# 63. Asymmetric Synthesis of α-Hydroxy-Esters *via* Ester Enolates with Very High Diastereoselectivity

by **Remo Gamboni** and **Christoph Tamm***

Institut für Organische Chemie der Universität, St. Johanns-Ring 19, CH-4056 Basel

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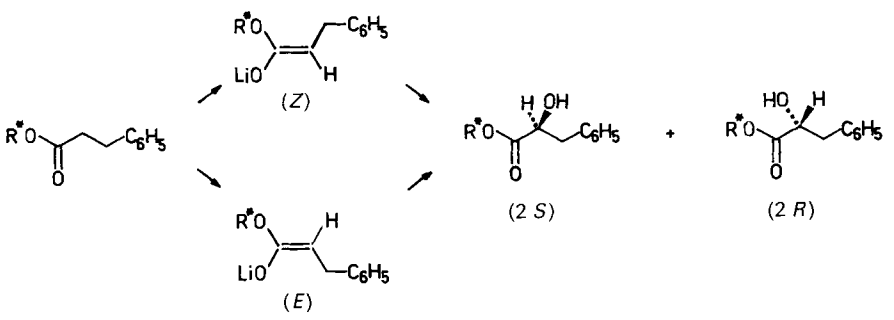
The α-hydroxylation of chiral esters of 3-phenylpropionic acid by $MoO_5 \cdot Py \cdot HMPT$ was optimized to 98% de and 73% yield by systematic variation of the reaction conditions. The addition of at least 3 equiv. of K(*sec*-BuO) proved to be essential.

Chiral α-hydroxy-carboxylic acids are important starting materials and intermediates for the synthesis of optically active natural products. In [1], we reported on the first results of the asymmetric synthesis of optically pure 2-hydroxy-3-phenylpropionates of chiral alcohols (R*OH) derived from (+)-camphor (*cf.* [2] [3]) by hydroxylation with $MoO_5 \cdot Py \cdot HMPT$ ( = MoOPH) [4]. Since then, the α-acetoxylation of *O*-silylated camphorsulfonamide esters with $Pb(OAc)_4$ [5] and the hydroxylation of oxazolidone carboximide enolates [6] and of amide enolates derived from phenylacetic acid and (+)-(*S*)-2-(hydroxymethyl)pyrrolidine [7] by 3-phenyl-2-(phenylsulfonyl)oxaziridine with high diastereoselectivities have been reported.

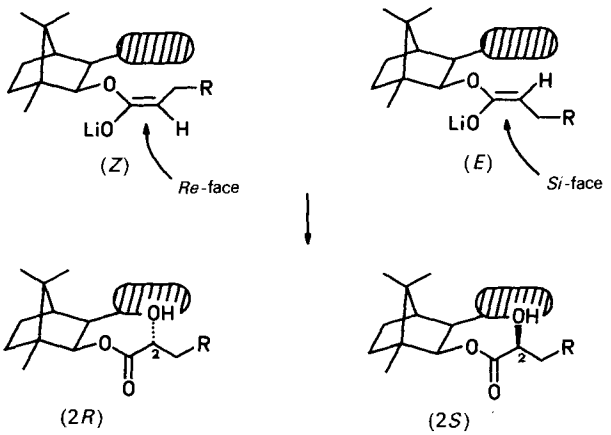
Here, we report on further results of our investigations of the hydroxylation with 3-phenyl-2-(phenylsulfonyl)-oxaziridine or with MoOPH [8]. With the latter reagent, a remarkable improvement of the diastereoisomeric excess up to 98% with a yield of isolated products of 73% has been achieved.

For the hydroxylation with MoOPH, the ester enolates must first be generated. It is known that both the (*Z*)- and (*E*)-isomers of the enolates are accessible by changing the conditions of deprotonation, *i.e.* by the use of lithium isopropylcyclohexylamide ( = LICA) and LICA/HMPT ( = hexamethylphosphoric triamide) as base in THF, respectively *(Scheme 1)*.

