Electronic Supplementary Material (ESI) for Chemical Communications.

Supporting Information

Synthesis of alkylidene pyrrolo[3,4-*b*]pyridin-3-one derivatives *via* Rh^{III}-catalyzed oxidative alkenylation/annulation of picolinamides

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Experimental procedures and data

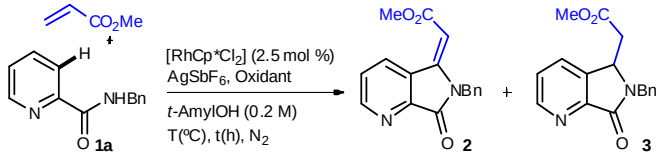
General Methods. The corresponding starting materials were synthetized using oven-dried glassware under a nitrogen atmosphere containing a teflon-coated stirrer bar and dry septum. All reactions were performed at ambient N_2 pressure in oven-dried 20 mL vessel containing a teflon-coated stirrer bar and dry septum. All reactions were monitored by GC using *n*-hexadecane as an internal standard. Response factors of the products with regard to *n*-hexadecane were obtained experimentally by analyzing known quantities of the substances. GC analyses were carried out using an HP-5 capillary column (Phenyl Methyl Siloxane 30 m x 320 x 0.25, 100/2.3-30-300/3) and a time program beginning with 2 min at 160 ºC followed by 30 ºC/min ramp to 300 ºC, then 9 min at this temperature. Flash column chromatography was performed using 230-400 mesh ultra-pure silica gel. NMR spectra were obtained on Bruker AC-300 or on Bruker AMX-500 systems using acetone-d_6 and $CDCl_3$ as solvents, with proton and carbon resonances at 300/500 MHz and 75/125 MHz, respectively. Mass spectral data were acquired on a VG *AutoSpec* mass spectrometer.

Solvents were purified by standard procedures prior to use. All other compounds are commercially available and were used without further purification.

All microwave irradiation experiments were carried out in a mono mode microwave apparatus equipped with a pressure control system and a vertically-focused IR temperature sensor (CEM).

1. Optimization studies

1.1. Selected screening results (Table S1)

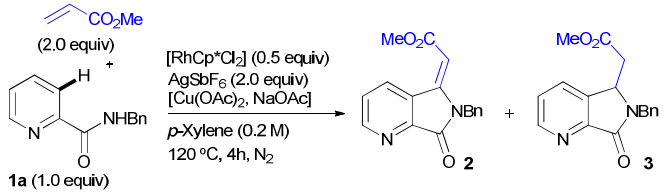


Entry	$AgSbF_6$ (%)	Oxidant (equiv)	T (°C)	t (h)	Conv (%)[a]	2 (%)[b]	3 (%)[b]
1	10 mol%	$Cu(OAc)_2$ (2.0 equiv)	120	0.5	45	42	3
2	10 mol%	$Cu(OAc)_2$ (2.0 equiv)	120	1	51	47	4
3	10 mol %	$Cu(OAc)_2$ (2.0 equiv)	120	3	70	64	6
4	10 mol %	$Cu(OAc)_2$ (2.0 equiv)	120	5	98	82(78)[c]	8
5	7.5 mol%	$Cu(OAc)_2$ (2.0 equiv)	120	3	58	53	5
6	5.0 mol%	$Cu(OAc)_2$ (2.0 equiv)	120	3	48	43	4
7	2.5 mol%	$Cu(OAc)_2$ (2.0 equiv)	120	3	46	43	3
8	2.5 mol%	$Cu(OAc)_2$ (2.0 equiv)	120	5	88	76	12
9	–	$Cu(OAc)_2$ (2.0 equiv)	120	3	12	11	1
10	–	$Cu(OAc)_2$ (2.0 equiv)	120	5	25	23	2
11	2.5 mol%	$Cu(OAc)_2$ (2.0 equiv)	100	3	25	24	1
12	2.5 mol%	$Cu(OAc)_2$ (2.0 equiv)	80	3	2	2	0
13	10 mol%	$Cu(OAc)_2$ (1.0 equiv)	120	1	37	26	9
14	10 mol%	$Cu(OAc)_2$ (1.0 equiv)	120	3	90	63	37
15	10 mol%	$Cu(OAc)_2$ (1.0 equiv) + O_2	120	3	17	18	0
16	10 mol%	$Cu(OAc)_2$ (0.5 equiv)+ O_2	120	3	3	3	0
17	–	Ag_2CO_3 (2.0 equiv)	120	3	0	–	

Conditions: N-benzylpicolinamide (**1a**) (0.15 mmol,1.00 equiv), methyl acrylate (0.15 mmol, 1.00 equiv), $[RhCl_2Cp^*]_2$ (2.5 mol%), $AgSbF_6$, oxidant, *t*-AmylOH (0.1 M), T (℃), t (h), N_2. [a] Determined by GC on the crude mixture with respect to **1a**. [b] GC yields (*n*-$C_{16}H_{34}$ as internal standard). [c] Isolated yield.

Those factors that could significantly influence this reaction were systematically screened in the model reaction of the *N*-benzylpicolinamide **1a** with methyl acrylate. Some selected examples are presented in Table S1. In the presence of 2.5 mol% of $[RhCl_2Cp^*]_2$ and 10 mol% of $AgSbF_6$ as the catalyst system, it was found that the use of 2.0 equiv of $Cu(OAc)_2$ as oxidant furnished the desired product **2** in 64% GC yield in conjunction with 6% of the reduced product **3**, after 3 h at 120 °C using *t*-AmylOH as solvent (entry 3). Longer reaction times led to isolate 78% of the desired product (entry 4). Any attempt to reduce the amount of silver led to lower conversions after 3h (entries 3, 5-7). In the case of using 2.5 mol% of $AgSbF_6$, 5h were required to achieve a synthetic useful yield (entry 8). Nevertheless, almost no reaction was observed in the absence of the silver salt (entries 9-10). Likewise, any attempt to reduce the amount of $Cu(OAc)_2$ led to increase the amount of **3** detected in the reaction mixture (entries 13-14). Remarkably, the use of O_2 as an external co-oxidant reduced considerable the reactivity (entries 15-16). Likewise, the use of 2.0 equiv of Ag_2CO_3 inhibited any reactivity and the starting material was recovered unaltered (entry 17).

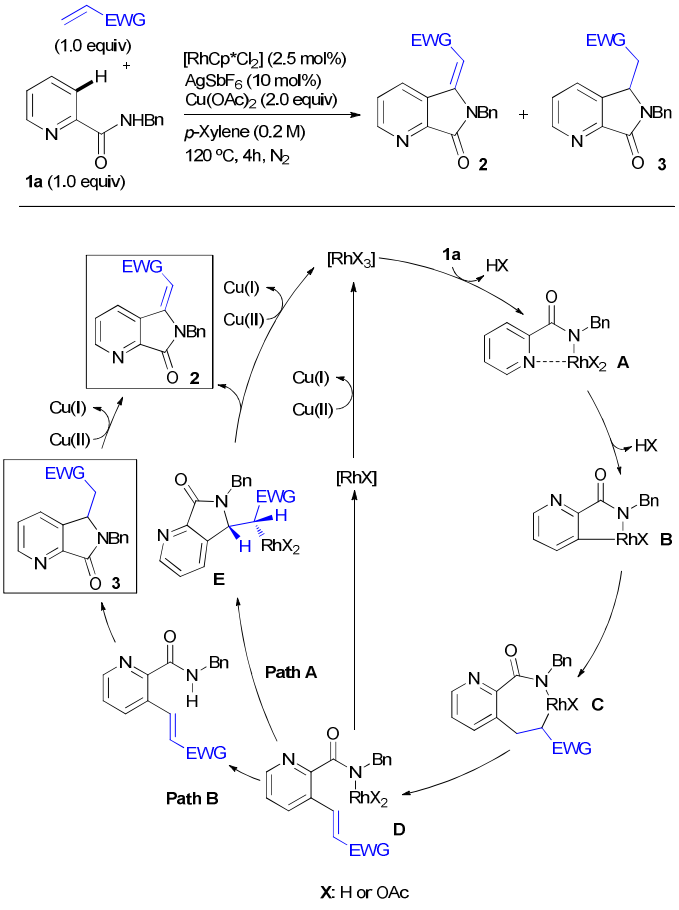
1.2. Stoichiometric experiments (Table S2)



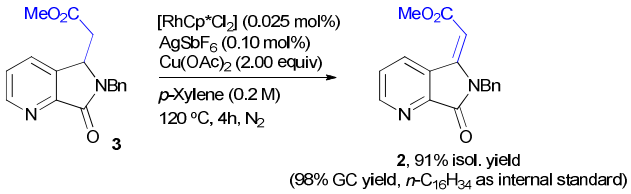
Entry	$Cu(OAc)_2$ (equiv)	NaOAc (equiv)	Conv (%)[a]	2 (%)[b]	3 (%)[b]
1	–	–	0	–	–
2	2.00	–	>99	80	18
3	–	4.00	78	36	42

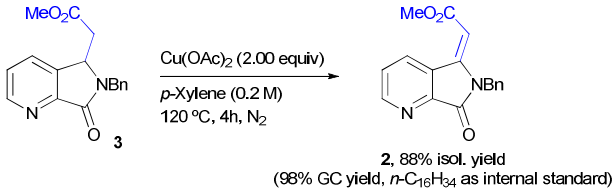
Conditions: N-benzylpicolinamide (**1a**) (10.6 mg, 0.05 mmol, 1.00 equiv), methyl acrylate (9.0 µL, 0.10 mmol, 2.00 equiv), $[RhCl_2Cp^*]_2$ (15.5 mg, 0.025 mmol, 0.50 equiv), $AgSbF_6$ (34.3 mg, 0.10 mmol, 2.00 equiv), $Cu(OAc)_2$, NaOAc, *p*-xylene (0.2 M), 120 ℃, 4h, N_2. [a] Determined by GC on the crude mixture with respect to **1a**. [b] GC yields (*n*-$C_{16}H_{34}$ as internal standard).

1.3. Plausible mechanistic pathways

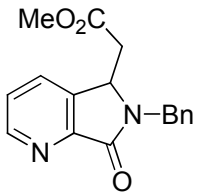


1.3.1 Reactivity of product 3

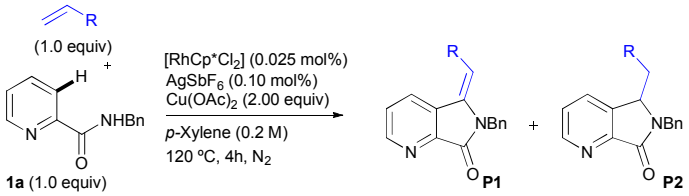




1.3.2 Rh(III)-catalyzed synthesis of methyl-2-(6-benzyl-7-oxo-6,7-dihydro-5H-pyrrolo[3,4-*b*]pyridin-5-yl)acetate (3). An oven-dried, nitrogen-flushed 20 mL vessel was charged with *N*-benzylpicolinamide (**1a**) (31.8 mg, 0.15 mmol, 1.00 equiv), pentamethylcyclopentadienylrhodium(III) chloride dimer (2.32 mg, 2.5 mol%), copper(II) acetate (27.3 mg, 0.15 mmol, 1.00 equiv), and silver hexafluoroantimonate (5.35 mg, 10 mol%). The reaction vessel was sealed with a Teflon lined cap, then evacuated and flushed with nitrogen three times. Under the atmosphere of nitrogen, 1,4-dioxane (1.00 mL) and methyl acrylate (13.5 µL, 0.15 mmol, 1.00 equiv) were added *via* syringe. The resulting mixture was stirred at room temperature for 10 min. Then the reaction vessel was placed in an aluminium block preheated at 120 °C. After 4 h the reaction was complete, the volatiles were removed *in vacuo* and the residue was purified by column chromatography (*n*-hexane-EtOAc 4:1), yielding **3** as a white solid; yield: 31.1 mg (70%); mp= 114-115 °C. **^{1}H NMR ($CDCl_3$, 300 MHz)** δ: 8.81 (s, 1H), 7.80 (s, 1H), 7.42 - 7.26 (m, 6H), 5.32 (d, *J* = 15.3 Hz, 1H), 4.88 - 4.73 (m, 1H), 4.41 (d, *J* = 15.3 Hz, 1H), 3.65 (s, 3H), 3.05 – 2.89 (m, 1H), 2.56 (dd, *J* = 16.3, 8.0 Hz, 1H). **^{13}C NMR ($CDCl_3$, 75 MHz)** δ: 170.4, 136.5, 129.0, 128.2, 128.0, 54.07, 52.3, 44.7, 36.8. **FB$^+$** calcd. for $C_{17}H_{17}N_2O_3$ $(M+H)^+$: 297.1239; Found: 297.1246. In this experiment, compound **2** is also isolated in 25% yield.



1.3.3 Reactivity of styrene (Table S3)



	Conv. (%)[a]	P1(%)[b]	P2(%)[b]
CO_2Me (1.0 equiv)	98	82	8
Ph (1.0 equiv)	0	–	–
CO_2Me (1.0 equiv) + Ph (1.0 equiv)	68	64, R = CO_2Me	4, R = CO_2Me

Conditions: N-benzylpicolinamide (**1a**) (31.8 mg, 0.15 mmol, 1.00 equiv), olefin (1.00 equiv), $[RhCl_2Cp^*]_2$ (2.32 mg, 2.5 mol%), $AgSbF_6$ (5.35 mg, 10 mol%), $Cu(OAc)_2$ (54.5 mg, 0.30 mmol, 2.00 equiv), *p*-xylene (0.2 M), 120 ℃, 4h, N_2. [a] Determined by GC on the crude mixture with respect to **1a**. [b] GC yields (*n*-$C_{16}H_{34}$ as internal standard).

In this table it is shown that no reactivity is observed when using styrene instead of methyl acrylate. Nonetheless, the presence styrene slows the rhodium-catalyzed reaction of *N*-benzylpicolinamide (**1a**) with methyl acrylate from a 98% conversion of **1a** to a 68%.

2. Typical procedure for the *N*-protection of amine derivatives

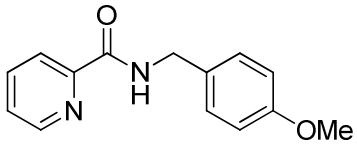
2.1. Synthesis of pyridinecarboxamide derivatives

Synthesis of *N*-benzylpicolinamide (1a).[1] A 50 mL round-bottomed flask immersed in a 0 °C bath (ice and water) was charged with picolinic acid (616 mg, 5.00 mmol) and CH_2Cl_2 (10 mL). To the stirred suspension was added oxalyl chloride (0.472 mL, 5.50 mmol) dropwise over a 15-minute period followed by addition of DMF (0.1 mL, catalytic amount) in one portion, producing a rust-red color and the evolution of a gas. The mixture was kept in the cooling bath for 1 h and then allowed to warm to room temperature. After gas evolution ceased, the mixture was again cooled to 0 °C and NEt_3 (1.40 mL, 10.0 mmol) was added dropwise over a 15-minute period followed by benzylamine (0.60 mL, 5.50 mmol) added dropwise over a 15-minute period. The brown mixture was left in the cooling bath for 30 minutes and then allowed to warm to room temperature. Stirring was continued at room temperature for 2 h. Removal of solvent *in vacuo* gave the crude product as a brown solid that was extracted with H_2O-CH_2Cl_2. The organic phases were combined and concentrated under reduced pressure to give **1a** as a white solid; yield: 1.04 g (98%); mp= 219-221 °C. The analytical data (NMR, HRMS analysis) matched those reported in the literature for *N*-

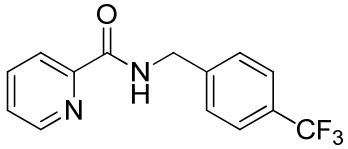
[1] (a) A. Jóźwiak, J. Z. Brzeziński, M. W. Płotka, A. K. Szcześniak, Z. Malinowski and J. Epsztajn, *Eur. J. Org. Chem.* 2004, 3254; (b) H. Brunner, B. Nuber and M. Prommesberger, *J. Organomet. Chem.* 1996, **523**, 179.

benzylpicolinamide [CAS: 18904-38-6]. **^{1}H NMR ($CDCl_3$, 300 MHz)** δ: 8.52 (ddd, *J* = 4.8, 1.7, 0.9 Hz, 1H), 8.39 (s, 1H), 8.24 (dt, *J* = 7.8, 1.1 Hz, 1H), 7.85 (td, *J* = 7.7, 1.7 Hz, 1H), 7.43 - 7.25 (m, 6H), 4.67 (d, 1H), 4.66 (d, 1H). **^{13}C NMR ($CDCl_3$, 75 MHz)** δ: 164.3, 149.9, 148.1, 138.3, 137.4, 128.8, 127.9, 127.5, 126.3, 122.4, 43.6. **ESI$^+$** calcd. for $C_{13}H_{13}N_2O$ $(M+H)^+$: 213.1022; Found: 213.1022.

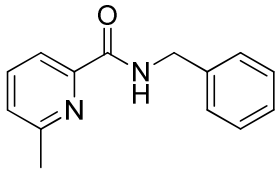
***N*-(4-Methoxybenzyl)picolinamide (1b)**. Compound **1b** was prepared following the typical procedure from (4-methoxyphenyl)methanamine (0.650 mL, 5.00 mmol), to give **1b** as a white solid; yield: 0.758 g (63%); mp= 52-53 °C. **^{1}H NMR ($CDCl_3$, 300 MHz)** δ: 8.88 (d, *J* = 4.7 Hz, 1H), 8.71 (s, 1H), 8.60 (d, *J* = 8.6 Hz, 1H), 8.21 (t, *J* = 7.7 Hz, 1H), 7.77 (s, 1H), 7.67 (d, *J* = 8.6 Hz, 2H), 7.25 (d, *J* = 8.7 Hz, 2H), 4.98 (d, *J* = 6.0 Hz, 2H), 4.16 (s, 3H). **^{13}C NMR ($CDCl_3$, 75 MHz)** δ: 164.2, 159.1, 150.0, 148.1, 137.4, 130.4, 129.3, 126.2, 122.4, 114.2, 55.3, 43.0. **ESI$^+$** calcd. for $C_{14}H_{15}N_2O_2$ $(M+H)^+$: 243.1128; Found: 243.1138.



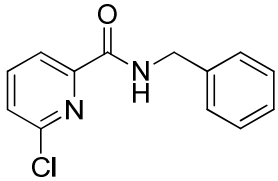
***N*-(4-(Trifluoromethyl)benzyl)picolinamide (1c)**. Compound **1c** was prepared following the typical procedure from (4-(trifluoromethyl)phenyl)-methanamine (0.713 mL, 5.00 mmol), to give **1c** as a yellow solid; yield: 1.02 g (73%); mp= 83-84 °C. **^{1}H NMR ($CDCl_3$, 300 MHz)** δ: 8.61 - 8.41 (m, 1H), 8.22 (d, *J* = 7.8 Hz, 1H), 7.85 (t, *J* = 7.7 Hz, 1H), 7.56 (t, *J* = 10.1 Hz, 2H), 7.53 - 7.38 (m, 3H), 4.72 (d, *J* = 6.2 Hz, 2H). **^{13}C NMR ($CDCl_3$, 75 MHz)** δ: 164.6, 149.7, 148.3, 142.6, 137.6, 128.1, 126.5, 125.7 (q, *J* = 3.8 Hz), 122.5, 43.1. **ESI$^+$** calcd. for $C_{14}H_{12}F_3N_2O$ $(M+H)^+$: 281.0896; Found: 281.0886.



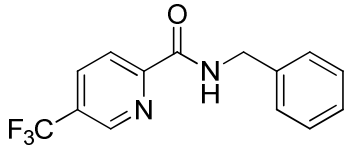
***N*-Benzyl-6-methylpicolinamide (13)**. Compound **13** was prepared following the typical procedure from 6-methylpicolinic acid (685 mg, 5.00 mmol), to give **13** as a pale orange solid; yield: 0.670 g (59%); mp= 104-105 °C. **^{1}H NMR ($CDCl_3$, 300 MHz)** δ: 8.46 (s, 1H), 8.05 (d, *J* = 7.7 Hz, 1H), 7.73 (t, *J* = 7.7 Hz, 1H), 7.45 - 7.23 (m, 6H), 4.68 (d, *J* = 6.2 Hz, 2H), 2.55 (s, 3H). **^{13}C NMR ($CDCl_3$, 75 MHz)** δ: 164.5, 157.3, 149.2, 138.6, 137.7, 128.8, 128.0, 127.5, 126.1, 119.6, 43.5, 24.3. **EI$^+$** calcd. for $C_{14}H_{14}N_2O$ $(M)^+$: 226.1106; Found: 226.1112.



***N*-Benzyl-6-chloropicolinamide (14)**. Compound **14** was prepared following the typical procedure from 6-chloropicolinic acid (788 mg, 5.00 mmol), to give **14** as a pale orange solid; yield: 0.825 mg (67%); mp= 116-117 °C. **^{1}H NMR ($CDCl_3$, 300 MHz)** δ: 8.25 - 8.09 (m, 1H), 7.80 (t, *J* = 7.8 Hz, 1H), 7.44 (d, *J* = 8.0 Hz, 1H), 7.38 - 7.24 (m, 5H), 4.65 (d, *J* = 6.2 Hz, 2H). **^{13}C NMR ($CDCl_3$, 75 MHz)** δ: 162.9, 150.5, 150.1, 140.1, 138.0, 128.8, 127.9, 127.6, 127.1, 121.2, 43.6. **EI$^+$** calcd. for $C_{13}H_{11}ClN_2O$ $(M)^+$: 246.0560; Found: 246.0558.



***N*-Benzyl-5-(trifluoromethyl)picolinamide (15)**. Compound **15** was prepared following the typical procedure from 5-(trifluoromethyl)picolinic acid (0.343 mL, 2.40 mmol), to give **15** as a yellow solid; yield: 0.468 g (71%); mp= 71-72 °C. **^{1}H NMR ($CDCl_3$, 300 MHz)** δ: 8.79 (s, 1H), 8.38 (d, *J* = 8.2 Hz, 1H), 8.33 (s, 1H), 8.11 (d, *J* = 8.2 Hz,



1H), 7.41 - 7.26 (m, 5H), 4.69 (d, *J* = 6.1 Hz, 2H). **^{13}C NMR ($CDCl_3$, 75 MHz)** δ: 163.0, 152.9, 145.3 (q, *J* = 3.9 Hz), 137.9, 134.9 (dd, *J* = 6.8, 3.4 Hz), 129.2, 128.9, 128.7, 127.9, 127.8, 122.3, 43.8. **ESI$^+$** calcd. for $C_{14}H_{12}F_3N_2O$ $(M+H)^+$: 281.0896; Found: 281.0897.

***N*-Benzyl-4-methylpicolinamide (16)**. Compound **16** was prepared following the typical procedure from 4-methylpicolinic acid (250 mg, 1.80 mmol), to give **16** as a pale green solid; yield: 0.325 g (80%); mp= 81-82 °C. **^{1}H NMR ($CDCl_3$, 300 MHz)** δ: 8.42 (s, 2H), 8.11 (s, 1H), 7.49 - 7.26 (m, 6H), 4.70 (d, *J* = 5.6 Hz, 2H), 2.45 (s, 3H).**^{13}C NMR (acetone-d_6, 75 MHz)** δ: 140.5, 129.2, 128.4, 127.8, 43.6, 21.1. **ESI$^+$** calcd. for $C_{14}H_{15}N_2O$ $(M+H)^+$: 227.1178; Found: 227.1174.

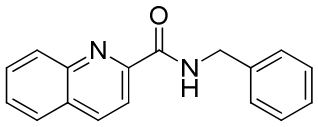
***N*-Ethylpicolinamide (28)**. Compound **28** was prepared following the typical procedure from a 2.0 M solution of ethylamine in THF (2,50 mL, 5.00 mmol), to give **28** as a colorless oil; yield: 0.654 g (87%). **^{1}H NMR ($CDCl_3$, 300 MHz)** δ: 8.42 (d, *J* = 4.7 Hz, 1H), 8.09 (d, *J* = 7.8 Hz, 1H), 7.99 (s, 1H), 7.72 (t, *J* = 7.7 Hz, 1H), 7.35 - 7.25 (m, 1H), 3.51 - 3.34 (m, 2H), 1.15 (t, *J* = 7.3 Hz, 3H). **^{13}C NMR ($CDCl_3$, 75 MHz)** δ: 164.1, 150.0, 147.9, 137.2, 125.9, 122.0, 34.2, 14.7. **EI$^+$** calcd. for $C_8H_{10}N_2O$ $(M)^+$: 150.0793; Found: 150.0800.

***N*-Phenylpicolinamide (29)**. Compound **29** was prepared following the typical procedure from aniline (0.50 mL, 5.50 mmol), to give **29** as a yellow solid; yield: 1.05 g (53%); mp= 76-77 °C. The analytical data (NMR, HRMS analysis) matched those reported in the literature for *N*-phenyl-2-pyridinecarboxamide [CAS: 10354-53-7]. **^{1}H NMR ($CDCl_3$, 300 MHz)** δ: 10.03 (s, 1H), 8.65 - 8.60 (m, 1H), 8.31 (d, *J* = 7.8 Hz, 1H), 7.92 (td, *J* = 7.7, 1.7 Hz, 1H), 7.79 (d, *J* = 8.4 Hz, 2H), 7.49 (ddd, *J* = 7.6, 4.8, 1.1 Hz, 1H), 7.39 (t, *J* = 7.9 Hz, 2H), 7.15 (t, *J* = 7.4 Hz, 1H). **EI$^+$** calcd. for $C_{12}H_{10}N_2O$ $(M)^+$: 198.0793; Found: 198.0794.

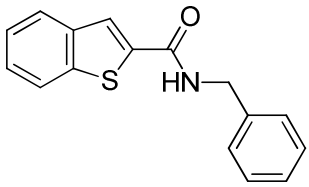
***N*-Phenethylpicolinamide (30)**. Compound **30** was prepared following the typical procedure from 2-phenylethanamine (0.630 mL, 5.00 mmol), to give **30** as a yellow oil; yield: 0.789 g (70%). **^{1}H NMR ($CDCl_3$, 300 MHz)** δ: 8.52 (d, *J* = 4.7 Hz, 1H), 8.35 - 8.13 (m, 2H), 7.84 (t, *J* = 7.7 Hz, 1H), 7.46 - 7.37 (m, 1H), 7.37 - 7.22 (m, 5H), 3.78 (dd, *J* = 13.6, 7.1 Hz, 2H), 2.98 (t, *J* = 7.3 Hz, 2H). **^{13}C NMR ($CDCl_3$, 75 MHz)** δ: 164.2, 149.9, 148.0, 138.9, 137.2, 128.7, 128.5, 126.4, 126.0, 122.1, 40.7, 35.9. **EI$^+$** calcd. for $C_{14}H_{14}N_2O$ $(M)^+$: 226.1106; Found: 226.1110.

2.3. Synthesis of *N*-benzyl-2-heteroaryl carboxamide derivatives

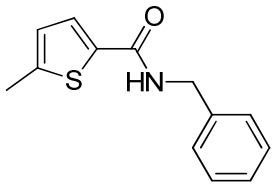
Synthesis of *N*-benzylquinoline-2-carboxamide (17). Compound **17** was prepared following the typical procedure for the synthesis of pyridinecarboxamide derivatives but from quinoline-2-carboxylic acid (960 mg, 5.00 mmol), to give **17** as a pale orange solid; yield: 0.720 g (55%); mp= 123-124 °C. **^{1}H NMR ($CDCl_3$, 300 MHz)** δ: 8.60 (s, 1H), 8.34 (d, *J* = 4.1 Hz, 2H), 8.07 (d, *J* = 8.5 Hz, 1H), 7.88 (d, *J* = 8.2 Hz, 1H), 7.k82 - 7.69 (m, 1H), 7.61 (t, *J* = 7.5 Hz, 1H), 7.47 - 7.26 (d, *J* = 55.9 Hz, 5H), 4.75 (d, *J* = 6.1 Hz, 2H). **^{13}C NMR ($CDCl_3$, 75 MHz)** δ: 164.5, 149.7, 146.5, 138.4, 137.5, 130.1, 129.7, 129.3, 128.7, 127.9, 127.7, 127.5, 118.9, 43.6. **ESI$^+$**calcd. for $C_{17}H_{15}N_2O$ $(M+H)^+$: 263.1178; Found: 263.1186.



***N*-Benzylbenzo[*b*]thiophene-2-carboxamide (18)**. Compound **18** was prepared following the typical procedure from benzo[*b*]thiophene-2-carboxylic acid (891 mg, 5.00 mmol), to give **18** as a yellow solid; yield: 0.909 g (68%); mp= 146-147 °C. **^{1}H NMR ($CDCl_3$, 300 MHz)** δ: 7.89 - 7.75 (m, 3H), 7.47 - 7.27 (m, 7H), 6.44 (s, 1H), 4.67 (d, *J* = 5.7 Hz, 2H). **^{13}C NMR ($CDCl_3$, 75 MHz)** δ: 162.3, 141.0, 139.2, 138.3, 138.0, 129.0, 128.1, 127.9, 126.5, 125.5, 125.2, 125.1, 122.9, 44.4. **EI$^+$** calcd. for $C_{16}H_{13}NOS$ $(M)^+$: 267.0718; Found: 267.0706.



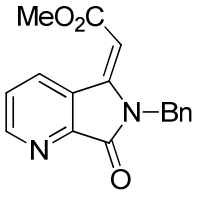
***N*-Benzyl-5-methylthiophene-2-carboxamide (19)**. Compound **19** was prepared following the typical procedure from 5-methylthiophene-2-carboxylic acid (711 mg, 5.00 mmol), to give **19** as a yellow solid; yield: 0.885 g (76%); mp= 145-146 °C. **^{1}H NMR (acetone-d_6, 300 MHz)** δ: 8.07 (s, 1H), 7.54 (d, *J* = 3.7 Hz, 1H), 7.41 - 7.15 (m, 6H), 6.89 - 6.66 (m, 1H), 4.54 (d, *J* = 6.1 Hz, 2H), 2.48 (d, *J* = 0.8 Hz, 4H). **^{13}C NMR ($CDCl_3$, 75 MHz)** δ: 162.0, 145.4, 138.4, 136.2, 128.8, 128.6, 127.9, 127.6, 126.1, 43.9, 15.7. **EI$^+$** calcd. for $C_{13}H_{13}NOS$ $(M)^+$: 231.0718; Found: 231.0719.



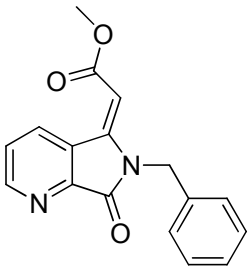
3. General procedures for the rhodium-catalyzed alkenylation and subsequent *N*-cyclization

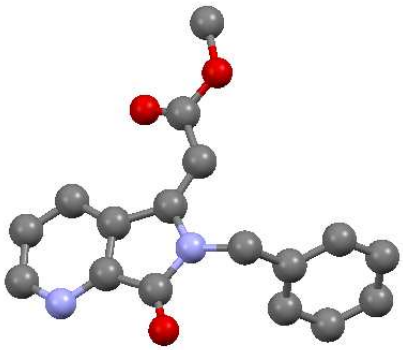
3.1. Scope with regard to the olefin (Scheme 1)

Synthesis of (*E*)-methyl 2-(6-benzyl-7-oxo-6,7-dihydro-5H-pyrrolo[3,4-*b*]pyridin-5-ylidene)acetate (2). An oven-dried, nitrogen-flushed 20 mL vessel was charged with *N*-benzylpicolinamide (**1a**) (31.8 mg, 0.15 mmol, 1.00 equiv), pentamethylcyclopentadienylrhodium(III) chloride dimer (2.32 mg, 0.00375 mmol, 0.025 equiv), copper(II) acetate (54.5 mg, 0.3 mmol, 2.00 equiv), and silver hexafluoroantimonate (5.35 mg, 0.015 mmol, 0.10 equiv). The reaction vessel was sealed with a Teflon lined cap, then evacuated and flushed with nitrogen three times. Under the atmosphere of nitrogen, *p*-xylene (1.00 mL) and methyl acrylate (13.5 µL, 0.15 mmol, 1.00 equiv) were added *via* syringe. The resulting mixture was then stirred at 120 °C for 5 h. After the reaction was complete, the volatiles were removed *in vacuo* and the residue was purified by column chromatography (*n*-hexane-EtOAc



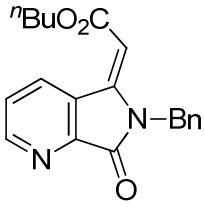
4:1), yielding **2** as a white solid; yield: 36.6 mg (83%); mp= 219-222 °C. **^{1}H NMR ($CDCl_3$, 300 MHz)** δ: 9.35 (dd, *J* = 8.1, 1.4 Hz, 1H), 8.86 (d, *J* = 3.5 Hz, 1H), 7.56 (dd, *J* = 8.1, 4.8 Hz, 1H), 7.37 - 7.22 (m, 5H), 5.79 (s, 1H), 5.08 (s, 2H), 3.75 (s, 3H).**^{13}C NMR (acetone-d_6, 75 MHz)** δ: 142.3, 141.5, 129.2, 124.9, 121.6, 112.3, 111.9, 105.3, 104.2, 103.2, 77.5, 28.1, 19.8. **EI$^+$** calcd. for $C_{17}H_{14}N_2O_3$ $(M)^+$: 294.1004; Found: 294.1011. The (*E*)-isomerism of this compound was confirmed by X-ray diffraction.





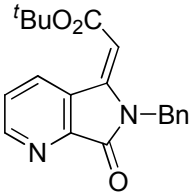
ORTEP view of **2**, hydrogen atoms have been removed for simplicity

(*E*)-*n*-Butyl 2-(6-benzyl-7-oxo-6,7-dihydro-5H-pyrrolo[3,4-*b*]pyridin-5-ylidene)acetate (4).



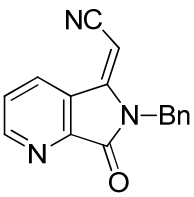
Compound **4** was prepared following the general protocol from *n*-butyl acrylate (23.7 µL, 0.15 mmol, 1.00 equiv), to give **4** as a white solid; yield: 41.9 mg (83%); mp= 131-132 °C. **^{1}H NMR ($CDCl_3$, 500 MHz)** δ: δ 9.53 - 9.28 (m, 1H), 8.90 (s, 1H), 7.70 - 7.47 (m, 1H), 7.50 - 7.17 (m, 5H), 5.84 (s, 1H), 5.13 (s, 2H), 4.20 (t, *J* = 6.8 Hz, 2H), 1.69 (dt, *J* = 14.6, 6.9 Hz, 2H), 1.49 - 1.37 (m, 2H), 0.98 (t, *J* = 7.4 Hz, 3H). **^{13}C NMR ($CDCl_3$, 126 MHz)** δ: 165.7, 165.3, 152.9, 148.5, 145.2, 136.3, 135.4, 129.0, 127.9, 127.1, 126.8, 101.9, 64.9, 43.7, 30.7, 19.3, 13.8. **ESI$^+$** calcd. for $C_{20}H_{21}N_2O_3$ $(M+H)^+$: 337.1546; Found: 337.1557.

