Australian Journal of Chemistry **2009**, *62*, 27. doi: 10.1071/CH08376

SUPPORTING INFORMATION

Diversity-Oriented Synthesis of Substituted Furo[2,3-*b*]pyrazines

Vaibhav P. Mehta,[a] *Sachin G. Modha,*[a] *Denis S. Ermolat'ev,*[a] *Kristof Van Hecke,*[b] *Luc Van Meervelt,*[b] *and Erik V. Van der Eycken* [a*]

[a]Laboratory for Organic & Microwave-Assisted Chemistry (LOMAC); [b]Biomolecular Architecture, Department of Chemistry , Katholieke Universiteit Leuven, Celestijnenlaan 200F, B-3001 Leuven, Belgium

* To whom correspondence should be addressed.

E-mail: erik.vandereycken@chem.kuleuven.be

Table of Contents

General experimental methods.

^{1}H NMR spectra were recorded on a Bruker Avance 300 MHz instrument using $CDCl_3$ as solvent unless otherwise stated. The ^{1}H and ^{13}C chemical shifts are reported in parts per million relative to tetramethylsilane using the residual solvent signal as an internal reference. Mass spectra were recorded by using a Kratos MS50TC and a Kratos Mach III system. The ion source temperature was 150-250°C, as required. High-resolution EI-mass spectra were performed with a resolution of 10 000. The low-resolution spectra were obtained with a HP5989A MS instrument. For thin-layer chromatography, analytical TLC plates (Alugram SIL G/UV_{254} and 70-230 mesh silica gel (E. M. Merck) were used.

Microwave Irradiation Experiments. A multimode Milestone MicroSYNTH microwave reactor (Laboratory Microwave Systems) was used in the standard configuration as delivered, including proprietary software. All experiments were carried out in sealed microwave process vials (15, 50 mL). A temperature control was performed using both external infrared and internal fiber optic sensors. After completion of the reaction, the vial was cooled to 25 °C via air jet cooling before opening.

A typical procedure for preparation of 1-(4-methoxybenzyl)-3,5-dichloropyrazin-2(1*H*)-ones 1a-d.

In a 1 L round-bottomed flask $NaHSO_3$ (26.1 g, 0.25 mol) was dissolved in 400 mL water and aldehyde was added dropwise under an argon atmosphere. After stirring for 45 min, a solution of 4-methoxybenzylamine (32 mL, 0.25 mol) in methanol (100 mL) was added dropwise to the reaction mixture and stirring was continued for 2 h at 60 °C. Then NaCN (14.7 g, 0.25 mol) was added and the reaction mixture was left stirring overnight at 60 °C (under hood!). The reaction mixture was cooled to the room temperature and extracted with dichloromethane (3×300 mL). The organic phases were combined, washed with brine (1×200 mL), then dried for 2 h over Na_2SO_4 and concentrated. The residue was dissolved in dry ether (500 mL) and the resulting solution was cooled to 0 °C. Dry HCl gas was bubbled through the solution upon vigorous stirring for 20 min and the precipitate was filtered off and dried. Then the precipitate was suspended in 1 L flask in dry toluene (400 mL) and oxalyl chloride (86 mL, 1 mol, 4.0

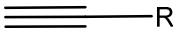
equiv) was added dropwise under an argon atmosphere. After stirring for 45 min, triethylamine hydrochloride (52 g, 0.38 mol, 1.5 equiv) was added by small portions, DMF (2 mL, 25 mmol, 0.1 equiv) and the reaction mixture was kept stirring for 2 days. The reaction mixture was concentrated and the residue was purified by silica gel column chromatography (from 10% to 30% EtOAc in petroleum ether) to afford 3,5-dichloropyrazin-2(1*H*)-one **1** as a white solid.

3,5-Dichloro-1-(4-methoxybenzyl)pyrazin-2(1*H*)-one (1a): 53% yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.29 (d, *J* = 7.2 Hz, 2H), 7.18 (s, 1H), 6.91 (d, *J* = 7.2 Hz, 2H), 5.04 (s, 2H), 3.81 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 160. 4, 152.0, 147.4, 130.6, 126.1, 125.5, 124.2, 114.9, 55.5, 53.4. HR-MS (EI): $C_{12}H_{10}Cl_2N_2O_2$ calcd. 285.0119, found 285.0119.

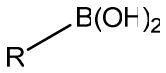
3,5-Dichloro-1-(4-methoxybenzyl)-6-methyl-pyrazin-2(1*H*)-one (1b): 51% yield. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.16 (d, *J* = 7.1 Hz, 2H), 6.86 (d, *J* = 7.3Hz, 2H), 5.29 (s, 2H), 3.79 (s, 3H), 2.44 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 159.6, 153.2, 143.7, 136.2, 128.7, 125.9, 123.9, 114.5, 55.4, 49.6, 16.8. DEPT (100 MHz, $CDCl_3$): δ 128.6, 114.5, 113.8, 55.3, - 49.8, 16.9. HR-MS (EI): $C_{13}H_{12}Cl_2N_2O_2$ calcd. 298.0276, found 298.0279.

6-Benzyl-3,5-Dichloro-1-(4-methoxybenzyl)pyrazin-2(1*H*)-one (1c): 32% yield. ^{1}HNMR (300 MHz, $CDCl_3$): δ 7.40 - 7.32 (m, 3H), 7.12 - 7.07 (m, 4H), 6.88 (d, *J* = 9.6 Hz, 2H), 5.10 (s, 2H), 4.15 (s, 2H), 3.80 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 159.7, 153.4, 145.3, 137.4, 133.9, 129.6, 128.2, 127.9, 127.5, 126.3, 125.4, 114.7, 55.5, 49.3, 32.3. DEPT (75 MHz, $CDCl_3$): δ 129.9, 128.5, 128.2, 127.8, 115.0, 55.7, - 49.6, - 35.6. HR-MS (EI): $C_{13}H_{15}ClN_2O$ calcd. 250.0873, found 250.0879.HR-MS (EI): $C_{19}H_{16}Cl_2N_2O_2$ calcd. 374.0589, found 374.0596.

3,5-Dichloro-1-(4-methoxybenzyl)-6-(4-methoxyphenyl)pyrazin-2(1*H*)-one (1d): 76% yield. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.04 (d, *J* = 7.2Hz, 2H), 6.97 (d, *J* = 7.3 Hz, 2H), 6.81 (d, *J* = 7.2 Hz, 2H), 6.72 (d, *J* = 7.1Hz, 2H), 5.05 (s, 2H), 3.88 (s, 3H), 3.76 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 161.1, 159.5, 152.9, 145.8 138.6, 130.9, 129.4, 126.9, 124.7, 122.3, 114.5, 113.9, 55.5, 55.3, 50.8. DEPT (100 MHz, $CDCl_3$): δ 130.9, 129.4, 114.4, 113.8, 55.4, 55.3, - 50.7. HR-MS (EI): $C_{19}H_{16}Cl_2N_2O_3$ calcd. 390.0538, found 390.0549.

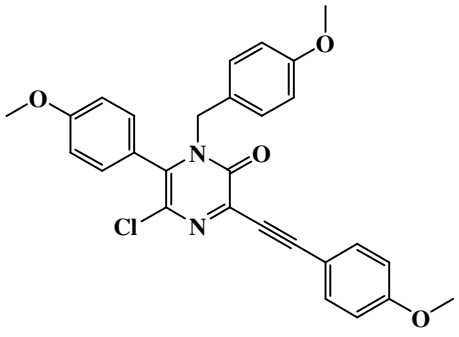


No.	R	No.	R	No.	R
2a	4-MeO-Ph	**2f**	Cyclopentyl	**2k**	Cyclopropyl
2b	4-Et-Ph	**2g**	2-Me-Ph	**2l**	Cyclohexyl
2c	4-BiPh	**2h**	3-F-Ph	**2m**	Phenyl
2d	4-pyridyl	**2i**	3-thiophene	**2n**	Hexyl
2e	4-Me-Ph	**2j**	4-^{t}Bu-Ph		

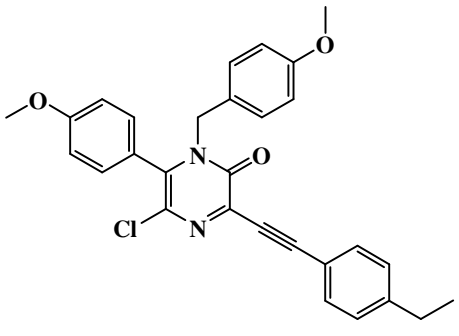


No.	R	No.	R	No.	R
6a	4-MeO-Ph	**6f**	4-^{t}Bu-Ph	**6k**	2-benzyloxy-Ph
6b	4-Me-Ph	**6g**	4-EtO-Ph	**6l**	4-CN-Ph
6c	3,5-diMe-Ph	**6h**	4-$COCH_3$-Ph	**6m**	3-EtO-Ph
6d	3-CF_3-Ph	**6i**	4-COOEt-Ph	**6n**	2-F-Ph
6e	1-Naphthyl	**6j**	3-Br-Ph	**6o**	4-F-Ph

Sonogashira coupling reaction on 1-(4-methoxybenzyl)-3,5-dichloropyrazin-2(1*H*)-ones 1a-d. A typical procedure. In a 50 mL microwave vial were successively dissolved in DMF/Et_3N (1:1, 20 mL) pyrazinone **1** (5 mmol), acetylene **2** (6.25-7.5 mmol), $Pd(PPh_3)Cl_2$ (35 mg, 1 mol %) and CuI (28 mg, 3 mol %). The reaction tube was sealed, and irradiated in microwave reactor at a ceiling temperature of 80 °C at 80 W maximum power for 10 min. After the reaction mixture was cooled with an air flow for 15 min, extracted with dichloromethane (2×150 mL) and dried over $MgSO_4$. The solvent was removed under reduced pressure and the residue was subjected to silica gel column chromatography (from 10% to 30% EtOAc in petroleum ether) to afford compounds **3a-k**.

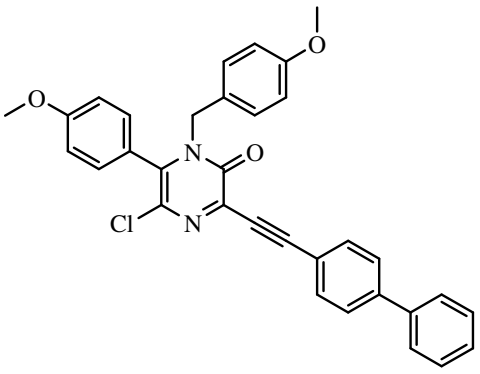


1-(4-methoxybenzyl)-5-chloro-6-(4-methoxyphenyl)-3-(2-(4-methoxyphenyl)ethynyl)pyrazin-2(1H)-one (3a): 99 % yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.63 (d, *J* = 8.91 Hz, 2H), 7.06 (d, *J* = 8.79 Hz, 2H), 6.96 (d, *J* = 8.43 Hz, 2H), 6.90 (d, *J* = 8.85 Hz, 2H), 6.84 (d, *J* = 8.49 Hz, 2H), 6.73 (d, *J* = 8.55 Hz, 2H), 5.05 (s, 2H), 3.87 (s, 3H), 3.84 (s, 3H), 3.76 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): 160.9, 159.3, 139.6, 138.1, 134.5, 131.0, 129.3, 127.6, 123.0, 114.3, 113.9, 98.9, 85.3, 55.5, 55.4, 55.3, 49.9. HRMS (EI): calcd for $C_{28}H_{23}O_4N_2Cl$: 486.1346, found: 486.1353.

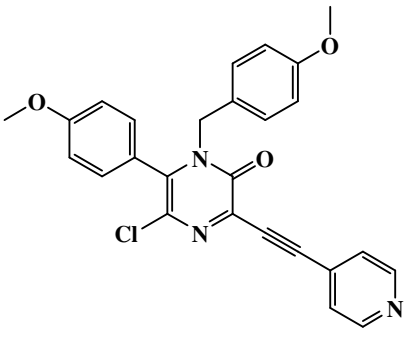


1-(4-methoxybenzyl)-5-chloro-3-(2-(4-ethylphenyl)-ethynyl)-6-(4-methoxyphenyl)pyrazin-2(1H)-one (3b): 92% yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.60 (d, *J* = 8.1 Hz, 2H), 7.22 (m, 2H), 7.05 (d, *J* = 8.4 Hz, 2H), 6.95 (d, *J* = 8.4 Hz,

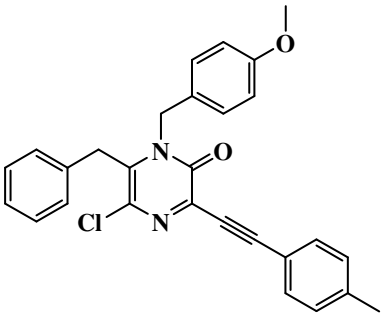
2H), 6.83 (d, *J* = 8.5 Hz, 2H), 6.73 (d, *J* = 8.5 Hz, 2H), 5.06 (s, 2H), 3.88 (s, 3H), 3.77 (s, 3H), 2.66 (m, 2H), 1.25 (t, *J* = 15.3, 7.5 Hz, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 161.3, 159.7, 156.2, 146.9, 139.8, 138.8, 133.2, 131.3, 129.6, 128.4, 127.9, 127.7, 123.3, 119.1, 114.7, 114.3, 99.0, 85.9, 55.8, 55.7, 50.3, 29.4, 15.6. HR-MS (EI): calcd for $C_{29}H_{25}O_3N_2Cl$: 484.1554, found: 484.1577.



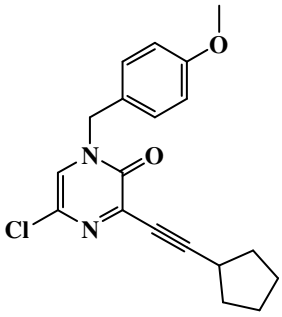
3-(1,1'-Biphenyl-4-ylethynyl)-5-chloro-1-(4-methoxybenzyl)-6-(4-methoxyphenyl)pyrazin-2(1*H*)-one (3c): 83% yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.75 (d, *J* = 8.2 Hz, 2H), 7.61 (m, 5H), 7.43 (m, 3H), 7.07 (d, *J* = 8.7 Hz, 2H), 6.97 (d, *J* = 8.8 Hz, 2H), 6.84 (d, *J* = 8.6 Hz, 2H), 6.73 (d, *J* = 8.5 Hz, 2H), 5.07 (s, 2H), 3.88 (s, 3H), 3.77 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 160.9, 159.3, 155.8, 142.5, 140.0, 139.1, 138.6, 133.1, 132.9, 130.9, 129.2, 128.9, 127.9, 127.6, 127.2, 127.1, 122.8, 120.4, 114.3, 113.9, 98.1, 86.5, 55.4, 55.2, 49.9. HR-MS (EI): calcd for $C_{33}H_{25}O_3N_2Cl$: 532.1554, found: 532.1549.



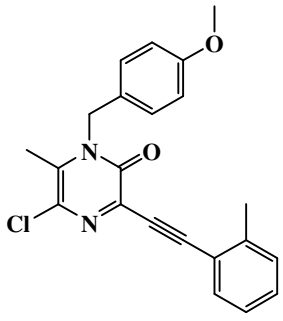
1-(4-methoxybenzyl)-5-chloro-6-(4-methoxyphenyl)-3-(2-(pyridin-4-yl)ethynyl)pyrazin-2(1H)-one (3d): 85 % yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.65 (d, *J* = 5.2 Hz, 2H), 7.50 (d, *J* = 6.0 Hz, 2H), 7.07 (d, *J* = 8.4 Hz, 2H), 6.97 (d, *J* = 8.7 Hz, 2H), 6.83 (d, *J* = 8.6 Hz, 2H), 6.74 (d, *J* = 8.4 Hz, 2H), 5.08 (s, 2H), 3.89 (s, 3H), 3.77 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 161.1, 159.4, 155.7, 149.9, 140.2, 130.7, 129.7, 129.3, 128.6, 128.4, 127.8, 126.9, 126.0, 114.4, 113.9, 93.7, 89.0, 55.5, 55.3, 50.1. HR-MS (EI): calcd for $C_{26}H_{20}ClN_3O_3$: 457.1193, found: 457.1208.



1-(4-methoxybenzyl)-6-benzyl-5-chloro-3-(2-p-tolylethynyl) pyrazin-2(1H)-one (3e): in 99 % yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.56 (d, *J* = 8.07 Hz, 2H), 7.38 – 7.33 (m, 3H), 7.19 – 7.10 (m, 6H), 6.88 (d, *J* = 8.79 Hz, 2H), 5.11 (s, 2H), 4.17 (s, 2H), 3.79 (s, 3H), 2.38 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): 159.5, 156.2, 140.4, 138.9, 137.3, 134.3, 132.6, 129.5, 128.3, 127.7, 126.6, 118.5, 114.6, 98.8, 85.3, 55.4, 48.4, 35.6, 21.8. HRMS (EI): calcd for $C_{28}H_{23}O_2N_2Cl$: 454.1448, found: 454.1464.

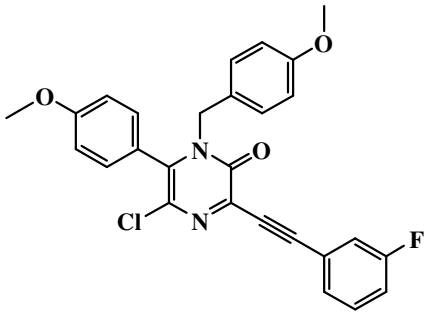


1-(4-methoxybenzyl)-5-chloro-3-(2-cyclopentylethynyl)pyrazin-2(1H)-one (3f): Yellow solid in 82 % yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.28 (d, *J* = 9.12 Hz, 2H), 7.10 (s, 1H), 6.90 (d, *J* = 9.12 Hz, 2H), 4.99 (s, 2H), 3.81 (s, 3H), 2.96 – 2.91 (m, 1H), 2.24 – 1.99 (m, 2H), 1.78 (s, 4H), 1.60 (s, 2H). ^{13}C NMR (75 MHz, $CDCl_3$): 160.1, 155.0, 141.4, 130.5, 126.4, 125.9, 125.4, 114.7, 106.0, 55.4, 52.5, 33.5, 31.0, 25.4. HRMS (EI): calcd for $C_{19}H_{19}O_2N_2Cl$: 342.1135, found: 342.1141.

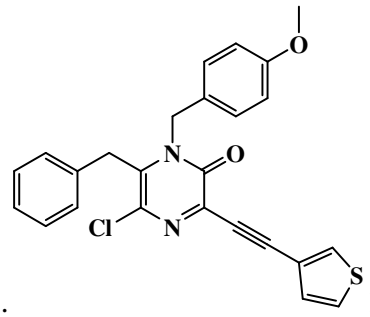


1-(4-methoxybenzyl)-5-chloro-6-methyl-3-(2-o-tolylethynyl) pyrazin-2(1H)-one (3g): Orange solid m.p. 144 - 147 °C in 94 % yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.61 (d, *J* = 7.32 Hz, 1H), 7.29 – 7.16 (m, 5H), 6.87 (d, *J* = 8.22 Hz, 2H), 5.32 (s, 2H), 3.79 (s,

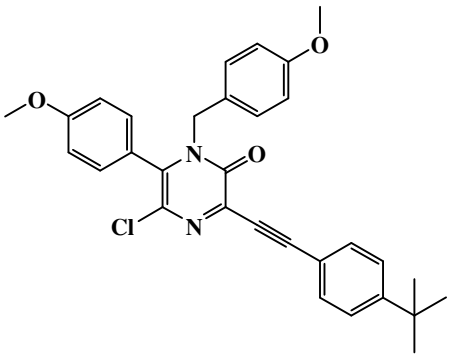
3H), 2.60 (s, 3H), 2.48 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): 159.5, 156.1, 141.7, 137.5, 136.3, 132.9, 129.8, 128.5, 126.8, 126.3, 125.7, 121.5, 114.5, 96.8, 89.4, 55.4, 48.9, 20.8, 17.3. HRMS (EI): calcd for $C_{22}H_{19}O_2N_2Cl$: 378.1135, found: 378.1141.



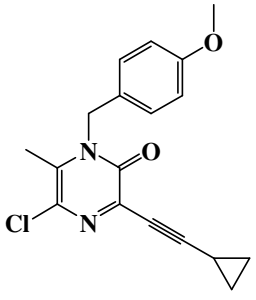
1-(4-methoxybenzyl)-5-chloro-3-(2-(3-fluorophenyl) ethyn- yl)-6-(4-methoxyphenyl)pyrazin-2(1H)-one (3h): Yellow solid m.p. 142 - 145 °C in 99 % yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.46 (d, *J* = 7.32 Hz, 1H), 7.38-7.32 (q, *J* = 5.49, 2.73, 2H), 7.11-7.05 (m, 3H), 6.97 (d, *J* = 8.22 Hz, 2H), 6.83 (d, *J* = 9.03 Hz, 2H), 6.72 (d, *J* = 9.12 Hz, 2H), 5.06 (s, 2H), 3.88 (s, 3H), 3.76 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): 163.9, 161.0, 159.4, 155.84, 139.3, 138.7, 130.9, 130.2, 129.3, 128.6, 127.6, 127.2, 123.5, 122.7, 119.5, 117.3, 114.4, 113.9, 96.1, 86.3, 55.5, 50.0. HRMS (EI): calcd for $C_{27}H_{20}O_3N_2ClF$: 474.1146, found: 474.1154.



. **1-(4-methoxybenzyl)-6-benzyl-5-chloro-3-(2-(thiophen-3-yl) ethynyl)pyrazin-2(1H)-one (3i):** 88% yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.76 (s, 1H), 7.38 – 7.30 (m, 5H), 7.14 – 7.09 (m, 4H), 6.88 (d, *J* = 8.94, 2H), 5.11 (s, 2H), 4.17 (s, 2H), 3.79 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): 159.5, 156.2, 138.7, 137.5, 134.3, 132.2, 130.3, 129.5, 128.3, 127.6, 126.5, 125.7, 120.8, 114.6, 93.5, 85.5, 55.4, 48.4, 35.6. HRMS (EI): calcd for $C_{25}H_{19}O_2N_2SCl$: 446.0856, found: 446.0858.



1-(4-methoxybenzyl)-3-(2-(4-tert-butylphenyl)ethynyl)-5-chloro-6-(4-methoxyphenyl)pyrazin-2(1H)-one (3j): Yellow solid m.p. 178 - 180 in 96 % yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.62 (d, *J* = 9.4 Hz, 2H), 7.39 (d, *J* = 9.1 Hz, 2H), 7.05 (d, *J* = 9.6 Hz, 2H), 6.96 (d, *J* = 9.2 Hz, 2H), 6.84 (d, *J* = 9.3 Hz, 2H), 6.73 (d, *J* = 9.4 Hz, 2H), 5.06 (s, 2H), 3.88 (s, 3H), 3.77 (s, 3H), 1.33 (s, 9H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 160.9, 159.3, 155.9, 153.4, 139.5, 138.4, 132.6, 131.0, 129.5, 129.3, 127.6, 127.4, 125.6, 123.0, 122.3, 118.6, 114.4, 113.9, 98.7, 85.6, 55.5, 55.3, 50.0, 35.1, 31.2. HRMS (EI): calcd for $C_{31}H_{29}O_3N_2Cl$: 512.1867, found: 512.1867.

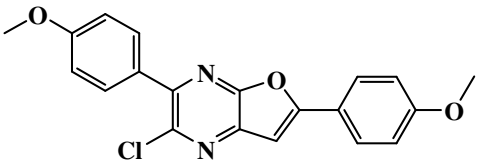


1-(4-methoxybenzyl)-5-chloro-3-(2-cyclopropylethynyl)-6-methyl pyrazin-2(1H)-one (3k): 84 % yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.17 (d, *J* = 8.22 Hz, 2H), 6.85 (d, *J* = 9.12 Hz, 2H), 5.25 (s, 2H), 3.78 (s, 3H), 2.44 (s, 3H), 1.61 – 1.57 (s, 1H), 0.97 – 0.93 (m, 4H). ^{13}C NMR (75 MHz, $CDCl_3$): 159.4, 156.2, 137.6, 135.5, 128.6, 126.4, 114.4, 103.7, 55.3, 48.8, 17.1, 9.5. HRMS (EI): calcd for $C_{18}H_{17}O_2N_2Cl$: 328.0979, found: 328.0982.

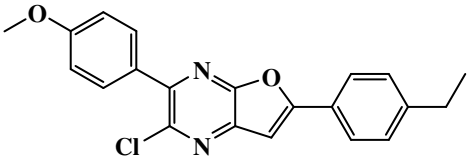
A typical procedure for the preparation of furopyrazines 4a-e.

In a 25 mL flask pyrazinone **3** (2 mmol) was dissolved in dry dichloromethane (12 mL). Then AgOTf (11 mg, 2 mol %) and trifluoroacetic acid (0.8 mL, 10 mmol, 5 equiv) were added and the reaction mixture was stirred at room temperature for 5-20 min. After reaction completion

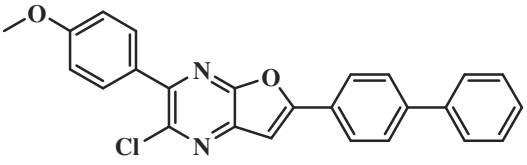
the solvent was evaporated and the residue was subjected to silica gel column chromatography (from 20% to 50% CH_2Cl_2 in petroleum ether) to afford compounds **4a-e.**



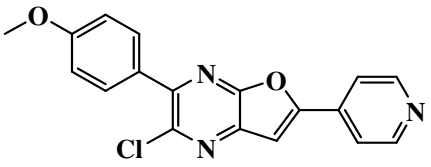
2-chloro-3,6-bis(4-methoxyphenyl)furo[2,3-b] pyrazine (4a): Yellow Colour m.p.118 – 119 °C in 96 % yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.88 (d, *J* = 9.1 Hz, 2H), 7.83 (d, *J* = 8.2 Hz, 2H), 7.04 – 6.99 (m, 5H), 3.89 (s, 6H). ^{13}C NMR (75 MHz, $CDCl_3$): 161.9, 161.7, 160.5, 154.1, 144.5, 143.1, 140.1, 131.4, 129.2, 129.1, 128.9, 127.5, 121.3, 114.7, 114.6, 113.7, 88.9, 55.6, 55.5. HRMS (EI): calcd for $C_{20}H_{15}O_3N_2Cl$: 366.0771, found: 366.0793.



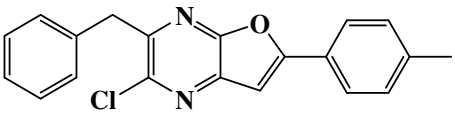
2-chloro-6-(4-ethylphenyl)-3-(4-methoxyphenyl) furo [2,3-b]pyrazine (4b): 92 % yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.85 (m, 4H), 7.34 (d, *J* = 8.1 Hz, 2H), 7.12 (s, 1H), 7.03 (d, *J* = 8.3 Hz, 2H), 3.89 (s, 3H), 2.72 (m, 2H), 1.28 (t, *J* = 7.4 Hz, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 162.3, 160.8, 154.4, 147.9, 145.2, 143.5, 140.1, 131.7, 129.4, 129.1, 126.5, 126.1, 114.0, 100.3, 55.8, 29.3, 15.7. HRMS (EI): calcd for $C_{21}H_{17}O_2N_2Cl$: 364.0979, found: 364.0975.



6-(1,1'-Biphenyl-4-yl)-2-chloro-3-(4-methoxy-phenyl)furo[2,3-*b*]pyrazine (4c): 91 % yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.03 (d, *J* = 9.00 Hz, 2H), 7.86 (d, *J* = 9.00 Hz, 2H), 7.77 – 7.65 (m, 4H), 7.52 – 7.47 (m, 3H), 7.21 (s, 1H), 7.05 (d, *J*= 9.00 Hz, 2H), 3.90 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): 161.3, 160.5, 145.2, 143.5, 139.9, 131.3, 129.0, 128.1, 127.8, 127.1, 126.2, 113.7, 100.6, 55.4. HRMS (EI): calcd for $C_{25}H_{17}O_2N_2Cl$: 412.0979, found: 412.0983.



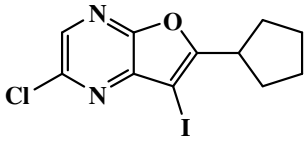
2-Chloro-3-(4-methoxyphenyl)-6-pyridin-4-ylfuro[2,3-*b*] pyrazine (4d): 79 % yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.84 (br, 2H), 7.89 (m, 4H), 7.48 (s, 1H), 7.05 (d, *J* = 8.8 Hz, 2H), 3.90 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 160.9, 157.3, 154.4, 149.4, 147.6, 144.4, 138.0, 136.9, 132.1, 131.5, 128.5, 128.4, 119.5, 113.8, 104.9, 55.4. HR-MS (EI): calcd for $C_{18}H_{12}O_2N_3Cl$: 337.0618, found: 337.0621.



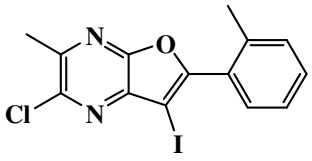
3-benzyl-2-chloro-6-p-tolylfuro[2,3-b]pyrazine (4e): White solid m.p. 214 – 216 °C in 91 % yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.80 (d, *J* = 9.0 Hz, 2H), 7.38 (d, *J* = 8.3 Hz, 2H), 7.33 – 7.22 (m, 5H), 7.05 (s, 1H), 4.37 (s, 2H), 2.42 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 161.6, 154.0, 146.5, 144.7, 141.3, 140.2, 137.6, 131.4, 129.9, 128.7, 126.9, 125.9, 125.7, 99.8, 42.3, 21.7 HRMS (EI): calcd for $C_{20}H_{15}ON_2Cl$: 334.0873, found: 334.0858.

A typical procedure for the preparation of furopyrazines 5a-g.

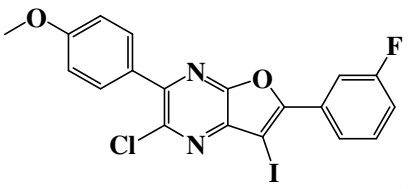
In a 25 mL flask pyrazinone **3** (2 mmol) was dissolved in dry dichloromethane (12 mL). Then I_2 (2.0 equiv) was added and the reaction mixture was stirred at room temperature for 5-15 min. After reaction completion the solvent was evaporated and the residue was subjected to silica gel column chromatography (from 5% to 10% CH_2Cl_2 in petroleum ether) to afford compounds **5a-g**.



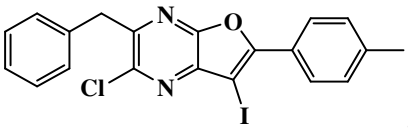
2-chloro-6-cyclopentyl-7-iodofuro[2,3-b]pyrazine (5a): White solid m.p. 128 – 131 °C in 76 % yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.17 (s, 1H), 3.56 – 3.45 (m, 1H), 2.13 – 2.07 (m, 2H), 1.93 (s, 4H), 1.76 (s, 2H). ^{13}C NMR (75 MHz, $CDCl_3$): 169.2, 153.4, 142.2, 136.8, 62.2, 39.5, 31.7, 26.2. HRMS (EI): calcd for $C_{11}H_{10}ON_2ICl$: 347.9526, found: 347.9547.



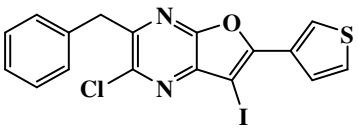
2-chloro-7-iodo-3-methyl-6-o-tolylfuro[2,3-b]pyrazine (5b): yellow solid m.p. 158– 161 °C in 86 % yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.61 (d, *J* = 7.32 Hz, 1H), 7.45 (m, 1H), 7.34 (m, 2H), 2.77 (s, 3H), 2.41 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$):160.9, 153.3, 147.3, 145.7, 139.8, 138.4, 131.1, 128.2, 125.8, 64.6, 22.6, 20.6. HRMS (EI): calcd for $C_{14}H_{10}ON_2ICl$: 383.9526, found: 383.9522.



2-chloro-6-(3-fluorophenyl)-7-iodo-3-(4-methoxyphenyl) furo[2,3-b]pyrazine (5c): light yellow solid m.p. 210 – 214 °C in 88 % yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.13 (d, *J* = 8.22 Hz, 1H), 8.03 (d, *J* = 10.05 Hz, 1H), 7.85 (d, *J* = 8.22 Hz, 2H), 7.53 (m, 1H), 7.24 (d, *J* = 2.73 Hz, 1H), 7.03 (d, *J* = 8.22 Hz, 2H), 3.89 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): 160.9, 156.4, 144.5, 131.6, 130.7, 128.4, 123.6, 118.2, 117.1, 114.9, 114.6, 113.8, 55.5. HRMS (EI): calcd for $C_{19}H_{11}O_2N_2ICIF$: 479.9538, found: 479.9565.

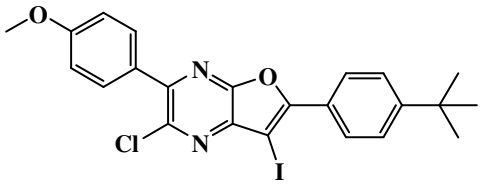


3-benzyl-2-chloro-7-iodo-6-p-tolylfuro[2,3-b]pyrazine (5d): yellow solid m.p. 157– 159 °C in 91 % yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.16 (d, *J* = 9.15 Hz, 2H), 7.37 – 7.26 (m, 7H), 4.40 (s, 2H), 2.44 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$):158.0, 152.8, 148.5, 145.5, 141.6, 141.2, 137.3, 129.6, 129.4, 128.7, 127.9, 126.9, 125.8, 59.7, 41.2, 21.7. HRMS (EI): calcd for $C_{20}H_{14}ON_2ICl$: 459.9839, found: 459.9829.

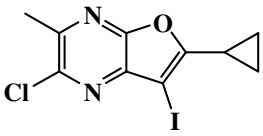


3-benzyl-2-chloro-7-iodo-6-(thiophen-3-yl)furo[2,3-b]pyrazine (5e): yellow solid m.p. 168– 171 °C in 96 % yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.40 (d, *J* = 1.83 Hz, 1H), 7.98 (d, *J* = 5.49 Hz, 7H), 7.50 – 7.48 (m, 1H), 7.37 - 7.23 (m, 5H), 4.40 (s, 2H). ^{13}C NMR (75 MHz, $CDCl_3$): 155.3, 152.5, 148.5, 145.6, 141.0, 137.2, 130.1, 129.1, 128.7,

127.8, 126.9, 126.2, 59.6, 41.2. HRMS (EI): calcd for $C_{17}H_{10}ON_2SICl$: 451.9247, found: 451.9242.



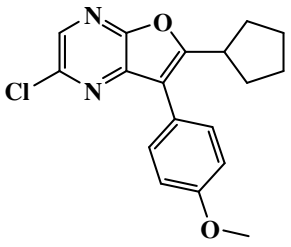
6-(4-tert-butylphenyl)-2-chloro-7-iodo-3-(4-methoxy phenyl)furo[2,3-b]pyrazine (5f): yellow solid m.p. 146 – 150 °C in 96 % yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.26 (d, *J* = 9.12 Hz, 2H), 7.85 (d, *J* = 9.12 Hz, 2H), 7.58 (d, *J* = 8.22 Hz, 1H), 7.03 (d, *J* = 9.15 Hz, 5H), 3.89 (s, 3H), 1.38 (s, 9H). ^{13}C NMR (75 MHz, $CDCl_3$):160.7, 158.4, 154.8, 152.9, 146.9, 144.1, 141.0, 131.5, 128.7, 127.8, 125.9, 113.8, 59.8, 55.5, 35.2, 31.2. HRMS (EI): calcd for $C_{23}H_{20}O_2N_2ICl$: 518.0258, found: 518.0268.



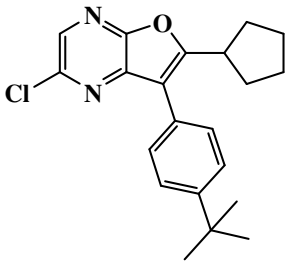
2-chloro-6-cyclopropyl-7-iodo-3-methylfuro[2,3-b]pyrazine (5g): yellow solid m.p. 82 – 85 °C in 68 % yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 2.69 (s, 3H), 2.34 – 2.25 (m, 1H), 1.31 – 1.19 (m, 4H). ^{13}C NMR (75 MHz, $CDCl_3$):164.9, 152.2, 145.1, 140.2, 130.1, 114.3, 60.7, 22.3, 11.0, 9.4. HRMS (EI): calcd for $C_{10}H_8ON_2ICl$: 333.9370, found: 333.9363.

A typical procedure for selective Suzuki-Miyaura reaction on compounds 5a-g.

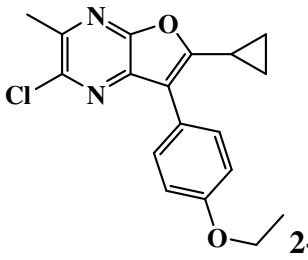
In a 15 mL microwave vial were successively dissolved in DMF (4 mL) furopyrazine **5a-g** (0.3 mmol), boronic acid **6a,b,f-l** (0.375 mmol, 1.25 equiv), $Pd(PPh_3)_4$ (3 mg, 1 mol %) and K_2CO_3 (82 mg, 2 equiv). The reaction tube was sealed and irradiated at a ceiling temperature of 120 °C at 100 W maximum power for 10-30 min. After the reaction mixture was cooled with an air flow for 15 min, extracted with dichloromethane (2×50 mL) and dried over $MgSO_4$. The solvent was removed under reduced pressure and the residue was subjected to silica gel chromatography (from 5% to 20% EtOAC in Heptane) to afford compounds **7a-j.**



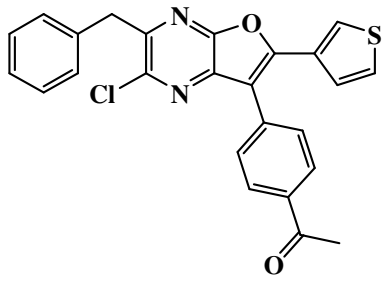
2-chloro-6-cyclopentyl-7-(4-methoxyphenyl)furo[2,3-b]pyrazine (7a): Yellow oil in 91 % yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.16 (s, 1H), 7.54 (d, *J* = 9.15 Hz, 2H), 7.04 (d, *J* = 9.15, 2H), 3.86 (s, 3H), 3.55 – 3.50 (m, 1H), 2.05 - 1.94 (m, 6H), 1.74 – 1.68 (m, 2H). ^{13}C NMR (75 MHz, $CDCl_3$):164.8, 159.4, 153.4, 145.1, 140.9, 135.4, 130.4, 121.6, 115.7, 114.5, 55.4, 37.7, 32.4, 26.4. HRMS (EI): calcd for $C_{18}H_{17}O_2N_2Cl$: 328.0979, found: 328.0987.



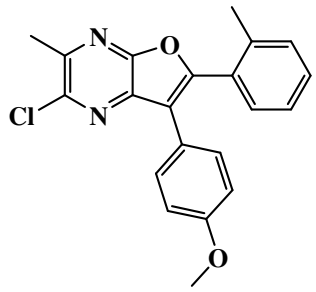
7-(4-tert-butylphenyl)-2-chloro-6-cyclopentylfuro[2,3-b]pyrazine (7b): White solid m.p. 97 – 99 °C in 78 % yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.17 (s, 1H), 7.57 – 7.50 (m, 4H), 3.59 – 3.53 (m, 1H), 2.06 - 1.94 (m, 6H), 1.75 – 1.71 (m, 2H), 1.36 (s, 9H). ^{13}C NMR (75 MHz, $CDCl_3$):165.2, 153.5, 151.1, 145.2, 140.9, 135.5, 128.9, 126.4, 126.0, 116.0, 37.8, 34.8, 32.5, 31.4, 26.4. HRMS (EI): calcd for $C_{21}H_{23}ON_2Cl$: 354.1499, found: 354.1506.



