# Supporting Information

## A productive isocyanide/$Ag_2CO_3$-promoted addition of heteroatoms to alkynes under mild condition

Jie Lei,[a] Jia Xu,[a] Ya-Fei Luo,[a] Jie Li,[a] Jing-Ya Wang,[a] Hong-yu Li,[b] Zhi-Gang Xu,*[a] Zhong-Zhu Chen*[a]

[a] College of Pharmacy, National & Local Joint Engineering Research Center of Targeted and Innovative Therapeutics, IATTI, Chongqing University of Arts and Sciences, Chongqing 402160, China. Email: 18883138277@163.com; xzg@cqwu.edu.cn
[b] Department of Pharmaceutical Sciences, College of Pharmacy, University of Arkansas for Medical Sciences, Little Rock, Arkansas 72205, USA. Email: HLi2@uams.edu

**Table of Contents** **Page**

## General Experimental

$^{1}H$ and $^{13}C$ NMR were recorded on a Bruker 400 spectrometer. $^{1}H$ NMR data are reported as follows: chemical shift in ppm (δ), multiplicity (s = singlet, d = doublet, t = triplet, m = multiplet), coupling constant (Hz), relative intensity. $^{13}C$ NMR data are reported as follows: chemical shift in ppm (δ). LC/MS analyses were performed on a Shimadzu-2020 LC-MS instrument using the following conditions: Shim-pack VP-ODS C18 column (reverse phase, 150 x 4.6 mm); a linear gradient from 10% water and 90% acetonitrile to 75% acetonitrile and 25% water over 6.0 min; flow rate of 0.5 mL/min; UV photodiode array detection from 200 to 400 nm. High-resolution mass spectra (HRMS) were recorded on Thermo Scientific Exactive Plus System. The products were purified by Biotage Isolera™ Spektra Systems and hexane/EtOAc solvent systems. All reagents and solvents were obtained from commercial sources and used without further purification.

**Table S1** Optimization of the reaction condition.[a]

| Entry | Solvent | Yield (%)[b] |
|---|---|---|
| 1 | EtOH | 93 |
| 2 | MeCN | 91 |
| 4 | $H_2O$ | 67 |
| 5 | Toluene | 39 |
| 6 | THF | <10 |
| 7 | DMF | 74 |
| 8 | DMSO | 55 |
| 9 | DCM | 84 |
| 10[c] | EtOH | 91 |

[a] Reaction condition:**1a** (0.3 mmol), 1 mol% $Ag_2CO_3$, 4 mol% *t*-BuNC, solvent (3.0 mL), room temperature, 30 min. [b] Isolated yield. [c]**1a** (0.3 mmol), 1 mol% $Ag_2CO_3$, 1.0 equiv. *t*-BuNC, solvent (3.0 mL), room temperature, 30 min.

## General procedures for condition A.

To a solution of ethanol (3.0 mL) in flask, substrate (0.3 mmol), *tert*-butyl isocyanide (4 mol%) and silver carbonate (1 mol%) were added at room temperature. And then the reaction mixture was stirred for 30 min. The reaction mixture was monitored by TLC.

When the reaction was completed, the solvent was removed under reduced pressure. Then the reaction mixture was diluted with EtOAc (15.0 mL), washed with sat. $Na_2CO_3$ and brine. The organic layer was dried over $MgSO_4$ and concentrated. The residue was purified by silica gel column chromatography using a gradient of ethyl acetate/hexane (0-100%) to afford the relative targeted product.

**General procedures for condition B.**

To a solution of ethanol (3.0 mL) in flask, substrate (0.3 mmol), *tert*-butyl isocyanide (16 mol%) and silver carbonate (3 mol%) were added at room temperature. And then, the reaction mixture was heated to 50 ℃ and stirred for 1 h. The reaction mixture was monitored by TLC. When the reaction was completed, the solvent was removed under reduced pressure. Then the reaction mixture was diluted with EtOAc (15.0 mL), washed with sat. $Na_2CO_3$ and brine. The organic layer was dried over $MgSO_4$ and concentrated. The residue was purified by silica gel column chromatography using a gradient of ethyl acetate/hexane (0-100%) to afford the relative targeted product.

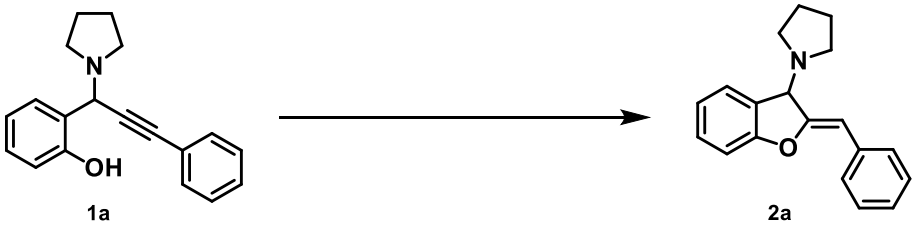
**General procedure for compound 19**

In a solution of compound **2l** (0.2 mmol) in DCE (3.0 mL), $BF_3 \cdot Et_2O$ (1.5 equiv) was added and stirred at room temperature for 2 h. When the reaction was completed, the reaction mixture was diluted with EtOAc (15.0 mL), washed with brine. The organic layer was dried over $MgSO_4$ and concentrated. The residue was purified by silica gel column chromatography using a gradient of ethyl acetate/hexane (0-100%) to afford the targeted product **19** in 73% yield.

**General procedure for compound 21**

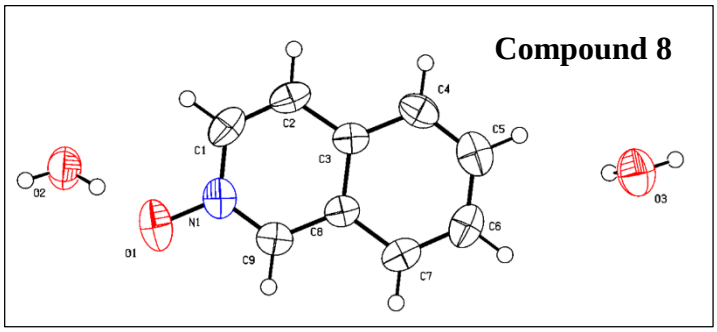
A mixture of **2l** (0.2 mmol) and **20** (0.3 mmol) was added to the solvent of PhCl (2.0 mL) in an oven dried reaction tube. Then $ZnI_2$ (20 mol%) was added to it and heated with microwave irradiation at 100 ℃ for 10 min. After the completion of the reaction, the reaction was cooled to room temperature an extracted with dichloromethane. The organic phase was dried over anhydrous $Na_2SO_4$. The crude residue was obtained after evaporating the solvent under vacuum; it was purified by column chromatography on a silica gel using a a gradient of ethyl acetate/hexane (0-100%) to afford the pure product **21** (51%) as a white solid.

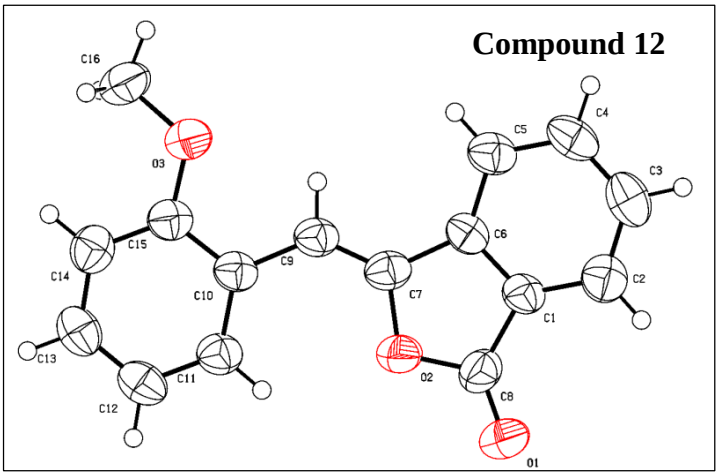
## Control experiments




| | Reaction Conditions | Yield % of **2a** |
|---|---|---|
| 1 | AgOAc (2 mol%), *t*-BuNC (8 mol%), EtOH, r.t., 30 min. | N/D |
| 2 | AgOAc (2 mol%), *t*-BuNC (8 mol%), $K_2CO_3$ (16 mol%), EtOH, r.t., 30 min. | 91% |
| 3 | $K_2CO_3$ (16 mol%), EtOH, r.t., 30 min. | N/D |
| 4 | $[Ag(t\text{-BuNC})_4]ClO_4$, EtOH, r.t., 30 min. | N/D |
| 5 | $[Ag(c\text{-HexNC})_2]ClO_4$, EtOH, r.t., 30 min. | N/D |
| 6 | $Ag_2CO_3$ (1 mol%), *t*-BuNC (4 mol%), TEMPO (2.0 equiv.), EtOH, r.t., 30 min. | 87% |
| 7 | $Ag_2CO_3$ (1 mol%), *t*-BuNC (4 mol%), BHT (2.0 equiv.), EtOH, r.t., 30 min. | 89% |
| 8 | Ag power (2 mol%), *t*-BuNC (8 mol%), EtOH, r.t., 30 min. | N/D |

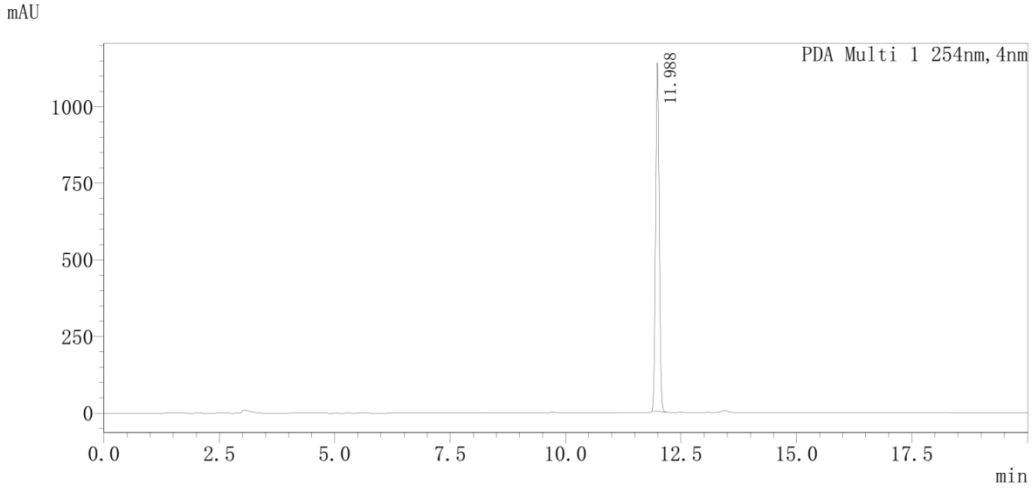
## X-ray structures of compound 8 and 12



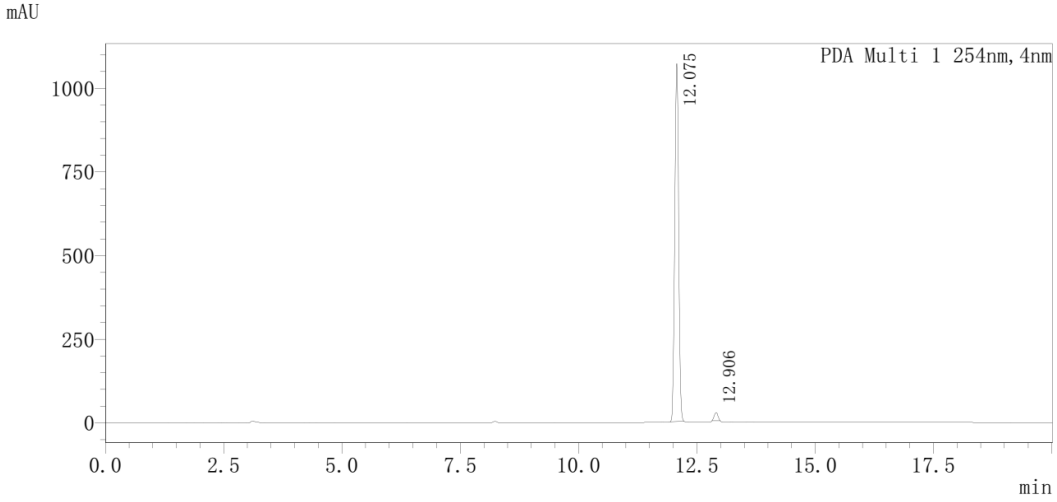



## HPLC conversion of yield and time

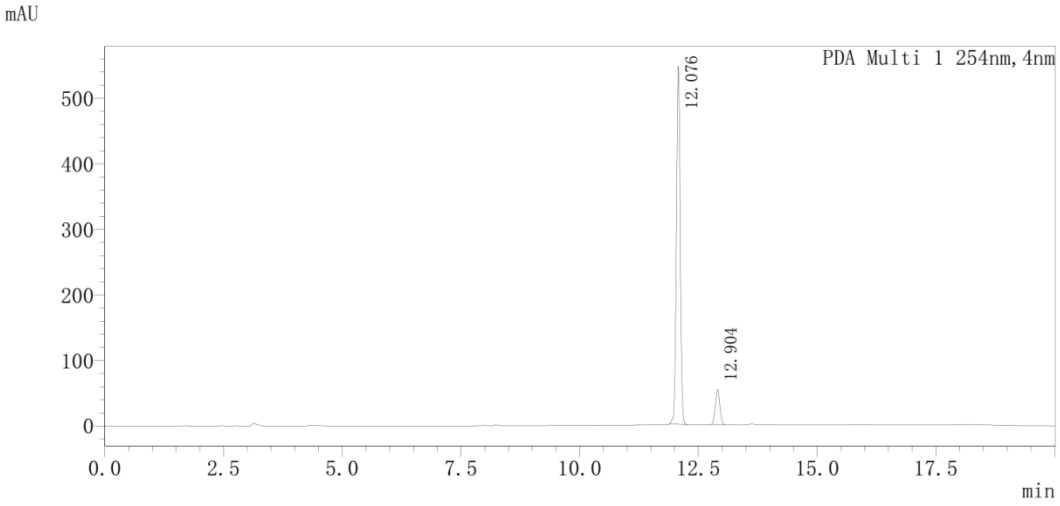
t = 5 min ($Ag_2CO_3$ and isocyanide were added)



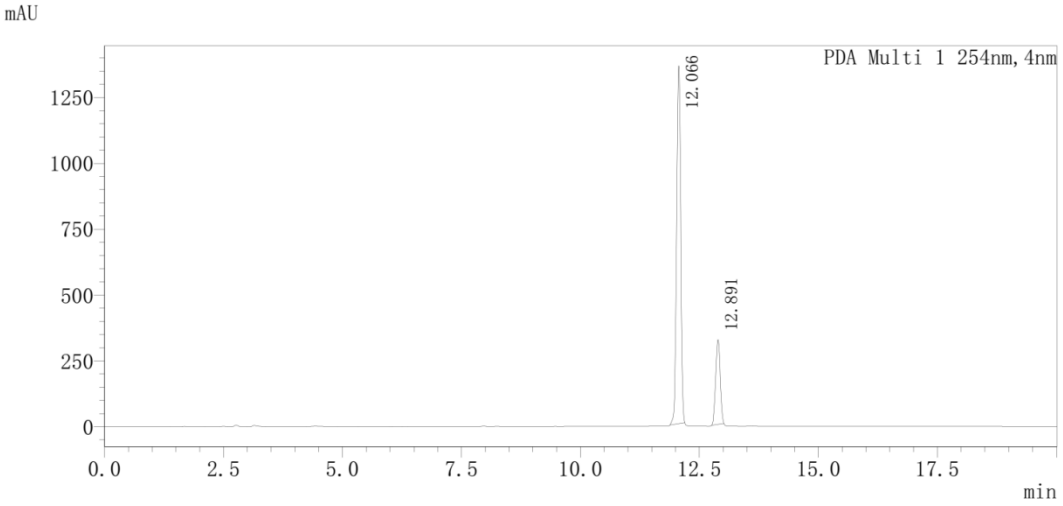

t = 6 min



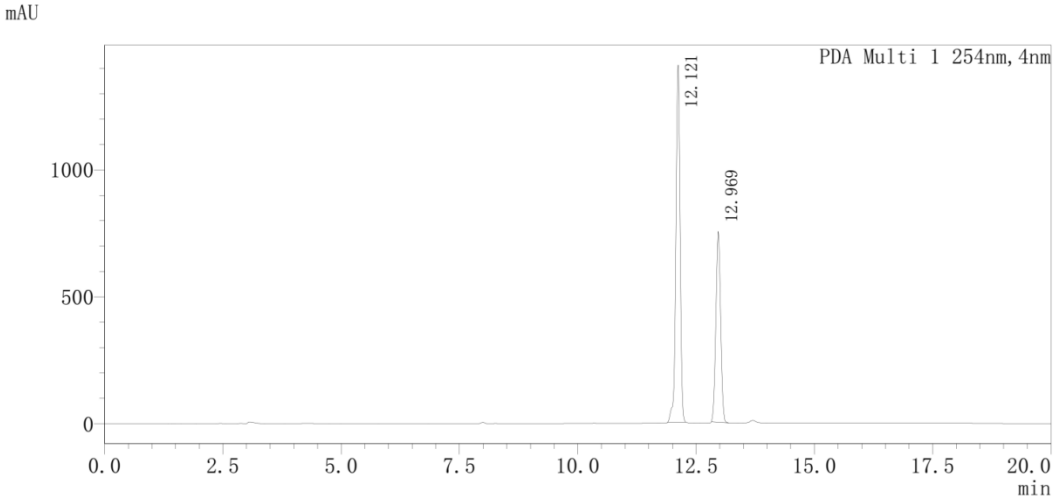

t = 8 min



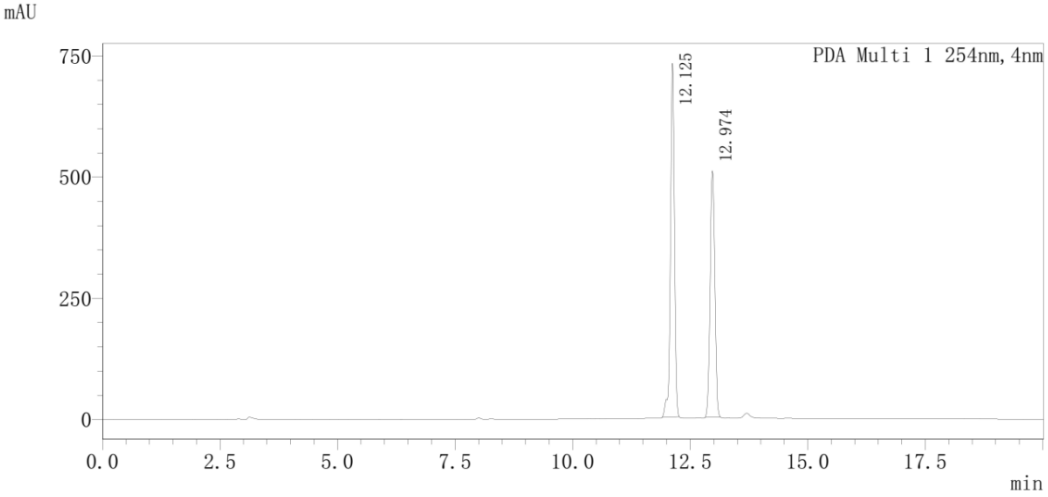
t = 10 min



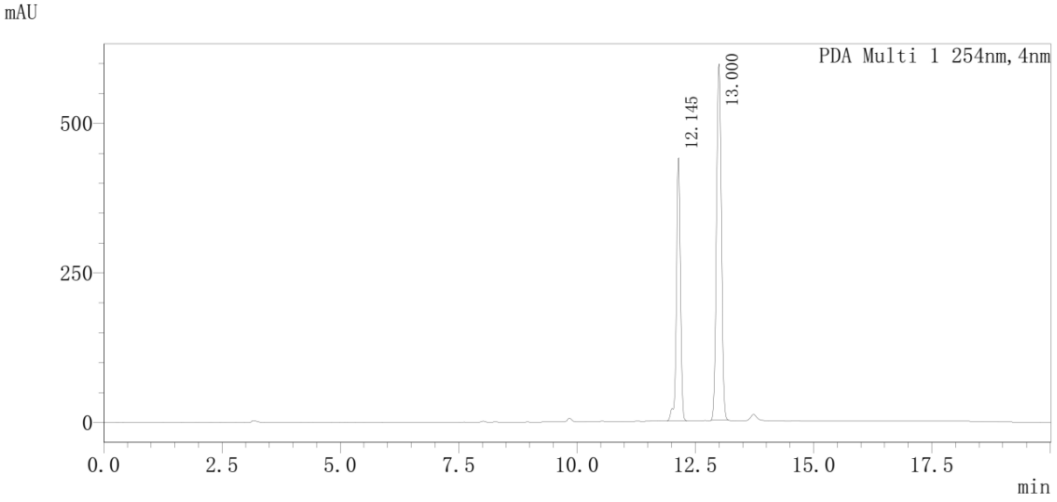

t = 15 min



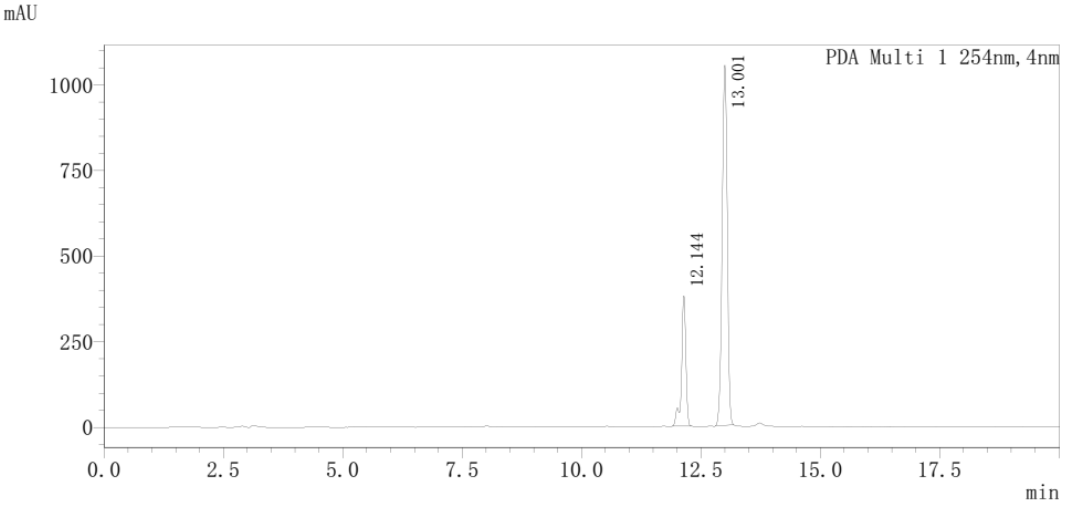

t = 17 min



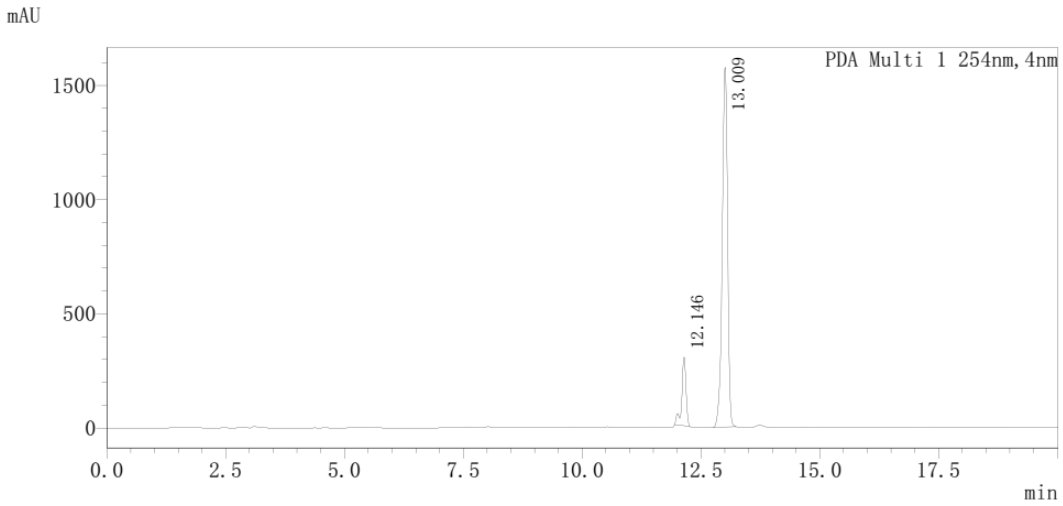
t = 20 min



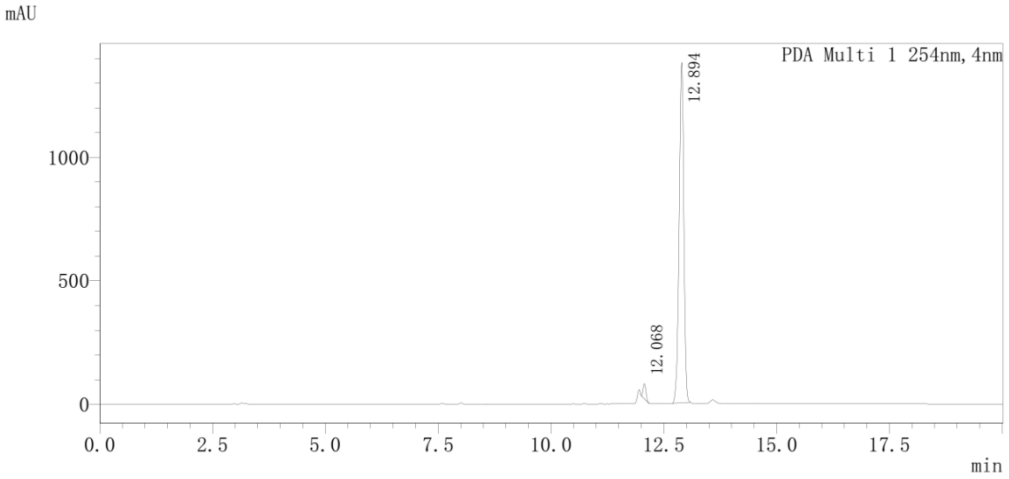

t = 24 min



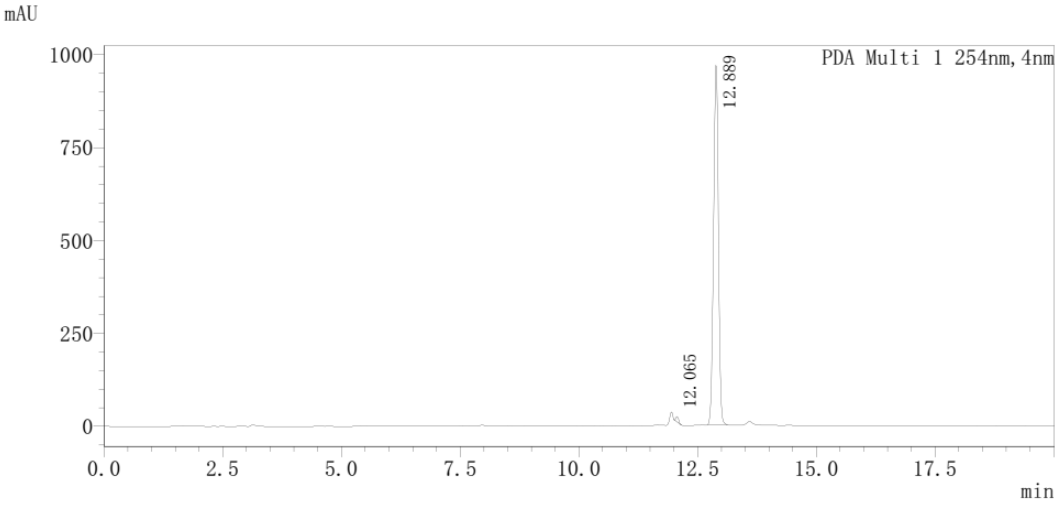

t = 27 min



t = 29 min

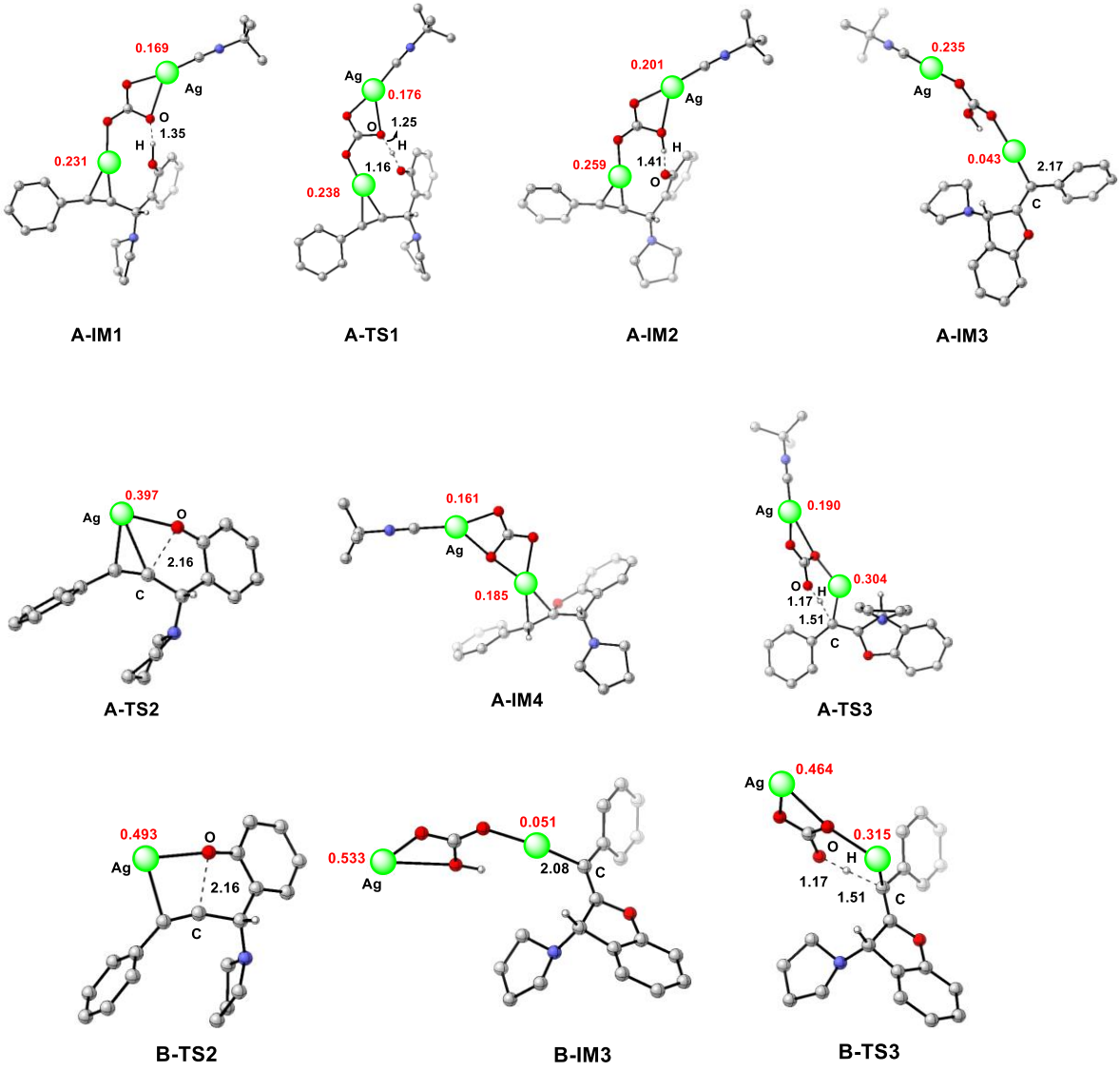



t = 30 min



## Density functional theory (DFT) calculations

Optimized structures




## Computational details

All calculations were performed using Gaussian 16 program package,[1] employing the B3LYP-D3(BJ)[2] density functional with the def2-SVP basis set. Geometries were optimized in toluene solvent and characterized by frequency analysis at 298.15K. Unless specified, the Gibbs free energies obtained at the B3LYP-D3(BJ)/def2-SVP (SMD, toluene) level at 298.15K were used in the discussion. The optimized molecular structures were visualized by CYLview (2.0 version) software.[3]

[1] M. J. Frisch, G. W. Trucks, H. B. Schlegel, G. E. Scuseria, M. A. Robb, J. R. Cheeseman, G. Scalmani, V. Barone, G. A. Petersson, H. Nakatsuji, X. Li, M. Caricato, A. V. Marenich, J. Bloino, B. G. Janesko, R. Gomperts, B. Mennucci, H. P. Hratchian, J. V. Ortiz, A. F. Izmaylov, J. L. Sonnenberg, D. Williams-Young, F. Ding, F. Lipparini, F. Egidi, J. Goings, B. Peng, A. Petrone, T. Henderson, D. Ranasinghe, V. G. Zakrzewski, J. Gao, N. Rega, G. Zheng, W. Liang, M. Hada, M. Ehara, K. Toyota, R. Fukuda, J. Hasegawa, M. Ishida, T. Nakajima, Y. Honda, O. Kitao, H. Nakai, T. Vreven, K. Throssell, J. A. Montgomery, Jr., J. E. Peralta, F. Ogliaro, M. J. Bearpark, J. J. Heyd, E. N. Brothers, K. N. Kudin, V. N. Staroverov, T. A. Keith, R. Kobayashi, J. Normand, K. Raghavachari, A. P. Rendell, J. C. Burant, S. S. Iyengar, J. Tomasi, M. Cossi, J. M. Millam, M. Klene, C. Adamo, R. Cammi, J. W. Ochterski, R. L. Martin, K. Morokuma, O. Farkas, J. B. Foresman, and D. J. Fox, Gaussian, Inc., Wallingford CT, 2016.

[2] Grimme, S.; Antony, J.; Ehrlich, S.; Krieg, H. A Consistent and Accurate Ab Initio Parametrization of Density Functional Dispersion Correction (DFT-D) for the 94 Elements H-Pu. *J. Chem. Phys.* **2010**, *132 (15)*, 154104.

[3] CYLview20; Legault, C. Y., Université de Sherbrooke, 2020 (http://www.cylview.org)

**Table S2** The ZPE-correct electronic energies ($E_{ZPE}$), enthalpies ($H$), and Gibbs free energies ($G$) for all stationary points (in Hartree), obtained at the B3LYP-D3(BJ)/def2-SVP theoretical level.

| Structures | [a]*ZPE* | [b]*Hc* | [c]*Gc* | $E_{ZPE}$ | *H* | *G* |
|---|---|---|---|---|---|---|
| **A-IM1** | 0.481562 | 0.517834 | 0.402703 | -1672.61641 | -1672.580139 | -1672.695269 |
| **A-TS1** | 0.479467 | 0.51525 | 0.401713 | -1672.618426 | -1672.582642 | -1672.69618 |
| **A-IM2** | 0.48193 | 0.518144 | 0.4045 | -1672.61718 | -1672.580966 | -1672.694611 |
| **A-TS2** | 0.480922 | 0.516996 | 0.391247 | -1672.522646 | -1672.486573 | -1672.612322 |
| **A-IM3** | 0.484819 | 0.520658 | 0.406037 | -1672.616147 | -1672.580308 | -1672.694929 |
| **A-TS3** | 0.479787 | 0.515056 | 0.40299 | -1672.589316 | -1672.554046 | -1672.666112 |
| **A-IM4** | 0.485134 | 0.520645 | 0.408011 | -1672.625899 | -1672.590388 | -1672.703022 |
| **B-TS2** | 0.349284 | 0.375564 | 0.280078 | -1422.078959 | -1422.052679 | -1422.148165 |
| **B-IM3** | 0.353078 | 0.380063 | 0.288941 | -1422.167279 | -1422.140294 | -1422.231416 |
| **B-TS3** | 0.348384 | 0.374658 | 0.286219 | -1422.149840 | -1422.123566 | -1422.212005 |

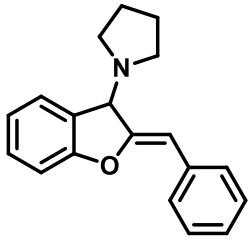
[a] Zero-point correction energy;

[b] Thermal correction to enthalpy;

[c] Thermal correction to Gibbs free energy.

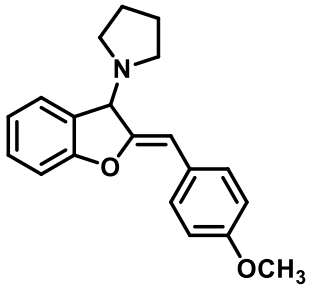
## NMR Characterization Data and Figures of Products

*(Z)-1-(2-benzylidene-2,3-dihydrobenzofuran-3-yl)pyrrolidine*



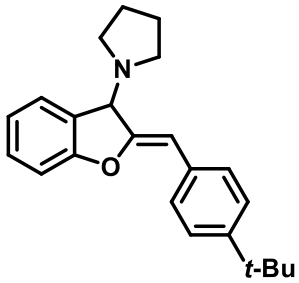

**2a**, 93%, white solid, mp. = 109-110 ℃, (EA/Hex = 10%, $R_f$ = 0.20). $^1$H NMR (400 MHz, $CDCl_3$) δ 7.72 (d, *J* = 7.9 Hz, 2H), 7.42 (d, *J* = 7.4 Hz, 1H), 7.36 (td, *J* = 7.9, 1.4 Hz, 2H), 7.32 – 7.27 (m, 1H), 7.20 (t, *J* = 7.4 Hz, 1H), 7.07 – 6.98 (m, 2H), 5.83 (s, 1H), 5.16 (s, 1H), 2.81 – 2.52 (m, 4H), 1.74 (s, 4H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ 158.18, 154.71, 135.12, 129.40, 128.47, 128.39, 126.23, 126.09, 125.54, 122.06, 110.16, 105.52, 63.78, 48.07, 23.36. HRMS (ESI) m/z calcd for $C_{19}H_{20}NO^+$ $(M+H)^+$ 278.1539, found 278.1548.

*(Z)-1-(2-(4-methoxybenzylidene)-2,3-dihydrobenzofuran-3-yl)pyrrolidine*



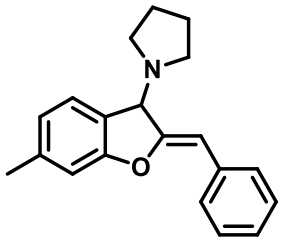

**2b**, 98%, white solid, mp. = 107-108 ℃, (EA/Hex = 10%, $R_f$ = 0.20). $^1$H NMR (400 MHz, $CDCl_3$) δ 7.66 (d, *J* = 8.8 Hz, 2H), 7.41 (d, *J* = 7.4 Hz, 1H), 7.28 (dd, *J* = 11.0, 3.5 Hz, 1H), 7.01 (dd, *J* = 15.2, 7.7 Hz, 2H), 6.93 – 6.89 (m, 2H), 5.77 (d, *J* = 1.1 Hz, 1H), 5.13 (s, 1H), 3.82 (s, 3H), 2.75 (dd, *J* = 9.3, 3.1 Hz, 2H), 2.61 (dd, *J* = 9.3, 3.1 Hz, 2H), 1.74 (t, *J* = 6.2 Hz, 4H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ 158.24, 158.01, 153.02, 129.69, 129.32, 127.96, 126.09, 125.69, 121.89, 113.83, 110.08, 105.13, 63.69, 55.31, 48.05, 23.33. HRMS (ESI) m/z calcd for $C_{20}H_{22}NO_2^+$ $(M+H)^+$ 308.1645, found 308.1645.

*(Z)-1-(2-(4-(tert-butyl)benzylidene)-2,3-dihydrobenzofuran-3-yl)pyrrolidine*



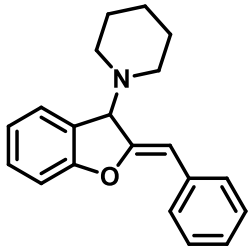

**2c**, 95%, white solid, mp. = 110-111 ℃, (EA/Hex =5%, $R_f$ = 0.20). $^1$H NMR (400 MHz, $CDCl_3$) δ 7.67 (d, *J* = 8.4 Hz, 2H), 7.41 (t, *J* = 7.4 Hz, 3H), 7.32 – 7.24 (m, 1H), 7.01 (dd, *J* = 14.7, 7.6 Hz, 2H), 5.82 (s, 1H), 5.15 (s, 1H), 2.82 – 2.56 (m, 4H), 1.74 (d, *J* = 6.1 Hz, 4H), 1.33 (s, 9H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ 158.24, 154.14, 149.21, 132.30, 129.35, 128.19, 126.08, 125.69, 125.32, 121.95, 110.12, 105.35, 63.71, 48.02, 34.56, 31.35, 23.34. HRMS (ESI) m/z calcd for $C_{23}H_{28}NO^+$ $(M+H)^+$ 334.2165, found 334.2169.

*(Z)-1-(2-benzylidene-6-methyl-2,3-dihydrobenzofuran-3-yl)pyrrolidine*



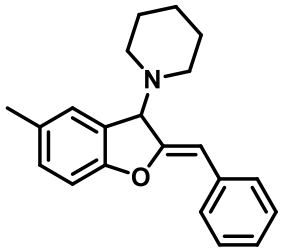

**2d**, 98%, white solid, mp. = 106-107 ℃, (EA/Hex = 15%, $R_f$ = 0.20). $^1$H NMR (400 MHz, $CDCl_3$) δ 7.71 (d, *J* = 7.6 Hz, 2H), 7.35 (t, *J* = 7.7 Hz, 2H), 7.29 (d, *J* = 7.5 Hz, 1H), 7.19 (t, *J* = 7.4 Hz, 1H), 6.88 (s, 1H), 6.83 (d, *J* = 7.5 Hz, 1H), 5.81 (s, 1H), 5.13 (s, 1H), 2.68 (dd, *J* = 55.9, 5.7 Hz, 4H), 2.37 (s, 3H), 1.74 (s, 4H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ 158.43, 155.26, 135.24, 128.37, 126.15, 125.67, 122.82, 110.80, 105.30, 63.65, 48.04, 23.35, 21.67. HRMS (ESI) m/z calcd for $C_{20}H_{22}NO^+$ $(M+H)^+$ 292.1696, found 292.1696.

*(Z)-1-(2-benzylidene-2,3-dihydrobenzofuran-3-yl)piperidine*



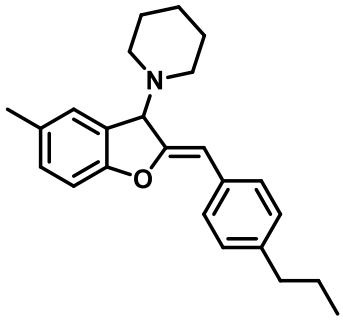
**2e**, 91%, white solid, mp. = 108-109 ℃, (EA/Hex = 15%, $R_f$ = 0.20). $^1$H NMR (400 MHz, $CDCl_3$) δ 7.73 (d, *J* = 7.8 Hz, 2H), 7.42 (d, *J* = 7.2 Hz, 1H), 7.37 (t, *J* = 7.7 Hz, 2H), 7.31 – 7.24 (m, 2H), 7.20 (t, *J* = 7.4 Hz, 1H), 7.02 (dd, *J* = 12.4, 5.0 Hz, 2H), 5.86 (d, *J* = 1.2 Hz, 1H), 4.97 (s, 1H), 2.69 (dt, *J* = 10.6, 5.3 Hz, 2H), 2.48 (dt, *J* = 10.5, 5.2 Hz, 2H), 1.54 (dd, *J* = 11.1, 5.7 Hz, 4H), 1.40 (dt, *J* = 11.9, 6.0 Hz, 2H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ 158.24, 154.76, 135.30, 129.28, 128.40, 126.14, 125.32, 122.00, 110.04, 104.94, 68.73, 49.71, 26.50, 24.49. HRMS (ESI) m/z calcd for $C_{20}H_{22}NO^+$ $(M+H)^+$ 292.1696, found 292.1698.

*(Z)-1-(2-benzylidene-5-methyl-2,3-dihydrobenzofuran-3-yl)piperidine*



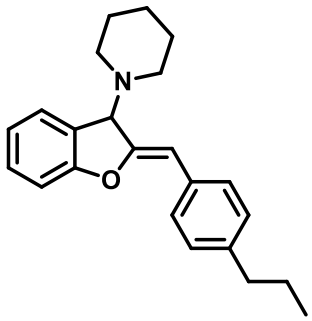
**2f**, 92%, white solid, mp. = 109-110 ℃, (EA/Hex = 10%, $R_f$ = 0.20). $^1$H NMR (400 MHz, $CDCl_3$) δ 7.72 (d, *J* = 7.9 Hz, 2H), 7.36 (t, *J* = 7.6 Hz, 2H), 7.20 (dd, *J* = 13.9, 6.5 Hz, 2H), 7.06 (d, *J* = 8.1 Hz, 1H), 6.91 (d, *J* = 8.1 Hz, 1H), 5.83 (s, 1H), 4.93 (s, 1H), 2.68 (dt, *J* = 10.4, 5.1 Hz, 2H), 2.55 – 2.44 (m, 2H), 2.35 (s, 3H), 1.61 – 1.51 (m, 4H), 1.40 (t, *J* = 10.0 Hz, 2H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ 156.18, 155.11, 135.40, 131.37, 129.72, 128.36, 126.56, 126.02, 125.2, 109.52, 104.67, 68.85, 49.68, 26.49, 24.48, 21.03. HRMS (ESI) m/z calcd for $C_{21}H_{24}NO^+$ $(M+H)^+$ 306.1852, found 306.1855.

*(Z)-1-(5-methyl-2-(4-propylbenzylidene)-2,3-dihydrobenzofuran-3-yl)piperidine*



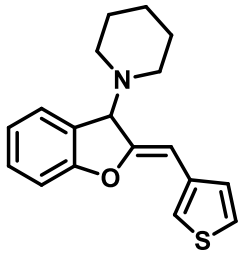
**2g**, 95%, white solid, mp. = 121-122 ℃, (EA/Hex = 10%, $R_f$ = 0.25). $^1$H NMR (400 MHz, $CDCl_3$) δ 7.63 (d, *J* = 8.1 Hz, 2H), 7.22 (s, 1H), 7.17 (d, *J* = 8.0 Hz, 2H), 7.06 (d, *J* = 8.1 Hz, 1H), 6.90 (d, *J* = 8.1 Hz, 1H), 5.81 (s, 1H), 4.92 (s, 1H), 2.67 (dt, *J* = 10.5, 5.1 Hz, 2H), 2.58 (t, *J* = 7.6 Hz, 2H), 2.47 (dt, *J* = 10.4, 5.0 Hz, 2H), 2.34 (s, 3H), 1.64 (dd, *J* = 15.0, 7.5 Hz, 2H), 1.58 – 1.50 (m, 4H), 1.44 – 1.37 (m, 2H), 0.95 (t, *J* = 7.3 Hz, 3H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ 156.25, 154.32, 140.64, 132.78, 131.25, 129.69, 128.51, 128.27, 126.57, 125.27, 109.50, 104.73, 68.75, 49.62, 37.86, 26.47, 24.63, 24.48, 21.05, 13.89. HRMS (ESI) m/z calcd for $C_{24}H_{30}NO^+$ $(M+H)^+$ 348.2322, found 348.2329.

