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Supporting Information

Access to Sulfonylated Furans or Imidazo[1,2-a]pyridines via a Metal-free Three-Component, Domino Reaction

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List of Contents

A. General consideration……S2

B. General procedure……..S2

C. Characterization data……S2

D. ^{1}H and ^{13}C NMR spectra …… S13

A. General consideration

^{1}H and ^{13}C NMR spectra were recorded at 400 and 100 Hz, respectively.. Mass spectra were recorded were obtained on a ESIMS. Elemental analyses were performed with a elemental analyzer. GC-MS was obtained using electron ionization. TLC was performed using commercially prepared 100-400 mesh silica gel plates.

B. General procedure.

Synthesis of 4a according to the following procedure:

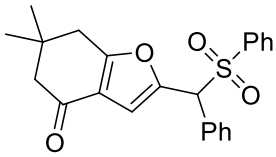
A 25 mL-schlenk tube was charged with a stirring bar, and added 5,5-dimethylcyclohexane-1,3-dione **1a** (0.084g or 0.140g, 1.2 equiv), 3-phenylpropiolaldehyde **2a** (0.065g or 0.130g, 1.0 equiv), sodium benzenesulfinate **3a** (0.114g or 0.230g, 1.4 equiv), and TFA (0.114g or 0.228g, 2.0 equiv) in CH_2Cl_2 (3 mL or 5 mL). The reaction was allowed to stir at room temperature under N_2 atmosphere until the complete consumption of **2a** was monitored by TLC analysis. And the solvent was then removed and the crude product was separated by column chromatography (eluted with petroleum ether : ethyl acetate = 5:1) to give a pure sample of **4a** in 85% or 83% yield (200.9mg or 370.2mg), respectively.

Synthesis of 5a according to the following procedure:

A 25 mL-schlenk tube was charged with a stirring bar, and added pentane-2,4-dione 1**d** (1.2 mmol), 3-phenylpropiolaldehyde **2a** (0.5 mmol), sodium benzenesulfinate **3a** (1.4 equiv), and TFA (10 mol%) in CH_2Cl_2 (3 mL). The reaction was allowed to stir at room temperature under N_2 atmosphere until the complete consumption of **2a** was monitored by TLC analysis. And the solvent was then removed and the crude product was separated by column chromatography (eluted with petroleum ether : ethyl acetate = 8:1) to give a pure sample of **5a**.

C. Characterization data

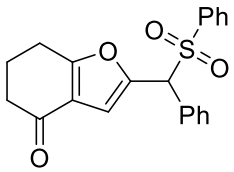
6,6-dimethyl-2-(phenyl(phenylsulfonyl)methyl)-6,7-dihydrobenzofuran-4(5*H*)-one (4a)



Yellow solid, 131-134℃. Yield: 81%, 160 mg. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.62-7.55 (m, 3H), 7.46-7.32 (m, 7H), 6.81 (s, 1H), 5.39 (s, 1H), 2.70 (s, 2H), 2.35 (s, 2H), 1.11 (s, 6H). ^{13}C NMR (100 MHz,

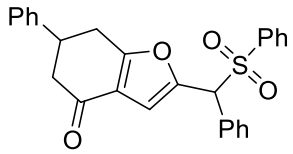
$CDCl_3$) δ 193.4, 166.8, 146.8, 137.4, 133.9, 130.3, 130.1, 129.4, 129.2, 128.8, 128.7, 121.0, 108.5, 70.7, 51.9, 37.3, 35.2, 28.6, 28.5. ESI-MS m/z (%) 395 (100)$[M+H]^+$; Anal. Calcd for $C_{23}H_{22}O_4S$ C,70.03 H, 5.62; Found: C,69.75 H, 5.64.

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



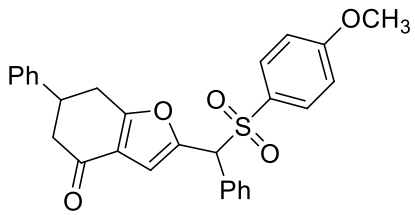
Yellow solid, 202-205℃. Yield: 77%, 141 mg. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.61-7.53 (m, 3H), 7.44-7.29 (m, 7H), 6.84 (s, 1H), 2.83-2.80 (m, 2H), 2.47-2.44 (m, 2H), 2.14 (t, J = 6.4 Hz 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 194.0, 167.7, 146.4, 137.3, 134.0, 130.3, 130.2, 129.3, 129.2, 128.8, 128.7, 122.2, 108.6, 70.6, 37.5, 23.3, 22.4. ESI-MS m/z (%) 367 (100)$[M+H]^+$; Anal. Calcd for $C_{21}H_{20}O_4S$ C,68.83 H, 4.95; Found: C,68.51 H, 4.97.

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



Brown solid, 123-126℃. Yield: 74%, 164 mg. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.60-7.52 (m, 5H), 7.42-7.22 (m, 10H), 6.87 (s, 1H), 5.43 (s, 1H), 3.54-3.39 (m, 1H), 3.12-2.91 (m, 2H), 2.72 (d, J = 8.4 Hz 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 192.6, 166.9, 147.1, 142.2, 137.3, 134.0, 130.3, 129.4, 129.2, 129.0, 128.8, 128.8, 127.4, 126.8, 126.7, 122.1, 108.6, 70.6, 44.8, 41.0, 31.1. ESI-MS m/z (%) 443 (100)$[M+H]^+$; Anal. Calcd for $C_{27}H_{22}O_4S$ C,73.28 H, 5.01; Found: C,72.88 H, 5.04.

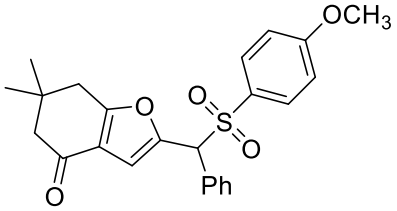
2-(((4-methoxyphenyl)sulfonyl)(phenyl)methyl)-6-phenyl-6,7-dihydrobenzofuran-4(5*H*)-one (4d)



Brown solid, 147-150℃. Yield: 78%, 184 mg. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.51-7.28 (m, 12H), 6.88-6.83 (m, 3H), 5.35 (s, 1H), 3.84 (s, 3H), 3.58-3.50 (m, 1H), 3.20-3.00 (m, 2H), 2.77 (d, J = 8.8 Hz 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 192.6, 166.7, 164.0, 147.4, 142.2, 131.5, 130.6, 130.3, 130.2, 129.3, 129.0, 128.7, 127.4, 126.8, 122.1, 114.0, 108.4, 70.9, 55.7, 44.9, 41.1,

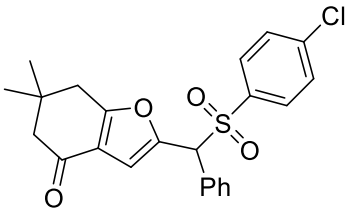
31.2. ESI-MS m/z (%) 473 (100)$[M+H]^+$; Anal. Calcd for $C_{28}H_{24}O_5S$ 71.17; H, 5.12; Found: C,70.86; H, 5.15.

2-(((4-methoxyphenyl)sulfonyl)(phenyl)methyl)-6,6-dimethyl-6,7-dihydrobenzofuran-4(5*H*)-one (4e)



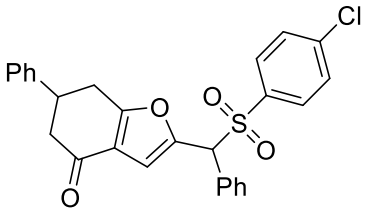
Yellow solid, 139-142℃. Yield: 82%, 174 mg. ^{1}H NMR (400MHz, $CDCl_3$) δ 7.51-7.44 (m, 4H), 7.38-7.31 (m, 3H), 6.85-6.81 (t, J = 9.8 Hz 3H), 5.36 (s, 1H), 3.83 (s, 3H), 2.71 (s, 2H), 2.35 (s, 2H), 1.12 (s, 3H), 1.11 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 193.5, 166.8, 163.9, 147.2, 131.4, 130.5, 130.3, 129.3, 128.7, 128.7, 121.0, 108.2, 70.9, 55.7, 51.9, 37.3, 35.2, 28.6, 28.5. ESI-MS m/z (%) 425 (100)$[M+H]^+$; Anal. Calcd for $C_{24}H_{24}O_5S$ C,67.90; H, 5.70; Found: C,67.55; H, 5.72.

2-(((4-chlorophenyl)sulfonyl)(phenyl)methyl)-6,6-dimethyl-6,7-dihydrobenzofuran-4(5*H*)-one (4f)



Yellow solid, 164-167℃. Yield: 80%, 172 mg. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.54 (d, J = 8.0 Hz 2H), 7.46-7.32 (m, 7H), 6.85 (s, 1H), 5.38 (s, 1H), 2.70 (s, 2H), 2.36 (s, 2H), 1.12 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 193.3, 166.8, 146.5, 140.8, 135.9, 130.7, 130.3, 129.8, 129.5, 129.1, 128.9, 121.1, 108.7, 70.9, 51.9, 37.3, 35.2, 28.6, 28.5. ESI-MS m/z (%) 429 (100)$[M+H]^+$; Anal. Calcd for $C_{23}H_{21}ClO_4S$ C,64.41; H, 4.94; Found: C,64.10; H, 4.96.

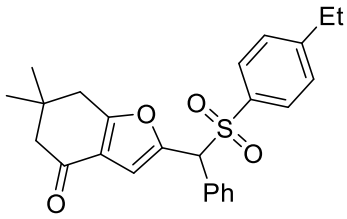
2-(((4-chlorophenyl)sulfonyl)(phenyl)methyl)-6-phenyl-6,7-dihydrobenzofuran-4(5*H*)-one (4g)



Brown solid, 133-136℃. Yield: 79%, 188 mg. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.53-7.28 (m, 14H), 6.93 (d, J = 10.0 Hz, 1H), 5.39 (s, 1H), 3.59-3.48 (m, 1H), 3.19-3.00 (m, 2H), 2.78 (d, J = 9.2, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 192.5, 166.9, 146.7, 142.1, 140.9, 130.7, 130.3, 130.2, 129.6, 129.1, 129.0, 128.9, 127.4, 126.8, 122.1, 108.9, 70.9,

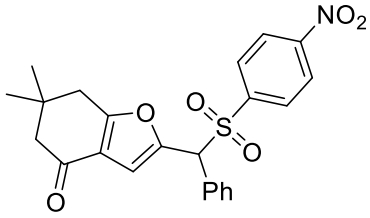
44.8, 41.1, 31.2. ESI-MS m/z (%) 477 (100)$[M+H]^+$; Anal. Calcd for $C_{27}H_{21}ClO_4S$ C,67.99; H, 4.44; Found: C,67.64; H, 4.47.

2-(((4-ethylphenyl)sulfonyl)(phenyl)methyl)-6,6-dimethyl-6,7-dihydrobenzofuran-4(5*H*)-one (4h)



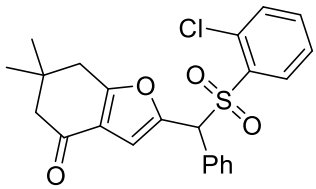
Brown solid, 145-148℃. Yield: 83%, 175 mg. ^{1}H NMR (400MHz, $CDCl_3$) δ 7.30-7.51 (m, 7H), 7.20 (d, J = 7.6 Hz, 2H), 6.80 (s, 1H), 5.36 (s, 1H), 2.63-2.73 (m, 5H), 2.34 (s, 2H), 1.22 (t, J = 7.6 Hz 3H), 1.15 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 193.4, 166.7, 151.1, 147.0, 134.5, 130.3, 129.3, 129.2, 128.6, 128.2, 121.1, 108.3, 70.7, 51.9, 37.3, 35.2, 28.6, 28.5, 21.0, 14.2. ESI-MS m/z (%) 423 (100)$[M+H]^+$; Anal. Calcd for $C_{25}H_{26}NO_4S$ C, 71.06; H, 6.20; Found: C, 70.73; H, 6.23.

6,6-dimethyl-2-(((4-nitrophenyl)sulfonyl)(phenyl)methyl)-6,7-dihydrobenzofuran-4(5*H*)-one (4i)



Brown solid, 168-171℃. Yield: 71%, 156 mg. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.15 (d, J = 8.0 Hz 2H), 7.74 (d, J = 8.0Hz 2H), 7.39-7.26 (m, 5H), 6.81 (s, 1H), 5.43 (s, 1H), 2.63 (s, 2H), 2.28 (s, 2H), 1.04 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 193.3, 167.2, 150.8, 145.7, 143.2, 130.7, 130.3, 129.9, 129.2, 129.0, 123.8, 121.1, 109.2, 70.7, 51.9, 37.3, 35.2, 28.6, 28.5. ESI-MS m/z (%) 440 (100)$[M+H]^+$; Anal. Calcd for $C_{23}H_{21}NO_6S$ C,62.86; H, 4.82; N, 3.19; Found: C,63.01; H, 4.80; N, 3.17.

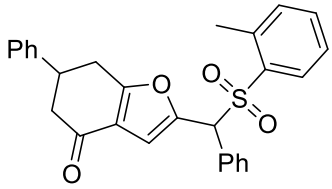
2-(((2-chlorophenyl)sulfonyl)(phenyl)methyl)-6,6-dimethyl-6,7-dihydrobenzofuran-4(5*H*)-onev (4j)



Brown solid, 160-163℃. Yield: 84%, 180 mg. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.66 (d, J = 8.0Hz 1H), 7.14-7.48 (m, 8H), 6.80 (s, 1H), 5.45 (s, 1H), 2.55 (s, 3H), 2.32 (s, 3H), 1.08 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 193.3, 166.7, 146.8, 139.0, 135.6, 133.9, 132.4, 131.5, 130.4, 130.3, 129.8, 129.4, 129.2, 128.7, 126.3, 123.0, 108.3, 69.9, 51.9, 37.2, 35.1, 28.6,

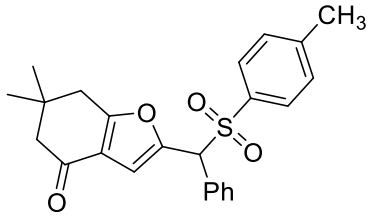
28.4, 20.5. ESI-MS m/z (%) 429 (100)$[M+H]^+$; Anal. Calcd for $C_{21}H_{20}O_4S$ C, 64.40; H, 4.93; Found: C, 64.09; H, 4.95.

6-phenyl-2-(phenyl(o-tolylsulfonyl)methyl)-6,7-dihydrobenzofuran-4(5*H*)-one (4k)



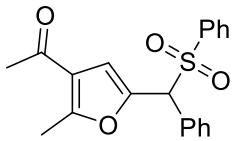
Brown solid, 136-139℃. Yield: 81%, 185 mg. ^{1}H NMR (400MHz, $CDCl_3$) δ 7.67 (d, J = 8.0 Hz 1H), 7.45-7.15 (m, 13H), 6.89 (d, J = 7.2 Hz 3H), 5.46 (s, 1H), 3.55-3.47 (m, 1H), 3.16-2.95 (m, 2H), 2.74 (d, J = 8.8 Hz 2H), 2.55 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 192.5, 166.7, 147.1, 147.1, 142.2, 142.2, 139.0, 139.0, 135.6, 133.9, 132.5, 131.6, 131.3, 129.4, 128.9, 128.7, 127.4, 126.8, 122.1, 108.6, 70.0, 44.9, 41.1, 31.2, 20.5. ESI-MS m/z (%) 457 (100)$[M+H]^+$; Anal. Calcd for $C_{28}H_{24}O_4S$ C,73.66; H, 5.30; Found: C,73.31; H, 5.33.

6,6-dimethyl-2-(phenyl(tosyl)methyl)-6,7-dihydrobenzofuran-4(5*H*)-one (4l)



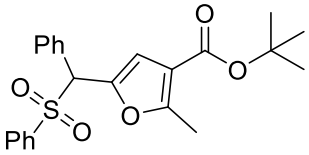
Yellow solid, 138-140℃. Yield: 83%, 170 mg. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.32-7.48 (m, 6H), 7.19 (d, J = 8.0 Hz 2H), 6.78 (s, 1H), 5.35 (s, 1H), 2.71 (s, 2H), 2.39 (s, 3H), 2.35 (s, 2H), 1.12 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 195.9, 166.7, 145.0, 134.3, 131.8, 130.3, 129.4, 129.3, 128.7, 127.9, 127.6, 121.0, 108.3, 70.7, 51.9, 37.3, 35.2, 28.6, 28.5, 21.0. ESI-MS m/z (%) 409 (100)$[M+H]^+$; Anal. Calcd for $C_{24}H_{24}NO_4S$ C, 70.56; H, 5.92; Found: C, 70.22; H, 5.95.

