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First example of quinine-squaramide catalyzed enantioselective addition of diphenyl phosphite to ketimines derived from isatins†

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A highly enantioselective addition of diphenyl phosphite to ketimines derived from isatins has been achieved using a bifunctional organocatalyst, quinine-derived squaramide catalyst. This method works efficiently with several ketimines to produce the corresponding 3-amino-2-oxoindolin-3-yl-phosphonates in excellent yields with high enantioselectivity (up to 98% ee).

Introduction

Phosphonic esters are common structural units in natural nucleotides, which play an important role as metabolic intermediates, regulatory switches for proteins, and backbones for genetic information.[1] In particular, α-aminophosphonic acid derivatives are known to exhibit a broad spectrum of biological activities such as peptide mimetics,[2] antibacterial,[3] antiviral agents,[4] and enzyme inhibitors.[5] The biological activity of α-aminophosphonates are connected with their absolute stereochemistry. Therefore, the synthesis of chiral α-aminophosphonates through asymmetric addition of phosphite nucleophiles to imines is of prime importance.[6] Though a variety of metal catalysts and organocatalysts have been developed for the enantioselective addition of phosphite to aldimines,[7] there are only a few reports on asymmetric addition of phosphite to simple ketimines.[8] Thus, an asymmetric addition of phosphite to functionalized ketimines still remains a challenging task because of their lower reactivity and difficulty in enantiofacial discrimination.

On the other hand, the 3-aminooxindole core with a quaternary carbon center is frequently found in various natural products, which are known to exhibit a broad spectrum of biological activities.[9] Due to their prominent importance in medicinal chemistry,[10] numerous catalytic methods such as α-amination of oxindoles[11] and nucleophilic addition of ketimines[12] have been developed for the synthesis of 3-aminooxindoles. Although a large number of oxindoles are known in the literature, an efficient asymmetric synthesis of oxindoles with two heteroatoms at the 3-position is still rare.[13]

Following our interest in asymmetric catalysis and also reactions of ketimines,[14] we wish to report a highly enantioselective approach for the addition of diphenyl phosphite to ketimines derived from isatins using quinine-squaramide organocatalyst.[15]

As a model reaction, we attempted the addition of diphenyl phosphite to ketimine **2a** derived from *N*-methylisatin using cinchona derived organocatalysts. The catalysts used in this study are shown in Fig. 1. As shown in Table 1, the reaction was quite slow with quinine (**1a**) and the desired α-aminophosphonate **4a** was obtained in 34% ee (Table 1, entry 1). In order to improve the ee, the next reaction was performed with 6′-hydroxyquinine catalyst **1b**. Unfortunately, **1b** also gave the product **4a** with low yield and enantioselectivity. Therefore, the

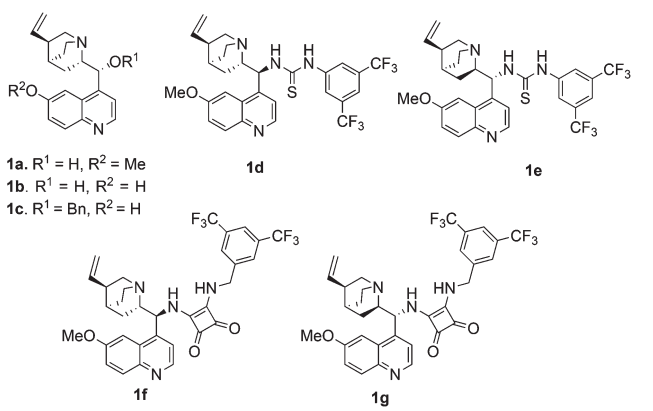

Fig. 1 Screening of various organocatalysts in asymmetric addition of phosphite to ketimines.

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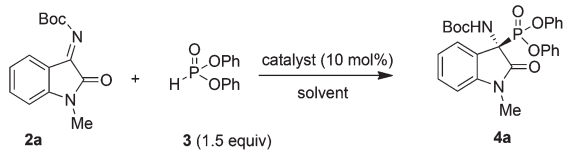
†Electronic supplementary information (ESI) available: Experimental procedures, spectral data, HPLC chromatogram of all products; X-ray crystal co-ordinate and CIF file format of **4b**. CCDC 960126. For ESI and crystallographic data in CIF or other electronic format see DOI: 10.1039/c3ob42026d

Table 1 Screening of organocatalysts for asymmetric addition of diphenyl phosphite to isatin-derived ketimines[a]



Entry	Catalyst	Solvent	Temp (°C)	Time (h)	Yield[b] (%)	ee[c] (%)
1	**1a**	CH_2Cl_2	25	24	78	34
2	**1b**	CH_2Cl_2	25	24	66	43
3	**1c**	CH_2Cl_2	25	2	91	0
4	**1d**	CH_2Cl_2	25	0.25	98	65
5	**1e**	CH_2Cl_2	25	0.5	98	60
6	**1d**	CH_2Cl_2	0	2.0	96	75
7	**1d**	CH_2Cl_2	−10	2.0	94	78
8	**1d**	CH_2Cl_2	−30	48	48	76
9	**1d**	Toluene	−10	5	95	68
10	**1d**	THF	−10	5	90	74
11	**1d**	DCE	−10	12	92	72
12	**1d**	$CHCl_3$	−10	24	85	65
13	**1f**	CH_2Cl_2	−10	24	96	88
14	**1g**	CH_2Cl_2	−10	48	91	84
13	**1f**	CH_2Cl_2	−20	70	87	90
13[d]	**1f**	CH_2Cl_2	−20	48	92	91
14[d,e]	**1f**	CH_2Cl_2	−20	40	95	91

[a] All reactions were carried out in 0.25 mmol scale in 2.0 mL solvent under nitrogen. [b] Yield refers to pure products after chromatography. [c] ee was determined by HPLC analysis on Chiralpak IC column. [d] Reaction was performed in presence of 100 mg of 4 Å MS. [e] 2.0 equiv. of **3** was used.

reaction was performed with another catalyst **1c** (*i.e.* 6′-hydroxy-*O*-benzyl quinine catalyst). Though the product **4a** was obtained in 91% yield, the ee was 0%. Further experiments were conducted with cinchona derived thiourea catalysts to improve the ee. Using 10 mol% of quinine derived thiourea **1d**, the product **4a** was obtained in 98% yield with 65% ee. Furthermore, quinidine based thiourea catalyst **1e** was found to be less effective as compared to quinine thiourea **1d**. Therefore, we decided to optimize the reaction with **1d** so as to improve the ee by changing the reaction parameters. At −10 °C, the catalyst **1d** gave the desired product **4a** in 94% yield with 78% ee. Further lowering the temperature resulted in the reverse effect on yield and enantiomeric excess. Thus the maximum ee was obtained at −10 °C using 10 mol% of **1d**. Next we tested the efficiency of different solvents such as dichloromethane, toluene, THF and DCE. Of these, dichloromethane was found to be the best for this transformation. The above results clearly indicate that quinine–thiourea can give the product only with moderate enantioselectivity (up to 78% ee). Therefore, we further decided to examine the efficiency of squaramide catalysts at −10 °C. Interestingly, squaramide catalysts gave the product in good to high enantiomeric excess (up to 88% ee). However, quinidine derived squaramide catalyst **1g** afforded the product with slightly lower enantiomeric excess (84% ee) compared to quinine-squaramide **1f**. At −20 °C, quinine-squaramide **1f** gave the product slightly in lower yield but with improved enantiomeric excess (90% ee). In addition, the presence of a 4 Å molecular sieve was found to enhance the rate of reaction.

