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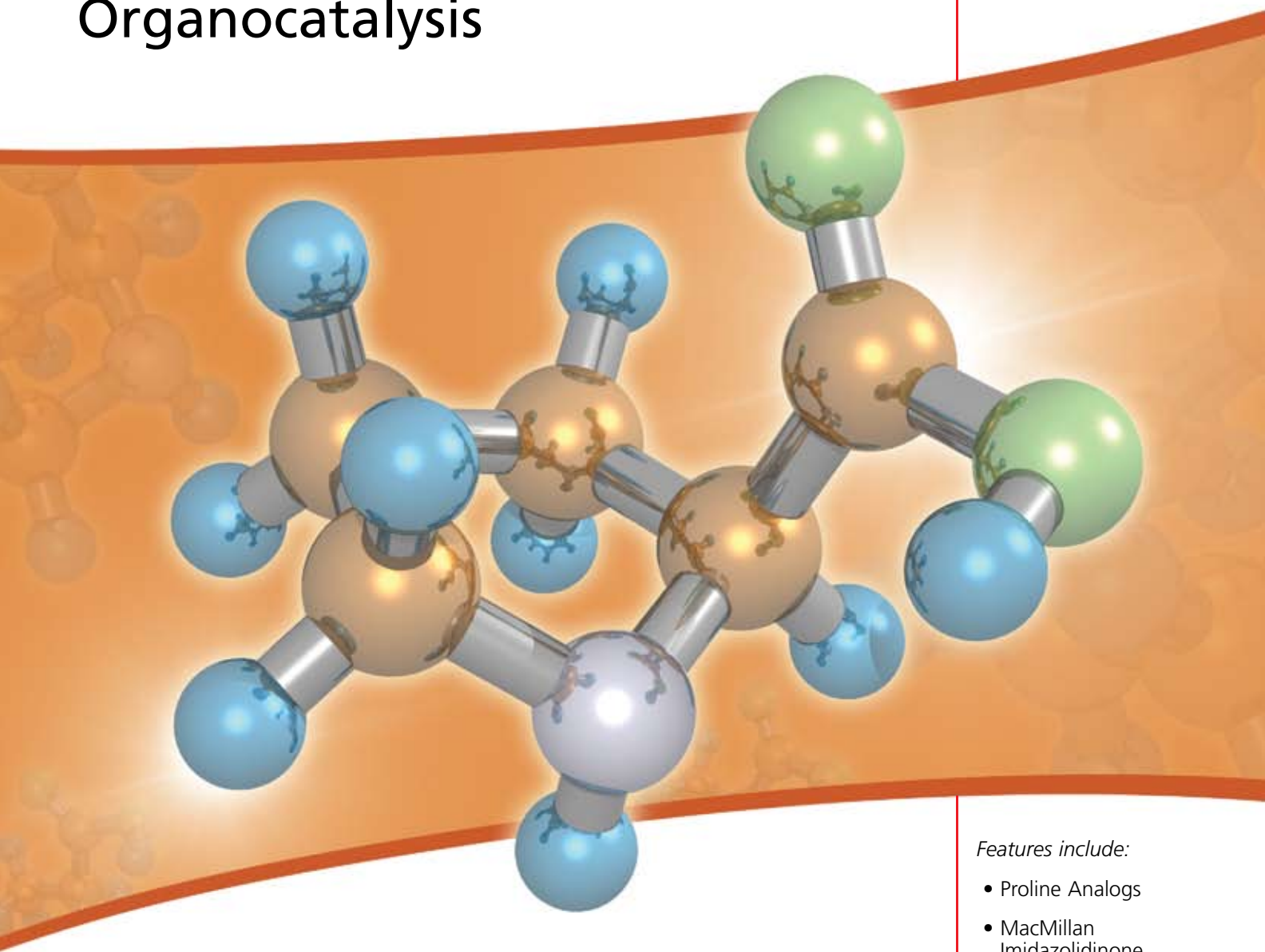
Vol. 7, No. 9

ALDRICH Chemistry

Organocatalysis



L-Proline, the archetype of modern asymmetric organocatalysts

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- MacMillan Imidazolidinone OrganoCatalysts™
- Chiral Phosphoric Acids
- Jacobsen Thioureas
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Introduction

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About Our Cover

The cover illustration depicts the proteinogenic amino acid L-proline. Labeled by Jacobsen as the "simplest enzyme", L-proline is capable of effecting a variety of organocatalytic asymmetric transformations.

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Proline Analogs

The first examples were reported in the mid-70s, when L-proline was applied to Robinson annulation reactions. However, the big potential of proline as an organocatalyst was discovered at the beginning of the 21st century.

The bifunctional structure of the sole cyclic proteinogenic amino acid is a crucial factor. L-proline contains both a nucleophilic secondary amino group and a carboxylic acid moiety functioning as a Brønsted acid. This facilitates a highly pre-organized transition state during the reaction pathway, which results in exceptionally high enantioselectivities.

As a small organic molecule, proline is available in both enantiomeric forms, which is a definite advantage over enzymatic methods. Numerous proline-catalyzed reactions have been developed (**Scheme 1**).[1]

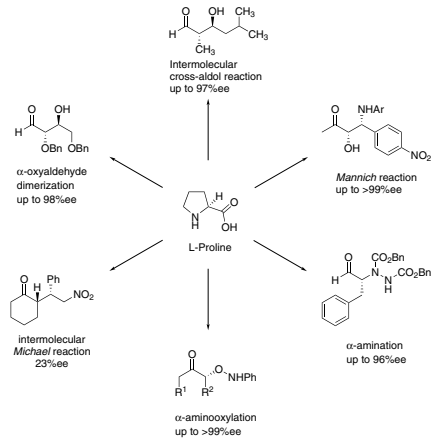
Stimulated by such a vast number of successful examples, many research groups have developed synthetic proline analogs with optimized properties. Some examples are presented here in more detail.

The catalytic asymmetric α-alkylation of aldehydes was described by List.[2] This transformation had been accomplished with the help of covalently attached auxiliaries. In comparison to L-proline, α-methyl-L-proline (**17249**) gives higher enantioselectivities and improved reaction rates (**Scheme 2**).

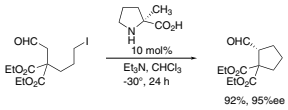
Organocatalytic cyclopropanation reactions were typically performed using catalyst-bound ylides. However, MacMillan demonstrated that activation of olefin substrates using catalytic (*S*)-(–)-indoline-2-carboxylic acid (**346802**) is a viable route for the formation of highly enantioenriched cyclopropanes (**Scheme 3**).[3]

Prof. Karl Anker Jørgensen and his group have developed (*R*)- and (*S*)-α,α-bis[3,5-bis(trifluoromethyl)phenyl]-2-pyrrolidinemethanol trimethylsilyl ether (**677019** and **677213** resp.), which serve as excellent chiral organocatalysts in the direct organocatalytic α-functionalization of aldehydes. In the field of asymmetric synthesis this stereoselective functionalization certainly represents an important breakthrough. Jørgensen's diarylprolinol silylether reagents were shown to catalyze a variety of bond-forming reactions such as C–C, C–N, C–O, C–S, and C–Hal in high yields and excellent levels of enantiocontrol (**Scheme 4**).[4]

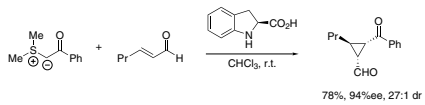
Enders and co-workers have developed a chemo-, diastereo-, and enantioselective three-component domino reaction, accomplished with proline-derived organocatalyst **677183** and low cost, simple starting materials, leading to tetra-substituted cyclohexene carbaldehydes (**Scheme 5**).[5] The four stereogenic centers are generated in three consecutive carbon–carbon bond formations, i.e., Michael/Michael/aldol condensation with high diastereo- and complete enantiocontrol. Thus, this domino reaction opens up a simple and flexible entry to polyfunctional cyclohexene building blocks.



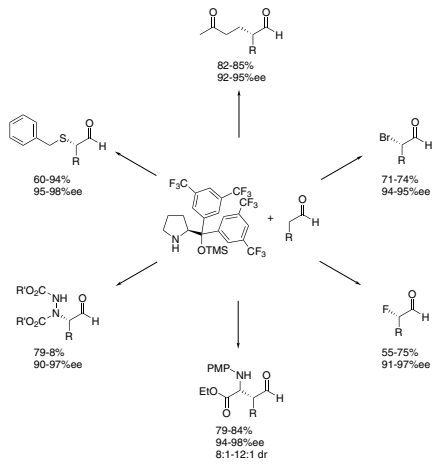
Scheme 1



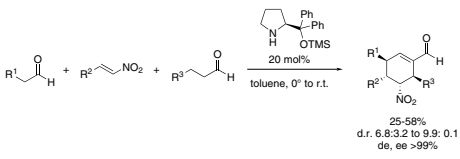
Scheme 2



Scheme 3



Scheme 4



Scheme 5

References: (1) (a) Mannich reaction: List, B.; Pojarliev, P.; Biller, W. T.; Martin, H. J. *J. Am. Chem. Soc.* **2002**, *124*, 827. (b) α-Amination: List, B. *J. Am. Chem. Soc.* **2002**, *124*, 5656. (c) α-Aminoxylation: Zhong, G. *Angew. Chem. Int. Ed.* **2003,** 42, 4247. Brown, S. P.; Brochu, M. P.; Sinz, C. J.; MacMillan, D. W. C. *J. Am. Chem. Soc.* **2003**, *125*, 10808; Bøgevig, A.; Sunden, H.; Córdova. A. *Angew. Chem. Int. Ed.* **2004**, *43*, 1109. (d) Michael addition: List, B.; Pojarliev, P.; Martin, H. J. *Org. Lett.* **2001**, *3*, 2423. (e) α-Oxyaldehyde dimerization: Northrup, A. B.; Mangion, I. K.; Hettche, F.; MacMillan, D. W. C. *Angew. Chem. Int. Ed.* **2004**, *43*, 2152. (f) Cross-aldol reaction: Northrup, A. B.; MacMillan, D. W. C. *J. Am. Chem. Soc.* **2002**, *124*, 6798. (2) Vignola, N.; List, B. *J. Am. Chem. Soc.* **2003**, *125*, 450. (3) Kunz, R. K.; MacMillan, D. W. C. *J. Am. Chem. Soc.* **2005**, *127*, 3240. (4) (a) Franzén, J.; Marigo, M.; Fielenbach, D.; Wabnitz, T. C.; Kjærsgaard, A.; Jørgensen, K. A. *J. Am. Chem. Soc.* **2005**, *127*, 18296. (b) Bøgevig, A.; Juhl, K.; Kumaragurubaran, N.; Zhuang, W.; Jørgensen, K. A. *Angew. Chem. Int. Ed.* **2002**, *41*, 1790. (c) Marigo, M.; Jørgensen, K. A. α-Heteroatom Functionalization. In *Enantioselective Organocatalysis*; Dalko, P. I., Ed.; Wiley-VCH: Weinheim, 2007; Chapter 2.2. (d) Marigo, M.; Schulte, T.; Franzén, J.; Jørgensen, K. A. *J. Am. Chem. Soc.* **2005**, *127*, 15710. (e) Marigo, M.; Franzén, J.; Poulsen, T. B.; Zhuang, W.; Jørgensen, K. A. *J. Am. Chem. Soc.* **2005**, *127*, 6964. (f) Carlone, A.; Bartoli, G.; Bosco, M.; Sambri, L.; Melchiorre, P. *Angew. Chem. Int. Ed.* **2007**, *46*, 4504. (g) Ibrahem, I.; Rios, R.; Vesely, J.; Hammar, P.; Eriksson, L.; Himo, F.; Córdova, A. *Angew. Chem. Int. Ed.* **2007**, *46*, 4507. (5) Enders, D.; Hüttl, M. R. M.; Grondal, C.; Raabe, G. *Science* **2006**, *441*, 861.