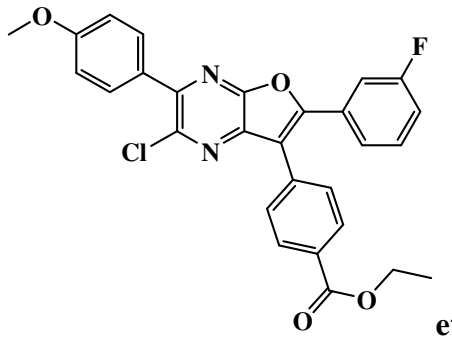
2-chloro-6-cyclopropyl-7-(4-ethoxyphenyl)-3-methylfuro[2,3-b] pyrazine (7c): White solid m.p. 82 – 85 °C in 86 % yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.71 (d, *J* = 8.22 Hz, 2H), 7.03 (d, *J* = 9.12 Hz, 2H), 4.12 – 4.05 (q, 2H), 2.68 (s, 3H), 2.35 – 2.33 (m, 1H), 1.45 (t, *J* = 13.71, 6.39 Hz, 3H), 1.29 – 1.26 (m, 4H). ^{13}C NMR (75 MHz, $CDCl_3$):160.3, 158.6, 152.5, 144.3, 143.6, 138.9, 130.1, 121.9, 115.0, 63.6, 22.4, 14.9, 9.5, 8.9. HRMS (EI): calcd for $C_{18}H_{17}O_2N_2Cl$: 328.0979, found: 328.0987.



1-(4-(3-benzyl-2-chloro-6-(thiophen-3-yl)furo[2,3-b]pyrazin-7-yl)phenyl)ethanone (7d) White solid m.p. 209 – 214 °C in 87 % yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.08 (d, *J* = 8.22 Hz, 2H), 7.84 (d, *J* = 2.76 Hz, 1H), 7.75 (d, *J* = 8.22 Hz, 2H), 7.40 – 7.23 (m, 7H), 4.40 (s, 2H), 2.66 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): 197.7, 153.2, 152.9, 147.7, 145.2, 139.0, 137.4, 137.0, 134.4, 130.1, 129.2, 128.7, 127.0, 126.9 126.0, 114.5, 41.4, 29.8, 26.8. HRMS (EI): calcd for $C_{25}H_{17}O_2N_2SCl$: 444.0699, found: 444.0691.

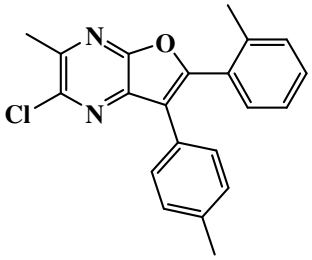


2-chloro-7-(4-methoxyphenyl)-3-methyl-6-o-tolylfuro[2,3-b]-pyrazine (7e): White solid m.p. 136 – 140 °C in 89 % yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.53 (d, *J* = 8.22 Hz, 2H), 7.44 (d, *J* = 8.19 Hz, 1H), 7.38 (d, *J* = 7.32 Hz, 1H), 7.32 – 7.23 (m, 2H), 6.88 (d, *J* = 9.15 Hz, 2H), 3.80 (s, 3H), 2.76 (s, 3H), 2.22 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): 159.4, 155.8, 153.7, 145.6, 144.7, 138.1, 131.1, 130.9, 130.4, 129.8, 129.4, 126.1, 122.1, 117.0, 114.3, 55.3, 22.7, 20.3. HRMS (EI): calcd for $C_{21}H_{17}O_2N_2Cl$: 364.0979, found: 364.0984.

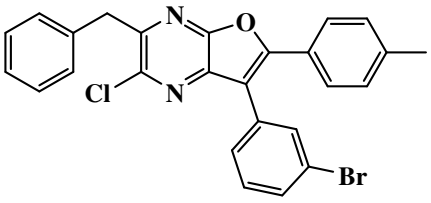


ethyl4-(2-chloro-6-(3-fluorophenyl)-3-(4-methoxyphenyl) furo[2,3-b]pyrazin-7-yl)benzoate (7f): White solid m.p. 163 – 167 °C in 78 % yield. ^{1}H NMR

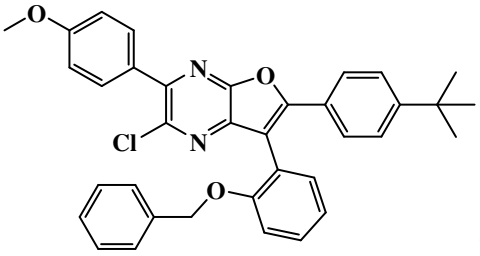
(300 MHz, $CDCl_3$): δ 8.18 (d, *J* = 7.29 Hz, 2H), 7.87 (d, *J* = 9.12 Hz, 2H), 7.73 (d, *J* = 8.22 Hz, 2H), 7.52 – 7.45 (m, 2H), 7.39 – 7.32 (q, 1H), 7.16 – 7.10 (m, 1H), 7.04 (d, *J* = 9.12 Hz, 2H), 4.46 – 4.39 (q, 2H), 3.89 (s, 3H), 1.45 – 1.40 (t, *J* = 14.61, 7.29 Hz, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): 166.3, 164.5, 161.2, 160.8, 154.8, 153.5, 146.8, 144.0, 138.3, 133.8, 131.5, 130.9, 130.6, 129.7, 128.8, 123.6, 117.8, 116.7, 114.9, 113.3, 61.3, 55.5, 14.5. HRMS (EI): calcd for $C_{28}H_{20}O_4N_2ClF$: 502.1096, found: 502.1089.



2-chloro-3-methyl-6-o-tolyl-7-p-tolylfuro[2,3-b]pyrazine (7g): White solid m.p. 97 – 99 °C in 90 % yield. ^1H NMR (300 MHz, $CDCl_3$): δ 7.48 – 7.39 (m, 4H), 7.36 - 7.22 (m, 2H), 7.15 (d, *J* = 7.32 Hz, 2H), 2.76 (s, 3H), 2.34 (s, 3H), 2.22 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$):156.2, 153.7, 145.7, 144.8, 138.1, 137.9, 131.1, 130.4, 129.5, 128.5, 126.8, 126.1, 117.4, 22.7, 21.4, 20.3. HRMS (EI): calcd for $C_{21}H_{17}ON_2Cl$: 348.1029, found: 348.1013.

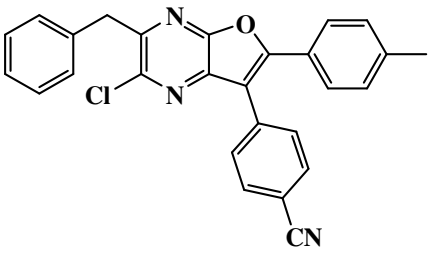


3-benzyl-7-(3-bromophenyl)-2-chloro-6-p-tolylfuro[2,3-b] pyrazine (7h): 79 % yield. ^1H NMR (300 MHz, $CDCl_3$): δ 7.73 (s, 1H), 7.62 - 7.49 (m, 4H), 7.39 – 7.28 (m, 5H), 7.26 – 7.18 (m, 3H), 4.40 (s, 2H), 2.39 (s, 3H). HRMS (EI): calcd for $C_{26}H_{18}ON_2BrCl$: 488.0291, found: 488.0303.



7-(2-(benzyloxy)phenyl)-6-(4-tert-butylphenyl)-2-chloro-3-(4-methoxyphenyl)furo[2,3-b]pyrazine (7i): White solid m.p. 61 – 65 °C in 89 %

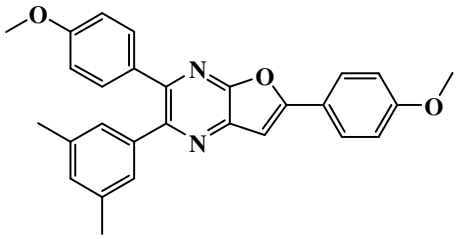
yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.83 (d, *J* = 9.12 Hz, 2H), 7.67 (d, *J* = 8.22 Hz, 2H), 7.50 – 7.35 (m, 4H), 7.17 – 7.13 (m, 3H), 7.11 – 7.00 (m, 6H), 4.96 (s, 2H), 3.87 (s, 3H), 1.31 (s, 9H). ^{13}C NMR (75 MHz, $CDCl_3$): 207.0, 160.4, 156.9, 156.6, 153.5, 153.3, 145.0, 143.1, 140.1, 136.6, 132.1, 131.3, 130.2, 129.3, 128.2, 127.6, 127.3, 127.0, 126.8, 125.6, 121.4, 119.1, 113.6, 113.0, 55.4, 34.9, 31.1. HRMS (EI): calcd for $C_{36}H_{31}O_3N_2Cl$: 574.2023, found: 574.2027.



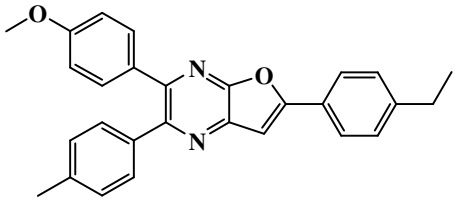
4-(3-benzyl-2-chloro-6-p-tolylfuro[2,3-b]pyrazin-7-yl)-benzonitrile (7j): White solid m.p. 158 – 162 °C in 91 % yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.74 (m, 4H), 7.58 (d, *J* = 8.22 Hz, 2H), 7.38 (d, *J* = 7.32 Hz, 2H), 7.33 – 7.21 (m, 5H), 4.46 (s, 2H), 2.41 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): 157.2, 153.4, 148.0, 145.1, 141.6, 138.6, 137.3, 134.8, 132.7, 130.2, 129.8, 129.1, 128.7, 128.0, 126.9, 125.6, 118.7, 114.0, 111.9, 41.3, 21.6. HRMS (EI): calcd for $C_{27}H_{18}ON_3Cl$: 435.1138, found: 435.1132.

A typical procedure for the preparation of furopyrazines 8a-d.

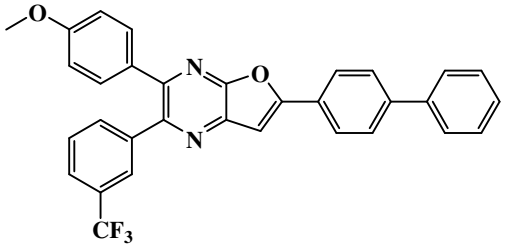
In a 15 mL microwave vial were successively dissolved in DMF/H_2O (1:1, 4 mL) furopyrazine **4a-c,e** (0.3 mmol), boronic acid **6b-e** (0.45 mmol, 1.50 equiv), $Pd(PPh_3)_4$ (3 mg, 1 mol %) and Na_2CO_3 (64 mg, 2 equiv). The reaction tube was sealed and irradiated at a ceiling temperature of 100 °C at 100 W maximum power for 10 min. After the reaction mixture was cooled with an air flow for 15 min, extracted with dichloromethane (2×50 mL) and dried over $MgSO_4$. The solvent was removed under reduced pressure and the residue was subjected to silica gel flash chromatography (from 10% to 50% CH_2Cl_2 in petroleum ether) to afford compounds **8a-d**.



2-(3,5-dimethylphenyl)-3,6-bis(4-methoxyphenyl) furo-[2,3-b]pyrazine (8a): Yellow solid m.p. 72 - 75 °C in 90 % yield. ^{1}H NMR (300 MHz, 2$CDCl_3$): δ 7.92 (d, *J* = 9.15, 2H), 7.43 (d, *J* = 9.12, 2H), 7.11 (s, 1H), 7.05 – 6.96 (m, 5H), 6.82 (d, *J* = 9.12, 2H), 3.89 (s, 3H), 3.81 (s, 3H), 2.26 (s, 6H). ^{13}C NMR (75 MHz, $CDCl_3$): 161.4, 160.6, 159.7, 154.4, 150.4, 145.6, 140.0, 137.9, 131.5, 129.8, 129.4, 128.8, 128.0, 127.7, 127.3, 121.9, 114.6, 113.5, 99.6, 55.5, 21.4. HRMS (EI): calcd for $C_{28}H_{24}O_3N_2$: 436.1787, found: 436.1793.

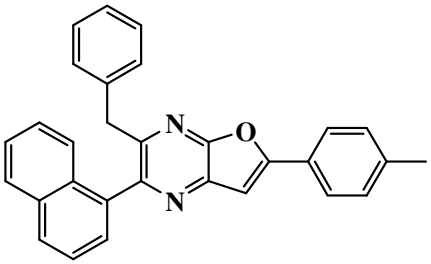


6-(4-ethylphenyl)-3-(4-methoxyphenyl)-2-p-tolylfuro-[2,3-b]pyrazine (8b): Light yellow solid m.p. 172 – 175 °C in 85 % yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.89 (d, *J* = 8.22, 2H), 7.43 (d, *J* = 9.12, 2H), 7.36 – 7.33 (m, 4H), 7.20 (s, 1H), 7.14 (d, *J* = 8.22, 2H), 6.83 (d, *J* = 8.22, 2H), 3.81 (s, 3H), 2.76 - 2.68 (m, 2H), 2.36 (s, 3H), 1.31 – 1.26 (t, *J* = 14.61, 7.29, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): 160.7, 159.8, 154.4, 150.3, 147.1, 146.0, 139.9, 138.0, 137.0, 131.5, 129.8, 128.7, 126.7, 125.7, 113.7, 100.6, 55.3, 29.0, 21.4, 15.5. HRMS (EI): calcd for $C_{28}H_{24}O_2N_2Cl$: 420.1838, found: 420.1821.



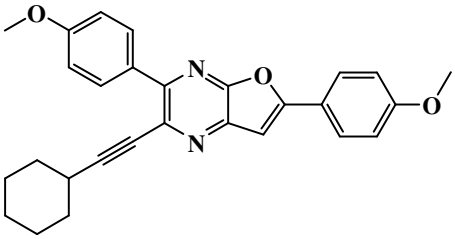
6-(biphenyl-4-yl)-3-(4-methoxyphenyl)-2-(3-(trifluoromethyl)phenyl)furo[2,3-b]pyrazine (8c): Yellow solid m.p. 150 – 153 °C in 87 % yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.06 (d, *J* = 8.22 Hz, 2H), 7.84 (s, 1H), 7.76 (d, *J* = 8.22 Hz, 2H), 7.67 (d, *J* = 7.32 Hz, 2H), 7.60 (d, *J* = 7.29 Hz, 2H), 7.51 – 7.37 (m, 7H), 7.31 (s, 1H), 6.85 (d, *J* = 8.22 Hz, 2H), 3.82 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): 160.7, 160.1, 148.7,

146.5, 143.3, 140.6, 140.0, 133.4, 131.6, 130.8, 130.5, 129.1, 128.7, 128.1, 127.2, 126.9, 126.2, 124.9, 113.9, 101.2, 55.4. HRMS (EI): calcd for $C_{32}H_{21}O_2N_2F_3$: 522.1555, found: 522.1566.



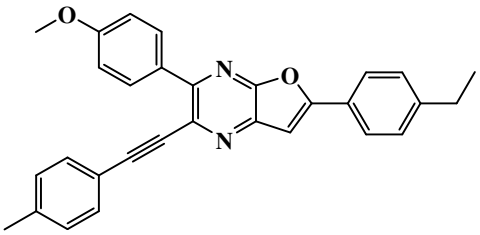
3-benzyl-2-(naphthalen-1-yl)-6-p-tolylfuro[2,3-b]pyrazine (8d): 100 % yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.89 (m, 4H), 7.52 (m, 2H), 7.35 (m, 5H), 7.16 (s, 1H), 7.10 (m, 3H), 6.90 (m, 2H), 3.95 (m, 2H), 2.44 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 160.6, 154.6, 150.5, 148.4, 140.0, 136.2, 133.7, 131.9, 129.8, 128.9, 128.4, 128.2, 127.7, 126.6, 126.2, 126.1, 125.3, 100.5, 41.3, 21.6 HRMS (EI): calcd for $C_{30}H_{22}ON_2$: 426.1732, found: 426.1735.

Sonogashira coupling reaction on substituted 2-chloro furo[2,3-*b*]pyrazine 4a-c. A typical procedure. In a 15 mL microwave vial were successively dissolved in DMF/Et_3N (1:1, 4 mL) pyrazine **4a-c** (0.3 mmol), acetylene **2e,l,m** (0.375 mmol, 1.25 equiv), $Pd(PPh_3)Cl_2$ (17 mg, 5 mol %) and CuI (5.7 mg, 10 mol %). The reaction tube was sealed, and irradiated in microwave reactor at a ceiling temperature of 100 °C at 80 W maximum power for 15 min. After the reaction mixture was cooled with an air flow for 15 min, extracted with dichloromethane (2×150 mL) and dried over $MgSO_4$. The solvent was removed under reduced pressure and the residue was subjected to silica gel column chromatography (from 10% to 30% EtOAc in Heptane) to afford compounds **9a-c**.

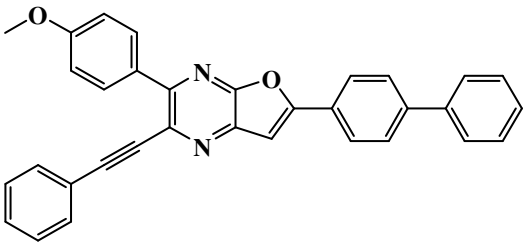


2-(2-cyclohexylethynyl)-3,6-bis(4-methoxyphenyl)furo-[2,3-b]pyrazine (9a): Yellow solid m.p. 140 – 143 °C in 85 % yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.09 (d, *J* = 9.15 Hz, 2H), 7.89 (d, *J* = 8.22 Hz, 2H), 7.03 - 6.98 (m, 5H), 3.89 (s,

6H), 2.66 -2.62 (m, 1H), 1.88 – 1.86 (m, 2H), 1.73 – 1.70 (m, 2H), 1.56 – 1.52 (m, 6H). ^{13}C NMR (75 MHz, $CDCl_3$): 161.4, 160.4, 153.6, 148.3, 139.9, 133.9, 131.1, 129.9, 129.1, 128.7, 127.3, 121.5, 114.5, 114.0, 113.3, 99.1, 79.7, 55.4, 31.9, 29.9, 25.8, 24.9. HRMS (EI): calcd for $C_{28}H_{26}O_3N_2$: 438.1943, found: 438.1964.



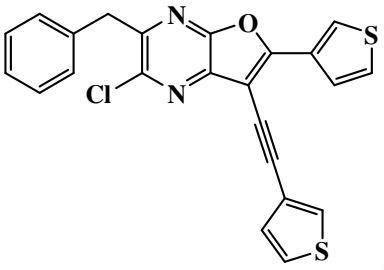
6-(4-ethylphenyl)-3-(4-methoxyphenyl)-2-(2-p-tolyl-ethynyl)furo[2,3-b]pyrazine (9b): Yellow solid m.p. 156 – 159 °C in 92 % yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.17 (d, *J* = 8.22 Hz, 2H), 7.89 (d, *J* = 8.22 Hz, 2H), 7.43 (d, *J* = 8.22 Hz, 2H), 7.35 (d, *J* = 8.22 Hz, 2H), 7.16 (d, *J* = 8.22 Hz, 2H), 7.05 (d, *J* = 8.22 Hz, 2H), 3.91 (s, 3H), 2.77 – 2.69 (m, 2H), 2.37 (s, 3H), 1.31 – 1.26 (t, *J* = 15.54, 7.32 Hz, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): 161.4, 160.6, 149.0, 147.3, 139.9, 133.6, 131.7, 131.1, 129.2, 128.6, 126.2, 125.7, 119.2, 113.4, 100.1, 93.1, 55.4, 28.9, 21.6, 15.3. HRMS (EI): calcd for $C_{30}H_{24}O_2N_2$: 444.1838, found: 444.1841.



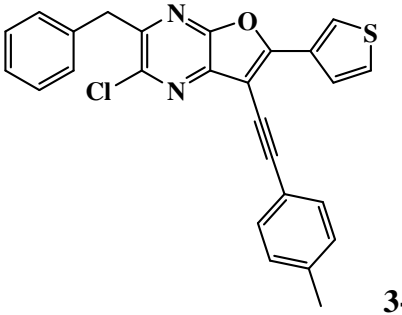
6-(biphenyl-4-yl)-3-(4-methoxyphenyl)-2-(phenyle-thynyl)furo[2,3-b]pyrazine (9c): Yellow solid m.p. 191 – 194 °C in 96 % yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.16 (d, *J* = 9.15 Hz, 2H), 8.04 (d, *J* = 8.22 Hz, 2H), 7.75 (d, *J* = 9.15 Hz, 2H), 7.66 (d, *J* = 7.32 Hz, 2H), 7.55 – 7.46 (m, 4H), 7.42 – 7.36 (m, 4H), 7.24 (s, 1H), 7.07 (d, *J* = 8.22 Hz, 2H), 3.91 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): 160.9, 154.1, 149.5, 143.3, 140.0, 133.7, 131.9, 131.3, 129.7, 129.2, 128.5, 128.1, 127.8, 127.6, 127.1, 126.2, 122.4, 113.6, 101.0, 93.0, 88.4, 55.5. HRMS (EI): calcd for $C_{33}H_{22}O_2N_2$: 478.1681, found: 478.1671.

A typical procedure for selective Sonogashira coupling reaction on dihalo-substituted furo[2,3-*b*]pyrazine 5c,e. In a 15 mL microwave vial were successively dissolved in DMF/Et_3N

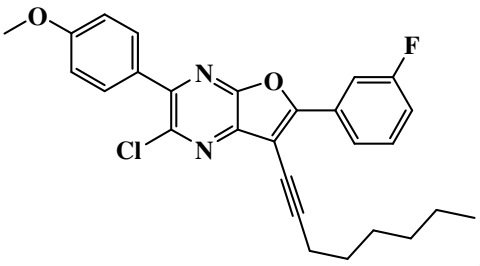
(1:1, 4 mL) pyrazine **5c,e** (0.3 mmol), acetylene **2i,e,n** (0.315 mmol, 1.05 equiv), $Pd(PPh_3)Cl_2$ (3.4 mg, 1 mol %) and CuI (2.0 mg, 3 mol %). The reaction tube was sealed, and irradiated in microwave reactor at a ceiling temperature of 95 °C at 80 W maximum power for 7-10 min. After the reaction mixture was cooled with an air flow for 15 min, extracted with dichloromethane (2×150 mL) and dried over $MgSO_4$. The solvent was removed under reduced pressure and the residue was subjected to silica gel column chromatography (from 5% to 10% EtOAc in Heptane) to afford compounds **10a-c**.



3-benzyl-2- chloro-6-(thiophen-3-yl)-7-(2-(thiophen-3-yl) ethynyl)furo[2,3-b]pyrazine (10a): Yellow solid m.p. 140 – 144 °C in 89 % yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.32 (d, *J* = 1.83 Hz, 1H), 7.97 (d, *J* = 5.49 Hz, 1H), 7.66 (d, *J* = 4.0 Hz, 1H), 7.48 – 7.45 (m, 2H), 7.35 - 7.28 (m, 6H), 4.39 (s, 2H). ^{13}C NMR (75 MHz, $CDCl_3$): 155.4, 152.6, 148.8, 145.2, 141.3, 137.4, 130.6, 129.2, 128.7, 128.2, 127.8, 126.9, 126.2, 125.8, 125.9, 116.0, 89.0, 77.8, 41.2. HRMS (EI): calcd for $C_{23}H_{13}ON_2S_2Cl$: 432.0158, found: 432.0145.



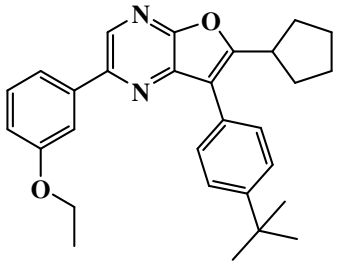
3-benzyl-2-chloro-6-(thiophen-3-yl)-7-(2-p-tolylethynyl) furo[2,3-b]pyrazine (10b): Yellow solid m.p. 121 – 125 °C in 86 % yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.33 (s, 1H), 7.98 (d, *J* = 5.49 Hz, 1H), 7.53 (d, *J* = 8.22 Hz, 2H), 7.47 – 7.43 (m, 1H), 7.37 – 7.19 (m, 7H), 4.39 (s, 2H), 2.39 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): 157.8, 153.0, 147.9, 145.3, 139.4, 138.4, 137.3, 132.0, 130.5, 129.4, 128.7, 126.9, 125.7, 119.5, 98.8, 98.3, 41.3, 21.7. HRMS (EI): calcd for $C_{26}H_{17}ON_2SCl$: 440.0750, found: 440.0746.



2-chloro-6-(3-fluorophenyl)-3-(4-methoxyphenyl)-7-(oct-1-ynyl)furo[2,3-b]pyrazine (10c): Yellow solid m.p. 97 – 100 °C in 74 % yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.14 (m, 2H), 7.85 (d, *J* = 8.19 Hz, 2H), 7.52 – 7.47 (m, 1H), 7.21 – 7.15 (m, 1H), 7.03 (d, *J* = 9.15 Hz, 2H), 3.89 (s, 3H), 2.66 – 2.61 (t, *J* = 13.71, 7.32 Hz, 2H), 1.79 – 1.69 (m, 2H), 1.57 – 1.54 (m, 2H), 1.37 – 1.35 (m, 4H), 0.94 – 0.89 (t, *J* = 13.71, 6.39 Hz, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): 164.5, 161.2, 160.8, 158.9, 152.9, 147.0, 144.1, 139.0, 131.5, 130.5, 128.7, 122.2, 117.6, 113.8, 113.2, 102.3, 69.1, 55.5, 31.4, 28.9, 28.4, 22.6, 20.3, 14.1. HRMS (EI): calcd for $C_{27}H_{24}O_2N_2ClF$: 462.1510, found: 462.1516.

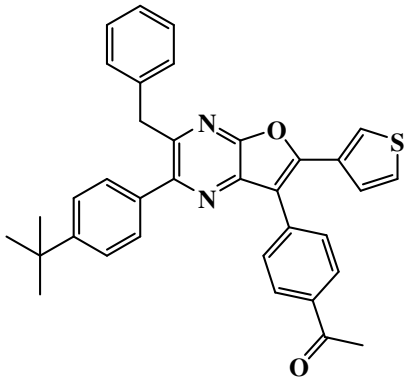
A typical procedure for the preparation of furopyrazines 11a-c.

In a 15 mL microwave vial were successively dissolved in DMF/H_2O (1:1, 4 mL) furopyrazine **7b,d,e** (0.3 mmol), boronic acid **6f,m,n** (0.45 mmol, 1.50 equiv), $Pd(PPh_3)_4$ (3 mg, 1 mol %) and Na_2CO_3 (64 mg, 2 equiv). The reaction tube was sealed and irradiated at a ceiling temperature of 100 °C at 100 W maximum power for 10 min. After the reaction mixture was cooled with an air flow for 15 min, extracted with dichloromethane (2×50 mL) and dried over $MgSO_4$. The solvent was removed under reduced pressure and the residue was subjected to silica gel flash chromatography (from 10% to 30% CH_2Cl_2 in petroleum ether) to afford compounds **11a-c**.

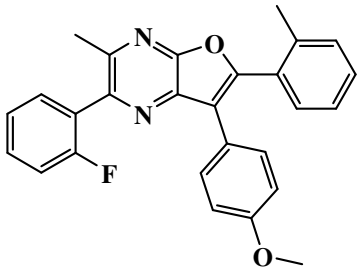


7-(4-tert-butylphenyl)-6-cyclopentyl-2-(3-ethoxyphenyl)furo[2,3-b]pyrazine (11a): White solid m.p. 102 – 104 °C in 92 % yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.60 (s, 1H), 7.70 (d, *J* = 8.22 Hz, 2H), 7.61 – 7.53 (m, 4H), 7.41 – 7.36 (t, *J* = 16.44, 8.22

Hz, 1H), 6.98 (d, *J* = 9.12 Hz, 1H), 4.15 – 4.08 (m, 2H), 3.67 – 3.56 (m, 1H), 2.11 – 1.96 (m, 6H), 1.74 – 1.72 (m, 2H), 1.47 – 1.39 (m, 12H). ^{13}C NMR (75 MHz, $CDCl_3$): 161.4, 160.6, 149.0, 147.3, 139.9, 133.6, 131.7, 131.1, 129.2, 128.6, 126.2, 125.7, 119.2, 113.4, 100.1, 93.1, 55.4, 28.9, 21.6, 15.3. HRMS (EI): calcd for $C_{29}H_{32}O_2N_2$: 440.2464, found: 440.2461.

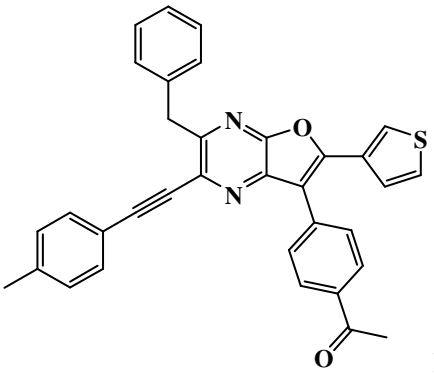


1-(4-(3-benzyl-2-(4-tert-butylphenyl)-6-(thiophen-3-yl)furo [2,3-b]pyrazin-7-yl)phenyl)ethanone (11b): White solid m.p. 149 – 152 °C in 87 % yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 8.04 (d, *J* = 8.22 Hz, 2H), 7.84 – 7.80 (m, 3H), 7.44 – 7.43 (m, 4H), 7.31 (s, 2H), 7.24 – 7.10 (m, 5H), 4.33 (s, 2H), 2.63 (s, 3H), 1.36 (s, 9H). ^{13}C NMR (75 MHz, $CDCl_3$): 197.8, 153.5, 152.2, 151.6, 148.0, 139.4, 136.6, 135.3, 130.5, 129.3, 128.9, 126.7, 126.4, 125.4, 115.0, 41.2, 34.8, 31.5, 26.8. HRMS (EI): calcd for $C_{35}H_{30}O_2N_2S$: 542.2028, found: 542.2029.



2-(2-fluorophenyl)-7-(4-methoxyphenyl)-3-methyl-6-o-tolylfuro [2,3-b]pyrazine (11c): 95 % yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.61 (m, 10H), 6.84 (d, *J* = 8.22 Hz, 2H), 3.77 (s, 3H), 2.60 (s, 3H), 2.26 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): 161.7, 159.1, 158.4, 154.9, 154.4, 146.9, 146.1, 138.1, 132.0, 131.0, 130.5, 129.9, 127.6, 126.1, 124.4, 122.7, 117.3, 115.9, 114.2, 55.2, 22.2, 20.3. HRMS (EI): calcd for $C_{27}H_{21}O_2N_2F$: 542.2028, found: 542.2035.

A typical sonogashira coupling for 11d. In a 15 mL microwave vial were successively dissolved in DMF/Et_3N (1:1, 4 mL) pyrazine **7d** (0.3 mmol), acetylene **2e** (0.39 mmol, 1.3 equiv), $Pd(PPh_3)Cl_2$ (17 mg, 5 mol %) and CuI (5.7 mg, 10 mol %). The reaction tube was sealed, and irradiated in microwave reactor at a ceiling temperature of 100 °C at 80 W maximum power for 15 min. After the reaction mixture was cooled with an air flow for 15 min, extracted with dichloromethane (2×150 mL) and dried over $MgSO_4$. The solvent was removed under reduced pressure and the residue was subjected to silica gel column chromatography (from 10% to 30% EtOAc in Heptane) to afford compounds **11d**.

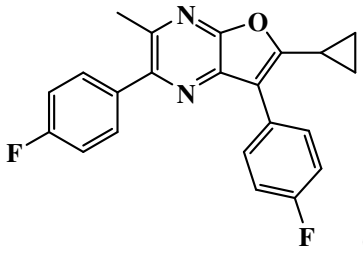


1-(4-(3-benzyl-6-(thiophen-3-yl)-2-(2-p-tolylethynyl)furo [2,3-b]pyrazin-7-yl)phenyl)ethanone (11d): Light yellow solid m.p. 210 – 215 °C in 86 % yield. ^1H NMR (300 MHz, $CDCl_3$): δ 8.08 (d, J = 8.22 Hz, 2H), 7.79 – 7.76 (m, 3H), 7.50 – 7.44 (m, 4H), 7.33 – 7.12 (m, 8H), 4.54 (s, 2H), 2.66 (s, 3H), 2.39 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): 197.8, 152.9, 152.4 139.7, 139.3, 138.5, 136.9, 136.1, 134.8, 131.9, 130.3, 129.4, 128.7, 126.9, 126.0, 119.1, 114.7, 94.8, 86.5, 41.9, 26.8, 21.7. HRMS (EI): calcd for $C_{34}H_{24}O_2N_2S$: 524.1558, found: 524.1551.

Disubstituted Suzuki Cross coupling. A typical procedure for the preparation of furopyrazine 12a.

In a 15 mL microwave vial were successively dissolved in DMF (4mL) furopyrazine **5g** (0.3 mmol), boronic acid **6o** (0.9 mmol, 3.0 equiv), $Pd(PPh_3)_4$ (16 mg, 5 mol %) and K_2CO_3 (166 mg, 5 equiv). The reaction tube was sealed and irradiated at a ceiling temperature of 140 °C at 300 W maximum power for 25 min. After the reaction mixture was cooled with an air flow for

15 min, extracted with dichloromethane (2×50 mL) and dried over $MgSO_4$. The solvent was removed under reduced pressure and the residue was subjected to silica gel flash chromatography (from 0% to 5%EtOAc in Heptane) to afford compound **12a** in 93% of yield



6-cyclopropyl-2,7-bis(4-fluorophenyl)-3-methylfuro[2,3-b]-pyrazine (12a): White solid m.p. 81 – 84 °C in 93 % yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.86 – 7.81 (m, 2H), 7.58 – 7.54 (m, 2H), 7.20 – 7.13 (m, 4H), 2.64 (s, 3H), 2.37 – 2.32 (m, 1H), 1.35 – 1.13 (m, 4H). ^{13}C NMR (75 MHz, $CDCl_3$): 164.5, 163.9, 161.2, 160.6, 159.8, 152.8, 149.5, 143.9, 138.6, 135.6, 131.4, 130.7, 126.3, 116.0, 115.5, 115.1, 23.3, 9.5, 8.8. HRMS (EI): calcd for $C_{22}H_{16}ON_2F_2$: 362.1231, found: 362.1225.

Description of X-ray structure of compound **8d**

The asymmetric unit of the X-ray structure consists of two molecules of compound **8d.** The benzyl and naphthyl aromatic rings are torsioned with respect to the furopyrazine moiety with angles of 63.5(3)° and 79.9(2)°, respectively, for the first molecule and 78.5(3)° and 73.3(2)°, respectively, for the second molecule (angles between planes through the component aromatic rings). This furopyrazine moiety is almost planar with the methylphenyl ring (angles of 6.9(3)° and 9.9(3)°between planes through the aromatic rings for the first and second molecule, respectively).

Clear π-π stacking is observed in the packing between the furan ring of the furopyrazine part of one of the molecules and the phenyl ring of the methylphenyl part of the other molecule in the asymmetric (distance of 3.547(4) Å between the ring centroids) and between the phenyl ring of the former molecule and the furan ring of a symmetry equivalent molecule (centroids distance of 3.539(4) Å).

Experimental: Crystallography

Compound **8d**: needle-shaped, transparent crystals grown, by vapor diffusion, from a 1:1 dichloromethane/heptane mixture at room temperature, $C_{30}H_{22}N_2O$, M = 426.50, monoclinic, $P2_1/n$ (No. 14), a = 10.2598(8), b = 12.2746(9), c = 35.342(2) Å, β = 97.671(4), V = 4411.0(5) Å^3, T = 100(2) K, Z = 8, D_c = 1.285 g cm^{-3}, μ(Cu-Kα) = 0.610 mm^{-1}, F(000) = 1792, crystal size 0.6 × 0.05 × 0.05 mm, 4607 independent reflections. Final R = 0.0736 for 1879 reflections with $I > 2\sigma(I)$ and $\omega R2$ = 0.1936 for all data and $GooF$ = 0.920.

Intensity data were collected on a SMART 6000 diffractometer equipped with CCD detector using Cu-Kα radiation (λ = 1.54178 Å). The images were interpreted and integrated with the program SAINT from Bruker[1] The structure was solved by direct methods and refined by full-matrix least-squares on F^2 using the SHELXTL program package.[2] Non-hydrogen atoms were anisotropically refined and the hydrogen atoms in the riding mode with isotropic temperature factors fixed at 1.2 times U(eq) of the parent atoms (1.5 times for methyl groups). **CCDC-698969** contains the supplementary crystallographic data for this paper and can be obtained free of charge via www.ccdc.cam.ac.uk/conts/retrieving.html (or from the Cambridge

Crystallographic Data Centre, 12, Union Road, Cambridge CB2 1EZ, UK; fax: +44-1223-336033; or deposit@ccdc.cam.ac.uk).

[1] SAINT, Manual Version 5/6.0, Bruker Analytical X-ray Systems Inc.: Madison, Wisconsin, 1997.

[2] SHELXTL-NT, Manual Version 5.1, Bruker Analytical X-ray Systems Inc.: Madison, Wisconsin, 1997.

