Driving Recursive Dehydration by P^{III}/P^{V} Catalysis: Annulation of Amines and Carboxylic Acids by Sequential C–N and C–C Bond Formation

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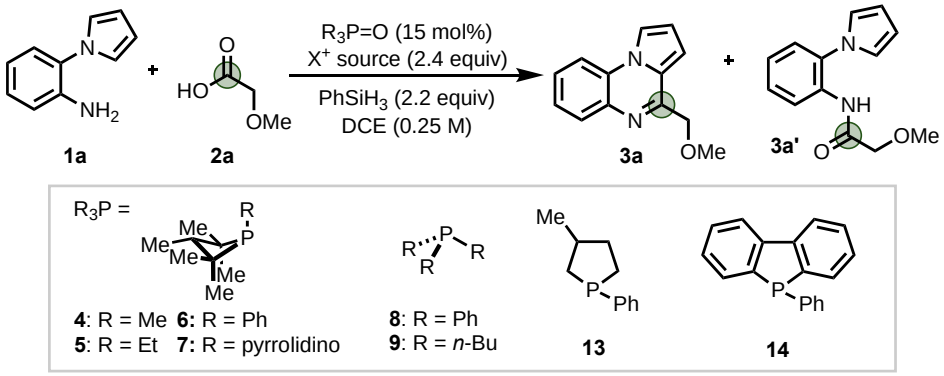
I. General Materials and Methods

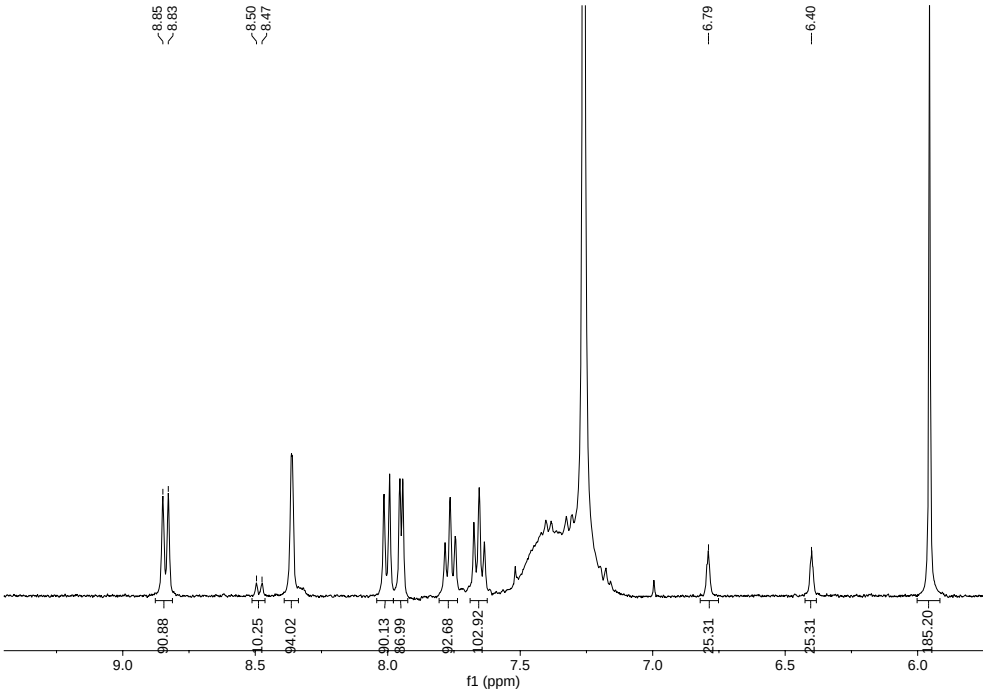
All reagents (including commercial phosphorus reagents used in optimization studies) were purchased from commercial vendors (Sigma-Aldrich, Alfa Aesar, Acros, TCI, or Oakwood Chemical, Combi-Blocks) and used without further purification unless otherwise indicated. Amides **S1** were prepared according to literature procedures or modified literature procedures and new compounds were characterized. Dichloromethane, acetonitrile, and tetrahydrofuran were purified and collected under argon using a Glass Contour Solvent Purification System. Anhydrous 1,2-dichoroethane was obtained from a Sigma-Aldrich (Sure/Seal® bottle) and used as received. All other solvents were ACS grade or better and were used without further purification unless otherwise noted. Manipulations were conducted under an atmosphere of dry N_2 gas unless otherwise noted. Column chromatography was carried out on silica gel (SiliFlash® Irregular Silica Gel, P60 40-63μm). ^{1}H, ^{13}C, and ^{31}P NMR were collected with Bruker Neo 600 (QCI-F helium cryoprobe), Bruker Neo 500 (BBO Prodigy nitrogen cryoprobe), or Bruker AVANCE III HD 400 (BBO Prodigy nitrogen cryoprobe) spectrometers and processed using MestReNova software. ^{1}H NMR chemical shifts are given in ppm with respect to solvent residual peak ($CDCl_3$, δ 7.26 ppm). $^{13}C\{^{1}H\}$ NMR shifts are given in ppm with respect to solvent peak ($CDCl_3$ δ 77.16 ppm). ^{31}P NMR shifts are given in ppm with respect to 85% H_3PO_4 (δ 0.0 ppm) as an external standard. Multiplicities are described as s = singlet, bs = broad singlet, d = doublet, t = triplet, q = quartet, dd = doublet of doublets, td = triplet of doublets, m = multiplet. Coupling constants are reported in Hertz (Hz). High-resolution mass spectra were obtained at the Mass Spectrometry Laboratory in the Department of Chemistry Instrumentation Facility, MIT, using either Agilent QTOF 6545 with ESI ionization source or a JEOL AccuTOF-DART (JMS-T100LP, ionSense DART source). Enantiomeric ratio (*e.r.*) was determined by HPLC analysis using Agilent 1200 Series and indicated chiral stationary phase columns.

II. Optimization of Reaction Conditions

A. Auto-Tandem Catalytic Amide Condensation/Cyclodehydration



An oven-dried 4 mL vial equipped with magnetic stir bar was charged with **1a** (32.3 mg, 0.2 mmol, 98%), organophosphorus catalyst (0.03 mmol, 0.15 equiv, indicated below), and halenium oxidant if solid (0.48 mmol, 2.4 equiv, indicated below). The vial was capped with a septum cap, sealed with Teflon tape and parafilm, and placed under N_2 atmosphere and evacuated/backfilled 3x with N_2. Under N_2 atmosphere, 1,2-dichloroethane (0.8 mL, 250 mM) was added by syringe, followed by **2a** (16.5 μL, 0.21 mmol, 1.05 equiv, 98%), halenium oxidant if liquid (0.48 mmol, 2.4 equiv, indicated below) and phenylsilane (55.4 μL, 0.44 mmol, 2.2 equiv, 98%). The N_2 inlet needle was removed and the septum was sealed with melted parafilm. The reaction mixture was heated to 80 °C and stirred for 14 h. Upon completion, the reaction was cooled to room temperature and 1,1,2,2-tetrachloroethane was added as internal standard (20 μL, 0.185 mmol, 0.926 equiv). An aliquot from the reaction was diluted with $CDCl_3$ and analyzed by ^1H NMR. The yield was determined by relative integration between $C_2H_2Cl_4$ (5.96 ppm, 0.926 equiv x 2H = 185.20%), product **3a** (8.84 ppm, 1H), intermediate amide [(8.48 ppm, 1H), (6.79 ppm, 2H), or (6.40 ppm, 2H)] and starting material **1a** [(6.85 ppm, 2H) or (6.33 pm, 2H)]. Other product resonances can be observed but are often inflated by coalescence with minor components.

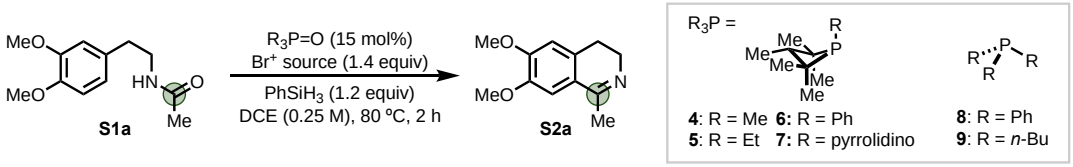


Entry	R_3P=O	X^+ source	**3a** (%)[a]	3a' (%)	**1a** (%)
1	**4**•[O]	DEBM	94	4	0
2	**4**•[O]	DEMBM	90	10	0
3	**4**•[O]	NBS	10	24	0
4	**4**•[O]	DECM	0	70	0
5	**4**•[O]	CCl_4	0	70	0
6	**5**•[O]	DEBM	26	60	0
7	**6**•[O]	DEBM	46	36	0
8	**7**•[O]	DEBM	50	10	0
9	**8**•[O]	DEBM	0	34	37
10	**9**•[O]	DEBM	0	29	42
11	**13**•[O]	DEBM	85	0	0
12	**14**•[O]	DEBM	65	0	0
13	none	DEBM	0	17	83
14	**4**•[O]	none	0	7	88
15	**4**•[O], no $PhSiH_3$	DEBM	0	0	99
16	**4**	DEBM	90	7	0
17	[**4**•Br]Br	DEBM	87	0	0
18	**4**•[O], 1 equiv EtN^iPr_2	DEBM	12	75	0
19	**4**•[O]], 2 equiv EtN^iPr_2	DEBM	4	72	4

Table S1. Optimization of organophosphorus catalyst and halenium oxidant, and control reactions, for the auto-tandem amide condensation/cyclodehydration annulation of amines and carboxylic acids.

The results of entries 4 and 5, in contrast to entries 1-3, indicate that while chlorophosphetanium is competent to catalyze amide condensation, it is not sufficiently reactive to induce cyclodehydration of the resultant amide. The production of amide in entries 9 and 10 indicate that, while the acylic phosphine oxides undergo very slow reduction under the reaction conditions, they do somewhat accelerate the background rate of amidation (entry 13). This is potentially attributed to a kinetically slow P^V cycle akin to that exploited by Denton[1] and Sun,[2] among others. In the case of the background amidation, comparison of entries 13-15 indicate that phenylsilane is required, suggesting the intermediacy of a silyl ester, which is prone to thermal amidation. The synthesis of [**4•**Br]Br is described in **Section VI-B**. The inclusion of base evidently slows the cyclodehydration step (entries 18-19).

B. Cyclodehydration

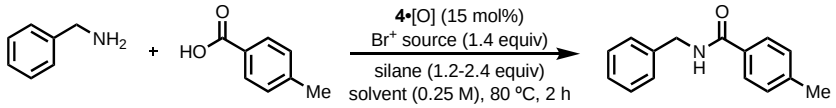


An oven-dried 4 mL vial equipped with magnetic stir bar was charged with **S1a** (0.4 mmol, 89 mg), organophosphorus catalyst (0.06 mmol, 0.15 equiv, indicated below), and bromeniun oxidant if solid (0.56 mmol, 1.4 equiv, indicated below). The vial was capped with a septum cap, sealed with Teflon tape and parafilm, and then placed under N_2 atmosphere and evacuated/backfilled 3x with N_2. Under N_2 atmosphere, 1,2-dichloroethane (0.8 mL, 250 mM) was added by syringe, followed by bromenium oxidant if liquid (0.56 mmol, 1.4 equiv, indicated below) and phenylsilane (59 µL, 0.48 mmol, 1.2 equiv, 98%). The N_2 inlet needle was removed and the septum was sealed with melted parafilm. The reaction mixture was heated to 80 °C and stirred for 2 h. Upon completion, the reaction was cooled to room temperature and 1,1,2,2-tetrachloroethane was added as internal standard (42 µL, 0.40 mmol, 1.0 equiv). An aliquot from the reaction was diluted with $CDCl_3$ and analyzed by ^1H NMR. The yield was determined by relative integration between $C_2H_2Cl_4$, **S2a**, and **S1a**.

Entry	R_3P=O	Br^+ source	**S2a** (%)	**S1a** (%)
1	**4**•[O]	CBr_4	0	71
2	**4**•[O]	NBS	18	63
3	**4**•[O]	DEBM	99	0
4	**5**•[O]	DEBM	86	0
5	**7**•[O]	DEBM	72	27
6	**7**•[O], **8**•[O], **9**•[O]	DEBM	0	100
7	none	DEBM	0	100
8	**4**•[O], no $PhSiH_3$	DEBM	0	100
9	**4**•[O]	none	0	100
10	**4**	DEBM	96	0
11	8 mol% **4**•[O]	DEBM	86	0
12	**4**•[O], 15 min	DEBM	0	74
13	**4**•[O], 30 min	DEBM	63	15
14	**4**•[O], 60 min	DEBM	97	0

Table S2. Optimization of organophosphorus catalyst and bromenium oxidant, and control reactions, for the cyclodehydration of tethered amides.

C. Amide Condensation



An oven-dried 4 mL vial equipped with magnetic stir bar was charged with *p*-toluic acid (29.5 mg, 0.21 mmol, 1.05 equiv, 97%) and **4•**[O] (5.2 mg, 0.03 mmol, 0.15 equiv). The vial was capped with a septum cap, sealed with Teflon tape and parafilm, and then placed under N_2 atmosphere and evacuated/backfilled 3x with N_2. Under N_2 atmosphere, solvent (0.8 mL, 250 mM) was added by syringe, followed by benzylamine (22.1 μL, 0.2 mmol, 1.0 equiv, 99%), X^+ source (0.28 mmol, 1.4 equiv) and silane (indicated below). The N_2 inlet needle was removed and the septum was sealed with melted parafilm. The reaction mixture was heated to 80 °C and stirred at 1200 rpm for 2 h, then cooled to room temperature and 25 μL 1,1,2,2-tetrachlorethane added as internal standard. An aliquot was diluted with $CDCl_3$, and the yield was determined by ^1H NMR.

Entry	X^+ source	silane	solvent	Yield (%)
1	CCl_4	$PhSiH_3$, 0.6 equiv	DCE	45
2	DEBM	$PhSiH_3$, 0.6 equiv	DCE	51
3	DEMBM	$PhSiH_3$, 0.6 equiv	DCE	58
4	CCl_4	Ph_2SiH_2, 1.2 equiv	MeCN	71
5	DEBM	Ph_2SiH_2, 1.2 equiv	MeCN	35
6	DEMBM	Ph_2SiH_2, 1.2 equiv	MeCN	70

Table S3. Comparison of halenium oxidant, silane and silane equivalencies, and solvent, in the amide condensation of amines and carboxylic acids.

The difference in yield between entries 5 and 6, and the comparatively low difference between entries 2 and 3, are a result of more prevalent S_N2 *N*-alkylation of the benzylamine by DEBM in the more polar MeCN. At this time, the reason for inferiority of CCl_4 in DCE is not well-understood.

The cost of DEBM and DEMBM are comparable, as 25 g of each can be purchased from Sigma-Aldrich for $50.70 (DEBM, 92%) and $59.50 (DEMBM, 98%), corresponding to a molar cost of $527/mol for DEBM and $614/mol for DEMBM. DEBM was also purchased from Combi-Blocks (25 g, $30, 98%), corresponding to a molar cost of $293/mol.

III. Examples of Auto-Tandem Catalytic Amide Condensation/Cyclodehydration

A. General Procedures

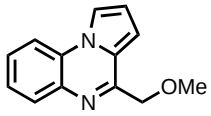
General Procedure 1A. An oven-dried 4 mL vial equipped with magnetic stir bar was charged with amine (0.4 mmol, if solid), acid (0.42 mmol, 1.05 equiv), and **4•**[O] (10.5 mg, 0.06 mmol, 0.15 equiv). The vial was capped with a septa cap, sealed with Teflon tape and parafilm, and then placed under N_2 atmosphere and evacuated/backfilled 3x with N_2. Under N_2 atmosphere, solvent (1.6 mL, 250 mM) was added by syringe, followed by bromomalonate (0.96 mmol, 2.4 equiv) and silane (indicated below). The N_2 inlet needle was removed and the septum was sealed with melted parafilm. The reaction mixture was heated to 80 °C and stirred for 14 h. Upon completion, the reaction was cooled to room temperature, poured into 20 mL of 1M aqueous NaOH solution, and extracted with 4x25 mL CH_2Cl_2. The combined CH_2Cl_2 layers were dried over $MgSO_4$, filtered, and concentrated. The crude residue was then purified by flash column chromatography on silica gel by eluting with the indicated solvent.

General Procedure 1B. An oven-dried 4 mL vial equipped with magnetic stir bar was charged with amine (0.4 mmol, if solid), acid (0.42 mmol, 1.05 equiv), and **4•**[O] (10.5 mg, 0.06 mmol, 0.15 equiv). The vial was capped with a septa cap, sealed with Teflon tape and parafilm, and then placed under N_2 atmosphere and evacuated/backfilled 3x with N_2. Under N_2 atmosphere, solvent (1.6 mL, 250 mM) was added by syringe, followed by bromomalonate (0.96 mmol, 2.4 equiv) and silane (indicated below). The N_2 inlet needle was removed and the septum was sealed with melted parafilm. The reaction mixture was heated to 80 °C and stirred for 14 h. Upon completion, the reaction was cooled to room temperature, poured into 20 mL of CH_2Cl_2 and extracted with 4x25 mL 10 M aqueous HCl solution. The combined aqueous layer was stirred in an ice bath and carefully basified by slow addition of 10 M aqueous NaOH solution. Upon reaching pH 14, the aqueous layer was extracted with 4x25 mL CH_2Cl_2. The combined CH_2Cl_2 layers were dried over $MgSO_4$, filtered, and concentrated. The crude residue was then purified by flash column chromatography on silica gel by eluting with the indicated solvent.

General Procedure 1C. An oven-dried 4 mL vial equipped with magnetic stir bar was charged with 2-(1*H*-pyrrol-1-yl)aniline (32.3 mg, 0.2 mmol) and chiral carboxylic acid (0.21 mmol, 1.05 equiv) and subsequently brought into the glovebox. To the vial was added [**4•**Br]Br (9.6 mg, 0.03

mmol, 0.15 equiv). The vial was capped with a septa cap, sealed with Teflon tape and parafilm, brought out from the glovebox, and placed under N_2 atmosphere. To the vial was added acetonitrile (0.8 mL, 0.25 M), diethyl bromomalonate (84 μL, 0.48 mmol, 2.4 equiv, 92%), and phenylsilane (55 μL, 0.44 mmol, 2.2 equiv, 98%). The N_2 inlet needle was removed and the septum was sealed with melted parafilm. The reaction mixture was heated to 50 °C and stirred for the indicated time. Upon completion, the reaction was cooled to room temperature and 1,1,2,2-tetrachloroethane was added as internal standard (20 μL, 0.185 mmol, 0.926 equiv). An aliquot from the reaction was diluted with $CDCl_3$ and analyzed by ^1H NMR. The remaining reaction mixture was poured into 20 mL of 1M aqueous NaOH solution, and extracted with 4x25 mL CH_2Cl_2. The combined CH_2Cl_2 layers were dried over $MgSO_4$, filtered, and concentrated. The crude residue was then purified by flash column chromatography on silica gel by eluting with the indicated solvent, and the enantiomeric ratio was determined by chiral HPLC as indicated.

B. Analytical Data

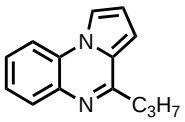


4-(Methoxymethyl)pyrrolo[1,2-a]quinoxaline (3a). Prepared according to **general procedure 1B** using 2-(1*H*-pyrrol-1-yl)aniline (63.3 mg, 0.4 mmol), methoxy acetic acid (33 μL, 0.42 mmol, 1.05 equiv, 98%), diethyl bromomalonate (178 μL, 0.96 mmol, 2.4 equiv, 92%), and phenylsilane (111 μL, 0.88 mmol, 2.2 equiv, 98%) in 1,2-dichloroethane. Column eluted with 50% EtOAc/hexanes. Yield: 84% (71.1 mg). Yellow oil.

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.00 (d, *J* = 8.1 Hz, 1H), 7.94 (d, *J* = 1.5 Hz, 1H), 7.86 (d, *J* = 8.2 Hz, 1H), 7.52 (td, *J* = 8.4, 7.8, 1.5 Hz, 1H), 7.45 (td, *J* = 7.8, 7.4, 1.4 Hz, 1H), 7.08 (d, *J* = 3.1 Hz, 1H), 6.89 (t, *J* = 3.4 Hz, 1H), 4.82 (s, 2H), 3.53 (s, 3H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 153.04, 135.64, 130.23, 127.89, 127.77, 125.32, 124.99, 114.40, 114.03, 113.81, 106.97, 74.57, 59.06.

HRMS (ESI) calculated for $C_{13}H_{13}N_2O$ $[M+H]^+$ 213.1022, found 213.1021.



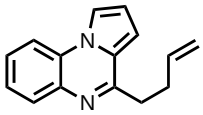
4-Propylpyrrolo[1,2-a]quinoxaline (3b). Prepared according to **general procedure 1B** using 2-(1*H*-pyrrol-1-yl)aniline (63.3 mg, 0.4 mmol), butyric acid (38.4 μL, 0.42 mmol, 1.05 equiv), diethyl bromomalonate (178 μL, 0.96 mmol, 2.4 equiv, 92%) and phenylsilane (111 μL, 0.88 mmol, 2.2 equiv, 98%) in 1,2-dichloroethane. Column eluted with 6% Et_2O/toluene. Yield: 90% (75.7 mg). Yellow solid.

5 mmol reaction performed according to adapted **general procedure 1B** with 2-(1H-pyrrol-1-yl)aniline (791 mg, 5 mmol), butyric acid (480 μL, 5.25 mmol, 1.05 equiv), diethyl bromomalonate (2.23 mL, 12 mmol, 2.4 equiv, 92%), phenylsilane (1.36 mL, 11 mmol, 2.2 equiv, 98%), and **4•**[O] (70 mg, 0.4 mmol, 0.08 equiv) in 33 mL 1,2-dichloroethane in a 100 mL round bottom flask. Column eluted with 50% EtOAc/hexanes. Yield: 99% (1.04 g).

^{z1}H NMR (400 MHz, $CDCl_3$) δ 7.95 – 7.89 (m, 1H), 7.85 – 7.81 (m, 1H), 7.78 – 7.72 (m, 1H), 7.44 – 7.36 (m, 2H), 6.87 (dd, *J* = 3.9, 1.3 Hz, 1H), 6.80 (dd, *J* = 4.0, 2.7 Hz, 1H), 3.03 – 2.94 (m, 2H), 2.01 – 1.87 (m, 2H), 1.08 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (126 MHz, $CDCl_3$) δ 157.4, 136.1, 129.5, 127.3, 126.8, 126.1, 125.0, 114.1, 113.6, 113.4, 106.3, 37.9, 22.0, 14.4.

HRMS (ESI) calculated for $C_{14}H_{15}N_2$ $[M+H]^+$ 211.1235, found 211.1228.

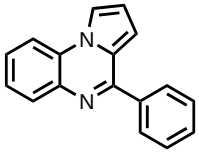


4-(3-butenyl)pyrrolo[1,2-a]quinoxaline (3c). Prepared according to **general procedure 1B** using 2-(1*H*-pyrrol-1-yl)aniline (63.3 mg, 0.4 mmol), 4-pentenoic acid (42.9 μL, 0.42 mmol, 1.05 equiv), diethyl bromomalonate (178 μL, 0.96 mmol, 2.4 equiv, 92%), and phenylsilane (111 μL, 0.88 mmol, 2.2 equiv, 98%) in 1,2-dichloroethane. Column eluted with 6% Et_2O/toluene. Yield: 80% (81.8 mg). Brown oil.

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.93 (dd, *J* = 7.9, 1.6 Hz, 1H), 7.90 (dd, *J* = 2.7, 1.3 Hz, 1H), 7.82 (dd, *J* = 8.0, 1.5 Hz, 1H), 7.49 – 7.40 (m, 2H), 6.91 (dd, *J* = 4.0, 1.3 Hz, 1H), 6.85 (dd, *J* = 4.0, 2.7 Hz, 1H), 5.99 (ddt, *J* = 16.9, 10.2, 6.6 Hz, 1H), 5.14 (dq, *J* = 17.1, 1.7 Hz, 1H), 5.02 (dq, *J* = 10.2, 1.4 Hz, 1H), 3.15 – 3.09 (m, 2H), 2.72 – 2.64 (m, 2H).

^{13}C NMR (126 MHz, $CDCl_3$) δ 156.6, 137.9, 136.1, 129.6, 127.4, 127.0, 126.1, 125.2, 115.3, 114.3, 113.7, 113.6, 106.3, 35.1, 32.4.

HRMS (ESI) calculated for $C_{15}H_{15}N_2$ $[M+H]^+$ 223.1235, found 223.1236.

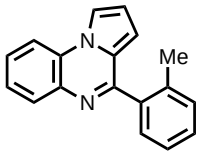


4-Phenylpyrrolo[1,2-a]quinoxaline (3d). Prepared according to **general procedure 1B** using 2-(1*H*-pyrrol-1-yl)aniline (63.3 mg, 0.4 mmol), benzoic acid (51.3 mg, 0.42 mmol, 1.05 equiv), diethyl bromomalonate (178 μL, 0.96 mmol, 2.4 equiv, 92%), and phenylsilane (111 μL, 0.88 mmol, 2.2 equiv, 98%) in 1,2-dichloroethane. Column eluted with 6% Et_2O/toluene. Yield: 83% (81.1 mg). Yellow solid.

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.06 (d, *J* = 8.0 Hz, 1H), 8.03 – 7.96 (m, 3H), 7.89 (d, *J* = 8.1 Hz, 1H), 7.59 – 7.49 (m, 4H), 7.47 (t, *J* = 7.7 Hz, 1H), 7.00 (d, J = 4.0 Hz, 1H), 6.91 (dd, J = 4.0, 2.7 Hz, 1H).

^{13}C NMR (126 MHz, $CDCl_3$) δ 154.6, 138.6, 136.4, 130.4, 129.9, 128.8, 128.7, 127.6, 127.3, 125.6, 125.4, 114.7, 114.1, 113.8, 108.8.

HRMS (ESI) calculated for $C_{17}H_{13}N_2$ $[M+H]^+$ 245.1079, found 245.1072.

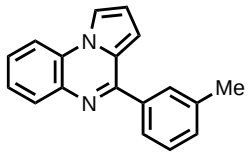


4-(2-Tolyl)-pyrrolo[1,2-a]quinoxaline (3e). Prepared according to **general procedure 1B** using 2-(1*H*-pyrrol-1-yl)aniline (63.3 mg, 0.4 mmol), *o*-toluic acid (57.2 mg, 0.42 mmol, 1.05 equiv), diethyl bromomalonate (178 μL, 0.96 mmol, 2.4 equiv, 92%), and phenylsilane (111 μL, 0.88 mmol, 2.2 equiv, 98%) in 1,2-dichloroethane. Column eluted with 2% EtOAc/hexanes. Yield: 85% (87.9 mg). Pale yellow solid.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.05 (d, *J* = 7.9 Hz, 1H), 7.98 (s, 1H), 7.90 (d, *J* = 8.1 Hz, 1H), 7.59 – 7.45 (m, 3H), 7.36 (tt, *J* = 15.3, 7.3 Hz, 3H), 6.85 (t, *J* = 3.5 Hz, 1H), 6.58 (d, *J* = 3.9 Hz, 1H), 2.34 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 155.74, 137.57, 136.56, 136.14, 130.88, 130.27, 129.13, 129.08, 128.99, 127.63, 127.36, 126.41, 125.73, 125.35, 114.58, 114.03, 113.79, 108.80, 19.85.

HRMS (ESI) calculated for $C_{18}H_{15}N_2$ $[M+H]^+$ 259.1230, found 259.1236.

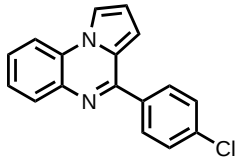


4-(3-Tolyl)-pyrrolo[1,2-a]quinoxaline (3f). Prepared according to **general procedure 1B** using 2-(1*H*-pyrrol-1-yl)aniline (63.3 mg, 0.4 mmol), *m*-toluic acid (57.2 mg, 0.42 mmol, 1.05 equiv), diethyl bromomalonate (178 μL, 0.96 mmol, 2.4 equiv, 92%), and phenylsilane (111 μL, 0.88 mmol, 2.2 equiv, 98%) in 1,2-dichloroethane. Column eluted with 2.5% EtOAc/hexanes. Yield 89% (92.1 mg). Pale yellow solid.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.05 (d, *J* = 7.9 Hz, 1H), 8.00 (s, 1H), 7.89 (d, *J* = 8.1 Hz, 1H), 7.84 – 7.76 (m, 2H), 7.52 (t, *J* = 7.6 Hz, 1H), 7.44 (dt, *J* = 14.7, 7.9 Hz, 2H), 7.34 (d, *J* = 7.6 Hz, 1H), 7.00 (d, *J* = 4.0 Hz, 1H), 6.90 (t, *J* = 3.3 Hz, 1H), 2.48 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 154.78, 138.53, 136.44, 130.71, 130.39, 129.33, 128.52, 127.54, 127.33, 125.87, 125.63, 125.40, 114.68, 114.06, 113.76, 108.91, 21.69.

HRMS (ESI) calculated for $C_{18}H_{15}N_2$ $[M+H]^+$ 259.1230, found 259.1227.

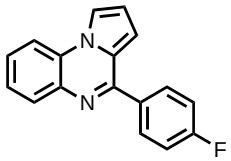


4-(4-Chlorophenyl)pyrrolo[1,2-a]quinoxaline (3g). Prepared according to **general procedure 1B** using 2-(1*H*-pyrrol-1-yl)aniline (63.3 mg, 0.4 mmol), 4-chlorobenzoic acid (65.8 mg, 0.42 mmol, 1.05 equiv), diethyl bromomalonate (178 μL, 0.96 mmol, 2.4 equiv, 92%), and phenylsilane (111 μL, 0.88 mmol, 2.2 equiv, 98%) in 1,2-dichloroethane. Column eluted with 10% EtOAc/hexanes. Yield: 54% (60.2 mg). White solid.

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.03 (dd, *J* = 8.1, 1.5 Hz, 1H), 8.01 – 7.99 (m, 1H), 7.96 (d, *J* = 8.5 Hz, 2H), 7.88 (dd, *J* = 8.1, 1.4 Hz, 1H), 7.55 – 7.50 (m, 3H), 7.49 – 7.45 (m, 1H), 6.96 (dd, *J* = 4.0, 1.3 Hz, 1H), 6.91 (dd, *J* = 4.0, 2.7 Hz, 1H).

^{13}C NMR (126 MHz, $CDCl_3$) δ 153.2, 137.1, 136.3, 136.0, 130.4, 130.1, 129.0, 127.8, 127.3, 125.5, 125.2, 114.9, 114.2, 113.8, 108.6.

HRMS (ESI) calculated for $C_{17}H_{12}ClN_2$ $[M+H]^+$ 279.0689, found 279.0681.



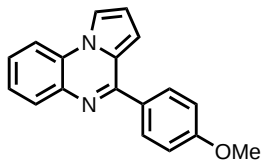
4-(4-Fluorophenyl)pyrrolo[1,2-a]quinoxaline (3h). Prepared according to **general procedure 1B** using 2-(1*H*-pyrrol-1-yl)aniline (63.3 mg, 0.4 mmol), 4-fluorobenzoic acid (58.9 mg, 0.42 mmol, 1.05 equiv), diethyl bromomalonate (178 μL, 0.96 mmol, 2.4 equiv, 92%), and phenylsilane (111 μL, 0.88 mmol, 2.2 equiv, 98%) in 1,2-dichloroethane. Column eluted with 10% EtOAc/hexanes. Yield: 75% (78.7 mg). Yellow solid.

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.07 – 7.97 (m, 4H), 7.88 (d, *J* = 8.1 Hz, 1H), 7.53 (t, *J* = 7.5 Hz, 1H), 7.47 (t, *J* = 7.4 Hz, 1H), 7.23 (t, *J* = 8.7 Hz, 2H), 6.96 (d, *J* = 4.0 Hz, 1H), 6.91 (t, *J* = 3.3 Hz, 1H).

^{13}C NMR (126 MHz, $CDCl_3$) δ 164.0 (d, *J* = 249.5 Hz), 153.4, 136.3, 134.8 (d, *J* = 3.3 Hz), 130.7 (d, *J* = 8.3 Hz), 130.4, 127.7, 127.3, 125.5, 125.4, 115.7 (d, *J* = 21.6 Hz), 114.9, 114.2, 113.8, 108.7.

^{19}F NMR (471 MHz, $CDCl_3$) δ -111.13.

HRMS (ESI) calculated for $C_{17}H_{12}FN_2$ $[M+H]^+$: 263.0985, found: 263.0976.

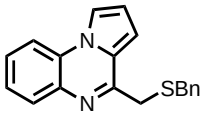


4-(4-Methoxyphenyl)pyrrolo[1,2-a]quinoxaline (3i). Prepared according to **general procedure 1B** using 2-(1*H*-pyrrol-1-yl)aniline (63.3 mg, 0.4 mmol), 4-methoxybenzoic acid (63.9 mg, 0.42 mmol, 1.05 equiv), diethyl bromomalonate (178 μL, 0.96 mmol, 2.4 equiv, 92%), and phenylsilane (111 μL, 0.88 mmol, 2.2 equiv, 98%) in 1,2-dichloroethane. Column eluted with 10% EtOAc/hexanes. Yield: 73% (80.1 mg). White solid.

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.04 – 7.98 (m, 3H), 7.95 (d, J = 1.5 Hz, 1H), 7.83 (dd, J = 7.9, 1.7 Hz, 1H), 7.45 (dtd, J = 16.9, 7.3, 1.6 Hz, 2H), 7.07 (d, J = 8.8 Hz, 2H), 7.00 (dd, J = 4.0, 1.3 Hz, 1H), 6.87 (dd, J = 4.0, 2.7 Hz, 1H), 3.89 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 161.02, 153.91, 136.38, 131.14, 130.11, 130.09, 127.18, 125.41, 125.24, 114.50, 113.99, 113.88, 113.61, 108.59, 55.45.

HRMS (ESI) calculated for $C_{18}H_{15}ON_2$ $[M+H]^+$ 275.1184, found 275.1176.

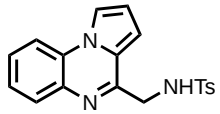


4-(Benzylthiomethyl)pyrrolo[1,2-a]quinoxaline (3j). Prepared according to **general procedure 1B** using 2-(1*H*-pyrrol-1-yl)aniline (63.3 mg, 0.4 mmol), (benzylthio)acetic acid (78.9 mg, 0.42 mmol, 1.05 equiv, 97%), diethyl bromomalonate (178 μL, 0.96 mmol, 2.4 equiv, 92%), and phenylsilane (111 μL, 0.88 mmol, 2.2 equiv, 98%) in 1,2-dichloroethane. Column eluted with gradient 15-25% EtOAc/hexanes. Yield: 41% (49.7 mg). Yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.98 (dd, *J* = 7.9, 1.6 Hz, 1H), 7.91 (dd, *J* = 2.8, 1.3 Hz, 1H), 7.83 (dd, *J* = 8.1, 1.5 Hz, 1H), 7.51 (td, *J* = 8.1, 7.7, 1.6 Hz, 1H), 7.49 – 7.38 (m, 3H), 7.33 – 7.27 (m, 2H), 7.27 – 7.20 (m, 1H), 6.89 (dd, *J* = 4.0, 1.4 Hz, 1H), 6.85 (dd, *J* = 4.0, 2.6 Hz, 1H), 3.95 (s, 2H), 3.85 (s, 2H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 153.28, 138.16, 135.80, 130.02, 129.36, 128.50, 127.58, 127.56, 127.08, 125.24, 125.17, 114.48, 113.79, 106.64, 36.51, 35.03.

HRMS (ESI) calculated for $C_{19}H_{17}N_2S$ $[M+H]^+$ 305.1107, found 305.1103.

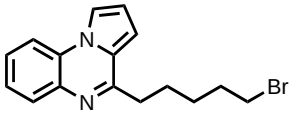


4-(Tosylaminomethyl)pyrrolo[1,2-a]quinoxaline (3k). Prepared according to **general procedure 1B** using 2-(1*H*-pyrrol-1-yl)aniline (63.3 mg, 0.4 mmol), *N*-tosyl glycine (99.3 mg, 0.42 mmol, 1.05 equiv, 97%), diethyl bromomalonate (178 μL, 0.96 mmol, 2.4 equiv, 92%), and phenylsilane (111 μL, 0.88 mmol, 2.2 equiv, 98%) in 1,2-dichloroethane. Column eluted with 30% EtOAc/hexanes. Yield: 90% (126.3 mg). Colorless crystalline solid.

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.89 (d, *J* = 3.4 Hz, 1H), 7.85 (d, *J* = 8.1 Hz, 1H), 7.82 – 7.77 (m, 3H), 7.54 – 7.48 (m, 1H), 7.44 (t, *J* = 7.6 Hz, 1H), 7.17 (d, *J* = 8.2 Hz, 2H), 6.85 – 6.79 (m, 2H), 6.43 (t, *J* = 4.7 Hz, 1H), 4.48 (d, *J* = 4.5 Hz, 2H), 2.29 (s, 3H).

^{13}C NMR (126 MHz, $CDCl_3$) δ 148.90, 143.49, 136.48, 134.70, 129.73, 129.66, 128.03, 127.52, 127.39, 125.49, 124.01, 114.95, 114.13, 113.82, 105.60, 44.36, 21.54.

HRMS (ESI) calculated for $C_{19}H_{18}N_3O_2S$ $[M+H]^+$ 352.1114, found 352.1116.

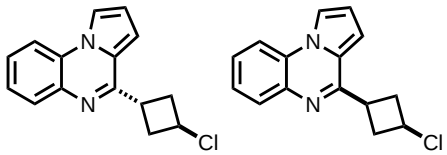


4-(5-Bromopentyl)pyrrolo[1,2-a]quinoxaline (3l). Prepared according to **general procedure 1A** using 2-(1*H*-pyrrol-1-yl)aniline (63.3 mg, 0.4 mmol), 6-bromohexanoic acid (84.5 mg, 0.42 mmol, 1.05 equiv, 97%), diethyl bromomalonate (168 μL, 0.96 mmol, 2.4 equiv, 98%), and diphenylsilane (336 μL, 1.76 mmol, 4.4 equiv, 97%) in MeCN at 60 ºC for 20 h. Column eluted with 10% EtOAc/hexanes. Yield: 93% (117.5 mg). Light yellow crystalline solid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.93 – 7.90 (m, 2H), 7.83 (dd, *J* = 8.1, 1.4 Hz, 1H), 7.48 (td, *J* = 8.1, 7.7, 1.5 Hz, 1H), 7.43 (td, *J* = 7.6, 1.4 Hz, 1H), 6.90 (dd, *J* = 3.9, 1.3 Hz, 1H), 6.85 (dd, *J* = 4.0, 2.7 Hz, 1H), 3.43 (t, *J* = 6.8 Hz, 2H), 3.06 – 3.01 (m, 2H), 1.95 (pd, *J* = 7.4, 3.0 Hz, 4H), 1.63 (ddd, *J* = 15.3, 9.0, 6.7 Hz, 3H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 157.08, 136.11, 129.61, 127.39, 127.09, 126.09, 125.25, 114.33, 113.77, 113.62, 106.29, 35.66, 33.85, 32.81, 28.43, 27.63.

HRMS (ESI) calculated for $C_{14}H_{14}N_2Br$ $[M+H]^+$ 317.0648, found 317.0649.



(±)-4-(*Trans*-3-hlorocyclobutyl)pyrrolo[1,2-a]quinoxaline (3m) and **(±)-4-(*Cis*-3-hlorocyclobutyl)pyrrolo[1,2-a]quinoxaline (3m')**. Prepared according to **general procedure 1A** using 2-(1*H*-pyrrol-1-yl)aniline (63.3 mg, 0.4 mmol), 3-chlorocyclobutane-1-carboxylic acid (59.5 mg, 0.42 mmol, 1.05 equiv, 95%), diethyl bromomalonate (168 μL, 0.96 mmol, 2.4 equiv, 98%), and phenylsilane (111 μL, 0.88 mmol, 2.2 equiv, 98%) in 1,2-dichloroethane. Column eluted with 2-3% EtOAc/hexanes. Yield of *trans* diastereomer (top spot): 60% (62.2 mg). Colorless oil. Yield of *cis* diastereomer (bottom spot): 38% (39.0 mg). White solid. Total yield: 98%. Diastereomers were assigned on the basis of NOESY correlation.

Major (*trans*) diastereomer (3m)

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.95 (dd, *J* = 8.0, 1.5 Hz, 1H), 7.91 (dd, *J* = 2.8, 1.3 Hz, 1H), 7.84 (dd, *J* = 8.1, 1.4 Hz, 1H), 7.49 (td, *J* = 7.7, 1.5 Hz, 1H), 7.44 (td, *J* = 7.6, 1.4 Hz, 1H), 6.84 (dd, *J* = 4.0, 2.7 Hz, 1H), 6.77 (dd, *J* = 4.0, 1.3 Hz, 1H), 4.77 (p, *J* = 6.6 Hz, 1H), 4.24 (tt, *J* = 9.9, 5.4 Hz, 1H), 3.23 – 3.15 (m, 2H), 2.82 – 2.68 (m, 2H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 157.07, 136.03, 129.98, 127.45, 127.31, 125.25, 125.20, 114.39, 113.76, 113.61, 105.79, 52.57, 38.23, 34.62.

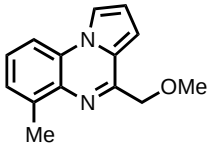
HRMS (ESI) calculated for $C_{15}H_{14}N_2Cl$ $[M+H]^+$ 257.0840, found 257.0850.

Minor (*cis*) diastereomer (3m')

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.98 (dd, *J* = 8.0, 1.6 Hz, 1H), 7.91 (dd, *J* = 2.7, 1.3 Hz, 1H), 7.83 (dd, *J* = 8.1, 1.4 Hz, 1H), 7.49 (td, *J* = 8.1, 7.7, 1.5 Hz, 1H), 7.44 (td, *J* = 7.6, 1.4 Hz, 1H), 6.84 (dd, *J* = 4.0, 2.7 Hz, 1H), 6.78 (dd, *J* = 4.0, 1.3 Hz, 1H), 4.57 (tt, *J* = 8.9, 7.4 Hz, 1H), 3.70 (tt, *J* = 9.8, 7.7 Hz, 1H), 3.06 – 2.93 (m, 4H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 156.08, 136.04, 130.10, 128.67, 127.38, 125.28, 125.13, 114.35, 113.72, 113.60, 105.71, 49.14, 39.02, 33.78.

HRMS (ESI) calculated for $C_{15}H_{14}N_2Cl$ $[M+H]^+$ 257.0840, found 257.0845.

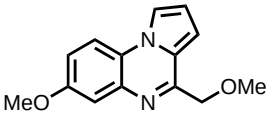


4-(Methoxymethyl)-6-methylpyrrolo[1,2-a]quinoxaline (3n). Prepared according to **general procedure 1B** using 2-methyl-6-(1*H*-pyrrol-1-yl)aniline, prepared according to literature procedure[3] (73.0 mg, 0.4 mmol, 95%), methoxy acetic acid (33 μL, 0.42 mmol, 1.05 equiv, 98%), diethyl bromomalonate (178 μL, 0.96 mmol, 2.4 equiv, 92%), and phenylsilane (111 μL, 0.88 mmol, 2.2 equiv, 98%) in 1,2-dichloroethane. Column eluted with 5% EtOAc/hexanes. Yield: 86% (78.0 mg). Yellow solid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.91 (dd, *J* = 2.7, 1.3 Hz, 1H), 7.70 (d, *J* = 8.2 Hz, 1H), 7.39 (t, *J* = 7.8 Hz, 1H), 7.30 (d, *J* = 7.4 Hz, 1H), 7.06 (dd, *J* = 4.0, 1.3 Hz, 1H), 6.86 (dd, *J* = 4.0, 2.7 Hz, 1H), 4.82 (s, 2H), 3.53 (s, 3H), 2.77 (s, 3H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 151.48, 138.82, 134.27, 127.65, 127.22, 126.31, 125.06, 114.20, 113.85, 111.55, 106.40, 75.18, 58.94, 18.31.

HRMS (ESI) calculated for $C_{14}H_{15}N_2O$ $[M+H]^+$ 227.1179, found 227.1182.

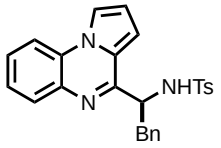


4-(Methoxymethyl)-7-methoxypyrrolo[1,2-a]quinoxaline (3o). Prepared according to **general procedure 1B** using 5-methoxy-2-(1*H*-pyrrol-1-yl)aniline (79.3 mg, 0.4 mmol, 95%), methoxy acetic acid (33 μL, 0.42 mmol, 1.05 equiv, 98%), diethyl bromomalonate (178 μL, 0.96 mmol, 2.4 equiv, 92%), and phenylsilane (111 μL, 0.88 mmol, 2.2 equiv, 98%) in 1,2-dichloroethane. Column eluted with 20-30% EtOAc/hexanes. Yield: 95% (92.2 mg). Yellow solid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.85 (dd, *J* = 2.7, 1.3 Hz, 1H), 7.75 (d, *J* = 9.0 Hz, 1H), 7.47 (d, *J* = 2.8 Hz, 1H), 7.12 (dd, *J* = 9.0, 2.8 Hz, 1H), 7.03 (dd, *J* = 4.0, 1.3 Hz, 1H), 6.84 (dd, *J* = 4.0, 2.6 Hz, 1H), 4.81 (s, 2H), 3.90 (s, 3H), 3.53 (s, 3H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 157.21, 153.28, 136.68, 124.67, 122.01, 117.03, 114.69, 114.05, 113.65, 111.39, 106.50, 74.38, 59.06, 55.83.

HRMS (ESI) calculated for $C_{14}H_{15}N_2O_2$ $[M+H]^+$ 243.1128, found 243.1132.



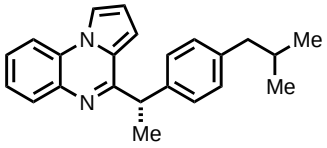
(*S*)-4-((1-Tosylamido)-2-phenylethyl)pyrrolo[1,2-a]quinoxaline (3p). Prepared according to **general procedure 1C** using *N*-tosyl-*L*-phenylalanine (68.5 mg, 0.21 mmol, 1.05 equiv, 98%) for 20 h. NMR analysis indicated 86% yield. Chiral separation of racemic product by HPLC (OD-H, OJ-H, AD-H) and SFC (OD-H, OJ-H, AD-H, AS-H, CEL 1, CEL 2) was unsuccessful, precluding determination of enantiomeric ratio.

Prepared according to **general procedure 1A** using 2-(1*H*-pyrrol-1-yl)aniline (63.3 mg, 0.4 mmol), *N*-tosyl-*L*-phenylalanine (136.9 mg, 0.42 mmol, 1.05 equiv, 98%), diethyl bromomalonate (178 μL, 0.96 mmol, 2.4 equiv, 92%), and phenylsilane (111 μL, 0.88 mmol, 2.2 equiv, 98%) in 1,2-dichloroethane. Column eluted with 25% EtOAc/hexanes. Yield: 88% (155.0 mg). Yellow solid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.80 (s, 1H), 7.73 (d, *J* = 8.1 Hz, 2H), 7.47 (t, *J* = 7.0 Hz, 1H), 7.43 – 7.37 (m, 3H), 7.16 – 7.10 (m, 3H), 7.07 – 7.03 (m, 2H), 6.76 – 6.75 (m, 1H), 6.66 (d, *J* = 8.2 Hz, 2H), 6.64 (d, *J* = 4.2 Hz, 1H), 6.25 (d, *J* = 9.4 Hz, 1H), 4.98 (dt, *J* = 9.4, 6.6 Hz, 1H), 3.24 (q, *J* = 7.1 Hz, 2H), 1.99 (s, 3H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 153.31, 142.65, 136.90, 136.45, 134.83, 134.19, 129.73, 129.68, 128.65, 128.32, 127.71, 127.03, 126.76, 125.22, 124.75, 114.49, 114.00, 113.49, 106.07, 56.39, 42.30, 21.20.

HRMS (ESI) calculated for $C_{26}H_{24}N_3O_2S$ $[M+H]^+$ 442.1584, found 442.1583.



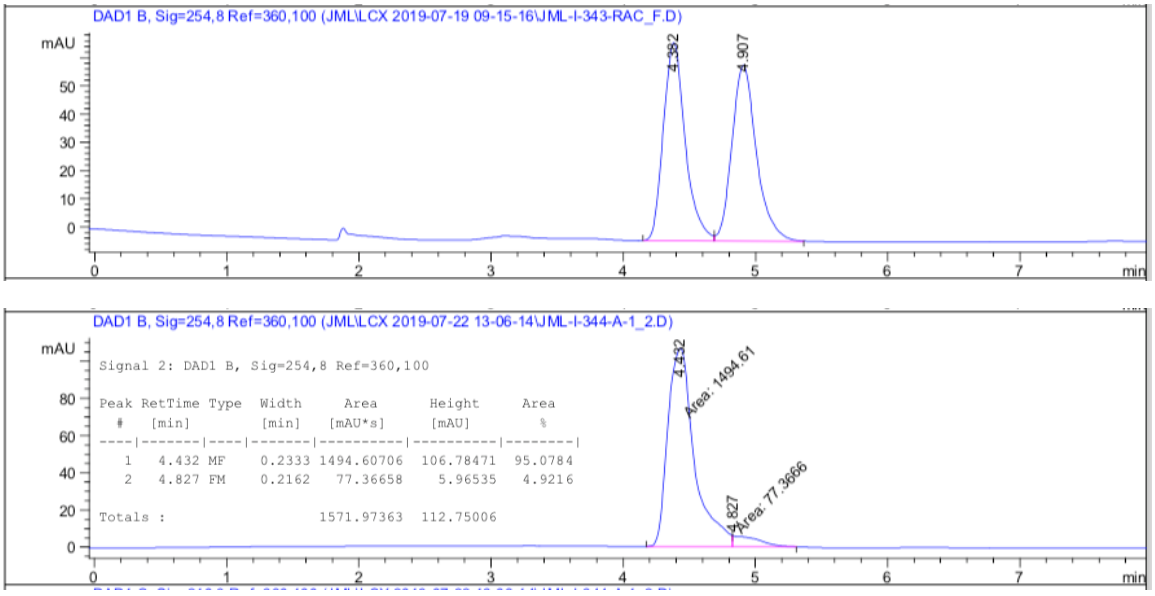
(*S*)-4-(1-(4-Isobutylphenyl)ethyl)pyrrolo[1,2-a]quinoxaline (3q). Prepared according to **general procedure 1C** using (*S*)-ibuprofen (43.8 mg, 0.21 mmol, 1.05 equiv, 99%) for 40 h. NMR analysis indicated 67% yield. HPLC analysis of purified product (Chiralcel OD-H, 5-8% IPA in hexanes, 1.0 mL/min, 6 minutes, 254 nm) indicated 95:5 er: t_R(major) = 4.4 min, t_R(minor) = 4.9 min.

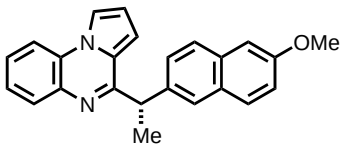
Prepared according to **general procedure 1A** using 2-(1*H*-pyrrol-1-yl)aniline (63.3 mg, 0.4 mmol), (*S*)-ibuprofen (87.5 mg, 0.42 mmol, 1.05 equiv, 99%), diethyl bromomalonate (178 µL, 0.96 mmol, 2.4 equiv, 92%), and phenylsilane (111 µL, 0.88 mmol, 2.2 equiv, 98%) in 1,2-dichloroethane. Column eluted with 3% EtOAc/hexanes. Yield: 69% yield (90.3 mg), racemic. Cloudy colorless oil.

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.04 (d, *J* = 7.0 Hz, 1H), 7.83 (bs, 1H), 7.79 (d, *J* = 7.3 Hz, 1H), 7.45 (p, *J* = 7.4 Hz, 2H), 7.37 (d, *J* = 8.1 Hz, 2H), 7.06 (d, *J* = 8.1 Hz, 2H), 6.80 (d, *J* = 4.3 Hz, 1H), 6.76 – 6.74 (m, 1H), 4.59 (q, *J* = 7.0 Hz, 1H), 2.42 (d, *J* = 7.2 Hz, 2H), 1.84 (d, *J* = 7.1 Hz, 3H), 1.85 – 1.78 (m, 1H), 0.88 (d, *J* = 6.7 Hz, 6H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 158.85, 141.56, 139.91, 136.16, 130.20, 129.30, 127.45, 127.10, 125.85, 125.01, 113.87, 113.62, 113.43, 106.59, 45.19, 44.44, 30.29, 22.56, 22.54, 20.31.

HRMS (ESI) calculated for $C_{23}H_{25}N_2$ $[M+H]^+$ 329.2012, found 329.2012.





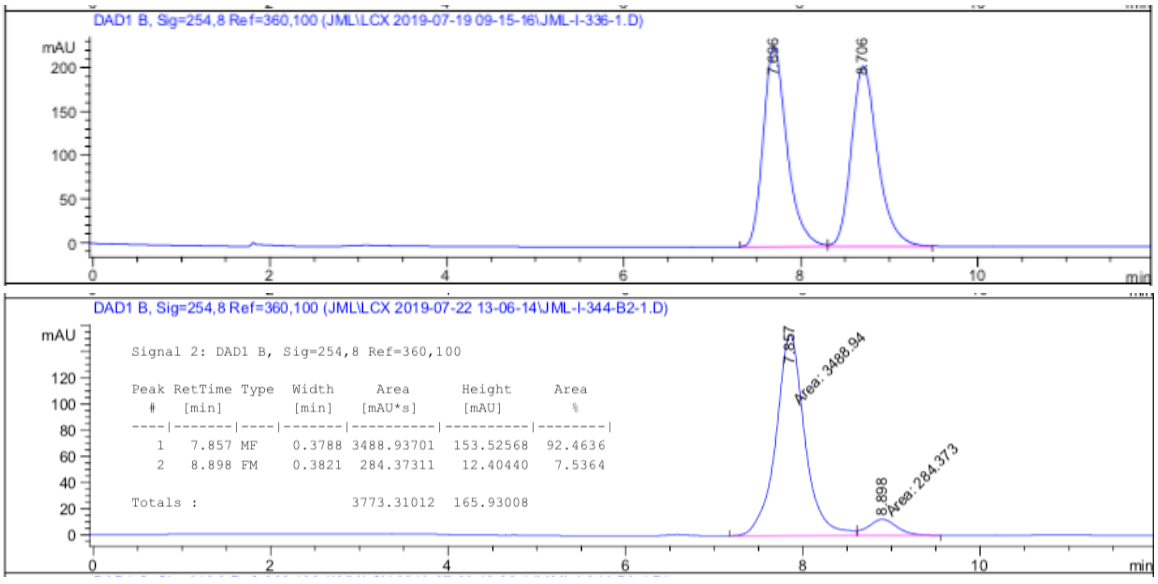
(*S*)-4-(1-(6-methoxynaphthalen-2-yl)ethyl)pyrrolo[1,2-a]quinoxaline (3r). Prepared according to **general procedure 1C** using 2-(1*H*-pyrrol-1-yl)aniline (32.3 mg, 0.2 mmol), (*S*)-naproxen (48.9 mg, 0.21 mmol, 1.05 equiv, 99%), diethyl bromomalonate (84 μL, 0.48 mmol, 2.4 equiv, 92%), and phenylsilane (55 μL, 0.44 mmol, 2.2 equiv, 98%) in acetonitrile at 50 ºC for 40 h. NMR analysis indicated 68% yield. HPLC analysis of purified product (Chiralcel OD-H, 5-10% IPA in hexanes, 1.0 mL/min, 10 minutes, 254 nm) indicated 92.5:7.5 er: t_R(major) = 7.8 min, t_R(minor) = 8.9 min.

