One pot cascade approach to phenanthridine-fused quinazoliniminiums from heteroenyne-allenes

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Supporting Information I

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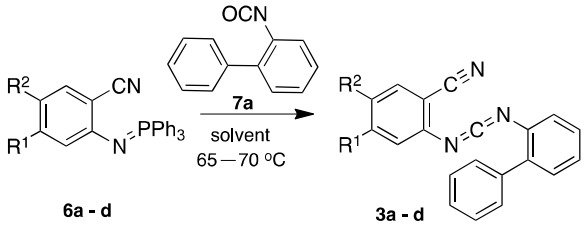
Experimental

General

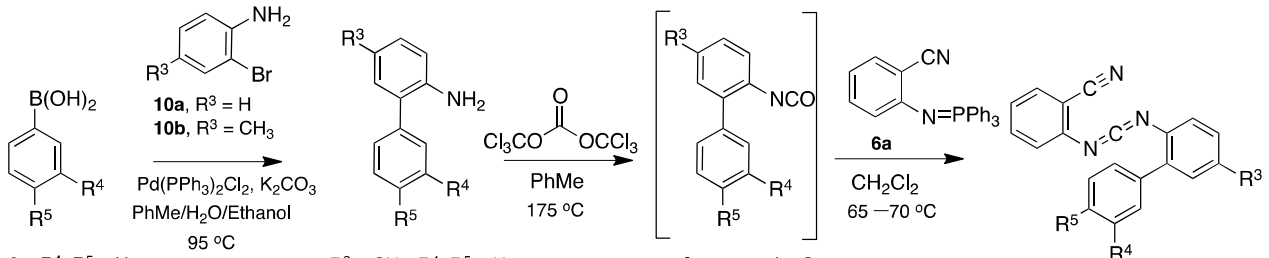
Thin layer chromatography was carried out on 250 μm silica gel plates and UV-light was used as a visualizing agent. Standard column chromatography was performed using 63–200 μm silica gel. Methylene chloride was dried by distillation over calcium hydride. Dry THF was obtained by distillation over sodium and benzophenone. Toluene was dried by distillation over calcium hydride. ^{1}H and ^{13}C NMR spectra were recorded on 400 MHz, 300 MHz and 200 MHz spectrometers as indicated. The carrier frequencies were 199.98 MHz (^{1}H) and 50.29 MHz (^{13}C) for the 200 MHz, 300.53 MHz (^{1}H) and 75.57 MHz (^{13}C) for 300 MHz and, 399.75 MHz (^{1}H) and 100.53 MHz (^{13}C) for 400 MHz spectrometers, respectively. Chemical shifts and the coupling constants are reported in parts per million and Hertz, respectively. The infrared frequencies are reported in cm^{-1}. High resolution mass spectra were acquired on a quadrupole/time-of-flight mass spectrometer. TOF scans were carried out in positive ionization mode.

2-Isocyanato-1,1'-biphenyl (**7a**), phenyl boronic acid (**9e**), *m*-tolylboronic acid (**9f**), *m*-chloroboronic acid (**9i**), 2-bromoaniline (**10a**) and 2-bromo-4-methylaniline (**10b**) were commercially obtained. Iminophosphoranes **6a**,[1] **6b**[2] and **6c**[2], boronic acids **9g**,[3] **k**,[4] and [1,1'-biphenyl]-2-amines **11e – k**[5] were prepared as reported before and their identity was confirmed by comparison of their ^{1}H and ^{13}C NMR to the literature values.

Scheme 1s. General scheme for the synthesis of heteroenyne-allenes **3a** – **d**.



Scheme 2s. General scheme for the synthesis of heteroenyne-allenes **3e – l**.



9e, R^4, R^5 = H
9f, R^4 = CH_3; R^5 = H
9g, R^4 = OCH_3; R^5 = H
9h, R^4 = F; R^5 = H
9i, R^4 = Cl; R^5 = H
9j, R^4 = CF_3; R^5 = H
9k, R^5 = CH_3; R^4 = H

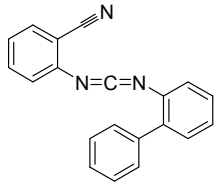
11e, R^3 = CH_3; R^4, R^5 = H
11f, R^4 = CH_3; R^3, R^5 = H
11g, R^4 = OCH_3; R^3, R^5 = H
11h, R^4 = F; R^3, R^5 = H
11i, R^4 = Cl; R^3, R^5 = H
11j, R^4 = CF_3; R^3, R^5 = H
11k, R^5 = CH_3; R^3, R^4 = H
11l, R^3 = CH_3; R^4 = OCH_3; R^5 = H

7e, R^3 = CH_3; R^4, R^5 = H
7f, R^4 = CH_3; R^3, R^5 = H
7g, R^4 = OCH_3; R^3, R^5 = H
7h, R^4 = F; R^3, R^5 = H
7i, R^4 = Cl; R^3, R^5 = H
7j, R^4 = CF_3; R^3, R^5 = H
7k, R^5 = CH_3; R^3, R^4 = H
7l, R^3 = CH_3; R^4 = OCH_3; R^5 = H

Synthesis of 2-((biphenylimino)methyleneamino) benzonitriles 3

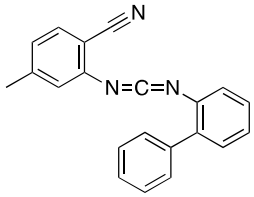
Method A: Iminophosphoranes **6a** – **d** (1 mmol) were added to dry toluene (3 mL) or a mixture of dry toluene and dry CH_2Cl_2 (1:1, 3 mL) and purged with argon for 10 min. To this solution was added commercially obtained 2-isocyanato-1,1'-biphenyl (**7a)** (1.1 mmol) and the reaction mixture was stirred at 60 ^oC for one to two hours under argon. Upon the completion of the reaction, the reaction mixture was concentrated on rotary evaporator, and purified by flash chromatography on silica gel to obtain pure heteroenyne-allenes **3a** – **d**.

Method B: A solution of iminophosphorane **6a** (5 mmol) in dry CH_2Cl_2 (15 mL) was added slowly to a stirring solution of corresponding freshly prepared isocyanates **7e – l** (5 mmol) in toluene (15 mL), and the resulting reaction mixture was stirred and heated at 65 ^OC under argon for 2-4 h. The reaction mixture was concentrated under reduced pressure, and the crude product was purified by a quick flash chromatography on silica gel using a EtOAc/hexane gradient elution to afford the corresponding 2-((biphenylimino)methyleneamino) benzonitriles **3e – l**.



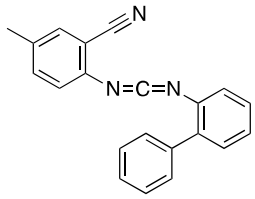
3a

2-((([1,1'-Biphenyl]-2-ylimino)methylene)amino)benzonitrile (3a): Following method A, Compound **3a** was prepared from iminophosphorane **6a** (0.16 g, 0.42 mmol) and isocyanate **7a** (0.09 g, 0.46 mmol) in dry toluene. Purification by column chromatography (SiO_2, hexane:ethyl acetate, 9:1) gave **3a** (0.1 g, 81%) as a colorless liquid: *Rf* 0.65 (9:1 hexane:ethyl acetate); FTIR (neat) ν_{max}: 3379, 2358, 2339, 2147, 2108, 1475, 1432, 1197, 756 cm^{-1}; ^1H NMR (400MHz, $CDCl_3$): δ 7.04 (d, *J* = 7.4 Hz, 1H), 7.15 – 7.29 (m, 6H), 7.33 – 7.44 (m, 6H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 107.8, 116.9, 125.0, 125.2, 125.9, 126.7, 127.9, 128.5, 128.7, 129.5, 130.2, 130.9, 133.3, 133.6, 133.7, 137.8, 138.6, 142.8; HRMS (FAB) for $C_{20}H_{14}N_3$ $[M+H]^+$: *m/z* calcd 296.1188, measured 296.1171.



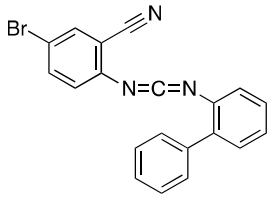
3b

2-((([1,1'-biphenyl]-2-ylimino)methylene)amino)-4-methylbenzonitrile (3b): Following method A, compound **3b** was prepared from iminophosphorane **6b** (0.26 g, 0.66 mmol) and isocyanate **7a** (0.14 g, 0.73 mmol) in a mixture of dry toluene and CH_2Cl_2. Purification by column chromatography (SiO_2, hexane:ethyl acetate, 9:1) gave **3b** (0.085 g, 42%) as a yellow liquid: *Rf* 0.75 (85:15 hexane:ethyl acetate); FTIR (neat) ν_{max}: 3233, 2143, 1606, 1563, 1536, 1397, 1264, 1233, 1169, 1111, 1074, 1010, 814, 756, 734, 700 cm^{-1}; ^1H NMR (500MHz, $CDCl_3$): δ 2.31 (s, 3H), 6.65 (s, 1H), 6.94 (d, *J* = 7.9 Hz, 1H), 7.27 – 7.30 (m, 2H), 7.34 – 7.38 (m, 5H), 7.41 (d, *J* = 7.8 Hz, 1H), 7.47 – 7.48 (m, 2H); ^{13}C NMR (125 MHz, $CDCl_3$): δ 21.8, 104.8, 117.1, 125.6, 125.8, 126.0, 126.5, 127.8, 128.5, 128.7, 129.5, 130.2, 130.9, 133.0, 133.9, 137.7, 138.7, 142.5, 144.8; HRMS (FAB) for $C_{21}H_{16}N_3$ $[M+H]^+$: *m/z* calcd 310.1344, measured 310.1351.



