Chelation-Assisted C–N Cross-Coupling of Phosphinamides and Aryl Bronic Acids with Copper Powder at Room Temperature

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1. General information

The reactions were carried out in 25-mL Schlenk tubes under O₂. Unless noted otherwise, the materials obtained from commercial suppliers were used without further purification, and solvents were purified according to standard operating procedures. Flash column chromatography was performed using Silica Gel 60 (300–400 mesh). Analytical thin layer chromatography (TLC) was performed on Haigang TLC silica gel GF254 (0.25 mm) plates. The ¹H, ¹³C NMR, ³¹P NMR and ¹⁹F NMR spectra were recorded on a Brucker ADVANCE III spectrometer operating at 400 MHz, 100 MHz, 162 MHz and 376 MHz, respectively; and chemical shifts are reported in ppm (δ) relative to internal tetramethylsilane (TMS). Data are reported as follows: chemical shift, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet), and coupling constants (J) were reported in hertz. The NMR yields were determined by ³¹P NMR spectra with triphenylphosphine oxide (at 29.0 ppm) as internal standard. The reactions were monitored by GC and GC-MS; GC-MS results were recorded on a GC-MS QP2010 while GC analyses on a GC 2014 plus equipment. The electron ionization (EI) approach was used as ionization method for HRMS measurements, and TOF was the mass analyzer type for EI.

Starting phosphinamides, e.g., P,P-diphenyl-N-(quinolin-8-yl)phosphinamide (1a), N-(quinolin-8-yl)-P,P-di-p-tolyolphosphinamide (1b), N-(quinolin-8-yl)-P,P-di-m-tolyolphosphinamide (1c), P,P-bis(4-fluorophenyl)-N-(quinolin-8-yl)phosphinamide (1d), P,P-bis(3-fluorophenyl)-N-(quinolin-8-yl)phosphinamide (1e), P,P-bis(4-chlorophenyl)-N-(quinolin-8-yl)phosphinamide (1f), P,P-bis(4-methoxyphenyl)-N-(quinolin-8-yl)phosphinamide (1g), N-(2-(1H-pyrazol-1-yl)phenyl)-P,P-diphenylphosphinamide (1h), N-(2-(4,5-dihydrooxazol-2-yl)phenyl)-P,P-diphenylphosphinamide (1i), N,P,P-triphenyl-phosphinamide, N-(naphthalen-1-yl)-P,P-diphenylphosphinamide, N-(perfluorophenyl)-P,P-diphenylphosphinamide, P,P-diphenyl-N-(pyridin-3-yl)phosphinamide and P,P-diphenyl-N-(pyridin-2-yl)phosphinamide were prepared according to literature procedures. Spectral data obtained for the starting phosphinamides are in good agreement with the reported data.¹ ²
2. Synthesis and characterization of starting materials

General procedure for the synthesis of phosphinamides

To a solution of arylmagnesium bromide (0.1 mol) in THF (100 mL), diethyl phosphate (4.1 g, 0.03 mol) in THF (20 mL) was added dropwise with vigorous stirring under the cooling of ice-water bath. Then the mixture thus obtained was heated under reflux for 1 h. After the reflux, the resulting reaction mixture was cooled to 0 °C, and hydrochloric acid (6 N, 50 mL) was added slowly upon stirring. The solution was then evaporated under reduced pressure. The residue was extracted with EtOAc (150 mL). The organic layer was dried over anhydrous Na$_2$SO$_4$ and concentrated in vacuo to give crude product A1 which was used directly for the next step without further purification.

Hydrogen peroxide (30%, 16 mL) was added dropwise to a suspension of A1 in aqueous NaOH (5 N, 16 mL) at 95 °C, and the mixture was stirred for 1 h at 100 °C. After the solution was cooled to 0 °C, concentrated hydrochloric acid (12 N) was added dropwise until no white solid was precipitated out. The precipitate was collected by filtration and washed with Et$_2$O, then dried in vacuo to give crude phosphinic acid A2 which was used directly without purification.

A suspension of A2 and thionyl chloride (20 mL) in anhydrous toluene (60 mL) was heated to 80 °C for 3 hours. After thionyl chloride and toluene were removed
under reduced pressure, the residue was re-dissolved in anhydrous toluene (50 mL) 
and evaporated to give phosphinic chloride A3.

To a solution of 8-aminquinoline (4.6 g, 32 mmol), triethylamine (5 mL, 35 
mml), and N,N-dimethyl-4-aminopyridine (120 mg, 0.98 mmol) in CH₂Cl₂ (40 mL), 
a suspension of A3 was added dropwise under N₂ atmosphere with vigorous stirring at 
0 °C. Then the resulting mixture was warm to room temperature. After stirring 
overnight, the reaction system was quenched with water (30 mL) and extracted with 
CH₂Cl₂ (3×50 mL). The combined organic layer was dried over anhydrous Na₂SO₄, 
filtered, and concentrated in vacuo. The residue was purified by flash column 
chromatography on silica gel to afford the corresponding P,P-diaryl-N-(quinolin-8- 
yl)phosphinamide.

Analytical data for new starting phosphinamides

**P,P-di-m-tolyl-N-(quinolin-8-yl)phosphinamide (1c)**

![Structure of 1c](image)

1c was synthesized in 45% yield in 4 steps as a brown solid. 
R_f = 0.43 (petroleum ether/ethyl acetate = 2:1), mp 165–166 
°C. ¹H NMR (400 MHz, CDCl₃) δ 8.76 (d, J = 3.7 Hz, 1H), 
8.10 (d, J = 8.1 Hz, 1H), 7.96 (d, J = 12.8 Hz, 1H), 7.82 (d, J = 12.8 Hz, 2H), 7.72–7.67 (m, 2H), 7.43–7.25 (m, 8H), 2.38 (s, 
6H); ¹³C NMR (100 MHz, CDCl₃) δ 147.9, 138.7 (d, J = 12.9 
Hz), 137.8, 136.3, 133.0 (d, J = 3.0 Hz), 132.6, 132.4 (d, J = 
10.0 Hz), 131.3, 128.7 (d, J = 23.5 Hz), 128.7, 128.4, 127.1, 121.6, 119.2, 113.8 (d, J = 3.9 Hz), 21.4; ³¹P NMR (162 Hz, CDCl₃) δ 19.6. HRMS (ESI) calcd. for 

**P,P-bis(3-fluorophenyl)-N-(quinolin-8-yl)phosphinamide (1e)**

![Structure of 1e](image)

1e was synthesized in 21% yield in 4 steps as a brown solid. 
R_f = 0.52 (petroleum ether/ethyl acetate = 2:1), mp 145–146 
°C. ¹H NMR (400 MHz, CDCl₃) δ 8.77 (d, J = 4.0 Hz, 1H), 
8.12 (d, J = 8.2 Hz, 1H), 8.05 (d, J = 13.5 Hz, 1H), 7.74 (dd, J 
= 12.1, 7.6 Hz, 2H), 7.66 (t, J = 10.9 Hz, 2H), 7.50–7.42 (m, 
3H), 7.39–7.34 (m, 2H), 7.30–7.22 (m, 3H); ¹³C NMR (100 
MHz, CDCl₃) δ 162.7 (dd, J = 249.0, 18.4 Hz), 148.2, 138.6 
(d, J = 7.2 Hz), 137.0, 136.3, 134.2 (dd, J = 128.7, 5.6 Hz), 130.9 (dd, J = 15.2, 7.4 
Hz), 128.4, 127.5 (dd, J = 9.5, 3.2 Hz), 127.0, 121.8, 119.9, 119.6 (dd, J = 21.1, 2.6 
Hz), 118.7 (q, J = 11.0 Hz), 113.8 (d, J = 3.8 Hz); ³¹P NMR (162 Hz, CDCl₃) δ 16.0 (t, 
J = 6.7 Hz); ¹⁹F NMR (376 MHz, CDCl₃): δ -110.43–110.51 (m). HRMS (ESI) calcd. 
for C₂₁H₁₆F₂N₂O₅P [M]+: 381.0963; found: 381.0952.

**N-(2-(1H-pyrazol-1-yl)phenyl)-P,P-diphenylphosphinamide (1h)**

![Structure of 1h](image)
1h was synthesized in 90% yield as a white solid. Rf = 0.34 (petroleum ether/ethyl acetate = 5:1), mp 124–126 °C. 1H NMR (400 MHz, CDCl3) δ 8.95 (d, J = 11.8 Hz, 1H), 7.85–7.80 (m, 5H), 7.66 (s, 1H), 7.48–7.43 (m, 3H), 7.40 (d, J = 7.0 Hz, 4H), 7.25 (d, J = 7.8 Hz, 1H), 7.04–7.01 (m, 1H), 6.91–6.87 (m, 1H), 6.46 (s, 1H). 13C NMR (100 MHz, CDCl3) δ 140.3, 134.2, 132.8, 131.8 (d, J = 2.5 Hz), 131.4 (d, J = 10.1 Hz), 129.5, 128.5 (d, J = 12.9 Hz), 128.2 (d, J = 7.6 Hz), 127.7, 122.0, 121.4, 120.3 (d, J = 4.5 Hz), 106.8. 31P NMR (162 MHz, CDCl3) δ 18.3. HRMS (ESI) calcd. for C21H18N3OP [M]+: 359.1387; found: 359.1382.

