+Supplementary Information

α-Angelica lactone Catalyzed Oxidation of Benzylic sp^3 C−H Bonds of Isochromans and Phthalans

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1. General information

All chemicals were obtained from commercial supplier and were used without further purification unless otherwise stated. Flash column chromatography was performed on Merck flash silica gel 230-400 mesh size. Unless otherwise specified, all reactions were carried out in oven dried glass vials under open atmosphere. All the solvents were distilled prior to use. Analytical thin layer chromatography (TLC) was performed with Merck silica gel 60 F-254 aluminium-backed plates. Visualization on TLC was monitored by UV light. ^{1}H and ^{13}C spectra were recorded at 400, 500MHz and 101, 126 MHz respectively on bruker AV400 and AV500 Avance using $CDCl_3$ as internal standard ($CDCl_3$ at 7.27 ppm for ^{1}H and 77.00 ppm for ^{13}C). All the NMR spectra were processed in either MestReNova or Bruker software; chemical shifts (δ) are given in ppm. High resolution mass spectroscopy (HRMS) was recorded using Q-exactive-orbitap spectrometer with electrospray ionization as ionization source.

2. Table S1: Solvent and base optimization[a]

Sr. no.	Base	Solvent	Catalyst	Time	Temp.	% of Yield[b]
1	DABCO	THF	A	36 h	rt	27
2	DMAP	THF	A	36 h	rt	34
3	DMAP	DEE	A	36 h	rt	27
4	DMAP	MTBE	A	36 h	rt	30
5	DMAP	MeOH	A	36 h	rt	N. D.
6	DMAP	DMF	A	36 h	rt	N. D.
7	DMAP	DMSO	A	36 h	rt	N. D.
8	DMAP	ACN	A	36 h	rt	47
9	DMAP	Toluene	A	36 h	rt	41
10	DMAP	Toluene	A	24 h	80 °C	47
11	DMAP	ACN	A	24 h	80 °C	68

12	DMAP	2-MeTHF	A	24 h	80 °C	81
13[c]	DMAP	2-MeTHF	A	24 h	80 °C	71
14[d]	DMAP	2-MeTHF	A	24 h	80 °C	62
15[e]	DMAP	2-MeTHF	A	24 h	80 °C	28
16	PPh_3	2-MeTHF	A	24 h	80 °C	N. D.
17	Pyridine	2-MeTHF	A	24 h	80 °C	18
18	2,6-Lutidine	2-MeTHF	A	24 h	80 °C	Trace
19	N-Methyl Morholine	2-MeTHF	A	24 h	80 °C	27
20	DIPEA	2-MeTHF	A	24 h	80 °C	Trace
21	Na_2CO_3	2-MeTHF	A	24 h	80 °C	N. D.
22	Cs_2CO_3	2-MeTHF	A	24 h	80 °C	N. D.

[a]Reaction condition: **1a** (0.1 mmol), DMAP (0.3 mmol), catalyst **A** (25 mol %), in 2-Me THF (1 mL) at 80 °C for 36 h under O_2 (balloon) atmosphere. [b]Isolated yields. [c]0.5 ml 2-MeTHF. [d]2 ml 2-MeTHF. [e]0.2 mmol DMAP was used.

3. General procedure for the oxidation of isochroman and phthalans

To a solution of isochromans[1] or phthalans[1] (0.1 mmol) and DMAP (0.3 mmol) in 2Me-THF (1 mL) was added the α-angelica lactone (25 mol%, 2.3 µL) at room temperature. The round bottom flask was equipped with balloon containing O_2 gas and the reaction was stirred at 80˚C for 12 h to 48 h. The progress of the reaction was monitored by TLC. Then reaction mixture was diluted with dichloromethane (2 mL) and washed with water (2 mL). The layers were separated and the aqueous layer was extracted with dichloromethane (3 ×5 mL). The combined organic layer was dried over Na_2SO_4 and concentrated under reduced pressure. The crude products were purified on a neutral alumina column using 20% pet ether/EtOAc.

4. Characterization of compounds

Isochroman-1-one (2a): Colourless oil (12 mg, 81%); TLC R_f = 0.5 (20% EtOAc/Pet ether); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.10 (d, *J* = 7.8 Hz, 1H), 7.57-7.51 (m, 1H), 7.43-7.37 (m, 1H), 7.29 – 7.25 (m, 1H), 4.55 (t, *J* = 6.2 Hz, 2H), 3.07 (t, *J* = 6.0 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 165.25, 139.63, 133.77, 130.51, 127.79, 127.32, 125.40, 67.40, 27.92. HRMS (ESI+) (*m/z*) calcd for $C_9H_9O_2$ [M+H] 149.0602 found 149.0597.

7-(*tert-butyl*)isochroman-1-one (2b): Colourless oil (15.7 mg, 77%); TLC R_f = 0.6 (20% EtOAc/Pet ether); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.13 (d, *J* = 2.3 Hz, 1H), 7.60-7.56 (m, 1H), 7.21 (d, *J* = 7.8 Hz, 1H), 4.52 (t, *J* = 6.0 Hz, 2H), 3.02 (t, *J* = 6.0 Hz, 2H), 1.34 (s, 9H).^{13}C NMR (101 MHz, $CDCl_3$) δ 165.70, 151.08, 136.71, 131.09, 127.16, 127.10, 124.91, 67.47, 34.84, 31.27, 27.50. HRMS (ESI+) (*m/z*) calcd for $C_{13}H_{17}O_2$ [M+H] 205.1229 found 205.1223.

7-Methylisochroman-1-one (2c): Yellow oil (11.3 mg, 70%); TLC R_f = 0.6 (20% EtOAc/Pet ether); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.92 (s, 1H), 7.35 (d, *J* = 7.7 Hz, 1H), 7.16 (d, *J* = 7.8 Hz, 1H), 4.52 (t, *J* = 6.7 Hz, 2H), 3.02 (t, *J* = 6.2 Hz, 2H), 2.39 (s, 3H).13C NMR (126 MHz, $CDCl_3$) δ 164.77, 137.67, 136.67, 134.65, 130.72, 127.21, 125.12,68.20, 27.55, 21.11. HRMS (ESI+) (*m/z*) calcd for $C_{10}H_{11}O_2$ [M+H] 163.0759 found 163.0754.

5-Methylisochroman-1-one (2d): Yellow oil (11 mg, 68%); TLC R_f = 0.6 (20% EtOAc/Pet ether); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.99 (d, *J* = 9.4 Hz, 1H), 7.42 (d, *J* = 7.0 Hz, 1H), 7.32-7.27 (m, 1H), 4.54 (t, *J* = 6.2 Hz, 2H), 2.99 (t, *J* = 6.1 Hz, 2H), 2.34 (s, 3H).^{13}C NMR (101 MHz, $CDCl_3$) δ 165.64, 138.26, 135.09, 128.34, 127.22, 125.40, 66.78, 25.01, 18.97. HRMS (ESI+) (*m/z*) calcd for $C_{10}H_{11}O_2$ [M+H] 163.0759 found 163.0754.

6-methoxyisochroman-1-one (2e): Yellow oil (10.3 mg, 58%); TLC R_f = 0.5 (30% EtOAc/Pet ether); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.59 (d, *J* = 2.7 Hz, 1H), 7.18 (d, *J* = 8.5 Hz, 1H), 7.11 (dd, *J* = 8.3, 2.7 Hz, 1H), 4.55 (t, *J* = 6.0 Hz, 2H), 3.85 (s, 3H), 3.00 (t, *J* = 6.0 Hz, 2H).^{13}C NMR (101 MHz, $CDCl_3$) δ 165.37, 159.08, 131.92, 128.50, 126.14, 121.77, 113.05, 67.74, 55.71, 27.09. HRMS (ESI+) (*m/z*) calcd for $C_{10}H_{11}O_3$ [M+H] 179.0708 found 179.0703.

6-(benzyloxy)isochroman-1-one (2f): Yellow oil (9.4 mg, 37%); TLC R_f = 0.5 (30% EtOAc/Pet ether); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.69 (s, 1H), 7.46-7.32 (m, 5H), 7.18 (s, 2H),

5.10 (s, 2H), 4.52 (t, *J* = 6.0 Hz, 2H), 2.99 (t, *J* = 6.0 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 165.26, 158.21, 136.43, 132.19, 128.74, 128.57, 128.25, 127.65, 126.19, 122.36, 114.25, 70.38, 67.70, 27.12. HRMS (ESI+) (*m/z*) calcd for $C_{10}H_{11}O_3$ [M+H] 255.1021 found 255.1016.

7-Bromoisochroman-1-one (2g): Yellow solid (9.9 mg, 44%); TLC R_f = 0.6 (30% EtOAc/Pet ether); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.24 (d, *J* = 2.0 Hz, 1H), 7.66 (dd, *J* = 7.7, 2.2 Hz, 1H), 7.17 (d, *J* = 8.2 Hz, 1H), 4.54 (t, *J* = 6.0 Hz, 2H), 3.03 (t, *J* = 6.0 Hz, 2H).^{13}C NMR (101 MHz, $CDCl_3$) δ 163.86, 138.31, 136.68, 133.26, 129.05, 127.07, 121.46, 67.30, 27.44. HRMS (ESI+) (*m/z*) calcd for $C_9H_8O_2Br$ [M+H] 226.9708 found 226.9702 and calcd for $C_9H_7O_2BrNa$ [M+Na] 248.9527 found 248.9522.

7-Fluoroisochroman-1-one (2h): White solid (5.5 mg, 33%); TLC R_f = 0.6 (30% EtOAc/Pet ether); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.79 (d, *J* = 10.0 Hz, 1H), 7.28 – 7.25 (m, 2H), 4.55 (t, *J* = 6.0 Hz, 2H), 3.05 (t, *J* = 5.9 Hz, 2H).^{13}C NMR (101 MHz, $CDCl_3$) δ 164.18, 163.18, 160.72, 135.35, 129.18 (d, *J* = 28 Hz), 127.07 (d, *J* = 32 Hz), 121.19 (*J* = 88 Hz), 116.90 (d, *J* = 96 Hz), 67.56, 27.23.HRMS (ESI+) (*m/z*) calcd for $C_9H_8O_2F$ [M+H] 167.0508 found 167.0503.

4-Methylisochroman-1-one (2i): Colourless oil (11.4 mg, 70%); TLC R_f = 0.7 (30% EtOAc/Pet ether); ^{1}H NMR (400 MHz, CDCl3) δ 8.10 (dd, *J* = 7.7, 1.5 Hz, 1H), 7.60-7.55 (m, 1H), 7.43-7.37 (m, 1H), 7.31 (d, *J* = 7.8 Hz, 1H), 4.53 (dd, *J* = 11.0, 4.1 Hz, 1H), 4.25 (dd, *J* = 10.9, 6.6 Hz, 1H), 3.21-3.12 (m, 1H), 1.38 (d, *J* = 7.3 Hz, 3H).^{13}C NMR (101 MHz, $CDCl_3$) δ 165.27, 144.64, 134.01, 130.56, 127.63, 125.78, 124.45, 72.55, 31.82, 16.78. HRMS (ESI+) (*m/z*) calcd for $C_{10}H_{11}O_2$ [M+H] 163.0759 found 163.0754.

3,3-dimethylisochroman-1-one (2j): Colourless oil (13.4 mg, 76%); TLC R_f = 0.7 (30% EtOAc/Pet ether); ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.10 (d, *J* = 7.8 Hz, 1H), 7.56-7.51 (m, 1H), 7.40-7.36 (m, 1H), 7.23 (d, *J* = 7.5 Hz, 1H), 3.03 (s, 2H), 1.46 (s, 6H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 165.18, 138.15, 133.85, 130.12, 128.02, 127.60, 124.88, 80.76, 39.54, 27.63. HRMS (ESI+) (*m/z*) calcd for $C_{11}H_{13}O_2$ [M+H] 177.0916 found 177.0910.

3-Ethylisochroman-1-one (2k): Yellow oil (11.4 mg, 65%); TLC R_f = 0.7 (30% EtOAc/Pet ether); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.10 (d, *J* = 7.8 Hz, 1H), 7.59-7.53 (m, 1H), 7.43-7.37 (m, 1H), 7.26 (d, *J* = 4.8 Hz, 1H), 4.55 (dd, *J* = 11.2, 3.2 Hz, 1H), 4.47 (dd, *J* = 11.2, 2.9 Hz, 1H), 2.81-2.74 (m, 1H), 1.82-1.71 (m, 2H), 1.04 – 1.00 (m, 3H).^{13}C NMR (101 MHz, $CDCl_3$) δ

165.24, 143.79, 133.65, 130.57, 127.72, 127.08, 124.58, 70.41, 39.12, 25.76, 11.85.HRMS (ESI+) (*m/z*) calcd for $C_{11}H_{13}O_2$ [M+H] 177.0916 found 177.0910.

4,6,6,7,8,8-hexamethyl-3,4,7,8-tetrahydrocyclopenta[g]isochromen-1(6H)-one (2l): White solid (19.3 mg, 71%); TLC R_f = 0.6 (30% EtOAc/Pet ether); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.90 (s, 1H), 7.04 (s, 1H), 4.52 – 4.45 (m, 1H), 4.25 – 4.18 (m, 1H), 3.17-3.09 (m, 1H), 1.92-1.84 (m, 1H), 1.38 – 1.35 (m, 3H), 1.31 – 1.29 (m, 6H), 1.09 (t, *J* = 4.5 Hz, 6H), 1.01 (d, *J* = 7.3 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 165.97, 158.46, 151.25, 143.62, 125.13, 123.02, 119.90, 72.58, 54.18, 45.32, 44.69, 32.12, 29.13, 28.79, 25.86, 25.77, 17.03, 8.53. HRMS (ESI+) (*m/z*) calcd for $C_{18}H_{25}O_2$ [M+H] 273.1855 found 273.1849.

1H-benzo[f]isochromen-4(2H)-one (2m): White solid (10.5 mg, 53%); TLC R_f = 0.6 (30% EtOAc/Pet ether); 1H NMR (400 MHz, CDCl3) δ 8.11 (d, *J* = 8.6 Hz, 1H), 8.02 (dd, *J* = 7.3, 2.3 Hz, 1H), 7.92 – 7.88 (m, 1H), 7.83 (d, *J* = 8.7 Hz, 1H), 7.67 – 7.59 (m, 2H), 4.66 (t, *J* = 6.1 Hz, 2H), 3.43 (t, *J* = 6.1 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 165.54, 138.59, 135.65, 130.72, 128.93, 128.73, 127.80, 127.27, 125.22, 124.44, 122.49, 66.73, 24.22. HRMS (ESI+) (*m/z*) calcd for $C_{13}H_{11}O_2$ [M+H] 199.0759 found 199.0754.

Benzo[de]isochromen-1(3H)-one (2n) (The product was obtained with some unknown impurities)**:** White solid (9.4 mg, 51%); TLC R_f = 0.6 (30% EtOAc/Pet ether); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.40 (d, *J* = 7.0 Hz, 1H), 8.11 (d, *J* = 8.2 Hz, 1H), 7.85 (d, *J* = 8.1 Hz, 1H), 7.68 – 7.63 (m, 1H), 7.58 – 7.52 (m, 1H), 7.37 (d, *J* = 7.2 Hz, 1H), 5.83 (s, 2H).^{13}C NMR (101 MHz, $CDCl_3$) δ 164.33, 133.66, 132.15, 129.31, 128.50, 127.31, 126.87, 126.68, 126.65, 121.64, 120.31, 70.18. HRMS (ESI+) (*m/z*) calcd for $C_{12}H_9O_2$ [M+H] 185.0603 found 185.0597.

7-chlorobenzo[de]isochromen-1(3H)-one (2o) (major regio-isomer is mentioned): White solid (9.4 mg, 43%); TLC R_f = 0.5 (30% EtOAc/Pet ether); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.52 (d, *J* = 8.5 Hz, 1H), 8.33 (d, *J* = 7.7 Hz, 1H), 7.77 (dd, *J* = 18.2, 7.8 Hz, 2H), 7.46 (d, *J* = 7.2 Hz, 1H), 5.84 (s, 2H).^{13}C NMR (101 MHz, $CDCl_3$) δ 163.76, 138.37, 130.46, 129.79, 129.53, 127.65, 127.11, 126.40, 123.88, 122.64, 70.04, 66.21. HRMS (ESI+) (*m/z*) calcd for $C_{12}H_8ClO_2$ [M+H] 219.0213 found 219.0207.

6,7-dihydro-4H-thieno[3,2-c]pyran-4-one (2p): White solid (7.6 mg, 49%); TLC R_f = 0.5 (30% EtOAc/Pet ether); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.46 (d, *J* = 5.2 Hz, 1H), 7.17 (d, *J* = 5.3

Hz, 1H), 4.60 (t, *J* = 6.1 Hz, 2H), 3.16 (t, *J* = 6.1 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 161.35, 149.01, 128.22, 127.03, 124.08, 67.79, 24.70. HRMS (ESI+) (*m/z*) calcd for $C_7H_7O_2S$ [M+H] 155.0167 found 155.0161.

4H-thieno[2,3-c]pyran-7(5H)-one (2q) (The product was obtained with some unknown impurities)**:** White solid (8.6 mg, 56%); TLC R_f = 0.5 (30% EtOAc/Pet ether); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.66 (d, *J* = 5.2 Hz, 1H), 7.01 (d, *J* = 4.7 Hz, 1H), 4.59 (t, *J* = 6.2 Hz, 2H), 3.02 (t, *J* = 6.1 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 161.29, 147.55, 134.52, 126.80, 126.64, 68.46, 25.18. HRMS (ESI+) (*m/z*) calcd for $C_7H_7O_2S$ [M+H] 155.0167 found 155.0161.

Isobenzofuran-1(3H)-one(2r) : White solid (9.5 mg, 71%); TLC R_f = 0.5 (30% EtOAc/Pet ether); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.94 (d, *J* = 7.7 Hz, 1H), 7.72-7.67 (m, 1H), 7.57 – 7.49 (m, 2H), 5.34 (s, 2H). ^{13}C NMR (101 MHz, CDCl3) δ 171.23, 146.61, 134.11, 129.14, 125.87, 122.19, 69.76. HRMS (ESI+) (*m/z*) calcd for $C_8H_7O_2$ [M+H] 135.0446 found 135.0441.

5-(*tert*-butyl)isobenzofuran-1(3H)-one (major regio-isomer is mentioned)(2s) : Yellow oil (9.8 mg, 52%); TLC R_f = 0.5 (30% EtOAc/Pet ether); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.85 (d, *J* = 8.4 Hz, 1H), 7.58 (d, *J* = 8.2 Hz, 1H), 7.49 (s, 1H), 5.30 (s, 2H), 1.38 (s, 9H).^{13}C NMR (101 MHz, $CDCl_3$) δ 171.30, 158.53, 147.03, 126.84, 125.41, 122.29, 118.75, 69.77, 35.67, 31.33. HRMS (ESI+) (*m/z*) calcd for $C_{12}H_{15}O_2$ [M+H] 191.1072 found 191.1067.

Benzophenone (2t): Yellow solid (3 mg, 17%); TLC R_f = 0.5 (30% EtOAc/Pet ether); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.80 (d, *J* = 7.5 Hz, 4H), 7.62-7.55 (m, 2H), 7.50-7.44 (m, 4H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 196.83, 137.66, 132.49, 130.13, 128.35. HRMS (ESI+) (*m/z*) calcd for $C_{13}H_{10}O$ [M+H] 183.0765 found 183.0804.

9H-fluoren-9-one (2u): Yellow solid (2.92 mg, 16%); TLC R_f = 0.5 (30% EtOAc/Pet ether); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.65 (d, *J* = 7.4 Hz, 2H), 7.52 – 7.45 (m, 4H), 7.30 – 7.26 (m, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 194.01, 144.50, 134.76, 134.22, 129.15, 124.38, 120.38. HRMS (ESI+) (*m/z*) calcd for $C_{13}H_8O$ [M+H] 181.0609 found 181.0648.

5. Experiment procedure of reaction isochroman 1a in the presence of H_2O^{18}

H_2O^{18} was purchased from sigma Aldrich (catalog no: 329878-250mg) with 97% isotopic purity. The experiment was carried out according to the procedure reported for the oxidation of **1a** to **2a** under 10 equiv of H_2O^{18} and 980µL 2Me-THF. The percentage of ^{18}O enrichment was examined by mass spectrometry as shown in following S45. The calculated data showed no enrichment of ^{18}O.

Reaction condition: Isochroman (0.1 mmol), DMAP (0.3 mmol), α-angelica lactone (25 mol%, 2Me-THF (980 µL) and H_2O^{18} (20 µL) were added in a Schlenk tube inside the glove box. The reaction mixture stirred under O_2 (balloon) at 25°C for 24 h. No isotopic enrichment in product **2a** was determined by GCMS and ESI-MS (shown in S45).

6. Experiment procedure of reaction isochroman 1a in the presence of catalase enzyme

Catalase enzyme was purchased from sigma Aldrich (catalog no:C1345-1g) with powder form. The experiment was carried out according to the procedure reported for the oxidation of **1a** to **2a** with 70 mg of Catalase enzyme.

Reaction condition: Isochroman (0.1 mmol), DMAP (0.3 mmol), α-angelica lactone (25 mol%, 2Me-THF (1 mL) and 70 mg of catalase enzyme were added. The reaction mixture stirred under O_2 (balloon) at 80 °C for 24 h. After completion of reaction time, product **2a** was obtained in the yield of 13%.

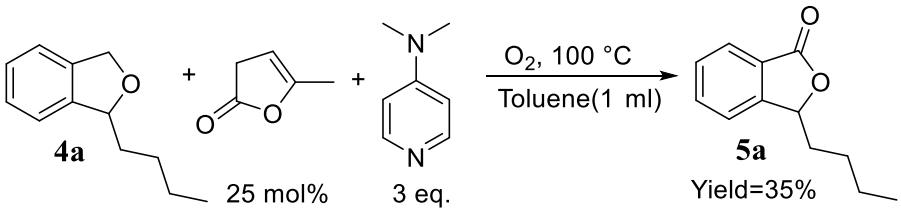
7. Experiment procedure of reaction isochroman 1a in the presence of $^{18}O_2$

$^{18}O_2$ was purchased from icon isotopes (catalog no: IO 6393) with 98% purity isotopic purity.
The experiment was carried out according to the procedure reported for the oxidation of **1a** to **2a** under $^{18}O_2$ atmosphere. The percentage of ^{18}O enrichment was examined by mass spectrometry as shown in following S46. The calculated data showed 82% of ^{18}O.

Reaction condition: Isochroman (0.1 mmol), DMAP (0.3 mmol), α-angelica lactone (25 mol%, 2Me-THF (1 mL) were added in a Schlenk tube inside glove box. The tube was filled with $^{18}O_2$ gas and the mixture was stirred at 80 °C for 24 h. 82% of ^{18}O isotopic enrichment in product **2a** was determined by GCMS and ESI-MS (shown in S46).

8. Synthesis of natural product 3-butylphthalide (5a)

Compound **4a** was prepared by following the literature procedure. [2]



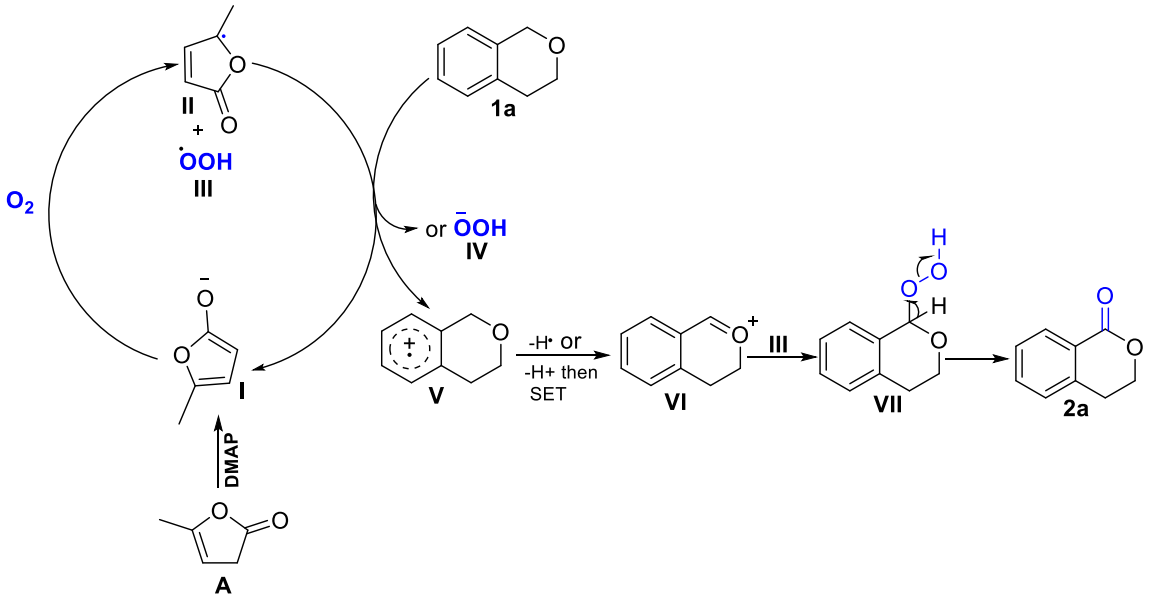
Synthesis of 3-butylphthalide:

To a solution of n-Butyl phthalan (0.3 mmol) and DMAP (3 equiv.) in toluene (1 mL) was added the α-angelica lactone (25 mol %) at room temperature. The round bottom flask was equipped with balloon containing O_2 gas and the reaction was stirred at preheated 100˚C temperature oil bath for 48 h. The resulting reaction mixture was monitored by TLC. Then reaction mixture was diluted with dichloromethane and washed with water. The layers were separated and the aqueous layer was extracted with dichloromethane. The combined organic layer was dried over Na_2SO_4 and concentrated under reduced pressure. The crude products were purified on a flash silica gel column using 20% pet ether/EtOAc to give a colourless oil in 19.9 mg (35% yield). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.90 (d, *J* = 7.6 Hz, 1H), 7.69-7.64 (m, 1H), 7.54-7.49 (m, 1H), 7.44 (d, *J* = 7.6 Hz, 1H), 5.48 (dd, *J* = 7.9, 4.1 Hz, 1H), 2.09 – 2.00 (m, 1H), 1.82 – 1.71 (m, 1H), 1.47 – 1.34 (m, 4H), 0.92 (t, *J* = 7.2 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 170.79, 150.22, 134.01, 129.10, 126.26, 125.80, 121.79, 81.53, 34.53, 26.96, 22.52, 13.94. HRMS (ESI+) (*m/z*) calcd for $C_{12}H_{15}O_2$ [M+H] 191.1027 found 191.1067.

9. Gram scale reaction procedure

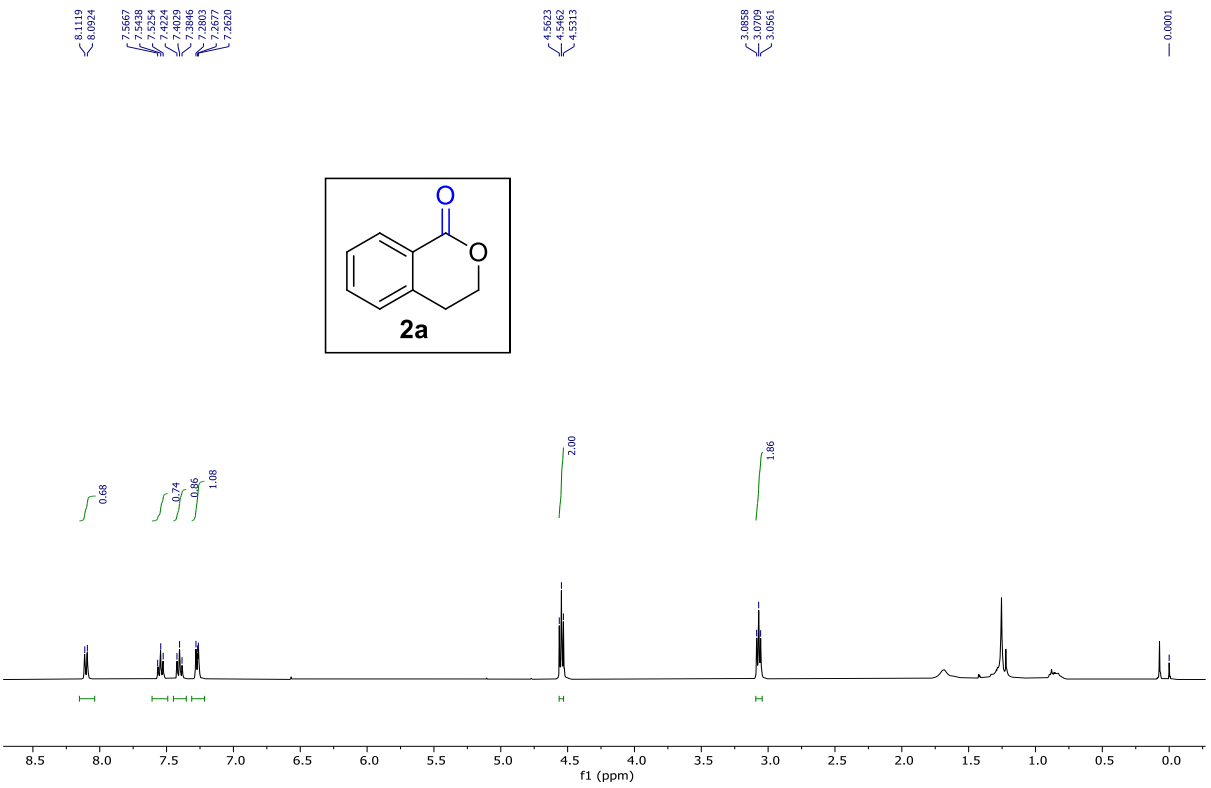
To a solution of isochromans[1] (12 mmol, 1.6 g) or phthalans[1] (13 mmol, 1.55g) and DMAP (36 mmol, 4.4 g) in 2Me-THF (20 mL) was added the α-angelica lactone (25 mol%, 270 µL) at 80˚C. The round bottom flask was equipped with balloon containing O_2 gas and the reaction was stirred at 80˚C for 24 h. The resulting reaction mixture was monitored by TLC. Then reaction mixture was diluted with dichloromethane (10 mL) and washed with water. The layers were separated and the aqueous layer was extracted with dichloromethane (3×10 mL). The combined organic layer was dried over Na_2SO_4 and concentrated under reduced pressure. The crude products were purified on a neutral alumina column using 20% pet ether/EtOAc in 1.38 g (78%) of **2a** and 1.2 g (69% yield) of **2r**.