*Scheme 1*



*Scheme 2*



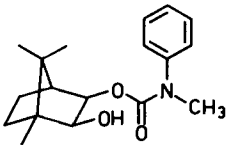

For steric reasons, the reagent attacks the enolates from the less hindered side of the enolate, *i.e.* the *Re-face* in the case of the (*Z*)-enolates and the *Si*-face in the case of the (*E*)-enolates leading to the (2*R*)- and (2*S*)-hydroxy-esters, respectively *(Scheme 2)*.

Best results were obtained with the esters of the alcohols **1** and **2**. As shown in *Table 1*, remarkable dependence of the (*R*)/(*S*)-ratio from the base used was noted for the esters of these alcohols with 3-phenylpropionic acid. To improve the diastereoselectivity of the hydroxylation and to avoid the toxic HMPT, reaction time, temperature, and base were varied.

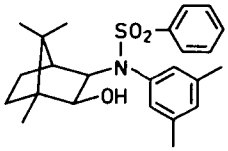
Table 1. *Hydroxylation of Esters of 3-Phenylpropionic Acid with MoOPH Complex*

| *Exper.* | Alcohol used for esterification | Base used for deprotonation | Reaction time | Temp. | (*R*)/(*S*)-Ratio[a]) | Yield[b]) [%] |
|---|---|---|---|---|---|---|
| *1* | **2** | 1.2 equiv. $Li(i\text{-}Pr)_2N$ | 5 h | −78° | 43:57 | 23 |
| *2* | **2** | 1 equiv. LICA | 3 h | −78° | 60:40 | 29 |
| *3* | **1** | 2 equiv. LICA | 2 h | −78° | 20:80 | 80 |
| *4* | **2** | 2 equiv. LICA | 8 h | −78° | 33:67 | 65 |
| *5* | **1** | 2 equiv. LICA after deprotonation +20% HMPT | 2 h | −52° | 43:57 | 57 |
| *6* | **2** | 2 equiv. LICA after deprotonation +20% HMPT | 1 h | −52° | 82:18 | 60 (55)[c]) |
| *7* | **2** | 2 equiv. $Li(i\text{-}Pr)_2N$ after deprotonation +20% DMPU | 1 h | −52° | 28:72 | 35 |
| *8* | **1** | 2 equiv. LICA/HMPT | 2 h | −52° | 14:86 | 50 |
| *9* | **2** | 2 equiv. LICA/HMPT | 2 h | −52° | 7:93 | 50 (40)[c]) |
| *10* | **2** | 2 equiv. LHMDS | 53 h | −52° | 9:91 | 30 |
| *11* | **2** | 1 equiv. KHMDS | 50 min | −78° | 23:77 | 20 |
| *12* | **2** | 2 equiv. KHMDS | 1 h | −78° | 68:32 | 80 |
| *13* | **2** | 3 equiv. KHMDS | 45 min | −62° to −52° | 57:43 | 62 |
| *14* | **2** | 10 equiv. KHMDS | 30 min | −78° | 41:59 | 40 |

[a]) Determination of the absolute configuration by hydrolysis to 2-hydroxy-3-phenylpropionic acid.
[b]) Total of both diastereoisomers determined by HPLC analysis.
[c]) Isolated yield of the major diastereoisomer.



