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of Reliable Methods
for the Preparation
of Organic Compounds

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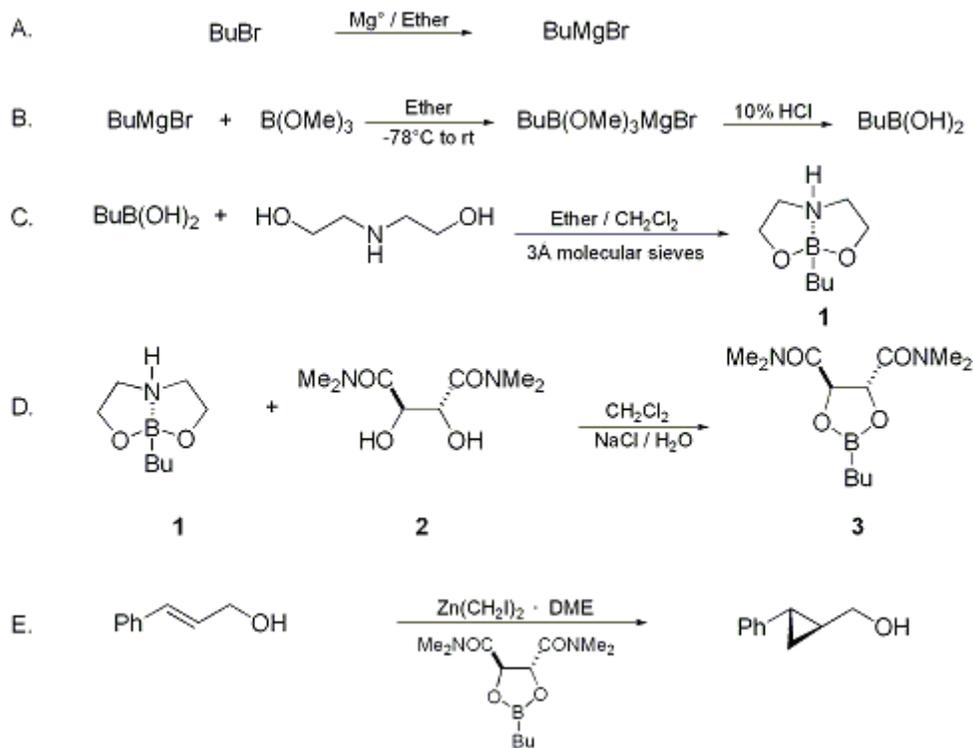
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September 2014: The paragraphs above replace the section "Handling and Disposal of Hazardous Chemicals" in the originally published version of this article. The statements above do not supersede any specific hazard caution notes and safety instructions included in the procedure.

Organic Syntheses, Coll. Vol. 10, p.613 (2004); Vol. 76, p.86 (1999).

(2S,3S)-(+)-(3-PHENYLCYCLOPROPYL)METHANOL

[Cyclopropanemethanol, 2-phenyl-, (1S-trans)-]



Submitted by André B. Charette and H  l  ne Lebel¹.

Checked by Kevin Minbiole, Patrick Verhoest, and Amos B. Smith, III.

1. Procedure

A. Butylmagnesium bromide. To a 500-mL, three-necked, round-bottomed flask equipped with an egg-shaped magnetic stirrer, 125-mL pressure-equalizing addition funnel, reflux condenser and a glass stopper (Note 1), is added 17.0 g (0.70 mol) of magnesium turnings (Note 2). Stirring is started, and the system is flame-dried for 2 min. The flask is cooled to room temperature under a flow of argon, and 30 mL of ether (Note 3) is introduced to cover the magnesium. A solution of 24 mL (0.22 mol) of bromobutane (Note 4) in 70 mL of ether is placed in the pressure-equalizing addition funnel. Then, 1 mL (0.01 mol) of bromobutane is added to the suspension of magnesium in ether. The mixture is heated gently to initiate the reaction (Note 5). When the reaction has started, the solution of bromide in ether is added dropwise at a rate sufficient to maintain a gentle reflux (Note 6). After completion of the addition, the funnel is rinsed with 5 mL of ether. The gray solution is stirred for 15 min and then transferred to a dry flask under argon via cannula. The Grignard reagent is titrated with a solution of isopropyl alcohol in benzene using 1,10-phenanthroline as the indicator (Note 7).² A 1.90-2.10 M solution of Grignard reagent is obtained.

