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Totally Selective Reaction of CO_2 with Enantiopure Amino Epoxides under Mild Reaction Conditions. Synthesis and Synthetic Applications of Enantiopure (4*R*,1′*S*)- or (4*S*,1′*S*)-4-(1-Aminoalkyl)-2-oxo-1,3-dioxolanes

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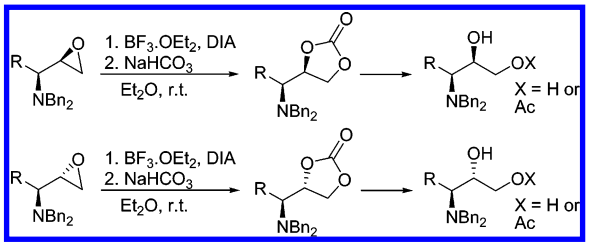

The reaction of chiral (2*R*,1′*S*)- or (2*S*,1′*S*)-2-(1-aminoalkyl)epoxides **1** or **2** with CO_2, generated from acidic treatment of an aqueous solution of $NaHCO_3$ at room temperature, efficiently afforded enantiopure cyclic carbonates **3** or **4**, respectively, with total selectivity. Compounds **3** and **4** were readily transformed into the corresponding diols **7** and **8** by reaction with $LiAlH_4$ or by basic hydrolysis. When compounds **3** or **4** were allowed to react with methyllithium at −78 °C, *O*[1]-acetylalkane-1,2-diols **9** and **10** were obtained with total or high selectivity.

Introduction

In recent years, the reaction of CO_2 with different organic compounds and catalyzed by transition metal has received much attention.[1] One of the most promising methodologies in this area has been the synthesis of five-membered cyclic carbonates by reaction of CO_2 with epoxides in the presence of a transition metal catalyst.[2] Two aspects of the CO_2 reaction with epoxides are noteworthy. First, one carbon atom and two oxygen atoms are incorporated in one step with total atom efficiency, and second, carbon dioxide is an attractive C-1 building block in organic synthesis since it is highly functional, abundant, inexpensive, nontoxic, and nonflammable.

Cyclic carbonates or dioxolanones offer important practical applications.[3] Hence, they are used in the manufacture of various polymers[2a,4] and cosmetic products[2a] and as key additives in solvent compositions to enhance cleaning power.[5] Some of them also offer biomedical applications,[6] and from a synthetic viewpoint, dioxolanones are useful intermediates, as for example in the stereoselective synthesis of vicinal diols through hydrolysis.[7]

In recent decades, numerous catalyst systems have been developed for the former's synthesis,[8] and the advances for the

(1) (a) Behr, A. In *Catalysis in C1 Chemistry*; Keim, W., Ed.; Reidel: Dordrecht, 1983. (b) Leitner, W. *Coord. Chem. Rev.* **1996**, *155*, 257−284. (c) Behr, A. *Carbon Dioxide Activation by Metal Complexes*; VCH Publishers: New York, 1988. (d) *Green Chemistry: Frontiers in Benign Chemical Syntheses and Processes*; Anastas, P. T., Williamson, T. C., Eds.; Oxford University Press: New York, 1998. (e) Inoue, S.; Yamazaki, Y. *Organic and Bio-organic Chemistry of Carbon Dioxide*; Kodansha, Ltd.: Tokyo, 1982. (f) Behr, A. *Carbon Dioxide Activation by Metal Complexes*; VCH: Weinheim, Germany, 1988. (g) Gibson, D. H. *Chem. Rev.* **1996**, *96*, 2063−2096. (h) Casadei, M. A.; Inesi, A.; Rossi, L. *Tetrahedron Lett.* **1997**, *38*, 3565−3568.

(2) (a) Shaikh, A. A. G.; Sivaram, S. *Chem. Rev.* **1996**, *96*, 951−976. (b) Darensbourg, D. J.; Holtcamp, M. W. *Coord. Chem. Rev.* **1996**, *153*, 155−174. (c) Ochiai, B.; Endo, T. *Prog. Polym. Sci.* **2005**, *30*, 183−215.

(3) To see a review of the synthetic applications of cyclic carbonates: Clements, J. H. *Ind. Eng. Chem. Res.* **2003**, *42*, 663−674.

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reaction of carbon dioxide promoted by transition metal[9] have been significant. However, unfortunately all described methods present some of the following drawbacks: low stability, reactivity, and air sensitivity of the catalyst, whose structure is generally complex, the need for a cosolvent, and the requirement for high pressures and/or high temperatures. Thus, an efficient method to react CO_2 with epoxides at room temperature and without external pressure by using a simple and more readily available catalyst would be desirable.

Previously, we reported the synthesis of both diastereoisomers (2*R*,1′*S*)- or (2*S*,1′*S*)-2-(1-aminoalkyl)epoxides **1** or **2** in enantiopure form.[10] Thus, *syn*-amino epoxides **1** were prepared by total stereoselective reduction with $LiAlH_4$ of the readily available α-amino-α′-chloro ketones, derived from natural α-amino acids. The anti diastereoisomers **2** were obtained by highly stereoselective addition of in situ generated iodomethyllithium (from diiodomethane and methyllithium) to α-amino aldehydes. Recently, we reported the ring opening of these epoxides **1** and **2** at C-3 by ketones,[11] nitriles,[12] carboxylic acids,[13] and organolithium compounds[14] with total regioselectivity.

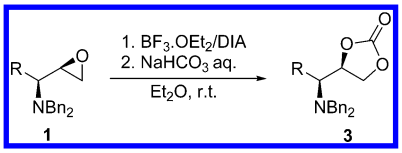
In the course of our quest to develop new synthetic applications of the enantiopure aminoepoxides **1** and **2**, we now report herein the selective reaction of chiral (2*R*,1′*S*)- or (2*S*,1′*S*)-2-(1-aminoalkyl)epoxides **1** or **2** with CO_2, generated from acidic treatment of an aqueous solution of $NaHCO_3$, at room temperature and without external pressure. So, enantiopure cyclic carbonates **3** or **4** were obtained efficiently. In addition, compounds **3** or **4** were readily transformed into diols **7** and **8** by reaction with $LiAlH_4$ or by basic hydrolysis and into O^1-acetylalkane-1,2-diols **9** and **10** by reaction with methyllithium at −78 °C.

TABLE 1. Synthesis of (4*R*,1′*S*)-4-(1-Aminoalkyl)-2-oxo-1,3-dioxolanes 3

entry	3[a]	R	*t* (min)	yield[b] (%)
1	**3a**	Me	5	85
2	**3b**	*i*-Bu	20	91
3	**3c**	Bn	10	88
4	**3d**	$BnOCH_2$	20	78

[a] Diastereoisomeric excess (^1H NMR of the crude products) of all compounds **3** > 98%. [b] Isolated yield after column chromatography based on the starting amino epoxide **1**.