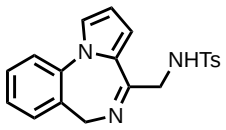
Prepared according to **general procedure 1A** using 2-(1*H*-pyrrol-1-yl)aniline (63.3 mg, 0.4 mmol), (*S*)-naproxen (87.5 mg, 0.42 mmol, 1.05 equiv, 99%), diethyl bromomalonate (178 μL, 0.96 mmol, 2.4 equiv, 92%), and phenylsilane (111 μL, 0.88 mmol, 2.2 equiv, 98%) in 1,2-dichloroethane. Column eluted with 3% EtOAc/hexanes. Yield: 69% yield (90.3 mg), racemic. Colorless solid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.05 (dd, *J* = 7.8, 1.7 Hz, 1H), 7.84 – 7.79 (m, 3H), 7.68 (d, *J* = 9.0 Hz, 1H), 7.63 (d, *J* = 8.5 Hz, 1H), 7.54 (dd, *J* = 8.5, 1.8 Hz, 1H), 7.47 (dtd, *J* = 19.0, 7.4, 1.6 Hz, 2H), 7.10 (dd, *J* = 8.9, 2.5 Hz, 1H), 7.07 (d, *J* = 2.5 Hz, 1H), 6.79 (dd, *J* = 4.0, 1.3 Hz, 1H), 6.71 (dd, *J* = 4.0, 2.7 Hz, 1H), 4.74 (q, *J* = 7.1 Hz, 1H), 3.88 (s, 3H), 1.90 (d, *J* = 7.1 Hz, 3H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 158.85, 141.56, 139.91, 136.16, 130.20, 129.30, 127.45, 127.10, 125.85, 125.01, 113.87, 113.62, 113.43, 106.59, 45.19, 44.44, 30.29, 22.56, 22.54, 20.31.

HRMS (ESI) calculated for $C_{24}H_{21}N_2O$ $[M+H]^+$ 353.1648, found 353.1662.



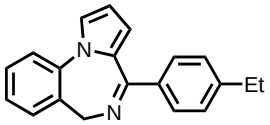


4-(Tosylaminomethyl)-6H-benzo[f]pyrrolo[1,2-a][1,4]diazepine (3s). Prepared according to **general procedure 1A** using 2-(1*H*-pyrrol-1-yl)benzylamine (71.8 mg, 0.4 mmol, 96%, prepared according to literature procedure[4]), *N*-tosyl glycine (99.3 mg, 0.42 mmol, 1.05 equiv, 97%), diethyl (methyl)bromomalonate (187 μL, 0.96 mmol, 2.4 equiv, 98%), and phenylsilane (111 μL, 0.88 mmol, 2.2 equiv, 98%) in 1,2-dichloroethane. Column eluted with 30% EtOAc/hexanes. Yield: 66% yield (96.0 mg). Off-white foam.

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.71 (d, *J* = 8.3 Hz, 2H), 7.40 – 7.33 (m, 2H), 7.31 – 7.27 (m, 2H), 7.22 (d, *J* = 7.9 Hz, 1H), 7.17 (d, *J* = 8.3 Hz, 2H), 6.62 (dd, *J* = 3.9, 1.6 Hz, 1H), 6.39 (t, *J* = 3.4 Hz, 1H), 6.14 – 6.05 (bs, 1H), 4.41 (bs, 2H), 3.99 (bs, 2H), 2.33 (s, 3H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 156.90, 143.30, 138.75, 136.60, 132.12, 129.58, 129.34, 128.99, 127.84, 127.34, 127.18, 124.60, 122.46, 112.83, 110.43, 53.24, 46.87, 21.62.

HRMS (ESI) calculated for $C_{20}H_{20}N_3O_2S$ $[M+H]^+$ 366.1271, found 366.1258.

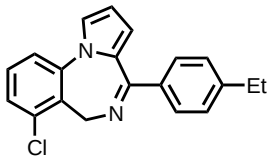


4-(4-Ethylphenyl)-6H-benzo[f]pyrrolo[1,2-a][1,4]diazepine (3t). Prepared according to **general procedure 1A** using 2-(1*H*-pyrrol-1-yl)benzylamine (71.8 mg, 0.4 mmol, 96%, prepared according to literature procedure[4]), *p*-ethylbenzoic acid (64.4 mg, 0.42 mmol, 98%), diethyl (methyl)bromomalonate (187 μL, 0.96 mmol, 2.4 equiv, 98%), and diphenylsilane (340 μL, 1.76 mmol, 4.4 equiv, 96%) in MeCN. Column eluted with 25% EtOAc/hexanes. Yield: 86% yield (98.6 mg). Waxy yellow solid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.63 (d, *J* = 8.2 Hz, 2H), 7.48 (d, *J* = 7.4 Hz, 1H), 7.39 – 7.36 (m, 2H), 7.36 – 7.33 (m, 1H), 7.31 – 7.25 (m, 1H), 7.18 (d, *J* = 8.2 Hz, 2H), 6.51 (dd, *J* = 3.9, 1.7 Hz, 1H), 6.43 (t, *J* = 3.3 Hz, 1H), 5.09 – 4.25 (m, 2H), 2.67 (q, *J* = 7.6 Hz, 2H), 1.23 (t, *J* = 7.6 Hz, 3H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 162.72, 146.66, 139.22, 137.66, 133.85, 129.97, 129.60, 129.25, 128.67, 127.54, 126.96, 123.91, 122.36, 116.28, 109.43, 54.45, 28.85, 15.58.

HRMS (ESI) calculated for $C_{20}H_{19}N_2$ $[M+H]^+$ 287.1543, found 287.1537.

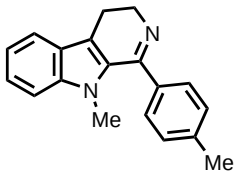


7-Chloro-4-(4-ethylphenyl)-6H-benzo[f]pyrrolo[1,2-a][1,4]diazepine (3u). Prepared according to **general procedure 1A** using 2-chloro-6-(1H-pyrrol-1-yl)benzylamine (87.0 mg, 0.4 mmol, 95%, prepared according to modified literature procedure described in **Section VII-C**), *p*-ethylbenzoic acid (64.4 mg, 0.42 mmol, 98%), diethyl (methyl)bromomalonate (187 μL, 0.96 mmol, 2.4 equiv, 98%), and diphenylsilane (340 μL, 1.76 mmol, 4.4 equiv, 96%) in MeCN. Column eluted with 5% EtOAc/hexanes. Yield: 73% yield (93.6 mg). Colorless solid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.64 (d, *J* = 8.2 Hz, 2H), 7.37 (dd, *J* = 7.3, 2.0 Hz, 1H), 7.34 – 7.30 (m, 1H), 7.30 – 7.26 (m, 2H), 7.19 (d, *J* = 8.3 Hz, 2H), 6.52 (dd, *J* = 3.9, 1.6 Hz, 1H), 6.44 (t, *J* = 3.4 Hz, 1H), 5.49 (bs, 1H), 4.16 (bs, 1H), 2.67 (q, *J* = 7.6 Hz, 2H), 1.24 (t, *J* = 7.6 Hz, 3H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 163.73, 146.84, 140.64, 137.33, 133.82, 131.95, 130.17, 129.68, 128.75, 127.89, 127.59, 124.22, 121.30, 116.47, 109.77, 50.23, 28.86, 15.60.

HRMS (ESI) calculated for $C_{20}H_{18}ClN_2$ $[M+H]^+$ 321.1153, found 321.1153.

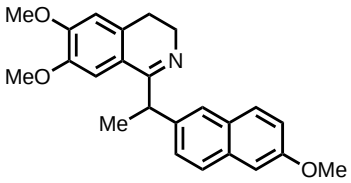


1-(*p*-Tolyl)-9-methyl-3,4-dihydro-β-carboline (3v). Prepared according to **general procedure 1A** using 1-methyltryptamine (72.6 mg, 0.4 mmol, 96%, prepared according to literature procedure[5]), *p*-toluic acid (58.4 mg, 0.42 mmol, 1.05 equiv, 98%), diethyl (methyl)bromomalonate (187 μL, 0.96 mmol, 2.4 equiv, 98%), and phenylsilane (111 μL, 0.88 mmol, 2.2 equiv, 98%) in 1,2-dichloroethane. Column eluted with gradient 1-5% MeOH/DCM. Yield: 77% yield (84.5 mg). Yellow foam.

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.57 (d, *J* = 8.0 Hz, 1H), 7.40 (d, *J* = 8.1 Hz, 2H), 7.27 – 7.21 (m, 2H), 7.17 (d, *J* = 8.1 Hz, 2H), 7.10 (t, *J* = 7.1 Hz, 1H), 3.83 (t, *J* = 7.9 Hz, 2H), 3.26 (s, 3H), 2.82 (t, *J* = 7.9 Hz, 2H), 2.33 (s, 3H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 160.26, 139.66, 139.29, 136.64, 131.11, 129.30, 128.05, 124.85, 124.41, 120.17, 119.57, 110.47, 48.88, 33.04, 21.53, 20.02.

HRMS (ESI) calculated for $C_{19}H_{19}N_2$ $[M+H]^+$ 275.1543, found 275.1544.



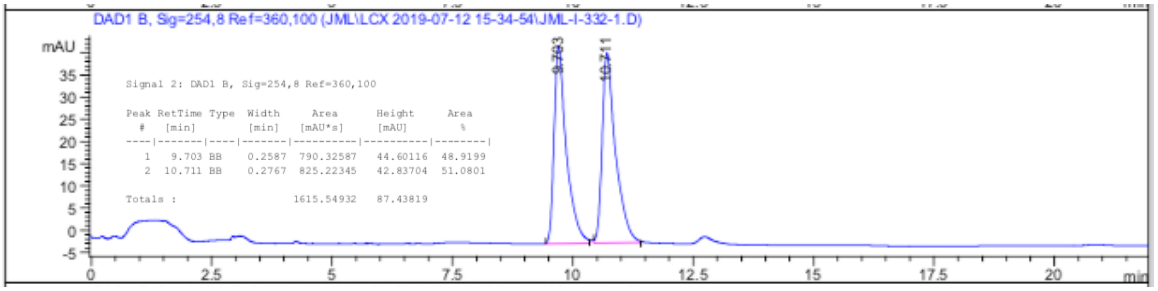
(±)-6,7-Dimethoxy-1-(1-(6-methoxynaphthalen-2-yl)ethyl)-3,4-dihydroisoquinoline (3w). Prepared according to **general procedure 1A** using 2-(3,4-dimethoxyphenyl)ethan-1-amine (69.1 µL, 0.4 mmol, 98%), (*S*)-naproxen (98.7 mg, 0.42 mmol, 1.05 equiv, 98%), diethyl (methyl)bromomalonate (187 µL, 0.96 mmol, 2.4 equiv, 98%), and phenylsilane (111 µL, 0.88 mmol, 2.2 equiv, 98%) in 1,2-dichloroethane. Column eluted with 75% EtOAc/hexanes + 1% NEt_3. Yield: 71% yield (106.3 mg), racemic. Waxy yellow solid. HPLC analysis of purified product (Chiralpak AD-H, 15-25% IPA in hexanes, 1.0 mL/min, 20 minutes, 254 nm) indicated 50:50 er: t_R(peak1) = 9.7 min, t_R(peak2) = 10.7 min.

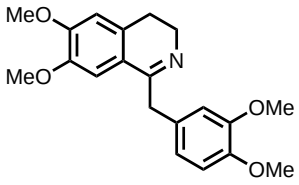
Under modified **general procedure 1C**, the purified product was also found to be racemic.

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.69 – 7.62 (m, 3H), 7.43 (dd, *J* = 8.4, 2.0 Hz, 1H), 7.10 (dd, *J* = 8.8, 2.6 Hz, 1H), 7.07 (d, *J* = 2.7 Hz, 1H), 6.98 (s, 1H), 6.61 (s, 1H), 4.41 (q, *J* = 6.9 Hz, 1H), 3.89 (s, 3H), 3.83 (s, 3H), 3.87 – 3.81 (m, 1H), 3.81 – 3.75 (m, 1H), 3.62 (s, 3H), 2.65 (tt, *J* = 6.4, 3.4 Hz, 2H), 1.61 (d, *J* = 6.9 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 167.80, 157.50, 150.34, 147.16, 140.14, 133.42, 131.95, 129.37, 129.16, 127.43, 126.58, 125.65, 122.19, 118.94, 110.22, 109.62, 105.74, 55.97, 55.41, 47.43, 45.08, 26.02, 21.15.

HRMS (ESI) calculated for $C_{24}H_{26}N_3O$ $[M+H]^+$ 376.1907, found 376.1913.

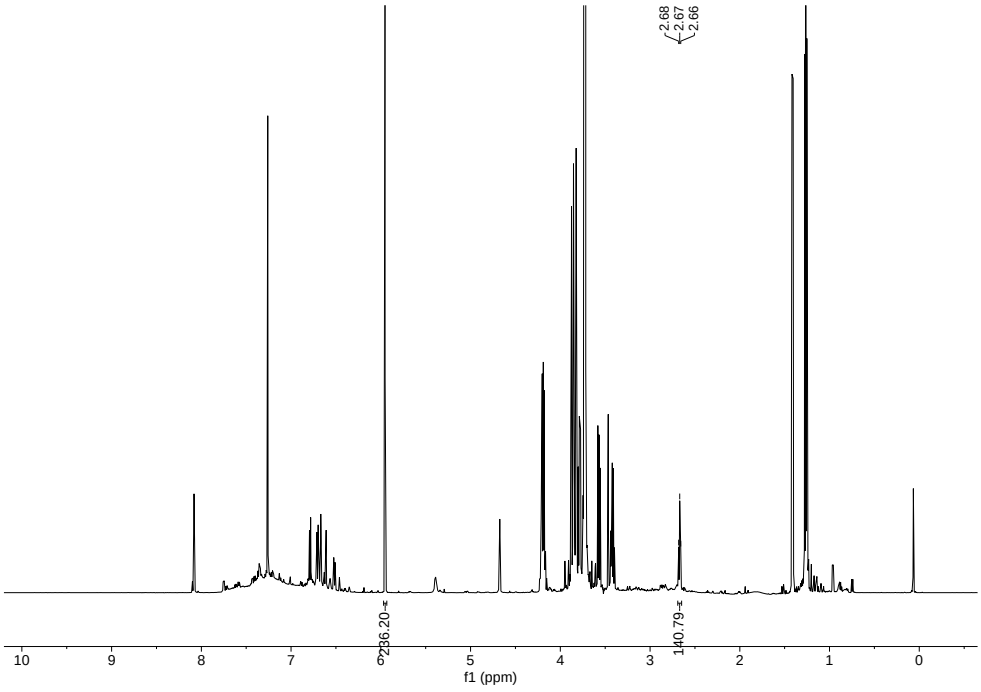




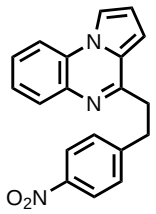
3,4-Dihydropapaverine (3x). Prepared according to **general procedure 1A** using 2-(3,4-dimethoxyphenyl)ethan-1-amine (68.9 μL, 0.4 mmol, 98%), 2-(3,4-dimethoxyphenyl)acetic acid (84.1 mg, 0.42 mmol, 98%), diethyl (methyl)bromomalonate (187 μL, 2.4 mmol, 2.4 equiv, 98%), and phenylsilane (111 μL, 0.88 mmol, 2.2 equiv) in 1,2-dichloromethane. After workup and concentration, to the crude residue was added 1,1,2,2-tetrachloroethane (50 μL, 0.472 mmol, 1.181 equiv) and 4 mL $CDCl_3$. An aliquot was diluted further with $CDCl_3$ for analysis by ^1H NMR, indicating 70% yield of **3o** based on the triplet resonance at 2.67 ppm in the reported spectra.[6] The crude residue could be purified by flash chromatography on silica, eluting with either 5% NEt_3/EtOAc or 10% MeOH/EtOAc, to render the product as a single spot by TLC. However, upon concentration of the column fractions, oxidative degradation to the corresponding ketone (6,7-dimethoxy-3,4-dihydroisoquinolin-1-yl)(3,4-dimethoxyphenyl)methanone was observed (16% impurity), and confirmed by HRMS.

HRMS (ESI) calculated for $C_{20}H_{24}NO_4$ $[M+H]^+$ 342.1700, found 342.1702.

HRMS (ESI) calculated for $C_{20}H_{22}NO_5$ $[M+H]^+$ 356.1492, found 356.1496 (ketone degradation).



IV. Iterative Dehydration/Deoxygenation of Bifunctional Nitroacid Substrate

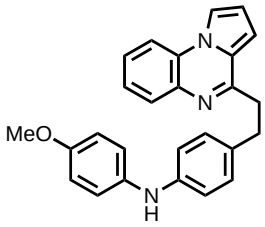


4-(4-Nitrophenethyl)pyrrolo[1,2-*a*]quinoxaline (11). An oven-dried 40 mL vial equipped with magnetic stir bar was charged with 2-(1*H*-pyrrol-1-yl)aniline (323 mg, 2.0 mmol), *p*-nitrohydrocinnamic acid (418 mg, 2.1 mmol, 1.05 equiv), and **4•**[O] (52.3 mg, 0.3 mmol, 0.15 equiv). The flask was capped with a septa cap, sealed with Teflon tape and parafilm, and then placed under N_2 atmosphere and evacuated/backfilled 3x with N_2. Under N_2 atmosphere, 1,2-dichloroethane (8 mL, 250 mM) was added by syringe, followed by diethylbromomalonate (0.84 mL, 4.8 mmol, 2.4 equiv, 98%) and phenylsilane (555 μL, 4.4 mmol, 2.2 equiv). The N_2 inlet needle was removed and the septum was sealed with melted parafilm. The reaction mixture was heated to 80 °C in an oil bath and stirred for 14 h. Upon completion, the reaction was cooled to room temperature, poured into 150 mL of 1M aqueous NaOH solution, and extracted with 4x75 mL DCM. The combined DCM layers were dried over $MgSO_4$, filtered, and concentrated. The crude residue was then adsorbed onto silica gel from DCM and purified by flash column chromatography on silica gel eluted with 30% EtOAc/hexanes to provide **11** as a pale yellow solid (617 mg, 97% yield).

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.13 (d, *J* = 8.6 Hz, 2H), 7.95 – 7.90 (m, 2H), 7.84 (dd, *J* = 8.2, 1.4 Hz, 1H), 7.50 (td, *J* = 7.7, 1.5 Hz, 1H), 7.47 – 7.42 (m, 3H), 6.85 (qd, *J* = 4.0, 1.9 Hz, 2H), 3.59 – 3.26 (m, 4H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 155.01, 149.68, 146.61, 135.91, 134.19, 129.64, 129.50, 127.41, 127.38, 125.90, 125.36, 123.81, 114.58, 113.83, 113.75, 106.03, 36.28, 33.51.

HRMS (ESI) calculated for $C_{19}H_{16}N_3O_2$ $[M+H]^+$ 318.1237, found 318.1232.



4-Methoxy-*N*-(4-(2-(pyrrolo[1,2-*a*]quinoxalin-4-yl)ethyl)phenyl)aniline (12). Prepared by reductive C–N cross-coupling.[7] An oven-dried 4 mL vial equipped with magnetic stir bar was charged with 4-(4-nitrophenethyl)pyrrolo[1,2-*a*]quinoxaline (**10**) (127 mg, 0.4 mmol), *p*-methoxyphenylboronic acid (66.9 mg, 0.44 mmol, 1.1 equiv), and **4•**[O] (10.5 mg, 0.06 mmol, 0.15 equiv). The vial was capped with a septa cap, sealed with Teflon tape and parafilm, and then placed under N_2 atmosphere and evacuated/backfilled 3x with N_2. Under N_2 atmosphere, *m*-xylene (0.8 mL, 500 mM) was added by syringe, followed by phenylsilane (101 μL, 0.8 mmol, 2.0 equiv). The N_2 inlet needle was removed and the septum was sealed with melted parafilm. The reaction mixture was heated to 120 °C and stirred for 8 h. Upon completion, the reaction was cooled to room temperature, poured into 25 mL of 1M aqueous NaOH solution, and extracted with 4x25 mL EtOAc. The combined EtOAc layers were dried over $MgSO_4$, filtered, and concentrated. The crude residue was then adsorbed onto silica gel from DCM and purified by flash column chromatography on silica gel eluted with 15% acetone/hexanes followed by a second column eluted with 0-4% EtOAc/DCM to provide **12** as an off-white solid (114.0 mg, 72% yield).

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.96 (d, *J* = 7.8 Hz, 1H), 7.92 (d, *J* = 2.7 Hz, 1H), 7.84 (d, *J* = 8.0 Hz, 1H), 7.47 (dt, *J* = 19.7, 7.3 Hz, 2H), 7.19 (d, *J* = 7.9 Hz, 2H), 7.05 (d, *J* = 8.5 Hz, 2H), 6.92 – 6.81 (m, 6H), 5.45 (bs, 1H), 3.80 (s, 3H), 3.30 (dd, *J* = 10.6, 5.9 Hz, 2H), 3.16 (dd, *J* = 10.4, 6.0 Hz, 2H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 156.64, 155.12, 143.30, 136.43, 136.16, 133.22, 129.65, 129.43, 127.45, 127.12, 126.10, 125.25, 121.66, 116.45, 114.81, 114.32, 113.79, 113.65, 106.32, 55.75, 38.05, 33.65.

HRMS (ESI) calculated for $C_{26}H_{24}N_3O$ $[M+H]^+$ 394.1914, found 394.1902.

V. Examples of Catalytic Cyclodehydration

A. Scope Table

Cyclodehydration of arene-tethered amides via the Bischler-Napieralski reaction is classically accomplished using superstoichiometric dehydrating reagents such as $POCl_3$ and P_2O_5.[8] Modern variants employing stoichiometrically-generated halophosphoniums from phosphites have recently been developed.[9] Using the conditions described in **Section II-B**, Table S4 describes the first reported phosphacatalytic variant of the Bischler-Napieralski cyclodehydration reaction.

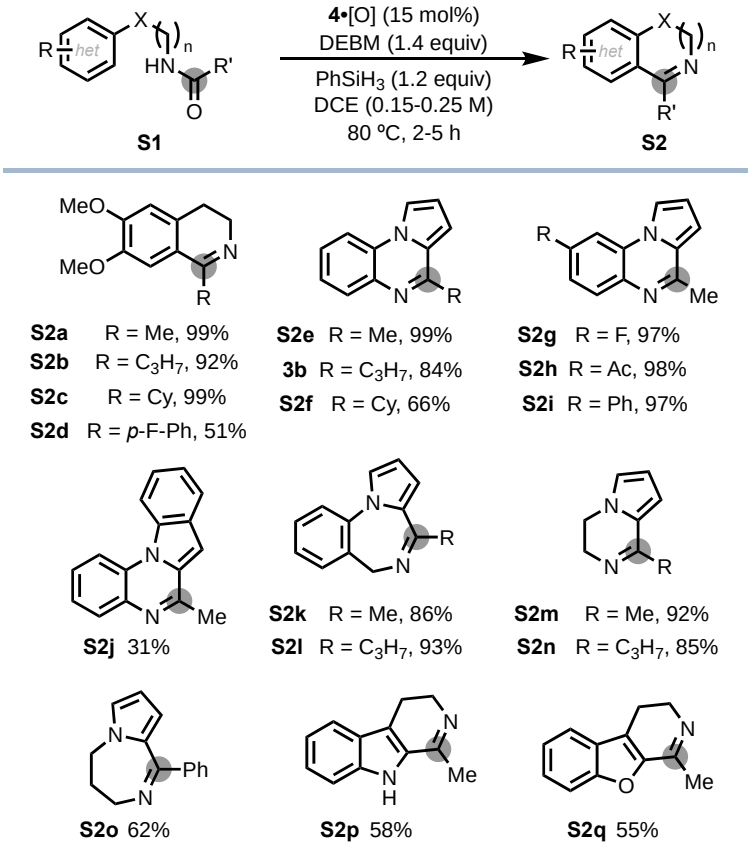
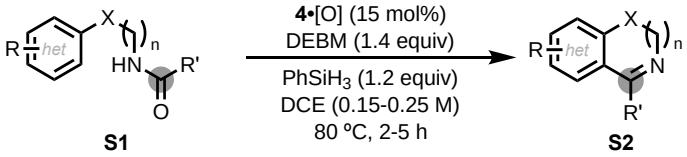


Table S4. Scope of the cyclodehydration of tethered amides. All yields isolated on 0.4 mmol scale. Full synthetic details available in **Section V-C**.

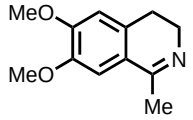
B. General Procedures



General Procedure 2A. An oven-dried 4 mL vial equipped with magnetic stir bar was charged with amide **S1** (0.4 mmol) and **4•**[O] (10.5 mg, 0.06 mmol, 0.15 equiv). The vial was capped with a septa cap, sealed with Teflon tape and parafilm, and then placed under N_2 atmosphere and evacuated/backfilled 3x with N_2. Under N_2 atmosphere, 1,2-dichloroethane (1.6 mL, 250 mM or 2.6 mL, 150 mM) was added by syringe, followed by diethyl bromomalonate (104 μL, 0.56 mmol, 1.2 equiv, 92%) and phenylsilane (59 μL, 0.48 mmol, 1.2 equiv, 98%). The N_2 inlet needle was removed and the septum was sealed with melted parafilm. The reaction mixture was heated to 80 °C and stirred for 2 h. Upon completion (as indicated by monitoring by TLC), the reaction was cooled to room temperature, poured into 20 mL of 1M aqueous NaOH solution, and extracted with 4x25 mL DCM. The combined DCM layers were dried over $MgSO_4$, filtered, and concentrated. The crude residue was then purified by flash column chromatography on silica gel by eluting with the indicated solvent.

General Procedure 2B. An oven-dried 4 mL vial equipped with magnetic stir bar was charged with amide **S1** (0.4 mmol) and **4•**[O] (10.5 mg, 0.06 mmol, 0.15 equiv). The vial was capped with a septa cap, sealed with Teflon tape and parafilm, and then placed under N_2 atmosphere and evacuated/backfilled 3x with N_2. Under N_2 atmosphere, 1,2-dichloroethane (1.6 mL, 250 mM or 2.6 mL, 150 mM) was added by syringe, followed by diethyl bromomalonate (104 μL, 0.56 mmol, 1.2 equiv, 92%) and phenylsilane (59 μL, 0.48 mmol, 1.2 equiv, 98%). The N_2 inlet needle was removed and the septum was sealed with melted parafilm. The reaction mixture was heated to 80 °C and stirred for 2 h. Upon completion (as indicated by monitoring by TLC), the reaction was cooled to room temperature, poured into 20 mL of DCM and extracted with 4x25 mL 10 M aqueous HCl solution. The combined aqueous layer was stirred in an ice bath and carefully basified by slow addition of 10 M aqueous NaOH solution. Upon reaching pH 14, the aqueous layer was extracted with 4x25 mL DCM. The combined DCM layers were dried over $MgSO_4$, filtered, and concentrated. The crude residue was then purified by flash column chromatography on silica gel by eluting with the indicated solvent.

B. Analytical Data

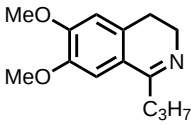


6,7-Dimethoxy-1-methyl-3,4-dihydroisoquinoline (S2a). Prepared according to **general procedure 2A** using *N*-(3,4-dimethoxyphenethyl)acetamide[10] (89 mg, 0.4 mmol) in 1,2-dichloroethane (1.6 mL, 250 mM) for 2 h. Column eluted with 1% NEt_3/EtOAc. Yield: 90% yield (74 mg). Pale yellow solid.

^{1}H NMR (400 MHz, $CDCl_3$) δ 6.98 (s, 1H), 6.68 (s, 1H), 3.91 (s, 3H), 3.90 (s, 3H), 3.62 (td, J = 7.5 and 1.1 Hz, 2H); 2.63 (t, J = 7.4 Hz, 2H); 2.36 (s, 3H).

^{13}C NMR (100 MHz, $CDCl_3$) δ 163.8, 150.9, 147.5, 131.2, 122.6, 110.3, 109.1, 56.3, 56.1, 47.2, 25.9, 23.6.

HRMS (ESI) calculated for $C_{12}H_{16}NO_2$ $[M+H]^+$ 206.1176, found 206.1173.

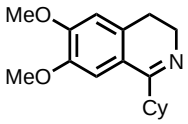


6,7-Dimethoxy-1-propyl-3,4-dihydroisoquinoline (S2b). Prepared according to **general procedure 2A** using *N*-(3,4-dimethoxyphenethyl)butyramide[10,11] (100 mg, 0.4 mmol) in 1,2-dichloroethane (1.6 mL, 250 mM) for 2 h. Column eluted with 1% NEt_3/EtOAc. Yield: 92% yield (86 mg). White solid.

^{1}H NMR (400 MHz, $CDCl_3$) δ 6.99 (s, 1H), 6.69 (s, 1H), 3.91 (s, 3H), 3.90 (s, 3H), 3.62 (t, J = 7.4 Hz, 2H); 2.66 (t, J = 7.6 Hz, 2H); 2.60 (t, J = 7.6 Hz, 2H); 1.68 (sext, J = 7.5 Hz, 2H); 0.98 (t, J = 7.4 Hz, 3H).

^{13}C NMR (100 MHz, $CDCl_3$) δ 166.7, 150.7, 147.5, 131.7, 122.1, 110.5, 109.0, 56.4, 56.1, 47.1, 38.2, 26.0, 20.6, 14.2.

HRMS (ESI) calculated for $C_{14}H_{20}NO_2$ $[M+H]^+$ 234.1489, found 234.1487.

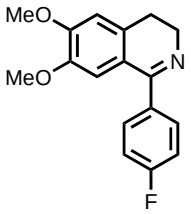


6,7-Dimethoxy-1-cyclohexyl-3,4-dihydroisoquinoline (S2c). Prepared according to **general procedure 2A** using *N*-(3,4-dimethoxyphenethyl)cyclohexanecarboxamide[11,12] (117 mg, 0.4 mmol) in 1,2-dichloroethane (1.6 mL, 250 mM) for 2 h. Column eluted with 1% NEt_3/EtOAc. Yield: 99% yield (109 mg). White solid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.03 (s, 1H), 6.69 (s, 1H), 3.91 (s, 3H), 3.91 (s, 3H), 3.61 (t, *J* = 7.5 Hz, 2H), 2.81 (app. tt, *J* = 11.2 and 3.4 Hz, 1H), 2.57 (t, *J* = 7.6 Hz, 2H), 1.91 – 1.81 (m, 4H), 1.77 – 1.71 (m, 1H), 1.49 – 1.34 (m, 4H), 1.31 – 1.22 (m, 1H).

^{13}C NMR (150 MHz, $CDCl_3$) δ 170.3, 150.7, 147.6, 132.2, 121.8, 110.6, 108.8, 56.5, 56.1, 47.1, 42.4, 31.5, 26.7, 26.4, 26.2.

HRMS (ESI) calculated for $C_{17}H_{24}NO_2$ $[M+H]^+$ 274.1802, found 274.1812.



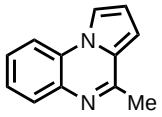
6,7-Dimethoxy-1-(4-fluorophenyl)-3,4-dihydroisoquinoline (S2d). Prepared according to **general procedure 2A** using *N*-(3,4-dimethoxyphenethyl)-4-fluorobenzamide[11] (121 mg, 0.4 mmol) in 1,2-dichloroethane (1.6 mL, 250 mM) for 2 h. Column eluted with 33% EtOAc/hexanes + 1% NEt_3. Yield: 51% yield (58.2 mg). White solid.

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.64 – 7.53 (m, 2H), 7.10 (t, *J* = 8.7 Hz, 2H), 6.76 (d, *J* = 14.7 Hz, 2H), 3.93 (s, 3H), 3.78 (t, *J* = 7.5 Hz, 2H), 3.72 (s, 3H), 2.71 (t, *J* = 7.5 Hz, 2H).

^{13}C NMR (126 MHz, $CDCl_3$) δ 165.8, 163.6 (d, *J* = 248.6 Hz), 151.1, 147.2, 135.4 (d, *J* = 3.2 Hz), 132.8, 130.7 (d, *J* = 8.3 Hz), 121.5, 115.2 (d, *J* = 21.4 Hz), 111.4, 110.4, 56.2, 56.1, 47.7, 26.1.

^{19}F NMR (471 MHz, $CDCl_3$) δ -112.03.

HRMS (ESI) Calculated for $C_{17}H_{17}FNO_2$ $[M+H]^+$ 286.1243, found: 286.1235.

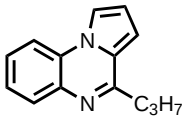


4-Methylpyrrolo[1,2-*a*]quinoxaline (S2e). Prepared according to **general procedure 2A** using *N*-(2-(1*H*-pyrrol-1-yl)phenyl)acetamide[13] (80 mg, 0.4 mmol) in 1,2-dichloroethane (2.6 mL, 150 mM) for 5 h. Column eluted with 20% EtOAc/hexanes. Yield: 99% yield (72 mg). Pale beige solid.

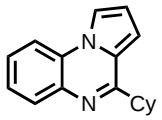
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.92 – 7.88 (m, 2H), 7.83 (dd, J = 8.0 and 1.5 Hz, 1H), 7.48 (td, J = 7.9 and 1.6 Hz, 1H), 7.42 (td, J = 7.8 and 1.6 Hz, 1H), 6.89 (dd, J = 3.9 and 1.3 Hz, 1H), 6.85 (dd, J = 4.0 and 2.7 Hz, 1H), 2.73 (s, 3H).

^{13}C NMR (100 MHz, $CDCl_3$) δ 153.8, 136.1, 129.4, 127.4, 127.1, 126.4, 125.2, 114.3, 113.8, 113.6, 106.6, 22.2.

HRMS (ESI) calculated for $C_{12}H_{11}N_2$ $[M+H]^+$ 183.0917, found 183.0930.



4-Propylpyrrolo[1,2-*a*]quinoxaline (3b). Prepared according to **general procedure 2B** using *N*-(2-(1*H*-pyrrol-1-yl)phenyl)butyramide[13] (91 mg, 0.4 mmol) in 1,2-dichloroethane (2.6 mL, 150 mM) for 5 h. Column eluted with 10% EtOAc/hexanes. Yield: 84% yield (70.5 mg). Pale orange solid. Characterization described in **Section III-B**.

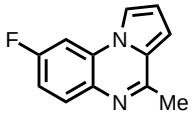


4-Cyclohexylpyrrolo[1,2-*a*]quinoxaline (S2f). Prepared according to **general procedure 2A** using *N*-(2-(1*H*-pyrrol-1-yl)phenyl)cyclohexanecarboxamide[13] (107 mg, 0.4 mmol) in 1,2-dichloroethane (1.6 mL, 250 mM) for 5 h. Column eluted with 10% EtOAc/hexanes. Yield: 66% yield (64 mg). White solid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.93 (d, *J* = 7.6 Hz, 1H), 7.89 (d, *J* = 1.3 Hz, 1H), 7.82 (d, *J* = 7.9 Hz, 1H), 7.47 – 7.43 (m, 1H), 7.42 – 7.39 (m, 1H), 6.96 (d , *J* = 3.5 Hz, 1H), 6.85 – 6.82 (m, 1H), 3.13 (tt, *J* = 11.8 and 3.3 Hz, 1H), 2.06 – 2.00 (m, 2H), 1.97 – 1.78 (m, 5H), 1.54 – 1.36 (m, 3H).

^{13}C NMR (150 MHz, $CDCl_3$) δ 161.2, 136.4, 129.9, 127.4, 126.8, 125.8, 125.1, 114.0, 113.6, 113.3, 105.8, 43.8, 31.4, 26.8, 26.3.

HRMS (ESI) calculated for $C_{17}H_{19}N_2$ $[M+H]^+$ 251.1543, found 251.1543.



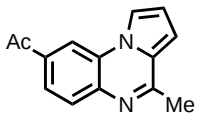
8-Fluoro-4-methylpyrrolo[1,2-*a*]quinoxaline (S2g). Prepared according to **general procedure 2A** using *N*-(4-fluoro-2-(1*H*-pyrrol-1-yl)phenyl)acetamide **S1g** (87.3 mg, 0.4 mmol, synthesis described in **Section VII**) in 1,2-dichloroethane (2.6 mL, 150 mM) for 5 h. Column eluted with 25% EtOAc/hexanes. Yield: 97% yield (77.7 mg). Yellow solid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.83 (dd, *J* = 8.9, 5.8 Hz, 1H), 7.71 (s, 1H), 7.41 (dd, *J* = 9.2, 2.7 Hz, 1H), 7.10 (td, *J* = 8.6, 2.7 Hz, 1H), 6.87 – 6.80 (m, *J* = 12.4, 3.6 Hz, 2H), 2.68 (s, 3H).

^{13}C NMR (150 MHz, $CDCl_3$) δ 161.0 (d, *J* = 247.1 Hz), 152.8, 132.5, 131.0 (d, *J* = 9.6 Hz), 127.9 (d, *J* = 11.1 Hz), 126.0, 114.4, 114.0, 112.9 (d, *J* = 23.0 Hz), 106.8, 100.5 (d, *J* = 26.8 Hz), 21.9.

^{19}F NMR (565 MHz, CDCl3) δ -111.94.

HRMS (ESI) calculated for $C_{12}H_{10}FN_2$ $[M+H]^+$ 201.0823, found: 201.0828.

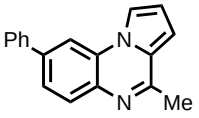


8-Acetyl-4-methylpyrrolo[1,2-*a*]quinoxaline (S2h). Prepared according to **general procedure 2A** using *N*-(4-acetyl-2-(1*H*-pyrrol-1-yl)phenyl)acetamide **S1h** (96.9 mg, 0.4 mmol, synthesis described in **Section VII**) in 1,2-dichloroethane (2.6 mL, 150 mM) for 5 h. Column eluted with 33% EtOAc/hexanes. Yield: 98% yield (87.9 mg). Yellow solid.

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.43 (d, *J* = 1.8 Hz, 1H), 8.01 (dd, *J* = 2.8, 1.3 Hz, 1H), 7.95 (dd, *J* = 8.4, 1.8 Hz, 1H), 7.91 (d, *J* = 8.4 Hz, 1H), 6.94 (dd, *J* = 4.1, 1.2 Hz, 1H), 6.87 (dd, *J* = 4.0, 2.7 Hz, 1H), 2.73 (s, 3H), 2.70 (s, 3H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 197.0, 156.2, 139.4, 134.8, 129.3, 127.3, 126.3, 125.2, 115.4, 114.1, 113.8, 107.9, 26.9, 22.2.

HRMS (ESI) calculated for $C_{14}H_{13}N_2O$ $[M+H]^+$ 225.1028, found: 225.1023.

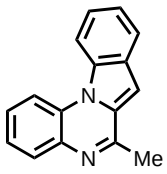


8-Phenyl-4-methylpyrrolo[1,2-*a*]quinoxaline (S2i). Prepared according to **general procedure 2A** using *N*-(4-phenyl-2-(1*H*-pyrrol-1-yl)phenyl)acetamide **S1i** (110.5 mg, 0.4 mmol, synthesis described in **Section VII**) in 1,2-dichloroethane (2.6 mL, 150 mM) for 5 h. Column eluted with 25% EtOAc/hexanes. Yield: 97% yield (100.2 mg). Colorless oil.

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.01 – 7.90 (m, 3H), 7.71 – 7.66 (m, 2H), 7.64 (d, *J* = 8.4 Hz, 1H), 7.51 – 7.47 (m, 2H), 7.40 (t, *J* = 7.4 Hz, 1H), 6.91 – 6.88 (m, 1H), 6.85 (dd, *J* = 4.0, 2.6 Hz, 1H), 2.73 (s, 3H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 153.6, 140.4, 140.1, 135.3, 129.6, 129.1, 127.9, 127.6, 127.4, 126.5, 124.3, 114.4, 113.7, 112.1, 106.8, 22.1.

HRMS (ESI) calculated for $C_{18}H_{15}N_2$ $[M+H]^+$ 259.1235, found: 259.1238.

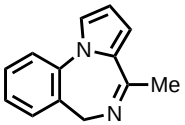


6-Methylindolo[1,2-*a*]quinoxaline (S2j). Prepared according to **general procedure 2A** using *N*-(2-(1*H*-indol-1-yl)phenyl)acetamide[14] **S1j** (100 mg, 0.4 mmol) in 1,2-dichloroethane (2.6 mL, 150 mM) for 5 h. Column eluted with 5% EtOAc/hexanes. Yield: 31% yield (29 mg). Pale yellow solid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.47 (dd, J = 13.3 and 8.3 Hz, 2H), 7.99 – 7.92 (m, 2H), 7.61 – 7.52 (m, 2H), 7.44 (dt, J = 12.5 and 7.6 Hz, 2H), 7.17 (s, 1H), 2.82 (s, 3H).

^{13}C NMR (150 MHz, $CDCl_3$) δ 155.4, 136.0, 133.1, 130.4, 130.0, 129.7, 129.2, 128.0, 124.4, 124.2, 122.8, 122.7, 114.8, 114.7, 100.2, 22.5.

HRMS (ESI) calculated for $C_{16}H_{13}N_2$ $[M+H]^+$ 233.1073, found 233.1074.

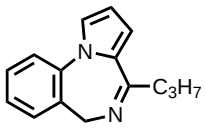


4-Methyl-6*H*-benzo[*f*]pyrrolo[1,2-*a*][1,4]diazepine (S2k). Prepared according to **general procedure 2A** using *N*-(2-(1*H*-pyrrol-1-yl)benzyl)acetamide[13,15] (86 mg, 0.4 mmol) in 1,2-dichloroethane (2.6 mL, 150 mM) for 5 h. Column eluted with 50% EtOAc/hexanes. Yield: 85% yield (67 mg). Pale yellow oil.

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.45 – 7.40 (m, 1H), 7.35 (td, J = 7.5, 1.6 Hz, 1H), 7.31 – 7.24 (m, 3H), 6.69 (dd, J = 3.8, 1.6 Hz, 1H), 6.43 – 6.38 (m, 1H), 4.45 (bs, 2H), 2.32 (s, 3H).

^{13}C NMR (126 MHz, $CDCl_3$) δ 161.65, 139.03, 132.71, 130.81, 129.19, 128.63, 128.61, 126.93, 123.51, 122.24, 113.46, 109.86, 54.00, 26.30.

HRMS (ESI) calculated for $C_{13}H_{13}N_2$ $[M+H]^+$ 197.1073, found 197.1074.

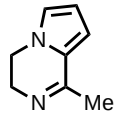


4-Propyl-6*H*-benzo[*f*]pyrrolo[1,2-*a*][1,4]diazepine (S2l). Prepared according to **general procedure 2A** using *N*-(2-(1*H*-pyrrol-1-yl)benzyl)butyramide[15] (97 mg, 0.4 mmol) in 1,2-dichloroethane (2.6 mL, 150 mM) for 5 h. Column eluted with 5% EtOAc/hexanes. Yield: 93% yield (83 mg). Pale yellow oil.

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.43 (d, *J* = 7.4 Hz, 1H), 7.35 (td, *J* = 7.7, 1.5 Hz, 1H), 7.31 – 7.27 (m, 3H), 6.68 (dd, *J* = 3.8, 1.6 Hz, 1H), 6.40 (t, *J* = 3.3 Hz, 1H), 4.45 (bs, 2H), 2.58 (t, *J* = 7.6 Hz, 2H), 1.56 (h, *J* = 7.4 Hz, 2H), 0.83 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 165.12, 139.01, 133.18, 130.70, 129.10, 128.55, 126.82, 123.41, 122.14, 112.87, 109.68, 53.91, 41.38, 20.86, 13.84.

HRMS (ESI) calculated for $C_{15}H_{17}N_2$ $[M+H]^+$ 225.1386, found 225.1389.

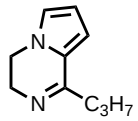


1-Methyl-3,4-dihydropyrrolo[1,2-a]pyrazine (S2m). Prepared according to **general procedure 2A** using *N*-(2-(1*H*-pyrrol-1-yl)ethyl)acetamide[16] **S1m** (61 mg, 0.4 mmol) in 1,2-dichloroethane (1.6 mL, 250 mM) for 5 h. Column eluted with 1% NEt_3/EtOAc. Yield: 91% yield (49 mg). Pale yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ 6.71 (s, 1H), 6.45 (d, *J* = 4.0 Hz, 1H), 6.18 (t, *J* = 3.2 Hz, 1H), 3.90 (t, *J* = 6.2 Hz, 2H), 3.84 – 3.79 (m, 2H), 2.27 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 158.90, 125.80, 122.98, 109.55, 108.62, 47.69, 42.33, 22.45.

HRMS (ESI) calculated for $C_8H_{11}N_2$ $[M+H]^+$ 135.0917, found 135.0922.

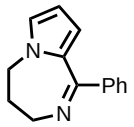


1-Propyl-3,4-dihydropyrrolo[1,2-a]pyrazine (S2n). Prepared according to **general procedure 2A** using *N*-(2-(1*H*-pyrrol-1-yl)ethyl)butyramide[16] **S1n** (72 mg, 0.4 mmol) in 1,2-dichloroethane (1.6 mL, 250 mM) for 5 h. Column eluted with 1% NEt_3/EtOAc. Yield: 85% yield (55 mg). Pale yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ 6.70 (s, 1H), 6.44 (dd, *J* = 3.7, 1.4 Hz, 1H), 6.18 (dd, *J* = 3.7, 2.5 Hz, 1H), 3.93 – 3.85 (m, 2H), 3.85 – 3.79 (m, 2H), 2.54 (t, *J* = 7.7 Hz, 2H), 1.71 (h, *J* = 7.4 Hz, 2H), 0.98 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 162.32, 125.47, 122.87, 109.23, 108.49, 47.68, 42.35, 37.94, 21.11, 14.17.

HRMS (ESI) calculated for $C_{10}H_{15}N_2$ $[M+H]^+$ 163.1230, found 163.1231.

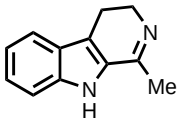


1-Phenyl-4,5-dihydro-3*H*-pyrrolo[1,2-*a*][1,4]diazepine (S2o). Prepared according to **general procedure 2A** using *N*-(3-(1*H*-pyrrol-1-yl)propyl)benzamide **S1o** (91.3 mg, 0.4 mmol, synthesis described in **Section VII**) in 1,2-dichloroethane (1.6 mL, 250 mM) for 5 h. Basic alumina column eluted with 10% EtOAc/hexanes, followed by silica gel column eluted with 1% NEt_3/EtOAc. Yield: 62% yield (52.2 mg). Brown oil.

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.78 (d, *J* = 7.3 Hz, 2H), 7.46 – 7.41 (m, 1H), 7.40 – 7.35 (m, 2H), 6.86 (t, *J* = 1.8 Hz, 1H), 6.25 (dd, *J* = 3.8, 1.6 Hz, 1H), 6.18 (dd, *J* = 3.8, 2.5 Hz, 1H), 4.05 (t, *J* = 7.0 Hz, 2H), 3.71 (t, *J* = 6.5 Hz, 2H), 2.40 (p, *J* = 6.7 Hz, 2H).

^{13}C NMR (126 MHz, $CDCl_3$) δ 164.8, 139.6, 130.2, 129.6, 129.1, 128.1, 124.1, 114.2, 107.5, 50.4, 46.0, 31.7.

HRMS (ESI) calculated for $C_{14}H_{15}N_2$ $[M+H]^+$ 211.1235, found: 211.1234.

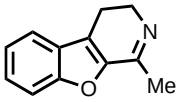


1-Methyl-3,4-dihydro-β-carboline (S2p). Prepared according to **general procedure 2A** using *N*-acetyltryptamine[17] **S1p** (81 mg, 0.4 mmol) in 1,2-dichloroethane (1.6 mL, 250 mM) for 2 h. Column eluted with 5% MeOH/EtOAc + 1% NEt_3. Yield: 58% yield (43 mg). Orange solid.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.73 (bs, 1H), 7.60 (d, *J* = 8.0 Hz, 1H), 7.41 (d, *J* = 8.3 Hz, 1H), 7.33 – 7.24 (m, 1H), 7.16 (t, *J* = 7.5 Hz, 1H), 3.88 (t, *J* = 8.1 Hz, 2H), 2.88 (t, *J* = 8.4 Hz, 2H), 2.39 (d, *J* = 1.6 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 157.88, 136.82, 129.16, 125.67, 124.72, 120.53, 120.23, 116.83, 112.12, 48.25, 22.10, 19.46.

HRMS (ESI) calculated for $C_{12}H_{13}N_2$ $[M+H]^+$ 185.1073, found 185.1087.



1-Methyl-3,4-dihydrobenzofuro[2,3-*c*]pyridine (S2q). Prepared according to **general procedure 2A** using *N*-(2-(benzofuran-3-yl)ethyl)acetamide[17,18] **S1q** (81.3 mg, 0.4 mmol) in 1,2-dichloroethane (1.6 mL, 250 mM) for 5 h. Column eluted with EtOAc. Yield: 55% yield (40.8 mg). Brown oil.

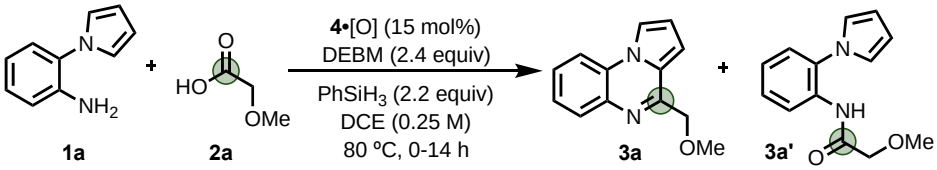
^{1}H NMR (600 MHz, $CDCl_3$) δ 7.55 (d, *J* = 7.8 Hz, 1H), 7.51 (d, *J* = 8.3 Hz, 1H), 7.38 (t, *J* = 7.8 Hz, 1H), 7.28 (t, *J* = 7.5 Hz, 1H), 3.90 (tq, *J* = 8.6, 1.3 Hz, 2H), 2.87 (t, *J* = 8.8 Hz, 2H), 2.38 (t, *J* = 1.7 Hz, 3H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 157.8, 154.9, 147.6, 126.6, 126.6, 123.4, 120.7, 119.8, 112.3, 47.8, 20.9, 19.6.

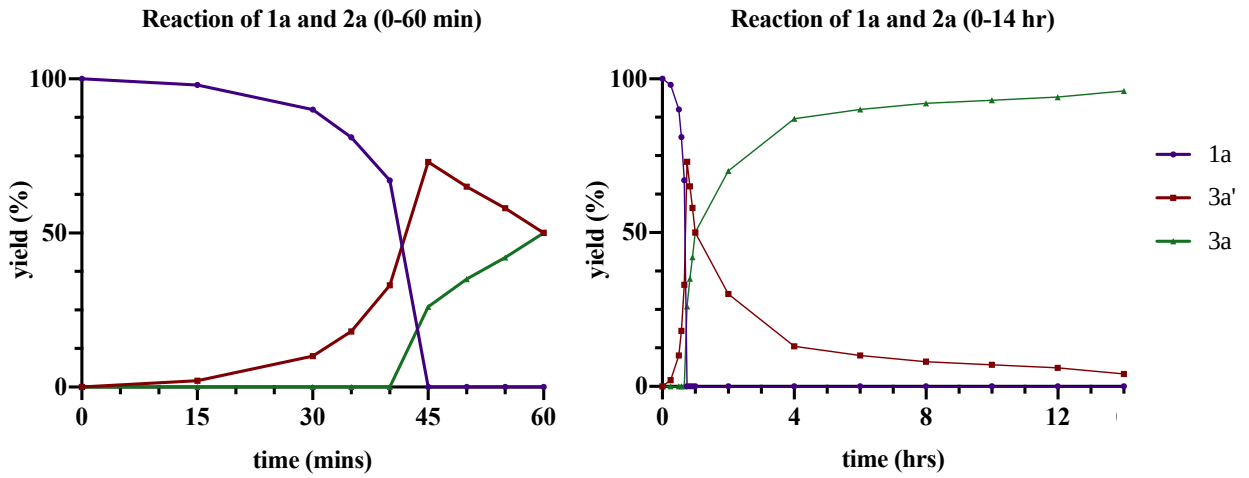
HRMS (ESI) calculated for $C_{12}H_{12}NO$ $[M+H]^+$ 186.0919, found: 186.0916.

VI. Preliminary Mechanistic Studies

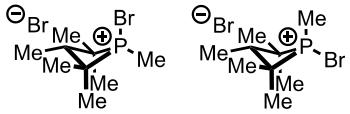
A. Time Study of Auto-Tandem Annulation



Oven-dried 4 mL vials equipped with magnetic stir bar were charged with **1a** (32.3 mg, 0.2 mmol, 98%) and **4•**[O] (5.3 mg, 0.03 mmol, 0.15 equiv). The vials were capped with septa caps, sealed with Teflon tape and parafilm, and placed under N_2 atmosphere and evacuated/backfilled 3x with N_2. Under N_2 atmosphere, 1,2-dichloroethane (0.8 mL, 250 mM) was added by syringe, followed by **2a** (16.5 µL, 0.21 mmol, 1.05 equiv, 98%), DEBM (83.7 µL, 0.48 mmol, 2.4 equiv, 98%) and phenylsilane (55.4 µL, 0.44 mmol, 2.2 equiv, 98%). The N_2 inlet needle was removed and the septum was sealed with melted parafilm. The reaction mixture was heated to 80 °C and stirred for 0-14 h (multiple, individual reactions set up in parallel). At the indicated time points, each individual reaction was cooled to room temperature and 1,1,2,2-tetrachloroethane was added as internal standard (20 µL, 0.185 mmol, 0.926 equiv). An aliquot from the reaction was diluted with $CDCl_3$ and analyzed by ^{1}H NMR as in Section **II-A**. The reaction profile consists of a brief induction period, followed by rapid conversion of **1a** to **3a′**, with complete consumption of **1a** complete within 45 minutes. Around that time, conversion of **3a′** to **3a** begins with a spike, followed by a gradual reaction until 90% of **3a** at 6 h, and slow but consistent further conversion to 96% at 14 h.