B. Butylboronic acid. To a 1-L, one-necked, round-bottomed flask equipped with an egg-shaped magnetic stirrer (Note 1) and an internal thermocouple probe (Note 11) is added 220 mL of ether (Note 3), followed by 10 mL (89.2 mmol) of trimethyl borate (Note 12). The clear solution is cooled to -75°C (internal temperature) and stirred vigorously, then 45 mL (87.8 mmol) of a 1.95 M solution of butylmagnesium bromide in ether (Note 13) is added dropwise via cannula at such a rate that the internal temperature does not exceed -65°C (Note 14). After the addition is complete, the resulting white slurry is stirred for an additional 2 hr at -75°C under argon. The cooling bath is removed, and the

reaction mixture is allowed to warm to room temperature (Note 15). Hydrolysis is carried out by the dropwise addition of 100 mL of an aqueous 10% solution of hydrochloric acid. The white precipitate is dissolved, and the resulting clear biphasic mixture is stirred for 15 min, at which time the two layers are separated. The aqueous layer is extracted with ether (2 × 50 mL), and the combined extracts are dried over magnesium sulfate. After concentration of the ethereal solution under reduced pressure, the residual white solid is purified by recrystallization as follows: After dissolution in hot water (25 mL), the resulting biphasic solution is cooled to 0°C to induce recrystallization of the boronic acid. The solid is collected on a Büchner funnel, washed with 50 mL of hexanes and placed under vacuum (0.2 mm) for 60 min (Note 16) and (Note 17). Between 5.0-6.5 g (55-72% yield) of the boronic acid is produced as a white solid (Note 18).

C. [(2-)-N,O,O'[2,2'-Iminobis[ethanolato]]]-2-butylboron, **1**. A 250-mL, one-necked, round-bottomed flask equipped with an egg-shaped magnetic stirrer (Note 1) is charged with 5.15 g (50.5 mmol) of butylboronic acid and 5.31 g (50.5 mmol) of diethanolamine (Note 19). Ether, 100 mL (Note 3) and 50 mL of dichloromethane (Note 20) are added, followed by about 10 g of molecular sieves 3Å (Note 21). The resulting heterogeneous solution (Note 22) is stirred for 2 hr under argon. The solid is triturated with dichloromethane (50 mL), filtered through a medium fritted disk funnel and washed with dichloromethane (2 × 50 mL). The filtrate is concentrated under reduced pressure to produce the crude desired complex. The diethanolamine complex is purified by recrystallization as follows: the white solid is dissolved in hot dichloromethane (20 mL), then ether (50 mL) is added to induce recrystallization of the complex. The mixture is cooled to 0°C and the solid is collected on a Büchner funnel and washed with ether (2 × 30 mL). The product is dried under reduced pressure (0.2 mm) to afford 7.70 g (89%) of the title compound as a white crystalline solid (Note 23).

D. (4R-trans)-2-Butyl-N,N,N',N'-tetramethyl[1,3,2]dioxaborolane-4,5-dicarboxamide **3**. A 500-mL, one-necked, round-bottomed flask equipped with an egg-shaped magnetic stirrer, under argon is charged with 7.70 g (45.0 mmol) of the butylboronate diethanolamine complex and 11.9 g (58.3 mmol) of (R,R)-(+)-N,N,N',N'-tetramethyltartaric acid diamide (Note 24). The solids dissolve upon the addition of 225 mL of dichloromethane. Brine (70 mL) is added, and the resulting biphasic solution is stirred for 30 min under argon. The two layers are separated, and the aqueous layer is extracted with dichloromethane (50 mL). The combined organic layers are washed with brine (50 mL), dried over magnesium sulfate and filtered. The filtrate is concentrated under reduced pressure and dried under reduced pressure (0.2 mm) to give 11.3 g (93%) of the title compound as a pale yellow oil (Note 25).