L-Proline, ≥99% (TLC)

$C_5H_9NO_2$
FW 115.13
[147-85-3]

P0380-10MG	10 mg
P0380-100G	100 g
P0380-1KG	1 kg
P0380-5KG	5 kg

D-Proline, ≥99%

$C_5H_9NO_2$
FW 115.13
[344-25-2]

858919-500MG	500 mg
858919-5G	5 g

α-Methyl-L-proline, ≥98.0% (TLC)

$C_6H_{11}NO_2$
FW 129.16
[42856-71-3]

17249-250MG	250 mg
17249-1G	1 g

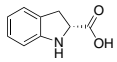
3,4-Dehydro-L-proline, ≥99.0% (TLC)

$C_5H_7NO_2$
FW 113.11
[4043-88-3]

30890-10MG	10 mg
30890-50MG	50 mg

(*R*)-(+)-Indoline-2-carboxylic acid, ≥97.0% (T)

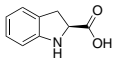
$C_9H_9NO_2$
FW 163.17
[98167-06-7]



51266-500MG-F	500 mg

(*S*)-(–)-Indoline-2-carboxylic acid, 99%

$C_9H_9NO_2$
FW 163.17
[79815-20-6]



346802-1G	1 g
346802-5G	5 g

L-Azetidine-2-carboxylic acid, ≥98.0% (NT)

$C_4H_7NO_2$
FW 101.10
[2133-34-8]

11542-500MG	500 mg
11542-2.5G	2.5 g

L-Pipecolic acid, 99%

$C_6H_{11}NO_2$
FW 129.16
[3105-95-1]

237752-25MG	25 mg
237752-100MG	100 mg

D-Pipecolinic acid, 99%

$C_6H_{11}NO_2$
FW 129.16
[1723-00-8]

268062-25MG	25 mg
268062-100MG	100 mg

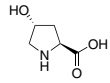
trans-3-Hydroxy-L-proline, ≥98.0% (NT)

$C_5H_9NO_3$
FW 131.13
[4298-08-2]

56244	

trans-4-Hydroxy-L-proline, ≥99%

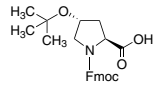
$C_5H_9NO_3$
FW 131.13
[51-35-4]



H54409-2.5G	2.5 g
H54409-10G	10 g
H54409-25G	25 g
H54409-100G	100 g

Fmoc-Hyp(tBu)-OH, ≥98.0% (HPLC)

$C_{24}H_{27}NO_5$
FW 409.47
[122996-47-8]



47517-5G-F	5 g

L-4-Thiazolidinecarboxylic acid, 98%

$C_4H_7NO_2S$
FW 133.17
[34592-47-7]

T27502-10G	10 g
T27502-100G	100 g

L-Prolinamide, 98%

$C_5H_{10}N_2O$
FW 114.15
[7531-52-4]

287059-250MG	250 mg
287059-1G	1 g

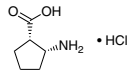
(*S*)-5-(–)-(2-Pyrrolidinyl)-1*H*-tetrazole NEW

$C_5H_9N_5$
FW 139.16
[33878-70-5]

684341-100MG	100 mg
684341-500MG	500 mg

cis-2-Amino-1-cyclopentanecarboxylic acid hydrochloride, ≥95.0% (AT)

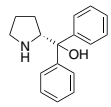
$C_6H_{11}NO_2 \cdot HCl$
FW 165.62
[18414-30-7]



30249-1G-F	1 g

(*R*)-(+)-α,α-Diphenyl-2-pyrrolidinemethanol, 98%

$C_{17}H_{19}NO$
FW 253.34
[22348-32-9]



382337-100MG	100 mg
382337-1G	1 g
382337-5G	5 g

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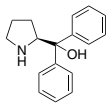
(*S*)-(–)-α,α-Diphenyl-2-pyrrolidinemethanol, 99%

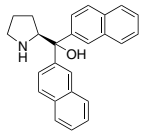
$C_{17}H_{19}NO$
FW 253.34
[112068-01-6]



368199-1G	1 g
368199-5G	5 g

(*S*)-(–)-α,α-Di(2-naphthyl)-2-pyrrolidinemethanol, 99%

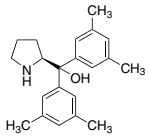
$C_{25}H_{23}NO$
FW 353.46
[127986-84-9]



445398-1G	1 g

(*S*)-α,α-Bis(3,5-dimethylphenyl)-2-pyrrolidinemethanol, ≥99% (HPLC) NEW

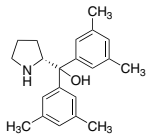
$C_{21}H_{27}NO$
FW 309.45
[131180-63-7]



670731-500MG	500 mg

(*R*)-α,α-Bis(3,5-dimethylphenyl)-2-pyrrolidinemethanol, ≥99% (HPLC) NEW

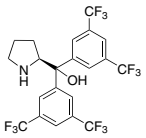
$C_{21}H_{27}NO$
FW 309.45
[948595-01-5]



670847-500MG	500 mg

(*S*)-α,α-Bis[3,5-bis(trifluoromethyl)phenyl]-2-pyrrolidinemethanol NEW

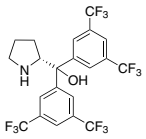
$C_{21}H_{15}F_{12}NO$
FW 525.33
[848821-76-1]



670960-1G	1 g

(*R*)-α,α-Bis[3,5-bis(trifluoromethyl)phenyl]-2-pyrrolidinemethanol NEW

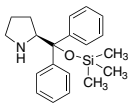
$C_{21}H_{15}F_{12}NO$
FW 525.33



671746-1G	1 g

(*S*)-(–)-α,α-Diphenyl-2-pyrrolidinemethanol trimethylsilyl ether, 95% NEW

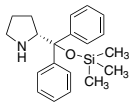
$C_{20}H_{27}NOSi$
FW 325.52
[848821-58-9]



677183-1G	1 g
677183-5G	5 g

(*R*)-(+)-α,α-Diphenyl-2-pyrrolidinemethanol trimethylsilyl ether, 96% NEW

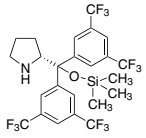
$C_{20}H_{27}NOSi$
FW 456.40



677191-1G	1 g
677191-5G	5 g

(*R*)-α,α-Bis[3,5-bis(trifluoromethyl)phenyl]-2-pyrrolidinemethanol trimethylsilyl ether, ≥97.0% NEW

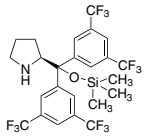
$C_{24}H_{23}F_{12}NOSi$
FW 597.51



677213-1G	1 g
677213-5G	5 g

(*S*)-α,α-Bis[3,5-bis(trifluoromethyl)phenyl]-2-pyrrolidinemethanol trimethylsilyl ether, ≥97.0% NEW

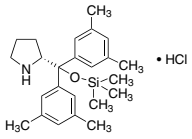
$C_{24}H_{23}F_{12}NOSi$
FW 597.51
[848821-61-4]



677019-1G	1 g
677019-5G	5 g

(*R*)-α,α-Bis(3,5-dimethylphenyl)-2-pyrrolidinemethanol trimethylsilyl ether hydrochloride NEW

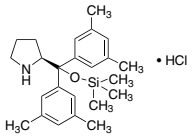
$C_{24}H_{35}NOSi \cdot HCl$
FW 418.09



671304-500MG	500 mg

(*S*)-α,α-Bis(3,5-dimethylphenyl)-2-pyrrolidinemethanol trimethylsilyl ether hydrochloride NEW

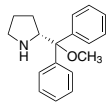
$C_{24}H_{35}NOSi \cdot HCl$
FW 418.09



671428-500MG	500 mg

(*R*)-2-(Methoxydiphenylmethyl)pyrrolidine, 95% (HPLC) NEW

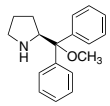
$C_{18}H_{21}NO$
FW 267.37
[948595-05-9]



670308-100MG	100 mg
670308-500MG	500 mg

(*S*)-2-(Methoxydiphenylmethyl)pyrrolidine, 95% (HPLC) NEW

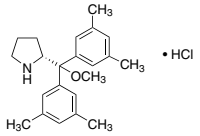
$C_{18}H_{21}NO$
FW 267.37
[118971-03-2]



670197-100MG	100 mg
670197-500MG	500 mg

(*R*)-2-[Bis(3,5-dimethylphenyl)methoxymethyl] pyrrolidine hydrochloride, ≥99.0% (HPLC) NEW

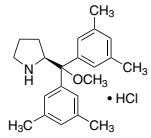
$C_{22}H_{29}NO \cdot HCl$
FW 359.93
[948595-02-6]



670634-500MG	500 mg

(*S*)-2-[Bis(3,5-dimethylphenyl)methoxymethyl] pyrrolidine hydrochloride, ≥99.0% (HPLC) NEW

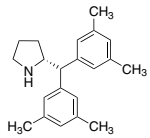
$C_{22}H_{29}NO \cdot HCl$
FW 359.93
[948595-07-1]



669644-500MG	500 mg

(*R*)-2-[Bis(3,5-dimethylphenyl)methyl]pyrrolidine, ≥98.0% (HPLC) NEW

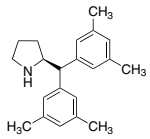
$C_{21}H_{27}N$
FW 293.45
[948595-04-8]



670405-100MG	100 mg
670405-500MG	500 mg

(*S*)-2-[Bis(3,5-dimethylphenyl)methyl]pyrrolidine, ≥98.0% (HPLC) NEW

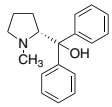
$C_{19}H_{36}N_2O_8$
FW 420.50
[553638-66-7]



669520-100MG	100 mg
669520-500MG	500 mg

α,α-Diphenyl-*N*-methyl-D-prolinol, ≥99% (GC, sum of enantiomers)

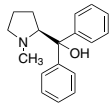
$C_{18}H_{21}NO$
FW 267.37
[144119-12-0]



43118-250MG	250 mg

α,α-Diphenyl-*N*-methyl-L-prolinol, ≥96.0% (GC, sum of enantiomers)

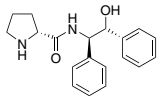
$C_{18}H_{21}NO$
FW 267.37
[110529-22-1]



43119-250MG	250 mg

(2*R*)-*N*-[(1*R*,2*R*)-2-Hydroxy-1,2-diphenylethyl]-2-pyrrolidinecarboxamide, ≥99.0% (HPLC) NEW

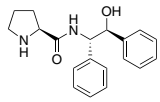
$C_{19}H_{22}N_2O_2$
FW 310.39
[948594-97-6]



671088-100MG	100 mg
671088-500MG	500 mg

(2*S*)-*N*-[(1*S*,2*S*)-2-Hydroxy-1,2-diphenylethyl]-2-pyrrolidinecarboxamide, ≥99% (HPLC) NEW

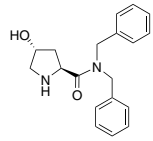
$C_{19}H_{22}N_2O_2$
FW 310.39
[529486-26-8]



671193-100MG	100 mg
671193-500MG	500 mg

(2*S*,4*R*)-4-Hydroxypyrrolidine-2-carboxylic acid dibenzyl amide, 99% (HPLC) NEW

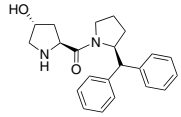
$C_{19}H_{22}N_2O_2$
FW 310.39
[915205-76-4]