*(Z)-1-(2-(4-propylbenzylidene)-2,3-dihydrobenzofuran-3-yl)piperidine*



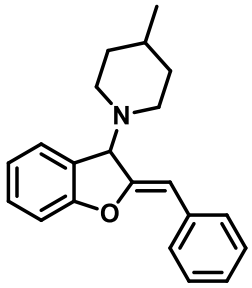

**2h**, 97%, white solid, mp. = 119-120 ℃, (EA/Hex = 10%, $R_f$ = 0.25). $^1$H NMR (400 MHz, $CDCl_3$) δ 7.64 (d, *J* = 8.0 Hz, 2H), 7.41 (d, *J* = 7.3 Hz, 1H), 7.30 – 7.22 (m, 1H), 7.18 (d, *J* = 8.0 Hz, 2H), 7.05 – 6.97 (m, 2H), 5.84 (s, 1H), 4.96 (s, 1H), 2.68 (dt, *J* = 10.5, 5.2 Hz, 2H), 2.59 (t, *J* = 7.6 Hz, 2H), 2.47 (dt, *J* = 10.5, 5.0 Hz, 2H), 1.65 (dd, *J* = 15.0, 7.5 Hz, 2H), 1.58 – 1.50 (m, 4H), 1.40 (dd, *J* = 11.1, 5.6 Hz, 2H), 0.95 (t, *J* = 7.3 Hz, 3H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ 158.22, 153.99, 140.74, 132.70, 129.24, 128.53, 128.33, 126.13, 125.39, 121.89, 110.01, 104.98, 68.65, 49.67, 37.87, 26.49, 24.61, 24.51, 13.88. HRMS (ESI) m/z calcd for $C_{23}H_{28}NO^+$ $(M+H)^+$ 334.2165, found 334.2169.

*(Z)-1-(2-(thiophen-3-ylmethylene)-2,3-dihydrobenzofuran-3-yl)piperidine*



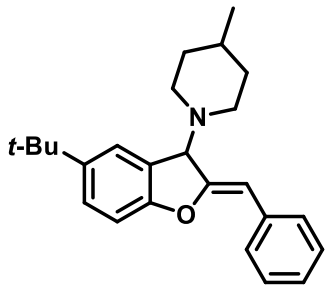
**2i**, 91%, white solid, mp. = 107-108 ℃, (EA/Hex = 15%, $R_f$ = 0.25). $^1$H NMR (400 MHz, $CDCl_3$) δ 7.53 (d, *J* = 1.7 Hz, 1H), 7.47 – 7.38 (m, 2H), 7.31 – 7.25 (m, 2H), 7.05 – 6.97 (m, 2H), 5.95 (d, *J* = 1.6 Hz, 1H), 4.96 (s, 1H), 2.73 – 2.62 (m, 2H), 2.53 – 2.40 (m, 2H), 1.54 (d, *J* = 3.7 Hz, 4H), 1.41 (d, *J* = 5.4 Hz, 2H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ 158.04, 153.81, 135.95, 129.28, 128.51, 126.18, 125.56, 124.81, 121.97, 109.98, 99.77, 68.23, 49.69, 26.48, 24.48. HRMS (ESI) m/z calcd for $C_{18}H_{20}NOS^+$ $(M+H)^+$ 298.1260, found 298.1260.

*(Z)-1-(2-benzylidene-2,3-dihydrobenzofuran-3-yl)-4-methylpiperidine*



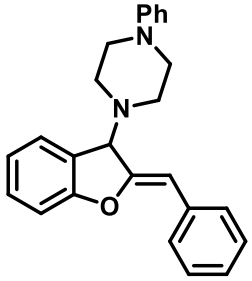
**2j**, 90%, white solid, mp. = 107-108 ℃, (EA/Hex = 5%, $R_f$ = 0.20). $^1$H NMR (400 MHz, $CDCl_3$) δ 7.72 (d, *J* = 7.5 Hz, 2H), 7.44 – 7.34 (m, 3H), 7.31 – 7.24 (m, 1H), 7.20 (t, *J* = 7.4 Hz, 1H), 7.07 – 6.99 (m, 2H), 5.85 (d, *J* = 1.3 Hz, 1H), 5.00 (s, 1H), 2.79 (dd, *J* = 18.2, 11.7 Hz, 2H), 2.58 (td, *J* = 11.2, 2.4 Hz, 1H), 2.21 (td, *J* = 11.1, 2.3 Hz, 1H), 1.66 – 1.54 (m, 3H), 1.36 – 1.23 (m, 2H), 0.89 (d, *J* = 6.2 Hz, 3H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ 158.12, 154.76, 135.28, 129.29, 128.42, 126.14, 125.33, 122.00, 110.06, 104.97, 68.35, 49.57, 48.47, 34.90, 30.88, 21.96. HRMS (ESI) m/z calcd for $C_{21}H_{24}NO^+$ $(M+H)^+$ 306.1852, found 306.1859.

*(Z)-1-(2-benzylidene-5-(tert-butyl)-2,3-dihydrobenzofuran-3-yl)-4-methylpiperidine*



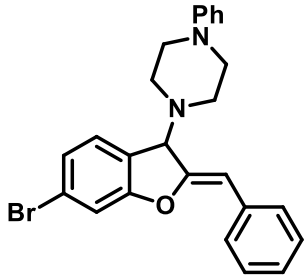

**2k**, 93%, white solid, mp. = 116-117 ℃, (EA/Hex = 5%, $R_f$ = 0.25). $^1$H NMR (400 MHz, $CDCl_3$) δ 7.72 (d, *J* = 7.3 Hz, 2H), 7.41 (d, *J* = 1.9 Hz, 1H), 7.36 (t, *J* = 7.7 Hz, 2H), 7.29 (dd, *J* = 8.4, 2.0 Hz, 1H), 7.19 (t, *J* = 7.4 Hz, 1H), 6.94 (d, *J* = 8.4 Hz, 1H), 5.82 (d, *J* = 1.4 Hz, 1H), 4.98 (s, 1H), 2.79 (dd, *J* = 14.2, 11.0 Hz, 2H), 2.56 (td, *J* = 11.1, 2.3 Hz, 1H), 2.27 – 2.16 (m, 1H), 1.64 – 1.55 (m, 3H), 1.33 (s, 9H), 1.25 (s, 2H), 0.90 (d, *J* = 6.3 Hz, 3H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ 155.35, 135.44, 128.36, 126.00, 124.88, 122.94, 109.1, 104.68, 68.60, 49.59, 48.55, 34.92, 34.74, 31.74, 30.91, 29.72. HRMS (ESI) m/z calcd for $C_{25}H_{32}NO^+$ $(M+H)^+$ 362.2478, found 362.2480.

*(Z)-1-(2-benzylidene-2,3-dihydrobenzofuran-3-yl)-4-phenylpiperazine*



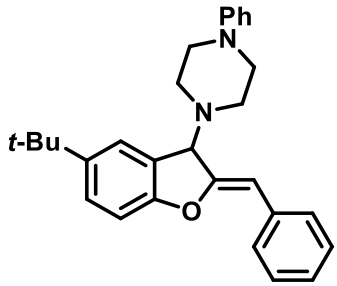

**2l**, 97%, white solid, mp. = 118-119 ℃, (EA/Hex = 10%, $R_f$ = 0.30). $^1$H NMR (400 MHz, $CDCl_3$) δ 7.73 (d, *J* = 7.5 Hz, 2H), 7.73 (d, *J* = 7.5 Hz, 2H), 7.45 (d, *J* = 7.4 Hz, 1H), 7.37 (t, *J* = 7.7 Hz, 2H), 7.30 (t, *J* = 7.5 Hz, 1H), 7.27 – 7.19 (m, 4H), 7.16 – 6.99 (m, 2H), 7.10 – 7.01 (m, 2H), 6.90 (d, *J* = 7.9 Hz, 2H), 6.99 – 6.79 (m, 3H), 6.84 (t, *J* = 7.3 Hz, 1H), 5.90 (d, *J* = 1.3 Hz, 1H), 5.10 (s, 1H), 3.26 – 3.11 (m, 4H), 2.93 (dt, *J* = 10.0, 4.9 Hz, 2H), 2.79 – 2.67 (m, 2H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ 158.16, 153.97, 151.43, 135.03, 129.63, 129.08, 128.48, 126.34, 126.21, 124.54, 122.22, 119.79, 116.25, 110.22, 105.53, 67.94, 49.79, 48.38. HRMS (ESI) m/z calcd for $C_{25}H_{25}N_2O^+$ $(M+H)^+$ 369.1961, found 369.1961.

*(Z)-1-(2-benzylidene-6-bromo-2,3-dihydrobenzofuran-3-yl)-4-phenylpiperazine*



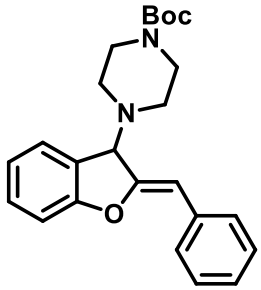

**2m**, 99%, white solid, mp. = 125-126 ℃, (EA/Hex = 10%, $R_f$ = 0.25). $^1$H NMR (400 MHz, $CDCl_3$) δ 7.69 (d, *J* = 7.9 Hz, 2H), 7.37 (t, *J* = 7.6 Hz, 2H), 7.30 (d, *J* = 7.9 Hz, 1H), 7.27 – 7.21 (m, 5H), 7.18 (d, *J* = 7.9 Hz, 1H), 6.92 – 6.82 (m, 3H), 5.91 (s, 1H), 5.04 (s, 1H), 3.23 – 3.12 (m, 4H), 2.95 – 2.86 (m, 2H), 2.76 – 2.67 (m, 2H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ 158.83, 153.54, 151.3, 134.58, 129.11, 128.57, 127.22, 126.65, 125.38, 123.83, 122.76, 119.91, 116.30, 113.93, 106.35, 67.46, 49.77, 48.36. HRMS (ESI) m/z calcd for $C_{25}H_{24}BrN_2O^+$ $(M+H)^+$ 447.1067, found 447.1068.

*(Z)-1-(2-benzylidene-5-(tert-butyl)-2,3-dihydrobenzofuran-3-yl)-4-phenylpiperazine*



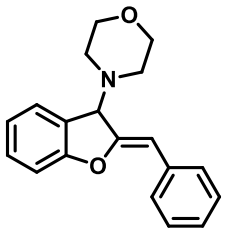

**2n**, 96%, white solid, mp. = 122-123 ℃, (EA/Hex = 5%, $R_f$ = 0.20). $^1$H NMR (400 MHz, $CDCl_3$) δ 7.72 (d, *J* = 7.8 Hz, 2H), 7.44 (s, 1H), 7.41 – 7.30 (m, 3H), 7.27 – 7.17 (m, 3H), 6.98 (d, *J* = 8.4 Hz, 1H), 6.90 (d, *J* = 8.2 Hz, 2H), 6.84 (t, *J* = 7.2 Hz, 1H), 5.88 (s, 1H), 5.07 (s, 1H), 3.19 (s, 4H), 2.99 – 2.88 (m, 2H), 2.78 – 2.68 (m, 2H), 1.33 (d, *J* = 1.4 Hz, 9H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ 156.07, 154.61, 151.43, 145.39, 135.21, 129.09, 128.45, 128.30, 126.54, 126.21, 124.08, 122.90, 119.73, 116.13, 109.39, 105.22, 68.22, 49.74, 48.48, 34.50, 31.75. HRMS (ESI) m/z calcd for $C_{29}H_{33}N_2O^+$ $(M+H)^+$ 425.2587, found 425.2589.

*tert-butyl (Z)-4-(2-benzylidene-2,3-dihydrobenzofuran-3-yl)piperazine-1-carboxylate*



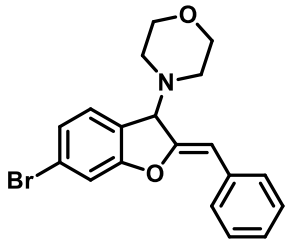

**2o**, 93%, white solid, mp. = 124-125 ℃, (EA/Hex = 5%, $R_f$ = 0.25). $^1$H NMR (400 MHz, $CDCl_3$) δ 7.71 (d, *J* = 7.9 Hz, 2H), 7.41 – 7.34 (m, 3H), 7.29 (t, *J* = 7.8 Hz, 1H), 7.21 (t, *J* = 7.4 Hz, 1H), 7.08 – 6.99 (m, 2H), 5.85 (s, 1H), 5.03 (s, 1H), 3.41 (s, 4H), 2.59 (d, *J* = 79.9 Hz, 4H), 1.42 (s, 9H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ 158.13, 154.69, 153.85, 134.94, 129.68, 128.47, 126.39, 126.08, 124.41, 122.24, 110.24, 105.55, 79.63, 68.11, 28.42. HRMS (ESI) m/z calcd for $C_{24}H_{29}N_2O_3^+$ $(M+H)^+$ 393.2173, found 393.2176.

*(Z)-4-(2-benzylidene-2,3-dihydrobenzofuran-3-yl)morpholine*



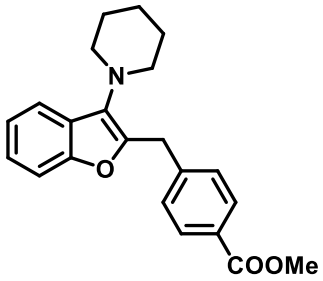

**2p**, 92%, white solid, mp. = 120-121 ℃, (EA/Hex = 10%, $R_f$ = 0.25). $^1$H NMR (400 MHz, $CDCl_3$) δ 7.72 (d, *J* = 7.3 Hz, 2H), 7.43 (d, *J* = 7.7 Hz, 1H), 7.37 (t, *J* = 7.7 Hz, 2H), 7.30 (t, *J* = 7.5 Hz, 1H), 7.22 (t, *J* = 7.4 Hz, 1H), 7.04 (t, *J* = 7.6 Hz, 2H), 5.88 (d, *J* = 1.5 Hz, 1H), 5.00 (s, 1H), 3.74 – 3.64 (m, 4H), 2.82 – 2.72 (m, 2H), 2.61 – 2.52 (m, 2H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ 158.16, 153.79, 134.94, 129.66, 128.45, 126.36, 126.13, 124.37, 122.22, 110.22, 105.57, 68.17, 67.41, 48.73. HRMS (ESI) m/z calcd for $C_{19}H_{20}NO_2^+$ $(M+H)^+$ 294.1489, found 294.1502.

*(Z)-4-(2-benzylidene-6-bromo-2,3-dihydrobenzofuran-3-yl)morpholine*



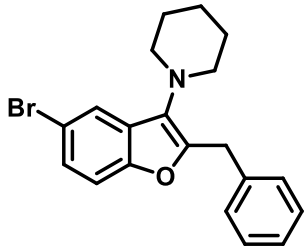
**2q**, 97%, white solid, mp. = 122-123 ℃, (EA/Hex = 10%, $R_f$ = 0.25). $^1$H NMR (400 MHz, $CDCl_3$) δ 7.68 (d, *J* = 8.0 Hz, 2H), 7.37 (t, *J* = 7.6 Hz, 2H), 7.28 (d, *J* = 7.9 Hz, 1H), 7.26 – 7.22 (m, 3H), 7.18 (dd, *J* = 7.9, 1.2 Hz, 1H), 5.89 (s, 1H), 4.94 (s, 1H), 3.72 – 3.65 (m, 4H), 2.76 – 2.70 (m, 2H), 2.59 – 2.50 (m, 2H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ 158.84, 153.35, 134.50, 128.55, 127.13, 126.68, 125.40, 123.66, 122.81, 113.93, 106.44, 67.70, 67.33, 48.70. HRMS (ESI) m/z calcd for $C_{19}H_{19}BrNO_2^+$ $(M+H)^+$ 372.0594, found 372.0591.

*methyl 4-((3-(piperidin-1-yl)benzofuran-2-yl)methyl)benzoate*




**4a**, 95%, white solid, mp. = 130-131 ℃, (EA/Hex = 10%, $R_f$ = 0.50). $^1$H NMR (400 MHz, $CDCl_3$) δ 8.03 – 7.93 (m, 2H), 7.70 – 7.63 (m, 1H), 7.41 – 7.31 (m, 3H), 7.23 – 7.12 (m, 2H), 4.20 (s, 2H), 3.89 (s, 3H), 3.16 – 3.07 (m, 4H), 1.74 – 1.58 (m, 6H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ 167.05, 153.51, 147.98, 143.97, 130.63, 129.85, 128.61, 128.33, 126.53, 123.42, 121.91, 120.28, 111.54, 53.76, 52.05, 32.51, 26.81, 24.29. HRMS (ESI) m/z calcd for $C_{22}H_{24}NO_3^+$ $(M+H)^+$ 350.1751, found 350.1759.

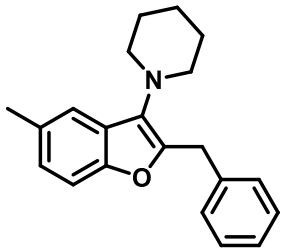
*1-(2-benzyl-5-bromobenzofuran-3-yl)piperidine*




**4c**, 80%, white solid, mp. = 132-133 ℃, (EA/Hex = 10%, $R_f$ = 0.50). $^1$H NMR (400 MHz, $CDCl_3$) δ 7.75 (d, *J* = 1.2 Hz, 1H), 7.30 (d, *J* = 7.9 Hz, 1H), 7.26 (d, *J* = 7.5 Hz, 4H), 7.21 (t, *J* = 8.6 Hz, 2H), 4.13 (s, 2H), 3.13 – 3.04 (m, 4H), 1.75 – 1.67 (m, 4H), 1.61 – 1.56 (m, 2H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ 152.22, 150.57, 138.14, 128.59,

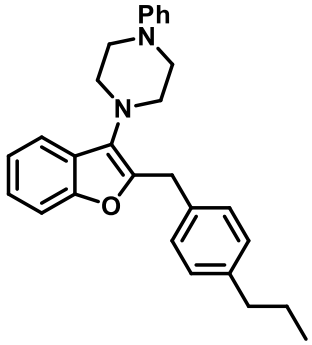
126.51, 126.05, 122.70, 114.95, 112.95, 53.73, 32.52, 26.80, 24.25. HRMS (ESI) m/z calcd for $C_{20}H_{21}BrNO^+$ $(M+H)^+$ 370.0801, found 370.0801.

*1-(2-benzyl-5-methylbenzofuran-3-yl)piperidine*



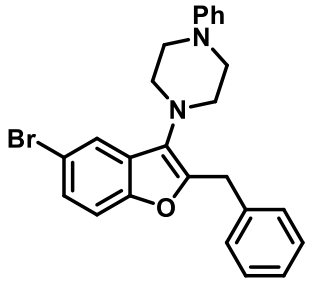
**4d**, 81%, white solid, mp. = 135-136 ℃, (EA/Hex = 10%, $R_f$ = 0.45). $^1$H NMR (400 MHz, $CDCl_3$) δ 7.42 (s, 1H), 7.29 – 7.24 (m, 4H), 7.22 – 7.16 (m, 2H), 6.98 (dd, *J* = 8.4, 1.3 Hz, 1H), 4.13 (s, 2H), 3.19 – 3.04 (m, 4H), 2.42 (s, 3H), 1.71 (dt, *J* = 10.8, 5.6 Hz, 4H), 1.59 (dd, *J* = 11.2, 5.7 Hz, 2H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ 151.90, 149.14, 138.68, 131.16, 130.04, 128.57, 128.46, 126.77, 126.28, 124.34, 120.02, 111.01, 53.77, 32.50, 26.88 , 24.36, 21.41. HRMS (ESI) m/z calcd for $C_{21}H_{24}NO^+$ $(M+H)^+$ 306.1852, found 306.1860.

*1-phenyl-4-(2-(4-propylbenzyl)benzofuran-3-yl)piperazine*



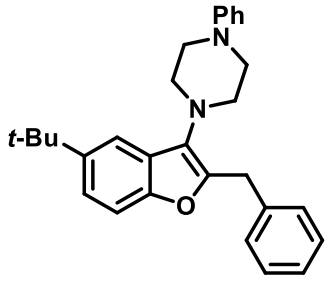
**4e**, 85%, white solid, mp. = 140-141 ℃, (EA/Hex = 5%, $R_f$ = 0.20). $^1$H NMR (400 MHz, $CDCl_3$) δ 7.72 – 7.65 (m, 1H), 7.38 (dd, *J* = 5.3, 2.9 Hz, 1H), 7.33 – 7.26 (m, 2H), 7.21 – 7.15 (m, 4H), 7.10 (d, *J* = 7.8 Hz, 2H), 7.00 (d, *J* = 7.8 Hz, 2H), 6.89 (t, *J* = 7.3 Hz, 1H), 4.14 (d, *J* = 3.0 Hz, 2H), 3.33 (s, 8H), 2.54 (t, *J* = 7.6 Hz, 2H), 1.59 (dd, *J* = 10.5, 4.5 Hz, 2H), 0.95 – 0.88 (m, 3H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ 153.51, 151.60, 150.29, 140.88, 135.44, 129.21, 128.73, 128.45, 126.32, 123.41, 122.06, 120.00, 119.98, 116.40, 111.70, 52.43, 50.24, 37.70, 32.00, 24.64, 13.91. HRMS (ESI) m/z calcd for $C_{28}H_{31}N_2O^+$ $(M+H)^+$ 411.2431, found 411.2437.

*1-(2-benzyl-5-bromobenzofuran-3-yl)-4-phenylpiperazine*



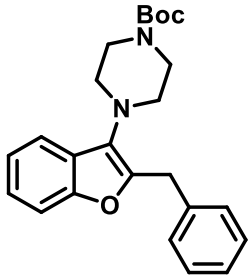

**4f**, 87%, white solid, mp. = 139-140 ℃, (EA/Hex = 10%, $R_f$ = 0.55). $^1$H NMR (400 MHz, $CDCl_3$) δ 7.53 (d, *J* = 9.1 Hz, 2H), 7.35 – 7.19 (m, 8H), 6.99 (d, *J* = 7.9 Hz, 2H), 6.90 (t, *J* = 7.3 Hz, 1H), 4.16 (s, 2H), 3.31 (s, 8H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ 153.85, 151.49, 150.69, 137.87, 129.22, 128.79, 128.65, 126.62, 125.42, 125.32, 120.88, 120.10, 116.77, 116.45, 115.12, 52.39, 50.20, 32.41. HRMS (ESI) m/z calcd for $C_{25}H_{24}BrN_2O^+$ $(M+H)^+$ 447.1067, found 447.1071.

*1-(2-benzyl-5-(tert-butyl)benzofuran-3-yl)-4-phenylpiperazine*



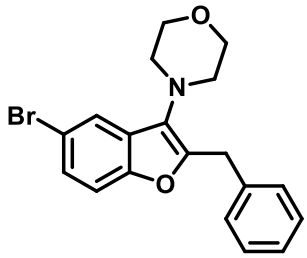

**4g**, 89%, white solid, mp. = 146-148 ℃, (EA/Hex = 5%, $R_f$ = 0.50). $^1$H NMR (400 MHz, $CDCl_3$) δ 7.66 (s, 1H), 7.36 – 7.30 (m, 3H), 7.28 (d, *J* = 4.3 Hz, 3H), 7.27 (s, 2H), 7.20 (dd, *J* = 8.7, 4.3 Hz, 1H), 7.02 (d, *J* = 8.2 Hz, 2H), 6.90 (t, *J* = 7.2 Hz, 1H), 4.16 (s, 2H), 3.35 (d, *J* = 2.4 Hz, 8H), 1.37 (s, 9H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ 151.72, 151.57, 150.37, 145.24, 138.37, 129.19, 128.88, 128.58, 126.39, 125.94, 121.36, 120.02, 116.36, 116.02, 110.96, 52.47, 50.26, 32.39, 31.92, 29.71. HRMS (ESI) m/z calcd for $C_{29}H_{33}N_2O^+$ $(M+H)^+$ 425.2587, found 425.2593.

*tert-butyl 4-(2-benzylbenzofuran-3-yl)piperazine-1-carboxylate*



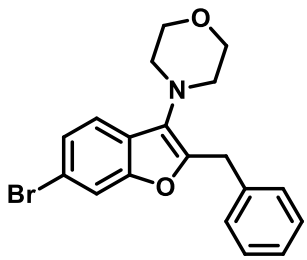

**4h**, 80%, white solid, mp. = 128-129 ℃, (EA/Hex = 5%, $R_f$ = 0.55). $^1$H NMR (400 MHz, $CDCl_3$) δ 7.60 (d, *J* = 7.5 Hz, 1H), 7.36 (d, *J* = 7.8 Hz, 1H), 7.31 – 7.24 (m, 4H), 7.17 (dt, *J* = 15.8, 6.9 Hz, 3H), 4.15 (s, 2H), 3.62 – 3.51 (m, 4H), 3.11 (s, 4H), 1.50 (s, 9H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ 154.89, 153.47, 150.07, 138.15, 128.82, 128.58, 126.50, 126.16, 123.50, 122.10, 119.88, 111.69, 79.83, 52.20, 32.35, 28.49. HRMS (ESI) m/z calcd for $C_{24}H_{29}N_2O_3^+$ $(M+H)^+$ 393.2173, found 393.2177.

*4-(2-benzyl-5-bromobenzofuran-3-yl)morpholine*



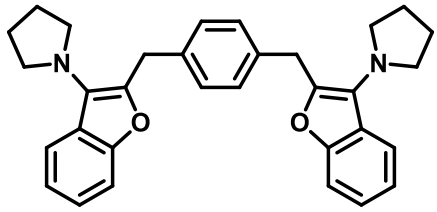

**4i**, 86%, white solid, mp. = 140-141 ℃, (EA/Hex = 10%, $R_f$ = 0.5). $^1$H NMR (400 MHz, $CDCl_3$) δ 7.78 (d, *J* = 1.5 Hz, 1H), 7.34 – 7.27 (m, 3H), 7.23 (dd, *J* = 14.2, 5.9 Hz, 4H), 4.15 (s, 2H), 3.90 – 3.80 (m, 4H), 3.19 – 3.08 (m, 4H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ 152.23, 151.72, 137.74, 128.66, 128.53, 128.29, 128.07, 126.66, 126.38, 122.47, 115.26, 113.13, 67.63, 52.50, 32.39. HRMS (ESI) m/z calcd for $C_{19}H_{19}BrNO_2^+$ $(M+H)^+$ 372.0594, found 372.0600.

*4-(2-benzyl-6-bromobenzofuran-3-yl)morpholine*



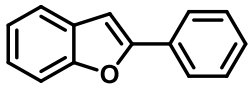
**4j**, 83%, white solid, mp. = 143-144 ℃, (EA/Hex = 10%, $R_f$ = 0.5). $^1$H NMR (400 MHz, $CDCl_3$) δ 7.55 – 7.47 (m, 2H), 7.32 – 7.26 (m, 3H), 7.22 (dd, *J* = 13.8, 7.0 Hz, 3H), 4.14 (s, 2H), 3.88 – 3.80 (m, 4H), 3.18 – 3.08 (m, 4H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ 153.83, 150.90, 137.78, 128.68, 128.51, 126.62, 125.43, 125.16, 120.75, 116.78, 115.14, 67.62, 52.55, 32.33. HRMS (ESI) m/z calcd for $C_{19}H_{19}BrNO_2^+$ $(M+H)^+$ 372.0594, found 372.0600.

*1,4-bis((3-(pyrrolidin-1-yl)benzofuran-2-yl)methyl)benzene*



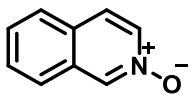
**4m**, 83%, white solid, mp. = 152-153 ℃, (EA/Hex =20%, $R_f$ = 0.6). $^1$H NMR (400 MHz, $CDCl_3$) δ 7.52 (dd, *J* = 7.6, 0.9 Hz, 2H), 7.24 (d, *J* = 7.6 Hz, 2H), 7.13 – 7.01 (m, 8H), 4.08 (s, 4H), 3.27 (t, *J* = 6.5 Hz, 8H), 1.94 – 1.84 (m, 8H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ 153.50, 146.04, 136.90, 128.53, 127.35, 125.93, 123.27, 121.53, 120.19, 111.47, 52.41, 32.50, 25.29. HRMS (ESI) m/z calcd for $C_{32}H_{33}N_2O_2^+$ $(M+H)^+$ 477.2537, found 477.2542.

*2-phenylbenzofuran*



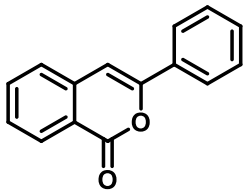
**6**, 95%, white solid, (EA/Hex = 10%, $R_f$ = 0.5). $^1$H NMR (400 MHz, $CDCl_3$) δ 7.87 (d, *J* = 8.2 Hz, 2H), 7.59 (d, *J* = 7.5 Hz, 1H), 7.53 (d, *J* = 8.0 Hz, 1H), 7.45 (t, *J* = 7.7 Hz, 2H), 7.35 (t, *J* = 7.3 Hz, 1H), 7.29 (t, *J* = 7.6 Hz, 1H), 7.26 – 7.20 (m, 1H), 7.03 (s, 1H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ 155.93, 154.90, 130.49, 129.23, 128.81, 128.57, 124.95, 124.28, 122.95, 120.92, 111.20, 101.32. HRMS (ESI) m/z calcd for $C_{14}H_{11}O^+$ $(M+H)^+$ 195.0804, found 195.0808.

*isoquinoline 2-oxide*



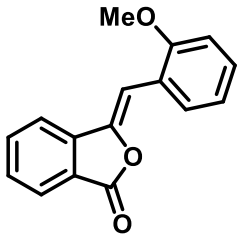
**8**, 93%, white solid, (EA/Hex = 10%, $R_f$ = 0.5). $^1$H NMR (400 MHz, $CDCl_3$) δ 8.70 (s, 1H), 8.07 (dd, *J* = 7.1, 1.5 Hz, 1H), 7.72 (d, *J* = 7.5 Hz, 1H), 7.65 (d, *J* = 7.6 Hz, 1H), 7.60 (d, *J* = 7.1 Hz, 1H), 7.58 – 7.49 (m, 2H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ 136.73, 136.29, 129.61, 129.24, 126.72, 125.11, 124.35. HRMS (ESI) m/z calcd for $C_9H_8NO_+(M+H)^+$ 146.0600, found 146.0637.

*3-phenyl-1H-isochromen-1-one*



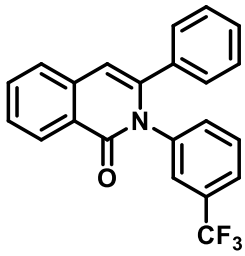

**10**, 92%, white solid, (EA/Hex = 5%, $R_f$ = 0.3). $^1$H NMR (400 MHz, $CDCl_3$) δ 7.83 (dd, *J* = 10.4, 3.5 Hz, 1H), 7.76 (dd, *J* = 7.1, 4.1 Hz, 2H), 7.71 – 7.59 (m, 2H), 7.49 – 7.41 (m, 1H), 7.32 (td, *J* = 7.6, 3.6 Hz, 2H), 7.27 – 7.19 (m, 1H), 6.33 (d, *J* = 5.5 Hz, 1H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ 167.12, 144.59, 140.61, 134.53, 133.10, 130.15, 129.81, 128.80, 128.46, 125.58, 123.39, 119.86, 107.11. HRMS (ESI) m/z calcd for $C_{15}H_{11}O_2^+$ $(M+H)^+$ 223.0754, found 223.0761.

*(Z)-3-(2-methoxybenzylidene)isobenzofuran-1(3H)-one*



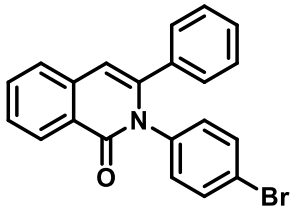

**12**, 89%, white solid, (EA/Hex = 5%, $R_f$ = 0.3). $^1$H NMR (400 MHz, $CDCl_3$) δ 8.19 (dd, *J* = 7.8, 1.4 Hz, 1H), 7.84 (d, *J* = 7.7 Hz, 1H), 7.74 (d, *J* = 7.9 Hz, 1H), 7.62 (t, *J* = 7.6 Hz, 1H), 7.44 (t, *J* = 7.5 Hz, 1H), 7.25 – 7.18 (m, 1H), 6.96 (t, *J* = 7.6 Hz, 1H), 6.88 (s, 1H), 6.83 (d, *J* = 8.3 Hz, 1H), 3.83 (s, 3H). $^{13}$C NMR (100MHz, $CDCl_3$) δ 167.37, 157.05, 144.47, 141.00, 134.38, 131.35, 129.78, 125.43, 123.29, 121.97, 121.09, 120.06, 110.47, 100.85, 55.62. HRMS (ESI) m/z calcd for $C_{16}H_{13}O_3^+$ $(M+H)^+$ 253.0859, found 253.0863.

*3-phenyl-2-(3-(trifluoromethyl)phenyl)isoquinolin-1(2H)-one*



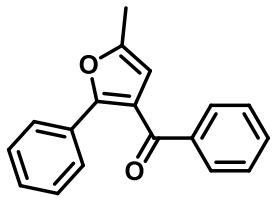

**16a**, 93%, white solid, (EA/Hex = 5%, $R_f$ = 0.3). $^1$H NMR (400 MHz, $CDCl_3$) δ 7.98 (dd, *J* = 7.3, 4.8 Hz, 1H), 7.88 (dd, *J* = 7.6, 4.7 Hz, 1H), 7.75 – 7.64 (m, 1H), 7.61 – 7.55 (m, 1H), 7.41 (d, *J* = 5.6 Hz, 1H), 7.36 – 7.19 (m, 3H), 7.05 – 6.92 (m, 3H), 6.91 – 6.75 (m, 3H). $^{13}$C NMR (100MHz, $CDCl_3$) δ 167.77, 138.52, 136.39, 134.02, 133.17, 132.87, 130.47, 129.48, 129.04, 128.76, 127.46, 127.02, 124.12, 123.99, 123.28, 119.60, 108.05. HRMS (ESI) m/z calcd for $C_{22}H_{15}F_3NO^+$ $(M+H)^+$ 366.1100, found 366.1109.

*2-(4-bromophenyl)-3-phenylisoquinolin-1(2H)-one*



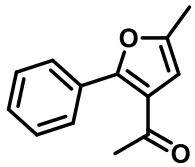

**16b**, 89%, white solid, (EA/Hex = 5%, $R_f$ = 0.3). $^1$H NMR (400 MHz, $CDCl_3$) δ 7.95 – 7.90 (m, 1H), 7.83 (d, *J* = 7.8 Hz, 1H), 7.68 – 7.64 (m, 1H), 7.53 (td, *J* = 7.5, 0.7 Hz, 1H), 7.41 – 7.36 (m, 1H), 7.21 – 7.14 (m, 2H), 7.04 (t, *J* = 7.4 Hz, 1H), 6.97 (d, *J* = 7.6 Hz, 1H), 6.94 – 6.90 (m, 2H), 6.84 (d, *J* = 8.5 Hz, 3H). $^{13}$C NMR (100MHz, $CDCl_3$) δ 167.74, 138.54, 133.37, 132.78, 131.23, 130.62, 129.41, 129.18, 128.72, 127.45, 126.95, 123.97, 123.25, 120.34, 119.52, 112.37, 107.85. HRMS (ESI) m/z calcd for $C_{21}H_{15}BrNO^+$ $(M+H)^+$ 376.0332, found 376.0340.

*(5-methyl-2-phenylfuran-3-yl)(phenyl)methanone*



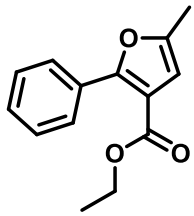
**18a**, 97%, yellow solid, (EA/Hex = 5%, $R_f$ = 0.5). $^1$H NMR (400 MHz, $CDCl_3$) δ 7.83 (d, *J* = 8.1 Hz, 2H), 7.67-7.63 (m, 2H), 7.49 (dd, *J* = 8.6, 4.3 Hz, 2H), 7.36 (t, *J* = 7.6 Hz, 3H), 7.28 (s, 1H), 6.30 (s, 1H), 2.40 (s, 3H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ 191.97, 154.51, 151.20, 138.25, 132.63, 130.04, 129.69, 128.59, 128.22, 127.28, 123.75, 121.77, 109.75, 13.42. HRMS (ESI) m/z calcd for $C_{18}H_{15}O_2^+$ $(M+H)^+$ 263.1067, found 263.1065.

*1-(5-methyl-2-phenylfuran-3-yl)ethan-1-one*



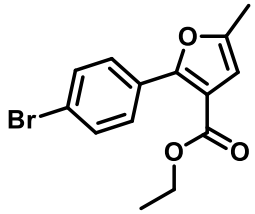
**18b**, 93%, light yellow solid, (EA/Hex = 5%, $R_f$ = 0.5). $^1$H NMR (400 MHz, $CDCl_3$) δ 7.65 (d, *J* = 7.4 Hz, 2H), 7.39 (t, *J* = 7.6 Hz, 2H), 7.29 (d, *J* = 7.4 Hz, 1H), 6.85 (s, 1H), 2.67 (s, 3H), 2.46 (s, 3H). $^{13}$C NMR (100 MHz, CDCl3) δ 194.11, 157.93, 151.71, 129.95, 128.77, 127.78, 123.70, 123.27, 105.08, 29.14, 14.52. HRMS (ESI) m/z calcd for $C_{13}H_{13}O_2^+$ $(M+H)^+$ 201.0910, found 201.1030.

*ethyl 5-methyl-2-phenylfuran-3-carboxylate*



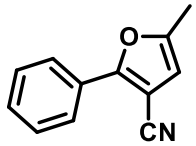
**18c**, 95%, yellow solid, (EA/Hex = 5%, $R_f$ = 0.5). $^1$H NMR (400 MHz, DMSO-$d_6$) δ 7.88 (dd, *J* = 7.9, 1.2 Hz, 2H), 7.51-7.39 (m, 3H), 6.50 (s, 1H), 4.22 (q, *J* = 7.1 Hz, 2H), 2.34 (s, 3H), 1.24 (t, *J* = 7.1 Hz, 3H). $^{13}$C NMR (100 MHz, DMSO-$d_6$) δ 163.29, 155.30, 129.88, 129.57, 128.61, 128.22, 114.72, 109.17, 60.58, 14.46, 13.37. HRMS (ESI) m/z calcd for $C_{14}H_{15}O_3^+$ $(M+H)^+$ 231.1016, found 231.1015.

*ethyl 2-(4-bromophenyl)-5-methylfuran-3-carboxylate*



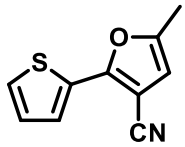

**18d**, 91%, light yellow, (EA/Hex = 5%, $R_f$ = 0.5). $^1$H NMR (400 MHz, $CDCl_3$) δ 7.88 (d, *J* = 8.6 Hz, 2H), 7.53 (d, *J* = 8.6 Hz, 2H), 6.44 (s, 1H), 4.28 (q, *J* = 7.1 Hz, 2H), 2.35 (s, 3H), 1.32 (d, *J* = 7.1 Hz, 3H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ 163.65, 154.67, 151.38, 131.22, 129.56, 128.95, 123.13, 109.02, 60.48, 14.24, 13.31. HRMS (ESI) m/z calcd for $C_{14}H_{14}BrO_3^+$ $(M+H)^+$ 309.0121, found 309.0129.

*5-methyl-2-phenylfuran-3-carbonitrile*



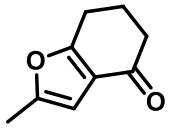

**18e**, 90%, light yellow solid, (EA/Hex = 5%, $R_f$ = 0.5). $^1$H NMR (400 MHz, $CDCl_3$) δ 7.95 (d, *J* = 7.3 Hz, 2H), 7.46 (t, *J* = 7.4 Hz, 2H), 7.39 (t, *J* = 7.3 Hz, 1H), 6.26 (s, 1H), 2.38 (s, 3H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ 158.45, 152.48, 129.64, 128.99, 128.39, 125.09, 115.29, 108.96, 92.01, 13.35. HRMS (ESI) m/z calcd for $C_{12}H_{10}NO^+$ $(M+H)^+$ 184.0757, found 184.0757.

*5-methyl-2-(thiophen-2-yl)furan-3-carbonitrile*



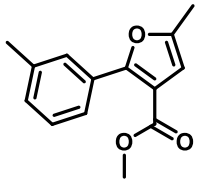

**18f**, 84%, yellow solid, (EA/Hex = 5%, $R_f$ = 0.5). $^1$H NMR (400 MHz, $CDCl_3$) δ 7.69 (dd, *J* = 3.7, 0.8 Hz, 1H), 7.41 (dd, *J* = 5.0, 0.8 Hz, 1H), 7.12 (dd, *J* = 4.9, 3.8 Hz, 1H), 6.22 (d, *J* = 0.8 Hz, 1H), 2.36 (s, 3H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ 154.79, 130.41, 128.12, 127.19, 114.72, 108.35, 90.94, 76.71, 13.33. HRMS (ESI) m/z calcd for $C_{10}H_8NOS^+$ $(M+H)^+$ 190.0321, found 190.0331.

*2-methyl-6,7-dihydrobenzofuran-4(5H)-one*



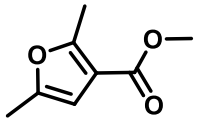
**18g**, 87%, yellow solid, (EA/Hex = 5%, $R_f$ = 0.5). $^1$H NMR (400 MHz, $CDCl_3$) δ 6.24 (s, 1H), 2.83 (t, *J* = 6.3 Hz, 2H), 2.49-2.43 (m, 2H), 2.29 (s, 3H), 2.19-2.11 (m, 2H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ 194.62, 166.00, 152.60, 122.05, 101.95, 37.57, 23.30, 22.68, 13.32. HRMS (ESI) m/z calcd for $C_9H_{11}O_2^+$ $(M+H)^+$ 151.0754, found 151.0756.

*methyl 5-methyl-2-(m-tolyl)furan-3-carboxylate*



**18h**, 91%, yellow solid, (EA/Hex = 5%, $R_f$ = 0.5). $^1$H NMR (400 MHz, $CDCl_3$) δ 7.76 (d, *J* = 7.8 Hz, 2H), 7.31 (t, *J* = 7.7 Hz, 1H), 7.19 (d, *J* = 7.5 Hz, 1H), 6.41 (s, 1H), 3.80 (s, 3H), 2.41 (s, 3H), 2.35 (s, 3H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ 164.26, 156.31, 151.03, 137.66, 129.94, 128.60, 127.98, 125.36, 114.04, 108.68, 51.46, 21.49, 13.33. HRMS (ESI) m/z calcd for $C_{14}H_{15}O_3^+$ $(M+H)^+$ 231.1016, found 231.1015.

*methyl 2,5-dimethylfuran-3-carboxylate*



**18i**, 89%, yellow solid, (EA/Hex = 5%, $R_f$ = 0.5). $^1$H NMR (400 MHz, $CDCl_3$) δ 6.20 (s, 1H), 3.79 (s, 3H), 2.52 (s, 3H), 2.23 (s, 3H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ 164.69, 157.67, 149.91, 113.71, 106.11, 51.07, 13.55, 13.09. HRMS (ESI) m/z calcd for $C_8H_{11}O_3^+$ $(M+H)^+$ 155.0703, found 155.0709.

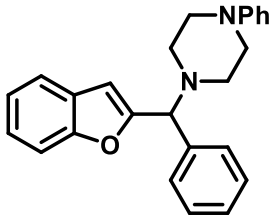
The known products **2r** and **2s**, [1] compound **2t**, **2u**, **4b**, **4k** and **4l**,[2] **14a** and **14b** [3] were unambiguously authenticated by comparing the obtained $^1$H NMR spectroscopic data with those reported in the literature.

[1] N. Wongsa, U. Sommart, T. Ritthiwigrom, A. Yazici, S. Kanokmedhakul, K. Kanokmedhakul, A. C. Willis, S. G. Pyne, *J. Org. Chem.* **2013**, *78*, 1138-1148.

[2] G. Purohit, U. C. Rajesh, D. S. Rawat, *ACS Sustainable Chem. Eng.* **2017**, *5*, 6466-6477.

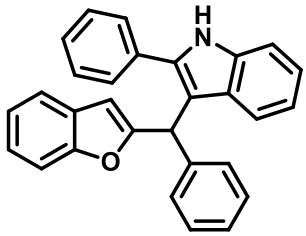
[3] N. Nebra, J. Monot, R. Shaw, B. Martin-Vaca, D. Bourissou, *ACS Catal.* **2013**, *3*, 2930-2934.

*1-(benzofuran-2-yl(phenyl)methyl)-4-phenylpiperazine*



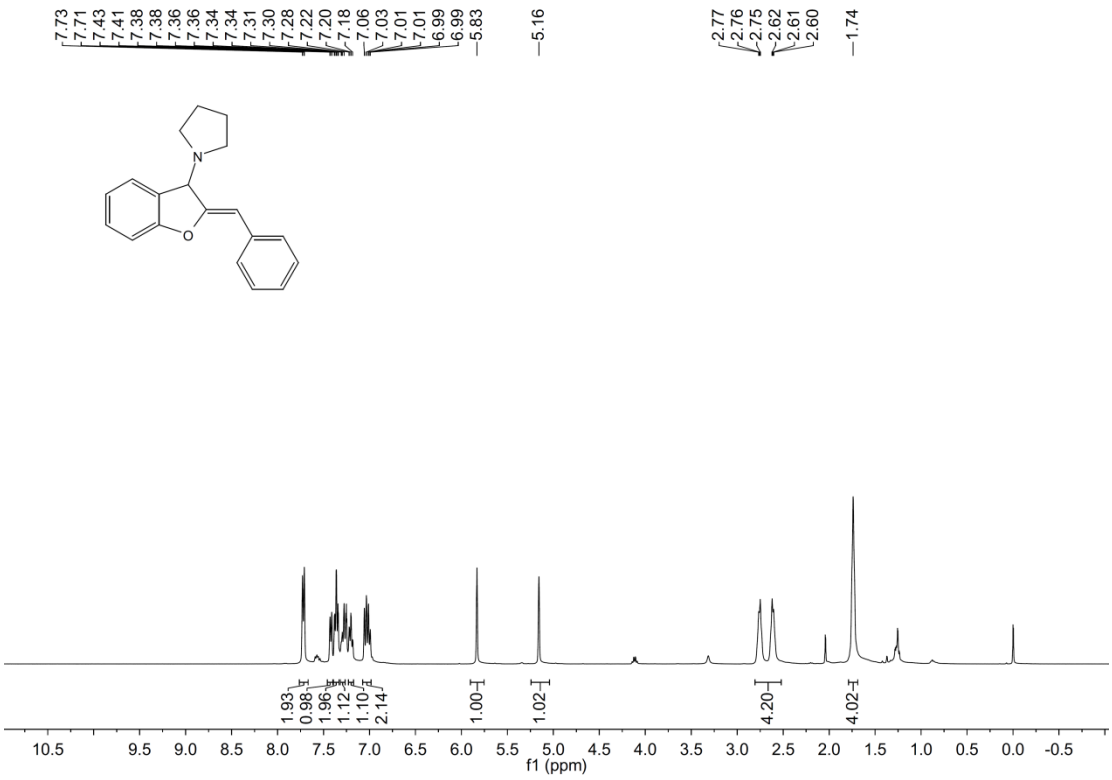

**19**, 73%, white solid, mp. = 149-150 ℃, (EA/Hex = 5%, $R_f$ = 0.3). $^1$H NMR (400 MHz, $CDCl_3$) δ 7.55 (d, *J* = 7.0 Hz, 2H), 7.52 – 7.43 (m, 2H), 7.38 – 7.31 (m, 2H), 7.30 – 7.15 (m, 5H), 6.89 (d, *J* = 7.9 Hz, 2H), 6.84 (t, *J* = 7.3 Hz, 1H), 6.68 (s, 1H), 4.59 (s, 1H), 3.22 (t, *J* = 4.8 Hz, 4H), 2.65 (d, *J* = 4.0 Hz, 4H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ 157.16, 155.02, 151.31, 138.90, 129.12, 128.59, 128.20, 127.80, 123.91, 122.75, 120.78, 119.70, 116.05, 111.47, 105.16, 69.34, 51.64, 49.25. HRMS (ESI) m/z calcd for $C_{25}H_{25}N_2O^+$ $(M+H)^+$ 369.1961, found 369.1983.

