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Supporting Information

Direct nitrogen interception from chitin/chitosan for imidazo[1,5-*a*]pyridines

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1. General information

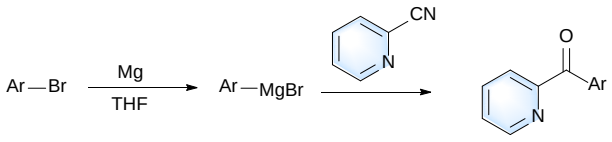
Unless otherwise specified, the chemicals were obtained commercially and used without further purification. All reactions were performed under an atmosphere of Ar unless specified otherwise. ^{1}H (300 or 400 MHz), ^{13}C (75 or 100 MHz) spectra were recorded on 300 MHz or 400 MHz spectrometers with the sample dissolved in $CDCl_3$. Coupling constants are reported in Hertz (Hz) and signal multiplicity is denoted as singlet (s), doublet (d), triplet (t), quartet (q), quintet (quin.), sextet (sex.), septet (sept.), multiplet (m), and broad (br). The solid ^{13}C CP-MAS NMR experiments were run on a Bruker 599 MHz magnet equipped with a 4 mm H/BB/BB MAS probe. The cross polarization (CP) spectrum was recorded at a spinning frequency of 8 kHz and a temperature set at 283 K with a cooling gas flow of 800 l/h. The proton to carbon CP transfer time is set to 3 ms and the inter-scan delay to 3 s. During CP a ramped pulse (80 to 100 percent) was applied at the proton channel. A total of 10240 scans were acquired for each sample. The spectrum was processed with a line broadening of 80 Hz. ESI mass spectra were recorded on Bruker Daltonic spectrometers maXis (ESI-QTOF-MS) and micrOTOF (ESI-TOF-MS). Chitosan was purchased from HEPPE MEDICAL CHITOSAN GmbH. The degree of deacetylation (DD) of chitosan is 97.6%. Practical grade of chitin from shrimp shells and crab shells was purchased from Sigma-Aldrich (Product number C7170). The DD of chitin is 0.025, which was tested by solid ^{13}C CP-MAS NMR analysis. Pyridine ketones **1b**−**1h** were prepared with the previous method. All other chemicals are commercially available and purchased from TH. GEYER Company. It will be mentioned if there is any further purification for the chemicals. Melt points were recorded on melting point apparatus, Electrothermal IA 9200.

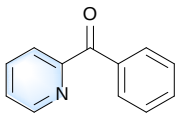
2. Preparation of pyridine ketone derivatives

1) A solution of the bromobenzene (10.0 mmol, 1.00 equiv) in dry THF (0.67 M) was added dropwise into magnesium (12 mmol, 1.2 equiv) and stirred under argon atomosphere at room temperature. After the formation of the Grignard reagent (the color changed to gray), the reaction was stopped. At the same time, picolinonitrile (8.0 mmol, 0.8 equiv) was dissolved in THF (0.8 M), which was added dropwise into the solution of Grignard reagent at 0 ºC. After the reaction was completed, the reaction was quenched by addition of a solution of saturated NH_4Cl. The organic layer was separated and extracted twice with CH_2Cl_2. After evaporation, the organic layer was redissolved in Et_2O (30.0 mL) and 6 M HCl (6 mL) was added. After 30 min, the organic layer was separated, and the aqueous layer was basified with

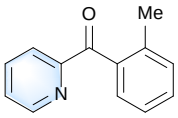
saturated $NaHCO_3$ and then extracted three times with CH_2Cl_2. The combined organic layers were dried over Na_2SO_4 and evaporated in vacuum. The residue was purified by column chromatography with *n*-hexane and EtOAc to afford **1b**. Other pyridine ketones **1b**−**1h** were prepared with the similar procedures.[1] The NMR and HRMS characterization data of those known substrates can be found in previous works. References: **1b**,[2] **1c**,[3] **1d**,[2] **1e**,[2] **1f**,[4] **1g**.[5]

Analytical data for unknown compound **1h:** work-up gave product **1h** (1186.2 mg, 3.5 mmol, isolated yield 35%) as a white green solid. **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.67 – 8.66 (m, 1H), 8.11 (s, 2H), 8.02 (d, *J* = 8.0 Hz, 1H), 7.87 – 7.83 (m, 1H), 7.80 (s, 1H), 7.48 – 7.44 (m, 1H). **^{13}C NMR** (100 MHz, $CDCl_3$): δ 190.6, 153.7, 148.7, 139.2, 137.8, 137.3, 132.6, 126.9, 124.8, 122.7. **ESI-HRMS**: m/z calcd. for $C_{12}H_7Br_2NO$ [M+H]+: 339.8973, found 339.8969.





1b



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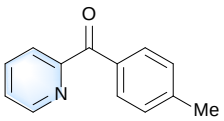

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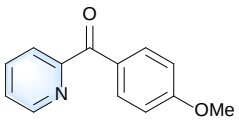
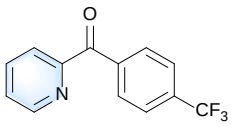


1e



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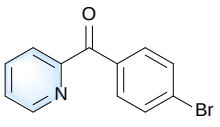

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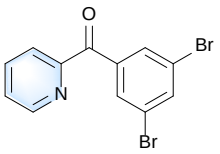
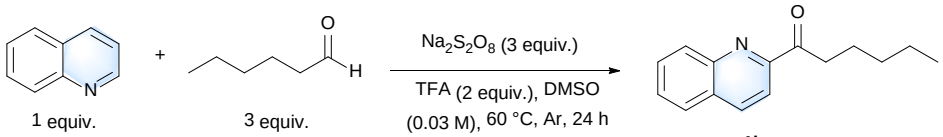


1h

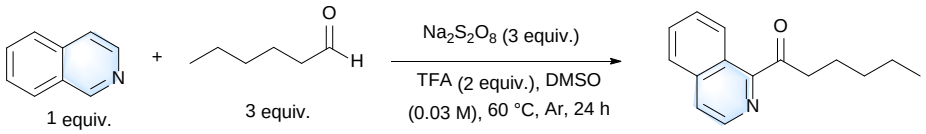
2) A mixture of quinolone or isoquinoline (1.0 mmol), hexanal (3 equiv.), $K_2S_2O_8$ (3 equiv.) and TFA (2 equiv.) in DMSO (0.03 M) was stirred at 60 ºC for 24 h under Ar atmosphere.[6] After the reaction completely, the mixture solution was dissolved with H_2O and extracted with ethyl actate. The organic phase was concentrated and the crude product was purified with flash chromatography on silica gel (EtOAc : *n*-hexane : Et_3N) to give the desired products. The NMR and HRMS characterization data of the known substrate can be found in previous works. References: **1j**[7]

Analytical data for unknown compound **1i:** work-up gave product **1i** (56.8 mg, 0.25 mmol, isolated yield 25%) as a brown liquid. **^{1}H NMR** (400 MHz, $CDCl_3$):δ 8.15 (d, *J* = 8.4 Hz, 1H), 8.10 (d, *J* = 8.4 Hz, 1H), 8.02 (d, *J* = 8.8 Hz, 1H), 7.76 (d, *J* = 8.4 Hz, 1H), 7.70 – 7.66

(m, 1H), 7.56 – 7.52 (m, 1H), 3.30 (t, *J* = 7.2 Hz, 2H), 1.75 – 1.68 (m, 2H), 1.35 – 1.31 (m, 4H), 0.84 (t, *J* = 6.8 Hz, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$): δ 202.8, 153.2, 147.2, 136.8, 130.6, 129.9, 129.6, 128.4, 127.7, 118.2, 37.4, 31.6, 23.9, 22.6, 14.0. **ESI-HRMS**: m/z calcd. for $C_{15}H_{17}NO$ $[M+H]^+$: 228.1388, found 228.1386.



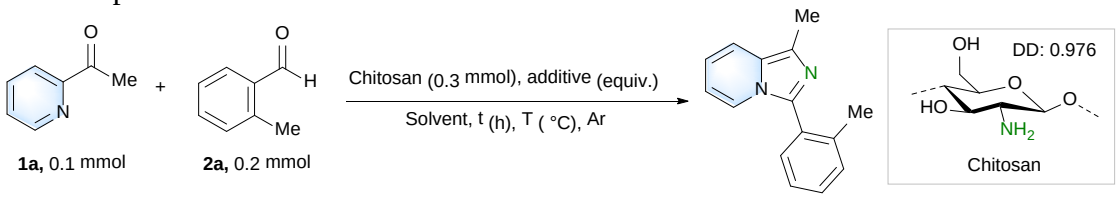
1i



1j

3. Optimization of the reaction conditions

Table S1. Optimization of the reaction conditions



1a, 0.1 mmol **2a,** 0.2 mmol

3

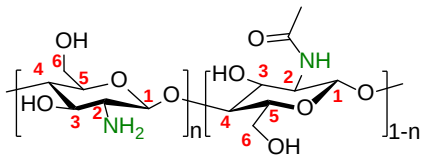
Entry	Additives	Solvent (mL)	t(h) / T(ºC)	Yield (%)[a]
1	-	AcOH	36 / 120	n.d.
2	-	AcOH : H_2O (0.9 : 0.1)	36 / 120	3
3	AgTFA	AcOH : H_2O (0.9 : 0.1)	36 / 120	13
4	AgOAc	AcOH : H_2O (0.9 : 0.1)	36 / 120	<1
5	-	CF_3COOH : H_2O (0.9 : 0.1)	36 / 120	29
6[b]	-	CF_3COOH (1.0)	36 / 120	61
7[b]	-	CF_3COOH (1.0)	36 / 90	4
8[b]	-	**CF_3COOH (1.0)**	**36 / 140**	**78**
9[b]	-	CF_3COOH (1.0)	12 / 140	31

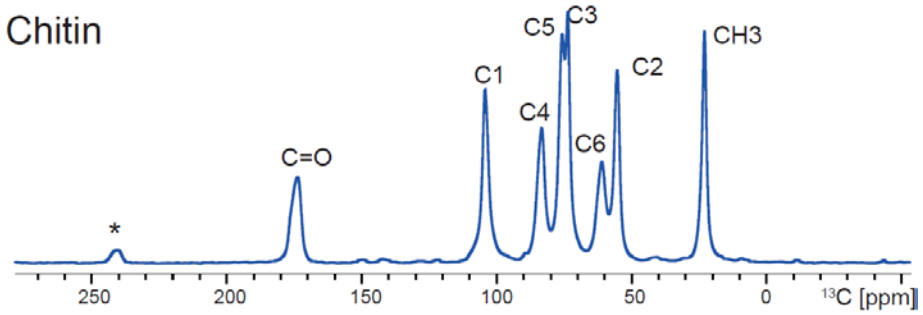
10[b]	-	CF_3COOH (1.0)	24 / 140	59
11[b, c]	-	CF_3COOH (1.0)	36 / 140	66

[a] Reactions were carried out with chitosan (0.3 mmol based on AGU 161 g/mol), 2-acetylpyridine (0.1 mmol), 2-methylbenzaldehyde (0.2 mmol) and solvent (0.1 M). Yields were detected by ^{1}H-NMR analysis with CH_2Br_2 as the internal standard. [b] Chitosan was dried at 100 ºC oven overnight. [c] Chitosan (0.2 mmol per AGU).

4. Solid ^{13}C CP-MAS NMR analysis of the degree of deacetylation (DD) of chitin

The DD of chitin was calculated *via* comparing the signal integrals of the **CH3** of acetyl group and **C1** of glucose unit.





Chemical groups	Shift (ppm)	Relative integral	Absolute integral
C1	104.5	1	159556917
CH3	21.5	0.975	155565921

Figure S1 Solid ^{13}C CP-MAS NMR analysis of the degree deacetylation of chitin

5. Preparation of imidazo[1,5-*a*]pyridine derivatives

Calculation of the molecular weight per average glucosamine unit of chitin/chitosan (M_{AGU}):

Formula: $C_{6+2*(1-x)}H_{10+x+3*(1-x)}O_{4+(1-x)}N$, where x is the degree of deacetylation of chtin/chitosan (DD).

The DD of chitosan in this work is 0.976. M_{AGU}=162.008 g/mol.

The DD of chitin in this work is 0.025. M_{AGU}=201.500 g/mol.

General procedure **A**

A mixture of 2-acetylpyridine (0.1 mmol), aldehyde (2.0 equiv.) and chitosan (3.0 equiv.) in CF_3COOH (0.1 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight.

General procedure **B**

A mixture of pyridine ketone (0.1 mmol), 2-methylbenzoaldehyde (4.0 equiv.) and chitosan (2.5 equiv.) in CF_3COOH (0.14 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight.

General procedure **C**

A mixture of pyridine ketone (0.1 mmol), aldehyde (2.0 equiv.) and chitin (3.0 equiv.) in CF_3COOH (0.1 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitin was dried at 100 ºC overnight.

General procedure **D**

A mixture of pyridine ketone (0.1 mmol), aldehyde (4.0 equiv.) and chitin (2.5 equiv.) in CF_3COOH (0.14 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitin was dried at 100 ºC oven overnight.

General procedure **E**

A mixture of 2-acetylpyridine (0.1 mmol), aldehyde (2.0 equiv.) and chitosan (3.0 equiv.) in CF_3COOD (0.1 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC oven overnight.

Workup: The reaction temperature was directly read from the temperature detector of the IKA apparatus and was calibrated by a thermometer. After cooling to room temperature, the

reaction mixture was basified up to pH = 7 *via* stad. Na_2CO_3 aqueous solution, then extracted by Et_2O (3×3.0 mL) and dried over anhydrous Na_2SO_4. After filtration and concentration in a rotary evaporator, the crude product was purified with flash chromatography on silica gel (EtOAc: *n*-hexane) to give the desired products.

6. Control experiments

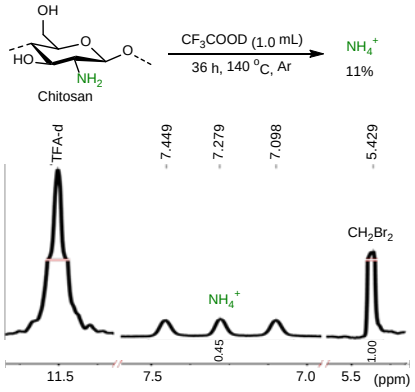


Figure S2. Control experiment for thermal deamination

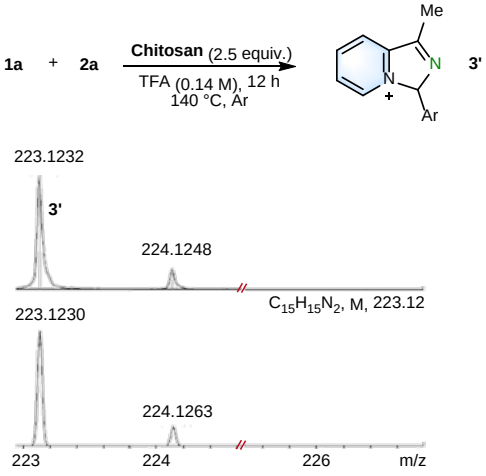


Figure S3. ESI-HRMS analysis of intermediate

7. Large scale reaction

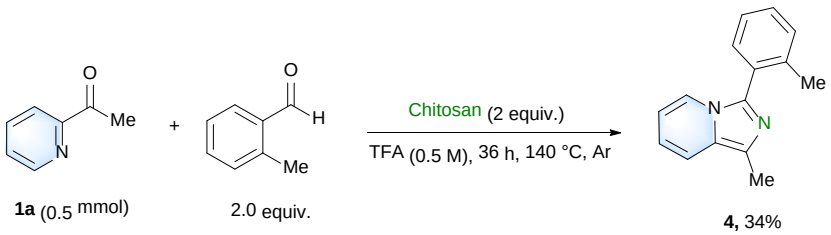
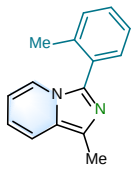


Figure S4. A larger-scale reaction with a smaller volume of TFA.

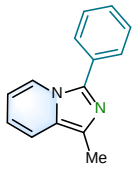
8. Analytical data for compounds



3

Methyl-3-(o-tolyl)imidazo[1,5-*a*]pyridine: Following the **General procedure A**, a mixture of 2-acetylpyridine (0.1 mmol), 2-methylbenzaldehyde (2.0 equiv.) and chitosan (3.0 equiv.) in CF_3COOH (0.1 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **3** (16.9 mg, 0.076 mmol, isolated yield 76%) as a yellow liquid. Following the **General procedure C**, a mixture of 2-acetylpyridine (0.1 mmol), 2-methylbenzaldehyde (2.0 equiv.) and chitin (3.0 equiv.) in the CF_3COOH (0.1 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitin was dried at 100 ºC overnight. Work-up gave product **3** (15.8 mg, 0.071 mmol, isolated yield 71%) as a yellow liquid.

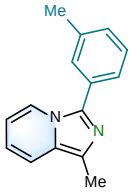
^{1}H NMR (300 MHz, $CDCl_3$) δ 7.41 (d, *J* = 7.2 Hz, 1H), 7.35–7.17 (m, 5H), 6.53 – 6.48 (m, 1H), 6.35–6.30 (m, 1H), 2.49 (s, 3H), 2.12 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 138.1, 136.2, 130.6, 130.4, 129.5, 129.1, 127.9, 126.7, 125.9, 121.2, 118.0, 116.6, 112.2, 19.6, 12.6. **ESI-HRMS**: *m/z* calcd. for $C_{15}H_{14}N_2$ $[M+H]^+$: 223.1235, found 223.1230.



4

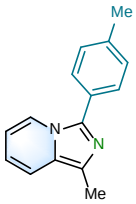
1-Methyl-3-phenylimidazo[1,5-*a*]pyridine: Following the **General procedure A**, a mixture of 2-acetylpyridine (0.1 mmol), benzaldehyde (2.0 equiv.) and chitosan (3.0 equiv.) in CF_3COOH (0.1 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **4** (17.1 mg, 0.082 mmol, isolated yield 82%) as a yellow liquid. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.09 (d, *J* = 7.2 Hz, 1H), 7.69 (d, *J* = 7.6 Hz, 2H), 7.41 (t, *J* = 7.6 Hz, 2H), 7.34 – 7.30 (m, 2H), 6.56 – 6.52 (m, 1H), 6.43 – 6.39 (m, 1H), 2.48 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) 136.5,

130.3, 128.9, 128.4, 127.9, 127.7, 121.1, 118.3, 117.1, 112.9, 12.4. The compound is known, and the NMR data is in accordance with the previous literature.[8]



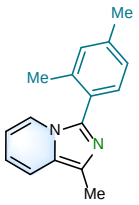
5

1-Methyl-3-(m-tolyl)imidazo[1,5-*a*]pyridine (5): Following the **General procedure A**, a mixture of 2-acetylpyridine (0.1 mmol), 3-methylbenzaldehyde (2.0 equiv.) and chitosan (3.0 equiv.) in CF_3COOH (0.1 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **5** (17.8 mg, 0.080 mmol, isolated yield 80%) as a yellow solid. **m.p.**: 104-106 ºC. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.10 (d, *J* = 7.2 Hz, 1H), 7.53 (s, 1H), 7.47 (d, *J* = 7.6 Hz, 1H), 7.31 (d, *J* = 8.0 Hz, 2H), 7.14 (d, *J* = 7.6 Hz, 1H), 6.54 (dd, *J* = 9.2, 6.4 Hz, 1H), 6.42 – 6.39 (m, 1H), 2.48 (s, 3H), 2.34 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 138.8, 136.7, 132.7, 130.2, 129.2, 128.7, 128.6, 127.9, 124.5, 121.2, 118.3, 117.0, 112.8, 21.4, 12.5. **ESI-HRMS**: *m/z* calcd. for $C_{15}H_{14}N_2$ $[M+H]^+$: 223.1235, found 223.1233.



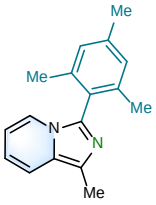
6

1-methyl-3-(p-tolyl)imidazo[1,5-*a*]pyridine: Following the **General procedure A**, a mixture of 2-acetylpyridine (0.1 mmol), 4-methylbenzaldehyde (2.0 equiv.) and chitosan (3.0 equiv.) in CF_3COOH (0.1 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **6** (17.6 mg, 0.079 mmol, isolated yield 79%) as a yellow solid. **m.p.**: 62-63 ºC. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.06 (d, *J* = 7.2 Hz, 1H), 7.58 (d, *J* = 8.0 Hz, 2H), 7.30 (d, *J* = 9.2 Hz, 1H), 7.23 (d, *J* = 8.0 Hz, 2H), 6.52 (dd, *J* = 9.2, 6.4 Hz, 1H), 6.41 – 6.37 (m, 1H), 2.49 (s, 3H), 2.34 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 138.4, 136.7, 129.6, 128.5, 127.7, 127.7, 127.4, 121.2, 118.3, 116.8, 112.7, 21.4, 12.5. **ESI-HRMS**: m/z calcd. for $C_{15}H_{14}N_2$ $[M+H]^+$: 223.1235, found 223.1234.



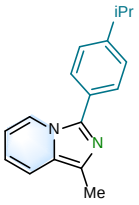
7

3-(2,4-dimethylphenyl)-1-methylimidazo[1,5-*a*]pyridine: Following the **General procedure A**, a mixture of 2-acetylpyridine (0.1 mmol), 2,4-dimethylbenzaldehyde (2.0 equiv.) and chitosan (3.0 equiv.) in CF_3COOH (0.1 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **7** (16.7 mg, 0.075 mmol, isolated yield 75%) as a brown solid. **m.p.**: 82-83 ºC. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.41 (d, *J* = 7.2 Hz, 1H), 7.30 (d, *J* = 9.2 Hz, 1H), 7.21 (d, *J* = 8.0 Hz, 1H), 7.07 (s, 1H), 7.02 (d, *J* = 8.0 Hz, 1H), 6.54 – 6.50 (m, 1H), 6.36 – 6.32 (m, 1H), 2.48 (s, 3H), 2.31 (s, 3H), 2.07 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 139.1, 137.9, 136.3, 131.4, 130.4, 127.6, 126.7, 126.4, 121.3, 118.0, 116.7, 112.2, 21.3, 19.5, 12.5. **ESI-HRMS**: *m/z* calcd. for $C_{16}H_{16}N_2$ $[M+H]^+$: 237.1392, found 237.1389.



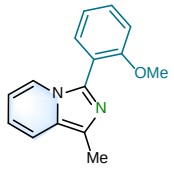
8

3-mesityl-1-methylimidazo[1,5-*a*]pyridine: Following the **General procedure A**, a mixture of 2-acetylpyridine (0.1 mmol), 2,4,6-trimethylbenzaldehyde (2.0 equiv.) and chitosan (3.0 equiv.) in CF_3COOH (0.1 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **8** (17.8 mg, 0.071 mmol, isolated yield 71%) as a yellow liquid. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.31 (d, *J* = 8.8 Hz, 1H), 7.13 (d, *J* = 7.2 Hz, 1H), 6.88 (s, 2H), 6.52 – 6.48 (m, 1H), 6.32 – 6.28 (m, 1H), 2.50 (s, 3H), 2.27 (s, 3H), 1.88 (s, 6H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 139.1, 135.5, 128.3, 127.5, 126.2, 126.2, 120.9, 118.0, 116.3, 112.1, 21.2, 19.5, 12.7. **ESI-HRMS**: m/z calcd. for $C_{17}H_{18}N_2$ $[M+H]^+$: 251.1548, found 251.1545.



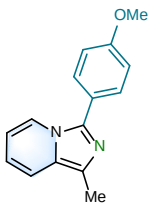
9

3-(4-isopropylphenyl)-1-methylimidazo[1,5-*a*]pyridine: Following the **General procedure A**, a mixture of 2-acetylpyridine (0.1 mmol), 4-isopropylbenzaldehyde (2.0 equiv.) and chitosan (3.0 equiv.) in CF_3COOH (0.1 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **9** (18.5 mg, 0.074 mmol, isolated yield 74%) as a brown solid. **m.p.**: 61-63 ºC. **^{1}H NMR** (300 MHz, $CDCl_3$) δ 8.08 (d, *J* = 7.2 Hz, 1H), 7.62 (d, *J* = 8.1 Hz, 2H), 7.31 – 7.26 (m, 3H), 6.53 (dd, *J* = 9.0, 6.4 Hz, 1H), 6.42 – 6.37 (m, 1H), 2.89 (hept, *J* = 6.9 Hz, 1H), 2.49 (s, 3H), 1.21 (d, *J* = 6.9 Hz, 6H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 149.4, 136.5, 128.3, 127.8, 127.7, 127.4, 127.0, 121.2, 118.3, 117.0, 112.9, 34.0, 23.8, 12.3. **ESI-HRMS**: m/z calcd. for $C_{17}H_{18}N_2$ $[M+H]^+$: 251.1548, found 251.1544.



10

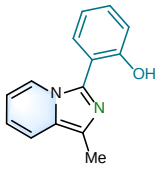
3-(2-methoxyphenyl)-1-methylimidazo[1,5-*a*]pyridine: Following the **General procedure A**, a mixture of 2-acetylpyridine (0.1 mmol), 2-methoxylbenzaldehyde (2.0 equiv.) and chitosan (3.0 equiv.) in CF_3COOH (0.1 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **10** (14.99 mg, 0.063 mmol, isolated yield 63%) as a yellow solid. **m.p.**: 55−57 ºC. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.50 (dd, *J* = 7.2, 1.2 Hz, 1H), 7.42 – 7.40 (m, 1H), 7.36 – 7.28 (m, 2H), 7.01 – 6.97 (m, 1H), 6.93 (d, *J* = 8.4 Hz, 1H), 6.54 – 6.50 (m, 1H), 6.36 – 6.32 (m, 1H), 3.70 (s, 3H), 2.49 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 157.1, 134.3, 132.3, 130.3, 128.1, 127.5, 122.8, 120.9, 119.2, 117.6, 116.7, 111.5, 111.0, 55.4, 12.5. **ESI-HRMS**: *m/z* calcd. for $C_{15}H_4N_2O$ $[M+H]^+$: 239.0402, found 239.0397.



11

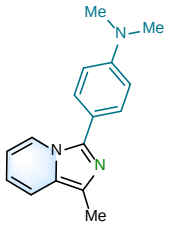
3-(4-methoxyphenyl)-1-methylimidazo[1,5-*a*]pyridine: Following the **General procedure A**, a mixture of 2-acetylpyridine (0.1 mmol), 4-methoxylbenzaldehyde (2.0 equiv.) and chitosan (3.0 equiv.) in CF_3COOH (0.1 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **11** (15.5 mg, 0.065 mmol, isolated yield 65%) as a yellow

solid. **m.p.**: 62−63 ºC. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.01 (d, *J* = 7.2 Hz, 1H), 7.61 (d, *J* = 8.4 Hz, 2H), 7.29 (d, *J* = 9.2 Hz, 1H), 6.95 (d, *J* = 8.4 Hz, 2H), 6.51 (dd, *J* = 9.2, 6.0 Hz, 1H), 6.40 – 6.37 (m, 1H), 3.79 (s, 3H), 2.47 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 159.7, 136.5, 129.2, 128.3, 127.5, 122.8, 121.1, 118.3, 116.7, 114.4, 112.7, 55.3, 12.4. **ESI-HRMS**: m/z calcd. for $C_{15}H_{14}N_2O$ $[M+H]^+$: 239.1184, found 239.1181.



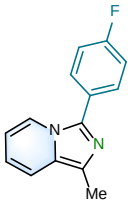
12

2-(1-methylimidazo[1,5-*a*]pyridin-3-yl)phenol: Following the **General procedure A**, a mixture of 2-acetylpyridine (0.1 mmol), 2-hydoxylbenzaldehyde (2.0 equiv.) and chitosan (3.0 equiv.) in CF_3COOH (0.1 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **12** (6.7 mg, 0.030 mmol, isolated yield 30%) as a white solid. **m.p.**: 136−138 ºC. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.34 (d, *J* = 7.2 Hz, 1H), 7.66 (d, *J* = 8.0 Hz, 1H), 7.36 (d, *J* = 9.2 Hz, 1H), 7.19 – 7.18 (m, 1H), 7.07 (d, *J* = 8.4 Hz, 1H), 6.92 – 6.88 (m, 1H), 6.64 – 6.60 (m, 1H), 6.55 – 6.51 (m, 1H), 2.48 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 156.3, 134.2, 129.4, 127.2, 127.0, 123.9, 121.9, 118.9, 118.6, 117.7, 117.7, 114.3, 113.7, 12.2. **ESI-HRMS**: *m/z* calcd. for $C_{14}H_{12}N_2O_1$ $[M+H]^+$: 225.1028, found 225.1026.



13

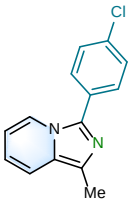
***N*,*N*-dimethyl-4-(1-methylimidazo[1,5-*a*]pyridin-3-yl)aniline:** Following the **General procedure A**, a mixture of 2-acetylpyridine (0.1 mmol), (*E*)-3-(4-(dimethylamino)phenyl)acrylaldehyde (2.0 equiv.) and chitosan (3.0 equiv.) in CF_3COOH (0.14 M) was stirred at 140 ºC under Ar atmosphere for 4 days. Chitosan was dried at 100 ºC overnight. Work-up gave product **13** (10.5 mg, 0.038 mmol, isolated yield 38%) as a yellow solid. **m.p.** 57−59 ºC. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.82 (d, *J* = 6.8 Hz, 1H), 7.52 (d, *J* = 16.0 Hz, 1H), 7.39 (d, *J* = 8.4 Hz, 2H), 7.25 (d, *J* = 9.2 Hz, 1H), 6.88 (d, *J* = 15.6 Hz, 1H), 6.64 (d, *J* = 8.8 Hz, 2H), 6.51 – 6.42 (m, 2H), 2.92 (s, 6H), 2.47 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 150.3, 135.9, 130.4, 129.7, 129.2, 127.7, 125.3, 120.5, 118.4, 116.5, 112.7, 112.3, 107.6, 40.4, 12.6. **ESI-HRMS**: m/z calcd. for $C_{18}H_{19}N_3$ $[M+H]^+$: 278.1652, found 278.1654.



14

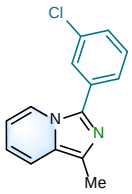
3-(4-fluorophenyl)-1-methylimidazo[1,5-*a*]pyridine: Following the **General procedure A**, a mixture of 2-acetylpyridine (0.1 mmol), 4-fluorobenzaldehyde (2.0 equiv.) and chitosan (3.0 equiv.) in CF_3COOH (0.1 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried under 100 ºC overnight. Work-up gave product **14** (17.6 mg, 0.078 mmol, isolated yield 78%) as a yellow solid. **m.p.**: 82−83 ºC. Following the **General procedure C**, a mixture of 2-acetylpyridine (0.1 mmol), 4-fluorobenzaldehyde (2.0 equiv.) and chitin (3.0 equiv.) in CF_3COOH (0.1 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitin was dried at 100 ºC overnight. Work-up gave product **14** (16.0 mg, 0.071 mmol, isolated yield 71%) as a yellow solid.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.02 (d, *J* = 7.2 Hz, 1H), 7.67 (dd, *J* = 8.8, 5.2 Hz, 2H), 7.33 (d, *J* = 9.2 Hz, 1H), 7.14 – 7.10 (m, 2H), 6.56 (dd, *J* = 9.2, 6.0 Hz, 1H), 6.45 – 6.42 (m, 1H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 162.7 (d, $^1J_{C\text{-}F}$ = 247.1 Hz), 135.5, 129.7 (d, $^3J_{C\text{-}F}$ = 8.2 Hz), 128.7, 127.9, 126.5 (d, $^4J_{C\text{-}F}$ = 3.3 Hz), 120.8, 118.4, 117.1, 116.1 (d, $^2J_{C\text{-}F}$ = 21.6 Hz), 113.1, 12.4. **ESI-HRMS**: *m/z* calcd. for $C_{14}H_{11}FN_2$ $[M+H]^+$: 227.0985, found 227.0980.



15

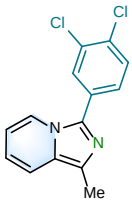
3-(4-chlorophenyl)-1-methylimidazo[1,5-*a*]pyridine: Following the **General procedure A**, a mixture of 2-acetylpyridine (0.1 mmol), 4-chlorobenzaldehyde (2.0 equiv.) and chitosan (3.0 equiv.) in CF_3COOH (0.1 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **15** (17.7 mg, 0.073 mmol, isolated yield 73%) as a yellow solid. **m.p**: 63−64 ºC. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.04 (d, *J* = 7.2 Hz, 1H), 7.63 (d, *J* = 8.4 Hz, 2H), 7.39 (d, *J* = 8.8 Hz, 2H), 7.33 (d, *J* = 10.0 Hz, 1H), 6.57 (dd, *J* = 8.8, 6.4 Hz, 1H), 6.47 – 6.43 (m, 1H), 2.47 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 135.3, 134.2, 129.2, 129.1, 128.9, 128.8, 128.2, 121.6, 120.9, 118.4, 117.3, 113.3, 12.4. **ESI-HRMS**: *m/z* calcd. for $C_{14}H_{11}ClN_2$ $[M+H]^+$: 243.0689, found 243.0687.



16

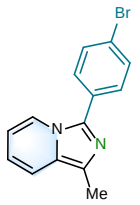
3-(3-chlorophenyl)-1-methylimidazo[1,5-*a*]pyridine: Following the **General procedure A**, a mixture of 2-acetylpyridine (0.1 mmol), 3-chlorobenzaldehyde (2.0 equiv.) and chitosan (3.0 equiv.) in CF_3COOH (0.1 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **16** (17.0 mg, 0.070 mmol, isolated yield 70%) as a brown solid. **m.p**: 70−71 ºC. Following the **General procedure C**, a mixture of 2-acetylpyridine (0.1 mmol), 3-chlorobenzaldehyde (2.0 equiv.) and chitin (3.0 equiv.) in the CF_3COOH (0.1 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitin was dried at 100 ºC oven overnight. Work-up gave product **16** (12.8 mg, 0.053 mmol, isolated yield 53%) as a brown solid.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.10 (d, *J* = 7.6 Hz, 1H), 7.71 (s, 1H), 7.59 (d, *J* = 7.6 Hz, 1H), 7.35 – 7.30 (m, 3H), 6.59 (dd, *J* = 9.2, 6.0 Hz, 1H), 6.50 – 6.46 (m, 1H), 2.49 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 134.9, 132.1, 130.2, 130.0, 129.3, 128.4, 128.3, 127.6, 125.6, 121.0, 118.5, 117.5, 113.4, 12.5. **ESI-HRMS**: m/z calcd. for $C_{14}H_{11}ClN_2$ $[M+H]^+$: 243.0689, found 243.0687.



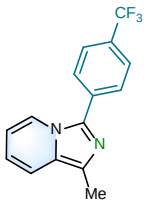
17

3-(3,4-dichlorophenyl)-1-methylimidazo[1,5-*a*]pyridine: Following the **General procedure A**, a mixture of 2-acetylpyridine (0.1 mmol), 3,4-dichlorobenzaldehyde (2.0 equiv.) and chitosan (3.0 equiv.) in CF_3COOH (0.1 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **17** (15.7 mg, 0.057 mmol, isolated yield 57%) as a yellow solid. **m.p.**: 116−117 ºC. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.05 (d, *J* = 7.2 Hz, 1H), 7.82 (s, 1H), 7.57 – 7.45 (m, 2H), 7.34 (d, *J* = 9.2 Hz, 1H), 6.61 – 6.58 (m, 1H), 6.50 – 6.47 (m, 1H), 2.48 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 134.0, 133.2, 132.0, 130.8, 130.4, 129.6, 129.2, 128.6, 126.4, 120.8, 118.5, 117.6, 113.6, 12.5. **ESI-HRMS**: m/z calcd. for $C_{14}H_{10}Cl_2N_2$ $[M+H]^+$: 277.0299, found 277.0295.



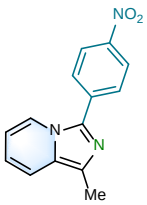
18

3-(4-bromophenyl)-1-methylimidazo[1,5-*a*]pyridine: Following the **General procedure A**, a mixture of 2-acetylpyridine (0.1 mmol), 4-bromobenzaldehyde (2.0 equiv.) and chitosan (3.0 equiv.) in CF_3COOH (0.1 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **18** (18.31 mg, 0.064 mmol, isolated yield 64%) as a yellow solid. **m.p.**: 90−91 ºC. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.05 – 8.03 (m, 1H), 7.58 – 7.53 (m, 4H), 7.34 – 7.31 (m, 1H), 6.57 (dd, *J* = 9.1, 6.4 Hz, 1H), 6.47 – 6.43 (m, 1H), 2.47 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 135.3, 132.1, 129.2, 129.1, 129.1, 128.2, 122.3, 120.9, 118.4, 117.3, 113.3, 12.4. **ESI-HRMS**: *m/z* calcd. for $C_{14}H_{11}BrN_2$ $[M+H]^+$: 287.0184, found 287.0181.



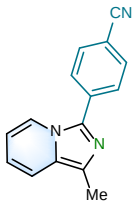
19

1-methyl-3-(4-(trifluoromethyl)phenyl)imidazo[1,5-*a*]pyridine: Following the **General procedure A**, a mixture of 2-acetylpyridine (0.1 mmol), 4-trifluoromethylbenzaldehyde (2.0 equiv.) and chitosan (3.0 equiv.) in CF_3COOH (0.1 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **19** (18.49 mg, 0.067 mmol, isolated yield 67%) as a yellow solid. **m.p.**: 72−73 ºC. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.15 – 8.12 (m, 1H), 7.85 (d, *J* = 8.0 Hz, 2H), 7.69 – 7.66 (m, 2H), 7.38 – 7.35 (m, 1H), 6.64 – 6.59 (m, 1H), 6.52 – 6.47 (m, 1H), 2.50 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 134.9, 133.9 (q, $^4J_{C\text{-}F}$ = 1.2 Hz), 129.8 (q, $^2J_{C\text{-}F}$ = 32.5 Hz), 129.8, 128.7, 127.6, 125.9 (q, $^3J_{C\text{-}F}$ = 3.8 Hz), 124.0 (q, $^1J_{C\text{-}F}$ = 270.4 Hz), 120.9, 118.5, 117.7, 113.6, 12.5. **^{19}F NMR** (377 MHz, $CDCl_3$) δ -62.6. **ESI-HRMS**: m/z calcd. for $C_{15}H_{11}F_3N_2$ $[M+H]^+$: 277.0953, found 277.0950.



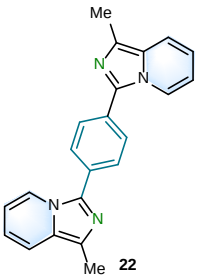
20

1-methyl-3-(4-nitrophenyl)imidazo[1,5-*a*]pyridine: Following the **General procedure A**, a mixture of 2-acetylpyridine (0.1 mmol), 4-nitrobenzaldehyde (2.0 equiv.) and chitosan (3.0 equiv.) in CF_3COOH (0.1 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **20** (10.6 mg, 0.042 mmol, isolated yield 42%) as a red solid. **m.p.**: 142−143 ºC. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.27 (d, *J* = 8.8 Hz, 2H), 8.22 (d, *J* = 7.2 Hz, 1H), 7.93 (d, *J* = 8.8 Hz, 2H), 7.41 (d, *J* = 9.2 Hz, 1H), 6.71 – 6.67 (m, 1H), 6.61 – 6.57 (m, 1H), 2.52 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 146.6, 136.5, 134.0, 131.0, 129.6, 127.3, 124.4, 121.0, 118.7, 118.4, 114.3, 12.6. **ESI-HRMS**: *m/z* calcd. for $C_{14}H_{11}N_3O_2$ $[M+H]^+$: 254.0930, found 254.0926.



21

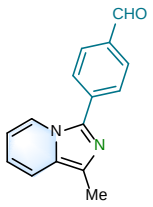
4-(1-methylimidazo[1,5-*a*]pyridin-3-yl)benzonitrile: Following the **General procedure A**, a mixture of 2-acetylpyridine (0.1 mmol), 4-formylbenzonitrile (2.0 equiv.) and chitosan (3.0 equiv.) in CF_3COOH (0.1 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **21** (8.4 mg, 0.036 mmol, isolated yield 36%) as a yellow solid. **m.p.**: 89−90 ºC. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.16 (d, *J* = 7.2 Hz, 1H), 7.87 (d, *J* = 8.0 Hz, 2H), 7.70 (d, *J* = 8.4 Hz, 2H), 7.39 (d, *J* = 9.2 Hz, 1H), 6.66 (dd, *J* = 8.9, 6.5 Hz, 1H), 6.57 – 6.54 (m, 1H), 2.50 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 134.6, 134.3, 132.7, 130.5, 129.2, 127.4, 120.9, 118.7, 118.6, 118.1, 114.0, 111.0, 12.5. **ESI-HRMS**: m/z calcd. for $C_{15}H_{11}N_3$ $[M+H]^+$: 234.1031, found 234.1030.



22

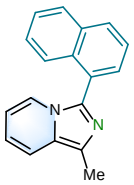
1,4-bis(1-methylimidazo[1,5-*a*]pyridin-3-yl)benzene: Following the **General procedure A**, a mixture of 2-acetylpyridine (0.1 mmol), terephthalaldehyde (2.0 equiv.) and chitosan (3.0 equiv.) in CF_3COOH (0.14 M) was stirred at 140 ºC under Ar atmosphere for 4 days. Chitosan was dried at 100 ºC overnight. Work-up gave product **22** (8.1 mg, 0.024 mmol, isolated yield 24%) as a brown red solid. **m.p.**: 212−214 ºC. **^{1}H NMR** (300 MHz, $CDCl_3$) δ 8.17 (d, *J* = 7.2 Hz, 2H), 7.86 (s, 4H), 7.35 (d, *J* = 9.3 Hz, 2H), 6.58 (dd, *J* = 9.0, 6.3 Hz, 2H), 6.49 – 6.44 (m, 2H), 2.52 (s, 6H). **^{13}C NMR** (75 MHz,

$CDCl_3$) δ 136.0, 130.1, 129.3, 128.3, 128.0, 121.2, 118.4, 117.2, 113.2, 12.6. **ESI-HRMS**: m/z calcd. for $C_{22}H_{18}N_4$ $[M+H]^+$: 338.1531, found 338.1526.



23

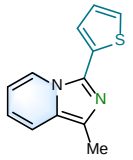
4-(1-methylimidazo[1,5-*a*]pyridin-3-yl)benzaldehyde: Following the **General procedure A**, a mixture of 2-acetylpyridine (0.1 mmol), terephthalaldehyde (2.0 equiv.) and chitosan (3.0 equiv.) in CF_3COOH (0.1 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **23** (12.5 mg, 0.053 mmol, isolated yield 53%) as a yellow solid. **m.p.**: 310−312 ºC. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 9.97 (s, 1H), 8.21 (d, *J* = 7.2 Hz, 1H), 7.92 (s, 4H), 7.38 (d, *J* = 8.8 Hz, 1H), 6.65 (dd, *J* = 9.2, 6.4 Hz, 1H), 6.54 (t, *J* = 6.8 Hz, 1H), 2.51 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 191.5, 136.0, 135.3, 135.0, 130.4, 130.3, 129.1, 127.4, 121.2, 118.6, 118.0, 113.9, 12.5. **ESI-HRMS**: *m/z* calcd. for $C_{15}H_{12}N_2O$ $[M+H]^+$: 237.1028, found 237.1024.



24

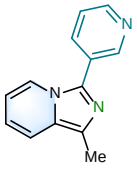
1-methyl-3-(naphthalen-1-yl)imidazo[1,5-*a*]pyridine: Following the **General procedure A**, a mixture of 2-acetylpyridine (0.1 mmol), 1-naphthaldehyde (2.0 equiv.) and chitosan (3.0 equiv.) in CF_3COOH (0.1 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **24** (8.0 mg, 0.031 mmol, isolated yield 31%) as a brown solid. **m.p.**: 90−93 ºC. Following the **General procedure C**, a mixture of 2-acetylpyridines (0.1 mmol), 1-naphthaldehyde (2.0 equiv.) and chitin (3.0 equiv.) in the CF_3COOH (0.1 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitin was dried at 100 ºC oven overnight. Work-up gave product **24** (7.5 mg, 0.029 mmol, isolated yield 29%) as a brown solid.

^{1}H NMR (300 MHz, $CDCl_3$) δ 7.91 – 7.85 (m, 2H), 7.66 – 7.62 (m, 2H), 7.53 – 7.48 (m, 2H), 7.44 (dd, *J* = 7.8, 1.2 Hz, 1H), 7.41 – 7.35 (m, 2H), 6.57 (dd, *J* = 9.0, 6.0 Hz, 1H), 6.35 – 6.30 (m, 1H), 2.57 (s, 3H). **^{13}C NMR** (75 MHz, $CDCl_3$) δ 135.3, 133.9, 131.8, 129.6, 128.8, 128.5, 128.5, 127.5, 127.4, 126.9, 126.2, 125.7, 125.3, 121.6, 118.1, 117.0, 112.3, 12.7. **ESI-HRMS**: m/z calcd. for $C_{18}H_{14}N_2$ $[M+H]^+$: 259.1235, found 259.1233.



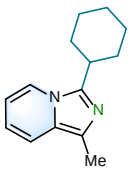
25

1-methyl-3-(thiophen-2-yl)imidazo[1,5-*a*]pyridine: Following the **General procedure A**, a mixture of 2-acetylpyridine (0.1 mmol), thiophene-2-carbaldehyde (2.0 equiv.) and chitosan (3.0 equiv.) in CF_3COOH (0.1 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **25** (5.8 mg, 0.027 mmol, isolated yield 27%) as a brown solid. **m.p.**: 79−81 ºC. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.17 (d, *J* = 6.8 Hz, 1H), 7.42 – 7.40 (m, 1H), 7.35 – 7.30 (m, 2H), 7.09 (dd, *J* = 5.2, 4.0 Hz, 1H), 6.60 – 6.56 (m, 1H), 6.54 – 6.50 (m, 1H), 2.48 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 132.7, 131.3, 129.3, 128.2, 127.6, 125.5, 124.0, 121.5, 118.4, 117.0, 113.5, 12.6. **ESI-HRMS**: *m/z* calcd. for $C_{12}H_{10}N_2S$ $[M+H]^+$: 215.0643, found 215.0641.



26

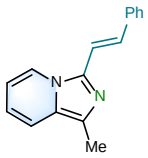
1-methyl-3-(pyridin-3-yl)imidazo[1,5-*a*]pyridine: Following the **General procedure A**, a mixture of 2-acetylpyridine (0.1 mmol), nicotinaldehyde (4.0 equiv.) and chitosan (2.5 equiv.) in CF_3COOH (0.14 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **26** (12.1 mg, 0.058 mmol, isolated yield 58%) as a brown liquid. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.99 (s, 1H), 8.56 (d, *J* = 4.4 Hz, 1H), 8.10 (d, *J* = 7.2 Hz, 1H), 8.05 (d, *J* = 8.0 Hz, 1H), 7.37 (d, *J* = 8.4 Hz, 2H), 6.64 – 6.60 (m, 1H), 6.50 (t, *J* = 6.8 Hz, 1H), 2.51 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 149.0, 148.2, 135.2, 133.3, 129.8, 128.6, 126.8, 123.8, 120.7, 118.5, 117.7, 113.7, 12.5. **ESI-HRMS**: *m/z* calcd. for $C_{13}H_{11}N_3$ $[M+H]^+$: 210.1031, found 210.1027.