N-(2-(4,5-dihydrooxazol-2-yl)phenyl)-P,P-diphenylphosphinamide (1i)

1i was synthesized in 40% yield as a yellow solid. Rf = 0.55 (petroleum ether/ethyl acetate = 2:1), mp 122–125 °C. 1H NMR (400 MHz, CDCl3) δ 11.00 (d, J = 13.0 Hz, 1H), 7.93–7.88 (m, 4H), 7.78 (d, J = 7.7 Hz, 1H), 7.46–7.35 (m, 7H), 7.15–7.11 (m, 1H), 6.84–6.81 (m, 1H), 4.29 (t, J = 9.3 Hz, 2H), 3.98 (t, J = 9.3 Hz, 2H). 13C NMR (100 MHz, CDCl3) δ 164.8 (d, J = 0.8 Hz), 142.8, 133.0, 131.9, 131.7 (d, J = 2.7 Hz), 131.4 (d, J = 10.1 Hz), 129.2, 128.4 (d, J = 12.9 Hz), 119.6, 117.9 (d, J = 5.0 Hz), 112.4 (d, J = 7.7 Hz), 65.8, 54.2. 31P NMR (162 MHz, CDCl3) δ 18.3. HRMS (ESI) calcd. for C21H19N2O2P [M]+: 362.1184; found: 362.1180.
General experimental procedure for the synthesis of \(\text{N-aryl phosphinamide}\)

An oven-dried 25-mL Schlenk tube, equipped with a magnetic stir bar and charged with phosphinamide (0.1 mmol), copper powder (6.4 mg, 1.0 equiv), and boronic acids (0.2 mmol, 2.0 equiv), was evacuated and backfilled with \(\text{O}_2\) three times. Then, acetonitrile (1.0 mL) was added under \(\text{O}_2\) atmosphere and the reaction mixture was stirred at 25–100 °C for 12–24 h and monitored by TLC or GC-MS analysis. Upon completion, the mixture was made to pass through a short pad of celite with \(\text{CH}_2\text{Cl}_2\) and the solution was concentrated in vacuo. The residue was purified by silica gel flash chromatography column to give the corresponding products.

3. \(^1\text{H}, ^{13}\text{C}, ^{31}\text{P}, ^{19}\text{F}\) NMR spectra data of the products

\(\text{N,\text{P,P}}\text{-triphenyl-\text{N-(quinolin-8-yl)phosphinamide (3a)}}\)

The phosphinamide compound was obtained as a yellow solid. \(R_f = 0.37\) (petroleum ether/ethyl acetate = 1:1), mp 210–212 °C. \(^1\text{H}\) NMR (400 MHz, CDCl\(_3\)) \(\delta\) 9.04 (d, \(J = 1.4\) Hz, 1H), 8.05–7.97 (m, 6H), 7.57 (d, \(J = 8.1\) Hz, 1H), 7.38–7.34 (m, 4H), 7.22–7.18 (m, 2H), 7.13 (d, \(J = 7.4\) Hz, 4H), 7.03 (t, \(J = 7.4\) Hz, 2H), 6.85 (t, \(J = 7.2\) Hz, 1H). \(^{13}\text{C}\) NMR (100 MHz, CDCl\(_3\)) \(\delta\) 150.2, 146.3 (d, \(J = 3.1\) Hz), 145.7 (d, \(J = 3.9\) Hz), 140.7 (d, \(J = 2.6\) Hz), 135.8, 132.9 (d, \(J = 9.6\) Hz), 132.5 (d, \(J = 3.2\) Hz), 131.5 (d, \(J = 130.5\) Hz), 131.1 (d, \(J = 2.8\) Hz), 129.0, 128.4, 128.0, 127.4 (d, \(J = 13.0\) Hz), 126.5 (d, \(J = 1.2\) Hz), 123.1 (d, \(J = 4.7\) Hz), 122.9, 121.3. \(^{31}\text{P}\) NMR (162 MHz, CDCl\(_3\)) \(\delta\) 25.0. HRMS (ESI) calcd. for C\(_{27}\)H\(_{21}\)N\(_2\)OP [M]+: 420.1391; found: 420.1386.

\(\text{N-(4-ethylphenyl)-\text{P,P-diphenyl-\text{N-(quinolin-8-yl)phosphinamide (3b)}}}\)

The phosphinamide compound was obtained as a yellow solid. \(R_f = 0.45\) (petroleum ether/ethyl acetate = 2:1), mp 130–132 °C. \(^1\text{H}\) NMR (400 MHz, CDCl\(_3\)) \(\delta\) 8.90 (d, \(J = 2.1\) Hz, 1H), 7.96–7.87 (m, 5H), 7.75 (d, \(J = 8.1\) Hz, 1H), 7.34 (d, \(J = 8.0\) Hz, 1H), 7.26 (d, \(J = 7.9\) Hz, 2H), 7.17–7.13 (t, \(J = 8.2\) Hz, 2H), 7.00–6.95 (m, 6H), 6.73 (d, \(J = 8.1\) Hz, 2H), 2.29–2.23 (m, 2H), 0.91–0.87 (t, \(J = 7.6\) Hz, 3H); \(^{13}\text{C}\) NMR (100 MHz, CDCl\(_3\)) \(\delta\) 149.9, 146.0 (d, \(J = 3.3\) Hz), 143.0 (d, \(J = 3.6\) Hz), 140.8 (d, \(J = 2.5\) Hz), 138.7, 135.6, 132.6 (d, \(J = 9.7\) Hz), 132.1 (d, \(J = 4.4\) Hz), 130.9 (d, \(J = 2.6\) Hz), 130.8, 128.7, 127.7, 127.5, 127.2 (d, \(J = 13.0\) Hz), 126.2, 123.5 (d, \(J = 4.7\) Hz), 121.0, 27.6, 15.0; \(^{31}\text{P}\) NMR (162 MHz, CDCl\(_3\)) \(\delta\) 24.7. HRMS (ESI) calcd. for C\(_{29}\)H\(_{25}\)N\(_2\)OP [M]+: 448.1704; found: 448.1699.
The phosphinamide compound was obtained as a yellow solid. 

\( R_f = 0.33 \) (petroleum ether/ethyl acetate = 2/1), mp 191–193 °C. 

\(^1\)H NMR (400 MHz, CDCl\(_3\)) \( \delta \): 8.97 (d, \( J = 1.8 \) Hz, 1H), 7.96–7.87 (m, 6H), 7.46 (d, \( J = 8.1 \) Hz, 1H), 7.28–7.19 (m, 4H), 7.13–7.04 (m, 6H), 6.81 (d, \( J = 8.0 \) Hz, 2H), 2.66–2.58 (m, 1H), 1.00 (d, \( J = 6.8 \) Hz, 6H); \(^1^3\)C NMR (100 MHz, CDCl\(_3\)) \( \delta \): 150.1, 146.3 (d, \( J = 3.1 \) Hz), 140.9 (d, \( J = 2.4 \) Hz), 135.8, 132.8 (d, \( J = 9.7 \) Hz), 132.4 (d, \( J = 3.3 \) Hz), 131.6 (d, \( J = 130.9 \) Hz), 131.1 (d, \( J = 2.6 \) Hz), 129.0, 127.8, 127.4 (d, \( J = 13.0 \) Hz), 126.5 (d, \( J = 1.1 \) Hz), 126.3, 123.4 (d, \( J = 4.7 \) Hz), 121.2, 33.1, 23.7; \(^3^1\)P NMR (162 MHz, CDCl\(_3\)) \( \delta \): 24.9. HRMS (ESI) calcd. for \( \text{C}_{30}\text{H}_{27}\text{N}_2\text{OP} [M]^+ \): 462.1861; found: 462.1856.

The phosphinamide compound was obtained as a white solid. 

\( R_f = 0.28 \) (petroleum ether/ethyl acetate = 2/1), mp 143–145 °C. 

\(^1\)H NMR (400 MHz, CDCl\(_3\)) \( \delta \): 9.03 (d, \( J = 4.0 \) Hz, 1H), 8.05–8.00 (m, 5H), 7.94 (d, \( J = 8.2 \) Hz, 1H), 7.53 (d, \( J = 8.2 \) Hz, 1H), 7.34–7.3 (m, 4H), 7.19–7.11 (m, 6H), 6.84 (d, \( J = 8.0 \) Hz, 2H), 2.39 (t, \( J = 7.7 \) Hz, 2H), 1.45–1.38 (m, 2H), 1.25–1.16 (m, 2H), 0.82 (t, \( J = 7.3 \) Hz, 3H); \(^1^3\)C NMR (100 MHz, CDCl\(_3\)) \( \delta \): 150.1, 146.2 (d, \( J = 3.4 \) Hz), 143.1 (d, \( J = 3.6 \) Hz), 140.9 (d, \( J = 2.6 \) Hz), 137.8, 135.8, 132.87 (d, \( J = 9.7 \) Hz), 132.3 (d, \( J = 3.3 \) Hz), 131.4 (d, \( J = 131.0 \) Hz), 131.1 (d, \( J = 2.7 \) Hz), 129.0, 128.3, 127.8 (d, \( J = 0.7 \) Hz), 127.4 (d, \( J = 13.1 \) Hz), 126.4 (d, \( J = 1.3 \) Hz), 123.8 (d, \( J = 4.7 \) Hz), 121.1, 34.7, 33.2, 22.1, 13.7; \(^3^1\)P NMR (162 MHz, CDCl\(_3\)) \( \delta \): 25.0. HRMS (ESI) calcd. for \( \text{C}_{31}\text{H}_{29}\text{N}_2\text{OP} [M]^+ \): 476.2018; found: 476.2033.

The phosphinamide compound was obtained as a yellow solid. 

\( R_f = 0.35 \) (petroleum ether/ethyl acetate = 2/1), mp 200–202 °C. 

