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Asymmetric Addition of Chiral 1,3,2-Benzoxazaphosphinine 2-Oxides to Aldehydes: Diastereoselective Synthesis of α-Substituted β-Hydroxyphosphonic Acids

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The addition of stabilized phosphorus anions to aldehydes leads to α-substituted β-hydroxyphosphonates. The diastereoselectivity of the process is strongly influenced by the substitution of the phosphorus atom. Whereas *P*-ethyl derivatives provide a mixture of three isomers, the presence of a benzyl group enhances the stereocontrol, providing two diastereomers in ratios of up to 5:1. Elimination of the aminomenthol appendage produces enantiopure α-phenyl-β-hydroxyphosphonic acids in high yields.

Introduction

α-Amino- and α-hydroxyphosphonic acid derivatives play an important role in biological processes.[1] Therefore, a number of easy and effective approaches to their synthesis have been developed, sometimes with high stereoselectivity.[2] In particular, chiral β-hydroxyphosphonic acids are precursors for the biosynthesis of antibiotics[3] and interesting building blocks for peptides and β-peptides.[4] Moreover, nonstabilized β-hydroxyphosphonates have been used in Horner–Wadsworth–Emmons-type coupling reactions with aldehydes or ketones.[5] Stereoselective approaches to these valuable compounds include the asymmetric reduction[6] or microbial and enzymatic reduction of β-ketophosphonates leading to chiral β-hydroxyphosphonates with high enantioselectivity.[7]

α-Substituted β-hydroxyphosphonates have been synthesized by the addition of phosphorylated anions to carbonyl groups[5] or by Baylis–Hillman reaction of vinylphosphonates.[8,9] The stereoselectivity of these processes is usually low and there are a few methods that lead to the creation of two new chiral centers with good diastereoselectivity.[10]

Recently, we[11] and others[12] reported on the stereoselective synthesis of α-alkylphosphonic acids using chiral perhydro-1,3,2-benzoxazaphosphinine 2-oxides derived from (–)-8-aminomenthol with good diastereocontrol and now we summarize our results on the preparation of enantiopure α-alkyl-substituted β-hydroxyphosphonic acids using the same chiral template.

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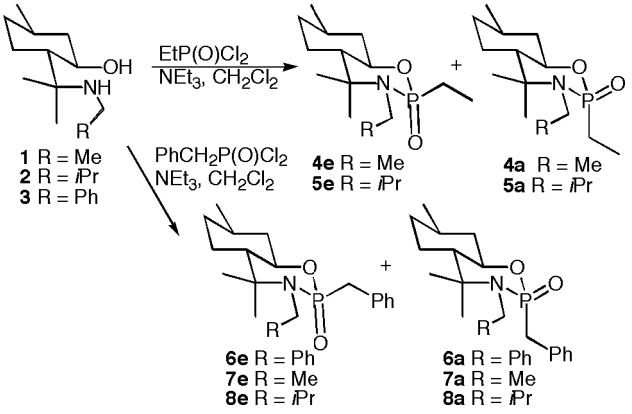
We have evaluated the effects of the nature of the substituents on the nitrogen and phosphorus atoms, their stereochemistry, and the structure of the carbonyl compound on the stereochemical outcome of the reaction.

Results and Discussion

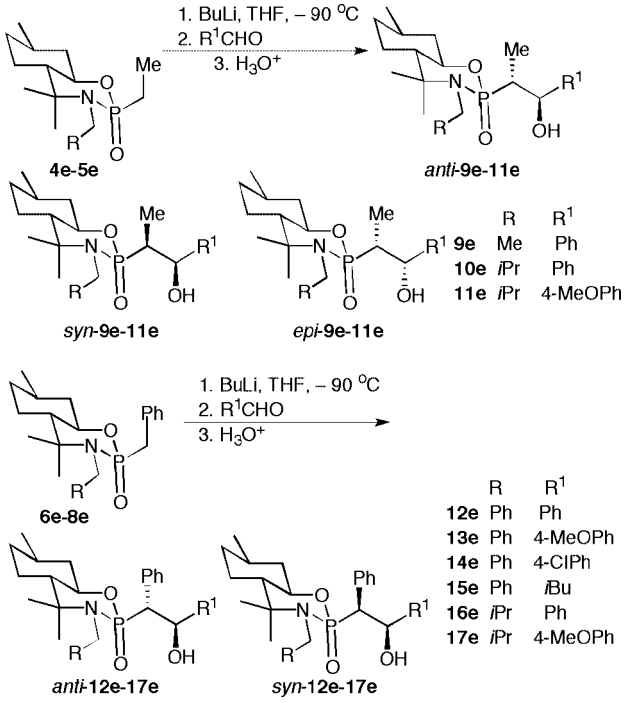
Perhydro-1,3,2-benzoxazaphosphinine 2-oxides **4**–**8** were obtained by the reaction[13] of the corresponding *N*-alkyl-substituted (–)-8-aminomenthols **1**–**3** with ethyl- or benzylphosphonyl dichloride, as depicted in Scheme 1. In each of these reactions a mixture of epimers was obtained with the substituent on the phosphorus atom either in equatorial (**4e**–**8e**) or axial (**4a**–**8a**) positions. As previously described,[14–16] the axially substituted phosphinines were obtained as the major diastereoisomers. These isomers were easily separated by flash chromatography and used sepa-



Scheme 1. Synthesis of 1,3,2-benzoxazaphosphinine 2-oxides **4**–**8**.

rately in the next step because the effect of the stereochemistry of the phosphorus atom on the diastereoselectivity of the reaction is known.[17]

We first studied the ethyl (**4e**, **5e**) and benzyl (**6e**–**8e**) equatorially substituted diastereoisomers. Different bases, such as *n*BuLi, *t*BuLi, or LDA, and experimental conditions were used to optimize the initial deprotonation of the phosphinines. In all cases, the best yields and diastereoselectivity were obtained with *n*BuLi (2 equiv., the yield decreased if only 1 equiv. was used) in THF at –90 °C, and these experimental conditions were thus used for all the reactions. The anions were formed by the reaction of **4e**–**8e** with *n*BuLi for 15 min followed by quenching with 1.2 equiv. of the appropriate aldehyde. The results are summarized in Scheme 2 and Table 1.



Scheme 2. Deprotonation of equatorially substituted phosphinines **4e**–**8e** and their subsequent addition to aldehydes.

The condensation reactions of oxazaphosphinine 2-oxides **4e**–**8e** with different aldehydes gave high yields and moderate diastereoselectivities, the values of which depended on the substituent on the phosphorus atom. Thus, the anions generated from phosphinines **4e** and **5e** with an ethyl substituent on the phosphorus atom gave a mixture of three diastereoisomers with quite similar diastereoselectivities irrespective of the size of the substituent on the nitrogen atom (Entries 1–3, Table 1). The chemical yield for the reaction with the less nucleophilic *p*-methoxybenzaldehyde was 72%. The reaction of the anion generated from **4e** with furaldehyde also gave a mixture of three diastereoisomers in a ratio of around 3.5:2:1.5, but they could not be separated by flash chromatography.

Table 1. Products **9e**–**17e** obtained from equatorially substituted phosphinines **4e**–**6e**,**8e**.

Entry	Phosphinine	Yield [%][a]	Products (*dr* [%])[b]
1	**4e**	86	*anti*-**9e** (63) *syn*-**9e** (30) *epi*-**9e** (7)
2	**5e**	96	*anti*-**10e** (67) *syn*-**10e** (21) *epi*-**10e** (12)
3	**5e**	72	*anti*-**11e** (63) *syn*-**11e** (22) *epi*-**11e** (15)
4	**6e**	60	*anti*-**12e** (82) *syn*-**12e** (18)
5	**6e**	44	*anti*-**13e** (81) *syn*-**13e** (19)
6	**6e**	67	*anti*-**14e** (77) *syn*-**14e** (23)
7	**6e**	76	*anti*-**15e** (78) *syn*-**15e** (22)
8	**8e**	84	*anti*-**16e** (81) *syn*-**16e** (19)
9	**8e**	77	*anti*-**17e** (80) *syn*-**17e** (20)

[a] The yields refer to the pure isolated compounds obtained after flash chromatography. [b] Determined by integration of the signals in the ^{31}P NMR spectrum of the reaction mixture.

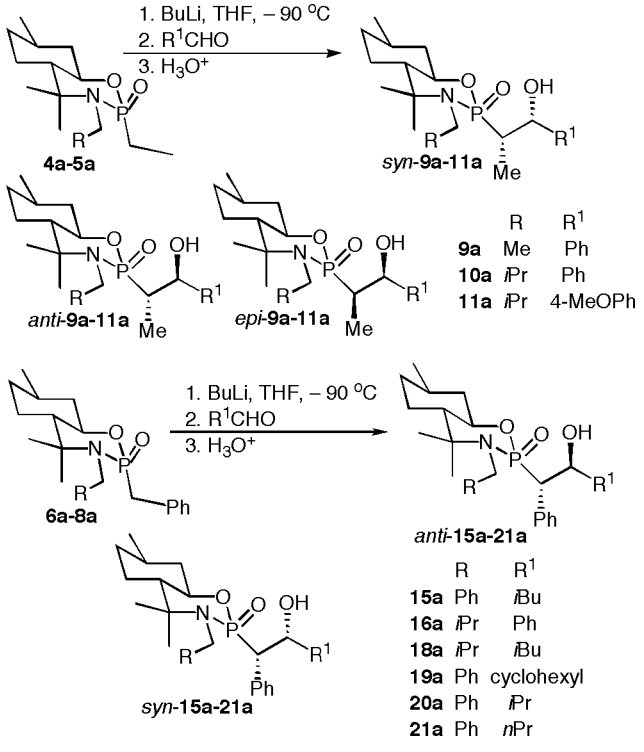
Much better diastereoselectivities were obtained in the reactions of the anions generated from *P*-benzylbenzoxazaphosphinine 2-oxides **6e** and **8e** (Entries 4–9 in Table 1). In these cases, only two stereoisomers, *anti*- and *syn*-**12e**–**17e**, were obtained in a ratio of around 4:1. Interestingly, the results revealed that the stereoselectivity was independent of the nature of the nitrogen substituent in the starting reagent. Similar results were obtained in the reaction of **7e** with benzaldehyde and *p*-methoxybenzaldehyde; the ^{31}P NMR spectra of the reaction mixtures showed that in each case a mixture of only two diastereoisomers (ca. 4:1) was formed, but the products could not be purified by flash chromatography.

The stereochemistries of the hydroxyoxazaphosphinine 2-oxides were determined on the basis of ^{1}H and ^{31}P NMR spectral characteristics and, in some cases, by X-ray diffraction analysis. In this way, the stereochemistries of the compounds obtained in the reaction of the anion generated from **5e** with benzaldehyde were assigned by X-ray diffraction analysis as *anti* (1*R*,2*R*) for the major diastereoisomer (*anti*-**10e**) and *syn* (1*S*,2*R*) for the second one (*syn*-**10e**).[18] The stereochemistry of the minor diastereoisomer obtained in this reaction (*epi*-**10e**) was assigned as *syn* (1*R*,2*S*), based on the chemical shift of the phosphorus signal (δ =32.5 ppm) and the coupling constant for the protons at C-1 and C-2. Interestingly, the signal in the ^{31}P NMR spectrum of *anti*-**10e** is more downfield-shifted (δ = 35.5 ppm) than that for *syn*-**10e** (δ = 32.6 ppm), whereas the coupling constant between the protons at C-1 and C-2 in *anti*-**10e** is larger than that for the same protons in *syn*-**10e** (see Exp. Sect.). This behavior is observed for all the diastereoisomers obtained in the reactions of **4e**–**8e** with aldehydes. The stereochemistries of *anti*-**9e**, **-11e**, *syn*-**9e**, **-11e**, and *epi*-**9e**, **-11e**

were assigned by extension of the previously determined stereochemistries of *anti*- and *syn*-**10e**, respectively, and corroborated for compound *syn*-**9e** by X-ray diffraction analysis.[18]

In the same way, X-ray diffraction analysis showed that the major diastereoisomer (*anti*-**12e**) formed in the reaction of the anion derived from **6e** and benzaldehyde was *anti* (1*R*,2*R*). Comparison of the chemical shifts in the ^{31}P NMR spectra and the coupling constants between protons at C-1 and C-2 in the ^{1}H NMR spectra allowed the assignment of the configuration of the minor diastereoisomer *syn*-**12e** as (1*S*,2*R*). Comparison of the relevant spectral data allowed these stereochemical assignments to be extended by inference to diastereomers *anti*- and *syn*-**13e**–**17e**.

The behavior of the axially *P*-substituted oxazaphosphinine 2-oxides **4a**–**8a** was similar to that shown by their equatorially substituted diastereoisomers, but only in part (Scheme 3 and Table 2). For instance, the carbanions generated under the above conditions from the *P*-ethyl-substituted substrates **4a** and **5a** reacted with benzaldehyde or 4-methoxybenzaldehyde to yield a mixture of three β-hydroxyphosphinines, *syn*-, *anti*-, and *epi*-**9a**–**11a**, in good to excellent yields, but with low diastereoselectivity (Entries 1–3, Table 2). The anion generated from **4a** also reacted with furaldehyde to give a mixture of three diastereoisomers (^{31}P NMR spectrum of the reaction mixture), but they could not be separated by flash chromatography.



Scheme 3. Deprotonation of axially substituted phosphinines **4a**–**8a** and their subsequent addition to aldehydes.

Contrary to observations with the axially substituted homologues, in these cases the major products formed were the *syn* diastereoisomers. Interestingly, the stereochemistries

Table 2. Products **9a**–**11a**, **15a**, **16a**, **and 18a**–**21a** obtained from axially substituted phosphinines **4a**–**6a** and **8a**.

Entry	Phosphinine	Yield[a] [%]	Products (*dr* [%])[b]
1	**4a**	91	*syn*-**9a** (60) *anti*-**9a** (22) *epi*-**9a** (18)
2	**5a**	98	*syn*-**10a** (43) *anti*-**10a** (39) *epi*-**10a** (18)
3	**5a**	69	*syn*-**11a** (39) *anti*-**11a** (32) *epi*-**11a** (29)
4	**6a**	74	*anti*-**15a** (72) *syn*-**15a** (28)
5	**6a**	84	*anti*-**19a** (83) *syn*-**19a** (17)
6	**6a**	88	*anti*-**20a** (85) *syn*-**20a** (15)
7	**6a**	88	*anti*-**21a** (76) *syn*-**21a** (24)
8	**8a**	81	*anti*-**16a** (76) *syn*-**16a** (24)
9	**8a**	71	*anti*-**18a** (54) *syn*-**18a** (46)

[a] Yields refer to the pure isolated compounds obtained after flash chromatography. [b] Determined by integration of the signals in the ^{31}P NMR spectrum of the reaction mixture.

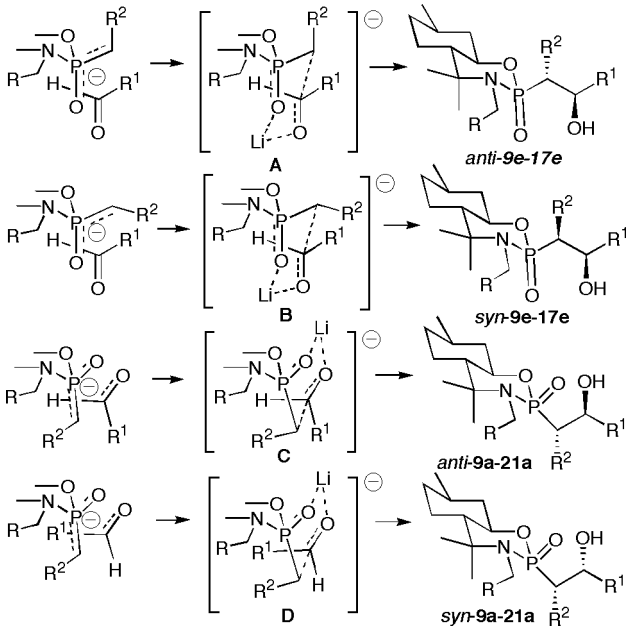
of the two stereocenters generated in *syn*-**9a**–**11a** (1*S*,2*R*) and *epi*-**9a**–**11a** (1*R*,2*S*) are coincident with those observed in *syn*-**9e**–**11e** and *epi*-**9e**–**11e**, but contrary to those observed in *anti*-**9a**–**11a** (1*S*,2*S*) and *anti*-**9e**–**11e** (1*R*,2*R*). The stereochemistries of diastereoisomers *anti*-**9a** and *epi*-**9a** were determined by X-ray diffraction analysis[18] and extended to *anti*-**10**,**11a** and *epi*-**10**,**11a**, respectively, whereas the stereochemistries of *syn*-**9a**–**11a** were established on the basis of the small coupling constants ($J < 2$ Hz) between the protons at C-1 and C-2.

