Auto tandem triple cascade organocatalysis: Access to bis-lactone and butenolide derivatives

Stéphane Wittmann, Elodie Deschamps, Chloée Bournaud, Regis Guillot, Jean-François Brière , Giang Vo-Thanh and Martial Toffano

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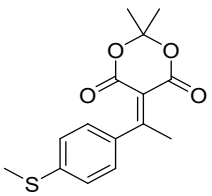
Preparation of Arylidene Meldrum's Acid derivatives 1a-w

General procedure: The arylidene Meldrum's acid precursors **1a-w** were synthesized according to a literature procedure without further adaptation or optimization to any substrate, otherwise noted.[1] Titanium tetrachloride (8.11 mL, 73.5 mmol) was added dropwise to dry THF (50 mL) at 0 °C; a yellow precipitate was formed. A solution of acetophenone derivative (38.5 mmol) and Meldrum's acid (5.04 g, 35 mmol) in THF (50 mL) was added slowly, followed by pyridine (14.2 mL, 175 mmol). The reaction mixture was stirred for 1 hour at 0 °C and then at room temperature for 19 hours. Distilled water (100 mL) and ethyl acetate (100 mL) were added and the phases were separated. The aqueous phase was extracted with ethyl acetate (2 × 100 mL). The combined organic phases were washed with a saturated aqueous solution of sodium bicarbonate (100 mL), washed with brine (100 mL), dried over magnesium sulfate and concentrated *in vacuo*. The crude product was recrystallized from ethanol or methanol to give the desired compounds **1a-w**.

2,2-Dimethyl-5-(1-(4-(methylthio)phenyl)ethylidene)-1,3-dioxane-4,6-dione (1g).

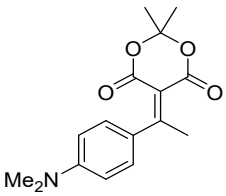


According to the *general procedure*, the title compound **1g** was obtained from Meldrum's acid and 4-(methylthio)acetophenone after purification by column chromatography on silica gel (petroleum ether/EtOAc: 85/15, 8/2, 6/4, then 1/1). Yellow solid. **m.p.**: 51-63°C.; isolated yield: 81% (4.130 g). **^{1}H NMR** (360 MHz, $CDCl_3$) δ (ppm): 7.25 (d, *J* = 8.5Hz, 2H), 7.15 (d, *J* = 8.5Hz, 2H), 2.72 (s, 3H), 2.50 (s, 3H), 1.84 (s, 6H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ (ppm): 172.6, 161.2, 160.7, 141.6, 137.8, 127.0, 125.5,

[1] a) S. Wittmann, T. Martzel, Cong Thanh Pham Truong, M. Toffano, S. Oudeyer, R. Guillot, C. Bournaud, V. Gandon, J.-F. Brière, G. Vo-Thanh. *Angew. Chem. Int. Ed.*, 2021, **60**, 11110. b) E. Fillion, A. Wilsily, *J. Am. Chem. Soc.* **2006**, *128*, 2774

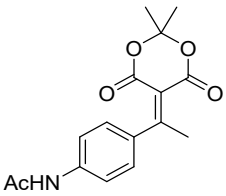
116.3, 103.8, 27.5, 26.3, 15.1. **HR-MS** (ESI, *m/z*): Calculated for $C_{15}H_{16}O_4NaS$ [(M+Na)$^+$]: 315.0661, found 315.0650.

5-(1-(4-(Dimethylamino)phenyl)ethylidene)-2,2-dimethyl-1,3-dioxane-4,6-dione (1h).



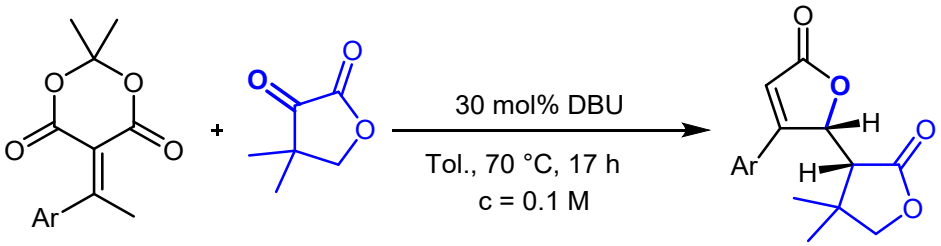
According to the *general procedure*, the title compound **1h** was obtained from Meldrum's acid and 4-dimethylacetophenone after recrystallization from methanol. Brown solid; isolated yield: 39% (1.974 g). **m.p.**: 149-150 °C. **^{1}H NMR** (360 MHz, $CDCl_3$) δ (ppm): 7.26 (d, *J* = 9.0 Hz, 2H), 6.65 (d, *J* = 9.0 Hz, 2H), 3.04 (s, 6H), 2.77 (s, 3H), 1.84 (s, 6H). **^{13}C NMR** (91 MHz, $CDCl_3$) δ (ppm): 174.2, 162.4, 162.1, 152.6, 130.6, 128.3, 112.3, 111.2, 103.4, 40.2, 27.5, 26.0. **HR-MS** (ESI, *m/z*): Calculated for $C_{16}H_{20}NO_4$ [(M+H)$^+$]: 290.1387, found 290.1378.

***N*-(4-(1-(2,2-Dimethyl-4,6-dioxo-1,3-dioxan-5-ylidene)ethyl)phenyl)acetamide (1r).**



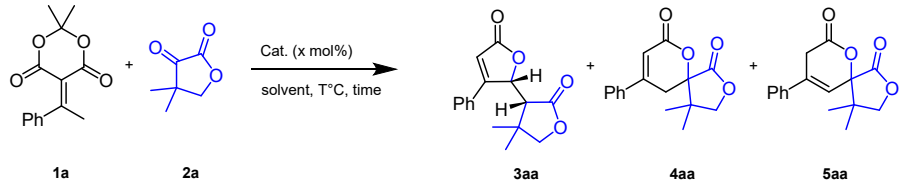
According to the *general procedure*, the title compound **1r** was obtained from Meldrum's acid (16.75 mmol and 4-acetamidoacetophenone (15.2mmol) after recrystallization from ethanol. Yellow solid; isolated yield: 48% (2.2 g). **m.p.**: 176.8–182 °C. **^{1}H NMR** (360 MHz, DMSO-d_6) δ (ppm): 10.17 (s, 1H), 7.62 (d, *J* = 8.7 Hz, 2H), 7.26 (d, *J* = 8.6 Hz, 2H), 2.67 (s, 3H), 2.11 (s, 3H), 1.84 (s, 6H). **^{13}C NMR** (91 MHz, DMSO-d_6) δ (ppm): 171.6, 168.6, 160.9, 160.5, 140.7, 136.0, 127.7, 118.3, 115.9, 103.9, 26.8, 25.4, 24.1. **HR-MS** (ESI, *m/z*): Calculated for $C_{16}H_{17}NaNO_5$ [(M+Na)$^+$]: 326.0998, found 326.0991.

. DBU-catalyzed synthesis of bislactones 3aa-3wa.



General procedure (otherwise noted): To a stirred solution of arylidene Meldrum's acid derivative (0.5 mmol) and dihydrofuran-2,3-dione derivative (furanedione) (0.525 mmol, 67.3mg) in 5mL of dry toluene (0.1M) was added 30 mol% of DBU (0.15mmol, 22.5μl) and the reaction mixture was stirred at 70 °C for 17 h. The reaction mixture was concentrated *in vacuo* and the crude product was purified by column chromatography on silica gel (mix of petroleum ether, DCM and EtOAc as eluent) to afford the desired bislactone **3aa-3wa** as a mixture of diastereoisomers.

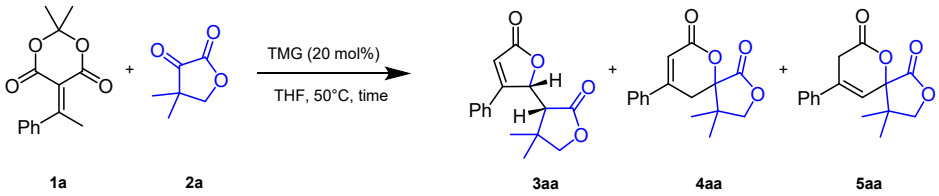
Parameters and Kinetic studies



	Cat.	solvent	°C %	Time (h)	Conv. (%)	**3aa/4aa/5aa**	Isolated Yields % (d.r)
	100% mol DMAP	DCM (0.5M)	24	24	99	0/100/0	-
	100% mol TEA	DCM (0.5M)	24	24	99	31/69/0	19 (75/25)
	100% mol TMG	DCM (0.5M)	24	24	98	87/13/0 and by products	18 (82/12) +
ED75	20mol% DBU	THF (0.25M)	50	24	99	70/30/0	nd
ED83	20mol% TMG	THF (0.5M)	50	16	99	53/40/7	nd
ED73	20mol% TMG	THF (0.5M)	50	24	99	98/2/0 and by products	66 (82/18)
ED117	20mol% TMG	Tol. (0.25M)	50	24	99	65/35/0 and by products	65 (90/10)
ED105	30mol% TMG	Tol. (0.1M)	50	90	99	78/22/0 and by products	35
ED123	30mol% TMG	Tol. (0.1M)	70	24	99	75/25/trace and by products	62 (84/16)
ED119	30mol% DBU	Tol (0.1M)	70	24	99	95/trace/0	70 (83/17)
ED125	30mol% DBU	Tol (0.1M)	70	17	99	98/2/0	77 (86/14)

By products are not isolated since it will be identified as polymers. nd : not determined

^{1H}NMR study of **1a**, **3aa**, **4aa** and **7aa** in THF with tetramethylguanidine.[a]

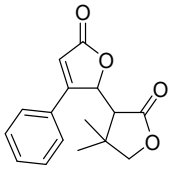


Time (h)	Conv. (%)	**1a**	**5aa**	**4aa**	**3aa**
0.5	28	72	24	5	0
1	43	43	1	47	9
2[b]	100	0	1	73	26
4[b]	100	0	1	55	44
6[b]	100	0	1	46	53
8[b]	100	0	0	35	65
25[b]	100	0	0	0	100

[a.]Values determined by 1H NMR after evaporation of THF at low temperature. [b.]Broad signals corresponding to the possible presence of polymer appears after 2hours reaction time.

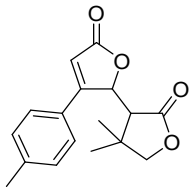
NMR data are described for the major isomer, while NMR spectra present a mixture of the two diastereoisomers, otherwise noted.

5-(4,4-dimethyl-2-oxotetrahydrofuran-3-yl)-4-phenylfuran-2(5*H*)-one (3aa).



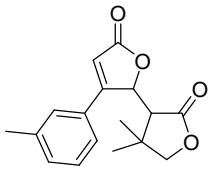
According to the *general procedure*, the title compound **3aa** was obtained from Meldrum's acid derivative **1a** and furandione **2a** after column chromatography (petroleum ether/EtOAc: 7/3) as a mixture of diastereomers. Pale yellow solid; isolated yield: 77% (105mg); d.r. = 86/14. **m.p.**: 150–162 °C. Recrystallization in EtOAc/hexane give a single stereoisomer as white solid. **^{1}H NMR** (300 MHz, $CDCl_3$) δ (ppm): 7.54–7.41 (m, 5H), 6.34 (d, *J* = 1.6 Hz, 1H), 5.65 (t, *J* = 1.6 Hz, 1H), 4.14 (d, *J* = 8.6 Hz, 1H), 3.89 (d, *J* = 8.6 Hz, 1H), 2.61 (d, *J* = 1.6 Hz, 1H), 1.40 (s, 3H), 1.27 (s, 3H). **^{13}C NMR** (75 MHz, $CDCl_3$) δ (ppm): 172.8, 171.8, 165.9, 131.5, 130.2, 129.6, 127.2, 116.4, 78.6, 78.0, 52.4, 39.2, 27.6, 21.6. **HR-MS** (ESI, *m/z*): Calculated for $C_{16}H_{17}O_4$ [(M+H)$^+$]: 273.1118, found: 273.1121.

5-(4,4-Dimethyl-2-oxotetrahydrofuran-3-yl)-4-(p-tolyl)furan-2(5*H*)-one (3ba).



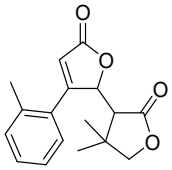
According to the *general procedure*, the title compound **3ba** was obtained from Meldrum's acid derivative **1b** and furandione **2a** after column chromatography (petroleum ether/DCM/EtOAc: 60/35/5) as a mixture of diastereomers. White solid; isolated yield: 85% (122mg); d.r. = 86/14. **m.p.**: 167.2–168.0 °C. **^{1}H NMR** (250 MHz, $CDCl_3$) δ (ppm): 7.47–7.26 (m, 4H), 6.32 (d, *J* = 1.5 Hz, 1H), 5.62 (s, 1H), 4.16 (d, *J* = 8.6 Hz, 1H), 3.89 (d, *J* = 8.6 Hz, 1H), 2.62 (d, *J* = 1.5 Hz, 1H), 2.42 (s, 3H), 1.41 (s, 3H), 1.28 (s, 3H). **^{13}C NMR** (91 MHz, $CDCl_3$) δ (ppm): 172.8, 172.0, 165.8, 142.2, 130.3, 127.1, 115.2, 78.5, 77.9, 52.4, 39.2, 27.4, 21.6, 21.6. **HR-MS** (ESI, *m/z*): Calculated for $C_{17}H_{19}O_4$ [(M+H)$^+$]: 287.1278, found: 287.1277.

5-(4,4-Dimethyl-2-oxotetrahydrofuran-3-yl)-4-(*m*-tolyl)furan-2(5*H*)-one (3ca).



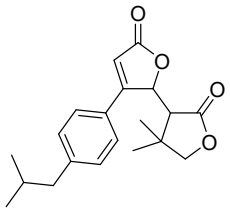
According to the *general procedure*, the title compound **3ca** was obtained from Meldrum's acid derivative **1c** and furandione **2a** after column chromatography (petroleum ether/DCM/EtOAc: 60/30/10) as a mixture of diastereomers. Off-white solid; isolated yield: 63% (90 mg); d.r. = 83/17. **m.p.**: 156–157 °C. **^{1}H NMR** (400 MHz, $CDCl_3$) δ (ppm): 7.42–7.25 (m, 3H), 7.24 (, *J* = 7.5 Hz, 1H), 6.4 (d, *J* = 1.6 Hz, 1H), 5.6 (t, *J* = 1.6 Hz, 1H), 4.16 (d, *J* = 8.6 Hz, 1H), 3.90 (d, *J* = 8.6 Hz, 1H), 2.63 (d, *J* = 1.6 Hz, 1H), 2.42 (s, 3H), 1.41 (s, 3H), 1.28 (s, 3H). **^{13}C NMR** (63 MHz, $CDCl_3$) δ (ppm): 172.8, 171.9, 166.0, 139.6, 132.4, 130.1, 129.4, 128.0, 124.0, 116.1, 78.6, 78.0, 52.4, 39.3, 27.5, 21.7, 21.6. **HR-MS** (ESI, *m/z*): Calculated for $C_{17}H_{19}O_4$ [(M+H)$^+$]: 287.1278, found 287.1268.

5-(4,4-Dimethyl-2-oxotetrahydrofuran-3-yl)-4-(*o*-tolyl)furan-2(5*H*)-one (3da).



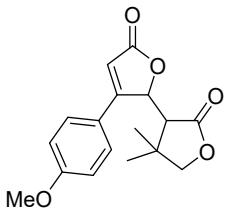
According to the *general procedure*, the title compound **3da** was obtained from Meldrum's acid derivative **1d** (0.25mmol) and furandione **2a** (0.275mmol) after column chromatography (petroleum ether/DCM/EtOAc: 60/35/5) as a mixture of diastereomers. Yellow solid; isolated yield: 45% (32 mg); d.r. > 95/5. **m.p.**: 146–148 °C. Recristallisation in hex/EtOAc offers pure colorless cristals. **^{1}H NMR** (400 MHz, $CDCl_3$) δ (ppm): 7.42–7.27 (m, 3H), 7.24–7.15 (m, 1H), 6.24 (s, 1H), 5.60 (s, 1H), 4.16 (d, *J* = 8.5 Hz, 1H), 3.88 (d, *J* = 8.5 Hz, 1H), 2.49 (s, 3H), 2.39 (s, 1H), 1.38 (s, 3H), 1.20 (s, 3H). **^{13}C NMR** (91 MHz, $CDCl_3$) δ (ppm): 173.0, 172.1, 165.9, 137.7, 132.2, 130.6, 130.2, 127.6, 126.7, 119.8, 79.5, 78.6, 52.1, 39.2, 27.6, 21.8, 21.0. **HR-MS** (ESI, *m/z*): Calculated for $C_{17}H_{19}O_4$ [(M+H)$^+$]: 287.1278, found 287.1272.

5-(4,4-Dimethyl-2-oxotetrahydrofuran-3-yl)-4-(4-isobutylphenyl)furan-2(5*H*)-one (3ea).



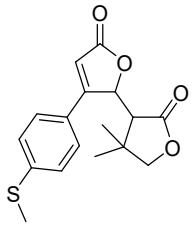
According to the *general procedure*, the title compound **x** was obtained from Meldrum's acid derivative **1e** and furandione **2a** after column chromatography (petroleum ether/DCM/EtOAc: 60/35/5) as a mixture of diastereomers. White solid; isolated yield: 95%; d.r. = 82/18. **m.p.**: 173.4–174.0 °C. **^{1}H NMR** (400 MHz, $CDCl_3$) δ (ppm): 7.36 (d, *J* = 8 Hz, 2H), 7.27 (d, *J* = 8 Hz, 2H), 6.33 (d, *J* = 1.5 Hz, 1H), 5.62 (t, *J* = 1.5 Hz, 1H), 4.15 (d, *J* = 8.5 Hz, 1H), 3.90 (d, *J* = 8.5 Hz, 1H), 2.64 (d, *J* = 1.5 Hz, 1H), 2.53 (d, *J* = 7.1 Hz, 2H), 1.90 (thept, *J* = 7.1, 6.6 Hz, 1H), 1.41 (s, 3H), 1.29 (s, 3H), 0.93 (d, *J* = 6.6 Hz, 3H), 0.93 (d, *J* = 6.6 Hz, 3H). **^{13}C NMR** (63 MHz, $CDCl_3$) δ (ppm): 172.8, 172.1, 165.8, 145.9, 130.3, 127.5, 127.0, 115.3, 78.5, 77.8, 52.5, 45.4, 39.2, 30.2, 27.4, 22.5, 21.6. **HR-MS** (ESI, *m/z*): Calculated for $C_{20}H_{25}O_4$ [(M+H)$^+$]: 329.1733, found: 329.1747.

5-(4,4-Dimethyl-2-oxotetrahydrofuran-3-yl)-4-(4-methoxyphenyl)furan-2(5*H*)-one (3fa).



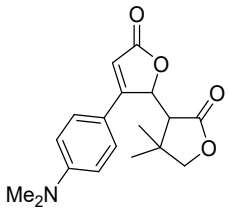
According to the *general procedure*, the title compound **3fa** was obtained from Meldrum's acid derivative **1f** and furandione **2a** after column chromatography (petroleum ether/EtOAc: 7/3) as a mixture of diastereomers. White solid; isolated yield: 77% (117mg); d.r. = 90/10. **m.p.**: 181.6–182.6 °C. **^{1}H NMR** (360 MHz, $CDCl_3$) δ (ppm): 7.40 (d, *J* = 8.8 Hz, 2H), 7.0 (d, *J* = 8.8 Hz, 2H), 6.26 (d, *J* = 1.6 Hz, 1H), 5.60 (t, *J* = 1.6 Hz, 1H), 4.17 (d, *J* = 8.5 Hz, 1H), 3.90 (d, *J* = 8.5 Hz, 1H), 3.87 (s, 3H), 2.64 (d, *J* = 1.5 Hz, 1H), 1.40 (s, 3H), 1.29 (s, 3H). **^{13}C NMR** (91 MHz, $CDCl_3$) δ (ppm): 172.8, 172.2, 165.3, 162.3, 128.9, 122.6, 115.1, 114.2, 78.6, 78.0, 55.7, 52.8, 39.3, 27.8, 21.7. **HR-MS** (ESI, *m/z*): Calculated for $C_{17}H_{19}O_5$ [(M+H)$^+$]: 303.1214, found: 303.1227.

5-(4,4-Dimethyl-2-oxotetrahydrofuran-3-yl)-4-(4-(methylthio)phenyl)furan-2(5*H*)-one (3ga)



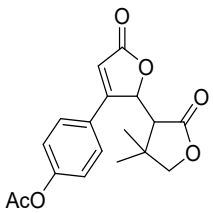
According to the *general procedure*, the title compound **3ga** was obtained from Meldrum's acid derivative **1g** (0.225mmol) and furandione **2a** (0.247mmol) after column chromatography (petroleum ether/DCM/EtOAc: 60/30/10) as a mixture of diastereomers. Yellow solid; isolated yield: 61% (44 mg); d.r. = 77/23. **m.p.**: 176–178 °C. **^{1}H NMR** (360 MHz, $CDCl_3$) δ (ppm): 7.40–7.30 (m, 4H), 6.31 (d, *J* = 1.7 Hz, 1H), 5.61 (t, *J* = 1.7 Hz, 1H), 4.16 (d, *J* = 8.6 Hz, 1H), 3.90 (d, *J* = 8.6 Hz, 1H), 2.60 (d, *J* = 1.6 Hz, 1H), 2.53 (s, 3H), 1.41 (s, 3H), 1.28 (s, 3H). **^{13}C NMR** (91 MHz, $CDCl_3$) δ (ppm): 172.7, 171.8, 165.2, 144.0, 127.5, 126.4, 126.5, 115.4, 78.7, 78.0, 52.7, 39.3, 27.8, 21.7, 15.2. **HR-MS** (ESI, *m/z*): Calculated for $C_{17}H_{19}O_4S$ [$(M+H)^+$]: 319.0999, found 319.0984.

5-(4,4-Dimethyl-2-oxotetrahydrofuran-3-yl)-4-(4-(dimethylamino)phenyl)furan-2(5*H*)-one (3ha)



According to the *general procedure*, the title compound **3ha** was obtained from Meldrum's acid derivative **1h** (0.25mmol) and furandione **2a** (0.275mmol) after column chromatography (petroleum ether/DCM/EtOAc: 60/35/5, then 60/30/10) as a mixture of diastereomers. Beige solid; isolated yield: 42% (33 mg); d.r. > 95/5. **m.p.**: 235–236 °C. **^{1}H NMR** (360 MHz, $CDCl_3$) δ (ppm): 7.31 (d, *J* = 9.0 Hz, 2H), 6.72 (d, *J* = 9.0 Hz, 2H), 6.16 (d, *J* = 1.5 Hz, 1H), 5.57 (t, *J* = 1.5 Hz, 1H), 4.16 (d, *J* = 8.5 Hz, 1H), 3.88 (d, *J* = 8.5 Hz, 1H), 3.05 (s, 6H), 2.70 (d, *J* = 1.5 Hz, 1H), 1.40 (s, 3H), 1.29 (s, 3H). **^{13}C NMR** (91 MHz, $CDCl_3$) δ (ppm): 172.9, 172.8, 165.6, 152.4, 128.7, 117.2, 112.1, 111.0, 78.5, 77.6, 53.1, 40.2, 39.3, 27.7, 21.7. **HR-MS** (ESI, *m/z*): Calculated for $C_{18}H_{22}NO_4$ [$(M+H)^+$]: 316.1543, found 316.1542.

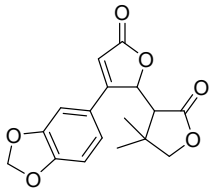
4-(2-(4,4-Dimethyl-2-oxotetrahydrofuran-3-yl)-5-oxo-2,5-dihydrofuran-3-yl)phenyl acetate (3ia).



According to the *general procedure*, the title compound **3ia** was obtained from Meldrum's acid derivative **1i** (0.25mmol) and furandione **2a** (0.275mmol) after column chromatography (petroleum ether/DCM/EtOAc: 60/20/20) as a mixture of diastereomers. Pale yellow solid; isolated yield: 58% (48 mg); d.r. = 77/23. **m.p.**: 182–184 °C. Recrystallization in EtOAc give a single stereoisomer as white solid. **^{1}H NMR** (400 MHz, $CDCl_3$) δ (ppm): 7.44-7.50 (m, 2H), 7.22-7.28 (m, 2H), 6.34 (d, *J* = 1.7 Hz, 1H), 5.61 (t, *J* = 1.7 Hz, 1H), 4.17 (d, *J* = 8.6 Hz, 1H), 3.92 (d, *J* = 8.6 Hz, 1H), 2.60 (d, *J* = 1.7 Hz, 1H), 2.34 (s, 3H),

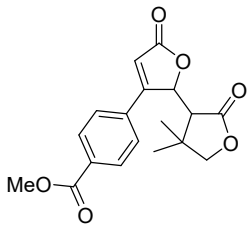
1.41 (s, 3H), 1.28 (s, 3H). **^{13}C NMR** (91 MHz, $CDCl_3$) δ (ppm): 172.8, 171.7, 169.3, 165.0, 153.2, 128.7, 128.1, 123.2, 117.0, 78.7, 78.1, 52.7, 39.4, 28.0, 21.9, 21.5. **HR-MS** (ESI, *m/z*): Calculated for $C_{18}H_{19}O_6$ [$(M+H)^+$]: 331.1176, found 331.1176.

4-(Benzo[*d*][1,3]dioxol-5-yl)-5-(4,4-dimethyl-2-oxotetrahydrofuran-3-yl)furan-2(5*H*)-one (3ja).



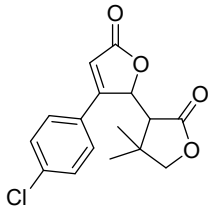
According to the *general procedure*, the title compound **3ja** was obtained from Meldrum's acid derivative **1j** and furandione **2a** after column chromatography (petroleum ether/DCM/EtOAc: 60/35/5) as a mixture of diastereomers. Pale yellow solid; isolated yield: 81% (128mg); d.r. = 83/17. **m.p.**: 158–160 °C. **^{1}H NMR** (400 MHz, $CDCl_3$) δ (ppm): 6.94 (t, *J* = 1.2 Hz, 1H), 6.90–6.93 (m, 2H), 6.24 (d, *J* = 1.4 Hz, 1H), 6.06 (s, 2H), 5.55 (t, *J* = 1.4 Hz, 1H), 4.17 (d, *J* = 8.6 Hz, 1H), 3.91 (d, *J* = 8.6 Hz, 1H), 2.63 (d, *J* = 1.4 Hz, 1H), 1.40 (s, 3H), 1.28 (s, 3H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ (ppm): 172.9, 172.0, 165.3, 150.6, 148.9, 124.1, 121.7, 114.8, 109.2, 107.4, 102.1, 78.7, 78.0, 52.7, 39.2, 27.6, 21.5. **HR-MS** (ESI, *m/z*): Calculated for $C_{17}H_{17}O_6$ [$(M+H)^+$]: 317.1018, found: 317.1020.

Methyl 4-(2-(4,4-dimethyl-2-oxotetrahydrofuran-3-yl)-5-oxo-2,5-dihydrofuran-3-yl)benzoate (3ka).



According to the *general procedure*, the title compound **3ka** was obtained from Meldrum's acid derivative **1k** and furandione **2a** after column chromatography (petroleum ether/EtOAc: 7/3) as a mixture of diastereomers. White solid; isolated yield: 78% (129mg); d.r. = 92/8. **m.p.**: 200–203 °C. Recrystallization in EtOAc give a single stereoisomer as white crystals. **^{1}H NMR** (300 MHz, $CDCl_3$) δ (ppm): 8.16 (d, *J* = 8.4 Hz, 2H), 7.52(d, *J* = 8.8 Hz, 2H), 6.43 (d, *J* = 1.7 Hz, 1H), 5.66 (t, *J* = 1.7 Hz, 1H), 4.16 (d, *J* = 10 Hz, 1H), 3.96 (s, 3H), 3.91 (d, *J* = 10 Hz, 1H), 2.54 (d, *J* = 1.7 Hz, 1H), 1.41 (s, 3H), 1.27 (s, 3H). **^{13}C NMR** (75 MHz, $CDCl_3$) δ (ppm): 172.7, 171.2, 166.2, 164.7, 134.4, 132.7, 130.8, 127.3, 118.3, 78.8, 78.2, 52.7, 52.5, 39.2, 27.8, 21.6. **HR-MS** (ESI, *m/z*): Calculated for $C_{18}H_{19}O_6$ [$(M+H)^+$]: 331.1176, found: 331.1176.

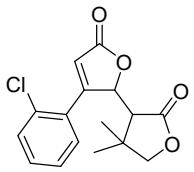
4-(4-Chlorophenyl)-5-(4,4-dimethyl-2-oxotetrahydrofuran-3-yl)furan-2(5*H*)-one (3la).



According to the *general procedure*, the title compound **3la** was obtained from Meldrum's acid derivative **3l** and furandione **2a** after column chromatography (petroleum ether/DCM/EtOAc: 60/35/5) as a mixture of diastereomers. Off-white solid; isolated yield: 49% (76mg); d.r. = 83/17. **m.p.**: 202.7–

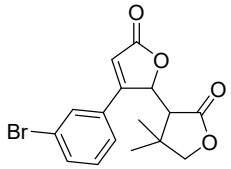
204.1 °C. **^{1}H NMR** (250 MHz, $CDCl_3$) δ (ppm): 7.53–7.43 (m, 2H), 7.43–7.33 (m, 2H), 6.35 (d, *J* = 1.7 Hz, 1H), 5.60 (t, *J* = 1.7 Hz, 1H), 4.18 (d, *J* = 8.6 Hz, 1H), 3.91 (d, *J* = 8.6 Hz, 1H), 2.54 (d, *J* = 1.7 Hz, 1H), 1.41 (s, 3H), 1.27 (s, 3H). **^{13}C NMR** (91 MHz, $CDCl_3$) δ (ppm): 172.8, 171.4, 164.7, 137.8, 130.0, 128.7, 128.5, 117.0, 78.8, 78.1, 52.5, 39.2, 27.8, 21.6. **HR-MS** (ESI, *m/z*): Calculated for $C_{16}H_{16}ClO_4$ [(M+H)$^+$]: 307.0732, found: 307.0723.

4-(2-Chlorophenyl)-5-(4,4-dimethyl-2-oxotetrahydrofuran-3-yl)furan-2(5*H*)-one (3ma).



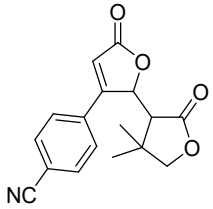
According to the *general procedure*, the title compound **3ma** was obtained from Meldrum's acid derivative **1m** and furandione **2a** after column chromatography (petroleum ether/DCM/EtOAc: 60/35/5) as a mixture of diastereomers. Off-white solid; isolated yield: 27% (42 mg); d.r. > 95/5. **m.p.**: 161–162 °C. **^{1}H NMR** (300 MHz, $CDCl_3$) δ (ppm): 7.64–7.54 (m, 1H), 7.53–7.38 (m, 3H), 6.31 (d, *J* = 1.8 Hz, 1H), 6.05 (t, *J* = 1.8 Hz, 1H), 4.16 (d, *J* = 8.6 Hz, 1H), 3.90 (d, *J* = 8.6 Hz, 1H), 2.38 (d, *J* = 1.8 Hz, 1H), 1.37 (s, 3H), 1.22 (s, 3H). **^{13}C NMR** (91 MHz, $CDCl_3$) δ (ppm): 173.1, 171.2, 165.6, 132.1, 132.0, 131.8, 130.7, 130.1, 128.0, 120.9, 79.4, 78.8, 52.0, 39.1, 27.8, 21.6. **HR-MS** (ESI, *m/z*): Calculated for $C_{16}H_{16}ClO_4$ [(M+H)$^+$]: 307.0732, found 307.0728.

4-(3-Bromophenyl)-5-(4,4-dimethyl-2-oxotetrahydrofuran-3-yl)furan-2(5*H*)-one (3na).



According to the *general procedure*, the title compound **3na** was obtained from Meldrum's acid derivative **1n** and furandione **2a** after column chromatography (petroleum ether/EtOAc: 7/3) as a mixture of diastereomers. White solid; isolated yield: 53% (93mg); d.r. = 90/10. **m.p.**: 181–184.5 °C. Recristallization in hex/AcOEt give pure stereoisomer as white cristals. **^{1}H NMR** (300 MHz, $CDCl_3$) δ (ppm): 7.72-7.52 (m, 2H), 7.46–7.30 (m, 2H), 6.36 (d, *J* = 1.5 Hz, 1H), 5.61 (t, *J* = 1.5 Hz, 1H), 4.15 (d, *J* = 8.7 Hz, 1H), 3.92 (d, *J* = 8.7 Hz, 1H), 2.57 (d, *J* = 1.5 Hz, 1H), 1.40 (s, 3H), 1.29 (s, 3H). **^{13}C NMR** (75.5 MHz, $CDCl_3$) δ (ppm): 172.7, 171.2, 164.3, 134.4, 132.3, 131.2, 130.2, 125.7, 123.7, 117.7, 78.7, 78.0, 52.4, 39.2, 27.7, 21.6. **HR-MS** (ESI, *m/z*): Calculated for for $C_{16}H_{16}\mu BrO_4$ [(M+H)$^+$]: 351.0226, found 351.0223.

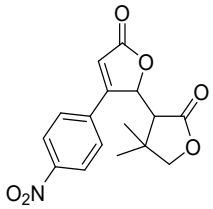
4-(2-(4,4-Dimethyl-2-oxotetrahydrofuran-3-yl)-5-oxo-2,5-dihydrofuran-3-yl)benzonitrile (3oa).



According to the *general procedure*, the title compound **3oa** was obtained from Meldrum's acid derivative **1o** and furandione **2a** after column chromatography (petroleum ether/EtOAc: 7/3) as a mixture of diastereomers. Pale yellow solid; isolated yield: 63% (94mg); d.r. = 93/7. **m.p.**: 200–202 °C.

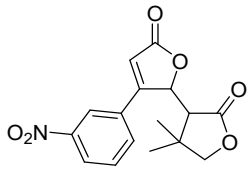
Recrystallization in hexane/EtOAc give a single stereoisomer as colorless crystals.**^{1}H NMR** (400 MHz, $CDCl_3$) δ (ppm): 7.81 (d, *J* = 8.4 Hz, 2H)–7.57 (d, *J* = 8.4 Hz, 2H), 6.44 (d, *J* = 1.8 Hz, 1H), 5.65 (t, *J* = 1.8 Hz, 1H), 4.19 (d, *J* = 8.6 Hz, 1H), 3.94 (d, *J* = 8.6 Hz, 1H), 2.48 (d, *J* = 1.8 Hz, 1H), 1.42 (s, 3H), 1.27 (s, 3H). **^{13}C NMR** (75 MHz, CD_2Cl_2) δ (ppm): 172.7, 170.6, 163.9, 134.6, 133.4, 128.0, 119.4, 118.0, 115.1, 79.0, 78.3, 52.6, 39.2, 28.1, 21.5. **HR-MS** (ESI, *m*/*z*): Calculated for $C_{17}H_{16}NO_4$ [(M+H)$^+$]: 298.1066, found: 298.1074.

5-(4,4-Dimethyl-2-oxotetrahydrofuran-3-yl)-4-(4-nitrophenyl)furan-2(5*H*)-one (3pa).



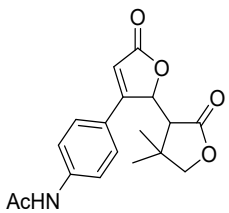
According to the *general procedure*, the title compound **3pa** was obtained from Meldrum's acid derivative **1p** and furandione **2a** after column chromatography (petroleum ether/DCM/EtOAc: 6/3/1) as a mixture of diastereomers. Off-white solid; isolated yield: 48% (77mg); d.r. = 94/6. **m.p.**: 223–224 °C. **^{1}H NMR** (360 MHz, $CDCl_3$) δ (ppm): 8.32–8.40 (m, 2H), 7.60–7.67 (m, 2H), 6.48 (d, *J* = 1.8 Hz, 1H), 5.67 (t, *J* = 1.8 Hz, 1H), 4.20 (d, *J* = 8.6 Hz, 1H), 3.94 (d, *J* = 8.6 Hz, 1H), 2.47 (d, *J* = 1.8 Hz, 1H), 1.43 (s, 3H), 1.28 (s, 3H). **^{13}C NMR** (91 MHz, $CDCl_3$) δ (ppm): 172.8, 170.5, 163.6, 149.3, 136.3, 128.4, 124.9, 119.8, 79.0, 78.5, 52.5, 39.2, 28.1, 21.4. **HR-MS** (ESI, *m*/*z*): Calculated for $C_{16}H_{16}NO_6$ [(M+H)$^+$]: 318.0972, found: 318.0967.

5-(4,4-Dimethyl-2-oxotetrahydrofuran-3-yl)-4-(3-nitrophenyl)furan-2(5*H*)-one (3qa).



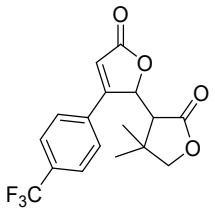
According to the *general procedure*, the title compound **3qa** was obtained from Meldrum's acid derivative **1q** (0.25mmol) and furandione **2a** (0.275mmol) after column chromatography (petroleum ether/DCM/EtOAc: 6/3/1) as a mixture of diastereomers. Pale yellow solid; isolated yield: 49% (39 mg); d.r. > 95/5. **m.p.**: 210.6–214.9 °C. **^{1}H NMR** (360 MHz, $CDCl_3$) δ (ppm): 8.37 (dd, *J* = 8.0, 1.6 Hz, 1H), 8.25 (t, *J* = 1.6 Hz, 1H), 7.86 (d, *J* = 8.0 Hz, 1H), 7.74 (dd, *J* = 8.0 and 8.0 Hz, 1H), 6.50 (d, *J* = 1.6 Hz, 1H), 5.69 (t, *J* = 1.6 Hz, 1H), 4.21 (d, *J* = 8.6 Hz, 1H), 3.92 (d, *J* = 8.6 Hz, 1H), 2.52 (d, *J* = 1.6 Hz, 1H), 1.44 (s, 3H), 1.30 (s, 3H). **^{13}C NMR** (101 MHz, DMSO-d_6) δ (ppm): 173.1, 171.9, 163.7, 148.3, 134.1, 131.2, 130.9, 125.5, 122.2, 117.8, 77.5, 76.7, 50.2, 39.5, 24.4, 21.9. **HR-MS** (ESI, *m/z*): Calculated for $C_{16}H_{16}NO_6$ [(M+H)$^+$]: 318.0972, found 318.0963.