671290-100MG	100 mg
671290-500MG	500 mg

((*S*)-2-Benzhydrylpyrrolidin-1-yl)((2*S*,4*R*)-4-hydroxypyrrolidin-2-yl)-methanone, 99% (HPLC) NEW

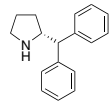
$C_{22}H_{26}N_2O_2$
FW 350.45



671622-100MG	100 mg
671622-500MG	500 mg

(*R*)-(+)-2-(Diphenylmethyl)pyrrolidine, 97%

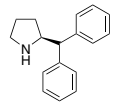
$C_{17}H_{19}N$
FW 237.34
[22348-31-8]



552542-500MG	500 mg
552542-1G	1 g

(*S*)-(–)-2-(Diphenylmethyl)pyrrolidine, 97%

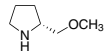
$C_{17}H_{19}N$
FW 237.34
[119237-64-8]



552534-500MG	500 mg

(*R*)-(–)-2-(Methoxymethyl)pyrrolidine, ≥98.0% (GC, sum of enantiomers)

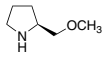
$C_6H_{13}NO$
FW 115.17
[84025-81-0]



65089-1ML	1 mL
65089-5ML	5 mL

(*S*)-(+)-2-(Methoxymethyl)pyrrolidine, 99%

$C_6H_{13}NO$
FW 115.17
[63126-47-6]



277053-100MG	100 mg
277053-500MG	500 mg
277053-5G	5 g

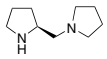
(*S*)-(–)-1-Methyl-2-pyrrolidinemethanol, 96%

N-Methyl-L-prolinol
$C_6H_{13}NO$
FW 115.17
[34381-71-0]

302767-5G	5 g
302767-25G	25 g

(*S*)-(+)-1-(2-Pyrrolidinylmethyl)pyrrolidine, 96%

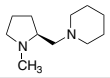
$C_9H_{18}N_2$
FW 154.25
[51207-66-0]



324450-250MG	250 mg
324450-1G	1 g

(*S*)-1-[(1-Methyl-2-pyrrolidinyl)methyl]piperidine, 97%

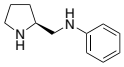
$C_{11}H_{22}N_2$
FW 182.31
[84466-85-3]



446351-1ML	1 mL

(*S*)-(+)-2-(Anilinomethyl)pyrrolidine, 96%

$C_{11}H_{16}N_2$
FW 176.26
[64030-44-0]



374911-1G	1 g

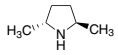
(*S*)-(+)-2-(Aminomethyl)pyrrolidine, 97%

$C_5H_{12}N_2$
FW 100.16
[69500-64-7]

422886-100MG	100 mg
422886-500MG	500 mg

(2*R*,5*R*)-(–)-*trans*-2,5-Dimethylpyrrolidine, ≥97.0% (GC)

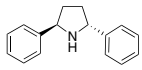
$C_6H_{13}N$
FW 99.17
[62617-70-3]



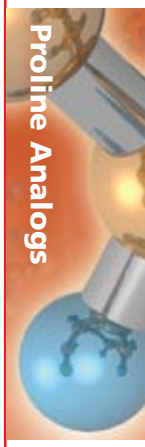
41566-50MG	50 mg
41566-250MG	250 mg

(2*R*,5*R*)-Diphenylpyrrolidine, 97% NEW

$C_{16}H_{17}N$
FW 223.31
[155155-73-0]

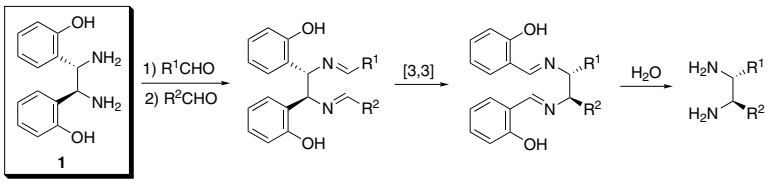


688274-100MG	100 mg
688274-500MG	500 mg

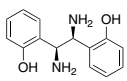


NEW Chiral Vicinal Diamines for Asymmetric Synthesis

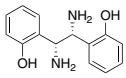
Chiral vicinal diamines are of tremendous interest to the synthetic chemist as they are found in many chiral catalysts and pharmaceuticals. Currently, there is no unified approach to making these chiral vicinal diamines, and they are often challenging to synthesize, especially if unsymmetrically substituted. Jik Chin and co-workers have recently reported some preliminary theoretical and experimental studies for converting a parent diamine (**1**) into other chiral vicinal diamines.[1] These diamines can be used as ligands for chiral catalysts, or they can be further elaborated to produce chiral heterocyclic rings and β-lactams via ring closure.



1

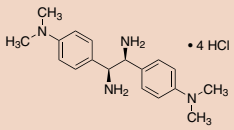


685879
(*S*,*S*)-1

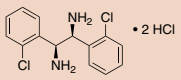


685860
(*R*,*R*)-1

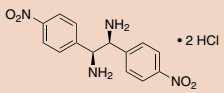
Other NEW Chiral Vicinal Diamines



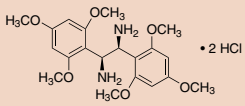
685186



684058



684031



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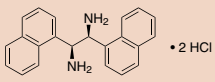

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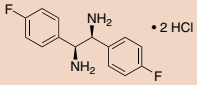
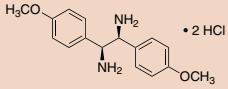


684139



684120

References: (1) (a) Chin, J. et al. *J. Am. Chem. Soc.* **2003**, *125*, 15276. (b) Kim, H.-J. et al. *J. Am. Chem. Soc.* **2005**, *127*, 16370. (c) Kim, H.-J. et al. *J. Am. Chem. Soc.* **2005**, *127*, 16776.

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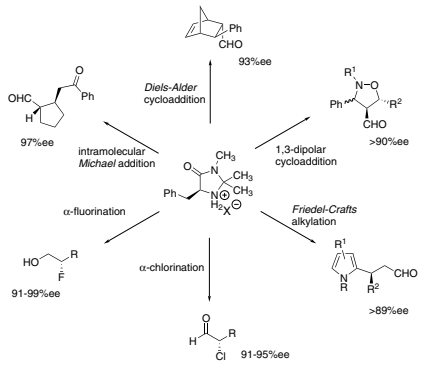
MacMillan Imidazolidinone OrganoCatalysts™

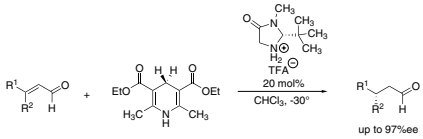
Developed by Professor David MacMillan at Caltech, imidazolidinone based OrganoCatalysts™ are designed to serve as general catalysts for a myriad of asymmetric transformations. The first highly enantioselective organocatalytic Diels–Alder reaction using a chiral OrganoCatalyst™ (**569763**) was reported in his pioneering work in 2000. The activated iminium ion, formed through condensation of the imidazolidinone and an α,β-unsaturated aldehyde, reacted with various dienes to give [4+2] cycloadducts in excellent yields and enantioselectivities (**Scheme 1**, top). Other organocatalytic transformations such as 1,3-dipolar cycloadditions, Friedel–Crafts alkylations, α-chlorinations, α-fluorinations, and intramolecular Michael reactions using MacMillan's OrganoCatalyst™ technology (**569763**) were reported, all proceeding with impressive levels of enantioselectivity (**Scheme 1**).[1]

Imitating nature's stereoselective enzymatic transfer hydrogenation with NADH cofactor, MacMillan has reported the combination of imidazolidinone OrganoCatalyst™ and Hantzsch ester to facilitate the first enantioselective organocatalytic hydride reduction of α,β-unsaturated aldehydes (**Scheme 2**).[2] In sharp contrast to metal-mediated hydrogenations, the *E/Z* geometry of the enal substrates did not have a significant influence on the outcome of the absolute configuration of the newly created stereocenter. (*R*)-Mac-H (**685429**) and (*S*)-Mac-H (**683558**) are convenient 6:1 formulations of the Hantzsch ester and OrganoCatalyst™ **661910** or **661902**, respectively, for asymmetric reductions.

References: (1) (a) Ahrendt, K. A.; Borths, C. J.; MacMillan, D. W. C. *J. Am. Chem. Soc.* **2000**, *122*, 4243. (b) Jen, W. S.; Wiener, J. J. M.; MacMillan, D. W. C. *J. Am. Chem. Soc.* **2000**, *122*, 9874. (c) Paras, N. A.; MacMillan, D. W. C. *J. Am. Chem. Soc.* **2001**, *123*, 4379. (d) Brochu, M. P.; Brown, S. P.; MacMillan, D. W. C. *J. Am. Chem. Soc.* **2004**, *126*, 4108. (e) Beeson, T. D.; MacMillan, D. W. C. *J. Am. Chem. Soc.* **2005**, *127*, 8826. (f) Fonseca, M. H.; List, B. *Angew. Chem. Int. Ed.* **2004**, *43*, 3958. (2) Ouellet, S. G. et. al. *J. Am. Chem. Soc.* **2005**, *127*, 32.



Scheme 1

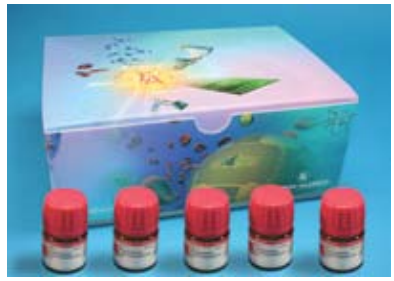


Scheme 2

MacMillan Imidazolidinone OrganoCatalysts™ Kit I

Components

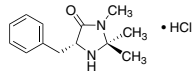
(5*S*)-(–)-2,2,3-Trimethyl-5-benzyl-4-imidazolidinone monohydrochloride (Aldrich 569763) 500 mg
(*S*)-(+)-2-(*tert*-Butyl)-3-methyl-4-imidazolidinone trifluoroacetic acid (Aldrich 661902) 500 mg
(5*S*)-(–)-2,2,3-Trimethyl-5-benzyl-4-imidazolidinone dichloroacetic acid (Aldrich 663085) 500 mg
(2*S*,5*S*)-(–)-2-*tert*-Butyl-3-methyl-5-benzyl-4-imidazolidinone (Aldrich 663107) 500 mg
(2*S*,5*S*)-5-Benzyl-3-methyl-2-(5-methyl-2-furyl)-4-imidazolidinone (Aldrich 668540) 250 mg



674575-1KT	1 kit

(5*R*)-(+)-2,2,3-Trimethyl-5-benzyl-4-imidazolidinone monohydrochloride, 97%

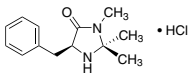
$C_{13}H_{19}ClN_2O$
FW 254.76
[323196-43-6]



663069-500MG	500 mg
663069-2G	2 g

(5*S*)-(–)-2,2,3-Trimethyl-5-benzyl-4-imidazolidinone monohydrochloride, 97%

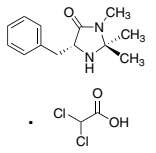
$C_{13}H_{18}N_2O \cdot HCl$
FW 254.76
[278173-23-2]



