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Chiral Bifunctional Thiourea–Phosphane Organocatalysts in Asymmetric Allylic Amination of Morita–Baylis–Hillman Acetates

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A series of new chiral bifunctional thiourea–phosphane catalysts was synthesized and successfully applied in the catalytic, asymmetric allylic amination of Morita–Baylis–Hillman (MBH) acetates derived from the methyl vinyl ketone (MVK) or ethyl vinyl ketone (EVK) system, with phthalimide, affording the amination products in up to over 99 % yield and 90 % *ee* for a wide range of substrates derived from different aromatic aldehydes.

Introduction

β-Hydroxy-α-methylene-carbonyl-containing compounds or their derivatives are valuable building blocks in organic synthesis, due to their densely multifunctional characteristics.[1] Recently, efforts to synthesize these chiral compounds have been directed toward the following two aspects: the asymmetric Morita–Baylis–Hillman (MBH) reaction and the asymmetric substitution of MBH acetates or carbonates. Compared with the asymmetric MBH reaction, the asymmetric substitution of MBH acetates or carbonates received wider interest from scientists, because it is applicable to a broader range of substrates.[2] In 2004, Krische[2b] first reported the asymmetric substitution of MBH acetates with phthalimide and its derivatives, catalyzed by chiral phosphanes, to give the corresponding substitution products in good yields along with moderate *ee* values. Later on, Lu[3a] and Hiemstra[3b] reported the asymmetric substitution of MBH carbonates with various nucleophiles, catalyzed by 4-(3-ethyl-4-oxa-1-azatricyclo[4,4,0,$0^{3,8}$]dec-5-yl)-quinolin-6-ol (β-ICD), affording the corresponding amination products in excellent yields along with modest *ee* values. In 2007, Hou and co-workers used planar chiral [2,2]-paracyclophane monophosphanes as catalysts to provide the allylic amination products in high regioselectivities and modest enantioselectivities (9–71 % *ee*s).[4] Moreover, thus far, Chen and co-workers have used $(DHQD)_2AQN$, $(DHQD)_2PHAL$, $(DHQD)_2PYR$, and β-ICD in asymmetric substitutions of MBH carbonates to achieve C–C bond,[5a–5d] C–N bond,[5e–5f] and C–O bond[5g–5h] formation in good yields along with high enantioselectivities. More recently, Wang and co-workers also reported the construction of chiral allylic phosphane oxides by using cinchona alkaloids as catalysts through substitution of MBH carbonates in excellent yields along with high enantioselectivities.[6] In these successful examples, acetates or carbonates of MBH alcohols derived from acrylate are commonly used starting materials; however, highly enantioselective substitutions of acetates or carbonates of MBH alcohols derived from methyl vinyl ketone (MVK) or ethyl vinyl ketone (EVK) have seldom been reported,[2b,3a,4,7] except by our group using chiral bifunctional phosphanes as catalysts to enantioselectively construct γ-butenolides in high yields and *ee* values.[8] At the present stage, finding new catalysts to achieve the highly enantioselective substitution of MBH acetates or carbonates derived from MVK or EVK is still a highly desirable goal.

Chiral bifunctional phosphane organocatalysts, which contain Lewis basic and Brønsted acidic sites within one molecule, have received considerable attention due to their high efficiency and excellent enantioselectivities in the asymmetric MBH/aza-MBH reaction, cycloaddition of allenic esters, and other related reactions.[9] Thus far, the groups of Miller[10] and Zhao[11] reported that chiral bifunctional phosphane catalysts derived from amino acids could catalyze [3+2] cycloaddition between allenic esters and electron-deficient olefins, affording the cyclopentene derivatives in excellent diastereo- and enantioselectivities, respectively. In 2008, Jacobsen developed a series of thiourea–phosphane catalysts derived from chiral *trans*-2-amino-1-(diphenylphosphanyl)cyclohexane, which succeeded in catalyzing imine-allene [3+2] cycloaddition with high enantioselectivities.[12] More recently, Wu and co-workers reported thiourea–phosphane catalysts with the *trans*-2-amino-1-(diphenylphosphanyl)cyclohexane skeleton, which could catalyze the asymmetric MBH reaction of aldehydes with MVK in excellent enantioselectivities,[13a] and thiourea–phosphane catalysts derived from amino acids succeeded in cata-