1-(2-methyl-5-(phenyl(phenylsulfonyl)methyl)furan-3-yl)ethan-1-one (5a)



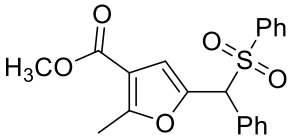
Brown oil. Yield: 79%, 140 mg. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.61-7.55 (m, 3H), 7.44-7.29 (m, 7H), 6.84 (s, 1H), 5.37 (s, 1H), 3.82 (s, 3H), 2.39 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 193.7, 159.2, 143.7, 137.4, 133.9, 130.3, 130.2, 129.3, 129.2, 128.8, 128.7, 122.6, 112.4, 70.6, 29.2, 14.4. ESI-MS m/z (%) 355 (100)$[M+H]^+$; Anal. Calcd for $C_{20}H_{18}O_4S$ C,67.78 H, 5.12; Found: C,67.49 H, 5.14.

tert-butyl 2-methyl-5-(phenyl(phenylsulfonyl)methyl)furan-3-carboxylate (5b)



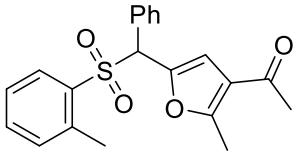
Brown solid, 78-81℃. Yield: 84%, 137 mg. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.61-7.54 (m, 3H), 7.43-7.27 (m, 7H), 6.85 (s, 1H), 5.32 (s, 1H), 2.48 (s, 3H), 1.54 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.9, 159.3, 143.3, 137.5, 133.8, 130.5, 130.3, 129.3, 129.2, 128.7, 128.6, 116.4, 113.1, 80.8, 70.7, 28.3, 13.8. ESI-MS m/z (%) 413 (100)$[M+H]^+$; Anal. Calcd for $C_{23}H_{24}O_5S$ C,66.97 H, 5.86; Found: C,66.64 H, 5.89.

methyl 2-methyl-5-(phenyl(phenylsulfonyl)methyl)furan-3-carboxylate (5c)



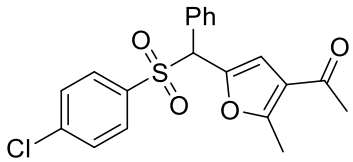
Brown solid, 103-107℃. Yield: 76%, 141 mg. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.62-7.55 (m, 3H), 7.45-7.30 (m, 7H), 6.86 (s, 1H), 5.34 (s, 1H), 3.81 (s, 3H), 2.50 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 163.9, 160.1, 143.9, 137.5, 133.8, 130.3, 129.3, 128.7, 128.7, 128.2, 114.7, 112.8, 70.6, 51.4, 13.7. ESI-MS m/z (%) 371 (100)$[M+H]^+$; Anal. Calcd for $C_{20}H_{18}O_5S$ C,64.85 H, 4.90; Found: C,64.53 H, 4.92.

1-(2-methyl-5-(phenyl(*o*-tolylsulfonyl)methyl)furan-3-yl)ethan-1-one (5d)



Brown oil. Yield: 71%, 131 mg. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.68 (d, J = 8.0 Hz 1H), 7.47-7.42 (m, 3H), 7.34-7.16 (m, 5H), 6.85 (s, 1H), 5.41 (s, 1H), 2.54 (s, 3H), 2.50 (s, 3H), 2.38 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 193.7, 159.1, 143.8, 139.1, 135.6, 133.9, 132.4, 131.5, 130.3, 130.3, 130.1, 129.4, 129.3, 129.2, 128.7, 126.3, 122.5, 112.4, 69.9, 29.1, 20.5, 14.3. ESI-MS m/z (%) 369 (100)$[M+H]^+$; Anal. Calcd for $C_{21}H_{20}O_4S$ C,68.46; H, 5.47; Found: C,68.15; H, 5.49.

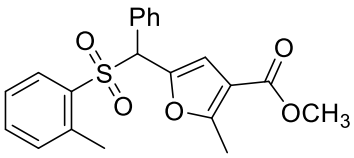
1-(5-(((4-chlorophenyl)sulfonyl)(phenyl)methyl)-2-methylfuran-3-yl)ethan-1-one (5e)



Brown solid, 87-91℃. Yield: 77%, 150 mg. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.53 (d, J = 8.4 Hz 2H), 7.44-7.31 (m, 7H), 6.86 (s, 1H), 5.36 (s, 1H), 2.54 (s, 3H), 2.40 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 193.6, 159.4, 143.4, 140.8, 135.9, 130.7, 130.2, 129.5, 129.1, 128.8, 122.6, 112.6, 107.2, 70.7, 29.2, 14.4. ESI-MS m/z (%) 389 (100)$[M+H]^+$; Anal. Calcd for $C_{20}H_{17}ClO_4S$ C,61.78;

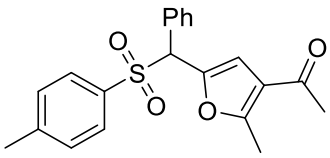
H, 4.41; Found: C,62.10; H, 4.39.

methyl 2-methyl-5-(phenyl(*o*-tolylsulfonyl)methyl)furan-3-carboxylate (5f)



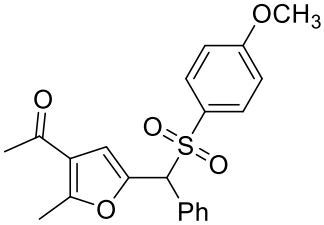
Yellow solid, 125-128℃. Yield: 70%, 135 mg. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.66 (d, J = 8.0 Hz 1H), 7.45 (t, J = 7.6 Hz 3H), 7.34 (t, J = 7.6 Hz 3H), 7.26-7.16 (m, 2H), 6.85 (s, 1H), 5.41 (s, 1H), 3.80 (s, 3H), 2.55 (s, 3H), 2.48 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 163.9, 160.0, 143.9, 139.1, 135.7, 133.8, 132.4, 131.6, 130.3, 130.1, 129.3, 128.7, 126.3, 114.6, 112.7, 69.9, 51.4, 20.5, 13.7. ESI-MS m/z (%) 385 (100)$[M+H]^+$; Anal. Calcd for $C_{21}H_{20}O_5S$ C,65.61; H, 5.24; Found: 65.29; H, 5.26.

1-(2-methyl-5-(phenyl(tosyl)methyl)furan-3-yl)ethan-1-one (5g)



Brown solid, 72-75℃. Yield: 144 mg. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.40-7.35 (t, J = 9.6 Hz 4H), 7.26-7.20 (m, 3H), 7.11 (d, J = 8.0 Hz 2H), 6.78 (s, 1H), 5.33 (s, 1H), 2.43 (s, 3H), 2.29 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 193.8, 159.0, 145.0, 144.0, 134.4, 130.5, 130.2, 129.4, 129.2, 128.6, 122.5, 112.3, 70.4, 29.1, 21.6, 14.4. ESI-MS m/z (%) 369 (100)$[M+H]^+$; Anal. Calcd for $C_{21}H_{20}O_4S$ C,68.46; H, 5.47; Found: C,68.13; H, 5.49.

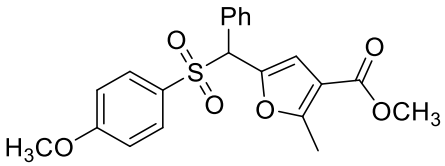
1-(5-(((4-methoxyphenyl)sulfonyl)(phenyl)methyl)-2-methylfuran-3-yl)ethan-1-one (5h)



Brown oil. Yield: 75%, 144 mg. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.50-7.31 (m, 7H), 6.86 (d, J = 6.4 Hz 3H), 5.34 (s, 1H), 3.83 (s, 3H), 2.53 (s, 3H), 2.40 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 193.8, 164.0, 159.1, 144.1, 131.4, 130.7, 130.2, 129.2, 128.7, 128.7, 122.5, 114.0, 112.2, 70.7, 55.7, 29.2, 14.4. ESI-MS m/z (%) 385 (100)$[M+H]^+$; Anal. Calcd for $C_{21}H_{20}O_5S$ C,65.61; H, 5.24; Found: C,65.29; H, 5.26.

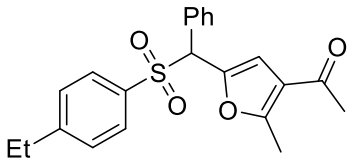
methyl

5-(((4-methoxyphenyl)sulfonyl)(phenyl)methyl)-2-methylfuran-3-carboxylate (5i)



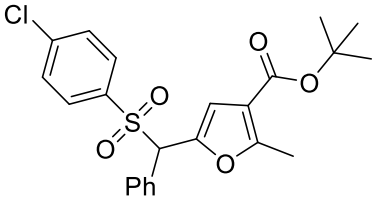
Brown oil. Yield: 72%, 144 mg. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.42-7.33 (m, 4H), 7.25 (t, J = 7.2Hz 3H), 6.77 (s, 3H), 5.24 (s, 1H), 3.73 (s, 3H), 3.71 (s, 3H), 2.43 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.0, 163.9, 159.9, 144.3, 131.4, 130.7, 130.2, 129.1, 128.8, 114.6, 113.9, 112.5, 70.7, 55.7, 51.4, 13.8. ESI-MS m/z (%) 401 (100)$[M+H]^+$; Anal. Calcd for $C_{21}H_{20}O_6S$ C,62.99; H, 5.03; Found: C,63.27; H, 5.01;

1-(5-(((4-ethylphenyl)sulfonyl)(phenyl)methyl)-2-methylfuran-3-yl)ethan-1-one (5j)



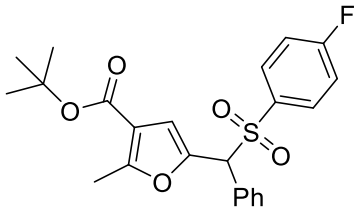
Brown oil. Yield: 76%, 145 mg. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.51-7.43 (m, 4H), 7.32 (t, J = 7.6 Hz 3H), 7.22 (d, J = 7.6 Hz 2H), 6.81 (s, 1H), 5.32 (s, 1H), 2.70 (q, J = 7.2 Hz 2H), 2.50 (s, 3H), 2.37 (s, 3H), 1.23 (t, J = 6.8 Hz 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 193.7, 159.0, 151.1, 144.0, 134.6, 130.5, 130.2, 129.3, 129.1, 128.6, 128.2, 122.5, 112.3, 70.5, 29.1, 28.8, 15.1, 14.3. ESI-MS m/z (%) 383 (100)$[M+H]^+$; Anal. Calcd for $C_{22}H_{22}O_4S$ C,69.09; H, 5.80; Found: C,68.75; H, 5.83.

tert-butyl 5-(((4-chlorophenyl)sulfonyl)(phenyl)methyl)-2-methylfuran-3-carboxylate (5k)



Brown oil. Yield: 83%, 186 mg. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.53 (d, J = 8.0 Hz 2H), 7.43-7.31 (m, 7H), 6.80 (s, 1H), 5.32 (s, 1H), 2.50 (s, 3H), 1.54 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.8, 159.4, 143.0, 140.7, 136.0, 130.8, 130.3, 130.2, 129.4, 129.0, 128.8, 116.5, 113.3, 81.0, 70.8, 28.3, 13.8. ESI-MS m/z (%) 447 (100)$[M+H]^+$; Anal. Calcd for $C_{23}H_{23}ClO_5S$ C,61.81; H, 5.19; Found: C,62.14; H, 5.16.

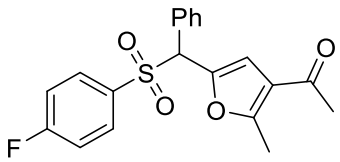
tert-butyl 5-(((4-fluorophenyl)sulfonyl)(phenyl)methyl)-2-methylfuran-3-carboxylate (5l)



Brown oil. Yield: 80%, 172 mg. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.62-7.58 (m, 2H), 7.43-7.30 (m, 5H), 7.10 (t, J = 8.4 Hz 2H),

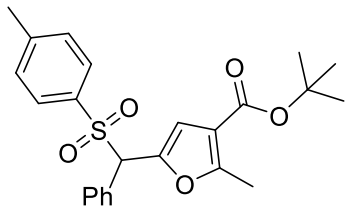
6.81 (s, 1H), 5.35 (s, 1H), 2.50 (s, 3H), 1.54 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.2, 164.6, 162.8, 159.4, 143.2, 133.3, 132.2, 132.1, 130.4, 130.2, 129.3, 128.7, 116.4, 116.1 (J = 92 Hz), 115.1, 113.2, 80.9, 70.8, 28.3, 13.8. ESI-MS m/z (%) 431 (100)$[M+H]^+$; Anal. Calcd for $C_{23}H_{23}FO_5S$ C,64.17; H, 5.39; Found: C,64.50; H, 5.36.

1-(5-(((4-fluorophenyl)sulfonyl)(phenyl)methyl)-2-methylfuran-3-yl)ethan-1-one (5m)



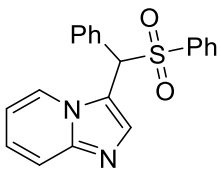
Brown oil. Yield: 78%, 145 mg. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.57-7.61 (m, 2H), 7.42-7.31 (m, 5H), 7.10 (t, J = 8.4 Hz 2H), 6.86 (s, 1H), 5.35 (s, 1H), 2.54 (s, 3H), 2.40 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 193.6, 167.2, 164.7, 159.3, 143.5, 133.4, 133.4, 132.2, 132.1, 130.2, 129.4, 128.8, 116.2 (J = 88 Hz), 112.5, 70.8, 29.1, 14.4. ESI-MS m/z (%) 373 (100)$[M+H]^+$; Anal. Calcd for $C_{20}H_{17}FO_4S$ C, 64.50; H, 4.60; Found: C, 64.81; H, 4.62.

tert-butyl 2-methyl-5-(phenyl(tosyl)methyl)furan-3-carboxylate (5n)



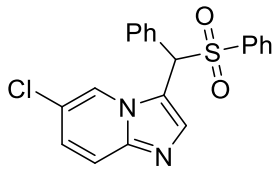
Brown oil. Yield: 80%, 171 mg. ^{1}H NMR (400MHz, $CDCl_3$) δ 7.41-7.47 (m, 4H), 7.18-7.32 (m, 5H), 6.79 (s, 1H), 5.31 (s, 1H), 2.48 (s, 3H), 2.40 (s, 3H), 1.54 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.9, 159.2, 144.8, 143.5, 130.6, 130.2, 129.3, 129.0, 128.7, 128.6, 116.3, 112.9, 80.8, 70.7, 28.3, 21.6, 13.8. ESI-MS m/z (%) 427 (100)$[M+H]^+$; Anal. Calcd for $C_{20}H_{17}FO_4S$ C, 74.43; H, 4.09; Found: C, 74.07; H, 4.11.

3-(phenyl(phenylsulfonyl)methyl)imidazo[1,2-*a*]pyridine (6a)



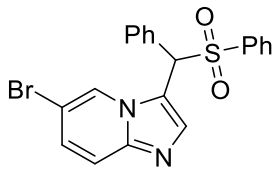
Yellow solid, 177-180℃. Yield: 65%, 113 mg. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.08 (d, J = 6.8 Hz, 1H), 7.97 (s, 1H), 7.63-7.30 (m, 11H), 7.19 (t, J = 7.2 Hz, 1H), 6.80 (t, J = 6.8 Hz, 1H), 5.71 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 146.4, 137.2, 135.5, 134.0, 130.6, 130.1, 129.4, 129.1, 128.9, 128.9, 126.4, 125.1, 123.6, 118.0, 115.9, 112.9, 67.9. ESI-MS m/z (%) 349(100) $[M+H]^+$; Anal. Calcd for $C_{20}H_{16}N_2O_2S$ C, 68.95; H, 4.63; N, 8.04; Found: C, 68.63; H, 4.65; N, 8.08.