27

3-cyclohexyl-1-methylimidazo[1,5-*a*]pyridine: Following the **General procedure A**, a mixture of 2-acetylpyridine (0.1 mmol), cyclohexanecarbaldehyde (2.0 equiv.) and chitosan (3.0 equiv.) in CF_3COOH (0.1 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC

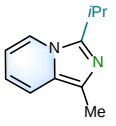
overnight. Work-up gave product **27** (14.8 mg, 0.069 mmol, isolated yield 69%) as a colorless solid. **m.p.**: 92−93 ºC. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.60 (d, *J* = 7.2 Hz, 1H), 7.22 (dd, *J* = 9.2 Hz, 0.8 Hz, 1H), 6.45 (dd, *J* = 9.2, 6.4 Hz, 1H), 6.39 – 6.35 (m, 1H), 2.85 (tt, *J* = 11.9, 3.4 Hz, 1H), 2.42 (s, 3H), 1.92 (d, *J* = 13.2 Hz, 2H), 1.83 (d, *J* = 12.8 Hz, 2H), 1.71 – 1.68 (m, 3H), 1.37 – 1.29 (m, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 141.2, 126.2, 126.1, 120.2, 118.3, 115.9, 111.9, 35.7, 30.8, 26.4, 25.9, 12.2. **ESI-HRMS**: *m/z* calcd. for $C_{14}H_{18}N_2$ $[M+H]^+$: 215.1548, found 215.1544.



28

(*E*)-1-methyl-3-styrylimidazo[1,5-*a*]pyridine: Following the **General procedure A**, a mixture of 2-acetylpyridine (0.1 mmol), cinnamaldehyde (2.0 equiv.) and chitosan (3.0 equiv.) in CF_3COOH (0.14 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **28** (6.6 mg, 0.028 mmol, isolated yield 28%) as a brown solid. **m.p.**: 110−111 ºC. Following the **General procedure C**, a mixture of 2-acetylpyridine (0.1 mmol), cinnamaldehyde (2.0 equiv.) and chitin (3.0 equiv.) in the CF_3COOH (0.1 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitin was dried at 100 ºC overnight. Work-up gave product **28** (4.0 mg, 0.017 mmol, isolated yield 17%) as a brown solid.

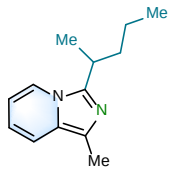
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.88 (d, *J* = 7.2 Hz, 1H), 7.56 (d, *J* = 16.0 Hz, 1H), 7.49 (d, *J* = 7.6 Hz, 2H), 7.31 – 7.28 (m, 3H), 7.21 – 7.18 (m, 2H), 6.58 – 6.49 (m, 2H), 2.49 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 137.1, 129.6, 128.7, 127.8, 126.5, 120.5, 118.5, 117.1, 113.2, 112.0, 12.7. **ESI-HRMS**: *m/z* calcd. for $C_{16}H_{14}N_2$ $[M+H]^+$: 235.1235, found 235.1229.



29

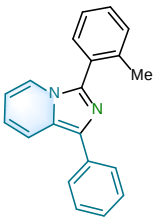
3-isopropyl-1-methylimidazo[1,5-*a*]pyridine: Following the **General procedure A**, a mixture of 2-acetylpyridine (0.1 mmol), isobutyraldehyde (2.0 equiv.) and chitosan (3.0 equiv.) in CF_3COOH (0.1 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **29** (8.7 mg, 0.050 mmol, isolated yield 50%) as a brown solid. **m.p.**: 93−95 ºC.

^{1}H NMR (300 MHz, $CDCl_3$) δ 7.58 (d, *J* = 7.2 Hz, 1H), 7.23 (d, *J* = 9.3 Hz, 1H), 6.46 (dd, *J* = 9.0, 6.3 Hz, 1H), 6.40 – 6.35 (m, 1H), 3.21 (hept, *J* = 6.9 Hz, 1H), 2.43 (s, 3H), 1.36 (d, *J* = 6.9 Hz, 5H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 141.8, 126.4, 120.2, 118.3, 115.6, 111.7, 25.9, 20.5, 12.5. **ESI-HRMS**: *m/z* calcd. for $C_{11}H_{14}N_2$ $[M+H]^+$: 175.1235, found 175.1227.



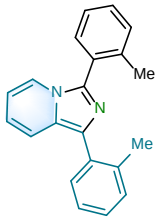
30

1-methyl-3-(pentan-2-yl)imidazo[1,5-*a*]pyridine: Following the **General procedure A**, a mixture of 2-acetylpyridine (0.1 mmol), 2-methylpentanal (2.0 equiv.) and chitosan (3.0 equiv.) in CF_3COOH (0.1 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **30** (10.5 mg, 0.052 mmol, isolated yield 52%) as a brown liquid. **^{1}H NMR** (300 MHz, $CDCl_3$) δ 7.65 (d, *J* = 7.2 Hz, 1H), 7.28 (d, *J* = 9.0 Hz, 1H), 6.50 (dd, *J* = 9.0, 6.3 Hz, 1H), 6.44 – 6.40 (m, 1H), 3.15 (h, *J* = 7.0 Hz, 1H), 2.48 (s, 3H), 1.93 – 1.85 (m, 1H), 1.73 – 1.65 (m, 1H), 1.39 (d, *J* = 6.9 Hz, 3H), 1.23 – 1.13 (m, 2H), 0.89 (t, *J* = 7.2 Hz, 3H). **^{13}C NMR** (75 MHz, $CDCl_3$) δ 141.4, 126.4, 126.1, 120.1, 118.2, 115.6, 111.7, 37.6, 30.9, 20.6, 18.6, 14.0, 12.3. **ESI-HRMS**: *m/z* calcd. for $C_{13}H_{18}N_2$ $[M+H]^+$: 203.1548, found 203.1543.



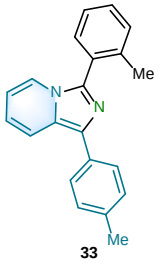
31

1-phenyl-3-(o-tolyl)imidazo[1,5-*a*]pyridine: Following the **General procedure B**, a mixture of phenyl(pyridin-2-yl)methanone (0.1 mmol), 2-methylbenzoaldehyde (4.0 equiv.) and chitosan (2.5 equiv.) in CF_3COOH (0.14 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **31** (20.2 mg, 0.071 mmol, isolated yield 71%) as a yellow liquid. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.88 (d, *J* = 7.6 Hz, 2H), 7.78 (d, *J* = 9.2 Hz, 1H), 7.52 (d, *J* = 6.8 Hz, 1H), 7.42 – 7.36 (m, 3H), 7.32 – 7.28 (m, 2H), 7.26 – 7.16 (m, 2H), 6.72 – 6.68 (m, 1H), 6.45 – 6.41 (m, 1H), 2.17 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 138.5, 137.8, 135.1, 131.1, 130.8, 130.6, 129.5, 129.2, 128.6, 126.6, 126.3, 126.1, 121.9, 119.5, 118.9, 112.8, 19.7. **ESI-HRMS**: *m/z* calcd. for $C_{20}H_{16}N_2$ $[M+H]^+$: 285.1392, found 285.1390.



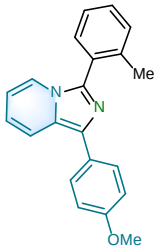
32

1,3-di-o-tolylimidazo[1,5-*a*]pyridine: Following the **General procedure B**, a mixture of pyridin-2-yl(o-tolyl)methanone (0.1 mmol), 2-methylbenzoaldehyde (4.0 equiv.) and chitosan (2.5 equiv.) in CF_3COOH (0.14 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **32** (16.1 mg, 0.054 mmol, isolated yield 54%) as a green solid. **m.p.**: 112−113 ºC. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.62 – 7.60 (m, 1H), 7.45 – 7.39 (m, 3H), 7.31 (d, *J* = 2.8 Hz, 2H), 7.27 – 7.23 (m, 2H), 7.21 – 7.18 (m, 2H), 6.67 – 6.64 (m, 1H), 6.49 – 6.44 (m, 1H), 2.41 (s, 3H), 2.24 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 138.5, 137.3, 130.9, 130.8, 130.3, 130.2, 129.5, 127.4, 126.0, 125.5, 121.5, 118.9, 112.9, 20.7, 19.9. **ESI-HRMS**: *m/z* calcd. for $C_{21}H_{18}N_2$ $[M+H]^+$: 299.1548, found 299.1546.



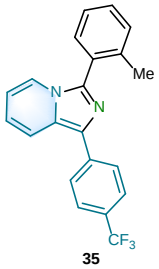
33

3-(o-tolyl)-1-(p-tolyl)imidazo[1,5-*a*]pyridine: Following the **General procedure B**, a mixture of pyridin-2-yl(p-tolyl)methanone (0.1 mmol), 2-methylbenzoaldehyde (4.0 equiv.) and chitosan (2.5 equiv.) in CF_3COOH (0.14 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **33** (20.2 mg, 0.083 mmol, isolated yield 68%) as a yellow liquid. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.79 – 7.75 (m, 3H), 7.52 (d, *J* = 7.2 Hz, 1H), 7.43 (d, *J* = 7.6 Hz, 1H), 7.35 – 7.18 (m, 5H), 6.69 (dd, *J* = 9.3, 6.3 Hz, 1H), 6.45 – 6.42 (m, 1H), 2.33 (s, 3H), 2.18 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 138.5, 137.6, 136.0, 132.2, 131.2, 130.8, 130.6, 129.5, 129.4, 129.3, 126.5, 126.3, 126.1, 121.8, 119.2, 119.1, 112.7, 21.2, 19.8. **ESI-HRMS**: *m/z* calcd. for $C_{21}H_{18}N_2$ $[M+H]^+$: 299.1548, found 299.1544.



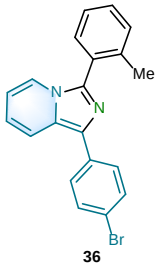
34

1-(4-methoxyphenyl)-3-(o-tolyl)imidazo[1,5-*a*]pyridine: Following the **General procedure B**, a mixture of (4-methoxyphenyl)(pyridin-2-yl)methanone (0.1 mmol), 2-methylbenzoaldehyde (4.0 equiv.) and chitosan (2.5 equiv.) in CF_3COOH (0.14 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **34** (22.9 mg, 0.073 mmol, isolated yield 73%) as a yellow liquid. **^{1}H NMR** (300 MHz, $CDCl_3$) δ 7.81 (d, *J* = 9.0 Hz, 2H), 7.73 (d, *J* = 9.3 Hz, 1H), 7.52 (d, *J* = 7.2 Hz, 1H), 7.43 (d, *J* = 7.2 Hz, 1H), 7.33 – 7.23 (m, 3H), 6.94 (d, *J* = 8.7 Hz, 2H), 6.68 (ddd, *J* = 9.3, 6.3, 0.9 Hz, 1H), 6.45 – 6.41 (m, 1H), 3.79 (s, 3H), 2.19 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 138.5, 137.3, 130.9, 130.8, 130.3, 130.2, 129.5, 127.4, 126.0, 125.5, 121.5, 118.9, 112.9, 20.7, 19.9. **ESI-HRMS**: *m/z* calcd. for $C_{21}H_{18}N_2O$ $[M+H]^+$: 315.1497, found 315.1495.



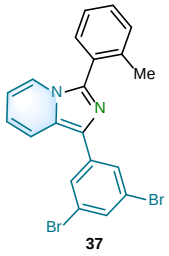
35

3-(o-tolyl)-1-(4-(trifluoromethyl)phenyl)imidazo[1,5-*a*]pyridine: Following the **General procedure B**, a mixture of pyridin-2-yl(4-(trifluoromethyl)phenyl)methanone (0.1 mmol), 2-methylbenzoaldehyde (4.0 equiv.) and chitosan (2.5 equiv.) in CF_3COOH (0.14 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **35** (28.5 mg, 0.081 mmol, isolated yield 81%) as a yellow liquid. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.01 (d, *J* = 8.0 Hz, 2H), 7.81 (d, *J* = 9.2 Hz, 1H), 7.64 – 7.58 (m, 3H), 7.43 (d, *J* = 7.6 Hz, 1H), 7.36 – 7.26 (m, 3H), 6.82 (dd, *J* = 9.2, 6.4 Hz, 1H), 6.54 – 6.50 (m, 1H), 2.19 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 138.7, 138.5, 138.4, 131.2, 130.9, 130.6, 129.8, 129.5, 128.9, 127.9 (q, $^2J_{C\text{-}F}$ = 33.4 Hz), 127.4, 126.3, 126.2, 125.6 (q, $^3J_{C\text{-}F}$ = 3.7 Hz), 124.5 (q, $^1J_{C\text{-}F}$ = 270.1 Hz), 122.3, 120.8, 118.6, 113.1, 19.8. **^{19}F NMR** (377 MHz, $CDCl_3$) δ -62.2. **ESI-HRMS**: *m/z* calcd. for $C_{21}H_{15}F_3N_2$ $[M+H]^+$: 353.1266, found 353.1261.



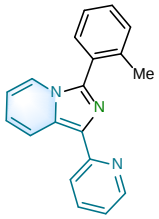
36

1-(4-bromophenyl)-3-(o-tolyl)imidazo[1,5-*a*]pyridine: Following the **General procedure B**, a mixture of (4-bromophenyl)(pyridin-2-yl)methanone (0.1 mmol), 2-methylbenzoaldehyde (4.0 equiv.) and chitosan (2.5 equiv.) in CF_3COOH (0.14 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **36** (27.1 mg, 0.075 mmol, isolated yield 75%) as a yellow solid. **m.p.**: 123−124 ºC. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.78 – 7.73 (m, 3H), 7.55 (d, *J* = 6.8 Hz, 1H), 7.50 (d, *J* = 8.4 Hz, 1H), 7.42 (d, *J* = 7.2 Hz, 1H), 7.34 – 7.26 (m, 3H), 6.78 – 6.74 (m, 1H), 6.50 – 6.47 (m, 1H), 2.18 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 138.5, 138.0, 134.1, 131.7, 130.9, 130.6, 129.8, 129.7, 128.0, 126.7, 126.2, 122.1, 120.1, 120.0, 118.7, 113.0, 19.8. **ESI-HRMS**: *m/z* calcd. for $C_{20}H_{15}BrN_2$ $[M+H]^+$: 363.0497, found 363.0494.



37

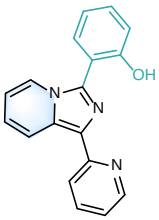
1-(3,5-dibromophenyl)-3-(o-tolyl)imidazo[1,5-*a*]pyridine: Following the **General procedure B**, a mixture of (3,5-dibromophenyl)(pyridin-2-yl)methanone (0.1 mmol), 2-methylbenzoaldehyde (4.0 equiv.) and chitosan (2.5 equiv.) in CF_3COOH (0.14 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **37** (28.2 mg, 0.064 mmol, isolated yield 64%) as a yellow solid. **m.p.**: 138−140 ºC. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.99 – 7.98 (m, 2H), 7.76 (d, *J* = 9.2 Hz, 1H), 7.57 (d, *J* = 7.2 Hz, 1H), 7.47 (dt, *J* = 3.2, 1.7 Hz, 1H), 7.41 (d, *J* = 7.2 Hz, 1H), 7.36 – 7.26 (m, 3H), 6.87 – 6.82 (m, 1H), 6.55 – 6.51 (m, 1H), 2.17 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 138.7, 138.5, 138.4, 131.3, 130.9, 130.6, 129.9, 128.7, 127.9, 127.7, 127.4, 126.2, 123.2, 122.3, 121.1, 118.4, 113.2, 19.7. **ESI-HRMS**: *m/z* calcd. for $C_{20}H_{14}Br_2N_2$ $[M+H]^+$: 440.9602, found 440.9609.



38

1-(pyridin-2-yl)-3-(o-tolyl)imidazo[1,5-*a*]pyridine: Following the **General procedure B**, a mixture of di(pyridin-2-yl)methanone (0.1 mmol), 2-methylbenzoaldehyde (4.0 equiv.) and chitosan (2.5 equiv.) in CF_3COOH (0.14 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **38** (18.5 mg, 0.065 mmol, isolated yield 65%) as a yellow solid. **m.p.**: 90−91 ºC. Following the **General procedure D**, a mixture of di(pyridin-2-yl)methanone (0.1 mmol), 2-methylbenzoaldehyde (4.0 equiv.) and chitin (2.5 equiv.) in CF_3COOH (0.14 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitin was dried at 100 ºC overnight. Work-up gave product **38** (7.4 mg, 0.026 mmol, isolated yield 26%) as a yellow solid.

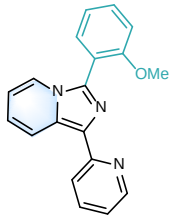
^{1}H NMR (400 MHz, $CDCl_3$) δ 8.73 (d, *J* = 9.2 Hz, 1H), 8.65 (d, *J* = 4.0 Hz, 1H), 8.26 (d, *J* = 8.0 Hz, 1H), 7.71 (t, *J* = 7.6 Hz, 1H), 7.64 (d, *J* = 7.2 Hz, 1H), 7.52 (d, *J* = 7.6 Hz, 1H), 7.44 – 7.33 (m, 3H), 7.11 – 7.08 (m, 1H), 6.94 – 6.90 (m, 1H), 6.59 (t, *J* = 6.8 Hz, 1H), 2.28 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 155.1, 148.9, 138.4, 137.6, 136.1, 130.7, 130.5, 129.8, 129.5, 129.1, 129.0, 126.0, 121.5, 121.5, 120.8, 120.2, 119.7, 113.5, 19.6. **ESI-HRMS**: *m/z* calcd. for $C_{19}H_{15}N_3$ $[M+H]^+$: 286.1344, found 286.1342.



39

2-(1-(pyridin-2-yl)imidazo[1,5-a]pyridin-3-yl)phenol: Following the **General procedure B**, a mixture of di(pyridin-2-yl)methanone (0.1 mmol), 2-hydroxybenzaldehyde (4.0 equiv.) and chitosan (2.5 equiv.) in CF_3COOH (0.14 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **39** (5.2 mg, 0.085 mmol, isolated yield 18%) as a yellow solid. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.73 (d, *J* = 9.2 Hz, 1H), 8.57 (d, *J* = 4.0 Hz, 1H), 8.48 (d, *J* = 7.2 Hz, 1H), 8.05 (d, *J* = 8.0 Hz, 1H), 7.72 (dd, *J* = 7.8, 1.4 Hz, 1H), 7.67 (td, *J* = 7.8, 2.0 Hz, 1H), 7.28 – 7.24 (m, 1H), 7.12 (dd, *J* = 8.2, 1.0 Hz, 1H), 7.06 (ddd, *J* = 7.2, 4.8, 1.2 Hz, 1H), 6.97 – 6.90 (m, 2H), 6.72 – 6.68 (m, 1H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 156.3, 153.9, 149.1, 136.4, 135.5, 130.1,

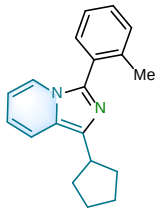
129.6, 128.6, 124.5, 122.3, 122.3, 121.7, 120.9, 119.8, 119.1, 117.8, 114.8, 114.0. The compound is known, and the NMR data is in accordance with the previous literature.[9]



40

3-(2-methoxyphenyl)-1-(pyridin-2-yl)imidazo[1,5-*a*]pyridine: Following the **General procedure B**, a mixture of di(pyridin-2-yl)methanone (0.1 mmol), 2-methoxybenzaldehyde (4.0 equiv.) and chitosan (2.5 equiv.) in CF_3COOH (0.14 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **40** (13.3 mg, 0.044 mmol, isolated yield 44%) as a yellow solid. Following the **General procedure D**, a mixture of di(pyridin-2-yl)methanone (0.1 mmol), 2-methoxybenzaldehyde (4.0 equiv.) and chitin (2.5 equiv.) in CF_3COOH (0.14 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitin was dried at 100 ºC overnight. Work-up gave product **40** (4.8 mg, 0.016 mmol, isolated yield 16%) as a yellow solid.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.62 (d, *J* = 9.2 Hz, 1H), 8.56 – 8.54 (m, 1H), 8.16 (d, *J* = 8.4 Hz, 1H), 7.64 – 7.58 (m, 2H), 7.54 (d, *J* = 7.2 Hz, 1H), 7.44 – 7.40 (m, 1H), 7.08 – 7.05 (m, 1H), 7.01 – 6.97 (m, 2H), 6.86 (dd, *J* = 9.2, 6.4 Hz, 1H), 6.55 – 6.52 (m, 1H), 3.73 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 157.6, 155.3, 148.9, 136.1, 132.8, 131.0, 130.1, 130.0, 123.3, 121.2, 121.2, 120.9, 120.2, 119.9, 119.1, 112.7, 111.2, 55.6. The compound is known, and the NMR data is in accordance with the previous literature.[10]

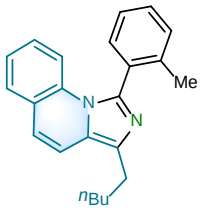


41

1-cyclopentyl-3-(o-tolyl)imidazo[1,5-*a*]pyridine: Following the **General procedure B**, a mixture of cyclopentyl(pyridin-2-yl)methanone (0.1 mmol), 2-methylbenzoaldehyde (4.0 equiv.) and chitosan (2.5 equiv.) in CF_3COOH (0.14 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **41** (25.36 mg, 0.092 mmol, isolated yield 92%) as a brown solid. **m.p.**: 72−73 ºC. Following the **General procedure D**, a mixture of cyclopentyl(pyridin-2-yl)methanone (0.1 mmol), 2-methylbenzoaldehyde (4.0 equiv.) and chitin (2.5 equiv.) in CF_3COOH

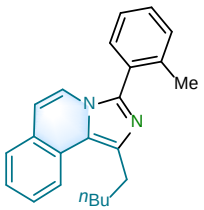
(0.14 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitin was dried at 100 ºC overnight. Work-up gave product **41** (24.6 mg, 0.089 mmol, isolated yield 89%) as a brown solid.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.42 (d, *J* = 7.2 Hz, 1H), 7.37 (d, *J* = 9.2 Hz, 1H), 7.32 (d, *J* = 7.2 Hz, 1H), 7.26 – 7.23 (m, 2H), 7.20 – 7.16 (m, 1H), 6.49 (ddd, *J* = 9.2, 6.3, 0.8 Hz, 1H), 6.34 – 6.30 (m, 1H), 3.37 – 3.28 (m, 1H), 2.10 (s, 3H), 2.04 – 1.99 (m, 2H), 1.91 – 1.87 (m, 2H), 1.81 – 1.78 (m, 2H), 1.64 – 1.60 (m, 2H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 138.4, 136.1, 135.9, 130.7, 130.4, 129.5, 129.2, 125.9, 125.8, 121.2, 118.2, 116.5, 112.3, 38.3, 33.4, 25.7, 19.6. **ESI-HRMS**: *m/z* calcd. for $C_{19}H_{20}N_2$ $[M+H]^+$: 277.1705, found 277.1703.



42

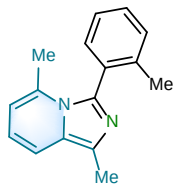
3-pentyl-1-(o-tolyl)imidazo[1,5-a]quinoline: Following the **General procedure B**, a mixture of 1-(quinolin-2-yl)hexan-1-one (0.1 mmol), 2-methylbenzoaldehyde (4.0 equiv.) and chitosan (2.5 equiv.) in CF_3COOH (0.14 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **42** (13.12 mg, 0.04 mmol, isolated yield 40%) as a red liquid. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.49 (d, *J* = 7.6 Hz, 1H), 7.40 – 7.35 (m, 2H), 7.28 – 7.21 (m, 3H), 7.18 – 7.15 (m, 1H), 7.09 (d, *J* = 8.4 Hz, 1H), 7.04 – 6.99 (m, 1H), 6.83 (d, *J* = 9.6 Hz, 1H), 2.82 (t, *J* = 7.6 Hz, 2H), 1.96 (s, 3H), 1.80 – 1.70 (m, 3H), 1.32 – 1.27 (m, 4H), 0.82 (t, *J* = 6.8 Hz, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$)δ 140.1, 138.4, 134.9, 134.0, 132.8, 130.5, 130.3, 129.6, 128.3, 127.6, 126.3, 125.7, 125.5, 124.8, 119.3, 116.8, 115.8, 31.7, 29.9, 27.2, 22.5, 19.6, 14.1. **ESI-HRMS**: *m/z* calcd. for $C_{23}H_{24}N_2$ $[M+H]^+$: 329.2018, found 329.2011.



43

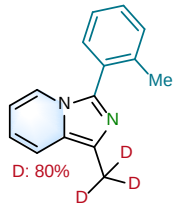
1-pentyl-3-(o-tolyl)imidazo[5,1-a]isoquinoline: Following the **General procedure B**, a mixture of 1-(isoquinolin-1-yl)hexan-1-one (0.1 mmol), 2-methylbenzoaldehyde (4.0 equiv.) and chitosan (2.5 equiv.) in CF_3COOH (0.14 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **43** (18.70 mg, 0.06 mmol, isolated yield 57%) as a

brown liquid. **^{1}H NMR** (400 MHz, $CDCl_3$)δ 8.03 (d, *J* = 8.4 Hz, 1H), 7.48 – 7.45 (m, 2H), 7.36 (d, *J* = 6.4 Hz, 1H), 7.33 – 7.21 (m, 5H), 6.56 (d, *J* = 7.6 Hz, 1H), 3.21 (t, *J* = 8.0 Hz, 2H), 2.14 (s, 3H), 1.87 – 1.79 (m, 2H), 1.47 – 1.30 (m, 4H), 0.85 (t, *J* = 7.2 Hz, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 138.5, 135.9, 130.7, 130.6, 129.5, 129.4, 128.2, 127.4, 127.0, 126.5, 125.9, 125.7, 122.6, 122.2, 120.8, 113.3, 32.0, 30.3, 28.8, 22.6, 19.7, 14.1. **ESI-HRMS**: *m/z* calcd. for $C_{23}H_{24}N_2$ $[M+H]^+$: 329.2018, found 329.2015.



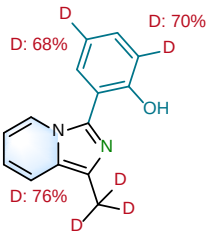
44

1,5-dimethyl-3-(o-tolyl)imidazo[1,5-a]pyridine: Following the **General procedure B**, a mixture of 1-(6-methylpyridin-2-yl)ethan-1-one (0.1 mmol), 2-methylbenzoaldehyde (4.0 equiv.) and chitosan (2.5 equiv.) in CF_3COOH (0.14 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **44** (20.77 mg, 0.088 mmol, isolated yield 44%) as a brown liquid. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.32 – 7.22 (m, 3H), 7.15 – 7.11 (m, 2H), 6.48 (dd, J = 9.2, 6.4 Hz, 1H), 6.11 (d, J = 6.4 Hz, 1H), 2.49 (s, 3H), 1.97 (s, 3H), 1.88 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$)δ 139.2, 136.3, 133.5, 132.4, 131.5, 129.3, 129.1, 128.2, 127.1, 124.7, 117.1, 116.2, 113.1, 20.4, 19.9, 12.5. **ESI-HRMS**: *m/z* calcd. for $C_{16}H_{16}N_2$ $[M+H]^+$: 237.1392, found 237.1390.



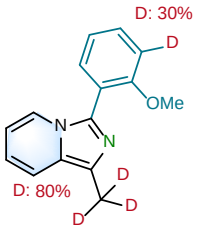
46

1-(methyl-d$_3$)-3-(o-tolyl)imidazo[1,5-*a*]pyridine: Following the **General procedure E**, a mixture of 2-acetylpyridine (0.1 mmol), 2-methylbenzaldehyde (2.0 equiv.) and chitosan (3.0 equiv.) in CF_3COOD (0.1 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **46** (16.4 mg, 0.073 mmol, isolated yield 73%) as a yellow solid. **m.p.** 62−64 ºC. D incorporation by ^{1}H NMR: 80%. **^{1}H NMR** (300 MHz, $CDCl_3$) δ 7.43 (d, *J* = 7.2 Hz, 1H), 7.37 – 7.19 (m, 5H), 6.53 (dd, *J* = 9.1, 6.3 Hz, 1H), 6.37 – 6.32 (m, 1H), 2.48 (s, 0.59H), 2.13 (s, 3H). **ESI-HRMS**: m/z calcd. for $C_{15}H_{11}D_3N_2$ $[M+H]^+$: 226.1424, found 226.1420.



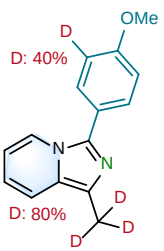
47

2-(1-(methyl-d_3)imidazo[1,5-*a*]pyridin-3-yl)phen-4,6-d_2-ol: Following the **General procedure E**, a mixture of 2-acetylpyridine (0.1 mmol), 2-hydroxybenzaldehyde (2.0 equiv.) and chitosan (3.0 equiv.) in CF_3COOD (0.1 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **47** (6.9 mg, 0.030 mmol, isolated yield 30%) as a white solid. **m.p.** 130−132 ºC. D incorporation by ^{1}H NMR: 76%, 70% and 68%. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.35 (dd, *J* = 7.0, 3.6 Hz, 1H), 7.67 – 7.65 (m, 1H), 7.38 – 7.34 (m, 1H), 7.19 (d, *J* = 4.4 Hz, 1H), 7.07 (dd, *J* = 8.0, 4.0 Hz, 0.32H), 6.93 – 6.88 (m, 0.30H), 6.65 – 6.60 (m, 1H), 6.56 – 6.51 (m, 1H), 2.46 (s, 0.73H). **ESI-HRMS**: m/z calcd. for $C_{14}H_7D_5N_2O$ $[M+H]^+$: 230.1342, found 230.1330.



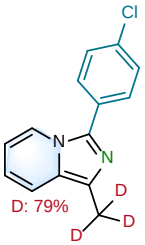
48

3-(2-3-(2-methoxyphenyl-3-d)-1-(methyl-d_3)imidazo[1,5-*a*]pyridine: Following the **General procedure E**, a mixture of 2-acetylpyridine (0.1 mmol), 2-methoxybenzaldehyde (2.0 equiv.) and chitosan (3.0 equiv.) in CF_3COOD (0.1 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **48** (14.7 mg, 0.061 mmol, isolated yield 61%) as a yellow solid; **m.p.** 44−46 ºC. D incorporation by ^{1}H NMR: 80% and 30%. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.53 (dd, *J* = 4.0, 1.6 Hz, 1H), 7.45 – 7.43 (m, 1H), 7.37 – 7.31 (m, 2H), 7.04 – 7.00 (m, 0.70H), 6.96 (dd, *J* = 8.4, 4.4 Hz, 1H), 6.57 – 6.53 (m, 1H), 6.40 – 6.35 (m, 1H), 3.73 (s, 3H), 2.49 (s, 0.59H). **ESI-HRMS**: m/z calcd. for $C_{15}H_{10}D_4N_2O$ $[M+H]^+$: 243.1435, found 243.1422.



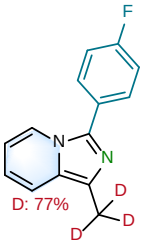
49

3-(4-methoxyphenyl-3-d)-1-(methyl-d_3)imidazo[1,5-*a*]pyridine: Following the **General procedure E**, a mixture of 2-acetylpyridine (0.1 mmol), 4-methoxybenzaldehyde (2.0 equiv.) and chitosan (3.0 equiv.) in CF_3COOD (0.1 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **49** (15.2 mg, 0.063 mmol, isolated yield 63%) as a yellow solid. D incorporation by ^{1}H NMR: 80% and 40%. **m.p.** 43−45 ºC. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.02 (d, *J* = 7.6 Hz, 1H), 7.62 (d, *J* = 8.8 Hz, 2H), 7.29 (d, *J* = 9.2 Hz, 1H), 6.96 (d, *J* = 9.2 Hz, 1.59H), 6.51 (ddd, *J* = 9.2, 6.4, 0.8 Hz, 1H), 6.38 (ddd, *J* = 7.6, 6.4, 1.2 Hz, 1H), 3.80 (s, 3H), 2.46 (s, 0.60H). **ESI-HRMS**: m/z calcd. for $C_{15}H_{10}D_4N_2O$ $[M+H]^+$: 243.1435, found 243.1422.



50

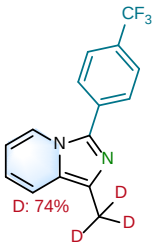
3-(4-chlorophenyl)-1-(methyl-d_3)imidazo[1,5-*a*]pyridine: Following the **General procedure E**, a mixture of 2-acetylpyridine (0.1 mmol), 4-chlorobenzaldehyde (2.0 equiv.) and chitosan (3.0 equiv.) in CF_3COOD (0.1 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **50** (18.6 mg, 0.076 mmol, isolated yield 76%) as a yellow solid. D incorporation by ^{1}H NMR: 79%. **m.p.** 84−86 ºC. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.04 (d, *J* = 7.2 Hz, 1H), 7.65 (d, *J* = 8.4 Hz, 2H), 7.40 (d, *J* = 8.4 Hz, 2H), 7.34 (d, *J* = 9.2 Hz, 1H), 6.60 (dd, *J* = 9.2, 6.4 Hz, 1H), 6.50 – 6.46 (m, 1H), 2.47 (s, 0.62H). **ESI-HRMS**: m/z calcd. for $C_{14}H_8D_3N_2Cl$ $[M+H]^+$: 246.0877, found 246.0873.



51

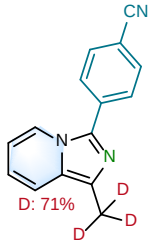
3-(4-fluorophenyl)-1-(methyl-d_3)imidazo[1,5-*a*]pyridine: Following the **General procedure E**, a mixture of 2-acetylpyridine (0.1 mmol), 4-fluorobenzaldehyde (2.0 equiv.) and chitosan (3.0 equiv.) in CF_3COOD (0.1 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **51** (16.9 mg, 0.074 mmol, isolated yield 74%) as a yellow solid. D incorporation by ^{1}H NMR: 77%. **m.p.** 93−95 ºC. **^{1}H NMR** (300 MHz, $CDCl_3$) δ 8.01 (d, *J* = 7.2 Hz,

1H), 7.67 (dd, *J* = 8.4, 5.4 Hz, 2H), 7.31 (d, *J* = 9.0 Hz, 1H), 7.14 – 7.09 (m, 2H), 6.54 (dd, *J* = 9.0, 6.3 Hz, 1H), 6.44 – 6.40 (m, 1H), 2.46 (s, 0.68H). **ESI-HRMS**: m/z calcd. for $C_{14}H_8D_3N_2F$ $[M+H]^+$: 230.1173, found 230.1168.



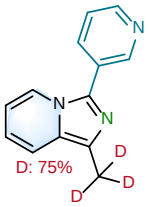
52

1-(methyl-d_3)-3-(4-(trifluoromethyl)phenyl)imidazo[1,5-*a*]pyridine: Following the **General procedure E**, a mixture of 2-acetylpyridine (0.1 mmol), 4-trifluoromethylbenzaldehyde (2.0 equiv.) and chitosan (3.0 equiv.) in CF_3COOD (0.1 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **52** (18.1 mg, 0.065 mmol, isolated yield 65%) as a yellow solid. D incorporation by ^{1}H NMR: 74%. **m.p.** 69−71 ºC. **^{1}H NMR** (300 MHz, $CDCl_3$) δ 8.12 (d, *J* = 7.2 Hz, 1H), 7.84 (d, *J* = 8.1 Hz, 2H), 7.66 (d, *J* = 8.1 Hz, 2H), 7.35 (d, *J* = 9.3 Hz, 1H), 6.63 – 6.58 (m, 1H), 6.51 – 6.46 (m, 1H), 2.47 (s, 0.77H). **ESI-HRMS**: m/z calcd. for $C_{15}H_8D_3F_3N_2$ $[M+H]^+$: 280.1141, found 280.1137.



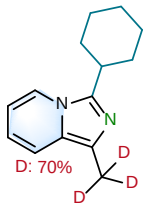
53

4-(1-methylimidazo[1,5-*a*]pyridin-3-yl)benzonitrile: Following the **General procedure E**, a mixture of 2-acetylpyridine (0.1 mmol), 4-formylbenzonitrile (2.0 equiv.) and chitosan (3.0 equiv.) in CF_3COOD (0.1 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **53** (7.8 mg, 0.033 mmol, isolated yield 33%) as a yellow solid. D incorporation by ^{1}H NMR: 71%. **m.p.** 120−122 ºC. **^{1}H NMR** (300 MHz, $CDCl_3$) δ 8.16 (d, *J* = 7.5 Hz, 1H), 7.85 (q, *J* = 8.4 Hz, 4H), 7.36 (d, *J* = 9.9 Hz, 1H), 6.64 – 6.59 (m, 1H), 6.52 – 6.48 (m, 1H), 2.48 (s, 0.86H). **ESI-HRMS**: m/z calcd. for $C_{15}H_8D_3N_3$ $[M+H]^+$: 237.1220, found 237.1219.



54

1-(methyl-d$_3$)-3-(pyridin-3-yl)imidazo[1,5-*a*]pyridine: Following the **General procedure E**, a mixture of 2-acetylpyridine (0.1 mmol), nicotinaldehyde (2.0 equiv.) and chitosan (3.0 equiv.) in CF_3COOD (0.1 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **54** (12.72 mg, 0.060 mmol, isolated yield 60%) as a yellow solid. D incorporation by ^{1}H NMR: 75%. **m.p.** 45−47 ºC. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.97 (s, 1H), 8.56 – 8.54 (m, 1H), 8.08 (d, *J* = 7.2 Hz, 1H), 8.03 (d, *J* = 8.0 Hz, 1H), 7.35 (dd, *J* = 7.6, 1.2 Hz, 2H), 6.63 – 6.59 (m, 1H), 6.51 – 6.47 (m, 1H), 2.47 (s, 0.75H). **ESI-HRMS**: m/z calcd. for $C_{13}H_8D_3N_3$ $[M+H]^+$: 213.1220, found 213.1213.



55

3-cyclohexyl-1-(methyl-d$_3$)imidazo[1,5-*a*]pyridine: Following the **General procedure E**, a mixture of 2-acetylpyridine (0.1 mmol), cyclohexanecarbaldehyde (2.0 equiv.) and chitosan (3.0 equiv.) in CF_3COOD (0.1 M) was stirred at 140 ºC under Ar atmosphere for 36 h. Chitosan was dried at 100 ºC overnight. Work-up gave product **55** (13.9 mg, 0.064 mmol, isolated yield 64%) as a white solid. D incorporation by ^{1}H NMR: 70%. **m.p.** 74−76 ºC. **^{1}H NMR** (300 MHz, $CDCl_3$) δ 7.58 (d, *J* = 7.2 Hz, 1H), 7.21 (d, *J* = 8.4 Hz, 1H), 6.45 – 6.32 (m, 2H), 2.39 (s, 0.90H), 1.94 – 1.64 (m, 8H), 1.37 – 1.31 (m, 3H). **ESI-HRMS**: m/z calcd. for $C_{14}H_{15}D_3N_2$ $[M+H]^+$: 218.1737, found 218.1736.

9. Reference

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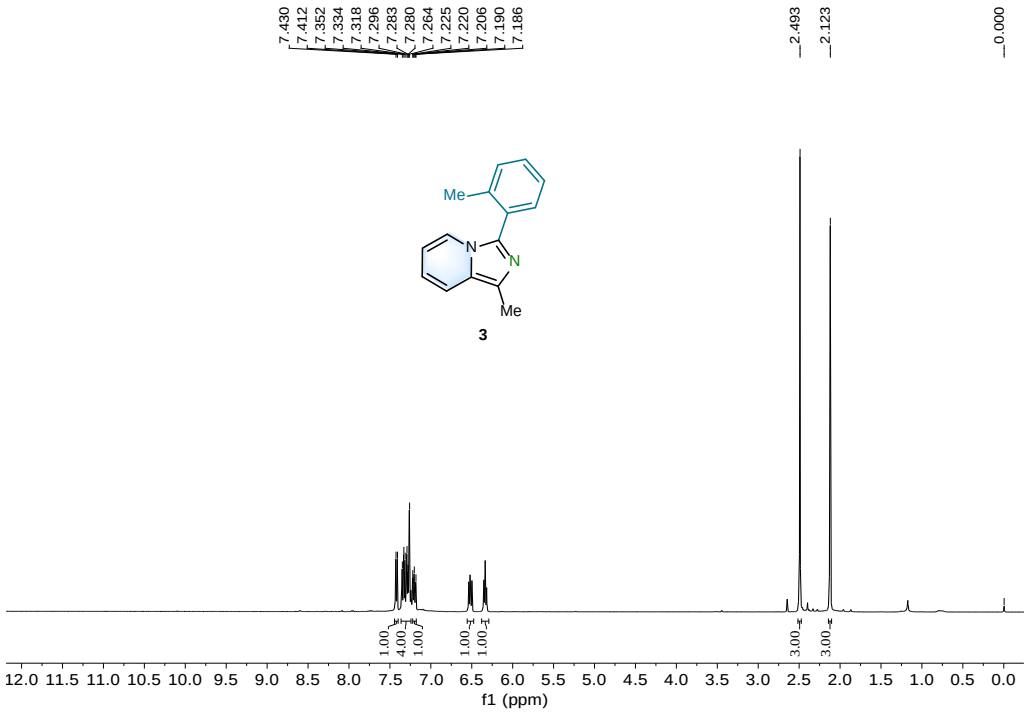
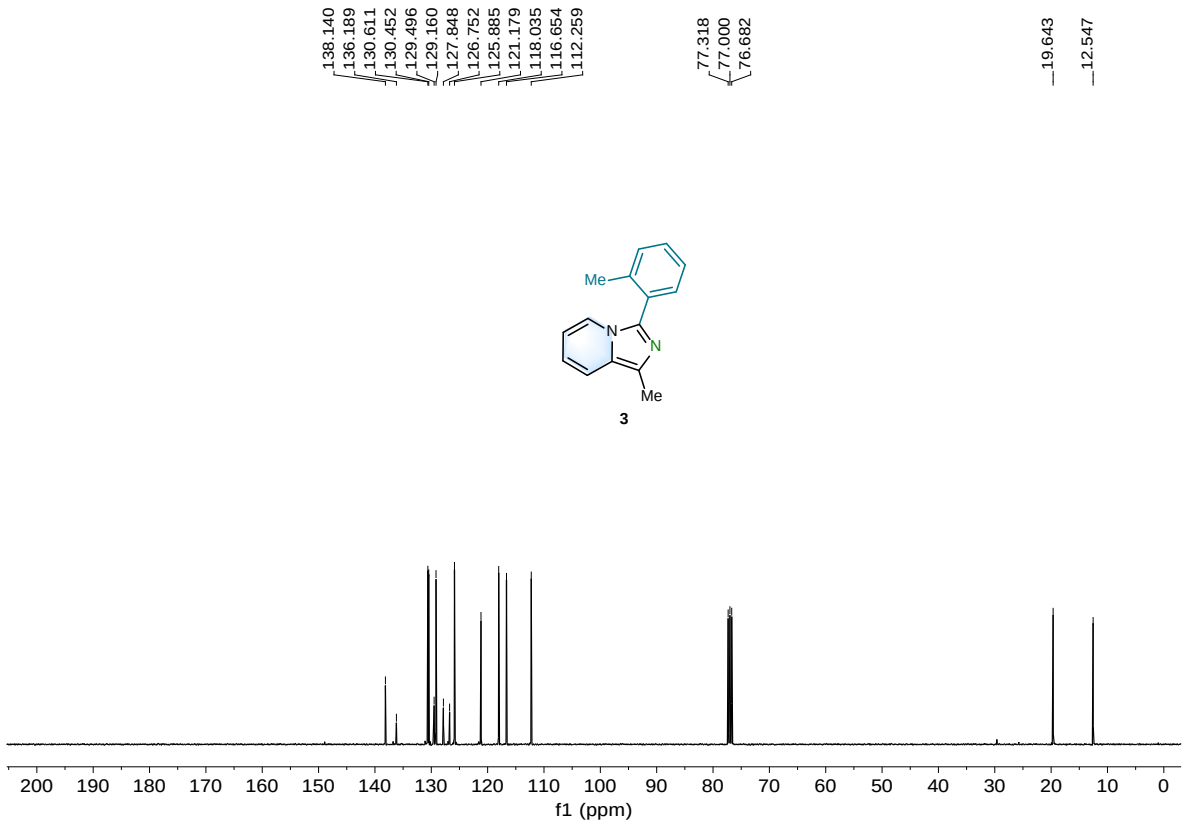
10. NMR spectra of compounds

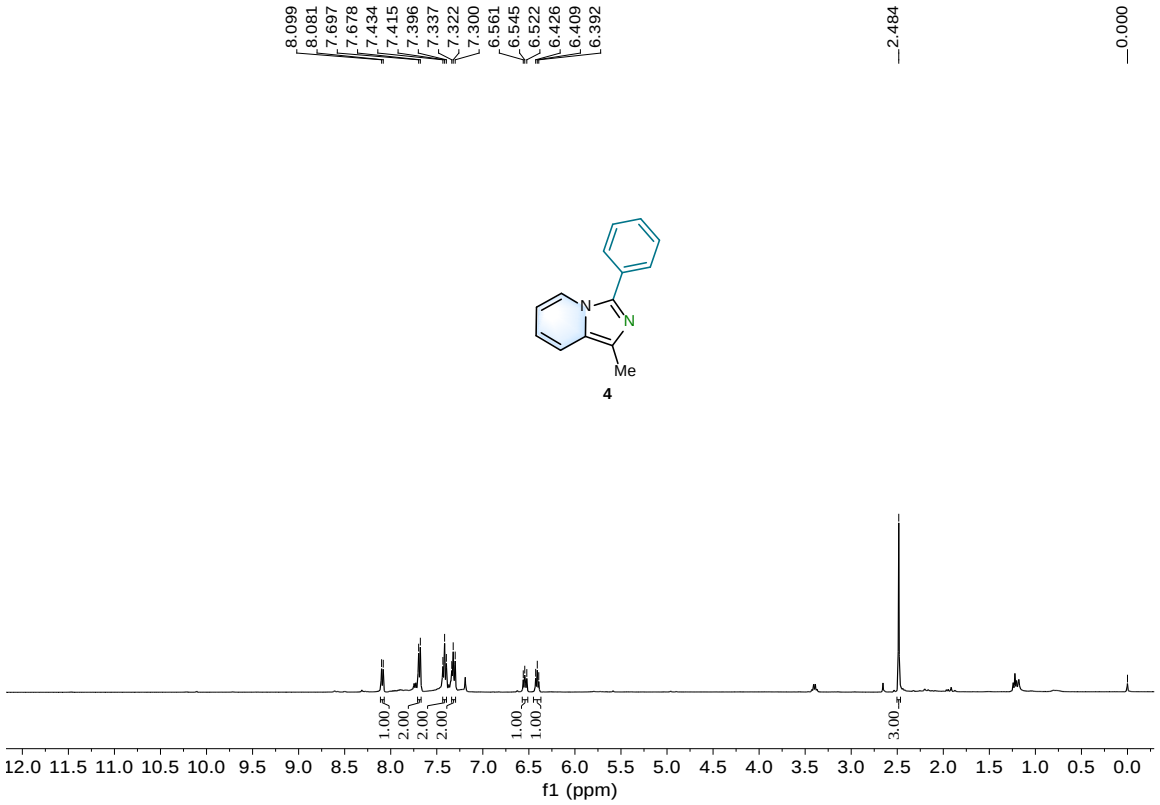
^{1}H NMR spectrum of **3** (300 MHz, $CDCl_3$)