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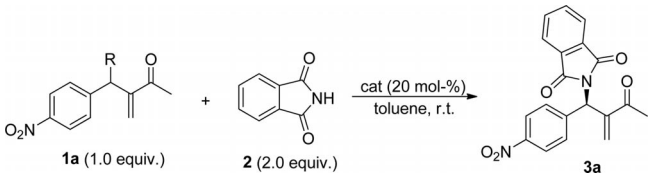
lyzing inter- and intramolecular asymmetric MBH reactions.[13b–13c] Our group has also developed a series of chiral bifunctional phosphane organocatalysts and demonstrated their excellent catalytic activities and enantioselectivities for the asymmetric aza-MBH reaction[14] and their good catalytic activities and modest enantioselectivities for the allylic amination of MBH acetates derived from MVK.[7] As a part of our continuing interest in chiral bifunctional phosphane organocatalysts,[15] we developed a series of chiral bifunctional thiourea–phosphane organocatalysts (**TP**) and examined their performance for the allylic amination of MBH acetates with phthalimide. Herein, we are delighted to report our new chiral bifunctional thiourea–phosphane organocatalysts, which can achieve highly enantioselective allylic amination of acetates of MBH alcohols derived from MVK and EVK for the first time.

Results and Discussion

Initially, we tested the chiral bifunctional thiourea–phosphane **TP1** (Figure 1), which was an excellent catalyst for the asymmetric aza-MBH reaction,[14g] in the reaction of MVK-derived MBH acetate **1a** with phthalimide **2** in toluene at room temperature, only to obtain unsatisfactory results (Table 1, entry 1). We then tuned the Brønsted acidic site of the catalyst in terms of electronic effects and structural flexibility, and synthesized catalysts **TP2** and **TP3** (Figure 1). Catalyst **TP2** with more acidic NH protons did not increase the yield significantly but improved the *ee* value to 56% (Table 1, entry 2). Surprisingly, a slightly structurally more flexible catalyst, **TP3**, afforded product **3a** in high yield (94%) along with good enantioselectivity (82% *ee*) (Table 1, entry 3). On the basis of these results, we continued to modify the catalysts and synthesized a series of chiral bifunctional thiourea–phosphane catalysts, **TP4**–**TP11**, whose structures are also summarized in Figure 1 (for synthetic details, see the Supporting Information). Under identical reaction conditions, catalysts **TP4**–**TP11** were all effective for this reaction, giving the desired product **3a** in modest to good yields and *ee* values (Table 1, entries 4–11). Among these catalysts, **TP5** showed the best enantioselectivity in this reaction, producing **3a** in 80% yield along with an value of 85% *ee* (Table 1, entry 5), and **TP4** was less effective because of its slower reaction rate and lower yield (Table 1, entry 4). Using **TP5** as catalyst, we also utilized MBH benzoate or MBH carbonate as substrate instead of MBH acetate in this reaction and found that MBH benzoate gave **3a** in a lower yield (Table 1, entry 12) and MBH carbonate afforded **3a** in a lower *ee* value under the standard conditions (Table 1, entry 13) employed.

Table 1. Catalyst screening for the reaction of MVK-derived MBH acetate **1a** with phthalimide **2**.



Entry[a]	Catalyst	R	Time [h]	Yield [%][a]	*ee* [%][b]
1	**TP1**	OAc	48	20	26
2	**TP2**	OAc	80	23	56
3	**TP3**	OAc	18	94	82
4	**TP4**	OAc	107	69	82
5	**TP5**	OAc	22	80	85
6	**TP6**	OAc	24	77	80
7	**TP7**	OAc	24	80	81
8	**TP8**	OAc	36	83	74
9	**TP9**	OAc	15	88	83
10	**TP10**	OAc	24	71	74
11	**TP11**	OAc	14	86	79
12	**TP5**	OBz	69	57	84
13	**TP5**	OBoc	24	80	67

[a] Isolated yields. [b] Determined by chiral HPLC.