6-chloro-3-(phenyl(phenylsulfonyl)methyl)imidazo[1,2-*a*]pyridine (6b)



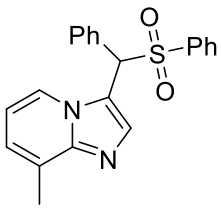
Yellow solid, m.p. 170-173℃. Yield: 75%, 143 mg. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.02 (s, 1H), 7.93 (s, 1H), 7.52-7.19 (m, 11H), 7.05 (d, J = 9.6 Hz, 1H), 5.62 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 144.7, 137.0, 136.4, 134.2, 130.4, 130.1, 129.5, 129.1, 129.0, 128.9, 126.4, 121.6, 121.3, 118.3, 116.7, 67.6. ESI-MS m/z (%) 383(100) $[M+H]^+$; Anal. Calcd for $C_{20}H_{15}ClN_2O_2S$, C, 62.74; H, 3.95; N, 7.32; Found: C, 62.35; H, 3.97; N, 7.35.

6-bromo-3-(phenyl(phenylsulfonyl)methyl)imidazo[1,2-*a*]pyridine (6c)



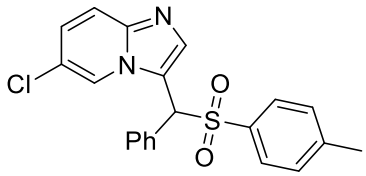
Yellow solid, m.p. 200-203℃. Yield: 62%, 132 mg. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.17 (d, J = 0.8 Hz, 1H), 7.99 (s, 1H), 7.61-7.23 (m, 12H), 5.65 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 144.8, 137.0, 136.2, 134.2, 130.3, 130.1, 129.6, 129.2, 129.0, 128.9, 128.5, 123.7, 118.6, 116.6, 107.9, 67.6. ESI-MS m/z (%) 427(100) $[M+H]^+$; Anal. Calcd for $C_{20}H_{15}BrN_2O_2S$, C, 56.22; H, 3.54; N, 6.56; Found: C, 56.43; H, 3.56; N, 6.59.

8-methyl-3-(phenyl(phenylsulfonyl)methyl)imidazo[1,2-*a*]pyridine (6d)



Yellow solid, m.p. 199-202℃. Yield: 45%, 81 mg. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.96 (s, 1H), 7.91 (d, J = 6.8 Hz, 1H), 7.61 (d, J = 7.6 Hz, 2H), 7.54-7.29 (m, 8H), 6.97 (d, J = 6.8 Hz, 1H), 6.70 (t, J = 6.8 Hz, 1H), 5.70 (s, 1H), 2.57 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 146.6, 137.2, 134.7, 134.0, 130.1, 129.3, 129.1, 128.9, 128.6, 127.8, 126.4, 123.9, 121.3, 116.2, 112.9, 67.9, 16.9. ESI-MS m/z (%) 363(100) $[M+H]^+$; Anal. Calcd for $C_{21}H_{18}N_2O_2S$ C, 69.59; H, 5.01; N, 7.73; Found: C, 69.27; H, 5.03; N, 7.76.

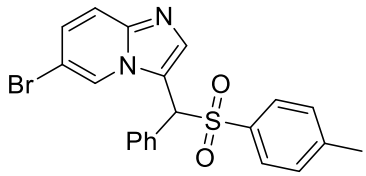
6-chloro-3-(phenyl(tosyl)methyl)imidazo[1,2-*a*]pyridine (6e)



Yellow solid, m.p. 135-138℃. Yield: 70%, 139 mg. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.04 (s, 1H), 7.97(s, 1H), 7.57 (d, J = 9.6 Hz, 1H), 7.46-7.32 (m, 7H), 7.17 (t, J = 7.2 Hz, 3H), 5.59 (s,

1H), 2.37 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 145.4, 136.4, 134.0, 130.5, 130.1, 129.6, 129.5, 129.2, 128.9, 128.7, 126.5, 126.3, 121.6, 121.2, 118.3, 67.6, 21.6. ESI-MS m/z (%) 397(100) $[M+H]^+$; Anal. Calcd for $C_{21}H_{17}ClN_2O_2S$, C, 63.55; H, 4.32; Cl, 8.93; N, 7.06; Found: C, 63.24; H, 4.34; N, 7.09.

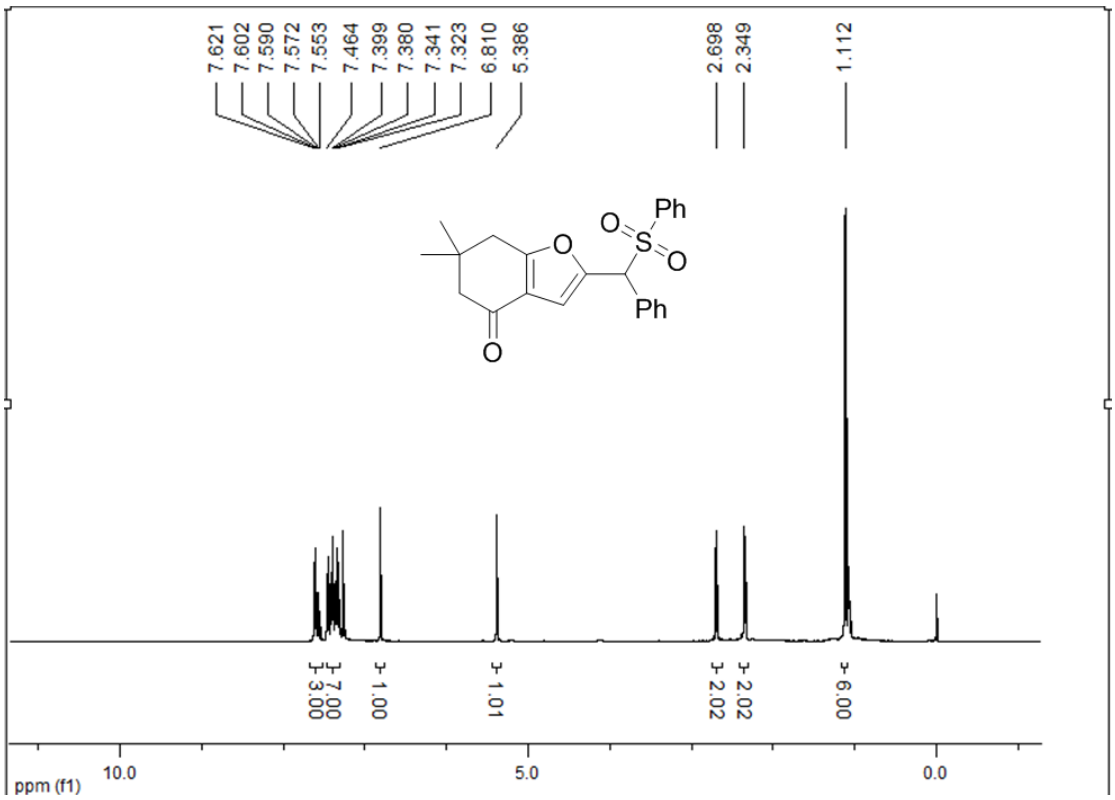
6-bromo-3-(phenyl(tosyl)methyl)imidazo[1,2-*a*]pyridine (6f)

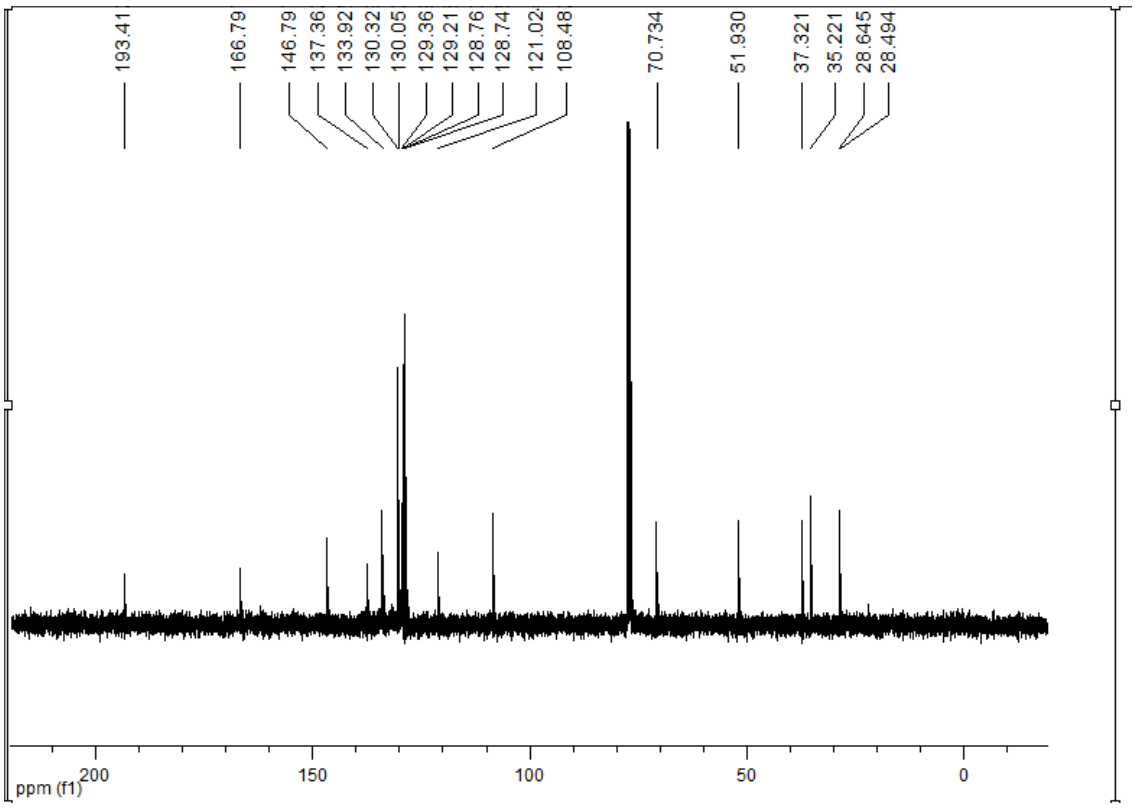


Yellow solid, m.p. 175-178℃. Yield: 68%, 150 mg. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.14 (s, 1H), 7.96 (s, 1H), 7.50-7.32 (m, 9H), 7.23 (d, J = 9.2 Hz, 1H), 7.16 (d, J = 8.0 Hz, 1H), 5.65 (s, 1H), 2.37 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 145.4, 136.2, 134.1, 130.5, 130.1, 129.6, 129.5, 129.2, 129.0, 129.0, 128.3, 123.7, 118.6, 107.7, 67.6, 21.7. ESI-MS m/z (%) 441(100) $[M+H]^+$; Anal. Calcd for $C_{21}H_{17}BrN_2O_2S$ C, 57.15; H, 3.88; N, 6.35; Found: C, 56.87; H, 3.90; N, 6.39.