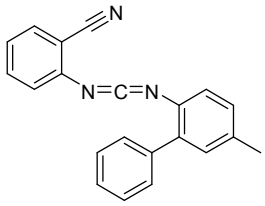
3c

2-((([1,1'-Biphenyl]-2-ylimino)methylene)amino)-5-methylbenzonitrile (3c): Following method A, compound **3c** was prepared from iminophosphorane **6c** (0.24 g, 0.61 mmol) and isocyanate **7a** (0.13 g, 0.67 mmol) in a mixture of dry toluene and CH_2Cl_2. Purification by column chromatography (SiO_2, hexane:ethyl acetate, 9:1) gave **3c** (0.108 g, 58%) as a yellow oil: *Rf* 0.61 (9:1 hexane:ethyl acetate); FTIR (neat) ν_{max}: 2226, 2136, 2116, 1568, 1522, 1499, 1480, 1251, 1210, 1111, 1006, 823, 756, 732, 700 cm^{-1}; ^1H NMR (500MHz, $CDCl_3$): δ 2.30 (s, 3H), 6.75 (d, J = 8.3 Hz, 1H), 7.18 (dd, J_1 = 8.4, J_2 = 1.8, 1H), 7.23 – 7.38 (m, 8H), 7.44 – 7.46 (m, 2H); ^{13}C NMR (125 MHz, $CDCl_3$): δ 20.7, 107.4, 116.9, 124.9, 125.8, 126.4, 127.8, 128.4, 128.6, 129.4, 130.7, 130.8, 133.3, 134.0, 134.5, 135.1, 137.6, 138.6, 139.9; HRMS (ESI) for $C_{21}H_{15}N_3Na[M+Na]^+$: *m/z* calcd 332.1164, measured 332.1164.



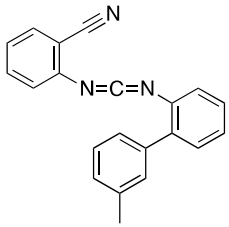
3d

2-((([1,1'-biphenyl]-2-ylimino)methylene)amino)-5-bromobenzonitrile (3d): Following method A, compound **3d** was prepared from iminophosphorane **6d** (0.35 g, 0.77 mmol) and isocyanate **7a** (0.16 g, 0.84 mmol) in a mixture of dry toluene and CH_2Cl_2. Purification by column chromatography (SiO_2, hexane:ethyl acetate, 9:1) gave **3d** (0.08 g, 28%) as a yellow oil: *Rf* 0.8 (85:15 hexane:ethyl acetate). Spectroscopic data could be obtained due to the instability of **3d**. This compound was immediately used for the next step to obtain **5d**.



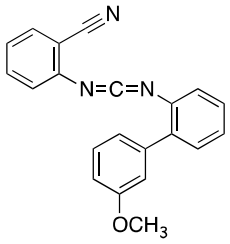
3e

2-((((5-methyl-[1,1'-biphenyl]-2-yl)imino)methylene)amino)benzonitrile (3e): Following method B, compound **3e** was prepared from iminophosphorane **6a** (2.07g, 5.46 mmol) and isocyanate **7e** (1.14 g, 5.46 mmol) and iminophosphorane following general procedure. Purification by column chromatography (SiO_2, hexane:ethyl acetate, 96:4) afforded **3e** as a clear viscous oil (1.23 g, 73%): R_f 0.45 (9:1 hexane:ethyl acetate); FTIR (neat) ν_{max}: 2225, 2131, 2113, 1593, 1570, 1481, 1271, 1213, 1112, 908, 815, 757 cm^{-1}; ^1H NMR (400MHz, $CDCl_3$): δ 2.38 (s, 3H), 6.85 (d, J = 8Hz, 1H), 7.10 – 7.16 (m, 3H), 7.21 – 7.29 (m, 2H), 7.33 – 7.40 (m, 3H), 7.43 – 7.46 (m, 2H), 7.51 (dd, J_1 = 7.6 Hz, J_2 = 1.8 Hz, 1H); ^{13}C NMR (100MHz, $CDCl_3$): δ 21.1, 107.6, 116.8, 124.7, 125.0, 125.6, 127.7, 128.4, 129.3, 129.4, 130.2, 130.8, 131.4, 133.2, 133.5, 136.5, 137.5, 138.7, 143.1; HRMS (ESI) for $C_{21}H_{16}N_3$ $[M+H]^+$: *m/z* calcd 310.1344, measured 310.1349.



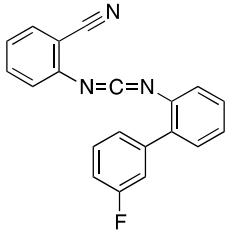
3f

2-((((3'-methyl-[1,1'-biphenyl]-2-yl)imino)methylene)amino)benzonitrile (3f): Following method B, compound **3f** was prepared from iminophosphorane **6a** (2.07g, mmol) and isocyanate **7f** (1.14 g, 5.46 mmol). Purification by column chromatography (SiO_2, hexane:ethyl acetate, 96:4) afforded **3f** as a clear oil (1.22 g, 73%): R_f 0.45 (9:1 hexane: ethyl acetate); FTIR (neat) ν_{max}: 2225, 2136, 2111,1592, 1569, 1474, 1442, 1256, 1212, 1104, 906, 793, 752, 730 cm^{-1}; ^1H NMR (400MHz, $CDCl_3$): δ 2.30 (s, 3H), 6.83 (d, J = 8.2Hz, 1H), 7.05 – 7.08 (m, 1H), 7.13 (dt, J_1 = 7.6 Hz, J_2 =1.1Hz, 1H), 7.23 – 7.40 (m, 8H), 7.52 (dd, J_1 = 8.0 Hz, J_2 = 1.7 Hz, 1H); ^{13}C NMR (100MHz, $CDCl_3$): δ 21.5, 107.8, 116.8, 124.8, 125.1, 125.6, 126.5, 128.50, 128.57, 128.66, 130.1, 130.8, 133.2, 133.5, 133.8, 138.1, 138.2, 138.5, 143.0; HRMS (ESI) for $C_{21}H_{16}N_3$ $[M+H]^+$: *m/z* calcd 310.1344, measured 310.1369.



3g

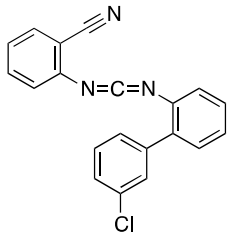
2-((((3'-methoxy-[1,1'-biphenyl]-2-yl)imino)methylene)amino)benzonitrile (3g): Following method B, compound **3g** was prepared from iminophosphorane **6a** (1.96g, 5.17 mmol) and isocyanate **7g** (1.16g, 5.17 mmol). Purification by column chromatography (SiO_2, hexane:ethyl acetate, 95:5) afforded **3g** as a viscous yellow oil (0.68g, 43%): R_f = 0.36 (8:2 hexane:ethyl acetate); FTIR (neat) ν_{max}: 2146, 2112, 1592, 1521, 1475, 1443, 1259, 1209, 1108, 1020, 875, 756, 732, 700 cm^{-1}; ^1H NMR (400MHz, $CDCl_3$): δ 3.77 (s, 3H), 6.79 (dd, J_1 = 8.4Hz, J_2 = 1.2Hz, 1H), 6.87 (dd, J_1 = 8.4Hz, J_2 = 0.8Hz, 1H), 6.97 – 7.03 (m, 2H), 7.14 (dt, J_1 = 7.6Hz, J_2 = 0.8Hz, 1H), 7.24 – 7.41 (m, 6H), 7.52 (dd, J_1 = 7.6Hz, J_2 = 1.6Hz, 1H); ^{13}C NMR (100MHz, $CDCl_3$): δ 55.3, 107.6, 113.4, 115.0, 116.8, 121.8, 124.9, 125.1, 125.6, 126.5, 128.7, 129.5, 130.3, 130.7, 133.2, 133.5, 133.7, 137.7, 139.8, 142.7, 159.5.