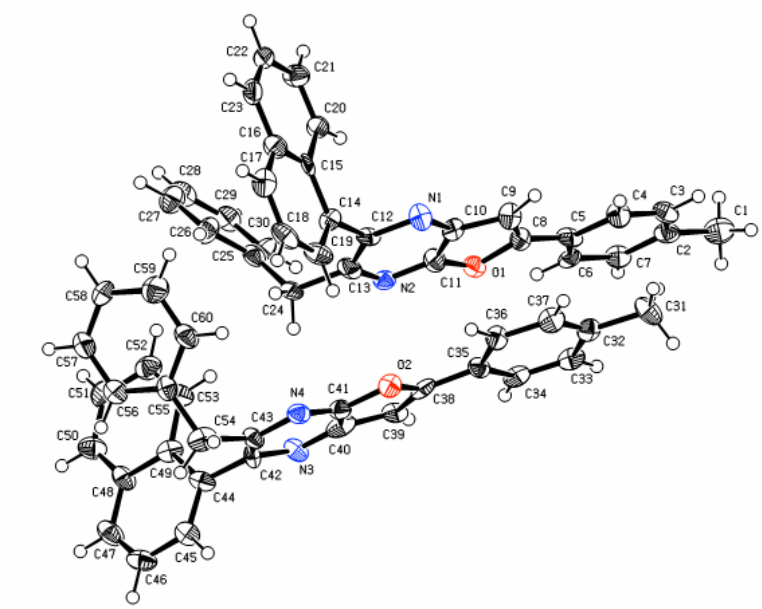
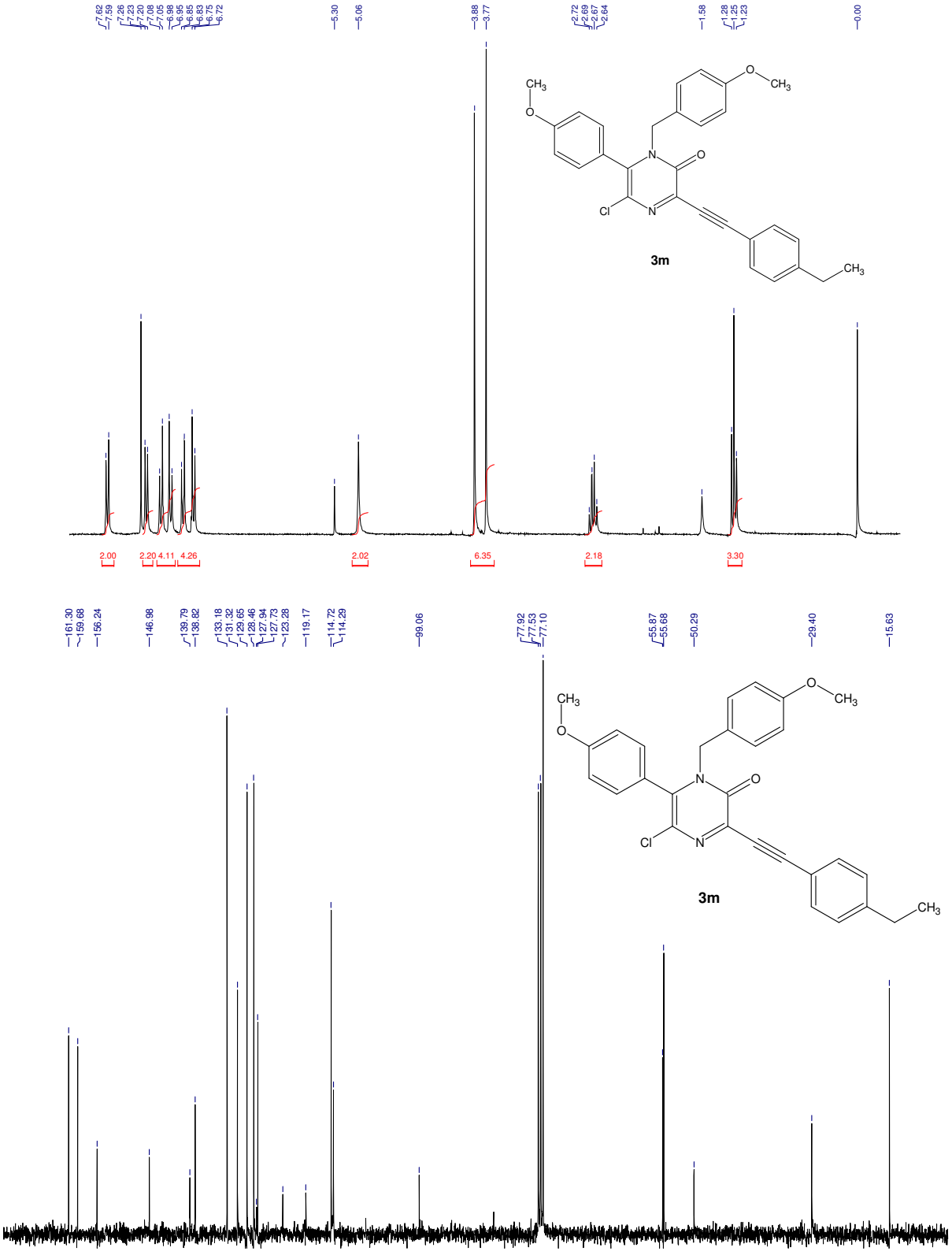
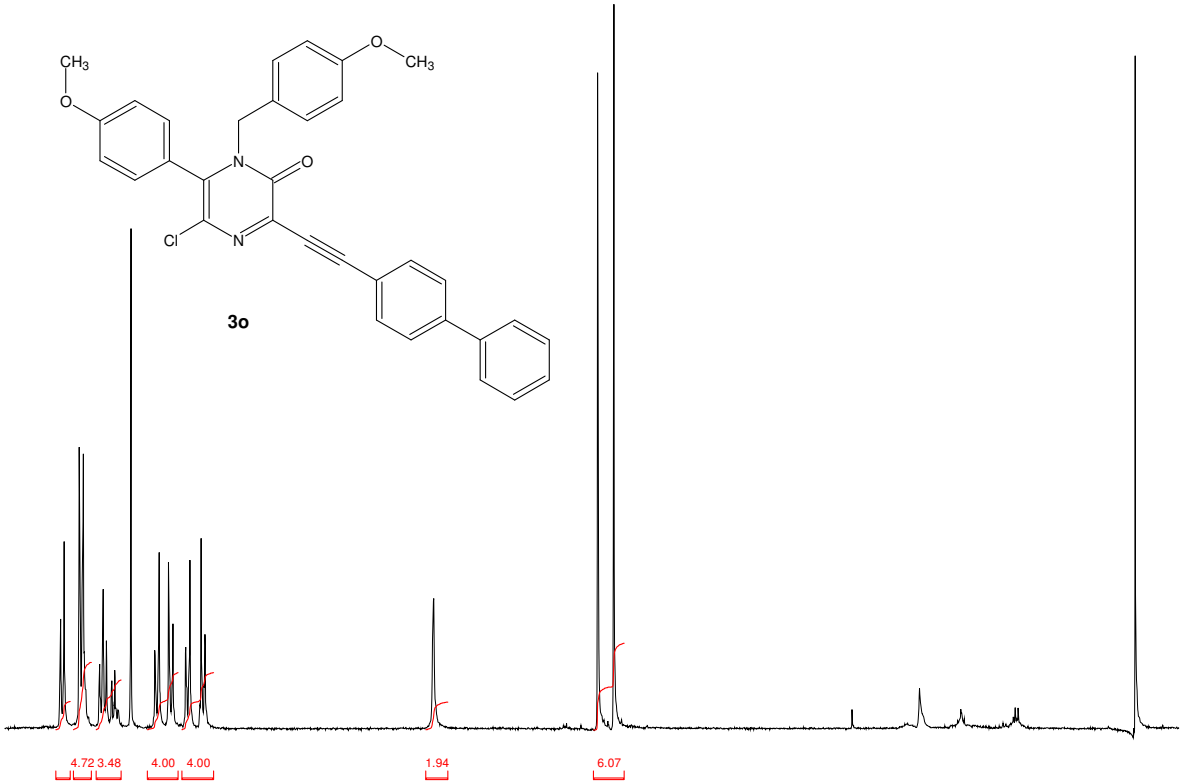


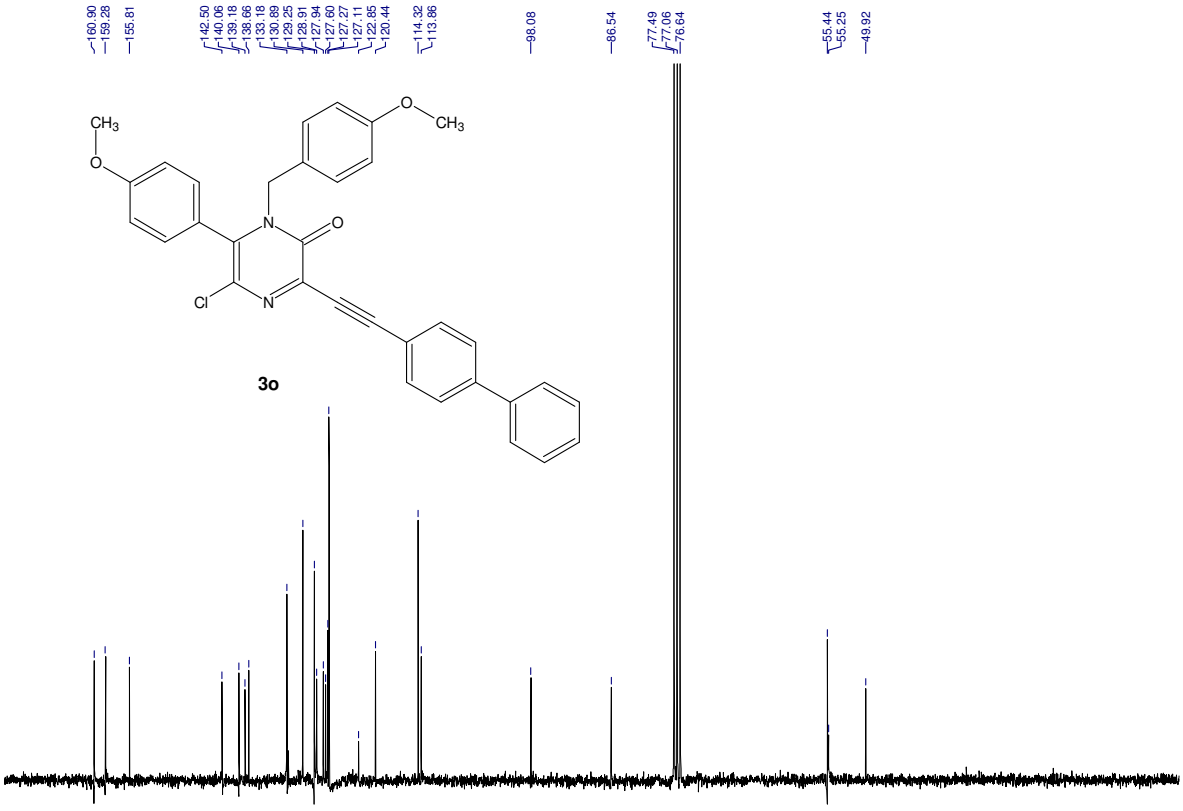
Figure. X-Ray crystal structure of **8d**. Thermal ellipsoids at the 50% probability level.

^{1}H and ^{13}C Spectra of compound 3b (300 MHz, $CDCl_3$).

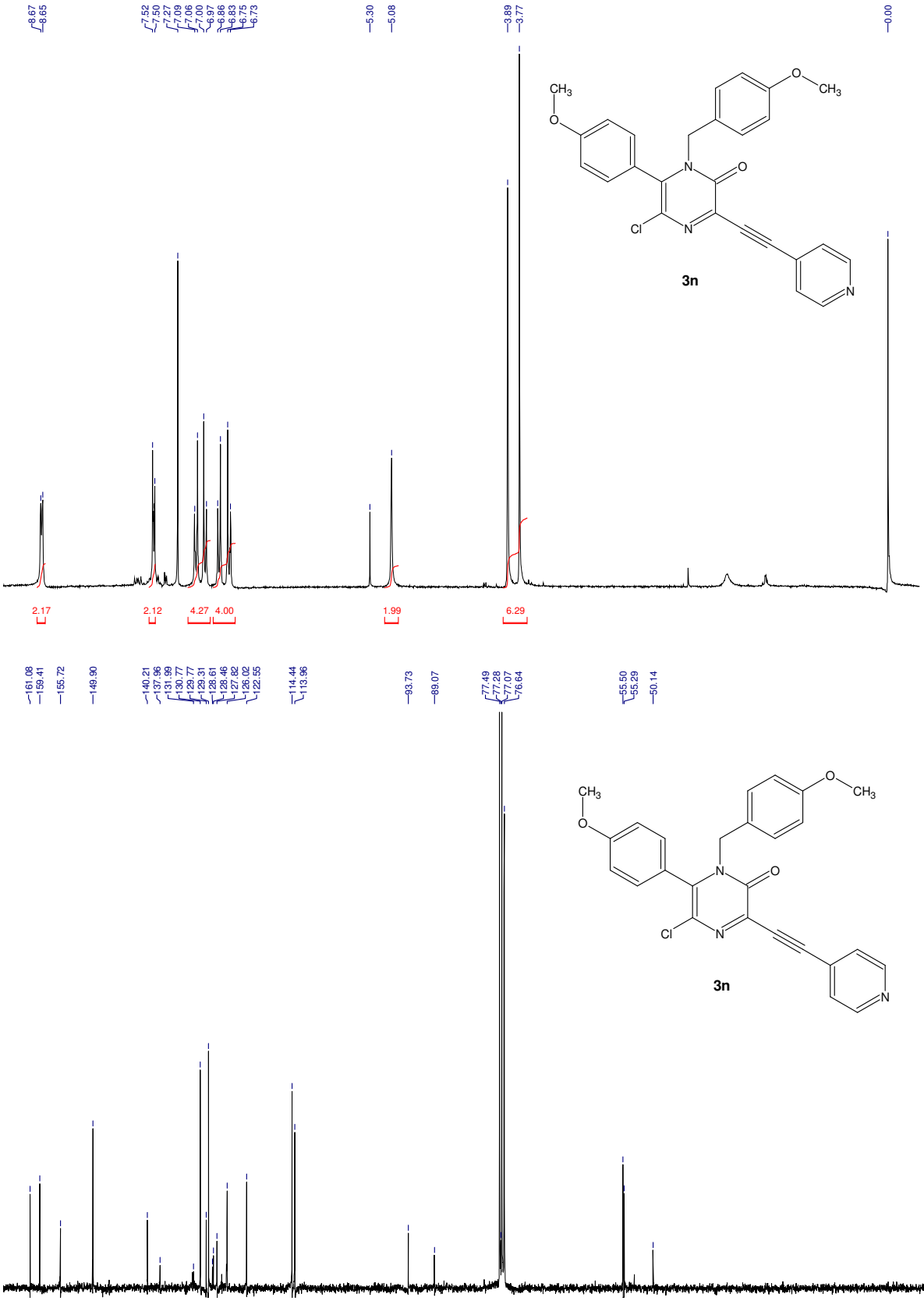


^{1}H and ^{13}C Spectra of compound 3c (300 MHz, $CDCl_3$).

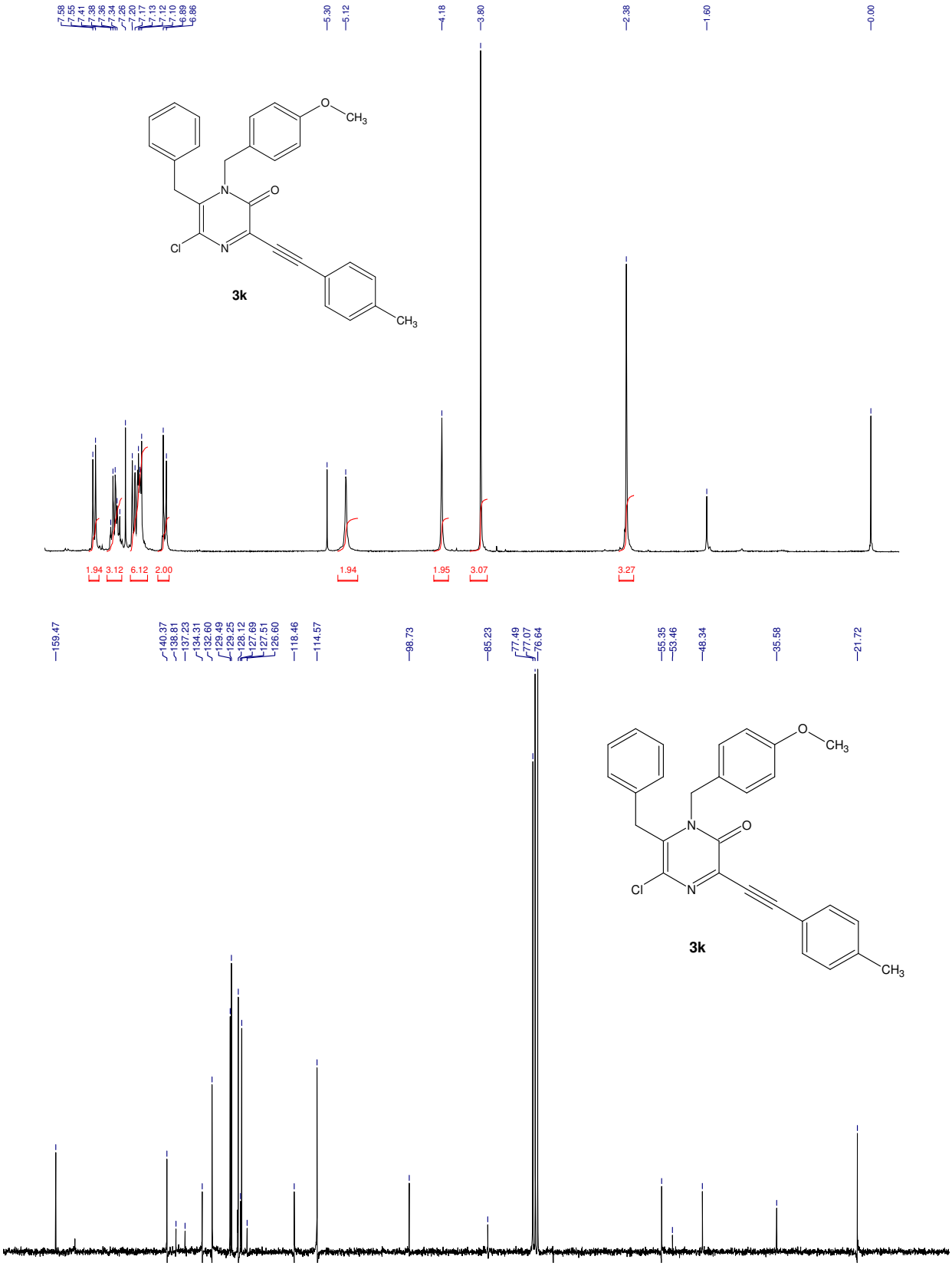




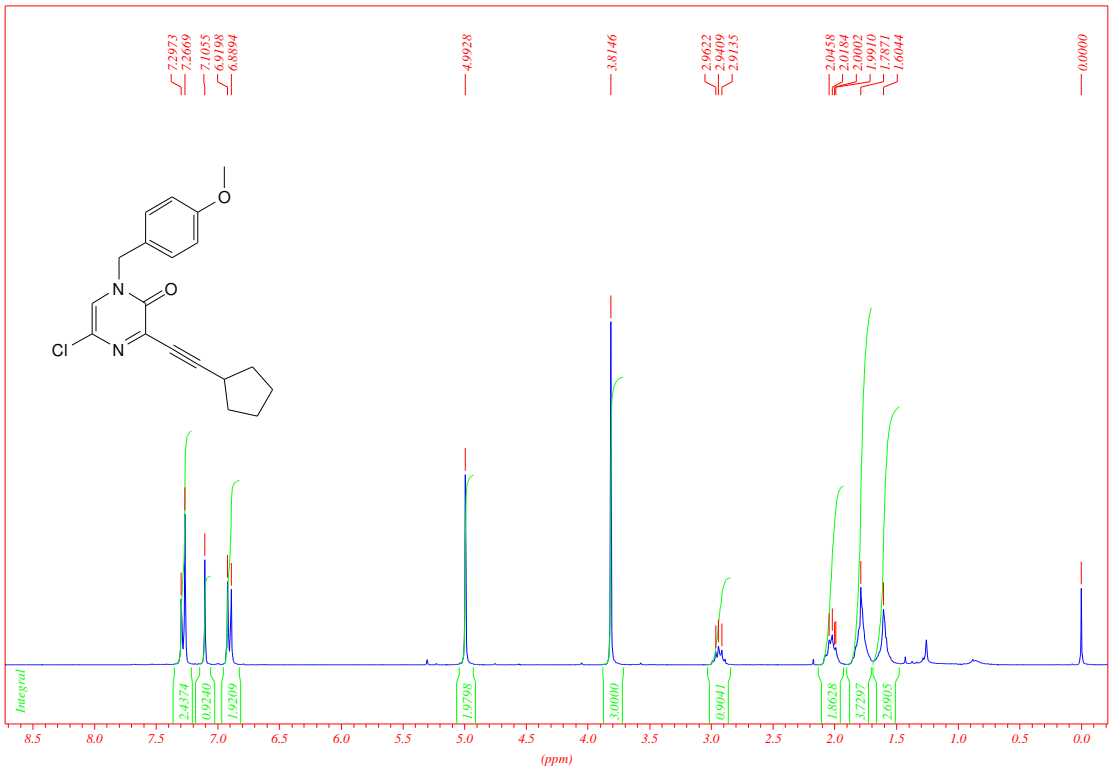
^{1}H and ^{13}C Spectra of compound 3d (300 MHz, $CDCl_3$).

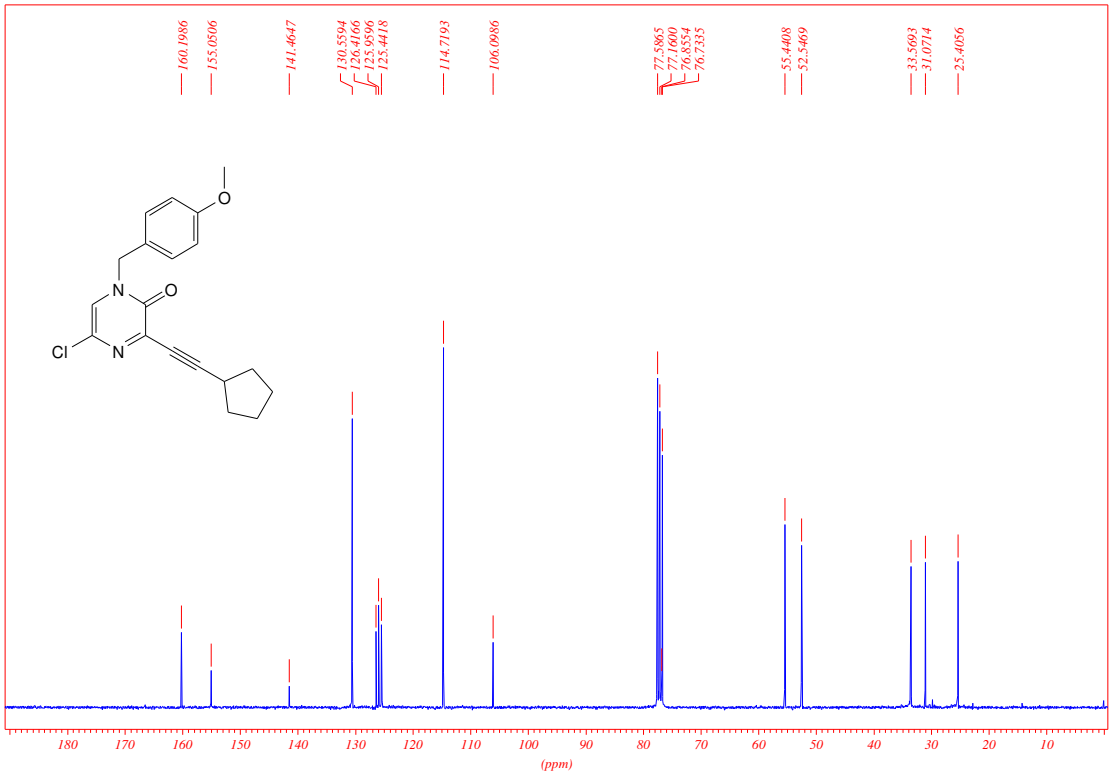


^{1}H and ^{13}C Spectra of compound 3e (300 MHz, $CDCl_3$).

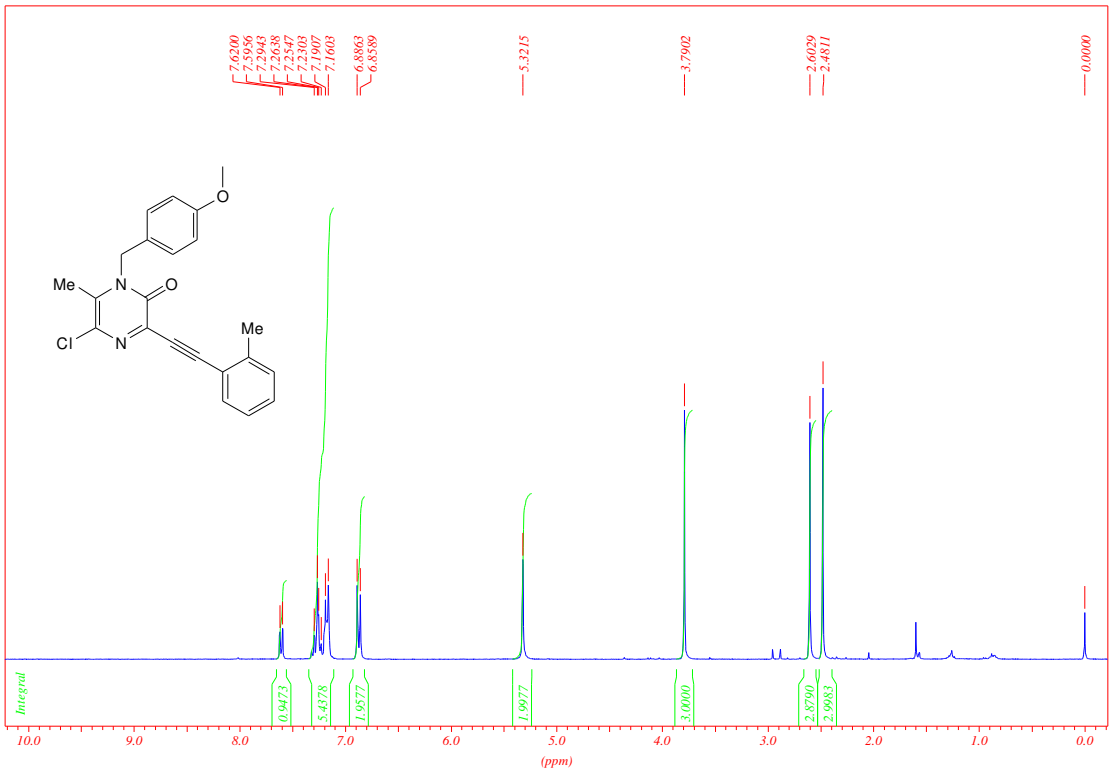


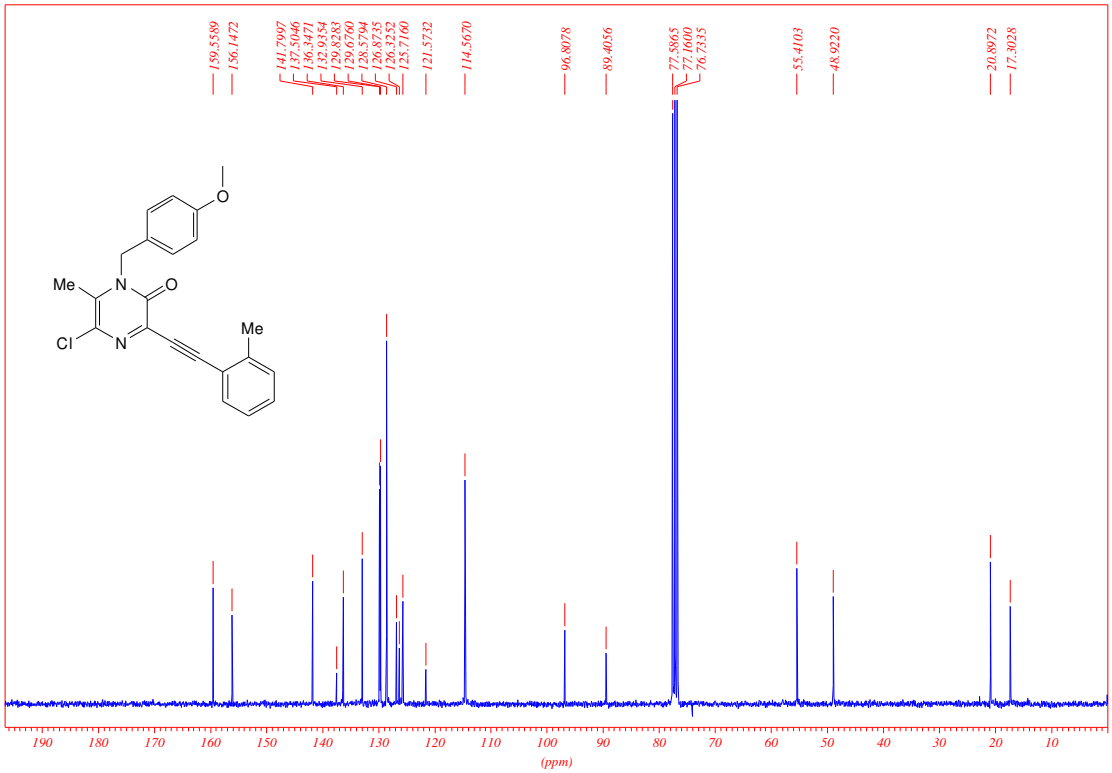
^{1}H and ^{13}C Spectra of compound 3f (300 MHz, $CDCl_3$).



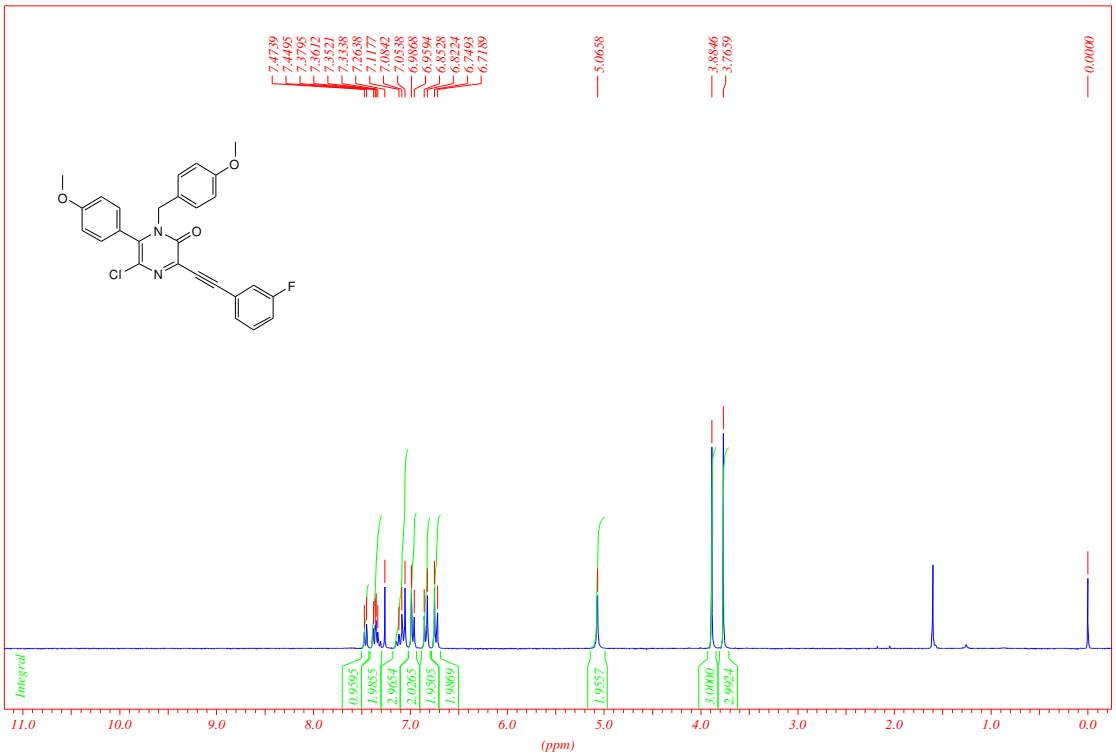


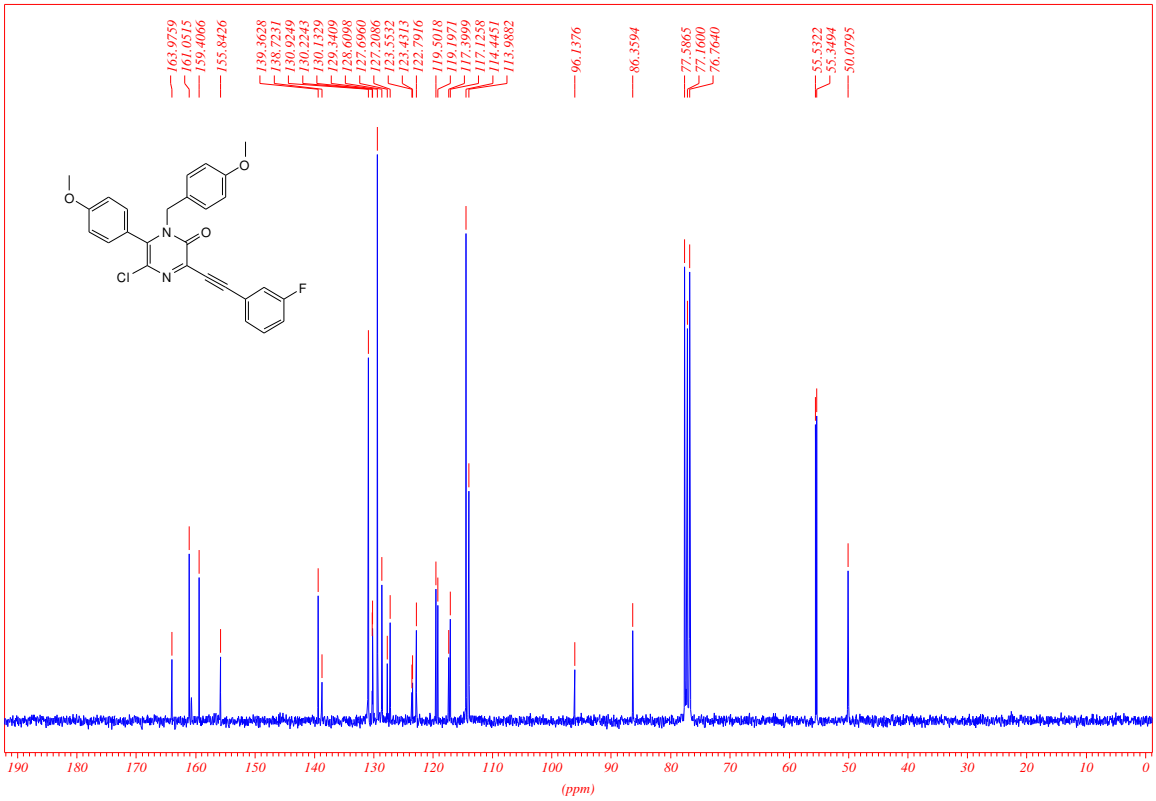
^{1}H and ^{13}C Spectra of compound 3g (300 MHz, $CDCl_3$).



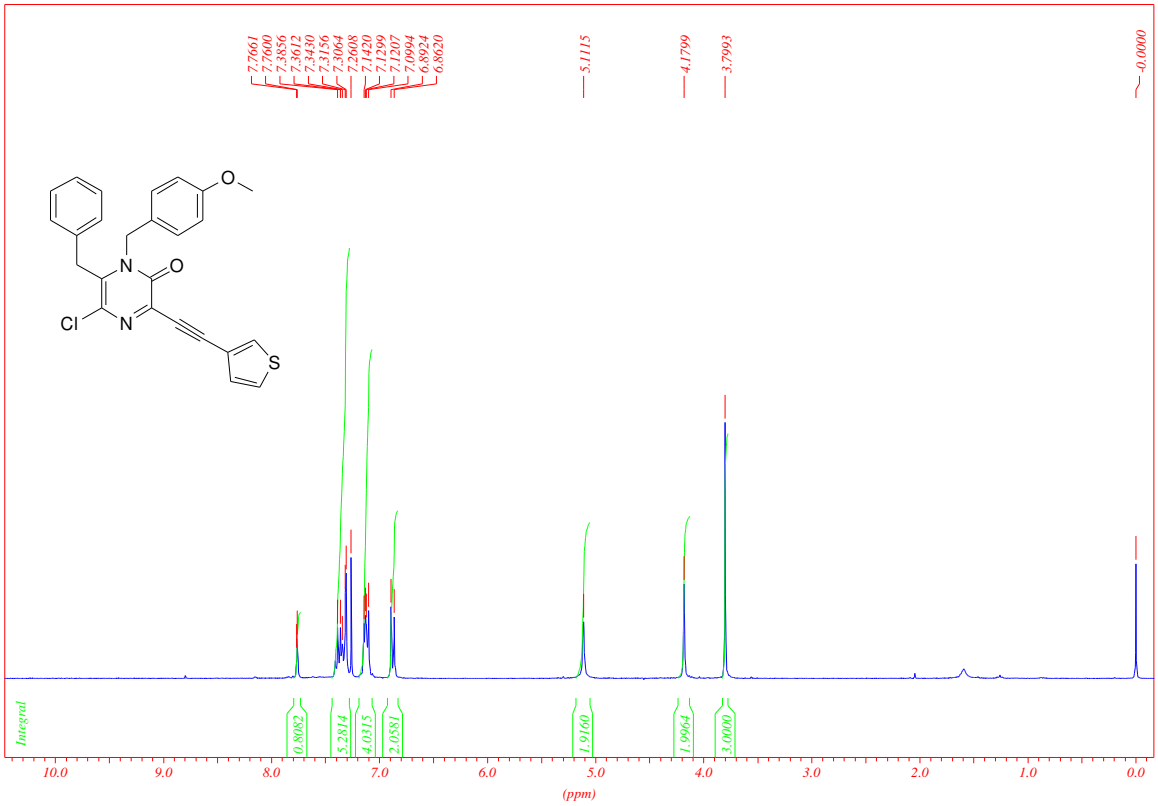


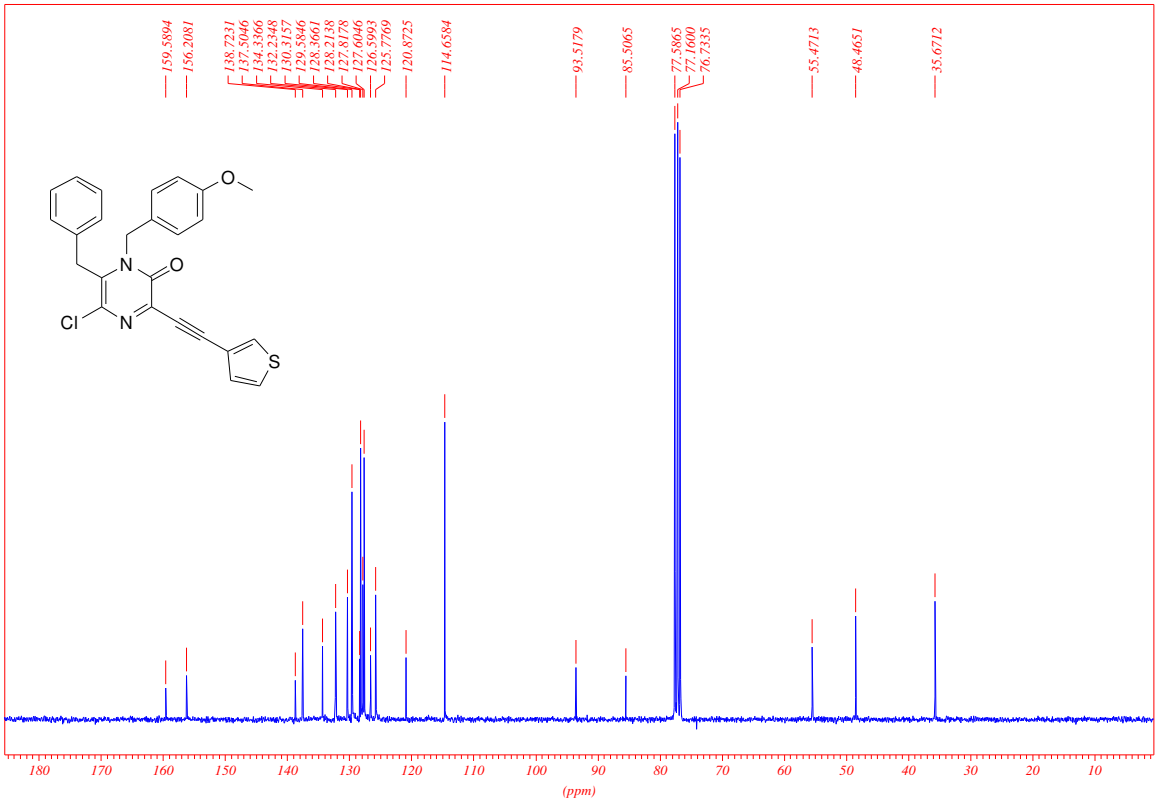
^{1}H and ^{13}C Spectra of compound 3h (300 MHz, $CDCl_3$).