E. (2S,3S)-(+)-(3-Phenylcyclopropyl)methanol. A 250-mL, one-necked, round-bottomed flask equipped with an egg-shaped magnetic stirrer (Note 26) and an internal thermocouple probe (Note 11), is charged with 45 mL of dichloromethane (Note 20) and 1.60 mL (14.9 mmol) of 1,2-dimethoxyethane (DME) (Note 27). The solution is cooled to -10°C (internal temperature) with an acetone/ice bath, and 1.50 mL (14.9 mmol) of diethylzinc is added (Note 28). To this stirred solution is added 2.40 mL (29.8 mmol) of diiodomethane (Note 29) over a 15-20 min period while maintaining the internal temperature between -8°C and -12°C. After the addition is complete, the resulting clear solution is stirred for 10 min at -10°C. A solution of 2.41 g (8.94 mmol) of the dioxaborolane ligand in 10 mL of dichloromethane is added via cannula under argon over a 5-6 min period while maintaining the internal temperature below -5°C. A solution of 1.00 g (7.45 mmol) of cinnamyl alcohol (Note 30) in 10 mL of dichloromethane is immediately added via cannula under argon over a 5-6 min period while maintaining the internal temperature under -5°C. The cooling bath is removed, and the reaction mixture is allowed to warm to room temperature and stirred for 8 hr at that temperature (Note 31).

Workup. Method A. The reaction is quenched with aqueous saturated ammonium chloride (10 mL) and aqueous 10% hydrochloric acid (40 mL). The mixture is then diluted with ether (60 mL) and transferred to a separatory funnel. The reaction flask is rinsed with ether (15 mL), and aqueous 10% hydrochloric acid (10 mL) and both solutions are transferred to the separatory funnel. The two layers are separated, and the aqueous layer is washed with ether (20 mL). The combined organic layers are transferred to an Erlenmeyer flask, and a solution containing 60 mL of aqueous 2 N sodium hydroxide and 10 mL of aqueous 30% hydrogen peroxide is added in one portion (Note 32). The resulting biphasic solution is stirred vigorously for 5 min. The two layers are separated and the organic layer is washed successively with aqueous 10% hydrochloric acid (50 mL), aqueous saturated sodium sulfite (50 mL),

aqueous saturated sodium bicarbonate (50 mL), and brine (50 mL). The organic layer is dried over magnesium sulfate and filtered, and the filtrate is concentrated under reduced pressure. The crude product is left under reduced pressure (0.2 mm) overnight (12-16 hr) to remove the butanol produced in this oxidative work-up. The product is purified by a Kugelrohr distillation (90°C, 0.8 mm) to afford 1.05 g (95%) of (2*S*,3*S*)-(+)-(3-phenylcyclopropyl)methanol as a colorless oil (Note 33) and (Note 34).

Workup. *Method B [with recovery of (R,R)-(+)-N,N,N',N'-tetramethyltartaric acid diamide].* The mixture is quenched with aqueous saturated ammonium chloride (80 mL), and the resulting biphasic mixture is stirred for 5 min. The two clear layers are separated, and the aqueous layer is washed with dichloromethane (20 mL) (Note 35). The combined organic layers are dried over magnesium sulfate and filtered, and the filtrate is concentrated under reduced pressure. The residual oil is dissolved in ether (75 mL) and water (50 mL). The resulting biphasic mixture is stirred for 1 hr. The layers are separated, and the aqueous layer is washed with ether (20 mL). This aqueous layer is kept for tetramethyltartaric acid diamide recovery (see below). The combined organic layers are treated with 60 mL of aqueous 2 N sodium hydroxide and 10 mL of aqueous 30% hydrogen peroxide (Note 32). The resulting biphasic mixture is stirred for 5 min. The two layers are separated and the organic layer is washed successively with aqueous 10% hydrochloric acid (50 mL), saturated aqueous sodium sulfite (50 mL), saturated aqueous sodium bicarbonate (50 mL), and brine (50 mL). The organic layer is dried over magnesium sulfate and filtered, and the filtrate is concentrated under reduced pressure. The crude product is left under reduced pressure (0.2 mm) overnight (12-16 hr) to remove butanol produced in this oxidative work-up. The product is purified by a Kugelrohr distillation (90°C, 0.8 mm) to afford 1.02 g (93%) of (2*S*,3*S*)-(+)-(3-phenylcyclopropyl)methanol as a colorless oil.

Recovery of (R,R)-(+)-N,N,N',N'-tetramethyltartaric acid diamide. The aqueous layer from the above extraction is concentrated under reduced pressure, and the crude product is recrystallized by an initial dissolution in hot dichloromethane (5 mL) followed by the addition of ethyl acetate (10 mL) to afford between 600 mg to 750 mg (33-41% yield) of the (R,R)-(+)-N,N,N',N'-tetramethyltartaric acid diamide (Note 36) and (Note 37).