B. Synthesis of [4•Br]Br



1-Bromo-1,2,2,3,4,4-pentamethylphosphetanium bromide [4•Br]Br. Prepared according to a modified literature procedure.[19] A 50 mL Schlenk flask with magnetic stir bar was charged with **4•**[O] (250 mg, 1.43 mmol, 1.0 equiv), sealed with a septum, and then placed under N_2 atmosphere and evacuated/backfilled 3x with N_2. Under N_2 atmosphere, 1,2-dichloroethane (5.75 mL, 250 mM) was added. A cannula needle pierced the septum and was submerged in an aqueous 1M NaOH solution on the other end to quench the released gas. Oxalyl bromide (2.0 M in CH_2Cl_2, 0.9 mL, 1.79 mmol, 1.25 equiv) was added slowly to the stirring solution. Upon completion of gas evolution (< 1 minute after completion of addition), the cannula needle was removed and the flask was placed under vacuum. Upon complete evaporation of the volatiles, the Schlenck flask was sealed and brought into an inert atmosphere glovebox, where the crude residue was transferred to a tared vial using CH_2Cl_2 and concentrated under vacuum, yielding the desired product as an off-white powder (422 mg, 93% yield, 3:1 dr).

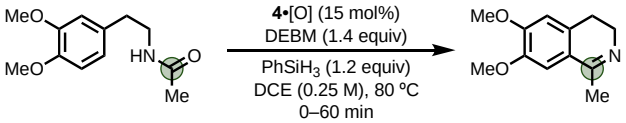
^{1}H NMR (400 MHz, $CDCl_3$) major diastereomer in **bold**, minor diastereomer in *italics*. δ **3.63 (dp, *J* = 7.0, 3.6 Hz, 1H)**, **3.56 (d, *J* = 11.2 Hz, 3H)**, *3.42 (d, J = 11.7 Hz, 3H), 2.74 (p, J = 7.2 Hz, 1H),* **1.80 (s, 3H)**, *1.77 (s, 3H),* **1.73 (s, 3H)**, *1.70 (s, 3H), 1.64 (s, 3H), 1.59 (s, 3H),* **1.52 (s, 3H)**, **1.46 (s, 3H)**, ***1.11 (d, J = 7.0 Hz, 4H, overlapping)***.

^{13}C NMR (101 MHz, $CDCl_3$) δ 52.65 (d, *J* = 4.0 Hz), 49.30 (d, *J* = 32.3 Hz), 48.60, 47.48, 27.40 (d, *J* = 6.3 Hz), 24.14 (d, *J* = 3.7 Hz), 21.35 (d, *J* = 5.5 Hz), 19.57, 14.03 (d, *J* = 12.5 Hz), 9.82 (d, *J* = 27.5 Hz), 9.49 (d, *J* = 23.1 Hz).

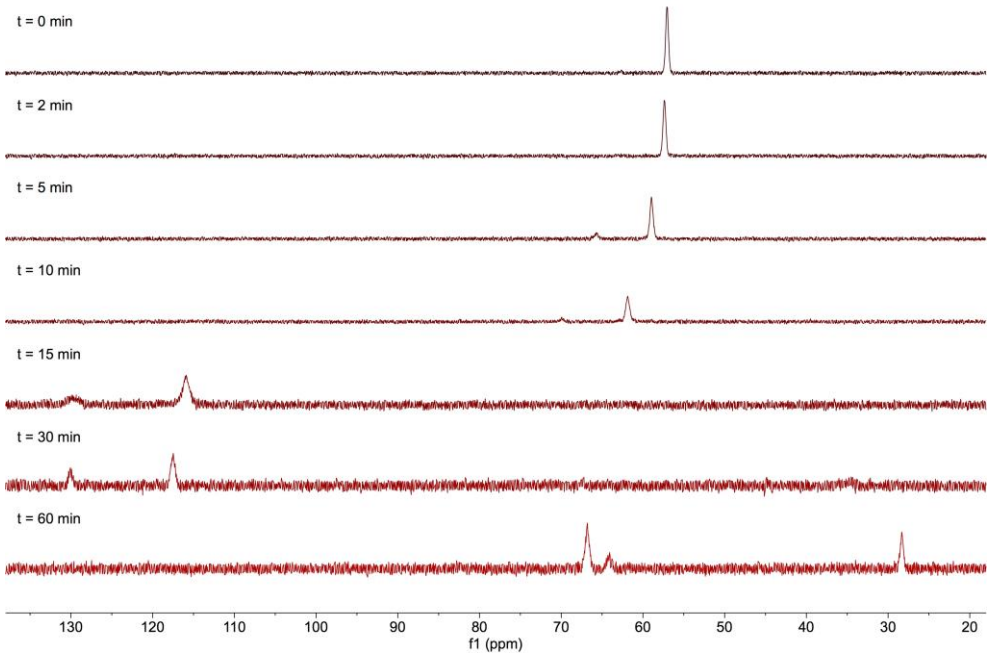
^{31}P NMR (162 MHz, $CDCl_3$) δ 119.4 (br), 106.6 (br).

HRMS (DART) calculated for $C_9H_{19}PBr$ $[M]^+$ 237.04023, found 237.04013.

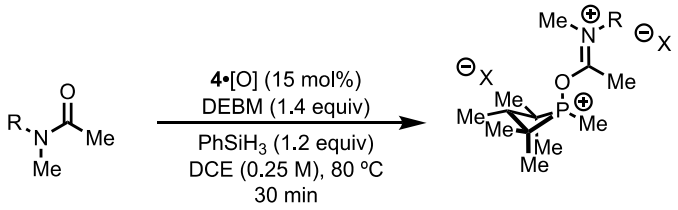
C. Catalytic Cyclodehydration ^{31}P NMR Time Study



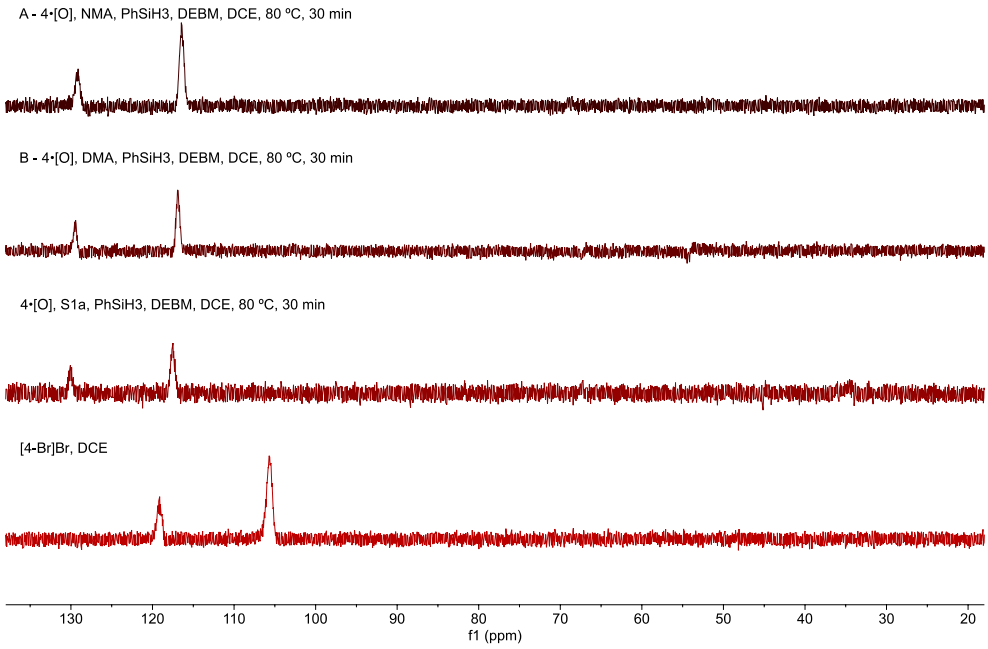
Seven oven-dried 4 mL vials equipped with magnetic stir bar were charged with **S1a** (44.7 mg, 0.2 mmol, 1.0 equiv) and **4•**[O] (5.3 mg, 0.03 mmol, 0.15 equiv). The vials were capped with septa caps, sealed with Teflon tape and parafilm, and then placed under N_2 atmosphere and evacuated/backfilled 3x with N_2. Under N_2 atmosphere, DCE (0.8 mL, 250 mM) was added by syringe, followed by diethyl bromomalonate (48.8 μL, 0.28 mmol, 1.4 equiv) and phenylsilane (30.9 μL, 0.24 mmol, 1.2 equiv). The N_2 inlet needles were removed and the septa were sealed with melted parafilm. The reactions were heated to 80 °C and stirred at 1200 rpm for the following reaction times: **A** – 0 min, **B** – 2 min, **C** – 5 min, **D** – 10 min, **E** – 15 min, **F** – 30 min, **G** – 60 min. At the indicated times, the reactions were removed from the heating block, allowed to cool to rt, and placed under N_2 atmosphere. Approximately 0.5 mL of the reaction mixture was transferred to a screw-cap NMR tube under N_2 atmosphere and analyzed by ^{31}P NMR. Reactions **E** and **F** were analyzed by DART HRMS, and no **4•**Br^+ was observed. Stacked ^{31}P NMR are below, indicating a 10-15 minute induction period exhibiting shifting of the resonance of **4•**[O] induced by acid, the presence of a phosphonium from 15 minutes until reaction completion, and finally regeneration of **4** and **4•**[O] (protonated) upon consumption of DEBM and phenylsilane.



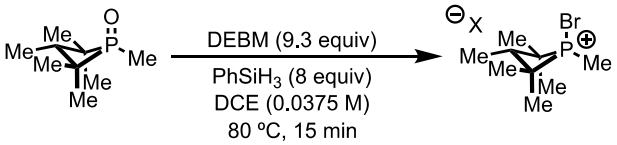
D. Reaction of Differentially-Substituted Amides Under Conditions of Catalysis



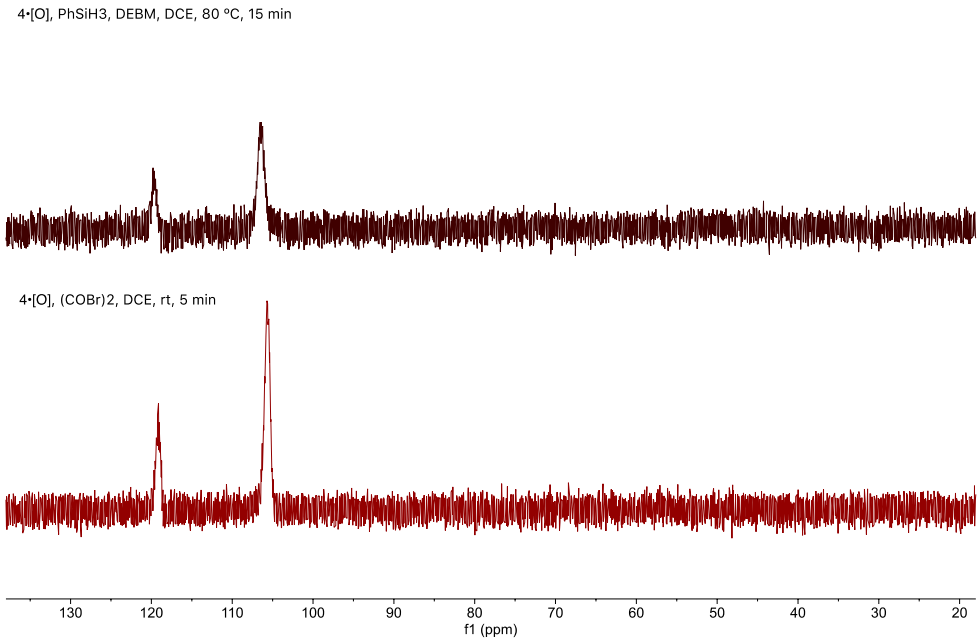
Two 4 mL vials equipped with magnetic stir bar were charged with **4•**[O] (5.3 mg, 0.03 mmol, 1.0 equiv). The vials were capped with septa caps, sealed with Teflon tape and parafilm, and then placed under N_2 atmosphere and evacuated/backfilled 3x with N_2. Under N_2 atmosphere, to **Reaction A** was added a 250 mM solution (600 μL, 0.15 mmol, 1.0 equiv) of *N*-methylacetamide in DCE (prepared from 54.8 mg NMA in 3 mL DCE) and to **Reaction B** was added DCE (0.6 mL, 250 mM) and *N*,*N*-dimethylacetamide (14 μL, 0.15 mmol, 1.0 equiv). Both reactions were then charged with diethyl bromomalonate (36.6 μL, 0.21 mmol, 1.4 equiv) and phenylsilane (23.1 μL, 0.18 mmol, 1.2 equiv). The N_2 inlet needles were removed and the septa were sealed with melted parafilm. The reactions were heated to 80 °C and stirred at 1200 rpm for 30 minutes. The reaction was then removed from the heating block, allowed to cool to room temperature, and placed under N_2 atmosphere. Approximately 0.5 mL of the reaction mixture was transferred to a screw-cap NMR tube under N_2 atmosphere and analyzed by ^{31}P NMR. Stacked ^{31}P NMR are below, along with that of the 30-minute time point in the standard catalytic reaction with **S1a**, as well as that of [**4•**Br]Br in DCE. No claims are made as to the counterion of the phosphonium.



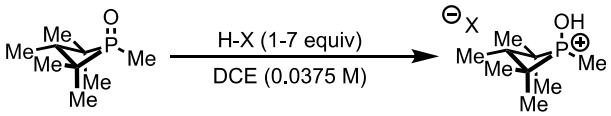
E. Generation of [4•Br]Br Under Conditions of Catalysis



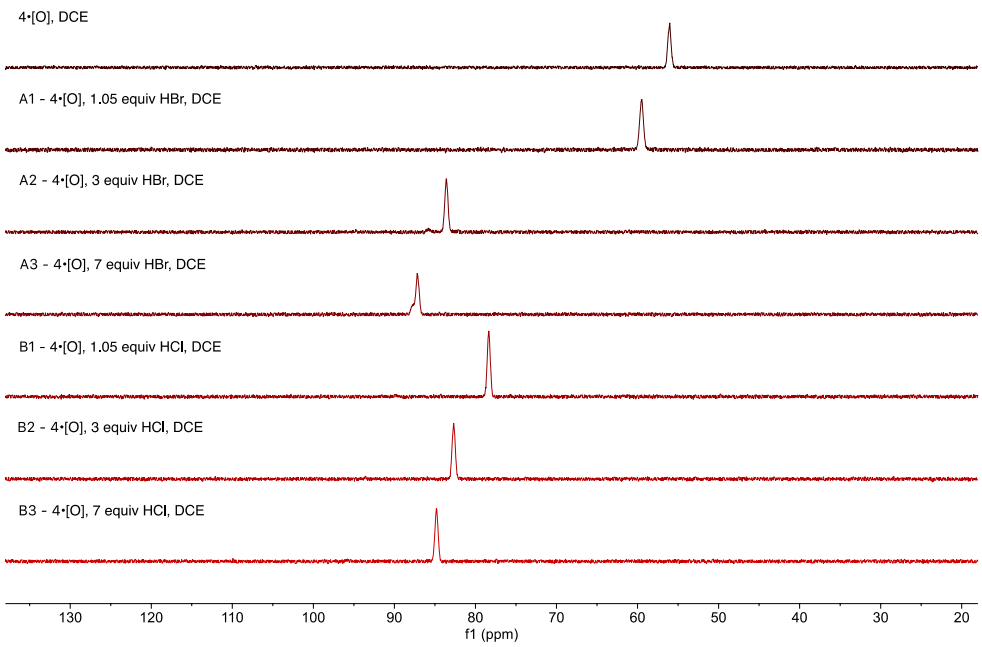
A 4 mL vial equipped with magnetic stir bar was charged with **4•**[O] (5.3 mg, 0.03 mmol, 1.0 equiv). The vial was capped with a septa cap, sealed with Teflon tape and parafilm, and then placed under N_2 atmosphere and evacuated/backfilled 3x with N_2. Under N_2 atmosphere, DCE (0.8 mL, 37.5 mM) was added by syringe, followed by diethyl bromomalonate (48.8 μL, 0.28 mmol, 9.3 equiv) and phenylsilane (30.9 μL, 0.24 mmol, 8.0 equiv). The N_2 inlet needle was removed and the septum was sealed with melted parafilm. The reaction was heated to 80 °C and stirred at 1200 rpm for 15 minutes. The reaction was then removed from the heating block, allowed to cool to room temperature, and placed under N_2 atmosphere. Approximately 0.5 mL of the reaction mixture was transferred to a screw-cap NMR tube under N_2 atmosphere and analyzed by ^{31}P NMR. The spectrum matches that of the [**4•**Br]Br prepared via reaction of **4•**[O] with $(COBr)_2$ in DCE as described above, shown below. No claims are made as to the counterion of the phosphonium in this *in situ* case. Note that the reaction conditions are identical to those for the standard catalytic cyclodehydrations reaction, without any **S1a**.



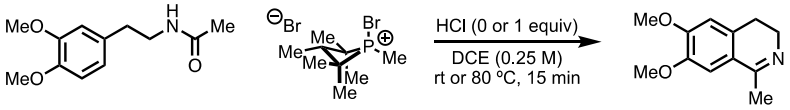
F. Titration of 4•[O] with Strong Acids



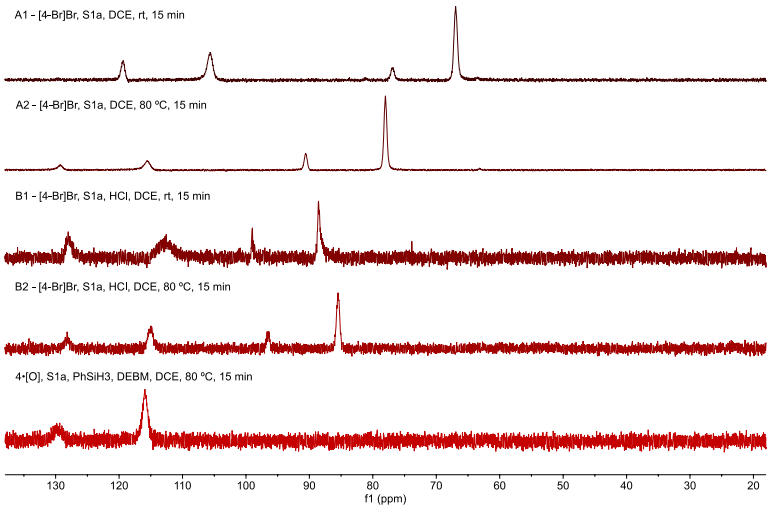
Six 4 mL vials equipped with magnetic stir bar were charged with **4•**[O] (10 mg, 0.0574 mmol, 1.0 equiv). The vials were capped with septa caps, sealed with Teflon tape and parafilm, and then placed under N_2 atmosphere and evacuated/backfilled 3x with N_2. Under N_2 atmosphere, DCE (1.5 mL, 37.5 mM) was added by syringe. The vials were then charged with either HBr (48% w/w in H_2O) or HCl (4M in dioxane) as follows: **A1** – 1.05 equiv HBr (6.8 μL), **A2** – 3 equiv HBr (19.5 μL), **A3** – 7 equiv HBr (45 μL), **B1** – 1.05 equiv HCl (15.1 μL), **B2** – 3 equiv HCl (43.1 μL), **B3** – 7 equiv HCl (100.5 μL). The reactions were stirred for 5 minutes and then transferred to screw-cap NMR tubes under N_2 atmosphere and analyzed by ^{31}P NMR. Stacked ^{31}P NMR are below, with the spectra of **4•**[O] at top for comparison.



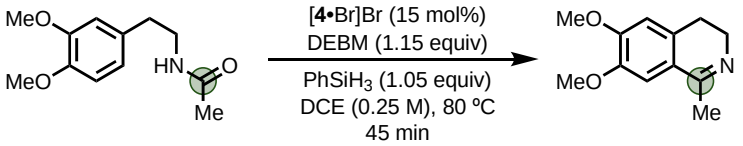
G. Effect of Acid on Stoichiometric Cyclodehydration of S1a with [4•Br]Br



In the glovebox, [**4**•Br]Br (50.1 mg, 0.1575 mmol, 1.05 equiv) was added to four 4 mL vials equipped with magnetic stir bar. The vials were capped with septa caps, sealed with Teflon tape, and brought out from the box and placed under N_2 atmosphere. To two separate 4 mL vials, a stock solution of **S1a** (83.7 mg, 0.375 mmol, 2.5 equiv) was prepared in DCE (1.5 mL, 250 mM) under N_2 atmosphere. To one of the vials was added HCl (4M in dioxane, 93.8 μL, 0.375 mmol, 2.5 equiv) (**Solution B**) and the other vial was kept as is (**Solution A**). 600 μL of **Solution A** was added to two vials containing [**4**•Br]Br each to make **Reaction A** and 640 μL of **Solution B** was added to each of the two remaining vials containing [**4**•Br]Br to make **Reaction B**. The N_2 inlet needles were removed and the septa were sealed with melted parafilm. One each of **Reactions A** and **B** were stirred at 1200 rpm for 15 minutes at room temperature (**A1** and **B1**) while the others of **Reactions A** and **B** were stirred at 1200 rpm for 15 minutes at 80 °C (**A2** and **B2**). After 15 minutes, **A1** and **B1** were placed under N_2 inlet needles and 20 μL 1,1,2,2-tetrachlorethane was added as internal standard. An aliquot was removed and diluted with $CDCl_3$, and the yield was determined by ^{1}H NMR. The remaining reaction volume (~ 0.5 mL) was added to a screw-cap NMR tube under N_2 atmosphere and analyzed by ^{31}P NMR. **A2** and **B2** were allowed to cool to room temperature and analyzed similarly. ^{1}H NMR yields of product **S2a** are as follows: **A1** – 38%, **A2** – 100%, **B1** – 0%, **B2** – 58%. Stacked ^{31}P NMR are below, above that of the 15-minute time point in the standard catalytic reaction with **S1a**.

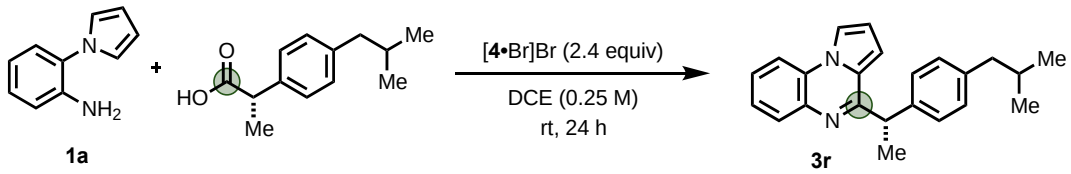


H. Catalytic Cyclodehydration of S1a with [4•Br]Br as Precatalyst

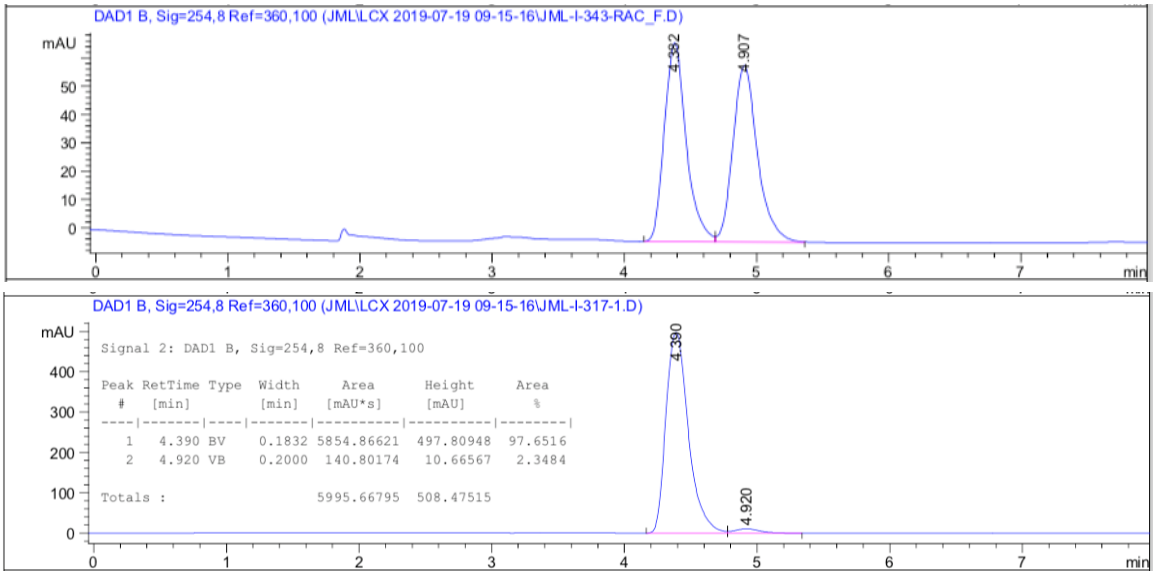


In the glovebox, [**4**•Br]Br (50.1 mg, 0.1575 mmol, 1.05 equiv) was added to a 4 mL vial equipped with magnetic stir bar. The vial was capped with a septa cap, sealed with Teflon tape, and brought out from the box and placed under N_2 atmosphere. To a separate 4 mL vial, a stock solution of **S1a** (50.2 mg, 0.22 mmol, 1.5 equiv) was prepared in DCE (800 μL, 250 mM) under N_2 atmosphere. 600 μL (0.15 mmol, 1.0 equiv) of this solution was transferred to the vial containing [**4**•Br]Br. Diethyl bromomalonate (32.7 μL, 0.1875 mmol, 1.25 equiv) and phenylsilane (20.3 μL, 0.1575 mmol, 1.05 equiv) were added. The N_2 inlet needle was removed and the septum was sealed with melted parafilm. The reaction was heated to 80 °C and stirred at 1200 rpm for 45 minutes. The reaction was allowed to cool to room temperature and 20 μL 1,1,2,2-tetrachlorethane was added as internal standard. An aliquot was removed and diluted with $CDCl_3$, and the yield of **S2a** was determined by ^1H NMR, indicating 100% yield.

I. Stoichiometric Annulation of 1a and (*S*)-Ibuprofen with [4•Br]Br

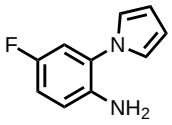


A 4 mL equipped with magnetic stir bar was charged with **1a** (32.3 mg, 0.2 mmol, 1.0 equiv) and (+)-ibuprofen (43.8 mg, 0.21 mmol, 1.05 equiv). The vial was brought into the glovebox, charged with [**4**•Br]Br (152.7 mg, 0.48 mmol, 2.4 equiv), sealed, and removed from the glovebox. The vial was placed under N_2 atmosphere, dissolved in DCE (800 µL, 250 mM), and 20 µL 1,1,2,2-tetrachlorethane was added as internal standard. The reaction was stirred under N_2 atmosphere at room temperature with monitoring by TLC and NMR analysis. After 24 h, an aliquot was diluted in $CDCl_3$ and analyzed by ^1H NMR, indicating 67% yield. The reaction mixture was poured into 20 mL of 1M aqueous NaOH solution and extracted with 3x25 mL DCM. The combined DCM layers were dried over $MgSO_4$, filtered, and concentrated. The crude residue was then adsorbed onto silica gel with DCM, and then purified by flash column chromatography on silica gel by eluting with 3% EtOAc in hexanes. HPLC analysis of purified product (Chiralcel OD-H, 5-8% IPA in hexanes, 1.0 mL/min, 6 minutes, 254 nm) indicated 97.6:2.4 er: t_R(major) = 4.4 min, t_R(minor) = 4.9 min.

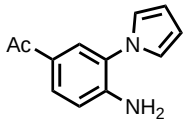


VII. Substrate Synthesis

A. Synthesis of *o*-Pyrroloaniline Precursors



4-Fluoro-2-(1*H*-pyrrol-1-yl)aniline (S3g). Prepared via a modified literature procedure (**general procedure S3**).[20] A mixture of 4-fluoro-2-iodoaniline (251 μL, 2.11 mmol), CuI (40 mg, 0.21 mmol, 0.1 equiv), DMEDA (45.4 μL, 0.42 mmol, 0.2 equiv), K_3PO_4 (0.985 g, 4.64 mmol, 2.25 equiv), pyrrole (176 μL, 2.53 mmol, 1.25 equiv), and toluene (20 mL, 0.1 M) was stirred at 110 ºC for 24 h. The crude reaction was cooled to room temperature and filtered through a silica plug with ethyl acetate. The filtrate was concentrated in vacuo and purified by flash chromatography on silica eluting with 67% toluene/hexanes to afford **S3g** as an orange solid (350 mg, 94% yield). NMR spectra matched those reported in the literature.

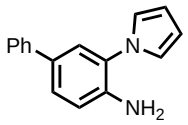


4-Acetyl-2-(1*H*-pyrrol-1-yl)aniline (S3h). Prepared according to **general procedure S3**. The cross-coupling of 3-iodo-4-aminoacetophenone (410 mg, 1.39 mmol) and pyrrole (0.45 mL, 5.46 mmol, 1.25 equiv) yielded **S3h** as a yellow solid (790 mg, 72% yield) after purification by flash chromatography on silica eluting with 20% EtOAc/CyH.

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.81 (dd, J = 8.4, 2.0 Hz, 1H), 7.78 (d, J = 1.9 Hz, 1H), 6.82 (t, J = 2.0 Hz, 2H), 6.79 (d, J = 8.4 Hz, 1H), 6.36 (t, J = 2.0 Hz, 2H), 4.21 (bs, 2H), 2.51 (s, 3H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 196.1, 147.0, 129.7, 128.3, 127.8, 126.4, 121.7, 114.9, 110.0, 26.2.

HRMS (ESI) calculated for $C_{12}H_{13}N_2O$ $[M+H]^+$ 201.1028, found 201.1020.



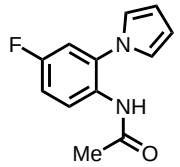
3-(1*H*-pyrrol-1-yl)-[1,1'-biphenyl]-4-amine (S3i). Prepared according to **general procedure S3**. The cross-coupling of 3-iodo-[1,1'-biphenyl]-4-amine (410 mg, 1.39 mmol) and pyrrole (0.12 mL, 1.7 mmol, 1.25 equiv) yielded **S3i** as a yellow solid (210 mg, 65% yield) after purification by flash chromatography on silica eluting with 11% EtOAc/hexanes.

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.58 (d, *J* = 7.7 Hz, 2H), 7.50 – 7.40 (m, 4H), 7.33 (t, *J* = 7.4 Hz, 1H), 6.93 (t, *J* = 2.2 Hz, 2H), 6.89 (d, *J* = 8.8 Hz, 1H), 6.45 – 6.38 (m, 2H), 3.81 (bs, 2H).

^{13}C NMR (126 MHz, $CDCl_3$) δ 141.4, 140.2, 131.7, 128.9, 127.9, 127.2, 126.8, 126.5, 125.8, 121.8, 116.5, 109.7.

HRMS (ESI) calculated for $C_{16}H_{15}N_2$ $[M+H]^+$ 235.1235, found 235.1237.

B. Synthesis of Amide Precursors



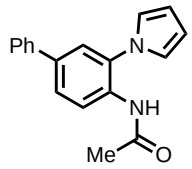
***N*-(4-Fluoro-2-(1*H*-pyrrol-1-yl)phenyl)acetamide (S1g)**. Prepared according to **general procedure S1**, described as follows. To a solution of 4-fluoro-2-(1H-pyrrol-1-yl)aniline **S3g** (1.0 g, 5.7 mmol) and NEt_3 (0.49 mL, 6.8 mmol, 1.2 equiv) in dichloromethane (11 mL, 0.5 M), was added acetyl chloride (1.2 mL, 8.5 mmol, 1.5 equiv) at 0 ºC. The reaction was stirred overnight at room temperature. The mixture was then quenched with HCl 1 M and the aqueous phase was extracted with dichloromethane. The combined organic phase was dried over $MgSO_4$ and concentrated. The crude residue was purified by flash chromatography on silica eluting with 11% EtOAc/hexanes to yield **S1g** as a white solid (93% yield, 1.15 g).

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.27 (dd, *J* = 9.3, 5.8 Hz, 1H), 7.13 – 7.06 (m, 1H), 7.01 (dd, *J* = 8.5, 3.0 Hz, 1H), 6.95 (bs, 1H), 6.79 (t, *J* = 2.1 Hz, 2H), 6.40 (t, *J* = 2.1 Hz, 2H), 2.04 (s, 3H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 168.5, 158.8 (d, *J* = 245.9 Hz), 132.1 (d, *J* = 9.8 Hz), 129.7, 123.7 (d, *J* = 8.6 Hz), 121.9, 115.3 (d, *J* = 21.8 Hz), 114.0 (d, *J* = 24.4 Hz), 111.0, 24.7.

^{19}F NMR (565 MHz, $CDCl_3$) δ -116.69.

HRMS (ESI) calculated for $C_{12}H_{12}FN_2O$ $[M+H]^+$ 219.0934, found 219.0932.

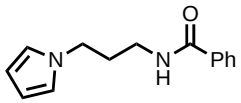


***N*-(4-Phenyl-2-(1*H*-pyrrol-1-yl)phenyl)acetamide (S1i)**. Prepared according to **general procedure S1**, the acylation of 3-(1H-pyrrol-1-yl)-[1,1'-biphenyl]-4-amine (**S3i**) (100 mg, 0.50 mmol) with acetyl chloride yielded **S1i** as a white solid (99 mg, 82% yield), after purification by flash chromatography on silica eluting with 33% EtOAc/CyH.

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.44 (d, *J* = 8.6 Hz, 1H), 7.63 (dd, *J* = 8.6, 2.2 Hz, 1H), 7.58 (d, *J* = 6.2 Hz, 2H), 7.52 (d, *J* = 2.2 Hz, 1H), 7.44 (t, *J* = 7.7 Hz, 2H), 7.35 (t, *J* = 7.4 Hz, 1H), 7.06 (bs, 1H), 6.85 (t, *J* = 2.1 Hz, 2H), 6.43 (t, *J* = 2.1 Hz, 2H), 2.08 (s, 3H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 168.6, 139.6, 137.4, 132.9, 131.0, 129.1, 127.7, 127.2, 126.9, 125.4, 122.2, 122.0, 110.7, 24.9.

HRMS (ESI) calculated for $C_{18}H_{17}N_2O$ $[M+H]^+$ 277.1341, found 277.1345.

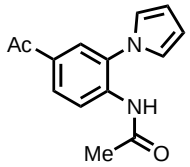


***N*-(3-1*H*-pyrrol-1-yl)propyl)benzamide (S1o)**. Prepared according to **general procedure S1**, the acylation of 3-(1*H*-pyrrol-1-yl)propan-1-amine (420 mg, 3.38 mmol) with benzoyl chloride (0.47 mL, 4.1 mmol, 1.2 equiv) yielded **S1o** as a colorless oil (425 mg, 55% yield), after purification by flash chromatography on silica eluting with 33% EtOAc/CyH.

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.66 (d, *J* = 8.0 Hz, 2H), 7.47 (t, *J* = 7.4 Hz, 1H), 7.39 (t, *J* = 7.6 Hz, 2H), 6.70 (s, 2H), 6.18 (s, 2H), 6.08 (bs, 1H), 4.05 – 3.96 (m, 2H), 3.52 – 3.42 (m, 2H), 2.12 – 2.01 (m, 2H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 167.6, 134.4, 131.5, 128.5, 127.0, 127.0, 120.6, 108.8, 48.1, 38.1, 31.3.

HRMS (ESI) calculated for $C_{14}H_{17}N_2O$ $[M+H]^+$ 229.1341, found 229.1341.



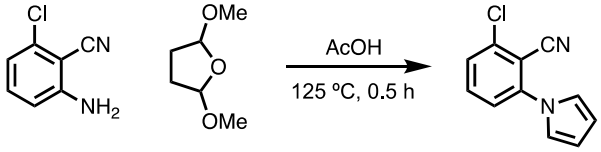
***N*-(4-Acetyl-2-(1*H*-pyrrol-1-yl)phenyl)acetamide (S1h)**. Acetic anhydride (0.18 mL, 2.0 mmol, 1.33 equiv) was added to a solution of 1-(4-amino-3-(1H-pyrrol-1-yl)phenyl)ethanone (**S3h**) (300 mg, 1.50 mmol) in toluene (8 mL, 0.1875 M) at 0 ºC and stirred overnight. The crude reaction was quenched with water (10 mL) and extracted with EtOAc (3x20 mL). The combined organic phase was dried over $MgSO_4$ and concentrated. Purification by column chromatography (hex/EtOAc 2:1) afforded 193 mg (53% yield) of **S1h** as a white solid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.56 (d, *J* = 8.7 Hz, 1H), 7.96 (dd, *J* = 8.7, 2.1 Hz, 1H), 7.87 (d, *J* = 2.1 Hz, 1H), 7.21 (bs, 1H), 6.79 (t, *J* = 2.1 Hz, 2H), 6.43 (t, *J* = 2.1 Hz, 2H), 2.57 (s, 3H), 2.07 (s, 3H).

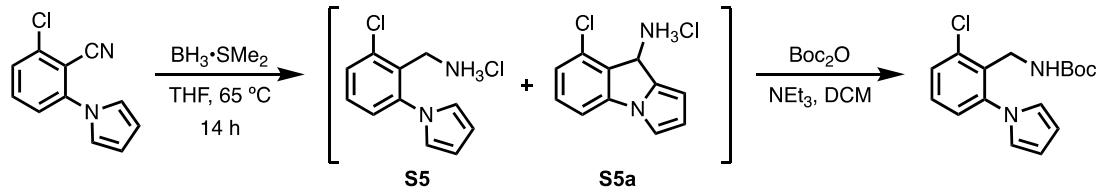
^{13}C NMR (151 MHz, $CDCl_3$) δ 196.3, 168.6, 138.1, 132.8, 130.1, 129.4, 127.0, 122.0, 120.4, 111.2, 26.6, 25.1.

HRMS (ESI) calculated for $C_{14}H_{15}N_2O_2$ $[M+H]^+$ 243.1134, found 243.1131.

C. Synthesis of Janssen Antifungal Precursors



2-Chloro-6-(1H-pyrrol-1-yl)benzonitrile S4. Prepared according to literature procedure.[21] A mixture of 2-amino-6-chlorobenzonitrile (4.98 g, 98% w/w, 32 mmol) and 2,5-dimethoxytetrahydrofuran (4.23 mL, 98% w/w, 32 mmol, 1.0 equiv) in glacial AcOH (27 mL, 1.15 M) in a 100 mL round-bottom flask equipped with magnetic stir bar was refluxed at 125 °C for 30 minutes. The mixture was then cooled to room temperature and the solvent was evaporated. The crude residue was purified by flash column chromatography eluting with DCM. The yellow solution was concentrated to yield the product as off-white powder (6.42 g, 99% yield). The NMR spectra were identical to those reported in the literature.



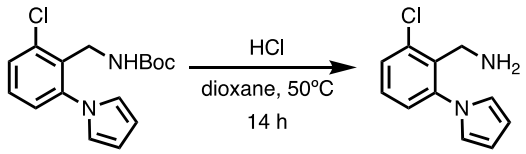
2-(1H-pyrrol-1-yl)-6-chloro-N-Boc-benzylamine S6. Prepared according to modified literature procedure.[21] A solution of 2-chloro-6-(1H-pyrrol-1-yl)benzonitrile (6.38 g, 31.5 mmol) in THF (25 mL, 1.25 M) in a 100 mL 3-neck round bottom flask with a magnetic stir bar equipped with a reflux condenser was heated to 65 °C under N_2 atmosphere. To this refluxing solution was slowly added a solution of borane in dimethyl sulfide (3.5 mL, 10 M, 34.6 mmol, 1.1 equiv). The solution was refluxed for 14 h, then cooled to room temperature. To this stirred solution at room temperature was slowly added 15 mL of aqueous 6M HCl solution. The mixture was then heated to 65 °C for 30 minutes. The reaction mixture was then cooled to 0 °C and slowly treated with 15 mL of aqueous 6M NaOH solution. The crude mixture was diluted with 50 mL water and extracted with DCM (2x125 mL). The combined organic layers were dried with Na_2SO_4, filtered, and concentrated. The crude residue was taken up in a 100 mL round-bottom flask equipped with magnetic stir bar under N_2 atmosphere in dry dioxane (25 mL, 1.25 M) and slowly treated with 4M HCl in dioxane (9.5 mL, 1.2 equiv), resulting in a suspension of gray solid in light-green

solution. This suspension was filtered over filter paper in a Buchner funnel and subsequently washed with ~ 100 mL dioxane. The gray solid was collected in a tared 250 mL round-bottom flask and dried under vacuum overnight (5.12 g, 67% crude yield). Crude NMR analysis in DMSO-d6 indicated a ~6:1 mixture of the desired benzylamine hydrochloride salt **S5** with **S5a**, which was not reported to form in the published literature route. To the flask containing the crude hydrochloride salt was added a magnetic stir bar and Boc_2O (4.60 g, 21 mmol, 1 equiv). The flask was capped with a rubber septum, placed under N_2 atmosphere, and dry DCM (85 mL, 0.25 M) was added. The suspension was cooled to 0 °C and stirred. Dry NEt_3 (5.9 mL, 42 mmol, 2.0 equiv) was added slowly, the ice bath removed, and the reaction was stirred overnight (15 h). The reaction was poured into 50 mL DCM, 75 mL water added, and the layers separated. The aqueous layer was extracted again with 85 mL DCM, the combined organic layers were dried over Na_2SO_4, filtered, and concentrated. Using DCM, the crude residue was adsorbed onto silica gel and purified via flash column chromatography, eluting with 5% acetone/hexanes to separate the two Boc-protected amines. Fractions containing pure "top" spot were combined, fractions containing both "top" and "bottom" spot were combined, and fractions containing pure "bottom" spot were discarded. The mixed fractions were concentrated, absorbed onto silica, and purified by an additional column using 5% acetone/hexanes. This process was repeated a third time, at which point all of the pure "top" spot material was combined and concentrated, yielding the desired product **S6** as an off-white solid (3.84 g, 40% yield over two steps).

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.44 (dd, *J* = 8.0, 1.4 Hz, 1H), 7.30 (t, *J* = 8.0 Hz, 1H), 7.22 (dd, *J* = 7.8, 1.4 Hz, 1H), 7.22 (dd, J = 7.8, 1.4 Hz, 1H), 6.78 (t, J = 2.1 Hz, 2H), 4.48 (bs, 1H), 4.32 (d, *J* = 5.7 Hz, 2H), 1.41 (s, 8H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 155.21, 142.47, 136.04, 132.74, 129.42, 129.15, 126.17, 122.56, 110.07, 38.79, 28.57, 28.48, 27.57.

HRMS (ESI) calculated for $C_{16}H_{20}ClN_2O_2$ $[M+H]^+$ 307.1208, found 307.1205.



2-(1H-pyrrol-1-yl)-6-chloro-benzylamine S7. To a stirring solution of 2-chloro-6-(1H-pyrrol-1-yl)benzylamine **S6** (1.54 g, 5 mmol) in dry dioxane (25 mL, 0.2 M) in a 100 mL round-bottom flask under N_2 atmosphere was slowly added 4M HCl in dioxane (3.75 mL, 3.0 equiv). The reaction was stirred at 50 °C overnight (14 h), cooled to room temperature, and the suspension of gray solid was filtered over filter paper in a Buchner funnel and subsequently washed with ~ 100 mL dioxane. The gray solid was collected and placed in a tared 40 mL vial and dried under vacuum overnight (870 mg, 71% yield). NMR analysis in DMSO-d6 indicated pure desired benzylamine hydrochloride salt **S5** with no **S5a** contaminant. The hydrochloride salt was poured into 50 mL aqueous saturated $NaHCO_3$ solution and extracted with DCM (3x50 mL). The combined organic layers were dried over Na_2SO_4, filtered, and concentrated, yielding the desired amine product as a brown oil (654 mg, 63% yield).

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.42 (dd, *J* = 7.8, 1.4 Hz, 1H), 7.27 – 7.19 (m, 2H), 6.87 (s, 2H), 6.33 (s, 2H), 3.75 (s, 2H), 1.44 (bs, 2H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 141.73, 137.36, 135.41, 129.31, 128.32, 126.02, 122.80, 109.65, 39.93.

HRMS (ESI) calculated for $C_{11}H_{12}ClN_2$ $[M+H]^+$ 207.0684, found 207.0680.

VIII. References

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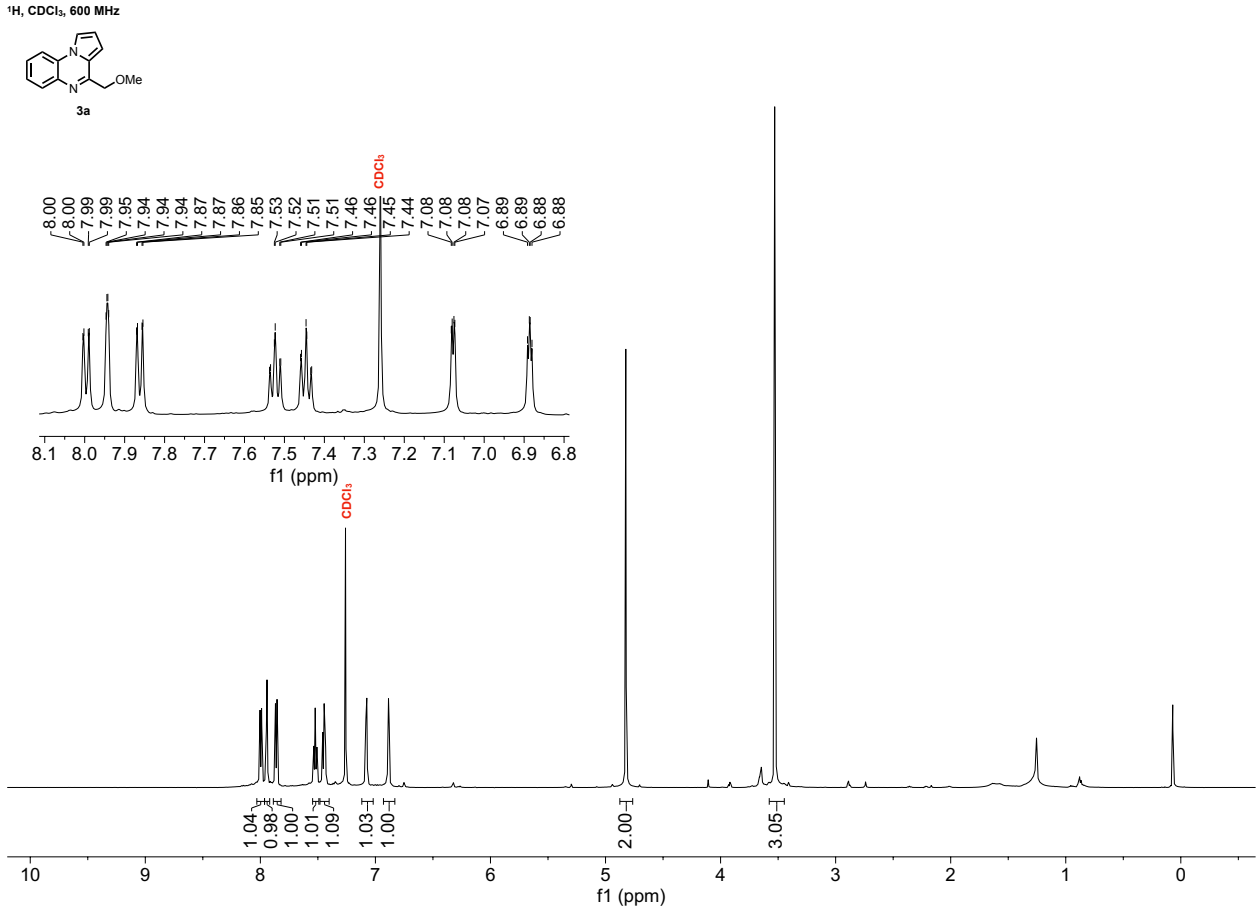
IX. NMR spectra of products and precursors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OMe
3a
CDCl₃
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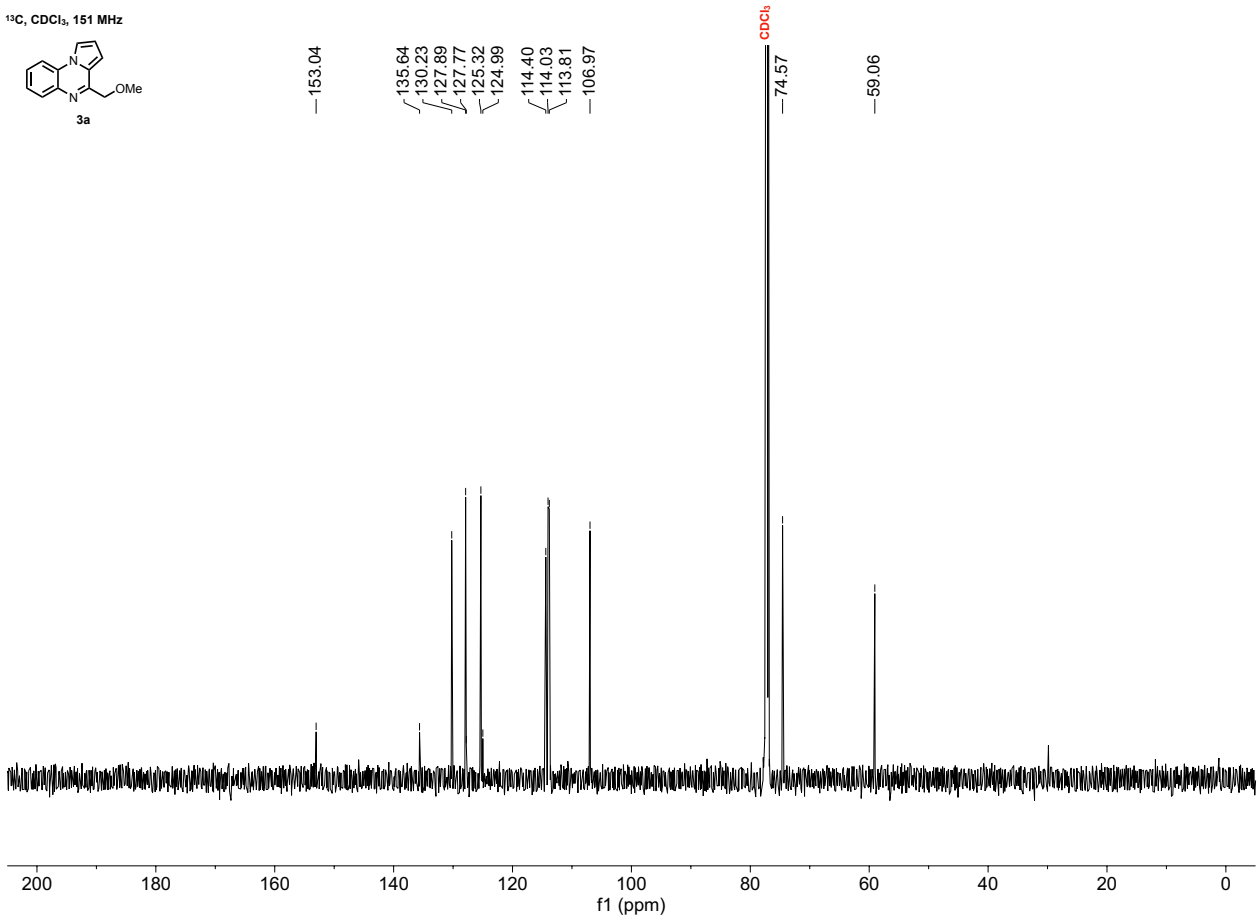
8.1 8.0 7.9 7.8 7.7 7.6 7.5 7.4 7.3 7.2 7.1 7.0 6.9 6.8
f1 (ppm)
CDCl₃
1.04 0.98 1.00 1.01 1.09 1.03 1.00 2.00 3.05
10 9 8 7 6 5 4 3 2 1 0
f1 (ppm)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OMe
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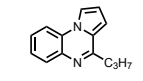
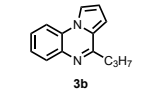
153.04
135.64 130.23 127.89 127.77 125.32 124.99
114.40 114.03 113.81
106.97
CDCl₃
74.57
59.06
200 180 160 140 120 100 80 60 40 20 0
f1 (ppm)