SCHEME 1. Synthesis of (4*R*,1′*S*)-4-(1-Aminoalkyl)-2-oxo-1,3-dioxolanes 3



Results and Discussion

Synthesis of (4*R*,1′*S*)- or (4*S*,1′*S*)-4-(1-Aminoalkyl)-2-oxo-1,3-dioxolanes. Initial attempts to obtain carbonates were performed from syn diastereoisomers **1**. Thus, a solution of amino epoxides (1 equiv) **1** in diethyl ether was successively treated with $BF_3{\cdot}Et_2O$ (5 equiv) and diisopropylamine (1.5 equiv). After the reaction mixture was stirred for the time shown in Table 1, it was treated with a saturated aqueous solution of $NaHCO_3$, and after the flask was sealed the mixture was stirred for 10 min. Then, the reaction mixture was neutralized with $NaHCO_3$ and stirred for an additional 10 min. Standard workup afforded the crude cyclic carbonate **3** (Scheme 1).

Importantly, no use of dry solvents or inert atmosphere was necessary to carry out the reactions. Moreover, the presence of both diisopropylamine and $BF_3{\cdot}Et_2O$ is essential to perform the transformation of **1** into **3**. In the absence of amine or $BF_3{\cdot}Et_2O$, unchanged amino epoxide **1** was fully recovered, and the use of an amount less than 5 equiv of $BF_3{\cdot}Et_2O$ produced a mixture of the starting epoxide **1** and the carbonate **3**. In addition, when no addition of $NaHCO_3$ was performed, as was expected, no cyclic carbonate was obtained and the unchanged starting compound **1** or **2** was isolated.

In a similar manner, *anti*-amino epoxides **2** afforded the corresponding carbonates **4**, under the same reaction conditions (Scheme 2, Table 2).

The results of the synthesis of carbonates **3** and **4** are listed in Tables 1 and 2. This process appears to be general, and no

(4) (a) Peppel, W. J. *Ind. Eng. Chem.* **1958**, *50*, 767−770. (b) Ratzenhofer, M.; Kisch, H. *Angew. Chem., Int. Ed. Engl.* **1980**, *19*, 317−318. (c) Rakicki, G.; Kuran, W.; Marciniak, B. P. *Monatsch. Chem.* **1984**, *115*, 205. (d) Kihara, N.; Hara, N.; Endo, T. *J. Org. Chem.* **1993**, *58*, 6198−6202. (e) Yano, T.; Matsui, H.; Koike, T.; Ishiguro, H.; Fujihara, H.; Yoshihara, M.; Maeshima, T. *Chem. Commun.* **1997**, 1129−1130. (f) Yoshira, M.; Ihara, M. *Chem. Eur. J.* **2004**, *10*, 2886−2893.

(5) (a) Duscher, P. A.; Whash, K. U.S. Pat 5.098.594, 1992; *Chem. Abstr.* **1992**, *112*, 121161t. (b) Duscher, P. A.; Whash, K. U.S. Pat 5.007.969, 1991; *Chem. Abstr.* **1992**, *112*, 121161t. (c) Duscher, P. A. U.S. Pat 5.204.026, 1993; *Chem. Abstr.* **1993**, *119*, 98532y.

(6) (a) Biggadike, K.; Angell, R. M.; Burgess, C. M.; Farrell, R. M.; Hancock, A. P.; Harker, A. J.; Irving, A. J.; Irving, W. R.; Ioannou, C.; Procopiou, P. A.; Shaw, R. E.; Solanke, Y. E.; Singh, O. M. P.; Snowden, M. A.; Stubbs, R.; Walton, S.; Weston, H. E. *J. Med. Chem.* **2000**, *43*, 19−21. (b) Shaikh, A. A. G.; Sivaram, S. *Chem. Rev.* **1996**, *96*, 951−976.

(7) Trost, B. M.; Angle, S. R. *J. Am. Chem. Soc.* **1985**, *107*, 6123−6124.

(8) (a) Yamaguchi, K.; Ebitani, K.; Yoshida, T.; Yoshida, H.; Kaneda, K. *J. Am. Chem. Soc.* **1999**, *121*, 4526−4527. (b) Kawanami, H.; Ikushima, Y. *Chem. Commun.* **2000**, 2089−2090. (c) Kim, H. S.; Kim, J.; Kimee, J.; Lee, B. G.; Jung, O. S.; Jang, H. G.; Kang, S. *Angew. Chem., Int. Ed.* **2000**, *39*, 4096−4098. (d) Paddock, R. L.; Nguyen, S. T. *J. Am. Chem. Soc.* **2001**, *123*, 11498−11499. (e) Tu, M.; Davis, R. J. *J. Catal.* **2001**, *199*, 85−91. (f) George, M.; Weiss, R. G. *J. Am. Chem. Soc.* **2001**, *123*, 10393−10394 and references cited therein. (g) Kim, H. S.; Kim, J. J.; Kwon, H. N.; Chung, M. J.; Lee, B. G.; Jang, H. G. *J. Catal.* **2002**, *205*, 226−229. (h) Yasuda, H.; He, L. N.; Sakakura, T. *J. Catal.* **2002**, *209*, 547−550. (i) Shen, Y. M.; Duan, W. L.; Shi, M. *J. Org. Chem.* **2003**, *68*, 1559−1562. (j) Kim, H. S.; Kim, J. J.; Lee, S. D.; Lah, M. S.; Moon, D.; Jang, H. G. O. *Chem. Eur. J.* **2003**, *9*, 678−686. (k) Aresta, M.; Dibenedetto, A.; Gianfrate, L.; Pastore, C. *Appl. Catal. A: General* **2003**, *255*, 5−11. (l) Paddock, R. L.; Hiyama, Y.; McKay, J. M.; Nguyen, S. T. *Tetrahedron Lett.* **2004**, *45*, 2023−2026. (m) Tanaka, H.; Kitaichi, Y.; Sato, M.; Ikeno, T.; Yamada, T. *Chem. Lett.* **2004**, *33*, 676−677. (n) Mori, K.; Mitani, Y. Hara, T.; Mizugati, T.; Ebitami, K.; Kaneda, K. *Chem. Commun.* **2005**, 3331−3333. (o) Doskocil, E. J. *J. Phys. Chem. B.* **2005**, *109*, 2315−2320. (p) Berkessel, A.; Brandenburg, M. *Org. Lett.* **2006**, *8*, 4401−4401.

(9) To see recent examples of the reaction of CO_2 with epoxides without the use of a metal catalyst: (a) Jagtap, S. R.; Raje, V. P.; Samant, S. D.; Bhanage, B. M. *J. Mol. Catal. A: Chem.* **2007**, *266*, 69−74. (b) Zhao, Y.; Tian, J.-S.; Qi, X.-H.; Han, Z.-N.; Zhuang, Y.-Y.; He, L.-N. *J. Mol. Catal. A: Chem.* **2007**, *271*, 284−289. (c) Chaorong, Q.; Huanfeng, J.; Zhaoyang, W.; Bo, Z.; Shaorong, Y. *Synlett* **2007**, 255−258. (d) Jiang, J.-L.; Hua, R. *Synth. Commun.* **2006**, *36*, 3141−3148.