\(^1\)H NMR (400 MHz, CDCl\(_3\)) \( \delta \): 8.97–8.96 (m, 1H), 7.96–7.87 (m, 6H), 7.46 (d, \( J = 8.1 \) Hz, 1H), 7.27–7.23 (m, 2H), 7.19 (d, \( J = 8.4 \) Hz, 2H), 7.12–7.08 (m, 2H), 7.05–7.02 (m, 4H), 6.96 (d, \( J = 7.6 \) Hz, 2H), 1.07 (s, 9H); \(^1^3\)C NMR (100 MHz, CDCl\(_3\)) \( \delta \): 150.16 (s), 145.6, 142.8 (d, \( J = 3.3 \) Hz), 140.8 (d, \( J = 1.6 \) Hz), 135.9, 132.8 (d, \( J = 9.6 \) Hz), 132.5 (d, \( J = 1.3 \) Hz), 132.2–132.1 (m), 131.1 (d, \( J = 2.2 \) Hz), 130.9, 129.0, 127.9, 127.4 (d, \( J = 12.9 \) Hz), 126.5, 125.2, 122.8 (d, \( J = 4.5 \) Hz), 121.2, 33.9, 31.1; \(^3^1\)P NMR (162 MHz, CDCl\(_3\)) \( \delta \): 24.94. HRMS (ESI) calcd. for \( \text{C}_{31}\text{H}_{29}\text{N}_2\text{OP} [M]^+ \): 476.2018; found: 476.2025.
**P,P-diphenyl-N-(quinolin-8-yl)-N-(p-tolyl)phosphinamide (3f)**

The phosphinamide compound was obtained as a yellow solid. 

\[ R_f = 0.40 \] (petroleum ether/ethyl acetate = 1/1), mp 195–197 °C. 

\[^1^H\text{ NMR (400 MHz, CDCl}_3\text{)} \delta 8.92–8.91 (1H), 7.96–7.89 (3H), 7.79 (d, \text{J} = 8.2 \text{ Hz}, 1H), 7.38 (d, \text{J} = 8.1 \text{ Hz}, 1H), 7.25 (d, \text{J} = 7.9 \text{ Hz}, 2H), 7.21–7.14 (m, 2H), 7.06–6.98 (m, 6H), 6.71 (d, \text{J} = 8.0 \text{ Hz}, 2H), 1.97 (s, 3H). 

\[^{13}^C\text{ NMR (100 Hz, CDCl}_3\text{)} \delta 150.0, 146.1 (d, \text{J} = 3.2 \text{ Hz}), 143.0 (d, \text{J} = 3.7 \text{ Hz}), 140.9 (d, \text{J} = 2.5 \text{ Hz}), 135.7, 132.7 (d, \text{J} = 9.7 \text{ Hz}), 132.6, 132.2, 132.1 (d, \text{J} = 1.6 \text{ Hz}), 130.9 (d, \text{J} = 2.6 \text{ Hz}), 130.8, 128.9, 127.7, 127.3 (d, \text{J} = 12.9 \text{ Hz}), 126.3 (d, \text{J} = 1.0 \text{ Hz}), 123.8 (d, \text{J} = 4.6 \text{ Hz}), 121.1, 20.4. 

\[^{31}^P\text{ NMR (162 MHz, CDCl}_3\text{)} \delta 24.8.\]

HRMS (ESI) calcd. for \(\text{C}_{28}\text{H}_{23}\text{N}_2\text{OP} [\text{M}]^+\): 434.1548; found: 434.1545.

**P,P-diphenyl-N-(quinolin-8-yl)-N-(m-tolyl)phosphinamide (3g)**

The phosphinamide compound was obtained as a white solid. \( R_f = 0.4 \) (petroleum ether /ethyl acetate = 1/1), mp 177–179 °C. 

\[^1^H\text{ NMR (400 MHz, CDCl}_3\text{)} \delta 8.95–8.94 (1H), 7.95–7.86 (m, 6H), 7.46 (d, \text{J} = 8.1 \text{ Hz}, 1H), 7.28–7.23 (m, 2H), 7.12–7.08 (m, 4H), 2.0 (s, 3H). 

\[^{13}^C\text{ NMR (100 MHz, CDCl}_3\text{)} \delta 150.1, 146.3 (d, \text{J} = 3.2 \text{ Hz}), 145.6 (d, \text{J} = 3.7 \text{ Hz}), 140.8 (d, \text{J} = 2.7 \text{ Hz}), 138.1, 135.8, 132.8 (d, \text{J} = 9.7 \text{ Hz}), 132.5 (d, \text{J} = 3.3 \text{ Hz}), 132.1, 131.1 (d, \text{J} = 2.7 \text{ Hz}), 130.8, 129.0, 128.1, 127.9, 127.4 (d, \text{J} = 13.1 \text{ Hz}), 126.4 (d, \text{J} = 1.4 \text{ Hz}), 124.0 (d, \text{J} = 6.4 \text{ Hz}), 121.2, 120.6 (d, \text{J} = 4.8 \text{ Hz}), 21.3. 

\[^{31}^P\text{ NMR (162 MHz, CDCl}_3\text{)} \delta 25.0.\]

HRMS (ESI) calcd. for \(\text{C}_{28}\text{H}_{23}\text{N}_2\text{OP} [\text{M}]^+\): 434.1548; found: 434.1543.

**P,P-diphenyl-N-(quinolin-8-yl)-N-(o-tolyl)phosphinamide (3h)**

The phosphinamide compound was obtained as a yellow solid. \( R_f = 0.42 \) (petroleum ether /ethyl acetate = 1/1), mp 207–208 °C. 

\[^1^H\text{ NMR (400 MHz, CDCl}_3\text{)} \delta 8.72–8.70 (1H), 8.33 (d, \text{J} = 7.5 \text{ Hz}, 1H), 7.87 (d, \text{J} = 8.2 \text{ Hz}, 1H), 7.83–7.81 (m, 1H), 7.77–7.72 (m, 4H), 7.43 (d, \text{J} = 8.1 \text{ Hz}, 1H), 7.27 (t, \text{J} = 7.6 \text{ Hz}, 1H), 7.23–7.14 (m, 3H), 7.12–7.08 (m, 4H), 2.30 (s, 3H). 

\[^{13}^C\text{ NMR (100 MHz, CDCl}_3\text{)} \delta 148.7, 144.7 (d, \text{J} = 5.3 \text{ Hz}), 141.9, 141.5 (d, \text{J} = 2.8 \text{ Hz}), 139.0 (d, \text{J} = 3.4 \text{ Hz}), 135.7, 133.8 (d, \text{J} = 2.8 \text{ Hz}), 132.7 (d, \text{J} = 9.5 \text{ Hz}), 132.2, 131.2 (d, \text{J} = 2.7 \text{ Hz}), 130.9, 130.7, 130.0 (d, \text{J} = 4.0 \text{ Hz}), 129.2, 127.6 (d, \text{J} = 12.9 \text{ Hz}), 126.5, 126.1 (d, \text{J} = 14.9 \text{ Hz}), 125.2, 120.8, 19.4. 

\[^{31}^P\text{ NMR (162 MHz, CDCl}_3\text{)} \delta 27.8.\]

HRMS (ESI) calcd. for \(\text{C}_{28}\text{H}_{23}\text{N}_2\text{OP} [\text{M}]^+\): 434.1548; found: 434.1560.
**N-(4-fluorophenyl)-P,P-diphenyl-N-(quinolin-8-yl)phosphinamide (3i)**

The phosphinamide compound was obtained as a yellow solid. 

R\(_f\) = 0.35 (petroleum ether / ethyl acetate = 1/1), mp 211–213 °C. 

\(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 8.97 (d, \(J = 1.8\) Hz, 1H), 7.95–7.89 (m, 6H), 7.48 (d, \(J = 8.0\) Hz, 1H), 7.40 (d, \(J = 4.2\) Hz 2H), 7.29–7.26 (m, 2H), 7.18–7.12 (m, 2H), 7.06 (s, 4H), 6.65 (t, \(J = 8.4\) Hz, 2H). 

\(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 160.5, 158.1, 150.2, 146.0 (d, \(J = 3.6\) Hz), 141.4 (t, \(J = 3.2\) Hz), 141.0 (d, \(J = 2.3\) Hz), 135.9, 132.8 (d, \(J = 9.7\) Hz), 132.0 (d, \(J = 3.3\) Hz), 131.0 (d, \(J = 13.1\) Hz), 131.3 (d, \(J = 2.7\) Hz), 129.1, 128.0, 127.5 (d, \(J = 13.1\) Hz), 126.4–126.23 (m), 121.3, 115.0 (d, \(J = 22.3\) Hz). 

\(^{31}\)P NMR (162 MHz, CDCl\(_3\)) \(\delta\) 25.6. 


**N-(4-chlorophenyl)-P,P-diphenyl-N-(quinolin-8-yl)phosphinamide (3j)**

The phosphinamide compound was obtained as a white solid. R\(_f\) = 0.55 (petroleum ether / ethyl acetate = 1:1), mp 184–186 °C. 

\(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 8.96 (d, \(J = 4.0\) Hz, 1H), 7.94–7.87 (m, 6H), 7.50 (d, \(J = 8.1\) Hz, 1H), 7.30–7.26 (m, 2H), 7.23 (d, \(J = 8.5\) Hz, 2H), 7.18–7.12 (m, 2H), 7.08–7.04 (m, 4H), 6.90 (d, \(J = 8.4\) Hz, 2H). 

\(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 150.3, 146.1 (d, \(J = 2.9\) Hz), 144.3 (d, \(J = 4.1\) Hz), 140.5 (d, \(J = 4.8\) Hz), 136.0, 132.8 (d, \(J = 9.8\) Hz), 132.4 (d, \(J = 3.1\) Hz), 131.7, 131.3 (d, \(J = 2.8\) Hz), 130.4, 129.0, 128.3 (d, \(J = 7.3\) Hz), 128.2 (d, \(J = 1.1\) Hz), 127.5 (d, \(J = 13.1\) Hz), 126.5 (d, \(J = 1.4\) Hz), 124.5 (d, \(J = 4.8\) Hz), 121.4. 

