Organic Syntheses

# Synthesis of Chiral Aziridine Ligands for Asymmetric Alkylation with Alkylzincs: Diphenyl((*S*)-1-((*S*)-1-phenylethyl)aziridin-2-yl)methanol

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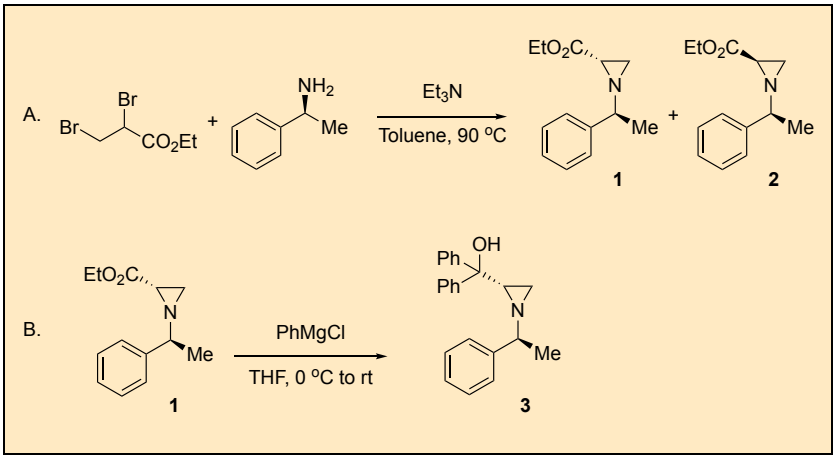



## **Procedure** (Note 1)

A. *Ethyl (S)-1-((S)-1-phenylethyl)aziridine-2-carboxylate (**1**).* An oven-dried (Note 2) 250-mL single-necked round bottomed flask (24/40 joint) is equipped with a Teflon coated magnetic stir bar (16 x 32 mm, egg-shape). The flask is sealed with a rubber septum, connected to a Schlenk line with a needle adapter and subsequently cooled to room temperature (Note 3). (*S*)-(-)-1-Phenylethanamine (3.0 mL, 23.0 mmol, 1.0 equiv) (Note 4), triethylamine (4.65 g, 6.41 mL, 46.0 mmol, 2.0 equiv) (Note 5) and toluene (46 mL) (Note 6) are added to the flask via syringes under nitrogen atmosphere (Figure 1A).

An oven-dried (Note 2) 100-mL single-necked, round-bottomed flask (14/20 joint) is sealed with a rubber septum, connected to a Schlenk line with a needle adapter, and subsequently cooled to room temperature (Note 3). Ethyl 2,3-dibromopropanoate (5.98 g, 3.34 mL, 23.0 mmol, 1.00 equiv) (Note 7) and toluene (46 mL) (Note 6) are added to the flask via syringes under nitrogen atmosphere (Note 8). The resulting clear solution is added to

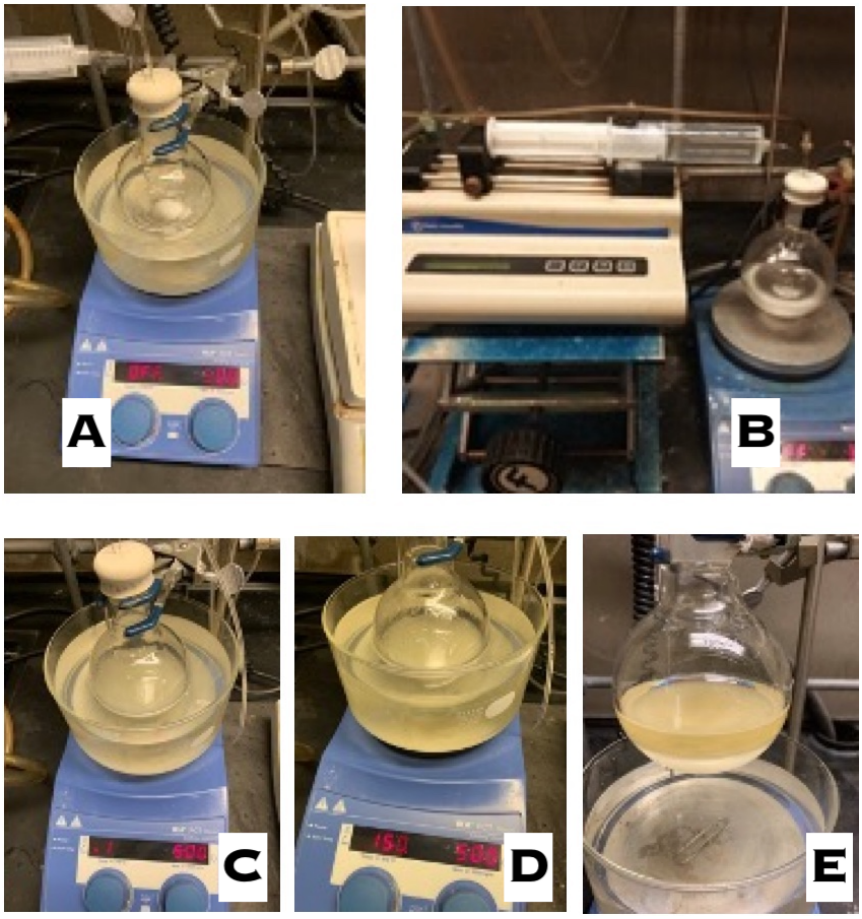



**Figure 1. A) Reaction flask set-up after the addition of toluene and (*S*)-(-)-1-phenylethanamine; B) addition of ethyl 2,3-dibromopropanoate; C) reaction mixture at the beginning of heating; D) reaction mixture after 6 hours of heating; E) reaction mixture after settling (photos provided by submitters)**