*3-(benzofuran-2-yl(phenyl)methyl)-2-phenyl-1H-indole*

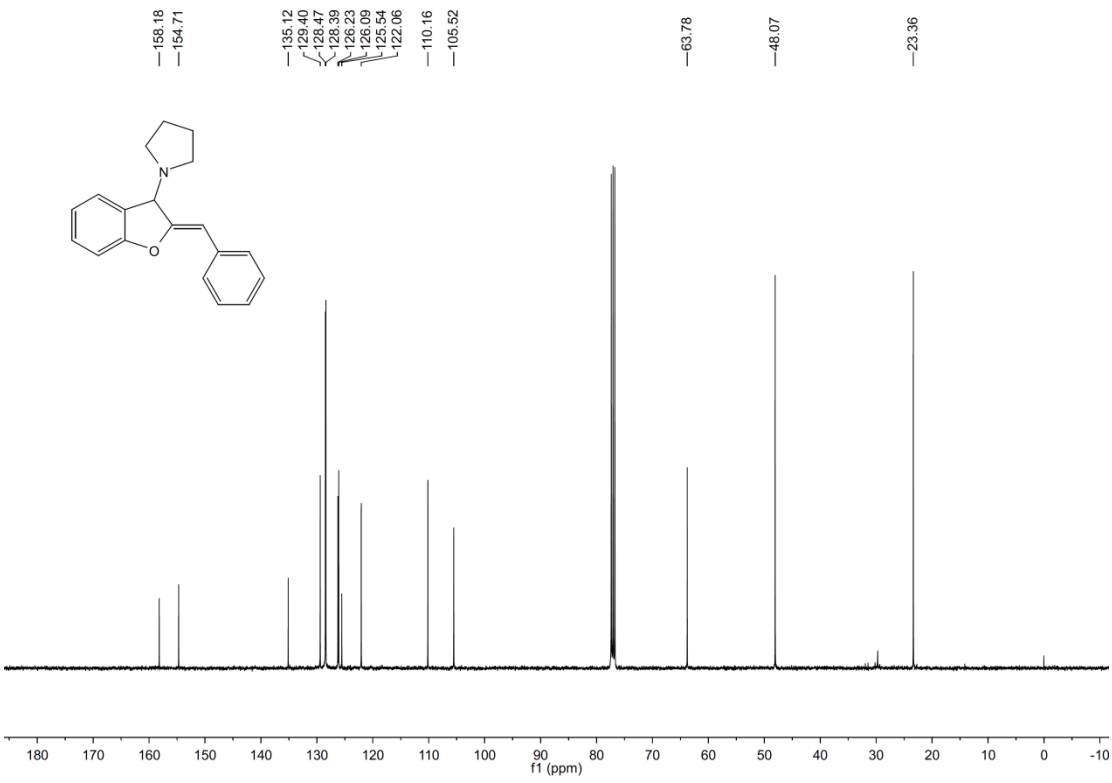



**21**, 51%, white solid, mp. = 151-152 ℃, (EA/Hex = 10%, $R_f$ = 0.3). $^1$H NMR (400 MHz, $CDCl_3$) δ 8.13 (s, 1H), 7.54 – 7.48 (m, 2H), 7.47 – 7.40 (m, 3H), 7.40 – 7.33 (m, 4H), 7.27 (dd, *J* = 5.6, 3.3 Hz, 4H), 7.23 – 7.12 (m, 4H), 6.99 – 6.90 (m, 1H), 6.48 – 6.36 (m, 1H), 5.94 (d, *J* = 3.4 Hz, 1H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ 160.16, 155.04, 141.45, 136.09, 132.58, 128.92, 128.66, 128.39, 128.09, 126.66, 123.50, 122.52, 122.23, 120.61, 119.97, 112.01, 111.24, 110.91, 105.35, 42.47. HRMS (ESI) m/z calcd for $C_{29}H_{22}NO^+$ $(M+H)^+$ 400.1696, found 400.1698.

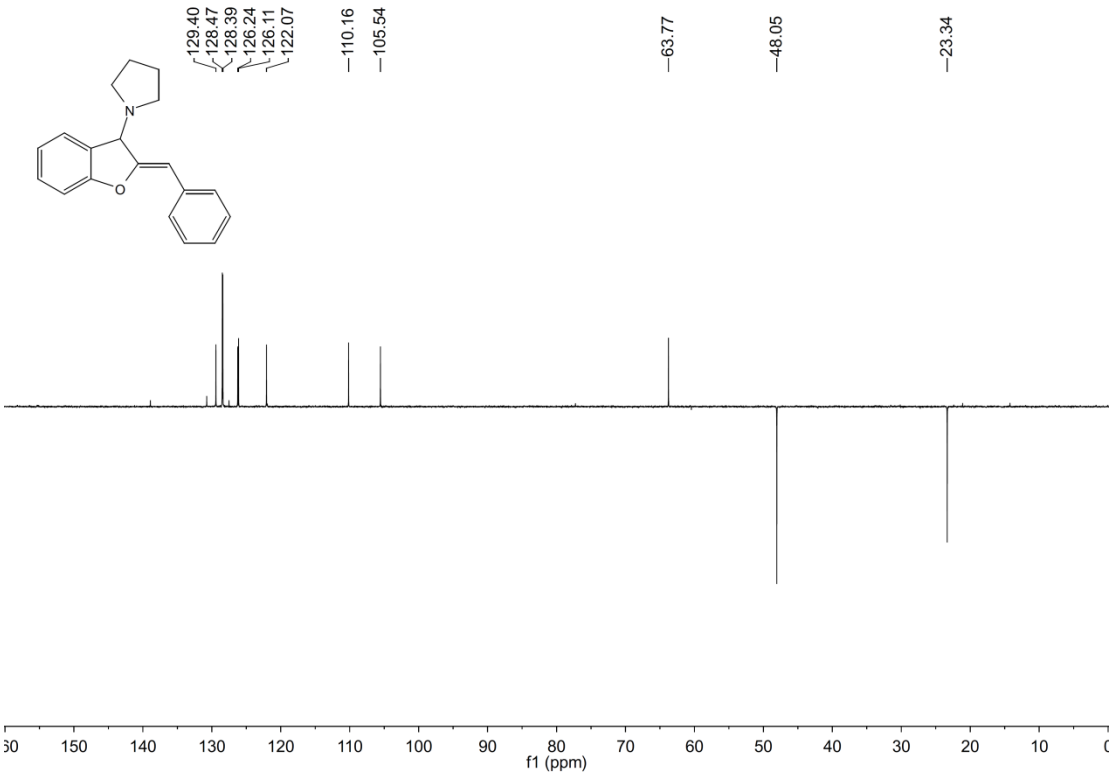
## NMR Figures of Products



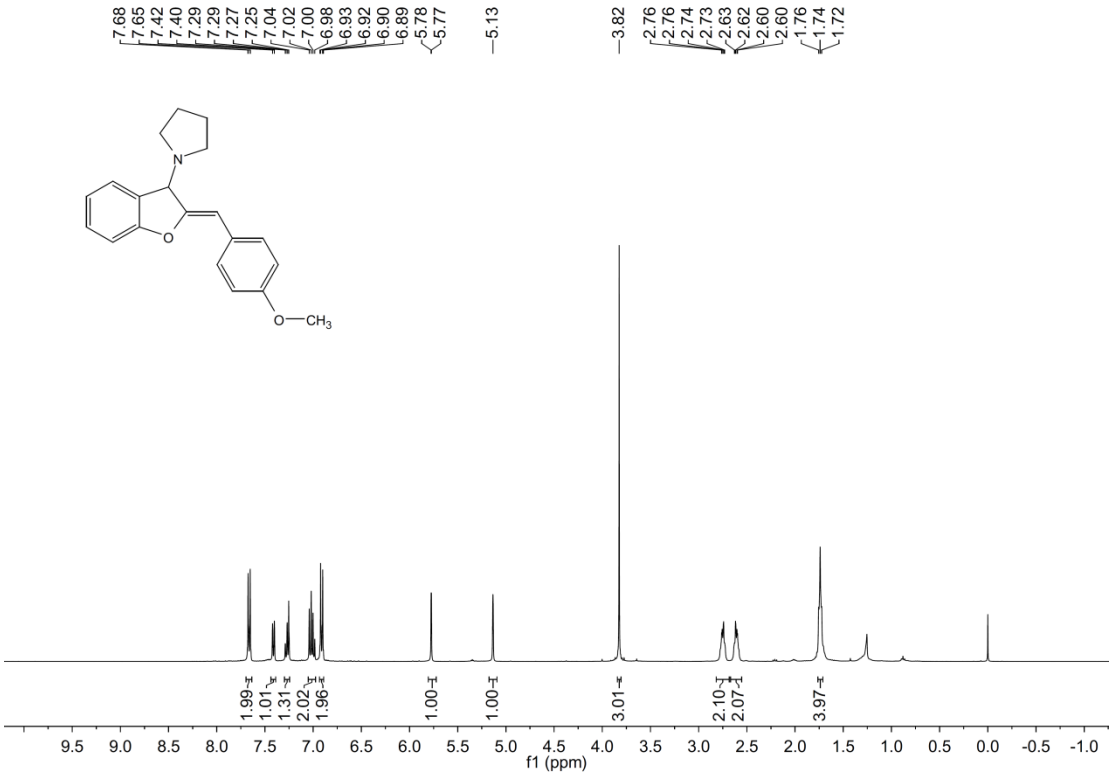

$^{1}$H NMR spectrum of **2a** (in $CDCl_3$)



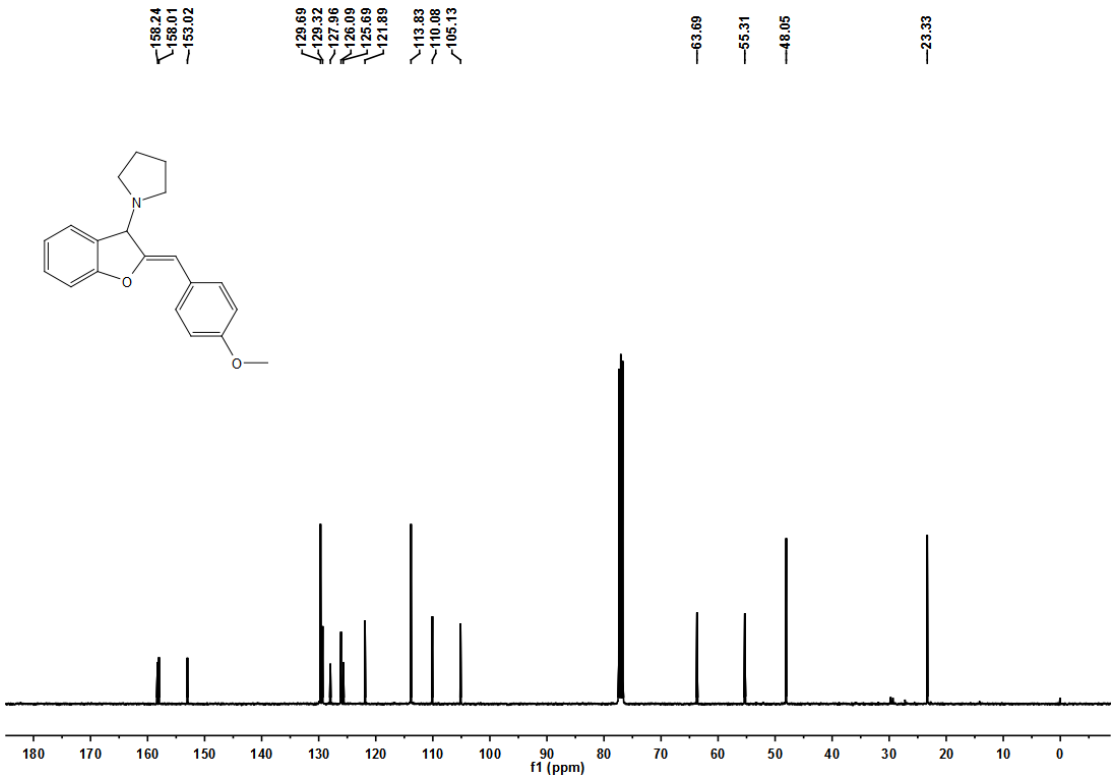

$^{13}$C NMR spectrum of **2a** (in $CDCl_3$)



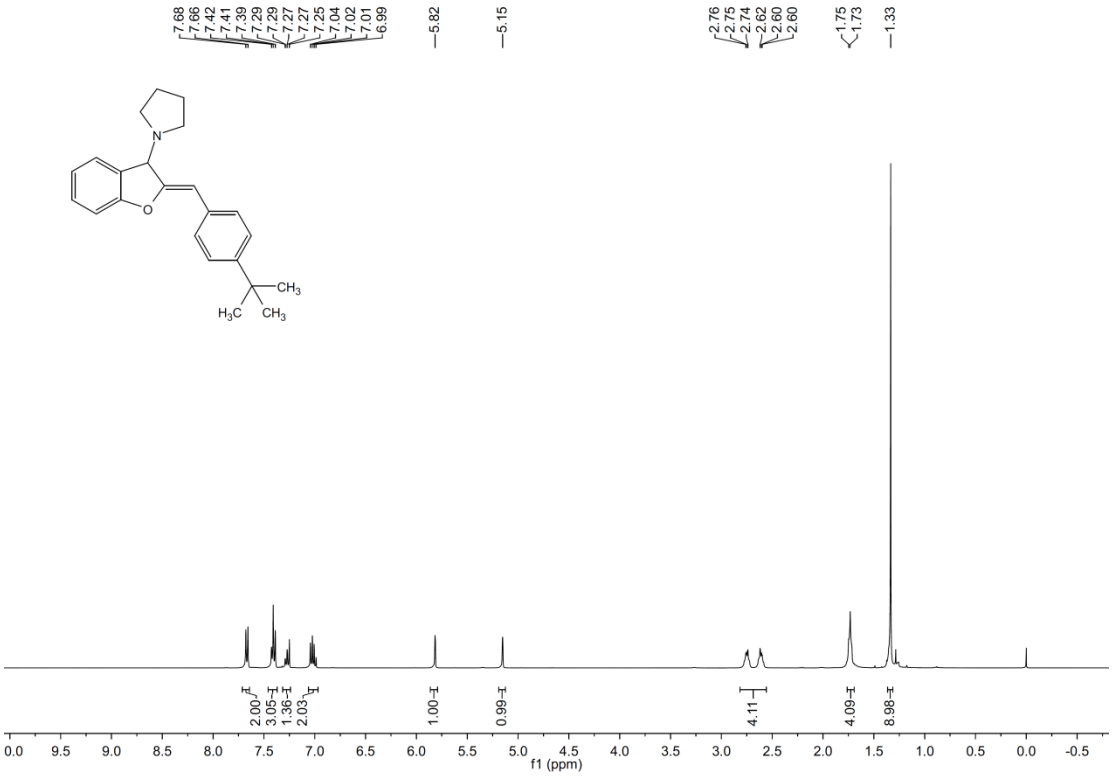

DEPT 135$^{o}$ spectrum of **2a** (in $CDCl_3$)



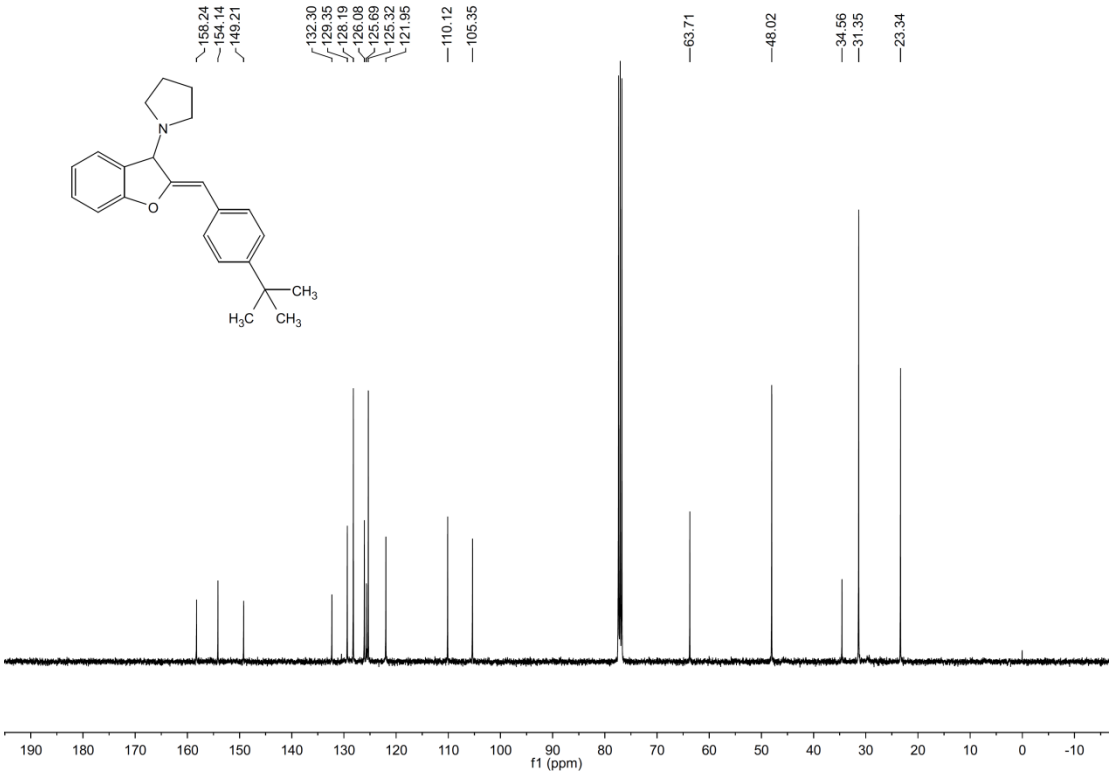

$^{1}$H NMR spectrum of **2b** (in $CDCl_3$)



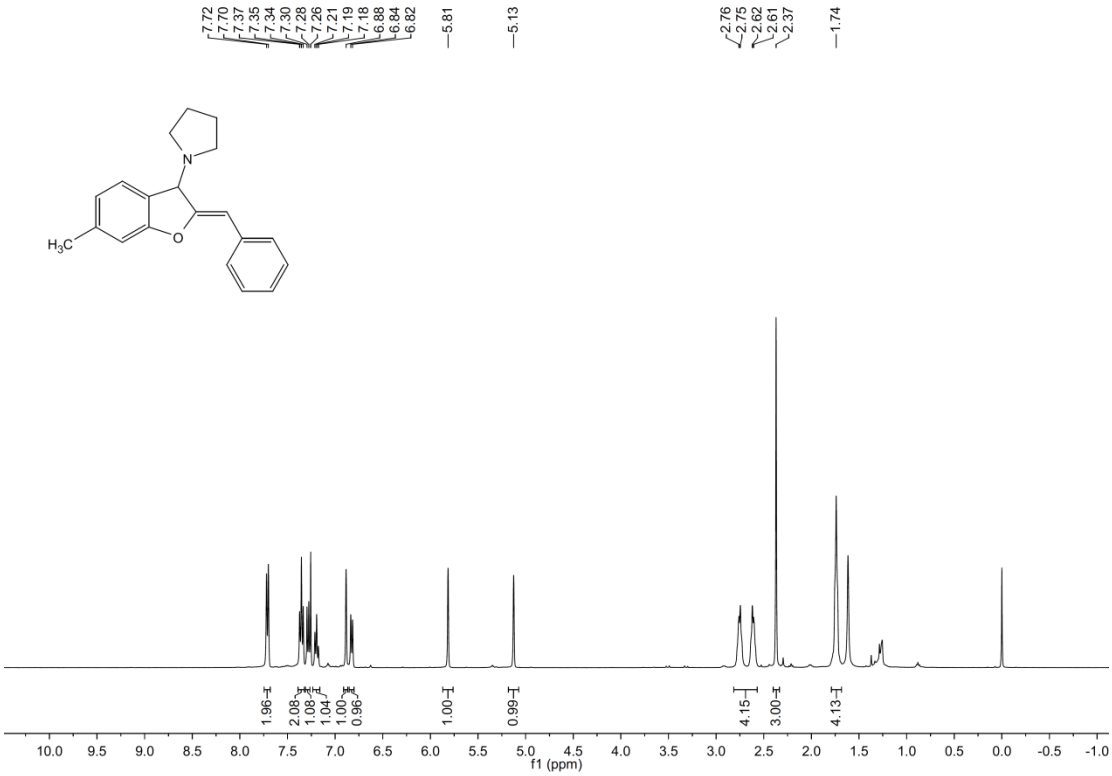

$^{13}$C NMR spectrum of **2b** (in $CDCl_3$)



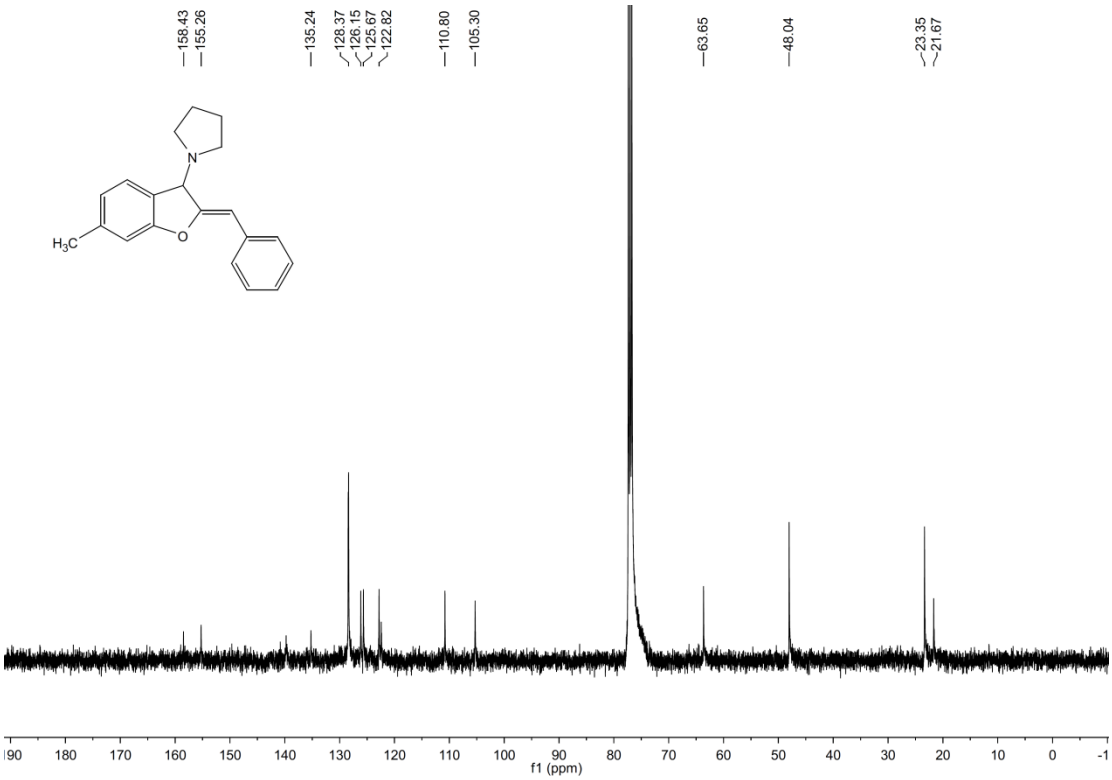

$^{1}$H NMR spectrum of **2c** (in $CDCl_3$)



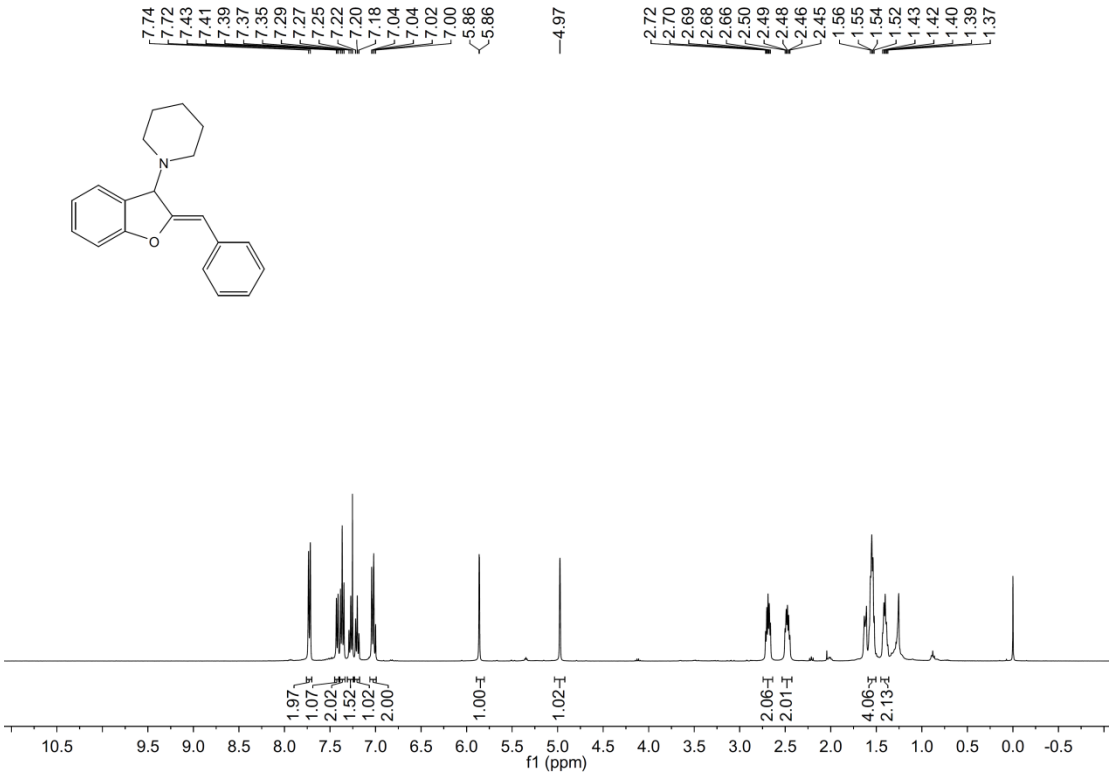

$^{13}$C NMR spectrum of **2c** (in $CDCl_3$)



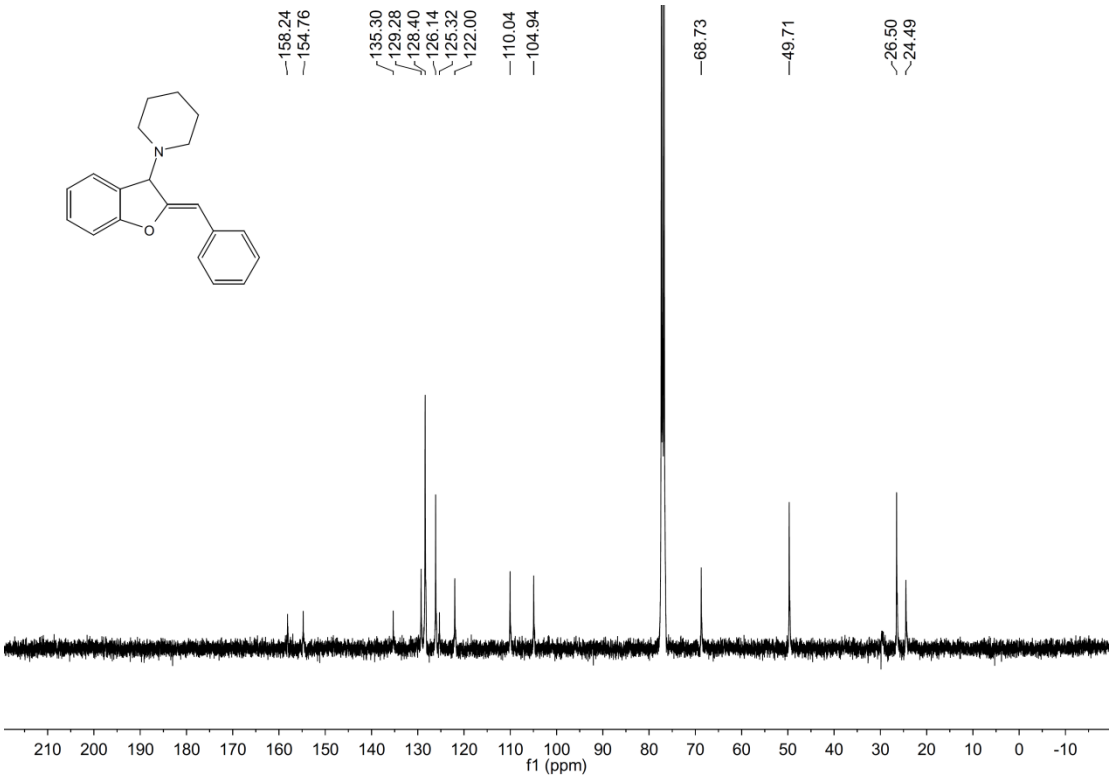

$^{1}$H NMR spectrum of **2d** (in $CDCl_3$)



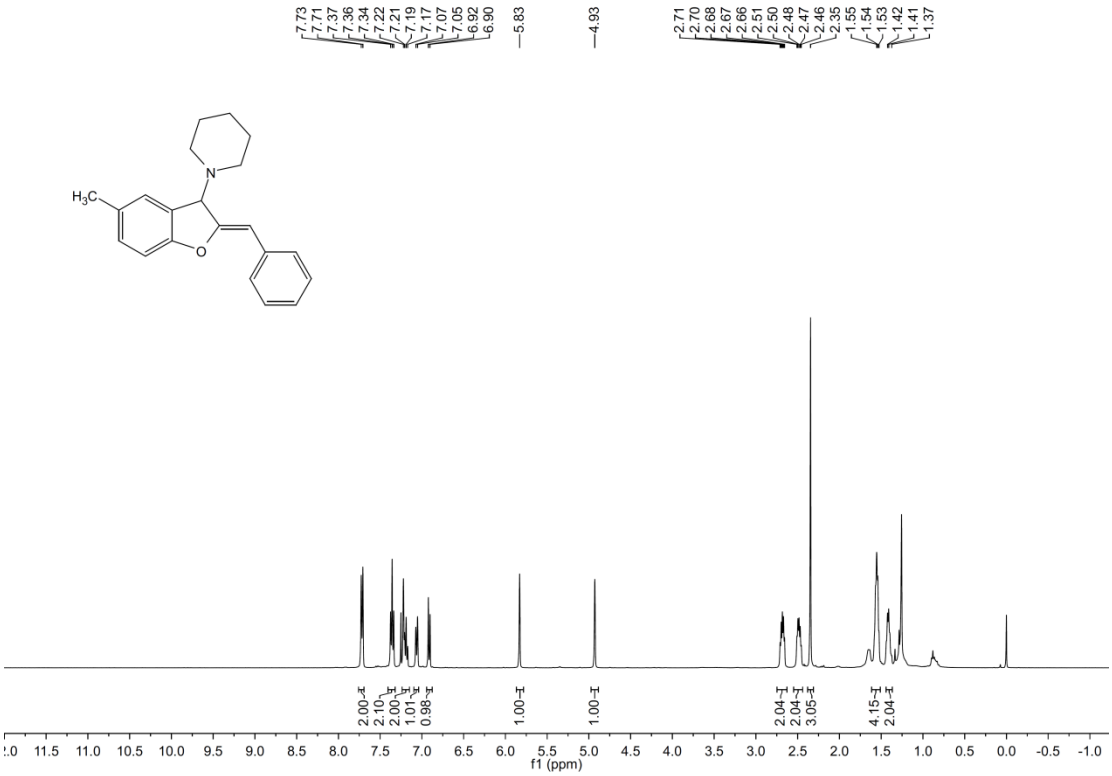

$^{13}$C NMR spectrum of **2d** (in $CDCl_3$)



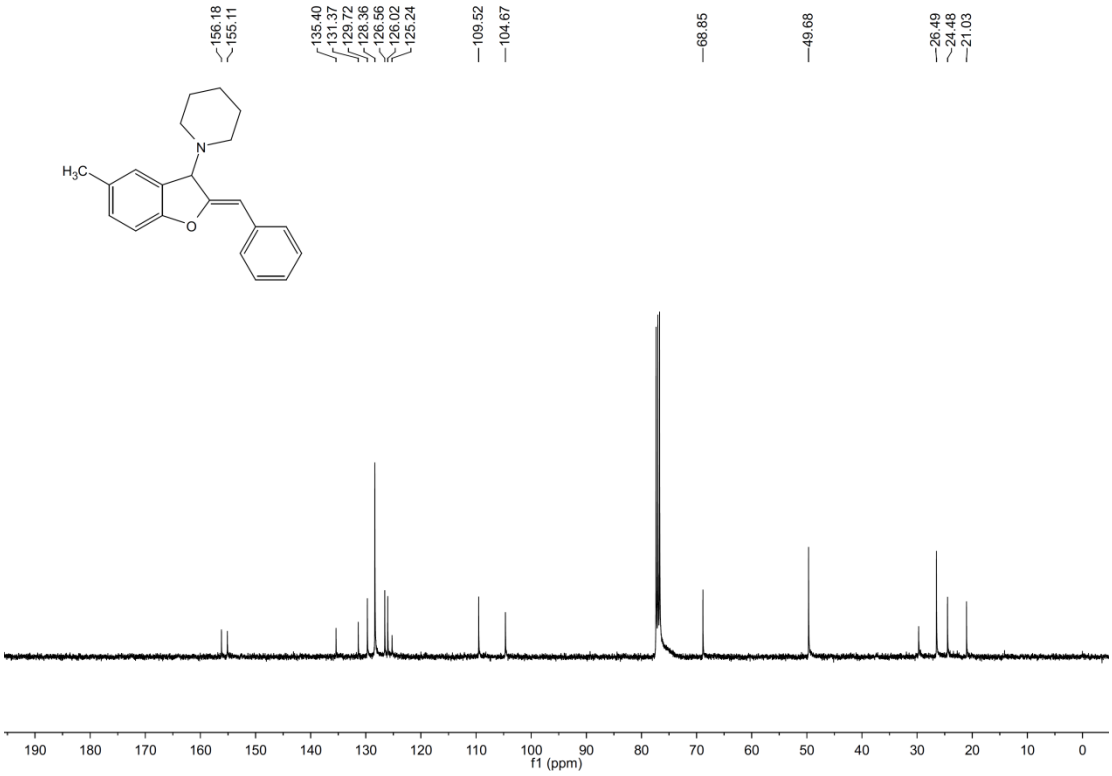

$^{1}$H NMR spectrum of **2e** (in $CDCl_3$)



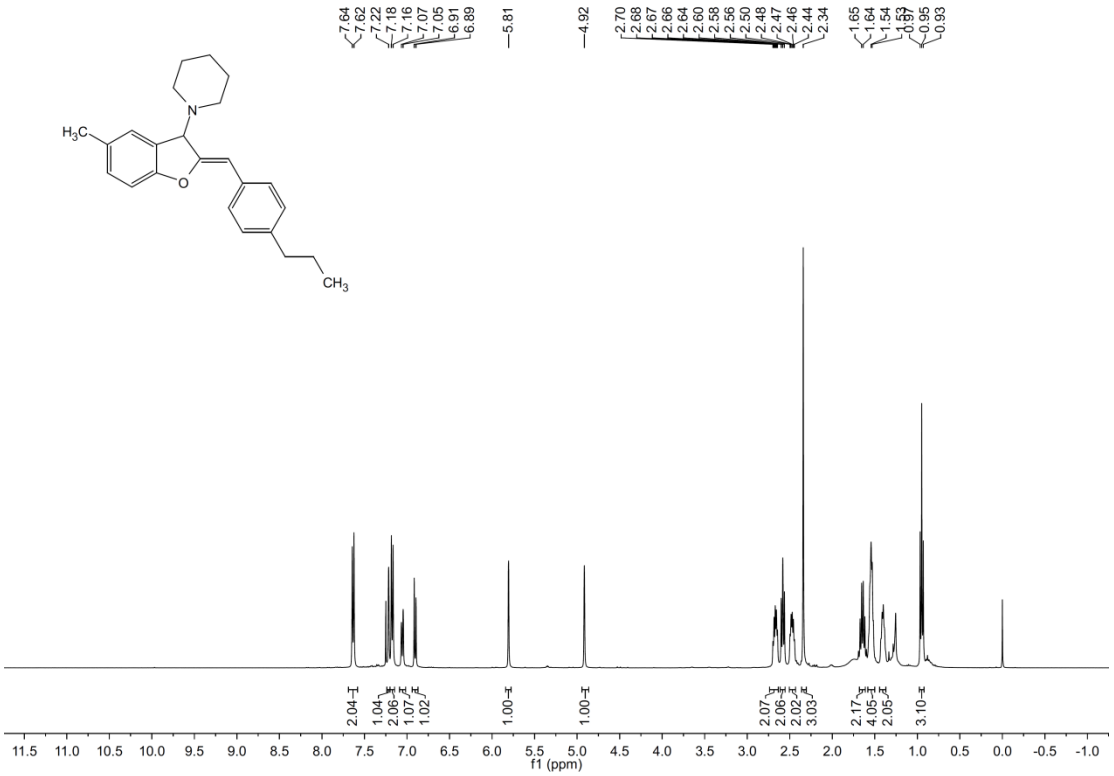

$^{13}$C NMR spectrum of **2e** (in $CDCl_3$)



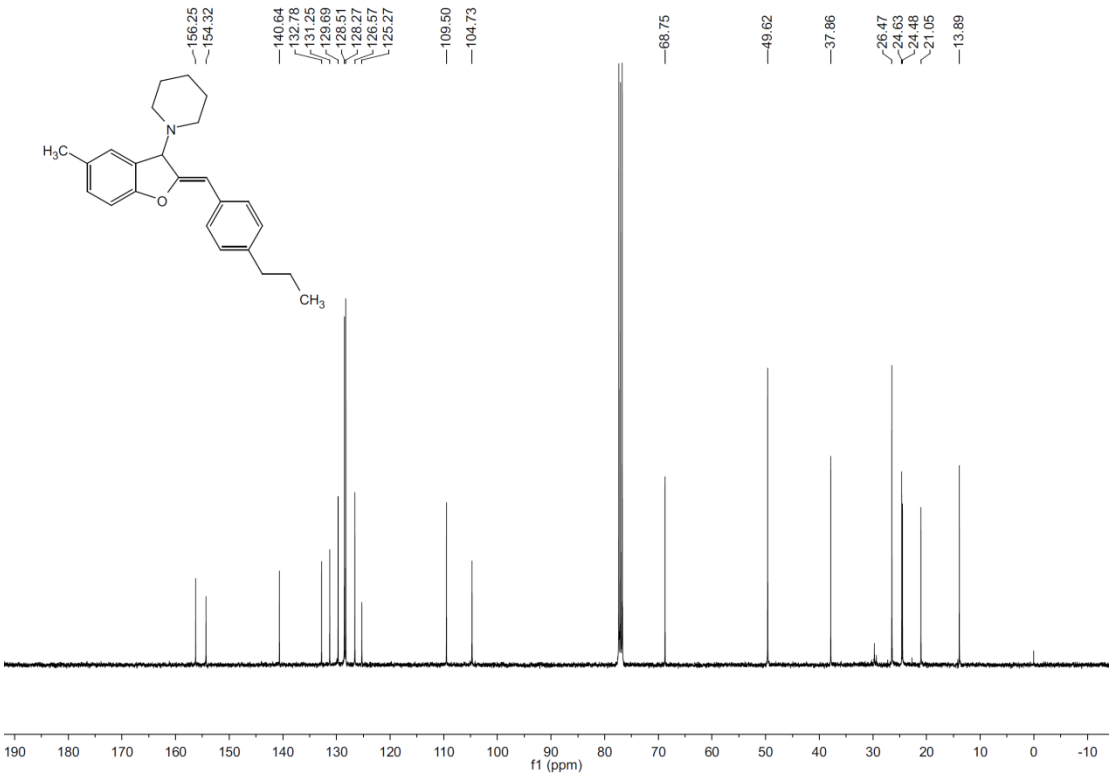

$^{1}$H NMR spectrum of **2f** (in $CDCl_3$)



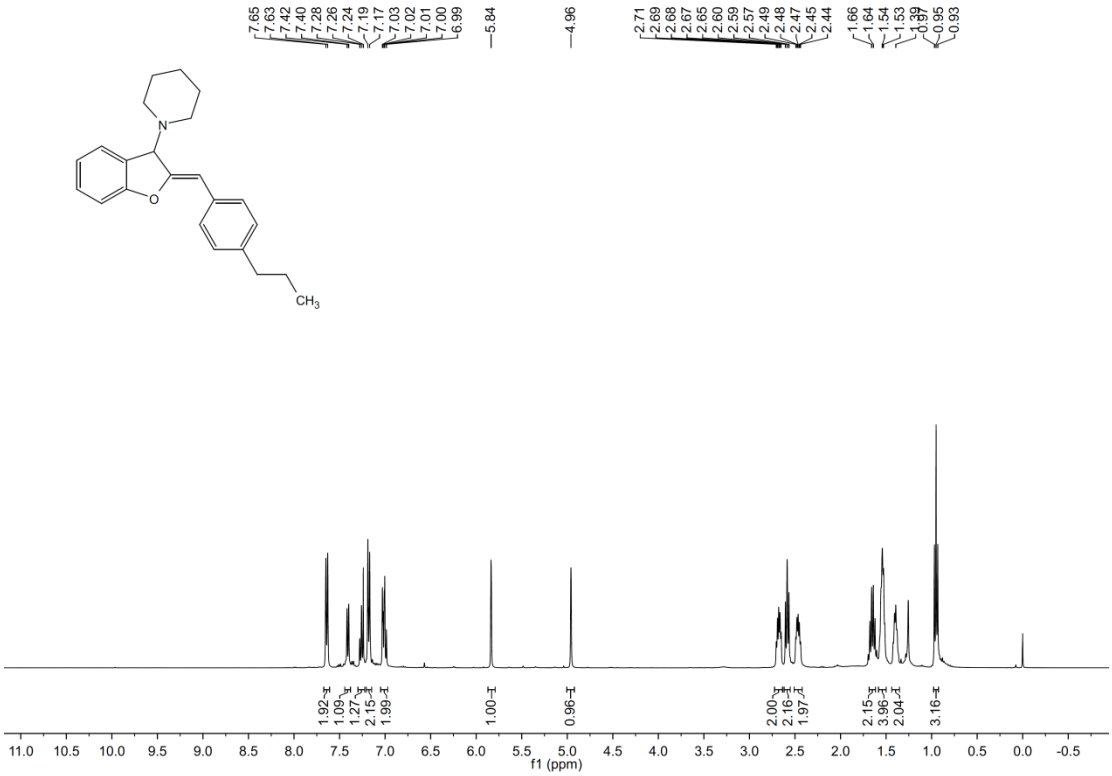

$^{13}$C NMR spectrum of **2f** (in $CDCl_3$)



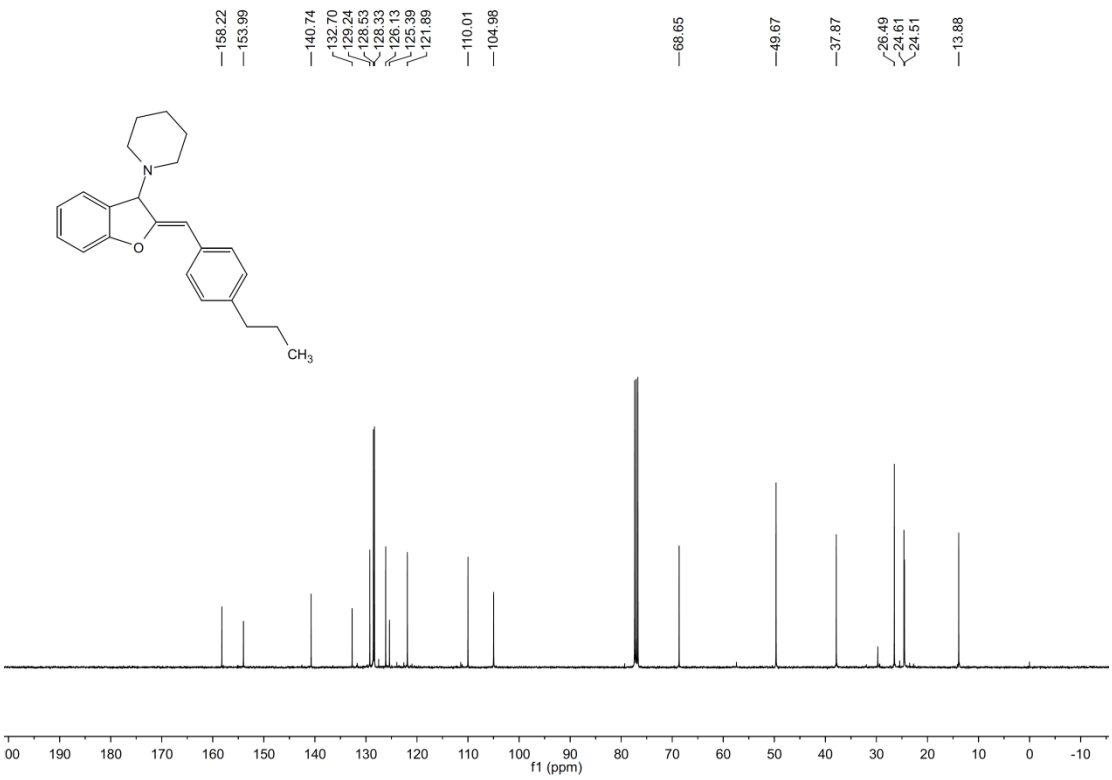

$^{1}$H NMR spectrum of **2g** (in $CDCl_3$)



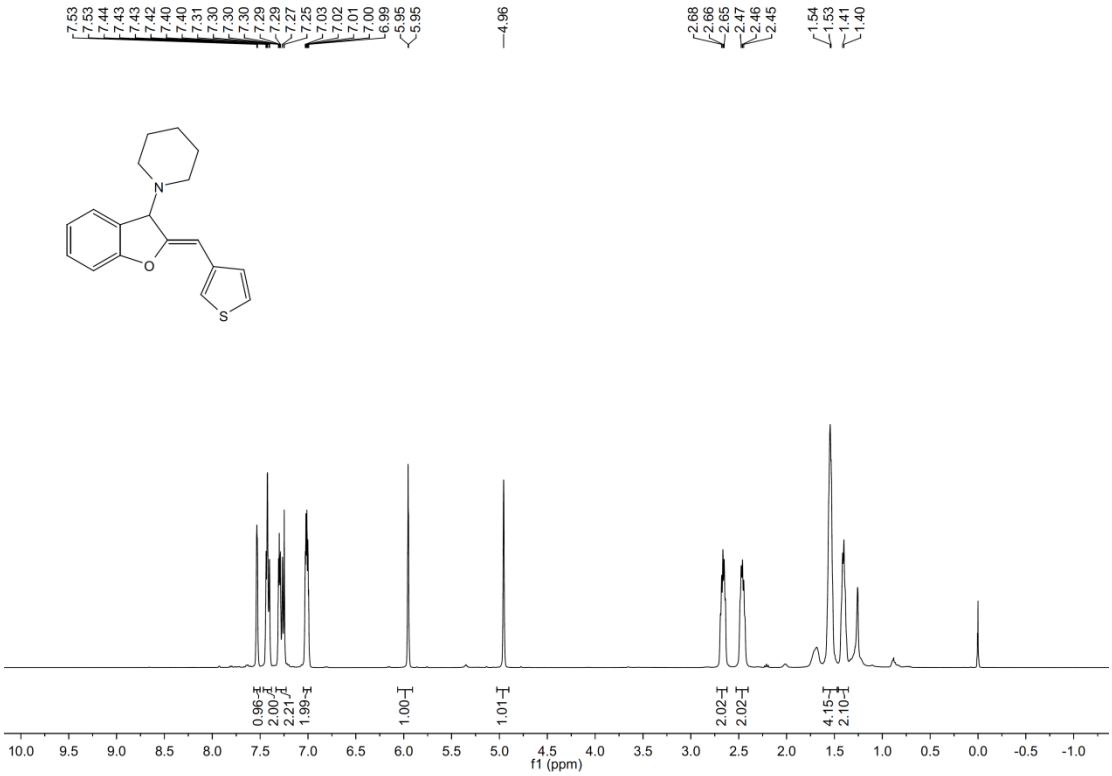

$^{13}$C NMR spectrum of **2g** (in $CDCl_3$)