2. Notes

1. All glassware was dried in an oven (110°C) and after assembly was allowed to cool under an atmosphere of argon.
2. Magnesium turnings were purchased from Sigma-Aldrich Fine Chemicals Company Inc. and were used without further purification.
3. Ether was freshly distilled from sodium/benzophenone.
4. Bromobutane was purchased from Fisher Scientific Company and was freshly distilled from phosphorus pentoxide (P₂O₅) (bp 100-104°C).
5. The formation of a gray cloudy suspension indicates that the reaction has started. Furthermore, the reaction is sufficiently exothermic to induce the ether to reflux even when the reaction flask is not heated. If the reaction does not start within 2 to 3 min, repeat the heating procedure.
6. Between 1.5 hr and 2 hr are needed for addition.
7. A dried 10-mL, one-necked, round-bottomed flask is charged with 1 mL of Grignard, some drops of THF (Note 8) and a crystal of 1,10-phenanthroline (Note 9). The slightly pink solution is titrated with a 0.5 M solution of isopropyl alcohol in benzene (Note 10). Between 3.8 and 4.2 mL (±0.2 mL) is obtained to give a clear colorless solution (three titrations).
8. THF was freshly distilled from sodium/benzophenone.
9. 1,10-Phenanthroline was purchased from Sigma-Aldrich Fine Chemicals Company Inc. and was used without further purification.
10. Isopropyl alcohol was freshly distilled from calcium hydride (CaH₂) and benzene was freshly distilled from sodium.
11. A Barnant 100, Type T Thermo-Couple Thermometer was used to monitor the internal temperature of the reaction solution.
12. Anhydrous trimethyl borate (with <5% of methanol) was purchased from Sigma-Aldrich Fine Chemicals Company Inc. and was used without further purification. Alternatively, a non anhydrous reagent can be dried by distillation from calcium hydride (bp 68-69°C).
13. Commercially available (Sigma-Aldrich Fine Chemicals Company Inc.), butylmagnesium chloride ,

