

Supporting Information

Synthesis of 3(2*H*)-Furanone Derivatives: *p*-TsOH/Halotrimethylsilane Promoted Cycloketonization of γ -Hydroxyl Ynones

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General Remarks

Column chromatography was carried out on silica gel (200-300 mesh). ^1H NMR spectra were recorded on 400, 500 or 600 MHz in CDCl_3 or d_6 -acetone and chemical shifts (ppm) were recorded with tetramethylsilane (TMS) as the internal reference standard. ^{13}C NMR spectra were recorded on 100, 126 or 151 MHz in CDCl_3 or d_6 -acetone, and ^{19}F spectra were recorded on 376 or 471 MHz in CDCl_3 or d_6 -acetone (CFCl_3 as outside standard and low field is positive). Multiplicities are given as: s (singlet), d (doublet), t (triplet), dd (doublet of doublets), or m (multiplet). IR spectra were recorded on a FT-IR spectrometer and only major peaks are reported in cm^{-1} . HR-MS was obtained using a Q-TOF instrument equipped with ESI source. X-Ray single crystal diffraction data were collected on a Bruker APEX-II CCD diffractometer equipped with liquid nitrogen cryogenic device. The crystal was grown in a mixed solvent of petroleum ether and CH_2Cl_2 with an approximate ratio of 5:1. The copies of NMR spectra of all compounds are provided in the Supporting Information. Room temperature is 23–25 °C. THF was distilled immediately before use from Na/benzophenone. 1,2-DCE was distilled from CaH_2 and stored in a dryer before use. Other commercially available reagents and solvents were used without further purification.

Computational Study

Computational methods

All calculations were carried out with the Gaussian 09 D.01 programs.¹ Ground state geometry were fully optimized by using density functional theory (DFT)² and the M06-2X³ method with the 6-31G** basic set all atoms. Frequency calculations have been performed to verify the optimized structures as local minima. The Mulliken charge analysis results are presented below.

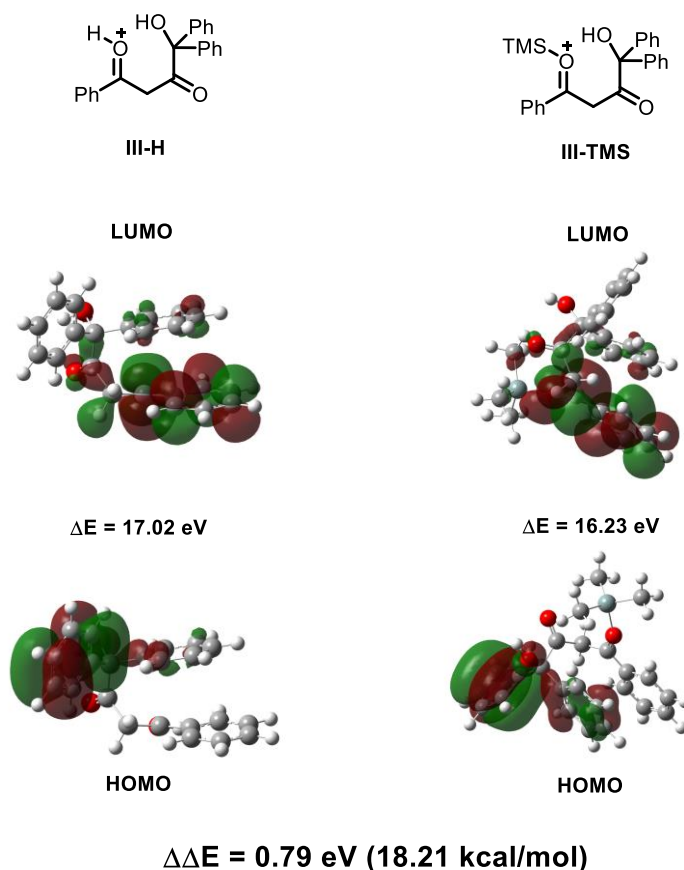


Figure 1 Frontier molecular orbital analysis of two potential activation scenarios for intermediate **III**

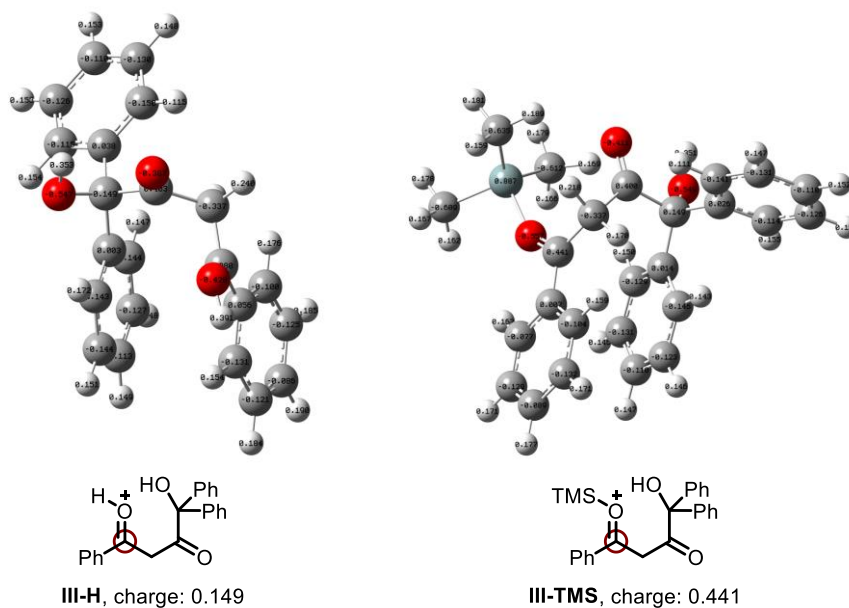


Figure 2 Charge analysis of two potential activation scenarios for intermediate **III**

Two potential activation scenarios for intermediate **III**, namely Brønsted acid (**III-H**) and TMSCl (**III-TMS**), were considered. Through DFT calculations, it was determined that TMSCl (**III-TMS**) exhibits a lower energy gap of 18.21 kcal/mol between the highest occupied molecular orbital (HOMO) and the lowest unoccupied molecular orbital (LUMO) of intermediate **III** compared to Brønsted acid (**III-H**). Therefore, TMSCl is preferred over Brønsted acid in activating intermediate **III**.

Simultaneously, the charge analysis of the intermediate **III** activated through the two different methods is also taken into consideration. Evidently, in the case of intermediate **III** activated by TMSCl, the carbonyl carbon participating in the reaction exhibits a reduced electron cloud density, indicating heightened electrophilic activity.

These computational results are in agreement with experimental

observations.

References:

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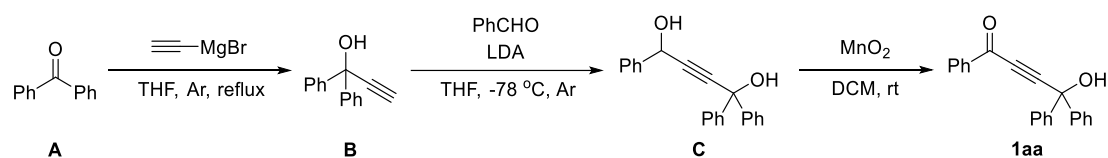
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3. (a) Zhao, Y.; Schultz, N. E.; Truhlar, D. G., *J. Chem. Theory Comput.* 2006, 2, 364–382. (b) Zhao, Y.; Truhlar, D. G., *J. Phys. Chem. A.* 2006, 110, 13126–13130. (c) Zhao, Y.; Truhlar, D. G., *Acc. Chem. Res.* 2008, 41, 157–167. (d) Zhao, Y.; Truhlar, D. G., *Theor. Chem. Acc.* 2008, 120, 215–241. (e) Zhao, Y.; Truhlar, D. G., *J. Chem. Theory Comput.* 2009, 5, 324–333.

General Procedure for the Preparation of Starting Materials

For the synthesis of **1aa**:

Ethynylmagnesium bromide (129.2 g/mol, 0.5 mol/L in THF, 24 mL, 1.2 equiv) was added dropwise into a stirred solution of benzophenone **A** (182.2 g/mol, 10 mmol, 1.82 g) in THF (35 mL) under argon. The mixture was allowed to stir at 65 °C in an oil bath for 4 h. After the completion of the reaction determined by TLC, the reaction mixture was quenched by addition of an aqueous saturated solution of NH₄Cl (35 mL) and extracted with ethyl acetate (2×50 mL). The combined organic layers were washed with brine, dried over Na₂SO₄, and concentrated under reduced pressure. The resulting material 1,1-diphenylprop-2-yn-1-ol **B** (208.3 g/mol, 94%, 1.96 g, 9.4 mmol) was directly used for the next step without further purification.



n-BuLi (64.1 g/mol, 2.5 mol/L in hexane, 14 mL) was added dropwise to a solution of diisopropylamine (101.2 g/mol, 3.54 g, 35 mmol) in anhydrous THF (10 mL) at -78 °C under an argon atmosphere. The mixture was allowed to stir for 1 h prior to subsequent slow addition of 1,1-diphenylprop-2-yn-1-ol **B** (208.3 g/mol, 2.08 g, 10 mmol). The mixture was allowed to stir at -78 °C for another 1 h. Benzaldehyde (106.1 g/mol, 1.59 g, 15 mmol, 1.5 equiv) dissolved in THF (5 mL) was added to the reaction

and stirred under the same conditions for 1 h. The mixture was then warmed to room temperature and stirred for 10 h. After the completion of the reaction determined by TLC, the reaction mixture was quenched by an aqueous saturated solution of NH_4Cl (30 mL) and extracted with ethyl acetate (2×50 mL). The organic layers were combined to be washed with brine and dried over MgSO_4 for 30 min. Then the solution would be concentrated under reduced pressure and further purified by flash column chromatography (silica gel, petroleum ether/ethyl acetate, 4:1) to give 1,1,4-triphenylbut-2-yne-1,4-diol **C** (314.4 g/mol, 72%, 2.26 g).

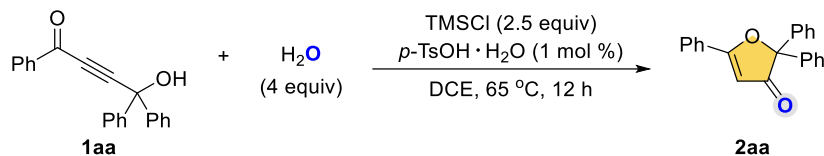
MnO_2 (86.9 g/mol, 6.53 g, 75 mmol, 15 equiv) was added to a solution of 1,1,4-triphenylbut-2-yne-1,4-diol (**C**, 314.4 g/mol, 5 mmol, 1.57 g) in CH_2Cl_2 (15 mL) at room temperature. The resulting mixture was stirred overnight. Then the solid was filtered, and the solvents were removed under reduced pressure. The residue was purified by flash column chromatography (silica gel, petroleum ether/ethyl acetate, 10:1) to give 4-hydroxy-1,4,4-triphenylbut-2-yn-1-one **1aa** (312.4 g/mol, 99%, 1.55 g).

References:

1. S. R. Mothe, S. J. L. Lauw, P. Kothandaraman, P. W. H. Chan, *J. Org. Chem.* 2012, **77**, 6937–6947.
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3. K. F. Lee, W. Bai, H. H. Y. Sung, I. D. Williams, Z. Lin, G. Jia, *Chem. – Eur. J.* 2018, **24**, 9760–9764.
4. Y.-F. Qiu, S.-P. Chen, J.-H. Cao, M. Li, Z.-J. Quan, X.-C. Wang, Y.-M. Liang, *Org. Lett.* 2022, **24**, 2264–2268.

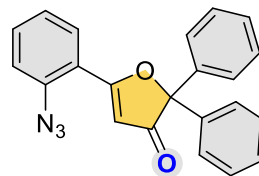
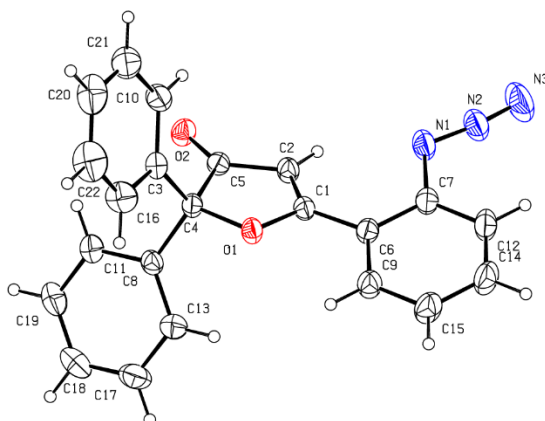
General Procedure for the Synthesis of Products

For the synthesis of **2aa**:



TMSCl (108.6 g/mol, 54.3mg, 2.5 equiv) was added to an oven-dried tube charged with of 4-hydroxy-1,4,4-triphenylbut-2-yn-1-one (**1aa**, 312.4 g/mol, 62.5 mg, 0.2 mmol) and *p*-TsOH·H₂O (**2a**, 190.21 g/mol, 0.4 mg, 1 mol %) in anhydrous 1,2-DCE (2 mL). The resulting mixture was allowed to stir at 65 °C in an oil bath for 12 h, and then extracted with ethyl ether (2×15 mL), washed with a saturated aqueous solution of saturated brine, dried over Na₂SO₄, and evaporated under reduced pressure. The residue was further purified by chromatography on silica gel (petroleum ether/ethyl acetate, 20:1) to afford the product 2,2,5-triphenylfuran-3(2*H*)-one (**2aa**, 313.4 g/mol, 59.5 mg) in 95% yield.

X-ray Single Crystal Diffraction Data



2ak CCDC: 2265194

The ellipsoid contour percent probability level is 30% in the caption of the thermal ellipsoid plot.

Bond precision: C-C = 0.0021 Å

Wavelength=1.54184

Cell: a=11.7255(2) b=19.0167(4) c=8.36520(18)
 alpha=90 beta=105.134(2) gamma=90
 Temperature: 296 K

	Calculated	Reported
Volume	1800.58(6)	1800.58(7)
Space group	P 21/c	P 1 21/c 1
Hall group	-P 2ybc	-P 2ybc
Moiety formula	C22 H15 N3 O2	C22 H15 N3 O2
Sum formula	C22 H15 N3 O2	C22 H15 N3 O2
Mr	353.37	353.37
Dx, g cm ⁻³	1.304	1.304
Z	4	4
Mu (mm ⁻¹)	0.692	0.692
F000	736.0	736.0
F000'	738.22	
h,k,lmax	14,24,10	14,23,10
Nref	3828	3640
Tmin,Tmax	0.913,0.940	0.683,1.000
Tmin'	0.901	

Correction method= # Reported T Limits: Tmin=0.683 Tmax=1.000

AbsCorr = MULTI-SCAN

Data completeness= 0.951

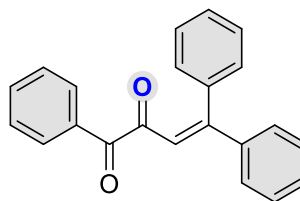
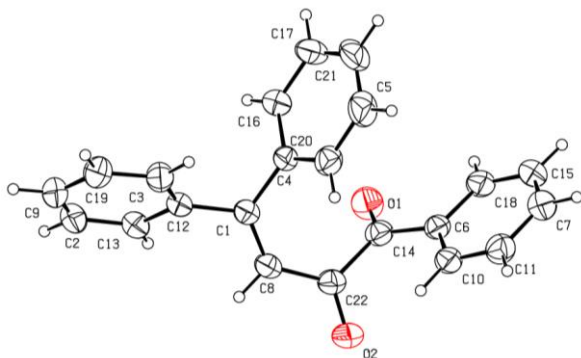
Theta(max)= 77.300

R(reflections)= 0.0488(3236)

wR2(reflections)= 0.1331(3640)

S = 1.066

Npar= 244



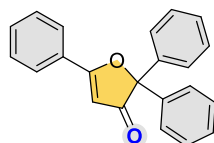
5aa CCDC: 2265196

The ellipsoid contour percent probability level is 30% in the caption of the thermal ellipsoid plot.

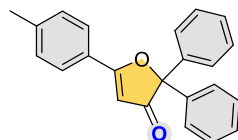
Bond precision:	C-C = 0.0021 Å	Wavelength=1.54184	
Cell:	a=11.4368(3)	b=6.67839(14)	c=22.2255(6)
	alpha=90	beta=91.647(2)	gamma=90
Temperature:	304 K		
	Calculated	Reported	
Volume	1696.87(7)	1696.87(8)	
Space group	P 21/n	P 1 21/n 1	
Hall group	-P 2yn	-P 2yn	
Moiety formula	C ₂₂ H ₁₆ O ₂	C ₂₂ H ₁₆ O ₂	
Sum formula	C ₂₂ H ₁₆ O ₂	C ₂₂ H ₁₆ O ₂	
Mr	312.35	312.35	
Dx, g cm ⁻³	1.223	1.223	
Z	4	4	
Mu (mm ⁻¹)	0.612	0.612	
F ₀₀₀	656.0	656.0	
F ₀₀₀ '	657.91		
h,k,lmax	14,8,27	14,8,27	
Nref	3545	3353	
Tmin,Tmax	0.912,0.935	0.430,1.000	
Tmin'	0.912		
Correction method= # Reported T Limits: Tmin=0.430 Tmax=1.000			
AbsCorr = MULTI-SCAN			
Data completeness=	0.946	Theta(max)= 76.059	
R(reflections)=	0.0422(2776)	wR2(reflections)= 0.1196(3353)	
S =	1.067	Npar= 217	

Characterization Data

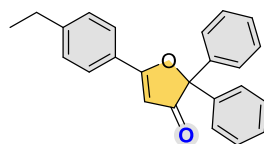
Characterization Data of 2aa–2ar



2,2,5-triphenylfuran-3(2H)-one (2aa): yellow solid; melting point 175–177 °C; 59.3 mg; 95%; ¹H NMR (400 MHz, CDCl₃) δ ppm 7.97 (d, *J* = 7.6 Hz, 2H), 7.61–7.51 (m, 7H), 7.37–7.32 (m, 6H), 6.10 (s, 1H); ¹³C NMR (151 MHz, CDCl₃) δ ppm 202.1, 184.1, 138.4, 133.0, 129.0, 128.7, 128.4, 128.4, 127.3, 126.6, 99.8, 92.9. IR (neat, cm⁻¹): 3085, 1695, 1603, 1351, 1173, 1054, 983, 881, 765, 694; HRMS (ESI) *m/z*: [M+H]⁺ Calcd for C₂₂H₁₇O₂ 313.1223; Found 313.1228 (1.6 ppm). This product was purified by flash column chromatography (silica gel, petroleum ether/ethyl acetate, 20:1).



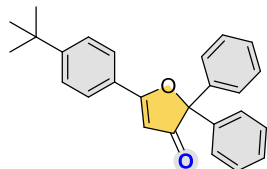
2,2-diphenyl-5-(*p*-tolyl)furan-3(2H)-one (2ab): yellow solid; melting point 149–151 °C; 58.8 mg; 90%; ¹H NMR (600 MHz, CDCl₃) δ ppm 7.84 (d, *J* = 8.4 Hz, 2H), 7.55–7.54 (m, 4H), 7.35–7.32 (m, 4H), 7.31–7.29 (m, 4H), 6.04 (s, 1H), 2.42 (s, 3H); ¹³C NMR (151 MHz, CDCl₃) δ ppm 201.9, 184.3, 143.9, 138.5, 129.6, 128.4, 128.3, 127.2, 126.6, 125.9, 99.1, 92.8, 21.7. IR (neat, cm⁻¹): 3065, 2917, 1695, 1565, 1349, 1173, 1056, 983, 822, 697; HRMS (ESI) *m/z*: [M+H]⁺ Calcd for C₂₃H₁₉O₂ 327.1380; Found 327.1381 (0.3 ppm). This product was purified by flash column chromatography (silica gel, petroleum ether/ethyl acetate, 20:1).



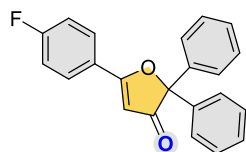
5-(4-ethylphenyl)-2,2-diphenylfuran-3(2H)-one (2ac): yellow solid; melting point 126–128 °C; 52.4 mg; 77%; ¹H NMR (600 MHz, CDCl₃) δ ppm 7.88 (d, *J* = 5.2 Hz, 2H), 7.55–7.54 (m, 4H), 7.35–7.29 (m, 8H), 6.05 (s, 1H), 2.72 (dd, *J* = 10.0 Hz 5.2 Hz, 2H), 1.26 (t, *J* = 5.2 Hz, 3H); ¹³C NMR (151 MHz, CDCl₃) δ ppm 202.0, 184.3, 150.1, 138.5, 128.5, 128.4, 128.3, 127.4, 126.6, 126.2, 99.1, 92.8, 29.0, 15.2. IR (neat, cm⁻¹): 3066, 2971, 1692, 1607, 1347, 1173, 1054,

909, 843, 698; HRMS (ESI) m/z : $[M+H]^+$ Calcd for $C_{24}H_{21}O_2$ 341.1536; Found 341.1531 (1.5 ppm).

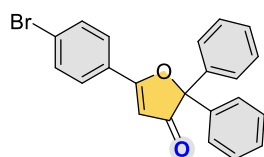
This product was purified by flash column chromatography (silica gel, petroleum ether/ethyl acetate, 20:1).



5-(4-(tert-butyl)phenyl)-2,2-diphenylfuran-3(2H)-one (2ad): yellow solid; melting point 181–183 °C; 70.0 mg; 95%; 1H NMR (400 MHz, $CDCl_3$) δ ppm 7.91 (d, $J = 7.2$ Hz, 2H), 7.55–7.53 (m, 6H), 7.35–7.33 (m, 6H), 6.06 (s, 1H), 1.36 (s, 9H); ^{13}C NMR (151 MHz, $CDCl_3$) δ ppm 202.0, 184.2, 156.9, 138.5, 128.4, 128.3, 127.2, 126.6, 126.0, 125.9, 99.2, 92.8, 35.2, 31.0. IR (neat, cm^{-1}): 3090, 2960, 1694, 1609, 1558, 1344, 1172, 1111, 987, 697; HRMS (ESI) m/z : $[M+H]^+$ Calcd for $C_{26}H_{25}O_2$ 369.1849; Found 369.1841 (2.2 ppm). This product was purified by flash column chromatography (silica gel, petroleum ether/ethyl acetate, 20:1).

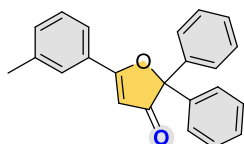


5-(4-fluorophenyl)-2,2-diphenylfuran-3(2H)-one (2ae): white solid; melting point 190–191 °C; 43.6 mg; 66%; 1H NMR (400 MHz, $CDCl_3$) δ ppm 7.98 (dd, $J = 7.6$ Hz 5.6 Hz, 2H), 7.52 (d, $J = 8.0$ Hz, 4H), 7.39–7.32 (m, 6H), 7.26–7.20 (m, 2H), 6.05 (s, 1H); ^{13}C NMR (151 MHz, $CDCl_3$) δ ppm 201.9, 182.9, 165.5 (d, $J = 254$ Hz, 1C), 138.3, 129.7 (d, $J = 9$ Hz, 1C), 128.5, 126.6, 125.1 (d, $J = 3$ Hz, 1C), 116.4, 116.3, 99.6 (d, $J = 1$ Hz, 1C), 93.2. IR (neat, cm^{-1}): 3057, 1652, 1598, 1324, 1069, 1055, 968, 757, 668; HRMS (ESI) m/z : $[M+H]^+$ Calcd for $C_{22}H_{16}FO_2$ 331.1129; Found 331.1126 (0.9 ppm). This product was purified by flash column chromatography (silica gel, petroleum ether/ethyl acetate, 20:1).

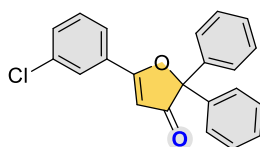


5-(4-bromophenyl)-2,2-diphenylfuran-3(2H)-one (2af): white solid; melting point

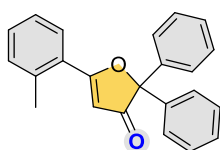
167–168 °C; 52.4 mg; 67%; ^1H NMR (600 MHz, CDCl_3) δ ppm 7.80 (d, $J = 5.6$ Hz, 2H), 7.65 (d, $J = 5.6$ Hz, 2H), 7.52–7.51 (m, 4H), 7.36–7.31 (m, 6H), 6.08 (s, 1H); ^{13}C NMR (151 MHz, CDCl_3) δ ppm 201.8, 182.8, 138.2, 132.3, 128.6, 128.5, 128.5, 127.8, 127.6, 126.6, 100.1, 93.1. IR (neat, cm^{-1}): 3061, 1699, 1602, 1342, 1173, 1072, 986, 885, 764, 696; HRMS (ESI) m/z : $[\text{M}+\text{H}]^+$ Calcd for $\text{C}_{22}\text{H}_{16}\text{BrO}_2$ 391.0328; Found 391.0322 (1.5 ppm). This product was purified by flash column chromatography (silica gel, petroleum ether/ethyl acetate, 20:1).



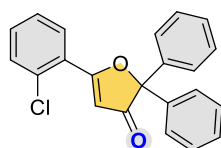
2,2-diphenyl-5-(*m*-tolyl)furan-3(2H)-one (2ag): yellow solid; melting point 172–173 °C; 43.1 mg; 66%; ^1H NMR (600 MHz, CDCl_3) δ ppm 7.76–7.74 (m, 2H), 7.55–7.53 (m, 4H), 7.41–7.38 (m, 2H), 7.36–7.30 (m, 6H), 6.07 (s, 1H), 2.43 (s, 3H); ^{13}C NMR (151 MHz, CDCl_3) δ ppm 202.1, 184.4, 138.8, 138.4, 133.8, 128.9, 128.7, 128.4, 128.4, 127.6, 126.7, 124.6, 99.7, 92.9, 21.4. IR (neat, cm^{-1}): 3061, 1698, 1605, 1572, 1348, 1171, 1060, 989, 785, 698; HRMS (ESI) m/z : $[\text{M}+\text{H}]^+$ Calcd for $\text{C}_{23}\text{H}_{19}\text{O}_2$ 327.1380; Found 327.1380 (0.0 ppm). This product was purified by flash column chromatography (silica gel, petroleum ether/ethyl acetate, 20:1).



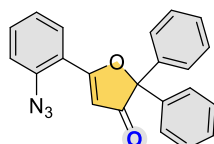
5-(3-chlorophenyl)-2,2-diphenylfuran-3(2H)-one (2ah): white solid; melting point 154–155 °C; 50.6 mg; 73%; ^1H NMR (400 MHz, CDCl_3) δ ppm 7.94 (d, $J = 1.2$ Hz, 1H), 7.81 (dd, $J = 7.6$ Hz 0.8 Hz, 1H), 7.55–7.51 (m, 5H), 7.45 (t, $J = 8.0$ Hz, 1H), 7.38–7.31 (m, 6H), 6.10 (s, 1H); ^{13}C NMR (151 MHz, CDCl_3) δ ppm 201.9, 182.4, 138.1, 135.3, 132.8, 130.5, 130.3, 128.5, 128.5, 127.0, 126.6, 125.5, 100.6, 93.2. IR (neat, cm^{-1}): 3093, 1698, 1606, 1563, 1349, 1174, 1058, 986, 765, 698; HRMS (ESI) m/z : $[\text{M}+\text{H}]^+$ Calcd for $\text{C}_{23}\text{H}_{19}\text{O}_2$ 347.0833; Found 347.0832 (0.3 ppm). This product was purified by flash column chromatography (silica gel, petroleum ether/ethyl acetate, 20:1).



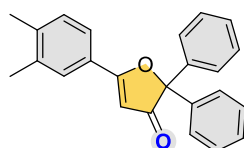
2,2-diphenyl-5-(*o*-tolyl)furan-3(2H)-one (2ai): white solid; melting point 134–135 °C; 56.8 mg; 87%; ¹H NMR (400 MHz, CDCl₃) δ ppm 7.92 (d, *J* = 7.6 Hz, 1H), 7.56–7.54 (m, 4H), 7.45 (t, *J* = 7.6 Hz, 1H), 7.38–7.31 (m, 8H), 6.00 (s, 1H), 2.54 (s, 3H); ¹³C NMR (151 MHz, CDCl₃) δ ppm 202.4, 185.0, 138.4, 138.1, 132.1, 131.9, 128.7, 128.6, 128.4, 128.3, 126.6, 126.3, 103.9, 92.0, 22.0. IR (neat, cm⁻¹): 3142, 1693, 1602, 1333, 1176, 1034, 984, 882, 770, 697; HRMS (ESI) *m/z*: [M+Na]⁺ Calcd for C₂₃H₁₈NaO₂ 349.1199; Found 349.1193 (1.7 ppm). This product was purified by flash column chromatography (silica gel, petroleum ether/ethyl acetate, 20:1).



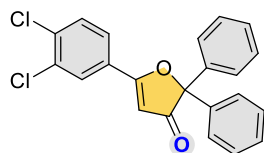
5-(2-chlorophenyl)-2,2-diphenylfuran-3(2H)-one (2aj): white solid; melting point 147–148 °C; 48.6 mg; 70%; ¹H NMR (400 MHz, CDCl₃) δ ppm 8.10–8.08 (m, 1H), 7.55–7.54 (m, 5H), 7.48–7.40 (m, 2H), 7.38–7.32 (m, 6H), 6.52 (s, 1H); ¹³C NMR (151 MHz, CDCl₃) δ ppm 202.8, 180.6, 138.2, 134.2, 132.9, 131.3, 129.5, 128.5, 128.4, 127.8, 127.1, 126.6, 105.5, 91.5. IR (neat, cm⁻¹): 3063, 1701, 1597, 1332, 1170, 1035, 985, 887, 763, 698; HRMS (ESI) *m/z*: [M+H]⁺ Calcd for C₂₂H₁₆ClO₂ 347.0833; Found 347.0830 (0.9 ppm). This product was purified by flash column chromatography (silica gel, petroleum ether/ethyl acetate, 20:1).



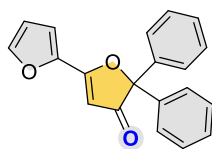
5-(2-azidophenyl)-2,2-diphenylfuran-3(2H)-one (2ak): yellow solid; melting point 177–178 °C; 44.5 mg; 63%; ¹H NMR (600 MHz, CDCl₃) δ ppm 8.16 (dd, *J* = 7.8 Hz 1.2 Hz, 1H), 7.57–7.55 (m, 1H), 7.54–7.52 (m, 4H), 7.35–7.26 (m, 8H), 6.56 (s, 1H); ¹³C NMR (151 MHz, CDCl₃) δ ppm 203.0, 179.1, 140.1, 138.4, 133.4, 128.7, 128.4, 128.3, 126.6, 124.9, 120.2, 119.2, 105.0, 91.0. IR (neat, cm⁻¹): 3062, 2927, 1697, 1602, 1341, 1270, 1169, 1039, 761, 697; HRMS (ESI) *m/z*: [M+H]⁺ Calcd for C₂₂H₁₆N₃O₂ 354.1237; Found 354.1237 (0.0 ppm). This product was purified by flash column chromatography (silica gel, petroleum ether/ethyl acetate, 20:1).



5-(3,4-dimethylphenyl)-2,2-diphenylfuran-3(2H)-one (2al): white solid; melting point 153–154 °C; 56.5 mg; 83%; ¹H NMR (600 MHz, CDCl₃) δ ppm 7.72 (s, 1H), 7.69 (d, *J* = 7.2 Hz, 1H), 7.55–7.53 (m, 4H), 7.36–7.30 (m, 6H), 7.26 (d, *J* = 8.4 Hz, 1H), 6.03 (s, 1H), 2.34 (s, 6H, two singlet peaks should be observed, however, due to the limitation of the resolution of the NMR machine, a singlet peak was identified); ¹³C NMR (151 MHz, CDCl₃) δ ppm 202.0, 184.6, 142.7, 138.5, 137.4, 130.2, 128.4, 128.3, 128.1, 126.7, 126.3, 125.0, 99.0, 92.8, 20.1, 19.8. IR (neat, cm⁻¹): 3061, 1696, 1594, 1495, 1448, 1342, 1170, 1063, 936, 698; HRMS (ESI) *m/z*: [M+Na]⁺ Calcd for C₂₄H₂₀NaO₂ 363.1356; Found 363.1347 (2.5 ppm). This product was purified by flash column chromatography (silica gel, petroleum ether/ethyl acetate, 20:1).

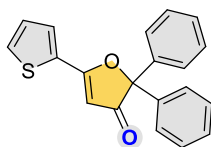


5-(3,4-dichlorophenyl)-2,2-diphenylfuran-3(2H)-one (2am): white solid; melting point 132–133 °C; 54.1 mg; 71%; ¹H NMR (400 MHz, CDCl₃) δ ppm 8.04 (s, 1H), 7.75 (d, *J* = 7.6 Hz, 1H), 7.60 (d, *J* = 8.0 Hz, 1H), 7.51–7.49 (m, 4H), 7.36–7.35 (m, 6H), 6.09 (s, 1H); ¹³C NMR (151 MHz, CDCl₃) δ ppm 201.7, 181.4, 138.0, 137.3, 133.8, 131.1, 128.7, 128.6, 128.6, 128.5, 126.6, 126.3, 100.8, 93.4. IR (neat, cm⁻¹): 3063, 2926, 1701, 1606, 1336, 1171, 1060, 986, 760, 697; HRMS (ESI) *m/z*: [M+H]⁺ Calcd for C₂₂H₁₅Cl₂O₂ 381.0444; Found 381.0440 (1.0 ppm). This product was purified by flash column chromatography (silica gel, petroleum ether/ethyl acetate, 20:1).

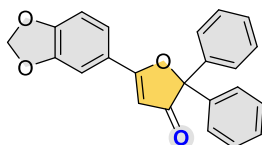


5,5-diphenyl-[2,2'-bifuran]-4(5H)-one (2an): white solid; melting point 171–173 °C; 32.0 mg; 53%; ¹H NMR (400 MHz, CDCl₃) δ ppm 7.68 (s, 1H), 7.51–7.49 (m, 4H), 7.37–7.32 (m, 6H), 7.25 (d, *J* = 3.0 Hz, 1H), 6.62 (t, *J* = 2.0 Hz, 1H), 5.97 (s, 1H); ¹³C NMR (151 MHz, CDCl₃) δ ppm 201.2, 174.3, 147.1, 144.9, 138.3, 128.4, 128.4, 126.7, 115.4, 112.6, 98.7, 92.7. IR (neat, cm⁻¹): 3059, 1698, 1623, 1351, 1169, 1068, 984, 844, 763, 697; HRMS (ESI) *m/z*: [M+H]⁺ Calcd for C₂₀H₁₅O₃ 303.1016; Found 303.1011 (1.6 ppm). This product was purified by flash column

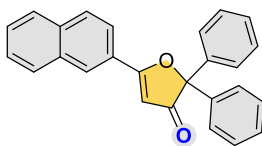
chromatography (silica gel, petroleum ether/ethyl acetate, 20:1).



2,2-diphenyl-5-(thiophen-2-yl)furan-3(2H)-one (2ao): yellow solid; melting point 177–179 °C; 45.8 mg; 72%; ^1H NMR (400 MHz, CDCl_3) δ ppm 7.79 (d, $J = 2.4$ Hz, 1H), 7.67–7.66 (m, 1H), 7.54–7.52 (m, 4H), 7.37–7.31 (m, 6H), 7.20 (dd, $J = 4.8$ Hz 4.0 Hz, 1H), 5.93 (s, 1H); ^{13}C NMR (151 MHz, CDCl_3) δ ppm 201.1, 178.4, 138.3, 132.2, 131.8, 130.9, 128.6, 128.4, 128.4, 126.7, 98.7, 93.1. IR (neat, cm^{-1}): 3092, 1694, 1583, 1377, 1168, 1025, 982, 835, 763, 698; HRMS (ESI) m/z : $[\text{M}+\text{H}]^+$ Calcd for $\text{C}_{20}\text{H}_{15}\text{O}_2\text{S}$ 319.0787; Found 319.0782 (1.6 ppm). This product was purified by flash column chromatography (silica gel, petroleum ether/ethyl acetate, 20:1).

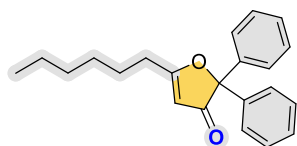


5-(benzo[d][1,3]dioxol-5-yl)-2,2-diphenylfuran-3(2H)-one (2ap): yellow solid; melting point 214–216 °C; 44.9 mg; 63%; ^1H NMR (400 MHz, CDCl_3) δ ppm 7.56–7.51 (m, 5H), 7.38–7.33 (m, 7H), 6.92 (d, $J = 8.4$ Hz, 1H), 6.06 (s, 2H), 5.95 (s, 1H); ^{13}C NMR (151 MHz, CDCl_3) δ ppm 201.6, 183.5, 151.7, 148.3, 138.5, 128.4, 128.3, 126.6, 123.1, 122.7, 108.8, 107.0, 102.0, 98.6, 92.9. IR (neat, cm^{-1}): 3061, 2919, 1690, 1574, 1448, 1318, 1036, 923, 759, 694; HRMS (ESI) m/z : $[\text{M}+\text{H}]^+$ Calcd for $\text{C}_{23}\text{H}_{17}\text{O}_4$ 357.1121; Found 357.1122 (0.3 ppm). This product was purified by flash column chromatography (silica gel, petroleum ether/ethyl acetate, 20:1).



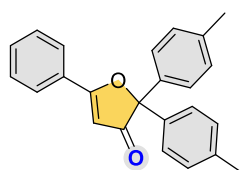
5-(naphthalen-2-yl)-2,2-diphenylfuran-3(2H)-one (2aq): yellow solid; melting point 160–162 °C; 60.9 mg; 84%; ^1H NMR (400 MHz, CDCl_3) δ ppm 8.56 (s, 1H), 7.99–7.88 (m, 4H), 7.63–7.58 (m, 6H), 7.39–7.32 (m, 6H), 6.21 (s, 1H); ^{13}C NMR (151 MHz, CDCl_3) δ ppm 202.1, 184.0, 138.5, 135.4, 132.7, 129.3, 128.8, 128.5, 128.5, 128.4, 127.9, 127.8, 127.2, 126.7, 125.9, 123.4, 100.2, 93.0. IR (neat, cm^{-1}): 3060, 1696, 1604, 1582, 1369, 1172, 1053, 988, 758, 699; HRMS (ESI) m/z : $[\text{M}+\text{Na}]^+$ Calcd for $\text{C}_{26}\text{H}_{18}\text{NaO}_2$ 385.1199; Found 385.1192 (1.8 ppm). This

product was purified by flash column chromatography (silica gel, petroleum ether/ethyl acetate, 20:1).

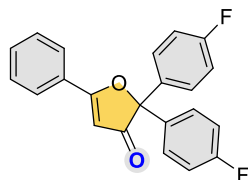


5-pentyl-2,2-diphenylfuran-3(2H)-one (2ar): yellow oil; 17.3 mg; 27%; ^1H NMR (400 MHz, CDCl_3) δ ppm 7.46–7.44 (m, 4H), 7.36–7.29 (m, 6H), 5.49 (m, 1H), 2.63 (t, $J = 7.6$ Hz, 2H), 1.78–1.71 (m, 2H), 1.41–1.36 (m, 2H), 1.31–1.30 (m, 4H), 0.88 (t, $J = 6.8$ Hz, 3H); ^{13}C NMR (151 MHz, CDCl_3) δ ppm 202.6, 192.9, 138.4, 128.4, 128.3, 126.5, 102.4, 92.5, 31.4, 30.9, 28.8, 26.1, 22.4, 14.0. IR (neat, cm^{-1}): 3062, 2929, 1704, 1601, 1449, 1369, 1170, 762, 697, 602; HRMS (ESI) m/z : $[\text{M}+\text{H}]^+$ Calcd for $\text{C}_{22}\text{H}_{25}\text{O}_2$ 321.1849; Found 321.1843 (1.9 ppm). This product was purified by flash column chromatography (silica gel, petroleum ether/ethyl acetate, 20:1).

Characterization Data of 2ba–2br

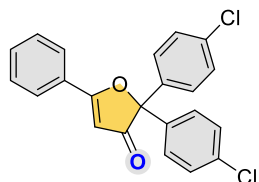


5-phenyl-2,2-di-p-tolylfuran-3(2H)-one (2ba): yellow oil; 46.3 mg; 68%; ^1H NMR (400 MHz, CDCl_3) δ ppm 7.94 (d, $J = 7.6$ Hz, 2H), 7.55 (t, $J = 7.2$ Hz, 1H), 7.49 (t, $J = 7.6$ Hz, 2H), 7.42–7.40 (m, 4H), 7.16–7.14 (m, 4H), 6.07 (s, 1H), 2.32 (s, 6H); ^{13}C NMR (151 MHz, CDCl_3) δ ppm 202.5, 184.0, 138.2, 135.6, 132.8, 129.1, 128.9, 128.8, 127.2, 126.6, 99.7, 93.1, 21.1. IR (neat, cm^{-1}): 3029, 1698, 1606, 1352, 1169, 1054, 987, 886, 767, 689; HRMS (ESI) m/z : $[\text{M}+\text{Na}]^+$ Calcd for $\text{C}_{24}\text{H}_{20}\text{NaO}_2$ 363.1356; Found 363.1354 (0.6 ppm). This product was purified by flash column chromatography (silica gel, petroleum ether/ethyl acetate, 20:1).

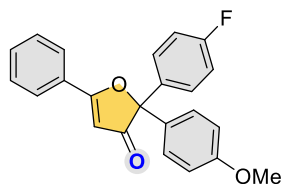


2,2-bis(4-fluorophenyl)-5-phenylfuran-3(2H)-one (2bb): white solid; melting point 137–138 °C; 64.8 mg; 93%; ^1H NMR (400 MHz, CDCl_3) δ ppm 7.96–7.94 (m, 2H), 7.61 (t, $J = 7.6$ Hz, 1H), 7.55–7.47 (m, 6H), 7.07–7.02 (m, 4H), 6.10 (s, 1H); ^{13}C NMR (151 MHz, CDCl_3) δ ppm

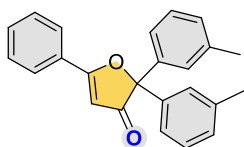
201.8, 184.2, 162.7 (d, $J^1 = 249.2$ Hz), 134.1 (d, $J^4 = 3.0$ Hz), 133.2, 129.1, 128.5 (d, $J^3 = 9.1$ Hz), 128.4, 127.3, 115.5 (d, $J^2 = 21.1$ Hz), 99.7, 91.9; ^{19}F NMR (376 MHz, CDCl_3) δ ppm -113.47--113.54 (m, 2F). IR (neat, cm^{-1}): 3070, 1698, 1605, 1352, 1185, 1054, 989, 887, 769, 688; HRMS (ESI) m/z : $[\text{M}+\text{Na}]^+$ Calcd for $\text{C}_{22}\text{H}_{14}\text{F}_2\text{NaO}_2$ 371.0854; Found 371.0847 (1.9 ppm). This product was purified by flash column chromatography (silica gel, petroleum ether/ethyl acetate, 20:1).



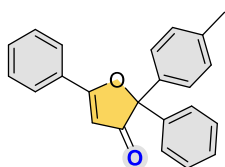
2,2-bis(4-chlorophenyl)-5-phenylfuran-3(2H)-one (2bc): yellow solid; melting point 141–142 °C; 63.3 mg; 83%; ^1H NMR (400 MHz, CDCl_3) δ ppm 7.94 (d, $J = 7.2$ Hz, 2H), 7.61 (t, $J = 7.6$ Hz, 1H), 7.55–7.51 (m, 2H), 7.47–7.45 (m, 4H), 7.34–7.32 (m, 4H), 6.10 (s, 1H); ^{13}C NMR (151 MHz, CDCl_3) δ ppm 201.1, 184.3, 136.5, 134.7, 133.3, 129.1, 128.7, 128.3, 127.9, 127.2, 99.7, 91.5. IR (neat, cm^{-1}): 3066, 1699, 1605, 1352, 1165, 1054, 988, 834, 769, 688; HRMS (ESI) m/z : $[\text{M}+\text{Na}]^+$ Calcd for $\text{C}_{22}\text{H}_{14}\text{Cl}_2\text{NaO}_2$ 403.0263; Found 403.0266 (0.7 ppm). This product was purified by flash column chromatography (silica gel, petroleum ether/ethyl acetate, 20:1).



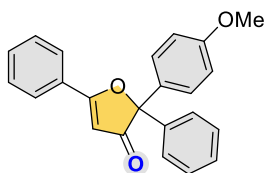
2-(4-fluorophenyl)-2-(4-methoxyphenyl)-5-phenylfuran-3(2H)-one (2bd): yellow oil; 40.4 mg; 56%; ^1H NMR (600 MHz, CDCl_3) δ ppm 7.94 (d, $J = 7.8$ Hz, 2H), 7.59 (t, $J = 8.4$ Hz, 1H), 7.53–7.49 (m, 4H), 7.41 (d, $J = 8.4$ Hz, 2H), 7.03 (t, $J = 9.0$ Hz, 2H), 6.88 (d, $J = 8.4$ Hz, 2H), 6.09 (s, 1H), 3.78 (s, 3H); ^{13}C NMR (151 MHz, CDCl_3) δ ppm 202.3, 184.1, 162.7 (d, $J^1 = 247.6$ Hz), 159.7, 134.4 (d, $J^4 = 3.0$ Hz), 133.0, 130.4, 129.0, 128.7, 128.5 (d, $J^3 = 7.6$ Hz), 128.2, 127.3, 115.3 (d, $J^2 = 21.1$ Hz), 113.9, 99.7, 92.5, 55.3; ^{19}F NMR (376 MHz, CDCl_3) δ ppm -118.70--118.75 (m, 1F). IR (neat, cm^{-1}): 3045, 1697, 1605, 1352, 1249, 1169, 887, 831, 768, 688; HRMS (ESI) m/z : $[\text{M}+\text{H}]^+$ Calcd for $\text{C}_{23}\text{H}_{18}\text{FO}_3$ 361.1234; Found 361.1228 (1.7 ppm). This product was purified by flash column chromatography (silica gel, petroleum ether/ethyl acetate, 20:1).



5-phenyl-2,2-di-m-tolylfuran-3(2H)-one (2be): yellow oil; 32.7 mg; 48%; ^1H NMR (400 MHz, CDCl_3) δ ppm 7.96 (d, $J = 4.8$ Hz, 2H), 7.60–7.57 (m, 1H), 7.52 (t, $J = 5.2$ Hz, 2H), 7.33–7.32 (m, 4H), 7.25–7.22 (m, 2H), 7.13 (d, $J = 4.8$ Hz, 2H), 6.08 (s, 1H), 2.33 (s, 6H); ^{13}C NMR (151 MHz, CDCl_3) δ ppm 202.3, 184.1, 138.4, 138.1, 132.9, 129.2, 129.0, 128.8, 128.3, 127.3, 127.2, 123.8, 99.8, 93.2, 21.6. IR (neat, cm^{-1}): 3058, 1698, 1606, 1351, 1288, 1152, 1056, 887, 767, 692; HRMS (ESI) m/z : $[\text{M}+\text{H}]^+$ Calcd for $\text{C}_{24}\text{H}_{21}\text{O}_2$ 341.1536; Found 341.1530 (1.8 ppm). This product was purified by flash column chromatography (silica gel, petroleum ether/ethyl acetate, 20:1).

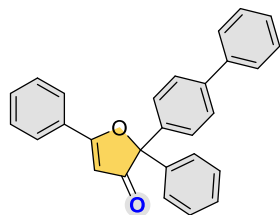


2,5-diphenyl-2-(p-tolyl)furan-3(2H)-one (2bf): colorless oil; 32.6 mg; 50%; ^1H NMR (600 MHz, CDCl_3) δ ppm 7.95 (d, $J = 7.8$ Hz, 2H), 7.58–7.49 (m, 5H), 7.41 (d, $J = 8.4$ Hz, 2H), 7.35–7.30 (m, 3H), 7.16 (d, $J = 7.8$ Hz, 2H), 6.08 (s, 1H), 2.32 (s, 3H); ^{13}C NMR (151 MHz, CDCl_3) δ ppm 202.3, 184.1, 138.5, 138.3, 135.5, 132.9, 129.1, 128.9, 128.8, 128.4, 128.3, 127.2, 126.7, 126.6, 99.8, 93.0, 21.1. IR (neat, cm^{-1}): 3060, 2919, 1697, 1606, 1352, 1171, 1054, 985, 768, 691; HRMS (ESI) m/z : $[\text{M}+\text{H}]^+$ Calcd for $\text{C}_{23}\text{H}_{19}\text{O}_2$ 327.1380; Found 327.1375 (1.5 ppm). This product was purified by flash column chromatography (silica gel, petroleum ether/ethyl acetate, 20:1).

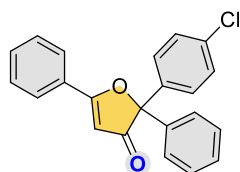


2-(4-methoxyphenyl)-2,5-diphenylfuran-3(2H)-one (2bg): yellow oil; 60.3 mg; 88%; ^1H NMR (600 MHz, CDCl_3) δ ppm 7.96–7.94 (m, 2H), 7.59–7.57 (m, 1H), 7.53–7.50 (m, 4H), 7.43 (d, $J = 9.0$ Hz, 2H), 7.36–7.30 (m, 3H), 6.88 (d, $J = 9.0$ Hz, 2H), 6.09 (s, 1H), 3.78 (s, 3H); ^{13}C NMR (151 MHz, CDCl_3) δ ppm 202.5, 184.1, 159.7, 138.5, 132.9, 130.6, 129.0, 128.8, 128.4, 128.3, 128.3, 127.3, 126.5, 113.8, 99.7, 93.0, 55.3. IR (neat, cm^{-1}): 3063, 2928, 1696, 1607, 1510, 1352, 1172, 885, 767, 691; HRMS (ESI) m/z : $[\text{M}+\text{Na}]^+$ Calcd for $\text{C}_{23}\text{H}_{18}\text{NaO}_3$ 365.1148; Found 365.1139 (2.5

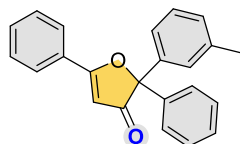
ppm). This product was purified by flash column chromatography (silica gel, petroleum ether/ethyl acetate, 20:1).



2-([1,1'-biphenyl]-4-yl)-2,5-diphenylfuran-3(2H)-one (2bh): colorless oil; 56.7 mg; 73%; ^1H NMR (400 MHz, CDCl_3) δ ppm 7.96 (d, $J = 6.8$ Hz, 2H), 7.63–7.48 (m, 11H), 7.42–7.32 (m, 6H), 6.11 (s, 1H); ^{13}C NMR (151 MHz, CDCl_3) δ ppm 202.0, 184.2, 141.3, 140.4, 138.3, 137.4, 133.0, 129.0, 128.7, 128.7, 128.5, 128.4, 127.4, 127.3, 127.2, 127.1, 127.1, 126.6, 99.8, 92.8. IR (neat, cm^{-1}): 3061, 1697, 1606, 1489, 1352, 1172, 1054, 986, 767, 654; HRMS (ESI) m/z : $[\text{M}+\text{Na}]^+$ Calcd for $\text{C}_{28}\text{H}_{20}\text{NaO}_2$ 411.1356; Found 411.1348 (1.9 ppm). This product was purified by flash column chromatography (silica gel, petroleum ether/ethyl acetate, 20:1).

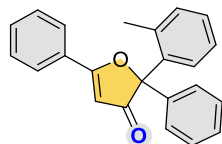


2-(4-chlorophenyl)-2,5-diphenylfuran-3(2H)-one (2bi): yellow oil; 57.6 mg; 83%; ^1H NMR (400 MHz, CDCl_3) δ ppm 7.95 (d, $J = 7.2$ Hz, 2H), 7.60 (t, $J = 7.2$ Hz, 1H), 7.55–7.48 (m, 6H), 7.35–7.31 (m, 5H), 6.10 (s, 1H); ^{13}C NMR (151 MHz, CDCl_3) δ ppm 201.6, 184.2, 138.0, 136.9, 134.5, 133.1, 129.0, 128.6, 128.6, 128.5, 128.5, 128.0, 127.2, 126.5, 99.7, 92.2. IR (neat, cm^{-1}): 3062, 1698, 1606, 1351, 1172, 1054, 987, 886, 769, 691; HRMS (ESI) m/z : $[\text{M}+\text{H}]^+$ Calcd for $\text{C}_{22}\text{H}_{16}\text{ClO}_2$ 347.0833; Found 347.0833 (0.0 ppm). This product was purified by flash column chromatography (silica gel, petroleum ether/ethyl acetate, 20:1).

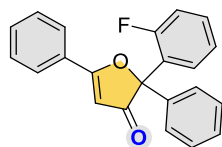


2,5-diphenyl-2-(m-tolyl)furan-3(2H)-one (2bj): yellow oil; 50.3 mg; 77%; ^1H NMR (400 MHz, CDCl_3) δ ppm 7.96 (d, $J = 7.2$ Hz, 2H), 7.60–7.50 (m, 5H), 7.37–7.30 (m, 5H), 7.24 (t, $J = 8.0$ Hz, 1H), 7.13 (d, $J = 7.6$ Hz, 1H), 6.09 (s, 1H), 2.32 (s, 3H); ^{13}C NMR (151 MHz, CDCl_3) δ ppm 202.2,

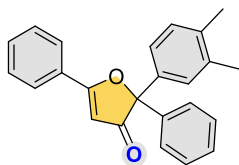
184.1, 138.4, 138.3, 138.1, 132.9, 129.2, 129.0, 128.8, 128.4, 128.3, 128.3, 127.3, 127.2, 126.6, 123.8, 99.8, 93.0, 21.5. IR (neat, cm^{-1}): 3061, 1697, 1606, 1352, 1171, 1054, 985, 885, 768, 691. HRMS (ESI) m/z : $[\text{M}+\text{H}]^+$ Calcd for $\text{C}_{23}\text{H}_{19}\text{O}_2$ 327.1380; Found 327.1375 (1.5 ppm). This product was purified by flash column chromatography (silica gel, petroleum ether/ethyl acetate, 20:1).



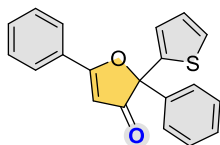
2,5-diphenyl-2-(*o*-tolyl)furan-3(2H)-one (2bk): yellow solid; melting point 171–172 °C; 55.5 mg; 85%; ^1H NMR (400 MHz, CDCl_3) δ ppm 7.94 (d, $J = 7.6$ Hz, 2H), 7.70–7.68 (m, 1H), 7.58 (t, $J = 7.6$ Hz, 1H), 7.53–7.50 (m, 2H), 7.31–7.26 (m, 6H), 7.24–7.20 (m, 2H), 6.09 (s, 1H), 2.23 (s, 3H); ^{13}C NMR (151 MHz, CDCl_3) δ ppm 202.0, 183.7, 139.1, 138.2, 135.1, 132.9, 132.5, 129.0, 128.9, 128.7, 128.5, 127.9, 127.2, 125.5, 125.3, 99.6, 94.6, 21.2. IR (neat, cm^{-1}): 3061, 1697, 1607, 1352, 1174, 1055, 983, 885, 764, 690; HRMS (ESI) m/z : $[\text{M}+\text{H}]^+$ Calcd for $\text{C}_{23}\text{H}_{19}\text{O}_2$ 327.1380; Found 327.1383 (0.9 ppm). This product was purified by flash column chromatography (silica gel, petroleum ether/ethyl acetate, 20:1).



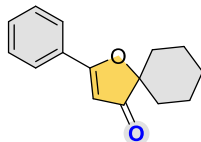
2-(2-fluorophenyl)-2,5-diphenylfuran-3(2H)-one (2bl): yellow solid; melting point 183–184 °C; 50.2 mg; 76%; ^1H NMR (600 MHz, CDCl_3) δ ppm 7.95 (d, $J = 7.2$ Hz, 2H), 7.58–7.55 (m, 3H), 7.50 (t, $J = 5.2$ Hz, 2H), 7.38–7.33 (m, 5H), 7.12–7.09 (m, 1H), 7.08–7.04 (m, 1H), 6.10 (s, 1H); ^{13}C NMR (151 MHz, CDCl_3) δ ppm 201.6, 183.9, 161.60 (d, $J^1 = 252.2$ Hz), 136.8, 132.9, 131.0 (d, $J^3 = 7.6$ Hz), 130.1 (d, $J^3 = 3.0$ Hz), 128.9, 128.7, 128.4, 128.4, 127.3, 125.7, 125.7 (d, $J^2 = 12.1$ Hz), 123.7 (d, $J^4 = 3.0$ Hz), 116.5 (d, $J^2 = 21.1$ Hz), 99.5 (d, $J^3 = 1.5$ Hz), 90.8; ^{19}F NMR (376 MHz, CDCl_3) δ ppm -113.97--114.03 (m, 1F). IR (neat, cm^{-1}): 3087, 1697, 1606, 1349, 1278, 1173, 1052, 990, 759, 684; HRMS (ESI) m/z : $[\text{M}+\text{H}]^+$ Calcd for $\text{C}_{22}\text{H}_{16}\text{FO}_2$ 331.1129; Found 331.1129 (0.0 ppm). This product was purified by flash column chromatography (silica gel, petroleum ether/ethyl acetate, 20:1).



2-(3,4-dimethylphenyl)-2,5-diphenylfuran-3(2H)-one (2bm): yellow solid; melting point 167–168 °C; 45.6 mg; 67%; ^1H NMR (400 MHz, CDCl_3) δ ppm 7.95 (d, $J = 7.2$ Hz, 2H), 7.55–7.48 (m, 5H), 7.34–7.24 (m, 5H), 7.11 (d, $J = 2.9$ Hz, 1H), 6.08 (s, 1H), 2.22 (s, 6H, two singlet peaks should be observed, however, due to the limitation of the resolution of the NMR machine, a singlet peak was identified); ^{13}C NMR (151 MHz, CDCl_3) δ ppm 202.3, 184.0, 138.5, 137.0, 136.7, 135.9, 132.8, 129.6, 128.9, 128.8, 128.3, 128.2, 127.9, 127.2, 126.5, 124.3, 99.7, 93.1, 19.9, 19.4. IR (neat, cm^{-1}): 3061, 1697, 1606, 1351, 1184, 1054, 1026, 888, 767, 692; HRMS (ESI) m/z : $[\text{M}+\text{H}]^+$ Calcd for $\text{C}_{24}\text{H}_{21}\text{O}_2$ 341.1536; Found 341.1531 (1.5 ppm). This product was purified by flash column chromatography (silica gel, petroleum ether/ethyl acetate, 20:1).

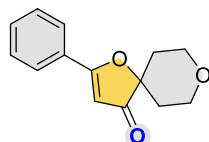


2,5-diphenyl-2-(thiophen-2-yl)furan-3(2H)-one (2bn): red solid; melting point 160–161 °C; 26.1 mg; 41%; ^1H NMR (400 MHz, CDCl_3) δ ppm 7.95 (d, $J = 7.6$ Hz, 2H), 7.61–7.57 (m, 3H), 7.54–7.50 (m, 2H), 7.38–7.32 (m, 4H), 7.23 (d, $J = 3.2$ Hz, 1H), 7.01–6.99 (m, 1H), 6.09 (s, 1H); ^{13}C NMR (151 MHz, CDCl_3) δ ppm 200.8, 184.1, 141.3, 137.8, 133.1, 129.0, 128.7, 128.6, 128.4, 127.3, 126.9, 126.7, 126.6, 125.8, 99.0, 90.5. IR (neat, cm^{-1}): 3064, 1701, 1604, 1588, 1491, 1349, 1157, 1051, 768, 694; HRMS (ESI) m/z : $[\text{M}+\text{H}]^+$ Calcd for $\text{C}_{20}\text{H}_{15}\text{O}_2\text{S}$ 319.0787; Found 319.0783 (1.3 ppm). This product was purified by flash column chromatography (silica gel, petroleum ether/ethyl acetate, 20:1).

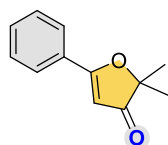


2-phenyl-1-oxaspiro[4.5]dec-2-en-4-one (2bo): colorless oil; 38.8 mg; 85%; ^1H NMR (400 MHz, CDCl_3) δ ppm 7.87–7.85 (m, 2H), 7.58–7.54 (m, 1H), 7.51–7.47 (m, 2H), 5.98 (s, 1H), 1.83–1.78 (m, 4H), 1.75–1.69 (m, 5H), 1.42–1.37 (m, 1H); ^{13}C NMR (151 MHz, CDCl_3) δ ppm 206.9, 183.4, 132.4, 129.3, 128.8, 127.1, 99.2, 90.7, 31.9, 24.5, 21.9. IR (neat, cm^{-1}): 3061, 1693,

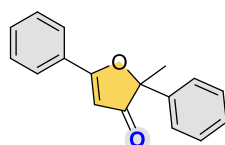
1606, 1567, 1449, 1363, 1258, 886, 771, 690; HRMS (ESI) m/z : $[M+H]^+$ Calcd for $C_{15}H_{17}O_2$ 229.1223; Found 229.1223 (0.0 ppm). This product was purified by flash column chromatography (silica gel, petroleum ether/ethyl acetate, 20:1).



2-phenyl-1,8-dioxaspiro[4.5]dec-2-en-4-one (2bp): white solid; melting point 147–148 °C; 41.9 mg; 91%; 1H NMR (400 MHz, $CDCl_3$) δ ppm 7.88–7.86 (m, 2H), 7.61–7.57 (m, 1H), 7.52 (t, $J = 7.6$ Hz, 2H), 6.03 (s, 1H), 4.09–4.05 (m, 2H), 3.91–3.85 (m, 2H), 2.17–2.10 (m, 2H), 1.62 (dd, $J = 14$ Hz 1.6 Hz, 2H); ^{13}C NMR (151 MHz, $CDCl_3$) δ ppm 204.8, 183.4, 132.8, 128.9, 128.9, 127.1, 99.5, 87.2, 63.8, 32.0. IR (neat, cm^{-1}): 3067, 1684, 1563, 1452, 1368, 1256, 1074, 1021, 886, 690; HRMS (ESI) m/z : $[M+H]^+$ Calcd for $C_{14}H_{15}O_3$ 231.1016; Found 231.1012 (1.7 ppm). This product was purified by flash column chromatography (silica gel, petroleum ether/ethyl acetate, 20:1).



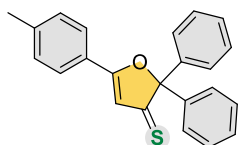
2,2-dimethyl-5-phenylfuran-3(2H)-one (2bq): yellow solid; melting point 70–72 °C; 35.8 mg; 95%; 1H NMR (600 MHz, $CDCl_3$) δ ppm 7.84 (d, $J = 7.8$ Hz, 2H), 7.56 (d, $J = 7.8$ Hz, 1H), 7.49 (d, $J = 7.8$ Hz, 2H), 5.97 (s, 1H), 1.50 (s, 6H); ^{13}C NMR (151 MHz, $CDCl_3$) δ ppm 206.9, 183.4, 132.5, 129.2, 128.8, 127.1, 98.5, 88.9, 23.1. IR (neat, cm^{-1}): 3063, 1696, 1600, 1360, 1172, 1050, 954, 855, 774, 690; HRMS (ESI) m/z : $[M+H]^+$ Calcd for $C_{12}H_{13}O_2$ 189.0910; Found 189.0910 (0.0 ppm). This product was purified by flash column chromatography (silica gel, petroleum ether/ethyl acetate, 20:1).



2-methyl-2,5-diphenylfuran-3(2H)-one (2br): colorless oil; 45.6 mg; 91%; 1H NMR (400 MHz, $CDCl_3$) δ ppm 7.93 (d, $J = 8.0$ Hz, 2H), 7.60–7.50 (m, 5H), 7.38–7.28 (m, 3H), 6.00 (s, 1H), 1.86 (s, 3H); ^{13}C NMR (151 MHz, $CDCl_3$) δ ppm 204.2, 183.8, 138.4, 132.8, 128.9, 128.8, 128.5, 128.0,

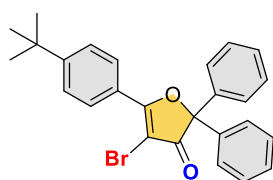
127.1, 124.5, 98.7, 90.3, 24.4. IR (neat, cm^{-1}): 3062, 1697, 1602, 1567, 1355, 1124, 1049, 862, 772, 692; HRMS (ESI) m/z : $[\text{M}+\text{H}]^+$ Calcd for $\text{C}_{17}\text{H}_{15}\text{O}_2$ 251.1067; Found 251.1063 (1.6 ppm). This product was purified by flash column chromatography (silica gel, petroleum ether/ethyl acetate, 20:1).

