) in MeOH (15 mL) was stirred at 0 °C for 1 h. The mixture was diluted with CH_2Cl_2 and washed with H_2O. The organic layer was dried (Na_2SO_4), evaporated, and chromatographed with AcOEt/hexane (2/8) to give **9a** (1.36 g, 82%) as an oil: NMR δ 7.30–6.75 (8 H, m, ArH × 8), 4.34 (1 H, s, C_3-H), 4.05 and 3.70 (each 1 H, each dd, J = 7, J = 12 Hz) 3.25 (1 H, s, OH), 3.20 (3 H, s, OMe), and 2.20 (1 H, t, J = 7 Hz, OH); $[\alpha]^{23}_D$ −80.8° (*c* 1.01, MeOH). Anal. Calcd for $C_{16}H_{16}O_3Cl_2$: C, 58.73; H, 4.93; Cl, 21.67. Found: C, 59.07; H, 4.86; Cl, 21.77.

(b) A mixture of the epoxide **8a** (295 mg, 1.0 mmol) and Nafion[14] (100 mg) in MeOH (3 mL) was stirred at 0 °C for 1 h. The mixture was filtered and evaporated to give **9a** (290 mg, 89%), which was identical with the authentic material prepared in a.

(2*S*,3*S*)-3-(4-Chlorophenyl)-2-(2,4-dichlorophenyl)-3-methoxypropane-1,2-diol (14b). A mixture of the epoxide **8b** (1.20 g, 3.64 mmol), BF_3-Et_2O (0.52 g, 3.64 mmol) in MeOH (24 mL) was refluxed for 6 h. The mixture was diluted with CH_2Cl_2 and washed with aqueous $NaHCO_3$ solution. The organic layer was dried (Na_2SO_4), evaporated, and chromatographed. Elution with hexane/AcOEt (8/2) gave **14b** (756 mg, 57%) as an oil: IR (film) 3450 cm^{-1}; NMR δ 7.40–6.85 (7 H, m, ArH × 7), 5.12 (1 H, s, C_3-H), 4.48 and 4.24 (each 1 H, each d, J = 12 Hz, CH_2O), 3.90 (2 H, brs, OH × 2), and 3.26 (3 H, s, OMe); $[\alpha]^{25}_D$ −73.9° (*c* 1.00, $CHCl_3$). Anal. Calcd for $C_{16}H_{15}O_3Cl_3$: C, 53.13; H, 4.18; Cl, 29.41. Found: C, 52.86; H, 4.16; Cl, 29.09.

(2*S*,3*R*)-2,3-Bis(4-chlorophenyl)-3-methoxy-1-[(*p*-tolylsulfonyl)oxy]propan-2-ol (10a). A mixture of the diol **9a** (1.51 g, 4.62 mmol), *p*-TsCl (0.88 g, 4.62 mmol), and pyridine (15 mL) was stirred at 0 °C for 15 h. The mixture was poured into ice and extracted with Et_2O. The organic layer was washed with brine, dried (Na_2SO_4), and evaporated. The residue was chromatographed (hexane/AcOEt, 8/2) to give **10a** (1.99 g, 90%) as an oil, which was used in the next step without further purification: NMR δ 7.75–6.70 (12 H, m, ArH × 12), 4.50 and 4.16 (each 1 H, each d, J = 12 Hz, CH_2O), 4.42 (1 H, s, C_3-H), 3.15 (3 H, s, OMe), and 2.42 (3 H, s, $ArCH_3$).

(2*S*,3*S*)-3-(4-Chlorophenyl)-2-(2,4-dichlorophenyl)-3-methoxy-1-[(*p*-tolylsulfonyl)oxy]propan-2-ol (15b). Tosylation of the diol **14b** (640 mg, 1.77 mmol) as above afforded **15b** (690 mg, 76%): mp 157–159 °C (Et_2O–hexane); NMR δ 7.75–6.85 (11 H, m, ArH × 11), 5.08 and 4.70 (each 1 H, each d, J = 12 Hz, CH_2O), 4.96 (1 H, s, C_3-H), 3.44 (1 H, s, OH), 3.22 (3 H, s, OMe), and 2.42 (3 H, s, $ArCH_3$); $[\alpha]^{23}_D$ −72.9° (*c* 1.00, $CHCl_3$). Anal. Calcd for $C_{23}H_{21}O_5Cl_3S$: C, 53.55; H, 4.10; Cl, 20.62; S, 6.22. Found: C, 53.27; H, 4.07; Cl, 20.91; S, 5.93.