the 250-mL flask with a syringe pump (Note 9) with a 60-mL syringe over 60 min (Figure 1B). The suspension is stirred (Note 10) for 5 min at room temperature (Note 3) and then heated to 90 °C (bath temperature) in an oil bath (Note 11) (Figure 1C). After 6 h (Note 12) (Figure 1D), the reaction mixture is removed from the oil bath and cooled to room temperature (Note 3), at which time the solution naturally separates into two layers (Figure 1E).

Deionized water (50 mL) (Note 13) is added to the reaction mixture, the stir bar is removed, and the biphasic mixture is transferred to a 250-mL separatory funnel. An additional portion of ethyl acetate (50 mL) (Note 14) is used to rinse the reaction flask and then poured into the separatory funnel. The organic layer is collected, and the aqueous layer is extracted with ethyl acetate (2 x 50 mL) (Note 14). The combined organic extracts are washed with saturated sodium chloride solution (50 mL) (Note 15) and dried with sodium sulfate (25 g) (Note 16). The solution is filtered (Note 17) into a 500-mL single-necked round-bottomed flask (24/40 joint) with ethyl acetate washings (3 x 10 mL) (Note 14) and then concentrated with the aid of a rotary evaporator (Note 18) to afford a crude, yellow oily mixture. The crude material is purified by chromatography on silica (Note 19) to afford ethyl (*S*)-1-((*S*)-1-phenylethyl)aziridine-2-carboxylate **1** (2.20 g, 43%, 97% purity) (Notes 20 and 21) as a yellow oil (Figure 2A) and ethyl (*R*)-1-((*S*)-1-phenylethyl)aziridine-2-carboxylate **2** (2.13 g, 42%, 99% purity) (Notes 22 and 23) as a yellow oil (Figure 2B).

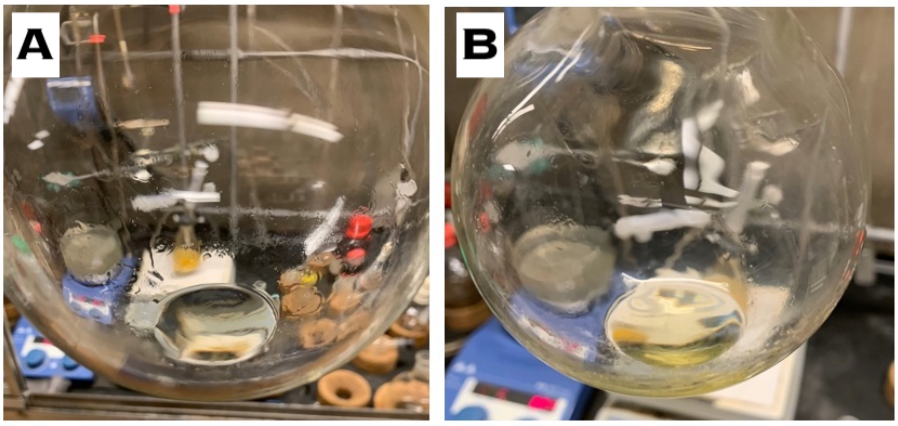



**Figure 2. A) Product 1; B) Product 2 (photos provided by submitters)**

B. *Diphenyl((S)-1-((S)-1-phenylethyl)aziridin-2-yl)methanol* (***3***). An oven-dried (Note 2) 100-mL single-neck round bottom flask (14/20 joint) is equipped with a Teflon coated magnetic stir bar (9 x 12 mm, octagon). The flask is sealed with a rubber septum, connected to a Schlenk line with a needle adapter and subsequently cooled to room temperature (Note 3). Phenylmagnesium chloride solution (5.45 g, 26.9 mL, 39.8 mmol, 4.0 equiv) (Note 24) is added via a syringe under nitrogen atmosphere and then cooled to 0 °C (Note 25) while stirring (Note 10) (Figure 3A).