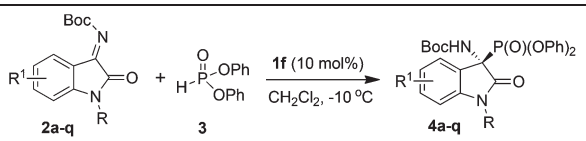
Therefore, all the reactions were carried out in the presence of 10 mol% of **1f** at −20 °C in dichloromethane to achieve the best results. From the above results, we found that quinine based organocatalysts are so effective than quinidine derived ones.

Our next attempt was to demonstrate the scope of the reaction. The ketimine derived from *N*-unsubstituted isatin, was also found to be effective in producing the corresponding phosphonate **4b** with good enantiomeric excess (91% ee, Table 2, entry 2). Also we performed the reaction with various ketimines derived from *N*-substituted isatins.

The *N*-substituted isatin imines had shown excellent reactivity and enantioselectivity in presence of 10 mol% of **1f**. Surprisingly, the reaction of *N*-benzylisatin imine with diphenyl phosphite was sluggish at −20 °C. Therefore, this reaction was carried out at −10 °C. Among various N-protected isatin imines, the best enantiomeric excess was obtained with ketimine derived from *N*-benzylisatin (97% ee, Table 2, entry 3).

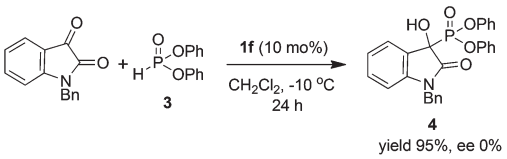
Next, we turned our attention to the reactivity of 5-substituted-*N*-benzylisatin imines. Remarkably, 5-substituted-*N*-benzylisatin imines showed excellent enantioselectivity (68–98% ee, Table 2, entries 6–10). Of these, 5-bromo-*N*-benzylisatin imine **2g** furnished the product with 98% ee (Table 2, entry 7). Similarly, 5-methyl- and 5-methoxy-*N*-benzylisatin imines **2h** and **2i** gave the products in good yields and enantioselectivity.

Table 2 Organocatalytic addition of diphenyl phosphite to ketimines derived from isatins[a]



Entry	**2a–r**(R,R[1])	Temp (°C)	*t* (h)	Yield[b] (%)	ee[c] (%)
1	**2a** (R = Me, R^1 = H)	−20	40	95	91
2	**2b** (R = H, R^1 = H)	−20	24	90	91
3	**2c** (R = Bn, R^1 = H)	−10	36	94	97
4	2d (R = Allyl, R^1 = H)	−20	48	92	90
5	**2e** (R = PMB, R^1 = H)	−10	24	92	89
6	**2f** (R = Bn, R^1 = 5-Cl)	−10	24	90	92
7	**2g** (R = Bn, R^1 = 5-Br)	−10	24	95	98
8	**2h** (R = Bn, R^1 = 5-Me)	−10	12	93	95
9	**2i** (R = Bn, R^1 = 5-OMe)	−10	24	93	90
10	**2j** (R = Bn, R^1 = 5-NO_2)	−10	12	96	68
11	**2k** (R = Bn, R^1 = 4-Br)	25	60	80	52
12	**2l** (R = Bn, R^1 = 6-Br)	−10	30	90	83
13	**2m** (R = Bn, R^1 = 7-Me)	−10	24	90	91
14	**2n** (R = Bn, R^1 = 7-Cl)	−10	36	85	91
15	**2o** (R = H, R^1 = 5-Br)	−20	40	91	86
16	**2p** (R = H, R^1 = 5-Me)	−20	40	92	92
17	**2q** (R = H, R^1 = 5-OMe)	−20	40	94	86

[a] All reactions were carried out in 0.25 mmol scale using 2.0 equiv. of diphenyl phosphite in 2.0 mL solvent in presence of 100 mg molecular sieves. [b] Yield refers to pure products after chromatography. [c] ee was determined by HPLC analysis on AD-H or IC column.



Scheme 1 Organocatalytic addition of diphenyl phosphite to *N*-benzyl isatin.

Surprisingly, 5-nitro-*N*-benzylisatin imine **2j** afforded the product with low enantioselectivity.

In contrast with 5-substituted variants, the 4-substituted isatin imine was less reactive in quinine-squaramide catalyzed asymmetric addition. For example, treatment of 4-substituted ketimine **2k** derived from 4-bromoisatin with diphenyl phosphite at room temperature furnished the corresponding phosphonate **4k** in 80% yield with 52% ee (Table 2, entry 11). Whereas the ketimine **2l** derived from 6-bromoisatin afforded the α-aminophosphonate **4l** in 90% yield with 83% ee. In a similar fashion, 7-methyl- and 7-chloroisatin imines gave the corresponding α-aminophosphonates **4m** and **4n** with 91% ee each (Table 2, entries 12 and 13).

Additionally, we examined the reactivity of a few more isatin imines derived from 5-substituted isatins without N-protection. These substrates also provided good to high enantiomeric excess under optimized conditions. Notably, the ketimine **2p** derived from 5-methylisatin afforded the respective α-aminophosphonate **4p** in 92% yield with 92% ee (Table 2, entry 16).

The asymmetric addition of diphenyl phosphite on simple isatin was unsuccessful. Though, the reaction proceeded smoothly to afford the 3-hydroxy-2-oxindolyl-3-phosphonate in 95% yield but the ee was 0%. The above experiment clearly indicates that the asymmetric addition was successful only with ketimines not with ketones (Scheme 1).

Furthermore, the reaction was unsuccessful with dialkyl phosphites such as diethyl- and dimethyl phosphites, due to their lower reactivity under optimized reaction conditions (Fig. 2).