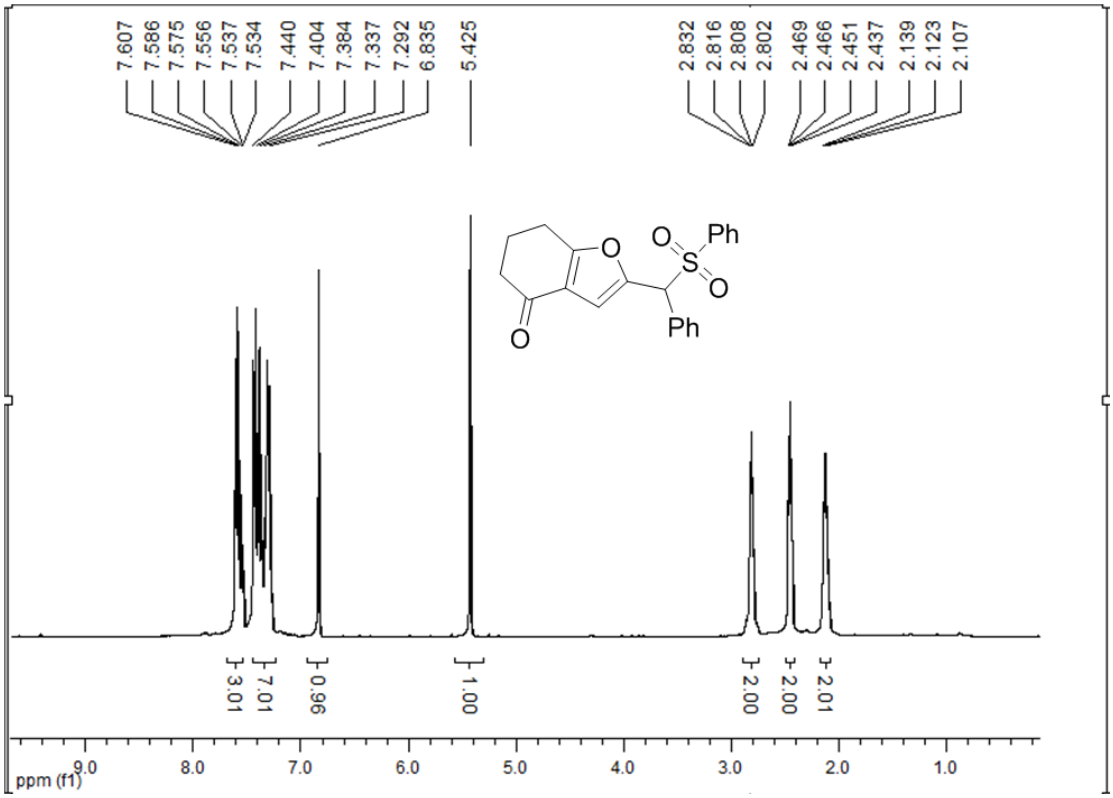
D. ^{1}H and ^{13}C NMR spectra

4a





4b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2.466
2.451
2.437
2.139
2.123
2.107
O
O
S
O
Ph
Ph
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7.01
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2.00
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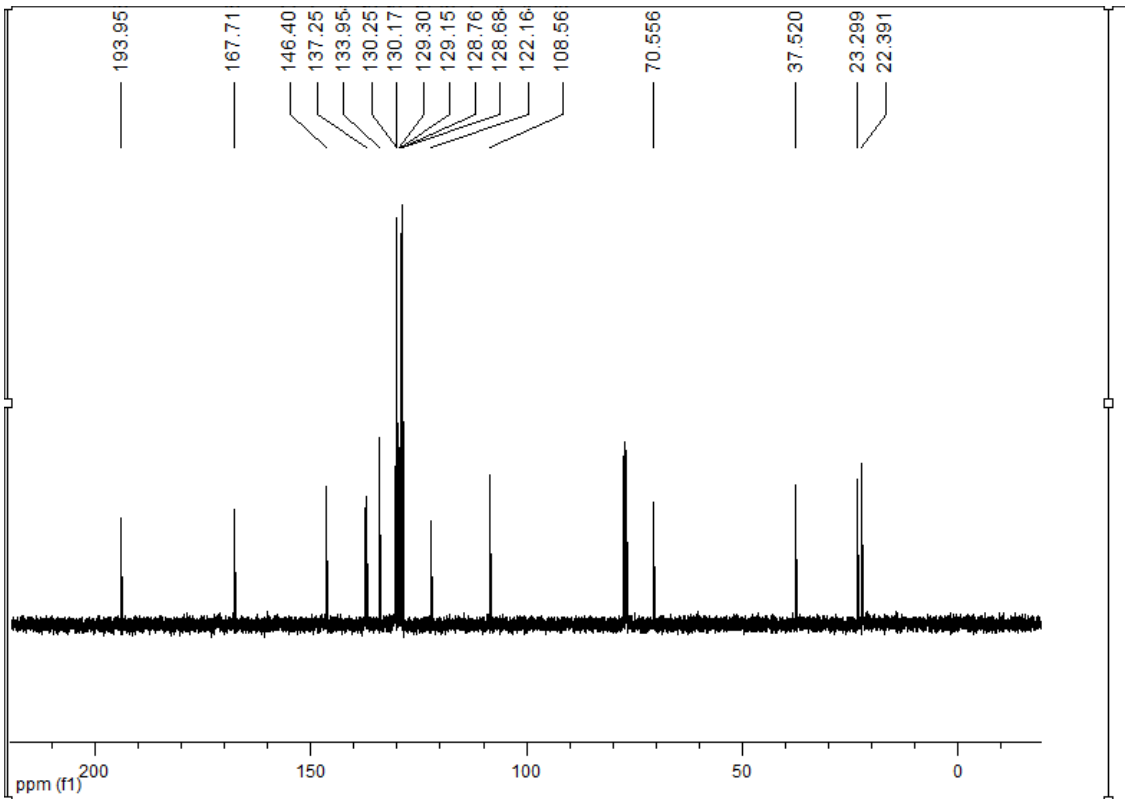
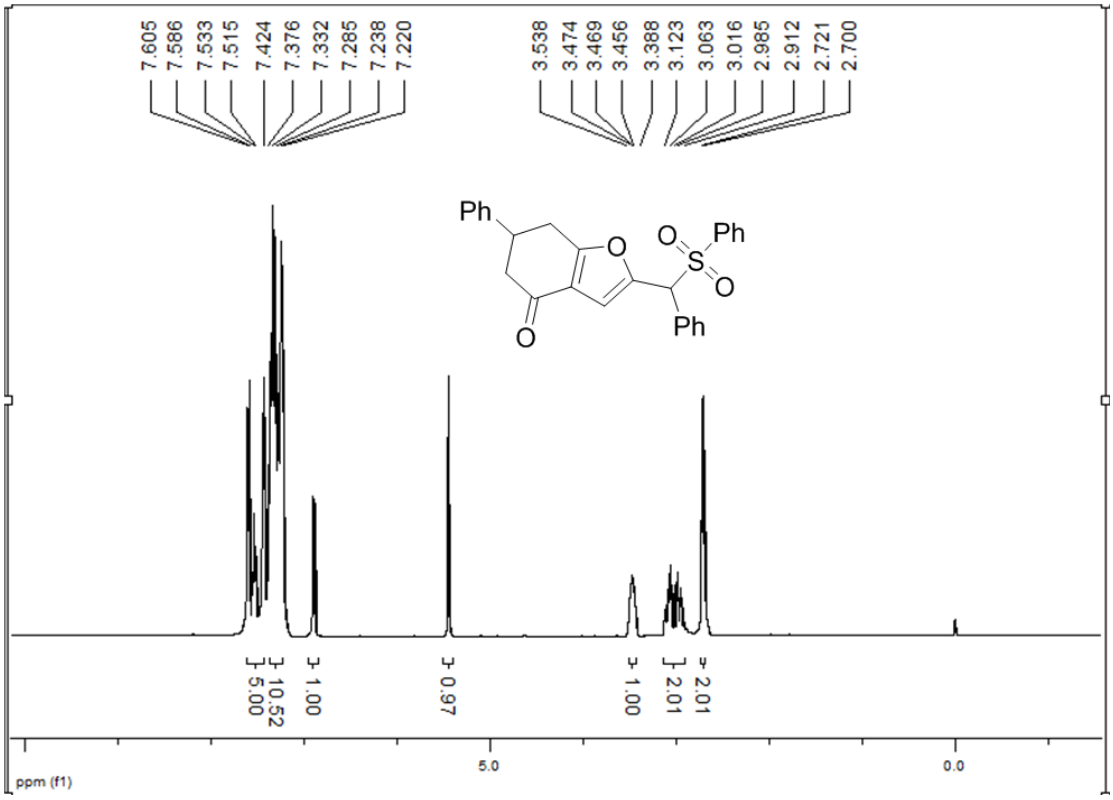
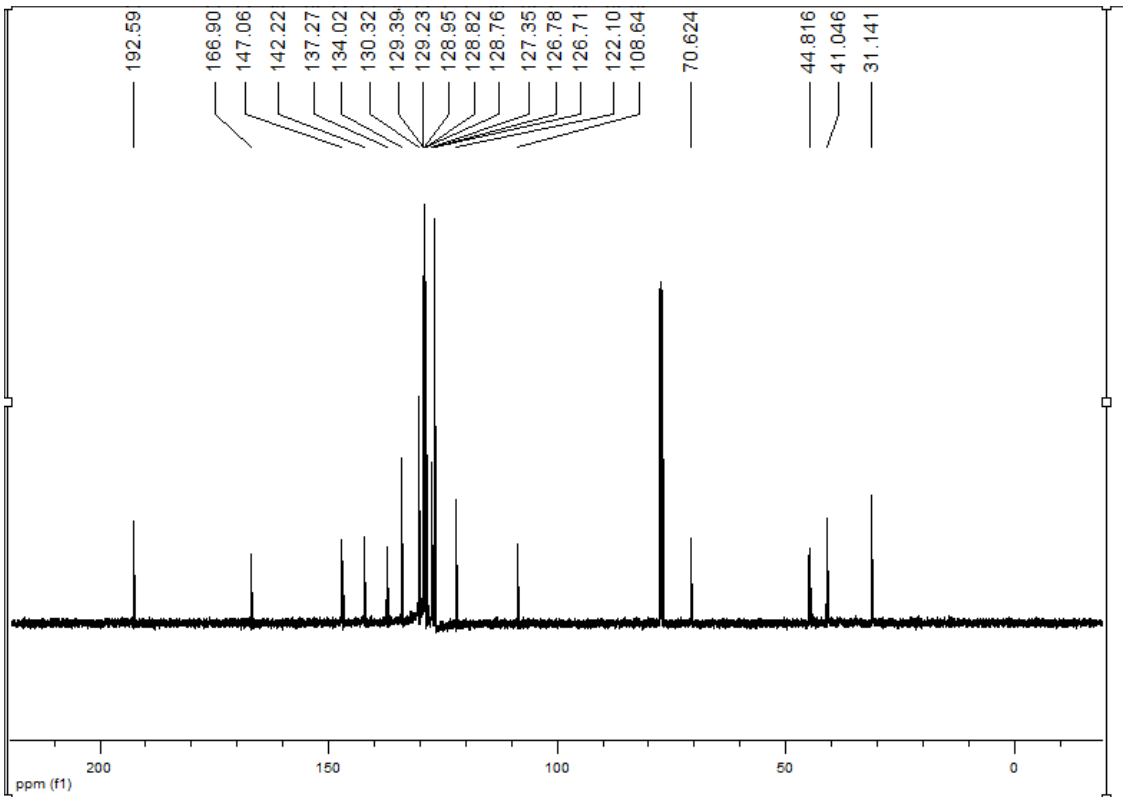
1.0

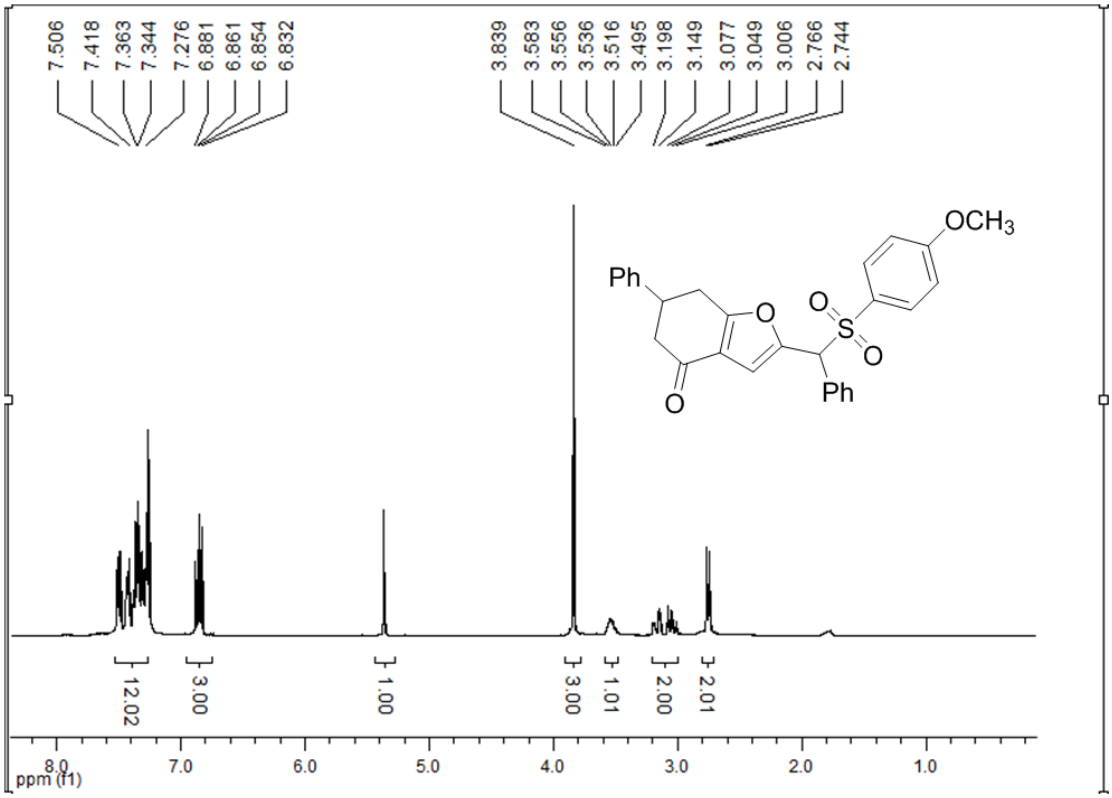

193.95
167.71
146.40
137.25
133.95
130.25
130.17
129.30
129.15
128.76
128.68
122.16
108.56
70.556
37.520
23.299
22.391
ppm (f1)
200
150
100
50
0

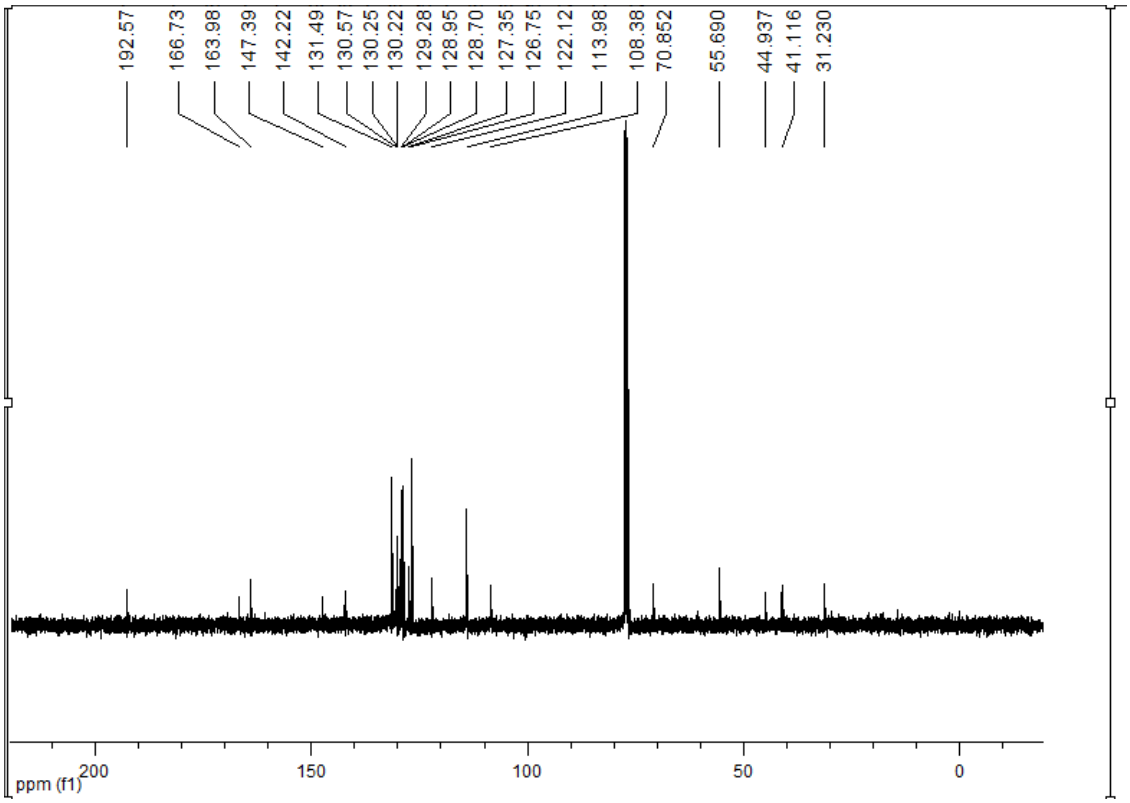
4c


7.605
7.586
7.533
7.515
7.424
7.376
7.332
7.285
7.238
7.220
3.538
3.474
3.469
3.456
3.388
3.123
3.063
3.016
2.985
2.912
2.721
2.700
Ph
O
O
S
Ph
O
Ph
5.00
10.52
1.00
0.97
1.00
2.01
2.01
5.0
0.0
ppm (f1)

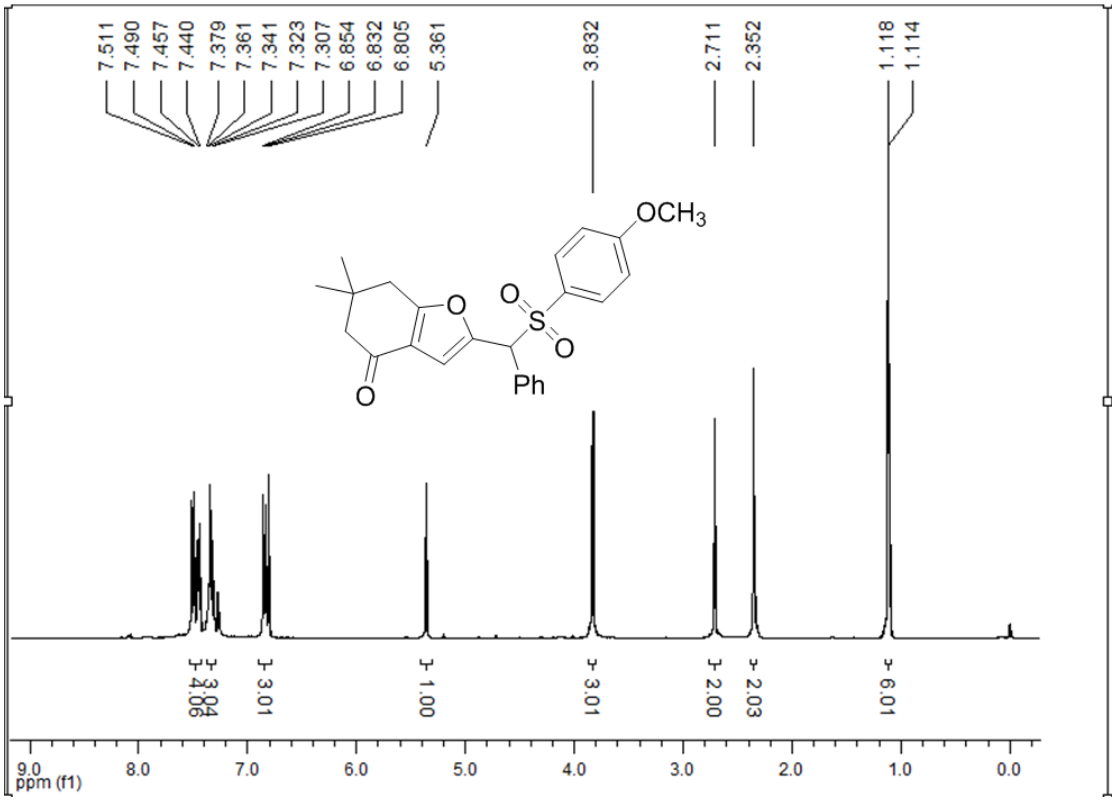

192.59
166.90
147.06
142.22
137.27
134.02
130.32
129.39
129.23
128.95
128.82
128.76
127.35
126.78
126.71
122.10
108.64
70.624
44.816
41.046
31.141
200
150
100
50
0
ppm (f1)