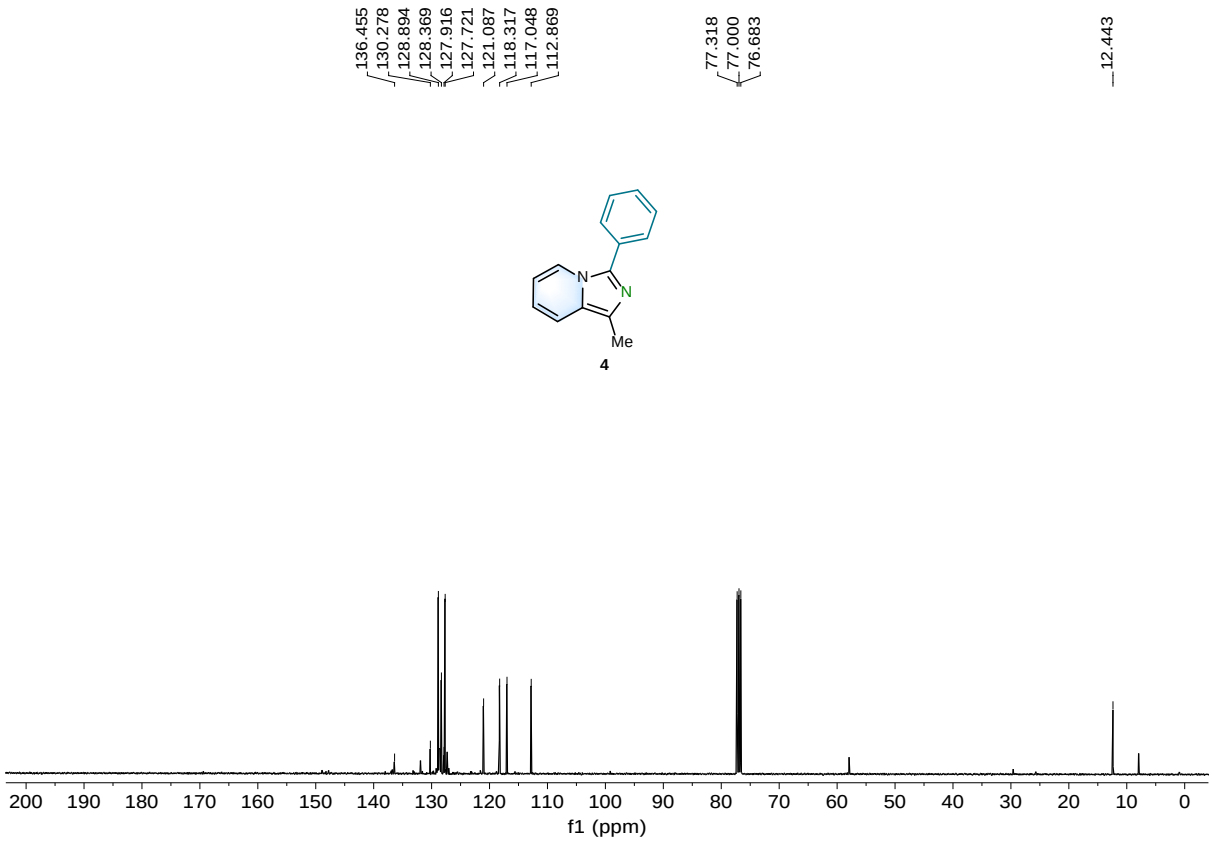
^{13}C NMR spectrum of **3** (100 MHz, $CDCl_3$)



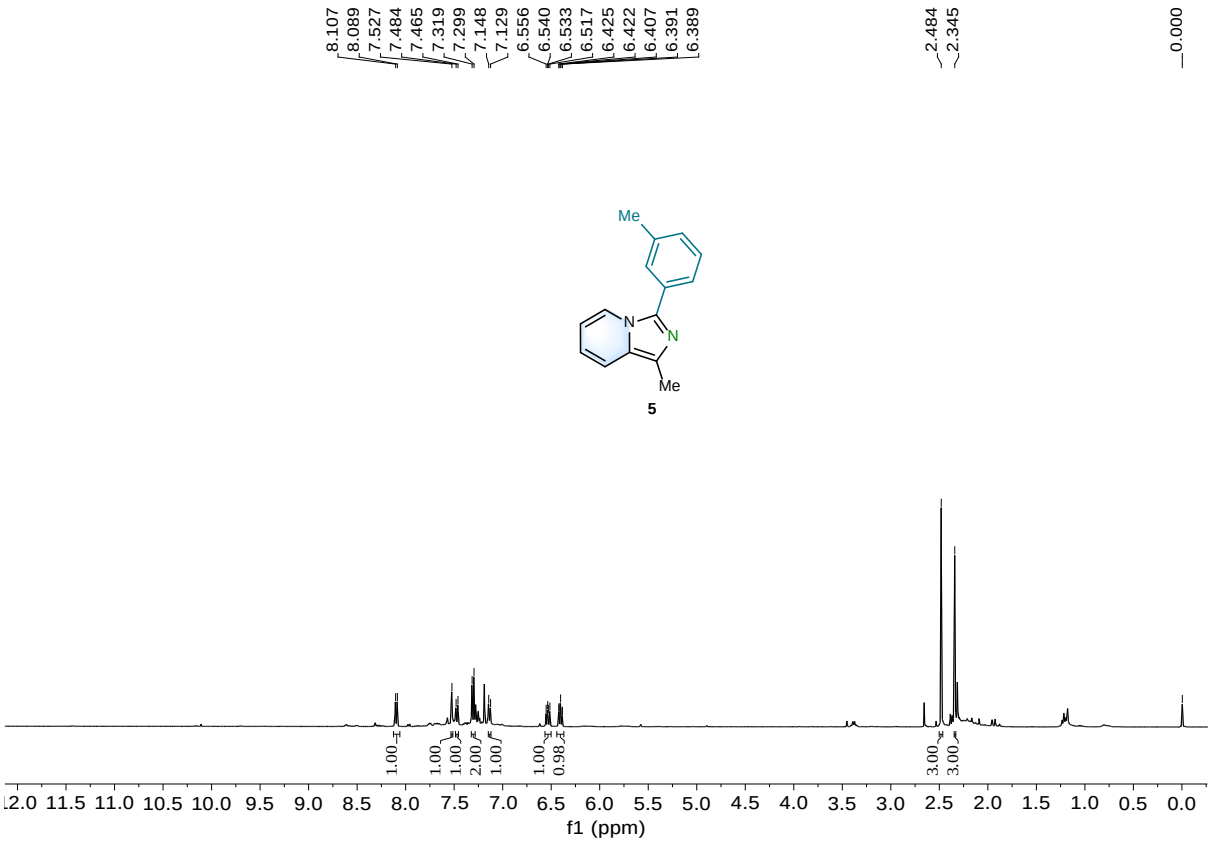
^{1}H NMR spectrum of **4** (400 MHz, $CDCl_3$)



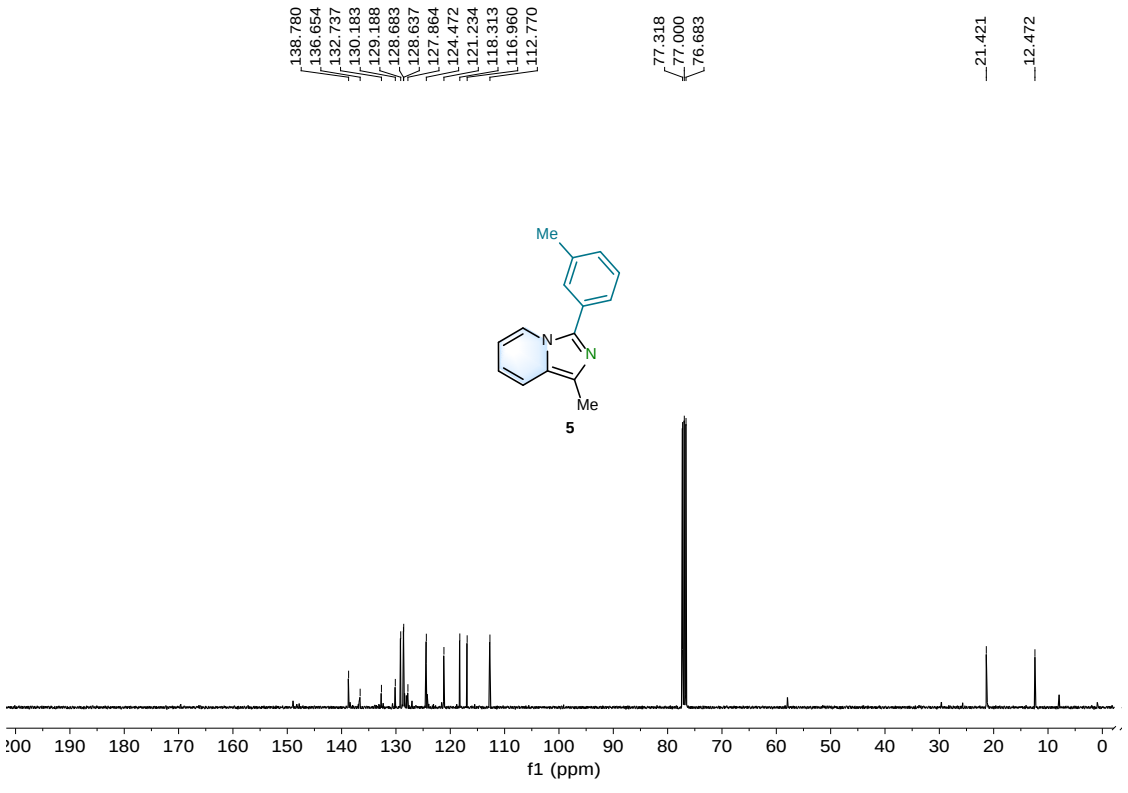
^{13}C NMR spectrum of **4** (100 MHz, $CDCl_3$)



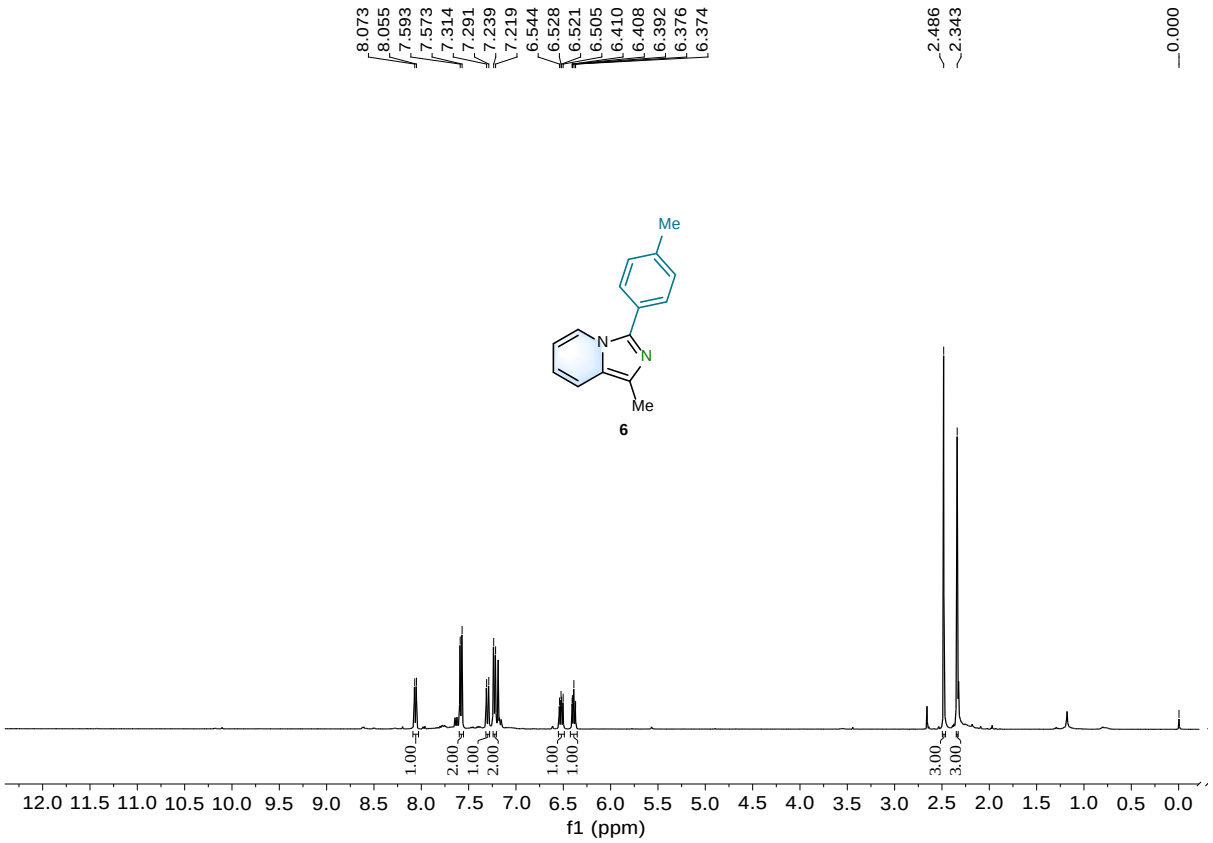
^{1}H NMR spectrum of **5** (400 MHz, $CDCl_3$)



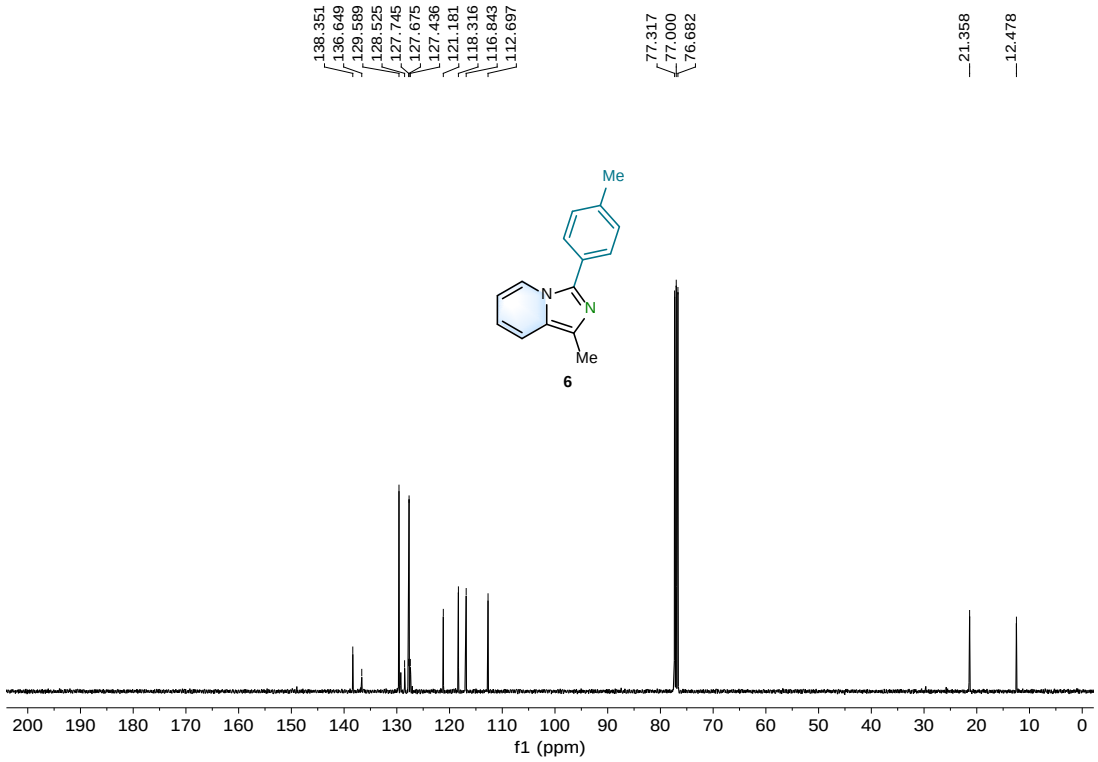
^{13}C NMR spectrum of **5** (100 MHz, $CDCl_3$)



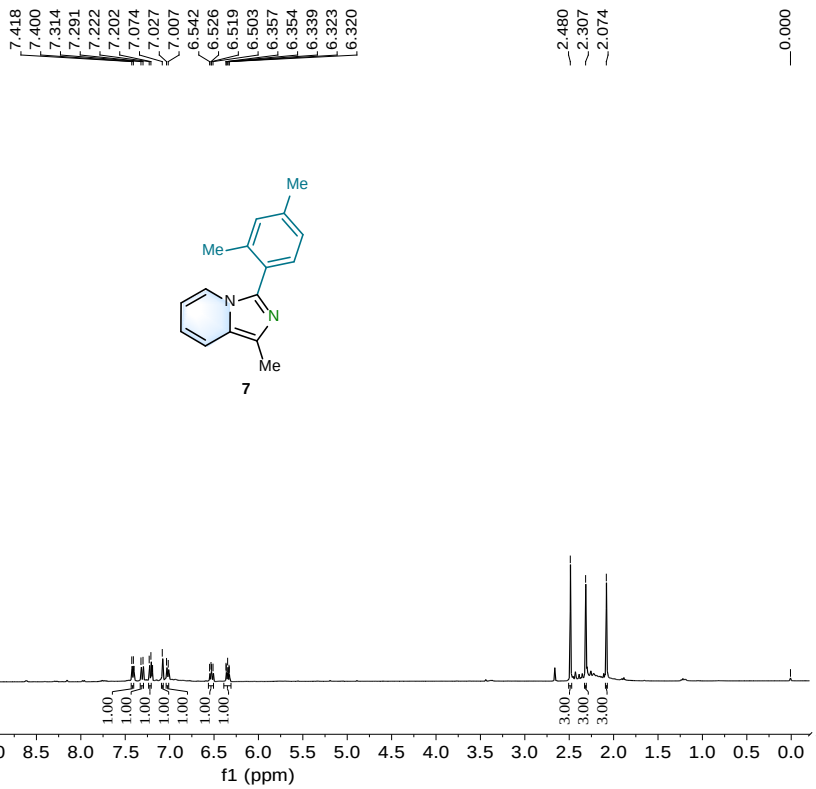
^{1}H NMR spectrum of **6** (400 MHz, $CDCl_3$)



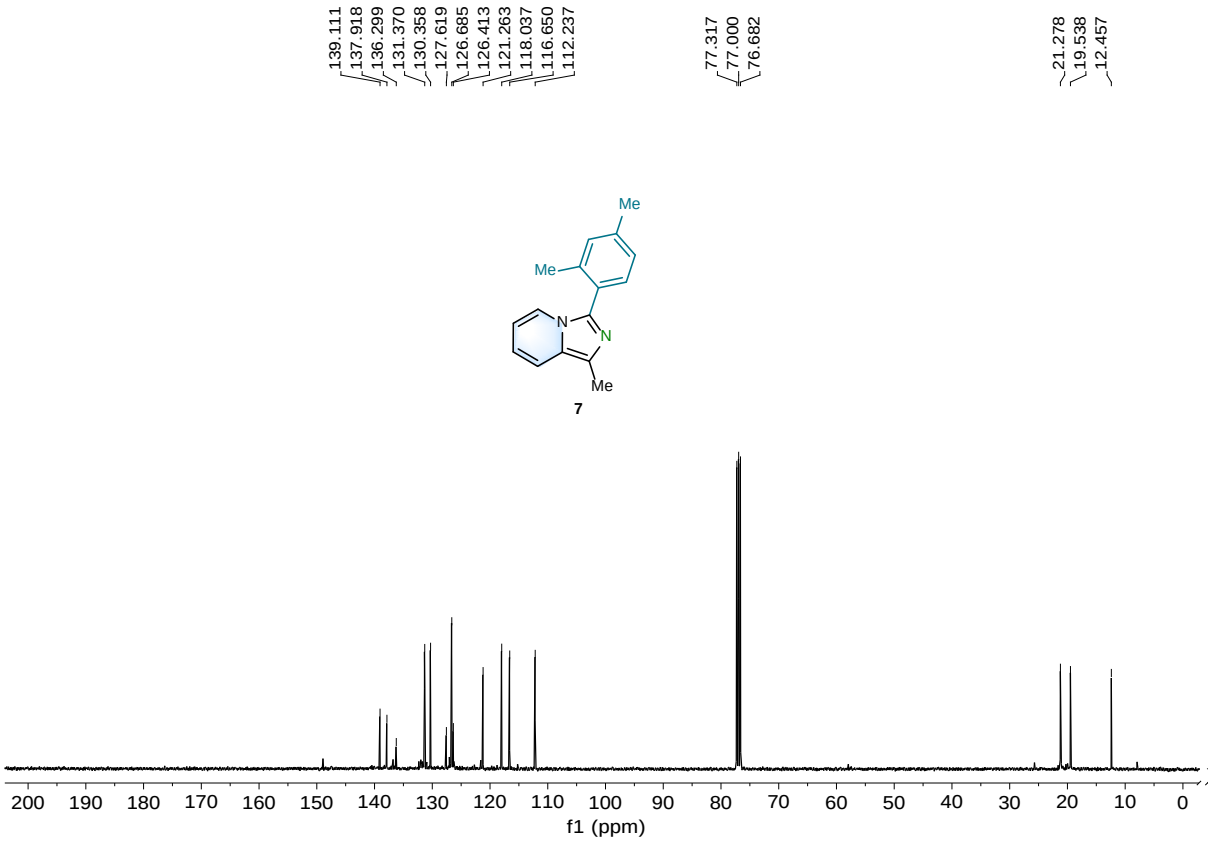
^{13}C NMR spectrum of **6** (100 MHz, $CDCl_3$)



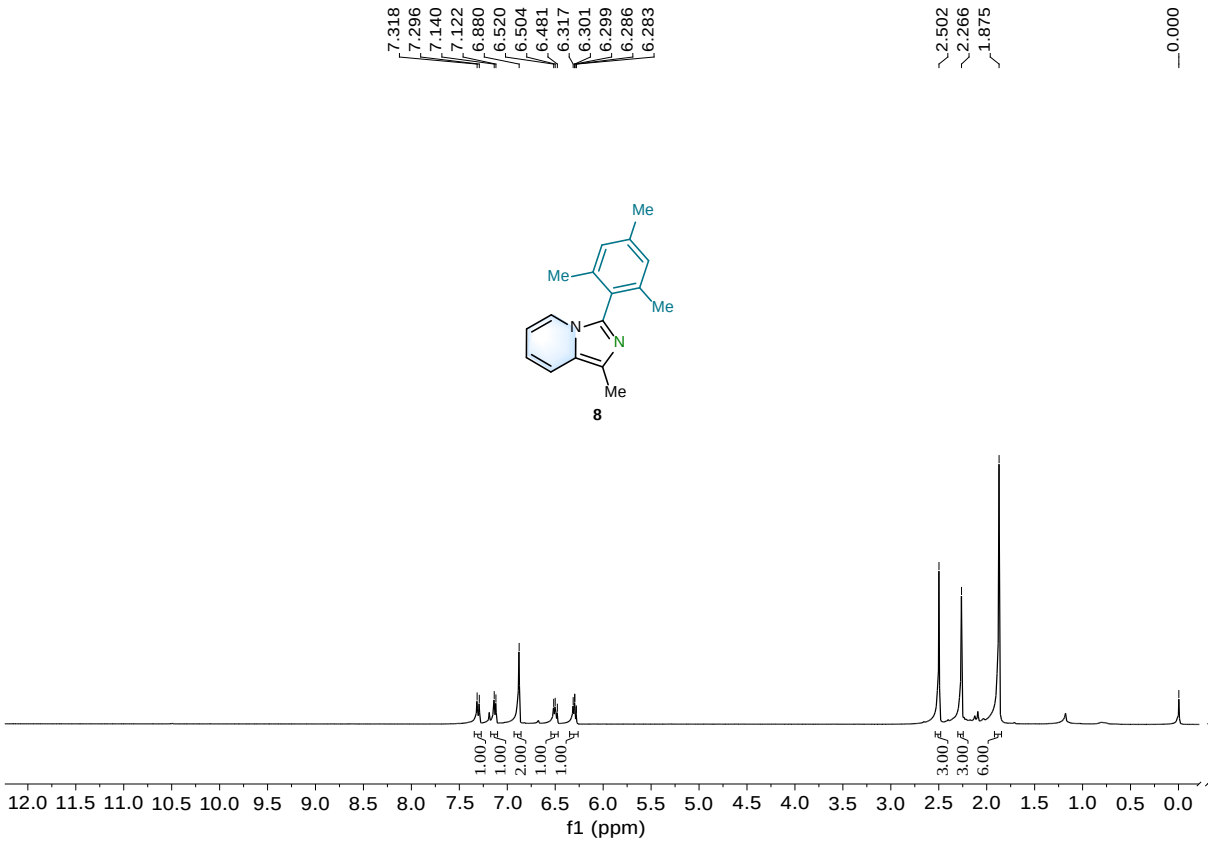
^{1}H NMR spectrum of **7** (400 MHz, $CDCl_3$)



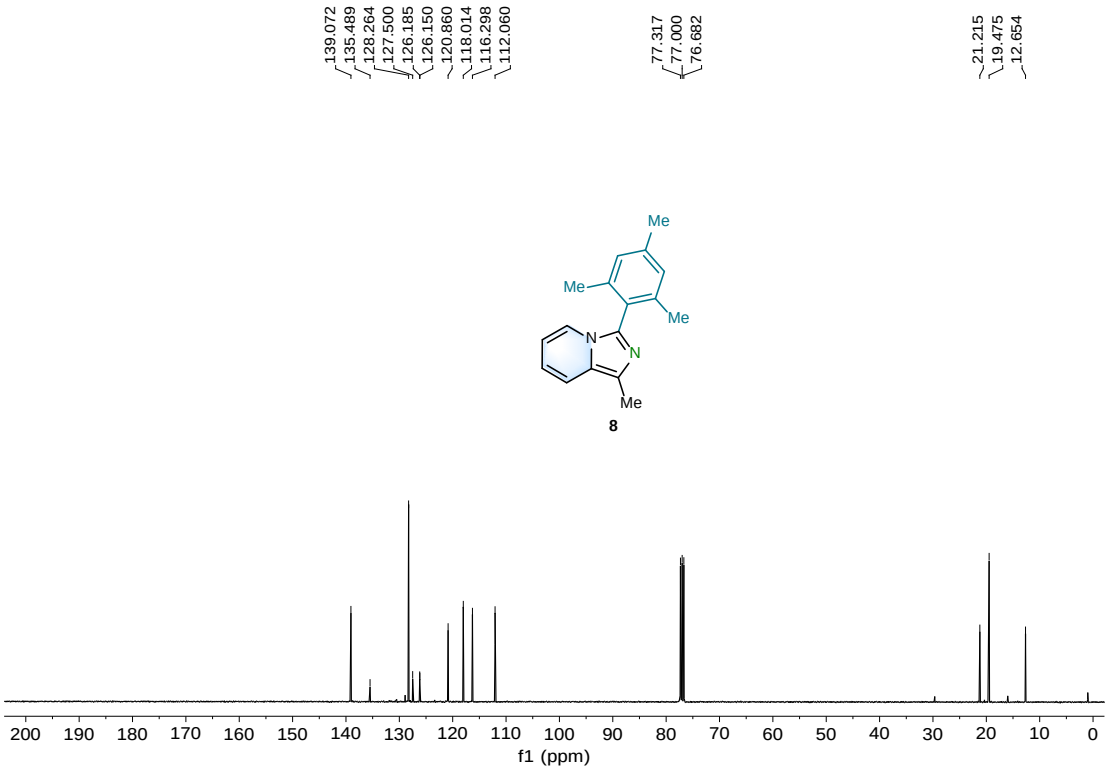
^{13}C NMR spectrum of **7** (100 MHz, $CDCl_3$)



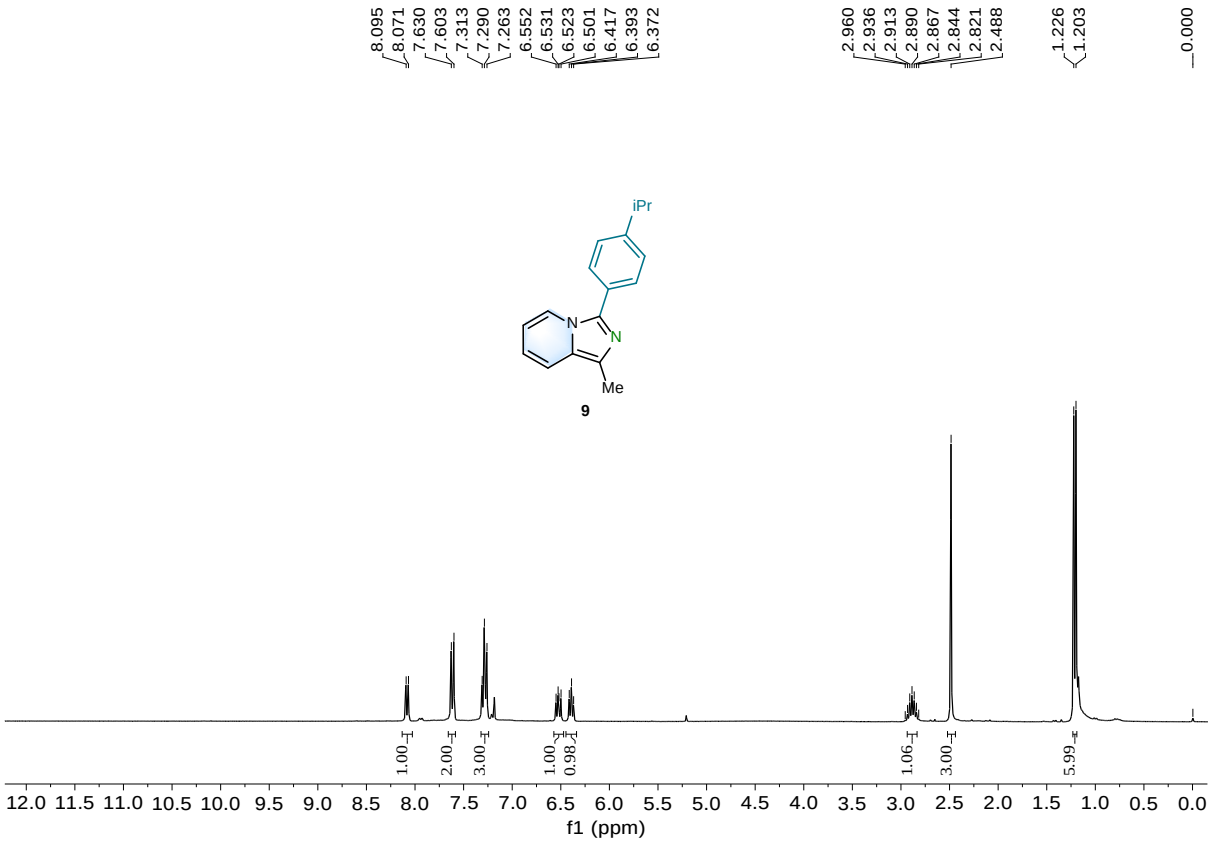
^{1}H NMR spectrum of **8** (400 MHz, $CDCl_3$)



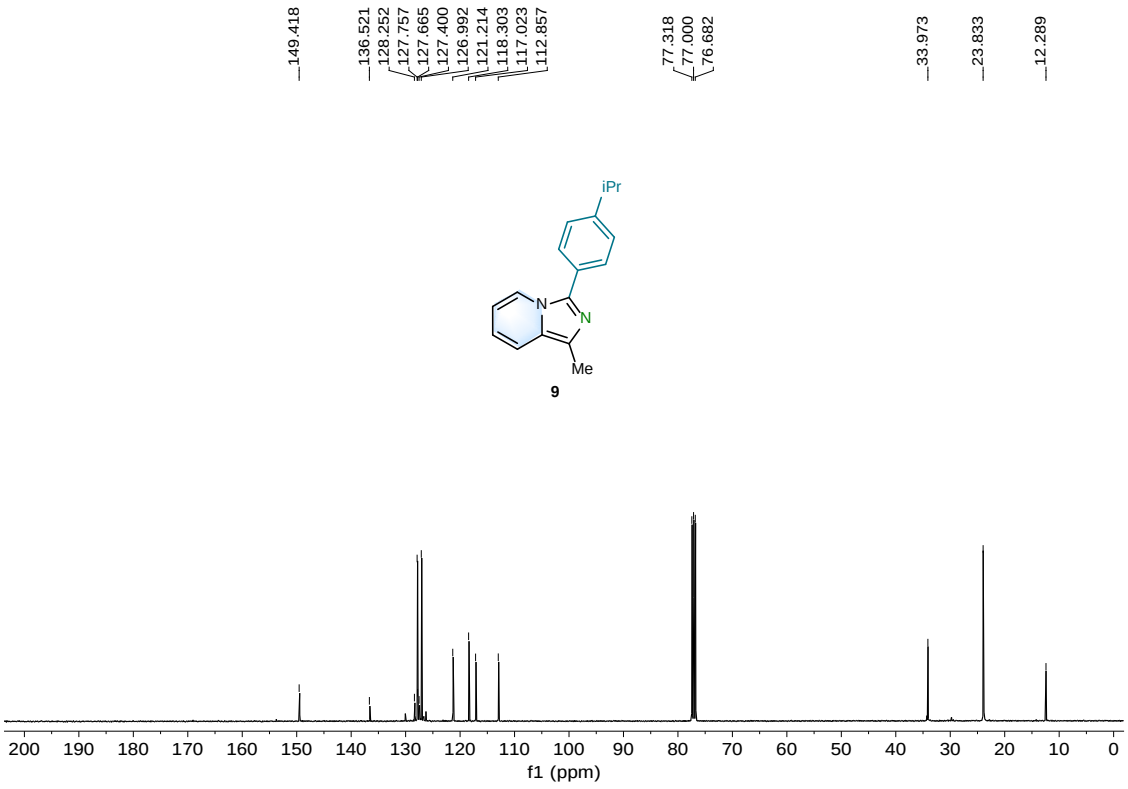
^{13}C NMR spectrum of **8** (100 MHz, $CDCl_3$)



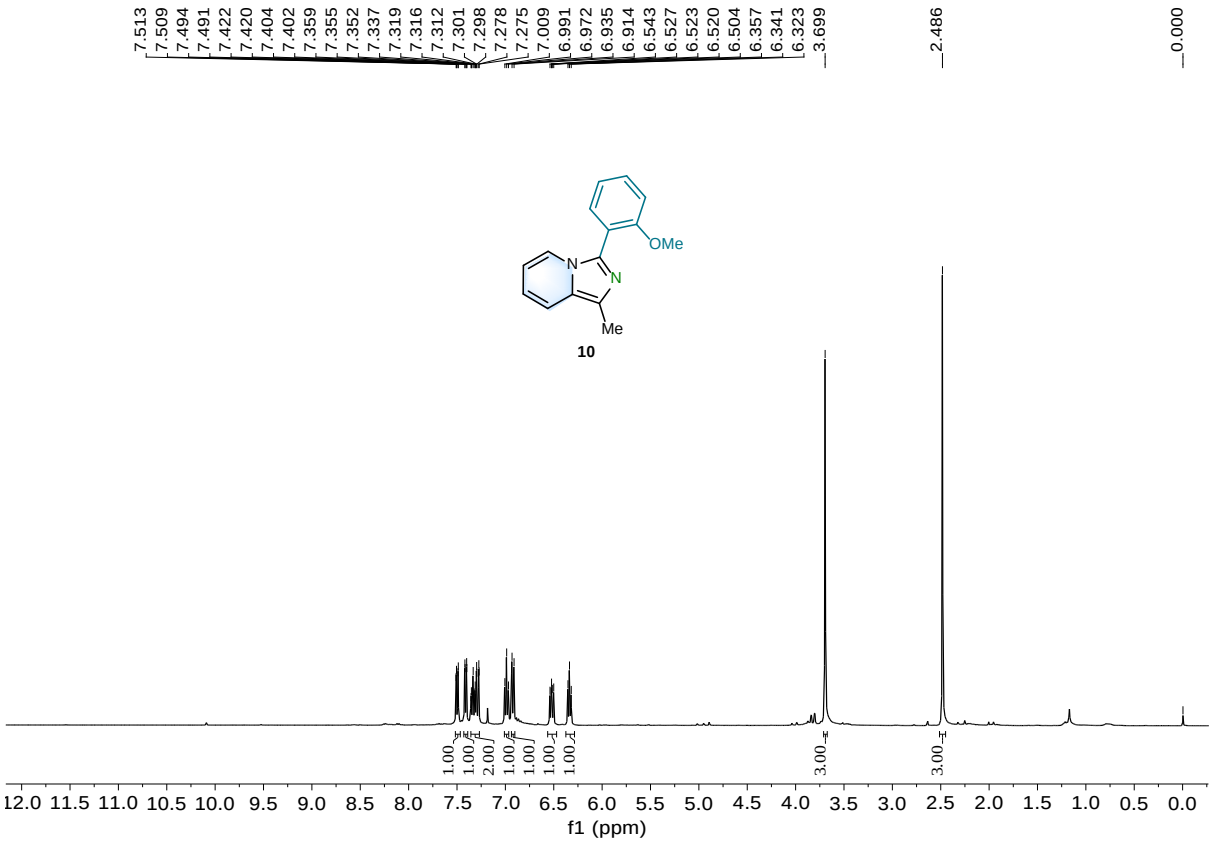
^{1}H NMR spectrum of **9** (300 MHz, $CDCl_3$)



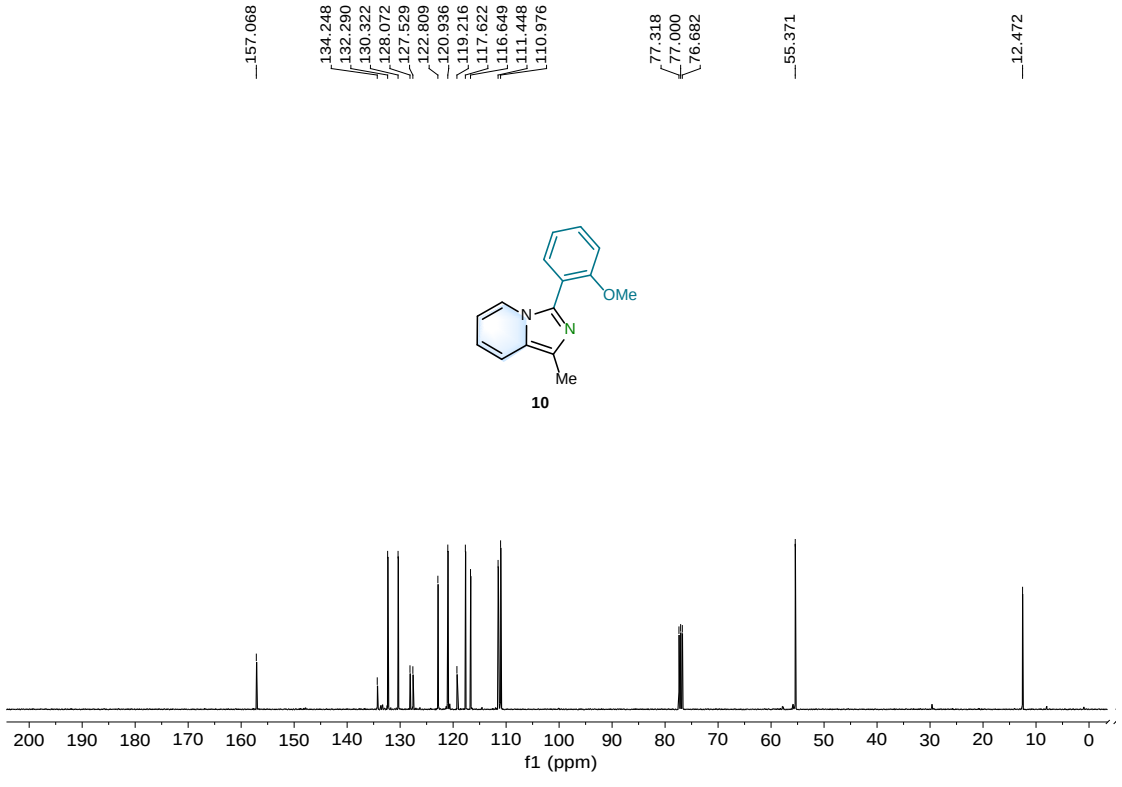
^{13}C NMR spectrum of **9** (300 MHz, $CDCl_3$)



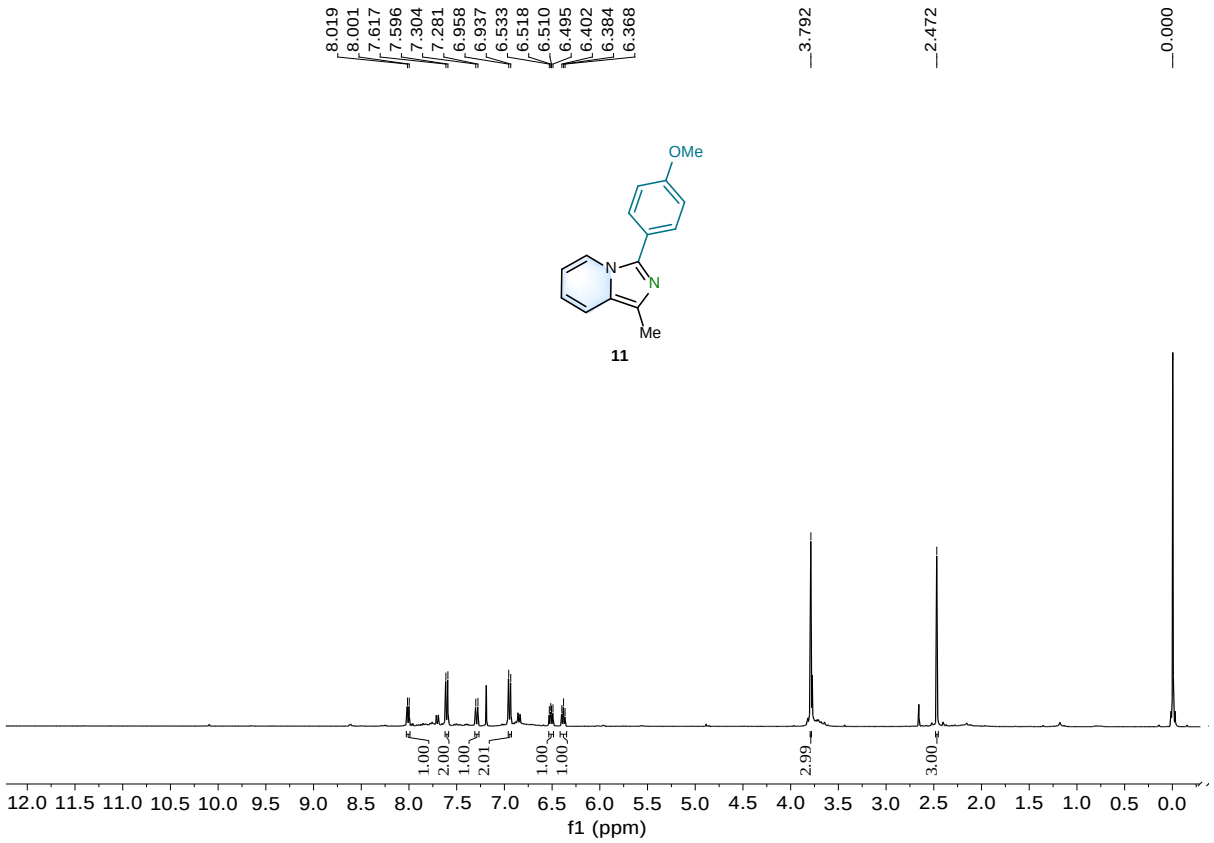
^{1}H NMR spectrum of **10** (400 MHz, $CDCl_3$)



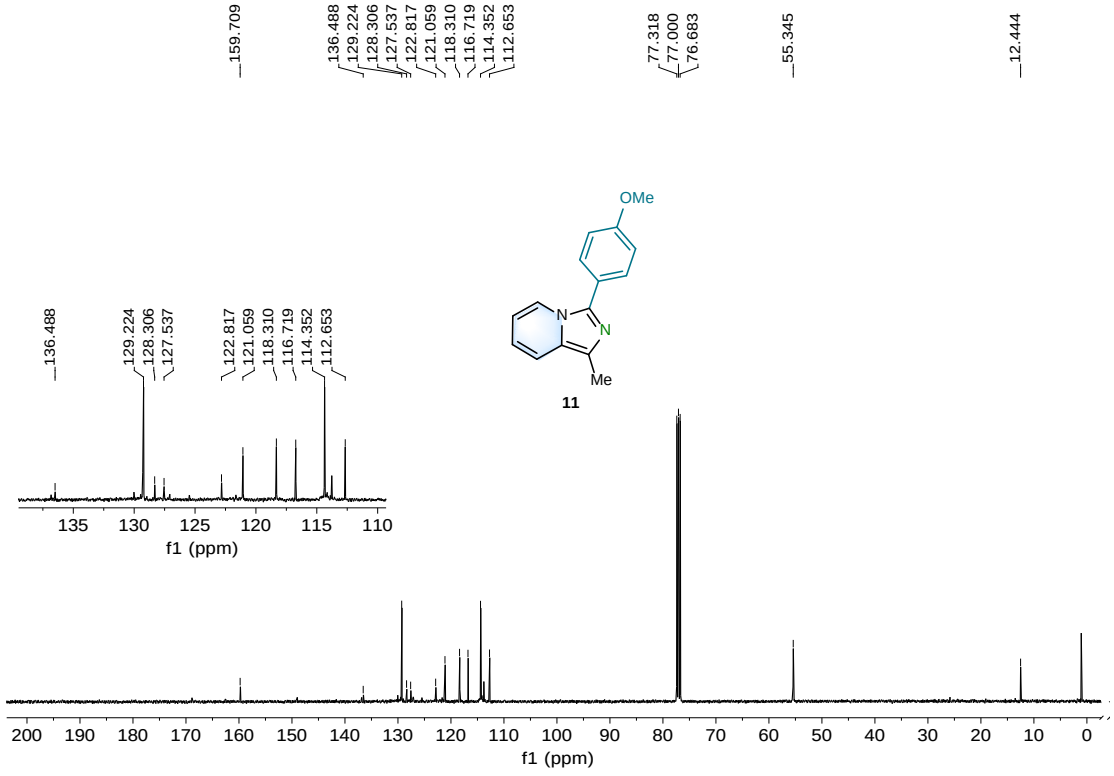
^{13}C NMR spectrum of **10** (100 MHz, $CDCl_3$)