Characterization Data of 3ab



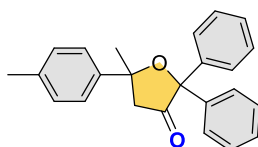
2,2-diphenyl-5-(p-tolyl)furan-3(2H)-thione (3ab): yellow solid; melting point 178–195 °C; 55.5 mg; 81%; ^1H NMR (400 MHz, CDCl_3) δ ppm 7.87 (d, J = 8.0 Hz, 2H), 7.53–7.50 (m, 4H), 7.33–7.29 (m, 8H), 6.89 (s, 1H), 2.41 (s, 3H); ^{13}C NMR (151 MHz, CDCl_3) δ ppm 229.9, 182.4, 144.7, 139.5, 130.0, 128.4, 128.1, 127.9, 127.6, 125.1, 118.4, 105.8, 21.9. IR (neat, cm^{-1}): 1610, 1556, 1498, 1376, 1316, 1180, 1062, 809, 763, 701; HRMS (ESI) m/z : $[\text{M}+\text{H}]^+$ Calcd for $\text{C}_{23}\text{H}_{19}\text{OS}$ 343.1151; Found 343.1151 (0.0 ppm). This product was purified by flash column chromatography (silica gel, petroleum ether/ethyl acetate, 20:1).

Characterization Data of 3ad



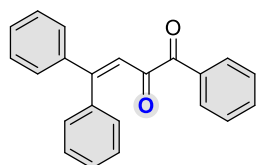
4-bromo-5-(4-(tert-butyl)phenyl)-2,2-diphenylfuran-3(2H)-one (3ad): white solid; melting point 194–195 °C; 82.3 mg; 92%; ^1H NMR (400 MHz, CDCl_3) δ ppm 8.32 (d, J = 8.4 Hz, 2H), 7.58 (d, J = 8.8 Hz, 2H), 7.55–7.53 (m, 4H), 7.37–7.30 (m, 6H), 1.37 (s, 9H); ^{13}C NMR (151 MHz, CDCl_3) δ ppm 196.5, 177.5, 157.1, 137.8, 128.6, 128.5, 128.5, 126.5, 125.8, 125.6, 93.9, 91.1, 35.3, 31.0. IR (neat, cm^{-1}): 1714, 1606, 1577, 1498, 1187, 1078, 910, 844, 765, 696; HRMS (ESI) m/z : $[\text{M}+\text{H}]^+$ Calcd for $\text{C}_{26}\text{H}_{24}\text{BrO}_2$ 447.0954; Found 447.0957 (0.7 ppm). This product was purified by flash column chromatography (silica gel, petroleum ether/ethyl acetate, 20:1).

Characterization Data of 4ab



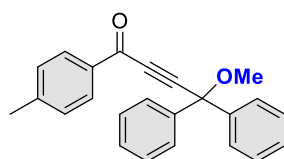
5-methyl-2,2-diphenyl-5-(p-tolyl)dihydrofuran-3(2H)-one (4ab): yellow oil; 34.9 mg; 51%; ¹H NMR (400 MHz, CDCl₃) δ ppm 7.72 (d, *J* = 7.6 Hz, 2H), 7.42–7.39 (m, 4H), 7.35 (t, *J* = 7.6 Hz, 2H), 7.28 (d, *J* = 7.2 Hz, 1H), 7.25–7.19 (m, 3H), 7.16 (d, *J* = 8.0 Hz, 2H), 3.08 (d, *J* = 17.6 Hz, 1H), 2.93 (d, *J* = 17.6 Hz, 1H), 2.34 (s, 3H), 1.53 (s, 3H); ¹³C NMR (151 MHz, CDCl₃) δ ppm 212.3, 143.6, 142.4, 142.0, 136.8, 129.0, 128.2, 128.1, 127.5, 127.4, 126.2, 126.2, 124.7, 86.7, 80.9, 49.7, 31.6, 21.0. IR (neat, cm⁻¹): 1753, 1491, 1447, 1159, 1046, 1026, 818, 754, 699, 608; HRMS (ESI) *m/z*: [M+H]⁺ Calcd for C₂₄H₂₃O₂ 343.1693; Found 343.1692 (0.3 ppm). This product was purified by flash column chromatography (silica gel, petroleum ether/ethyl acetate, 20:1).

Characterization Data of 5aa



1,4,4-triphenylbut-3-ene-1,2-dione (5aa): yellow solid; melting point 97–98 °C; 39.4 mg; 63%; ¹H NMR (400 MHz, CDCl₃) δ ppm 7.72 (d, *J* = 7.2 Hz, 2H), 7.54 (t, *J* = 7.6 Hz, 1H), 7.44–7.34 (m, 7H), 7.19–7.16 (m, 1H), 7.11–7.05 (m, 4H), 6.93 (s, 1H); ¹³C NMR (151 MHz, CDCl₃) δ ppm 194.1, 191.9, 160.1, 139.7, 137.8, 133.8, 132.7, 130.5, 130.4, 129.7, 129.2, 128.8, 128.5, 128.2, 128.0, 123.4. IR (neat, cm⁻¹): 2920, 2850, 1675, 1639, 1444, 1172, 959, 745, 697; HRMS (ESI) *m/z*: [M+H]⁺ Calcd for C₂₂H₁₇O₂ 313.1223; Found 313.1223 (0.0 ppm). This product was purified by flash column chromatography (silica gel, petroleum ether/ethyl acetate, 50:1).

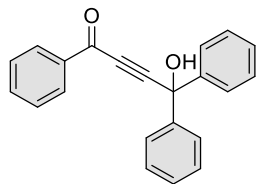
Characterization Data of 1ab-OMe



4-methoxy-4,4-diphenyl-1-(p-tolyl)but-2-yn-1-one (1ab-OMe): yellow oil; ¹H NMR (400 MHz, CDCl₃) δ ppm 8.02 (d, *J* = 8.0 Hz, 2H), 7.59–7.57 (m, 4H), 7.37–7.33 (m, 4H), 7.31–7.26 (m, 4H), 3.44 (s, 3H), 2.41 (s, 3H); ¹³C NMR (151 MHz, CDCl₃) δ ppm 177.0, 145.5, 141.9, 134.4, 129.6, 129.4, 128.4, 128.1, 126.7, 92.1, 86.9, 81.2, 53.1, 21.8. IR (neat, cm⁻¹): 2929, 2218, 1645, 1620, 1448, 1264, 1175, 1072, 734, 698; HRMS (ESI) *m/z*: [M+H]⁺ Calcd for C₂₄H₂₁O₂ 341.1536; Found 341.1537 (0.3 ppm). This product was purified by flash column chromatography (silica

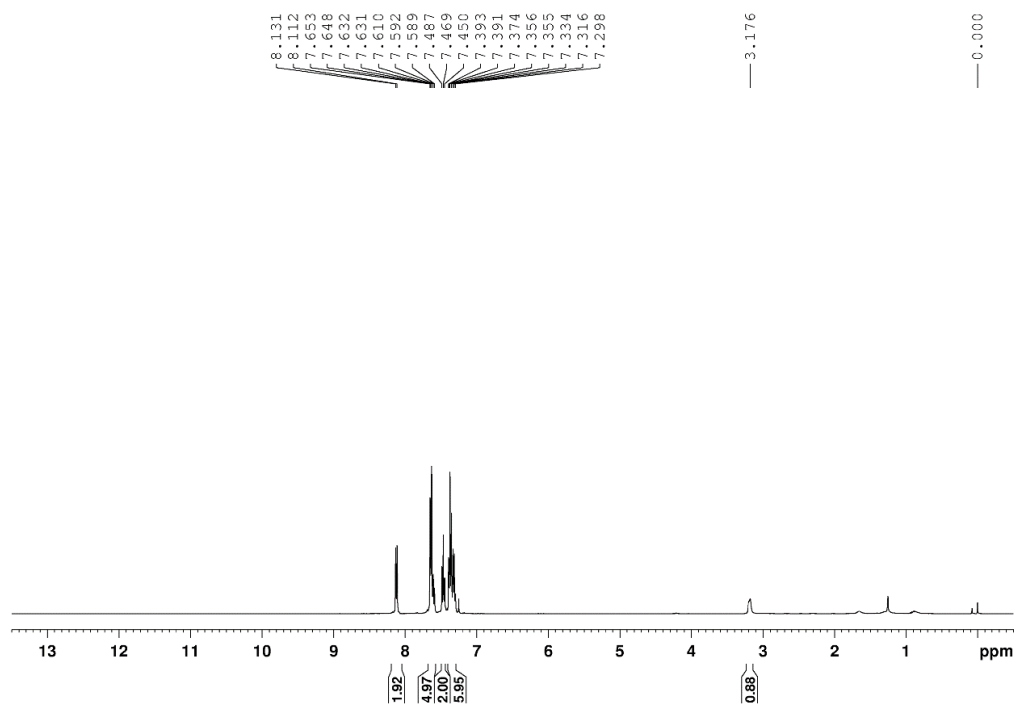
gel, petroleum ether/ethyl acetate, 30:1).

^1H , ^{13}C , and ^{19}F NMR Spectra

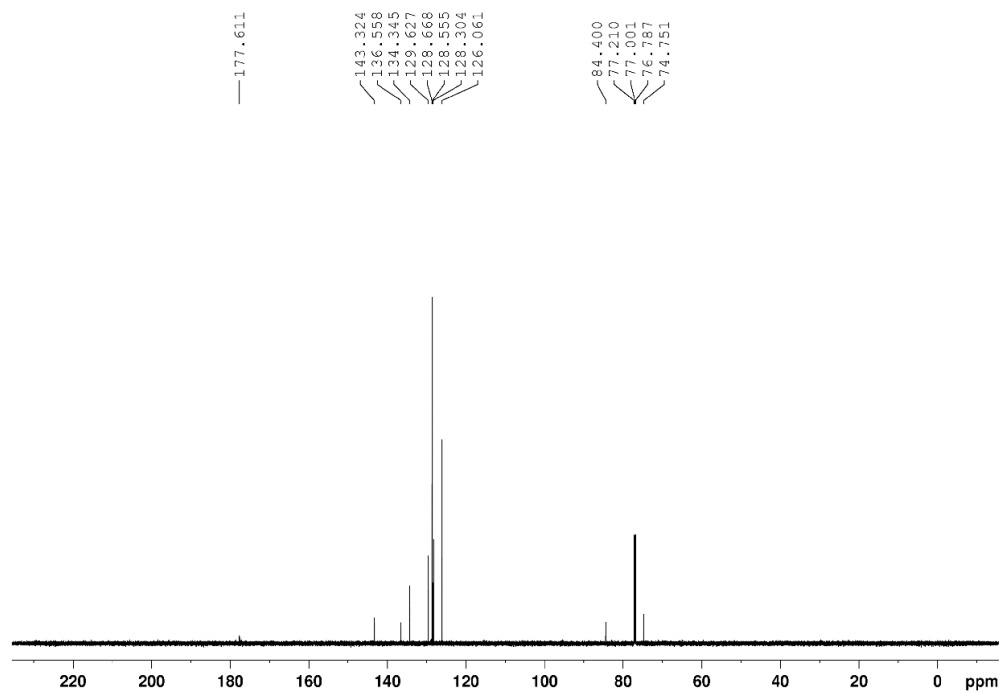


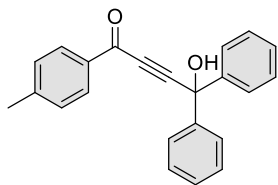
1aa

^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .



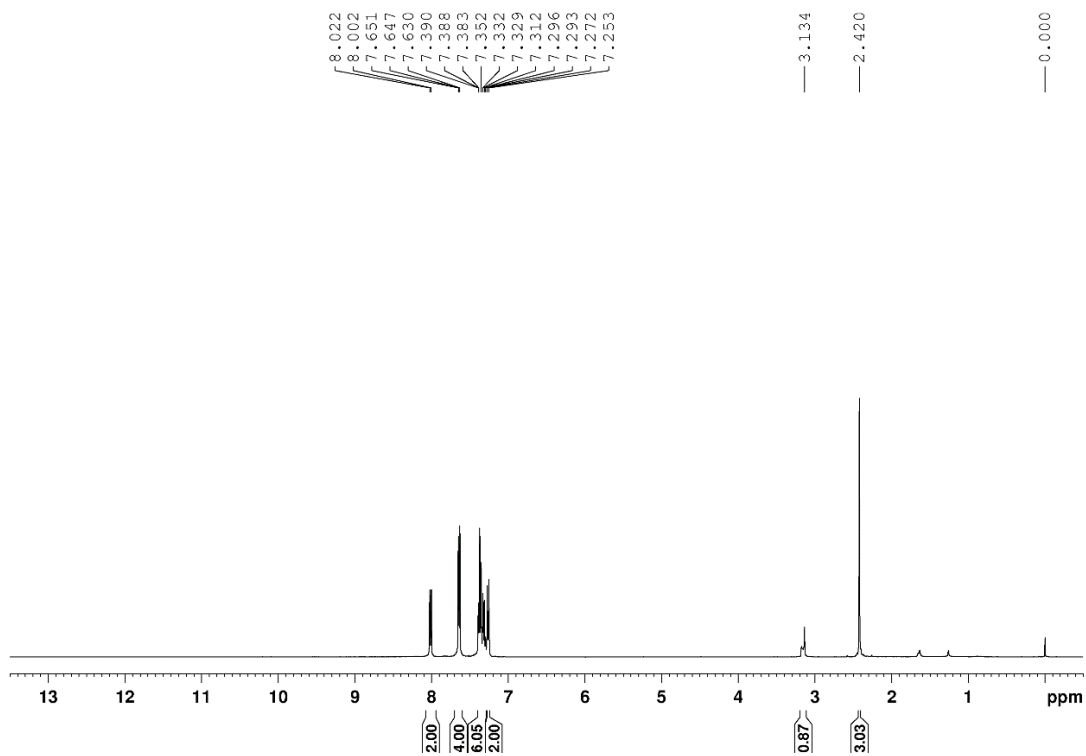
$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



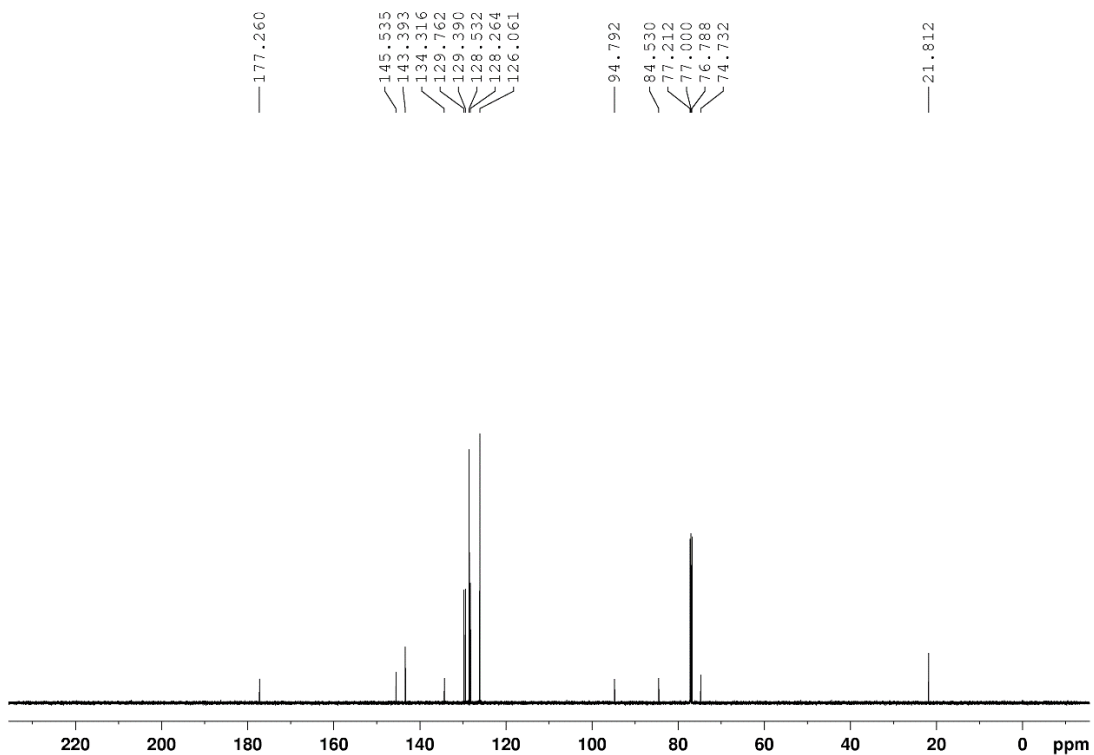


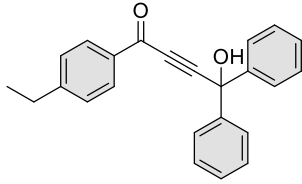
1ab

^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .



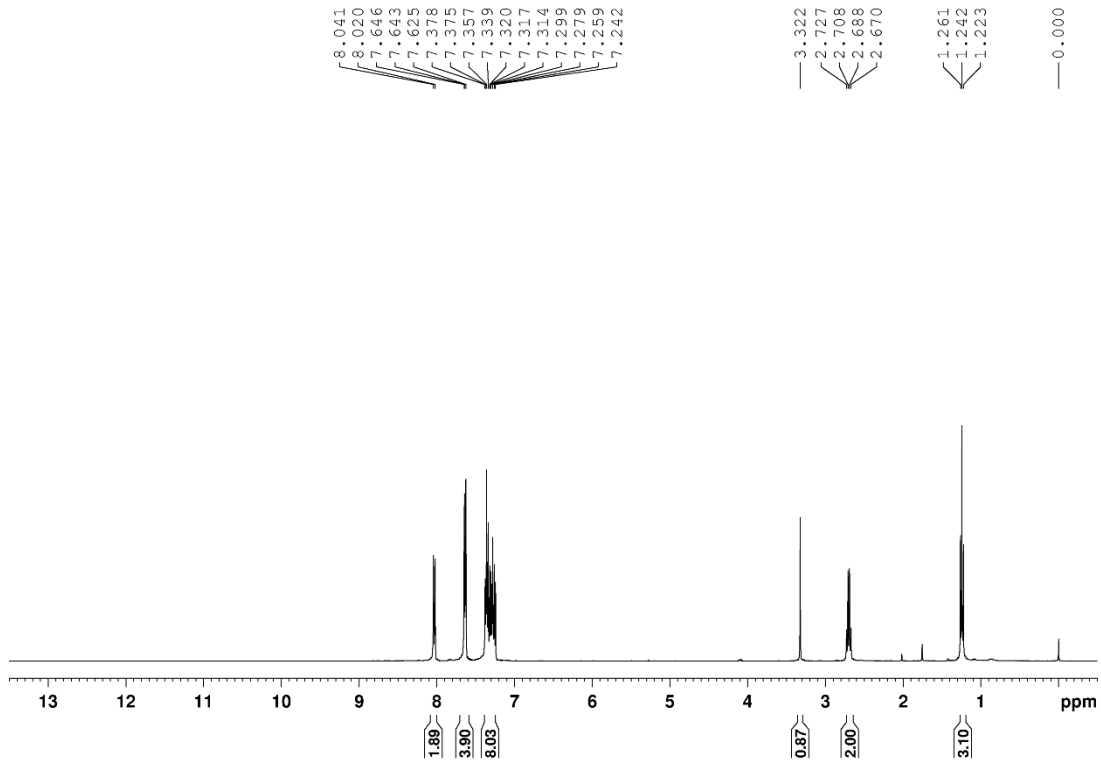
$^{13}\text{C}\{\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



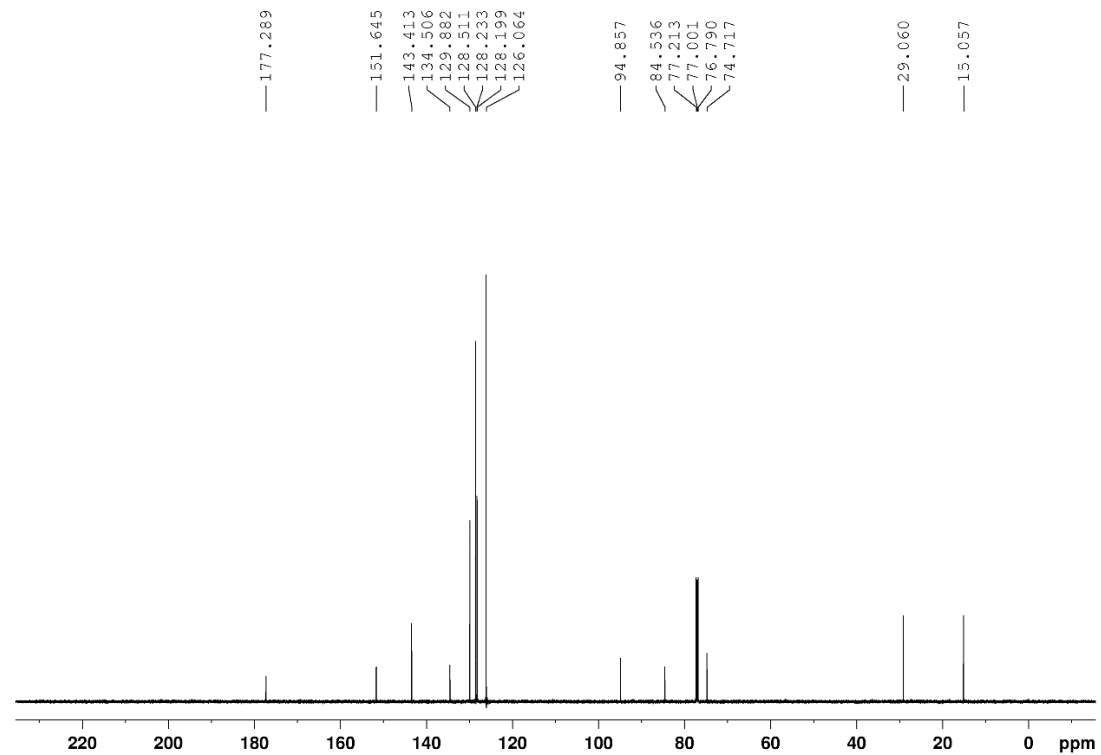


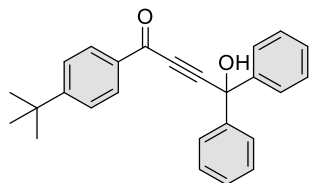
1ac

^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .



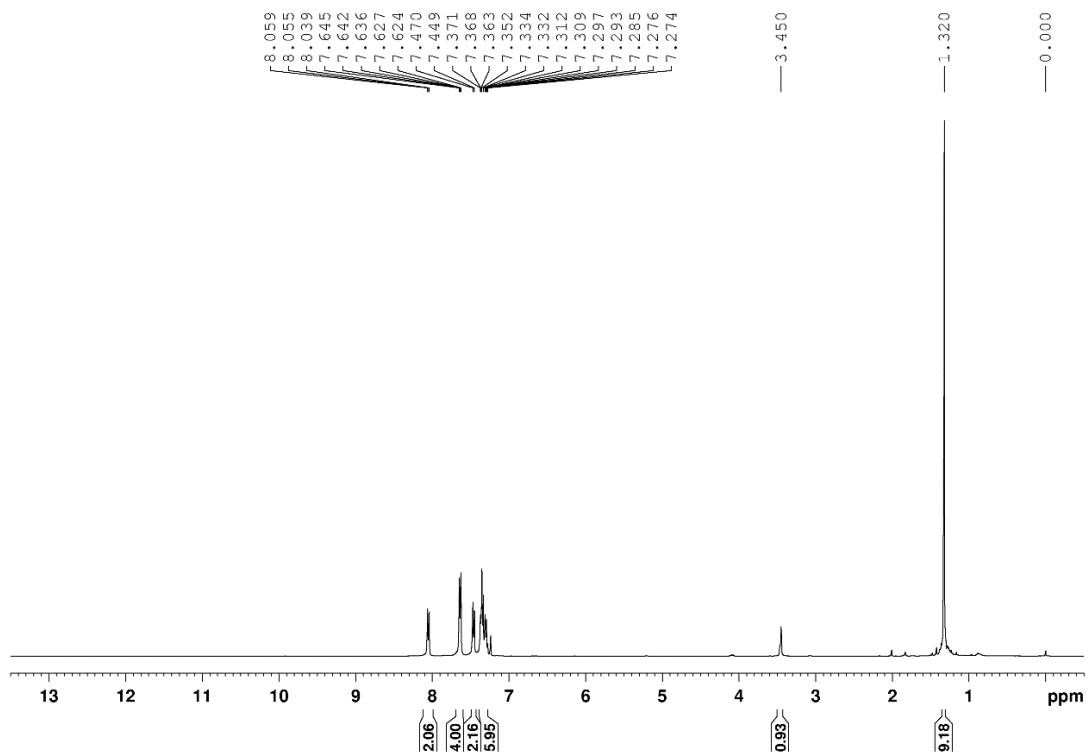
$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



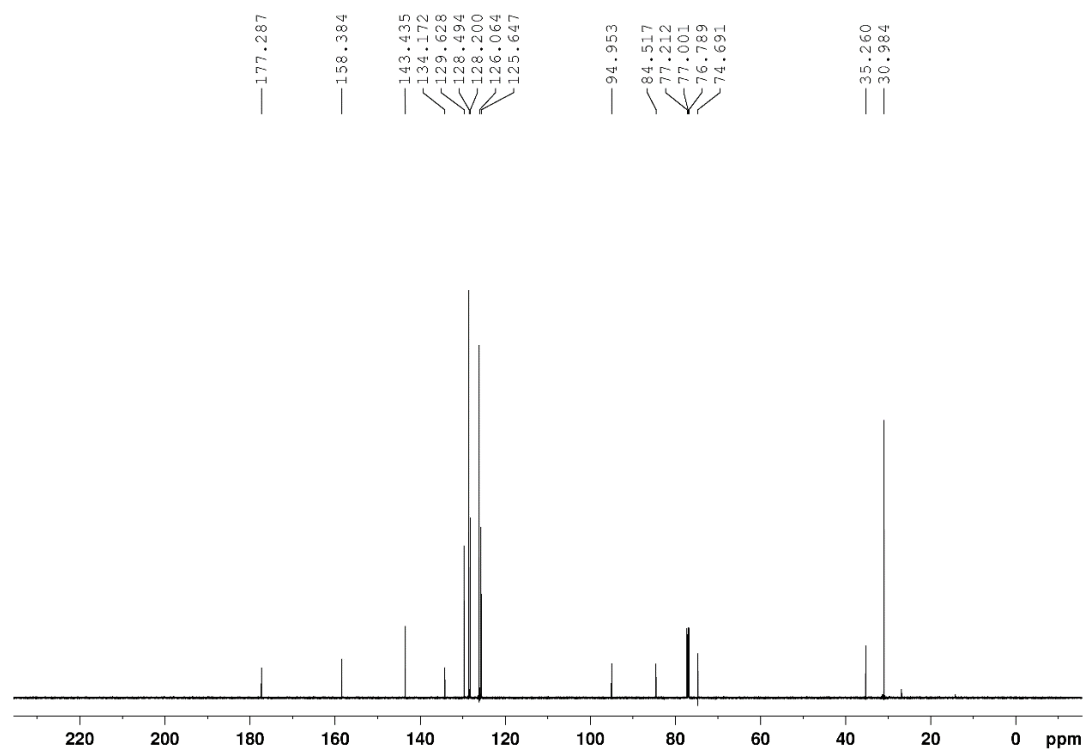


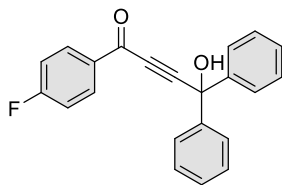
1ad

¹H NMR spectrum was recorded on 400 MHz in CDCl₃.



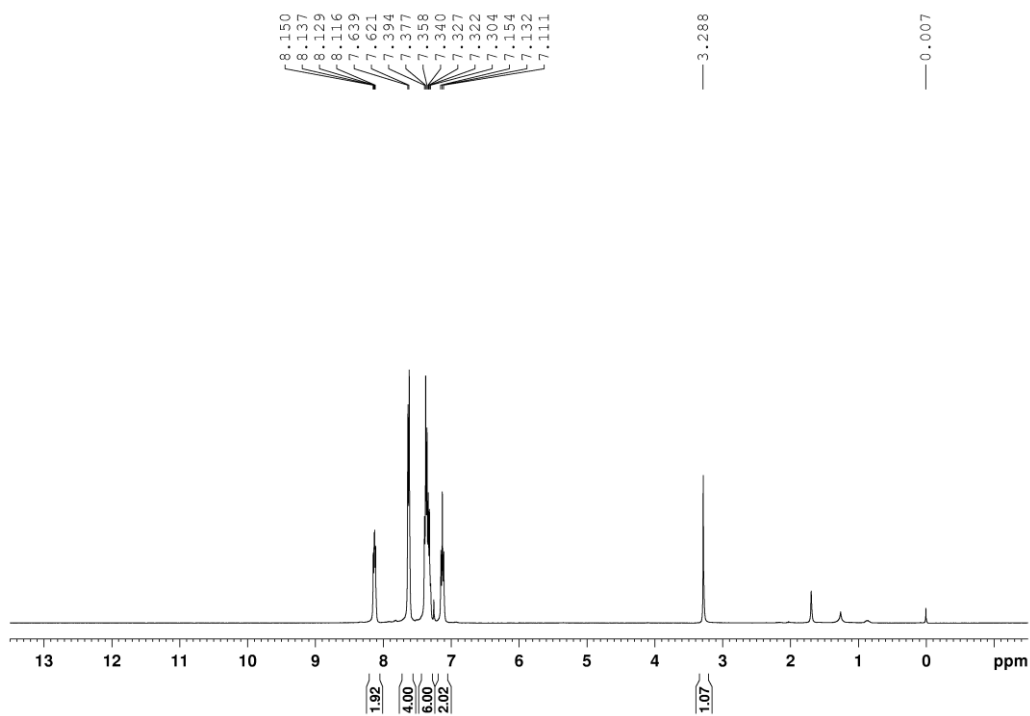
¹³C{¹H} NMR spectrum was recorded on 151 MHz in CDCl₃.



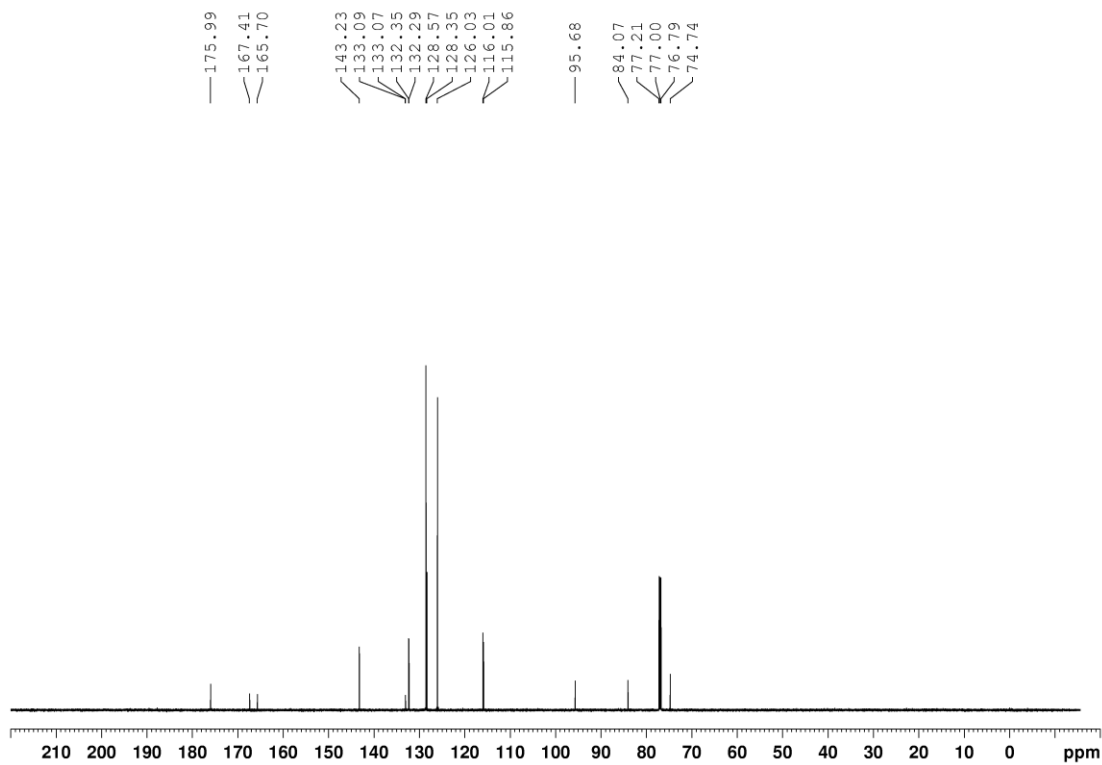


1ae

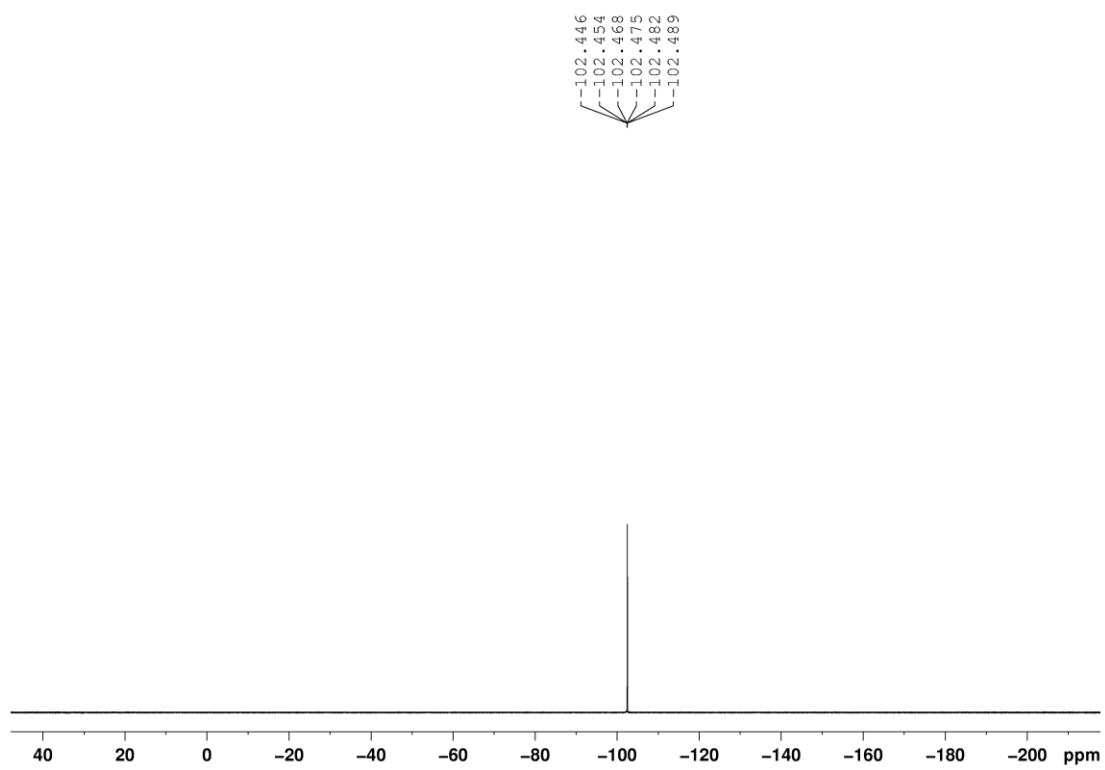
^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .

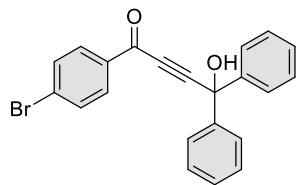


$^{13}\text{C}\{\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



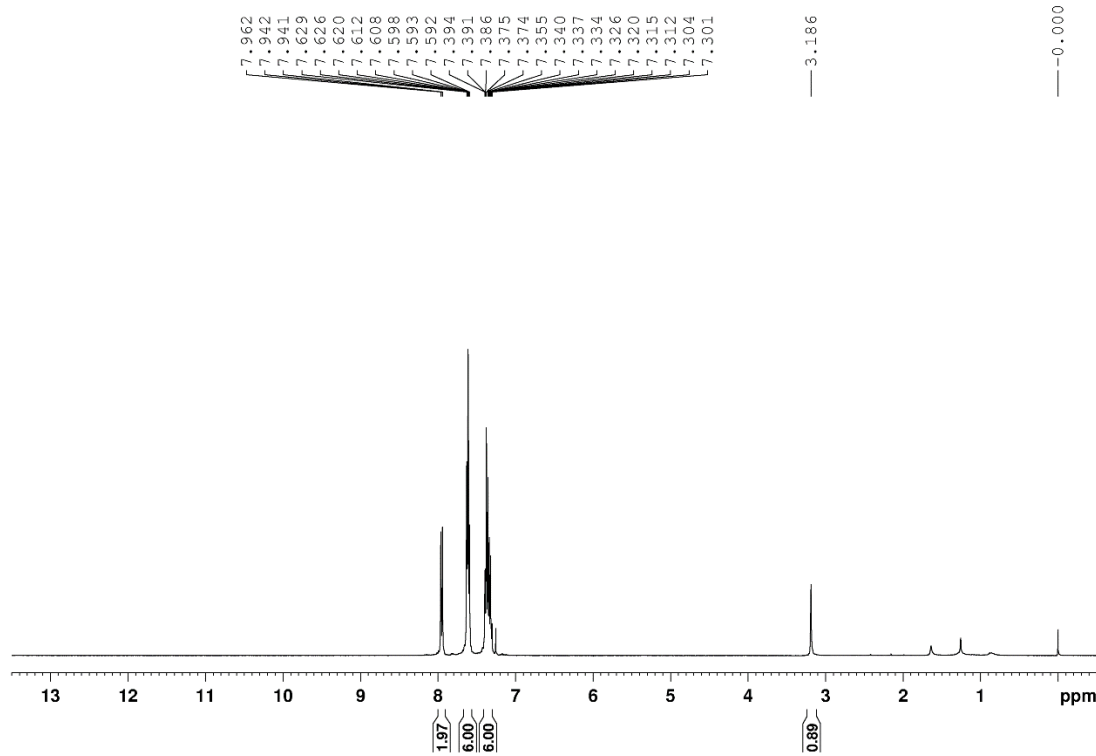
¹⁹F spectrum was recorded on 376 MHz in CDCl₃.



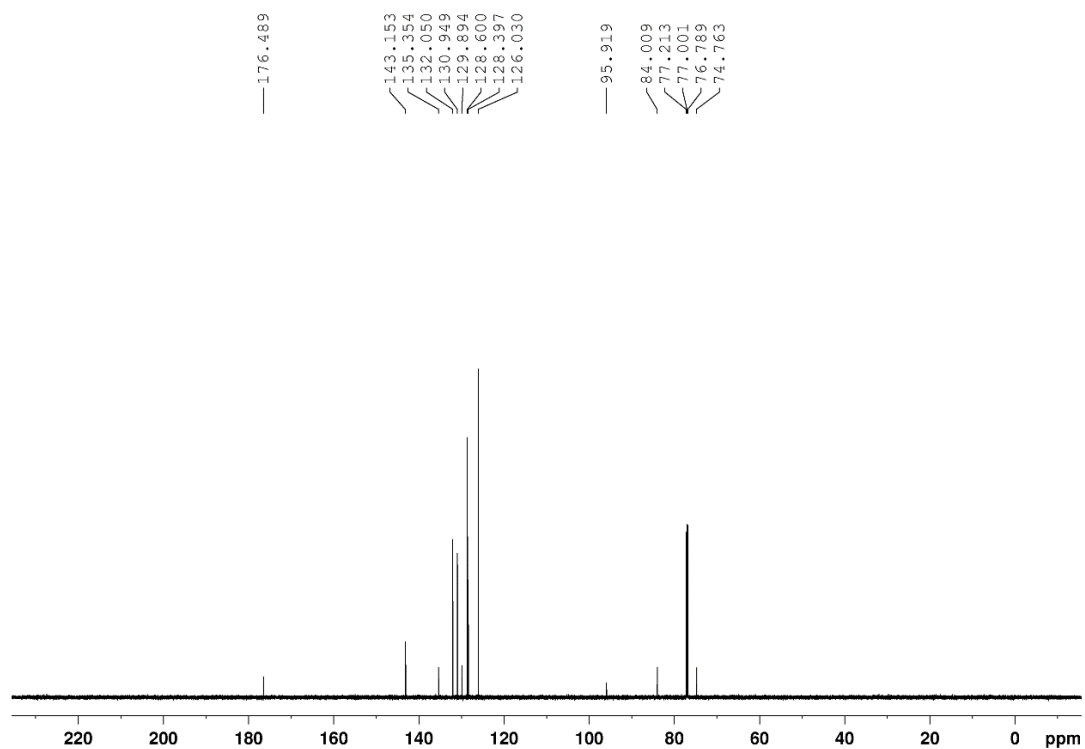


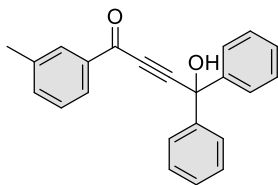
1af

^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .



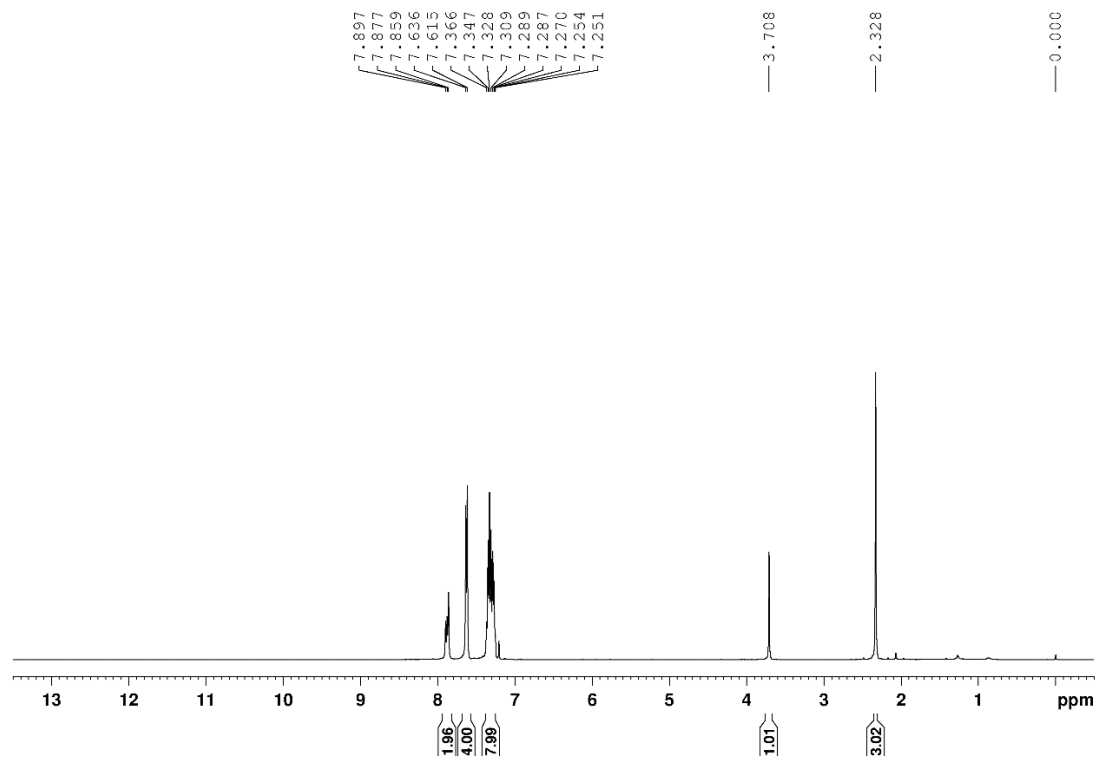
$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



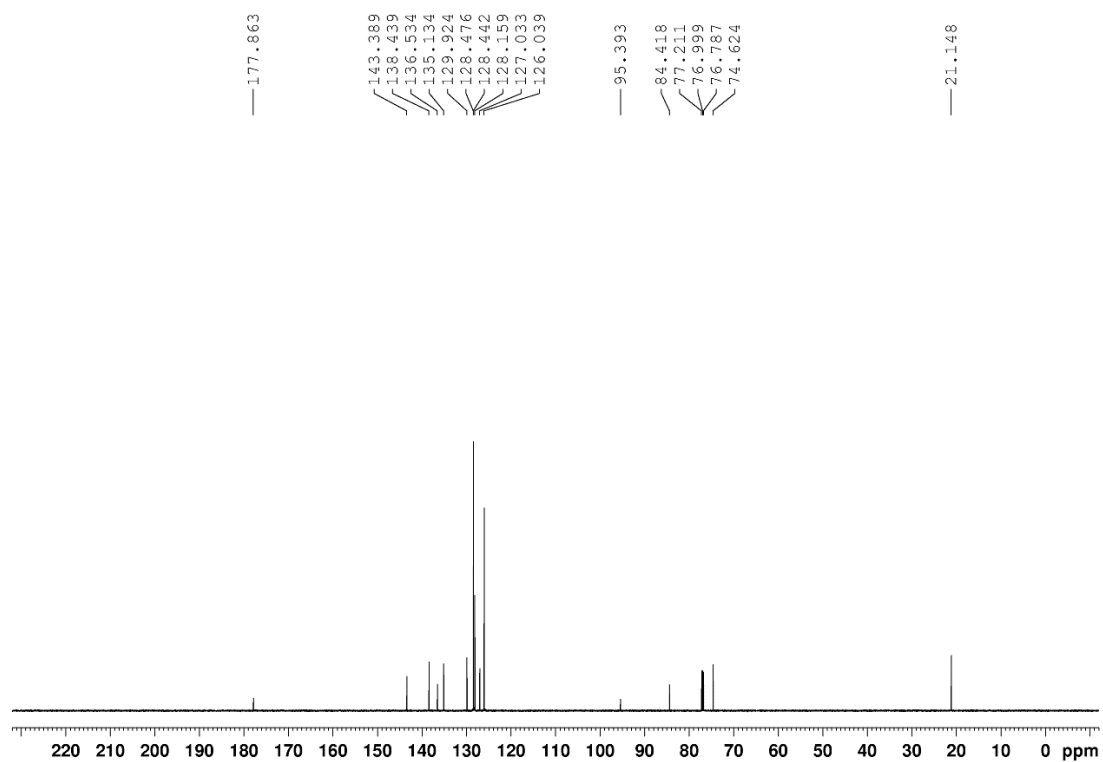


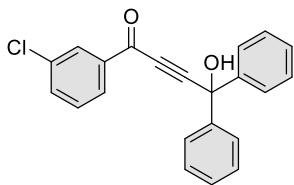
1ag

^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .



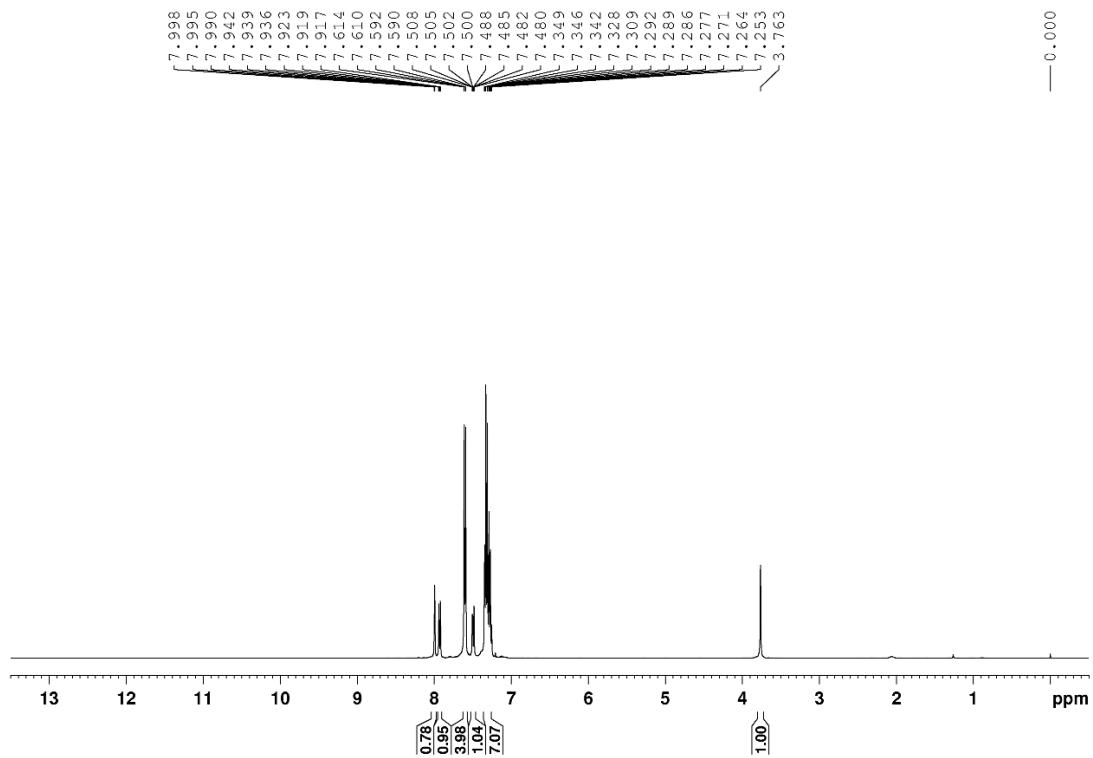
$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .





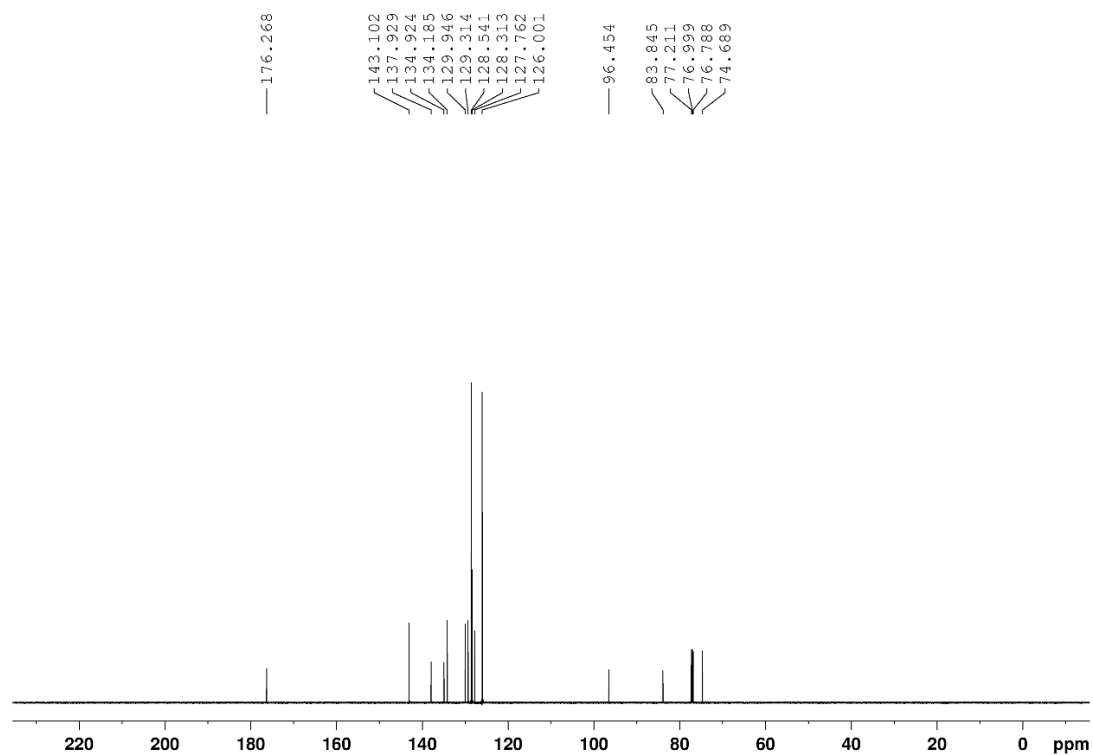
1ah

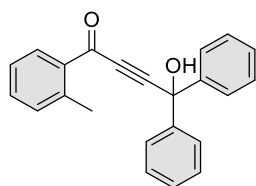
¹H NMR spectrum was recorded on 400 MHz in CDCl₃.



— 0.000

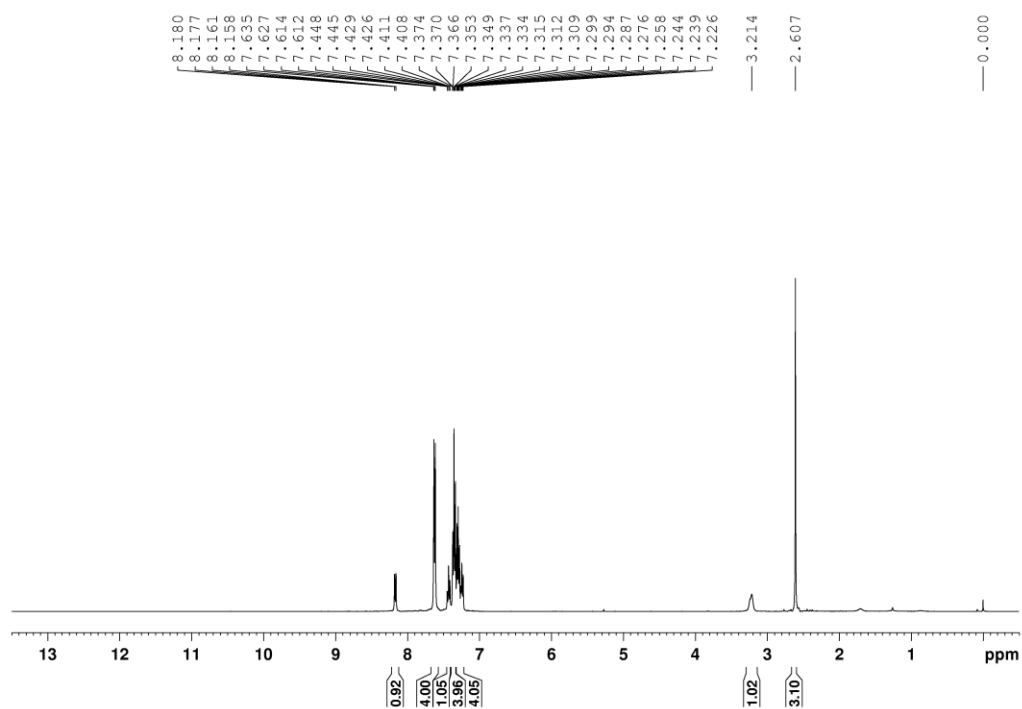
¹³C{H} NMR spectrum was recorded on 151 MHz in CDCl₃.



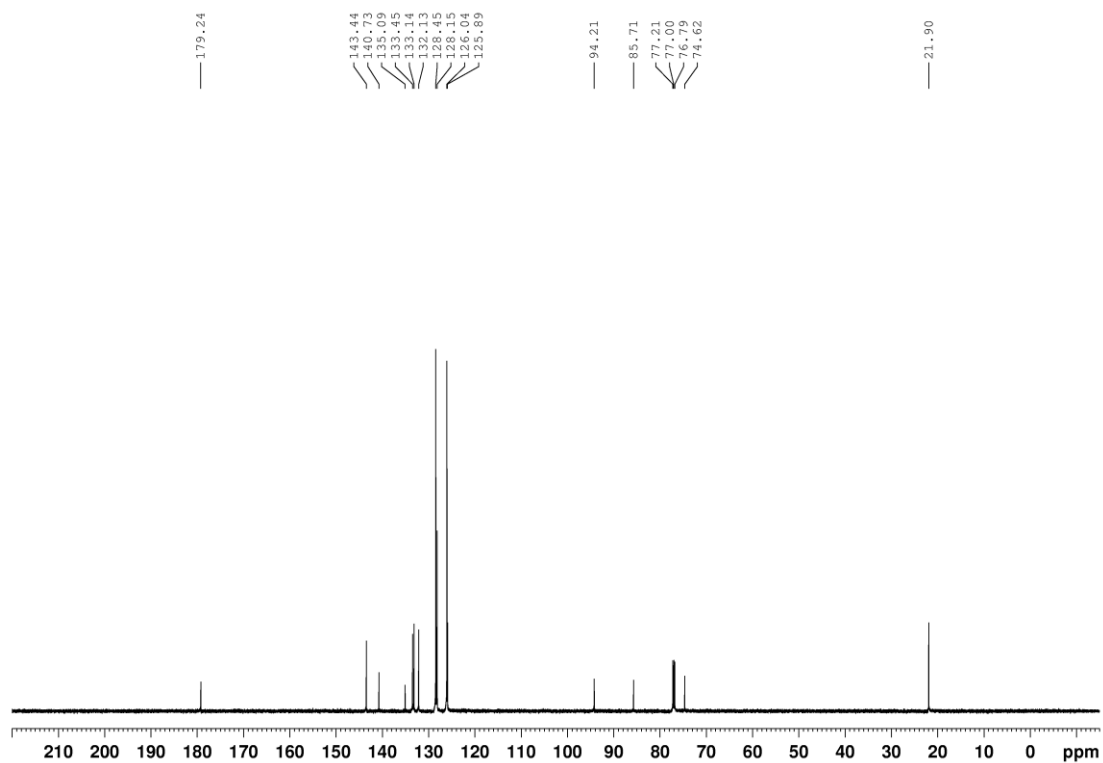


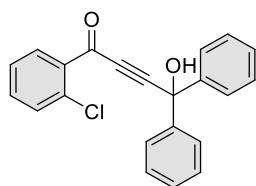
1ai

^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .



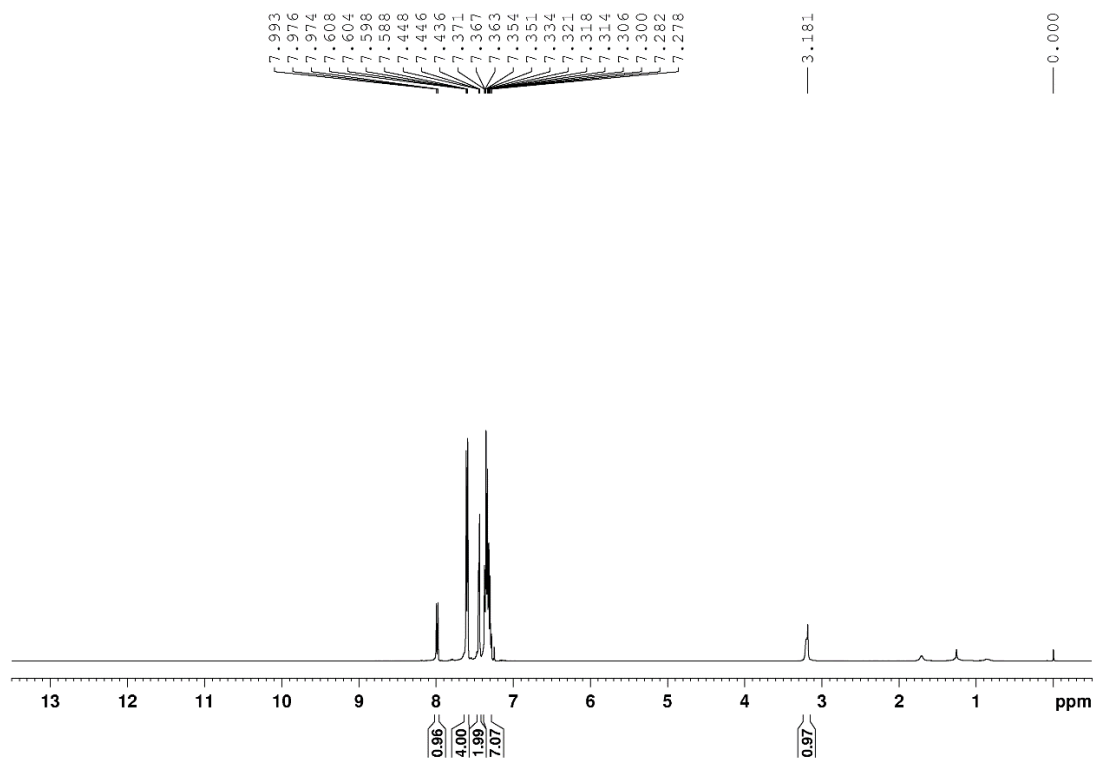
$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



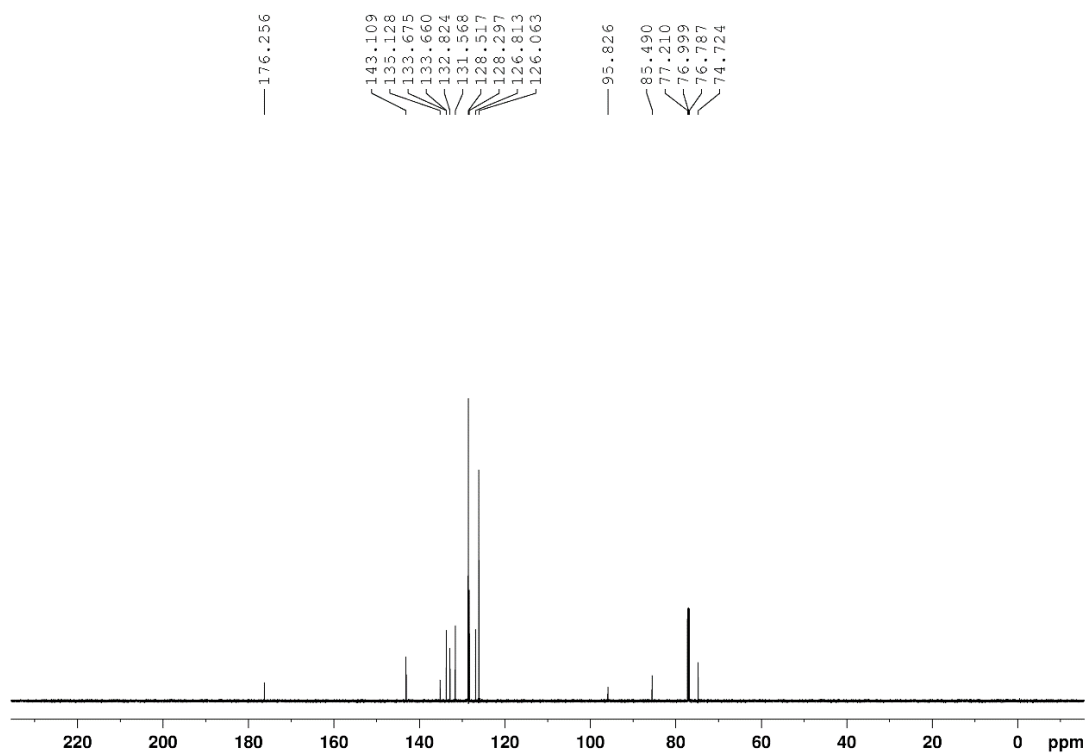


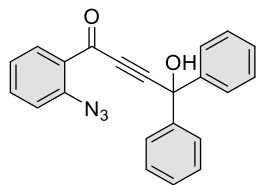
1aj

^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .



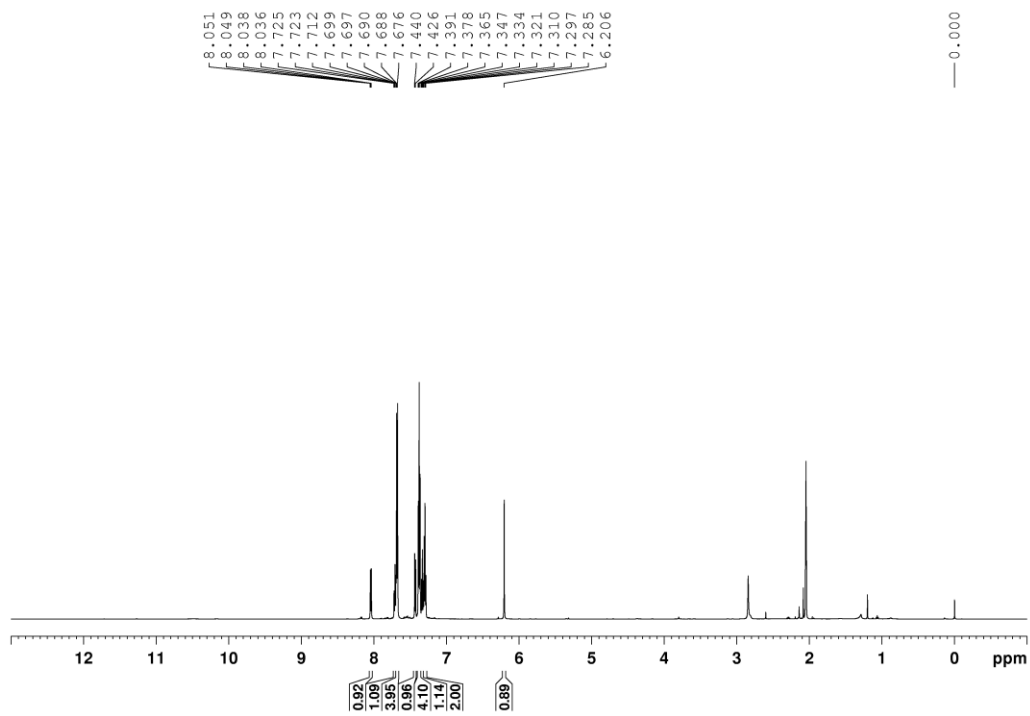
$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



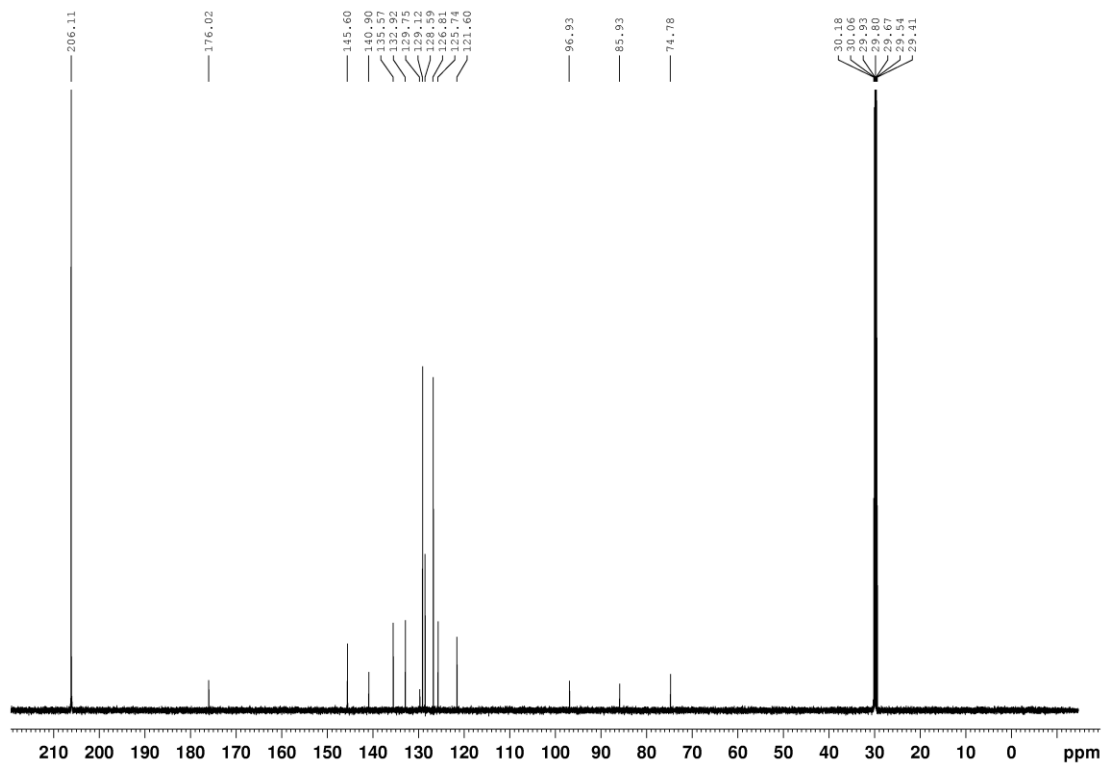


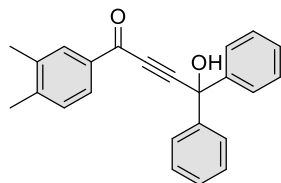
1ak

¹H NMR spectrum was recorded on 600 MHz in d₆-acetone.



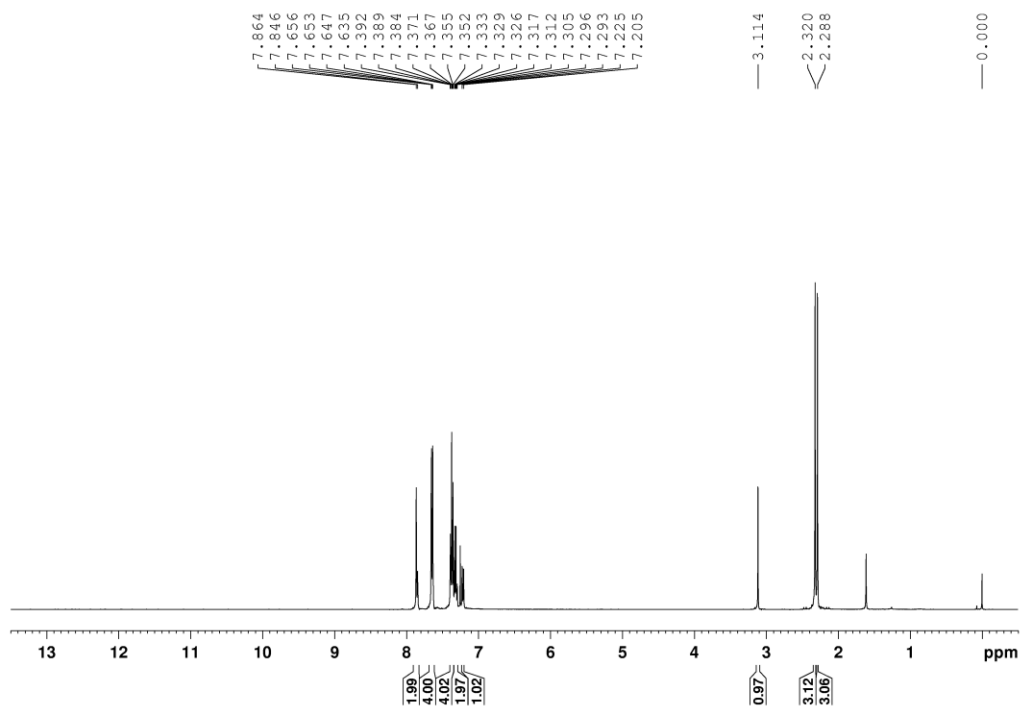
¹³C{¹H} NMR spectrum was recorded on 151 MHz in d₆-acetone



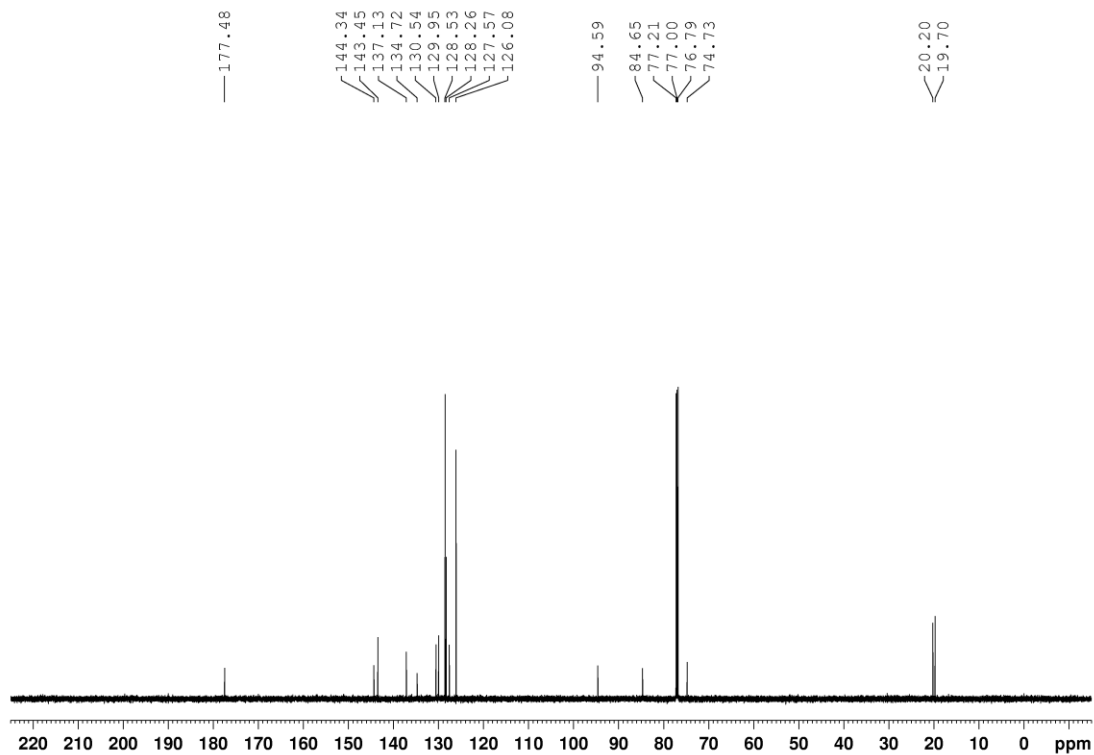


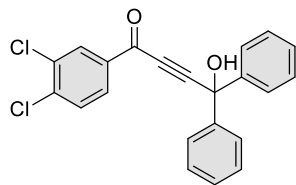
1a

^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .



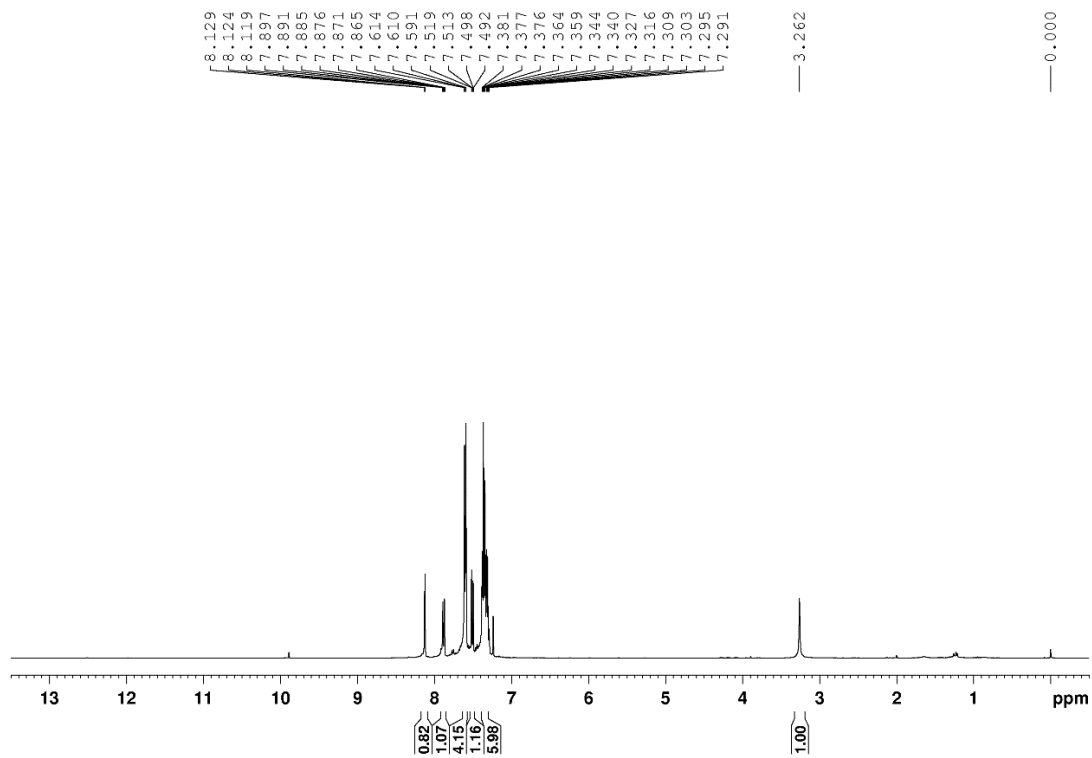
$^{13}\text{C}\{\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



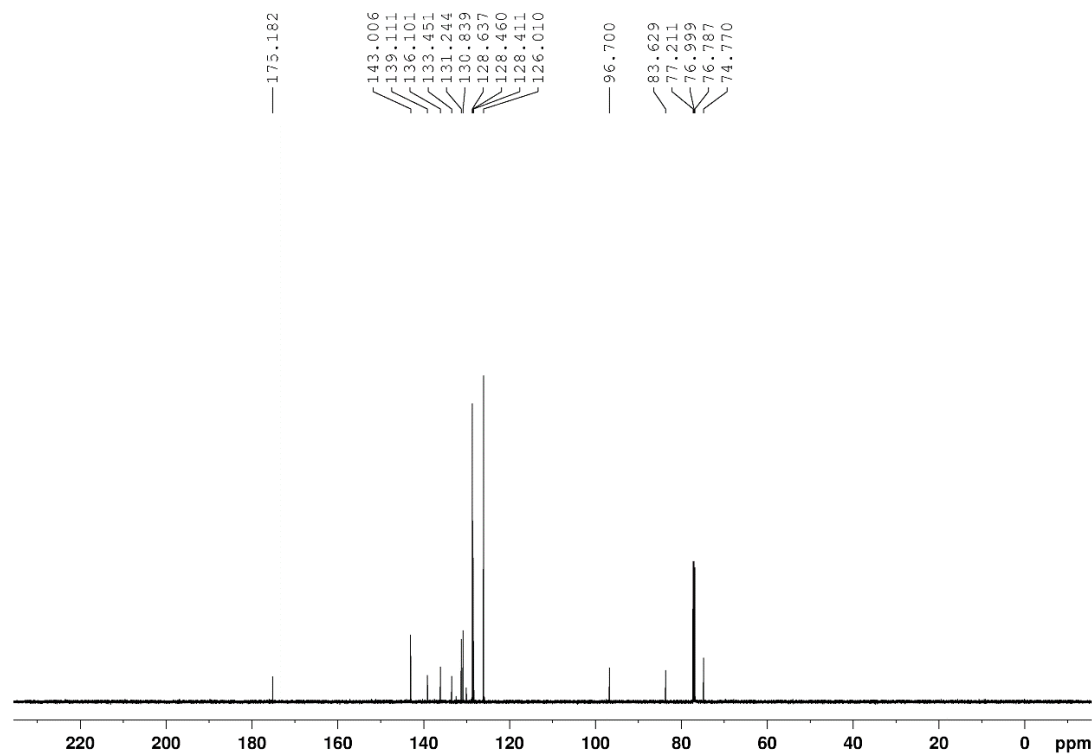


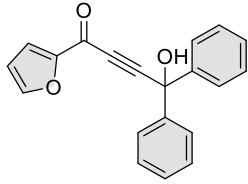
1am

¹H NMR spectrum was recorded on 400 MHz in CDCl₃.



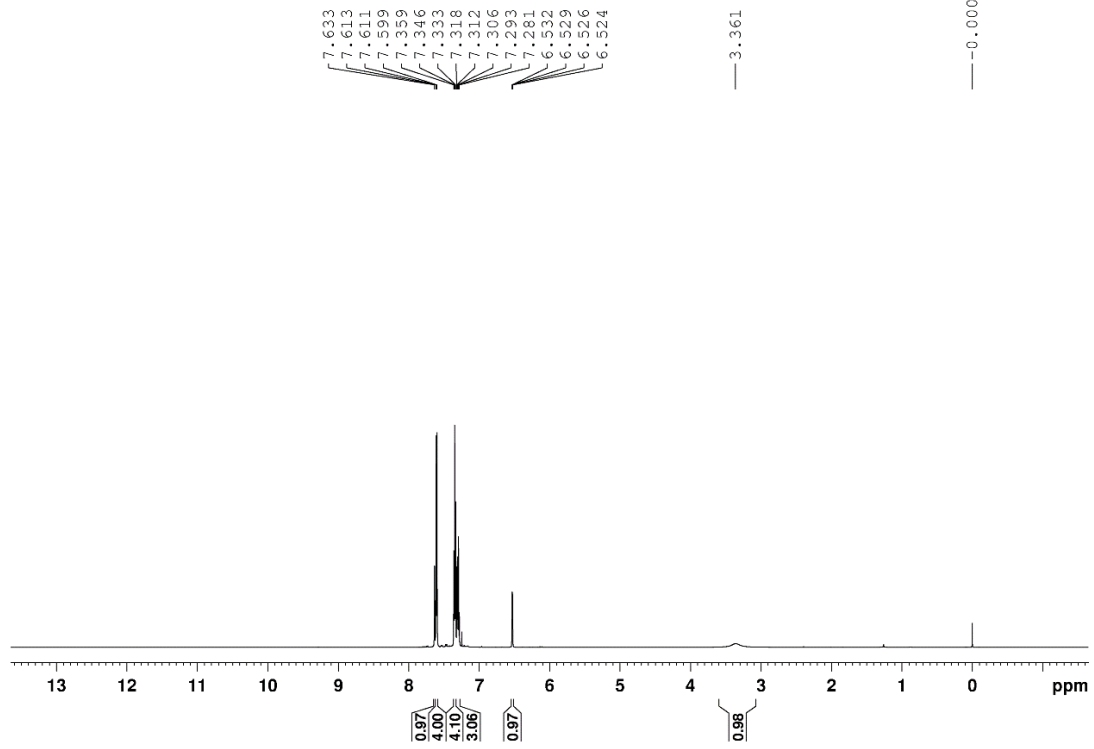
¹³C{¹H} NMR spectrum was recorded on 151 MHz in CDCl₃.



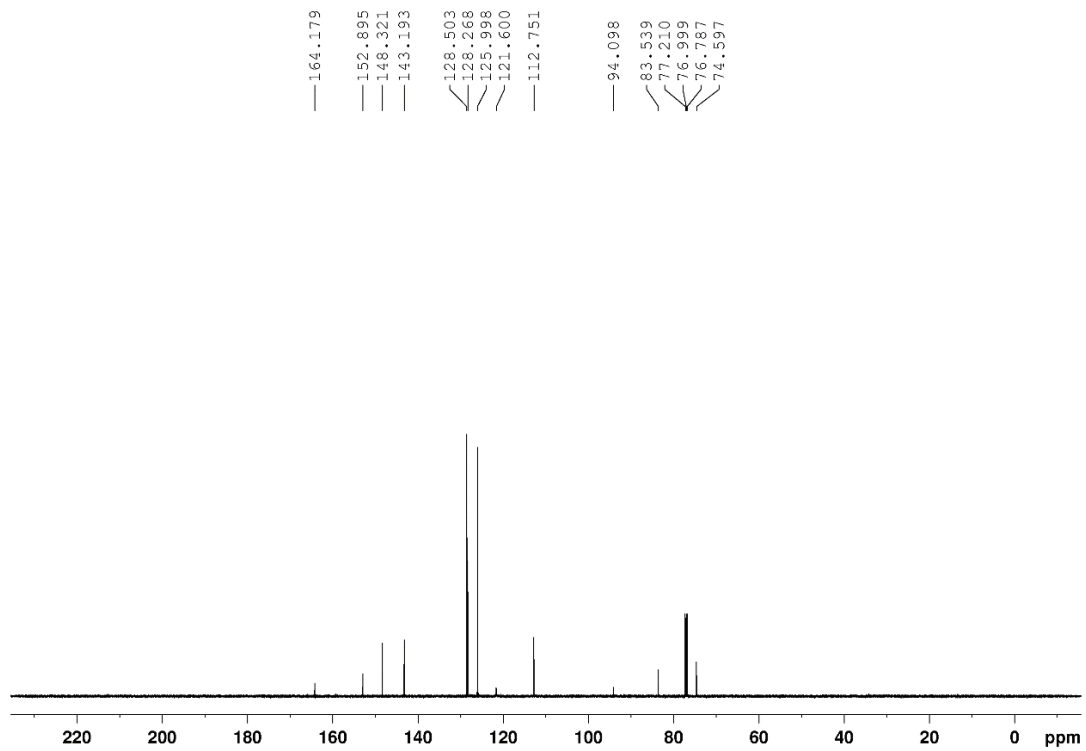


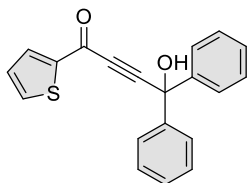
1an

^1H NMR spectrum was recorded on 600 MHz in CDCl_3 .



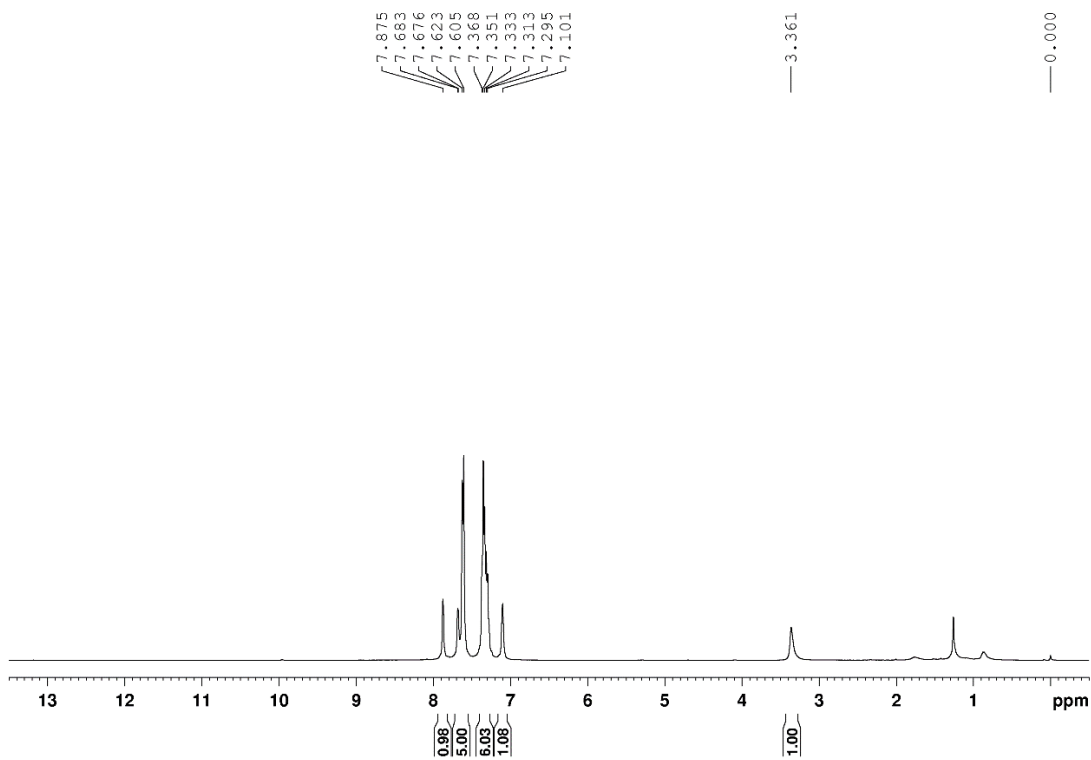
$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



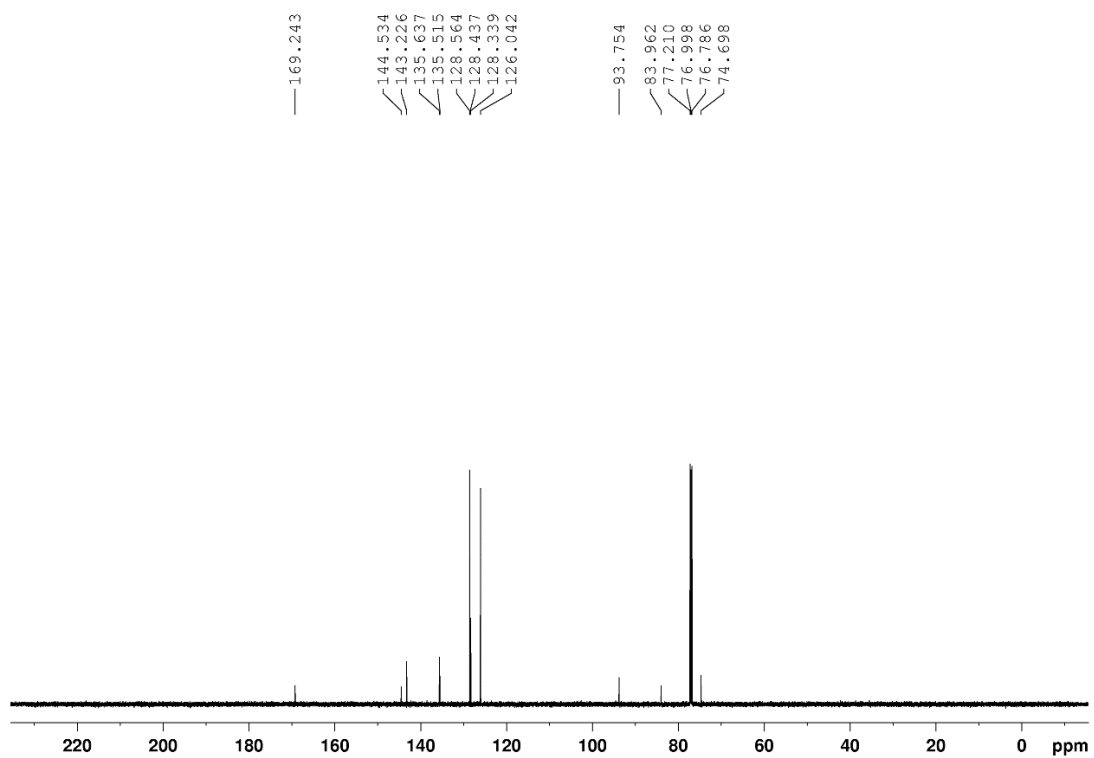


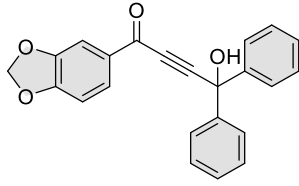
1ao

^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .



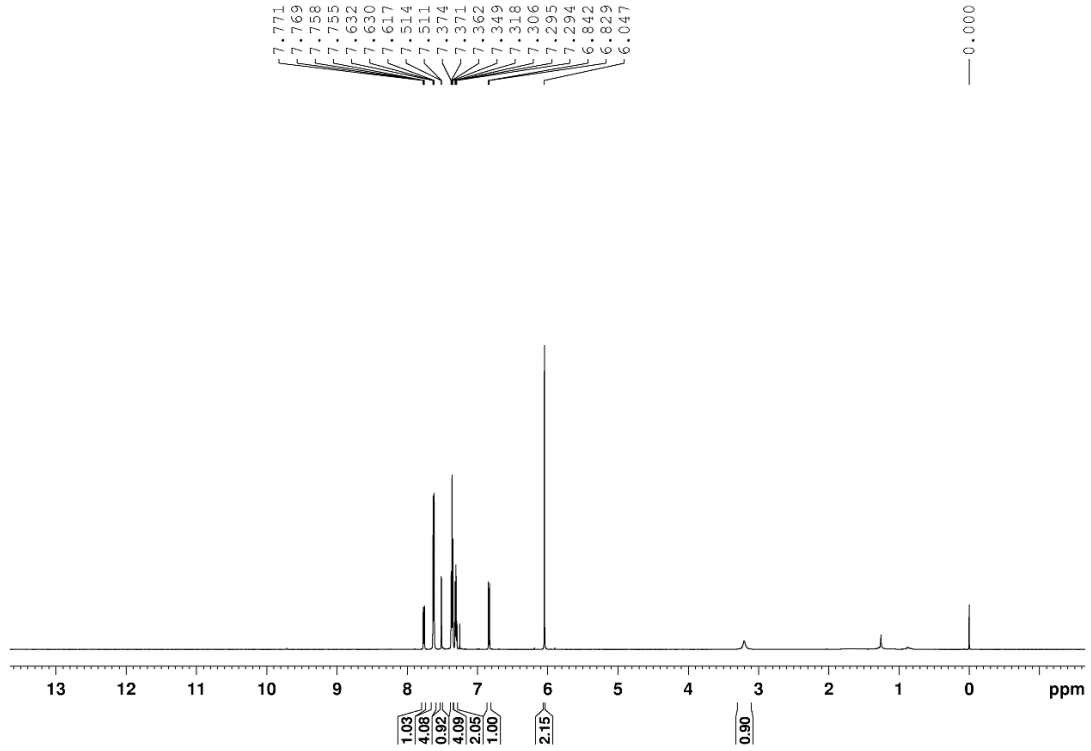
$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



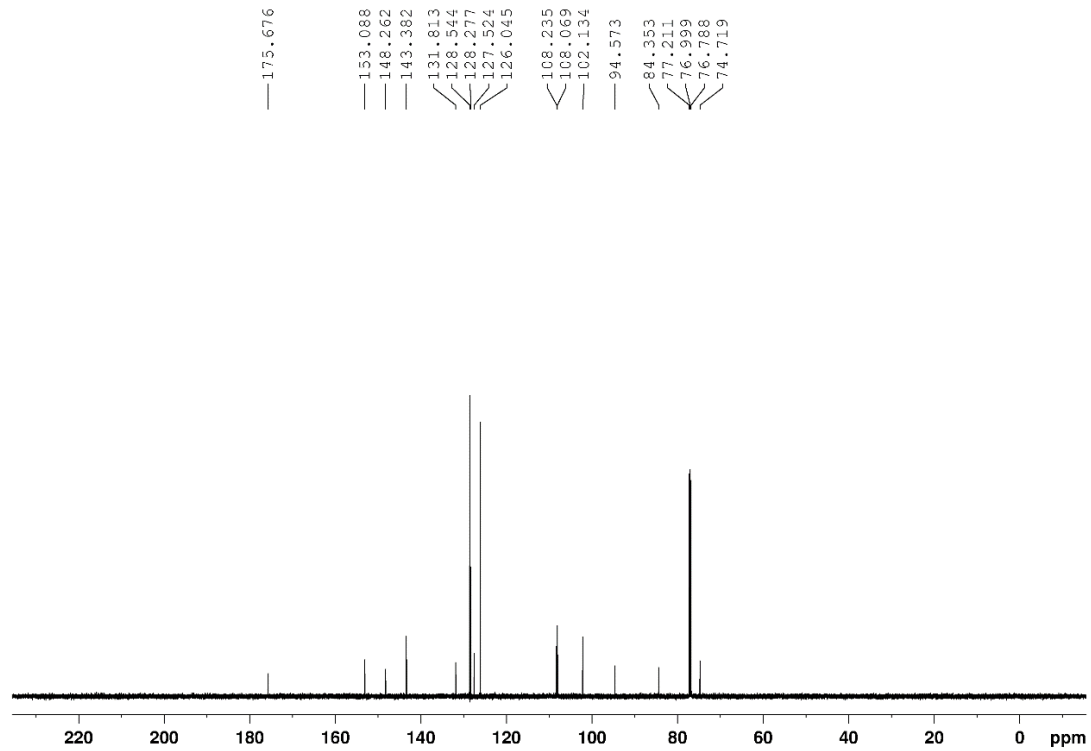


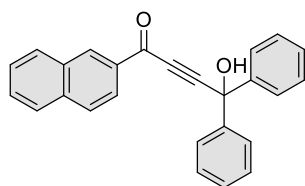
1ap

¹H NMR spectrum was recorded on 600 MHz in CDCl₃.



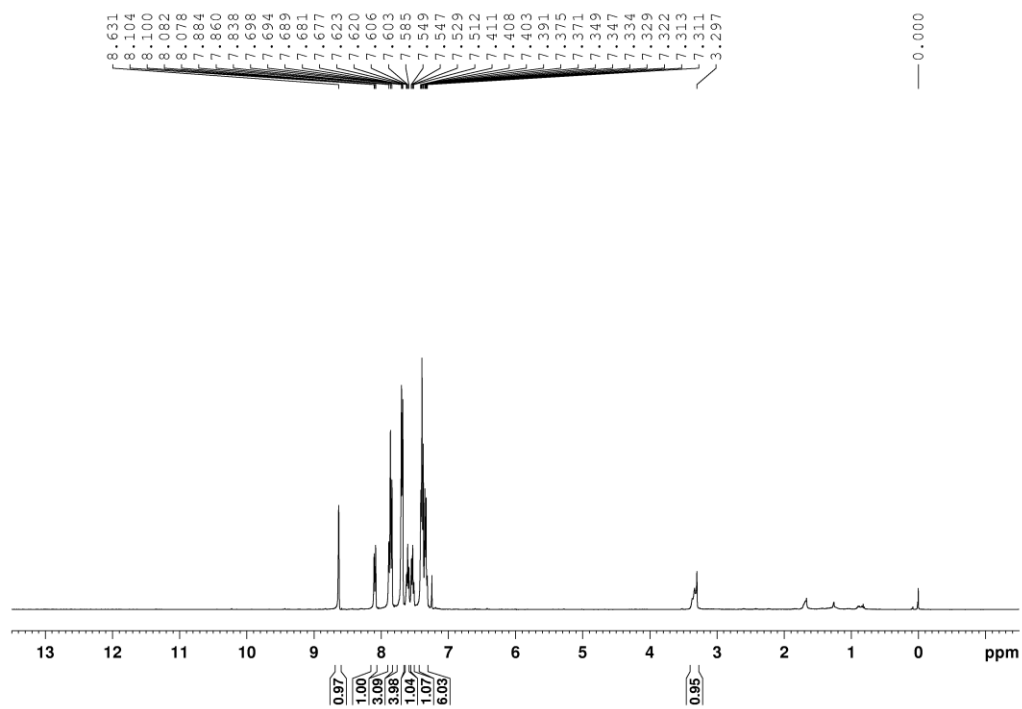
¹³C{¹H} NMR spectrum was recorded on 151 MHz in CDCl₃.



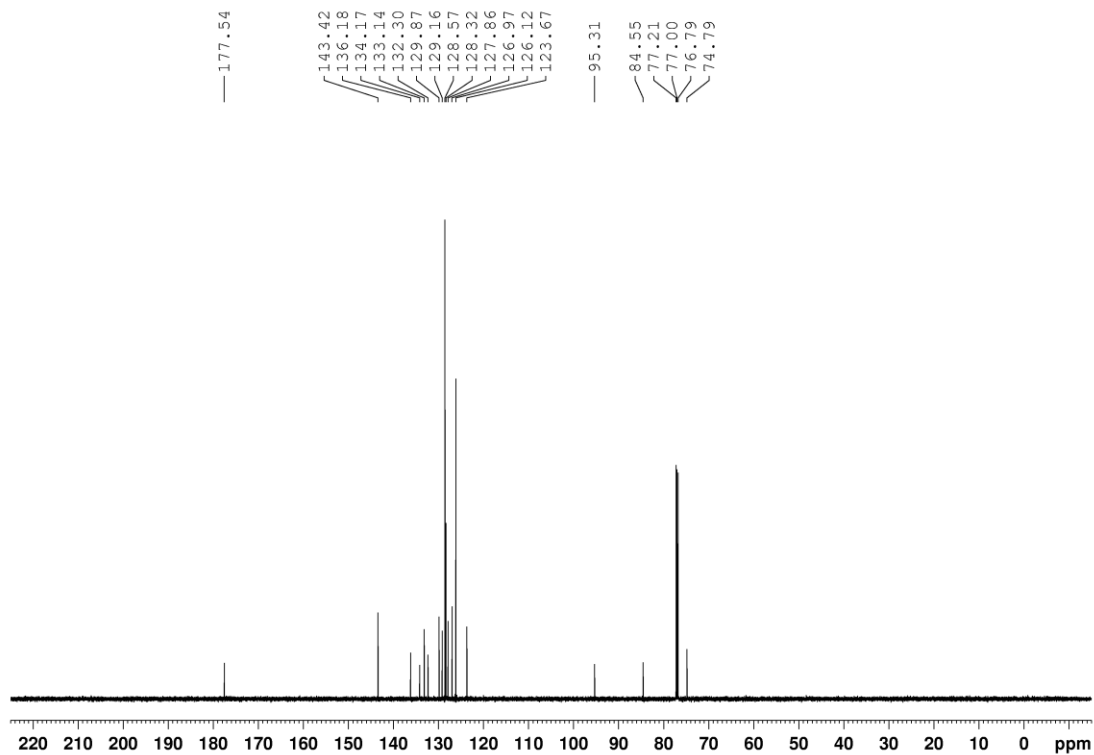


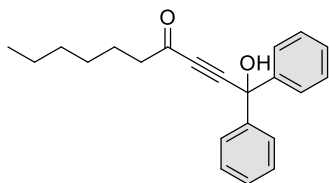
1aq

¹H NMR spectrum was recorded on 400 MHz in CDCl₃.



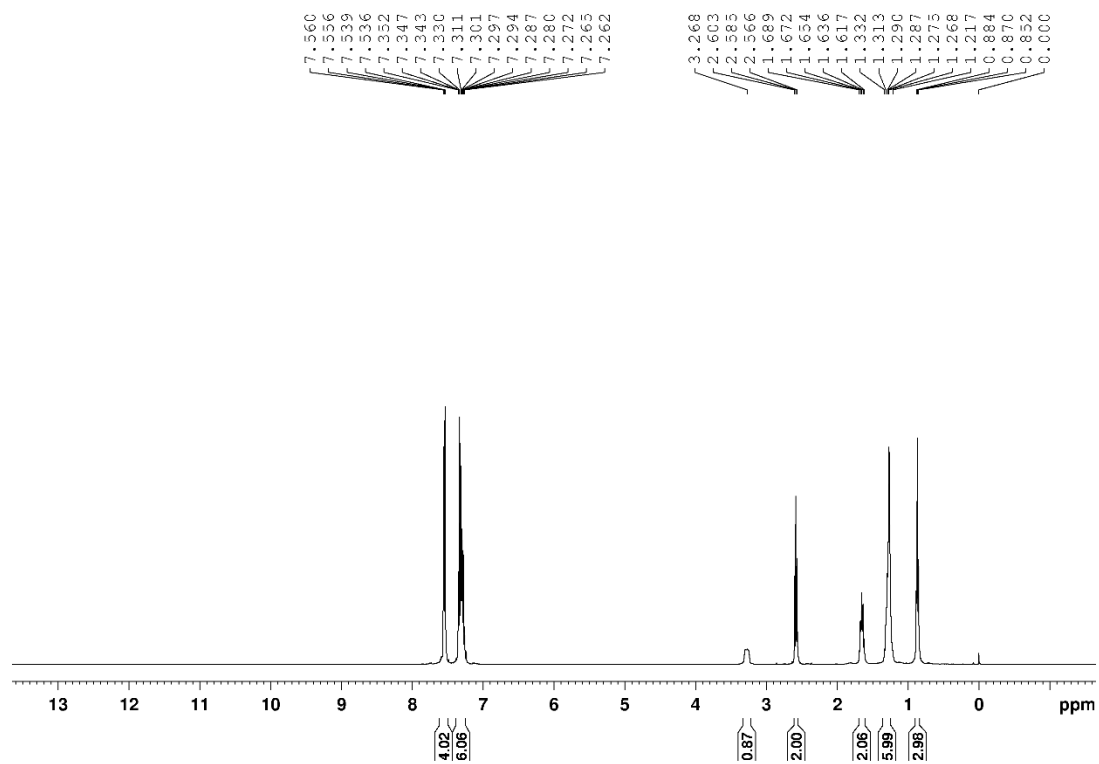
¹³C{H} NMR spectrum was recorded on 151 MHz in CDCl₃.



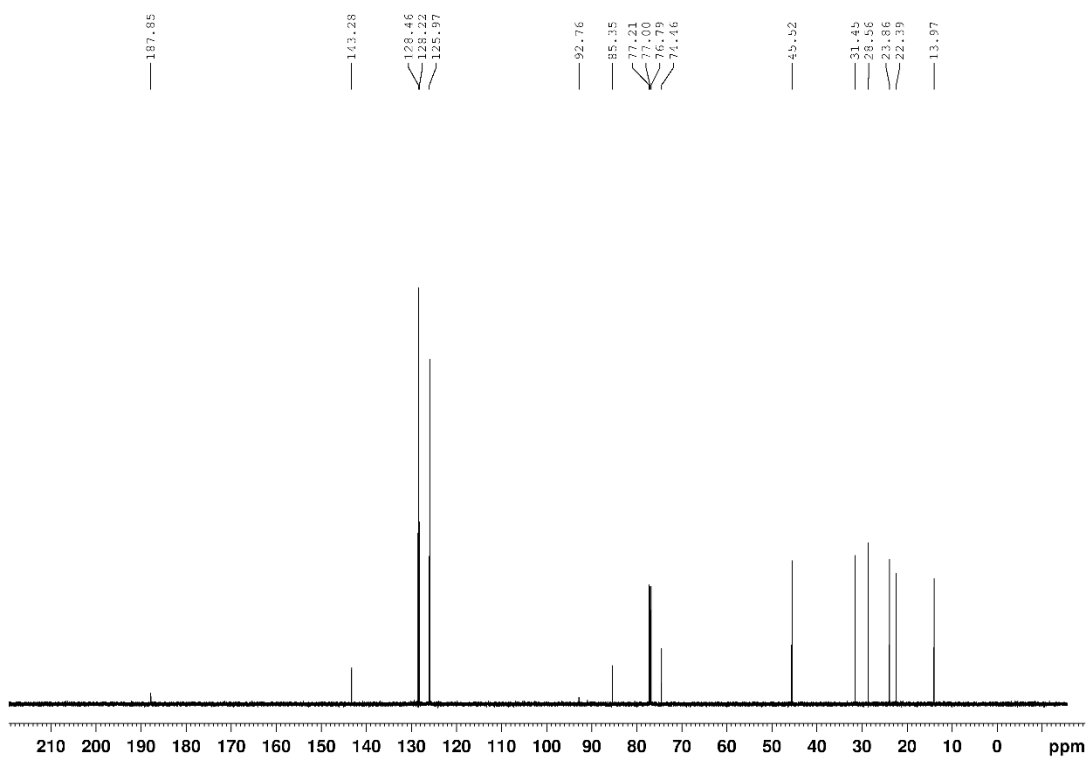


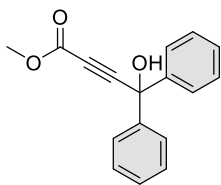
1ar

¹H NMR spectrum was recorded on 400 MHz in CDCl₃.



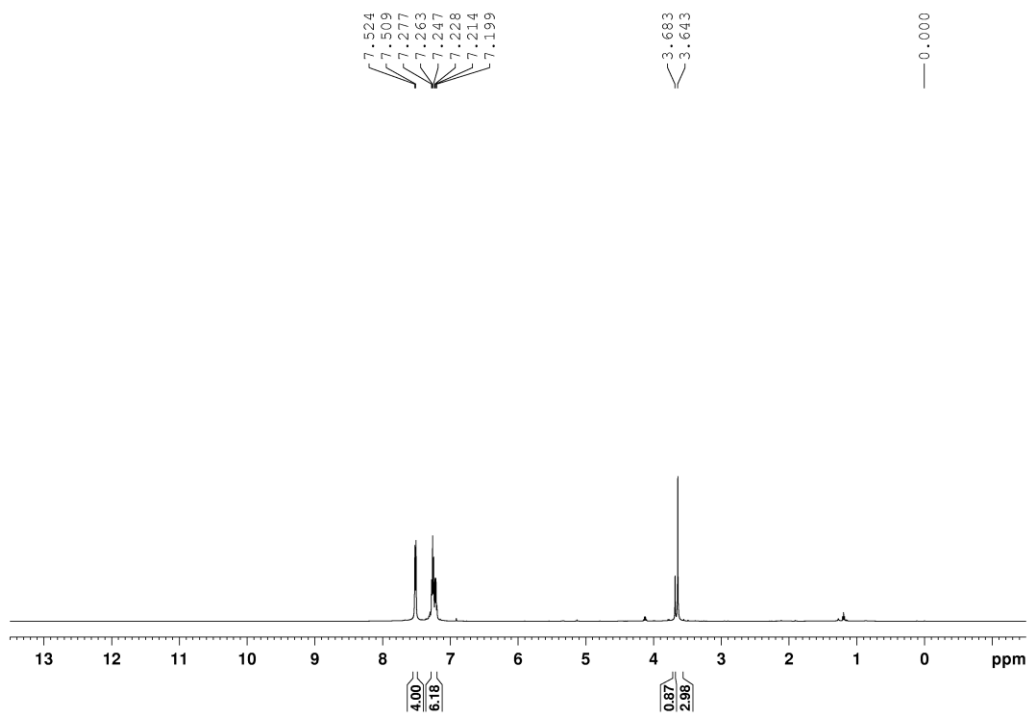
¹³C{¹H} NMR spectrum was recorded on 151 MHz in CDCl₃.



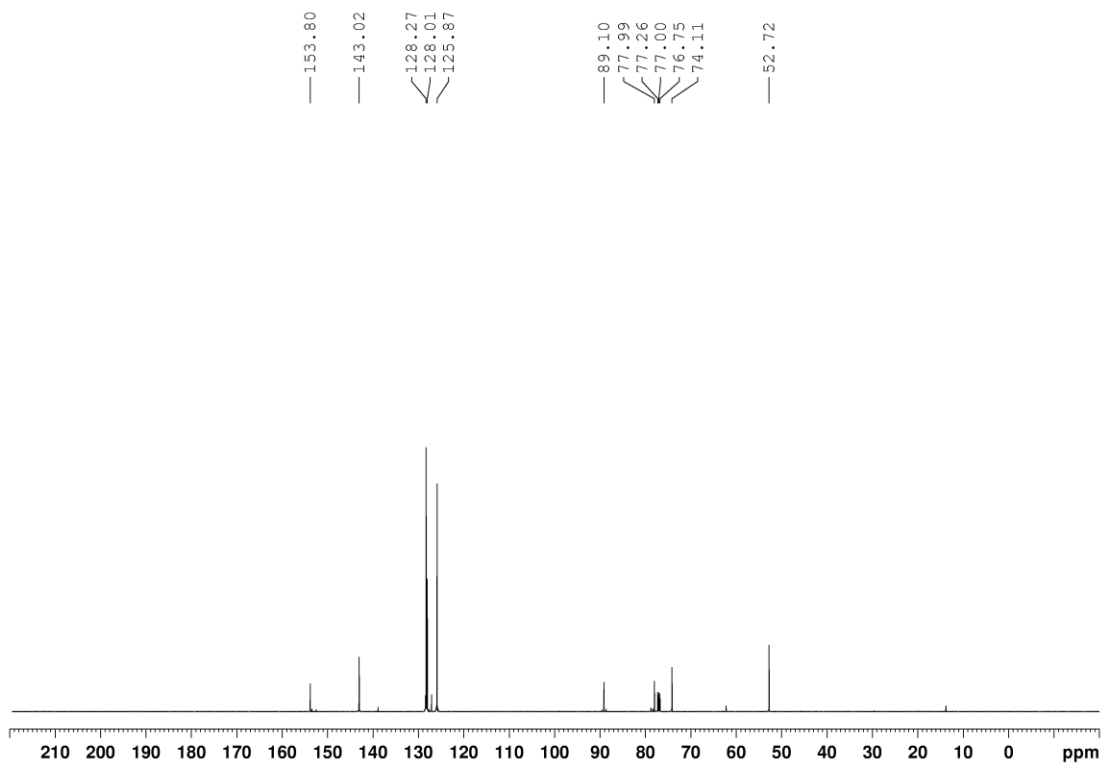


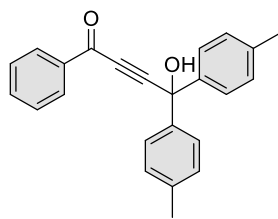
1as

¹H NMR spectrum was recorded on 500 MHz in CDCl₃.



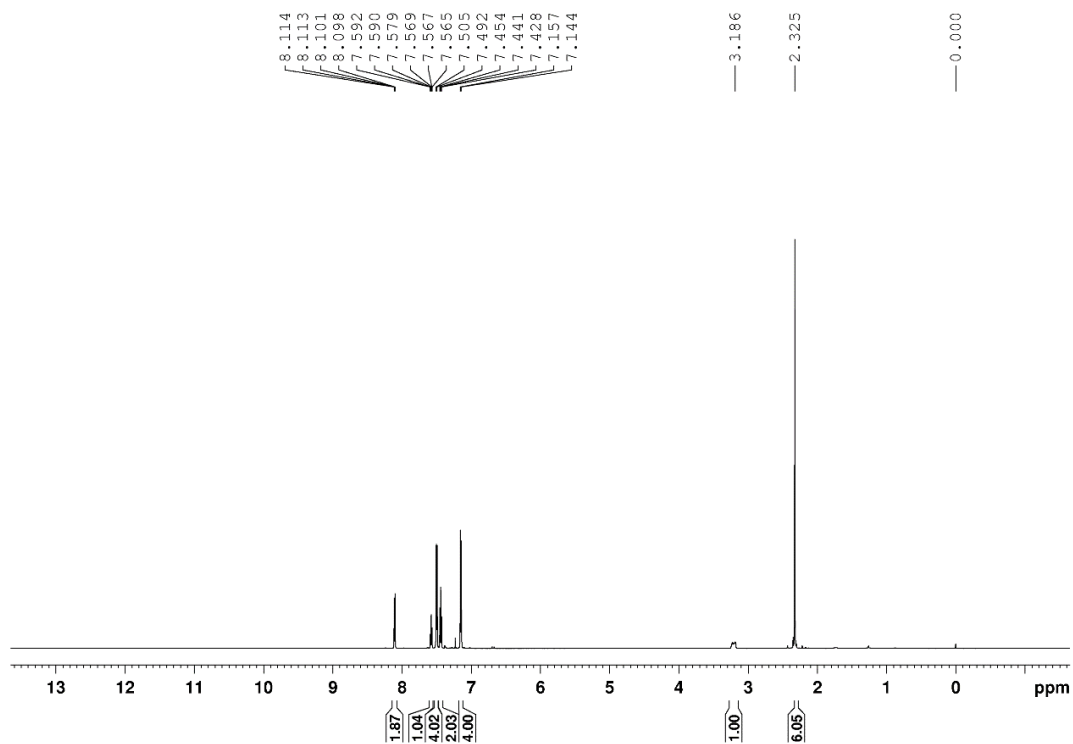
¹³C{¹H} NMR spectrum was recorded on 126 MHz in CDCl₃.



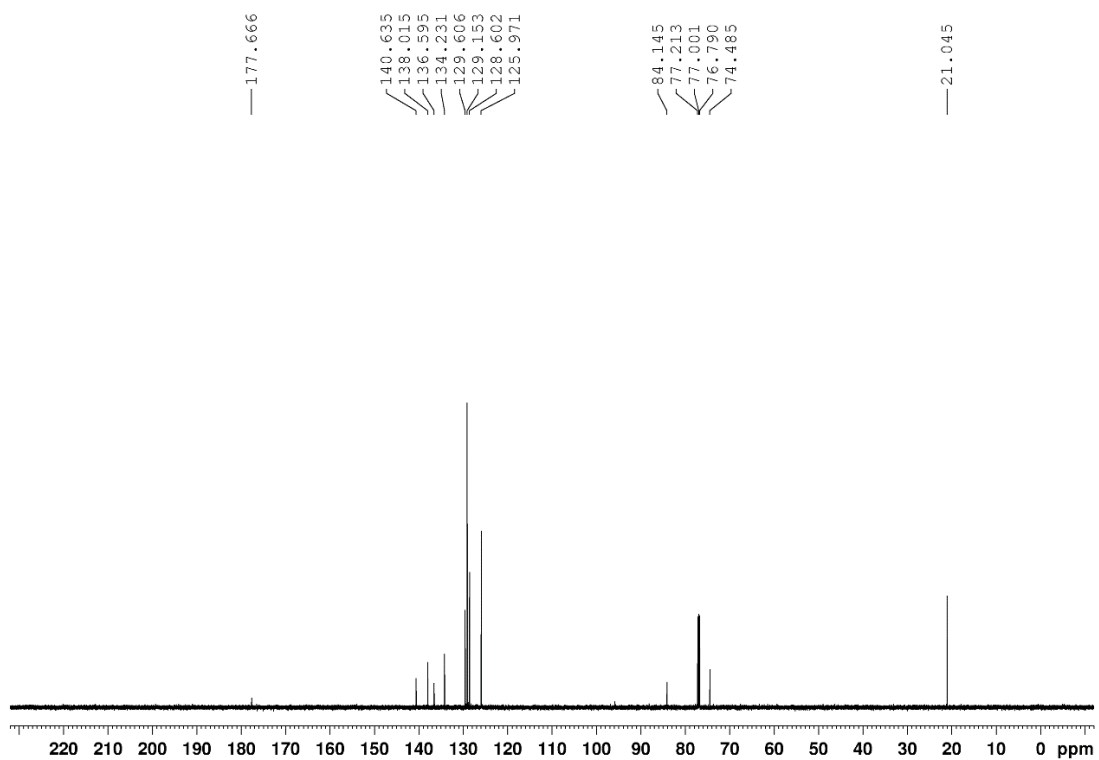


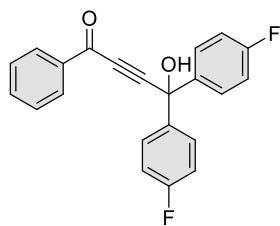
1ba

^1H NMR spectrum was recorded on 600 MHz in CDCl_3 .



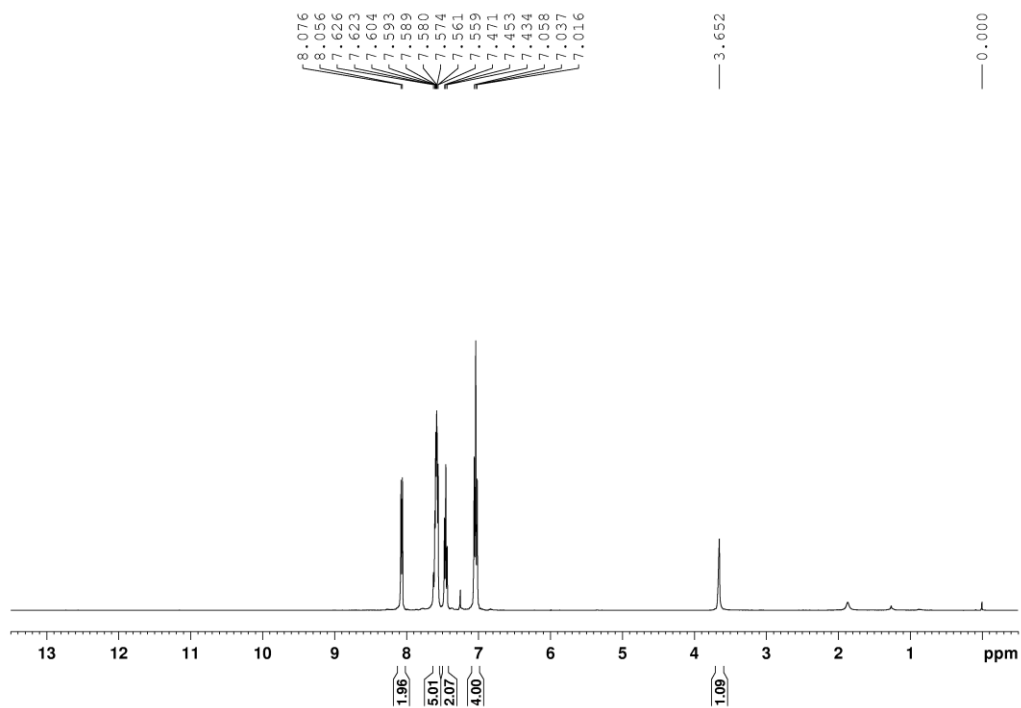
$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



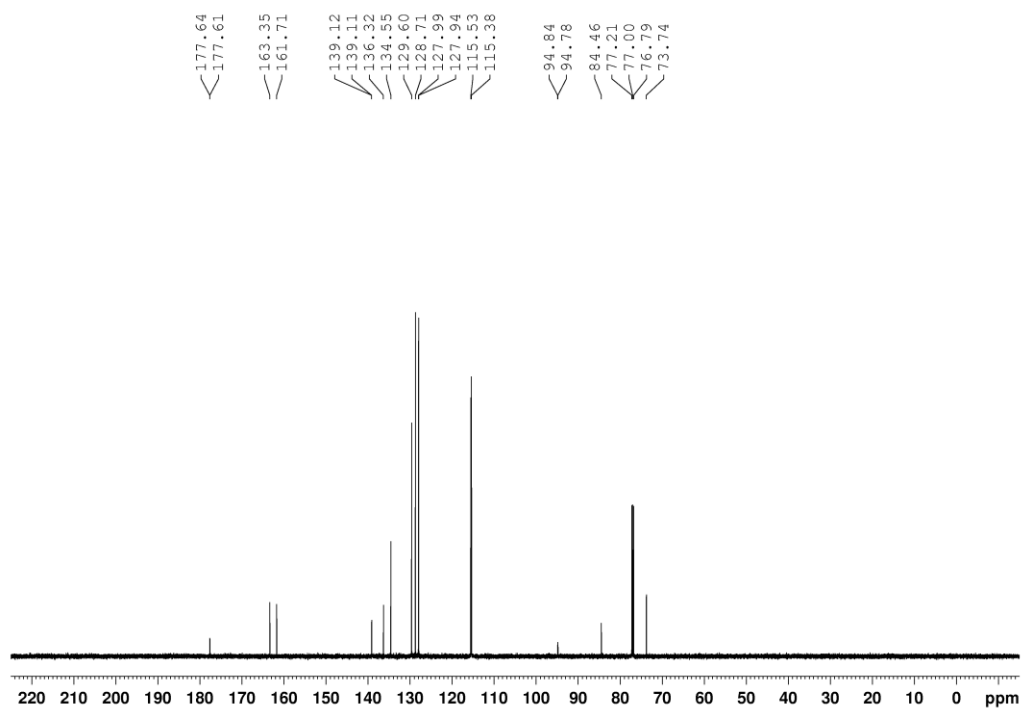


1bb

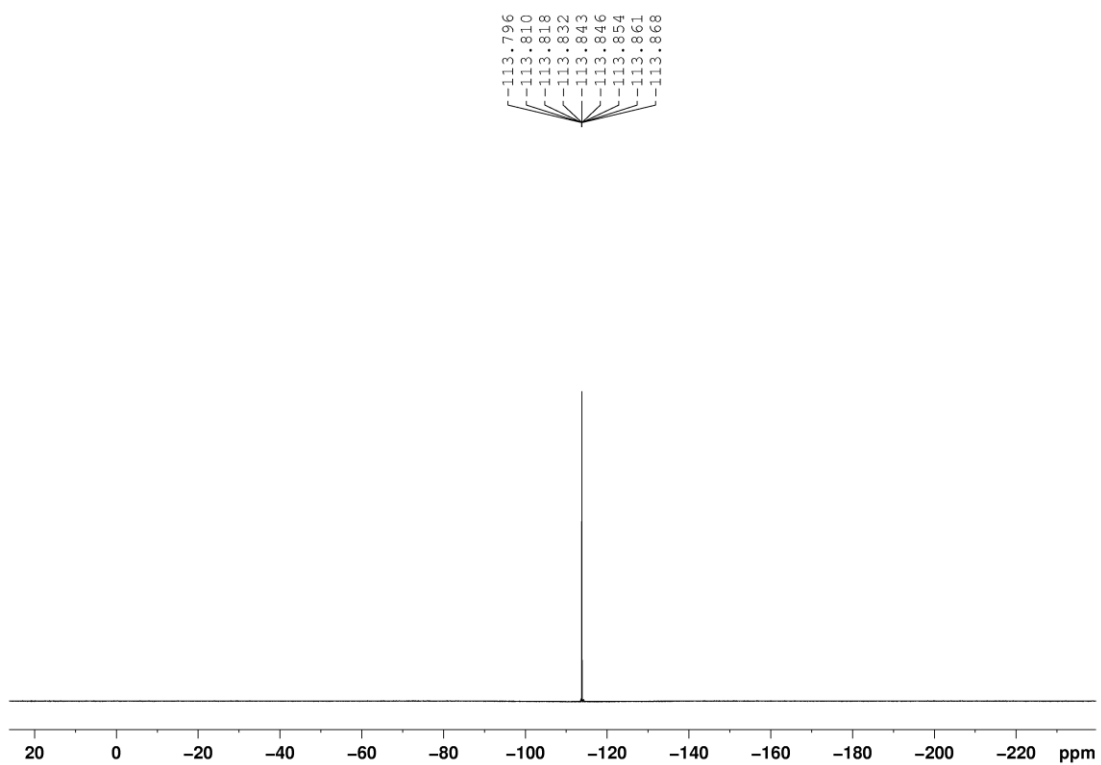
^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .

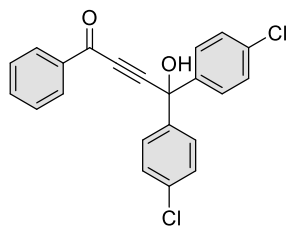


$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



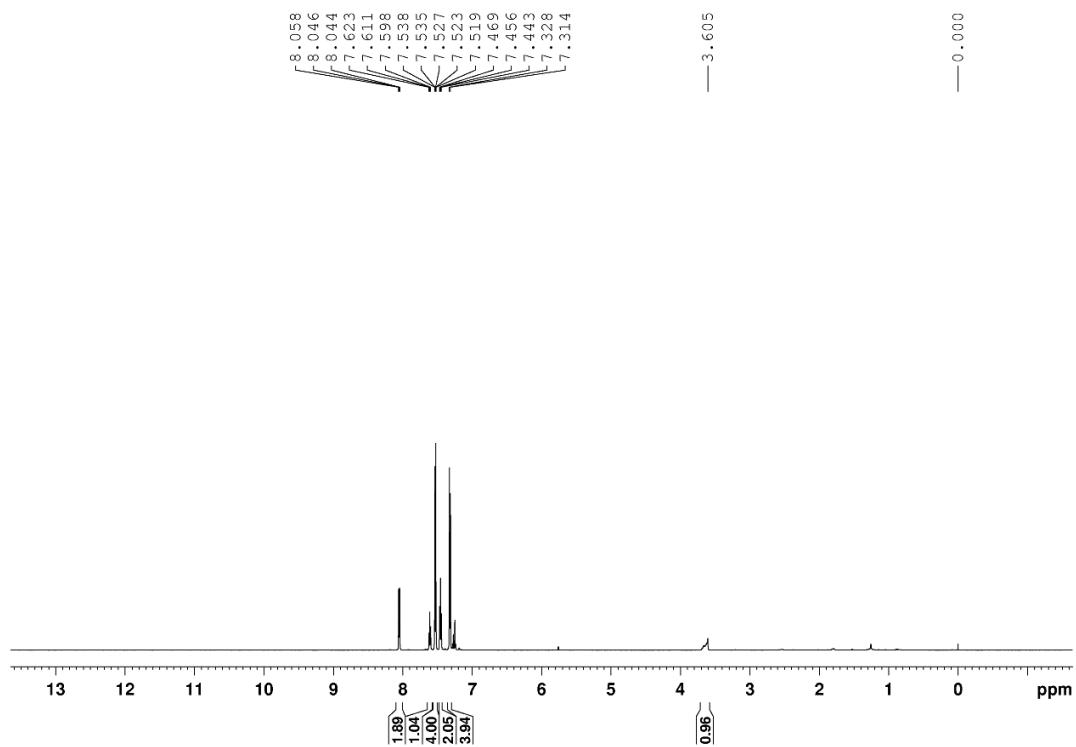
¹⁹F spectrum was recorded on 376 MHz in CDCl₃.