***N*-(4-(2-(4,4-Dimethyl-2-oxotetrahydrofuran-3-yl)-5-oxo-2,5-dihydrofuran-3-yl)phenyl)acetamide (3ra).**



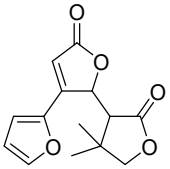
According to the *general procedure* (DMF used instead of toluene), the title compound **3ra** was obtained from Meldrum's acid derivative **1r** (0.25mmol) and furandione **2a** (0.275mmol) after column chromatography (petroleum ether/EtOAc: 1/1, then 4/6) as a mixture of diastereomers. Off-white solid; isolated yield: 67% (55 mg); d.r. = 71/29. **m.p.**: 234–236 °C. **^{1}H NMR** (400 MHz, DMSO-d_6) δ (ppm): 10.35 (s, 1H), 7.78–7.66 (m, 2H), 7.62–7.55 (m, 2H), 6.61 (d, *J* = 1.5 Hz, 1H), 6.03 (t, *J* = 1.5 Hz, 1H), 3.98–3.90 (m, 2H), 2.90 (d, *J* = 1.5 Hz, 1H), 2.08 (s, 3H), 1.28 (s, 3H), 1.24 (s, 3H). **^{13}C NMR** (101 MHz, DMSO-d_6) δ (ppm): 173.1, 172.4, 168.8, 165.4, 142.0, 128.5, 124.1, 119.0, 113.4, 77.4, 76.6, 51.0, 39.4, 24.8, 24.2, 21.8. **HR-MS** (ESI, *m/z*): Calculated for $C_{18}H_{20}NO_5$ [(M+H)$^+$]: 330.1336, found 330.1333.

5-(4,4-Dimethyl-2-oxotetrahydrofuran-3-yl)-4-(4-(trifluoromethyl)phenyl)furan-2(5*H*)-one (3sa).



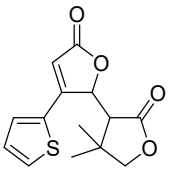
According to the *general procedure* (reaction temperature changed to 60 °C in this case), the title compound **3sa** was obtained from Meldrum's acid derivative **1s** and furandione **2a** after column chromatography (petroleum ether/DCM/EtOAc: 60/35/5) as a mixture of diastereomers. White solid; isolated yield: 51% (87mg); d.r. = 87/13. **m.p.**: 169–174 °C. **^{1}H NMR** (400 MHz, $CDCl_3$) δ (ppm): 7.80–7.75 (m, 2H), 7.62–7.56 (m, 2H), 6.43 (d, *J* = 1.6 Hz, 1H), 5.68 (t, *J* = 1.6 Hz, 1H), 4.17 (d, *J* = 8.6 Hz, 1H), 3.92 (d, *J* = 8.6 Hz, 1H), 2.53 (d, *J* = 1.6 Hz, 1H), 1.41 (s, 3H), 1.28 (s, 3H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ (ppm): 172.8, 171.1, 164.5, 133.7, 133.0 (q, *J* = 32 Hz), 127.7, 126.6, 123.6(q, *J* = 273 Hz),118.5, 78.8, 78.3, 52.4, 51.3, 39.2, 27.8, 21.5. **HR-MS** (ESI, *m/z*): Calculated for $C_{17}H_{16}F_3O_4$ [(M+H)$^+$]: 341.0999, found: 341.0995.

2'-(4,4-Dimethyl-2-oxotetrahydrofuran-3-yl)-[2,3'-bifuran]-5'(2'*H*)-one (3ta).



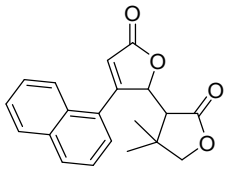
According to the *general procedure*, the title compound **3ta** was obtained from Meldrum's acid derivative **1t** (0.25mmol) and furandione **2a** (0.275mmol) after column chromatography (petroleum ether/DCM/EtOAc: 60/35/5) as a mixture of diastereomers. Orange solid; isolated yield: 53% (35mg); d.r. = 77/23. **m.p.**: 150.8–152.0 °C. **^{1}H NMR** (360 MHz, $CDCl_3$) δ (ppm): 7.61 (d, *J* = 1.8 Hz, 1H), 6.87 (d, *J* = 3.6 Hz, 1H), 6.60 (dd, *J* = 3.6, 1.8 Hz, 1H), 6.27 (d, *J* = 1.8 Hz, 1H), 5.49 (t, *J* = 1.8 Hz, 1H), 4.18 (d, *J* = 8.5 Hz, 1H), 3.94 (d, *J* = 8.5 Hz, 1H), 2.92 (d, *J* = 1.8 Hz, 1H), 1.38 (s, 3H), 1.32 (s, 3H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ (ppm): 173.1, 171.8, 153.6, 146.0, 145.9, 114.6, 113.0, 112.4, 78.8, 77.2, 53.3, 39.3, 27.9, 21.5. **HR-MS** (ESI, *m/z*): Calculated for $C_{14}H_{15}O_5$ [(M+H)$^+$]: 263.0914, found: 263.0914.

5-(4,4-Dimethyl-2-oxotetrahydrofuran-3-yl)-4-(thiophen-2-yl)furan-2(5*H*)-one (3ua).



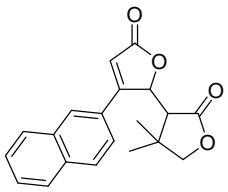
According to the *general procedure*, the title compound **3ua** was obtained from Meldrum's acid derivative **1u** (0.25mmol) and furandione **2a** (0.275mmol) after column chromatography (petroleum ether/DCM/EtOAc: 60/30/10) as a mixture of diastereomers. Off-white solid; isolated yield: 53% (37 mg); d.r. = 78/22. **m.p.**: 156–158 °C. **^{1}H NMR** (40 MHz, $CDCl_3$) δ (ppm): 7.60 (dd, *J* = 5.0, 1.1 Hz, 1H), 7.28 (dd, *J* = 3.8, 1.1 Hz, 1H), 7.18 (dd, *J* = 5.0, 3.8 Hz, 1H), 6.27 (d, *J* = 1.5 Hz, 1H), 5.49 (t, *J* = 1.5 Hz, 1H), 4.17 (d, *J* = 8.6 Hz, 1H), 3.94 (d, *J* = 8.6 Hz, 1H), 2.85 (d, *J* = 1.5 Hz, 1H), 1.40 (s, 3H), 1.33 (s, 3H). **^{13}C NMR** (63 MHz, $CDCl_3$) δ (ppm): 172.7, 171.6, 158.6, 158.3, 132.7, 130.6, 128.8, 114.3, 78.7, 77.9, 53.2, 39.4, 27.6, 21.7. **HR-MS** (ESI, *m/z*): Calculated for $C_{14}H_{15}O_4S$ [$(M+H)^+$]: 279.0686, found 279.0679.

5-(4,4-Dimethyl-2-oxotetrahydrofuran-3-yl)-4-(naphthalen-1-yl)furan-2(5*H*)-one (3va).



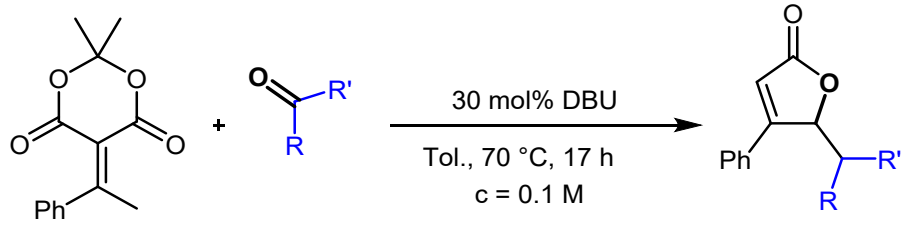
According to the *general procedure*, the title compound **3va** was obtained from Meldrum's acid derivative **1v** and furandione **2a** after column chromatography (petroleum ether/DCM/EtOAc: 60/35/5) as a mixture of diastereomers. White solid; isolated yield: 68% (110mg); d.r. = 93/7. **m.p.**: 90–94 °C. **^{1}H NMR** (400 MHz, $CDCl_3$) δ (ppm): 8.23–8.19 (m, 1H), 7.97–7.90 (m, 2H), 7.62–7.53 (m, 3H), 7.47–7.45 (m, 1H), 6.43 (d, *J* = 1.8 Hz, 1H), 5.74 (t, *J* = 1.8 Hz, 1H), 4.13 (d, *J* = 8.6 Hz, 1H), 3.83 (d, *J* = 8.6 Hz, 1H), 2.42 (d, *J* = 1.8 Hz, 1H), 1.37 (s, 3H), 1.13 (s, 3H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ (ppm): 173.1, 171.9, 165.3, 134.1, 131.1, 130.8, 128.8, 128.5, 127.8, 127.0, 125.5, 125.2, 125.1, 120.9, 79.7, 78.6, 51.9, 39.1, 27.0, 21.8. **HR-MS** (ESI, *m/z*): Calculated for $C_{20}H_{19}O_4$ [$(M+H)^+$]: 323.1274, found: 323.1278.

5-(4,4-Dimethyl-2-oxotetrahydrofuran-3-yl)-4-(naphthalen-2-yl)furan-2(5*H*)-one (3wa).



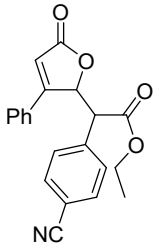
According to the *general procedure*, the title compound **3wa** was obtained from Meldrum's acid derivative **1w** and furandione **2a** after column chromatography (petroleum ether/DCM/EtOAc: 60/35/5) as a mixture of diastereomers. Pale yellow solid; isolated yield: 75% (121mg); d.r. = 82/18. **m.p.**: 215.8–221.2 °C. Recrystallization in AcOEt give one stereoisomer as white cristals. **^{1}H NMR** (300 MHz, CD_2Cl_2) δ (ppm): 8.05–7.9 (m, 4H), 7.50–7.70 (m, 3H), 6.48 (d, *J* = 1.7 Hz, 1H), 5.77 (t, *J* = 1.7 Hz, 1H), 4.12 (d, *J* = 8.5 Hz, 1H), 3.87 (d, *J* = 8.5 Hz, 1H), 2.72 (d, *J* = 1.7 Hz, 1H), 1.42 (s, 3H), 1.31 (s, 3H). **^{13}C NMR** (75 MHz, CD_2Cl_2) δ (ppm): 172.4, 171.4, 166.2, 134.2, 132.8, 129.2, 128.5, 127.8, 127.7, 127.2, 127.1, 126.8, 123.8, 116.1, 78.2, 77.4, 52.0, 39.0, 26.6, 21.2. **HR-MS** (ESI, *m/z*): Calculated for $C_{20}H_{19}O_4$ [$(M+H)^+$]: 323.1278, found: 323.1277.

DBU-catalyzed synthesis of bislactones 3ab-3ah.



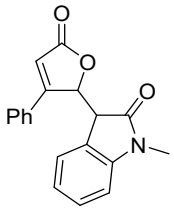
General procedure: To a stirred solution of Ph-arylidene Meldrum's acid derivative (0.5 mmol, 123mg) and electrophile (0.525 mmol) in 5mL of dry toluene (0.1M) was added 30 mol% of DBU (0.15mmol, 22.5µl). The reaction mixture was stirred at 70 °C for 17 h, then concentrated *in vacuo* and the crude product was purified by column chromatography on silica gel (mix of petroleum ether, DCM and EtOAc as eluent) to afford the desired bislactone **3ab-3ah**.

Ethyl 2-(4-cyanophenyl)-2-(5-oxo-3-phenyl-2,5-dihydrofuran-2-yl)acetate (3ab)



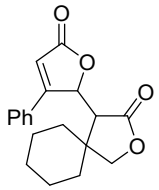
According to the *general procedure*, the title compound **3ab** was obtained from Meldrum's acid derivative **1a** and ethyl 4-cyanobenzoylformate **2b** after column chromatography (petroleum ether/DCM/EtOAc: 60/35/5) as a mixture of diastereomers. Pale yellow oil; isolated yield: 32% (14 mg); d.r. = 70/30. **^{1}H NMR** (250 MHz, $CDCl_3$) δ (ppm): 7.58–7.35 (m, 7H), 6.99 (d, *J* = 8.3 Hz, 2H), 6.34 (dd, *J* = 2.8, 1.5 Hz, 1H), 6.00 (d, *J* = 1.5 Hz, 1H), 4.34–4.22 (m, 2H), 4.10 (d, *J* = 2.8 Hz, 1H), 1.29 (t, *J* = 7.2 Hz, 3H). **^{13}C NMR** (91 MHz, $CDCl_3$) δ (ppm): 171.5, 169.2, 165.1, 136.5, 132.4, 131.9, 131.0, 130.3, 129.8, 127.2, 118.5, 116.5, 112.5, 80.8, 62.5, 53.6, 14.2. **HR-MS** (ESI, *m/z*): Calculated for $C_{21}H_{18}NO_4$ [(M+H)$^+$]: 348.1230, found 348.1233.

1-Methyl-3-(5-oxo-3-phenyl-2,5-dihydrofuran-2-yl)indolin-2-one (3ac).



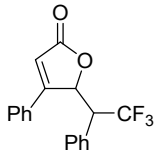
According to the *general procedure*, the title compound **3ac** was obtained from Meldrum's acid derivative **1a** and *N*-methylisatin **2c** after column chromatography (petroleum ether/DCM/EtOAc: 60/35/5, then 6/3/1) as a mixture of diastereomers. Solid; isolated yield: 18% (7 mg); d.r. = 69/31. **m.p.**: °C. **^{1}H NMR** (400 MHz, $CDCl_3$) δ (ppm): 7.74-7.68 (m, 2H), 7.64-7.54. (m, 2H), 7.26 (m, 1H), 6.90 (dd, *J* = 7.5, 1 Hz, 1H), 6.82 (d, *J* = 8 Hz, 1H), 6.70 (d, *J* = 7.5 Hz, 1H), 6.44 (d, *J* = 1.2 Hz, 1H), 6.25 (m, 1H), 3.81 (m, 1H), 3.17 (s, 3H). **^{13}C NMR** (75 MHz, $CDCl_3$) δ (ppm): 174.3, 171.5, 166.0, 145.4, 132.2, 130.0, 129.7, 129.5, 127.4, 124.5, 122.5, 121.5, 116.5, 108.9, 180.6, 48.0, 26.8. **HR-MS** (ESI, *m/z*): Calculated for $C_{19}H_{16}NO_3$ [(M+H)$^+$]: 306.1125, found 306.1125.

4-(5-Oxo-3-phenyl-2,5-dihydrofuran-2-yl)-2-oxaspiro[4.5]decan-3-one (3ad).



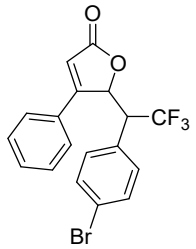
According to the *general procedure*, the title compound **3ad** was obtained from Meldrum's acid derivative **1a** and furandione **2d** after column chromatography (petroleum ether/DCM/EtOAc: 60/35/5) as a mixture of diastereomers. Off-white solid; isolated yield: 59% (46 mg); d.r. > 95/5. **m.p.**: 220–221 °C. **^{1}H NMR** (360 MHz, $CDCl_3$) δ (ppm): 7.52–7.49 (m, 3H), 7.48–7.44 (m, 2H), 6.34 (d, *J* = 1.7 Hz, 1H), 5.70 (t, *J* = 1.7 Hz, 1H), 4.28 (d, *J* = 8.8 Hz, 1H), 4.05 (d, *J* = 8.8 Hz, 1H), 2.67 (d, *J* = 1.7 Hz, 1H), 1.91–1.82 (m, 2H), 1.65–1.48 (m, 8H). **^{13}C NMR** (91 MHz, $CDCl_3$) δ (ppm): 173.0, 171.5, 166.2, 131.5, 130.4, 129.6, 127.2, 116.3, 78.1, 76.2, 52.1, 42.2, 36.6, 30.3, 25.6, 23.3, 22.7. **HR-MS** (ESI, *m/z*): Calculated for $C_{19}H_{21}O_4$ [$(M+H)^+$]: 313.1434, found 313.1433.

4-Phenyl-5-(2,2,2-trifluoro-1-phenylethyl)furan-2(5*H*)-one (3ae).



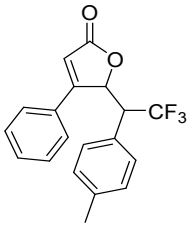
According to the *general procedure*, the title compound **3ae** was obtained from Meldrum's acid derivative **1a** (0.25 mmol) and **2e** after column chromatography (petroleum ether/EtOAc: 95/5, then 9/1) as an off-white solid; isolated yield: 52% (42 mg). **m.p.**: 101–104 °C. Recrystallization in hexane/AcOEt give one stereoisomer as colorless cristals. **^{1}H NMR** (400 MHz, $CDCl_3$) δ (ppm): 7.61-7.51 (m, 3H), 7.38-7.28 (m, 3H), 7.26-7.20 (m, 2H), 7.01-6.94 (m, 2H), 6.07 (br s, 1H), 6.01 (m, 1H), 3.72 (qd, *J* = 9.8 Hz and 1.5Hz, 1H). **^{13}C NMR** (75 MHz, $CDCl_3$) δ (ppm): 171.8, 164.9, 132.0, 130.2 (q, *J* = 1.1 Hz), 129.9, 129.7, 129.4, 128.7, 127.3 (q, *J* = 1.6 Hz), 127.2, 126.0 (q, *J* = 285 Hz), 116.8, 78.0 (q, *J* = 2.5 Hz), 52.3 (q, *J* = 27.6 Hz). **HR-MS** (ESI, *m/z*): Calculated for $C_{18}H_{14}F_3O_2$ [$(M+H)^+$]: 319.0940, found 309.0935.

5-(1-(4-Bromophenyl)-2,2,2-trifluoroethyl)-4-phenylfuran-2(5*H*)-one (3af).



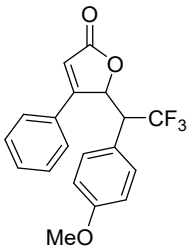
According to the *general procedure*, the title compound **3af** was obtained from Meldrum's acid derivative **x** (0.125 mmol) and **x** after column chromatography (petroleum ether/EtOAc: 95/5, then 92/8) as an off-white solid; isolated yield: 60% (30 mg). **m.p.**: 181–183 °C. Recrystallization in hexane/AcOEt give one stereoisomer as white solid. **^{1}H NMR** (400 MHz, $CDCl_3$) δ (ppm): 7.60–7.50 (m, 3H), 7.40–7.30 (m, 4H), 6.85 (d, *J* = 8.4 Hz, 2H), 6.06 (br s, 2H), 3.70 (q, *J* = 9.7 Hz, 1H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ (ppm): 171.6, 164.6, 132.2, 132.0, 131.8, 130.0, 129.5, 127.0, 126.3, 125.6 (q, *J* = 280.9 Hz), 124.0, 116.9, 77.6, 51.7 (q, *J* = 27.9 Hz). **HR-MS** (ESI, *m/z*): Calculated for $C_{18}H_{13}BrF_3O_2$ [$(M+H)^+$]:

4-Phenyl-5-(2,2,2-trifluoro-1-(*p*-tolyl)ethyl)furan-2(5*H*)-one (3ag).



According to the *general procedure*, the title compound **3ag** was obtained from Meldrum's acid derivative **1a** (0.125 mmol) and **2g** after column chromatography (petroleum ether/EtOAc: 95/5, then 92/8) as an off-white solid; isolated yield: 43% (18 mg). **m.p.**: 128–131 °C. Recrystallization in hexane/AcOEt give one stereoisomer as white solid. **^{1}H NMR** (600 MHz, $CDCl_3$) δ (ppm): 7.60–7.50 (m, 3H), 7.40–7.33 (m, 2H), 7.02 (d, *J* = 7.9 Hz, 2H), 6.85 (d, *J* = 7.9 Hz, 2H), 6.05 (br s, 1H), 6.03 (d, *J* = 1.4 Hz, 1H), 3.67 (q, *J* = 9.6, 1H), 2.28 (s, 3H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ (ppm): 172.0, 164.9, 139.3, 132.0, 130.1, 129.9, 129.8, 129.5, 127.3, 126.0 (q, *J* = 280.8 Hz), 123.2, 116.8, 78.1, 52.0 (q, *J* = 27.5 Hz), 21.3. **HR-MS** (ESI, *m/z*): Calculated for $C_{19}H_{16}F_3O_2$ [$(M+H)^+$]: 333.1096, found 333.1091.

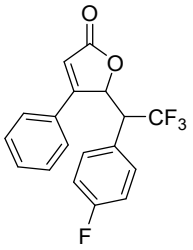
4-Phenyl-5-(2,2,2-trifluoro-1-(4-methoxyphenyl)ethyl)furan-2(5*H*)-one (3ah).



According to the *general procedure*, the title compound **3ah** was obtained from Meldrum's acid derivative **1a** (0.25 mmol) and **2h** after column chromatography (petroleum ether/EtOAc: 95/5, then 9/1) as an off-white solid; isolated yield: 25% (22 mg). **m.p.**: 135–138 °C. Recrystallization in hexane/AcOEt give one stereoisomer as white solid. **^{1}H NMR** (400 MHz, $CDCl_3$) δ (ppm): 7.61–7.50 (m, 3H), 7.40–7.30 (m, 2H), 6.89 (d, *J* = 8.5 Hz, 2H), 6.75 (d, *J* = 8.5 Hz, 2H), 6.04 (br s, 1H), 6.03 (br s, 1H), 3.76 (s, 3H), 3.67 (qd, *J* = 10, 1.1 Hz, 1H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ (ppm): 172.0, 165.0, 160.3, 132.0, 131.4, 129.9, 129.8, 127.2, 126.0 (q, *J* = 280.9 Hz), 119.1, 116.8, 114.1, 78.2, 55.3, 51.6 (q, *J* = 27.6 Hz). **HR-MS** (ESI, *m/z*): Calculated for $C_{18}H_{14}F_3O_3$ [$(M+H)^+$]: 349.1046, found 349.1039.

397.0045, found 397.0039.

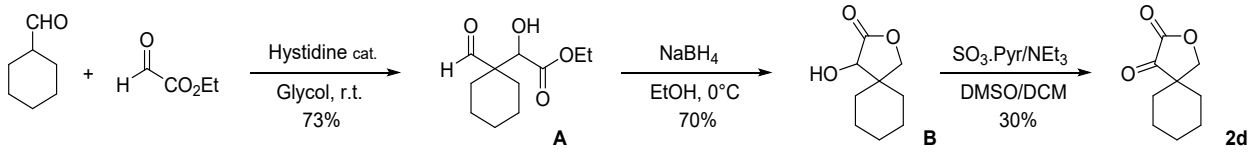
4-Phenyl-5-(2,2,2-trifluoro-1-(4-fluorophenyl)ethyl)furan-2(5*H*)-one (3ai).



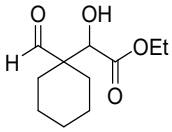
According to the *general procedure*, the title compound **3ai** was obtained from Meldrum's acid derivative **1a** (0.25 mmol) and **2i** after column chromatography (petroleum ether/EtOAc: 95/5, then 9/1) as an off-white solid; isolated yield: 58% (49 mg). **m.p.**: 145–146 °C. **^{1}H NMR** (400 MHz, $CDCl_3$) δ (ppm): 7.62–7.50 (m, 3H), 7.40–7.31 (m, 2H), 6.99–6.88 (m, 4H), 6.05 (m, 2H), 3.72 (qd, *J* = 9.7, 1.2 Hz,

1H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ (ppm): 171.7, 164.8, 163.4 (d, *J* = 249 Hz), 132.1, 132.0 (d, *J* = 8.2 Hz), 130.0, 129.6, 127.2, 125.7 (q, *J* = 281 Hz), 123.1, 116.8, 115.9 (d, *J* = 21.7 Hz), 77.8, 51.6 (q, *J* = 28.1 Hz). **HR-MS** (ESI, *m/z*): Calculated for $C_{18}H_{13}F_4O_2$ [(M+H)$^+$]: 337.0846, found 337.0842.

Synthesis of 2-Oxaspiro[4.5]decane-3,4-dione (2d).



Ethyl 2-(1-formylcyclohexyl)-2-hydroxyacetate (A)

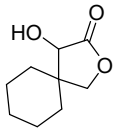


Aldehyde **A** was obtained as described in the literature. Scheffler, U.; Mahrwald, R. *J. Org. Chem.* **2012**, *77*, 2310–2330.

To a stirred solution of cyclohexanecarboxaldehyde (6.50 mL, 53.7 mmol) and ethyl glyoxylate (10.0 mL, 50.4 mmol, 50% in toluene) in glycol (5.0 mL) was added histidine (775 mg, 4.99 mmol) and the reaction mixture was stirred for 40 h at room temperature. Water (15 mL) and ethyl acetate (10 mL) were added and the phases were separated. The aqueous phase was extracted with ethyl acetate (2 × 15 mL) and the combined organic phases were washed with a saturated aqueous solution of sodium chloride (30 mL), dried over magnesium sulfate, filtered and concentrated under vacuum. The crude product was purified by column chromatography on silica gel (petroleum ether/EtOAc, 9/1) to afford the desired aldehyde (7.85 g, 73%) as a colorless oil. The NMR data matched the one described in the literature.

4-Hydroxy-2-oxaspiro[4.5]decan-3-one (B)

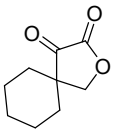
Clark, R. W.; Deaton, T. M.; Zhang, Y.; Moore, M. I.; Wiskur, S. L. *Org. Lett.* **2013**, *15*, 6132–6135. (product). Du, Z.-H.; Tao, B.-X.; Yuan, M.; Qin, W.-J.; Xu, Y.-L.; Wang, P.; Da, C.-S. *Org. Lett.* **2020**, *22*, 4444–4450. (procedure).



$NaBH_4$ (216 mg, 5.71 mmol) was slowly added to the solution of aldehyde **A** (1.03 g, 4.81 mmol) in EtOH (24 mL) at 0 °C. The mixture was stirred at 0 °C for 40 min and was then quenched by addition of a 5% aqueous solution of hydrochloric acid (20 mL). The mixture was extracted with ethyl acetate (3 × 40 mL) and the combined organic phases were washed with brine (20 mL), dried over magnesium sulfate, filtered and concentrated under vacuum. The crude product was purified by column chromatography on silica gel (petroleum ether/EtOAc, 85/15, then 8/2) to afford the desired lactone **B** (574 mg, 70%) as a white solid. The NMR data matched the one described in the literature.

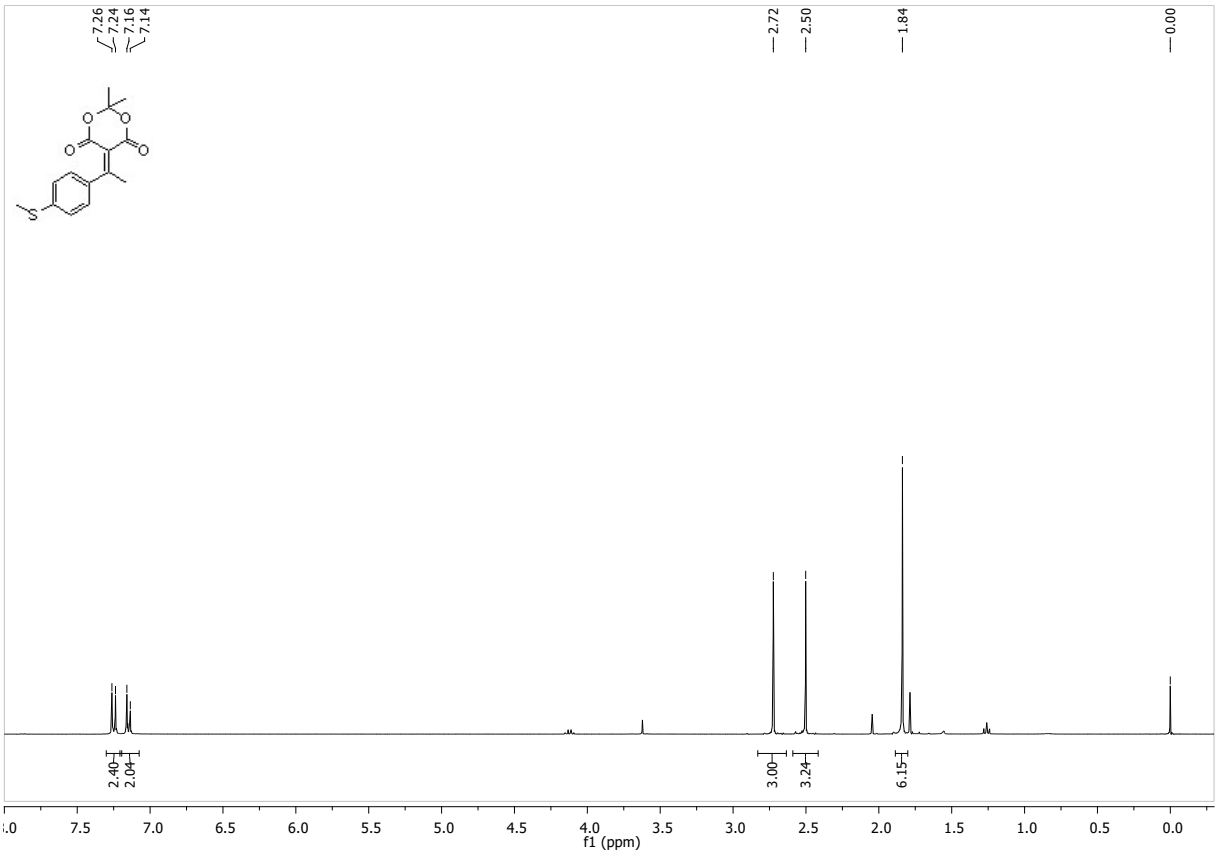
2-Oxaspiro[4.5]decane-3,4-dione (2d).

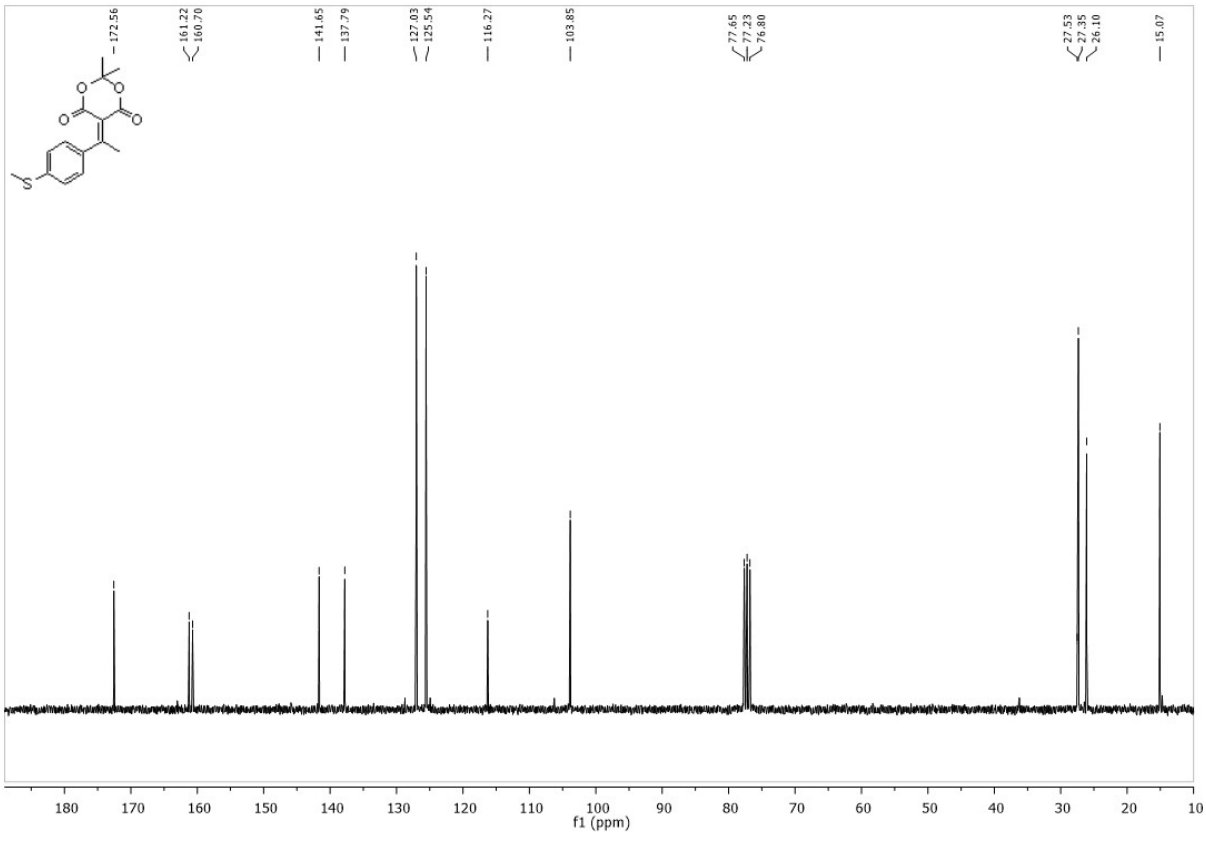
Clark, R. W.; Deaton, T. M.; Zhang, Y.; Moore, M. I.; Wiskur, S. L. *Org. Lett.* **2013**, *15*, 6132–6135.



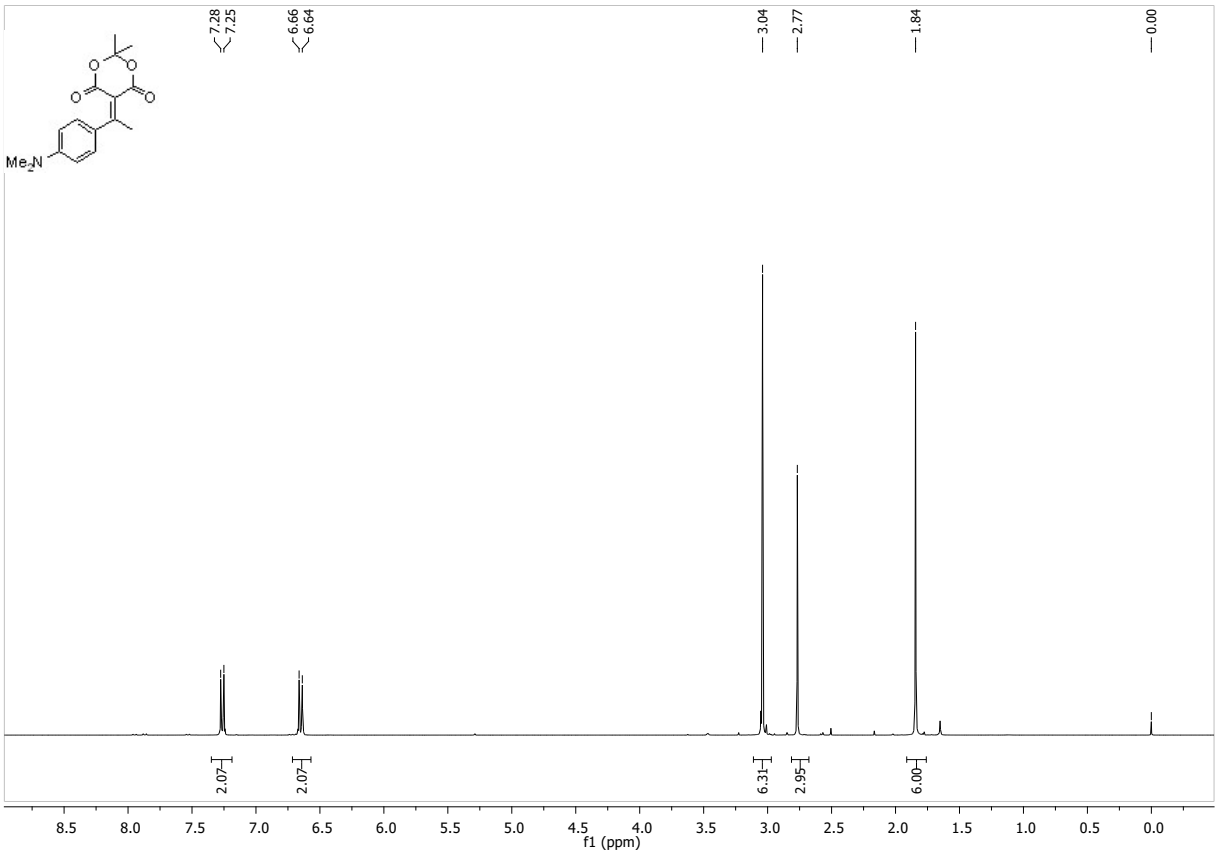
To a stirred solution of alcohol **B** (565 mg, 3.32 mmol) in a mixture of DMSO (7.4 mL) and dichloromethane (8.2 mL) were added triethylamine (4.60 mL, 33.0 mmol) and sulfur trioxide pyridine complex (1.76 g, 11.1 mmol), followed by more sulfur trioxide pyridine complex (1.40 g, 8.80 mmol) 5 min later. The reaction mixture was stirred at room temperature for 2.5 h. Dichloromethane (20 mL) and a saturated aqueous solution of sodium bicarbonate (20 mL) were then added and the phases were separated. The aqueous phase was extracted with dichloromethane (2×20 mL) and the combined organic phases were dried over magnesium sulfate, filtered and concentrated under vacuum. The crude product was purified by column chromatography on silica gel (petroleum ether/EtOAc, 9/1, 8/2, then 7/3) to afford the desired lactone **2d** (170 mg, 30%) as a white solid. The NMR data matched the one described in the literature.