A single crystal X-ray analysis shows that the configuration of the product **4b** was (*R*)-isomer.[17] Based on the stereochemical

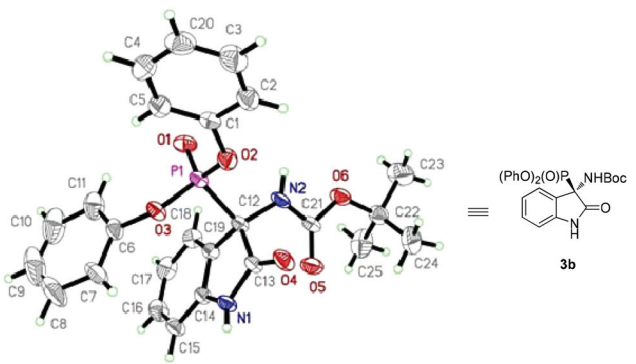


Fig. 2 ORTEP diagram of **4b**.

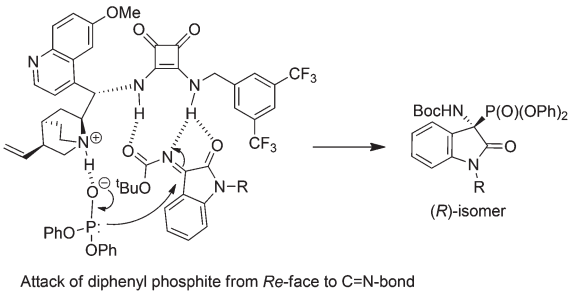


Fig. 3 A plausible ternary complex model.

outcome of the reaction, we proposed a ternary complex model to understand how the catalyst controls the stereochemistry. As in the usual way, squaramide binds with isatin imine whereas quinuclidine moiety abstracts the acidic proton from phosphite to facilitate the reaction. A preferential *Re-face* attack of phosphite nucleophile to ketimine affords the (*R*)-isomer (Fig. 3).

Conclusions

In conclusion, we have developed a highly efficient organocatalytic approach for the enantioselective addition of diphenyl phosphite to ketimines derived from isatins using 10 mol% of quinine-derived squaramide as the catalyst. A variety of chiral 3-amino-2-oxoindolin-3-ylphosphonates were prepared in excellent yields with high enantiomeric excess (up to 98% ee). Further application and biological evaluation of these chiral α-aminophosphonates are in progress in our laboratory.

Experimental

General remarks

All the solvents were dried according to standard procedures. The reactions were carried out under a nitrogen atmosphere. The isatin derivatives were purchased from commercial sources and used as such. The isatin derived ketimines were prepared according to previously reported procedure.[12c] Diphenyl phosphite was purchased from Sigma Aldrich and used without any purification. The enantiomeric excess was determined by HPLC analysis on chiral stationary phase (Chiralpak AD-H and IC column) using a mixture of hexane–isopropyl alcohol as eluent. Racemic samples were prepared by performing the reaction in the presence of triethylamine as catalyst. All the compounds were purified by column chromatography on 100–200 mesh silica gel using hexanes–ethyl acetate as eluent. All the reactions were monitored by TLC analysis. ^{1}H NMR spectra were recorded on 500 MHz or 300 MHz instruments using $CDCl_3$ as solvent and TMS as an internal standard. ^{13}C NMR spectra were recorded at 75 MHz or 125 MHz using $CDCl_3$ as solvent and reference. Optical rotation was recorded on a Perkin Elmer-343 Polarimeter. Absolute configuration of the product was determined by single crystal X-ray analysis.

Based on the stereochemistry of **4b**, the relative configuration of all the products were determined.

Quinine and quinidine were purchased from Sigma Aldrich. Catalysts **1b** and **1c** were prepared according to the literature procedure.[16a] The catalysts **1d** and **1e** were prepared according to the previously reported procedures.[16b] The catalysts **1f** and **1g** were also prepared based on previous procedures.[15a]

General procedure for the asymmetric addition of phosphite to isatin derived ketimines

To a stirred mixture of isatin derived ketimine (0.25 mmol), squaramide catalyst **1f** (16.6 mg, 10 mol%) and 100 mg of 4 Å MS was charged in a flame dried Schlenk tube under a nitrogen atmosphere. Dry DCM (2.0 mL) was added and the suspension was cooled to a prescribed temperature (−10 °C or −20 °C). After stirring for 15 min, diphenyl phosphite (117 mg, 0.50 mmol) was added to the reaction mixture through a syringe and then allowed to stir at the same temperature until completion of the reaction (as indicated by TLC analysis). The solvent was removed under reduced pressure and the resulting residue was purified by column chromatography on silica gel (100–200 mesh) using hexane–ethyl acetate as eluent.

(*R*)-*tert*-Butyl 3-(diphenoxyphosphoryl)-1-methyl-2-oxoindolin-3-yl carbamate (4a). Purified by column chromatography on silica gel using 30% EtOAc in hexane as eluent; 95% yield and 91% ee; viscous liquid; α_D^{25} = −16.5 (*c* = 0.5, $CHCl_3$); ^{1}H NMR ($CDCl_3$, 500 MHz) *δ*: 1.26 (s, 9H), 3.29 (s, 3H), 5.87 (d, *J* = 11.1 Hz, 1H), 6.70 (d, *J* = 7.9 Hz, 2H), 6.85 (d, *J* = 7.9 Hz, 1H), 7.05 (dd, *J* = 7.3, 14.3 Hz, 2H), 7.14–7.26 (m, 5H), 7.30–7.40 (m, 3H), 7.52 (dd, *J* = 1.32, 7.3 Hz, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) *δ*: 27.0, 27.9, 81.3, 108.4, 120.1 (d, *J* = 3.6 Hz), 120.8 (d, *J* = 3.6 Hz), 122.9 (d, *J* = 2.7 Hz), 125.1 (d, *J* = 3.6 Hz), 125.5, 125.8, 129.5, 129.8, 130.1 (d, *J* = 2.7 Hz), 144.4 (d, *J* = 7.3 Hz), 150.0 (dd, *J* = 9.9, 16.3 Hz), 153.6 (d, *J* = 18.2 Hz), 170.9; IR (KBr): 3431, 3272, 3061, 2925, 2853, 1729, 1611, 1591, 1489, 1369, 1346, 1280, 1208, 1182, 1161, 956, 754 cm^{-1}; HPLC on Ic column (70 : 30 hexane–IPA, 1.0 mL min^{-1}, 254 nm); t_R = 11.79 min (minor) and t_R = 17.18 min (major); HRMS (ESI) *m*/*z*: calculated mass for $C_{26}H_{27}N_2NaO_6P$ $[M + Na]^+$ = 517.1499; found 517.1484.