\(^{31}\)P NMR (162 MHz, CDCl\(_3\)) \(\delta\) 25.5. HRMS (ESI) calcd. for C\(_{27}\)H\(_{20}\)ClN\(_2\)O\(_3\)P [M]+: 454.1002; found: 454.0996.

**N-(4-bromophenyl)-P,P-diphenyl-N-(quinolin-8-yl)phosphinamide (3k)**

The phosphinamide compound was obtained as a white solid. R\(_f\) = 0.41 (petroleum ether / ethyl acetate = 1/1), mp 201–203 °C. 

\(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 8.96–8.95 (m, 1H), 7.94–7.85 (m, 6H), 7.51 (d, \(J = 8.1\) Hz, 1H), 7.30–7.26 (m, 2H), 7.23 (d, \(J = 8.5\) Hz, 2H), 7.18–7.12 (m, 2H), 7.08–7.04 (m, 4H), 6.90 (d, \(J = 8.4\) Hz, 2H). 

\(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 150.3, 146.1 (d, \(J = 3.1\) Hz), 144.3 (d, \(J = 4.1\) Hz), 140.5 (d, \(J = 4.8\) Hz), 136.0, 132.8 (d, \(J = 9.8\) Hz), 132.4 (d, \(J = 3.1\) Hz), 131.7, 131.3 (d, \(J = 2.8\) Hz), 130.4, 129.0, 128.3 (d, \(J = 7.3\) Hz), 128.2 (d, \(J = 1.1\) Hz), 127.5 (d, \(J = 13.1\) Hz), 126.5 (d, \(J = 1.4\) Hz), 124.5 (d, \(J = 4.8\) Hz), 121.4. 

\(^{31}\)P NMR (162 MHz, CDCl\(_3\)) \(\delta\) 25.5. HRMS (ESI) calcd. for C\(_{27}\)H\(_{20}\)BrN\(_2\)O\(_3\)P [M]+: 498.0497; found: 498.0491.

**N-(4-iodophenyl)-P,P-diphenyl-N-(quinolin-8-yl)phosphinamide (3l)**

The phosphinamide compound was obtained as a yellow solid. 

R\(_f\) = 0.35 (petroleum ether / ethyl acetate = 1/1), mp 211–213 °C. 

\(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 8.97 (d, \(J = 1.8\) Hz, 1H), 7.95–7.89 (m, 6H), 7.48 (d, \(J = 8.0\) Hz, 1H), 7.40 (d, \(J = 4.2\) Hz 2H), 7.29–7.26 (m, 2H), 7.18–7.12 (m, 2H), 7.06 (s, 4H), 6.65 (t, \(J = 8.4\) Hz, 2H). 

\(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 160.5, 158.1, 150.2, 146.0 (d, \(J = 3.6\) Hz), 141.4 (t, \(J = 3.2\) Hz), 141.0 (d, \(J = 2.3\) Hz), 135.9, 132.8 (d, \(J = 9.7\) Hz), 132.0 (d, \(J = 3.3\) Hz), 131.0 (d, \(J = 13.1\) Hz), 131.3 (d, \(J = 2.7\) Hz), 129.1, 128.0, 127.5 (d, \(J = 13.1\) Hz), 126.4–126.23 (m), 121.3, 115.0 (d, \(J = 22.3\) Hz). 

\(^{31}\)P NMR (162 MHz, CDCl\(_3\)) \(\delta\) 25.6. HRMS (ESI) calcd. for C\(_{27}\)H\(_{20}\)FN\(_2\)OP [M]+: 438.1297; found: 438.1295.
The phosphinamide compound was obtained as a yellow solid. 

**N-(3-fluorophenyl)-P,P-diphenyl-N-(quinolin-8-yl)phosphinamide (3m)**

The phosphinamide compound was obtained as a yellow solid. 

**N-(4-methoxyphenyl)-P,P-diphenyl-N-(quinolin-8-yl)phosphinamide (3n)**

The phosphinamide compound was obtained as a yellow solid.

**P,P-diphenyl-N-(quinolin-8-yl)-N-(4-vinylphenyl)phosphinamide (3o)**

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The phosphinamide compound was obtained as a yellow solid. 
$R_f = 0.42$ (petroleum ether /ethyl acetate = 1/1), mp 114–116 °C. 
$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 8.95–8.89 (m, 1H), 7.96–7.89 (m, 5H), 7.79 (d, $J = 8.2$ Hz, 1H), 7.38 (d, $J = 8.1$ Hz, 1H), 7.25 (d, $J = 7.9$ Hz, 2H), 6.71 (d, $J = 7.9$ Hz, 2H), 7.21–7.14 (m, 2H), 7.05–6.98 (m, 6H), 1.97 (s, 3H).

$^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 150.0, 146.1 (d, $J = 3.2$ Hz), 143.0 (d, $J = 3.6$ Hz), 140.9 (d, $J = 2.5$ Hz), 135.7, 132.7 (d, $J = 9.7$ Hz), 132.6, 132.1, 132.1 (d, $J = 1.6$ Hz), 130.9 (d, $J = 2.6$ Hz), 130.8, 127.7, 127.3 (d, $J = 13.0$ Hz), 126.2 (d, $J = 1$ Hz), 123.8 (d, $J = 4.6$ Hz), 121.1, 20.4. $^{31}$P NMR (162 MHz, CDCl$_3$) $\delta$ 24.8. HRMS (ESI) calcd. for C$_{29}$H$_{23}$N$_2$OP [$M^+$]: 446.1548; found: 446.1543.

$N$-(4-formylphenyl)-$P,P$-diphenyl-$N$-(quinolin-8-yl)phosphinamide (3p)

The phosphinamide compound was obtained as a yellow solid. 
$R_f = 0.34$ (petroleum ether /ethyl acetate = 2/1), mp 134–136 °C. 
$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 9.65 (s, 1H), 8.94–8.93 (m, 1H), 7.94–7.87 (m, 5H), 7.77 (d, $J = 7.2$ Hz, 1H), 7.54 (d, $J = 8.1$ Hz, 1H), 7.44 (d, $J = 8.0$ Hz, 2H), 7.32–7.28 (m, 2H), 7.16–7.11 (m, 3H), 7.09–7.05 (m, 5H). $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 190.8, 151.3 (d, $J = 4.6$ Hz), 150.5, 145.9 (d, $J = 2.3$ Hz), 139.0 (d, $J = 2.2$ Hz), 136.0, 132.6 (d, $J = 10.1$ Hz), 132.5 (d, $J = 2.8$ Hz), 131.6 (d, $J = 2.7$ Hz), 131.1, 130.4, 130.1, 129.8, 128.9 (d, $J = 7.3$ Hz), 127.6 (d, $J = 13.3$ Hz), 126.5 (d, $J = 1.5$ Hz), 121.6, 120.4 (d, $J = 5.0$ Hz). $^{31}$P NMR (162 MHz, CDCl$_3$) $\delta$ 26.9. HRMS (ESI) calcd. for C$_{28}$H$_{21}$N$_2$O$_2$P [$M^+$]: 448.1341; found: 448.1335.

$N$-(3-formylphenyl)-$P,P$-diphenyl-$N$-(quinolin-8-yl)phosphinamide (3q)

The phosphinamide compound was obtained as a yellow solid. 
$R_f = 0.28$ (petroleum ether /ethyl acetate = 1/1), mp 128–130 °C. 
$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 9.71 (s, 1H), 9.04 (d, $J = 1.4$ Hz, 1H), 8.03–7.95 (m, 6H), 7.68 (d, $J = 8.0$ Hz, 1H), 7.64 (s, 1H), 7.60 (d, $J = 8.1$ Hz, 1H), 7.39–7.35 (m, 3H), 7.23–7.20 (m, 2H), 7.18–7.12 (m, 5H). $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 192.1, 150.4, 146.5 (d, $J = 4.2$ Hz), 146.0 (d, $J = 2.8$ Hz), 139.8 (d, $J = 2.2$ Hz), 136.6, 136.0, 132.7 (d, $J = 9.8$ Hz), 132.3 (d, $J = 3.0$ Hz), 131.4 (d, $J = 2.7$ Hz), 130.1, 129.0, 128.9, 128.5, 128.4 (d, $J = 4.7$ Hz), 127.5 (d, $J = 13.1$ Hz), 126.4 (d, $J = 0.9$ Hz), 123.9 (d, $J = 4.9$ Hz), 123.3, 121.5. $^{31}$P NMR (162 MHz, CDCl$_3$) $\delta$ 26.0. HRMS (ESI) calcd. for C$_{29}$H$_{21}$N$_2$O$_2$P [$M^+$]: 448.1341; found: 448.1332.
**N-(4-acetylphenyl)-P,P-diphenyl-N-(quinolin-8-yl)phosphinamide (3r)**

The phosphinamide compound was obtained as a yellow solid. 
$R_f = 0.23$ (petroleum ether/ethyl acetate = 1/1), mp 205–207 °C.
$^1$H NMR (400 MHz, CDCl$_3$) δ 9.03 (s, 1H), 8.02–7.97 (m, 5H), 7.86 (d, $J = 6.9$ Hz, 1H), 7.64–7.60 (m, 3H), 7.40–7.35 (m, 2H), 7.24–7.20 (m, 2H), 7.15 (d, $J = 8.0$ Hz, 6H), 2.40 (s, 3H).
$^{13}$C NMR (100 MHz, CDCl$_3$) δ 196.7, 150.4, 150.1 (d, $J = 4.5$ Hz), 145.9 (d, $J = 2.2$ Hz), 139.1 (d, $J = 1.7$ Hz), 136.0, 132.6 (d, $J = 10.0$ Hz), 132.4 (d, $J = 2.8$ Hz), 131.4–131.3 (m), 130.5, 130.0, 128.9, 128.8 128.7, 127.5 (d, $J = 13.2$ Hz), 126.4 (d, $J = 0.5$ Hz), 121.5, 119.9 (d, $J = 4.8$ Hz), 26.0. $^{31}$P NMR (162 MHz, CDCl$_3$) δ 26.3. HRMS (ESI) calcd. for C$_{29}$H$_{23}$N$_2$O$_2$P [M]$^+$: 462.1497; found: 462.1492.