Next, we further examined the solvent and temperature effects with **TP3** or **TP5** as catalyst in this reaction. The results are summarized in Table 2. It was found that toluene is the best solvent to afford **3a** in higher yield as well as good enantioselectivity (Table 2, entries 1–6 and 8), with **TP3** as catalyst. Decreasing the temperature, diluting the concentration of substrates, and changing the ratio of substrates did not afford **3a** in higher yield and *ee* (Table 2, entries 6–11). Using **TP5** as catalyst, we found that toluene, benzene, and 1,2-dichlorobenzene (DCE) were better solvents than others, affording **3a** in higher *ee* values (Table 2, entries 12–17). Choosing 1,2-dichlorobenzene as solvent due to its better solubility for phthalimide, we found that, when the reaction was carried out at 10 °C, **3a** was obtained in higher yield and *ee*. Furthermore, when we increased the

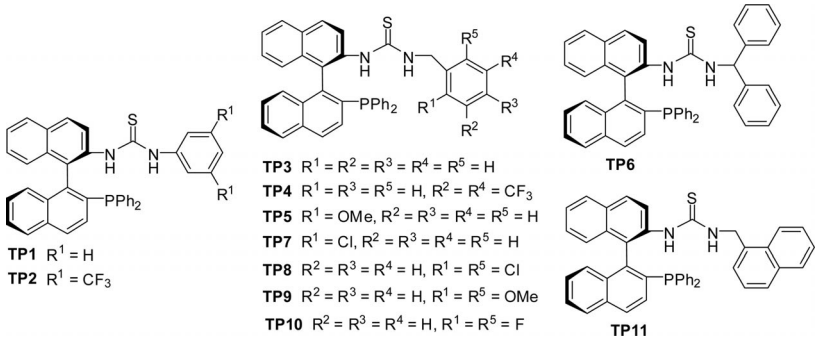
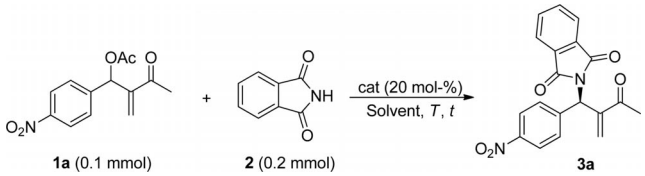


Figure 1. Chiral bifunctional thiourea–phosphane organocatalysts **TP1**–**TP11**.

Table 2. Optimization of the reaction conditions for the reaction of MVK-derived MBH acetate **1a** with phthalimide **2**.



Entry	Catalyst	Solvent [mL]	*T* [°C]	*t* [h]	Yield [%][a]	*ee* [%][b]
1	**TP3**	CH_3CN (0.5)	room temp.	40	34	74
2	**TP3**	DCM (0.5)	room temp.	40	60	81
3	**TP3**	CCl_4 (0.5)	room temp.	60	43	70
4	**TP3**	DCE (0.5)	room temp.	24	69	85
5	**TP3**	*para*-xylene (0.5)	room temp.	36	51	75
6	**TP3**	THF (0.5)	room temp.	24	80	73
7	**TP3**	THF (0.5)	0	42	71	77
8	**TP3**	toluene (0.5)	room temp.	18, 24[c]	94, 88[c]	82, 82[c]
9	**TP3**	toluene (0.5)	10	48	40	83
10	**TP3**	toluene (0.5)	0	42	49	82
11	**TP3**	toluene (2.0)	room temp.	30	63	82
12	**TP5**	DCE (1.0)	room temp.	56, 80[c]	69, 77[c]	82, 83[c]
13	**TP5**	$CHCl_3$ (1.0)	room temp.	21	91	80
14	**TP5**	*para*-xylene (1.0)	room temp.	57	68	80
15	**TP5**	toluene (0.5)	room temp.	24	80	85
16	**TP5**	benzene (0.5)	room temp.	12	91	85
17	**TP5**	1,2-dichlorobenzene (0.5)	room temp.	22	86	83
18	**TP5**	1,2-dichlorobenzene (0.5)	10	72[d], 61[d,e]	94[d], 91[d,e]	89[d], 90[d,e]

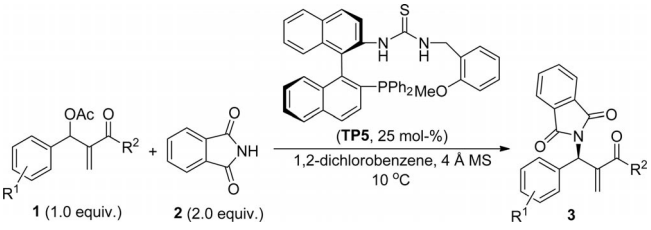
[a] Isolated yields. [b] Determined by chiral HPLC. [c] The reaction was performed by using **1a** (0.2 mmol), **2** (0.1 mmol). [d] 4 Å molecular sieves (MS) was added. [e] 25 mol-% catalyst was used.

amount of catalyst employed to 25 mol-% and added 4 Å molecular sieves (MS), we obtained **3a** in 91% yield and 90% *ee* (Table 2, entries 17 and 18).