(10) (a) Barluenga, J.; Baragaña, B.; Alonso, A; Concellón, J. M. *J. Chem. Soc., Chem. Commun.* **1994**, 969−970. (b) Barluenga, J.; Baragaña, B.; Concellón, J. M. *J. Org. Chem.* **1995**, *60*, 6696−6699.

(11) Concellón, J. M.; Suárez, J. R.; García-Granda, S.; Díaz, M. R. *Org. Lett.* **2005**, *7*, 247−250.

(12) Concellón, J. M.; Suárez, J. R.; del Solar, V. *J. Org. Chem.* **2005**, *70*, 7447−7450.

(13) Concellón, J. M.; Suárez, J. R.; del Solar, V.; Llavona, R. *J. Org. Chem.* **2005**, *70*, 10348−10353.

(14) Concellón, J. M.; Bernad, P. L.; del Solar, V; Suárez, J. R.; García-Granda, S.; Díaz, M. R. *J. Org. Chem.* **2006**, *71*, 6420−6426.

SCHEME 2. Synthesis of (4*S*,1′*S*)-4-(1-Aminoalkyl)-2-oxo-1,3-dioxolanes 4

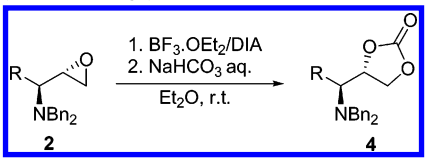


TABLE 2. Synthesis of (4*S*,1′*S*)-4-(1-Aminoalkyl)-2-oxo-1,3-dioxolanes 4

entry	4	R	*t* (min)	de[a] (%)	yield[b] (%)
1	**4a**	Me	10	>98 (>98)	80
2	**4b**	*i*-Bu	20	91 (91)	89
3	**4c**	Bn	10	91 (92)	82

[a] Diastereoisomeric excess determined by ^{1}H NMR analysis of the crude products **4**; de of the starting amino epoxides **2** is given in parentheses. [b] Isolated yield after column chromatography based on the starting amino epoxide **2**.

important differences in the reaction were observed when the structure of R or the absolute configuration of the oxirane of the starting amino epoxide was changed.

The selectivity of the reactions was determined by ^{1}H NMR spectroscopy (300 MHz) of the crude reaction products. All carbonates **3** were obtained as single isomers. Carbonates **4** were obtained as a mixture of diastereoisomers, in the same relationship to that of the starting aminoepoxides **2**. The synthesis of 2-oxo-1,3-dioxolanes **4** with the same diastereoisomeric excess as that of the starting aminoepoxides **2** could be indirect support of the total selectivity of the ring-opening reaction. After purification of carbonates **4** by column chromatography, the major diastereoisomer was isolated as a single enantioisomer.

The structure and the absolute configuration of compound **3c** was established unambiguously by single-crystal X-ray analysis,[15] and the structure and absolute configuration of the other cyclic carbonates **3** or **4**, as depicted in Schemes 1 and 2, were assigned by analogy. The X-ray analysis of **3c** showed that the absolute configurations are the same as the starting amino epoxide **1c**.

To the best of our knowledge, no previous synthesis of cyclic carbonates by reaction of epoxides with CO_2 has been described at room temperature and without to use a metal catalyst[9] or external pressure.[16] In addition, from a preparative viewpoint it is the first time in which two diastereoisomers of cyclic carbonates are obtained in enantiopure form.[17]

This transformation and the observed stereochemistry of products **3** and **4** may be explained by assuming the generation of CO_2 from the reaction of the aqueous solution of $NaHCO_3$ with the BF_3·Et_2O, present in the reaction mixture. Support for this is provided by (a) the observation of CO_2 effervescence and (b) the isolation of unchanged amino epoxide **1** or **2** (instead of carbonates **3** or **4**) when the reaction was carried out in an open flask.[16] In addition, to unambiguously prove the participation of CO_2 in the reaction, two experiments were performed by bubbling gas CO_2 and by using dry CO_2 instead of the aqueous solution of $NaHCO_3$. Thus, the synthesis of cyclic carbonate **4c** was performed by bubbling gas CO_2 through a solution of the amino epoxide **2c**, diisopropylamine, and BF_3·Et_2O in diethyl ether for 2 h at room temperature in an open flask. After usual workup, carbonate **4c** (62% yield) and epoxide **2c** (14% yield) were isolated. The lower yield of **4c** could be explained by taking into account that this experiment was performed in an open flask.[16] The reaction with dry CO_2 was performed from amino epoxide **1a**, and no important differences were detected. Thus, carbonate **4a** was obtained in 80% yield (similar to the shown in Table 1) by treatment of a solution of amino epoxide **1a**, diisopropylamine and 1 equiv of BF_3·Et_2O (instead of 5 equiv)[18] in diethyl ether with dry CO_2 (4 equiv) for 45 min. Finally, no important differences were observed when the synthesis of cyclic carbonates was carried out at higher scale: 78% of **3a** was obtained starting from 8 mmol of **1a**.

When the described reaction of CO_2 was performed, under the same reaction conditions, from 2-cyclohexyloxirane instead of the amino epoxides **1** or **2**, no chemical fixation of CO_2 was observed. This result suggested the essential participation of the dibenzylamino group in the reaction. So, presumably, the ring opening of **1** could proceeds through an effective cooperation between the BF_3·Et_2O and the dibenzylamino group.[19] The Lewis acid, which was added in excess (5 equiv), could activate the oxirane by coordination of the epoxide oxygen to the Lewis acid.[20] Then, an intramolecular ring opening at C-2 by the dibenzylamino group, with inversion of configuration, would afford the aziridinium salt **5**,[21] which could be in

(15) **Crystallographic Data for 3c.** A colorless, prismatic crystal, 0.20 × 0.15 × 0.10 mm^3 was selected for the experiment. Cu Kα was used on a Nonius Kappa-CCD (λ = 1.54184 Å) single-crystal diffractometer: T = 293(2) K. Unit cell dimensions: a = 11.0013(8), b = 9.2305(6), c = 21.6130(2), b = 91.697(7). Space group $P2_1$. Absolute structure was checked using Friedel pairs and chemical information. CCDC-630533 (**3c**) contains the supplementary crystallographic data for this paper. These data can be obtained free of charge via www.ccdc-.cam.ac.uk/conts/retrieving.html (or the Cambridge Data Center, 12 Union Road, Cambridge CB21EZ, UK; fax (+44)1223-336.033; or deposit@ccdc.cam.ac.uk).

(16) When CO_2 is generated, pressure builds up in the flask. So, an experiment was carried out to determinate the generated pressure after addition of the aqueous solution of $NaHCO_3$. The reaction was performed starting from 0.43 mmol of epoxide **1a** and by using a 38 mL flask. When the flask was sealed (after addition of the solution of $NaHCO_3$), the pressure measured inside the flask was 1.15 bar.