10. Alternative Plausible Mechanism

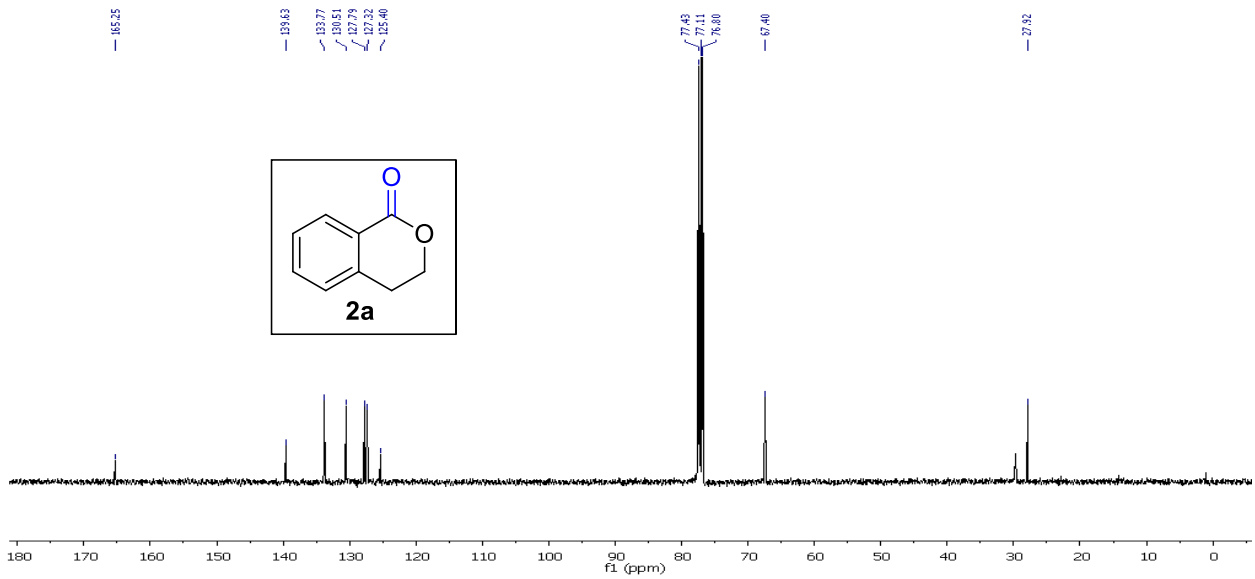


11. ^{1}H NMR, ^{13}C NMR, Mass spectra of compounds

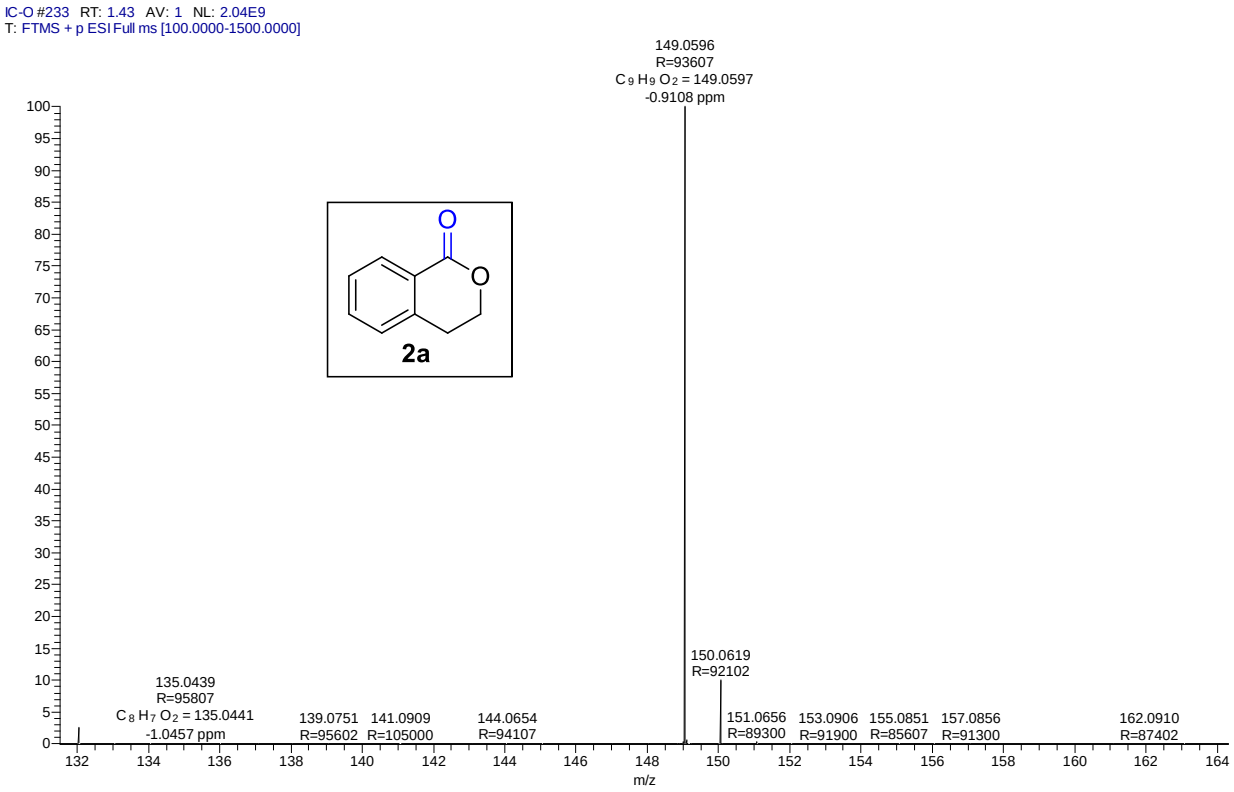
^{1}H NMR of compound **(2a)** in $CDCl_3$



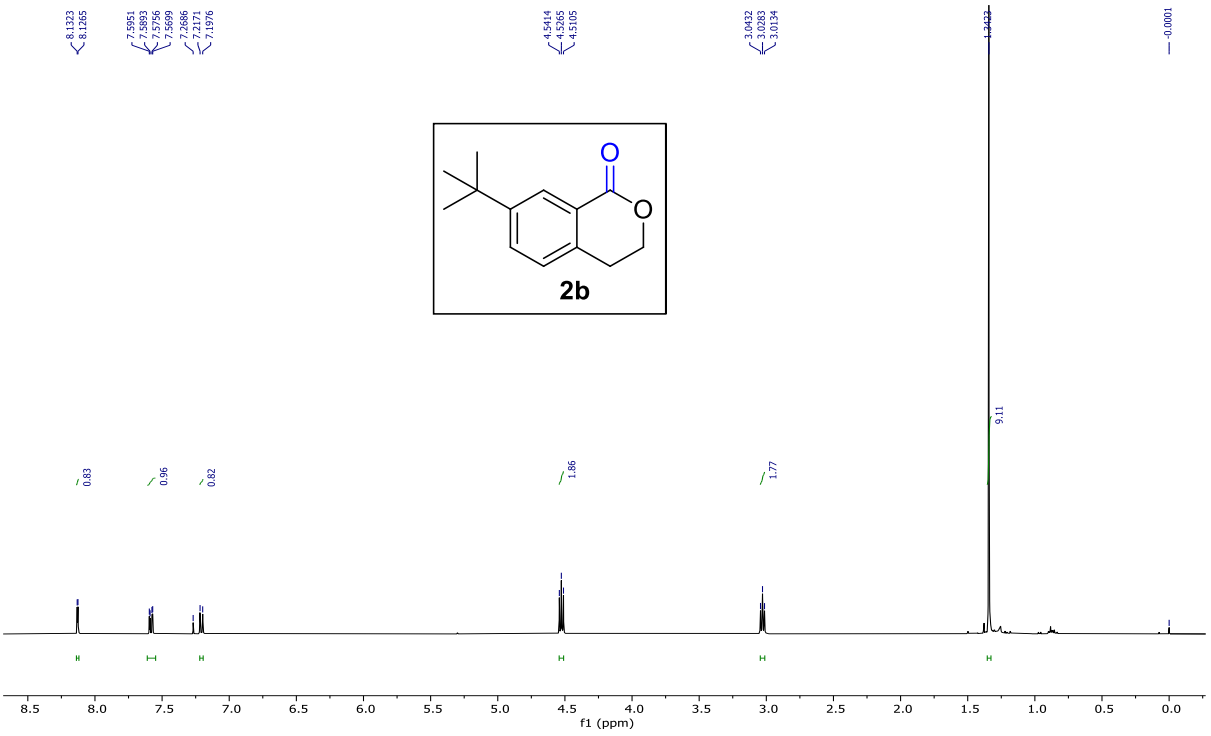
^{13}C NMR of compound **(2a)** in $CDCl_3$



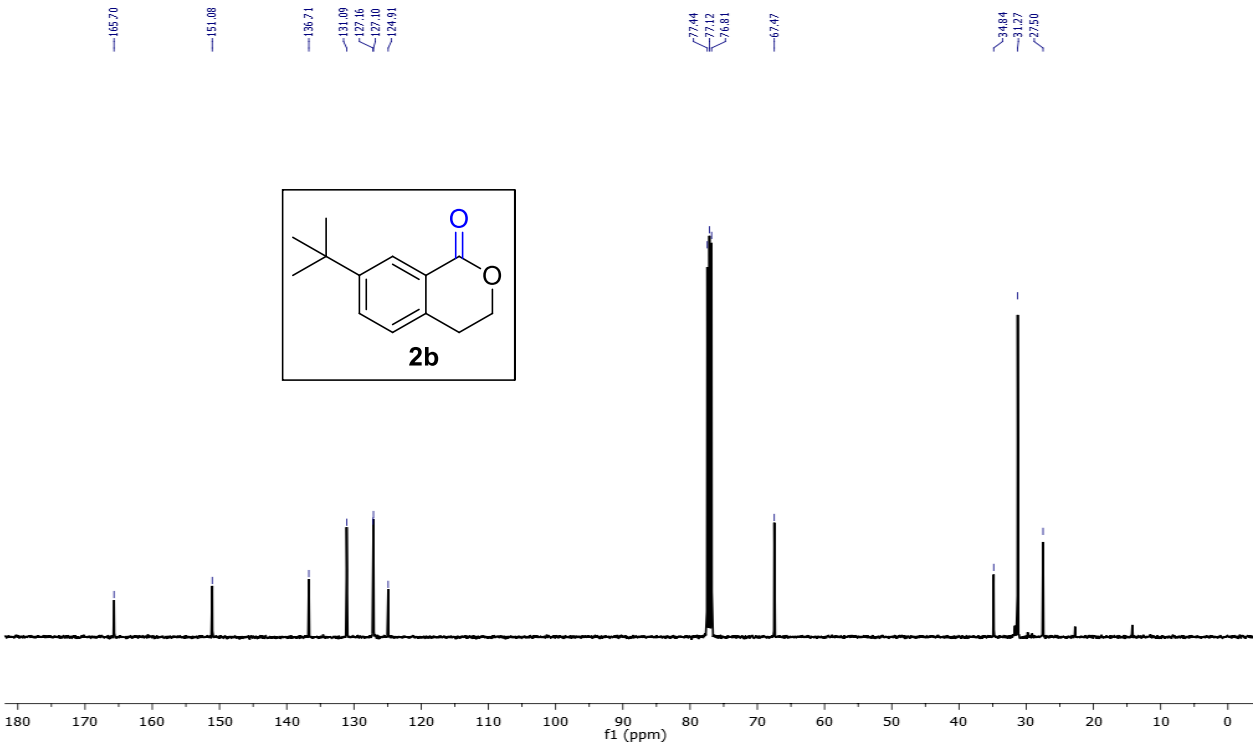
HRMS of compound **(2a)**



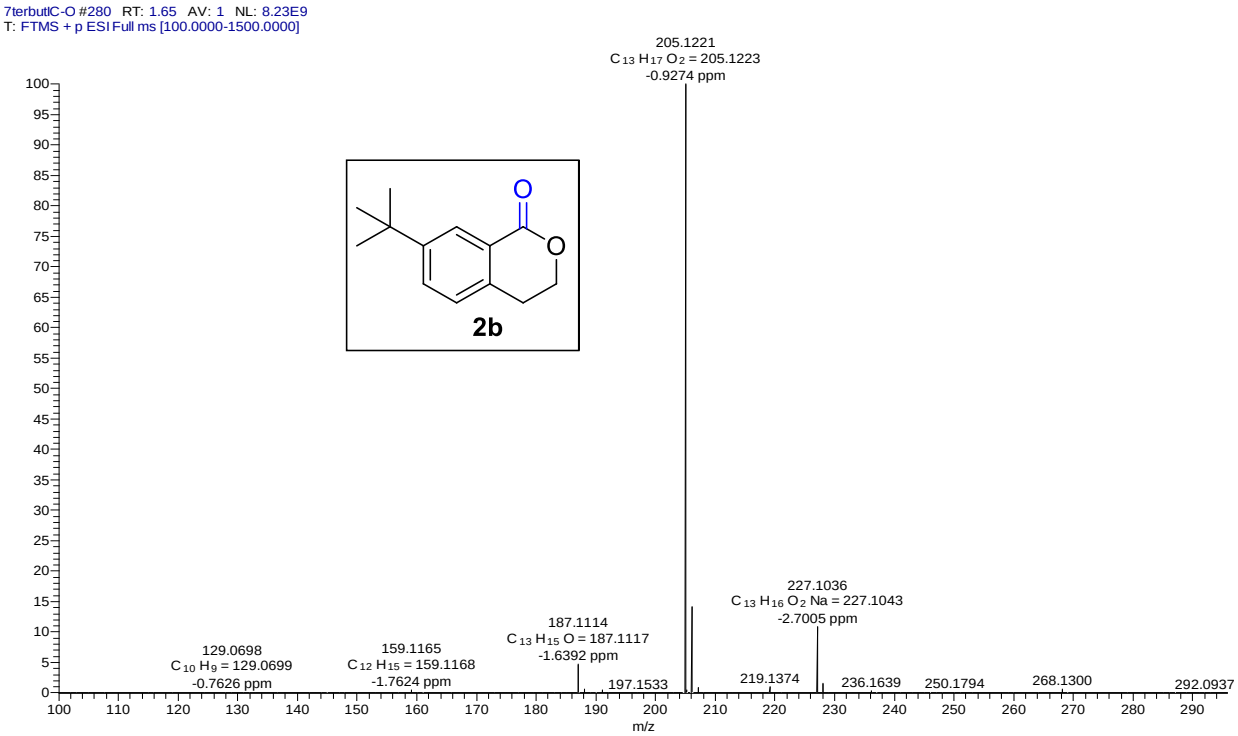
^{1}H NMR of compound **(2b)** in $CDCl_3$



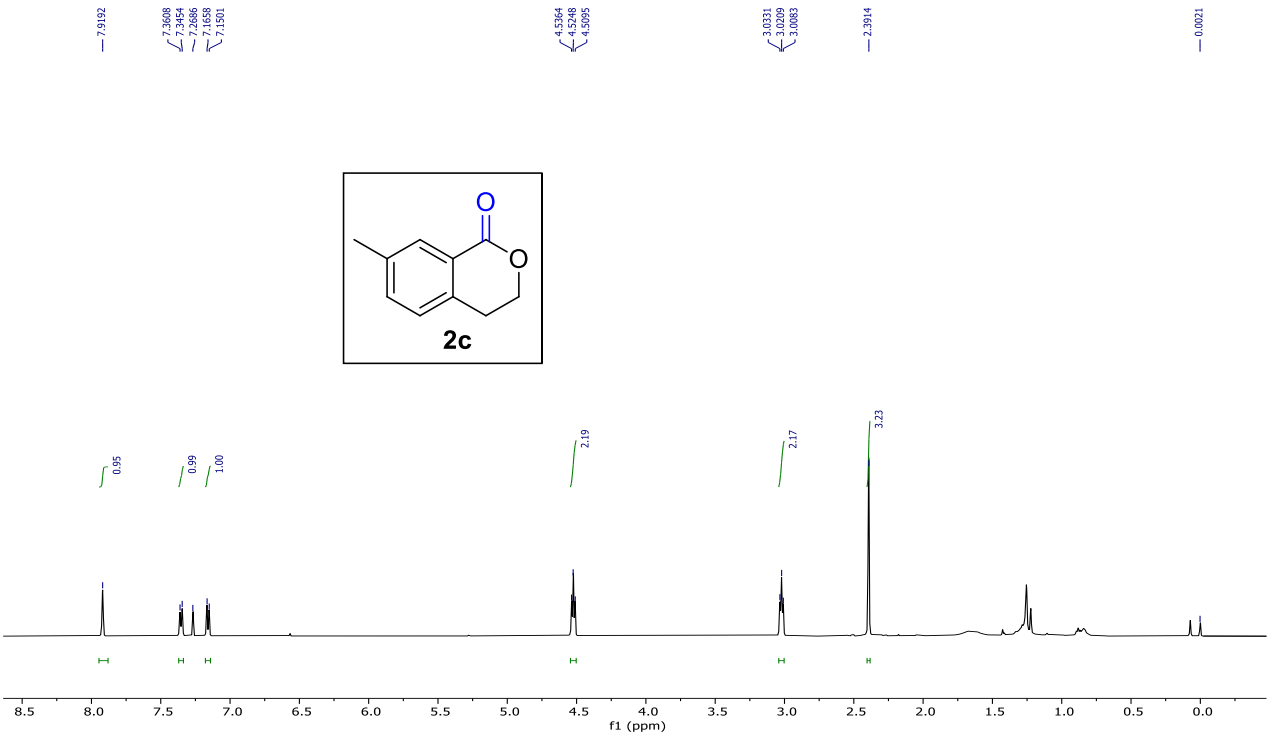
^{13}C NMR of compound **(2b)** in $CDCl_3$



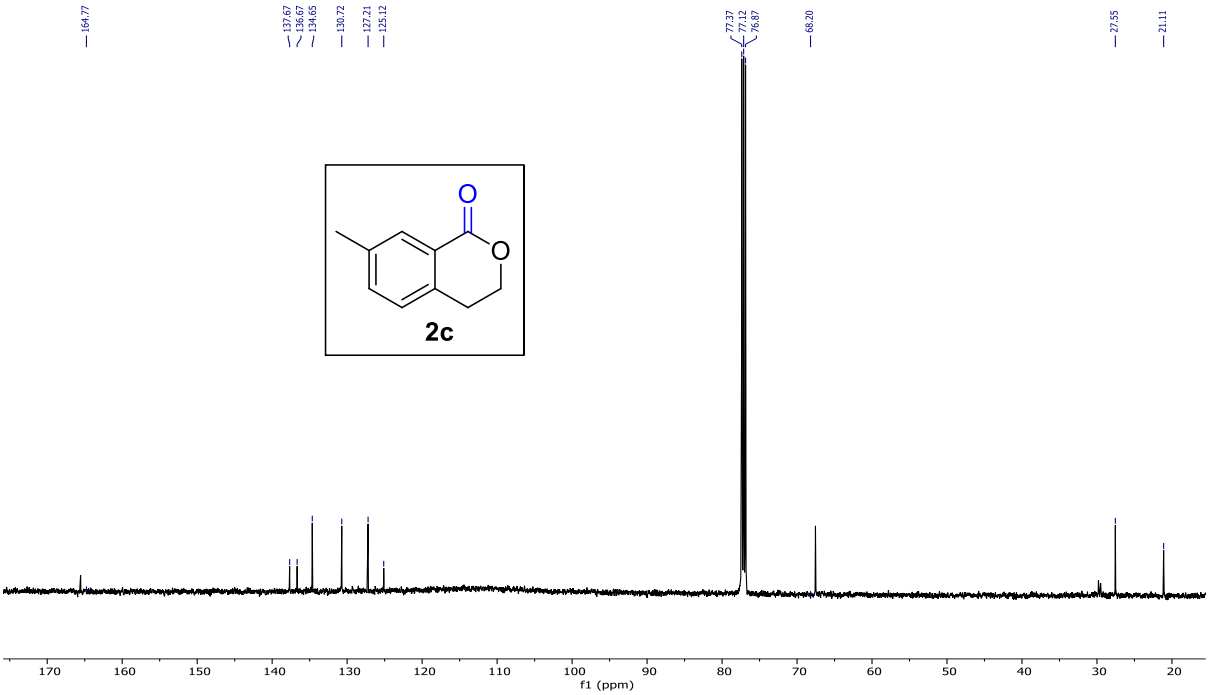
HRMS of compound **(2b)**



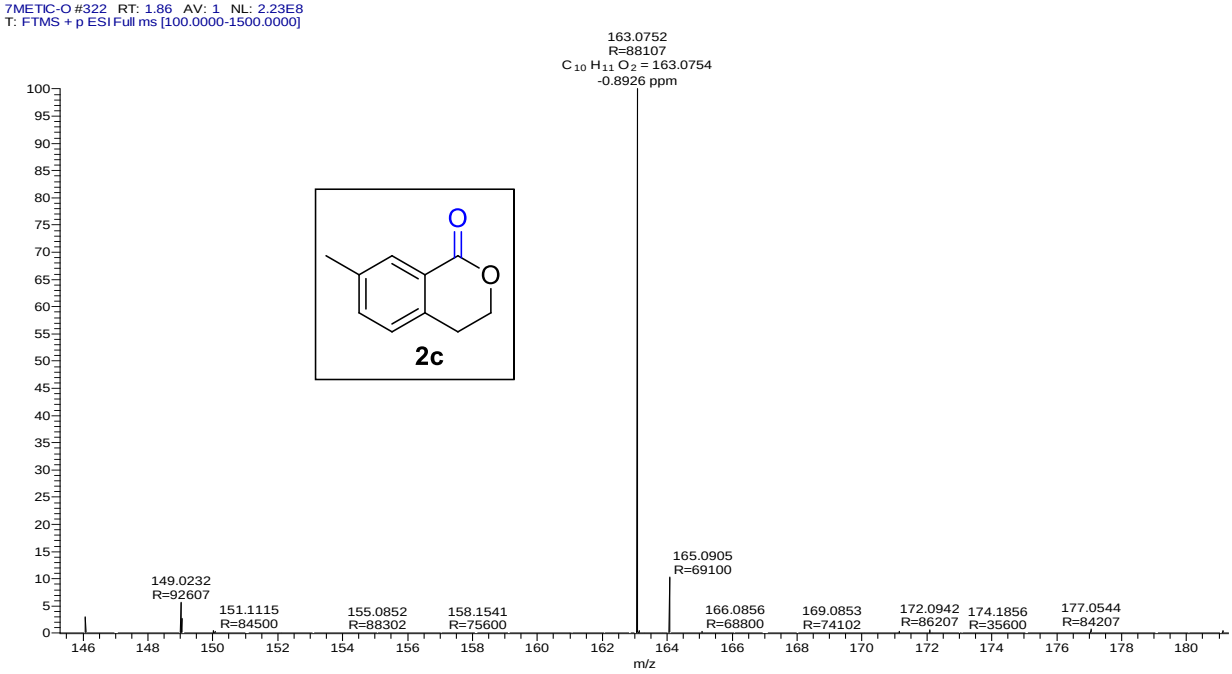
^{1}H NMR of compound **(2c)** in $CDCl_3$



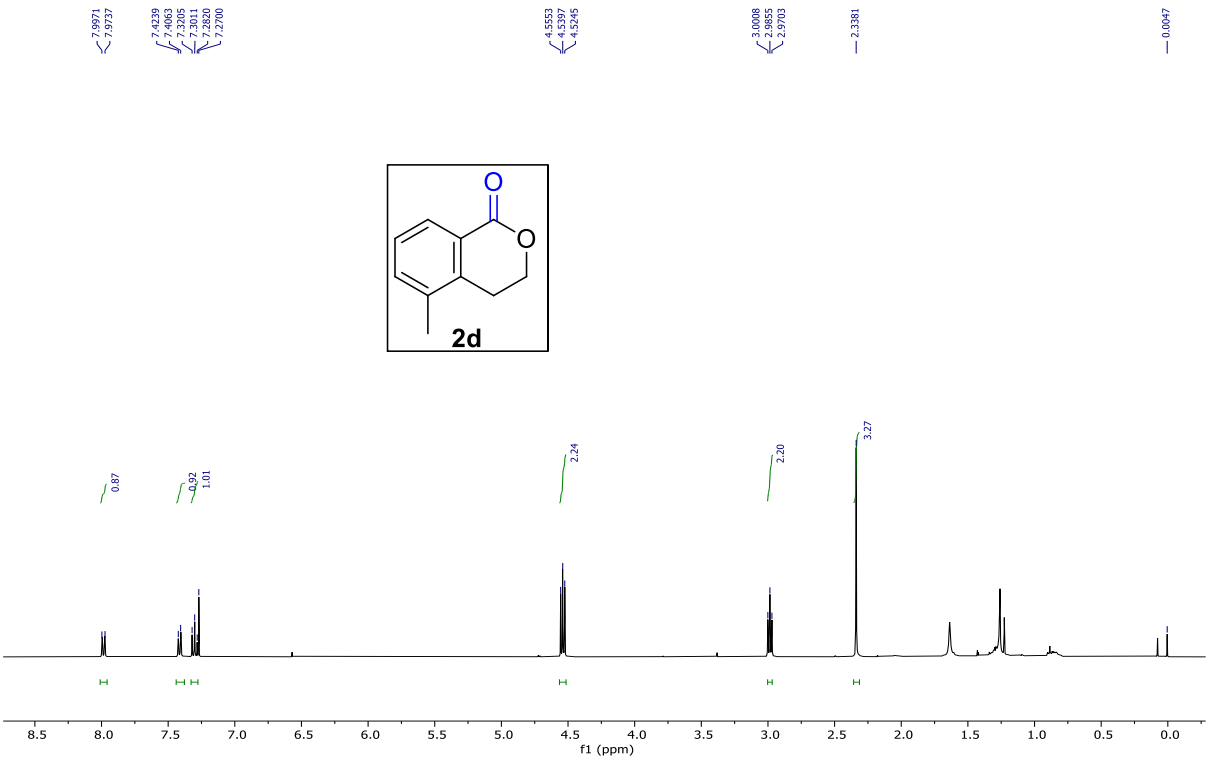
^{13}C NMR of compound **(2c)** in $CDCl_3$