As noted for the equatorial diastereoisomers, the anions generated from *P*-benzyl-substituted phosphinine 2-oxides **6a** and **8a** reacted more stereoselectively than the *P*-ethyl-substituted ones. Thus, deprotonation of **6a** and **8a** with BuLi in THF at –90 °C, followed by reaction with different aldehydes, led to a mixture of only two diastereoisomeric β-hydroxyoxazaphosphinine 2-oxides, *anti*-**15a**–**21a** and *syn*-**15a**–**21a**, in good yields and diastereoselectivity (Scheme 3 and Table 2). The only exception relates to the reaction of the anion derived from **8a** with isovaleraldehyde, which gave a near equimolar mixture of diastereoisomers *anti*-**18a** and *syn*-**18a** (Entry 9, Table 2). α-Substitution of the aldehyde chain enhanced the selectivity with the best diastereoselectivity being observed in the reactions with branched aldehydes (Entries 5 and 6, Table 2).

Also, in these cases the configurations of the new stereocenters in the major diastereoisomers *anti*-**15a**–**21a** (1*S*,2*S*) differ from those of the major isomers (*anti*-**12e**–**17e**) obtained in the reactions with the equatorially substituted derivatives, whereas they are the same (1*S*,2*R*) for the minor *syn* epimers. The stereochemistries of *anti*- and *syn*-**15a** were determined by X-ray diffraction analysis[18] and

extended by inference to the rest of the diastereoisomers on the basis of their ^{31}P and ^{1}H NMR spectroscopic data.

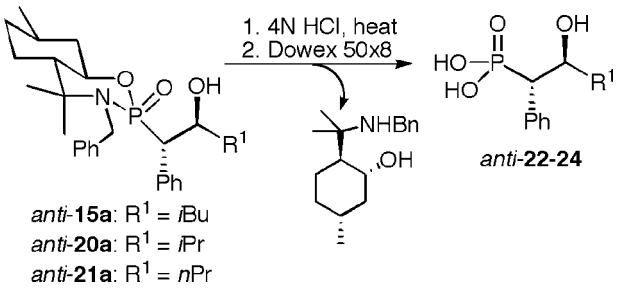
The formation of the major diastereoisomers can be rationalized by taking into account the stereochemistry of the anions derived from the 1,3,2-oxazaphosphinine 2-oxides[19] and by accepting that the anions add to the aldehyde from the less hindered oxygen face of the oxazaphosphinine 2-oxide. By adopting a simplified model (Scheme 4), the formation of *anti* (1*R*,2*R*)-**9e**–**17e** as the major diastereoisomers from the equatorially *P*-substituted oxazaphosphinine **4e**–**8e** can be explained by approach of the aldehydes from the *Si* face to the anion through a Zimmerman–Traxler model **A**.[20] Bearing in mind that the rotational barrier of the P–C bond in this class of anions is extremely low,[21] the minor *syn* (1*S*,2*R*)-**9e**–**17e** isomers will be formed from a different anion conformer through transition state **B**, which is less stable than **A**.



Scheme 4. Proposed intermediates in the formation of the *anti* and *syn* diastereoisomers of oxazaphosphinine 2-oxide.

In contrast, the formation of *anti* (1*S*,2*S*)-**9a**–**21a** and *syn* (1*S*,2*R*)-**9a**–**21a** from the axially substituted oxazaphosphinines **4a**–**8a** can only be explained by a single anion conformer acting on the *Re* face (transition state **C**) of the aldehydes in the former case or on the *Si* face (transition state **D**) of the aldehydes in the latter case.

The value of the condensation products was tested by their transformation into enantioenriched 1-substituted 2-hydroxyalkylphosphonic acids. In this way, after separation by flash chromatography, *anti*-**15a**, -**20a**, and -**21a** were transformed into phosphonic acid derivatives *anti*-**22**–**24** by heating with a 4 N HCl solution followed by chromatography on Dowex resin. The (benzylamino)menthol used as the template can be recovered by extraction from the reaction mixture after basification (Scheme 5).



Scheme 5. Transformation of oxaphosphinines into 1-substituted 2-hydroxyalkylphosphonic acids.

Conclusion

The diastereoselective addition of α-carbanions of perhydro-1,3,2-benzoxazaphosphinine 2-oxides derived from (–)-8-aminomenthol to aldehydes provides β-hydroxyphosphinines with two new stereocenters. The stereoselectivity is highly dependent on the substitution at the phosphorus atom with *P*-benzyl derivatives giving better results than ethyl-substituted ones. Removal of the chiral auxiliary led to enantioenriched α-substituted β-hydroxyphosphonic acids.

Experimental Section

General Methods: ^{1}H (300 MHz) and ^{13}C NMR (75 MHz) spectra were recorded in $CDCl_3$ and chemical shifts are reported relative to tetramethylsilane as the internal reference. ^{31}P NMR spectra were recorded using 85% H_3PO_4 in D_2O as the external reference. All the NMR experiments were recorded with a Bruker AC 300 spectrometer. Optical rotations were measured with a digital Perkin-Elmer 241 polarimeter and the concentrations are given in g/100 mL. Melting points were measured in capillary open tubes and are uncorrected. Organic solvents were dried by standard methods. All reactions were monitored by TLC using silica gel 60 F_{254} coated plates. Flash chromatography was carried out using 230–240 mesh silica gel. Benzylphosphonic dichloride was prepared according to a literature method.[22] The *N*-substituted amino alcohols derived from (–)-8-aminomenthol[23] were synthesized by condensation with the appropriate aldehydes and subsequent reductive ring-opening of the N,O-acetal moiety with $LiAlH_4/AlCl_3$.[11b] The synthesis of 1,3,2-benzoxazaphosphinines **4e**, **4a**, and **6e** has been described previously.[11b]

Preparation of 1,3,2-Benzoxazaphosphinine 2-Oxides:[11b] A solution of ethylphosphonic dichloride (1.5 mL, 14.4 mmol, 1.5 equiv.) or benzylphosphonic dichloride (1.6 mL, 14.4 mmol, 1.5 equiv.) in dry dichloromethane (25 mL) and a solution of 3-(alkyl- or benzylamino)-substituted alcohol (9.6 mmol) in dry dichloromethane (25 mL) were simultaneously added to a solution of anhydrous triethylamine (4.0 mL, 28.8 mmol, 3.0 equiv.) in dry dichloromethane (40 mL) in a three-necked flask. The reaction mixture was refluxed until the initial compound had disappeared and was then quenched by the addition of water (25 mL). The aqueous layer was separated and extracted with diethyl ether (3 × 50 mL). The combined extracts were dried with $MgSO_4$. The solvent was evaporated under vacuum to give a mixture of two diastereomers that was purified by flash chromatography (silica gel, hexane/EtOAc).

(2*R*,4a*S*,7*R*,8a*R*)-2-Ethyl-3-isobutyl-4,4,7-trimethyloctahydro-2*H*-1,3,2-benzoxazaphosphinine 2-Oxide (5e): White solid, m.p. 92–94 °C (hexane/EtOAc). R_f = 0.29 (EtOAc). $[\alpha]_D^{25}$ = +9.2 (*c* = 0.85, $CHCl_3$). ^{1}H NMR ($CDCl_3$): δ = 0.79–0.98 (m, 1 H), 0.80 (d, *J* = 6.8 Hz, 3 H), 0.83 (d, *J* = 7.2 Hz, 3 H), 0.85 (d, *J* = 6.8 Hz, 3 H), 1.01–1.11 (m, 2 H), 1.04 (dt, J_1 = 19.3 Hz, J_2 = 7.5 Hz, 3 H), 1.09 (s, 3 H), 1.11 (s, 3 H), 1.40–1.86 (m, 7 H), 2.01–2.05 (m, 1 H), 2.47–2.60 (m, 1 H), 2.99–3.10 (m, 1 H), 4.07–4.14 (m, 1 H) ppm. ^{31}P NMR ($CDCl_3$): δ = 32.7 ppm. ^{13}C NMR ($CDCl_3$): δ = 7.4 (d, $^2J_{C,P}$ = 6.8 Hz), 20.0, 20.7, 20.8, 21.6, 25.1 (d, $^1J_{C,P}$ = 134.7 Hz), 25.9, 26.5 (d, $^3J_{C,P}$ = 5.6 Hz), 28.8, 30.7, 34.0, 42.4 (d, $^2J_{C,P}$ = 5.9 Hz), 50.0, 50.4 (d, $^3J_{C,P}$ = 5.7 Hz), 59.4, 74.3 (d, $^2J_{C,P}$ = 7.5 Hz) ppm. IR (KBr): $\tilde{\nu}$ = 1389, 1247, 1212, 868, 738 cm^{-1}. $C_{16}H_{32}NO_2P$ (301.40): calcd. C 63.76, H 10.70, N 4.65; found C 63.63, H 10.84, N 4.52.

(2*S*,4a*S*,7*R*,8a*R*)-2-Ethyl-3-isobutyl-4,4,7-trimethyloctahydro-2*H*-1,3,2-benzoxazaphosphinine 2-Oxide (5a): White solid, m.p. 165–166 °C (hexane/EtOAc). R_f = 0.46 (EtOAc). $[\alpha]_D^{25}$ = +40.7 (*c* = 0.96, $CHCl_3$). ^{1}H NMR ($CDCl_3$): δ = 0.77–0.95 (m, 2 H), 0.78 (d, *J* = 6.6 Hz, 3 H), 0.83 (d, *J* = 6.6 Hz, 3 H), 0.85 (d, *J* = 6.9 Hz, 3 H), 0.98 (s, 3 H), 1.05 (dt, $^3J_{H,P}$ = 18.2 Hz, *J* = 7.7 Hz, 3 H), 1.12 (s, 3 H), 1.15–1.23 (m, 1 H), 1.28–1.49 (m, 1 H), 1.51–1.74 (m, 5 H), 1.76–1.90 (m, 1 H), 1.94–2.08 (m, 1 H), 2.61–2.64 (m, 1 H), 2.66 (d, $^3J_{H,P} \approx J$ = 7.4 Hz, 1 H), 3.77–3.86 (m, 1 H) ppm. ^{31}P NMR ($CDCl_3$): δ = 30.1 ppm. ^{13}C NMR ($CDCl_3$): δ = 7.2 (d, $^2J_{C,P}$ = 6.7 Hz), 19.9 (d, $^1J_{C,P}$ = 121.0 Hz), 20.2 (2 C), 20.4, 21.5, 25.7, 27.1 (d, $^3J_{C,P}$ = 5.3 Hz), 29.8, 30.8, 33.8, 42.4 (d, $^2J_{C,P}$ = 6.5 Hz), 49.6 (d, $^3J_{C,P}$ = 4.4 Hz), 50.6 (d, $^3J_{C,P}$ = 6.4 Hz), 59.4, 75.2 (d, $^2J_{C,P}$ = 7.0 Hz) ppm. IR (KBr): $\tilde{\nu}$ = 1370, 1254, 1225, 885, 730 cm^{-1}. $C_{16}H_{32}NO_2P$ (301.40): calcd. C 63.76, H 10.70, N 4.65; found C 63.81, H 10.62, N 4.77.

(2*S*,4a*S*,7*R*,8a*R*)-2,3-Dibenzyl-4,4,7-trimethyloctahydro-2*H*-1,3,2-benzoxazaphosphinine 2-Oxide (6a): White solid, m.p. 145–147 °C (hexane/EtOAc). R_f = 0.44 (hexane/EtOAc, 1:1). $[\alpha]_D^{23}$ = +57.5 (*c* = 0.86, $CHCl_3$). ^{1}H NMR ($CDCl_3$): δ = 0.89 (s, 3 H), 0.94 (d, *J* = 6.3 Hz, 3 H), 1.07 (s, 3 H), 0.93–1.14 (m, 1 H), 1.21–1.44 (m, 1 H), 1.44–1.55 (m, 1 H), 1.69–1.77 (m, 4 H), 2.11–2.15 (m, 1 H), 3.24 (dd, $^2J_{H,P}$ = 33.2 Hz, *J* = 15.0 Hz, 1 H), 3.30 (dd, $^2J_{H,P}$ = 35.2 Hz, *J* = 15.0 Hz, 1 H), 3.74 (dd, *J* = 17.2 Hz, $^2J_{H,P}$ = 10.2 Hz, 1 H), 4.06–4.12 (m, 1 H), 4.22 (dd, *J* = 17.2 Hz, $^2J_{H,P}$ = 10.5 Hz, 1 H), 7.12–7.45 (m, 10 H) ppm. ^{31}P NMR ($CDCl_3$): δ = 23.1 ppm. ^{13}C NMR ($CDCl_3$): δ = 20.2, 21.7, 25.5, 27.8 (d, $^3J_{C,P}$ = 5.2 Hz), 30.8, 33.8, 35.5 (d, $^1J_{C,P}$ = 114.6 Hz), 42.3 (d, $^3J_{C,P}$ = 7.1 Hz), 45.8, 50.8 (d, $^3J_{C,P}$ = 4.9 Hz), 60.4, 75.9 (d, $^2J_{C,P}$ = 7.2 Hz), 126.2, 126.9 (2 C), 127.9 (2 C), 128.3 (2 C), 129.7 (d, $^3J_{C,P}$ = 5.5 Hz, 2 C), 133.0 (d, $^2J_{C,P}$ = 8.6 Hz), 141.8 ppm. IR (KBr): $\tilde{\nu}$ = 1243, 1026, 1010, 873 cm^{-1}. MS (EI): *m*/*z* (%) = 397 (23) $[M]^+$, 382 (18), 302 (58), 260 (60), 91 (100).

(2*R*,4a*S*,7*R*,8a*R*)-2-Benzyl-3-ethyl-4,4,7-trimethyloctahydro-2*H*-1,3,2-benzoxazaphosphinine 2-Oxide (7e): White solid, m.p. 114–115 °C (hexane/EtOAc). R_f = 0.15 (EtOAc). $[\alpha]_D^{23}$ = +25.0 (*c* = 1.01, $CHCl_3$). ^{1}H NMR ($CDCl_3$): δ = 0.48–0.62 (m, 2 H), 0.87 (d, *J* = 6.5 Hz, 3 H), 0.80–0.98 (m, 2 H), 1.00 (s, 3 H), 1.11 (s, 3 H), 1.17–1.41 (m, 1 H), 1.28 (d, *J* = 7.1 Hz, 3 H), 1.46–1.64 (m, 2 H), 1.98–2.02 (m, 1 H), 2.94–3.12 (m, 1 H), 3.19 (d, $^2J_{H,P}$ = 19.9 Hz, 2 H), 3.28–3.47 (m, 1 H), 4.10 (td, J_1 = 10.8 Hz, J_2 = 4.7 Hz, 1 H), 7.21–7.32 (m, 5 H) ppm. ^{31}P NMR ($CDCl_3$): δ = 23.8 ppm. ^{13}C NMR ($CDCl_3$): δ = 18.3, 21.7, 21.8, 25.5, 25.6, 30.6, 33.8, 36.9 (d, $^3J_{C,P}$ = 4.3 Hz), 38.5 (d, $^1J_{C,P}$ = 127.8 Hz), 41.7 (d, $^2J_{C,P}$ = 6.7 Hz), 48.9 (d, $^3J_{C,P}$ = 5.4 Hz), 59.2, 75.0 (d, $^2J_{C,P}$ = 8.4 Hz), 126.5, 128.1 (2 C), 130.2 (d, $^3J_{C,P}$ = 5.6 Hz, 2 C), 133.6 (d, $^2J_{C,P}$ = 9.6 Hz) ppm. IR (KBr): $\tilde{\nu}$ = 1261, 1034, 1016, 890 cm^{-1}. $C_{19}H_{30}NO_2P$ (335.42): calcd. C 68.03, H 9.02, N 4.18; found C 67.90, H 8.88, N 4.09.