^{1}H, $CDCl_3$, 400 MHz



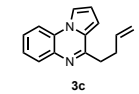
3b

^{13}C, $CDCl_3$, 126 MHz

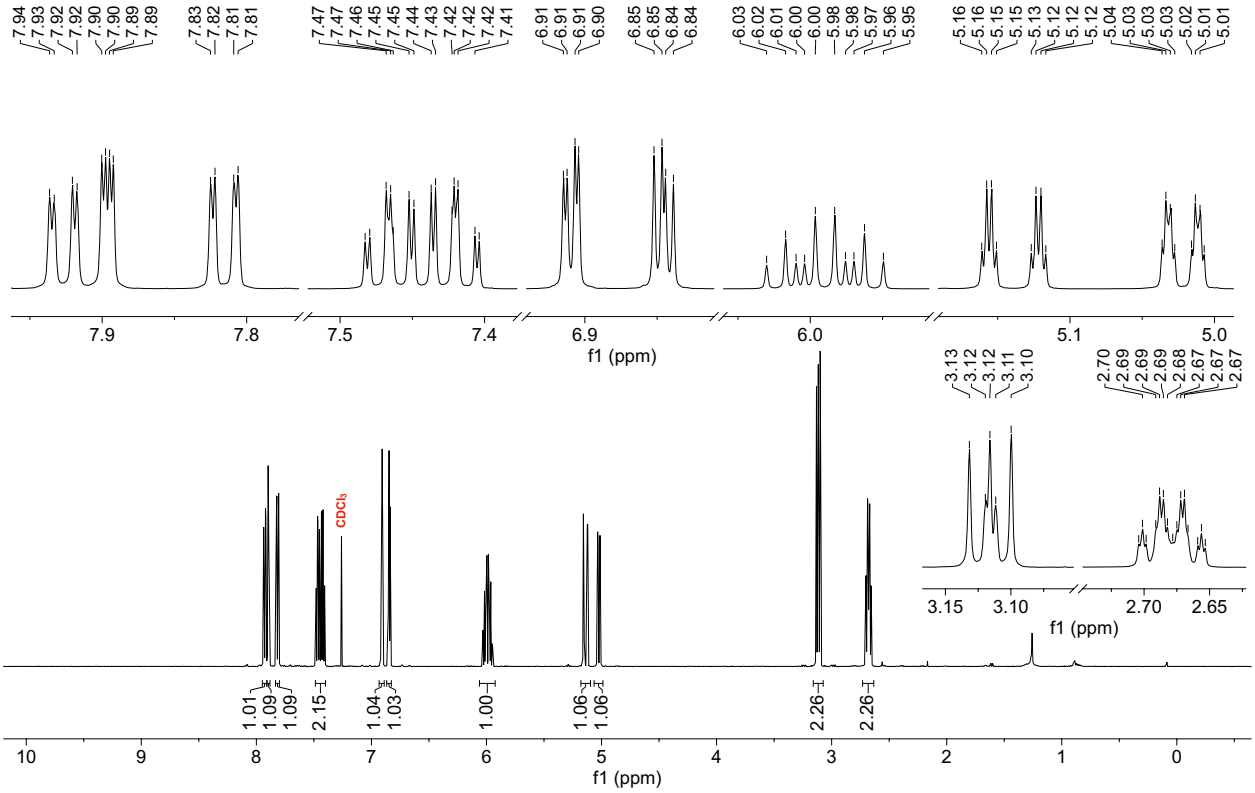


3b

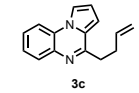
^{1}H, $CDCl_3$, 500 MHz



3c

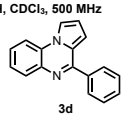


^{13}C, $CDCl_3$, 126 MHz

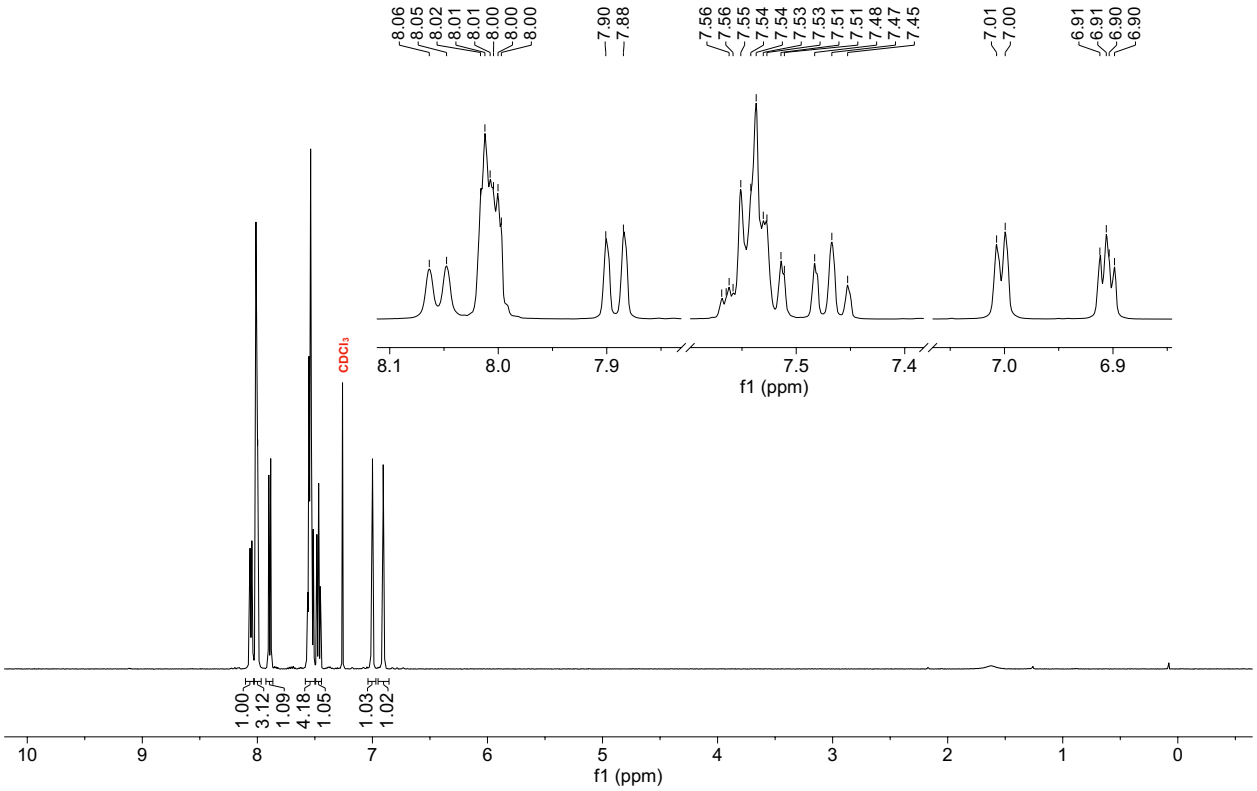


3c

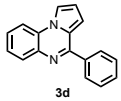
^{1}H, $CDCl_3$, 500 MHz



3d

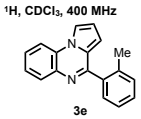


^{13}C, $CDCl_3$, 126 MHz



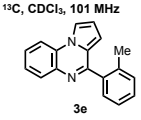
3d

^{1}H, $CDCl_3$, 400 MHz

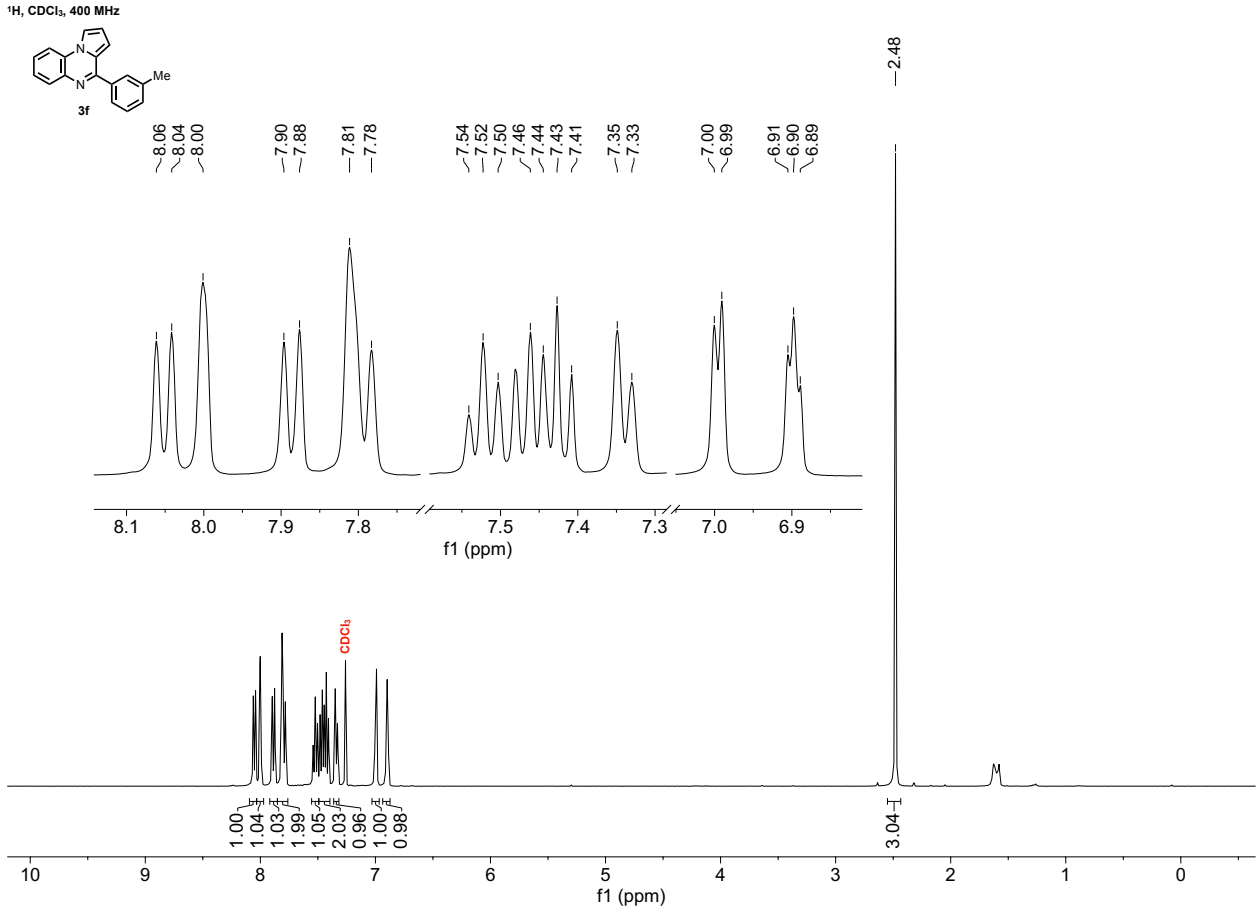


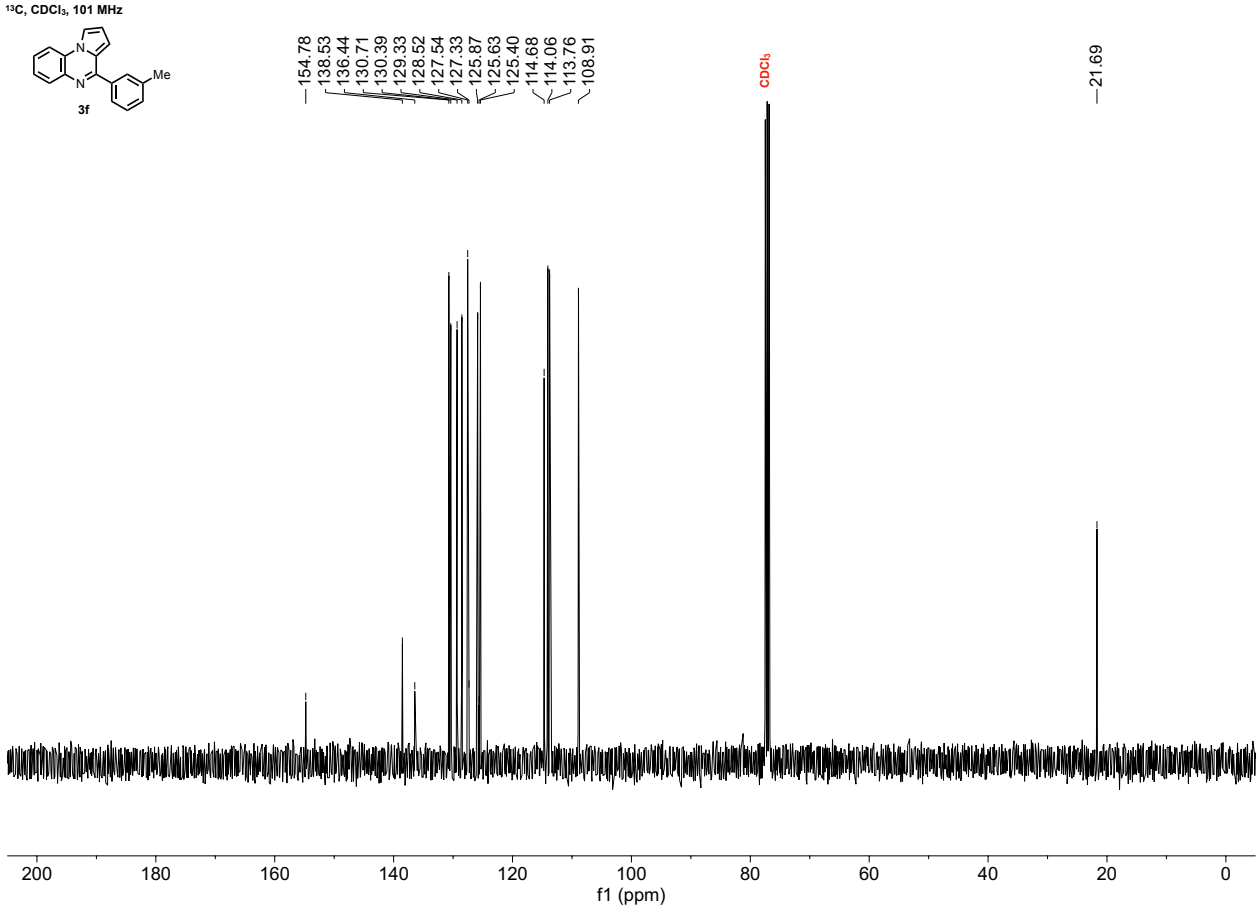
3e

^{13}C, $CDCl_3$, 101 MHz

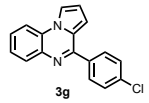


3e

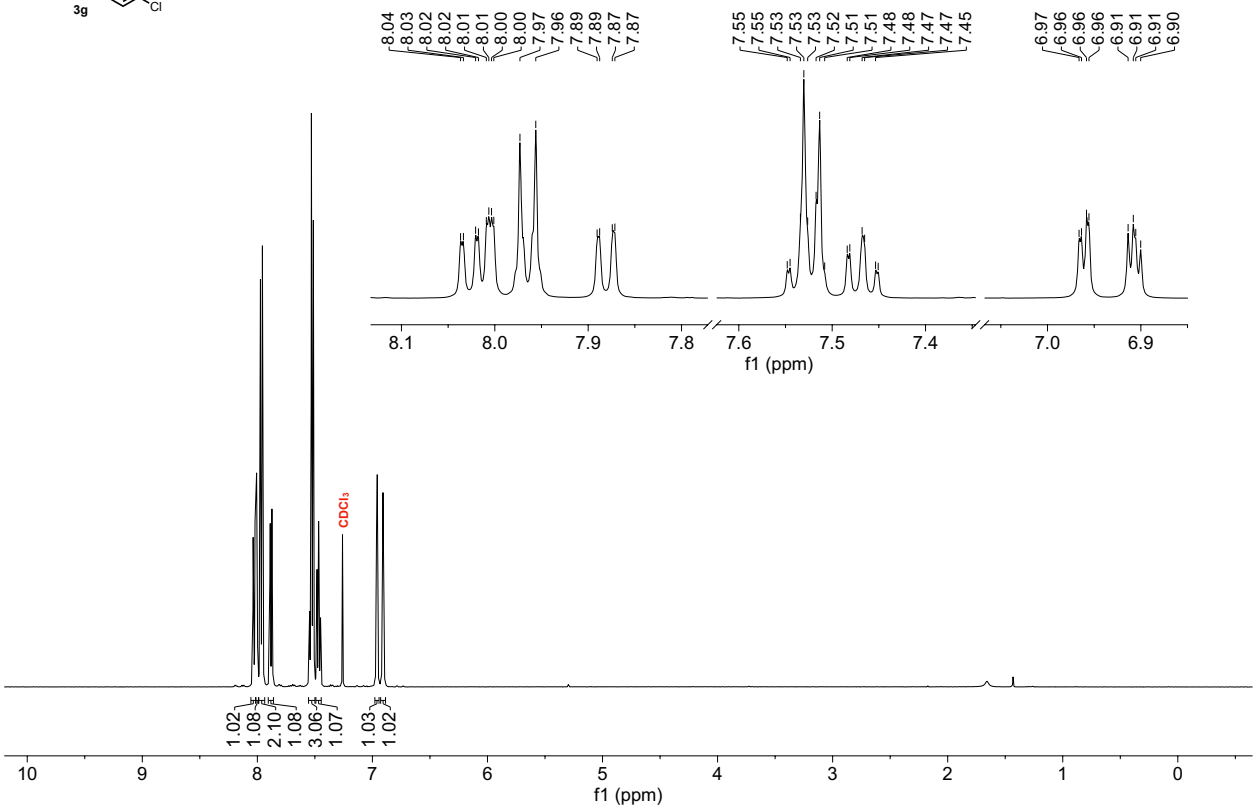

¹H, CDCl₃, 400 MHz
Me
3f
8.06
8.04
8.00
7.90
7.88
7.81
7.78
7.54
7.52
7.50
7.46
7.44
7.43
7.41
7.35
7.33
7.00
6.99
6.91
6.90
6.89
2.48
CDCl₃
1.00
1.04
1.03
1.99
1.05
2.03
0.96
1.00
0.98
3.04
f1 (ppm)


¹³C, CDCl₃, 101 MHz
Me
3f
154.78
138.53
136.44
130.71
130.39
129.33
128.52
127.54
127.33
125.87
125.63
125.40
114.68
114.06
113.76
108.91
CDCl₃
21.69
f1 (ppm)

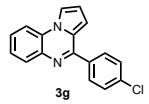
^{1}H, $CDCl_3$, 500 MHz



3g

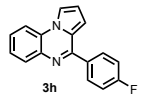


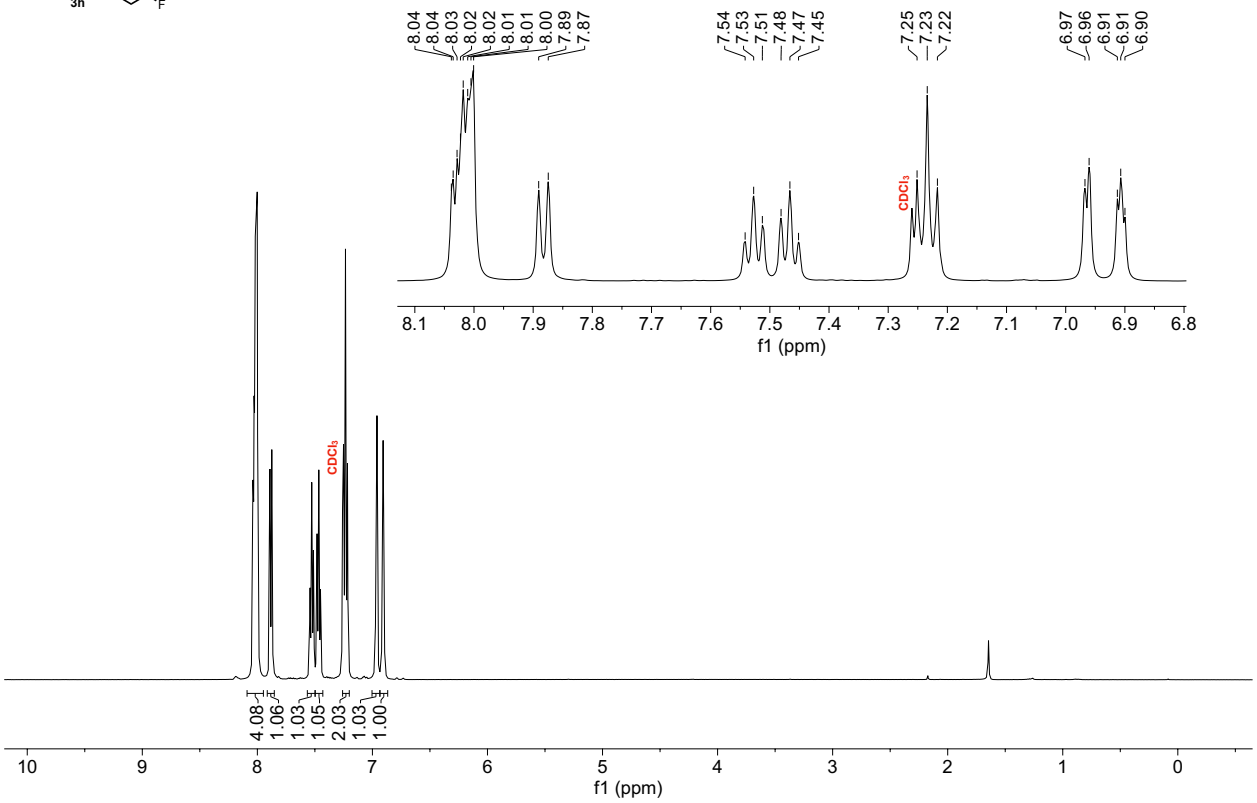
^{13}C, $CDCl_3$, 126 MHz



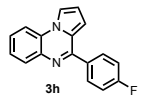
3g

^{1}H, $CDCl_3$, 500 MHz

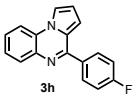




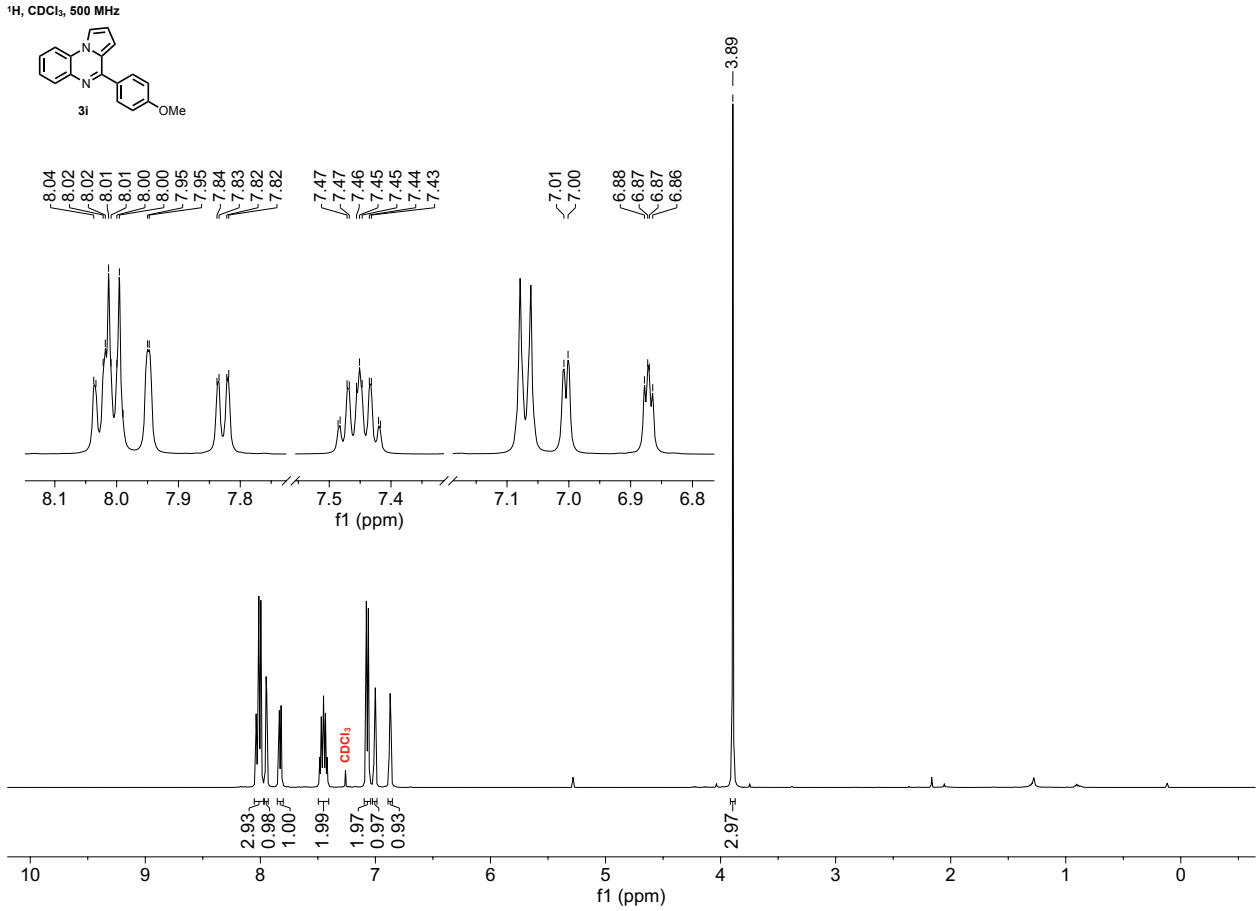
^{13}C, $CDCl_3$, 126 MHz

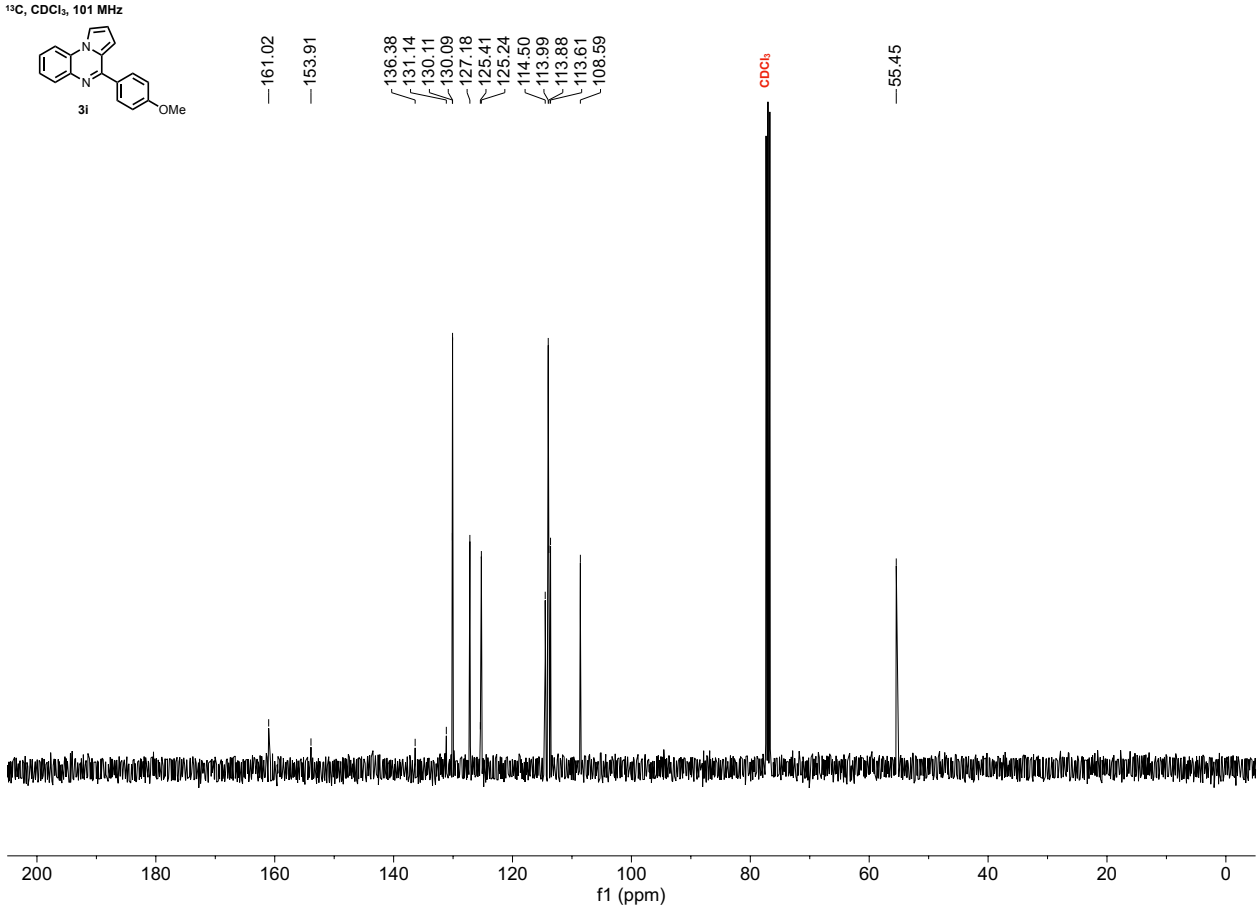


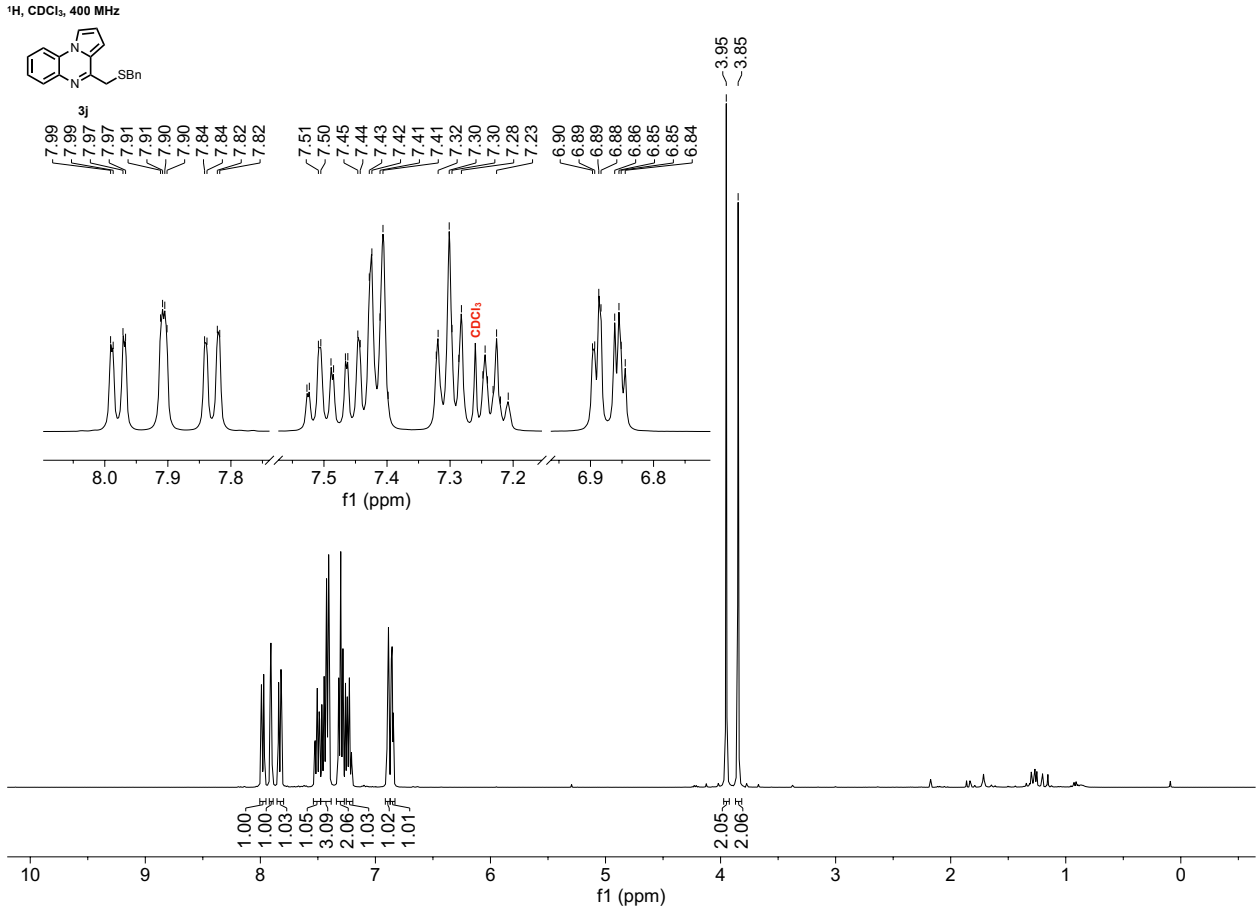
^{19}F $CDCl_3$, 471 MHz

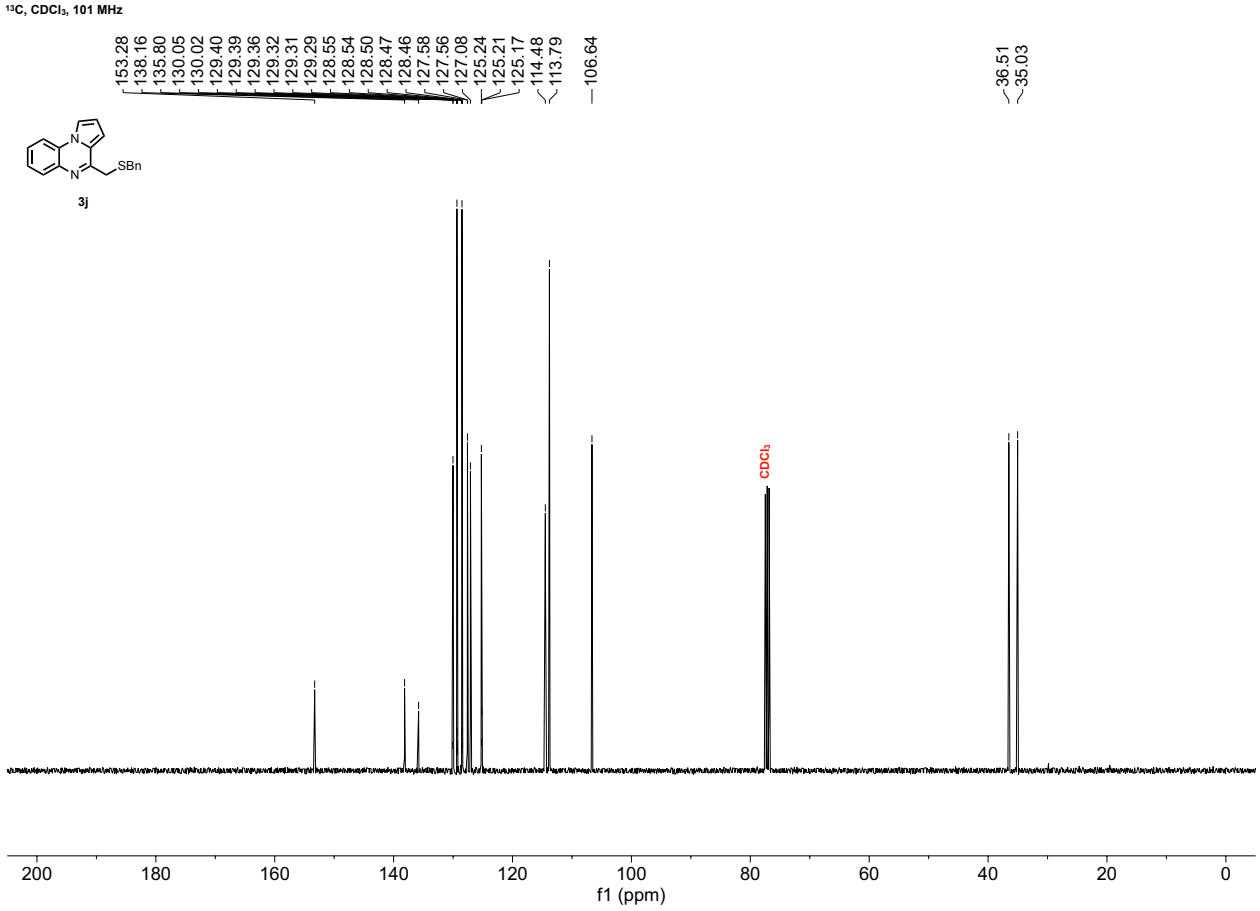


3h

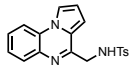

¹H, CDCl₃, 500 MHz
3i
OMe
8.04
8.02
8.02
8.01
8.01
8.00
8.00
7.95
7.95
7.84
7.83
7.82
7.82
7.47
7.47
7.46
7.45
7.45
7.44
7.43
7.01
7.00
6.88
6.87
6.87
6.86
3.89
f1 (ppm)
CDCl₃
2.93
0.98
1.00
1.99
1.97
0.97
0.93
2.97


¹³C, CDCl₃, 101 MHz
3i
OMe
161.02
153.91
136.38
131.14
130.11
130.09
127.18
125.41
125.24
114.50
113.99
113.88
113.61
108.59
CDCl₃
55.45
f1 (ppm)


¹H, CDCl₃, 400 MHz
SBn
3j
7.99
7.99
7.97
7.97
7.91
7.91
7.90
7.90
7.84
7.84
7.82
7.82
7.51
7.50
7.45
7.44
7.43
7.42
7.41
7.41
7.32
7.30
7.30
7.28
7.23
6.90
6.89
6.89
6.88
6.86
6.85
6.85
6.84
3.95
3.85
CDCl₃
8.0
7.9
7.8
7.5
7.4
7.3
7.2
6.9
6.8
f1 (ppm)
1.00
1.00
1.03
1.05
3.09
2.06
1.03
1.02
1.01
2.05
2.06
10
9
8
7
6
5
4
3
2
1
0
f1 (ppm)

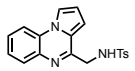

¹³C, CDCl₃, 101 MHz
153.28
138.16
135.80
130.05
130.02
129.40
129.39
129.36
129.32
129.31
129.29
128.55
128.54
128.50
128.47
128.46
127.58
127.56
127.08
125.24
125.21
125.17
114.48
113.79
106.64
36.51
35.03
SBn
3j
CDCl₃
200
180
160
140
120
100
80
60
40
20
0
f1 (ppm)

^{1}H, $CDCl_3$, 500 MHz

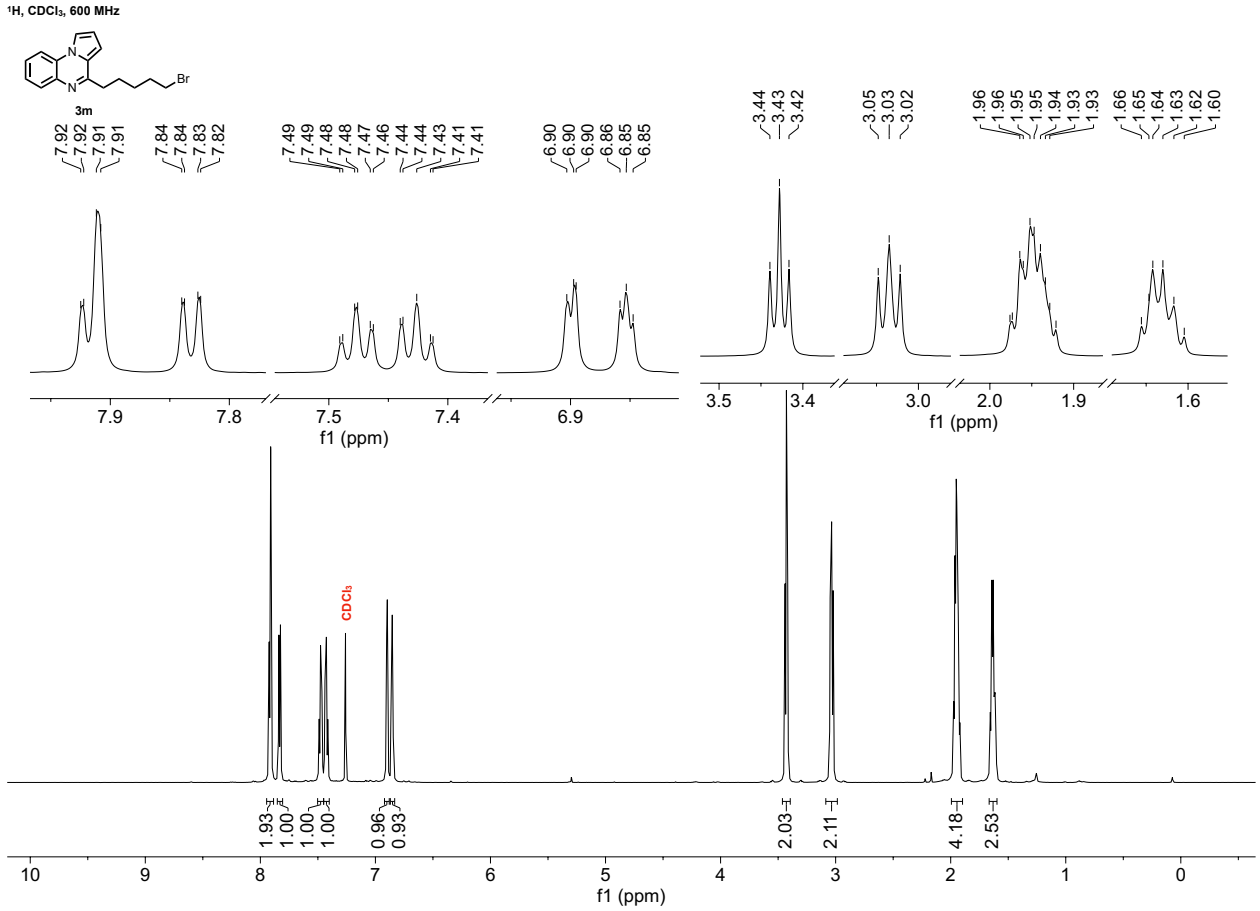


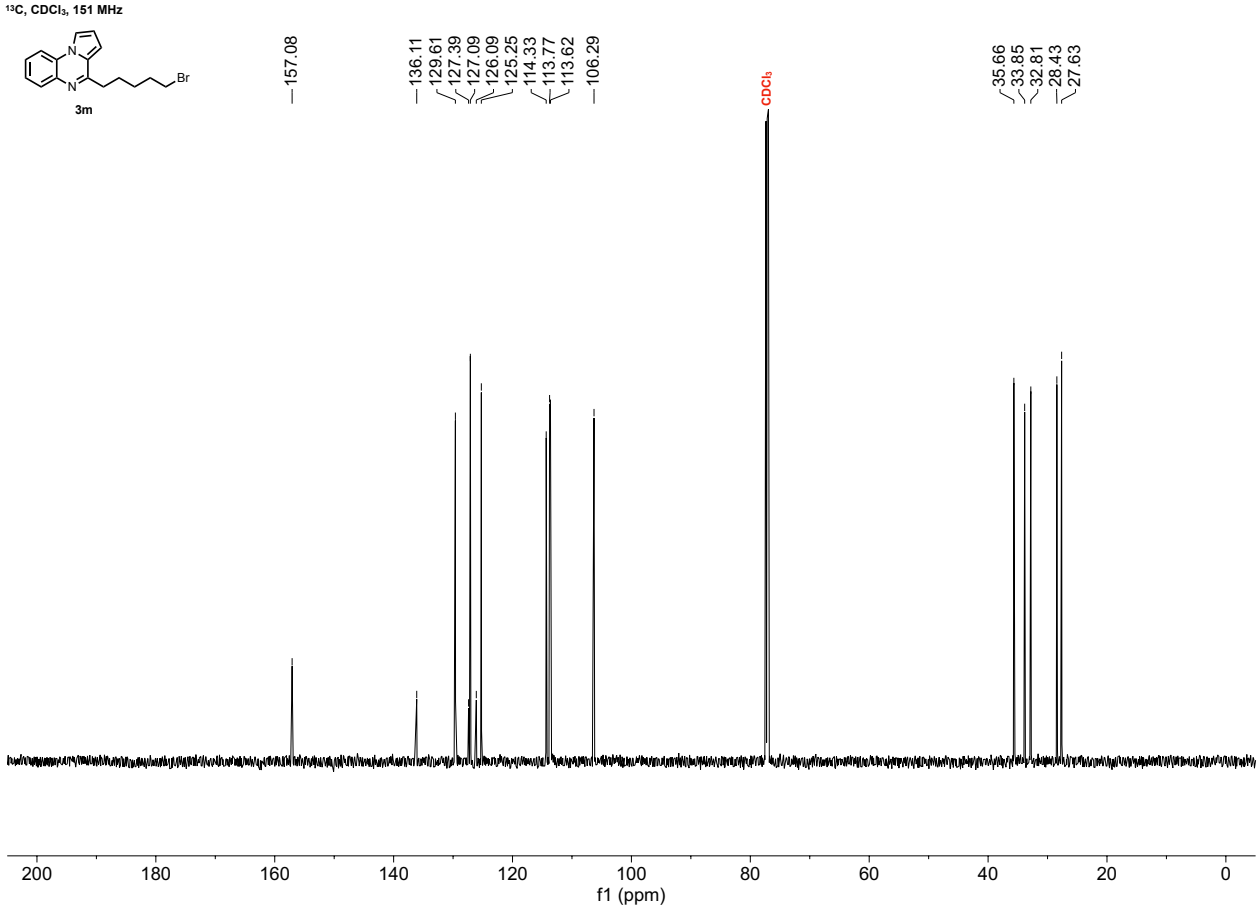
3k

^{13}C, $CDCl_3$, 126 MHz

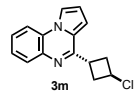


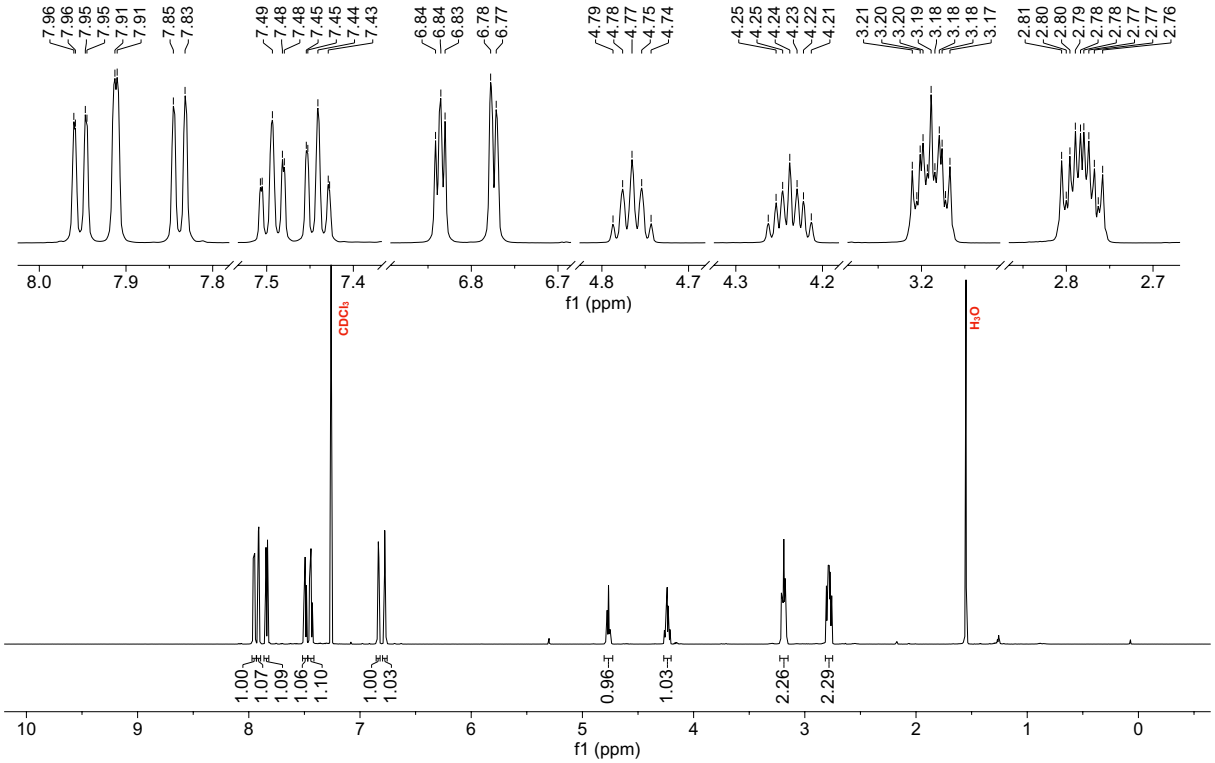
3k


¹H, CDCl₃, 600 MHz
3m
Br
7.92
7.92
7.91
7.91
7.84
7.84
7.83
7.82
7.49
7.49
7.48
7.48
7.47
7.46
7.44
7.44
7.43
7.41
7.41
6.90
6.90
6.90
6.86
6.85
6.85
3.44
3.43
3.42
3.05
3.03
3.02
1.96
1.96
1.95
1.95
1.94
1.93
1.93
1.66
1.65
1.64
1.63
1.62
1.60
7.9
7.8
7.5
7.4
6.9
f1 (ppm)
3.5
3.4
3.0
2.0
1.9
1.6
f1 (ppm)
CDCl₃
1.93
1.00
1.00
1.00
0.96
0.93
2.03
2.11
4.18
2.53
10
9
8
7
6
5
4
3
2
1
0
f1 (ppm)

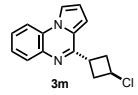

¹³C, CDCl₃, 151 MHz
3m
Br
157.08
136.11
129.61
127.39
127.09
126.09
125.25
114.33
113.77
113.62
106.29
CDCl₃
35.66
33.85
32.81
28.43
27.63
200
180
160
140
120
100
80
60
40
20
0
f1 (ppm)

^{1}H, $CDCl_3$, 600 MHz

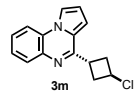




^{13}C, $CDCl_3$, 151 MHz

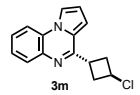


1D NOESY, $CDCl_3$, 600 MHz

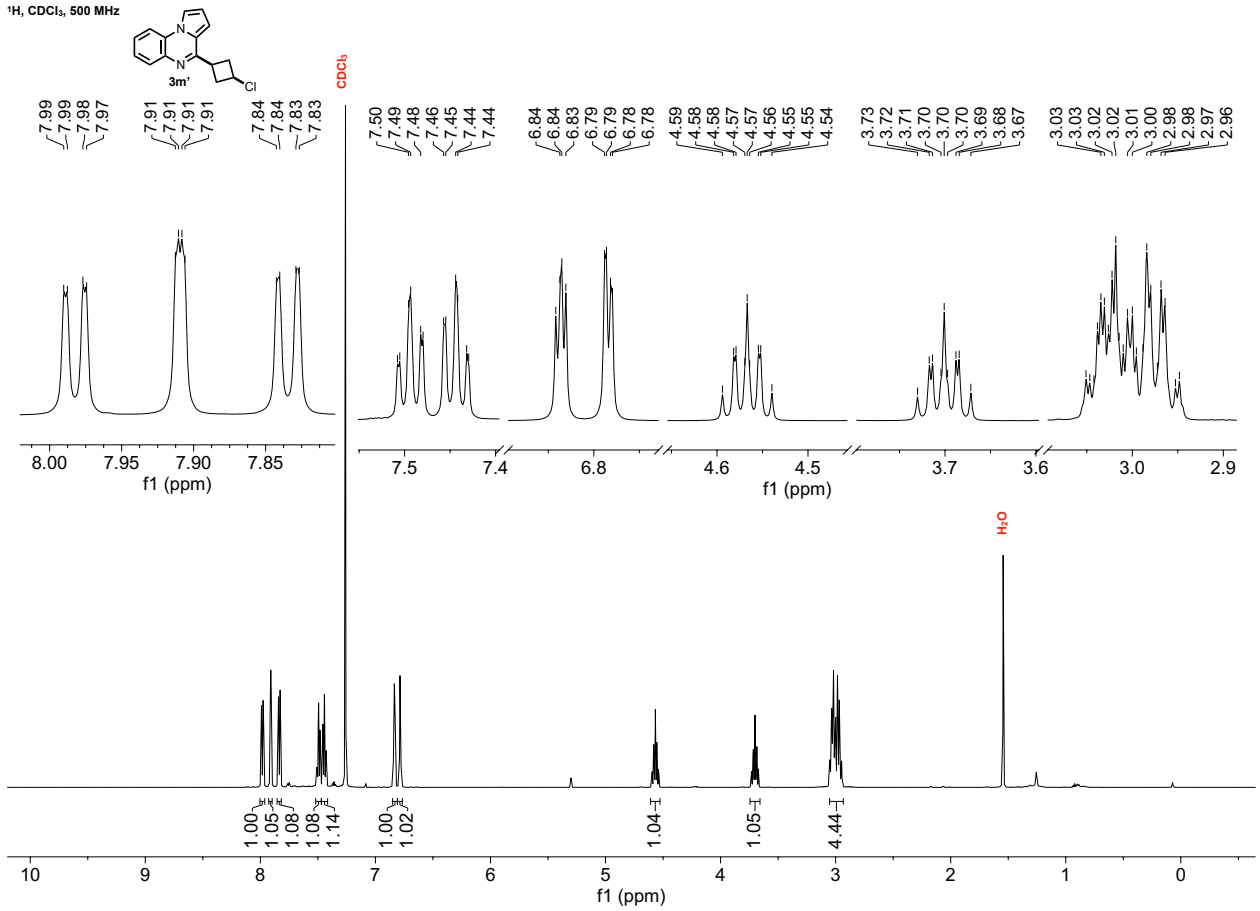


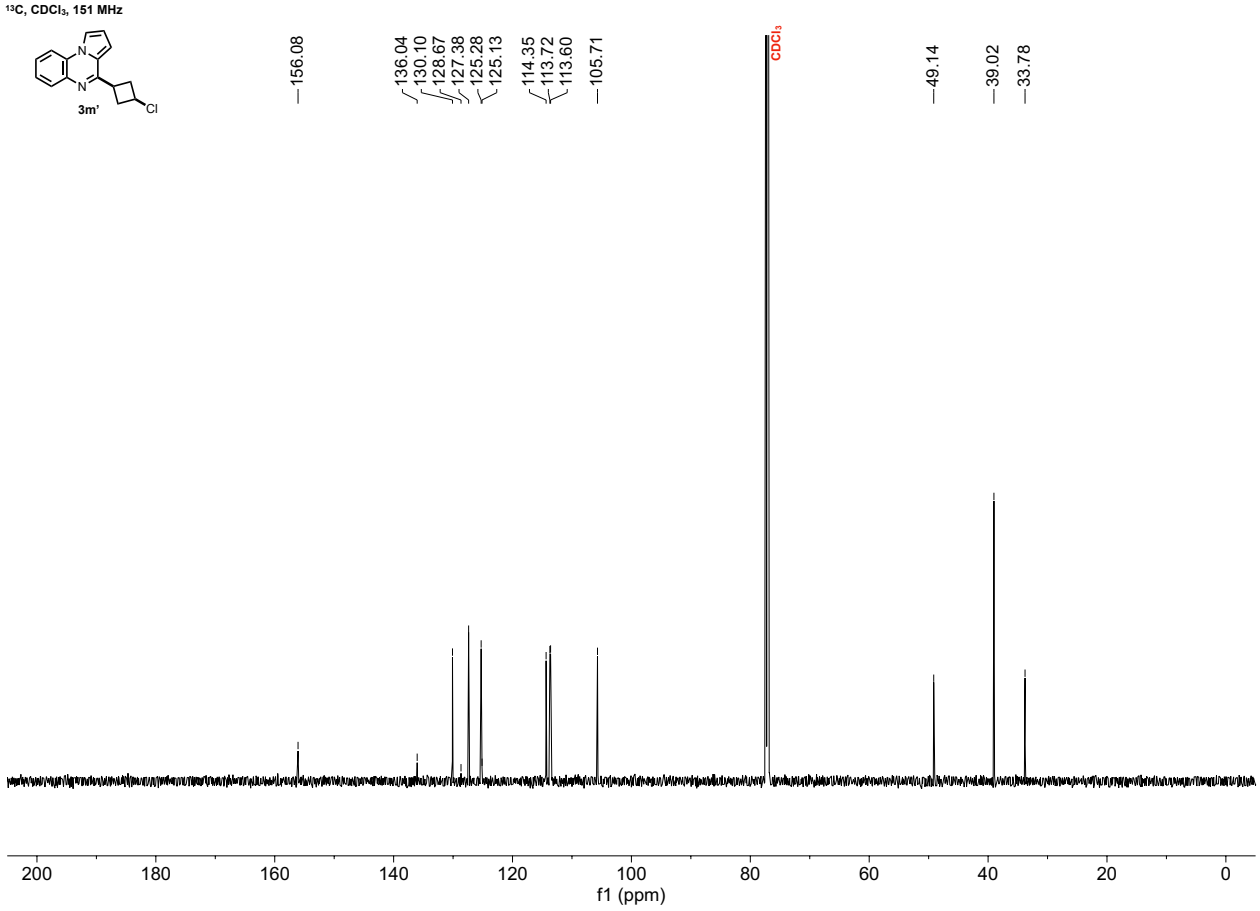
3m

1D NOESY, $CDCl_3$, 600 MHz

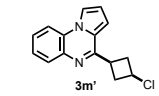


3m

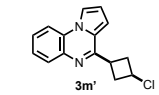

¹H, CDCl₃, 500 MHz
3m'
Cl
CDCl₃
H₂O
7.99 7.99 7.98 7.97
7.91 7.91 7.91 7.91
7.84 7.84 7.83 7.83
7.50 7.49 7.48 7.46 7.45 7.44 7.44
6.84 6.84 6.83 6.79 6.79 6.78 6.78
4.59 4.58 4.58 4.57 4.57 4.56 4.55 4.55 4.54
3.73 3.72 3.71 3.70 3.70 3.70 3.69 3.68 3.67
3.03 3.03 3.02 3.02 3.01 3.00 2.98 2.98 2.97 2.96
8.00 7.95 7.90 7.85
f1 (ppm)
7.5 7.4 6.8 4.6 4.5 3.7 3.6 3.0 2.9
f1 (ppm)
1.00 1.05 1.08 1.08 1.14 1.00 1.02 1.04 1.05 4.44
10 9 8 7 6 5 4 3 2 1 0
f1 (ppm)