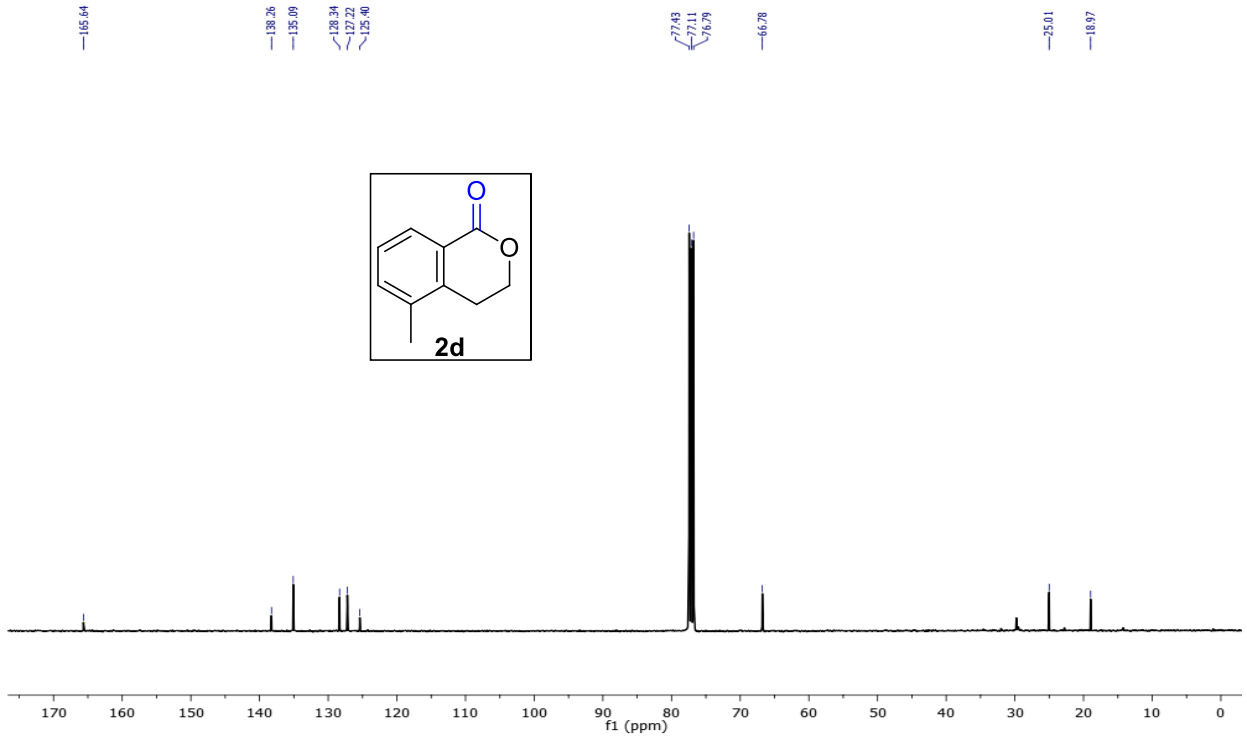
HRMS of compound **(2c)**



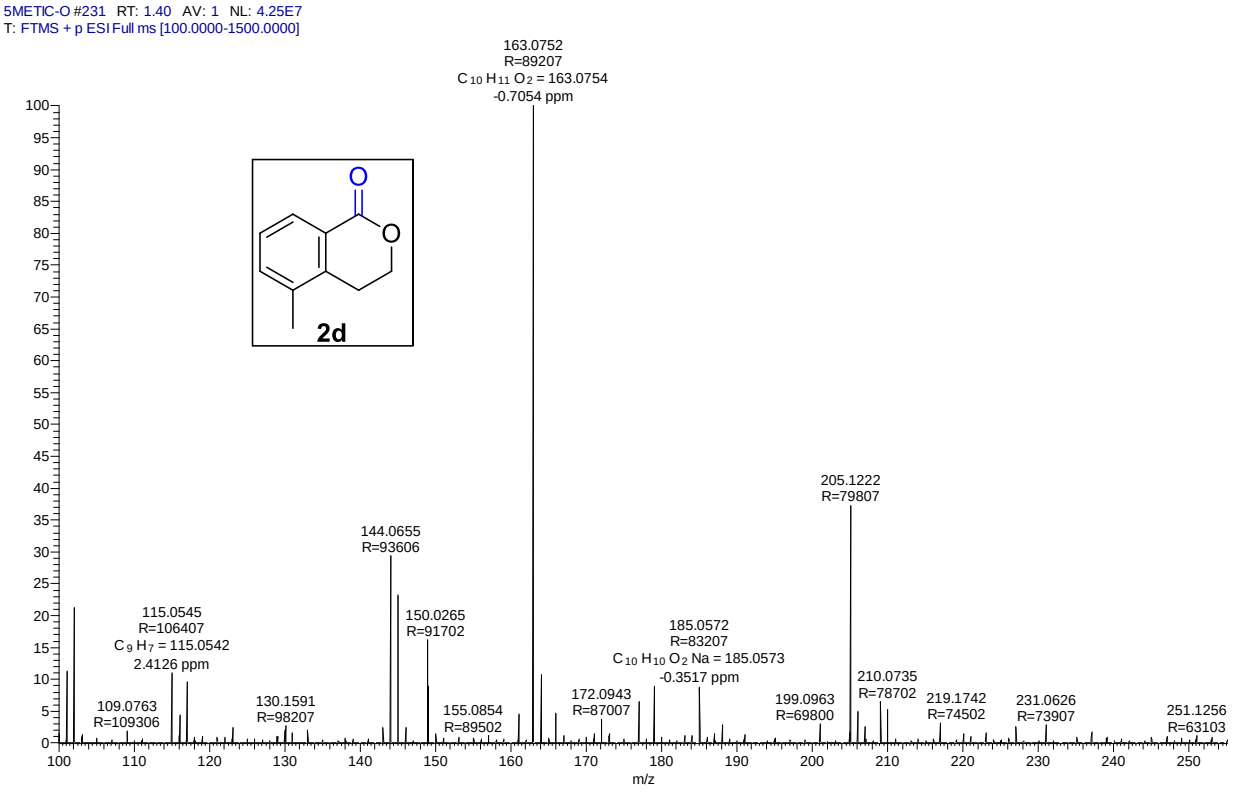
^{1}H NMR of compound **(2d)** in $CDCl_3$



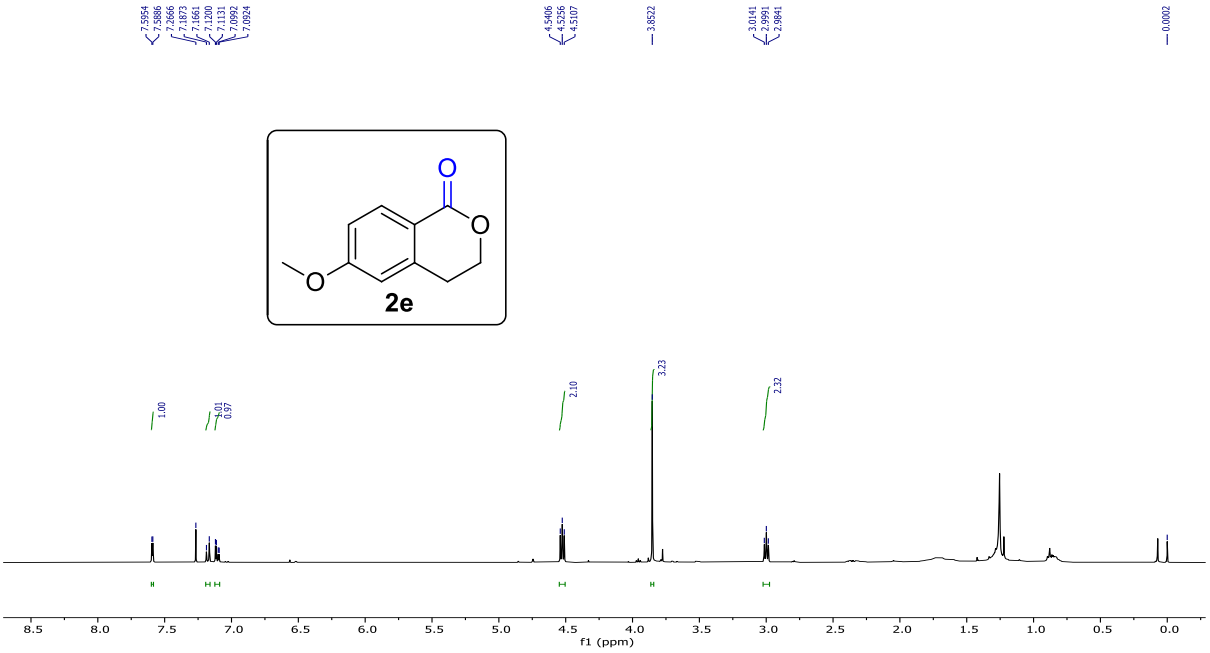
^{13}C NMR of compound **(2d)** in $CDCl_3$



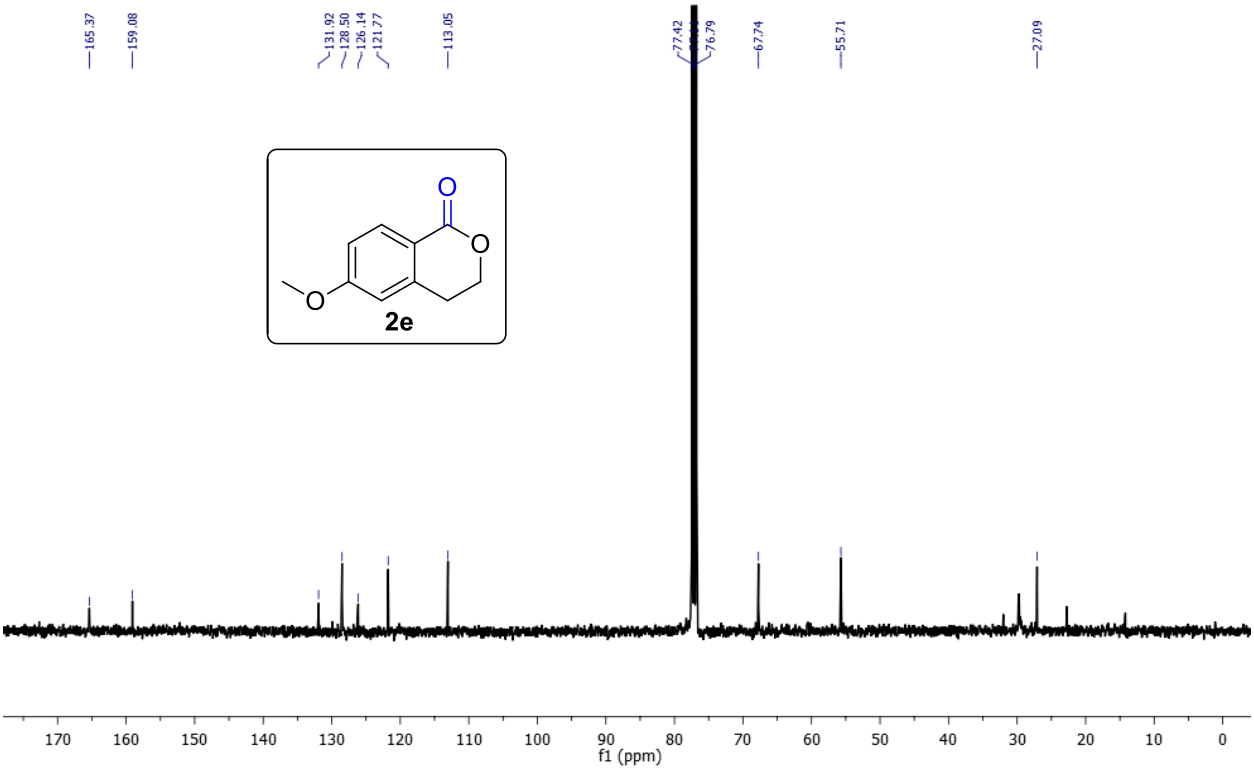
HRMS of compound **(2d)**



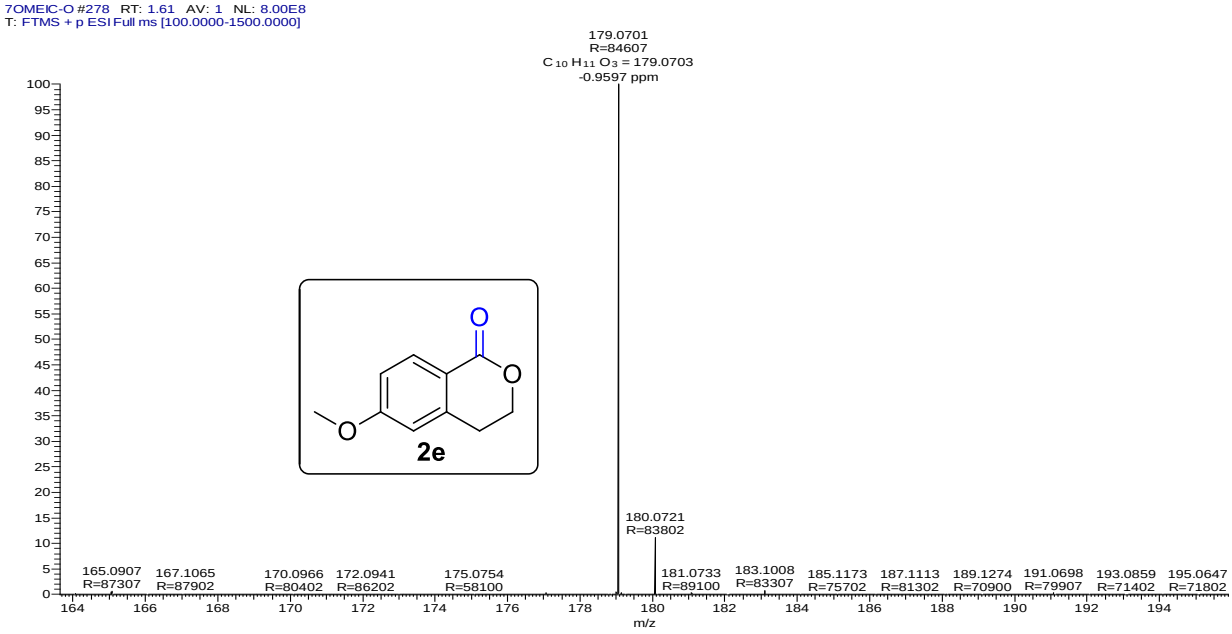
^{1}H NMR of compound **(2e)** in $CDCl_3$



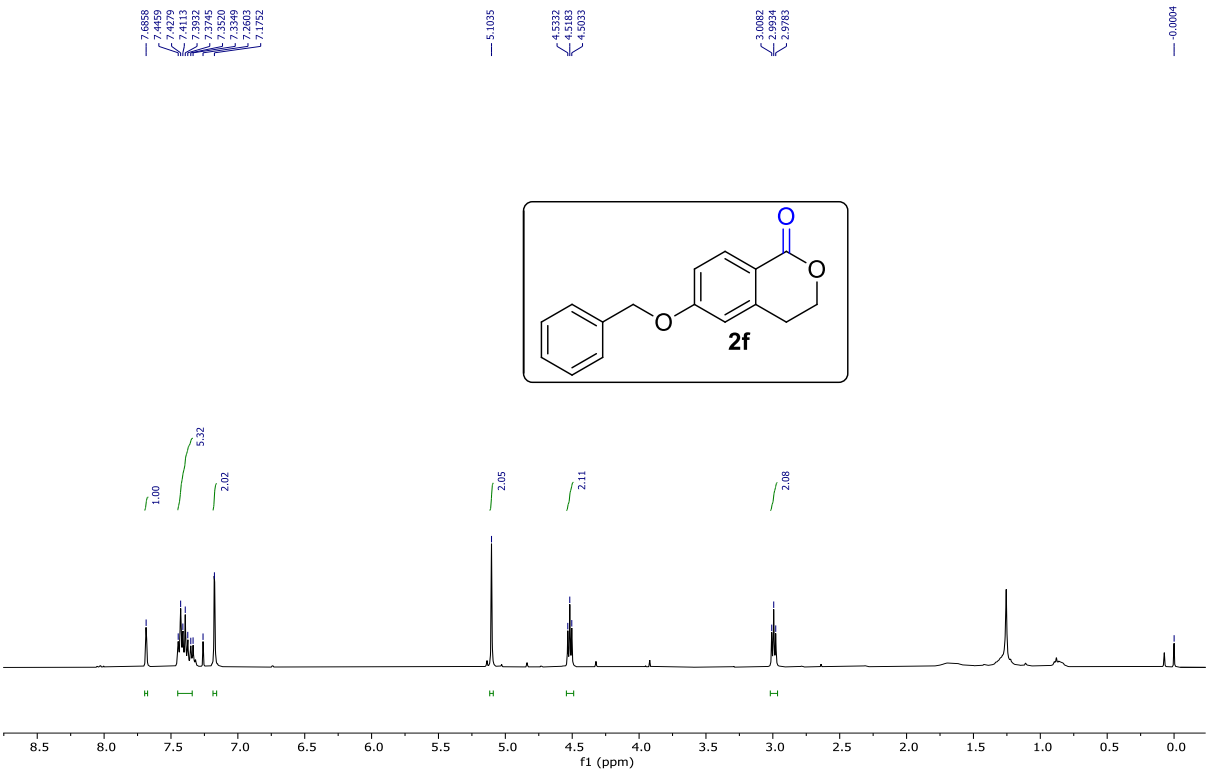
^{13}C NMR of compound **(2e)** in $CDCl_3$



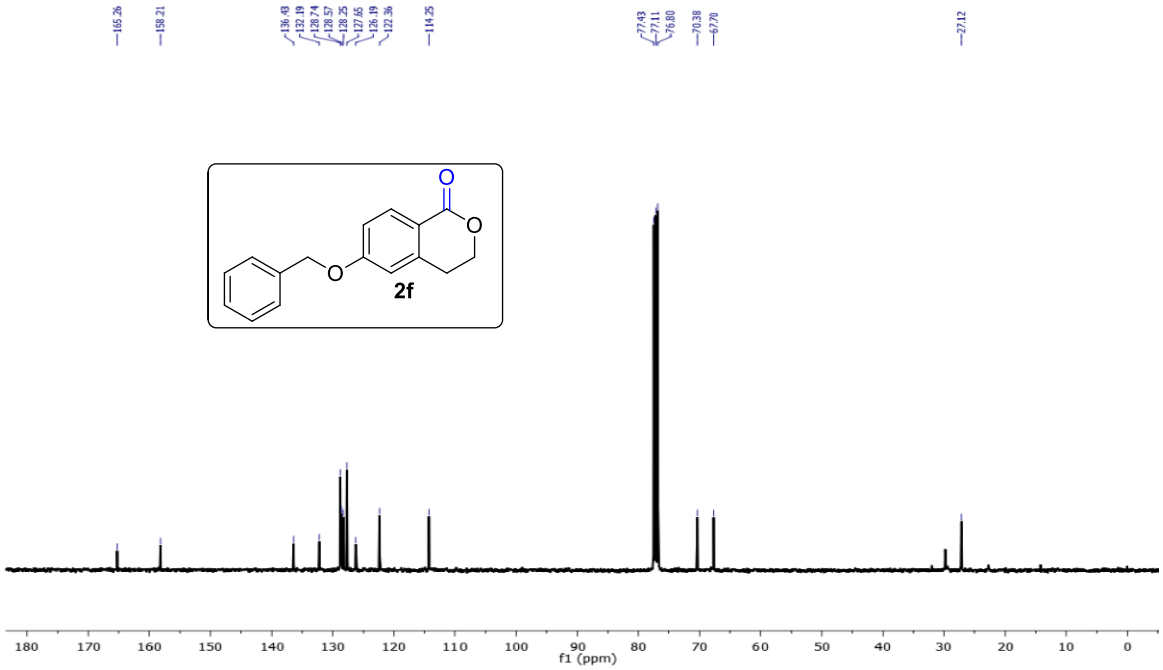
HRMS of compound **(2e)**



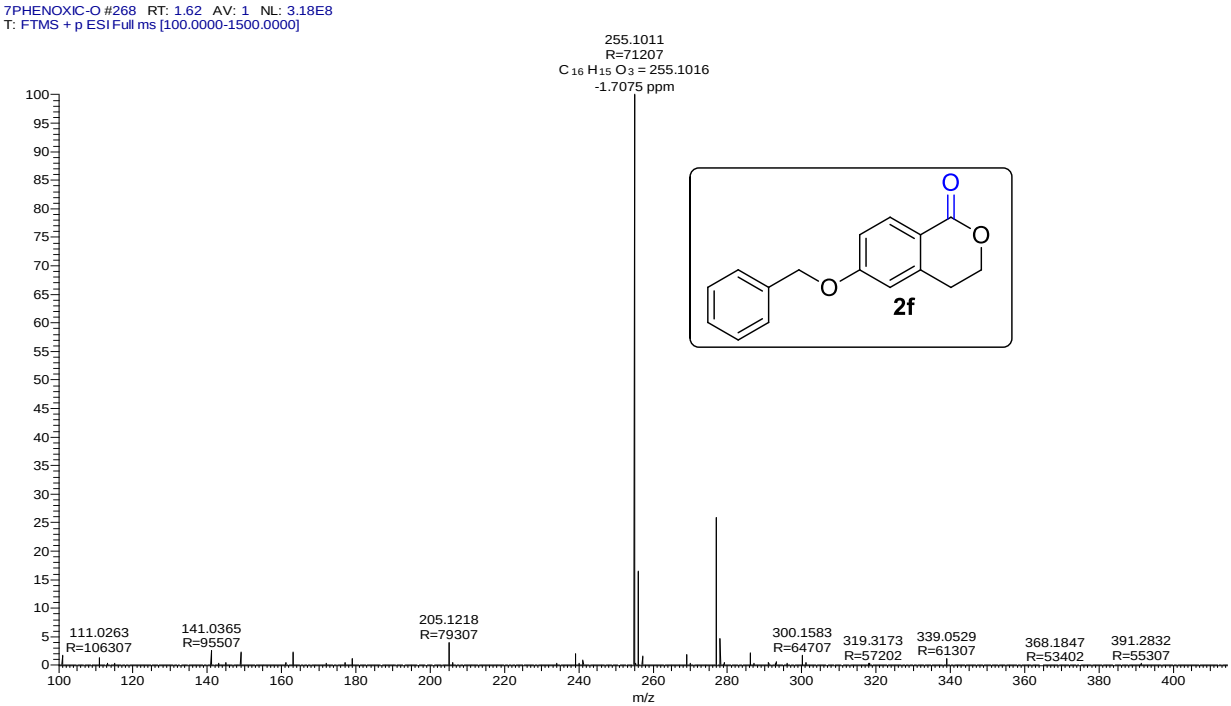
^{1}H NMR of compound **(2f)** in $CDCl_3$



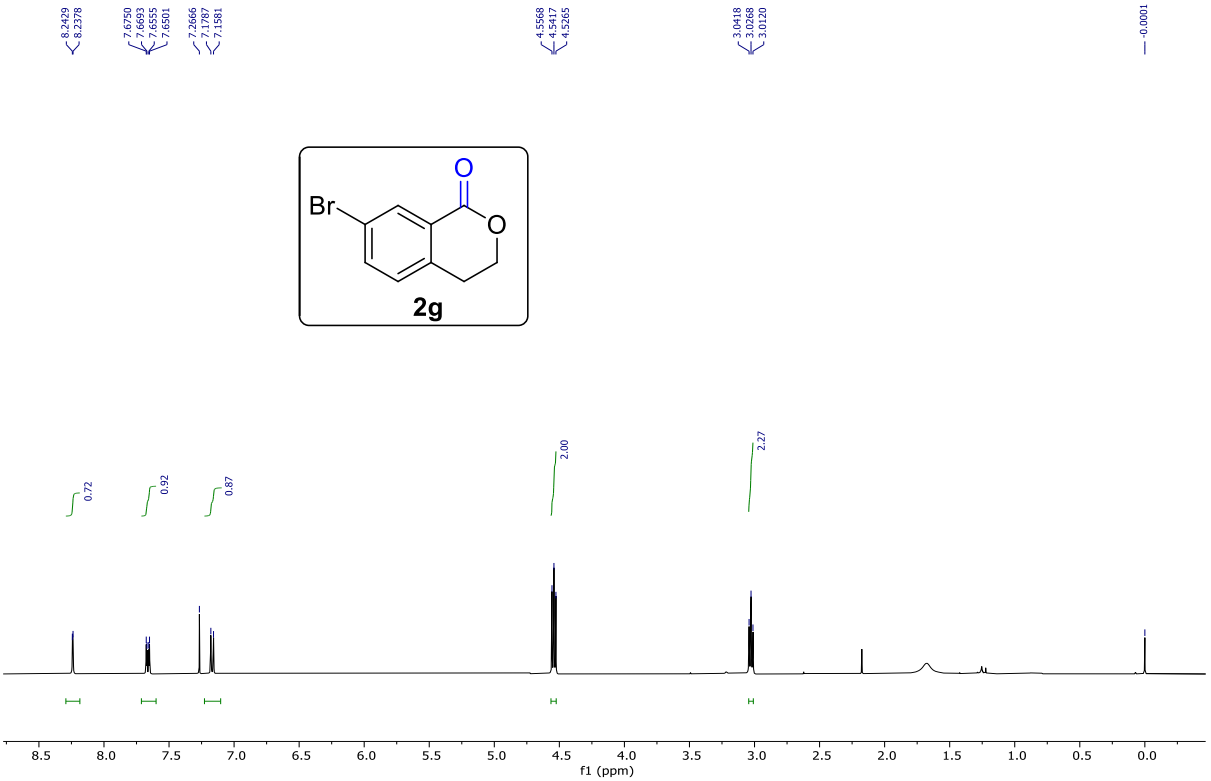
^{13}C NMR of compound **(2f)** in $CDCl_3$



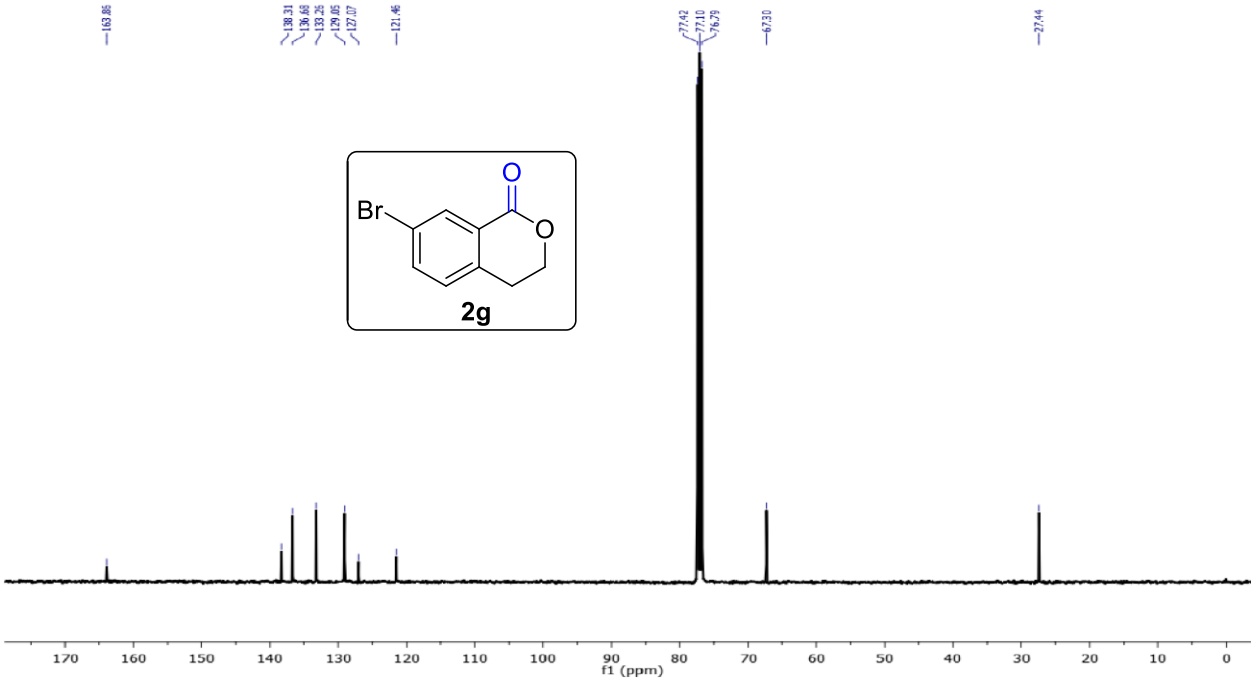
HRMS of compound **(2f)**



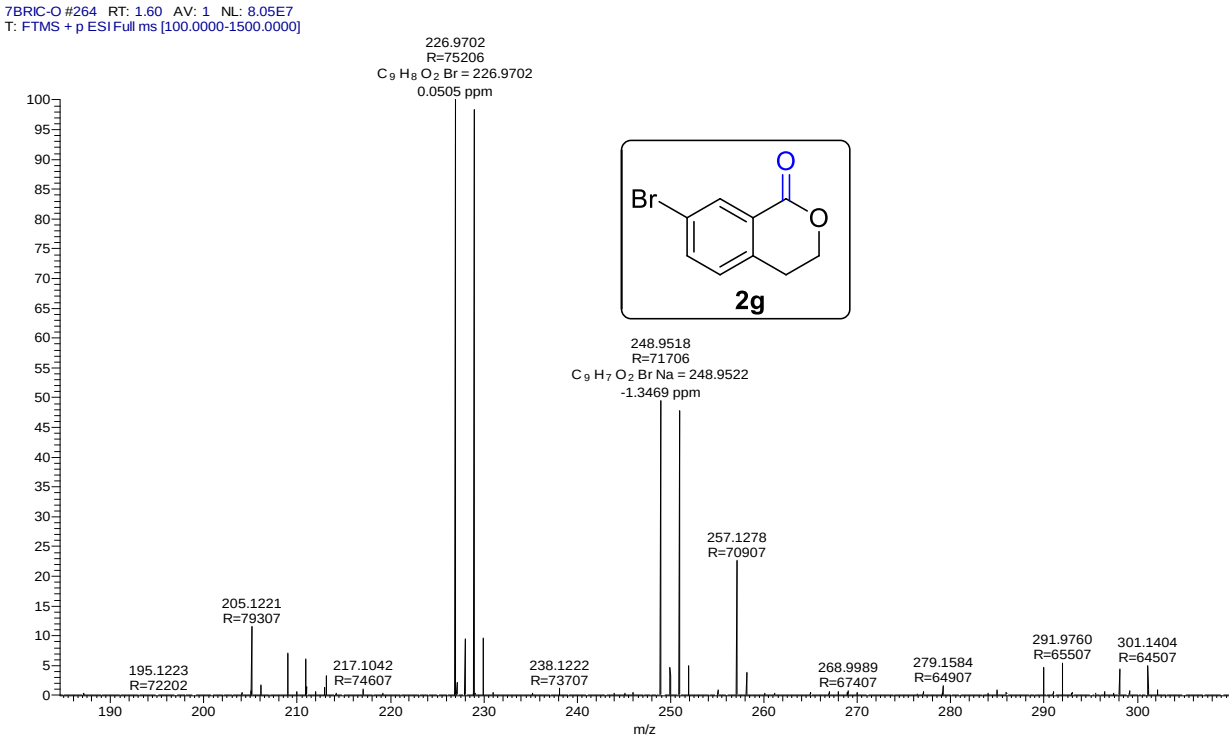
^{1}H NMR of compound **(2g)** in $CDCl_3$