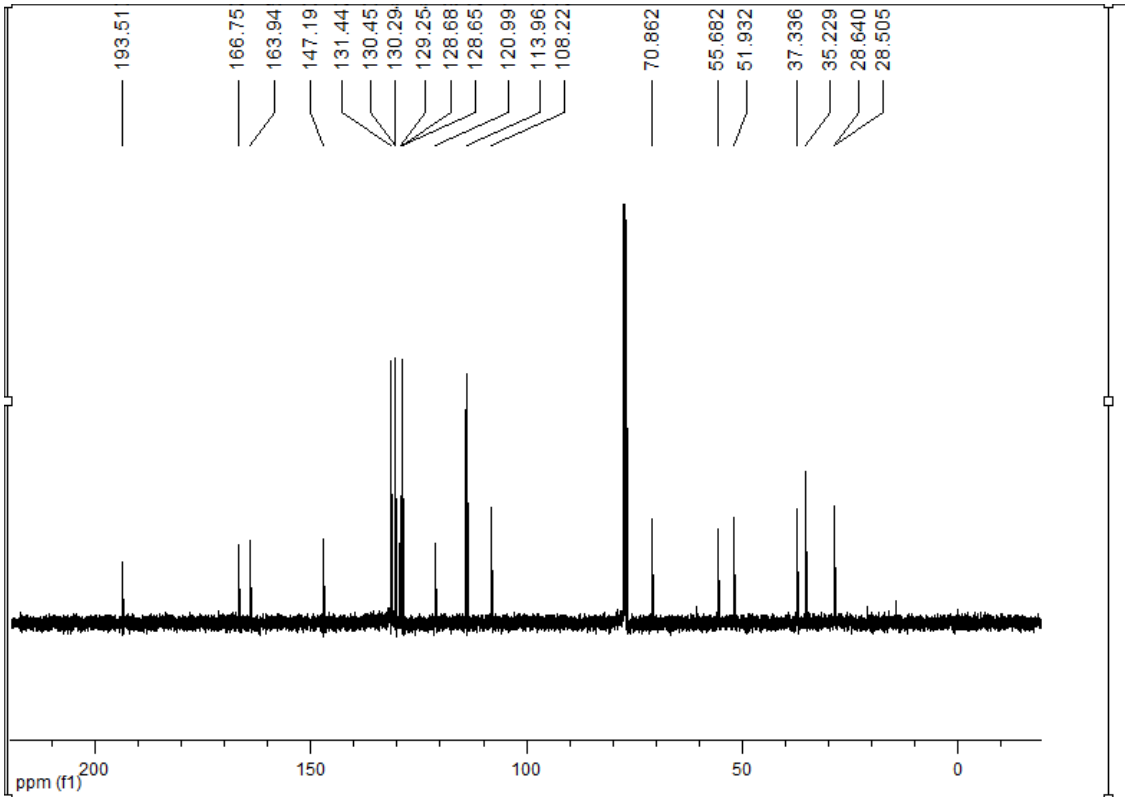
4d


7.506
7.418
7.363
7.344
7.276
6.881
6.861
6.854
6.832
3.839
3.583
3.556
3.536
3.516
3.495
3.198
3.149
3.077
3.049
3.006
2.766
2.744
OCH3
Ph
O
O
S
O
Ph
O
12.02
3.00
1.00
3.00
1.01
2.00
2.01
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
ppm (f1)

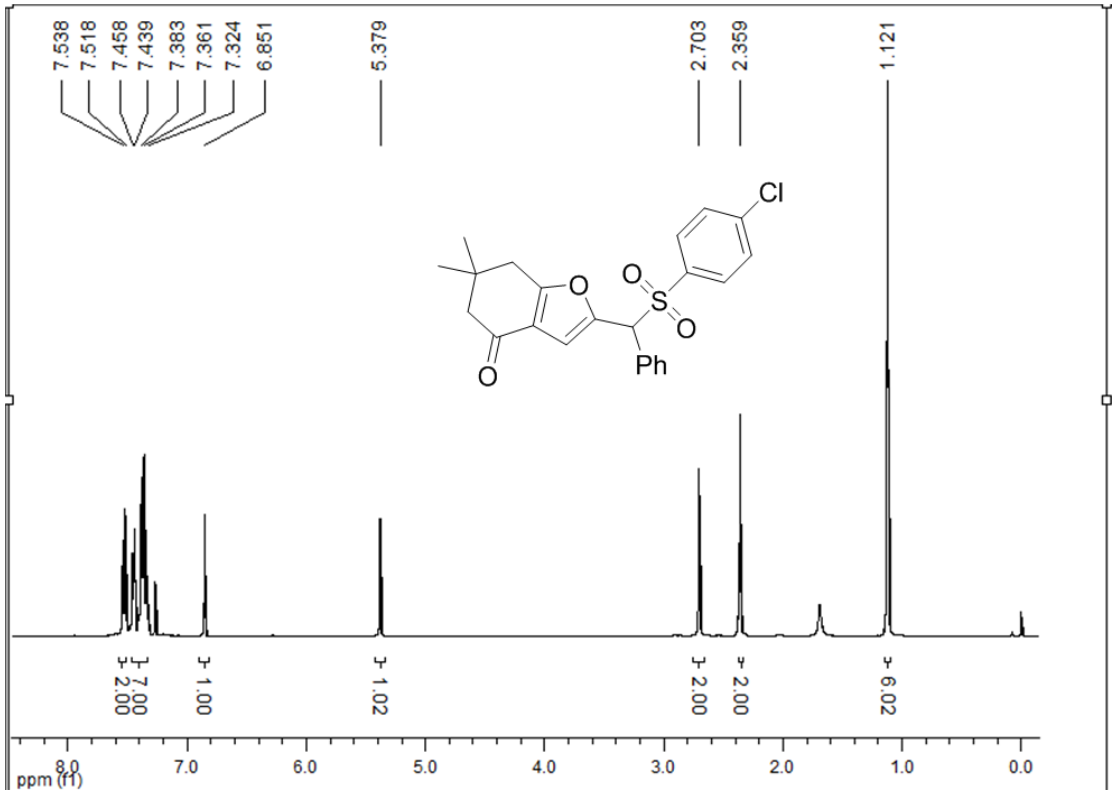

192.57
166.73
163.98
147.39
142.22
131.49
130.57
130.25
130.22
129.28
128.95
128.70
127.35
126.75
122.12
113.98
108.38
70.852
55.690
44.937
41.116
31.230
200
150
100
50
0
ppm (f1)

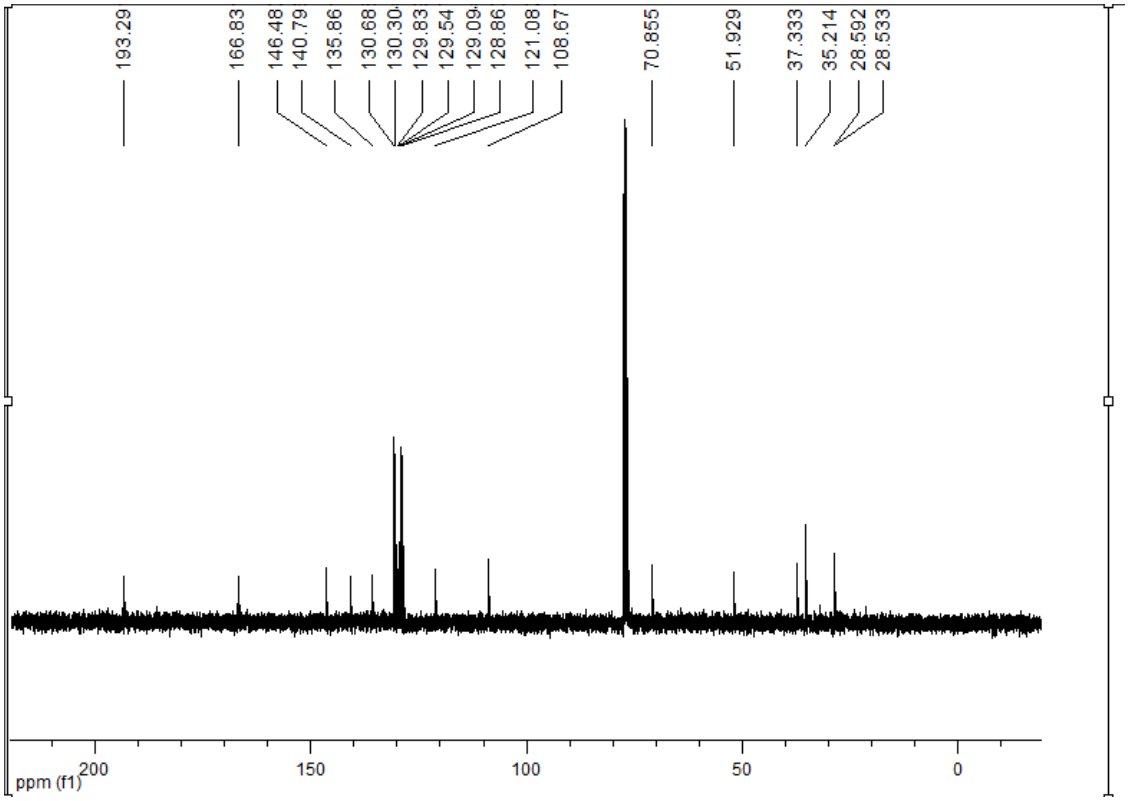
4e


7.511
7.490
7.457
7.440
7.379
7.361
7.341
7.323
7.307
6.854
6.832
6.805
5.361
3.832
2.711
2.352
1.118
1.114
OCH3
O
S
O
O
O
Ph
4.06
3.84
3.01
1.00
3.01
2.00
2.03
6.01
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
ppm (f1)

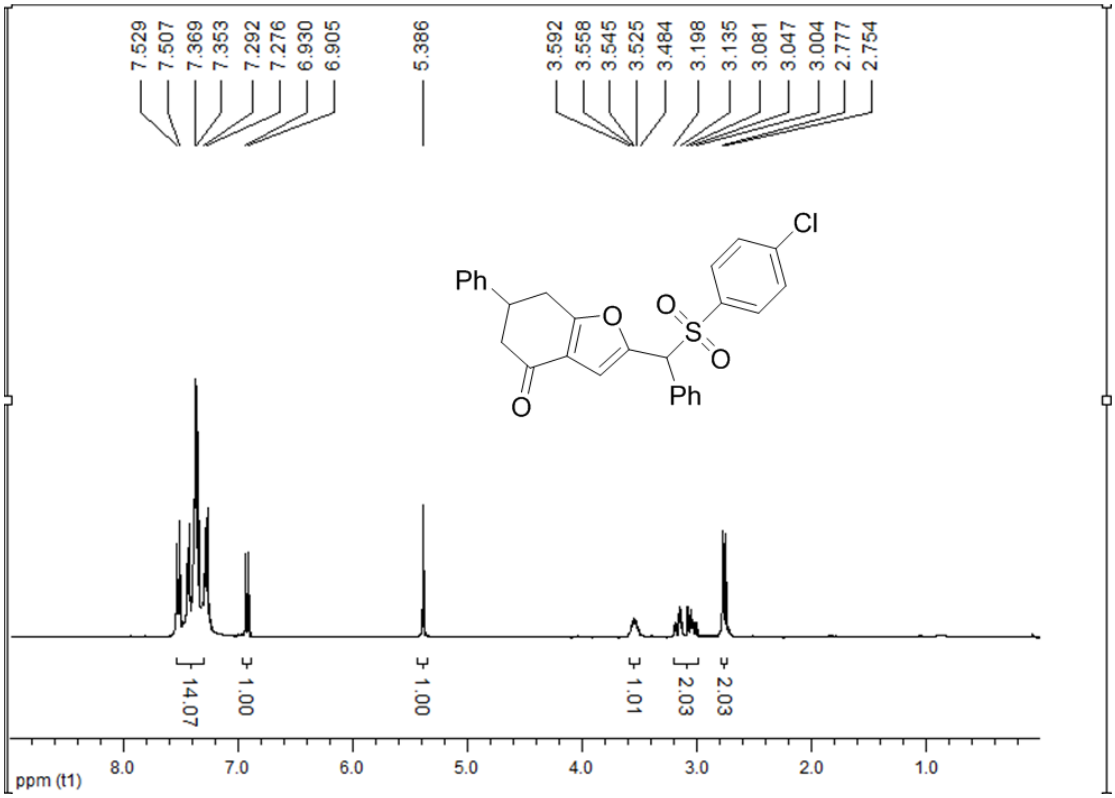

193.51
166.75
163.94
147.19
131.44
130.45
130.29
129.25
128.68
128.65
120.99
113.96
108.22
70.862
55.682
51.932
37.336
35.229
28.640
28.505
200
150
100
50
0
ppm (f1)

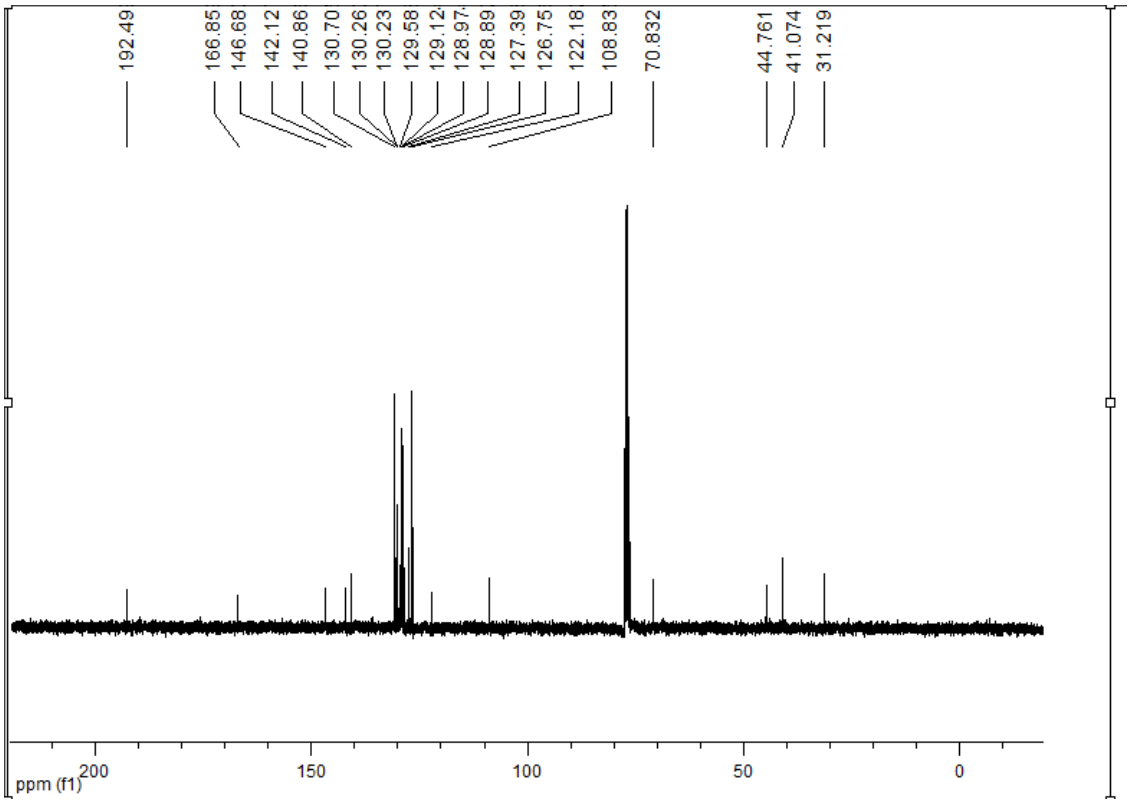
4f


7.538
7.518
7.458
7.439
7.383
7.361
7.324
6.851
5.379
2.703
2.359
1.121
Cl
O
S
O
O
O
Ph
2.00
7.00
1.00
1.02
2.00
2.00
6.02
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
ppm (f1)

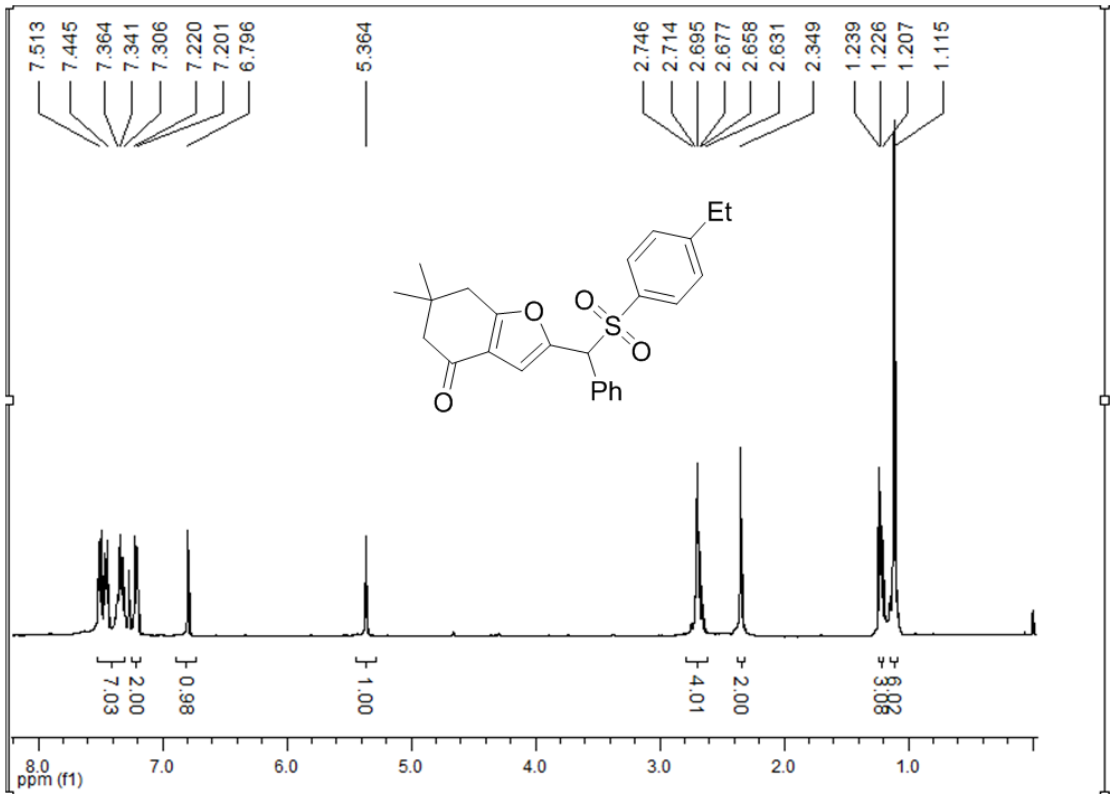

193.29
166.83
146.48
140.79
135.86
130.68
130.30
129.83
129.54
129.09
128.86
121.08
108.67
70.855
51.929
37.333
35.214
28.592
28.533
200
150
100
50
0
ppm (f1)