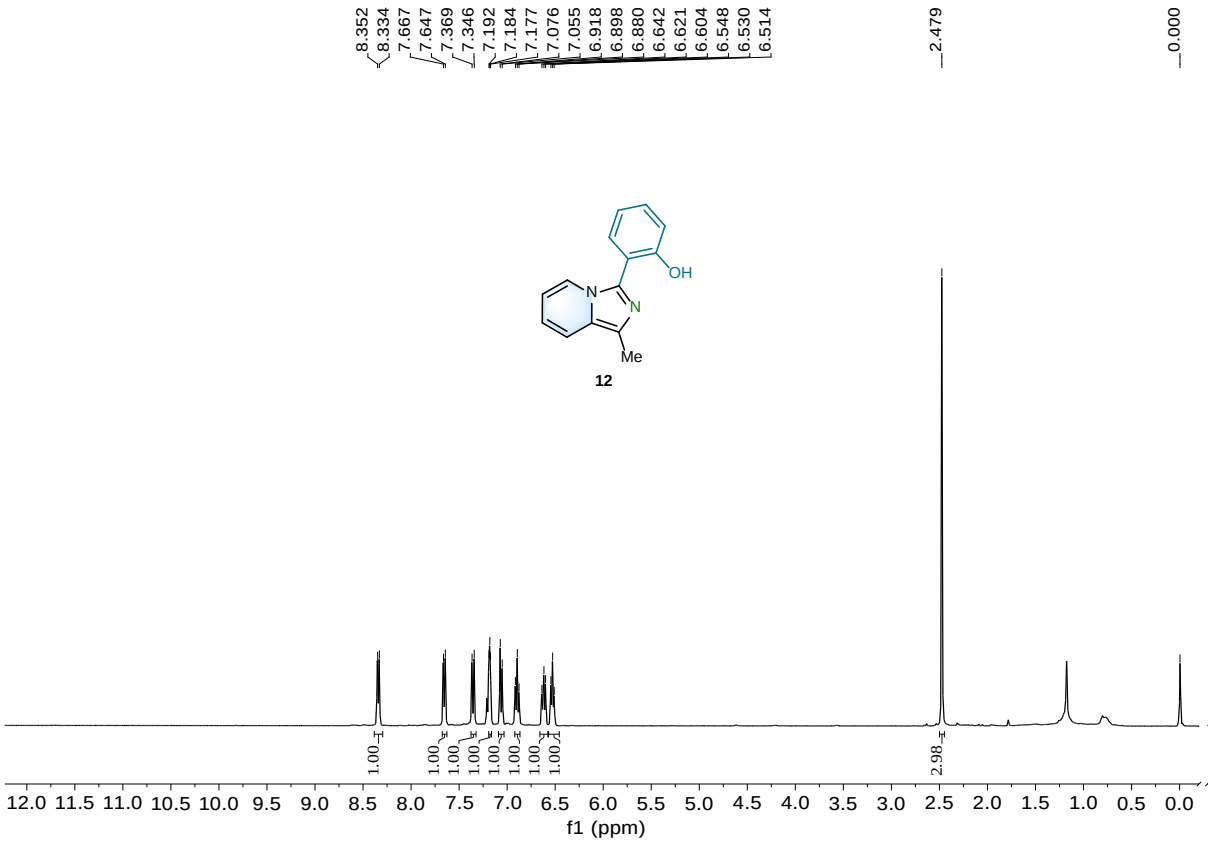
^{1}H NMR spectrum of **11** (400 MHz, $CDCl_3$)



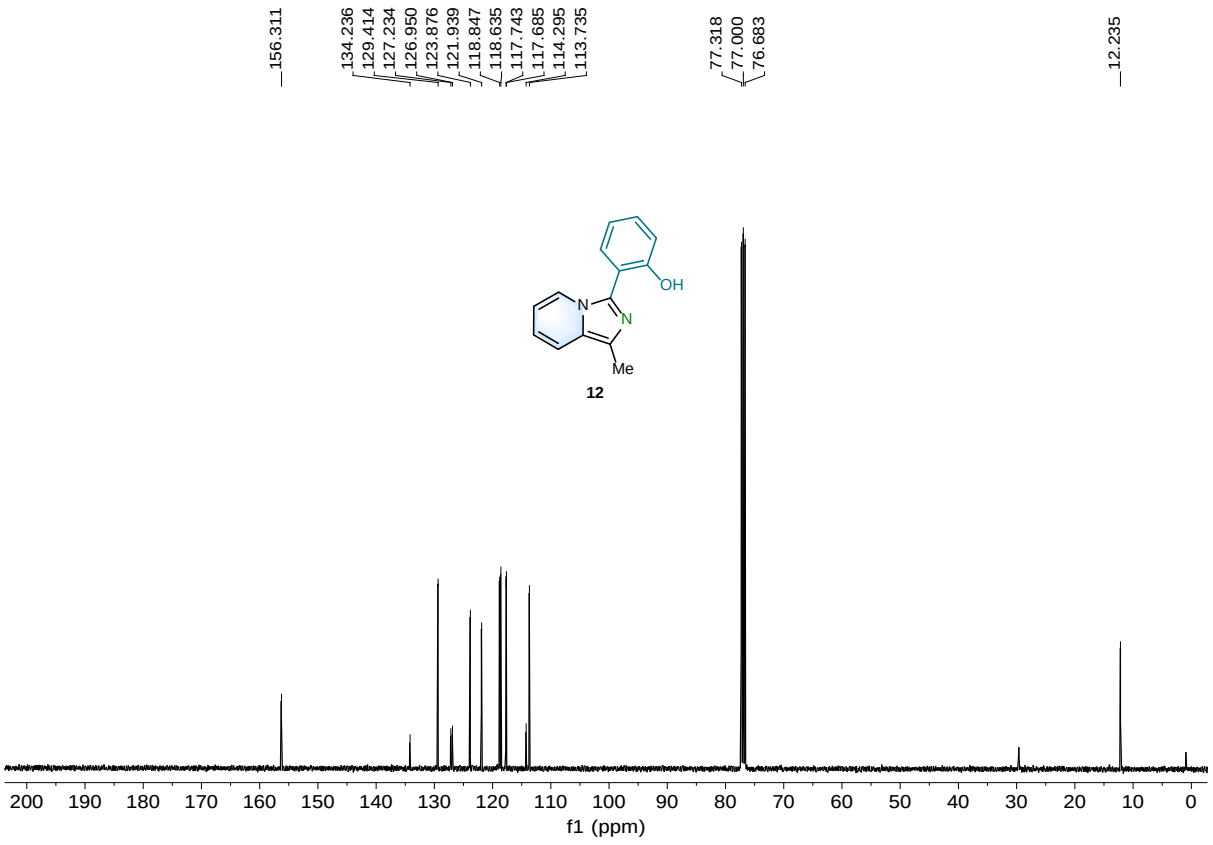
^{13}C NMR spectrum of **11** (100 MHz, $CDCl_3$)



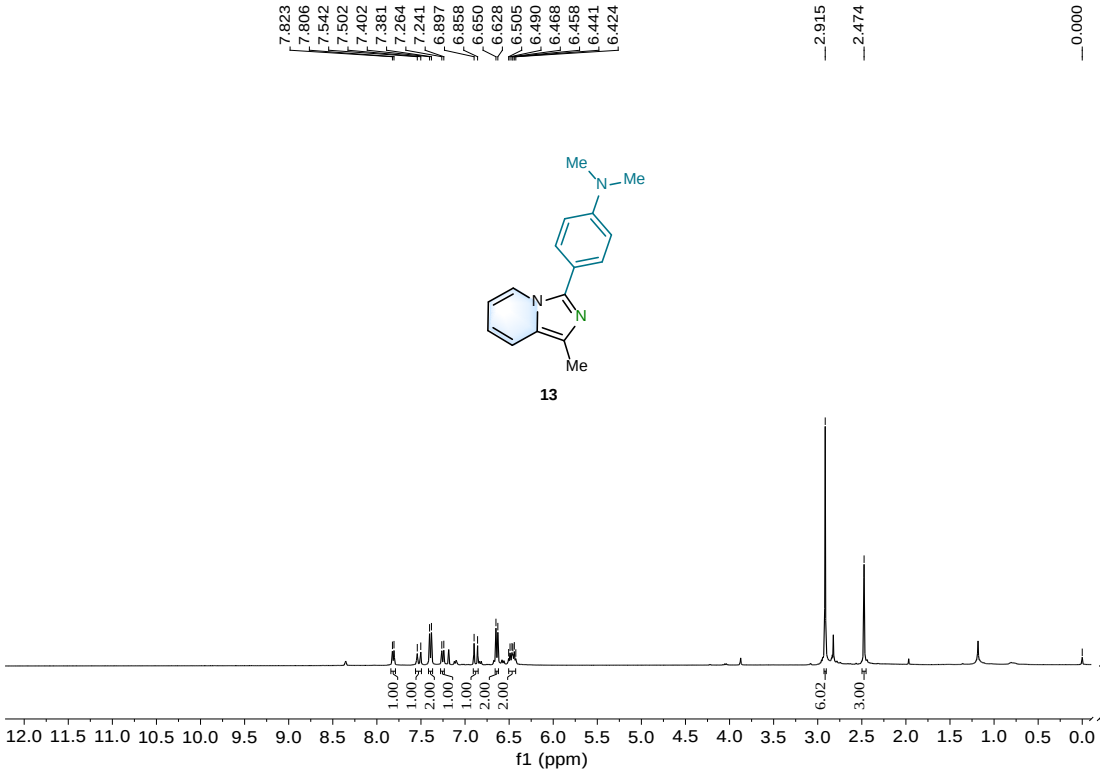
^{1}H NMR spectrum of **12** (400 MHz, $CDCl_3$)



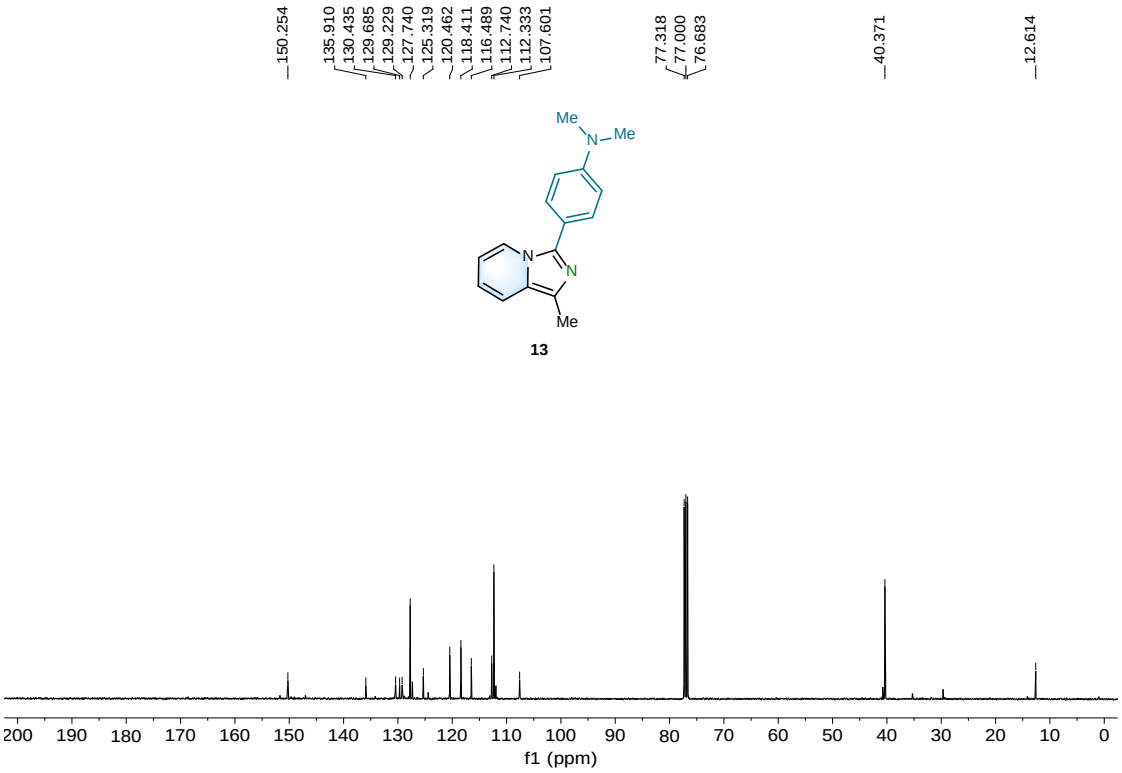
^{13}C NMR spectrum of (**12**) $CDCl_3$



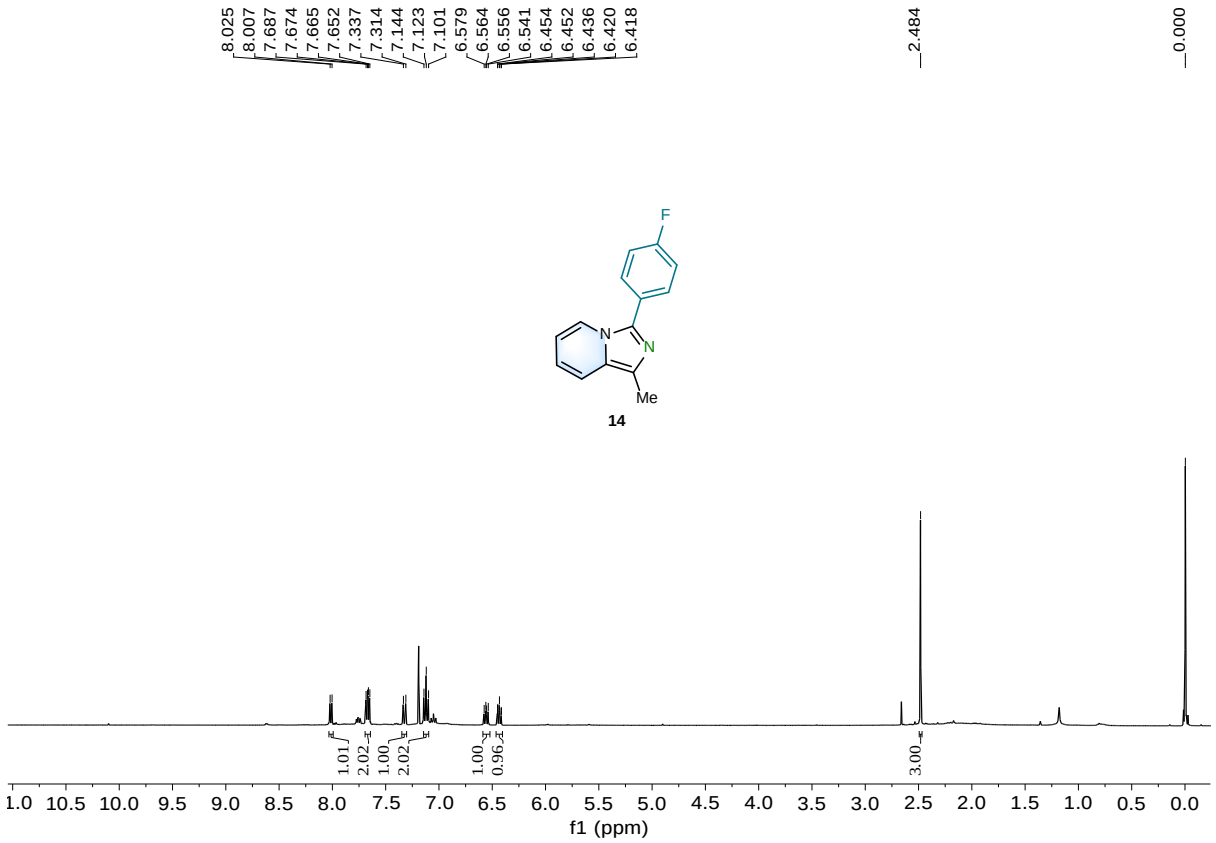
^{1}H NMR spectrum of **13** (400 MHz, $CDCl_3$)



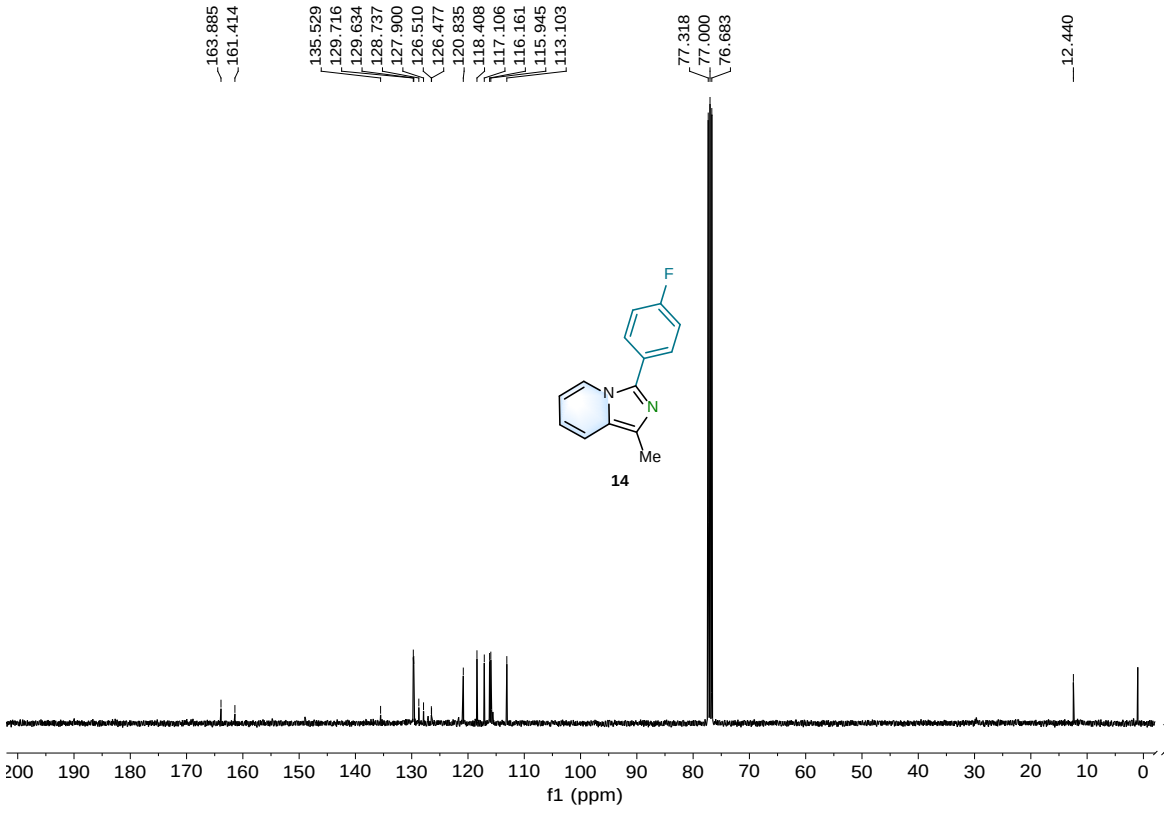
^{13}C NMR spectrum of **13** (100 MHz, $CDCl_3$)



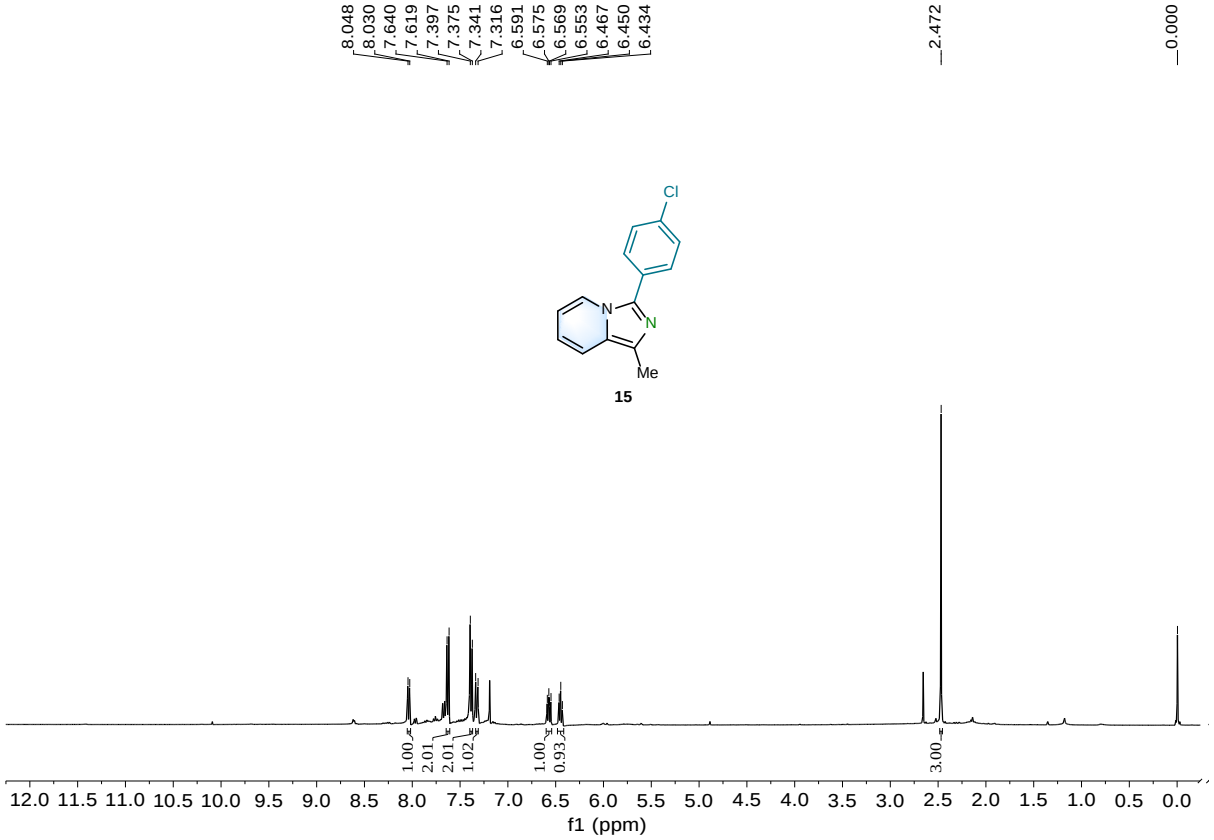
^{1}H NMR spectrum of **14** (400 MHz,) $CDCl_3$



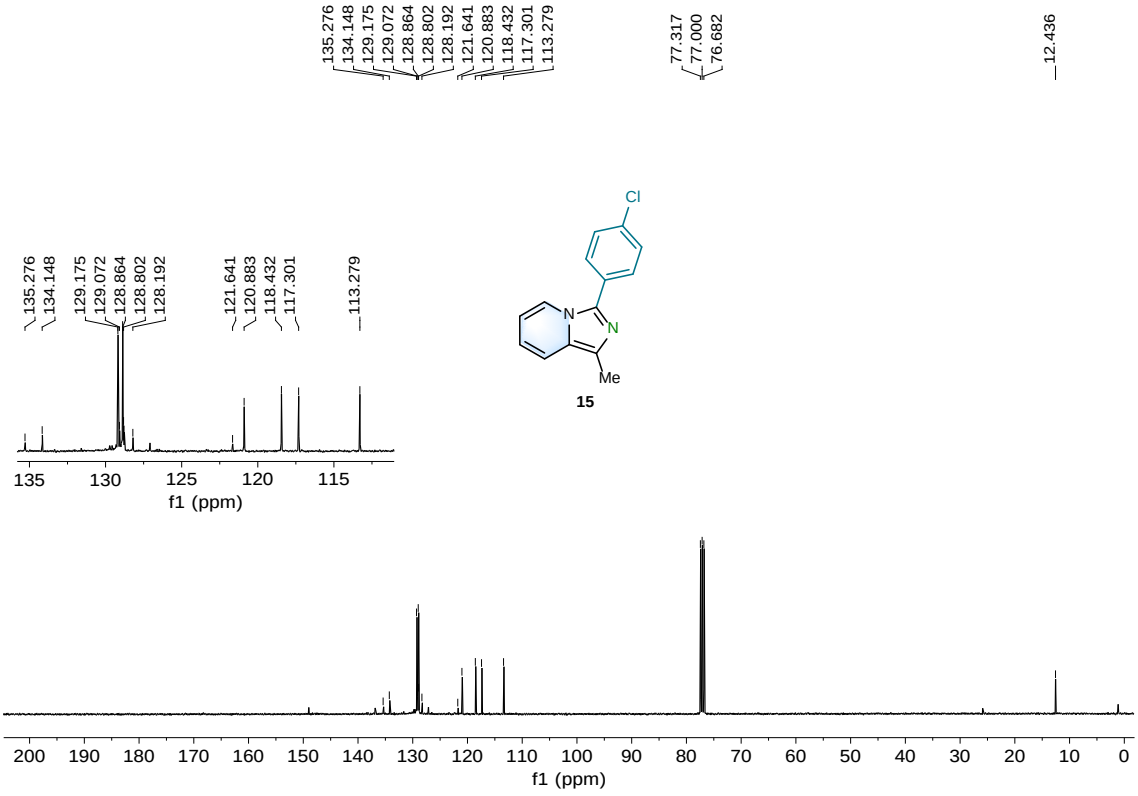
^{13}C NMR spectrum of **14** (100 MHz, $CDCl_3$)



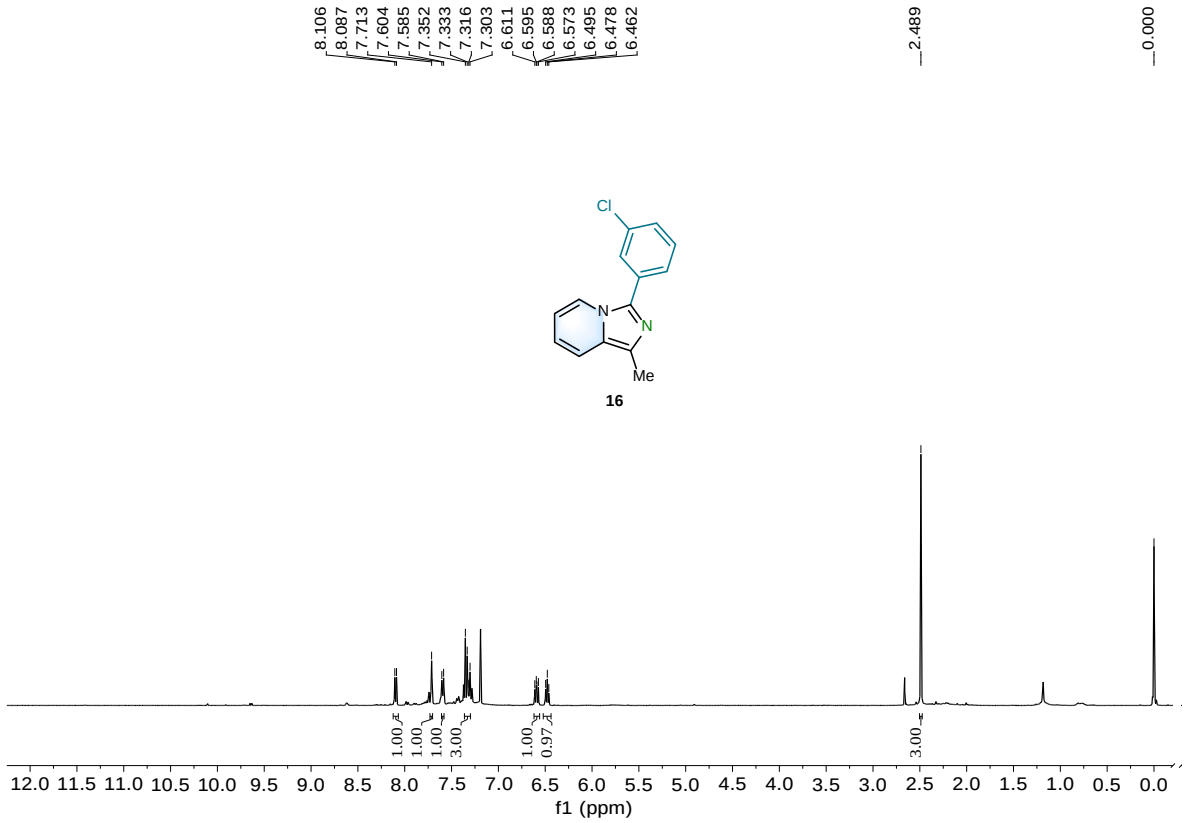
^{1}H NMR spectrum of **15** (400 MHz, $CDCl_3$)



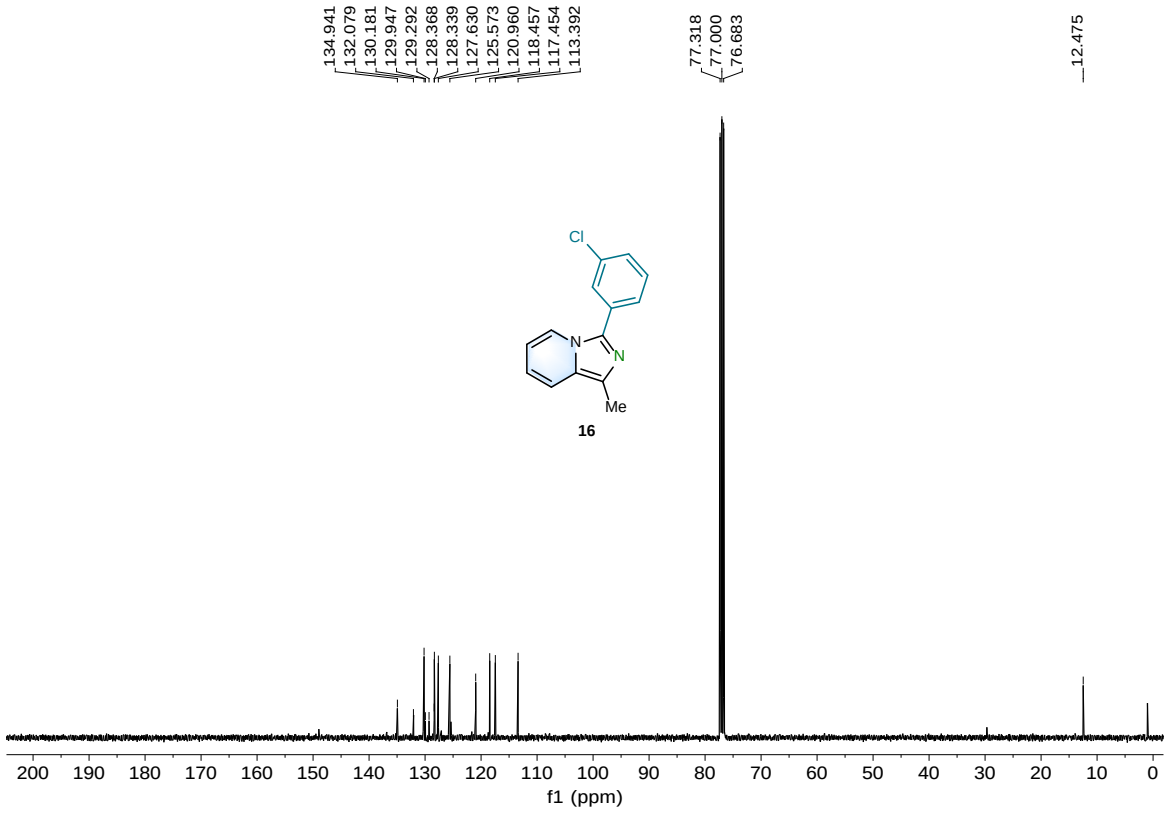
^{13}C NMR spectrum of **15** (100 MHz, $CDCl_3$)



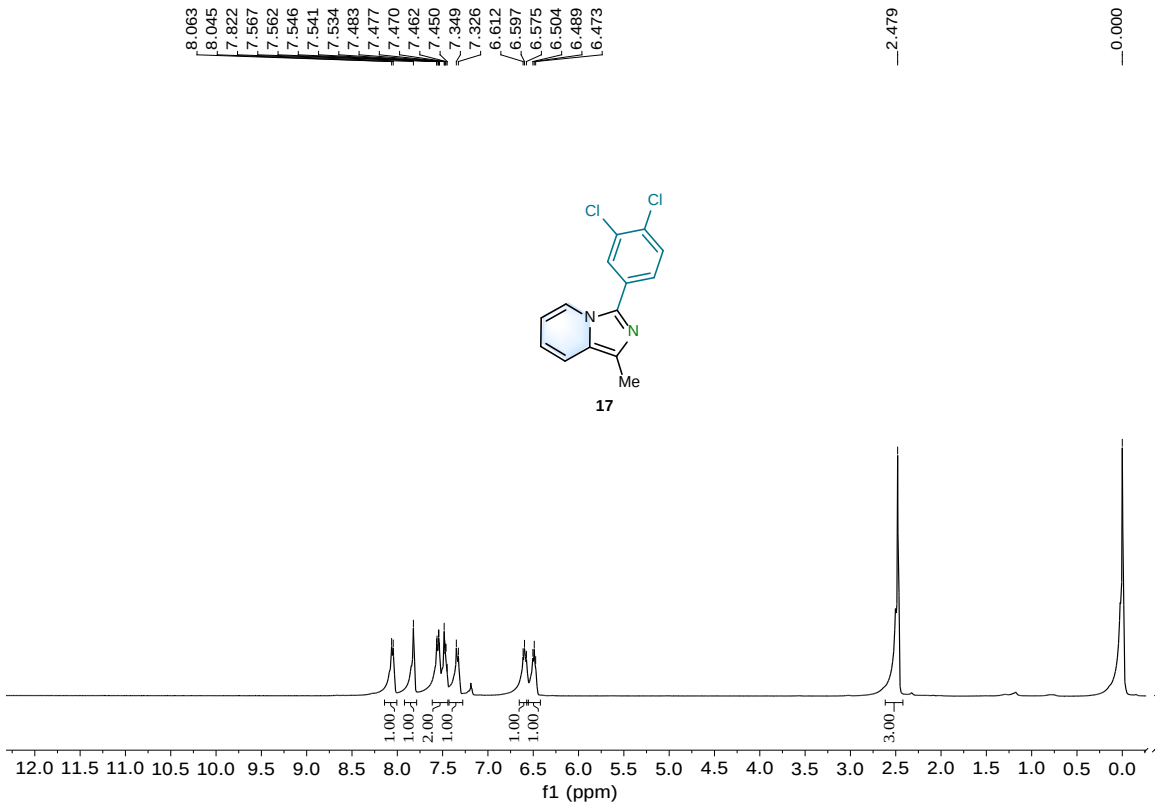
^{1}H NMR spectrum of **16** (400 MHz, $CDCl_3$)



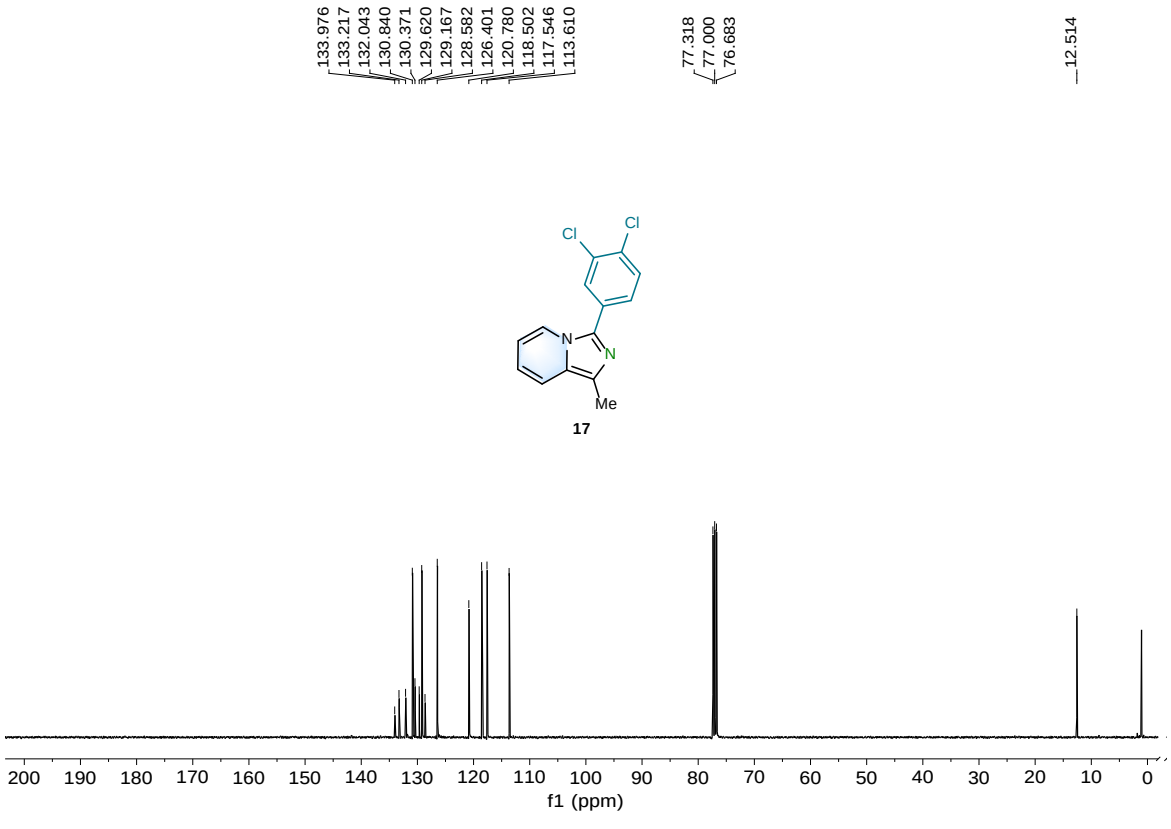
^{13}C NMR spectrum of **16** (100 MHz, $CDCl_3$)



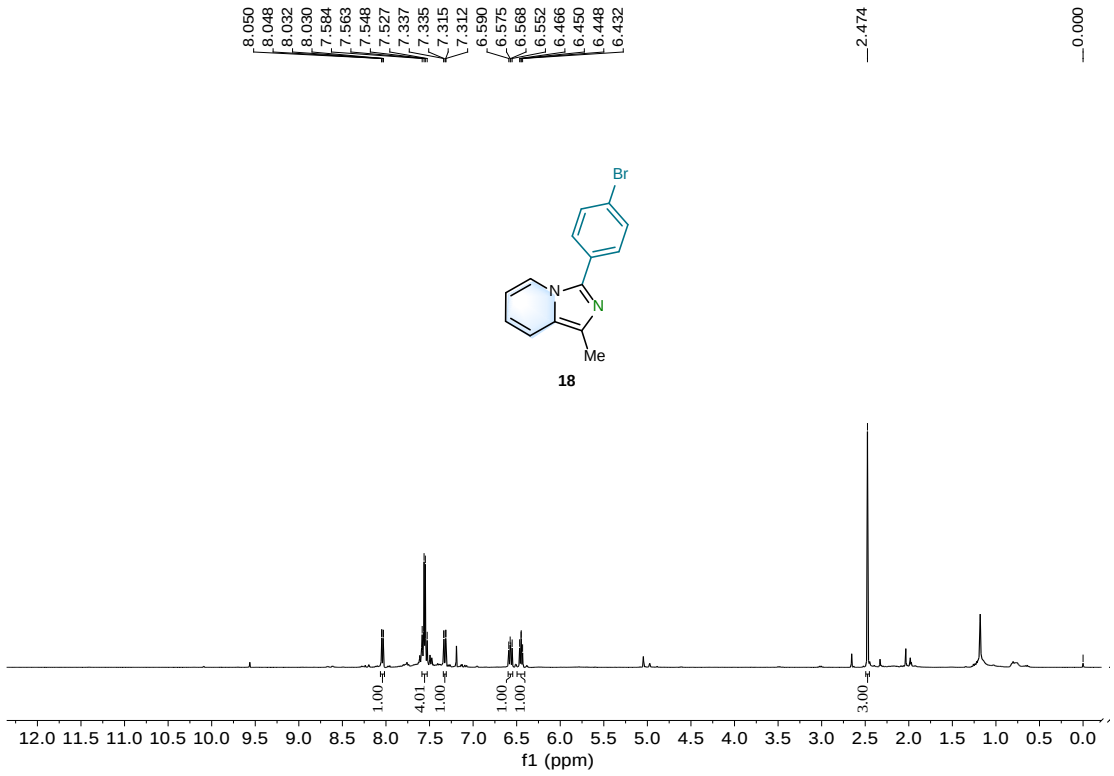
^{1}H NMR spectrum of **17** (400 MHz, $CDCl_3$)



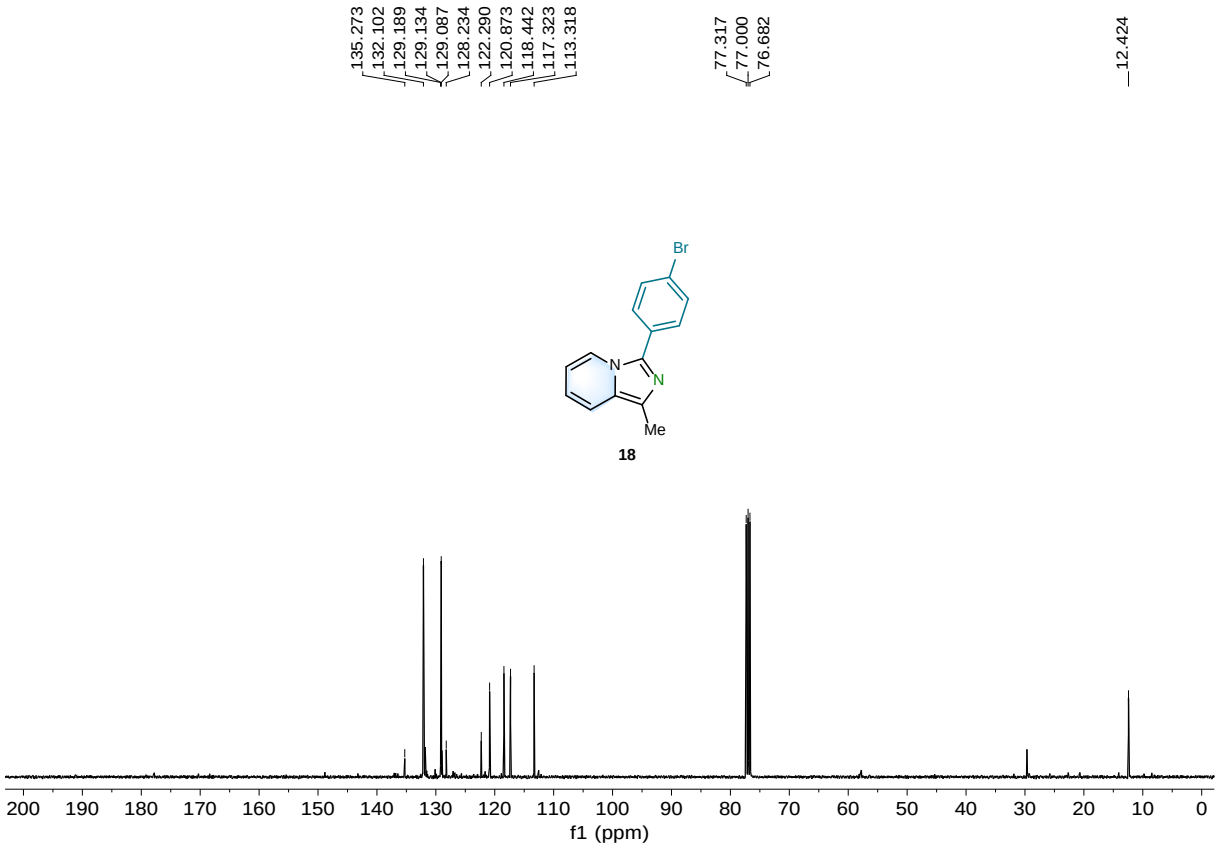
^{13}C NMR spectrum of **17** (100 MHz, $CDCl_3$)



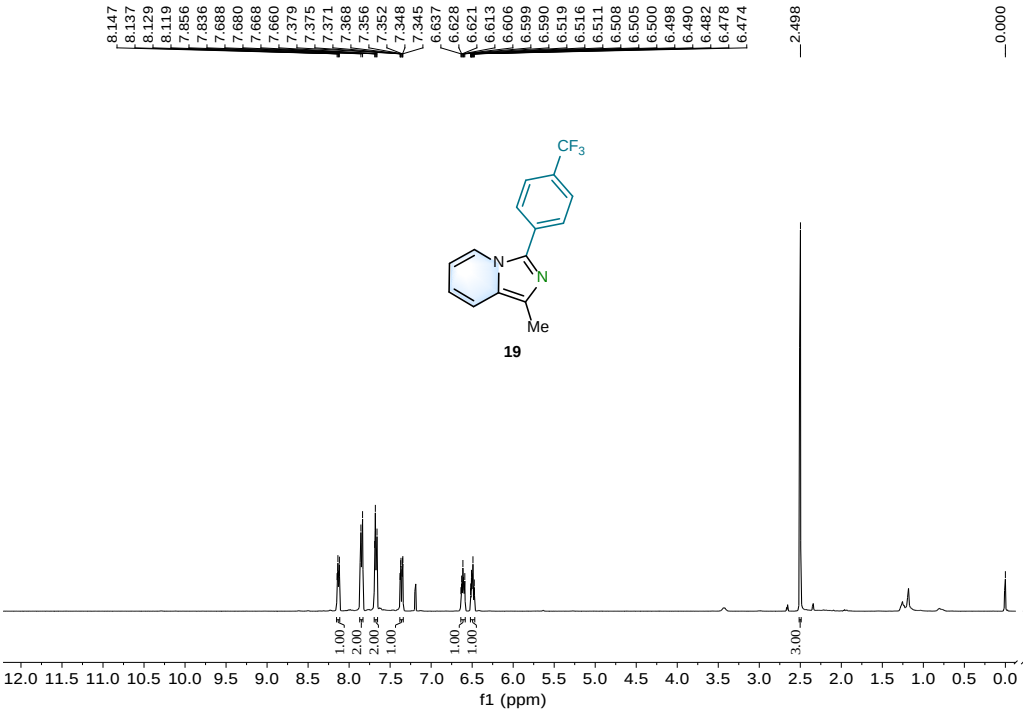
^{1}H NMR spectrum of **18** (400 MHz, $CDCl_3$)