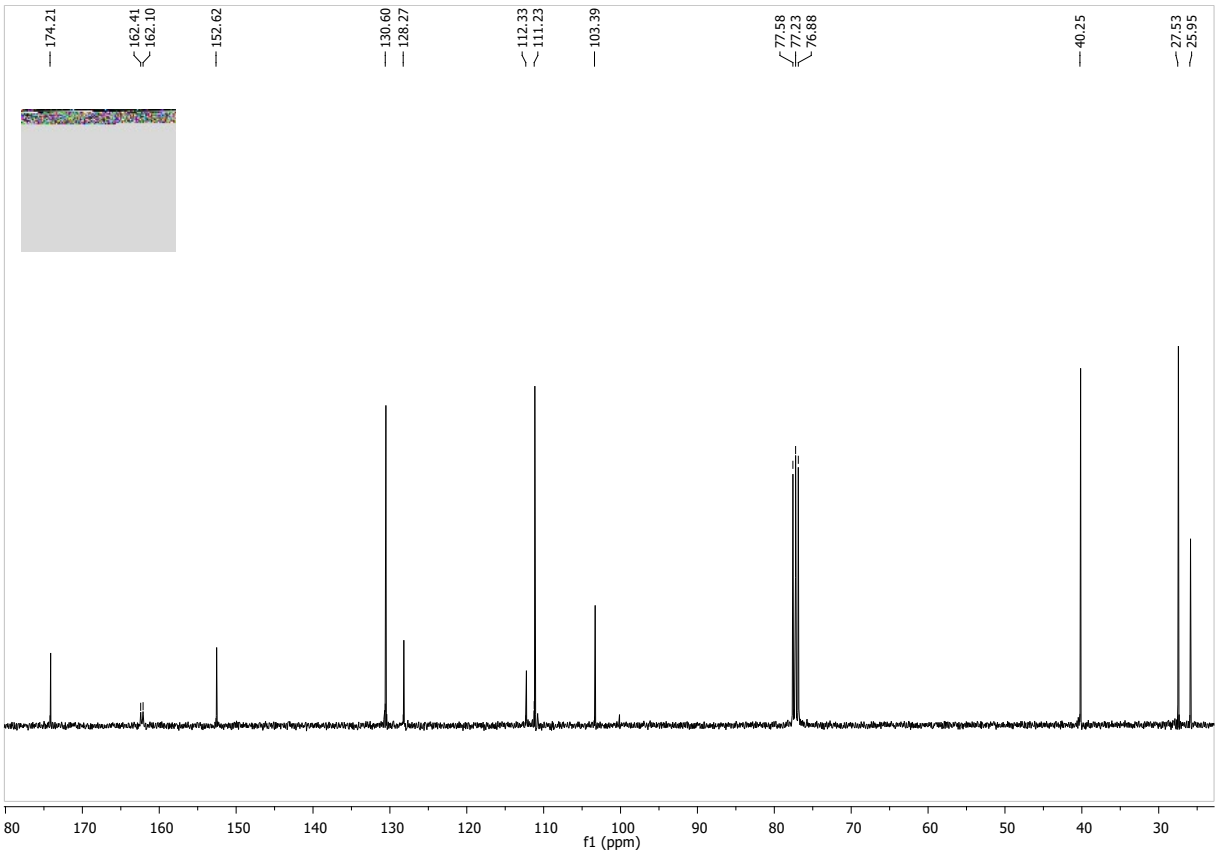
2,2-Dimethyl-5-(1-(4-(methylthio)phenyl)ethylidene)-1,3-dioxane-4,6-dione (1g)



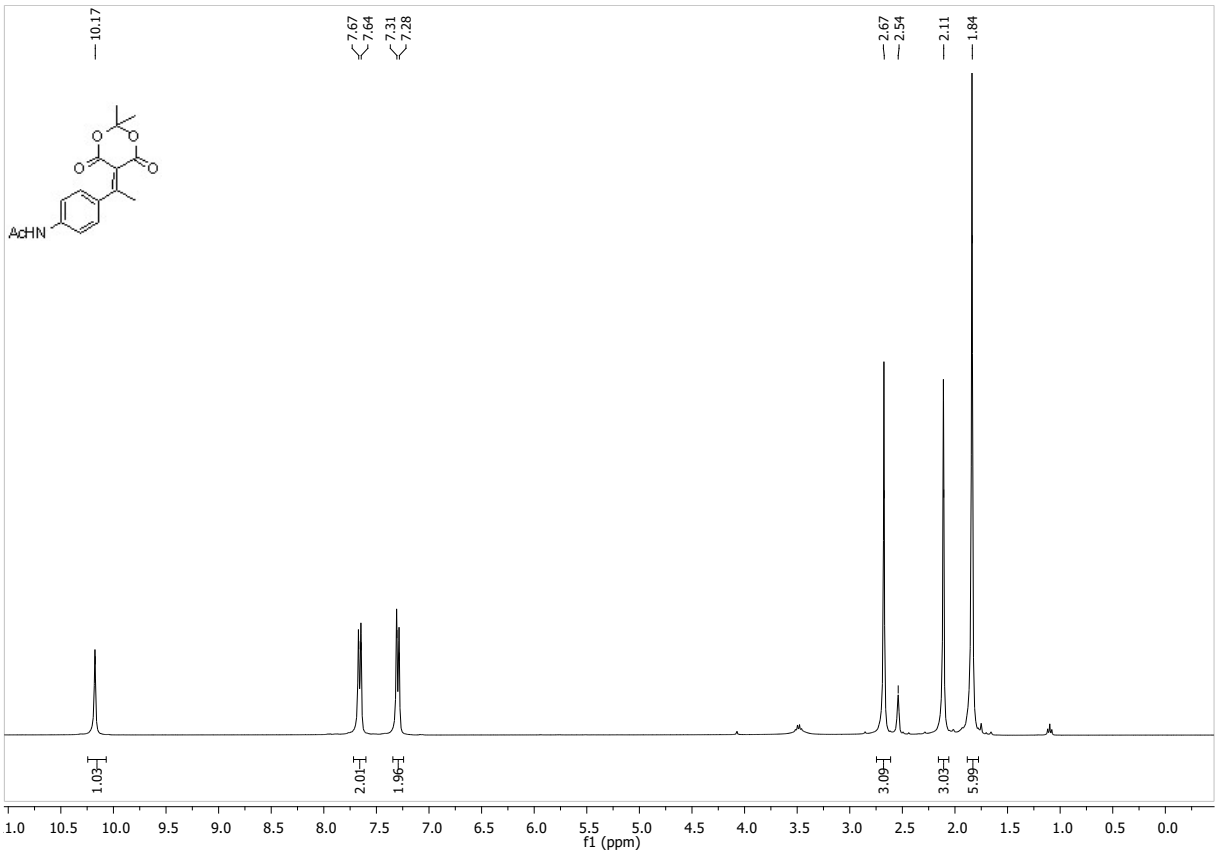


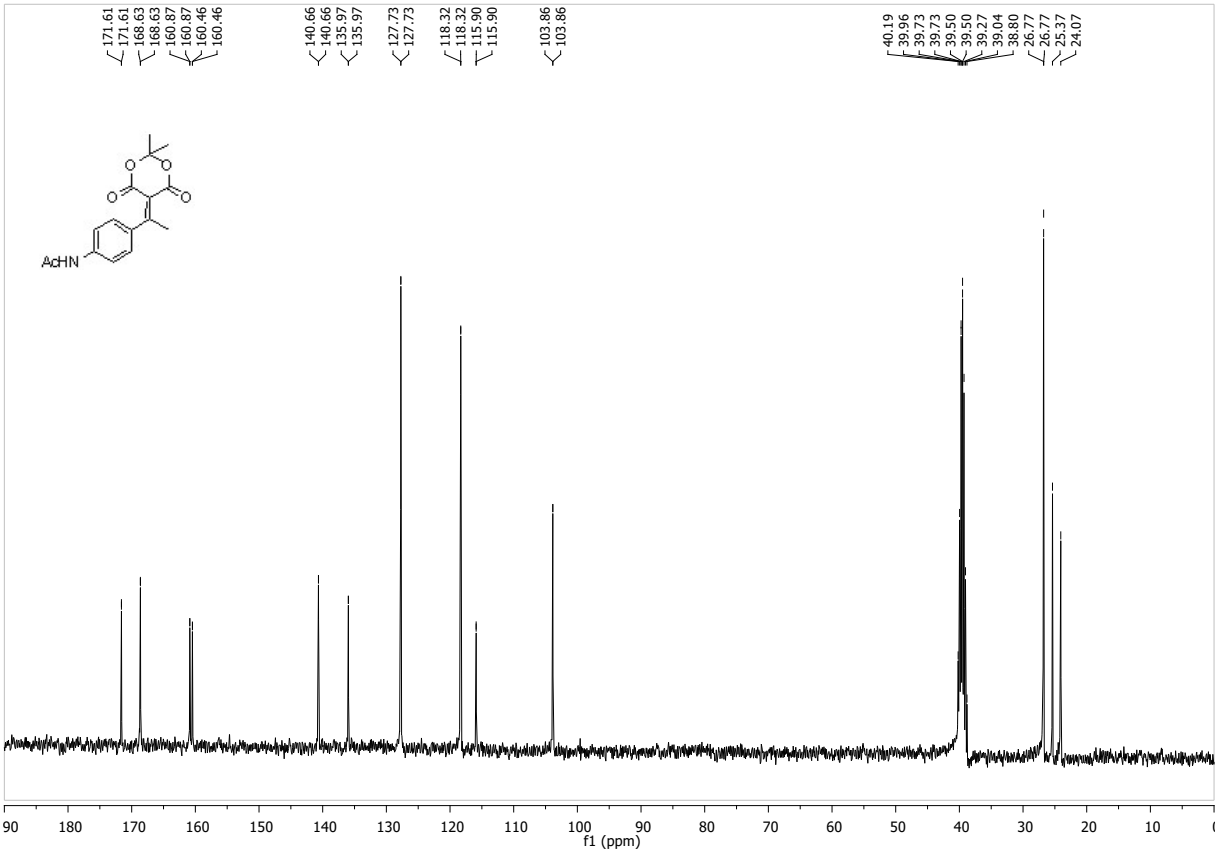
5-(1-(4-(Dimethylamino)phenyl)ethylidene)-2,2-dimethyl-1,3-dioxane-4,6-dione (1h).



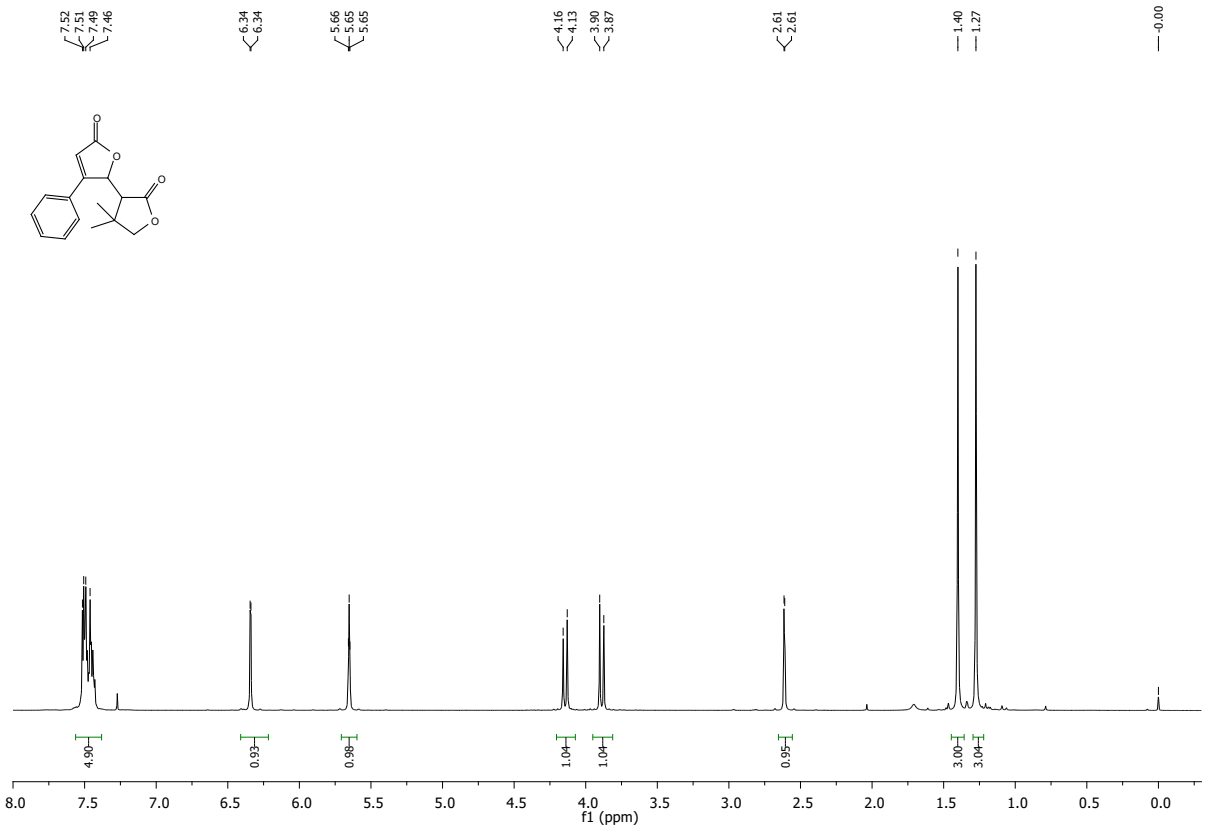


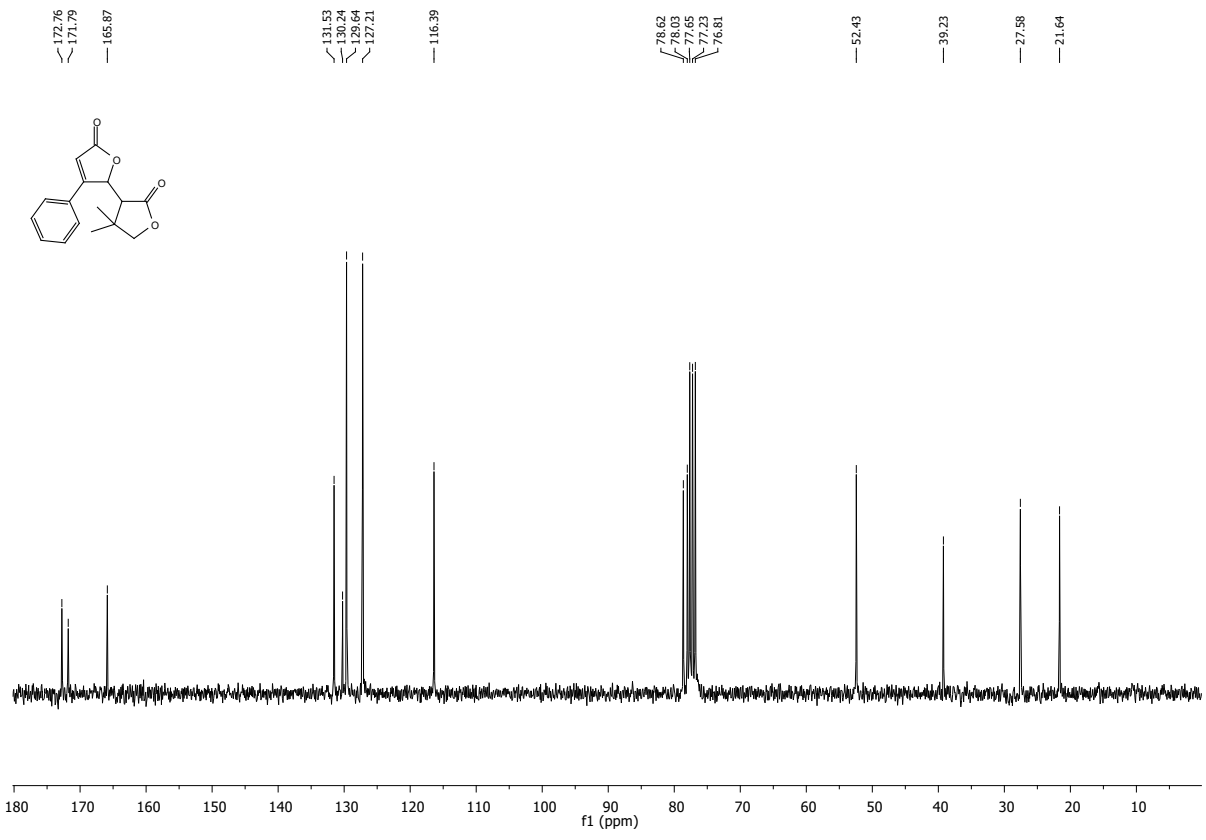
***N*-(4-(1-(2,2-Dimethyl-4,6-dioxo-1,3-dioxan-5-ylidene)ethyl)phenyl)acetamide (1r)**


10.17
7.67
7.64
7.31
7.28
2.67
2.54
2.11
1.84
AcHN
1.03
2.01
1.96
3.09
3.03
5.99
f1 (ppm)

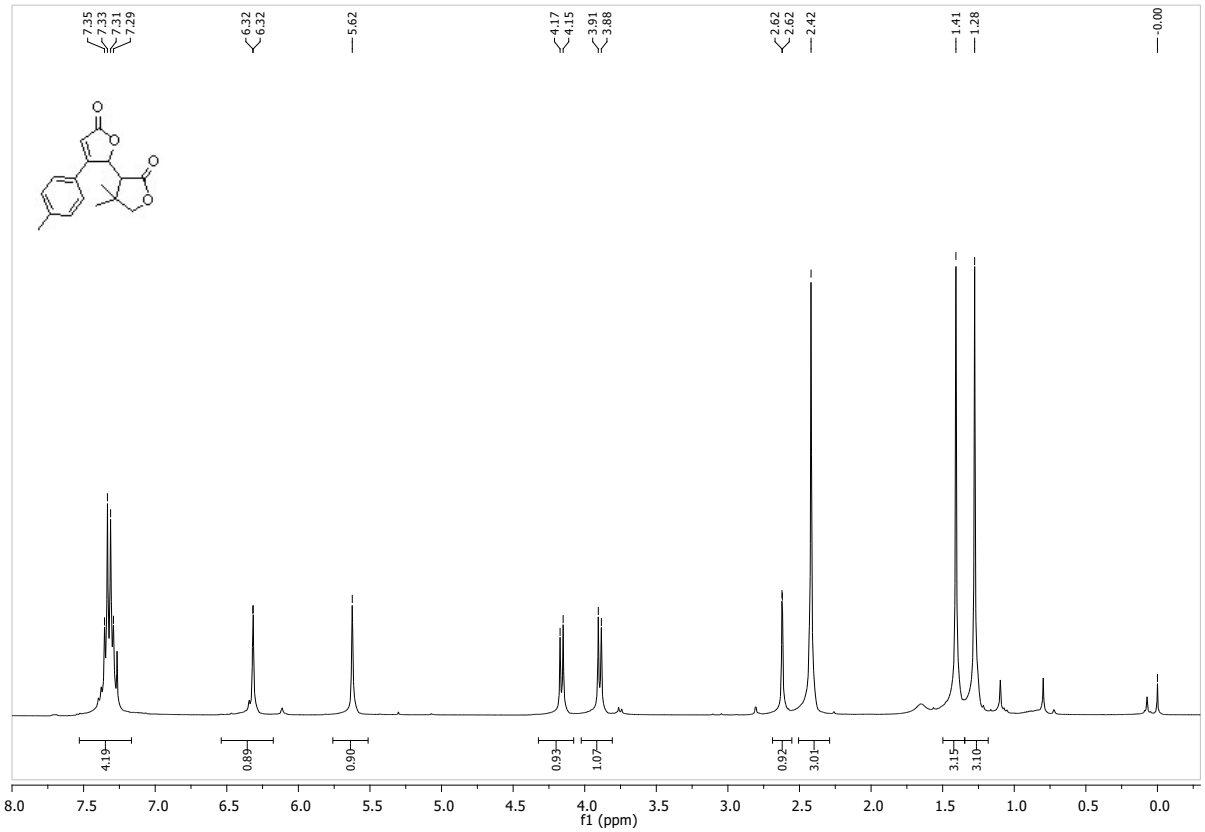

171.61
171.61
168.63
168.63
160.87
160.87
160.46
160.46
140.66
140.66
135.97
135.97
127.73
127.73
118.32
118.32
115.90
115.90
103.86
103.86
40.19
39.96
39.73
39.73
39.50
39.50
39.27
39.04
38.80
26.77
26.77
25.37
24.07
AcHN
f1 (ppm)

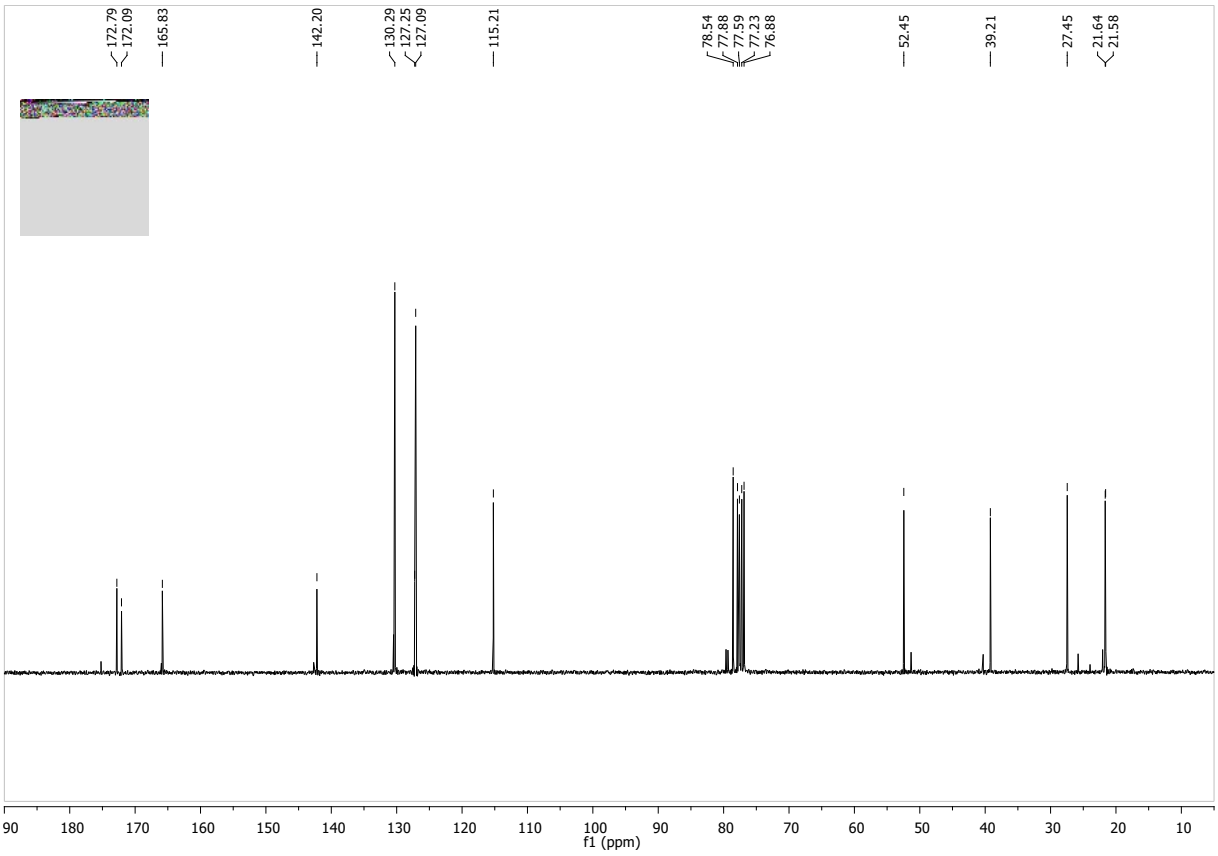
5-(4,4-dimethyl-2-oxotetrahydrofuran-3-yl)-4-phenylfuran-2(5*H*)-one (3aa).



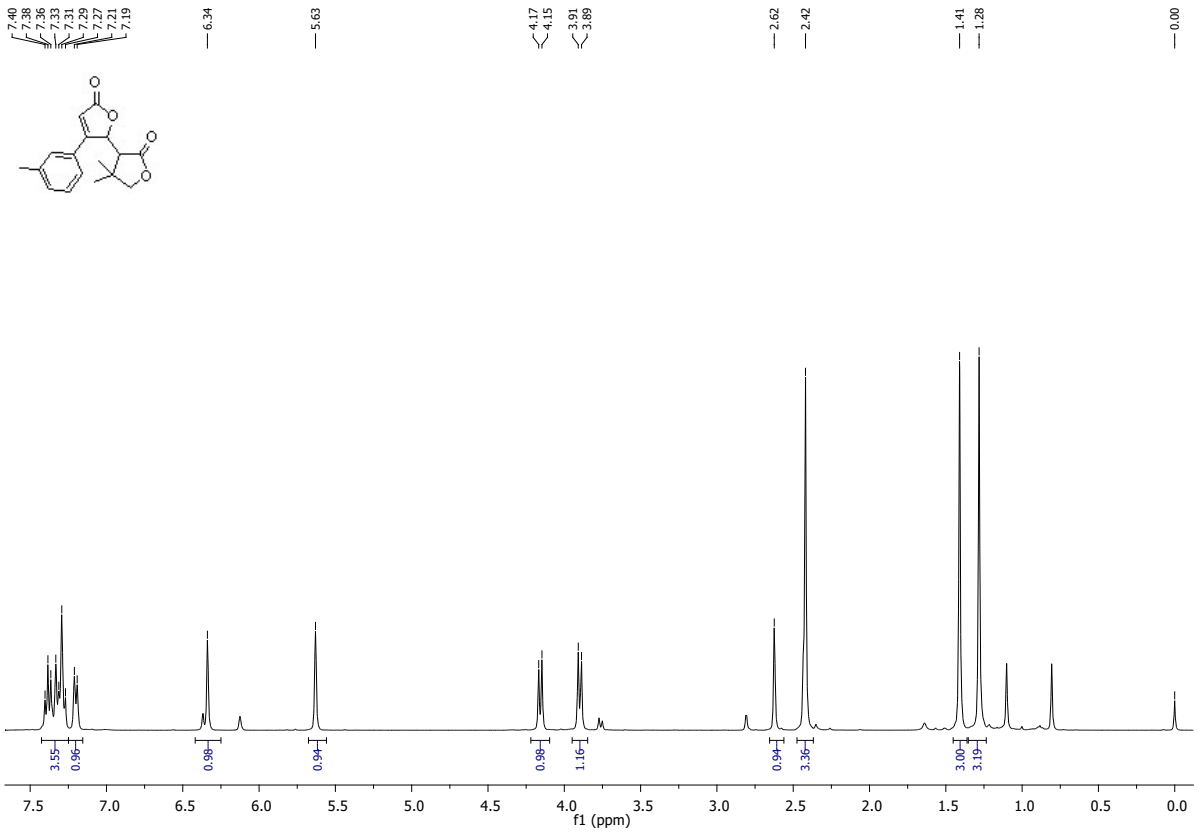


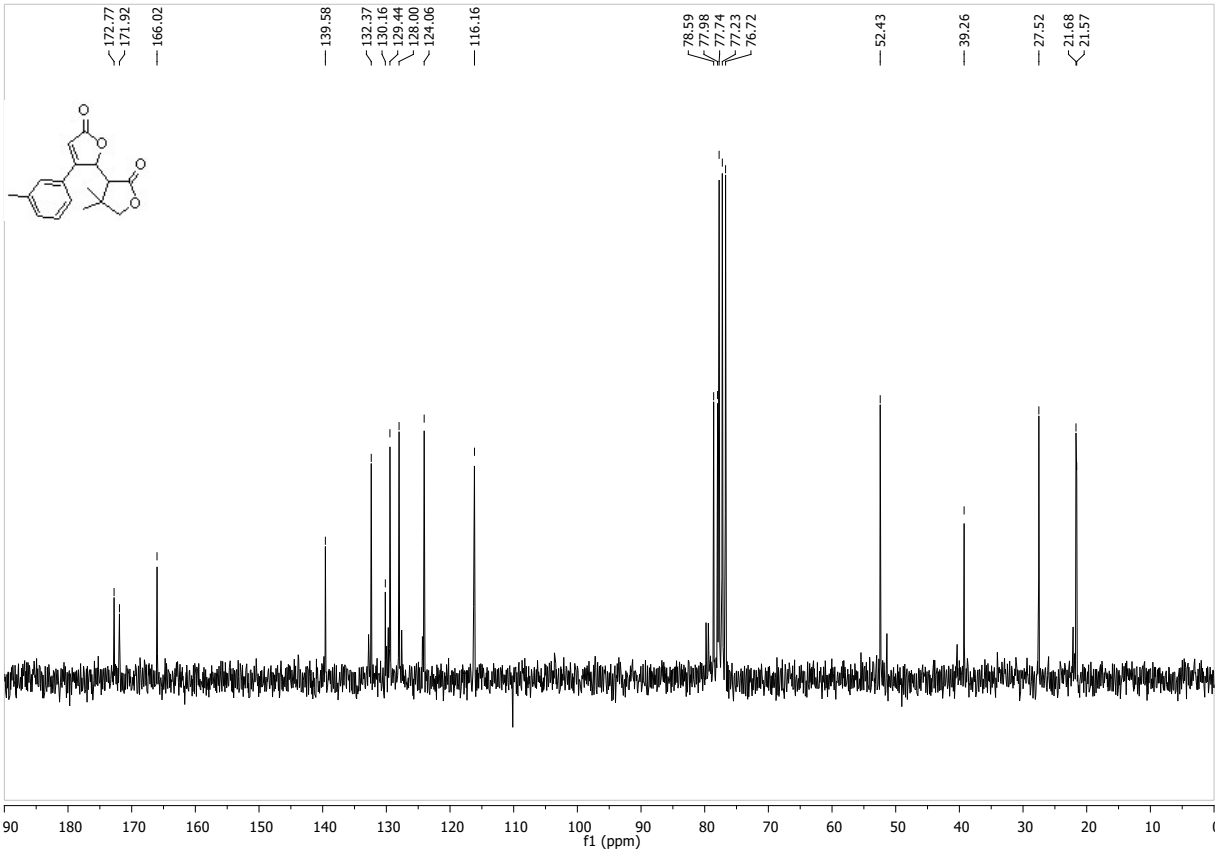
5-(4,4-Dimethyl-2-oxotetrahydrofuran-3-yl)-4-(p-tolyl)furan-2(5*H*)-one (3ba).



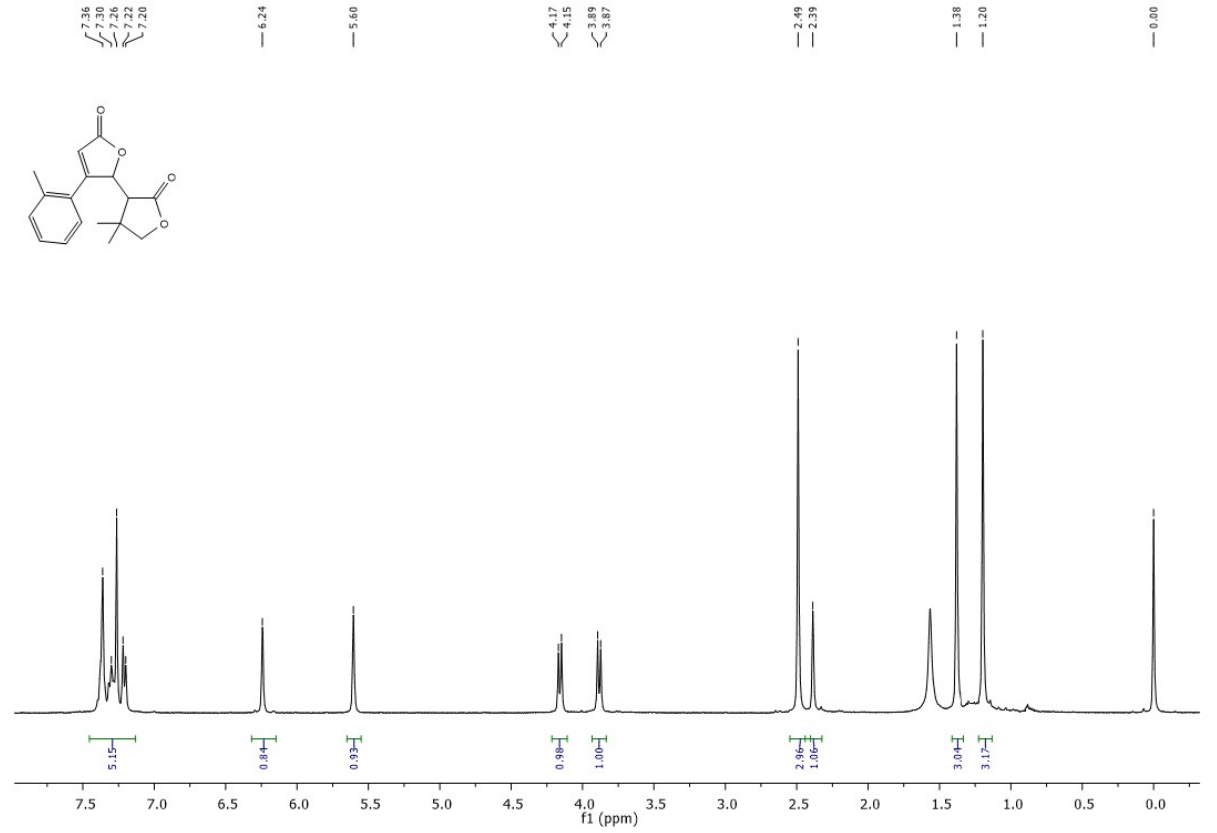


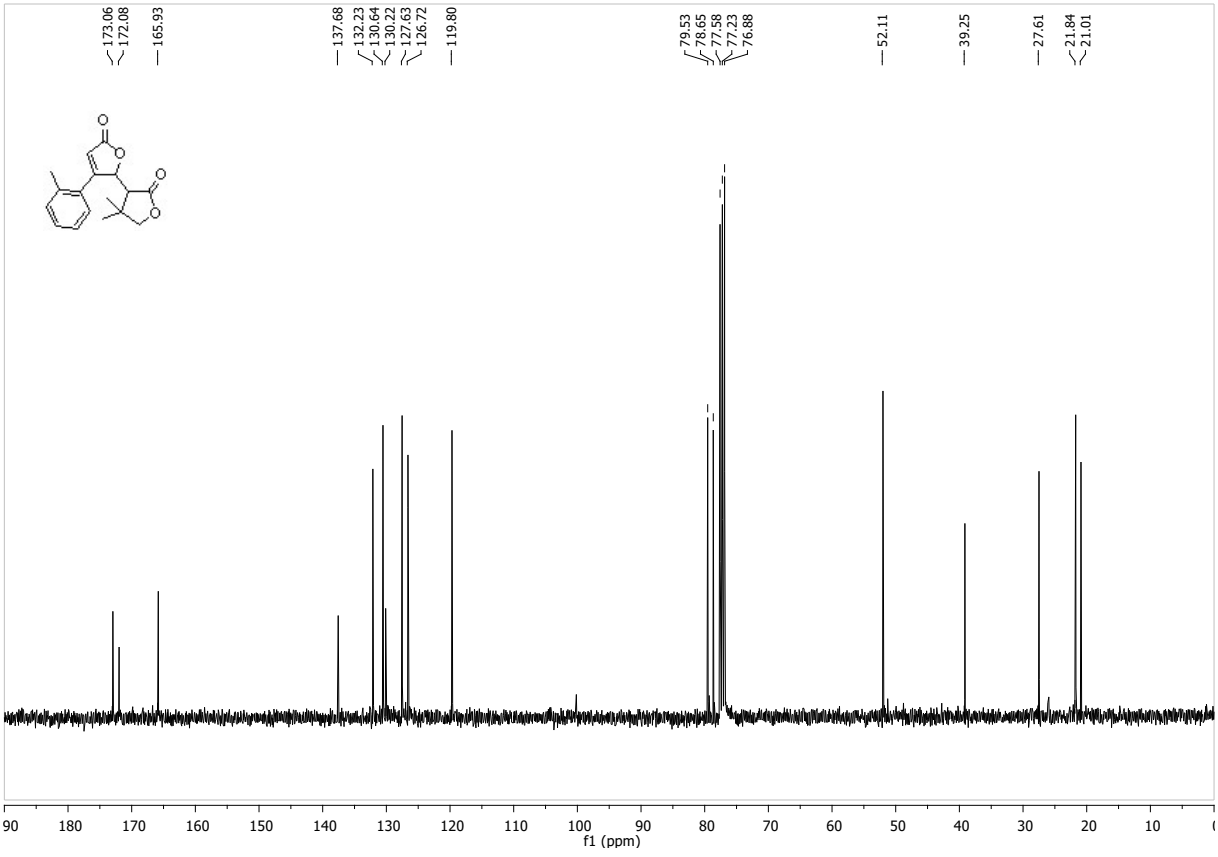
5-(4,4-Dimethyl-2-oxotetrahydrofuran-3-yl)-4-(*m*-tolyl)furan-2(5*H*)-one (3ca)


7.40
7.38
7.36
7.33
7.31
7.29
7.27
7.21
7.19
6.34
5.63
4.17
4.15
3.91
3.89
2.62
2.42
1.41
1.28
0.00
3.55
0.96
0.98
0.94
0.98
1.16
0.94
3.36
3.00
3.19
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

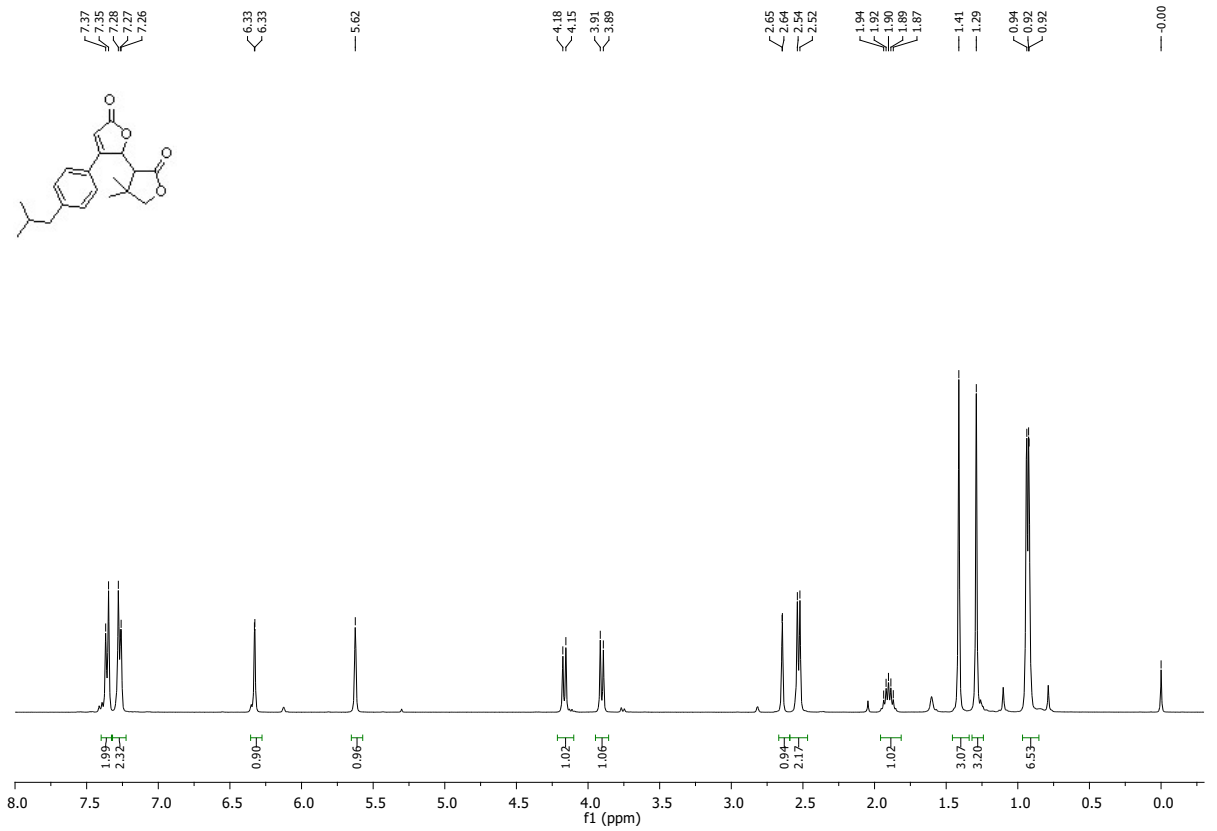

172.77
171.92
166.02
139.58
132.37
130.16
129.44
128.00
124.06
116.16
78.59
77.98
77.74
77.23
76.72
52.43
39.26
27.52
21.68
21.57
90
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