3h

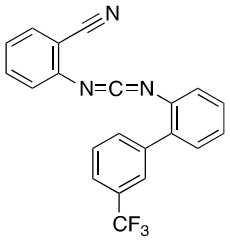
2-((((3'-fluoro-[1,1'-biphenyl]-2-yl)imino)methylene)amino)benzonitrile (3h): Following method B, compound **3h** was prepared from iminophosphorane **6a** (2.02 g, 5.34 mmol) and isocyanate **7h** (1.14 g, 5.34 mmol). Purification by column chromatography (SiO_2, hexane:ethyl acetate, 95:5) afforded **3h** as a clear oil (1.04 g, 62%): R_f = 0.43 (9:1, hexane:ethyl acetate); FTIR (neat) ν_{max}: 2225, 2135, 2109,1591,1570, 1473, 1443, 1256, 1212, 1181, 1157, 1104, 882, 753 cm^{-1}; ^1H NMR (400MHz, $CDCl_3$): δ 6.96 – 7.00 (m, 2H), 7.15 – 7.20 (m, 2H), 7.24 – 7.40 (m, 6H), 7.42 – 7.46 (m, 1H), 7.55 (dd, J_1 = 8Hz, J_2 = 1.6Hz, 1H); ^{13}C NMR (100MHz, $CDCl_3$): δ 108.0, 114.7 (d, J_{CF} = 22 Hz), 116.6 (d, J_{CF} = 22.3 Hz), 116.8, 125.2 (d, J_{CF} = 3.8 Hz), 125.4 (d, J_{CF} = 3 Hz), 126.1, 126.7, 129.2, 130.1 (d, J_{CF} = 8 Hz), 130.3, 130.7, 133.4,

133.8, 133.9, 136.3 (d, J_{CF} = 2 Hz), 140.8 (d, J_{CF} = 7.8 Hz), 142.4, 162.7 (d, J_{CF} = 249 Hz); HRMS (ESI) for $C_{20}H_{13}N_3F$ $[M+H]^+$: *m/z* calcd 314.1094, measured 314.1117.



3i

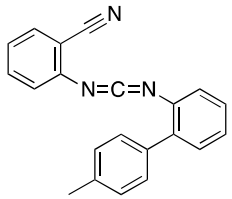
2-((((3'-chloro-[1,1'-biphenyl]-2-yl)imino)methylene)amino)benzonitrile (3i): Following method B, compound **3i** was prepared from iminophosphorane **6a** (0.57 g, 1.51 mmol) and isocyanate **7i** (0.35 g, 1.51 mmol). Purification by column chromatography (SiO_2, hexane:ethyl acetate, 96:4) afforded **3i** as a clear oil (0.24 g, 48%): R_f = 0.45 (9:1, hexane:ethyl acetate); FTIR (neat) ν_{max}: 2227, 2148, 2116, 1595, 1573, 1489, 1473, 1445, 1273, 1249, 1213, 1162, 1107, 1080, 906, 729 cm^{-1}; ^1H NMR (400MHz, $CDCl_3$): δ 6.88 (d, J = 8.3 Hz 1H), 7.08 (t, 1H), 7.13 – 7.31 (m, 7H), 7.36 (t, 2H), 7.45 (dd, J_1 = 7.9 Hz, J_2 = 1.4 Hz, 1H); ^{13}C NMR (75MHz, $CDCl_3$): δ 107.9, 116.7, 125.10, 125.15, 125.9, 125.6, 127.8, 127.9, 129.2, 129.5, 130.3, 130.6, 133.3, 133.7, 133.8, 134.3, 136.1, 140.3, 142.2; HRMS (ESI) for $C_{20}H_{12}N_3Cl$ $[M+Na]^+$: *m/z* calcd 352.0622, measured 352.0617.



3j

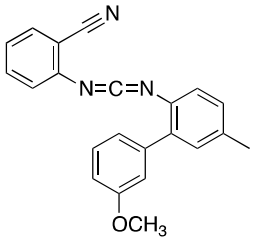
2-((((3'-(trifluoromethyl)-[1,1'-biphenyl]-2-yl)imino)methylene)amino)benzonitrile (3i): Following method B, compound **3j** was prepared from iminophosphorane **6a** (1.19 g, 3.16 mmol) and isocyanate **7j** (0.83 g, 3.16 mmol). Purification by column chromatography (SiO_2, hexane:ethyl acetate, 96:4) afforded **3j** as a viscous yellow oil (0.48 g, 42%): R_f = 0.45 (9:1, hexane:ethyl acetate); FTIR (neat) ν_{max}: 2221, 2143, 2113, 1593, 1570, 1478, 1333, 1247, 1163, 1121, 1073, 805, 756 cm^{-1}; ^1H NMR (400MHz, $CDCl_3$): δ 6.96 (dd, J_1 = 8.4Hz, J_2 = 0.8Hz, 1H), 7.18 (dt, J_1 = 7.6 Hz, J_2 = 1.2 Hz, 1H), 7.31 – 7.46 (m, 5H), 7.53 – 7.57 (m, 3H), 7.69 – 7.74 (m,

2H); ^{13}C NMR (100MHz, $CDCl_3$): δ 107.9, 116.7, 124.1 (q, J_{CF} = 271Hz), 124.5 (q, J_{CF} = 3.8 Hz), 125.0, 125.3, 126.1, 126.2 (q, J_{CF} = 3.7Hz), 126.8, 128.9, 129.4, 130.5, 130.4, 130.8 (q, J_{CF} = 32Hz), 133.0, 133.4, 133.8, 133.9, 135.9, 139.3, 142.1; HRMS (ESI) for $C_{21}H_{13}N_3F_3$ $[M+H]^+$: *m/z* calcd 364.1062, measured 364.1093.



3k

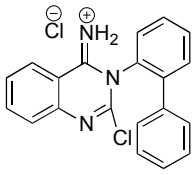
2-((((4'-methyl-[1,1'-biphenyl]-2-yl)imino)methylene)amino)benzonitrile (3j): Following method B, compound **3k** was prepared from iminophosphorane **6a** (2.07g, 5.46 mmol) and isocyanate **7k** (1.14 g, 5.46 mmol). Purification by column chromatography (SiO_2, hexane:ethyl acetate, 93:7) afforded **3k** as a viscous yellow oil (1.09 g, 65%): R_f = 0.48 (8:2, hexane:ethyl acetate); FTIR (neat) ν_{max}: 2226, 2138, 2106, 1592, 1570, 1514, 1476, 1441, 1210, 1160, 1103, 1041, 818, 752 cm^{-1}; ^{1}H NMR (400MHz, $CDCl_3$): δ 2.28 (s, 3H), 6.83 (d, J = 8Hz, 1H), 7.10 – 7.15 (m, 3H), 7.23 – 7.34 (m, 6H), 7.37 (dt, J_1 = 7.4 Hz, J_2 = 2.0 Hz, 1H), 7.51 (dt, J_1 = 8.0 Hz, J_2 = 1.2 Hz, 1H); ^{13}C NMR (100MHz, $CDCl_3$): δ 21.3, 107.7, 116.7, 124.8, 125.1, 125.6, 126.5, 128.4, 129.20, 129.27, 129.28, 130.7, 133.2, 133.4, 133.7, 135.6, 137.7, 137.9, 142.8; HRMS (ESI) for $C_{21}H_{16}N_3$ $[M+H]^+$: *m/z* calcd 310.1344, measured 310.1324.



3l

2-((((3'-methoxy-5-methyl-[1,1'-biphenyl]-2-yl)imino)methylene)amino)benzonitrile (3k): Following method B, compound **3l** was prepared from iminophosphorane **6a** (1.60g, 4.22 mmol) and isocyanate **7l** (1.00 g, 4.22 mmol). Purification by column chromatography (SiO_2, hexane:ethyl acetate, 94:6) afforded afforded **3l** as a viscous pale yellow oil (0.91 g, 63%), R_f = 0.45 (9:1, hexane ethyl acetate); FTIR (neat) ν_{max}: 2226, 2128, 2114, 1593, 1570, 1477, 1429,

1259, 1215, 1161, 1111, 1050, 1032, 820, 757 cm^{-1}; ^1H NMR (400MHz, $CDCl_3$): δ 2.37 (s, 3H), 3.76 (s, 3H), 6.78 (dd, J_1 = 8.4Hz, J_2 = 2.2Hz, 1H), 6.86 (d, J = 8.4Hz, 1H), 6.95 – 6.96 (m, 1H), 7.01 (d, J = 7.6 Hz, 1H), 7.10 – 7.16 (m, 3H), 7.20 – 7.27 (m, 2H), 7.38 (dt, J_1 = 8Hz, J_2 = 1.6Hz, 1H), 7.51 (dd, J_1 = 7.6Hz, J_2 = 1.2Hz, 1H); ^{13}C NMR (100MHz, $CDCl_3$): δ 21.1, 55.3, 107.7, 113.4, 114.9, 116.8, 121.8, 124.7, 125.0, 125.5, 129.3, 129.5, 130.3, 130.8, 131.3, 133.2, 133.5, 136.4, 137.6, 140.0, 143.1, 159.5; HRMS (ESI) for $C_{22}H_{18}N_3O$ $[M+H]^+$: *m/z* calcd 340.1450, measured 340.1456.