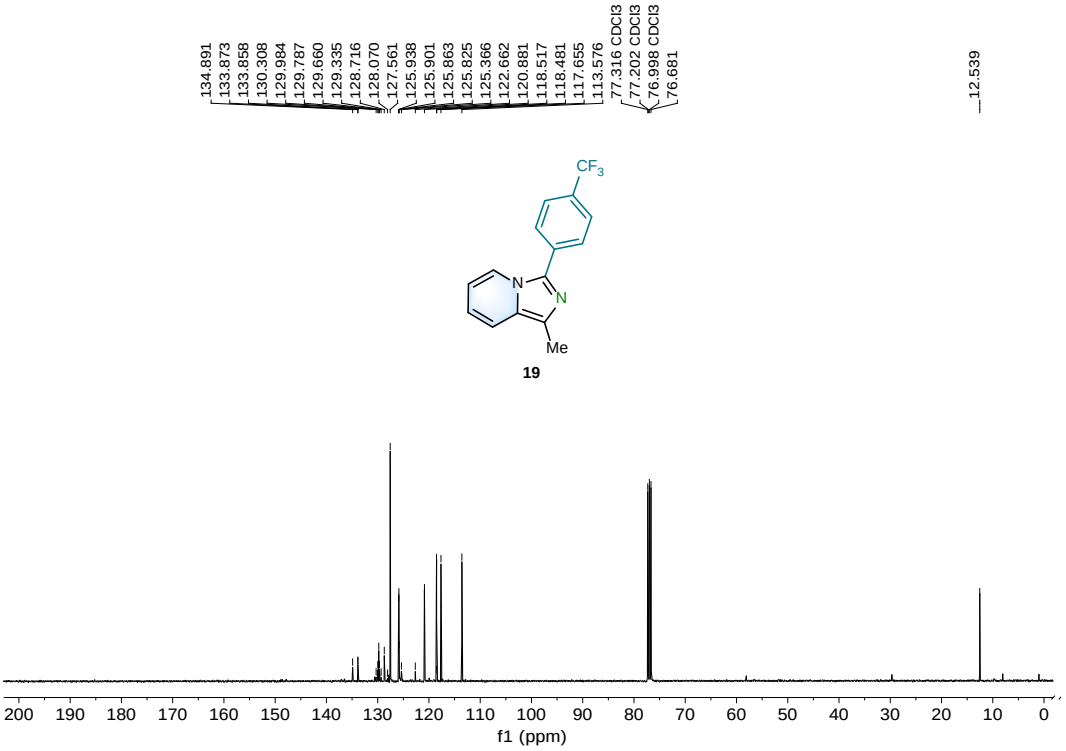
^{13}C NMR spectrum of **18** (100 MHz, $CDCl_3$)



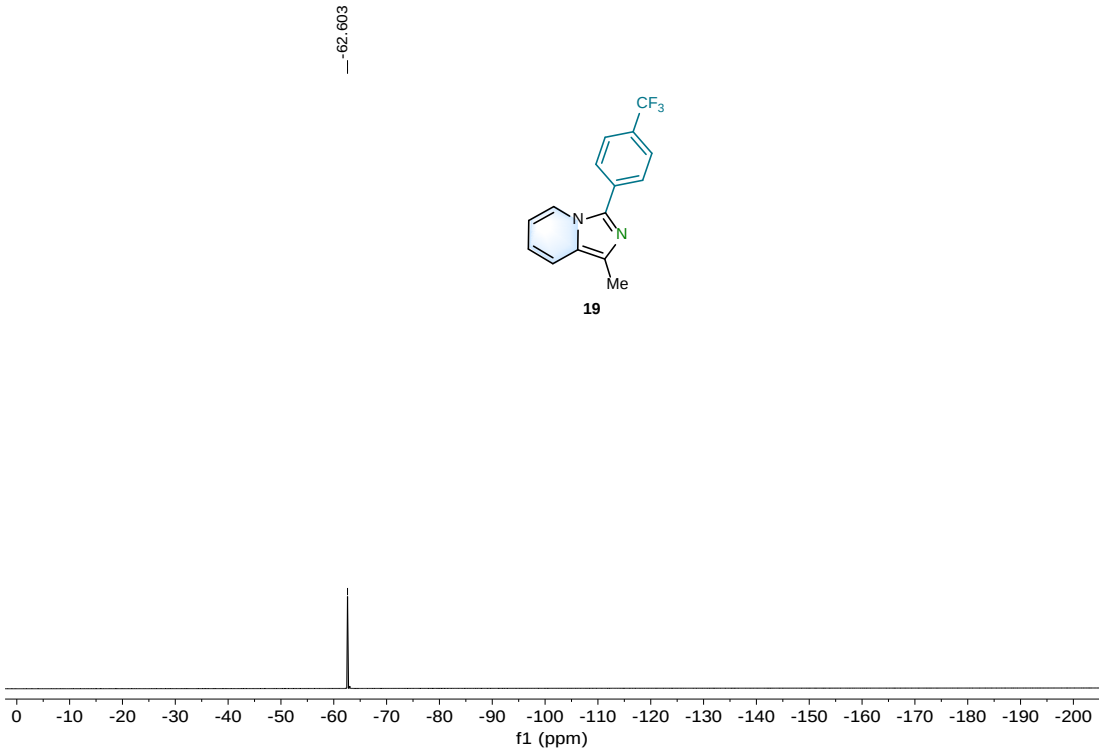
^{1}H NMR spectrum of **19** (400 MHz, $CDCl_3$)



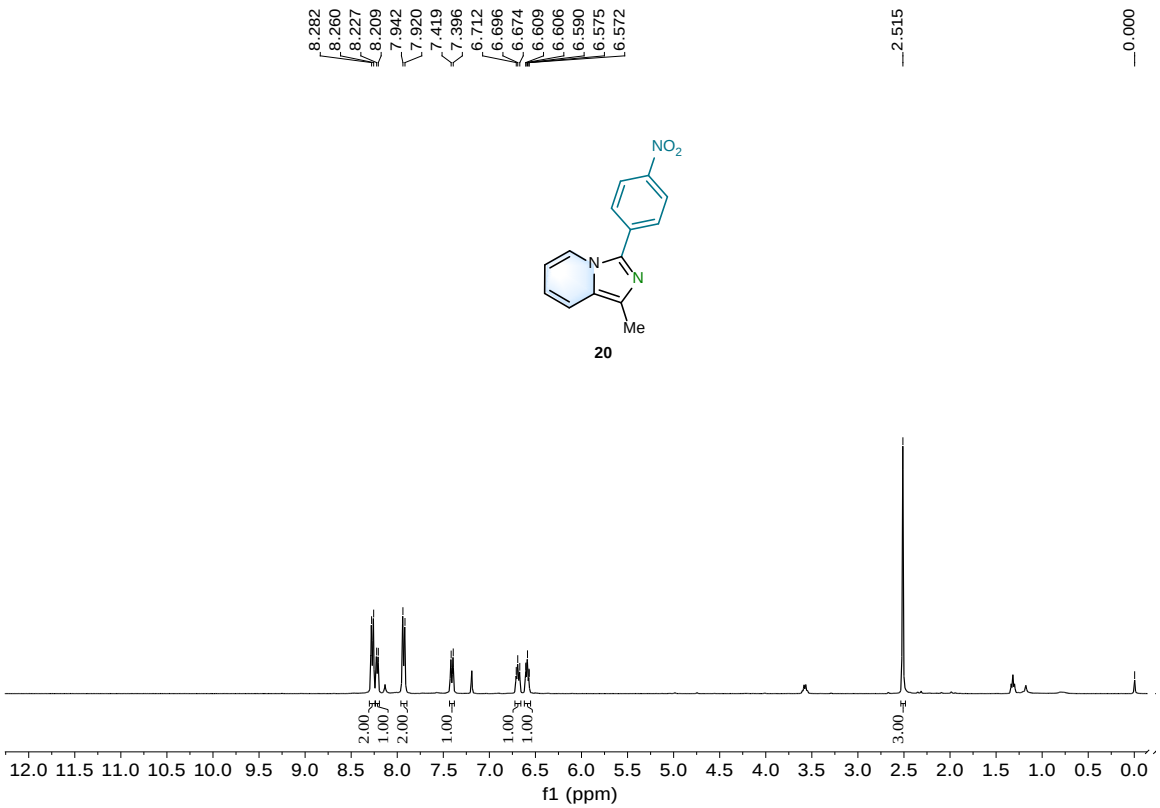
^{13}C NMR spectrum of **19** (100 MHz, $CDCl_3$)



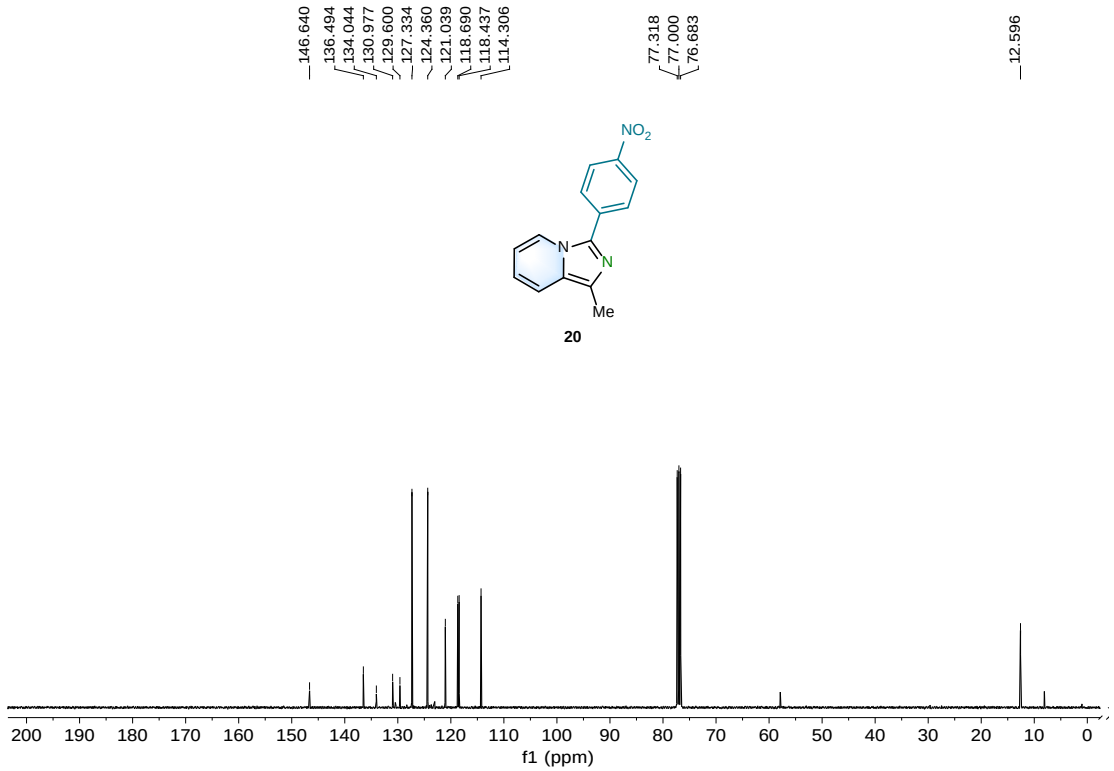
^{19}F NMR spectrum of **19** (377 MHz, $CDCl_3$)



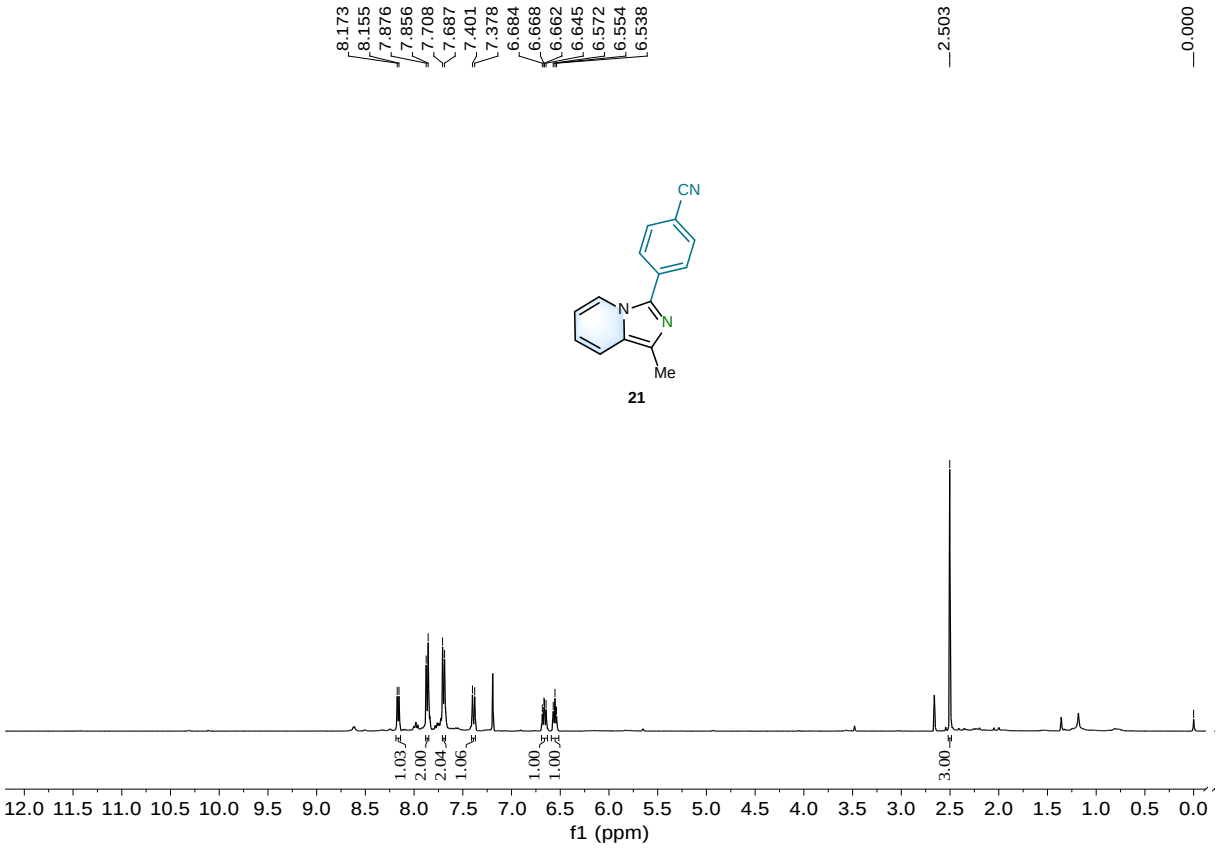
^{1}H NMR spectrum of **20** (400 MHz, $CDCl_3$)



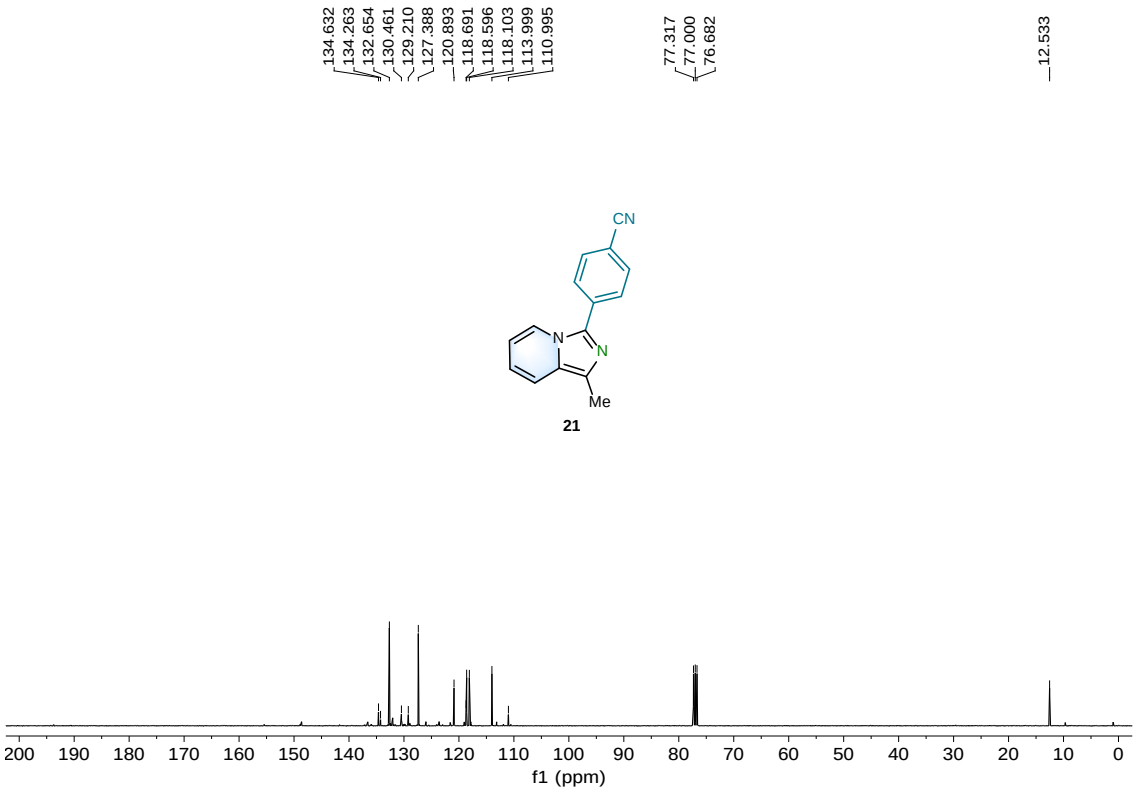
^{13}C NMR spectrum of **20** (100 MHz, $CDCl_3$)



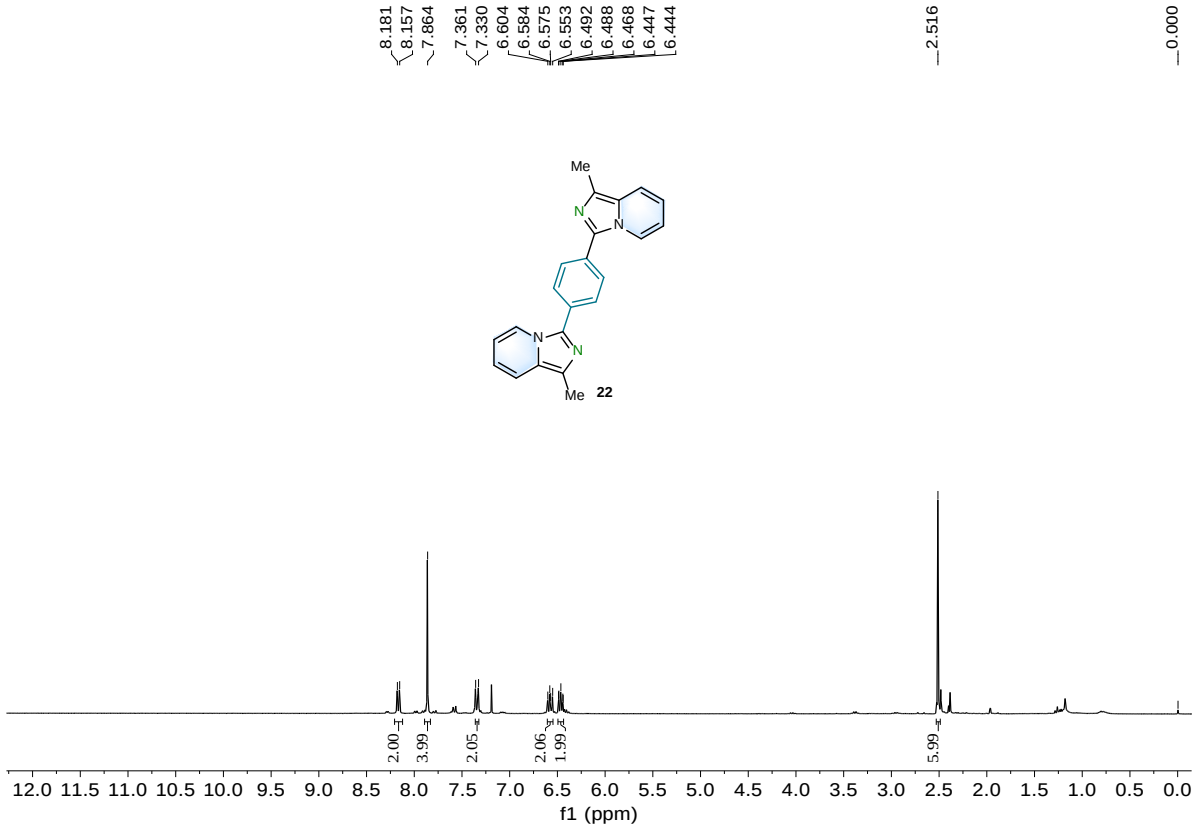
^{1}H NMR spectrum of **21** (400 MHz, $CDCl_3$)



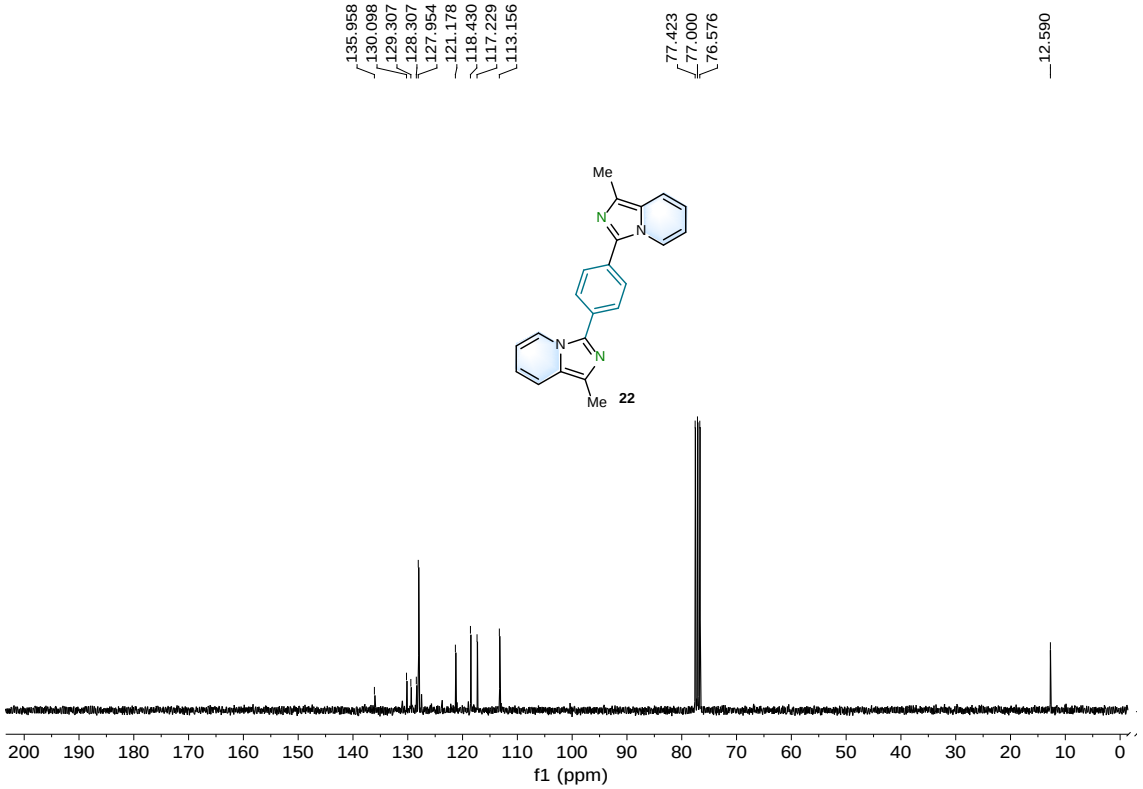
^{13}C NMR spectrum of **21** (100 MHz, $CDCl_3$)



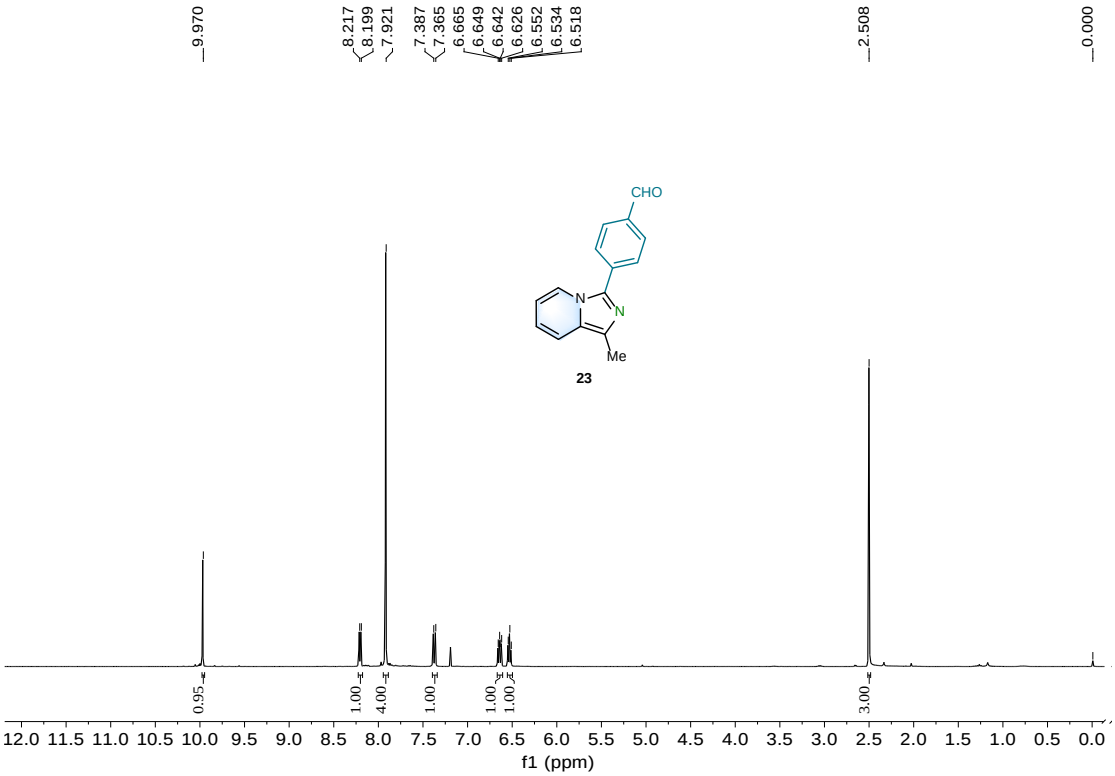
^{1}H NMR spectrum of **22** (300 MHz, $CDCl_3$)



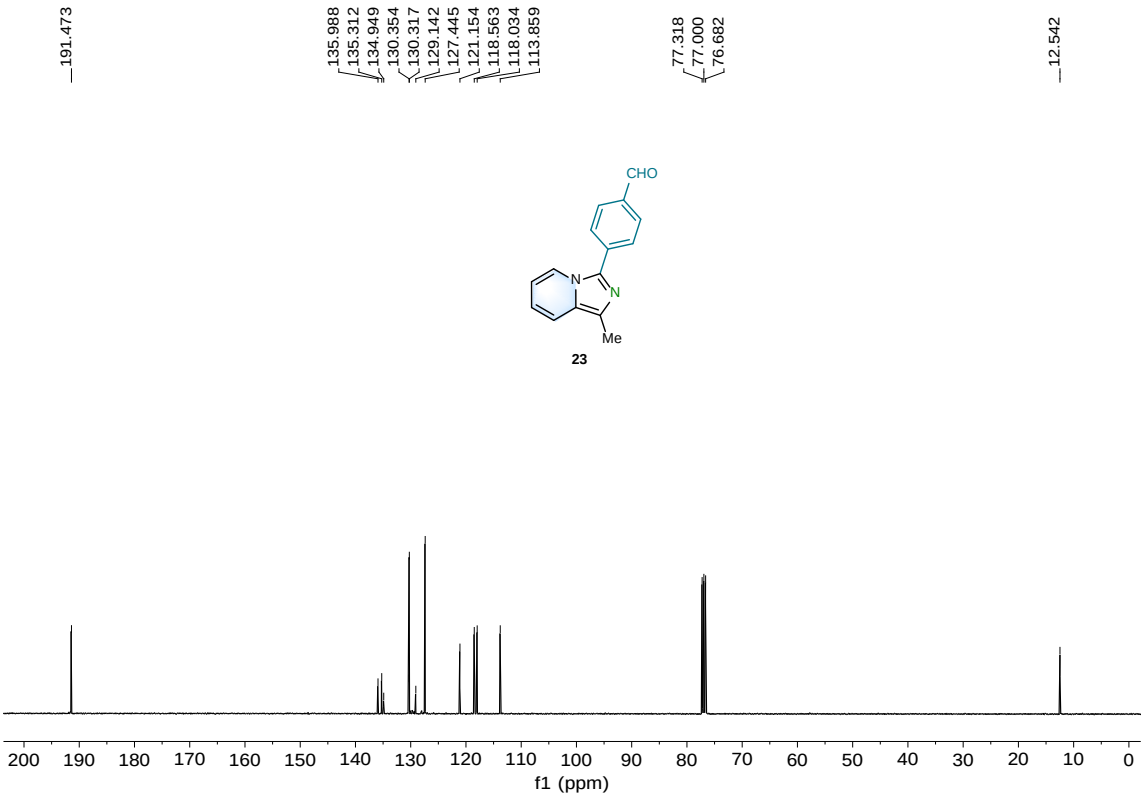
^{13}C NMR spectrum of **22** (75 MHz, $CDCl_3$)



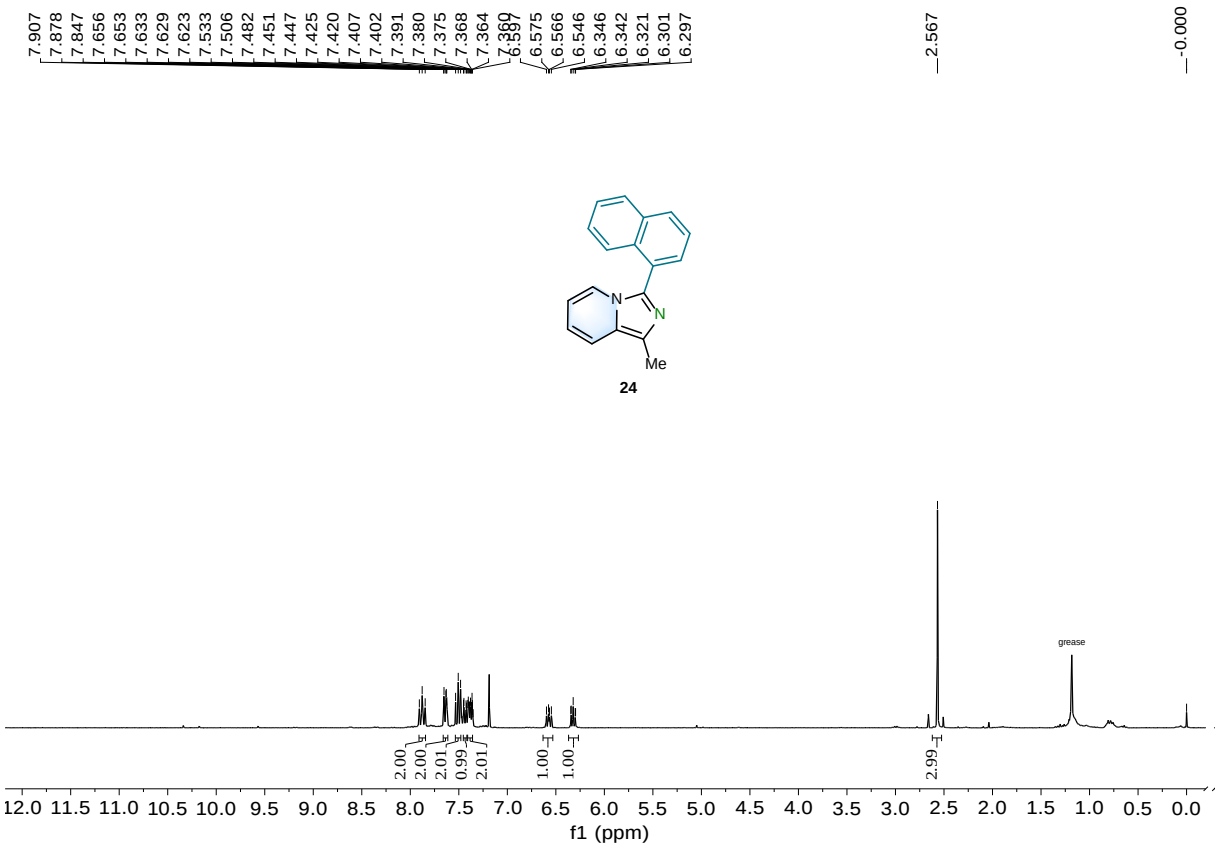
^{1}H NMR spectrum of **23** (400 MHz, $CDCl_3$)



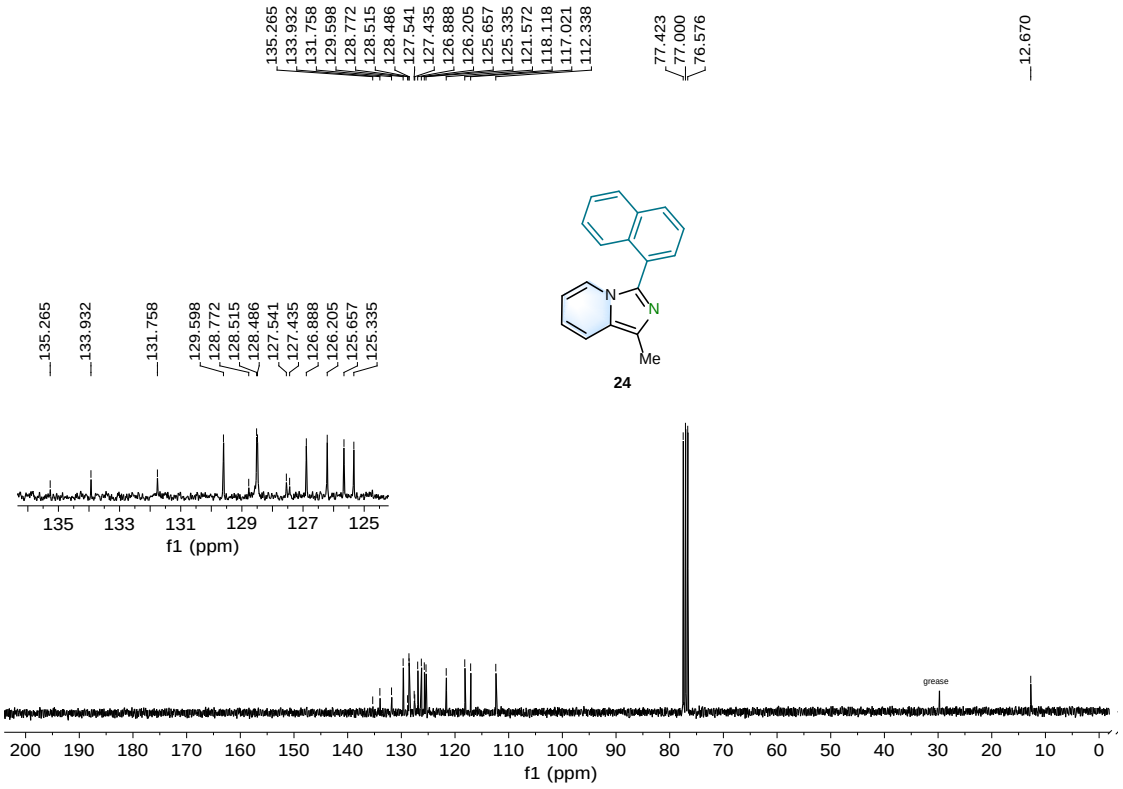
^{13}C NMR spectrum of **23** (100 MHz, $CDCl_3$)



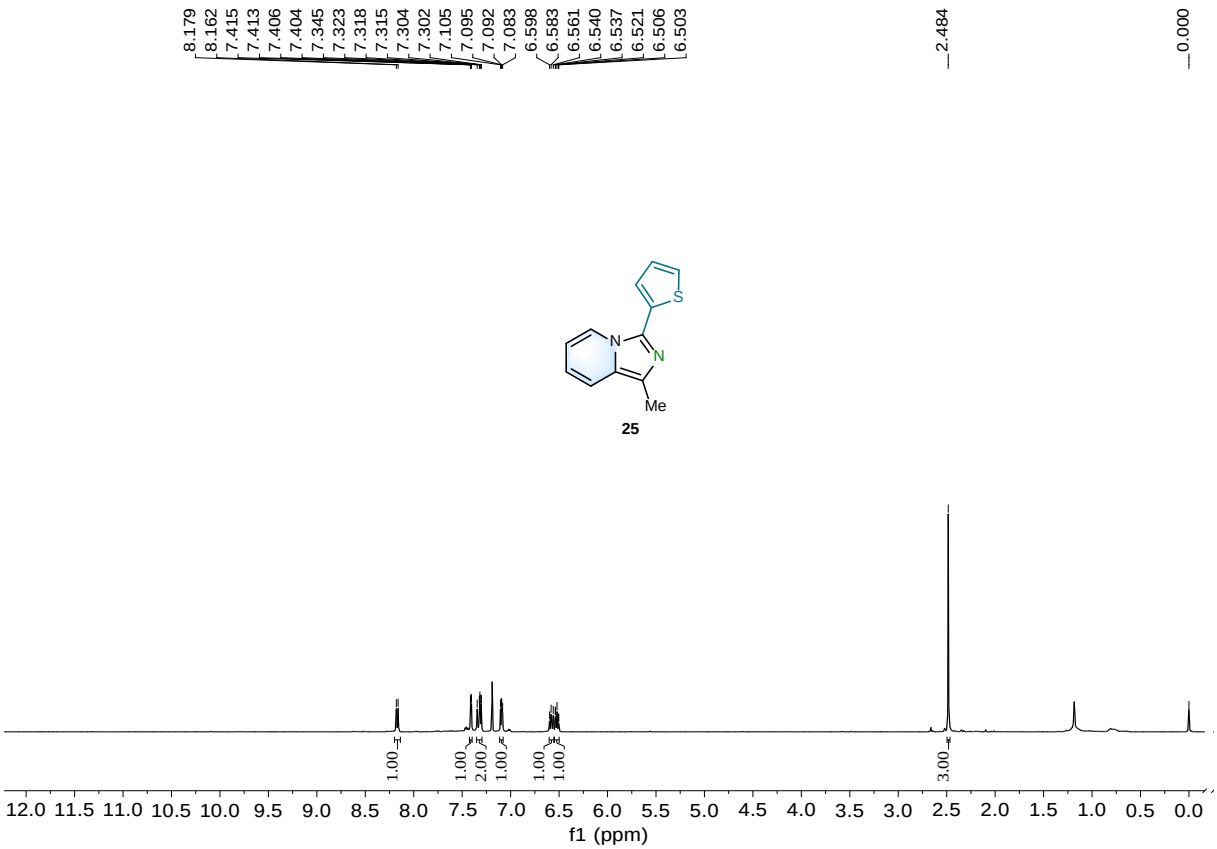
^{1}H NMR spectrum of **24** (400 MHz, $CDCl_3$)



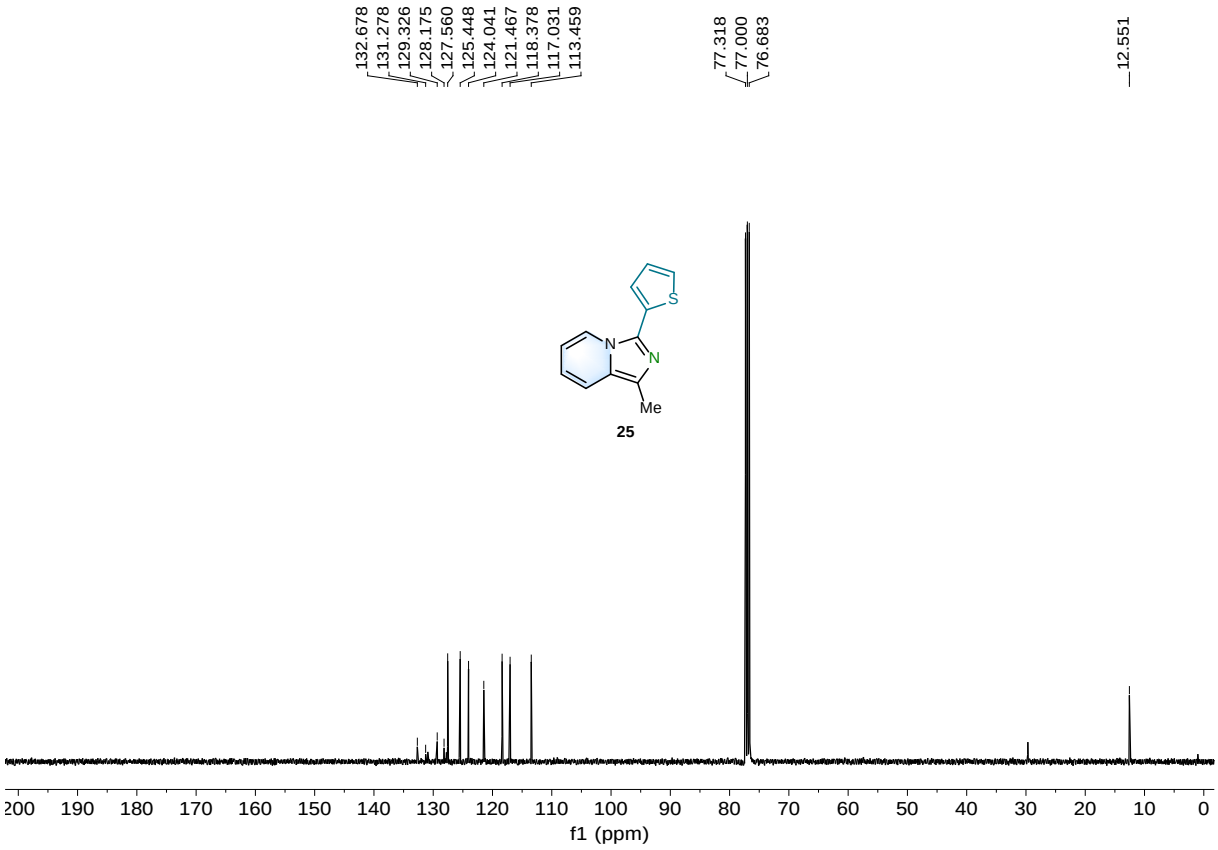
^{13}C NMR spectrum of **24** (100 MHz, $CDCl_3$)



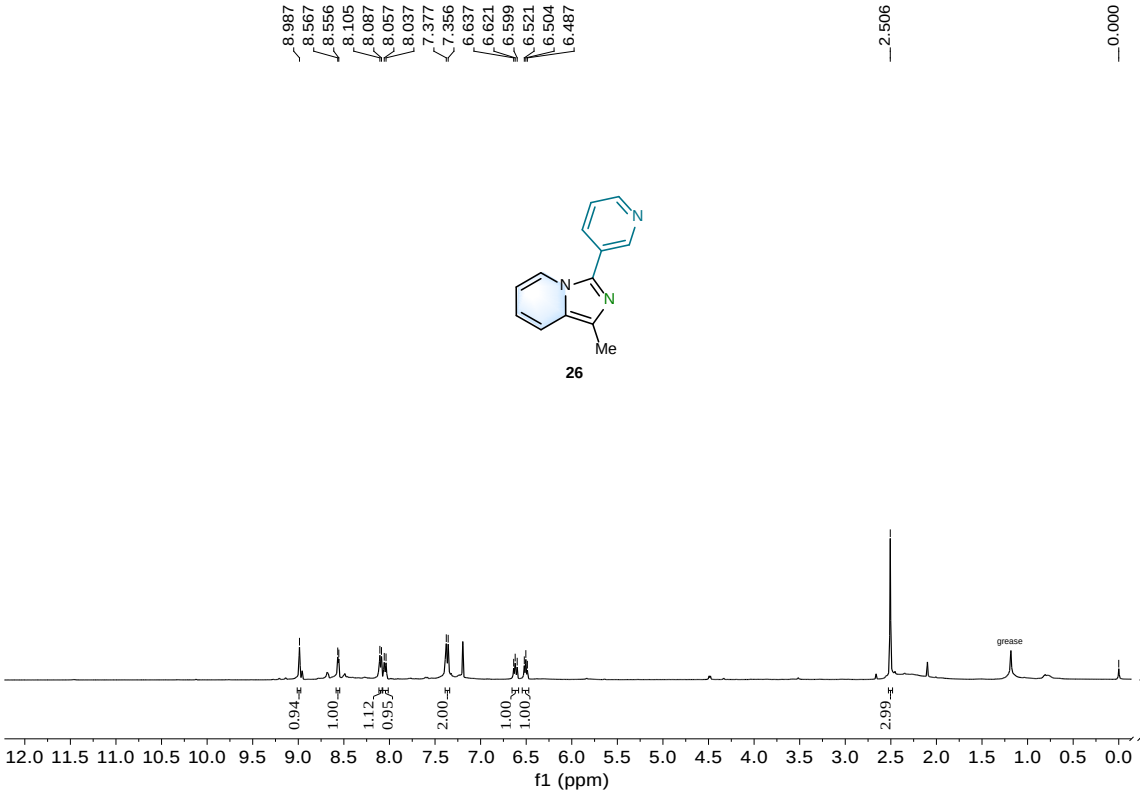
^{1}H NMR spectrum of **25** (400 MHz, $CDCl_3$)



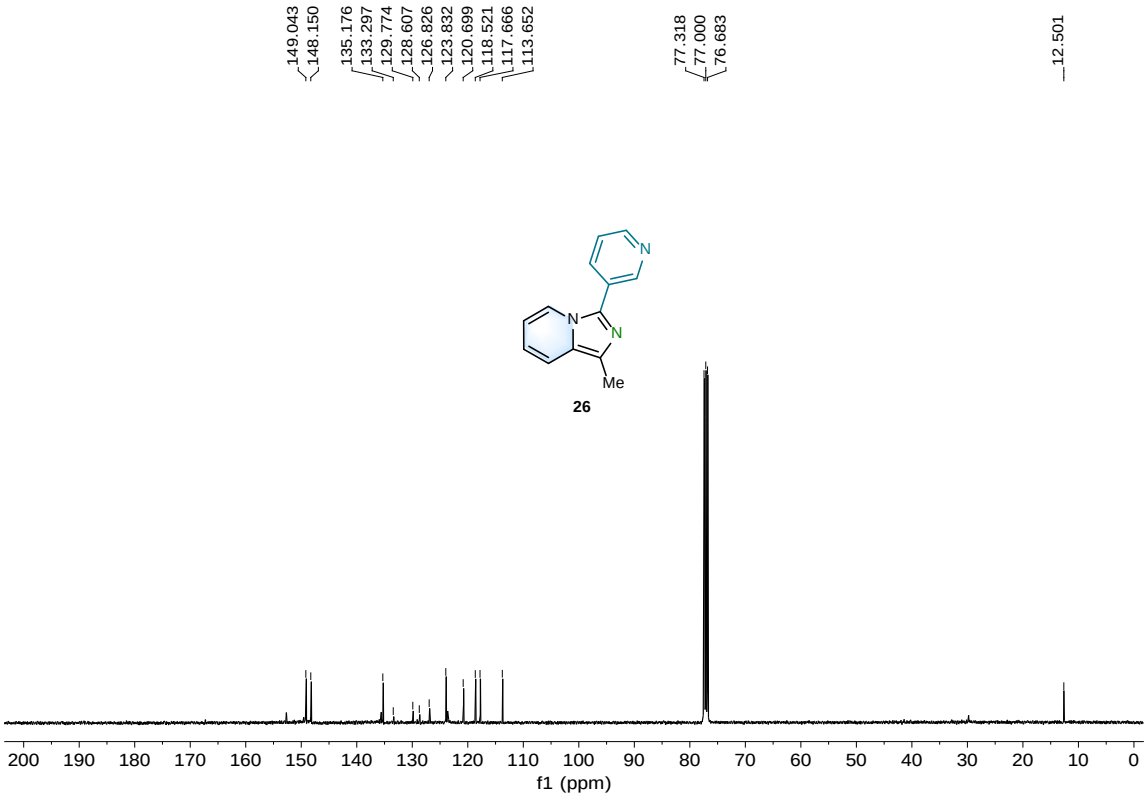
^{13}C NMR spectrum of **25** (100 MHz, $CDCl_3$)