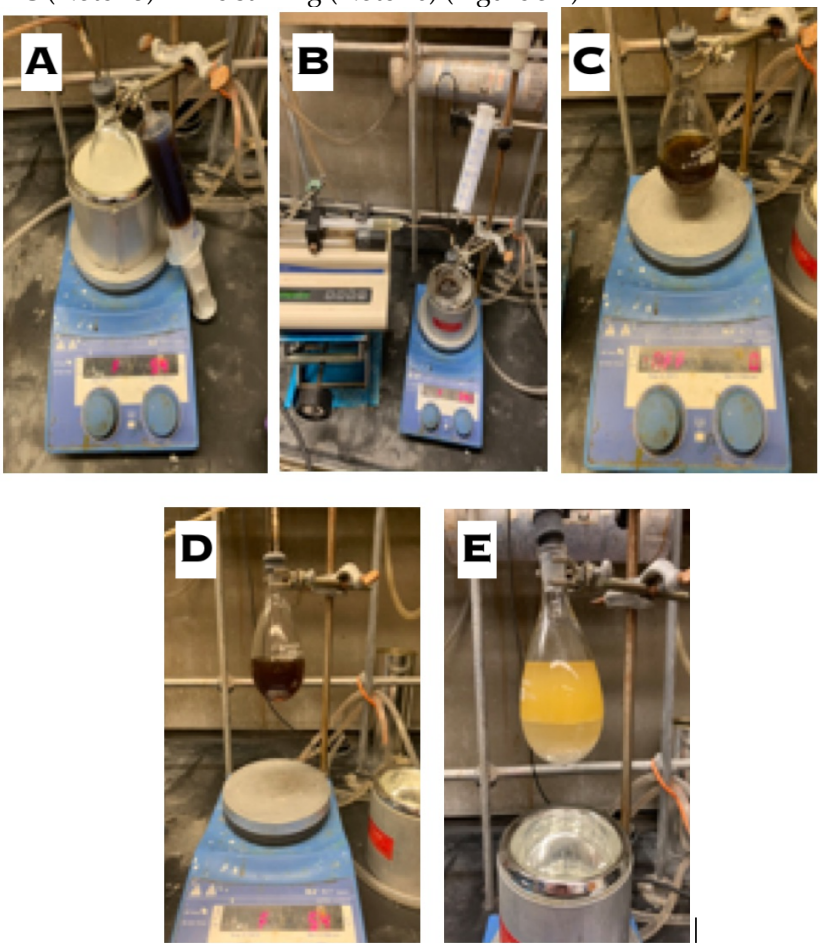



**Figure 3. A) Reaction flask set-up after addition of PhMgCl solution; B) addition of starting material (1); C) reaction solution after the addition; D) reaction solution before work-up; E) reaction mixture after work-up (photos provided by submitters)**

An oven-dried (Note 2) 50-mL single-necked round-bottomed flask (14/20 joint) is sealed with a rubber septum, connected to a Schlenk line with a needle adapter, and subsequently cooled to room temperature (Note 3). Ethyl 1-((*S*)-1-phenylethyl)aziridine-2-carboxylate (**1**) (2.18 g, 9.94 mmol, 1.00 equiv.) and THF (26 mL) (Note 26) are added via syringes under nitrogen atmosphere (Note 8). The resulting yellow solution is added to the 100-mL flask with the syringe pump (Note 9) at 0 °C (Note 26) over 40 minutes (Figure 3B) (Note 27). The solution is slowly warmed to room temperature (Note 3) (Figure 3C) and stirred (Note 10) for 12 h (Note 28) (Figure 3D). The reaction flask is cooled to 0 °C (Note 24) and saturated ammonium chloride solution (20 mL) (Notes 29 and 30) (Figure 3E) and 1N HCl solution (30 mL) (Note 31) are added slowly. The biphasic mixture is transferred to a 250-mL separatory funnel (Note 13). The organic layer is collected, and the aqueous layer is extracted with ethyl acetate (4 x 40 mL) (Note 14). The combined organic phases are dried with sodium sulfate (30 g) (Note 16), filtered (Note 18) into a 500-mL single-necked round-bottomed flask (24/40 joint) with ethyl acetate washings (3 x 15 mL) (Note 14). The solution is concentrated with the aid of a rotary evaporator (Note 18) to afford crude, light yellow solids. The crude product is purified by chromatography on silica (Note 32) to afford diphenyl((*S*)-1-((*S*)-1-phenylethyl)aziridin-2-yl)methanol **3** (2.97 g, 91%, 99% ee, 99% purity) (Notes 33, 34, and 35) as a white solid (Figure 4).