(2*S*,4a*S*,7*R*,8a*R*)-2-Benzyl-3-ethyl-4,4,7-trimethyloctahydro-2*H*-1,3,2-benzoxazaphosphinine 2-Oxide (7a): White solid, m.p. 213–214 °C (hexane/EtOAc). R_f = 0.35 (EtOAc). $[\alpha]_D^{23}$ = +37.4 (*c* = 0.90, $CHCl_3$). ^{1}H NMR ($CDCl_3$): δ = 0.82–1.06 (m, 2 H), 0.88 (s, 3 H), 0.94 (d, *J* = 6.5 Hz, 3 H), 1.11–1.31 (m, 1 H), 1.20 (t, *J* = 7.0 Hz, 3 H), 1.25 (s, 3 H), 1.33–1.45 (m, 1 H), 1.64–1.79 (m, 3 H), 2.03–2.10 (m, 1 H), 2.85–3.13 (m, 2 H), 3.21 (d, $^2J_{H,P}$ = 18.2 Hz, 2 H), 3.90 (tdd, J_1 = 10.5 Hz, J_2 = 4.6 Hz, $^3J_{H,P}$ = 2.0 Hz, 1 H), 7.17–7.37 (m, 5 H) ppm. ^{31}P NMR ($CDCl_3$): δ = 21.9 ppm. ^{13}C NMR ($CDCl_3$): δ = 18.8, 21.1, 21.6, 25.8, 26.8 (d, $^3J_{C,P}$ = 4.5 Hz), 30.9, 33.9, 35.0 (d, $^1J_{C,P}$ = 116.8 Hz), 37.0 (d, $^3J_{C,P}$ = 5.1 Hz), 42.3 (d, $^2J_{C,P}$ = 6.9 Hz), 50.6 (d, $^3J_{C,P}$ = 6.3 Hz), 59.7, 75.8 (d, $^2J_{C,P}$ = 7.5 Hz), 126.4, 128.4 (2 C), 129.7 (d, $^3J_{C,P}$ = 5.5 Hz, 2 C), 133.3 (d, $^2J_{C,P}$ = 8.6 Hz) ppm. IR (KBr): $\tilde{\nu}$ = 1239, 1028, 1012, 883 cm^{-1}. $C_{19}H_{30}NO_2P$ (335.42): calcd. C 68.03, H 9.02, N 4.18; found C 68.17, H 9.14, N 4.27.

(2*R*,4a*S*,7*R*,8a*R*)-2-Benzyl-3-isobutyl-4,4,7-trimethyloctahydro-2*H*-1,3,2-benzoxazaphosphinine 2-Oxide (8e): White solid, m.p. 93–95 °C (hexane/EtOAc). R_f = 0.44 (hexane/EtOAc, 1:2). $[\alpha]_D^{23}$ = +14.7 (*c* = 0.87, $CHCl_3$). ^{1}H NMR ($CDCl_3$): δ = 0.52–0.78 (m, 2 H), 0.86–1.00 (m, 2 H), 0.89 (d, *J* = 6.5 Hz, 3 H), 0.94 (d, *J* = 6.6 Hz, 3 H), 1.03 (d, *J* = 6.6 Hz, 3 H), 1.06 (s, 3 H), 1.14 (s, 3 H), 1.25–1.37 (m, 1 H), 1.55–1.60 (m, 2 H), 1.98–2.10 (m, 2 H), 2.67 (td, J_1 = 14.5 Hz, J_2 = 10.1 Hz, 1 H), 3.09–3.30 (m, 1 H), 4.11 (tdd, J_1 = 10.8 Hz, J_2 = 4.6 Hz, $^3J_{H,P}$ = 2.3 Hz, 1 H), 7.20–7.34 (m, 5 H) ppm. ^{31}P NMR ($CDCl_3$): δ = 24.0 ppm. ^{13}C NMR ($CDCl_3$): δ = 20.1, 21.1, 21.8, 22.0, 25.4 (d, $^3J_{C,P}$ = 4.3 Hz), 25.8, 28.6, 30.7, 33.9, 39.2 (d, $^1J_{C,P}$ = 127.9 Hz), 41.7 (d, $^3J_{C,P}$ = 6.0 Hz), 49.2 (d, $^3J_{C,P}$ = 6.1 Hz), 51.0, 59.2, 75.4 (d, $^2J_{C,P}$ = 8.4 Hz), 126.5, 128.1 (2 C), 130.2 (d, $^3J_{C,P}$ = 5.9 Hz, 2 C), 133.6 (d, $^2J_{C,P}$ = 9.4 Hz) ppm. IR (KBr): $\tilde{\nu}$ = 1231, 1038, 1013, 868 cm^{-1}. $C_{21}H_{34}NO_2P$ (363.47): calcd. C 69.39, H 9.43, N 3.85; found C 69.51, H 9.30, N 3.90.

(2*S*,4a*S*,7*R*,8a*R*)-2-Benzyl-3-isobutyl-4,4,7-trimethyloctahydro-2*H*-1,3,2-benzoxazaphosphinine 2-Oxide (8a): White solid, m.p. 171–173 °C (hexane/EtOAc). R_f = 0.50 (hexane/EtOAc, 1:2). $[\alpha]_D^{23}$ = +48.8 (*c* = 0.85, $CHCl_3$). ^{1}H NMR ($CDCl_3$): δ = 0.85–0.93 (m, 1 H), 0.86 (d, *J* = 6.7 Hz, 3 H), 0.93–0.97 (m, 1 H), 0.94 (d, *J* = 6.4 Hz, 3 H), 0.96 (d, *J* = 6.8 Hz, 3 H), 0.98 (s, 3 H), 1.18–1.30 (m, 1 H), 1.21 (s, 3 H), 1.38–1.47 (m, 1 H), 1.67–1.82 (m, 3 H), 1.94–2.15 (m, 2 H), 2.64–2.71 (m, 2 H), 3.20 (d, $^2J_{H,P}$ = 18.0 Hz, 2 H), 3.96 (tdd, J_1 = 10.6 Hz, J_2 = 4.5 Hz, $^3J_{H,P}$ = 2.4 Hz, 1 H), 7.18–7.33 (m, 5 H) ppm. ^{31}P NMR ($CDCl_3$): δ = 22.6 ppm. ^{13}C NMR ($CDCl_3$): δ = 20.3, 20.4, 20.6, 21.6, 25.8, 27.3, 29.7, 30.9, 33.9, 35.1 (d, $^1J_{C,P}$ = 114.4 Hz), 42.2 (d, $^3J_{C,P}$ = 7.0 Hz), 49.9, 50.5 (d, $^3J_{C,P}$ = 6.2 Hz), 59.9, 75.8 (d, $^2J_{C,P}$ = 7.3 Hz), 126.3, 128.3 (2 C), 129.7 (d, $^3J_{C,P}$ = 5.9 Hz, 2 C), 133.3 (d, $^2J_{C,P}$ = 8.7 Hz) ppm. IR (KBr): $\tilde{\nu}$ = 1243, 1030, 1012, 859 cm^{-1}. MS (EI): *m*/*z* (%) = 363 (4) $[M]^+$, 320 (88), 184 (100), 91 (22). $C_{21}H_{34}NO_2P$ (363.47): calcd. C 69.39, H 9.43, N 3.85; found C 69.26, H 9.52, N 3.71.

General Procedure for the Preparation of Perhydro-β-hydroxy-1,3,2-benzoxazaphosphinines 9–21: *n*BuLi (1.8 mL, 1.6 M in hexane, 2.8 mmol) was added to a stirred solution of oxazaphosphinine **4**–**8** (1.4 mmol) in dry THF (65 mL) at –90 °C under argon. The reaction mixture was stirred at –90 °C for 15 min and then 1.2 mmol of the aldehyde in THF was added. After 5 min, the intense yellow color of the solution disappeared. The reaction mixture was hydrolyzed at –90 °C with water (10 mL) or methanol (2 mL) and warmed to room temp. THF was removed under reduced pressure and the aqueous solution was extracted with CH_2Cl_2 (3 × 25 mL). The combined organic layers were dried (anhydrous $MgSO_4$), filtered, and concentrated. The residue was purified by flash chromatography on silica gel with hexane/EtOAc mixtures as eluent.

(1*S*,2*R*)-2-[(2*S*,4a*S*,7*R*,8a*R*)-3-Ethyl-4,4,7-trimethyl-2-oxooctahydro-2*H*-1,3,2-benzoxazaphosphinin-2-yl]-1-phenylpropanol (*syn*-9e): White solid, m.p. 206–208 °C (hexane/EtOAc). R_f = 0.48 (EtOAc). $[\alpha]_D^{25}$ = +27.2 (*c* = 0.51, $CHCl_3$). ^1H NMR ($CDCl_3$): δ = 0.88–1.26 (m, 2 H), 1.01 (d, *J* = 6.8 Hz, 3 H), 1.04 (dd, $^3J_{H,P}$ = 18.2 Hz, *J* = 7.1 Hz, 3 H), 1.22 (s, 3 H), 1.23 (s, 3 H), 1.30 (t, *J* = 7.0 Hz, 3 H), 1.38–1.65 (m, 3 H), 1.75–1.90 (m, 3 H), 2.28–2.32 (m, 1 H), 3.09–4.23 (m, 2 H), 4.26–4.35 (m, 1 H), 4.51 (s, 1 H), 5.38 (dd, J_1 = 8.3 Hz, J_2 = 1.2 Hz, 1 H), 7.22–7.36 (m, 5 H) ppm. ^{31}P NMR ($CDCl_3$): δ = 32.5 ppm. ^{13}C NMR ($CDCl_3$): δ = 6.1, 19.6, 21.7, 22.5, 26.2, 26.5, 30.9, 34.0, 37.6, 43.0 (d, $^3J_{C,P}$ = 5.6 Hz), 45.6 (d, $^1J_{C,P}$ = 121.7 Hz), 50.3 (d, $^3J_{C,P}$ = 8.3 Hz), 59.7, 70.6 (d, $^2J_{C,P}$ = 4.6 Hz), 75.8 (d, $^2J_{C,P}$ = 7.1 Hz), 125.8 (2 C), 126.8, 128.0 (2 C), 142.1 (d, $^3J_{C,P}$ = 16.3 Hz) ppm. IR (KBr): $\tilde{\nu}$ = 3260, 1199, 1048 cm^{-1}. $C_{21}H_{34}NO_3P$ (379.47): calcd. C 66.47, H 9.03, N 3.69; found C 66.56, H 8.93, N 3.81.

(1*S*,2*R*)-2-[(2*S*,4a*S*,7*R*,8a*R*)-3-Ethyl-4,4,7-trimethyl-2-oxooctahydro-2*H*-1,3,2-benzoxazaphosphinin-2-yl]-1-phenylpropanol (*syn*-9a): White solid, m.p. 105–106 °C (hexane/EtOAc). R_f = 0.61 (EtOAc). $[\alpha]_D^{25}$ = +45.6 (*c* = 1.12, $CHCl_3$). ^1H NMR ($CDCl_3$): δ = 0.87–0.99 (m, 1 H), 0.93 (d, *J* = 6.4 Hz, 3 H), 0.97 (dd, $^3J_{H,P}$ = 16.8 Hz, *J* = 7.2 Hz, 3 H), 1.22 (s, 3 H), 1.29 (t, *J* = 6.8 Hz, 3 H), 1.19–1.31 (m, 3 H), 1.36 (s, 3 H), 1.68–1.82 (m, 3 H), 1.98–2.03 (m, 1 H), 2.14–2.27 (m, 1 H), 3.12–3.28 (m, 1 H), 3.36–3.51 (m, 1 H), 3.81–3.97 (m, 1 H), 4.62 (s, 1 H), 5.26 (dd, J_1 = 10.0 Hz, J_2 = 1.9 Hz, 1 H), 7.20–7.35 (m, 5 H) ppm. ^{31}P NMR ($CDCl_3$): δ = 31.3 ppm. ^{13}C NMR ($CDCl_3$): δ = 7.7 (d, $^2J_{C,P}$ = 3.3 Hz), 19.5, 21.6, 22.0, 26.0, 26.7 (d, $^3J_{C,P}$ = 4.8 Hz), 31.1, 33.9, 37.7 (d, $^2J_{C,P}$ = 4.7 Hz), 40.4 (d, $^1J_{C,P}$ = 114.6 Hz), 42.4 (d, $^3J_{C,P}$ = 6.7 Hz), 51.0 (d, $^3J_{C,P}$ = 6.1 Hz), 59.6, 71.5, 75.8 (d, $^2J_{C,P}$ = 6.6 Hz), 125.8 (2 C), 126.9, 127.9 (2 C), 141.9 (d, $^3J_{C,P}$ = 15.4 Hz) ppm. IR (KBr): $\tilde{\nu}$ = 3285, 1449, 1374, 1226, 1034 cm^{-1}. $C_{21}H_{34}NO_3P$ (379.47): calcd. C 66.47, H 9.03, N 3.69; found C 66.38, H 9.16, N 3.52.

(1*S*,2*S*)-2-[(2*S*,4a*S*,7*R*,8a*R*)-3-Ethyl-4,4,7-trimethyl-2-oxooctahydro-2*H*-1,3,2-benzoxazaphosphinin-2-yl]-1-phenylpropanol (*anti*-9a): White solid, m.p. 157–159 °C (hexane/EtOAc). R_f = 0.34 (EtOAc). $[\alpha]_D^{25}$ = +37.5 (*c* = 0.98, $CHCl_3$). ^1H NMR ($CDCl_3$): δ = 0.73 (dd, $^3J_{H,P}$ = 18.0 Hz, *J* = 7.3 Hz, 3 H), 0.88–1.09 (m, 2 H), 0.96 (d, *J* = 6.1 Hz, 3 H), 1.13 (s, 3 H), 1.24 (t, *J* = 7.1 Hz, 3 H), 1.32 (s, 3 H), 1.37–1.45 (m, 2 H), 1.68–1.72 (m, 1 H), 1.83–1.91 (m, 1 H), 1.92–1.98 (m, 1 H), 2.10–2.23 (m, 2 H), 3.07–3.24 (m, 2 H), 3.99–4.10 (m, 1 H), 4.70 (d, *J* = 10.0 Hz, 1 H), 6.2 (s, 1 H), 7.23–7.39 (m, 5 H) ppm. ^{31}P NMR ($CDCl_3$): δ = 31.7 ppm. ^{13}C NMR ($CDCl_3$): δ = 6.1, 19.8, 21.1, 21.7, 25.9, 26.8 (d, $^3J_{C,P}$ = 5.7 Hz), 31.1, 33.9, 37.7, 40.6 (d, $^1J_{C,P}$ = 112.4 Hz), 42.4 (d, $^2J_{C,P}$ = 7.5 Hz), 51.1 (d, $^3J_{C,P}$ = 4.6 Hz), 59.9, 71.0, 75.9 (d, $^2J_{C,P}$ = 6.4 Hz), 125.8 (2 C), 126.8, 128.0 (2 C), 141.9 (d, $^3J_{C,P}$ = 15.4 Hz) ppm. IR (KBr): $\tilde{\nu}$ = 3317, 1457, 1333, 1200, 1051 cm^{-1}. $C_{21}H_{34}NO_3P$ (379.47): calcd. C 66.47, H 9.03, N 3.69; found C 66.42, H 9.18, N 3.47.