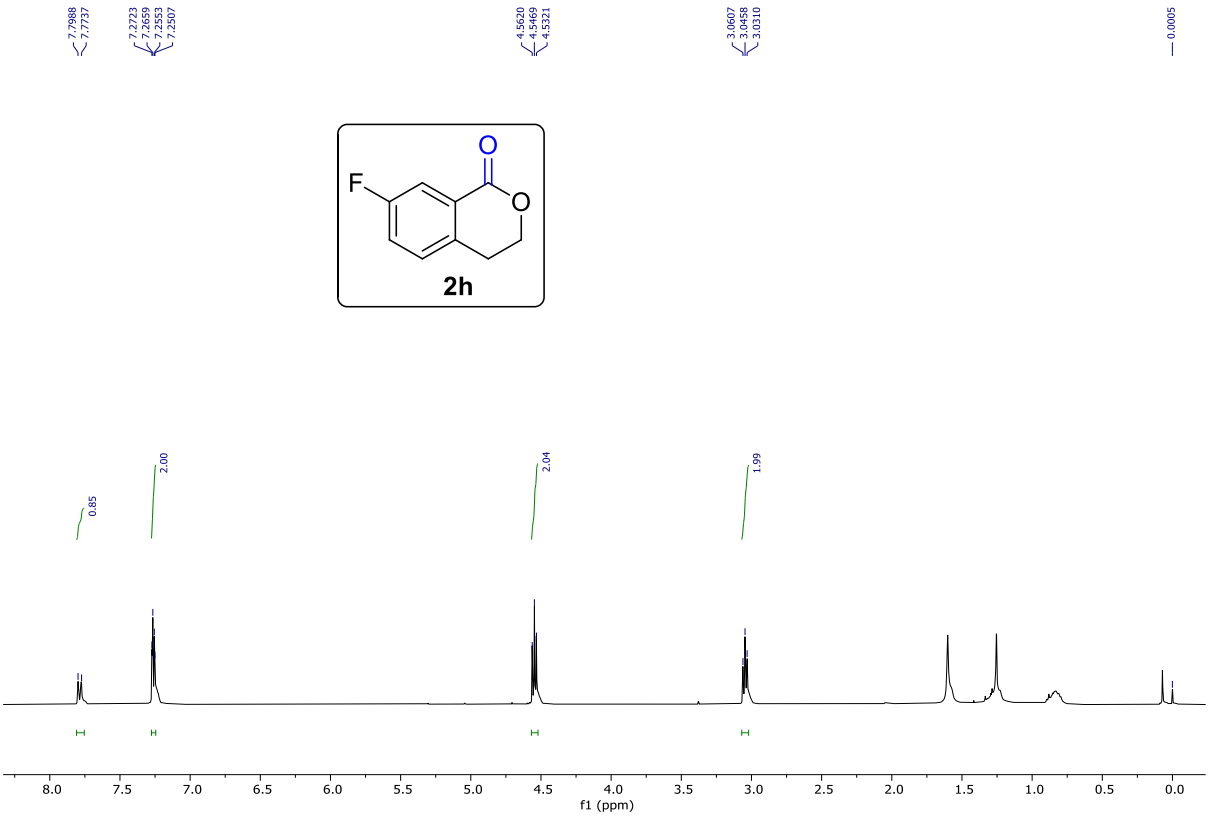
^{13}C NMR of compound **(2g)** in $CDCl_3$



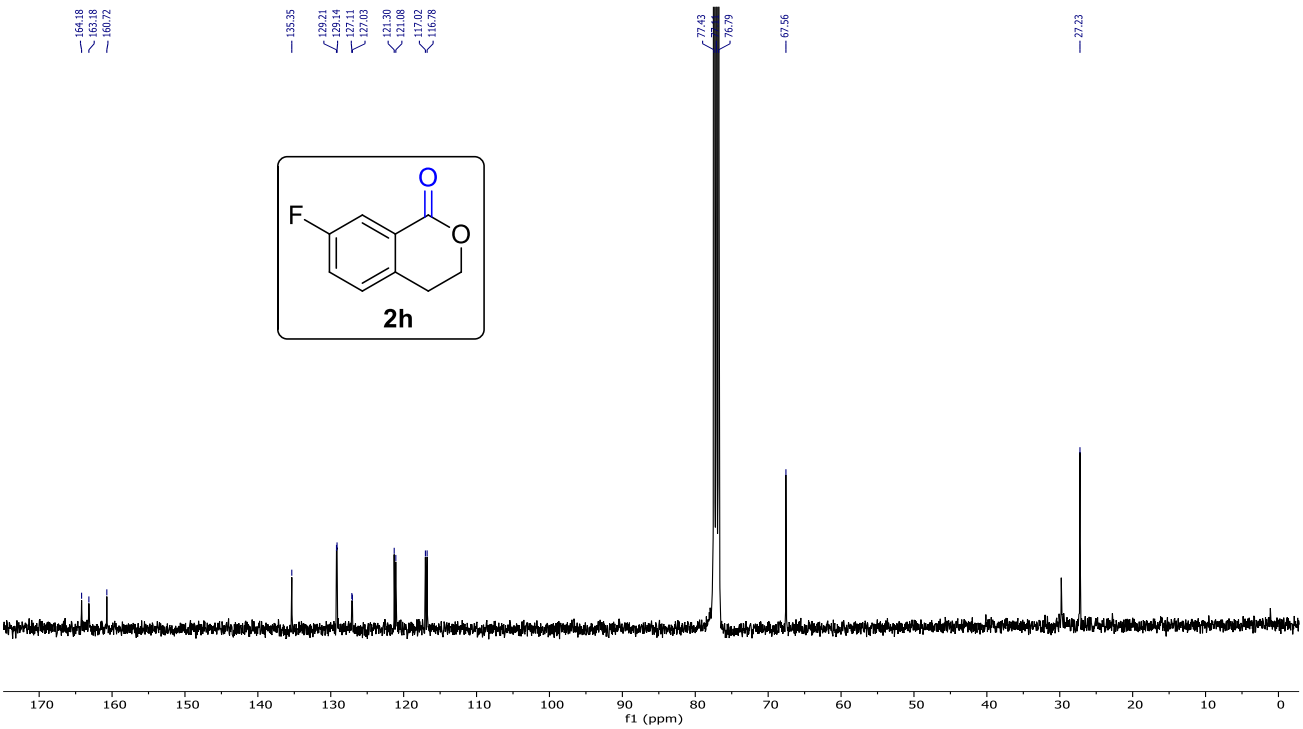
HRMS of compound **(2g)**



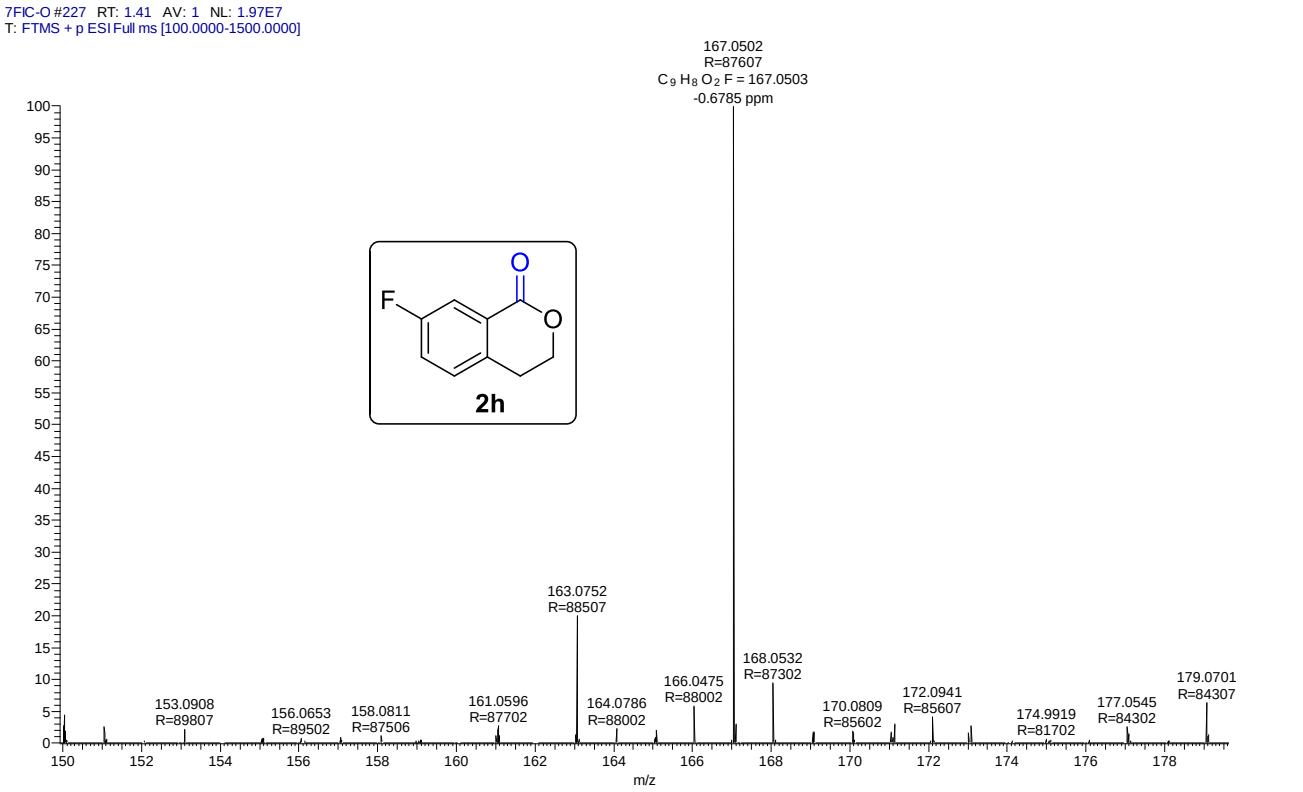
^{1}H NMR of compound **(2h)** in $CDCl_3$



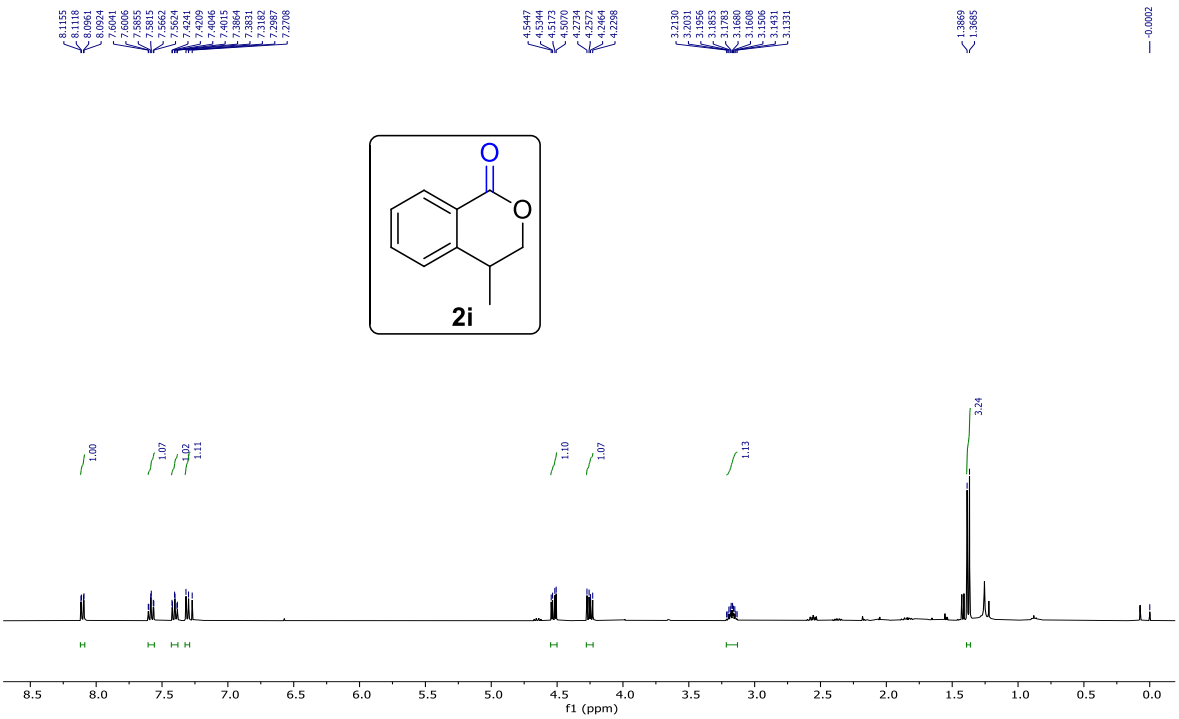
^{13}C NMR of compound **(2h)** in $CDCl_3$



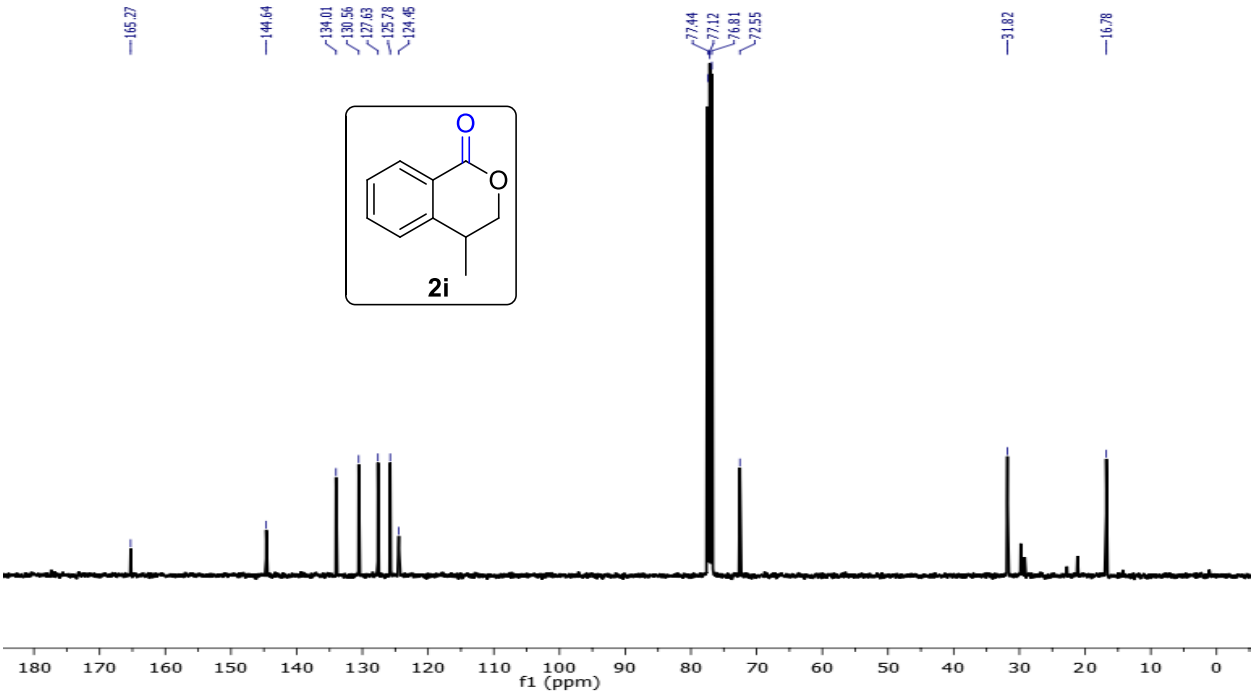
HRMS of compound **(2h)**



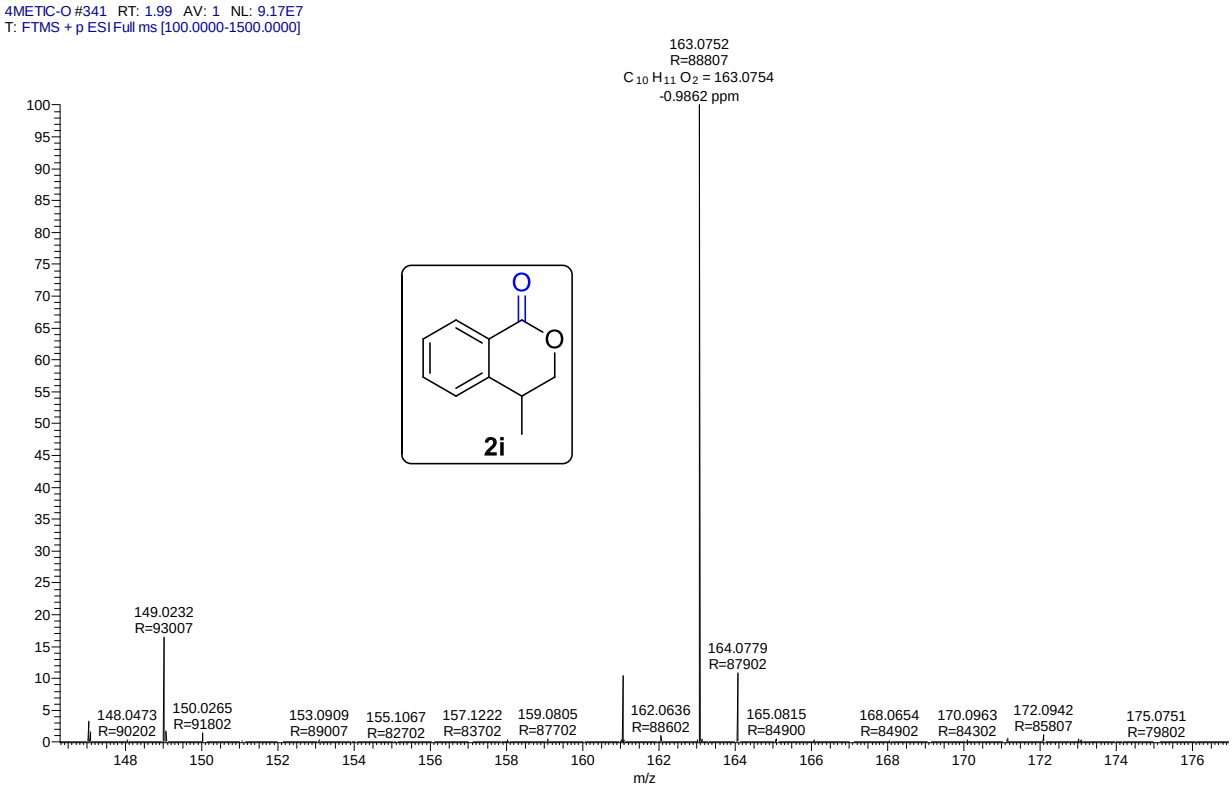
^{1}H NMR of compound **(2i)** in $CDCl_3$



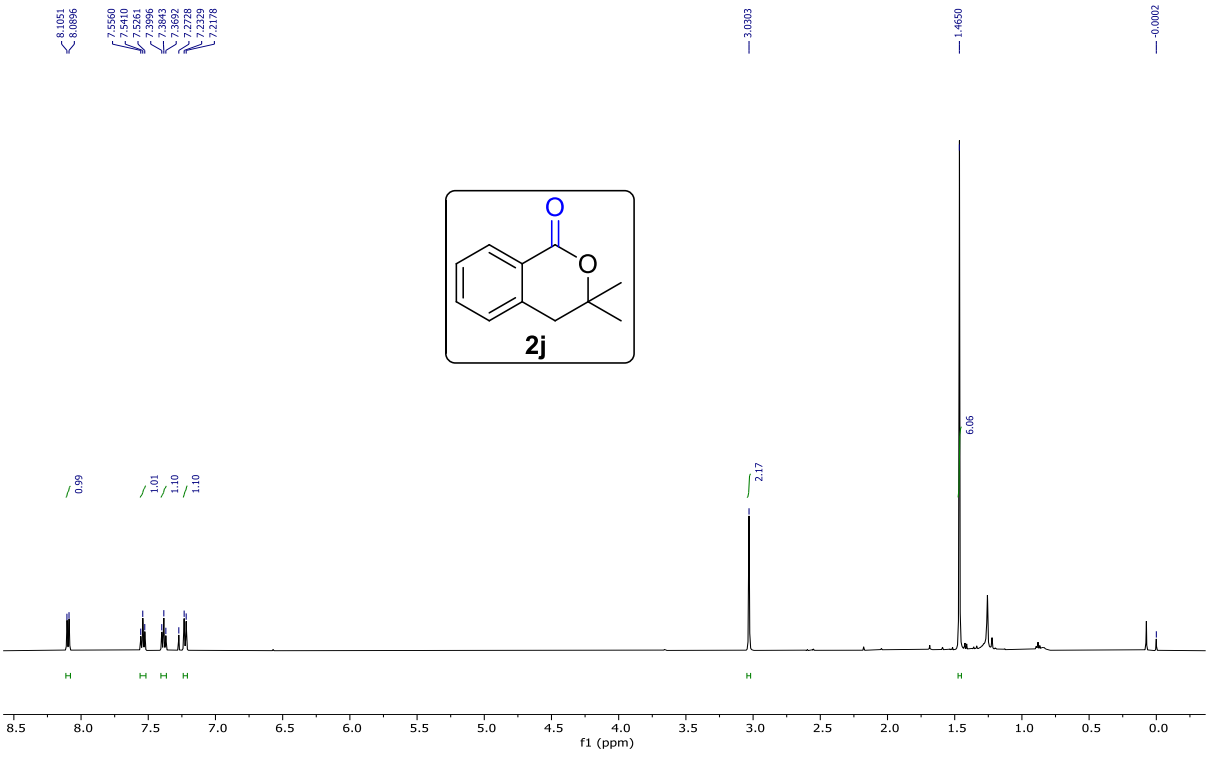
^{13}C NMR of compound **(2i)** in $CDCl_3$



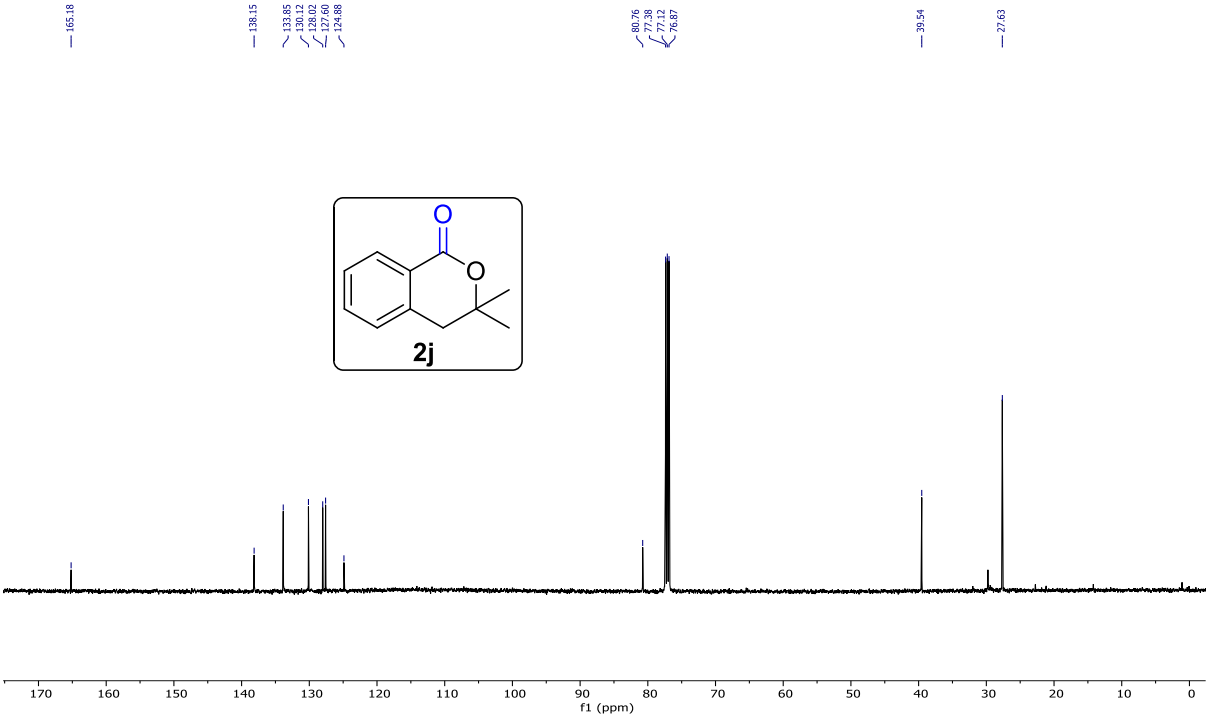
HRMS of compound **(2i)**



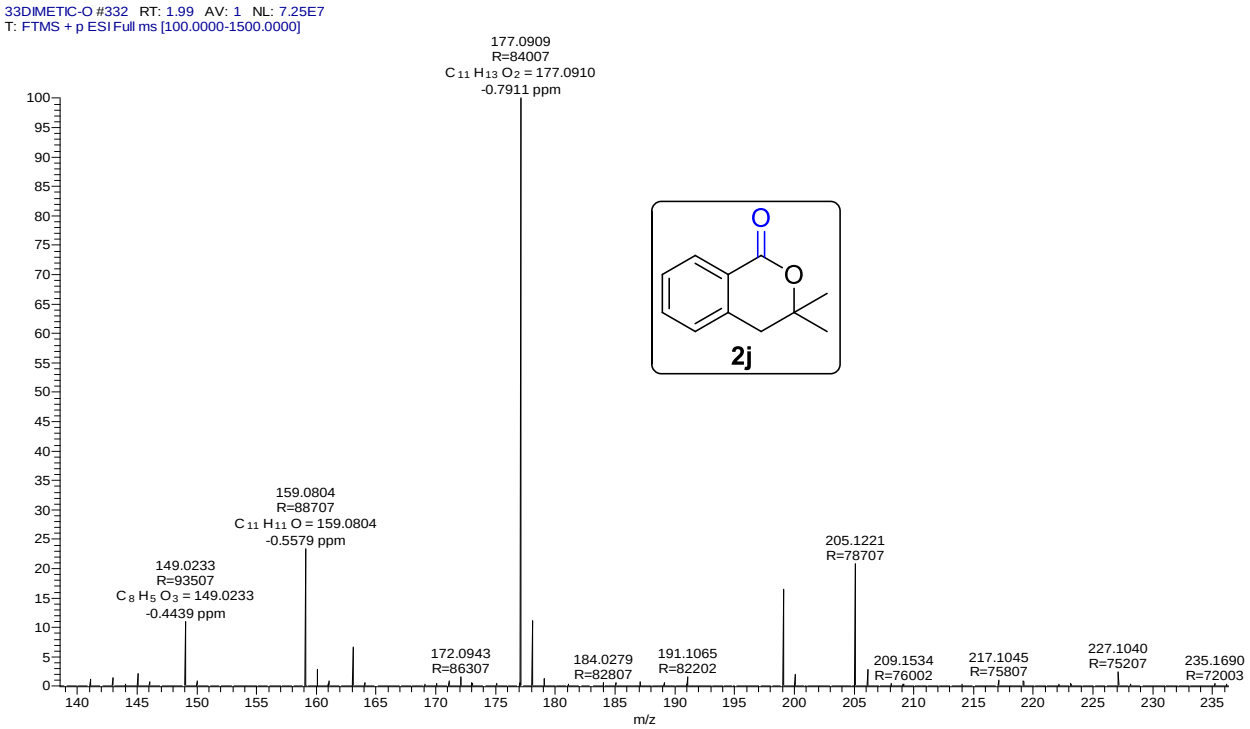
^{1}H NMR of compound **(2j)** in $CDCl_3$



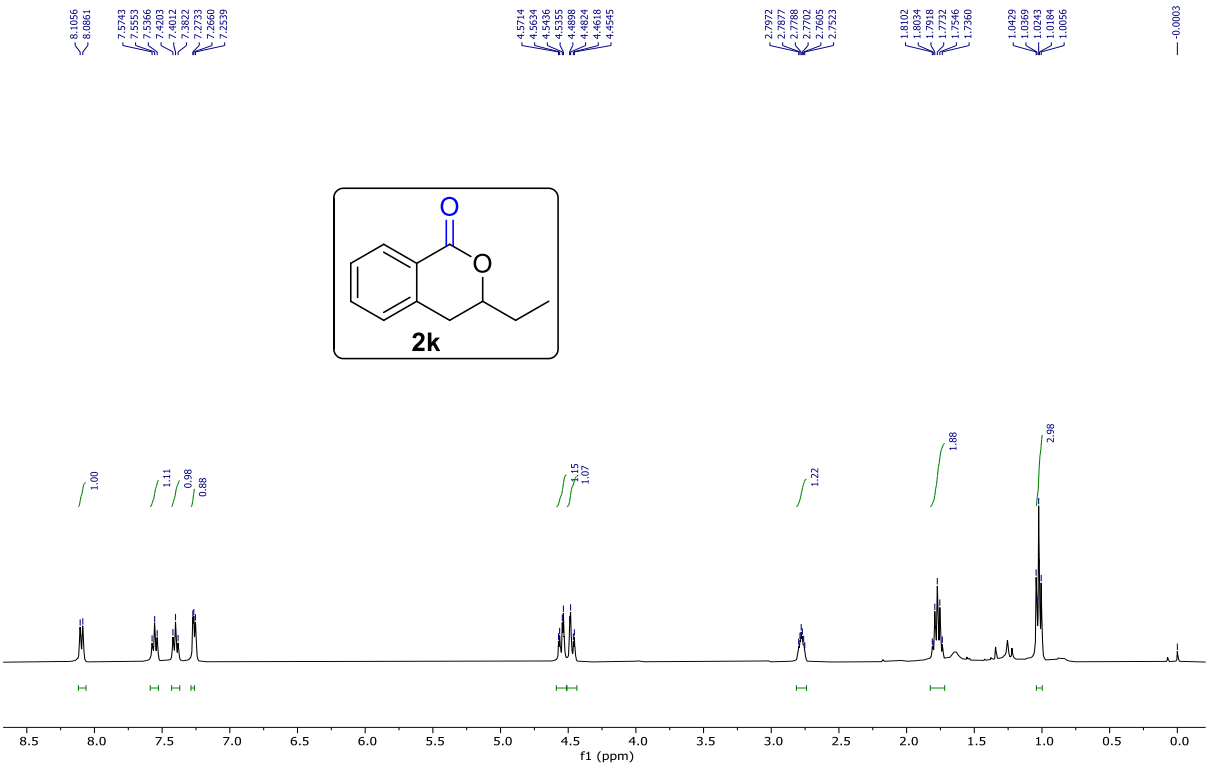
^{13}C NMR of compound **(2j)** in $CDCl_3$