1



2

The hydroxylation of the (*Z*)-enolate derived from the alcohol **1** *(Exper. 3)* did not lead to the expected (2*R*)-, but to the (2*S*)-diastereoisomer in excess. Relatively low diastereoselection was observed during hydroxylation of the (*Z*)-enolate derived from the alcohol **2** *(Exper. 1, 2,* and *4)*. This fact demonstrated that 2 equiv. of the base are required for obtaining a good chemical yield. If 20% HMPT was added after deprotonation of the ester of alcohol **2**, the (2*R*)-isomer was accessible in a ratio of 82:18 with the (2*S*)-isomer *(Exper. 6)*. The same trend was observed in the case of the ester derived from alcohol **1** *(Exper. 5)*. The replacement of HMPT by DMPU (1,3-dimethyl-3,4,5,6-tetrahydro-2(1*H*)-pyrimidinone) did not lead to any improvement; diastereoselection and yield were rather lower. In contrast to the results of the (*Z*)-ester enolates, the hydroxylations of the (*E*)-ester enolates from **1** and **2** showed a very high diastereoselection with a (*R*)/(*S*)-ratio of 14:86 and 7:93, respectively *(Exper. 8* and *9)*.

A dramatic change of diastereoselection was observed using LHMDS ( = lithium hexamethyldisilazide) [9] as base *(Exper. 10)*. Unfortunately, the reaction was too slow to be of any synthetic value. After 53 h, the reaction was quenched by addition of 2N HCl. *Exper. 11–14* demonstrate that no selectivity was observed using simply the stronger base KHMDS ( = potassium hexamethyldisilazide). The ratio of the two diastereoisomers depends also on the amount of KHMDS used.

Despite these results, KHMDS was chosen as base to demonstrate the possible influence of a chiral alkoxide *(Table 2)*. The addition of 1 equiv. of the potassium alkoxide of **2** *(Exper. 1)* caused a change of diastereoselection from 2:1 to 1:2. More interesting was the fact that the chirality of potassium menthoxide *(Exper. 2* and *3)* exerted little or no influence, since both enantiomers of potassium menthoxide showed *ca.* the same ratio of the two diastereoisomeric hydroxy-esters.

Table 2. *Diastereoselective Hydroxylation of 3-Phenylpropionate of* **2** *with MoOPH Complex Using 2 equiv. KHMDS as Base and Different Alkoxides*

| *Exper.* | Alkoxides[d]) | Reaction time | Temp. | (*R*)/(*S*)-Ratio[a]) | Yield[b]) [%] |
|---|---|---|---|---|---|
| *1* | 1 equiv. KOR[e]) | 90 min | −78° | 32:68 | 72 |
| *2* | 1 equiv. (+)-Potassium menthoxide | 30 min | −52° | 13:87 | 76 |
| *3* | 1 equiv. (−)-Potassium menthoxide | 40 min | −52° | 18:82 | 81 |
| *4* | 1 equiv. K(*sec*-BuO) | 45 min | −52° | 5:95 | 71 (64)[c]) |
| *5* | 1 equiv. KOR[f]) | 20 min–2 h | −52° | 5:95 | 64–90 |
| *6* | 2 equiv. K(*sec*-BuO) | 75 min | −52° | 4:96 | 51 |
| *7* | 3 equiv. K(*sec*-BuO) | 2 h 20 min | −52° to −46° | 1:99 | 71 (66)[c]) |
| *8* | 8 equiv. K(*sec*-BuO) | 40 min | −52° to −46° | 1:99 | 80 (73)[c]) |

[a])–[c]) See *Table 1.*

[d]) The alkoxide was prepared by adding *x* equiv. of the alcohol to *x* + 2 equiv. of KHMDS.

[e]) $R^1OH$ = **2**.

[f]) $R^2$ = Et, i-Pr, Bu, *t*-Bu.

These results gave rise to an experiment in which 1 equiv. of K(*sec*-BuO) *(Exper. 4)* was added during deprotonation. The ratio of 5:95 as well as the isolated yield of 64% were very promising. By using KHMDS as base and K(*sec*-BuO), we even could attain a better yield and diastereoselection than by using LICA/HMPT as base [1].