(1*R*,2*S*)-2-[(2*S*,4a*S*,7*R*,8a*R*)-3-Ethyl-4,4,7-trimethyl-2-oxooctahydro-2*H*-1,3,2-benzoxazaphosphinin-2-yl]-1-phenylpropanol (*epi*-9a): White solid, m.p. 133–134 °C (hexane/EtOAc). R_f = 0.77 (EtOAc). $[\alpha]_D^{25}$ = +11.0 (*c* = 0.98, $CHCl_3$). ^1H NMR ($CDCl_3$): δ = 0.71–1.10 (m, 2 H), 0.71–1.10 (m, 3 H), 0.96 (d, *J* = 6.6 Hz, 3 H), 1.04 (s, 3 H), 1.10–1.39 (m, 1 H), 1.22 (t, *J* = 6.7 Hz, 3 H), 1.29 (s, 3 H), 1.42–1.60 (m, 1 H), 1.63–1.80 (m, 3 H), 1.93–2.05 (m, 1 H), 2.10–2.24 (m, 1 H), 2.88–3.04 (m, 1 H), 3.25–3.40 (m, 1 H), 4.02 (td, J_1 = 10.5 Hz, J_2 = 4.5 Hz, 1 H), 4.61 (s, 1 H), 5.27 (d, *J* = 7.9 Hz, 1 H), 7.18–7.31 (m, 5 H) ppm. ^{31}P NMR ($CDCl_3$): δ = 32.4 ppm. ^{13}C NMR ($CDCl_3$): δ = 6.1, 19.8, 21.1, 21.7, 25.9, 26.8 (d, $^3J_{C,P}$ = 5.2 Hz), 31.2, 33.9, 37.8 (d, $^2J_{C,P}$ = 4.4 Hz), 40.7 (d, $^1J_{C,P}$ = 112.8 Hz), 42.4 (d, $^3J_{C,P}$ = 8.2 Hz), 51.1 (d, $^3J_{C,P}$ = 4.9 Hz), 59.9, 71.0 (d, $^2J_{C,P}$ = 4.8 Hz), 75.9 (d, $^2J_{C,P}$ = 6.3 Hz), 125.8 (2 C), 126.8, 128.0 (2 C), 141.9 (d, $^3J_{C,P}$ = 14.8 Hz) ppm. IR (KBr): $\tilde{\nu}$ = 3402, 1455, 1376, 1202, 1029 cm^{-1}. $C_{21}H_{34}NO_3P$ (379.47): calcd. C 66.47, H 9.03, N 3.69; found C 66.39, H 9.15, N 3.59.

(1*S*,2*R*)-2-[(2*R*,4a*S*,7*R*,8a*R*)-3-Isobutyl-4,4,7-trimethyl-2-oxooctahydro-2*H*-1,3,2-benzoxazaphosphinin-2-yl]-1-phenylpropanol (*syn*-10e): White solid, m.p. 146–147 °C (hexane/EtOAc). R_f = 0.56 (hexane/EtOAc, 1:1). $[\alpha]_D^{25}$ = +2.8 (*c* = 0.65, $CHCl_3$). ^1H NMR ($CDCl_3$): δ = 0.90 (d, *J* = 6.6 Hz, 3 H), 0.97–1.05 (m, 9 H), 1.10–1.28 (m, 3 H), 1.24 (s, 3 H), 1.25 (s, 3 H), 1.52–1.54 (m, 1 H), 1.61–1.69 (m, 1 H), 1.75–1.89 (m, 3 H), 1.91–2.05 (m, 1 H), 2.32–2.36 (m, 1 H), 2.86–3.09 (m, 2 H), 4.24–4.35 (m, 1 H), 4.70 (s, 1 H), 5.37 (d, *J* = 7.9 Hz, 1 H), 7.22–7.36 (m, 5 H) ppm. ^{31}P NMR ($CDCl_3$): δ = 32.6 ppm. ^{13}C NMR ($CDCl_3$): δ = 6.0, 19.7, 20.8, 21.8, 23.2, 25.2, 26.6, 29.3, 31.0, 34.1, 43.0, 46.6 (d, $^1J_{C,P}$ = 119.3 Hz), 50.5 (d, $^3J_{C,P}$ = 9.1 Hz), 50.8, 59.6, 70.8, 76.5, 125.8 (2 C), 126.8, 128.0 (2 C), 142.1 (d, $^3J_{C,P}$ = 16.3 Hz) ppm. IR (KBr): $\tilde{\nu}$ = 3314, 1452, 1202, 1167, 1012, 876 cm^{-1}. $C_{23}H_{38}NO_3P$ (407.53): calcd. C 67.79, H 9.40, N 3.44; found C 67.91, H 9.52, N 3.27.

(1*R*,2*R*)-2-[(2*R*,4a*S*,7*R*,8a*R*)-3-Isobutyl-4,4,7-trimethyl-2-oxooctahydro-2*H*-1,3,2-benzoxazaphosphinin-2-yl]-1-phenylpropanol (*anti*-10e): White solid, m.p. 124–125 °C (hexane/EtOAc). R_f = 0.32 (hexane/EtOAc, 1:1). $[\alpha]_D^{25}$ = –17.1 (*c* = 0.94, $CHCl_3$). ^1H NMR ($CDCl_3$): δ = 0.72 (dd, $^3J_{H,P}$ = 18.0, *J* = 7.0 Hz, 3 H), 0.83–0.95 (m, 2 H), 0.83–0.95 (m, 6 H), 0.98 (d, *J* = 6.5 Hz, 3 H), 1.02–1.18 (m, 1 H), 1.20 (s, 3 H), 1.26 (s, 3 H), 1.45–1.54 (m, 2 H), 1.57–1.99 (m, 2 H), 2.02–2.14 (m, 2 H), 2.18–2.22 (m, 1 H), 2.63–2.76 (m, 1 H), 3.16–3.27 (m, 1 H), 4.32 (td, J_1 = 10.7 Hz, J_2 = 4.6 Hz, 1 H), 4.69 (t, $J_1 \approx J_2$ = 9.2 Hz, 1 H), 7.25–7.38 (m, 5 H) ppm. ^{31}P NMR ($CDCl_3$): δ = 35.5 ppm. ^{13}C NMR ($CDCl_3$): δ = 12.7 (d, $^2J_{C,P}$ = 4.8 Hz), 20.2, 21.0 (2 C), 21.7, 25.9, 26.4 (d, $^3J_{C,P}$ = 6.3 Hz), 28.8, 30.7, 33.9, 40.5 (d, $^1J_{C,P}$ = 129.1 Hz), 42.2 (d, $^2J_{C,P}$ = 7.3 Hz), 50.3 (d, $^3J_{C,P}$ = 3.8 Hz), 50.6, 60.1, 74.3 (d, $^2J_{C,P}$ = 8.5 Hz), 74.7, 127.0 (2 C), 127.6, 128.1 (2 C), 142.2 (d, $^3J_{C,P}$ = 16.5 Hz) ppm. IR (KBr): $\tilde{\nu}$ = 3318, 1542, 1200, 1158, 1037, 889 cm^{-1}. $C_{23}H_{38}NO_3P$ (407.53): calcd. C 67.79, H 9.40, N 3.44; found C 67.90, H 9.48, N 3.30.

(1*S*,2*R*)-2-[(2*S*,4a*S*,7*R*,8a*R*)-3-Isobutyl-4,4,7-trimethyl-2-oxooctahydro-2*H*-1,3,2-benzoxazaphosphinin-2-yl]-1-phenylpropanol (*syn*-10a): White solid, m.p. 151–153 °C (hexane/EtOAc). R_f = 0.73 (hexane/EtOAc, 1:1). $[\alpha]_D^{25}$ = –50.7 (*c* = 0.58, $CHCl_3$). ^1H NMR ($CDCl_3$): δ = 0.80–1.14 (m, 3 H), 0.89 (d, *J* = 6.6 Hz, 3 H), 0.93 (d, *J* = 6.3 Hz, 3 H), 0.96 (dd, $^3J_{H,P}$ = 16.6 Hz, *J* = 7.3 Hz, 3 H), 1.03 (d, *J* = 6.7 Hz, 3 H), 1.21–1.60 (m, 1 H), 1.24 (s, 3 H), 1.31 (s, 3 H), 1.68–1.90 (m, 3 H), 1.92–2.02 (m, 2 H), 2.19–2.31 (m, 1 H), 2.90–3.12 (m, 2 H), 3.87–3.96 (m, 1 H), 4.78 (s, 1 H), 5.20 (dd, J_1 = 10.2 Hz, J_2 = 1.7 Hz, 1 H), 7.19–7.35 (m, 5 H) ppm. ^{31}P NMR ($CDCl_3$): δ = 32.0 ppm. ^{13}C NMR ($CDCl_3$): δ = 7.7, 20.1, 20.7, 21.1, 21.6, 25.9, 27.6 (d, $^3J_{C,P}$ = 5.5 Hz), 30.3, 31.1, 33.9, 40.2 (d, $^1J_{C,P}$ = 112.2 Hz), 42.3 (d, $^2J_{C,P}$ = 6.9 Hz), 50.5, 50.8 (d, $^3J_{C,P}$ = 5.6 Hz), 60.1, 71.5, 75.8 (d, $^2J_{C,P}$ = 6.2 Hz), 125.8 (2 C), 126.9, 127.9 (2 C), 141.9 (d, $^3J_{C,P}$ = 14.9 Hz) ppm. IR (KBr): $\tilde{\nu}$ = 3430, 3222, 1522, 1377, 1156 cm^{-1}. $C_{23}H_{38}NO_3P$ (407.53): calcd. C 67.79, H 9.40, N 3.44; found C 67.66, H 9.47, N 3.53.

(1*S*,2*S*)-2-[(2*S*,4a*S*,7*R*,8a*R*)-3-Isobutyl-4,4,7-trimethyl-2-oxooctahydro-2*H*-1,3,2-benzoxazaphosphinin-2-yl]-1-phenylpropanol (*anti*-10a): White solid, m.p. 153–154 °C (hexane/EtOAc). R_f = 0.45 (hexane/EtOAc, 1:1). $[\alpha]_D^{25}$ = +58.2 (*c* = 0.71, $CHCl_3$). ^1H NMR ($CDCl_3$): δ = 0.74 (dd, $^3J_{H,P}$ = 17.7, *J* = 7.2 Hz, 3 H), 0.80–1.10 (m, 2 H), 0.80–1.10 (m, 9 H), 1.13 (s, 3 H), 1.29 (s, 3 H), 133–1.48 (m, 2 H), 1.69–1.72 (m, 1 H), 1.82–1.90 (m, 1 H), 1.92–2.10 (m, 2 H), 2.12–2.27 (m, 2 H), 2.68–2.87 (m, 2 H), 3.99–4.09 (m, 1 H), 4.72 (dd, $^3J_{H,P}$ = 9.8 Hz, *J* = 8.4 Hz), 6.20 (s, 1 H), 7.23–7.39 (m,

5 H) ppm. ^{31}P NMR ($CDCl_3$): δ = 32.8 ppm. ^{13}C NMR ($CDCl_3$): δ = 12.1 (d, $^2J_{C,P}$ = 4.3 Hz), 20.2, 20.8, 21.6, 22.3, 25.8, 26.2, 29.7, 31.1, 33.9, 38.6 (d, $^1J_{C,P}$ = 124.7 Hz), 42.9, 50.3 (d, $^3J_{C,P}$ = 5.7 Hz), 51.1 (d, $^3J_{C,P}$ = 11.9 Hz), 59.2, 74.4, 77.0 (d, $^2J_{C,P}$ = 7.7 Hz), 127.0 (2 C), 127.6, 128.2 (2 C), 142.3 (d, $^3J_{C,P}$ = 16.2 Hz) ppm. IR (KBr): $\tilde{\nu}$ = 3430, 3222, 1522, 1377, 1156 cm^{-1}. $C_{23}H_{38}NO_3P$ (407.53): calcd. C 67.79, H 9.40, N 3.44; found C 67.70, H 9.31, N 3.30.

(1*R*,2*S*)-2-[(2*S*,4a*S*,7*R*,8a*R*)-3-Isobutyl-4,4,7-trimethyl-2-oxooctahydro-2*H*-1,3,2-benzoxazaphosphinin-2-yl]-1-phenylpropanol (*epi*-10a): White solid, m.p. 182–183 °C (hexane/EtOAc). R_f = 0.86 (hexane/EtOAc, 1:1). $[\alpha]_D^{25}$ = –3.3 (*c* = 0.94, $CHCl_3$). ^{1}H NMR ($CDCl_3$): δ = 0.86 (d, *J* = 6.6 Hz, 3 H), 0.89–1.09 (m, 1 H), 1.00 (d, *J* = 6.4 Hz, 3 H), 1.00 (dd, $^3J_{H,P}$ = 17.3 Hz, *J* = 7.3 Hz, 3 H), 1.05 (d, *J* = 6.7 Hz, 3 H), 1.11 (s, 3 H), 1.14–1.41 (m, 2 H), 1.27 (s, 3 H), 1.49–1.52 (m, 1 H), 1.66–1.76 (m, 2 H), 1.81–1.92 (m, 2 H), 1.99–2.08 (m, 1 H), 2.11–2.17 (m, 1 H), 2.81–2.99 (m, 2 H), 4.06 (td, J_1 = 10.7 Hz, J_2 = 4.1 Hz, 1 H), 4.70 (s, 1 H), 5.28 (dd, J_1 = 7.7 Hz, J_2 = 1.2 Hz, 1 H), 7.21–7.40 (m, 5 H) ppm. ^{31}P NMR ($CDCl_3$): δ = 33.0 ppm. ^{13}C NMR ($CDCl_3$): δ = 5.9, 19.7, 20.2, 20.8, 21.7, 25.7, 27.8 (d, $^3J_{C,P}$ = 6.5 Hz), 30.3, 31.1, 33.9, 41.0 (d, $^1J_{C,P}$ = 110.2 Hz), 42.4 (d, $^2J_{C,P}$ = 7.9 Hz), 50.5, 51.1 (d, $^3J_{C,P}$ = 4.3 Hz), 60.2, 71.1 (d, $^2J_{C,P}$ = 4.1 Hz), 76.2 (d, $^2J_{C,P}$ = 6.6 Hz), 125.8 (2 C), 126.8, 128.0 (2 C), 141.9 (d, $^3J_{C,P}$ = 15.5 Hz) ppm. IR (KBr): $\tilde{\nu}$ = 3402, 3302, 1457, 1389, 1199 cm^{-1}. $C_{23}H_{38}NO_3P$ (407.53): calcd. C 67.79, H 9.40, N 3.44; found C 67.89, H 9.53, N 3.32.

(1*R*,2*S*)-2-[(2*R*,4a*S*,7*R*,8a*R*)-3-Isobutyl-4,4,7-trimethyl-2-oxooctahydro-2*H*-1,3,2-benzoxazaphosphinin-2-yl]-1-(4-methoxyphenyl)propanol (*epi*-11e): White solid, m.p. 143–145 °C (hexane/EtOAc). R_f = 0.51 (hexane/EtOAc, 1:1). $[\alpha]_D^{23}$ = +32.7 (*c* = 0.69, $CHCl_3$). ^{1}H NMR ($CDCl_3$): δ = 0.87–1.03 (m, 1 H), 0.87 (d, J_1 = 6.6 Hz, 3 H), 0.98 (dd, $^3J_{H,P}$ = 18.3 Hz, *J* = 7.4 Hz, 3 H), 0.99 (d, *J* = 4.7 Hz, 3 H), 1.01 (d, *J* = 4.8 Hz, 3 H), 1.04–1.28 (s, 2 H), 1.20 (s, 3 H), 1.21 (s, 3 H), 1.47–1.52 (m, 1 H), 1.57–1.66 (m, 1 H), 1.72–1.83 (m, 3 H), 1.95–2.02 (m, 1 H), 2.27–2.31 (m, 1 H), 2.83–3.06 (m, 2 H), 3.78 (s, 3 H), 4.23–4.30 (m, 1 H), 4.64 (s, 1 H), 5.30 (d, *J* = 7.8 Hz, 1 H), 6.87 (d, *J* = 8.6 Hz, 2 H), 7.24 (d, *J* = 8.6 Hz, 2 H) ppm. ^{31}P NMR ($CDCl_3$): δ = 32.7 ppm. ^{13}C NMR ($CDCl_3$): δ = 5.9, 19.7, 20.8, 21.7, 23.2, 25.2, 26.6, 29.3, 31.0, 34.0, 43.0, 46.7 (d, $^1J_{C,P}$ = 118.7 Hz), 50.4 (d, $^3J_{C,P}$ = 9.2 Hz), 50.8, 55.2, 59.5, 70.4 (d, $^2J_{C,P}$ = 4.4 Hz), 76.5, 113.4 (2 C), 126.8 (2 C), 134.2 (d, $^3J_{H,P}$ = 16.6 Hz), 158.4 ppm. IR (KBr): $\tilde{\nu}$ = 3228, 1246, 1045, 822 cm^{-1}. $C_{24}H_{40}NO_4P$ (437.55): calcd. C 65.88, H 9.21, N 3.20; found C 66.00, H 9.33, N 3.31.