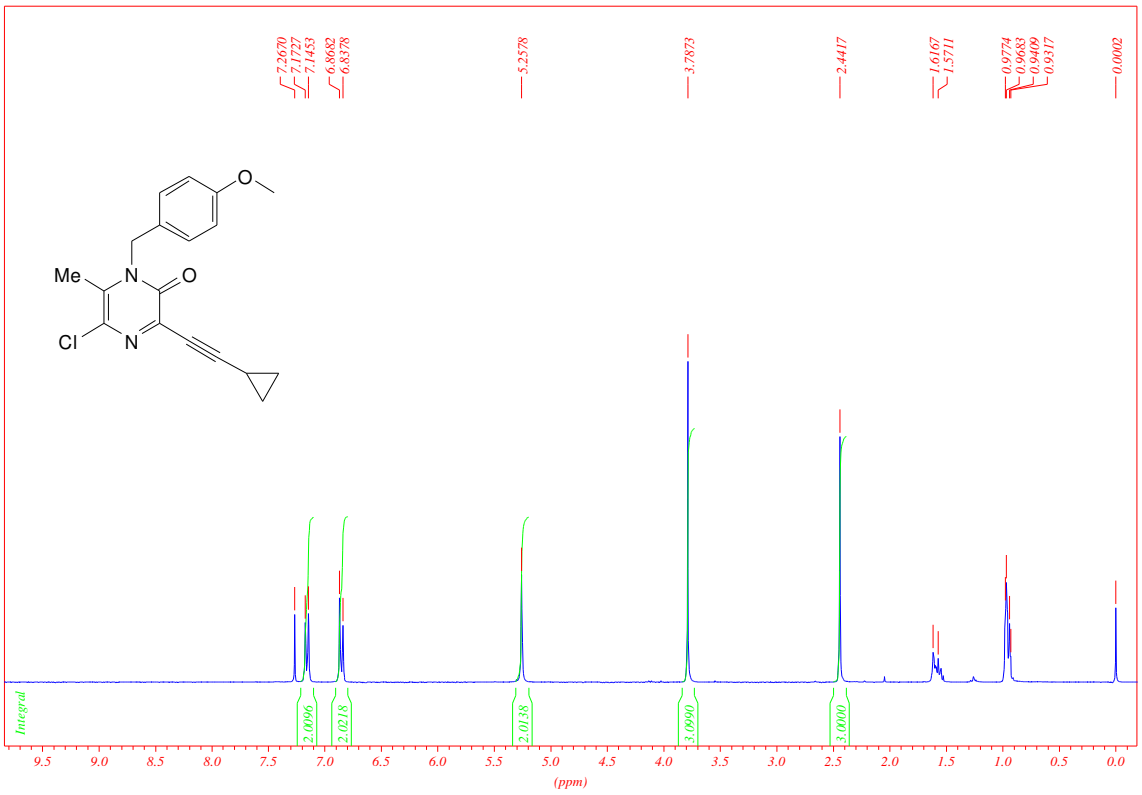


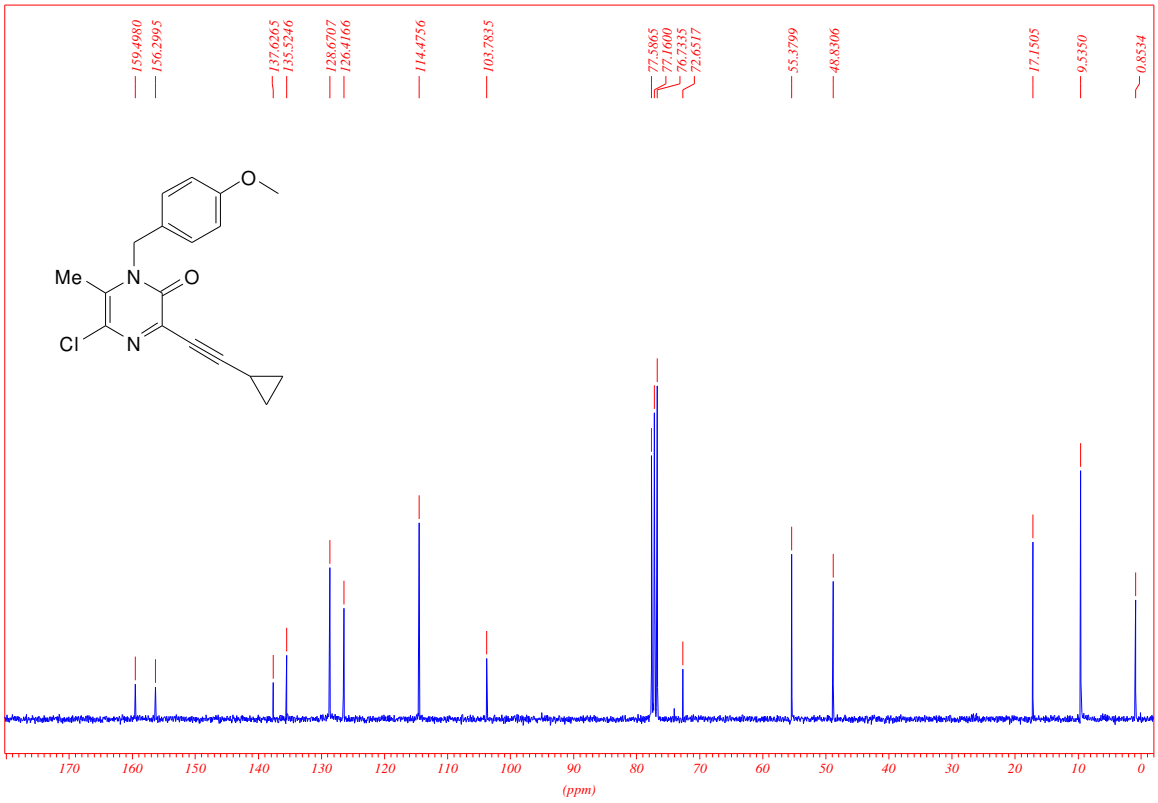
^{1}H and ^{13}C Spectra of compound 3i (300 MHz, $CDCl_3$).



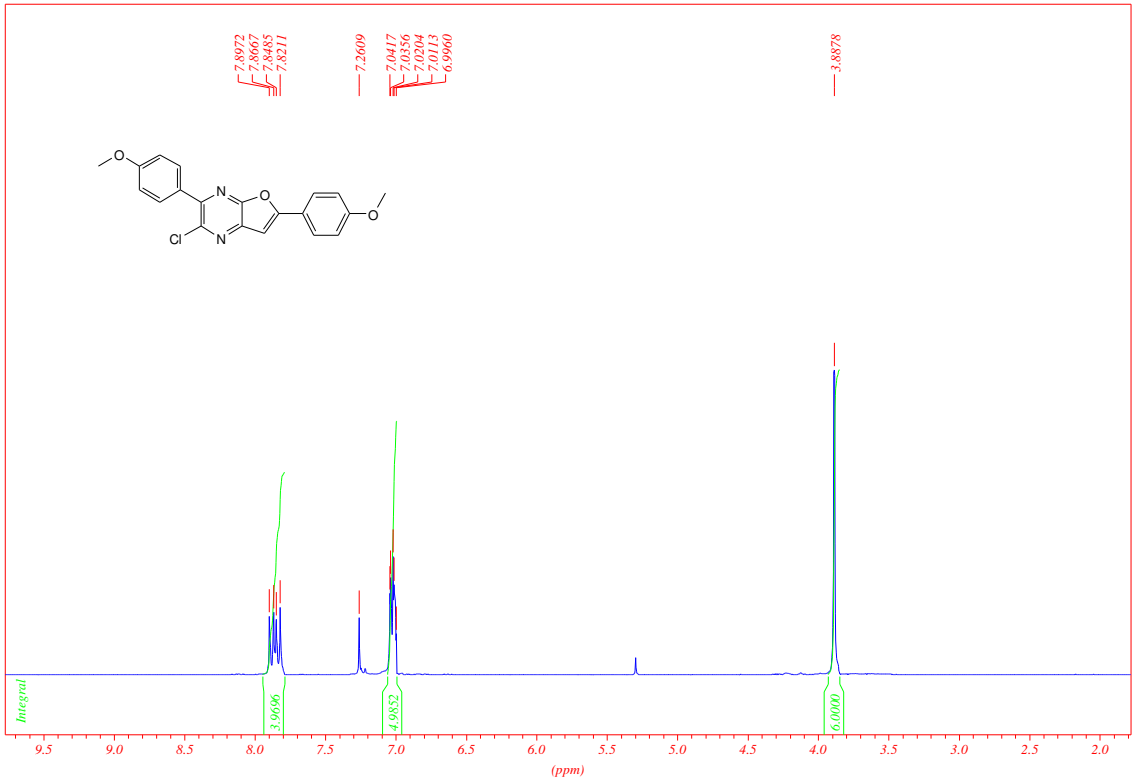


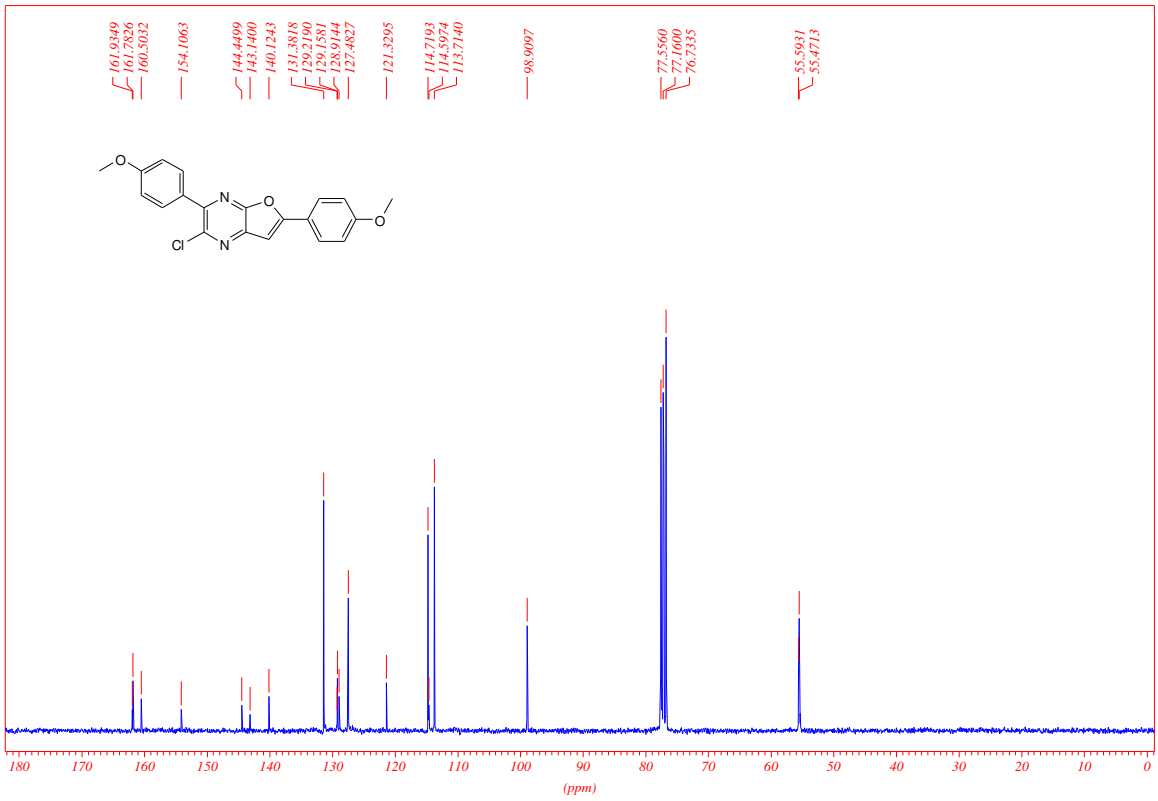
^{1}H and ^{13}C Spectra of compound 3k (300 MHz, $CDCl_3$).



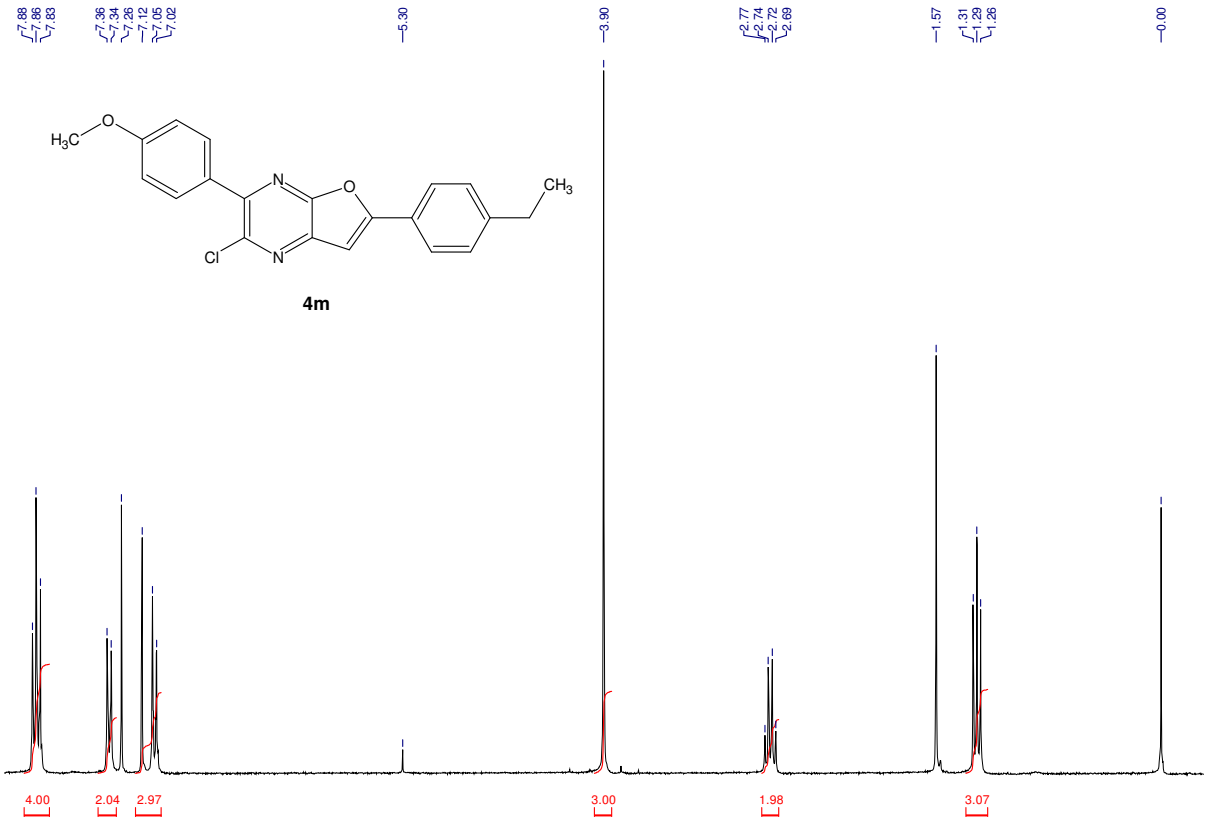


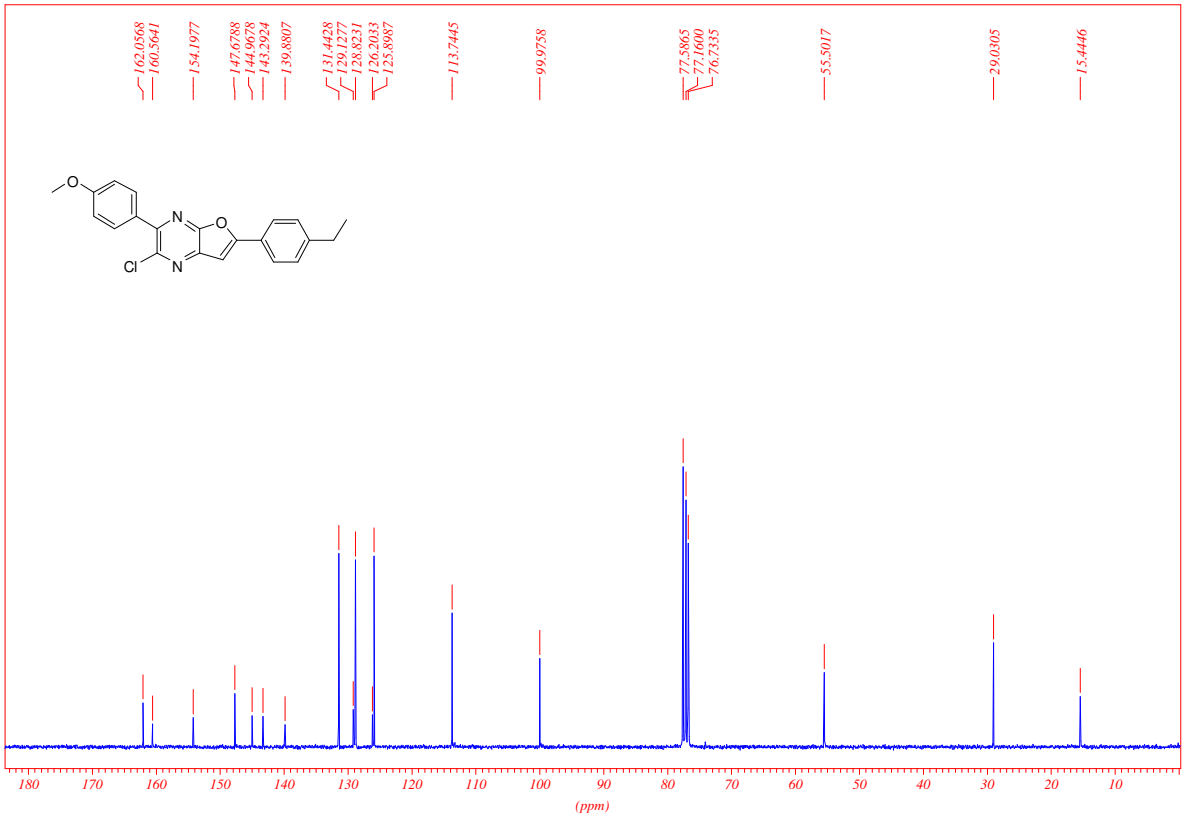
^{1}H and ^{13}C Spectra of compound 4a (300 MHz, $CDCl_3$).



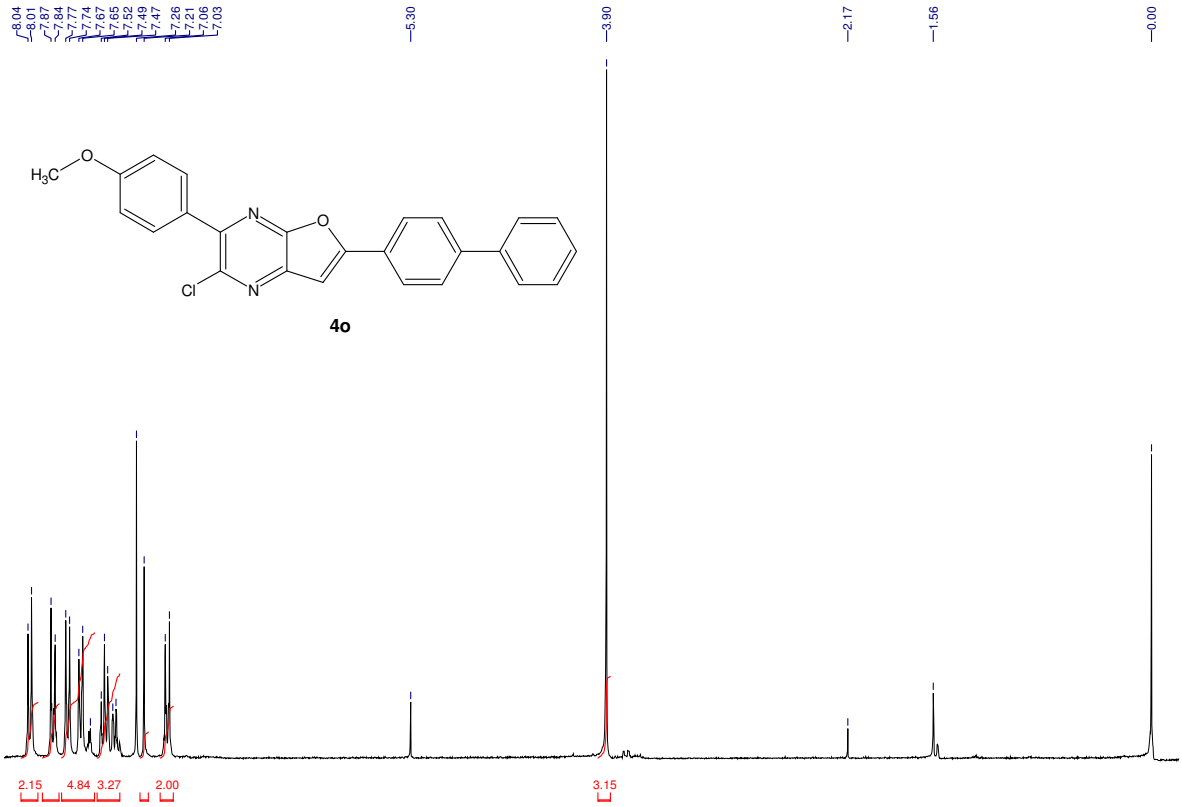


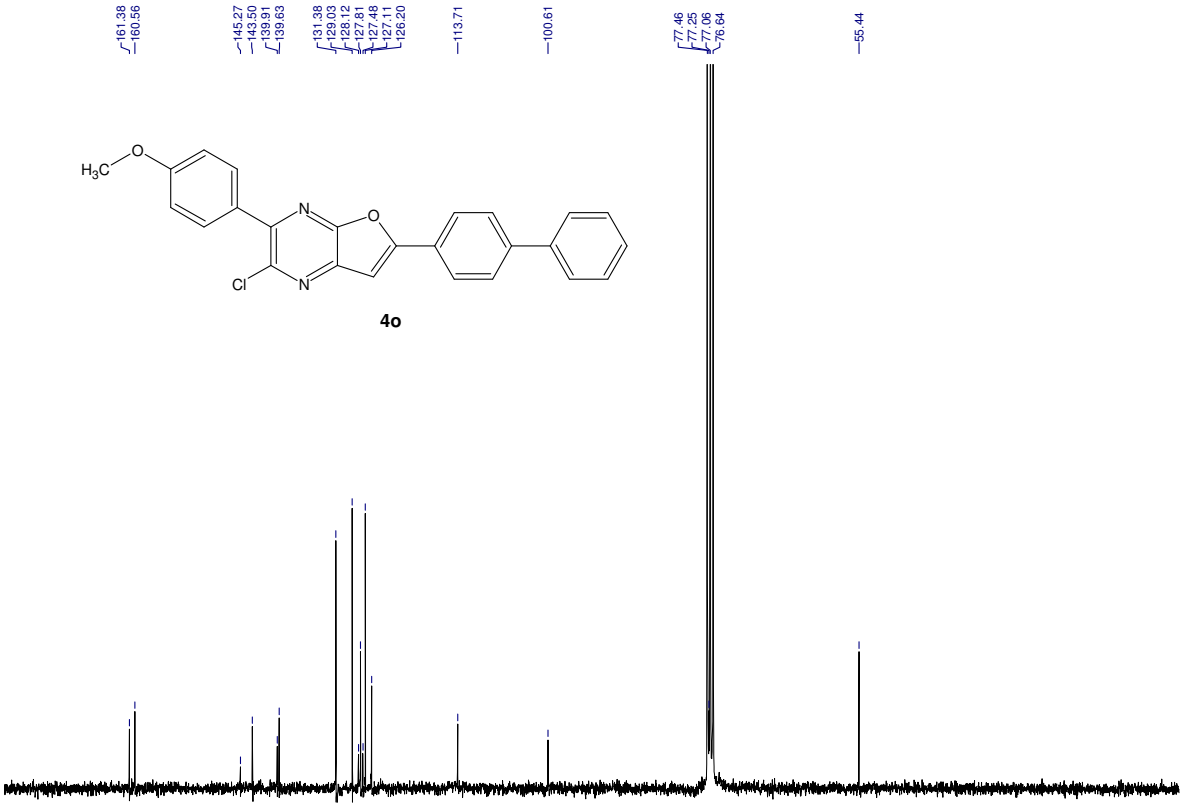
^{1}H and ^{13}C Spectra of compound 4b (300 MHz, $CDCl_3$).



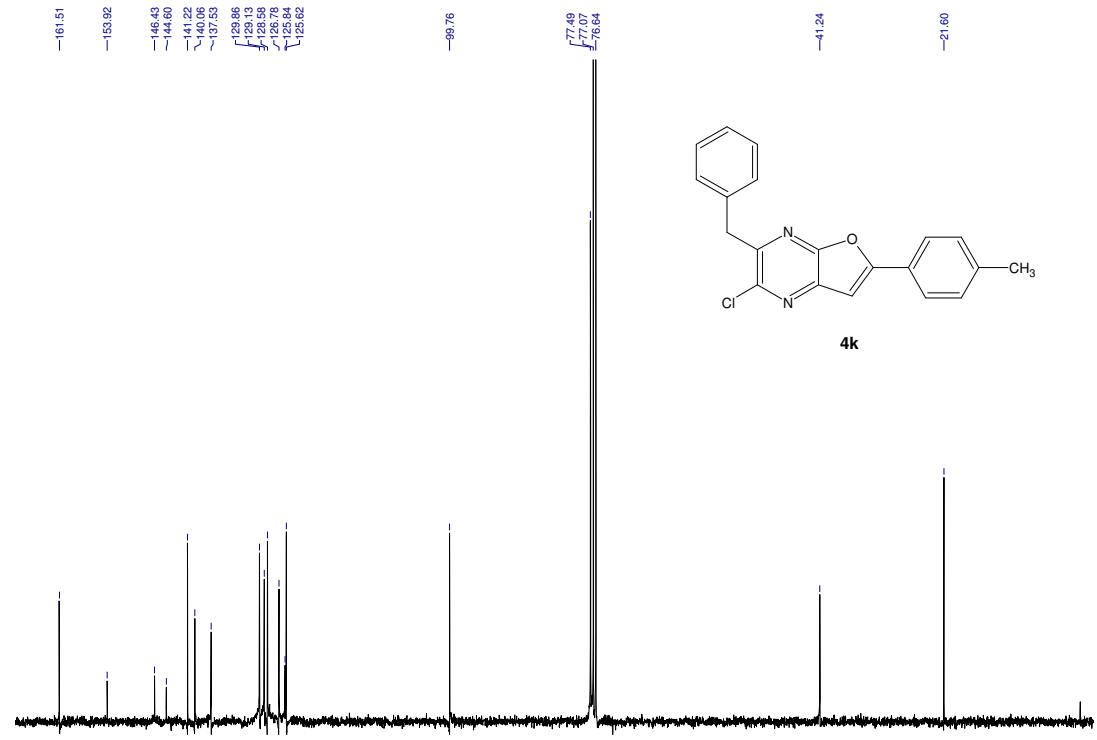


^{1}H and ^{13}C Spectra of compound 4c (300 MHz, $CDCl_3$).

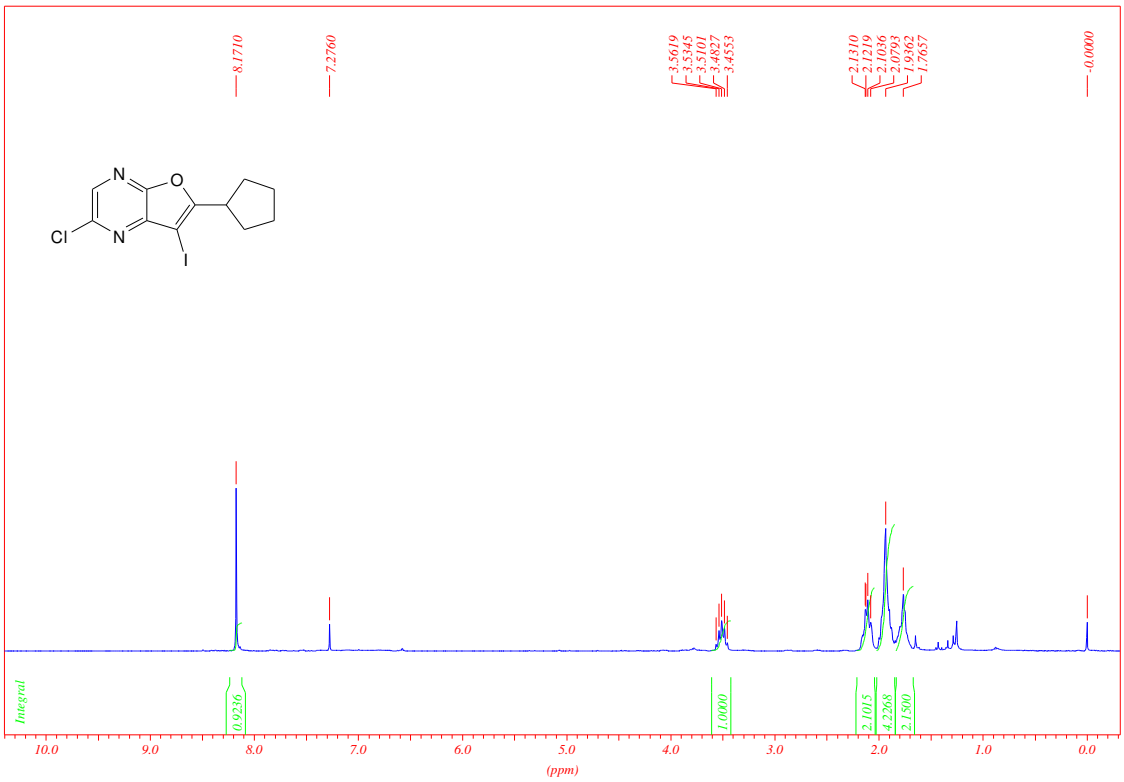


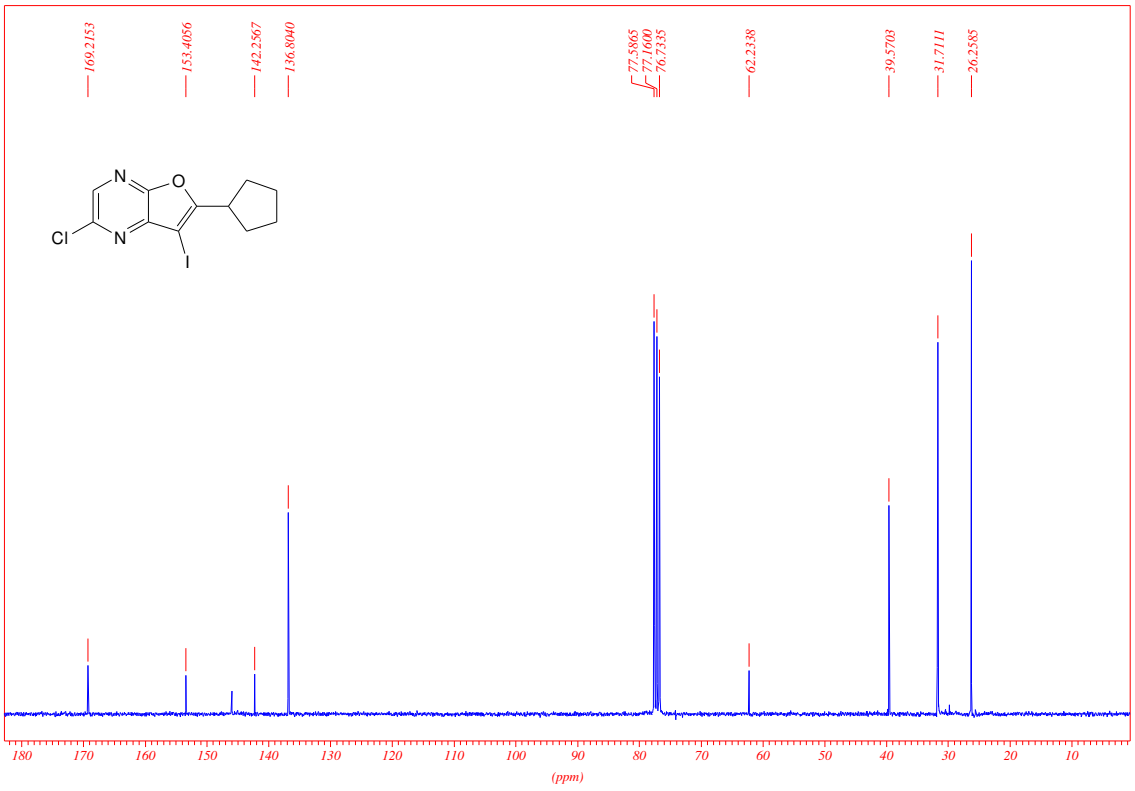


^{1}H and ^{13}C Spectra of compound 4e (300 MHz, $CDCl_3$).

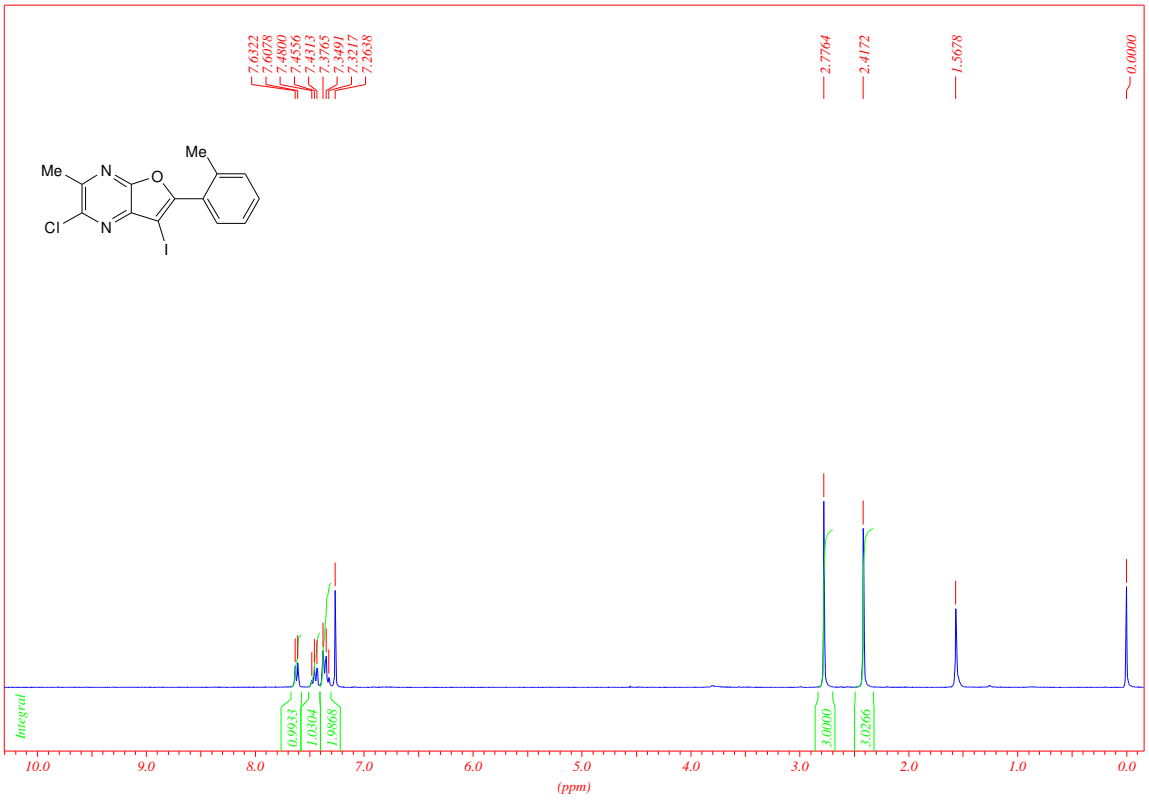


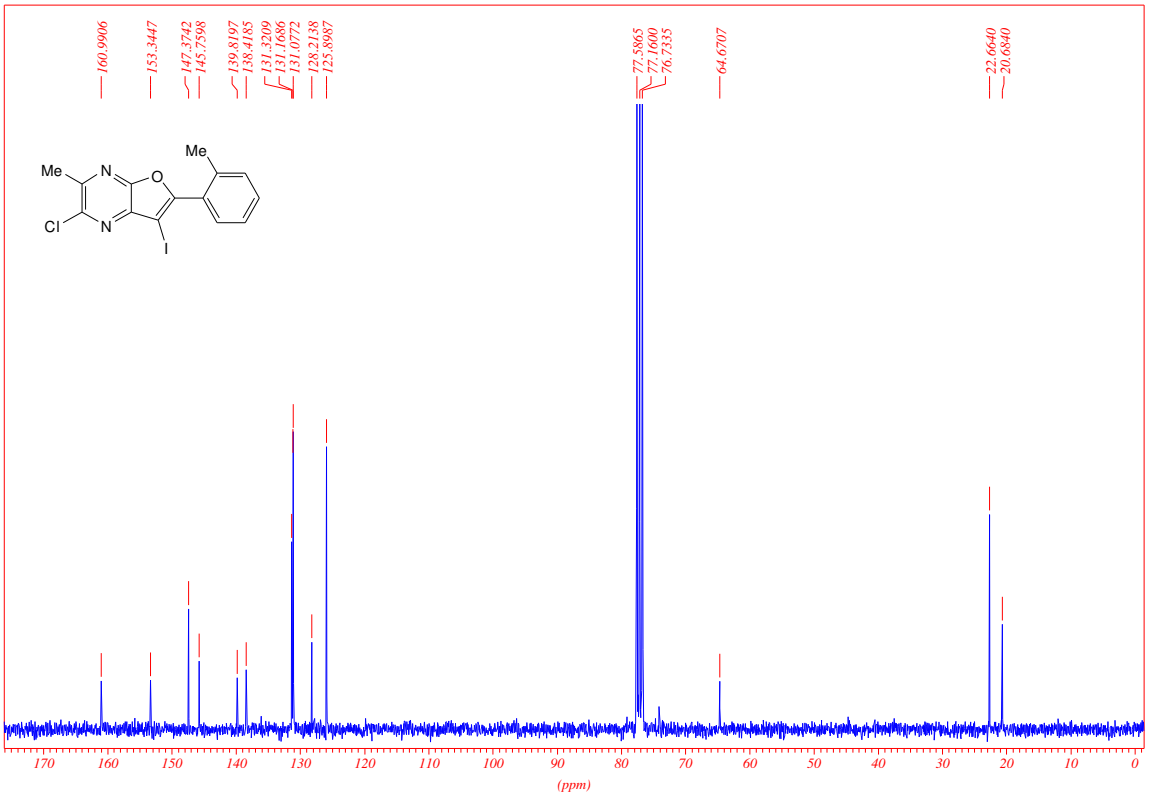
^{1}H and ^{13}C Spectra of compound 5a (300 MHz, $CDCl_3$).