**N-(3-acetylphenyl)-P,P-diphenyl-N-(quinolin-8-yl)phosphinamide (3s)**

The phosphinamide compound was obtained as a yellow solid. 
$R_f = 0.26$ (petroleum ether /ethyl acetate = 1/1), mp 156–158 °C.
$^1$H NMR (400 MHz, CDCl$_3$) δ 8.96 (d, $J = 3.9$ Hz, 1H), 7.96–7.90 (m, 6H), 7.83 (s, 1H), 7.51 (d, $J = 8.1$ Hz, 1H), 7.42 (d, $J = 8.0$ Hz, 1H), 7.37 (d, $J = 7.6$ Hz, 1H), 7.30–7.26 (m, 2H), 7.18–7.11 (m, 2H), 7.07–6.99 (m, 5H), 2.25 (s, 3H).
$^{13}$C NMR (100 MHz, CDCl$_3$) δ 197.8, 150.3, 145.9 (d, $J = 2.8$ Hz), 145.7 (d, $J = 4.0$ Hz), 139.8 (d, $J = 1.8$ Hz), 137.0, 135.9, 132.6 (d, $J = 9.8$ Hz), 132.2 (d, $J = 3.0$ Hz), 131.4–131.3 (m), 130.0, 128.9, 128.5, 128.3, 127.5 (d, $J = 13.1$ Hz), 127.3 (d, $J = 4.4$ Hz), 126.4, 122.9 (d, $J = 4.6$ Hz), 122.4, 121.4, 26.3. $^{31}$P NMR (162 MHz, CDCl$_3$) δ 25.8. HRMS (ESI) calcd. for C$_{29}$H$_{23}$N$_2$O$_2$P [M]$^+$: 462.1497; found: 462.1495.

**N-(4-(methylsulfonyl)phenyl)-P,P-diphenyl-N-(quinolin-8-yl)phosphinamide (3t)**

The phosphinamide compound was obtained as a white solid. $R_f = 0.08$ (petroleum ether /ethyl acetate = 1/1), mp 250–251 °C.
$^1$H NMR (400 MHz, CDCl$_3$) δ 8.97 (d, $J = 3.8$ Hz, 1H), 7.97 (d, $J = 8.2$ Hz, 1H), 7.94–7.86 (m, 4H), 7.77 (d, $J = 7.2$ Hz, 1H), 7.58 (d, $J = 8.2$ Hz, 1H), 7.48 (d, $J = 8.5$ Hz, 2H), 7.37–7.30 (m, 2H), 7.19–7.16 (m, 2H), 7.13–7.08 (m, 6H), 2.85 (s, 3H).
$^{13}$C NMR (100 MHz, CDCl$_3$) δ 150.7 (d, $J = 1.2$ Hz), 150.6 (d, $J = 4.6$ Hz), 146.0 (d, $J = 2.6$ Hz), 139.0–138.9 (m), 136.1 (d, $J = 0.9$ Hz), 132.7 (d, $J = 10.0$ Hz), 132.5 (d, $J = 3.2$ Hz), 131.7, 131.1 (d, $J = 3.3$ Hz), 129.8 (d, $J = 3.3$ Hz), 129.0, 128.0 (d, $J = 0.8$ Hz), 127.7 (d, $J = 13.2$ Hz), 126.6, 121.8 (d, $J = 1.0$ Hz), 120.5, 120.4 (d, $J = 5.0$ Hz), 44.6. $^{31}$P NMR (162 MHz, CDCl$_3$) δ 27.0. HRMS (ESI) calcd. for C$_{28}$H$_{23}$N$_2$O$_3$PS [M]$^+$: 498.1167; found: 498.1162.
**N-(3-((diphenylphosphoryl)(quinolin-8-yl)amino)phenyl)acetamide (3u)**

The phosphinamide compound was obtained as a yellow solid. \( R_f = 0.51 \) (petroleum ether/ethyl acetate = 1/1), mp 123–125 °C. \(^1\)H NMR (400 MHz, CDCl\(_3\)) \( \delta \) 8.90 (s, 1H), 8.46 (d, \( J = 56.0 \) Hz, 1H), 7.90 (s, 4H), 7.79 (d, \( J = 17.0 \) Hz, 2H), 7.42 (d, \( J = 23.4 \) Hz, 2H), 7.29 (s, 1H), 7.14 (d, \( J = 37.8 \) Hz, 4H), 7.01 (s, 5H), 6.83 (s, 1H), 1.78 (s, 3H).

\(^{13}\)C NMR (100 MHz, DMSO) \( \delta \) 168.5, 151.2, 146.6 (d, \( J = 4.1 \) Hz), 146.2 (d, \( J = 2.7 \) Hz), 140.52 (d, \( J = 9.4 \) Hz), 132.8 (d, \( J = 2.8 \) Hz), 131.95 (d, \( J = 1.2 \) Hz), 131.6, 129.4, 128.9 (d, \( J = 14.6 \) Hz), 128.2 (d, \( J = 12.5 \) Hz), 126.9, 122.3, 117.91 (d, \( J = 4.4 \) Hz), 114.2, 113.7 (d, \( J = 5.0 \) Hz), 24.3. \(^{31}\)P NMR (162 MHz, CDCl\(_3\)) \( \delta \) 26.2. HRMS (ESI) calcd. for C\(_{29}\)H\(_{24}\)N\(_3\)O\(_2\)P [M]\(^+\): 477.1606; found: 477.1600.

**N-(4-cyanophenyl)-P,P-diphenyl-N-(quinolin-8-yl)phosphinamide (3v)**

The phosphinamide compound was obtained as a white solid. \( R_f = 0.39 \) (petroleum ether/ethyl acetate = 1/1), mp 158–160 °C. \(^1\)H NMR (400 MHz, CDCl\(_3\)) \( \delta \) 8.95 (d, \( J = 4.0 \) Hz, 1H), 7.94 (d, \( J = 8.3 \) Hz, 1H), 7.91–7.86 (m, 3H), 7.75 (d, \( J = 7.1 \) Hz, 1H), 7.55 (d, \( J = 8.1 \) Hz, 1H), 7.34–7.27 (m, 2H), 7.20–7.18 (m, 3H), 7.15 (d, \( J = 7.2 \) Hz, 2H), 7.05 (d, \( J = 8.4 \) Hz, 6H), \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \( \delta \) 150.6, 149.6 (d, \( J = 4.8 \) Hz), 145.8 (d, \( J = 2.3 \) Hz), 138.7 (d, \( J = 2.2 \) Hz), 136.1, 132.6 (d, \( J = 10.1 \) Hz), 132.4, 131.7 (d, \( J = 2.8 \) Hz), 130.9, 129.6, 129.0–128.8 (m), 127.6 (d, \( J = 13.3 \) Hz), 126.5 (d, \( J = 1.5 \) Hz), 121.7, 120.6 (d, \( J = 5.0 \) Hz), 119.1, 104.4. \(^{31}\)P NMR (162 MHz, CDCl\(_3\)) \( \delta \) 27.0. HRMS (ESI) calcd. for C\(_{28}\)H\(_{20}\)N\(_3\)OP [M]\(^+\): 445.1344; found: 445.1339.

**P,P-diphenyl-N-(quinolin-8-yl)-N-(4-(trifluoromethyl)phenyl)phosphinamide (3w)**

The phosphinamide compound was obtained as a white solid. \( R_f = 0.53 \) (petroleum ether/ethyl acetate = 1/1), mp 98–100 °C. \(^1\)H NMR (400 MHz, CDCl\(_3\)) \( \delta \) 8.96 (d, \( J = 4.0 \) Hz, 1H), 7.94–7.87 (m, 6H), 7.50 (d, \( J = 8.1 \) Hz, 1H), 7.30–7.26 (m, 2H), 7.23 (d, \( J = 8.5 \) Hz, 2H), 7.18–7.12 (m, 2H), 7.08–7.04 (m, 4H), 6.90 (d, \( J = 8.4 \) Hz, 2H), \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \( \delta \) 150.5, 148.7 (d, \( J = 5.2 \) Hz), 146.0 (d, \( J = 2.4 \) Hz), 139.4, 136.0, 132.6 (d, \( J = 9.9 \) Hz), 132.4 (d, \( J = 2.7 \) Hz), 131.5–131.4 (m), 130.1, 128.8 (d, \( J = 25.5 \) Hz), 127.5 (d, \( J = 13.2 \) Hz), 126.4, 125.5–125.4 (m), 123.7, 123.4, 122.8, 121.5, 120.8 (d, \( J = 4.9 \) Hz), \(^{31}\)P NMR (162 MHz, CDCl\(_3\)) \( \delta \) 26.2. \(^{19}\)F NMR (376 MHz, CDCl\(_3\)) \( \delta \) -61.7 (d, \( J = 3.4 \) Hz). HRMS (ESI) calcd. for C\(_{28}\)H\(_{20}\)F\(_3\)N\(_2\)OP [M]\(^+\): 488.1265; found: 488.1260.