(*E*)-*tert*-Butyl-2-(6-benzyl-7-oxo-6,7-dihydro-5H-pyrrolo[3,4-*b*]pyridin-5-ylidene)acetate (5).



Compound **5** was prepared following the general protocol from *tert*-butyl acrylate (24.2 µL, 0.15 mmol, 1.00 equiv), to give **5** as a white solid; yield: 43.5 mg (86%); mp= 156-157 °C. **^{1}H NMR ($CDCl_3$, 500 MHz)** δ: 9.32 (d, *J* = 8.0 Hz, 1H), 8.85 (s, 1H), 7.55 (s, 1H), 7.37 - 7.22 (m, 5H), 5.74 (s, 1H), 5.07 (s, 2H), 1.50 (s, 9H). **^{13}C NMR ($CDCl_3$, 126 MHz)** δ: 165.0, 152.7, 148.5, 144.3, 136.3, 135.6, 129.0, 127.9, 127.1, 104.1, 81.5, 43.6, 28.3. **FB$^+$** calcd. for $C_{20}H_{21}N_2O_3$ $(M+H)^+$: 337.1552; Found: 337.1558.

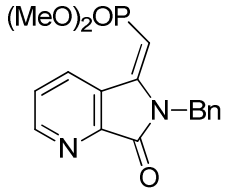
(*E*)-2-(6-Benzyl-7-oxo-6,7-dihydro-5H-pyrrolo[3,4-*b*]pyridin-5-ylidene)acetonitrile (6).



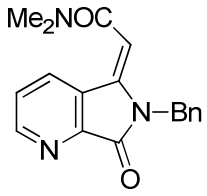
Compound **6** was prepared following the general protocol from acrylonitrile (11.4 µL, 0.30 mmol, 2.00 equiv) and increasing the amount of pentamethylcyclopentadienylrhodium(III) chloride dimer (4.64 mg, 0.05 equiv) and silver hexafluoroantimonate (10.7 mg, 0.2 equiv), to give **6** as a pale yellow solid; yield: 27.2 mg (69%); mp= 88-89 °C. **^{1}H NMR ($CDCl_3$, 500 MHz)** δ: 9.04 - 8.86 (m, 1H), 8.75 (dd, *J* = 8.0, 1.4 Hz, 1H), 7.63 (dd, *J* = 8.0, 4.9 Hz, 1H), 7.39 - 7.20 (m, 5H), 5.10 (s, 1H), 5.05 (s, 2H). **^{13}C NMR ($CDCl_3$, 126 MHz)** δ:

164.3, 154.0, 148.6, 147.8, 134.5, 131.8, 129.4, 128.5, 127.2, 127.1, 116.4, 76.0, 44.0, 1.2. **FB$^+$** calcd. for $C_{16}H_{12}N_3O$ $(M+H)^+$: 262.0980; Found: 262.0991.

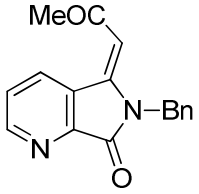
(*E*)-Dimethyl ((6-benzyl-7-oxo-6,7-dihydro-5H-pyrrolo[3,4-*b*]pyridin-5-ylidene)methyl)-phosphonate (7). Compound **7** was prepared following the general protocol from dimethyl vinylphosphonate (35.6 µL, 0.30 mmol, 2.00 equiv) and increasing the amount of pentamethylcyclopentadienylrhodium(III) chloride dimer (4.64 mg, 0.05 equiv) and silver hexafluoroantimonate (10.7 mg, 0.2 equiv), to give **7** as a pale yellow solid; yield: 43.0 mg (83%); mp= 101-102 °C. **^{1}H NMR ($CDCl_3$, 300 MHz)** δ: 9.17 (d, *J* = 7.8 Hz, 1H), 8.87 (s, 1H), 7.56 (s, 1H), 5.30 (s, 1H), 7.36 - 7.18 (m, 5H), 5.09 (s, 2H), 3.64 (dd, *J* = 11.4, 1.6 Hz, 6H). **^{13}C NMR ($CDCl_3$, 75 MHz)** δ: 165.0, 152.9, 148.3, 147.4, 147.1, 135.2, 134.7, 129.1, 128.0, 127.1, 95.2, 92.5, 52.8, 52.7, 43.5. **ESI$^+$** calcd. for $C_{17}H_{18}N_2O_4P$ $(M+H)^+$: 345.0998; Found: 345.0999.



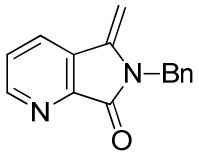
(*E*)-2-(6-Benzyl-7-oxo-6,7-dihydro-5H-pyrrolo[3,4-*b*]pyridin-5-ylidene)-*N*,*N*-dimethyl-acetamide (8). Compound **8** was prepared following the general protocol from *N*,*N*-dimethylacrylamide (30.9 µL, 0.30 mmol, 2.00 equiv) and increasing the amount of pentamethylcyclopentadienylrhodium(III) (4.64 mg, 0.05 equiv), silver hexafluoroantimonate (10.7 mg, 0.2 equiv) and copper(II) acetate (108.9 mg, 4.00 equiv), to give **8** as a pale yellow solid; yield: 40.0 mg (87%); mp= 154-155 °C. **^{1}H NMR ($CDCl_3$, 300 MHz)** δ: 8.60 (m, 2H), 7.45 (s, 1H), 7.34 - 7.16 (m, 5H), 5.87 (s, 1H), 5.07 (s, 2H), 2.97 (s, 3H), 2.67 (s, 3H).**^{13}C NMR (acetone-d_6, 126 MHz)** δ: 165.7, 152.9, 149.2, 139.8, 137.7, 135.0, 129.7, 128.3, 127.9, 105.6, 43.6, 37.8, 35.1. **EI$^+$** calcd. for $C_{18}H_{17}N_3O_2$ $(M)^+$: 307.1321; Found: 307.1315.



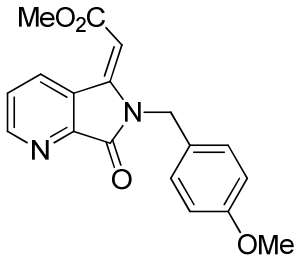
(*E*)-6-Benzyl-5-(2-oxopropylidene)-5H-pyrrolo[3,4-*b*]pyridin-7(6H)-one (9). Compound **9** was prepared following the general protocol from but-3-en-2-one (24.9 µg, 0.30 mmol, 2.00 equiv) and using pentamethylcyclopentadienylrhodium(III) (4.64 mg, 0.05 equiv), silver hexafluoroantimonate (10.7 mg, 0.2 equiv) and copper (II) acetate (108.9 mg, 4.00 equiv), to give **9** as a white solid; yield: 40.0 mg (96%); mp= 158-159 °C. **^{1}H NMR ($CDCl_3$, 300 MHz)** δ: 9.26 (d, *J* = 8.1 Hz, 1H), 8.86 (s, 1H), 7.55 (s, 1H), 7.44 - 7.09 (m, 5H), 6.13 (s, 1H), 5.10 (s, 2H), 2.29 (s, 3H).**^{13}C NMR ($CDCl_3$, 126 MHz)** δ: 196.5, 165.7, 153.3, 148.5, 143.8, 136.0, 135.4, 129.1, 128.1, 127.0, 109.0, 43.8, 32.7. **ESI$^+$** calcd. for $C_{17}H_{15}N_2O_2$ $(M+H)^+$: 279.1128; Found: 279.1134.



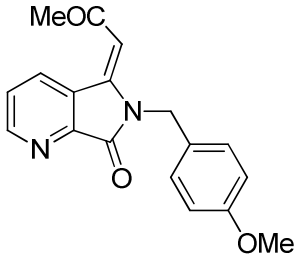
6-Benzyl-5-methylene-5H-pyrrolo[3,4-*b*]pyridin-7(6H)-one (10). Compound **10** was prepared in a 0.30 mmol-scale following the general protocol from (vinylsulfonyl)benzene (55.5 mg, 0.30 mmol, 1.00 equiv), to give **10** as a pale yellow solid; yield: 24.4 mg (70%); mp= 125-127 °C. **^{1}H NMR ($CDCl_3$, 300 MHz)** δ: 8.79 (d, *J* = 4.2 Hz, 1H), 7.95 (d, *J* = 7.8 Hz, 1H), 7.46 (dd, *J* = 7.8, 4.8 Hz, 1H), 7.34 - 7.19 (m, 5H), 5.17 (d, *J* = 2.5 Hz, 1H), 5.05 (s, 2H), 4.92 (d, *J* = 2.5 Hz, 1H). **^{13}C NMR ($CDCl_3$, 126 MHz)** δ: 165.2, 152.1, 147.8, 138.9, 136.4, 130.9, 128.9, 128.2, 127.7, 127.4, 126.0, 92.6, 43.6. **FB$^+$** calcd. for $C_{15}H_{13}N_2O$ $(M+H)^+$: 237.1028; Found: 237.1021.



Compound **10** was also obtained following the general protocol from phenyl ethenesulfonate (60.8 mg, 0.30 mmol, 1.00 equiv) to give **10** as a pale yellow solid; yield: 53.0 mg (75%).

(*E*)-Methyl 2-(6-(4-methoxybenzyl)-7-oxo-6,7-dihydro-5H-pyrrolo[3,4-*b*]pyridin-5-ylidene)-acetate (11). 

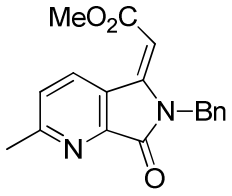
Compound **11** was prepared following the general protocol from *N*-(4-methoxybenzyl)picolinamide (**1b**) (36.3 mg, 0.15 mmol, 1.00 equiv) and methyl acrylate (13.5 µL, 0.15 mmol, 1.00 equiv), to give **11** as a white solid; yield: 33.9 mg (69%); mp= 176-177 °C. **^{1}H NMR ($CDCl_3$, 300 MHz)** δ: 9.32 (d, *J* = 8.1 Hz, 1H), 8.85 (s, 1H), 7.54 (s, 1H), 7.19 (d, *J* = 8.7 Hz, 2H), 6.84 (d, *J* = 8.7 Hz, 2H), 5.81 (s, 1H), 5.00 (s, 2H), 3.76 (s, 3H), 3.75 (s, 3H). **^{13}C NMR ($CDCl_3$, 75 MHz)** δ: 166.1, 165.2, 159.3, 152.9, 148.6, 145.4, 136.2, 128.6, 127.4, 126.8, 114.4, 101.3, 55.4, 51.9, 43.2. **EI$^+$** calcd. for $C_{18}H_{16}N_2O_4$ $(M)^+$: 324.1110; Found: 324.1108.

(*E*)-6-(4-Methoxybenzyl)-5-(2-oxopropylidene)-5H-pyrrolo[3,4-*b*]pyridin-7(6H)-one (12). 

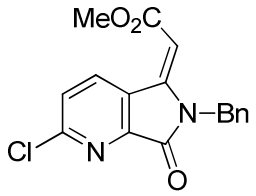
Compound **12** was prepared following the general protocol from *N*-(4-methoxybenzyl)picolinamide (**1b**) (36.3 mg, 0.15 mmol, 1.00 equiv) and but-3-en-2-one (24.9 µL, 0.30 mmol, 2.00 equiv), using pentamethylcyclopentadienylrhodium(III) (4.64 mg, 0.05 equiv) and silver hexafluoroantimonate (10.7 mg, 0.2 equiv), to give **12** as a yellow oil; yield: 27.0 mg (58%). **^{1}H NMR (300 MHz, $CDCl_3$)** δ: 9.25 (d, *J* = 7.9 Hz, 1H), 8.86 (s, 1H), 7.55 (s, 1H), 7.20 (d, *J* = 8.6 Hz, 2H), 6.86 (d, *J* = 8.7 Hz, 2H), 6.16 (s, 1H), 5.03 (s, 2H), 3.79 (s, 3H), 2.31 (s, 3H). **^{13}C NMR (75 MHz, $CDCl_3$)** δ: 196.5, 165.7, 159.3, 153.2, 148.5, 143.8, 135.9, 129.3, 128.4, 127.4, 127.0, 114.5, 109.0, 55.4, 43.2, 32.7. **EI$^+$** calcd. for $C_{18}H_{16}N_2O_3$ $(M)^+$: 308.1161; Found: 308.1152.

3.2. Scope with regard to the heteroaryl moiety (Scheme 2)

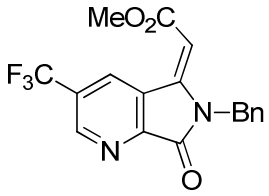
The general protocol is similar to the one used for evaluating the scope with regard to the olefin coupling partner (See section 3.1).

(*E*)-Methyl 2-(6-benzyl-2-methyl-7-oxo-6,7-dihydro-5H-pyrrolo[3,4-*b*]pyridin-5-ylidene)-acetate (20). 

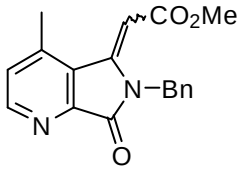
Compound **20** was prepared following the general protocol from *N*-benzyl-6-methylpicolinamide (**13**) (33.9 mg, 0.15 mmol, 1.00 equiv), to give **20** as a white solid; yield: 40.0 mg (86%); mp= 190-191 °C. **^{1}H NMR ($CDCl_3$, 300 MHz)** δ: 9.22 (d, *J* = 8.2 Hz, 1H), 7.44 (d, *J* = 8.3 Hz, 1H), 7.41 - 7.22 (m, 5H), 5.76 (s, 1H), 5.10 (s, 2H), 3.77 (s, 3H), 2.78 (s, 3H). **^{13}C NMR ($CDCl_3$, 75 MHz)** δ: 166.2, 165.6, 163.3, 148.3, 145.8, 136.2, 135.5, 129.0, 127.9, 127.1, 126.8, 126.7, 100.6, 51.8, 43.6, 24.7. **EI$^+$** calcd. for $C_{18}H_{16}N_2O_3$ $(M)^+$: 308.1161; Found: 308.1150.

(*E*)-Methyl 2-(6-benzyl-2-chloro-7-oxo-6,7-dihydro-5H-pyrrolo[3,4-*b*]pyridin-5-ylidene)-acetate (21). 

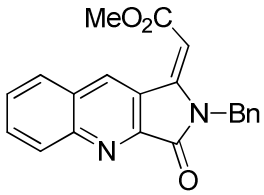
Compound **21** was prepared following the general protocol from *N*-benzyl-6-chloropicolinamide (**14**) (37.0 mg, 0.15 mmol, 1.00 equiv) and using pentamethylcyclopentadienylrhodium(III) (4.64 mg, 0.05 equiv), silver hexafluoroantimonate (10.7 mg, 0.2 equiv). to give **21** as a white solid after 16h at 140 °C; yield: 19.7 mg (40%); mp= 192-194 °C. **^{1}H NMR ($CDCl_3$, 300 MHz)** δ: 9.33 (d, *J* = 8.5 Hz, 1H), 7.58 (d, *J* = 8.5 Hz, 1H), 7.39 - 7.18 (s, 5H), 5.81 (s, 1H), 5.07 (s, 2H), 3.76 (s, 3H). **^{13}C NMR ($CDCl_3$, 75 MHz)** δ: 166.0, 163.9, 155.8, 144.5, 138.7, 135.2, 129.2, 128.1, 127.7, 127.1, 102.1, 52.1, 43.9. **EI$^+$** calcd. for $C_{17}H_{13}ClN_2O_3$ $(M)^+$: 328.0615; Found: 328.0602.

(*E*)-Methyl 2-(6-benzyl-7-oxo-3-(trifluoromethyl)-6,7-dihydro-5H-pyrrolo[3,4-*b*]pyridin-5-ylidene)acetate (22). 

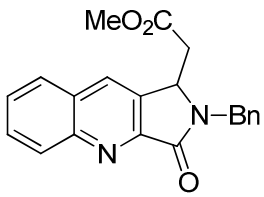
Compound **22** was prepared following the general protocol from *N*-benzyl-5-(trifluoromethyl)picolinamide (**15**) (42.0 mg, 0.15 mmol, 1.00 equiv) and using pentamethylcyclopenta-dienylrhodium(III) (4.64 mg, 0.05 equiv), silver hexafluoroantimonate (10.7 mg, 0.2 equiv). The reaction was performed at 140 °C for 16h to give **22** as a white solid; yield: 37.9 mg (90%); mp= 172-173 °C. **^{1}H NMR ($CDCl_3$, 300 MHz)** δ: 9.73 (s, 1H), 9.13 (s, 1H), 7.45 - 7.19 (m, 5H), 5.89 (s, 1H), 5.11 (s, 2H), 3.78 (s, 3H). **^{13}C NMR (acetone-d_6, 75 MHz)** δ: 166.8 (s), 164.3 (s), 152.6 (s), 150.4 (q, *J* = 4.0 Hz), 145.0 (s), 136.6 (s), 134.0 (q, *J* = 4.0 Hz), 129.7 (s), 128.5 (s), 127.8 (s), 103.0 (s), 52.3 (s), 44.0 (s). **EI$^+$** calcd. for $C_{14}H_{11}F_3N_2O$ $(M)^+$: 362.0878; Found: 362.0871.

(*E*)-6-Benzyl-4-methyl-5-(2-oxopropylidene)-5H-pyrrolo[3,4-*b*]pyridin-7(6H)-one (23). 

Compound **23** was prepared following the general protocol from *N*-benzyl-4-methylpicolinamide (**16**) (33.9 mg, 0.15 mmol, 1.00 equiv), to give **23** with a 10% GC-yield; **MS (EI 70 eV) m/z:** 308.1 (M^+, 14%), 280.1 (4%), 277.1 (3%), 249.0 (37%), 221.0 (14%), 187.0 (22%), 91.0 (100%). The stereochemistry has not been determined.

(*E*)-Methyl 2-(2-benzyl-3-oxo-2,3-dihydro-1H-pyrrolo[3,4-*b*]quinolin-1-ylidene)acetate (24). 

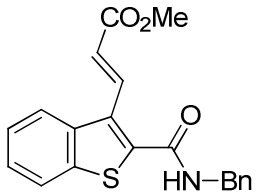
Compound **24** was prepared following the general protocol from *N*-benzylquinoline-2-carboxamide (**17**) (39.3 mg, 0.15 mmol, 1.00 equiv), to give **24** as a pale yellow solid; yield: 39.0 mg (76%); mp= 232-234 °C. **^{1}H NMR ($CDCl_3$, 300 MHz)** δ: 9.85 (s, 1H), 8.31 (d, *J* = 8.6 Hz, 1H), 7.97 (d, *J* = 8.1 Hz, 1H), 7.79 (t, *J* = 7.5 Hz, 1H), 7.61 (t, *J* = 7.5 Hz, 1H), 7.32 - 7.16 (m, 1H), 5.70 (s, 1H), 5.08 (s, 1H), 3.70 (s, 1H). **^{13}C NMR ($CDCl_3$, 75 MHz)** δ: 166.4, 165.2, 149.5, 148.3, 146.0, 137.8, 135.2, 132.0, 130.9, 130.1, 129.3, 129.1, 128.8, 128.0, 127.1, 124.2, 99.8, 51.8, 44.1.

In the same experiment, **methyl 2-(2-benzyl-3-oxo-2,3-dihydro-1H-pyrrolo[3,4-*b*]quinolin-1-yl)acetate (27)** 

was also isolated as a white solid; yield: 5.20 mg (10%); mp= 173-174 °C. **^{1}H NMR ($CDCl_3$, 300 MHz)** δ: 8.40 (d, *J* = 8.5 Hz, 1H), 8.25 (s, 1H), 7.89 (d, *J* = 8.2 Hz, 1H), 7.86 - 7.76 (m, 1H), 7.64 (t, *J* = 7.5 Hz, 1H), 7.37 - 7.27 (m, 5H), 5.41 (d, *J* = 15.3 Hz, 1H), 4.96 (dd, *J* = 8.0, 4.4 Hz, 1H), 4.48 (d, *J* = 15.3 Hz, 1H), 3.67 (s, 3H), 3.07 (dd, *J* = 16.5, 4.4

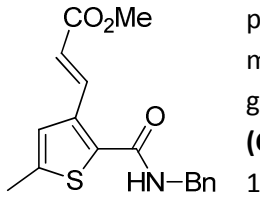
Hz, 1H), 2.65 (dd, *J* = 16.5, 8.1 Hz, 1H). **^{13}C NMR ($CDCl_3$, 75 MHz)** δ: 170.5, 166.2, 150.4, 149.2, 136.2, 133.9, 131.2, 130.9, 130.6, 129.1, 128.9, 128.4, 128.3, 128.2, 128.1, 53.9, 52.3, 45.0, 37.3.

(*Z*)-Methyl 3-(2-(benzylcarbamoyl)benzo[*b*]thiophen-3-yl)acrylate (25). Compound **25** was



prepared following the general protocol from *N*-benzylbenzo[*b*]thiophene-2-carboxamide (**18**) (40.0 mg, 0.15 mmol, 1.00 equiv), to give **25** as a white solid; yield: 47.0 mg (89%); mp= 133-134 °C. **^{1}H NMR ($CDCl_3$, 300 MHz)** δ: 8.24 (d, *J* = 16.4 Hz, 1H), 8.04 - 7.92 (m, 1H), 7.90 - 7.73 (m, 1H), 7.54 - 7.41 (m, 2H), 7.41 - 7.28 (m, 5H), 6.50 (d, *J* = 16.5 Hz, 1H), 6.39 (s, 1H), 4.64 (d, *J* = 5.6 Hz, 2H), 3.82 (s, 3H). **^{13}C NMR ($CDCl_3$, 75 MHz)** δ: 166.9, 162.5, 139.1, 137.7, 137.5, 136.9, 136.3, 132.8, 129.0, 128.0, 127.9, 126.9, 125.7, 124.1, 123.7, 122.9, 52.0, 44.6. **ESI$^+$** calcd. for $C_{20}H_{15}NO_3S$ (M-2H)$^+$: 349.0773; Found: 349.0775.

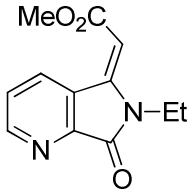
(*Z*)-Methyl 3-(2-(benzylcarbamoyl)-5-methylthiophen-3-yl)acrylate (26). Compound **26** was



prepared following the general protocol from *N*-benzyl-5-methylthiophene-2-carboxamide (**19**) (34.7 mg, 0.15 mmol, 1.00 equiv), to give **26** as a white solid; yield: 39.0 g (83%); mp= 161-160 °C. **^{1}H NMR ($CDCl_3$, 300 MHz)** δ: 8.32 (d, *J* = 16.1 Hz, 1H), 7.40 - 7.24 (m, 5H), 6.97 (s, 1H), 6.25 (d, *J* = 16.1 Hz, 1H), 6.10 (s, 1H), 4.60 (d, *J* = 5.7 Hz, 2H), 3.77 (s, 3H), 2.46 (s, 3H). **^{13}C NMR ($CDCl_3$, 75 MHz)** δ: 167.4, 162.0, 142.2, 139.4, 137.9, 137.1, 133.8, 128.9, 128.0, 127.8, 125.2, 120.8, 51.9, 44.3, 15.5. **ESI$^+$** calcd. for $C_{17}H_{15}NO_3S$ (M-2H)$^+$: 313.0773; Found: 313.0783.

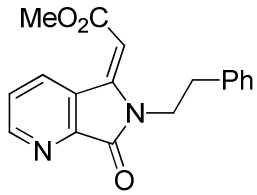
3.3. Evaluation of different *N*-substituents (Table 2)

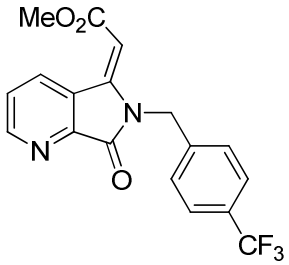
(*E*)-Methyl 2-(6-ethyl-7-oxo-6,7-dihydro-5H-pyrrolo[3,4-*b*]pyridin-5-ylidene)acetate (31).



Compound **31** was prepared following the general protocol from *N*-ethylpicolinamide (**28**) (22.5 mg, 0.15 mmol, 1.00 equiv), to give **31** as a white solid; yield: 20.0 mg (57%); mp= 139-141 °C. **^{1}H NMR (acetone-d_6, 300 MHz)** δ: 9.37 (d, *J* = 8.0 Hz, 1H), 8.86 (s, 1H), 7.71 (s, 1H), 5.99 (s, 1H), 3.96 (q, *J* = 7.2 Hz, 2H), 3.81 (s, 3H), 1.26 (t, *J* = 7.2 Hz, 3H). **^{13}C NMR (acetone-d_6, 75 MHz)** δ: 181.2, 167.0, 153.4, 149.7, 146.0, 136.2, 135.7, 114.6, 100.0, 52.0, 35.1, 13.3.

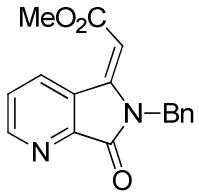
(*E*)-Methyl 2-(7-oxo-6-phenethyl-6,7-dihydro-5H-pyrrolo[3,4-*b*]pyridin-5-ylidene)acetate (33). Compound **33** was prepared following the general protocol from *N*-ethylpicolinamide (**30**) (22.5 mg, 0.15 mmol, 1.00 equiv), to give **30** as a white solid; yield: 41.0 mg (89%); mp= 155-157 °C. **^{1}H NMR (acetone-d_6, 300 MHz)** δ: 9.35 (d, *J* = 8.1 Hz, 1H), 8.83 (s, 1H), 7.69 (dd, *J* = 8.1, 4.8 Hz, 1H), 7.17 (s, 6H), 6.01 (s, 1H), 4.23 - 4.06 (m, 2H), 3.81 (s, 3H), 3.07 - 2.96 (m, 2H). **^{13}C NMR (acetone-d_6, 75 MHz)** δ: 167.0, 165.0, 153.6, 149.6, 146.2, 139.2, 136.3, 129.7, 129.4, 127.4, 100.4, 52.0, 41.7, 34.5. In the same experiment, 10% of the *Z*-**33** compound was also detected by ^{1}H NMR of the crude.



(*E*)-Methyl 2-(7-oxo-6-(4-(trifluoromethyl)benzyl)-6,7-dihydro-5H-pyrrolo[3,4-*b*]pyridin-5-ylidene)acetate (34). 

Compound **34** was prepared following the general protocol from *N*-(4-(trifluoromethyl)benzyl)picolinamide (**1c**) (42.0 mg, 0.15 mmol), to give **34** as a white solid; yield: 43.1 mg (79%); mp= 231-232 °C. **^{1}H NMR ($CDCl_3$, 300 MHz)** δ: 9.38 (d, *J* = 7.8 Hz, 1H), 8.95 (s, 1H), 7.70 - 7.53 (m, 3H), 7.38 (d, *J* = 8.1 Hz, 2H), 5.72 (s, 1H), 5.14 (s, 2H), 3.77 (s, 3H). **^{13}C NMR (acetone-d_6, 75 MHz)** δ: 166.6, 165.5, 164.6, 153.8, 149.5, 146.1, 141.9, 136.5, 128.5, 127.6, 126.6 (q, *J* = 3.9 Hz), 101.4, 52.1, 43.3. **EI$^+$** calcd. for $C_{18}H_{13}F_3N_2O_3$ $(M)^+$: 362.0878; Found: 362.0882.

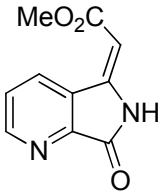
4. Scale up of the Rh(III)-catalyzed 3-alkenylation and subsequent *N*-cyclization of 1a



An oven-dried, nitrogen-flushed 20 mL vessel was charged with *N*-benzylpicolinamide (**1a**) (424 mg, 2.00 mmol, 1.00 equiv), pentamethylcyclopentadienylrhodium(III) chloride dimer (31.0 mg, 0.05 mmol, 0.025 equiv), copper(II) acetate (727 mg, 4.00 mmol, 2.00 equiv), and silver hexafluoroantimonate (68.7 mg, 0.2 mmol, 0.1 equiv). The reaction vessel was sealed with a Teflon lined cap, then evacuated and flushed with nitrogen three times. Under the atmosphere of nitrogen, *p*-xylene (15.0 mL) and methyl acrylate (200 µL, 2.1 mmol, 1.05 equiv) were added *via* syringe. The resulting mixture was then stirred at 120 °C for 4 h. After the reaction was complete, the volatiles were removed *in vacuo* and the residue was purified by column chromatography (*n*-hexane-EtOAc 3:1), yielding **2** as a white solid; yield: 494 mg (84%); mp= 219-222 °C. The analytical data (NMR and HRMS analysis) matched those obtained previously for compound **2**.

5. Typical procedure for the cleavage of the benzyl group[2]

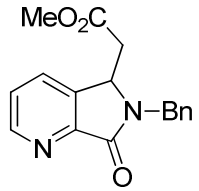
Synthesis of (*E*)-methyl 2-(7-oxo-6,7-dihydro-5H-pyrrolo[3,4-*b*]pyridin-5-ylidene)acetate (35)



An oven-dried, argon flushed 10 mL microwave vessel was charged with (*E*)-methyl 2-(6-benzyl-7-oxo-6,7-dihydro-5H-pyrrolo[3,4-*b*]pyridin-5-ylidene)acetate (**2**) (88.2 mg, 0.30 mmol, 1.00 equiv) and then sealed with a Teflon lined cap, evacuated and flushed with argon three times. Under the atmosphere of argon, toluene (1.00 mL) and triflic acid (106 µL, 1.20 mmol, 4.00 equiv) were added *via* syringe. The resulting solution was then stirred for 5 min at room temperature followed by microwave irradiation at 150 °C for 5 min. Removal of solvent *in vacuo* gave the crude product as a brown solid that was extracted with H_2O-CH_2Cl_2. The organic phases were combined and concentrated under reduced pressure. The residue was purified by column chromatography (*n*-hexane-EtOAc 1:1 with 10% of MeOH), yielding **(35)** as a white solid; yield: 42.8 mg (70%); mp= 221-222 °C. **^{1}H NMR ($CDCl_3$, 300 MHz)** δ: 9.88 (s, 1H), 8.91 (d, *J* = 4.3 Hz, 1H), 8.04 (d, *J* = 7.8 Hz, 1H), 7.55 (s, 1H), 5.82 (s, 1H), 3.84 (s, 3H). **^{13}C NMR ($CDCl_3$, 75 MHz)** δ: 167.5, 165.7, 153.9, 148.5, 144.5, 130.3, 129.2, 126.5, 93.5, 52.2. **EI$^+$** calcd. for $C_{10}H_8N_2O_3$ $(M)^+$: 204.0535; Found: 204.0530.

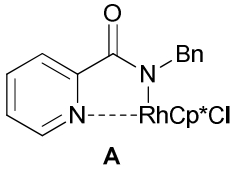
6. Pd/C-Catalyzed chemoselective hydrogenation

Synthesis of methyl 2-(6-benzyl-7-oxo-6,7-dihydro-5H-pyrrolo[3,4-*b*]pyridin-5-yl)acetate (3)



After two vacuum/H_2 cycles to replace the air inside the reaction vessel with hydrogen, the mixture of **2** (60.9 mg, 0.20 mmol) and 10% Pd/C (7.23 mg, 10 wt % of **2**) in MeOH (2.0 mL) was vigorously stirred at room temperature (ca. 20°C) under ordinary hydrogen pressure (balloon) for 48 h. Then, the reaction mixture was filtered through a Celite® pad (9 cm x inches) eluting with MeOH. The volatiles were subsequently removed *in vacuo* and the residue was purified by column chromatography (*n*-hexane-EtOAc 2:1) to afford **3** in 74% yield (43.7 mg). The analytical data (NMR and HRMS analysis) matched those obtained previously for compound **3**.

7. Synthesis of the Rh(III)-complex, intermediate A

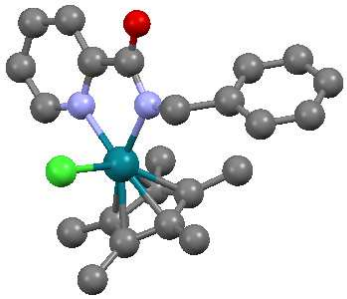


A

An oven-dried, nitrogen-flushed 20 mL vessel was charged with *N*-benzylpicolinamide (**1a**) (21.2 mg, 0.10 mmol, 1.00 equiv), pentamethylcyclopentadienylrhodium(III) chloride dimer (30.5 mg, 0.05 mmol, 0.5 equiv), sodium acetate (61.5 mg, 0.75 mmol, 7.50 equiv). The reaction vessel was sealed with a Teflon lined cap, then evacuated and flushed with nitrogen three times. Under the atmosphere of nitrogen, CH_2Cl_2 (10.0 mL) was added *via* syringe. After stirring the resulting mixture at room temperature for 16 h, the volatiles were partially removed *in vacuo* until observing the formation of an orange solid that

[2] F. Rombouts, D. Franken, C. Martínez-Lamenca, M. Braeken, C. Zavattaro, J. Chen and A. A. Trabanco, *Tetrahedron Lett*. 2010, **51**, 4815.

it was characterized as the Rh(III)-complex, intermediate **A**; yield: 36.6 mg (83%); mp= 219-222 °C. **^{1}H NMR ($CDCl_3$, 300 MHz)** δ: 8.61 (d, *J* = 5.4 Hz, 1H), 8.09 (d, *J* = 7.8 Hz, 1H), 7.90 (t, *J* = 7.7 Hz, 1H), 7.48 (d, *J* = 7.3 Hz, 2H), 7.30 - 7.21 (m, 2H), 7.14 (t, *J* = 7.3 Hz, 1H), 4.97 (q, *J* = 15.2 Hz, 2H), 1.59 (s, 15H).**^{13}C NMR ($CDCl_3$, 75 MHz)** δ: 169.6 (d, *J* = 1.7 Hz), 156.4, 149.3, 141.5, 138.8, 128.0, 128.0, 126.6 (d, *J* = 1.1 Hz), 126.0, 125.8 (d, *J* = 1.2 Hz), 94.7 (d, *J* = 8.0 Hz), 54.9, 9.3. This compound was also characterized by X-ray diffraction.