The observation that the diastereoselection of the hydroxylation is enhanced by the addition of K(*sec*-BuO) led us to test further alkoxides. *Exper. 5* demonstrated that the 4 different potassium alkoxides used exerted the same effect. By raising the amount of added K(*sec*-BuO), nearly pure (2*S*)-hydroxy-ester was obtained in an isolated yield of 73% *(Exper. 6–8)*. The addition of K(*sec*-BuO) seems to change the environment of the enolate in such a way that the Mo reagent can better distinguish between the two faces of the enolate. The effect of K(*sec*-BuO) requires the presence of both the shielding group and the base KHMDS, since after replacement of KHMDS by LICA in *Exper. 4* of *Table 2*, only a (*R*)/(*S*)-ratio of 29:71 was found. This ratio is nearly the same as observed in the experiment with LICA without the addition of an alkoxide *(cf. Exper. 4, Table 1)*. Furthermore, the replacement of the shielding sulfonamide group by a neopentyl ether (*t*-BuCH$_2$O) showed absolutely no effect on the diastereoselectivity of the reaction after addition of 1 equiv. of K(*sec*-BuO)[1]).

In the course of these investigations, *Davis et al.* [10] reported that chiral lactones could be hydroxylated by 3-phenyl-2-(phenylsulfonyl)oxaziridine with a higher diastereoselectivity than by MoOPH. In contrast to the observations of *Davis et al.*, but in agreement with the results reported by *Evans et al.* [6] we found MoOPH to be more stereoselective. Using LICA as base, we obtained a (*R*)/(*S*)-ratio of approximately 89:11. Side reactions, however, prevented the isolation of the product and the determination of the exact ratio[2]). After replacement of LICA by KHMDS, neither diastereoselection nor side reactions were observed at −78° ((*R*)/(*S*)-ratio 45:55).

The final problem, the removal of the chiral auxiliary group, was solved in a satisfactory manner. By treatment of the α-hydroxy-esters with KOH in MeOH/H$_2$O at 20° the α-hydroxy-acid was obtained without any notable racemization.

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## Experimental Part

*General.* THF was dried by distilling over LiAlH$_4$. The org. extracts were dried over Na$_2$SO$_4$ and evaporated under reduced pressure below 50°. The m.p. are corrected. HPLC: *LiChrospher* column *Si100* 5 μm *(Merck)* using AcOEt/pentane 15:85. TLC: silica gel *60 $F_{254}$ (Merck)*; detection with 10% $H_2SO_4$ soln. in MeOH or $KMnO_4$ soln. $[\alpha]_D$: *Perkin-Elmer* model *141* polarimeter. IR: *Perkin-Elmer* model *177* grating spectrometer. NMR: *Varian EM 360* spectrometer ($^1$H, 60 MHz), *Bruker WH-90* spectrometer with *Fourier* transform ($^1$H, 90 MHz; $^{13}$C, 22.63 MHz); the assignments of the resonances marked with an asterix are not certain. MS: *VG-70-250* instrument.

*(1′R)-3′*-exo-*(N-Methyl-N-phenylcarbamoyloxy)-2′*-exo-*bornyl 3-Phenylpropionate* (**3**). A soln. of 3.8 g (12.5 mmol) of **1** and 4.2 g (25 mmol) of 3-phenylpropionyl chloride [2c] in 36 ml of $CCl_4$ was kept for 8 h at 80°. After removal of the solvent and purification by column chromatography (AcOEt/pentane 15:85), 4.7 g (87%) of **3** was obtained as an oil. Spectra: [2c].

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[1]) These results indicate that a potassium (*Z*)-enolate derived from **2** could be selectively oxidized to the (2*R*)-isomer after addition of K(*sec*-BuO). Attempts with K(i-Pr)$_2$N/Li(*t*-BuO) failed. We obtained predominantly the (2*S*)-isomer in poor yield.

[2]) The side reaction(s) could be an aldol reaction of the sulfonylimine with the ester enolate [6].