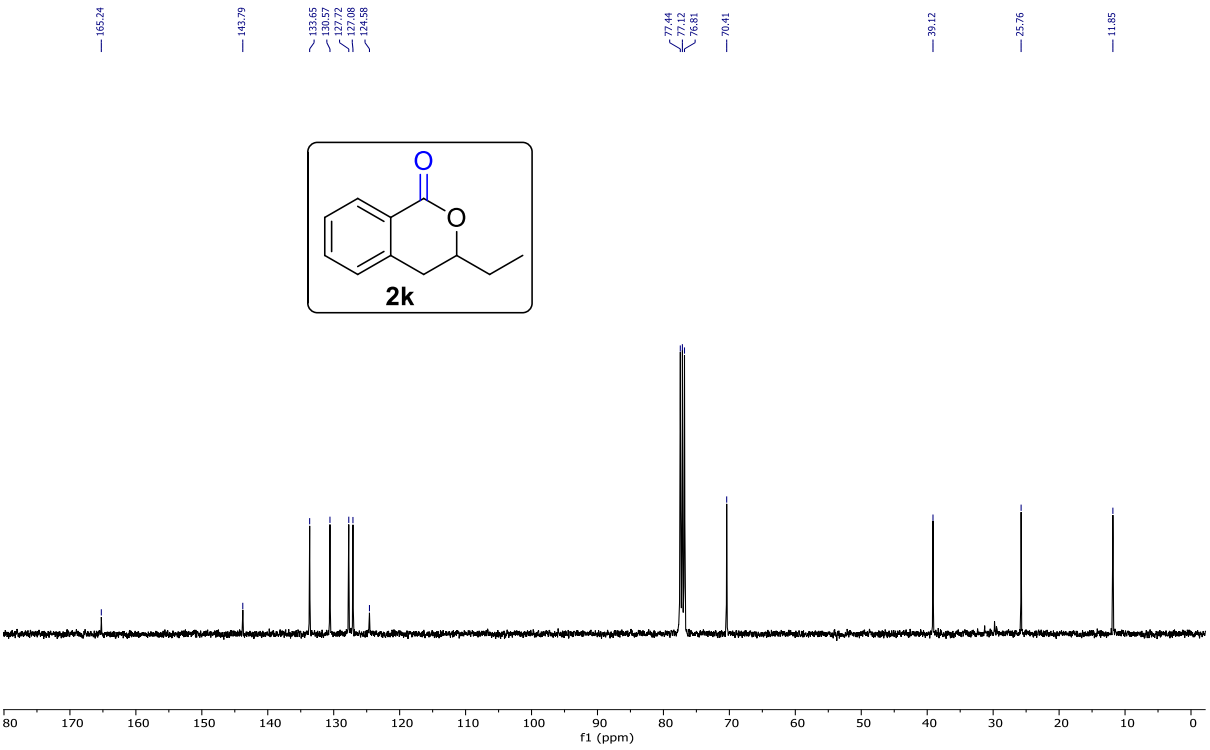
HRMS of compound **(2j)**



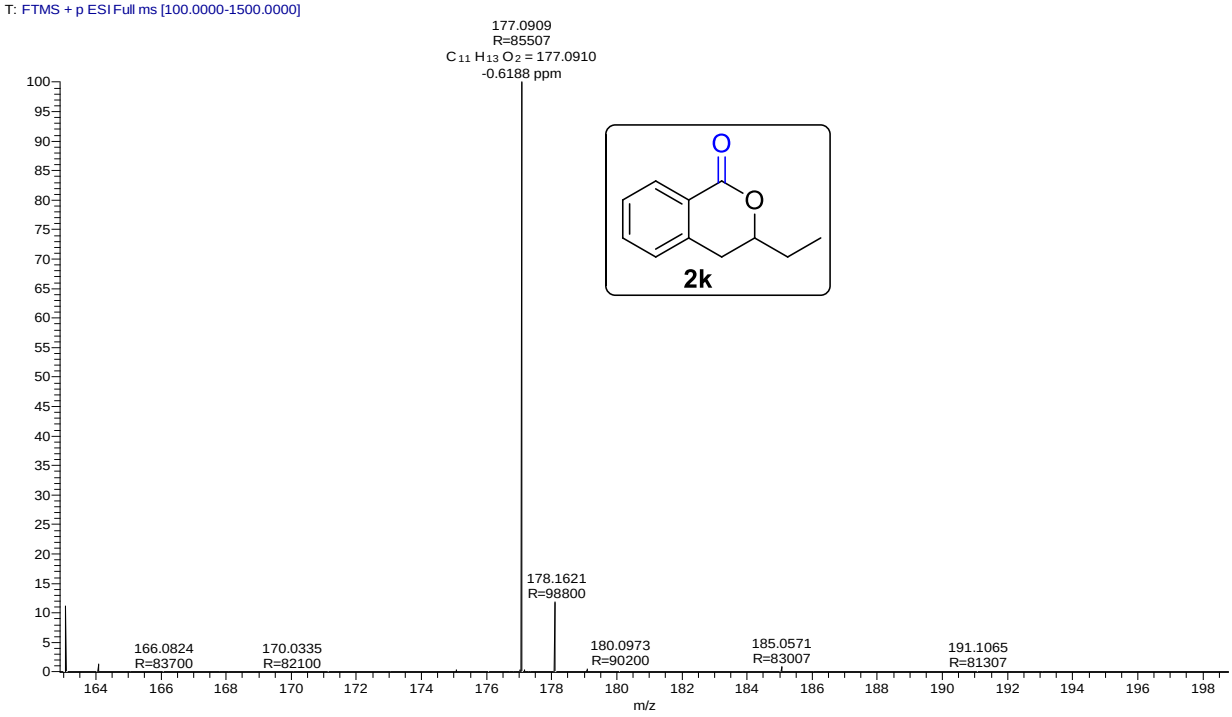
^{1}H NMR of compound **(2k)** in $CDCl_3$



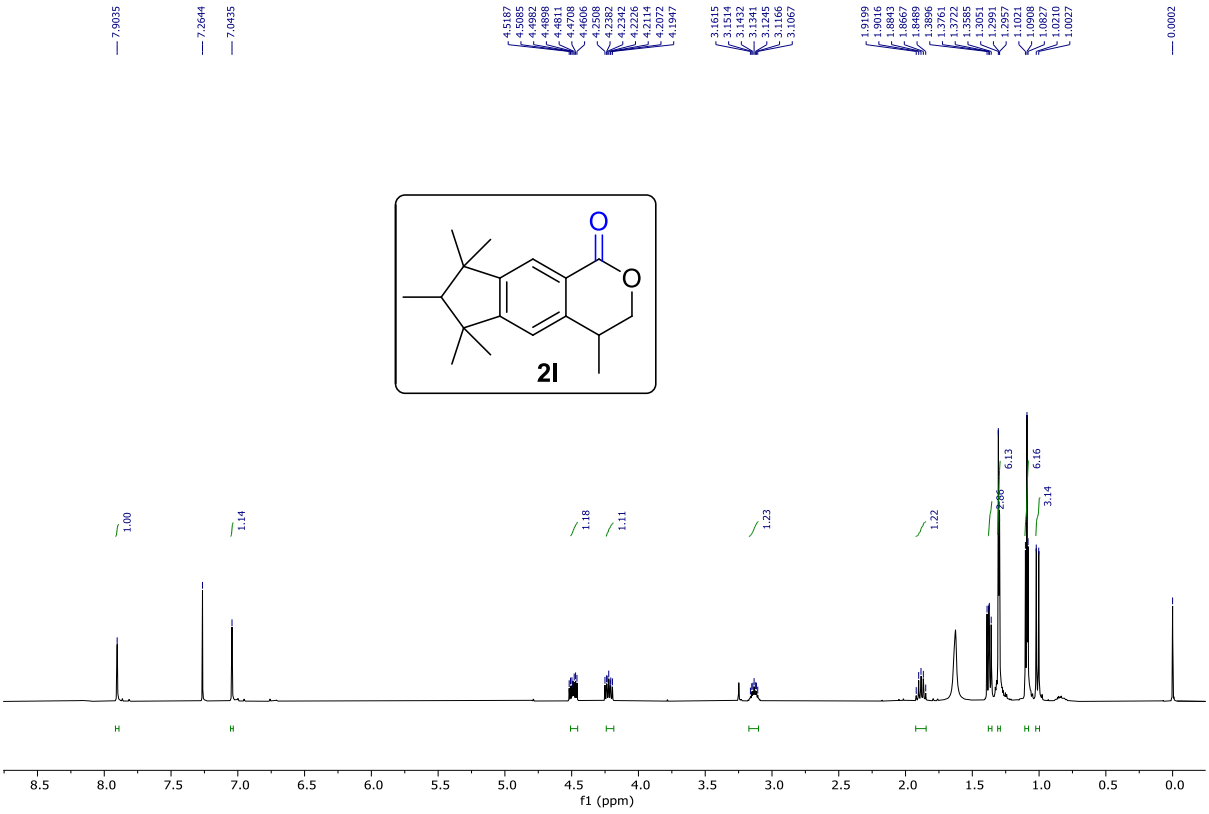
^{13}C NMR of compound **(2k)** in $CDCl_3$



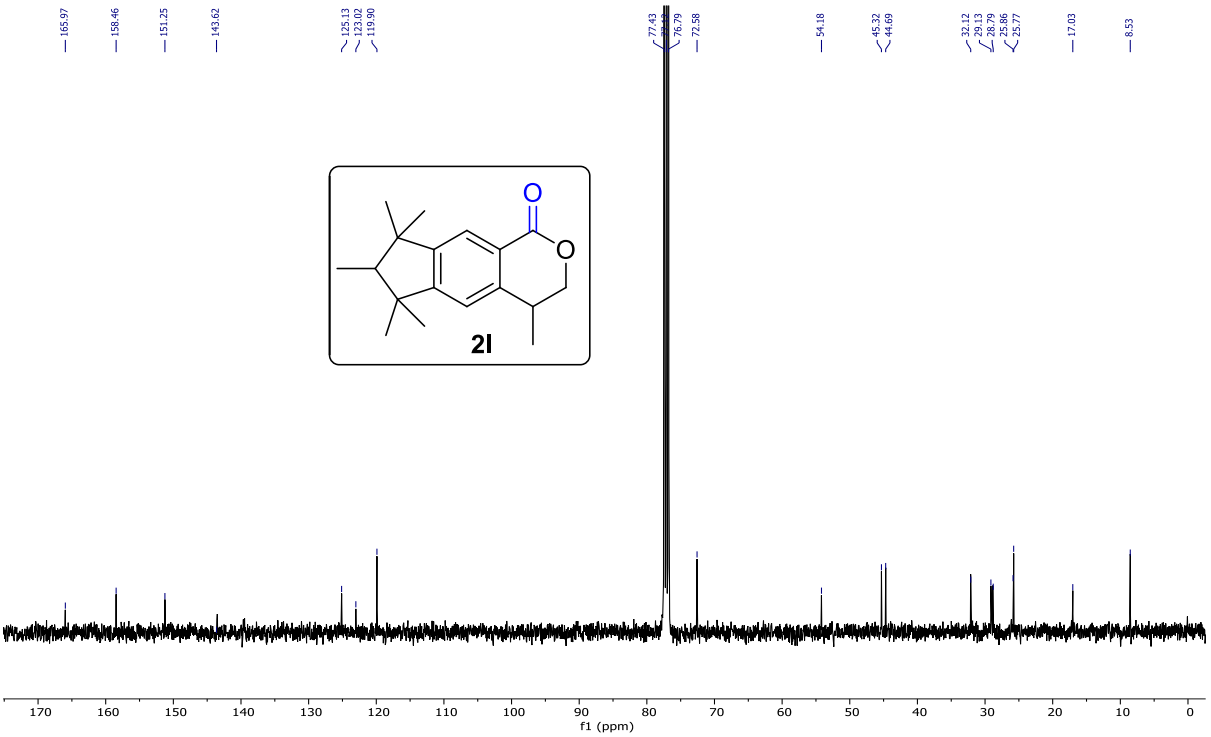
HRMS of compound **(2k)**



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



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



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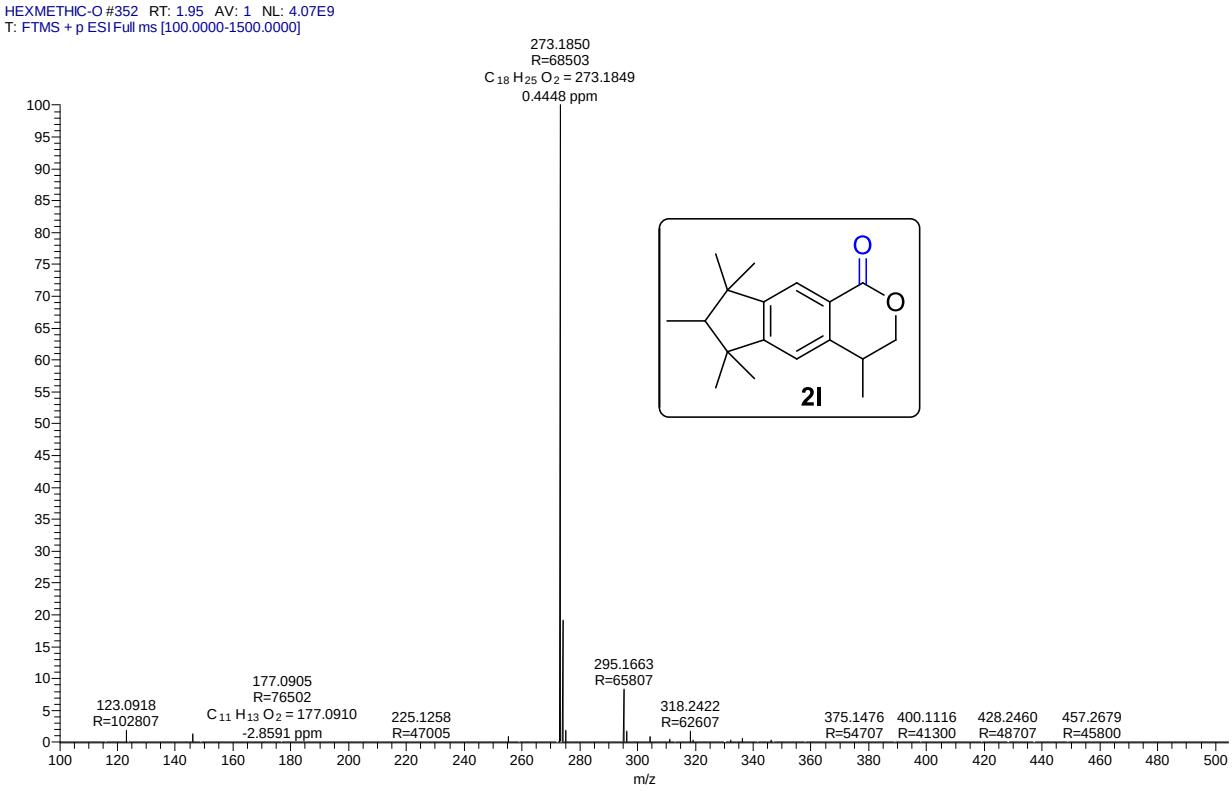
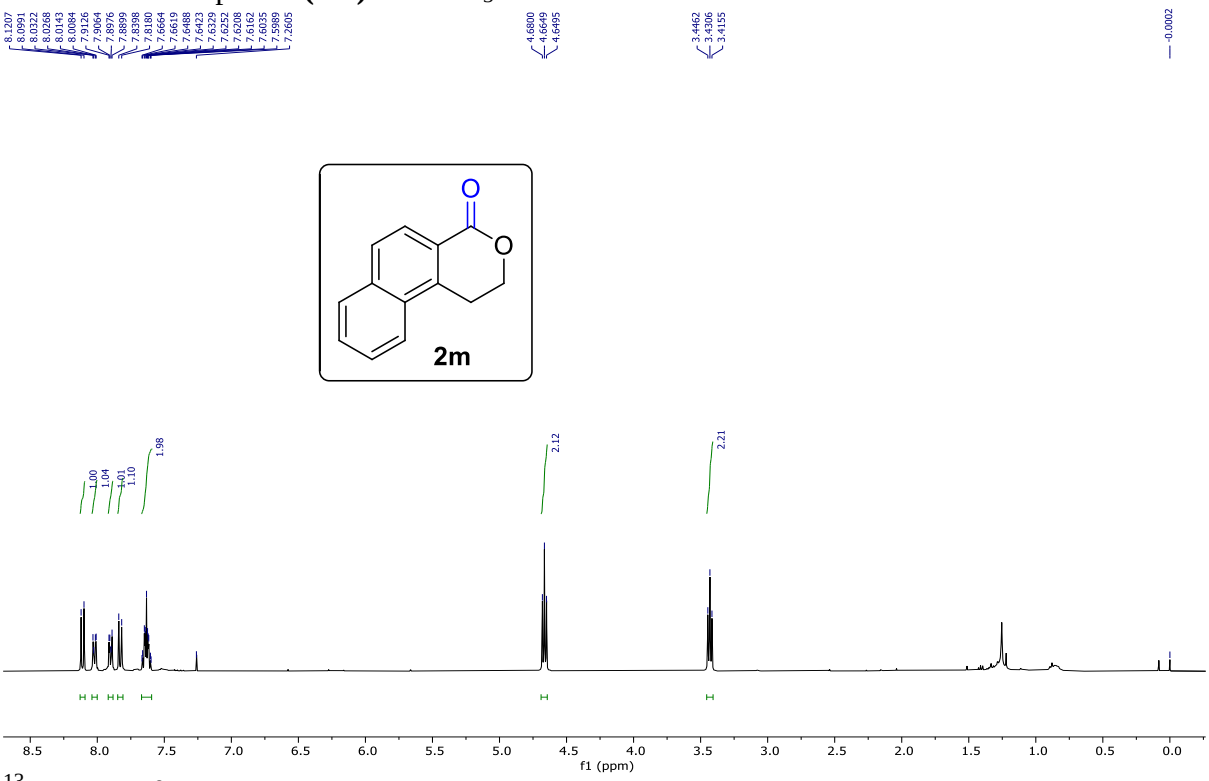
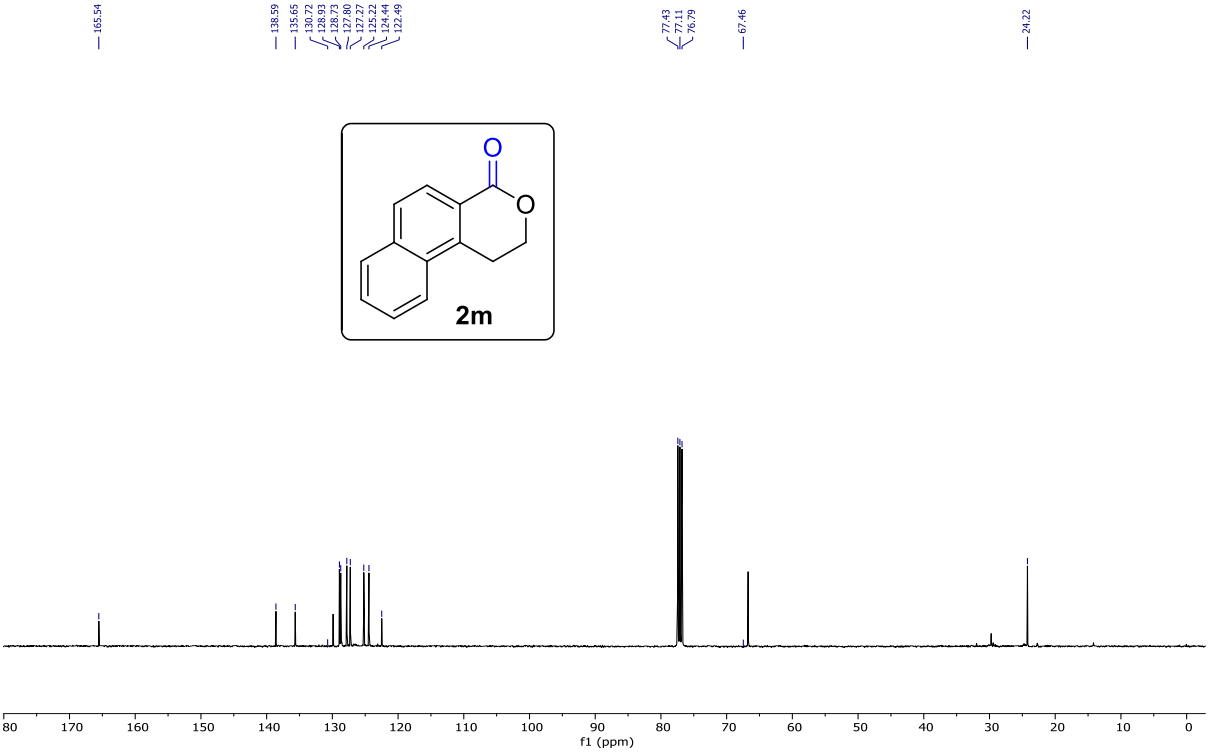


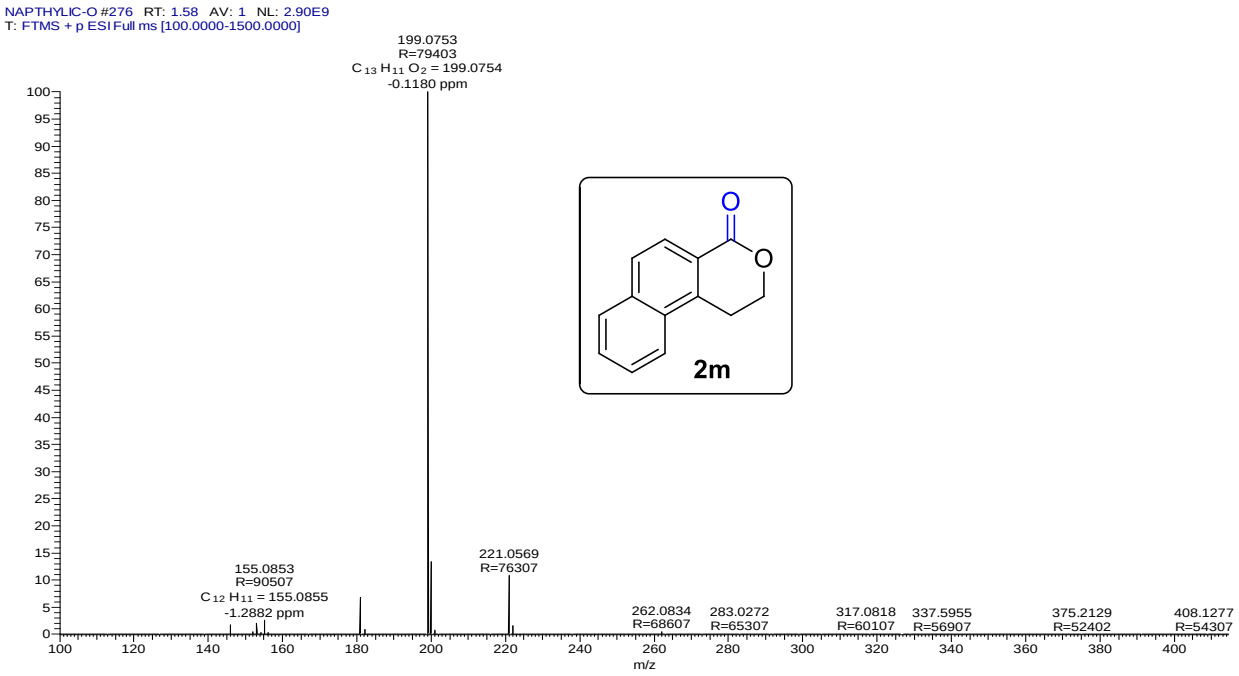
^{1}H NMR of compound **(2m)** in $CDCl_3$



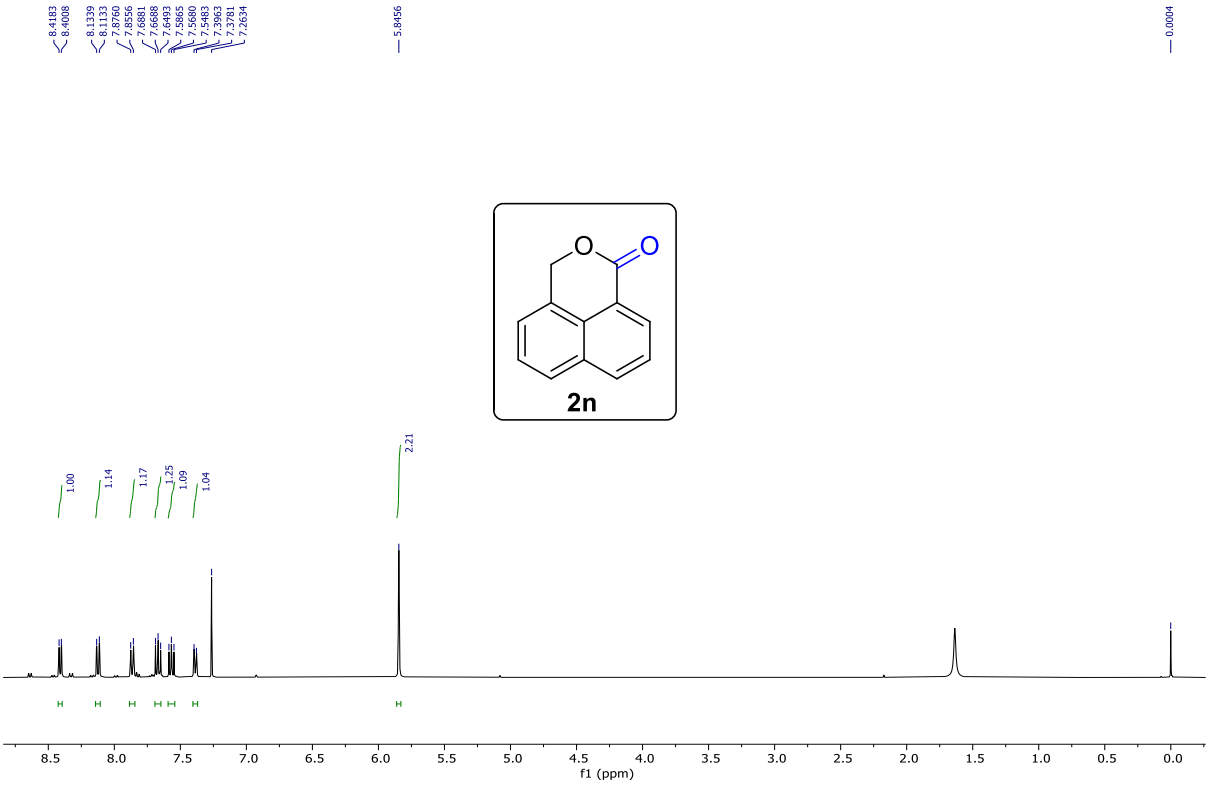
^{13}C NMR of compound **(2m)** in $CDCl_3$



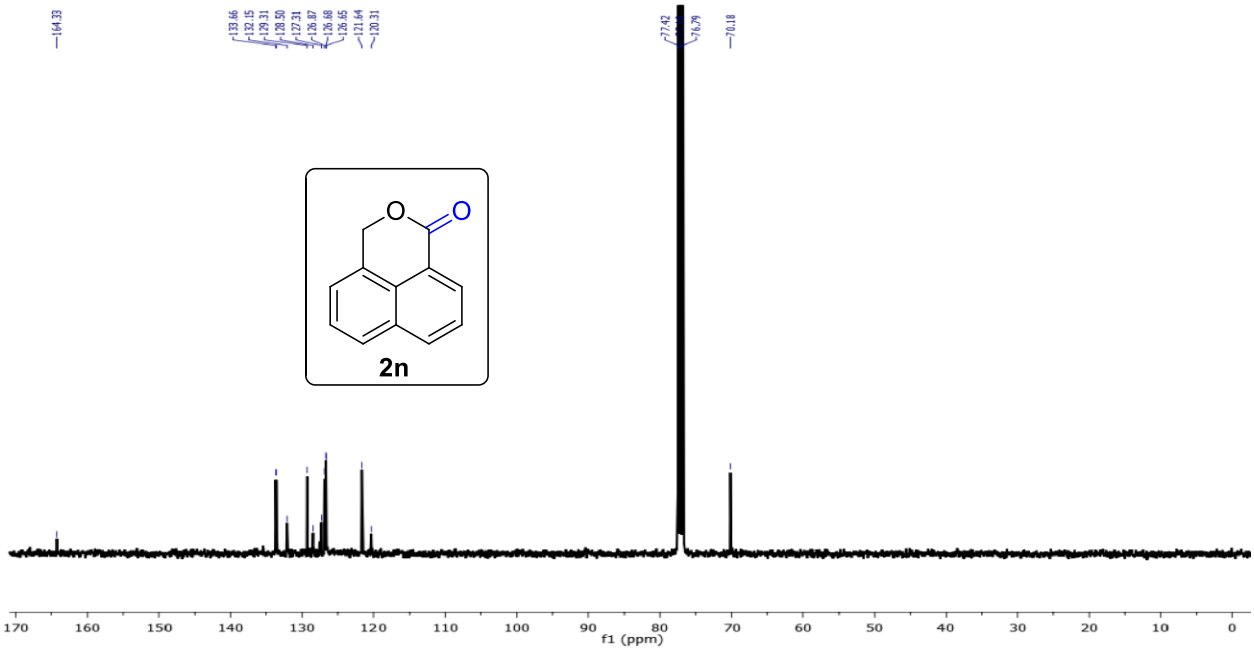
HRMS of compound **(2m)**



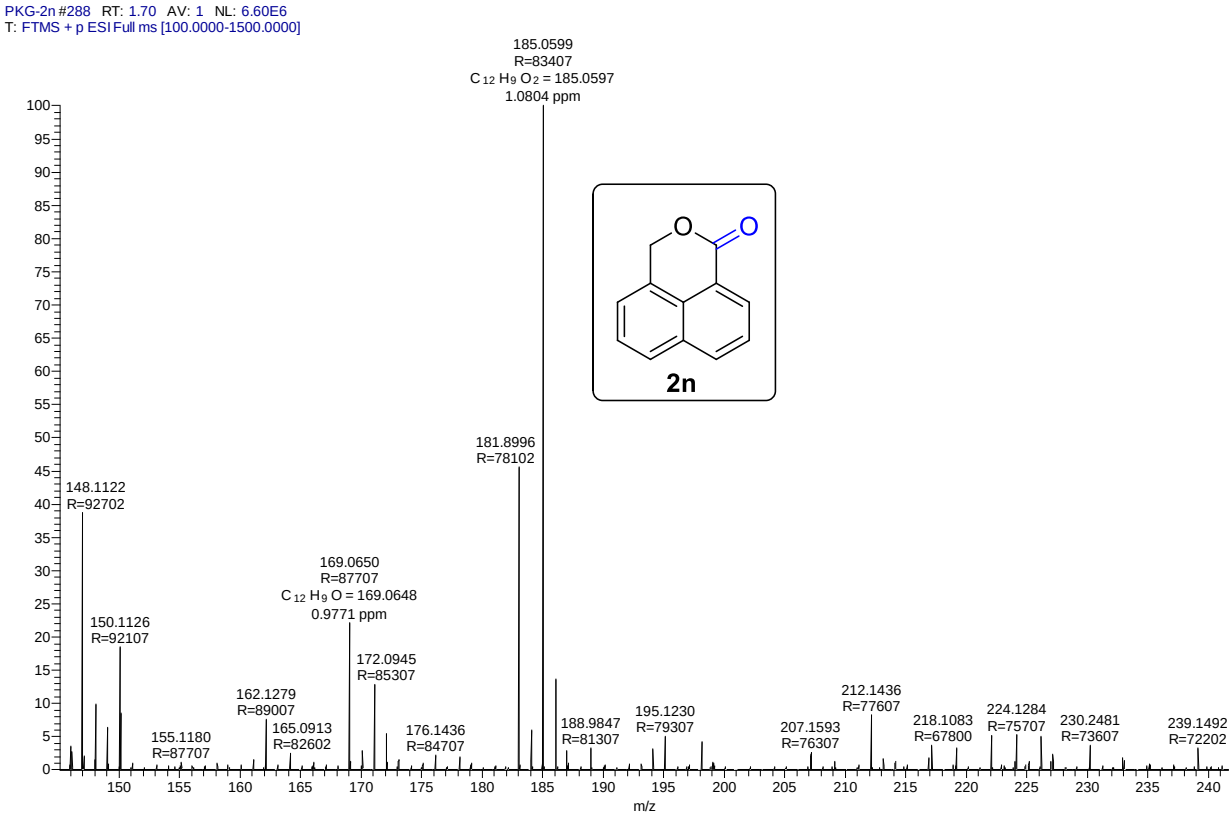
^{1}H NMR of compound **(2n)** in $CDCl_3$