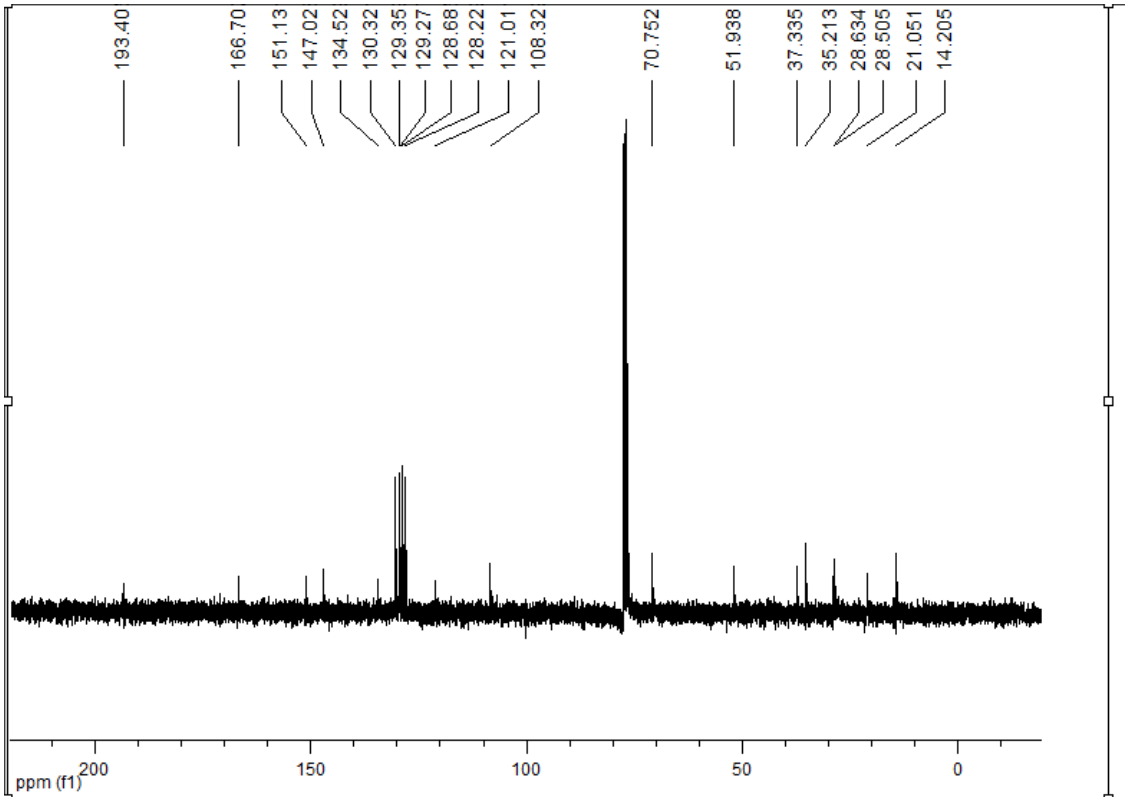
4g


7.529
7.507
7.369
7.353
7.292
7.276
6.930
6.905
5.386
3.592
3.558
3.545
3.525
3.484
3.198
3.135
3.081
3.047
3.004
2.777
2.754
Cl
Ph
O
S
O
O
Ph
O
14.07
1.00
1.00
1.01
2.03
2.03
ppm (t1)
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0

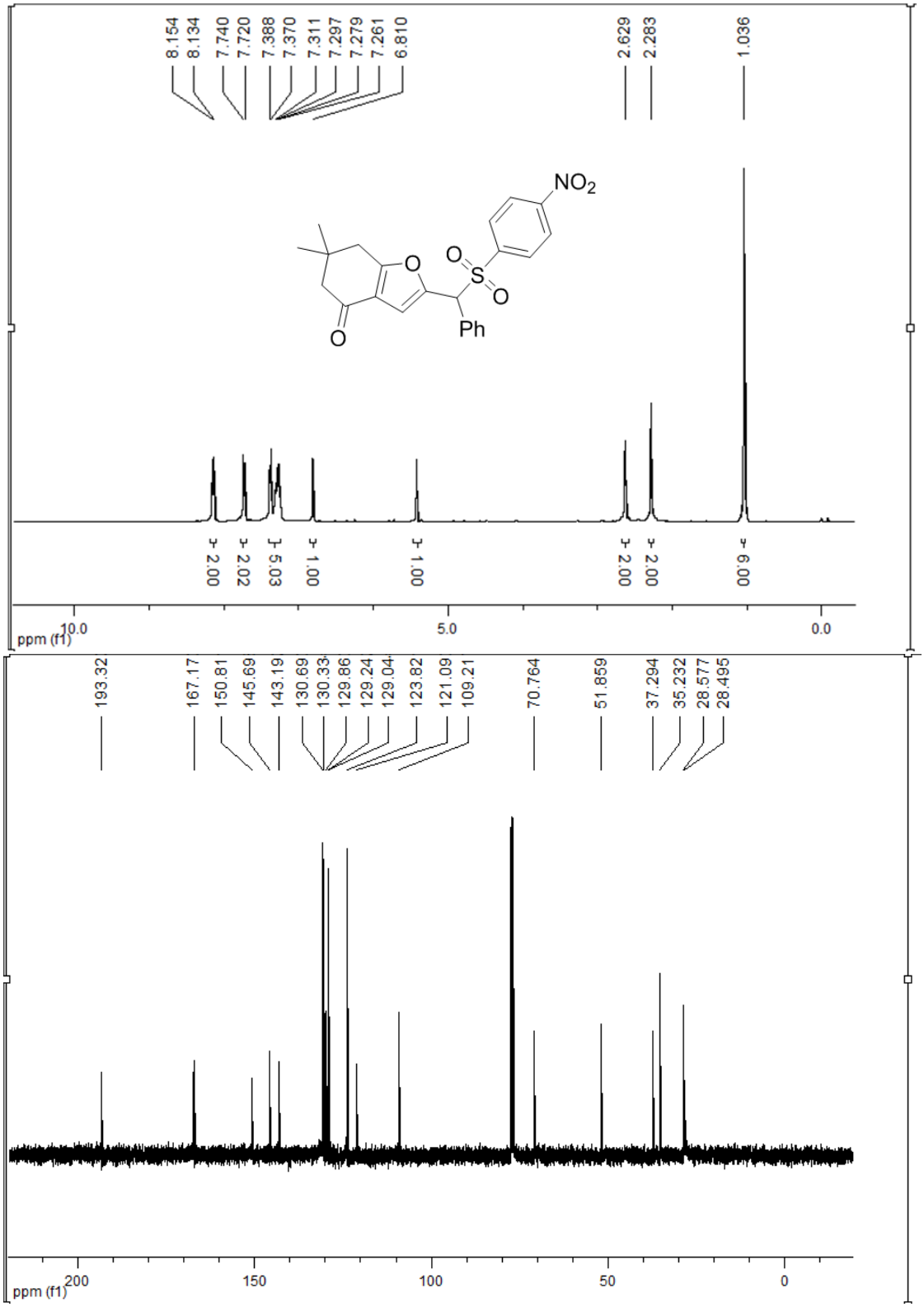

192.49
166.85
146.68
142.12
140.86
130.70
130.26
130.23
129.58
129.12
128.97
128.89
127.39
126.75
122.18
108.83
70.832
44.761
41.074
31.219
ppm (f1)
200
150
100
50
0

4h

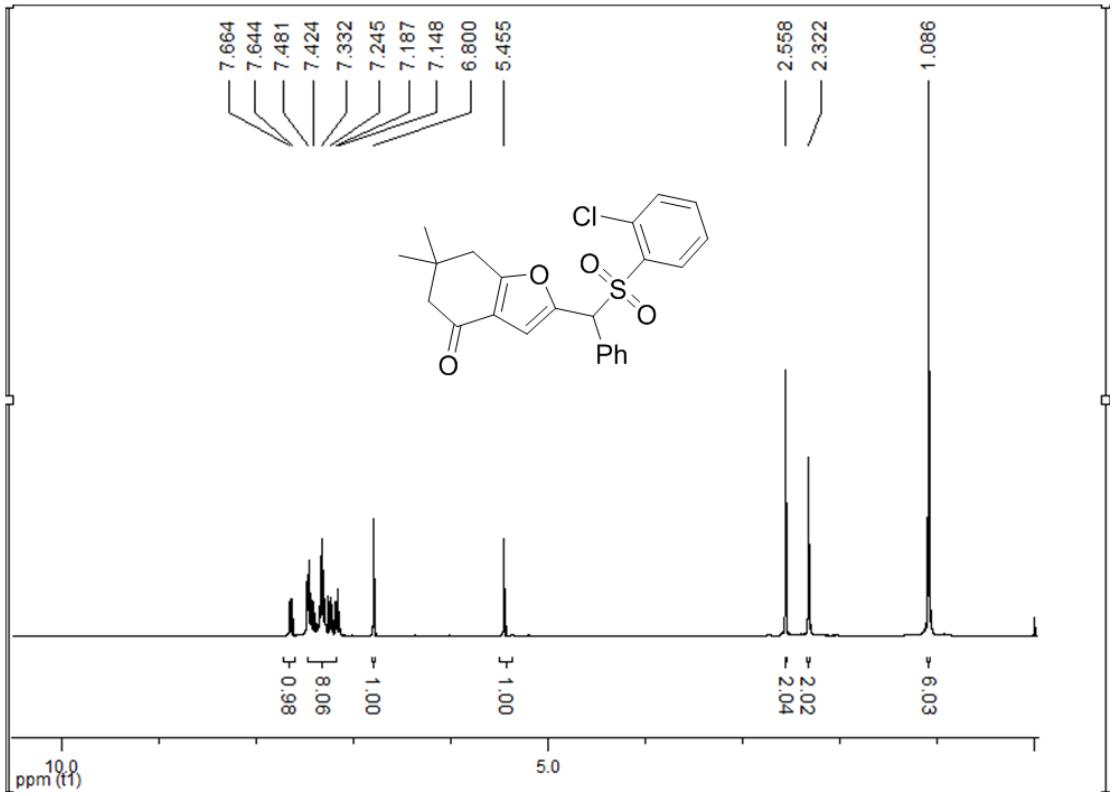

7.513
7.445
7.364
7.341
7.306
7.220
7.201
6.796
5.364
2.746
2.714
2.695
2.677
2.658
2.631
2.349
1.239
1.226
1.207
1.115
Et
O
S
O
O
O
Ph
7.03
2.00
0.98
1.00
4.01
2.00
3.08
6.08
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
ppm (f1)

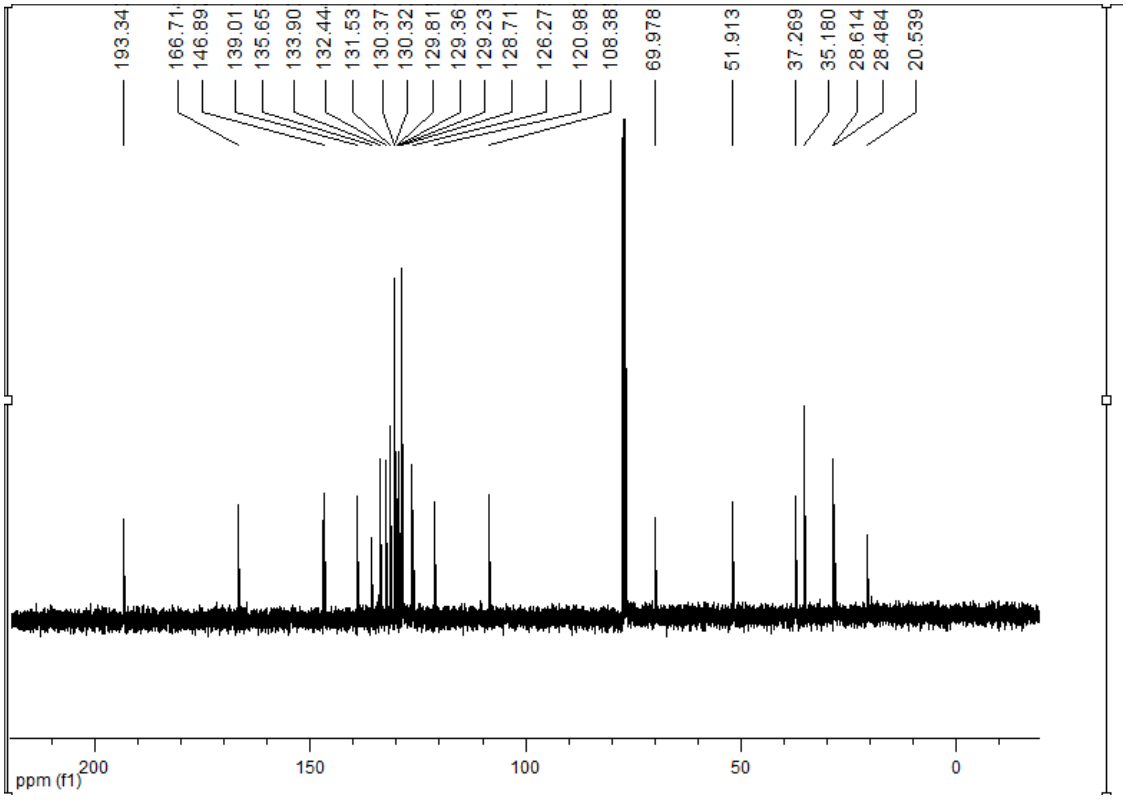

193.40
166.70
151.13
147.02
134.52
130.32
129.35
129.27
128.68
128.22
121.01
108.32
70.752
51.938
37.335
35.213
28.634
28.505
21.051
14.205
200
150
100
50
0
ppm (f1)

4i

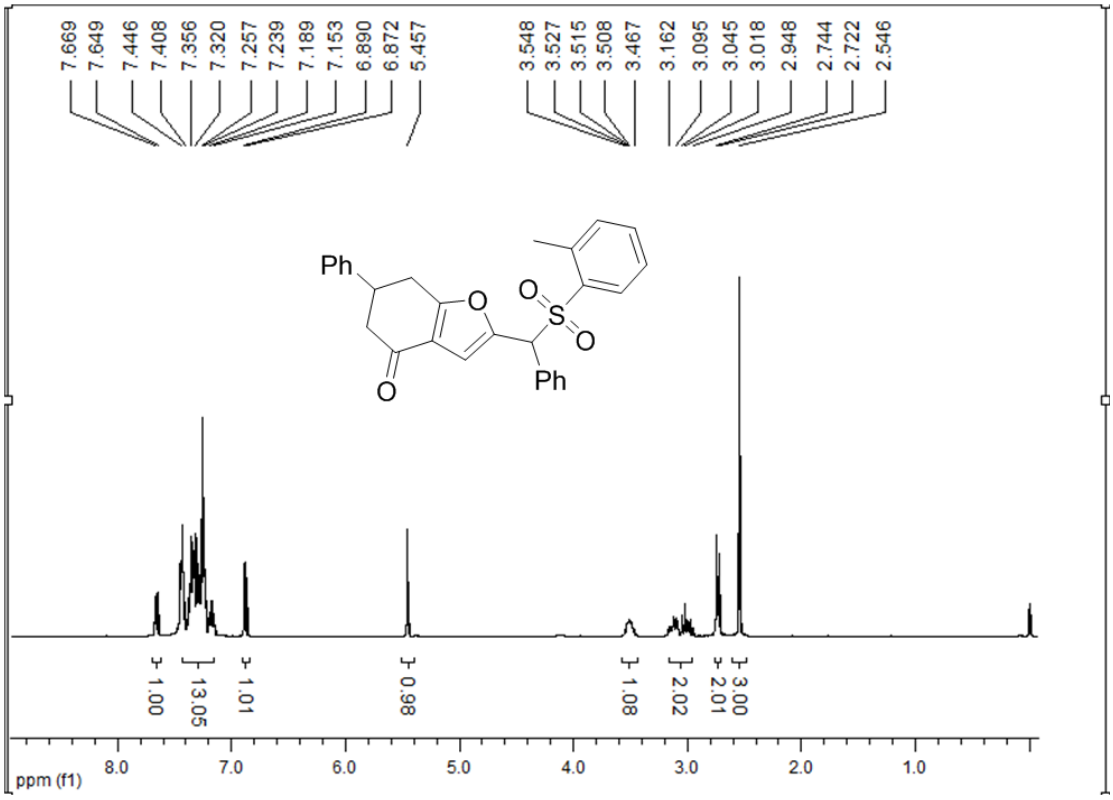

8.154
8.134
7.740
7.720
7.388
7.370
7.311
7.297
7.279
7.261
6.810
2.629
2.283
1.036
NO2
O
S
O
O
O
Ph
2.00
2.02
5.03
1.00
1.00
2.00
2.00
6.00
ppm (f1)
10.0
5.0
0.0
193.32
167.17
150.81
145.69
143.19
130.69
130.33
129.86
129.24
129.04
123.82
121.09
109.21
70.764
51.859
37.294
35.232
28.577
28.495
ppm (f1)
200
150
100
50
0