(1*S*,2*R*)-2-[(2*S*,4a*S*,7*R*,8a*R*)-3-Isobutyl-4,4,7-trimethyl-2-oxooctahydro-2*H*-1,3,2-benzoxazaphosphinin-2-yl]-1-(4-methoxyphenyl)propanol (*syn*-11a): Colorless oil. R_f = 0.68 (hexane/EtOAc, 1:1). $[\alpha]_D^{23}$ = +36.2 (*c* = 1.54, $CHCl_3$). ^{1}H NMR ($CDCl_3$): δ = 0.89–1.20 (m, 1 H), 0.90 (d, *J* = 6.6 Hz, 3 H), 0.94 (d, *J* = 6.4 Hz, 3 H), 0.97 (dd, $^3J_{H,P}$ = 16.6 Hz, *J* = 7.3 Hz, 3 H), 1.04 (d, *J* = 6.7 Hz, 3 H), 1.21–1.57 (m, 3 H), 1.25 (s, 3 H), 1.32 (s, 3 H), 1.73–1.91 (m, 3 H), 1.93–2.17 (m, 2 H), 2.19–2.26 (m, 1 H), 2.90–3.12 (m, 2 H), 3.79 (s, 3 H), 3.86–3.96 (m, 1 H), 4.84 (s, 1 H), 5.23 (d, *J* = 10.3 Hz, 1 H), 6.90 (d, *J* = 8.7 Hz, 2 H), 7.24 (d, *J* = 8.7 Hz, 2 H) ppm. ^{31}P NMR ($CDCl_3$): δ = 32.2 ppm. ^{13}C NMR ($CDCl_3$): δ = 7.7, 20.1, 20.7, 21.0, 21.6, 25.8, 27.5 (d, $^3J_{C,P}$ = 5.0 Hz), 30.3, 31.0, 33.9, 40.2 (d, $^1J_{C,P}$ = 111.8 Hz), 42.3 (d, $^2J_{C,P}$ = 6.7 Hz), 50.5, 50.8 (d, $^3J_{C,P}$ = 5.8 Hz), 55.1, 60.0, 71.1, 75.7 (d, $^2J_{C,P}$ = 6.5 Hz), 113.3 (2 C), 126.8 (2 C), 134.0 (d, $^3J_{C,P}$ = 15.2 Hz), 158.4 ppm. IR (KBr): $\tilde{\nu}$ = 3366, 1245, 1009, 884 cm^{-1}. $C_{28}H_{40}NO_3P$ (469.60): calcd. C 71.61, H 8.59, N 2.98; found C 71.77, H 8.74, N 3.11.

(1*S*,2*S*)-2-[(2*S*,4a*S*,7*R*,8a*R*)-3-Isobutyl-4,4,7-trimethyl-2-oxooctahydro-2*H*-1,3,2-benzoxazaphosphinin-2-yl]-1-(4-methoxyphenyl)propanol (*anti*-11a): White solid, m.p. 173–174 °C (hexane/EtOAc). R_f = 0.40 (hexane/EtOAc, 1:1). $[\alpha]_D^{23}$ = +48.9 (*c* = 0.85, $CHCl_3$). ^{1}H NMR ($CDCl_3$): δ = 0.73 (dd, $^3J_{H,P}$ = 17.7 Hz, *J* = 7.2 Hz, 3 H), 0.81–0.92 (m, 1 H), 0.95–1.10 (m, 1 H), 0.96 (d, *J* = 6.3 Hz, 6 H), 0.98 (d, *J* = 6.6 Hz, 3 H), 1.13 (s, 3 H), 1.29 (s, 3 H), 1.33–1.57 (s, 1 H), 1.69–1.72 (m, 1 H), 1.79–1.90 (m, 2 H), 1.96–2.09 (m, 2 H), 2.10–2.31 (m, 2 H), 2.68–2.87 (m, 2 H), 3.80 (s, 3 H), 4.00–4.13 (m, 1 H), 4.69 (dd, $^3J_{H,P} \approx J$ = 9.1 Hz, 1 H), 6.16 (s, 1 H), 6.87 (d, *J* = 8.6 Hz, 2 H), 6.90 (d, *J* = 8.6 Hz, 2 H) ppm. ^{31}P NMR ($CDCl_3$): δ = 33.0 ppm. ^{13}C NMR ($CDCl_3$): δ = 12.1 (d, $^2J_{C,P}$ = 4.0 Hz), 20.2, 20.8, 21.6, 22.3, 25.8, 26.2, 29.7, 31.1, 33.9, 38.7 (d, $^1J_{C,P}$ = 124.4 Hz), 42.9, 50.3 (d, $^3J_{C,P}$ = 5.6 Hz), 51.1 (d, $^3J_{C,P}$ = 11.5 Hz), 55.2, 59.2, 73.8, 77.0 (d, $^2J_{C,P}$ = 8.1 Hz), 113.6 (2 C), 128.1 (2 C), 134.5 (d, $^3J_{C,P}$ = 15.8 Hz), 159.0 ppm. IR (KBr): $\tilde{\nu}$ = 3298, 1240, 1034, 829 cm^{-1}. $C_{24}H_{40}NO_4P$ (437.55): calcd. C 65.88, H 9.21, N 3.20; found C 65.76, H 9.14, N 3.11.

(1*R*,2*S*)-2-[(2*S*,4a*S*,7*R*,8a*R*)-3-Isobutyl-4,4,7-trimethyl-2-oxooctahydro-2*H*-1,3,2-benzoxazaphosphinin-2-yl]-1-(4-methoxyphenyl)propanol (*epi*-11a): White solid, m.p. 224–226 °C (hexane/EtOAc). R_f = 0.81 (hexane/EtOAc, 1:1). $[\alpha]_D^{23}$ = –3.3 (*c* = 0.60, $CHCl_3$). ^{1}H NMR ($CDCl_3$): δ = 0.90–1.05 (m, 2 H), 0.86 (d, J_1 = 6.6 Hz, 3 H), 0.99 (d, *J* = 6.1 Hz, 3 H), 1.00 (dd, $^3J_{H,P}$ = 17.1 Hz, *J* = 7.5 Hz, 3 H), 1.04 (d, *J* = 6.6 Hz, 3 H), 1.10 (s, 3 H), 1.17–1.40 (s, 1 H), 1.27 (s, 3 H), 1.51–1.60 (m, 1 H), 1.61–1.67 (m, 2 H), 1.70–1.90 (m, 2 H), 1.94–2.12 (m, 1 H), 2.15–2.23 (m, 1 H), 2.86–2.96 (m, 2 H), 3.87 (s, 3 H), 4.03 (td, J_1 = 10.5 Hz, J_2 = 4.0 Hz, 1 H), 4.73 (s, 1 H), 5.24 (d, *J* = 7.5 Hz, 1 H), 6.87 (d, *J* = 8.8 Hz, 2 H), 7.26 (d, *J* = 8.8 Hz, 2 H) ppm. ^{31}P NMR ($CDCl_3$): δ = 33.2 ppm. ^{13}C NMR ($CDCl_3$): δ = 5.9, 19.7, 20.1, 20.8, 21.7, 25.7, 27.8, 30.3, 31.2, 33.9, 41.1 (d, $^1J_{C,P}$ = 109.4 Hz), 42.3, 50.5, 51.1, 55.2, 60.1, 70.7, 76.2, 113.3 (2 C), 126.9 (2 C), 134.5 (d, $^3J_{C,P}$ = 15.2 Hz), 158.4 ppm. IR (KBr): $\tilde{\nu}$ = 3348, 1241, 1011, 808 cm^{-1}. $C_{24}H_{40}NO_4P$ (437.55): calcd. C 65.88, H 9.21, N 3.20; found C 65.97, H 9.29, N 3.28.

(1*R*,2*R*)-2-[(2*R*,4a*S*,7*R*,8a*R*)-3-Benzyl-4,4,7-trimethyl-2-oxooctahydro-2*H*-1,3,2-benzoxazaphosphinin-2-yl]-1,2-diphenylethanol (*anti*-12e): White solid, m.p. 213–214 °C (hexane/EtOAc). R_f = 0.51 (EtOAc). $[\alpha]_D^{23}$ = –31.2 (*c* = 1.03, $CHCl_3$). ^{1}H NMR ($CDCl_3$): δ = 0.18–0.27 (m, 1 H), 0.42–0.56 (m, 1 H), 0.80–1.09 (m, 1 H), 0.91 (d, *J* = 6.5 Hz, 3 H), 0.96 (s, 3 H), 1.01 (s, 3 H), 1.25–1.45 (m, 3 H), 1.48–1.53 (m, 1 H), 2.08–2.12 (m, 1 H), 2.79 (dd, $^2J_{H,P}$ = 16.9 Hz, *J* = 10.1 Hz, 1 H), 4.26 (td, J_1 = 10.7 Hz, J_2 = 5.0 Hz, 1 H), 4.33 (dd, *J* = 15.4 Hz, $^3J_{H,P}$ = 9.0 Hz, 1 H), 4.47 (dd, $J_{H,P}$ = 15.4 Hz, $J_{H,H}$ = 15.3 Hz, 1 H), 5.21 (dd, $J_{H,P}$ = 9.8 Hz, $J_{H,H}$ = 9.7 Hz, 1 H), 6.36 (s, 1 H), 6.89–7.63 (m, 15 H) ppm. ^{31}P NMR ($CDCl_3$): δ = 28.7 ppm. ^{13}C NMR ($CDCl_3$): δ = 21.8, 22.1, 25.8 (2 C), 30.7, 33.7, 41.1 (d, $^3J_{C,P}$ = 7.3 Hz), 46.3, 47.9, 55.0 (d, $^1J_{C,P}$ = 122.1 Hz), 60.2, 73.9, 75.6 (d, $^2J_{C,P}$ = 8.8 Hz), 126.7, 127.0, 127.2 (2 C), 127.6 (5 C), 128.5 (2 C), 129.7 (2 C), 130.8 (d, $^3J_{C,P}$ = 5.0 Hz, 2 C), 135.2 (d, $^2J_{C,P}$ = 7.1 Hz), 138.9, 142.1 (d, $^3J_{C,P}$ = 16.2 Hz) ppm. IR (KBr): $\tilde{\nu}$ = 3434, 1160, 1030, 1024, 891 cm^{-1}. $C_{31}H_{38}NO_3P$ (503.61): calcd. C 73.93, H 7.61, N 2.78; found C 74.04, H 7.78, N 2.92.

(1*S*,2*R*)-2-[(2*R*,4a*S*,7*R*,8a*R*)-3-Benzyl-4,4,7-trimethyl-2-oxooctahydro-2*H*-1,3,2-benzoxazaphosphinin-2-yl]-1,2-diphenylethanol (*syn*-12e): White solid, m.p. 206–209 °C (hexane/EtOAc). R_f = 0.23 (EtOAc). $[\alpha]_D^{23}$ = –30.1 (*c* = 0.27, $CHCl_3$). ^{1}H NMR ($CDCl_3$): δ = 0.52–0.76 (m, 2 H), 0.80 (d, *J* = 6.5 Hz, 3 H), 0.97 (s, 3 H), 0.99–1.07 (m, 1 H), 1.29 (s, 3 H), 1.20–1.30 (m, 2 H), 1.58–1.65 (m, 2 H), 1.82–1.86 (m, 1 H), 3.02 (dd, $^2J_{H,P}$ = 19.0 Hz, *J* = 2.5 Hz, 1 H), 4.23 (tdd, J_1 = 10.8 Hz, J_2 = 4.8 Hz, $^3J_{H,P}$ = 1.8 Hz, 1 H), 4.39 (dd, *J* = 16.6 Hz, $^3J_{H,P}$ = 11.5 Hz, 1 H), 4.71 (dd, *J* = 16.6 Hz, $^3J_{H,P}$ = 11.8 Hz, 1 H), 4.79 (d, *J* = 2.0 Hz, 1 H), 5.33 (ddd, $^3J_{H,P}$ = 8.4 Hz, J_1 = 2.5 Hz, J_2 = 2.0 Hz, 1 H), 6.88–7.53 (m, 15 H) ppm.

^{31}P NMR ($CDCl_3$): δ = 27.4 ppm. ^{13}C NMR ($CDCl_3$): δ = 21.6, 22.5, 25.8, 26.1, 30.6, 33.7, 41.2 (d, $^3J_{C,P}$ = 6.7 Hz), 46.2, 49.5 (d, $^3J_{C,P}$ = 6.9 Hz), 58.3 (d, $^1J_{C,P}$ = 121.1 Hz), 60.4, 72.9, 75.9 (d, $^2J_{C,P}$ = 7.8 Hz), 126.0 (2 C), 126.7 (2 C), 127.0, 127.4 (4 C), 127.7 (2 C), 128.4 (2 C), 131.2 (d, $^3J_{C,P}$ = 6.9 Hz, 2 C), 133.4, 140.6, 141.4 (d, $^3J_{C,P}$ = 15.1 Hz) ppm. IR (KBr): $\tilde{\nu}$ = 3422, 1162, 1055, 1040, 884 cm^{-1}. $C_{31}H_{38}NO_3P$ (503.61): calcd. C 73.93, H 7.61, N 2.78; found C 73.80, H 7.50, N 2.65.

(1*R*,2*R*)-2-[(2*R*,4a*S*,7*R*,8a*R*)-3-Benzyl-4,4,7-trimethyl-2-oxooctahydro-2*H*-1,3,2-benzoxazaphosphinin-2-yl]-1-(4-methoxyphenyl)-2-phenylethanol (*anti*-13e): White solid, m.p. 184–185 °C (hexane/EtOAc). R_f = 0.64 (hexane/EtOAc, 1:1). $[\alpha]_D^{23}$ = –25.7 (*c* = 0.95, $CHCl_3$). ^{1}H NMR ($CDCl_3$): δ = 0.17–0.26 (m, 1 H), 0.47–0.52 (m, 1 H), 0.85–0.93 (m, 1 H), 0.92 (d, *J* = 6.5 Hz, 3 H), 0.97 (s, 3 H), 0.97–1.09 (m, 1 H), 1.03 (s, 3 H), 1.22–1.30 (m, 1 H), 1.31–1.45 (m, 1 H), 1.49–1.55 (m, 1 H), 2.08–2.12 (m, 1 H), 2.79 (dd, $^2J_{H,P}$ = 16.9 Hz, *J* = 10.0 Hz, 1 H), 3.65 (s, 3 H), 4.26 (td, J_1 = 10.7 Hz, J_2 = 5.0 Hz, 1 H), 4.35 (dd, *J* = 15.4 Hz, $^3J_{H,P}$ = 9.0 Hz, 1 H), 4.48 (dd, $^3J_{H,P} \approx J$ = 15.4 Hz, 1 H), 5.19 (dd, $^3J_{H,P} \approx J$ = 10.0 Hz, 1 H), 6.31 (s, 1 H), 6.55–7.65 (m, 14 H) ppm. ^{31}P NMR ($CDCl_3$): δ = 28.7 ppm. ^{13}C NMR ($CDCl_3$): δ = 21.8, 22.1, 25.6, 25.7, 30.7, 33.6, 41.1 (d, $^3J_{C,P}$ = 7.4 Hz), 46.3, 47.8, 54.9 (d, $^1J_{C,P}$ = 121.9 Hz), 54.9, 60.2, 73.3, 75.5 (d, $^2J_{C,P}$ = 8.8 Hz), 113.0 (2 C), 126.7 (2 C), 127.6 (2 C), 128.2 (2 C), 128.5 (2 C), 129.7 (2 C), 130.8 (2 C), 134.4 (d, $^3J_{C,P}$ = 16.9 Hz), 135.4, 138.9 (d, $^3J_{C,P}$ = 15.1 Hz), 158.4 ppm. IR (KBr): $\tilde{\nu}$ = 3421, 3291, 1192, 1026, 890 cm^{-1}. MS: *m*/*z* (%) = 533 (3) [M$^+$], 397 (39), 382 (26), 302 (97), 260 (100), 135 (26), 91 (95).