4a

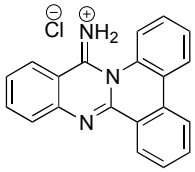
Synthesis of 3-([1,1'-biphenyl]-2-yl)-2-chloroquinazolin-4(3*H*)-iminium chloride (4a)

Freshly prepared carbodiimide **3a** (0.04 g, 0.14 mmol) was dissolved in dry methylene chloride (2 mL). To this solution was added trimethylsilyl chloride (0.059 g, 0.56 mmol). The reaction mixture was stirred for 16 – 48 hours at 23 °C. The precipitates formed were filtered, washed and dried. **4a** (0.04 g, 78%) was obtained as a white solid: *Rf* 0.6 (95:5 dichloromethane:methanol); FTIR (neat) ν_{max}: 3019, 2929, 1667, 1606, 1572, 1563, 1504, 1480, 1467, 1435, 1328, 1279, 1213, 1163, 1137, 964, 777, 764, 748, 733, 699 cm^{-1}; ^1H NMR (400MHz, DMSO-d_6): δ 7.24 – 7.44 (m, 5H), 7.68 (d, J = 6.8 Hz, 1H), 7.77 – 7.91 (m, 5H), 8.10 (t, J = 7.8 Hz, 1H), 9.00 (d, J = 8.2 Hz, 1H), 9.74 (br s, 1H), 11.56 (br s, 1H); ^{13}C NMR (100 MHz, DMSO-d_6): δ 113.3, 126.7, 127.5, 127.7, 128.5, 128.7, 128.8, 129.6, 130.6, 132.3, 132.4, 132.5, 136.3, 138.0, 139.7, 142.5, 144.7, 158.5; HRMS (ESI) for $C_{20}H_{15}N_3Cl$ $[M+H]^+$: *m/z* calcd 332.0955 measured 332.0950.

Synthesis of phenanthridine *N*-quinazoliniminiums 5

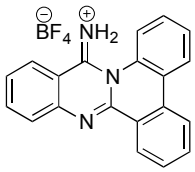
Freshly prepared cyano-ene-carbodiimides **3** (0.3 mmol) were dissolved in nitromethane (3 mL) and to this stirring solution was added Lewis acid (1.2 mmol) and if necessary, water (1.2 mmol). (*Note: Water was needed when anhydrous nitromethane was used, however, 95% nitromethane didn't require any addition of water. In some cases, added water hydrolyzed the*

carbodiimide). In most cases, the reaction mixture turned green/red after the addition of Lewis acid. The reaction mixture was continuously stirred at 23 ^{o}C for 16-48 h. Upon completion of the reaction, the precipitates formed were filtered and washed with hexane/CH_2Cl_2 to afford the corresponding phenanthridine-fused quinazoliniminium salts. However in the cases where precipitates were not observed, CH_2Cl_2 (6 mL) was added to the reaction mixture after 48 h to precipitate out the desired compound which was filtered, washed and dried under vacuum.



5a

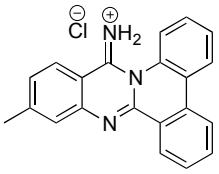
14*H*-quinazolino[3,2-*f*]phenanthridin-14-iminium chloride (5a): Compound **5a** was prepared from **3a** (0.014 g, 0.048 mmol) and tin tetrachloride (0.05 g, 0.19 mmol) following the general procedure. Water (0.003g, 0.19 mmol) was also added to that reaction mixture. Upon completion of the reaction, addition of methylene chloride gave **5a** (0.012 g, 75%) as a light yellow solid: *Rf* 0.52 (95:5 CH_2Cl_2/MeOH); FTIR (neat) ν_{max}: 3339, 3242, 1656, 1609, 1597, 1588, 1568, 1532, 1476, 1491, 1451, 1432, 1347, 1296, 1166,1109, 1054, 1028, 1015, 990, 974, 958, 816 cm^{-1}; ^{1}H NMR (400MHz, DMSO-d_6): δ 7.63 – 7.65 (m, 2H), 7.72 – 7.77 (m, 2H), 7.89 – 7.92 (m, 2H), 8.02 (t, J = 7.4 Hz, 1H), 8.47 – 8.57 (m, 4H), 8.78 (d, J = 8.2 Hz, 1H), 10.92 (br s, 1H); ^{13}C NMR (100 MHz, DMSO-d_6): δ 114.9, 121.3, 123.0, 124.6, 125.1, 125.7, 125.8, 127.4, 127.5, 127.9, 128.7, 129.0, 129.5, 130.6, 131.0, 133.5, 136.9, 144.5, 144.6, 158.2; HRMS (ESI) for $C_{20}H_{14}N_3^+$: *m/z* calcd 296.1188, measured 296.1179.



5a'

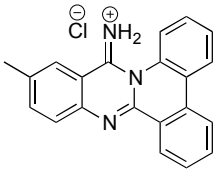
14*H*-Quinazolino[3,2-*f*]phenanthridin-14-iminium tetraflouoroborate (5a′): Compound **5a′** was prepared from **3a** (0.070 g, 0.24 mmol) and boron trifloride diethyletherate (0.135 g, 0.95 mmol) following the general procedure. Water (0.017g, 0.95 mmol) was also added to that reaction mixture. Upon completion of the reaction, addition of methylene chloride gave **5a′**

(0.058 g, 63%) as a light yellow solid: *Rf* 0.54 (95:5 dichloromethane:methanol); FTIR (neat) ν_{max}: 3341, 3238, 1655, 1609, 1597, 1588, 1567, 1530, 1475, 1450, 1348, 1296, 1167, 1052, 1014, 779, 759, 722 cm^{-1}; ^1H NMR (400MHz, DMSO-d_6): δ 7.66 – 7.73 (m, 2H), 7.76 – 7.84 (m, 2H), 7.92 – 7.96 (m, 1H), 8.01 (d, J = 8.3 Hz, 1H), 8.11 – 8.15 (m, 1H), 8.45 (d, J = 8.2 Hz, 1H), 8.56 – 8.62 (m, 3H), 8.80 – 8.82 (m, 1H), 11.07 (br s, 2H); ^{13}C NMR (100 MHz, DMSO-d_6): δ 114.9, 121.3, 123.1, 124.7, 125.2, 125.7, 125.8, 127.46, 127.51, 128.0, 128.8, 129.0, 129.6, 130.6, 130.9, 133.6, 137.0, 144.5, 144.6, 158.3.



5b

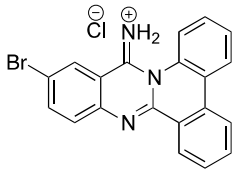
11-Methyl-14*H*-quinazolino[3,2-*f*]phenanthridin-14-iminium chloride (5b): Compound **5b** was prepared from **3b** (0.064 g, 0.21 mmol) and tin tetrachloride (0.22 g, 0.83 mmol) following the general procedure. Water (0.015 g, 0.83 mmol) was also added to that reaction mixture. Upon completion of the reaction, addition of methylene chloride gave **5b** (0.045 g, 63%) as a light yellow solid: *Rf* 0.38 (95:5 CH_2Cl_2/MeOH); FTIR (neat) ν_{max}: 3138, 1671, 1640, 1605, 1564, 1498, 1488, 1478, 1444, 1350, 1303, 1263, 1250, 1194, 1123, 1010, 885, 818, 781, 759, 701, 668 cm^{-1}; ^1H NMR (500 MHz, DMSO-d_6): δ 2.58 (s, 3H), 7.63 (d, J = 8.6 Hz, 1H), 7.66 – 7.72 (m, 2H), 7.74 – 7.77 (m, 2H), 7.91 (t, J = 8.1 Hz, 1H), 8.42 (dd, J_1 = 8.1 Hz, J_2 =1.5 Hz, 1H), 8.54 (t, J = 7.6 Hz, 3H), 8.74 (d, J = 7.6 Hz, 1H), 10.86 (br s, 1H); ^{13}C NMR (125 MHz, DMSO-d_6): δ 21.7, 112.4, 121.2, 123.0, 124.5, 125.2, 125.5, 125.7, 126.8, 127.3, 128.6, 129.0, 129.5, 129.6, 130.6, 130.9, 133.5, 144.59, 144.63, 148.4, 157.8; HRMS (ESI) for $C_{21}H_{16}N_3^+$: *m/z* calcd 310.1344, measured 310.1340.



5c

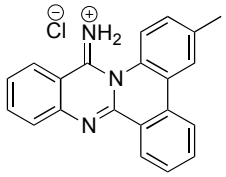
12-Methyl-14*H*-quinazolino[3,2-*f*]phenanthridin-14-iminium chloride (5c): Compound **5c** was prepared from **3c** (0.07 g, 0.227 mmol) and tin tetrachloride (0.236 g, 0.91 mmol)

following the general procedure. Water (0.016g, 0.91 mmol) was also added to that reaction mixture. Upon completion of the reaction, addition of methylene chloride gave **5c** (0.048 g, 61%) as a light yellow solid: *Rf* 0.47 (95:5 CH_2Cl_2/MeOH); FTIR (neat) ν_{max}: 3420, 3191, 1666, 1637, 1603, 1490, 1471, 1367, 1299, 1273, 1246, 1229, 1163, 1127, 1004, 829, 780, 758, 719, 696, 676 cm^{-1}; ^1H NMR (500MHz, DMSO-d_6): δ 2.57 (s, 3H), 7.65 – 7.71 (m, 2H), 7.75 (t, J = 7.4 Hz, 1H), 7.88 – 7.92 (m, 2H), 7.95 (d, J = 8.1, 1H), 8.41 (dd, J_1 = 8.1 Hz, J_2 = 1.5 Hz, 1H), 8.54 – 8.55 (m, 3H), 8.75 (d, J = 8.1 Hz, 1H), 10.95 (br s, 1H); ^{13}C NMR (125 MHz, DMSO-d_6): δ 21.2, 114.6, 121.2, 123.0, 124.6, 125.0, 125.2, 125.8, 127.25, 127.3, 128.7, 129.0, 129.5, 130.4, 131.0, 133.3, 138.1, 138.4, 142.7, 143.9, 157.9; HRMS (ESI) for $C_{21}H_{16}N_3^+$: *m/z* calcd 310.1344, measured 310.1330.