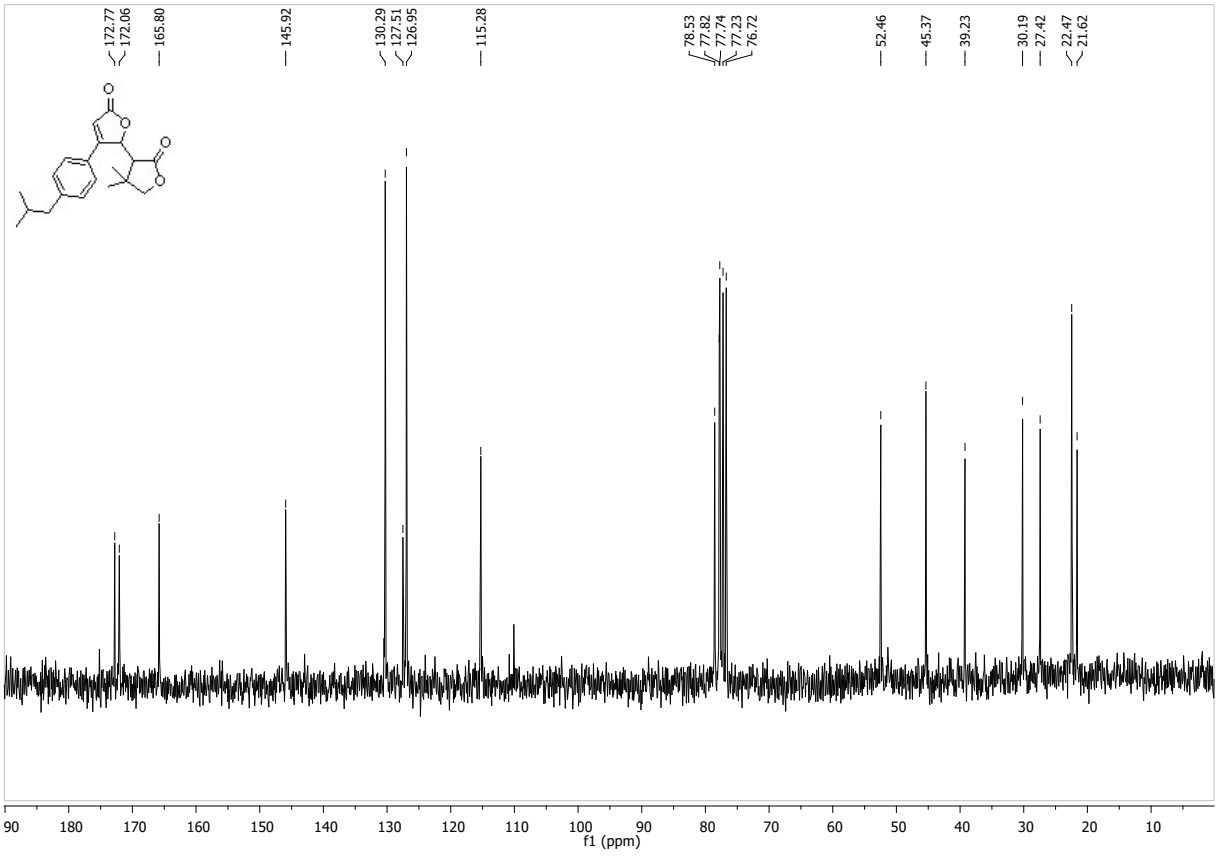
5-(4,4-Dimethyl-2-oxotetrahydrofuran-3-yl)-4-(*o*-tolyl)furan-2(5*H*)-one (3da)



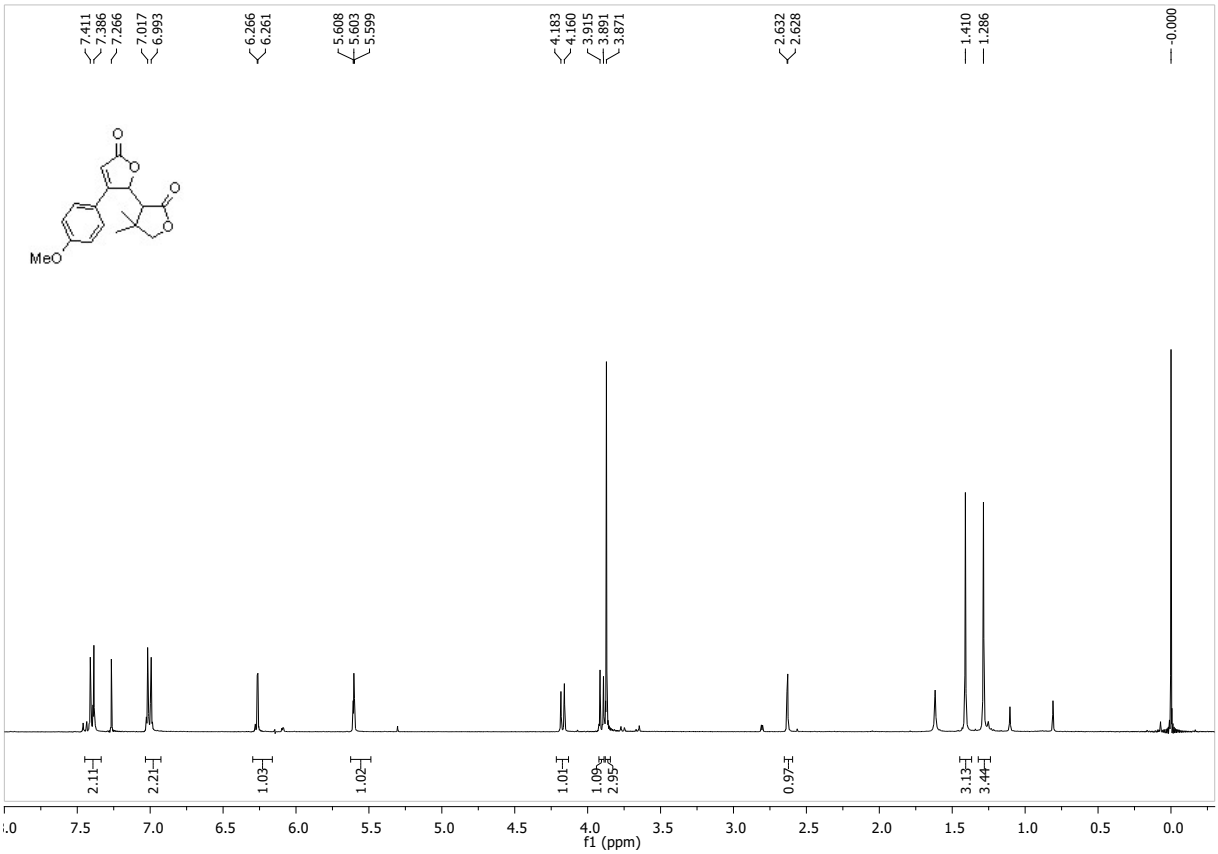


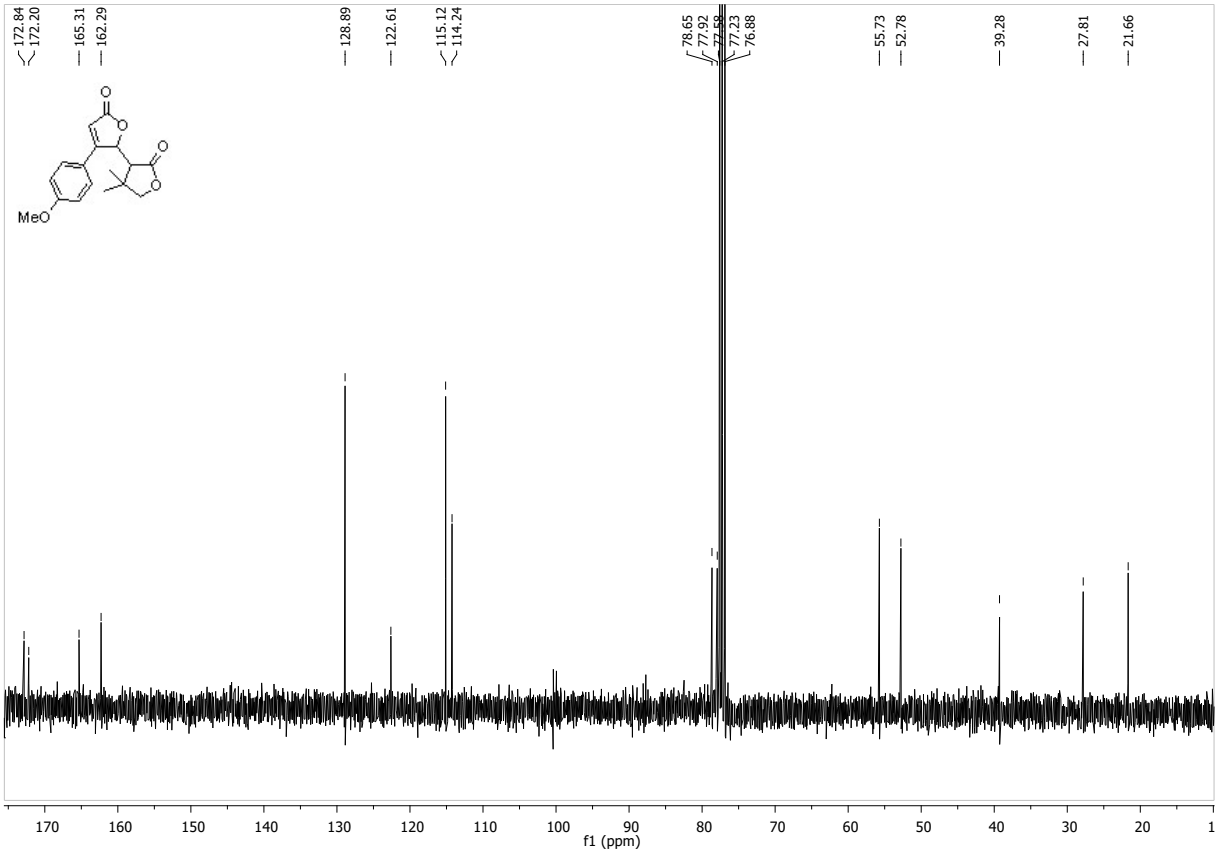
5-(4,4-Dimethyl-2-oxotetrahydrofuran-3-yl)-4-(4-isobutylphenyl)furan-2(5*H*)-one (3ea).



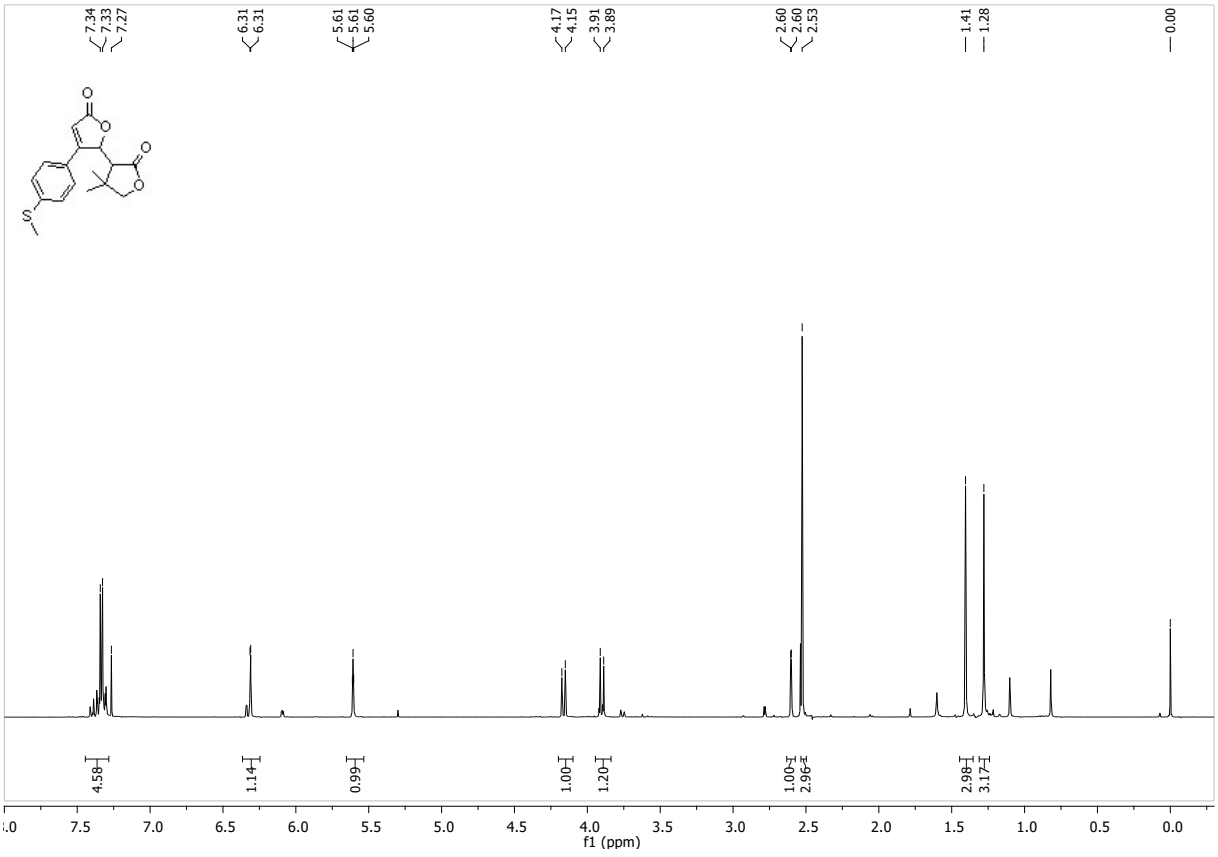


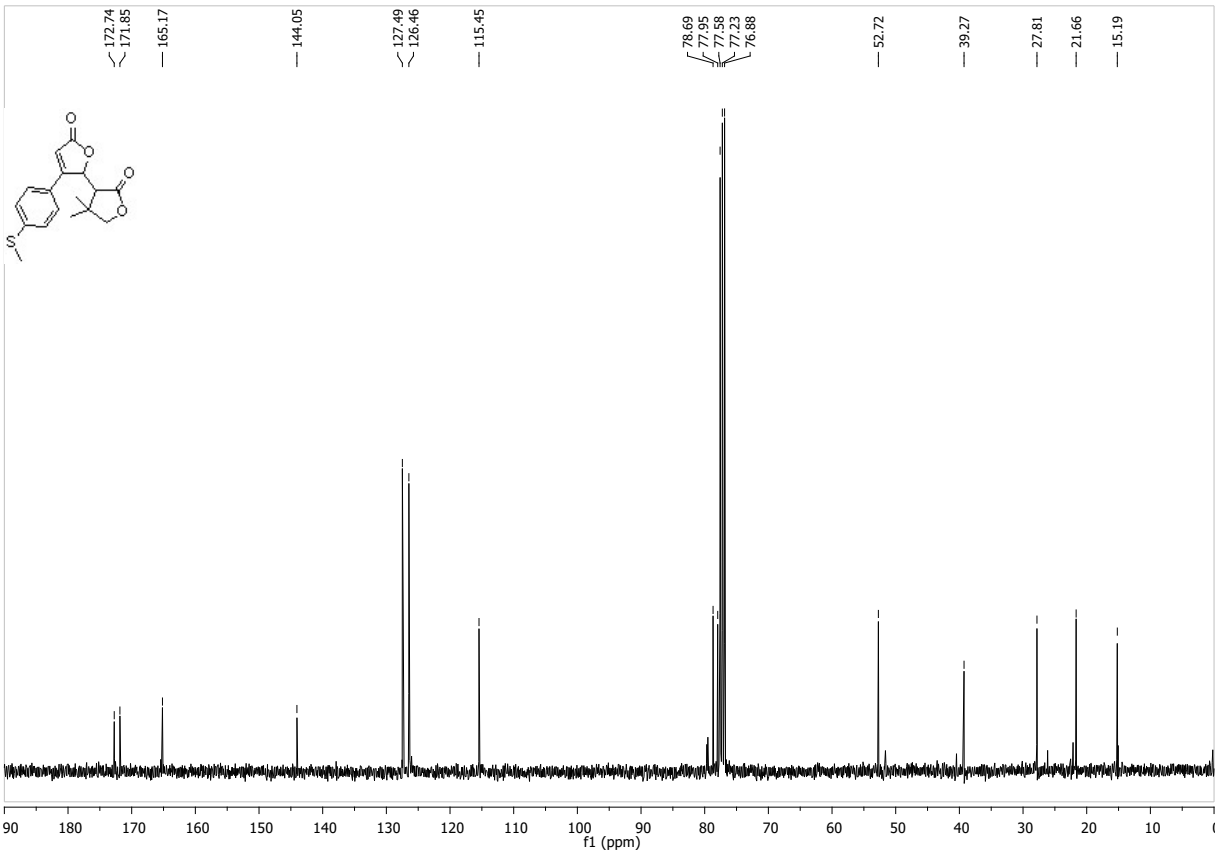
5-(4,4-Dimethyl-2-oxotetrahydrofuran-3-yl)-4-(4-methoxyphenyl)furan-2(5*H*)-one (3fa)



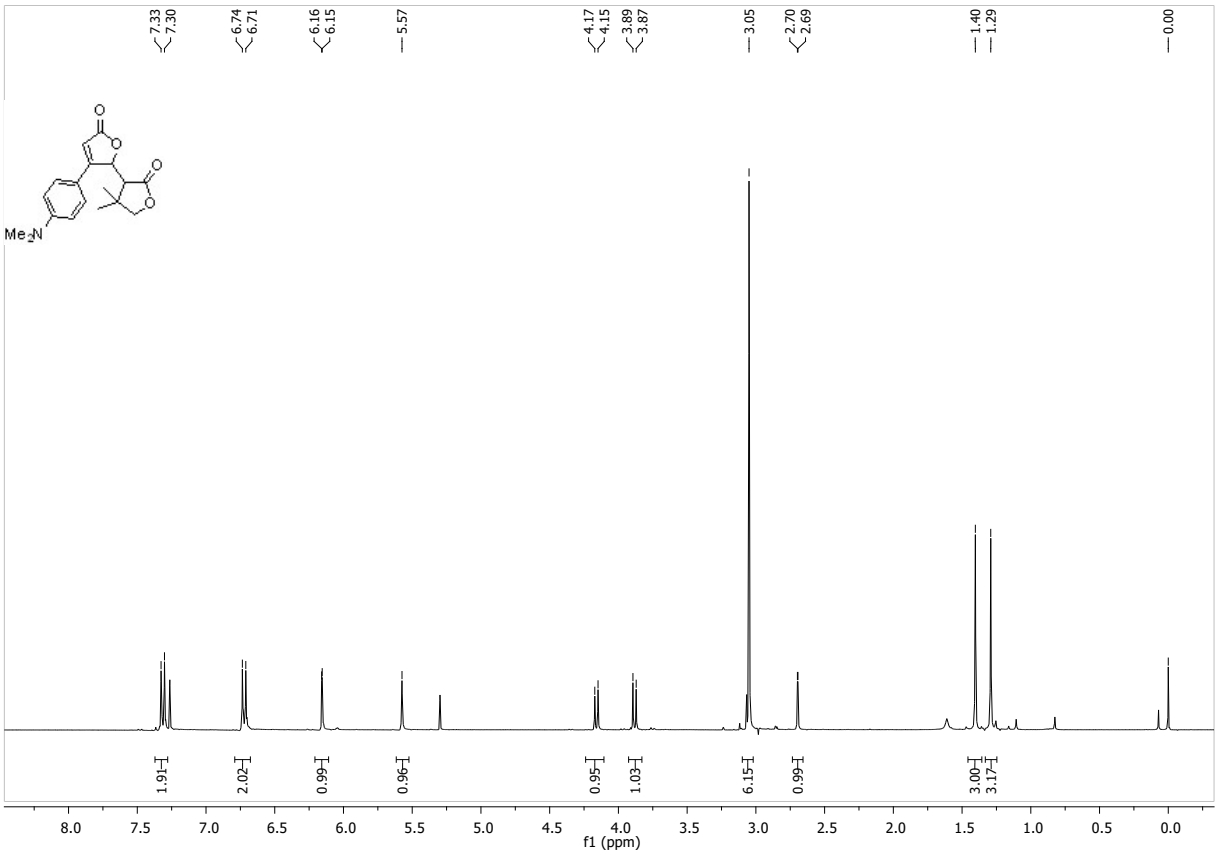


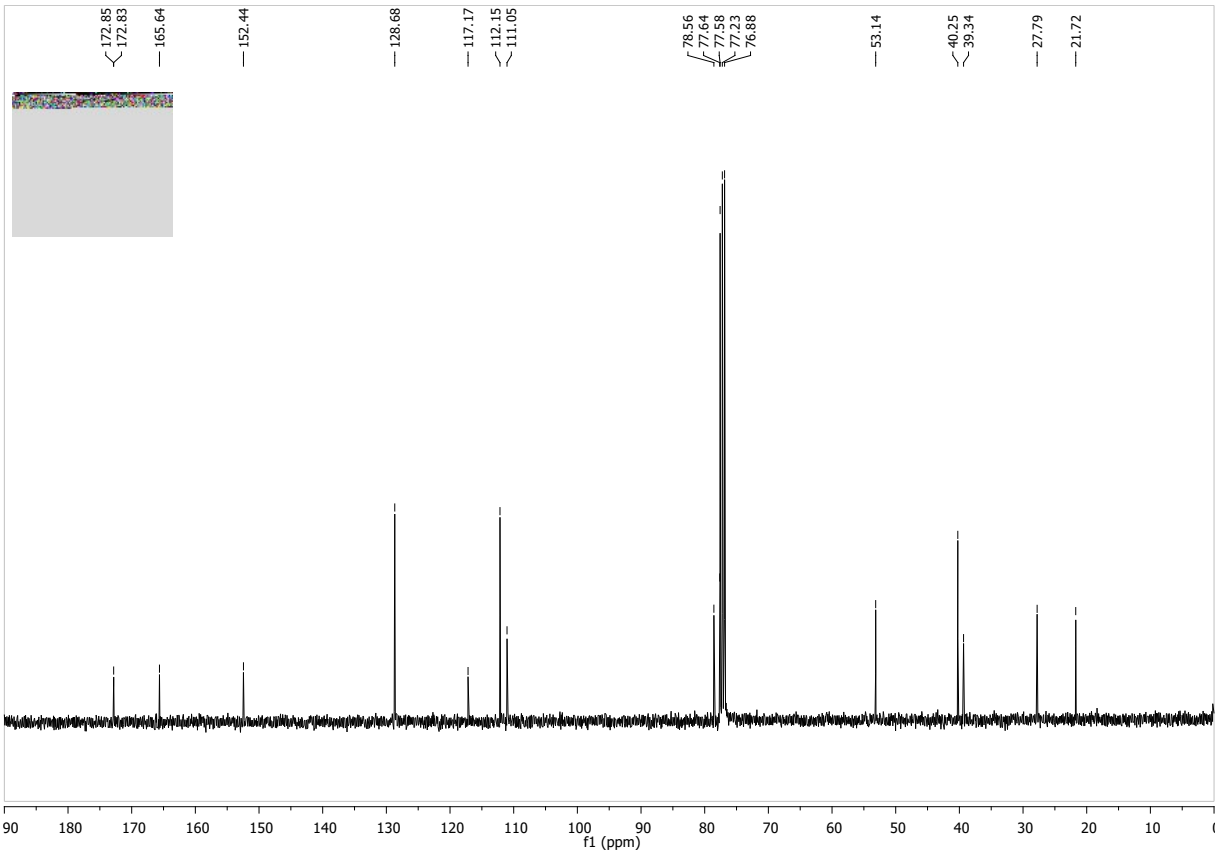
5-(4,4-Dimethyl-2-oxotetrahydrofuran-3-yl)-4-(4-(methylthio)phenyl)furan-2(5*H*)-one (3ga)



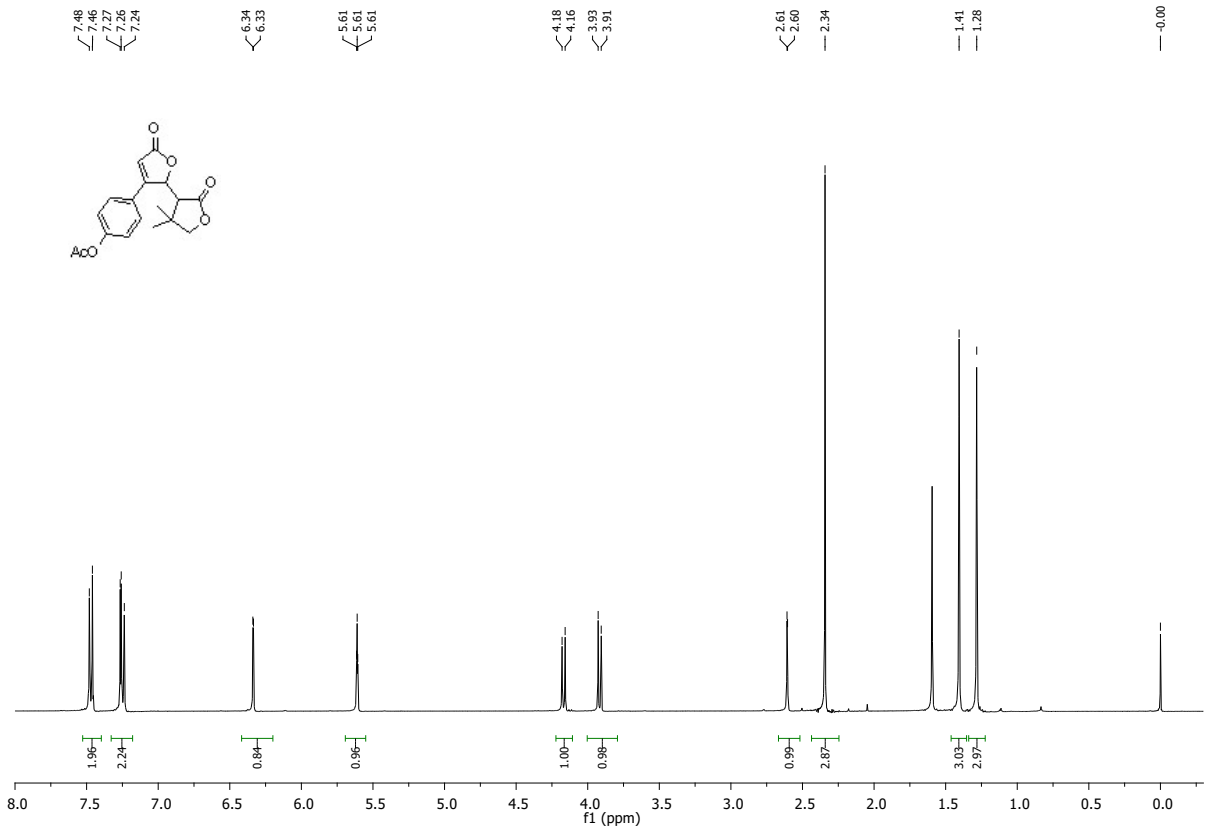


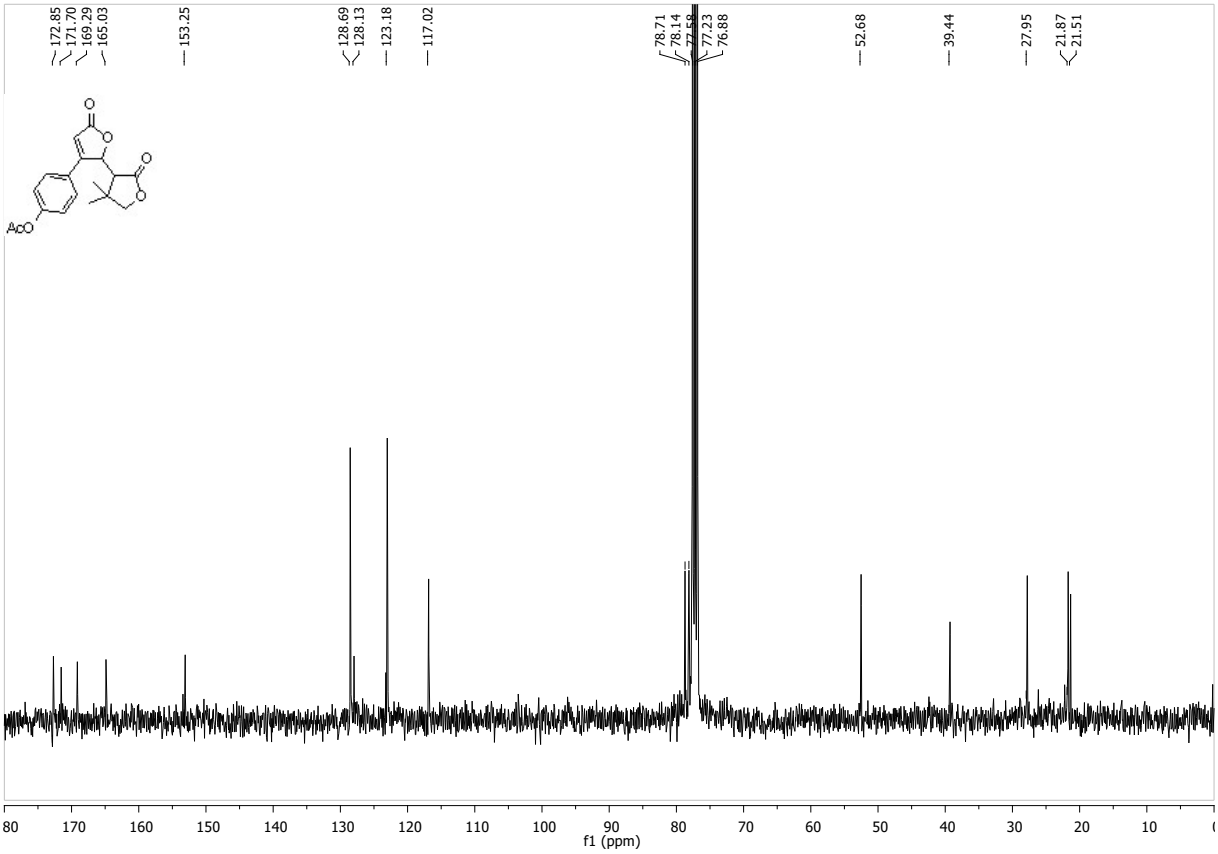
5-(4,4-Dimethyl-2-oxotetrahydrofuran-3-yl)-4-(4-(dimethylamino)phenyl)furan-2(5*H*)-one (3ha)



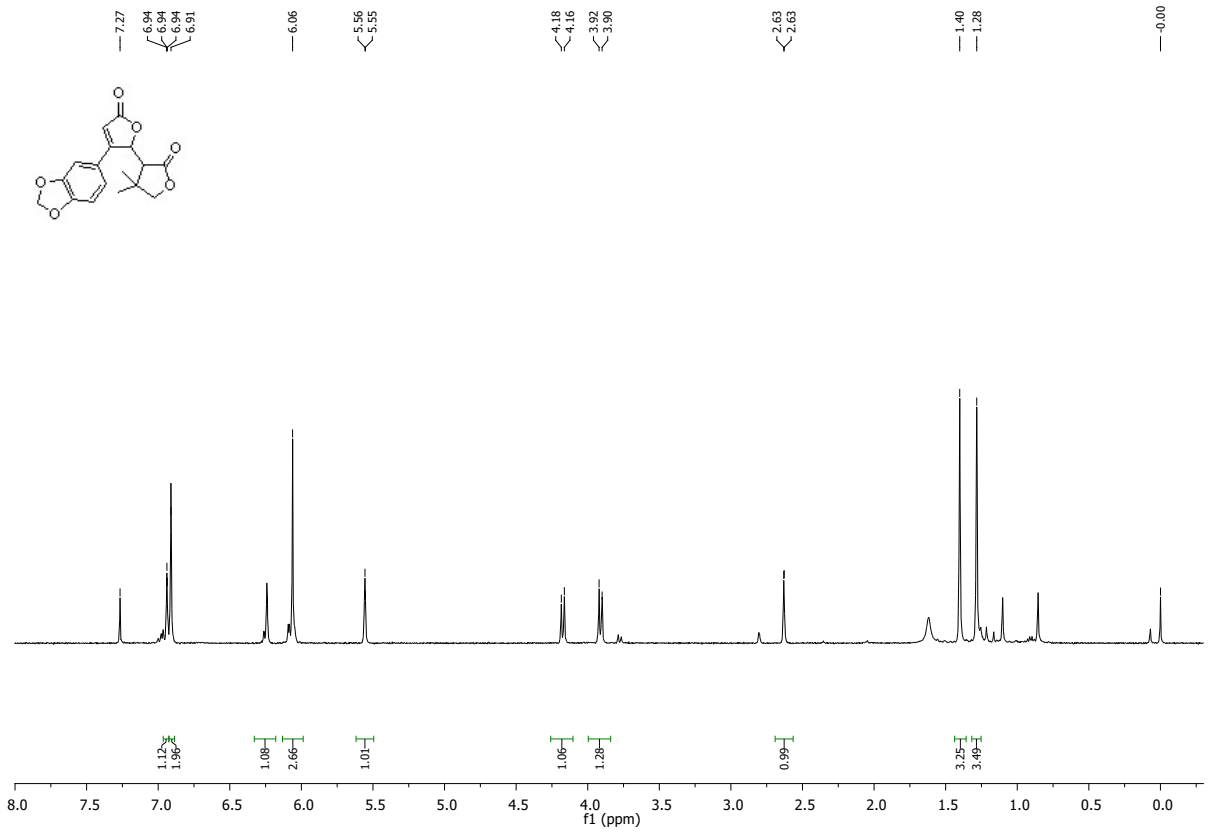


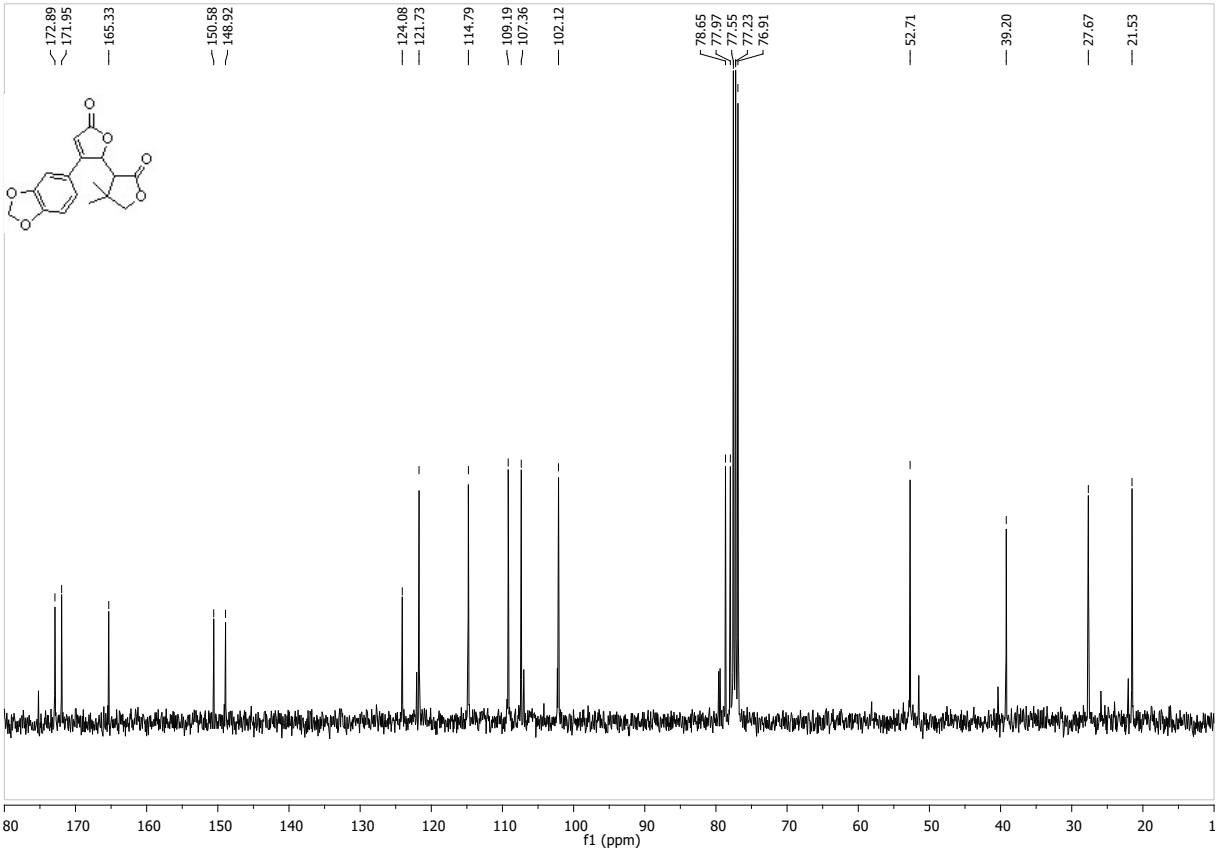
4-(2-(4,4-Dimethyl-2-oxotetrahydrofuran-3-yl)-5-oxo-2,5-dihydrofuran-3-yl)phenyl acetate (3ia).


7.48
7.46
7.27
7.26
7.24
6.34
6.33
5.61
5.61
5.61
4.18
4.16
3.93
3.91
2.61
2.60
2.34
1.41
1.28
0.00
AcO
1.96
2.24
0.84
0.96
1.00
0.98
0.99
2.87
3.03
2.97
f1 (ppm)

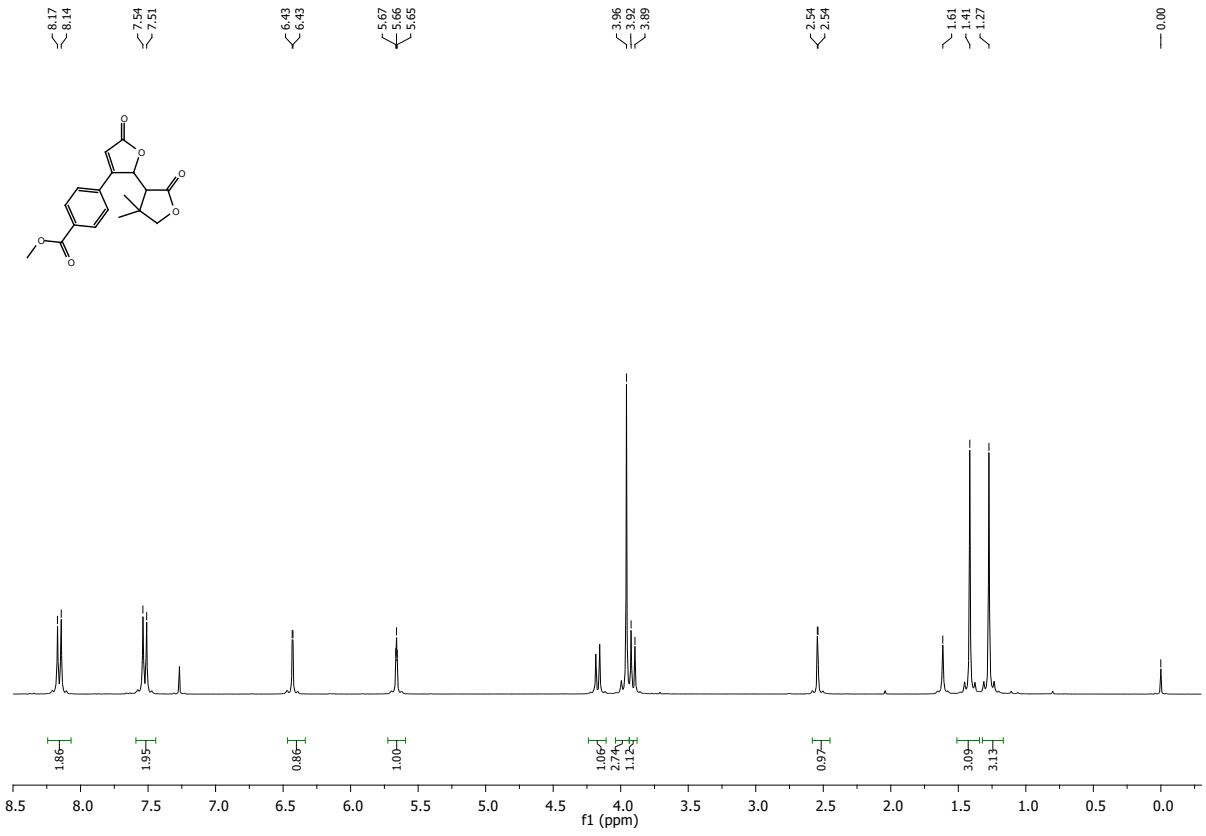

172.85
171.70
169.29
165.03
153.25
128.69
128.13
123.18
117.02
78.71
78.14
77.23
76.88
52.68
39.44
27.95
21.87
21.51
AcO
f1 (ppm)

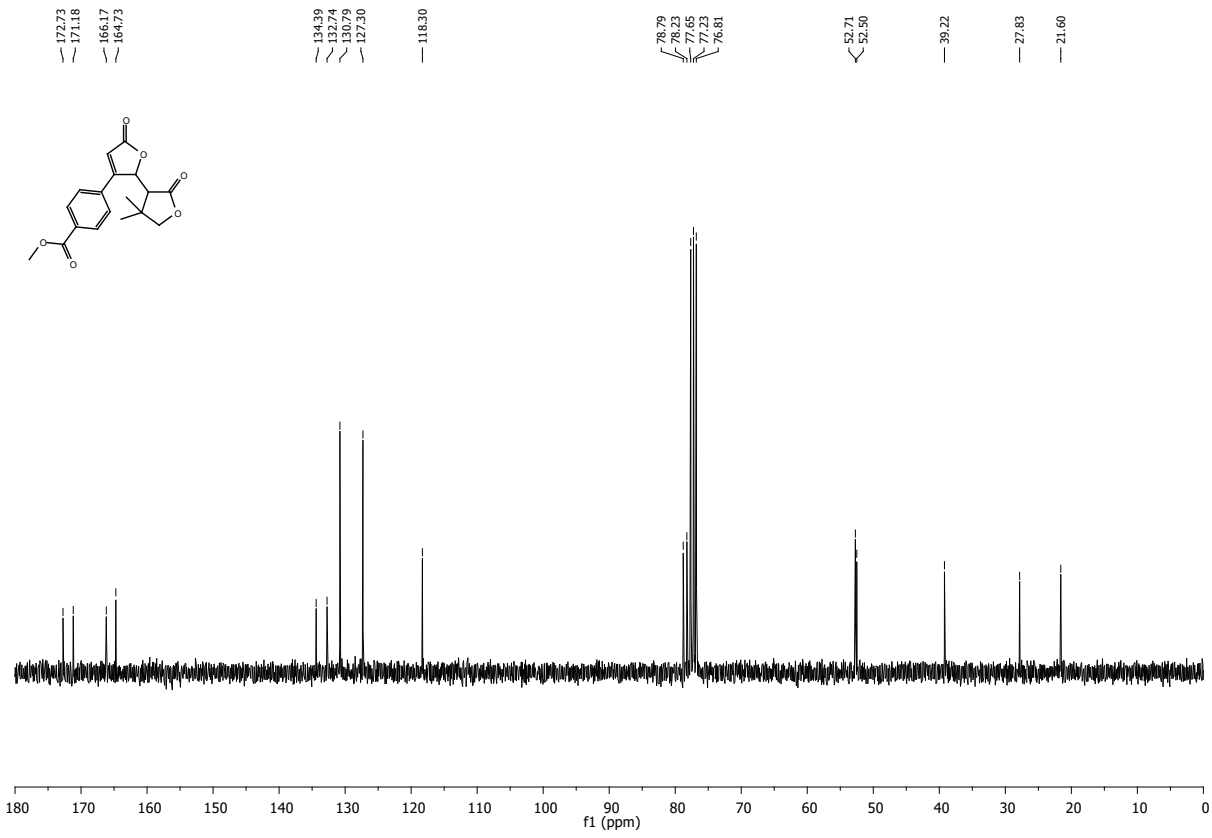
4-(Benzo[*d*][1,3]dioxol-5-yl)-5-(4,4-dimethyl-2-oxotetrahydrofuran-3-yl)furan-2(5*H*)-one (3ja).