Under these optimal conditions, we next examined the generality of this reaction with various MBH acetates **1**, and the results are summarized in Table 3. All of the reactions proceeded smoothly under the optimal conditions, producing the desired products **3** in good to excellent yields (71–99%) along with good to excellent enantioselectivities (81–90% *ee*s), regardless of whether they had electron-withdrawing or electron-donating substituents on their aromatic rings (Table 3, entries 1–12). The substrates derived from ethyl vinyl ketone (EVK) also exhibited good results under identical conditions (Table 3, entry 13). Multiple substituents on the aromatic ring (Table 3, entry 14) also gave the corresponding product **3n** in excellent yield along with a good *ee* value. The absolute configuration of products **3** was unequivocally assigned as (*R*) by X-ray diffraction analysis of **3e** bearing a bromine atom on the benzene ring (see the Supporting Information). This asymmetric catalytic system is not applicable to MBH acetates derived from acrylates, because these chiral bifunctional thiourea–phosphane catalysts showed lower catalytic activities toward MBH acetates derived from acrylates.

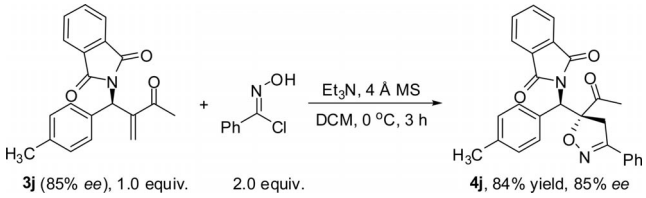
We have further explored the transformation of the obtained products **3** in order to illustrate their synthetic versatility. For example, product **3j** could be smoothly transformed into a synthetically more useful compound through [3+2] cycloaddition with chlorobenzaldoxime in dichloromethane (DCM) at 0 °C, affording the major diastereomeric product **4j** in 84% isolated yield with *ee* value retained (the total diastereomeric selectivity was 6:1) (Scheme 1).[5e]

Table 3. Asymmetric allylic amination of various MBH acetates **1** with phthalimide **2** catalyzed by **TP 5**.



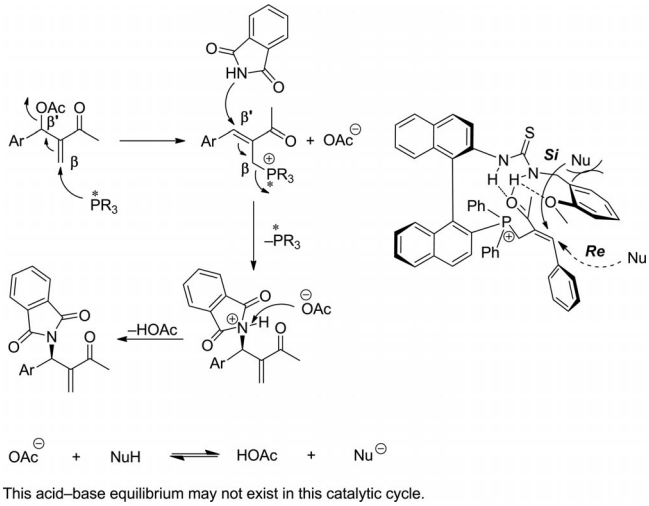
Entry[a]	R^1	R^2	Time [h]	Yield [%][b]	*ee* [%][c]
1	**1a**, 4-NO_2	Me	61	**3a**, 91	90
2	**1b**, 3-NO_2	Me	65	**3b**, 80	85
3	**1c**, 4-CF_3	Me	85	**3c**, 78	87
4	**1d**, 4-CN	Me	87	**3d**, >99	85
5	**1e**, 4-Br	Me	86	**3e**, 86	88
6	**1f**, 2-Br	Me	96	**3f**, 73	84
7	**1g**, 4-Cl	Me	87	**3g**, 77	86
8	**1h**, 3-Cl	Me	86	**3h**, 82	84
9	**1i**, 2-Cl	Me	86	**3i**, 71	85
10	**1j**, 4-Me	Me	118	**3j**, 83	85
11	**1k**, 3-Me	Me	111	**3k**, 75	83
12	**1l**, H	Me	111	**3l**, 72	81
13	**1m**, 4-NO_2	Et	70	**3m**, 85	90
14	**1n**, 3,5-$(CF_3)_2$	Et	62	**3n**, 99	80

[a] Reaction was carried out with **1** (0.1 mmol), **2** (0.2 mmol), and 4 Å molecular sieves (MS) (20 mg) in 0.5 mL of 1,2-dichlorobenzene. [b] Isolated yields. [c] Determined by chiral HPLC.