(1*S*,2*R*)-2-[(2*R*,4a*S*,7*R*,8a*R*)-3-Benzyl-4,4,7-trimethyl-2-oxooctahydro-2*H*-1,3,2-benzoxazaphosphinin-2-yl]-1-(4-methoxyphenyl)-2-phenylethanol (*syn*-13e): White solid, m.p. 221–222 °C (hexane/EtOAc). R_f = 0.42 (hexane/EtOAc, 1:1). $[\alpha]_D^{23}$ = –46.1 (*c* = 0.25, $CHCl_3$). ^{1}H NMR ($CDCl_3$): δ = 0.56–0.76 (m, 2 H), 0.81 (d, *J* = 6.5 Hz, 3 H), 0.88–1.11 (m, 2 H), 0.97 (s, 3 H), 1.19–1.40 (m, 1 H), 1.28 (s, 3 H), 1.58–1.85 (m, 3 H), 3.06 (dd, $^2J_{H,P}$ = 18.8 Hz, *J* = 2.6 Hz, 1 H), 3.71 (s, 3 H), 4.24 (td, J_1 = 9.2 Hz, J_2 = 4.7 Hz, 1 H), 4.38 (dd, *J* = 16.5 Hz, $^3J_{H,P}$ = 11.6 Hz, 1 H), 4.70 (dd, *J* = 16.5 Hz, $^3J_{H,P}$ = 11.5 Hz, 1 H), 4.76 (s, 1 H), 5.28–5.30 (m, 1 H), 6.63–6.84 (m, 4 H), 7.10–7.59 (m, 10 H) ppm. ^{31}P NMR ($CDCl_3$): δ = 27.5 ppm. ^{13}C NMR ($CDCl_3$): δ = 21.6, 22.5, 25.8, 26.1, 30.6, 33.7, 41.3, 46.2, 49.6, 55.1, 58.4 (d, $^1J_{C,P}$ = 120.4 Hz), 60.4, 72.7, 76.0, 112.9 (2 C), 126.8 (2 C), 127.3 (2 C), 127.5 (2 C), 127.7 (2 C), 128.4 (2 C), 131.3 (2 C), (d, $^3J_{C,P}$ = 6.8 Hz), 133.6 (2 C), 140.8, 158.4 ppm. IR (KBr): $\tilde{\nu}$ = 3436, 1163, 1054, 1037, 880 cm^{-1}. $C_{32}H_{40}NO_4P$ (533.64): calcd. C 72.02, H 7.56, N 2.62; found C 72.18, H 7.43, N 2.76.

(1*R*,2*R*)-2-[(2*R*,4a*S*,7*R*,8a*R*)-3-Benzyl-4,4,7-trimethyl-2-oxooctahydro-2*H*-1,3,2-benzoxazaphosphinin-2-yl]-1-(4-chlorophenyl)-2-phenylethanol (*anti*-14e): White solid, m.p. 227–228 °C (hexane/EtOAc). R_f = 0.35 (hexane/EtOAc, 2:1). $[\alpha]_D^{23}$ = –10.2 (*c* = 0.98, $CHCl_3$). ^{1}H NMR ($CDCl_3$): δ = 0.14–0.23 (m, 1 H), 0.42–0.55 (m, 1 H), 0.70–0.97 (m, 1 H), 0.91 (d, *J* = 6.5 Hz, 3 H), 0.98 (s, 3 H), 1.02 (s, 3 H), 1.06–1.19 (m, 1 H), 1.28–1.39 (m, 1 H), 1.40–1.46 (m, 1 H), 1.50–1.58 (m, 1 H), 2.04–2.13 (m, 1 H), 2.63 (dd, $^2J_{H,P}$ = 17.1 Hz, *J* = 10.5 Hz, 1 H), 4.27 (td, J_1 = 10.7 Hz, J_2 = 4.9 Hz, 1 H), 4.35 (dd, *J* = 15.3 Hz, $^3J_{H,P}$ = 9.0 Hz, 1 H), 4.44 (dd, $J_{H,P}$ = 15.3 Hz, $J_{H,H}$ = 15.2 Hz, 1 H), 5.17 (dd, *J* = 10.5 Hz, $^3J_{H,P}$ = 8.8 Hz, 1 H), 6.50 (s, 1 H), 6.86–7.63 (m, 14 H) ppm. ^{31}P NMR ($CDCl_3$): δ = 28.4 ppm. ^{13}C NMR ($CDCl_3$): δ = 21.8, 21.9, 25.8 (2 C), 30.7, 33.6, 41.1 (d, $^3J_{C,P}$ = 7.4 Hz), 46.3 (d, $^2J_{C,P}$ = 4.5 Hz), 47.8 (d, $^3J_{C,P}$ = 4.7 Hz), 54.9 (d, $^1J_{C,P}$ = 122.5 Hz), 60.3, 73.2, 75.6 (d, $^2J_{C,P}$ = 8.9 Hz), 127.0, 127.6 (2 C), 127.7 (6 C), 128.5 (d, $^2J_{C,P}$ = 4.4 Hz, 2 C), 129.9 (2 C), 130.8, 132.5, 134.7 (d, $^3J_{C,P}$ = 7.4 Hz, C), 138.6, 140.8 (d, $^2J_{C,P}$ = 16.9 Hz, C) ppm. IR (KBr): $\tilde{\nu}$ = 3424, 3271, 1159, 1023, 889 cm^{-1}. MS (EI): *m*/*z* (%) = 539 (1) [M]$^+$, 397 (38), 302 (17), 261 (16), 260 (100), 91 (50), 57 (21), 55 (20).

(1*S*,2*R*)-2-[(2*R*,4a*S*,7*R*,8a*R*)-3-Benzyl-4,4,7-trimethyl-2-oxooctahydro-2*H*-1,3,2-benzoxazaphosphinin-2-yl]-1-(4-chlorophenyl)-2-phenylethanol (*syn*-14e): White solid, m.p. 254–255 °C (hexane/EtOAc). R_f = 0.10 (hexane/EtOAc, 2:1). $[\alpha]_D^{23}$ = –19.4 (*c* = 0.75, $CHCl_3$). ^{1}H NMR ($CDCl_3$): δ = 0.50–0.74 (m, 2 H), 0.80 (d, *J* = 6.5 Hz, 3 H), 0.92–0.97 (m, 1 H), 1.00 (s, 3 H), 1.05–1.34 (m, 2 H), 1.27 (s, 3 H), 1.57–1.66 (m, 2 H), 1.80–1.95 (m, 1 H), 3.00 (dd, $^2J_{H,P}$ = 19.4 Hz, *J* = 2.7 Hz, 1 H), 4.24 (tdd, J_1 = 10.7 Hz, J_2 = 4.8 Hz, $^3J_{H,P}$ = 1.7 Hz, 1 H), 4.43 (dd, *J* = 16.5 Hz, $^3J_{H,P}$ = 11.3 Hz, 1 H), 4.67 (dd, *J* = 16.5 Hz, $^3J_{H,P}$ = 12.5 Hz, 1 H), 4.90 (d, *J* = 2.4 Hz, 1 H), 5.26 (ddd, $^3J_{H,P}$ = 8.4 Hz, J_1 = 2.7 Hz, J_2 = 2.4 Hz, 1 H), 6.78–7.54 (m, 14 H) ppm. ^{31}P NMR ($CDCl_3$): δ = 27.2 ppm. ^{13}C NMR ($CDCl_3$): δ = 21.6, 22.3, 26.0, 26.1, 30.6, 33.7, 41.1 (d, $^3J_{C,P}$ = 6.5 Hz), 46.1, 49.5 (d, $^3J_{C,P}$ = 6.9 Hz), 57.8 (d, $^1J_{C,P}$ = 121.5 Hz), 60.4, 72.5, 76.0 (d, $^2J_{C,P}$ = 8.0 Hz), 126.9, 127.1, 127.4 (2 C), 127.6 (4 C), 127.9 (2 C), 128.4 (2 C), 131.2 (d, $^3J_{C,P}$ = 6.9 Hz, 2 C), 132.3, 133.2, 140.0, 140.4 (d, $^3J_{C,P}$ = 15.2 Hz) ppm. IR (KBr): $\tilde{\nu}$ = 3420, 1162, 1052, 1036, 880 cm^{-1}. $C_{31}H_{37}ClNO_3P$ (538.06): calcd. C 69.20, H 6.93, N 2.60; found C 69.33, H 7.05, N 2.51.

(1*R*,2*R*)-1-[(2*R*,4a*S*,7*R*,8a*R*)-3-Benzyl-4,4,7-trimethyl-2-oxooctahydro-2*H*-1,3,2-benzoxazaphosphinin-2-yl]-4-methyl-1-phenylpentan-2-ol (*anti*-15e): White solid, m.p. 256–257 °C (hexane/EtOAc). R_f = 0.93 (hexane/EtOAc, 1:1). $[\alpha]_D^{23}$ = –35.7 (*c* = 0.89, $CHCl_3$). ^{1}H NMR ($CDCl_3$): δ = 0.14–0.23 (m, 1 H), 0.43–0.65 (m, 1 H), 0.73 (d, *J* = 6.8 Hz, 3 H), 0.81 (d, *J* = 6.5 Hz, 3 H), 0.85–1.17 (m, 3 H), 0.89 (s, 3 H), 0.90 (d, *J* = 5.7 Hz, 3 H), 0.96–1.03 (m, 1 H), 1.00 (s, 3 H), 1.22–1.31 (m, 2 H), 1.49–1.54 (m, 1 H), 1.78–1.90 (m, 1 H), 2.03–2.07 (m, 1 H), 2.55 (dd, $^2J_{H,P}$ = 16.5 Hz, *J* = 10.1 Hz, 1 H), 4.20 (td, J_1 = 10.7 Hz, J_2 = 4.9 Hz, 1 H), 4.30 (dd, *J* = 15.5 Hz, $^3J_{H,P}$ = 9.7 Hz, 1 H), 4.30–4.39 (m, 1 H), 4.47 (dd, $^3J_{H,P} \approx J$ = 15.5 Hz, 1 H), 5.80 (d, *J* = 0.7 Hz, 1 H), 7.18–7.69 (m, 10 H) ppm. ^{31}P NMR ($CDCl_3$): δ = 29.3 ppm. ^{13}C NMR ($CDCl_3$): δ = 21.1, 21.8, 22.2, 23.9 (2 C), 25.4 (d, $^3J_{C,P}$ = 3.9 Hz), 25.6, 30.7, 33.6, 41.0 (d, $^3J_{C,P}$ = 7.4 Hz), 44.9 (d, $^2J_{C,P}$ = 14.5 Hz), 46.1 (d, $^2J_{C,P}$ = 5.4 Hz), 47.9 (d, $^3J_{C,P}$ = 4.9 Hz), 54.0 (d, $^1J_{C,P}$ = 123.6 Hz), 60.0, 68.0 (d, $^2J_{C,P}$ = 4.7 Hz), 75.4 (d, $^2J_{C,P}$ = 8.7 Hz), 126.9 (d, $^5J_{C,P}$ = 3.5 Hz), 127.4, 127.9 (d, $^4J_{C,P}$ = 2.4 Hz, 2 C), 128.3 (2 C), 129.2 (2 C), 130.5 (d, $^3J_{C,P}$ = 6.0 Hz, 2 C), 136.2, 139.0 ppm. IR (KBr): $\tilde{\nu}$ = 3424, 3300, 1184, 1066, 1026, 874 cm^{-1}. $C_{29}H_{42}NO_3P$ (483.62): calcd. C 72.02, H 8.75, N 2.90; found C 72.16, H 8.63, N 3.02.

(1*S*,2*R*)-1-[(2*R*,4a*S*,7*R*,8a*R*)-3-Benzyl-4,4,7-trimethyl-2-oxooctahydro-2*H*-1,3,2-benzoxazaphosphinin-2-yl]-4-methyl-1-phenylpentan-2-ol (*syn*-15e): White solid, m.p. 202–204 °C (hexane/EtOAc). R_f = 0.41 (hexane/EtOAc, 1:1). $[\alpha]_D^{23}$ = –64.2 (*c* = 0.37, $CHCl_3$). ^{1}H NMR ($CDCl_3$): δ = 0.66–0.75 (m, 1 H), 0.77 (d, *J* = 6.6 Hz, 3 H), 0.80 (d, *J* = 6.7 Hz, 3 H), 0.85 (d, *J* = 6.5 Hz, 3 H), 0.93 (s, 3 H), 0.96–1.12 (m, 2 H), 1.15 (s, 3 H), 1.20–1.32 (m, 3 H), 1.57–1.70 (m, 4 H), 1.88–1.92 (m, 1 H), 2.85 (dd, $^2J_{H,P}$ = 20.4 Hz, *J* = 2.6 Hz, 1 H), 4.09 (d, *J* = 2.4 Hz, 1 H), 4.18–4.33 (m, 2 H), 4.32 (dd, *J* = 16.5 Hz, $^3J_{H,P}$ = 11.4 Hz, 1 H), 4.62 (dd, *J* = 16.5 Hz, $^3J_{H,P}$ = 11.6 Hz, 1 H), 7.21–7.49 (m, 10 H) ppm. ^{31}P NMR ($CDCl_3$): δ = 28.0 ppm. ^{13}C NMR ($CDCl_3$): δ = 21.7, 22.1, 22.5, 23.2, 24.4, 25.7, 26.0, 30.7, 33.8, 41.3 (d, $^3J_{C,P}$ = 6.8 Hz), 43.8 (d, $^3J_{C,P}$ = 12.6 Hz), 46.1, 49.3 (d, $^3J_{C,P}$ = 6.2 Hz), 55.3 (d, $^1J_{C,P}$ = 123.0 Hz), 60.1, 69.0, 75.7 (d, $^2J_{C,P}$ = 8.2 Hz), 126.9, 127.0, 127.8 (2 C), 127.9 (2 C), 128.3 (2 C), 131.1 (d, $^3J_{C,P}$ = 6.7 Hz, 2 C), 134.6, 140.4 ppm. IR (KBr): $\tilde{\nu}$ = 3411, 1196, 1050, 1030, 874 cm^{-1}. $C_{29}H_{42}NO_3P$ (483.62): calcd. C 72.02, H 8.75, N 2.90; found C 72.14, H 8.90, N 2.99.