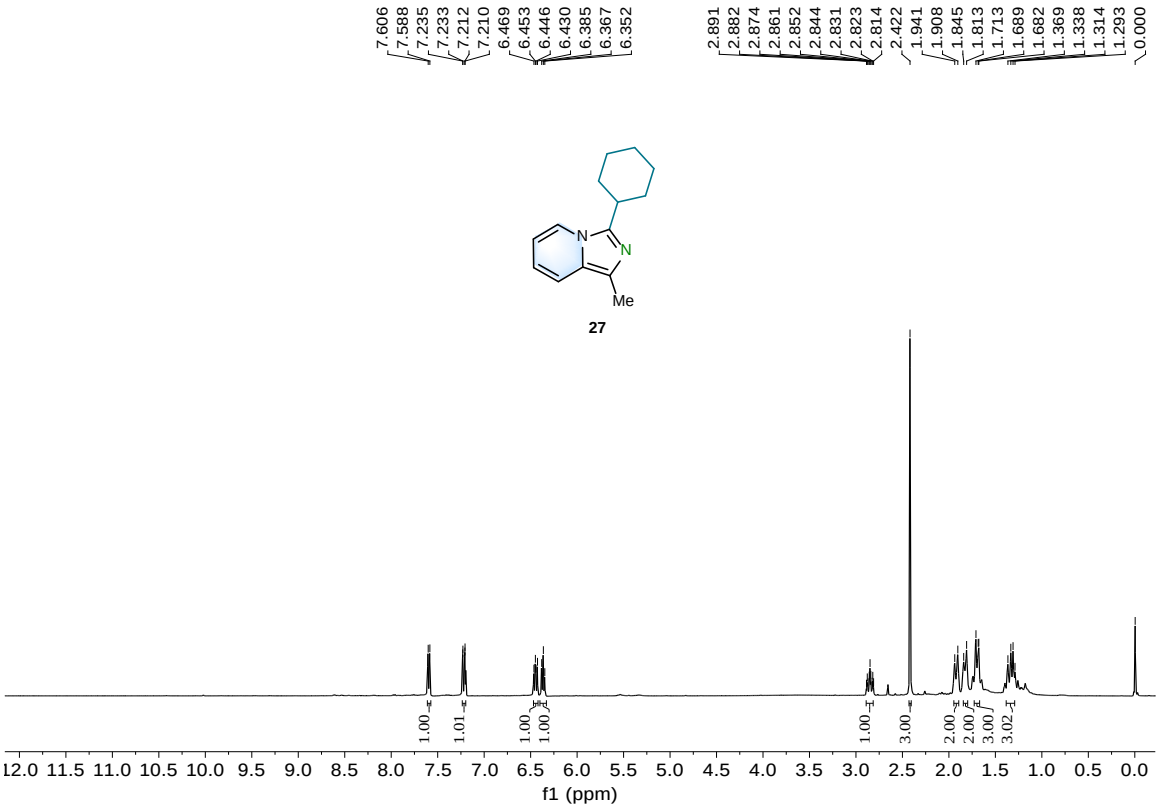
^{1}H NMR spectrum of **26** (300 MHz, $CDCl_3$)



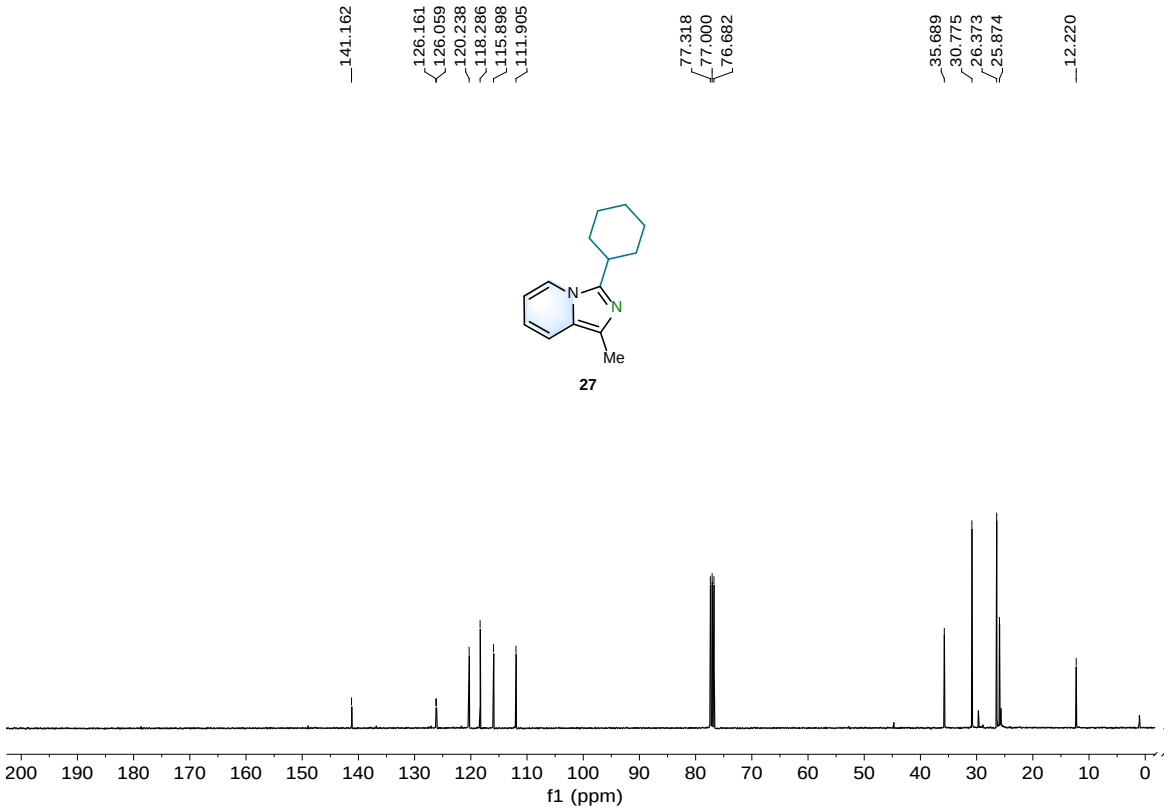
^{13}C NMR spectrum of **26** (75 MHz, $CDCl_3$)



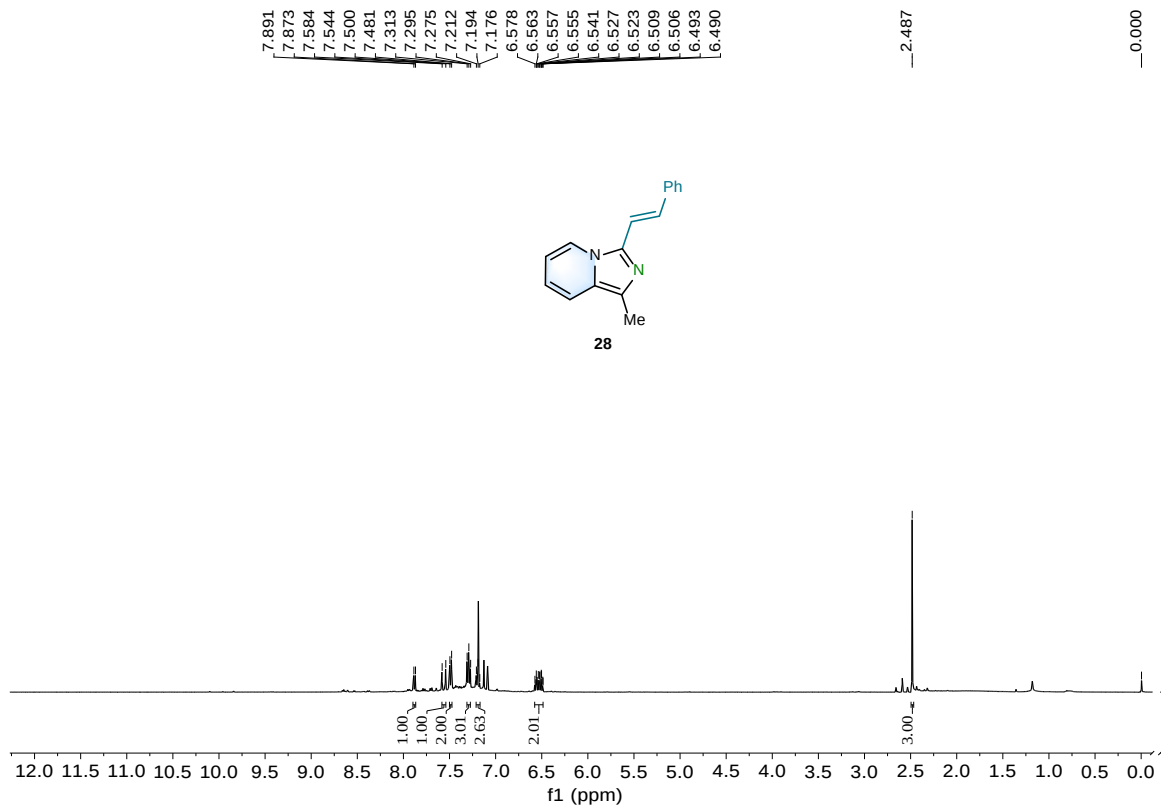
^{1}H NMR spectrum of **27** (400 MHz, $CDCl_3$)



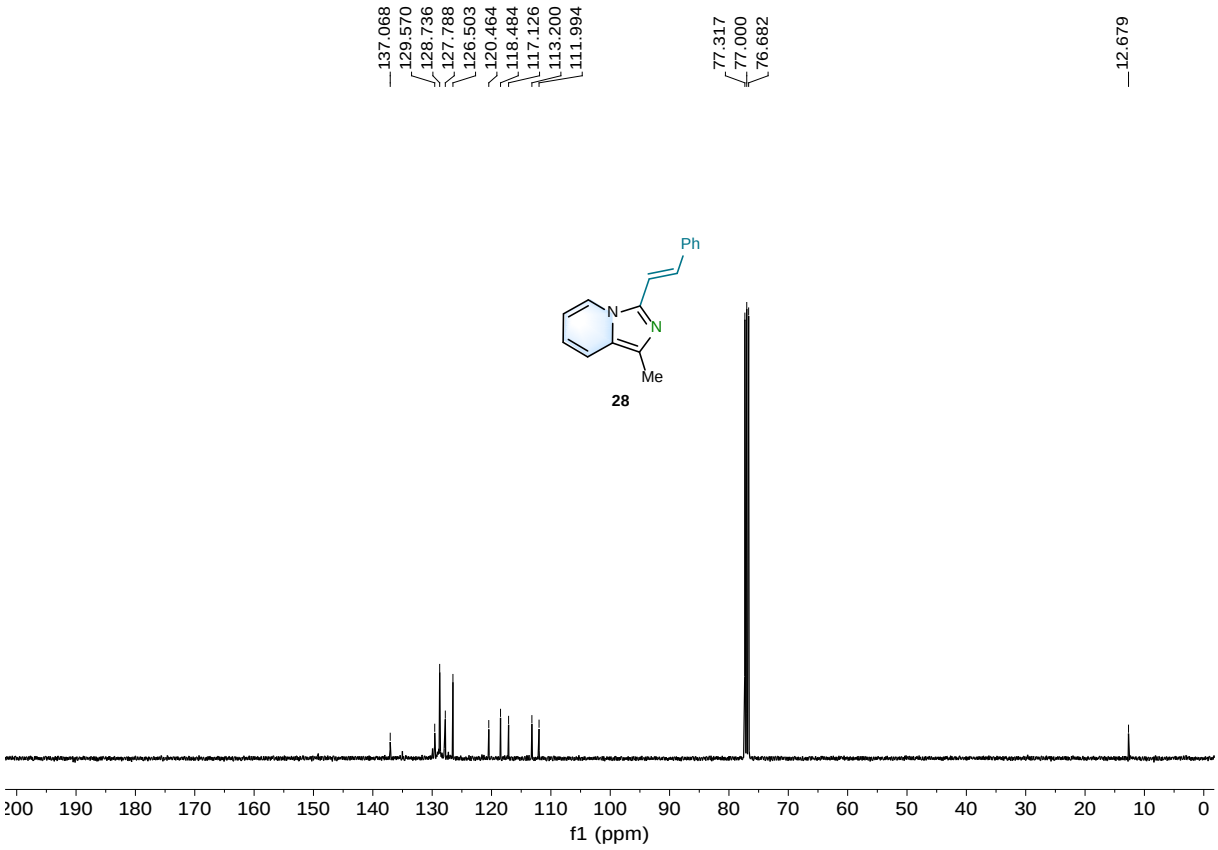
^{13}C NMR spectrum of **27** (100 MHz, $CDCl_3$)



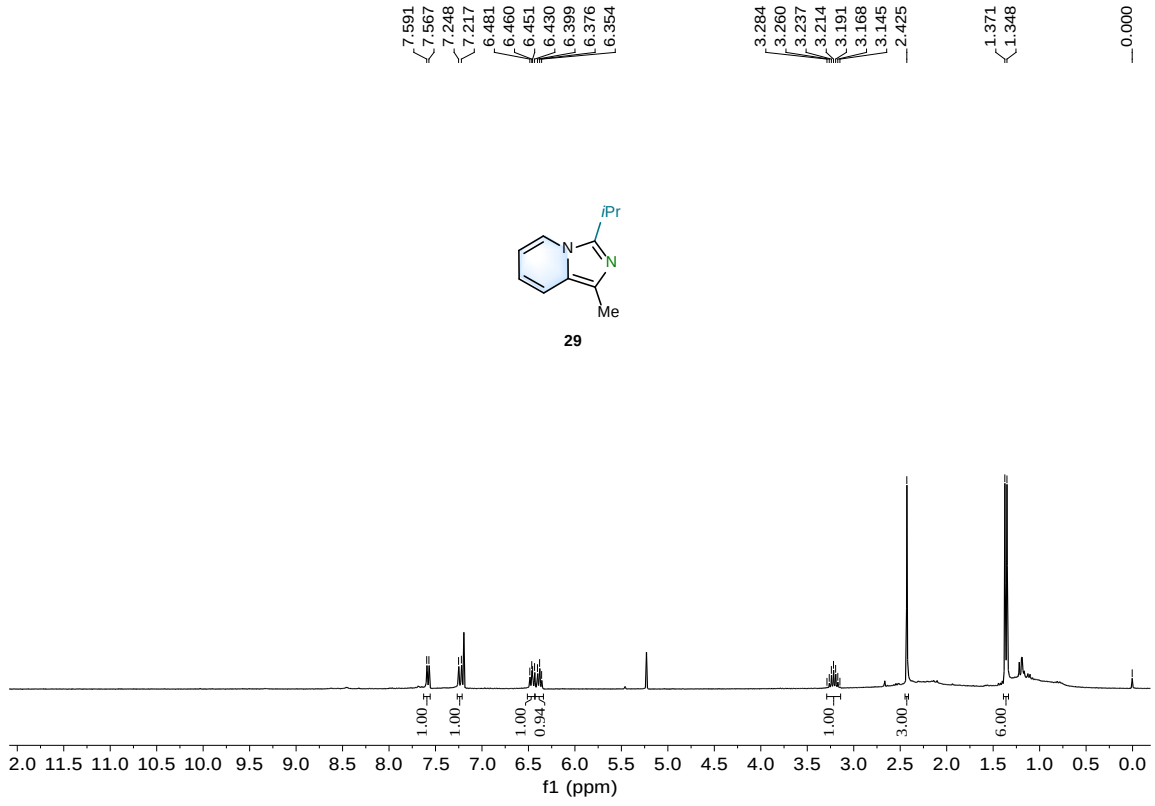
^{1}H NMR spectrum of **28** (400 MHz, $CDCl_3$)



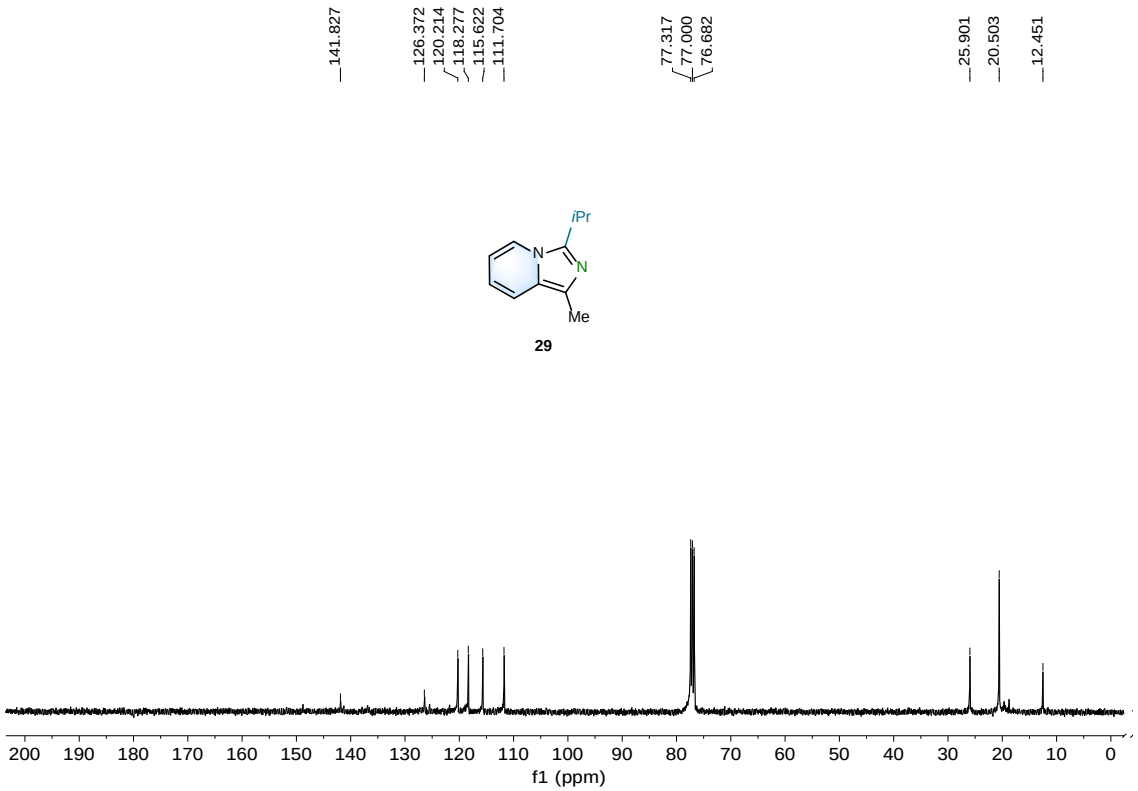
^{13}C NMR spectrum of **28** (100 MHz, $CDCl_3$)



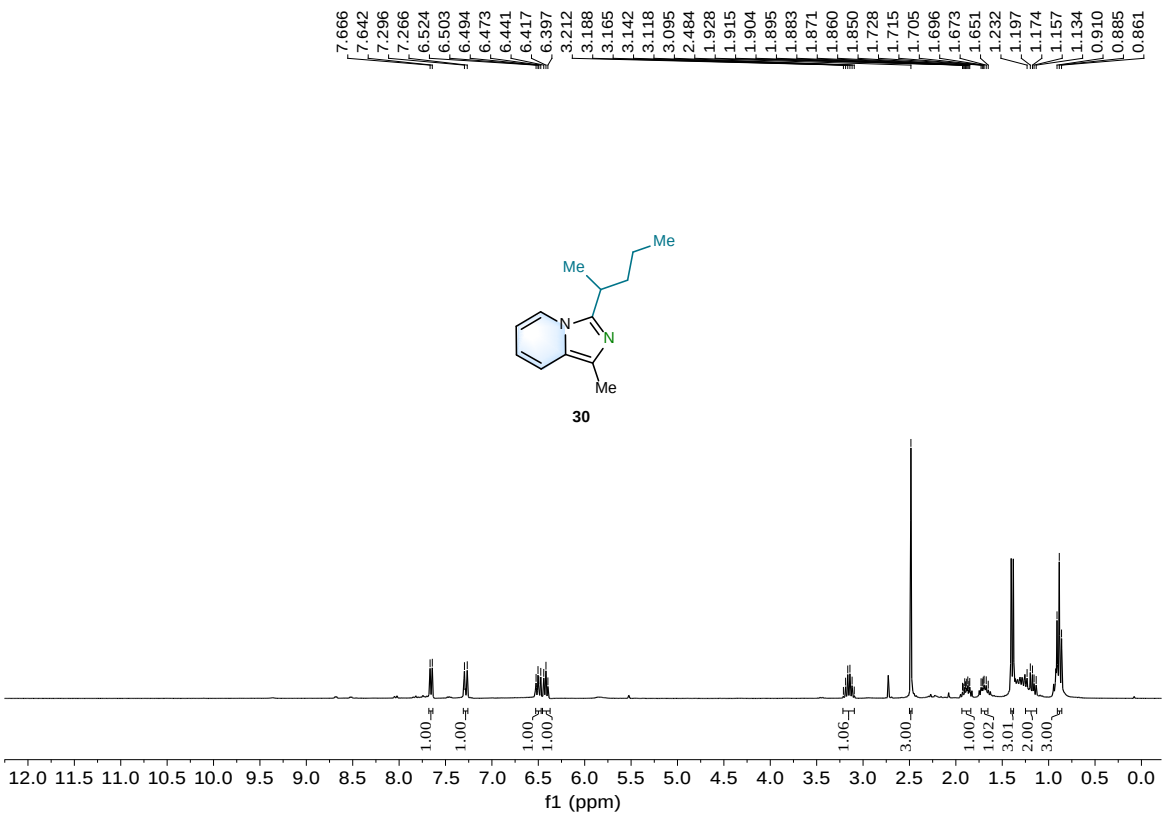
^{1}H NMR spectrum of **29** (300 MHz, $CDCl_3$)



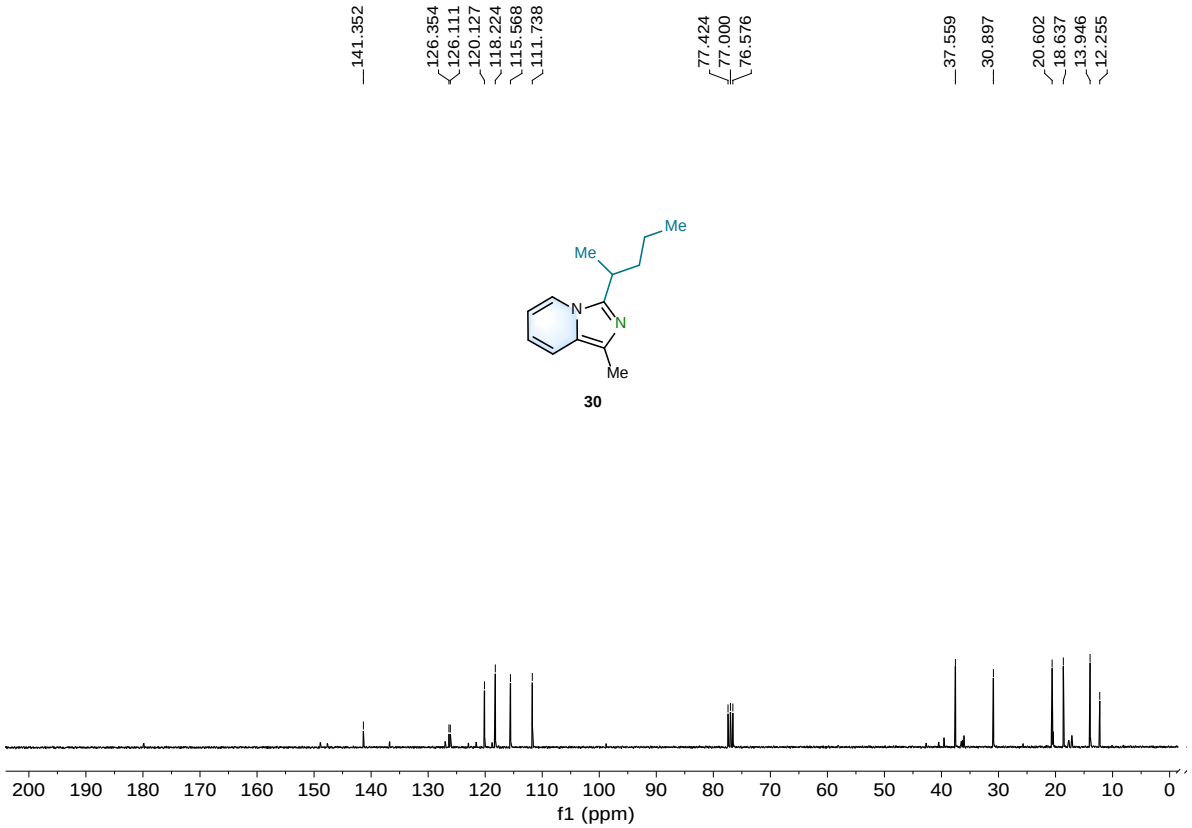
^{13}C NMR spectrum of **29** (100 MHz, $CDCl_3$)



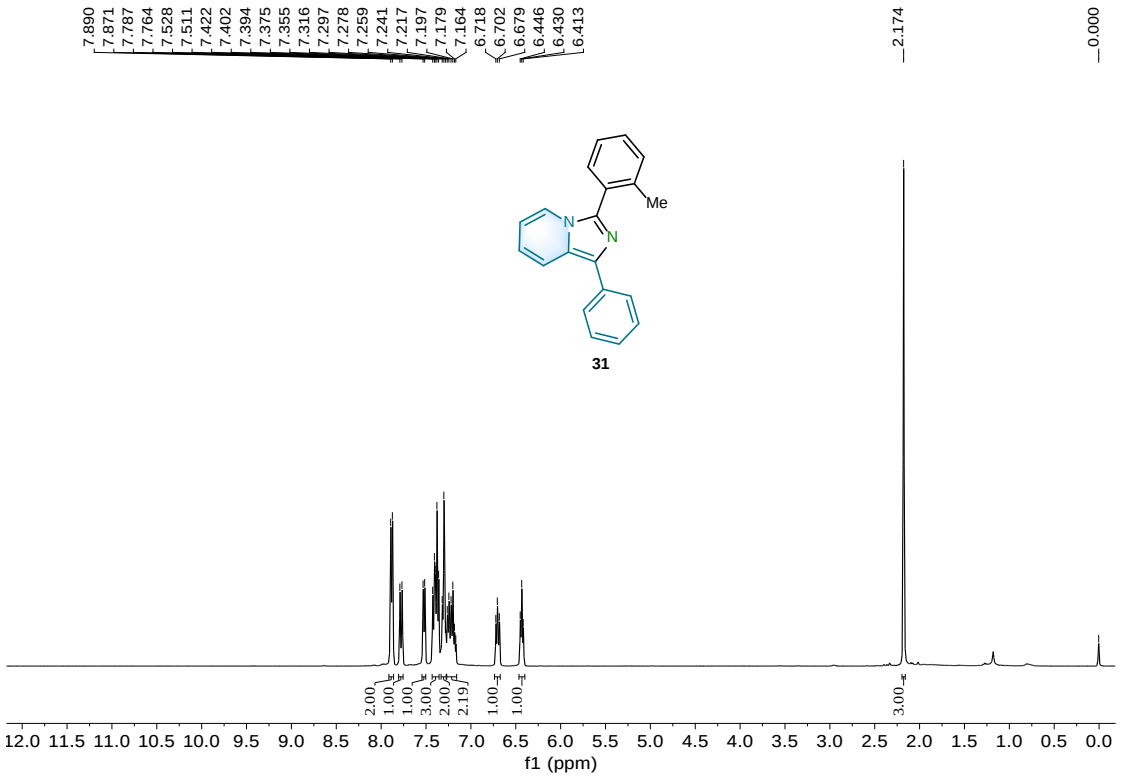
^{1}H NMR spectrum of **30** (300 MHz, $CDCl_3$)



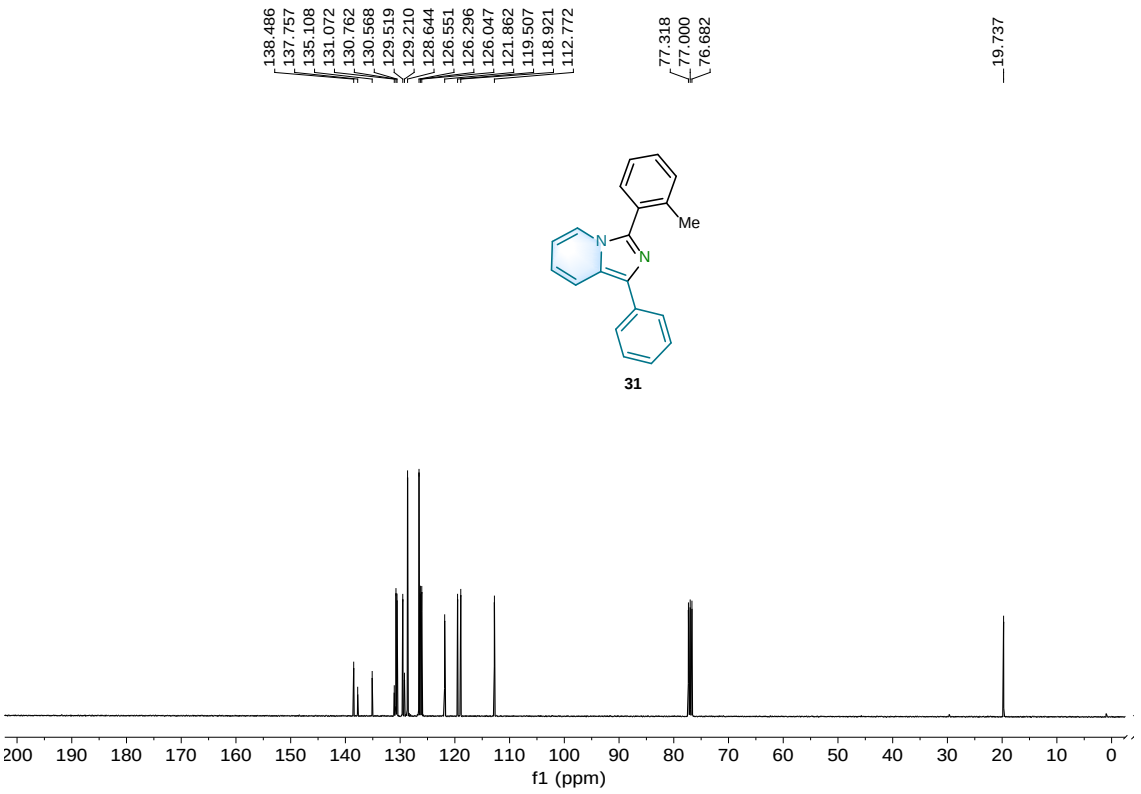
^{13}C NMR spectrum of **30** (75 MHz, $CDCl_3$)



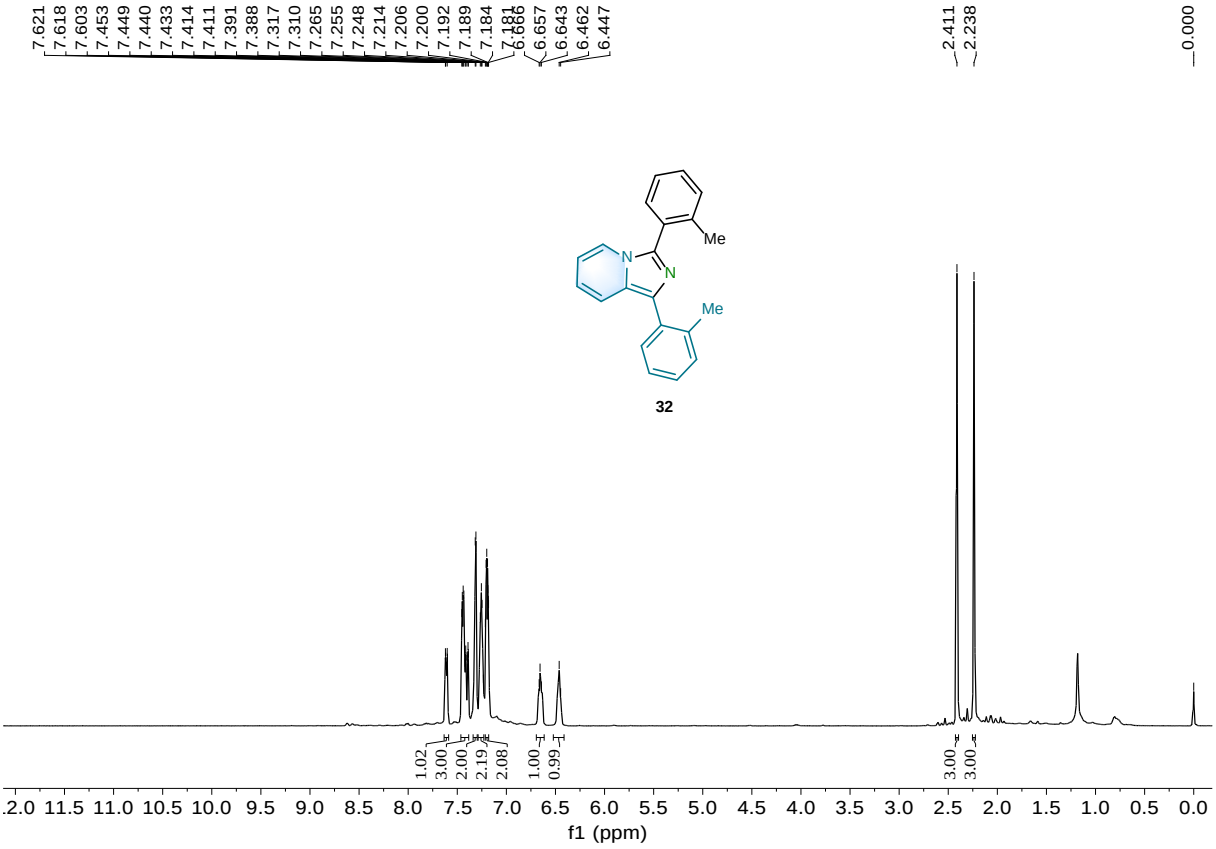
^{1}H NMR spectrum of **31** (400 MHz, $CDCl_3$)



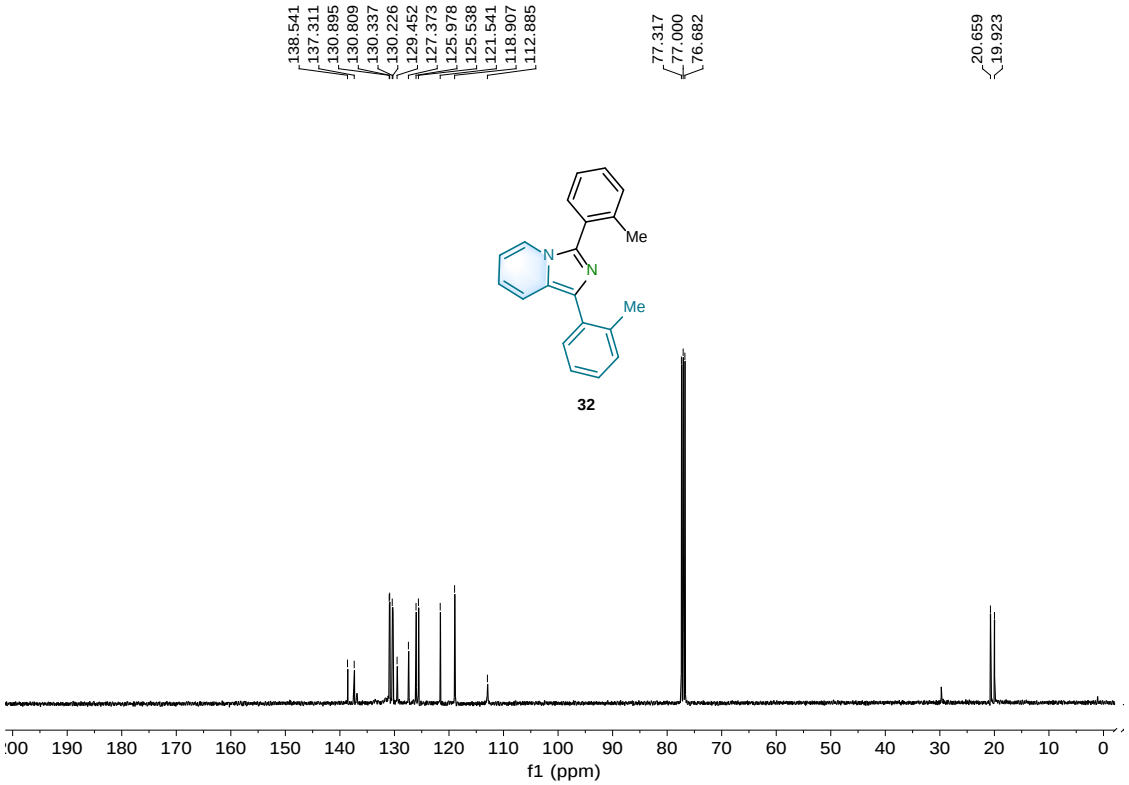
^{13}C NMR spectrum of **31** (100 MHz, $CDCl_3$)



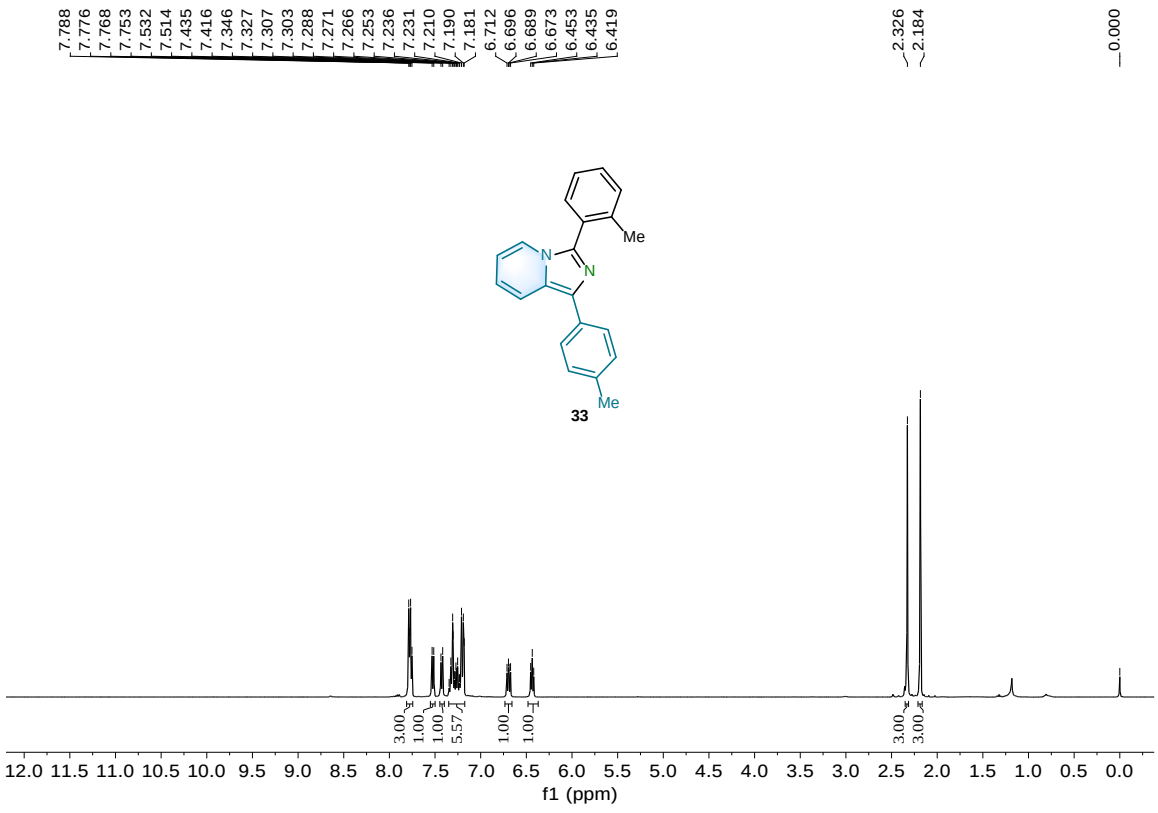
^{1}H NMR spectrum of **32** (400 MHz, $CDCl_3$)



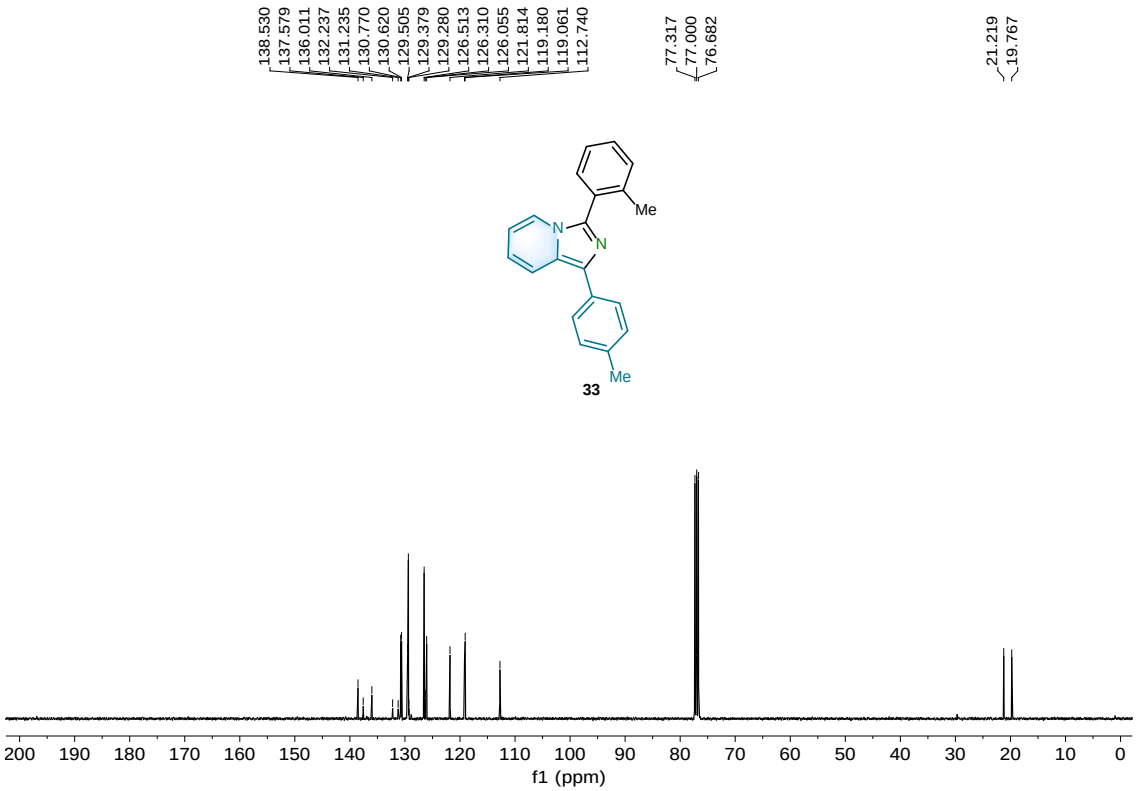
^{13}C NMR spectrum of **32** (100 MHz, $CDCl_3$)



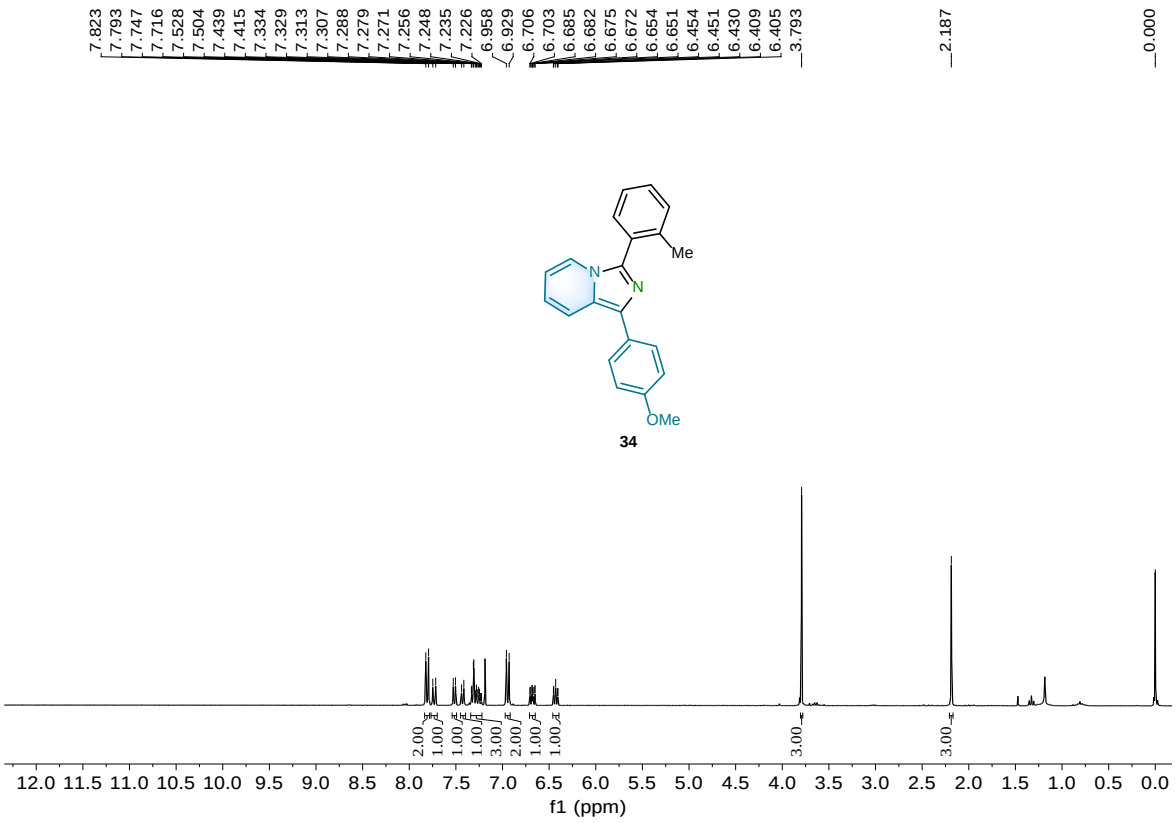
^{1}H NMR spectrum of **33** (400 MHz, $CDCl_3$)