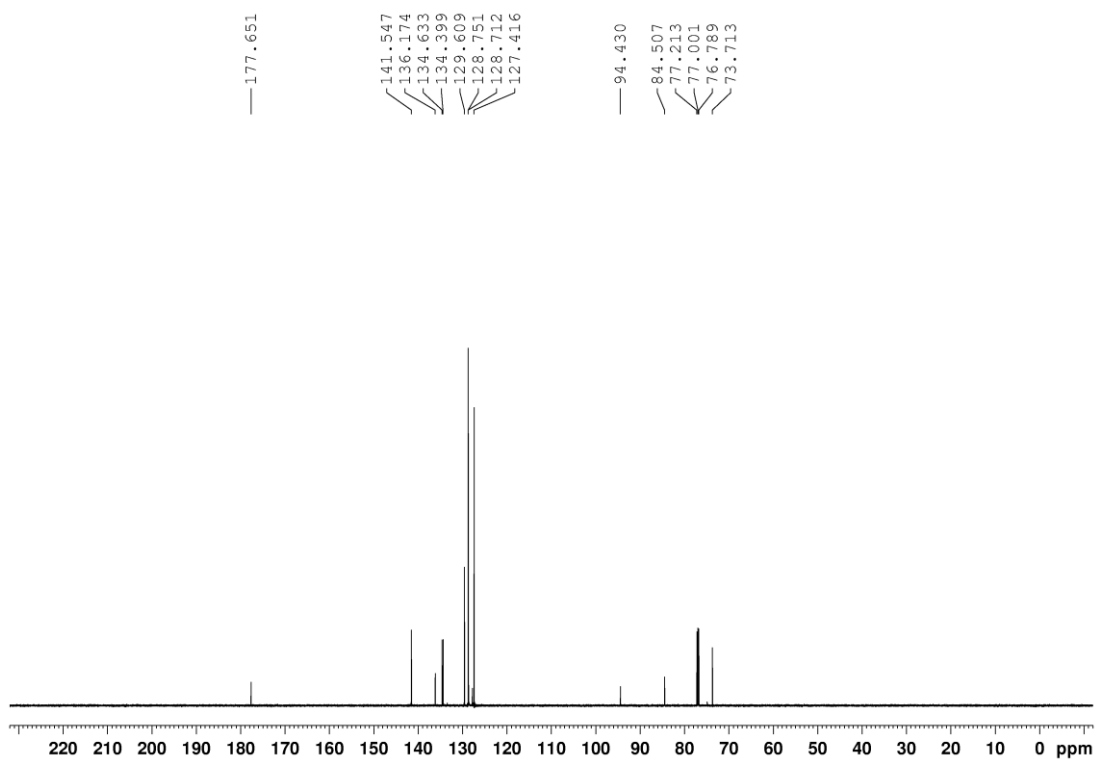


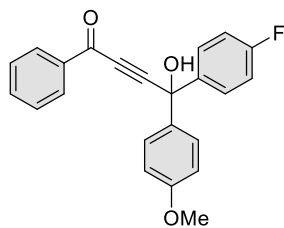
1bc

¹H NMR spectrum was recorded on 600 MHz in CDCl₃.



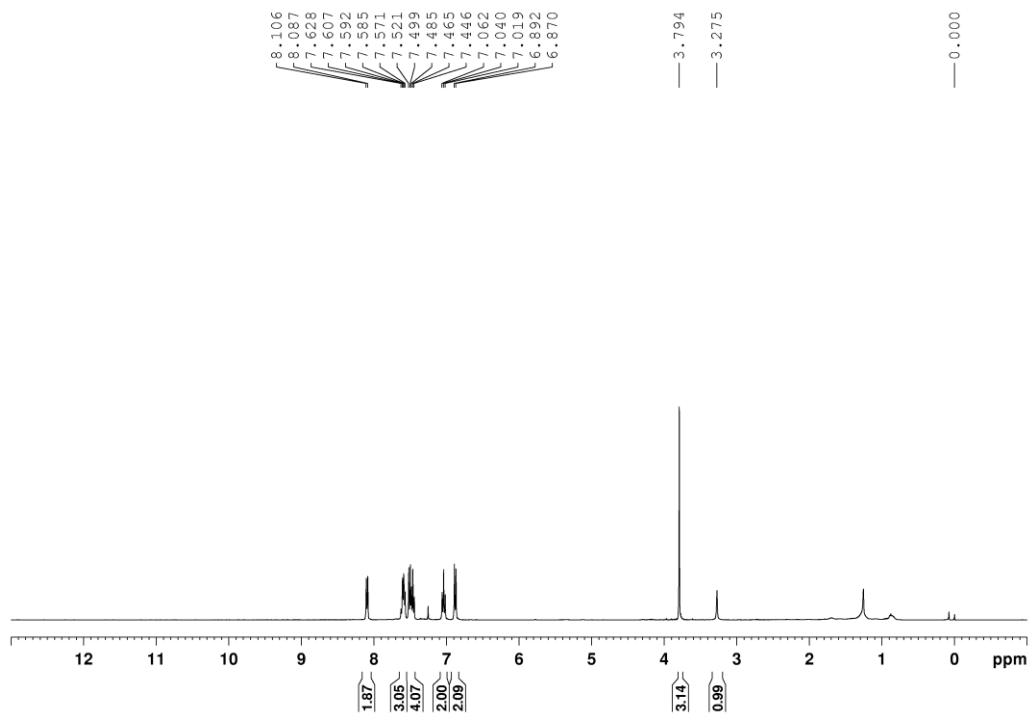
¹³C{¹H} NMR spectrum was recorded on 151 MHz in CDCl₃.



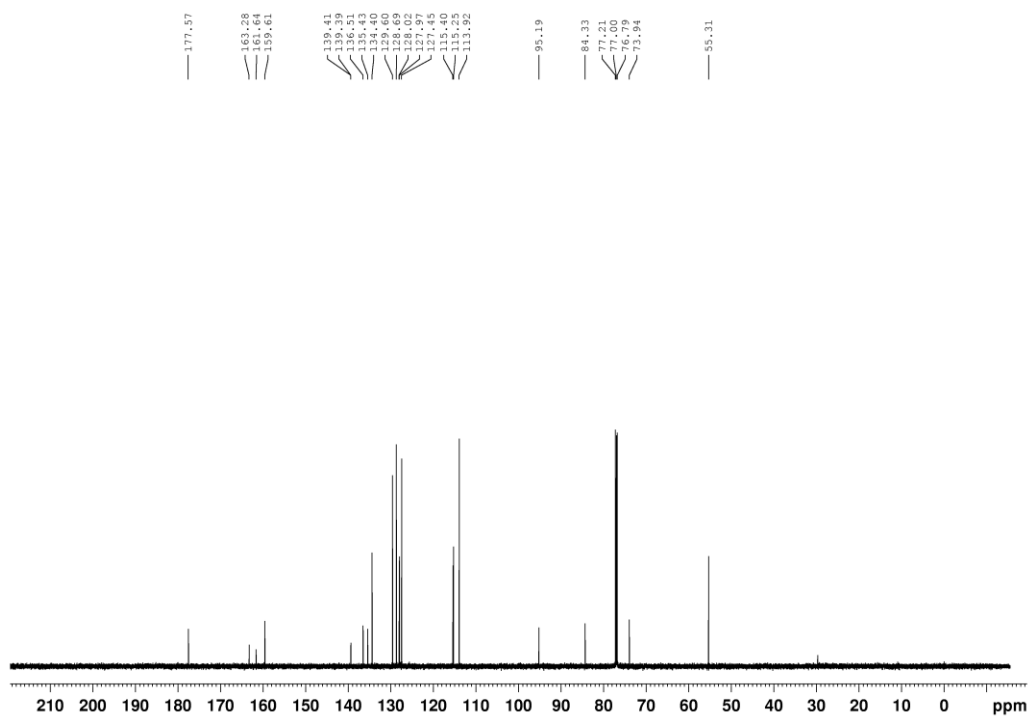


1bd

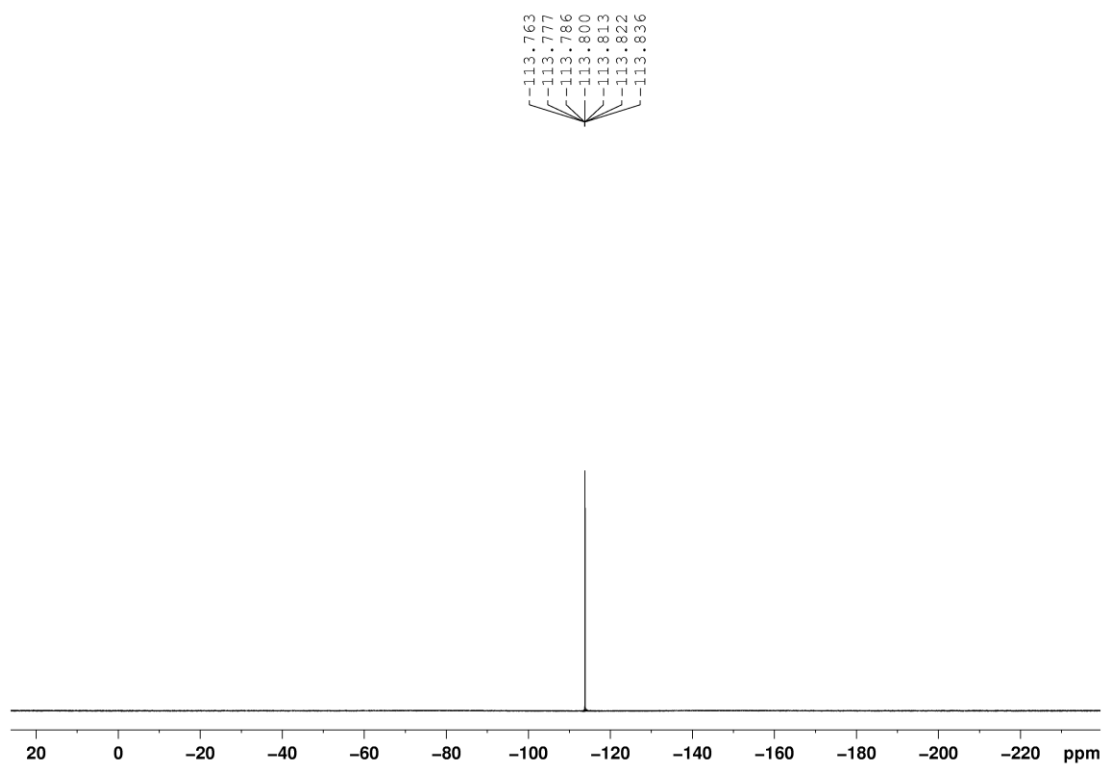
^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .

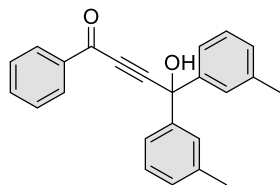


$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



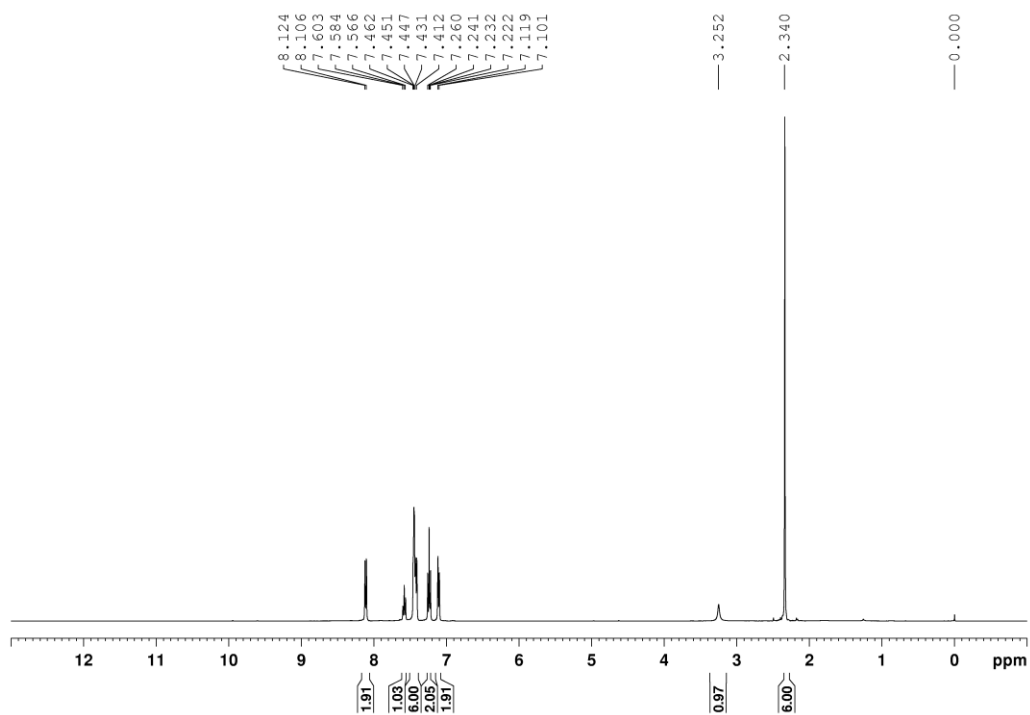
¹⁹F spectrum was recorded on 376 MHz in CDCl₃.



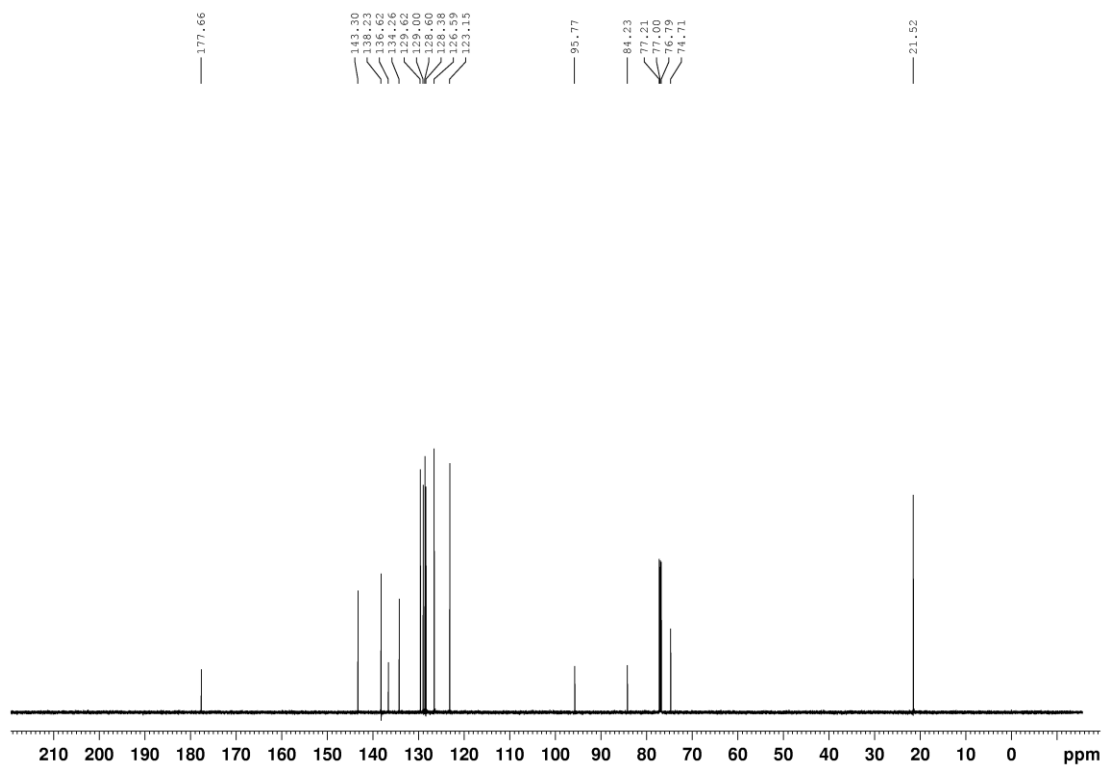


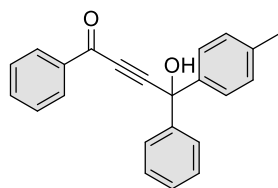
1be

^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .



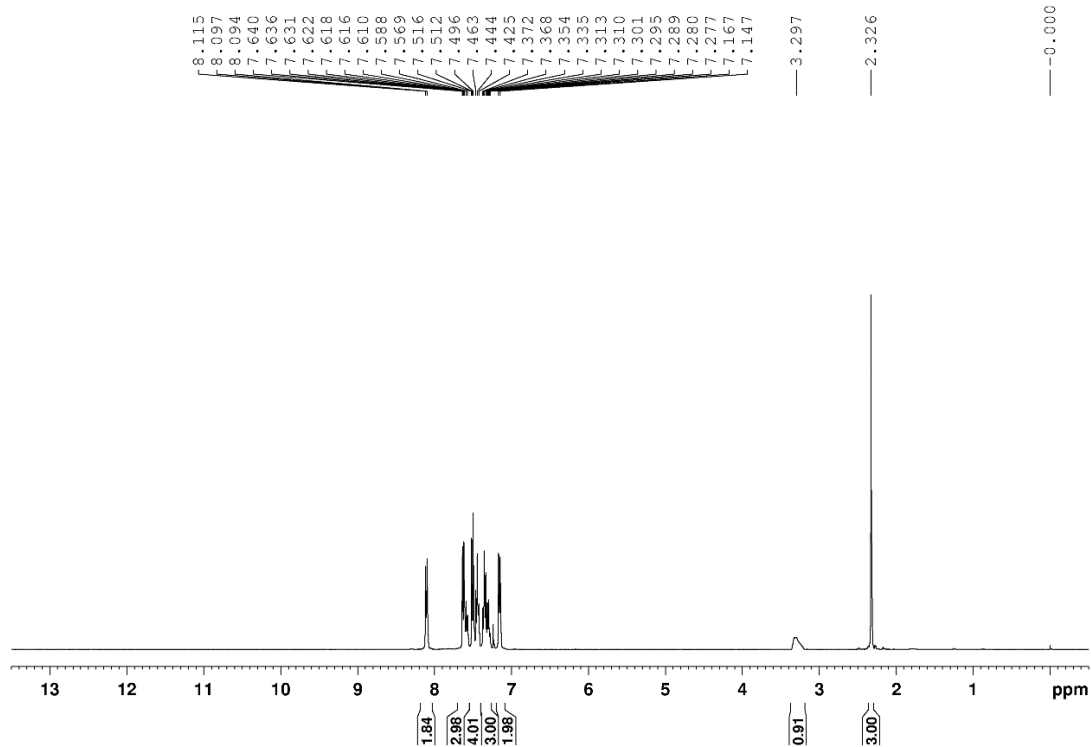
$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



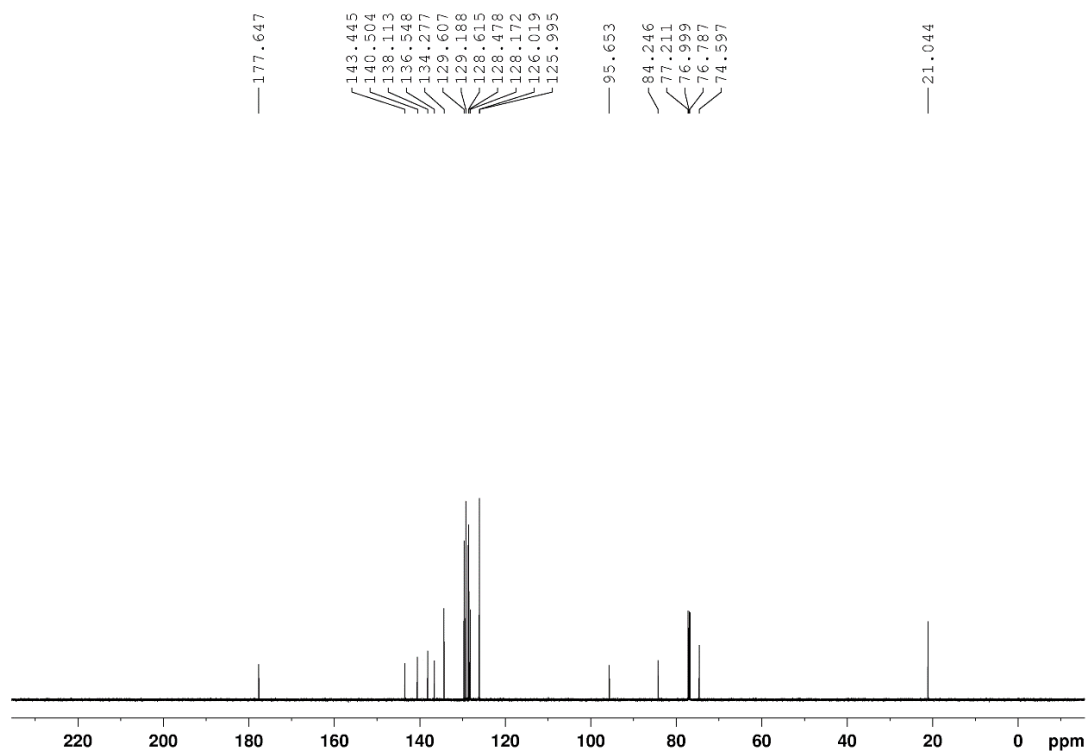


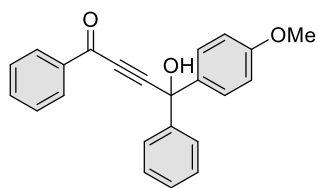
1bf

^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .



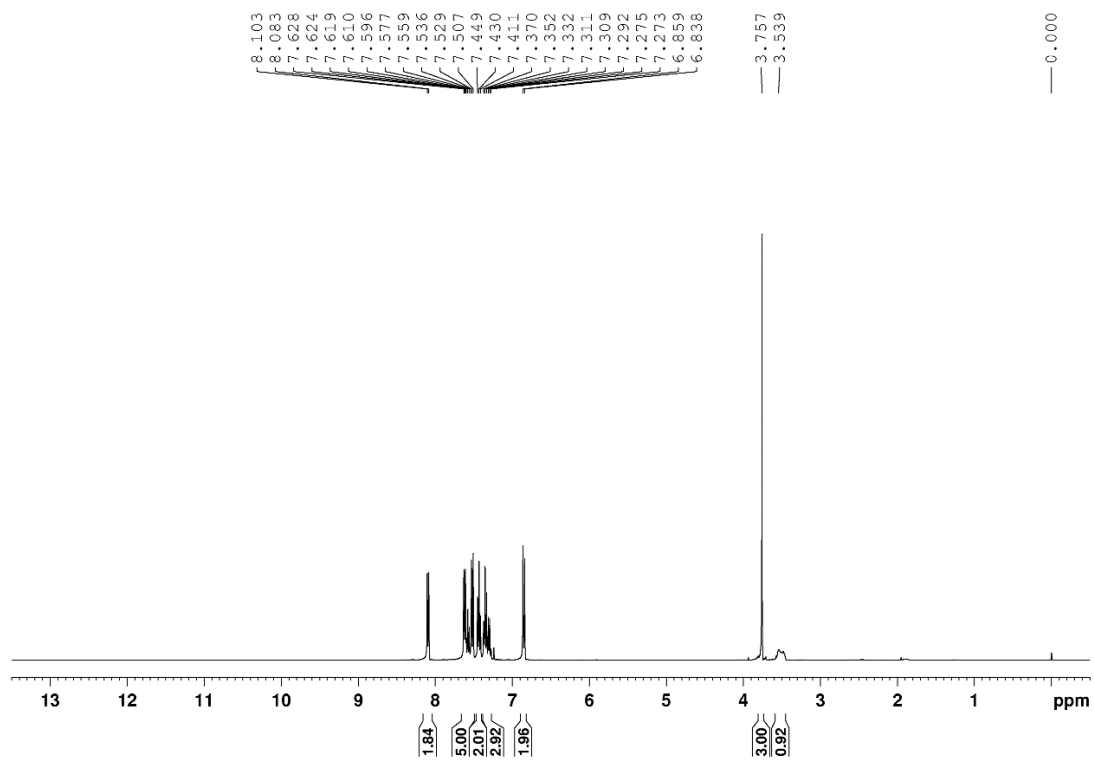
$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



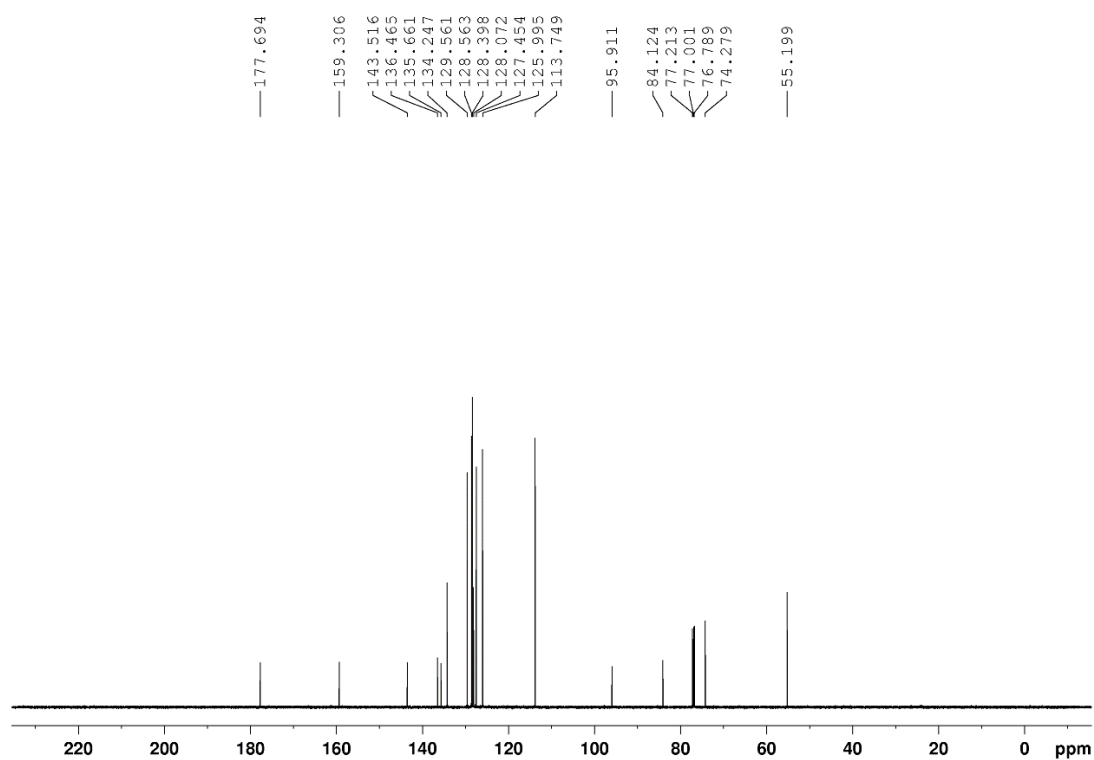


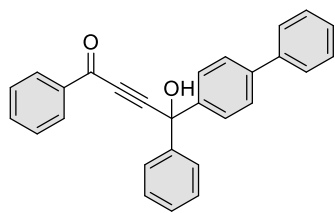
1bg

^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .



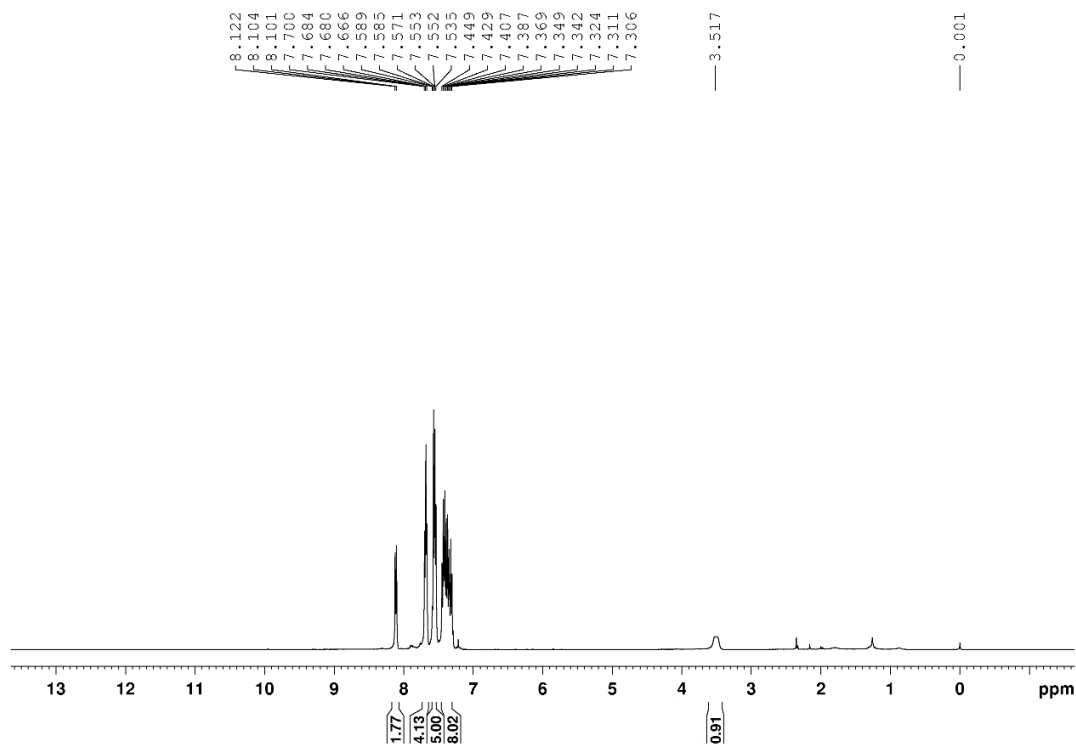
$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



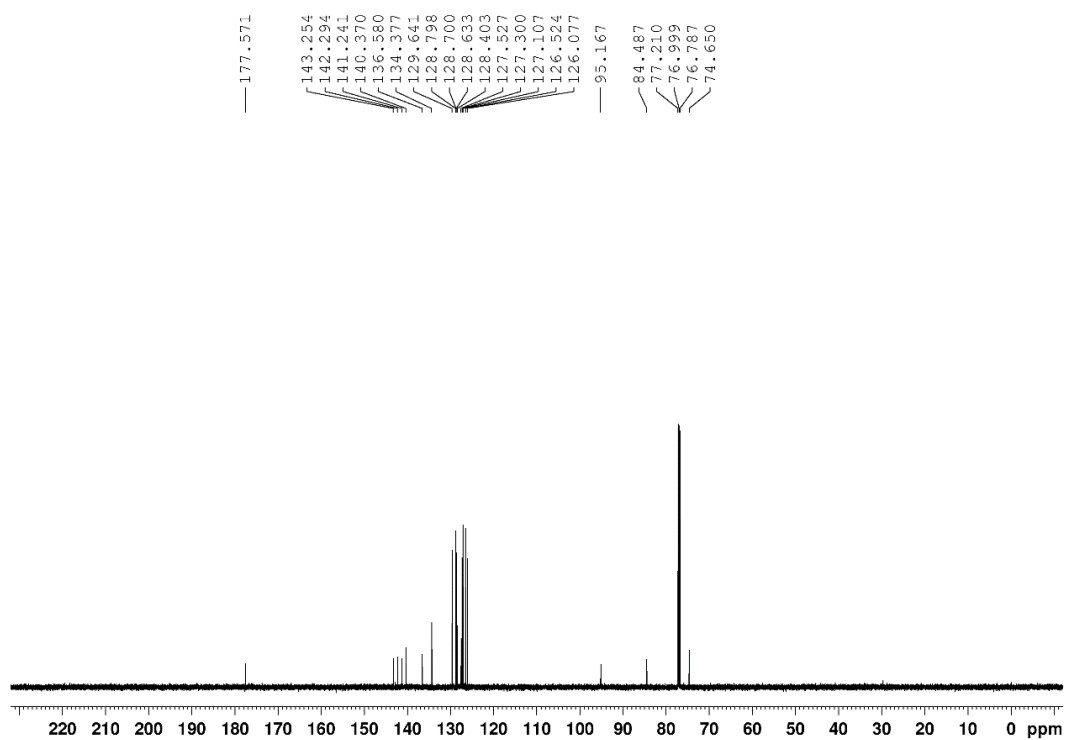


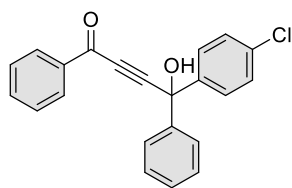
1bh

¹H NMR spectrum was recorded on 400 MHz in CDCl₃.



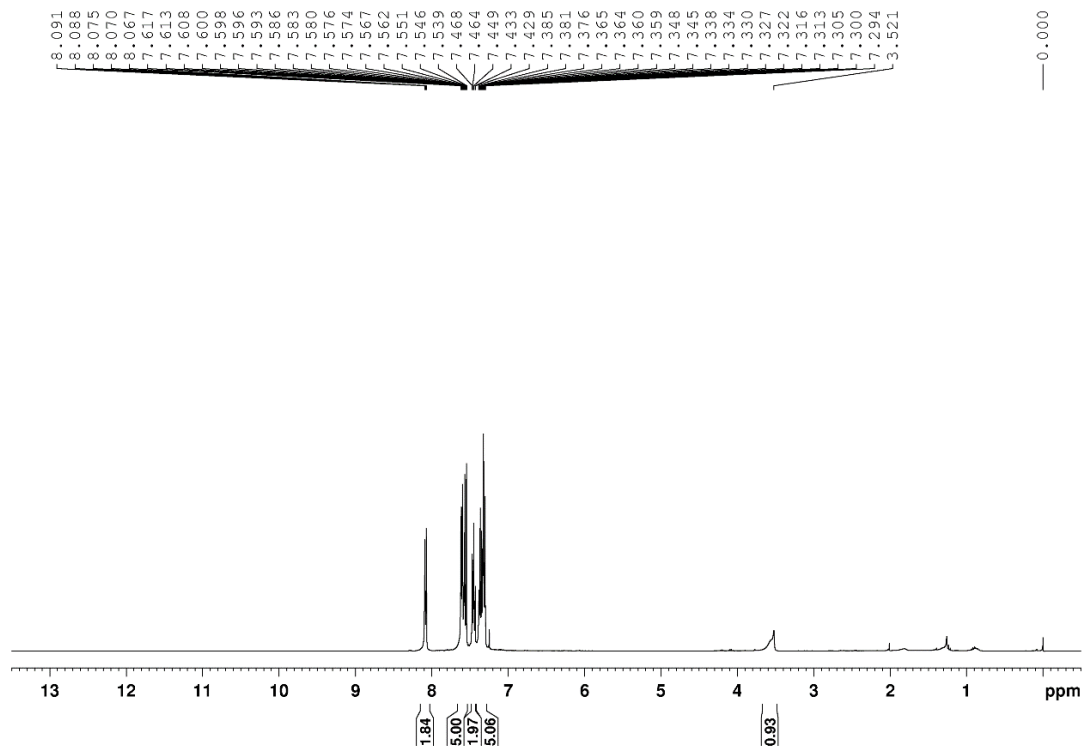
¹³C{¹H} NMR spectrum was recorded on 151 MHz in CDCl₃.



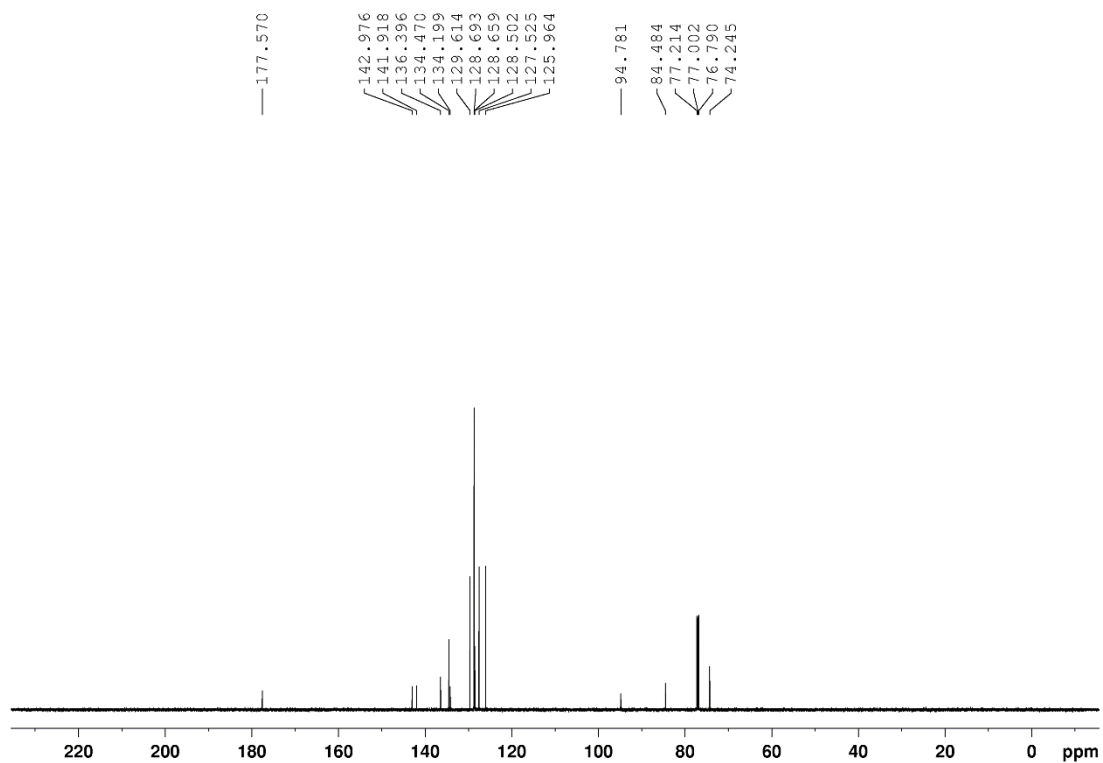


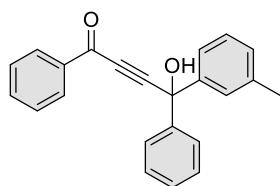
1bi

^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .



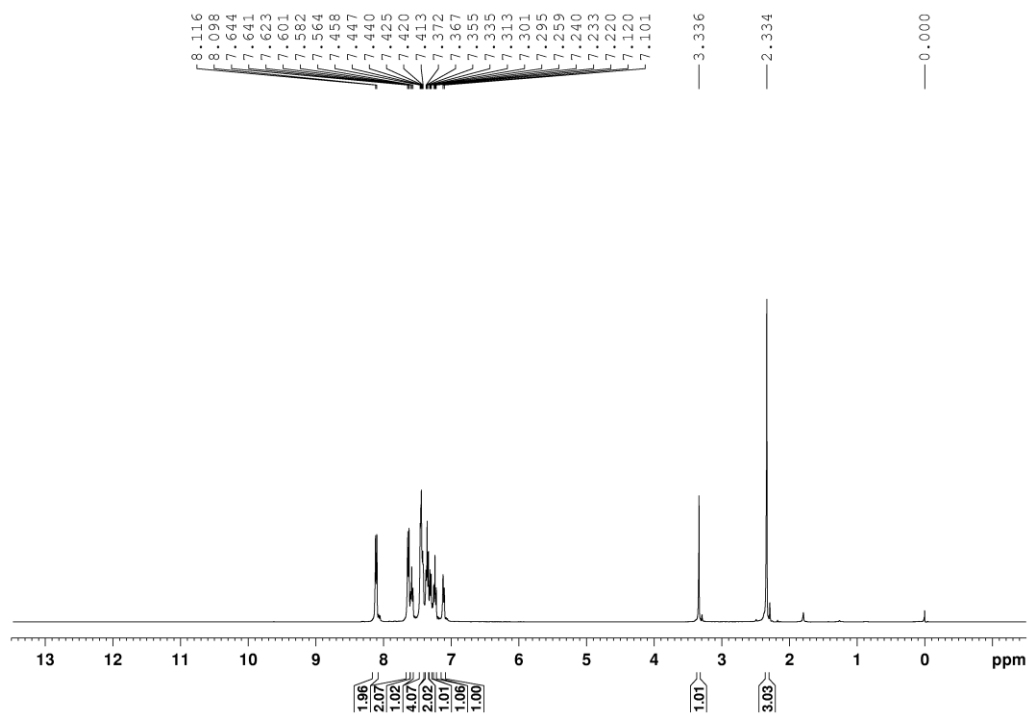
$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



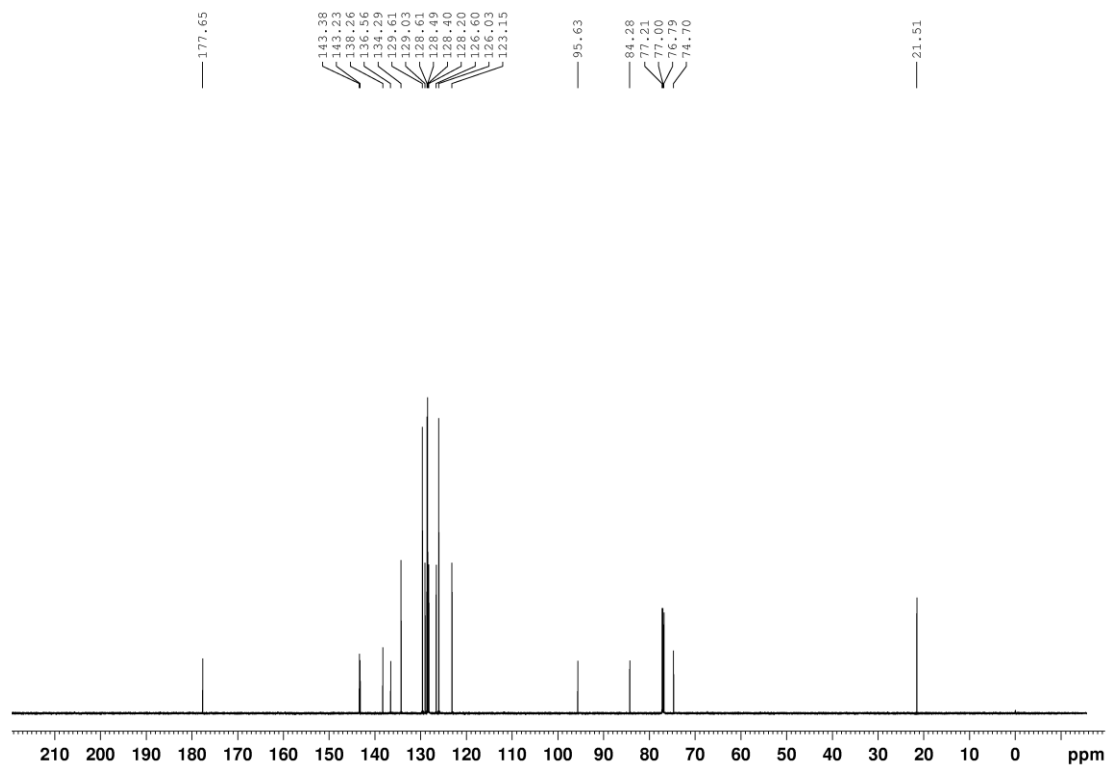


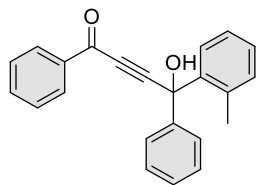
1bj

^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .



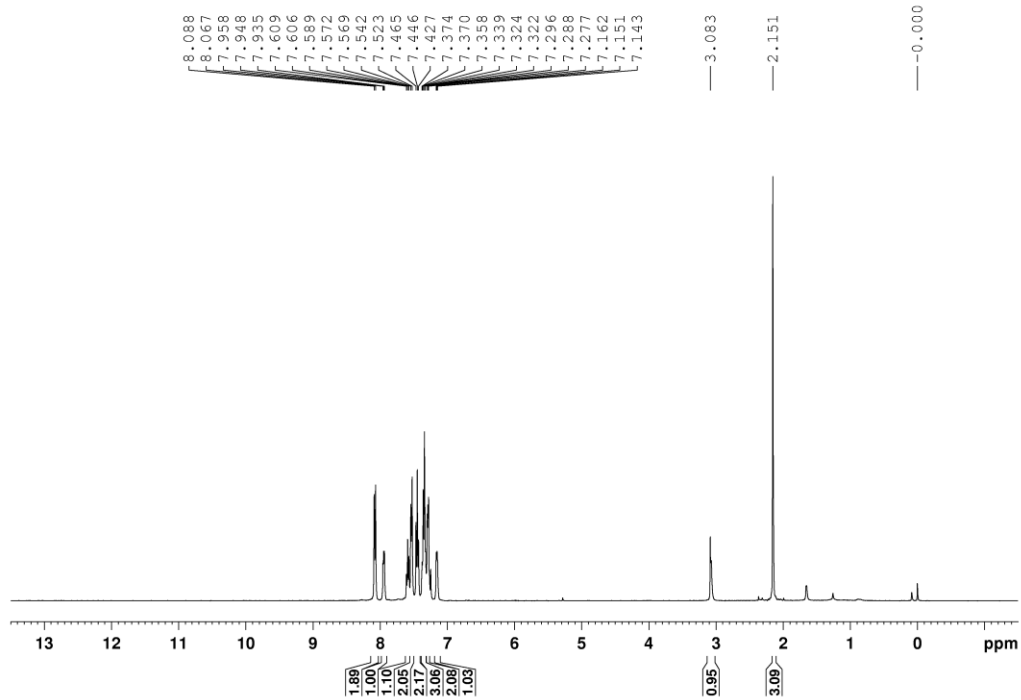
$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



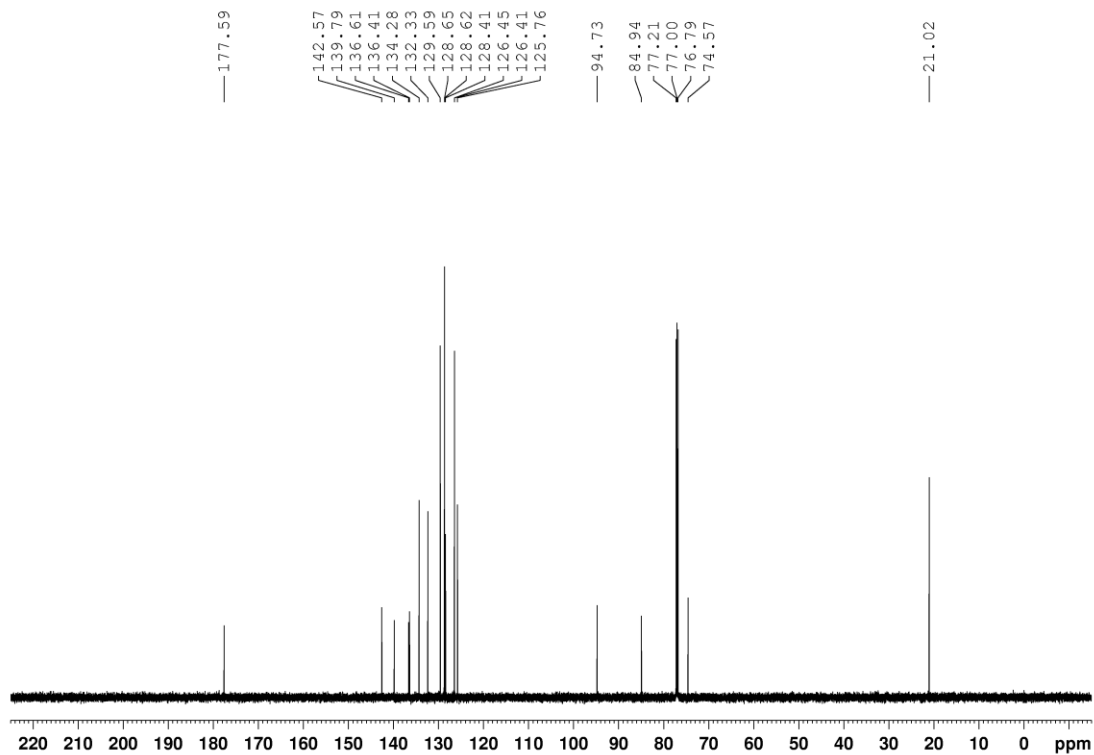


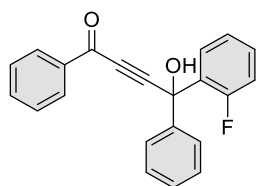
1bk

^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .



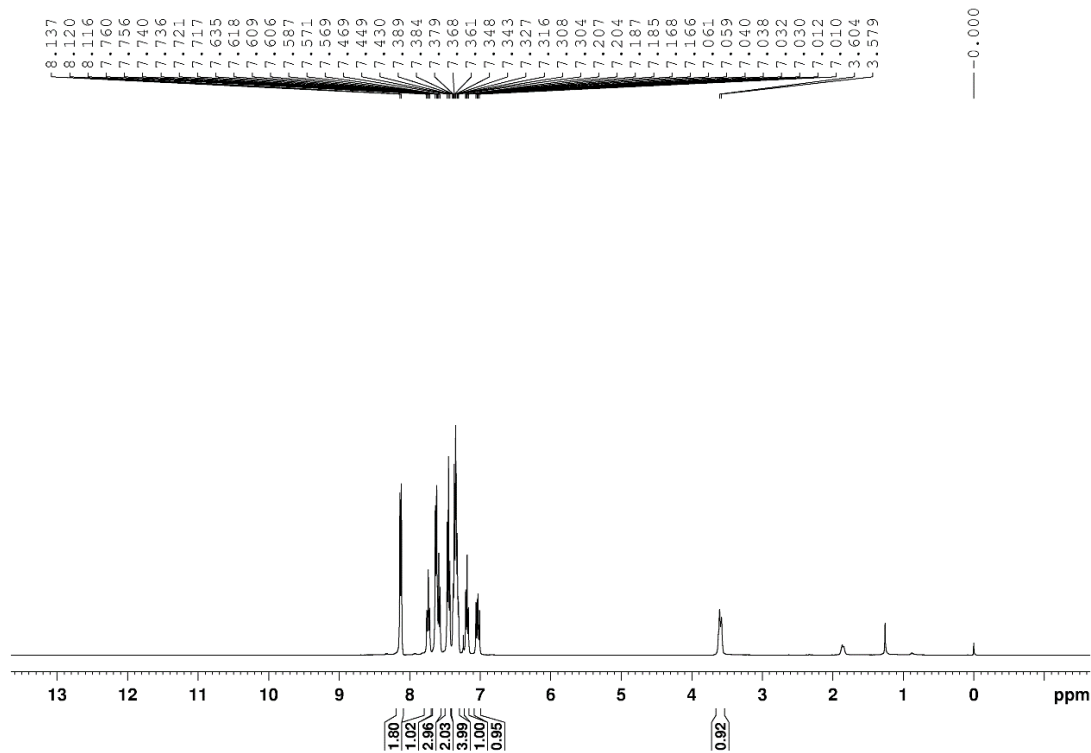
$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



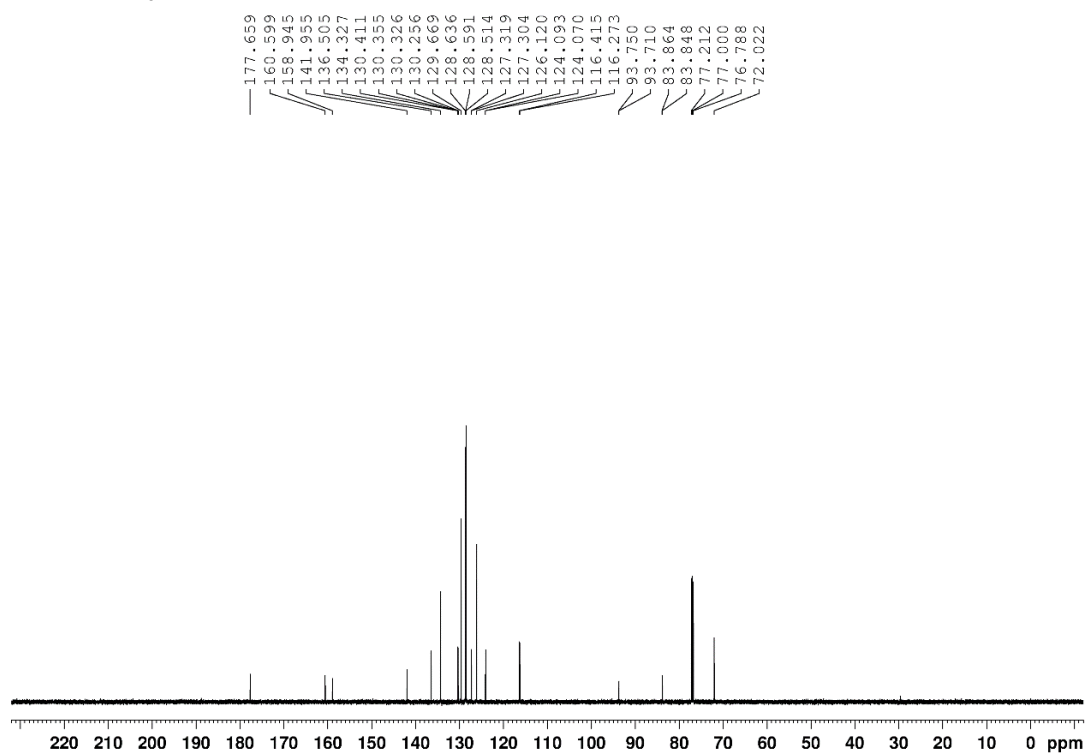


1bl

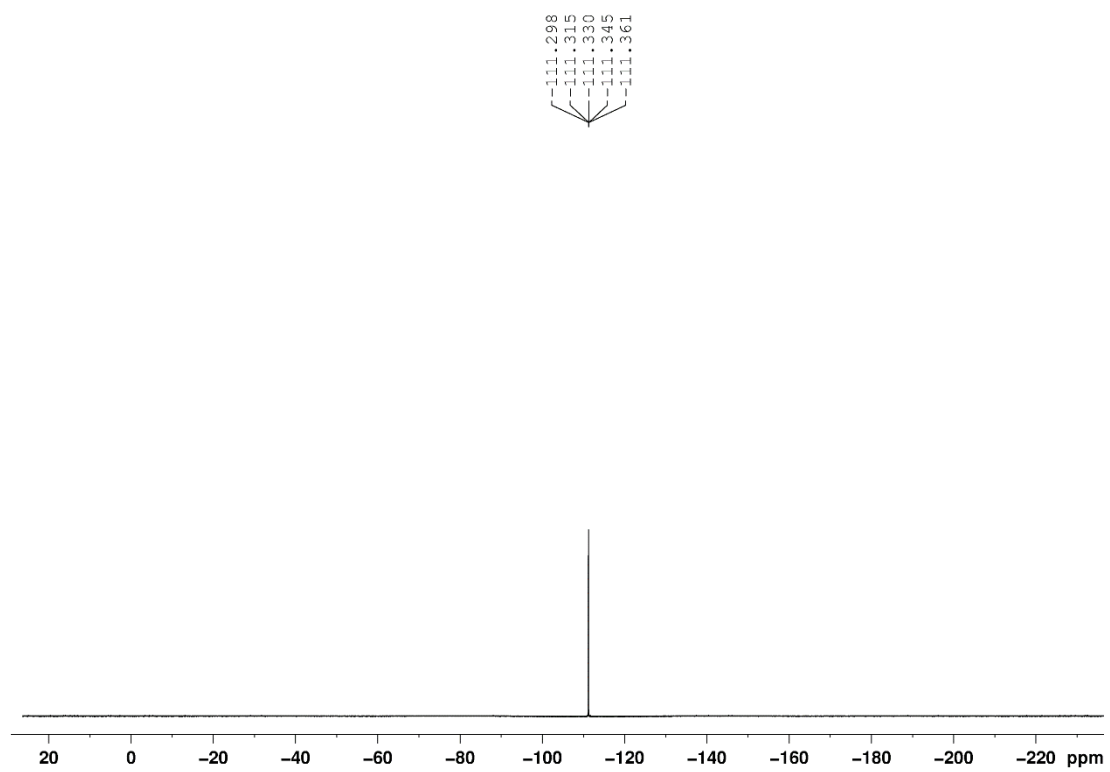
^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .

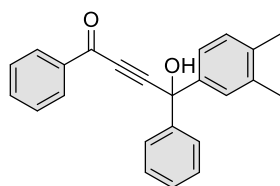


$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



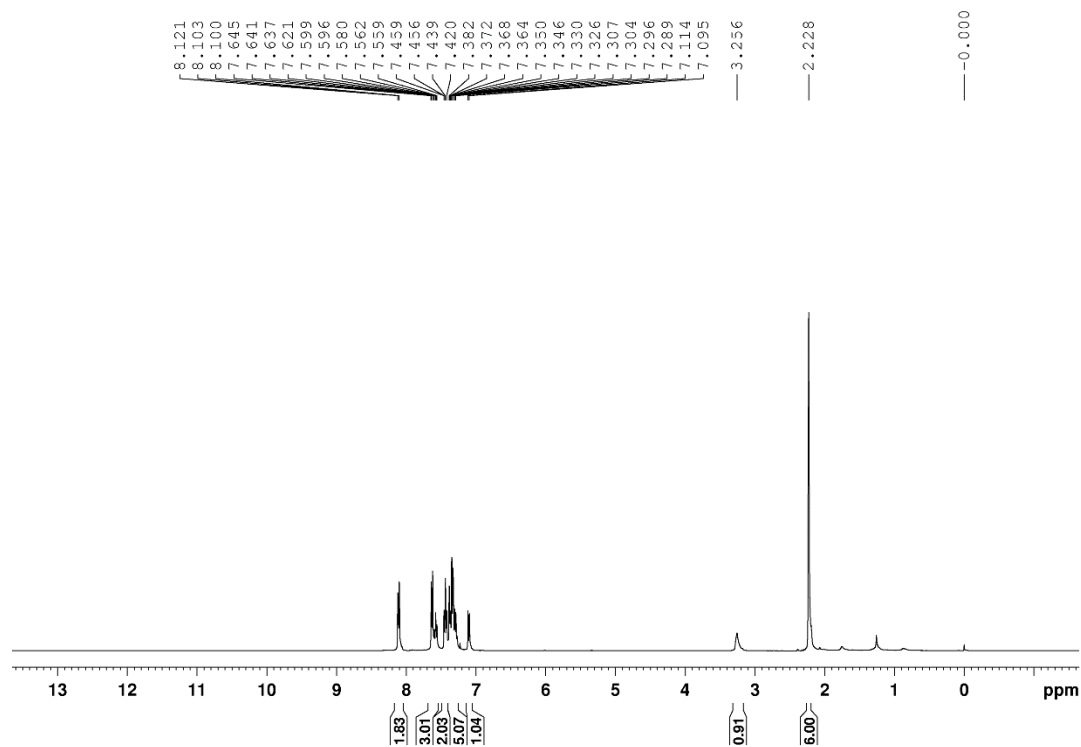
^{19}F spectrum was recorded on 376 MHz in CDCl_3 .



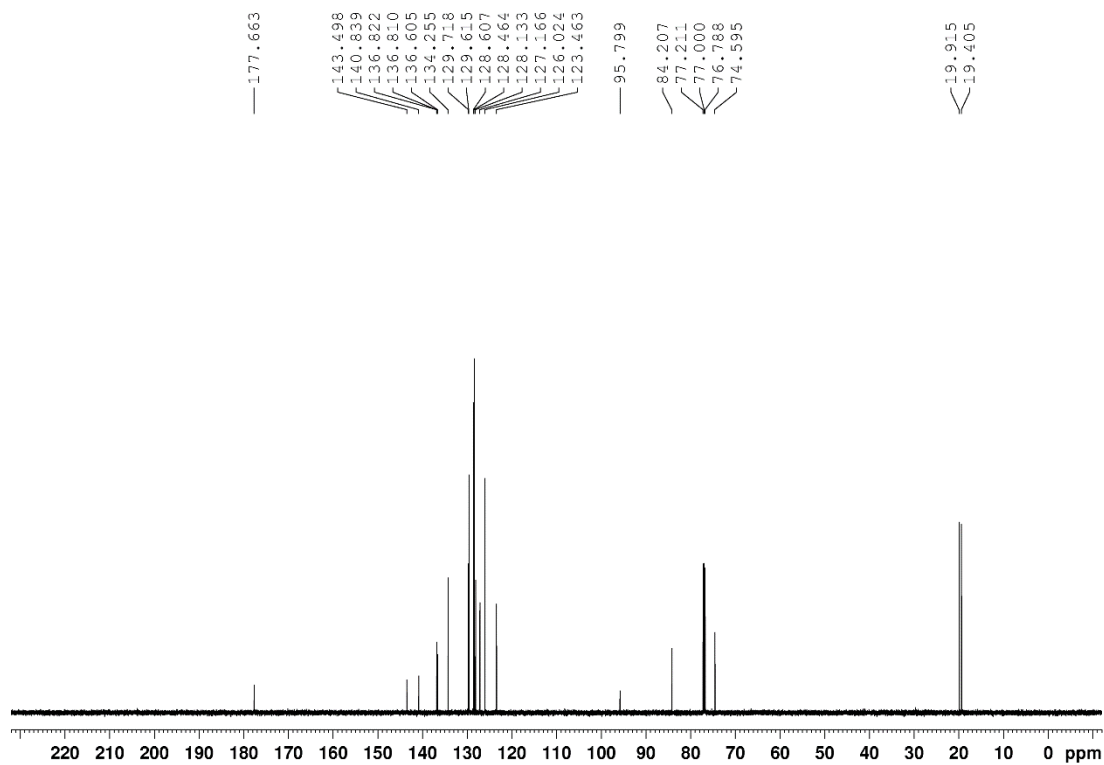


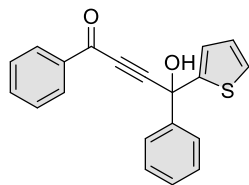
1bm

^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .



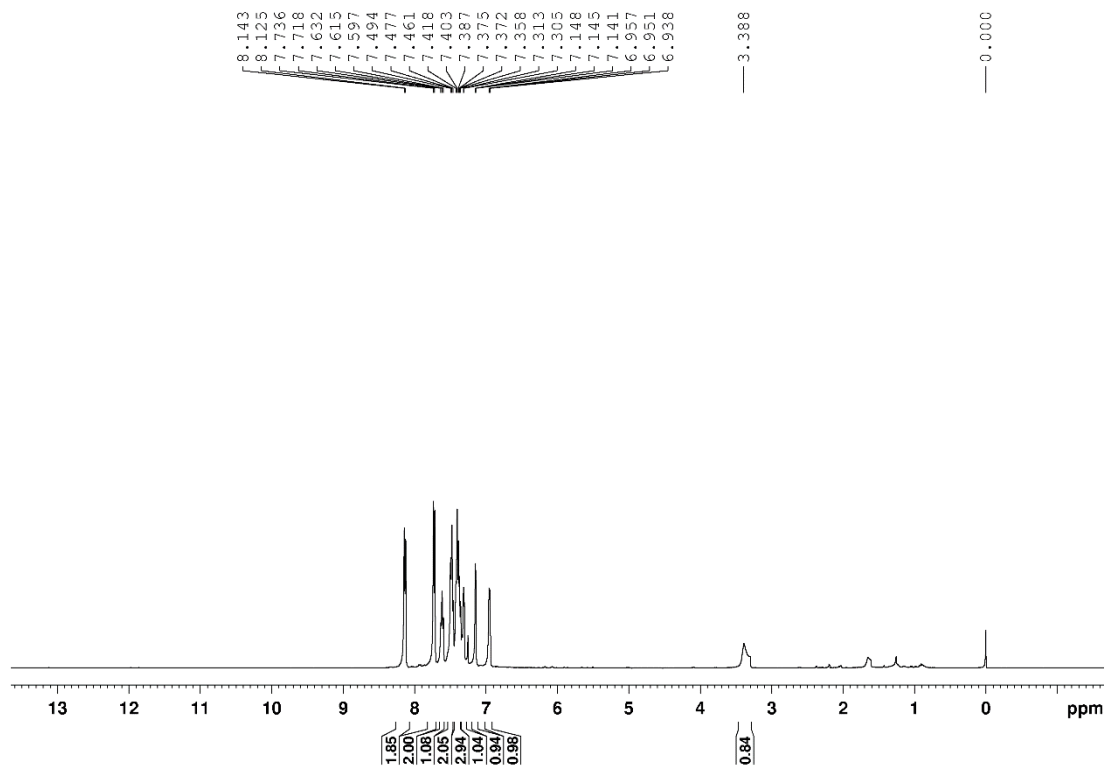
$^{13}\text{C}\{\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



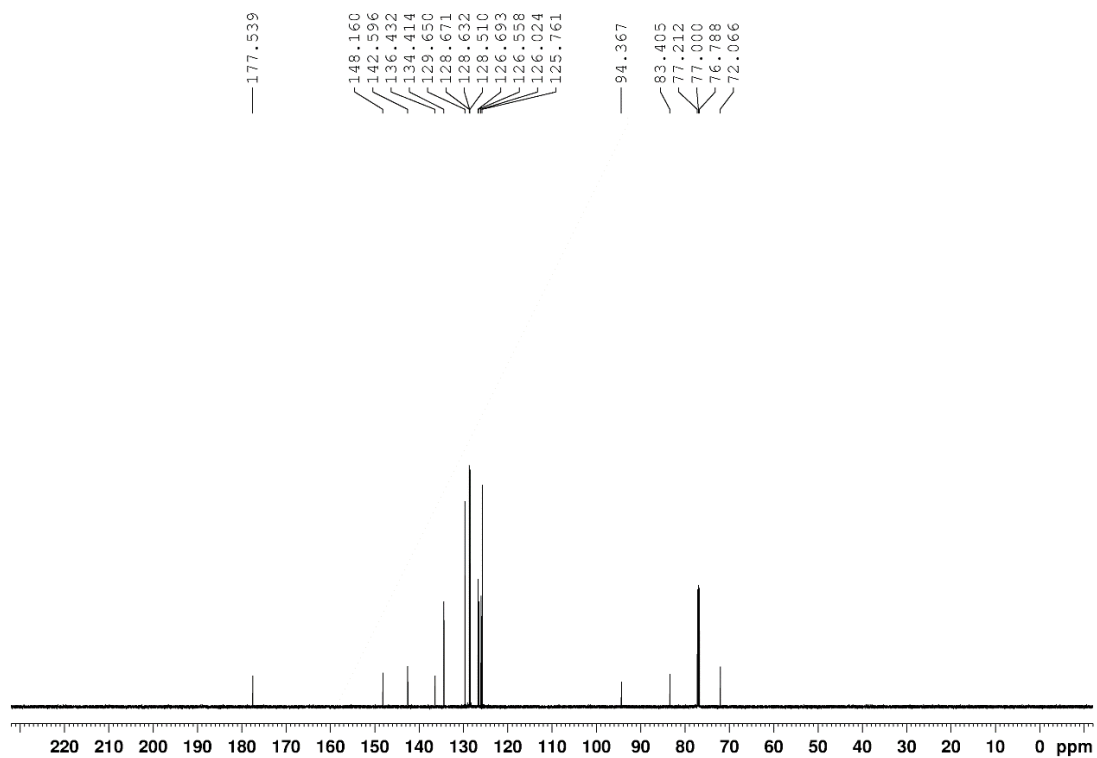


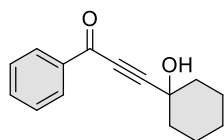
1bn

¹H NMR spectrum was recorded on 400 MHz in CDCl₃.