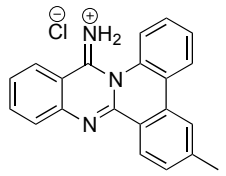
5d

12-Bromo-14*H*-quinazolino[3,2-*f*]phenanthridin-14-iminium chloride (5d): Compound **5d** was prepared from **3d** (0.07 g, 0.19 mmol) and tin tetrachloride (0.195 g, 0.75 mmol) following the general procedure. Water (0.014g, 0.75 mmol) was also added to that reaction mixture. Upon completion of the reaction, addition of methylene chloride gave **5d** (0.042 g, 54%) as a light yellow solid: *Rf* 0.44 (95:5 CH_2Cl_2/MeOH); FTIR (neat) ν_{max}: 3409, 3158, 1669, 1635, 1603, 1562, 1482, 1470, 1365, 1346, 1296, 1267, 1245, 1176, 1165, 1130, 1088, 948, 893, 873, 833, 779, 758, 719, 703 cm^{-1}; ^1H NMR (400 MHz, DMSO-d_6): δ 7.66 – 7.78 (m, 3H), 7.90 (d, J = 9.0 Hz, 1H), 7.94 (d, J = 7.4 Hz, 1H), 8.22 (dd, J_1 = 8.6 Hz, J_2 = 2.0 Hz, 1H), 8.43 – 8.45 (m, 1H), 8.53 – 8.56 (m, 2H), 8.75 (d, J = 8.2 Hz, 1H), 9.0 (ds, J = 2 Hz, 1H), 11.30 (br s, 1H); ^{13}C NMR (100 MHz, DMSO-d_6): δ 116.6, 120.2, 121.2, 123.0, 124.6, 125.2, 125.5, 127.5, 128.3, 128.9, 129.1, 129.4, 129.6, 130.7, 130.8, 133.7, 139.5, 143.5, 145.0, 157.3; HRMS (ESI) for $C_{20}H_{13}N_3Br^+$: *m/z* calcd 374.0293, measured 374.0309.



5e

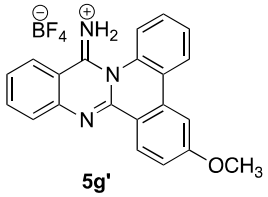
3-Methyl-14*H*-quinazolino[3,2-*f*]phenanthridin-14-iminium chloride (5e): Compound **5e** was prepared from **3e** (0.1 g, 0.32 mmol) and $SnCl_4$ (0.34 g, 1.29 mmol) by following general procedure. Water (0.023 g, 1.29 mmol) was also added to that reaction mixture. Upon completion of the reaction, the filtration of the resulting precipitate afforded **5e** as a pale green solid (0.091 g, 75%): R_f = 0.4 (9.5:0.5, CH_2Cl_2/MeOH); FTIR (neat) ν_{max}: 3188, 2359, 2342, 1674, 1634, 1608, 1564, 1541, 1484, 1365, 1172, 829, 781, 767, 753 cm^{-1}; ^1H NMR (400MHz, DMSO-d_6): δ 2.53 (s, 3H), 7.50 (d, J = 8.8 Hz, 1H), 7.77 – 7.83 (m, 2H), 7.93 (t, J = 7.2 Hz, 1H), 7.99 – 8.01 (m, 1H), 8.12 (t, J = 7.7 Hz, 1H), 8.32 (d, J = 8.4 Hz, 1H), 8.39 (s, 1H), 8.56 (d, J = 8.0 Hz, 1H), 8.71 (t, J = 8.2 Hz, 1H), 8.81 (d, J = 8.2 Hz, 1H), 10.94 (br s, 1H), 11.25 (br s, 1H); ^{13}C NMR (100MHz, DMSO-d_6): 20.8, 114.7, 121.1, 123.0, 124.5, 125.0, 125.70, 125.74, 127.4, 127.5, 128.0, 128.6, 129.4, 129.7, 130.6, 133.5, 136.9, 138.5, 144.4, 144.5, 158.0; HRMS (ESI) for $C_{21}H_{16}N_3^+$: *m/z* calcd 310.1344, measured 310.1377.



5f

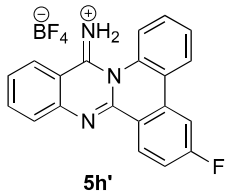
6-Methyl-14*H*-quinazolino[3,2-*f*]phenanthridin-14-iminium chloride (5f): Compound **5f** was prepared from **3f** (0.074 g, 0.24 mmol) and $SnCl_4$ (0.25 g, 0.96 mmol) by following general procedure. Water (0.017 g, 0.96 mmol) was also added to that reaction mixture. Upon completion of the reaction, the filtration of the resulting precipitate afforded **5f** as a green solid (0.070 g, 82%): R_f = 0.43 (9.5:0.5, CH_2Cl_2/MeOH). IR (ZnSe ATR crystal; neat, cm^{-1}): 3210, 1674, 1638, 1610, 1560, 1485, 1363, 1263, 1181, 812, 761; ^1H NMR (400MHz, DMSO-d_6): δ 2.54 (s, 3H), 7.53 (d, J = 8.4 Hz, 1H), 7.63 – 7.71 (m, 2H), 7.77 (t, J = 8.0 Hz, 1H), 7.90 (d, J = 8.0 Hz, 1H), 8.08 (t, J = 7.9 Hz, 1H), 8.33 (s, 1H), 8.40 (dd, J_1 = 8.0 Hz, J_2 = 2.0 Hz, 1H), 8.51 (dd, J_1 = 8.0 Hz, J_2 = 2.0 Hz, 1H), 8.57 (d, J = 8.2 Hz, 1H), 8.63 (d, J = 8.2 Hz, 1H), 10.99 (br s, 1H), 11.20 (br s, 1H); ^{13}C NMR (100MHz, DMSO-d_6): 21.6, 114.6, 121.2, 123.0, 123.1, 124.6, 125.1, 125.8, 127.2, 127.4,

127.8, 128.7, 128.9, 130.5, 130.6, 131.0, 137.0, 144.2, 144.6, 158.1; HRMS (ESI) for $C_{21}H_{16}N_3^+$: *m/z* calcd 310.1344, found 310.1334.



5g'

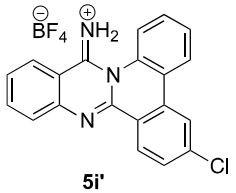
6-Methoxy-14*H*-quinazolino[3,2-*f*]phenanthridin-14-iminium tetrafluoroborate (5g′): Compound **5g′** was prepared from **3g** (0.37 g, 1.14 mmol) and $BF_3.OEt_2$ (0.64 g, 4.55 mmol) by following general procedure. Yellow precipitates appeared within 5 minutes of the addition of the Lewis acid. Upon completion of the reaction, the filtration of the resulting precipitate afforded **5g′** as a green solid (0.24 g, 51%). R_f = 0.37 (9.5:0.5, CH_2Cl_2/MeOH); IR (neat) ν_{max}: 3104, 1680, 1597, 1565, 1506, 1474, 1352, 1314, 1297, 1233, 1170, 1052, 1014, 874, 768 cm^{-1}; ^1H NMR (400MHz, DMSO-d_6): δ 4.02 (s, 3H), 7.32 (dd, J_1 = 8.8 Hz, J_2 = 2.8 Hz, 1H), 7.66 – 7.79 (m, 3H), 7.90 (d, J = 7.6 Hz, 1H), 7.96 (ds, J = 2.4 Hz, 1H), 8.07 (t, J_1 = 8.0 Hz, 1H), 8.41 – 8.45 (m, 1H), 8.56 (d, J = 8.3 Hz, 1H), 8.60 – 8.62 (m, 1H), 8.66 (d, J = 8.8 Hz, 1H), 11.05 (br s, 2H); ^{13}C NMR (100MHz, DMSO-d_6): 56.2, 106.2, 114.4, 117.6, 118.6, 121.4, 124.6, 125.7, 127.2, 127.5, 128.7, 129.2, 129.8, 131.2, 132.7, 137.0, 144.6, 144.9, 158.2, 163.6; HRMS (ESI) for $C_{21}H_{16}N_3O^+$: *m/z* calcd 326.1288, found 326.1286.