**P,P-diphenyl-N-(quinolin-8-yl)-N-(3-(trifluoromethyl)phenyl)phosphinamide (3x)**

The phosphinamide compound was obtained as a white solid. \( R_f = 0.53 \) (petroleum ether/ethyl acetate = 1/1), mp 98–100 °C. \(^1\)H NMR (400 MHz, CDCl\(_3\)) \( \delta \) 8.95 (d, \( J = 4.0 \) Hz, 1H), 7.94–7.87 (m, 6H), 7.50 (d, \( J = 8.1 \) Hz, 1H), 7.30–7.26 (m, 2H), 7.23 (d, \( J = 8.5 \) Hz, 2H), 7.18–7.12 (m, 2H), 7.08–7.04 (m, 4H), 6.90 (d, \( J = 8.4 \) Hz, 2H), \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \( \delta \) 150.5, 148.7 (d, \( J = 5.2 \) Hz), 146.0 (d, \( J = 2.4 \) Hz), 139.4, 136.0, 132.6 (d, \( J = 9.9 \) Hz), 132.4 (d, \( J = 2.7 \) Hz), 131.5–131.4 (m), 130.1, 128.8 (d, \( J = 25.5 \) Hz), 127.5 (d, \( J = 13.2 \) Hz), 126.4, 125.5–125.4 (m), 123.7, 123.4, 122.8, 121.5, 120.8 (d, \( J = 4.9 \) Hz). HRMS (ESI) calcd. for C\(_{28}\)H\(_{20}\)F\(_3\)N\(_2\)OP [M]\(^+\): 488.1265; found: 488.1260.
The phosphinamide compound was obtained as a white solid. $R_f$ = 0.59 (petroleum ether/ethyl acetate = 1/1), mp 162–164 °C. $^1$H NMR (400 MHz, CDCl$_3$) δ 8.95 (d, $J = 2.4$ Hz, 1H), 7.95–7.90 (m, 6H), 7.52–7.47 (m, 2H), 7.39 (s, 1H), 7.31–7.27 (m, 2H), 7.18–7.12 (m, 2H), 7.08–7.00 (m, 6H). $^{13}$C NMR (100 MHz, CDCl$_3$) δ 150.4, 146.1–146.0 (m), 139.9 (d, $J = 2.3$ Hz), 136.0, 132.8 (d, $J = 9.8$ Hz), 132.3 (d, $J = 3.1$ Hz), 131.5–131.4 (m), 130.7, 130.4, 129.6 (d, $J = 115.0$ Hz), 128.7, 128.5, 127.6 (d, $J = 13.1$ Hz), 126.5 (d, $J = 1.2$ Hz), 126.0 (d, $J = 3.7$ Hz), 125.1, 122.4, 121.5–121.4 (m), 119.8–119.6 (m), 119.4–119.3 (m). $^{31}$P NMR (162 MHz, CDCl$_3$) δ 25.8. $^{19}$F NMR (376 MHz, CDCl$_3$) δ -62.7. HRMS (ESI) calcd. for C$_{28}$H$_{20}$F$_3$N$_2$O$^+P$: 488.1265; found: 488.1268.

N-(3,5-bis(trifluoromethyl)phenyl)-P,P-diphenyl-N-(quinolin-8-yl)phosphinamide (3y)

The phosphinamide compound was obtained as a yellow solid. $R_f$ 0.71 (petroleum ether/ethyl acetate = 1/1), mp 118–120 °C. $^1$H NMR (400 MHz, CDCl$_3$) δ 8.95 (d, $J = 1.9$ Hz, 1H), 7.97–7.89 (m, 6H), 7.57 (s, 3H), 7.35–7.31 (m, 2H), 7.26 (s, 1H), 7.17 (d, $J = 7.5$ Hz, 2H), 7.09 (s, 4H). $^{13}$C NMR (100 MHz, CDCl$_3$; list of signals, C–P and C–F coupling not resolved) δ 168.7, 150.6, 148.1, 146.9, 145.8, 145.8, 139.1, 139.1, 138.3, 138.2, 134.5, 132.8, 132.7, 132.2, 132.2, 131.8, 131.5, 131.2, 130.9, 129.6, 129.2, 129.0, 127.9, 127.9, 127.7, 127.4, 126.6, 126.4, 122.5, 122.4, 122.4, 121.8, 121.6, 121.4, 116.4, 116.1, 116.1, 116.0, 116.0. $^{31}$P NMR (162 MHz, CDCl$_3$) δ -63.0. HRMS (ESI) calcd. for C$_{29}$H$_{19}$F$_6$N$_2$O$_1$P$^+M$: 556.1139; found: 556.1134.

N-(4-nitrophenyl)-P,P-diphenyl-N-(quinolin-8-yl)phosphinamide (3z)

The phosphinamide compound was obtained as a yellow solid. $R_f$ 0.31 (petroleum ether/ethyl acetate = 1/1), mp 143–145 °C. $^1$H NMR (400 MHz, CDCl$_3$) δ 9.04 (s, 1H), 8.05 (d, $J = 8.2$ Hz, 1H), 7.98 (s, 3H), 7.89 (d, $J = 8.2$ Hz, 2H), 7.84 (d, $J = 7.2$ Hz, 1H), 7.66 (d, $J = 8.1$ Hz, 1H), 7.45–7.39 (m, 2H), 7.26 (d, $J = 5.8$ Hz, 3H), 7.16–7.10 (m, 6H). $^{13}$C NMR (100 MHz, CDCl$_3$) δ 151.6 (d, $J = 4.8$ Hz), 150.7, 145.7 (d, $J = 2.2$ Hz), 141.7, 138.7 (d, $J = 2.1$ Hz), 136.2, 132.6 (d, $J = 10.1$ Hz), 132.5 (d, $J = 2.7$ Hz), 131.9 (d, $J = 2.7$ Hz), 130.7 (d, $J = 4.9$ Hz), 129.3 (d, $J = 45.0$ Hz), 129.1 (d, $J = 1.2$ Hz), 127.8 (d, $J = 13.3$ Hz), 126.6 (d, $J = 1.3$ Hz), 124.3, 121.8, 119.9–119.8 (m). $^{31}$P NMR (162 MHz, CDCl$_3$) δ 27.6. HRMS (ESI) calcd. for C$_{27}$H$_{20}$N$_3$O$_3$P$^+M$: 465.1242; found: 465.1237.

N-phenyl-N-(quinolin-8-yl)-P,P-di-p-tolylphosphinamide (3ba)
The phosphinamide compound was obtained as a white solid. R<sub>f</sub> = 0.33 (petroleum ether/ethyl acetate = 1/1), mp 97–99 °C. <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 8.93 (d, J = 2.0 Hz, 1H), 7.89–7.86 (m, 2H), 7.82–7.77 (m, 4H), 7.46–7.42 (m, 1H), 7.28–7.23 (m, 4H), 6.92 (t, J = 7.5 Hz, 2H), 6.83 (d, J = 5.7 Hz, 4H), 6.76–6.72 (m, 1H), 2.06 (s, 6H).<sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) δ 150.1, 146.3 (d, J = 2.9 Hz, 1H), 145.8 (d, J = 3.7 Hz, 1H), 141.3 (d, J = 2.8 Hz), 140.9 (d, J = 1.8 Hz), 135.8, 132.7 (d, J = 10.0 Hz), 132.4 (d, J = 3.2 Hz), 131.9 (d, J = 10.1 Hz), 129.1 (d, J = 6.4 Hz), 128.9, 128.2 (d, J = 13.6 Hz), 127.8, 126.4 (d, J = 1.0 Hz), 123.2 (d, J = 4.7 Hz), 122.7, 121.1, 21.3. <sup>31</sup>P NMR (162 MHz, CDCl<sub>3</sub>) δ 26.2. HRMS (ESI) calcd. for C<sub>29</sub>H<sub>25</sub>N<sub>2</sub>O[P] [M]<sup>+</sup>: 448.1704; found: 448.1697.

**N-phenyl-N-(quinolin-8-yl)-P,P-di-m-tolylphosphinamide (3ca)**

The phosphinamide compound was obtained as a yellow solid. R<sub>f</sub> = 0.51 (petroleum ether /ethyl acetate = 1/1), mp 145–147 °C. <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 8.96 (d, J = 2.2 Hz, 1H), 7.89–7.86 (m, 2H), 7.80–7.76 (m, J = 11.7 Hz, 2H), 7.71 (d, J = 12.6 Hz, 2H), 7.50–7.43 (m, 1H), 7.29 (d, J = 8.0 Hz, 2H), 7.22 (d, J = 3.6 Hz, 2H), 6.94–6.88 (m, 6H), 6.76–6.72 (m, 1H), 2.03 (s, 6H).<sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) δ 149.9, 146.3 (d, J = 3.2 Hz), 145.7 (d, J = 3.7 Hz), 140.8 (d, J = 2.5 Hz, 137.0 (d, J = 12.9 Hz), 135.8, 133.3 (d, J = 9.8 Hz), 132.2–132.2 (m), 131.9 (d, J = 2.9 Hz), 131.3 (d, J = 129.8 Hz) 129.8 (d, J = 9.7 Hz), 129.1–128.9 (m), 128.2, 128.1 (d, J = 12.8 Hz), 127.9, 127.2 (d, J = 13.7 Hz), 126.3 (d, J = 1.3 Hz), 123.2 (d, J = 4.7 Hz), 121.9 (d, J = 170.0 Hz), 21.0. <sup>31</sup>P NMR (162 MHz, CDCl<sub>3</sub>) δ 26.0. HRMS (ESI) calcd. for C<sub>29</sub>H<sub>25</sub>N<sub>2</sub>O[P] [M]<sup>+</sup>: 448.1704; found: 448.1699.