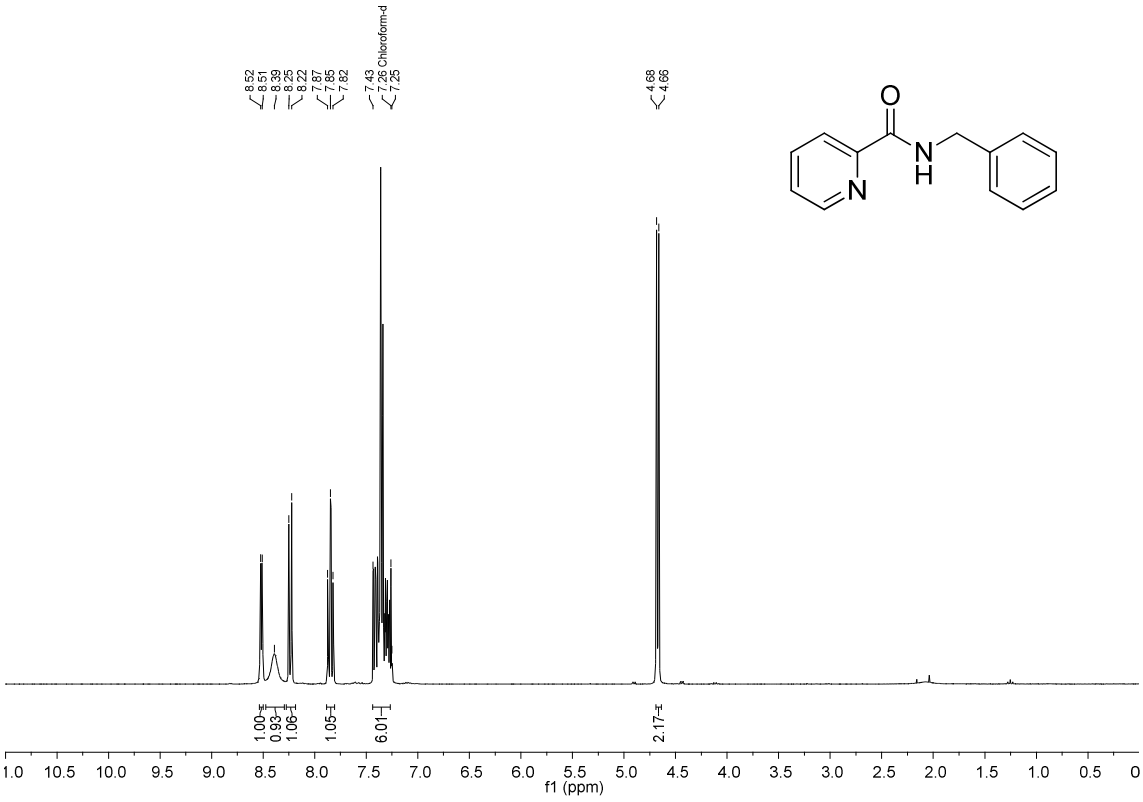


ORTEP view of **A**, hydrogen atoms have been removed for simplicity

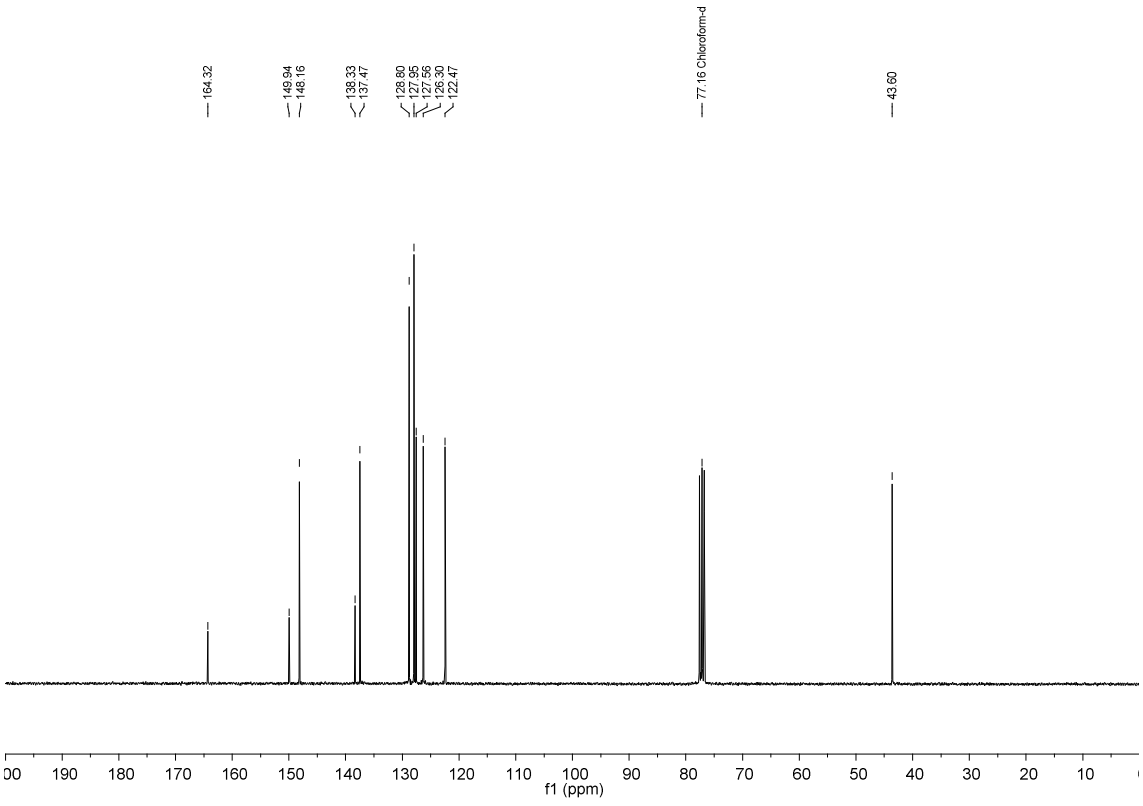
8. NMR Spectra

N-Benzylpicolinamide (1a)

^{1}H NMR ($CDCl_3$, 300 MHz)

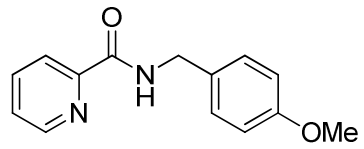


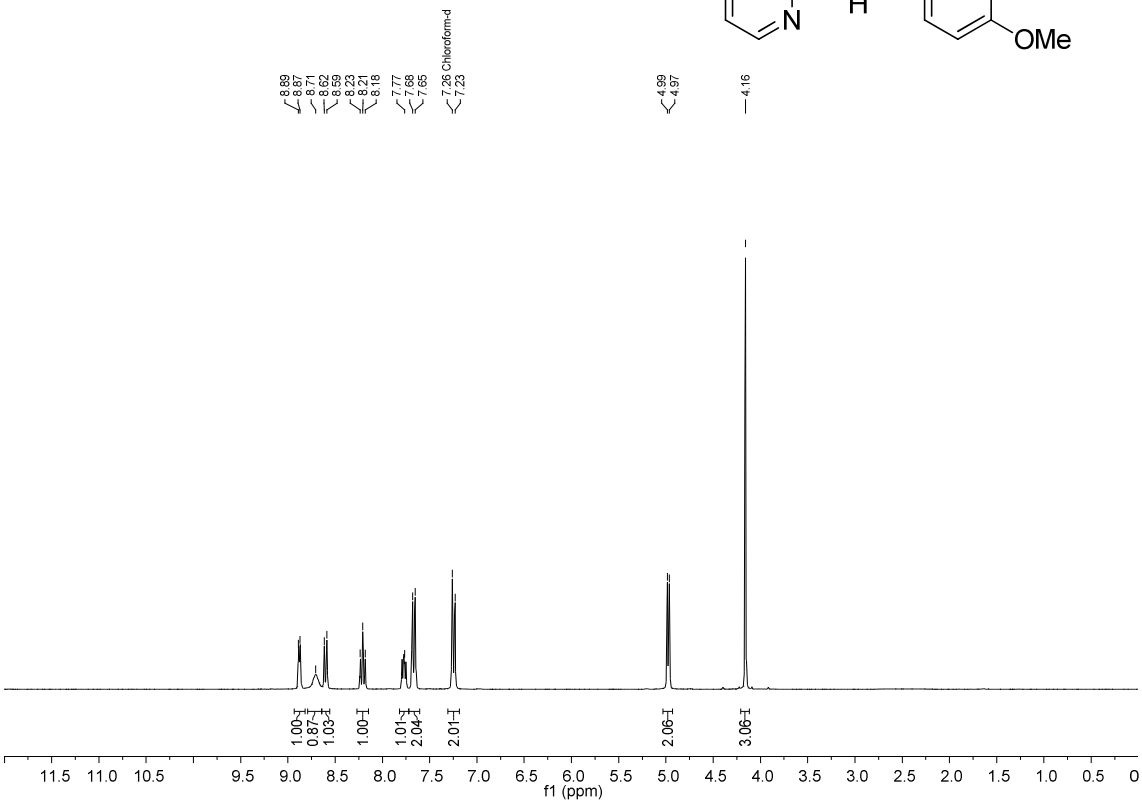
^{13}C NMR ($CDCl_3$, 75 MHz)



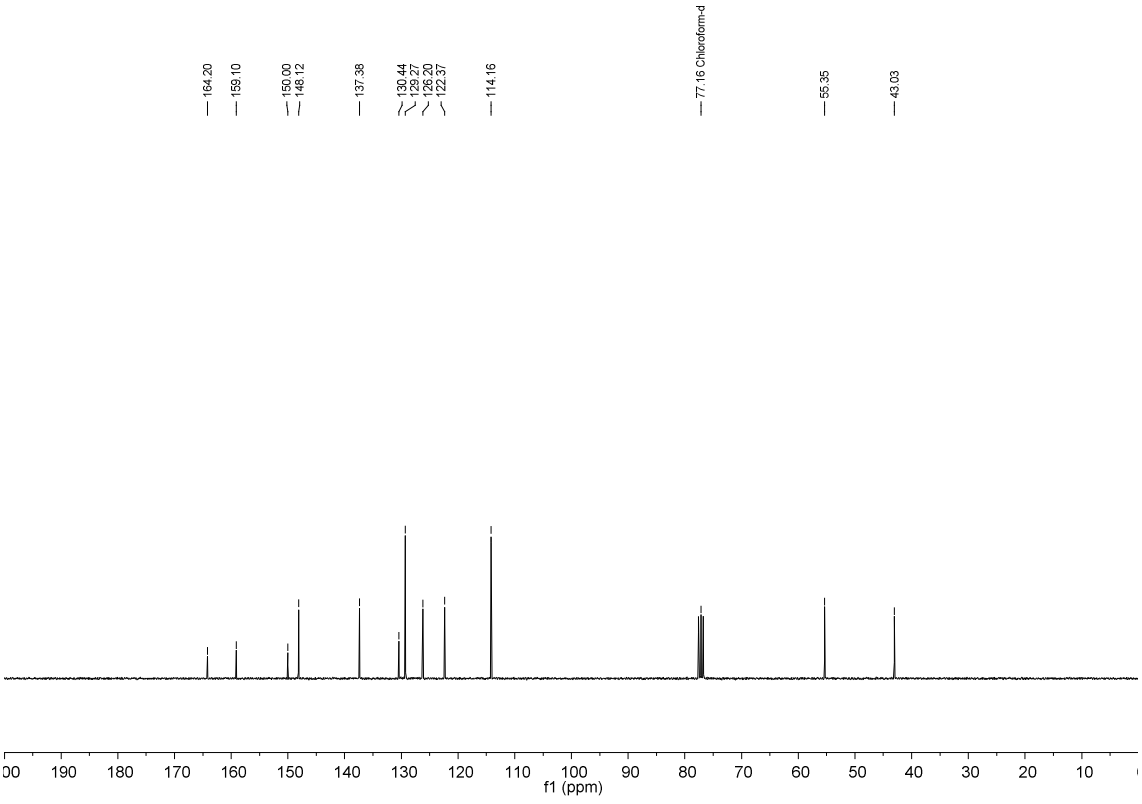
***N*-(4-Methoxybenzyl)picolinamide (1b)**

^{1}H NMR ($CDCl_3$, 300 MHz)

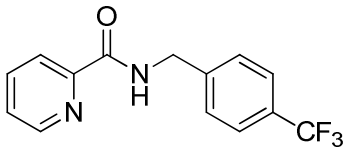




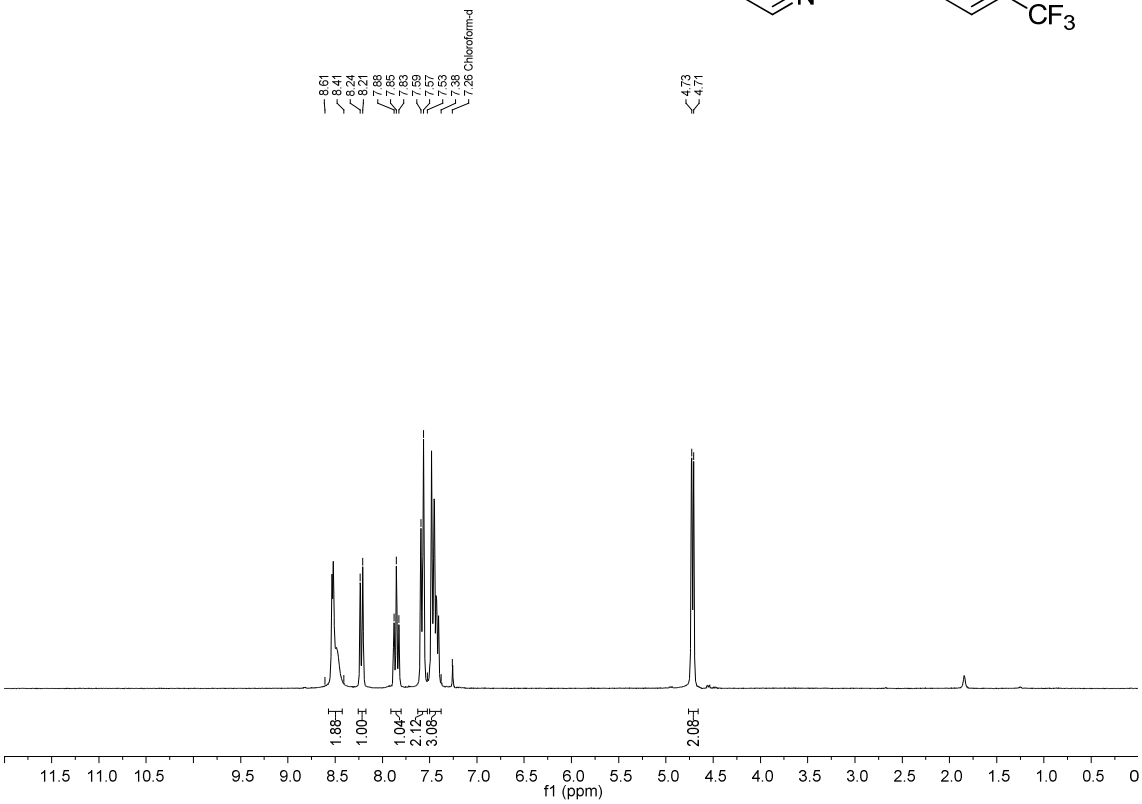
^{13}C NMR ($CDCl_3$, 75 MHz)



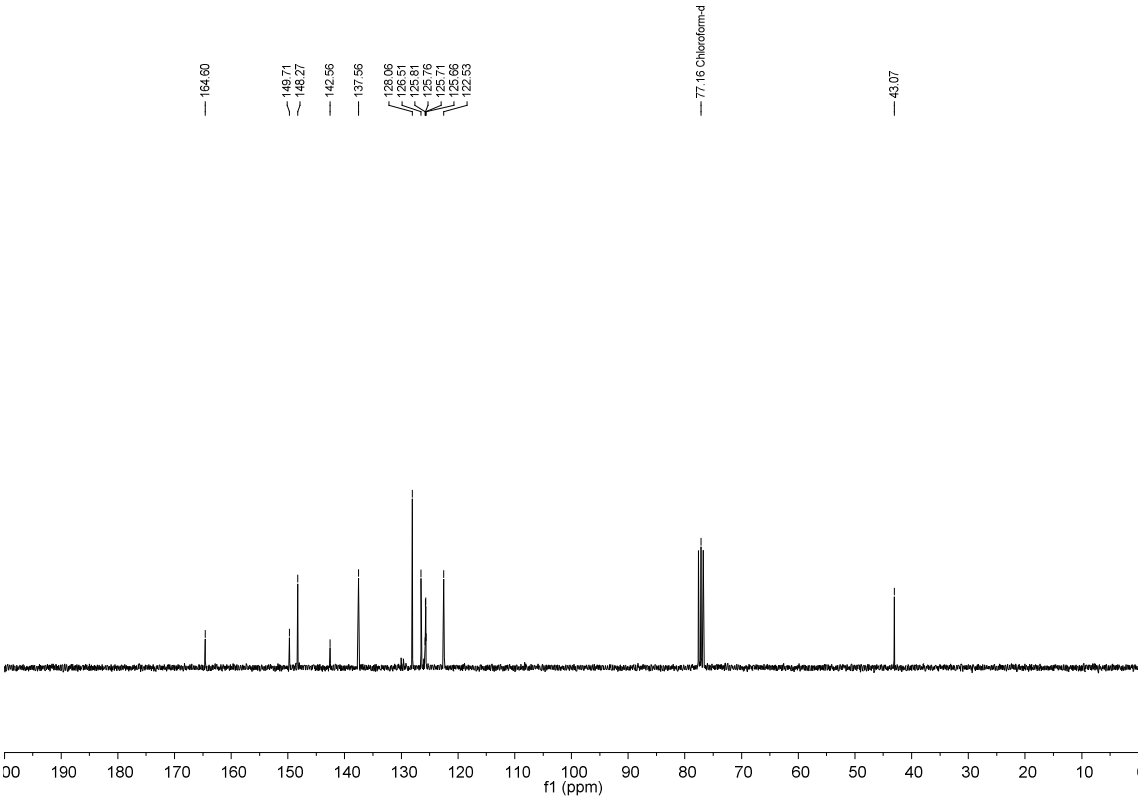
***N*-(4-(Trifluoromethyl)benzyl)picolinamide (1c)**



^{1}H NMR ($CDCl_3$, 300 MHz)

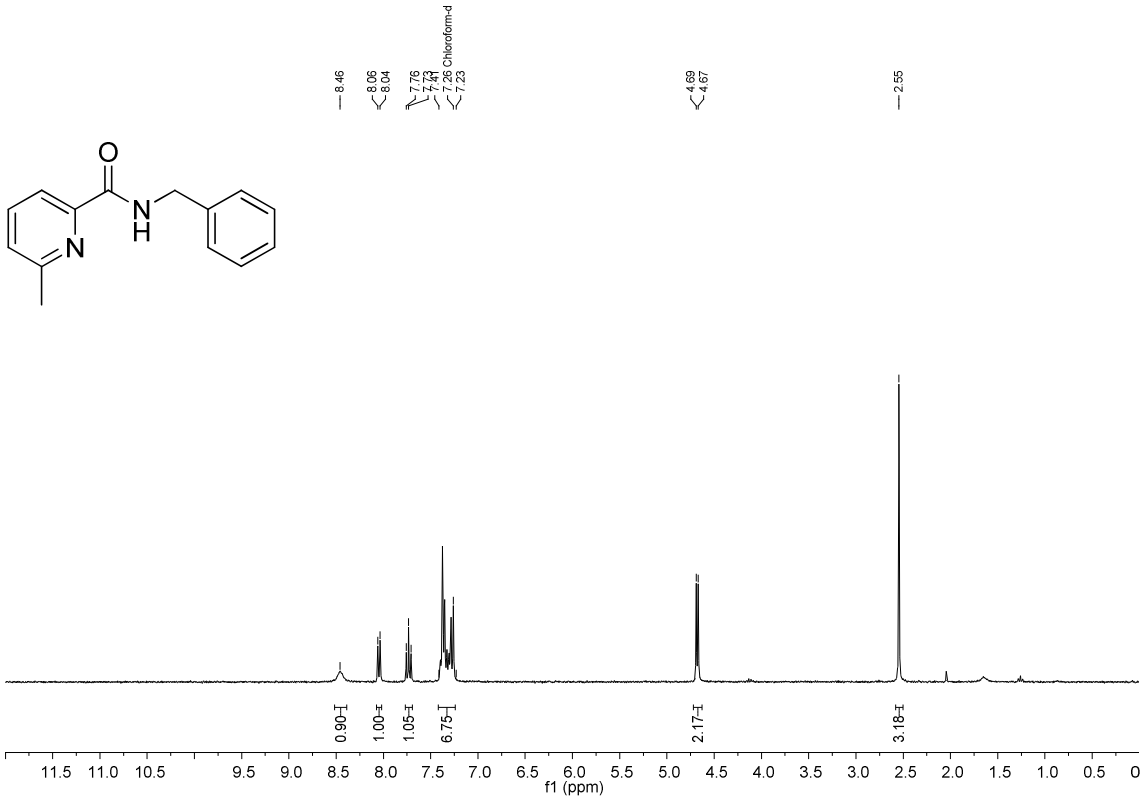


^{13}C NMR ($CDCl_3$, 75 MHz)

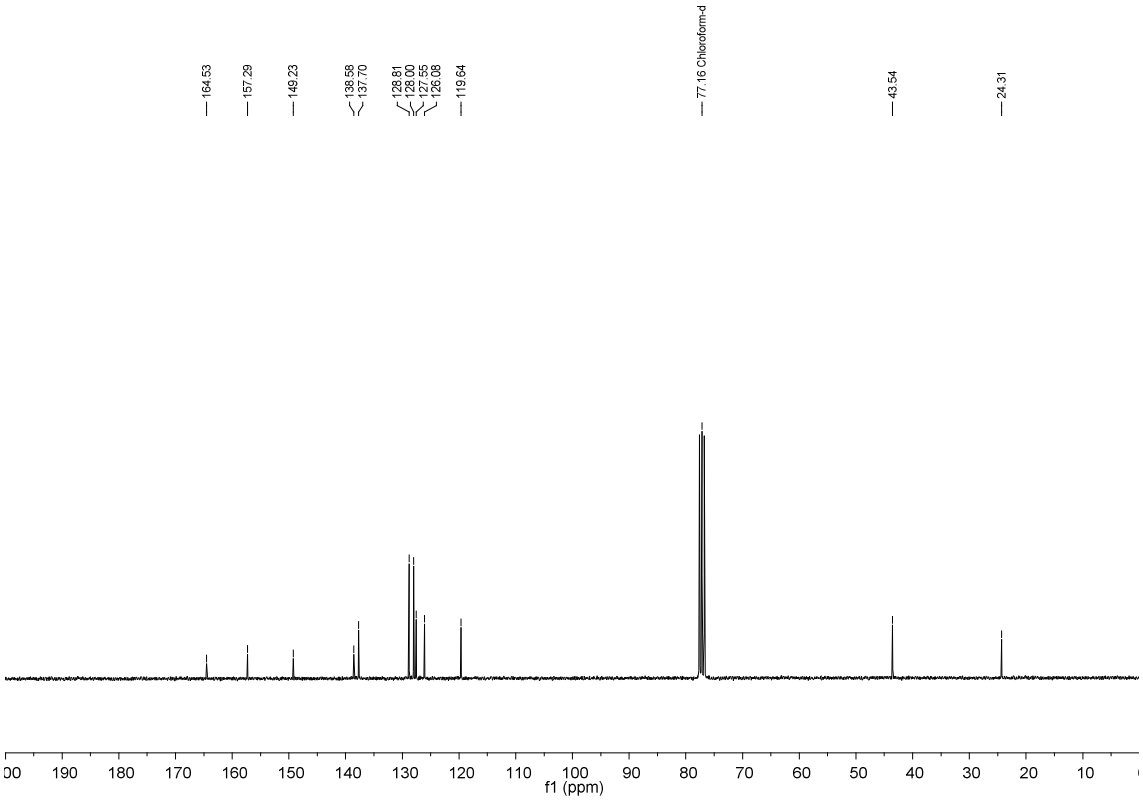


_N_-Benzyl-6-methylpicolinamide (13)

^{1}H NMR ($CDCl_3$, 300 MHz)

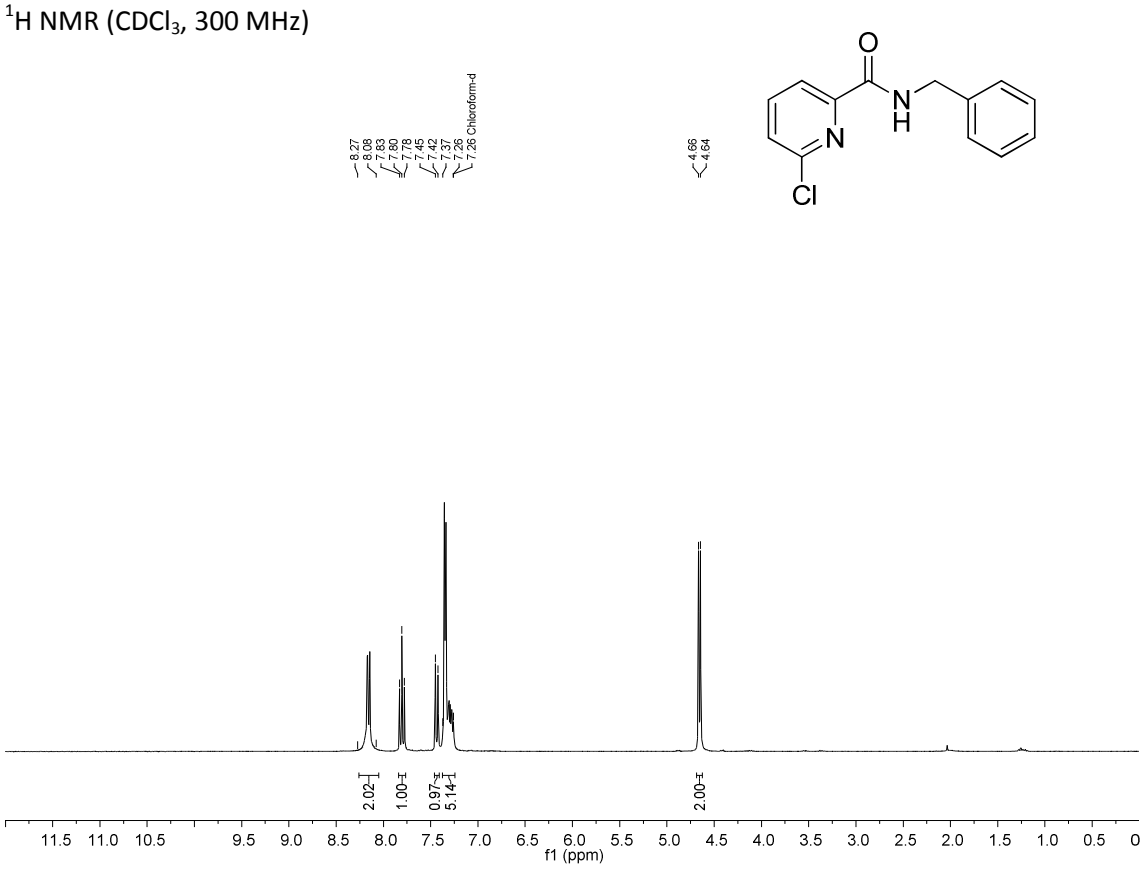


^{13}C NMR ($CDCl_3$, 75 MHz)

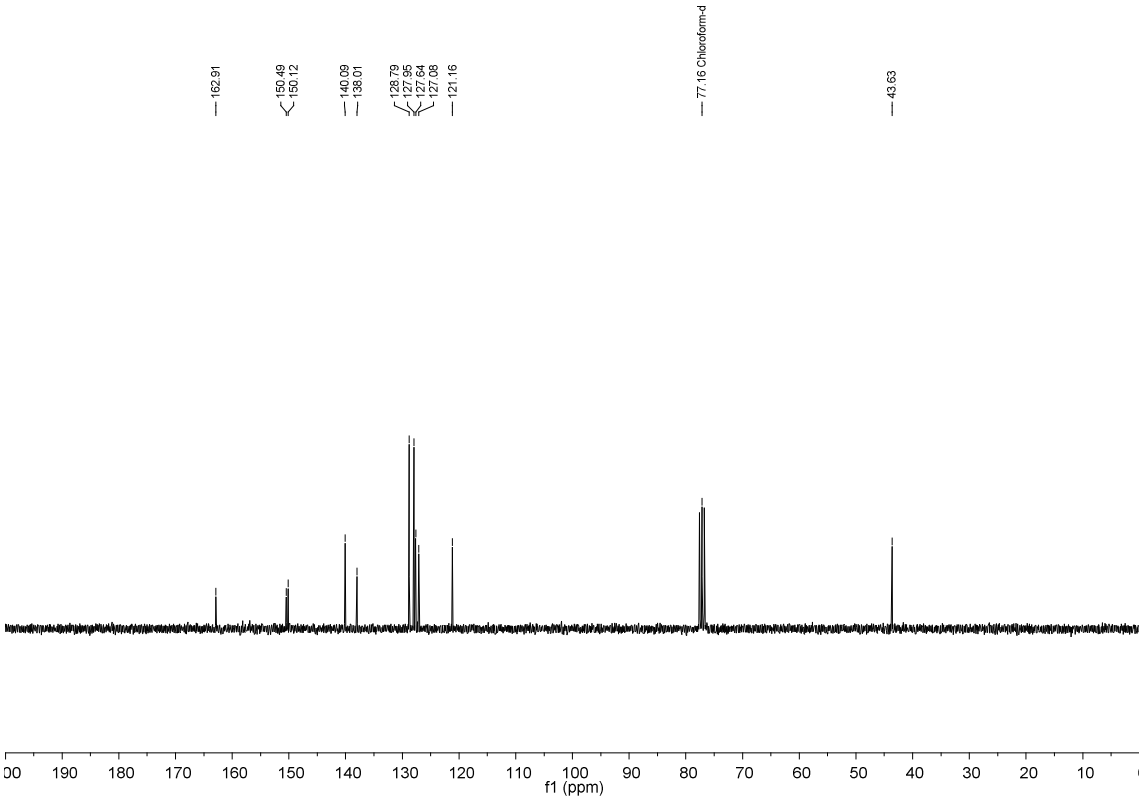


N-Benzyl-6-chloropicolinamide (14)

^{1}H NMR ($CDCl_3$, 300 MHz)

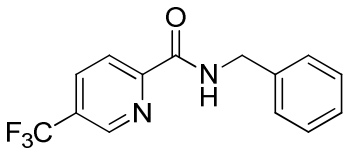


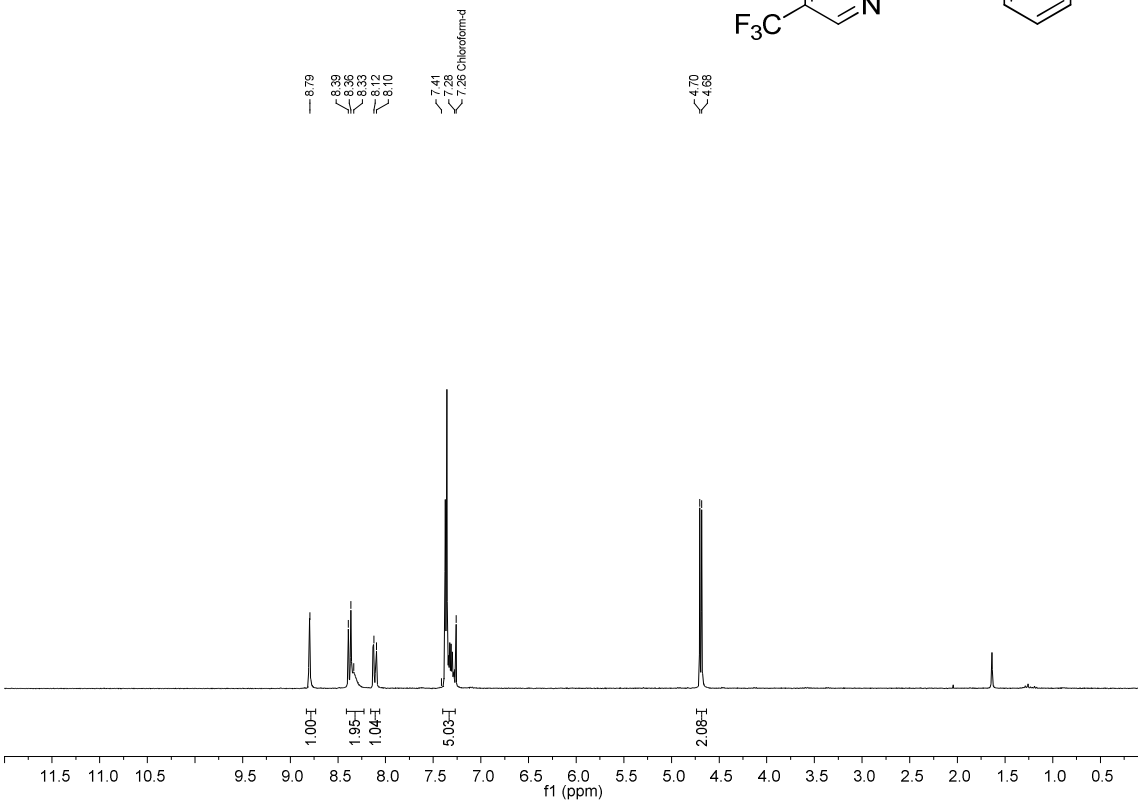
^{13}C NMR ($CDCl_3$, 75 MHz)