569763-500MG	500 mg
569763-2G	2 g

(5*R*)-(+)-2,2,3-Trimethyl-5-benzyl-4-imidazolidinone dichloroacetic acid, 97%

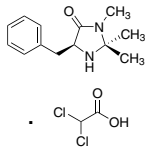
$C_{15}H_{20}Cl_2N_2O_3$
FW 347.24



663077-500MG	500 mg
663077-2G	2 g

(5*S*)-(–)-2,2,3-Trimethyl-5-benzyl-4-imidazolidinone dichloroacetic acid, 97%

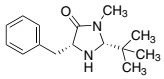
$C_{15}H_{20}Cl_2N_2O_3$
FW 347.24



663085-500MG	500 mg
663085-2G	2 g

(2*R*,5*R*)-(+)-2-*tert*-Butyl-3-methyl-5-benzyl-4-imidazolidinone, 97%

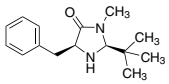
$C_{15}H_{22}N_2O$
FW 246.35
[390766-89-9]



663093-500MG	500 mg
663093-1G	1 g

(2*S*,5*S*)-(–)-2-*tert*-Butyl-3-methyl-5-benzyl-4-imidazolidinone, 97%

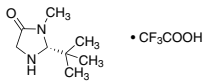
$C_{15}H_{22}N_2O$
FW 246.35
[346440-54-8]



663107-500MG	500 mg
663107-1G	1 g

(*R*)-(–)-2-(*tert*-Butyl)-3-methyl-4-imidazolidinone trifluoroacetic acid, 96%

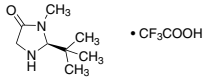
$C_{10}H_{17}N_2O_3F_3$
FW 270.25



661910-500MG	500 mg
661910-2G	2 g

(*S*)-(+)-2-(*tert*-Butyl)-3-methyl-4-imidazolidinone trifluoroacetic acid, 96%

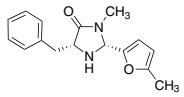
$C_{10}H_{17}N_2O_3F_3$
FW 270.25



661902-500MG	500 mg
661902-2G	2 g

(2*R*,5*R*)-(+)-5-Benzyl-3-methyl-2-(5-methyl-2-furyl)-4-imidazolidinone, 97%

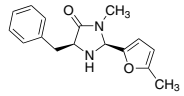
$C_{16}H_{18}N_2O_2$
FW 270.33



668842-250MG	250 mg
668842-1G	1 g

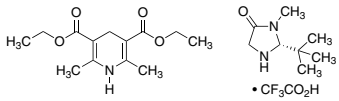
(2*S*,5*S*)-5-Benzyl-3-methyl-2-(5-methyl-2-furyl)-4-imidazolidinone, 95%

$C_{16}H_{18}N_2O_2$
FW 270.33
[415678-40-9]



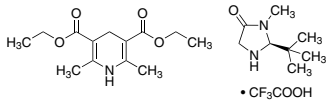
668540-250MG	250 mg
668540-1G	1 g

(*R*)-Mac-H NEW



685429-1G	1 g

(*S*)-Mac-H NEW



683558-1G	1 g

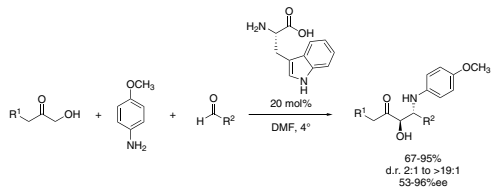
Other Amino Acids

Barbas and co-workers found the proteinogenic amino acid tryptophan (**93660**) to be an excellent organocatalyst for the Mannich reaction of hydroxyacetone with a variety of imines performed in DMF (**Scheme 1**). The desired *anti* amino alcohols were obtained in good yields with excellent diastereoselectivities (up to >19:1) and enantioselectivities (90–98% ee) in most cases.[1]

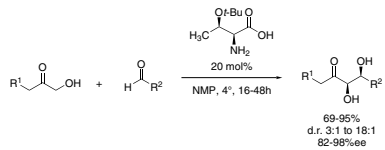
Similarly, *t*-butyl protected threonine (**20644**) catalyzed the aldol reaction of hydroxyacetone and various aldehydes in NMP to give the corresponding *syn*-aldol adducts in high yields and good to excellent enantio- and diastereoselectivities (**Scheme 2**).[1]

Professors Marc Snapper and Amir Hoveyda at Boston College have recently reported[2] the development of an amino-acid-based small molecule **680826** capable of promoting asymmetric monosilylation of *meso*-1,2-diols (**Scheme 3**). The catalyst is compatible with a variety of silyl chlorides and generally provides enantioselectivities above 88%, and the reactions do not require rigorous exclusion of air or moisture. Furthermore, the catalyst can be easily recovered in near-quantitative yield and subsequently reused with identical efficiency. This catalyst greatly increases the efficiency with which optically enriched molecules can be prepared.

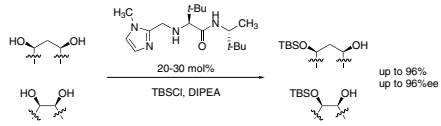
References: (1) Ramasastry, S. S. V.; Zhang, H.; Tanaka, F.; Barbas, C. F., III *J. Am. Chem. Soc.* **2007**, *129*, 288. (2) Zhao, Y.; Rodrigo, J.; Hoveyda, A. H.; Snapper, M. L. *Nature* **2006**, *443*, 67.



Scheme 1



Scheme 2



Scheme 3

L-Alanine, 99%

$C_3H_7NO_2$
FW 89.09
[56-41-7]

A26802-2.5G	2.5 g
A26802-25G	25 g
A26802-100G	100 g

D-Alanine, ≥99.0% (NT)

$C_3H_7NO_2$
FW 89.09
[338-69-2]

05140-1G	1 g
05140-5G	5 g
05140-25G	25 g

Ala-Ala, ≥99.0% (NT)

$C_6H_{12}N_2O_3$
FW 160.17
[1948-31-8]

05250-250MG	250 mg
05250-1G	1 g

L-Threonine, ≥99.0% (NT)

$C_4H_9NO_3$
FW 119.12
[72-19-5]

89180-25G	25 g
89180-100G	100 g
89180-1KG	1 kg

D-Threonine, ≥99.0% (NT)

$C_4H_9NO_3$
FW 119.12
[632-20-2]

89190-10G	10 g
89190-50G	50 g

O-tert-Butyl-L-threonine, ≥98.0% (T)

$C_8H_{17}NO_3$
FW 175.23
[4378-13-6]

20644-5G-F	5 g

L-Tryptophan, ≥99.0% (NT)

$C_{11}H_{12}N_2O_2$
FW 204.23
[73-22-3]

93660-25G	25 g
93660-100G	100 g
93660-1KG	1 kg

D-Tryptophan, ≥99.0% (NT)

$C_{11}H_{12}N_2O_2$
FW 204.23
[153-94-6]

93670-1G	1 g
93670-5G	5 g
93670-25G	25 g

(–)-(*S*)-*N*-((*R*)-3,3-Dimethylbutan-2-yl)-3,3-dimethyl-2-((1-methyl-1*H*-imidazol-2-yl)methylamino)butanamide, 97% NEW

$C_{17}H_{32}N_4O$
FW 308.46

680826-1G	1 g

Poly-L-leucine-1,3-diaminopropane

93197-1G-F	1 g

Chiral Phosphoric Acids

BINOL-derived phosphoric acids are capable of catalyzing a range of interesting processes of which nucleophilic addition reactions to imine substrates are particularly noteworthy. List and co-workers reported[1] a direct Pictet-Spengler reaction with a range of aldehydes using organocatalyst (*R*)-TRIP (**689890**) to form isoquinolines in high yields and enantiomeric excess (**Scheme 1**). A geminally disubstituted tryptamine is needed, but this limitation does not significantly affect the utility of this process.

An enantioselective reductive amination has been reported by several research groups.[2] Rueping first reported that phosphoric acid **674605** catalyzed the reduction of an imine with a Hantzsch ester in good enantiomeric excess (**Scheme 2,** top). List reported an improvement to this method using **689890** and highlighted the ability to perform a one-pot process from aldehyde to amine in enantiomeric excesses up to 92% (**Scheme 2,** bottom).

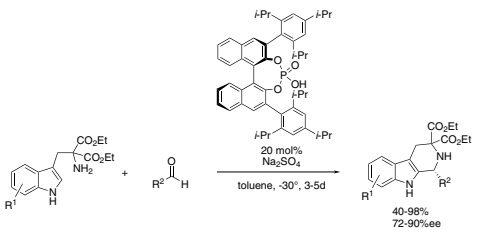
MacMillan finally reported a one-pot, direct, reductive amination with broad substrate scope that enables the effective reductive amination of a range of methyl ketones and aryl amines (**Scheme 3**).[3] It is even possible to obtain good enantiomeric excess with 2-butanone where the silylated phosphoric acid MacMillan TiPSY catalyst (**674745**) can distinguish between a methyl group and an ethyl group, delivering the product in high enantiomeric excess.

Recently, List reported an elegant, highly enantioselective cascade reaction.[4] The synthesis of pharmaceutically relevant 3-substituted cyclohexylamines from 2,6-diketones via an aldolization-dehydration-conjugate reduction-reductive amination cascade that is catalyzed by the chiral Brønsted acid (*R*)-TRIP (**689890**) and accelerated by the achiral amine substrate, which is ultimately incorporated into the product (**Scheme 4**).

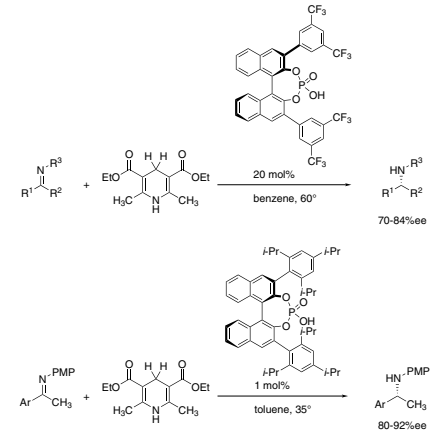
Antilla and co-workers reported on the use of VAPOL derived phosphoric acid derivative **675512** in the addition of sulfonamides to Boc-protected aryl imines, giving rise to protected aminals in excellent enantioselectivities (**Scheme 5**).[5]

The aza-Diels-Alder reaction of aldimines with Danishefsky's diene to afford piperidinone derivatives proceeded with high enantioselectivity using (*R*)-TRIP (**689890**). Addition of acetic acid improved both reactivity and enantioselectivity (**Scheme 6**).[6]

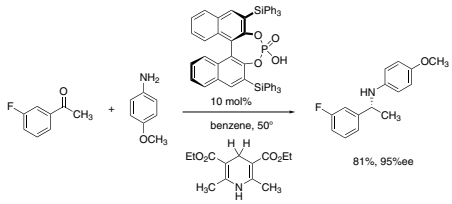
References: (1) Seayad, J.; Seayad, A. M.; List, B. *J. Am. Chem. Soc.* **2006**, *128*, 1086. (2) (a) Rueping, M.; Sugiono, E.; Azap, C.; Theissmann, T.; Bolte, M. *Org. Lett.* **2005**, *7*, 3781. (b) Hoffmann, S.; Seayad, A. M.; List, B. *Angew. Chem. Int. Ed.* **2005**, *44*, 7424. (3) Storer, R. I.; Carrera, D. E.; Ni, Y.; MacMillan, D. W. C. *J. Am. Chem. Soc.* **2006**, *128*, 84. (4) Zhou, J.; List, B. *J. Am. Chem. Soc.* **2007**, *129*, 7498. (5) Gerald, B.; Rowland, G. B.; Zhang, H.; Rowland, E. B.; Chennamadhavuni, S.; Wang, Y.; Antilla, J. C. *J. Am. Chem. Soc.* **2005**, *127*, 15696. (6) Akiyama, T.; Tamura, Y.; Itoh, J.; Morita, H.; Fuchibe, K. *Synlett* **2006**, 141.