**Figure 4. Product 3 (photo provided by submitter)**

## Notes

1. Prior to performing each reaction, a thorough hazard analysis and risk assessment should be carried out with regard to each chemical substance and experimental operation on the scale planned and in the context of the laboratory where the procedures will be carried out. Guidelines for carrying out risk assessments and for analyzing the hazards associated with chemicals can be found in references such as Chapter 4 of "Prudent Practices in the Laboratory" (The National Academies Press, Washington, D.C., 2011; the full text can be accessed free of charge at https://www.nap.edu/catalog/12654/prudent-practices-in-the-laboratory-handling-and-management-of-chemical. See also "Identifying and Evaluating Hazards in Research Laboratories" (American Chemical Society, 2015) which is available via the associated website "Hazard Assessment in Research Laboratories" at https://www.acs.org/content/acs/en/about/governance/committees/chemicalsafety/hazard-assessment.html. In the case of this procedure, the risk assessment should include (but not necessarily be limited to) an evaluation of the potential hazards associated with (S)-(–)-1-phenylethylamine, ammonium chloride, chloroform, , 1,3,5-trimethoxybenzene, ethyl 2,3-dibromopropanoate, ethyl acetate, hexanes, hydrochloric acid, magnesium sulfate anhydrous, methylene chloride, phenylmagnesium chloride, silica, sodium bicarbonate, sodium chloride, sodium sulfate anhydrous, THF, toluene, triethylamine, as well as the proper procedures for working with dry ice and under an inert atmosphere.
2. Unless otherwise reported, all glassware was dried in a 120 °C oven prior to use and then brought down to room temperature under an inert atmosphere.
3. The room temperature throughout this manuscript refers to temperatures between 22 °C and 23 °C. Room temperature in the checker's lab was 21 °C.
4. (*S*)-(–)-1-Phenylethylamine (98%, 98% ee) was purchased from Sigma-Aldrich and used as received.
5. Triethylamine (99%) purchased from Sigma Aldrich under SureSeal is sufficiently dry (KF < 200 ppm) and does not require distillation over NaH. The submitters purchased triethylamine (99%) from Fisher

Scientific and distilled the liquid under nitrogen from sodium hydride before the use.

6. The checkers purchased toluene from Sigma Aldrich (SureSeal) and used the material as received. The submitters purchased toluene (Certified ACS) from Fisher Scientific and purified it by pressure filtration under nitrogen through activated alumina prior to use.
7. Ethyl 2,3-dibromopropanoate (for synthesis, >98%) was purchased from Sigma-Aldrich and used as received.
8. The submitters report that the flask and its contents were sonicated for 30 sec. Branson® Ultrasonic Bath (115 Vac, 60 Hz) was used with 2.8 L (0.75-gal) tank filled with water at room temperature.
9. The Fisherbrand™ syringe pump was setup with a built-in syringe size table for Air-Tite™ All-Plastic Norm-Ject™ Syringes. A minor exotherm from 21 °C to 23 °C was observed throughout addition.
10. IKA RET basic hot plate stirrer (115V, 620W, 50-60 Hz) and Cole-Parmer IKA C-Mag hot plate stirrer (115V, 1000W, 50-60 Hz) were used. Unless indicated otherwise, 500 rpm was used for stirring.
11. The submitter's studies used Fisher Chemical™ silicone oil for the oil bath. Unless specified differently, the oil in the oil bath should cover the reaction mixture in the reaction flask while heating. Unless otherwise reported, the temperatures throughout this manuscript refer to temperatures of oil in oil baths which were detected by the stirring plates' temperature probes. The checkers confirmed that aluminum heating mantels were also suitable heat sources.
12. The reaction can be monitored by TLC ($SiO_2$, hexanes/EtOAc 4/1, starting material **a**: $R_f$ 0.17, starting material **b**: $R_f$ 0.62, product **1**: $R_f$ 0.42, product **2**: $R_f$ 0.30; UV-C 254 nm) to observe complete consumption of starting material **a** (S refers to starting materials **a** and **b**. C refers to co-spot of reaction mixture and starting materials. R refers to the reaction mixture.).

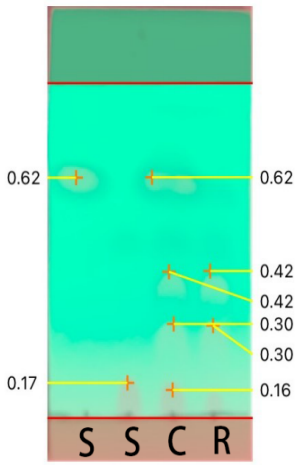



**Figure 5. TLC monitoring of Step A (photo provided by submittters)**

13. The quality of the deionized water was not determined.
14. Ethyl acetate (Certified ACS) was purchased from Fisher Scientific and used as received.
15. Sodium chloride (Crystalline/Certified ACS) was purchased from Fisher Scientific and added to a bottle of deionized water until solids crashed out.
16. Sodium sulfate anhydrous (Granular/Certified ACS) was purchased from Fisher Scientific and used as received.
17. To wash the filter cake effectively, vacuum was turned off between separate washing cycles, washing solvent was added and the resultant mixture was stirred thoroughly with a stainless-steel spatula before the washing solvent was removed by vacuum suction.
18. BUCHI™ Rotavapor™ Scholar with Dry Ice Cold Trap Condenser was connected to Heidolph™ Valve-Regulated Vacuum Pump. Unless specified differently, water bath remained at 30 °C and the vacuum was regulated to 20 mmHg.
19. The crude material was loaded onto a slurry-packed (hexane) column (ID 42 mm) containing $SiO_2$ (150 g, 40 – 63 μm, 60 Å silica gel purchased from SiliCycle Inc.), and the flask was then rinsed with hexanes (7 mL) which was loaded afterwards. After loading, solvents were eluted under positive nitrogen pressure and fractions were taken in 25-mL tubes. The solvent system was switched to 900 mL of 8/1 hexane/EtOAc (ACS grade purchased from Fisher Scientific which was used as received) and