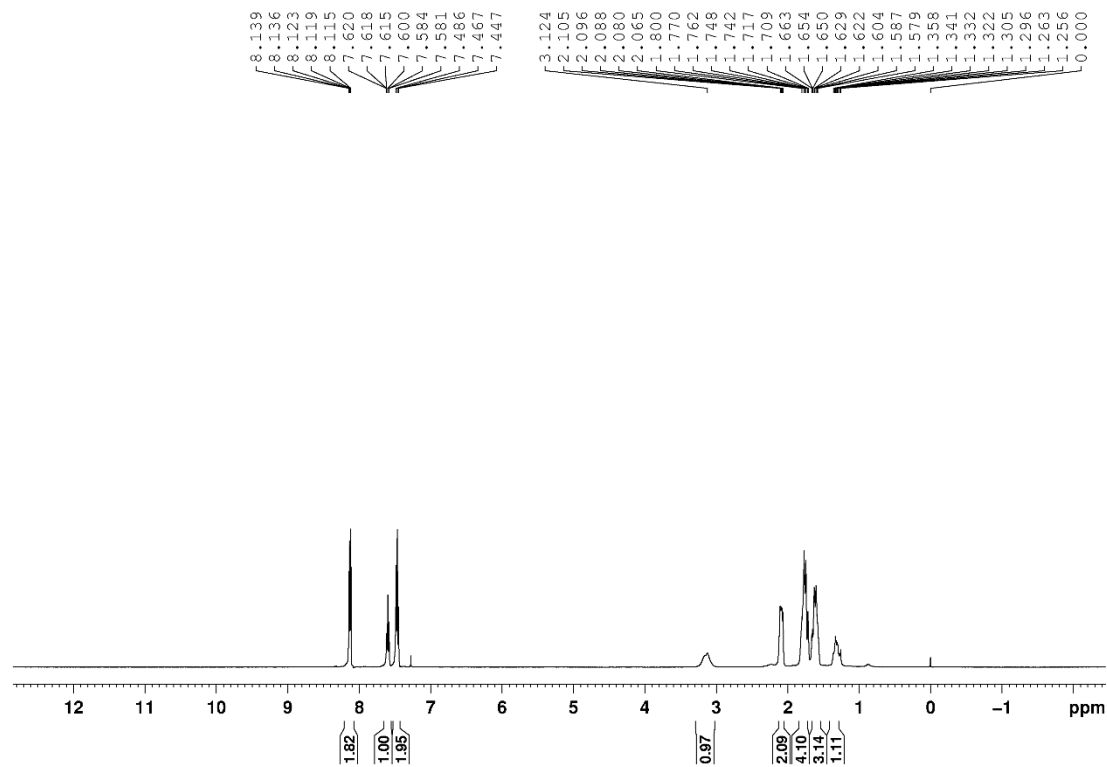
¹³C{H} NMR spectrum was recorded on 151 MHz in CDCl₃.



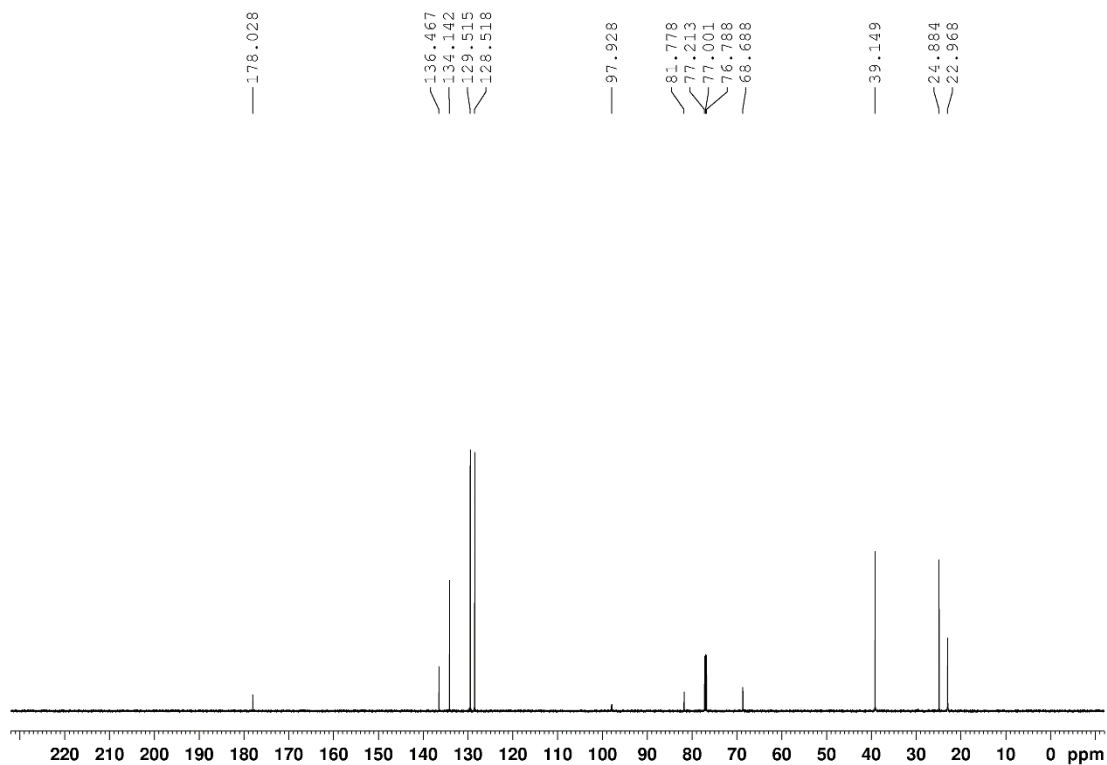


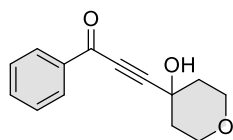
1bo

^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .



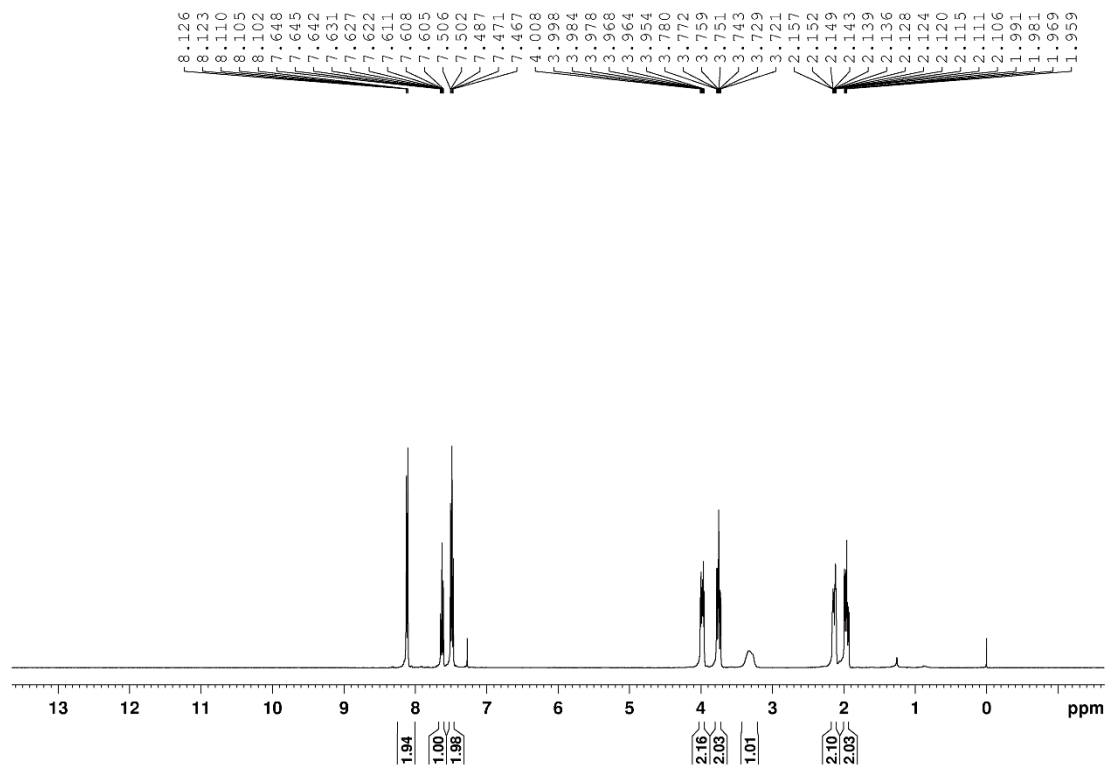
$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



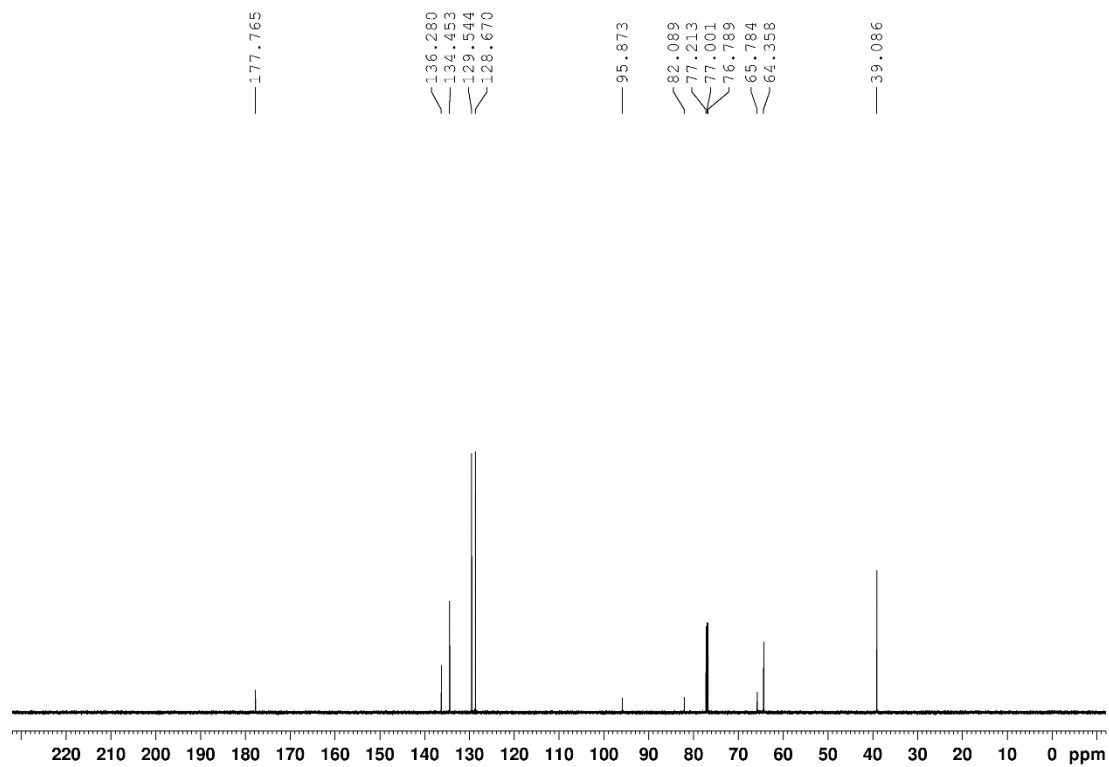


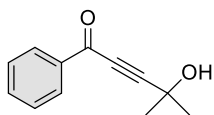
1bp

^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .



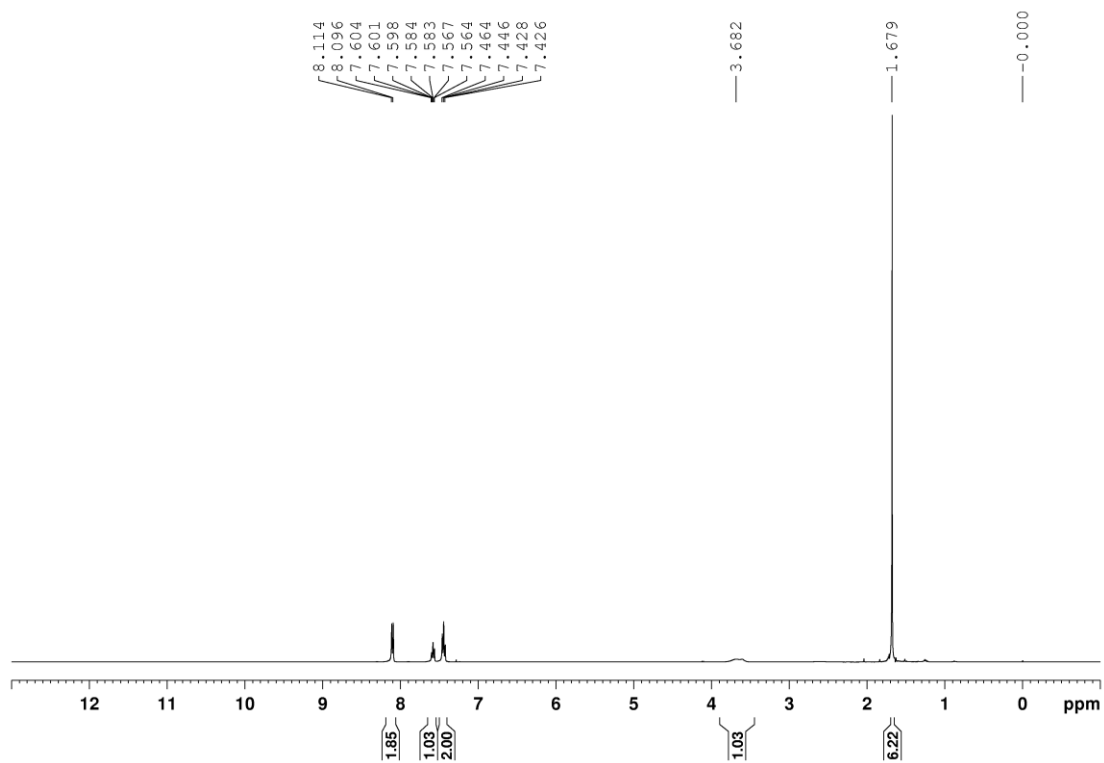
$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



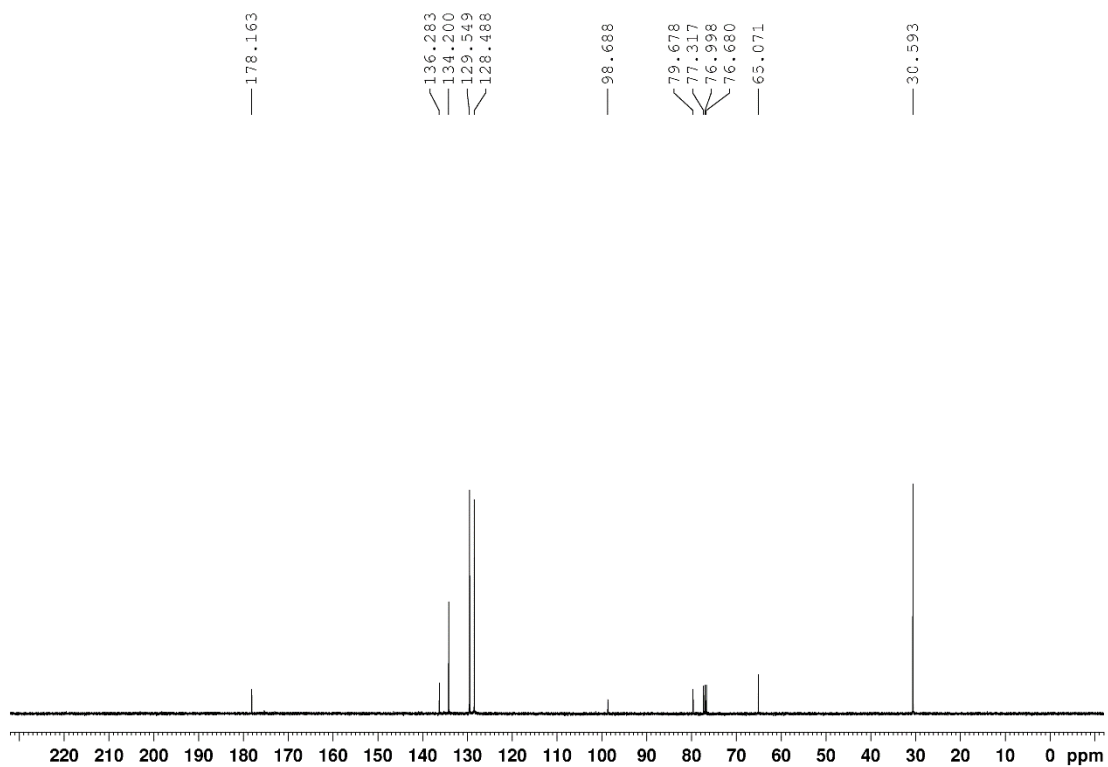


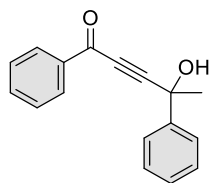
1bq

^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .



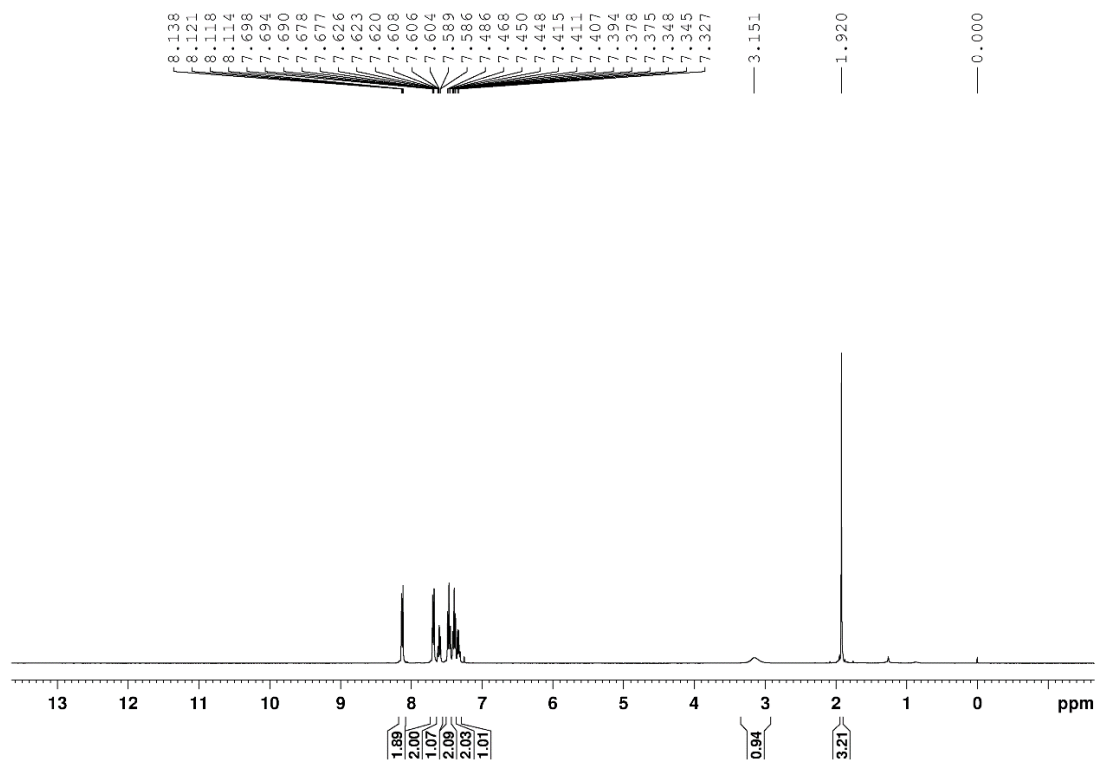
$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 100 MHz in CDCl_3 .



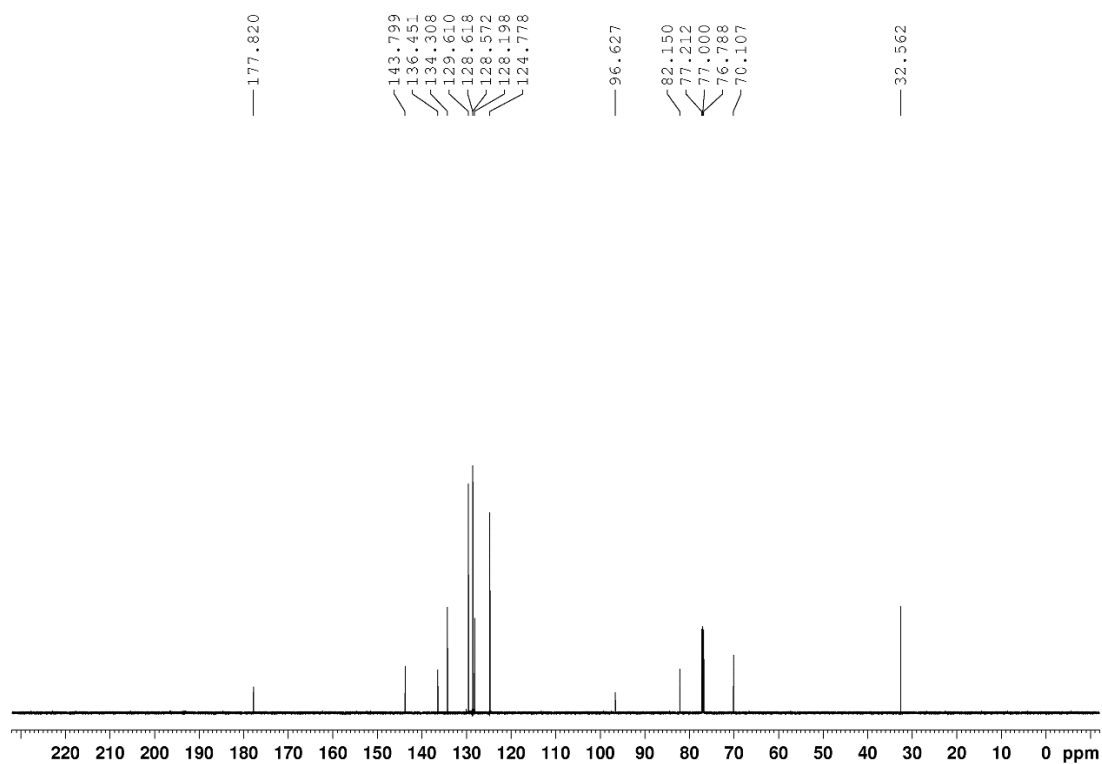


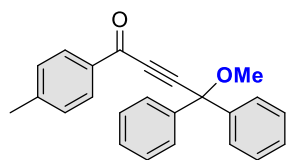
1b

^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .



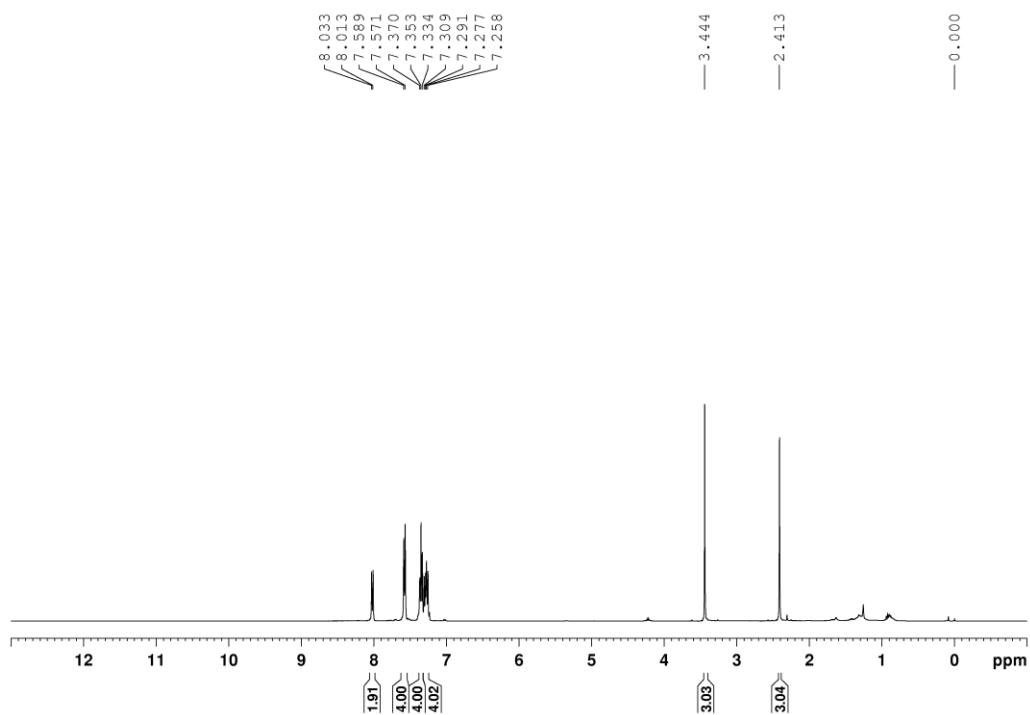
$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



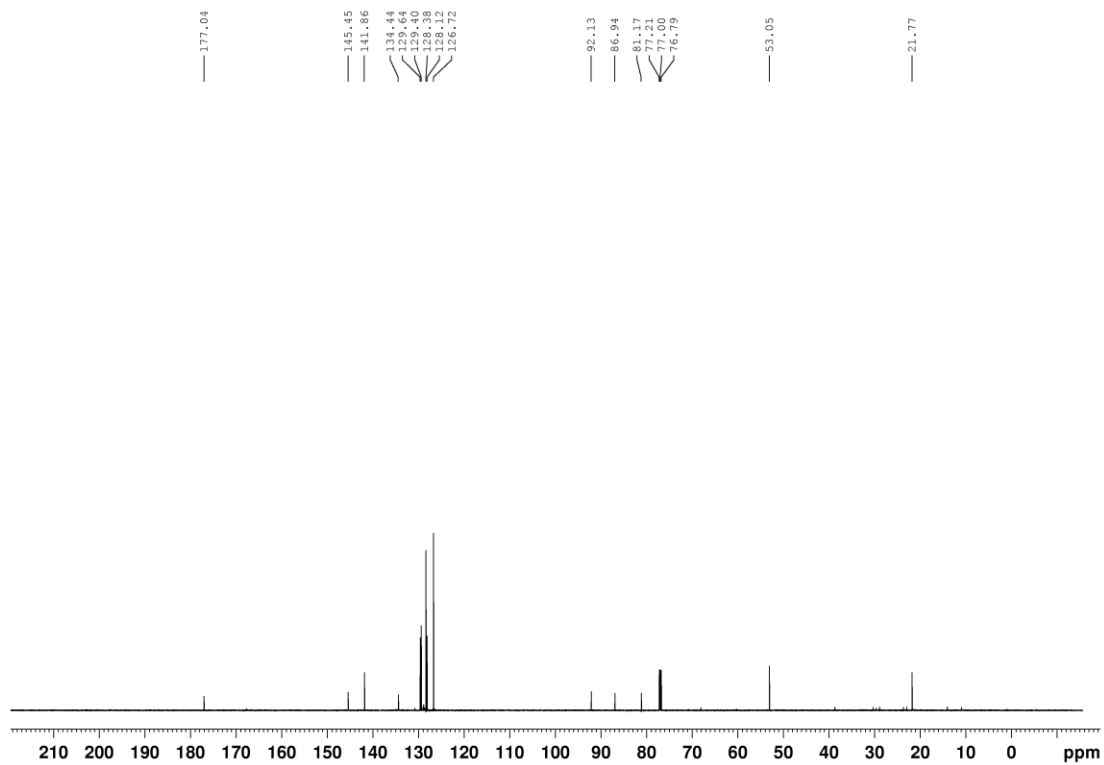


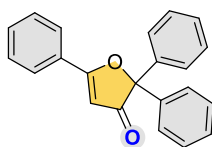
1ab-OMe

^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .



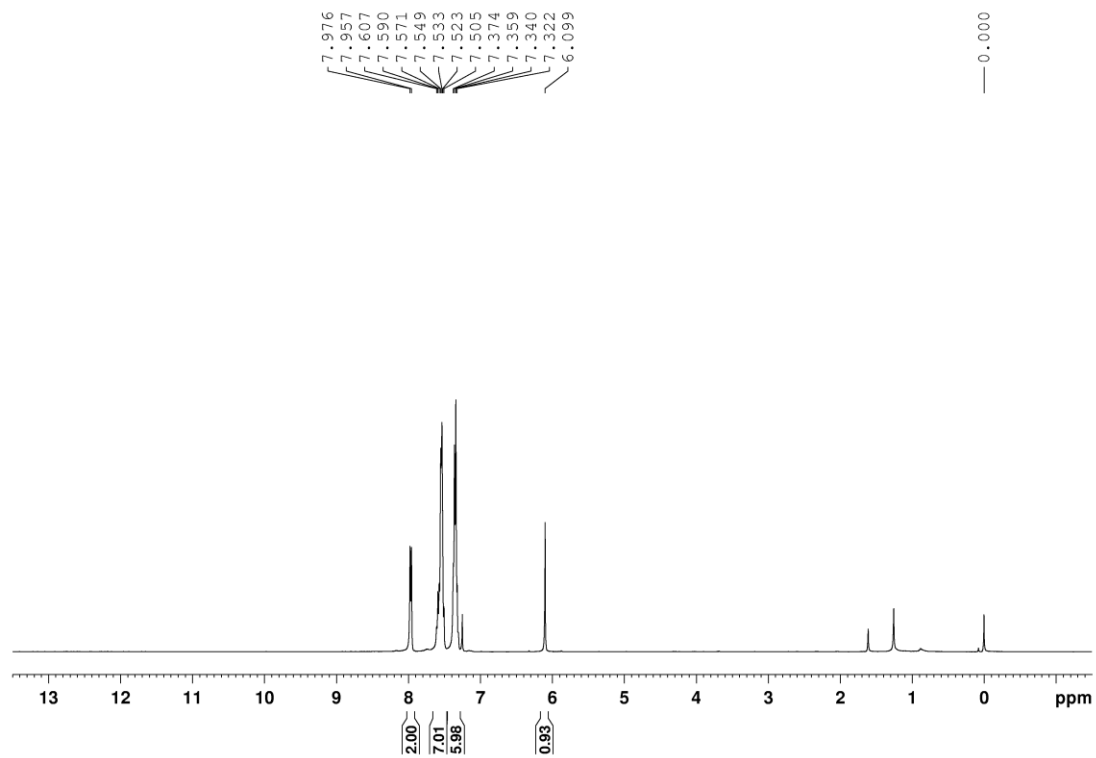
$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



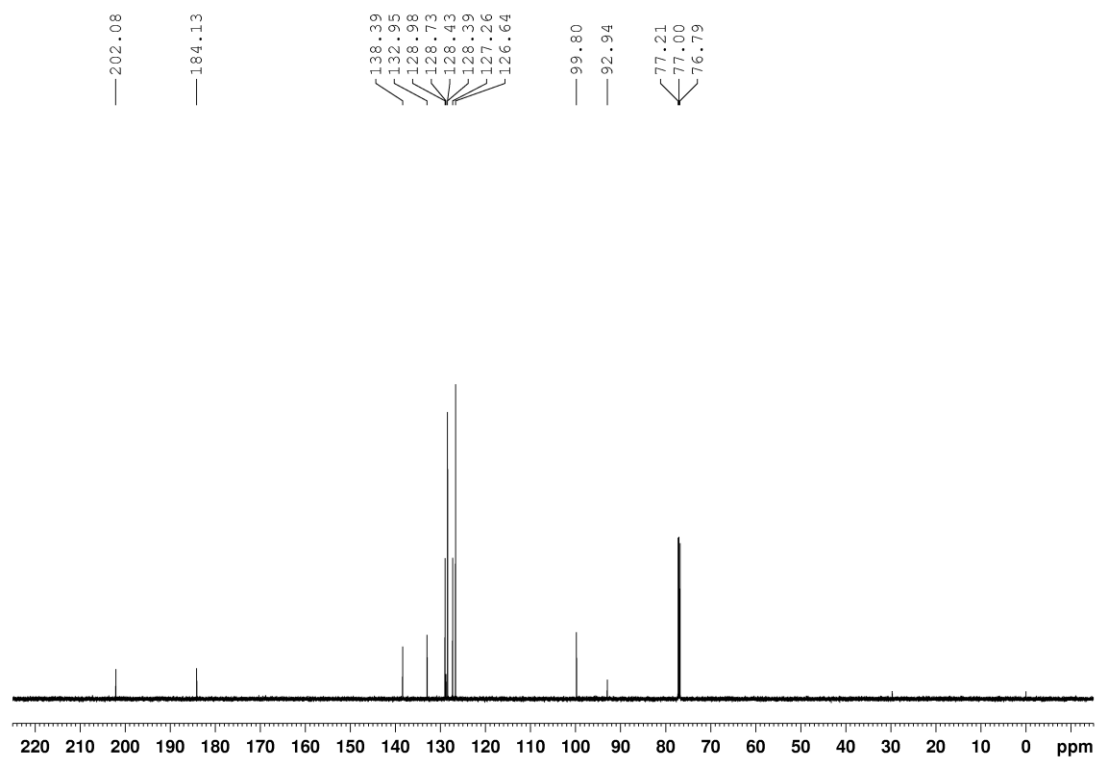


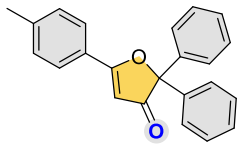
2aa

^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .



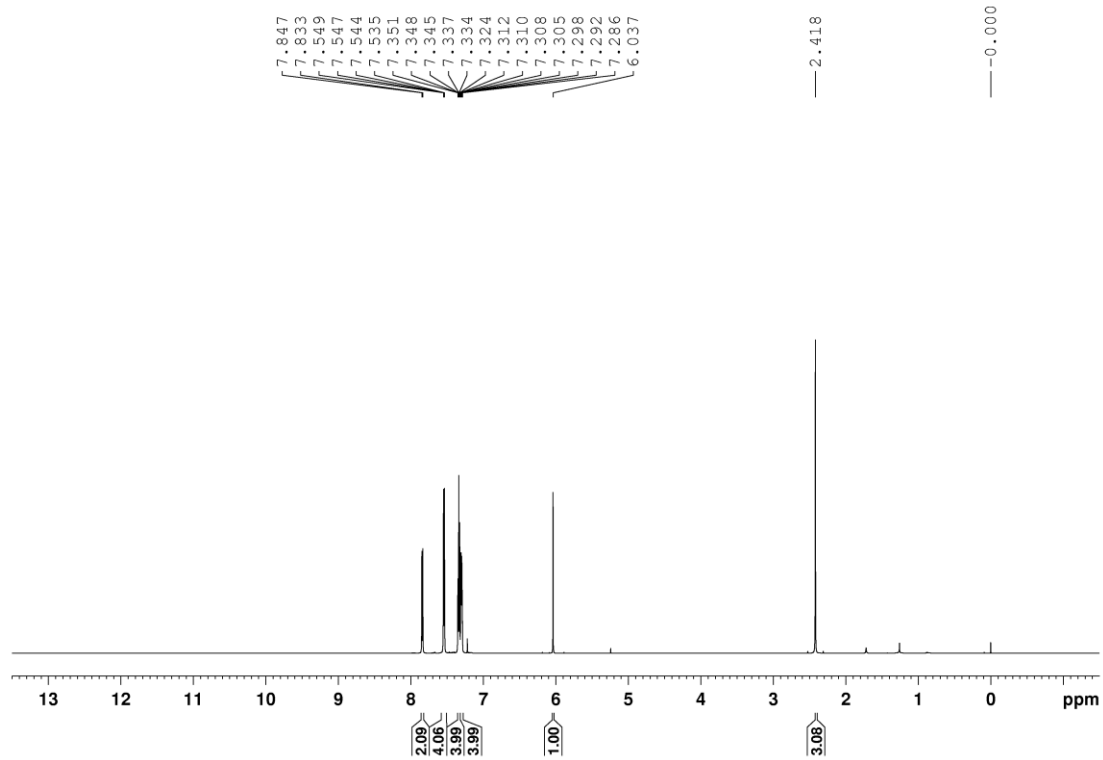
$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



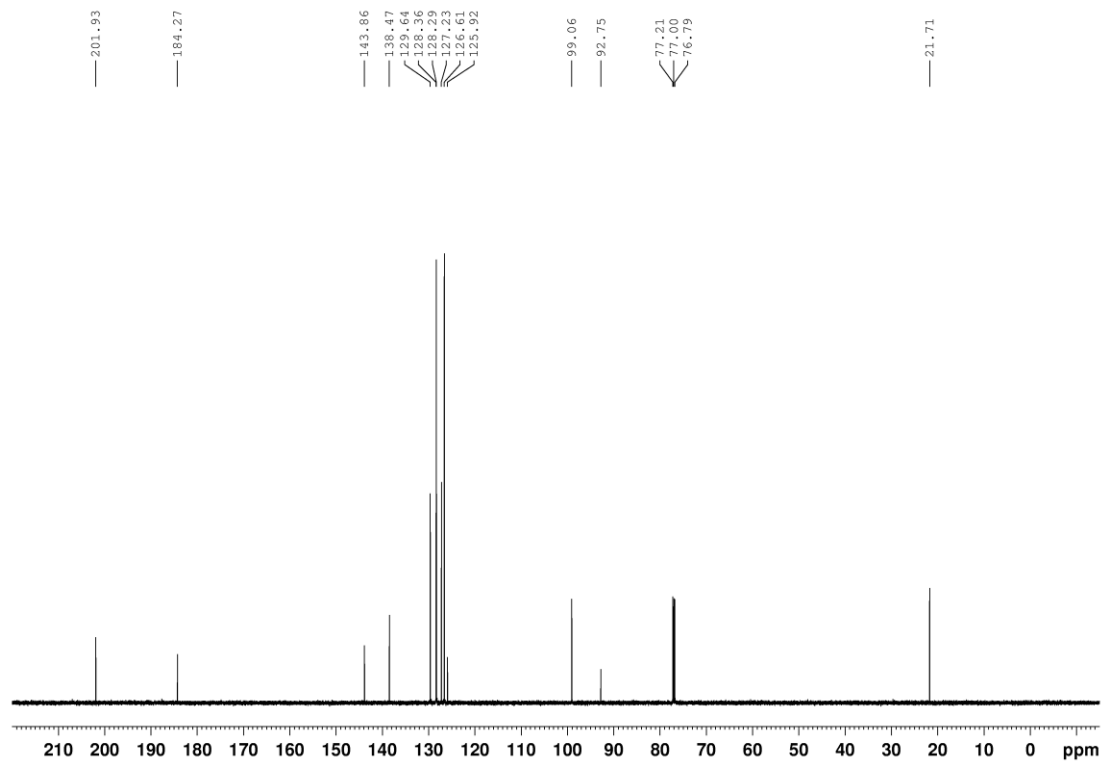


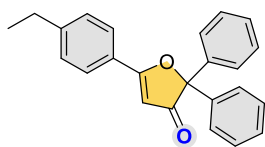
2ab

^1H NMR spectrum was recorded on 600 MHz in CDCl_3 .



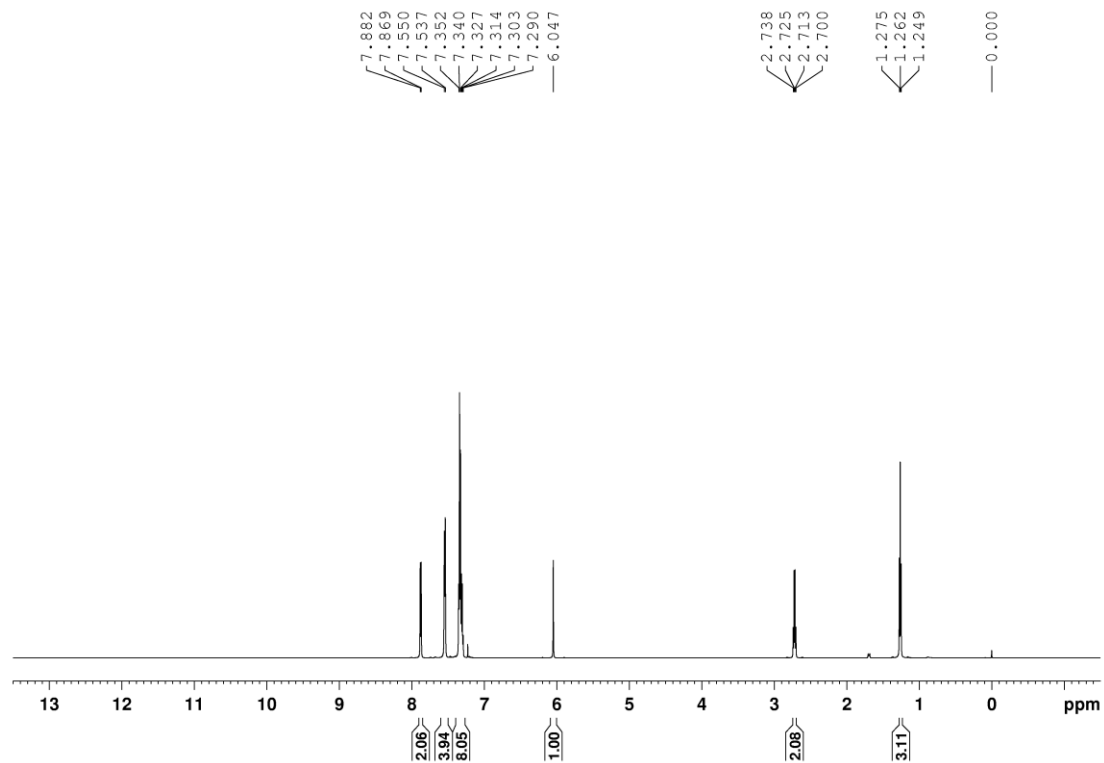
$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



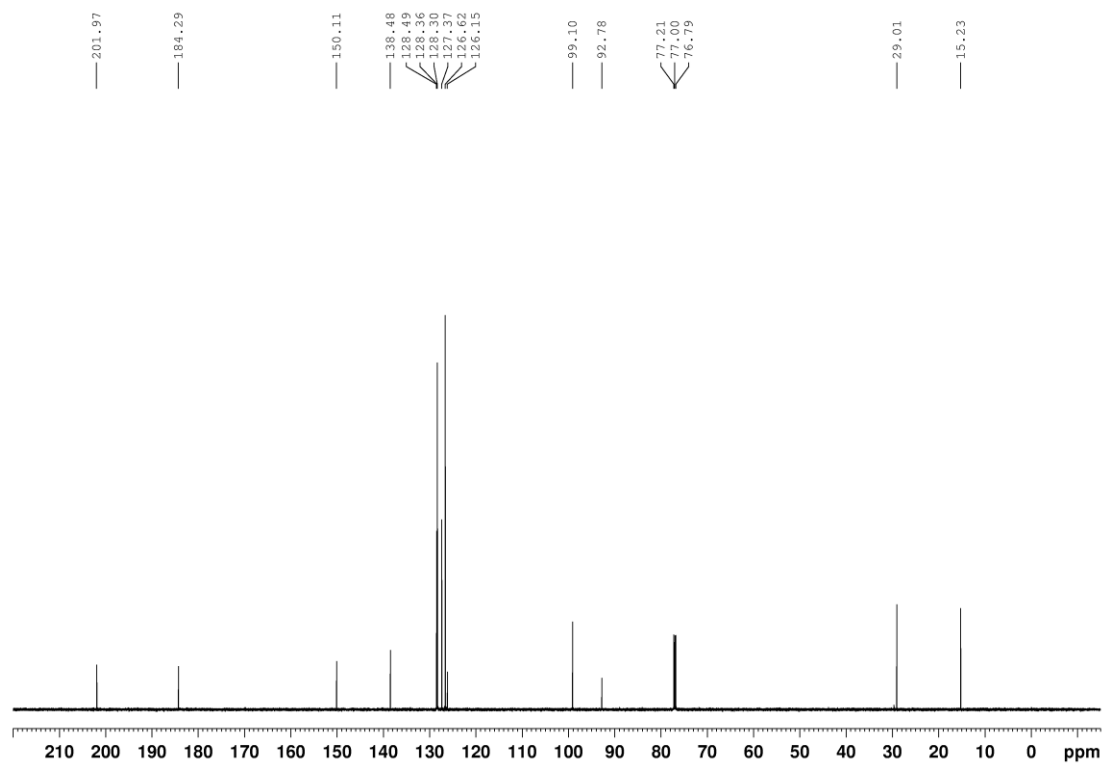


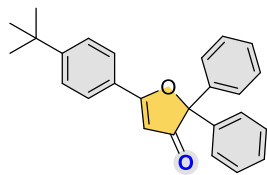
2ac

^1H NMR spectrum was recorded on 600 MHz in CDCl_3 .



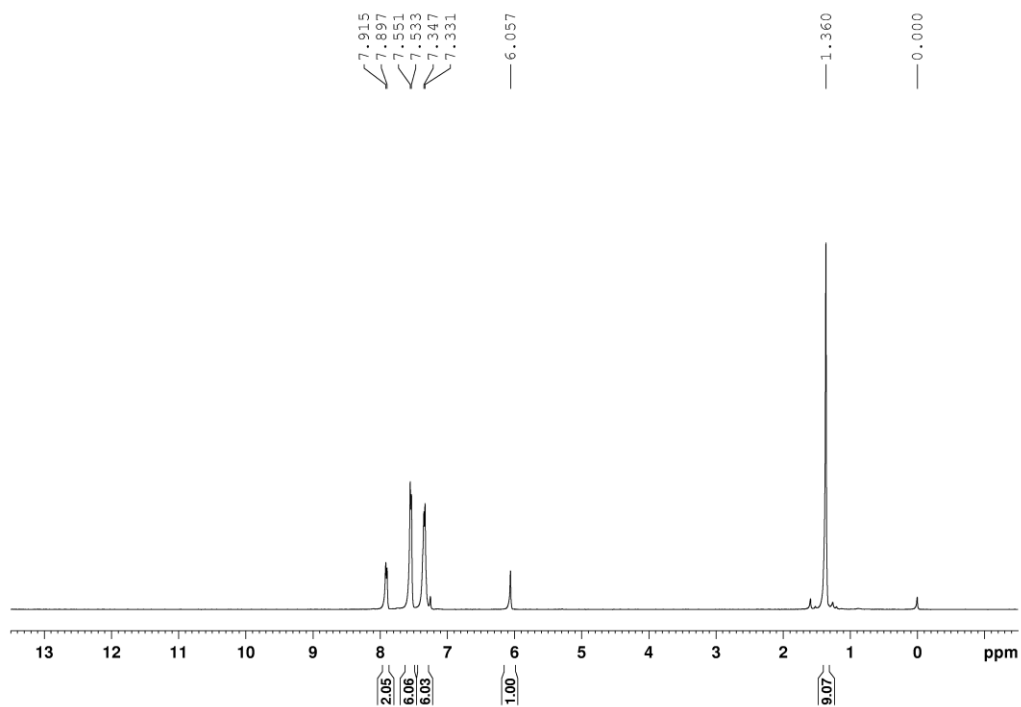
$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



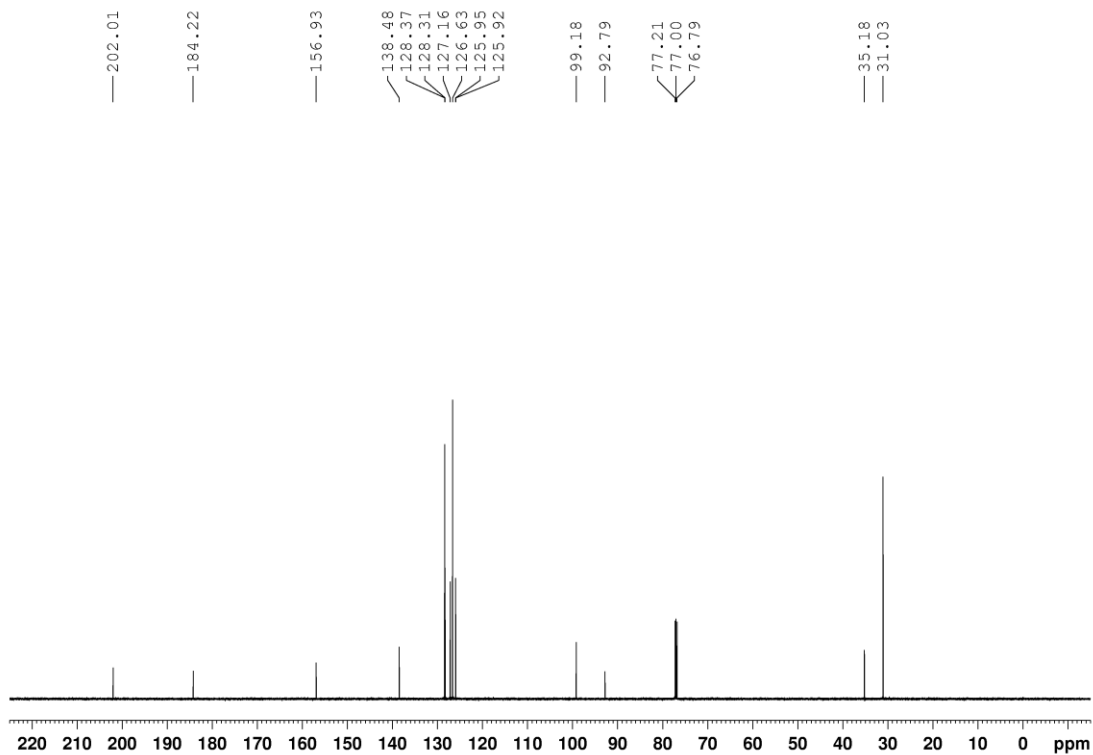


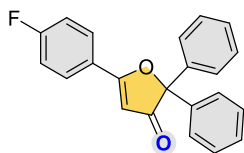
2ad

^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .



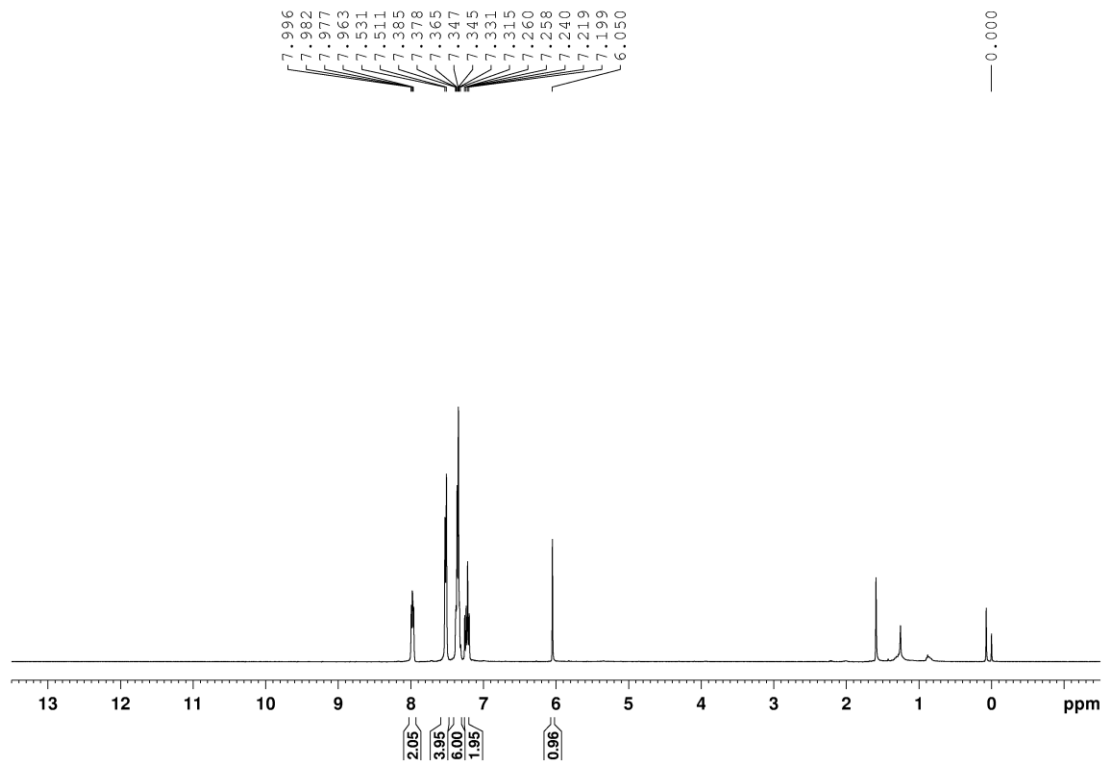
$^{13}\text{C}\{\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



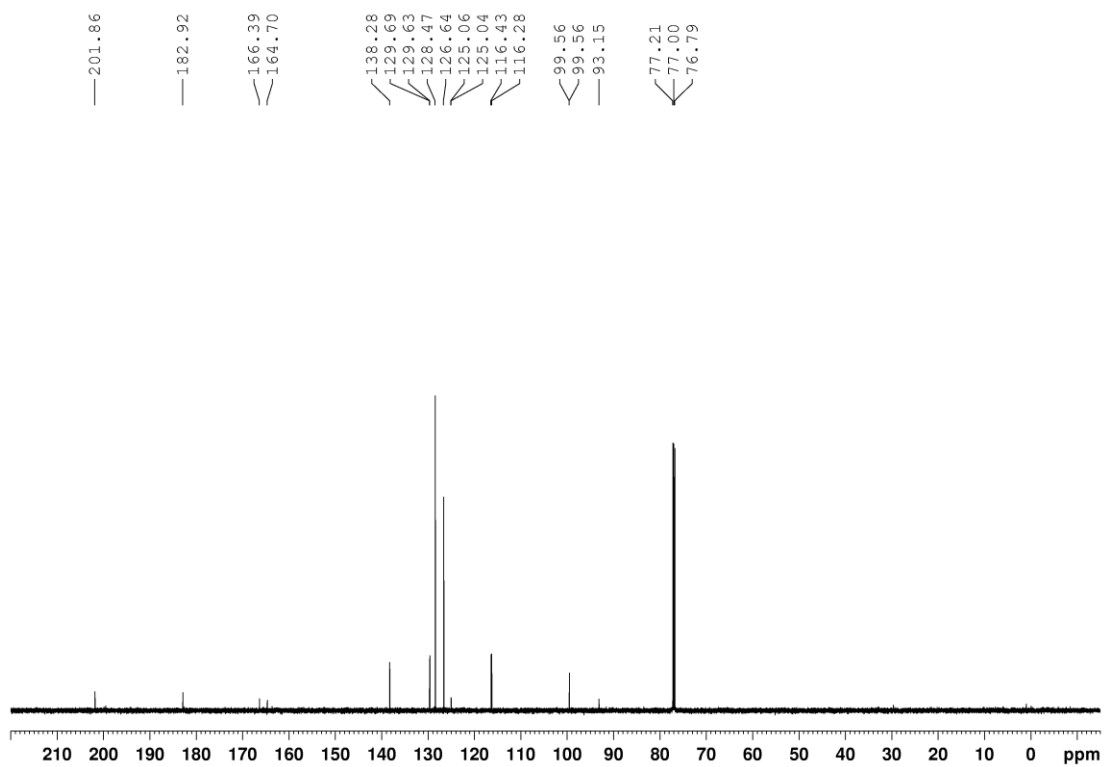


2ae

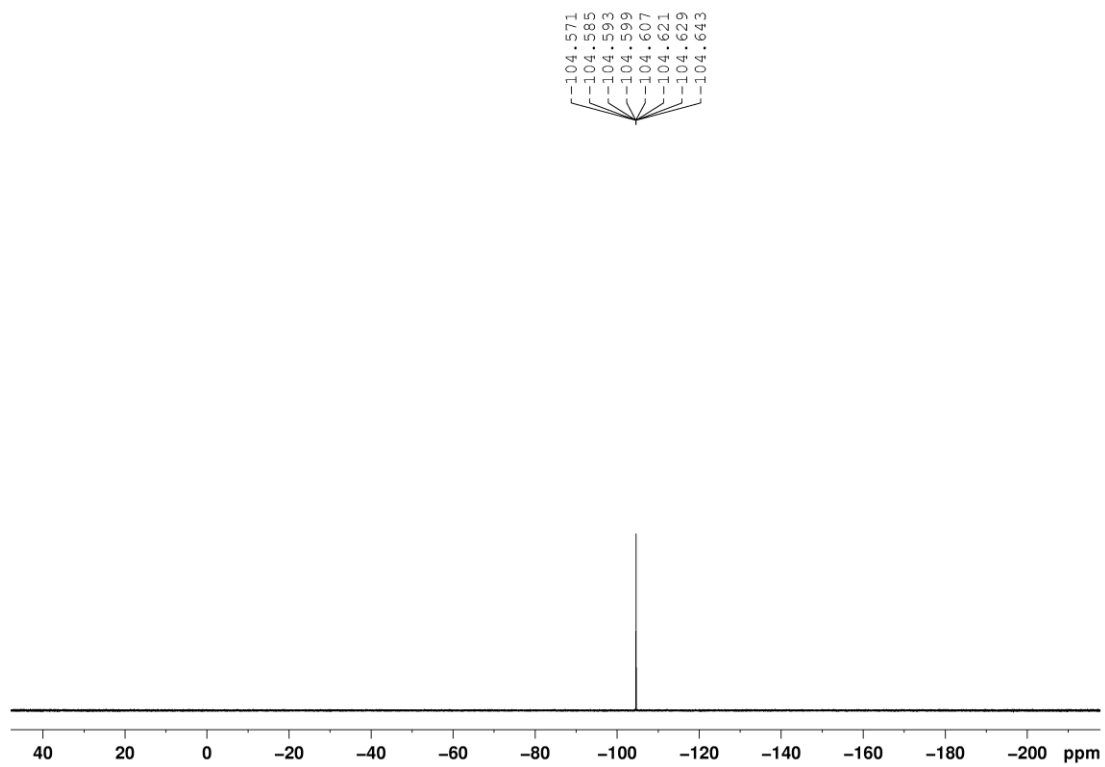
¹H NMR spectrum was recorded on 400 MHz in CDCl₃.

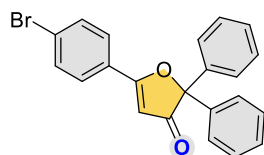


¹³C{¹H} NMR spectrum was recorded on 151 MHz in CDCl₃.



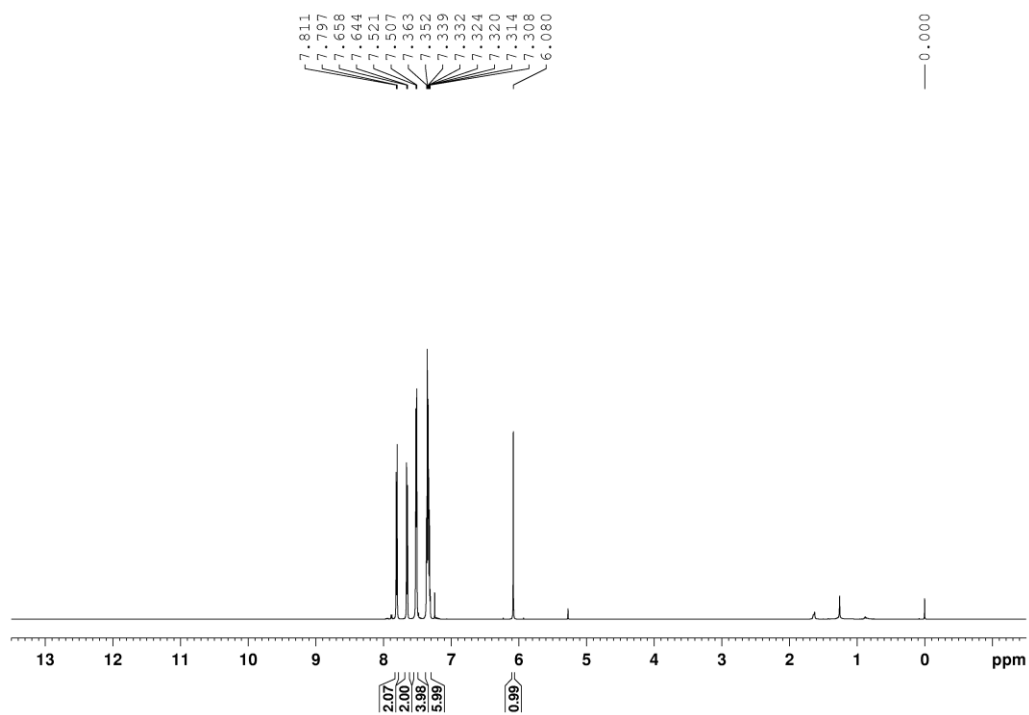
¹⁹F spectrum was recorded on 376 MHz in CDCl₃.



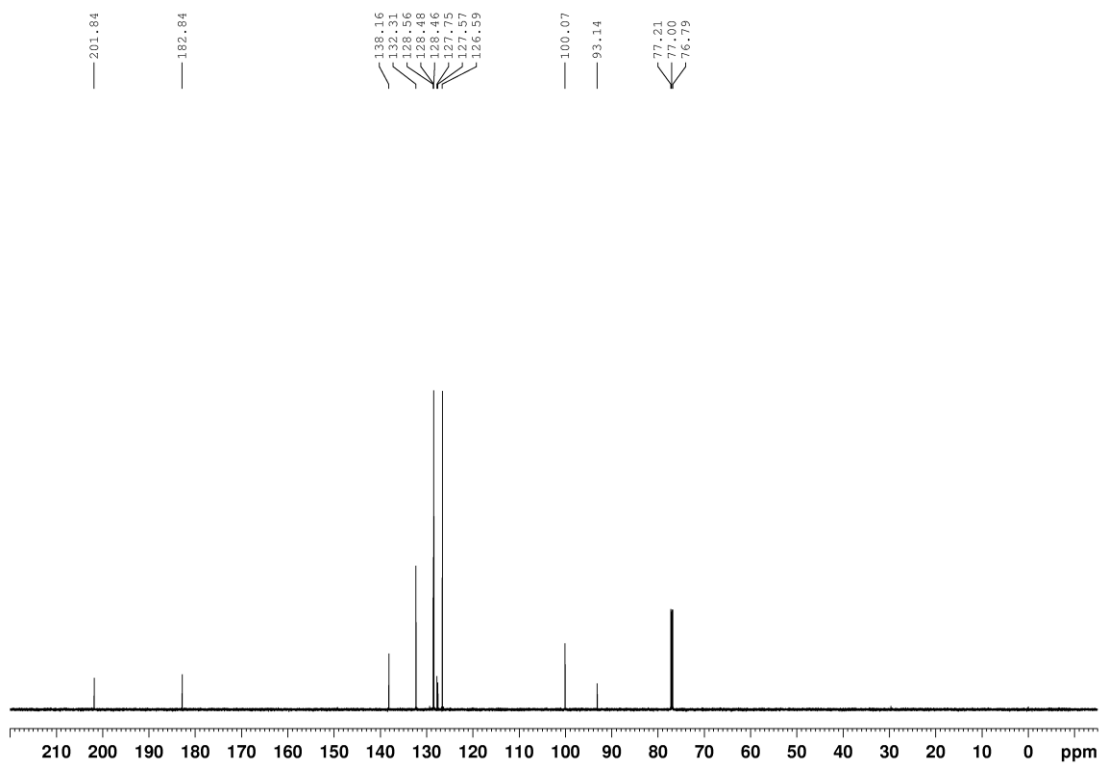


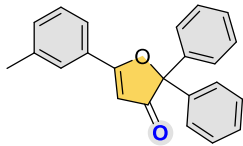
2af

^1H NMR spectrum was recorded on 600 MHz in CDCl_3 .