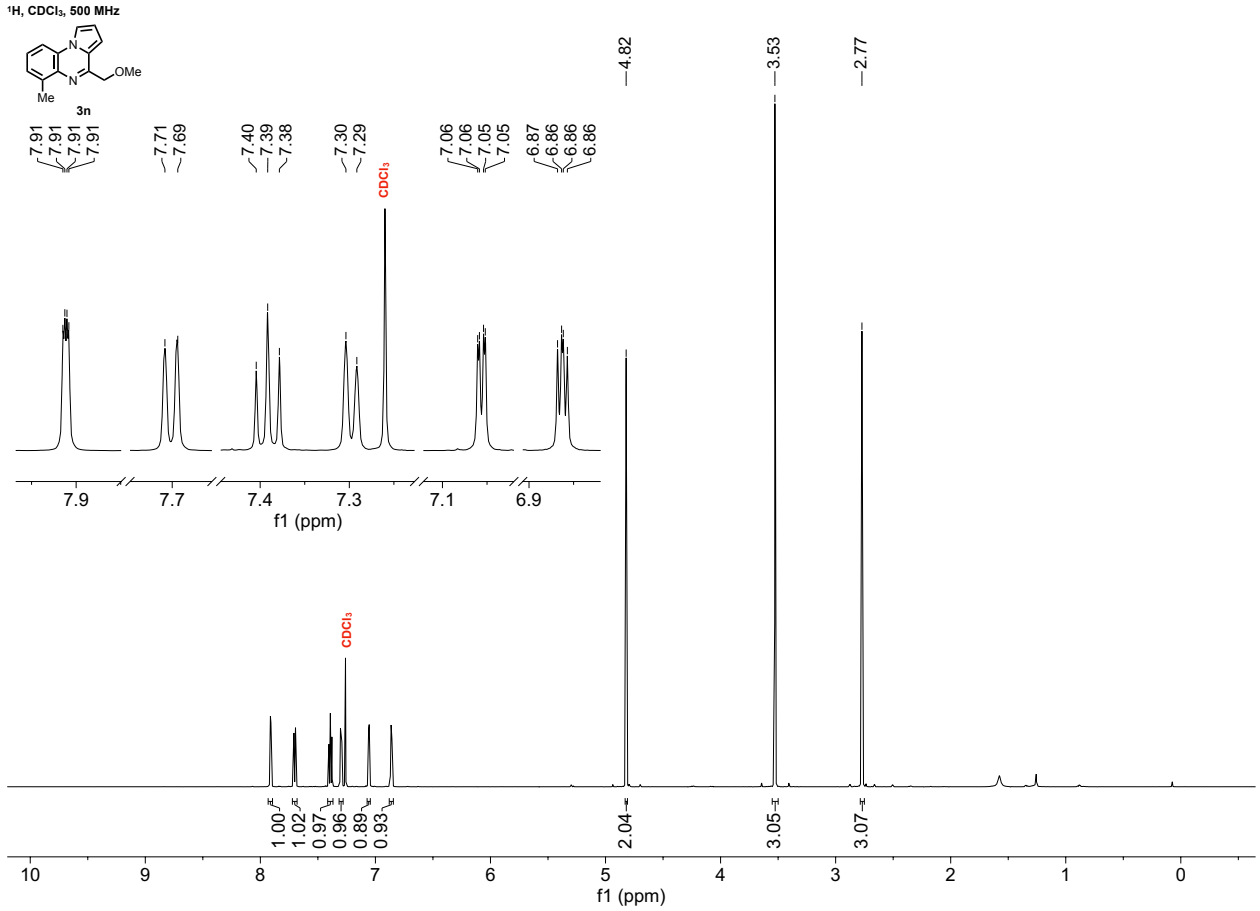

¹³C, CDCl₃, 151 MHz
3m'
Cl
CDCl₃
156.08
136.04 130.10 128.67 127.38 125.28 125.13
114.35 113.72 113.60
105.71
49.14
39.02
33.78
200 180 160 140 120 100 80 60 40 20 0
f1 (ppm)

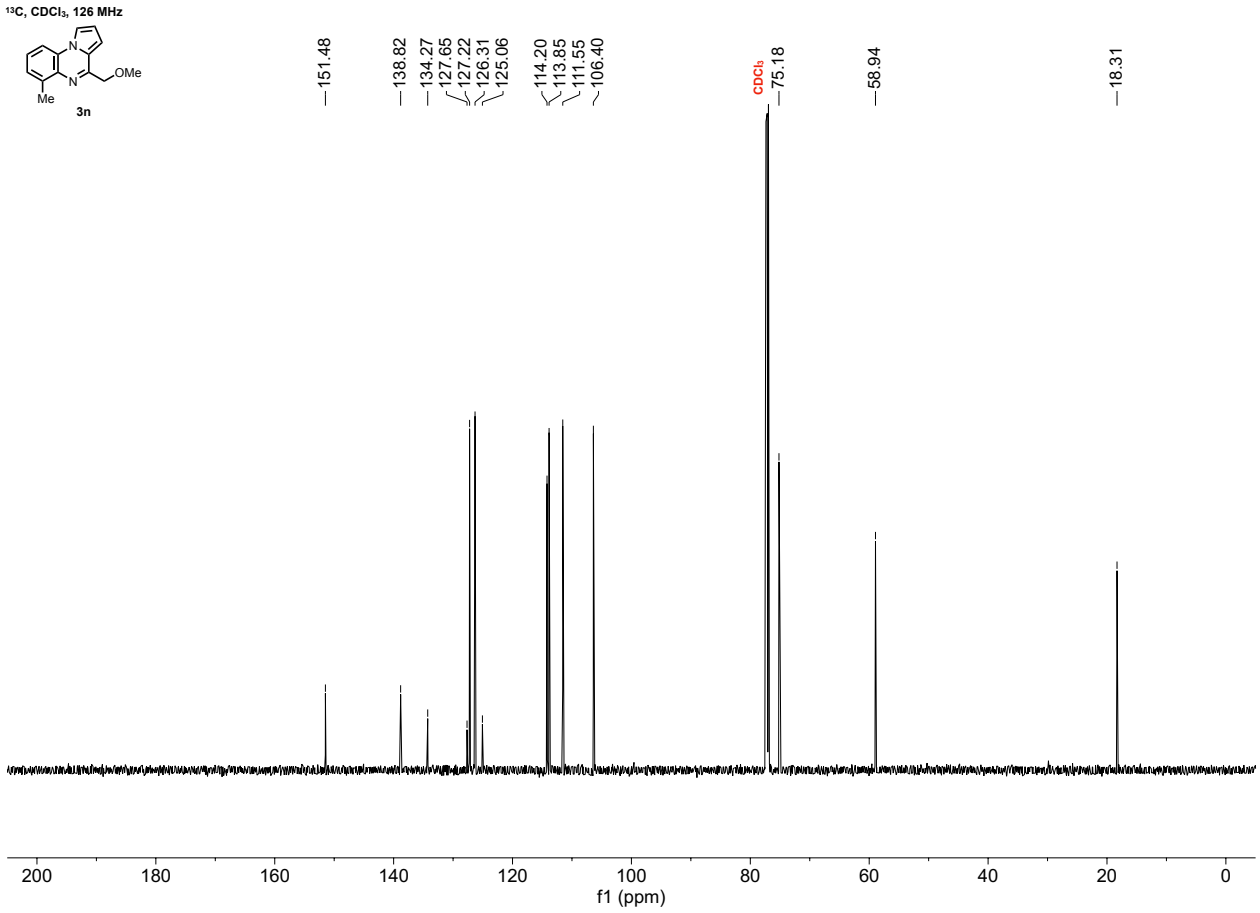
1D NOESY, $CDCl_3$, 600 MHz

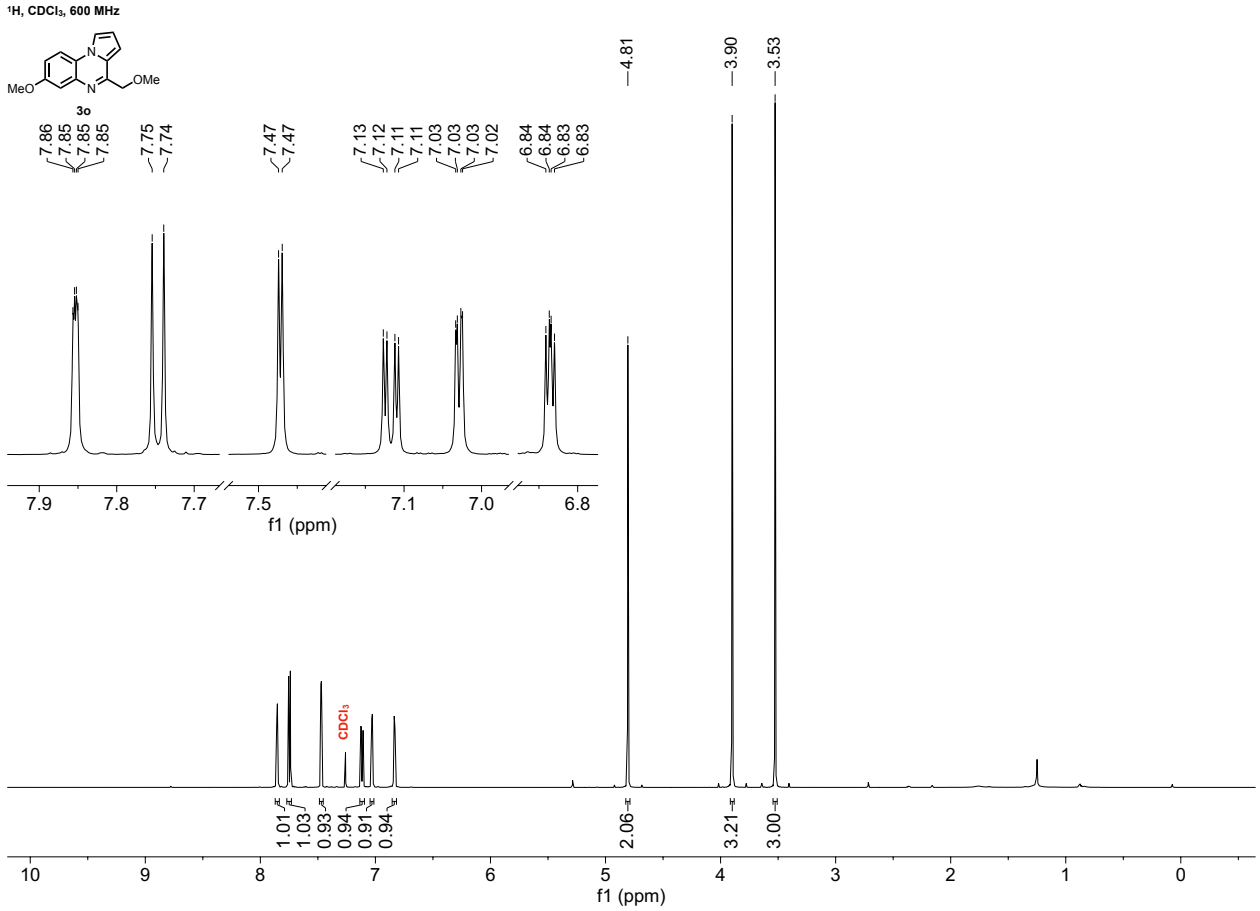


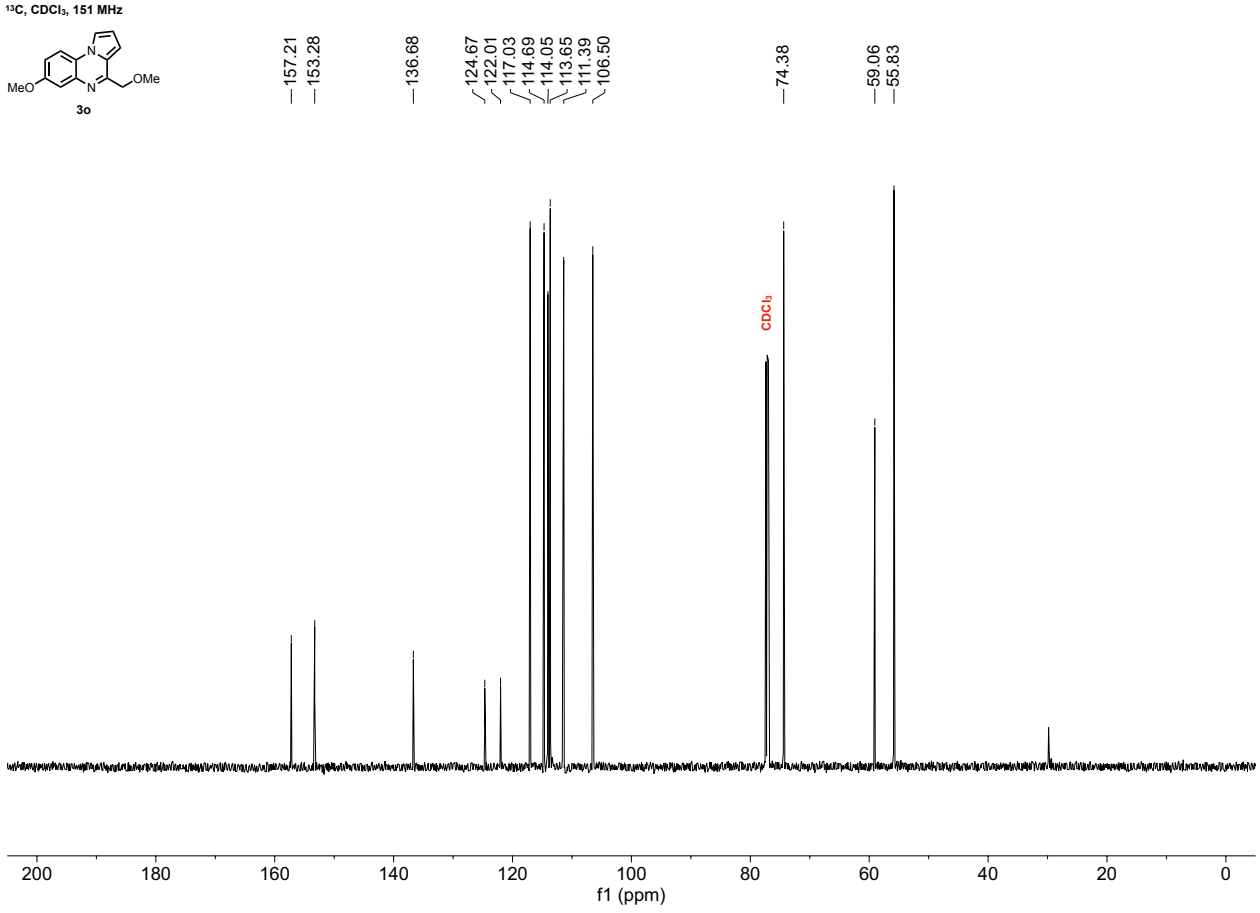
1D NOESY, $CDCl_3$, 600 MHz



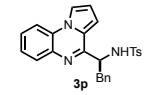

¹H, CDCl₃, 500 MHz
OMe
Me
3n
7.91
7.91
7.91
7.91
7.71
7.69
7.40
7.39
7.38
7.30
7.29
CDCl₃
7.06
7.06
7.05
7.05
6.87
6.86
6.86
6.86
4.82
3.53
2.77
7.9
7.7
7.4
7.3
7.1
6.9
f1 (ppm)
CDCl₃
1.00
1.02
0.97
0.96
0.89
0.93
2.04
3.05
3.07
10
9
8
7
6
5
4
3
2
1
0
f1 (ppm)


¹³C, CDCl₃, 126 MHz
OMe
Me
3n
151.48
138.82
134.27
127.65
127.22
126.31
125.06
114.20
113.85
111.55
106.40
CDCl₃
75.18
58.94
18.31
200
180
160
140
120
100
80
60
40
20
0
f1 (ppm)


¹H, CDCl₃, 600 MHz
MeO
OMe
3o
7.86
7.85
7.85
7.85
7.75
7.74
7.47
7.47
7.13
7.12
7.11
7.11
7.03
7.03
7.03
7.02
6.84
6.84
6.83
6.83
4.81
3.90
3.53
CDCl₃
1.01
1.03
0.93
0.94
0.91
0.94
2.06
3.21
3.00
f1 (ppm)

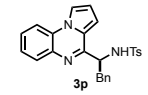

¹³C, CDCl₃, 151 MHz
MeO
OMe
3o
157.21
153.28
136.68
124.67
122.01
117.03
114.69
114.05
113.65
111.39
106.50
74.38
59.06
55.83
CDCl₃
f1 (ppm)

^{1}H, $CDCl_3$, 600 MHz



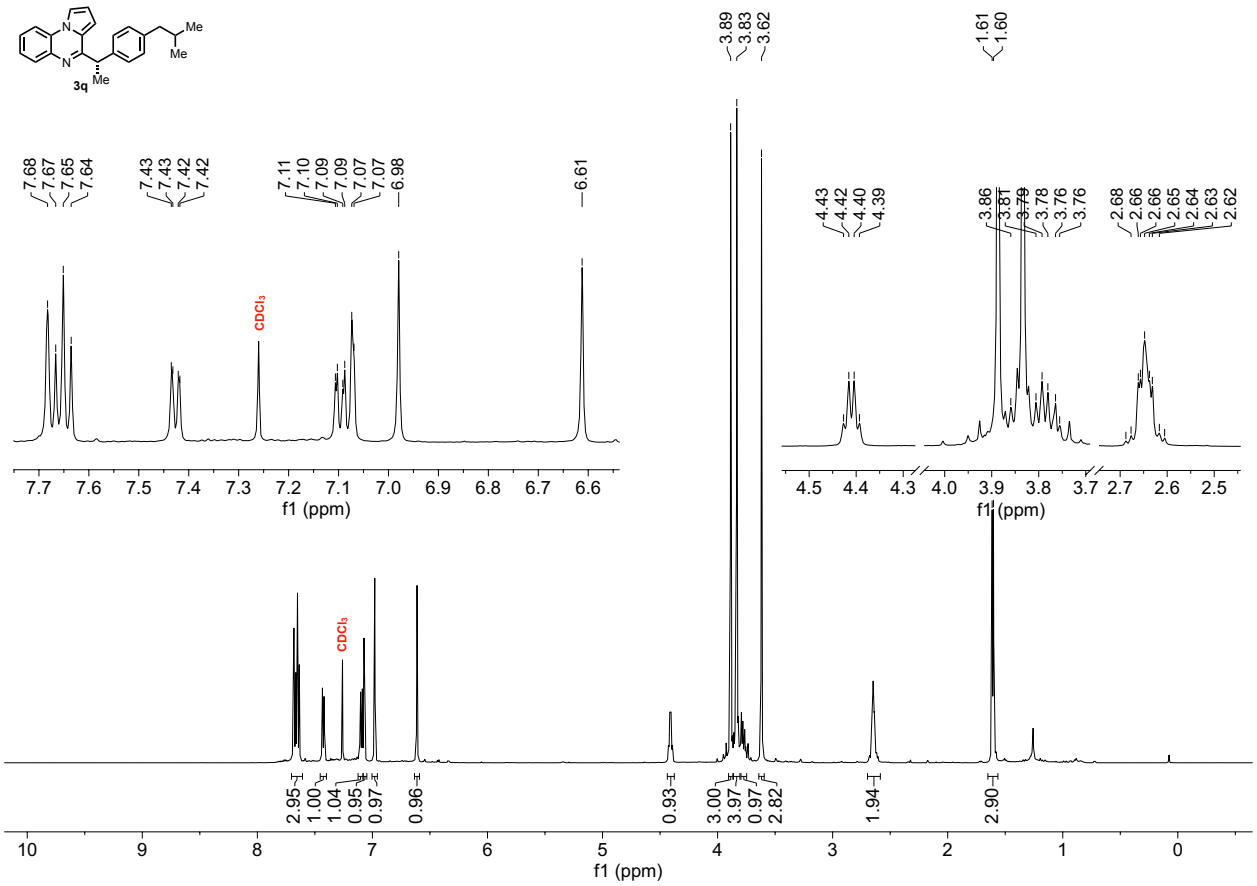
3p

^{13}C, $CDCl_3$, 151 MHz

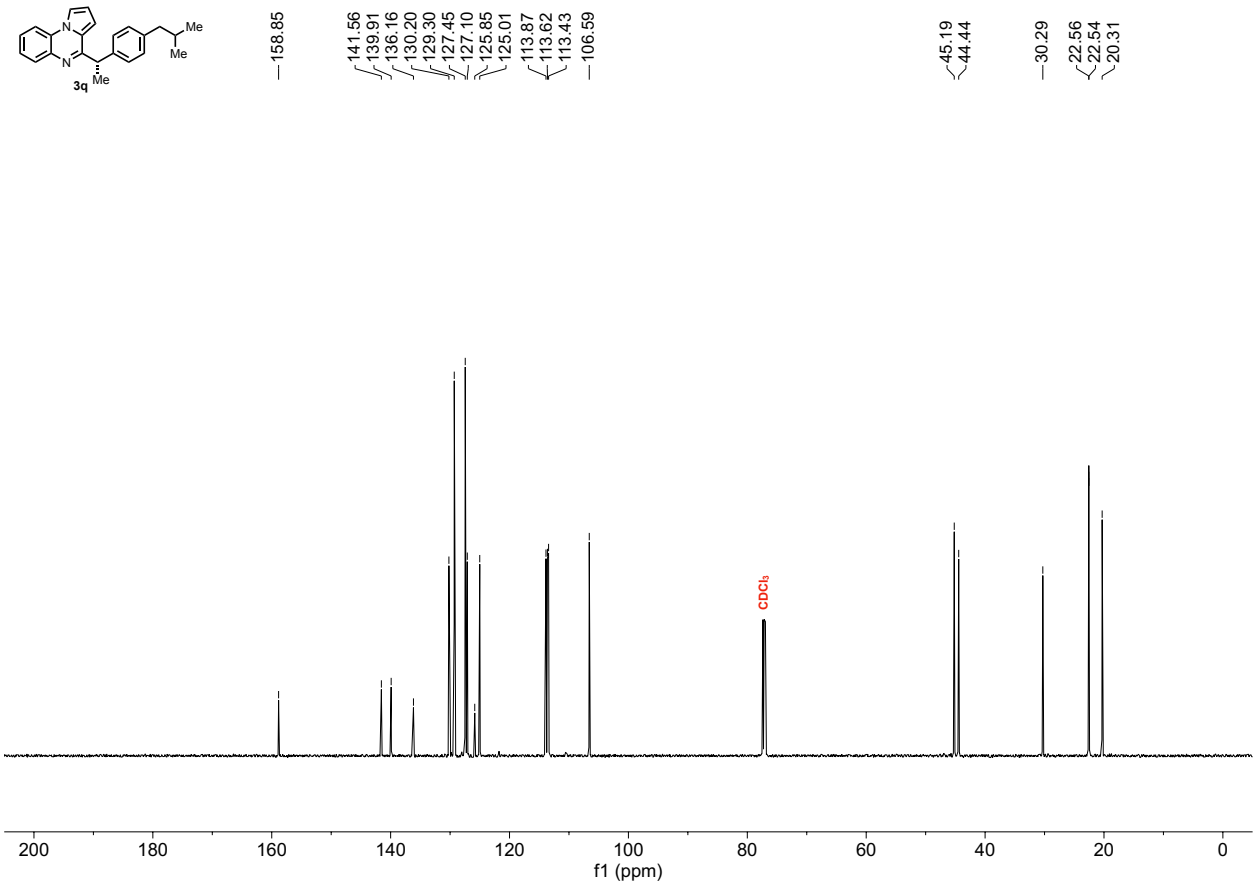


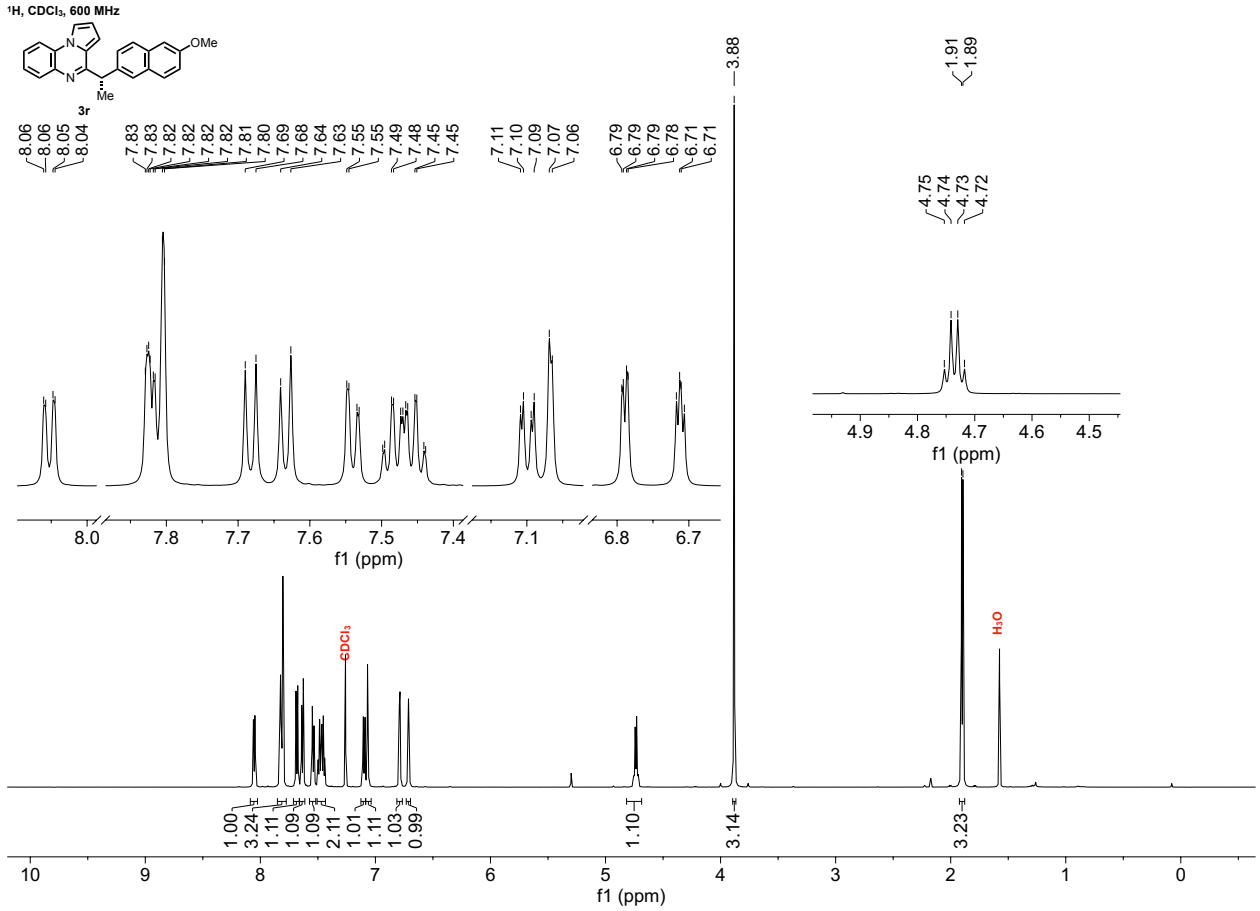
3p

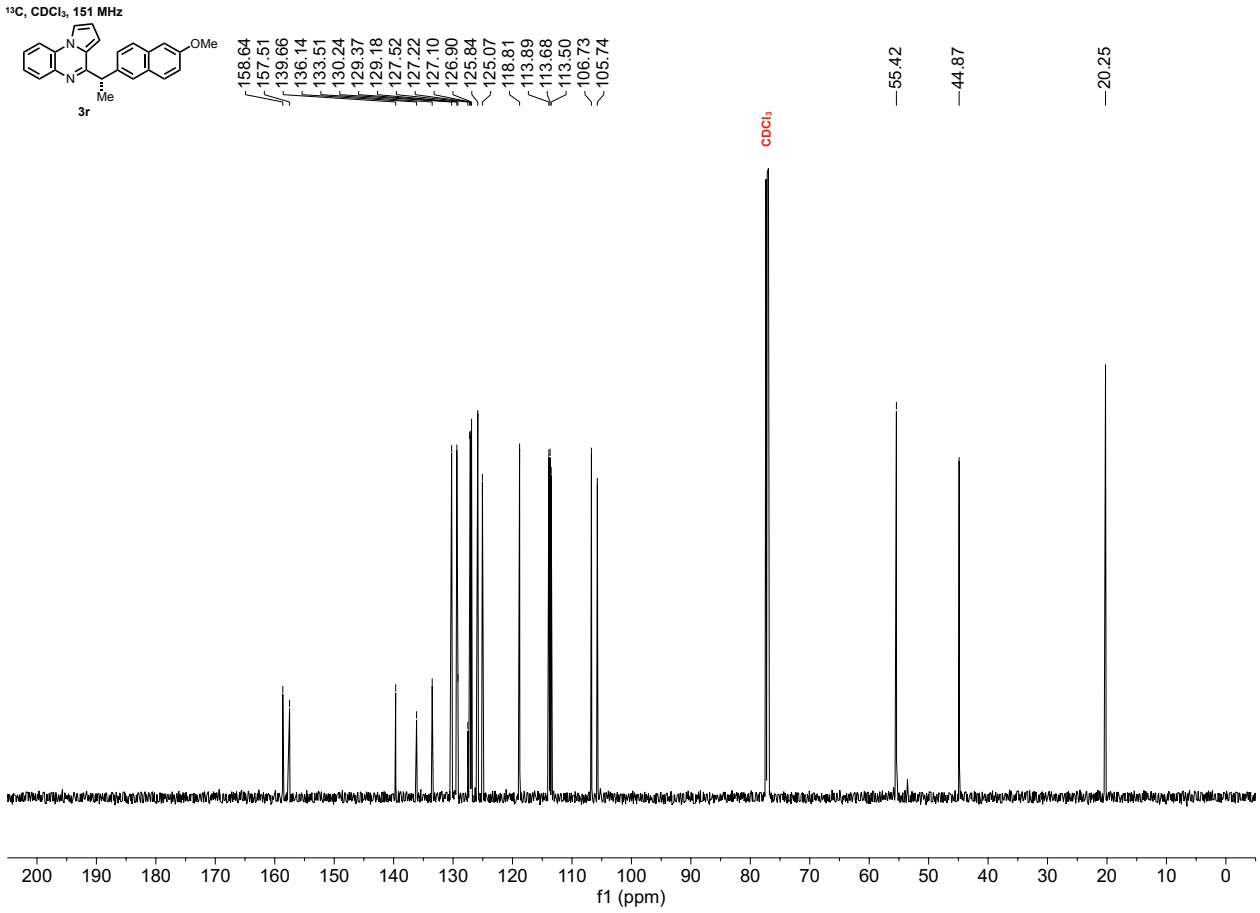
^{1}H, $CDCl_3$, 600 MHz



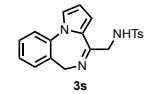
^{13}C, $CDCl_3$, 151 MHz




¹H, CDCl₃, 600 MHz
OMe
Me
3r
8.06
8.06
8.05
8.04
7.83
7.83
7.82
7.82
7.82
7.81
7.80
7.69
7.68
7.64
7.63
7.55
7.55
7.49
7.48
7.45
7.45
7.11
7.10
7.09
7.07
7.06
6.79
6.79
6.79
6.78
6.71
6.71
3.88
1.91
1.89
4.75
4.74
4.73
4.72
f1 (ppm)
CDCl₃
H₂O
1.00
3.24
1.11
1.09
1.09
2.11
1.01
1.11
1.03
0.99
1.10
3.14
3.23
f1 (ppm)

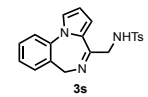

¹³C, CDCl₃, 151 MHz
OMe
Me
3r
158.64
157.51
139.66
136.14
133.51
130.24
129.37
129.18
127.52
127.22
127.10
126.90
125.84
125.07
118.81
113.89
113.68
113.50
106.73
105.74
55.42
44.87
20.25
CDCl₃
f1 (ppm)

^{1}H, $CDCl_3$, 600 MHz



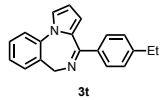
3s

^{13}C, $CDCl_3$, 151 MHz



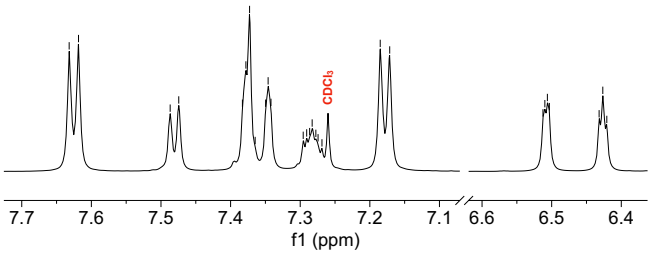
3s

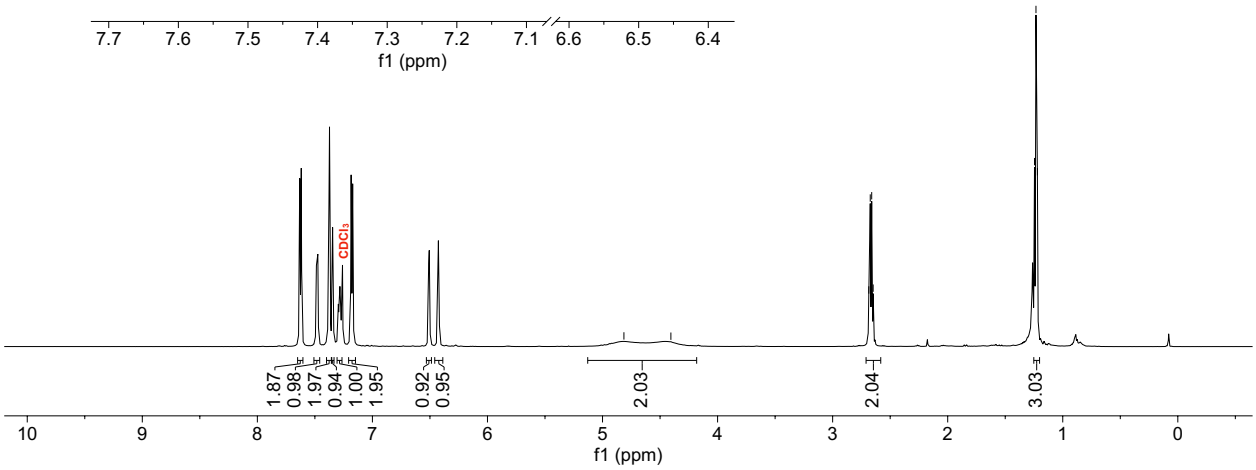
^{1}H, $CDCl_3$, 600 MHz



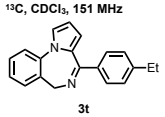
3t

7.63 7.62 7.49 7.47 7.38 7.38 7.37 7.36 7.35 7.35 7.34 7.30 7.29 7.29 7.28 7.28 7.27 7.27 7.19 7.17 6.51 6.51 6.51 6.50 6.43 6.43 6.42 4.81 4.41 2.69 2.67 2.66 2.65 1.25 1.23 1.22



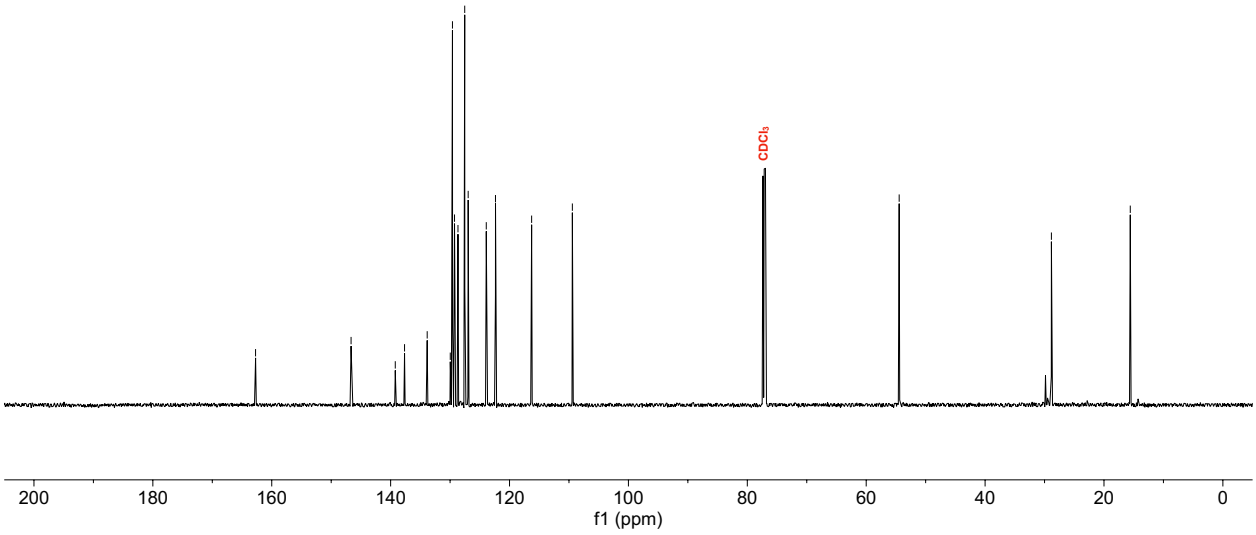


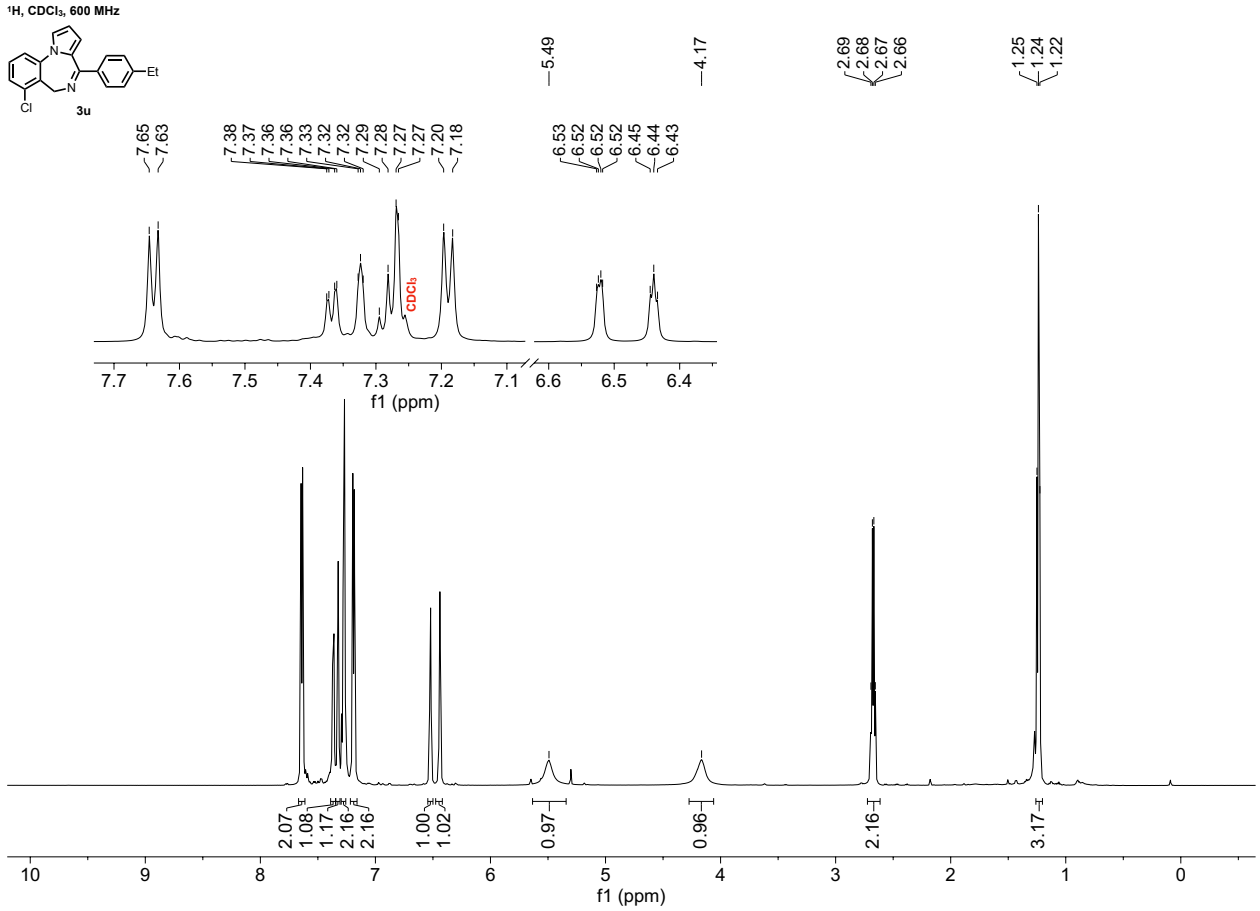
^{13}C, $CDCl_3$, 151 MHz

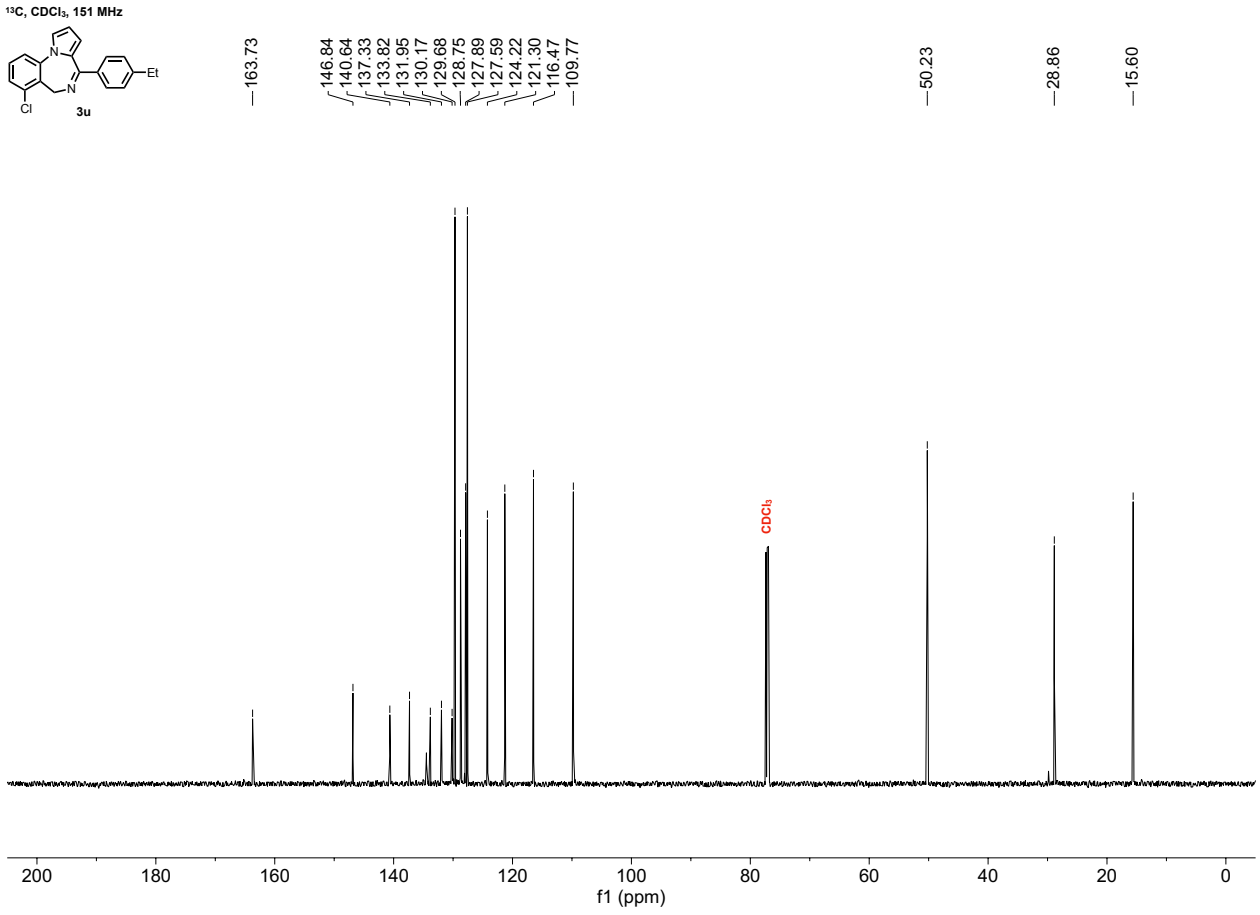


3t

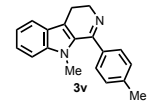
162.72 146.66 139.22 137.66 133.85 129.97 129.60 129.25 128.67 127.54 126.96 123.91 122.36 116.28 109.43 54.45 28.85 15.58




¹H, CDCl₃, 600 MHz
3u
5.49
4.17
2.69
2.68
2.67
2.66
1.25
1.24
1.22
7.65
7.63
7.38
7.37
7.36
7.36
7.33
7.32
7.32
7.29
7.28
7.27
7.27
7.20
7.18
6.53
6.52
6.52
6.52
6.45
6.44
6.43
CDCl₃
f1 (ppm)
2.07
1.08
1.17
2.16
2.16
1.00
1.02
0.97
0.96
2.16
3.17
f1 (ppm)

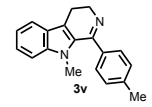

¹³C, CDCl₃, 151 MHz
3u
163.73
146.84
140.64
137.33
133.82
131.95
130.17
129.68
128.75
127.89
127.59
124.22
121.30
116.47
109.77
50.23
28.86
15.60
CDCl₃
f1 (ppm)

^{1}H, $CDCl_3$, 600 MHz

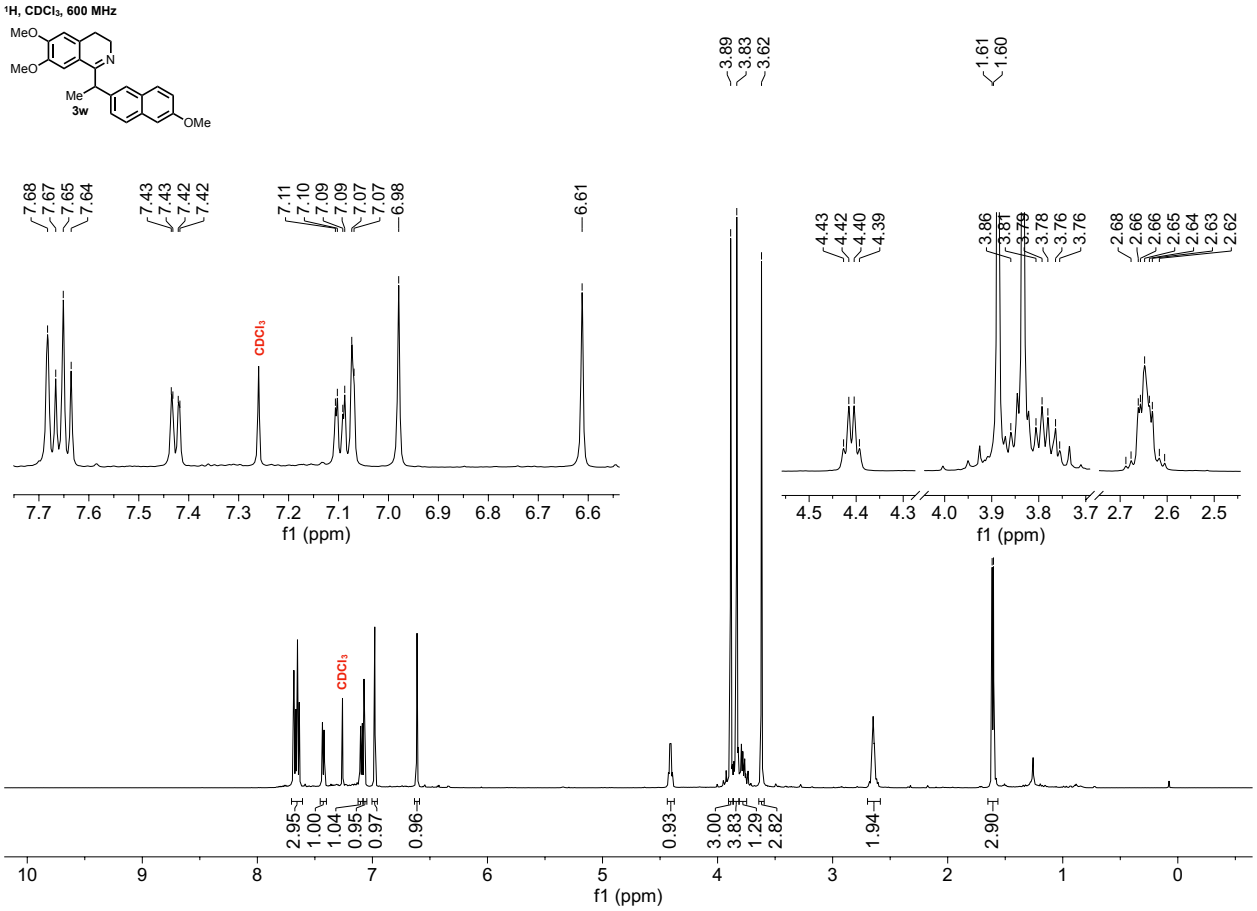


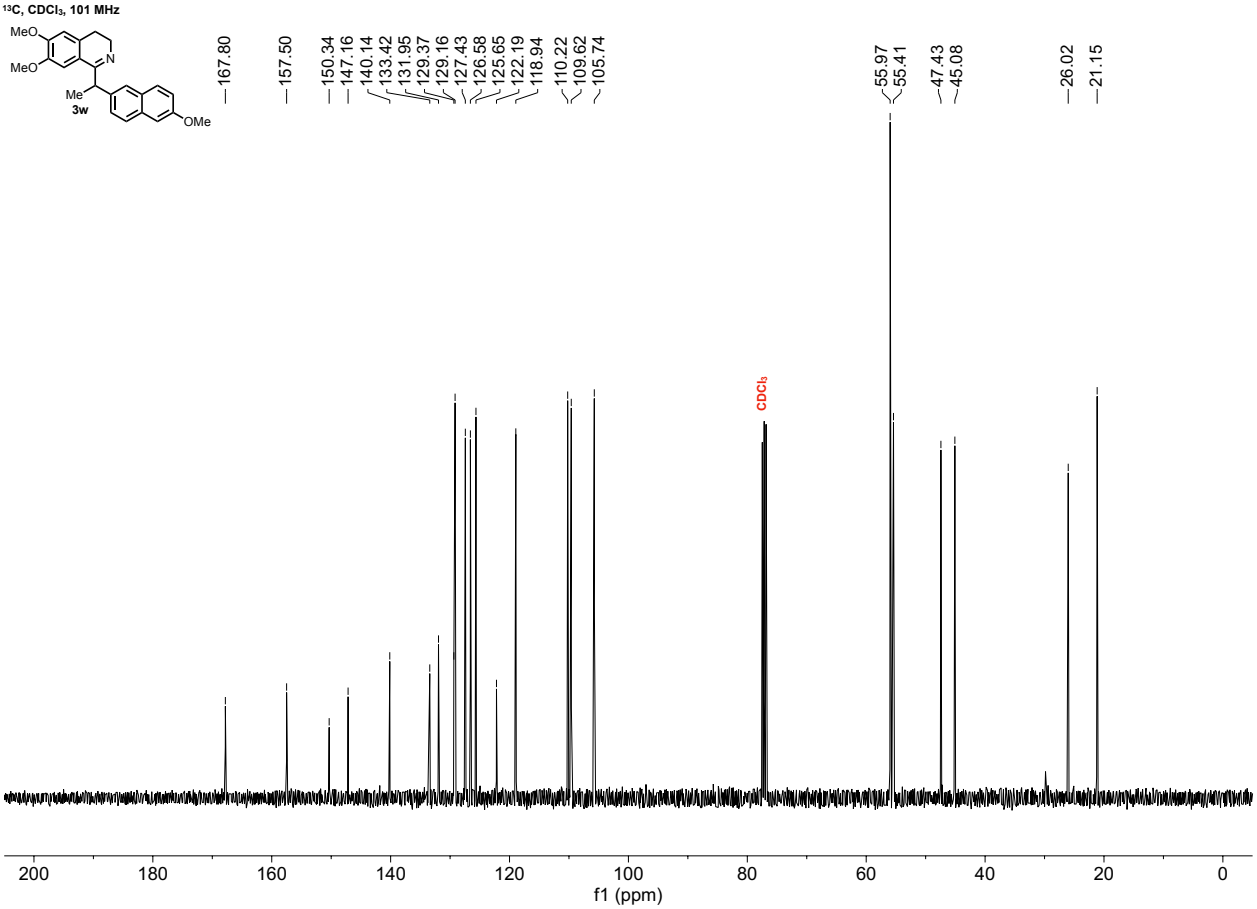
3v

^{13}C, $CDCl_3$, 151 MHz

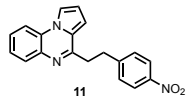


3v

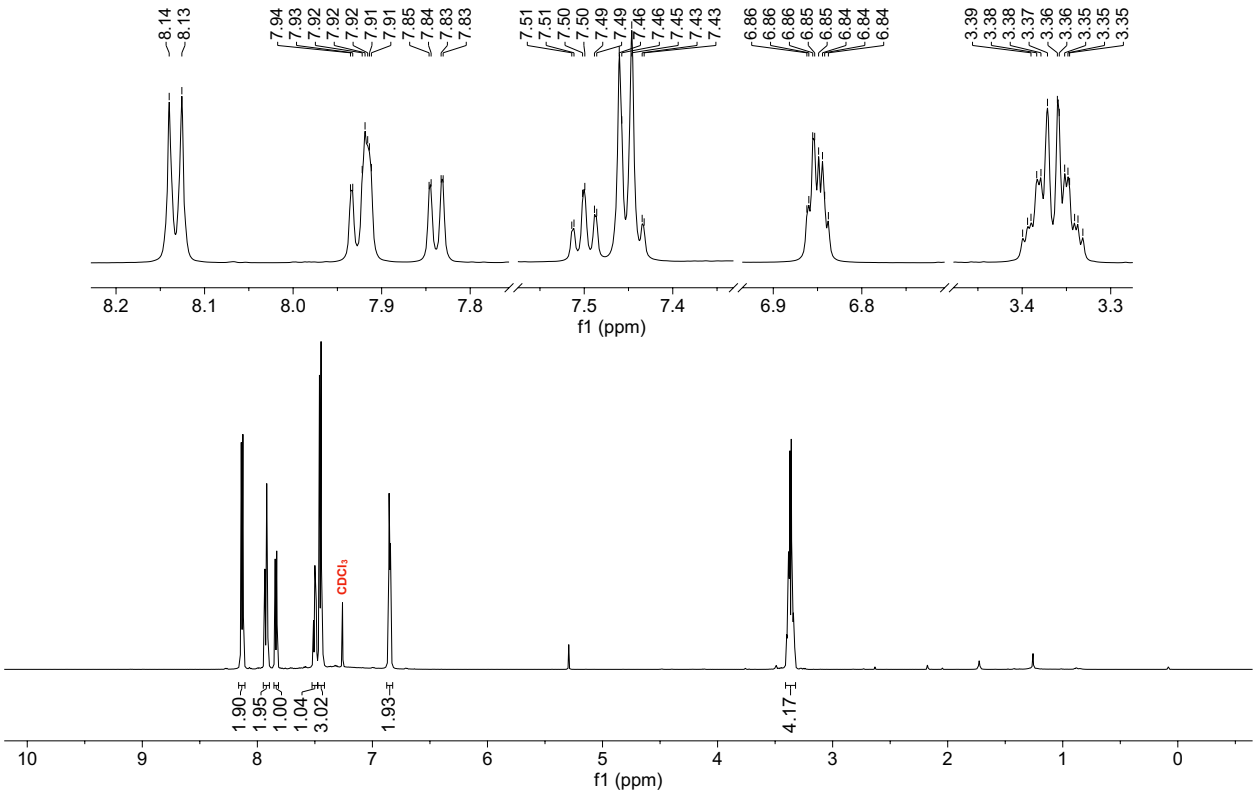

¹H, CDCl₃, 600 MHz
MeO
MeO
N
Me
3w
OMe
7.68
7.67
7.65
7.64
7.43
7.43
7.42
7.42
7.11
7.10
7.09
7.09
7.07
7.07
6.98
6.61
CDCl₃
3.89
3.83
3.62
1.61
1.60
4.43
4.42
4.40
4.39
3.86
3.81
3.79
3.78
3.76
3.76
2.68
2.66
2.66
2.65
2.64
2.63
2.62
f1 (ppm)
2.95
1.00
1.04
0.95
0.97
0.96
0.93
3.00
3.83
1.29
2.82
1.94
2.90