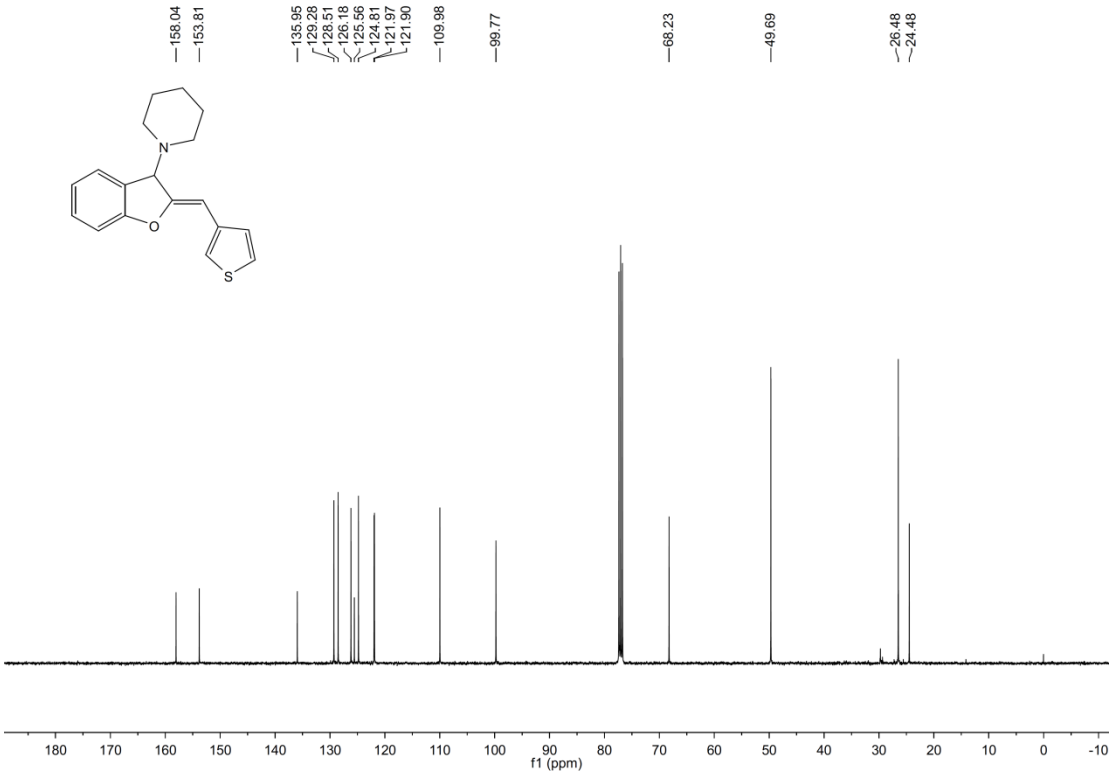

$^{1}$H NMR spectrum of **2h** (in $CDCl_3$)



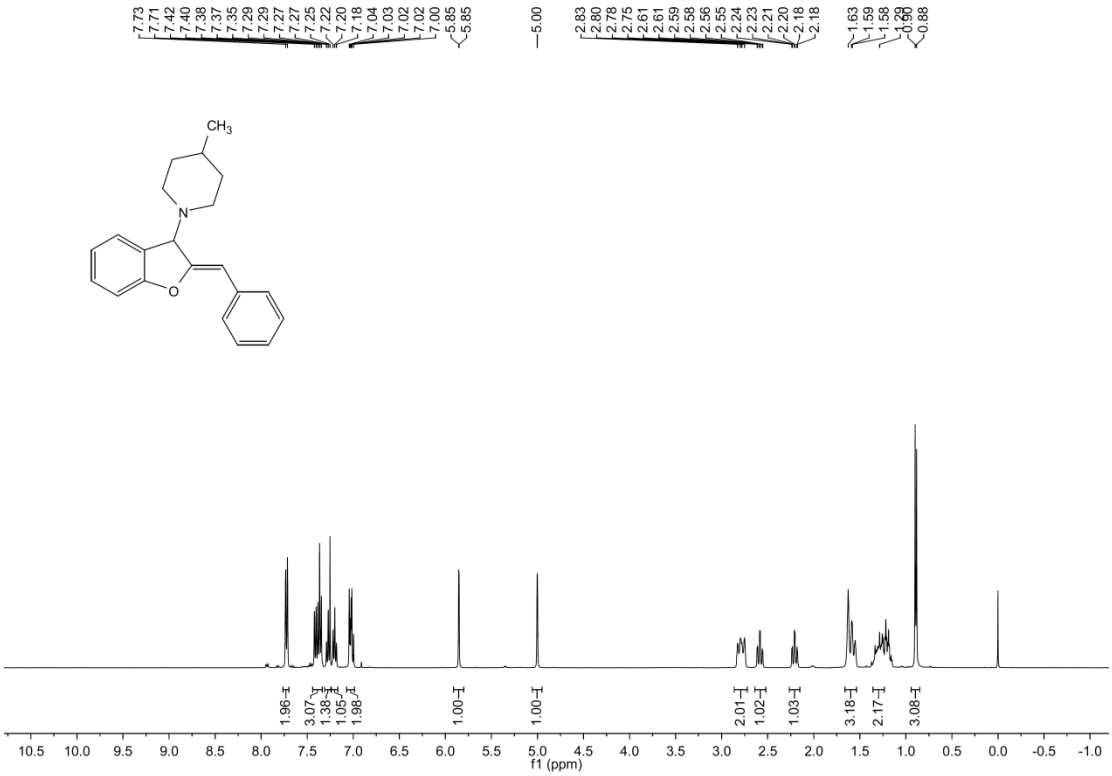

$^{13}$C NMR spectrum of **2h** (in $CDCl_3$)



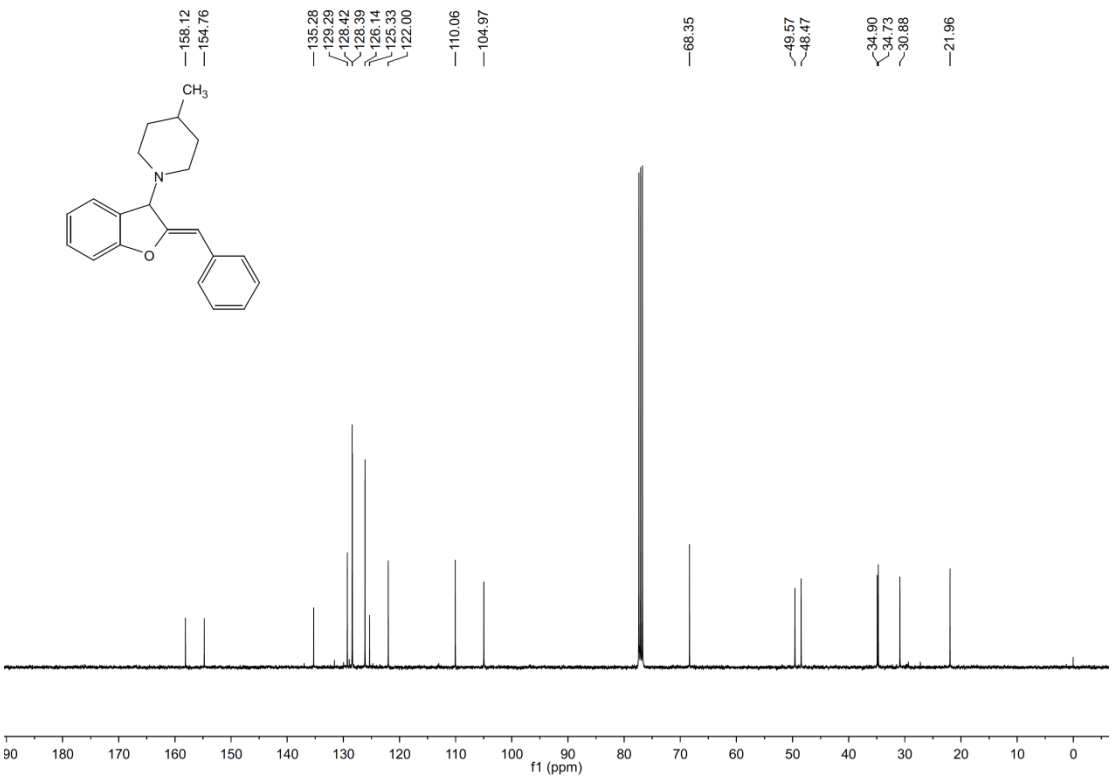

$^{1}$H NMR spectrum of **2i** (in $CDCl_3$)



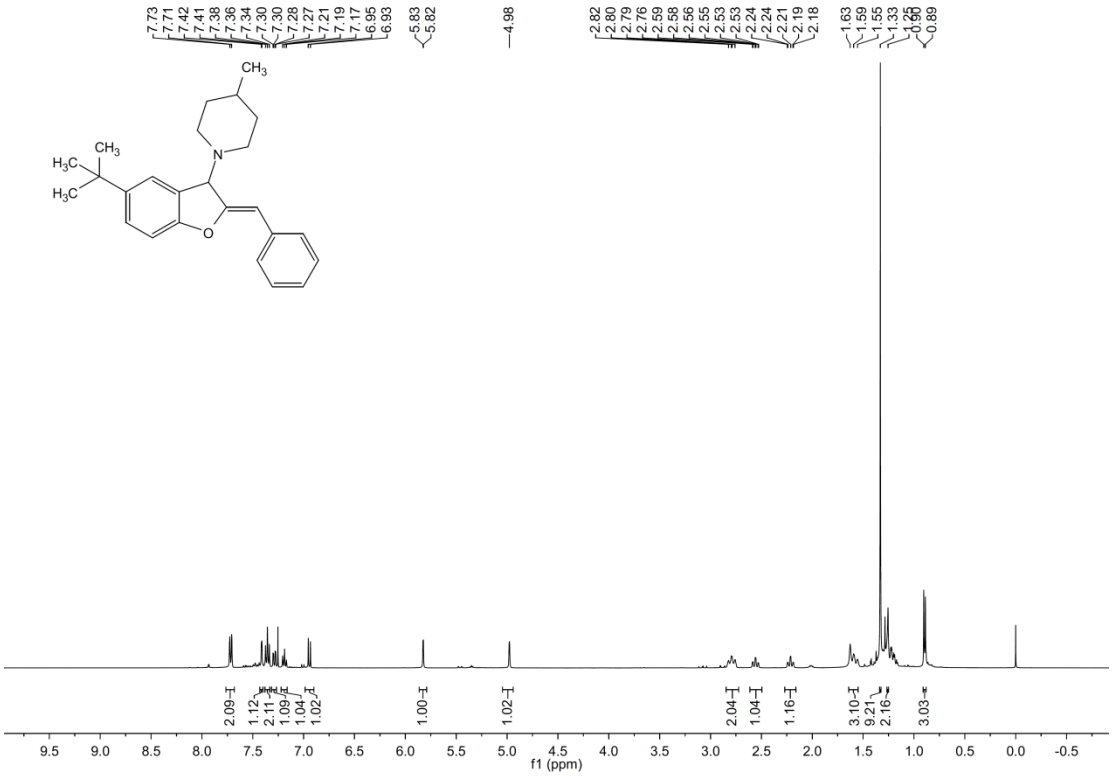

$^{13}$C NMR spectrum of **2i** (in $CDCl_3$)



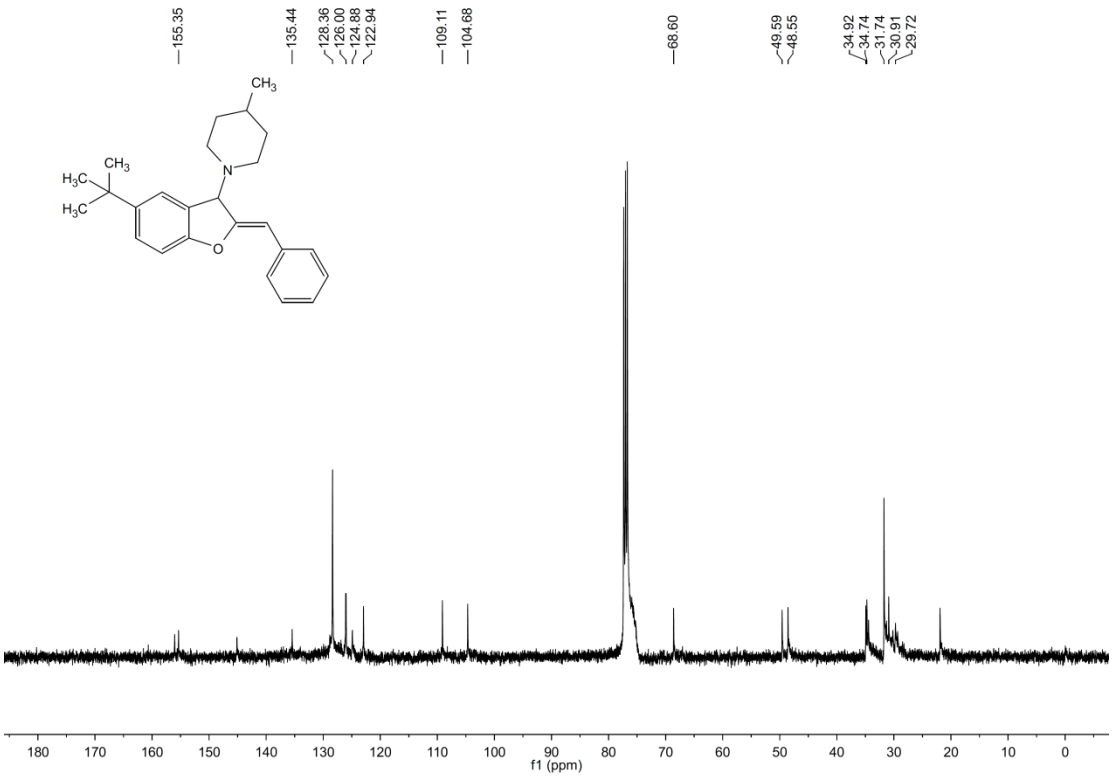

$^{1}$H NMR spectrum of **2j** (in $CDCl_3$)



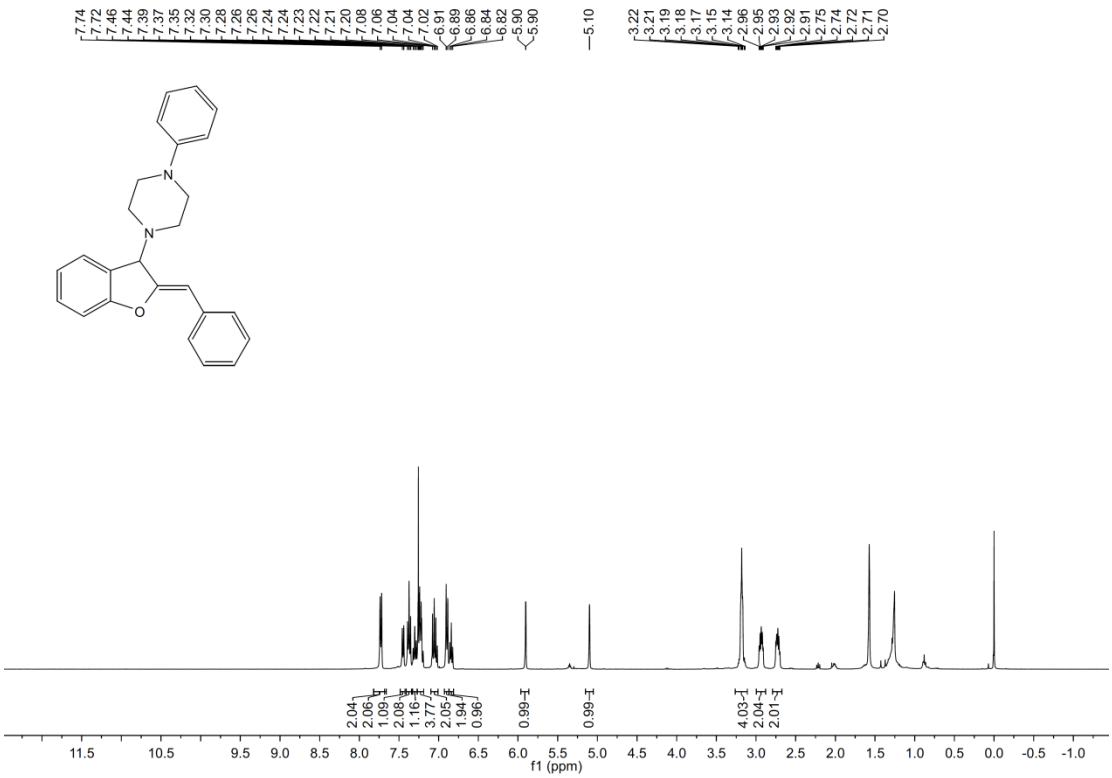

$^{13}$C NMR spectrum of **2j** (in $CDCl_3$)



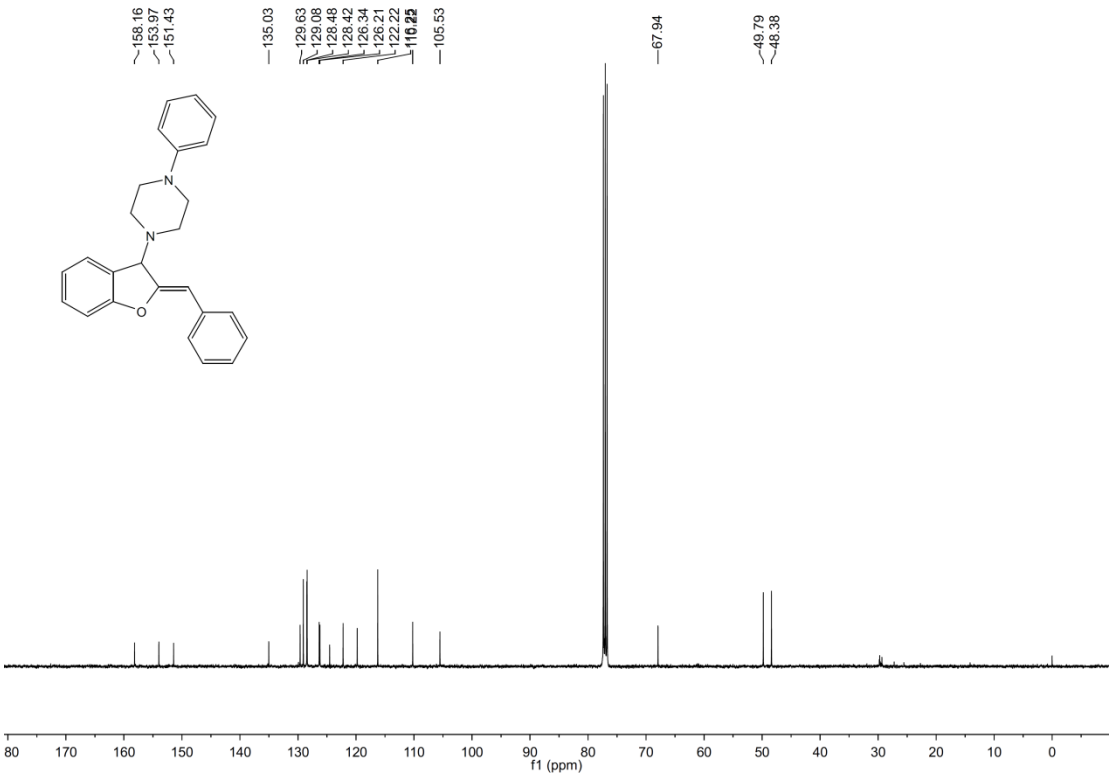

$^{1}$H NMR spectrum of **2k** (in $CDCl_3$)



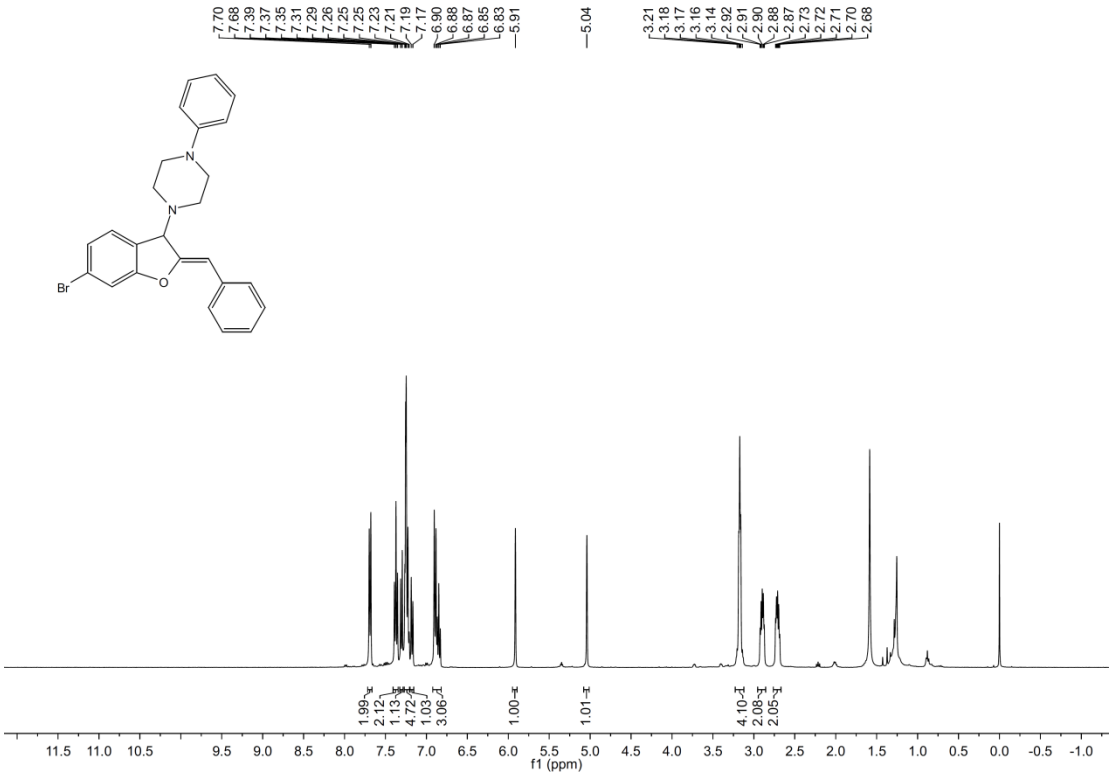

$^{13}$C NMR spectrum of **2k** (in $CDCl_3$)



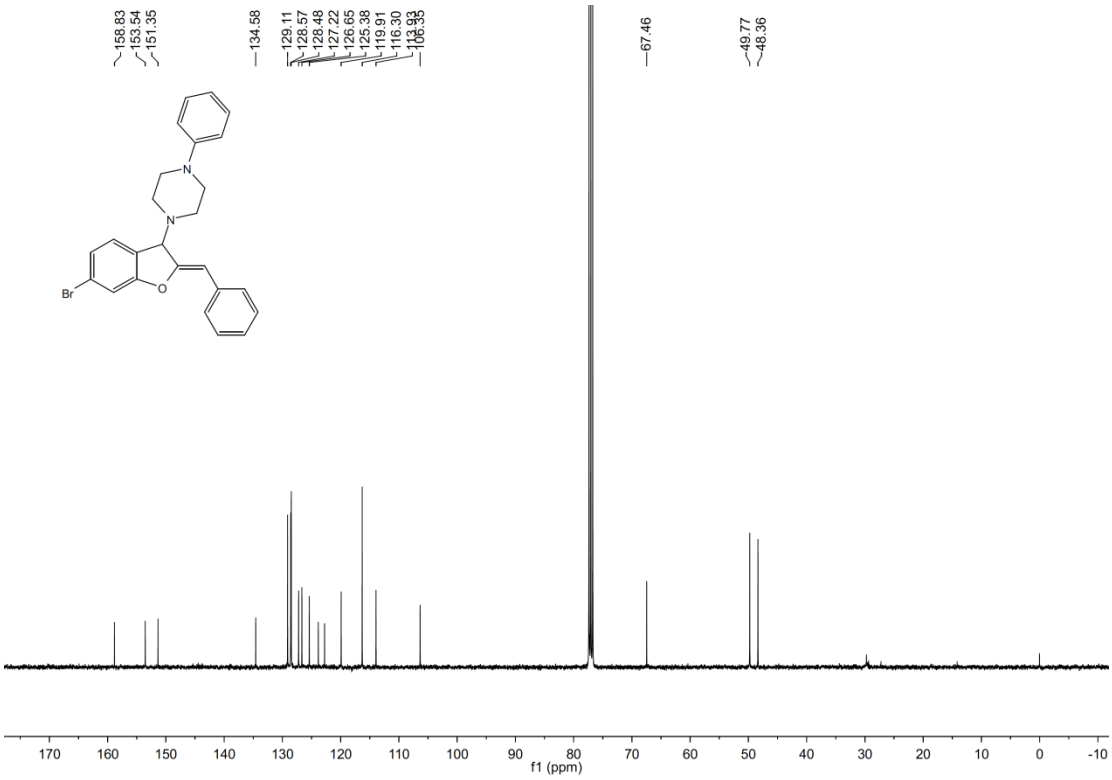

$^{1}$H NMR spectrum of **2l** (in $CDCl_3$)



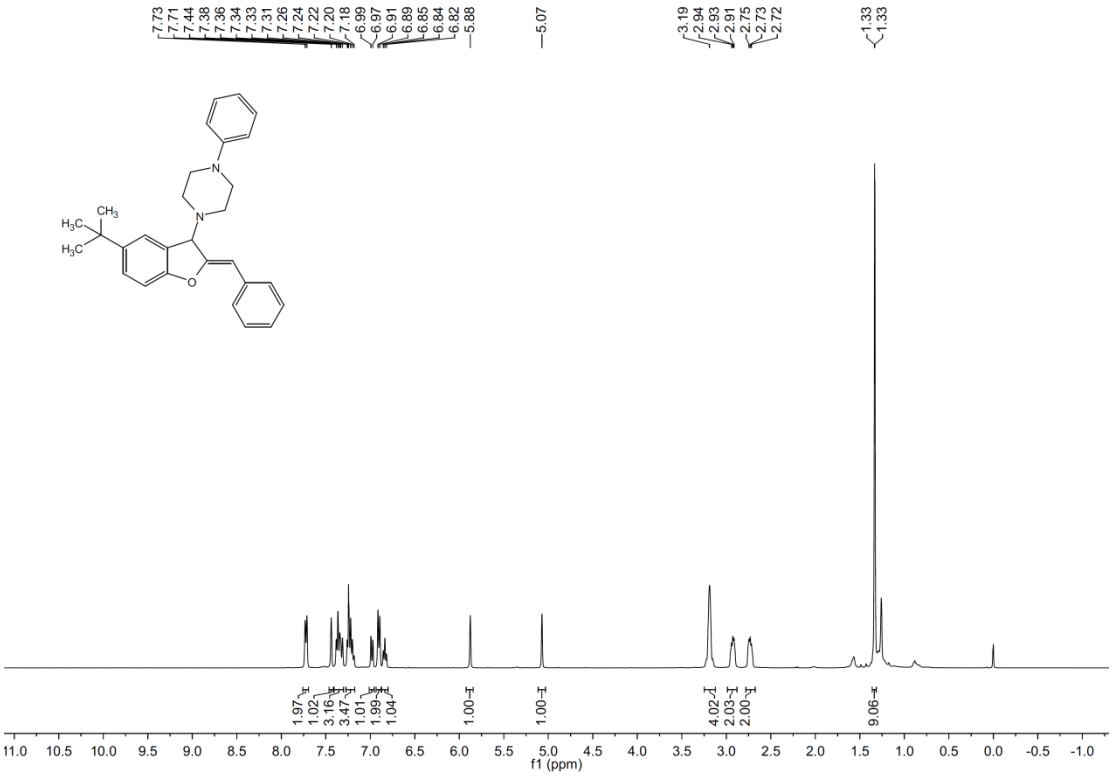

$^{13}$C NMR spectrum of **2l** (in $CDCl_3$)



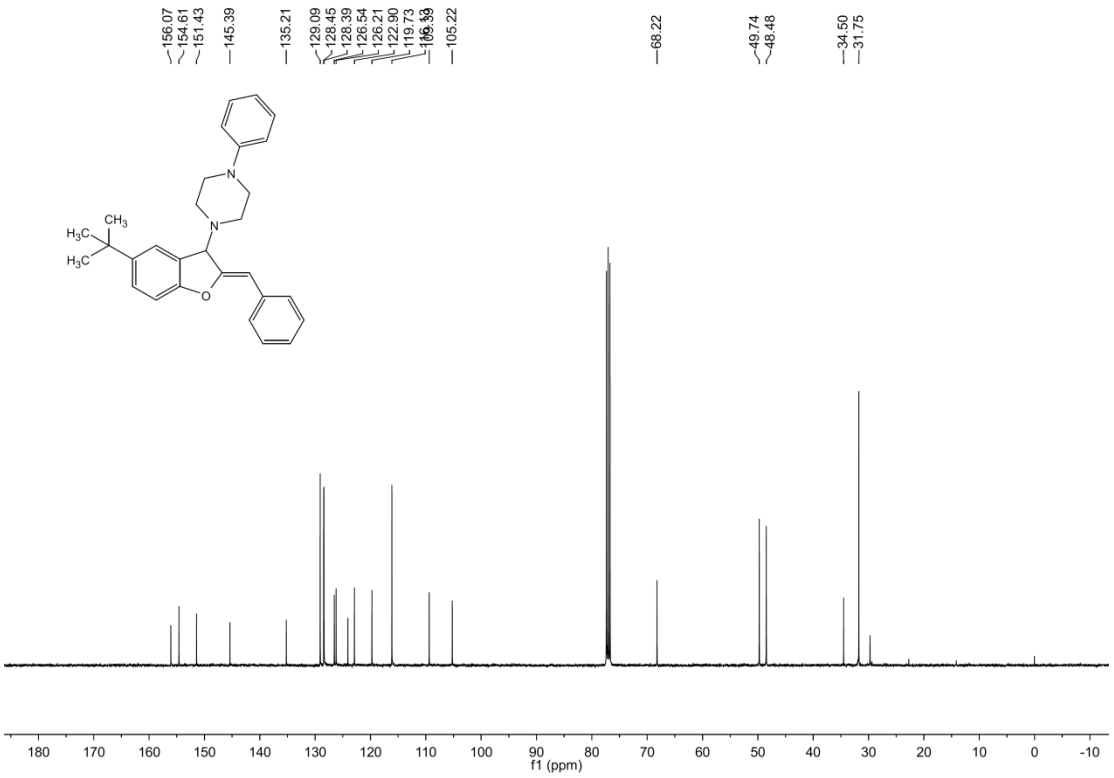

$^{1}$H NMR spectrum of **2m** (in $CDCl_3$)



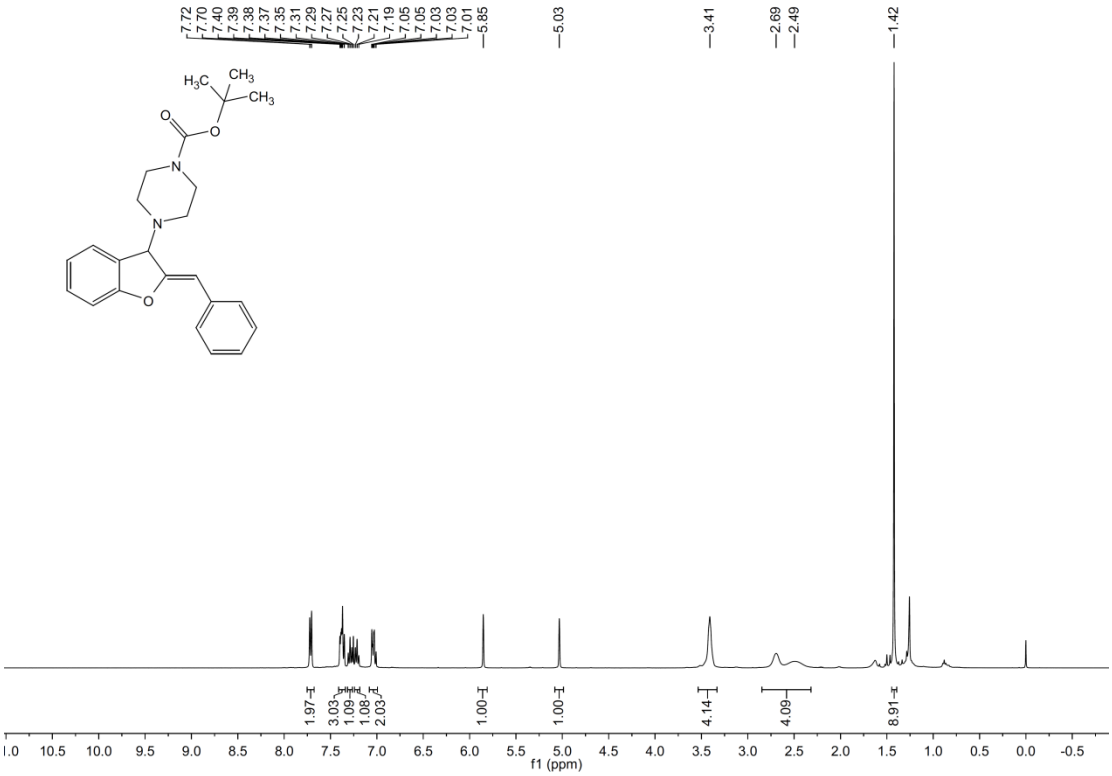

$^{13}$C NMR spectrum of **2m** (in $CDCl_3$)



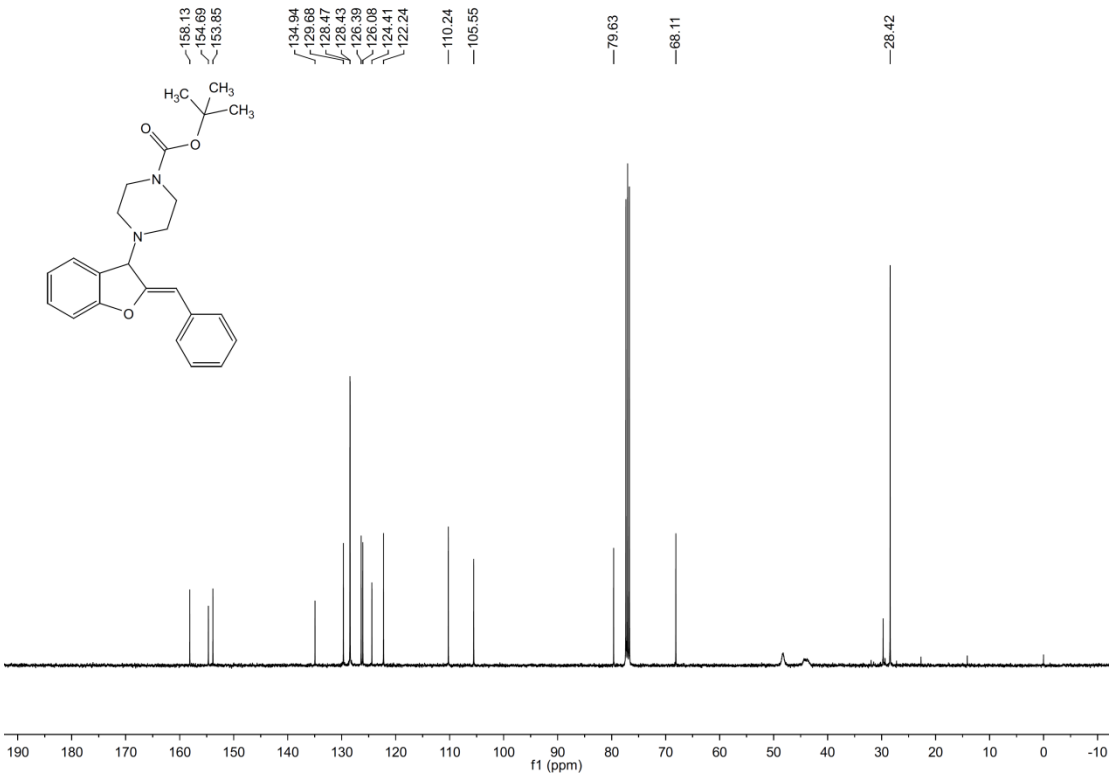

$^{1}$H NMR spectrum of **2n** (in $CDCl_3$)



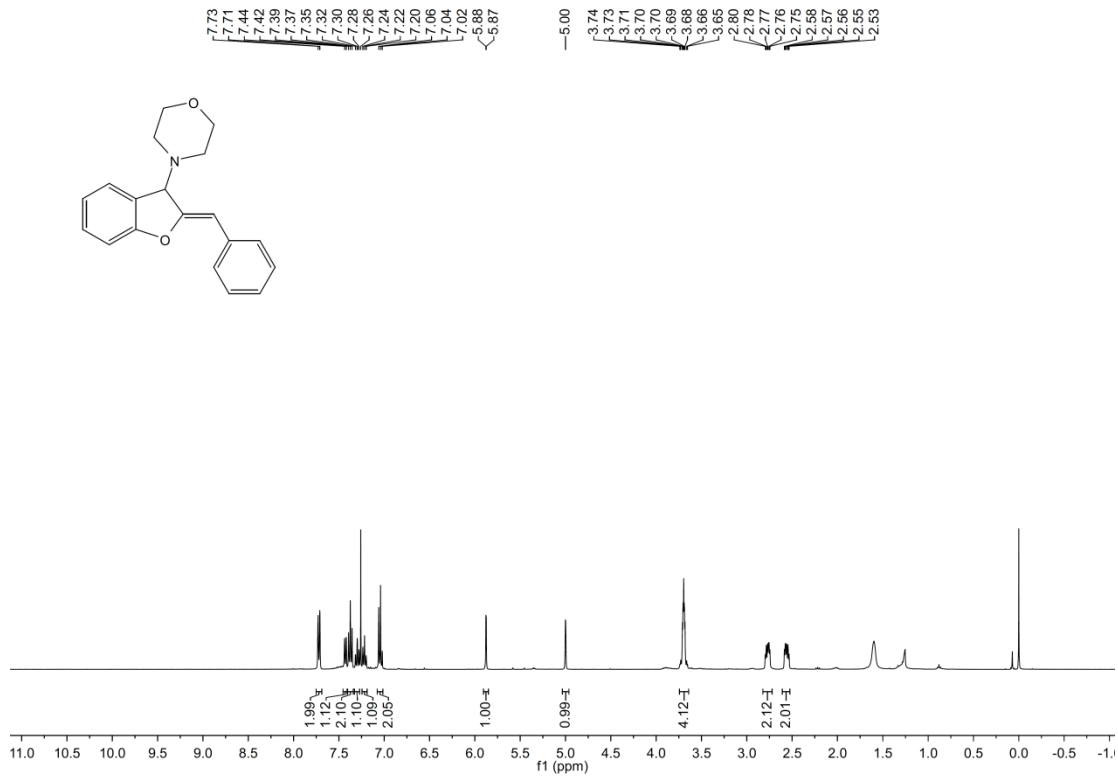

$^{13}$C NMR spectrum of **2n** (in $CDCl_3$)



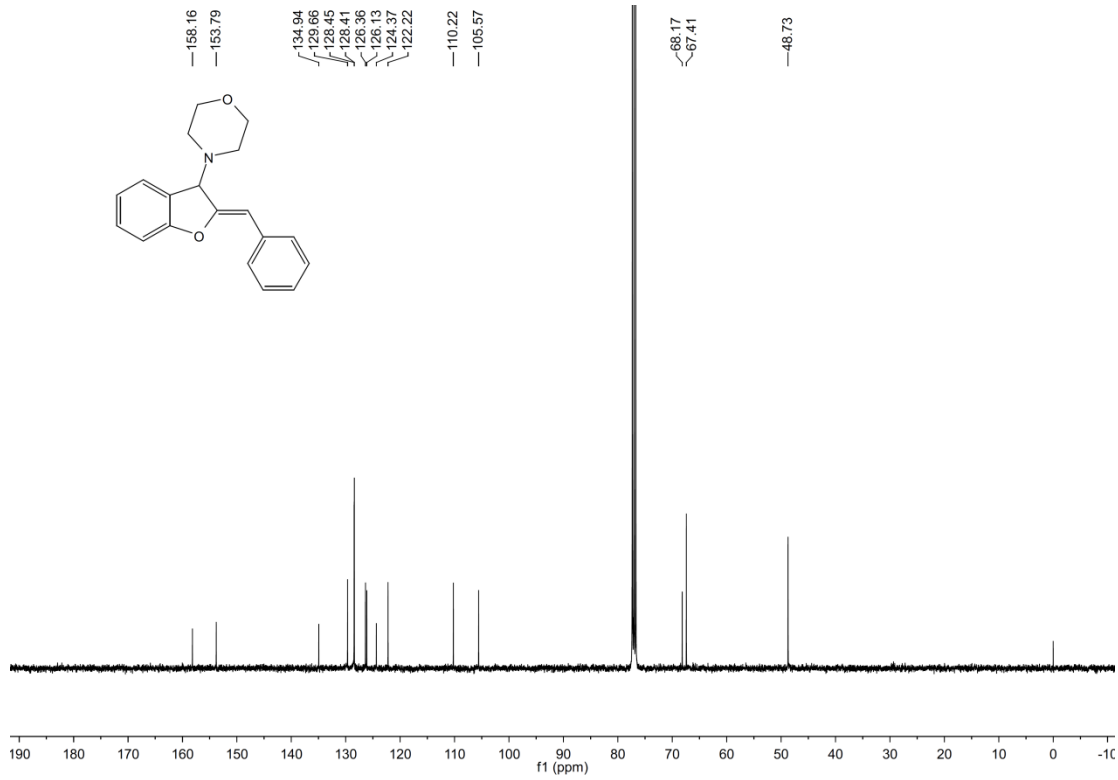

$^{1}$H NMR spectrum of **2o** (in $CDCl_3$)



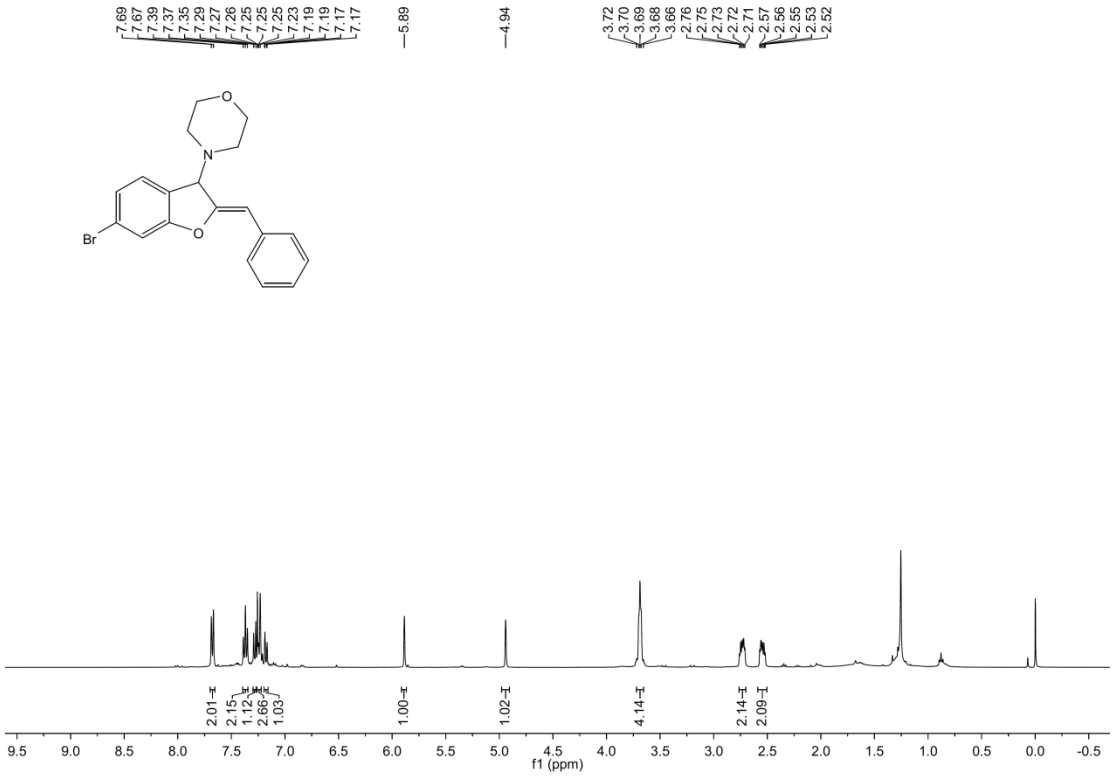

$^{13}$C NMR spectrum of **2o** (in $CDCl_3$)



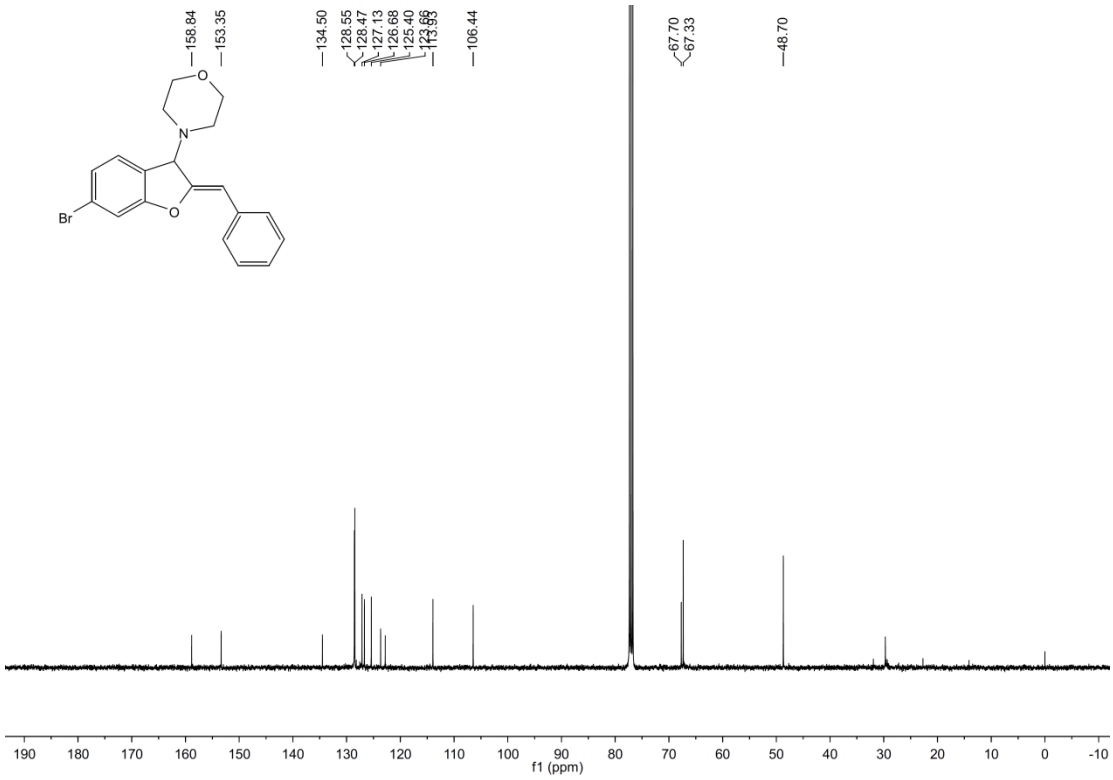

$^{1}$H NMR spectrum of **2p** (in $CDCl_3$)