- 2.0 M in ether, can be used and a similar yield is observed.
14. Between 20 and 30 min are needed for the addition.
15. Between 1 hr and 1.5 hr are needed.
16. The amount of the boroxine significantly increases if the solid is left under reduced pressure for a longer period of time. The boroxine is always a contaminant of the boronic acid (see discussion).
17. Sometimes a second recrystallization is needed to obtain pure boronic acid by removing by-products resulting from autooxidation.
18. The physical properties are as follows: mp 95-97°C; ¹H NMR (400 MHz, DMSO) δ: 0.56 (t, 2 H, J = 7.6), 0.83 (t, 3 H, J = 7.2), 1.31-1.19 (m, 4 H), 7.34 (br s, 2 H); ¹³C NMR (100 MHz, DMSO) δ: 13.9, 15.3 (br), 25.1, 26.5; ¹¹B NMR (128.4 MHz, DMSO) δ: 32.7.
19. Diethanolamine was purchased from Fisher Scientific Company and was used without further purification.
20. Dichloromethane was freshly distilled from CaH₂.
21. Molecular sieves, 3Å, powder, average particle size 3-5 μ were purchased from Sigma-Aldrich Fine Chemicals Company Inc. and dried under vacuum at 250°C for 24 hr, before using.
22. A few minutes after the addition of the molecular sieves, a white precipitate forms and sometimes maintaining stirring becomes difficult.
23. The physical properties are as follows: mp 145-148°C; ¹H NMR (400 MHz, CDCl₃) δ: 0.44-0.48 (m, 2 H), 0.88 (t, 3 H, J = 7.1), 1.21-1.37 (m, 4 H), 2.79 (br s, 2 H), 3.26 (br s, 2 H), 3.88 (br s, 2 H), 3.98 (br s, 2 H), 4.80-4.98 (m, 1 H); ¹³C NMR (100 MHz, CDCl₃) δ: 14.1, 18.4 (br), 26.5, 28.1, 51.4, 62.5; ¹¹B NMR (128.4 MHz, CDCl₃) δ: 13.1, 32.7. Anal. Calcd for C₈H₁₈BN₂O₂: C, 56.18; H, 10.61; N, 8.19. Found: C, 56.15; H, 10.86; N, 8.07.
24. (R,R)-(+)-N,N,N',N'-Tetramethyltartaric acid diamide was prepared from diethyl tartrate and dimethylamine and was freshly recrystallized with methanol and ethyl acetate.³ The physical properties are as follows: mp 186-187°C [lit.² 189-190°C]; ¹H NMR (400 MHz, CDCl₃) δ: 3.01 (s, 6 H), 3.13 (s, 6 H), 4.21 (br s, 2 H), 4.65 (s, 2 H); ¹³C NMR (100 MHz, CDCl₃) δ: 36.1, 36.9, 69.8, 170.8; [α]_D²⁰ +43° (EtOH, c 2.03) [lit.² [α]_D²⁰ +43° (EtOH, c 3.0)]. This product is also commercially available from Sigma-Aldrich Fine Chemicals Company Inc.
25. The physical properties are as follows: ¹H NMR (400 MHz, CDCl₃) δ: 0.85 (t, 2 H, J = 7.7); 0.87 (t, 3 H, J = 7.2), 1.29-1.41 (m, 4 H), 2.98 (s, 6 H), 3.20 (s, 6 H), 5.53 (s, 2 H); ¹³C NMR (100 MHz, CDCl₃) δ: 9.9 (br), 13.6, 25.0, 25.7, 35.7, 36.9, 75.6, 168.23; ¹¹B NMR (128.4 MHz, CDCl₃) δ: 34.2; [α]_D²⁰ -104.4° (CHCl₃, c 1.70). HRMS Calcd for C₁₂H₂₃BN₂O₄: 270.1751. Found: 270.1746. Anal. Calcd for C₁₂H₂₃BN₂O₄: C, 53.35; H, 8.58; N, 10.37. Found: C, 53.67; H, 9.07; N, 10.21.
26. All glassware was flame dried, then cooled under a flow of dry argon.
27. DME was freshly distilled from sodium/benzophenone.
28. Diethylzinc is a moisture sensitive and pyrophoric liquid and must be manipulated in an inert atmosphere with gas-tight syringes. Neat diethylzinc was purchased from Akzo Nobel Chemicals Company Inc. and was used without further purification.
29. Diiodomethane was purchased from Acros-Fisher Scientific Company and used without further purification. If necessary, diiodomethane can be purified if it shows any signs of slight decomposition (orange or red color develops over time): diiodomethane is washed with aqueous saturated sodium sulfite, dried over sodium sulfate (Na₂SO₄), and distilled from copper (40°C, 1.0 mm). The pale yellow liquid is collected on copper.
30. Cinnamyl alcohol was purchased from Sigma-Aldrich Fine Chemicals Company Inc. and was freshly purified by Kugelrohr distillation: a first fraction boiling at <70°C (1.0 mm) was discarded, and the alcohol was collected as a white solid at 80°C (1.0 mm).
31. A similar yield is obtained when the submitters stirred this mixture for 14 hr. No noticeable decomposition and side reactions are observed after slightly longer periods of time.
32. Hydrogen peroxide was purchased from ACP Chemicals Company Inc. and used without further purification.
33. Alternatively, the product can be purified by flash chromatography on silica gel (78.5 g, 4 cm × 16 cm) using 30% ethyl acetate in hexanes as the mobile phase (800 ml) to afford 1.06 g (96%) of the title compound.
34. The physical properties are as follows: bp 90°C, 0.8 mm; IR (film) cm⁻¹: 3350, 3050, 3000, 2950, 2900, 1600, 1500, 1450, 1100, 1050, 1000, 750, 700; ¹H NMR (400 MHz, CDCl₃) δ: 0.92-1.01 (m, 2 H), 1.43-1.51 (m, 1 H), 1.75 (br s, 1 H), 1.82-1.86 (m, 1 H), 3.59-3.67 (m, 2 H), 7.07-7.10 (m, 2 H),