(17) A catalytic resolution of racemic epoxides by reaction with CO_2 by using chiral Salen Co(III)/quaternary ammonium halide as the catalyst system is described in: Lu, X. B.; Liang, B.; Tian, Y.-J.; Wang, Y. M.; Bai, C. X.; Wang, H.; Zhang, R. *J. Am. Chem. Soc.* **2004**, *126*, 3732−3733.

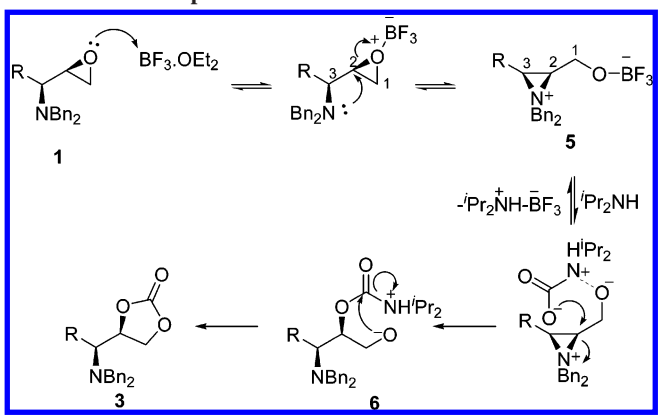
(18) A minor amount of BF_3·Et_2O was used in this reaction because the Lewis acid was not necessary to generate CO_2 from $NaHCO_3$.

(19) To explain the ring opening of amino epoxides **1** or **2** by other nucleophiles (refs 11−14), a direct attack of the nucleophiles to the oxirane ring, without participation of the dibenzylamino group, was proposed because the reaction took place (under the same reaction conditions) on epoxides without a dibenzylamino group.

(20) The selective coordination of the Lewis acid with the epoxide instead of the nitrogen of dibenzylamino group is proposed on the basis of previous results. Thus, the treatment of dibenzylamino aziridines with BF_3 and further treatment with lithium aluminium hydride afforded the corresponding complex aziridine−borane with total selectivity, and no complex of dibenzylamino-borane was detected on the crude reactions. The aziridine-borane complex was isolated, and its structure was established by single-crystal X-ray diffraction analysis: Concellón, J. M.; Suárez, J. R.; García-Granda, S.; Díaz, M. R. *Angew. Chem., Int. Ed.* **2004**, *43*, 4333−4336.

(21) The same participation of the dibenzylamino group in ring-opening of amino epoxides by ketones was previously proposed: (a) Concellón, J. M.; Suárez, J. R.; García-Granda, S.; Díaz, M. R. *Org. Lett.* **2005**, *7*, 247−250. A similar participation of the dibenzylamino group to justify the ring-opening of amino aziridines by various nucleophiles was also proposed: (b) Concellón, J. M.; Riego, E. *J. Org. Chem.* **2003**, *68*, 6407−6410. (c) Concellón, J. M.; Riego, E.; Súarez, J. R. *J. Org. Chem.* **2003**, *68*, 9242−9246. (d) Concellón, J. M.; Suárez, J. R.; García-Granda, S.; Díaz, M. R. *Angew. Chem., Int. Ed.* **2004**, *43*, 4333−4336. (e) Concellón, J. M.; Suárez, J. R.; García-Granda, S.; Díaz, M. R. *Org. Lett.* **2004**, *6*, 4499−4501. (f) Concellón, J. M.; Bernad, P. L.; Suárez, J. R.; García-Granda, S.; Díaz, M. R. *J. Org. Chem.* **2005**, *70*, 9411−9416.

SCHEME 3. Proposed Mechanism



equilibrium with the salt derived of the amine and BF_3. The generated CO_2 could be activated by diisopropylamine[22] and would attack at C-2 the aziridinium salt **5** with a second inversion of configuration to afford the intermediate **6**, which could cycle to give the corresponding cyclic carbonate **3** (Scheme 3).

An attack at C-3 of the aziridinium salt by the activated CO_2 would be also possible. The complete regioselectivity observed could be explained as consequence of an interaction between the $^{+}NH^{i}Pr_2$ and the $^{-}OBF_3$ groups. A similar explanation has been used to justify the observed regioselectivity on the nucleophilic ring opening of similar compounds such as amino aziridines.[23] The same mechanism would justify the synthesis of **4**.

Preparation of (2*S*,3*S*)- or (2*R*,3*S*)-3-Aminoalkan-1,2-diols 7 or 8 Using $LiAlH_4$ or KOH 50%. To prove the synthetic applications of these cyclic carbonates **3** and **4**, they were transformed into the corresponding 3-dibenzylaminoalkane-1,2-diols **7** or **8**. Thus, treatment of a solution of cyclic carbonates **3a**,**b** or **4b** in methanol with KOH (1 mL of a 50% aqueous solution) at room temperature for 1 h afforded enantiopure diols **7a**,**b** or **8b** in high yield (Table 3).

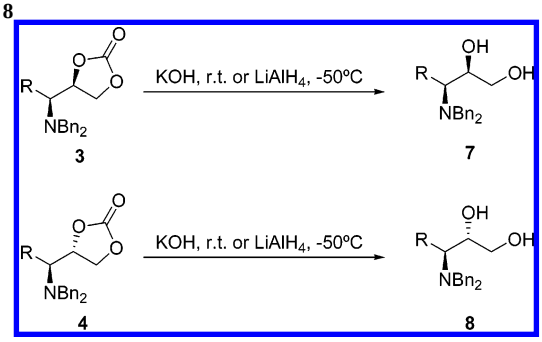
Alternatively, diols **7a**,**b** and **8b** were also obtained by reduction of cyclic carbonates with $LiAlH_4$ (Table 3) in very similar yields.

The structure of diols **7b** and **8b**, as depicted in Table 3, was unambiguously established by comparison of the NMR spectroscopic data of **7b** and **8b** with the ^1H and ^{13}C NMR spectra of authentic samples, previously described in the literature.[11] The structure and absolute configuration of **7a** was assigned by analogy.

Preparation of (2*S*,3*S*)- or (2*R*,3*S*)-*O*^{1}-Acetyl-3-aminoalkane-1,2-diol 9 or 10 Using MeLi. When the reaction with MeLi was carried out at room or −10 °C a complex mixture of products was obtained. However, the reaction of a solution of cyclic carbonates **3a**,**b** and **4a** in THF at −78 °C with 1.1 equiv of MeLi for 30 min afforded, after standard workup, the corresponding enantiopure *O*^{1}-acetyl alkane-1,2-diols **9a**,**b** and **10a**,**b** in good yield and with high (**10a**,**b**) or total (**9a**,**b**) regioselectivity (Scheme 4 and Table 4).