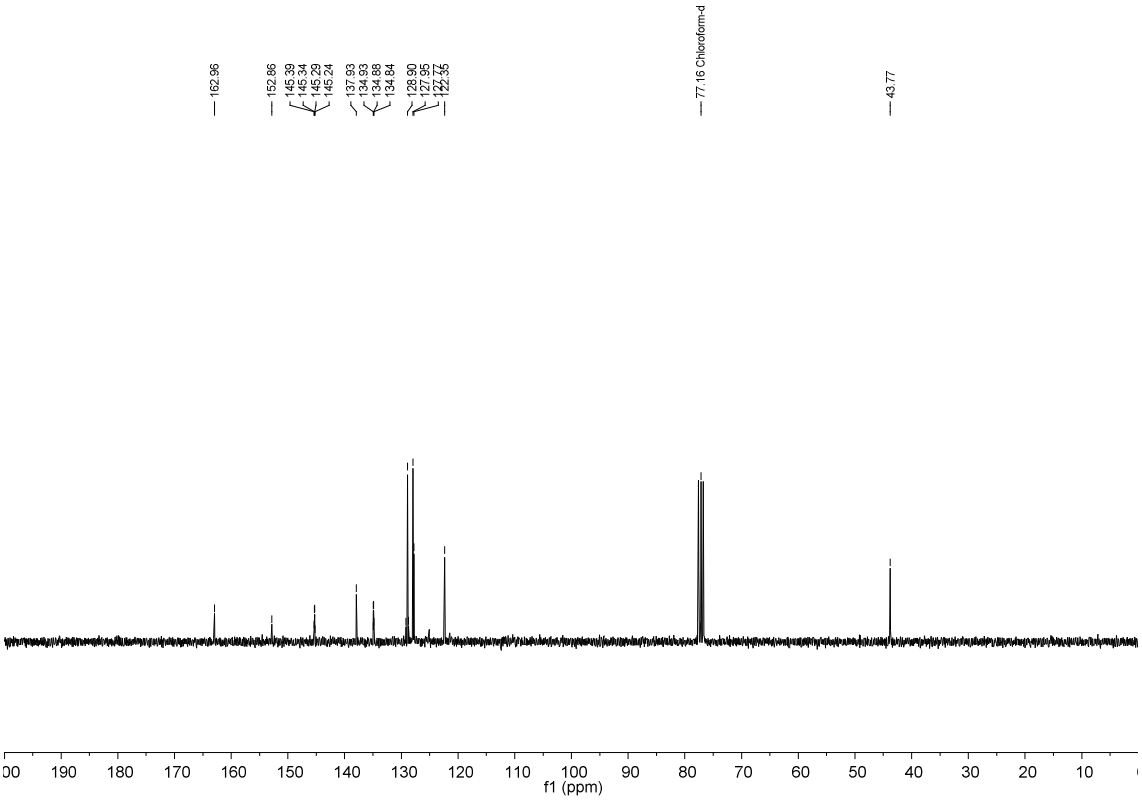
***N*-Benzyl-5-(trifluoromethyl)picolinamide (15)**

^{1}H NMR ($CDCl_3$, 300 MHz)



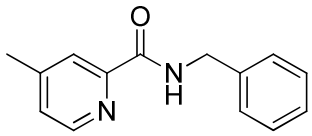


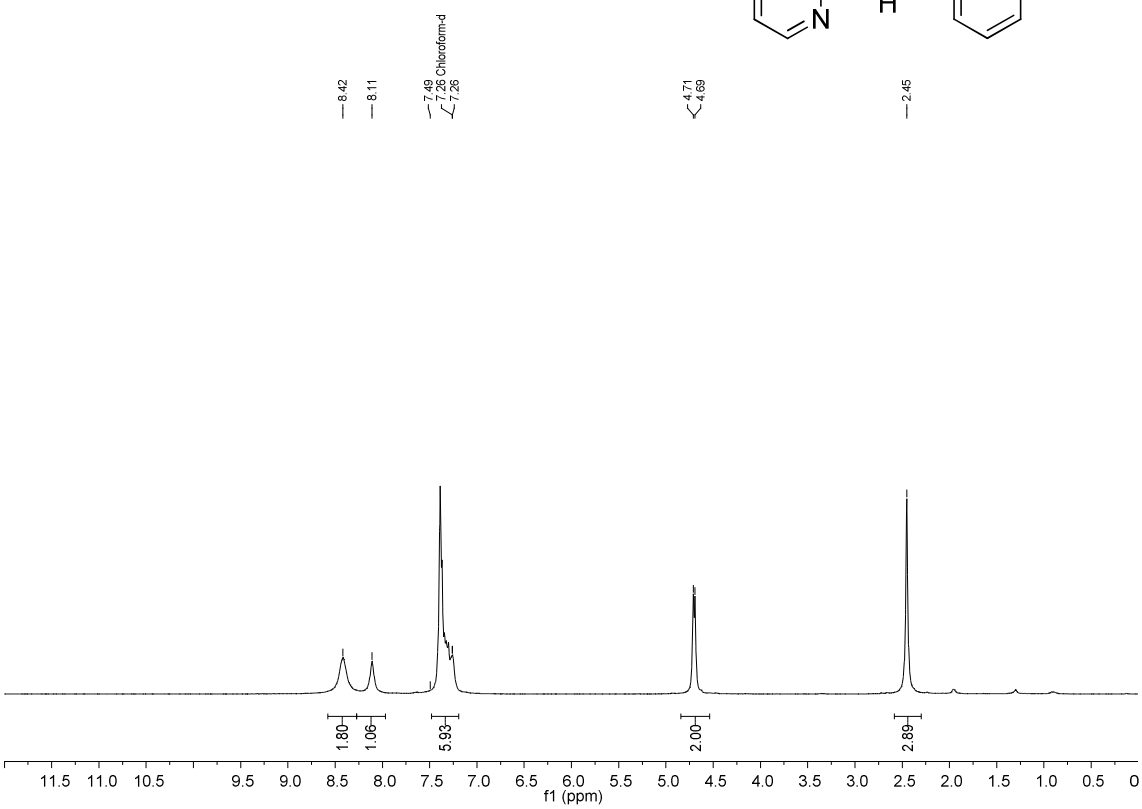
^{13}C NMR ($CDCl_3$, 75 MHz)



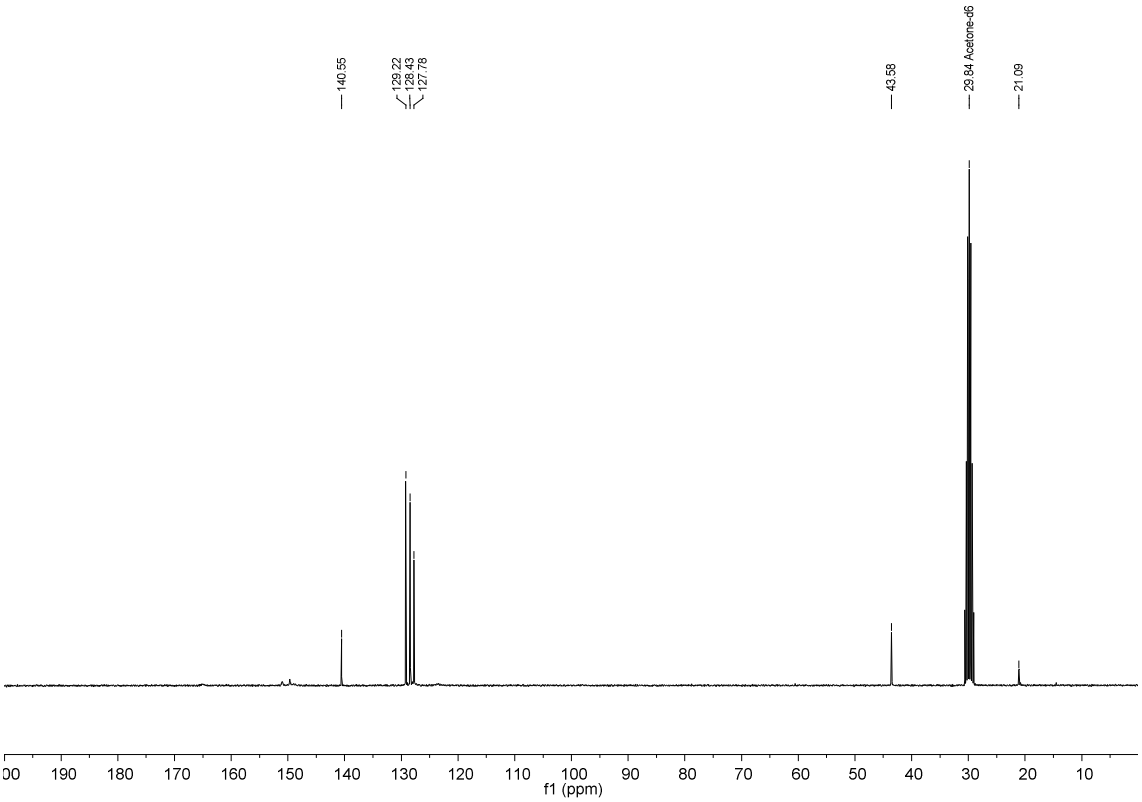
_N_-Benzyl-4-methylpicolinamide (16)

^{1}H NMR ($CDCl_3$, 300 MHz)



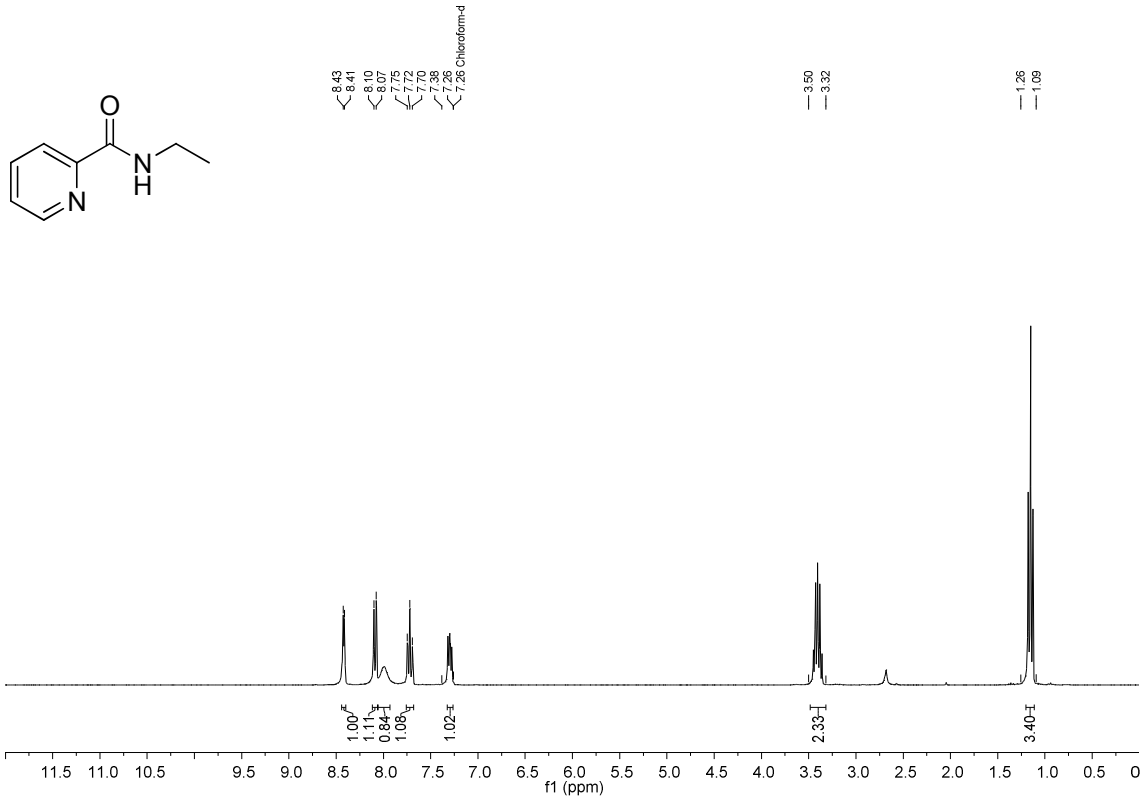


^{13}C NMR (acetone-d_6, 75 MHz)

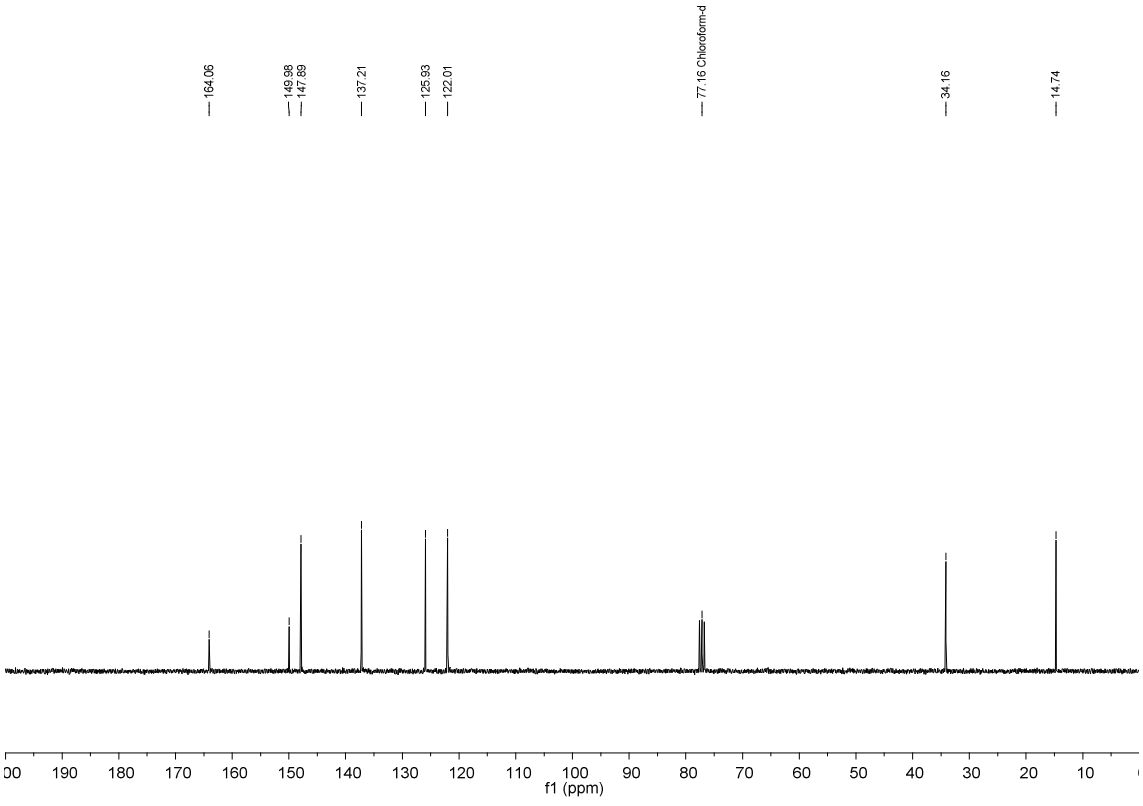


***N*-Ethylpicolinamide (28)**.

^{1}H NMR ($CDCl_3$, 300 MHz)

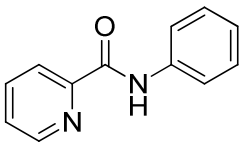


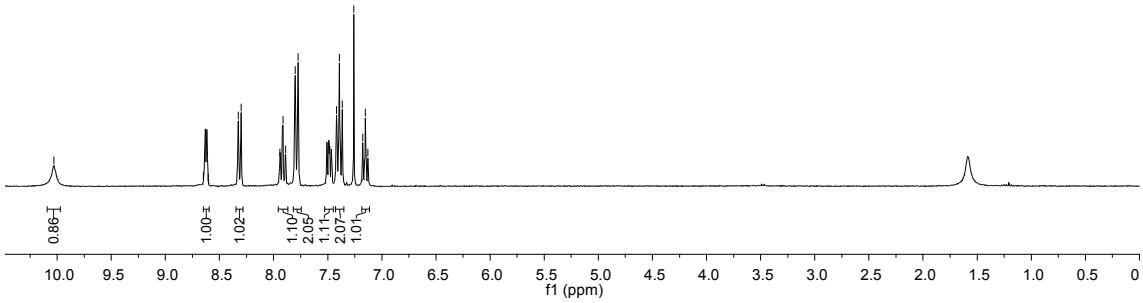
^{13}C NMR ($CDCl_3$, 75MHz)



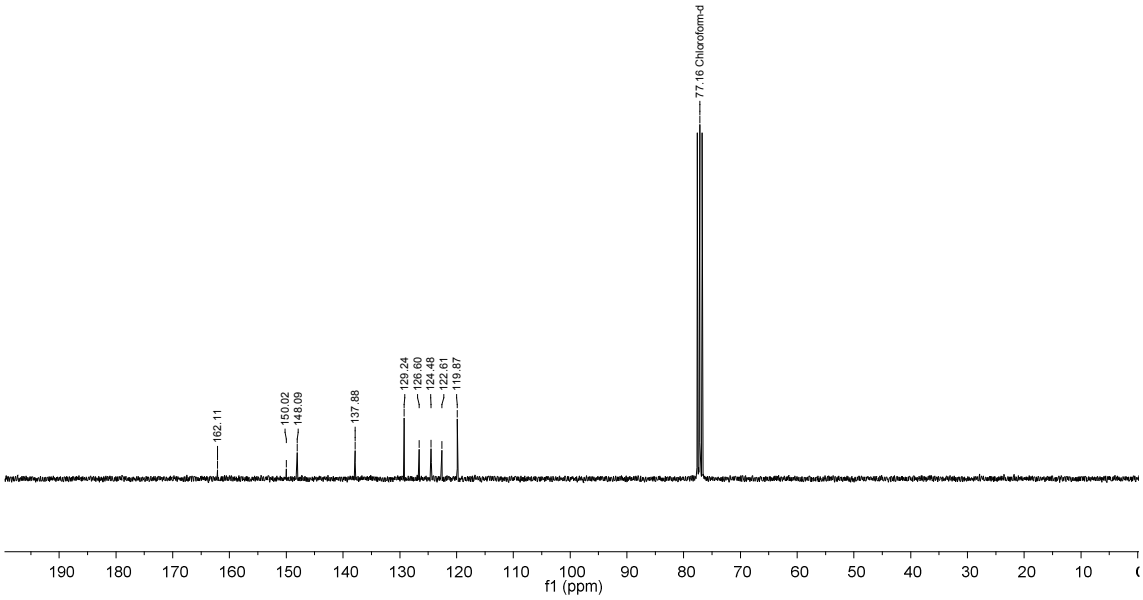
N-Phenylpicolinamide (29)

^{1}H NMR ($CDCl_3$, 300 MHz)



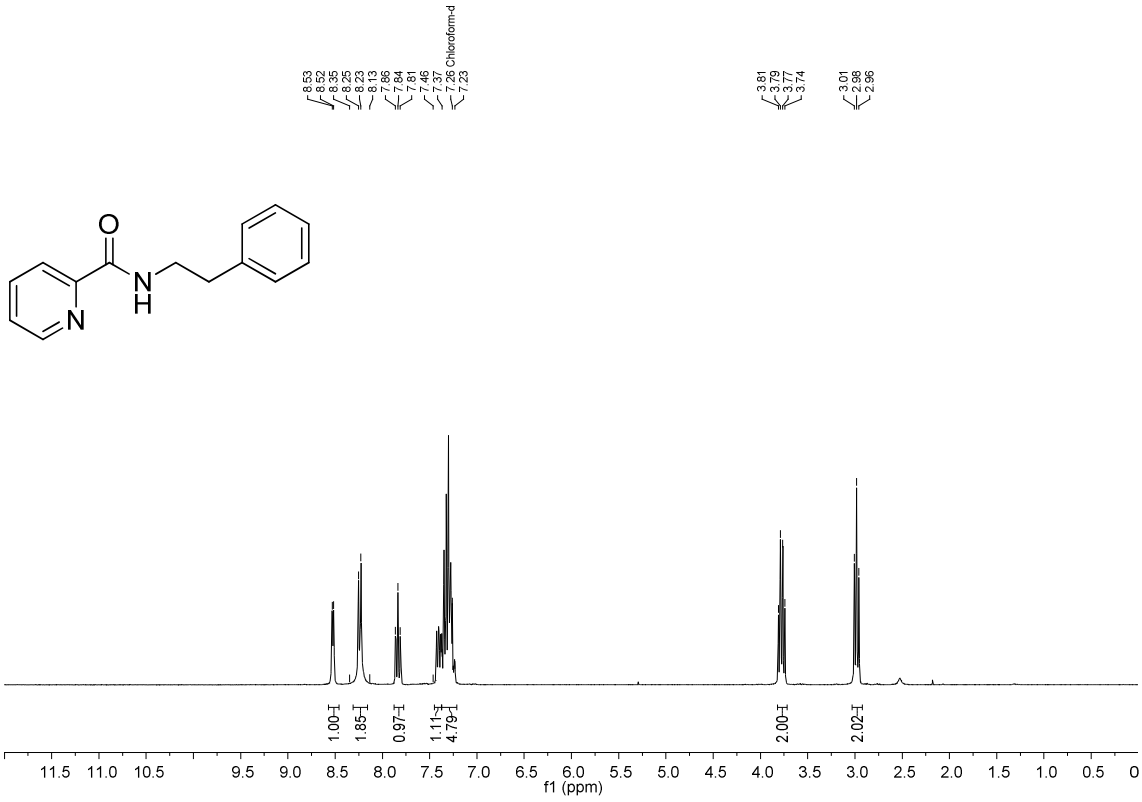


^{13}C NMR ($CDCl_3$, 75 MHz)

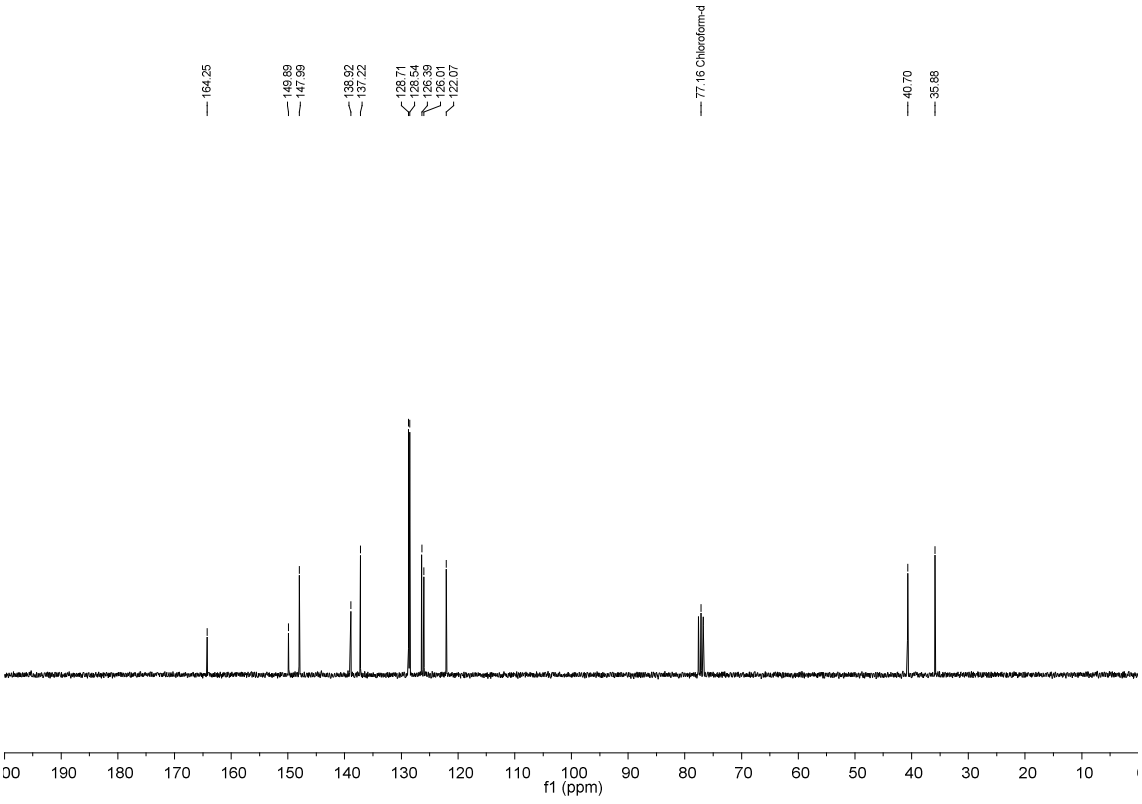


***N*-Phenethylpicolinamide (30)**.

^{1}H NMR ($CDCl_3$, 300 MHz)

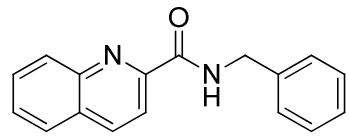


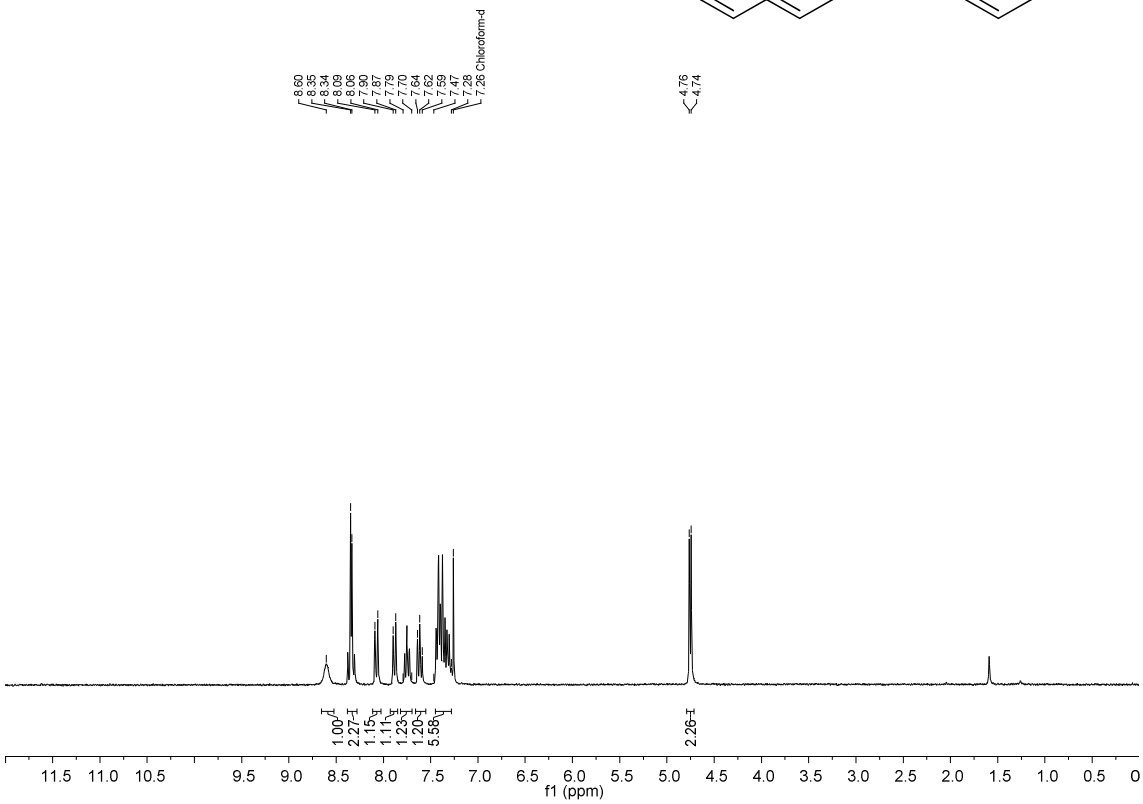
^{13}C NMR ($CDCl_3$, 75 MHz)



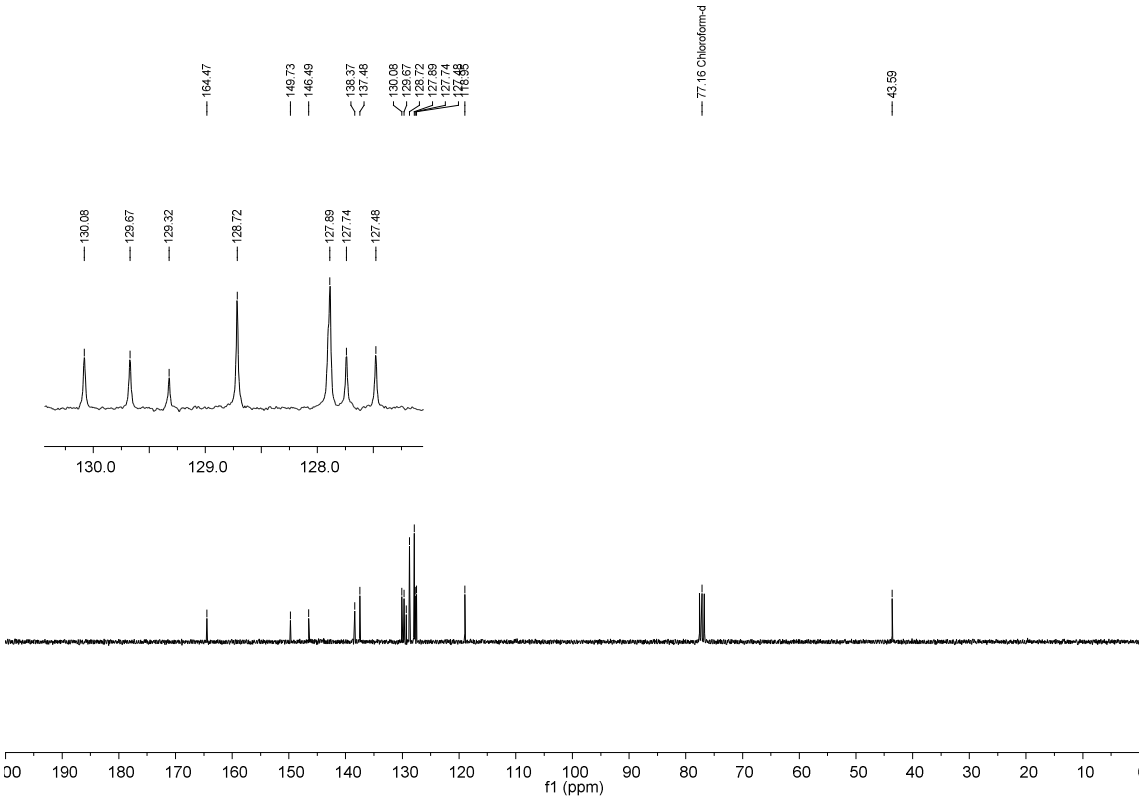
_N_-Benzylquinoline-2-carboxamide (17)

^{1}H NMR ($CDCl_3$, 300 MHz)



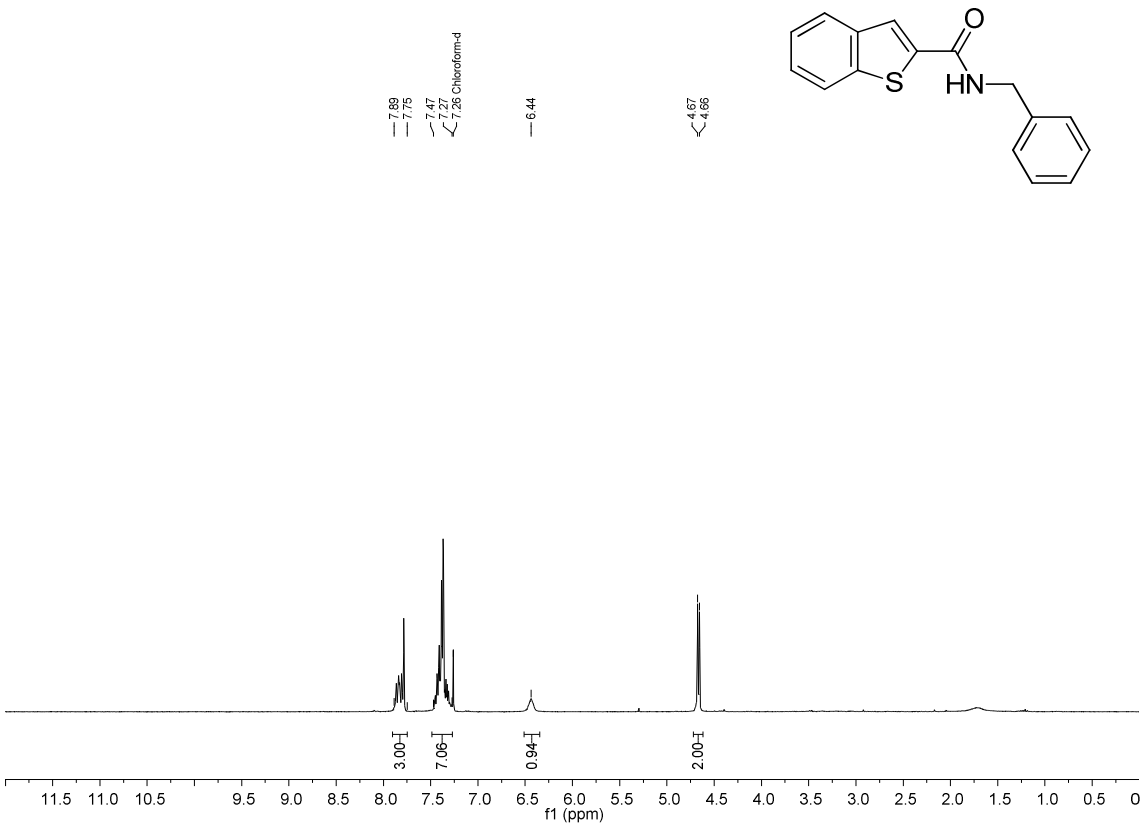


^{13}C NMR ($CDCl_3$, 75 MHz)

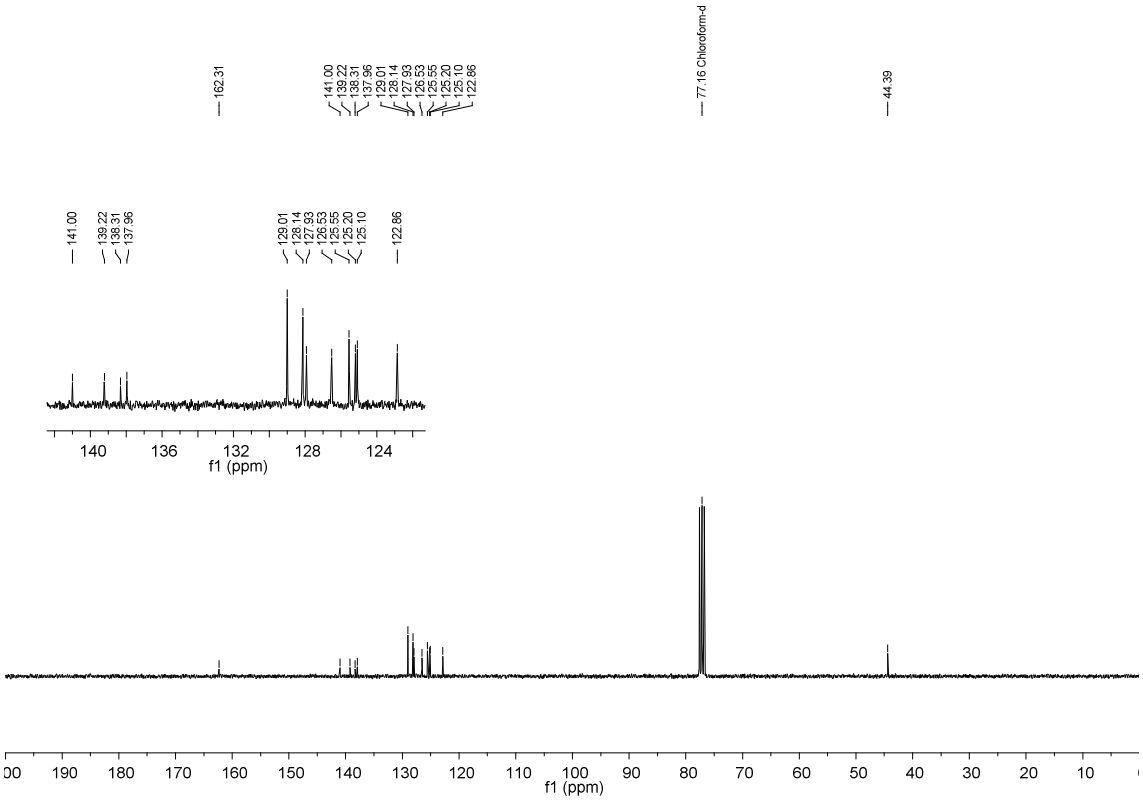


_N_-Benzylbenzo[_b_]thiophene-2-carboxamide (18)