5h'

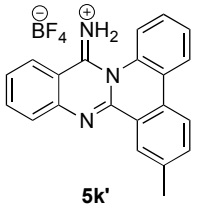
6-Fluoro-14*H*-quinazolino[3,2-*f*]phenanthridin-14-iminium tetrafluoroborate (5h′): Compound **5h′** was prepared from **3h** (0.24 g, 0.77 mmol) and $BF_3.OEt_2$ (0.44 g, 3.08 mmol) by following general procedure. The reaction mixture turned orange/brown upon addition of the Lewis acid and then stirred for an additional 27 h. Upon completion of the reaction, the filtration of the resulting precipitate afforded **5h′** as a green solid (0.14 g, 45%): R_f = 0.7 (9.5:0.5; CH_2Cl_2/MeOH); IR (neat) ν_{max}: 3222, 1685, 1591, 1565, 1475, 1354, 1302, 1201, 1085, 1053, 992, 877, 764 cm^{-1}; ^1H NMR (400MHz, DMSO-d_6): δ 7.65 (dt, J_1 = 8.2 Hz, J_2 = 2.5 Hz, 1H), 7.69 – 7.73 (m, 2H), 7.82 (t, J = 7.5 Hz, 1H), 8.00 (d, J = 8.1 Hz, 1H), 8.13 (t, J = 7.5 Hz, 1H), 8.45 –

8.50 (m, 2H), 8.57 – 8.61 (m, 2H), 8.85 – 8.88 (m, 1H), 11.08 (br s, 2H); ^{13}C NMR (100MHz, DMSO-d_6): 109.3 (d, J_{CF} = 24.0 Hz), 114.7, 117.5 (d, J_{CF} = 22.0 Hz), 121.3, 122.5 (d, J_{CF} = 2Hz), 123.8 (d, J_{CF} = 3 Hz), 125.7, 127.4, 128.0, 128.7, 129.8, 130.9 (d, J_{CF} = 10.0 Hz), 131.3, 133.4 (d, J_{CF} = 10.0 Hz), 137.1, 144.0, 144.4, 158.3, 165.4 (d, J_{CF} = 250Hz); HRMS (ESI) for $C_{20}H_{13}N_3F^+$: *m/z* calcd 314.1094, found 314.1078.



5i'

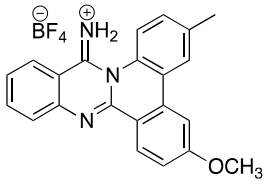
6-Chloro-14*H*-quinazolino[3,2-*f*]phenanthridin-14-iminium tetrafluoroborate (5i′): Compound **5i′** was prepared from **3i** (0.31 g, 0.94 mmol) and $BF_3.OEt_2$ (0.53 g, 3.74 mmol) by following general procedure. The reaction mixture turned orange/brown upon addition of the Lewis acid and then stirred for an additional 27 h. Upon completion of the reaction, the filtration of the resulting precipitate afforded **5i′** as a green solid (0.12 g, 39%): R_f = 0.8 (9.5:0.5; CH_2Cl_2/MeOH); IR (neat) ν_{max}: 3331, 1645, 1618, 1598, 1569, 1471, 1431, 1397, 1371, 1294, 992, 822, 749, 727 cm^{-1}; ^{1}H NMR (400MHz, DMSO-d_6): δ 7.70 – 7.72 (m, 2H), 7.79 – 7.86 (m, 2H), 7.99 (d, J = 8.1 Hz, 1H), 8.12 (t, J_1 = 7.8 Hz, J_2 = 1.2 Hz, 1H), 8.43 – 8.46 (m, 1H), 8.59 – 8.64 (m, 2H), 8.69 (ds, J = 2.0 Hz, 1H), 8.76 (d, J = 8.6 Hz, 1H), 11.1 (br s, 2H); ^{13}C NMR (75MHz, DMSO-d_6): 114.9, 121.4, 122.8, 123.5, 124.6, 125.70, 125.72, 127.4, 128.2, 128.8, 129.60, 129.65, 129.8, 131.4, 132.4, 137.1, 138.8, 144.1, 144.4, 158.3; HRMS (ESI) for $C_{20}H_{13}N_3Cl^+$: *m/z* calcd 330.0798, found 330.0809.



5k'

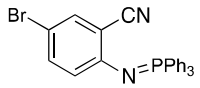
7-Methyl-14*H*-quinazolino[3,2-*f*]phenanthridin-14-iminium tetrafluoroborate (5k′): Compound **5k′** was prepared from **3k** (0.21 g, 0.69 mmol) and $BF_3.OEt_2$ (0.39 g, 2.77 mmol) by following general procedure. The reaction mixture turned light red after addition of the Lewis acid and stirred for an additional 25 h. Upon completion of the reaction, the filtration of the resulting precipitate afforded **5k′** as a pale green solid (0.19 g, 70%): R_f = 0.51 (9.5:0.5, CH_2Cl_2/MeOH); IR

(neat) ν_{max}: 3366, 3218, 1660, 1594, 1566, 1474, 1345,1085, 1053, 1011, 828, 764 cm^{-1}; ^1H NMR (400MHz, DMSO-d_6): δ 2.54 (s, 3H), 7.63 – 7.71 (m, 2H), 7.75 (d, J = 8 Hz, 1H), 7.82 (t, J = 8 Hz, 1H), 8.00 (d, J = 8.0 Hz, 1H), 8.12 (t, J = 7.4 Hz, 1H), 8.44 (t, J = 9.8 Hz, 2H), 8.52 (d, J = 7.8 Hz, 1H), 8.59 – 8.61 (m, 2H), 11.04 (br s, 2H); ^{13}C NMR (100MHz, DMSO-d_6): 21.0, 114.8, 121.2, 123.0, 124.7, 124.9, 125.6, 125.7, 127.1, 127.4, 128.0, 128.2, 128.5, 128.7, 130.6, 134.6, 137.0, 139.5, 144.5, 158.2. HRMS (ESI) for $C_{21}H_{16}N_3^+$: *m/z* calcd 310.1344, measured 310.1331.



5l'

6-methoxy-3-methyl-14*H*-quinazolino[3,2-*f*]phenanthridin-14-iminium tetrafluoroborate (5l′): Compound **5l′** was prepared from **3l** (0.29 g, 0.85 mmol) and $BF_3.OEt_2$ (0.48 g, 3.42 mmol) by following the general procedure. The reaction mixture turned light red after addition of the Lewis acid and stirred for an additional 12 h. Upon completion of the reaction, the filtration of the resulting precipitate afforded **5l′** as a pale green solid (0.14 g, 37%): R_f = 0.31 (9.5:0.5, CH_2Cl_2/MeOH); IR (neat) ν_{max}: 3201, 1658, 1600, 1566, 1473, 1411, 1364, 1301, 1235, 1192, 1097, 1051, 1006, 836, 767 cm^{-1}; ^1H NMR (400MHz, DMSO-d_6): δ 2.54 (s, 3H), 4.05 (s, 3H), 7.34 (dd, J_1 = 8.8 Hz, J_2 = 2.5 Hz, 1H), 7.51 (dd, J_1 = 8.8 Hz, J_2 = 1.5 Hz, 1H), 7.76 (t, J = 7.5 Hz, 1H), 7.93 (d, J = 8.5 Hz, 1H), 7.98 (ds, J = 2.2 Hz, 1H), 8.08 (dt, J_1 = 7.6 Hz, J_2 = 1.2 Hz, 1H), 8.30 (d, J = 8.3 Hz, 1H), 8.46 (s, 1H), 8.56 (d, J = 8 Hz, 1H), 8.71 (d, J = 8.8 Hz, 1H); ^{13}C NMR (100MHz, DMSO-d_6): 20.7, 56.2, 106.0, 114.2, 117.6, 118.6, 121.1, 124.4, 125.4, 125.6, 127.2, 127.4, 128.9, 129.80, 129.82, 132.7, 136.8, 138.6, 144.5, 144.8, 158.0, 163.6; HRMS (ESI) for $C_{22}H_{18}N_3O^+$: *m/z* calcd 340.1450, measured 340.1449.



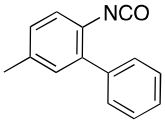
6d

Synthesis of 5-Bromo-2-(triphenylphosphoranylidene)amino benzonitrile (6d)

To a stirred solution of triphenylphosphine dibromide (0.95 g, 2.28 mmol) in dry CH_2Cl_2 (10 mL) cooled to 0 ^oC, was added triethylamine (0.64 mL, 4.56 mmol) under argon. This was followed by the addition of a solution of 2-amino-5-bromobenzonitrile (0.45 g, 2.28 mmol) in dry CH_2Cl_2 (1.0 mL). Reaction mixture was gradually allowed to warm to 23 ^oC. After 24 h, water was added and reaction mixture was extracted with CH_2Cl_2 (thrice). The combined organic layers were dried over $MgSO_4$ and concentrated on a rotary evaporator. The product was purified by flash chromatography on silica gel. White solid (0.58 g, 56%): R_f (hexane:ethyl acetate, 4:1) 0.46; FTIR (neat) ν_{max}: 2216, 1580, 1472, 1437, 1398, 1349, 1310, 1270, 1170, 1108, 1018, 998, 908, 836, 812, 717, 693 cm^{-1}; ^1H NMR (400MHz, $CDCl_3$): δ 6.25 (dd, J_1 = 8.8 Hz, J_2 = 1.1 Hz,1H), 7.04 (dd, J_1 = 8.8 Hz, J_2 = 2.7 Hz, 1H), 7.46 – 7.51 (m, 7H), 7.54-7.59 (m, 3H), 7.75-7.81 (m, 6H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 107.5, 109.4, 109.6, 119.3, 122.4, 122.5, 129.0, 129.1, 130.1, 132.40, 132.43, 132.6, 132.7, 135.4, 135.5, 154.6; HRMS (ESI) for $C_{25}H_{19}N_2PBr$ $[M+H]^+$: *m/z* calcd 457.0469, measured 457.0452.