**P,P-bis(4-fluorophenyl)-N-phenyl-N-(quinolin-8-yl)phosphinamide (3da)**

The phosphinamide compound was obtained as a yellow solid. R<sub>f</sub> = 0.62 (petroleum ether/ethyl acetate = 1/1), mp 97–99 °C. <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 9.04 (d, J = 1.6 Hz, 1H), 8.06–7.96 (m, 6H), 7.67–7.60 (m, 1H), 7.41–7.35 (m, 4H), 7.04 (t, J = 7.4 Hz, 2H), 6.89–6.87 (m, 1H), 6.82 (t, J = 8.5 Hz, 4H). <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) δ 165.5 (dd, J = 251.2 Hz, 3.4 Hz), 150.3, 146.2 (d, J = 3.1 Hz), 145.5 (d, J = 4.0 Hz), 140.6 (d, J = 2.5 Hz), 136.2, 135.4 (dd, J = 11.1 Hz, 8.8 Hz), 132.6 (d, J = 3.1 Hz), 129.1, 128.6, 128.3, 127.2 (dd, J = 135.2 Hz, 3.3 Hz), 126.6 (d, J = 1.5 Hz), 123.4, 123.3 (d, J = 4.9 Hz), 121.5, 114.9 (dd, J = 21.1, 14.3 Hz). <sup>31</sup>P NMR (162 MHz, CDCl<sub>3</sub>) δ 23.1. <sup>19</sup>F NMR (376 MHz, CDCl<sub>3</sub>) δ -107.4. HRMS (ESI) calcd. for C<sub>27</sub>H<sub>19</sub>F<sub>2</sub>N<sub>2</sub>O[P] [M]<sup>+</sup>: 456.1203; found: 456.1200.
**P,P-bis(3-fluorophenyl)-N-phenyl-N-(quinolin-8-yl)phosphinamide (3ea)**

The phosphinamide compound was obtained as a yellow solid. $R_f = 0.56$ (petroleum ether /ethyl acetate = 1/1), mp 125–127 °C. $^1H$ NMR (400 MHz, CDCl$_3$) $\delta$ 8.98 (d, $J = 2.2$ Hz, 1H), 7.90 (t, $J = 8.9$ Hz, 2H), 7.76–7.69 (m, 4H), 7.50 (d, $J = 8.1$ Hz, 1H), 7.36–7.25 (m, 4H), 7.02–6.93 (m, 4H), 6.79 (t, $J = 7.4$ Hz, 3H). $^{13}C$ NMR (100 MHz, CDCl$_3$) $\delta$ 161.8 (dd, $J = 247.1$ Hz, 18.6 Hz), 150.4, 145.6 (dd, $J = 89.3$ Hz, 3.1 Hz), 140.2 (d, $J = 2.5$ Hz), 136.1, 133.6 (dd, $J = 133.7$ Hz), 129.4 (q, $J = 7.3$ Hz), 129.0, 128.7 (d, $J = 3.1$ Hz), 128.6, 128.6, 126.4, 126.5 (d, $J = 1.1$ Hz), 123.7, 123.5 (d, $J = 4.9$ Hz), 121.5, 119.6 (q, $J = 10.7$ Hz), 118.6 (dd, $J = 21.1$, 2.5 Hz). $^{31}P$ NMR (162 MHz, CDCl$_3$) $\delta$ 22.0 (t, $J = 6.8$ Hz). HRMS (ESI) calcd. for C$_{27}$H$_{19}$F$_2$N$_2$OP [M$^+$]: 456.1203; found: 456.1198.

**P,P-bis(4-chlorophenyl)-N-phenyl-N-(quinolin-8-yl)phosphinamide (3fa)**

The phosphinamide compound was obtained as a white solid. $R_f = 0.77$ (petroleum ether/ethyl acetate = 1/1), mp 225–227 °C. $^1H$ NMR (400 MHz, CDCl$_3$) $\delta$ 8.97 (s, 1H), 7.97 (d, $J = 8.2$ Hz, 1H), 7.92–7.85 (m, 5H), 7.56 (d, $J = 8.1$ Hz, 1H), 7.34–7.29 (m, 4H), 7.04 (d, $J = 8.1$ Hz, 4H), 6.98 (t, $J = 7.4$ Hz, 2H), 6.83 (t, $J = 7.3$ Hz, 1H). $^{13}C$ NMR (100 MHz, CDCl$_3$) $\delta$ 150.3, 146.1 (d, $J = 2.8$ Hz), 145.2 (d, $J = 4.0$ Hz), 140.3 (d, $J = 2.6$ Hz), 138.0 (d, $J = 3.5$ Hz), 136.2, 134.3 (d, $J = 10.6$ Hz), 132.5 (d, $J = 3.2$ Hz), 129.6 (d, $J = 133.7$ Hz), 129.1, 128.6, 128.4, 127.9 (d, $J = 13.7$ Hz), 126.6 (d, $J = 1.2$ Hz), 123.6, 123.5 (d, $J = 4.9$ Hz), 121.5. $^{31}P$ NMR (162 MHz, CDCl$_3$) $\delta$ 22.0 (t, $J = 6.8$ Hz). HRMS (ESI) calcd. for C$_{27}$H$_{19}$Cl$_2$N$_2$OP [M$^+$]: 488.0612; found: 488.0607.

**P,P-bis(4-methoxyphenyl)-N-phenyl-N-(quinolin-8-yl)phosphinamide (3ga)**

The phosphinamide compound was obtained as a white solid. $R_f = 0.19$ (petroleum ether/ethyl acetate = 1/1), mp 284–286 °C. $^1H$ NMR (400 MHz, CDCl$_3$) $\delta$ 8.94 (d, $J = 1.4$ Hz, 1H), 7.87–7.82 (m, 6H), 7.47 (d, $J = 8.1$ Hz, 1H), 7.26 (t, $J = 8.1$ Hz, 4H), 6.93 (t, $J = 7.4$ Hz, 2H), 6.74 (t, $J = 7.2$ Hz, 1H), 6.54 (d, $J = 8.0$ Hz, 4H), 3.54 (s, 6H). $^{13}C$ NMR (100 MHz, CDCl$_3$) $\delta$ 161.6 (d, $J = 2.8$ Hz), 150.1, 146.33 (d, $J = 2.8$ Hz), 145.8 (d, $J = 3.8$ Hz), 140.9 (d, $J = 2.2$ Hz), 135.9, 134.5 (d, $J = 11.1$ Hz), 132.4 (d, $J = 2.9$ Hz), 128.9, 128.2, 127.1 (d, $J = 141.4$ Hz), 123.8, 123.0 (d, $J = 4.5$ Hz), 122.6, 122.4, 121.2, 112.9 (d, $J = 14.0$ Hz), 54.9. $^{31}P$ NMR (162 MHz, CDCl$_3$) $\delta$ 25.5. HRMS (ESI) calcd. for C$_{29}$H$_{25}$O$_3$P [M$^+$]: 480.1603; found: 480.1597.
The phosphinamide compound was obtained as a white solid. 

R_f = 0.25 (petroleum ether/ethyl acetate = 2/1), mp 92–95 °C. 

\[ \text{^1H NMR (400 MHz, CDCl}_3\text{)} \delta 7.73–7.68 (m, 4H), 7.54 (d, J = 7.8 Hz, 1H), 7.44 (d, J = 7.6 Hz, 1H), 7.22 (d, J = 7.7 Hz, 4H), 7.18–7.14 (m, 4H), 7.03–6.99 (m, 1H), 6.95–6.91 (m, 2H), 6.78–6.75 (m, 1H), 4.15 (t, J = 9.5 Hz, 2H), 3.87 (t, J = 9.5 Hz, 2H). \]

\[ \text{^13C NMR (100 MHz, CDCl}_3\text{)} \delta 162.6, 145.3 (d, J = 2.5 Hz), 142.5 (d, J = 1.3 Hz), 132.8 (d, J = 2.9 Hz), 132.5 (d, J = 9.7 Hz), 131.7, 131.3 (d, J = 2.7 Hz), 131.2, 130.5 (d, J = 12.4 Hz), 128.3 (d, J = 4.1 Hz), 128.1, 127.6 (d, J = 12.9 Hz), 126.69, 124.6 (d, J = 5.2 Hz), 123.4, 66.6, 54.8. \]

\[ \text{^31P NMR (162 MHz, CDCl}_3\text{)} \delta 25.4. \]

HRMS (ESI) calcd. for C_{27}H_{23}N_2O_2P [M]^+: 438.1497; found: 438.1495.
4. References

Copies of $^1$H, $^{13}$C, $^{31}$P, $^{19}$F NMR charts of the Compounds

$^1$H NMR (400MHz, CDCl$_3$) spectrum of compound 1c

$^{13}$C NMR (100MHz, CDCl$_3$) spectra of compound 1c
$^3$P NMR (162MHz, CDCl$_3$) spectrum of compound 1c

$^1$H NMR (400MHz, CDCl$_3$) spectrum of compound 1e
$^{13}$C NMR (100MHz, CDCl$_3$) spectra of compound 1e

$^{31}$P NMR (162MHz, CDCl$_3$) spectra of compound 1e
$^{19}$F NMR (376MHz, CDCl$_3$) spectra of compound 1e

$^1$H NMR (400MHz, CDCl$_3$) spectrum of compound 1h
$^{13}$C NMR (100MHz, CDCl$_3$) spectra of compound 1h