The selectivity of the reaction was determined by ^1H NMR spectroscopy (300 MHz) of the crude mixture products, showing the presence of a single regioisomer in the synthesis of **9a**,**b**. On the contrary, **10a**,**b** were obtained as a mixture of the two possible regioisomers (1,2-diols *O*^{1}-acetylated or *O*^{2}-acetylated) in a relationship of 5/1 and 7/1, respectively. No separation of regioisomers by conventional column chromatography was possible. The regiochemistry of the ester group in compounds **9** and **10** (major regioisomer) was determined by the HMBC 2D-NMR experiment performed on **9b**, which showed correlation between the methylene hydrogens of *CH*$_2$OCOMe and the carbonyl compound CH_2OCOMe, and no interaction between the hydrogens of C*H*OH and the carbonyl carbon. Consequently, the acetylated hydroxyl group of **9b** would be the primary alcohol function. In addition, the structure of compounds **9b** and **10b** was also established by comparison of their NMR spectroscopic data with the ^1H and ^{13}C NMR spectra of the same compound previously described in the literature.[13]

TABLE 3. Synthesis of (2*S*,3*S*)- or (2*R*,3*S*)-3-Aminoalkan-1,2-diols 7 or 8



entry	compd	R	yield[a] (%) $LiAlH_4$	yield[a] (%) KOH 50%
1	**7a**	Me	82	84
2	**7b**	*i*-Bu	88	87
3	**8b**	*i*-Bu	84	83

[a] Isolated yield after column chromatography based on the starting cyclic carbonates **3** and **4**.

SCHEME 4. Synthesis of (2*S*,3*S*)- or (2*R*,3*S*)-*O*^{1}-Acetyl-3-aminoalkane-1,2-diol 9 or 10

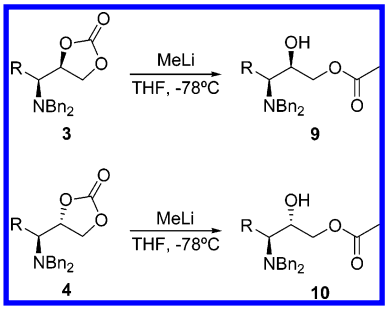


TABLE 4. Synthesis of (2*S*,3*S*)- or (2*R*,3*S*)-*O*^{1}-Acetyl-3-aminoalkane-1,2-diol 9 or 10

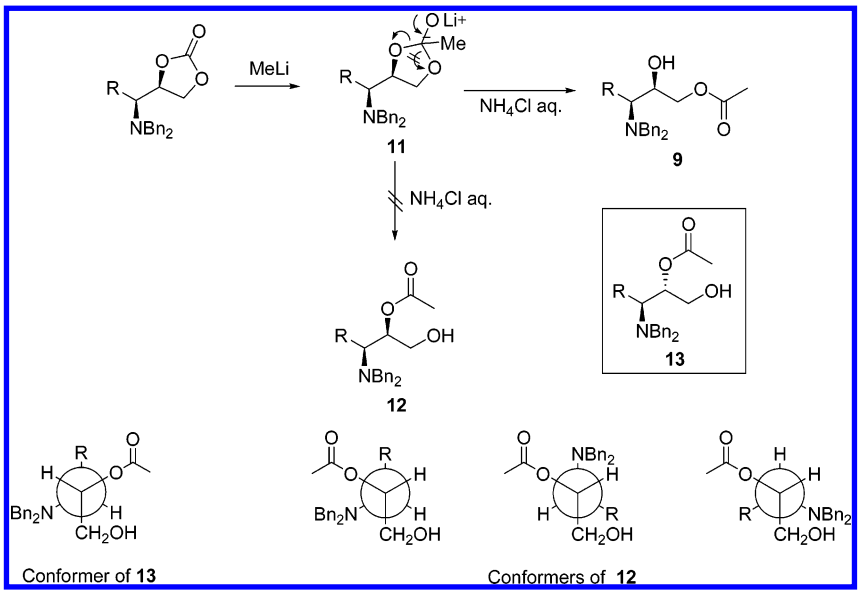
entry	compd	R	yield[a] (%)
1	**9a**	Me	66
2	**9b**	*i*-Bu	67
3	**10a**	Me	65[b]
4	**10b**	*i*-Bu	64[c]

[a] Isolated yield after column chromatography based on the starting cyclic carbonates **3** and **4**. [b] As a 5/1 mixture of regioisomers of **10a** (major) and the corresponding *O*^{2}-acetyl regioisomer (minor). [b] As a 7/1 mixture of regioisomers of **10b** (major) and the corresponding *O*^{2}-acetyl regioisomer (minor).

(22) The activation of CO_2 by a base has been previously proposed by other authors to explain the reaction of CO_2 with epoxides: refs 7a and 7l and references cited therein.

(23) Concellón, J. M.; Riego, E.; Súarez, J. R. *J. Org. Chem.* **2003**, *68*, 9242−9246.

SCHEME 5. Proposed Mechanism



To explain the transformation of cyclic carbonates **3** or **4** into O^1-acetylalkane-1,2-diols **9** and **10**, we propose the mechanism depicted in Scheme 5. Thus, the addition of MeLi to the cyclic carbonate **3** would afford the cyclic intermediate **11**, which could undergo two different opening of the oxirane to give the regioisomers **9** or **12**. A possible explanation of the selective ring-opening, to afford the 1,2-diols O^1-acetylated **9** as single regioisomer could be based on steric hindrance between the bulkiest groups *O*-acetyl and dibenzylamino. Thus, regioisomer **9** (the former groups are in a relative 1,3-position) is favored versus **12** (1,2-position). Further studies to justify the selectivity of this transformation are currently under investigation.

The lower regioselectivity observed in the synthesis of **10a**, **b** could be also explained based on steric hindrance. So, the steric hindrance is higher in the O^2-acetylated *syn*-diol **12** than in the O^2 acetylated *anti*-diol **13**, as is shown in their Newman projections (Scheme 5). Thus, formation of **13** is more favored than formation of **12**. Therefore, **9** would be the only regioisomer obtained from **3** and a mixture of the O^1 and O^2 acetylated regioisomers could be obtained from **4**.

Conclusions

In conclusion, we have described the reaction of chiral *anti*- or *syn*-amino epoxides **1** or **2** with CO_2 (generated by reaction of aqueous solution of $NaHCO_3$ with $BF_3{\cdot}Et_2O$) in the presence of diisopropylamine, affording the corresponding enantiopure carbonates **3** or **4**. The structure of the cyclic carbonate was established on the basis of the results of the X-ray analysis of **3c**. A mechanism has been proposed to explain this transformation. Basic hydrolysis or reduction with $LiAlH_4$ of carbonates **3** or **4** afforded the corresponding enantiopure diols **7** or **8**, respectively, in high yields. The treatment of cyclic carbonates **3** or **4** with MeLi at low temperature (−78 °C) gave the optically active 1,2-diol O^1-acetylated **9** or **10**, respectively, in good yield and with complete or high regioselectivity. A possible explanation to justify the regioselectivity of this transformation is given. The synthetic applications of the obtained cyclic carbonates and studies directed toward fully delineating the factors involved in these transformations are currently under investigation in our laboratory.