*(1'R)-3'*-exo-*(*N*-Methyl-*N*-phenylcarbamoyloxy)-2'*-exo-*bornyl 2-Hydroxy-3-phenylpropionate* (**4**). *General Procedure for the Hydroxylation of* **3**. A soln. of LICA (2 mmol) was prepared by adding 1.3 ml of 1.5M BuLi (hexane) to 0.37 ml of *N*-isopropylcyclohexylamine in 3 ml of THF at 0°. After stirring for 5 min, the LICA soln. was cooled to −78°. In cases, in which **3** was deprotonated in the presence of HMPT, 2 ml of HMPT were added. A soln. of 436 mg (1 mmol) of **3** in 5 ml of THF was added within 3 min. After 35 min, the enolate was warmed up to the desired temp. In cases, in which HMPT was added after the ester deprotonation, the mixture was diluted with 2 ml of HMPT. After 2–3 min, 651 mg (1.5 mmol) MoOPH were added to the soln. within a few seconds. The reaction was quenched in 8 ml of 2N HCl and 10 ml of $Et_2O$ by shaking at r.t. after having analyzed some samples by HPLC (AcOEt/pentane 1:9). The org. layer was diluted with 15 ml of $Et_2O$, washed twice with 20 ml of $H_2O$, and dried. After removal of the solvent, the crude product was separated by careful column chromatography (AcOEt/pentane 1:9).

*(2S)-Isomer* **4a**. $^1$H-NMR (60 MHz, $CDCl_3/D_2O$): 0.7, 0.8, 0.9 (3*s*, 3 $CH_3$); 0.7–2.0 (*m*, 5 H of bornyl); 2.3–3.2 (*AB* of *ABX*, 8 signals, 2 H–C(3)); 3.25 (*s*, $CH_3N$); 4.1–4.4 (*X* of *ABX*, 4 signals, H–C(2)); 4.9 (*s*, H–C(2'), H–C(3')); 7.15 (2*s*, 2 Ph).

*(2R)-Isomer* **4b**. $^1$H-NMR (60 MHz, $CDCl_3/D_2O$): 0.7–2.0 (*m*, 14 H of bornyl); 2.6–3.0 (*AB* of *ABX*, 8 signals, 2 H–C(3)); 3.25 (*s*, $CH_3N$); 3.7–4.0 (*X*of *ABX*, 4 signals, H–C(2)); 4.8 (*AB*, *J*(2',3') = 7, H–C(2'), H–C(3')); 7.25 (*s*, 2 Ph).

*(2S)-2-Hydroxy-3-phenylpropionic Acid* (**5a**) *from* **4a**. To a soln. of 190 mg (0.42 mmol) of **4a** in 10 ml of MeOH, 1.1 g KOH in 10 ml MeOH/$H_2O$ 1:1 were added. After 5 h, the MeOH was removed and 10 ml of $H_2O$ were added. The $H_2O$ layer was extracted twice with 25 ml of $Et_2O$. They contained 70 ml of bornane-2,3-diol. The $H_2O$ phase was acidified with conc. HCl and removed under reduced pressure. The residue was washed 3 times with 15 ml of $Et_2O$ and the $Et_2O$ soln. dried. After removal of the solvent, 57 mg (81%) of **5a** were obtained. $[\alpha]_D^{20} = -29.8°$ (acetone, *c* = 1.1; [11]: −28.1° (acetone, *c* = 1.1)). $^1$H-NMR (60 MHz, ($D_6$)acetone): 2.7–3.4 (*AB* of *ABX*, 8 signals, 2 H–C(3)); 4.3–4.6 (*X* of *ABX*, 4 signals, H–C(2)); 7.3 (*s*, 5 Ph).

*(2R)-2-Hydroxy-3-phenylpropionic Acid* (**5b**) *from* **4b**. A soln. of 79 mg (0.17 mmol) **4b** in MeOH was treated as described for **4a**. After workup, 29 mg of bornane-2,3-diol and 26 mg of **5b** (93%) were obtained. $[\alpha]_D^{20} = +27.1°$ (acetone, *c* = 1.1) $^1$H-NMR: *cf.* **5a**.