Scheme 1. [3+2] Cycloaddition of product **3j** with chlorobenzaldoxime.

On the basis of the experimental results and Krische's proposed tandem S_N2'–S_N2' mechanism,[2c,2d] a plausible mechanism and an activation model are outlined in Scheme 2. The direct addition of nucleophilic bifunctional thiourea–phosphane catalyst to the MBH acetate generates the electrophilic leaving group (OAc^-) ion pair. In the mechanism proposed by Krische, the acetate engages in an acid–base equilibrium involving deprotonation of the pronucleophile. In our case, the pK_a value of pronucleophile phthalimide (pK_a = 8.3)[16] is larger than that of acetic acid (pK_a = 4.8),[17] which should not allow the acetate to deprotonate the phthalimide. Thus, we propose that the phthalimide directly attacks the β′-position of the olefin from *Re* face of the olefin due to a steric repulsion between the aromatic group of the catalyst and the phthalimide if it attacks from the *Si* face of the olefin. Finally, the acetate takes off a proton to produce the product. It is worth noting that catalyst **TP1**, subtly modified by adding one methylene group between the thiourea moiety and the phenyl ring, is very important in increasing the catalytic activity and enantioselectivity. Presumably, it gives some structural flexibility and prevents the catalyst and the MBH acetate from approaching too closely to react with the nucleophile.



Scheme 2. Possible mechanism and activation model.

In summary, we have synthesized a series of chiral bifunctional thiourea–phosphane catalysts and developed a new highly efficient catalytic, asymmetric allylic amination of MBH acetates derived from the MVK or EVK system for the first time, which is applicable to a wide range of substrates from different aromatic aldehydes. The catalytic system reported here afforded the amination products **3** in up to >99% yield along with 90% *ee*. Current efforts are in progress to use these chiral bifunctional thiourea–phosphane catalysts for other asymmetric substitutions of MBH acetates.

Experimental Section

General Remarks: Melting points were determined with a digital melting point apparatus. Optical rotations were determined at 589 nm (sodium D line) by using a Perkin–Elmer-341 MC digital polarimeter. Values of $[\alpha]_D$ are given in units of 10^{-1} cm^2 g^{-1}. ^{1}H NMR spectra were recorded with a Bruker AM-300 and an AM-400 spectrometer for solution in $CDCl_3$ with tetramethylsilane (TMS) as an internal standard; coupling constants, *J*, are given in Hz. ^{13}C NMR spectra were recorded with Bruker AM-300 or AM-400 spectrophotometers (75 or 100 MHz, respectively) with complete proton decoupling spectrophotometers ($CDCl_3$: 77.0 ppm). Infrared spectra were recorded with a Perkin–Elmer PE-983 spectrometer with absorption in cm^{-1}. Flash column chromatography was performed by using 300–400 mesh silica gel. For thin-layer chromatography (TLC), silica gel plates (Huanghai GF254) were used. Chiral HPLC was performed with a SHIMADZU SPD-10A *vp* series instrument with chiral columns [Chiralpak AD-H, OD-H, and IC-H columns 4.6 × 250 mm, (Daicel Chemical Ind., Ltd.)]. Mass spectra (EI, ESI, MALDI, and HRMS) were measured with a HP-5989 instrument.