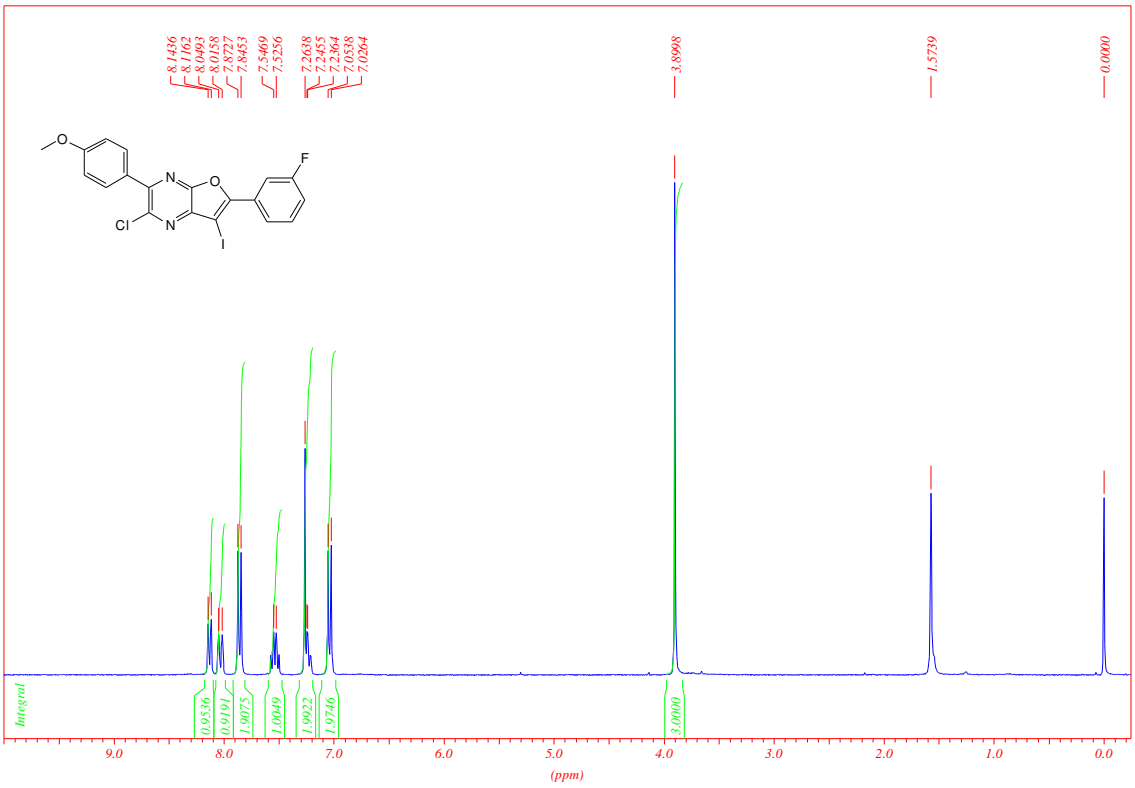


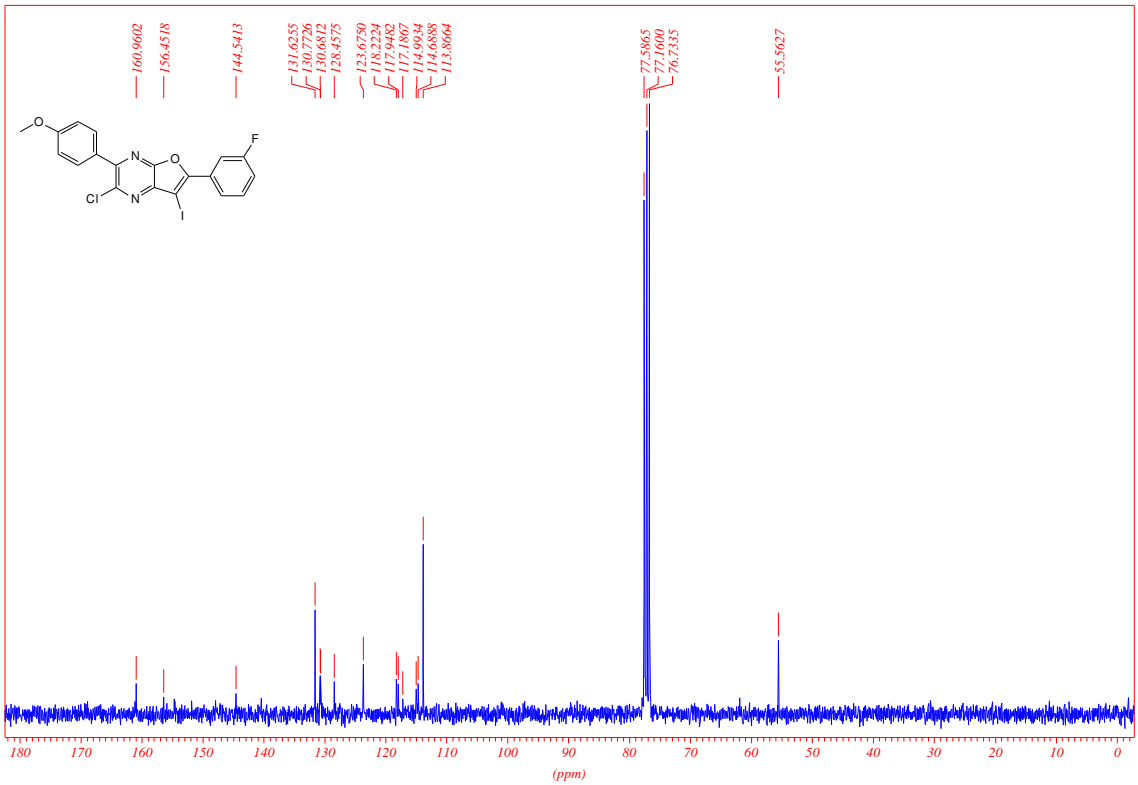
^{1}H and ^{13}C Spectra of compound 5b (300 MHz, $CDCl_3$).



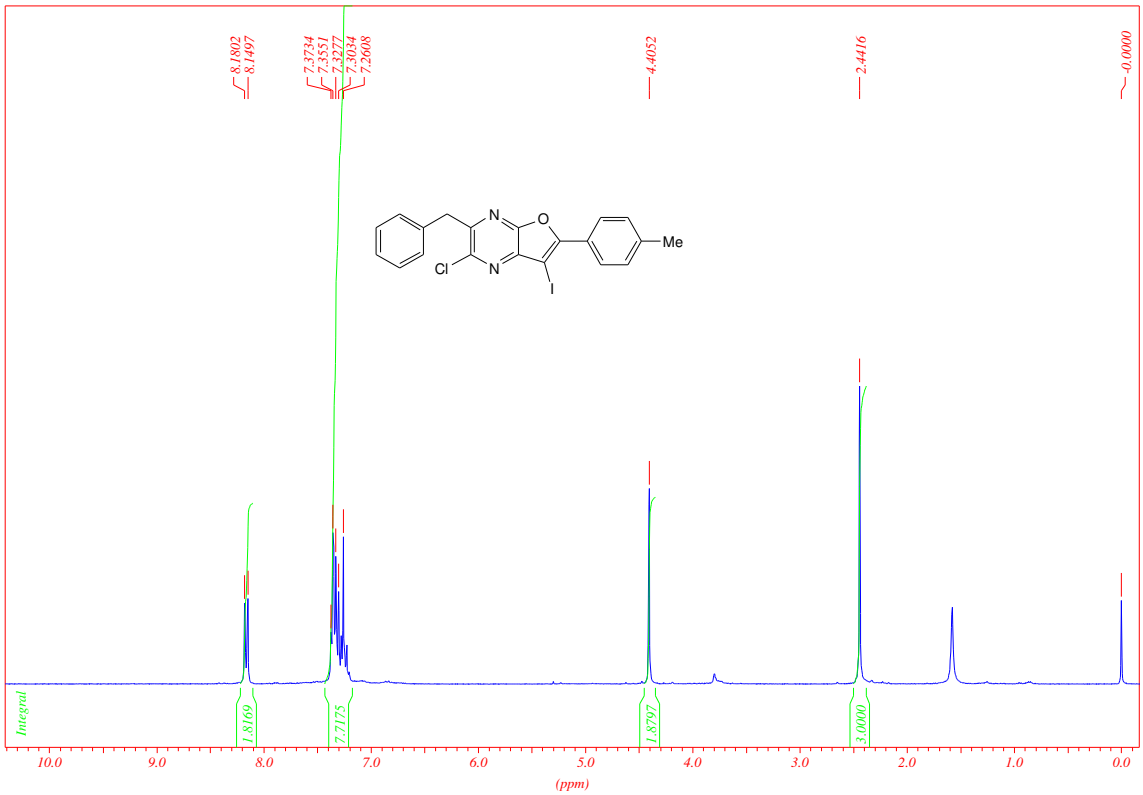


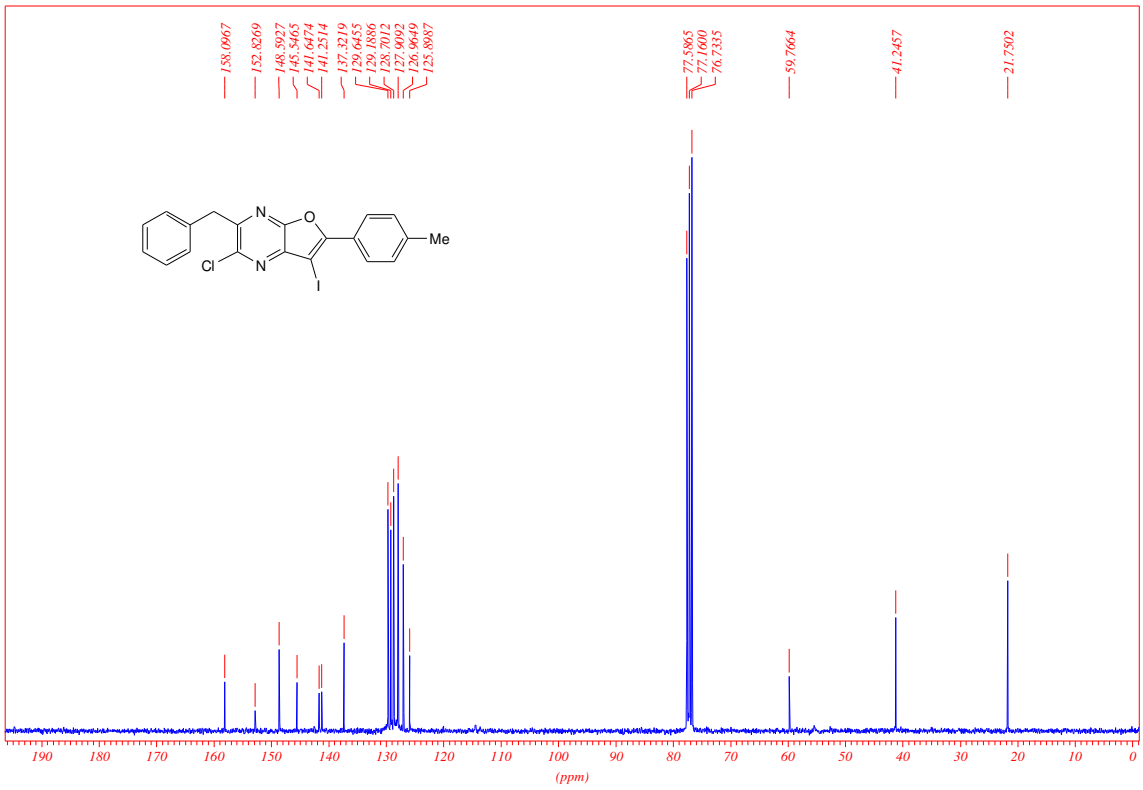
^{1}H and ^{13}C Spectra of compound 5c (300 MHz, $CDCl_3$).



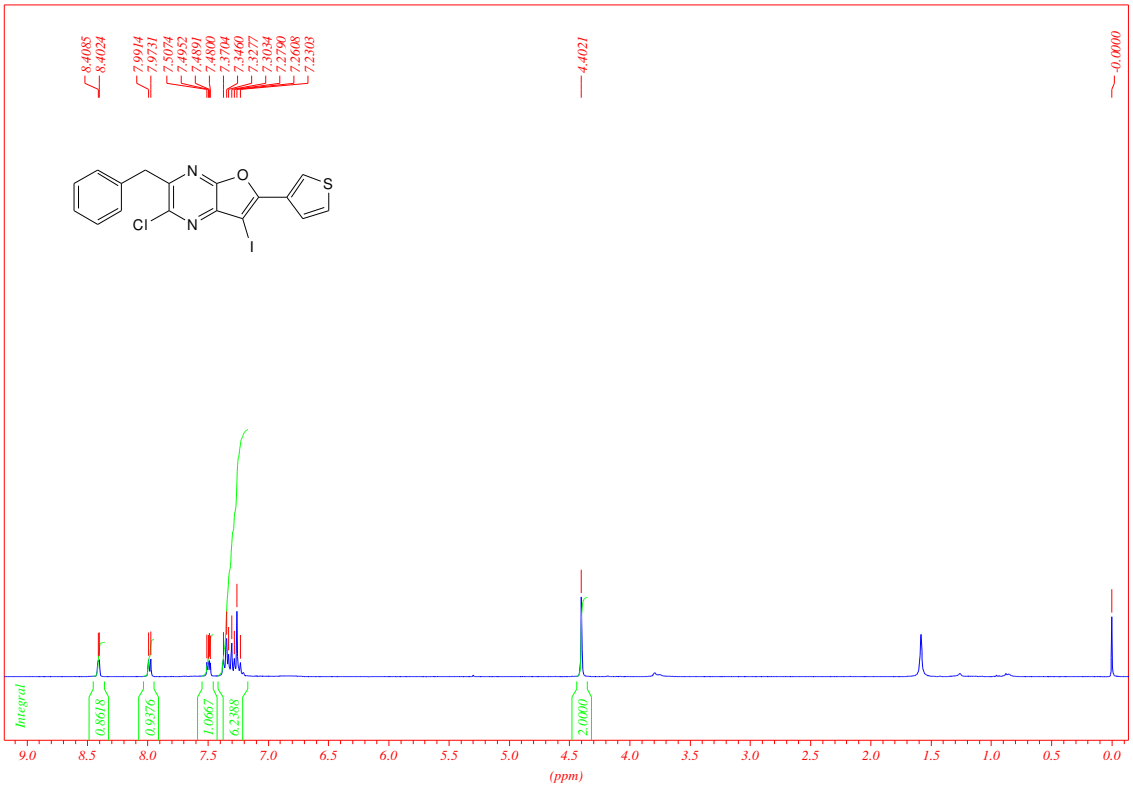


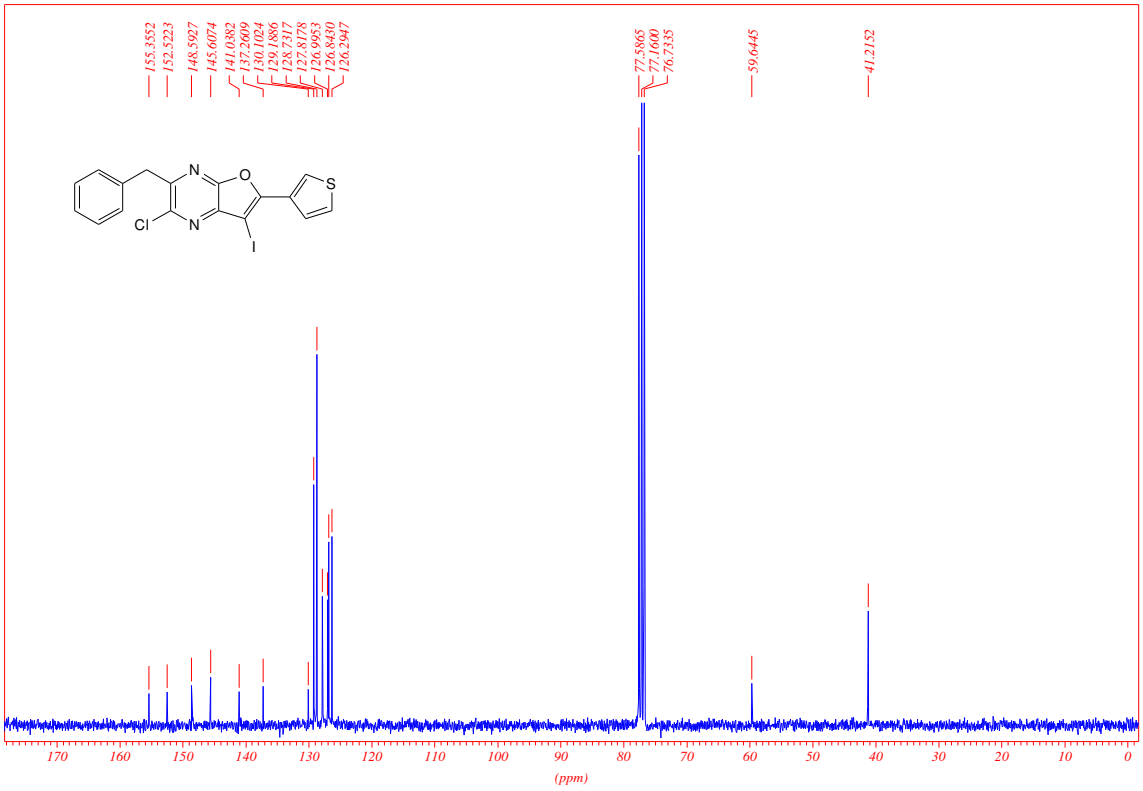
^{1}H and ^{13}C Spectra of compound 5d (300 MHz, $CDCl_3$).



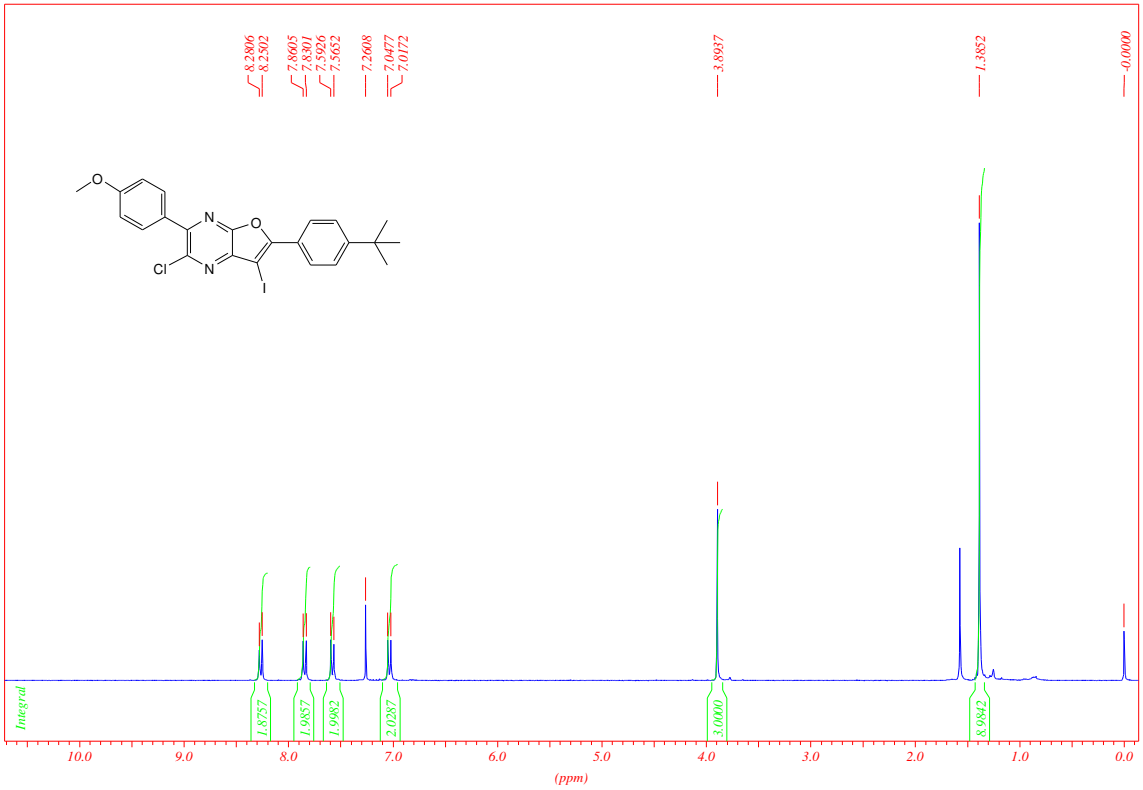


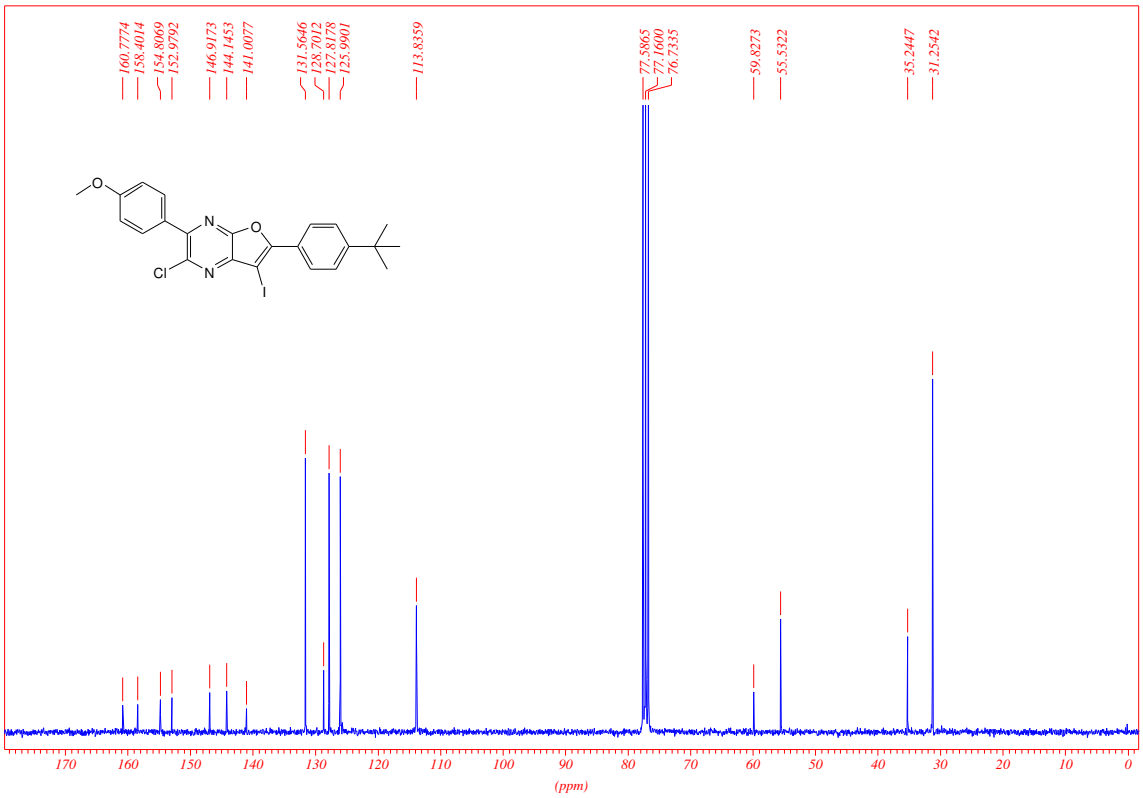
^{1}H and ^{13}C Spectra of compound 5e (300 MHz, $CDCl_3$).



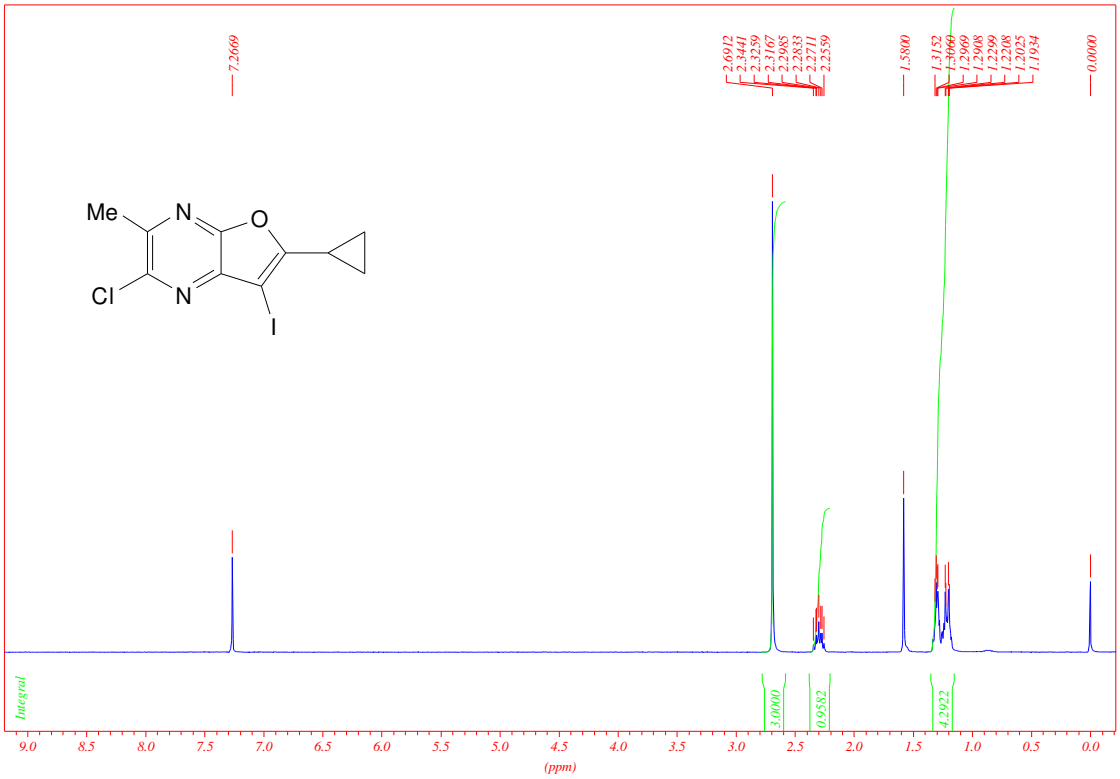


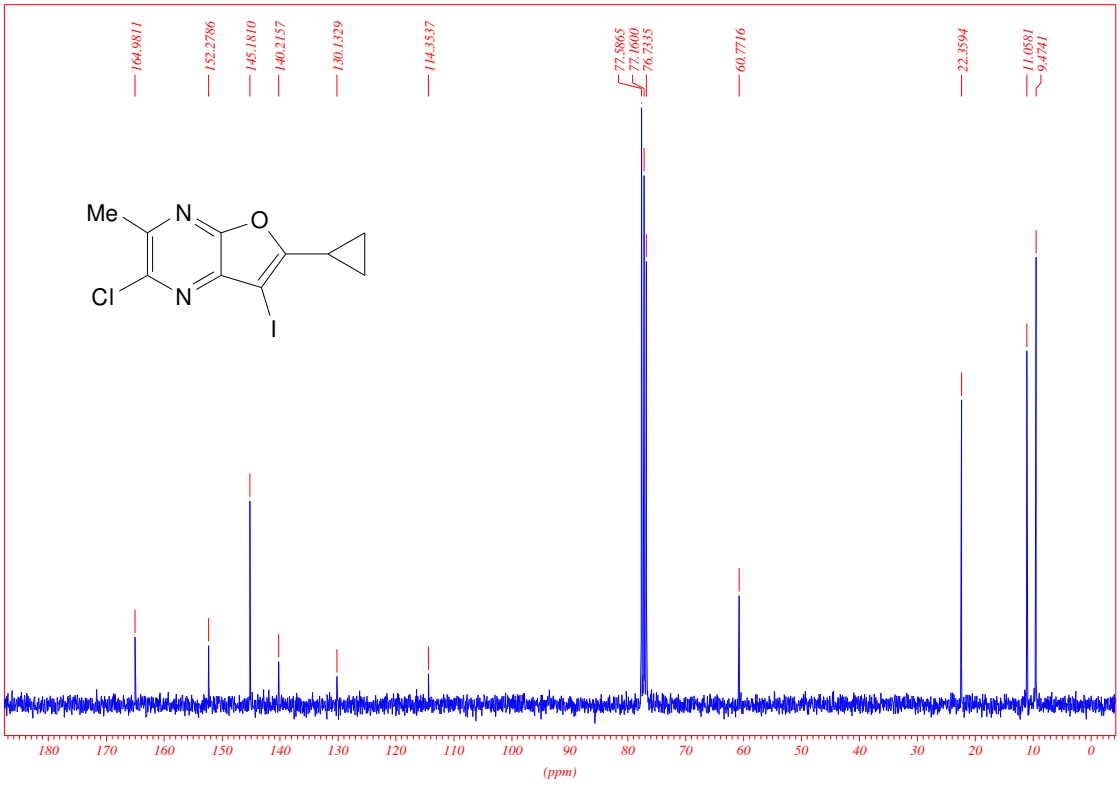
^{1}H and ^{13}C Spectra of compound 5f (300 MHz, $CDCl_3$).



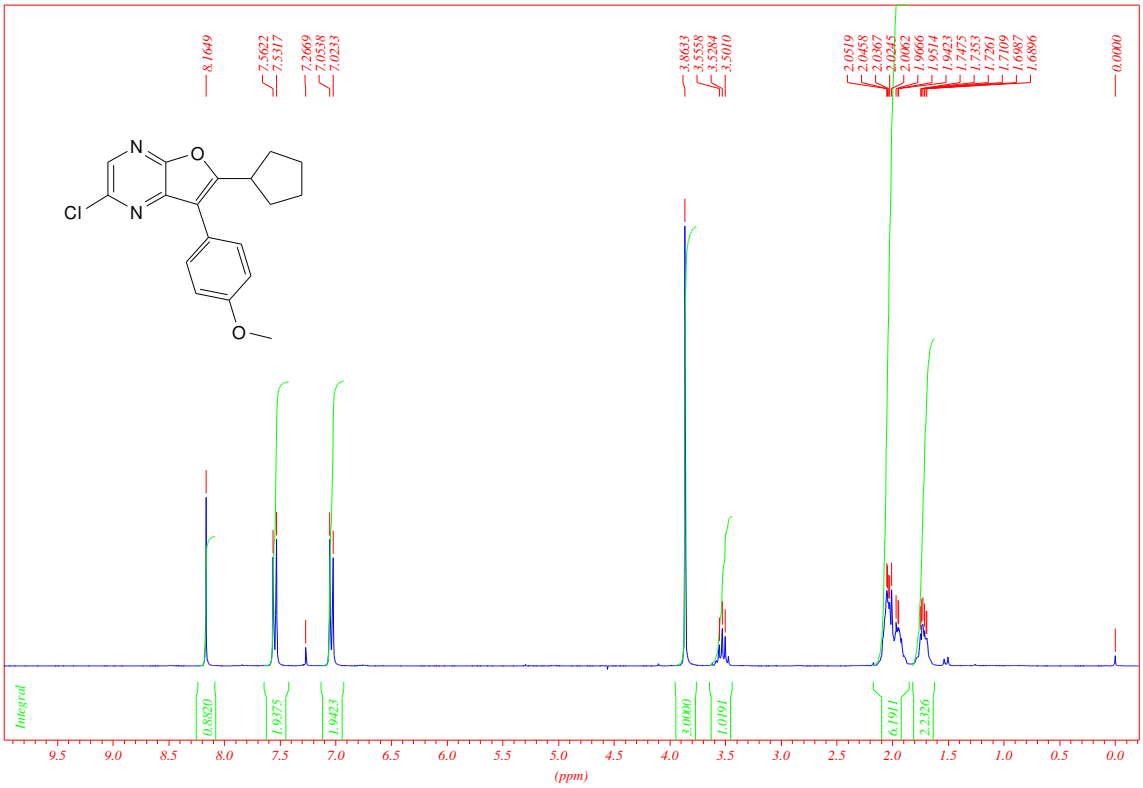


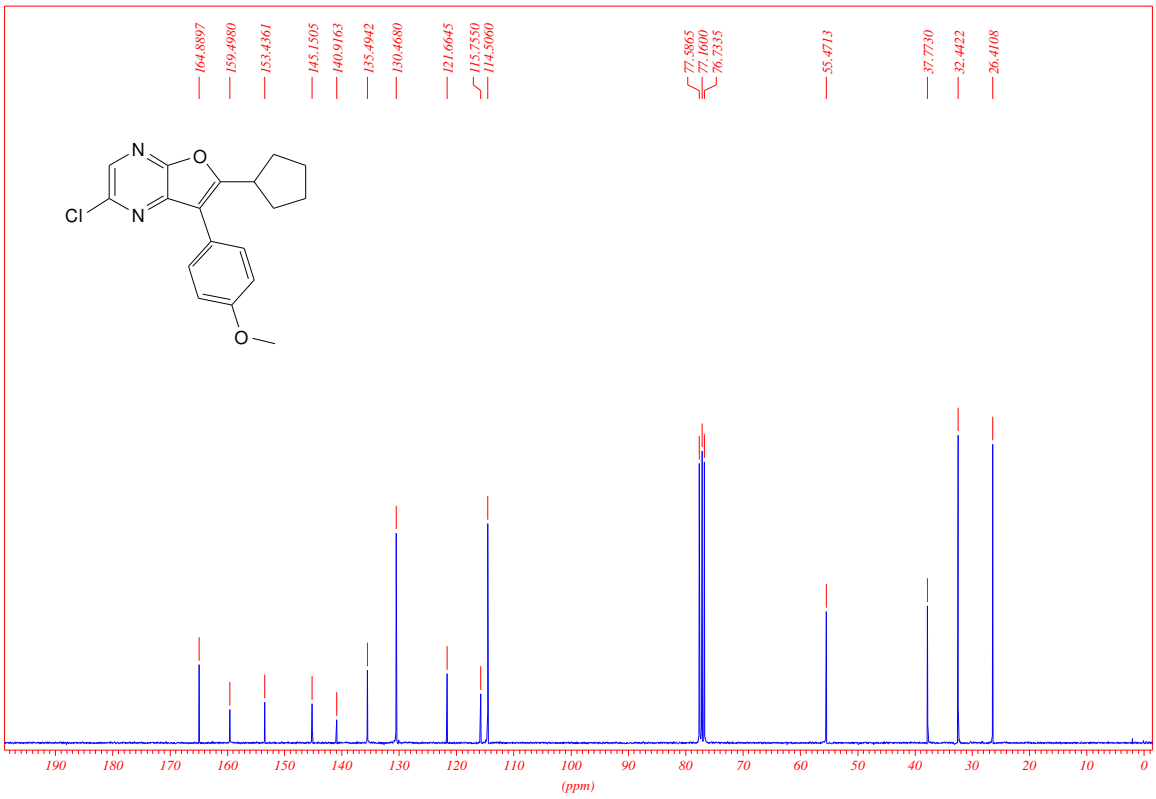
^{1}H and ^{13}C Spectra of compound 5g (300 MHz, $CDCl_3$).



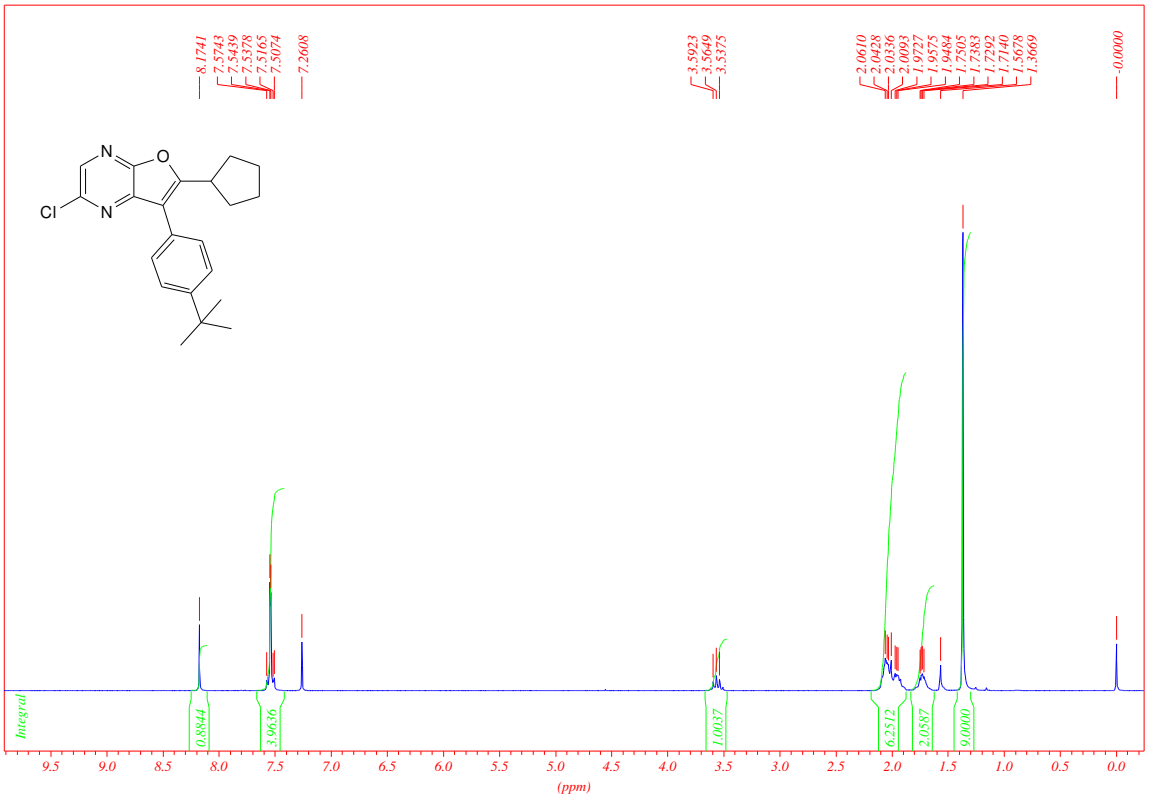


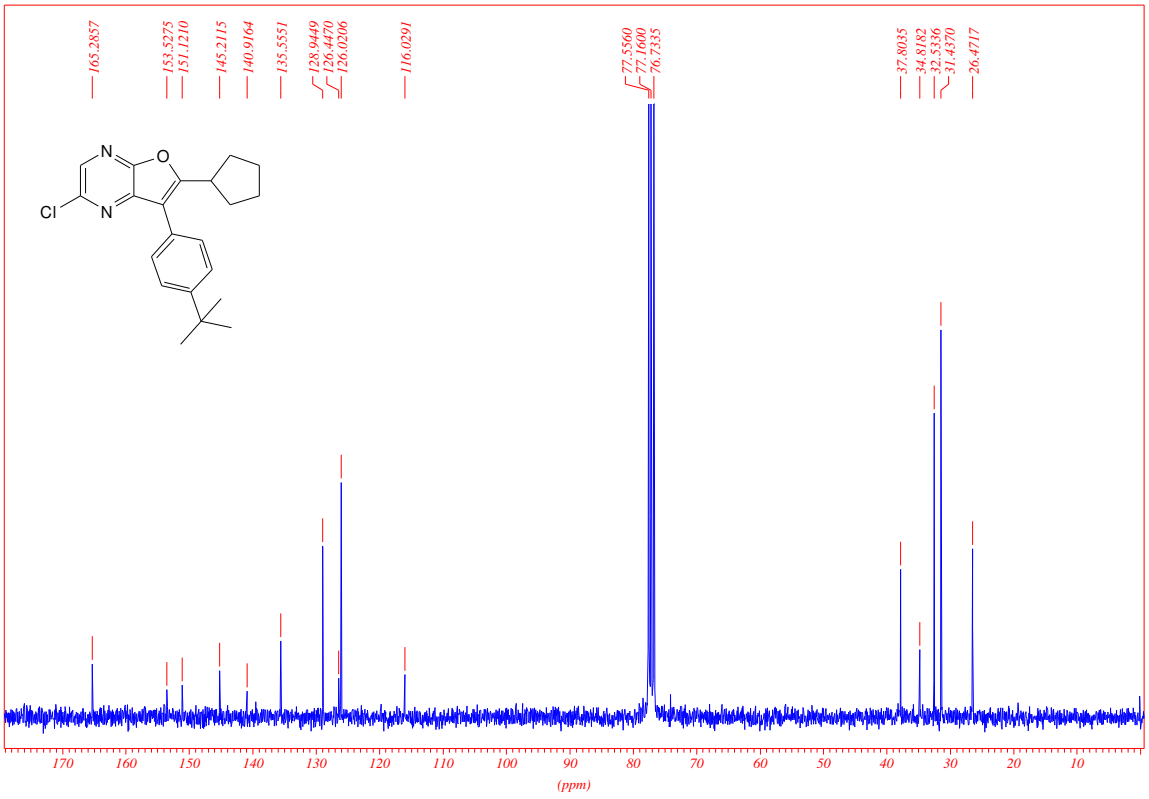
^{1}H and ^{13}C Spectra of compound 7a (300 MHz, $CDCl_3$).