(*R*)-*tert*-Butyl 3-(diphenoxyphosphoryl)-2-oxoindolin-3-yl carbamate (4b). Purified by column chromatography on silica gel using 40% EtOAc in hexane as eluent; 90% yield and 91% ee; solid mp. 158–160 °C; α_D^{25} = −12.7 (*c* = 0.6, $CHCl_3$); ^{1}H NMR ($CDCl_3$, 300 MHz) *δ*: 1.31 (s, 9H), 5.94 (d, *J* = 11.7 Hz, 1H), 6.66 (d, *J* = 7.7 Hz, 2H), 6.84 (d, *J* = 7.7 Hz, 1H), 7.02–7.38 (m, 10H), 7.30–7.48 (d, *J* = 5.9 Hz, 1H), 8.08 (s, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) *δ*: 27.9, 81.7, 110.4, 120.2 (d, *J* = 3.6 Hz), 120.9 (d, *J* = 3.6 Hz), 122.8 (d, *J* = 1.8 Hz), 125.4 (d, *J* = 3.6 Hz), 125.5, 125.8, 129.5, 129.8, 130.1 (d, *J* = 2.7 Hz), 141.6 (d, *J* = 7.3 Hz), 149.6 (dd, *J* = 9.9, 16.3 Hz), 153.6 (d, *J* = 18.2 Hz), 172.4; IR (KBr): 3244, 2977, 1739, 1708, 1618, 1591, 1489, 1366, 1259, 1208, 1186, 1163, 959, 756 cm^{-1}; HPLC on AD-H column (70 : 30 hexane–IPA, 1.0 mL min^{-1}, 254 nm); t_R = 13.07 min (major) and t_R = 19.96 min (minor); HRMS (ESI) *m*/*z*: calculated mass for $C_{25}H_{25}N_2NaO_6P$ $[M + Na]^+$ = 503.1342; found 503.1329.

(*R*)-*tert*-Butyl 1-benzyl-3-(diphenoxyphosphoryl)-2-oxoindolin-3-yl carbamate (4c). Purified by column chromatography on silica gel using 30% EtOAc in hexane as eluent; 94% yield and 97% ee; solid mp. 196–198 °C; α_D^{25} = +2.8 (*c* = 1.0, $CHCl_3$); ^{1}H NMR ($CDCl_3$, 500 MHz) *δ*: 1.29 (s, 9H), 4.76 (s, 1H), 5.27 (d, *J* = 15.6 Hz, 1H), 5.96 (d, *J* = 11.4 Hz, 1H), 6.60 (d, *J* = 8.0 Hz, 2H), 6.70 (d, *J* = 8.0 Hz, 1H), 7.02–7.16 (m, 2H), 7.16–7.28 (m, 6H), 7.30 (t, *J* = 8.0 Hz, 1H), 7.36–7.40 (m, 2H), 7.52 (dd, *J* = 1.0, 7.3 Hz, 1H); ^{13}C NMR ($CDCl_3$, 125 MHz) *δ*: 28.0, 44.6, 81.4, 109.4, 120.1 (d, *J* = 3.6 Hz), 120.9 (d, *J* = 3.6 Hz), 122.9 (d, *J* = 2.7 Hz), 125.2 (d, *J* = 4.5 Hz), 125.5, 125.8, 127.2, 128.6, 129.5, 129.8, 129.9, 135.3, 143.6 (d, *J* = 6.3 Hz), 149.9 (dd, *J* = 9.9, 26.3 Hz), 153.6 (d, *J* = 18.1 Hz), 171.1; IR (KBr): 3268, 3061, 2975, 2926, 2854, 1733, 1610, 1591, 1488, 1364, 1281, 1207, 1182, 1159, 956, 753 cm^{-1}; HPLC on Ic column (70 : 30 hexane–IPA, 1.0 mL min^{-1}, 254 nm); t_R = 8.55 min (minor) and t_R = 11.57 min (major); HRMS (ESI) *m*/*z*: calculated mass $C_{32}H_{31}N_2NaO_6P$ $[M + Na]^+$ = 593.1812; found 593.1794.

(*R*)-*tert*-Butyl 1-allyl-3-(diphenoxyphosphoryl)-2-oxoindolin-3-yl carbamate (4d). Purified by column chromatography on silica gel using 30% EtOAc in hexane as eluent; 92% yield and 90% ee; solid mp. 134–136 °C; α_D^{25} = −14.3 (*c* = 0.4, $CHCl_3$); ^{1}H NMR ($CDCl_3$, 500 MHz) *δ*: 1.28 (s, 9H), 4.22 (d, *J* = 11.8 Hz, 1H), 4.62 (d, *J* = 15.3 Hz, 1H), 5.16 (d, *J* = 10.4 Hz, 1H), 5.36 (d, *J* = 17.2 Hz, 1H), 5.78–5.96 (m, 2H), 6.68 (d, *J* = 7.9 Hz, 2H), 6.86 (d, *J* = 7.8 Hz, 1H), 7.06 (t, *J* = 7.0 Hz, 2H), 7.12–7.26 (m, 5H), 7.28–7.38 (m, 3H), 7.52 (dd, *J* = 6.7 Hz, 1H); ^{13}C NMR ($CDCl_3$, 125 MHz) *δ*: 27.9, 43.0, 81.3, 109.3, 117.6, 120.2 (d, *J* = 4.5 Hz), 120.8 (d, *J* = 4.5 Hz), 122.8 (d, *J* = 3.6 Hz), 125.1 (d, *J* = 3.6 Hz), 125.5, 125.8, 129.5, 129.7, 129.9 (d, *J* = 2.7 Hz), 130.8, 143.6 (d, *J* = 6.3 Hz), 149.8 (dd, *J* = 9.9, 24.5 Hz), 153.4 (d, *J* = 17.3 Hz), 170.6; IR (KBr): 3260, 3023, 2984, 2928, 1740, 1706, 1609, 1592, 1531, 1488, 1358, 1284, 1265, 1207, 1185, 1163, 957, 933, 769, 751 cm^{-1}; HPLC on Ic column (70 : 30 hexane–IPA, 1.0 mL min^{-1}, 254 nm); t_R = 7.93 min (minor) and t_R = 10.93 min (major); HRMS (ESI) *m*/*z*: calculated mass $C_{28}H_{29}N_2NaO_6P$ $[M + Na]^+$ = 543.1655; found 543.1631.