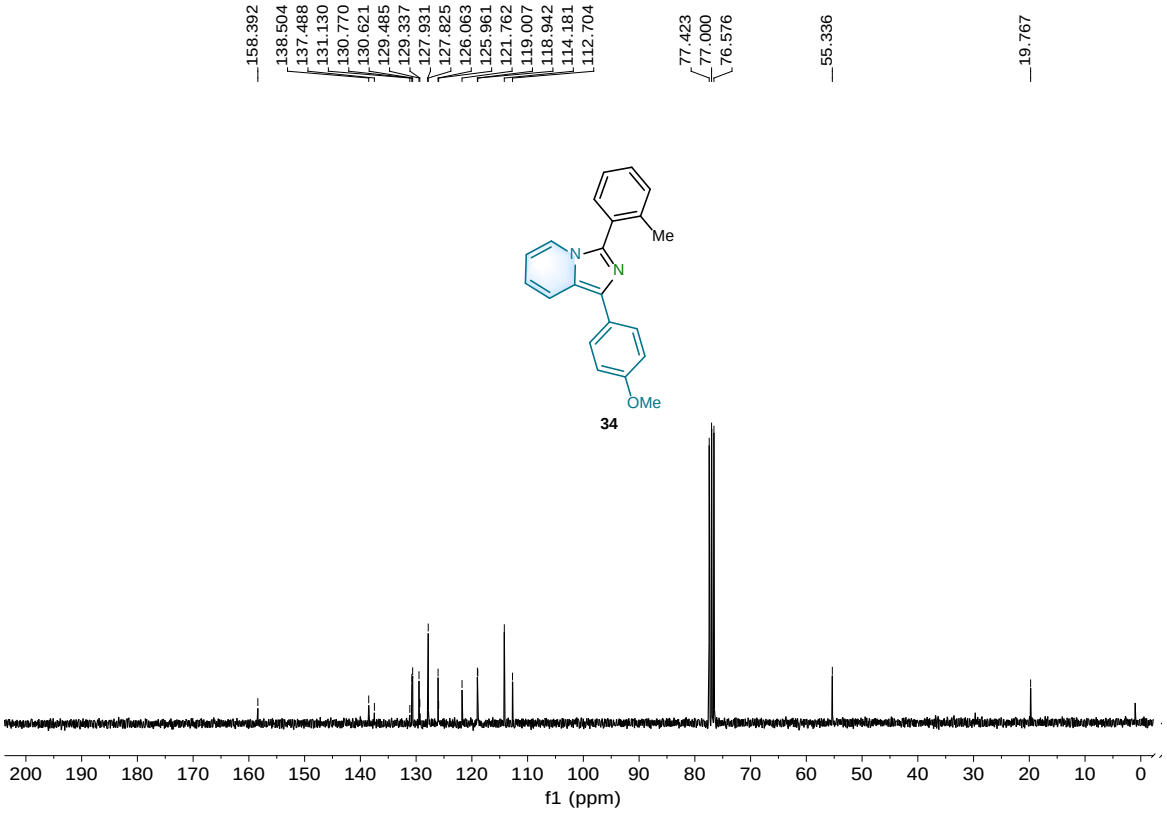
^{13}C NMR spectrum of **33** (100 MHz, $CDCl_3$)



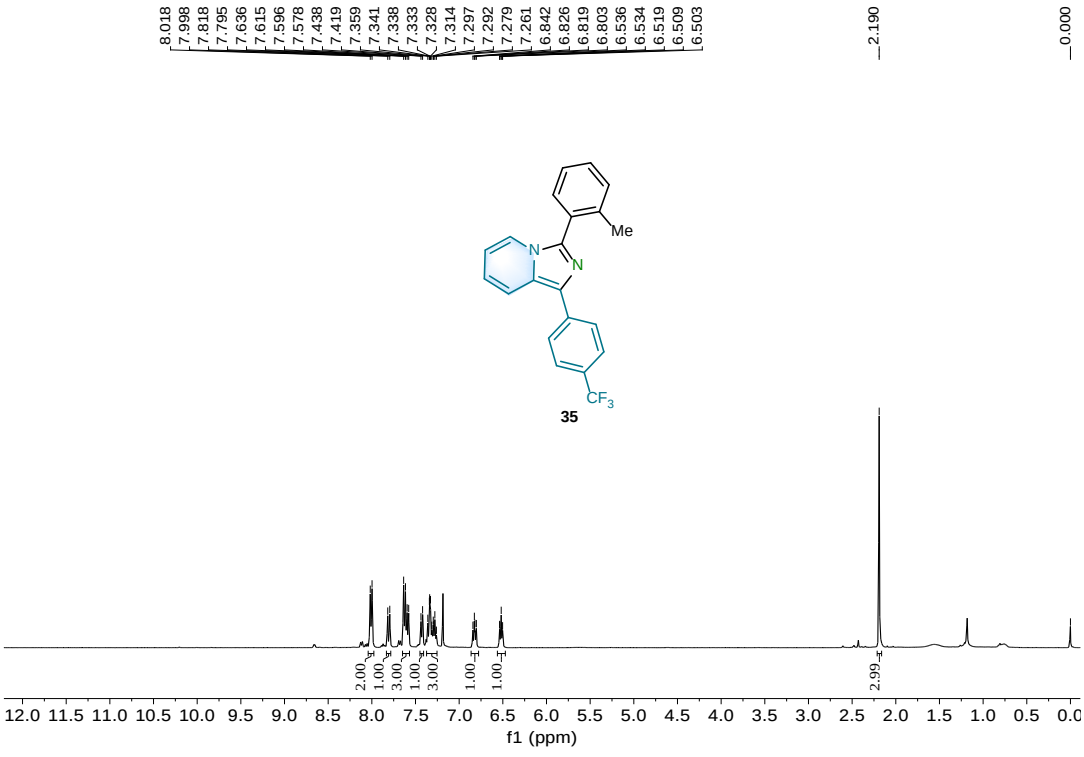
^{1}H NMR spectrum of **34** (300 MHz, $CDCl_3$)



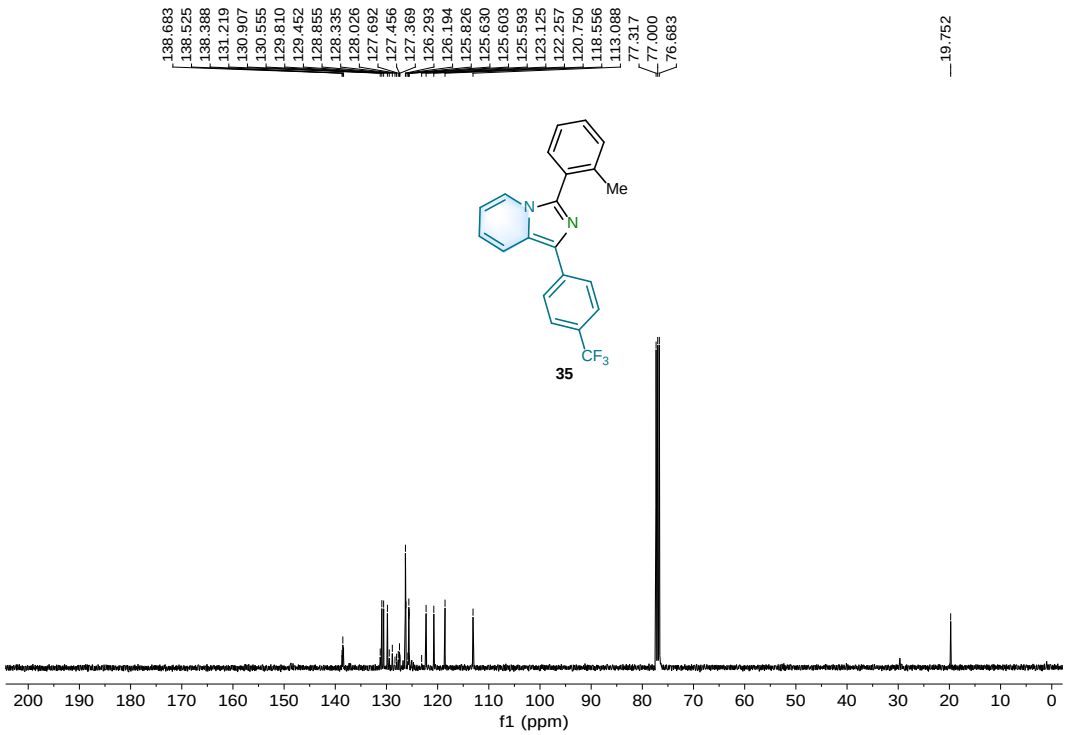
^{13}C NMR spectrum of **34** (100 MHz, $CDCl_3$)



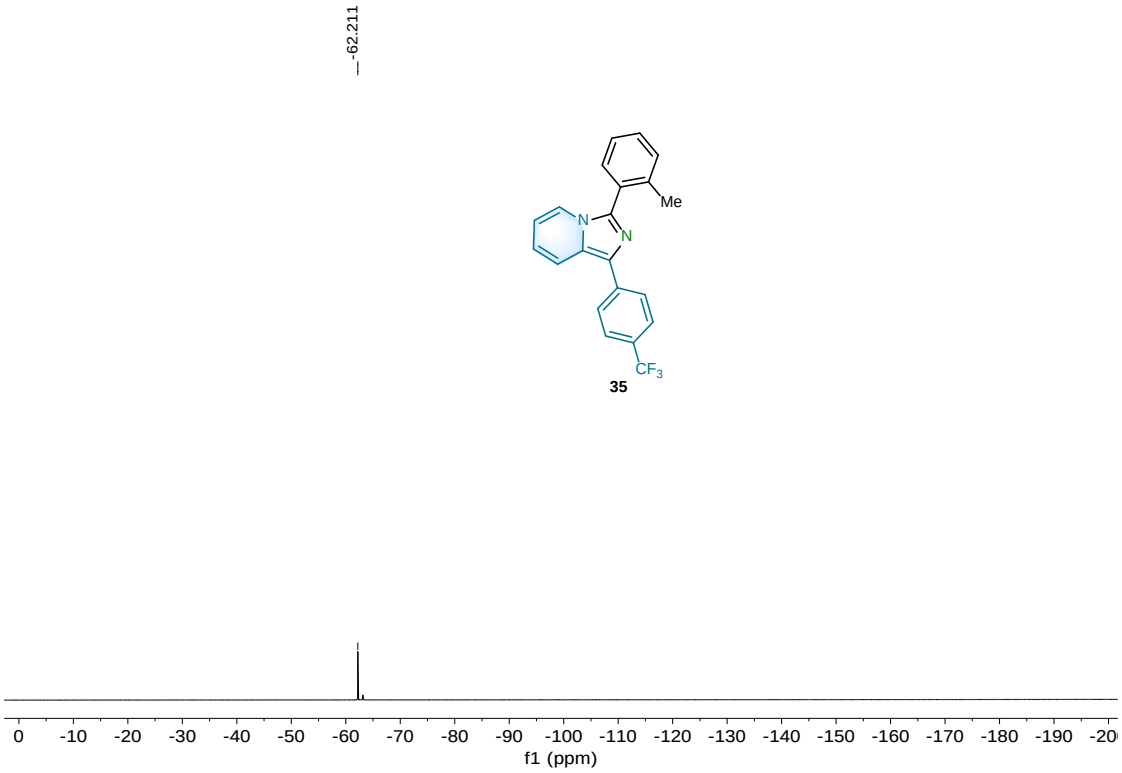
^{1}H NMR spectrum of **35** (400 MHz, $CDCl_3$)



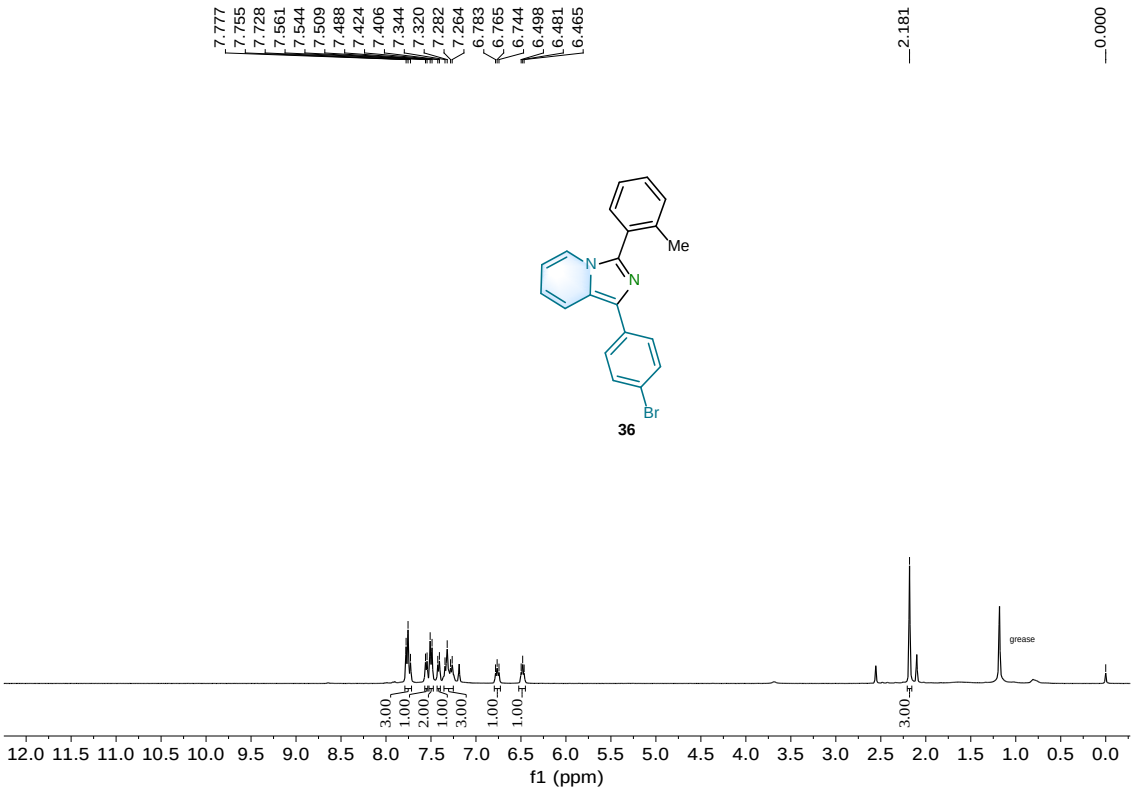
^{13}C NMR spectrum of **35** (100 MHz, $CDCl_3$)



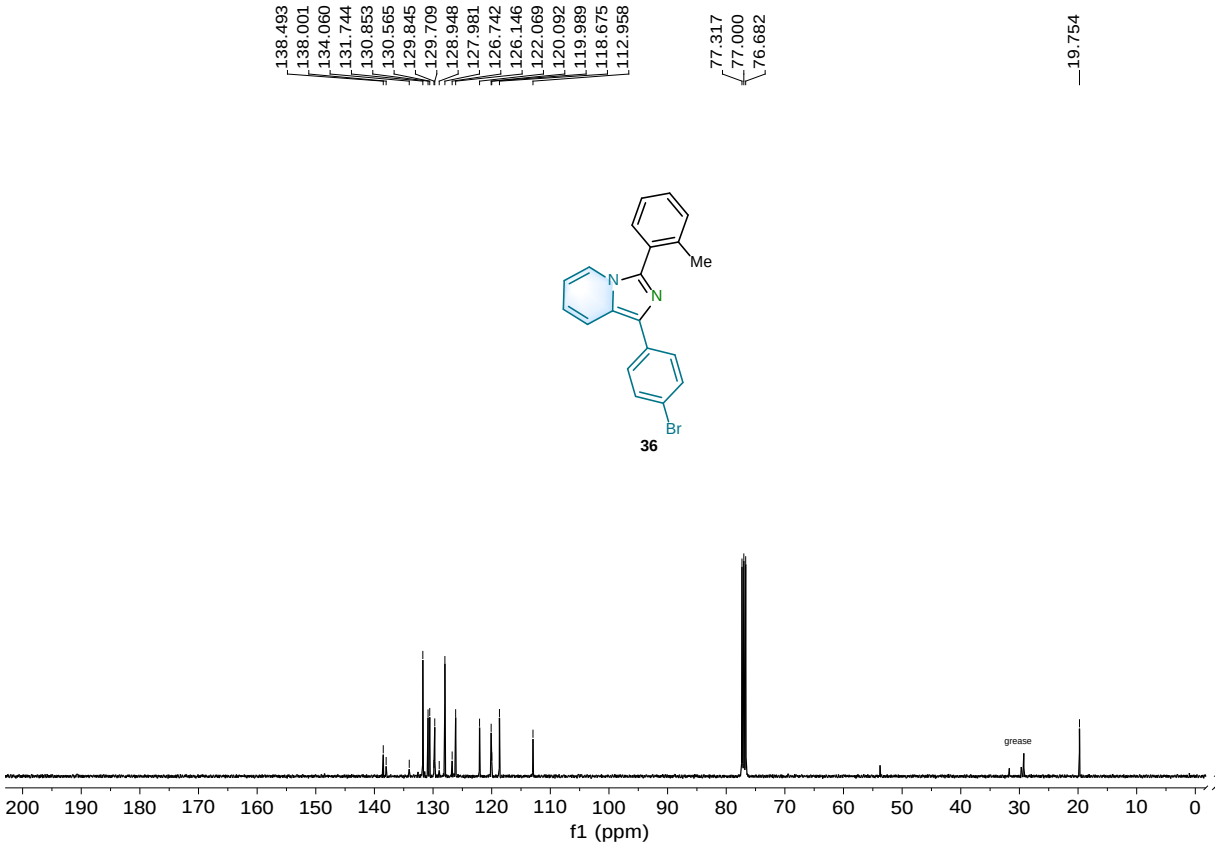
^{19}F NMR spectrum of **35** (377 MHz, $CDCl_3$)



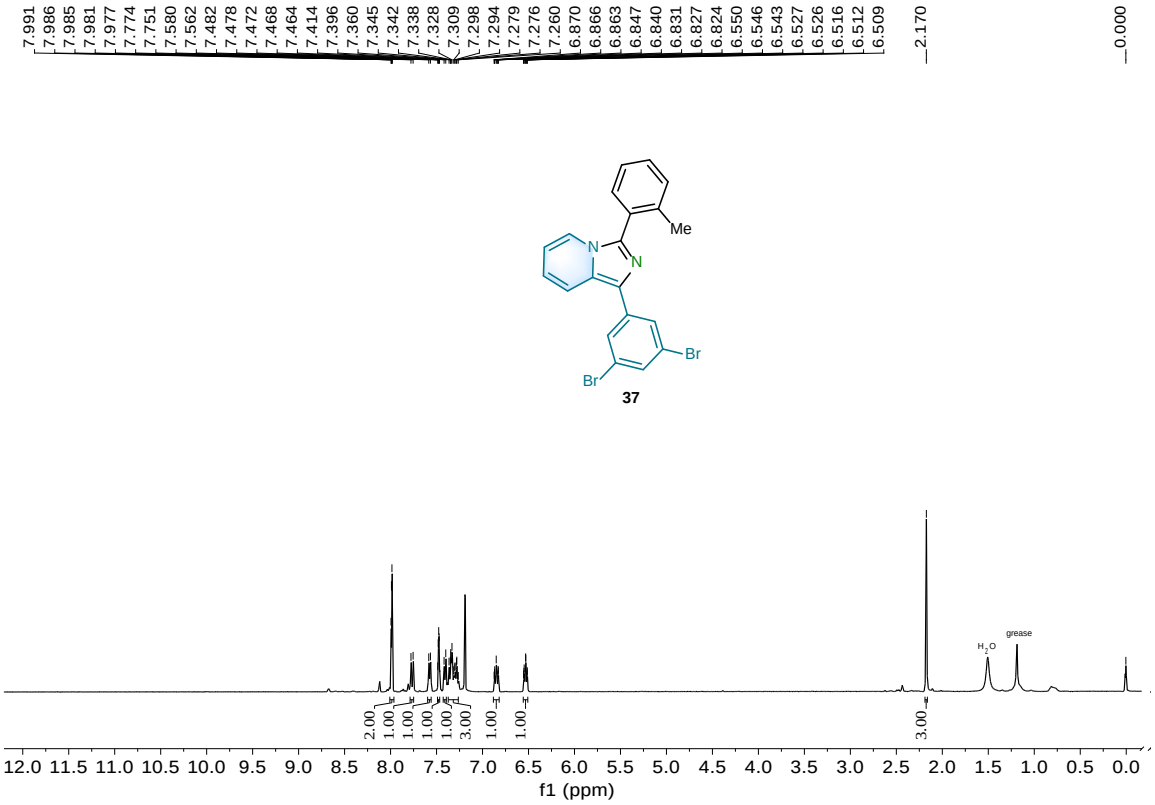
^{1}H NMR spectrum of **36** (400 MHz, $CDCl_3$)



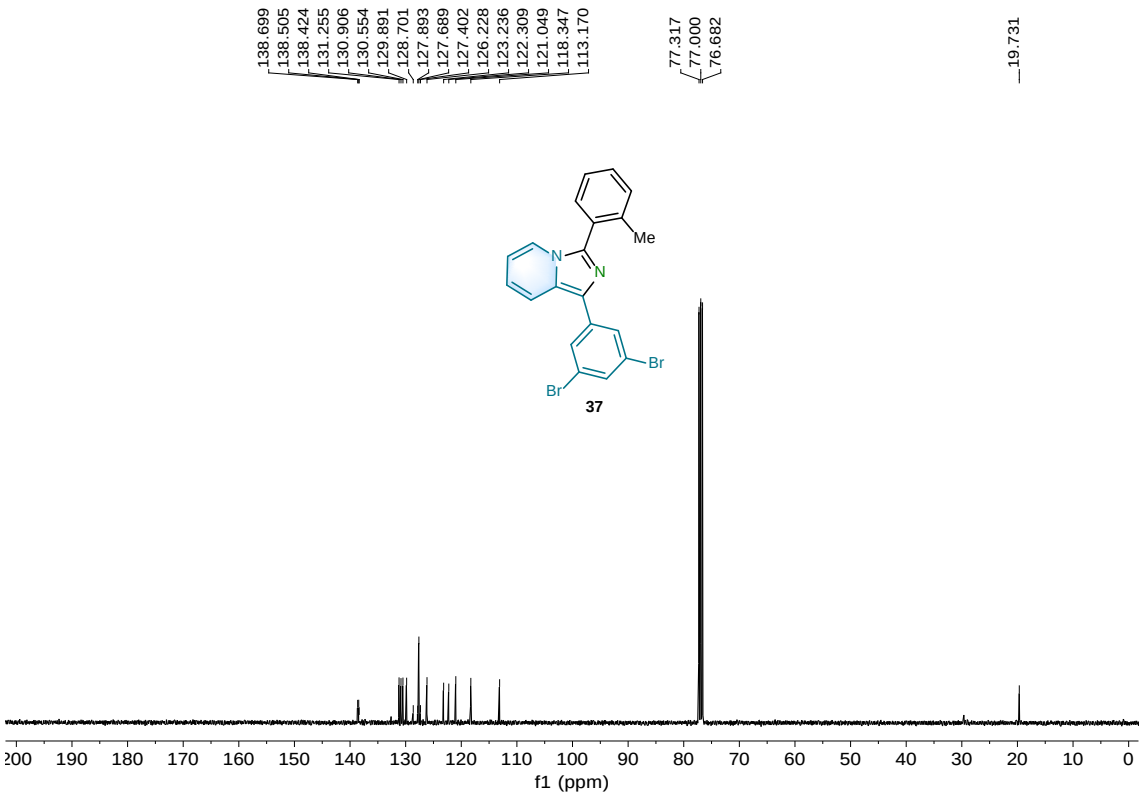
^{13}C NMR spectrum of **36** (100 MHz, $CDCl_3$)



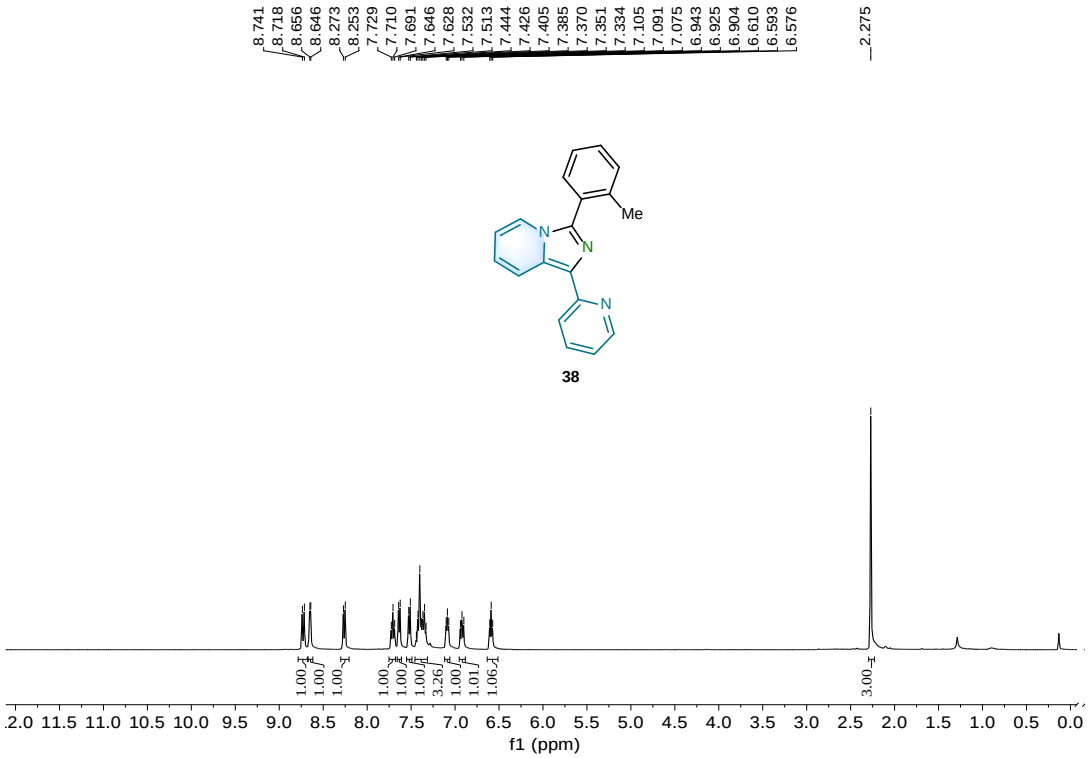
^{1}H NMR spectrum of **37** (400 MHz, $CDCl_3$)



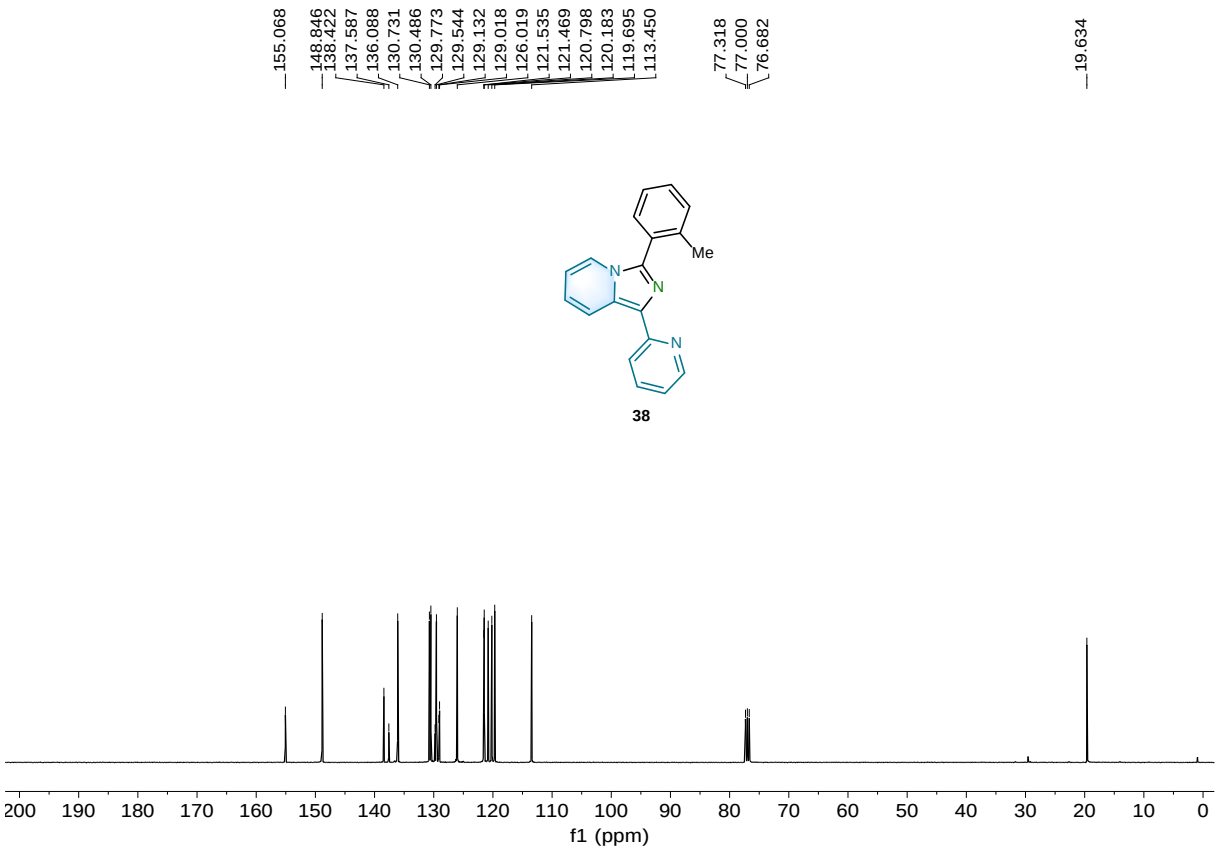
^{13}C NMR spectrum of **37** (100 MHz, $CDCl_3$)



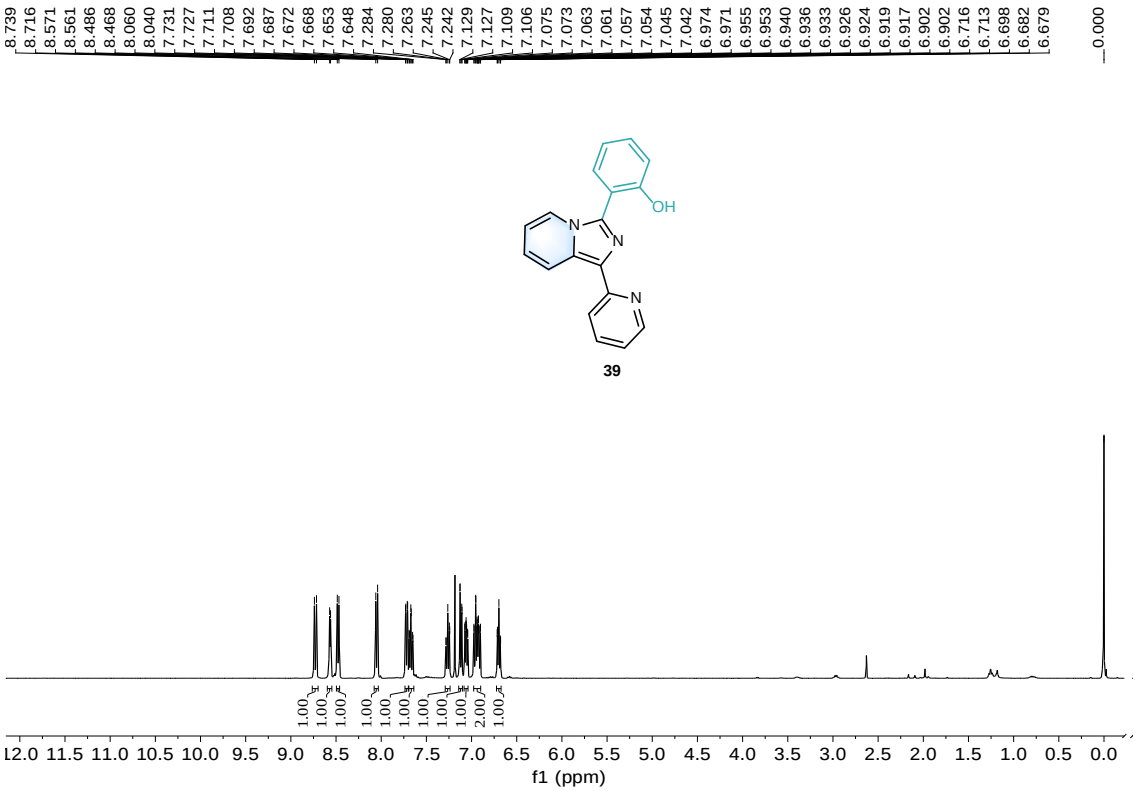
^{1}H NMR spectrum of **38** (400 MHz, $CDCl_3$)



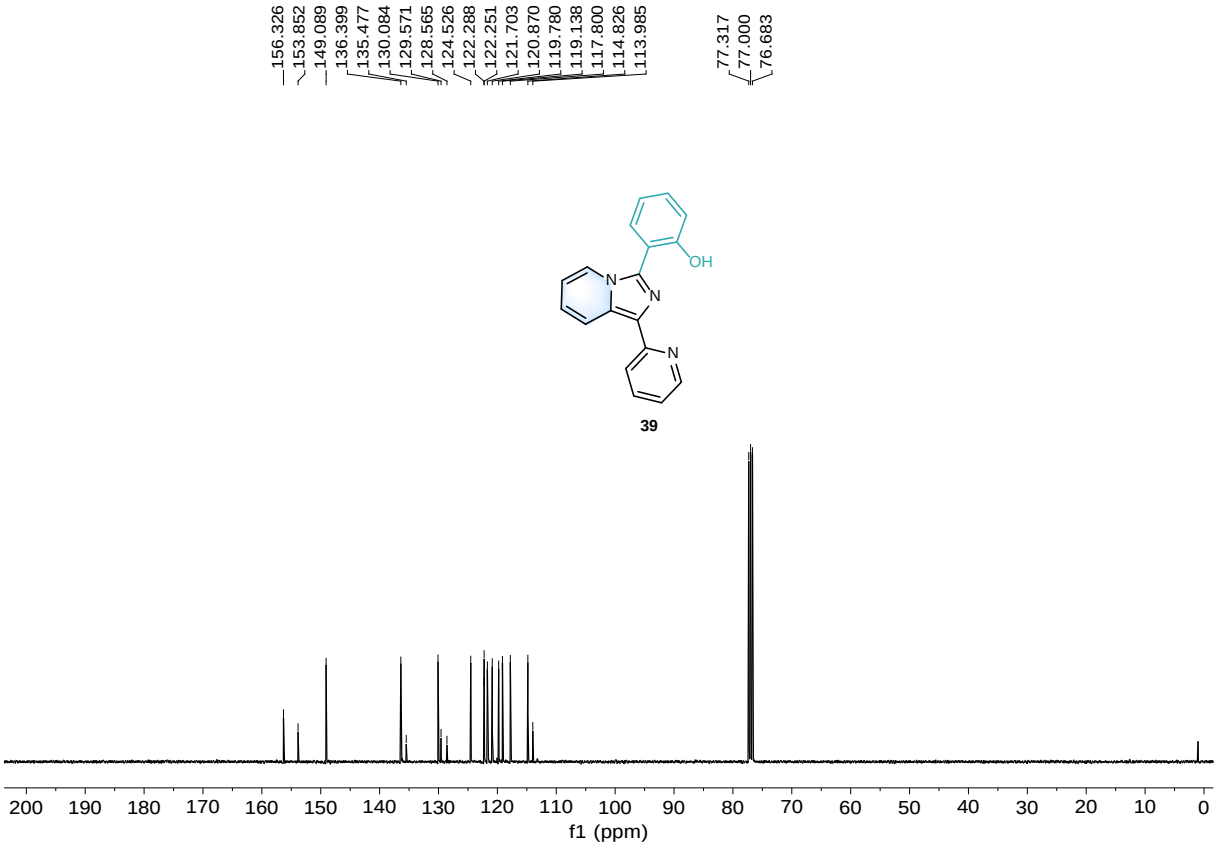
^{13}C NMR spectrum of **38** (100 MHz, $CDCl_3$)



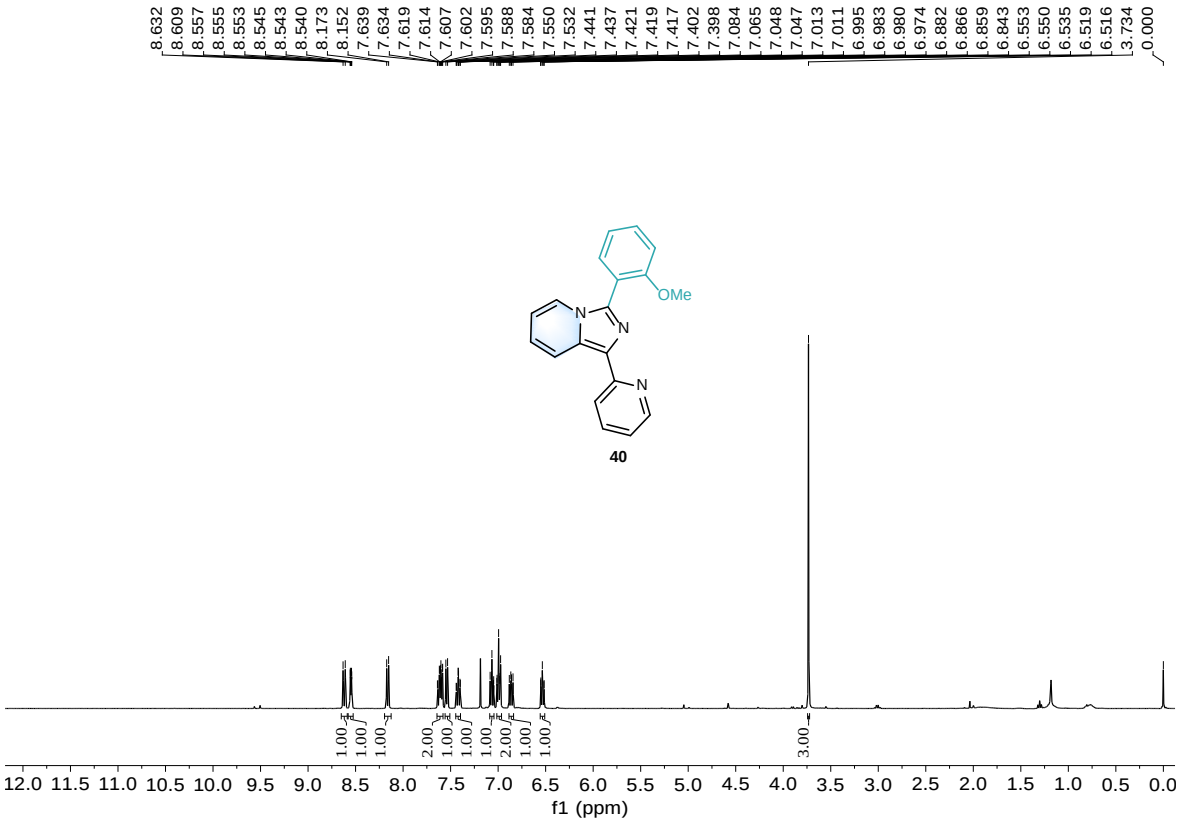
^{1}H NMR spectrum of **39** (400 MHz, $CDCl_3$)



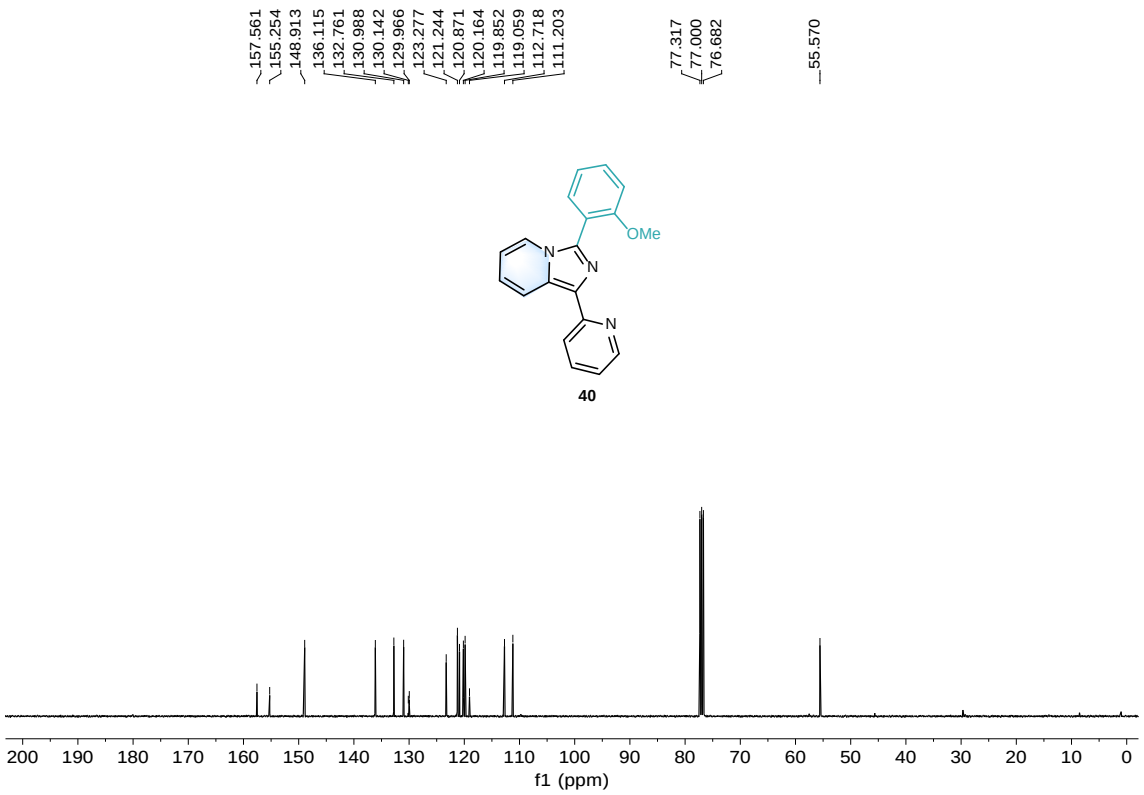
^{13}C NMR spectrum of **39** (100 MHz, $CDCl_3$)



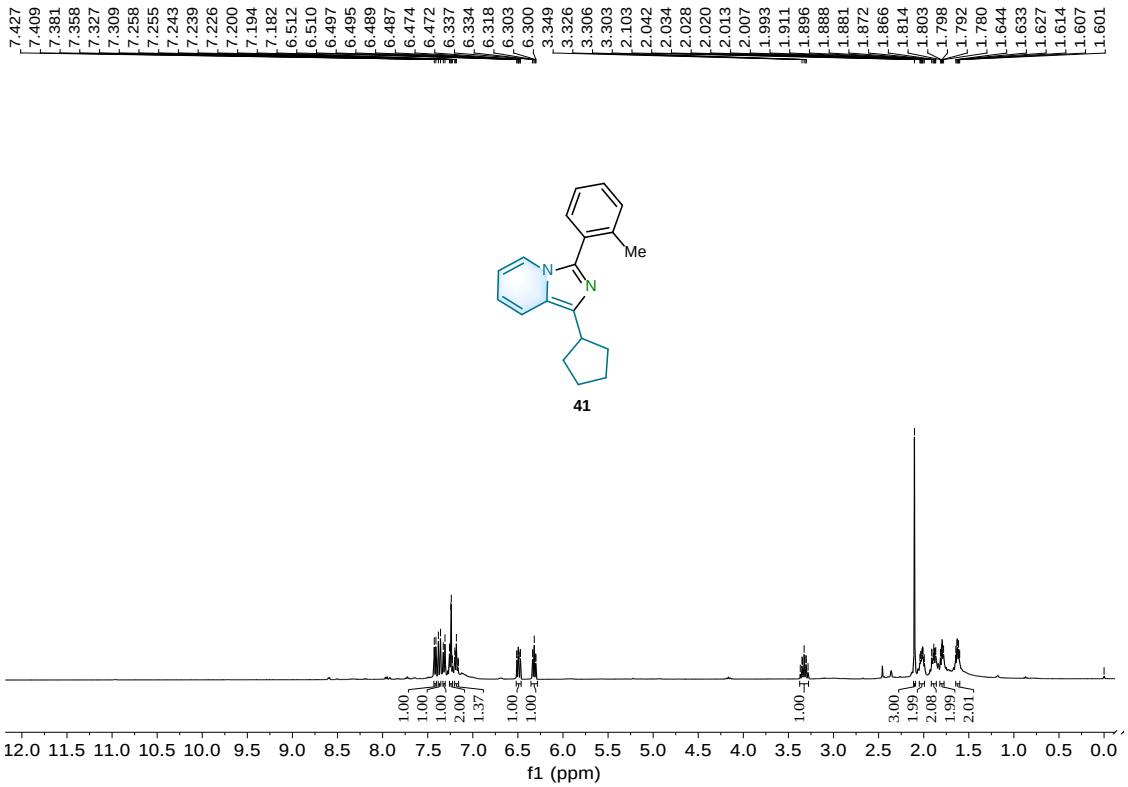
^{1}H NMR spectrum of **40** (400 MHz, $CDCl_3$)



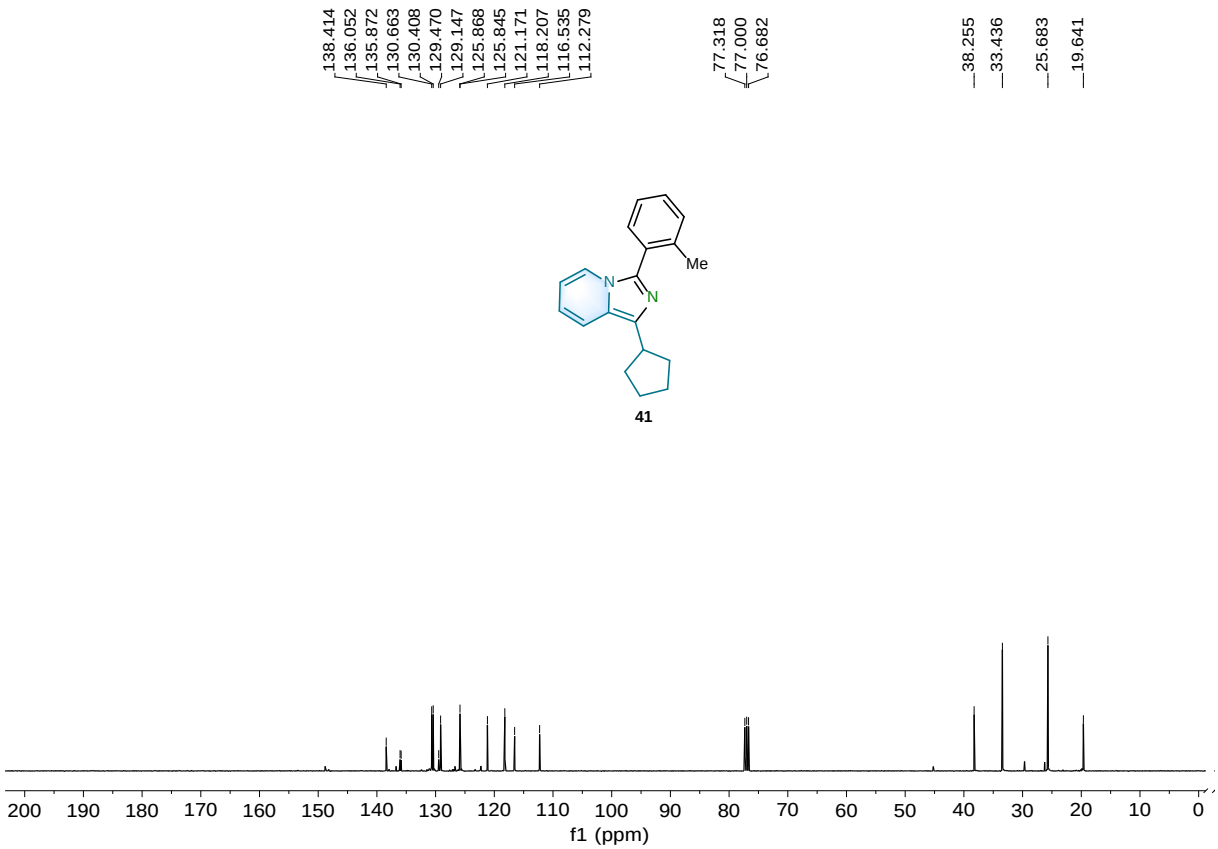
^{13}C NMR spectrum of **40** (100 MHz, $CDCl_3$)