$^{31}$P NMR (162MHz, CDCl$_3$) spectra of compound 1h
$^1$H NMR (400MHz, CDCl$_3$) spectrum of compound 1i

$^{13}$C NMR (100MHz, CDCl$_3$) spectra of compound 1i
$^{31}$P NMR (162MHz, CDCl$_3$) spectra of compound 1i

$^1$H NMR (400MHz, CDCl$_3$) spectra of compound 3a
$^{13}$C NMR (100MHz, CDCl$_3$) spectra of compound 3a

$^{31}$P NMR (162MHz, CDCl$_3$) spectrum of compound 3a
$^1$H NMR (400MHz, CDCl$_3$) spectra of compound 3b

$^{13}$C NMR (100MHz, CDCl$_3$) spectra of compound 3b
$^{31}$P NMR (162MHz, CDCl$_3$) spectrum of compound 3b

$^1$H NMR (400MHz, CDCl$_3$) spectra of compound 3c
\[ ^{13}\text{C NMR (100MHz, CDCl}_3\text{)} \text{ spectra of compound 3c} \]

\[ ^{31}\text{P NMR (162MHz, CDCl}_3\text{)} \text{ spectrum of compound 3c} \]
$^{1}H$ NMR (400MHz, CDCl$_3$) spectra of compound 3d

$^{13}C$ NMR (100MHz, CDCl$_3$) spectra of compound 3d
$^{31}$P NMR (162MHz, CDCl$_3$) spectrum of compound 3d

$^1$H NMR (400MHz, CDCl$_3$) spectra of compound 3e
$^{13}$C NMR (100MHz, CDCl$_3$) spectra of compound 3e

$^{31}$P NMR (162MHz, CDCl$_3$) spectrum of compound 3e
$^{1}$H NMR (400MHz, CDCl$_3$) spectra of compound 3f

$^{13}$C NMR (100MHz, CDCl$_3$) spectra of compound 3f
$^{31}$P NMR (162MHz, CDCl$_3$) spectrum of compound 3f

$^1$H NMR (400MHz, CDCl$_3$) spectra of compound 3g
$^{13}$C NMR (100MHz, CDCl$_3$) spectra of compound 3g

$^{31}$P NMR (162MHz, CDCl$_3$) spectrum of compound 3g
$^1$H NMR (400MHz, CDCl$_3$) spectra of compound 3h

$^{13}$C NMR (100MHz, CDCl$_3$) spectra of compound 3h
$^{31}$P NMR (162MHz, CDCl$_3$) spectrum of compound 3h

$^1$H NMR (400MHz, CDCl$_3$) spectra of compound 3i
$^{13}$C NMR (100MHz, CDCl$_3$) spectra of compound 3i

$^{31}$P NMR (162MHz, CDCl$_3$) spectrum of compound 3i
$^{19}$F NMR (376MHz, CDCl$_3$) spectrum of compound 3i

$^1$H NMR (400MHz, CDCl$_3$) spectra of compound 3j
$^{13}$C NMR (100MHz, CDCl$_3$) spectra of compound 3j

$^{31}$P NMR (162MHz, CDCl$_3$) spectrum of compound 3j
$^1$H NMR (400MHz, CDCl$_3$) spectra of compound 3k

$^{13}$C NMR (100MHz, CDCl$_3$) spectra of compound 3k
$^{31}$P NMR (162MHz, CDCl$_3$) spectrum of compound 3k

$^1$H NMR (400MHz, CDCl$_3$) spectra of compound 3l
$^{13}\text{C NMR (100MHz, CDCl}_3\text{)}$ spectra of compound 3l

$^{31}\text{P NMR (162MHz, CDCl}_3\text{)}$ spectrum of compound 3l
$^1$H NMR (400MHz, CDCl$_3$) spectra of compound 3m

$^{13}$C NMR (100MHz, CDCl$_3$) spectra of compound 3m
$^{31}$P NMR (162MHz, CDCl$_3$) spectrum of compound 3m

$^{19}$F NMR (376MHz, CDCl$_3$) spectrum of compound 3m
$^1$H NMR (400MHz, CDCl$_3$) spectra of compound 3n

$^{13}$C NMR (100MHz, CDCl$_3$) spectra of compound 3n
$^{31}$P NMR (162MHz, CDCl$_3$) spectrum of compound 3n

$^1$H NMR (400MHz, CDCl$_3$) spectra of compound 3o
$^{13}$C NMR (100MHz, CDCl$_3$) spectra of compound 3o

$^{31}$P NMR (162MHz, CDCl$_3$) spectrum of compound 3o
$^1$H NMR (400MHz, CDCl$_3$) spectra of compound 3p

$^{13}$C NMR (100MHz, CDCl$_3$) spectra of compound 3p
$^{31}$P NMR (162MHz, CDCl$_3$) spectrum of compound 3p

$^1$H NMR (400MHz, CDCl$_3$) spectra of compound 3q
$^{13}$C NMR (100MHz, CDCl$_3$) spectra of compound 3q

$^{31}$P NMR (162MHz, CDCl$_3$) spectrum of compound 3q
$^1$H NMR (400MHz, CDCl$_3$) spectra of compound 3r

$^{13}$C NMR (100MHz, CDCl$_3$) spectra of compound 3r
$^3$P NMR (162MHz, CDCl$_3$) spectrum of compound 3r

$^1$H NMR (400MHz, CDCl$_3$) spectra of compound 3s
$^{13}\text{C}$ NMR (100MHz, CDCl$_3$) spectra of compound 3s

$^{31}\text{P}$ NMR (162MHz, CDCl$_3$) spectrum of compound 3s
$^1$H NMR (400MHz, CDCl$_3$) spectra of compound 3t

$^{13}$C NMR (100MHz, CDCl$_3$) spectra of compound 3t
$^{31}$P NMR (162MHz, CDCl$_3$) spectrum of compound 3t

$^1$H NMR (400MHz, CDCl$_3$) spectra of compound 3u
$^{13}$C NMR (100MHz, CD$_3$SOCD$_3$) spectra of compound 3u

$^{31}$P NMR (162MHz, CDCl$_3$) spectrum of compound 3u
$^1$H NMR (400MHz, CDCl$_3$) spectra of compound 3v

$^{13}$C NMR (100MHz, CDCl$_3$) spectra of compound 3v
$^{31}\text{P NMR (162MHz, CDCl}_3\text{)}$ spectrum of compound 3v

$^{1}\text{H NMR (400MHz, CDCl}_3\text{)}$ spectra of compound 3w
$^{13}$C NMR (100MHz, CDCl$_3$) spectra of compound 3w

$^{31}$P NMR (162MHz, CDCl$_3$) spectrum of compound 3w
$^{19}$F NMR (376MHz, CDCl$_3$) spectrum of compound 3w

$^1$H NMR (400MHz, CDCl$_3$) spectra of compound 3x
$^{13}$C NMR (100MHz, CDCl$_3$) spectra of compound 3x

$^{31}$P NMR (162MHz, CDCl$_3$) spectrum of compound 3x
$^{19}$F NMR (376MHz, CDCl$_3$) spectrum of compound $3x$

$^1$H NMR (400MHz, CDCl$_3$) spectra of compound $3y$
$^{13}$C NMR (100MHz, CDCl$_3$) spectra of compound 3y

$^{31}$P NMR (162MHz, CDCl$_3$) spectrum of compound 3y
$^{19}$F NMR (376MHz, CDCl$_3$) spectrum of compound 3y

$^1$H NMR (400MHz, CDCl$_3$) spectra of compound 3z
$^{13}$C NMR (100MHz, CDCl$_3$) spectra of compound 3z

$^{31}$P NMR (162MHz, CDCl$_3$) spectrum of compound 3z
\( ^1\)H NMR (400MHz, CDCl\(_3\)) spectra of compound 3ba

\( ^{13}\)C NMR (100MHz, CDCl\(_3\)) spectra of compound 3ba
$^{31}$P NMR (162MHz, CDCl$_3$) spectrum of compound 3ba

$^1$H NMR (400MHz, CDCl$_3$) spectra of compound 3ca
$^{13}$C NMR (100MHz, CDCl$_3$) spectra of compound 3ca

$^{31}$P NMR (162MHz, CDCl$_3$) spectrum of compound 3ca
$^1$H NMR (400MHz, CDCl$_3$) spectra of compound 3da

$^{13}$C NMR (100MHz, CDCl$_3$) spectra of compound 3da
$^{31}$P NMR (162MHz, CDCl$_3$) spectra of compound 3da

$^{19}$F NMR (376MHz, CDCl$_3$) spectrum of compound 3da
$^1$H NMR (400MHz, CDCl$_3$) spectra of compound 3ea

$^{13}$C NMR (100MHz, CDCl$_3$) spectra of compound 3ea
$^{31}$P NMR (162MHz, CDCl$_3$) spectrum of compound 3ea

$^{19}$F NMR (376MHz, CDCl$_3$) spectrum of compound 3ea
$^1$H NMR (400MHz, CDCl$_3$) spectra of compound 3fa

$^{13}$C NMR (100MHz, CDCl$_3$) spectra of compound 3fa
$^{31}$P NMR (162MHz, CDCl$_3$) spectrum of compound 3fa

$^1$H NMR (400MHz, CDCl$_3$) spectra of compound 3ga
$^{13}$C NMR (100MHz, CDCl$_3$) spectra of compound 3ga

$^{31}$P NMR (162MHz, CDCl$_3$) spectrum of compound 3ga
$^1$H NMR (400MHz, CDCl$_3$) spectra of compound 4

$^{13}$C NMR (100MHz, CDCl$_3$) spectra of compound 4
$^{31}$P NMR (162MHz, CDCl$_3$) spectrum of compound 4