Experimental Section

General Procedure of the Synthesis of 3 and 4. $BF_3{\cdot}OEt_2$ (5 equiv, 1 mmol, 0.15 mL) and diisopropylamine (1.5 equiv, 0.3 mmol, 0.040 mL) were added to a stirred solution of the corresponding amino epoxide **1** or **2**[10] (0.2 mmol) in Et_2O (2 mL) at room temperature. After the mixture was stirred for the time indicated in Tables 1 and 2, an aqueous saturated solution of $NaHCO_3$ (2 mL) was added, and after the flask was sealed, the mixture was stirred for 10 min. Then, the reaction was neutralized by adding an aqueous saturated solution of $NaHCO_3$ (5 mL), and the mixture was stirred for 10 min. The resulting mixture was extracted with diethyl ether (3 × 5 mL), and the combined organic layers were dried over anhydrous Na_2SO_4, filtered, and concentrated in vacuo. Flash column chromatography on silica gel (hexane/EtOAc 20:1) provided pure compounds **3** or **4**.

When the synthesis of **3a** was performed at higher scale from 8 mmol of **1a**, the reaction was carried out in a flask of 500 mL. So, a solution of 6 mL of $BF_3{\cdot}OEt_2$ (40 mmol) and 1.6 mL of diisopropylamine (12 mmol) in 75 mL of Et_2O was stirred for 15 min, and **1a**[10] (8 mmol, 2.024 g) and an aqueous saturated solution of $NaHCO_3$ (80 mL) were added successively at room temperature. After the flask was sealed, the mixture was stirred for 30 min.

Synthesis of 3a Using dry CO_2. $BF_3{\cdot}OEt_2$ (1,1 equiv, 0.44 mmol, 0.066 mL) and diisopropylamine (1.5 equiv, 0.6 mmol, 0.080 mL) were added to a stirred solution of the amino epoxide **1a**[10] (0.4 mmol, 0.101 g) in Et_2O (3 mL) at room temperature. After the mixture was stirred for 5 min, 12.5 equiv of dry CO_2 (5 mmol, 240 mg) was added, and after the flask was sealed, the mixture was stirred for 75 min. Then, the reaction was neutralized by adding an aqueous saturated solution of $NaHCO_3$ (3 mL), and the mixture was stirred for 10 min. The resulting mixture was extracted with diethyl ether (3 × 5 mL), and the combined organic layers were dried over anhydrous Na_2SO_4, filtered, and concentrated in vacuo. Flash column chromatography on silica gel (hexane/EtOAc 20:1) provided pure compounds **3a**.

(4*R*)-4-[(*S*)-1-(Dibenzylamino)ethyl]-1,3-dioxolan-2-one (3a): white solid; mp = 79 °C; $[\alpha]^{20}_D = -17.2$ (*c* 1.27, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 7.37−7.21 (m, 10 H), 4.63 (dt, J = 7.8, 5.2 Hz, 1 H), 4.24 (apparent t, J = 8.3 Hz, 1 H), 4.17 (apparent t, J = 7.8 Hz, 1 H), 3.88 (d, J = 13.4 Hz, 2 H), 3.46 (d, J = 13.4 Hz, 2 H), 2.93−2.84 (m, 1 H), 1.20 (d, J = 6.8 Hz, 3 H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 155.0 (C), 139.2 (2 × C), 128.8 (4 × CH), 128.3 (4 × CH), 127.1 (2 × CH), 79.7 (CH), 66.7 (CH_2), 54.9 (2 × CH_2), 53.9 (CH), 9.9 (CH_3); MS (70 eV, EI) *m*/*z* (%)

311 (M^+, <1), 224 (20), 181 (17), 91 (100; HRMS (70 eV) calcd for $C_{19}H_{21}NO_3$ (M^+) 311.1521, found 311.1550; IR (neat) 3397, 3061, 2972, 2834, 1795, 1602, 1494, 1453, 1377 cm^{-1}; $R_f = 0.11$ (hexane/EtOAc 10:1).

(4*R*)-4-[(*S*)-1-(Dibenzylamino)-3-methylbutyl]-1,3-dioxolan-2-one (3b): white solid; mp = 99 °C; $[\alpha]^{20}_D = -35.6$ (*c* 1.36, $CHCl_3$); ^1H NMR (400 MHz, $CDCl_3$) δ 7.25−7.12 (m, 10 H), 4.66 (dt, *J* = 7.9, 5.7 Hz, 1 H), 4.17 (apparent t, *J* = 8.1 Hz, 1 H), 4.05 (apparent t, *J* = 7.9 Hz, 1 H), 3.73 (d, *J* = 13.1 Hz, 2 H), 3.49 (d, *J* = 13.1 Hz, 2 H), 2.63 (apparent q, *J* = 6.5 Hz, 1 H), 1.72−1.63 (m, 1 H), 1.49−1.40 (m, 1 H), 1.16−1.04 (m, 1 H), 0.79 (d, *J* = 6.6 Hz, 3 H), 0.62 (d, *J* = 6.5 Hz, 3 H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 154.9 (C), 139.3 (2 × C), 129.1 (4 × CH), 128.3 (4 × CH), 127.1 (2 × CH), 78.1 (CH), 67.0 (CH_2), 55.9 (CH), 55.0 (2 × CH_2), 34.8 (CH_2), 24.4 (CH), 22.7 (CH_3), 22.4 (CH_3); MS (70 eV, EI) *m*/*z* 353 (M^+, 3), 267 (88), 266 (100), 210 (33), 181 (67), 131 (29); HRMS (70 eV) calcd for $C_{22}H_{27}NO_3$ (M^+) 353.1991, found 353.2065; IR (neat) 3408, 3028, 2957, 2868, 1798, 1495, 1454, 1376 cm^{-1}; $R_f = 0.13$ (hexane/EtOAc 10:1).

(4*R*)-4-[(*S*)-1-(Dibenzylamino)-2-phenylethyl]-1,3-dioxolan-2-one (3c): white solid; mp = 150 °C; $[\alpha]^{20}_D = +17.6$ (*c* 1.89, $CHCl_3$); ^1H NMR (400 MHz, $CDCl_3$) δ 7.37−7.19 (m, 15 H), 4.56 (ddd, *J* = 8.6, 7.1, 3.2 Hz, 1 H), 4.24 (apparent t, *J* = 7.5 Hz, 1 H), 4.06 (d, *J* = 13.5 Hz, 2 H), 4.02 (apparent t, *J* = 8.3 Hz, 1 H), 3.56 (d, *J* = 13.5 Hz, 2 H), 3.26 (dd, *J* = 13.2, 3.9 Hz, 1 H), 2.97 (apparent t, *J* = 12.0 Hz, 1 H), 2.81 (dt, *J* = 10.8, 3.9 Hz, 1 H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 154.9 (C), 138.8 (2 × C), 138.2 (C), 129.2 (2 × CH), 129.0 (4 × CH), 128.8 (2 × CH), 128.4 (4 × CH), 127.3 (2 × CH), 126.6 (CH), 76.8 (CH), 66.2 (CH_2), 60.1 (CH), 55.7 (2 × CH_2), 30.9 (CH_2); MS (70 eV, EI) *m*/*z* 296 (M^+ − Bn, 60), 91 (100); HRMS (70 eV) calcd for $C_{18}H_{18}NO_3$ (M^+ − Bn) 296.1287, found 296.1300; IR (neat) 3423, 3063, 3028, 2816, 1797, 1601, 1494, 1454, 1398 cm^{-1}; $R_f = 0.10$ (hexane/EtOAc 10:1).