product **1** ($R_f$ 0.42, hexane/EtOAc 4/1, v/v) eluted first and was typically removed with this mixture. Fractions 21 through 35 were combined, concentrated on a rotary evaporator (30 °C, 780 to 20 mmHg), and dried in vacuo (1–2 mmHg) at ambient temperature for 12 h. After elution of product **1**, the solvent system was switched to 800 mL of 5/1 hexane/EtOAc, and elution of the product **2** ($R_f$ 0.30, hexane/EtOAc 4/1, v/v) was completed this solvent mixture. Fractions 45 through 60 were combined, concentrated on a rotary evaporator (30 °C, 780 to 20 mmHg), and dried in vacuo (1-2 mmHg) at ambient temperature for 12 h.

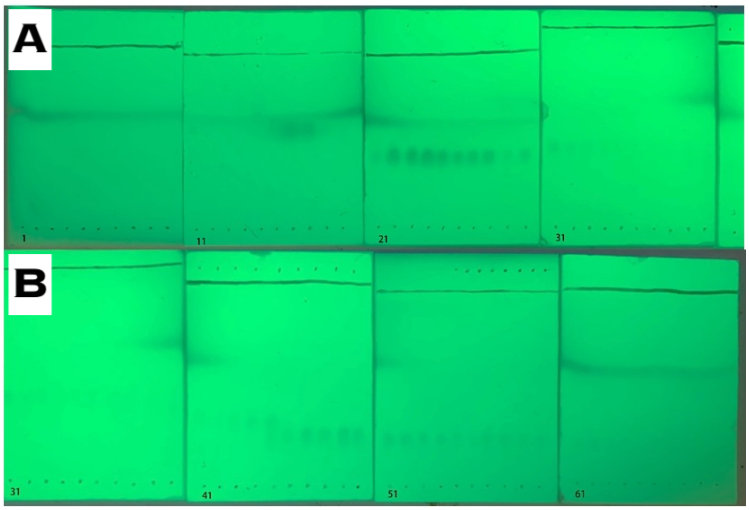



**Figure 6. TLC analysis of the fractions. (Visualization with UV-C 254 nm) A) fractions 1 through 40; B) fractions 31 through 70 (photos provided by submittters)**

20. The product **(1)** exhibited the following properties: $[\alpha]_D^{23}$ –80.43 (*c* 0.50, $CHCl_3$); $R_f$ 0.42 (4/1, hexane/EtOAc, v/v); IR (film): 3062, 2978, 2929, 1741, 1725, 1601, 1494, 1448, 1410, 1384, 1281, 1233, 1182, 1086, 1028, 959, 763, 698 $cm^{-1}$; $^1H$ NMR (500 MHz, $CDCl_3$) δ: 1.32 (t, *J* = 7.1, 3H), 1.50 (d, *J* = 6.6 Hz, 3H), 1.61 (dd, *J* = 6.4, 0.9 Hz, 1H), 2.16 (dd, *J* = 3.2, 1.1 Hz, 1H), 2.22 (dd, *J* = 6.4, 3.2 Hz, 1H), 2.5 (q, *J* = 6.6 Hz, 1H), 4.16 – 4.32 (m, 2H), 7.24 – 7.29 (m, 1H), 7.31 – 7.38 (m, 2H), 7.41 (d, *J* = 7.3, 2H). $^{13}C$ NMR (126 MHz, $CDCl_3$) δ: 14.3, 23.3, 34.01, 38.3, 61.2, 70.1, 127.0, 127.4, 128.5, 143.6, 171.0; HRMS (ESI) *m*/*z* calcd for $C_{13}H_{17}NO_2Na$ $[M+Na]^+$ 242.1151, found 242.1148. Purity was determined by quantitative $^1H$ NMR spectroscopic

analysis using 1,3,5-trimethoxybenzene as an internal standard to be 97% by weight. The corrected yield based on purity was 2.13 g (42%). (The enantiomeric excess (ee) of this product could not be determined by the available HPLC or SFC techniques, and the product ee is reported based on the ee of precursor measured after the Grignard reaction step.)