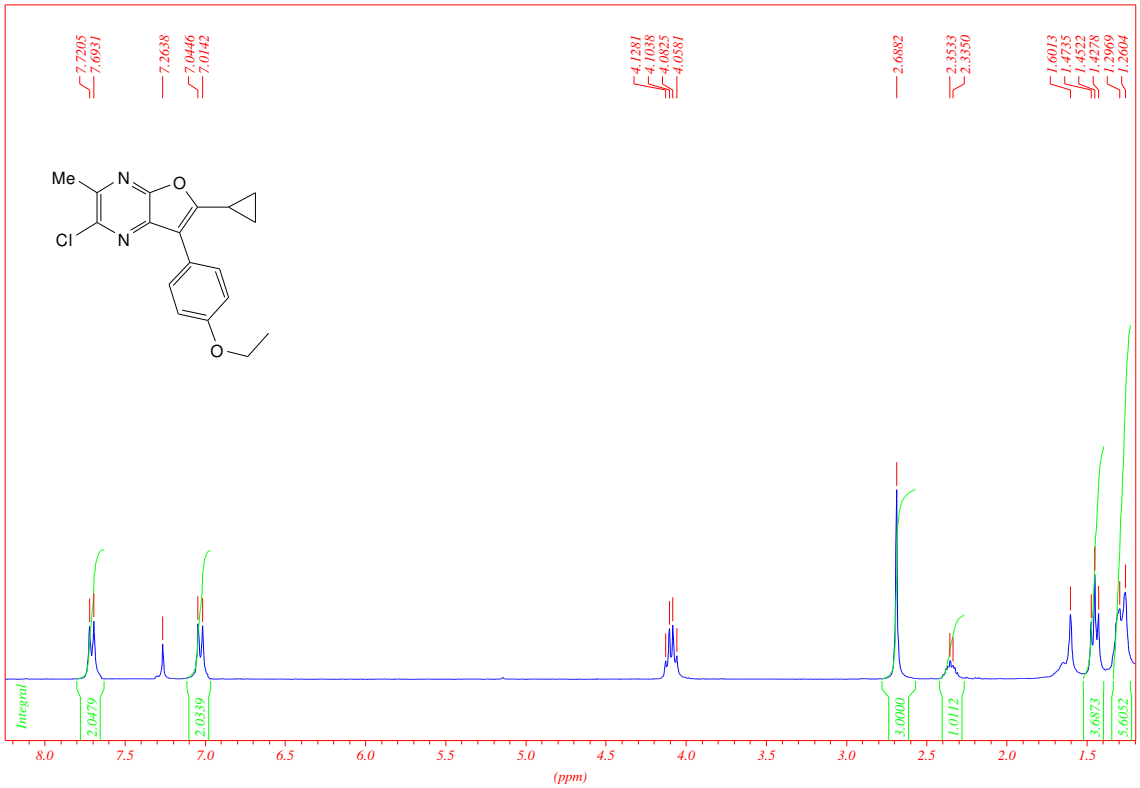


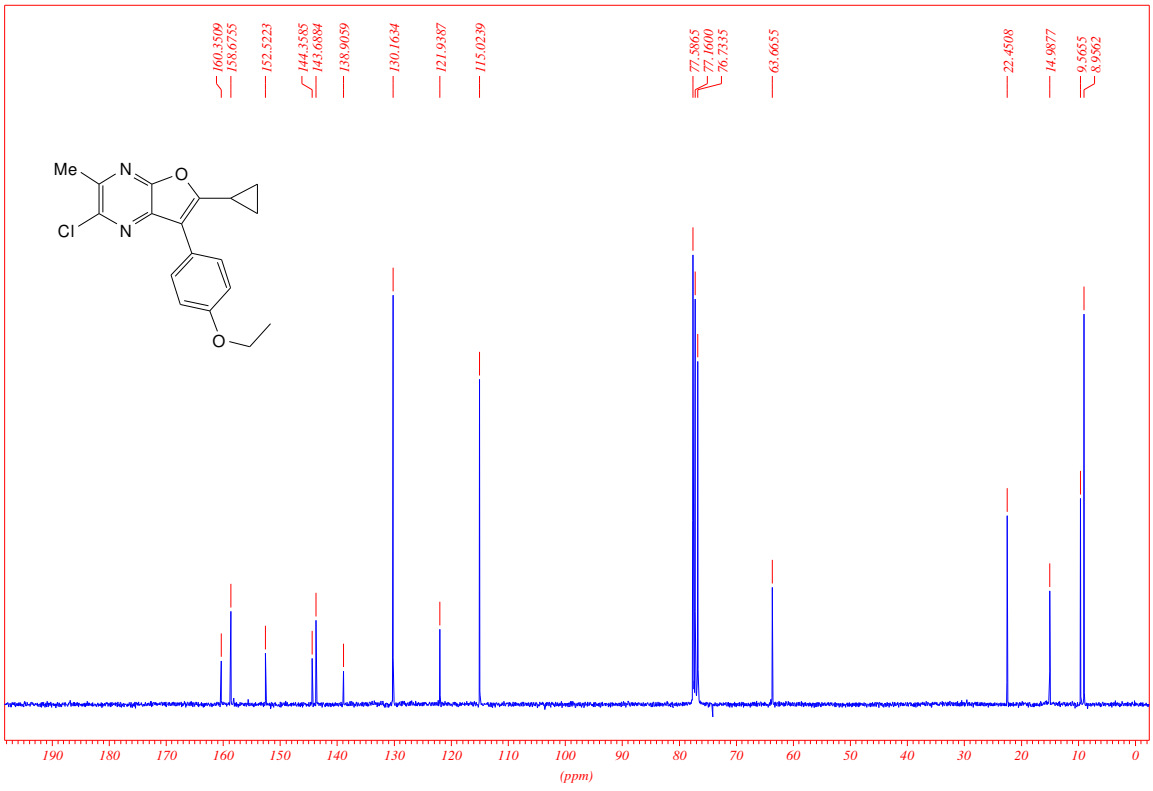
^{1}H and ^{13}C Spectra of compound 7b (300 MHz, $CDCl_3$).



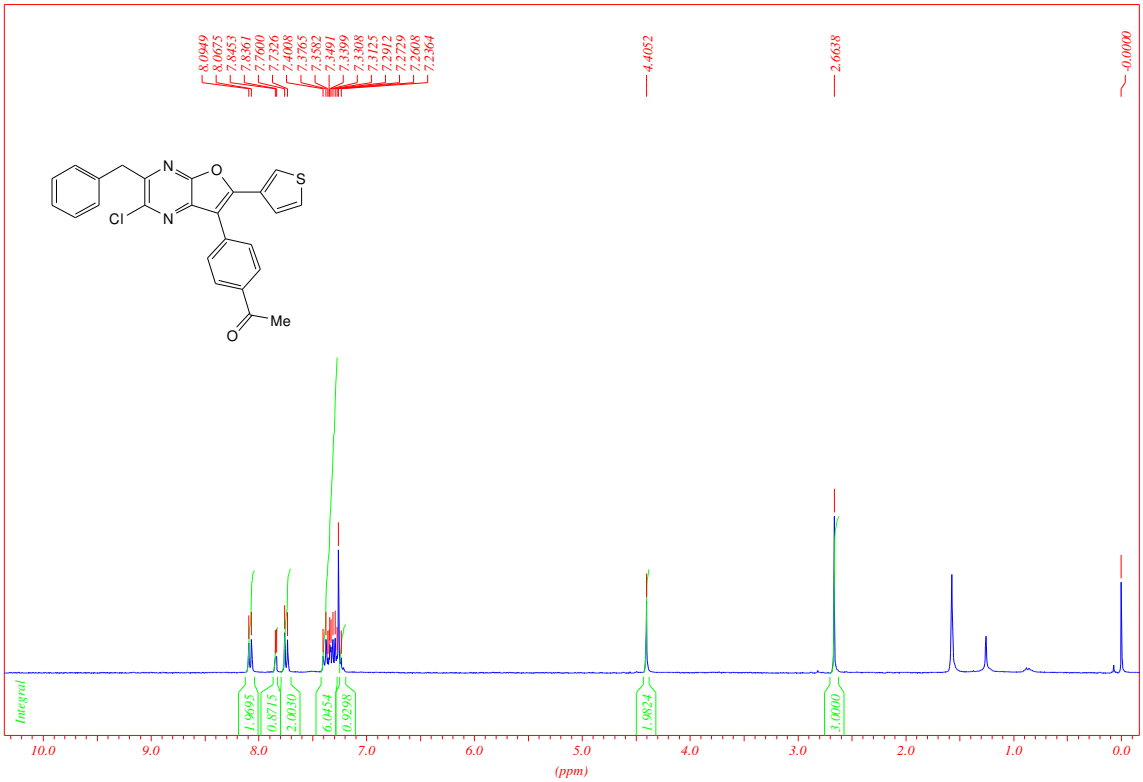


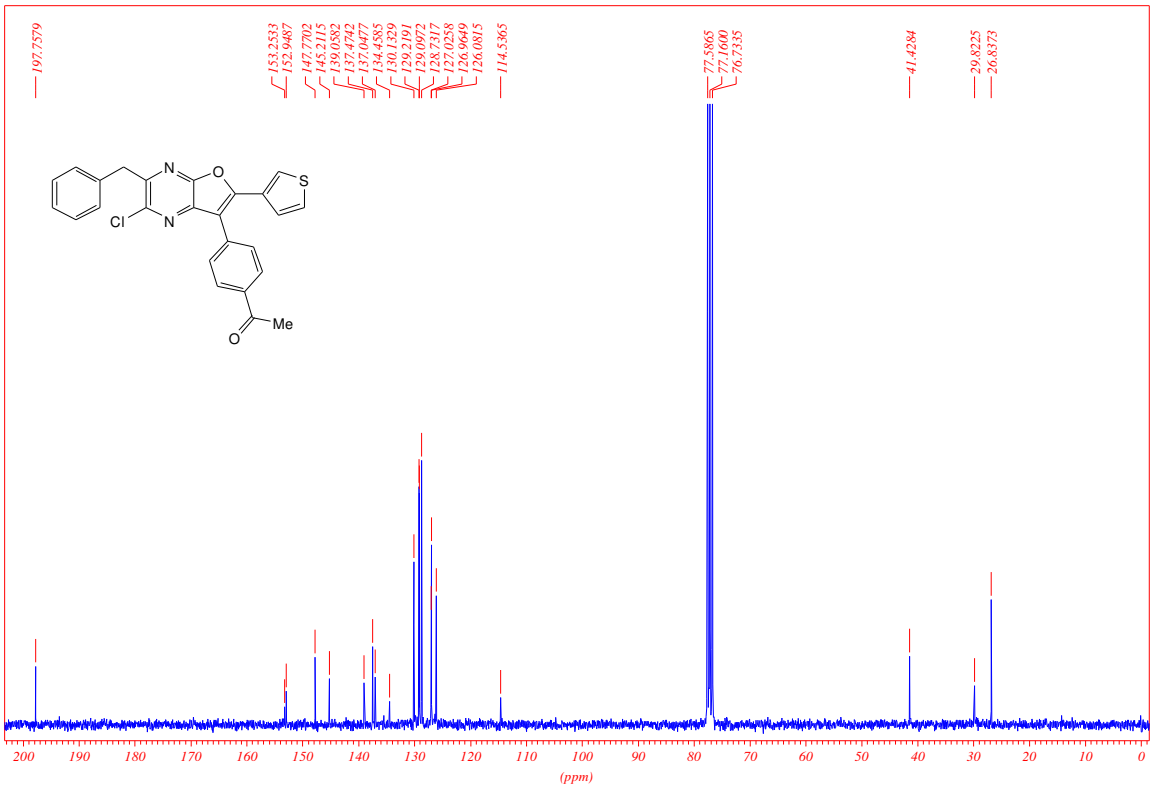
^{1}H and ^{13}C Spectra of compound 7c (300 MHz, $CDCl_3$).



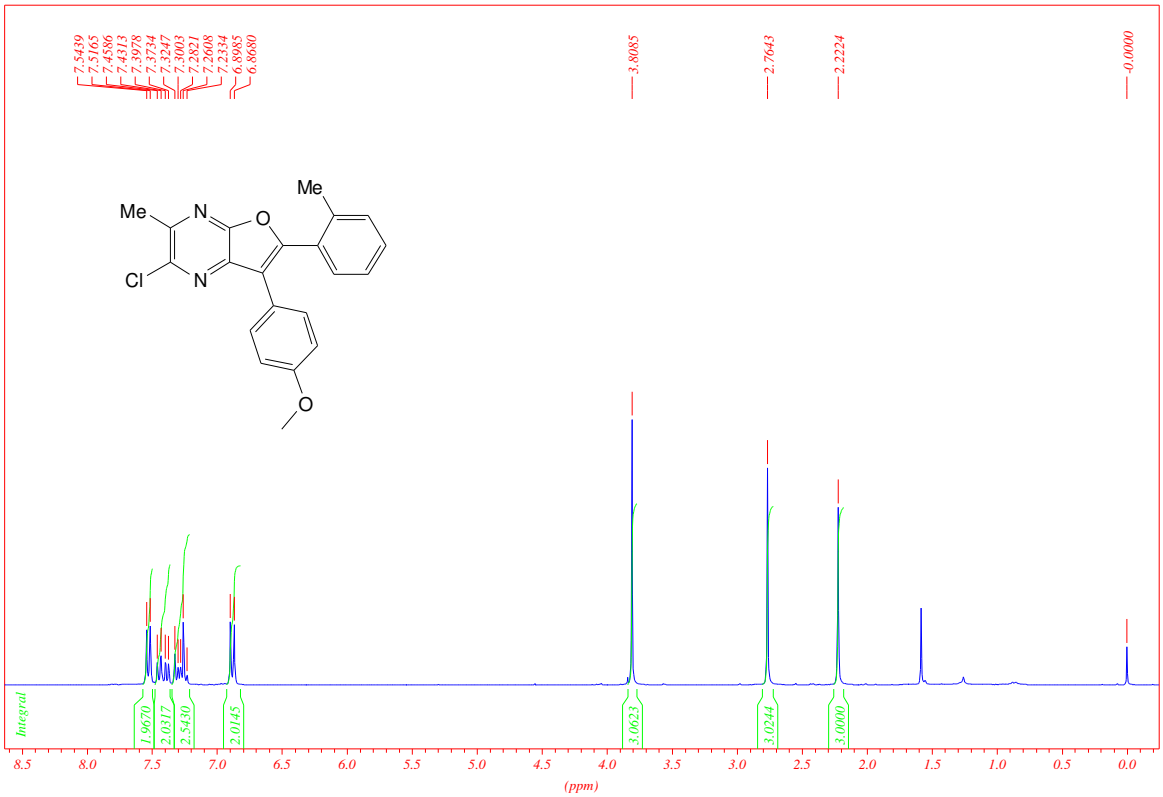


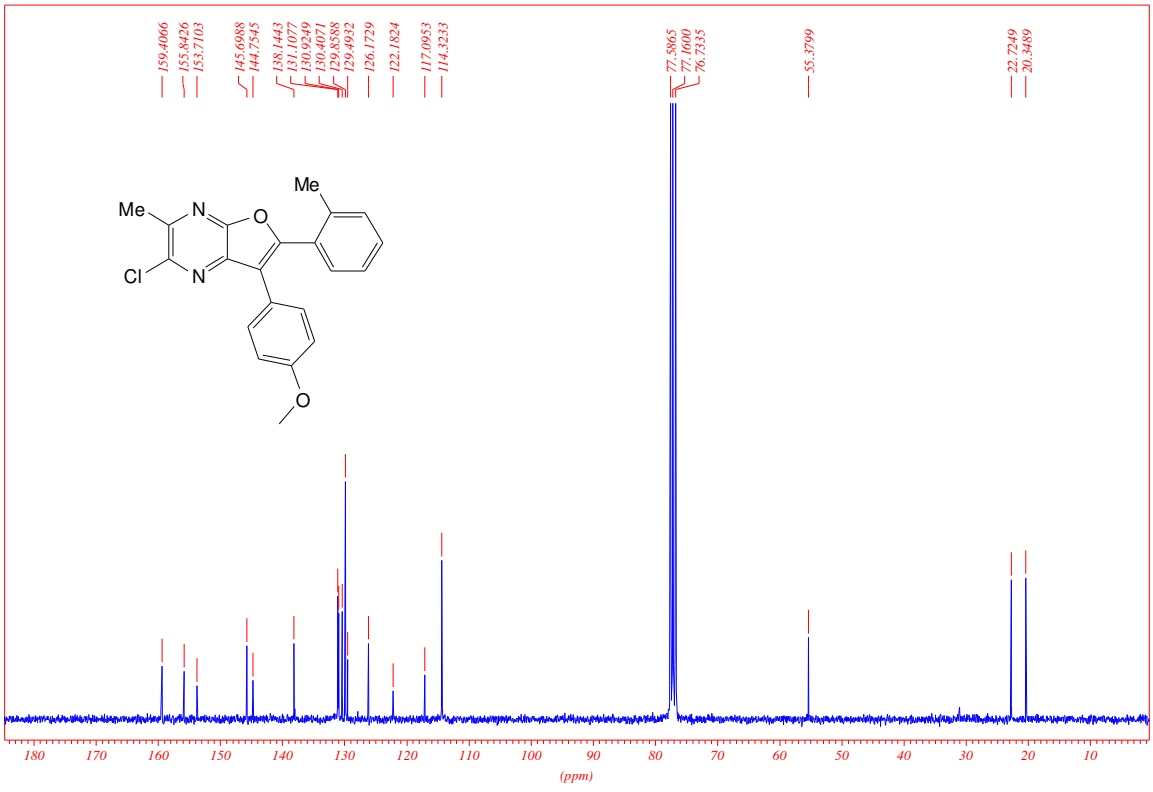
^{1}H and ^{13}C Spectra of compound 7d (300 MHz, $CDCl_3$).



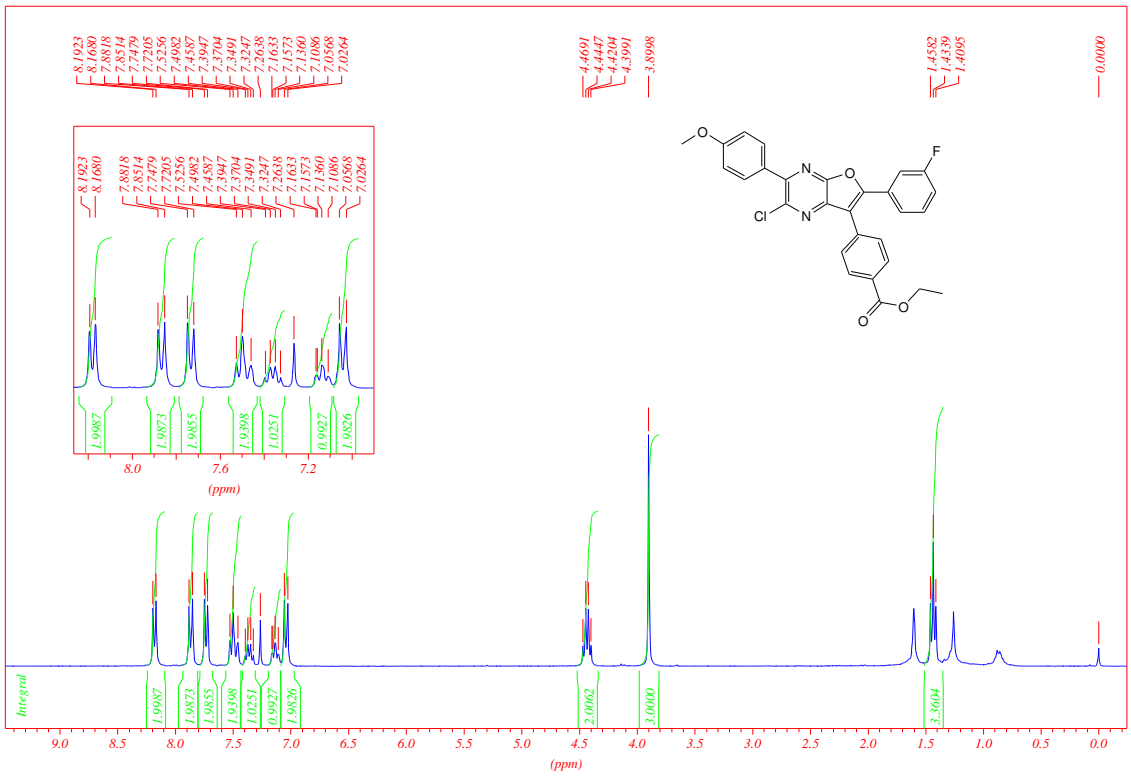


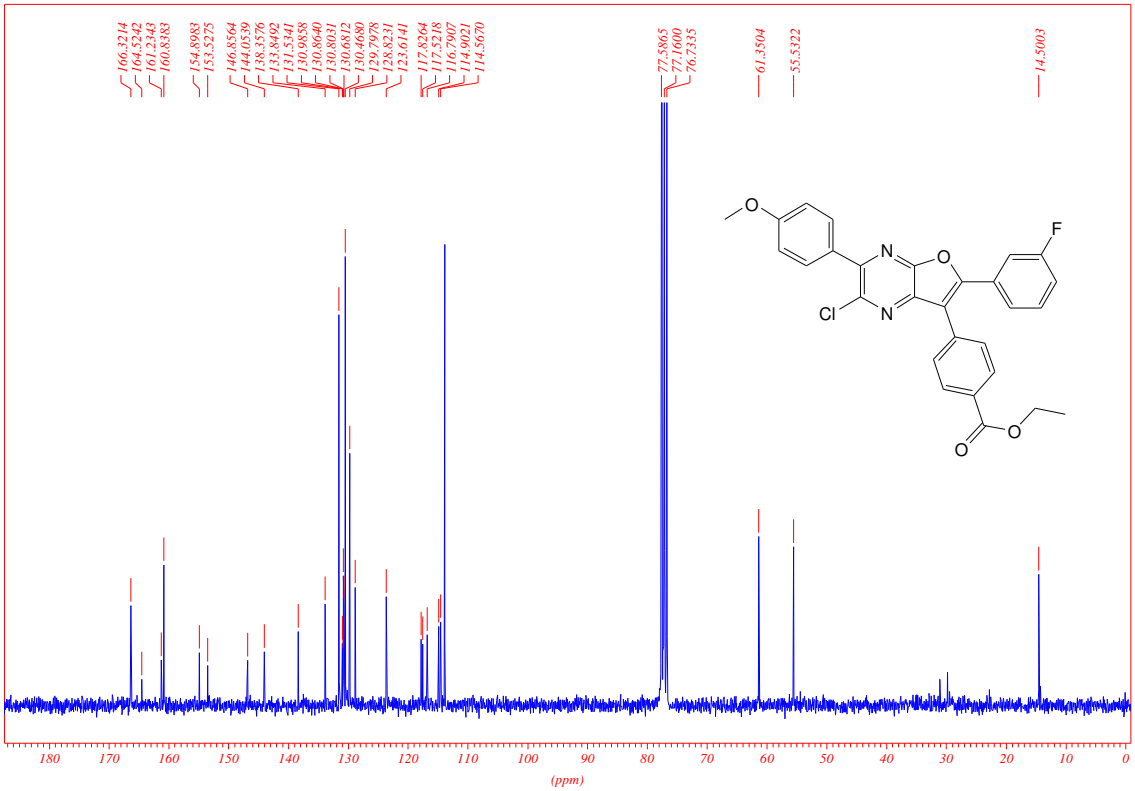
^{1}H and ^{13}C Spectra of compound 7e (300 MHz, $CDCl_3$).



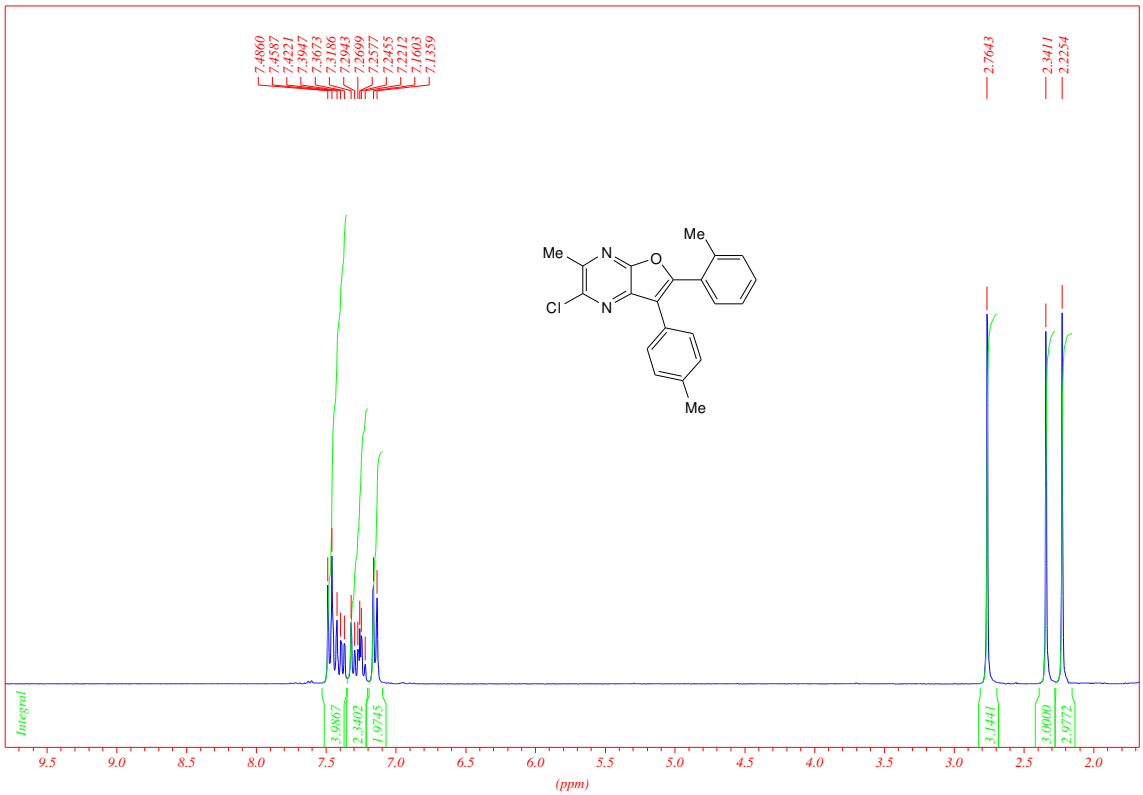


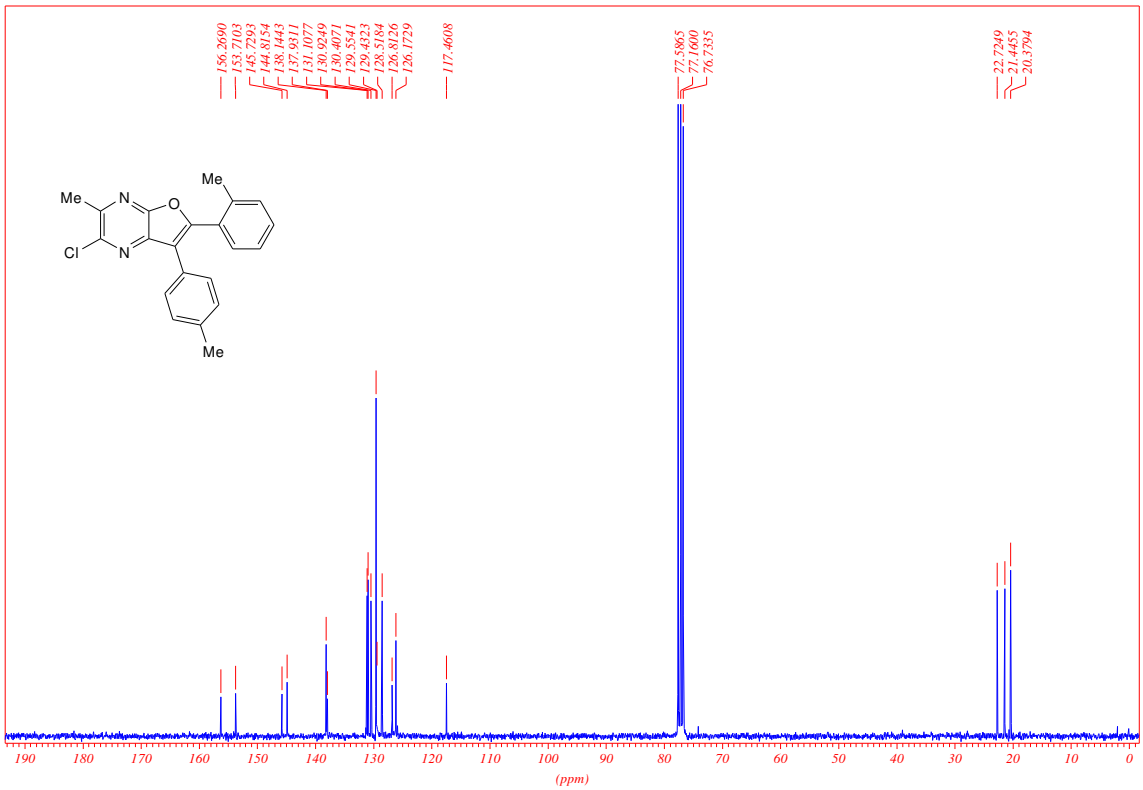
^{1}H and ^{13}C Spectra of compound 7f (300 MHz, $CDCl_3$).



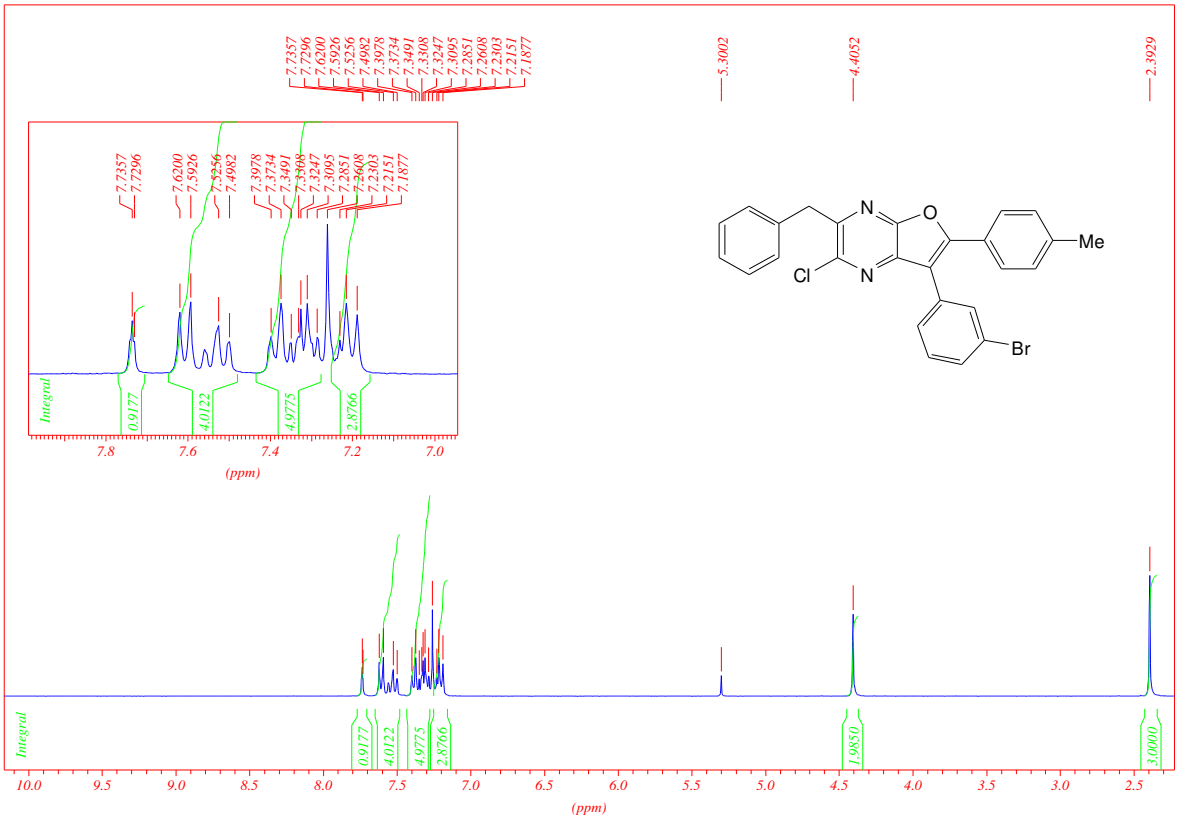


^{1}H and ^{13}C Spectra of compound 7g (300 MHz, $CDCl_3$).

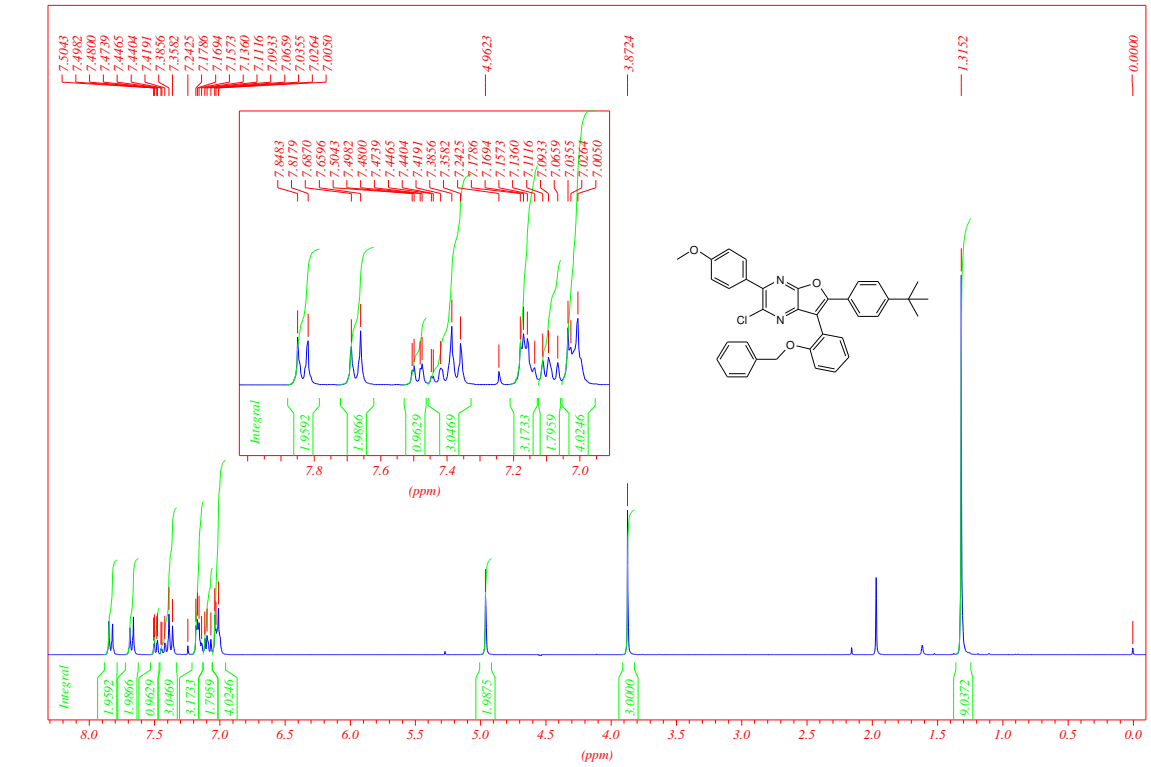


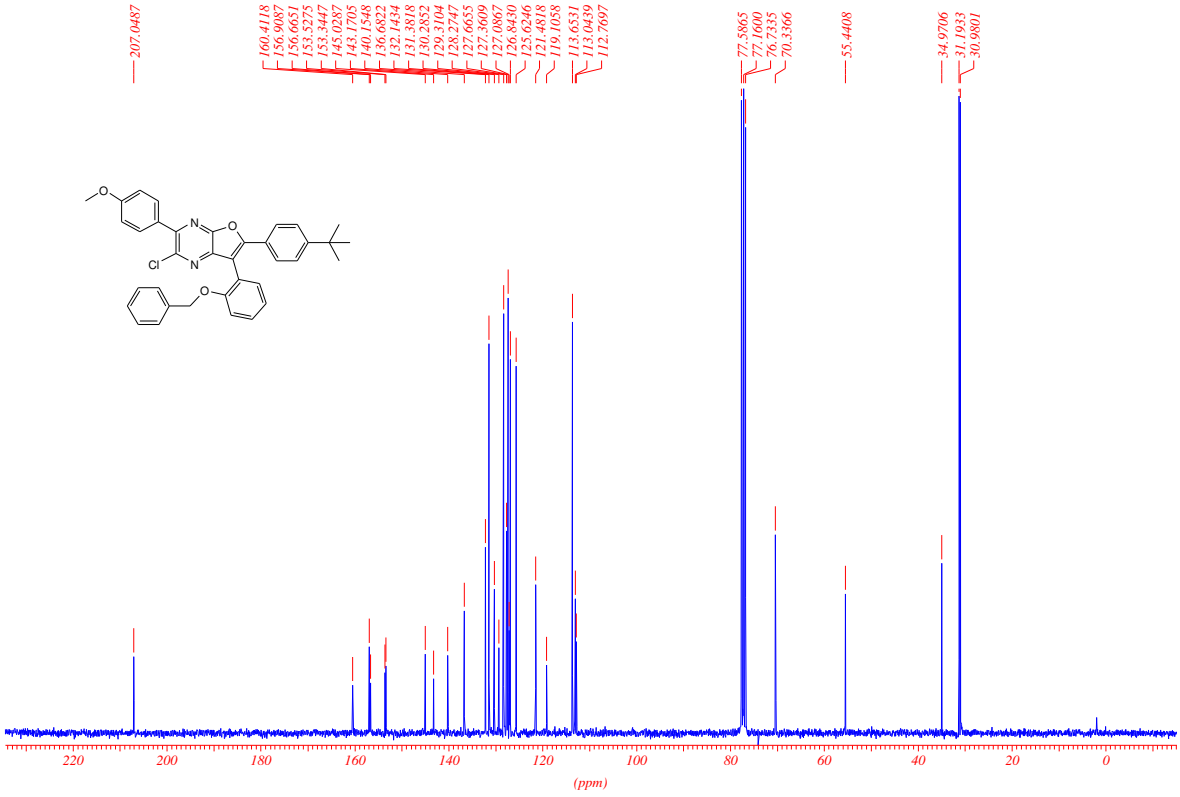


^{1}H Spectra of compound 7h (300 MHz, $CDCl_3$).