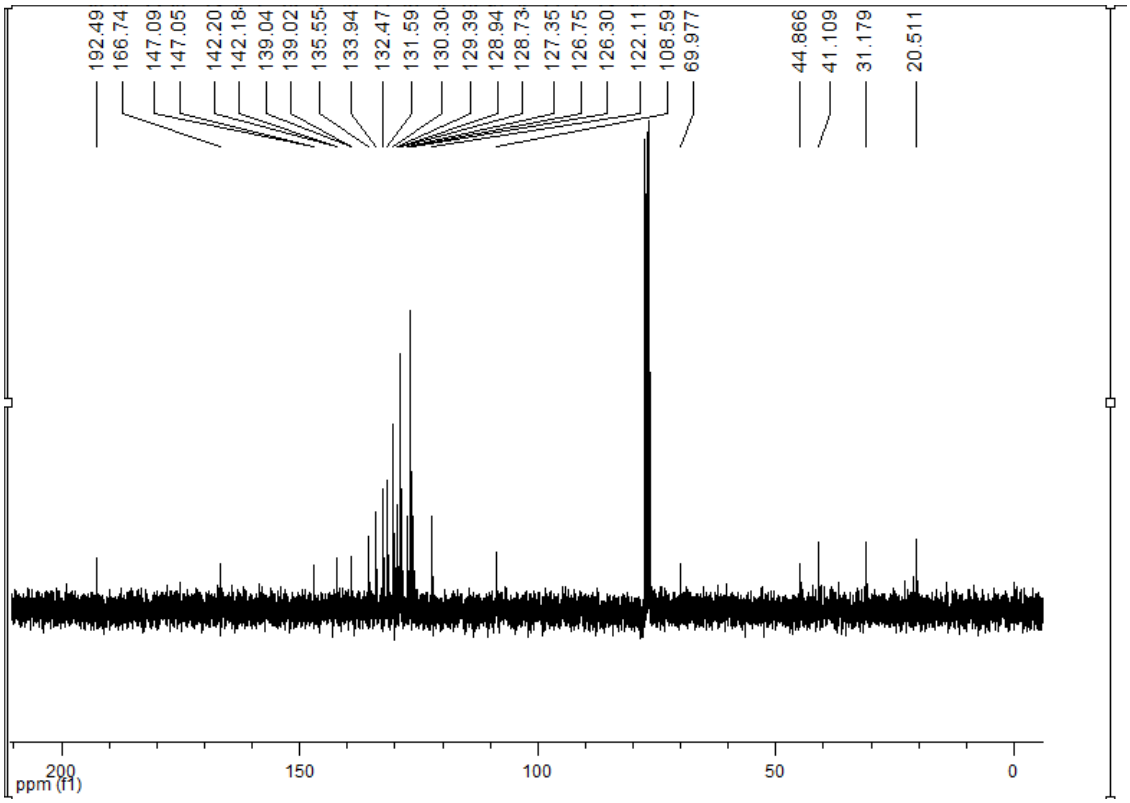
4j


7.664
7.644
7.481
7.424
7.332
7.245
7.187
7.148
6.800
5.455
2.558
2.322
1.086
Cl
O
S
O
O
O
Ph
0.98
8.06
1.00
1.00
2.04
2.02
6.03
10.0
5.0
ppm (f1)

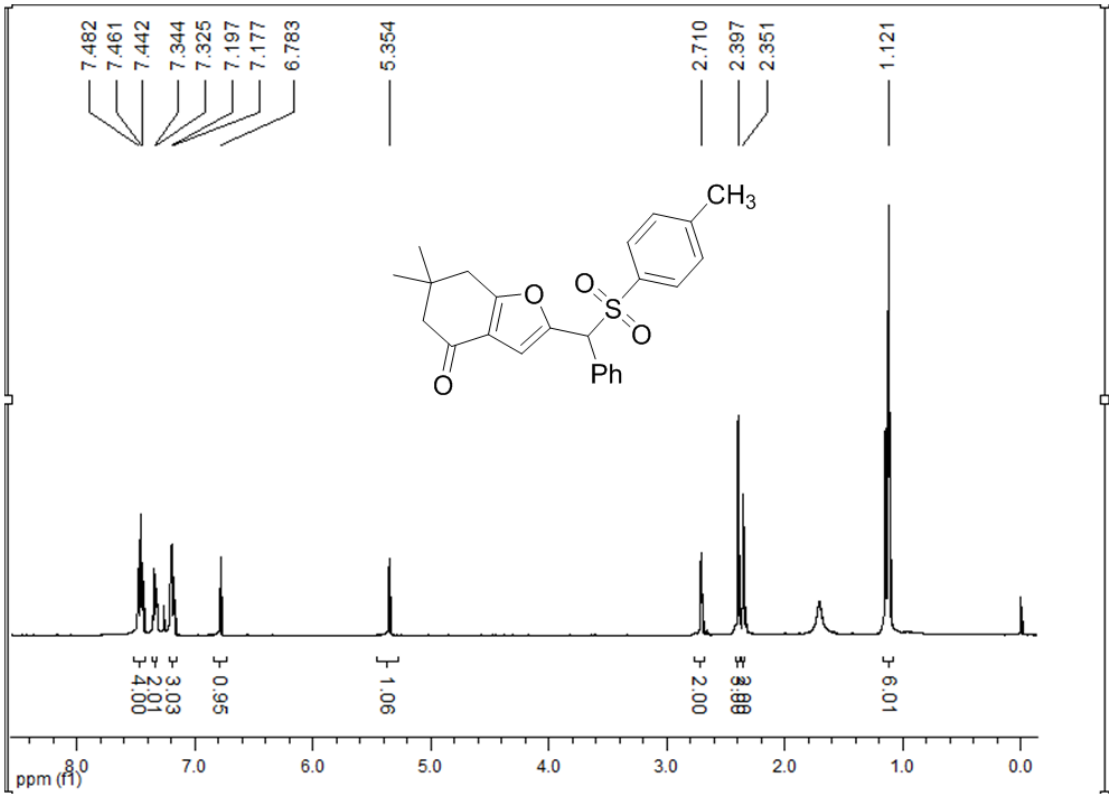

193.34
166.71
146.89
139.01
135.65
133.90
132.44
131.53
130.37
130.32
129.81
129.36
129.23
128.71
126.27
120.98
108.38
69.978
51.913
37.269
35.180
28.614
28.484
20.539
200
150
100
50
0
ppm (f1)

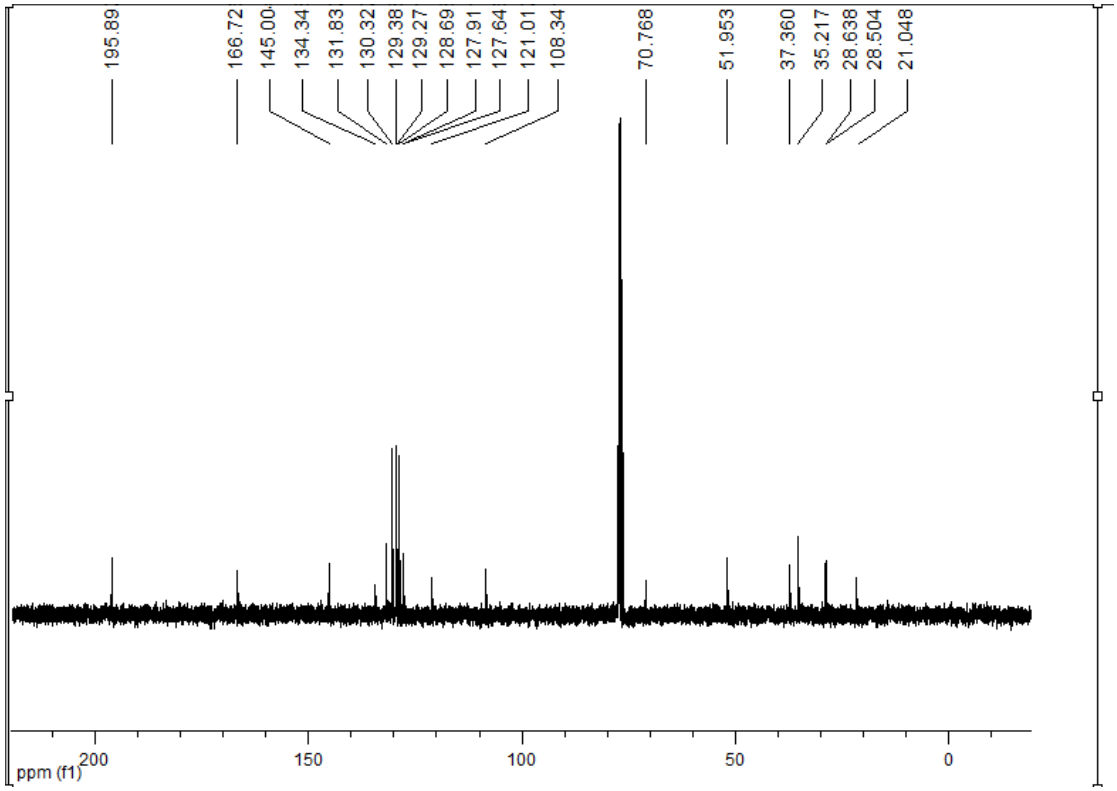
4k


7.669
7.649
7.446
7.408
7.356
7.320
7.257
7.239
7.189
7.153
6.890
6.872
5.457
3.548
3.527
3.515
3.508
3.467
3.162
3.095
3.045
3.018
2.948
2.744
2.722
2.546
Ph
O
O
S
O
Ph
O
1.00
13.05
1.01
0.98
1.08
2.02
2.01
3.00
ppm (f1)
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0

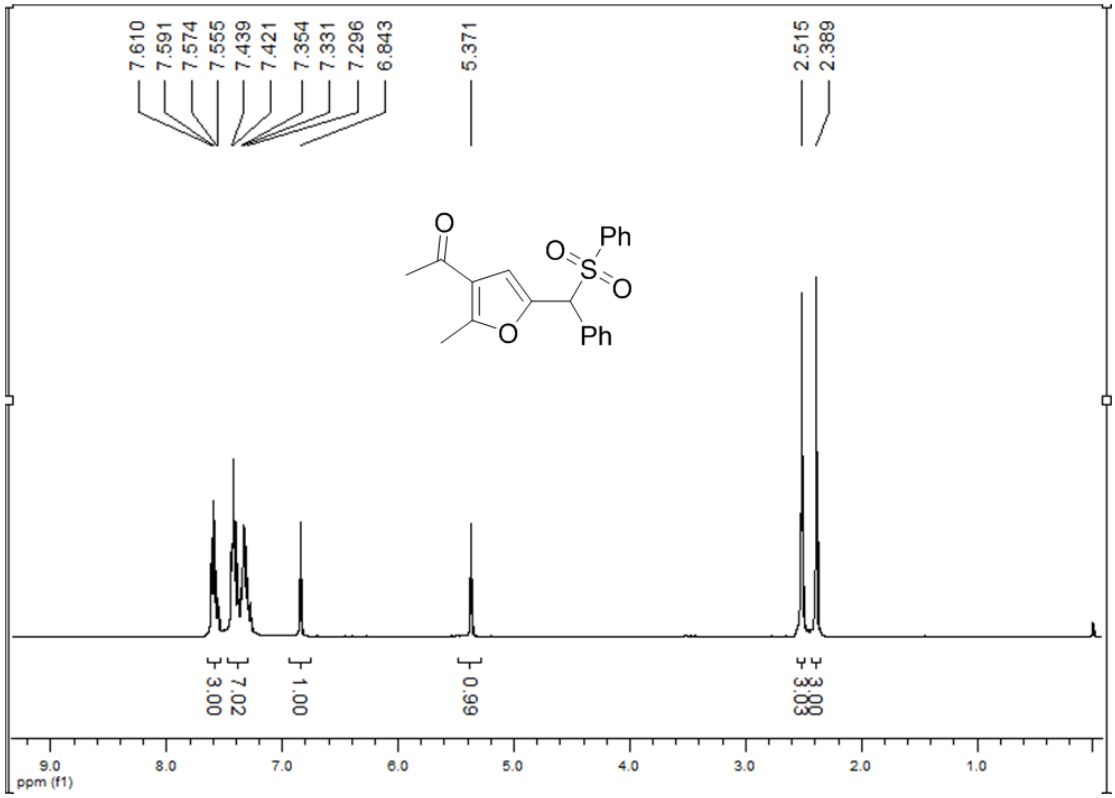

192.49
166.74
147.09
147.05
142.20
142.18
139.04
139.02
135.55
133.94
132.47
131.59
130.30
129.39
128.94
128.73
127.35
126.75
126.30
122.11
108.59
69.977
44.866
41.109
31.179
20.511
ppm (f1)
200
150
100
50
0

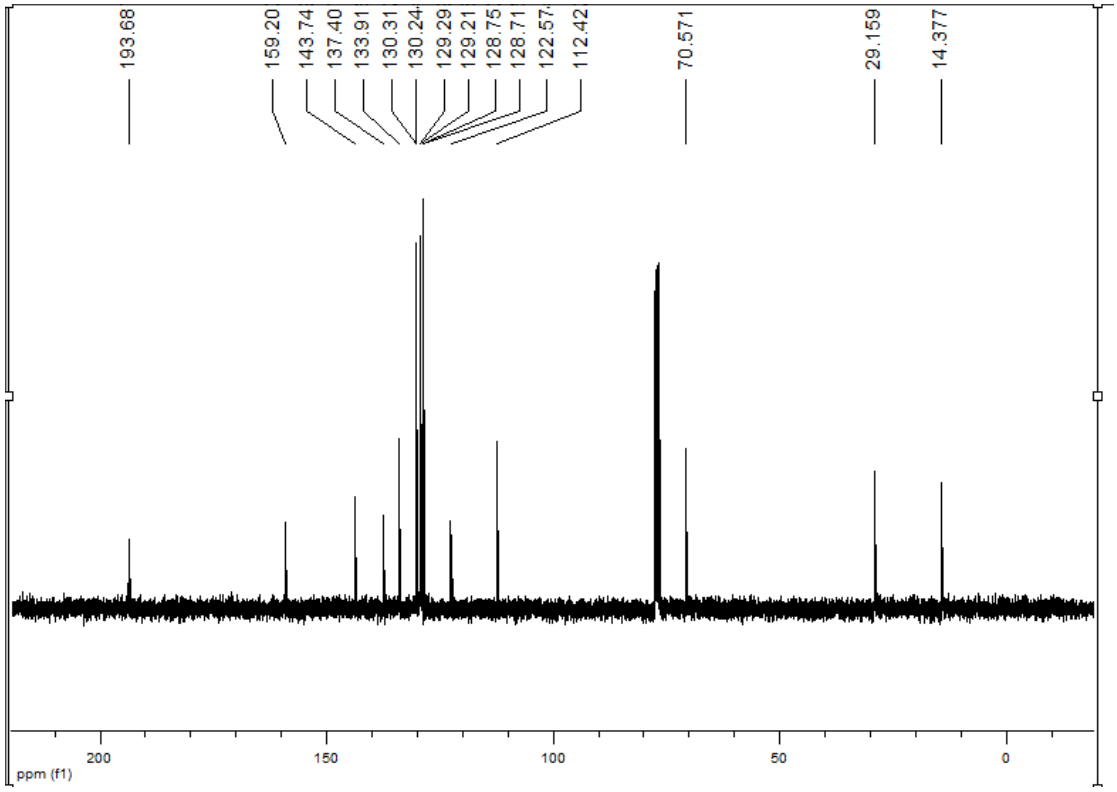
4l


7.482
7.461
7.442
7.344
7.325
7.197
7.177
6.783
5.354
2.710
2.397
2.351
1.121
CH3
O
S
O
O
O
Ph
4.00
1.01
3.03
0.95
1.06
2.00
3.00
6.01
ppm (f1)
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0