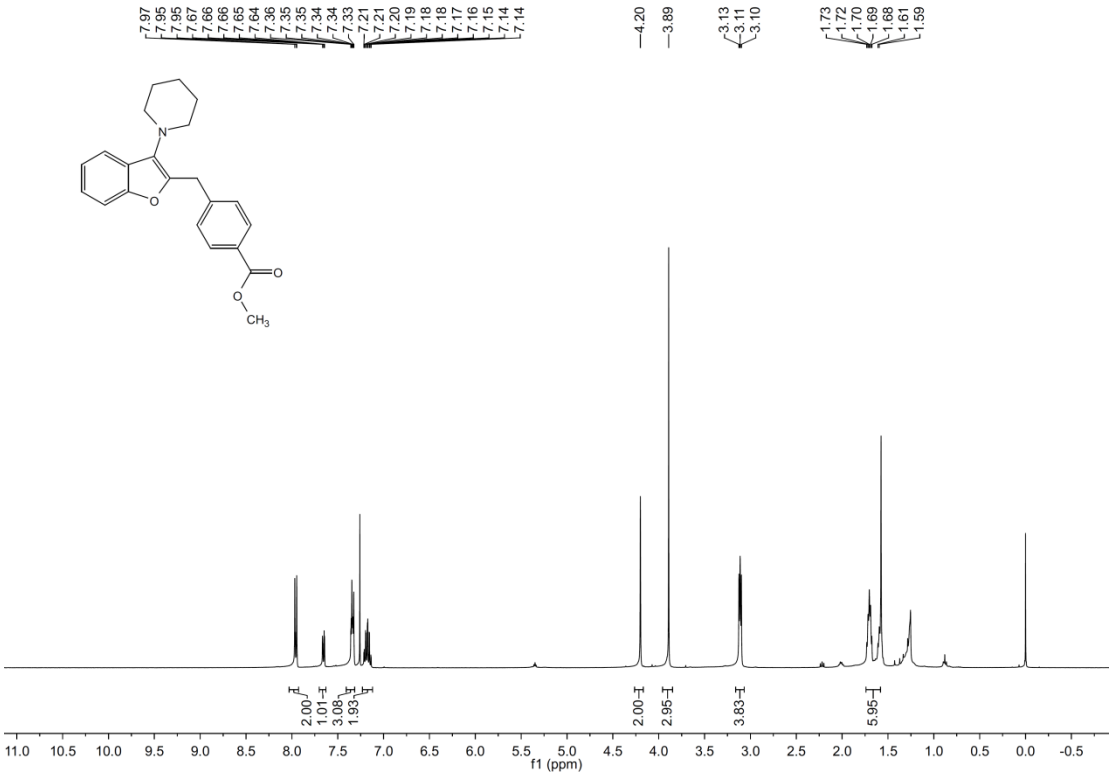

$^{13}$C NMR spectrum of **2p** (in $CDCl_3$)



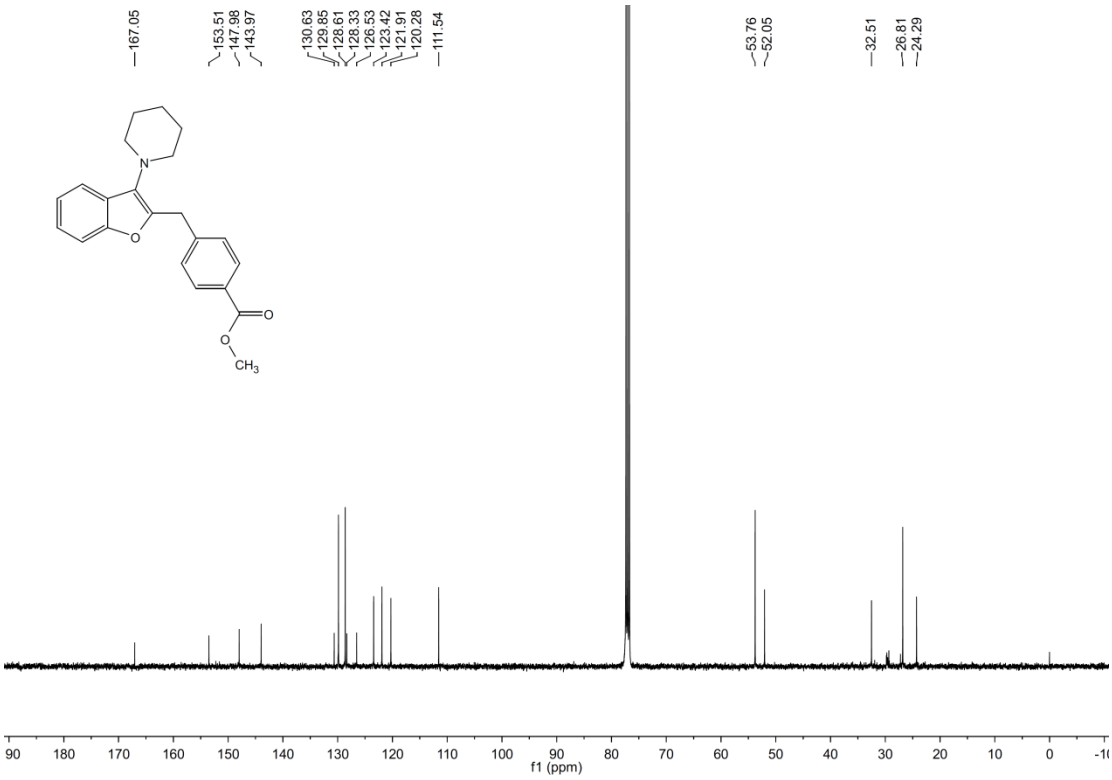

$^{1}$H NMR spectrum of **2q** (in $CDCl_3$)



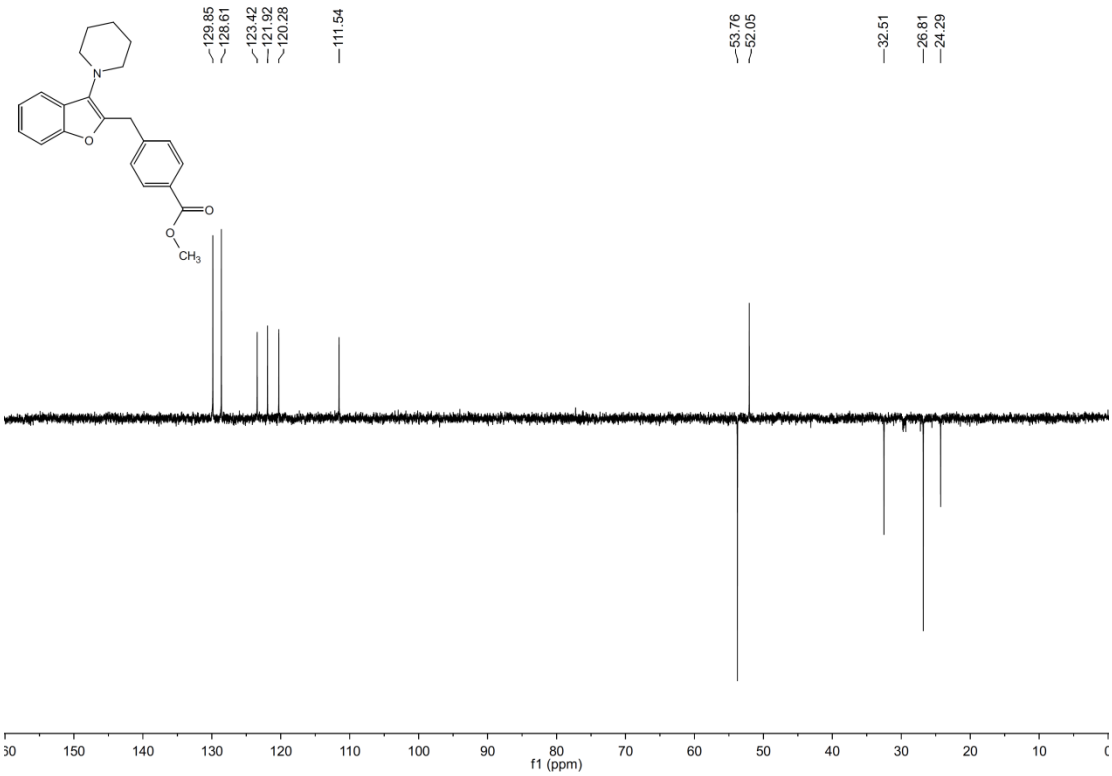

$^{13}$C NMR spectrum of **2q** (in $CDCl_3$)



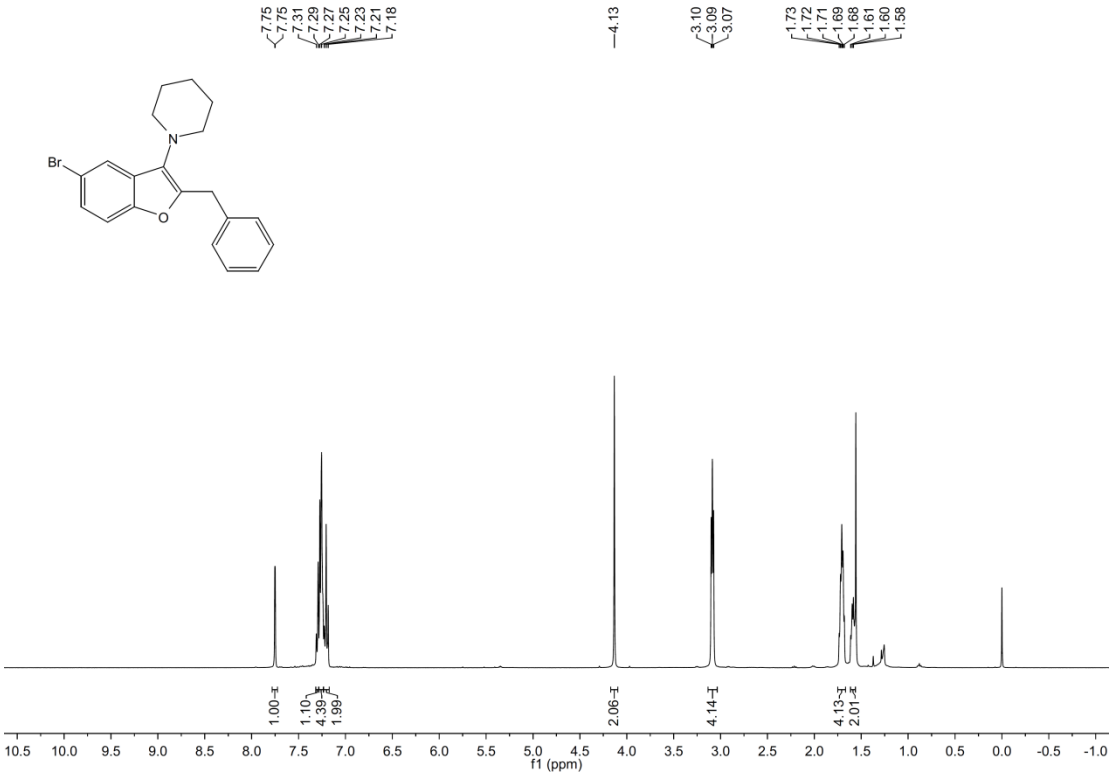

$^{1}$H NMR spectrum of **4a** (in $CDCl_3$)



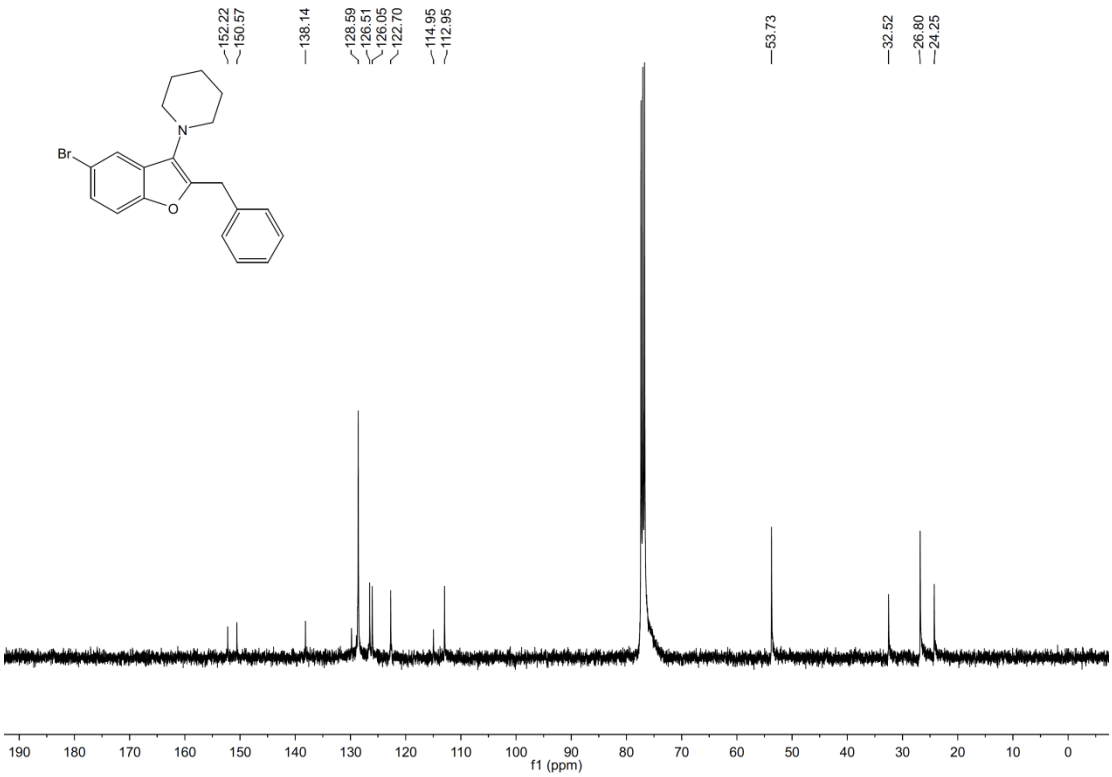

$^{13}$C NMR spectrum of **4a** (in $CDCl_3$)



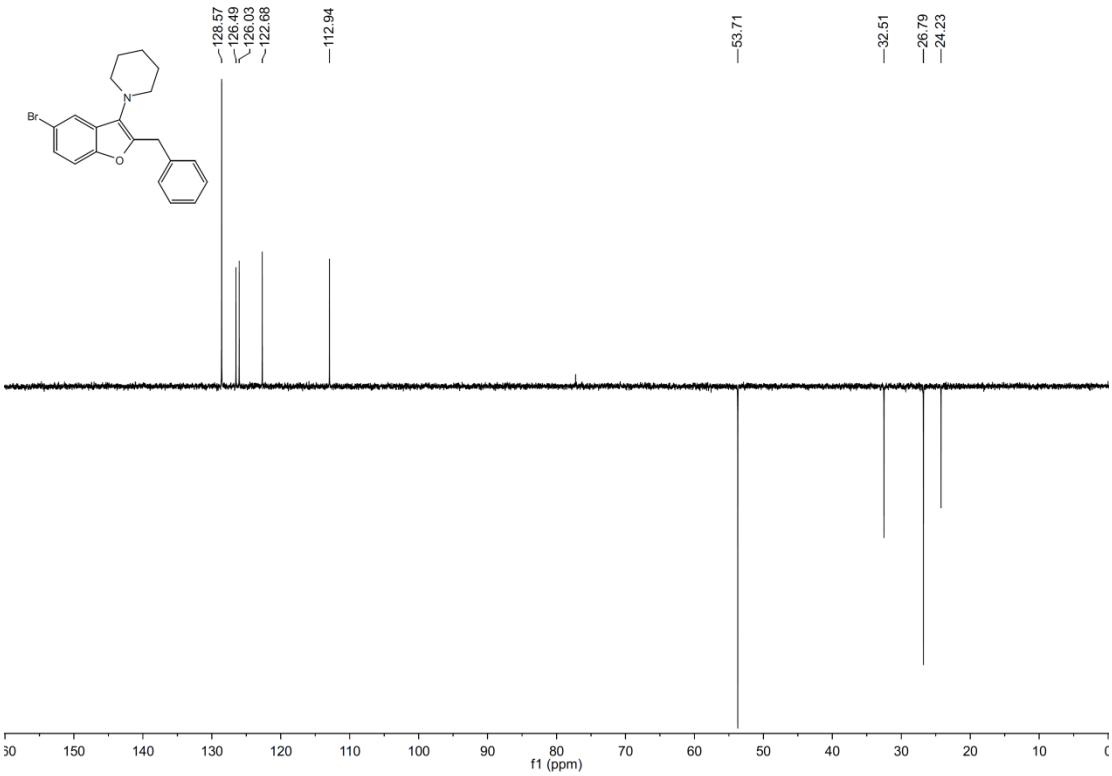

DEPT 135$^{o}$ spectrum of **4a** (in $CDCl_3$)



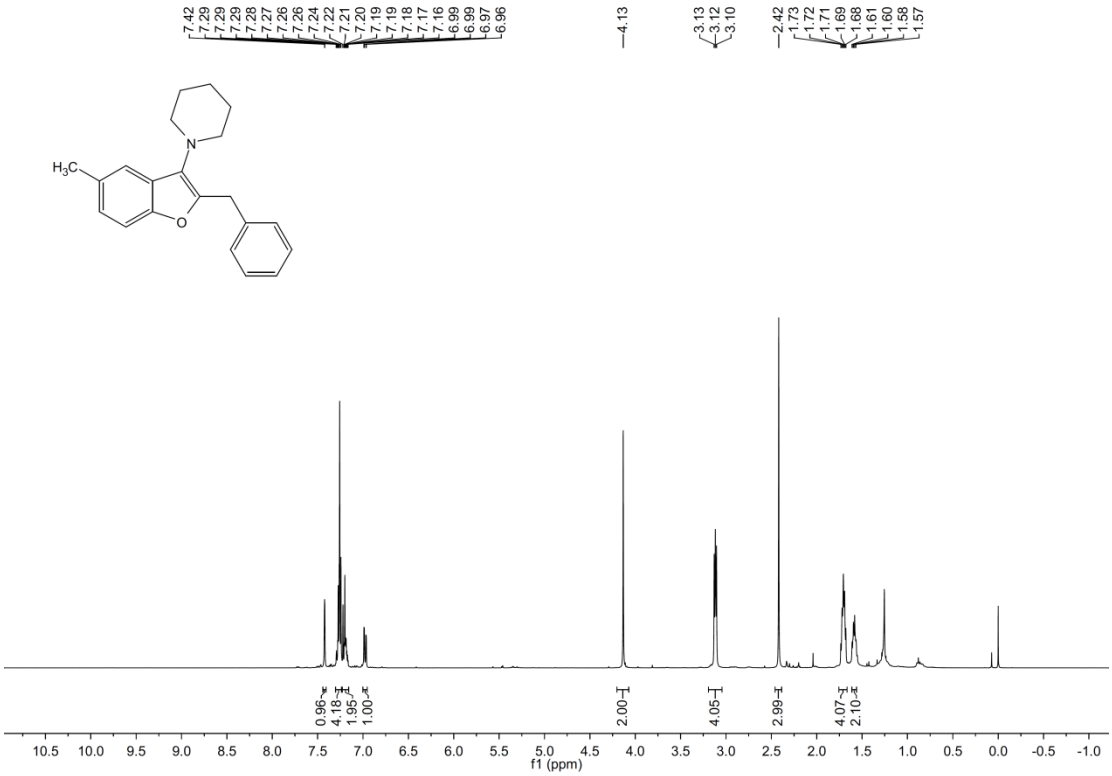

$^{1}$H NMR spectrum of **4c** (in $CDCl_3$)



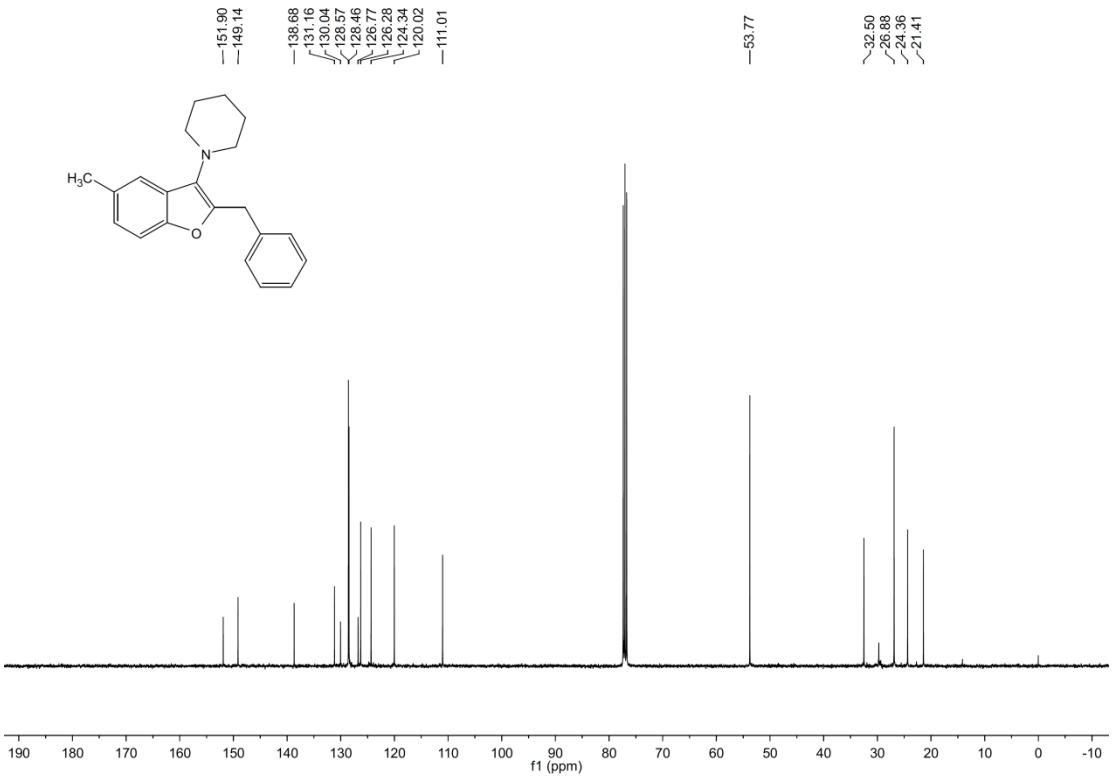

$^{13}$C NMR spectrum of **4c**



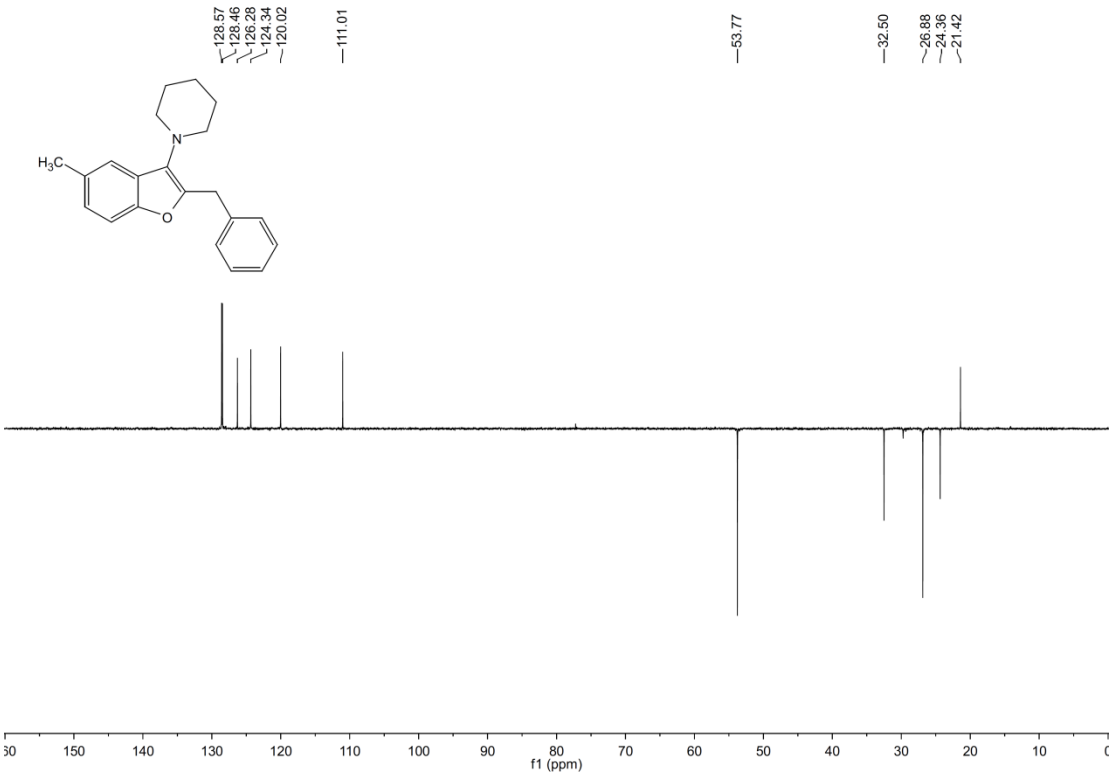

DEPT 135 °spectrum of **4c** (in $CDCl_3$)



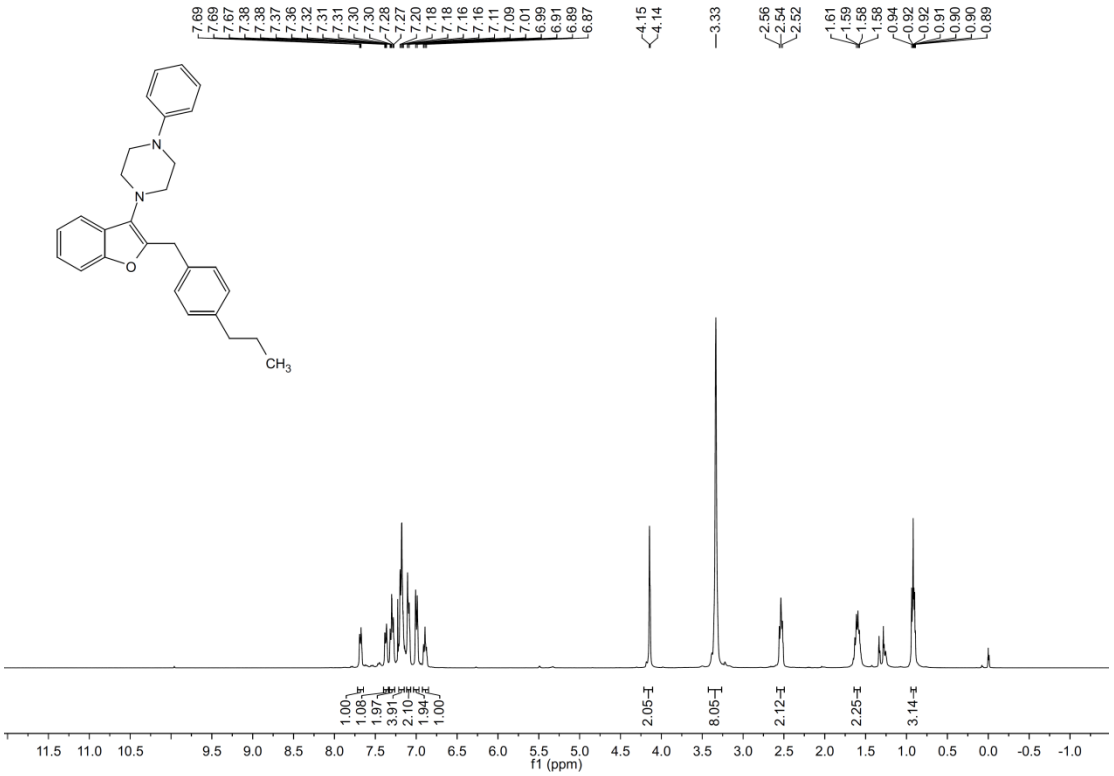

$^{1}$H NMR spectrum of **4d** (in $CDCl_3$)



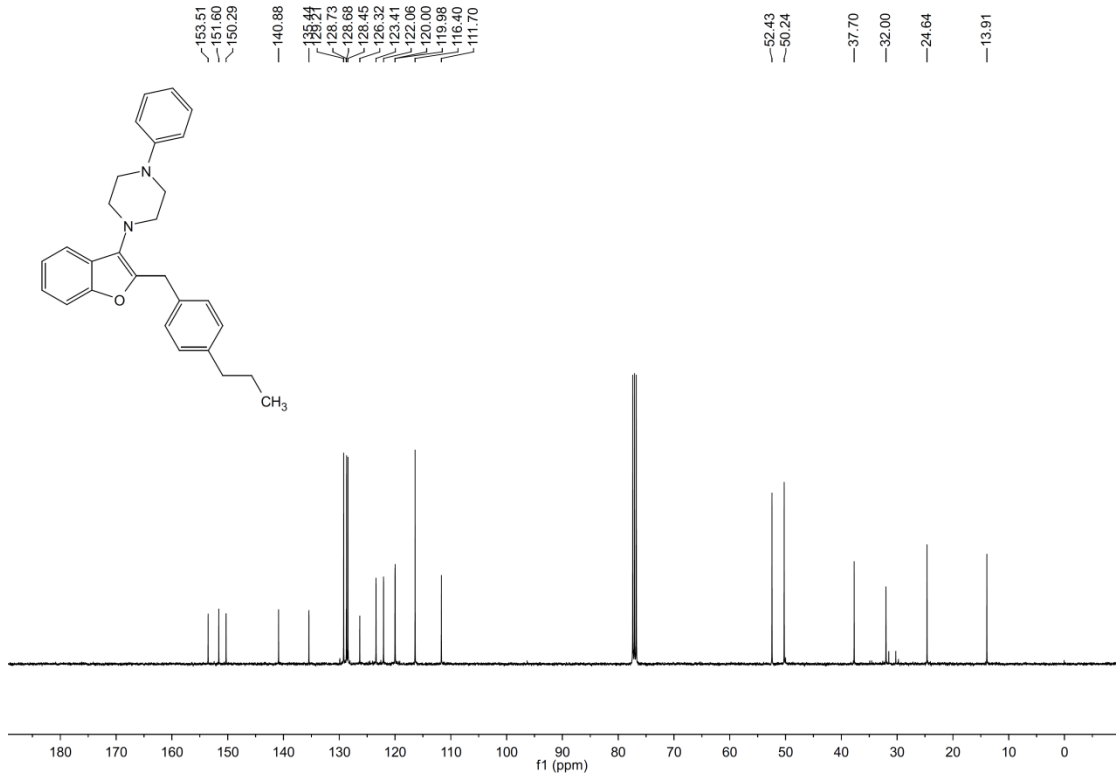

$^{13}$C NMR spectrum of **4d** (in $CDCl_3$)



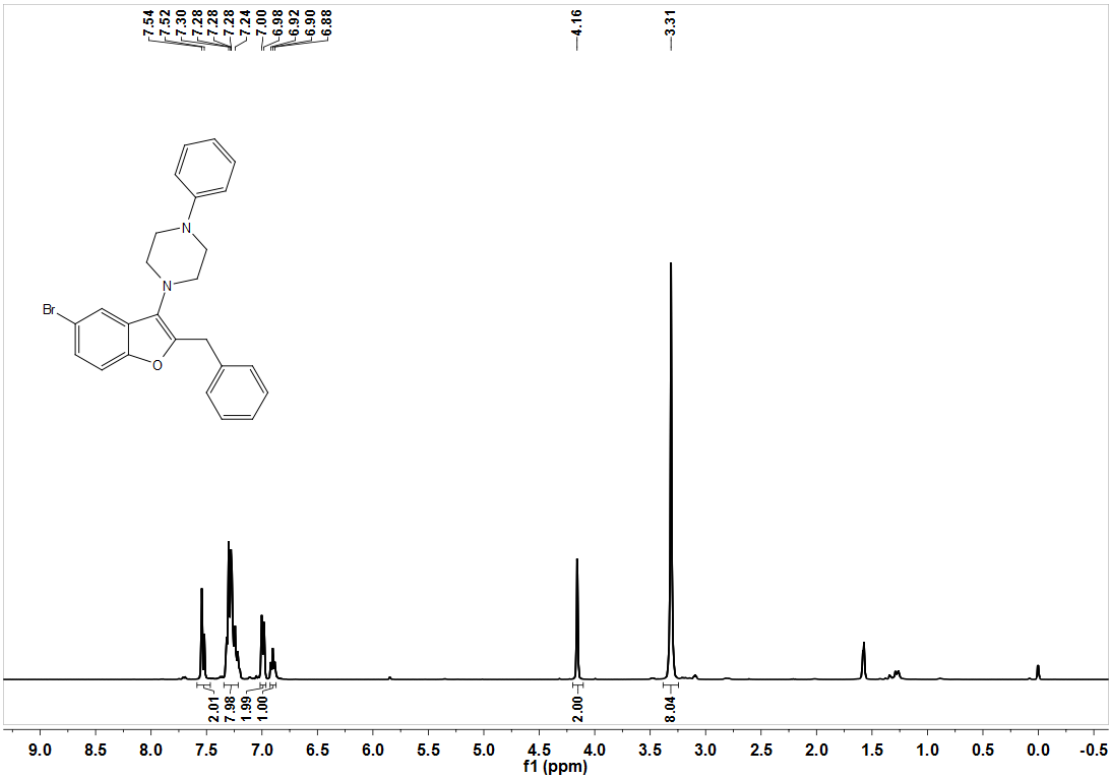

DEPT 135 °spectrum of **4d** (in $CDCl_3$)



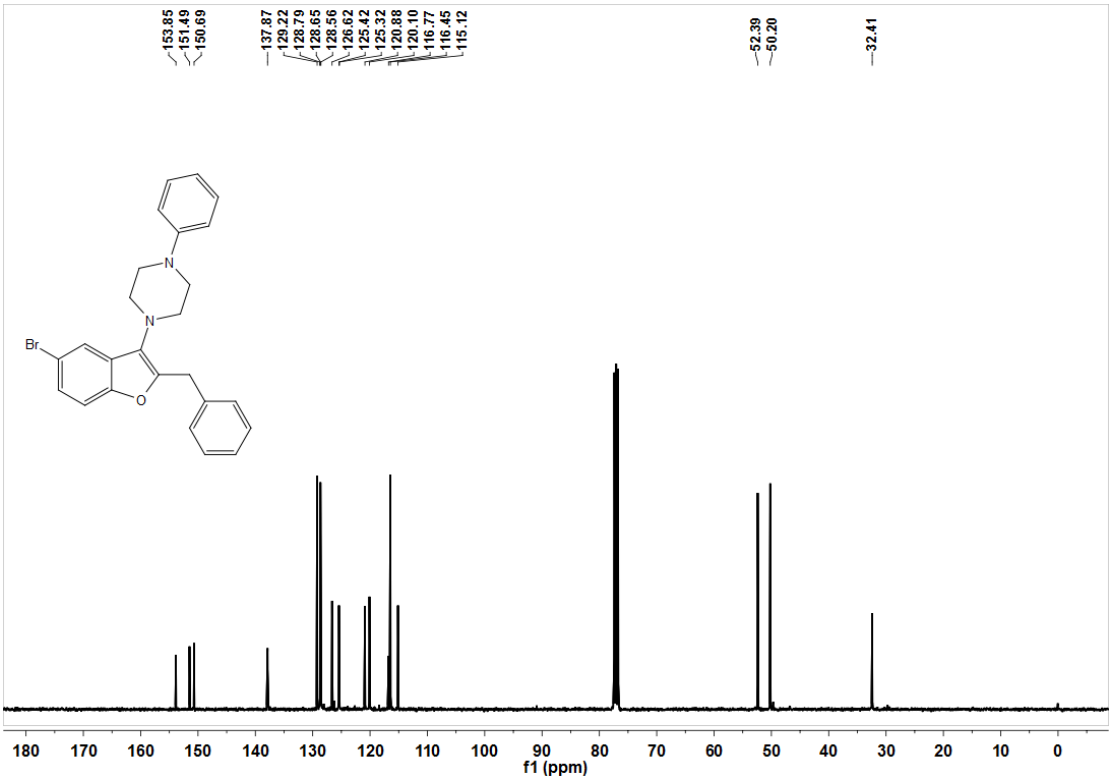

$^1$H NMR spectrum of **4e** (in $CDCl_3$)



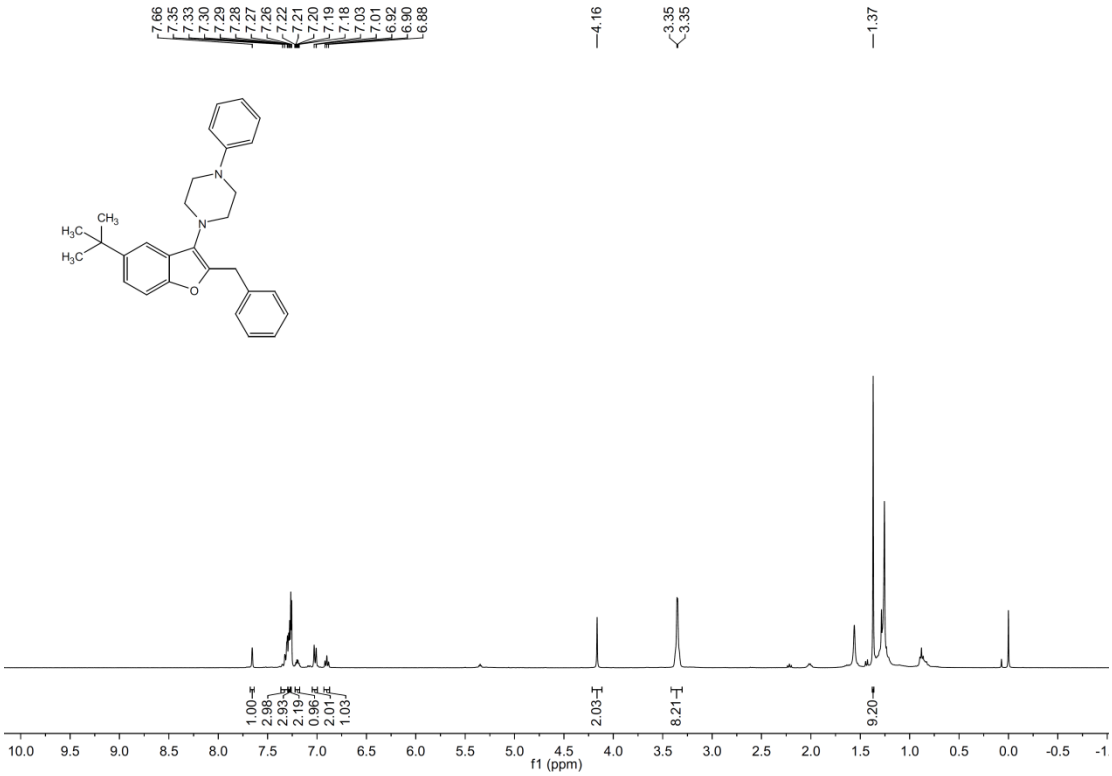

$^1$H NMR spectrum of **4e** (in $CDCl_3$)



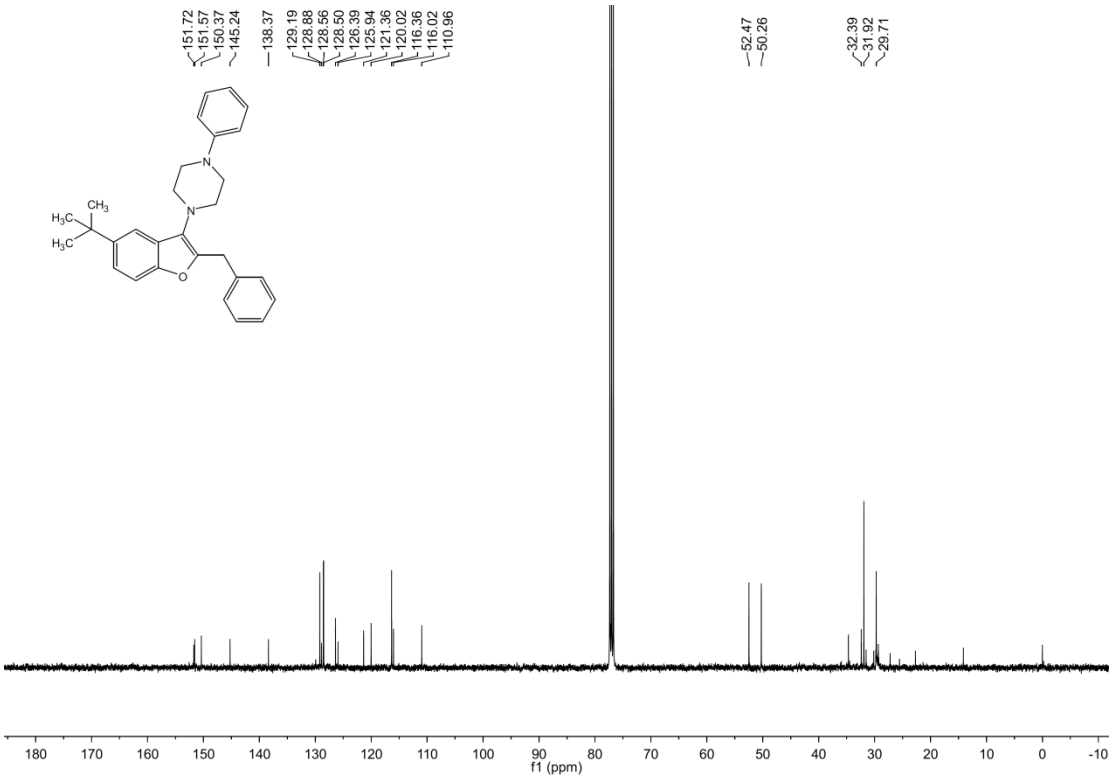

$^{1}$H NMR spectrum of **4f** (in $CDCl_3$)



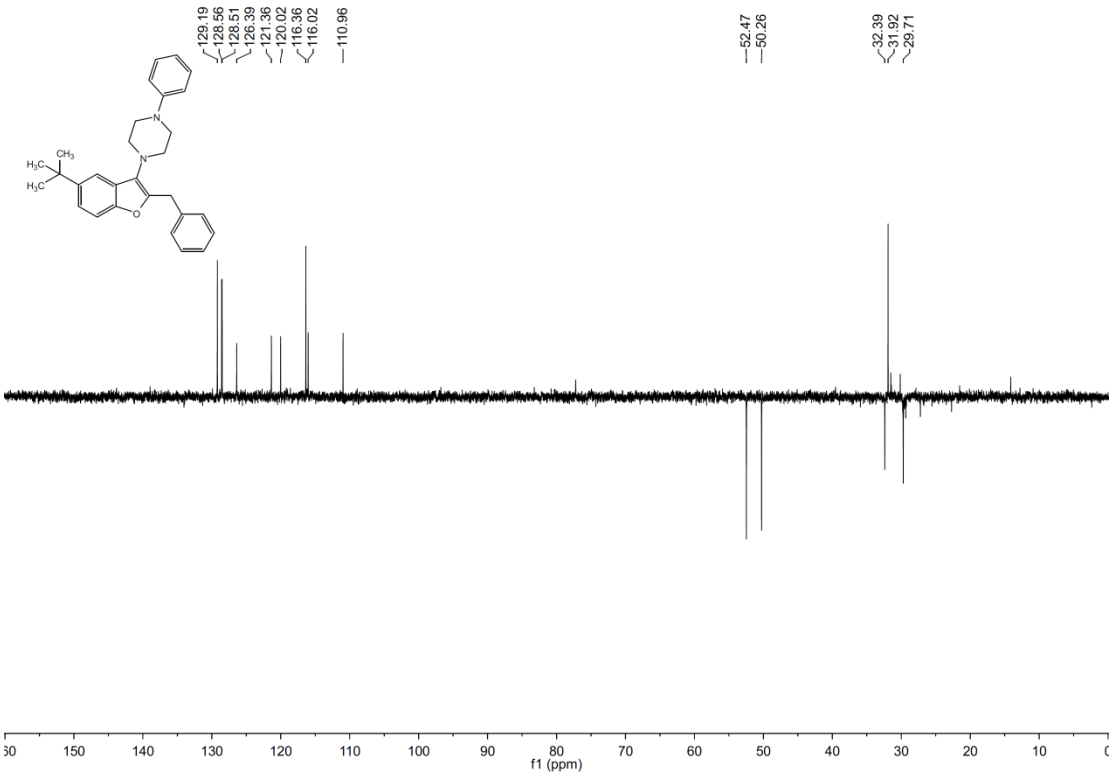

$^{13}$C NMR spectrum of **4f** (in $CDCl_3$)



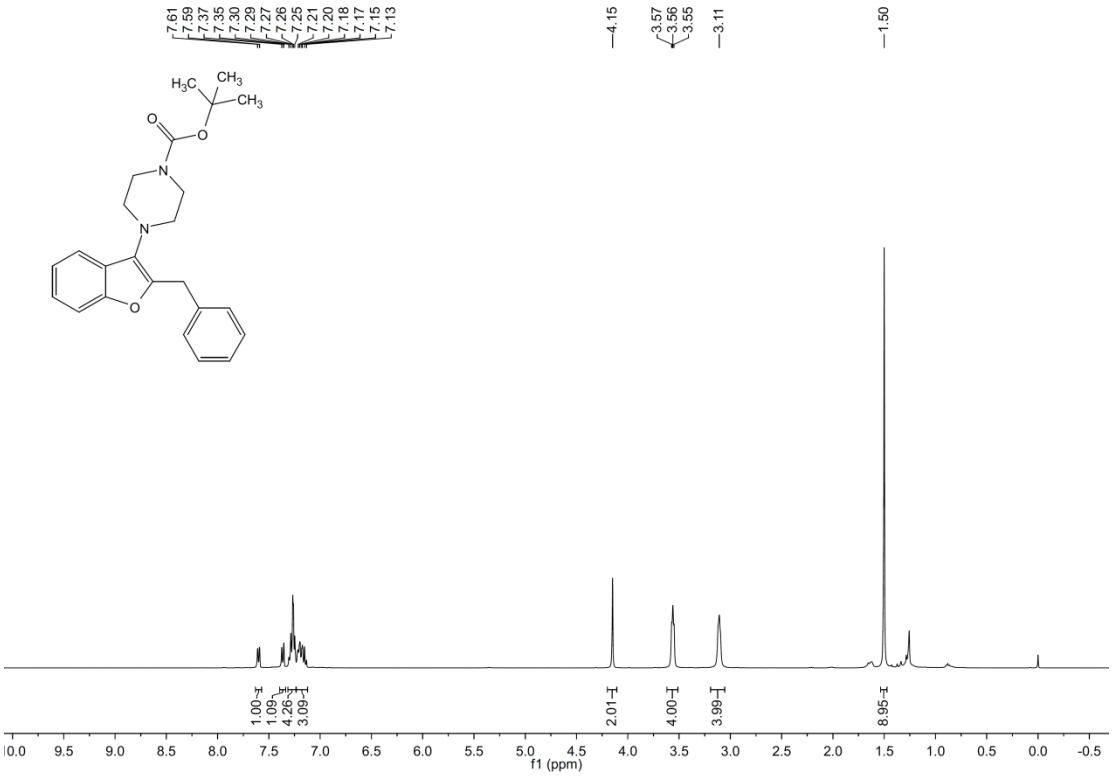

$^{1}$H NMR spectrum of **4g** (in $CDCl_3$)