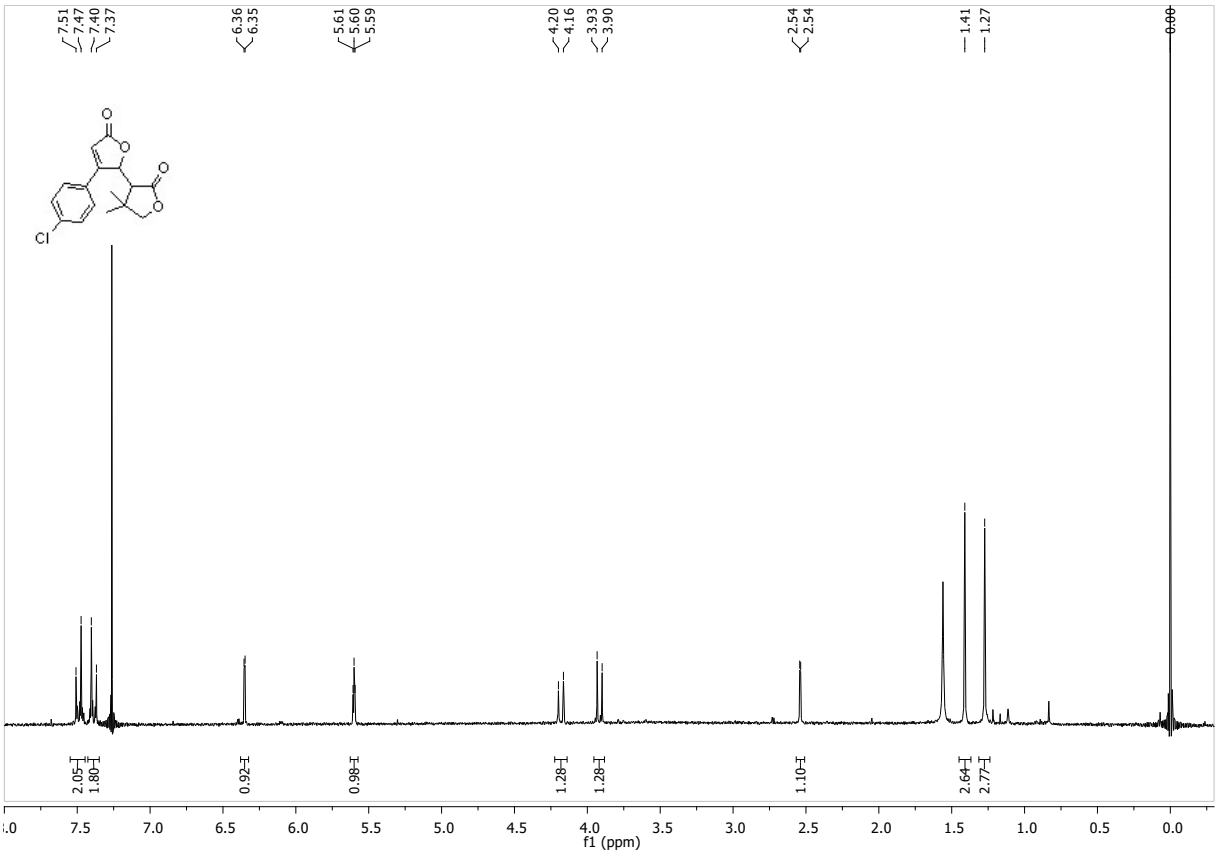


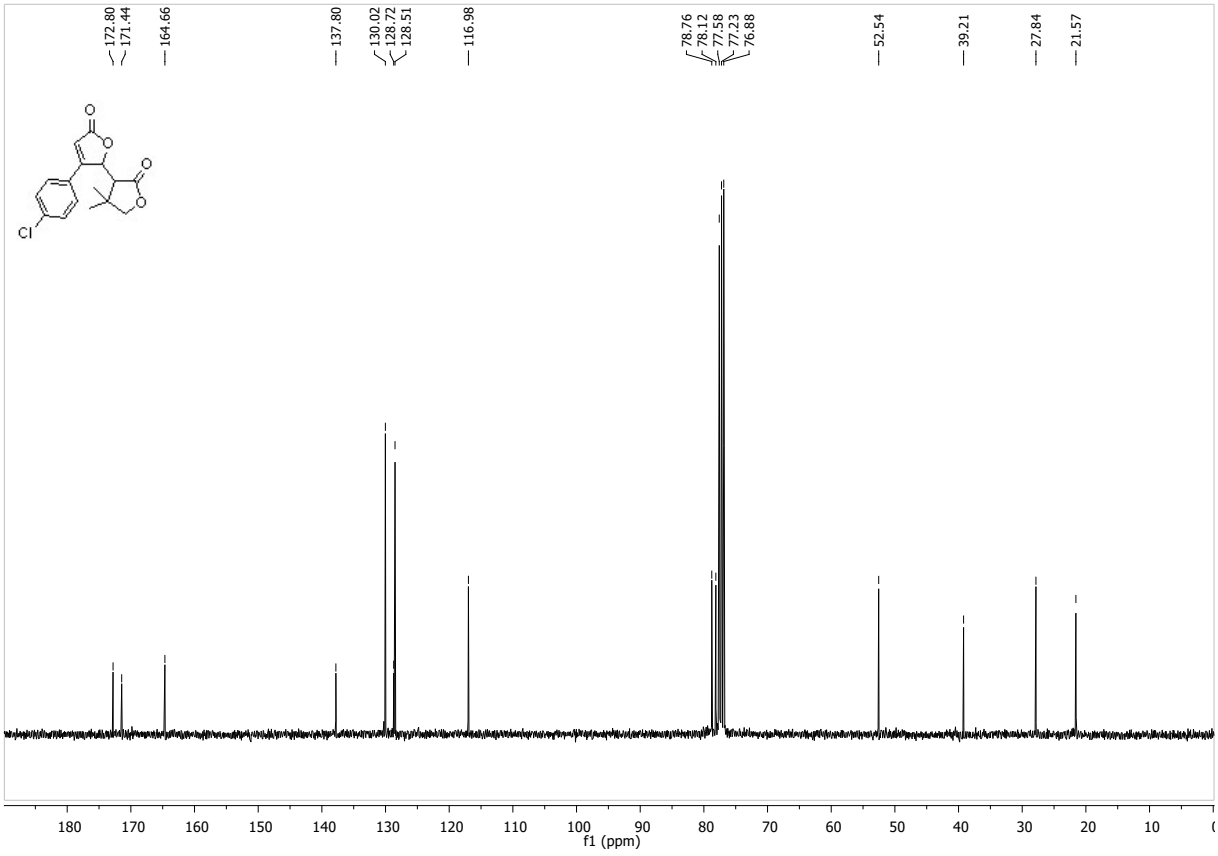
Methyl 4-(2-(4,4-dimethyl-2-oxotetrahydrofuran-3-yl)-5-oxo-2,5-dihydrofuran-3-yl)benzoate (3ka).



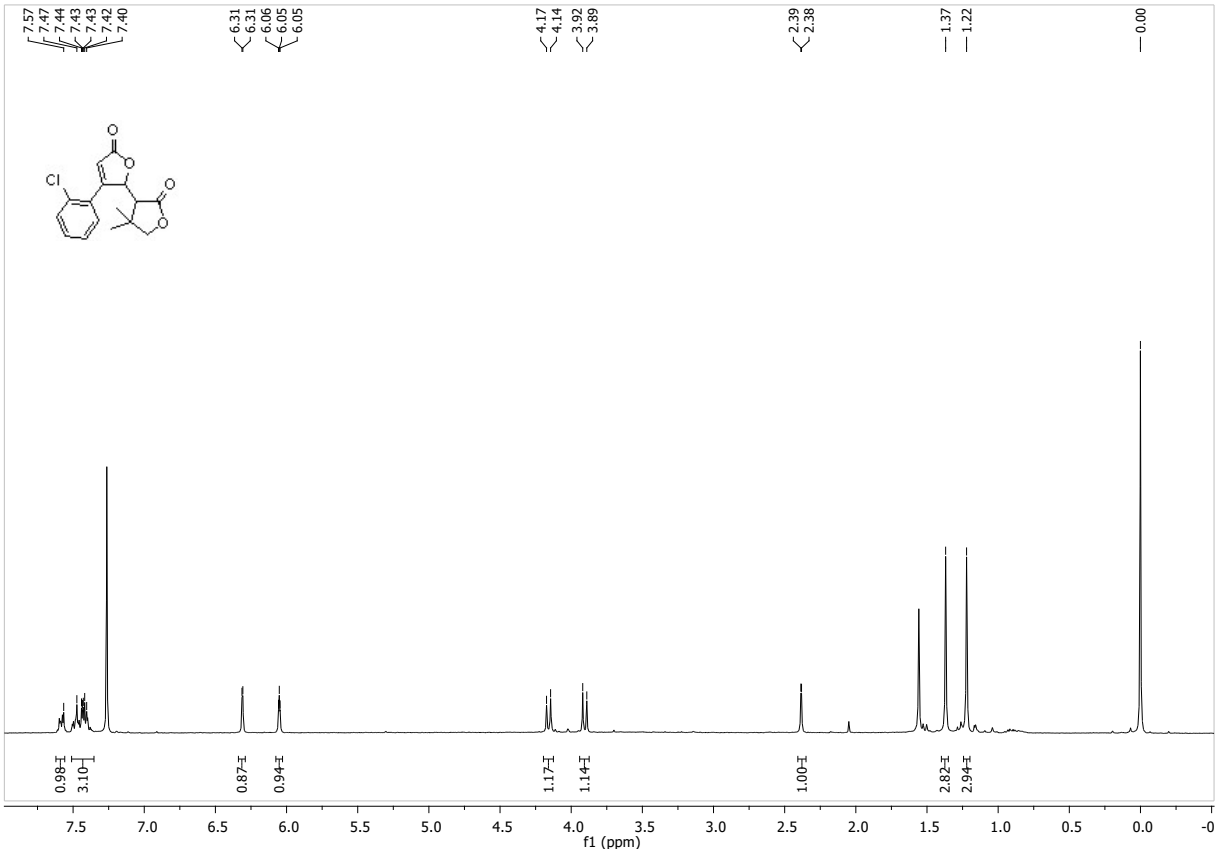


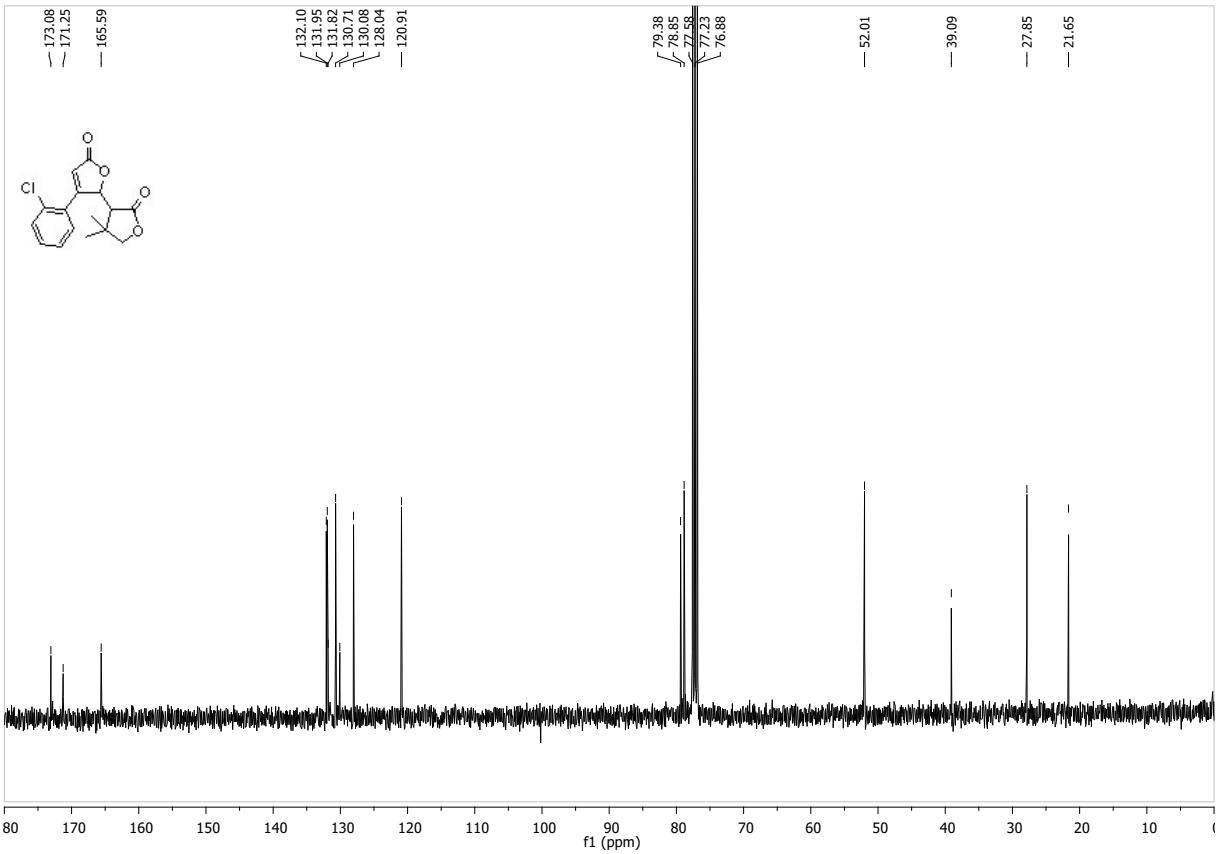
4-(4-Chlorophenyl)-5-(4,4-dimethyl-2-oxotetrahydrofuran-3-yl)furan-2(5*H*)-one (3la).


7.51
7.47
7.40
7.37
6.36
6.35
5.61
5.60
5.59
4.20
4.16
3.93
3.90
2.54
2.54
1.41
1.27
0.00
Cl
2.05
1.80
0.92
0.98
1.28
1.28
1.10
2.64
2.77
f1 (ppm)

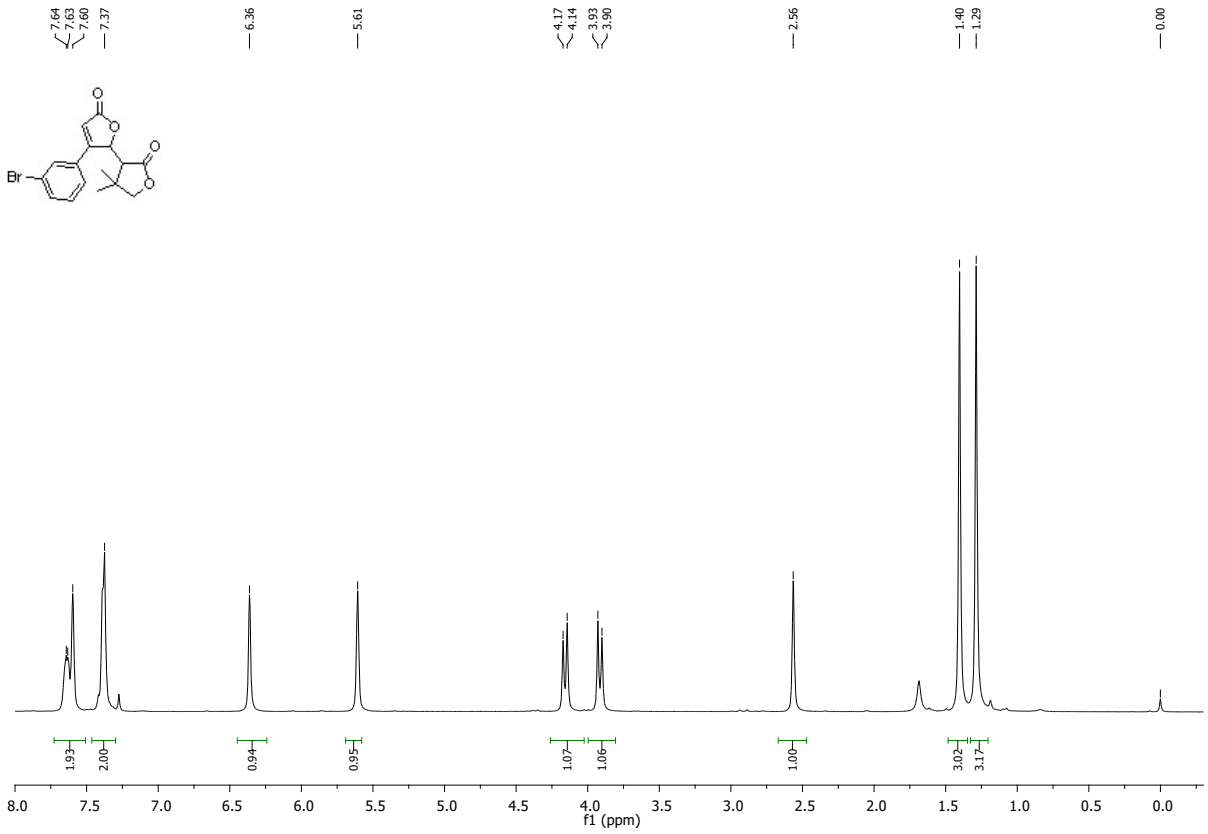

172.80
171.44
164.66
137.80
130.02
128.72
128.51
116.98
78.76
78.12
77.58
77.23
76.88
52.54
39.21
27.84
21.57
Cl
f1 (ppm)

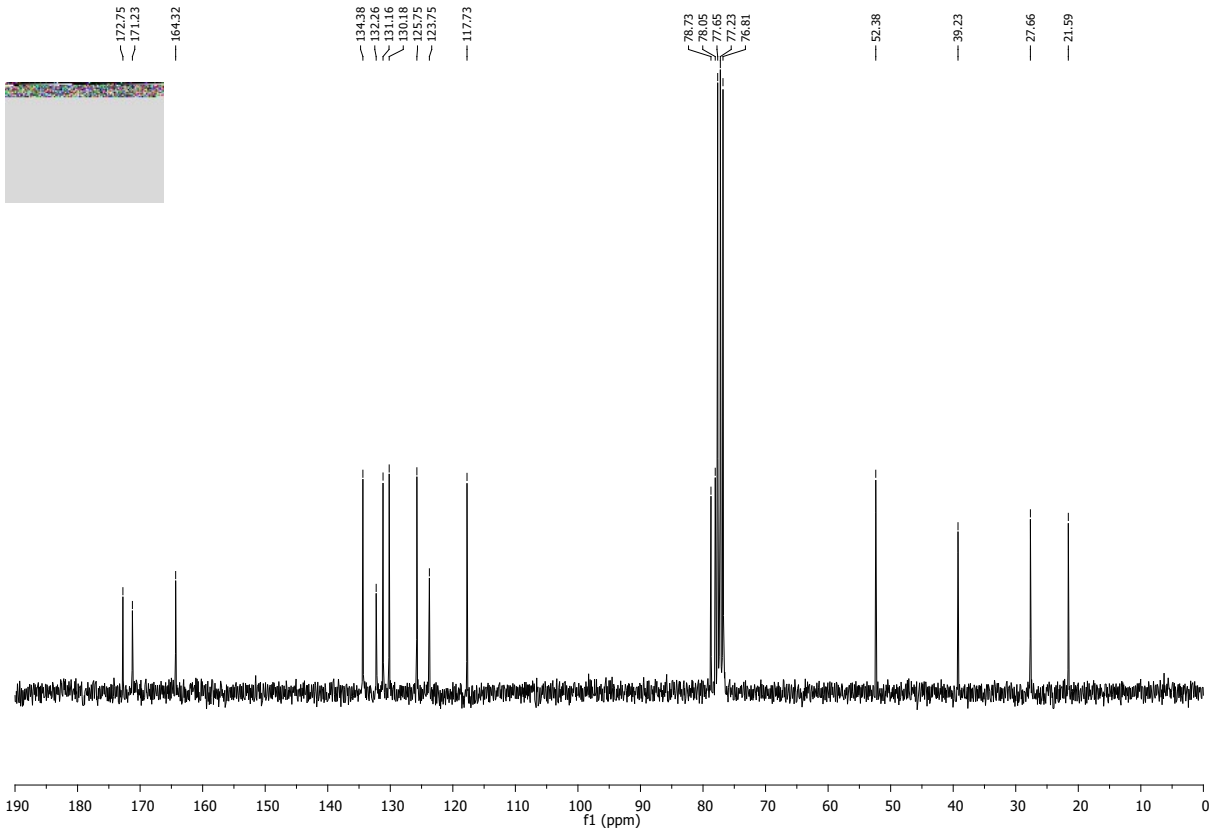
4-(2-Chlorophenyl)-5-(4,4-dimethyl-2-oxotetrahydrofuran-3-yl)furan-2(5*H*)-one (3ma).



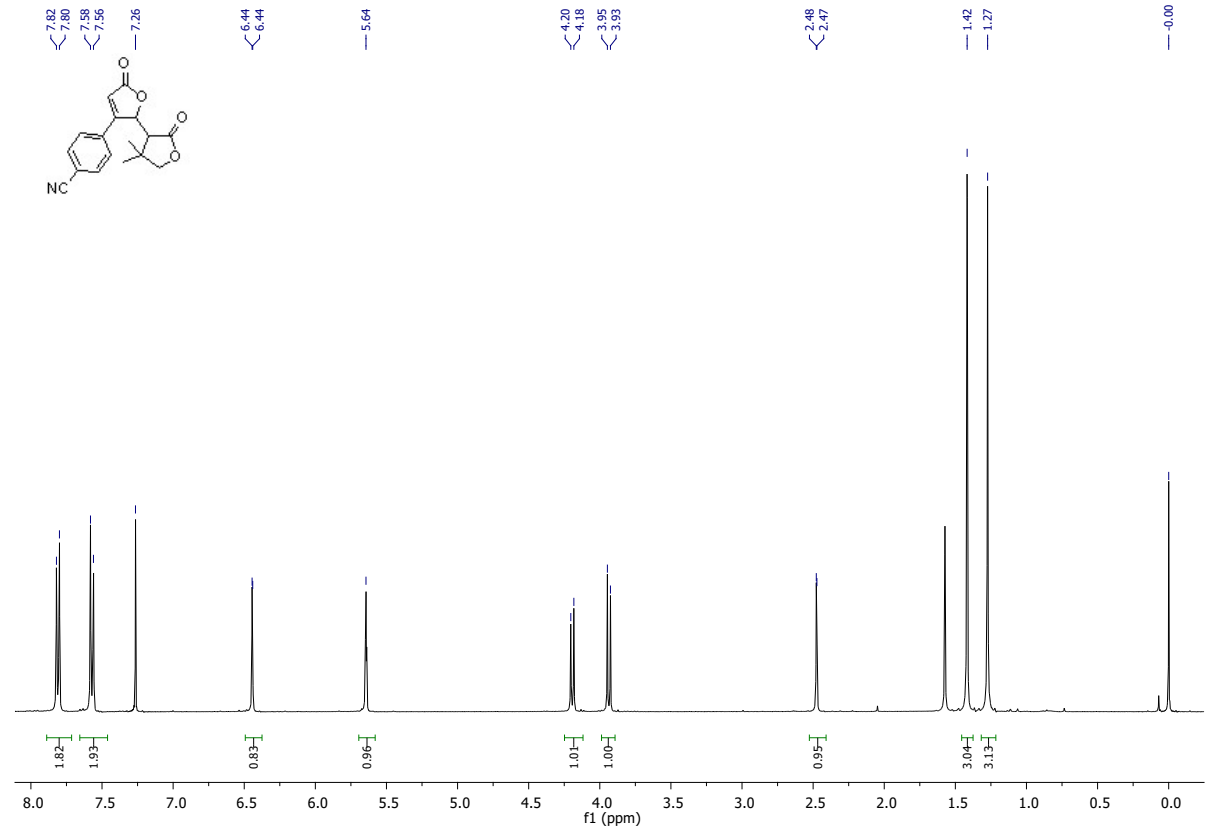


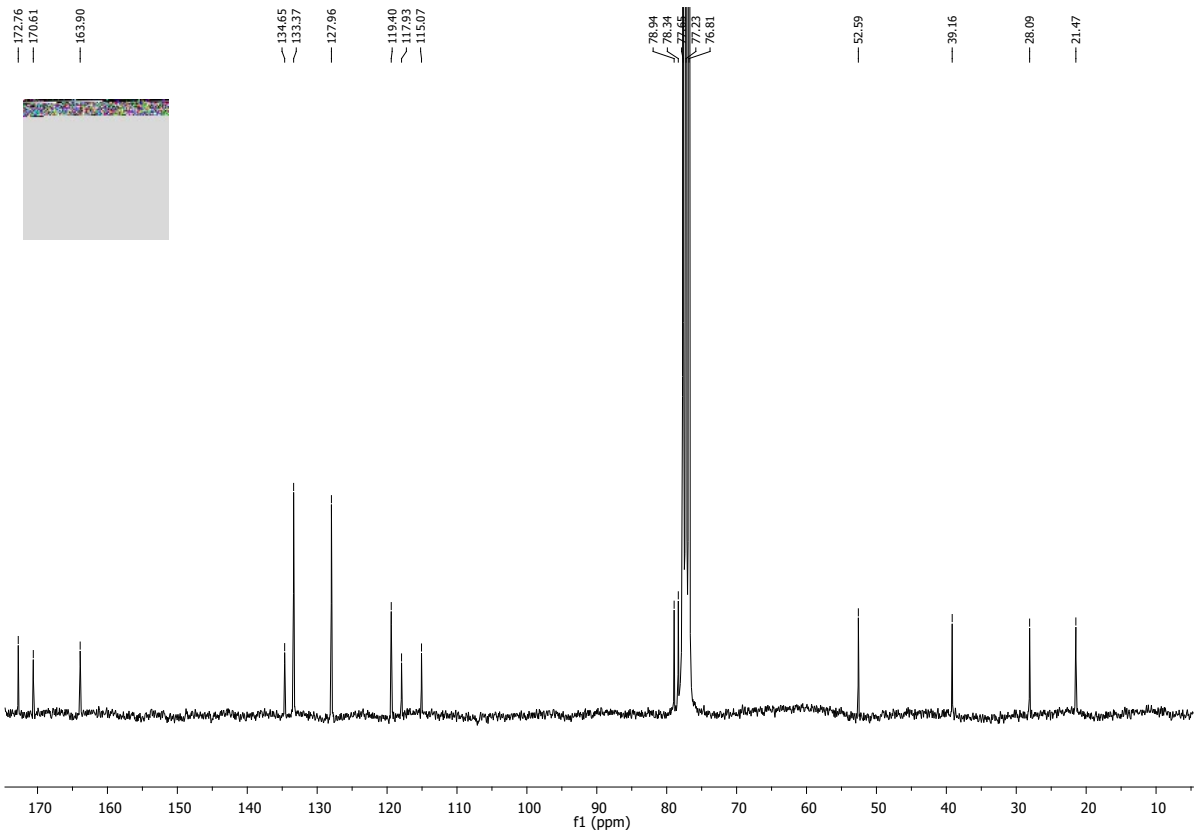
4-(3-Bromophenyl)-5-(4,4-dimethyl-2-oxotetrahydrofuran-3-yl)furan-2(5*H*)-one (3na)



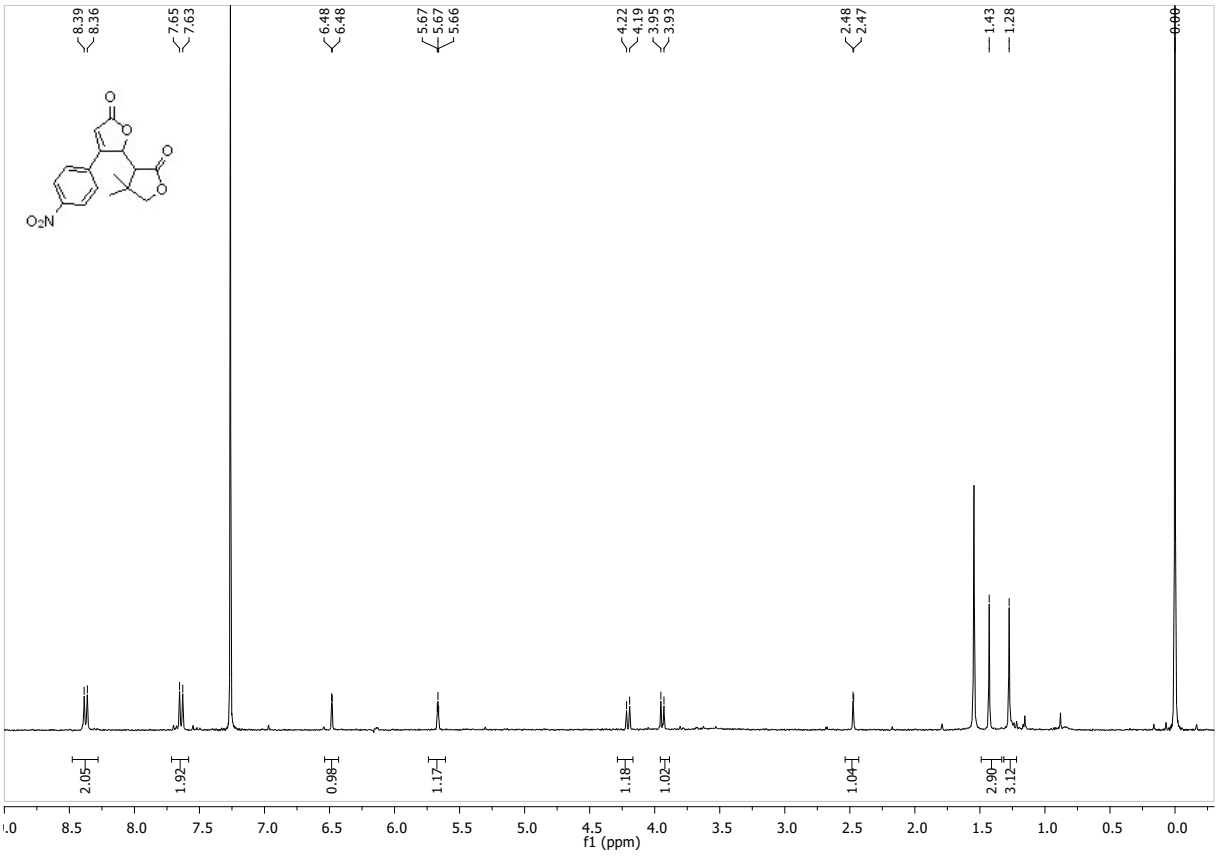


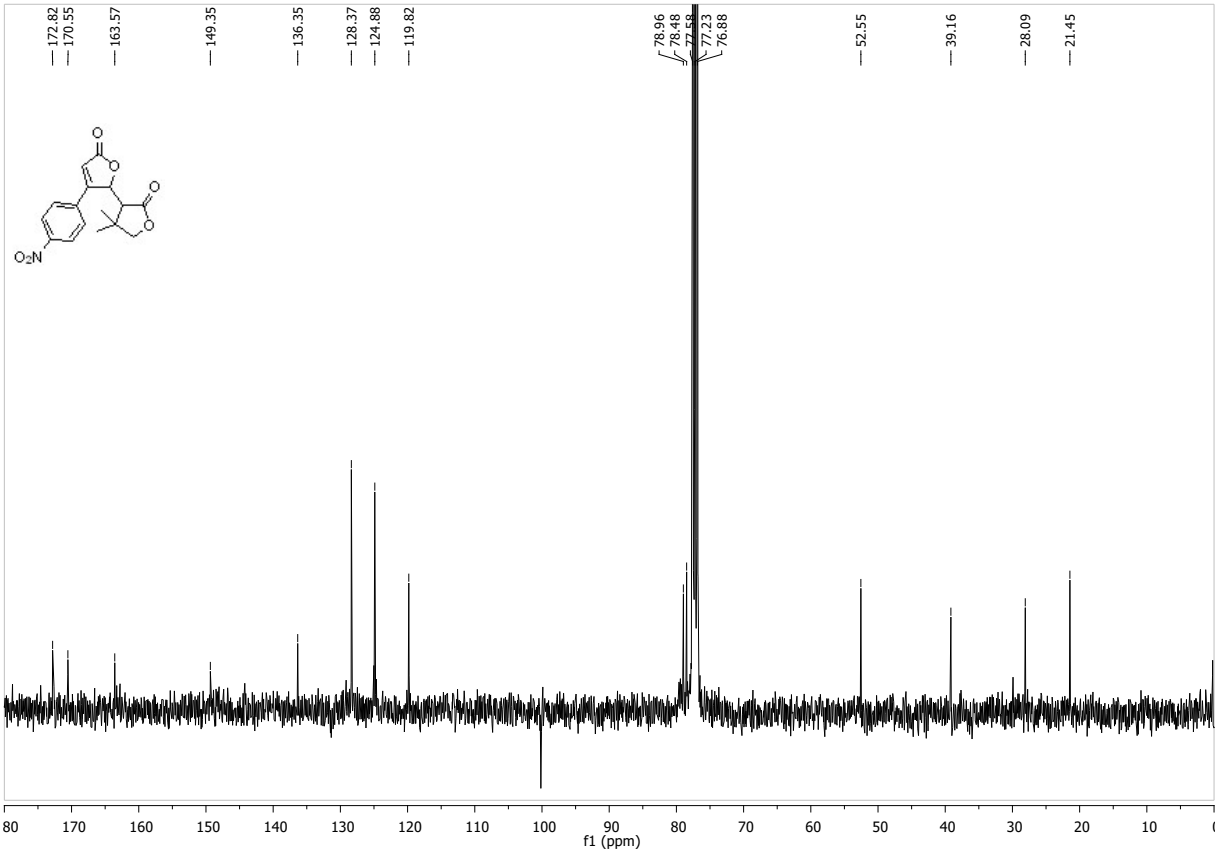
4-(2-(4,4-Dimethyl-2-oxotetrahydrofuran-3-yl)-5-oxo-2,5-dihydrofuran-3-yl)benzonitrile (3oa).