7.15-7.20 (m, 1 H), 7.25-7.30 (m, 2 H) ; ^{13}C NMR (100 MHz, CDCl_3) δ : 13.8, 21.2, 25.2, 66.3, 125.6, 125.8, 128.3, 142.5 ; $[\alpha]_D^{20} +82^\circ$ (EtOH, c 1.74) [lit.⁴ (2R,3R)-cyclopropylmethanol $>99\%$ ee $[\alpha]_D^{20} -92^\circ$ (EtOH, c 1.23)]. Anal. Calcd for $\text{C}_{10}\text{H}_{12}\text{O}$: C, 81.04 H, 8.16. Found: C, 81.15; H, 8.30. The enantiomeric excess of the product is determined precisely by GC analysis of the corresponding trifluoroacetate ester derivative: To a solution of 10 mg of the crude alcohol in 0.75 mL of pyridine is added 0.25 mL of trifluoroacetic anhydride (TFAA). After 30 min at room temperature, an additional 0.25 mL of TFAA is added. After 30 min, the reaction mixture is diluted with 5 mL of ether. This solution was injected directly into the GC (0.5 μL) with the following conditions: Cyclodex G-TA, 0.32 \times 30 m; pressure 25 psi; isotherm: 110 $^\circ\text{C}$, T_r (minor) 11.5 min, T_r (major) 12.0 min; enantiomeric ratio: 29:1 (93% ee).

35. If the resulting organic layers are not clear, the combined organic layers should be washed with an additional 50 mL of aqueous saturated ammonium chloride.

36. An additional 10-15% of the diol can be recovered from the first aqueous saturated ammonium chloride extract (Note 38): the layer is concentrated on a rotatory evaporator and the white solid is triturated with cold methanol (30 mL), the mixture is filtered on a Büchner funnel, and the solid is washed with cold methanol (20 mL). The filtrate is concentrated to ca. 25 mL and treated with 2.5 g of sodium sulfide (Note 39). The resulting mixture is stirred for 30 min and then filtered on Celite (6 g, 1 cm \times 4 cm). The filtrate is concentrated by rotary evaporation, and the residue is purified by flash chromatography on silica gel (75 g, 3.5 cm \times 14.5 cm) by dissolving it in 10 mL of 10% methanol in chloroform and eluting with 10% methanol in chloroform. A recrystallization with dichloromethane and ethyl acetate give pure material.

37. The physical properties are identical to those of (Note 24).

38. The diol decomposes after a few hours at room temperature in this layer.

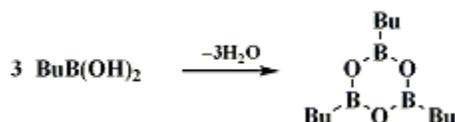
39. Sodium sulfide was purchased from Anachemia Science and was used without further purification.

Waste Disposal Information

All toxic materials were disposed of in accordance with "Prudent Practices in the Laboratory"; National Academy Press; Washington, DC, 1995.

3. Discussion

Parts A-D. The preparation of boronic acids by the addition of a Grignard reagent to a trialkyl borate is one of the most convenient and well-established methods involving relatively inexpensive starting materials.⁵⁻⁶ The carefully monitored addition of butylmagnesium bromide to trimethyl borate avoids any complications resulting from overaddition, and relatively good yields of the butylboronic acid are obtained after acid hydrolysis. Usually, alkylboronic acids are relatively difficult to characterize and to obtain analytically pure,⁷⁻⁸ because they readily tend to form boroxines (anhydrides) under dehydrating conditions (when heated or when left under reduced pressure). The white solid (butylboronic acid) is transformed into a colorless oil (tributylboroxine) if dehydration is pushed to completion. Conversely, butylboronic acid and its boroxine are also readily oxidized by air to generate 1-butanol and boric acid.⁹⁻¹⁰ For these reasons, it is almost impossible to isolate butylboronic acid without any traces of water, its boroxine or oxidation by-products.



In order to avoid these complications, butylboronic acid is quickly converted to its air-stable and more robust diethanolamine derivative **1**.¹¹ Complex **1** could be contaminated with some unseparable diethanolamine if a small excess of diethanolamine is used in its preparation. However, this has no effect on the efficiency of the synthesis of the chiral dioxaborolane ligand **3**. Diethanolamine complex **1** reacts quantitatively with a slight excess of tetramethyltartramide **2** under biphasic conditions to produce the desired chiral dioxaborolane ligand **3**. Ligand **3** is relatively stable, and is neither excessively hygroscopic nor oxygen-sensitive. It must be stored under argon for longer periods of time. However, the submitters have shown that the enantioselectivities are directly related to the ligand purity.

Consequently, it is generally preferable to use freshly prepared ligand for obtaining optimal results.