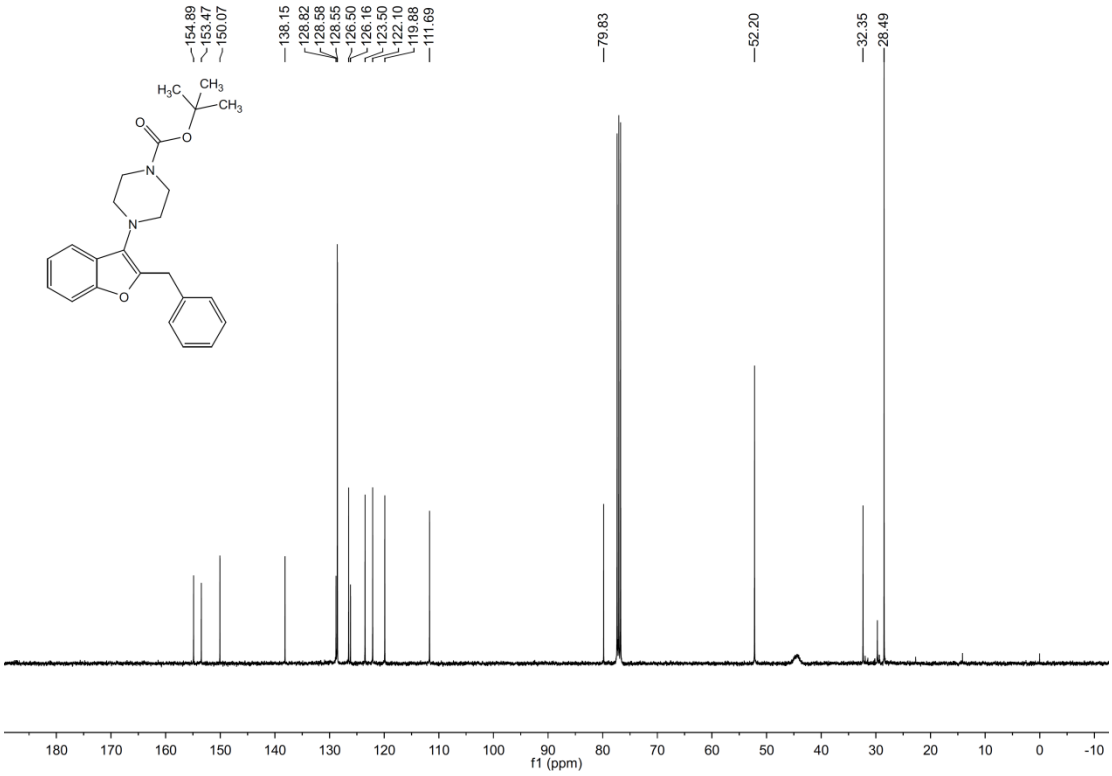

$^{13}$C NMR spectrum of **4g** (in $CDCl_3$)



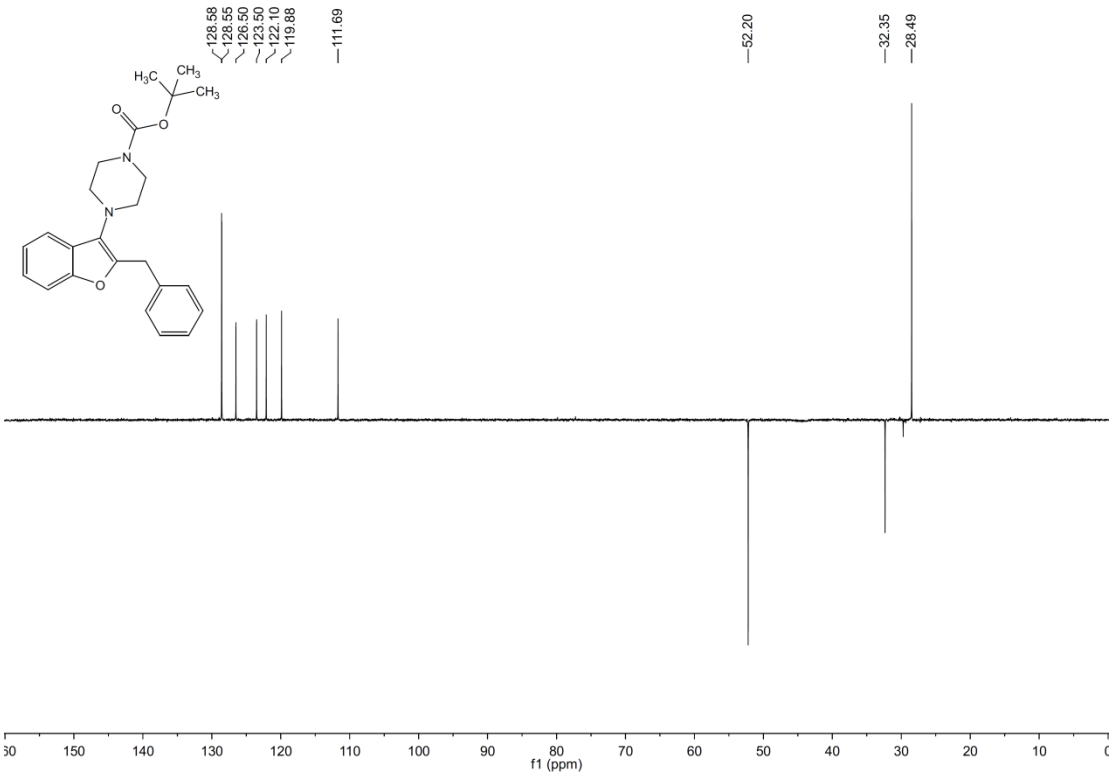

DEPT 135 °spectrum of **4g** (in $CDCl_3$)



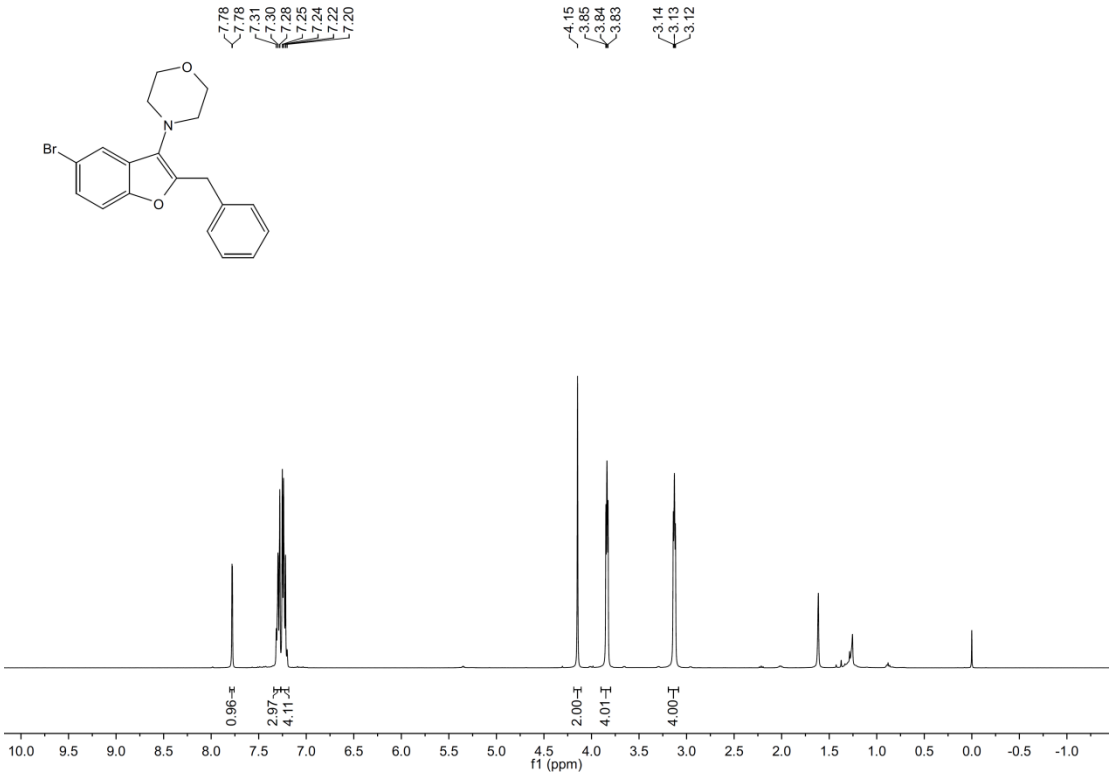

$^{1}$H NMR spectrum of **4h** (in $CDCl_3$)



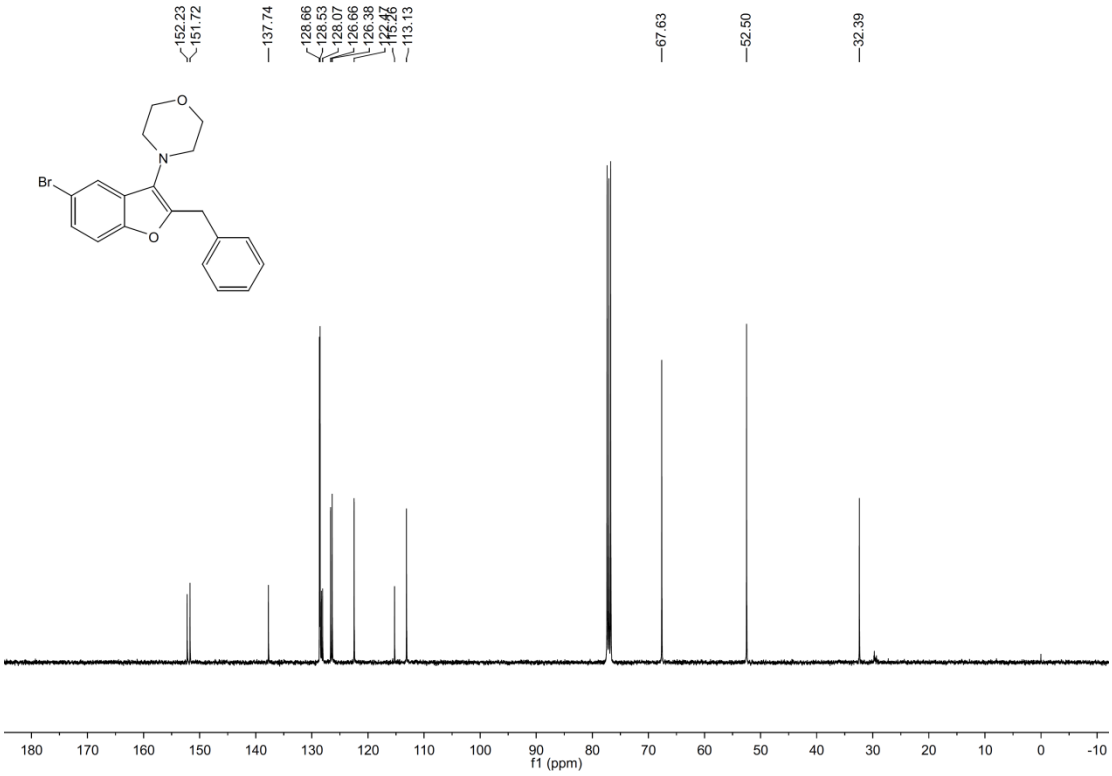

$^{13}$C NMR spectrum of **4h** (in $CDCl_3$)



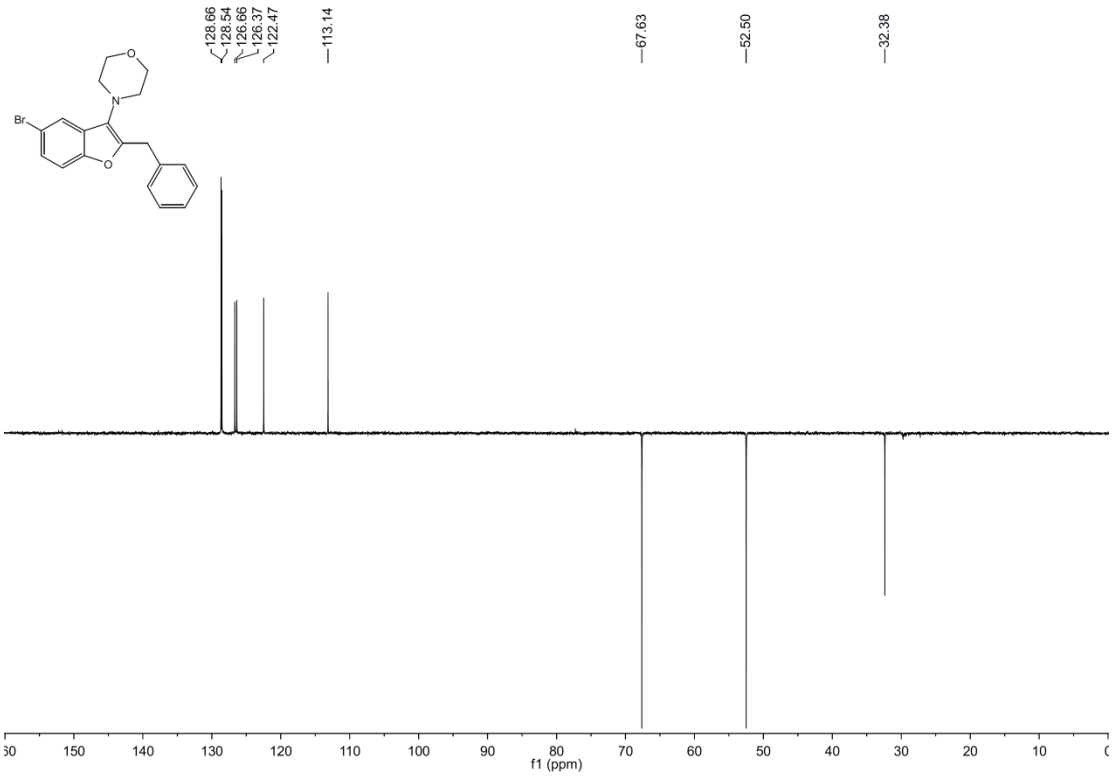

DEPT 135 °spectrum of **4h** (in $CDCl_3$)



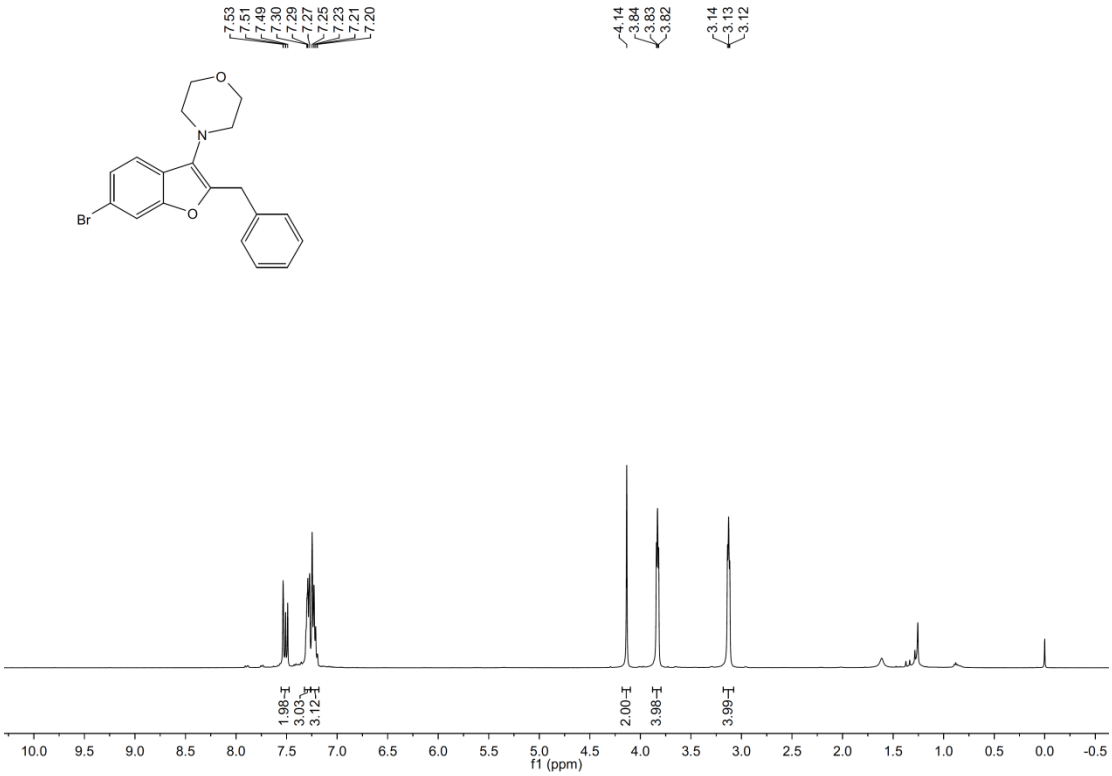

$^{1}$H NMR spectrum of **4i** (in $CDCl_3$)



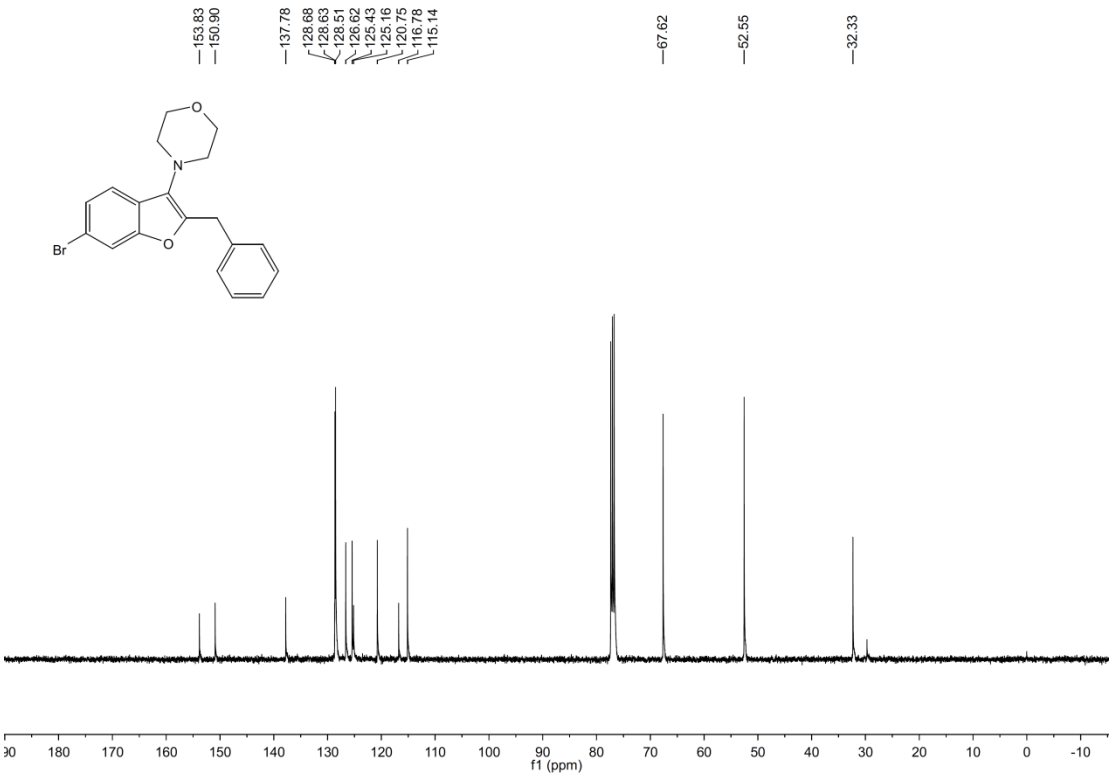

$^{13}$C NMR spectrum of **4i** (in $CDCl_3$)



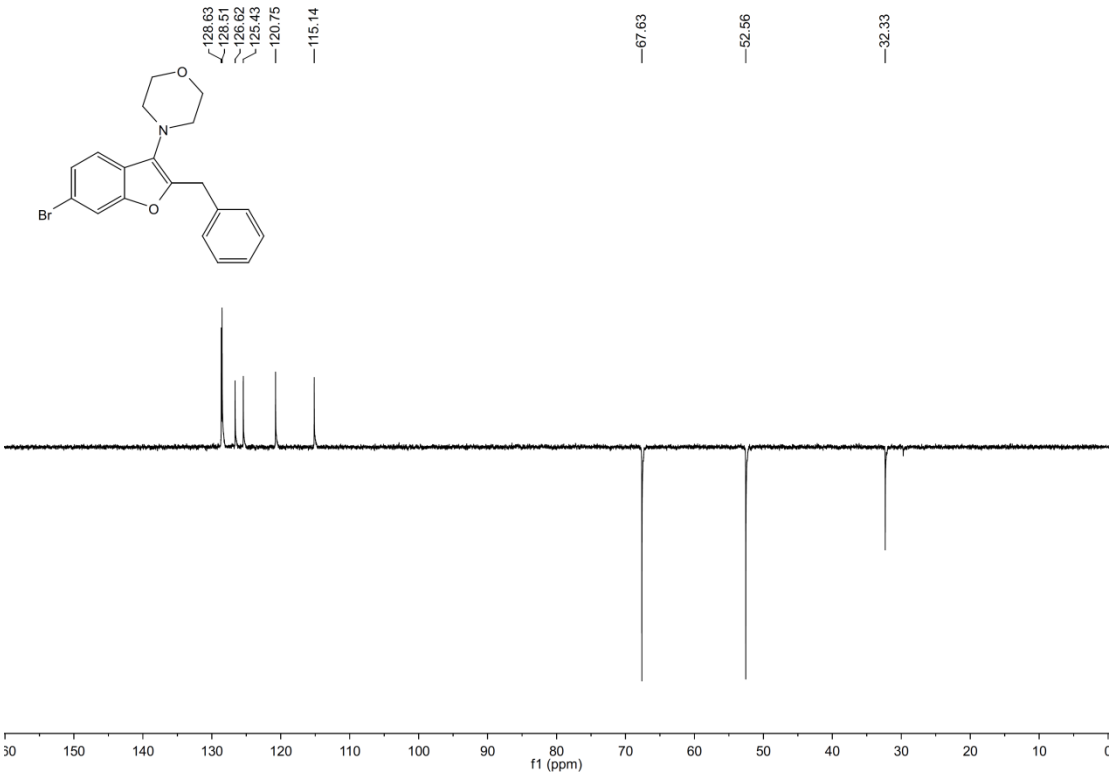

DEPT 135 °spectrum of **4i** (in $CDCl_3$)



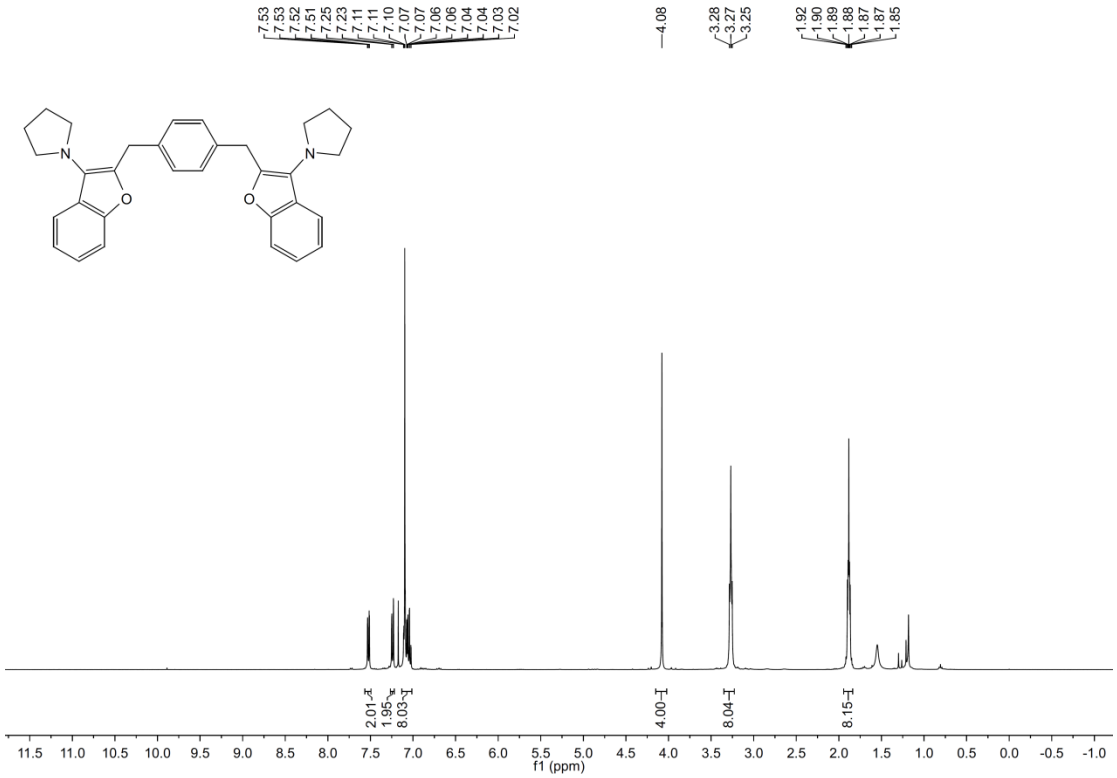

$^{1}$H NMR spectrum of **4j** (in $CDCl_3$)



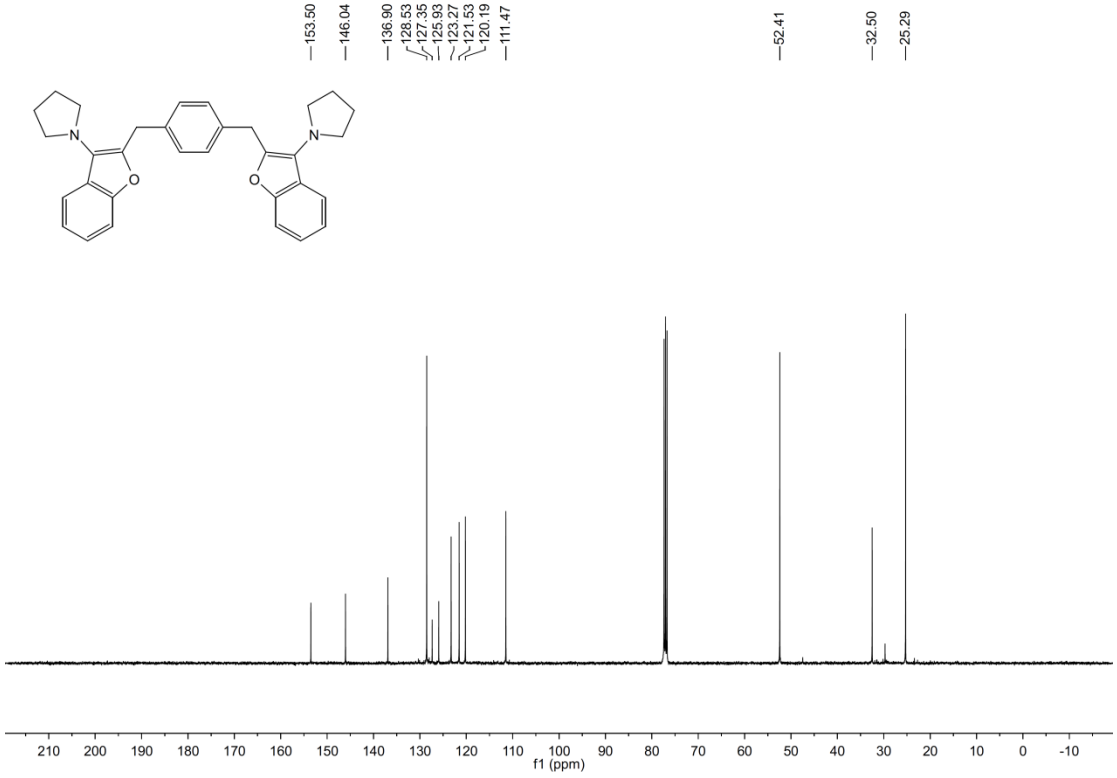

$^{13}$C NMR spectrum of **4j** (in $CDCl_3$)



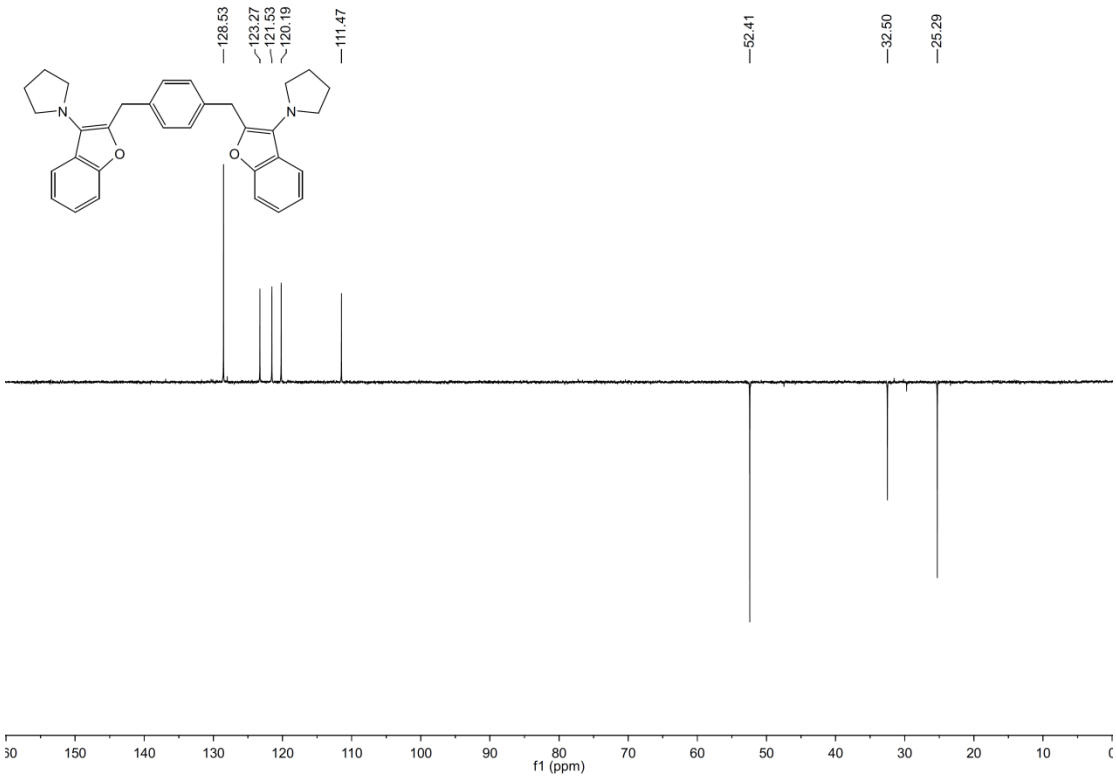

DEPT 135 °spectrum of **4j** (in $CDCl_3$)



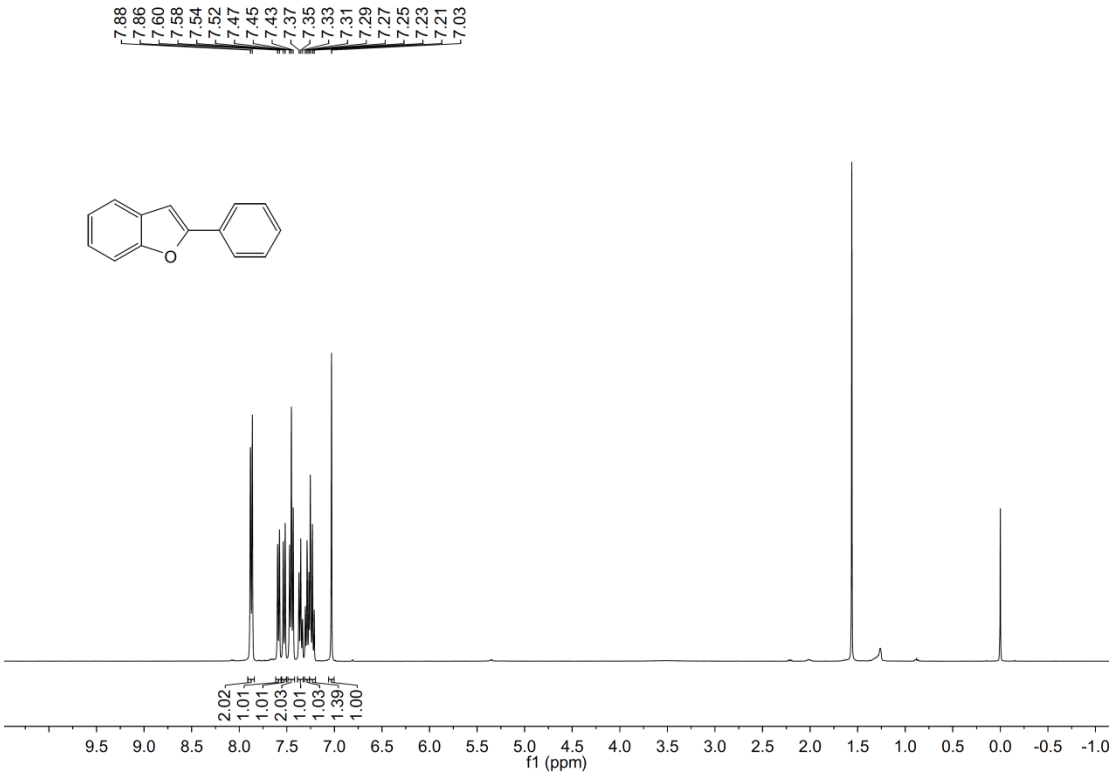

$^{1}$H NMR spectrum of **4m** (in $CDCl_3$)



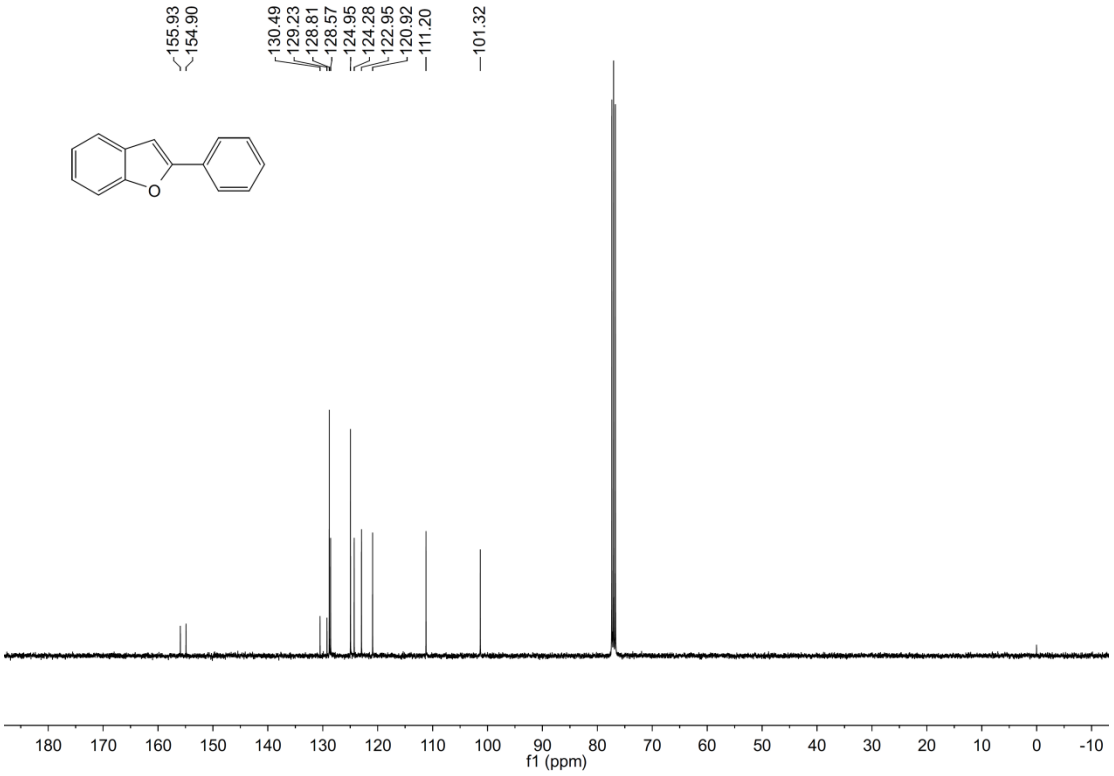

$^{13}$C NMR spectrum of **4m** (in $CDCl_3$)



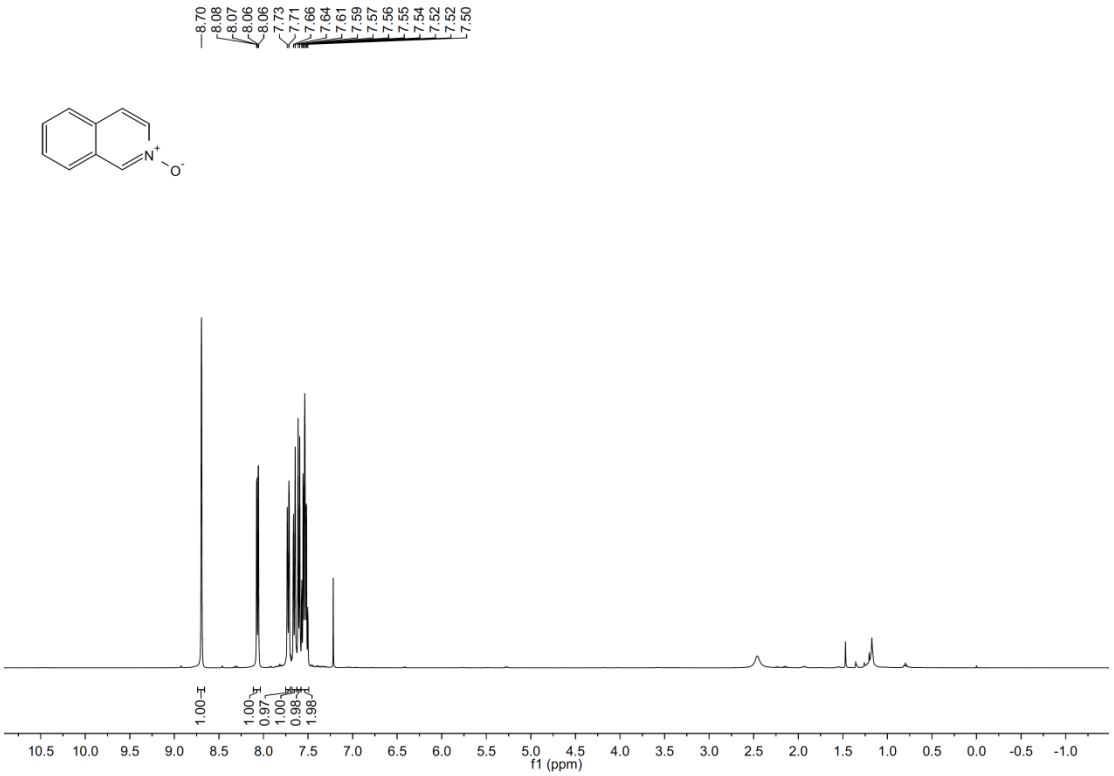

DEPT 135 °spectrum of **4m** (in $CDCl_3$)



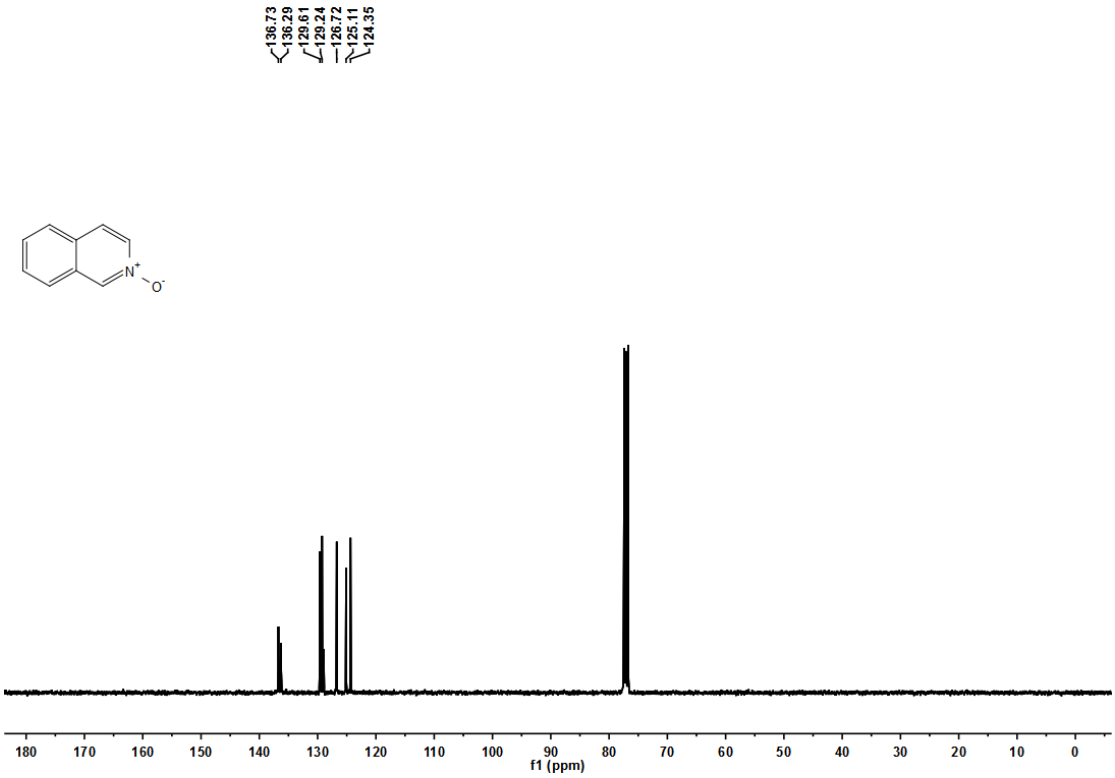

$^{1}$H NMR spectrum of **6** (in $CDCl_3$)



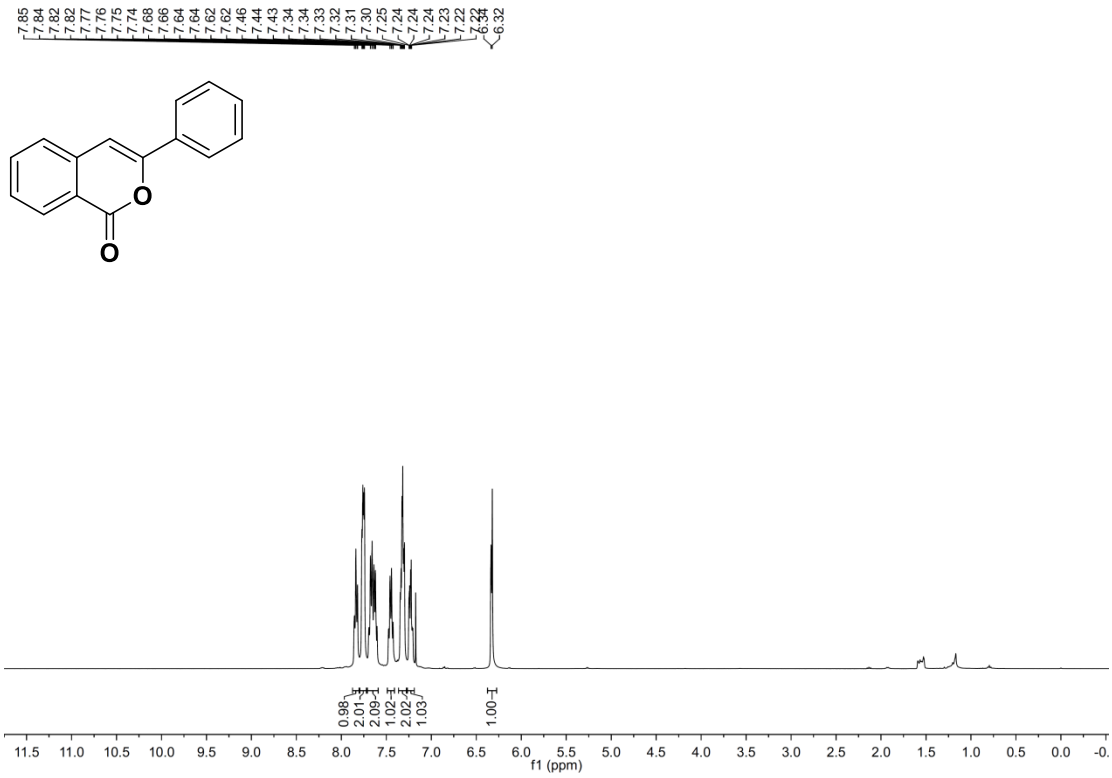

$^{13}$C NMR spectrum of **6** (in $CDCl_3$)



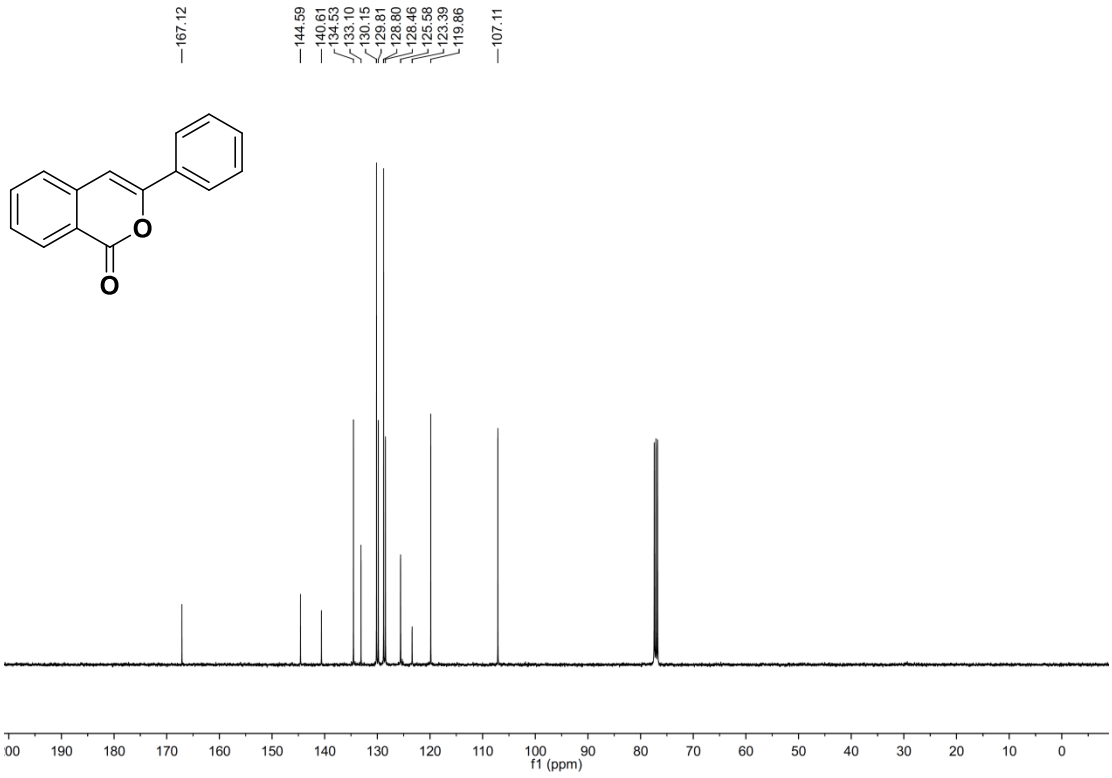

$^{1}$H NMR spectrum of **8** (in $CDCl_3$)