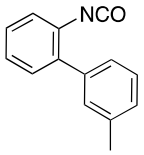
Synthesis of biphenylyl isocyanates 7e – l

Triphosgene (0.40 mmol) was added to a stirring solution of 2-amino biphenyls **11e – l** (1.00 mmol) in dry toluene (3 mL) at 25 ^OC, resulting in the formation of precipitate and then the reaction mixture was slowly brought to reflux at 175 ^OC under argon for 2 – 4 h. Aliquot of the cooled, crude reaction mixture was removed to confirm the formation of corresponding isocyanates using IR spectroscopy (strong NCO peak at 2250-2290 cm^{-1}). The crude biphenylyl isocyanates **7e – l** were used immediately in the next reaction without further purification. (*Caution: This reaction should be carried out under a well-ventilated hood as toxic gases, phosgene and hydrogen chloride are released).*



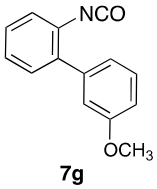
7e

2-Isocyanato-5-methyl-1,1'-biphenyl (7e): This compound was synthesized from 5-methyl-[1,1'-biphenyl]-2-amine (**11e**) (1.00 g, 5.46 mmol): R_f = 0.75 (7:3, hexane/CH_2Cl_2); FTIR (neat) ν_{max}: 2260 cm^{-1}.



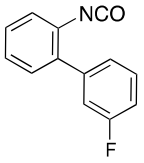
7f

2-Isocyanato-3'-methyl-1,1'-biphenyl (7f): This compound was synthesized from 3'-methyl-[1,1'-biphenyl]-2-amine (**11f**) (1.00g, 5.46 mmol): R_f = 0.93 (7:3, hexane/CH_2Cl_2); FTIR (neat) ν_{max}: NCO: 2248 cm^{-1}.



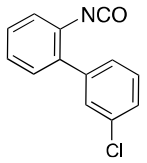
7g

2-Isocyanato-3'-methoxy-1,1'-biphenyl (7g): This compound was synthesized from 3'-methoxy-[1,1'-biphenyl]-2-amine (**11g**) (1.03 g, 5.17 mmol): R_f = 0.61 (1:1, hexane/CH_2Cl_2); FTIR (neat) ν_{max}: 2255 cm^{-1}.



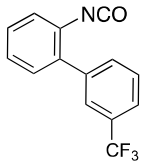
7h

3'-Fluoro-2-isocyanato-1,1'-biphenyl (7h): This compound was synthesized from 3'-fluoro-[1,1'-biphenyl]-2-amine (**11h**) (1.00 g, 5.34 mmol): R_f = 0.78 (7:3, hexane/CH_2Cl_2); FTIR (neat) ν_{max}: 2251 cm^{-1}.



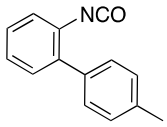
7i

3'-Chloro-2-isocyanato-1,1'-biphenyl (7i): This compound was synthesized from 3'-chloro-[1,1'-biphenyl]-2-amine (**11i**) (0.31 g, 1.51 mmol): R_f = 0.88 (7:3, hexane/CH_2Cl_2); FTIR (neat) ν_{max}: 2271 cm^{-1}.



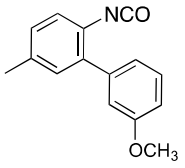
7j

2-Isocyanato-3'-(trifluoromethyl)-1,1'-biphenyl (7j): This compound was synthesized from 3'-(trifluoromethyl)-[1,1'-biphenyl]-2-amine (**11j**) (0.75 g, 3.16 mmol): R_f = 0.78 (1:1, hexane/CH_2Cl_2); FTIR (neat) ν_{max}: 2254 cm^{-1}.



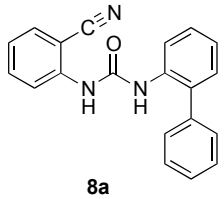
7k

2-Isocyanato-4'-methyl-1,1'-biphenyl (7k): This compound was synthesized from 4'-methyl-[1,1'-biphenyl]-2-amine (**11k**) (1.00 g, 5.46 mmol): R_f = 0.61 (1:1, hexane/CH_2Cl_2); FTIR (neat) ν_{max}: 2249 cm^{-1}.



7l

2-Isocyanato-3'-methoxy-5-methyl-1,1'-biphenyl (7l): This compound was synthesized from 3'-methoxy-5-methyl-[1,1'-biphenyl]-2-amine (**11l**) (0.90 g, 4.22 mmol): R_f = 0.64 (7:3, hexane/CH_2Cl_2); FTIR (neat) ν_{max}: 2255 cm^{-1}.



8a

Synthesis of 1-([1,1'-biphenyl]-2-yl)-3-(2-cyanophenyl)urea (8a)

Freshly prepared carbodiimide **3a** (0.038 g, 0.13 mmol) was dissolved in dry methylene chloride (2 mL). To this solution was added trimethylsilyl bromide (0.13 g, 0.52 mmol) or tin tetrachloride (0.13 g, 0.52 mmol). The reaction mixture was stirred for 16 – 48 hours at 23 ^{o}C. The precipitates formed were filtered, washed and dried. Purification by crystallization in nitromethane and methylene chloride gave **8a** (TMSBr: 0.023 g, 57%, $SnCl_4$: 0.026 g, 65%) as a white solid: *Rf* 0.56 (95:5 dichloromethane:methanol); FTIR (neat) ν_{max}: 3361, 3187, 2225, 1720, 1654, 1579, 1521, 1474, 1445, 1434, 1295, 1278, 1253, 1224, 1177, 1158, 1101, 1072, 1038, 747, 698, 680, 659 cm^{-1}; ^{1}H NMR (400MHz, DMSO-d_6): δ 7.23 – 7.25 (m, 2H), 7.29 – 7.38 (m, 5H), 7.61 (dd, J_1 = 7.2 Hz, J_2 = 1.7 Hz, 1H), 7.68 – 7.77 (m, 3H), 7.87 (t, J = 8.2 Hz, 1H), 8.33 (d, J = 8.3 Hz, 1H), 9.1 (br s, 1H), 10.52 (br s, 1H); ^{13}C NMR (100 MHz, DMSO-d_6): δ 106.7, 116.3, 123.9, 126.3, 127.6, 128.2, 128.5, 129.2, 129.9, 130.3, 131.2, 131.7, 137.1, 138.0, 139.9, 140.1, 146.8, 159.0; HRMS (ESI) for $C_{20}H_{16}N_3O$ $[M+H]^+$: *m/z* calcd 314.1293, measured 314.1287.

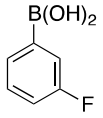
Synthesis of arylboronic acids 9

General Procedure A

n-Butyllithium (11 mmol, 2.5 M in hexane) was added dropwise to a stirring solution of aryl bromide (10 mmol) in dry THF:toluene (1:2) (20:40 mL) at -78 ^{o}C under argon. After 1.5 h (at -78 ^{o}C), trimethyl borate (12 mmol) was added dropwise. The solution was stirred for an additional 1 h after which the reaction mixture was allowed to warm to room temperature and quenched with saturated NH_4Cl. The aqueous and organic layers were separated, and the aqueous layer was extracted with CH_2Cl_2 (3 X 30 mL). The organic layers were combined, dried over Na_2SO_4, filtered and concentrated under reduced pressure to give the crude solid which was recrystallized from acetonitrile to afford the corresponding arylboronic acids **9**.

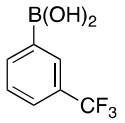
General Procedure B

n-Butyllithium (12 mmol, 2.5 M in hexane) was added dropwise to a stirring solution of aryl bromide (10 mmol) in dry THF (25 mL) at -78 ^{o}C under argon. After the addition was complete, the -78 ^{o}C bath was replaced by an ice bath and the solution was warmed up to about -20 ^{o}C to allow thorough mixing of the lithium salts, then re-cooled to -78 ^{o}C, and stirred further for 1.5 h. Trimethyl borate (12.5 mmol) was added dropwise and solution was stirred for an additional 1 h at -78 ^{o}C, following which the reaction mixture was warmed to room temperature and quenched with 2N HCl. The aqueous and organic layers were separated, and the aqueous layer was extracted with ethyl acetate (3 X 20 mL). The organic layers were combined, dried over $MgSO_4$, filtered and concentrated under reduced pressure to give a pale white solid which was recrystallized from ethyl acetate-hexane to afford the corresponding arylboronic acids **9**.



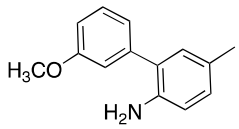
9h

3-Fluorophenylboronic acid (9h): Following the general procedure A, **9h** was prepared from 1-bromo-3-fluorobenzene (3.2 mL, 28.6 mmol) as a white solid (2.8 g, 70% yield). ^{1}H NMR (400MHz, DMSO-d_6): δ 7.21 (dt, J_1 = 8.7 Hz, J_2 = 2.6 Hz, 1H), 7.36 – 7.45 (m, 1H), 7.49 – 7.62 (m, 1H), 7.69 – 7.71(m, 1H), 8.21 (br s, 2H).



9j

3-(Trifluoromethyl)phenylboronic acid (**9j)**: Following the general procedure B, **9j** was prepared from 3-bromo-(trifluoromethyl) benzene (1.2 mL, 8.90 mmol) as a white solid (1.4 g, 80% yield). ^{1}H NMR (400MHz, $CDCl_3$): δ 7.67 (t, J = 8.0 Hz, 1H), 7.85 – 7.92 (m, 1H), 8.39 – 8.47 (m, 2H).