21. A second reaction on identical scale provided 1.92 g (42%) of the same compound.
22. The product **(2)** exhibited the following properties: $[\alpha]_D^{23}$ +41.70 (*c* 0.35, $CHCl_3$); $R_f$ 0.28 (4/1, hexanes/EtOAc, v/v); IR (film): 3061, 2976, 2928, 17439, 1493, 1447, 1412, 1282, 1235, 1184, 1089, 1028, 960, 759, 699 $cm^{-1}$; $^1H$ NMR (500 MHz, $CDCl_3$) δ: 1.23 (t, *J* = 7.1 Hz, 3H), 1.48 (d, *J* = 6.6 Hz, 3H), 1.79 (dd, *J* = 6.5, 1.0 Hz, 1H), 2.07 (dd, *J* = 6.5, 3.1 Hz, 1H), 2.35 (dd, *J* = 3.1, 1.0 Hz, 1H), 2.59 (q, *J* = 6.6 Hz, 1H), 4.17 (qd, *J* = 7.1, 3.0 Hz, 2H), 7.23 – 7.30 (m, 1H), 7.32 – 7.40 (m, 3H); $^{13}C$ NMR (126 MHz, $CDCl_3$) δ: 14.2, 23.6, 34.9, 37.2, 61.0, 69.8, 126.5, 127.2, 128.5, 143.8, 170.7. HRMS (ESI) *m*/*z* calcd for $C_{13}H_{17}NO_2Na$ $[M+Na]^+$ 242.1157, found 242.1154. Purity was determined by quantitative $^1H$ NMR spectroscopic analysis using trimethoxybenzene as an internal standard to be 96% by weight.
23. A second reaction on identical scale provided 1.82 g (40%) of the same compound.
24. Phenylmagnesium chloride solution (2.0 M in THF) was purchased from Sigma-Aldrich and titrated to be 1.48M before use.
25. The 0 °C temperature was reached and maintained by mixing water with ice.
26. Tetrahydrofuran (HPLC) was purchased from Fisher Scientific and purified by pressure filtration under nitrogen through activated alumina prior to use.
27. There is an exotherm in the first 5 min of addition, from 0.5 °C to 5.5 °C. After this exotherm, the solution cools back to 0–0.5 °C).
28. The reaction can be monitored by TLC ($SiO_2$, Hexane/EtOAc 4/1, starting material **1**: $R_f$ 0.42, product **3**: $R_f$ 0.78; UV-C 254 nm) to observe complete consumption of starting material **1** (S refers to starting material **1**. C refers to co-spot of reaction mixture and starting material. R refers to the reaction mixture.).

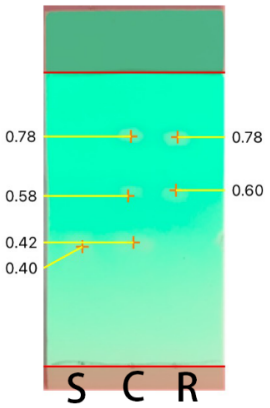



**Figure 7. TLC monitoring of Step B**

29. Ammonium chloride (Crystalline/Certified ACS) was purchased from Fisher Scientific and added to a bottle of deionized water until solids crashed out.
30. A very strong exotherm was observed. The temperature rises from 0.5 °C to 40.4 °C in 2–3 minutes if the ammonium chloride solution is added at rate of ~4 mL/min. It is recommended that an addition of <1 mL/min be performed using an addition funnel, with the expectation that a temperature rise to 25-30 °C will be observed. After ~5 mL of sat. aq. $NH_4Cl$ are added, no further exotherm is observed.
31. Hydrochloric acid (ACS reagent, 37%) was purchased from Sigma-Aldrich and diluted to 1N with deionized water. No exotherm was observed with 1N HCl solution, when added at 10 mL/min.
32. The crude was loaded onto a slurry-packed (hexane) column (ID 42 mm) containing $SiO_2$ (150 g, 40 - 63 μm, 60 Å silica gels purchased from SiliCycle Inc.), and the flask was then rinsed with hexanes (10 mL) which was loaded afterwards. After loading, solvents were eluted under positive nitrogen pressure and fractions were taken in 25-mL tubes. The solvent system was switched to 420 mL of 20/1 hexane/EtOAc (ACS grade purchased from Fisher Scientific which was used as received) and followed by 450 mL of 15/1 hexane/EtOAc. Product **3** ($R_f$ 0.78, hexane/EtOAc 4/1, v/v) eluted, fractions 36 through 52 were combined, concentrated on a rotary evaporator (30 °C, 780 to 20 mmHg), and dried in vacuo (1-2 mmHg) at ambient temperature for 12 h.

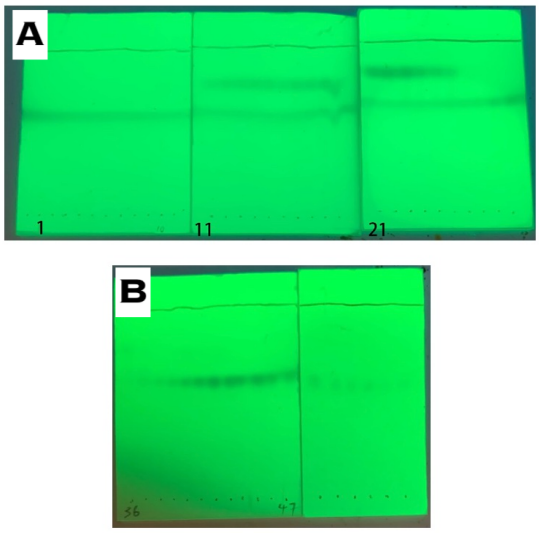



**Figure 8. TLC analysis of the fractions. (Visualization with UV-C 254 nm) A) fractions 1 through 30; B) fractions 36 through 53**