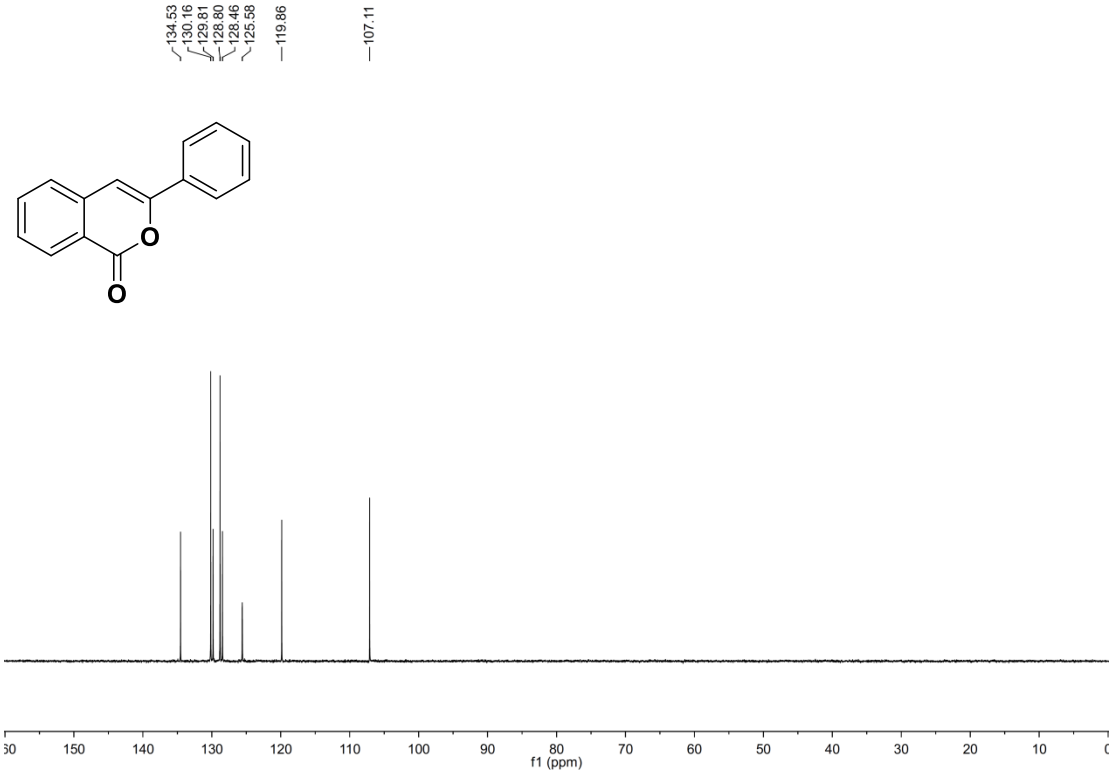

$^{13}$C NMR spectrum of **8** (in $CDCl_3$)



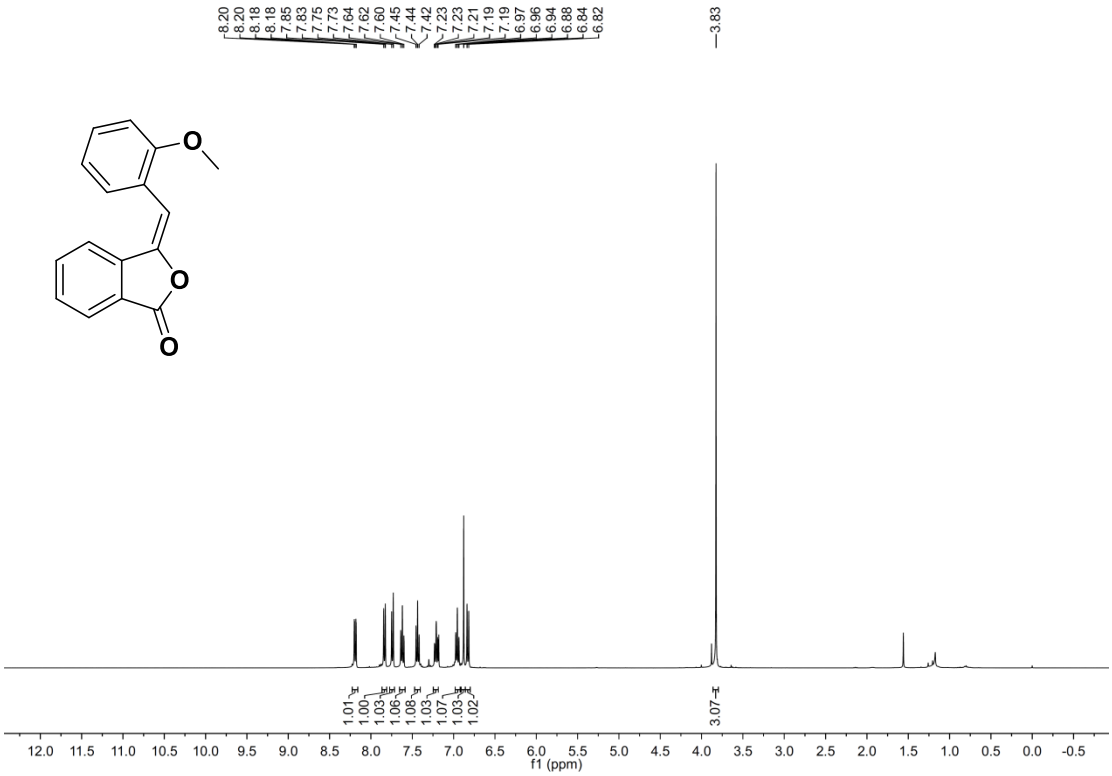

$^{1}$H NMR spectrum of **10** (in $CDCl_3$)



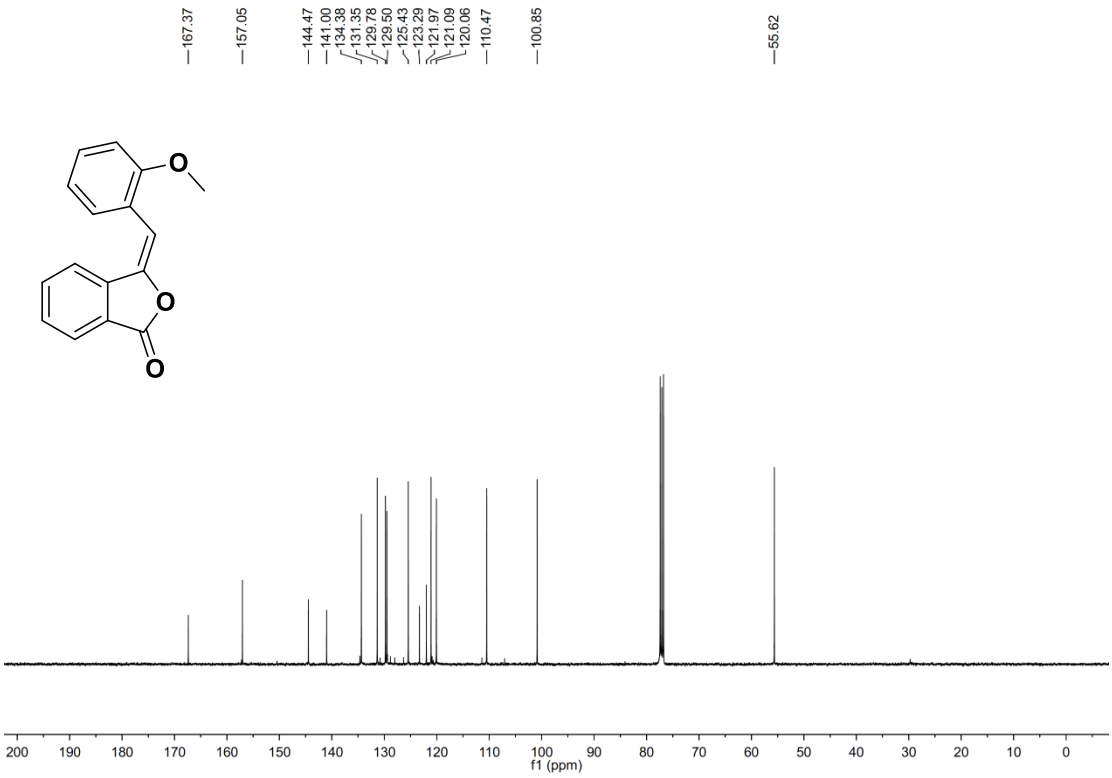

$^{13}$C NMR spectrum of **10** (in $CDCl_3$)



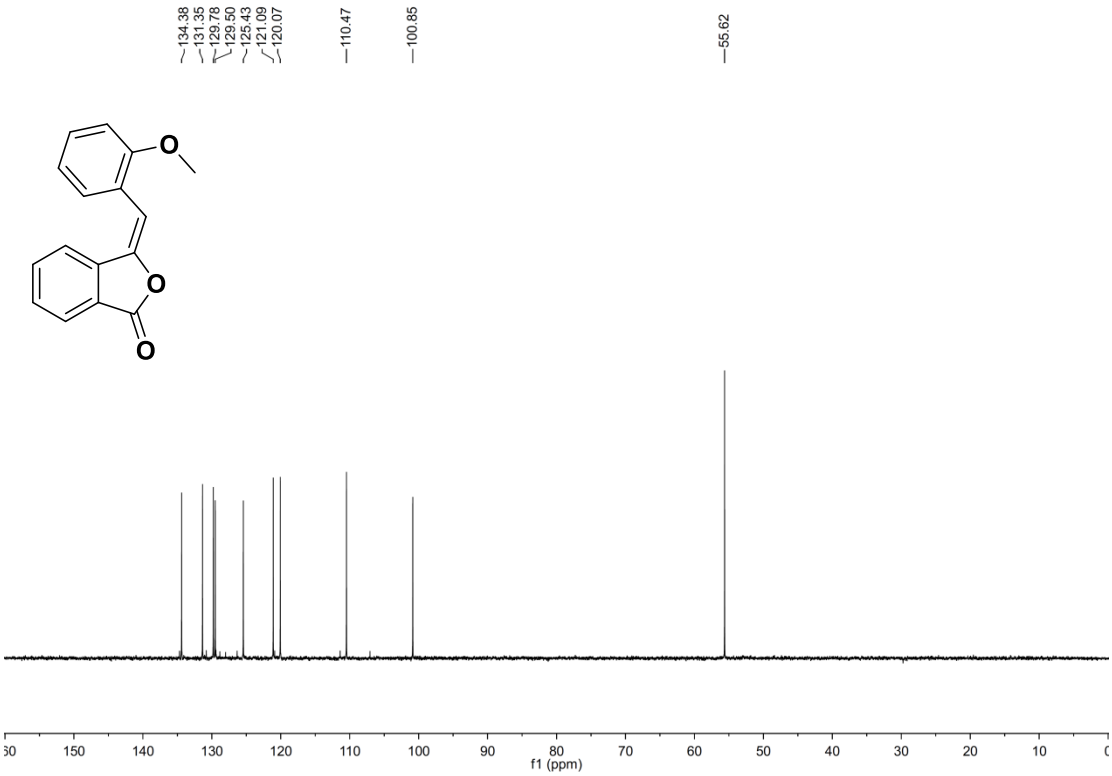

DEPT 135 °spectrum of **10** (in $CDCl_3$)



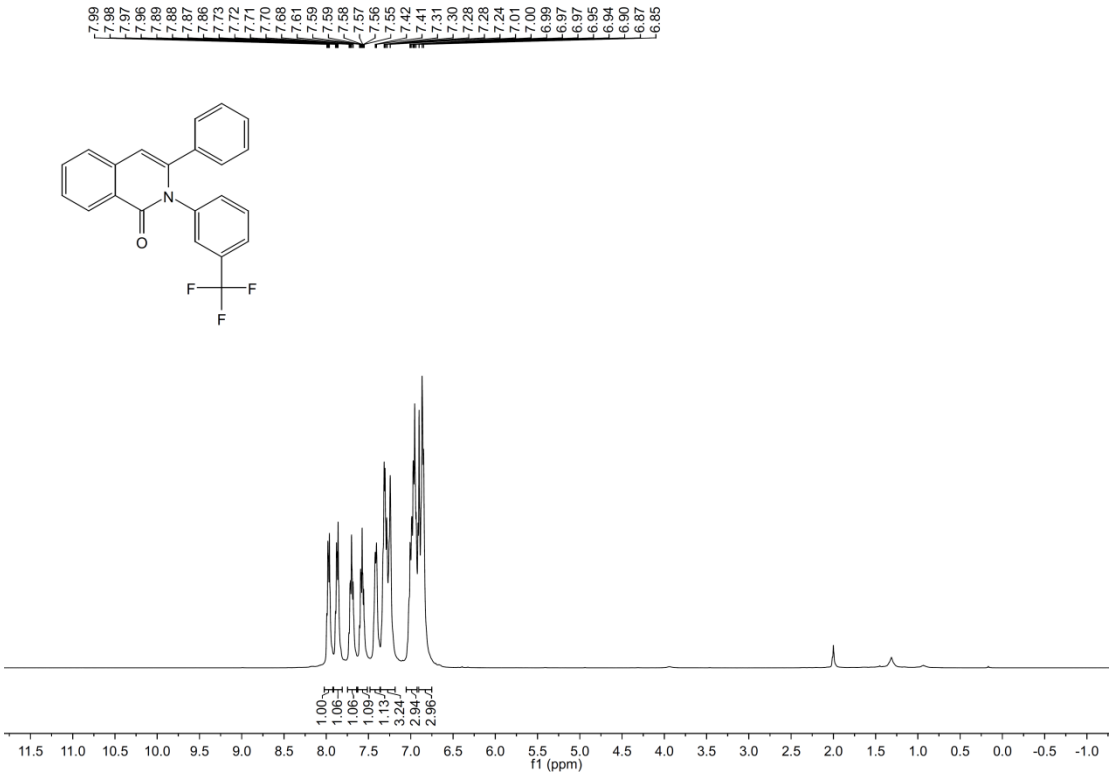

$^{1}$H NMR spectrum of **12** (in $CDCl_3$)



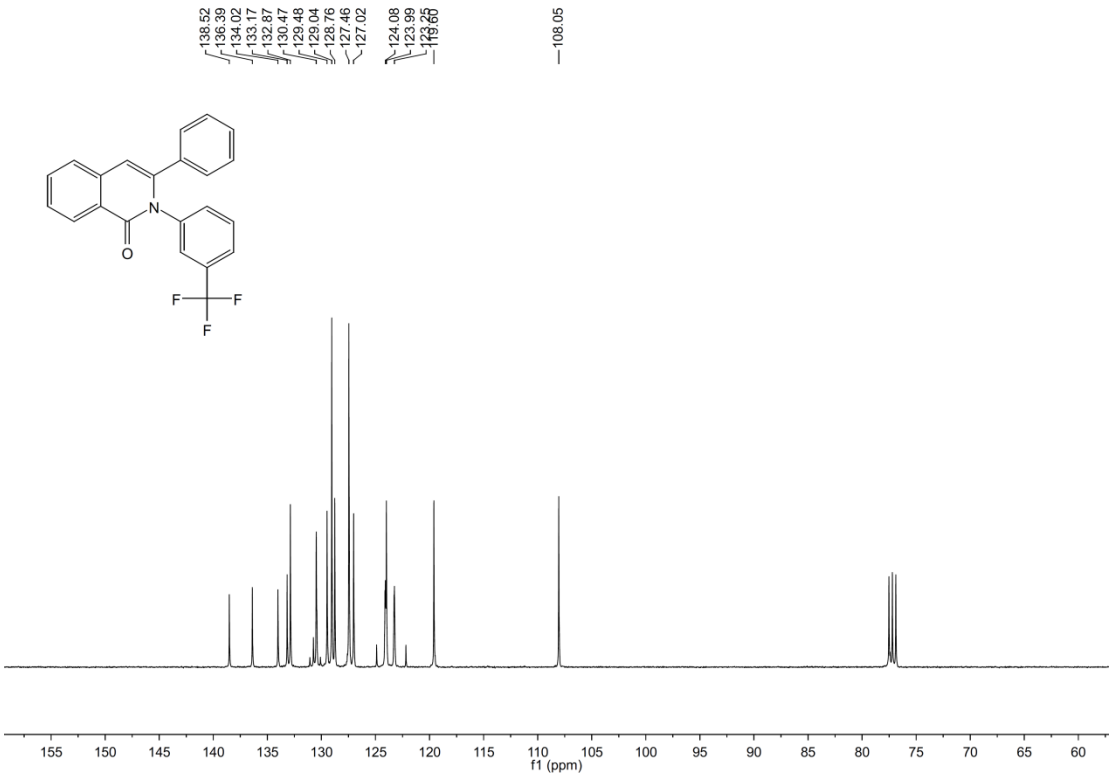

$^{13}$C NMR spectrum of **12** (in $CDCl_3$)



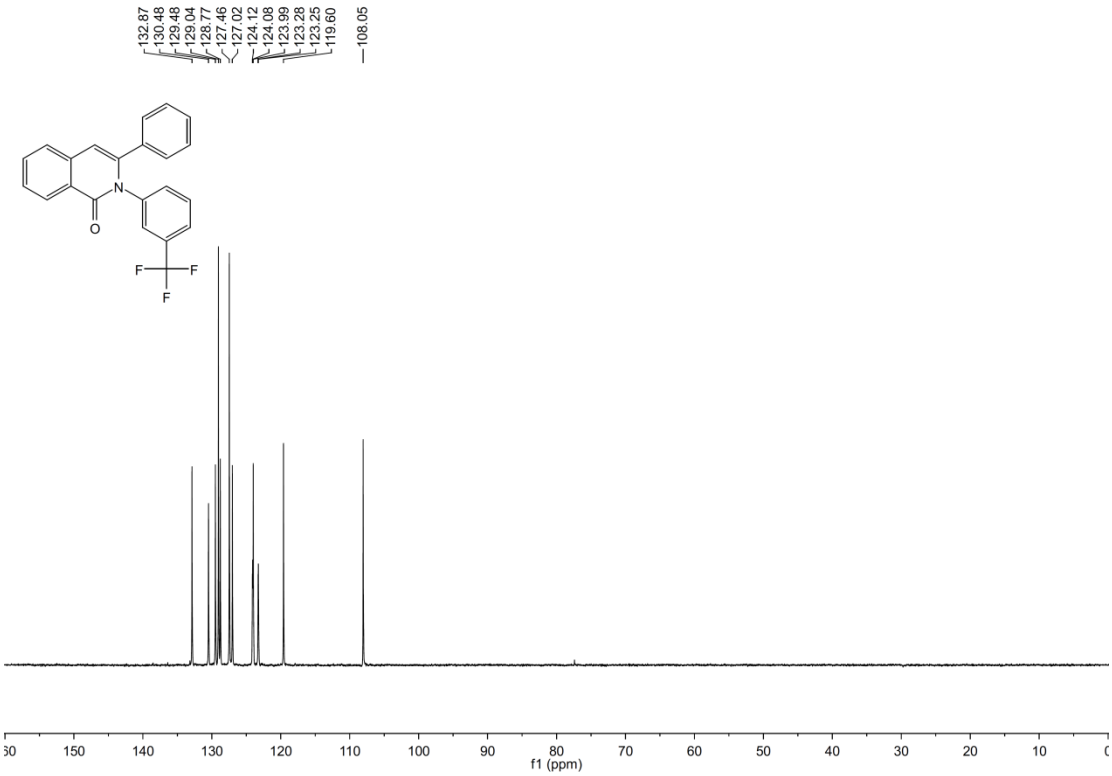

DEPT 135 °spectrum of **12** (in $CDCl_3$)



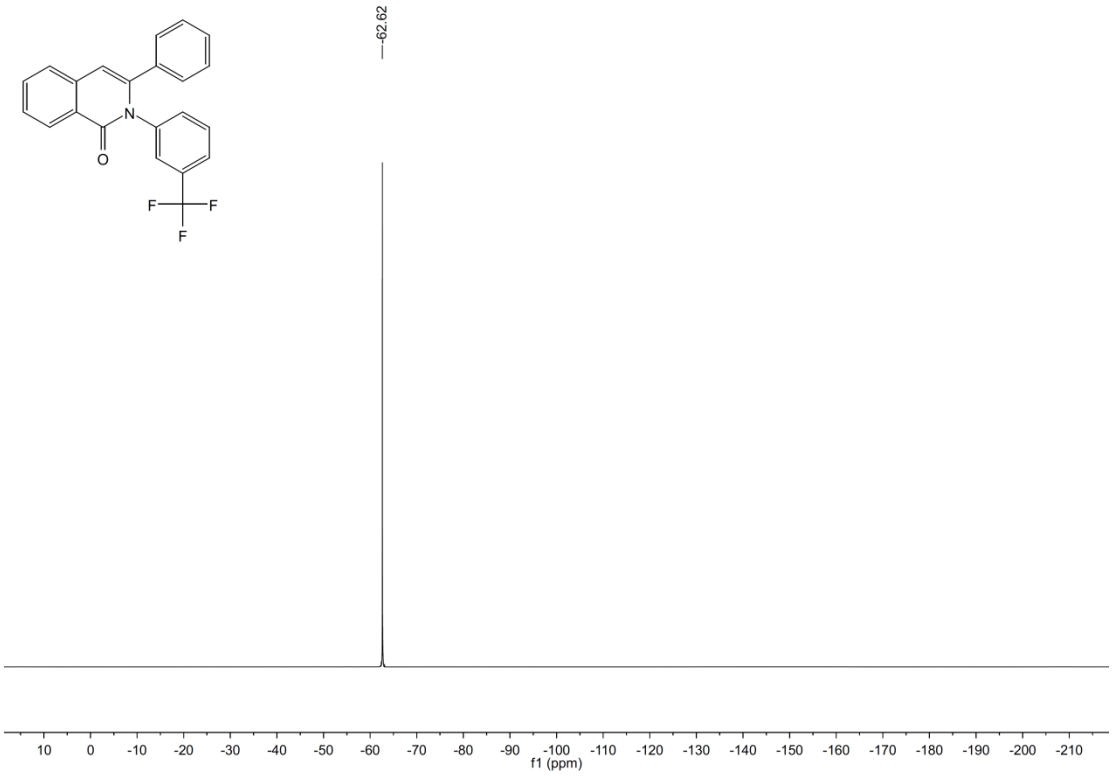

$^{1}$H NMR spectrum of **16a** (in $CDCl_3$)



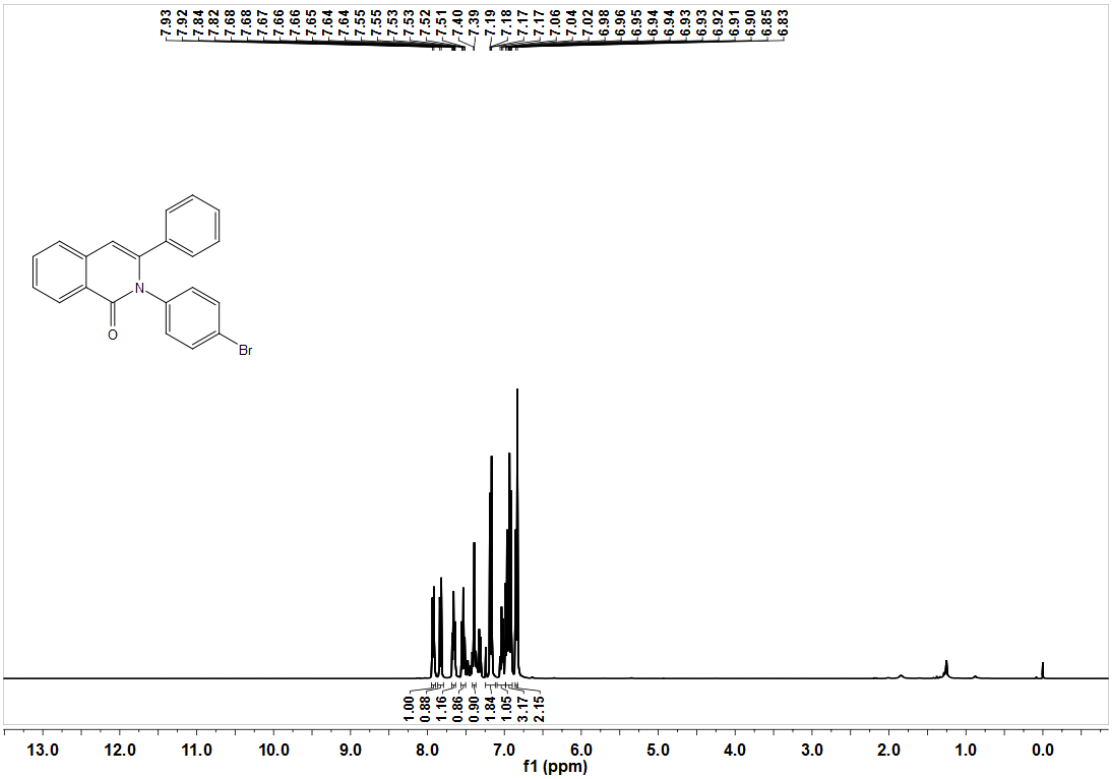

$^{13}$C NMR spectrum of **16a** (in $CDCl_3$)



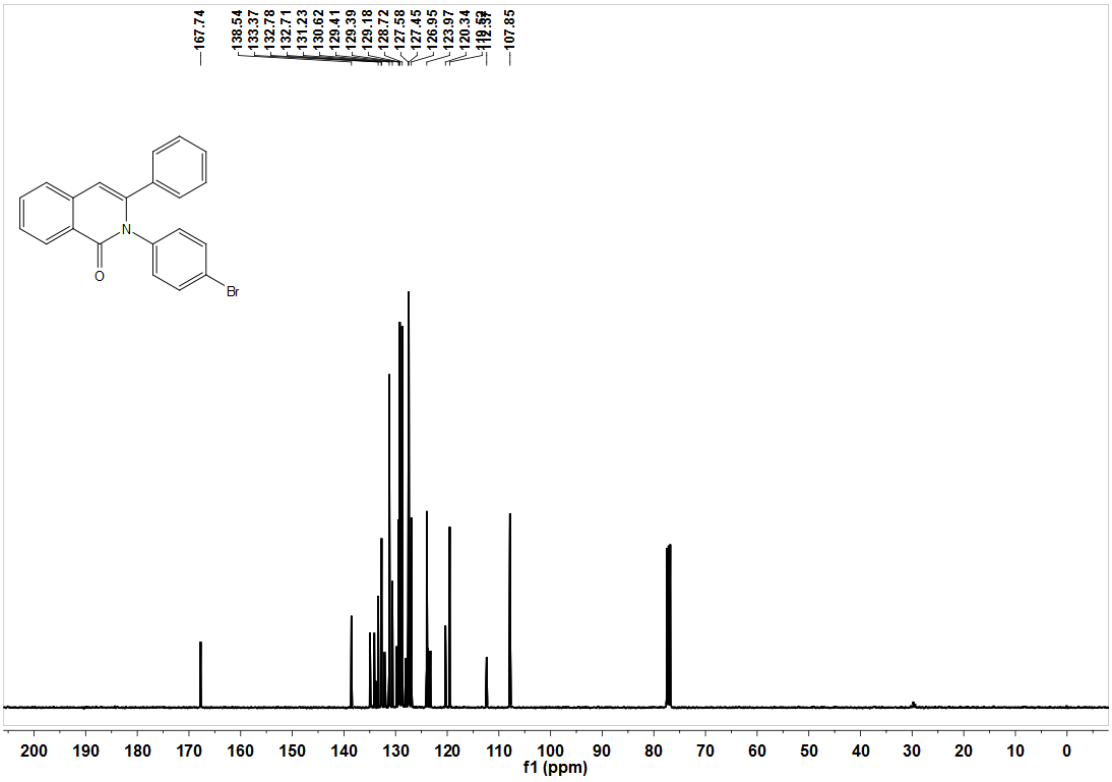

DEPT 135 °spectrum of **16a** (in $CDCl_3$)



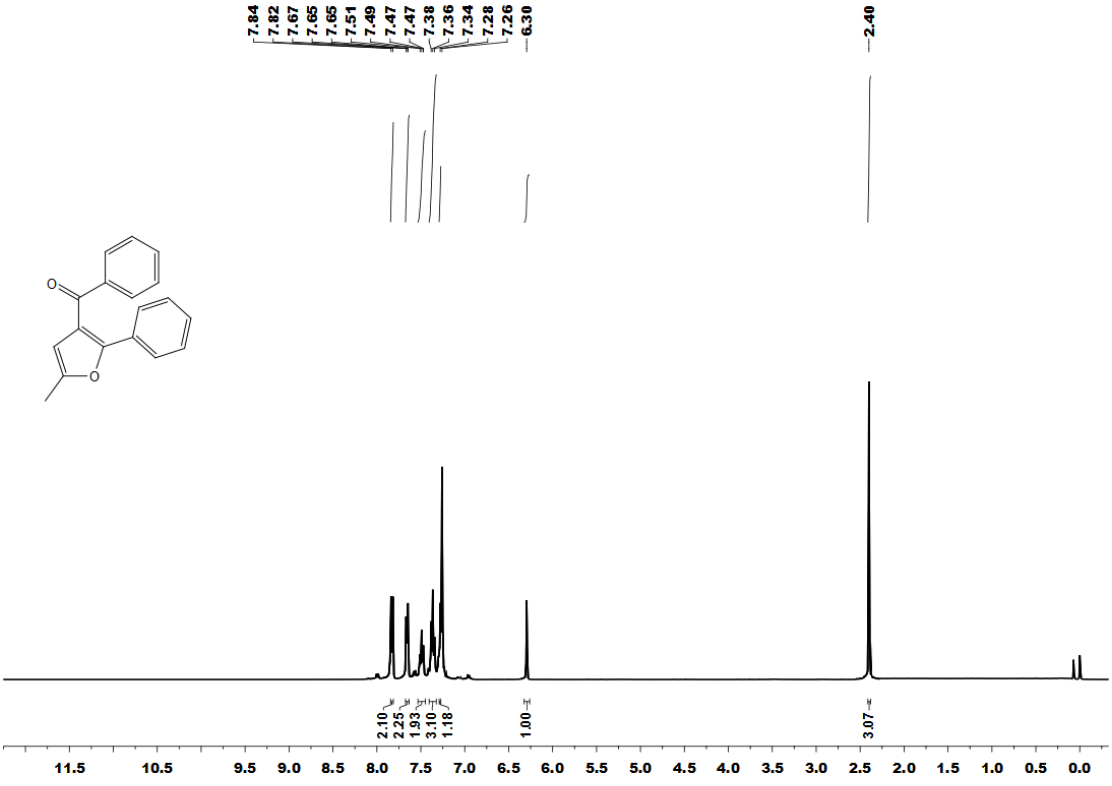

$^{19}F$ NMR spectrum of **16a** (in $CDCl_3$)



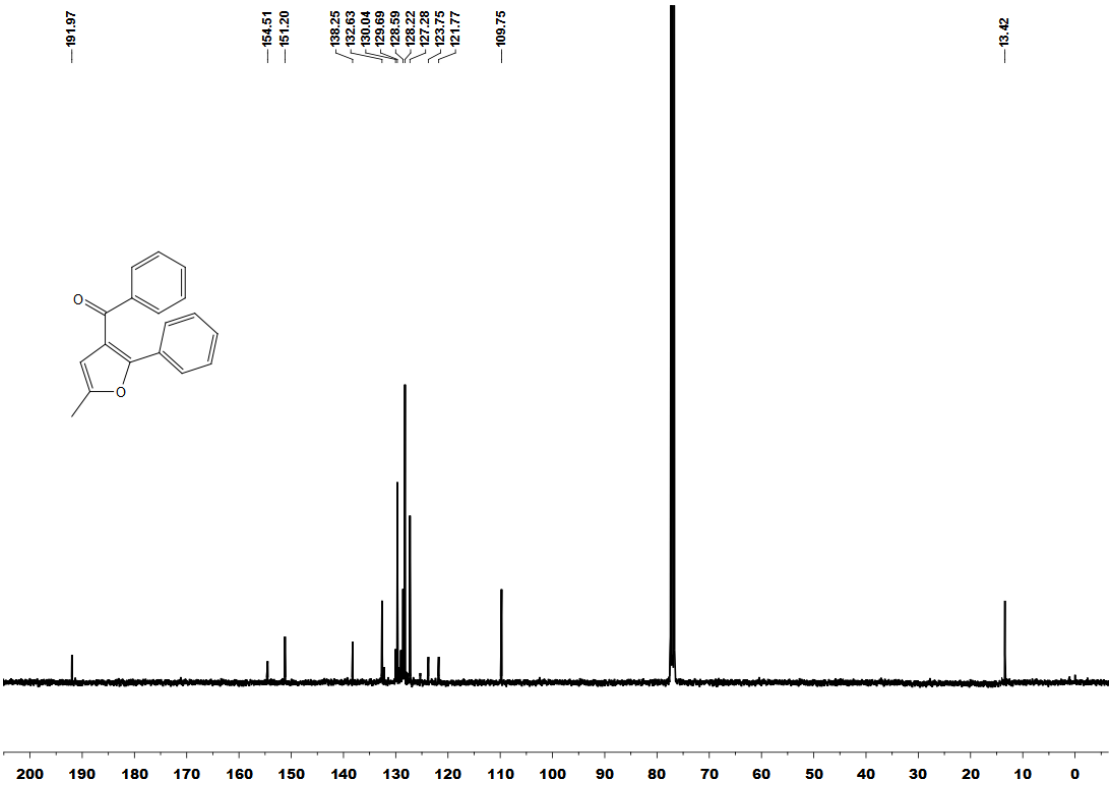

$^{1}$H NMR spectrum of **16b** (in $CDCl_3$)



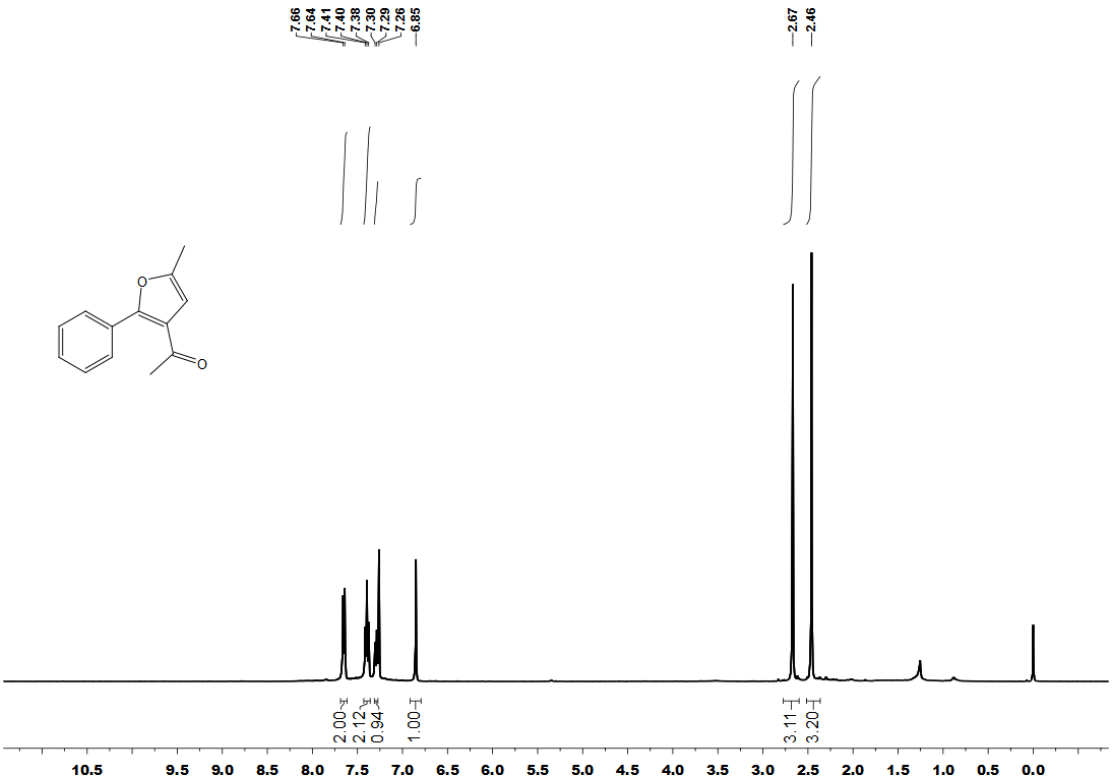

$^{13}$C NMR spectrum of **16b** (in $CDCl_3$)



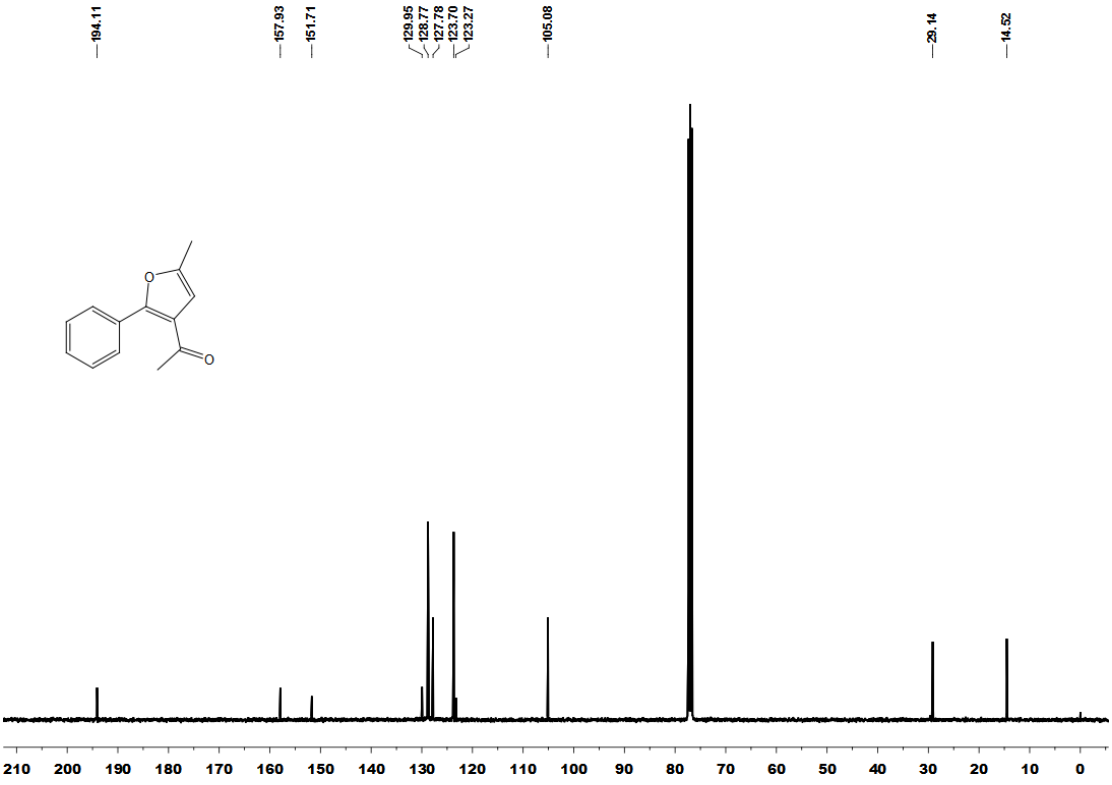

$^{1}$H NMR spectrum of **18a** (in $CDCl_3$)



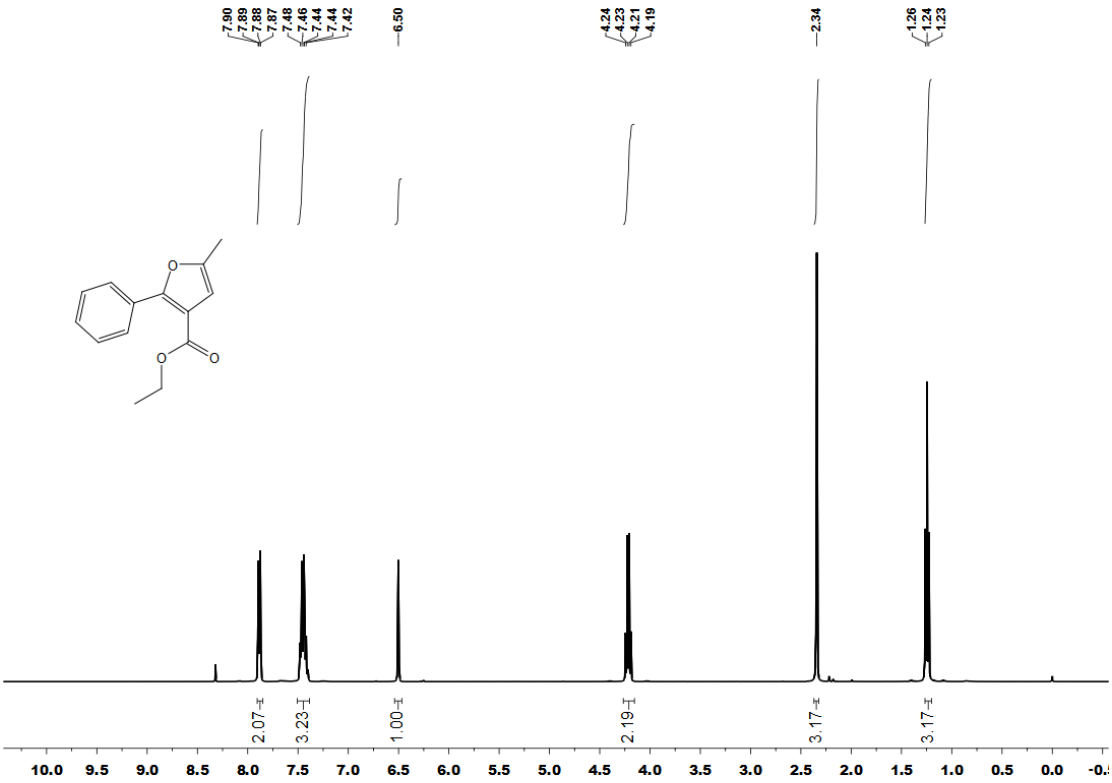

$^{13}$C NMR spectrum of **18a** (in $CDCl_3$)



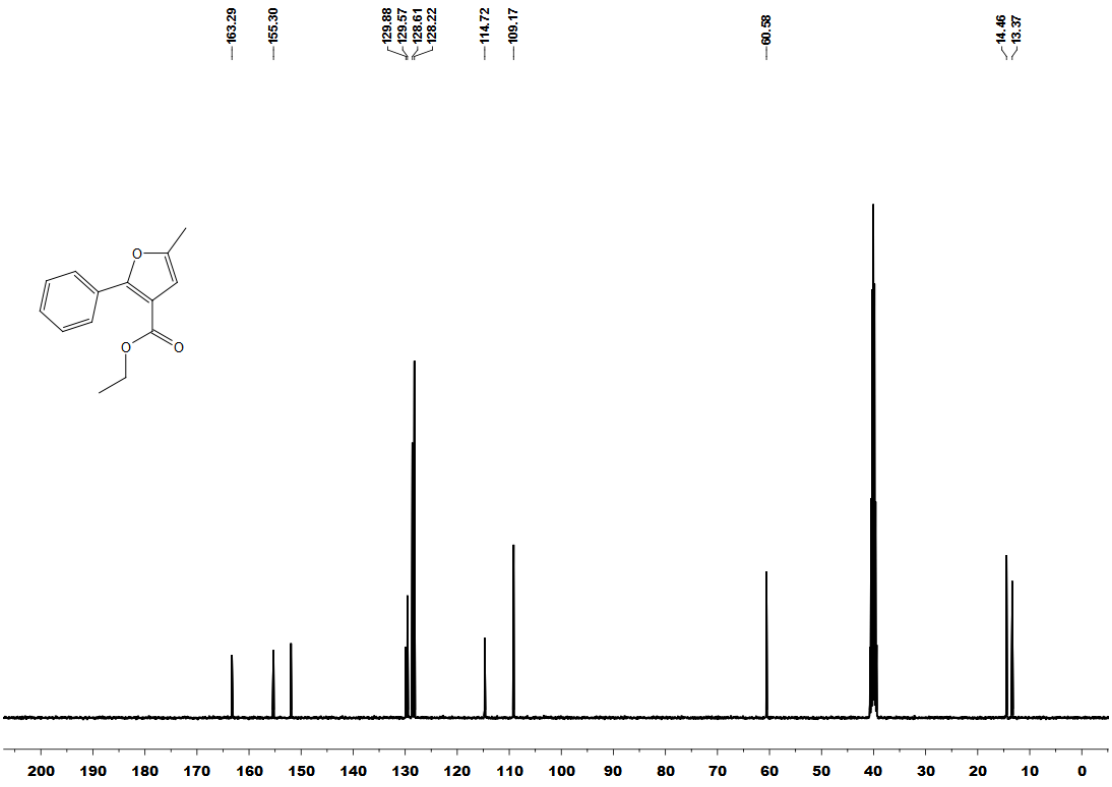

$^{1}$H NMR spectrum of **18b** (in $CDCl_3$)



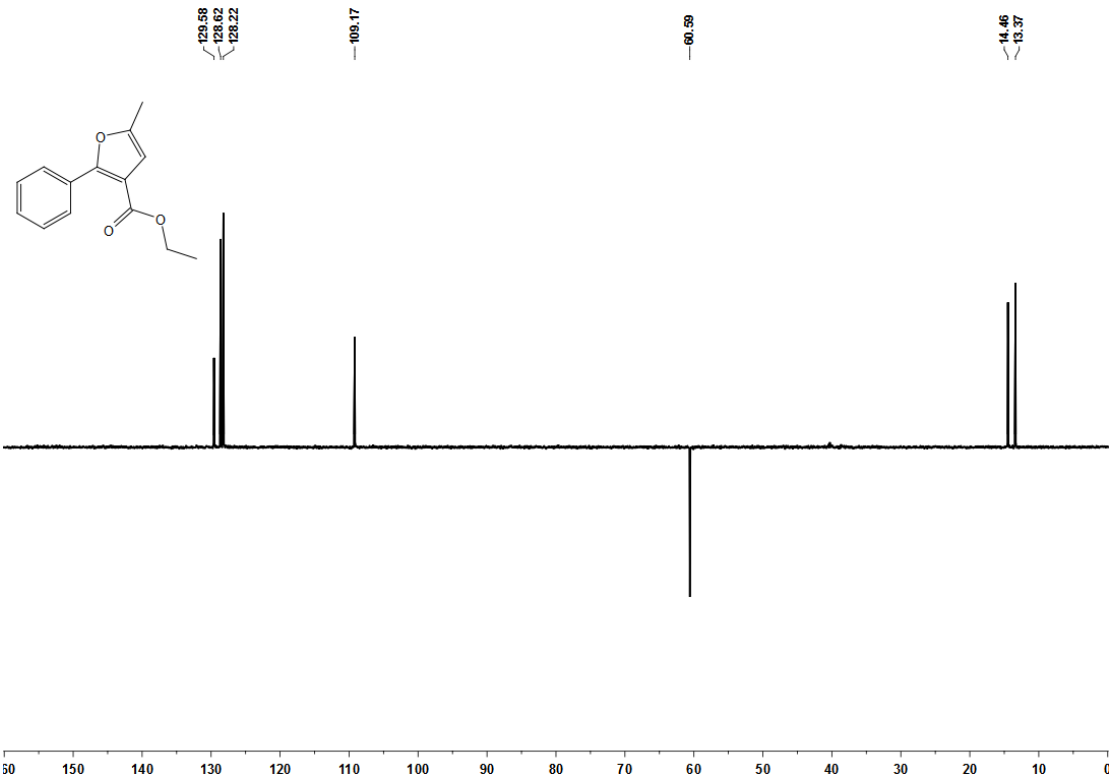

$^{13}$C NMR spectrum of **18b** (in $CDCl_3$)