*(1'R)-3'*-exo-*[*N*-Benzenesulfonyl-*N*-(3,5-dimethylphenyl)amino]-2'*-exo-*bornyl 3-Phenylpropionate* (**6**). *A*) A soln. of 6 g (14.5 mmol) of **2** and 2.7 g (16 mmol) of 3-phenylpropionyl chloride [2c] in 20 ml of $CCl_4$ was kept for 5 h at 80°. After removal of the solvent and purification of the residue by column chromatography (AcOEt/pentane 10:90) 3.9 g (50%) of **6** were obtained. IR($CCl_4$): u.a. 2980, 2865, 1745, 1360, 1170, 1070, 910, 705, 600. $^1$H-NMR (60 MHz, $CDCl_3$): 0.5–1.8 (*m*, 5 H of bornyl); 0.55, 0.7, 0.8 (3*s*, 3 $CH_3$); 1.9–2.3 (br. *s*, $(CH_3)_2$Ph); 2.5–3.2 ($A_2B_2$, 2 H–C(2), 2 H–C(3)); 3.75 (*d*, *J*(2',3') = 7, H–C(3')); 5.15 (*d*, *J*(2',3') = 7, H–C(2')); 5.8–7.5 (*m*, 3 H, $(CH_3)_2$*Ph*); 7,15 (*s*, 5 H, Ph); 7.25 (*s*, 5 H, Ph). $^{13}$C-NMR (22.63 MHz, $CDCl_3$): 11.2 (*q*, *I* = 345); 20.8 (*q*, *I* = 256); 21.0 (*q*, *I* = 575); 21.2 (*q*, *I* = 515); 27.7* (*t*, C(5')); 30.9* (*t*, C(3')); 32.2* (*t*, C(6')); 36.1* (*t*, C(2)); 47.3* (*s*, C(1') od. C(7')); 48.7 (*d*, C(4')); 50.1* (*s*, C(7') od. C(1')); 67.5 (*d*, C(3')); 81.1 (*d*, C(2')); 126.0 (*I* = 307, Ar); 128.1 (*I* = 696, Ar); 128.3 (*I* = 2323, Ar); 129.2 (*I* = 477, Ar); 129.6 (*I* = 731, Ar); 132.4 (*I* = 324, Ar); 137.5 (*I* = 829, Ar); 139.2 (*I* = 275, Ar); 141.1 (*I* = 250, Ar); 172.0 (*s*, C(1)). Cl-MS: u.a. 546 (27, $M^+ + 1$), 407 (43), 406 (100), 405 (73), 396 (19), 274 (11), 256 (14).

*B*) A mixture of 2.85 g (12 mmol) of 3-phenyl-*S*-(2'pyridyl)thiopropionate (prepared in 90–95% yield according to [12]), 4.7 g (11.4 mmol) of **2** and 2.7 g (12 mmol) of $CuBr_2$ were stirred in 40 ml of $CH_3CN$ for 3 h at 60°. The mixture was filtered through cotton wool and washed with 50 ml of $CH_2Cl_2$. The green mixture was diluted with 300 ml of $CH_2Cl_2/H_2O$ 1:2. The org. layer was washed with 100 ml of $H_2O$ and dried. After evaporation, the residue was filtered through 30 g of silica gel. The crude product yielded, after purification by column chromatography (AcOEt/pentane 1:9), 5.3 g (85%) of **6**.