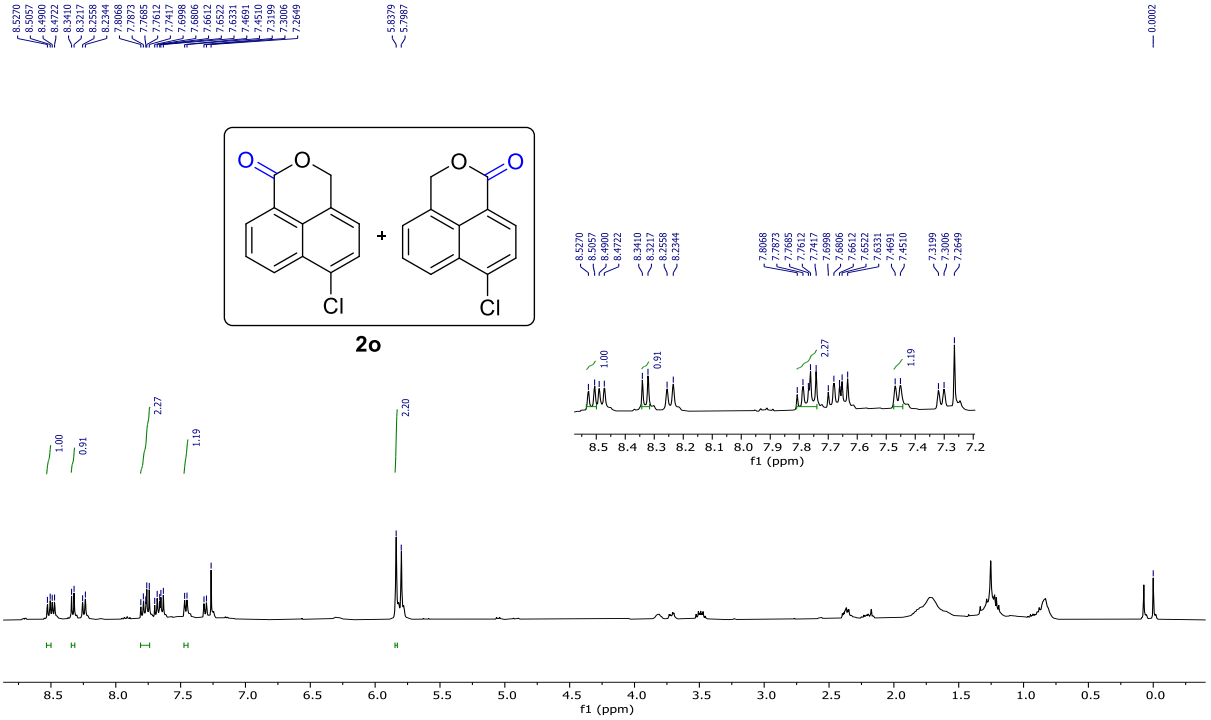
^{13}C NMR of compound **(2n)** in $CDCl_3$



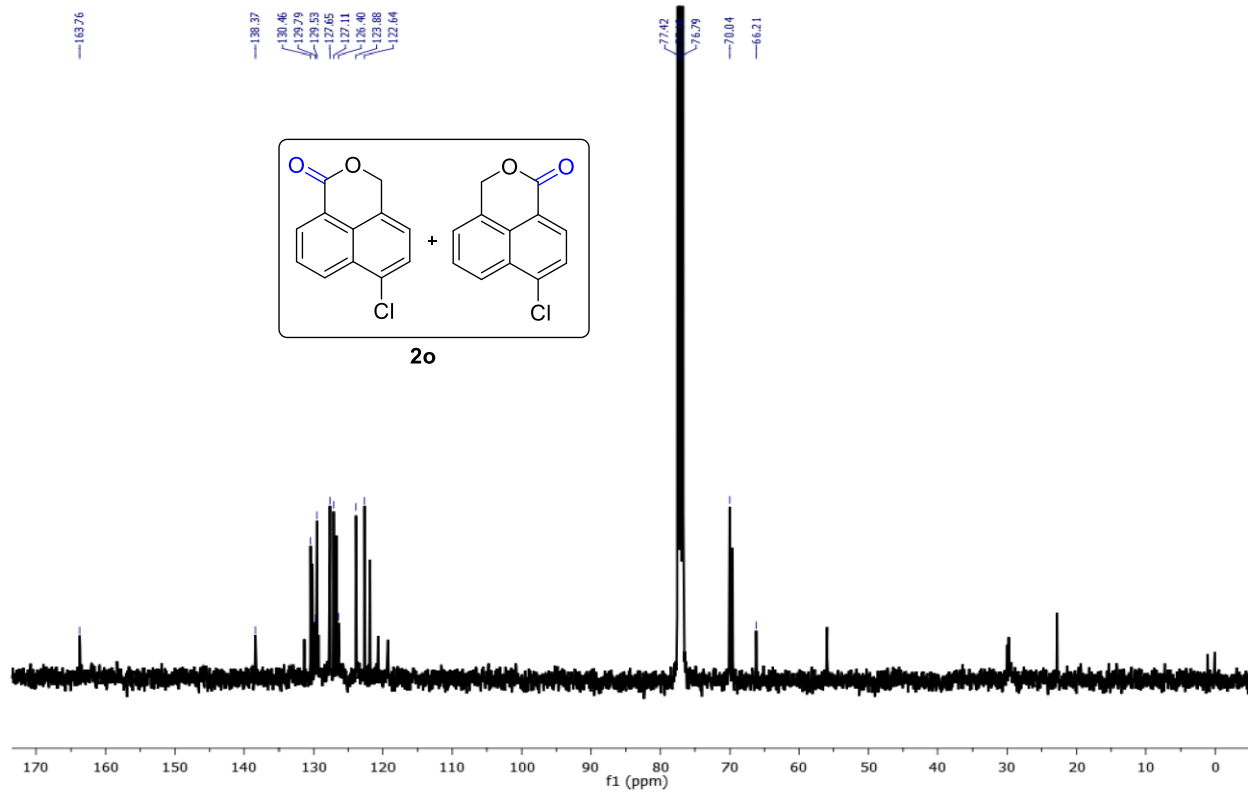
HRMS of compound **(2n)**



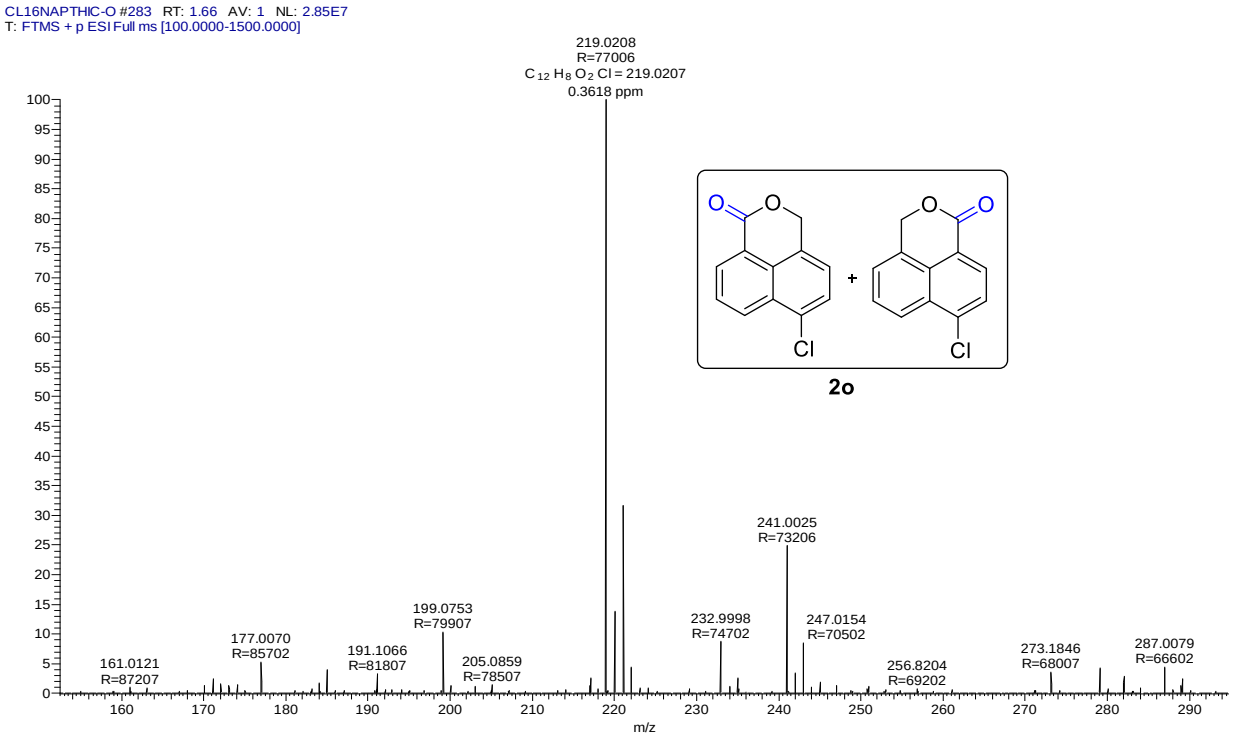
^{1}H NMR of compound **(2o)** in $CDCl_3$



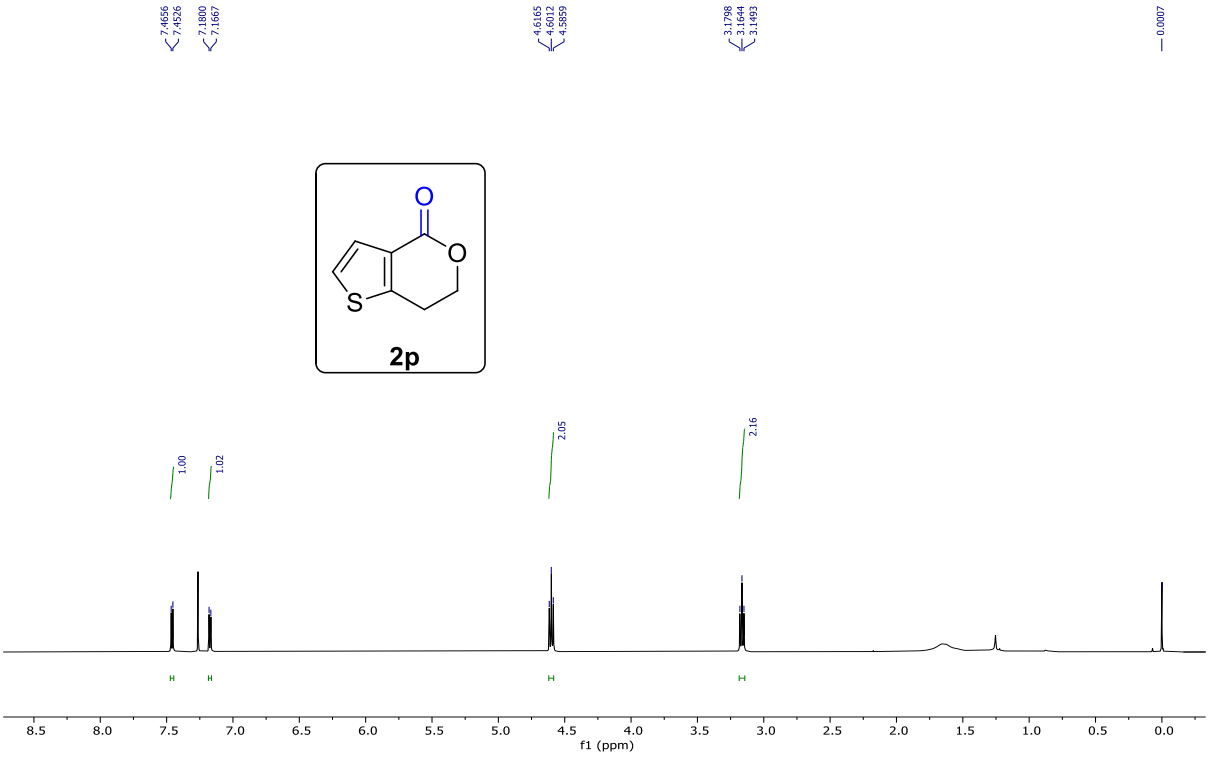
^{13}C NMR of compound **(2o)** in $CDCl_3$



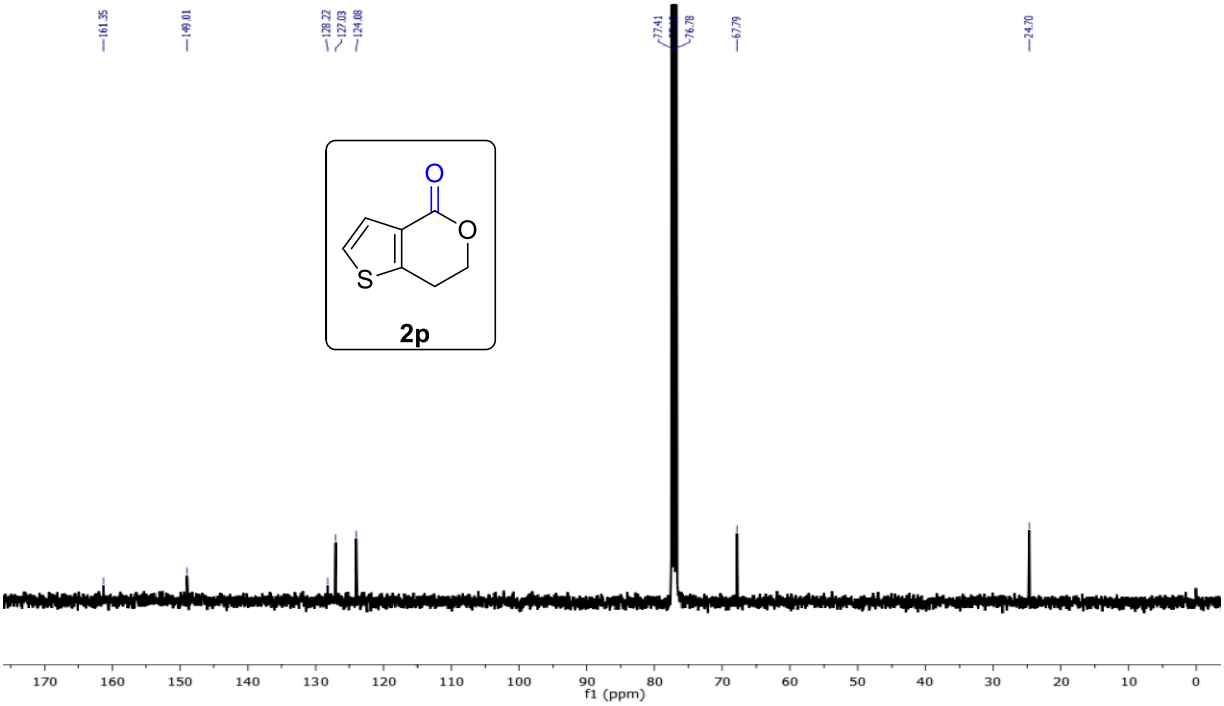
HRMS of compound **(2o)**



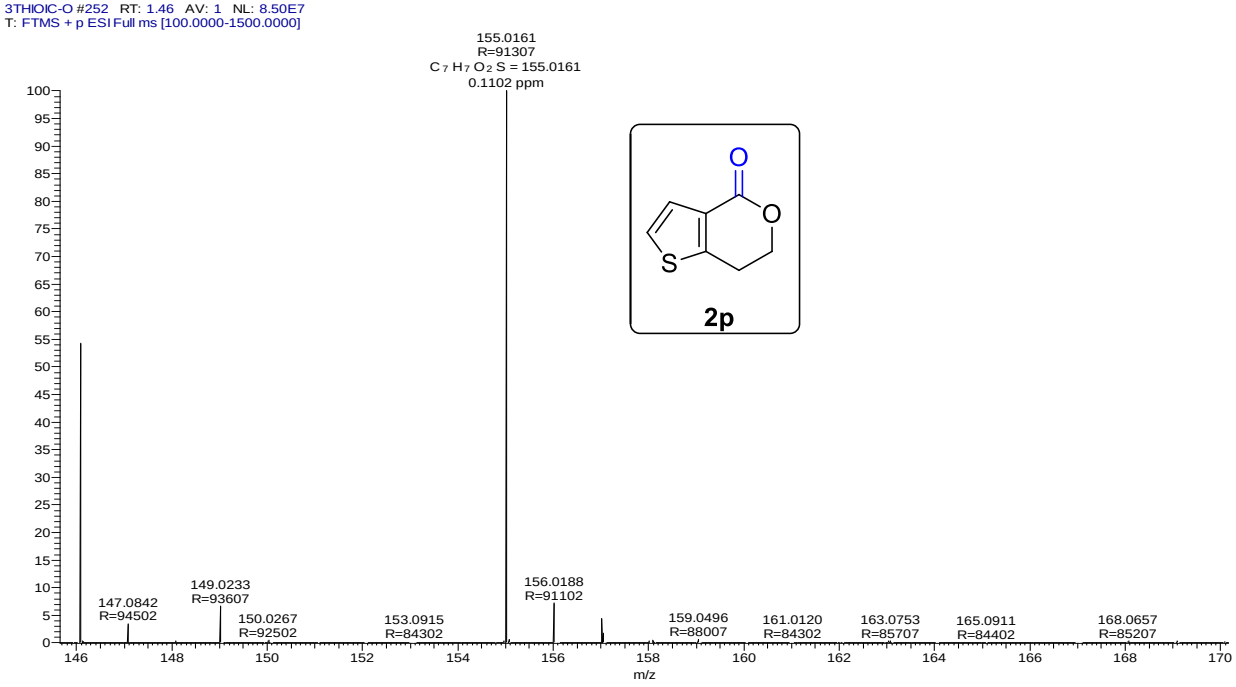
^{1}H NMR of compound **(2p)** in $CDCl_3$



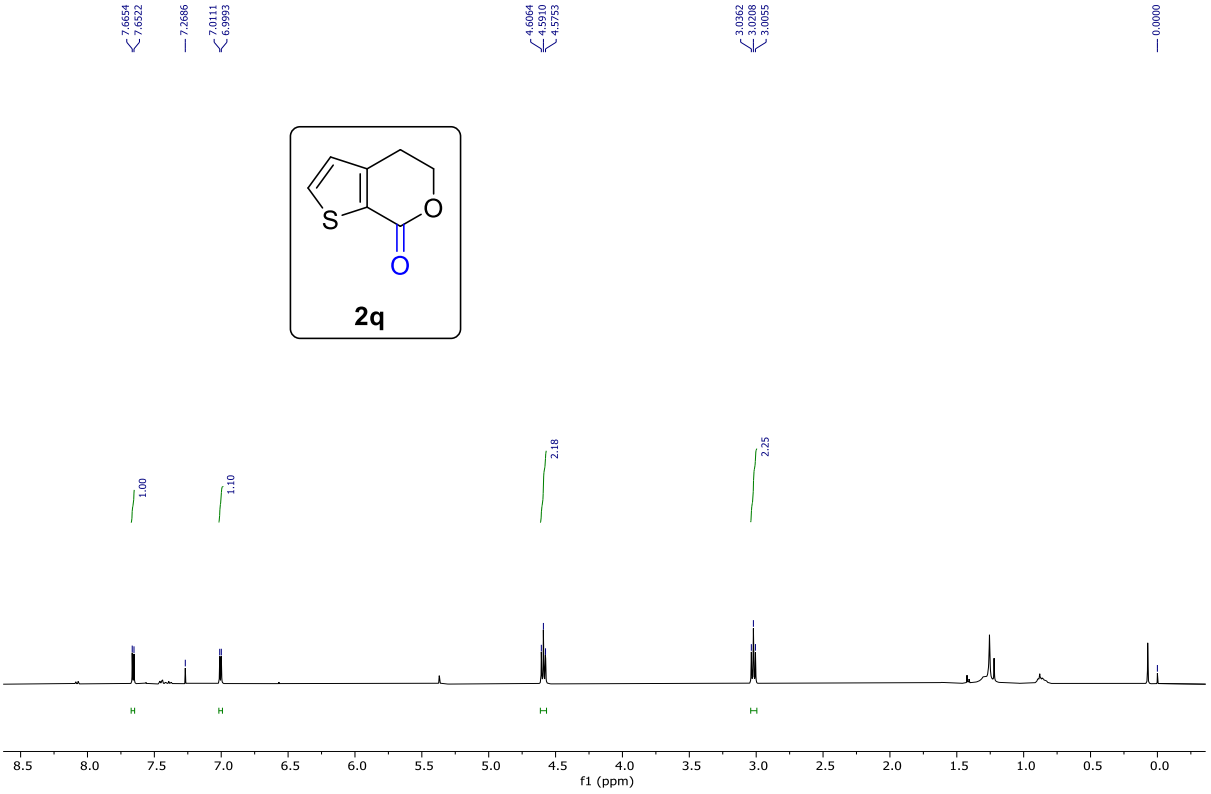
^{13}C NMR of compound **(2p)** in $CDCl_3$



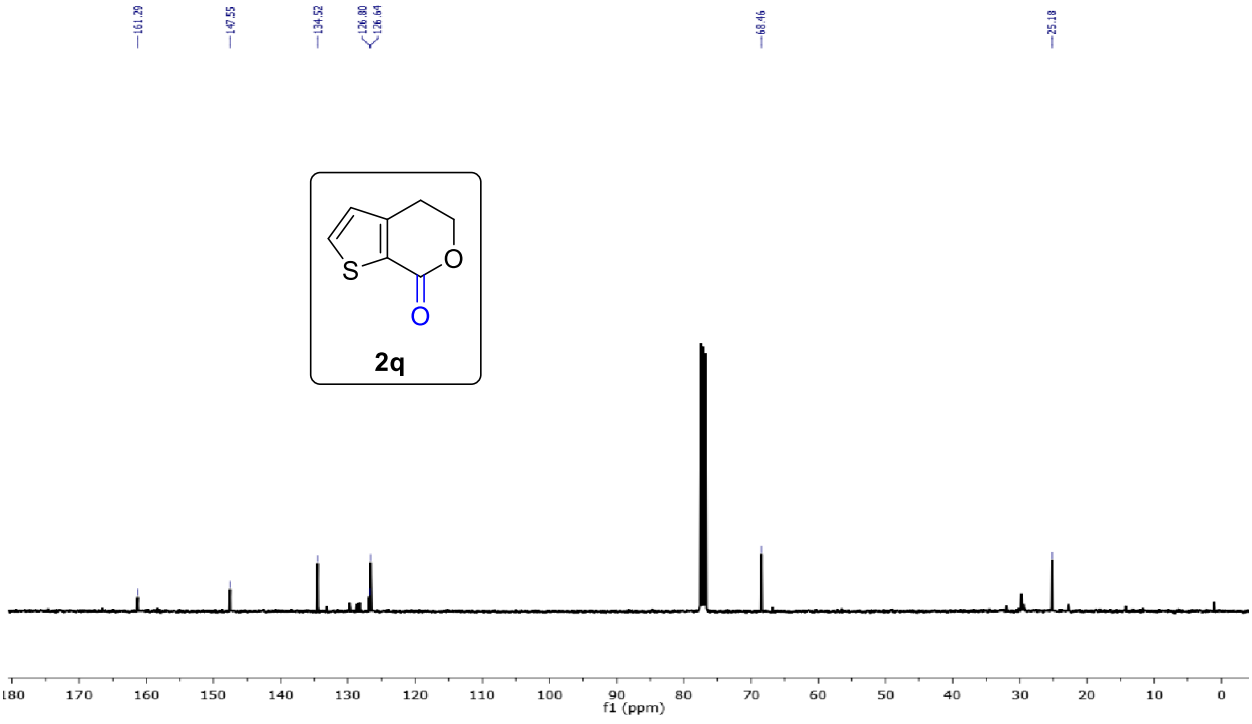
HRMS of compound **(2p)**



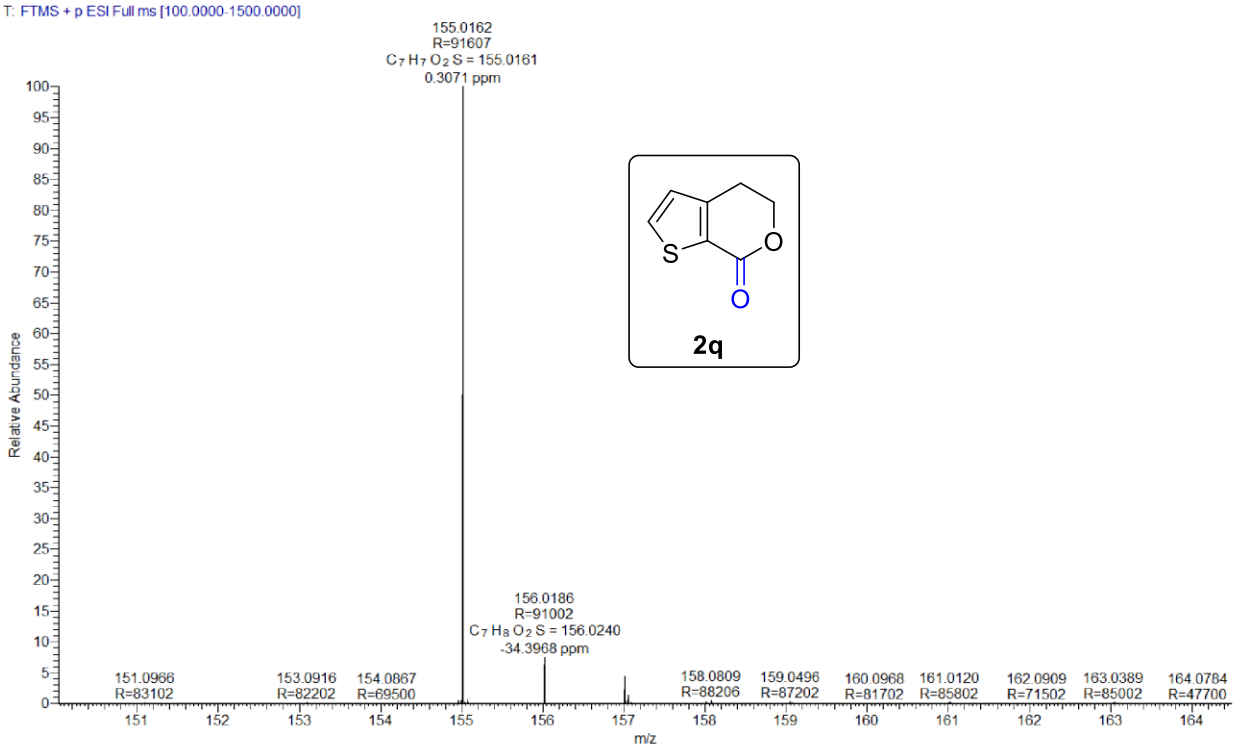
^{1}H NMR of compound **(2q)** in $CDCl_3$