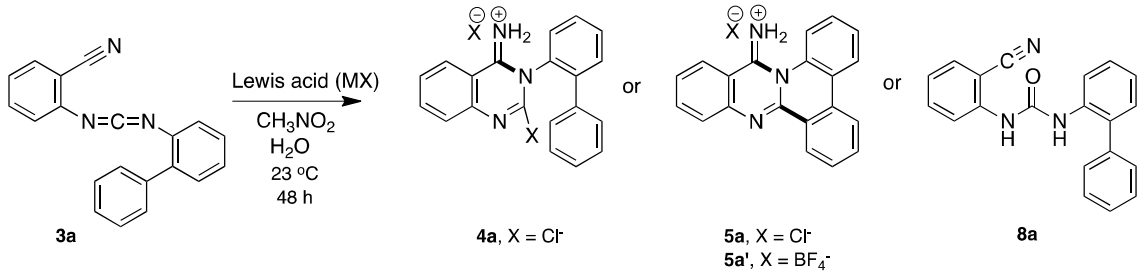


11l

Synthesis of 3'-methoxy-5-methyl-[1,1'-biphenyl]-2-amine (11l)

In a round bottom flask, 2-bromo-4-methylaniline (**10b**) (2.5 g, 13.44 mmol), 3-methoxyphenylboronic acid (**7g**) (2.25 g, 14.78 mmol), K_2CO_3 (7.43g, 53.8 mmol) and $Pd(PPh_3)_2Cl_2$ (0.75g, 1.08 mmol) were dissolved in toluene (50 mL), water (30 mL) and ethanol (15 mL), and the mixture was stirred for 18 – 24 h at 95 ^oC. After cooling, the reaction mixture was diluted with saturated aqueous NH_4Cl (100 mL) and extracted with CH_2Cl_2 (3 X 100 mL). The combined organic layers were dried over Na_2SO_4, filtered and concentrated under reduced pressure. Purification of the crude by column chromatography on silica gel using a gradient eluent of 5% EtOAc in hexane afforded 2-amino-3′-methoxy-5-methyl-biphenyl **11l** as a brown oil (1.74 g, 61%), R_f = 0.53 (8:2, hexane/EtOAc); ^1H NMR (400MHz, $CDCl_3$): δ 2.31 (s, 3H), 3.68 (s, 2H), 3.86 (s, 3H), 6.71 (d, J = 8.7 Hz, 1H), 6.92 (ddd, J_1 = 8.4 Hz, J_2 = 2.8 Hz, J_3 = 1.1 Hz, 1H), 7.00-7.08 (m, 4H), 7.38 (t, J = 7.8 Hz, 1H).

Table 1s. Screening different Lewis acids in nitromethane/water.



entry	Lewis acid	H_2O (equiv)	X^-	Product (%)		
				4	**5**	**8**
1	$BF_3.OEt_2$	4	BF_4^-	0	**5a':** 60	
2	TMSCl	4	Cl^-	**4a:** 69	0	
3	TMSBr	4	Br^-			**8a:** 44
4	TMSI	4	I^-		None[a]	
5	$AlCl_3$	4	Cl^-	**4a:** 55	0	
6	$SnCl_4$	4	Cl^-	0	**5a:** 75[b]	
7	SnF_4	4	F^-			**8a:** 64
8	BCl_3	4	Cl^-	**4a:** 53		
9	BBr_3	4			None[a]	

[a] A complex mixture of products formed which were not identified. [b] Reaction required 16 h.

X-ray crystallography

Experimental details for 5a′

X-ray data were collected on a Bruker SMART APEX II four-circle CCD diffractometer using a fine-focus molybdenum Kα tube. Temperature control was provided by a Cryostream 700 LT device. Data were collected using the APEX2[6] software. Initial cell constants were found by small widely separated "matrix" runs. Data collection strategy was determined with the aid of COSMO.[7] Scan speed and scan width were chosen based on scattering power and peak rocking curves.

Unit cell constants and orientation matrix were improved by least-squares refinement of reflections thresholded from the entire dataset. Integration was performed with SAINT,[8] using this improved unit cell as a starting point. Precise unit cell constants were calculated in SAINT from the final merged dataset. Lorenz and polarization corrections were applied. Absorption correction was applied using the SADABS[9] multi-scan procedure. Laué symmetry, space group, and unit cell contents were found with XPREP.

Data were reduced with SHELXTL.[10] The structure was solved by direct methods without incident. Hydrogens were assigned to idealized positions and were allowed to ride, with the exception of amine hydrogens H14A&B, whose coordinates were allowed to refine. Isotropic thermal parameters for the hydrogen atoms were constrained to be 1.2x that of the connected atom. Heavy atoms were refined with anisotropic thermal parameters.

Table 2s. X-ray crystallographic data for 5a′.

Systematic name	**5a′**
Formula moiety	$(C_{20}H_{14}N_3)$ (BF_4)
Empirical formula	$C_{20}H_{14}BF_4N_3$
Molecular weight	383.15
Color, Habit	yellow prism
Crystal size, mm x mm x mm	0.24 x 0.24 x 0.28
Crystal system	Monoclinic
Space group, Z	P2(1)/n, 4
a, Å	11.0318(6)
b, Å	6.8167(3)
c, Å	21.8563(11)
α, °	90.00
β, °	94.287(2)
γ, °	90.00
Volume, $Å^3$	1639.01(14)
Density, g / cm^3	1.553
Temperature, K	120
X-ray wavelength, Å	0.71073
μ, mm^{-1}	0.125
Absorption corr	multi-scan
Trans min/max	0.9660 / 0.9707
R_{int}	0.0571
Reflections	
collected	23114
independent	5967
observed	4794
Threshold expression	$>2\sigma(I)$
R1 (observed)	0.0461
wR2 (all)	0.1422
S	1.092
Δρ max / min	0.452 / -0.322

ORTEP diagram for 5k′

(one of the four crystallographically unique ion pair).

The C(14)-N(14) and C(14)-N(13) bond lengths are 1.312Å and 1.379Å, respectively, confirming an exocyclic C=N bond and thus, the presence of a protonated imine in solid state.

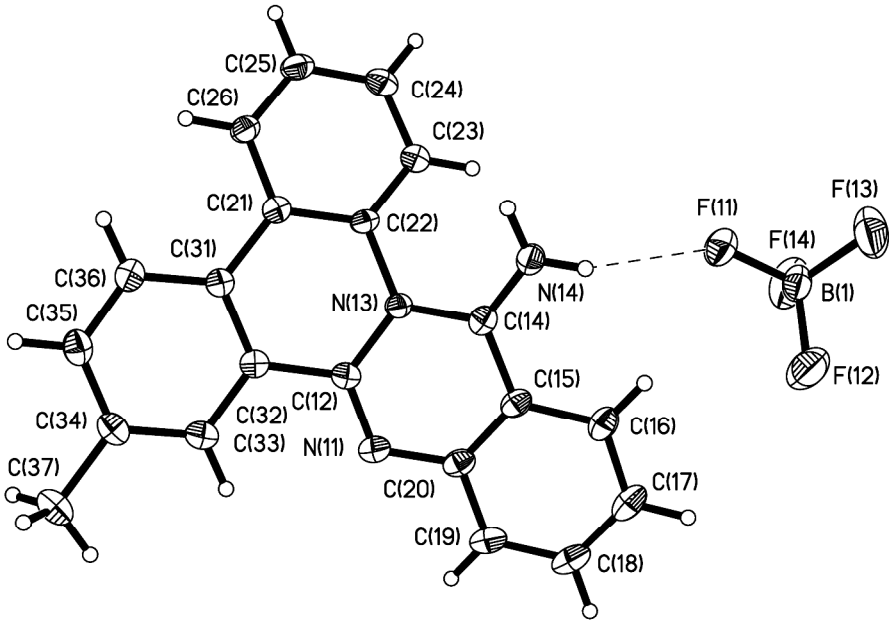


Table 3s. X-ray crystallographic data for 5k′.

Systematic name	**5k′**
Formula moiety	$(C_{21}H_{16}N_3)$ (BF_4)
Empirical formula	$C_{21}H_{16}BF_4N_3$
Molecular weight	397.18
Color, Habit	yellow
Crystal size, mm x mm x mm	0.28 x 0.26 x 0.16
Crystal system	Triclinic
Space group, Z	P-1
a, Å	13.1171(8)
b, Å	13.5030(8)
c, Å	22.5774(13)
α, °	95.970(3)
β, °	100.719(3)
γ, °	115.780(3)
Volume, $Å^3$	3459.9(4)
Density, g / cm^3	1.525
Temperature, K	120(2)
X-ray wavelength, Å	0.71073
μ, mm^{-1}	0.121
Absorption corr	Semi-empirical from equivalents
Trans min/max	0.9669 / 0.9809
R_{int}	0.0000
Reflections	
collected	43257
independent	43257
observed	26108
Threshold expression	$>2\sigma(I)$
R1 (observed)	0.0680
wR2 (all)	0.1873
S	1.020
Δρ max / min	0.541 / -0.399

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