¹³C, CDCl₃, 101 MHz
MeO
MeO
N
Me
3w
OMe
167.80
157.50
150.34
147.16
140.14
133.42
131.95
129.37
129.16
127.43
126.58
125.65
122.19
118.94
110.22
109.62
105.74
55.97
55.41
47.43
45.08
26.02
21.15
CDCl₃
f1 (ppm)

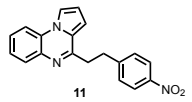
^{1}H, $CDCl_3$, 600 MHz



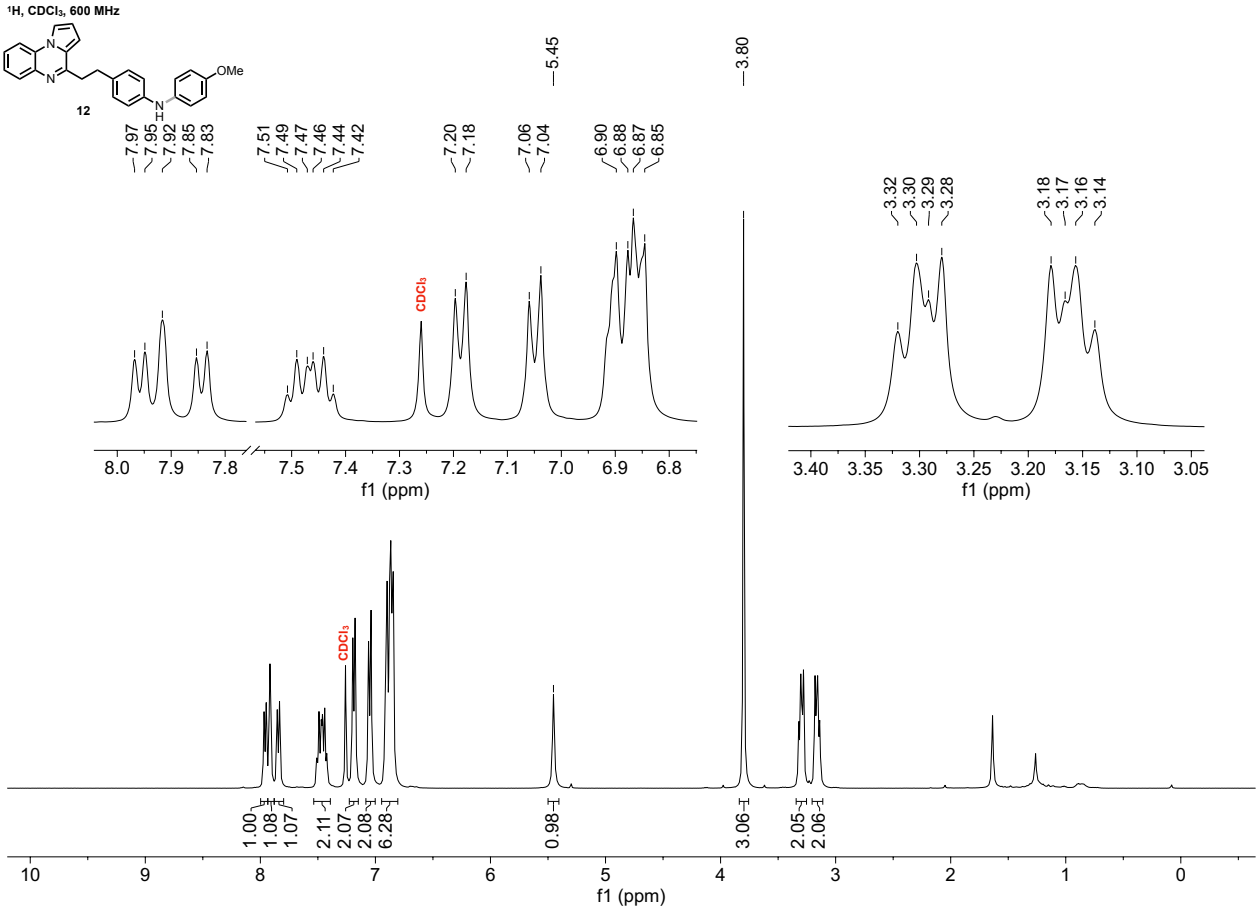
11

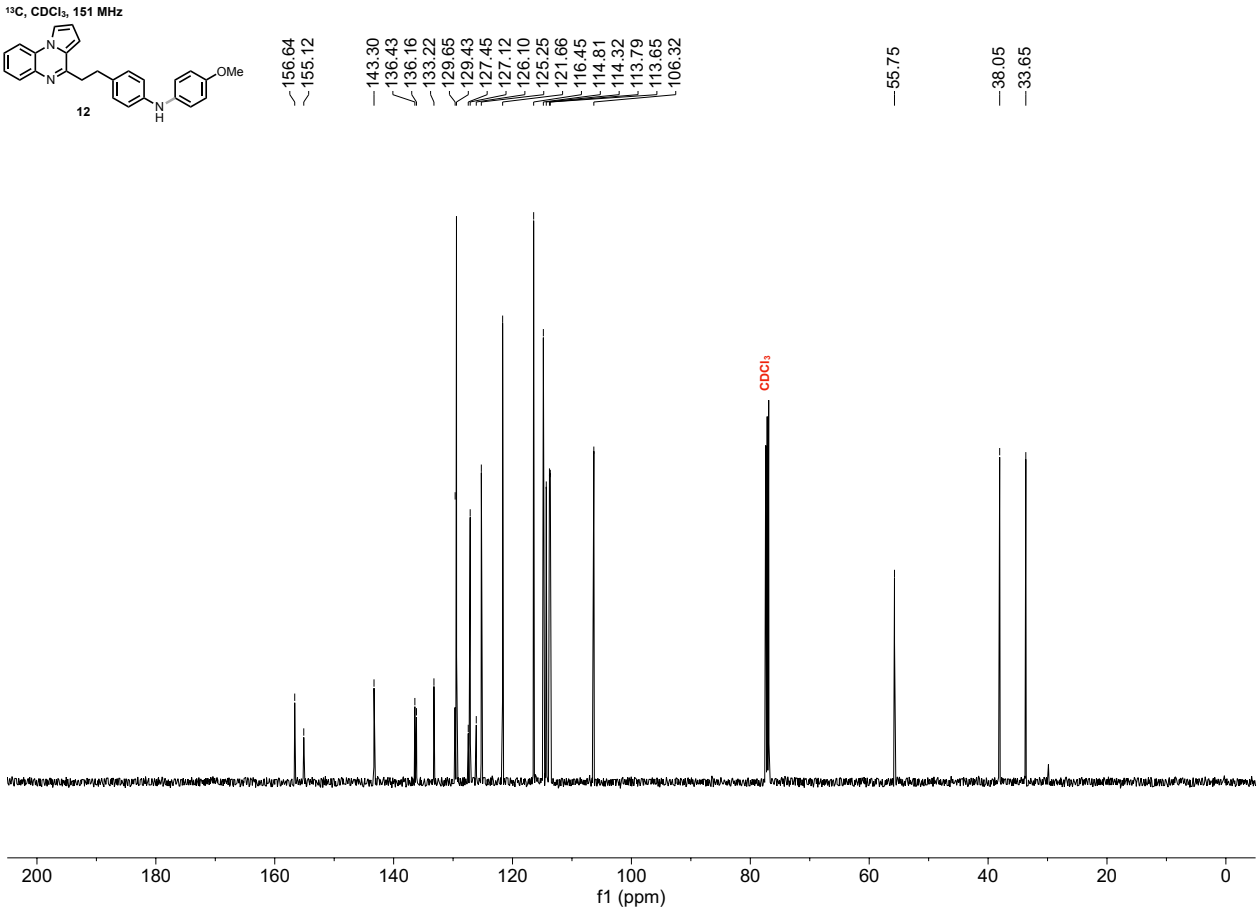


^{13}C, $CDCl_3$, 151 MHz

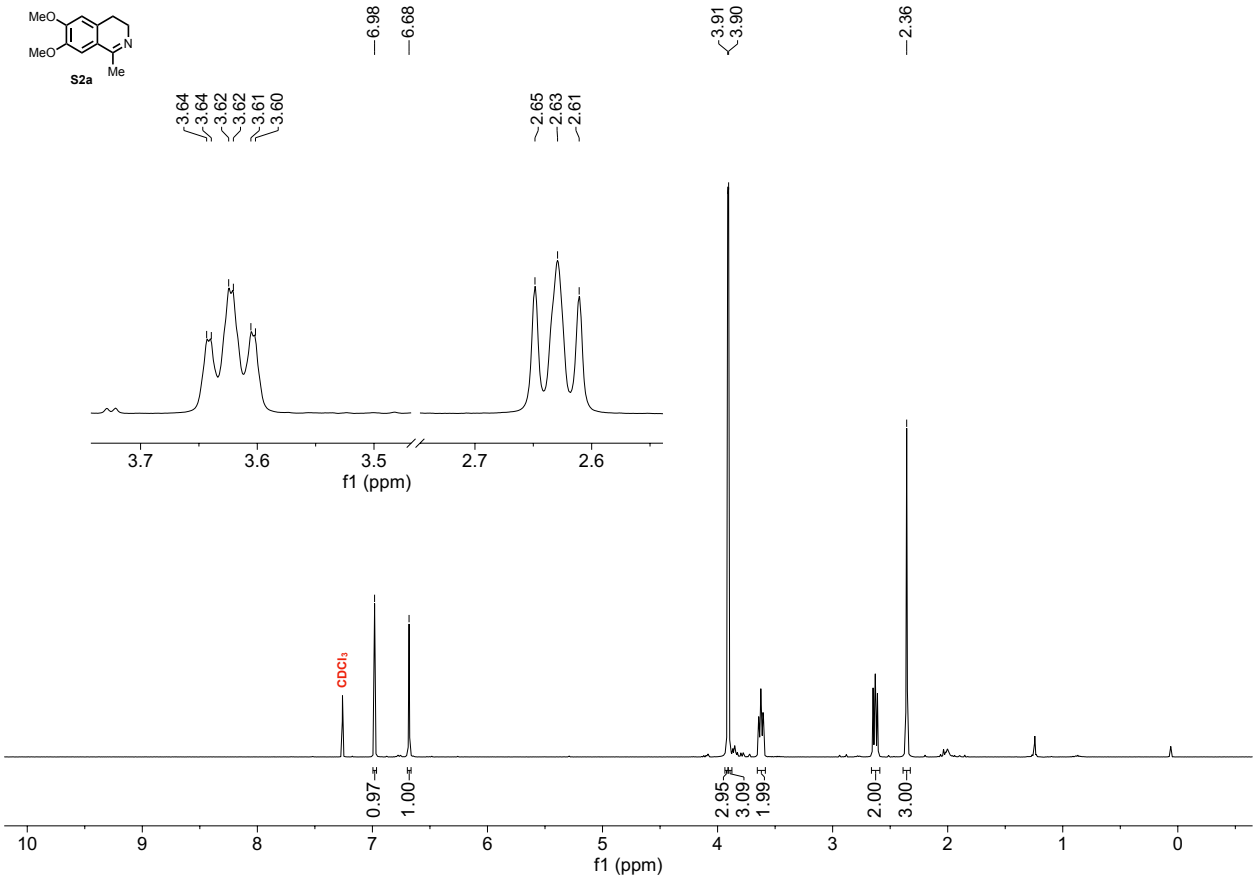


11

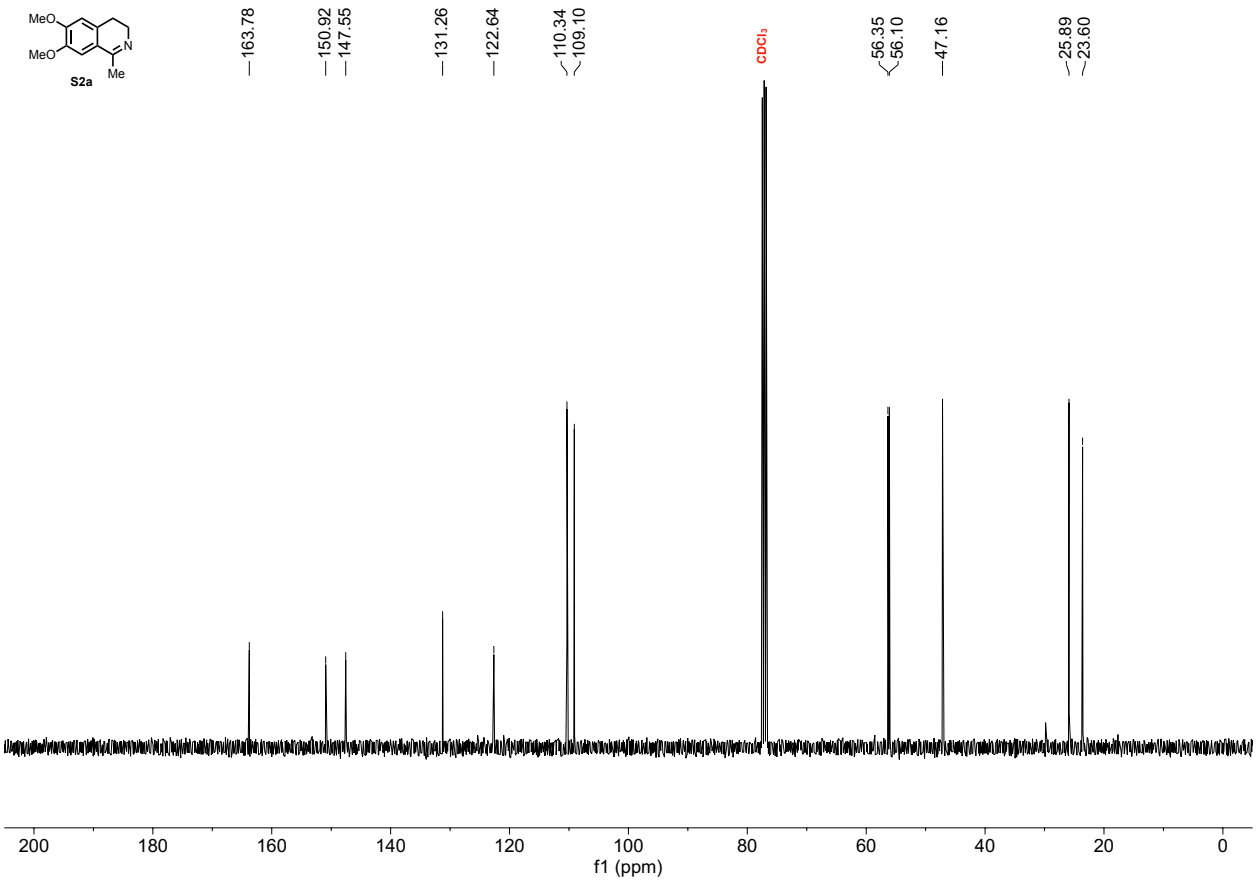

¹H, CDCl₃, 600 MHz
12
OMe
N
H
7.97
7.95
7.92
7.85
7.83
7.51
7.49
7.47
7.46
7.44
7.42
7.20
7.18
7.06
7.04
6.90
6.88
6.87
6.85
5.45
3.80
3.32
3.30
3.29
3.28
3.18
3.17
3.16
3.14
CDCl₃
f1 (ppm)
1.00
1.08
1.07
2.11
2.07
2.08
6.28
0.98
3.06
2.05
2.06

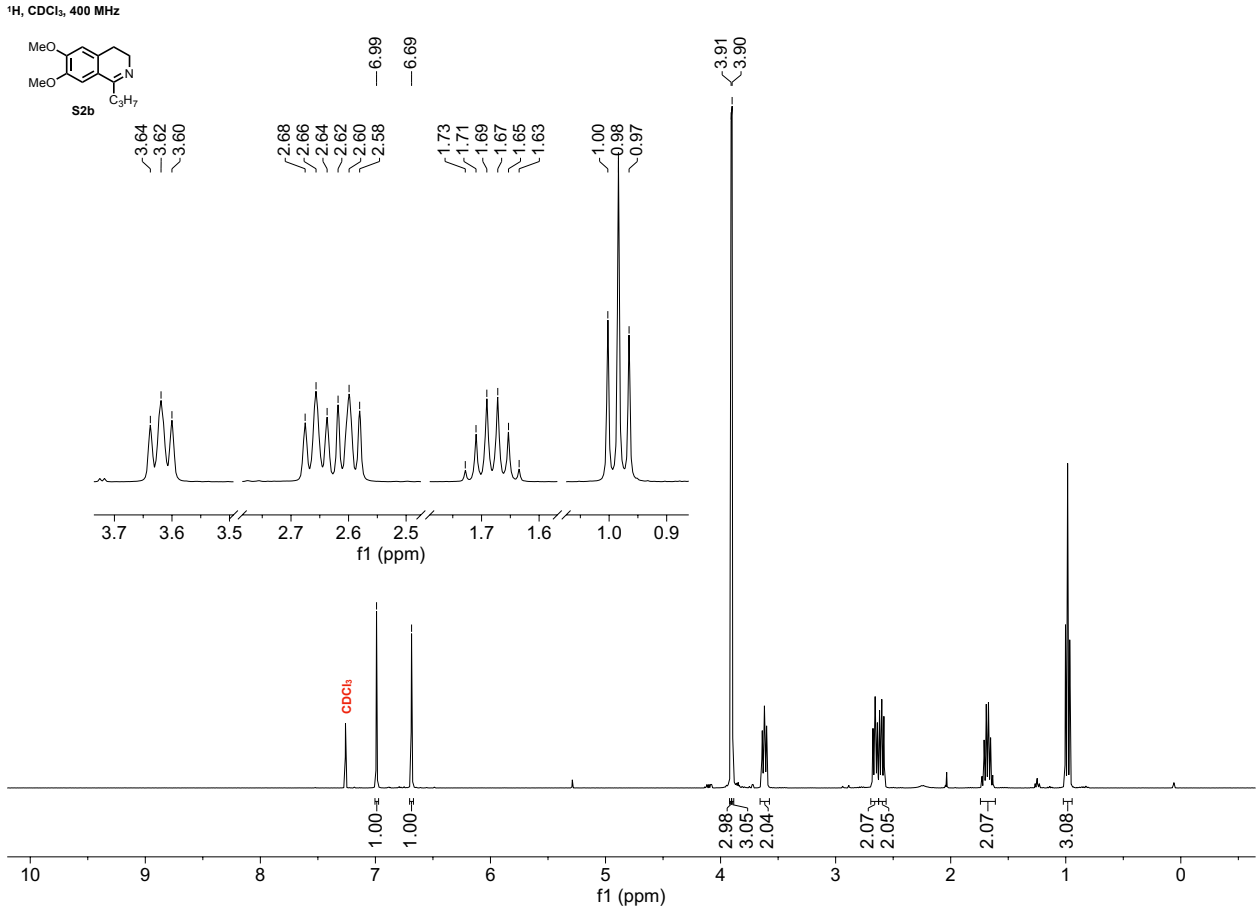

¹³C, CDCl₃, 151 MHz
12
OMe
N
H
156.64
155.12
143.30
136.43
136.16
133.22
129.65
129.43
127.45
127.12
126.10
125.25
121.66
116.45
114.81
114.32
113.79
113.65
106.32
55.75
38.05
33.65
CDCl₃
f1 (ppm)

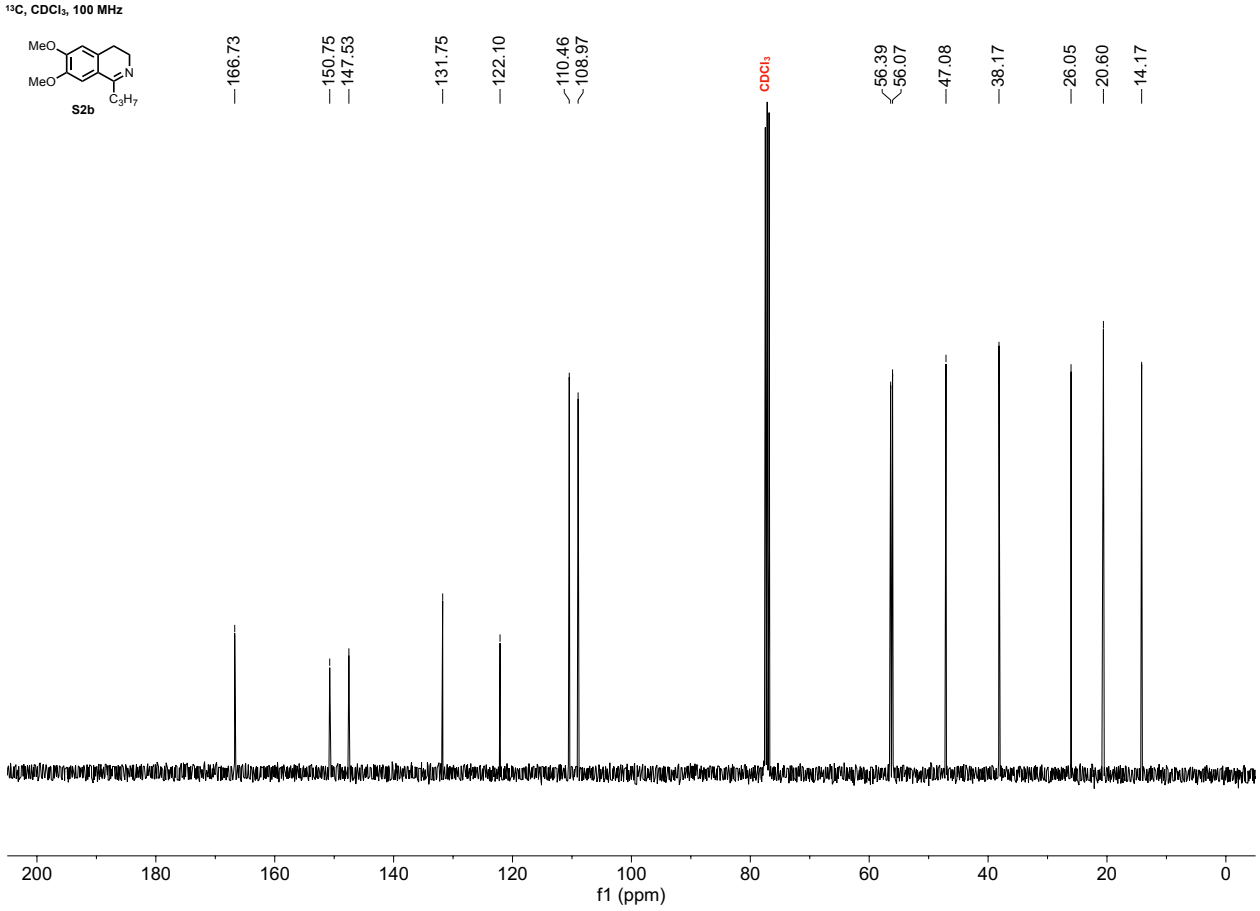
^{1}H, $CDCl_3$, 400 MHz

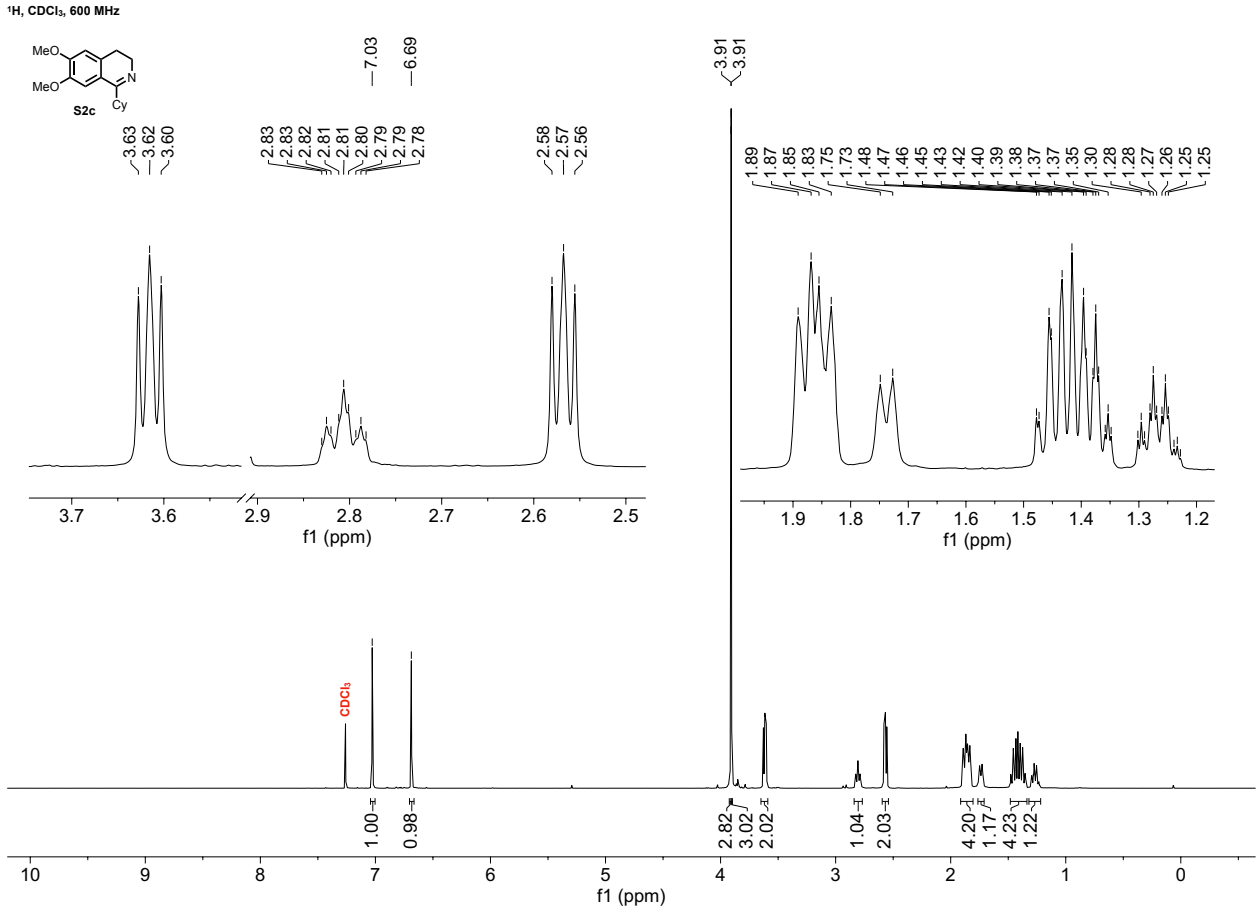


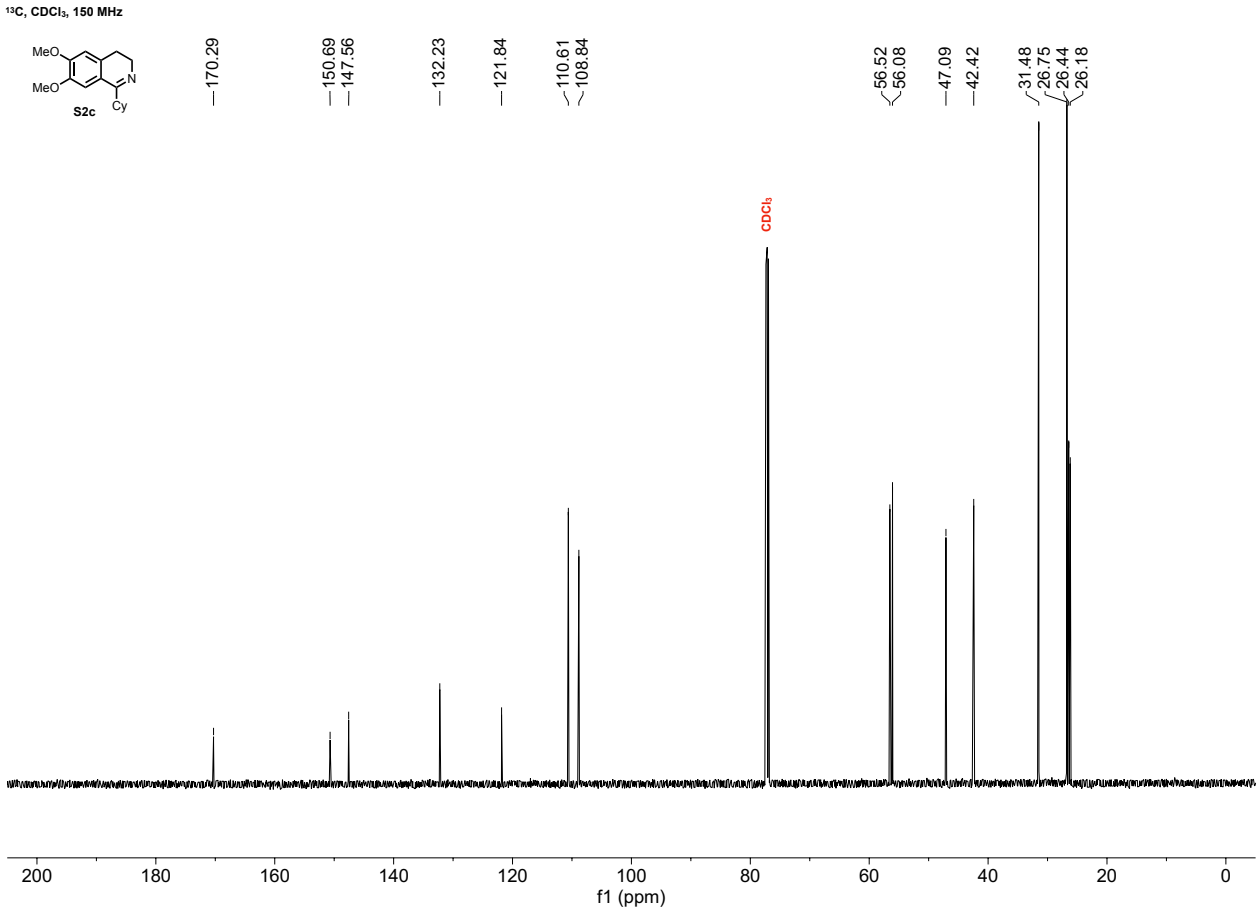
^{13}C, $CDCl_3$, 100 MHz

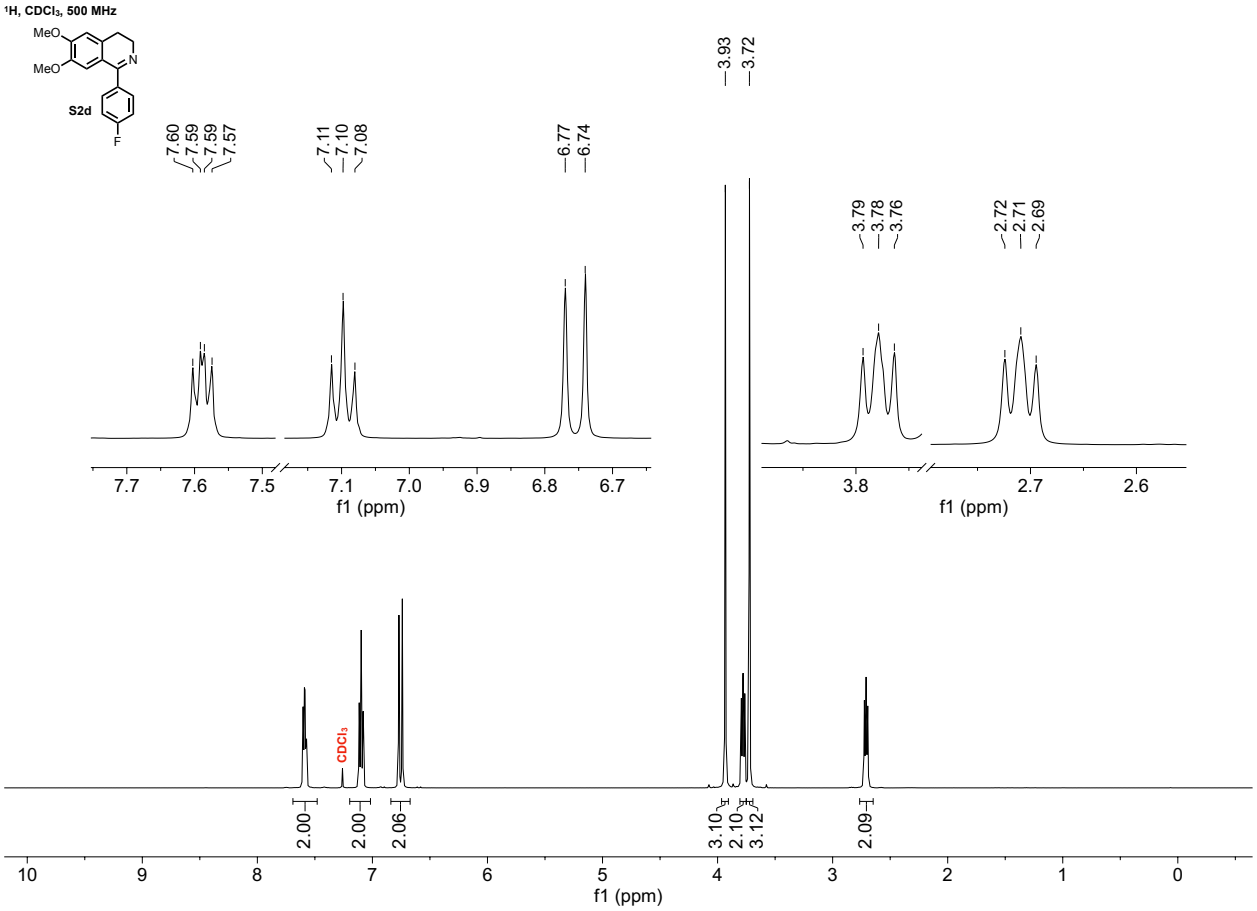


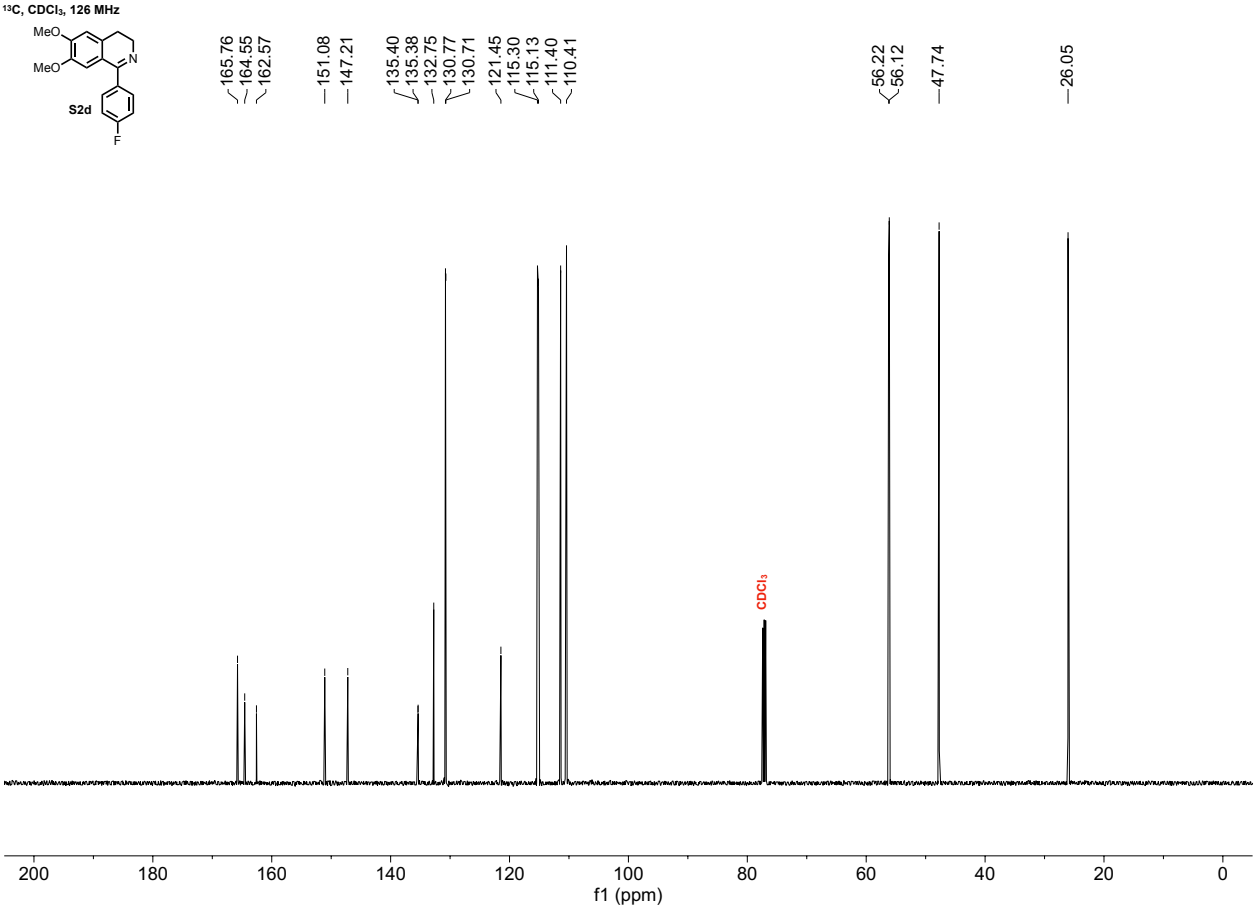

¹H, CDCl₃, 400 MHz
S2b
MeO
MeO
N
C₃H₇
6.99
6.69
3.91
3.90
3.64
3.62
3.60
2.68
2.66
2.64
2.62
2.60
2.58
1.73
1.71
1.69
1.67
1.65
1.63
1.00
0.98
0.97
CDCl₃
1.00
1.00
2.98
3.05
2.04
2.07
2.05
2.07
3.08
f1 (ppm)

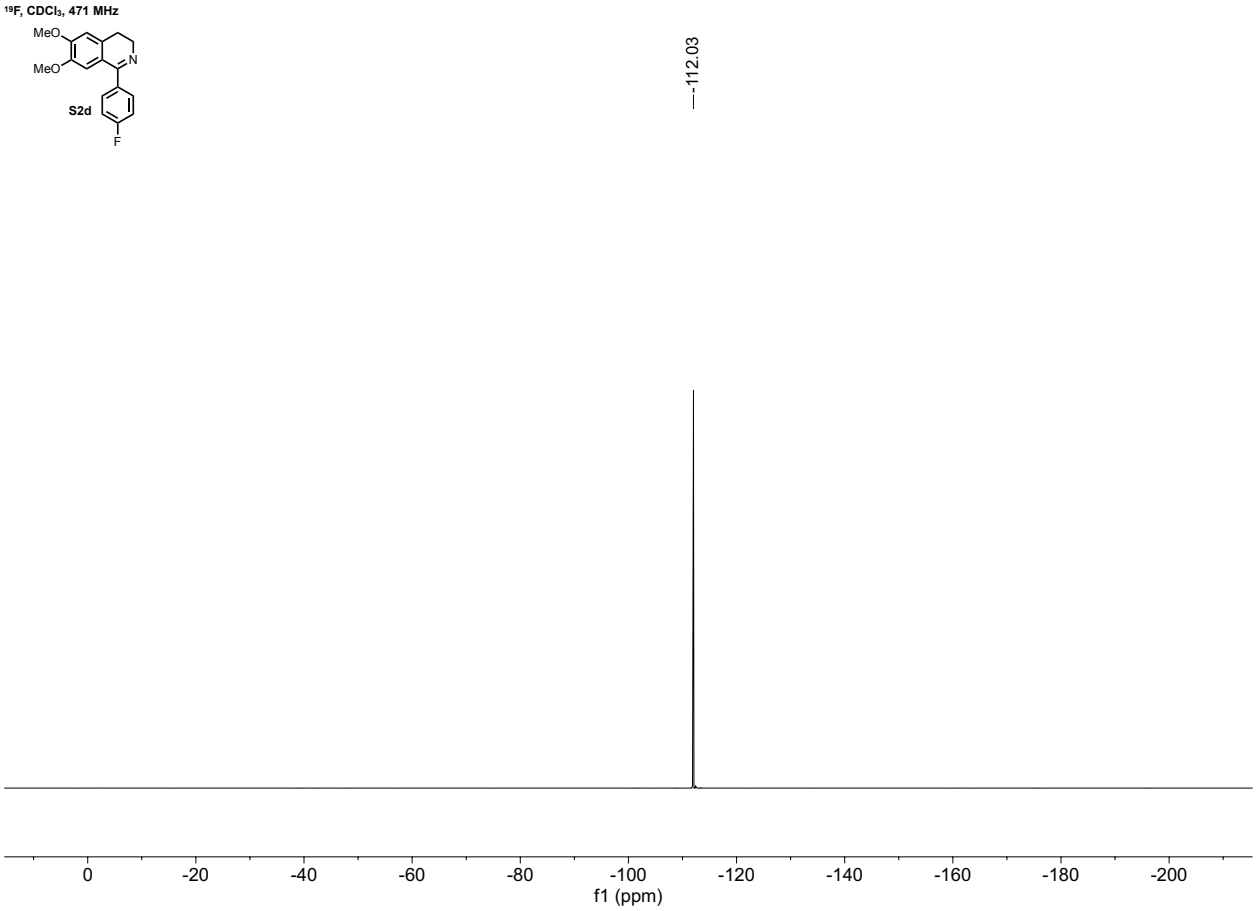

¹³C, CDCl₃, 100 MHz
S2b
MeO
MeO
N
C₃H₇
166.73
150.75
147.53
131.75
122.10
110.46
108.97
CDCl₃
56.39
56.07
47.08
38.17
26.05
20.60
14.17
f1 (ppm)

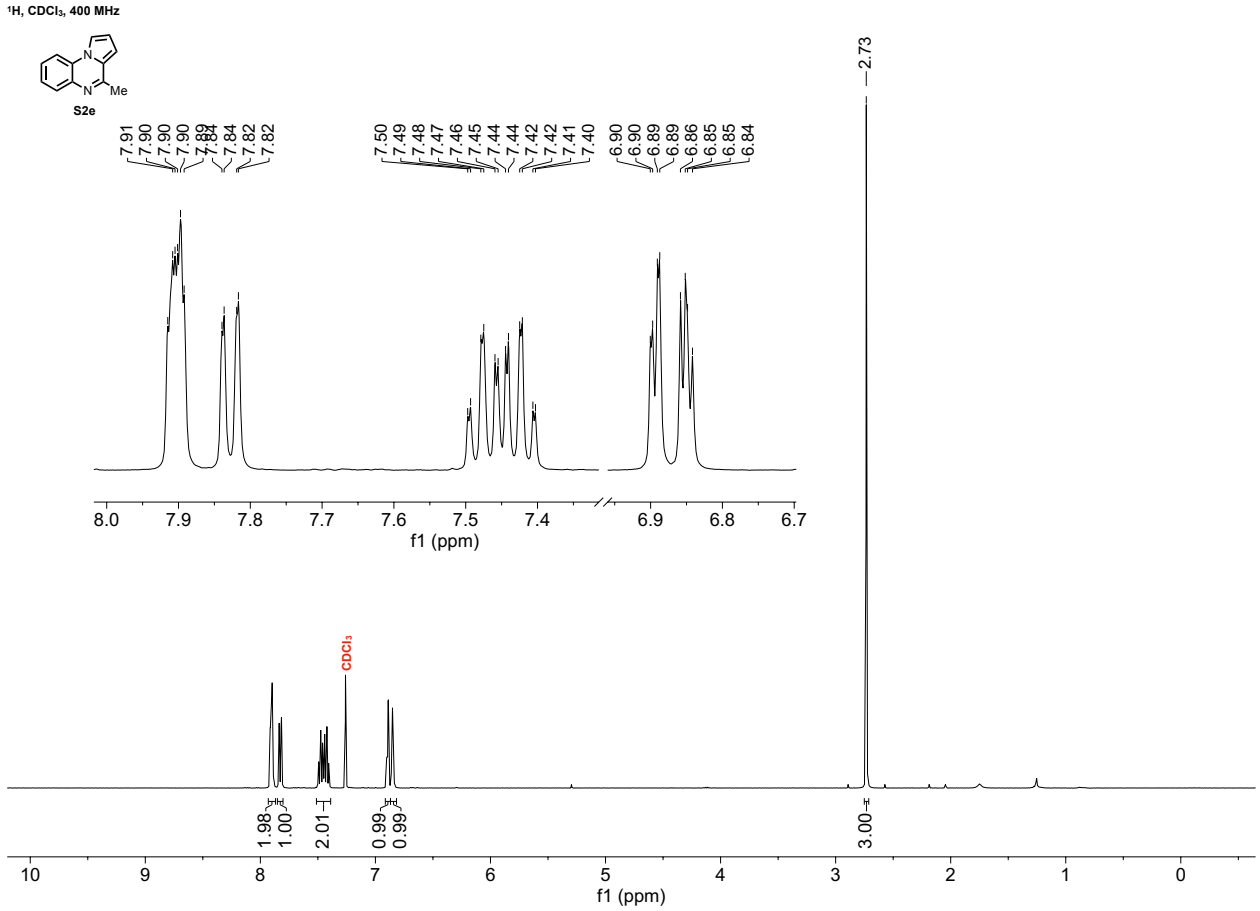

¹H, CDCl₃, 600 MHz
MeO
MeO
N
Cy
S2c
7.03
6.69
3.91
3.91
3.63
3.62
3.60
2.83
2.83
2.82
2.81
2.81
2.80
2.79
2.79
2.78
2.58
2.57
2.56
1.89
1.87
1.85
1.83
1.75
1.73
1.48
1.47
1.46
1.45
1.43
1.42
1.40
1.39
1.38
1.37
1.37
1.35
1.30
1.28
1.28
1.27
1.26
1.25
1.25
f1 (ppm)
CDCl₃
1.00
0.98
2.82
3.02
2.02
1.04
2.03
4.20
1.17
4.23
1.22
f1 (ppm)

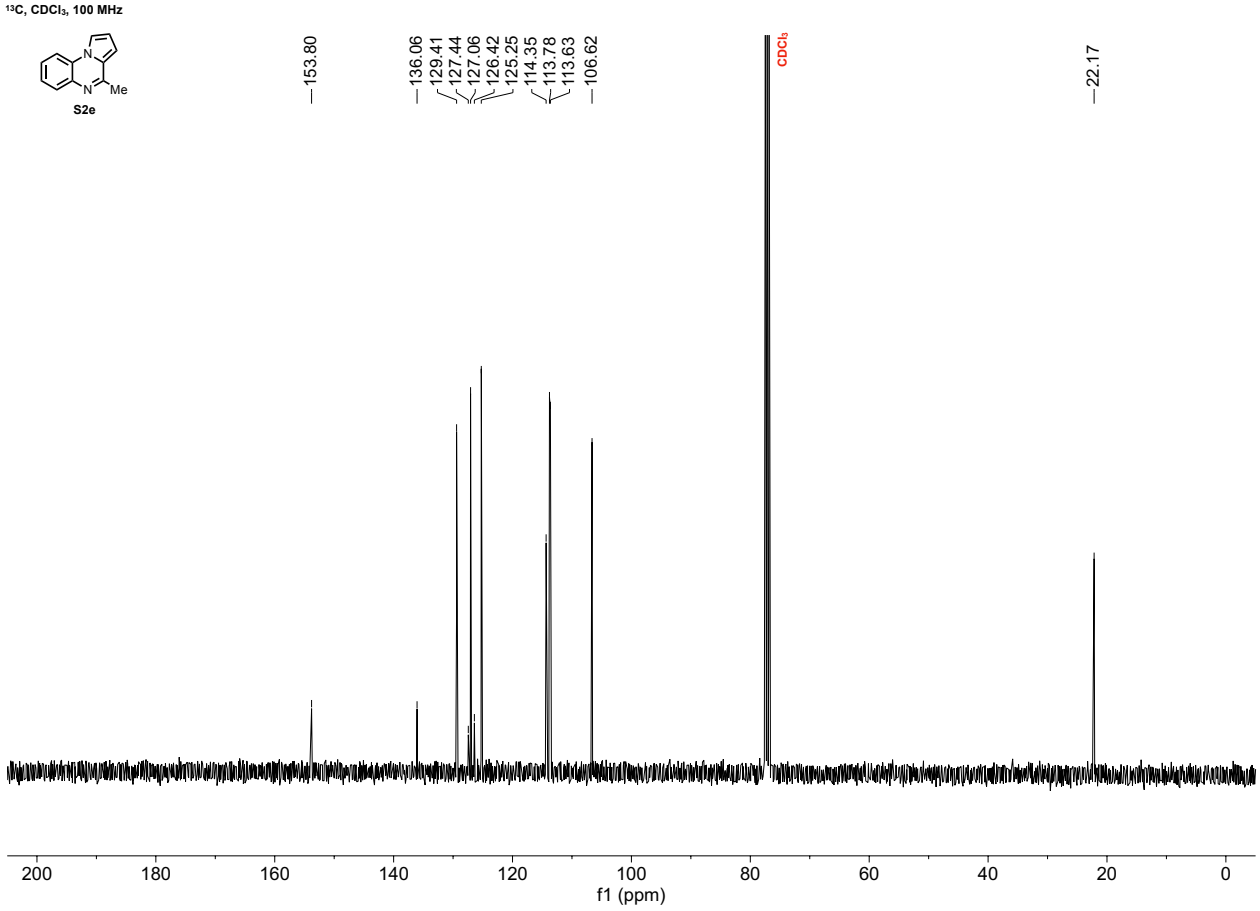

¹³C, CDCl₃, 150 MHz
MeO
MeO
N
Cy
S2c
170.29
150.69
147.56
132.23
121.84
110.61
108.84
56.52
56.08
47.09
42.42
31.48
26.75
26.44
26.18
CDCl₃
f1 (ppm)


¹H, CDCl₃, 500 MHz
MeO
MeO
N
S2d
F
7.60
7.59
7.59
7.57
7.11
7.10
7.08
6.77
6.74
3.93
3.72
3.79
3.78
3.76
2.72
2.71
2.69
CDCl₃
2.00
2.00
2.06
3.10
2.10
3.12
2.09
f1 (ppm)

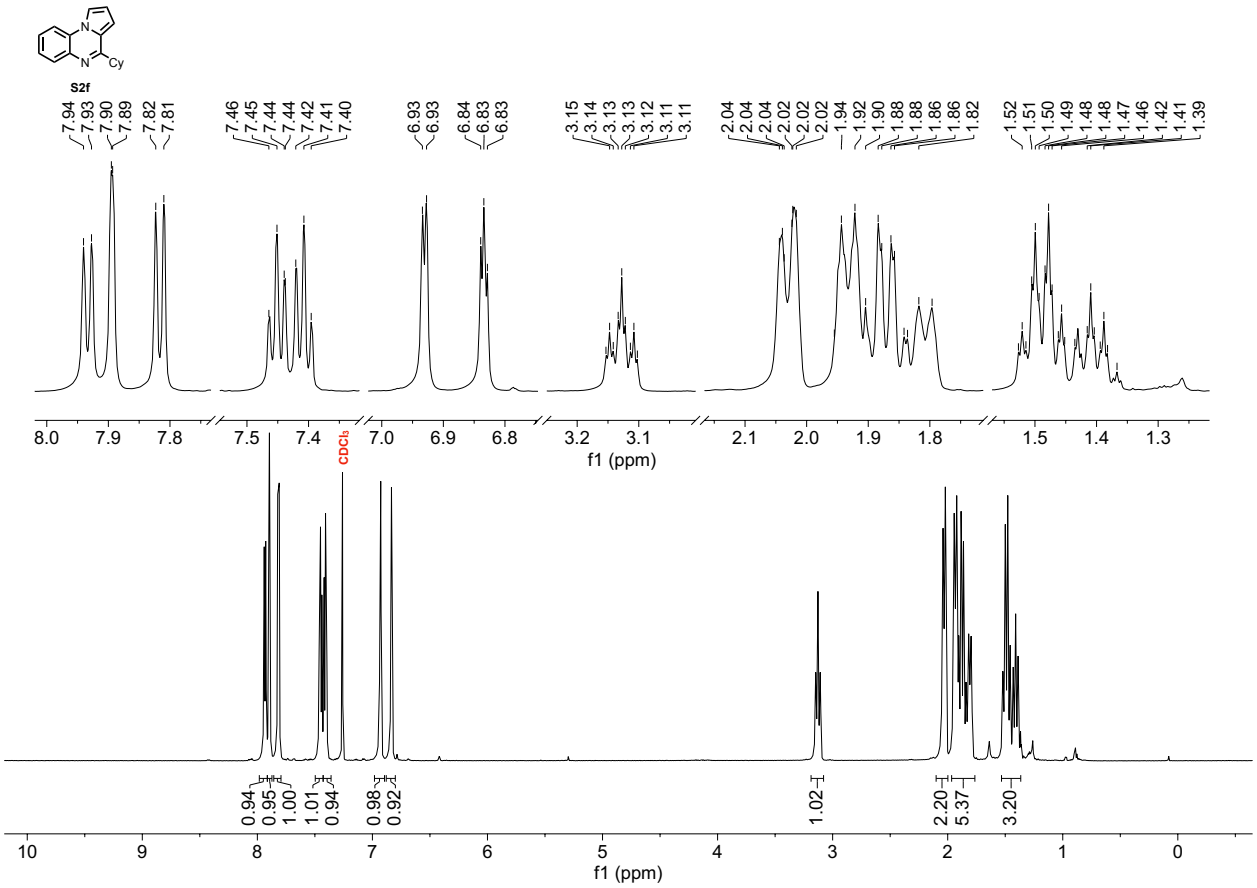

¹³C, CDCl₃, 126 MHz
MeO
MeO
N
S2d
F
165.76
164.55
162.57
151.08
147.21
135.40
135.38
132.75
130.77
130.71
121.45
115.30
115.13
111.40
110.41
56.22
56.12
47.74
26.05
CDCl₃
f1 (ppm)