(1*S*,2*S*)-1-[(2*S*,4a*S*,7*R*,8a*R*)-3-Benzyl-4,4,7-trimethyl-2-oxooctahydro-2*H*-1,3,2-benzoxazaphosphinin-2-yl]-4-methyl-1-phenylpentan-2-

ol (*anti*-15a): White solid, m.p. 246–247 °C (hexane/EtOAc). R_f = 0.50 (hexane/EtOAc, 3:1). $[\alpha]_D^{23}$ = +74.7 (*c* = 1.00, $CHCl_3$). ^1H NMR ($CDCl_3$): δ = 0.53 (s, 3 H), 0.63–1.01 (m, 1 H), 0.76 (d, *J* = 6.8 Hz, 3 H), 0.78 (d, *J* = 6.6 Hz, 3 H), 0.82 (s, 3 H), 0.89 (d, *J* = 6.0 Hz, 3 H), 1.13–1.43 (m, 4 H), 1.53–1.61 (m, 2 H), 1.67–1.74 (m, 2 H), 1.80–1.95 (m, 2 H), 3.11 (dd, $^2J_{H,P}$ = 13.6 Hz, *J* = 9.9 Hz, 1 H), 3.30–3.39 (m, 1 H), 3.98 (dd, *J* = 17.4 Hz, $^3J_{H,P}$ = 11.6 Hz, 1 H), 4.27–4.37 (m, 1 H), 4.65 (dd, *J* = 17.4 Hz, $^3J_{H,P}$ = 11.0 Hz, 1 H), 5.69 (d, *J* = 1.0 Hz, 1 H), 7.17–7.56 (m, 10 H) ppm. ^{31}P NMR ($CDCl_3$): δ = 26.9 ppm. ^{13}C NMR ($CDCl_3$): δ = 20.2, 21.1, 21.6, 23.9, 24.1, 25.5, 27.8, 30.8, 33.7, 42.3 (d, $^3J_{C,P}$ = 13.4 Hz), 44.6 (d, $^3J_{C,P}$ = 5.4 Hz), 45.5, 50.8 (d, $^3J_{C,P}$ = 7.4 Hz), 54.6 (d, $^1J_{C,P}$ = 116.3 Hz), 60.5, 69.3, 77.5 (d, $^2J_{C,P}$ = 9.4 Hz), 126.5, 126.9 (2 C), 127.2, 128.1 (2 C), 128.5 (2 C), 130.1 (2 C), 135.9, 141.3 ppm. IR (KBr): $\tilde{\nu}$ = 3424, 1165, 1047, 1031, 874 cm^{-1}. MS (EI): *m*/*z* (%) = 483 (2) $[M]^+$, 397 (40), 260 (100), 91 (47).

(1*S*,2*R*)-1-[(2*S*,4a*S*,7*R*,8a*R*)-3-Benzyl-4,4,7-trimethyl-2-oxooctahydro-2*H*-1,3,2-benzoxazaphosphinin-2-yl]-4-methyl-1-phenylpentan-2-ol (*syn*-15a): White solid, m.p. 199–200 °C (hexane/EtOAc). R_f = 0.38 (hexane/EtOAc, 3:1). $[\alpha]_D^{23}$ = +81.1 (*c* = 0.41, $CHCl_3$). ^1H NMR ($CDCl_3$): δ = 0.74–0.90 (m, 1 H), 0.85 (d, *J* = 6.5 Hz, 6 H), 0.86 (d, *J* = 6.7 Hz, 3 H), 0.93 (s, 3 H), 0.96–1.03 (m, 1 H), 1.07 (s, 3 H), 1.11–1.26 (m, 3 H), 1.57–1.78 (m, 6 H), 3.20 (dd, $^2J_{H,P}$ = 17.4 Hz, *J* = 2.3 Hz, 1 H), 3.64–3.56 (m, 1 H), 4.09 (dd, *J* = 16.9 Hz, $^3J_{H,P}$ = 10.3 Hz, 1 H), 4.42–4.35 (m, 1 H), 4.60 (s, 1 H), 4.76 (dd, *J* = 16.9 Hz, $^3J_{H,P}$ = 10.4 Hz, 1 H), 7.18–7.69 (m, 10 H) ppm. ^{31}P NMR ($CDCl_3$): δ = 26.3 ppm. ^{13}C NMR ($CDCl_3$): δ = 20.7, 21.6, 22.3, 23.0, 24.4, 25.6, 27.8, 30.9, 33.7, 41.8 (d, $^3J_{C,P}$ = 8.0 Hz), 43.8 (d, $^3J_{C,P}$ = 12.3 Hz), 46.2, 50.7 (d, $^3J_{C,P}$ = 5.1 Hz), 53.1 (d, $^1J_{C,P}$ = 112.3 Hz), 60.8, 69.6 (d, $^2J_{C,P}$ = 4.8 Hz), 76.1 (d, $^2J_{C,P}$ = 7.8 Hz), 126.6, 126.8 (2 C), 127.0, 128.1 (2 C), 128.3 (2 C), 130.8 (d, $^3J_{C,P}$ = 7.0 Hz, 2 C), 134.1, 141.5 ppm. IR (KBr): $\tilde{\nu}$ = 3413, 1199, 1030, 1018, 873 cm^{-1}. $C_{29}H_{42}NO_3P$ (483.62): calcd. C 72.02, H 8.75, N 2.90; found C 71.94, H 8.86, N 2.77.

(1*R*,2*R*)-2-[(2*R*,4a*S*,7*R*,8a*R*)-3-Isobutyl-4,4,7-trimethyl-2-oxooctahydro-2*H*-1,3,2-benzoxazaphosphinin-2-yl]-1,2-diphenylethanol (*anti*-16e): White solid, m.p. 201–203 °C (hexane/EtOAc). R_f = 0.54 (hexane/EtOAc, 1:1). $[\alpha]_D^{23}$ = +42.3 (*c* = 0.95, $CHCl_3$). ^1H NMR ($CDCl_3$): δ = 0.12–0.20 (m, 1 H), 0.37–0.49 (m, 1 H), 0.80–1.02 (m, 1 H), 0.86 (s, 3 H), 0.89 (d, *J* = 6.5 Hz, 3 H), 1.01 (d, *J* = 6.5 Hz, 3 H), 1.09 (s, 3 H), 1.11 (d, *J* = 6.9 Hz, 3 H), 1.16–1.29 (m, 1 H), 1.36–1.41 (m, 1 H), 1.47–1.51 (m, 1 H), 1.79–1.84 (m, 1 H), 2.04–2.08 (m, 1 H), 2.27–2.30 (m, 1 H), 2.73–2.86 (m, 1 H), 3.12–3.29 (m, 1 H), 3.44 (dd, $^2J_{H,P}$ = 16.1 Hz, *J* = 10.2 Hz, 1 H), 4.21 (td, J_1 = 10.6 Hz, J_2 = 4.9 Hz, 1 H), 5.32 (dd, *J* = 10.2 Hz, $^2J_{H,P}$ = 9.8 Hz, 1 H), 6.56 (s, 1 H), 7.04–7.27 (m, 10 H) ppm. ^{31}P NMR ($CDCl_3$): δ = 27.4 ppm. ^{13}C NMR ($CDCl_3$): δ = 20.2, 21.3, 21.8, 22.3, 24.8, 25.8, 28.2, 30.7, 33.6, 41.0 (d, $^3J_{C,P}$ = 7.0 Hz), 47.9 (d, $^3J_{C,P}$ = 5.3 Hz), 51.4, 55.5 (d, $^1J_{C,P}$ = 122.2 Hz), 59.5, 74.1, 75.7 (d, $^2J_{C,P}$ = 8.9 Hz), 126.8, 127.1 (2 C), 127.3 (2 C), 127.7 (3 C), 130.7, 130.8, 135.5, 142.0 (d, $^3J_{C,P}$ = 16.2 Hz) ppm. IR (KBr): $\tilde{\nu}$ = 3349, 1170, 1036, 1020, 880 cm^{-1}. MS (EI): *m*/*z* (%) = 469 (3) $[M]^+$, 363 (33), 137 (19), 91 (9).

(1*S*,2*S*)-2-[(2*S*,4a*S*,7*R*,8a*R*)-3-Isobutyl-4,4,7-trimethyl-2-oxooctahydro-2*H*-1,3,2-benzoxazaphosphinin-2-yl]-1,2-diphenylethanol (*anti*-16a): White solid, m.p. 172–175 °C (hexane/EtOAc). R_f = 0.40 (Et_2O/CH_2Cl_2, 1:5). $[\alpha]_D^{23}$ = +36.6 (*c* = 0.96, $CHCl_3$). ^1H NMR ($CDCl_3$): δ = 0.82 (d, *J* = 6.4 Hz, 3 H), 085–0.92 (m, 2 H), 0.93 (d, *J* = 6.6 Hz, 3 H), 1.03 (s, 3 H), 1.06 (d, *J* = 6.7 Hz, 3 H), 1.14–1.21 (m, 1 H), 1.26 (s, 3 H), 1.45–1.50 (m, 1 H), 1.59–1.79 (m, 4 H), 1.97–2.07 (m, 1 H), 2.10 (s, 3 H), 2.77 (ddd, J_1 = 14.9 Hz, J_2 = 13.1 Hz, $^3J_{H,P}$ = 6.0 Hz, 1 H), 3.00 (dt, J_1 = 14.9 Hz, $^3J_{H,P} \approx J_2$ = 9.2 Hz, 1 H), 3.52 (tdd, J_1 = 10.6 Hz, J_2 = 4.5 Hz, $^3J_{H,P}$ = 2.6 Hz, 1 H), 3.69 (dd, $^2J_{H,P}$ = 12.7 Hz, *J* = 9.7 Hz, 1 H), 6.32 (dd, *J* = 9.7 Hz, $^3J_{H,P}$ = 8.1 Hz, 1 H), 7.02–7.16 (m, 10 H) ppm. ^{31}P NMR ($CDCl_3$): δ = 22.4 ppm. ^{13}C NMR ($CDCl_3$): δ = 20.1, 20.9 (2 C), 21.6 (2 C), 25.7, 27.8, 29.9, 30.8, 33.8, 41.7 (d, $^3J_{C,P}$ = 7.0 Hz), 49.8, 50.4 (d, $^3J_{C,P}$ = 4.8 Hz), 53.5 (d, $^1J_{C,P}$ = 111.4 Hz), 60.3, 45.2, 77.0, 126.8, 127.3 (2 C), 127.4, 127.6 (2 C), 127.8 (2 C), 130.2, 130.3, 134.6 (d, $^2J_{C,P}$ = 5.8 Hz), 139.0 (d, $^3J_{C,P}$ = 11.0 Hz), 169.1 ppm. IR (KBr): $\tilde{\nu}$ = 3426, 1742, 1246, 1023, 1013, 884 cm^{-1}. $C_{30}H_{42}NO_4P$ (511.63): calcd. C 70.43, H 8.27, N 2.74; found C 70.58, H 8.42, N 2.80.

(1*R*,2*R*)-2-[(2*R*,4a*S*,7*R*,8a*R*)-3-Isobutyl-4,4,7-trimethyl-2-oxooctahydro-2*H*-1,3,2-benzoxazaphosphinin-2-yl]-1-(4-methoxyphenyl)-2-phenylethanol (*anti*-17e): White solid, m.p. 148–149 °C (hexane/EtOAc). R_f = 0.68 (hexane/EtOAc, 1:1). $[\alpha]_D^{23}$ = +42.3 (*c* = 0.95, $CHCl_3$). ^1H NMR ($CDCl_3$): δ = 0.07–0.16 (m, 1 H), 0.39–0.49 (m, 1 H), 0.83–1.12 (m, 2 H), 0.86 (s, 3 H), 0.88 (d, *J* = 6.5 Hz, 3 H), 1.00 (d, *J* = 6.5 Hz, 3 H), 1.08 (s, 3 H), 1.12 (d, *J* = 6.6 Hz, 3 H), 1.15–1.32 (m, 1 H), 1.34–1.41 (m, 1 H), 1.42–1.50 (m, 1 H), 2.02–2.16 (m, 1 H), 2.24–2.28 (m, 1 H), 2.73–2.75 (m, 1 H), 3.12–3.21 (m, 1 H), 3.41 (dd, $^2J_{H,P}$ = 16.2 Hz, *J* = 10.2 Hz, 1 H), 3.66 (s, 3 H), 4.19 (td, J_1 = 10.7 Hz, J_2 = 5.0 Hz, 1 H), 5.28 (dd, *J* = 10.2 Hz, $^3J_{H,P}$ = 9.8 Hz, 1 H), 6.51 (s, 1 H), 6.60–6.66 (m, 2 H), 7.04 (m, 7 H) ppm. ^{31}P NMR ($CDCl_3$): δ = 27.5 ppm. ^{13}C NMR ($CDCl_3$): δ = 20.2, 21.2, 21.8, 22.3, 24.7, 25.8, 28.2, 30.7, 33.6, 40.9 (d, $^3J_{C,P}$ = 7.0 Hz), 47.9 (d, $^3J_{C,P}$ = 5.1 Hz), 51.4, 54.5 (d, $^1J_{C,P}$ = 121.8 Hz), 55.5, 59.5, 73.5, 75.6 (d, $^2J_{C,P}$ = 9.1 Hz), 113.1 (2 C), 126.7, 127.8 (2 C), 128.4 (2 C), 130.7, 130.8, 134.4 (d, $^3J_{C,P}$ = 16.5 Hz), 135.7 (d, $^2J_{C,P}$ = 7.1 Hz), 158.5 ppm. IR (KBr): $\tilde{\nu}$ = 3226, 1246, 1007, 882 cm^{-1}. $C_{29}H_{42}NO_4P$ (499.62): calcd. C 69.71, H 8.47, N 2.80; found C 69.88, H 8.61, N 2.69.

(1*S*,2*S*)-1-[(2*S*,4a*S*,7*R*,8a*R*)-3-Isobutyl-4,4,7-trimethyl-2-oxooctahydro-2*H*-1,3,2-benzoxazaphosphinin-2-yl]-4-methyl-1-phenylpentan-2-ol (*anti*-18a): White solid, m.p. 177–178 °C (hexane/EtOAc). R_f = 0.65 (hexane/EtOAc, 1:1). $[\alpha]_D^{23}$ = +15.5 (*c* = 0.60, $CHCl_3$). ^1H NMR ($CDCl_3$): δ = 0.45 (s, 3 H), 0.64–0.73 (m, 1 H), 0.77 (d, *J* = 6.3 Hz, 3 H), 0.79 (d, *J* = 6.1 Hz, 3 H), 0.83–0.92 (m, 2 H), 0.90 (d, *J* = 5.9 Hz, 3 H), 0.97 (d, *J* = 6.6 Hz, 3 H), 1.03 (d, *J* = 6.7 Hz, 3 H), 1.08–1.24 (m, 3 H), 1.15 (s, 3 H), 1.56–1.76 (m, 3 H), 1.79–1.97 (m, 2 H), 2.05–2.21 (m, 1 H), 2.66 (ddd, J_1 = 18.2 Hz, J_2 = 15.0 Hz, $^3J_{H,P}$ = 8.0 Hz, 1 H), 2.96 (dt, J_1 = 15.0 Hz, $^3J_{H,P} \approx J_2$ = 7.0 Hz, 1 H), 3.09 (dd, $^2J_{H,P}$ = 13.1 Hz, *J* = 9.9 Hz, 1 H), 3.16–3.23 (m, 1 H), 4.23–4.40 (m, 1 H), 6.00 (s, 1 H), 7.1–7.50 (m, 5 H) ppm. ^{31}P NMR ($CDCl_3$): δ = 25.6 ppm. ^{13}C NMR ($CDCl_3$): δ = 20.3, 20.6, 21.0 (2 C), 21.6, 23.9, 24.0, 25.7, 27.0, 29.5, 30.6, 33.7, 42.2 (d, $^3J_{C,P}$ = 5.7 Hz), 44.5 (d, $^3J_{C,P}$ = 13.6 Hz), 49.8 (d, J_P = 5.7 Hz), 50.1 (d, J_P = 7.7 Hz), 53.1 (d, $^1J_{C,P}$ = 114.7 Hz), 60.3, 69.0 (d, $^2J_{C,P}$ = 4.4 Hz), 76.6, 127.0, 128.3 (2 C), 129.9 (2 C), 135.7 (d, $^2J_{C,P}$ = 6.1 Hz) ppm. IR (KBr): $\tilde{\nu}$ = 3389, 1204, 1034, 1019, 895 cm^{-1}. $C_{26}H_{44}NO_3P$ (449.61): calcd. C 69.46, H 9.86, N 3.12; found C 69.59, H 10.00, N 3.33.