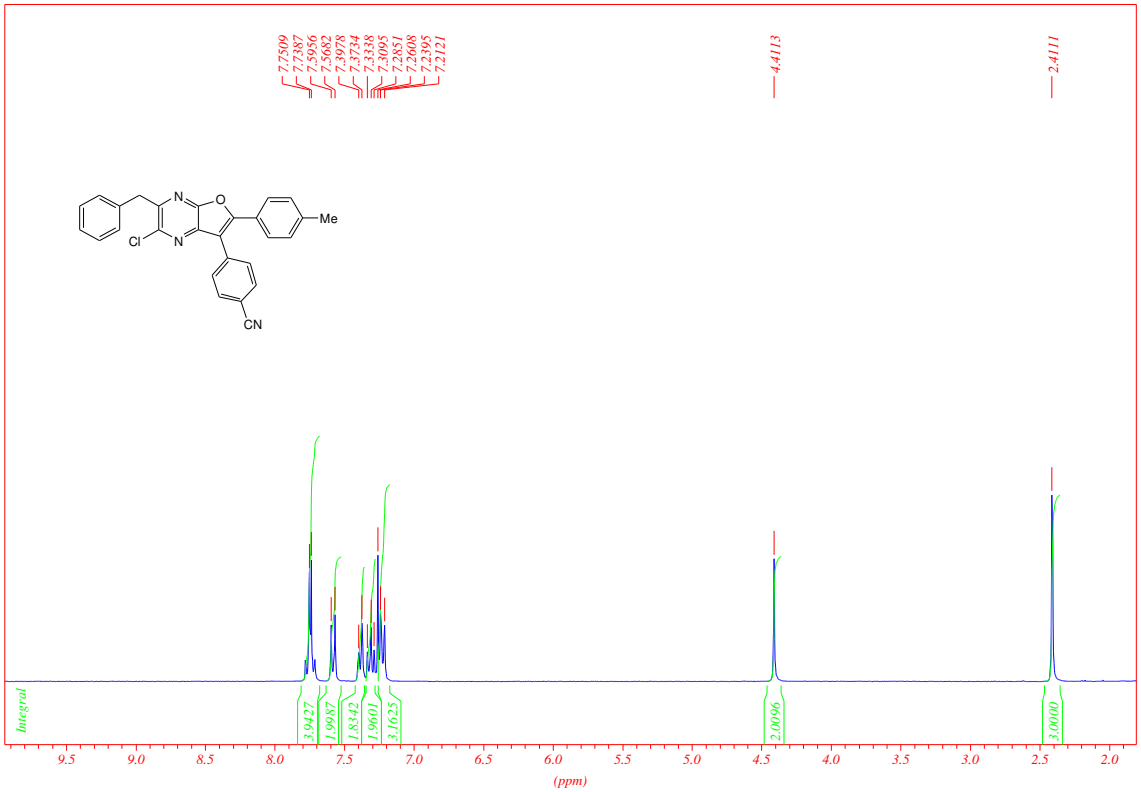


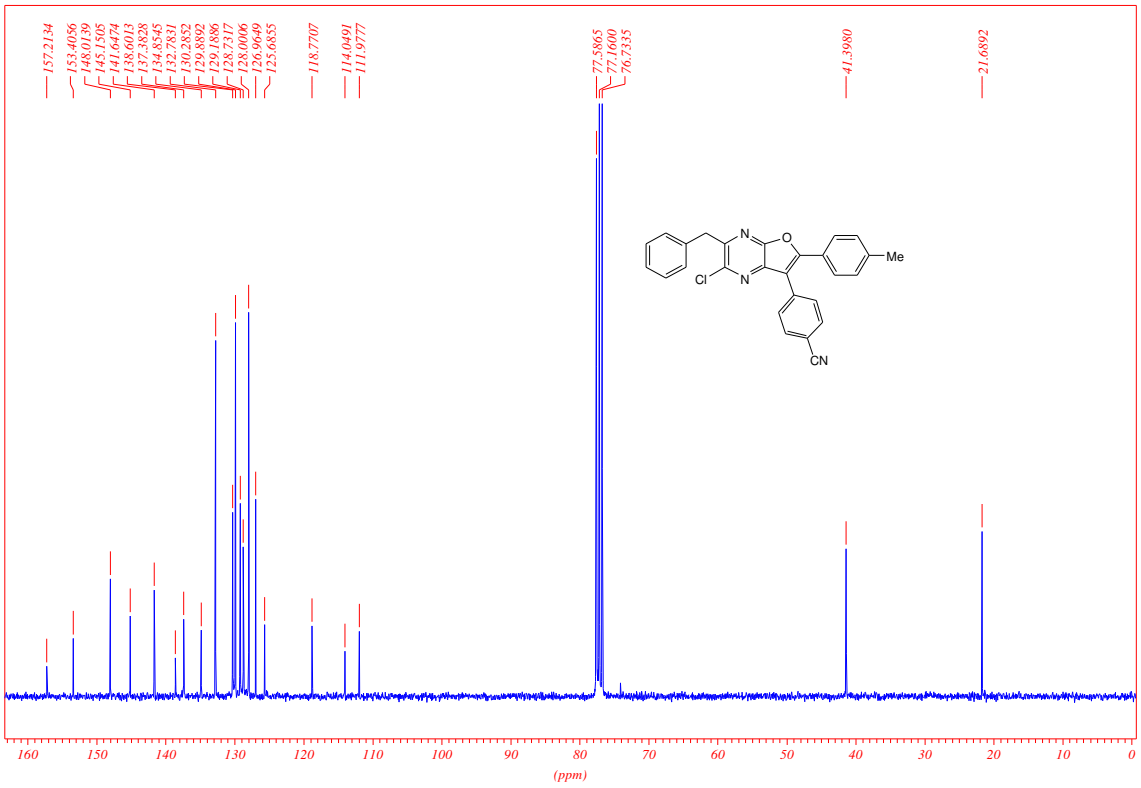
^{1}H and ^{13}C Spectra of compound 7i (300 MHz, $CDCl_3$).



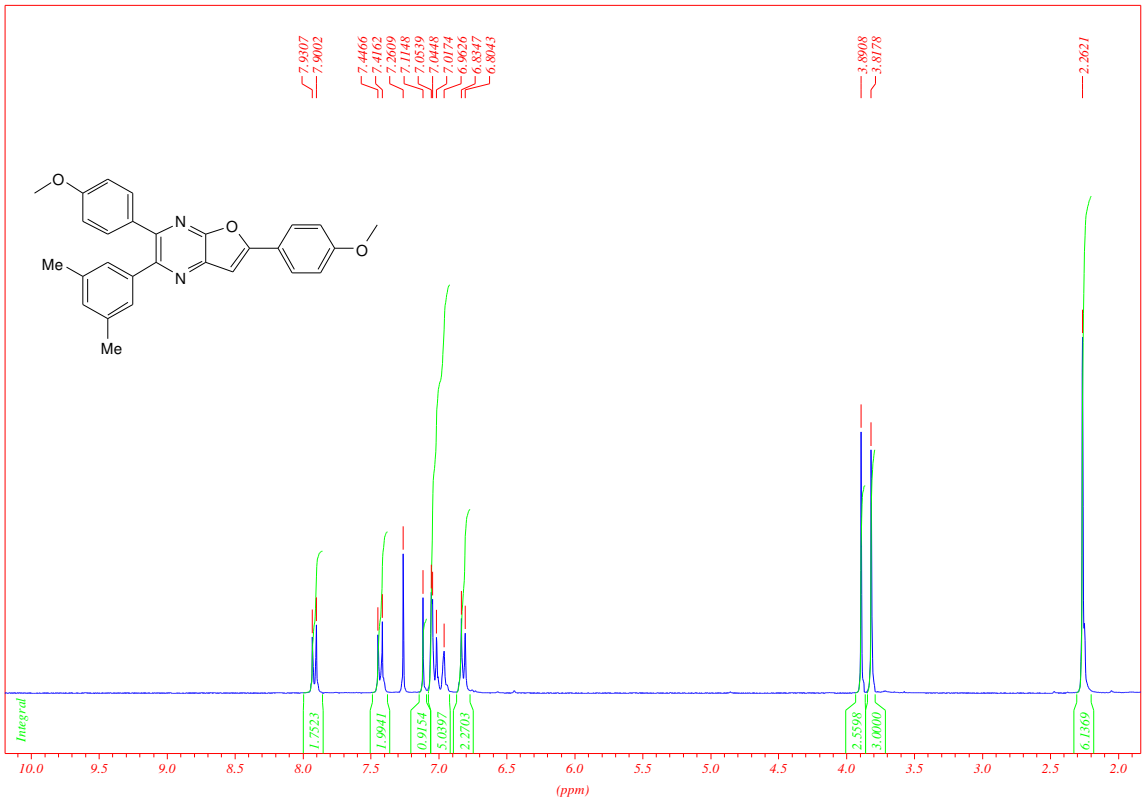


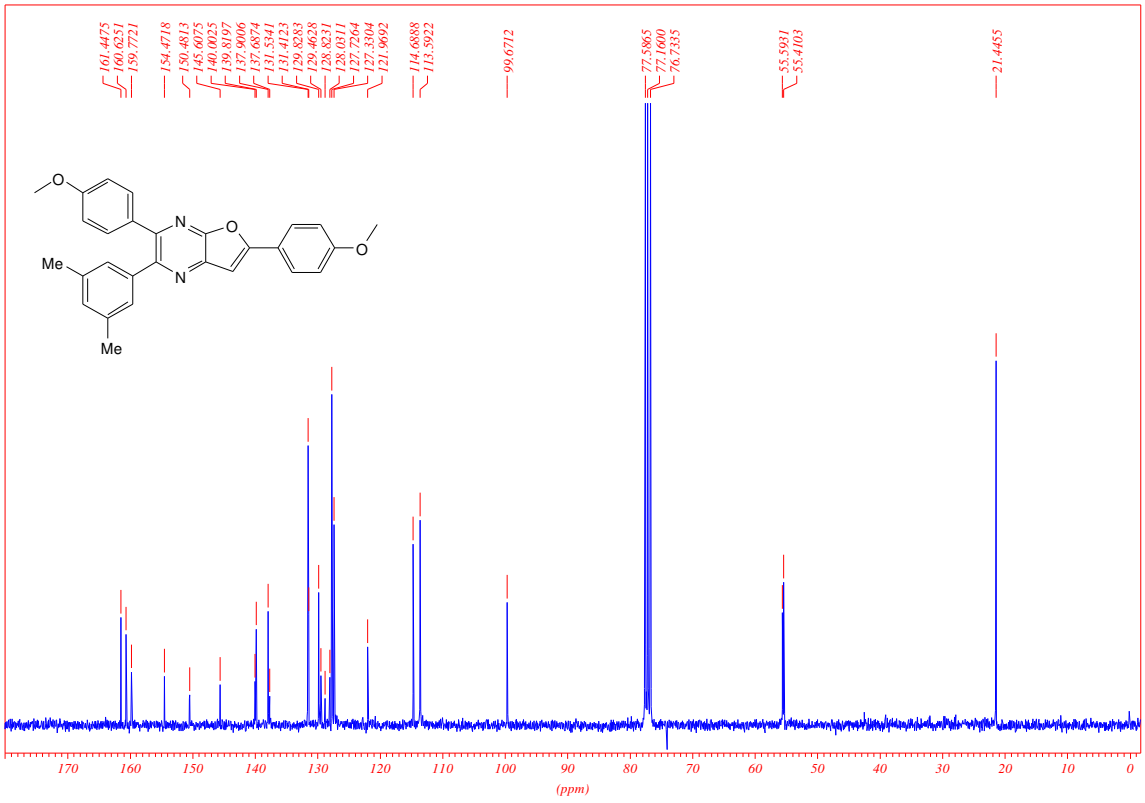
^{1}H and ^{13}C Spectra of compound 7j (300 MHz, $CDCl_3$).



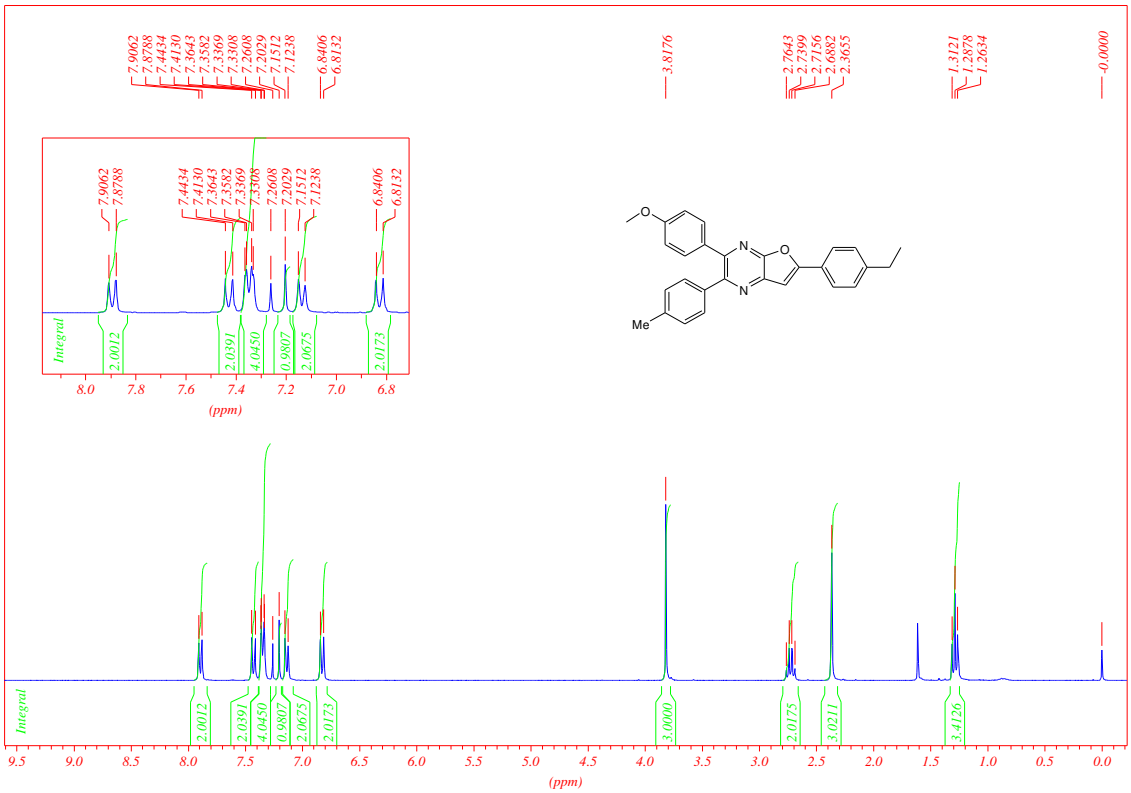


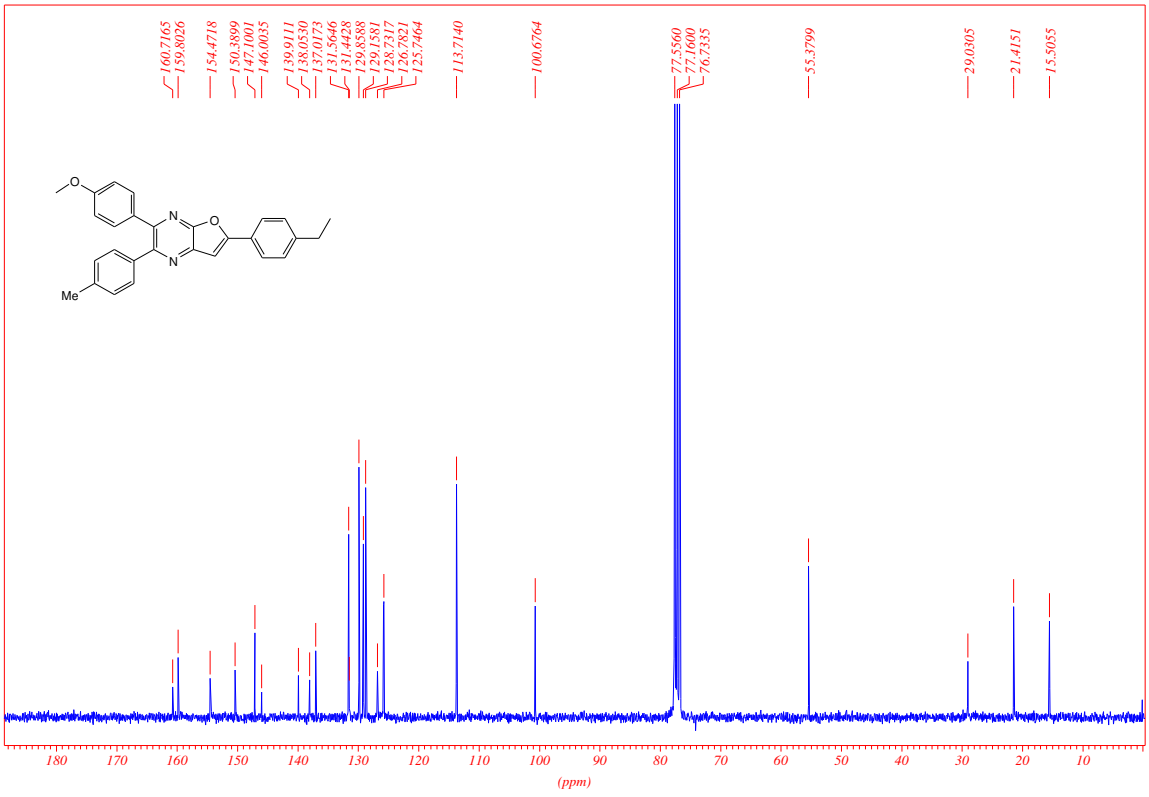
^{1}H and ^{13}C Spectra of compound 8a (300 MHz, $CDCl_3$).



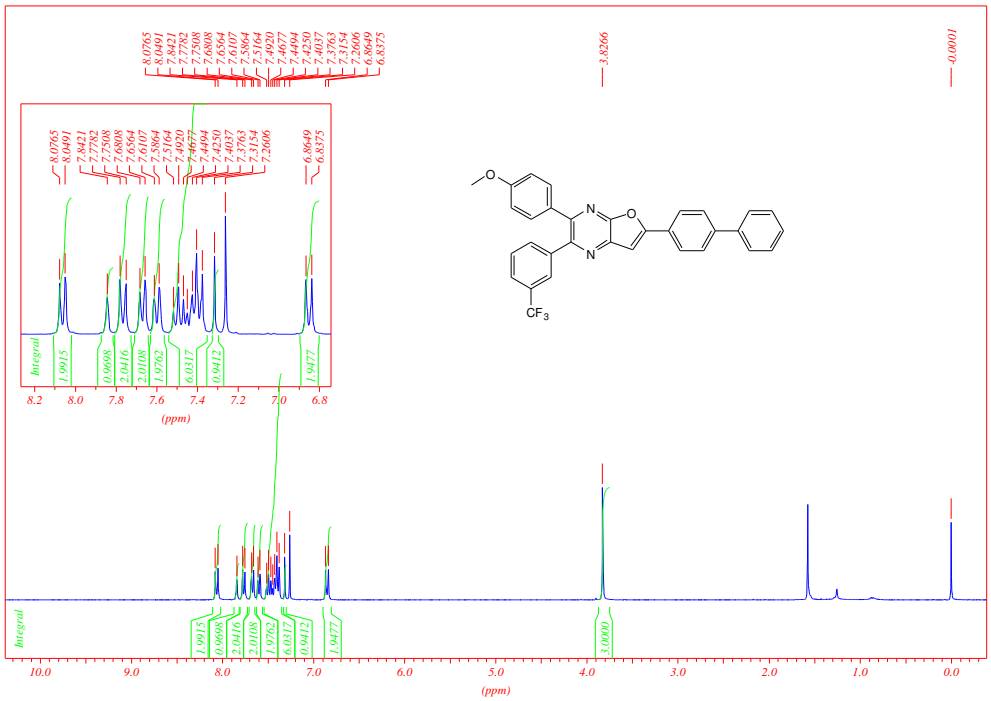


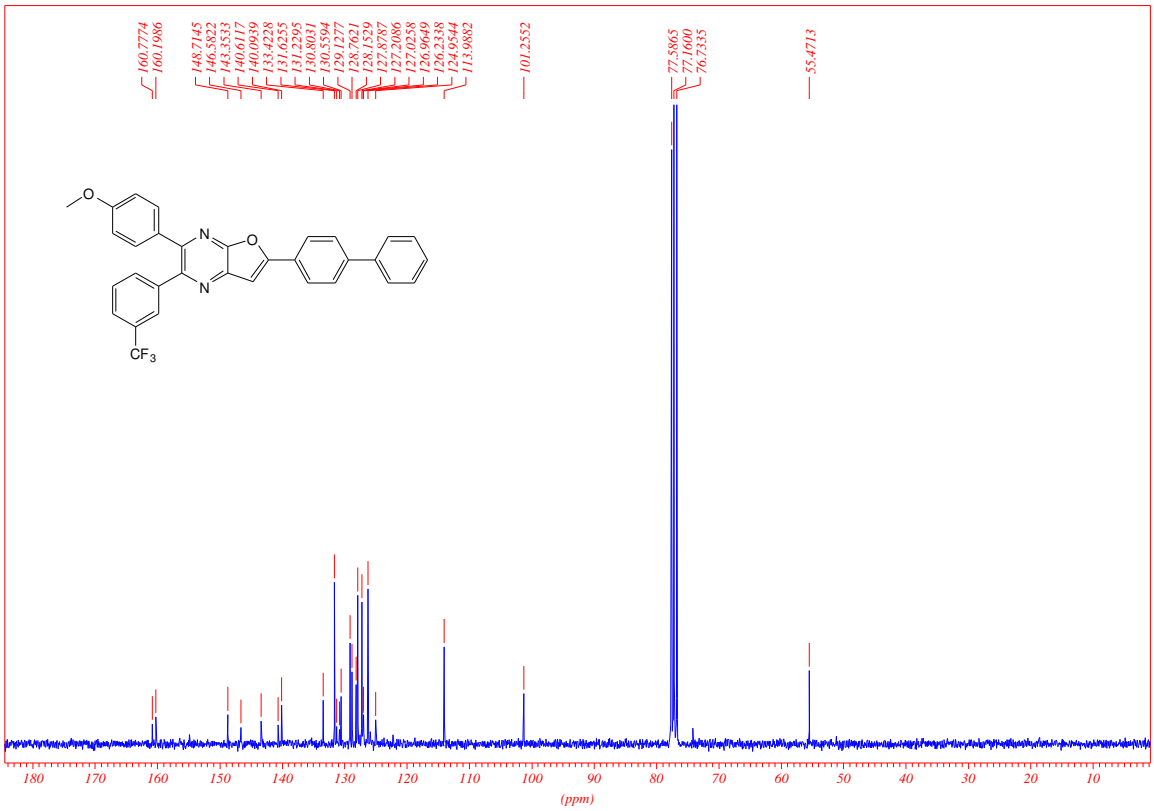
^{1}H and ^{13}C Spectra of compound 8b (300 MHz, $CDCl_3$).



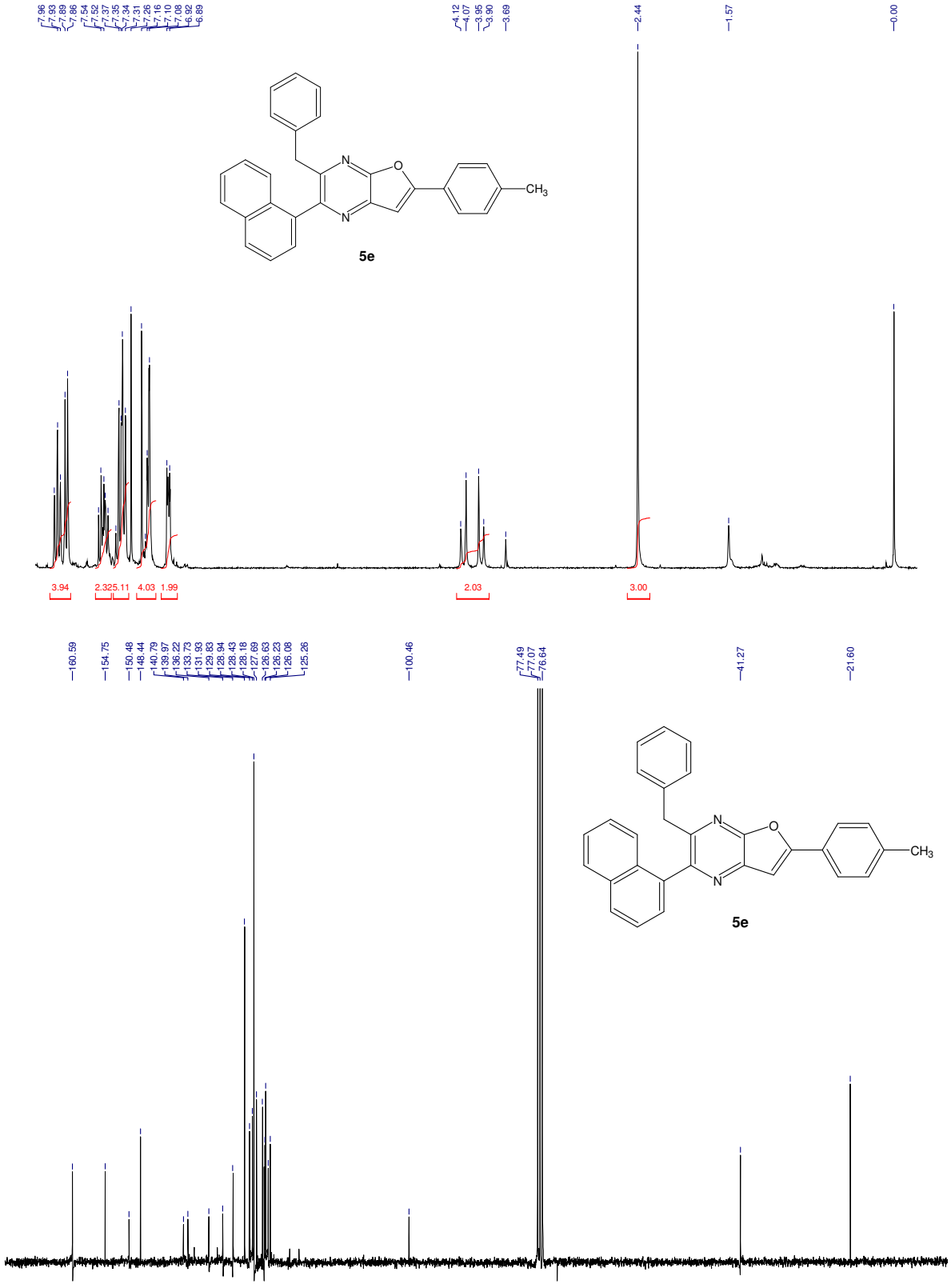


^{1}H and ^{13}C Spectra of compound 8c (300 MHz, $CDCl_3$)

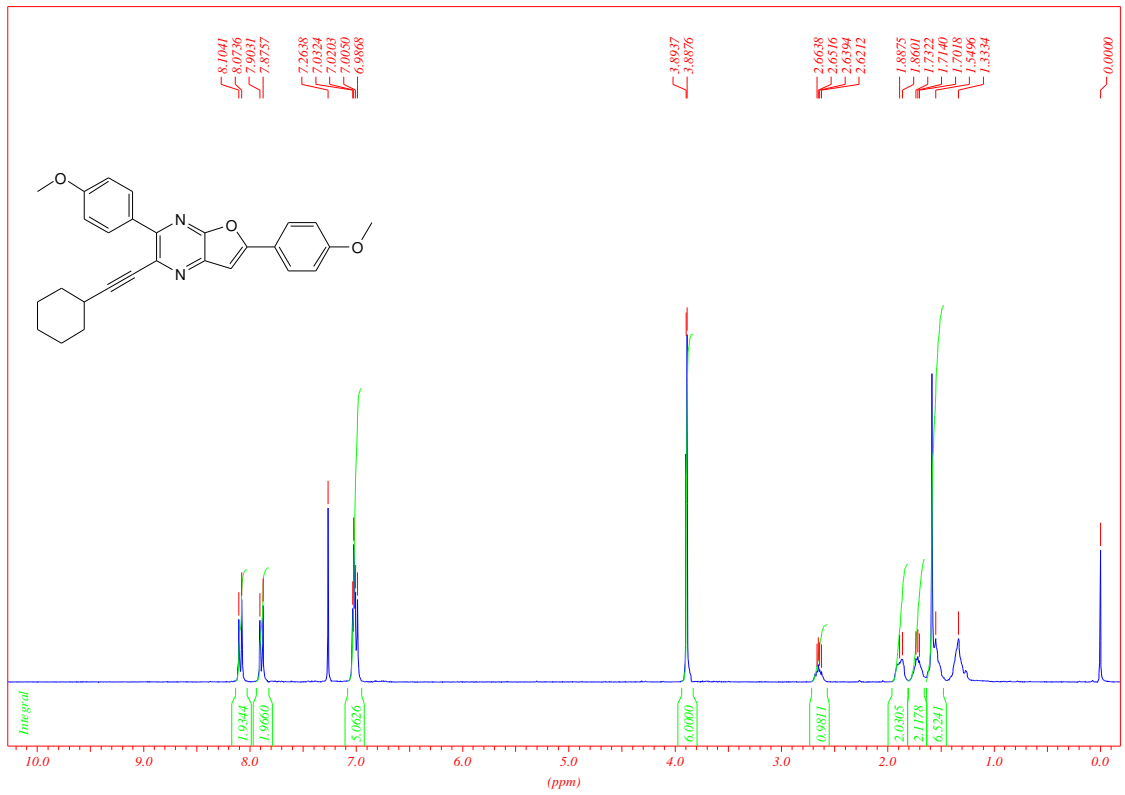


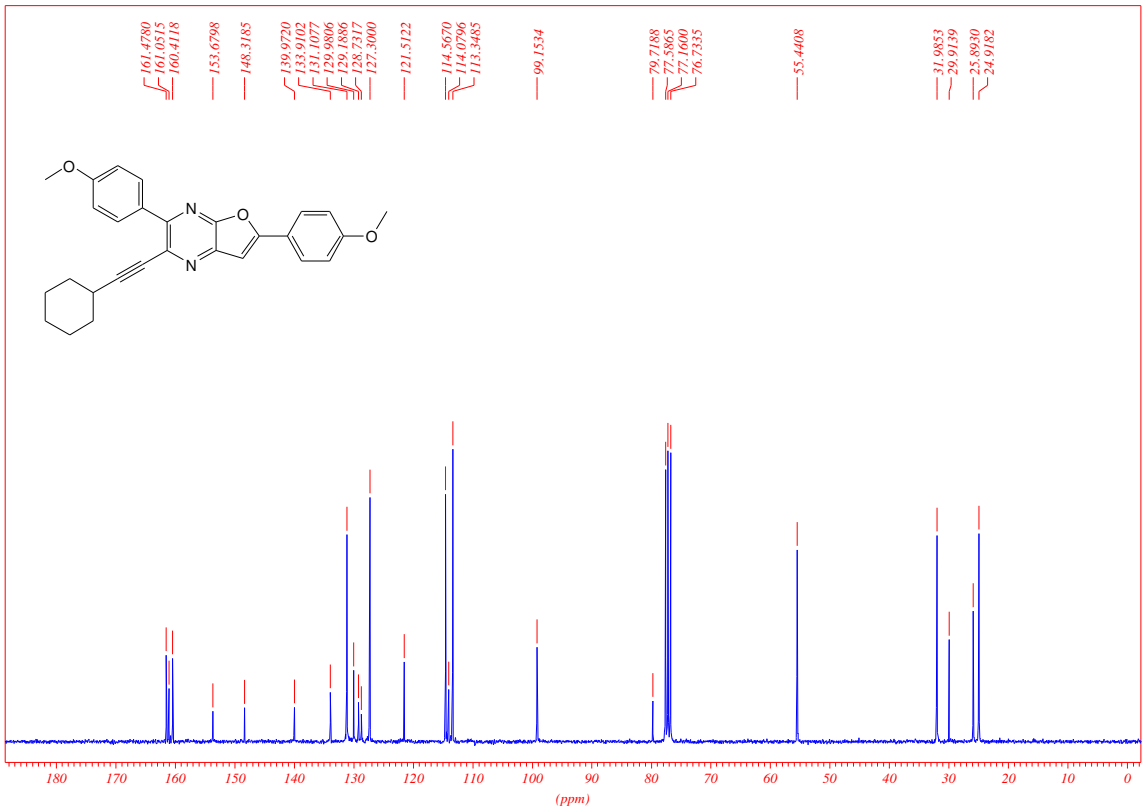


^{1}H and ^{13}C Spectra of compound 8d (300 MHz, $CDCl_3$).

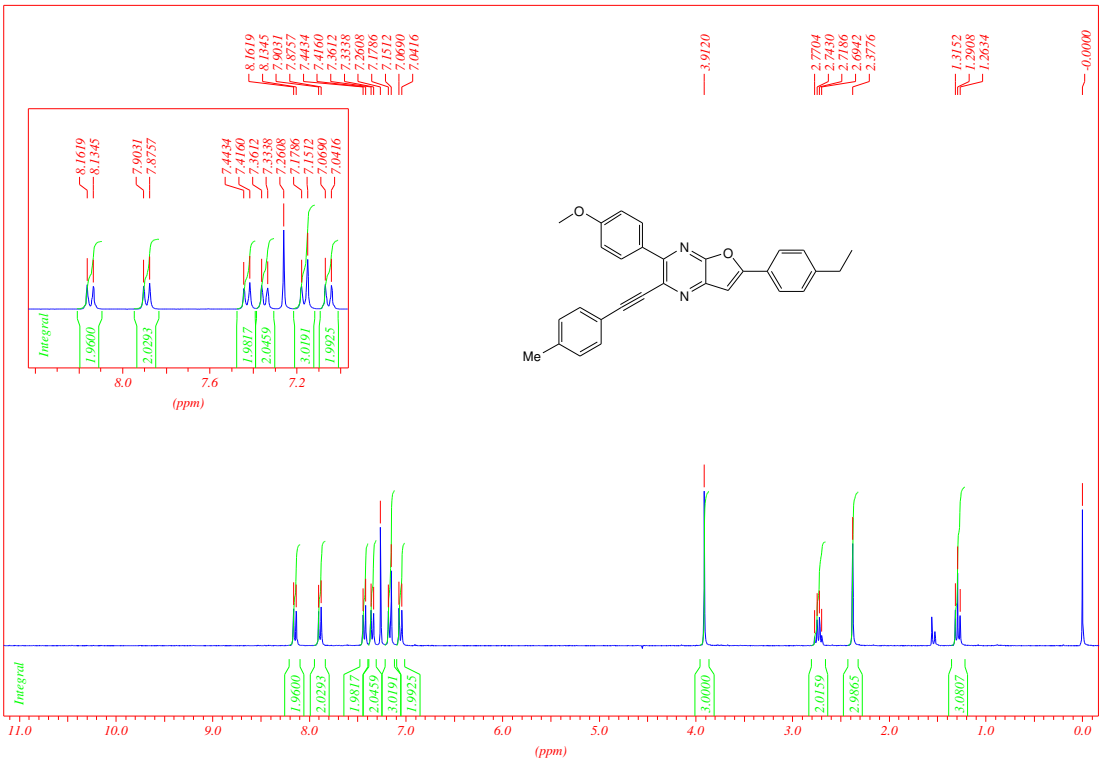


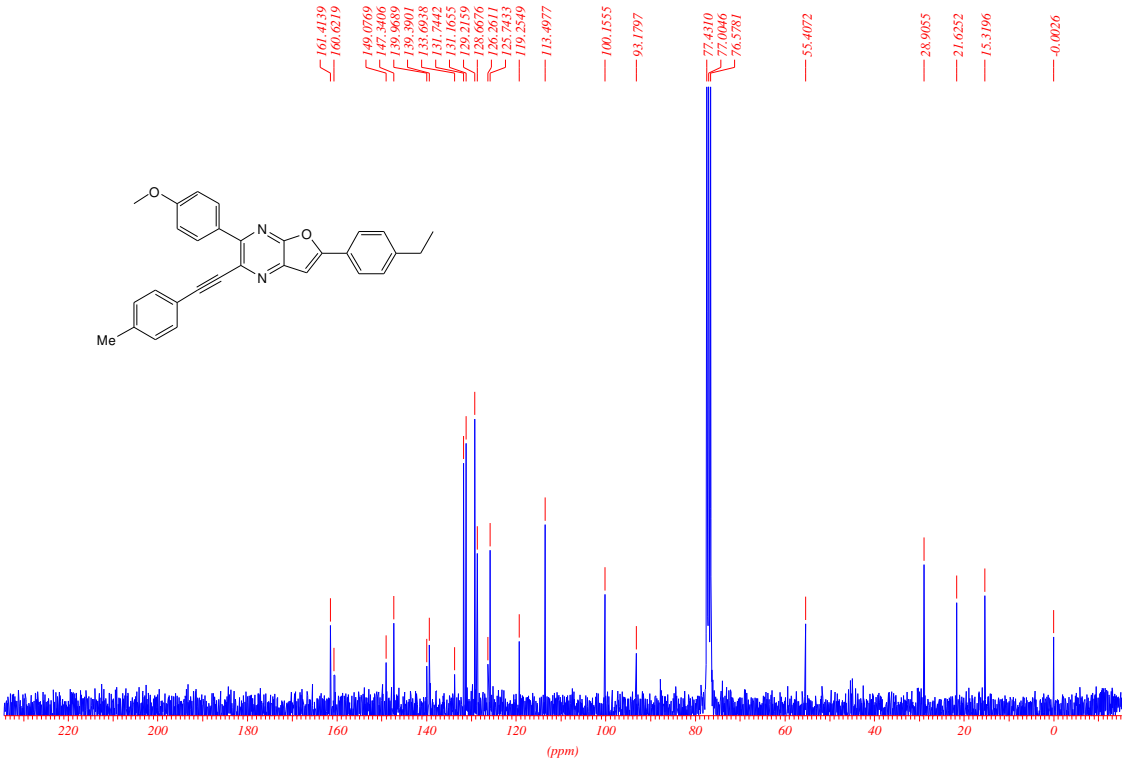
^{1}H and ^{13}C Spectra of compound 9a (300 MHz, $CDCl_3$).



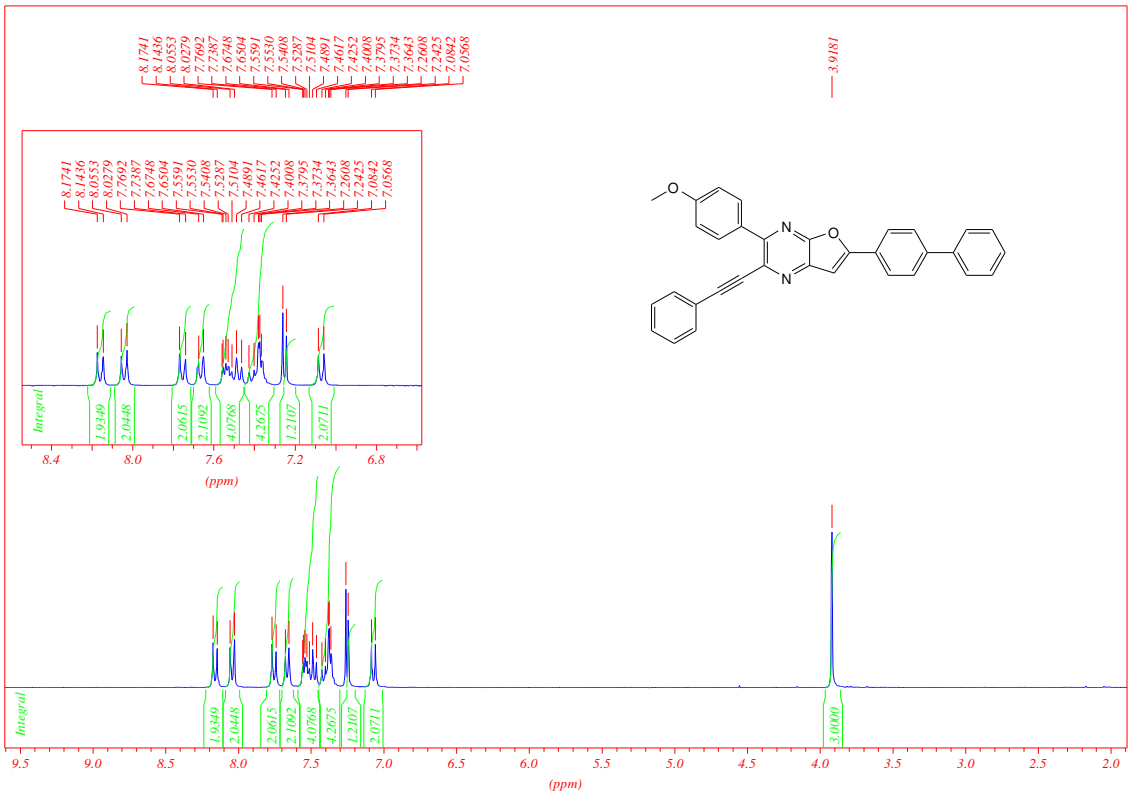


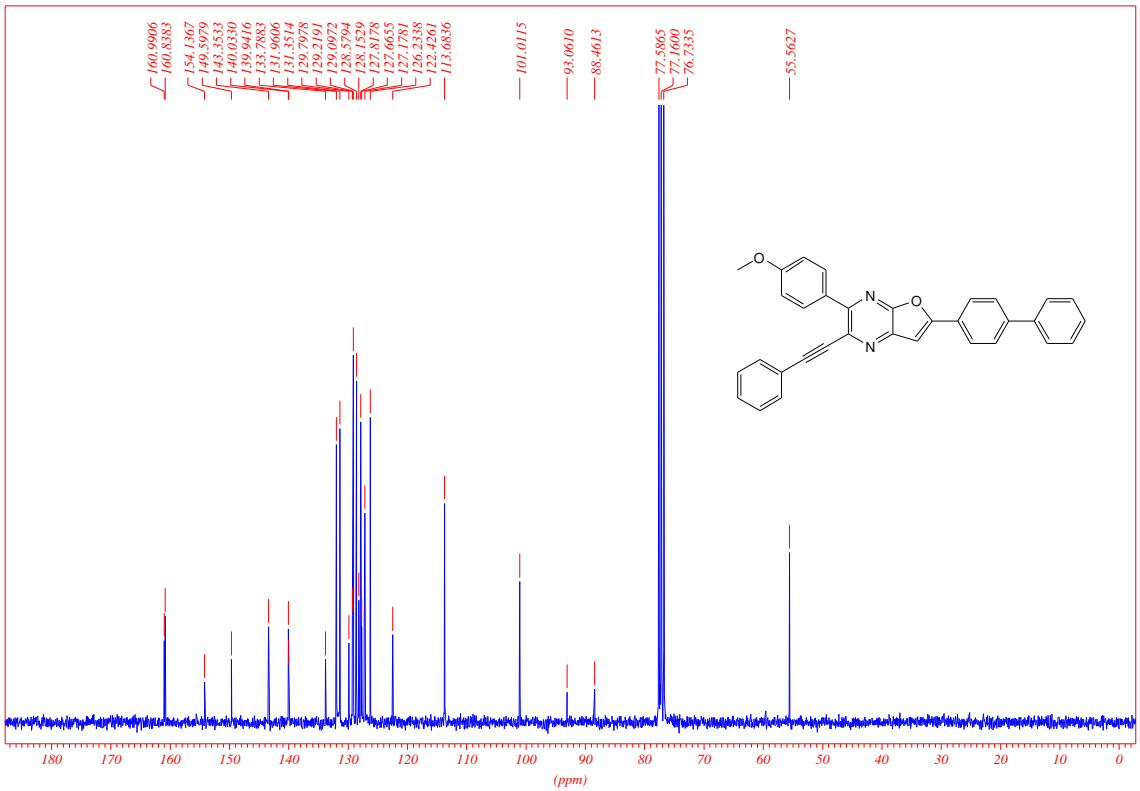
^{1}H and ^{13}C Spectra of compound 9b (300 MHz, $CDCl_3$).