General Procedure for the Preparation of Catalysts

(*R*)-1-[2′-(Diphenylphosphanyl)-1,1′-binaphthyl-2-yl]-3-(2-methoxybenzyl)thiourea (TP5): The compound was prepared according to General Procedure C (see p. 20 in the Supporting Information). Under an argon atmosphere, a mixture of (*R*)-2′-(diphenylphosphanyl)-1,1′-binaphthyl-2-amine (**II**)[14i,18] (363 mg, 1.0 equiv.) and isothiocyanate (287 mg, 2.0 equiv.) in THF (1.0 mL) was heated at reflux for 4 d. Then, the solvent was removed under reduced pressure, and the residue was chromatographed on silica gel (elution with petroleum ether/EtOAc 20:1–8:1) to give catalyst **TP5**. Yield: 275 mg, 54%; syrupy oil. IR (CH_2Cl_2): $\tilde{\nu}$ = 3375, 2956, 2925, 2855, 1740, 1671, 1592, 1529, 1461, 1434, 1377, 1315, 1277, 1246, 1163, 1136, 1094, 1027, 950, 817, 744, 697, 660, 623 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ = 3.63 (s, 3 H), 4.20–4.25 (m, 1 H), 4.73–4.76 (m, 1 H), 6.73–6.81 (m, 4 H), 6.95–7.05 (m, 5 H), 7.08–7.13 (m, 5 H), 7.16–7.22 (m, 3 H), 7.28–7.30 (m, 3 H), 7.34–7.41 (m, 2 H), 7.46–7.50 (m, 2 H), 7.85 (d, *J* = 8.0 Hz, 1 H), 7.90 (dd, *J* = 6.0, 8.0 Hz, 2 H), 7.95 (d, *J* = 8.8 Hz, 1 H) ppm. ^{31}P NMR (161.93 MHz, $CDCl_3$, 85% H_3PO_4): δ = –14.76 ppm. MS (ESI): *m*/*z* (%) = 633.5 (100) $[M + 1]^+$. HRMS (ESI): calcd. for $C_{41}H_{33}N_2NaOPS^{+1}$ $[M + Na]^+$ 655.1943; found 655.1961. $[\alpha]_D^{20}$ = +197.0 (*c* = 1.0, $CHCl_3$).

General Procedure for the Asymmetric Allylic Amination of Morita–Baylis–Hillman Acetates: Under an argon atmosphere, a solution of MBH acetate **1a** (0.1 mmol, 26 mg), compound **2** (0.2 mmol, 29 mg), catalyst **TP5** (0.025 mmol, 16 mg), and 4 Å molecular sieves (MS) (20 mg) in 1,2-dichlorobenzene (0.5 mL) was stirred at 10 °C. After compound **1a** was completely consumed, the solvent was removed under reduced pressure, and the residue was chromatographed on silica gel (elution with petroleum ether/EtOAc 10:1–4:1) to provide compound **3a** (32 mg, 91% yield).

(R)-2-[2-Methylene-1-(4-nitrophenyl)-3-oxobutyl]isoindoline-1,3-dione (3a): This is a known compound.[2b] ^{1}H NMR (300 MHz, $CDCl_3$, TMS): δ = 2.43 (s, 3 H, CH_3), 5.77 (s, 1 H, CH), 6.44 (s, 1

H, CH), 6.53 (s, 1 H, CH), 7.57 (d, J = 8.7 Hz, 2 H, ArH), 7.73–7.76 (m, 2 H, ArH), 7.83–7.86 (m, 2 H, ArH), 8.21 (d, J = 8.7 Hz, 2 H, ArH) ppm. The enantiomeric excess was determined by HPLC with a Chiralcel OD-H column [λ = 214 nm; eluent: Hexane/Isopropyl alcohol 70:30; flow rate: 0.7 mL/min; t_{major} = 21.19 min, t_{minor} = 30.55 min; *ee*% = 90%. $[a]_D^{20}$ = +66.5 (c = 1.0, $CHCl_3$)].

Supporting Information (see footnote on the first page of this article): Spectroscopic data and chiral HPLC traces of the compounds shown in Tables 1, 2, and 3, X-ray crystallographic data for **3e**, and the detailed descriptions of the experimental procedures.

Acknowledgments

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[1] For selected reviews on the Morita–Baylis–Hillman reaction, see: a) S. E. Drewes, G. H. P. Roos, *Tetrahedron* **1988**, *44*, 4653–4670; b) D. Basavaiah, P. D. Rao, R. S. Hyma, *Tetrahedron* **1996**, *52*, 8001–8062; c) E. Ciganek in *Organic Reactions* (Ed.: L. A. Paquette), Wiley, New York, **1997**, vol. 51, pp. 201–350; d) P. Langer, *Angew. Chem.* **2000**, *112*, 3177–3180; *Angew. Chem. Int. Ed.* **2000**, *39*, 3049–3051; e) D. Basavaiah, A. J. Rao, T. Satyanarayana, *Chem. Rev.* **2003**, *103*, 811–892; f) Y.-L. Shi, M. Shi, *Eur. J. Org. Chem.* **2007**, 2905–2916; g) G. Masson, C. Housseman, J.-P. Zhu, *Angew. Chem.* **2007**, *119*, 4698–4712; *Angew. Chem. Int. Ed.* **2007**, *46*, 4614–4628; h) D. Basavaiah, K. V. Rao, R. J. Reddy, *Chem. Soc. Rev.* **2007**, *36*, 1581–1588; i) C. Menozzi, P. I. Dalko, "Organocatalytic Enantioselective Morita–Baylis–Hillman Reactions in Enantioselective Organocatalysis" in *Reactions and Experimental Procedures* (Ed.: P. I. Dalko), Wiley-VCH, Weinheim, **2007**; j) V. Dederck, J. Mattinez, F. Lamaty, *Chem. Rev.* **2009**, *109*, 1–48; k) G.-N. Ma, J.-J. Jiang, M. Shi, Y. Wei, *Chem. Commun.* **2009**, *45*, 5496–5514; l) D. Basavaiah, B. S. Reddy, S. S. Badsara, *Chem. Rev.* **2010**, *110*, 5447–5674.