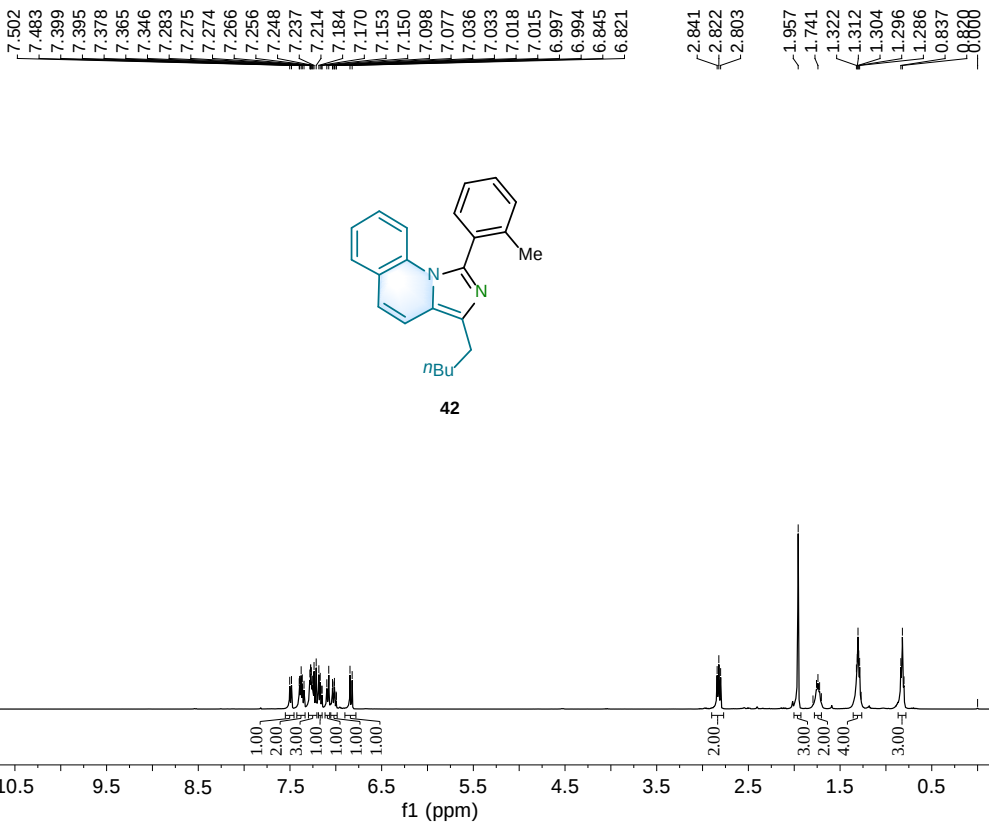
^{1}H NMR spectrum of **41** (400 MHz, $CDCl_3$)



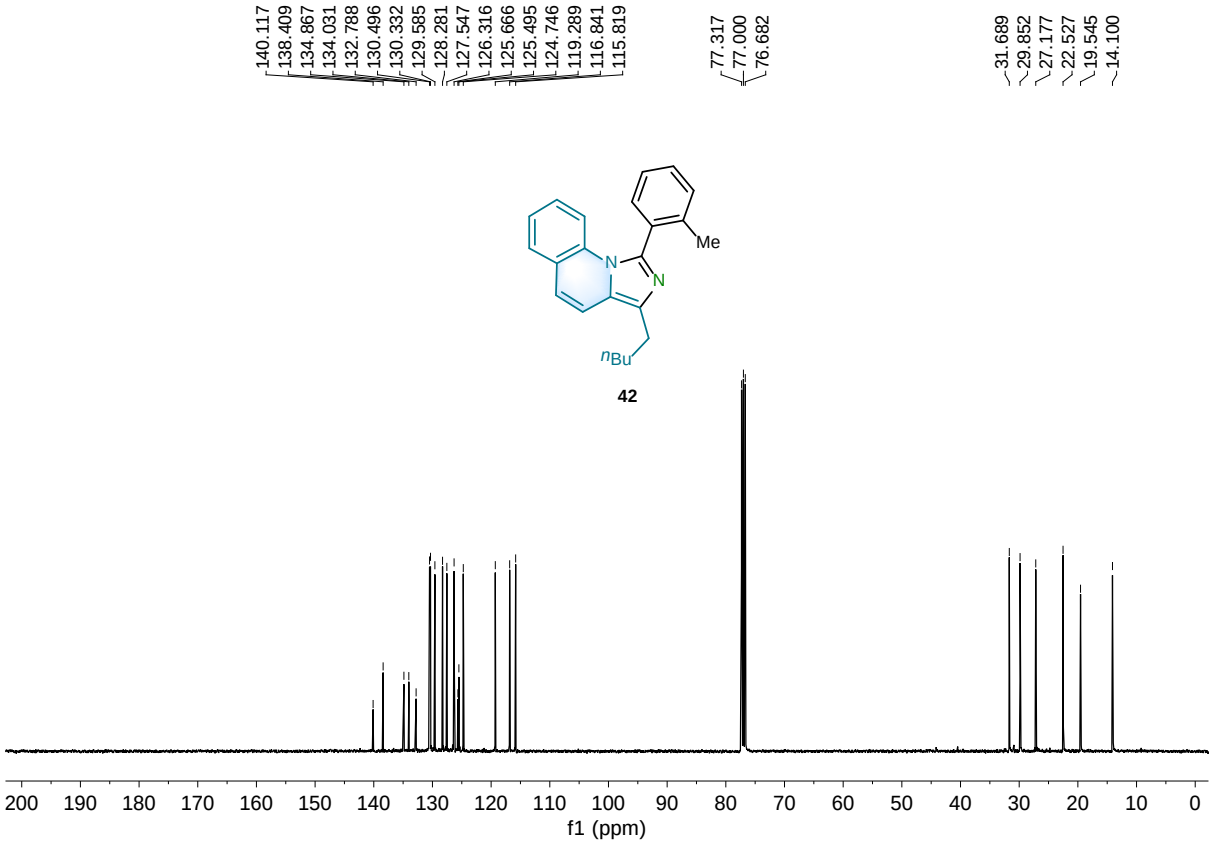
^{13}C NMR spectrum of **41** (100 MHz, $CDCl_3$)



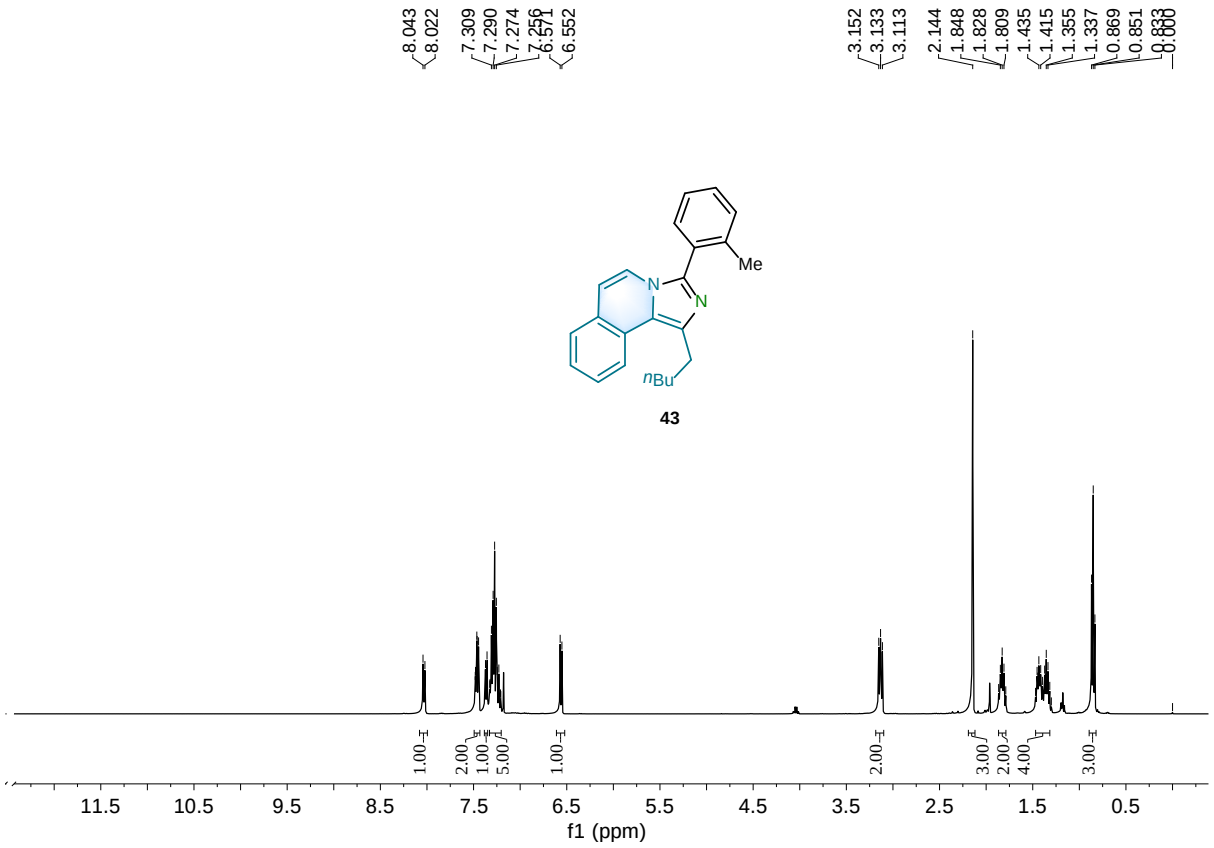
^{1}H NMR spectrum of **42** (400 MHz, $CDCl_3$)



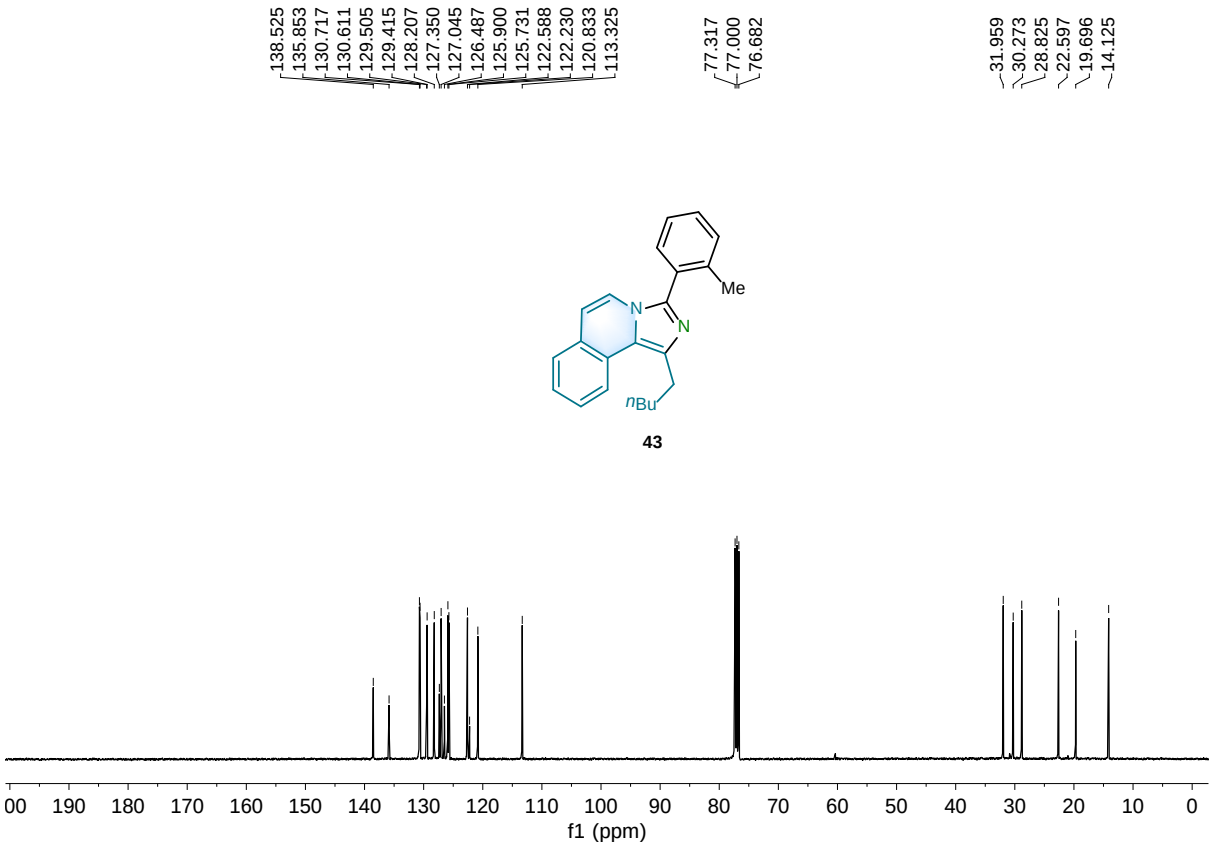
^{13}C NMR spectrum of **42** (100 MHz, $CDCl_3$)



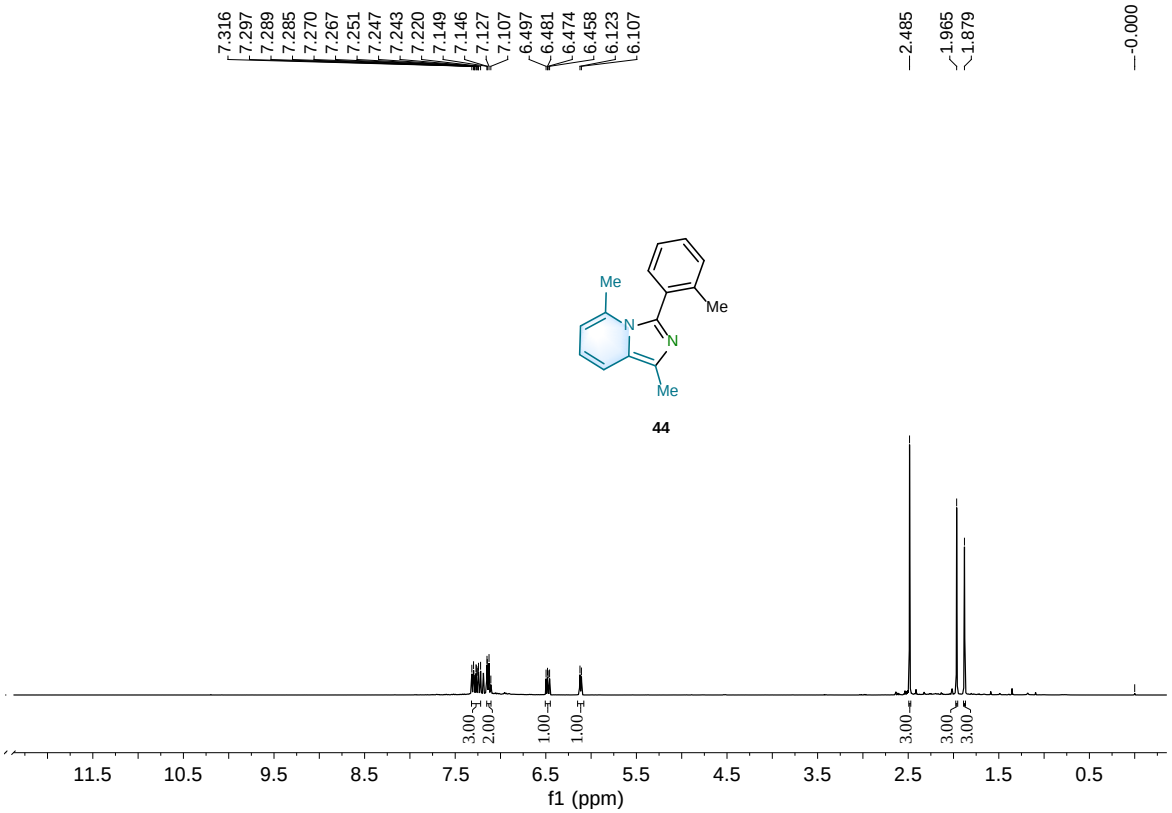
^{1}H NMR spectrum of **43** (400 MHz, $CDCl_3$)



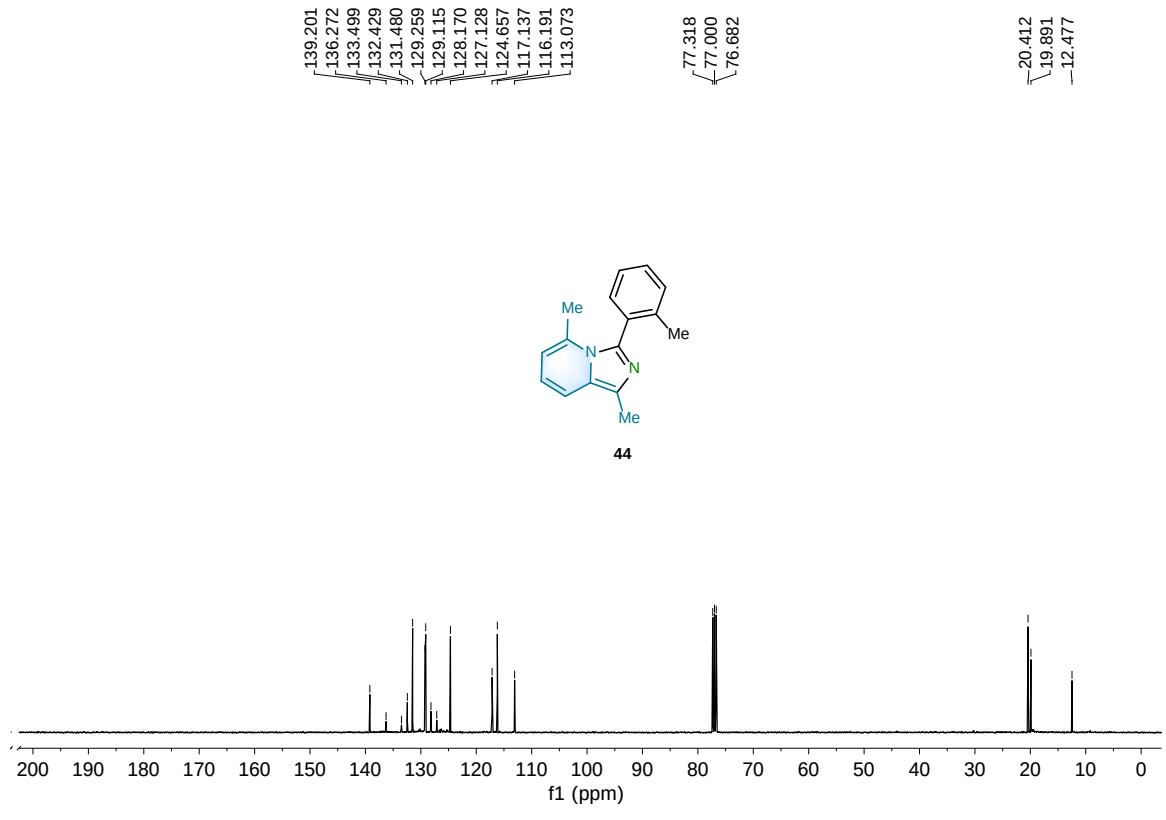
^{13}C NMR spectrum of **43** (100 MHz, $CDCl_3$)



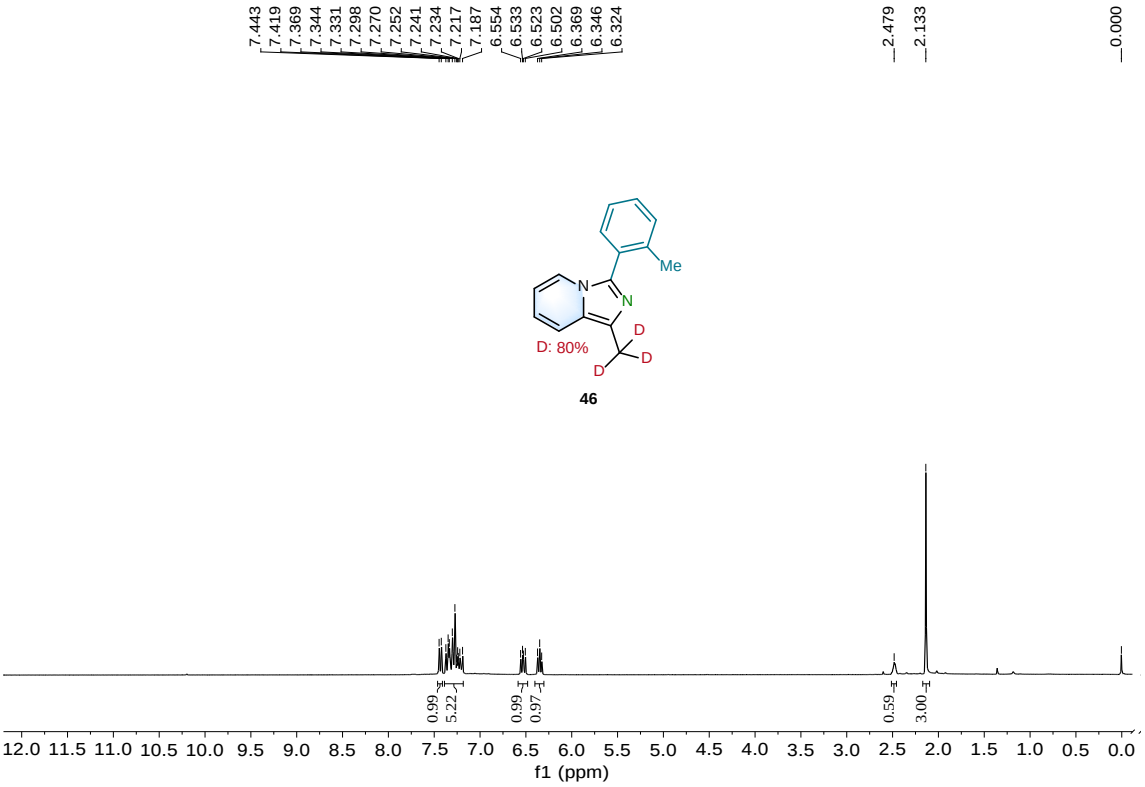
^{1}H NMR spectrum of **44** (400 MHz, $CDCl_3$)



^{13}C NMR spectrum of **44** (100 MHz, $CDCl_3$)

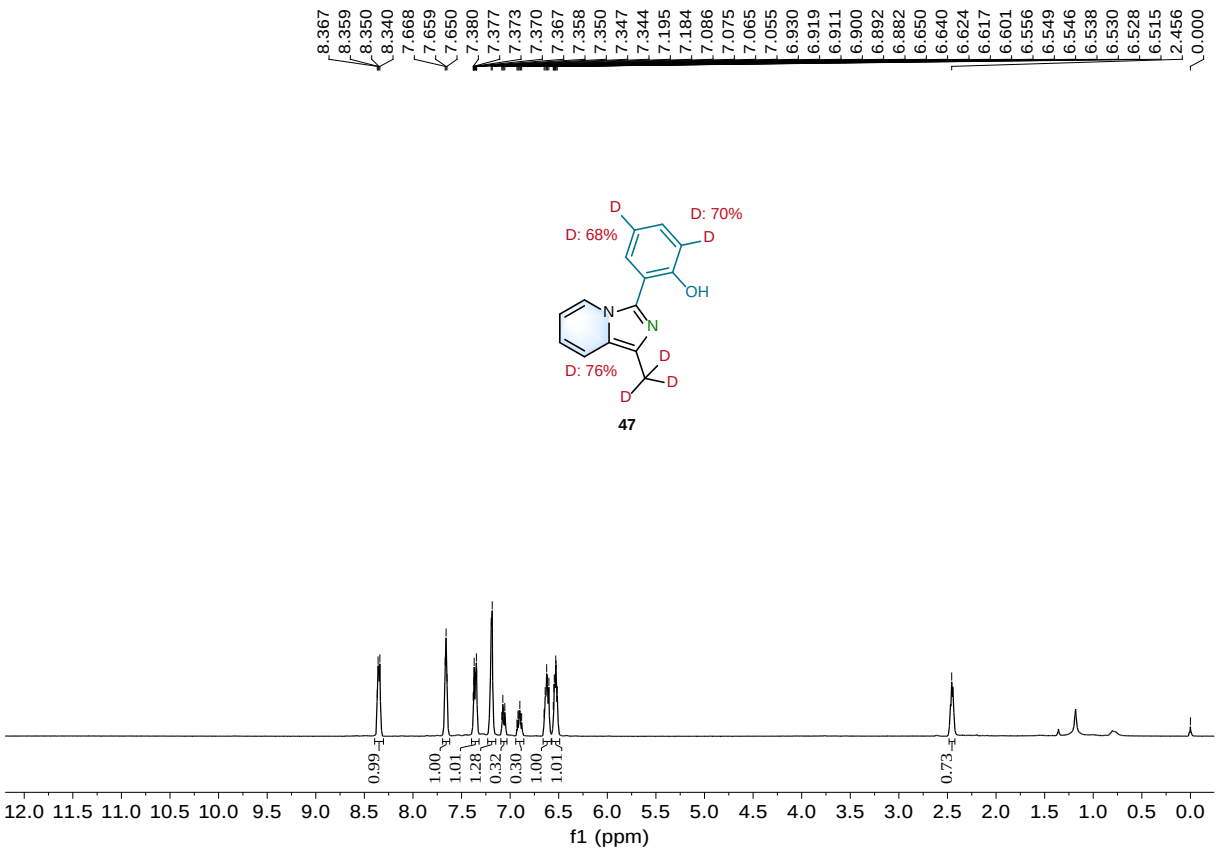


^{1}H NMR spectrum of **46** (300 MHz, $CDCl_3$)



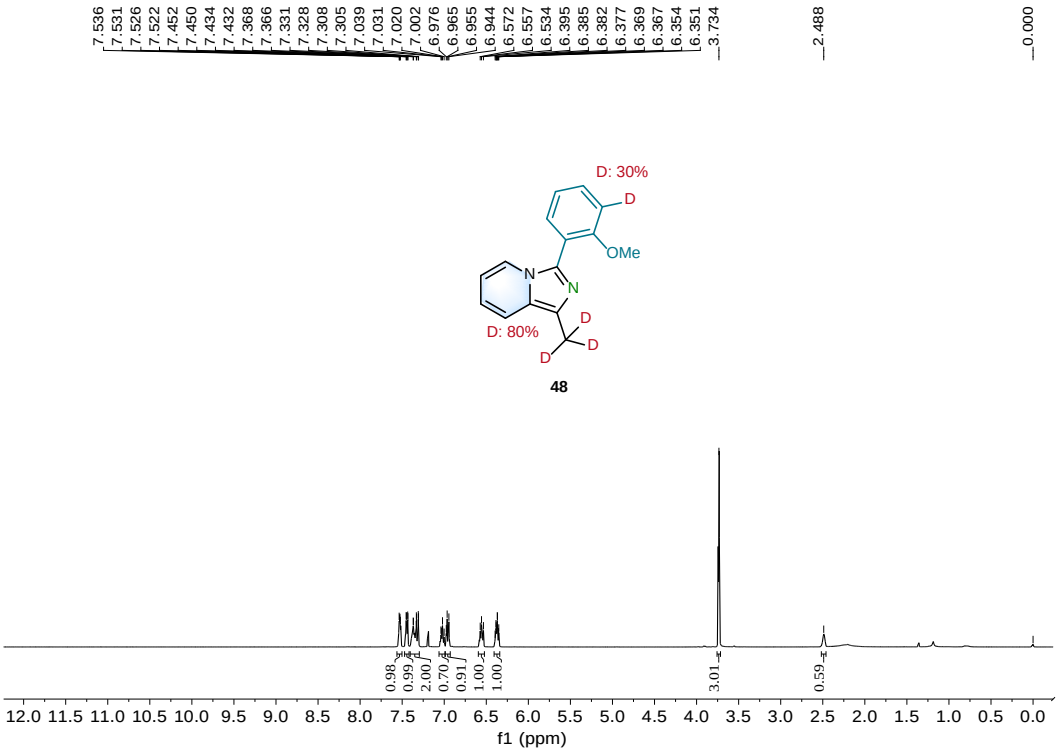
46

^{1}H NMR spectrum of **47** (400 MHz, $CDCl_3$)

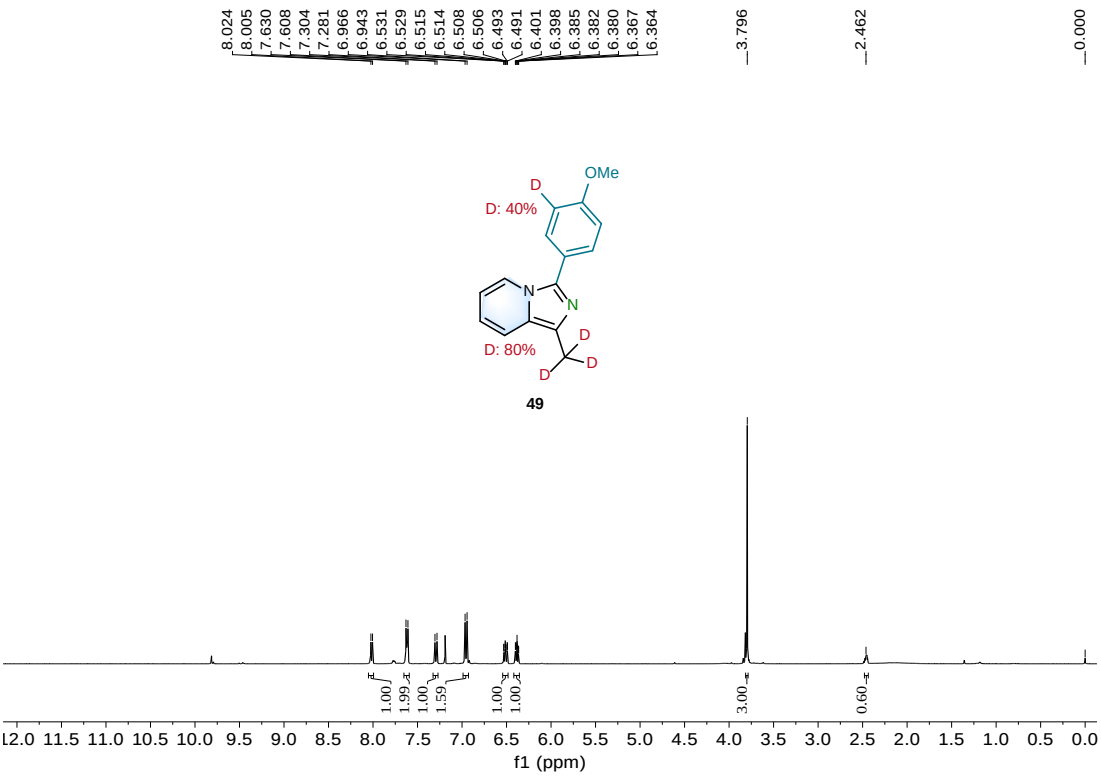


47

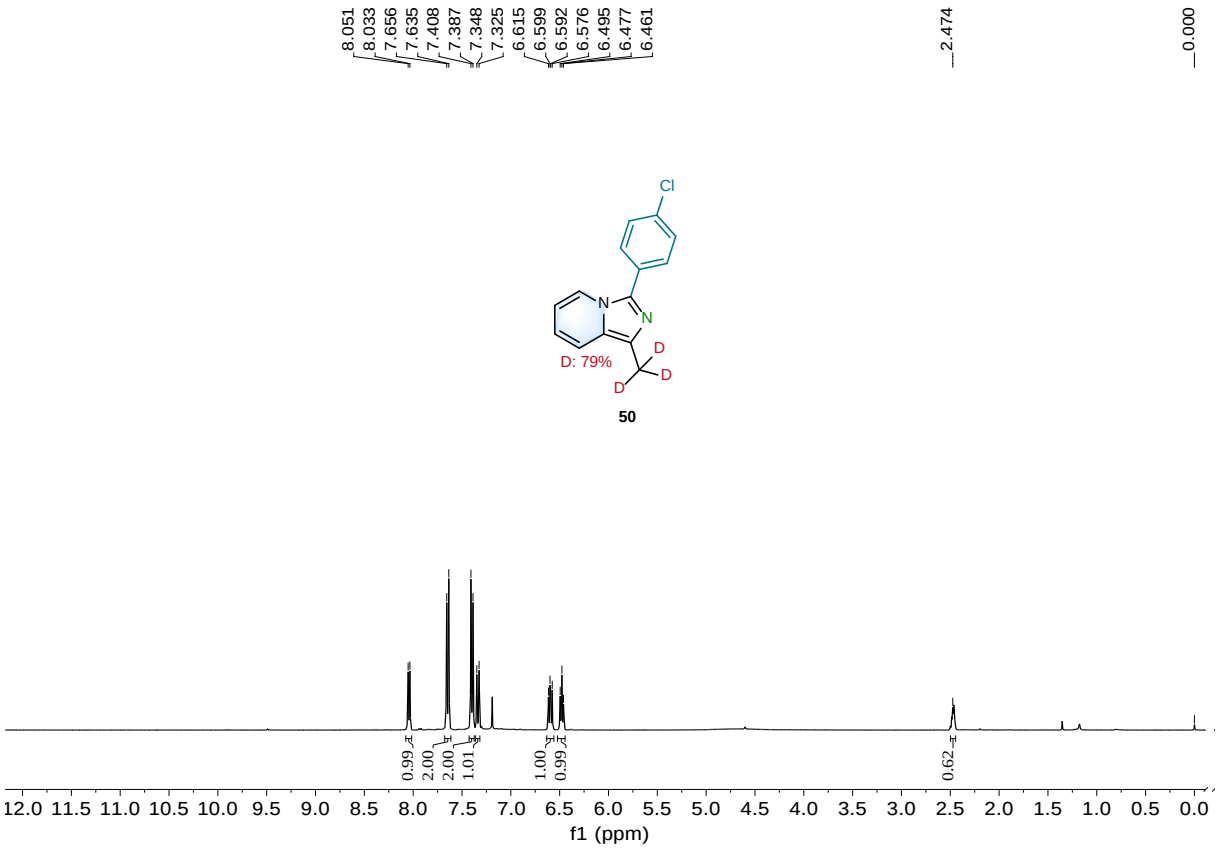
^{1}H NMR spectrum of **48** (400 MHz, $CDCl_3$)



^{1}H NMR spectrum of **49** (400 MHz, $CDCl_3$)

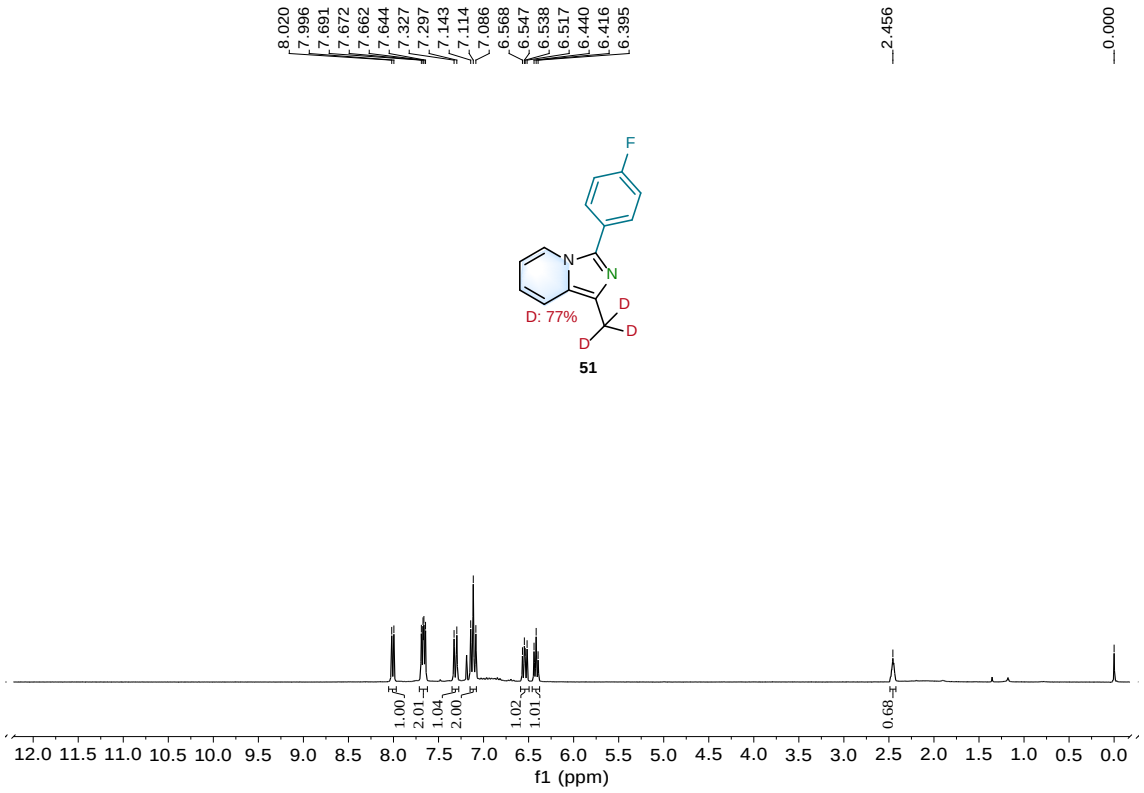


^{1}H NMR spectrum of **50** (400 MHz, $CDCl_3$)



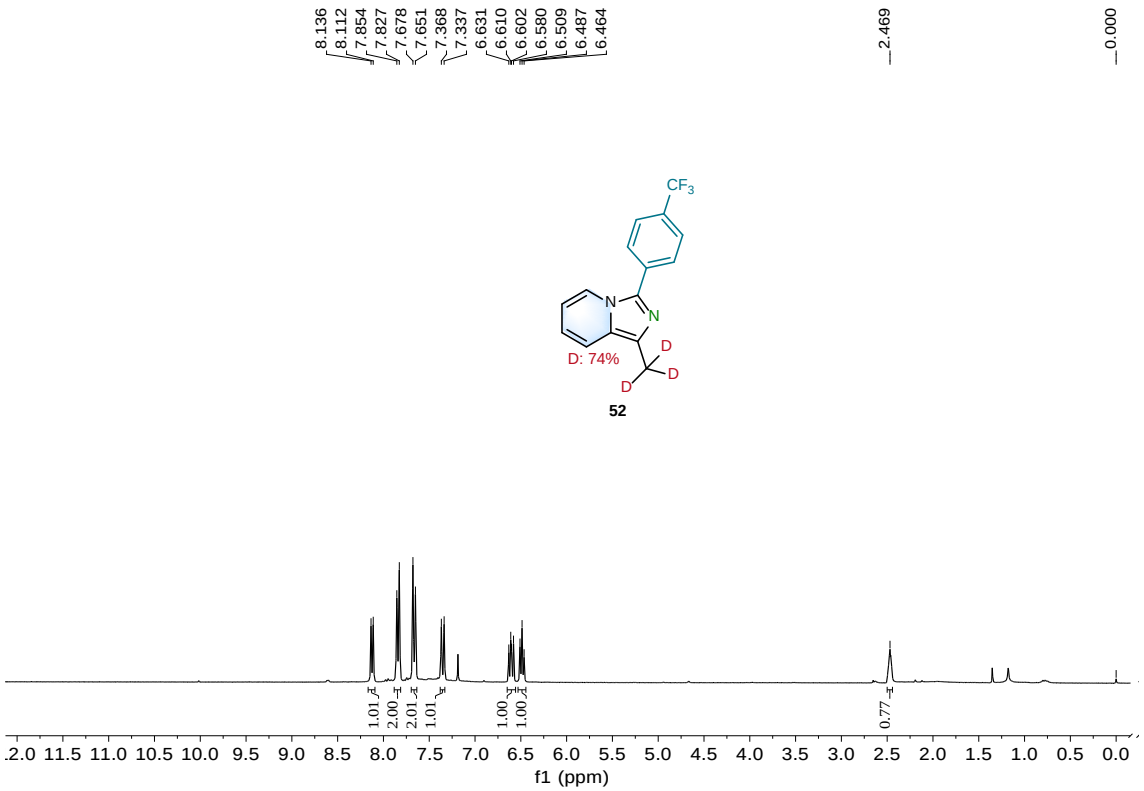
50

^{1}H NMR spectrum of **51** (300 MHz, $CDCl_3$)

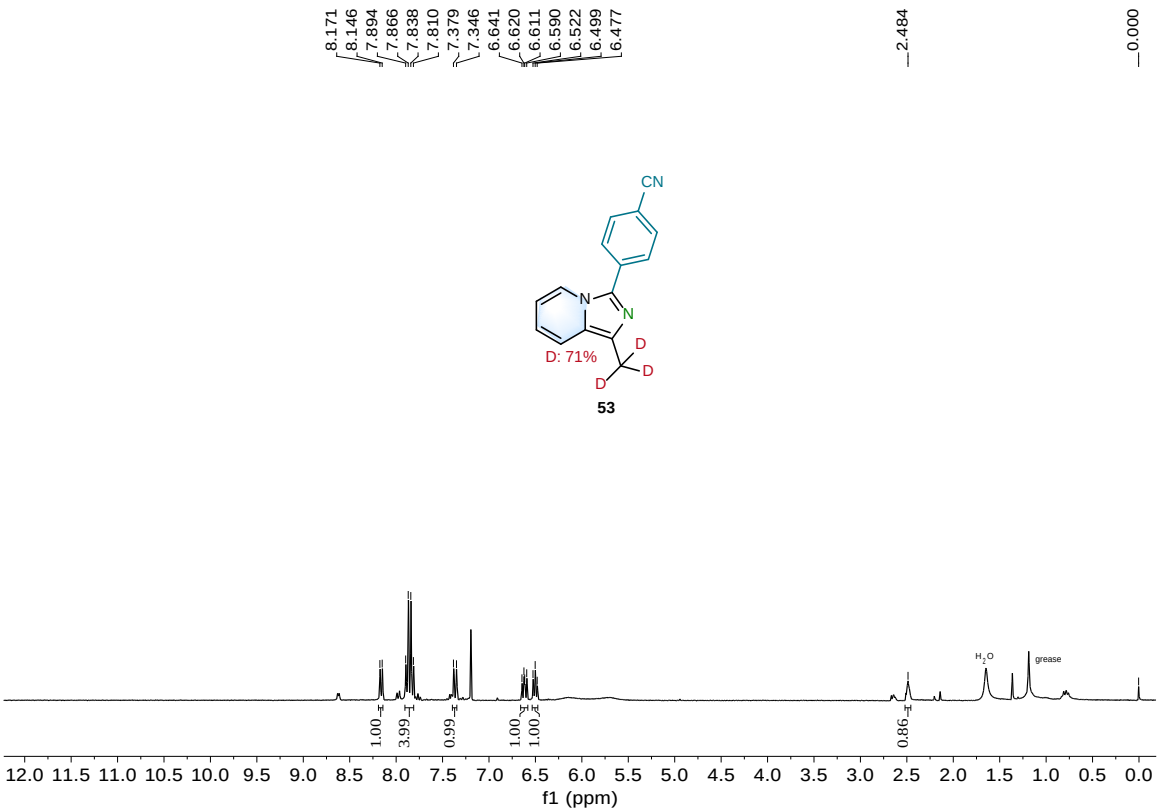


51

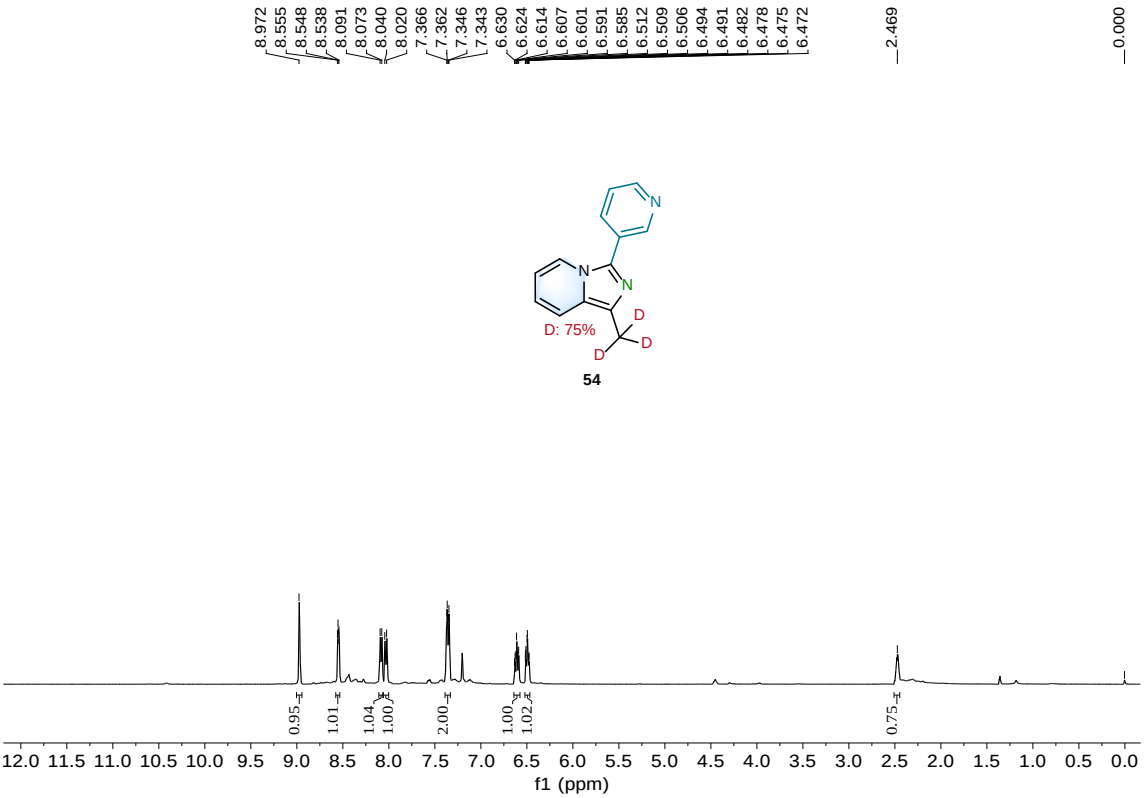
^{1}H NMR spectrum of **52** (300 MHz, $CDCl_3$)



^{1}H NMR spectrum of **53** (300 MHz, $CDCl_3$)



^{1}H NMR spectrum of **54** (400 MHz, $CDCl_3$)



^{1}H NMR spectrum of **55** (300 MHz, $CDCl_3$)