19F, CDCl3, 471 MHz
MeO
MeO
N
S2d
F
-112.03
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
f1 (ppm)

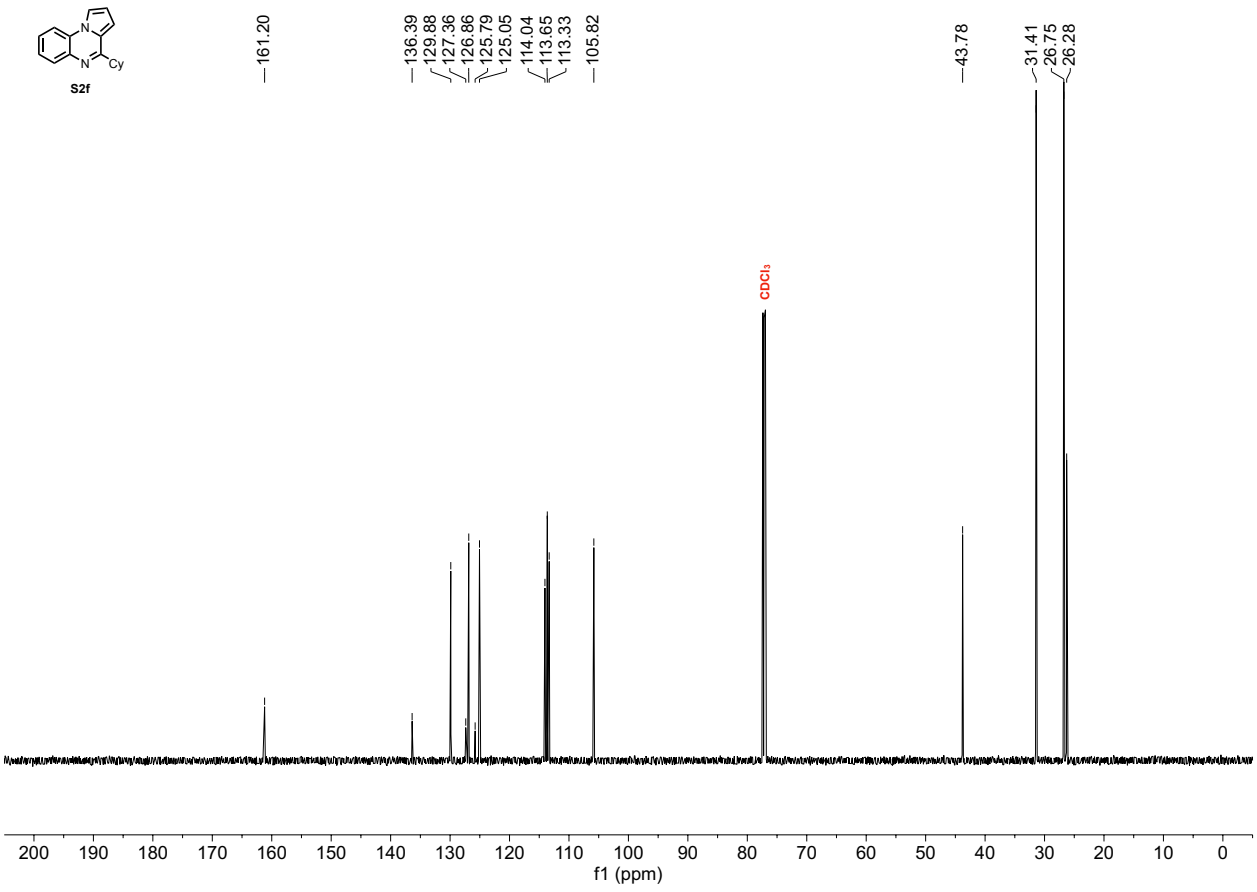

¹H, CDCl₃, 400 MHz
S2e
Me
7.91
7.90
7.90
7.90
7.84
7.84
7.82
7.82
7.50
7.49
7.48
7.47
7.46
7.45
7.44
7.44
7.42
7.42
7.41
7.40
6.90
6.90
6.89
6.89
6.86
6.85
6.85
6.84
2.73
8.0
7.9
7.8
7.7
7.6
7.5
7.4
6.9
6.8
6.7
f1 (ppm)
CDCl₃
1.98
1.00
2.01
0.99
0.99
3.00
10
9
8
7
6
5
4
3
2
1
0
f1 (ppm)

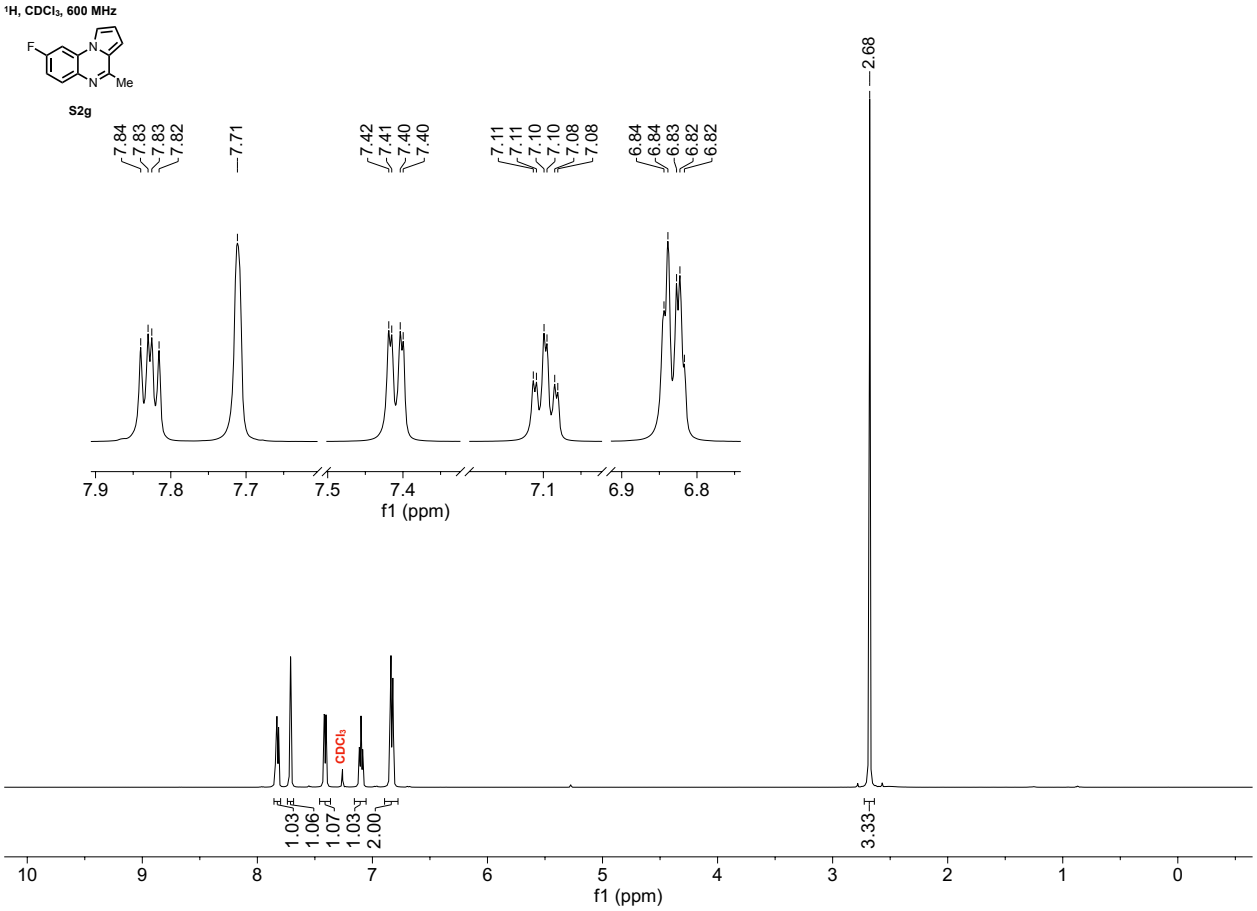

¹³C, CDCl₃, 100 MHz
S2e
Me
153.80
136.06
129.41
127.44
127.06
126.42
125.25
114.35
113.78
113.63
106.62
CDCl₃
22.17
200
180
160
140
120
100
80
60
40
20
0
f1 (ppm)

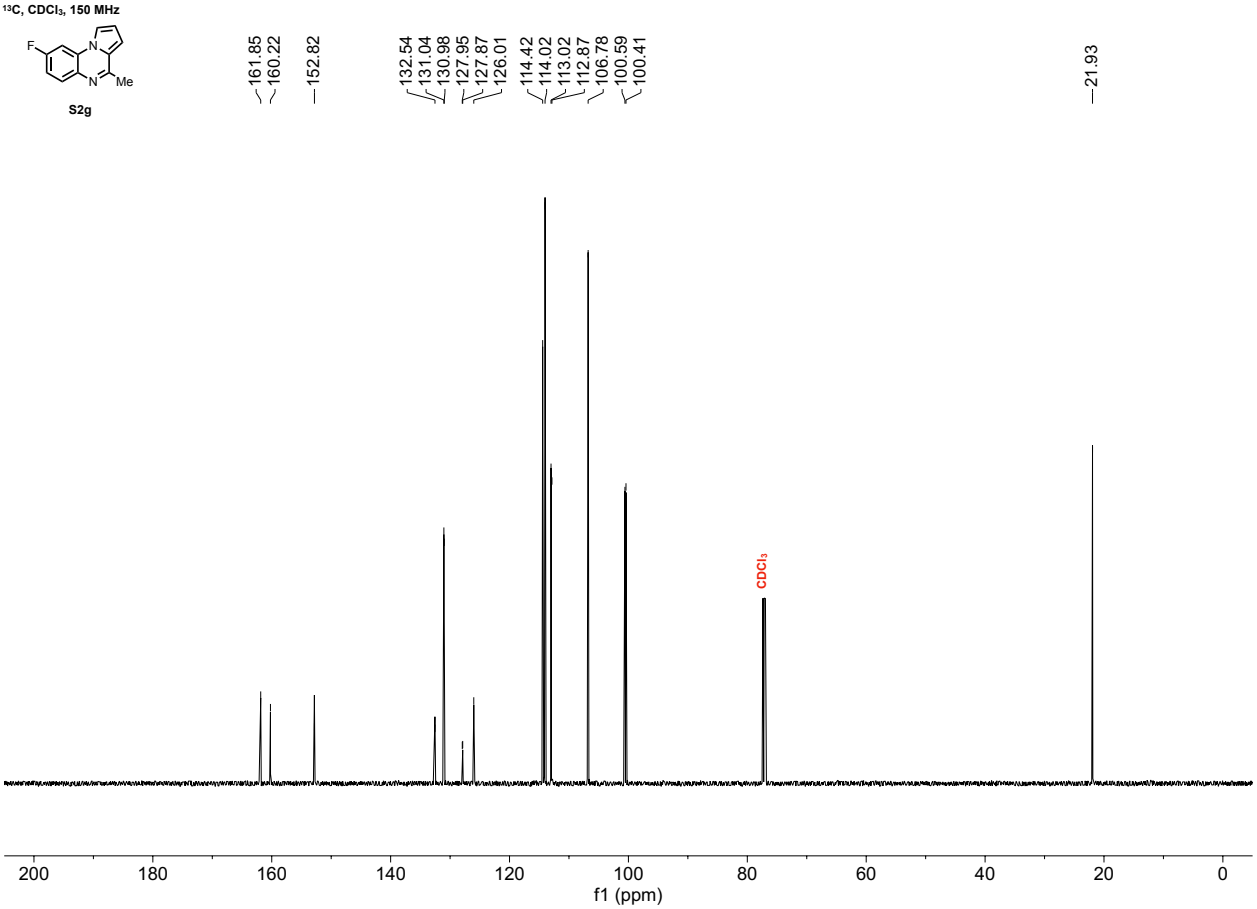
^{1}H, $CDCl_3$, 600 MHz



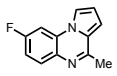
^{13}C, $CDCl_3$, 150 MHz




¹H, CDCl₃, 600 MHz
S2g
7.84
7.83
7.83
7.82
7.71
7.42
7.41
7.40
7.40
7.11
7.11
7.10
7.10
7.08
7.08
6.84
6.84
6.83
6.82
6.82
2.68
CDCl₃
1.03
1.06
1.07
1.03
2.00
3.33
f1 (ppm)

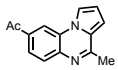

¹³C, CDCl₃, 150 MHz
S2g
161.85
160.22
152.82
132.54
131.04
130.98
127.95
127.87
126.01
114.42
114.02
113.02
112.87
106.78
100.59
100.41
21.93
CDCl₃
f1 (ppm)

^{19}F, $CDCl_3$, 565 MHz



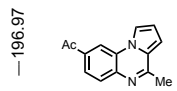
S2g

^{1}H, $CDCl_3$, 500 MHz



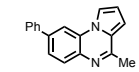
S2h

^{13}C, $CDCl_3$, 151 MHz



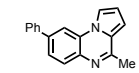
S2h

^{1}H, $CDCl_3$, 600 MHz

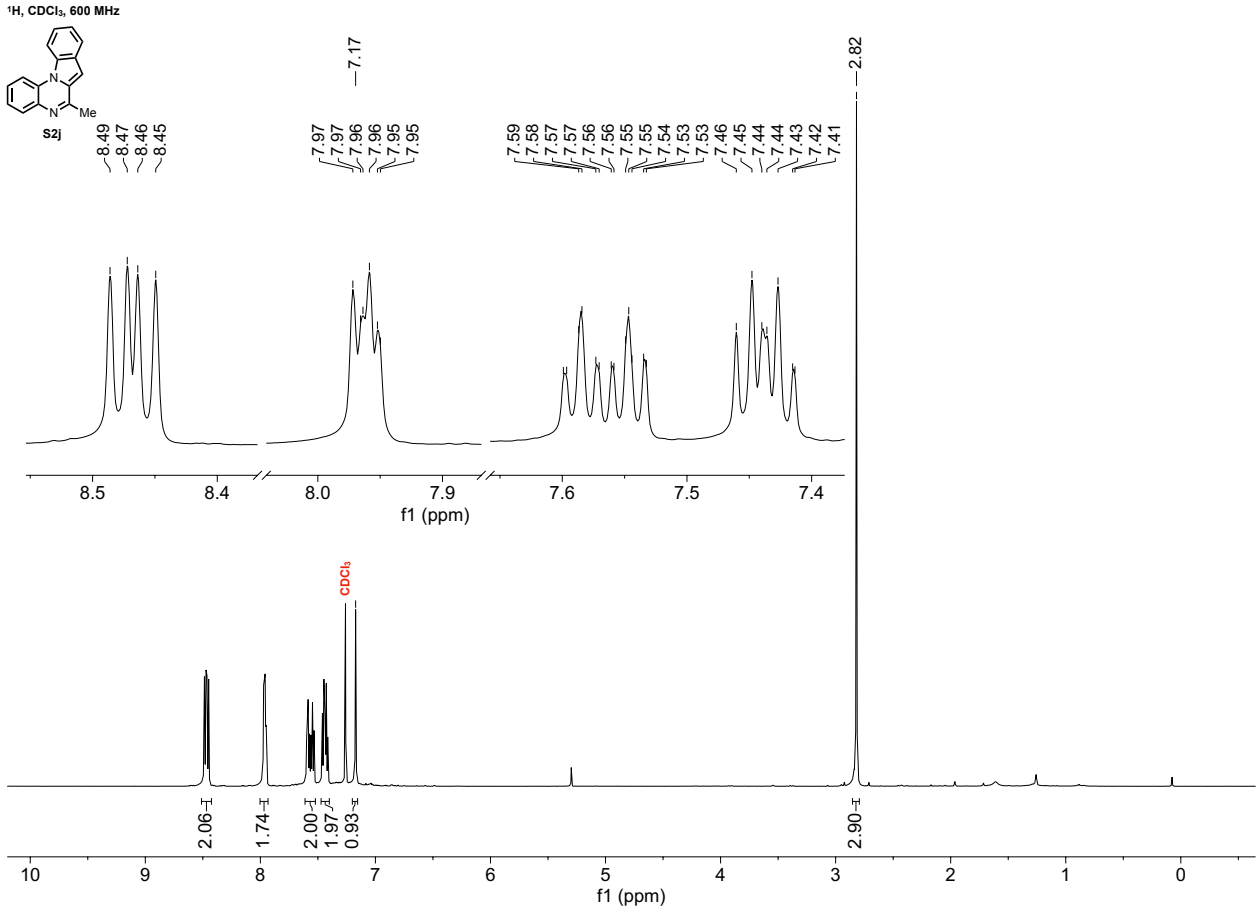


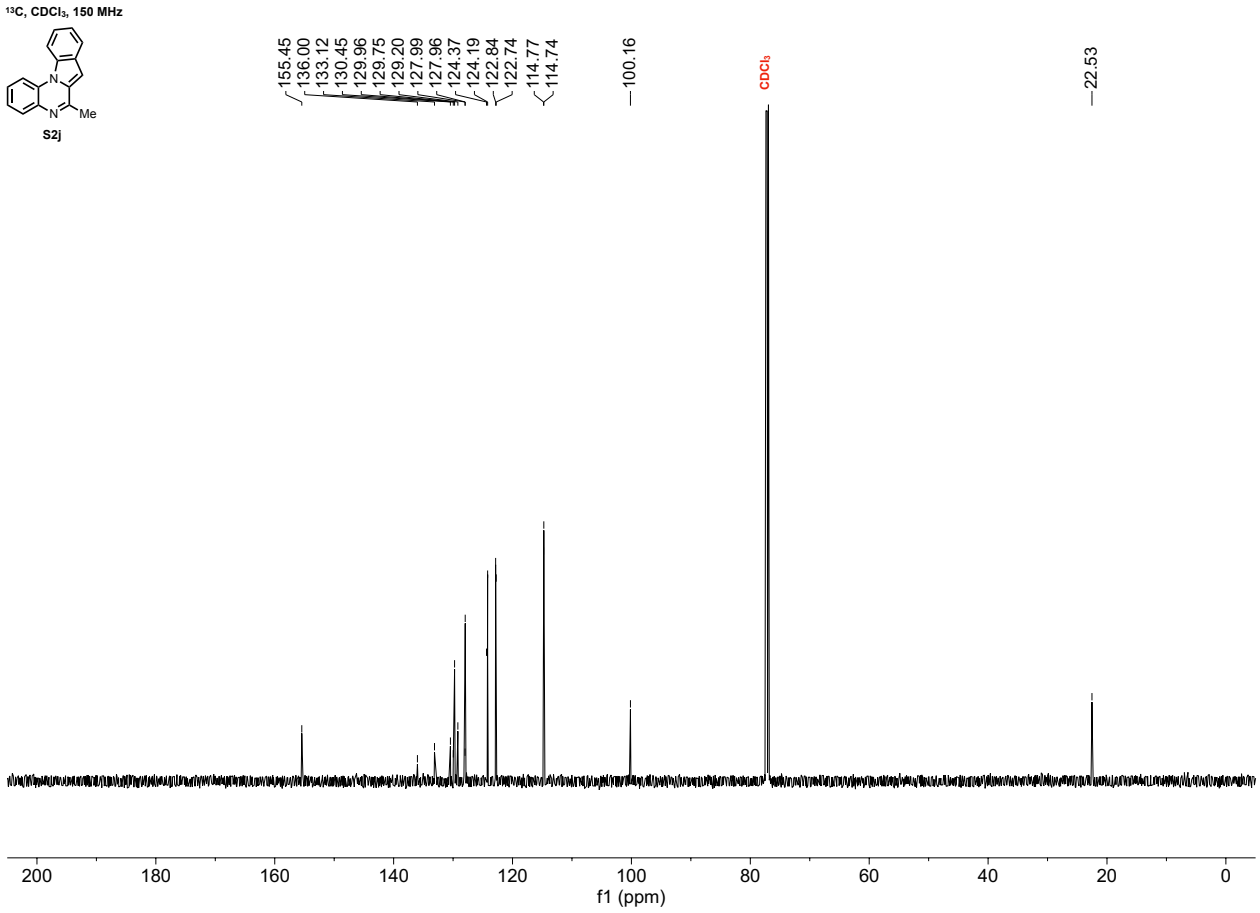
S2i

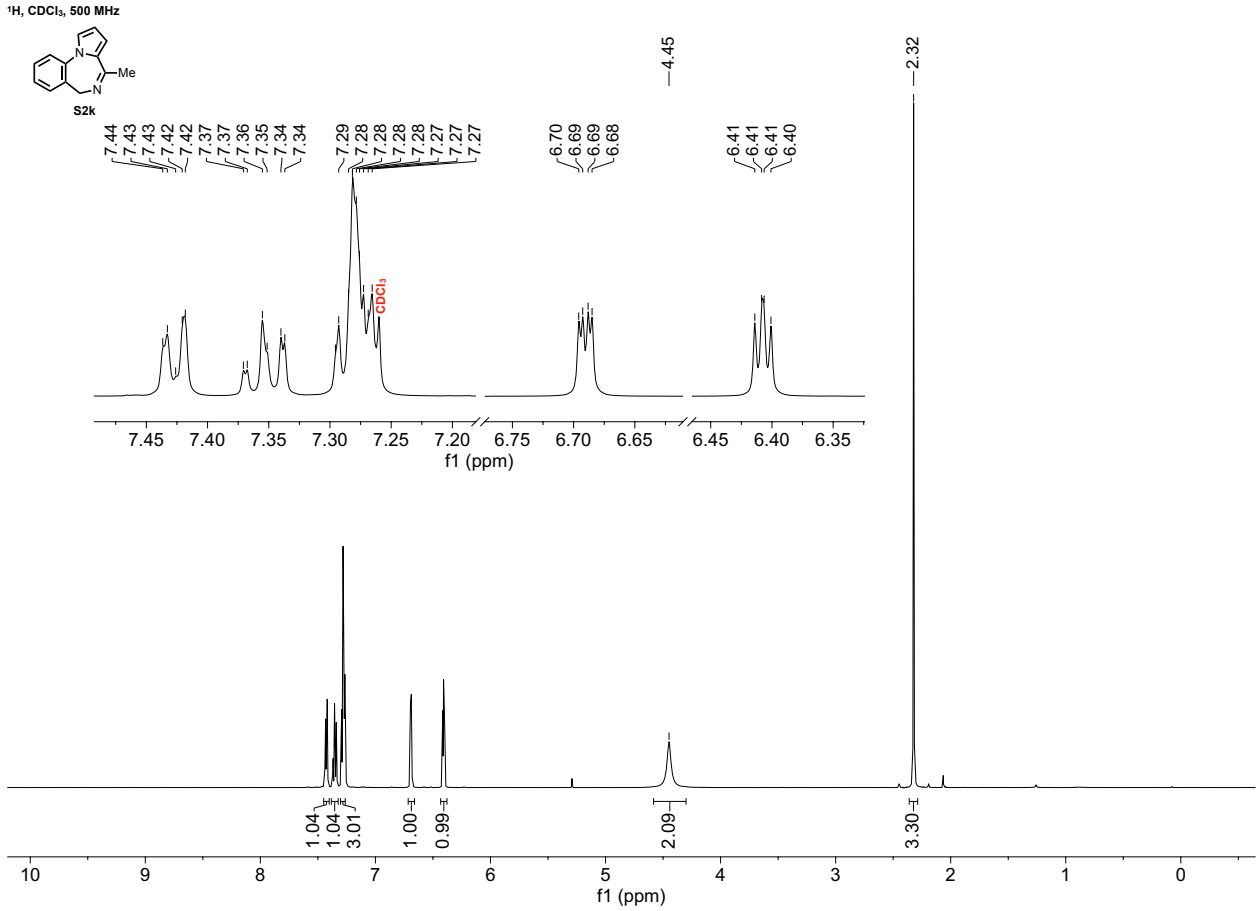
^{13}C, $CDCl_3$, 151 MHz

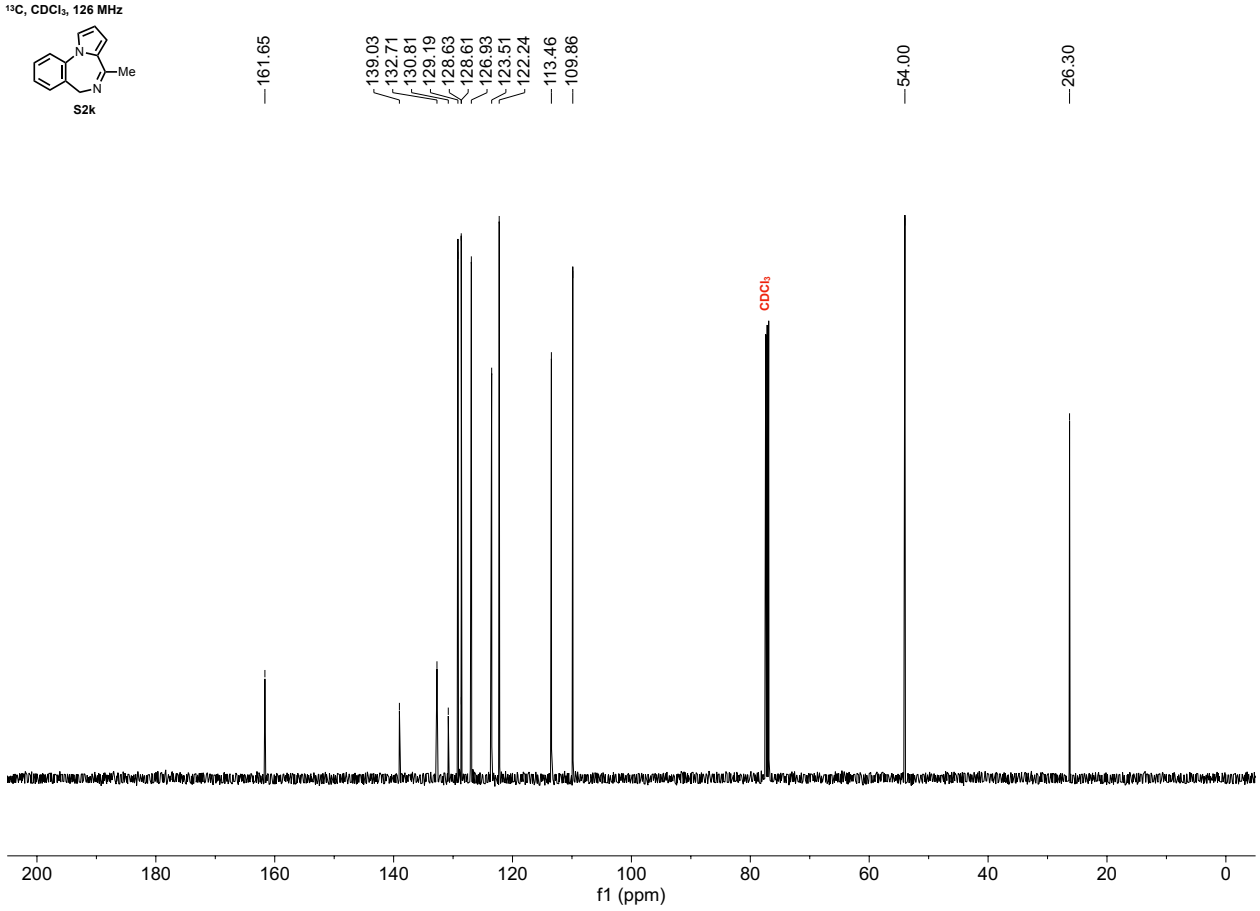


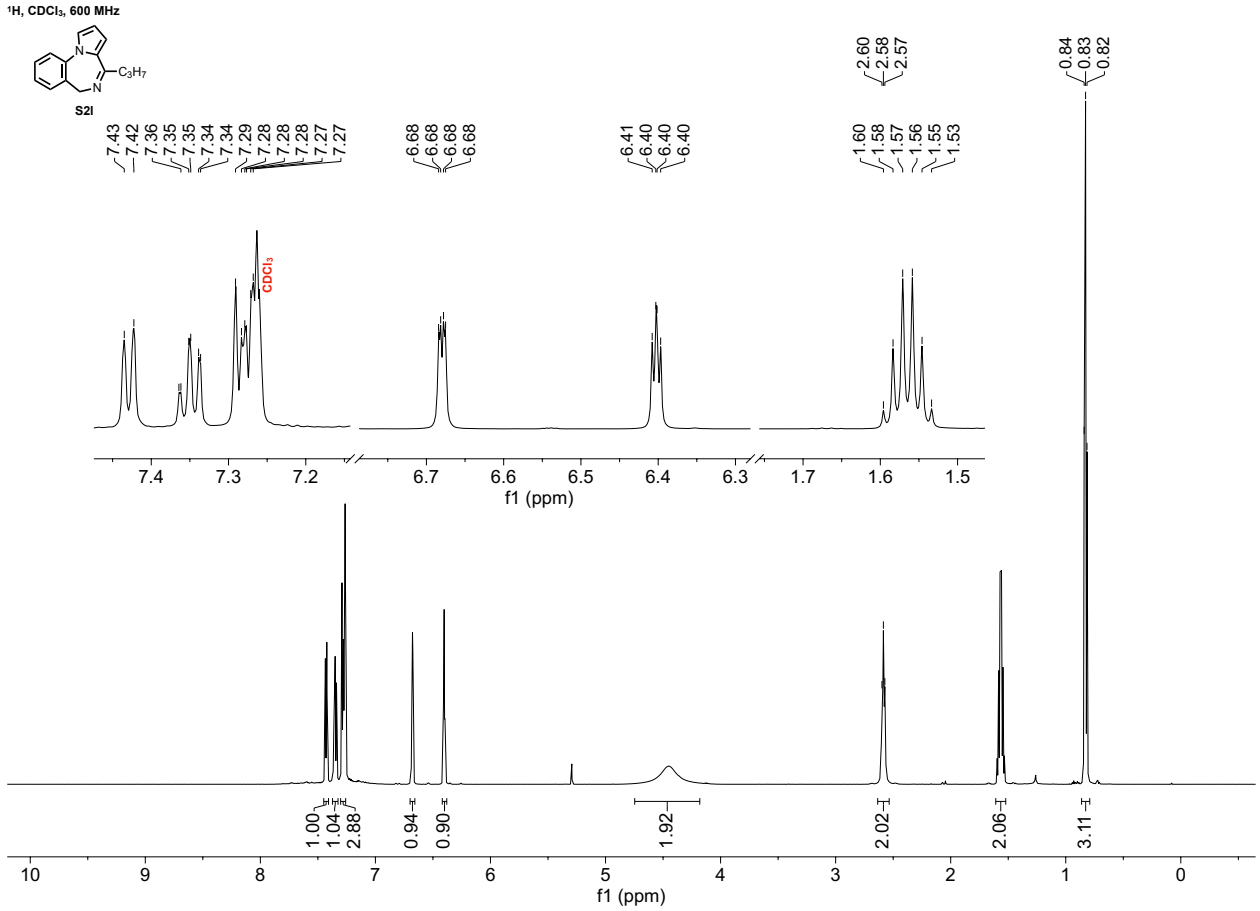
S2i

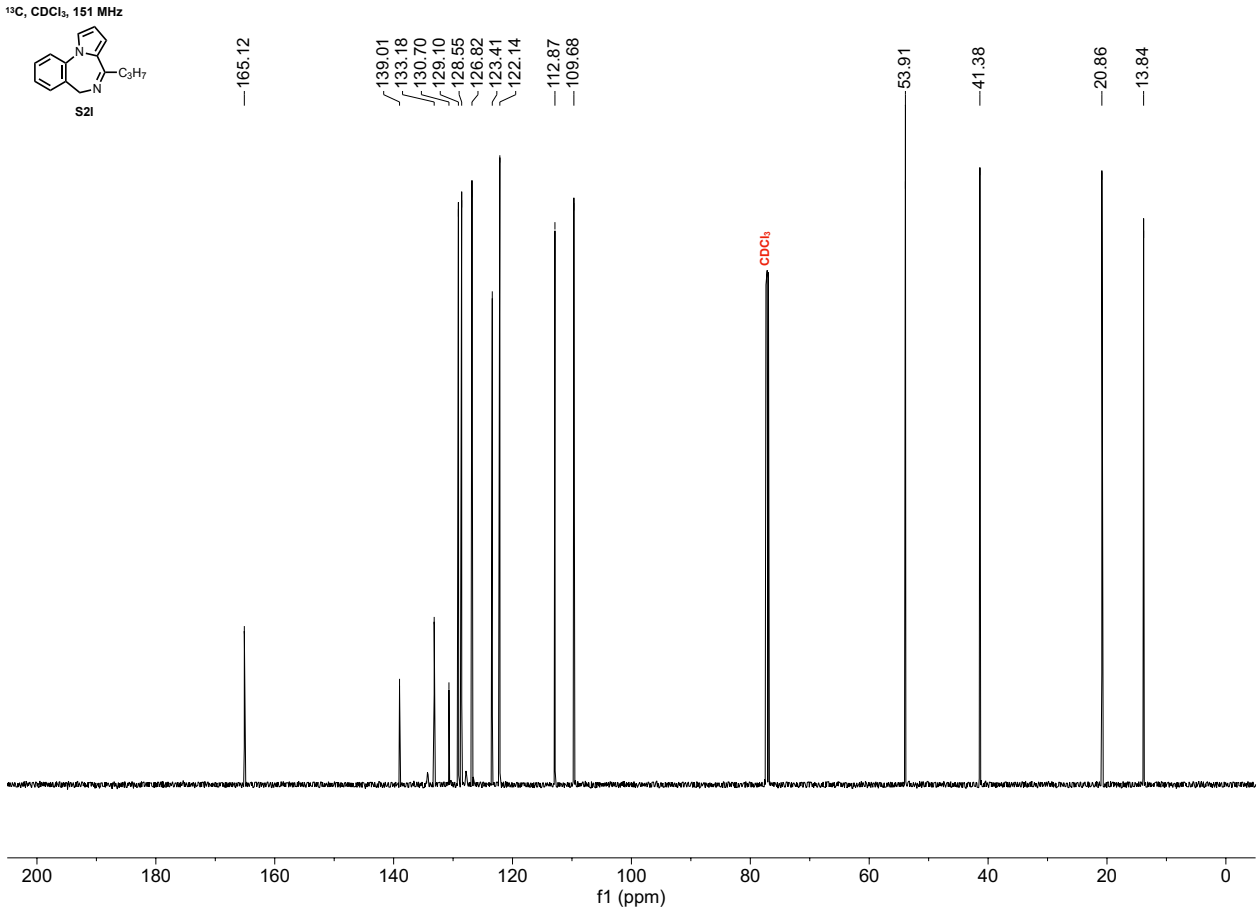

¹H, CDCl₃, 600 MHz
S2j
Me
8.49
8.47
8.46
8.45
7.97
7.97
7.96
7.96
7.95
7.95
7.17
7.59
7.58
7.57
7.57
7.56
7.56
7.55
7.55
7.54
7.53
7.53
7.46
7.45
7.44
7.44
7.43
7.42
7.41
2.82
8.5
8.4
8.0
7.9
7.6
7.5
7.4
f1 (ppm)
CDCl₃
2.06
1.74
2.00
1.97
0.93
2.90
10
9
8
7
6
5
4
3
2
1
0
f1 (ppm)

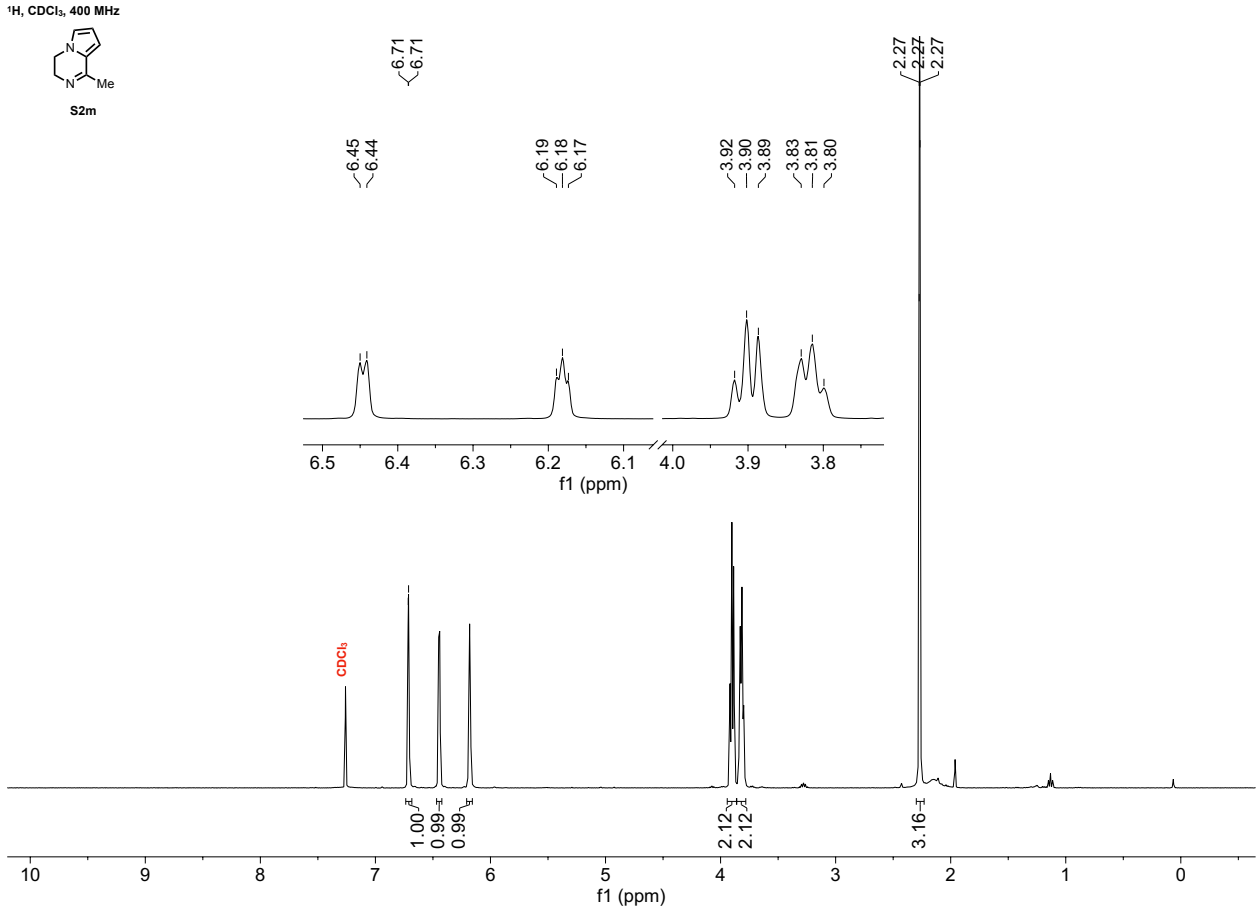

¹³C, CDCl₃, 150 MHz
S2j
Me
155.45
136.00
133.12
130.45
129.96
129.75
129.20
127.99
127.96
124.37
124.19
122.84
122.74
114.77
114.74
100.16
CDCl₃
22.53
200
180
160
140
120
100
80
60
40
20
0
f1 (ppm)

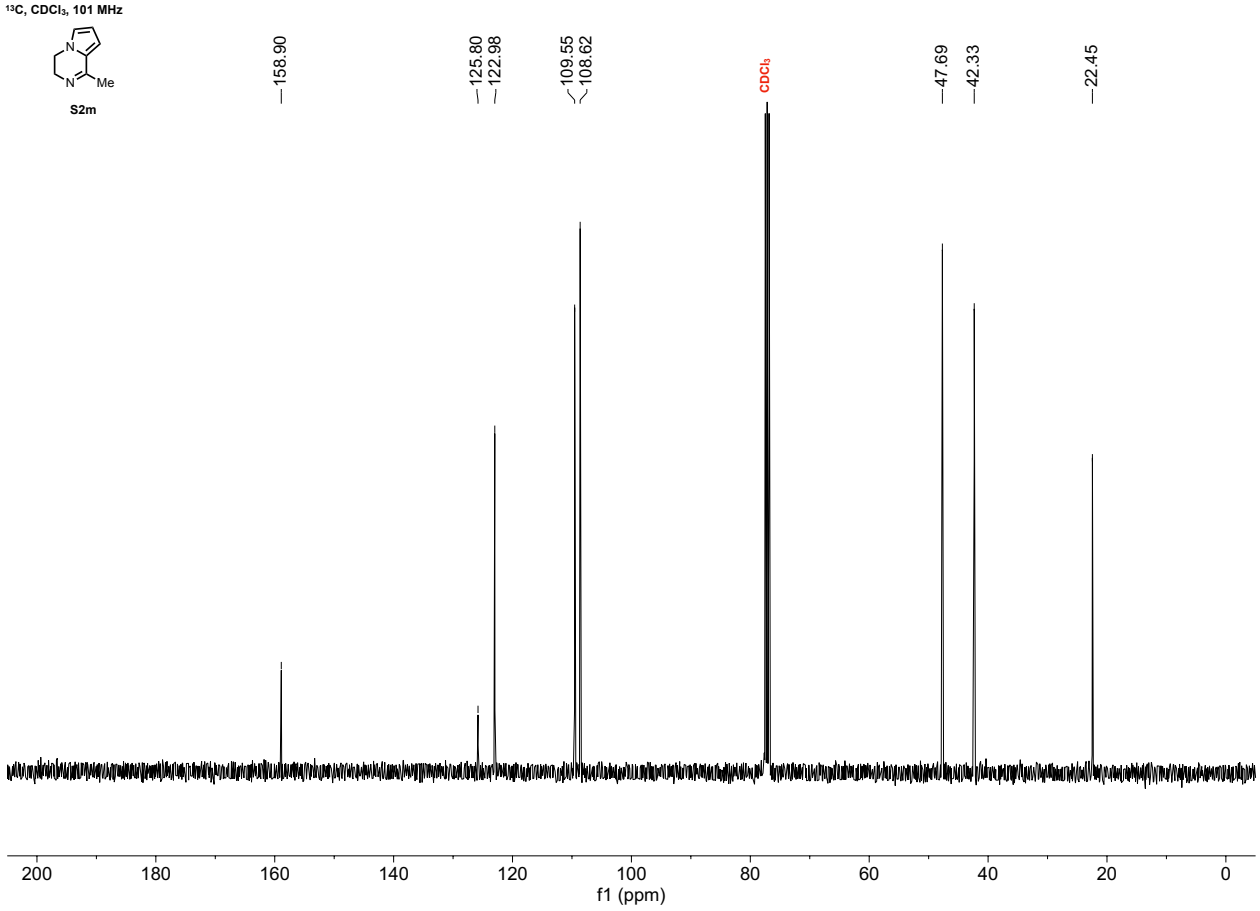

¹H, CDCl₃, 500 MHz
S2k
Me
N
N
7.44
7.43
7.43
7.42
7.42
7.37
7.37
7.36
7.35
7.34
7.34
7.29
7.28
7.28
7.28
7.27
7.27
7.27
6.70
6.69
6.69
6.68
6.41
6.41
6.41
6.40
4.45
2.32
CDCl₃
7.45 7.40 7.35 7.30 7.25 7.20 6.75 6.70 6.65 6.45 6.40 6.35
f1 (ppm)
1.04
1.04
3.01
1.00
0.99
2.09
3.30
10 9 8 7 6 5 4 3 2 1 0
f1 (ppm)


¹³C, CDCl₃, 126 MHz
S2k
Me
N
N
161.65
139.03
132.71
130.81
129.19
128.63
128.61
126.93
123.51
122.24
113.46
109.86
54.00
26.30
CDCl₃
200 180 160 140 120 100 80 60 40 20 0
f1 (ppm)


¹H, CDCl₃, 600 MHz
S2l
7.43
7.42
7.36
7.35
7.35
7.34
7.34
7.29
7.28
7.28
7.28
7.27
7.27
6.68
6.68
6.68
6.68
6.41
6.40
6.40
6.40
2.60
2.58
2.57
1.60
1.58
1.57
1.56
1.55
1.53
0.84
0.83
0.82
CDCl₃
f1 (ppm)
1.00
1.04
2.88
0.94
0.90
1.92
2.02
2.06
3.11


¹³C, CDCl₃, 151 MHz
S2l
165.12
139.01
133.18
130.70
129.10
128.55
126.82
123.41
122.14
112.87
109.68
53.91
41.38
20.86
13.84
CDCl₃
f1 (ppm)


¹H, CDCl₃, 400 MHz
Me
S2m
6.71
6.71
6.45
6.44
6.19
6.18
6.17
3.92
3.90
3.89
3.83
3.81
3.80
2.27
2.27
2.27
6.5
6.4
6.3
6.2
6.1
4.0
3.9
3.8
f1 (ppm)
CDCl3
1.00
0.99
0.99
2.12
2.12
3.16
10
9
8
7
6
5
4
3
2
1
0
f1 (ppm)


¹³C, CDCl₃, 101 MHz
Me
S2m
158.90
125.80
122.98
109.55
108.62
CDCl3
47.69
42.33
22.45
200
180
160
140
120
100
80
60
40
20
0
f1 (ppm)

^{1}H, $CDCl_3$, 400 MHz

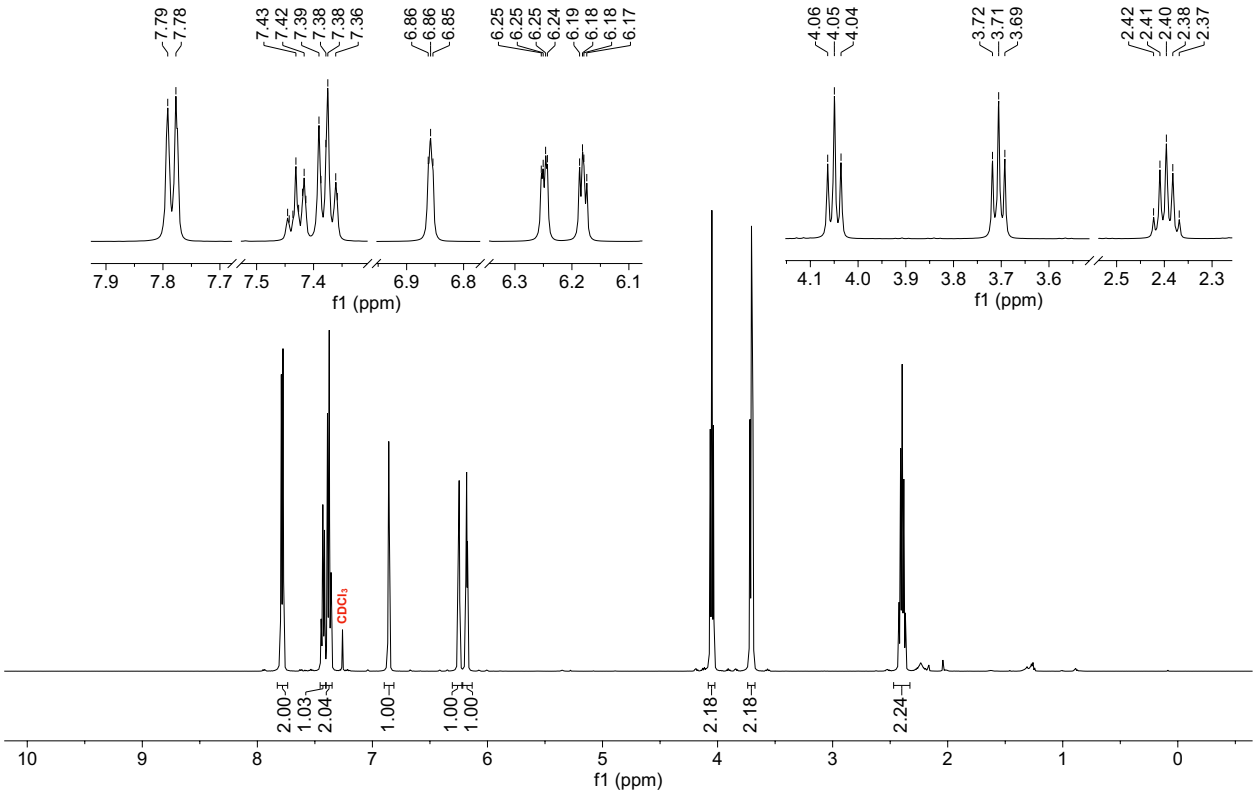
S2n

^{13}C, $CDCl_3$, 101 MHz

S2n

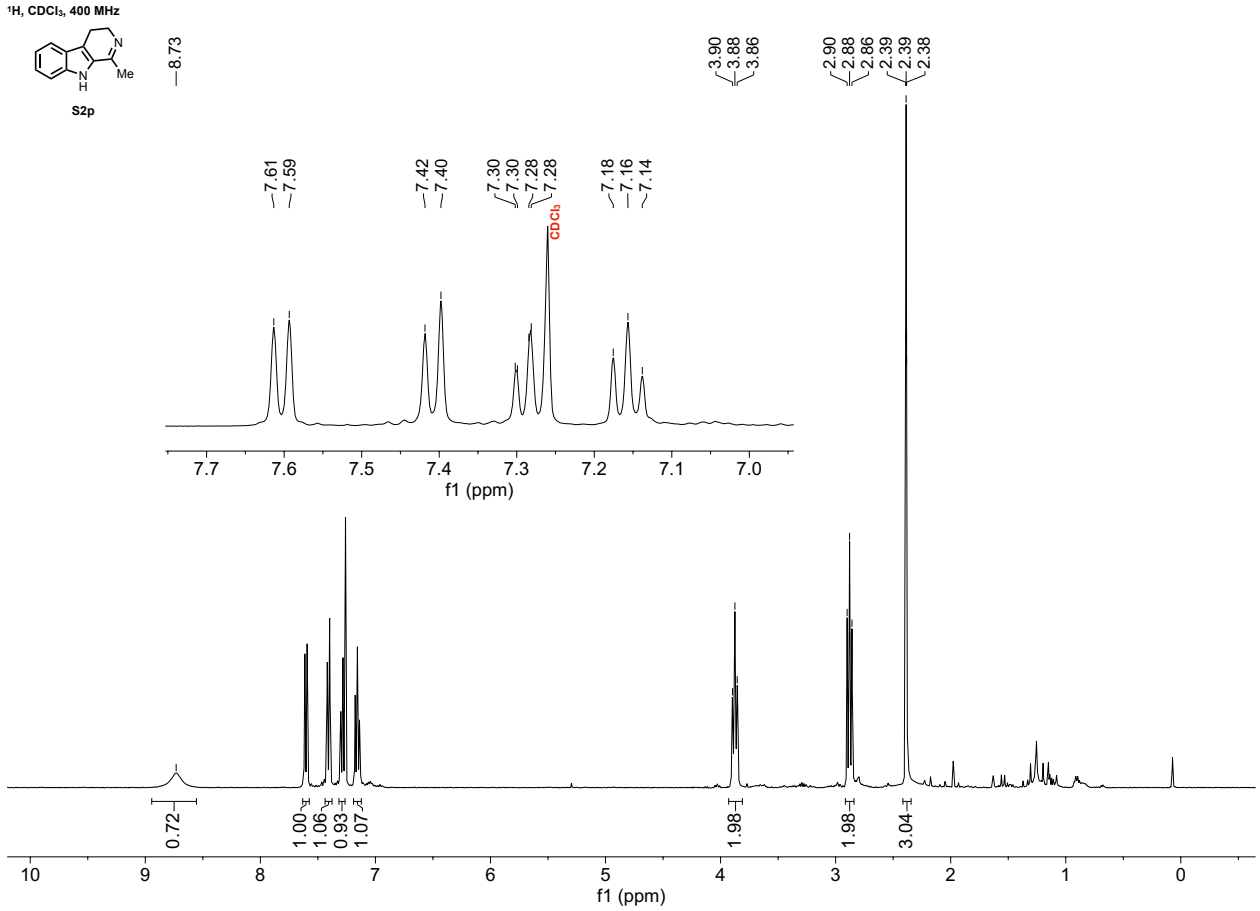
^{1}H, $CDCl_3$, 500 MHz

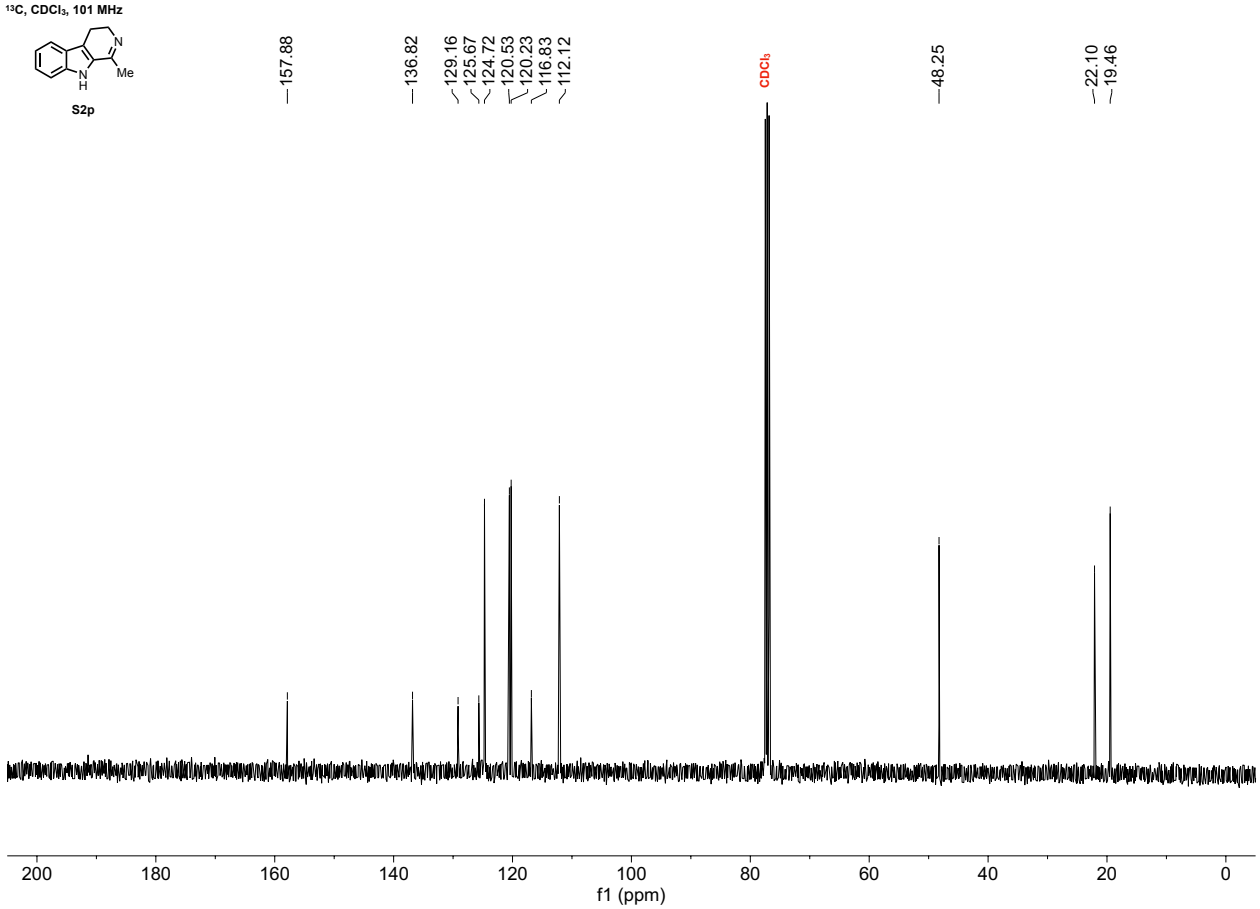
S2o



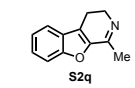
^{13}C, $CDCl_3$, 126 MHz

S2o

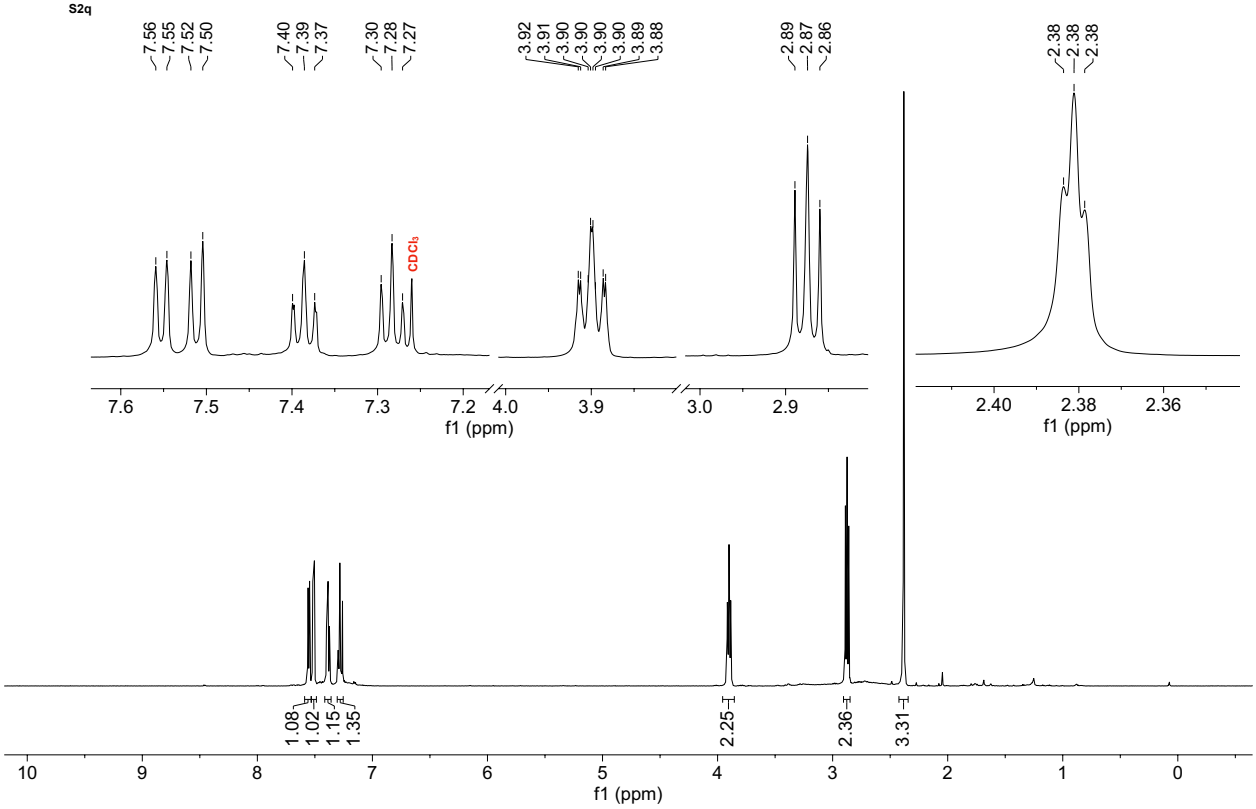

¹H, CDCl₃, 400 MHz
S2p
8.73
7.61
7.59
7.42
7.40
7.30
7.30
7.28
7.28
CDCl₃
7.18
7.16
7.14
3.90
3.88
3.86
2.90
2.88
2.86
2.39
2.39
2.38
0.72
1.00
1.06
0.93
1.07
1.98
1.98
3.04
f1 (ppm)