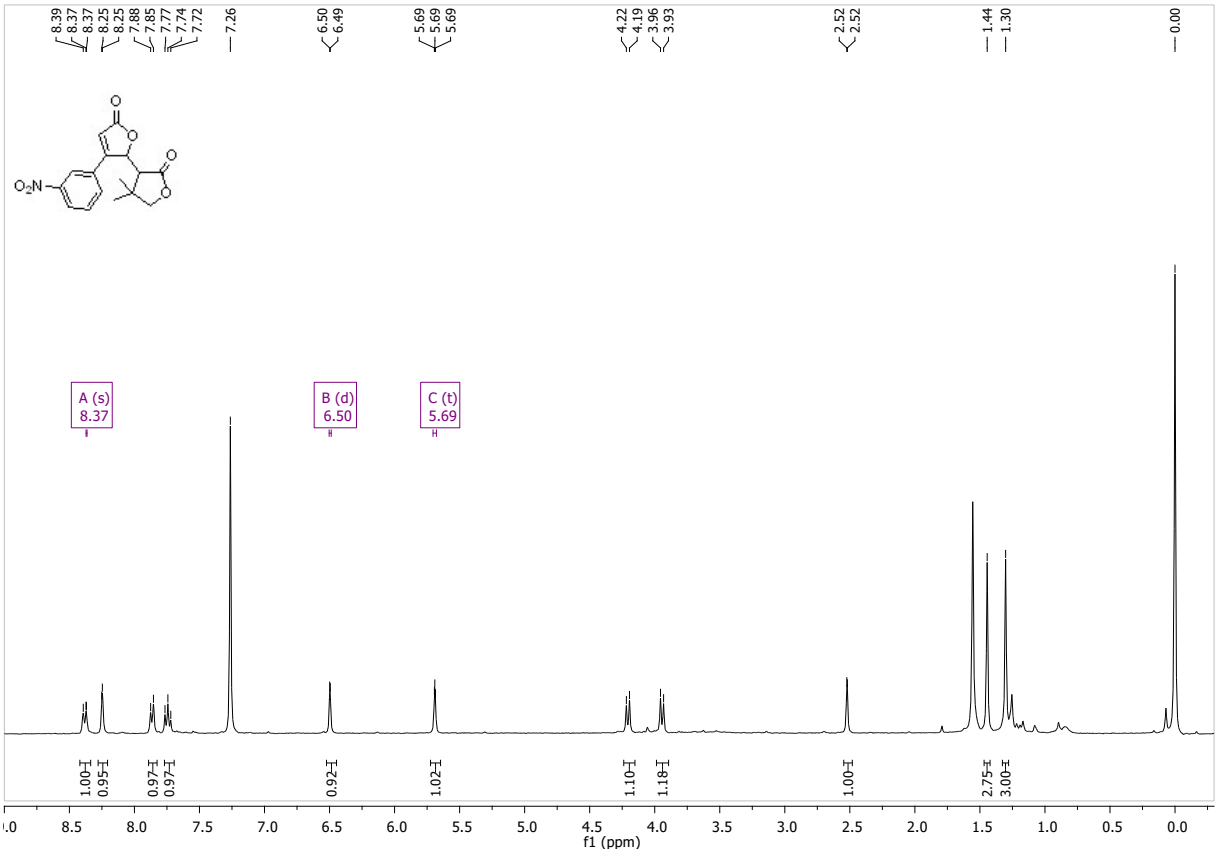


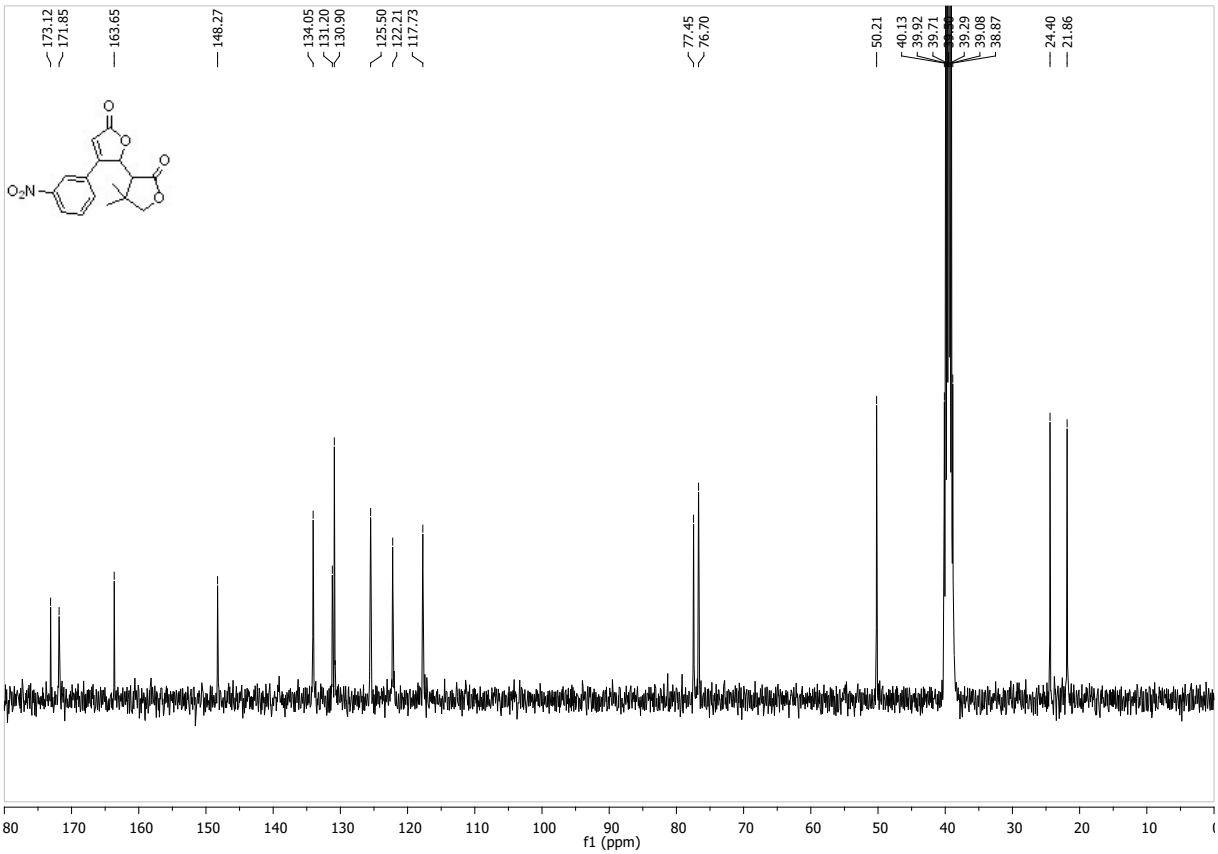
5-(4,4-Dimethyl-2-oxotetrahydrofuran-3-yl)-4-(4-nitrophenyl)furan-2(5*H*)-one (3pa).


8.39
8.36
7.65
7.63
6.48
6.48
5.67
5.67
5.66
4.22
4.19
3.95
3.93
2.48
2.47
1.43
1.28
0.00
O2N
2.05
1.92
0.98
1.17
1.18
1.02
1.04
2.90
3.12
f1 (ppm)

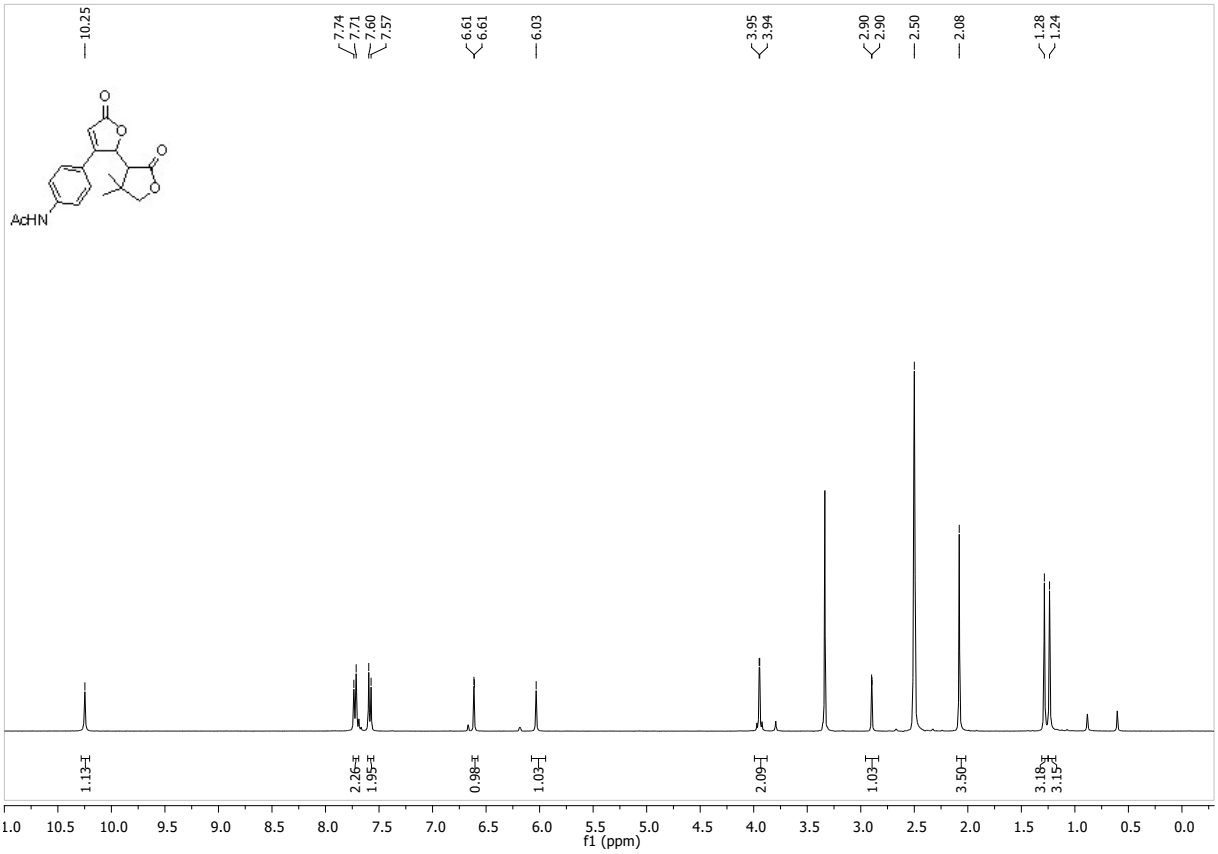

172.82
170.55
163.57
149.35
136.35
128.37
124.88
119.82
78.96
78.48
77.58
77.23
76.88
52.55
39.16
28.09
21.45
O2N
f1 (ppm)

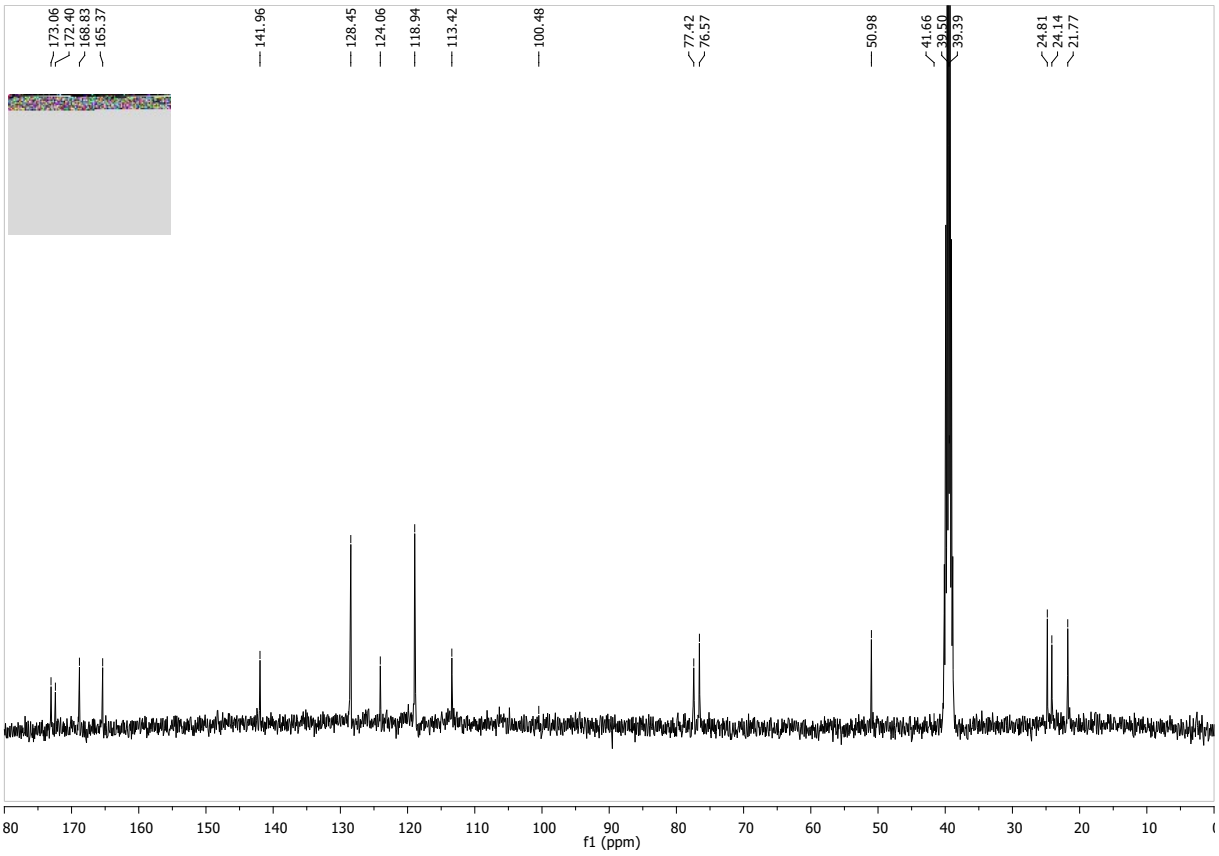
5-(4,4-Dimethyl-2-oxotetrahydrofuran-3-yl)-4-(3-nitrophenyl)furan-2(5*H*)-one (3qa)



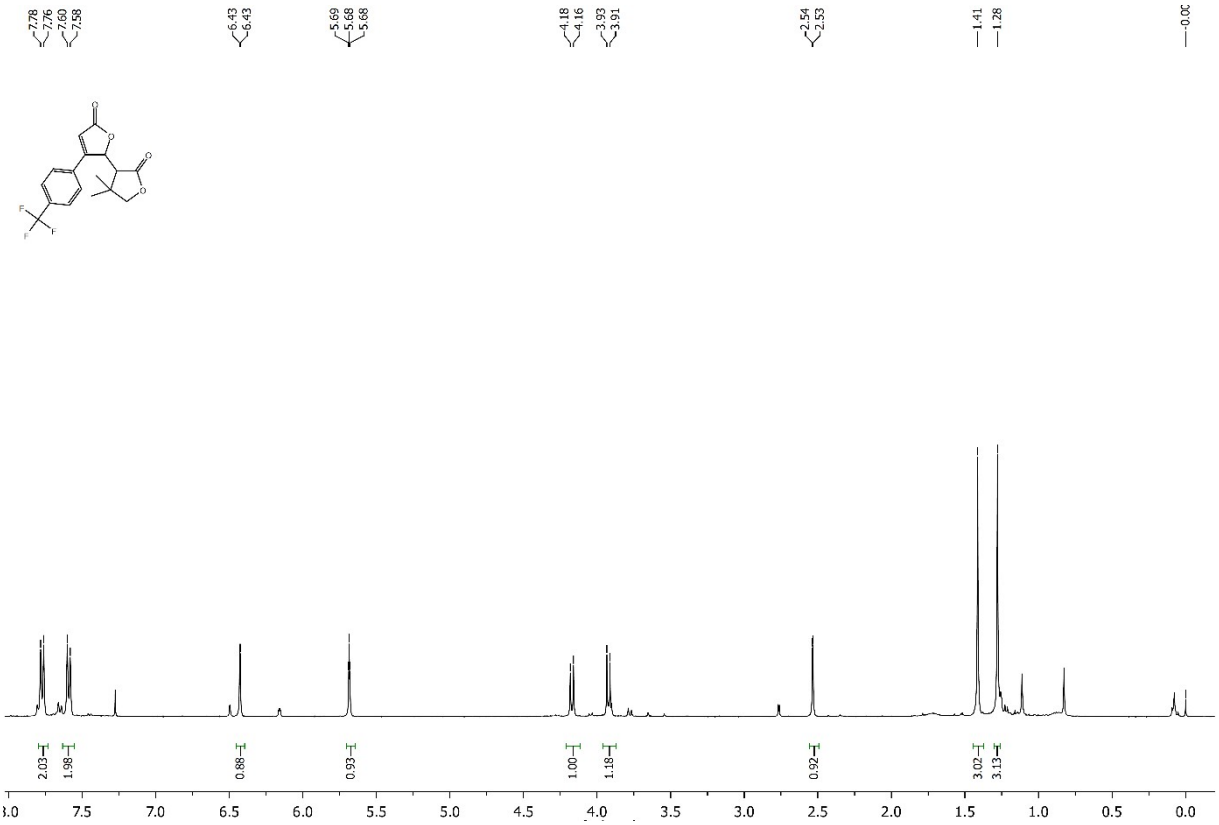


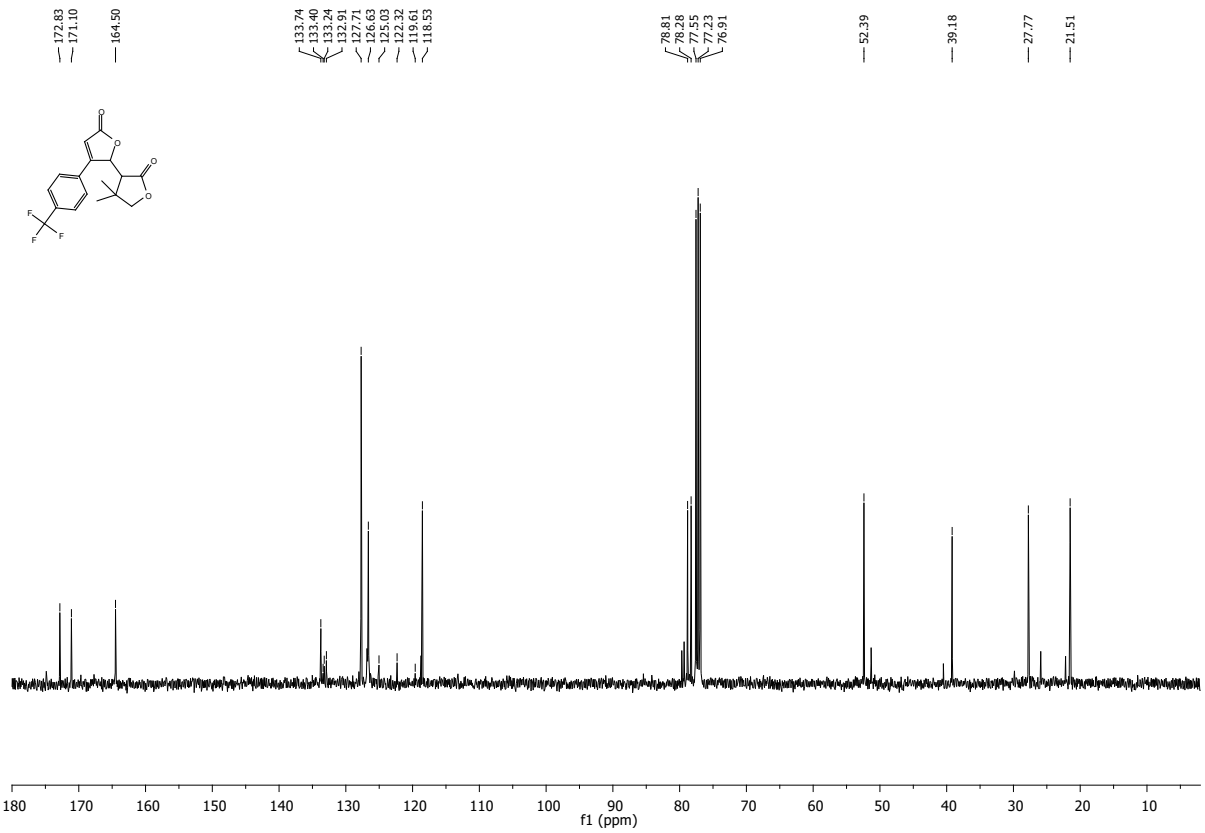
***N*-(4-(2-(4,4-Dimethyl-2-oxotetrahydrofuran-3-yl)-5-oxo-2,5-dihydrofuran-3-yl)phenyl)acetamide (3ra)**



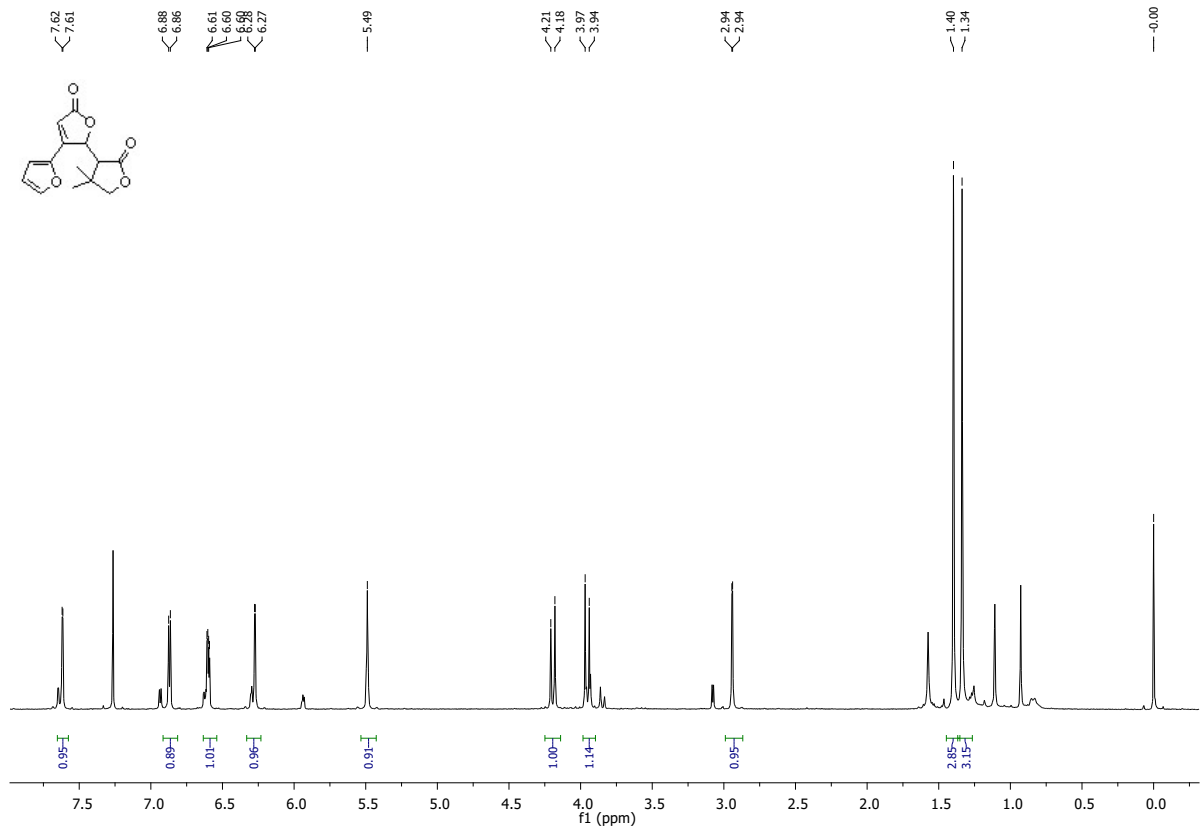


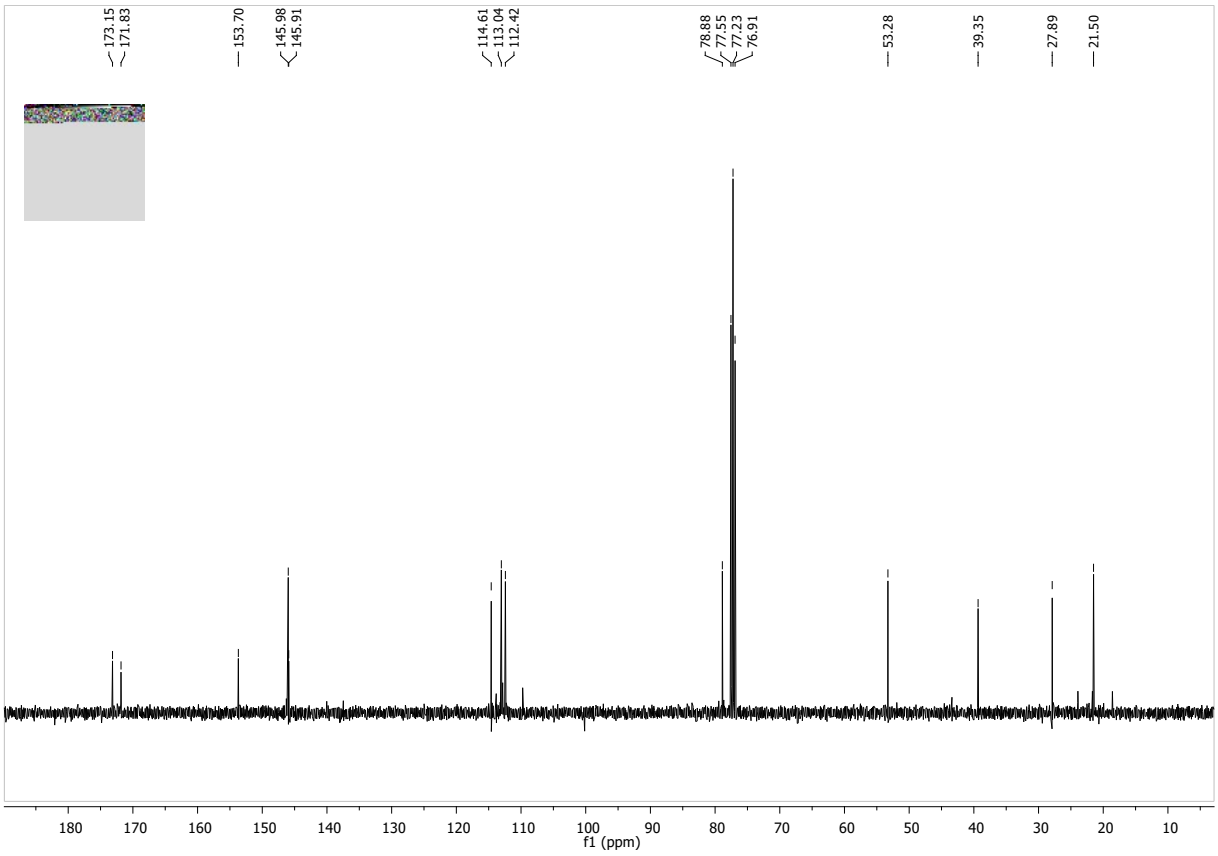
5-(4,4-Dimethyl-2-oxotetrahydrofuran-3-yl)-4-(4-(trifluoromethyl)phenyl)furan-2(5*H*)-one (3sa).



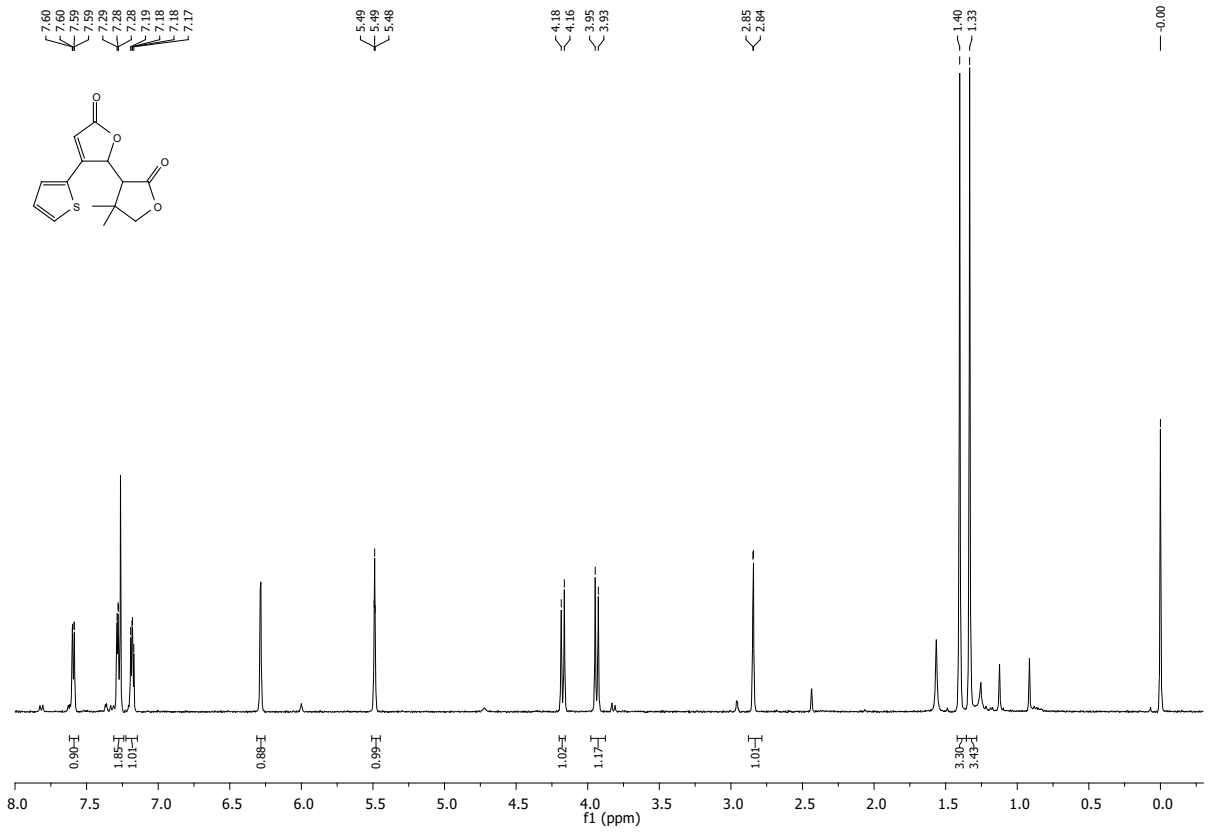


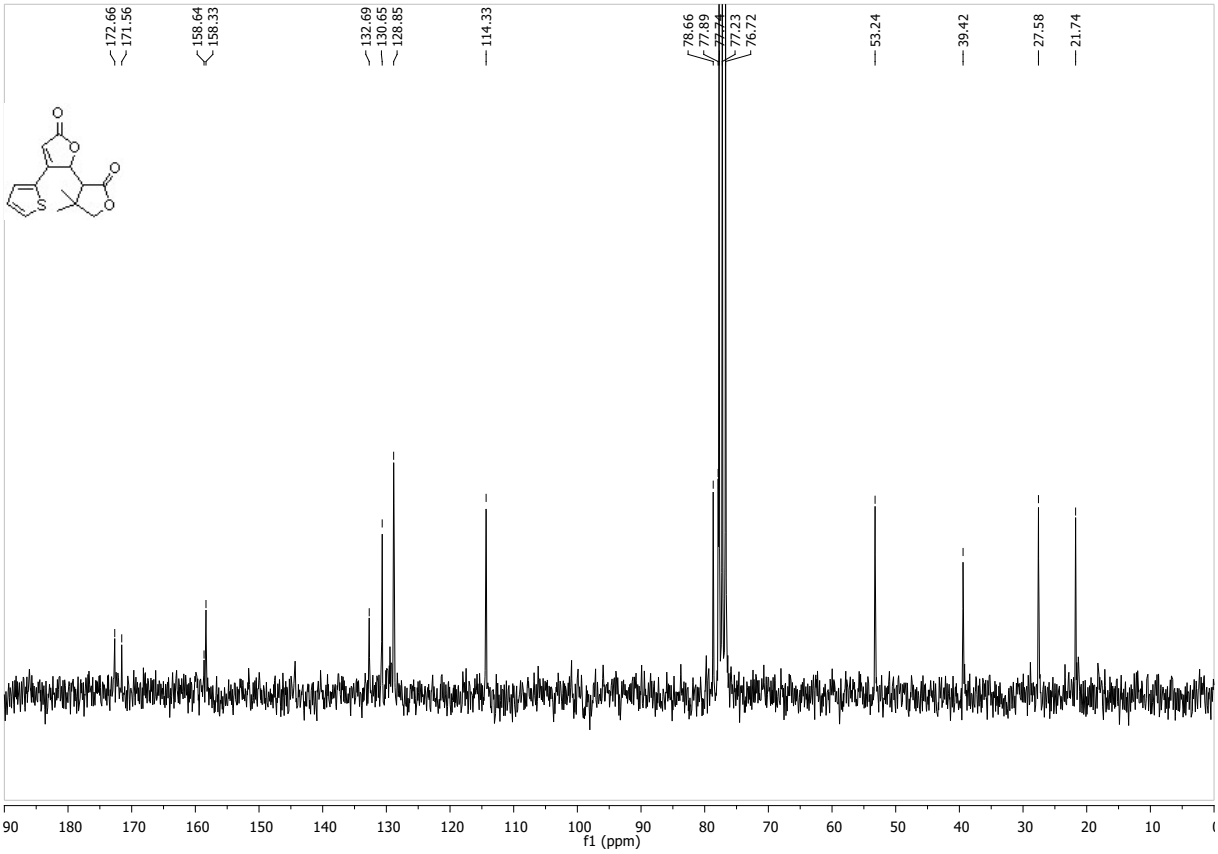
2'-(4,4-Dimethyl-2-oxotetrahydrofuran-3-yl)-[2,3'-bifuran]-5'(2'*H*)-one (3ta)



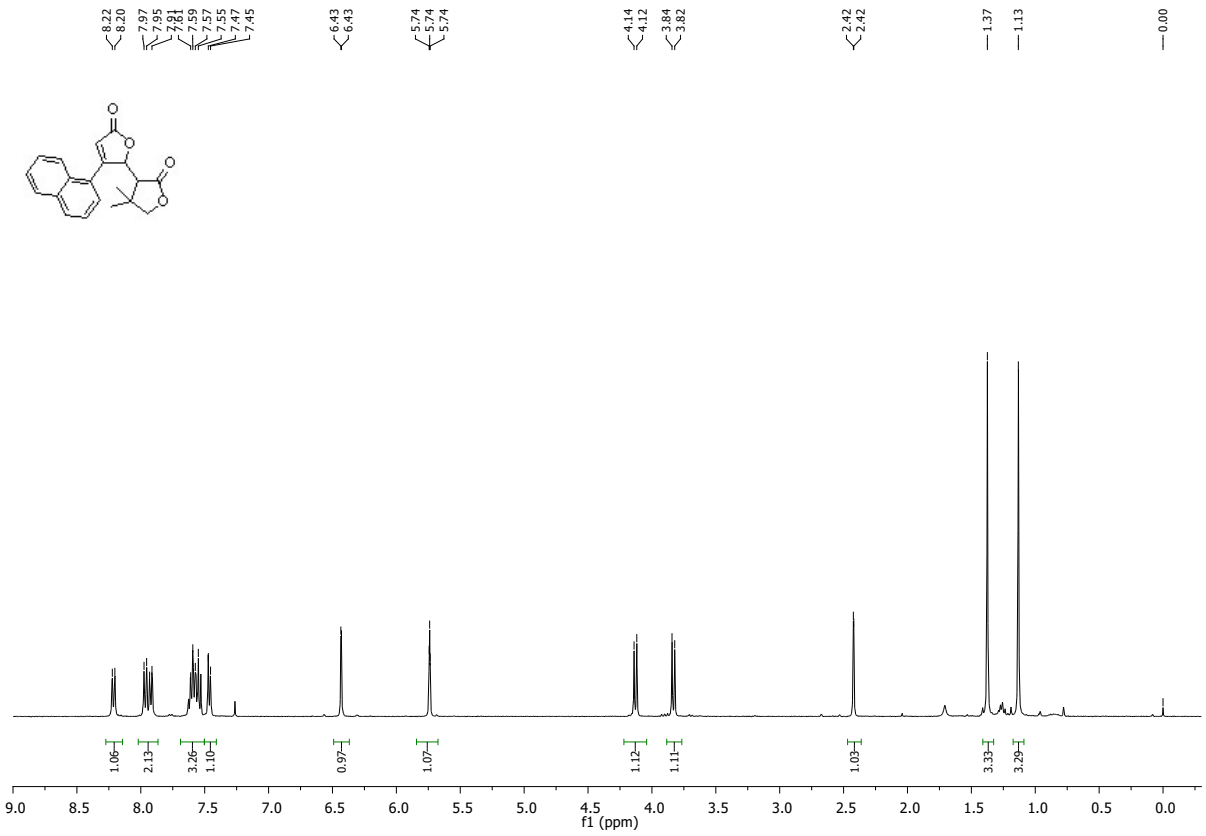


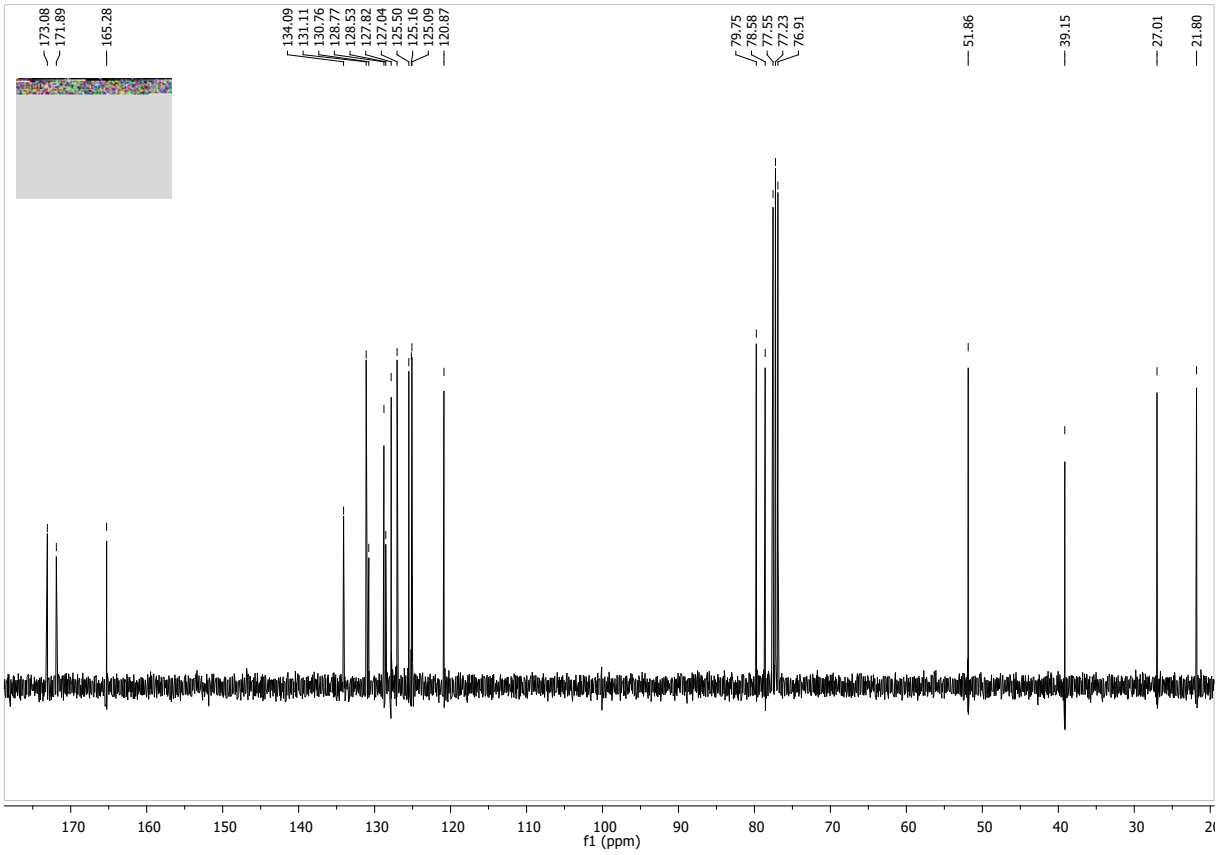
5-(4,4-Dimethyl-2-oxotetrahydrofuran-3-yl)-4-(thiophen-2-yl)furan-2(5*H*)-one (3ua)


7.60
7.60
7.59
7.59
7.29
7.28
7.28
7.19
7.18
7.18
7.17
5.49
5.49
5.48
4.18
4.16
3.95
3.93
2.85
2.84
1.40
1.33
0.00
0.90
1.85
1.01
0.88
0.99
1.02
1.17
1.01
3.30
3.43
f1 (ppm)