Part E. The enantioselective cyclopropanation of allylic alcohols using the chiral dioxaborolane ligand **3** and $\text{Zn}(\text{CH}_2\text{I})_2 \cdot \text{DME}$ is a powerful tool for synthesizing three-membered rings. This method is much simpler and produces superior enantiomeric excesses compared to those using other stoichiometric chiral ligands.^{12–14} The scope of the reaction is wide and a variety of allylic alcohols have been converted into their cyclopropane derivatives in excellent enantiomeric excesses (88–94%).¹⁵ It was also shown that polyenes can be cyclopropanated at the allylic alcohol position with excellent chemo- and enantioselectivities.¹⁷ Recently, this reaction has been used in the synthesis of cyclopropane containing natural products.^{18–20, 21}

Caution! The previously reported preparation of $\text{Zn}(\text{CH}_2\text{I})_2$ without a complexing additive²² is highly exothermic, and a violent decomposition sometimes occurred. For safety reasons, the use of the $\text{Zn}(\text{CH}_2\text{I})_2 \cdot \text{DME}$ as reported here is mandatory if this reaction is carried out on a =8 mmole scale.²³ If the internal temperature during the formation of the reagent is carefully monitored, the procedure reported here is extremely safe even on larger scales.

Note that the structure of $\text{Zn}(\text{CH}_2\text{I})_2 \cdot \text{DME}$ is derived from the stoichiometry of the reactants (Et_2Zn , CH_2I_2 , DME). Substantial quantities of $\text{IZnCH}_2\text{I} \cdot \text{DME}$ are necessarily formed at the reaction temperature and as a by-product of the cyclopropanation. Another improvement was made in this procedure: the number of equivalents of the reagent has been decreased to 2.0 equiv (vs 5 equiv in the original paper). However, under these conditions that minimize the amount of Et_2Zn used but require longer reaction times, the yield of the diol recovery dropped to ca. 50%.

The cyclopropanation of cinnamyl alcohol is a good example of the use of dioxaborolane ligand **3** as chiral additive to synthesize chiral cyclopropanes.

References and Notes

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Appendix
Chemical Abstracts Nomenclature (Collective Index Number);
(Registry Number)

(2S,3S)-(+)-(3-Phenylcyclopropyl)methanol:
Cyclopropanemethanol, 2-phenyl-,(1S-trans)- (12); (110659-58-0)

Butylmagnesium bromide:
Magnesium, bromobutyl- (8,9); (693-03-8)

Magnesium (8,9); (7439-95-4)

1-Bromobutane:
Butane, 1-bromo- (8,9); (109-65-9)

Isopropyl alcohol:
2-Propanol (8,9); (67-63-0)

1,10-Phenanthroline (8,9); (66-71-7)

Butylboronic acid:
1-Butaneboronic acid (8);
Boronic acid, butyl- (9); (4426-47-5)

Trimethyl borate:
Boric acid, trimethyl ester (8,9); (121-43-7)

Diethanolamine:
Ethanol, 2,2'-iminodi- (8);
Ethanol, 2,2'-iminobis- (9); (111-42-2)

(4R-trans)-2-Butyl-N,N,N',N'-tetramethyl[1,3,2]dioxaborolane-4,5-dicarboxamide:
1,3,2-Dioxaborolane-4,5-dicarboxamide, 2-butyl-N,N,N',N'-tetramethyl-, (4R-trans)- (13); (161344-85-0)

(R,R)-(+)-N,N,N',N'-Tetramethyltartaric acid diamide:
Tartramide, N,N,N',N'-tetramethyl-, (+)- (8);
Butanediamide, 2,3-dihydroxy-N,N,N',N'-tetramethyl-, [R-(R,R)]- (9); (26549-65-5)

Dimethoxyethane:
Ethane, 1,2-dimethoxy- (8,9); (110-71-4)

Diethylzinc:
Zinc, diethyl- (8,9); (557-20-0)

Diiodomethane:
Methane, diiodo- (8,9); (75-11-6)

Cinnamyl alcohol (8);
2-Propen-1-ol, 3-phenyl- (9); (104-54-1)

Hydrogen peroxide (8,9); (7722-84-1)

Sodium sulfite:
Sulfurous acid, disodium salt (8,9); (7757-83-7)

Copper (8,9); (7440-50-8)

Trifluoroacetic anhydride:
Acetic acid, trifluoro-, anhydride (8,9); (407-25-0)

Sodium sulfide (8,9); (1313-82-2)