¹³C, CDCl₃, 101 MHz
S2p
157.88
136.82
129.16
125.67
124.72
120.53
120.23
116.83
112.12
CDCl₃
48.25
22.10
19.46
f1 (ppm)

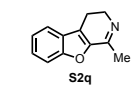
^{1}H, $CDCl_3$, 600 MHz



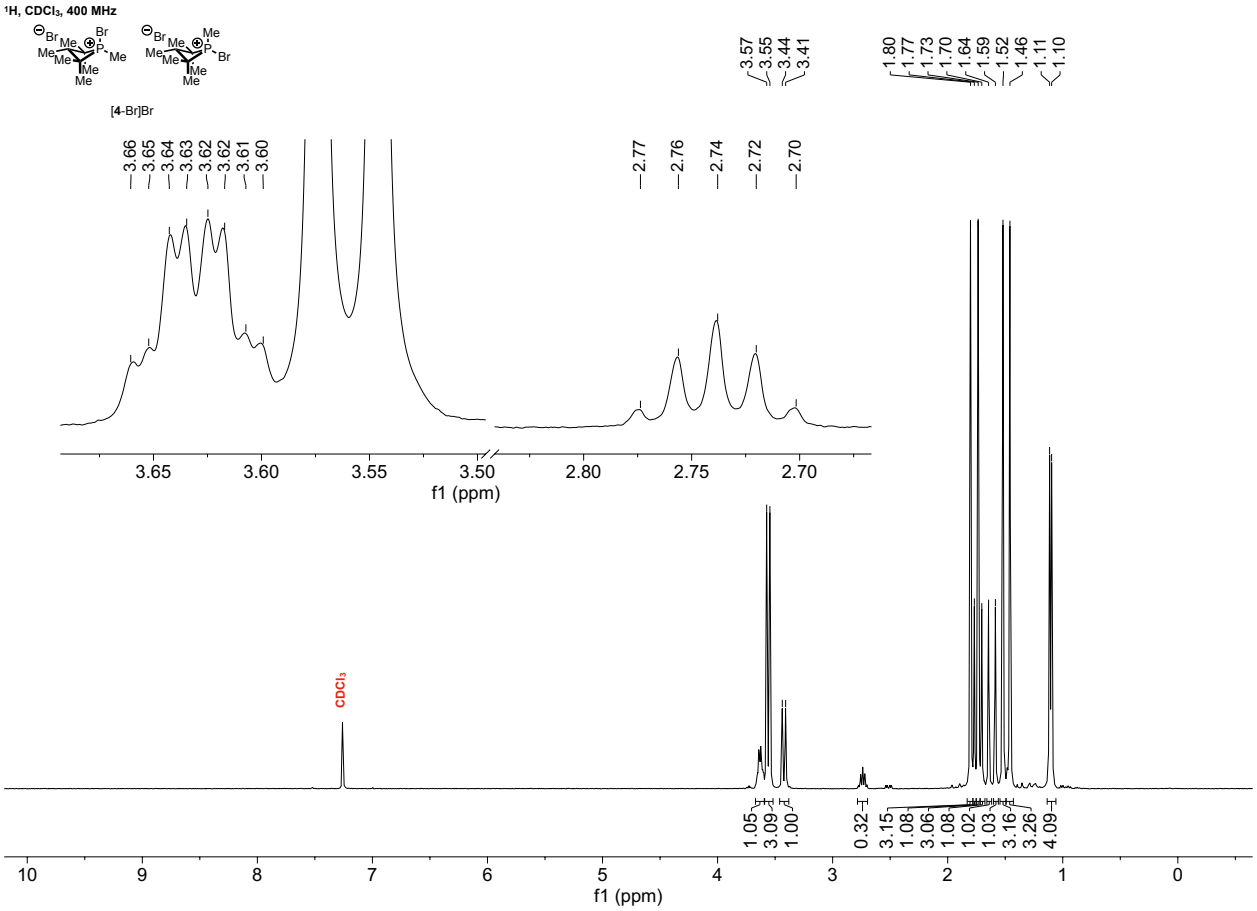
S2q

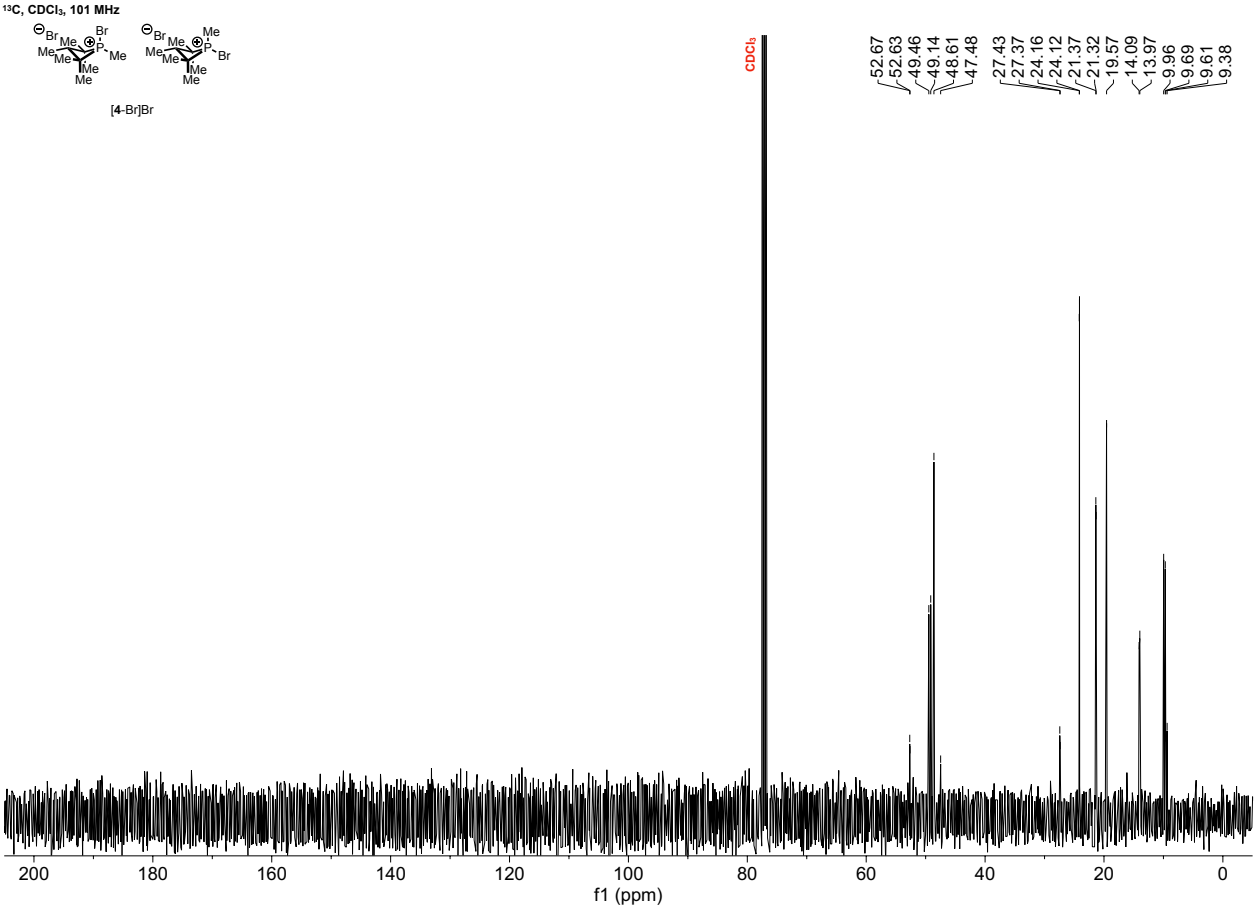


^{13}C, $CDCl_3$, 151 MHz

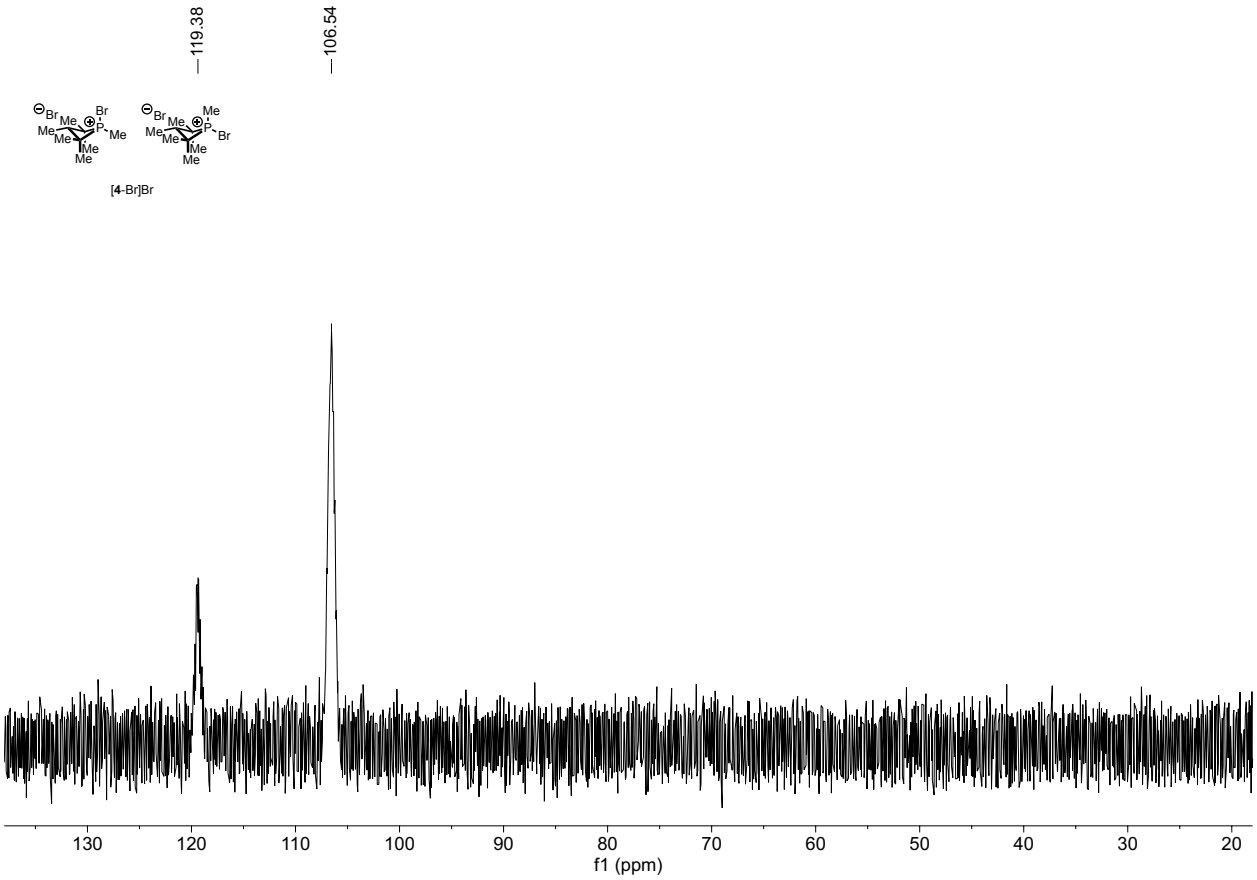


S2q

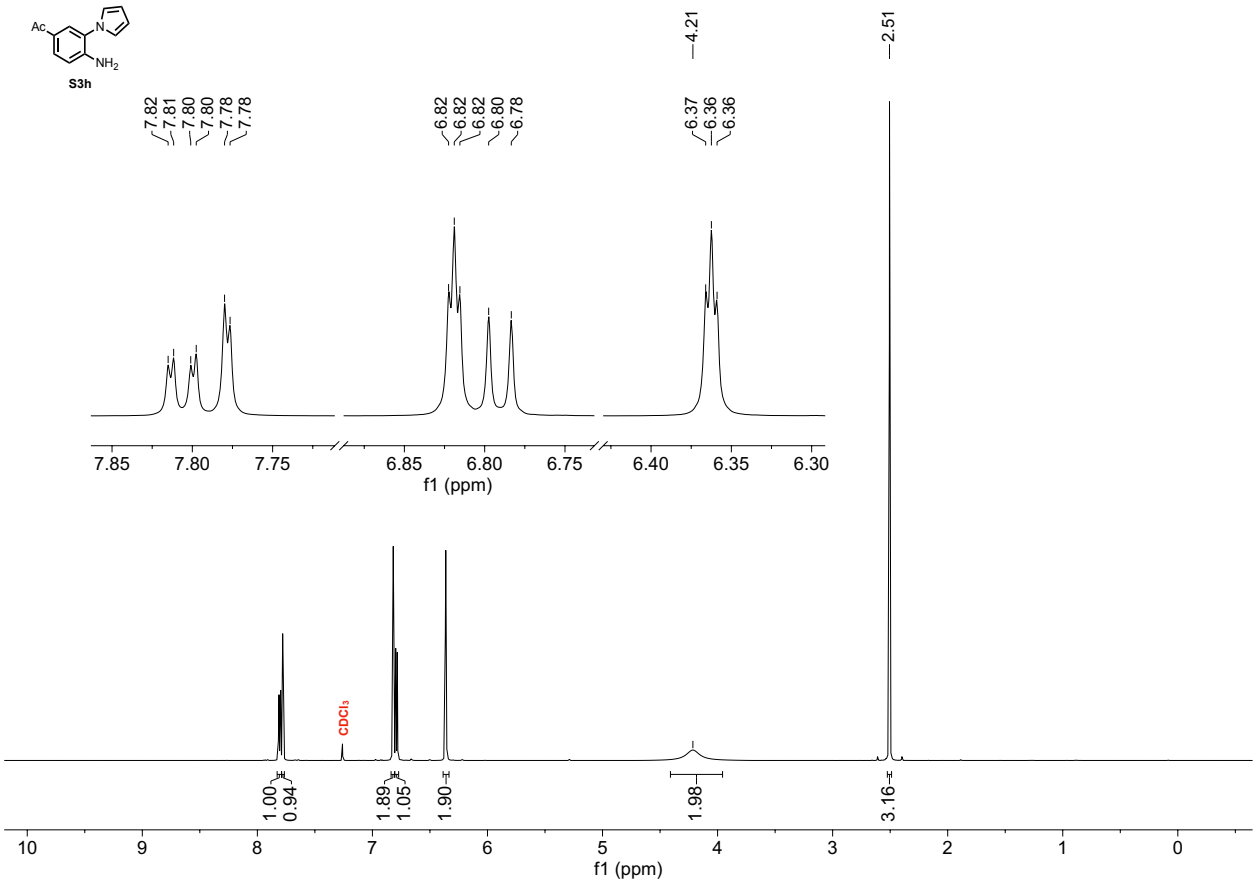

¹H, CDCl₃, 400 MHz
[4-Br]Br
3.66
3.65
3.64
3.63
3.62
3.62
3.61
3.60
2.77
2.76
2.74
2.72
2.70
3.57
3.55
3.44
3.41
1.80
1.77
1.73
1.70
1.64
1.59
1.52
1.46
1.11
1.10
CDCl3
1.05
3.09
1.00
0.32
3.15
1.08
3.06
1.08
1.02
1.03
3.16
3.26
4.09
f1 (ppm)


¹³C, CDCl₃, 101 MHz
[4-Br]Br
CDCl3
52.67
52.63
49.46
49.14
48.61
47.48
27.43
27.37
24.16
24.12
21.37
21.32
19.57
14.09
13.97
9.96
9.69
9.61
9.38
f1 (ppm)

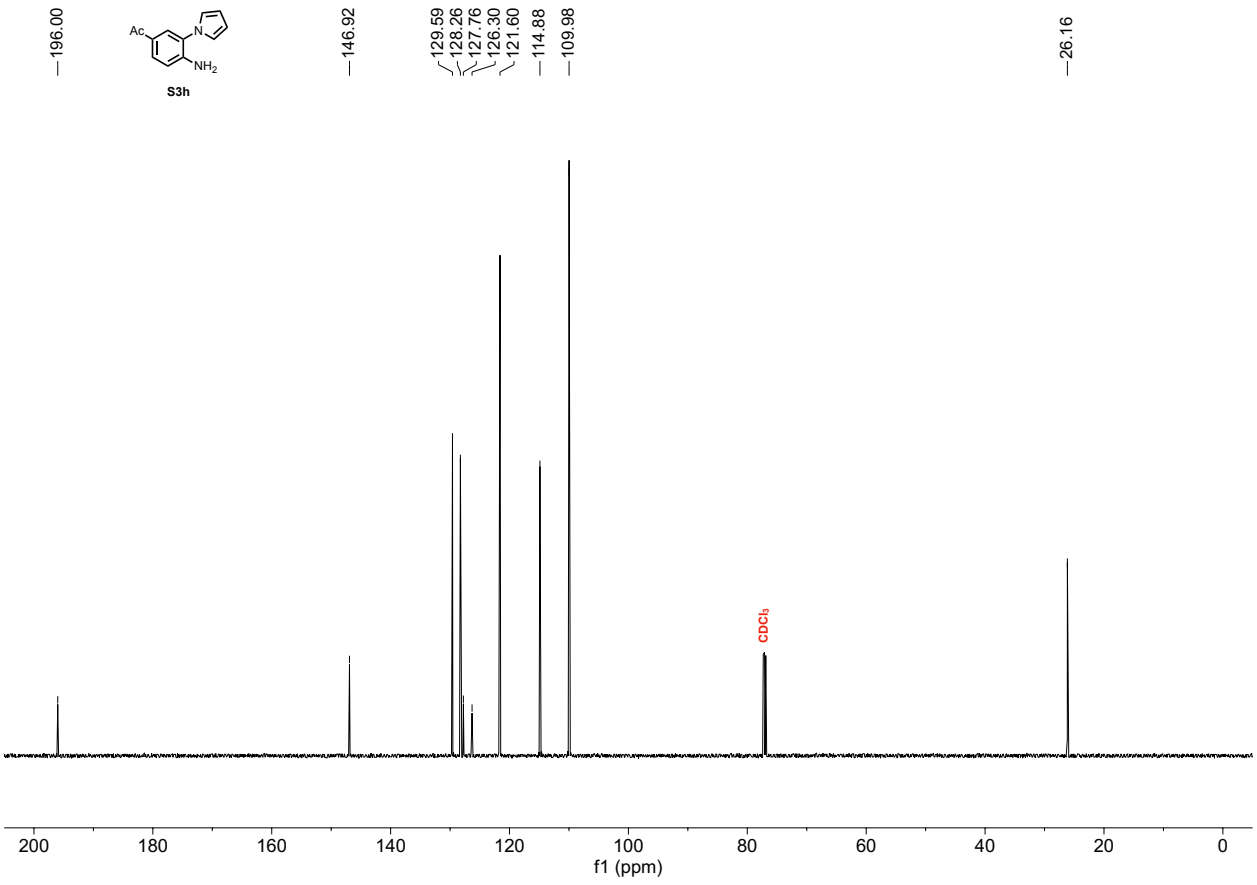
^{31}P, $CDCl_3$, 162 MHz



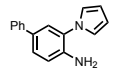
^{1}H, $CDCl_3$, 600 MHz



^{13}C, $CDCl_3$, 151 MHz

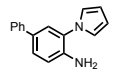


^{1}H, $CDCl_3$, 500 MHz



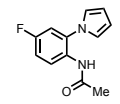
S3i

^{13}C, $CDCl_3$, 126 MHz



S3i

^{1}H, $CDCl_3$, 600 MHz



S1g

8.28 8.27 8.26 8.25 7.10 7.10 7.09 7.09 7.09 7.08 7.08 7.07 7.02 7.02 7.01 7.00 6.95 6.79 6.79 6.79 6.40 6.40 6.40 2.04

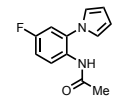
f1 (ppm)

$CDCl_3$

1.00 1.12 1.06 1.00 2.09 2.03 3.37

f1 (ppm)

^{13}C, $CDCl_3$, 151 MHz



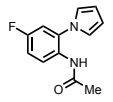
S1g

168.53 159.61 157.99 132.17 132.10 129.67 123.73 123.67 121.88 115.38 115.23 114.09 113.93 111.00 24.65

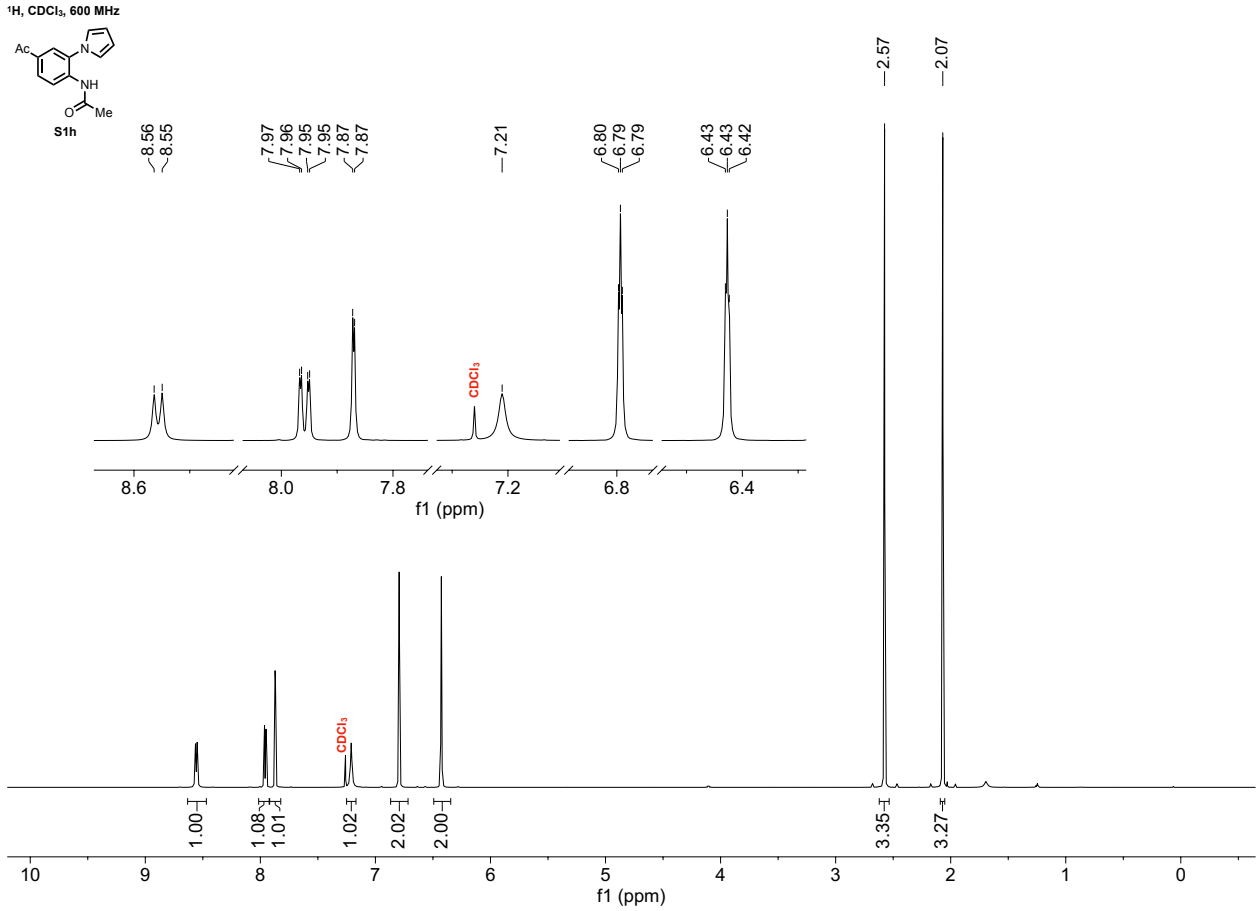
$CDCl_3$

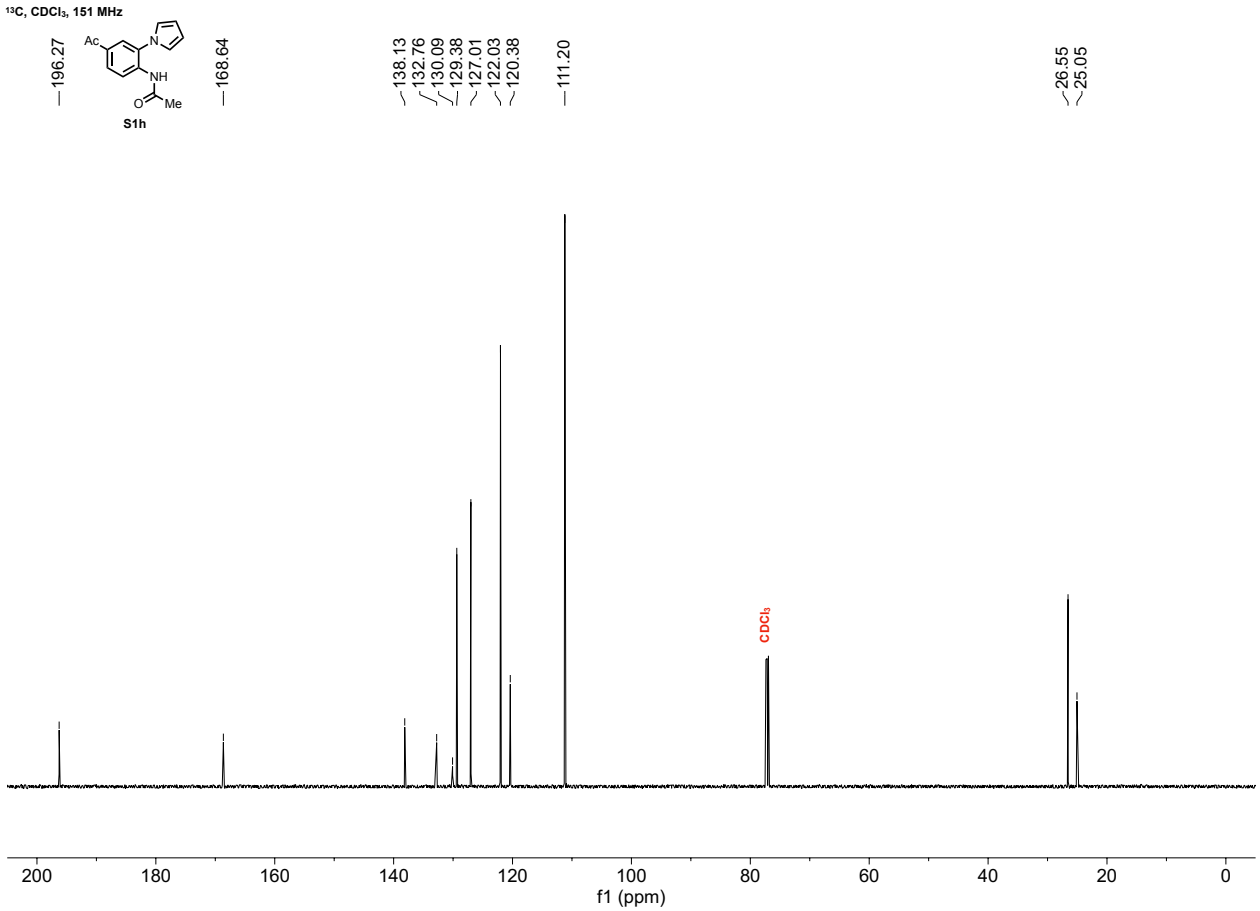
f1 (ppm)

^{19}F, $CDCl_3$, 565 MHz

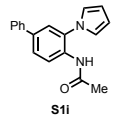


S1g


¹H, CDCl₃, 600 MHz
S1h
8.56
8.55
7.97
7.96
7.95
7.95
7.87
7.87
7.21
6.80
6.79
6.79
6.43
6.43
6.42
2.57
2.07
CDCl₃
f1 (ppm)
1.00
1.08
1.01
1.02
2.02
2.00
3.35
3.27

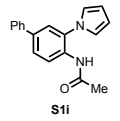

¹³C, CDCl₃, 151 MHz
S1h
196.27
168.64
138.13
132.76
130.09
129.38
127.01
122.03
120.38
111.20
26.55
25.05
CDCl₃
f1 (ppm)

^{1}H, $CDCl_3$, 600 MHz



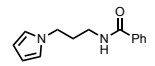
S1i

^{13}C, $CDCl_3$, 151 MHz



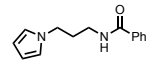
S1i

^{1}H, $CDCl_3$, 600 MHz



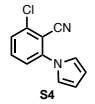
S1o

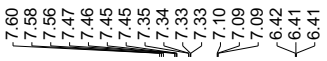
^{13}C, $CDCl_3$, 151 MHz

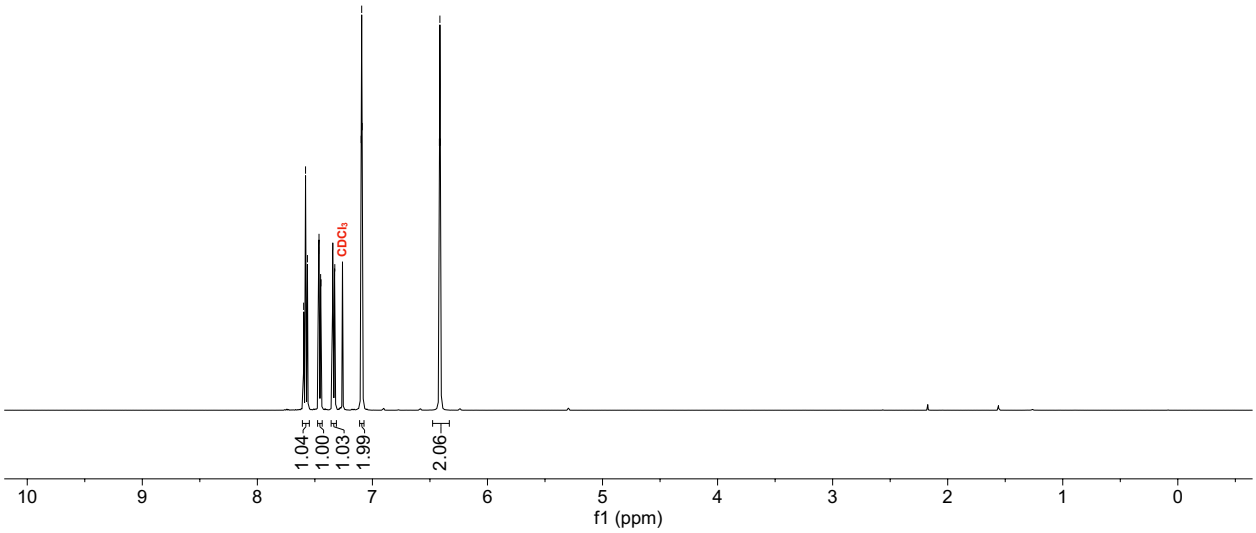


S1o

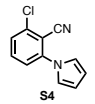
^{1}H, $CDCl_3$, 500 MHz

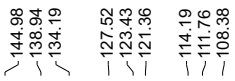


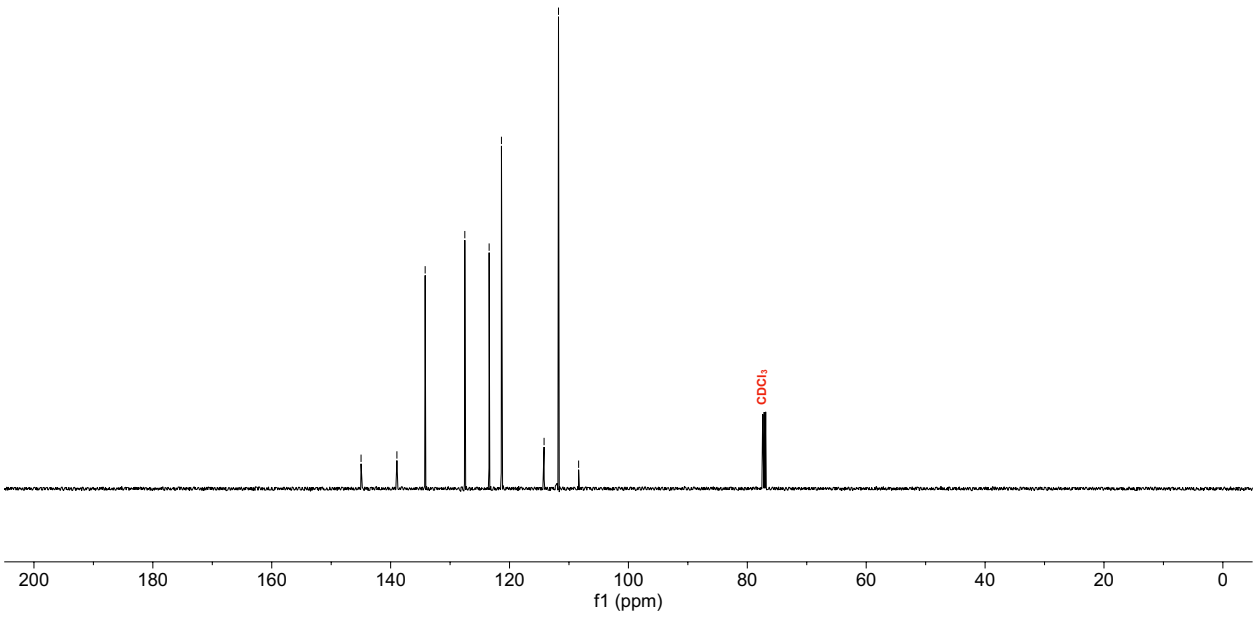


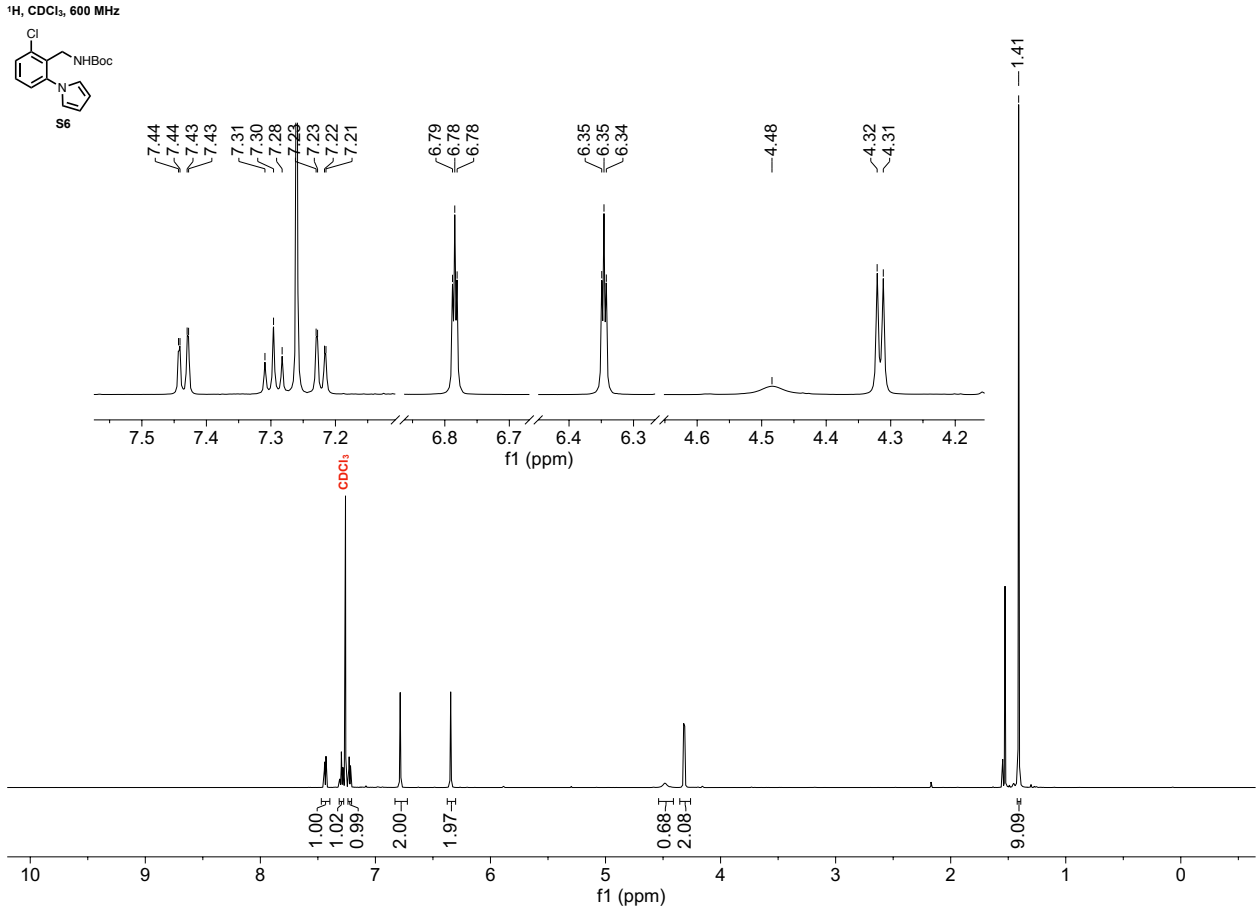


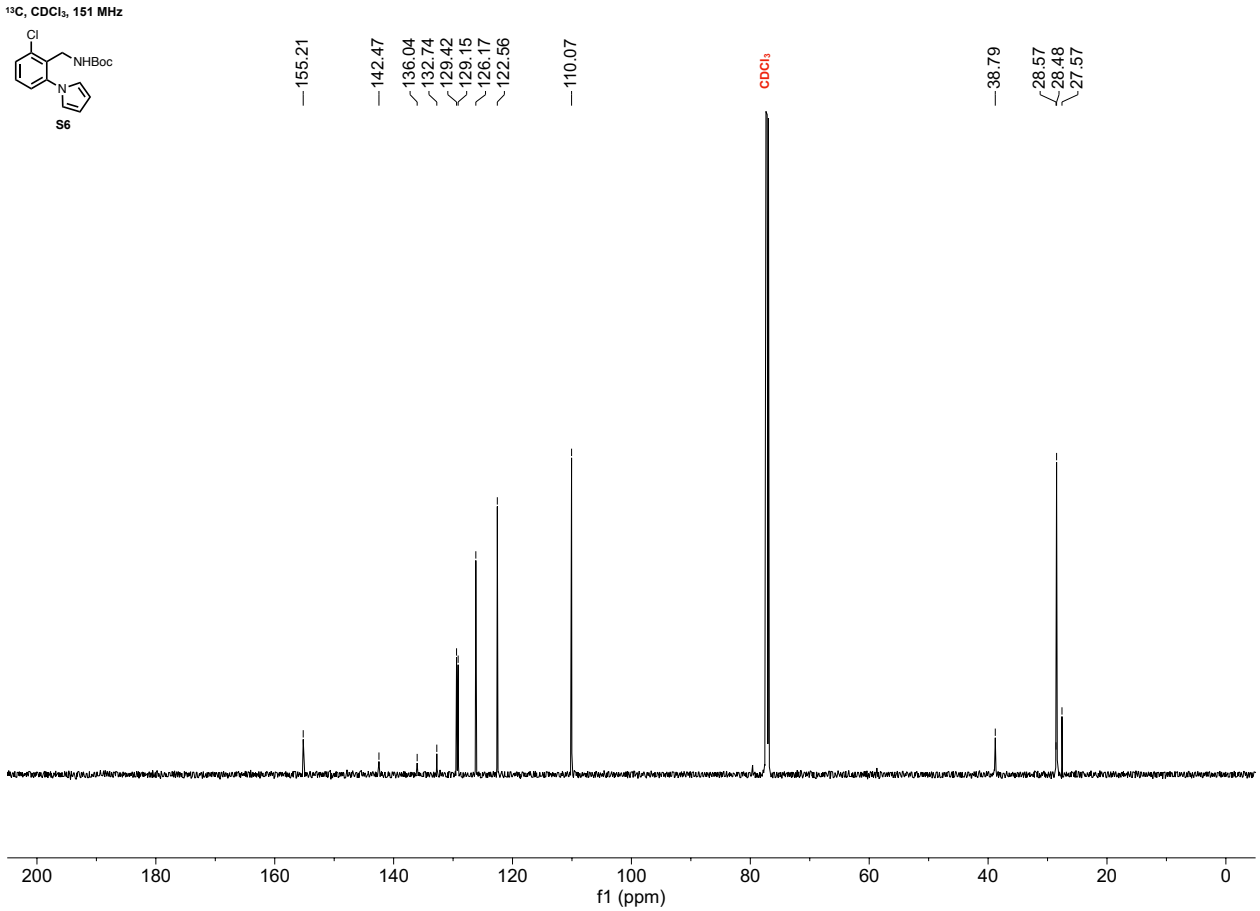
^{13}C, $CDCl_3$, 126 MHz

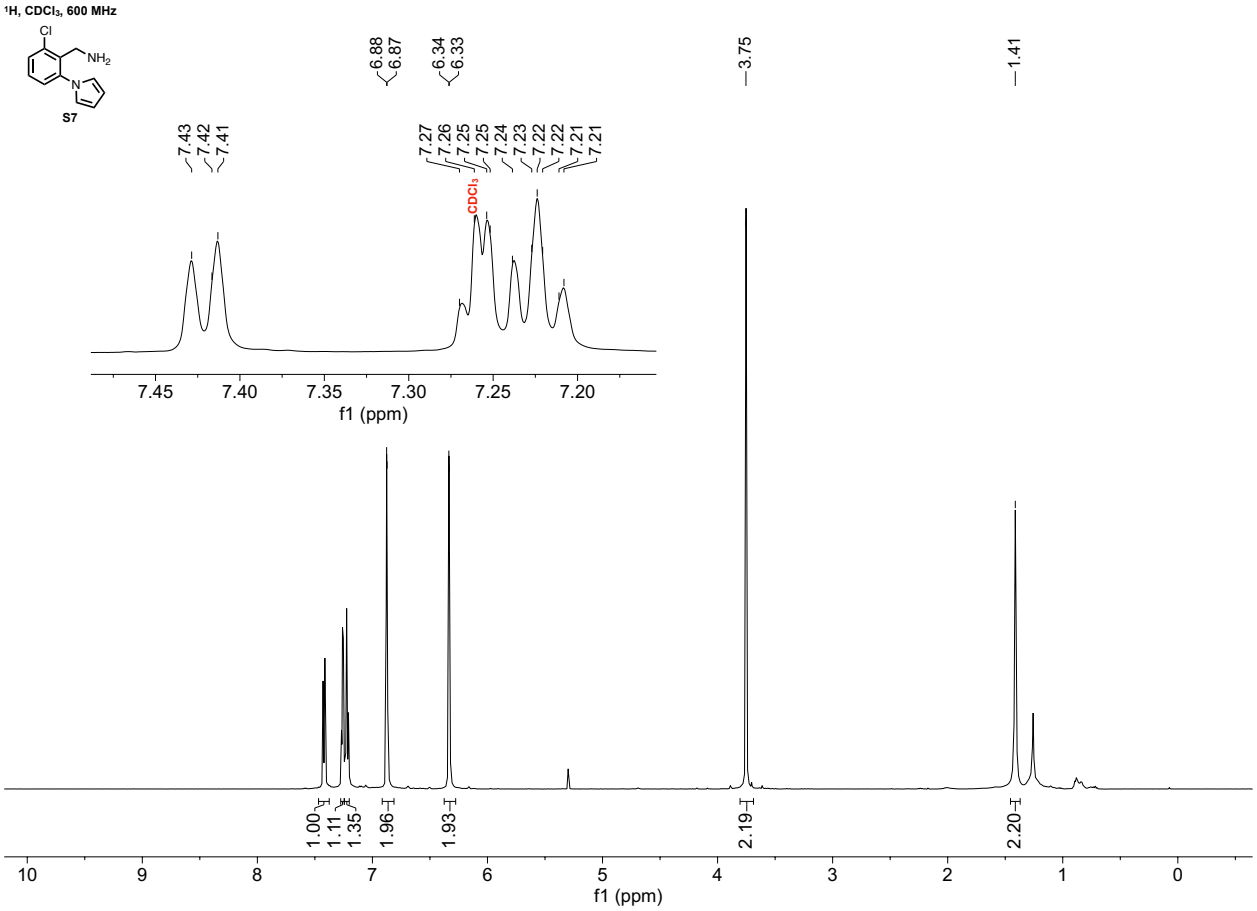


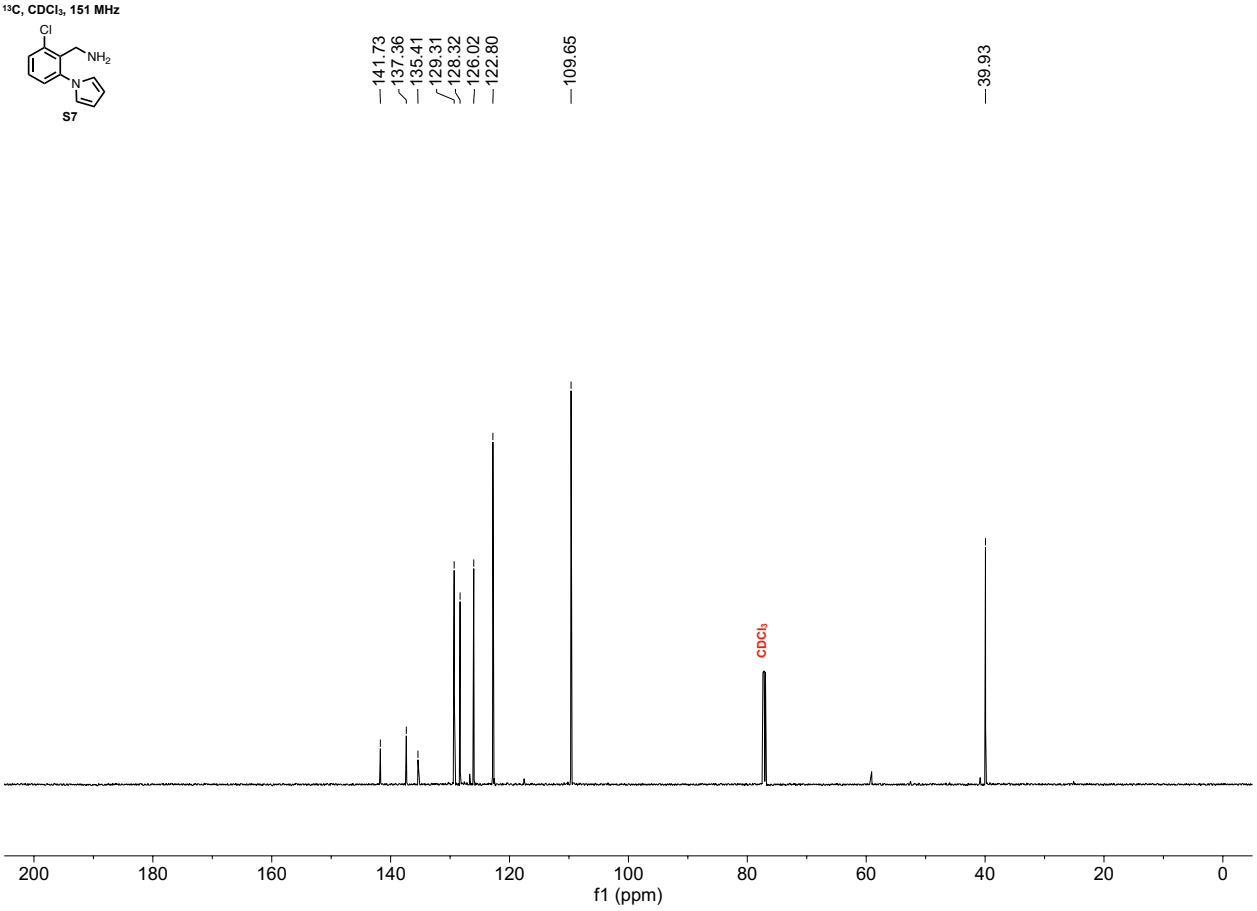





¹H, CDCl₃, 600 MHz
Cl
NHBoc
N
S6
7.44
7.44
7.43
7.43
7.31
7.30
7.28
7.23
7.22
7.21
6.79
6.78
6.78
6.35
6.35
6.34
4.48
4.32
4.31
1.41
CDCl₃
1.00
1.02
0.99
2.00
1.97
0.68
2.08
9.09
f1 (ppm)


¹³C, CDCl₃, 151 MHz
Cl
NHBoc
N
S6
155.21
142.47
136.04
132.74
129.42
129.15
126.17
122.56
110.07
CDCl₃
38.79
28.57
28.48
27.57
f1 (ppm)


¹H, CDCl₃, 600 MHz
Cl
NH₂
N
S7
6.88
6.87
6.34
6.33
3.75
1.41
7.43
7.42
7.41
7.27
7.26
7.25
7.25
7.24
7.23
7.22
7.22
7.21
7.21
CDCl₃
7.45
7.40
7.35
7.30
7.25
7.20
f1 (ppm)
1.00
1.11
1.35
1.96
1.93
2.19
2.20
10
9
8
7
6
5
4
3
2
1
0
f1 (ppm)


¹³C, CDCl₃, 151 MHz
Cl
NH₂
N
S7
141.73
137.36
135.41
129.31
128.32
126.02
122.80
109.65
39.93
CDCl₃
200
180
160
140
120
100
80
60
40
20
0
f1 (ppm)