(2*S*,3*R*)-2,3-Bis(4-chlorophenyl)-3-methoxy-1-(1*H*-1,2,4-triazol-1-yl)propan-2-ol (11a). A mixture of the tosylate **10a** (1.90 g, 3.95 mmol), 1,2,4-triazole (0.55 g, 7.90 mmol), NaH (50% mineral oil dispersion, 0.379 g, 7.90 mmol), and DMF (10 mL) was stirred at 70 °C for 2 h. The mixture was poured into ice and extracted with CH_2Cl_2. The organic layer was dried (Na_2SO_4) and evaporated to leave an oil which was chromatographed. Elution with CH_2Cl_2/MeOH (95/5) gave **11a** (1.25 g, 84%) as an oil: NMR δ 8.00 and 7.80 (each 1 H, each s, triazole H × 2), 7.30–6.70 (8 H, m, ArH × 8), 4.72 and 4.55 (each 1 H, each d, J = 12 Hz, CH_2N), 4.02 (1 H, s, C_3-H), and 3.16 (3 H, s, OMe). Oxalate: mp 159–161 °C (Et_2O); $[\alpha]^{23}_D$ −82.0° (*c* 1.02, EtOH). Anal. Calcd for $C_{20}H_{19}N_3O_6Cl_2$: C, 51.29; H, 4.09; N, 8.97; Cl, 15.14. Found: C, 51.29; H, 4.06; N, 9.01; Cl, 15.38.

(2*S*,3*S*)-3-(4-Chlorophenyl)-2-(2,4-dichlorophenyl)-3-methoxy-1-(1*H*-1,2,4-triazol-1-yl)propan-2-ol (16b). Similar reaction of the tosylate **15b** (690 mg, 1.34 mmol) as above gave **16b** (440 mg, 80%) as an oil: NMR δ 7.96 and 7.76 (each 1 H, each s, triazole H × 2), 7.30–6.80 (7 H, m, ArH × 7), 5.52 and 4.94 (each 1 H, each d, J = 15 Hz, CH_2N), 5.18 (1 H, s, C_3-H), 4.54 (1 H, s, OH), and 3.32 (3 H, s, OMe). Oxalate: mp 92–94 °C (AcOEt/Et_2O); $[\alpha]^{23}_D$ −11.3° (*c* 1.01, EtOH). Anal. Calcd for $C_{20}H_{19}N_3O_6Cl_3$: C, 47.68; H, 3.80; N, 8.34; Cl, 21.12. Found: C, 47.44; H, 3.96; N, 8.21; Cl, 21.36.

(2*S*,3*R*)-2,3-Bis(4-chlorophenyl)-1-(1*H*-1,2,4-triazol-1-yl)propane-2,3-diol (12a). A mixture of **11a** (1.30 g, 3.44 mmol), $AlCl_3$ (1.37 g, 10.3 mmol), and NaI (1.55 g, 10.3 mmol) in MeCN (10 mL) was refluxed for 8 h. The mixture was diluted with CH_2Cl_2 and washed with aqueous $Na_2S_2O_3$ solution. The organic layer was dried (Na_2SO_4) and evaporated, and the residue was chromatographed. Elution with CH_2Cl_2/MeOH (95/5) gave the starting material **11a** (340 mg, 26%). Further elution afforded **12a** (640 mg, 51%): mp 181–183 °C (Et_2O); NMR δ 7.94 and 7.74 (each 1 H, each s, triazole H × 2), 7.30–6.80 (8 H, m, ArH × 8), 4.76 and 4.46 (each 1 H, each d, J = 13 Hz, CH_2N), 4.55 (1 H, s, C_3-H); $[\alpha]^{25}_D$ −0.7° (*c* 1.01, $CHCl_3$). Anal. Calcd for $C_{17}H_{15}N_3O_2Cl_2$: C, 56.06; H, 4.15; N, 11.54; Cl, 19.47. Found: C, 55.98; H, 4.19; N, 11.42; Cl, 19.18.

(2*S*,3*S*)-3-(4-Chlorophenyl)-2-(2,4-dichlorophenyl)-1-(1*H*-1,2,4-triazol-1-yl)propane-2,3-diol (17b). Similar reaction of **16b** (340 mg, 0.82 mmol) as above yielded **17b** (254 mg, 78%): mp 164–166 °C (Et_2O); NMR (Me_2SO-d_6) δ 8.32 and 7.54 (each 1 H, each s, triazole H × 2), 7.40–6.90 (7 H, m, ArH × 7), 5.90 (1 H, s, C_2-OH), 6.26 (1 H, d, J = 5 Hz, C_3-OH), 5.60 (1 H, d, J = 5 Hz, C_3-H), 5.46 and 4.84 (each 1 H, each d, J = 15 Hz, CH_2N); $[\alpha]^{23}_D$ −47.1° (*c* 1.00, MeOH). Anal. Calcd for $C_{17}H_{14}N_3O_2Cl_3$: C, 51.21; H, 3.54; N, 10.61; Cl, 26.68. Found: C, 51.31; H, 3.61; N, 10.53; Cl, 26.75.