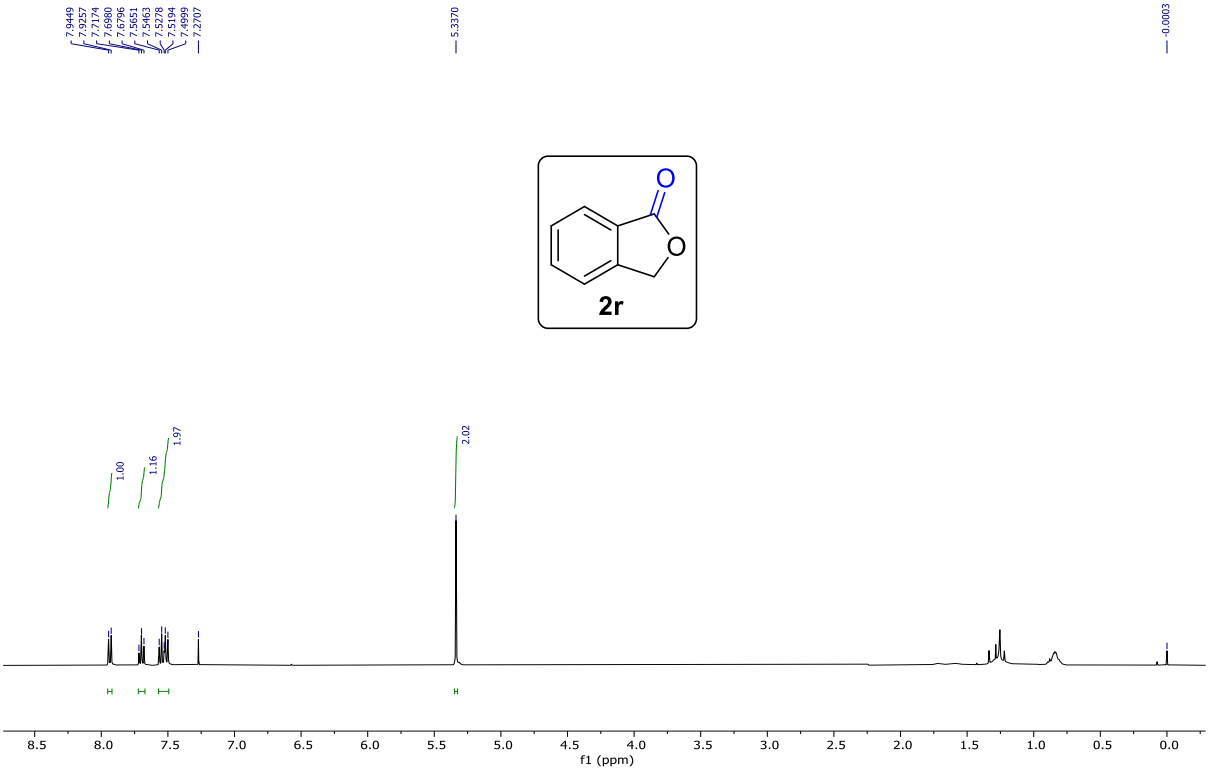
^{13}C NMR of compound **(2q)** in $CDCl_3$



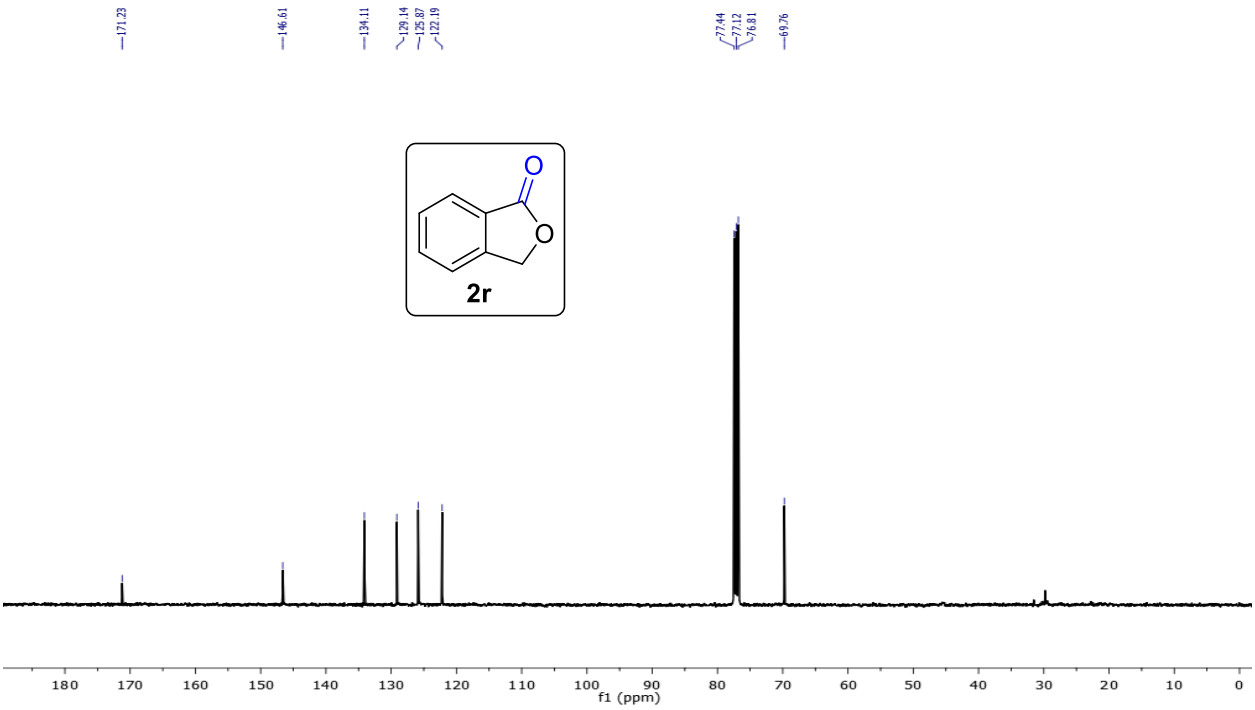
HRMS of compound **(2q)**



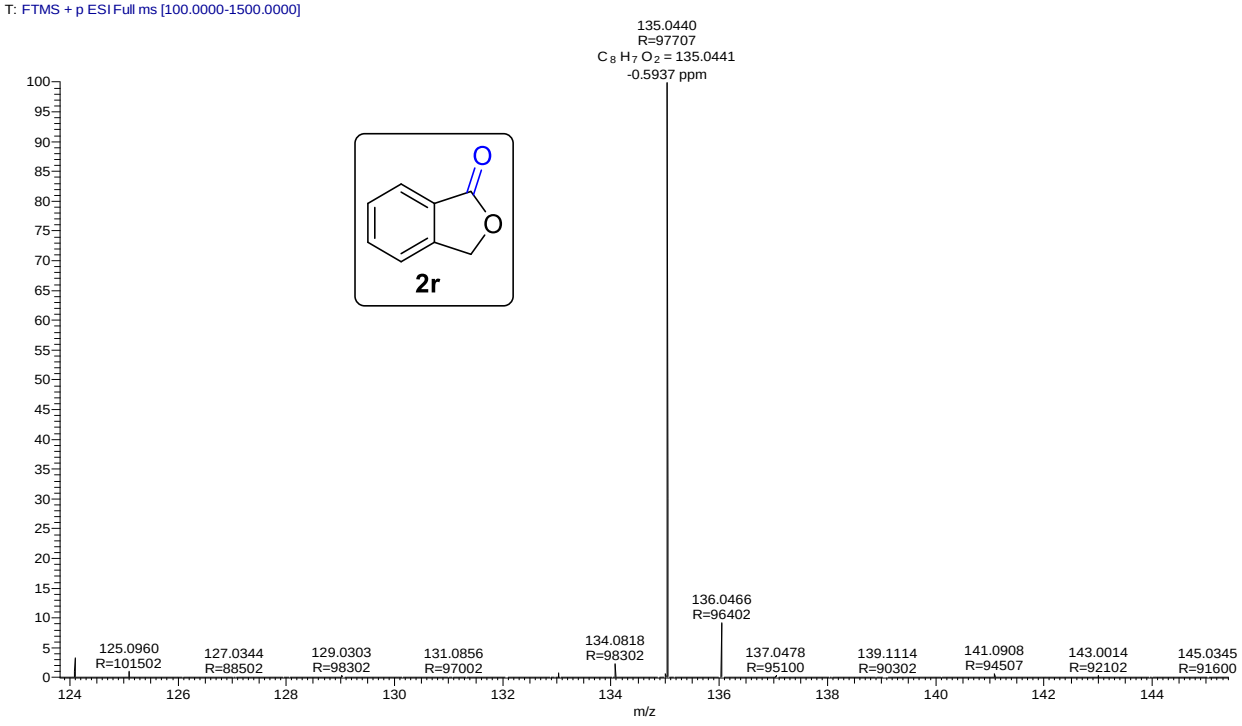
^{1}H NMR of compound **(2r)** in $CDCl_3$



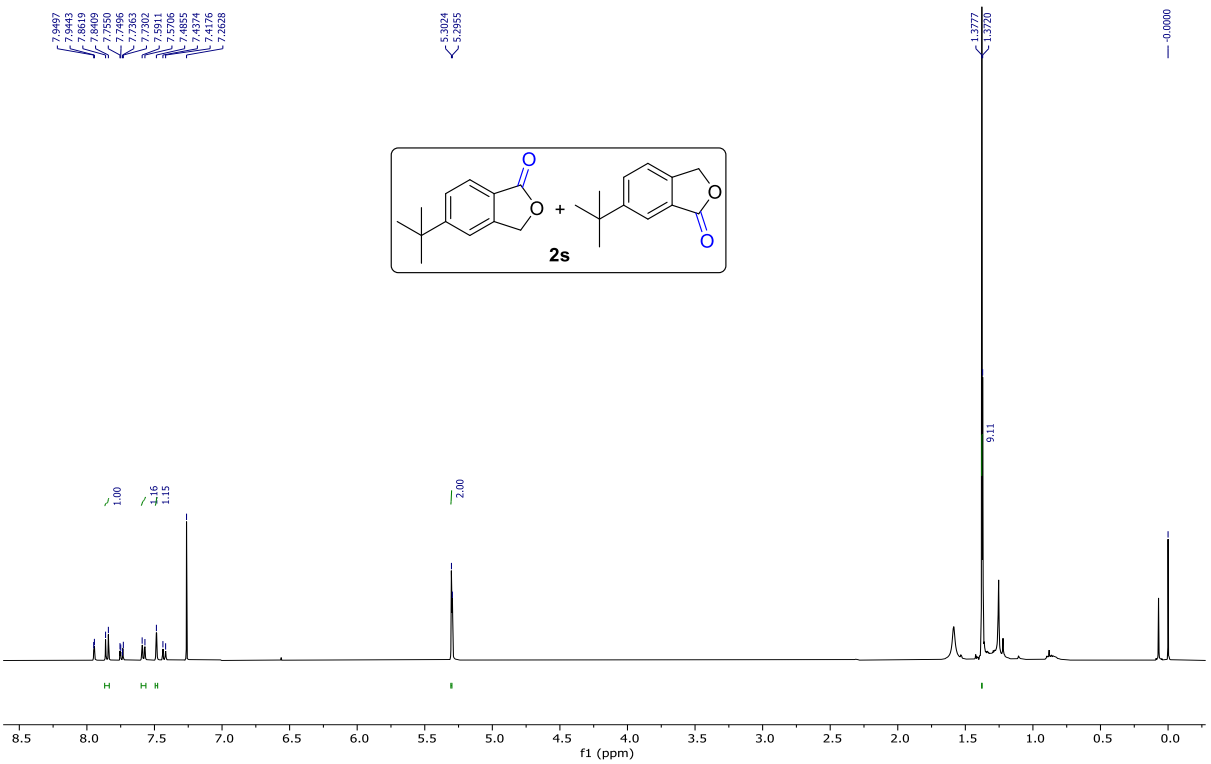
^{13}C NMR of compound **(2r)** in $CDCl_3$



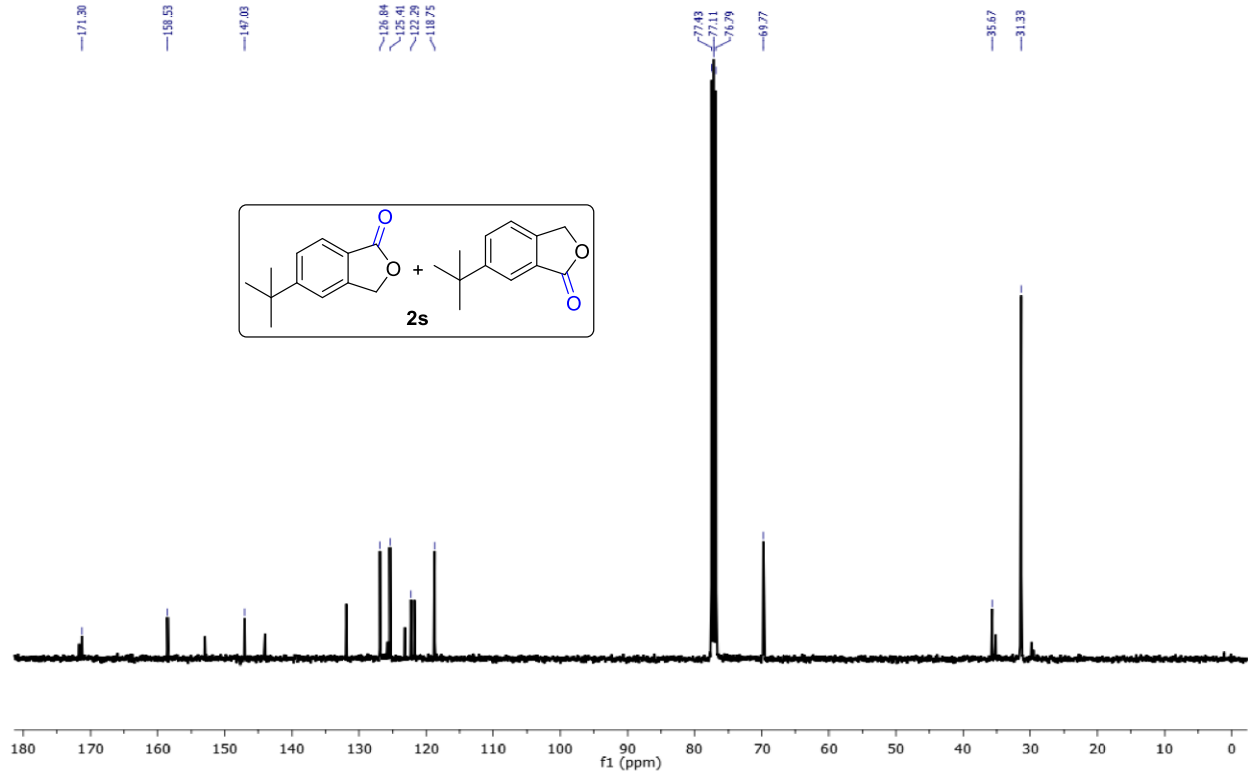
HRMS of compound **(2r)**



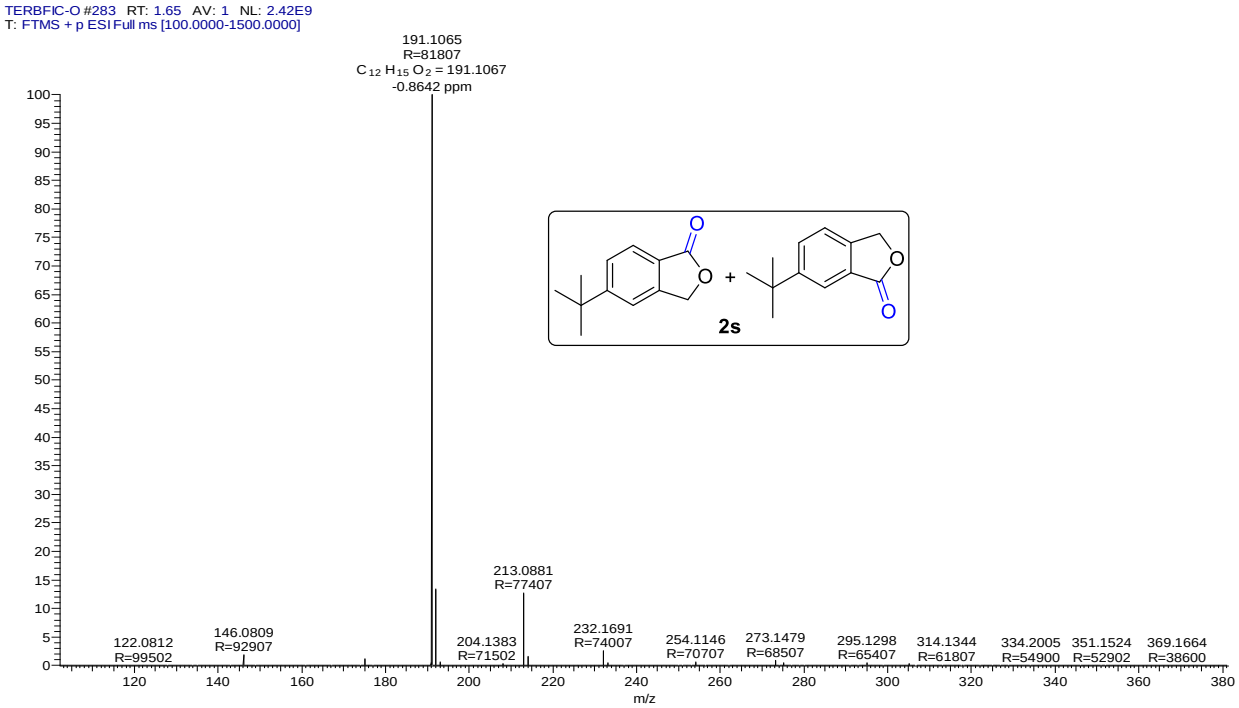
^{1}H NMR of compound **(2s)** in $CDCl_3$



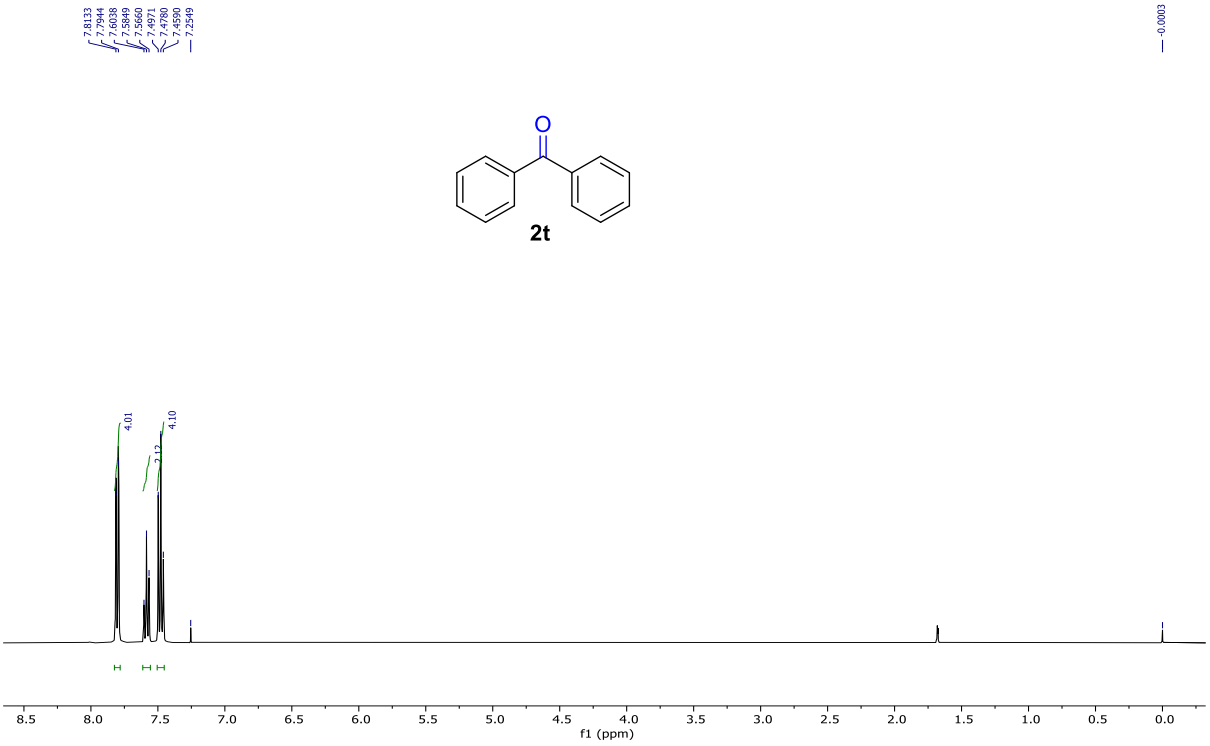
^{13}C NMR of compound **(2s)** in $CDCl_3$



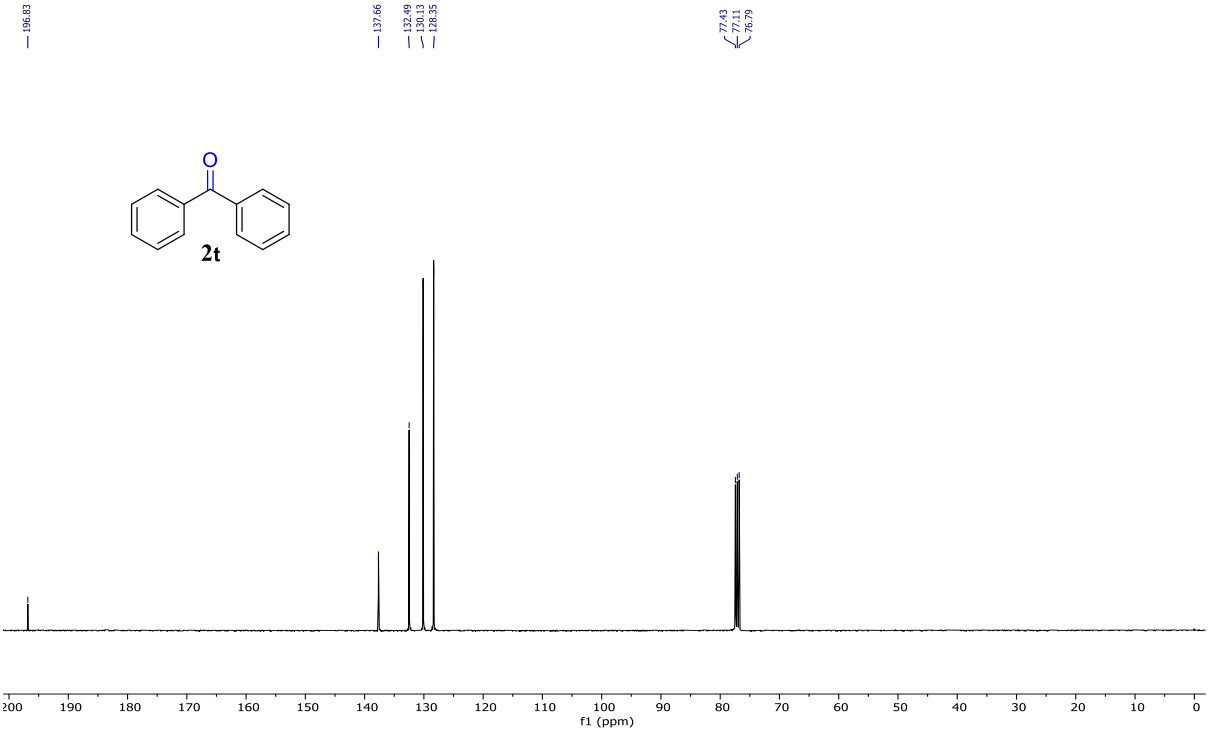
HRMS of compound **(2s)**



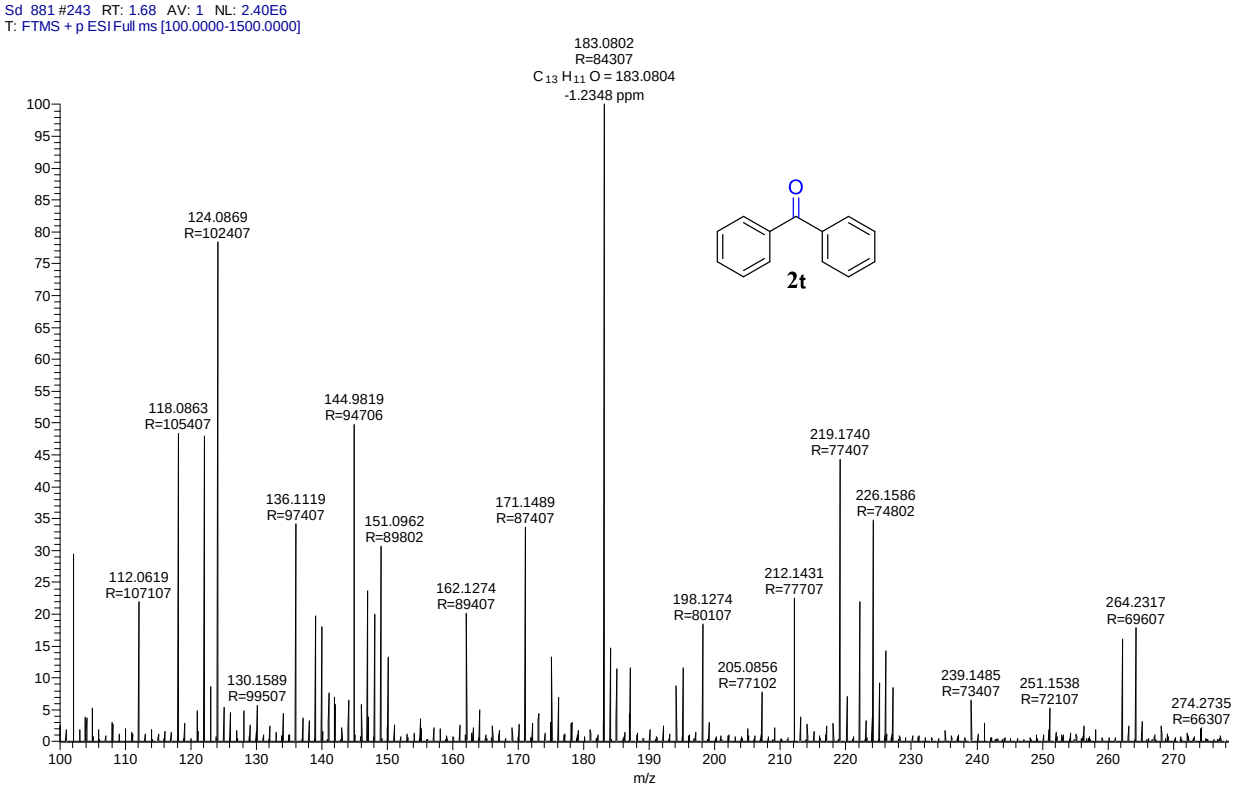
^{1}H NMR of compound **(2t)** in $CDCl_3$



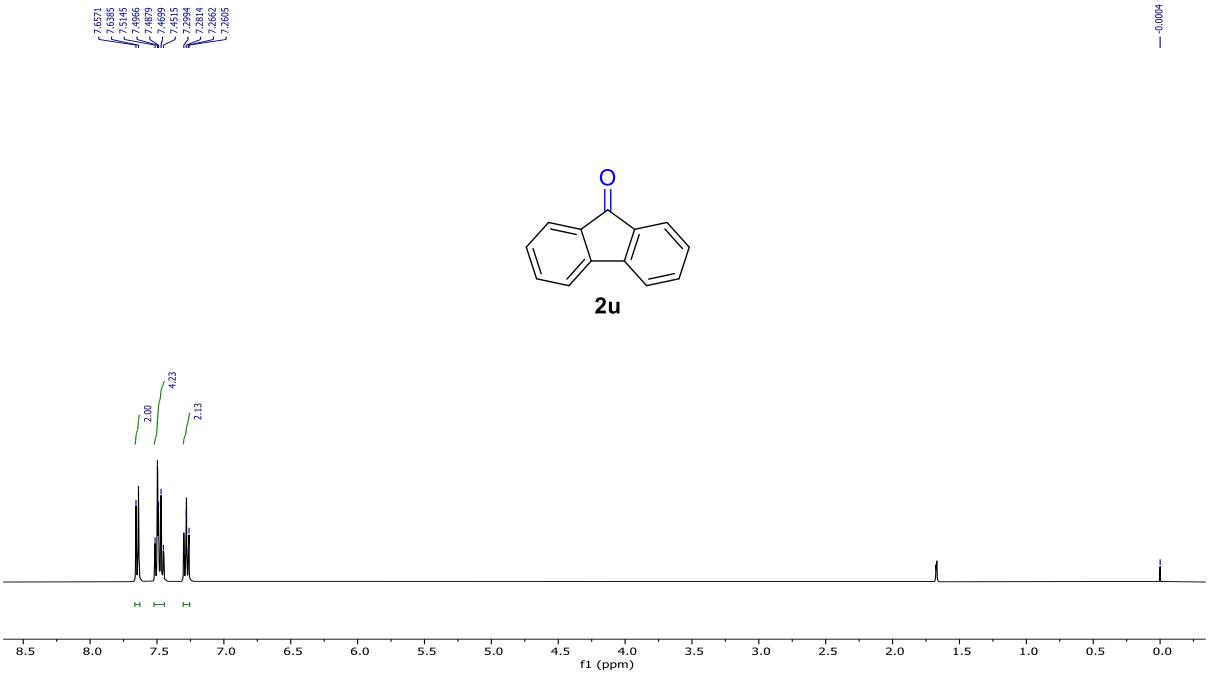
^{13}C NMR of compound **(2t)** in $CDCl_3$