(4*R*)-4-[(*S*)-2-(Benzyloxy)-1-(dibenzylamino)ethyl]-1,3-dioxolan-2-one (3d): white solid; mp= 170 °C; $[\alpha]^{20}_D = +15.1$ (*c* 1.08, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 7.42−7.23 (m, 15 H), 4.94 (dt, *J* = 7.9, 5.4 Hz, 1 H), 4.53 (s, 2 H), 4.24 (apparent t, *J* = 8.4 Hz, 1 H), 4.14 (apparent t, *J* = 8.0 Hz, 1 H), 3.96 (d, *J* = 13.4 Hz, 2 H); 3.88 (dd, *J* = 9.4, 5.4 Hz, 1 H), 3.75 (dd, *J* = 9.4, 7.7 Hz, 1 H), 3.61 (d, *J* = 13.4 Hz, 2 H), 2.99 (dt, *J* = 7.7, 5.4 Hz, 1 H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 155.0 (C), 139.1 (2 × C), 137.4 (C), 128.9 (4 × CH), 128.5 (2 × CH), 128.4 (4 × CH), 128.0 (CH), 127.6 (2 × C), 127.3 (2 × C), 77.2 (CH), 73.6 (CH_2), 67.0 (2 × CH_2), 57.9 (CH); 55.6 (2 × CH_2); HRMS (70 eV) calcd for $C_{26}H_{27}NO_4$ (M^+) 417.1940, found 417.1931; IR (neat) 3442, 3019, 2865, 1793, 1520, 1496, 1454, 1363 cm^{-1}; $R_f = 0.10$ (hexane/EtOAc 10:1).

(4*S*)-4-[(*S*)-1-(Dibenzylamino)ethyl]-1,3-dioxolan-2-one (4a): white solid; mp = 87 °C; $[\alpha]^{20}_D = +38.9$ (*c* 1.24, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 7.26−7.14 (m, 10 H), 4.37−4.27 (m, 2 H), 3.95−3.88 (m, 1 H), 3.60 (d, *J* = 13.4 Hz, 2 H), 3.35 (d, *J* = 13.4 Hz, 2 H), 2.980−2.71 (m, 1 H); 1.15 (d, *J* = 6.6 Hz, 3 H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 154.9 (C), 138.7 (2 × C), 128.7 (4 × CH), 128.5 (4 × CH), 127.5 (2 × CH), 77.8 (CH), 68.9 (CH_2), 56.4 (CH), 54.6 (2 × CH_2), 8.7 (CH_3); MS (70 eV, EI) *m*/*z* 311 (M^+, <1), 91 (100); HRMS (70 eV) calcd for $C_{19}H_{21}NO_3$ (M^+) 311.1521, found 311.1584; IR (neat) 3453, 3028, 2976, 2841, 1085, 1494, 1453, 1380 cm^{-1}; $R_f = 0.11$ (hexane/EtOAc 10:1).

(4*S*)-4-[(*S*)-1-(Dibenzylamino)-3-methylbutyl]-1,3-dioxolan-2-one (4b): colorless oil; $[\alpha]^{20}_D = -3.1$ (*c* 1.02, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 7.35−7.25 (m, 10 H), 4.64 (apparent q, *J* = 7.8 Hz, 1 H), 4.45 (t, *J* = 8.4 Hz, 1 H), 3.96 (t, *J* = 8.4 Hz, 1 H), 3.64 (s, 4 H), 2.78 (apparent q, *J* = 6.6 Hz, 1 H), 2.02−1.89 (m, 1 H), 1.80−1.71 (m, 1 H), 1.42−1.33 (m, 1 H), 0.95 (d, *J* = 6.5 Hz, 3 H), 0.86 (d, *J* = 6.5 Hz, 3 H); ^{13}C NMR (50 MHz, $CDCl_3$) δ 155.0 (C), 138.9 (2 × C), 128.8 (4 × CH), 128.5 (4 × CH), 127.4 (2 × CH), 77.4 (CH), 68.9 (CH_2), 58.1 (CH), 54.7 (2 × CH_2), 35.7 (CH_2), 24.9 (CH), 22.9 (CH_3), 22.8 (CH_3); MS (70 eV, EI) *m*/*z* 310 ($M^+ - {}^i$Pr, <1), 266 (100), 91 (90); HRMS (70 eV) calcd for $C_{19}H_{20}NO_3$ ($M^+ - {}^i$Pr) 310.1443, found 310.1405; IR (neat) 3381, 3029, 2960, 1807, 1494, 1454, 1369 cm^{-1}; $R_f = 0.14$ (hexane/EtOAc 10:1).

(4*S*)-4-[(*S*)-1-(Dibenzylamino)-2-phenylethyl]-1,3-dioxolan-2-one (4c): white solid; mp = 98 °C; $[\alpha]^{20}_D = +22.9$ (*c* 1.64, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 7.45−7.24 (m, 11 H), 7.16−7.11 (m, 4 H), 4.70 (apparent q, *J* = 7.7 Hz, 1 H), 4.44 (apparent t, *J* = 8.4 Hz, 1 H), 3.93 (apparent t, *J* = 8.2 Hz, 1 H), 3.73 (d, *J* = 13.7 Hz, 2 H), 3.57 (d, *J* = 13.7 Hz, 2 H), 3.21−2.99 (m, 2 H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 154.8 (C), 139.1 (C), 138.6 (2 × C), 129.5 (2 × CH), 128.7 (4 × CH), 128.6 (2 × CH), 128.4 (4 × CH), 127.4 (2 × CH), 126.6 (CH), 77.0 (CH), 68.8 (CH_2), 62.2 (CH), 54.8 (2 × CH_2), 32.9 (CH_2); HRMS (70 eV) calcd for $C_{25}H_{25}NO_3$ (M^+) 387.1834, found 387.1819; IR (neat) 3492, 3028, 2852, 1806, 1602, 1495, 1454, 1370 cm^{-1}; $R_f = 0.13$ (hexane/EtOAc 10:1).