(*R*)-*tert*-Butyl 3-(diphenoxyphosphoryl)-1-(4-methoxybenzyl)-2-oxoindolin-3-yl carbamate (4e). Purified by column chromatography on silica gel using 30% EtOAc in hexane as eluent; 92% yield and 89% ee; solid mp. 188–190 °C; α_D^{25} = +6.5 (*c* = 1.0, $CHCl_3$); ^{1}H NMR ($CDCl_3$, 500 MHz) *δ*: 1.29 (s, 9H), 3.70 (s, 3H), 4.70 (s, 1H), 5.20 (d, *J* = 15.1 Hz, 1H), 5.94 (d, *J* = 11.3 Hz, 1H), 6.58 (d, *J* = 7.9 Hz, 2H), 6.72 (dd, *J* = 8.8, 18.2 Hz, 3H), 7.06 (dd ~ q, *J* = 7.5, 7.3 Hz, 2H), 7.12 (dd, *J* = 7.4 Hz, 15.6 Hz, 2H), 7.18–7.26 (m, 4H), 7.30–7.34 (m, 4H), 7.52 (td, *J* = 1.3, 2.3, 8.9 Hz, 1H); ^{13}C NMR ($CDCl_3$, 125 MHz) *δ*: 27.9, 44.0, 81.3, 109.4, 114.0, 120.1 (d, *J* = 3.8 Hz), 120.9 (d, *J* = 3.8 Hz), 122.8 (d, *J* = 2.7 Hz), 125.2 (d, *J* = 3.8 Hz), 125.4, 125.8, 127.4, 128.6, 129.5, 129.8, 129.9 (d, *J* = 2.7 Hz), 143.6 (d, *J* = 7.1 Hz), 150.1 (q, *J* = 9.9 Hz), 153.4(d, *J* = 18.1 Hz), 171.9; IR (KBr): 3270, 2976, 2931, 1739, 1709, 1611, 1590, 1515, 1488, 1356, 1284, 1249, 1183, 958, 760 cm^{-1}; HPLC on Ic column

(70 : 30 hexane–IPA, 1.0 mL min^{-1}, 254 nm); t_R = 11.26 min (minor) and t_R = 13.41 min (major); HRMS (ESI) *m*/*z*: calculated mass $C_{33}H_{34}N_2O_7P$ $[M + H]^+$ = 601.2098; found 601.2103.

(*R*)-*tert*-Butyl 1-benzyl-5-chloro-3-(diphenoxyphosphoryl)-2-oxoindolin-3-yl carbamate (4f). Purified by column chromatography on silica gel using 30% EtOAc in hexane as eluent; 90% yield and 92% ee; solid mp. 220–222 °C; α_D^{25} = +22.5 (*c* = 0.9, $CHCl_3$); ^1H NMR ($CDCl_3$, 500 MHz) δ: 1.34 (s, 9 H), 4.76 (d, *J* = 15.3 Hz, 1H), 5.20 (d, *J* = 15.8 Hz, 1H), 5.92 (d, *J* = 11.5 Hz, 1H), 6.60 (d, *J* = 8.3 Hz, 1H), 6.72 (d, *J* = 8.1 Hz, 2H), 7.02–7.26 (m, 10H), 7.28–7.42 (m, 4H), 7.48 (t, *J* = 2.1 Hz, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ: 28.1, 44.7, 81.7, 110.4, 120.1 (d, *J* = 3.1 Hz), 120.8 (d, *J* = 3.6 Hz), 125.4 (d, *J* = 4.5 Hz), 125.7, 125.9, 127.2, 127.6, 128.3 (d, *J* = 3.6 Hz), 128.7, 129.6, 129.8, 134.9, 142.1 (d, *J* = 7.2 Hz), 149.9 (dd, *J* = 9.9, 16.3 Hz), 153.6 (d, *J* = 18.6 Hz), 170.7; IR (KBr): 3259, 3028, 2974, 2925, 1744, 1711, 1642, 1606, 1531, 1488, 1285, 1266, 1207, 1184, 1162, 964 cm^{-1}; HPLC on Ic column (70 : 30 hexane–IPA, 1.0 mL min^{-1}, 254 nm); t_R = 5.93 min (minor) and t_R = 7.33 min (major); HRMS (ESI) *m*/*z*: calculated mass $C_{32}H_{30}ClN_2NaO_6P$ $[M + Na]^+$ = 527.1422; found 527.1404.

(*R*)-*tert*-Butyl 1-benzyl-5-bromo-3-(diphenoxyphosphoryl)-2-oxoindolin-3-yl carbamate (4g). Purified by column chromatography on silica gel using 30% EtOAc in hexane as eluent; 95% yield and 98% ee; solid mp. 216–218 °C; α_D^{25} = +19.3 (*c* = 1.0, $CHCl_3$); ^1H NMR ($CDCl_3$, 500 MHz) δ: 1.34 (s, 9 H), 4.78 (d, *J* = 7.6 Hz, 1H), 5.20 (d, *J* = 16.1 Hz, 1H), 5.90 (d, *J* = 11.5 Hz, 1H), 6.56 (d, *J* = 8.3 Hz, 1H), 6.74 (d, *J* = 8.3 Hz, 2H), 7.02–7.36 (m, 16H), 7.62 (t, *J* = 1.8 Hz, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ: 28.1, 44.7, 81.7, 110.9, 115.5, 120.1, 120.7, 125.7, 125.9, 127.2, 127.7, 128.1, 128.7, 129.6, 129.9, 132.7, 134.9, 142.6, 149.9 (q, *J* = 8.2 Hz), 153.6 (d, *J* = 18.6 Hz), 170.7; IR (KBr): 3259, 3025, 2974, 2925, 1743, 1711, 1608, 1585, 1530, 1487, 1284, 1206, 1184, 1161, 963, 764 cm^{-1}; HPLC on Ic column (70 : 30 hexane–IPA, 1.0 mL min^{-1}, 254 nm); t_R = 6.07 min (minor) and t_R = 7.58 min (major); HRMS (ESI) *m*/*z*: calculated mass $C_{32}H_{30}BrN_2NaO_6P$ $[M + Na]^+$ = 671.0917; found 671.0905.

(*R*)-*tert*-Butyl 1-benzyl-3-(diphenoxyphosphoryl)-5-methyl-2-oxoindolin-3-yl carbamate (4h). Purified by column chromatography on silica gel using 30% EtOAc in hexane as eluent; 93% yield and 95% ee; solid mp. 204–206 °C; α_D^{25} = +10.9 (*c* = 0.6, $CHCl_3$); ^1H NMR ($CDCl_3$, 500 MHz) δ: 1.30 (s, 9 H), 2.25 (s, 3H), 4.76 (s, 1H), 5.24 (d, *J* = 14.9 Hz, 1H), 5.92 (d, *J* = 11.1 Hz, 1H), 6.58 (d, *J* = 7.9 Hz, 1H), 6.62 (d, *J* = 8.2 Hz, 2H), 7.0 (d, *J* = 8.0 Hz, 1H), 7.06 (t, *J* = 7.2 Hz, 1H), 7.12 (t, *J* = 7.6 Hz, 2H), 7.16–7.22 (m, 4H), 7.24–7.28 (m, 2H), 7.30–7.42 (m, 5H); ^{13}C NMR ($CDCl_3$, 125 MHz) δ: 20.9, 27.9, 44.5, 81.4, 109.2, 115.3, 119.7, 120.0 (d, *J* = 4.5 Hz), 120.8 (d, *J* = 3.6 Hz), 125.4, 125.7, 127.1, 127.4, 128.6, 129.3, 129.4, 129.7, 130.3, 132.5, 135.4, 141.1 (d, *J* = 7.3 Hz), 150.1 (dd, *J* = 9.9 Hz), 153.7 (d, *J* = 18.2 Hz), 170.9; IR (KBr): 3279, 2977, 2927, 1735, 1625, 1590, 1532, 1490, 1368, 1263, 1203, 1185, 958, 765 cm^{-1}; HPLC on Ic column (70 : 30 hexane–IPA, 1.0 mL min^{-1}, 254 nm); t_R = 8.47 min (minor) and t_R = 10.29 min (major); HRMS (ESI) *m*/*z*: calculated mass for $C_{33}H_{33}N_2NaO_6P$ $[M + Na]^+$ = 607.1968; found 607.1951.