33. The product **(3)** exhibited the following properties: $\alpha]_D^{23}$ -68.20 (*c* 0.10, $CHCl_3$); $R_f$ 0.66 (4/1, hexanes/EtOAc, v/v); mp 125.3–125.5 °C; IR (powder): 3351 (br), 3059, 3027, 2981, 2966, 2926, 1599, 1492, 1449, 1354, 1342, 1300, 1188, 1167, 1066, 1029, 1014, 981, 931, 768, 747, 691, 644, 638, 612 $cm^{-1}$; $^1H$ NMR (500 MHz, $CDCl_3$) δ: 0.91 (d, *J* = 6.2 Hz, 3H), 1.60 (d, *J* = 6.0 Hz, 1H), 1.99 (bs, 1H), 2.56 (bs, 1H), 2.75 (q, *J* = 6.2 Hz, 1H), 4.14 (s, 1H), 7.24 – 7.32 (m, 3H), 7.31 – 7.42 (m, 8H), 7.51 – 7.60 (m, 4H); $^{13}C$ NMR (176 MHz, $CDCl_3$) δ: 23.6, 30.8, 47.5, 68.2, 74.0, 126.1, 126.78, 126.8, 126.9, 127.3, 127.4, 128.1, 128.3, 128.5, 144.3, 145.0, 148.0; HRMS (ESI) *m*/*z* calcd for $C_{23}H_{23}NONa$ $[M+Na]^+$ 352.1677, found 352.1673. Purity was determined by quantitative $^1H$ NMR spectroscopic analysis using 1,3,5-trimethoxybenzene as an internal standard to be 99% by weight.
34. The ee was determined to be 99% by HPLC analysis with a Waters Alliance e2695 Separations Module HPLC system equipped with a CHIRALPAK IA column (length 250 mm, I.D. 4.6 mm) (90:10 hexanes/isopropanol, 1.0 ml/min), tr = 5.7 min (*S*), 6.6 min (*R*).
35. A second reaction on a similar scale provided 2.46 g (93%) of the same product.

## Working with Hazardous Chemicals

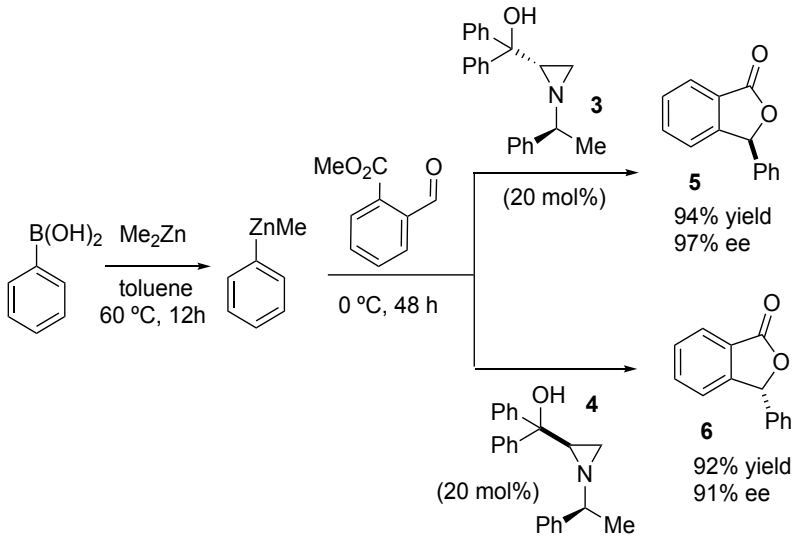
The procedures in *Organic Syntheses* are intended for use only by persons with proper training in experimental organic chemistry. All hazardous materials should be handled using the standard procedures for work with chemicals described in references such as "Prudent Practices in the Laboratory" (The National Academies Press, Washington, D.C., 2011; the full text can be accessed free of charge at http://www.nap.edu/catalog.php?record_id=12654). All chemical waste should be disposed of in accordance with local regulations. For general guidelines for the management of chemical waste, see Chapter 8 of Prudent Practices.

In some articles in *Organic Syntheses*, chemical-specific hazards are highlighted in red "Caution Notes" within a procedure. It is important to recognize that the absence of a caution note does not imply that no significant hazards are associated with the chemicals involved in that procedure. Prior to performing a reaction, a thorough risk assessment should be carried out that includes a review of the potential hazards associated with each chemical and experimental operation on the scale that is planned for the procedure. Guidelines for carrying out a risk assessment and for analyzing the hazards associated with chemicals can be found in Chapter 4 of Prudent Practices.

The procedures described in *Organic Syntheses* are provided as published and are conducted at one's own risk. *Organic Syntheses, Inc.*, its Editors, and its Board of Directors do not warrant or guarantee the safety of individuals using these procedures and hereby disclaim any liability for any injuries or damages claimed to have resulted from or related in any way to the procedures herein.