(*S*)-(+)-2,3-Bis(4-chlorophenyl)-3-oxo-1-(1*H*-1,2,4-triazol-1-yl)propan-2-ol [(*S*)-(+)-1a]. Me_2SO (1 mL) was added dropwise to a stirred solution of oxalyl chloride (127 mg, 1 mmol) in CH_2Cl_2 (2 mL) at −78 °C. Diol **12a** (364 mg, 1 mmol) was added and the solution was stirred at −78 °C for 15 min. Et_3N (2 mL) was added, and the solution was stirred at room temperature for 15 min. The mixture was diluted with CH_2Cl_2 and washed with brine, and the organic layer was dried (Na_2SO_4) and evaporated. The residue was chromatographed (CH_2Cl_2/MeOH, 98/2), yielding (*S*)-(+)-(**1a**) (293 mg, 81%): mp 161–163 °C (Et_2O); IR ($CHCl_3$) 1720 cm^{-1}; NMR δ 8.02 and 7.86 (each 1 H, each s, triazole H × 2), 7.90–7.20 (8 H, m, ArH × 8), 6.30 (1 H, brs, OH), 5.03 and 4.37 (each 1 H, each d, J = 13 Hz, CH_2N); $[\alpha]^{23}_D$ +117.3° (*c* 1.00, $CHCl_3$). Anal. Calcd for $C_{17}H_{13}N_3O_2Cl_2$: C, 56.38; H, 3.62; N, 11.60; Cl, 19.58. Found: C, 56.43; H, 4.01; N, 11.95; Cl, 19.83.

(*S*)-(+)-3-(4-Chlorophenyl)-2-(2,4-dichlorophenyl)-3-oxo-1-(1*H*-1,2,4-triazol-1-yl)propan-2-ol [(*S*)-(+)-1b]. Oxidation of the diol **17b** (127 mg, 1 mmol) as above provided (*S*)-(+)-**1b** (122 mg, 81%): mp 200–202 °C (Et_2O); IR ($CHCl_3$) 1720 cm^{-1}; NMR 7.88 and 7.66 (each 1 H, each s, triazol H × 2), 7.80–7.20 (7 H, m, ArH × 7), 6.75 (1 H, brs, OH) 5.12 and 4.84 (each 1 H, each d, J = 15 Hz, CH_2N); $[\alpha]^{23}_D$ +282.0° (*c* 1.01, $CHCl_3$). Anal. Calcd for $C_{17}H_{12}N_3O_2Cl_3$: C, 51.47; H, 3.05; N, 10.59; Cl, 26.82. Found: C, 51.41; H, 3.21; N, 10.61; Cl, 26.91.

Facile De-*tert*-butoxycarbonylations of β-Keto Esters and Mixed Malonate Esters Using Water in Dimethyl Sulfoxide

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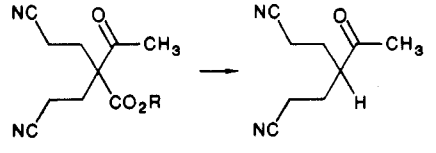
Dealkoxycarbonylations of malonate esters, β-keto esters, and α-cyano esters (and other related activated substrates) to esters, ketones, and cyanides, respectively, using water or water/LiCl (or other salts) in dipolar aprotic solvents such as Me_2SO are important synthetic reactions.[1]

During the course of preparation of 4-acetylheptane-1,7-dinitrile (**2**), we have investigated the dealkoxycarbonylations of the β-keto esters **1a** and **1b** under several reaction conditions.



1a, R = CH_2CH_3
b, R = $C(CH_3)_3$

2

On heating the β-keto ester **1a** with water/Me_2SO/LiCl for 5 h at reflux, the dinitrile **2** could be isolated in a 60% yield. In the absence of the LiCl only about 10% reaction occurred under reflux for 3 days.

(1) (a) Krapcho, A. P. *Synthesis* **1982**, 805. (b) Krapcho, A. P. *Synthesis* **1982**, 893.

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