^{1}H NMR ($CDCl_3$, 300 MHz)

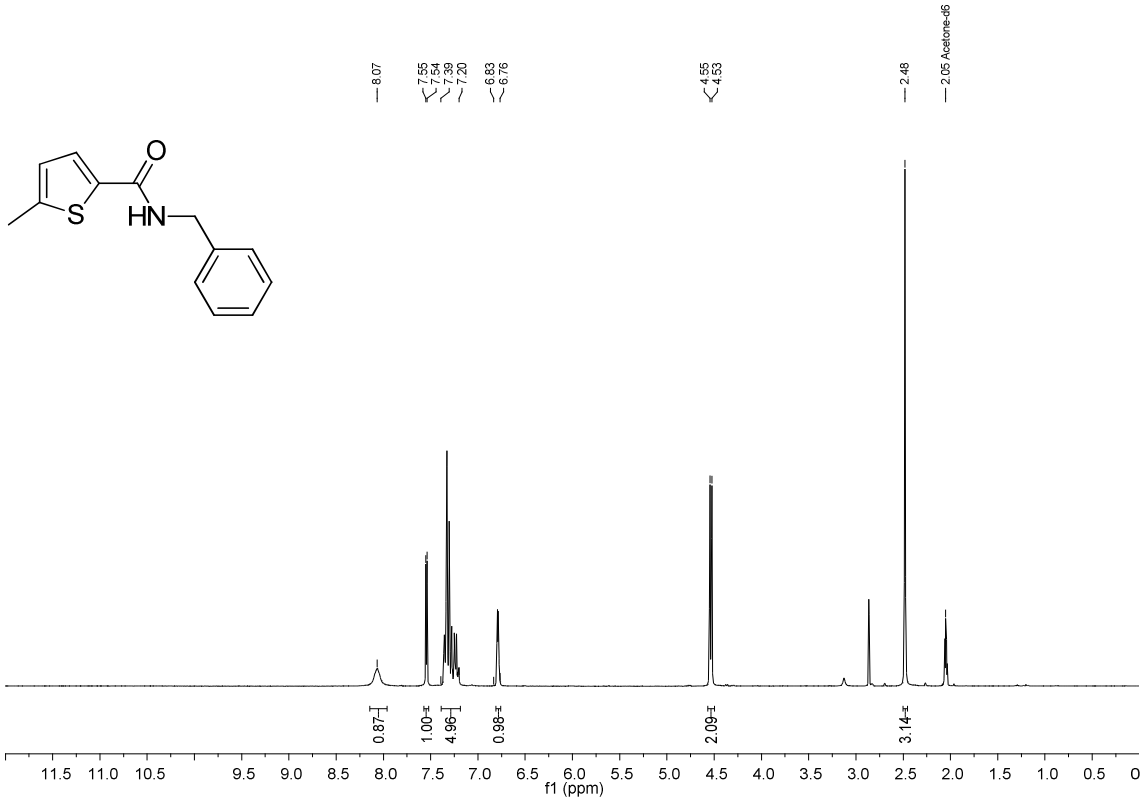


^{13}C NMR ($CDCl_3$, 75 MHz)

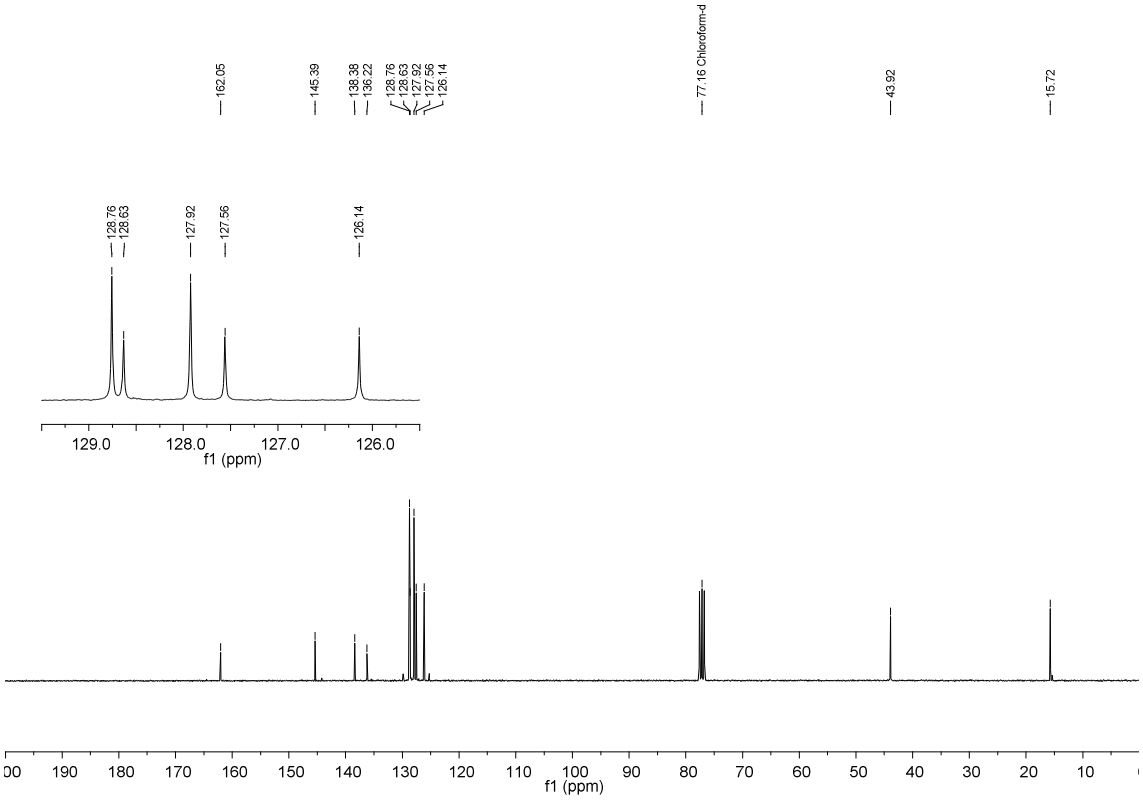


***N*-Benzyl-5-methylthiophene-2-carboxamide (19)**.

^{1}H NMR (acetone-d_6, 300 MHz)

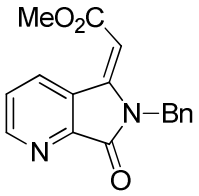


^{13}C NMR ($CDCl_3$, 75 MHz)

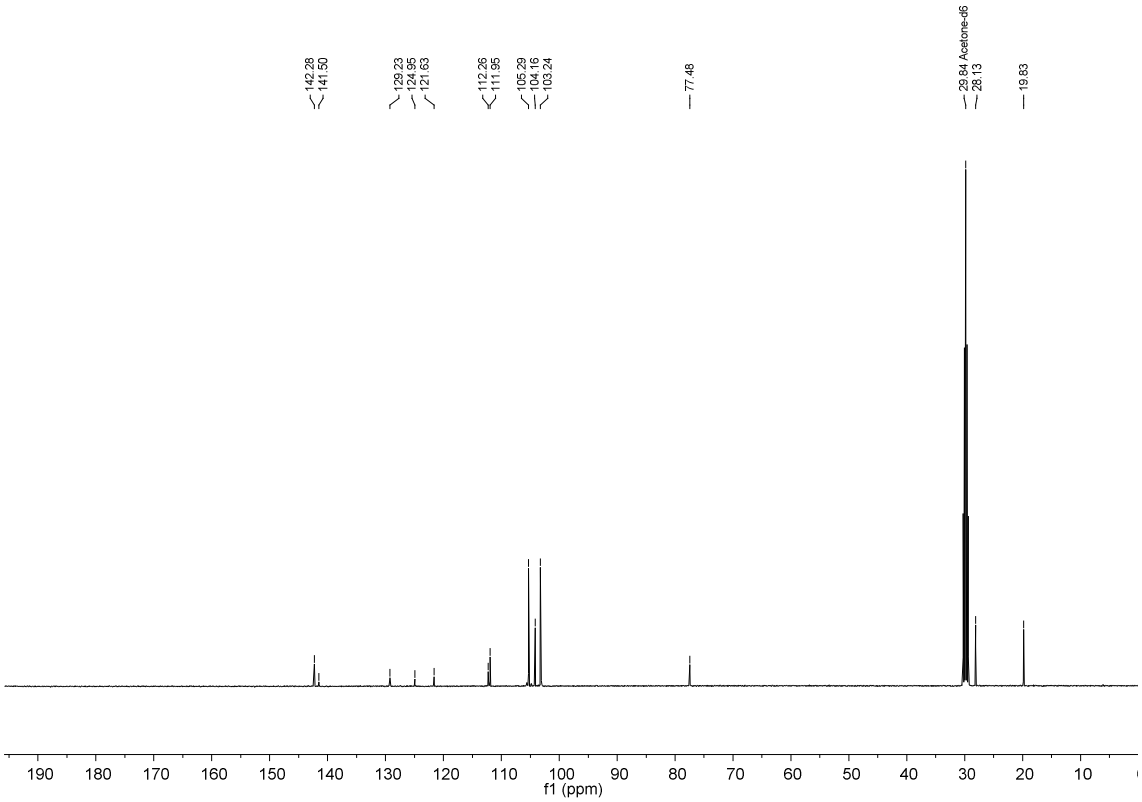


(*E*)-Methyl 2-(6-benzyl-7-oxo-6,7-dihydro-5H-pyrrolo[3,4-*b*]pyridin-5-ylidene)acetate (2)

^{1}H NMR ($CDCl_3$, 300 MHz)

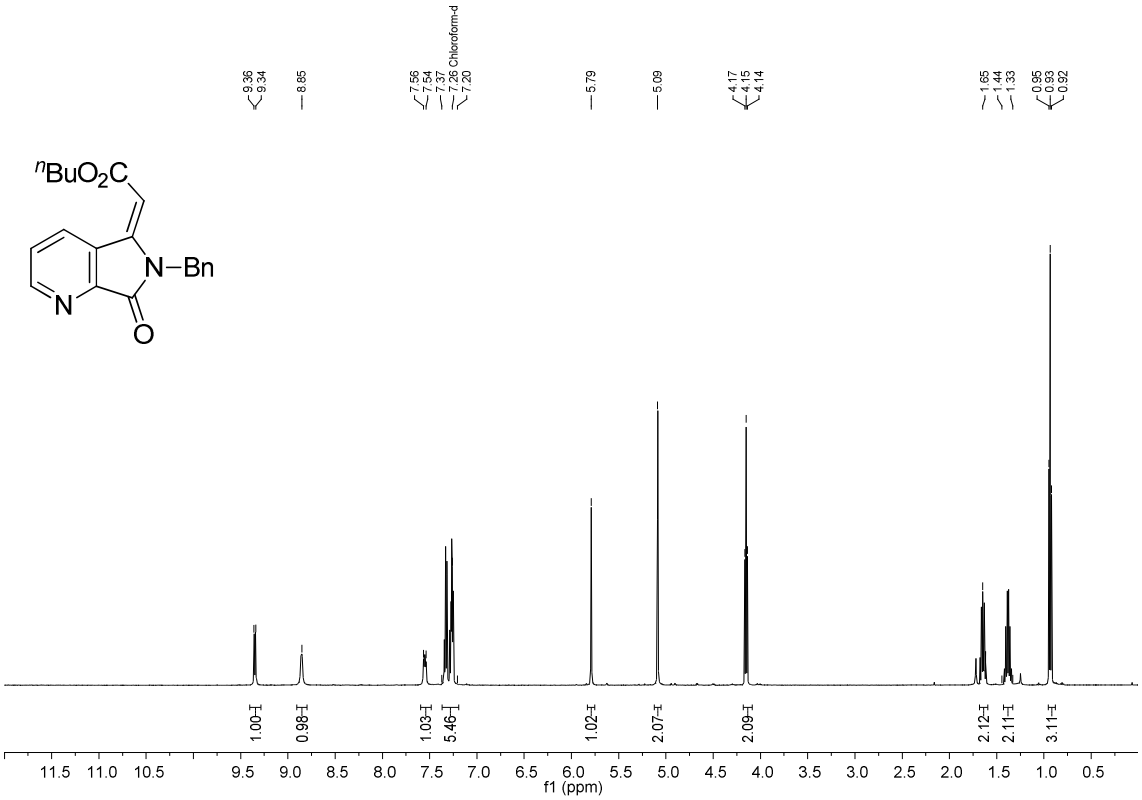


^{13}C NMR (acetone-d_6, 126 MHz)

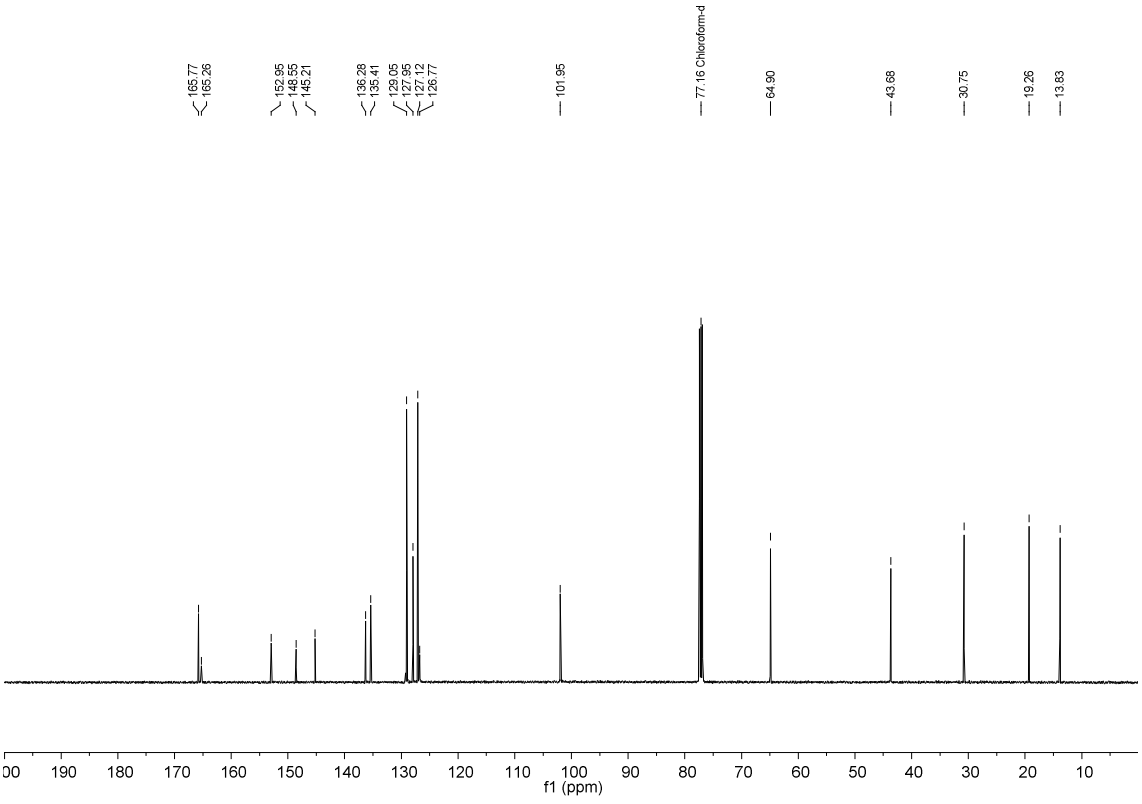


(*E*)-*n*-Butyl 2-(6-benzyl-7-oxo-6,7-dihydro-5H-pyrrolo[3,4-*b*]pyridin-5-ylidene)acetate (4)

^{1}H NMR ($CDCl_3$, 500 MHz)

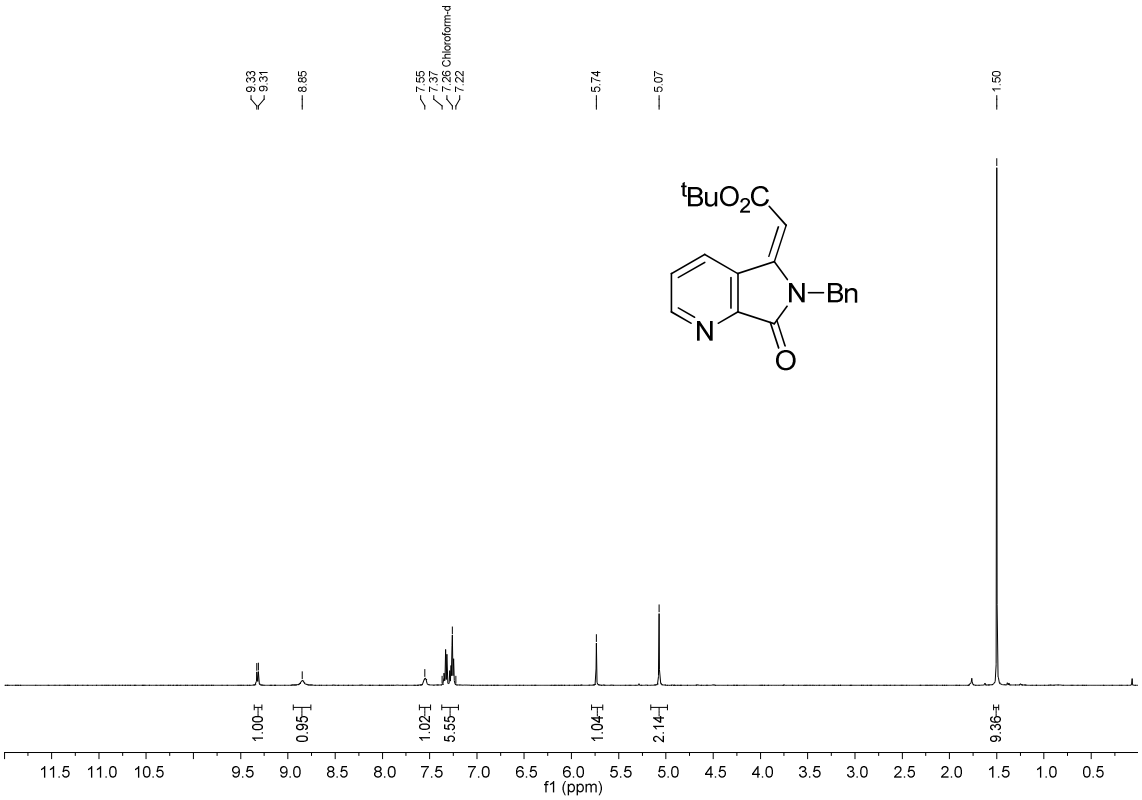


^{13}C NMR ($CDCl_3$, 126 MHz)

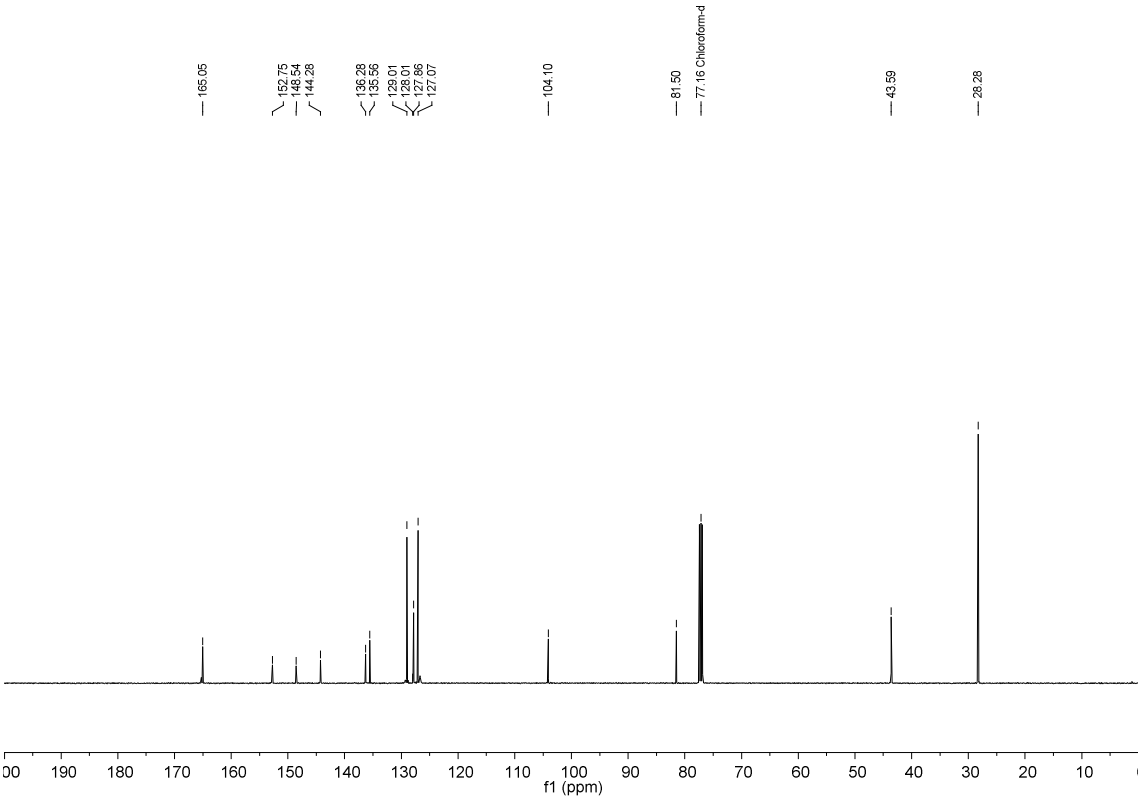


(*E*)-*tert*-Butyl 2-(6-benzyl-7-oxo-6,7-dihydro-5H-pyrrolo[3,4-*b*]pyridin-5-ylidene)acetate (5)

^{1}H NMR ($CDCl_3$, 500 MHz)

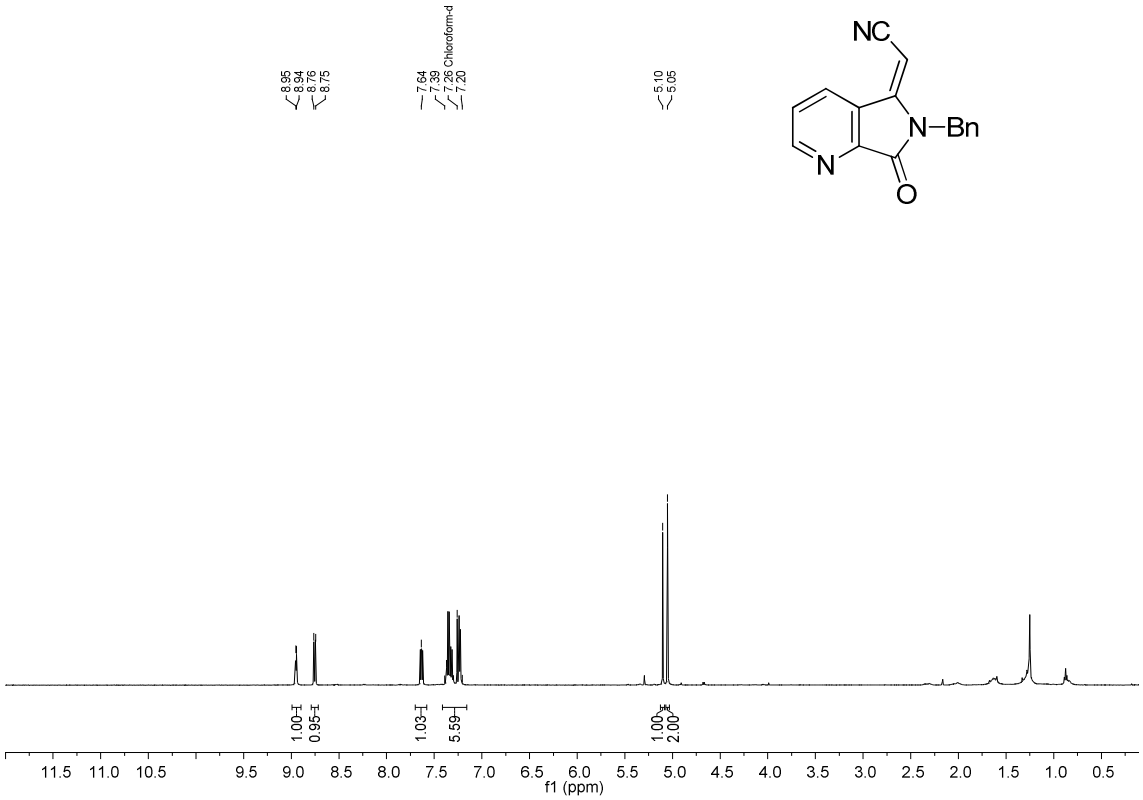


^{13}C NMR ($CDCl_3$, 126 MHz)

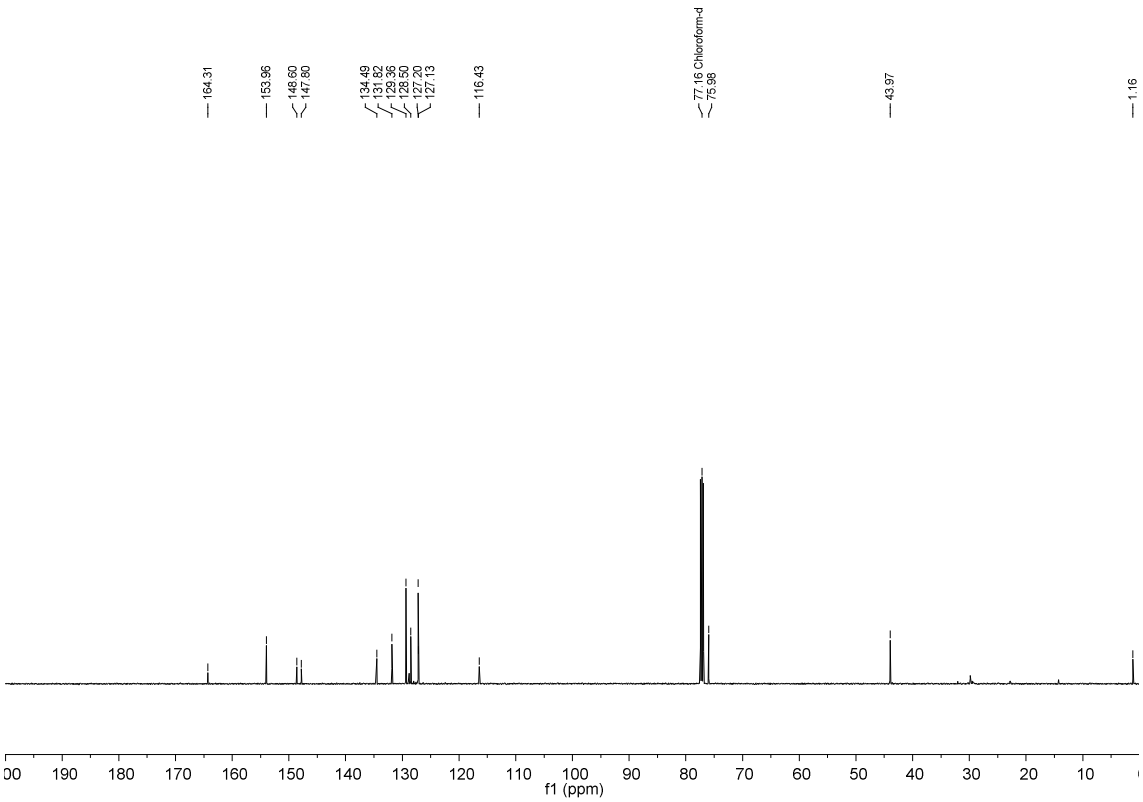


(*E*)-2-(6-Benzyl-7-oxo-6,7-dihydro-5H-pyrrolo[3,4-*b*]pyridin-5-ylidene)acetonitrile (6)

^{1}H NMR ($CDCl_3$, 500 MHz)

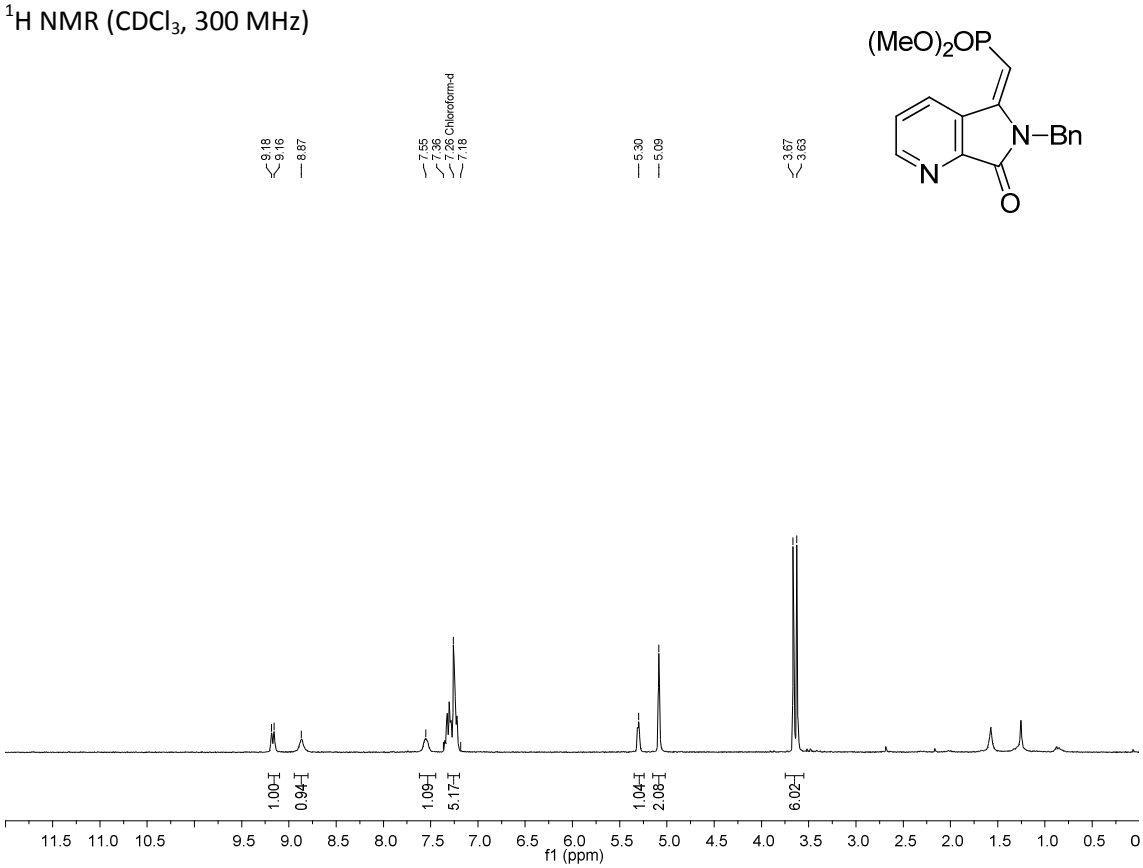


^{13}C NMR ($CDCl_3$, 126 MHz)

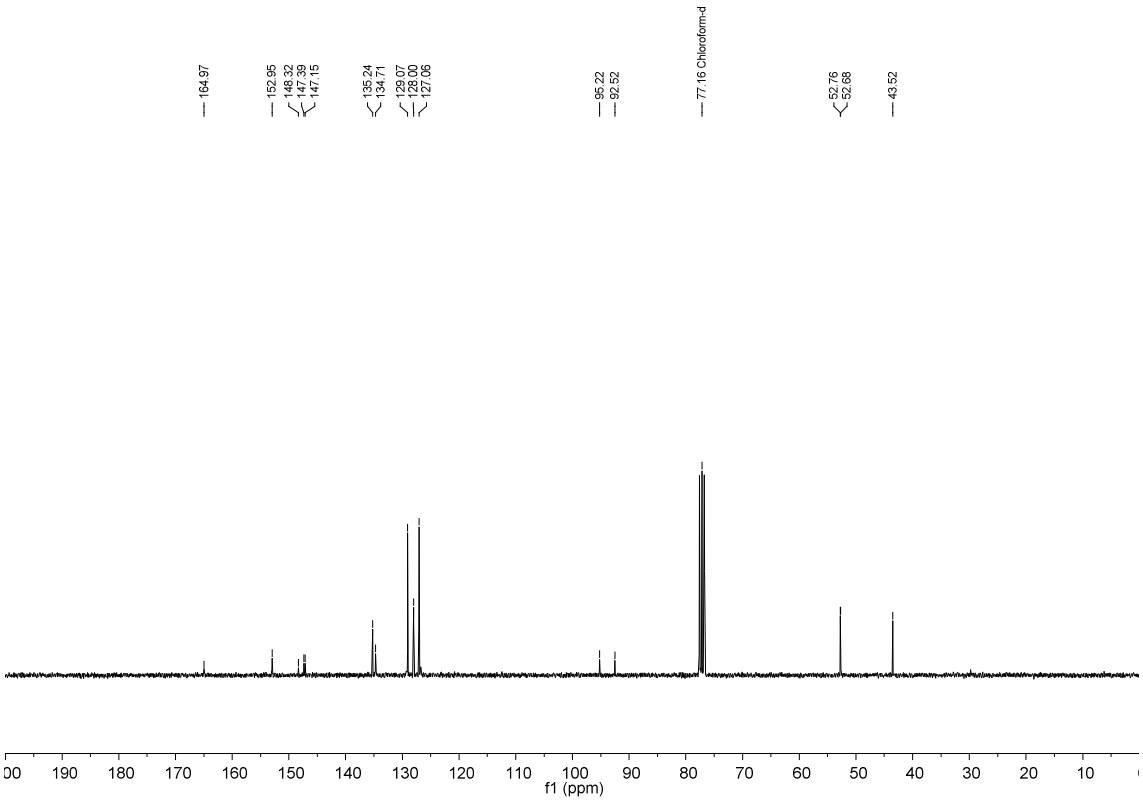


(*E*)-Dimethyl ((6-benzyl-7-oxo-6,7-dihydro-5H-pyrrolo[3,4-*b*]pyridin-5-ylidene)methyl)-phosphonate (7)