[2] For selected reports on S_N2'–S_N2' substitution of Morita–Baylis–Hillman acetates or carbonates, see: a) B. M. Trost, M. R. Machacek, H. C. Tsui, *J. Am. Chem. Soc.* **2005**, *127*, 7014–7024; b) C.-W. Cho, J.-R. Kong, M. J. Krische, *Org. Lett.* **2004**, *6*, 1337–1339; c) C.-W. Cho, M. J. Krische, *Angew. Chem.* **2004**, *116*, 6857–6859; *Angew. Chem. Int. Ed.* **2004**, *43*, 6689–6691; d) H. Park, C.-W. Cho, M. J. Krische, *J. Org. Chem.* **2006**, *71*, 7892–7894; e) S. Kobbelgaard, S. Brandes, K. A. Jørgensen, *Chem. Eur. J.* **2008**, *14*, 1464–1471.

[3] a) Y.-S. Du, X.-L. Han, X.-Y. Lu, *Tetrahedron Lett.* **2004**, *45*, 4967–4971; b) D. J. V. C. van Steenis, T. Marcelli, M. Lutz, A. L. Spek, J. H. van Maarseveen, H. Hiemstra, *Adv. Synth. Catal.* **2007**, *349*, 281–286.

[4] T.-Z. Zhang, L.-X. Dai, X.-L. Hou, *Tetrahedron: Asymmetry* **2007**, *18*, 1990–1994.

[5] a) K. Jiang, J. Peng, H.-L. Cui, Y.-C. Chen, *Chem. Commun.* **2009**, *45*, 3955–3957; b) H.-L. Cui, J. Peng, X. Feng, W. Du, K. Jiang, Y.-C. Chen, *Chem. Eur. J.* **2009**, *15*, 1574–1577; c) H.-L. Cui, J.-R. Huang, J. Lei, Z.-F. Wang, S. Chen, L. Wu, Y.-C. Chen, *Org. Lett.* **2010**, *12*, 720–723; d) J. Peng, X. Huang, H.-L. Cui, Y.-C. Chen, *Org. Lett.* **2010**, *12*, 4260–4263; e) S.-J. Zhang, H.-L. Cui, K. Jiang, R. Li, Z.-Y. Ding, Y.-C. Chen, *Eur. J. Org. Chem.* **2009**, 5804–5809; f) H.-L. Cui, X. Feng, J. Peng, J. Lei, K. Jiang, Y.-C. Chen, *Angew. Chem.* **2009**, *121*, 5847–5850; *Angew. Chem. Int. Ed.* **2009**, *48*, 5737–5740; g) Z.-K. Hu, H.-L. Cui, K. Jiang, Y.-C. Chen, *Sci. China, Ser.B Chem.* **2009**, *52*, 1309–1313; h) X. Feng, Y.-Q. Yuan, H.-L. Cui, K. Jiang, Y.-C. Chen, *Org. Biomol. Chem.* **2009**, *7*, 3660–3662.

[6] a) L. Hong, W.-S. Sun, C.-X. Liu, D.-P. Zhao, R. Wang, *Chem. Commun.* **2010**, *46*, 2856–2858; b) W.-S. Sun, L. Hong, C.-X. Liu, R. Wang, *Org. Lett.* **2010**, *12*, 3914–3917.

[7] G.-N. Ma, S.-H. Cao, M. Shi, *Tetrahedron: Asymmetry* **2009**, *20*, 1086–1092. In this paper, enantioselective allylic substitution of Morita–Baylis–Hillman (MBH) acetates with phthalimide was realized in the presence of a new L-proline-derived chiral trifunctional phosphane amide ligand to give the corresponding allylic amination adducts in good yields (70–95%) and modest to good enantioselectivities (34–78% *ee*).