(1*S*,2*R*)-1-[(2*S*,4a*S*,7*R*,8a*R*)-3-Isobutyl-4,4,7-trimethyl-2-oxooctahydro-2*H*-1,3,2-benzoxazaphosphinin-2-yl]-4-methyl-1-phenylpentan-2-ol (*syn*-18a): White solid, m.p. 195–197 °C (hexane/EtOAc). R_f = 0.58 (hexane/EtOAc, 1:1). $[\alpha]_D^{23}$ = +49.0 (*c* = 0.40, $CHCl_3$). ^1H NMR ($CDCl_3$): δ = 0.81 (d, *J* = 6.4 Hz, 3 H), 0.83 (d, *J* = 6.6 Hz, 3 H), 0.84 (d, *J* = 6.8 Hz, 3 H), 0.89–0.96 (m, 2 H), 0.93 (d, *J* = 6.6 Hz, 3 H), 0.97 (s, 3 H), 0.98–1.03 (m, 1 H), 1.01 (d, *J* = 6.7 Hz, 3 H), 1.06–1.20 (m, 3 H), 1.22 (s, 3 H), 1.49–1.79 (m, 5 H), 2.02–2.13 (m, 1 H), 2.76–3.03 (m, 2 H), 3.13 (dd, $^2J_{H,P}$ = 16.7 Hz, *J* = 2.4 Hz, 1 H), 3.38 (tdd, J_1 = 10.5 Hz, J_2 = 4.5 Hz, $^3J_{H,P}$ = 1.9 Hz, 1 H), 4.31–4.35 (m, 1 H), 4.80 (s, 1 H), 7.19–7.46

(m, 5 H) ppm. ^{31}P NMR ($CDCl_3$): δ = 26.2 ppm. ^{13}C NMR ($CDCl_3$): δ = 20.4 (2 C), 20.6, 21.6, 22.3, 23.0, 24.4, 25.7, 27.5, 29.9, 30.7, 33.8, 41.7 (d, $^3J_{C,P}$ = 8.1 Hz), 43.6, 43.7, 50.2 (d, $^3J_{C,P}$ = 4.6 Hz), 52.5 (d, $^1J_{C,P}$ = 109.8 Hz), 60.6, 70.2, 75.4 (d, $^2J_{C,P}$ = 7.5 Hz), 126.8, 127.9 (2 C), 130.8 (2 C), 134.2 ppm. IR (KBr): $\tilde{\nu}$ = 3392, 1198, 1046, 1021, 894 cm^{-1}. MS (EI): *m*/*z* (%) = 449 (1) [M]$^+$, 406 (44), 363 (59), 270 (25), 212 (100), 91 (14).

(1*S*,2*S*)-2-[(2*S*,4a*S*,7*R*,8a*R*)-3-Benzyl-4,4,7-trimethyl-2-oxooctahydro-2*H*-1,3,2-benzoxazaphosphinin-2-yl]-1-cyclohexyl-2-phenylethanol (anti-19a): White solid, m.p. 221–223 °C (hexane/EtOAc). R_f = 0.41 (hexane/EtOAc, 4:1). $[\alpha]_D^{23}$ = +78.3 (*c* = 0.84, $CHCl_3$). ^{1}H NMR ($CDCl_3$): δ = 0.41 (s, 3 H), 0.69–0.87 (m, 2 H), 0.81 (s, 3 H), 0.88–1.07 (m, 4 H), 0.91 (d, *J* = 5.9 Hz, 3 H), 1.10–1.33 (m, 4 H), 1.47–1.78 (m, 8 H), 1.97–2.01 (m, 1 H), 3.38 (dd, $^2J_{H,P}$ = 14.9 Hz, *J* = 10.2 Hz, 1 H), 3.46–3.53 (m, 1 H), 3.97 (dd, *J* = 17.3 Hz, $^3J_{H,P}$ = 12.1 Hz, 1 H), 4.17–4.24 (m, 1 H), 4.69 (dd, *J* = 17.3 Hz, $^3J_{H,P}$ = 10.8 Hz, 1 H), 5.55 (s, 1 H), 7.17–7.69 (m, 10 H) ppm. ^{31}P NMR ($CDCl_3$): δ = 27.6 ppm. ^{13}C NMR ($CDCl_3$): δ = 19.8, 21.6, 23.6, 25.5, 26.0, 26.3, 26.6, 27.8 30.7, 30.8, 33.7, 39.5 (d, $^3J_{C,P}$ = 12.5 Hz), 42.4 (d, $^3J_{C,P}$ = 4.9 Hz), 45.6 (d, $^2J_{C,P}$ = 6.1 Hz), 49.9 (d, $^1J_{C,P}$ = 118.3 Hz), 51.0 (d, $^3J_{C,P}$ = 7.7 Hz), 60.5, 74.2 (d, $^2J_{C,P}$ = 4.5 Hz), 77.7 (d, $^2J_{C,P}$ = 8.9 Hz), 126.5, 127.0, 127.1 (2 C), 128.2 (2 C), 128.5 (2 C), 129.9 (2 C), 135.6 (d, $^2J_{C,P}$ = 6.8 Hz), 141.3 ppm. IR (KBr): $\tilde{\nu}$ = 3324, 1201, 1045, 878 cm^{-1}. $C_{31}H_{44}NO_3P$ (509.66): calcd. C 73.05, H 8.70, N 2.75; found C 73.19, H 8.87, N 2.99.

(1*S*,2*S*)-1-[(2*S*,4a*S*,7*R*,8a*R*)-3-Benzyl-4,4,7-trimethyl-2-oxooctahydro-2*H*-1,3,2-benzoxazaphosphinin-2-yl]-3-methyl-1-phenylbutan-2-ol (*anti*-20a): White solid, m.p. 214–215 °C (hexane/EtOAc). R_f = 0.18 (hexane/EtOAc, 4:1). $[\alpha]_D^{23}$ = +73.6 (*c* = 0.84, CH_3OH). ^{1}H NMR ($CDCl_3$): δ = 0.34 (s, 3 H), 0.69–0.87 (m, 2 H), 0.74 (d, *J* = 6.7 Hz, 3 H), 0.81 (s, 3 H), 0.92 (d, *J* = 5.9 Hz, 3 H), 0.96 (d, *J* = 6.9 Hz, 3 H), 1.25–1.40 (m, 3 H), 1.56–1.62 (m, 2 H), 1.71–1.78 (m, 1 H), 2.02–2.03 (m, 1 H), 3.31 (dd, $^2J_{H,P}$ = 15.1 Hz, *J* = 10.3 Hz, 1 H), 3.51–3.54 (m, 1 H), 3.98 (dd, *J* = 17.4 Hz, $^3J_{H,P}$ = 12.1 Hz, 1 H), 4.24–4.31 (m, 1 H), 4.65 (dd, *J* = 17.4 Hz, $^3J_{H,P}$ = 11.0 Hz, 1 H), 5.58 (s, 1 H), 7.18–7.59 (m, 10 H) ppm. ^{31}P NMR ($CDCl_3$): δ = 27.3 ppm. ^{13}C NMR ($CDCl_3$): δ = 13.7, 20.8, 21.3, 22.1, 26.9, 28.4, 31.0 (d, $^3J_{C,P}$ = 13.0 Hz), 32.3, 35.2, 43.6, 47.3, 52.9 (d, $^3J_{C,P}$ = 5.7 Hz), 53.2 (d, $^1J_{C,P}$ = 116.2 Hz), 62.5, 76.3, 78.4 (d, $^2J_{C,P}$ = 7.7 Hz), 127.6, 128.3 (2 C), 128.5, 129.3 (2 C), 129.8 (2 C), 131.2 (d, $^3J_{C,P}$ = 6.3 Hz, 2 C), 137.4 (d, $^3J_{C,P}$ = 5.2 Hz), 143.7 ppm. IR (KBr): $\tilde{\nu}$ = 3399, 1208, 1028, 885 cm^{-1}. $C_{28}H_{40}NO_3P$ (469.60): calcd. C 71.61, H 8.59, N 2.98; found C 71.52, H 8.49, N 2.87.

(1*S*,2*S*)-1-[(2*S*,4a*S*,7*R*,8a*R*)-3-Benzyl-4,4,7-trimethyl-2-oxooctahydro-2*H*-1,3,2-benzoxazaphosphinin-2-yl]-1-phenylpentan-2-ol (*anti*-21a): White solid, m.p. 201–203 °C (hexane/EtOAc). R_f = 0.25 (hexane/EtOAc, 4:1). $[\alpha]_D^{23}$ = +86.4 (*c* = 0.94, $CHCl_3$). ^{1}H NMR ($CDCl_3$): δ = 0.47 (s, 3 H), 0.68–0.91 (m, 2 H), 0.75 (t, *J* = 7.3 Hz, 3 H), 0.81 (s, 3 H), 0.90 (d, *J* = 5.9 Hz, 3 H), 1.11–1.62 (m, 8 H), 1.68–1.76 (m, 1 H), 1.93–1.98 (m, 1 H), 3.16 (dd, $^2J_{H,P}$ = 14.0 Hz, *J* = 10.0 Hz, 1 H), 3.39–3.42 (m, 1 H), 3.98 (dd, *J* = 17.4 Hz, $^3J_{H,P}$ = 11.8 Hz, 3 H), 4.25–4.36 (m, 1 H), 4.64 (dd, *J* = 17.4 Hz, $^3J_{H,P}$ = 10.8 Hz, 1 H), 5.74 (s, 1 H), 7.17–7.56 (m, 10 H) ppm. ^{31}P NMR ($CDCl_3$): δ = 27.6 ppm. ^{13}C NMR ($CDCl_3$): δ = 13.9, 18.0, 20.0, 21.6, 25.4, 27.7 (d, $^3J_{C,P}$ = 3.9 Hz), 30.7, 33.6, 37.2 (d, $^3J_{C,P}$ = 13.5 Hz), 42.2 (d, $^3J_{C,P}$ = 5.2 Hz), 45.5 (d, $^2J_{C,P}$ = 6.3 Hz), 50.8 (d, $^3J_{C,P}$ = 7.3 Hz), 53.3 (d, $^1J_{C,P}$ = 117.0 Hz), 60.5, 70.5 (d, $^2J_{C,P}$ = 4.5 Hz), 77.6 (d, $^2J_{C,P}$ = 9.0 Hz), 126.4, 126.9 (2 C), 127.2, 128.1 (2 C), 128.5 (2 C), 129.9 (d, $^3J_{C,P}$ = 5.8 Hz, 2 C), 135.6 (d, $^2J_{C,P}$ = 6.2 Hz), 141.3 ppm. IR (KBr): $\tilde{\nu}$ = 3420, 3290, 1204, 1034, 875 cm^{-1}. $C_{28}H_{40}NO_3P$ (469.60): calcd. C 71.61, H 8.59, N 2.98; found C 71.60, H 8.46, N 2.87.

General Procedure for the Synthesis of Hydroxyphosphonic Acids: A solution of hydroxyphosphinine *anti*-**15a** (0.3 mmol) in 4 N HCl (20 mL) was placed in a 25-mL round-bottomed flask equipped with a reflux condenser. The reaction mixture was refluxed for 9 h and then concentrated under reduced pressure. The residue was passed through an ion-exchange column (Dowex 50×8) using water as eluent. The aqueous fraction was collected and concentrated to give the phosphonic acid as a white solid. This procedure was repeated with *anti*-**20a** and -**21a**.

[(1*S*,2*S*)-2-Hydroxy-4-methyl-1-phenylpentyl]phosphonic Acid (*anti*-22): White solid (52%), m.p. 150–152 °C (methanol/H_2O). $[\alpha]_D^{23}$ = –15.3 (*c* = 0.35, methanol). ^{1}H NMR (CD_3OD): δ = 0.79 (d, *J* = 6.6 Hz, 3 H), 0.81 (d, *J* = 6.4 Hz, 3 H), 1.01–1.09 (m, 1 H), 1.21–1.29 (m, 1 H), 1.79–1.85 (m, 1 H), 3.04 (dd, $^2J_{H,P}$ = 19.8 Hz, *J* = 9.4 Hz, 1 H), 4.29–4.32 (m, 1 H), 4.99 (s, 3 H), 7.23–7.31 (m, 5 H) ppm. ^{31}P NMR (CD_3OD): δ = 26.2 ppm. ^{13}C NMR (CD_3OD): δ = 21.6, 24.5, 25.4, 45.9 (d, $^3J_{C,P}$ = 11.3 Hz), 54.7 (d, $^1J_{C,P}$ = 132.7 Hz), 71.2, 128.2, 129.6 (2 C), 131.0 (d, $^3J_{C,P}$ = 7.0 Hz, 2 C), 137.5 (d, $^2J_{C,P}$ = 6.8 Hz) ppm. IR (KBr): $\tilde{\nu}$ = 3345, 1138, 1108, 1022, 696 cm^{-1}.

[(1*S*,2*S*)-2-Hydroxy-3-methyl-1-phenylbutyl]phosphonic Acid (*anti*-23): White solid (58%), m.p. 148–149 °C (methanol/H_2O). $[\alpha]_D^{23}$ = +6.8 (*c* = 0.56, methanol). ^{1}H NMR (CD_3OD): δ = 0.77 (d, *J* = 6.8 Hz, 3 H), 0.92 (d, *J* = 7.0 Hz, 3 H), 1.35–1.47 (m, 1 H), 3.16 (dd, $^2J_{H,P}$ = 20.3 Hz, *J* = 10.5 Hz, 1 H), 4.17 (ddd, $J_1 \approx J_2$ = 10.5 Hz, $^3J_{H,P}$ = 2.2 Hz, 1 H), 4.95 (s, 3 H), 7.20–7.37 (m, 5 H) ppm. ^{31}P NMR (CD_3OD): δ = 27.1 ppm. ^{13}C NMR (CD_3OD): δ = 14.0, 20.7, 30.9 (d, $^3J_{C,P}$ = 13.0 Hz), 51.3 (d, $^1J_{C,P}$ = 132.2 Hz), 76.5 (d, $^2J_{C,P}$ = 4.9 Hz), 128.2, 129.7 (2 C), 130.8 (d, $^3J_{C,P}$ = 6.2 Hz, 2 C), 137.4 (d, $^2J_{C,P}$ = 7.6 Hz) ppm. IR (KBr): $\tilde{\nu}$ = 3369, 3204, 1172, 1127, 997, 697 cm^{-1}.

[(1*S*,2*S*)-2-Hydroxy-1-phenylpentyl]phosphonic Acid (*anti*-24): White solid (57%), m.p. 162–163 °C (methanol/H_2O). $[\alpha]_D^{23}$ = –7.3 (*c* = 0.88, CH_3OH). ^{1}H NMR (CD_3OD): δ = 0.80 (t, *J* = 7.0 Hz, 3 H), 1.16–1.54 (m, 4 H), 3.09 (dd, $^2J_{H,P}$ = 20.4 Hz, J_H = 9.1 Hz, 1 H), 4.24 (ddd, $J_1 \approx J_2$ = 9.1 Hz, $^3J_{H,P}$ = 2.2 Hz, 1 H), 4.96 (s, 2 H), 5.49 (s, 1 H), 7.23–7.32 (m, 5 H) ppm. ^{31}P NMR (CD_3OD): δ = 26.2 ppm. ^{13}C NMR (CD_3OD): δ = 14.4, 19.5, 38.5 (d, $^3J_{C,P}$ = 11.6 Hz), 54.0 (d, $^1J_{C,P}$ = 132.8 Hz), 72.7, 128.2, 129.6 (2 C), 131.0 (d, $^3J_{C,P}$ = 6.9 Hz, 2 C), 137.4 (d, $^2J_{C,P}$ = 6.8 Hz) ppm. IR (KBr): $\tilde{\nu}$ = 3418, 1165, 1125, 996, 699 cm^{-1}.

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