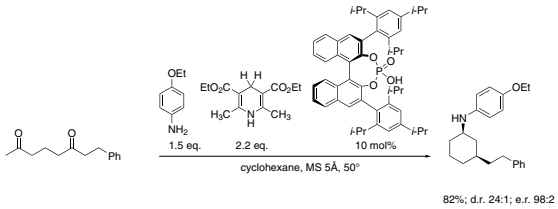
Scheme 1



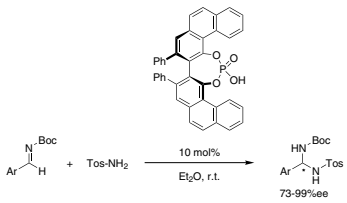
Scheme 2



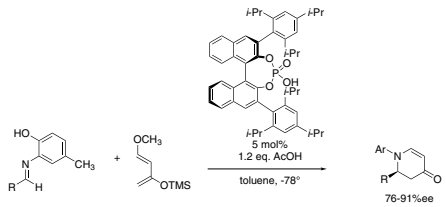
Scheme 3



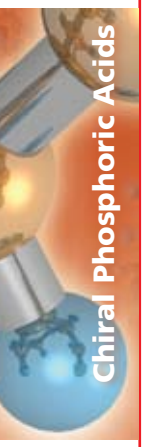
Scheme 4



Scheme 5

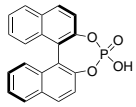


Scheme 6



(*R*)-(–)-1,1′-Binaphthyl-2,2′-diyl hydrogenphosphate, ≥98%

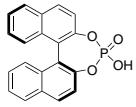
$C_{20}H_{13}O_4P$
FW 348.29
[39648-67-4]



248932-250MG	250 mg
248932-1G	1 g
248932-5G	5 g

(*S*)-(+)-1,1′-Binaphthyl-2,2′-diyl hydrogenphosphate, 97%

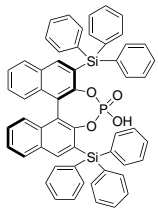
$C_{20}H_{13}O_4P$
FW 348.29
[35193-64-7]



248940-250MG	250 mg
248940-1G	1 g
248940-5G	5 g

(*R*)-(–)-3,3′-Bis(triphenylsilyl)-1,1′-binaphthyl-2,2′-diyl hydrogenphosphate, 96%

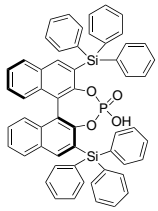
$C_{56}H_{41}O_4PSi_2$
FW 865.07
[791616-55-2]



674745-100MG	100 mg

(*S*)-3,3′-Bis(triphenylsilyl)-1,1′-binaphthyl-2,2′-diyl hydrogenphosphate, 96% NEW

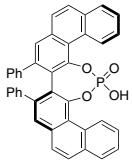
$C_{56}H_{41}O_4PSi_2$
FW 865.07



680184-100MG	100 mg

(*R*)-(–)-VAPOL hydrogenphosphate

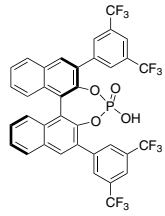
$C_{40}H_{25}O_4P$
FW 600.60
[871130-18-6]



675512-100MG	100 mg
675512-500MG	500 mg

(*R*)-3,3′-Bis[3,5-bis(trifluoromethyl)phenyl]-1,1′-binaphthyl-2,2′-diyl hydrogenphosphate, 95%

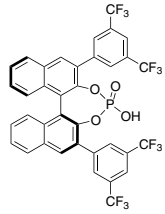
$C_{36}H_{17}F_{12}O_4P$
FW 772.47
[791616-62-1]



674605-100MG	100 mg

(*S*)-(+)-3,3′-Bis(3,5-bis(trifluoromethyl)phenyl)-1,1′-binaphthyl-2,2′-diyl hydrogenphosphate, 95% NEW

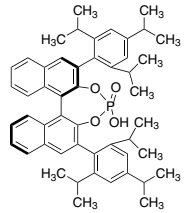
$C_{36}H_{17}F_{12}O_4P$
FW 772.47
[878111-17-2]



681520-100MG	100 mg

(*R*)-3,3′-Bis(2,4,6-triisopropylphenyl)-1,1′-binaphthyl-2,2′-diyl hydrogenphosphate NEW

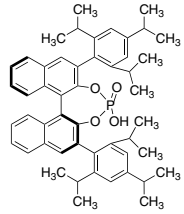
$C_{50}H_{57}O_4P$
FW 752.96
[791616-63-2]



689890-100MG	100 mg
689890-500MG	500 mg

(*S*)-3,3′-Bis(2,4,6-triisopropylphenyl)-1,1′-binaphthyl-2,2′-diyl hydrogenphosphate NEW

$C_{50}H_{57}O_4P$
FW 752.96



689785-100MG	100 mg
689785-500MG	500 mg

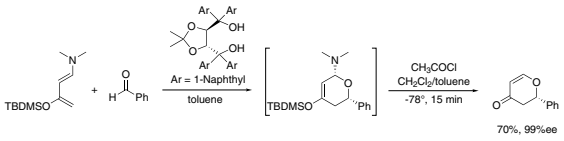
Chiral Diols

Apart from numerous examples using TADDOLs in metal-catalyzed asymmetric reactions, Rawal recently reported that TADDOLs could be used as Brønsted acid organocatalysts in highly stereoselective hetero-Diels–Alder reactions.[1] The reaction of an electron-rich diene with benzaldehyde using 10 mol % TADDOL **395242** provides the dihydropyrone as a single stereoisomer (**Scheme 1**).

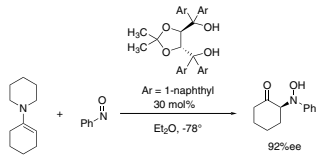
The α-amination of carbonyl compounds has also been accomplished by using the 1-naphthyl TADDOL derivative as a Brønsted acid catalyst (**Scheme 2**).[2] The reaction of different enamines with nitrosobenzene gave exclusively the N-regioisomers in a highly enantioselective manner.

A highly enantioselective addition of cyclohexenone to different aldehydes (asymmetric Morita–Baylis–Hillman reaction) catalyzed by octahydro-BINOL-derived Brønsted acid **669172** was reported by Schaus (**Scheme 3**).[3] Important for achieving high enantioselectivity were both the partial saturation and substitution at the 3,3′-positions of the BINOL derivative.

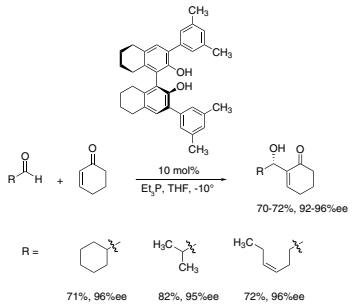
References: (1) Huang, Y.; Unni, A. K.; Thadani, A. N.; Rawal, V. H. *Nature* **2003**, *424*, 146. (2) Guo, H.-M.; Cheng, L.; Cun, L.-F.; Gong, L.-Z.; Mi, A.-Q.; Jiang, Y.-Z. *Chem. Commun.* **2006**, 429. (3) McDougal, N. T.; Schaus, S. E. *J. Am. Chem. Soc.* **2003**, *125*, 12094.



Scheme 1



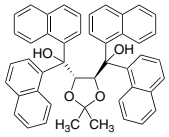
Scheme 2



Scheme 3

(4*S*-*trans*)-2,2-Dimethyl-α,α,α′,α′-tetra(1-naphthyl)-1,3-dioxolane-4,5-dimethanol, 99%

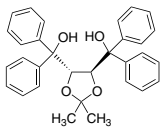
$C_{47}H_{38}O_4$
FW 666.80
[171086-52-5]



395242-1G	1 g

(4*S*,5*S*)-2,2-Dimethyl-α,α,α′,α′-tetraphenyldioxolane-4,5-dimethanol

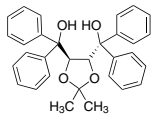
$C_{31}H_{30}O_4$
FW 466.57
[93379-49-8]



264997-250MG	250 mg
264997-1G	1 g

(4*R*,5*R*)-2,2-Dimethyl-α,α,α′,α′-tetraphenyldioxolane-4,5-dimethanol

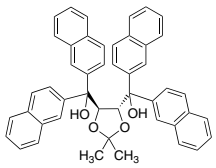
$C_{31}H_{30}O_4$
FW 466.57
[93379-48-7]



265004-250MG	250 mg
265004-1G	1 g

(4*R*,5*R*)-2,2-Dimethyl-α,α,α′,α′-tetra(2-naphthyl)dioxolane-4,5-dimethanol, ≥99.0% (HPLC, sum of enantiomers)

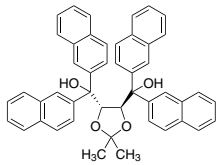
$C_{47}H_{38}O_4$
FW 666.80
[137365-09-4]



59490-1G-F	1 g
59490-5G-F	5 g

(4*S*-*trans*)-2,2-Dimethyl-α,α,α′,α′-tetra(2-naphthyl)-1,3-dioxolane-4,5-dimethanol, 98%

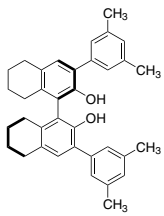
$C_{47}H_{38}O_4$
FW 666.80
[137365-16-3]



393762-250MG	250 mg
393762-1G	1 g

(*R*)-(–)-3,3′-Bis(3,5-dimethylphenyl)-5,5′,6,6′,7,7′,8,8′-octahydro-1,1′-bi-2-naphthol, 97%

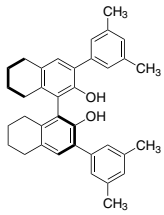
$C_{36}H_{38}O_2$
FW 502.69



669180-100MG	100 mg

(*S*)-(+)-3,3′-Bis-(3,5-dimethylphenyl)-5,5′,6,6′,7,7′,8,8′-octahydro-1,1′-bi-2-naphthol, 97%

$C_{36}H_{38}O_2$
FW 502.69



669172-100MG	100 mg

Jacobsen Thioureas

Jacobsen's group has developed a range of chiral thioureas that are versatile and effective organocatalysts. A range of latent nucleophiles can be added to mostly imine-type electrophiles in excellent enantiomeric excesses and, in general, with a broad substrate scope.

The thiourea organocatalyst depicted in **Figure 1** was reported by Jacobsen to have a very broad scope in the Strecker reaction (**Scheme 1**).[1] Both aldimines and ketonimines underwent hydrocyanation with very high enantioselectivities in the presence of 1 mol % of the catalyst. Similarly, imine hydrophosphonylation occurred in the presence of 10 mol % of the catalyst (**Scheme 2**).[2] The reaction was particularly effective with electron-withdrawing ester substituents on the phosphite, and was tolerant of a wide variety of aldimines.

Mannich reactions of Boc-protected imines have also been reported by the Jacobsen group.[3] A wide variety of *N*-Boc arylimines underwent addition with good to excellent yields and enantioselectivities when catalyzed by thiourea organocatalysts (**Scheme 3**). Again the organocatalytic reaction shows excellent substrate tolerance, particularly for heterocyclic substrates.

More recently, the cyanosilylation of ketones has also been achieved using a slightly different version of the thiourea organocatalyst (**Scheme 4**).[4] The reaction proceeds for ketones and aldehydes as well in high yields and enantiomeric excesses. In addition, the catalyst can be recovered in near quantitative yield by silica gel chromatography.