^{1}H NMR ($CDCl_3$, 300 MHz)

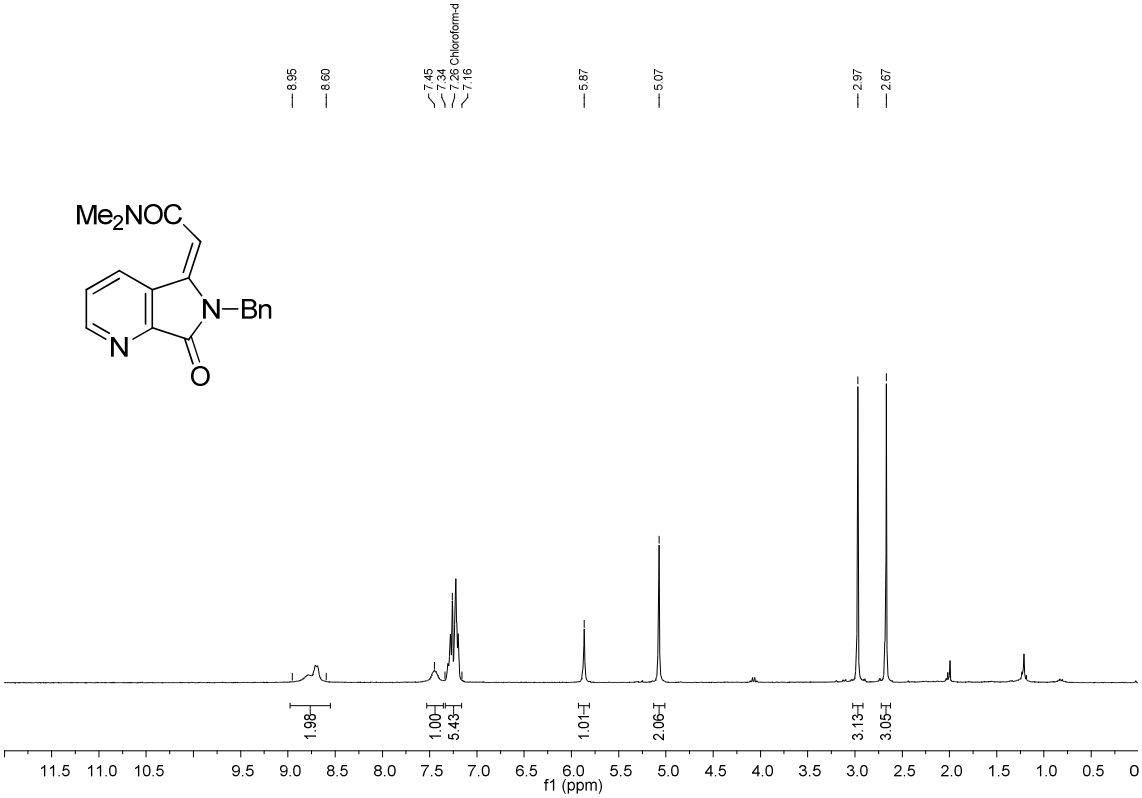


^{13}C NMR ($CDCl_3$, 75 MHz)

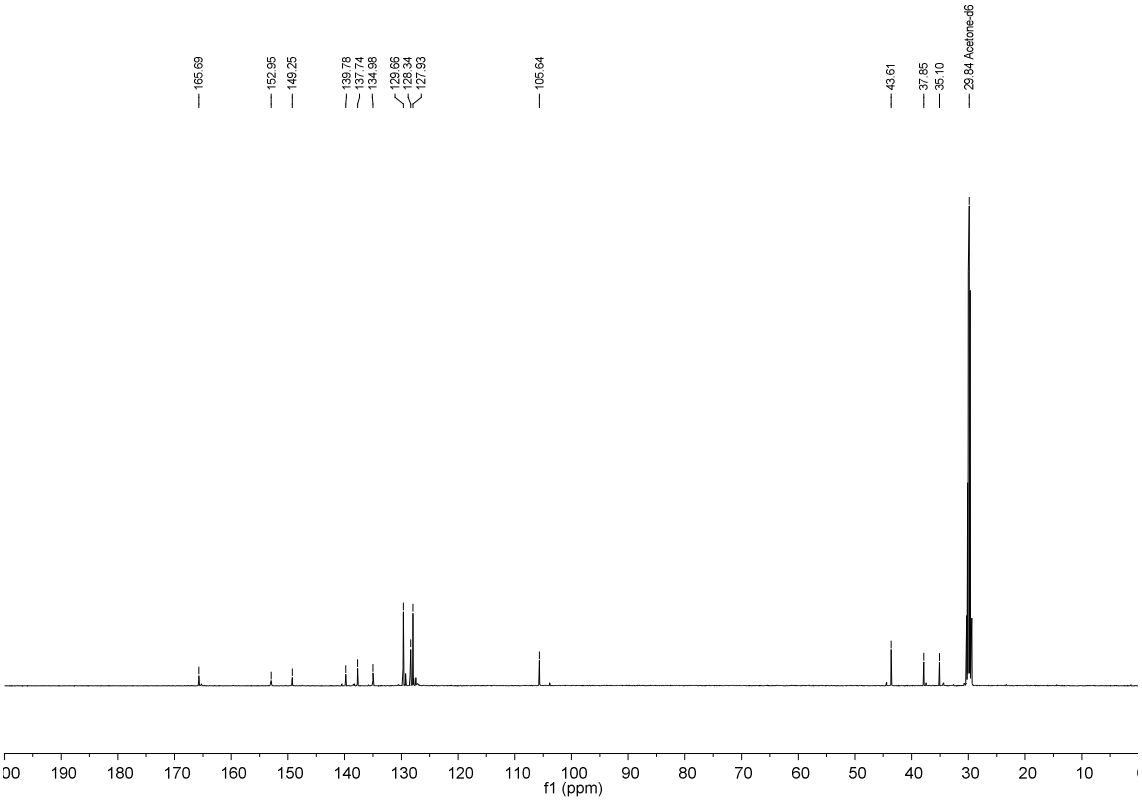


(*E*)-2-(6-benzyl-7-oxo-6,7-dihydro-5H-pyrrolo[3,4-*b*]pyridin-5-ylidene)-*N*,*N*-dimethylacetamide (8)

^{1}H NMR ($CDCl_3$, 300 MHz)

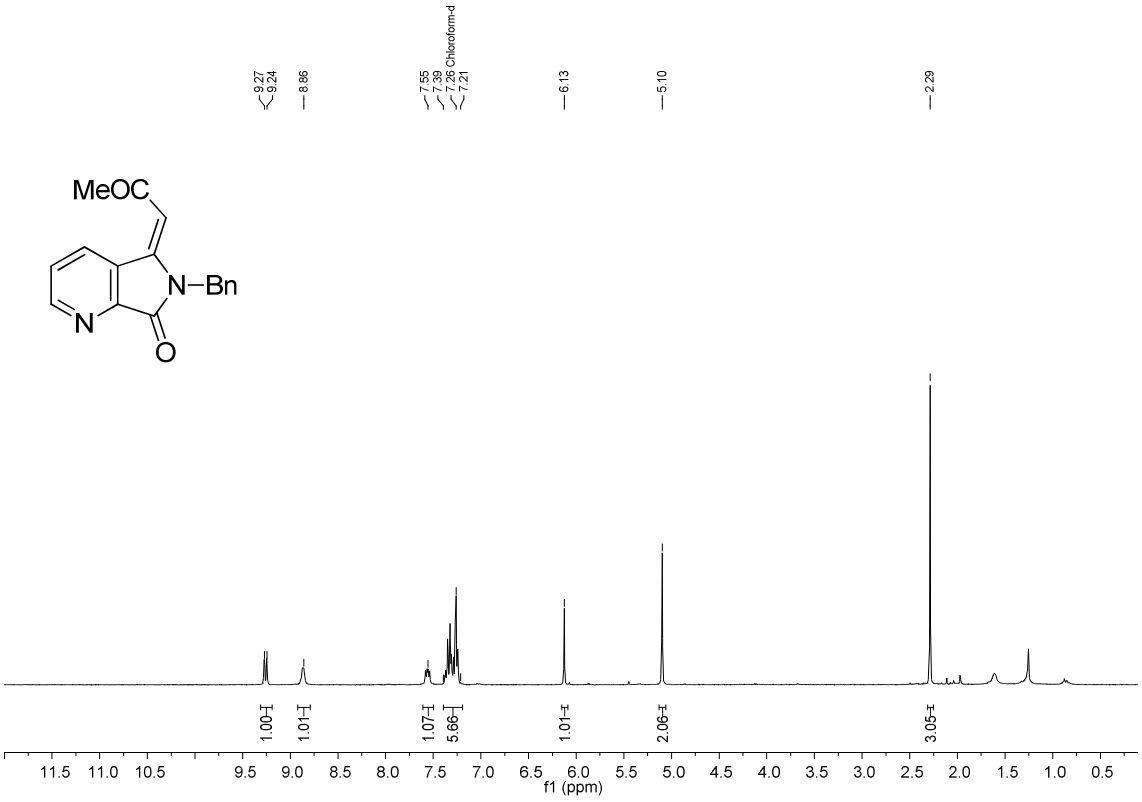


^{13}C NMR (acetone-d_6, 126 MHz)

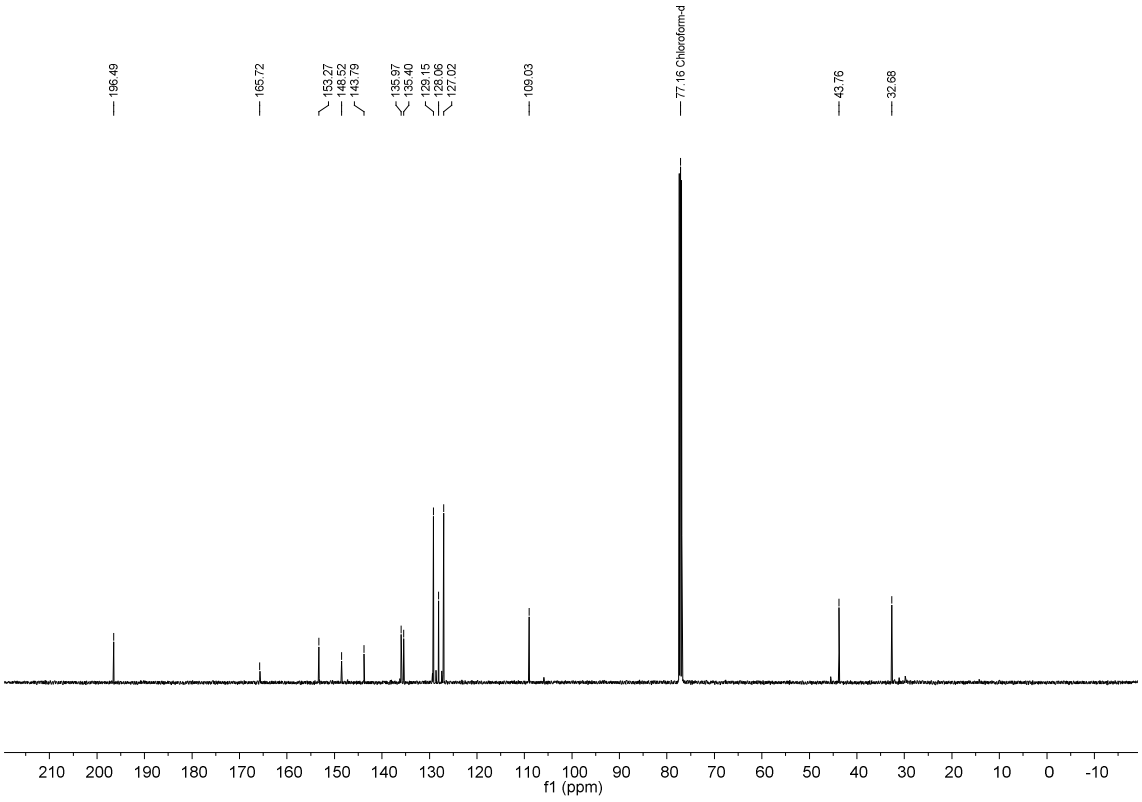


(*E*)-6-Benzyl-5-(2-oxopropylidene)-5H-pyrrolo[3,4-*b*]pyridin-7(6H)-one (9)

^{1}H NMR ($CDCl_3$, 300 MHz)

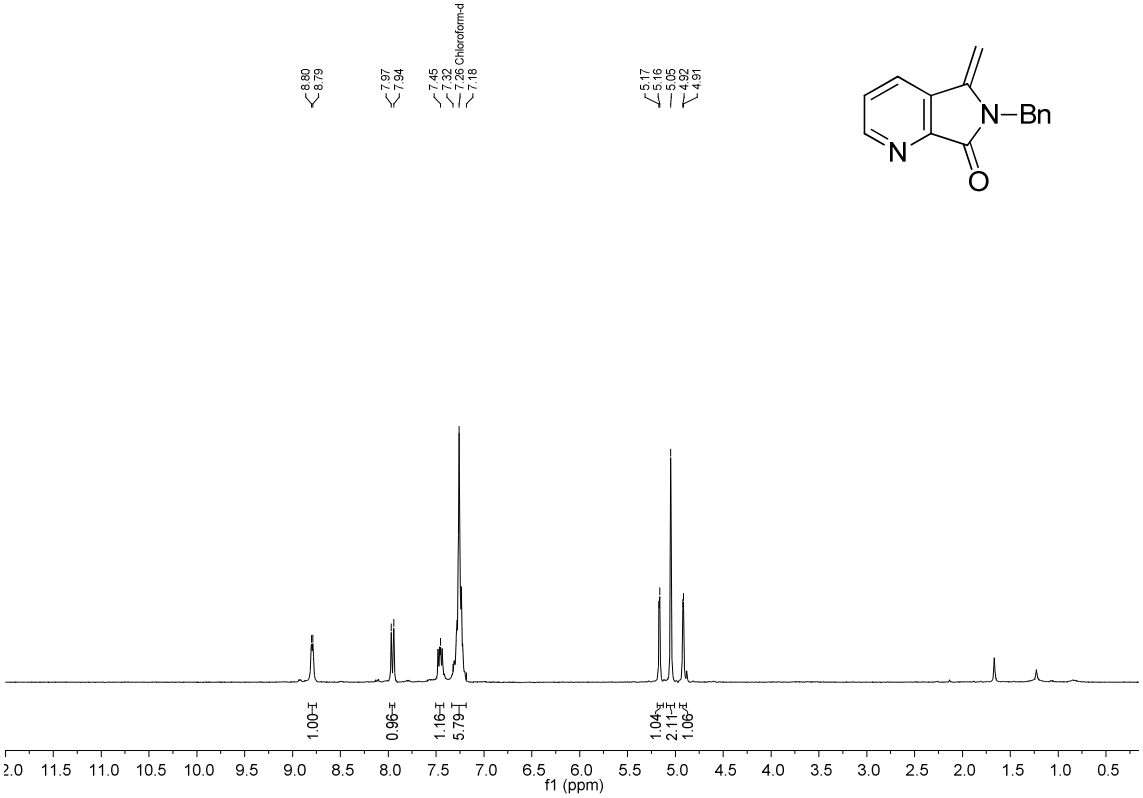


^{13}C NMR ($CDCl_3$, 126 MHz)

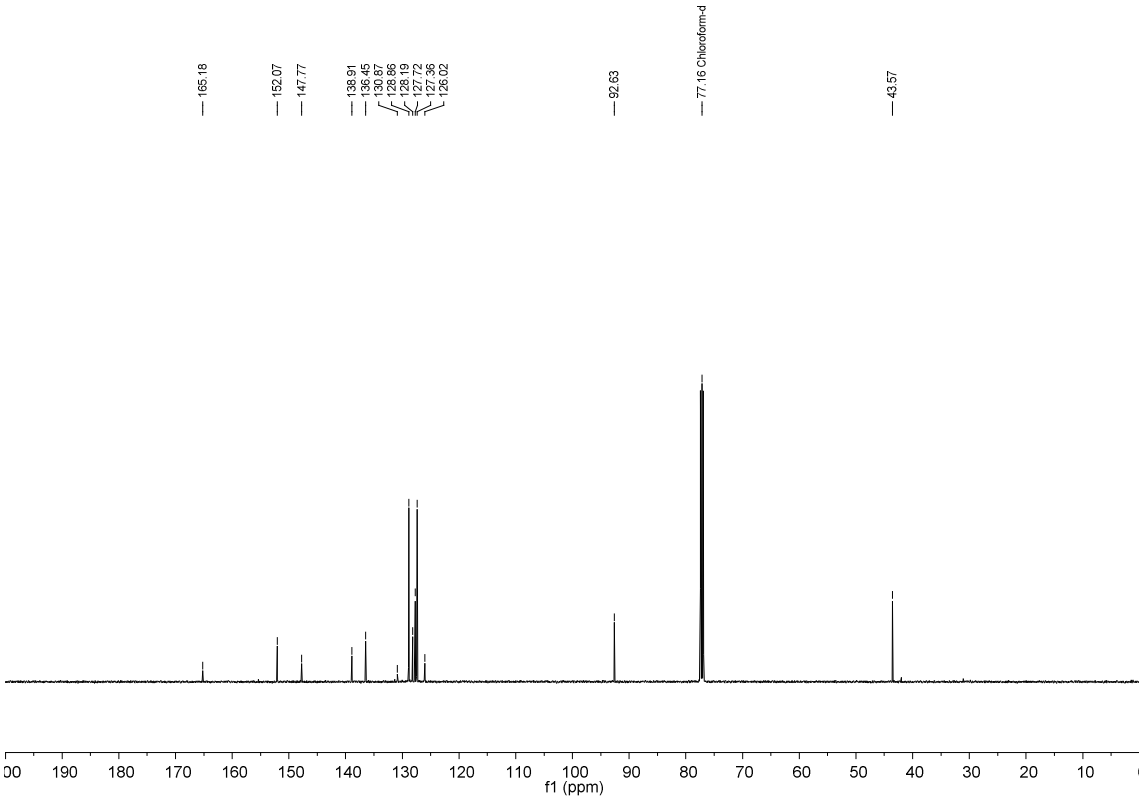


6-Benzyl-5-methylene-5H-pyrrolo[3,4-*b*]pyridin-7(6H)-one (10)

^{1}H NMR ($CDCl_3$, 300 MHz)

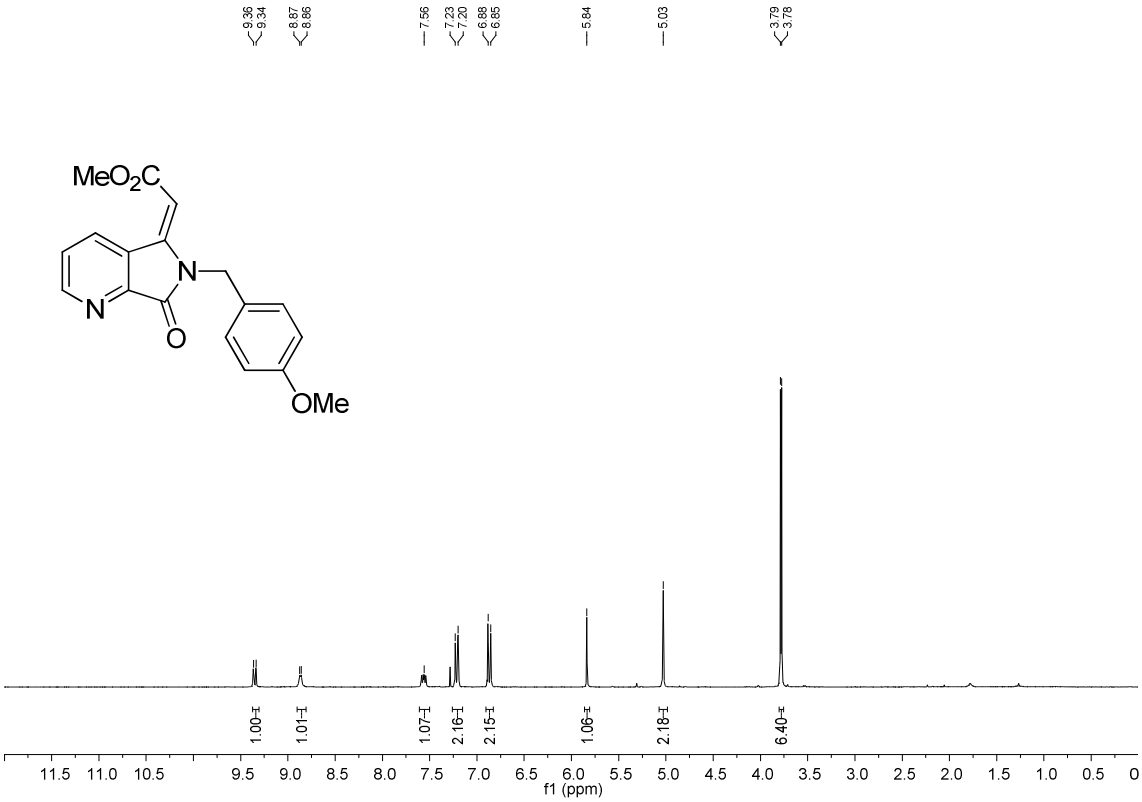


^{13}C NMR ($CDCl_3$, 126 MHz)

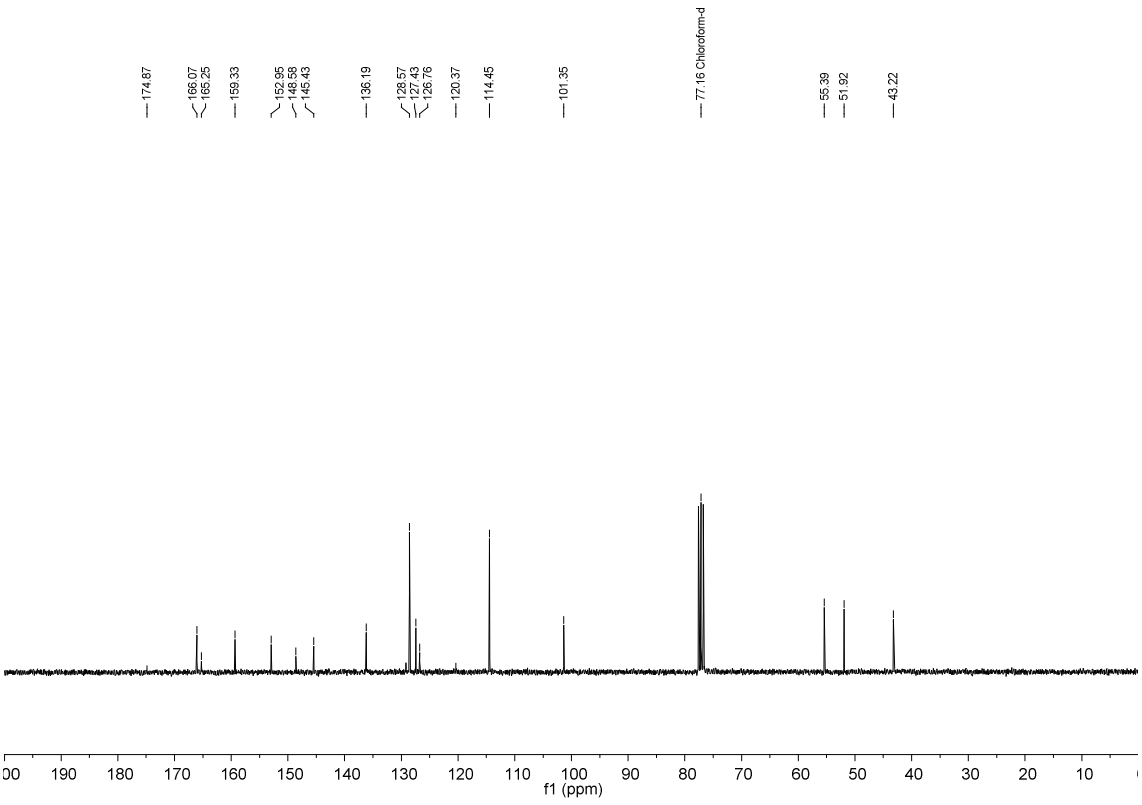


(*E*)-Methyl 2-(6-(4-methoxybenzyl)-7-oxo-6,7-dihydro-5H-pyrrolo[3,4-*b*]pyridin-5-ylidene)acetate (11)

^{1}H NMR ($CDCl_3$, 300 MHz)

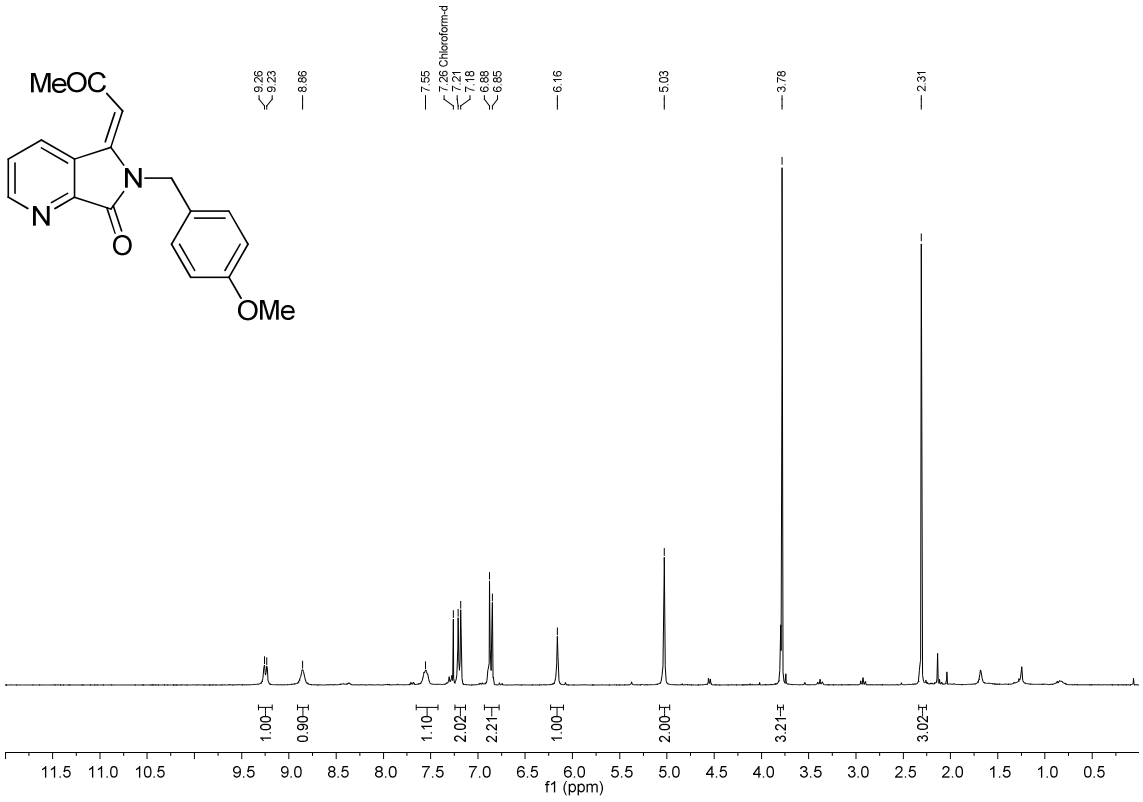


^{13}C NMR ($CDCl_3$, 75 MHz)

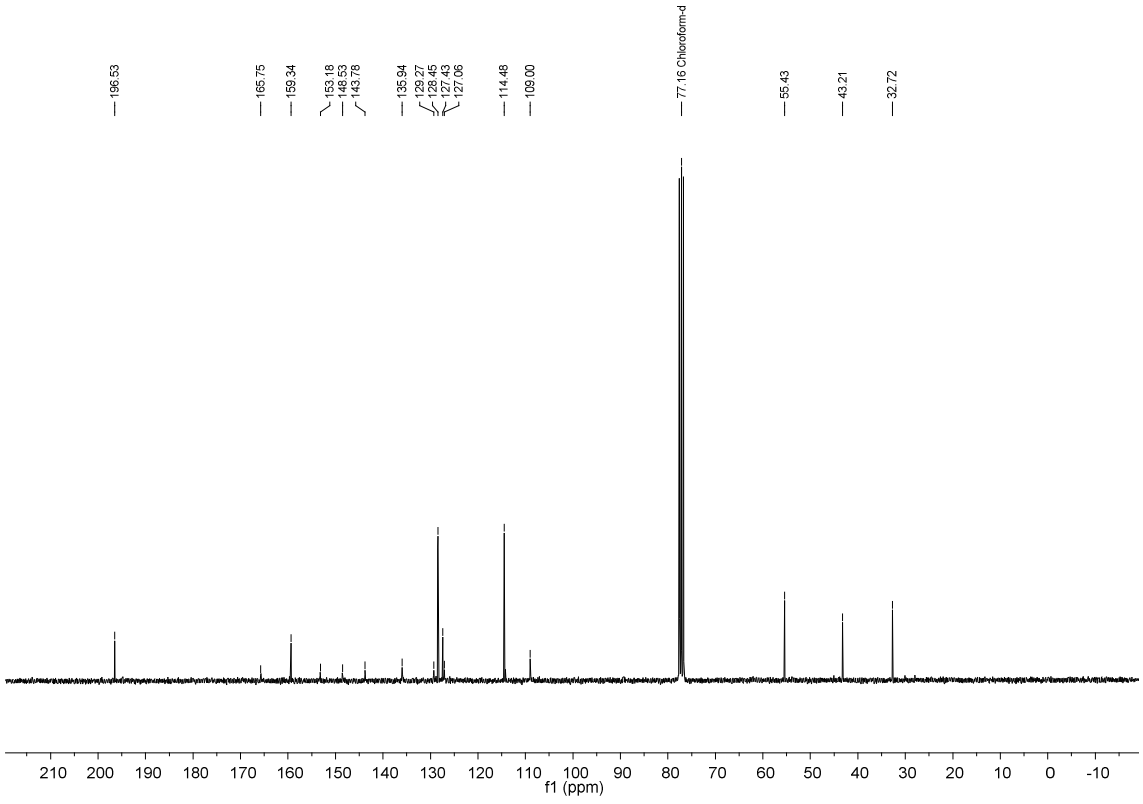


(*E*)-6-(4-methoxybenzyl)-5-(2-oxopropylidene)-5H-pyrrolo[3,4-*b*]pyridin-7(6H)-one (12)

^{1}H NMR (300 MHz, $CDCl_3$)

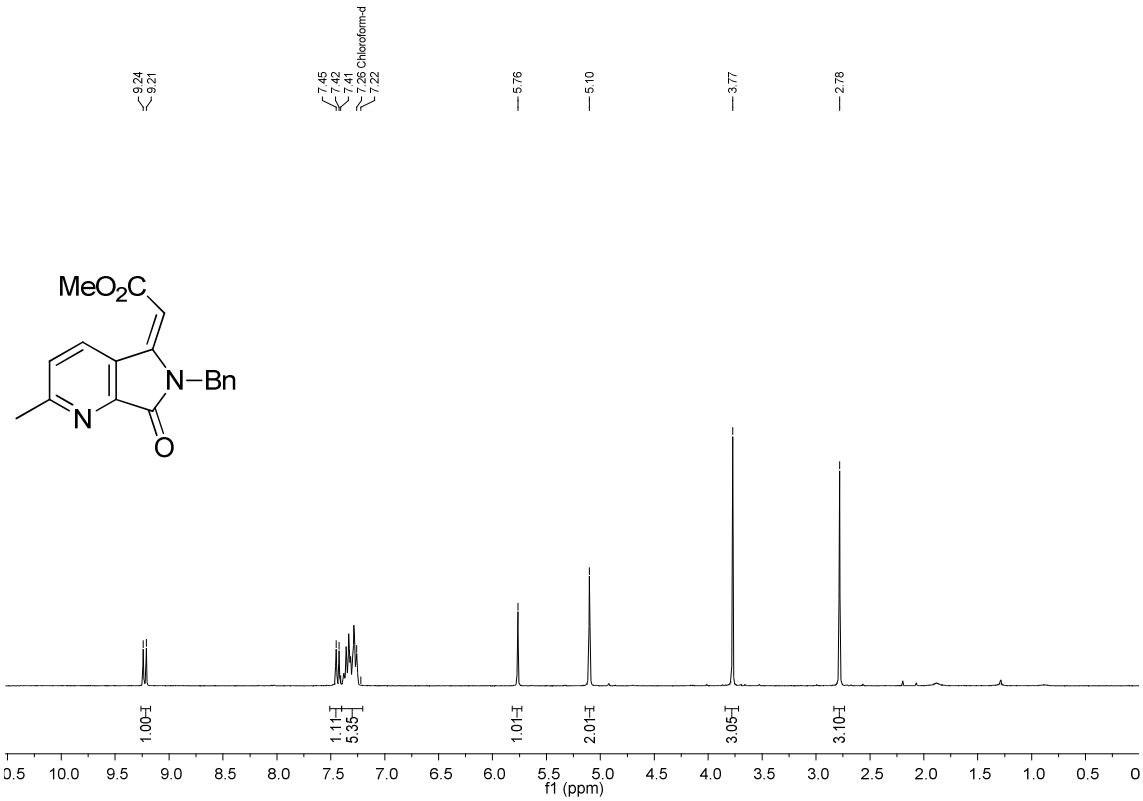


^{13}C NMR (75 MHz, $CDCl_3$)