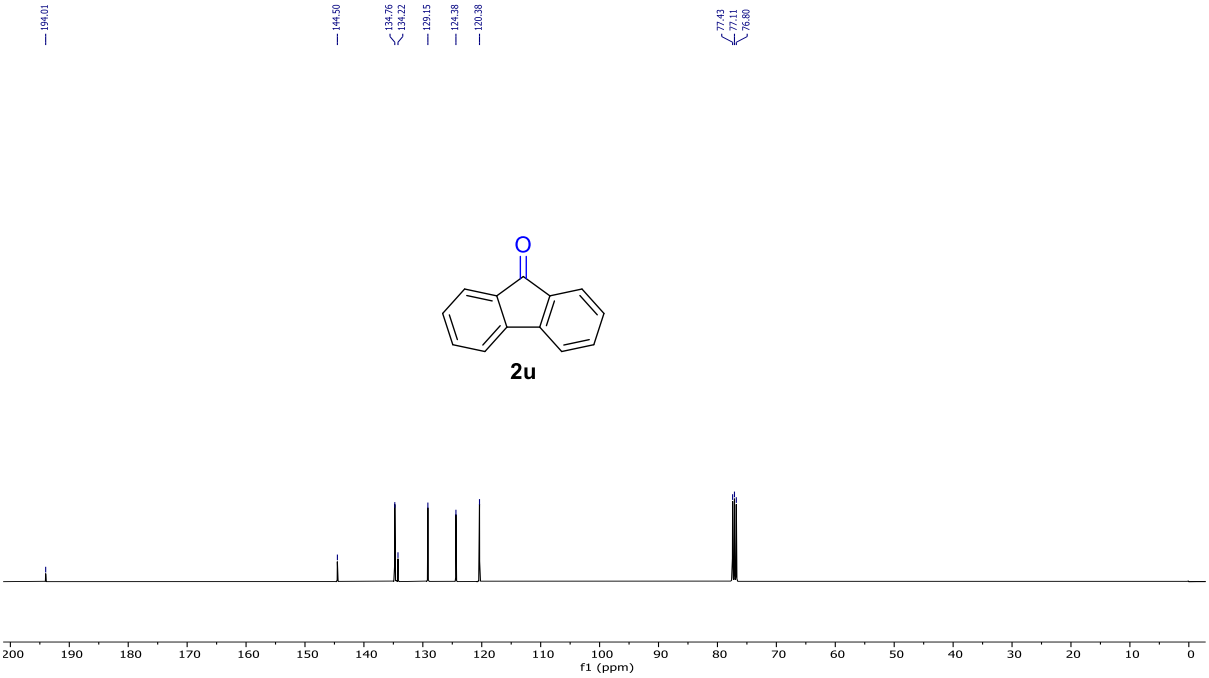
HRMS of compound **(2t)**



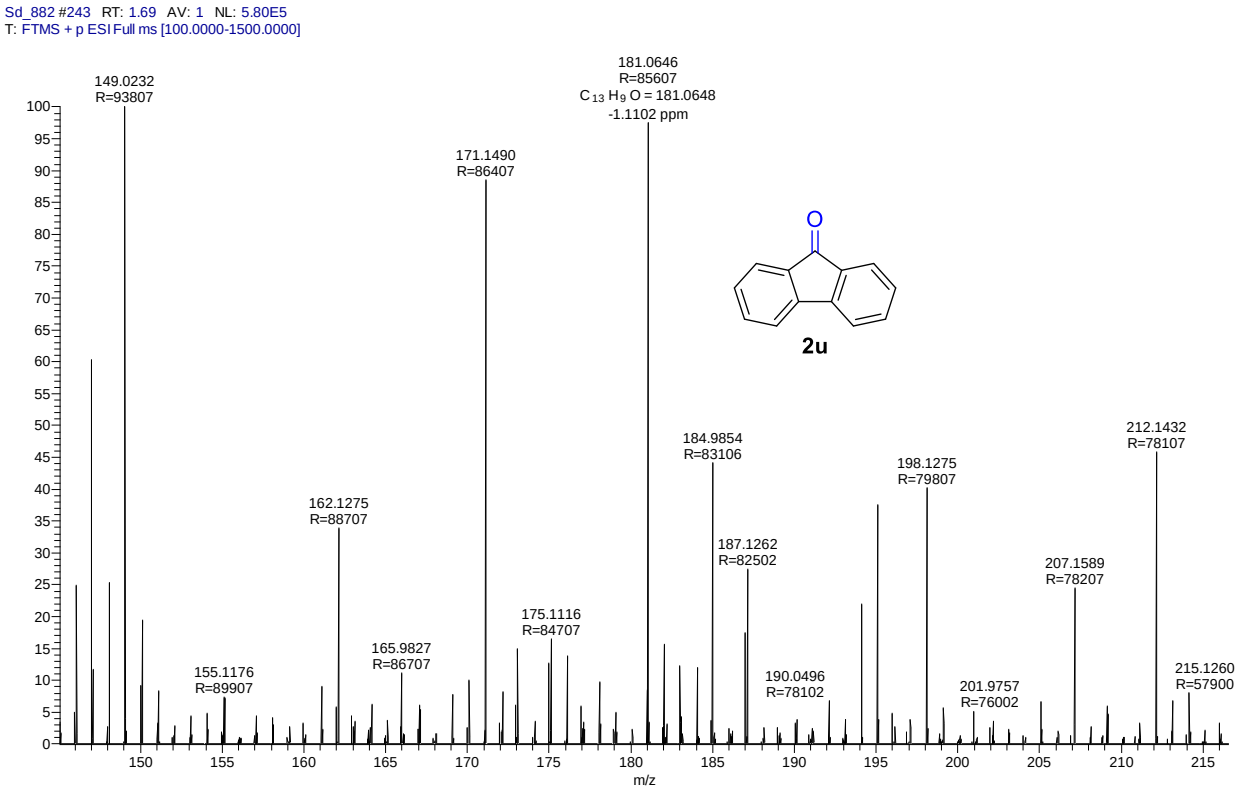
^{1}H NMR of compound **(2u)** in $CDCl_3$



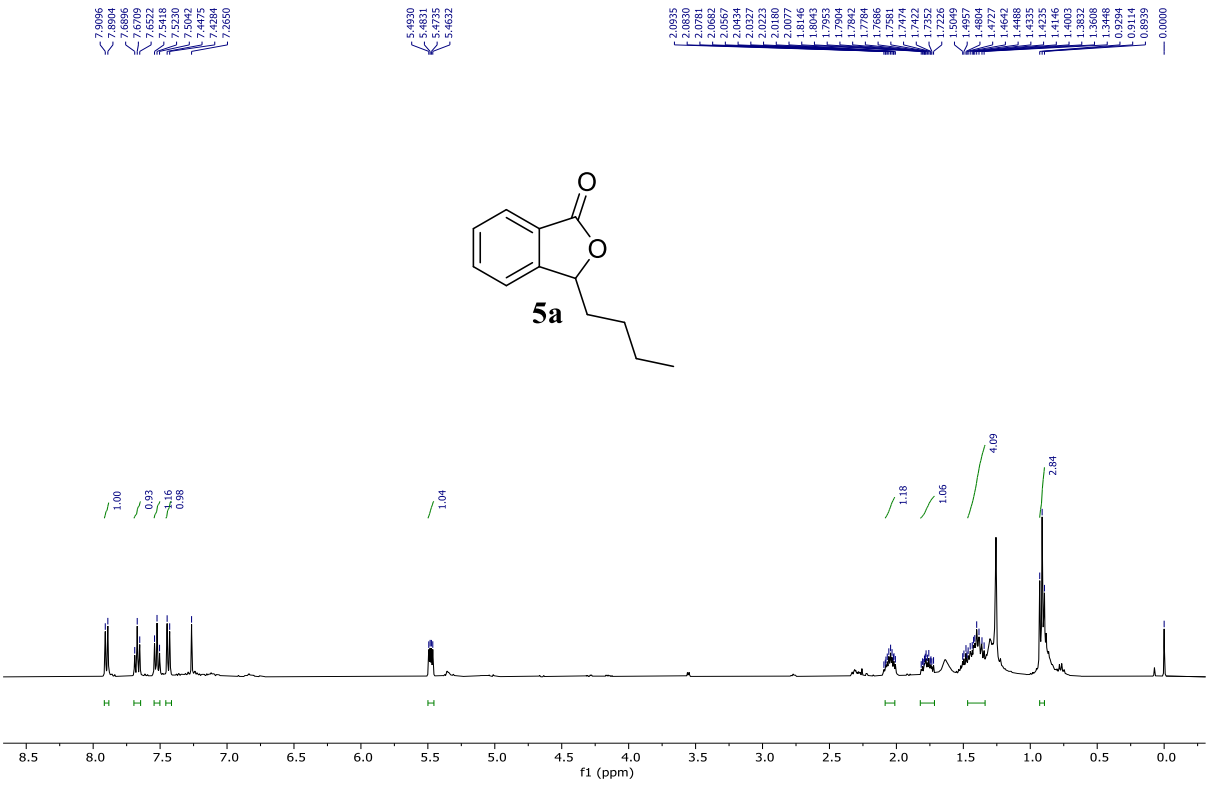
^{13}C NMR of compound **(2u)** in $CDCl_3$



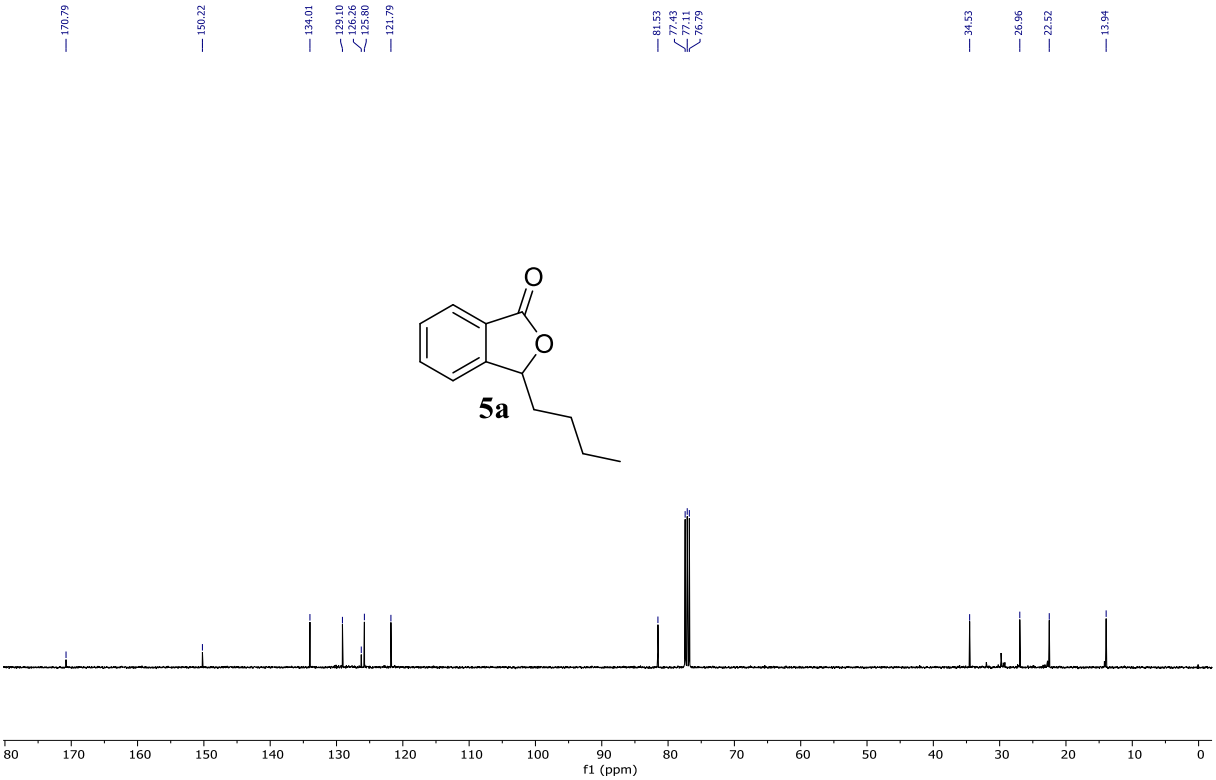
HRMS of compound **(2u)**



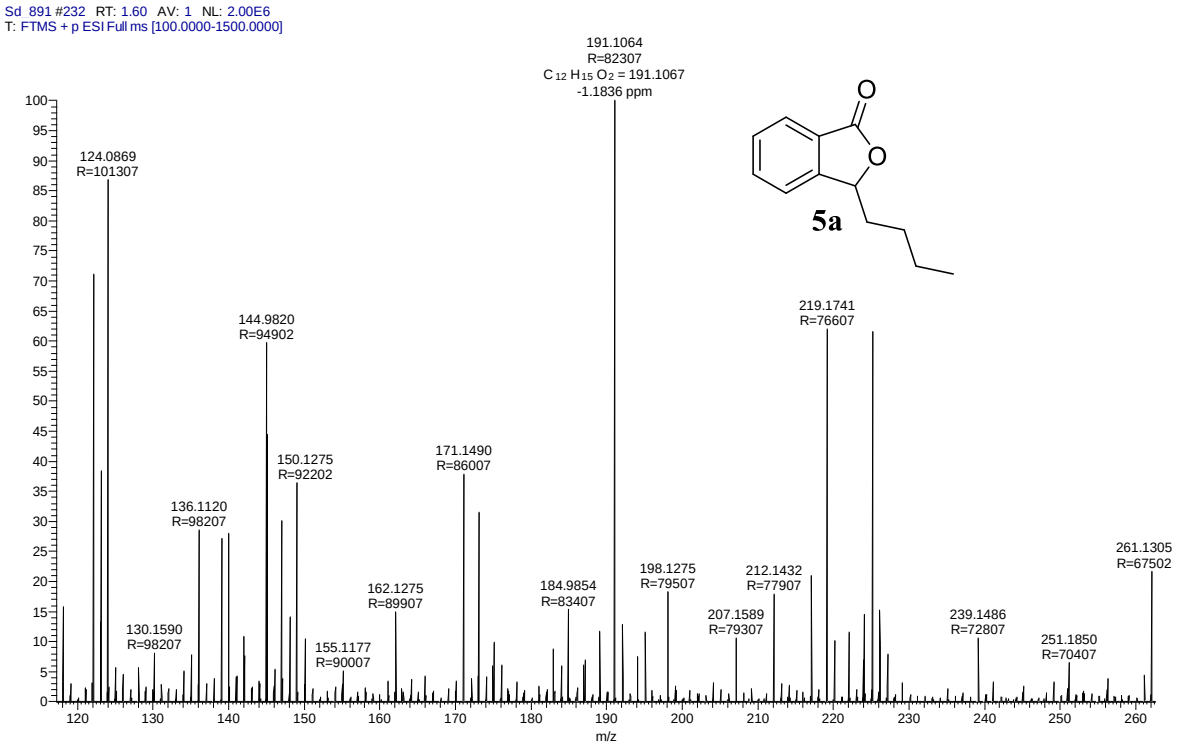
^{1}H NMR of compound **(5a)** in $CDCl_3$



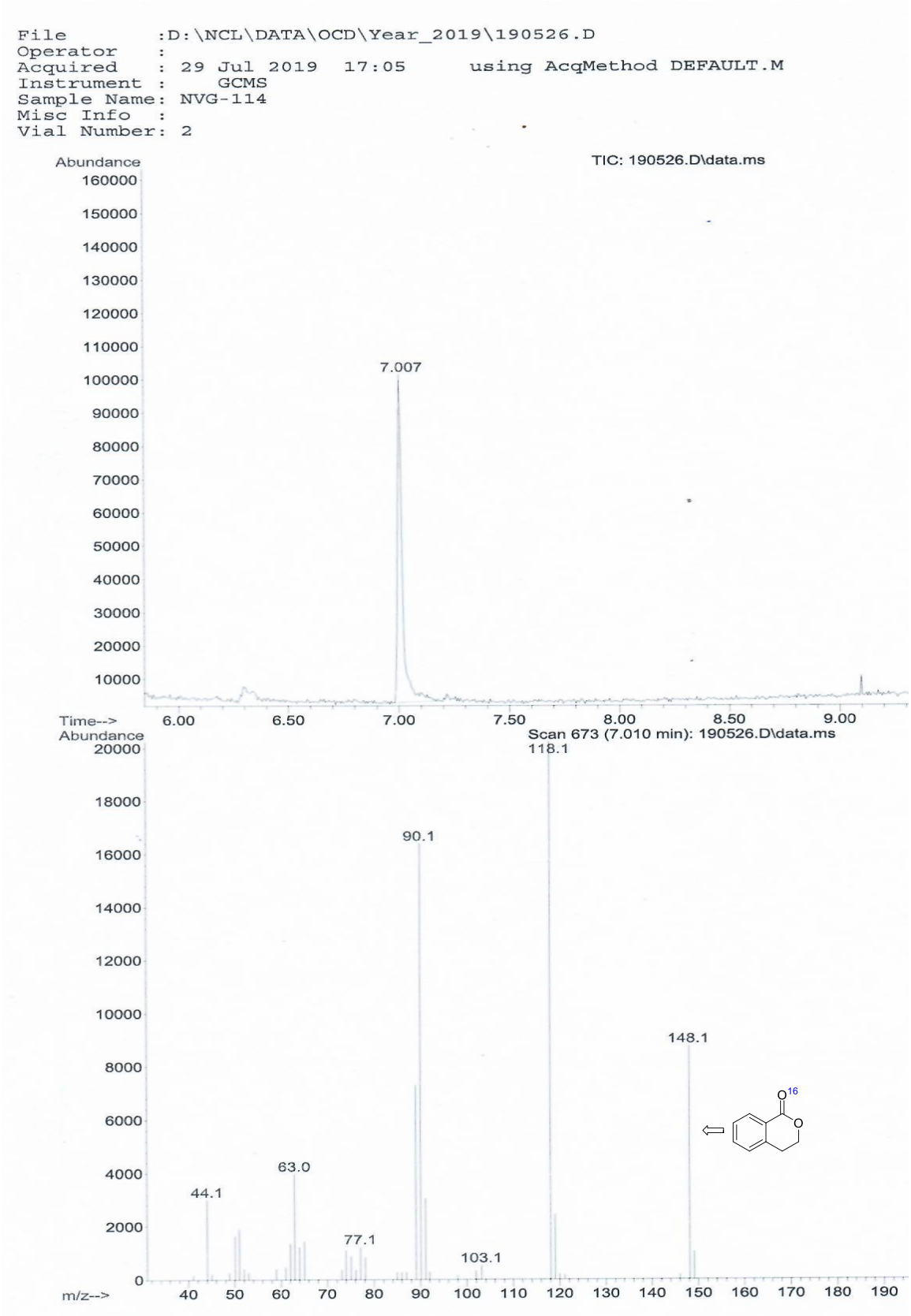
^{13}C NMR of compound **(5a)** in $CDCl_3$



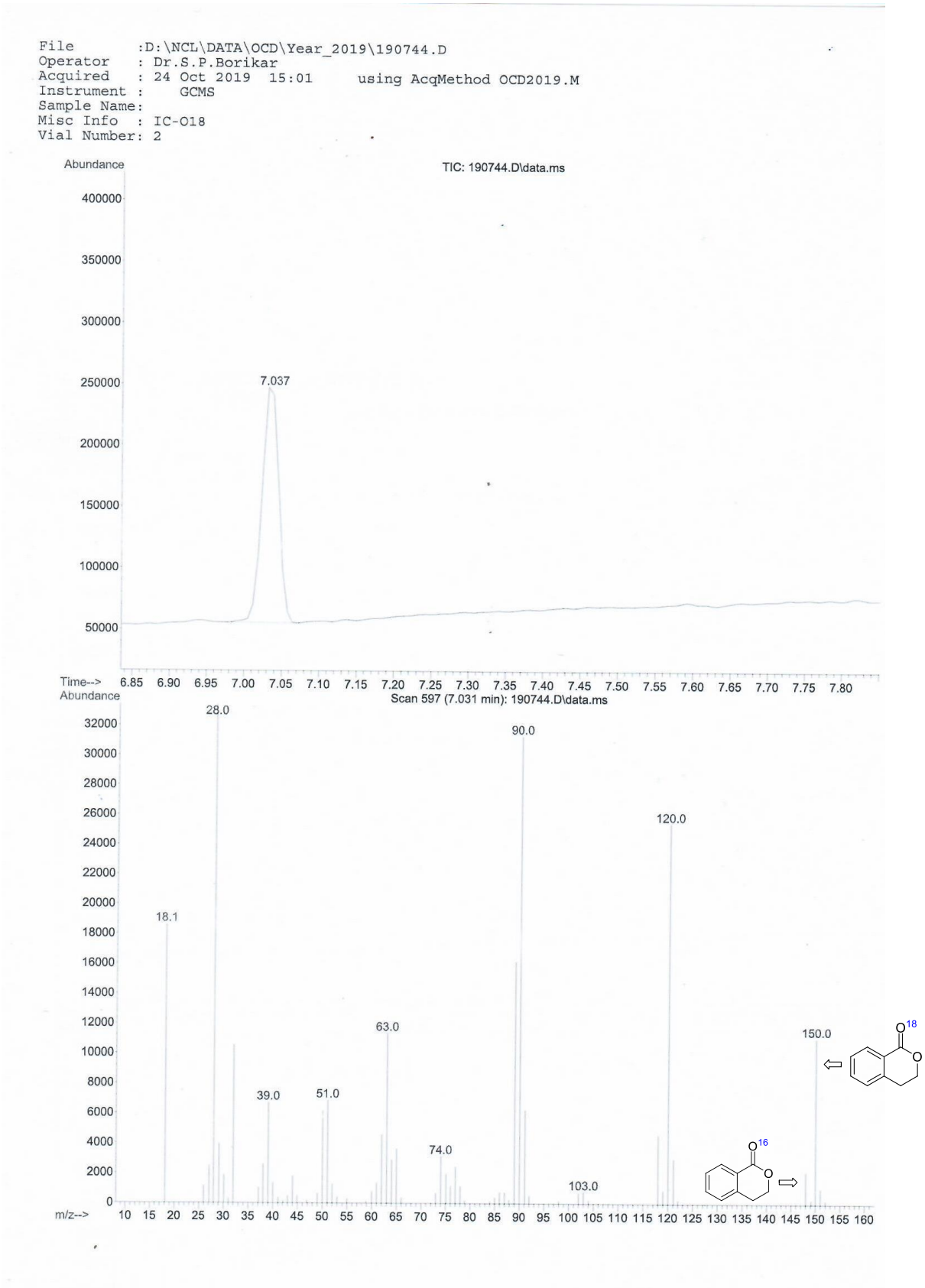
HRMS of compound **(5a)**



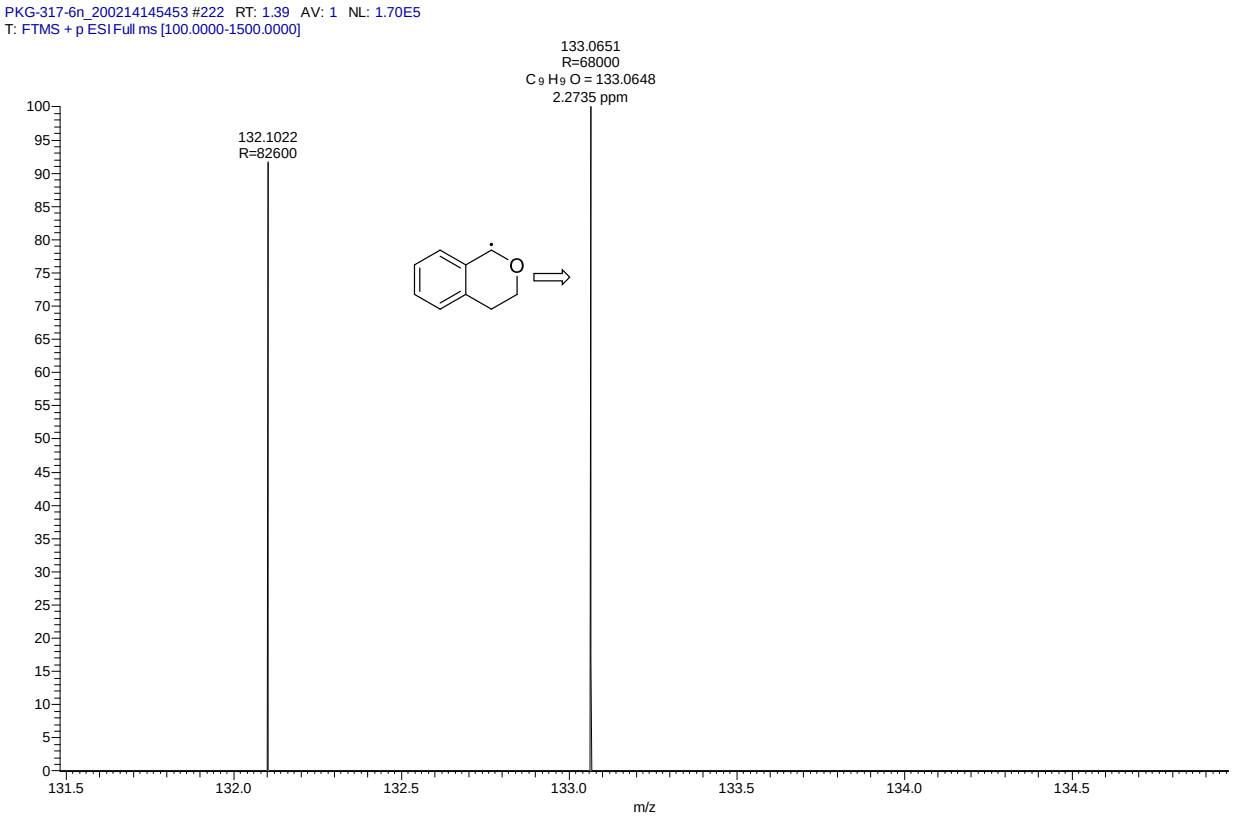
12.GC-MS spectrum of the reaction of isochroman **1a** in the presence of H_2O^{18}



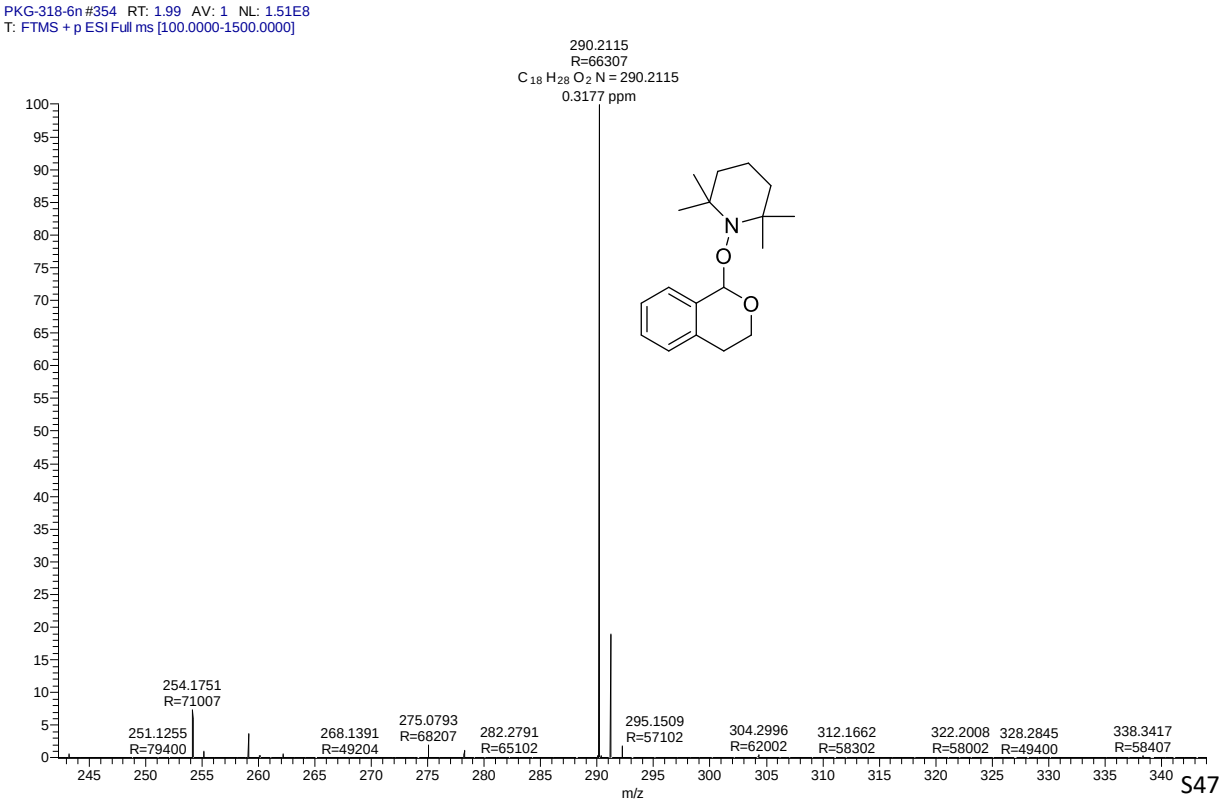
13. GC-MS spectrum of the reaction of isochroman **1a** in the presence of $^{18}O_2$



14. **HRMS spectrum for the detection of intermediate VI**



15. **HRMS spectrum for the detection of intermediate VI trapped by TEMPO**



16. **References**

1. Xia, Q.; Wang, Q.; Yan, C.; Dong, J.; Song, H.; Li, L.; Liu, Y.; Wang, Q.; Liu, X.; Song, a. H. *Chem. Eur. J.* **2017**, *23*, 10871. (b) Favor, D. A.; Johnson, D. S.; Powers, J. J.; Li, T.; Madabattula, a. R., *Tetrahedron Letters* **2007,** *48*, 3039.

2. Takabe, K.; Mizutani, M.; Yoda, H. *Heterocycles*, **1998**, *48*, 679.