The Jacobsen group has also developed the thiourea organocatalyst depicted in **Figure 2** and applied it in the acyl-Pictet–Spengler reaction to form tetrahydro-β-carbolines (**Scheme 5**).[5] This same organocatalyst is also effective in the acyl-Mannich reaction, providing a route to enantioenriched heterocycles from aromatic starting materials and trichloroethyl chloroformate (TrocCl) (**Scheme 6**).[6]

References: (1) Vachal, P.; Jacobsen, E. N. *J. Am. Chem. Soc.* **2002**, *124*, 10012. (2) Joly, G. D.; Jacobsen, E. N. *J. Am. Chem. Soc.* **2004**, *126*, 4102. (3) Wenzel, A. G.; Jacobsen, E. N. *J. Am. Chem. Soc.* **2002**, *124*, 12964. (4) Fuerst, D. E.; Jacobsen, E. N. *J. Am. Chem. Soc.* **2005**, *127*, 8964. (5) Taylor, M. S.; Jacobsen, E. N. *J. Am. Chem. Soc.* **2004**, *126*, 10558. (6) Talyor, M. S. et al. *Angew. Chem. Int. Ed.* **2005**, *44*, 6700.

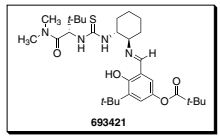
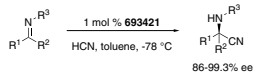
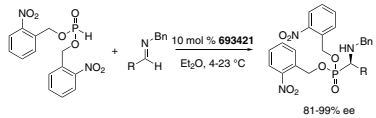


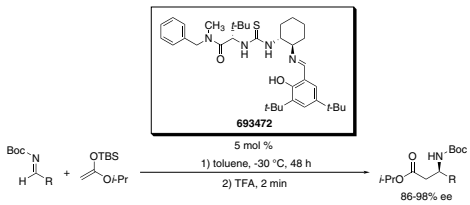
Figure 1



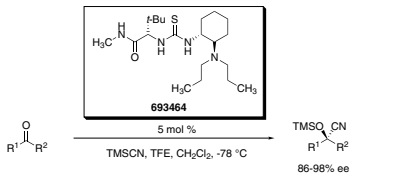
Scheme 1



Scheme 2



Scheme 3



Scheme 4

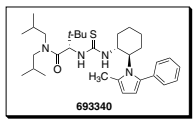
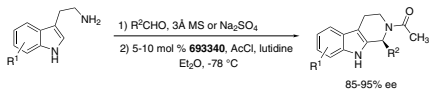
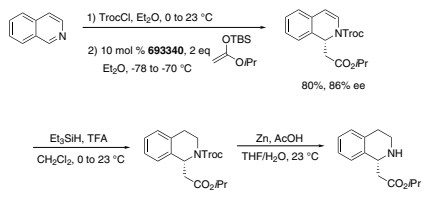


Figure 2



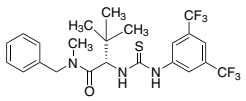
Scheme 5



Scheme 6

(*S*)-2-[[3,5-Bis(trifluoromethyl)phenyl]thioureido]-*N*-benzyl-*N*,3,3-trimethylbutanamide NEW

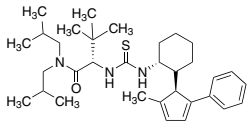
$C_{23}H_{25}F_6N_3OS$
FW 505.52



693316-100MG	100 mg
693316-500MG	500 mg

(2*S*)-3,3-Dimethyl-2-[[(1*R*,2*R*)-2-(2-methyl-5-phenyl-1-pyrrolyl)cyclohexyl]thioureido]-*N*,*N*-bis(2-isobutyl)butanamide NEW

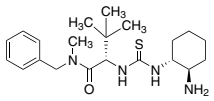
$C_{32}H_{50}N_4OS$
FW 538.83
[764650-97-7]



693340-100MG	100 mg
693340-500MG	500 mg

(*S*)-2-[[(1*R*,2*R*)-2-Aminocyclohexyl]thioureido]-*N*-benzyl-*N*,3,3-trimethylbutanamide NEW

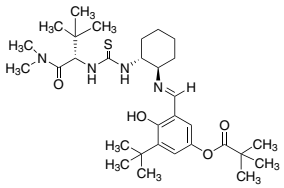
$C_{21}H_{34}N_4OS$
FW 390.59
[479423-21-7]



693413-100MG	100 mg
693413-500MG	500 mg

3-[(*E*)-[[(1*R*,2*R*)-2-[[(1*S*)-1-[(Dimethylamino)carbonyl]-2,2-dimethylpropyl]thioureido]cyclohexyl]imino]methyl]-5-(*tert*-butyl)-4-hydroxyphenyl pivalate NEW

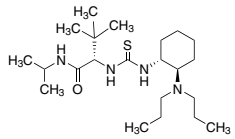
$C_{31}H_{50}N_4O_4S$
FW 574.82
[462632-54-8]



693421-100MG	100 mg
693421-500MG	500 mg

(*S*)-2-[3-[(1*R*,2*R*)-2-(Dipropylamino)cyclohexyl]thioureido]-*N*-isopropyl-3,3-dimethylbutanamide NEW

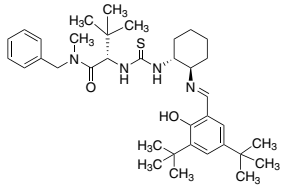
$C_{22}H_{44}N_4OS$
FW 412.68



693464-100MG	100 mg
693464-500MG	500 mg

(*S*)-2-[[(1*R*,2*R*)-2-[[[3,5-Bis(*tert*-butyl)-2-hydroxyphenyl]methylene]amino]cyclohexyl]thioureido]-*N*-benzyl-*N*,3,3-trimethylbutanamide NEW

$C_{36}H_{54}N_4O_2S$
FW 606.90
[479423-24-0]



693472-100MG	100 mg
693472-500MG	500 mg

Cinchona Alkaloids

Asymmetric phase-transfer catalysis (PTC) has been recognized as a "green" alternative to many homogeneous synthetic organic transformations, and has found widespread application. Synthetically modified cinchona alkaloids are typical chiral organocatalysts used in asymmetric PTC. Several generations of *O*-alkyl *N*-arylmethyl derivatives were developed, which finally led to highly enantioselective alkylation reactions of glycine imines to generate a range of α-amino acid derivatives (**Table 1**).

In an attempt to further improve catalyst enantioselectivities, Jew and Park linked two cinchona alkaloid moieties via spacer units. With such a dimeric cinchona alkaloid (**06542**), enantioselectivity for the above mentioned glycine imine alkylation was optimized to 97–99% ee.[1]

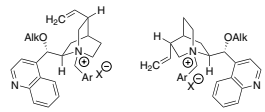
Nucleophilic catalysts have had a wide-ranging role in the development of new synthetic methods. In particular, the cinchona alkaloids catalyze many useful processes with high enantioselectivities. Cinchona alkaloids can be used as bases to deprotonate substrates with relatively acidic protons forming a contact ion pair between the resulting anion and protonated amine. This interaction leads to a chiral environment around the anion and permits enantioselective reactions with electrophiles.

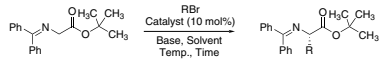
Important in many of these processes is the ability to control the formation of quaternary asymmetric centers with high enantiomeric excesses. Using the $(DHQD)_2AQN$ (**456713**) catalyst it is possible to affect the α-functionalization of ketones by the addition of TMSCN to the corresponding cyanohydrin in excellent yield and enantiomeric excess (**Scheme 1**).[2]

The metal-free, allylic amination reaction provides a useful extension to the conventional palladium catalyzed π-allylic methodology. Amination with diimides at the remote γ-position can be carried out using $(DHQ)_2PYR$ (**418978**) (**Scheme 2**) to form a diverse range of highly functionalized amine compounds.[3]

Finally, Jørgensen and co-workers have developed the first catalytic enantioselective conjugate addition to alkynones using $(DHQ)_2PHAL$ (**392723**).[4] For both aromatic and aliphatic alkynones the addition of β-diketones proceeds in high yields and enantioselectivity giving a mixture of (*E*)- and (*Z*)-enones (**Scheme 3**).

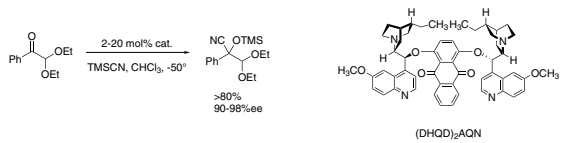
References: (1) (a) O'Donnell, M. J. *Acc. Chem. Res.* **2004**, *37*, 506. (b) Lygo, B.; Andrews, B. J. *Acc. Chem. Res.* **2004**, *37*, 518. (c) Jew, S.-S.; Jeong, B.-S.; Yoo, M.-S.; Huh, H.; Park, H.-G. *Chem. Commun.* **2001**, 1244. (2) Tian, S.-K. et al. *J. Am. Chem. Soc.* **2003**, *125*, 9900. (3) Poulsen, T. B. et al. *J. Am. Chem. Soc.* **2005**, *127*, 11614. (4) Bella, M. et al. *J. Am. Chem. Soc.* **2004**, *126*, 5672.



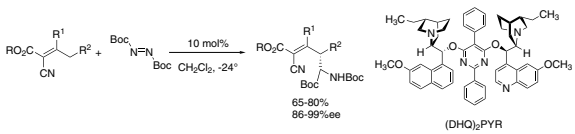


Prod. No.	Cinchona PTC				R-Br	%Y	%ee
	N-Ar	O-Alk	X^-	Cat. Gen.			
524433	Benzyl	H	Br	1st	$PhCH_2$-	85	60
359580	Benzyl	H	Cl	1st	4-Cl-C_6H_4-CH_2-	95	66
514276	Benzyl	Allyl	Br	2nd	4-Cl-C_6H_4-CH_2-	–	81
515701	9-Anthracenyl-methyl	H	Cl	3rd	$PhCH_2$-	68	91
499617	9-Anthracenyl-methyl	Allyl	Br	3rd	$PhCH_2$-	87	94
06542	2,7-Naphthalene-diyldimethyl	Allyl	Br	dimeric	4-NO_2-C_6H_4-CH_2-	91	99

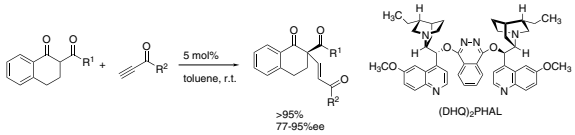
Table 1



Scheme 1



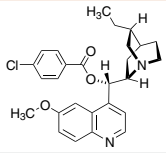
Scheme 2



Scheme 3

Hydroquinidine 4-chlorobenzoate, 98%

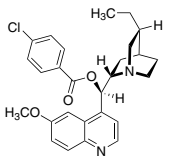
$C_{27}H_{29}ClN_2O_3$
FW 464.98
[113162-02-0]



336483-1G	1 g
336483-5G	5 g

O-(4-Chlorobenzoyl)hydroquinine, 98%

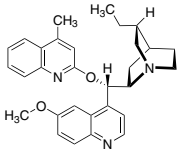
$C_{27}H_{29}ClN_2O_3$
FW 464.98
[113216-88-9]



336491-1G	1 g

Hydroquinidine 4-methyl-2-quinolyl ether, 97%

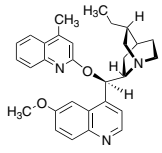
$C_{30}H_{33}N_3O_2$
FW 467.60
[135042-89-6]



381942-1G	1 g

Hydroquinine 4-methyl-2-quinolyl ether, 98%

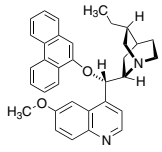
$C_{30}H_{33}N_3O_2$
FW 467.60
[135096-79-6]



381969-1G	1 g

Hydroquinidine 9-phenanthryl ether, 96%

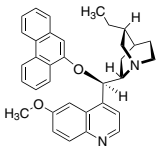
$C_{34}H_{34}N_2O_2$
FW 502.65
[135042-88-5]