General Procedure for the Synthesis of Compounds 7 and 8. $LiAlH_4$ (1.1 equiv, 0.2 mmol, 0.2 mL, 1 M in THF) was added to a stirred solution of the corresponding cyclic carbonate **3** or **4** (0.2 mmol) in THF (2 mL) at −50 °C. After the mixture was stirred at this temperature for 30 min, an aqueous saturated solution of NH_4Cl (5 mL) was added, and the mixture was stirred for 5 min at room temperature. Then, the aqueous phase was extracted with diethyl ether (3 × 5 mL), and the combined organic layers were dried over anhydrous Na_2SO_4, filtered, and concentrated in vacuo. Flash column chromatography on silica gel (hexane/EtOAc 10:1) provided pure compounds **7** or **8**.

An aqueous solution of KOH (50%, 1 mL) was added to a stirred solution of the corresponding cyclic carbonate **3** or **4** (0.2 mmol) in MeOH (2 mL) at room temperature. The reaction was stirred for 1 h, and H_2O (5 mL) was added to the mixture, which was stirred for additional 5 min. Then, the aqueous phase was extracted with diethyl ether (3 × 5 mL), and the combined organic layers were dried over anhydrous Na_2SO_4, filtered, and concentrated in vacuo. Flash column chromatography on silica gel (hexane/EtOAc 10:1) provided pure compounds **7** or **8**.

(2*R*,3*S*)-3-(Dibenzylamino)butane-1,2-diol (7a): colorless oil; $[\alpha]^{20}_D = +46.7$ (*c* 1.49, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 7.24−7.12 (m, 10 H), 3.72 (d, *J* = 13.3 Hz, 2 H), 3.64 (dd, *J* = 11.7, 2.8 Hz, 1 H), 3.42 (ddd, *J* = 9.6, 4.2, 2.8 Hz, 1 H), 3.27 (dd, *J* = 11.7, 4.2 Hz, 1 H), 3.23 (d, *J* = 13.3 Hz, 2 H), 2.76 (dq, *J* = 9.6, 6.6 Hz, 1 H), 0.95 (d, *J* = 6.6 Hz, 3 H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 138.6 (2 × C), 128.9 (4 × CH), 128.3 (4 × CH), 127.1 (2 × CH), 71.5 (CH), 63.2 (CH_2), 54.1 (CH), 53.2 (2 × CH_2), 8.0 (CH_3); HRMS (70 eV) calcd for $C_{17}H_{20}NO$ (M^+ − CH_2OH) 254.1545, found 254.1543; IR (neat) 3406, 3028, 2932, 1602, 1495, 1453, 1378 cm^{-1}; $R_f = 0.27$ (hexane/EtOAc 3:1).

(2*R*,3*S*)-3-(dibenzylamino)-5-methylhexane-1,2-diol (7b). See ref 11.

(2*S*,3*S*)-3-(dibenzylamino)-5-methylhexane-1,2-diol (8b). See ref 11.

General Procedure for the Synthesis of Compounds 9 and 10. MeLi (1.1 equiv, 0.2 mmol, 0.15 mL) was added to a stirred solution of the corresponding cyclic carbonate **3** or **4** (0.2 mmol) in THF (2 mL) at −78 °C. After the mixture was stirred at this temperature for 30 min, an aqueous saturated solution of NH_4Cl (5 mL) was added, and the resulting mixture was stirred at room temperature for 5 min. Then, the aqueous phase was extracted with diethyl ether (3 × 5 mL), and the combined organic layers were dried over anhydrous Na_2SO_4, filtered, and concentrated in vacuo. Flash column chromatography on silica gel (hexane/EtOAc 10:1) provided pure compounds **9** or **10**.

(2*R*,3*S*)-*O*^{1}-Acetyl-3-(dibenzylamino)butane-1,2-diol (9a): colorless oil; $[\alpha]^{20}_D = +45.9$ (*c* 1.54, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 7.35−7.22 (m, 10 H), 4.60 (br s, 1 H), 4.22 (dd, *J* = 11.7, 2.6 Hz, 1 H), 3.88 (dd, *J* = 11.7, 5.4 Hz, 1 H), 3.83 (d, *J* = 13.1 Hz, 2 H), 3.69 (ddd, *J* = 9.7, 5.4, 2.6 Hz, 1 H), 3.33 (d, *J* = 13.1 Hz, 2 H), 2.73 (dq, *J* = 9.7, 6.8 Hz, 1 H), 1.94 (s, 3 H), 1.08

(d, J = 6.8 Hz, 3 H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 171.0 (C), 138.4 (2 × C), 129.0 (4 × CH), 128.5 (4 × CH), 127.3 (2 × CH), 69.4 (CH), 65.6 (CH_2), 54.2 (CH), 53.1 (2 × CH_2), 20.6 (CH_3), 8.2 (CH_3); MS (70 eV, EI) m/z 310 ($M^+ - OH$, 26), 231 (49), 219 (41), 132 (44), 69 (100); HRMS (70 eV) calcd for $C_{20}H_{24}NO_2$ ($M^+ - OH$) 310.1807, found 310.1775; IR (neat) 3407, 3028, 2968, 2840, 1806, 1738, 1495, 1453, 1378 cm^{-1}; R_f = 0.16 (hexane/EtOAc 5:1).

(2*R*,3*S*)-*O*^{1}-Acetyl-3-(dibenzylamino)-5-methylhexane-1,2-diol (9b). See ref 13.

(2*S*,3*S*)-*O*^{1}-Acetyl-3-(dibenzylamino)butane-1,2-diol (10a): colorless oil; $[\alpha]^{20}_D$ = +33.8 (*c* 1.03, $CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.37−7.20 (m, 10 H), 4.42 (dd, J = 11.4, 2.9 Hz, 1 H), 4.03 (dd, J = 11.4, 6.6 Hz, 1 H), 3.86−3.79 (m, 1 H), 3.60 (d, J = 13.5 Hz, 2 H), 3.40 (d, J = 13.5 Hz, 2 H), 2.80 (apparent qt, J = 6.8 Hz, 1 H), 1.94 (s, 3 H), 1.18 (d, J = 6.7 Hz, 3 H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 171.2 (C), 138.9 (2 × C), 128.8 (4 × CH), 128.3 (4 × CH), 127.0 (2 × CH), 67.7 (CH), 65.8 (CH_2), 55.9 (CH), 54.1 (2 × CH_2), 25.4 (CH_3), 8.3 (CH_3); MS (70 eV, EI) m/z 327 (M^+, 2), 224 (100), 181 (37); HRMS (70 eV) calcd for $C_{20}H_{25}NO_3$ (M^+) 327.1834, found 327.1824; IR (neat) 3452, 3028, 2933, 2805, 1738,1494, 1453, 1378 cm^{-1}; R_f = 0.11 (hexane/EtOAc 5:1).

(2*S*,3*S*)-*O*^{1}-Acetyl-3-dibenzylamino-5-methylhexane-1,2-diol (10b). See ref 13.

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Supporting Information Available: Full experimental procedures, characterization data, and ^{1}H and ^{13}C NMR spectra of **3**, **4**, **7**, **9**, and **10** and X-ray crystallographic information of **3c** (CIF). This material is available free of charge via the Internet at http://pubs.acs.org.

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