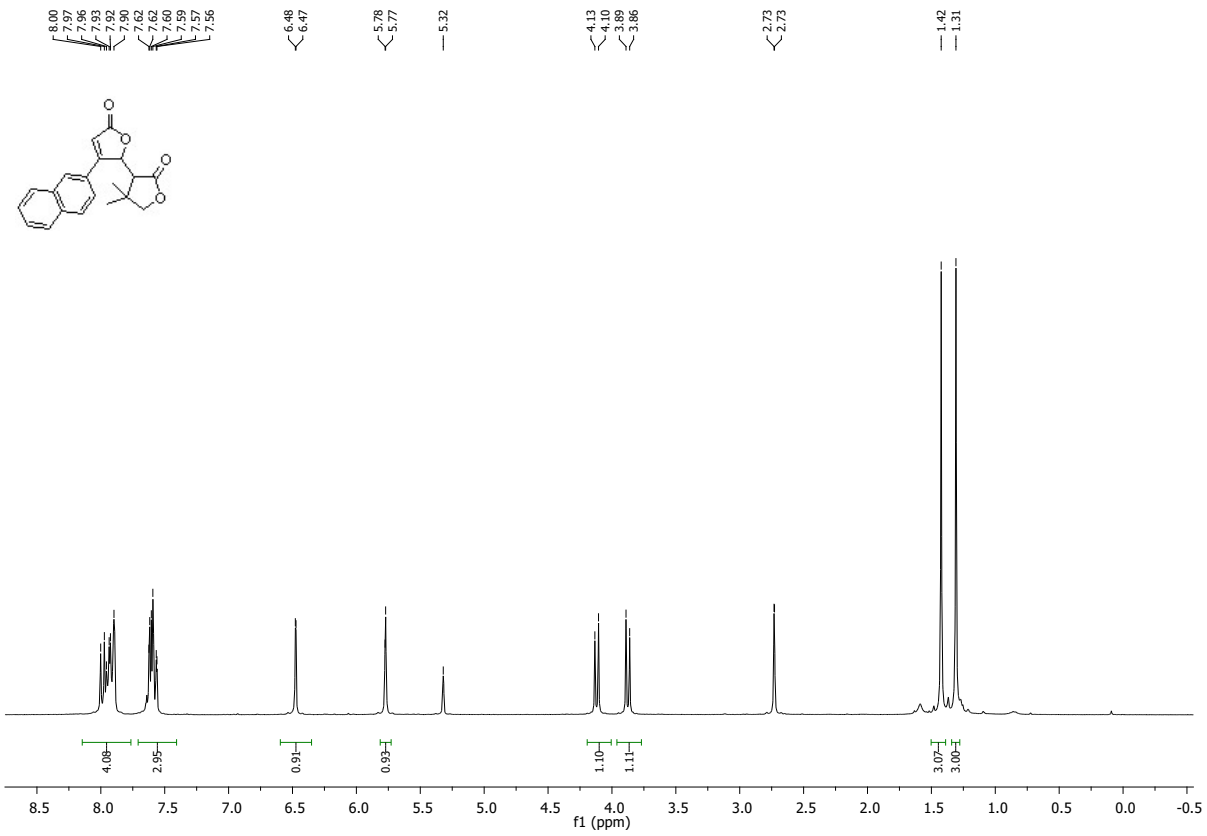

172.66
171.56
158.64
158.33
132.69
130.65
128.85
114.33
78.66
77.89
77.74
77.23
76.72
53.24
39.42
27.58
21.74
f1 (ppm)

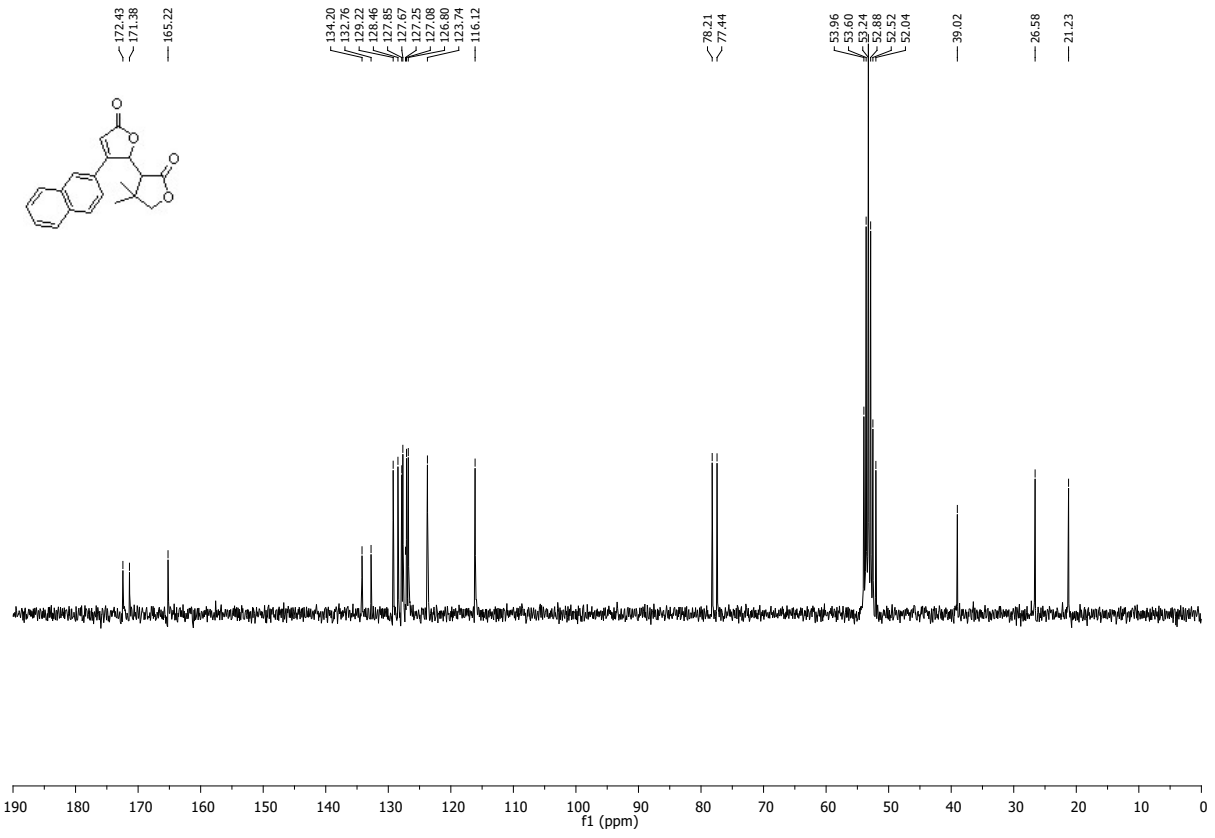
5-(4,4-Dimethyl-2-oxotetrahydrofuran-3-yl)-4-(naphthalen-1-yl)furan-2(5*H*)-one (3va)



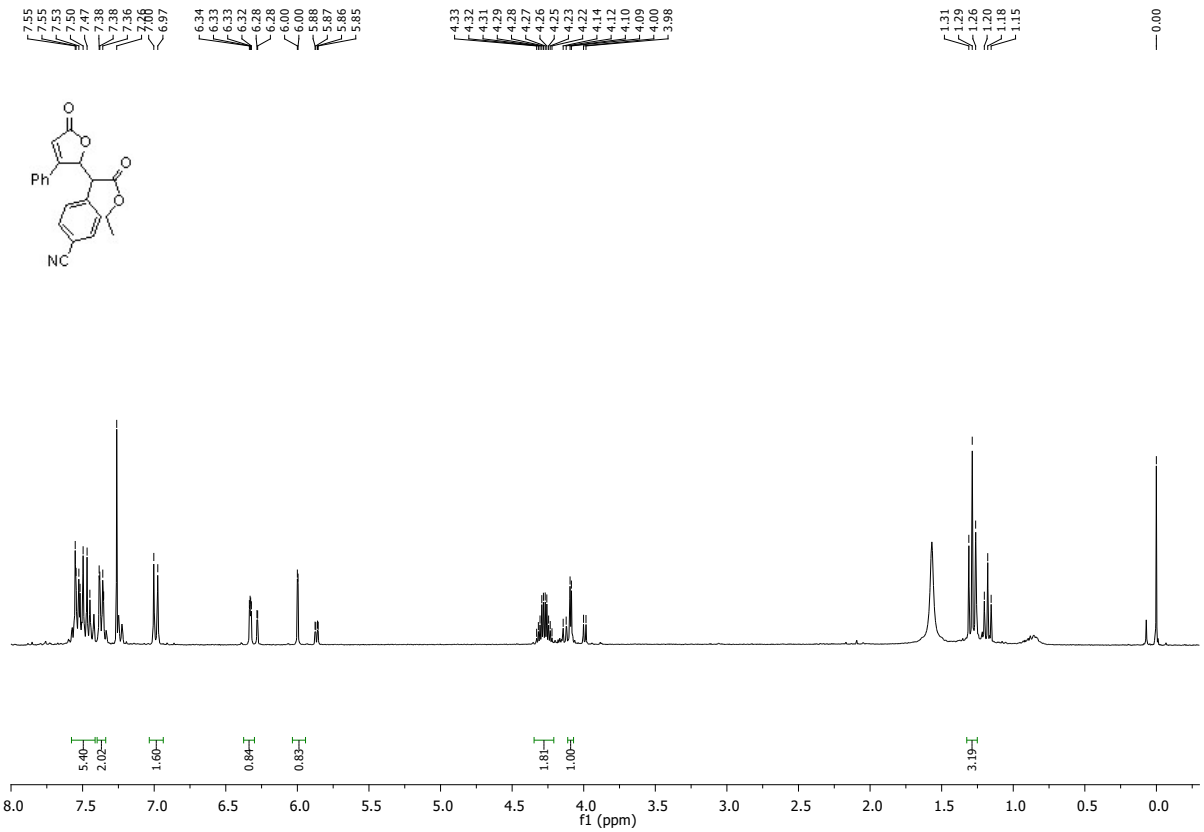


5-(4,4-Dimethyl-2-oxotetrahydrofuran-3-yl)-4-(naphthalen-2-yl)furan-2(5*H*)-one (3wa).

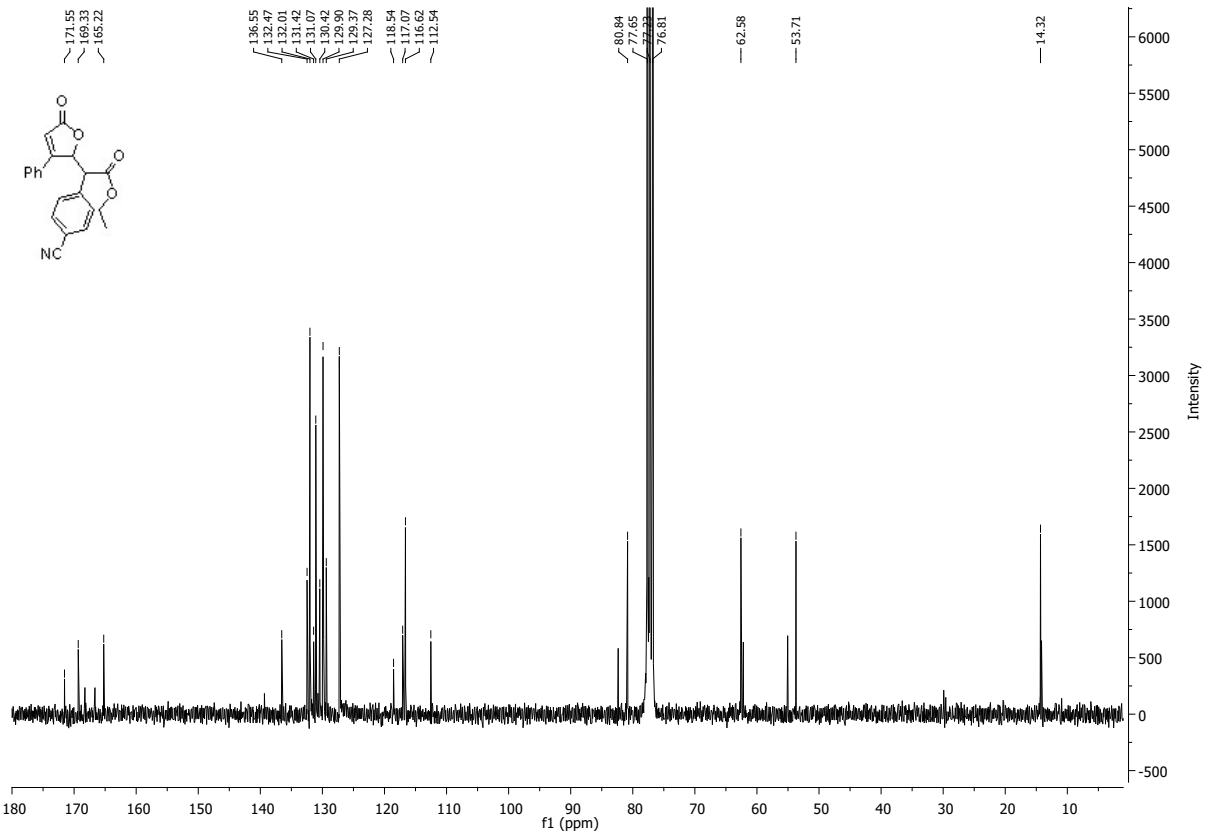

8.00
7.97
7.96
7.93
7.92
7.90
7.62
7.62
7.60
7.59
7.57
7.56
6.48
6.47
5.78
5.77
5.32
4.13
4.10
3.89
3.86
2.73
2.73
1.42
1.31
4.08
2.95
0.91
0.93
1.10
1.11
3.07
3.00
f1 (ppm)


172.43
171.38
165.22
134.20
132.76
129.22
128.46
127.85
127.67
127.25
127.08
126.80
123.74
116.12
78.21
77.44
53.96
53.60
53.24
52.88
52.52
52.04
39.02
26.58
21.23
f1 (ppm)

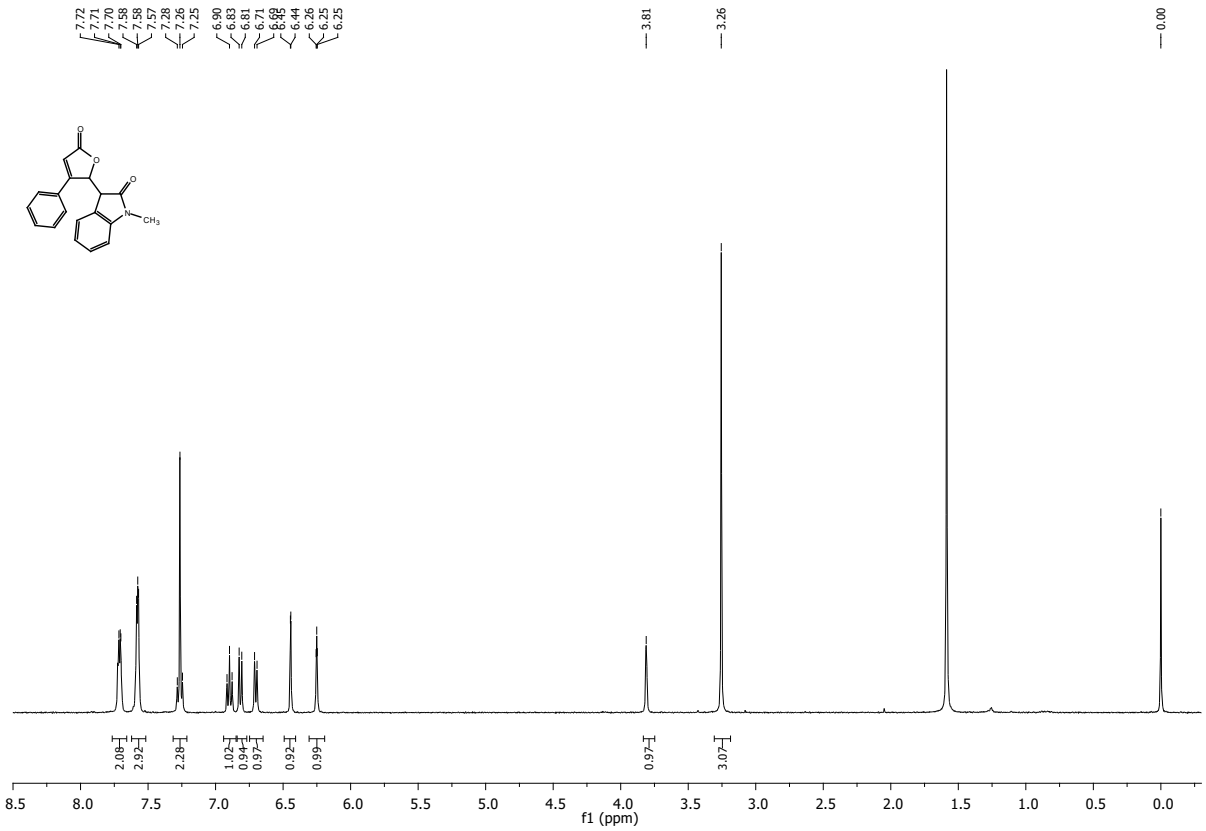
Ethyl 2-(4-cyanophenyl)-2-(5-oxo-3-phenyl-2,5-dihydrofuran-2-yl)acetate (3ab)

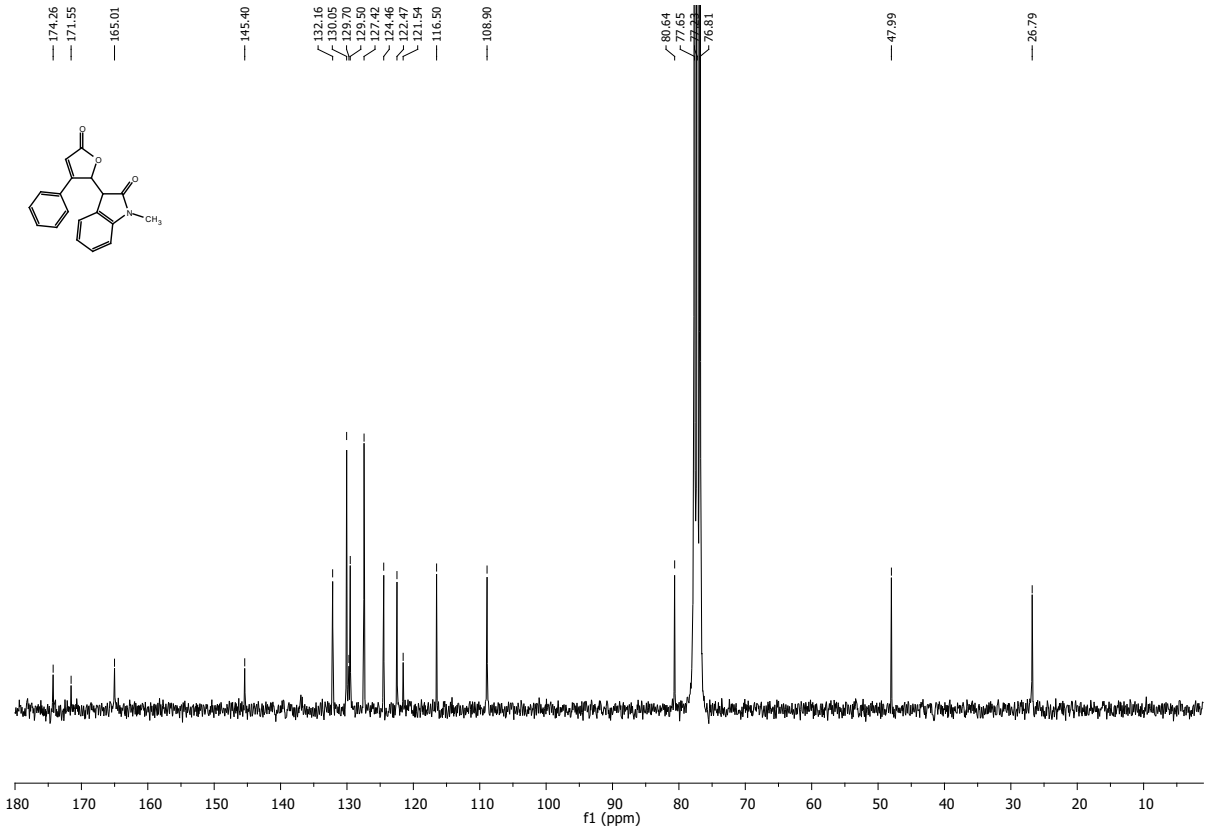


d.r. 73/27

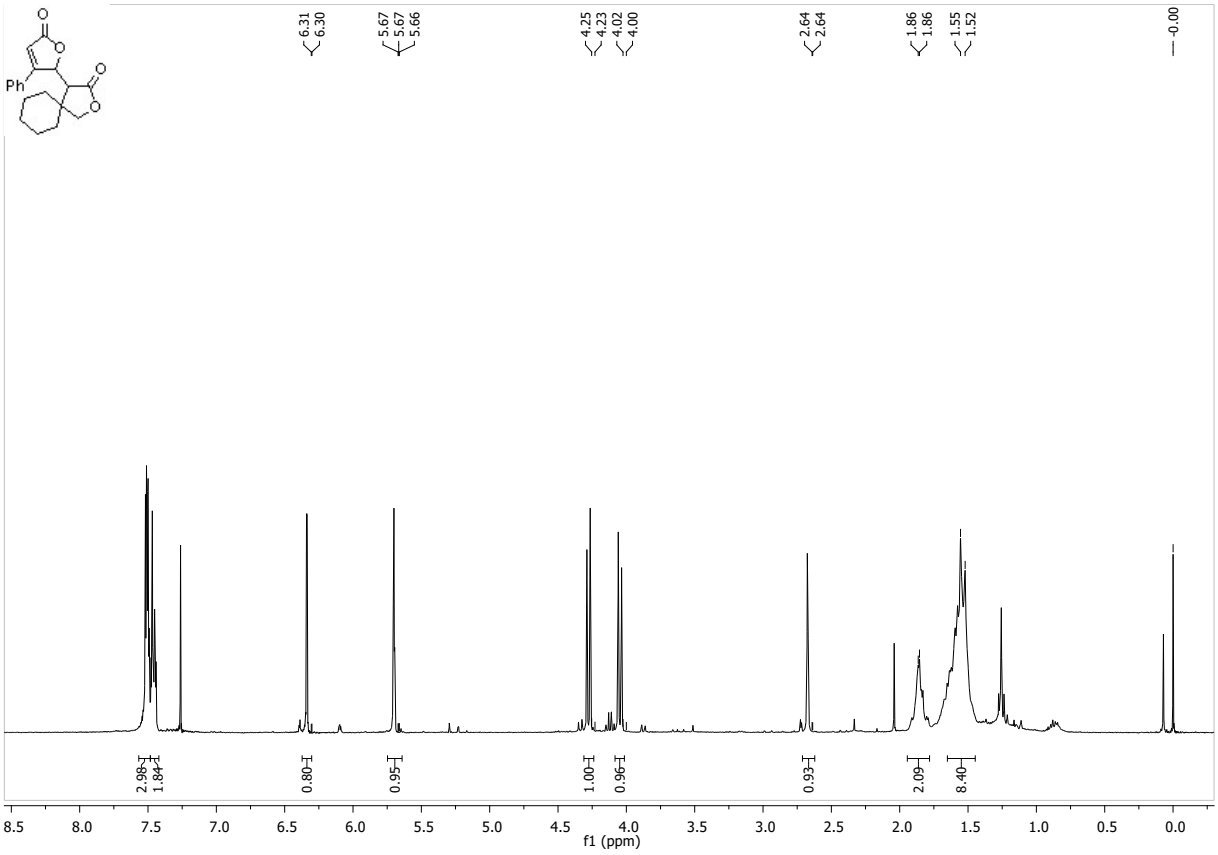


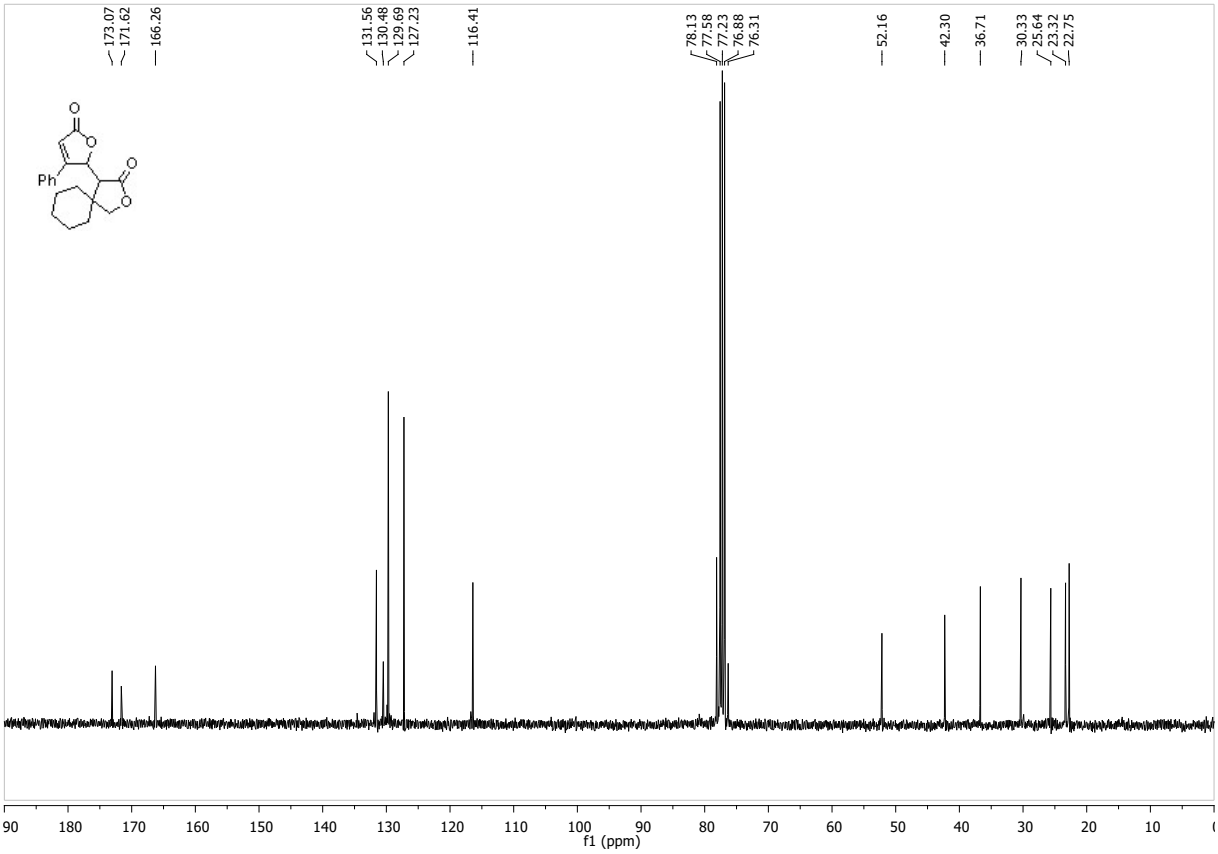
1-Methyl-3-(5-oxo-3-phenyl-2,5-dihydrofuran-2-yl)indolin-2-one (3ac)



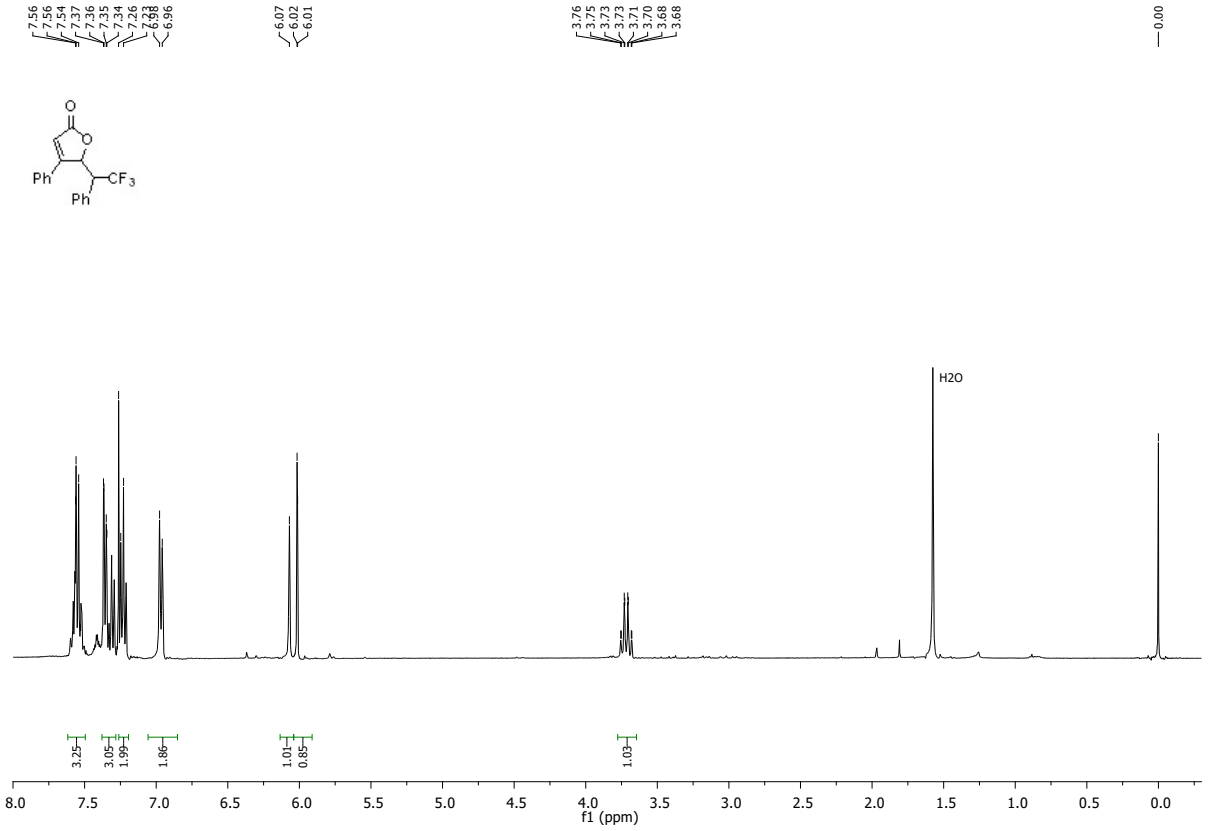


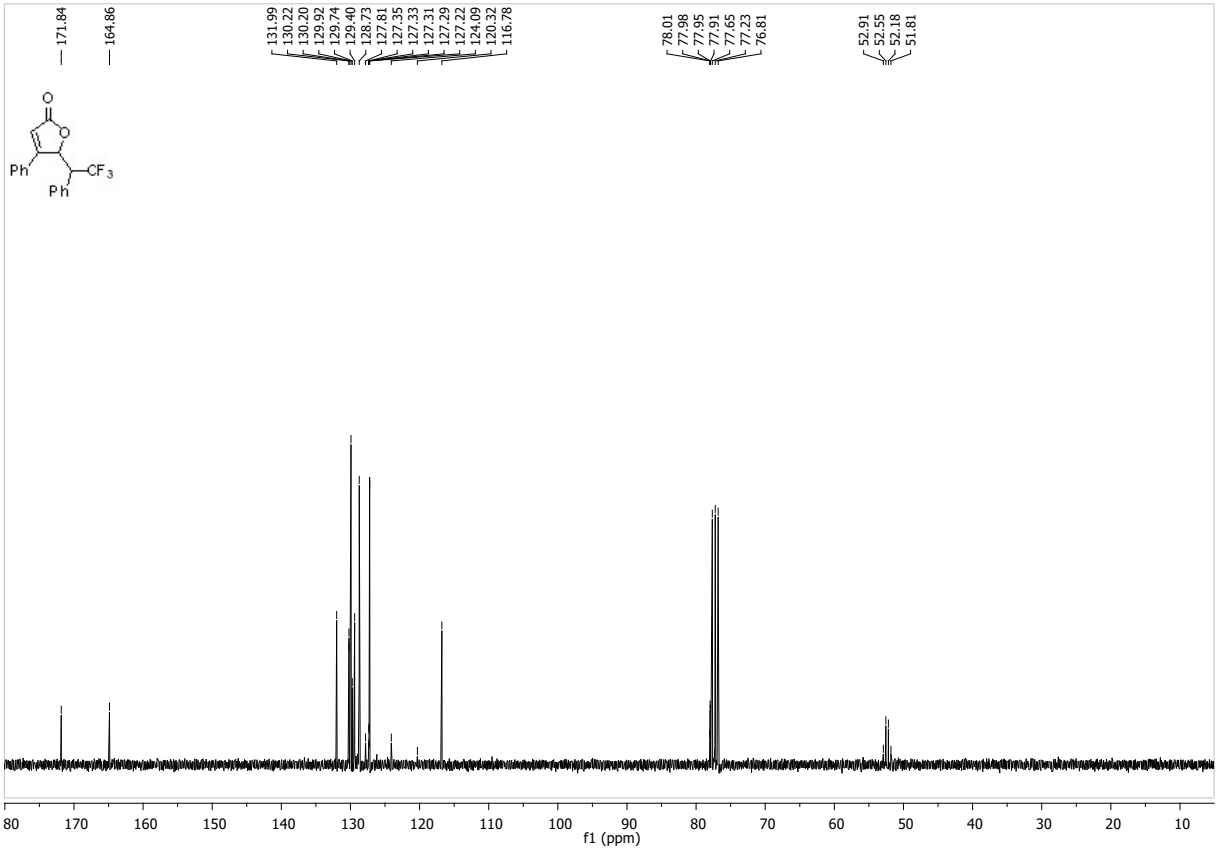
4-(5-Oxo-3-phenyl-2,5-dihydrofuran-2-yl)-2-oxaspiro[4.5]decan-3-one (3ad).


Ph
6.31
6.30
5.67
5.67
5.66
4.25
4.23
4.02
4.00
2.64
2.64
1.86
1.86
1.55
1.52
-0.00
2.98
1.84
0.80
0.95
1.00
0.96
0.93
2.09
8.40
f1 (ppm)

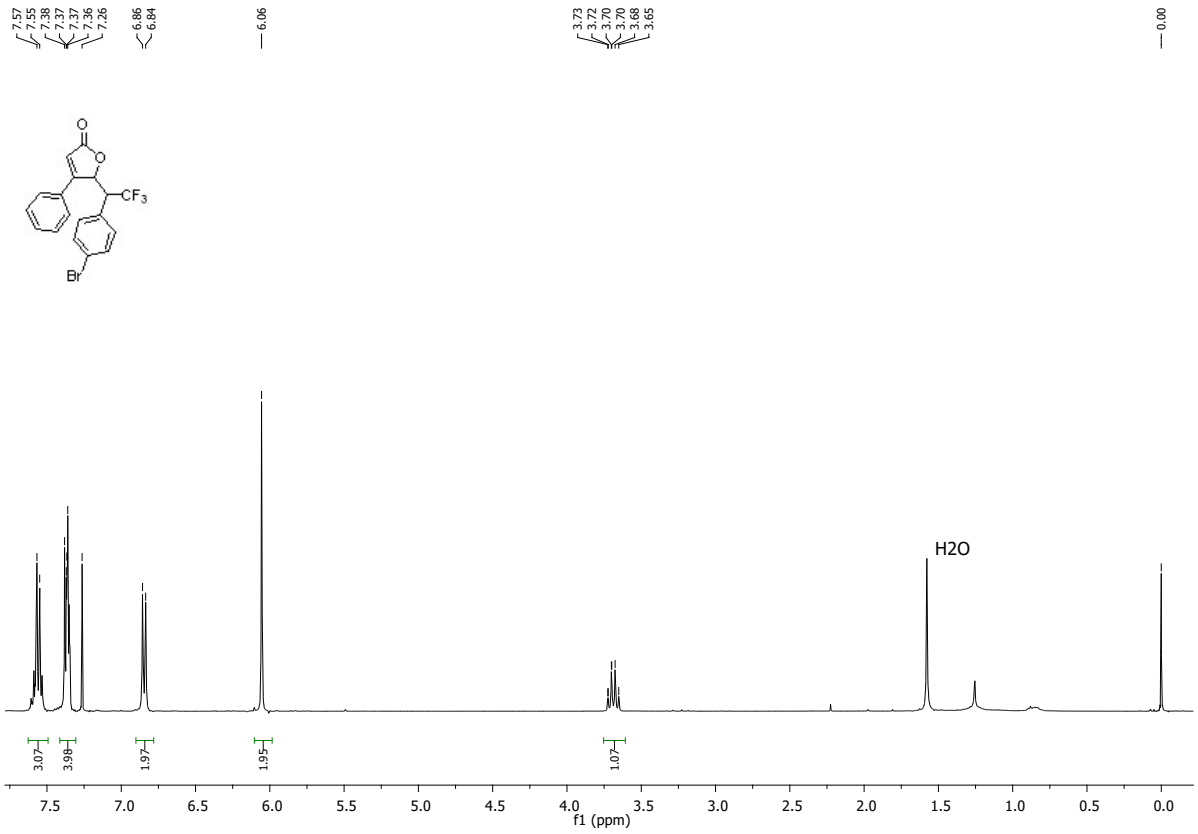

Ph
173.07
171.62
166.26
131.56
130.48
129.69
127.23
116.41
78.13
77.58
77.23
76.88
76.31
52.16
42.30
36.71
30.33
25.64
23.32
22.75
f1 (ppm)

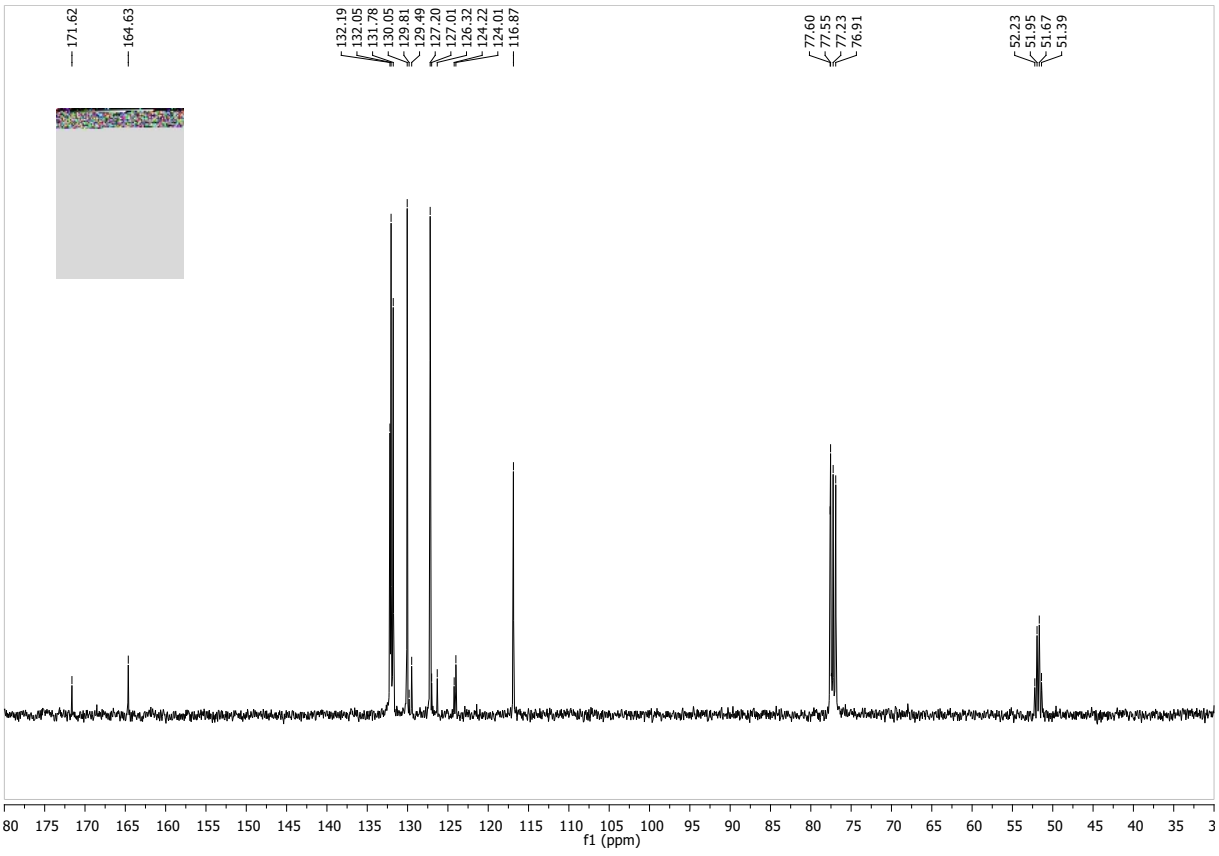
4-Phenyl-5-(2,2,2-trifluoro-1-phenylethyl)furan-2(5*H*)-one (3ae).