(*R*)-*tert*-Butyl 1-benzyl-3-(diphenoxyphosphoryl)-5-methoxy-2-oxoindolin-3-yl carbamate (4i). Purified by column chromatography on silica gel using 30% EtOAc in hexane as eluent; 93% yield and 90% ee; solid mp. 188–190 °C; α_D^{25} = +14.3 (*c* = 0.9, $CHCl_3$); ^1H NMR ($CDCl_3$, 500 MHz) δ: 1.32 (s, 9 H), 3.70 (s, 3H), 4.75 (s, 1H), 5.24 (d, *J* = 13.6 Hz, 1H), 5.92 (d, *J* = 10.7 Hz, 1H), 6.60 (d, *J* = 8.4 Hz, 1H), 6.66 (d, *J* = 7.8 Hz, 2H), 6.74 (d, *J* = 8.2 Hz, 2H), 7.04–7.40 (m, 14H), ^{13}C NMR ($CDCl_3$, 75 MHz) δ: 28.0, 44.6, 55.8, 81.4, 109.1, 111.9, 115.0, 120.1 (d, *J* = 4.5 Hz), 120.9 (d, *J* = 3.6 Hz, 125.5, 125.8, 127.2, 127.5, 128.6, 129.5, 129.8, 135.4, 136.9 (d, *J* = 6.4 Hz), 150.1 (q, *J* = 9.9 Hz), 153.6 (d, *J* = 17.2 Hz), 156.0 (d, *J* = 2.7 Hz, 170.8; IR (KBr): 3263, 2976, 1734, 1709, 1595, 1528, 1492, 1457, 1360, 1272, 1183, 957, 767 cm^{-1}; HPLC on AD-H column (70 : 30 hexane–IPA, 1.0 mL min^{-1}, 254 nm); t_R = 12.27 min (minor) and t_R = 17.71 min (major); HRMS (ESI) *m*/*z*: calculated mass for $C_{33}H_{33}N_2NaO_7P$ $[M + Na]^+$ = 623.1917; found 623.1900.

(*R*)-*tert*-Butyl 1-benzyl-3-(diphenoxyphosphoryl)-5-nitro-2-oxoindolin-3-yl carbamate (4j). Purified by column chromatography on silica gel using 40% EtOAc in hexane as eluent; 96% yield and 68% ee; solid mp. 198–200 °C; α_D^{25} = +16.2 (*c* = 1.00, $CHCl_3$); ^1H NMR ($CDCl_3$, 500 MHz) δ: 1.36 (s, 9 H), 4.88 (d, *J* = 15.7 Hz, 1H), 5.22 (d, *J* = 15.8 Hz, 1H), 6.08 (d, *J* = 11.3 Hz, 1H), 6.80 (d, *J* = 8.5 Hz, 1H), 6.82 (d, *J* = 8.3 Hz, 2H), 7.10–7.40 (m, 13H), 8.16 (d, *J* = 8.7 Hz. 1H), 8.40 (t, *J* = 2.3 Hz, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ: 28.1, 44.9, 82.2, 109.2, 119.9 (d, *J* = 4.5 Hz), 120.5 (d, *J* = 4.5 Hz), 120.8 (d, *J* = 3.6 Hz), 125.9, 126.1, 126.8 (d, *J* = 2.7 Hz), 127.2, 127.9, 128.9, 129.8, 129.9, 134.2, 143.2, 148.9 (d, *J* = 6.3 Hz, 149.8 (d, *J* = 9.0 Hz), 171.5 (dd, *J* = 2.7, 3.6 Hz); IR (KBr): 3251, 3064, 3026, 2976, 2934, 1753, 1706, 1613, 1527, 1489, 1450, 1390, 1337, 1288, 1267, 1181, 1160, 1070, 964, 932, 761 cm^{-1}; HPLC on Ic column (70 : 30 hexane–IPA, 1.0 mL min^{-1}, 254 nm); t_R = 7.68 min (minor) and t_R = 8.790 min (major); HRMS (ESI) *m*/*z*: calculated mass for $C_{32}H_{30}3N_3NaO_8P$ $[M + Na]^+$ = 638.1662; found 638.1670.

(*R*)-*tert*-Butyl 1-benzyl-4-bromo-3-(diphenoxyphosphoryl)-2-oxoindolin-3-yl carbamate (4k). Purified by column chromatography on silica gel using 30% EtOAc in hexane as eluent; 80% yield and 52% ee; solid mp. 170–172 °C; α_D^{25} = +18.8 (*c* = 1.15, $CHCl_3$); ^1H NMR ($CDCl_3$, 500 MHz) δ: 1.41 (s, 9 H), 4.78 (d, *J* = 15.9 Hz, 1H), 5.26 (d, *J* = 15.4 Hz, 1H), 6.16 (d, *J* = 9.7 Hz, 1H), 6.66 (d, *J* = 7.1 Hz, 1H), 6.70–6.78 (m, 2H), 7.02–7.26 (m, 10H), 7.30 (dd ~ t, *J* = 8.2, 7.6 Hz, 3H)), 7.36–7.42 (m, 2H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ: 28.1, 44.8, 81.3, 108.6, 120.1 (d, *J* = 3.6 Hz), 120.8, 125.5, 125.7, 127.2, 127.6 (d, *J* = 11.8 Hz), 128.7, 129.5, 129.7, 130.8, 135.0, 145.3 (d, *J* = 6.4 Hz), 150.0 (dd, *J* = 8.2, 30.8 Hz), 170.6; IR (KBr): 3445, 3288, 3032, 2975, 2925, 1736, 1697, 1597, 1520, 1488, 1450, 1364, 1289, 1209, 1179, 964, 765 cm^{-1}; HPLC on Ic column (70 : 30 hexane–IPA, 1.0 mL min^{-1}, 254 nm); t_R = 8.38 min (minor) and t_R = 13.07 min (major); HRMS (ESI) *m*/*z*: calculated mass for $C_{32}H_{30}BrN_2NaO_6P$ $[M + Na]^+$ = 671.0917; found 671.0923.