381950-250MG	250 mg
381950-1G	1 g

Hydroquinine-9-phenanthryl ether, 97%

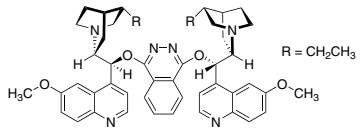
$C_{34}H_{34}N_2O_2$
FW 502.65
[135096-78-5]



381977-100MG	100 mg
381977-500MG	500 mg

$(DHQD)_2PHAL$, ≥95%

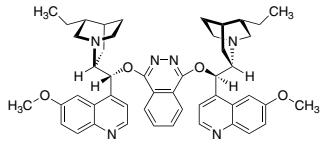
Hydroquinidine 1,4-phthalazinediyl diether
$C_{48}H_{54}N_6O_4$
FW 778.98
[140853-10-7]



392731-1G	1 g

$(DHQ)_2PHAL$, ≥95%

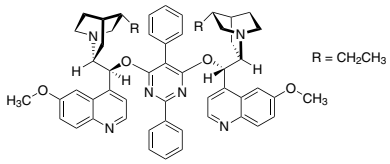
Hydroquinine 1,4-phthalazinediyl diether
$C_{48}H_{54}N_6O_4$
FW 778.98
[140924-50-1]



392723-500MG	500 mg

$(DHQD)_2Pyr$, 97%

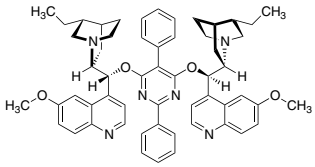
Hydroquinidine-2,5-diphenyl-4,6-pyrimidinediyl diether
$C_{56}H_{60}N_6O_4$
FW 881.11
[149725-81-5]



418951-250MG	250 mg
418951-1G	1 g

$(DHQ)_2Pyr$, 97%

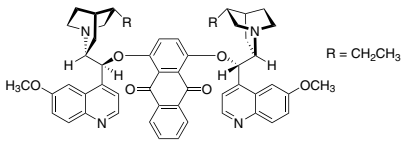
Hydroquinine 2,5-diphenyl-4,6-pyrimidinediyl diether
$C_{56}H_{60}N_6O_4$
FW 881.11
[149820-65-5]



418978-250MG	250 mg
418978-1G	1 g

$(DHQD)_2AQN$, 95%

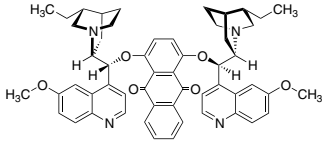
$C_{54}H_{56}N_4O_6$
FW 857.05
[176298-44-5]



456713-500MG	500 mg

$(DHQ)_2AQN$, 95%

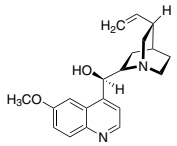
$C_{54}H_{56}N_4O_6$
FW 857.05
[176097-24-8]



456705-500MG	500 mg

Quinine, 90%

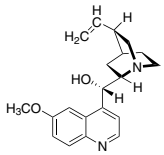
$C_{20}H_{24}N_2O_2$
FW 324.42
[130-95-0]



145904-10G	10 g
145904-50G	50 g

Quinidine, ≥98.0% (NT, dried material)

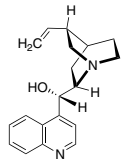
$C_{20}H_{24}N_2O_2$
FW 324.42
[56-54-2]



22600-10G-F	10 g
22600-50G-F	50 g

Cinchonine, ≥98.0% (NT)

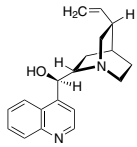
$C_{19}H_{22}N_2O$
FW 294.39
[118-10-5]



27370-25G	25 g
27370-100G	100 g

Cinchonidine, 96%

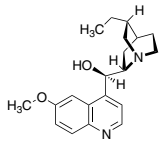
$C_{19}H_{22}N_2O$
FW 294.39
[485-71-2]



C80407-10G	10 g
C80407-100G	100 g

Hydroquinine, 98%

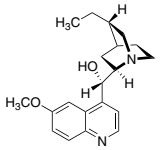
$C_{20}H_{26}N_2O_2$
FW 326.43
[522-66-7]



337714-1G	1 g
337714-5G	5 g

Hydroquinidine, 95%

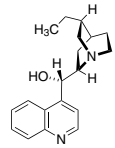
$C_{20}H_{26}N_2O_2$
FW 326.43
[1435-55-8]



359343-1G	1 g
359343-5G	5 g

Hydrocinchonine, ≥97.0% (GC, sum of enantiomers)

$C_{19}H_{24}N_2O$
FW 296.41
[485-65-4]



54060-500MG	500 mg

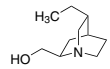
(2*S*,4*S*,5*R*)-2-Hydroxymethyl-5-ethylquinuclidine, ≥99.0% (GC)

$C_{10}H_{19}NO$
FW 169.26
[219794-79-3]

51957-100MG-F	100 mg
51957-500MG-F	500 mg

(2*R*,4*S*,5*R*)-2-Hydroxymethyl-5-ethylquinuclidine, ≥99.0% (GC)

$C_{10}H_{19}NO$
FW 169.26
[219794-81-7]



49463-100MG-F	100 mg
49463-500MG-F	500 mg

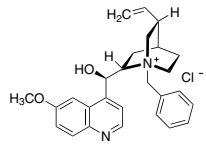
(2*S*,4*S*,5*R*)-2-Aminomethyl-5-ethylquinuclidine, ≥95.0% (GC)

$C_{10}H_{20}N_2$
FW 168.28
[475160-59-9]

07317-100MG-F	100 mg
07317-500MG-F	500 mg

N-Benzylquininium chloride, 95%

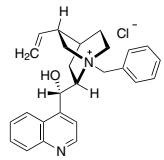
$C_{27}H_{31}ClN_2O_2$
FW 451.00
[67174-25-8]



374482-1G	1 g
374482-5G	5 g

N-Benzylcinchoninium chloride, ≥98.0% (AT)

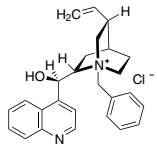
$C_{26}H_{29}ClN_2O$
FW 420.97
[69221-14-3]



13288	

(8*S*,9*R*)-(–)-*N*-Benzylcinchonidinium chloride, 98%

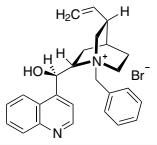
$C_{26}H_{29}ClN_2O$
FW 420.97
[69257-04-1]



359580-2G	2 g
359580-10G	10 g

N-Benzylcinchonidinium bromide, 97%

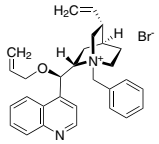
$C_{26}H_{29}BrN_2O$
FW 465.43
[118089-84-2]



524433-5G 5 g

O-Allyl-*N*-benzylcinchonidinium bromide

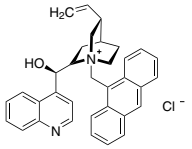
$C_{29}H_{33}BrN_2O$
FW 505.49
[158195-40-5]



514276-1G 1 g

N-(9-Anthracenylmethyl)cinchonindinium chloride, 85%

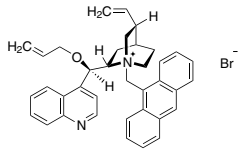
$C_{34}H_{33}ClN_2O$
FW 521.09
[199588-80-2]



515701-5G 5 g
515701-25G 25 g

O-Allyl-*N*-(9-anthracenylmethyl)cinchonidinium bromide, 90%

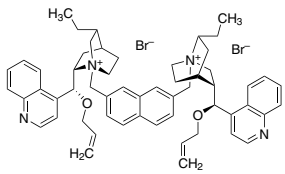
$C_{37}H_{37}BrN_2O$
FW 605.61
[200132-54-3]



499617-1G 1 g
499617-5G 5 g

O,*O*′-Diallyl-*N*,*N*′-(2,7-naphthalenediyldimethyl)bis(hydrocinchonidinium) dibromide, ≥97.0%

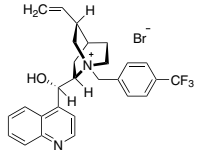
$C_{56}H_{66}Br_2N_4O_2$
FW 986.96
[480427-57-4]



06542-100MG-F 100 mg

N-(4-Trifluoromethylbenzyl)cinchoninium bromide, ≥98.0% (AT)

$C_{27}H_{28}BrF_3N_2O$
FW 533.42
[95088-20-3]

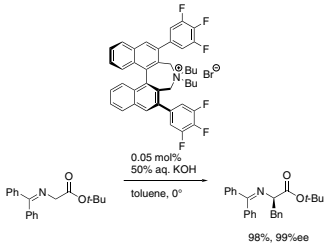


91851-1G 1 g
91851-5G 5 g

Maruoka Phase-Transfer Catalysts

Chiral quaternary ammonium catalysts can be particularly useful in the field of asymmetric synthesis. Maruoka and co-workers have reported potent C_2-symmetric ammonium salts that catalyze alkylation reactions under remarkably low catalyst loadings.[1] This methodology has been applied to the enantiocontrolled synthesis of α-alkyl-α-amino acids by monoalkylation of glycine-derived Schiff bases with alkyl halides (**Scheme 1**).

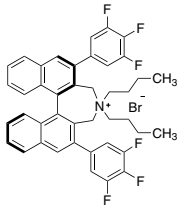
References: (1) (a) Kitamura, M. et al. *Angew. Chem., Int. Ed.* **2005**, *44*, 1549. (b) Ooi, T. et al. *Tetrahedron: Asymmetry* **2006**, *17*, 603. (c) Ooi, T.; Maruoka, K. *Aldrichimica Acta* **2007**, *40*, 77.



Scheme 1

(11b*R*)-(–)-4,4-Dibutyl-4,5-dihydro-2,6-bis(3,4,5-trifluorophenyl)-3*H*-dinaphth[2,1-*c*:1′,2′-*e*]azepinium bromide NEW

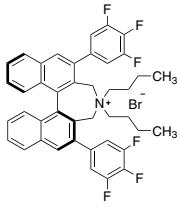
$C_{42}H_{36}BrF_6N$
FW 748.64
[887938-70-7]



687596-50MG 50 mg

(11b*S*)-(+)-4,4-Dibutyl-4,5-dihydro-2,6-bis(3,4,5-trifluorophenyl)-3*H*-dinaphth[2,1-*c*:1′,2′-*e*]azepinium bromide NEW

$C_{42}H_{36}BrF_6N$
FW 748.64
[851942-93-3]



677086-50MG 50 mg

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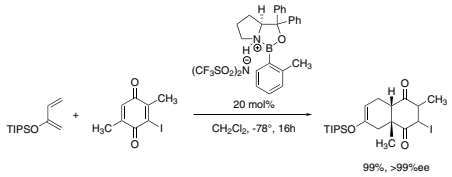
CBS Oxazaborolidines

Since 1987, the series of chiral oxazaborolidines known as CBS catalysts (after Corey, Bakshi, and Shibata) have been used for the catalytic reduction of prochiral ketones, imines, and oximes to produce chiral alcohols, amines, and amino alcohols, respectively, in excellent yields and enantiomeric excesses. The chiral Lewis acid generated from *o*-tolyl-CBS-oxazaborolidine after protonation with trifluoromethanesulfonimide has demonstrated great utility in the enantioselective Diels–Alder reaction (**Scheme 1**).[1]

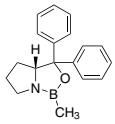


Scheme 1

References: (1) (a) Corey, E. J. et al. *J. Am. Chem. Soc.* **1987**, *109*, 5551. (b) Corey, E. J. et al. *J. Am. Chem. Soc.* **1987**, *109*, 7925. (c) Kirton, E. H. M. et al. *Tetrahedron Lett.* **2004**, *45*, 853. (d) Cho, B. T.; Chun, Y. S. *Tetrahedron: Asymmetry* **1992**, *3*, 337. (e) Cho, B. T.; Chun, Y. S. *J. Chem. Soc., Perkin Trans. 1* **1990**, 3200. (f) Tillyer, R. D. et al. *Tetrahedron Lett.* **1995**, *36*, 4337. (g) Ryu, D. H.; Corey, E. J. *J. Am. Chem. Soc.* **2003**, *125*, 6388.