[8] Y.-Q. Jiang, Y.-L. Shi, M. Shi, *J. Am. Chem. Soc.* **2008**, *130*, 7202–7203.

[9] Y. Wei, M. Shi, *Acc. Chem. Res.* **2010**, *43*, 1005–1018.

[10] B. J. Cowen, S. J. Miller, *J. Am. Chem. Soc.* **2007**, *129*, 10988–10989.

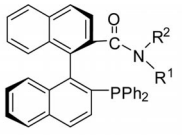
[11] H. Xiao, Z. Chai, C.-W. Zheng, Y.-Q. Yang, W. Liu, J.-K. Zhang, G. Zhao, *Angew. Chem.* **2010**, *122*, 4569–4572; *Angew. Chem. Int. Ed.* **2010**, *49*, 4467–4470.

[12] Y.-Q. Fang, E. N. Jacobsen, *J. Am. Chem. Soc.* **2008**, *130*, 5660–5661.

[13] a) K. Yuan, L. Zhang, H.-L. Song, Y. Hu, X.-Y. Wu, *Tetrahedron Lett.* **2008**, *49*, 6262–6264; b) J.-J. Gong, K. Yuan, X.-Y. Wu, *Tetrahedron: Asymmetry* **2009**, *20*, 2117–2120; c) K. Yuan, H.-L. Song, Y. Hu, J.-F. Fang, X.-Y. Wu, *Tetrahedron: Asymmetry* **2010**, *21*, 903–908.

[14] a) M. Shi, L.-H. Chen, *Chem. Commun.* **2003**, *39*, 1310–1311; b) M. Shi, L.-H. Chen, C.-Q. Li, *J. Am. Chem. Soc.* **2005**, *127*, 3790–3800; c) M. Shi, C.-Q. Li, *Tetrahedron: Asymmetry* **2005**, *16*, 1385–1391; d) M. Shi, L.-H. Chen, W.-D. Teng, *Adv. Synth. Catal.* **2005**, *347*, 1781–1789; e) Y.-H. Liu, L.-H. Chen, M. Shi, *Adv. Synth. Catal.* **2006**, *348*, 973–979; f) M. Shi, G.-N. Ma, J. Gao, *J. Org. Chem.* **2007**, *72*, 9779–9781; g) Y.-L. Shi, M. Shi, *Adv. Synth. Catal.* **2007**, *349*, 2129–2135; h) M. Shi, Y.-H. Liu, L.-H. Chen, *Chirality* **2007**, *19*, 124–128; i) M.-J. Qi, T. Ai, M. Shi, G. Li, *Tetrahedron* **2008**, *64*, 1181–1186; j) Y.-H. Liu, M. Shi, *Adv. Synth. Catal.* **2008**, *350*, 122–128; k) Z.-Y. Lei, G.-N. Ma, M. Shi, *Eur. J. Org. Chem.* **2008**, 3817–3820; l) Z.-Y. Lei, X.-G. Liu, M. Shi, M. Zhao, *Tetrahedron: Asymmetry* **2008**, *19*, 2058–2062; m) X.-Y. Guan, Y.-Q. Jiang, M. Shi, *Eur. J. Org. Chem.* **2008**, 2150–2155.

[15] We initially synthesized a series of chiral bifunctional amide–phosphane organocatalysts (**AP**) and used them in the catalytic asymmetric allylic amination of MBH acetates derived from MVK with phthalimide, but the obtained results are not successful (see Table S1 in the Supporting Information).



AP

[16] R. P. Bell, W. C. E. Higginson, *Proc. R. Soc.* **1949**, *197*, 141–159.

[17] J. F. J. Dippy, S. R. C. Hughes, A. Rozanski, *J. Chem. Soc.* **1959**, 2492–2498.

[18] a) K. Sumi, T. Ikariya, R. Noyori, *Can. J. Chem.* **2000**, *78*, 697–703; b) P. N. M. Botman, O. David, A. Amore, J. Dinkelaar, M. T. Vlaar, K. Goubitz, J. Fraanje, H. Schenk, H. Hiemsta, J. H. van Maarseveen, *Angew. Chem.* **2004**, *116*, 3553–3555; *Angew. Chem. Int. Ed.* **2004**, *43*, 3471–3473.

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