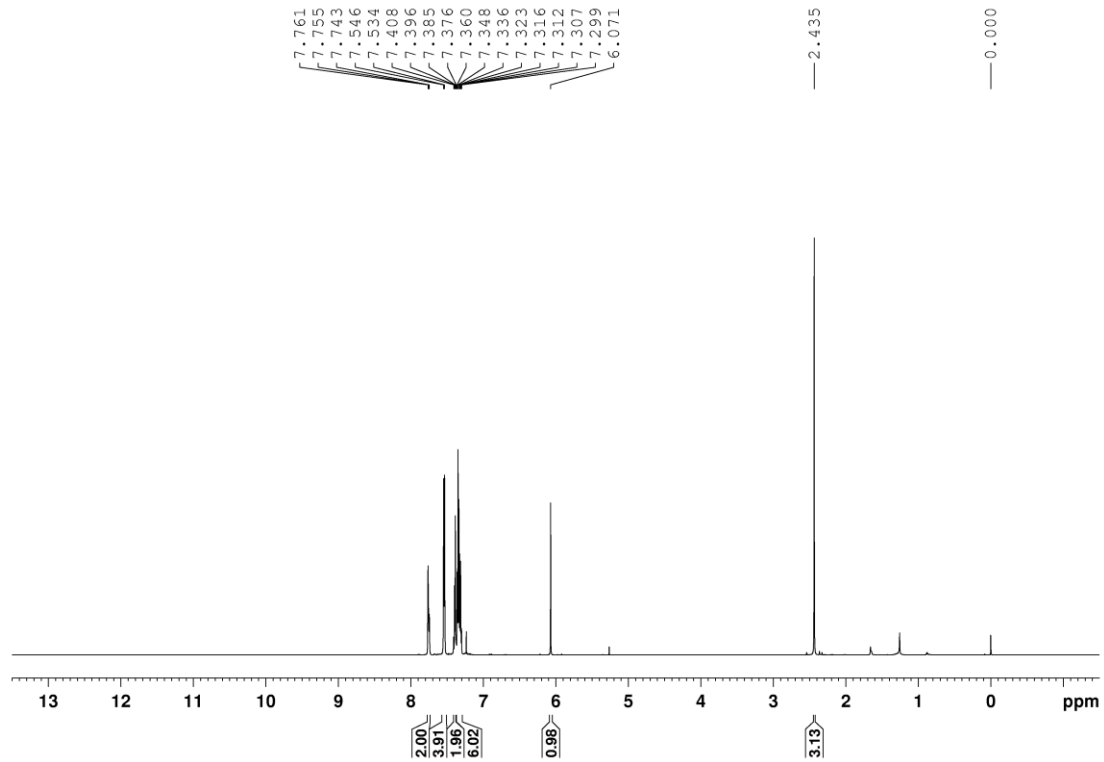
$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



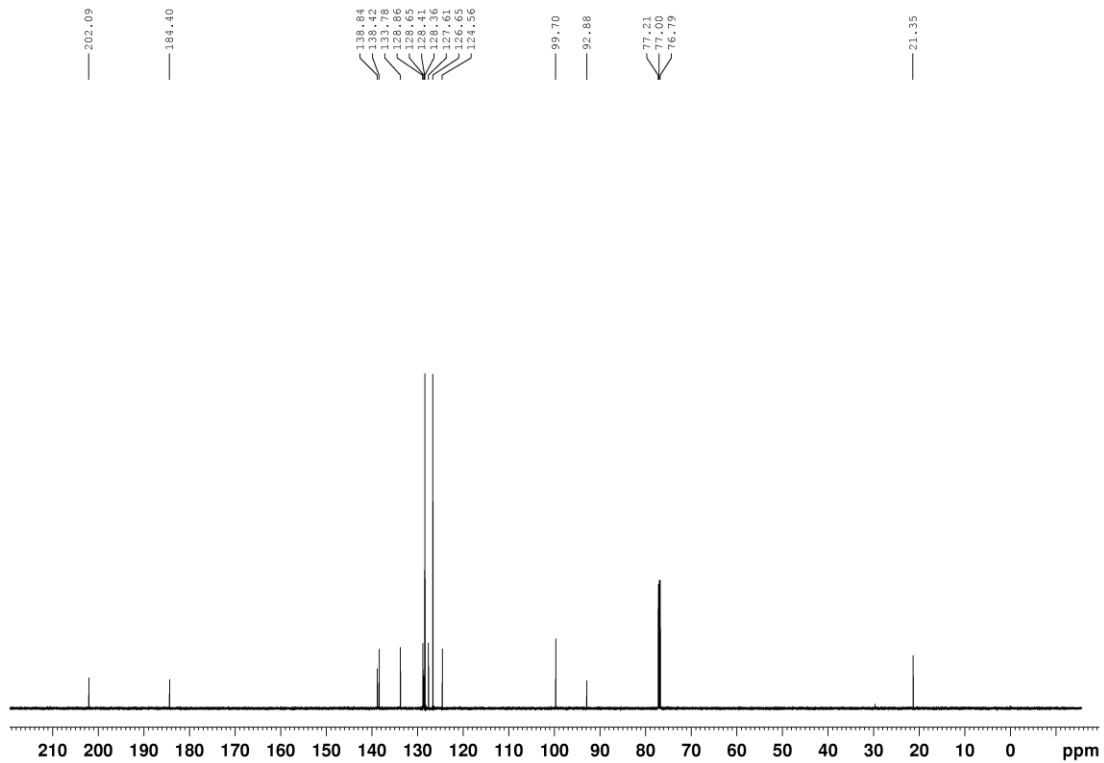


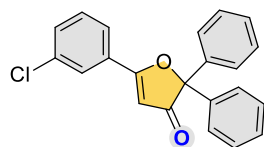
2ag

^1H NMR spectrum was recorded on 600 MHz in CDCl_3 .



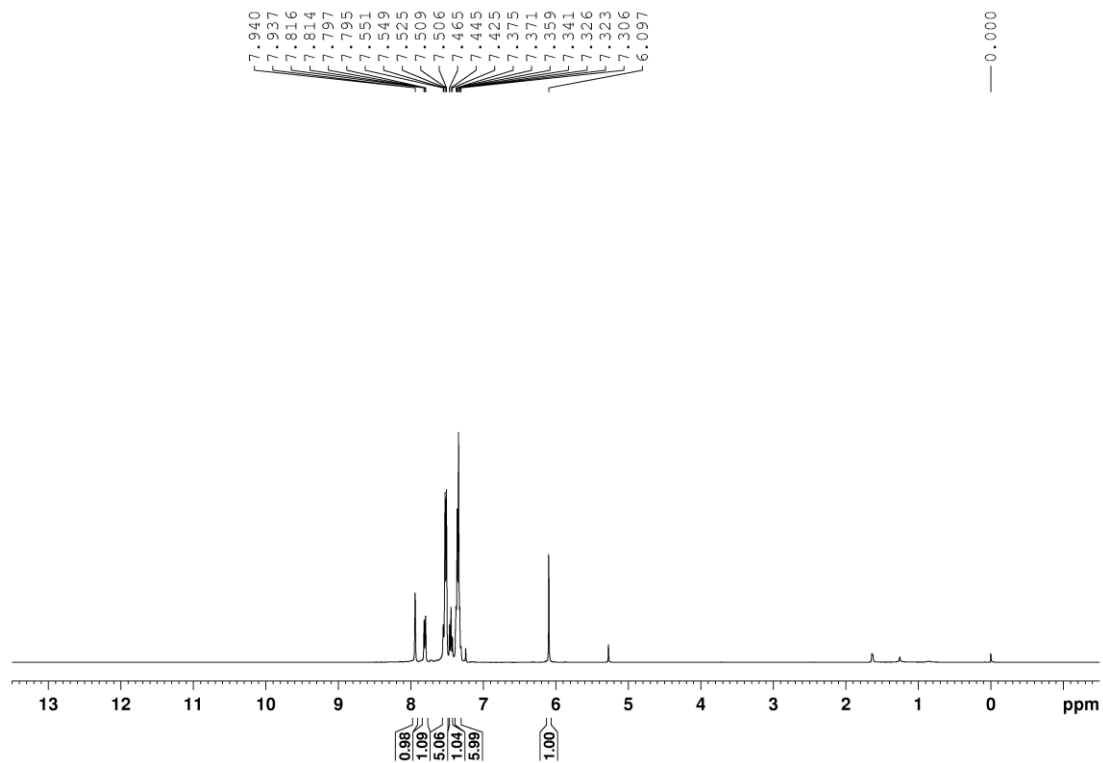
$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



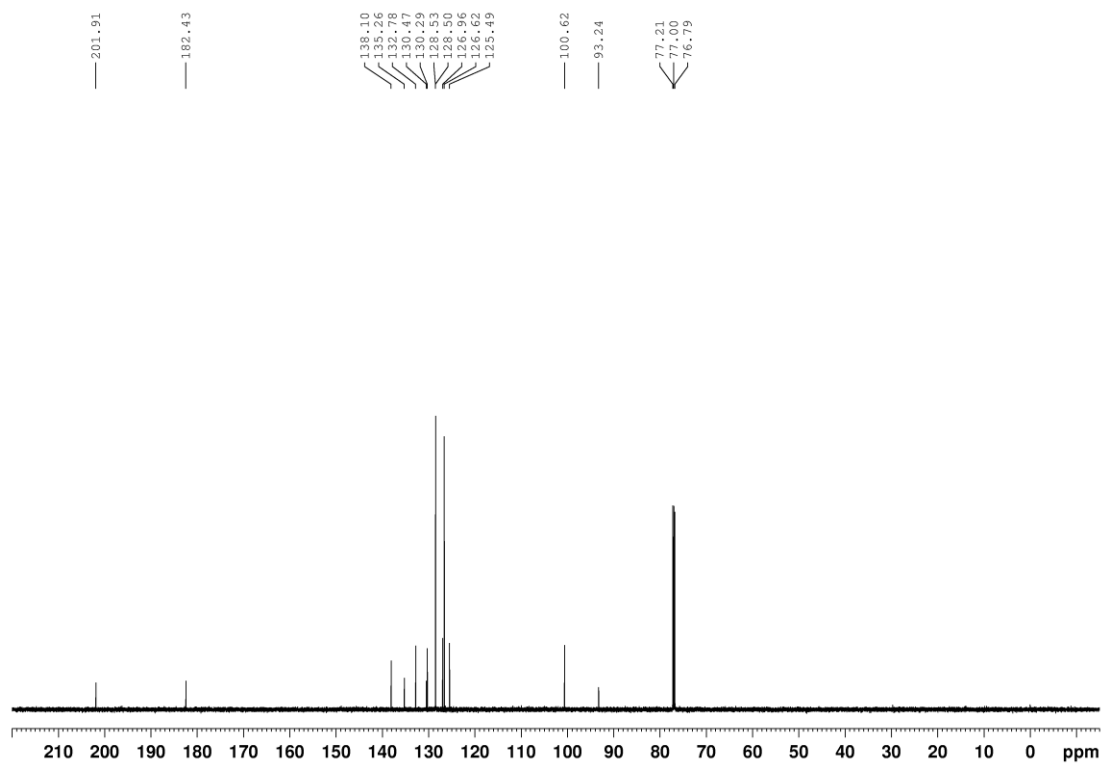


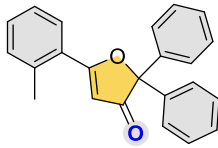
2ah

^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .



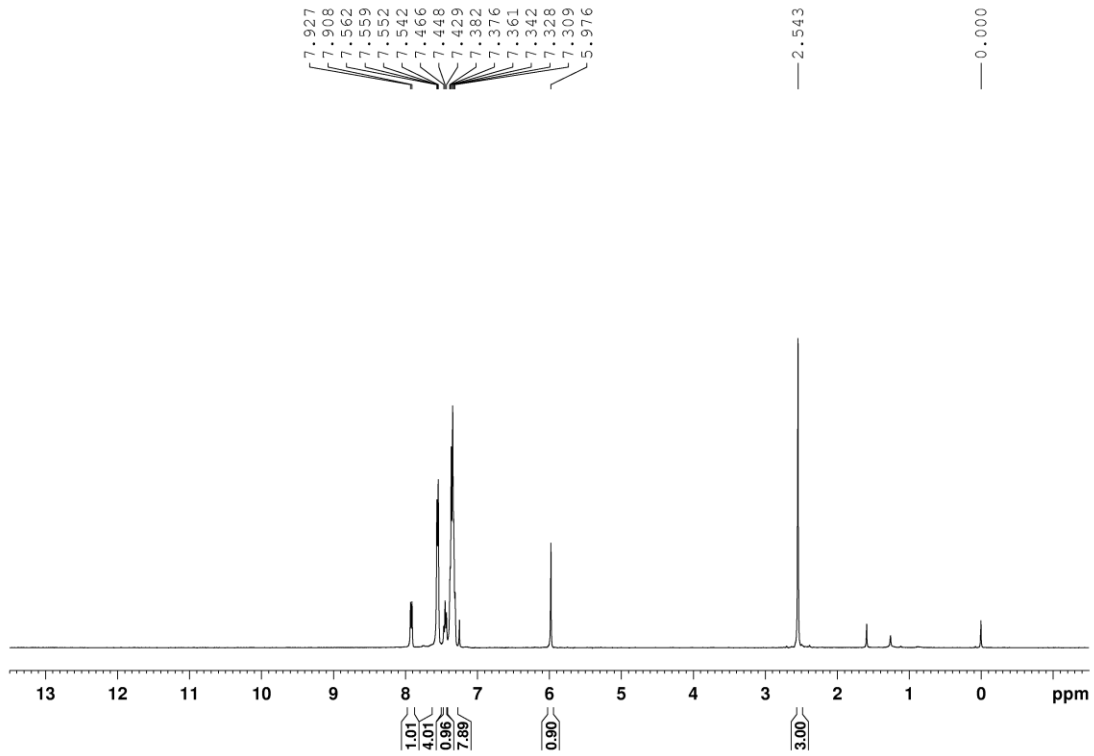
$^{13}\text{C}\{\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



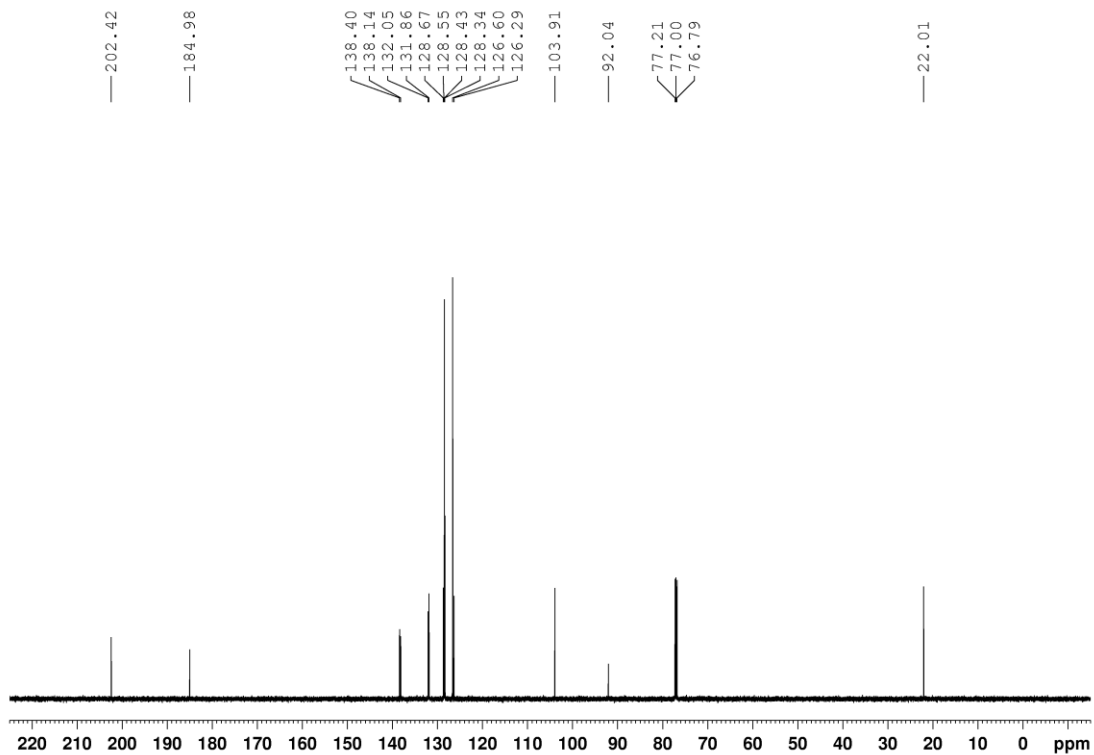


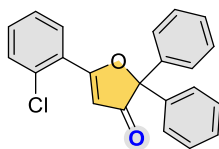
2ai

^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .



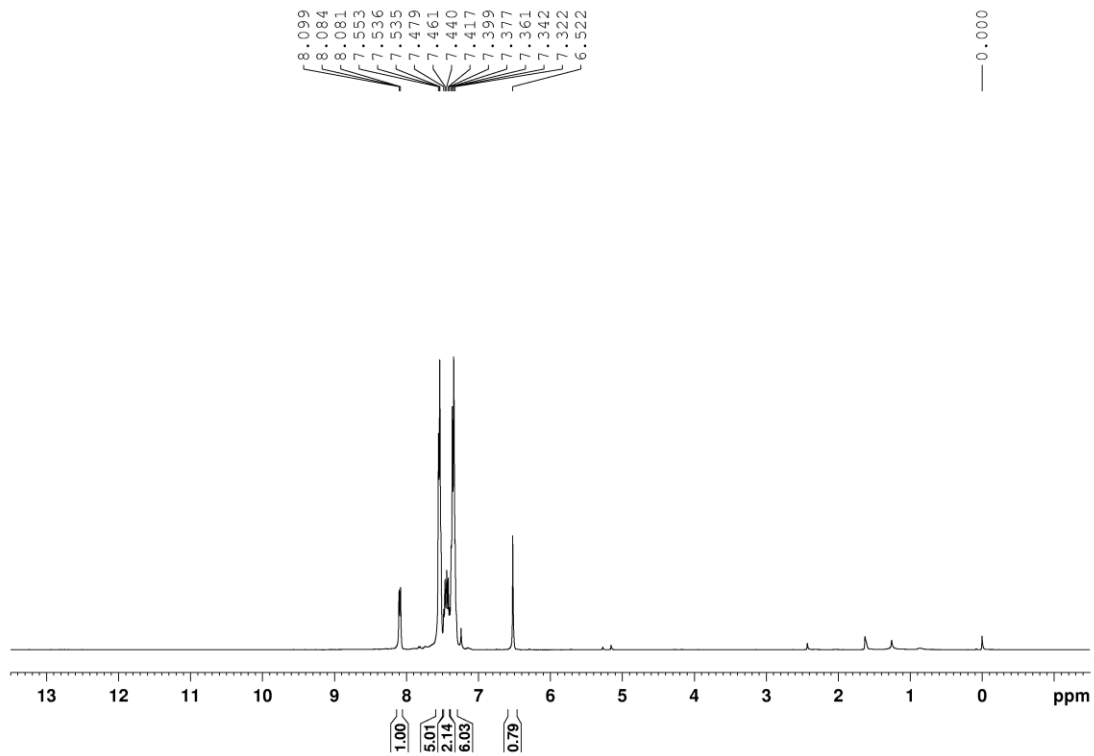
$^{13}\text{C}\{\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



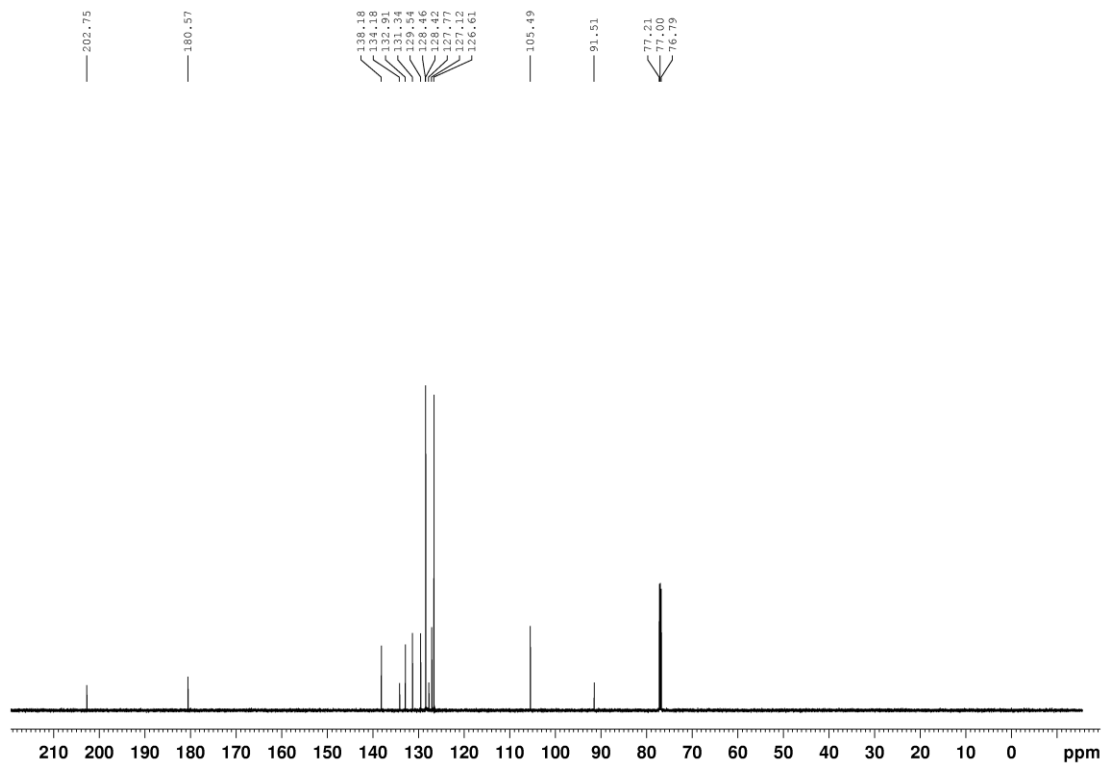


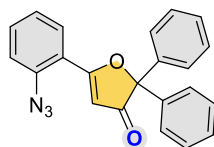
2aj

^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .



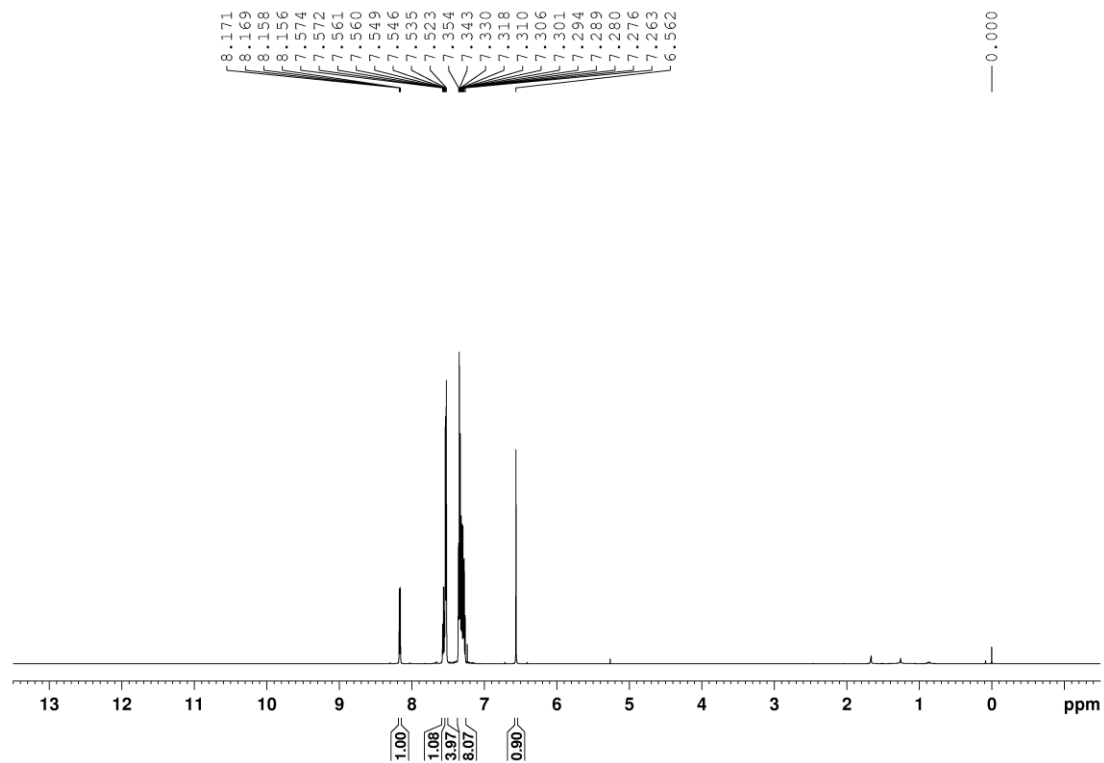
$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



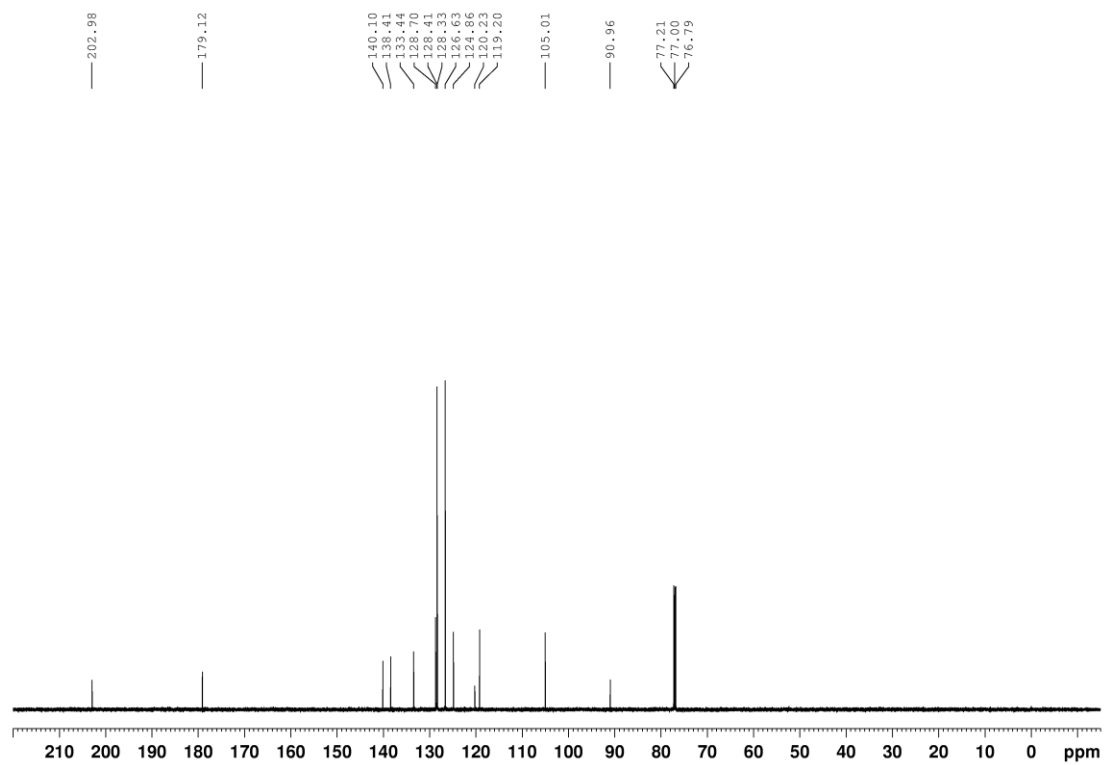


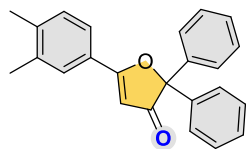
2ak

^1H NMR spectrum was recorded on 600 MHz in CDCl_3 .



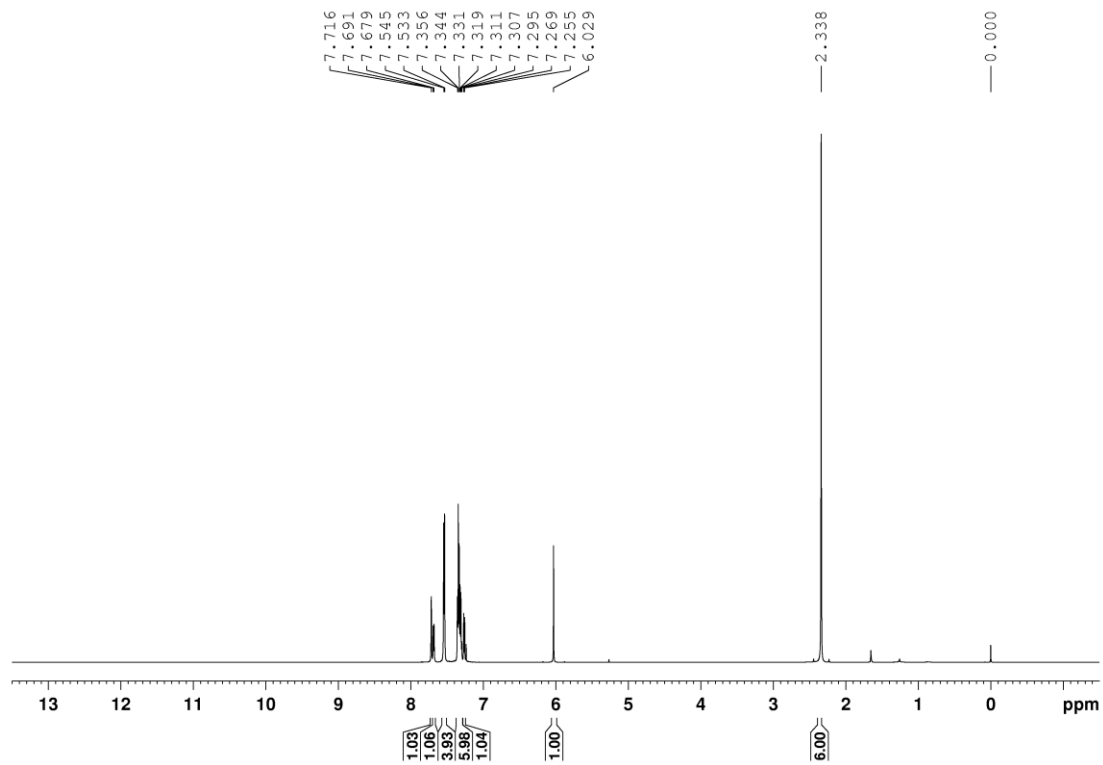
$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



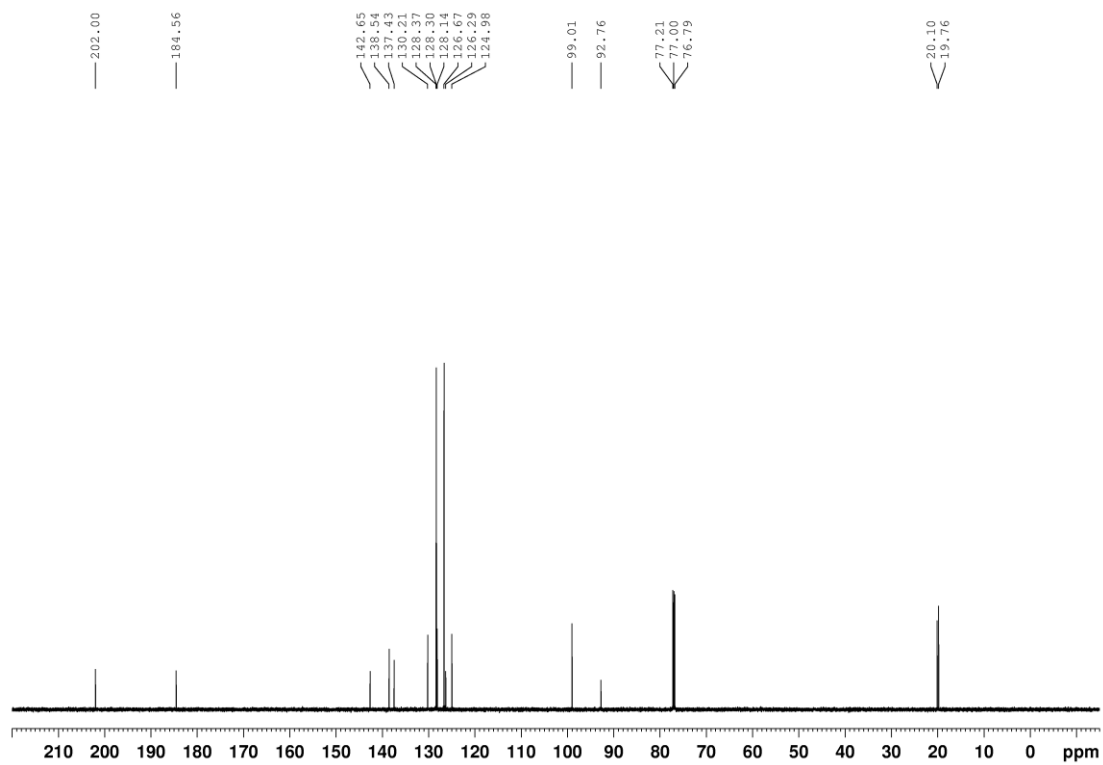


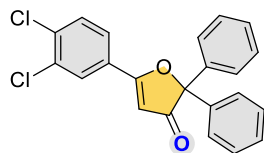
2aI

^1H NMR spectrum was recorded on 600 MHz in CDCl_3 .



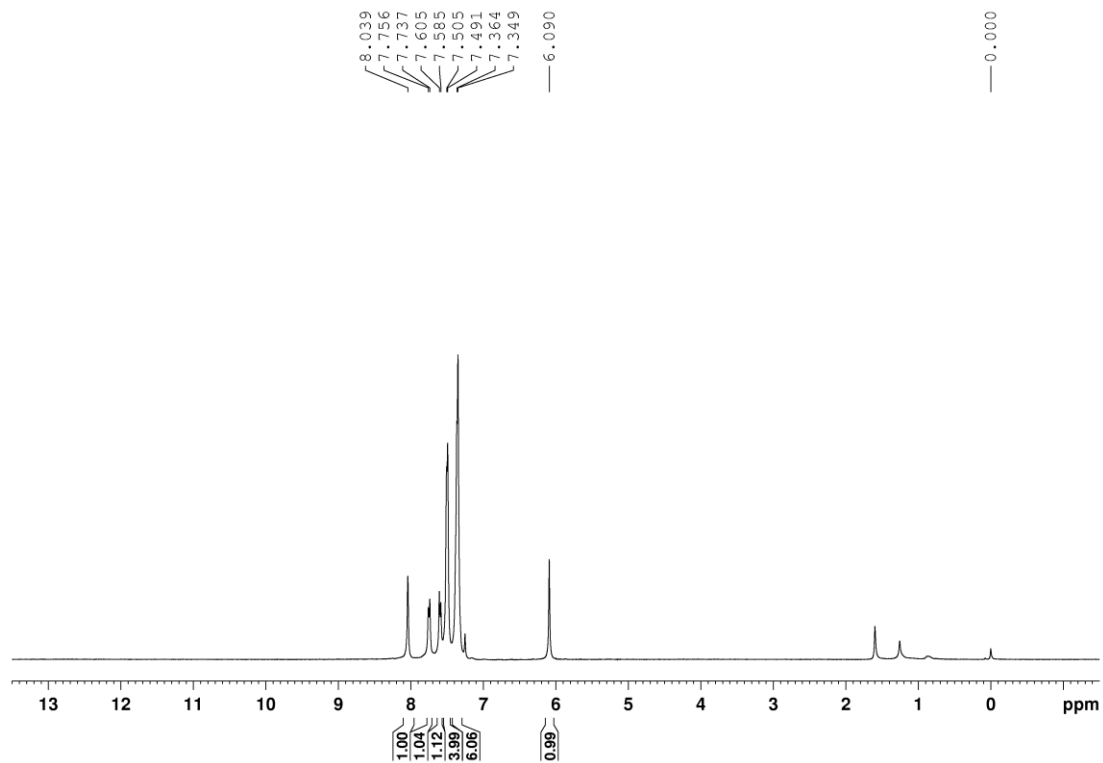
$^{13}\text{C}\{\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



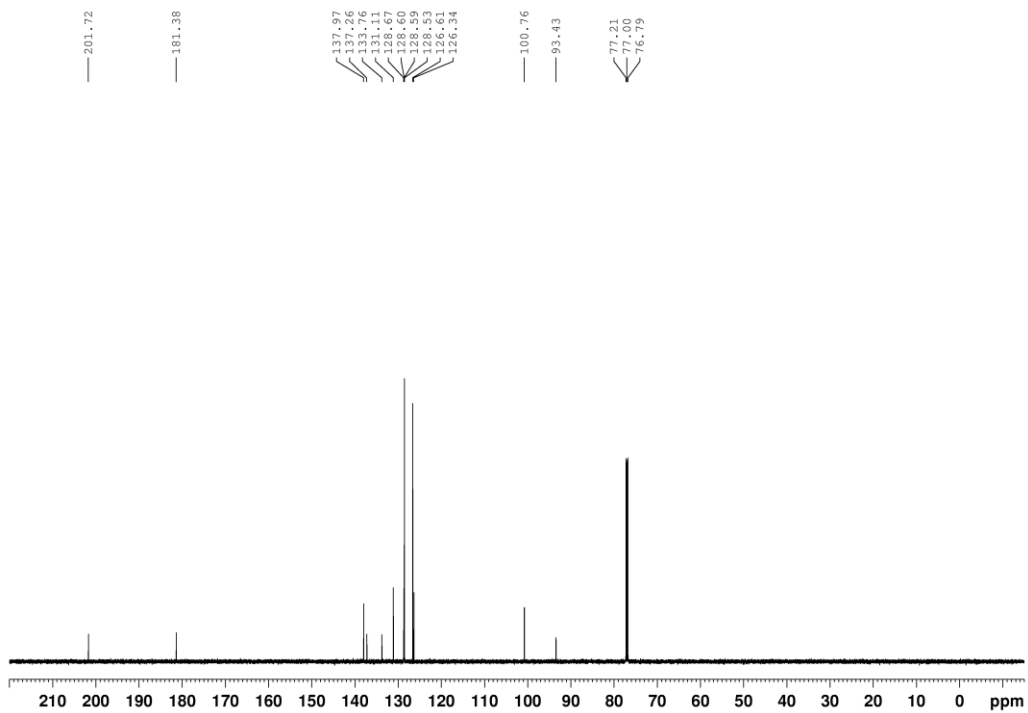


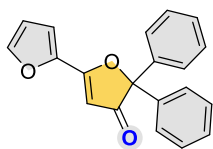
2am

^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .



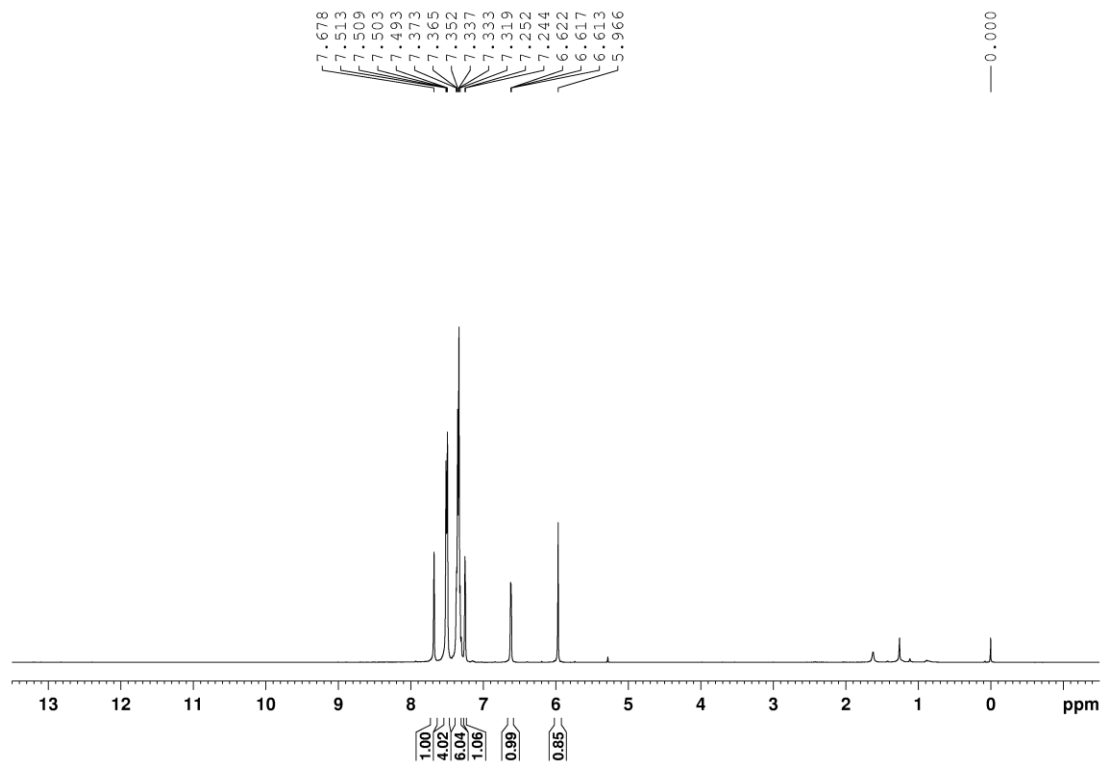
$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



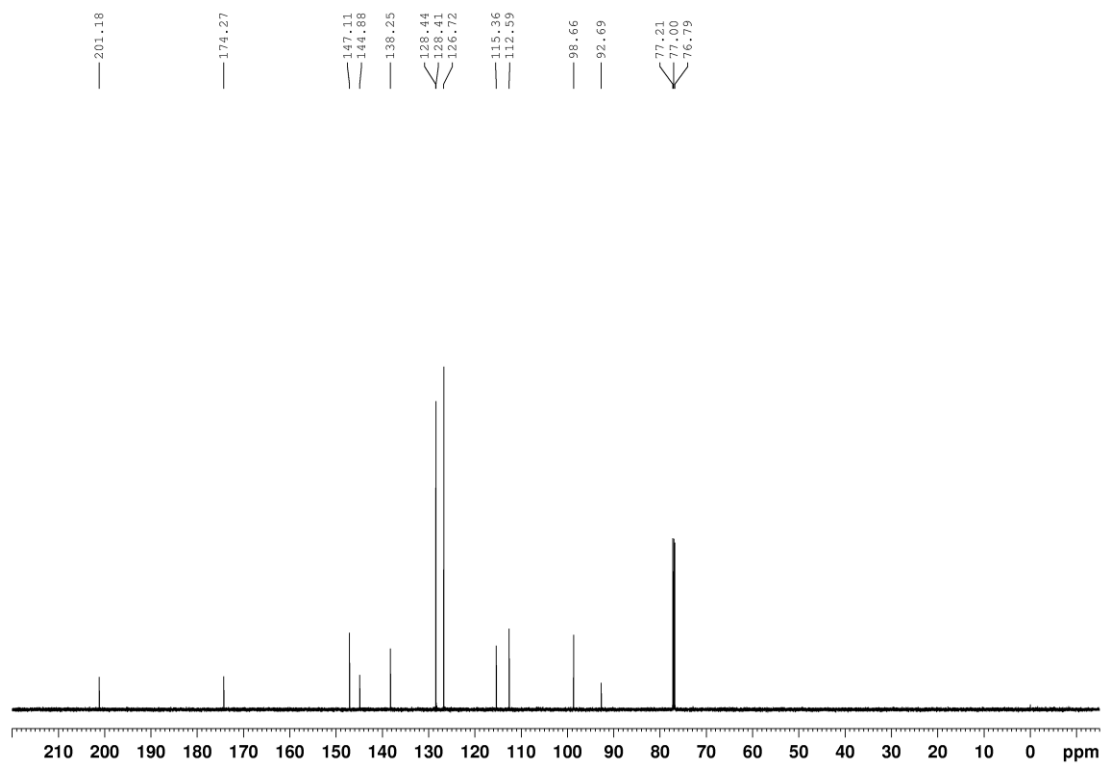


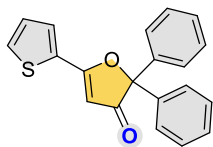
2an

¹H NMR spectrum was recorded on 400 MHz in CDCl₃.



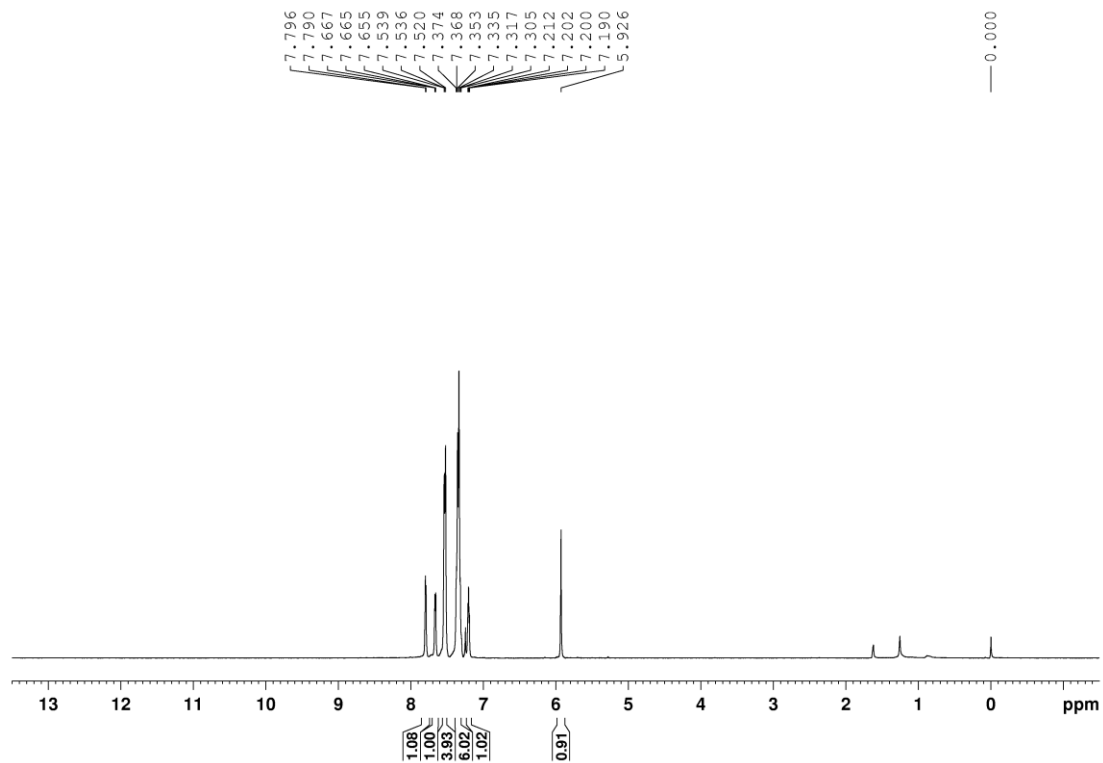
¹³C{¹H} NMR spectrum was recorded on 151 MHz in CDCl₃.



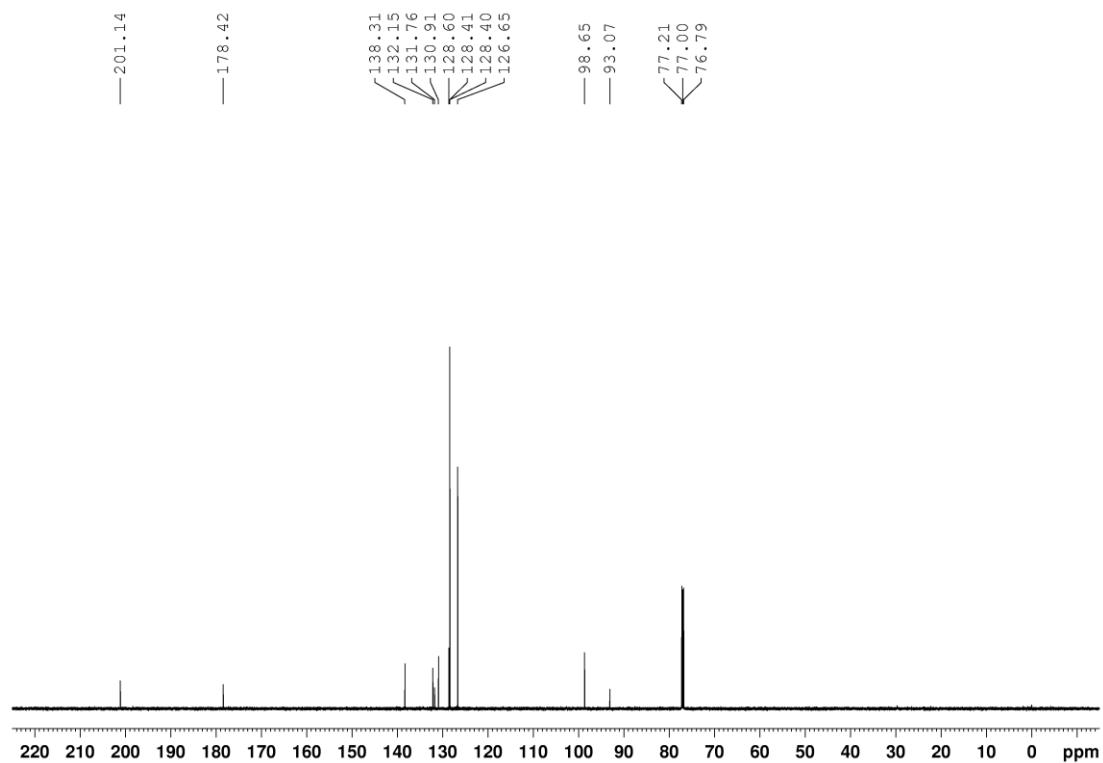


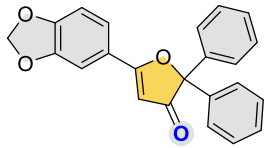
2ao

^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .



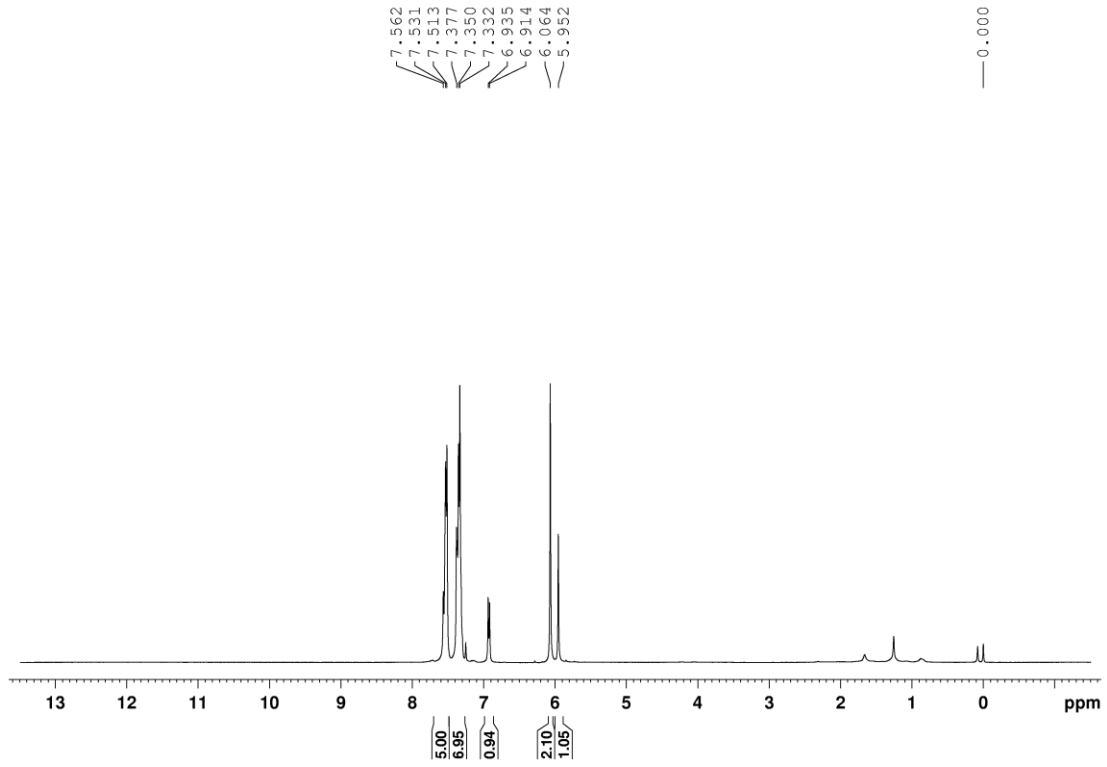
$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



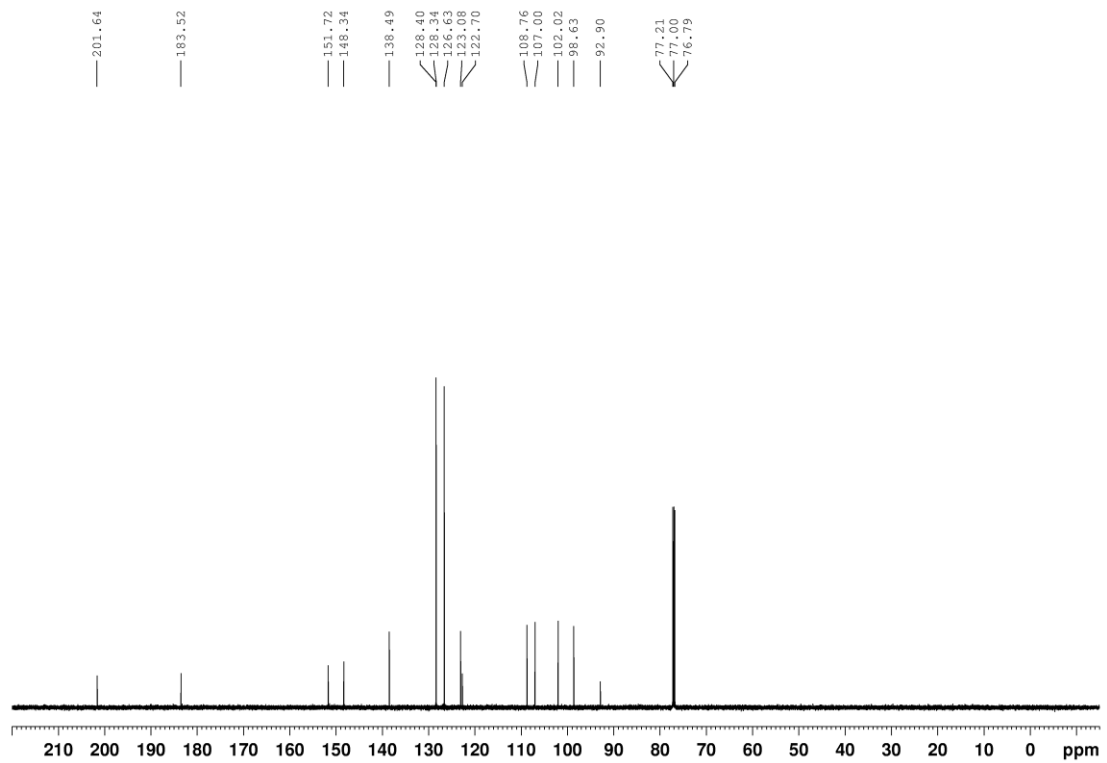


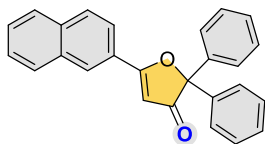
2ap

¹H NMR spectrum was recorded on 400 MHz in CDCl₃.



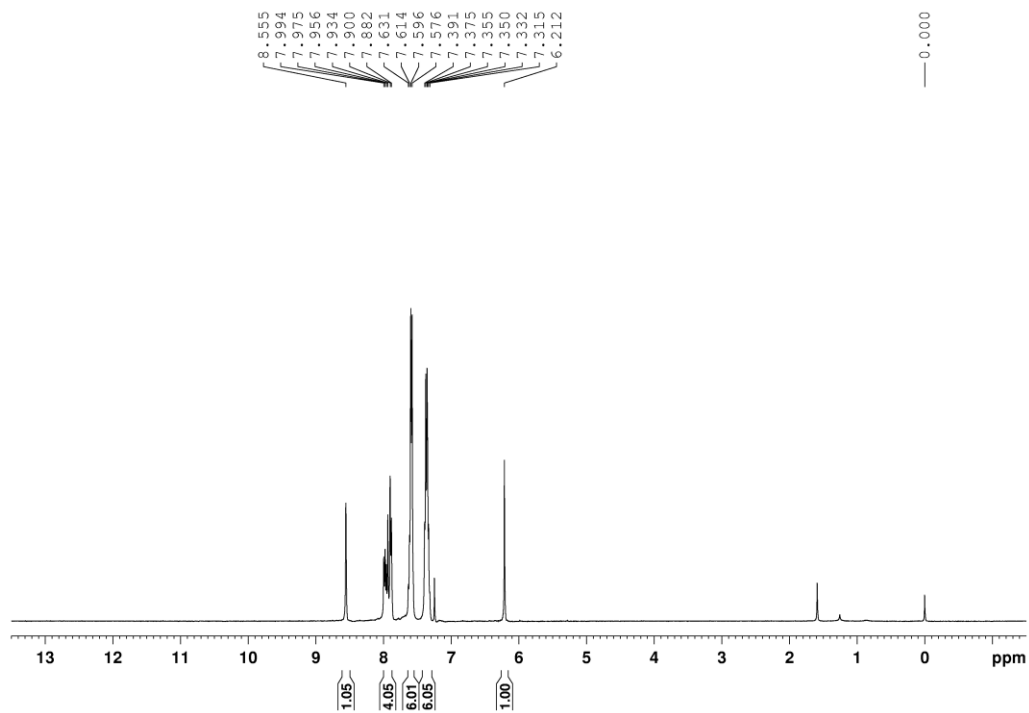
¹³C{¹H} NMR spectrum was recorded on 151 MHz in CDCl₃.



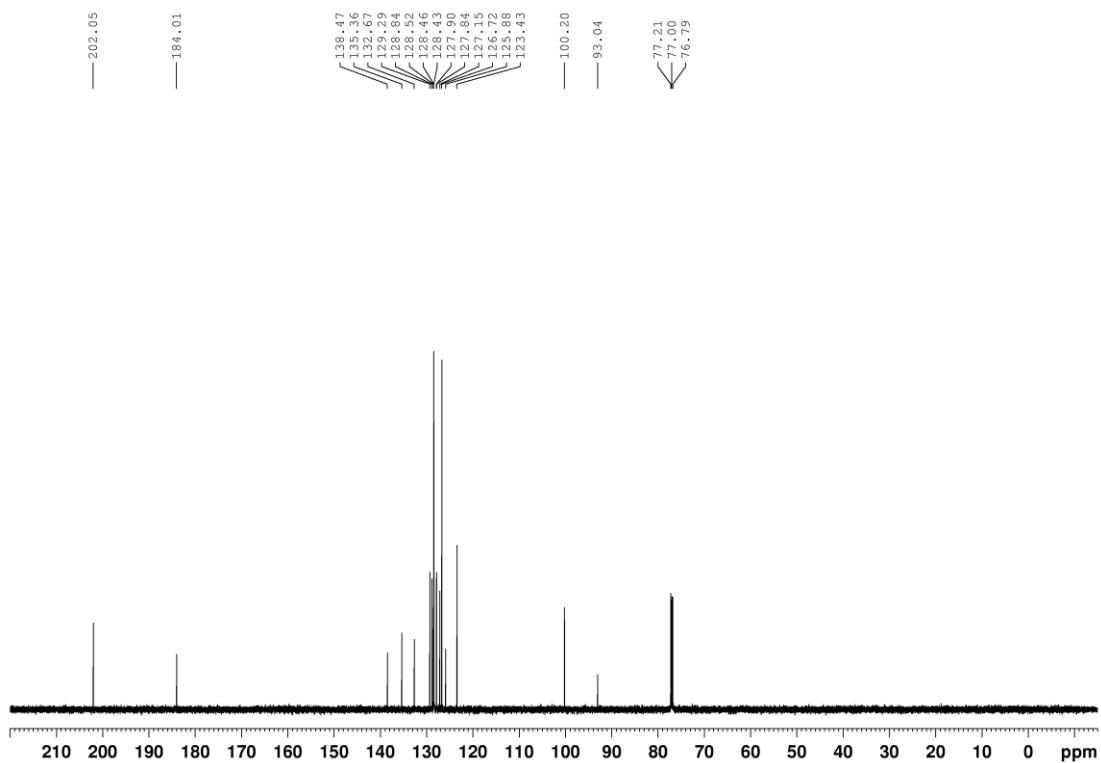


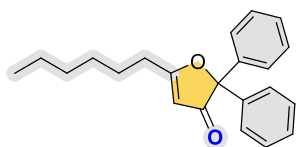
2aq

^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .



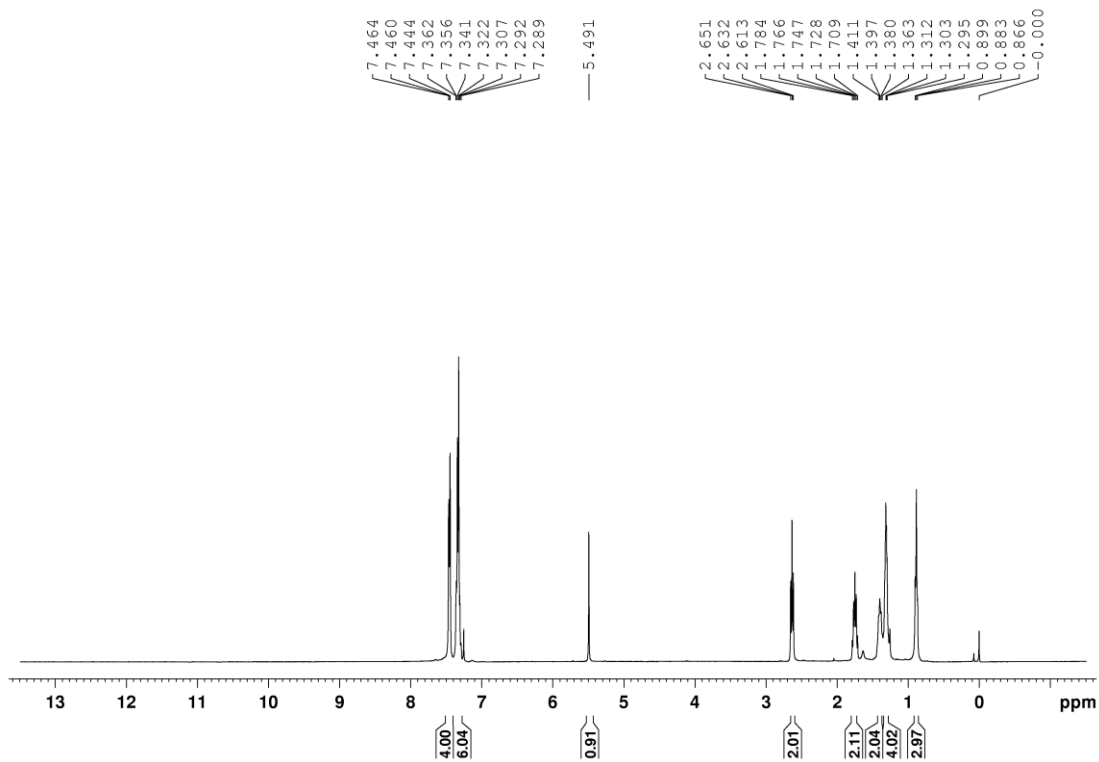
$^{13}\text{C}\{\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



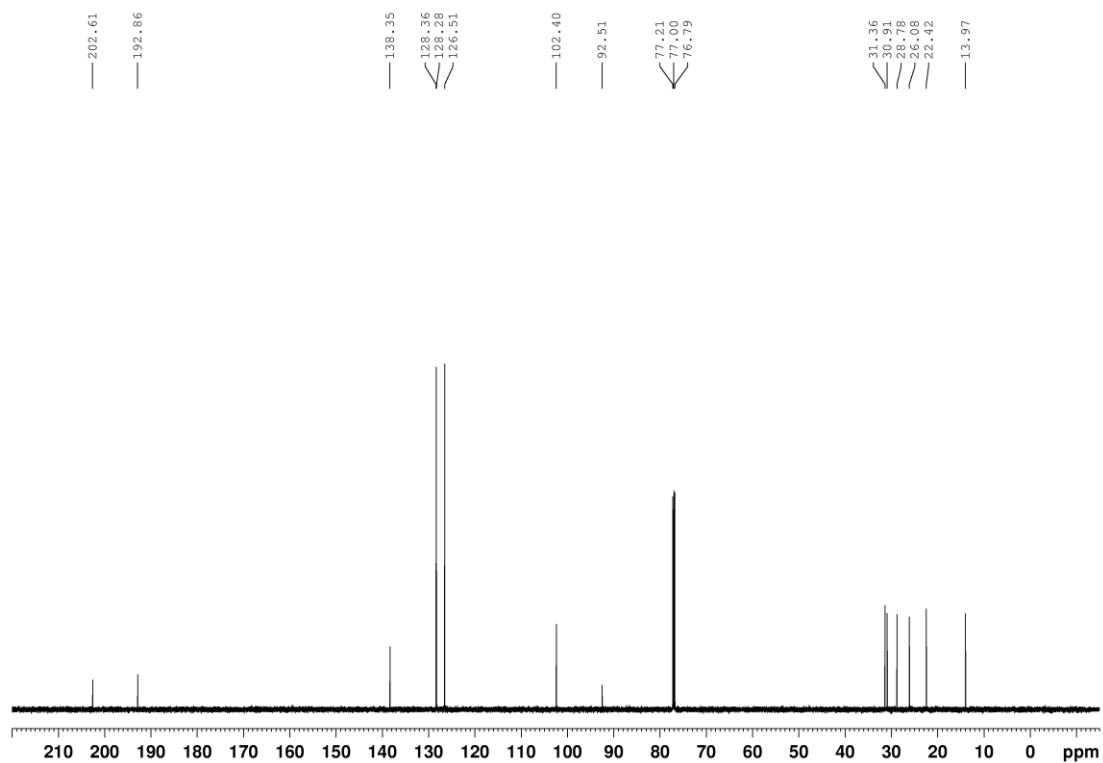


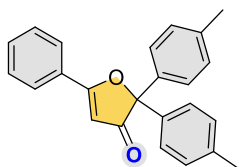
2ar

^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .



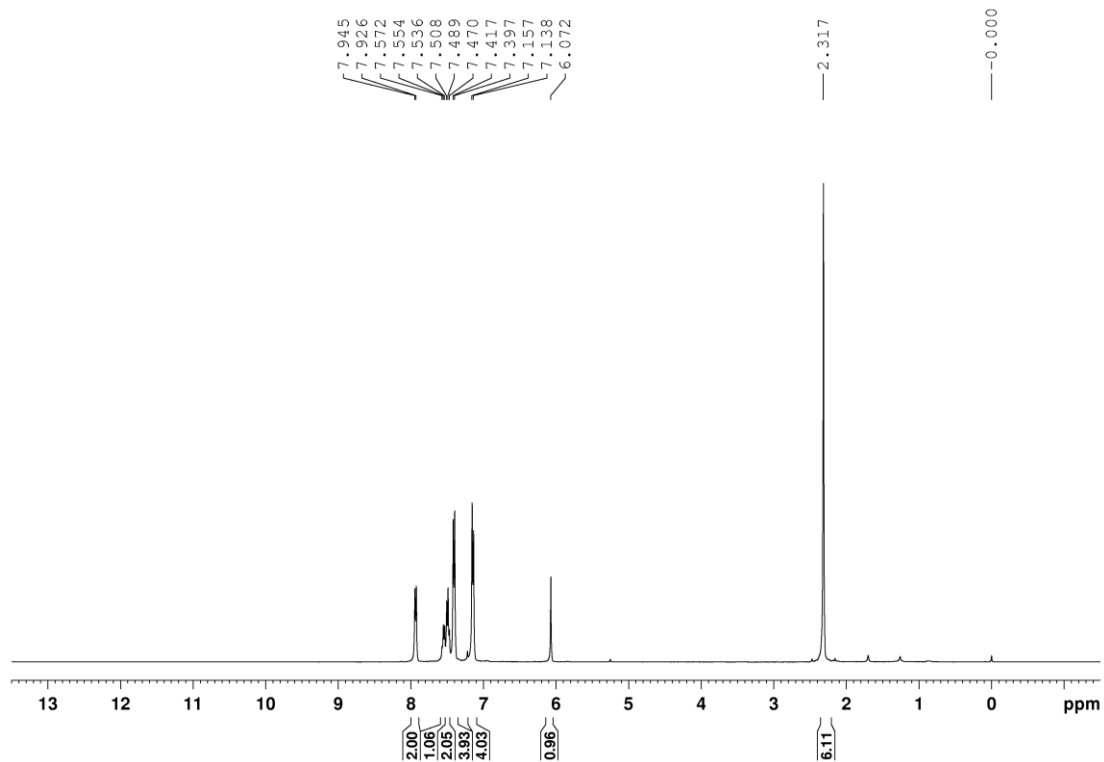
$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



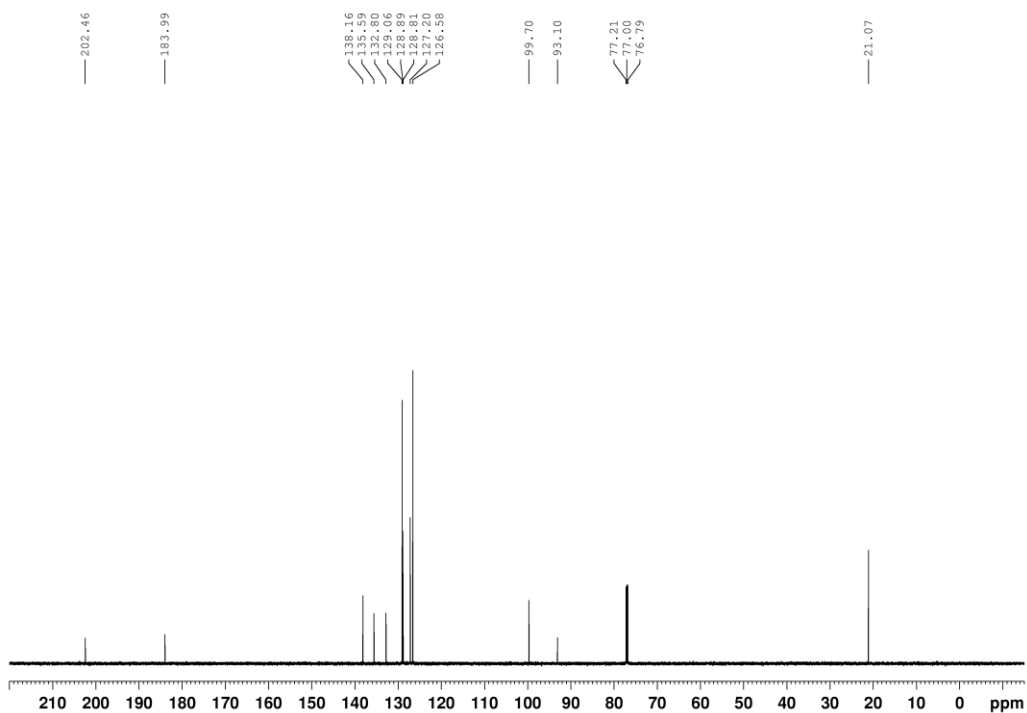


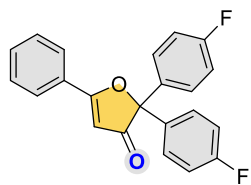
2ba

^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .



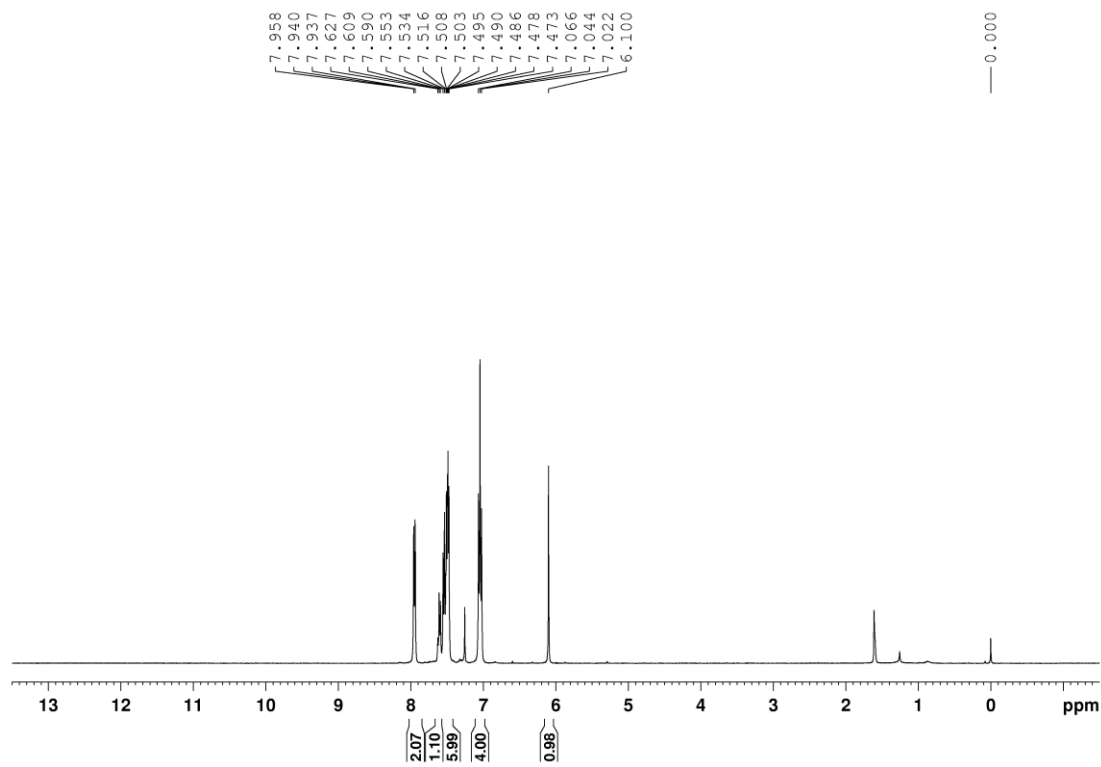
$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



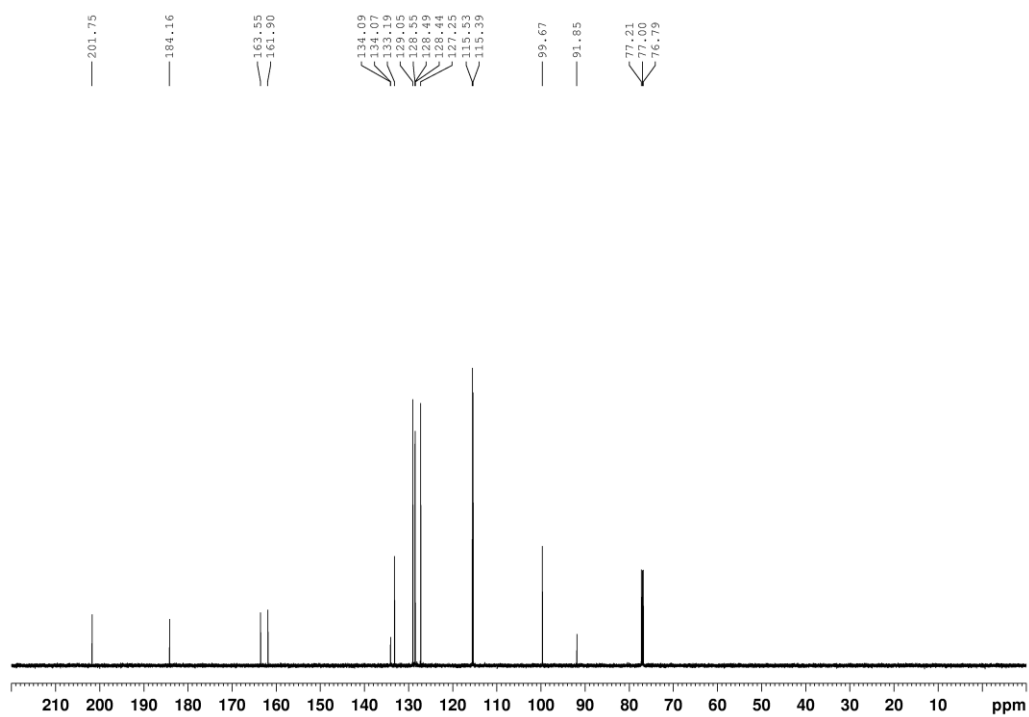


2bb

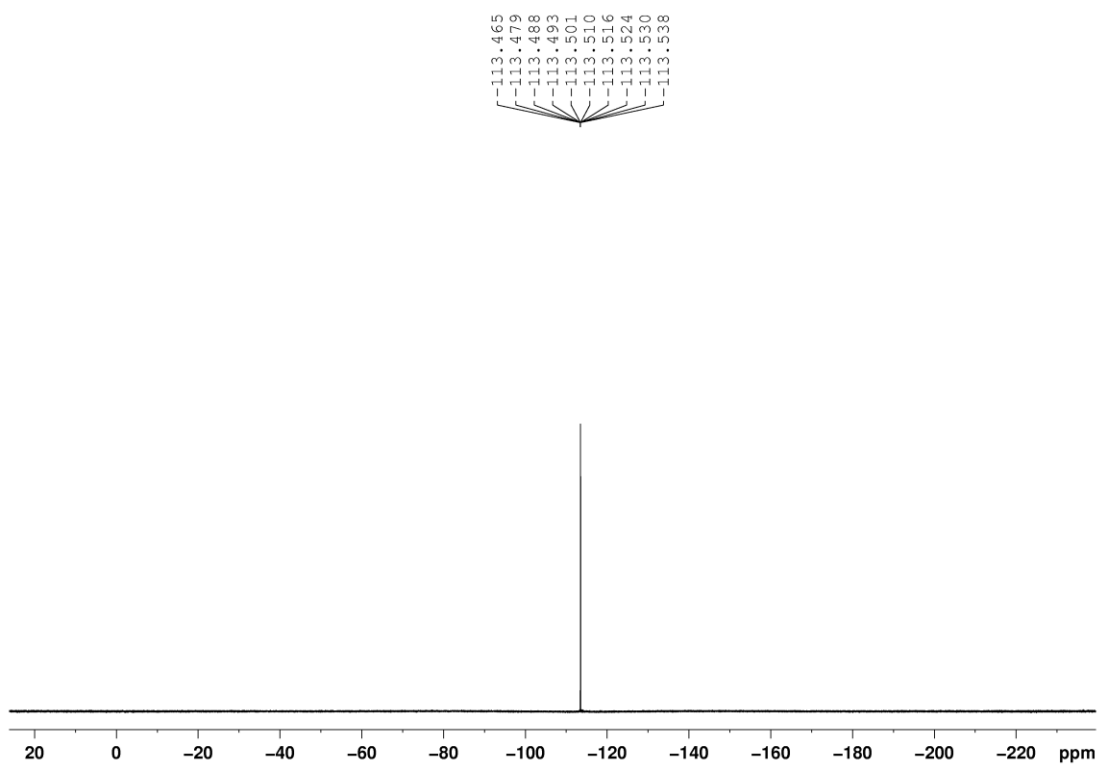
^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .

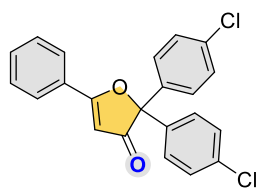


$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



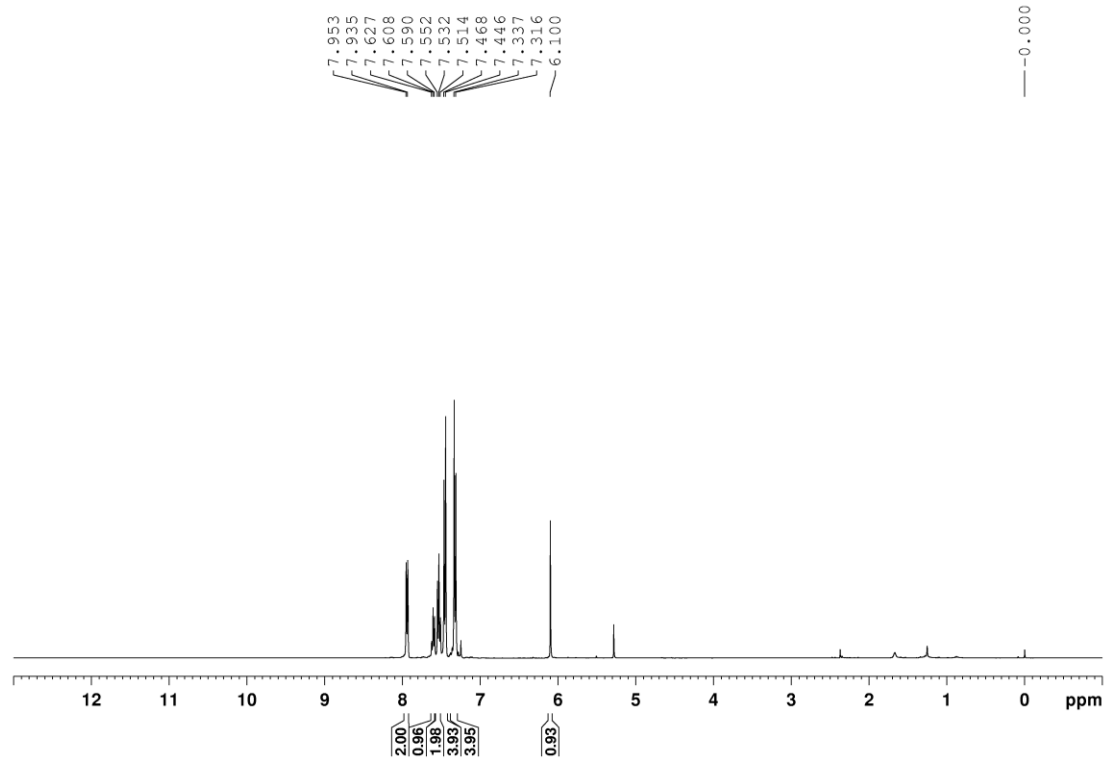
¹⁹F spectrum was recorded on 376 MHz in CDCl₃.



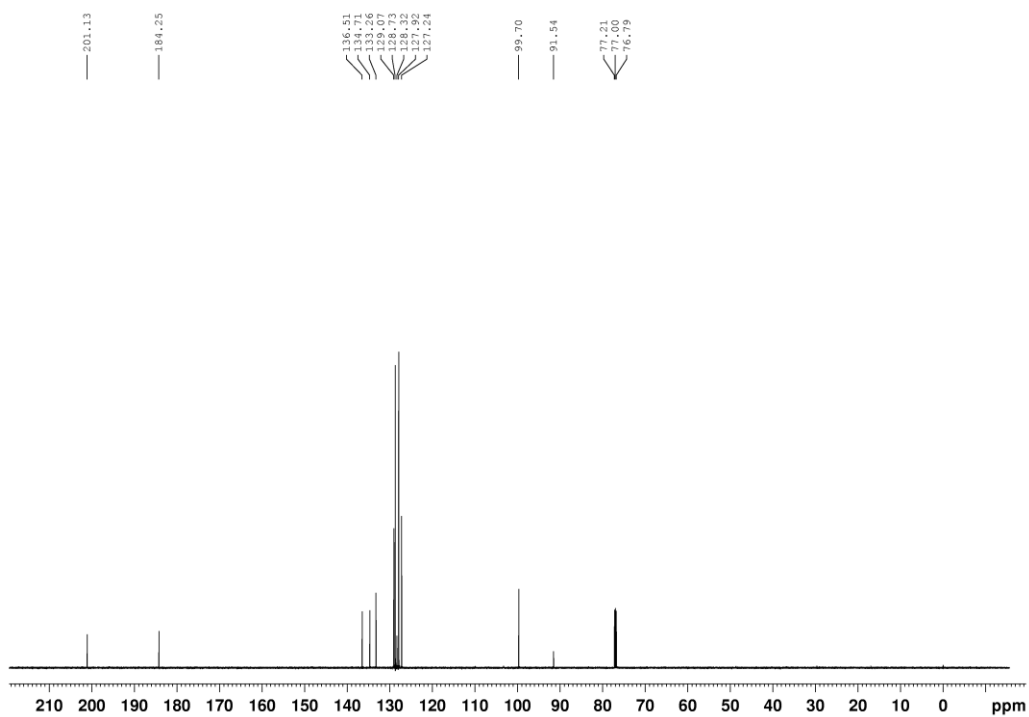


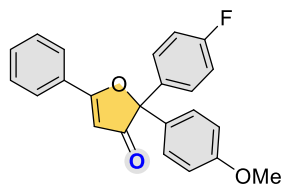
2bc

^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .



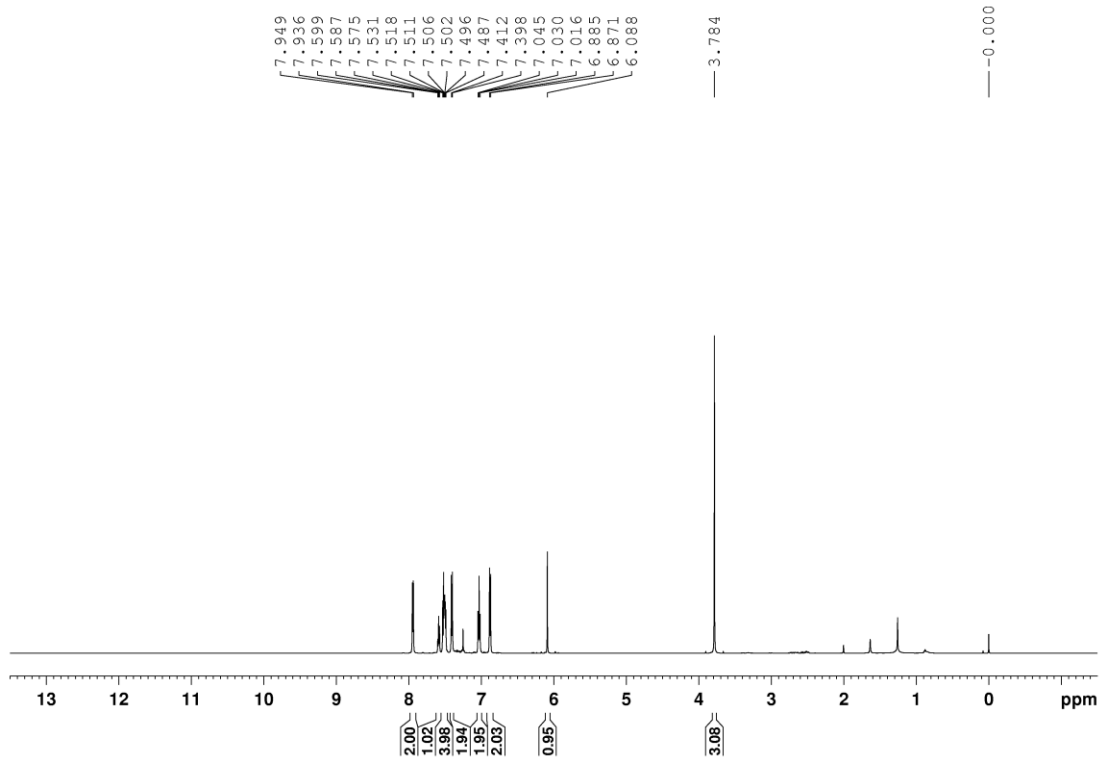
$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



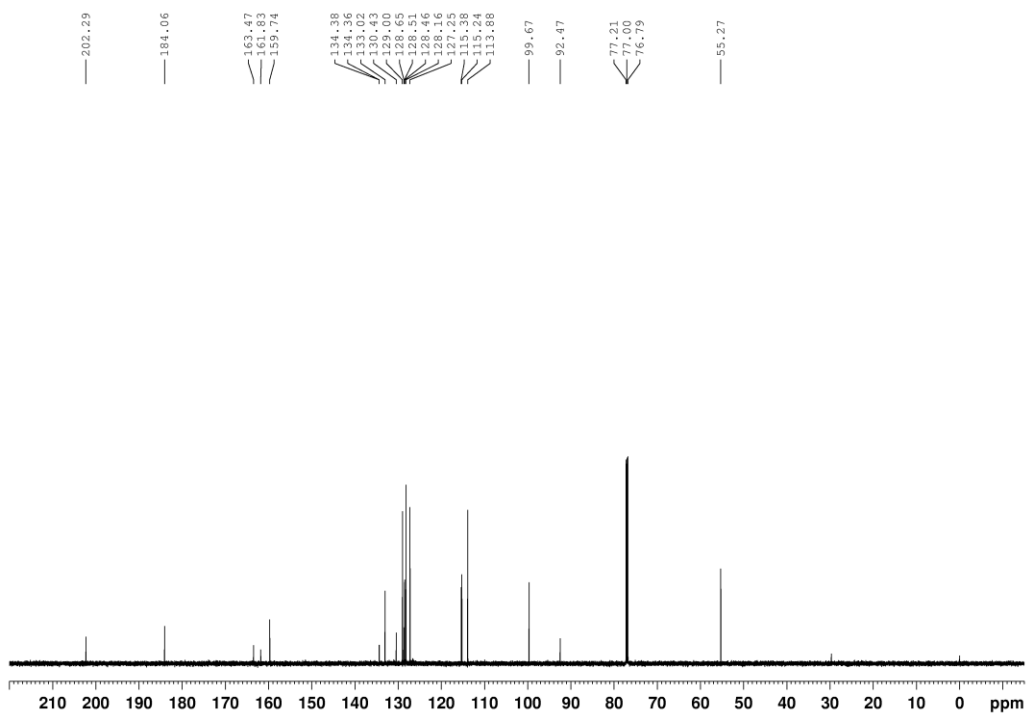


2bd

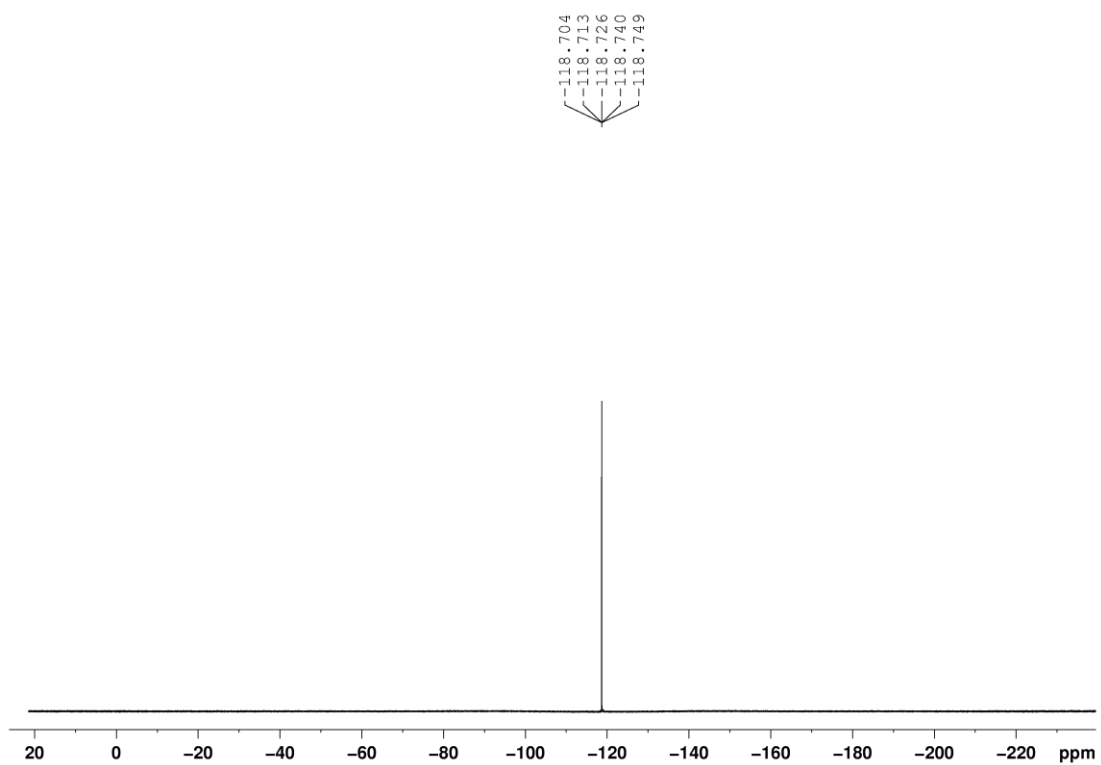
^1H NMR spectrum was recorded on 600 MHz in CDCl_3 .

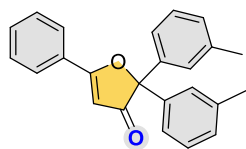


$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



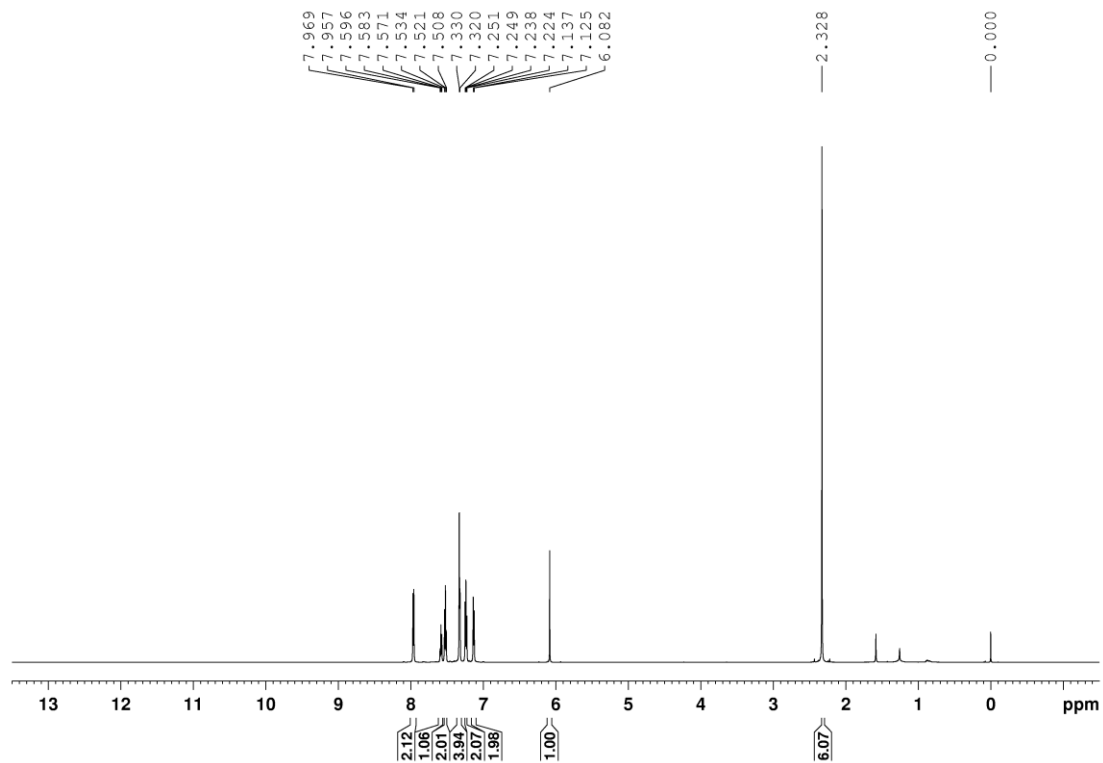
^{19}F spectrum was recorded on 376 MHz in CDCl_3 .



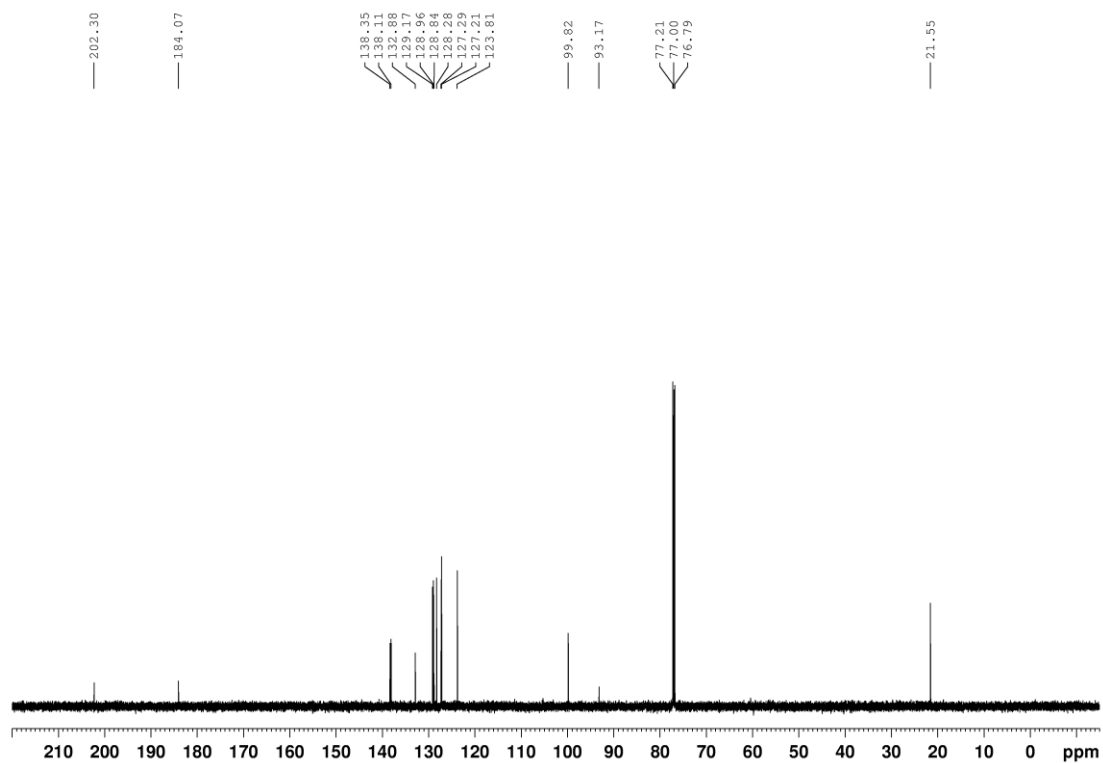


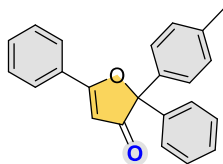
2be

^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .



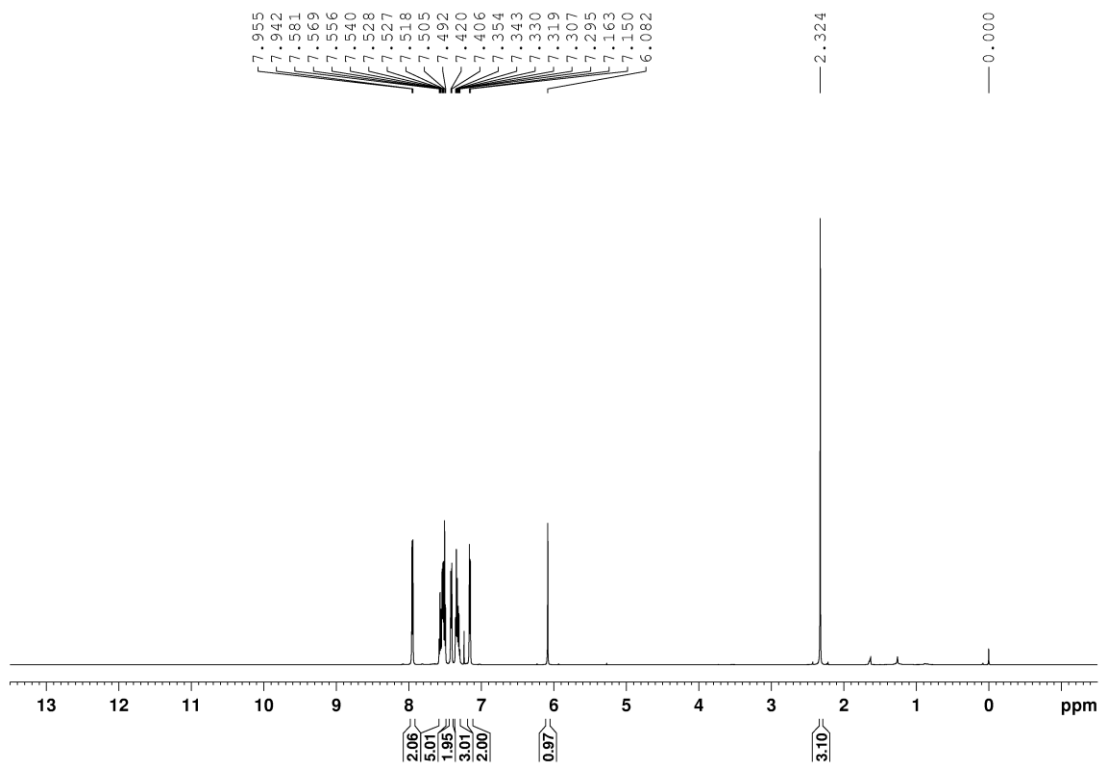
$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



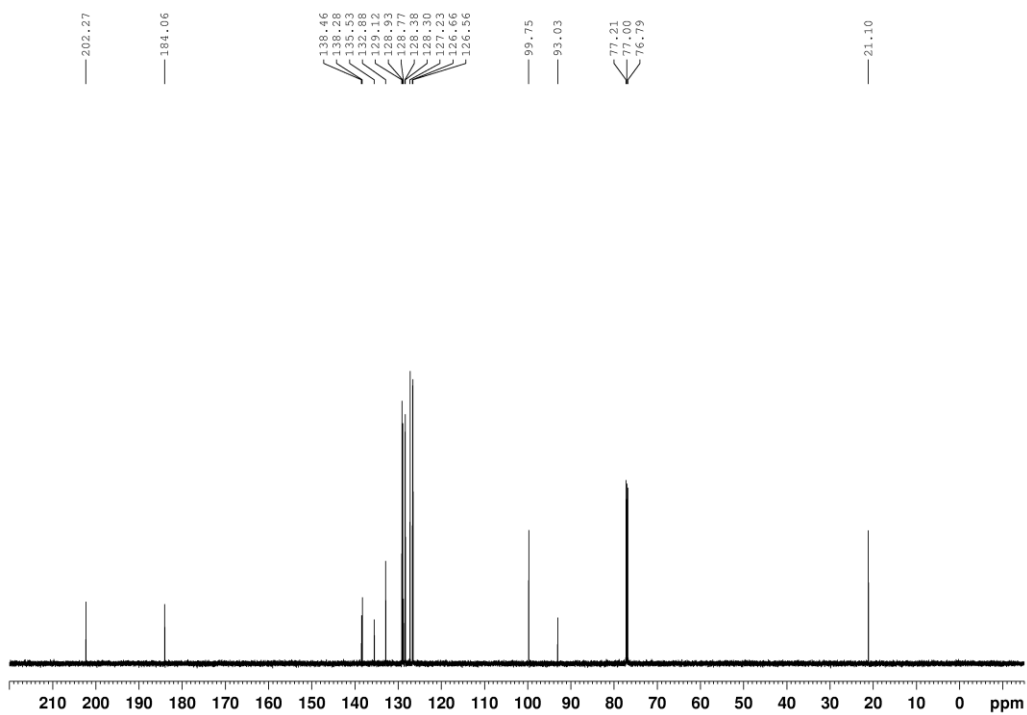


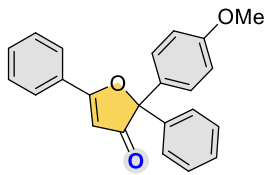
2b

¹H NMR spectrum was recorded on 600 MHz in CDCl₃.



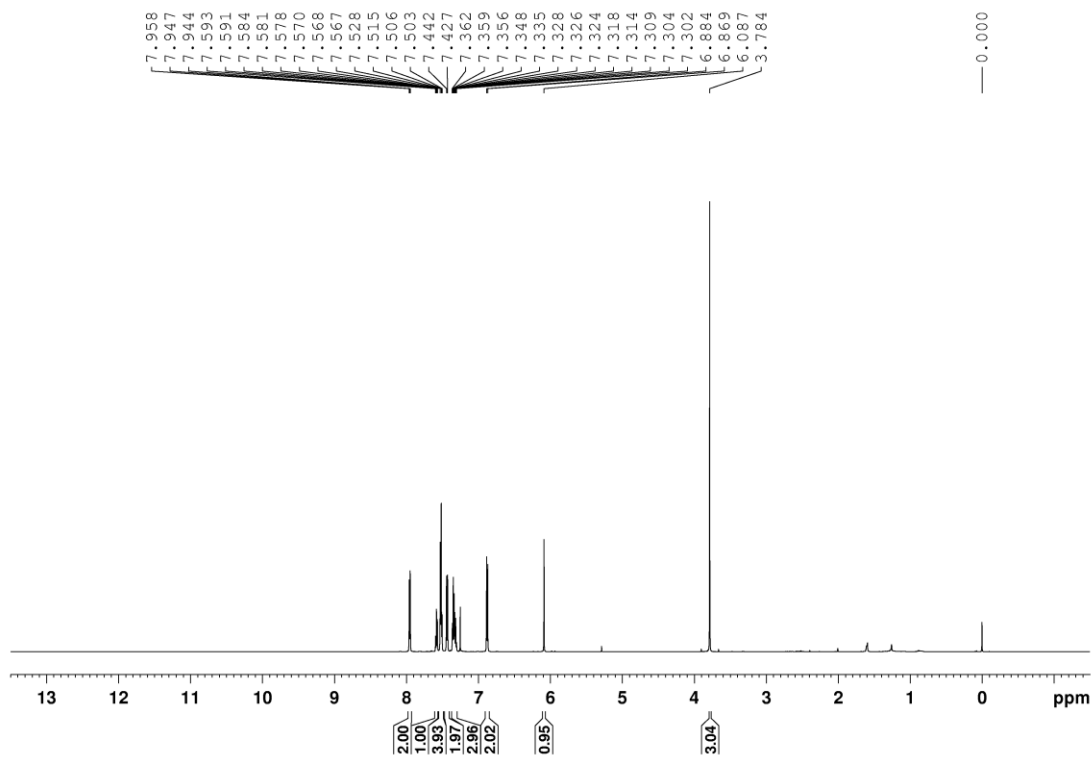
¹³C{H} NMR spectrum was recorded on 151 MHz in CDCl₃.



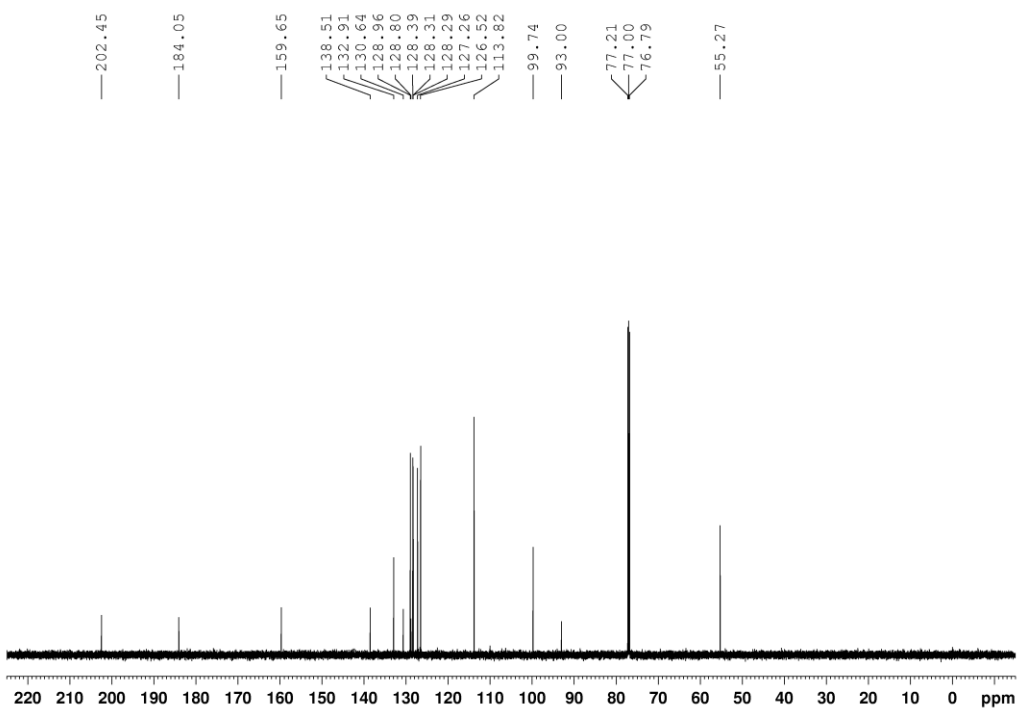


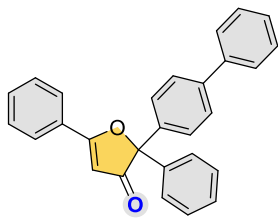
2bg

^1H NMR spectrum was recorded on 600 MHz in CDCl_3 .



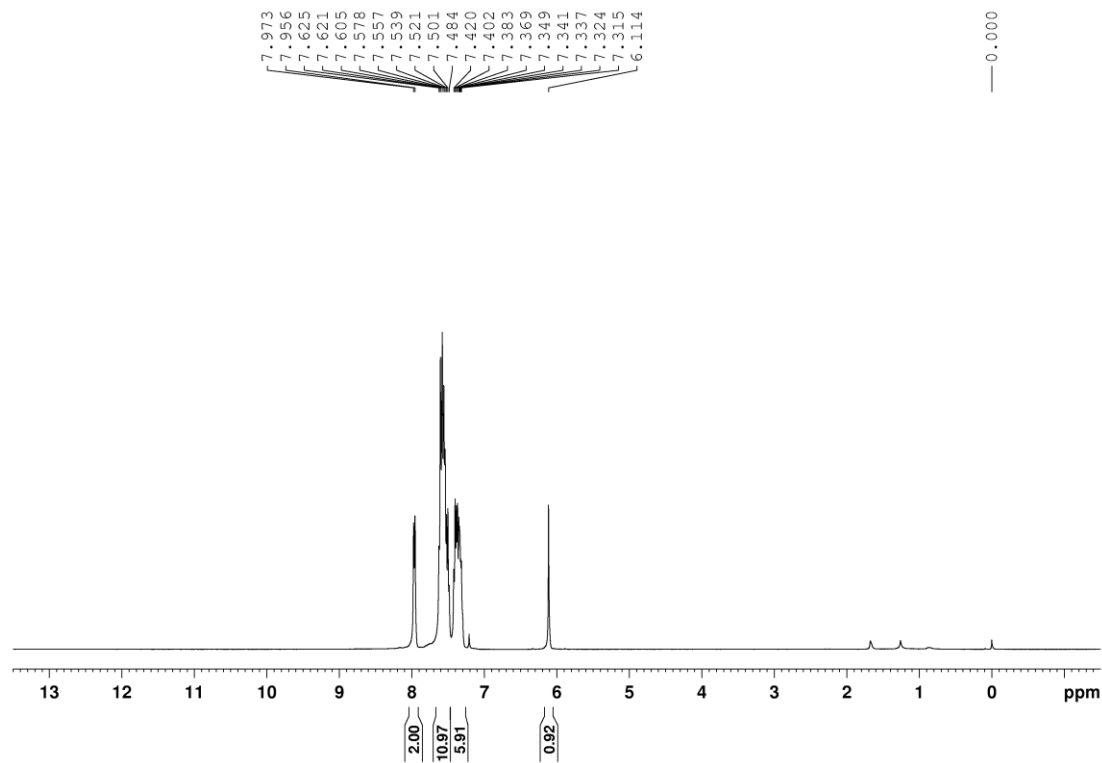
$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



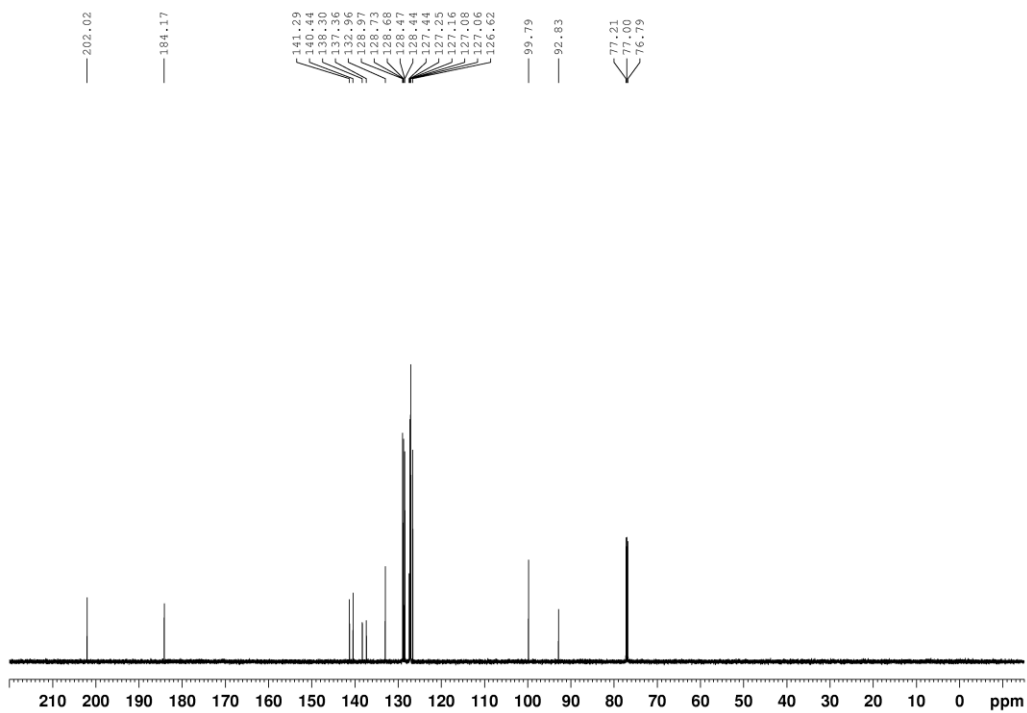


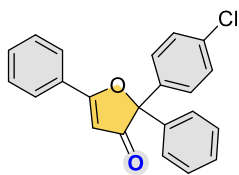
2bh

^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .



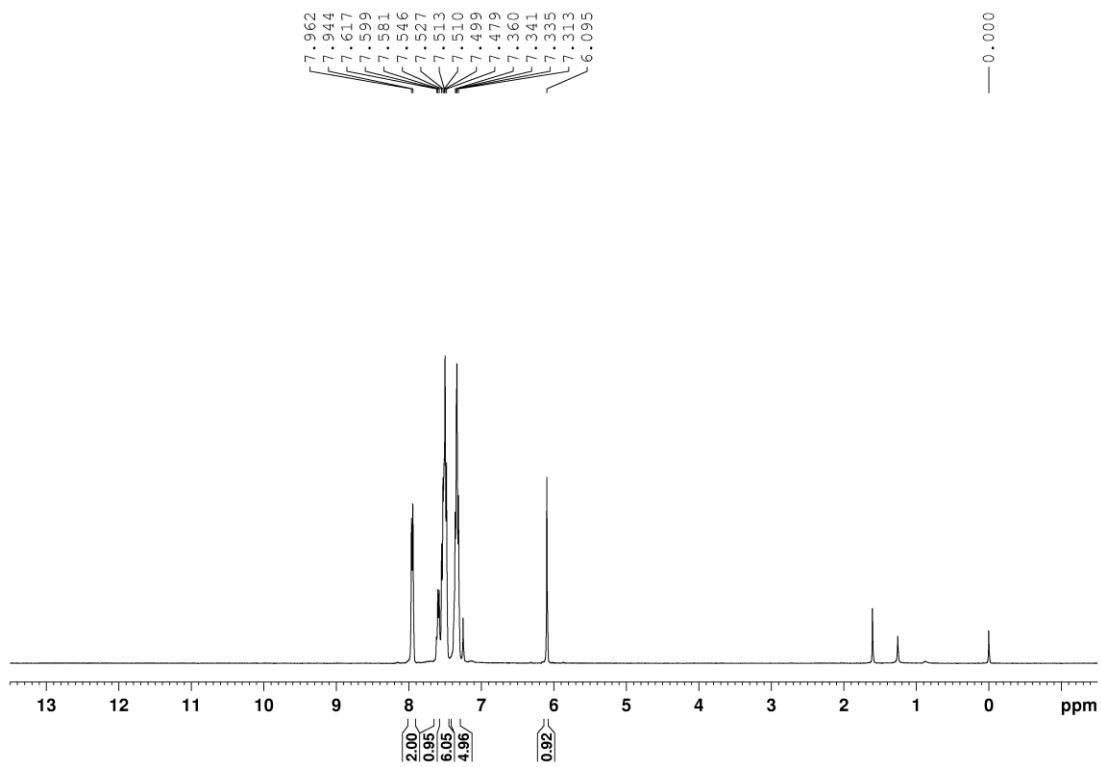
$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



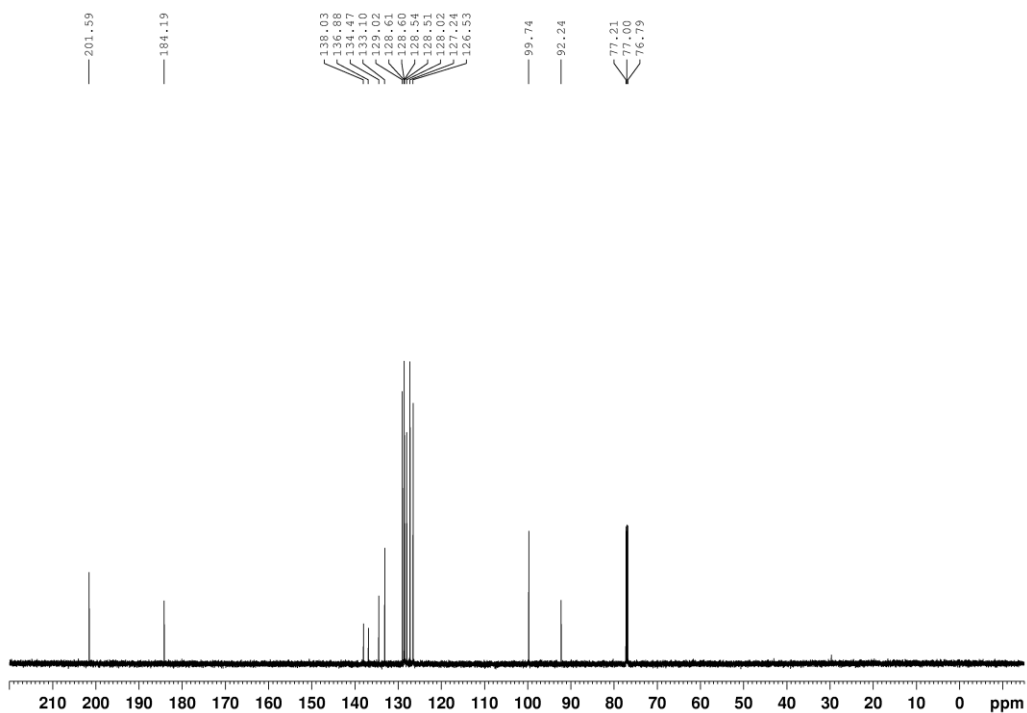


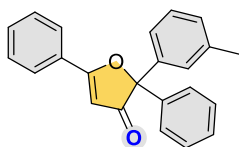
2bi

^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .



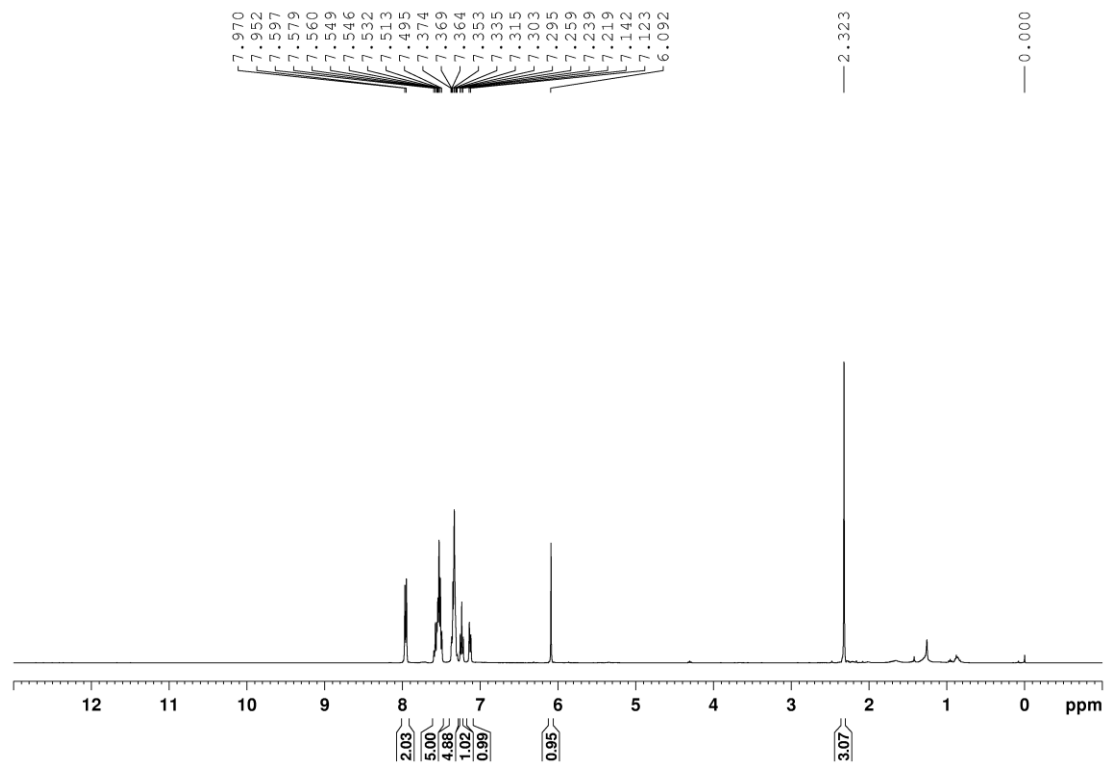
$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



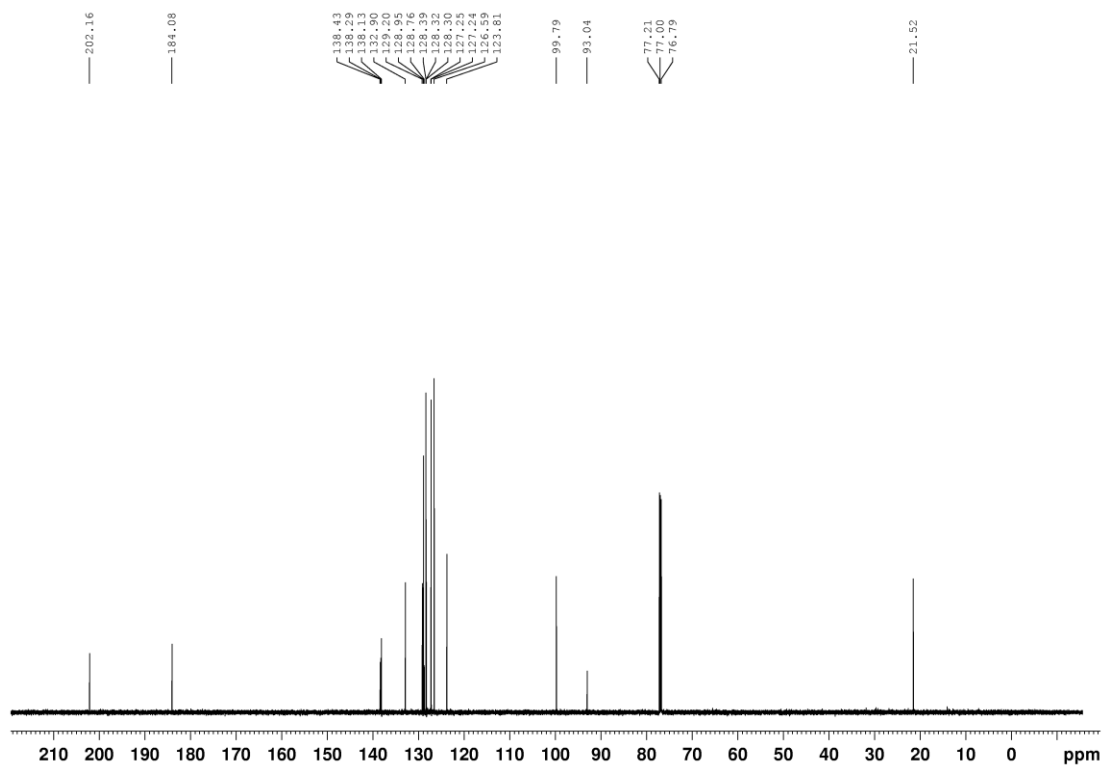


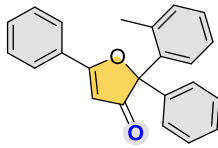
2bj

^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .



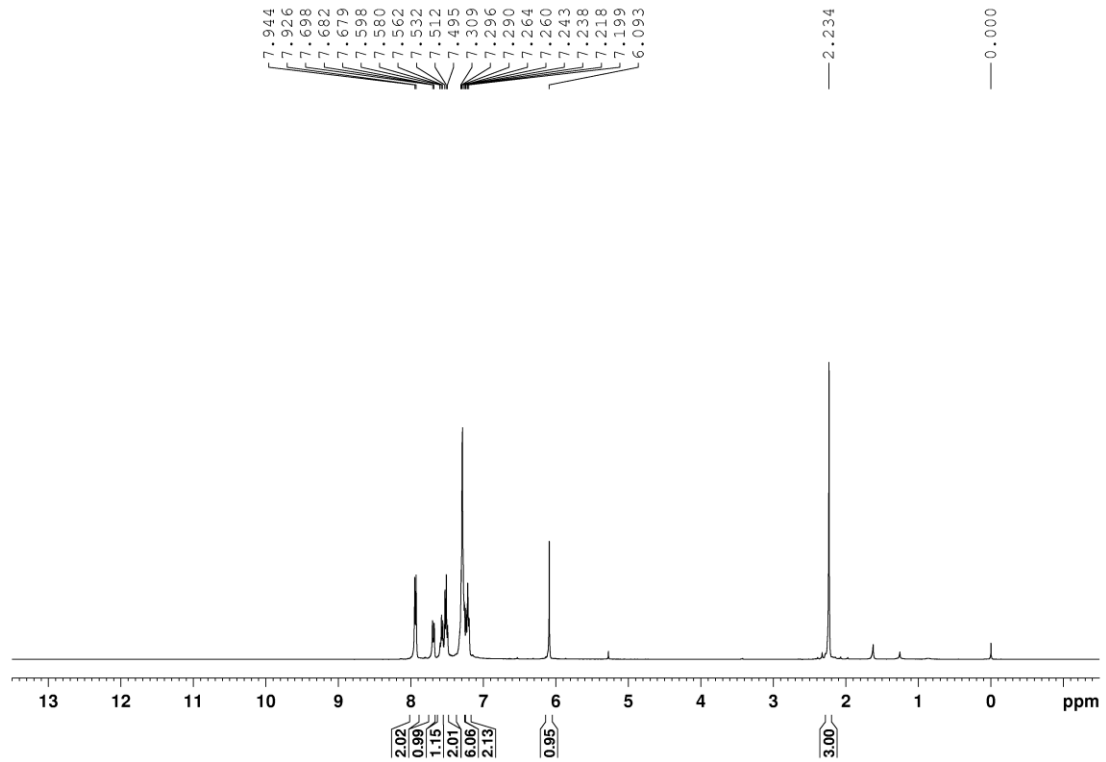
$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



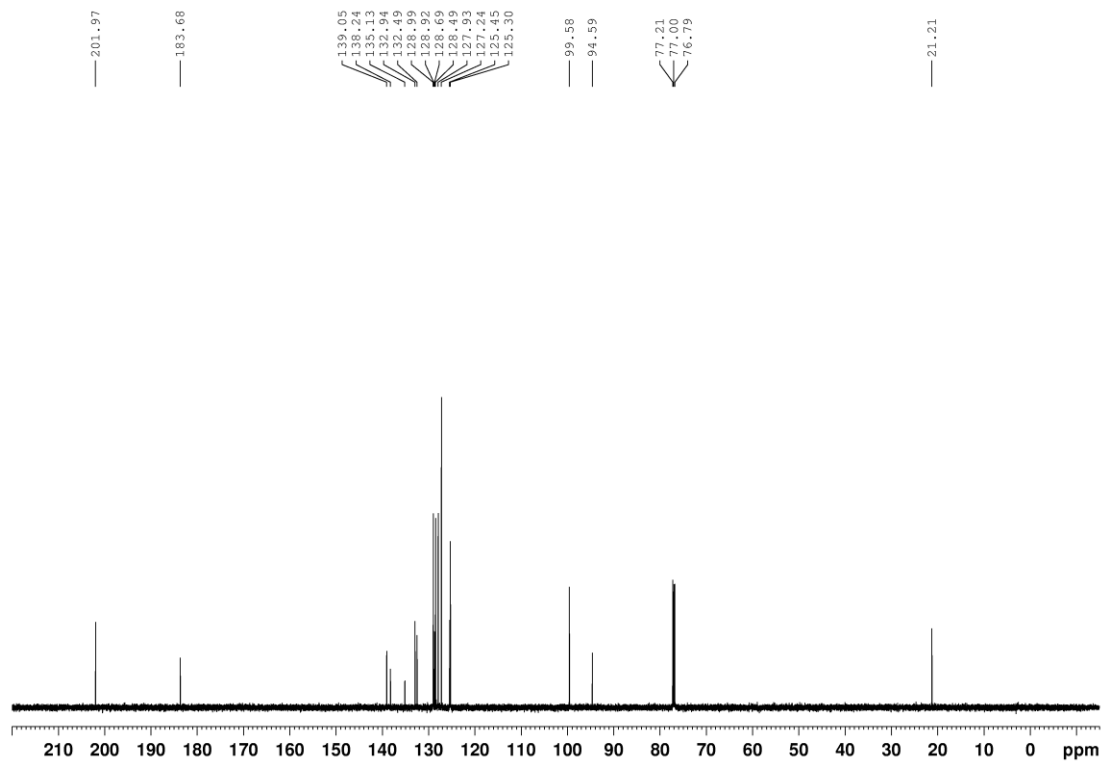


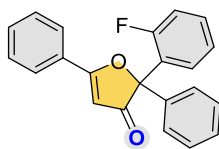
2bk

¹H NMR spectrum was recorded on 400 MHz in CDCl₃.



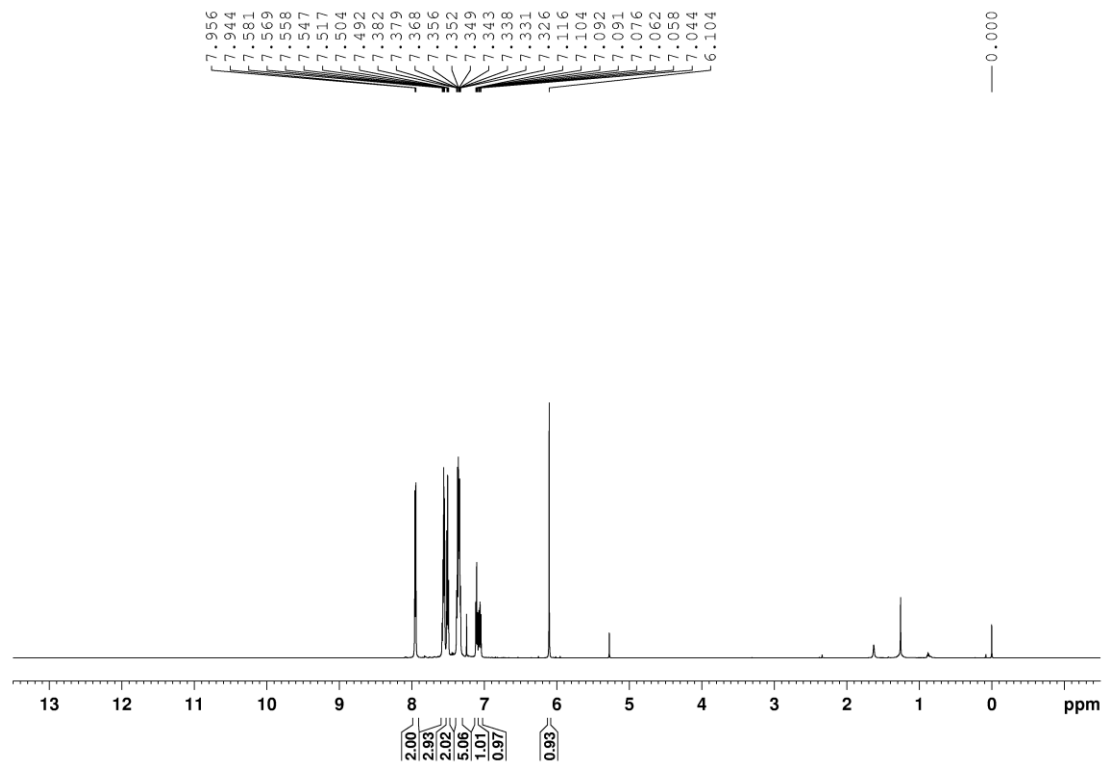
¹³C{¹H} NMR spectrum was recorded on 151 MHz in CDCl₃.



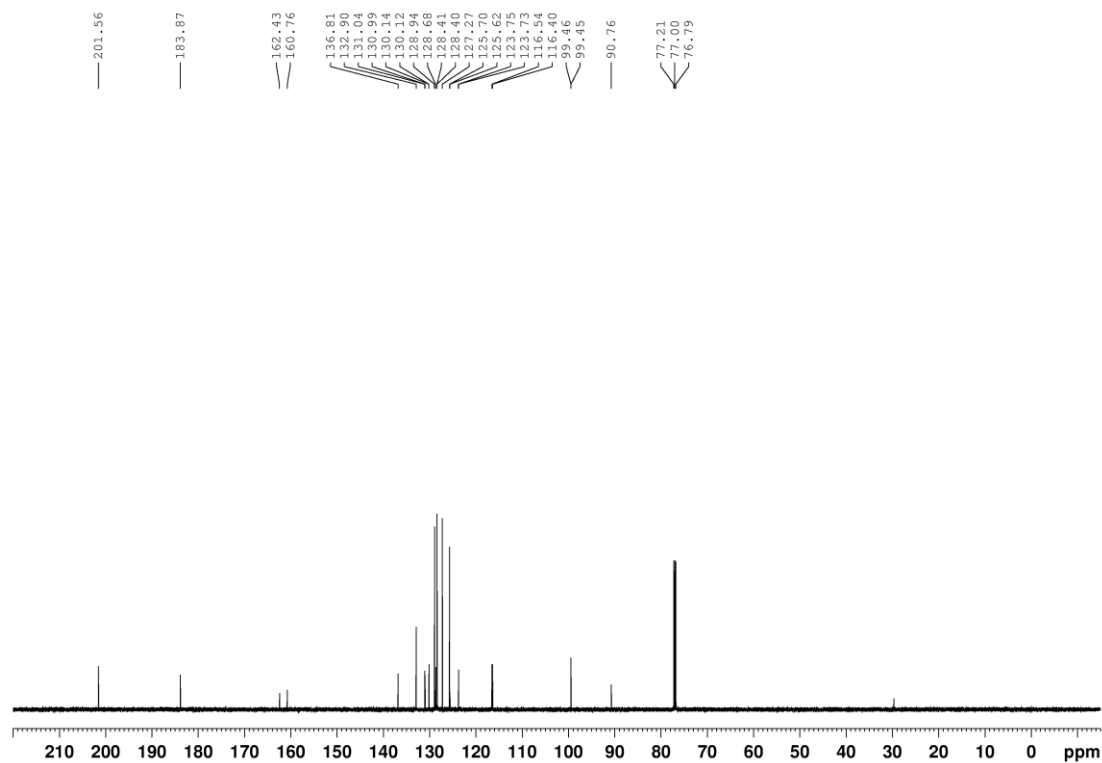


2bl

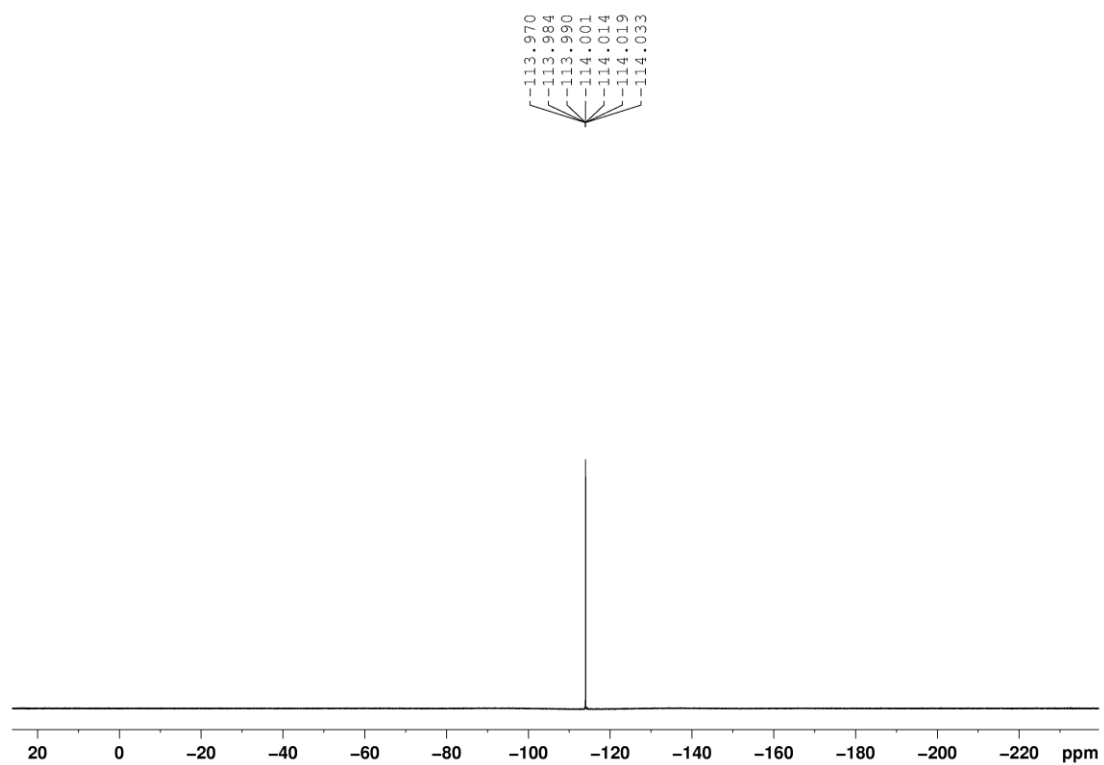
¹H NMR spectrum was recorded on 600 MHz in CDCl₃.

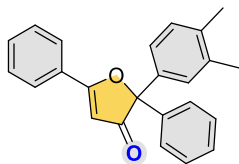


¹³C{H} NMR spectrum was recorded on 151 MHz in CDCl₃.



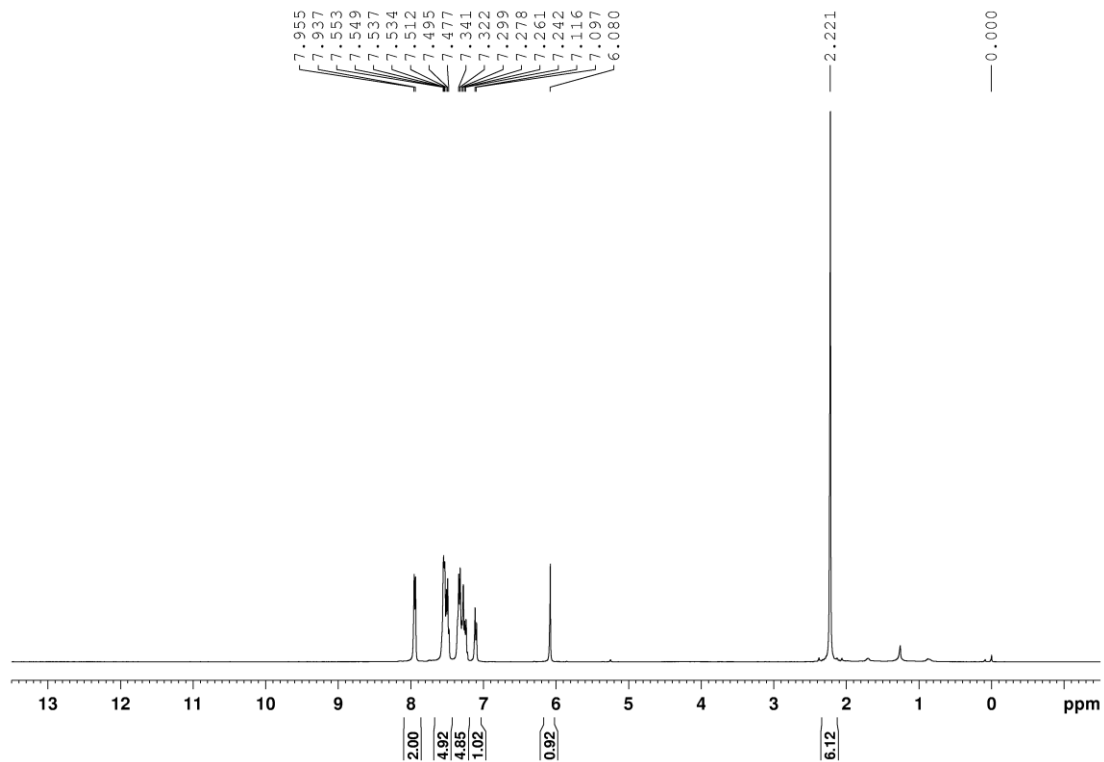
¹⁹F spectrum was recorded on 376 MHz in CDCl₃.



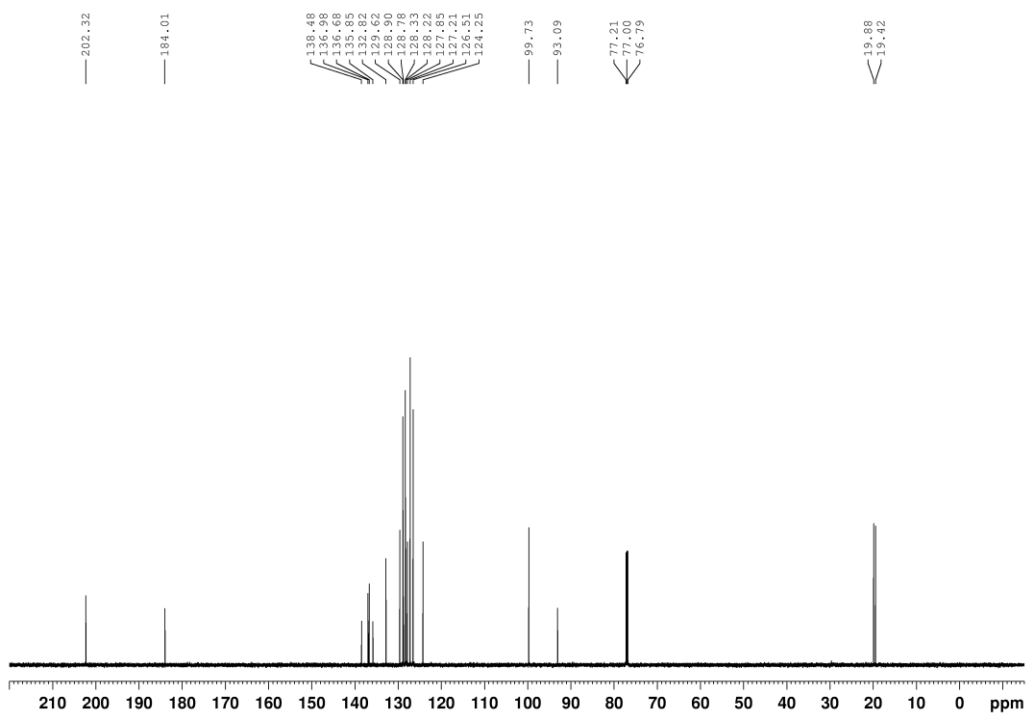


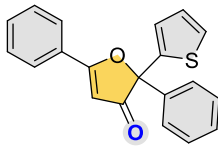
2bm

¹H NMR spectrum was recorded on 400 MHz in CDCl₃.



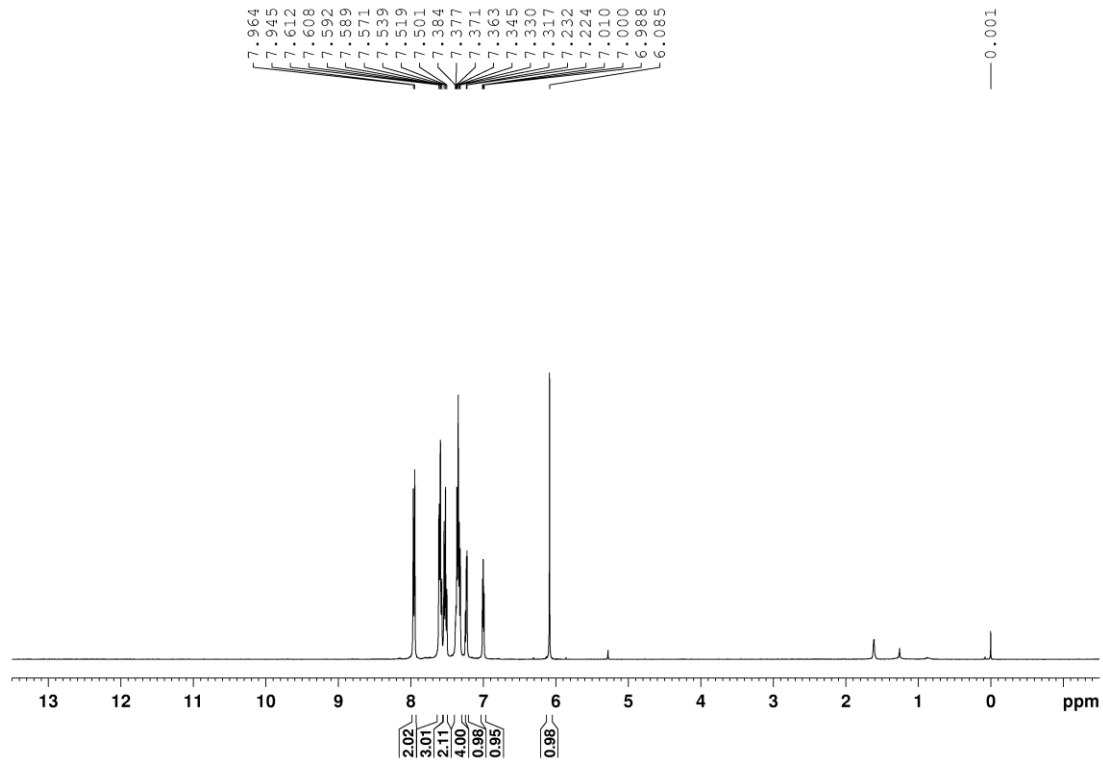
¹³C{¹H} NMR spectrum was recorded on 151 MHz in CDCl₃.



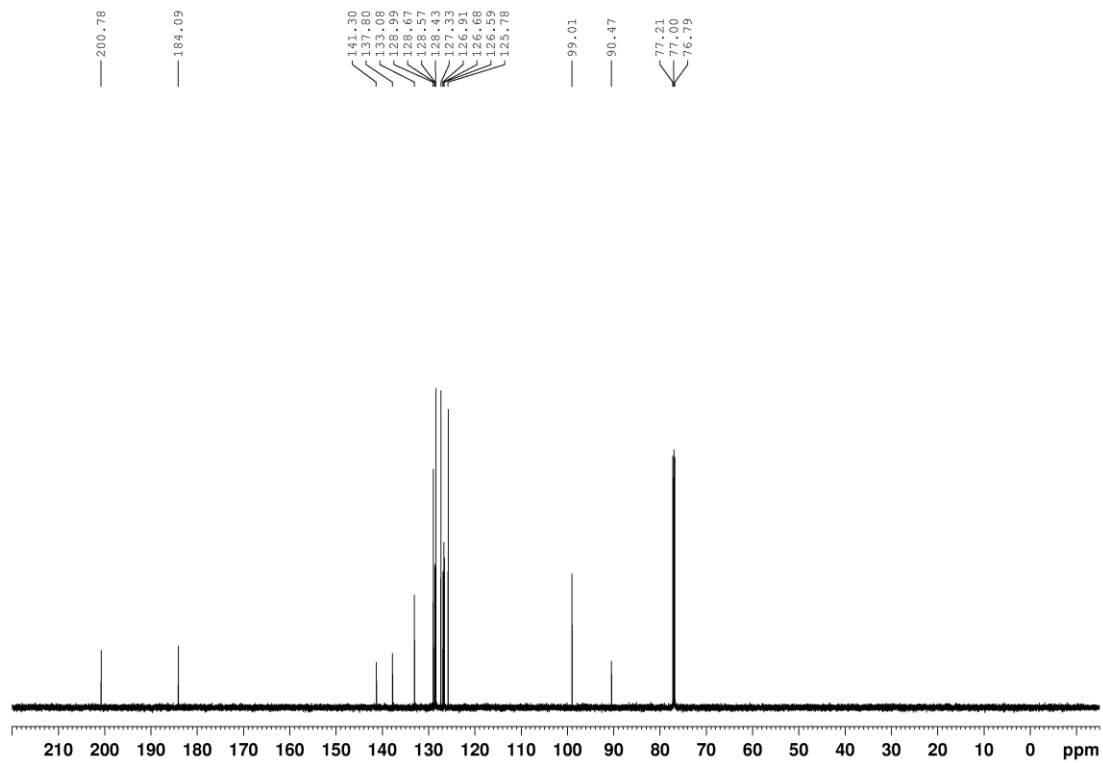


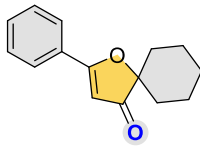
2bn

^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .



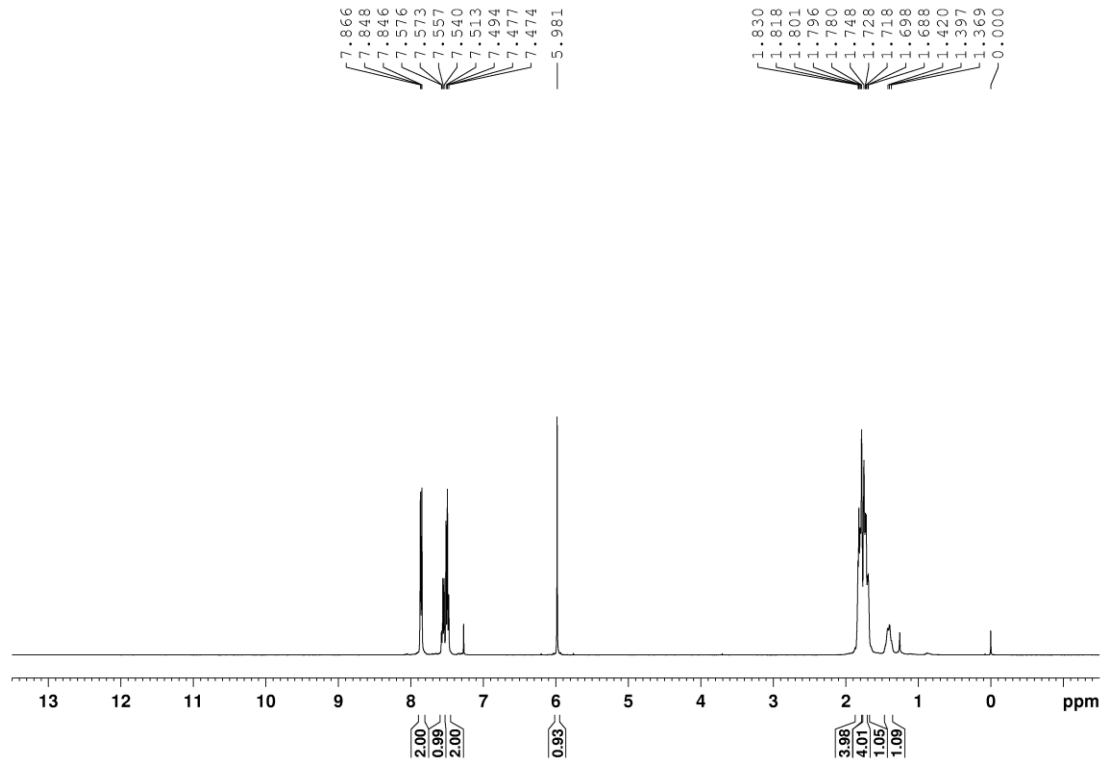
$^{13}\text{C}\{\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



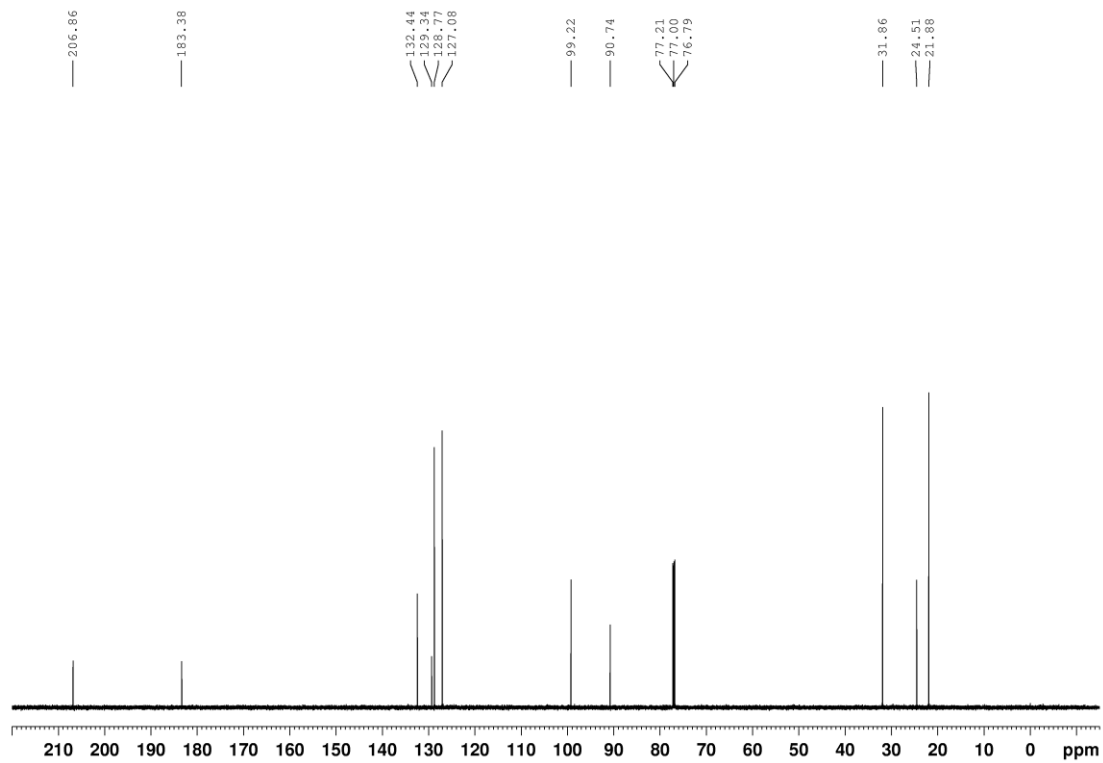


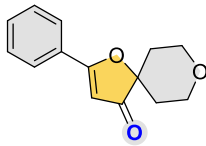
2bo

^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .



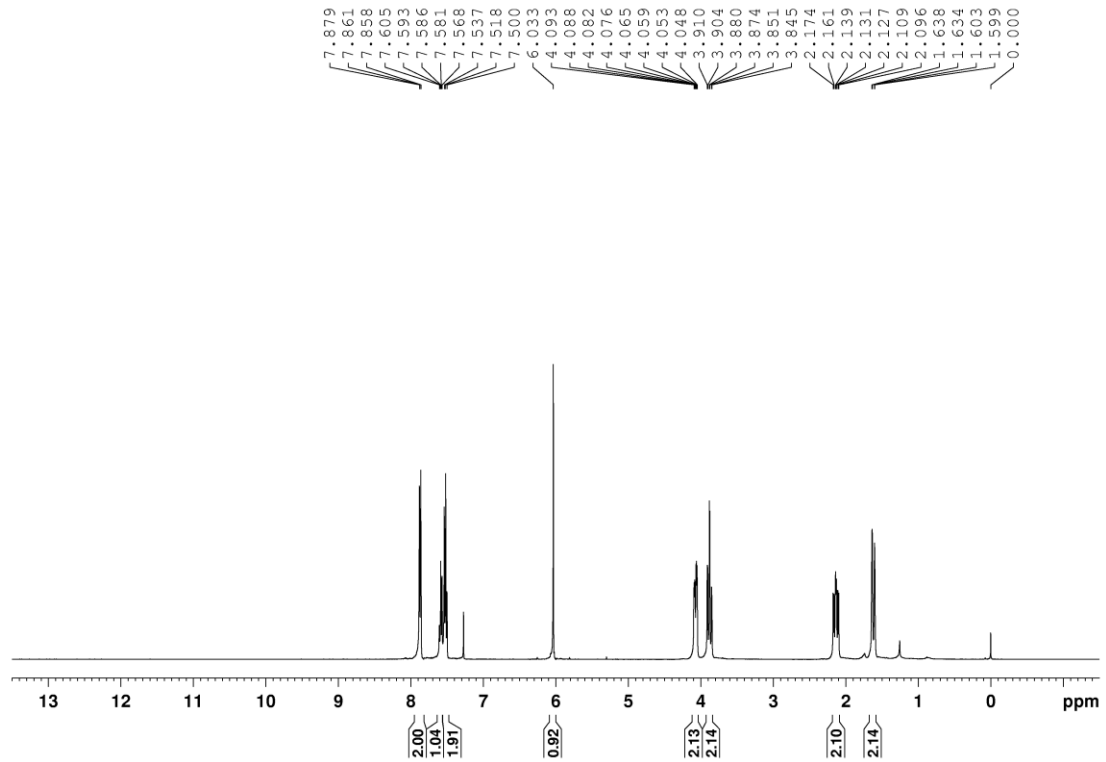
$^{13}\text{C}\{\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



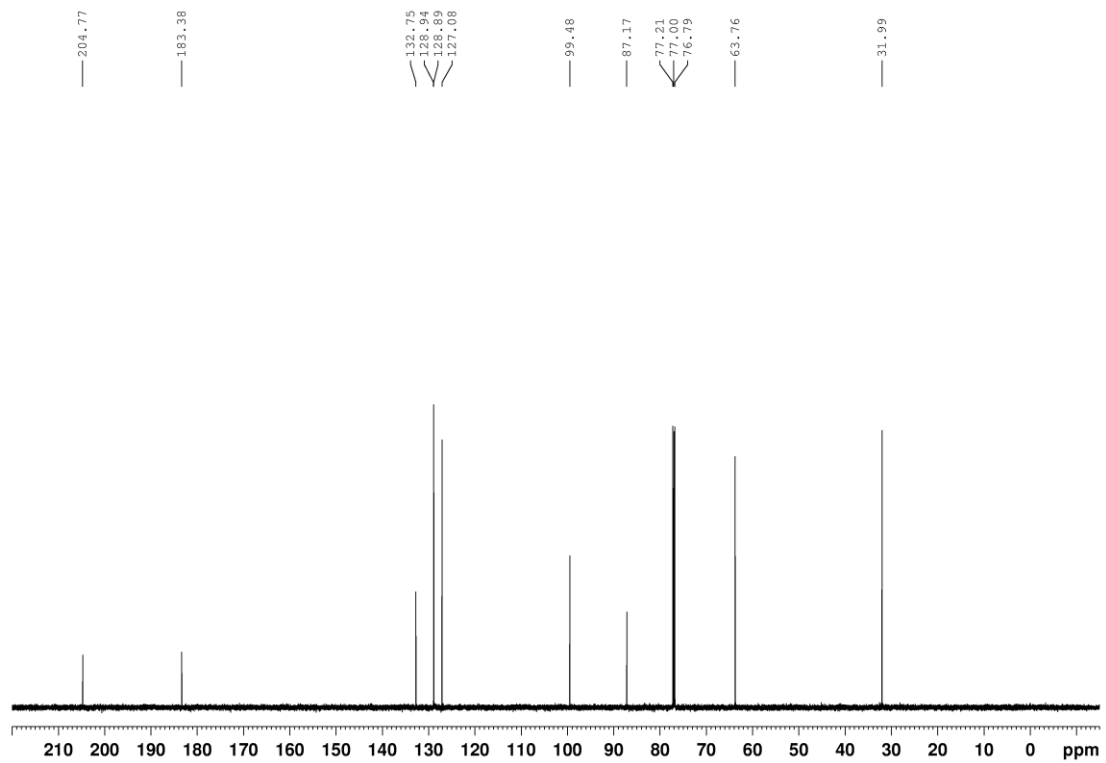


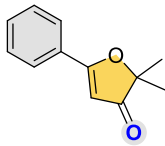
2p

^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .



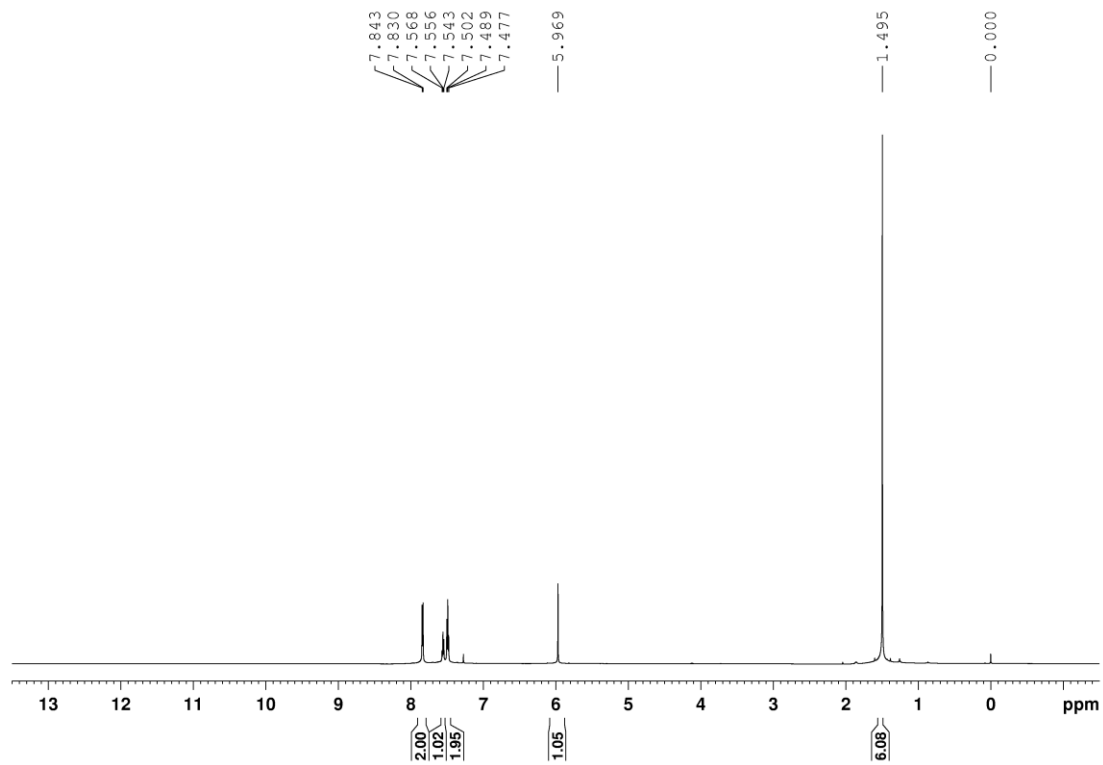
$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



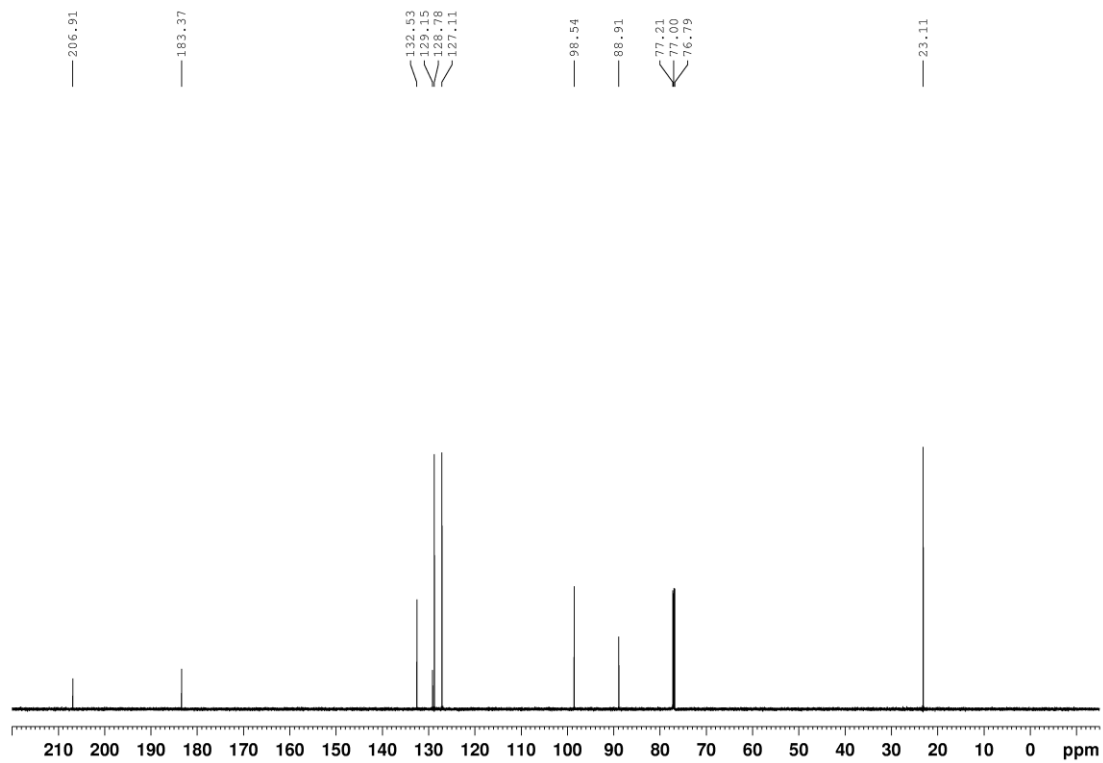


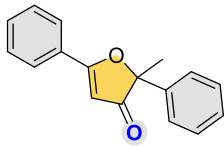
2bq

^1H NMR spectrum was recorded on 600 MHz in CDCl_3 .



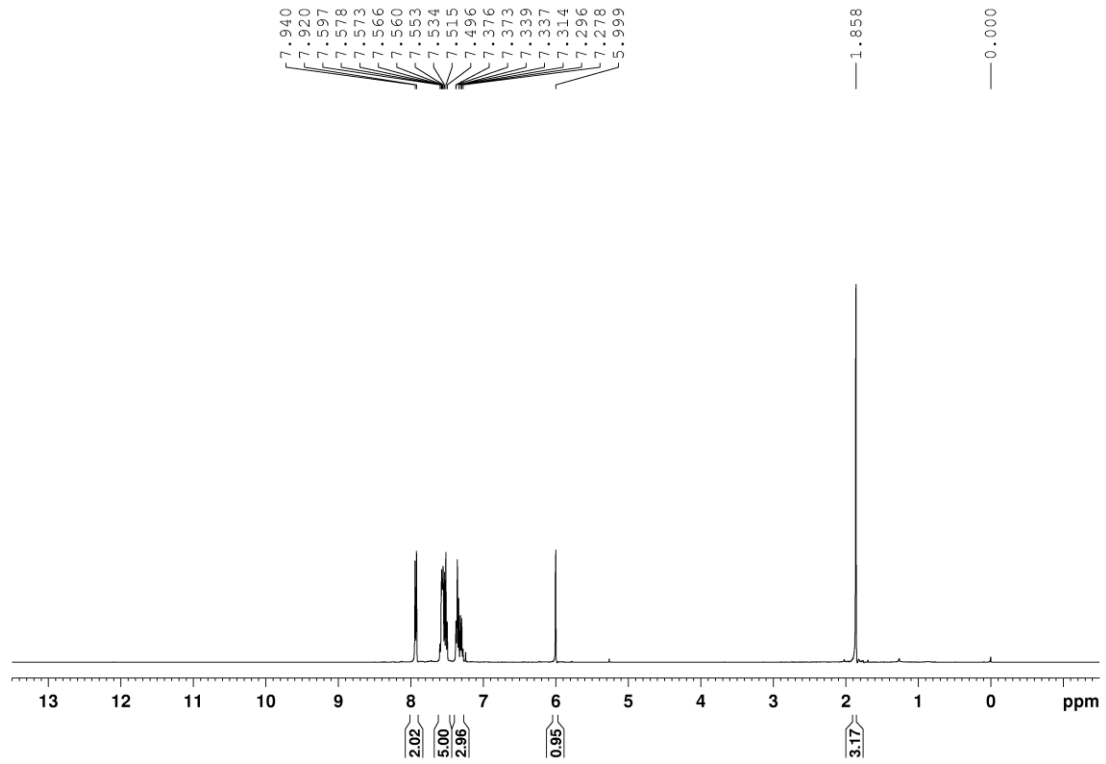
$^{13}\text{C}\{\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



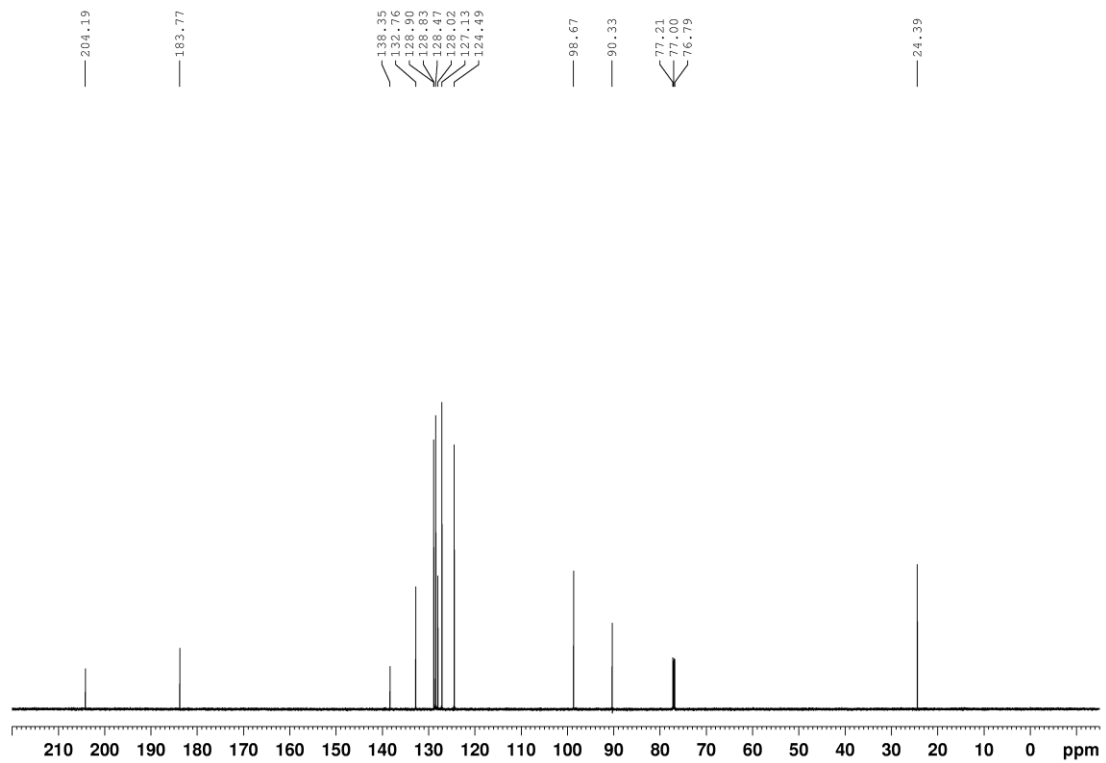


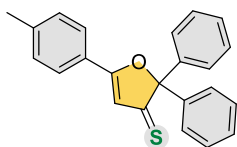
2br

¹H NMR spectrum was recorded on 400 MHz in CDCl₃.



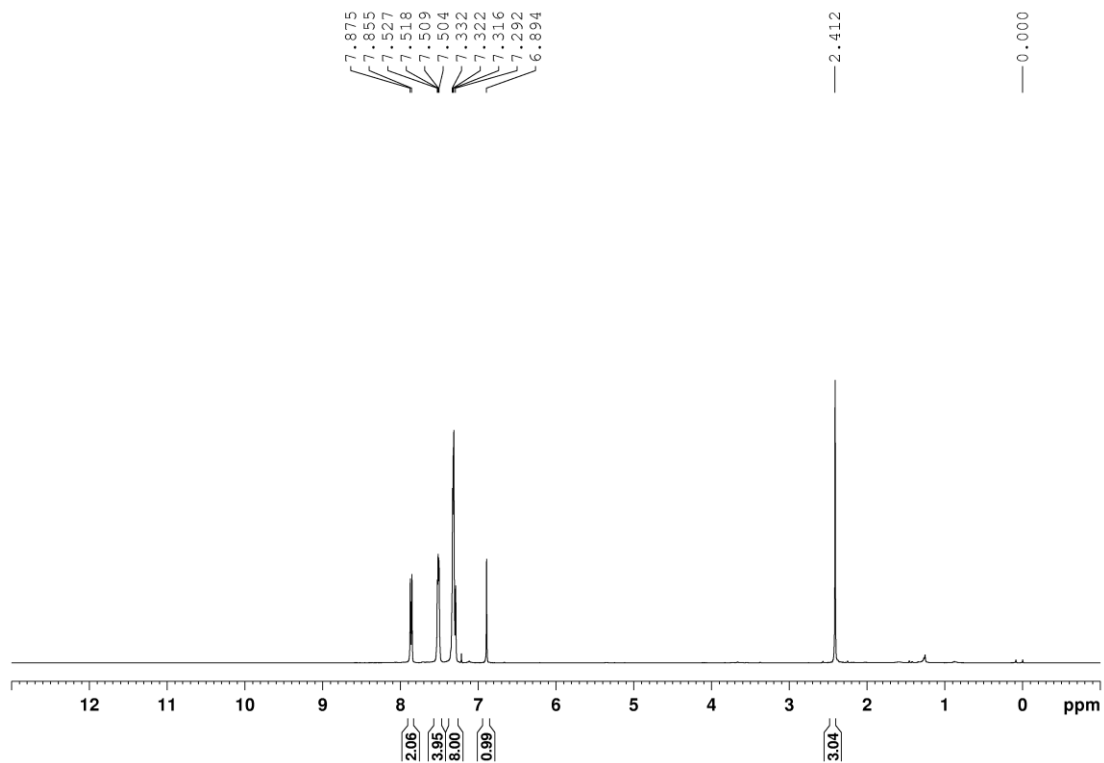
¹³C{¹H} NMR spectrum was recorded on 151 MHz in CDCl₃.



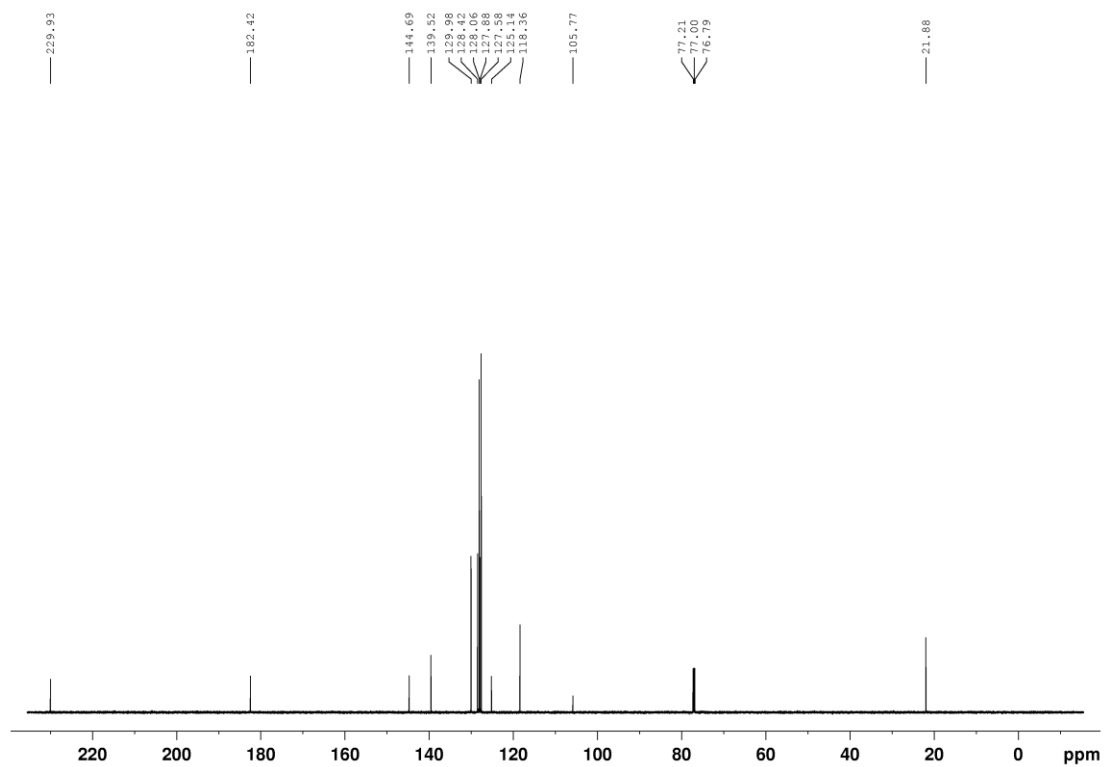


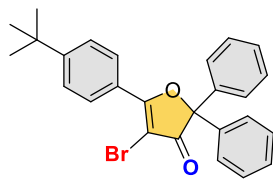
3ab

^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .



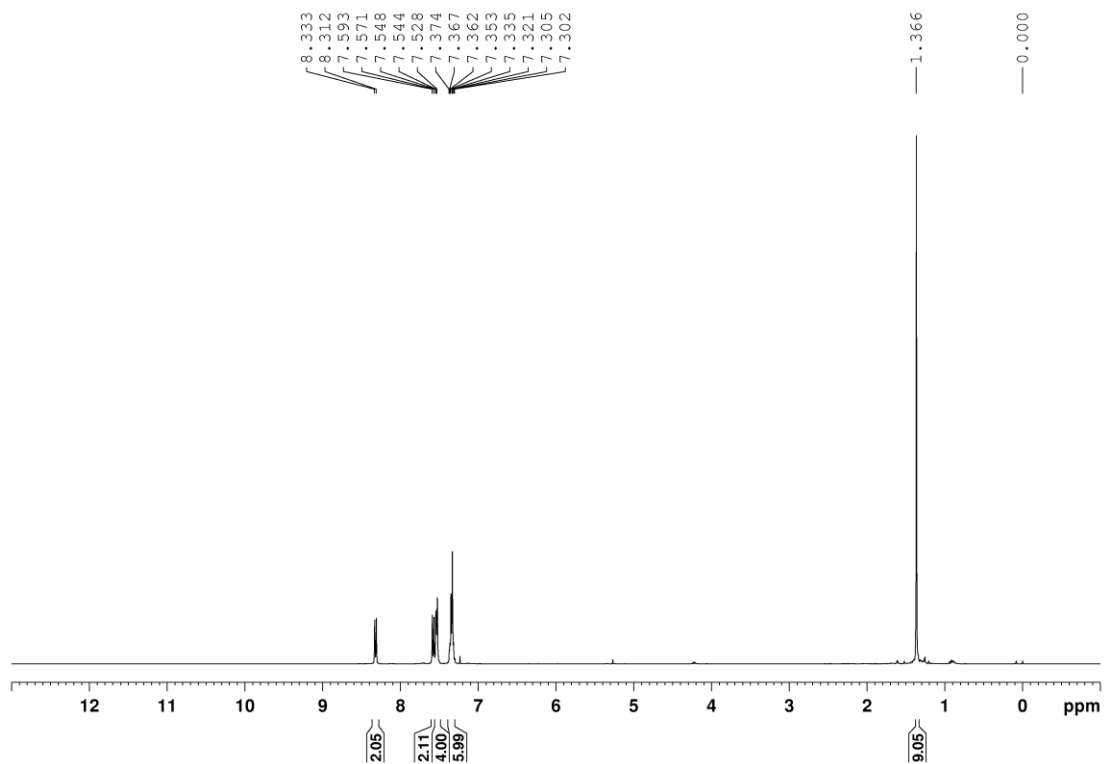
$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



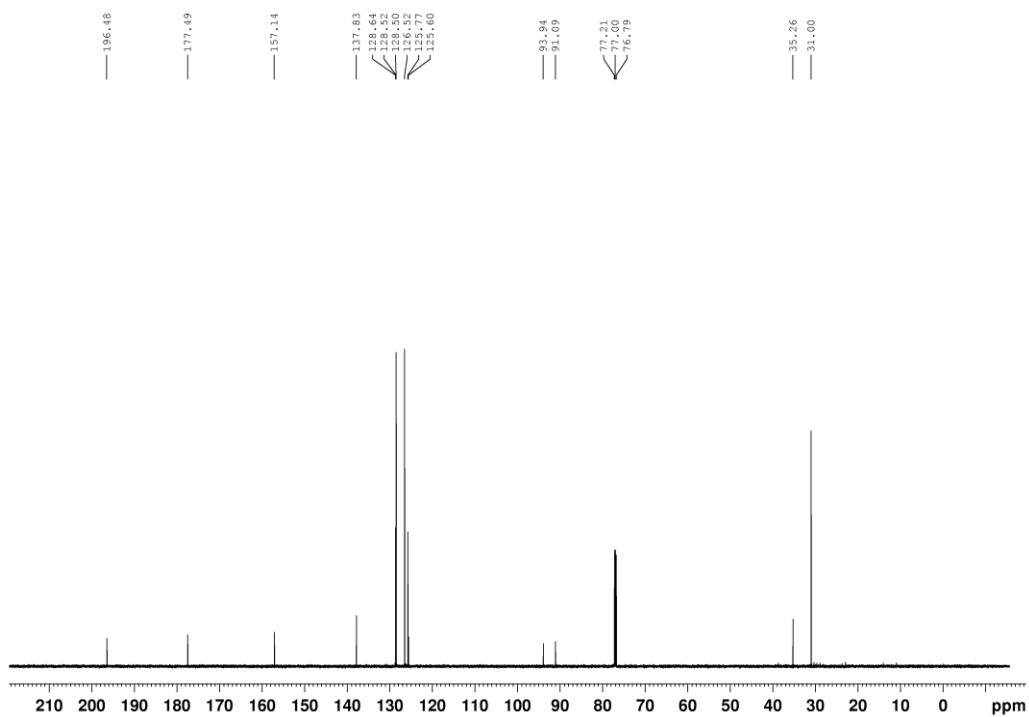


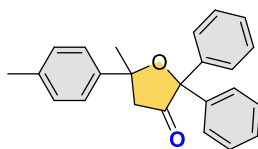
3ad

^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .



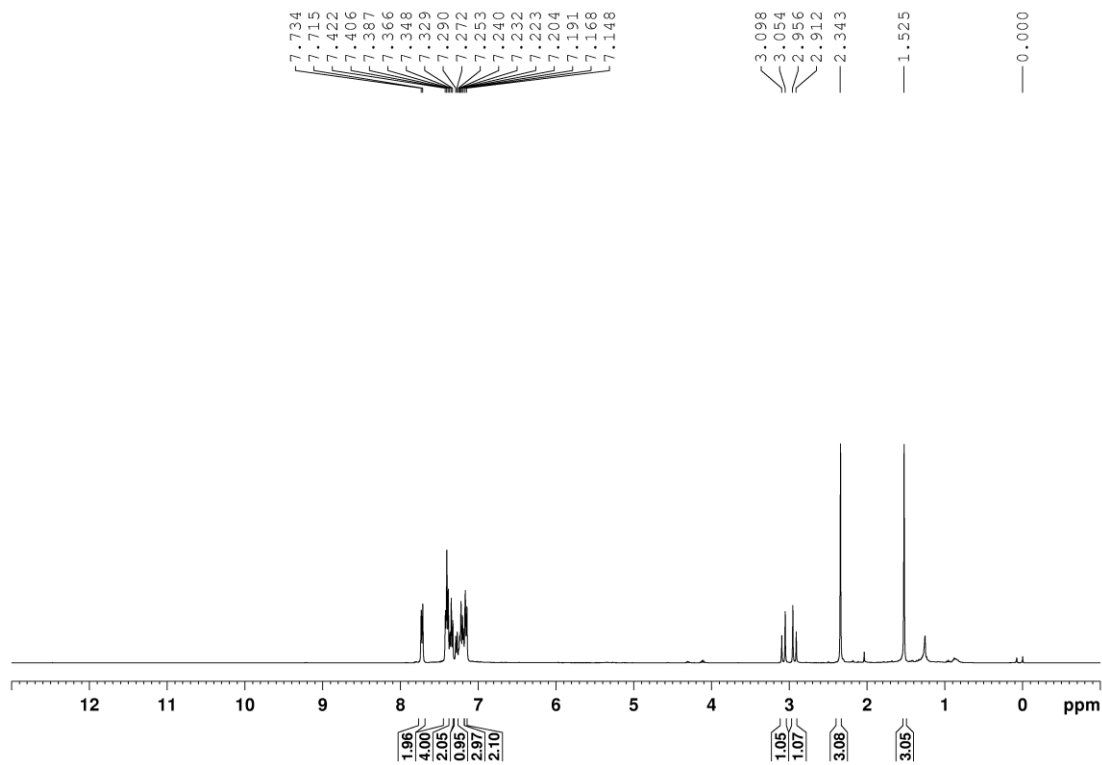
$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .



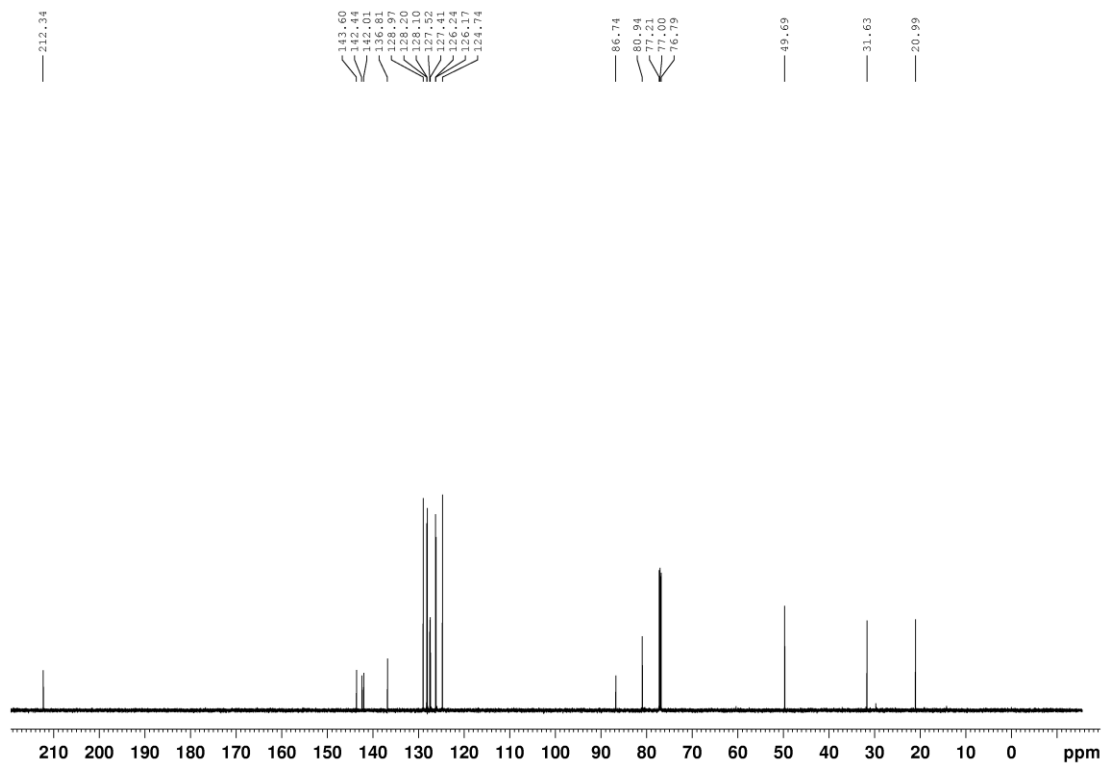


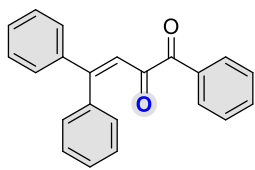
4ab

^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .



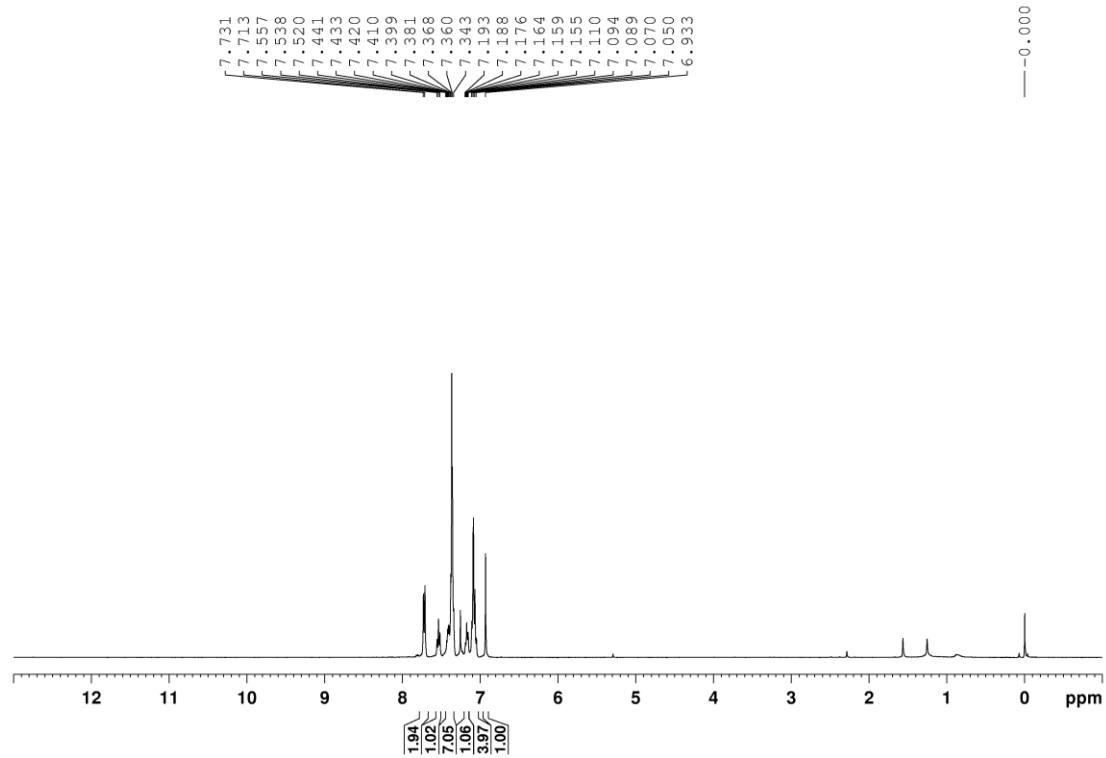
$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .





5a

^1H NMR spectrum was recorded on 400 MHz in CDCl_3 .



$^{13}\text{C}\{^1\text{H}\}$ NMR spectrum was recorded on 151 MHz in CDCl_3 .