(*R*)-(+)-2-Methyl-CBS-oxazaborolidine

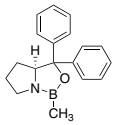
$C_{18}H_{20}BNO$
FW 277.17
[112022-83-0]



649317-1G	1 g
649317-10G	10 g

(*S*)-(–)-2-Methyl-CBS-oxazaborolidine

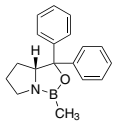
$C_{18}H_{20}BNO$
FW 277.17
[112022-81-8]



649309-1G	1 g
649309-10G	10 g

(*R*)-(+)-2-Methyl-CBS-oxazaborolidine solution

$C_{18}H_{20}BNO$
FW 277.17
[112022-83-0]

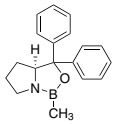


▸ **1 M in toluene**

457698-5ML	5 mL
457698-25ML	25 mL

(*S*)-(–)-2-Methyl-CBS-oxazaborolidine solution

$C_{18}H_{20}BNO$
FW 277.17
[112022-81-8]

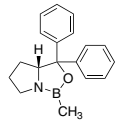


▸ **1 M in toluene**

457701-5ML	5 mL
457701-25ML	25 mL

(*R*)-(+)-2-Methyl-CBS-oxazaborolidine solution

$C_{18}H_{20}BNO$
FW 277.17
[112022-83-0]

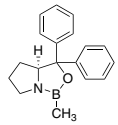


▸ **1 M in tetrahydrofuran**

674656-5ML	5 mL
674656-25ML	25 mL

(*S*)-(–)-2-Methyl-CBS-oxazaborolidine solution

$C_{18}H_{20}BNO$
FW 277.17
[112022-81-8]

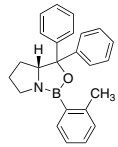


▸ **1 M in tetrahydrofuran**

674648-5ML	5 mL
674648-25ML	25 mL

(*R*)-(+)-*o*-Tolyl-CBS-oxazaborolidine solution

$C_{24}H_{24}BNO$
FW 353.26
[865812-10-8]

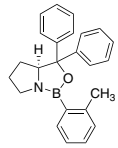


▸ **0.5 M in toluene**

654299-5ML	5 mL
654299-25ML	25 mL

(*S*)-(–)-*o*-Tolyl-CBS-oxazaborolidine solution

$C_{24}H_{24}BNO$
FW 353.26
[463941-07-3]



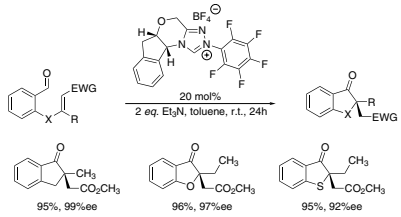
▸ **0.5 M in toluene**

654302-5ML	5 mL
654302-25ML	25 mL

N-Heterocyclic Carbene (NHC) Compounds

Rovis Catalysts

Rovis has demonstrated that triazolium salt **667080** in the presence of a base can act as an N-heterocyclic carbene organocatalyst[1] in highly enantioselective intramolecular Stetter reactions.[2] The Stetter reaction (conjugate addition of an aldehyde to an α,β-unsaturated compound) is a superb method for the construction of 1,4-dicarbonyl compounds bearing quaternary stereocenters (**Scheme 1**).

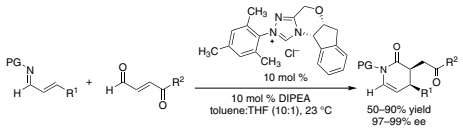


Scheme 1

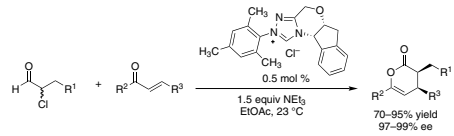
Bode Catalysts

Beginning in 2004, Bode and co-workers extended the use of NHCs as organocatalysts by developing new approaches to the catalytic generation of reactive species including activated carboxylates, homoenolates, and enolates. Critical to the success of these processes is an N-mesityl substituent on an imidazolium or triazolium NHC precursor. These novel catalysts and reactions make possible a new generation of highly enantioselective annulations from simple starting materials under mild reaction conditions, usually at room temperature and without added reagents. For example, chiral **683973** catalyzes an inverse-electron demand Diels–Alder reaction of activated enals and α,β-unsaturated imines to afford *cis*-dihydropyridinones with outstanding selectivity (**Scheme 2**).[3] The use of α-chloro aldehydes as starting materials is viable, and also makes possible enantioselective annulations with enones using less than 1 mol % of the chiral NHC catalysts (**Scheme 3**).[4] These catalysts promote highly enantioselective cyclopentene-forming annulations of simple enals and activated enones (**Scheme 4**).[5] Achiral catalyst **688487** is also useful for redox esterifications and amidations of α-functionalized aldehydes.[6]

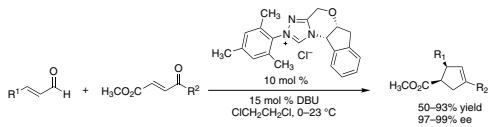
**Bode Catalysts are sold in collaboration with BioBlocks, Inc.*



Scheme 2



Scheme 3

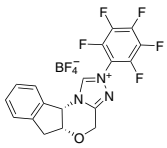


Scheme 4

References: (1) For a review on NHC organocatalysts, see: Marion, N.; Díez-González, S.; Nolan, S. P. *Angew. Chem. Int. Ed.* **2007**, *46*, 2. (2) Kerr, M. S.; Rovis, T. *J. Am. Chem. Soc.* **2004**, *126*, 8876. (3) He, M.; Struble, J. R.; Bode, J. W. *J. Am. Chem. Soc.* **2006**, *128*, 8418. (4) He, M.; Uc, G. J.; Bode, J. W. *J. Am. Chem. Soc.* **2006**, *128*, 15088. (5) Chiang, P.-C.; Kaeobamrung, J.; Bode, J. W. *J. Am. Chem. Soc.* **2007**, *129*, 3520. (6) Sohn, S. S.; Bode, J. W. *Angew. Chem., Int. Ed.* **2006**, *45*, 6021.

5a(*R*),10b(*S*)-5a,10b-Dihydro-2-(pentafluorophenyl)-4*H*,6*H*-indeno[2,1-*b*][1,2,4]triazolo[4,3-*d*][1,4]oxazinium tetrafluoroborate, 97%

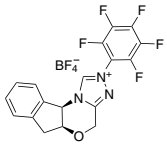
$C_{18}H_{11}BF_9N_3O$
FW 467.10
[872143-57-2]



674788-250MG	250 mg

5a(*S*),10b(*R*)-5a,10b-Dihydro-2-(pentafluorophenyl)-4*H*,6*H*-indeno[2,1-*b*][1,2,4]triazolo[4,3-*d*][1,4]oxazinium tetrafluoroborate, 97%

$C_{18}H_{11}BF_9N_3O$
FW 467.10
[740816-14-2]

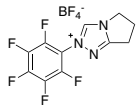


667080-250MG	250 mg

6,7-Dihydro-2-pentafluorophenyl-5*H*-pyrrolo[2,1-*c*]-1,2,4-triazolium tetrafluoroborate, 97%

NEW

$C_{11}H_7BF_9N_3$
FW 362.99
[862095-91-8]

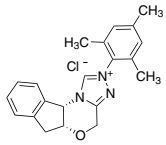


683701-100MG	100 mg
683701-500MG	500 mg

(5a*R*,10b*S*)-5a,10b-Dihydro-2-(2′,2,4′,6′-trimethylphenyl)-4*H*,6*H*-indeno[2,1-*b*]-1,2,4-triazolo[4,3-*d*]-1,4-oxazinium chloride monohydrate, 97%

NEW

$C_{21}H_{22}ClN_3O$
FW 367.87
[903571-02-8]

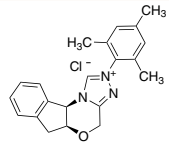


683973-100MG	100 mg
683973-250MG	250 mg

(5a*S*,10b*R*)-5a,10b-Dihydro-2-(2′,4′,6′-trimethylphenyl)-4*H*, 6*H*-indeno[2,1-*b*]-1,2,4-triazolo[4,3-*d*]-1,4-oxazinium chloride monohydrate, 97%

NEW

$C_{21}H_{22}ClN_3O$
FW 367.87

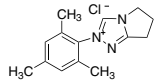


683981-100MG	100 mg
683981-250MG	250 mg

2-Mesityl-2,5,6,7-tetrahydropyrrolo[2,1-*c*][1,2,4]triazol-4-ium chloride, 97%

NEW

$C_{14}H_{18}ClN_3$
FW 263.77

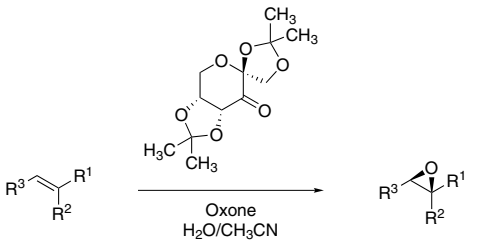


688487-100MG	100 mg
688487-250MG	250 mg

Shi Epoxidation Catalyst

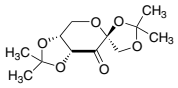
This organocatalyst is able to epoxidize *trans* alkenes and certain *cis* alkenes with good to excellent yields and selectivities.

Reference: (1) Wang, Z.-X.; Tu, Y.; Frohn, M.; Zhang, J.-R.; Shi, Y. *J. Am. Chem. Soc.* **1997**, *119*, 11224.



1,2:4,5-Di-*O*-isopropylidene-β-D-*erythro*-2,3-hexodiulo-2,6-pyranose, 98%

$C_{12}H_{18}O_6$
FW 258.27
[18422-53-2]



520160-1G	1 g
520160-5G	5 g

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(1) *Enantioselective Organocatalysis: Reactions and Experimental Procedures*; Dalko, P. I., Ed.; Wiley-VCH: Weinheim, 2007.

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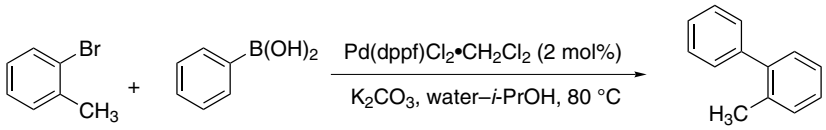

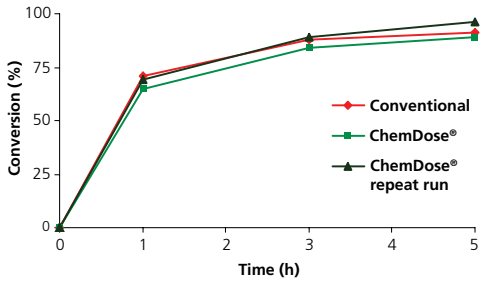

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Reference (1) Ruhland, T. et al. *J. Comb. Chem.* **2007**, *9*, 301.

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