*(1'R)-3'-exo-[*N*-Benzenesulfonyl-N-(3,5-dimethylphenyl)amino]-2'*-exo-*bornyl 2-Hydroxy-3-phenylpropionate* (**7**). *A*) *General Procedure for the Experiments of* Table 1. A soln. of 1 mmol of Li(i-Pr)$_2$N was prepared by adding 0.77 ml of 1.3M BuLi (hexane) to 0.14 ml of (i-Pr)$_2$NH in 3 ml of THF at 0°. After stirring for 5 min, the Li(i-Pr)$_2$N soln. was cooled to −78°. (KHMDS was prepared according to [13] in THF, and the 1.8M soln. was stored at 0°.) In cases, in which **6** was deprotonated in the presence of HMPT, 2 ml of HMPT were added. The soln. of 273 mg (0.5 mmol) of **6** in 5 ml of THF were added during 3 min. After 35 min, the enolate was warmed up to the desired temp. In cases, in which HMPT was added after ester deprotonation the mixture was diluted with 2 ml of HMPT. After 2–3 min, 330 mg (0.75 mmol) of MoOPH were added to the soln. within a few seconds. The reaction was quenched in 8 ml of 2N HCl and 10 ml of $Et_2O$ by shaking at r.t. after having analyzed some samples by HPLC (AcOEt/pentane 1:9). The org. layer was diluted with another 15 ml of $Et_2O$, washed twice with 20 ml of $H_2O$, and

dried. After removal of the solvent, the crude product was separated by careful column chromatography (AcOEt/pentane 1:9).

*(2S)-Isomer* **7a**. IR (KBr): u.a. 3500, 2960, 2935, 1740, 1450, 1350, 1170, 1090, 720, 705, 605. $^1$H-NMR (90 MHz, $CDCl_3/D_2O$): 0.6, 0.8, 0.95 (3*s*, 3 $CH_3$); 0.5–2.4 (*m*, 5 H of bornyl); 2.1 (br. *s*, $(CH_3)_2Ph$); 3.0–3.6 (*AB* of *ABX*, 8 signals, 2 H–C (3)); 3.95 (*d*, $J(2',3') = 5$, H–C (3')); 4.6–4.75 (*X* of *ABX*, 4 signals, H–C (2)); 5.3 (*d*, $J(2',3') = 5$, H–C (2')); 5.6–5.85 (*m*, 1 H, $(CH_3)_2Ph$); 6.8 (*s*, 1H, $(CH_3)_2Ph$); 6.8–7.6 (*m*, 11 H, $(CH_3)_2Ph$, Ph). $^{13}$C-NMR (22.63 MHz, $CDCl_3$): 11.2 (*q*, $I = 111$); 20.7 (*q*, $I = 99$); 21.0 (*q*, $I = 194$); 21.3 (*q*, $I = 86$); 27.7* (*t*, C(5')); 32.2* (*t*, C(6')); 40.3* (*t*, C(3)); 47.3 (*s*, C(1') or C(7')); 48.7 (*d*, C(4')); 50.5* (*s*, C(7') or C(1')); 67.8 (*d*, C(3')); 72.5 (*d*, C(2)); 82.6 (*d*, C(2')); 126.3 ($I = 106$, Ar); 128.2 ($I = 717$, Ar); 129.5 ($I = 179$, Ar); 129.7 ($I = 249$, Ar); 132.6 ($I = 98$, Ar); 137.2 ($I = 69$), Ar); 137.7 ($I = 113$, Ar); 138.3 ($I = 73$, Ar); 138.4 ($I = 79$, Ar); 173.1 (*s*, C(1)). CI-MS: u.a. 562 (12, $M^+ + 1$), 422 (39), 421 (71), 397 (11), 396 (38), 300 (22), 257 (19), 256 (100), 255 (75), 254 (17), 122 (15).