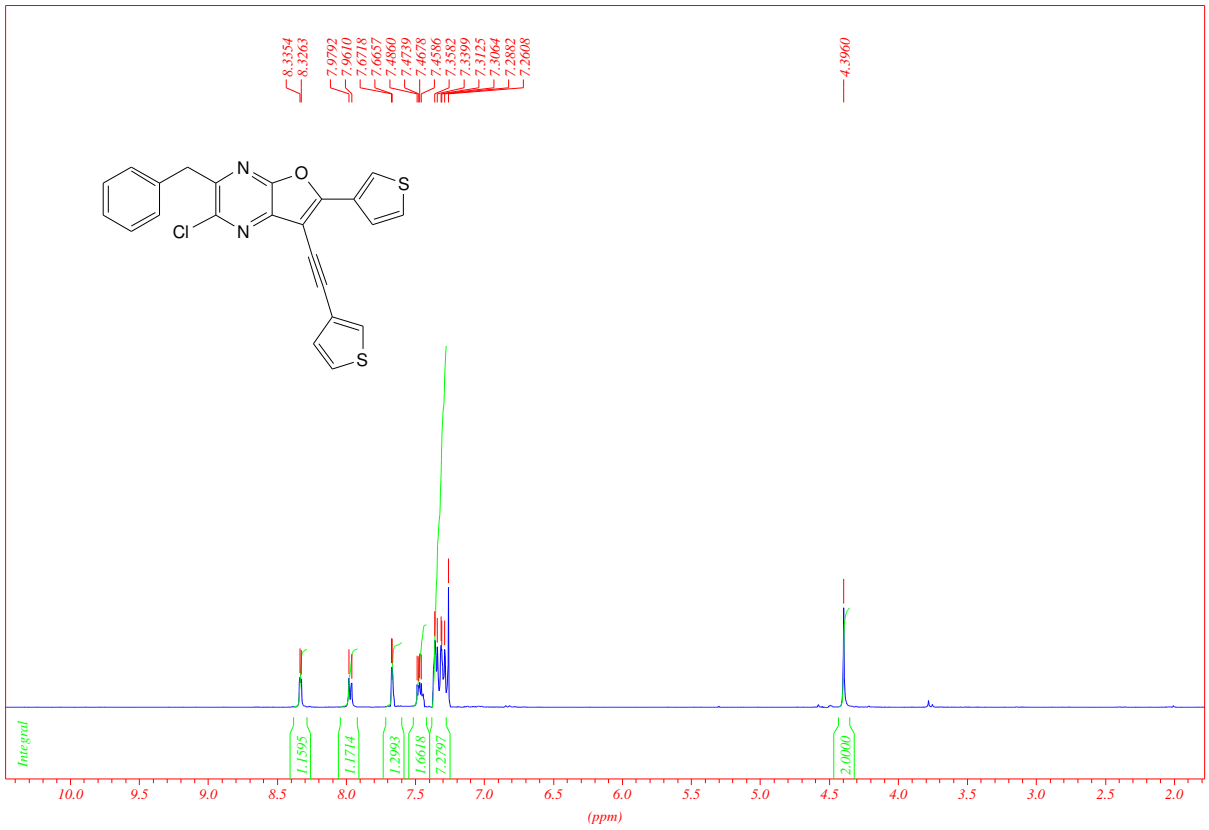


^{1}H and ^{13}C Spectra of compound 9c (300 MHz, $CDCl_3$).

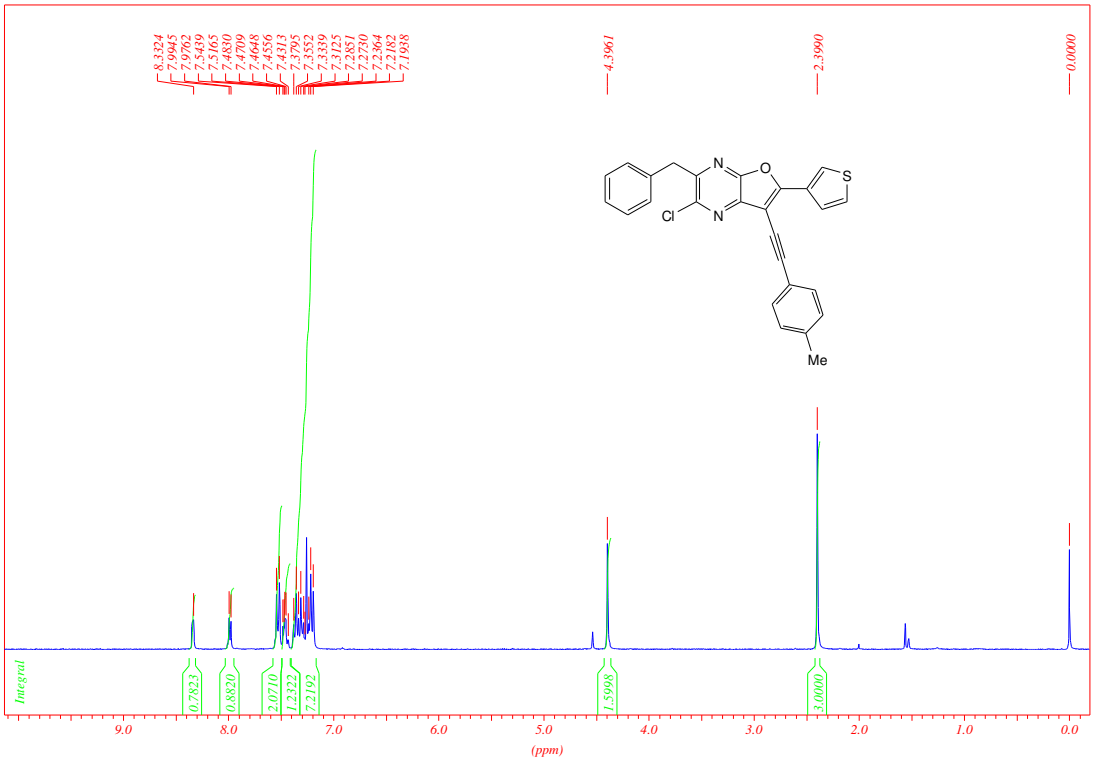


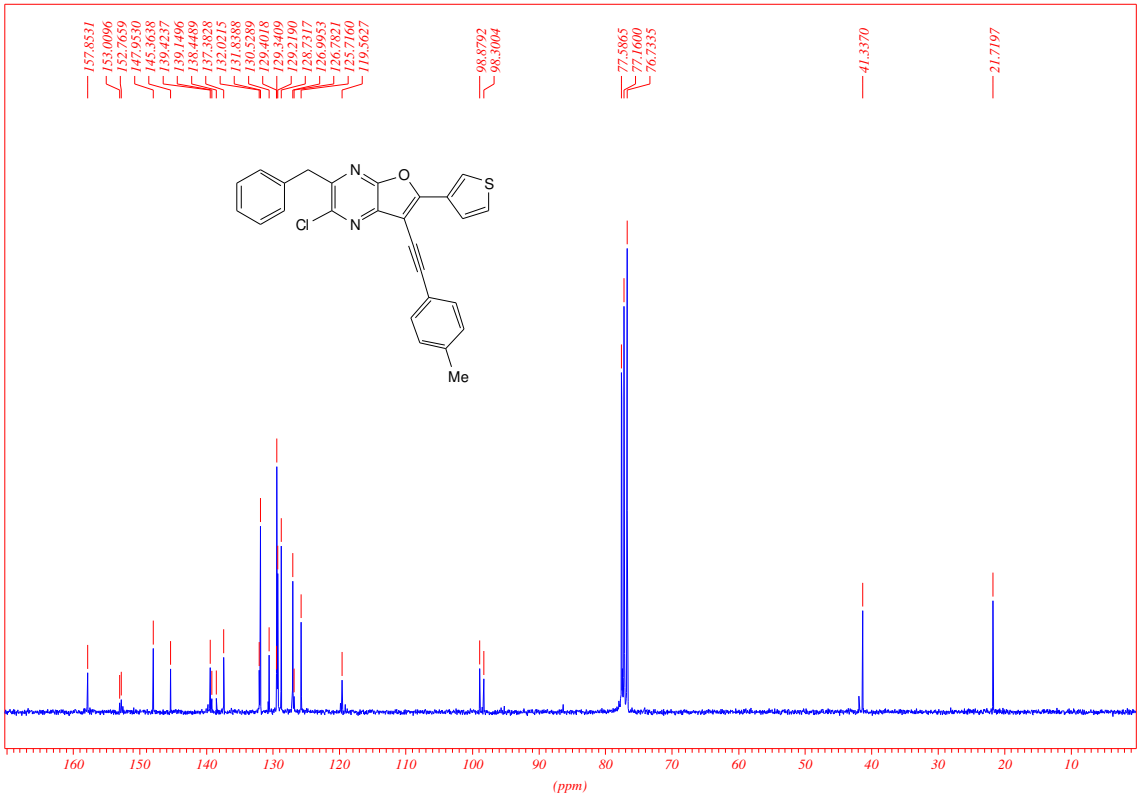


^{1}H and ^{13}C Spectra of compound 10a (300 MHz, $CDCl_3$).

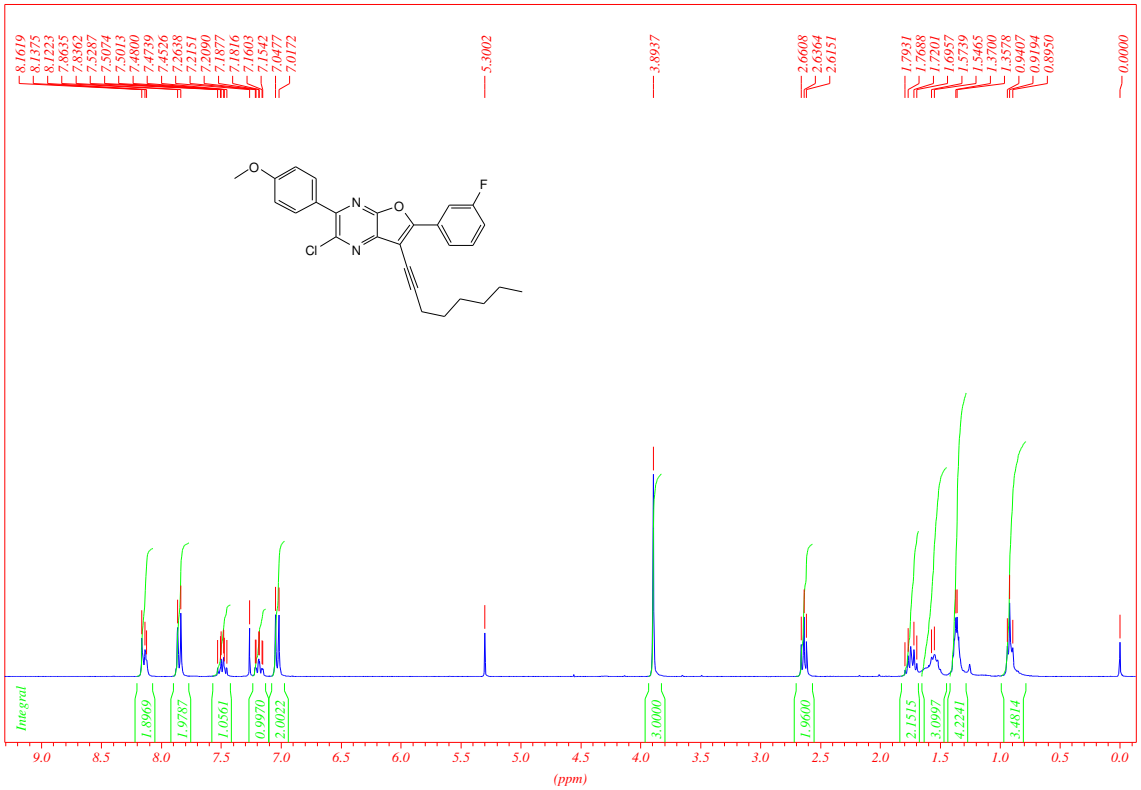


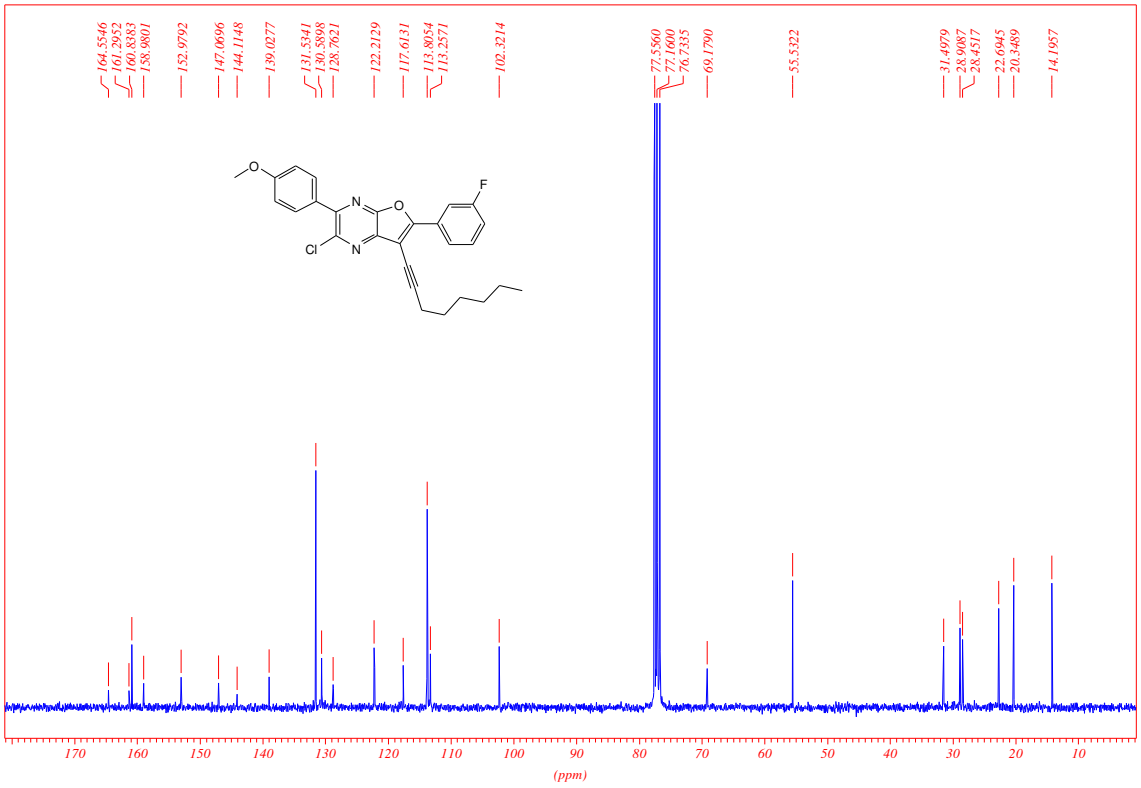
^{1}H and ^{13}C Spectra of compound 10b (300 MHz, $CDCl_3$).



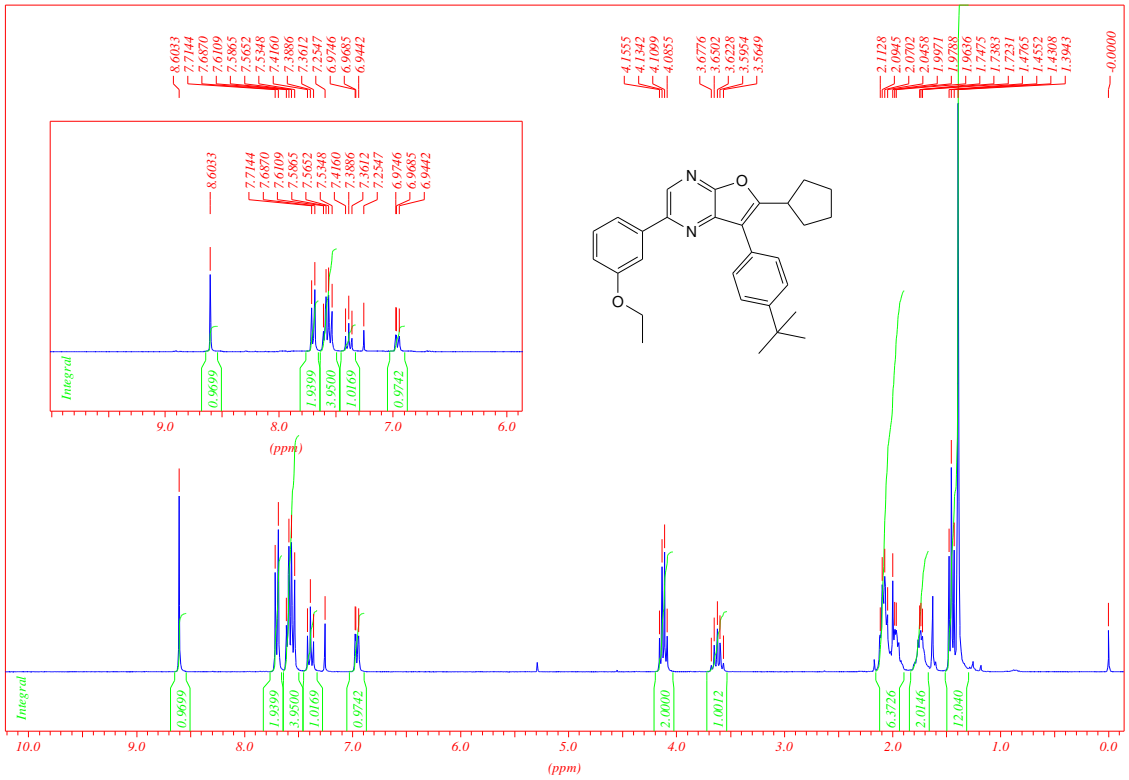


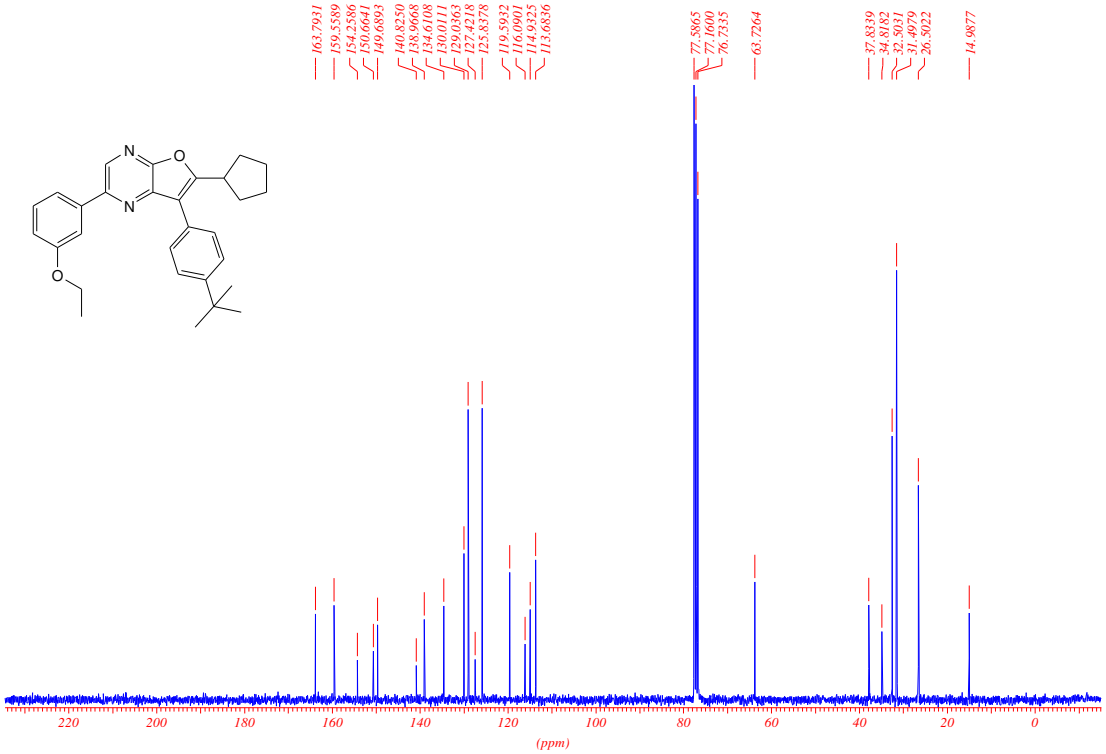
^{1}H and ^{13}C Spectra of compound 10c (300 MHz, $CDCl_3$).



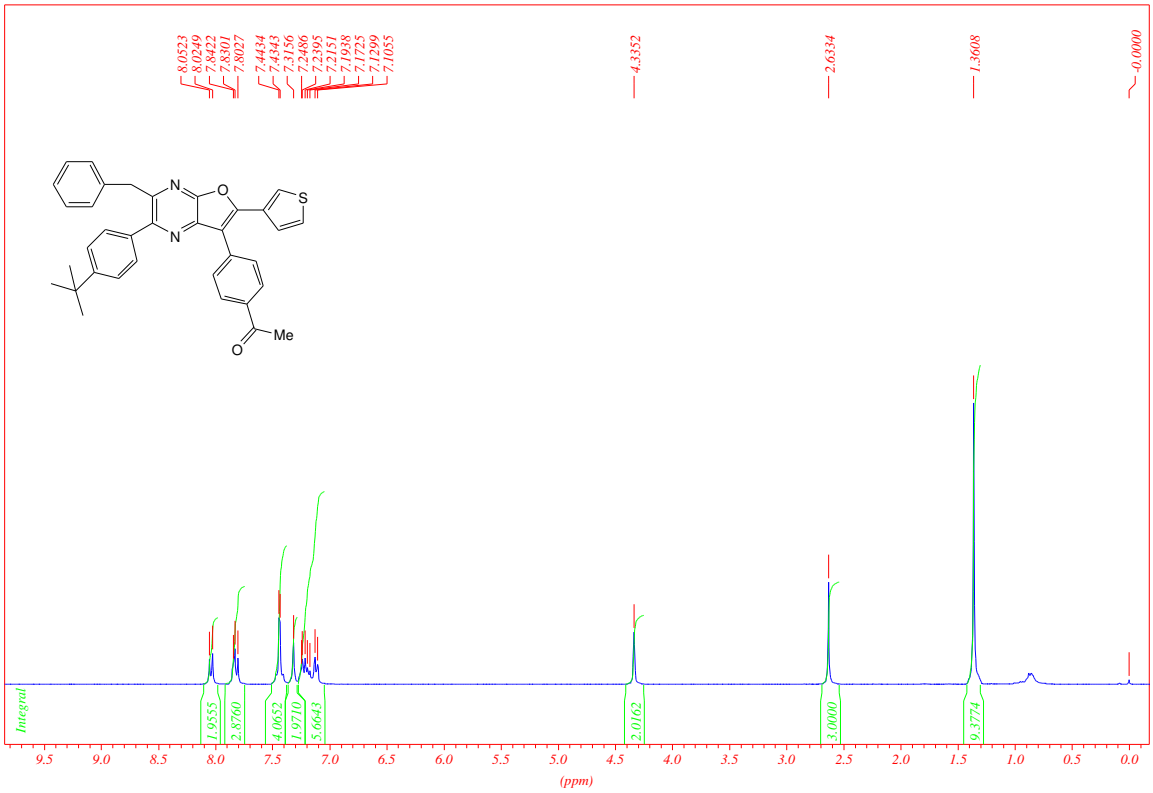


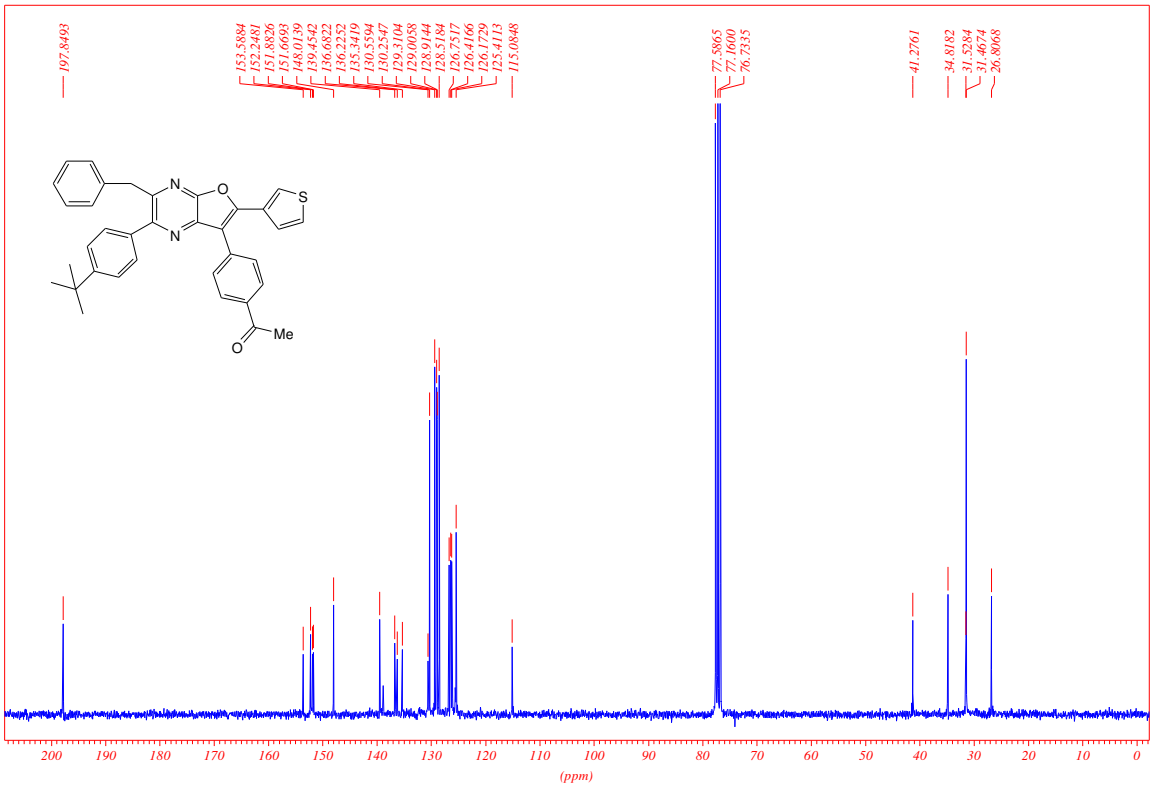
^{1}H and ^{13}C Spectra of compound 11a (300 MHz, $CDCl_3$).



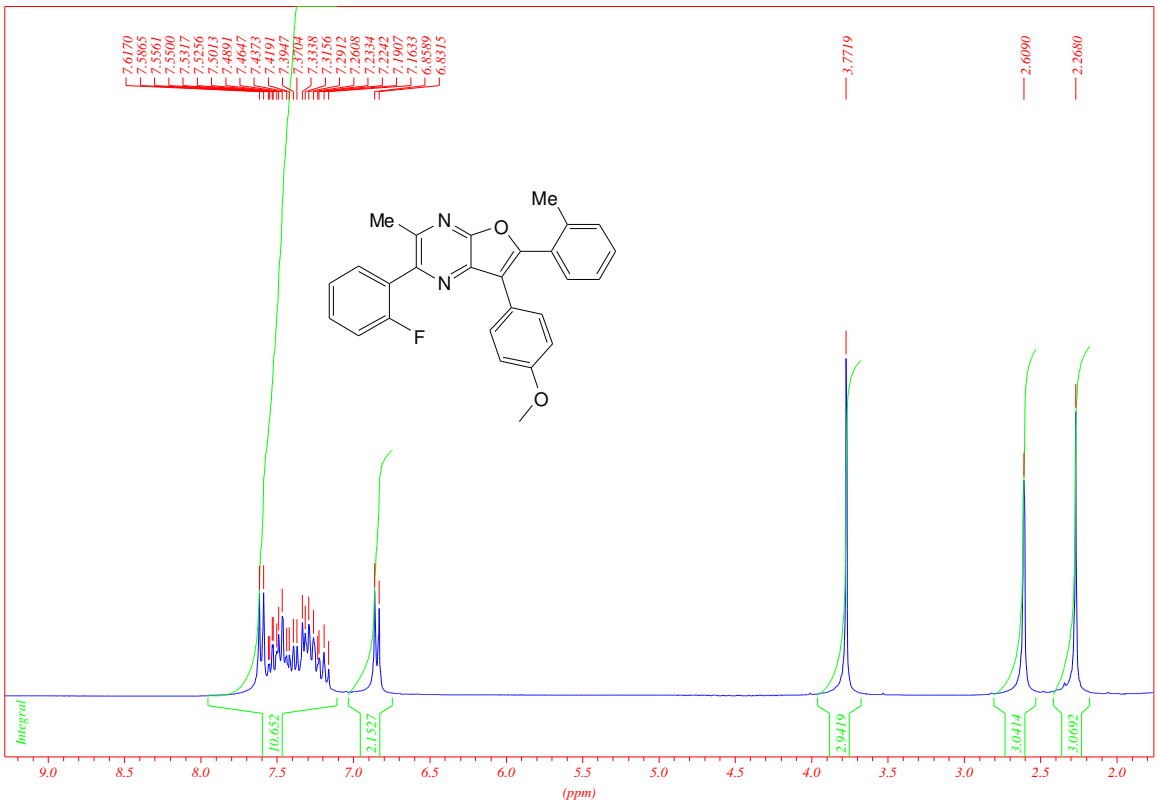


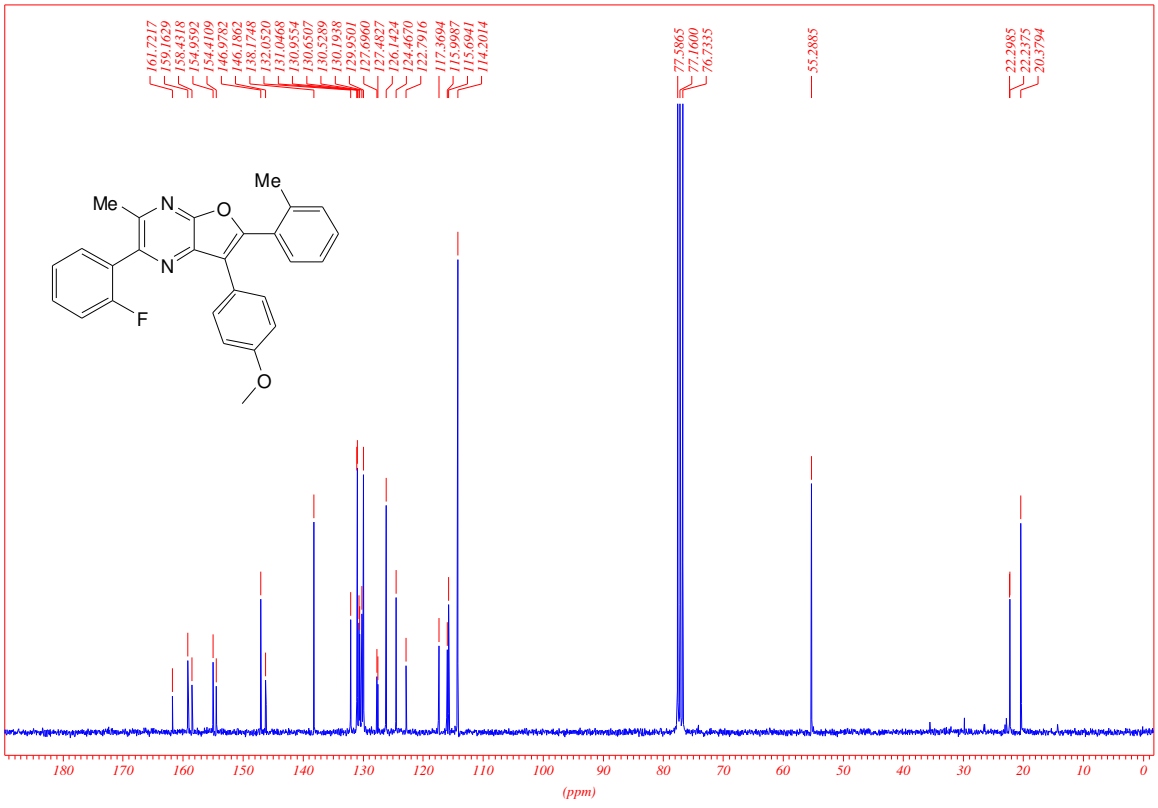
^{1}H and ^{13}C Spectra of compound 11b (300 MHz, $CDCl_3$).



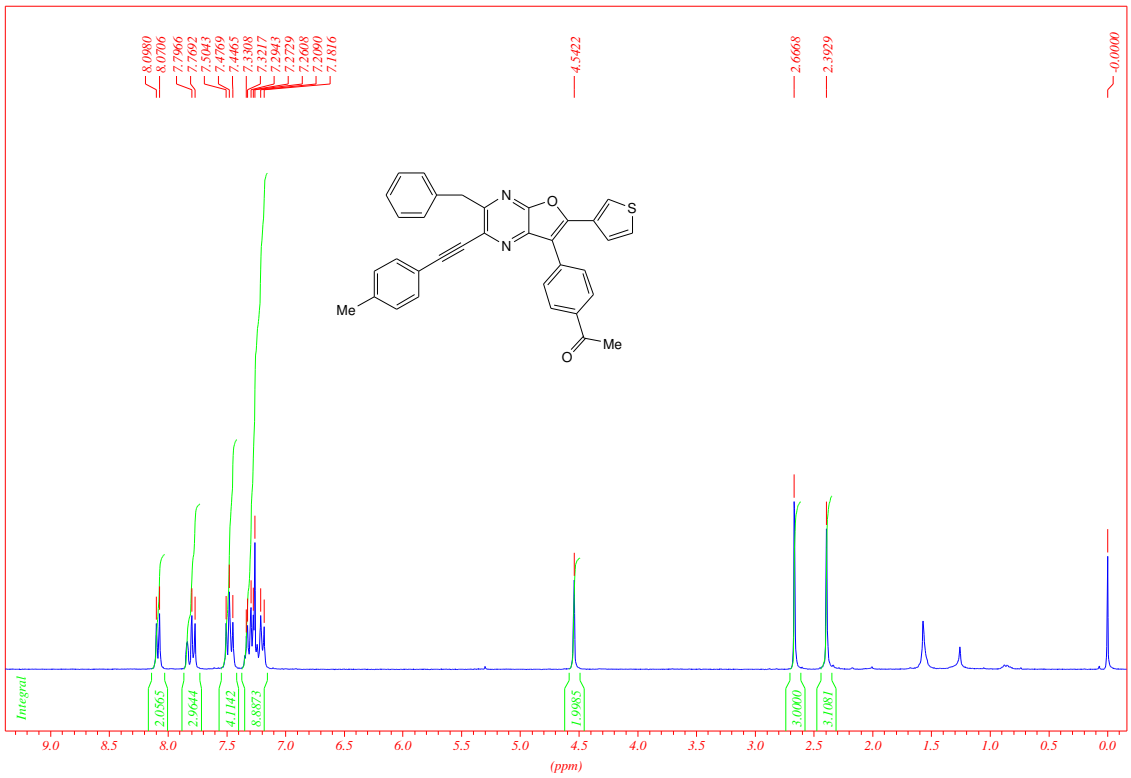


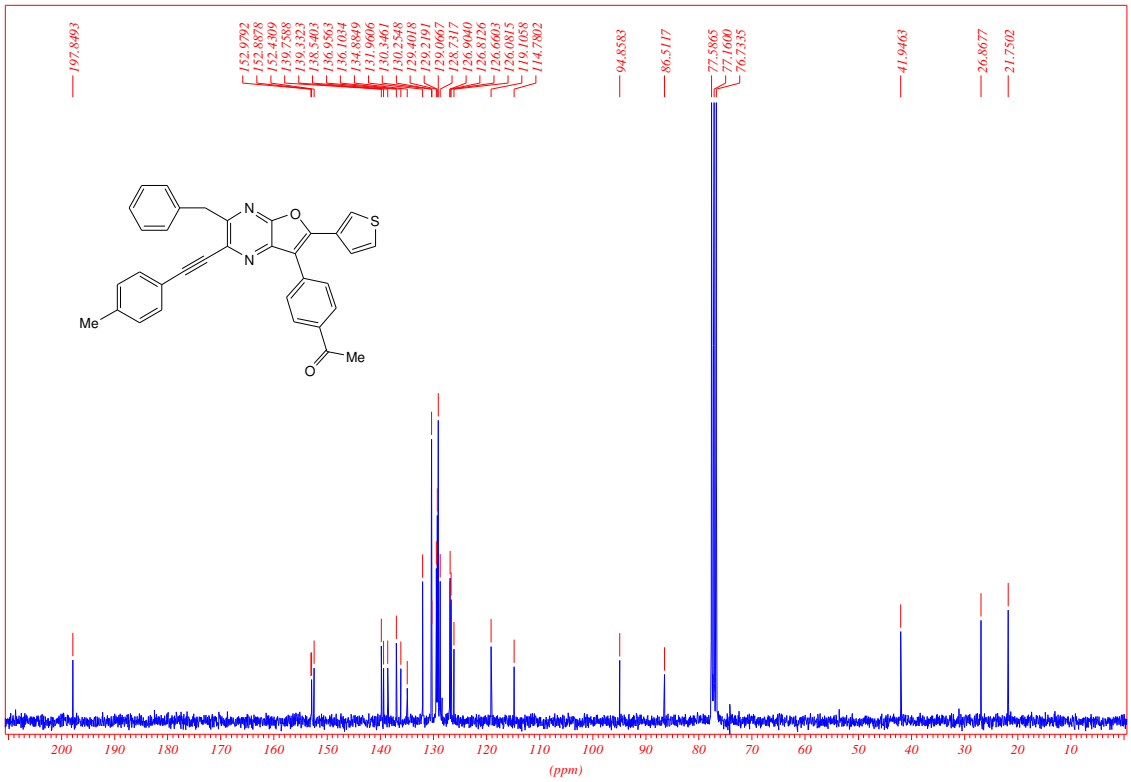
^{1}H and ^{13}C Spectra of compound 11c (300 MHz, $CDCl_3$).





^{1}H and ^{13}C Spectra of compound 11d (300 MHz, $CDCl_3$).





^{1}H and ^{13}C Spectra of compound 12a (300 MHz, $CDCl_3$).