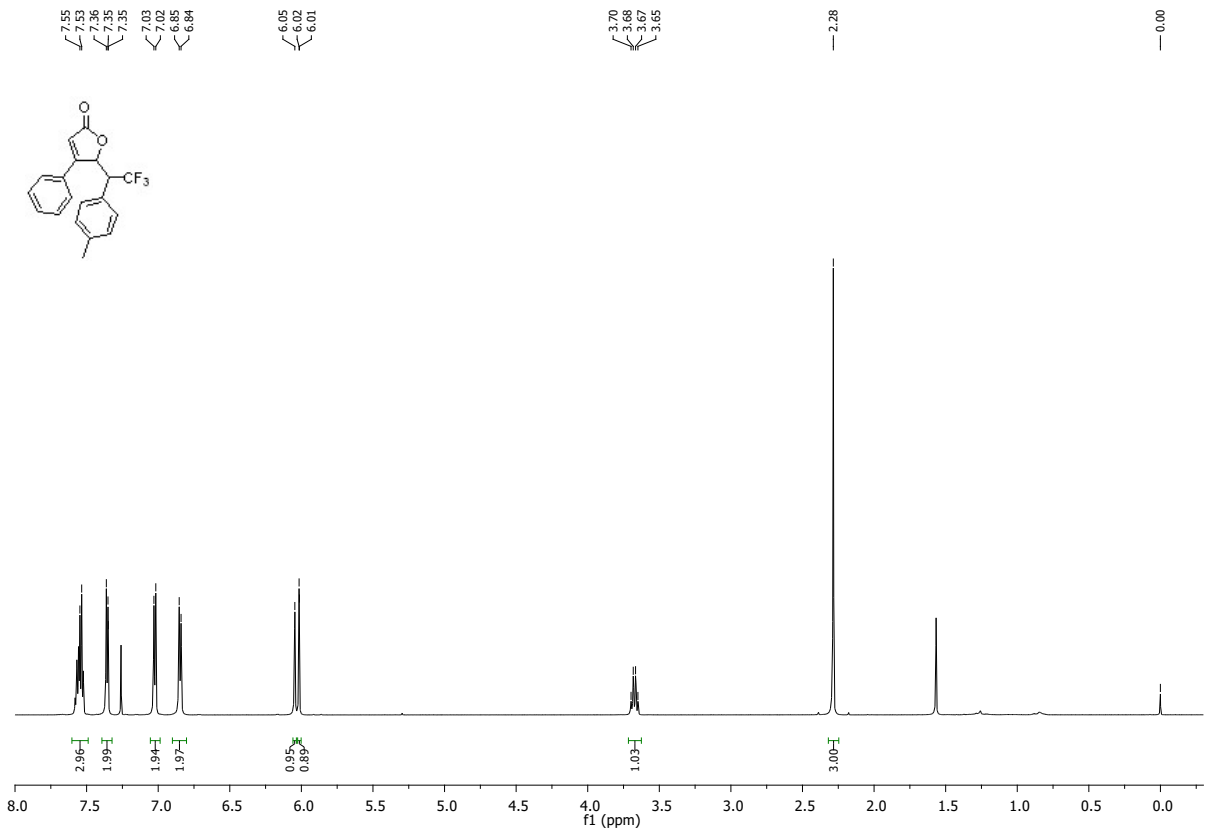


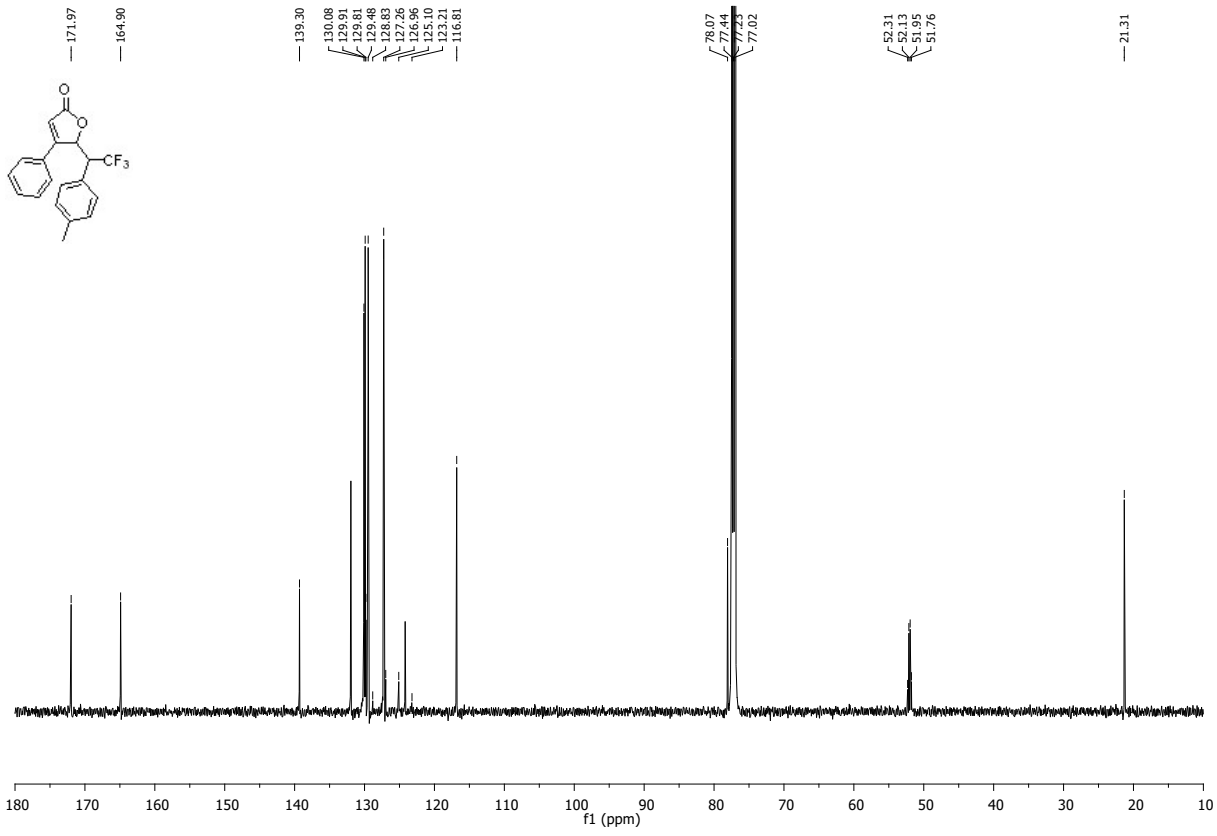
5-(1-(4-Bromophenyl)-2,2,2-trifluoroethyl)-4-phenylfuran-2(5*H*)-one (3af).



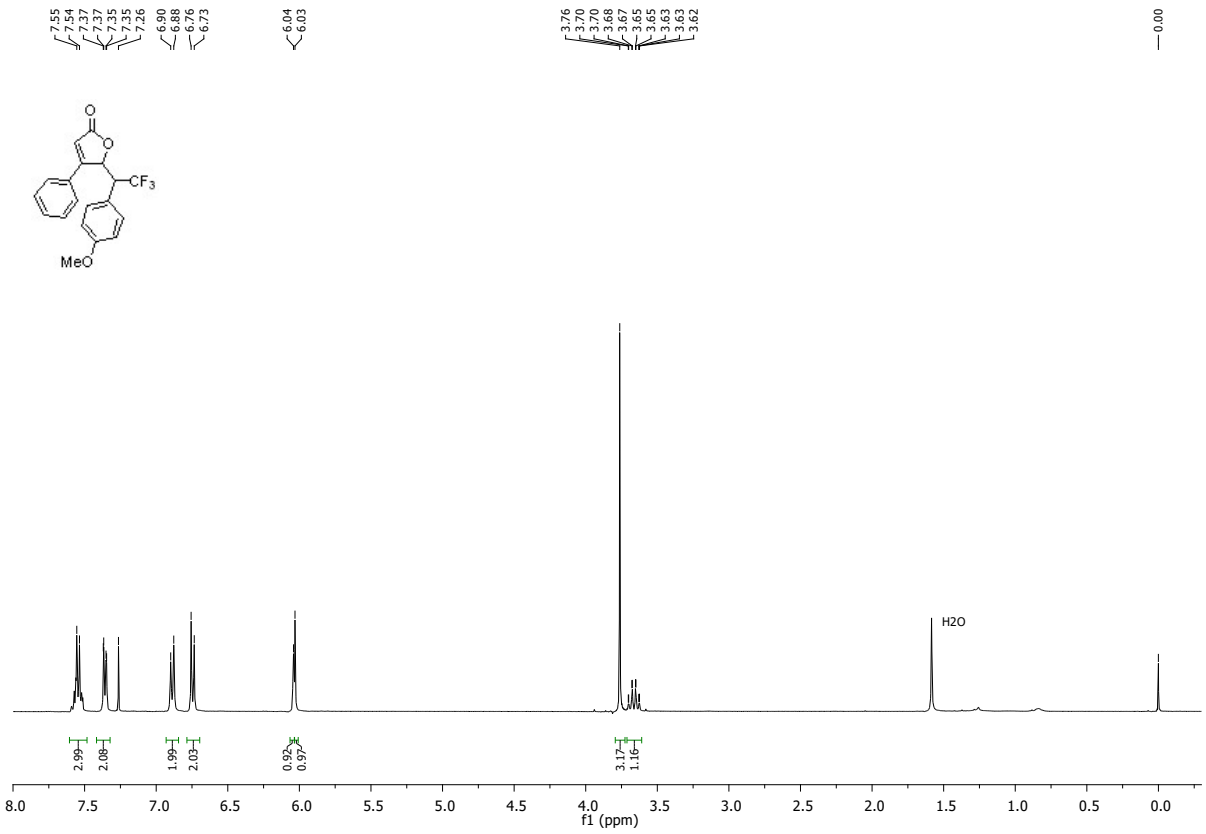


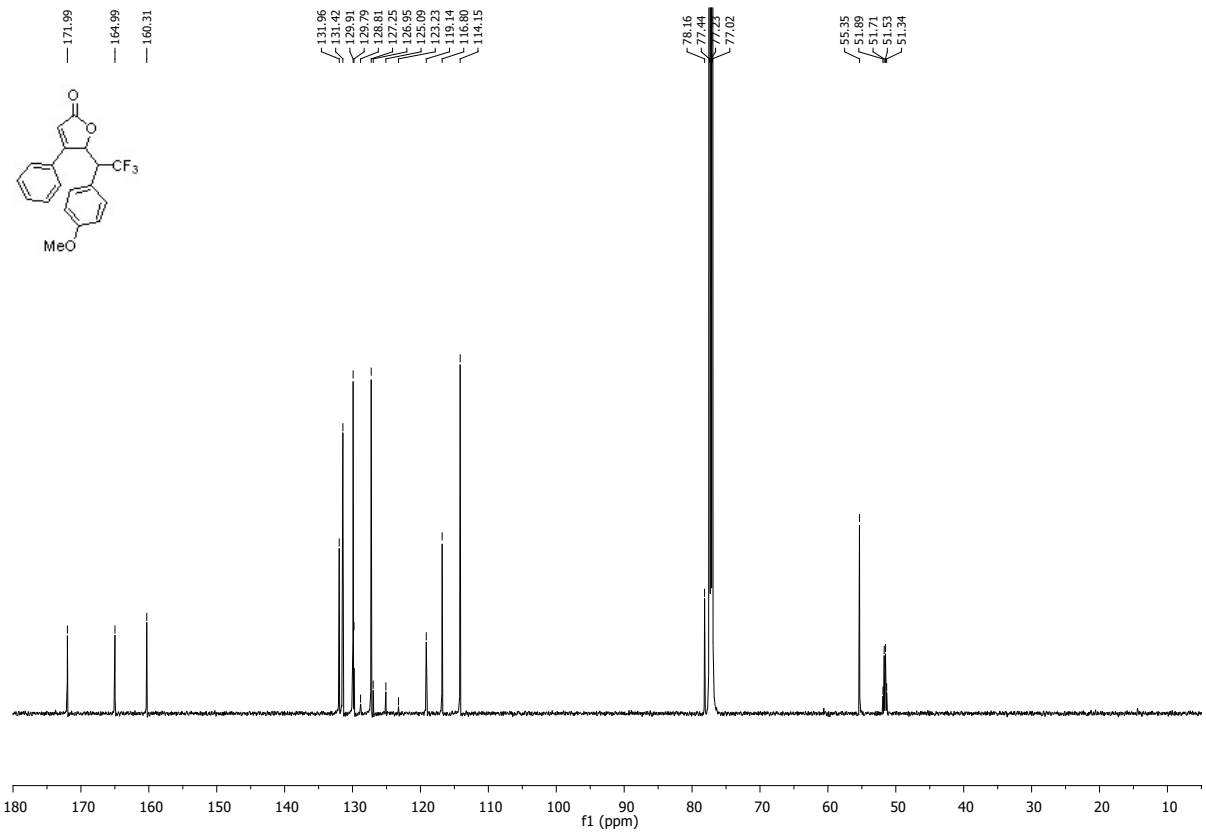
4-Phenyl-5-(2,2,2-trifluoro-1-(*p*-tolyl)ethyl)furan-2(5*H*)-one (3ag).


7.55
7.53
7.36
7.35
7.35
7.03
7.02
6.85
6.84
6.05
6.02
6.01
3.70
3.68
3.67
3.65
2.28
0.00
O
O
CF3
2.96
1.99
1.94
1.97
0.95
0.89
1.03
3.00
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

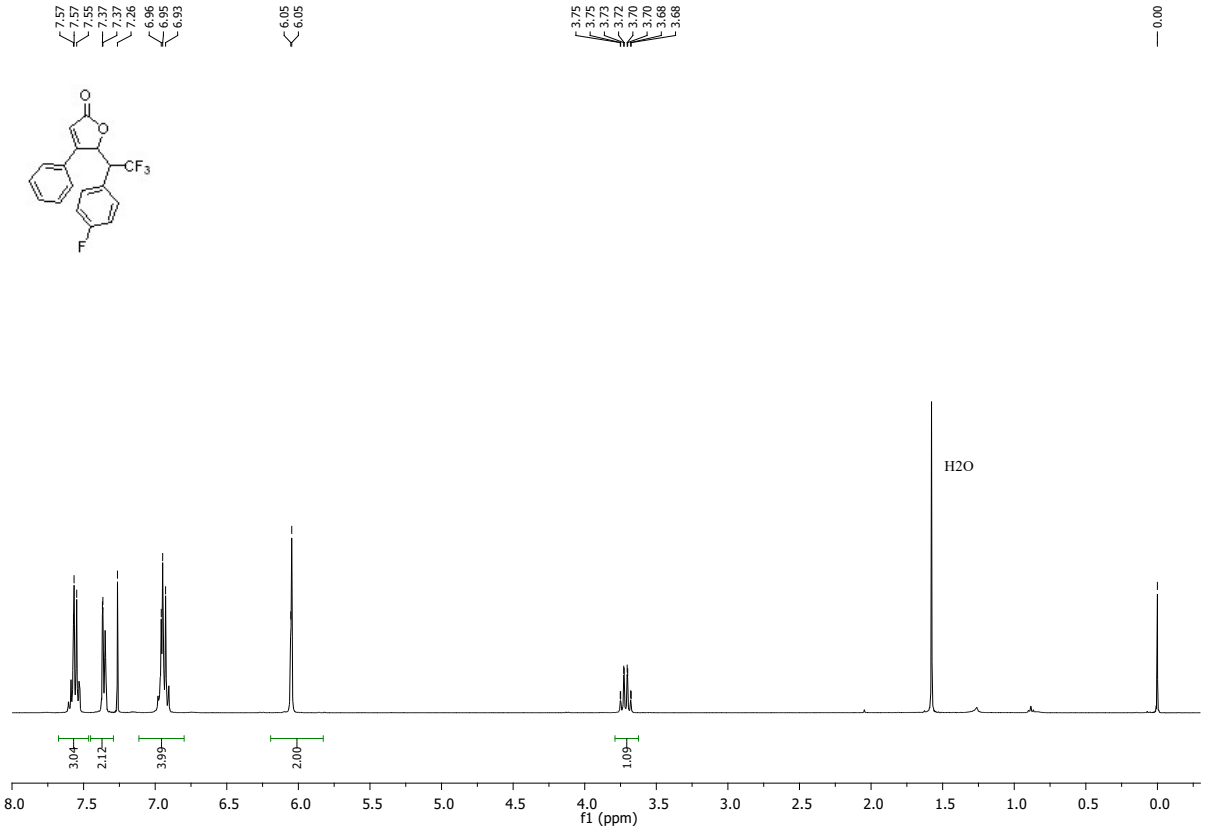

171.97
164.90
139.30
130.08
129.91
129.81
129.48
128.83
127.26
126.96
125.10
123.21
116.81
78.07
77.44
77.23
77.02
52.31
52.13
51.95
51.76
21.31
O
O
CF3
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

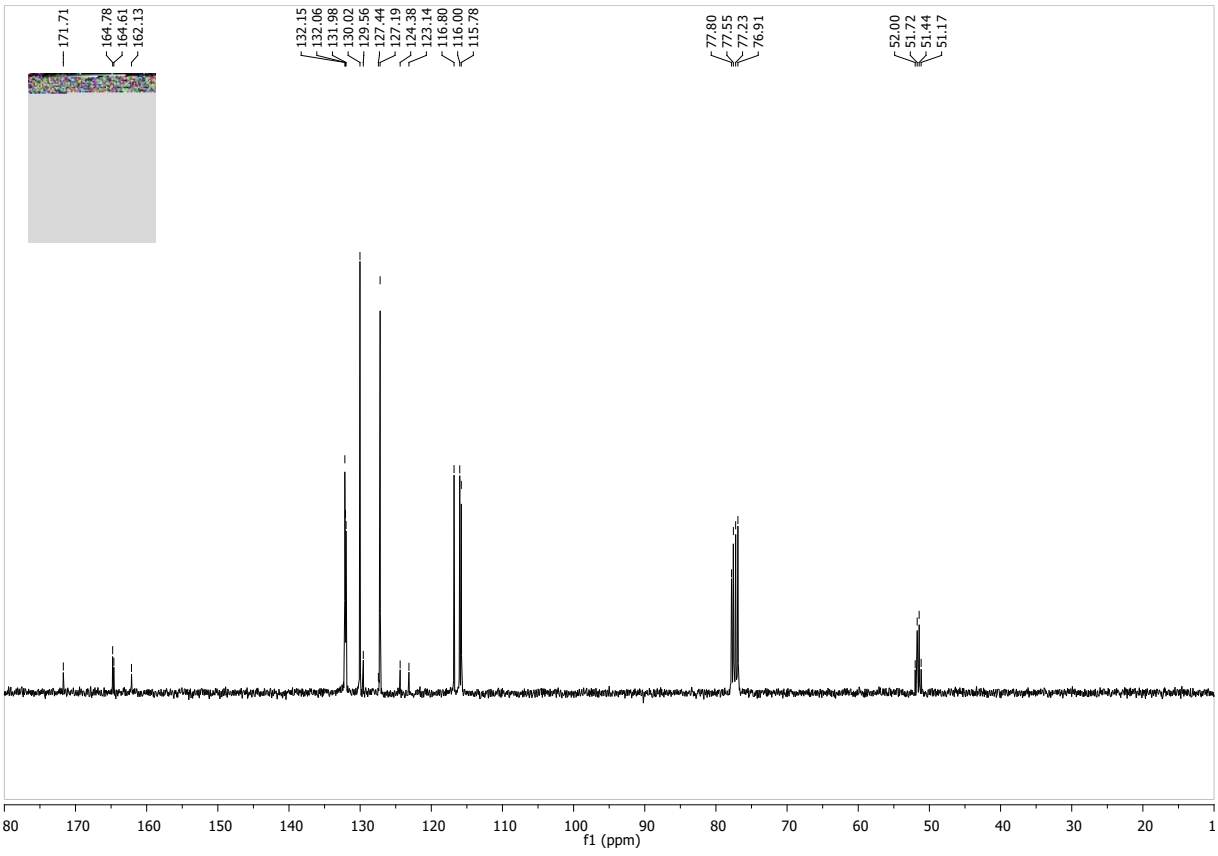
4-Phenyl-5-(2,2,2-trifluoro-1-(4-methoxyphenyl)ethyl)furan-2(5*H*)-one (3ah).



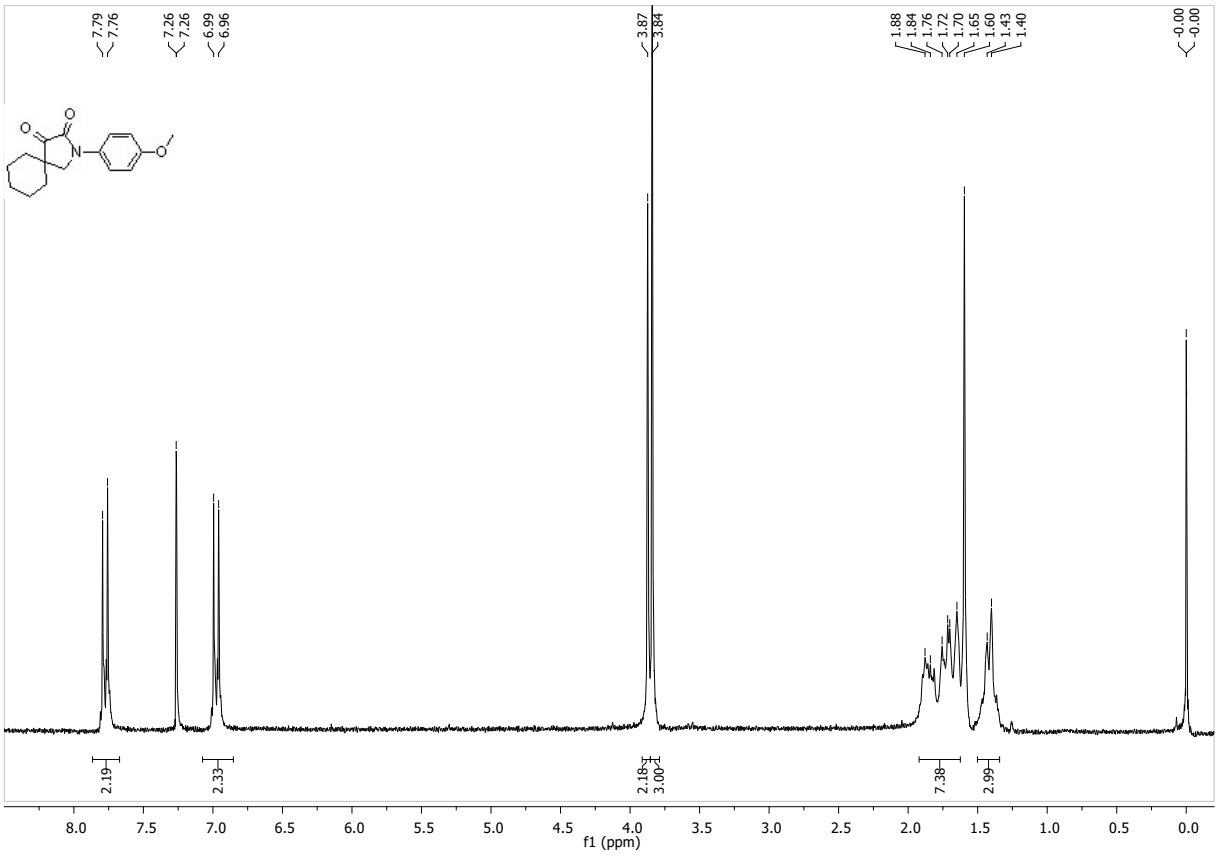


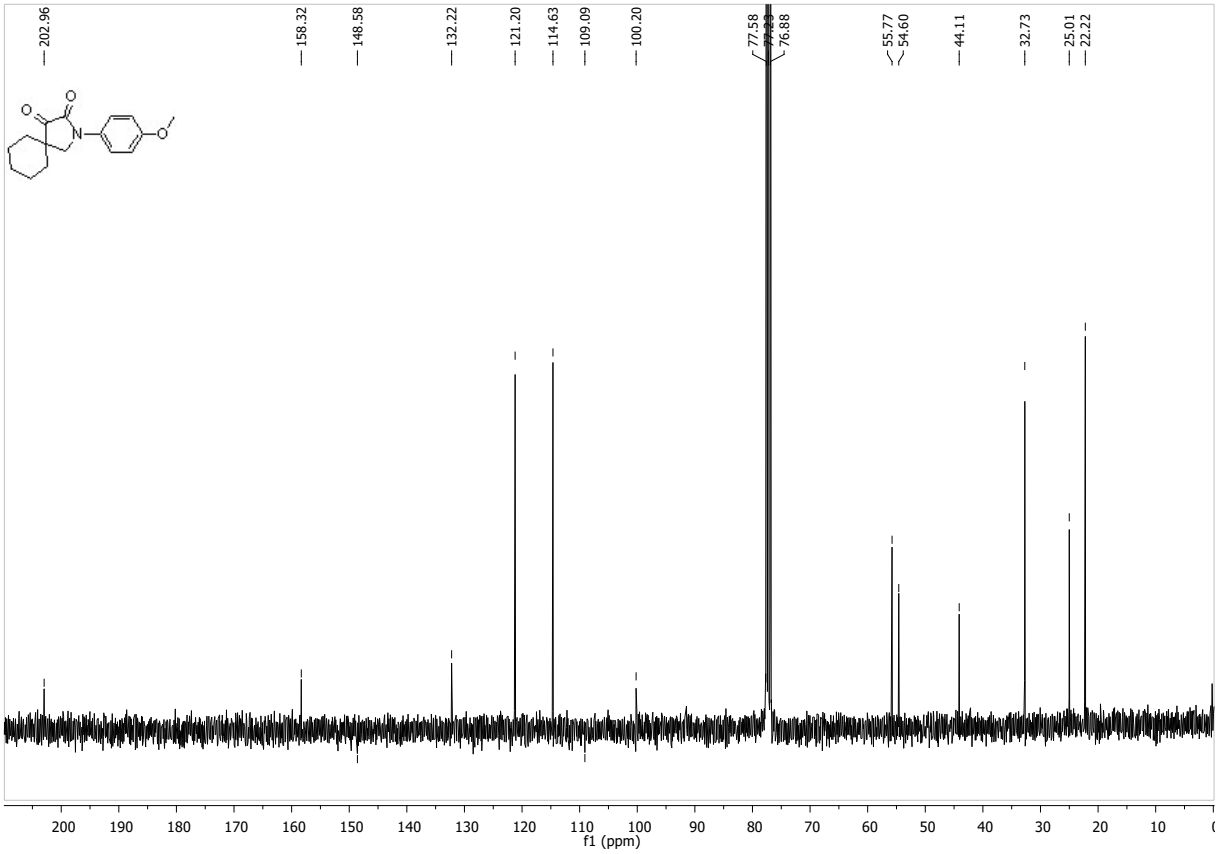
4-Phenyl-5-(2,2,2-trifluoro-1-(4-fluorophenyl)ethyl)furan-2(5*H*)-one (3ai).



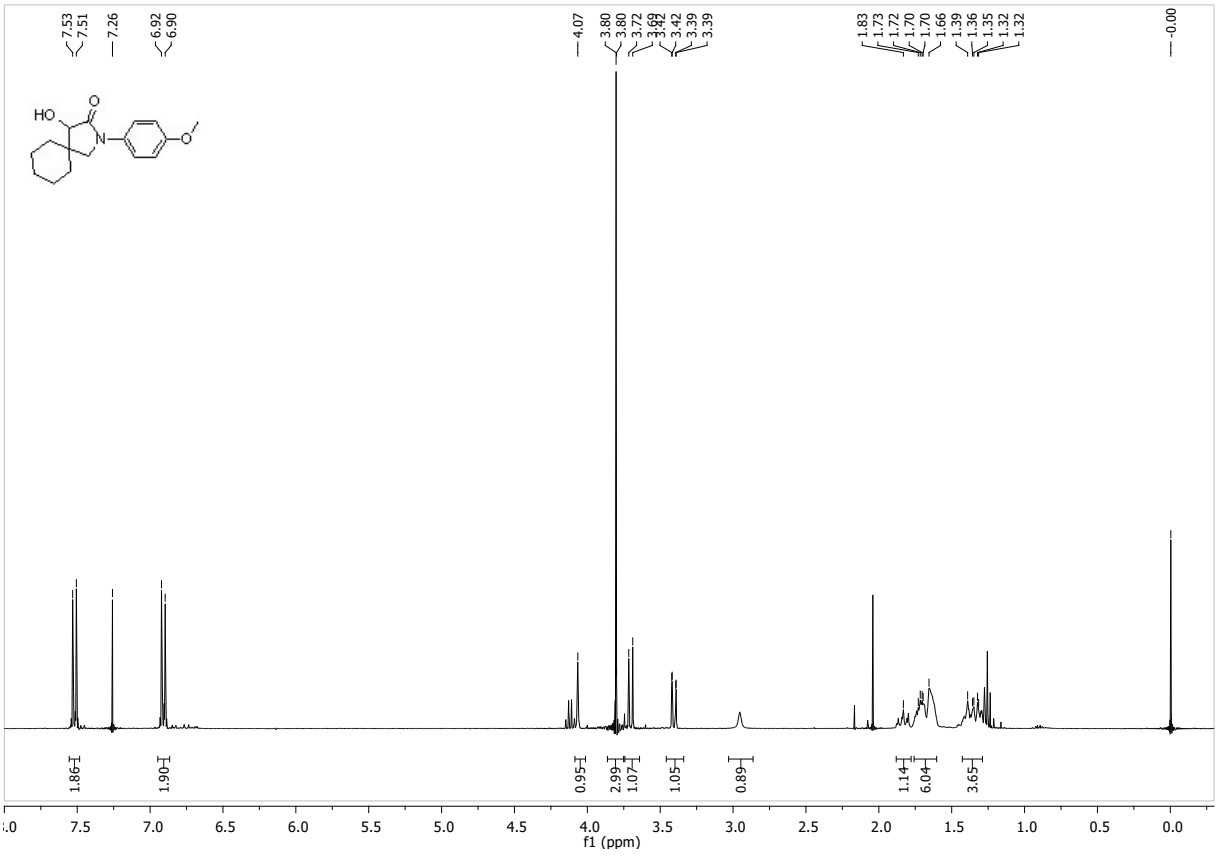


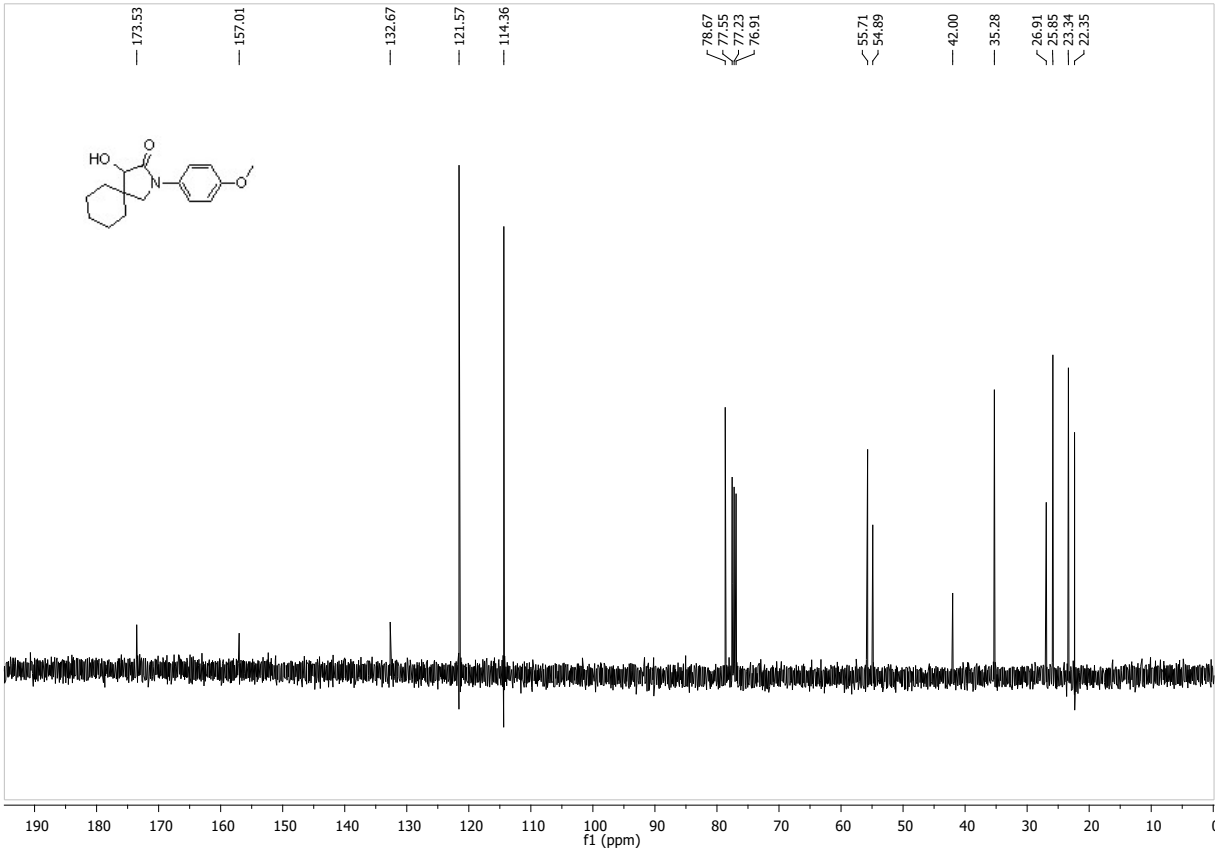
2-Oxaspiro[4.5]decane-3,4-dione (2d)


7.79
7.76
7.26
7.26
6.99
6.96
3.87
3.84
1.88
1.84
1.76
1.72
1.70
1.65
1.60
1.43
1.40
-0.00
-0.00
2.19
2.33
2.18
3.00
7.38
2.99
f1 (ppm)


202.96
158.32
148.58
132.22
121.20
114.63
109.09
100.20
77.58
76.88
55.77
54.60
44.11
32.73
25.01
22.22
f1 (ppm)

4-Hydroxy-2-oxaspiro[4.5]decan-3-one (B)





Crystallographic data for 3aa.

Single-Crystal X-ray Diffraction for 3aa.

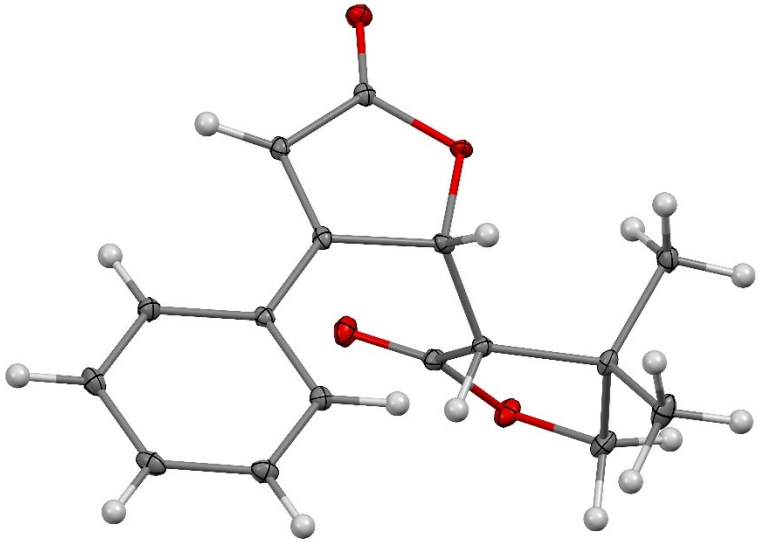


Figure S1 - An ORTEP drawing of compound **3aa.** *Thermal ellipsoids are shown at the 30% level.*

X-ray diffraction data for compound **3aa** were collected by using a VENTURE PHOTON100 CMOS Bruker diffractometer with Micro-focus IuS source Mo Kα radiation. Crystal of compound was selected under a polarizing optical microscope and glued in paratone oil. Crystal was mounted on a CryoLoop (Hampton Research) with Paratone-N (Hampton Research) as cryoprotectant and then flashfrozen in a nitrogen-gas stream at 100 K. The temperature of the crystal was maintained at the selected value by means of a N-Helix cooling device to within an accuracy of ±1K. Data reduction was accomplished using SAINT V7.53a. The substantial redundancy in data allowed a semi-empirical absorption correction (SADABS V2.10) to be applied, on the basis of multiple measurements of equivalent reflections. The structures were solved by direct methods using SHELXS-97[2] and refined against F^2 by full-matrix least-squares techniques using SHELXL-2018[3] with anisotropic displacement parameters for all non-hydrogen atoms. Hydrogen atoms were located on a difference Fourier map and introduced into the calculations as a riding model with isotropic thermal parameters. All calculations were performed by using the Crystal Structure crystallographic software package WINGX.[4]

CCDC 2350164 contains the supplementary crystallographic data for this paper. These data can be obtained free of charge from the Cambridge Crystallographic Data Centre and Fachinformationszentrum Karlsruhe via http://www.ccdc.cam.ac.uk/structures/.

The crystal data collection and refinement parameters are given in Table SRX1.

Table SRX1 - ***Crystallographic data and structure refinement details.***

[2] G. M. Sheldrick, SHELXS-97, Program for Crystal Structure Solution, University of Göttingen, Göttingen, Germany, **1997**.
[3] G. M. Sheldrick, *Acta Crystallogr., Sect. A: Found. Crystallogr.,* **2008**, *64*, 112-122.
[4] L. J. Farrugia, *J. Appl. Cryst*. **1999**, *32*, 837.
[4] G. Bernardinelli and H. D. Flack, Acta Crystallogr., Sect. A: Found. Crystallogr., **1985**, 41, 500-511

Compound	**3aa**
CCDC	2350164
Empirical Formula	$C_{16}H_{16}O_4$
M_r	272.29
Crystal size, mm^3	0.12 x 0.05 x 0.04
Crystal system	monoclinic
Space group	$P\ 2_1/n$
a, Å	6.2670(4)
b, Å	24.5964(17)
c, Å	8.6870(6)
α, °	90
β, °	97.236(2)
γ, °	90
Cell volume, $Å^3$	1328.40(16)
Z ; Z’	4 ; 1
T, K	100(1)
Radiation type ; wavelength Å	MoKα ; 0.71073
F_{000}	576
μ, mm^{-1}	0.098
range, °	2.504 - 32.640
Reflection collected	43 783
Reflections unique	4 855
R_{int}	0.1547
GOF	1.011
Refl. obs. (I>2(I))	3 046
Parameters ; restraints	183 ; 0
wR_2 (all data)	0.1257
R value (I>2(I))	0.0633
Largest diff. peak and hole (e-.$Å^{-3}$)	0.444 ; -0.310