(*R*)-*tert*-Butyl 1-benzyl-6-bromo-3-(diphenoxyphosphoryl)-2-oxoindolin-3-yl carbamate (4l). Purified by column

chromatography on silica gel using 30% EtOAc in hexane as eluent; 90% yield and 83% ee; solid mp. 198–200 °C; α_D^{25} = −7.2 (*c* = 1.0, $CHCl_3$); ^{1}H NMR ($CDCl_3$, 500 MHz) *δ*: 1.33 (s, 9 H), 4.76 (s, 1H), 5.22 (dd ~ t, *J* = 6.7, 16.2 Hz, 1H), 5.94 (d, *J* = 11.1 Hz, 1H), 6.68 (d, *J* = 8.1 Hz, 2H), 6.86 (s, 1H), 7.10 (dd ~ t, *J* = 7.1, 14.6 Hz, 1H), 7.18 (dd ~ t, *J* = 7.9, 16.2 Hz, 3H), 7.20–7.26 (m, 5H), 7.30–740 (m, 6H); ^{13}C NMR ($CDCl_3$, 75 MHz) *δ*: 28.0, 44.7, 81.7, 112.8 (d, *J* = 2.72 Hz), 120.0 (d, *J* = 4.5 Hz), 120.8 (d, *J* = 4.5 Hz), 125.6, 125.8 (d, *J* = 3.6 Hz), 125.9, 126.2 (d, *J* = 3.6 Hz), 127.2, 127.7, 128.8, 128.9, 129.6, 129.8, 134.7, 144.8, 149.8 (q, *J* = 10.0 Hz), 153.6 (d, *J* = 4.5 Hz), 170.9; IR (KBr): 3431, 3246, 3065, 3011, 2976, 2926, 1733, 1698, 1597, 1526, 1488, 1288, 1275, 1204, 1180, 1163, 960, 770 cm^{-1}; HPLC on Ic column (70 : 30 hexane–IPA, 1.0 mL min^{-1}, 254 nm); t_R = 6.12 min (minor) and t_R = 8.51 min (major); HRMS (ESI) *m*/*z*: calculated mass for $C_{32}H_{30}BrN_2NaO_6P$ $[M + Na]^+$ = 673.0902; found 673.0907.

(*R*)-*tert*-Butyl 1-benzyl-3-(diphenoxyphosphoryl)-7-methyl-2-oxoindolin-3-yl carbamate (4m). Purified by column chromatography on silica gel using 30% EtOAc in hexane as eluent; 90% yield and 91% ee; solid mp. 170–172 °C; α_D^{25} = −8.2 (*c* = 0.75, $CHCl_3$); ^{1}H NMR ($CDCl_3$, 500 MHz) *δ*: 1.33 (s, 9 H), 2.24 (s, 3H), 5.02 (m, 1H), 5.40 (d, *J* = 14.5 Hz, 1H), 5.96 (d, *J* = 10.7 Hz, 1H), 6.71 (d, *J* = 8.1 Hz, 2H), 6.96–7.02 (m, 2H), 7.08 (dd ~ t, *J* = 7.6, 7.8 Hz, 1H), 7.14–7.24 (m, 8H), 7.28–7.36 (m, 4H), 7.42 (d, *J* = 7.2 Hz, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) *δ*: 18.7, 28.1, 45.9, 81.4, 119.9 (d, *J* = 2.7 Hz), 120.2 (d, *J* = 3.6 Hz), 120.9 (d, *J* = 4.5, 122.9 (d, *J* = 3.6 Hz), 123.1 (d, *J* = 4.5 Hz), 125.5, 125.8, 125.9, 127.0, 128.7, 129.6, 129.8, 134.0 (d, *J* = 2.7 Hz), 137.5, 141.7 (d, *J* = 7.3 Hz), 150.1 (dd, *J* = 10.9, 23.6 Hz), 153.6 (d, *J* = 18.2 Hz), 171.9; IR (KBr): 3270, 3061, 3024, 2932, 1738, 1712, 1599, 1528, 1490, 1446, 1354, 1282, 1261, 1202, 1164, 953, 767 cm^{-1}; HPLC on Ic column (70 : 30 hexane–IPA, 1.0 mL min^{-1}, 254 nm); t_R = 8.14 min (minor) and t_R = 12.13 min (major); HRMS (ESI) *m*/*z*: calculated mass for $C_{33}H_{33}N_2NaO_6P$ $[M + Na]^+$ = 607.1968; found 607.1971.

(*R*)-*tert*-Butyl 1-benzyl-7-chloro-3-(diphenoxyphosphoryl)-2-oxoindolin-3-yl carbamate (4n). Purified by column chromatography on silica gel using 30% EtOAc in hexane as eluent; 85% yield and 91% ee; solid mp. 178–180 °C; α_D^{25} = −10.6 (*c* = 1.0, $CHCl_3$); ^{1}H NMR ($CDCl_3$, 300 MHz) *δ*: 1.33 (s, 9 H), 5.40 (s, 2H), 5.94 (d, *J* = 11.1 Hz, 1H), 6.68 (d, *J* = 8.1 Hz, 2H), 7.0 (t, *J* = 7.4 Hz, 1H), 7.06–7.40 (m, 14H), 7.46 (d, *J* = 1.5, 7.4 Hz, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) *δ*: 28.0, 45.7, 81.7, 115.6, 120.0 (d, *J* = 3.8 Hz), 120.8 (d, *J* = 3.8 Hz), 123.6, 125.6, 125.9, 126.6, 126.9, 128.4, 129.6, 129.8, 132.5 (d, *J* = 2.2 Hz), 137.3, 139.7 (d, *J* = 6.5 Hz), 150.0 (dd, *J* = 4.9, 10.0 Hz), 153.3 (d, *J* = 17.6 Hz), 171.5; IR (KBr): 3238, 3013, 2929, 1739, 1708, 1593, 1525, 1482, 1357, 1260, 1175, 964 cm^{-1}; HPLC on Ic column (70 : 30 hexane–IPA, 1.0 mL min^{-1}, 254 nm); t_R = 6.39 min (minor) and t_R = 8.82 min (major); HRMS (ESI) *m*/*z*: calculated mass for $C_{32}H_{30}ClN_2NaO_6P$ $[M + Na]^+$ = 627.1422; found 627.1428.