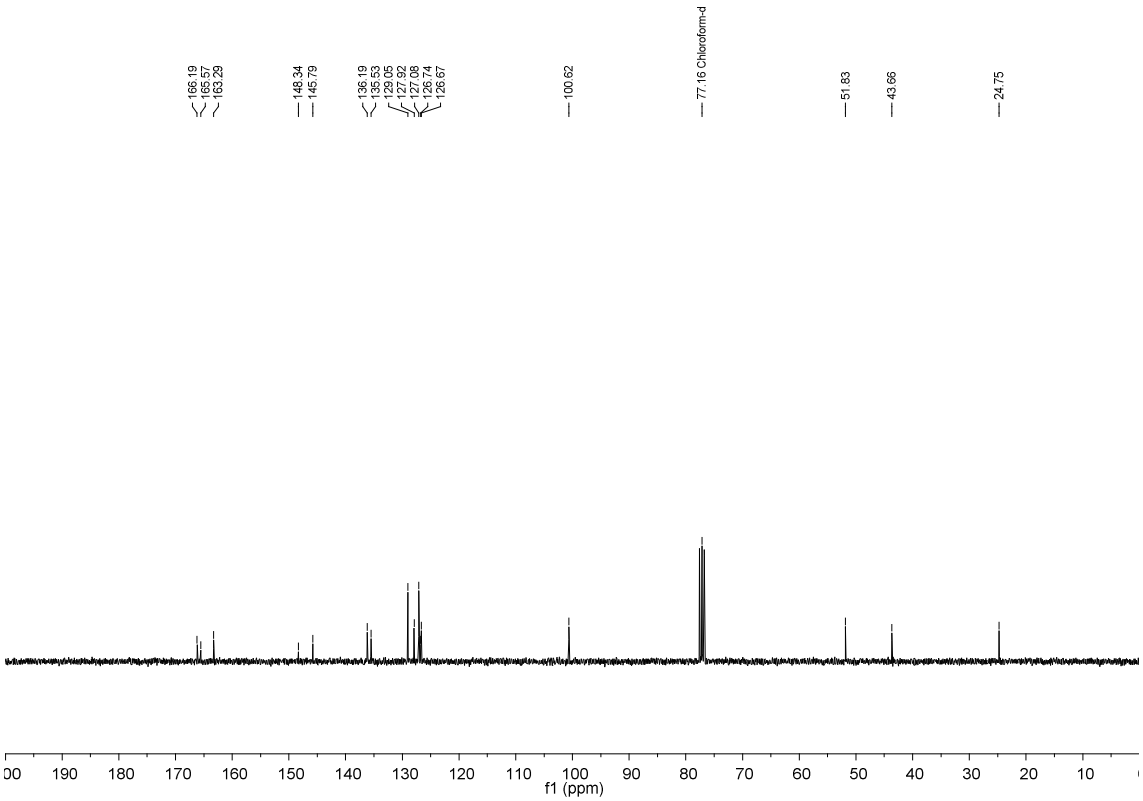


(*E*)-Methyl 2-(6-benzyl-2-methyl-7-oxo-6,7-dihydro-5H-pyrrolo[3,4-*b*]pyridin-5-ylidene)-acetate (20)

^{1}H NMR ($CDCl_3$, 300 MHz)

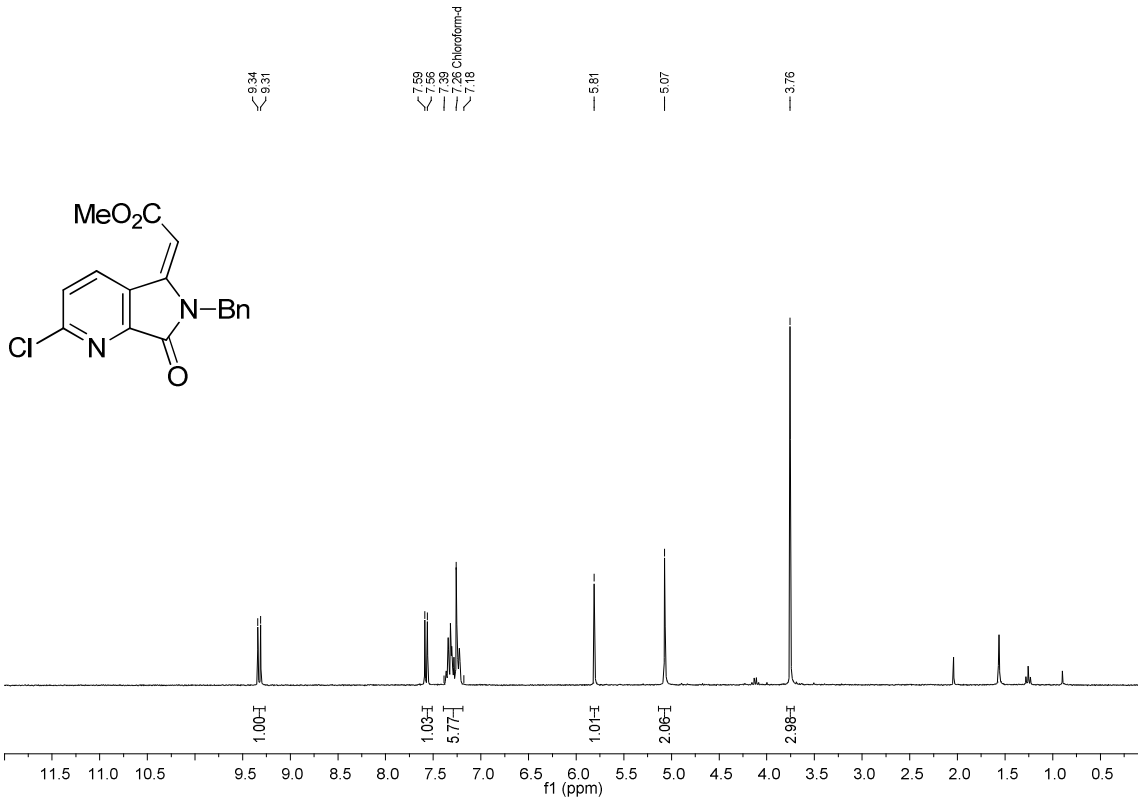


^{13}C NMR ($CDCl_3$, 75 MHz)

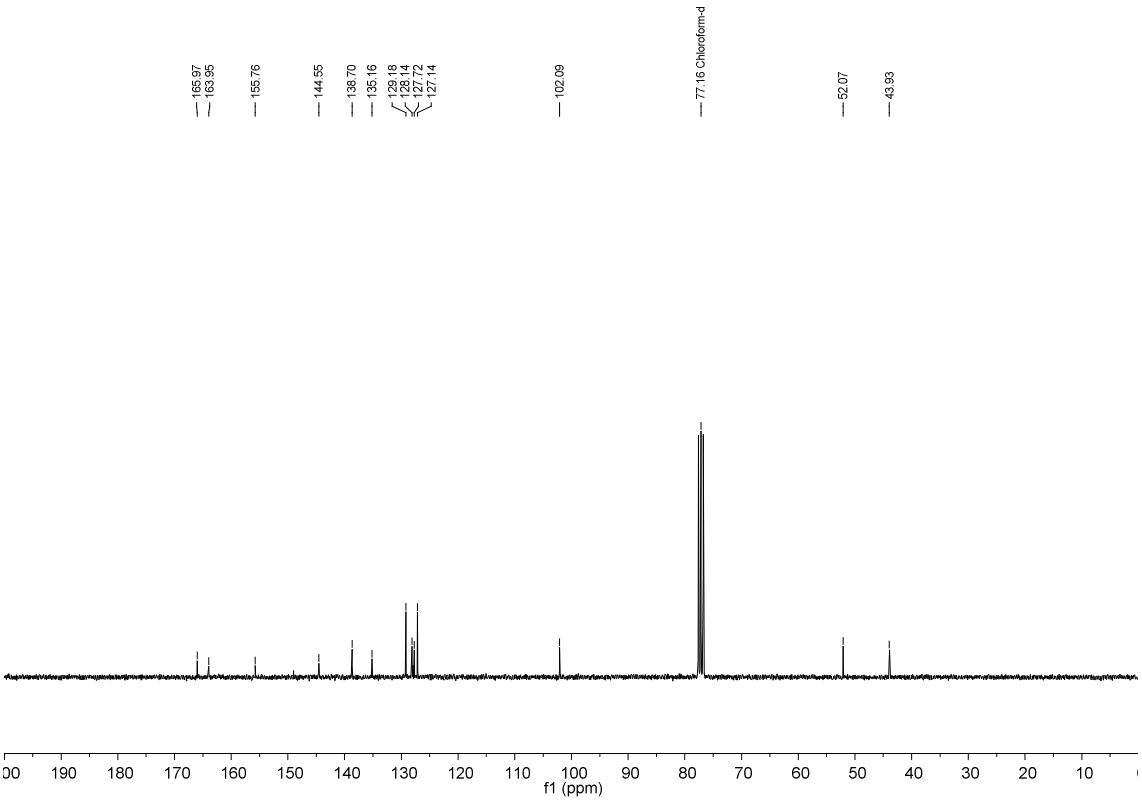


(*E*)-Methyl 2-(6-benzyl-2-chloro-7-oxo-6,7-dihydro-5H-pyrrolo[3,4-*b*]pyridin-5-ylidene)-acetate (21)

^{1}H NMR ($CDCl_3$, 300 MHz)

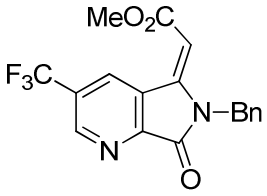


^{13}C NMR ($CDCl_3$, 75 MHz)

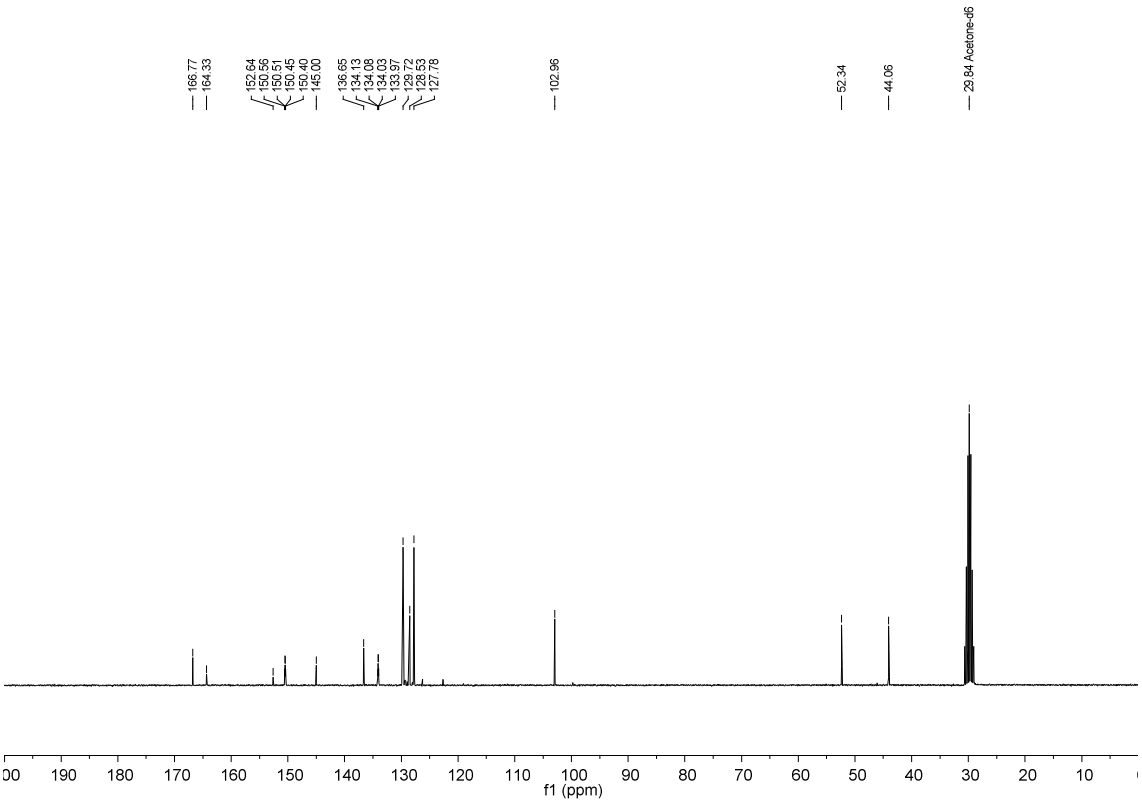


(*E*)-Methyl 2-(6-benzyl-7-oxo-3-(trifluoromethyl)-6,7-dihydro-5H-pyrrolo[3,4-*b*]pyridin-5-ylidene)acetate (22)

^{1}H NMR ($CDCl_3$, 300 MHz)

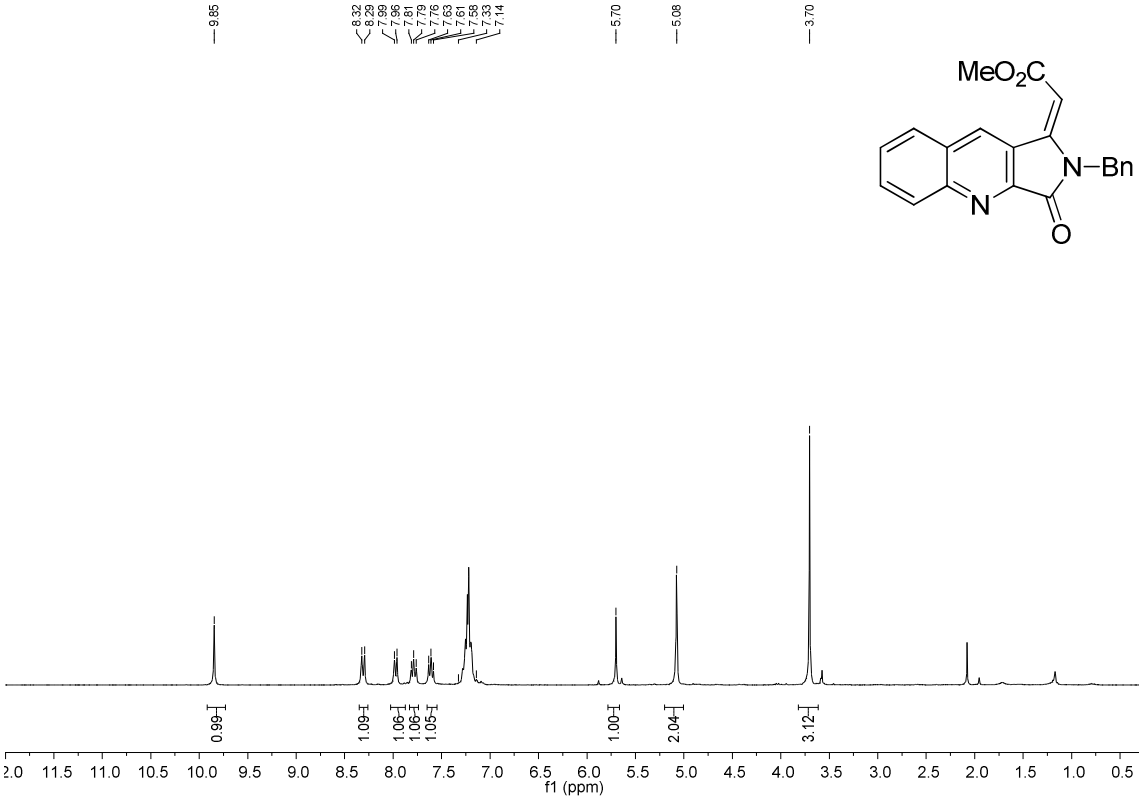


^{13}C NMR (acetone-d_6, 75 MHz)

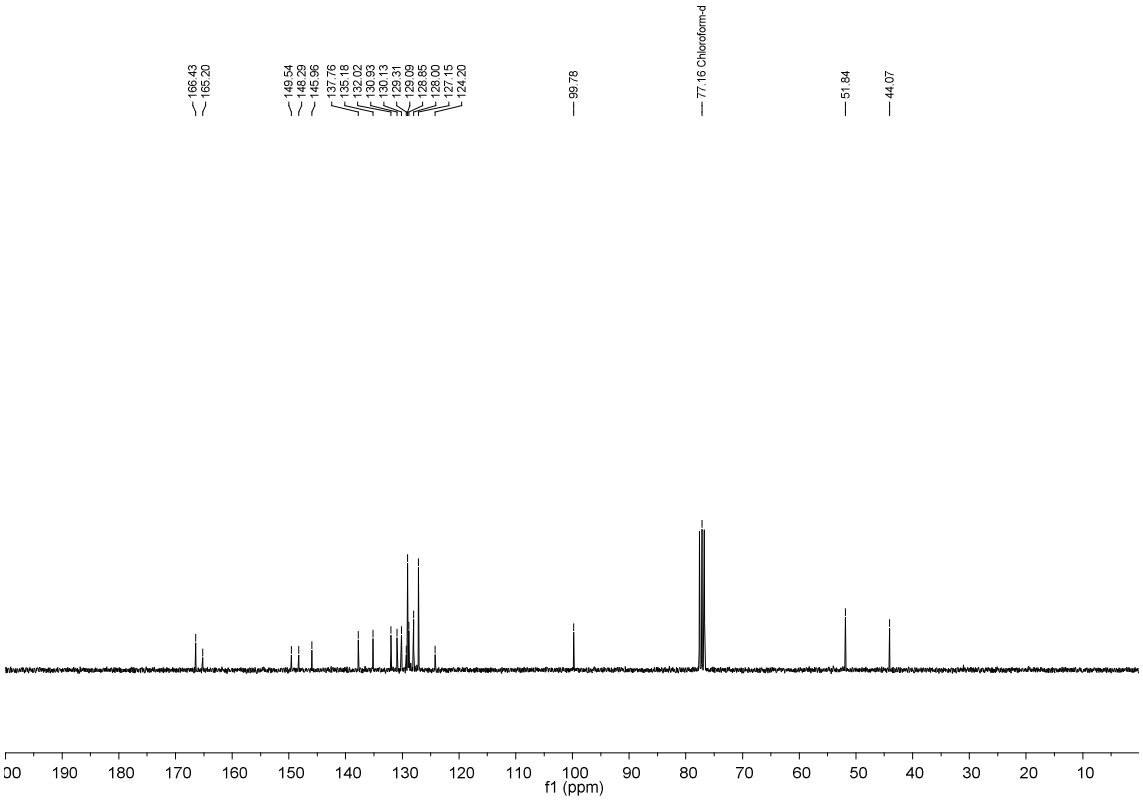


(*E*)-Methyl 2-(2-benzyl-3-oxo-2,3-dihydro-1H-pyrrolo[3,4-*b*]quinolin-1-ylidene)acetate (24)

^{1}H NMR ($CDCl_3$, 300 MHz)

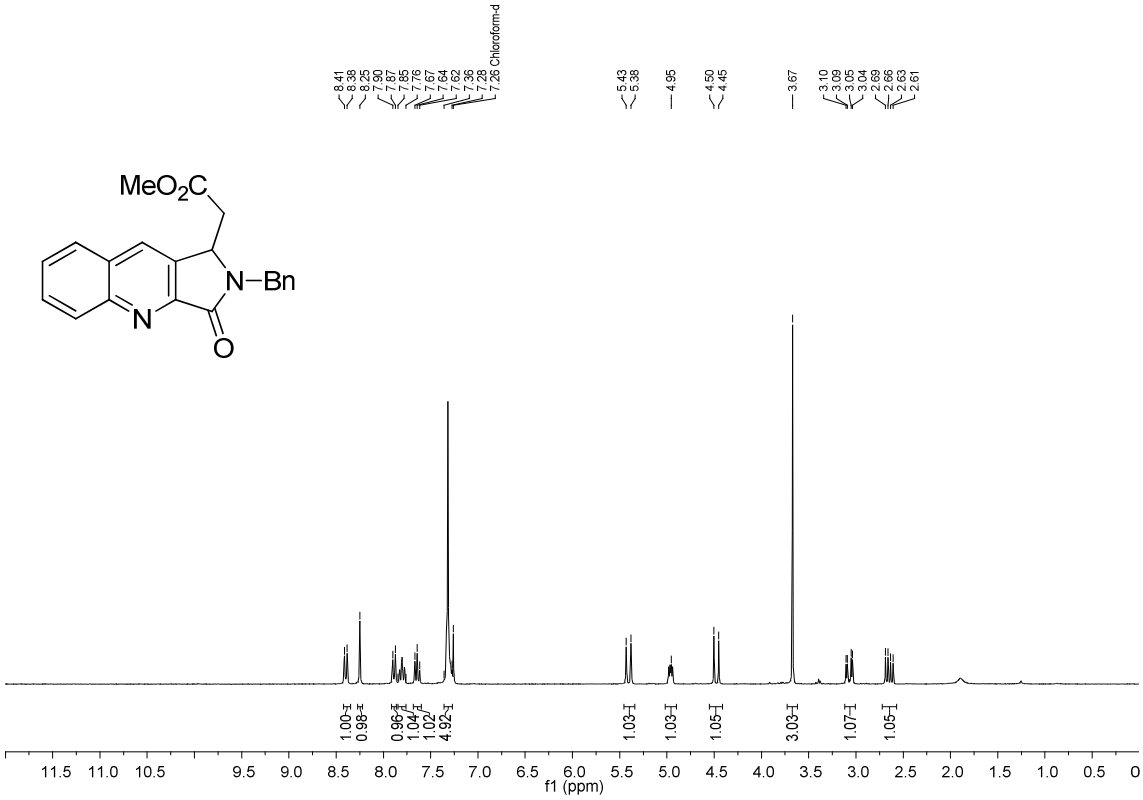


^{13}C NMR ($CDCl_3$, 75 MHz)

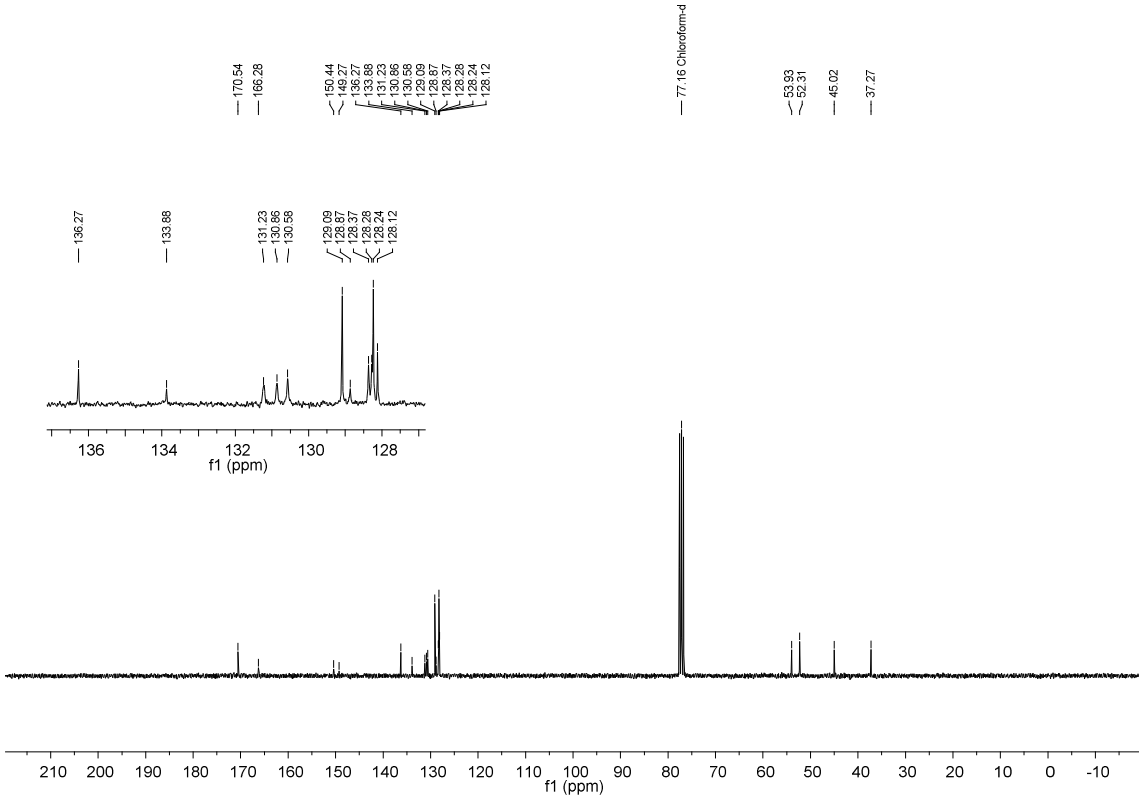


Methyl 2-(2-benzyl-3-oxo-2,3-dihydro-1H-pyrrolo[3,4-*b*]quinolin-1-yl)acetate (27)

^{1}H NMR ($CDCl_3$, 300 MHz)

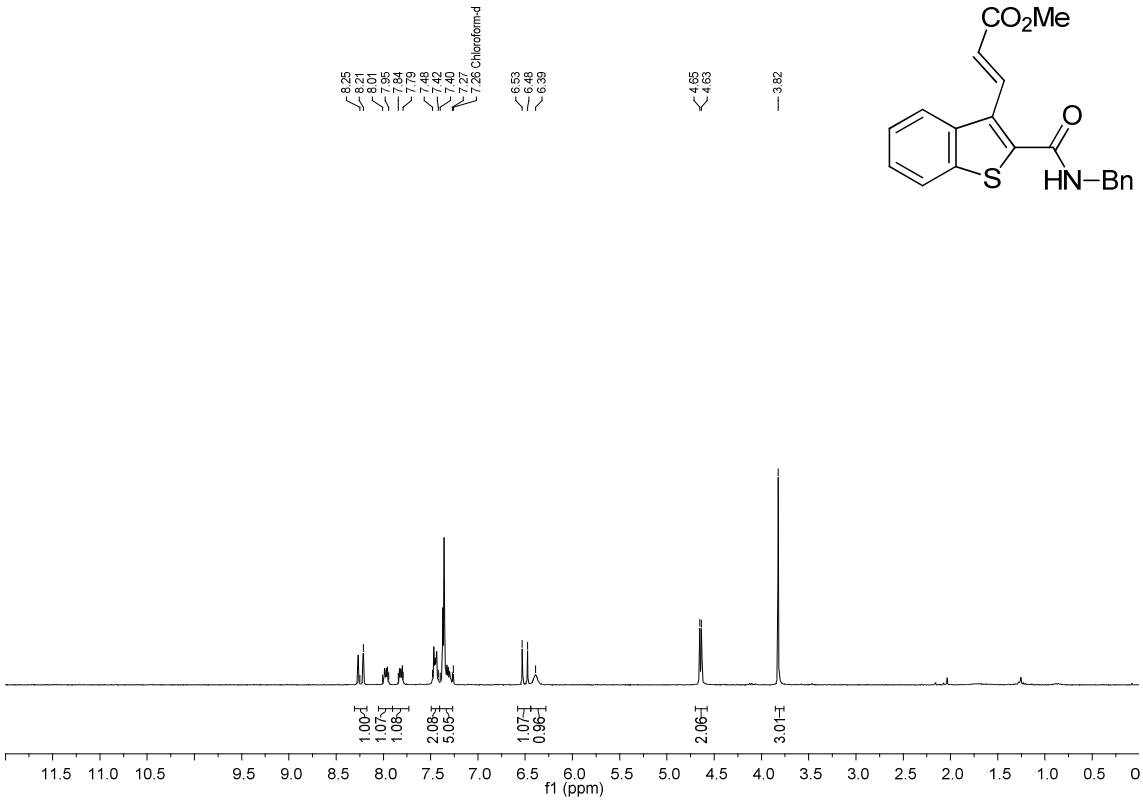


^{13}C NMR ($CDCl_3$, 75 MHz)

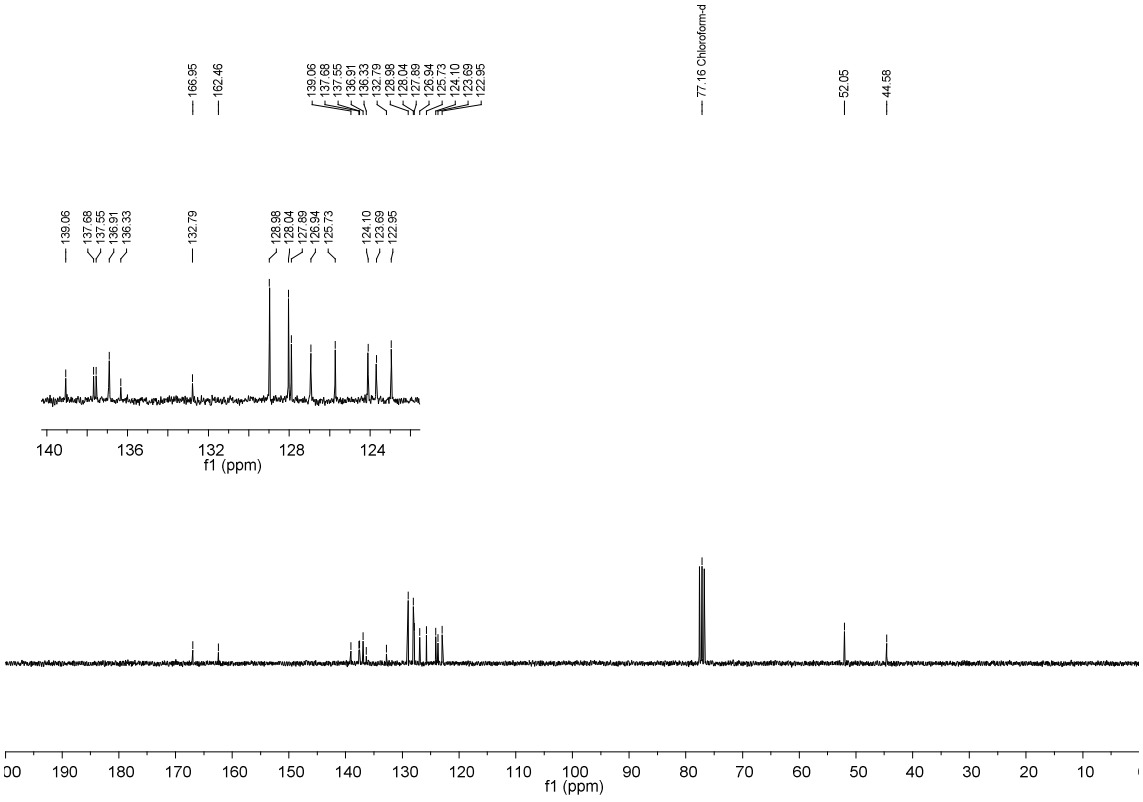


(*Z*)-Methyl 3-(2-(benzylcarbamoyl)benzo[*b*]thiophen-3-yl)acrylate (25)

^{1}H NMR ($CDCl_3$, 300 MHz)

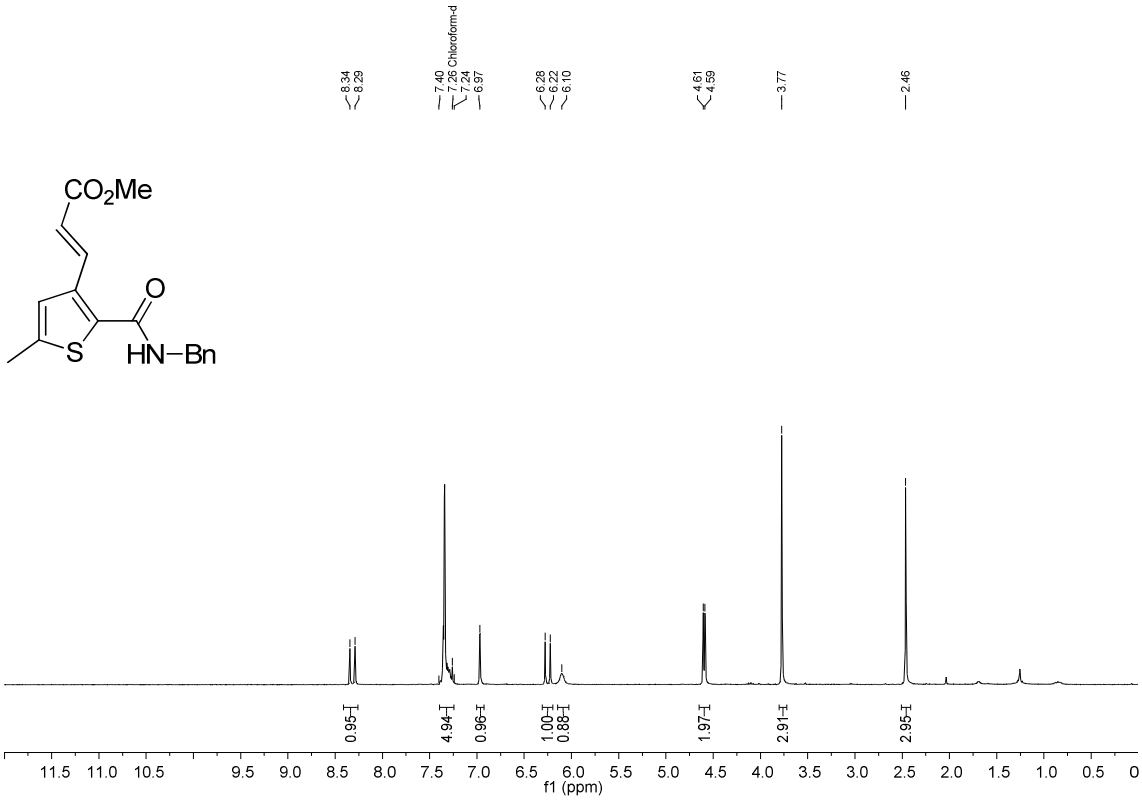


^{13}C NMR ($CDCl_3$, 75 MHz)

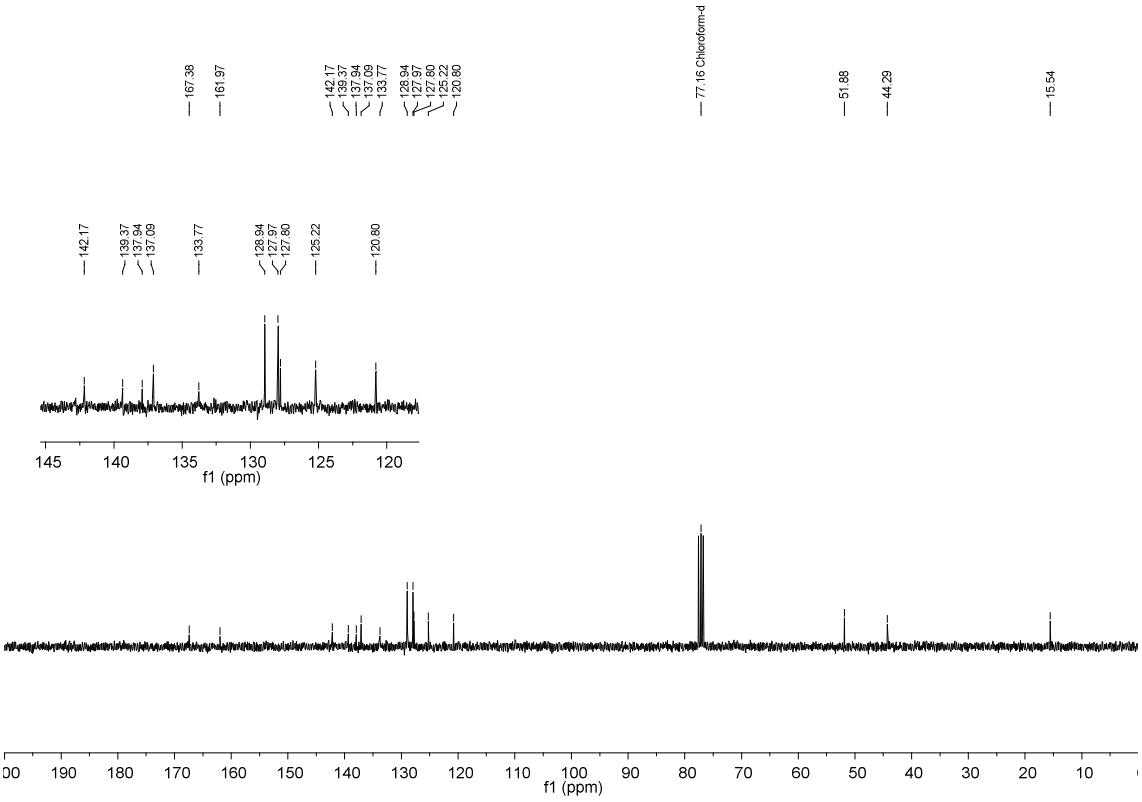


(*Z*)-Methyl 3-(2-(benzylcarbamoyl)-5-methylthiophen-3-yl)acrylate (26)