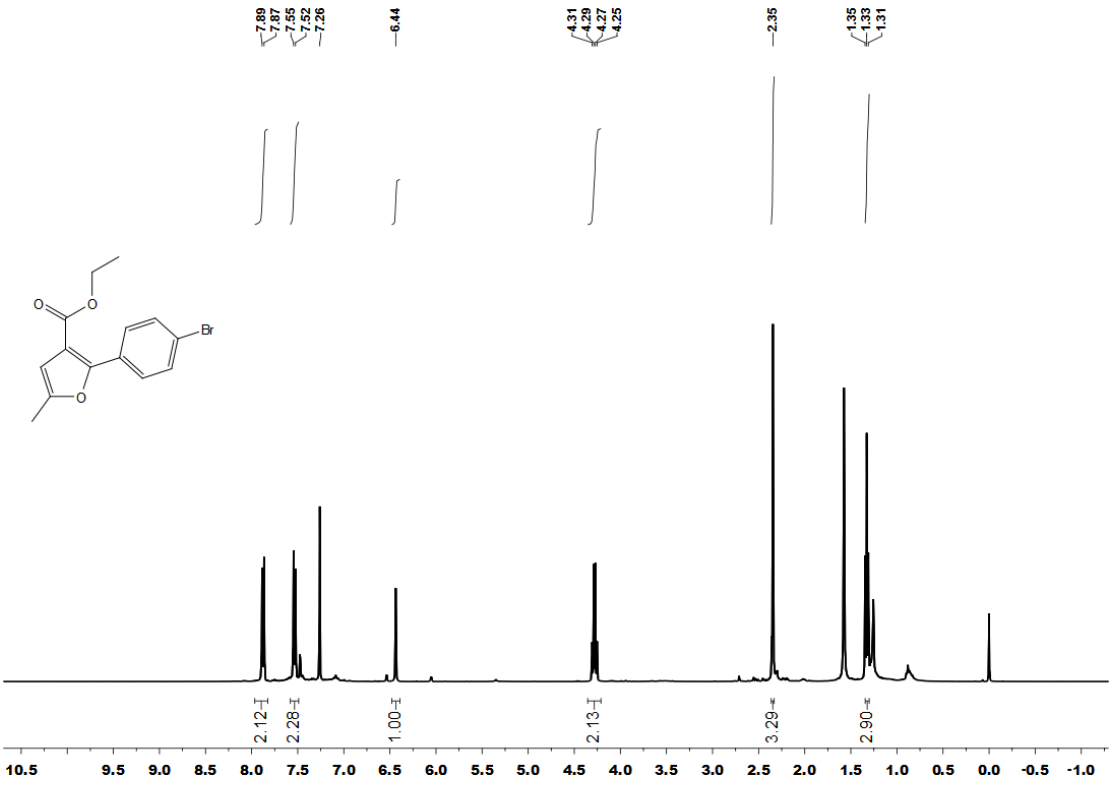

$^{1}$H NMR spectrum of **18c** (in DMSO-$d_6$)



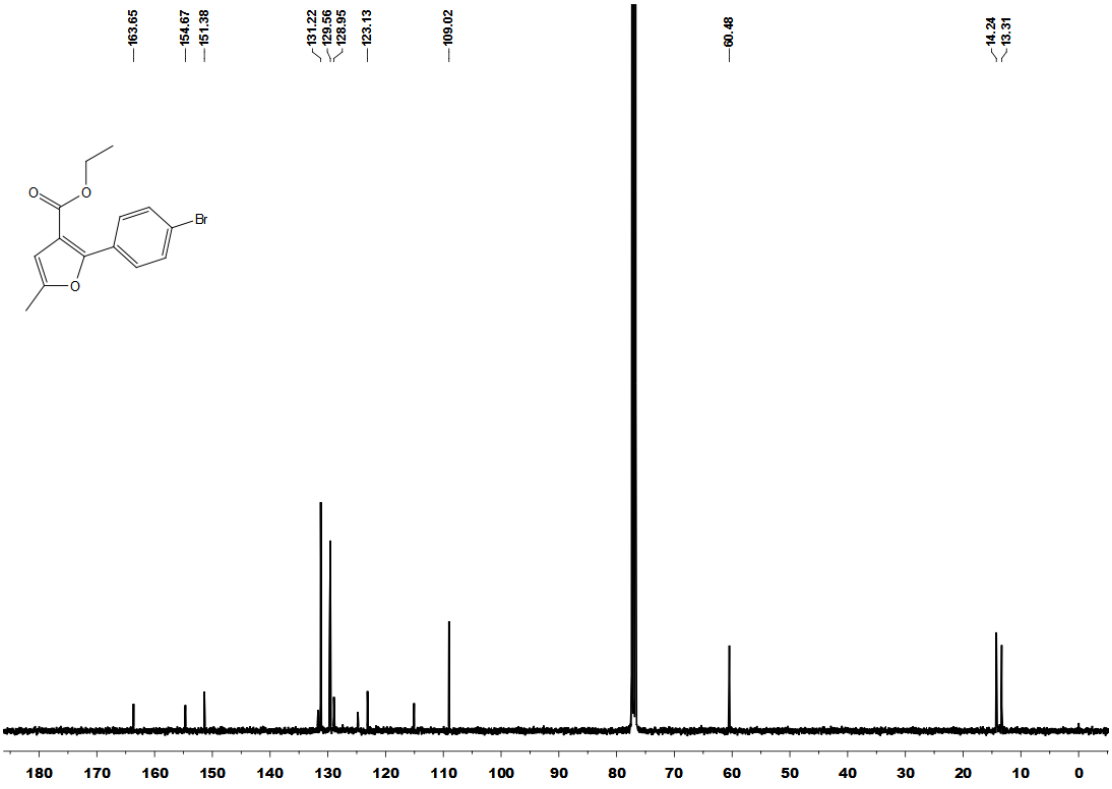

$^{13}$C NMR spectrum of **18c** (in DMSO-$d_6$)



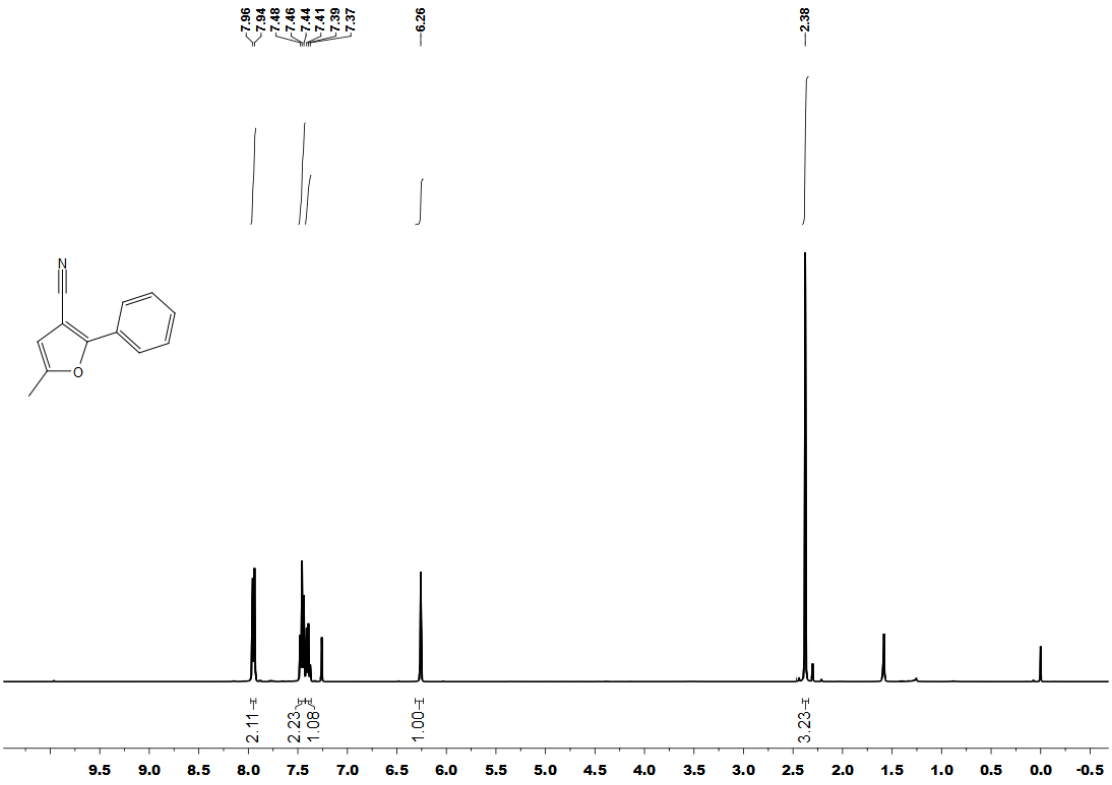

DEPT 135 °spectrum of **18c** (in DMSO-$d_6$)



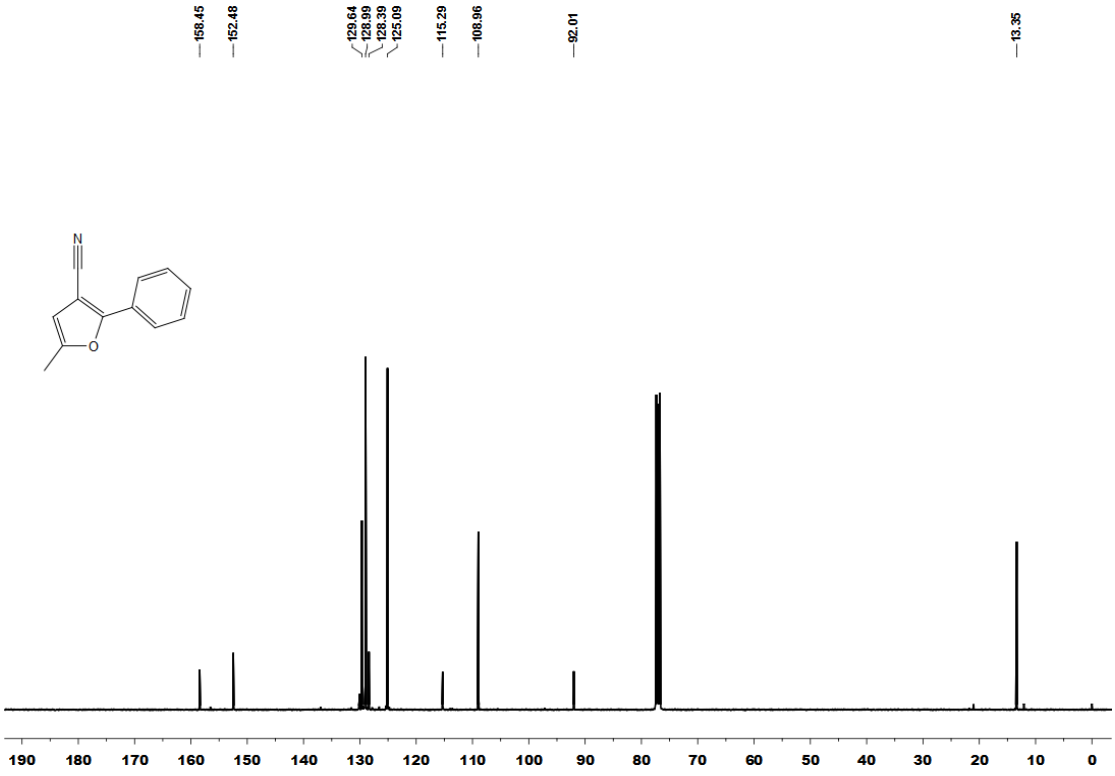

$^{1}$H NMR spectrum of **18d** (in $CDCl_3$)



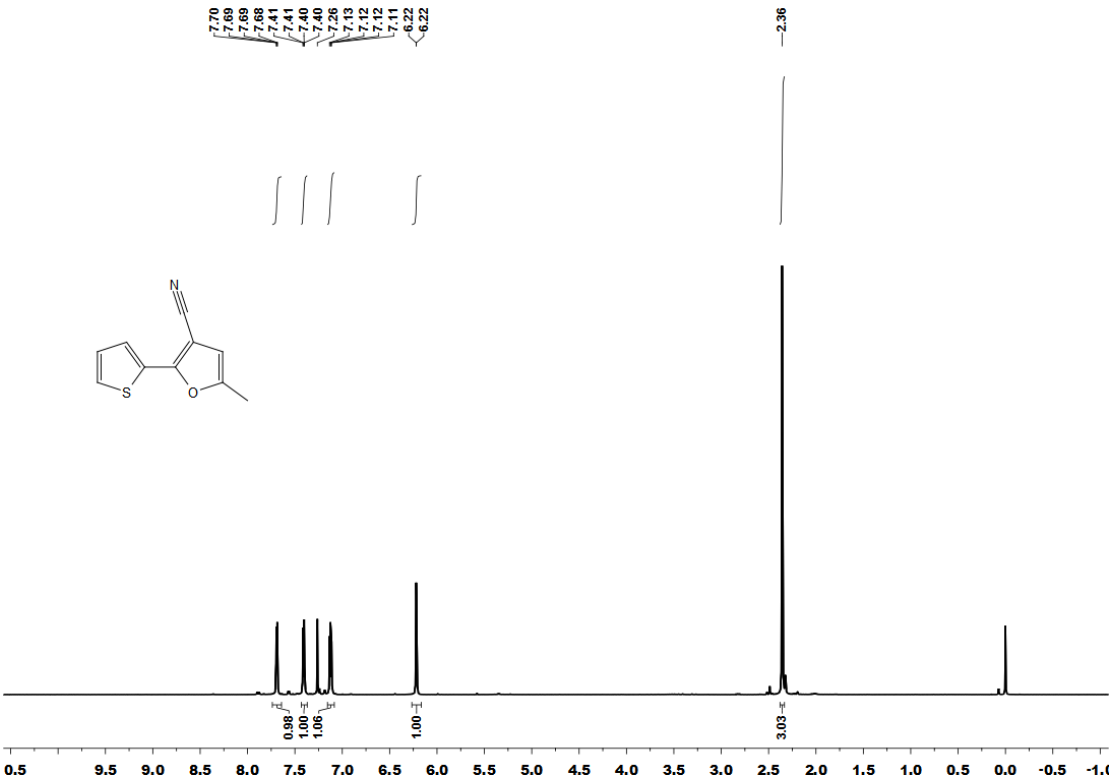

$^{13}$C NMR spectrum of **18d** (in $CDCl_3$)



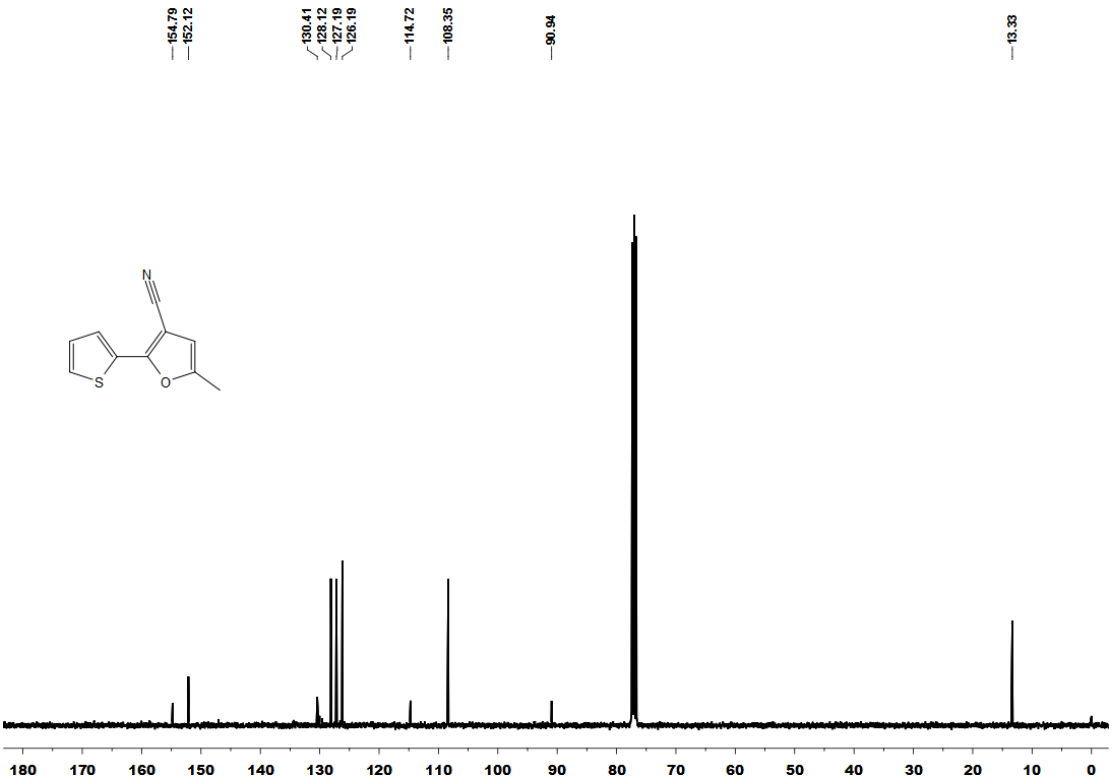

$^{1}$H NMR spectrum of **18e** (in $CDCl_3$)



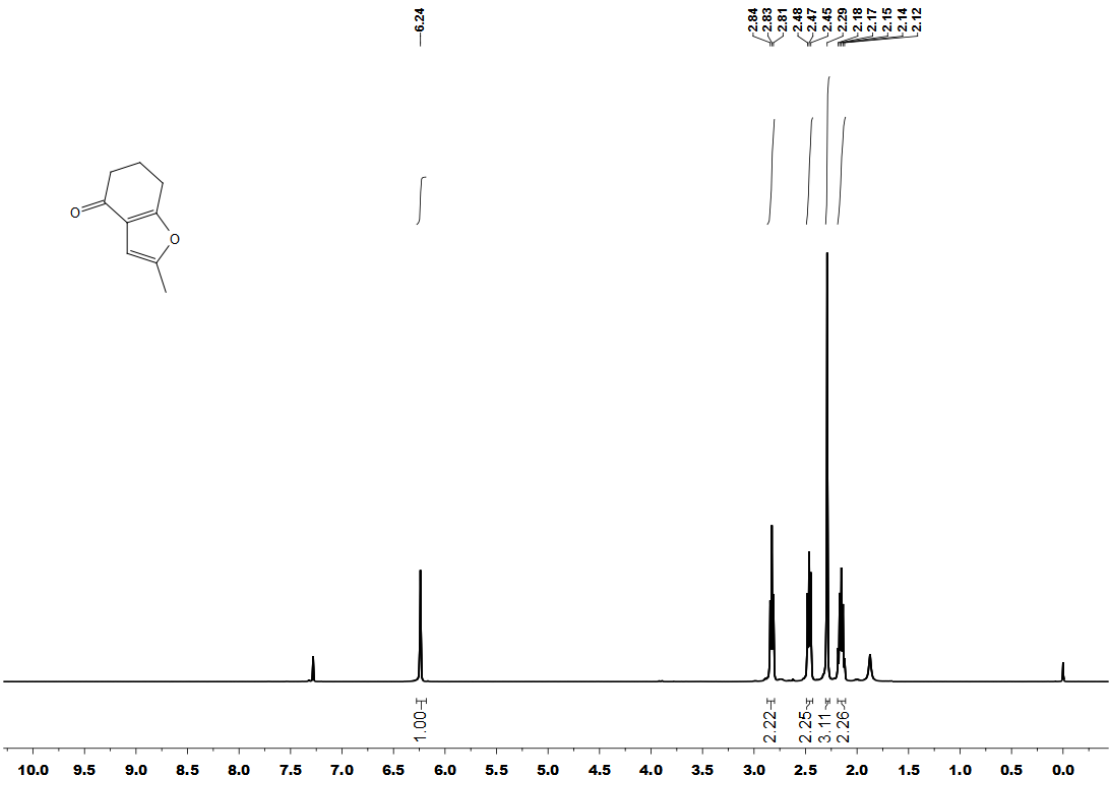

$^{13}$C NMR spectrum of **18e** (in $CDCl_3$)



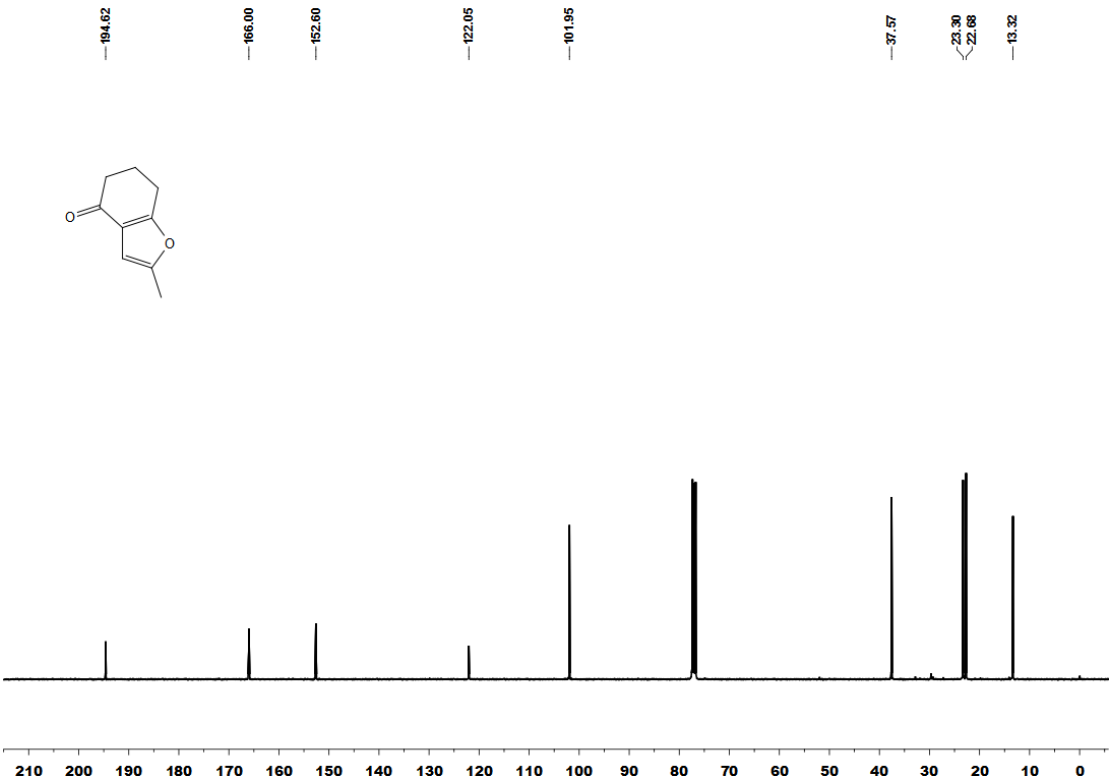

$^{1}$H NMR spectrum of **18f** (in $CDCl_3$)



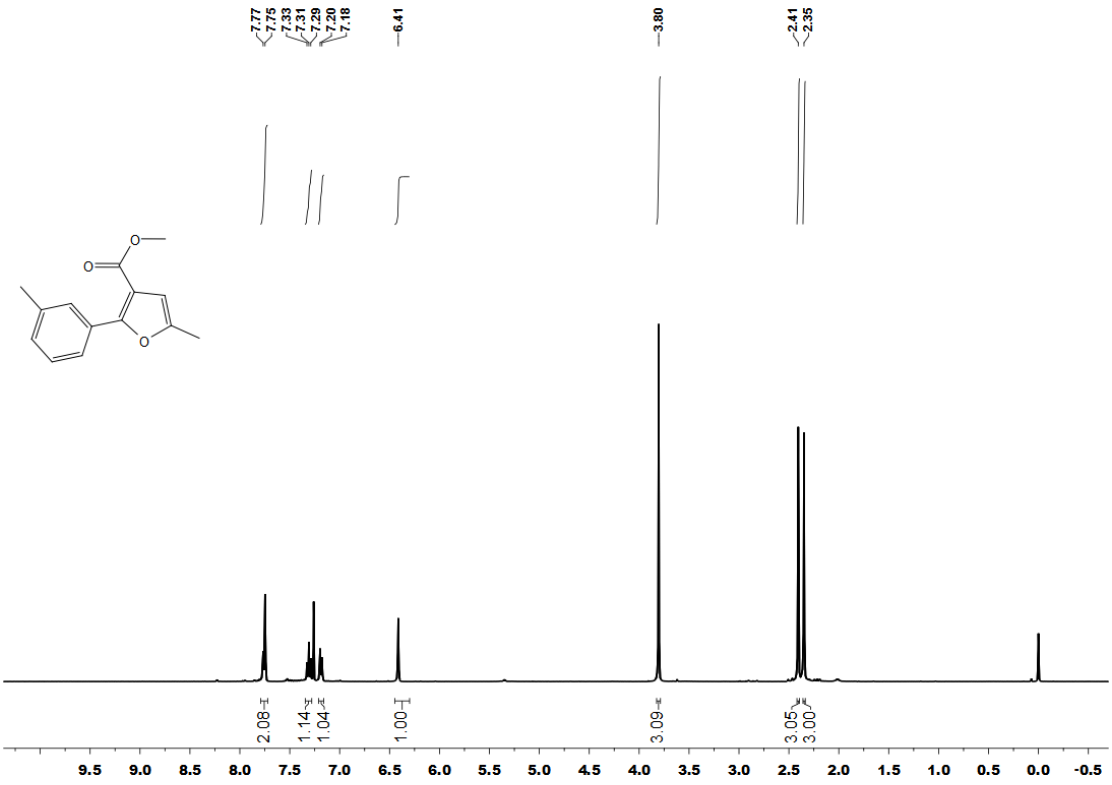

$^{13}$C NMR spectrum of **18f** (in $CDCl_3$)



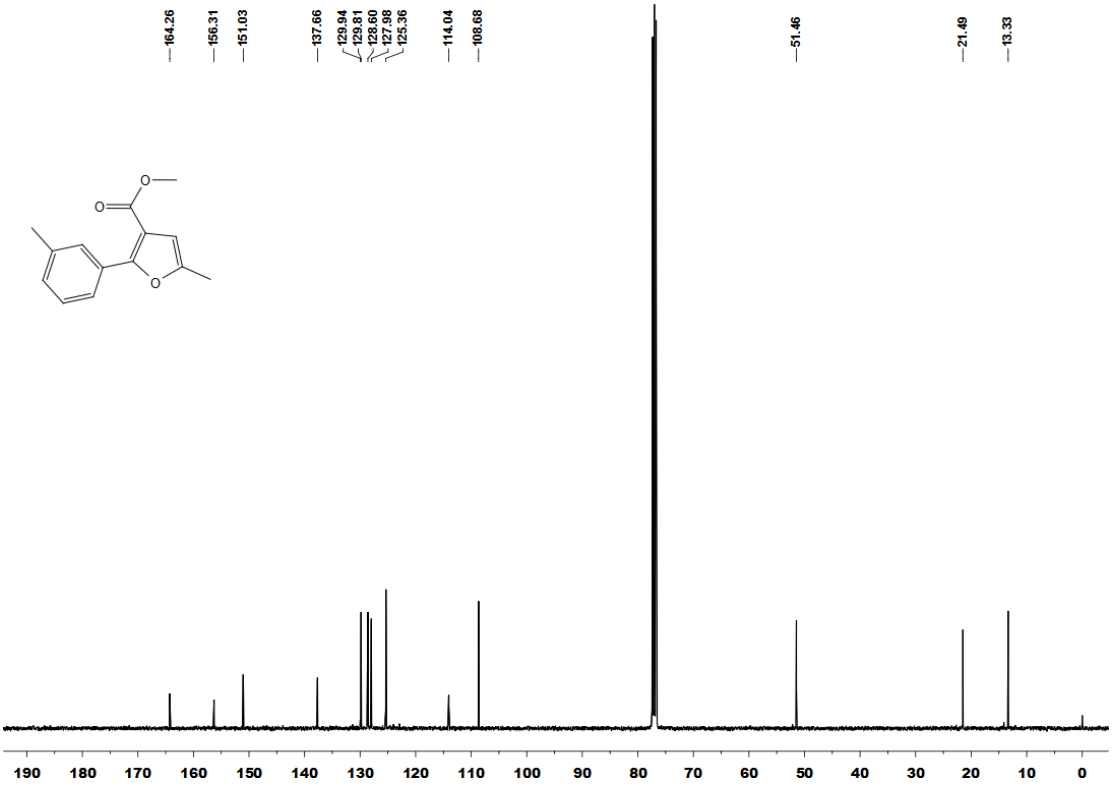

$^{1}$H NMR spectrum of **18g** (in $CDCl_3$)



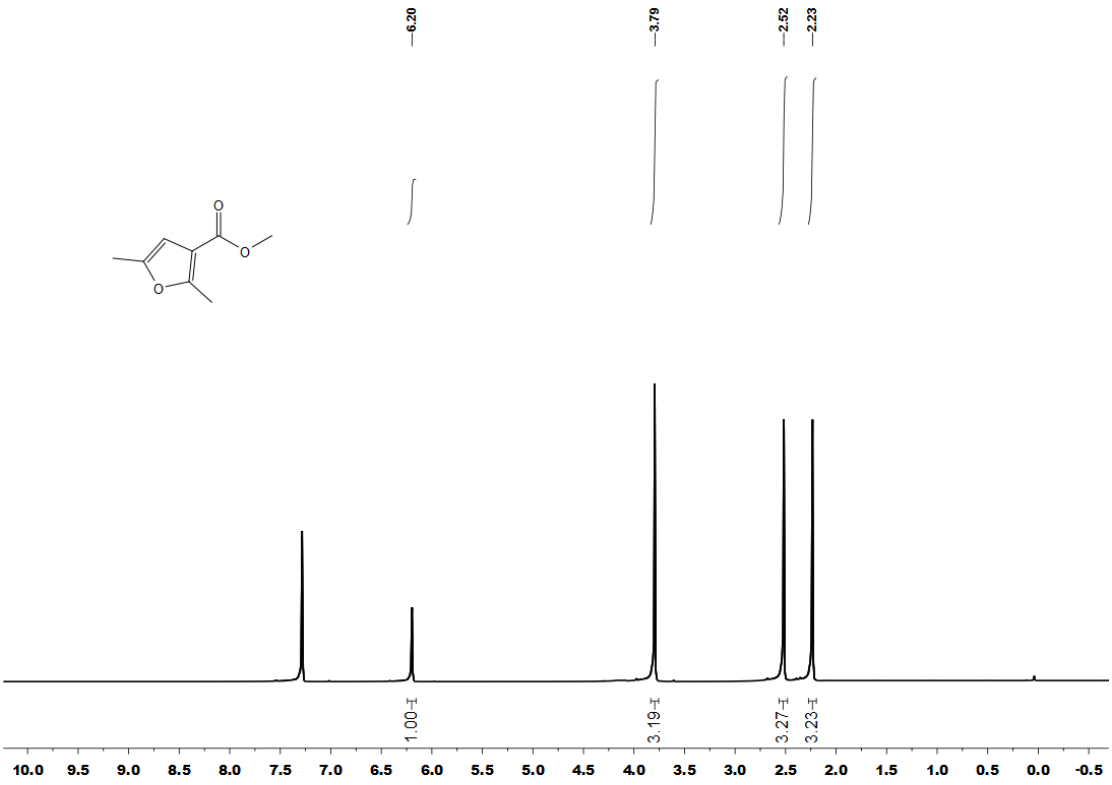

$^{13}$C NMR spectrum of **18g** (in $CDCl_3$)



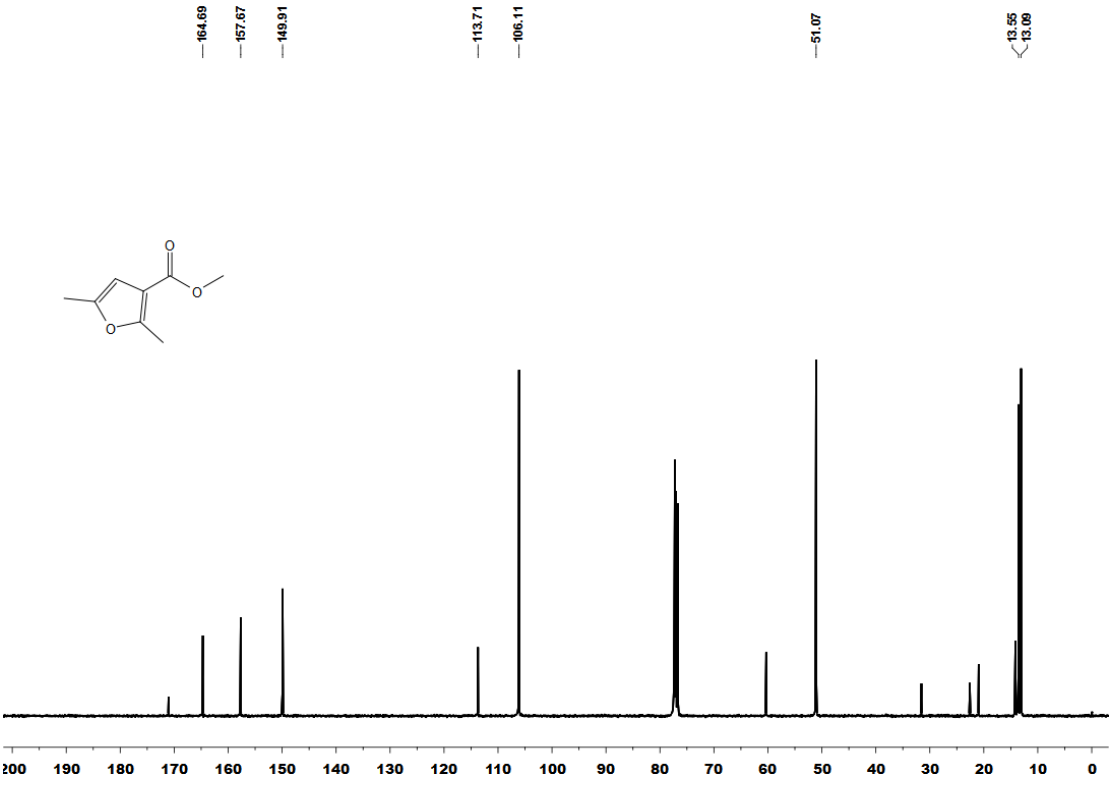

$^{1}$H NMR spectrum of **18h** (in $CDCl_3$)



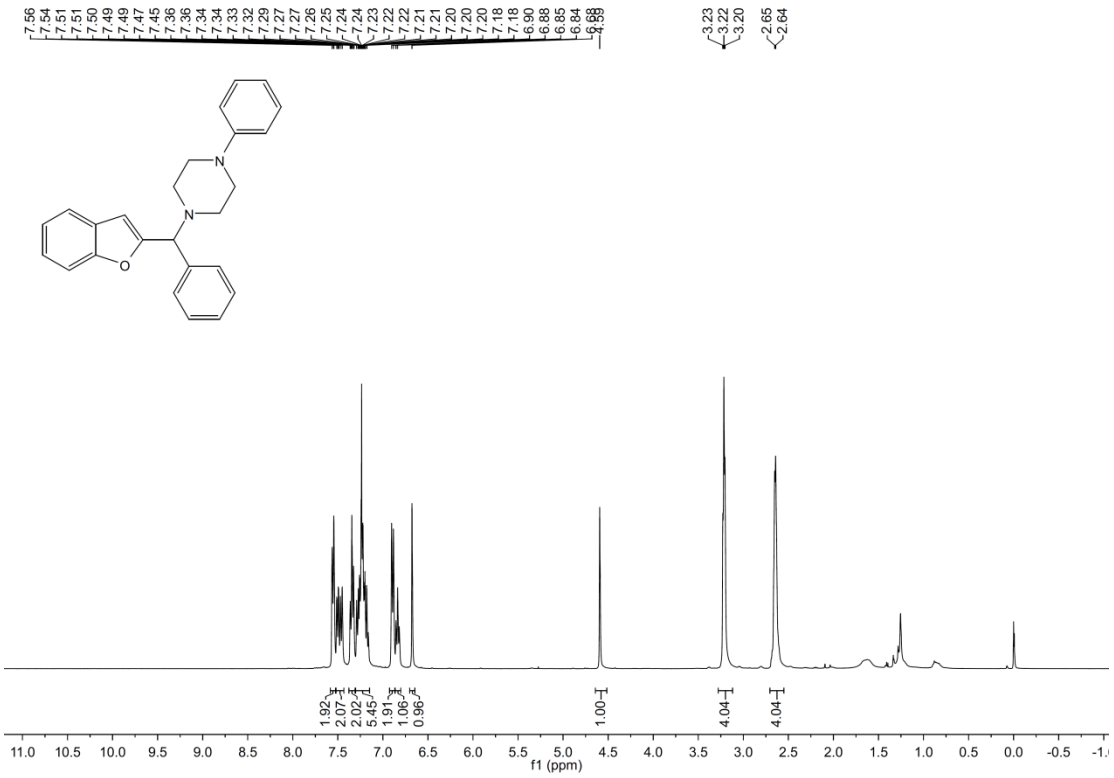

$^{13}$C NMR spectrum of **18h** (in $CDCl_3$)



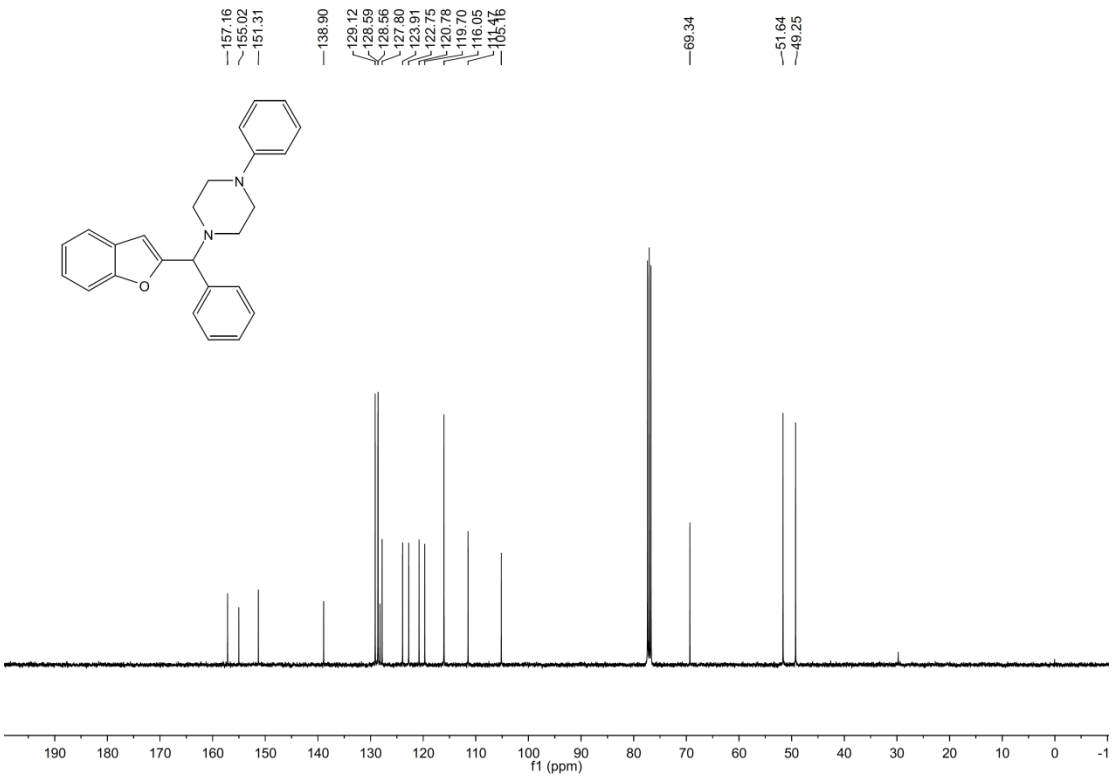

$^{1}$H NMR spectrum of **18i** (in $CDCl_3$)



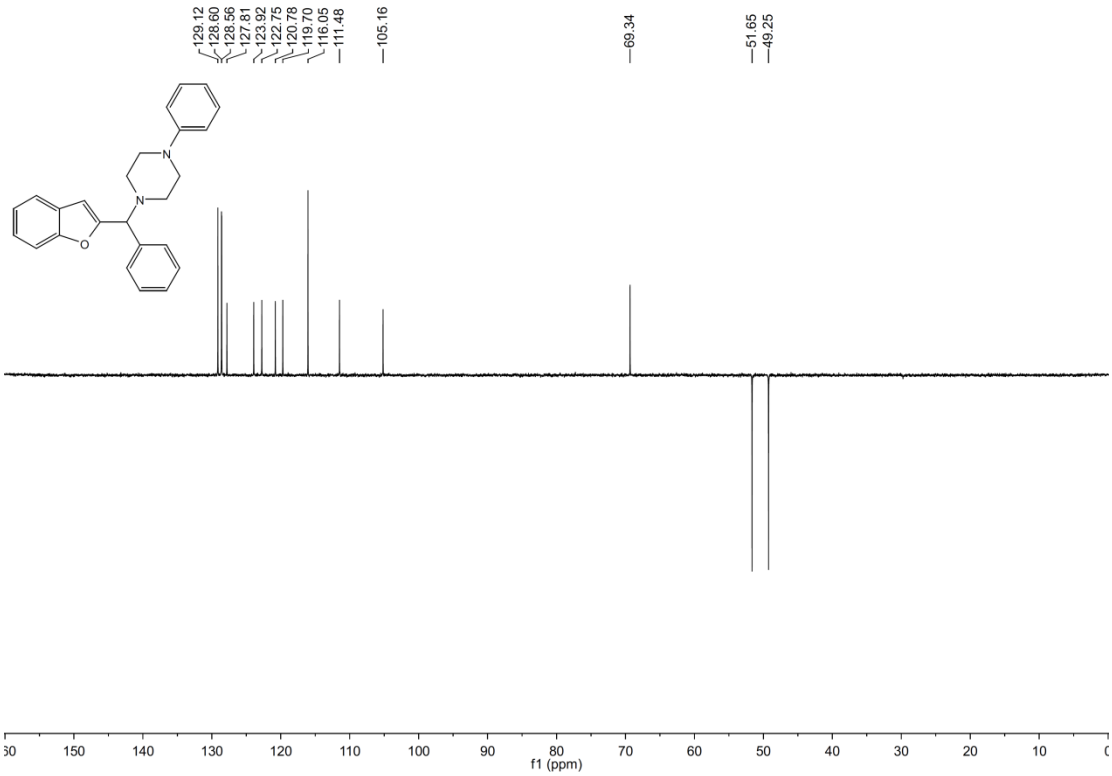

$^{13}$C NMR spectrum of **18i** (in $CDCl_3$)



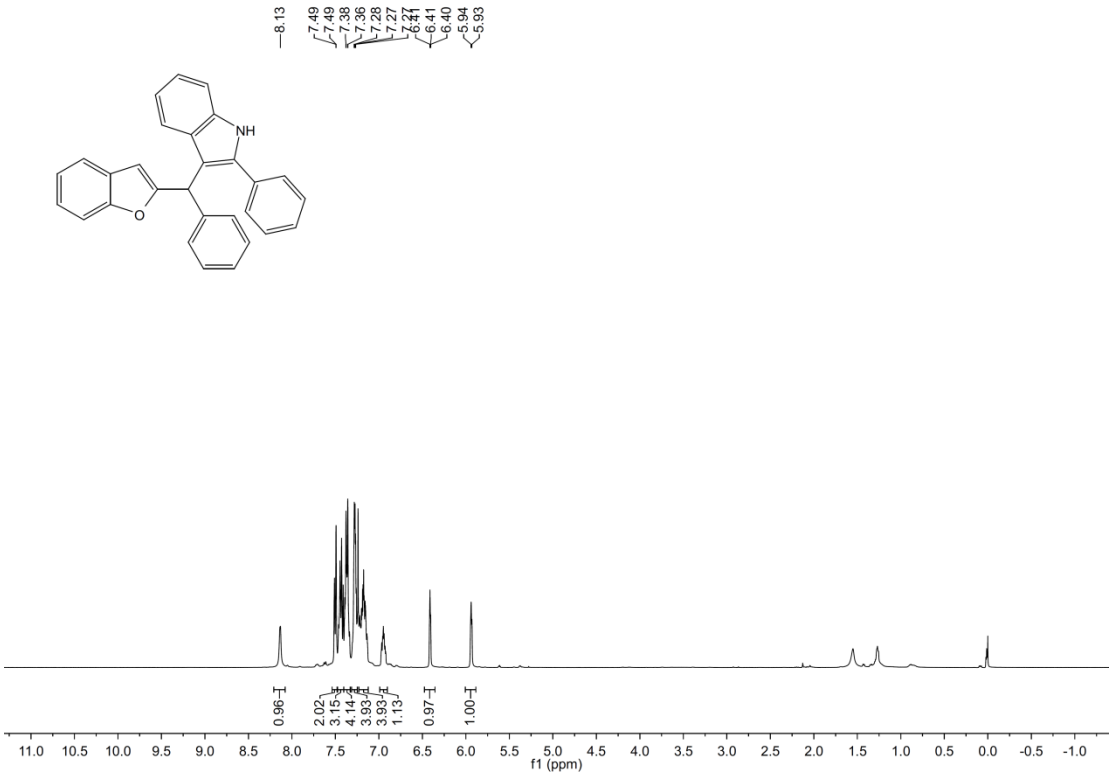

$^{1}$H NMR spectrum of **19** (in $CDCl_3$)



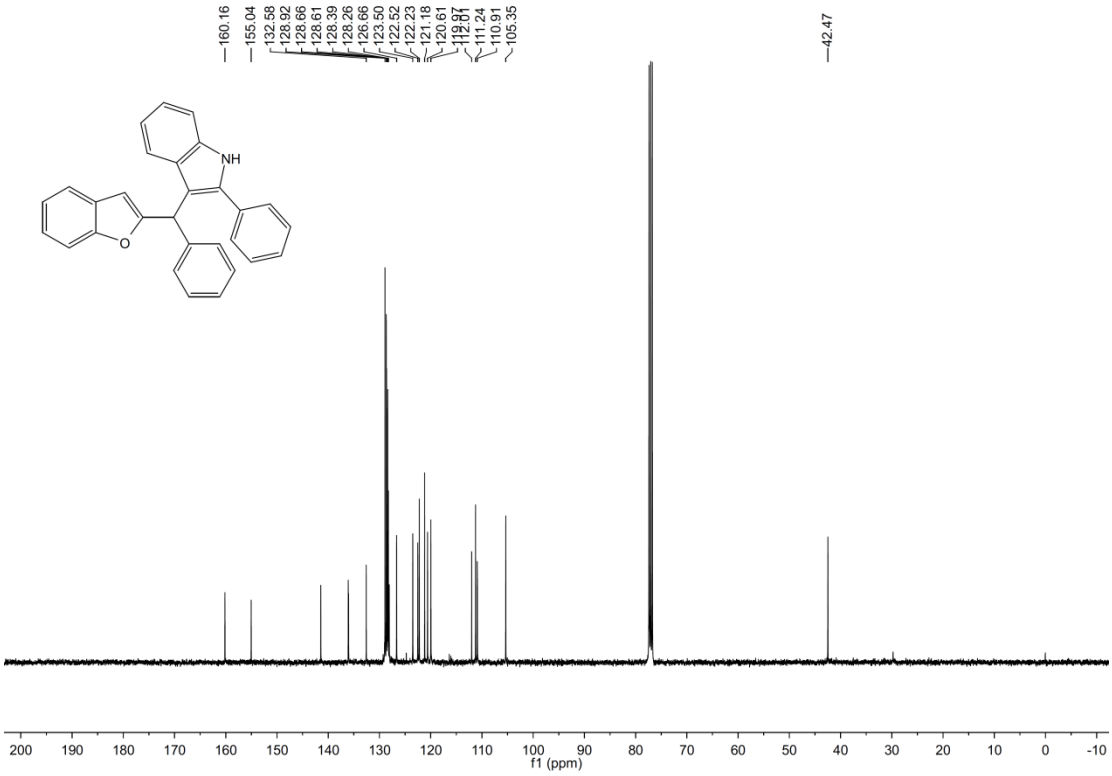

$^{13}$C NMR spectrum of **19** (in $CDCl_3$)




DEPT 135 °spectrum of **19** (in $CDCl_3$)




$^{1}$H NMR spectrum of **21** (in $CDCl_3$)




$^{13}$C NMR spectrum of **21** (in $CDCl_3$)