*(2R)-Isomer* **7b**. Mp. 132–133.5°, after recrystallization from hexane. IR(KBr): u.a. 3520, 2960, 2930, 1740, 1450, 1350, 1170, 1090, 720, 705, 605. $^1$H-NMR (90 MHz, $CDCl_3$ $D_2O$): 0.65, 0.8, 1.0 (3*s*, 3 $CH_3$); 0.7–2.5 (*m*, 5 H of bornyl, $(CH_3)_2Ph$); 2.85–3.6 (*AB* von *ABX*, 8 signals, 2 H–C (3)); 3.95 (*d*, $J(2',3') = 5$, H–C(3')); 4.65–4.8 (*X* of *ABX*, 4 signals, H–C(2)); 5.25 (*d*, $J(2',3') = 5$, H–C(2')); 5.6–5.9 (*m*, 1 H, $(CH_3)_2Ph$); 6.8 (*s*, 1 H, $(CH_3)_2Ph$); 6.8–7.7 (m, 11 H, $(CH_3)_2Ph$, Ph). $^{13}$C-NMR (22.63 MHz, $CDCl_3$): 11.3 (*q*, $I = 185$); 20.8 (*q*, $I = 187$); 21.1 (*q*, $I = 340$); 21.4 (*q*, $I = 177$); 27.7* (*t*, C(5')); 32.3* (*t*, C(6')); 40.2 (*t*, C(3)); 47.5* (*s*); 48.7 (*d*, C(4')); 50.4* (*s*); 67.7 (*d*, C(3')); 72.2 (*d*, C(2)); 82.9 (*d*, C(2')); 126.5 ($I = 183$, Ar); 128.2 ($I = 1461$, Ar); 128.4 ($I = 508$, Ar); 129.5 ($I = 618$, Ar); 129.7 ($I = 146$, Ar); 130.0 ($I = 106$, Ar); 132.6 ($I = 180$, Ar); 137.4 ($I = 144$, Ar); 137.7 ($I = 231$, Ar); 138.2 ($I = 134$, Ar); 138.8 ($I = 139$, Ar); 173.9 (*s*, C(1)). CI-MS: u.a. 562 (11, $M^+ + 1$), 423 (12), 422 (51), 421 (74), 405 (19), 404 (46), 397 (17), 396 (60), 301 (11), 300 (29), 274 (13), 273 (18), 272 (16), 257 (19), 256 (100), 255 (89), 254 (19), 135 (18), 122 (12).

*B) General Procedure for the Experiments of* Table 2 *(e.g. Exper.8)*. To a soln. of 2.8 ml (5 mmol) of 1.8M KHMDS in 3 ml of THF at −78°, 273 mg (0.5 mmol) of **6** in 5 ml THF were added during 2 min. Immediately afterwards, 296 mg (4 mmol) of *sec*-BuOH in 2ml of THF were followed. After 35 min, the enolate was allowed to warm up to the desired temp. (usually −52°), and 330 mg (0.75 mmol) of MoOPH were added within a few seconds. The mixture was treated as described for *Procedure A*.

*(2S)-2-Hydroxy-3-phenylpropionic Acid* (**5a**) *from* **7a**. To a soln. of 119 mg (0.21 mmol) of **7a** in 7 ml of MeOH, 1 g of KOH in 5 ml of $MeOH/H_2O$ 1:1 was added. After 7 h, MeOH was removed and 10 ml of $H_2O$ were added. The aq. layer was extracted twice with 25 ml of $Et_2O$. The $Et_2O$ extracts yielded 80 mg of **2** (92%). The $H_2O$ soln. was acidified with conc. HCl and evaporated under reduced pressure. The residue was washed 3 times with 10 ml of $Et_2O$. The $Et_2O$ was dried and after removal of the solvent 25 mg (74%) of **5a** were obtained. $[\alpha]_D^{20} = -28.3°$ (acetone, $c = 0.6$).

*(2R)-2-Hydroxy-3-phenylpropionic Acid* (**5b**) *from* **7b**. To a soln. of 100 mg (0.178 mmol) of **7b** in 7 ml of MeOH, 1 g of KOH in 5 ml of $MeOH/H_2O$ 1:1 were added. After 9 h, the mixture was treated as described for **7a**. After workup 71 mg of **2** (97%) and 24 mg (83%) of **5b** were obtained. $[\alpha]_D^{20} = +27.1°$ (acetone, $c = 0.7$).

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