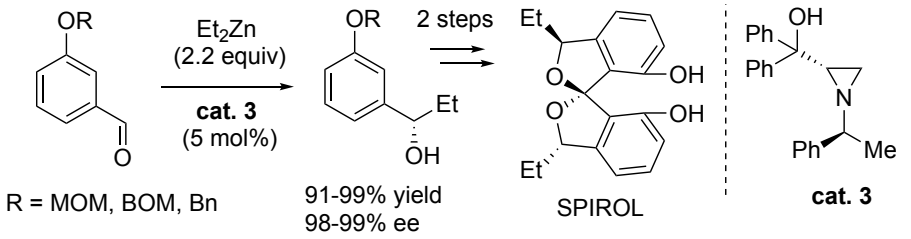
## Discussion

Enantioselective alkylation is one of the most important transformations in the asymmetric catalysis towards biologically and pharmacologically valuable compounds.[2] Particularly, asymmetric addition of alkyl- and arylzinc species with chiral ligands to aromatic aldehydes has been extensively studied.[3] *N,N*-Dibutylnorephedrine (DBNE) is often considered as one of the most versatile ligands in this field.[4]




**Scheme 1. Application to enantioselective synthesis of 3-aryl phthalides**

Aziridines have gained significant amounts of attention in synthesis and drug discovery as they are featured in various natural products.[5] Recent years have seen a rise in the number of asymmetric catalysis with aziridine-based catalysts as well. Such examples include enantioselective arylation with ligand **3** as well as its diastereomer **4** derived from alkylation side-product **2**. For the reaction with aromatic aldehydes, ligand **3** often exhibits better selectivity profiles. One of the selected applications of this ligand involved the enantioselective formation of 3-aryl phthalides such as **5** and **6** (Scheme 1) starting with methyl 2-formylbenzoate and various arylboronic acids.[6] In our recent studies of novel $C_2$-symmetric SPIROL ligands[7], we discovered that the enantiopurity of benzylic alcohol is a key factor to the selectivity of diastereoselective spiroketalization. Commercially available (-)-DBNE would only yield up to 94% ee in this transformation while catalyst **3** could provide products in 99% ee when R is MOM (Scheme 2). The procedure described here is adapted from the previous report.[8] It is comprised of a two-step synthesis of chiral aziridine catalyst **3** from commercially available starting materials.




**Scheme 2. Application to the synthesis of SPIROL C2-symmetric ligands**

## References


1. Department of Chemistry, University of Michigan, Ann Arbor, MI 48109, USA, E-mail: nagorny@umich.edu; ORCID: 0000-0002-7043-984X. Financial support from National Science Foundation (grant CHE-1955069 to PN) is gratefully acknowledged.
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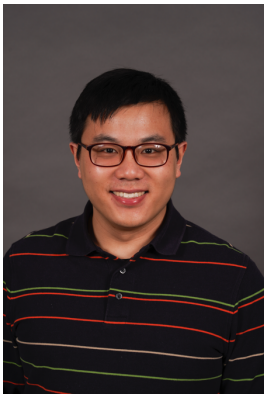
### Appendix
### Chemical Abstracts Nomenclature (Registry Number)

(*S*)-(-)-1-Phenylethanamine: S-1-Phenylethylamine; (2627-86-3)
Triethylamine (121-44-8)

Ethyl 2,3-dibromopropanoate: Ethyl 2,3-dibromopropionate; (3674-13-3)
Toluene: Benzene, methyl-; (108-88-3)
Ethyl acetate; (141-78-6)
Phenylmagnesium chloride; (100-59-4)



Siyuan Sun was born in Suzhou, China. He obtained a B.S. degree from the Purdue University, where he studied the monoterpene indole alkaloids synthesis under the direction of Prof. Mingji Dai. He is currently pursuing his Ph.D. in the laboratory of Prof. Pavel Nagorny at the University of Michigan, Ann Arbor where he studies the synthesis and catalysis of novel SPIROL-based ligands for asymmetric catalysis.

Dr. Pavel Nagorny received his B.S. degree in chemistry in 2001 from the Oregon State University. After earning his Ph.D. degree in chemistry from Harvard University in 2007, he spent three years as a postdoctoral fellow with at the Memorial Sloan-Kettering Cancer Center. In 2010, Pavel joined the faculty of the University of Michigan. From 2014-2017 he was appointed as a William R. Roush Assistant Professor in Chemistry, and in 2017 he was promoted to the rank of Associate Professor with tenure. Pavel's research group interests range from natural product synthesis to asymmetric catalysis, organocatalysis and carbohydrate chemistry.

Matthew S. Winston joined Small Molecule Process Research and Development at Merck & Co., Inc. in 2018. His research focuses on using mechanistic analysis to solve critical problems in process chemistry. He received his A.B. degree from Harvard University, and his Ph.D. under the supervision of Professor John E. Bercaw at the California Institute of Technology. He was then a NIH postdoctoral fellow with Professor F. Dean Toste at the University of California-Berkeley, and a Glenn T. Seaborg Fellow at Los Alamos National Laboratory.