(*R*)-*tert*-Butyl 5-bromo-3-(diphenoxyphosphoryl)-2-oxoindolin-3-yl carbamate (4o). Purified by column chromatography on silica gel using 40% EtOAc in hexane as eluent; 91% yield and 86% ee; solid mp 110–112 °C; α_D^{25} = +25 (*c* = 0.45, $CHCl_3$); ^{1}H NMR ($CDCl_3$, 500 MHz) *δ*: 1.34 (s, 9H), 5.98 (d, *J* = 11.4 Hz, 1H), 6.64 (d, *J* = 8.2 Hz, 1H), 6.83 (d, *J* = 8.2 Hz, 2H), 7.12 (t, *J* = 7.3 Hz, 1H), 7.16–7.24 (m, 5H), 7.34 (t, *J* = 8.0 Hz, 3H), 7.58 (t, *J* = 2.1 Hz, 1H), 8.46 (s, 1H); ^{13}C NMR ($CDCl_3$ + DMSO-d_6, 75 MHz) *δ*: 27.2, 80.3, 110.4, 119.4, 119.9, 124.8, 124.9, 125.0, 127.2, 128.9 (d, *J* = 15.9 Hz), 131.8 (d, *J* = 8.8 Hz), 141.4 (d, *J* = 9.3 Hz), 149.0 (d, *J* = 10.5 Hz), 152.8 (d, *J* = 17.1 Hz), 173; IR (KBr): 3262, 2976, 1736, 1616, 1591, 1484, 1367, 1262, 1187, 1159, 960, 762 cm^{-1}; HPLC on AD-H column (70 : 30 hexane–IPA, 1.0 mL min^{-1}, 254 nm); t_R = 9.51 min (major) and t_R = 22.79 min (minor); HRMS (ESI) *m*/*z*: calculated mass for $C_{25}H_{25}BrN_2O_6P$ $[M + H]^+$ = 559.0628; found 559.0633.

(*R*)-*tert*-Butyl 3-(diphenoxyphosphoryl)-5-methyl-2-oxoindolin-3-yl carbamate (4p). Purified by column chromatography on silica gel using 40% EtOAc in hexane as eluent; 92% yield and 92% ee; solid mp 96–98 °C; α_D^{25} = +8.5 (*c* = 1.00, $CHCl_3$); ^{1}H NMR ($CDCl_3$ + DMSO-d_6, 500 MHz) *δ*: 1.30 (s, 9 H), 2.26 (s, 3H), 6.06 (d, *J* = 11.7 Hz, 1H), 6.70 (d, *J* = 7.9 Hz, 2H), 6.78 (d, *J* = 7.9 Hz, 1H), 7.07 (t, *J* = 7.2 Hz, 2H), 7.12–7.40 (m, 8H), 7.34 (t, *J* = 8.0 Hz, 3H), 9.95 (s, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) *δ*: 21.0, 27.9, 81.6, 110.2, 120.2 (d, J = 4.5 Hz), 120.8 (d, *J* = 4.5 Hz), 125.4, 125.7, 125.8 (d, *J* = 3.6 Hz), 129.4, 129.7, 130.4 (d, *J* = 1.8 Hz), 132.3 (d, *J* = 2.7 Hz), 139.3 (d, *J* = 8.1 Hz), 150.0 (d, *J* = 9.9 Hz), 153.8 (d, *J* = 17.2 Hz), 172.5; IR (KBr): 3279, 2977, 2926, 1734, 1693, 1624, 1591, 1532, 1490, 1368, 1262, 1186, 1160, 960, 766 cm^{-1}; HPLC on AD-H column (70 : 30 hexane–IPA, 1.0 mL min^{-1}, 254 nm); t_R = 12.18 min (major) and t_R = 21.93 min (minor); HRMS (ESI) *m*/*z*: calculated mass for $C_{26}H_{27}N_2NaO_6P$ $[M + Na]^+$ = 517.1499; found 517.1505.

(*R*)-*tert*-Butyl 3-(diphenoxyphosphoryl)-5-methoxy-2-oxoindolin-3-yl carbamate (4q). Purified by column chromatography on silica gel using 40% EtOAc in hexane as eluent; 94% yield and 86% ee; solid mp 86–88 °C; α_D^{25} = +13.9 (*c* = 0.55, $CHCl_3$); ^{1}H NMR ($CDCl_3$, 500 MHz) *δ*: 1.32 (s, 9 H), 3.72 (s, 3H), 5.94 (d, *J* = 11.5 Hz, 1H), 6.70–6.84 (m, 4H), 7.02–7.25 (m, 7H), 7.32 (dd, *J* = 7.9, 7.4 Hz, 2H), 8.30 (s, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) *δ*: 27.9, 55.8, 81.7, 111.7 (d, *J* = 2.2 Hz), 115.5 (d, *J* = 1.6 Hz), 120.2 (d, *J* = 3.8 Hz), 120.8 (d, *J* = 3.8 Hz), 125.5, 125.8, 129.5, 129.8, 135.1 (d, *J* = 7.1 Hz), 150.0 (dd, *J* = 2.7, 9.3 Hz), 153.8 (d, *J* = 18.1 Hz), 155.9 (d, *J* = 2.7 Hz), 172.5; IR (KBr): 3263, 2976, 2974, 2928, 2231, 1727, 1645, 1593, 1491, 1268, 1203, 1159, 1027, 955 cm^{-1}; HPLC on Ic column (70 : 30 hexane–IPA, 1.0 mL min^{-1}, 254 nm); t_R = 15.18 min (major) and t_R = 22.22 min (minor); HRMS (ESI) *m*/*z*: calculated mass for $C_{26}H_{27}N_2NaO_7P$ $[M + Na]^+$ = 533.1448, found 533.1452.

Diphenyl 1-benzyl-3-hydroxy-2-oxoindolin-3-yl phosphonate (5). Purified by column chromatography on silica gel using 30% EtOAc in hexane as eluent; 94% yield and 0% ee; semi-solid; ^{1}H NMR ($CDCl_3$, 500 MHz) *δ*: 2.54 (brs, 1H), 4.86 (d, *J* = 15.7 Hz, 1H), 4.90 (d, *J* = 15.7 Hz, 1H), 5.88 (d, *J* = 11.8 Hz, 2H), 6.68 (d, *J* = 7.9 Hz, 1H), 6.96 (d, *J* = 7.6 Hz, 1H), 7.18–7.34 (m, 12H), 7.36 (d, *J* = 4.2 Hz, 4H); ^{13}C NMR ($CDCl_3$, 75 MHz) *δ*: 43.9, 73.5 (d, *J* = 6.1 Hz), 109.6, 120.4 (t, *J* = 5.5 Hz), 123.2, 125.6, 126.1, 127.3, 127.8, 128.8, 129.7, 130.8, 134.9, 143.4,

150.5 (q, J = 7.7 Hz), 171.1 (d, J = 7.1 Hz); IR (KBr): 3451, 3062, 2926, 1734, 1615, 1590, 1489, 1469, 1289, 1187, 1101, 1076, 1024, 959 cm^{-1}; HPLC on AD-H column (70 : 30 hexane–IPA, 1.0 mL min^{-1}, 254 nm); t_R = 16.53 min and t_R = 21.75 min; HRMS (ESI) m/z: calculated mass for $C_{27}H_{22}NNaO_5P$ $[M + Na]^+$ = 494.1128, found 494.1135.

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