^{1}H NMR ($CDCl_3$, 300 MHz)

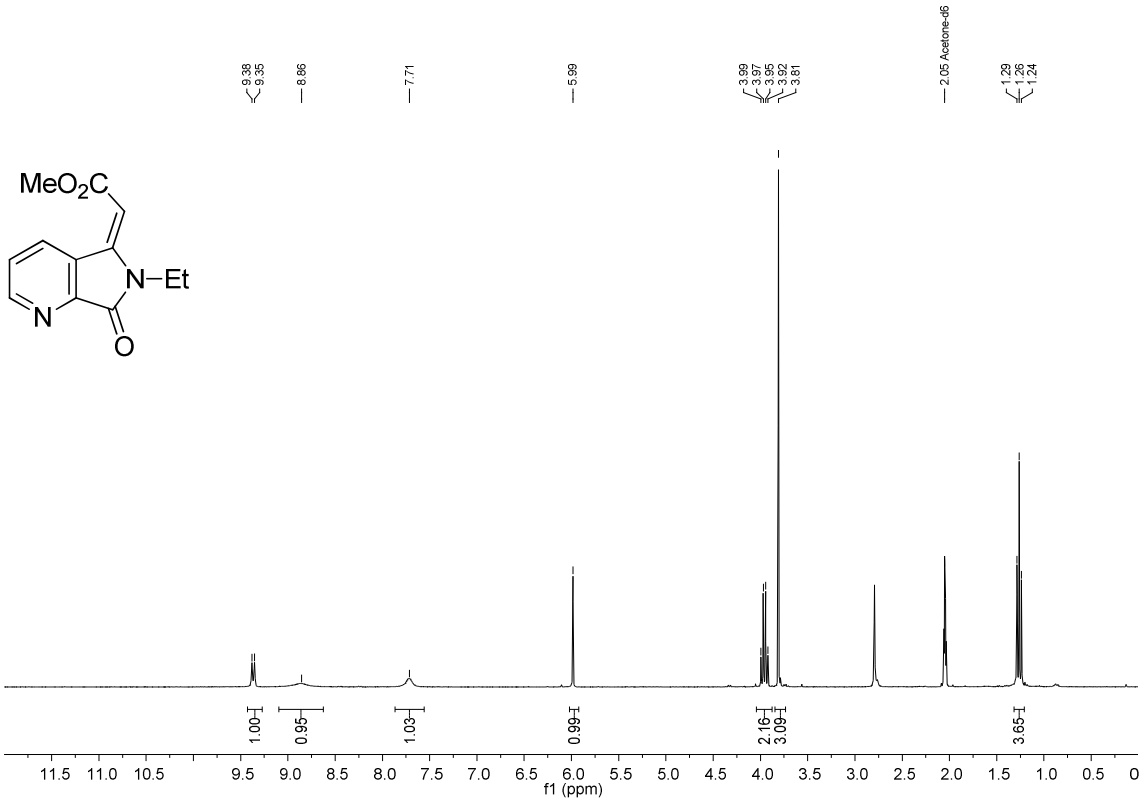


^{13}C NMR ($CDCl_3$, 75 MHz)

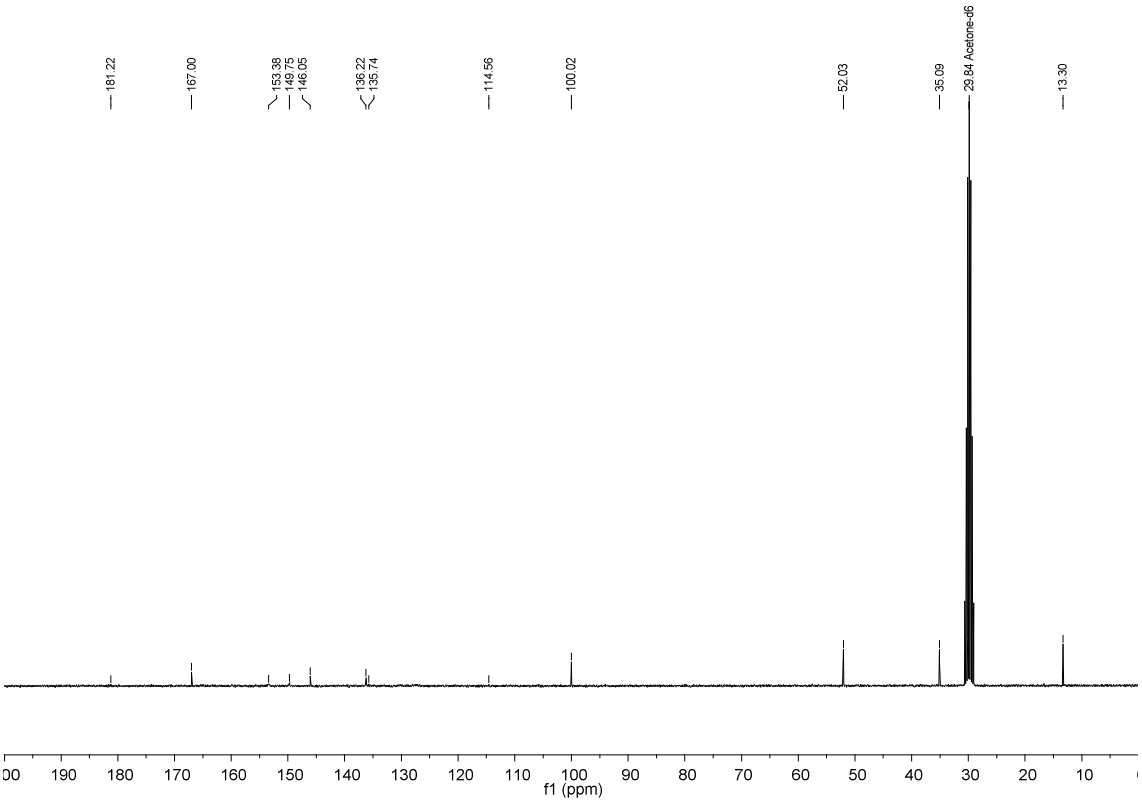


(*E*)-Methyl 2-(6-ethyl-7-oxo-6,7-dihydro-5H-pyrrolo[3,4-*b*]pyridin-5-ylidene)acetate (31)

^{1}H NMR (acetone-d_6, 300 MHz)

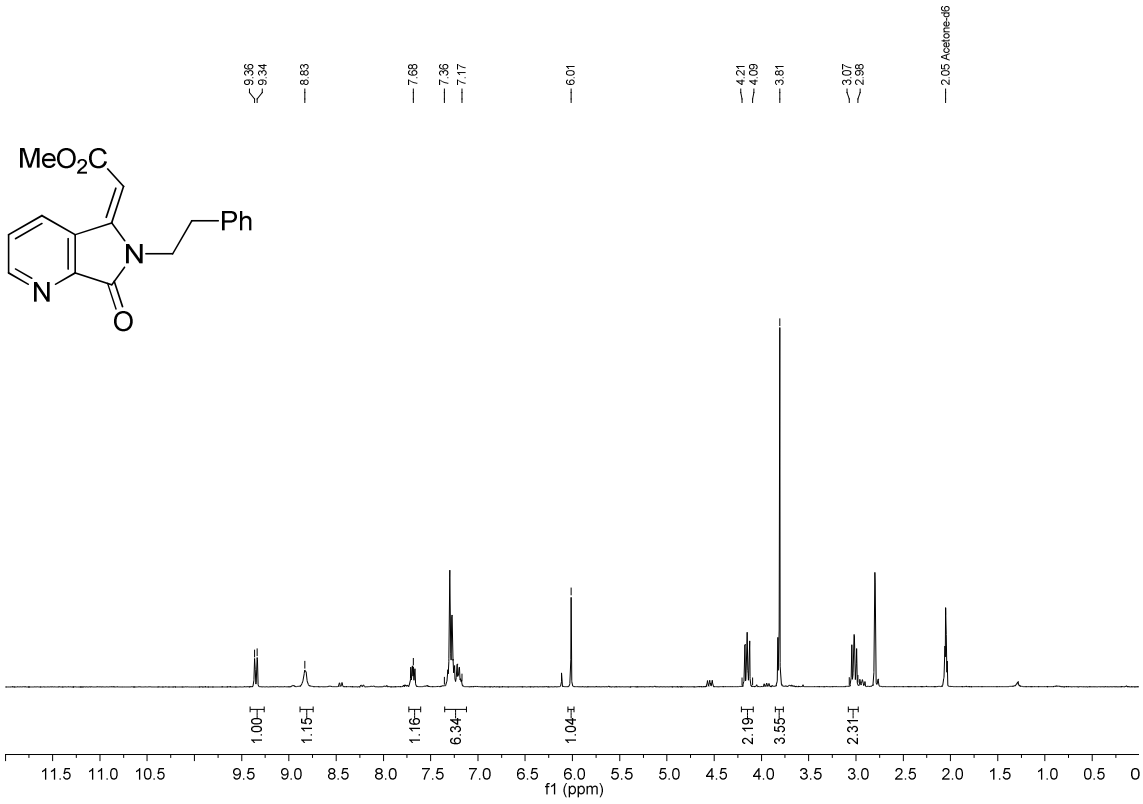


^{13}C NMR (acetone-d_6, 75 MHz)

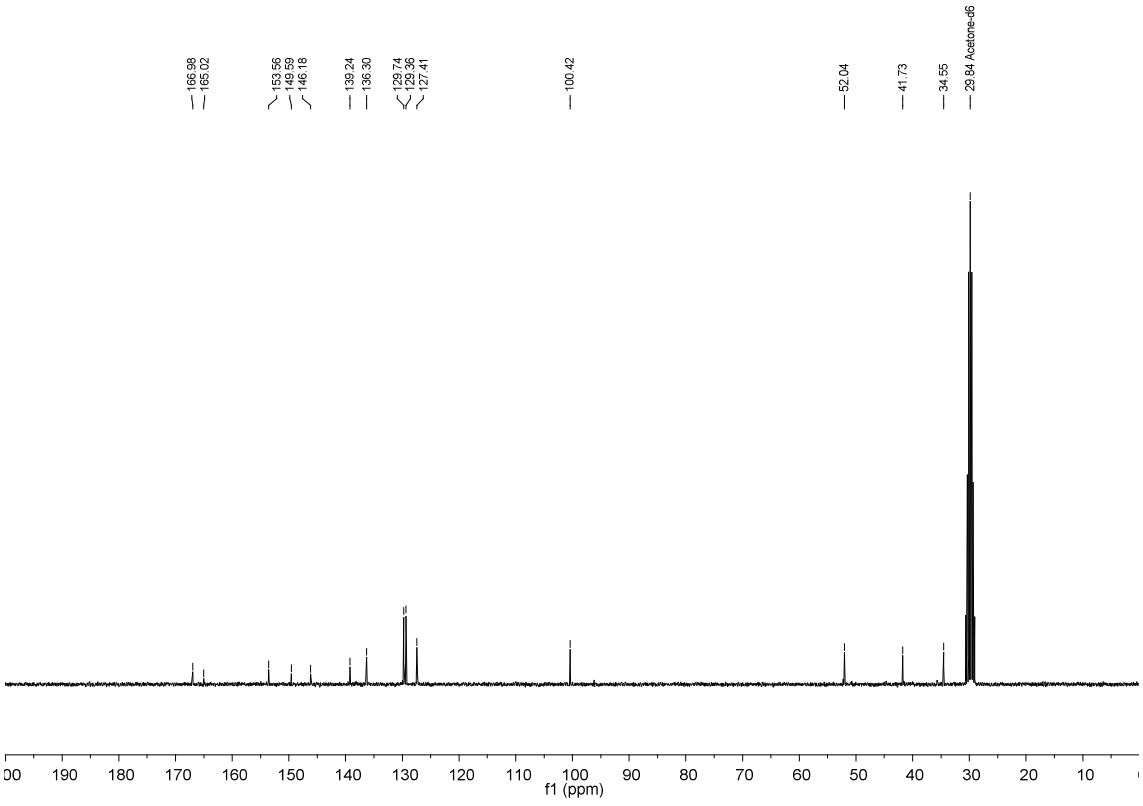


(*E*)-Methyl 2-(7-oxo-6-phenethyl-6,7-dihydro-5H-pyrrolo[3,4-*b*]pyridin-5-ylidene)acetate (33)

^{1}H NMR (acetone-d_6, 300 MHz)

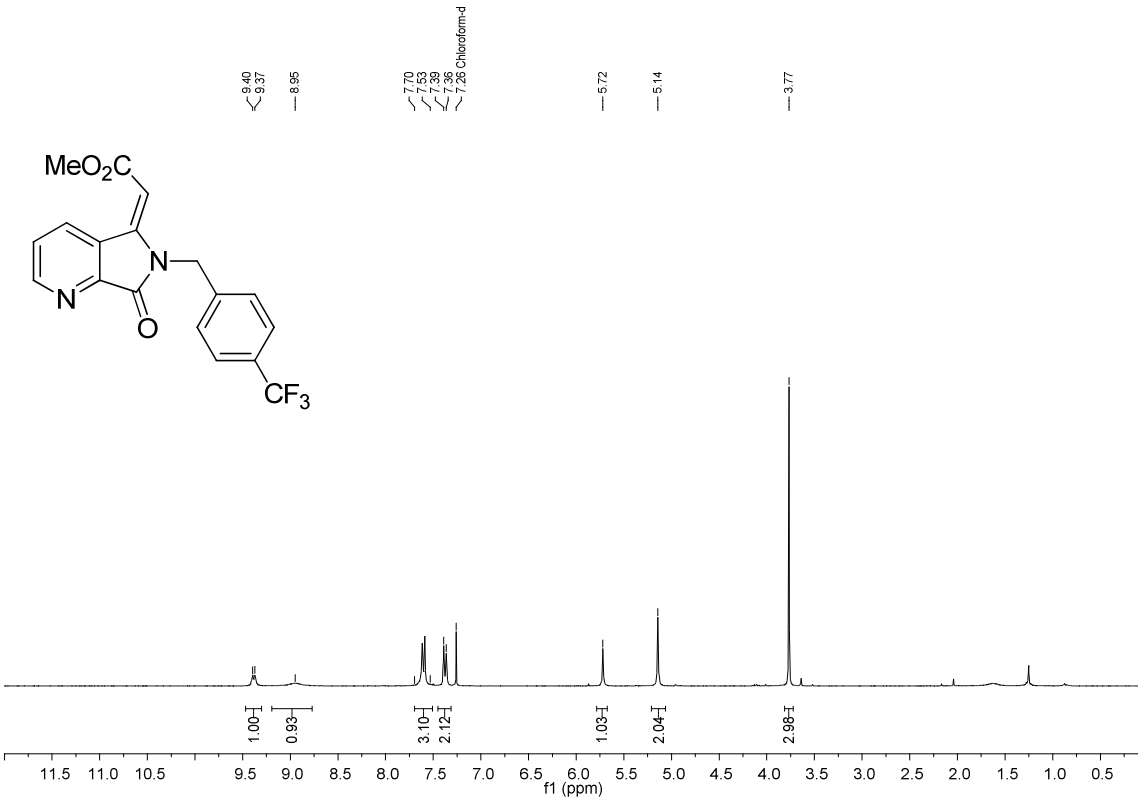


^{13}C NMR (acetone-d_6, 75 MHz)

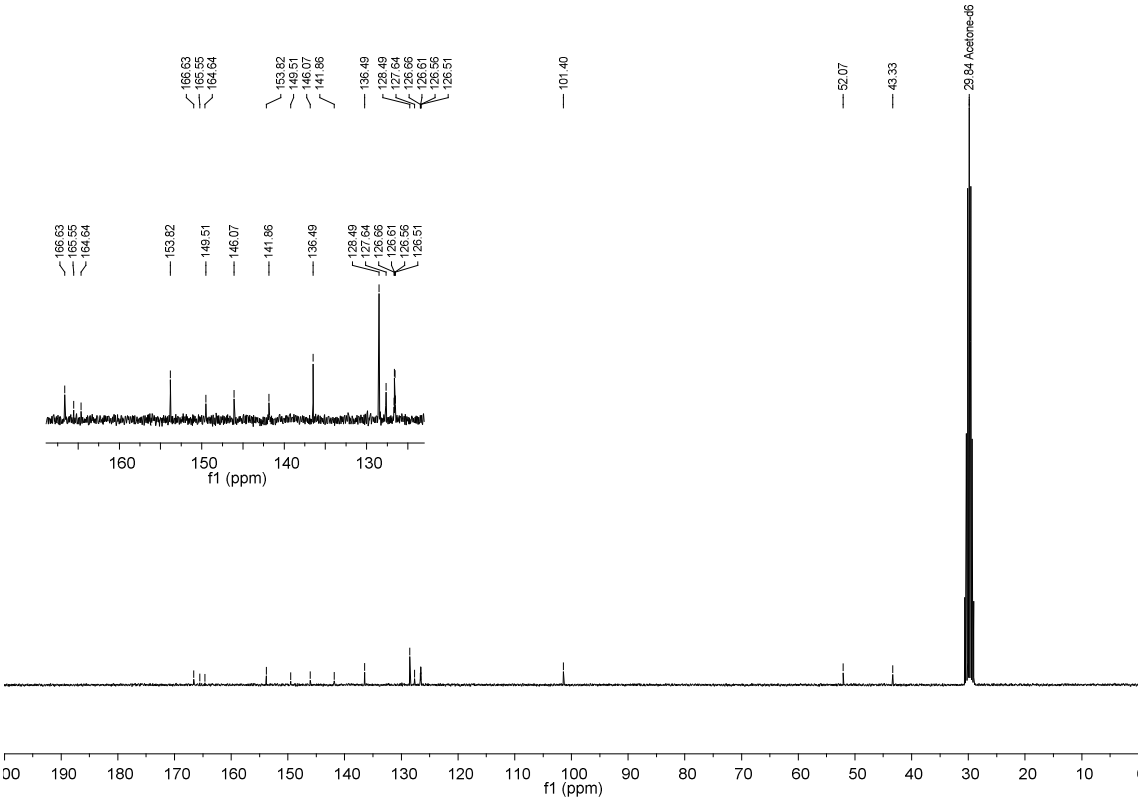


(*E*)-Methyl 2-(7-oxo-6-(4-(trifluoromethyl)benzyl)-6,7-dihydro-5H-pyrrolo[3,4-*b*]pyridin-5-ylidene)acetate (34)

^{1}H NMR ($CDCl_3$, 300 MHz)

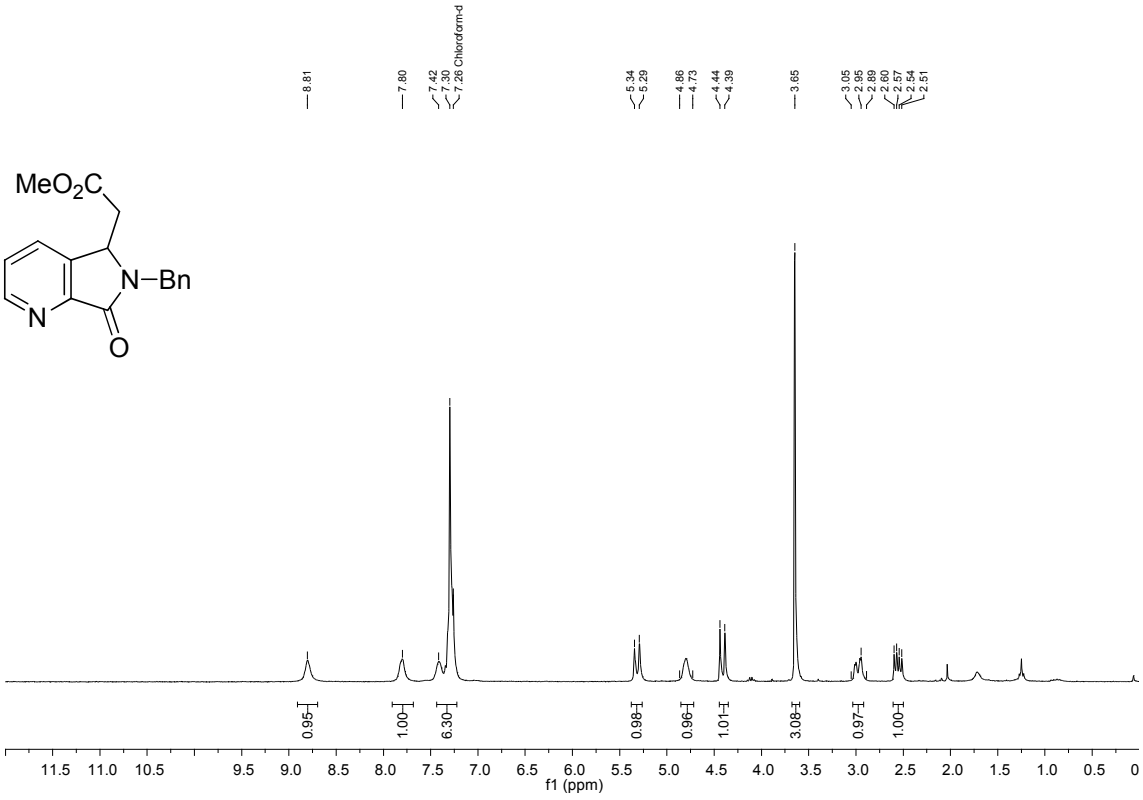


^{13}C NMR (acetone-d_6, 75 MHz)

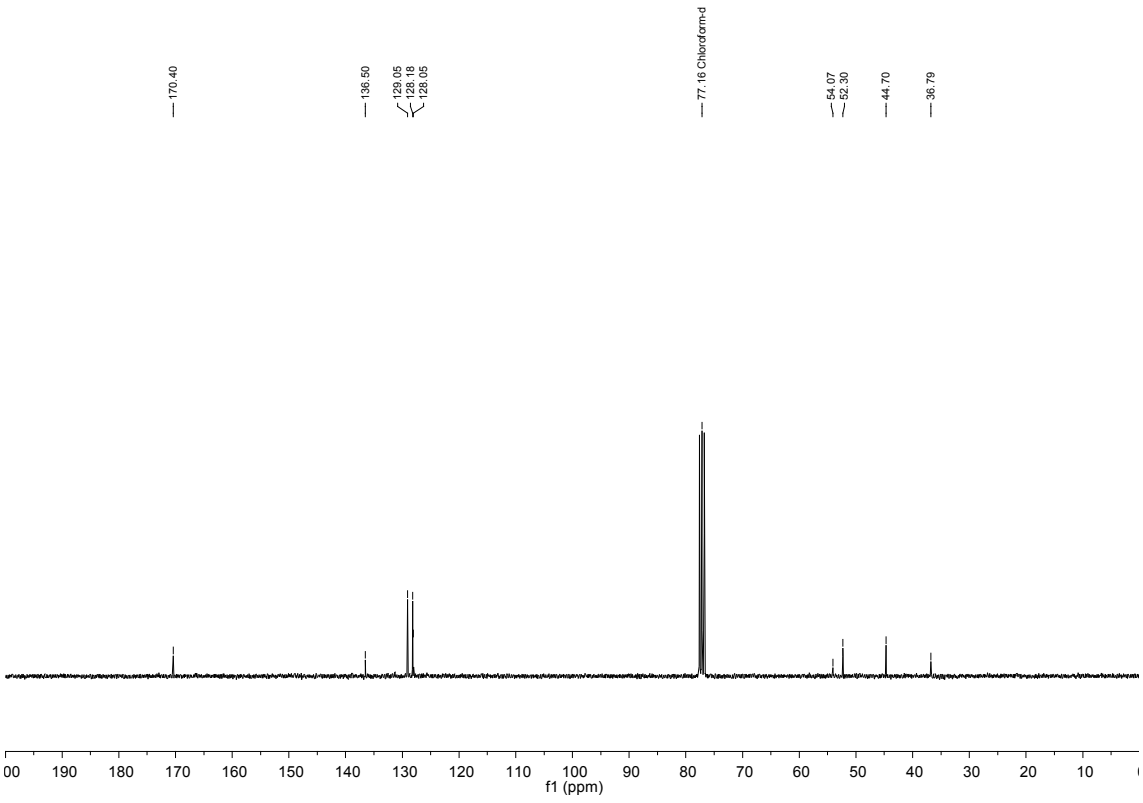


Methyl-2-(6-benzyl-7-oxo-6,7-dihydro-5H-pyrrolo[3,4-*b*]pyridin-5-yl)acetate (3)

^{1}H NMR ($CDCl_3$, 300 MHz)

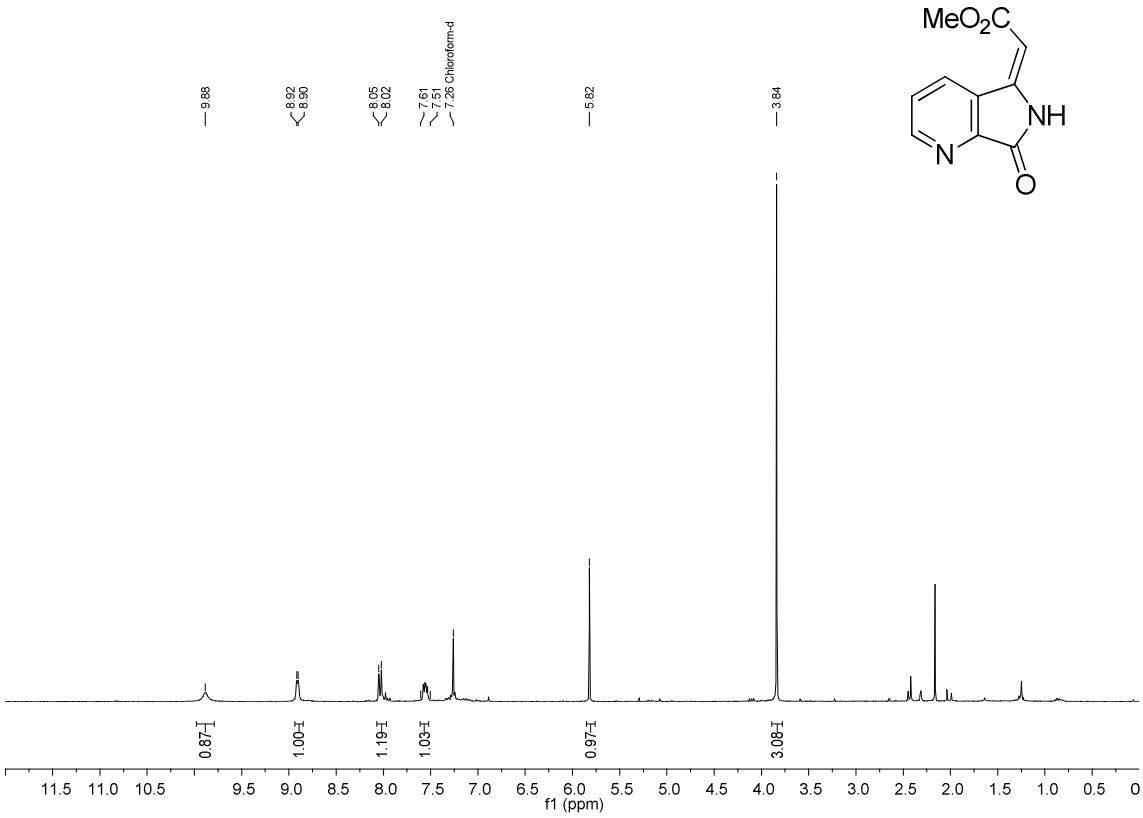


^{13}C NMR ($CDCl_3$, 75 MHz)

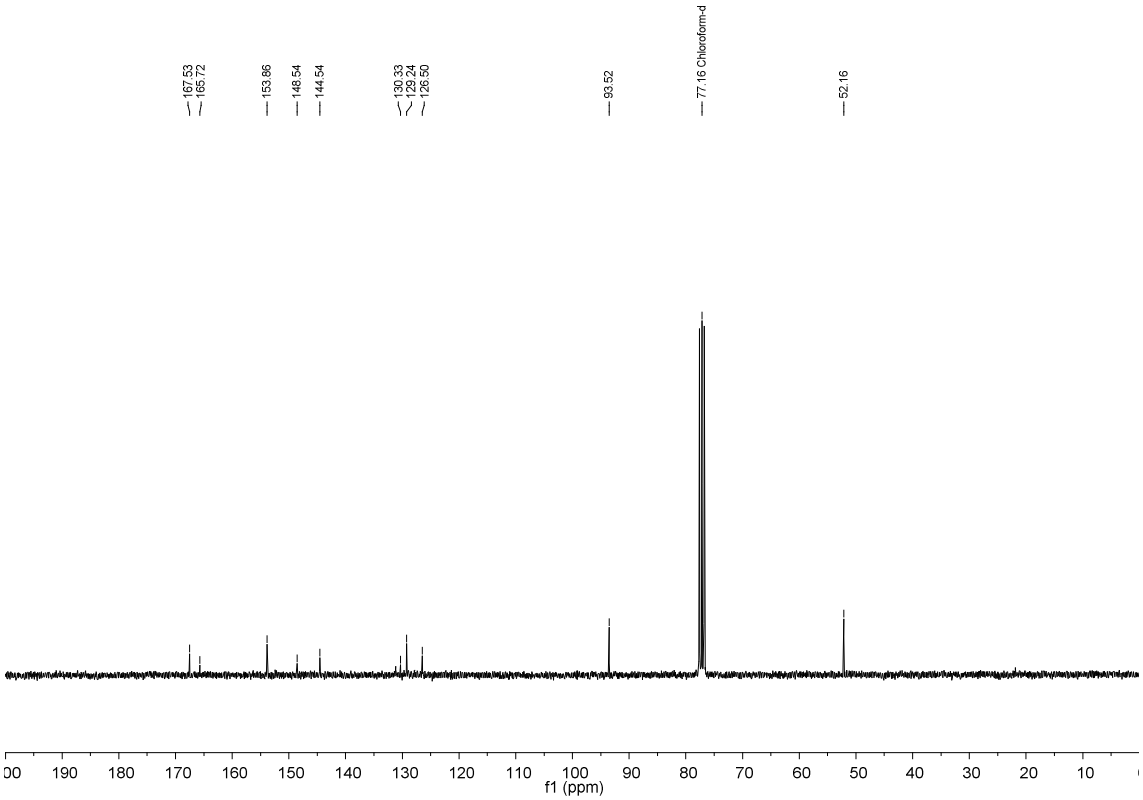


(*E*)-Methyl 2-(7-oxo-6,7-dihydro-5H-pyrrolo[3,4-*b*]pyridin-5-ylidene)acetate (35)

^{1}H NMR ($CDCl_3$, 300 MHz)

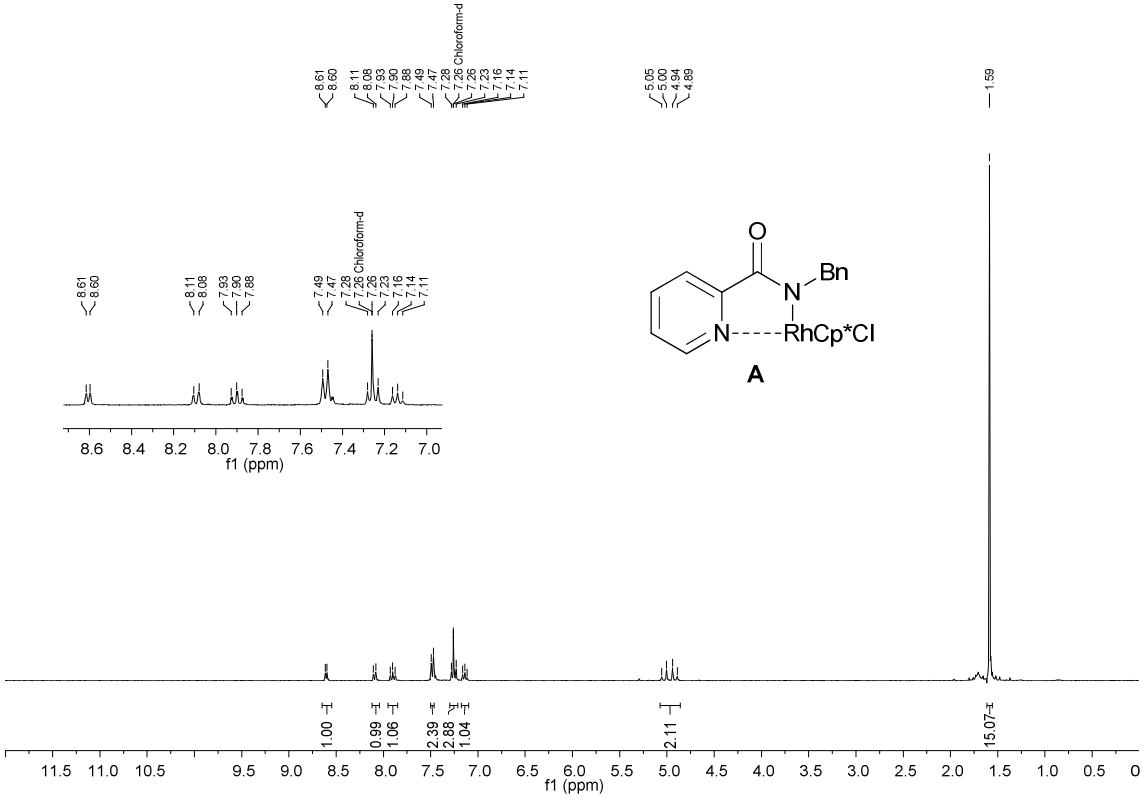


^{13}C NMR ($CDCl_3$, 75 MHz)



Rh(III)-complex, intermediate A

^{1}H NMR ($CDCl_3$, 300 MHz)



^{13}C NMR ($CDCl_3$, 75 MHz)