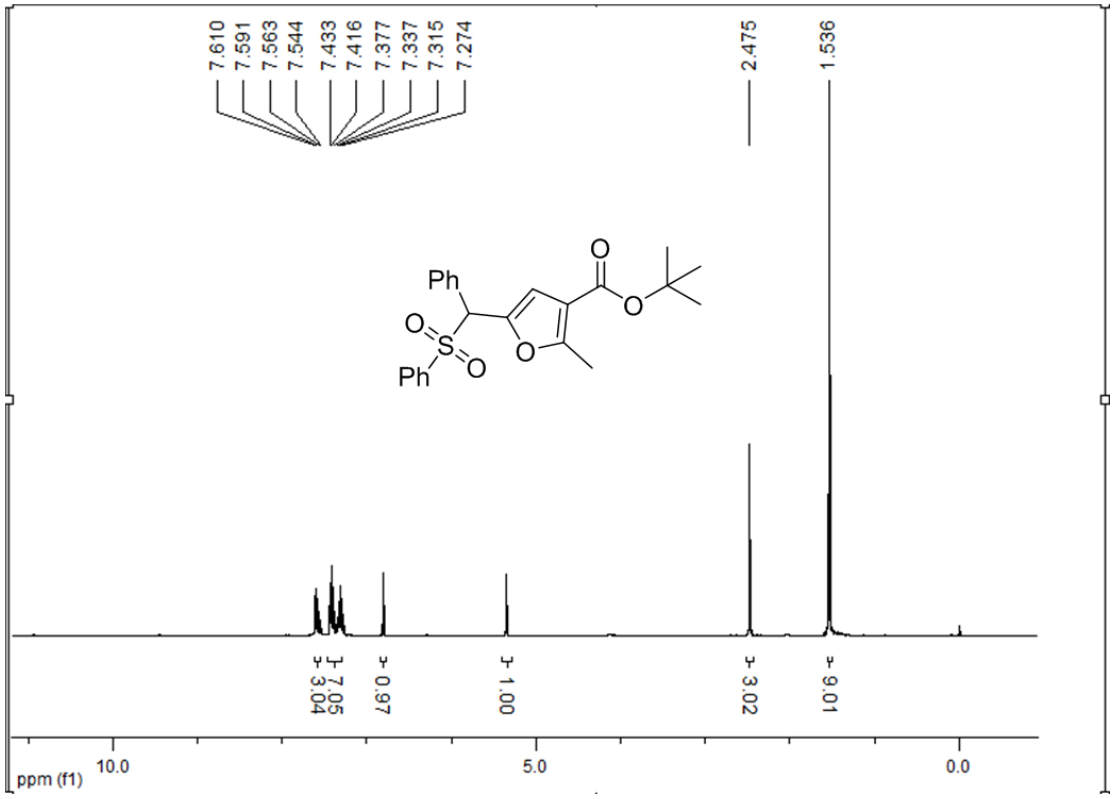

195.89
166.72
145.00
134.34
131.83
130.32
129.38
129.27
128.69
127.91
127.64
121.01
108.34
70.768
51.953
37.360
35.217
28.638
28.504
21.048
ppm (f1)
200
150
100
50
0

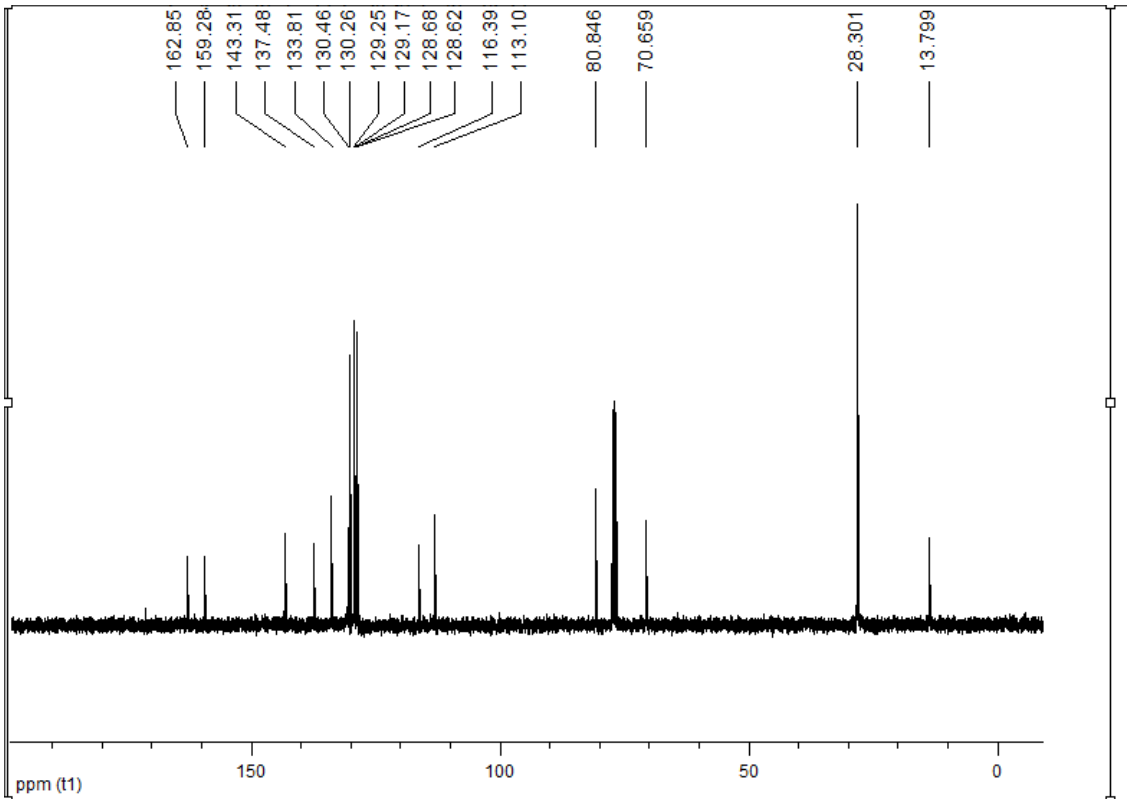
5a


7.610
7.591
7.574
7.555
7.439
7.421
7.354
7.331
7.296
6.843
5.371
2.515
2.389
O
Ph
O
S
O
O
Ph
3.00
7.02
1.00
0.99
3.09
3.00
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
ppm (f1)

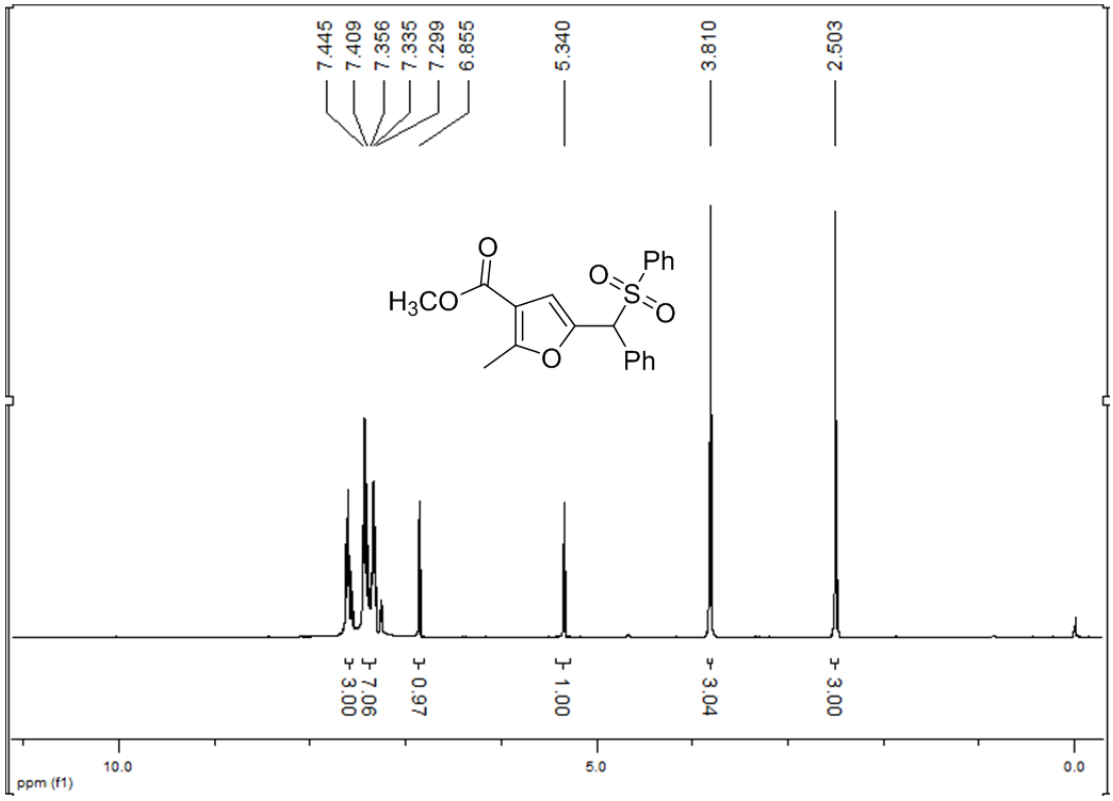

193.68
159.20
143.74
137.40
133.91
130.31
130.24
129.29
129.21
128.75
128.71
122.57
112.42
70.571
29.159
14.377
200
150
100
50
0
ppm (f1)

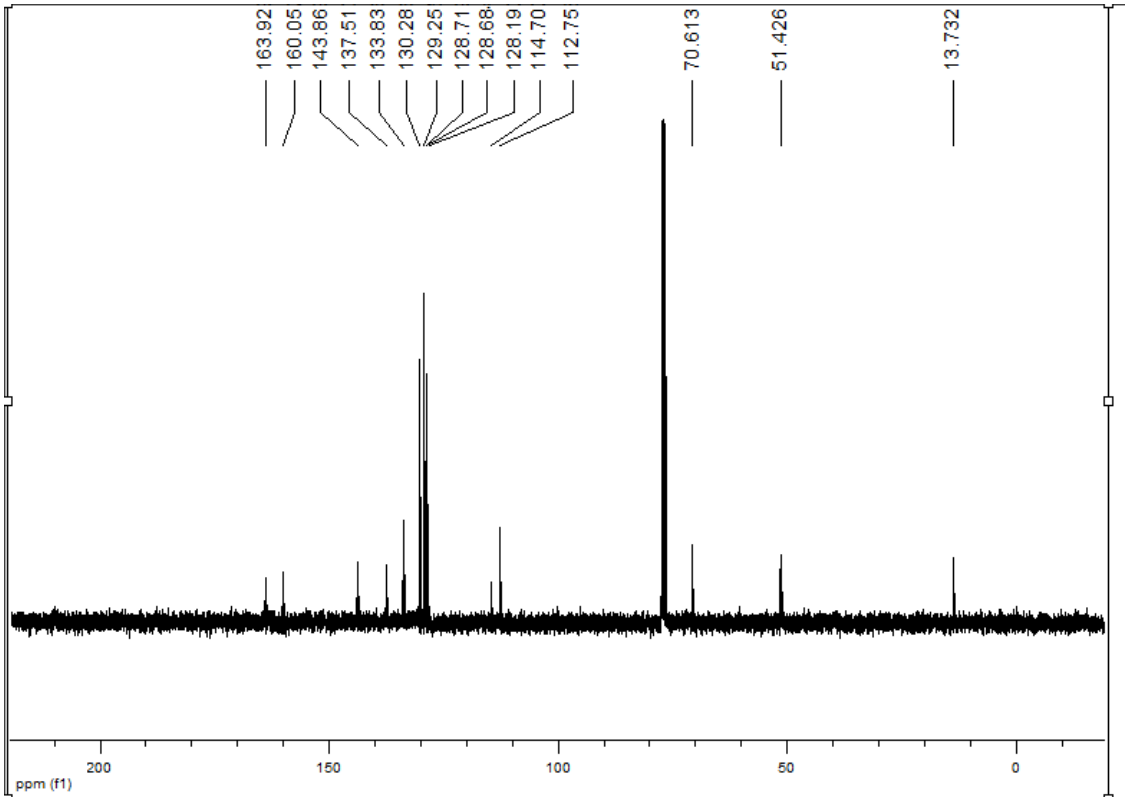
5b


7.610
7.591
7.563
7.544
7.433
7.416
7.377
7.337
7.315
7.274
2.475
1.536
Ph
O
S
O
Ph
O
O
O
3.04
7.05
0.97
1.00
3.02
9.01
10.0
5.0
0.0
ppm (f1)

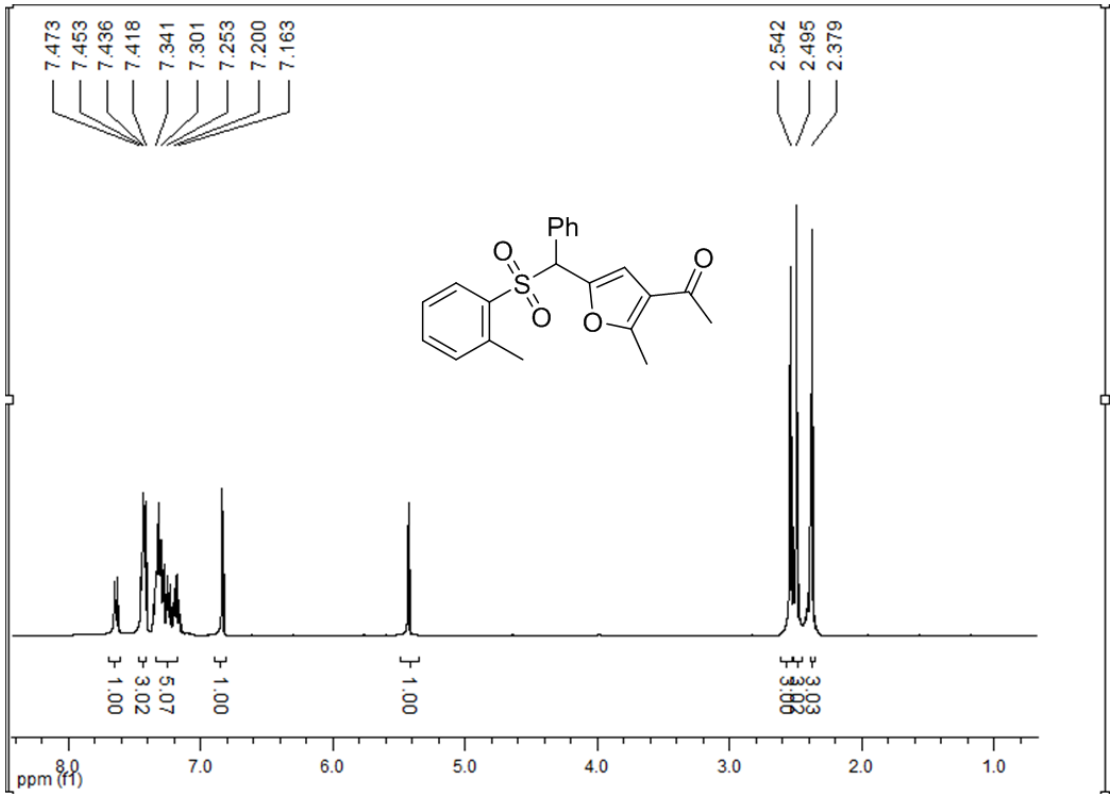

162.85
159.28
143.31
137.48
133.81
130.46
130.26
129.25
129.17
128.68
128.62
116.39
113.10
80.846
70.659
28.301
13.799
150
100
50
0
ppm (t1)

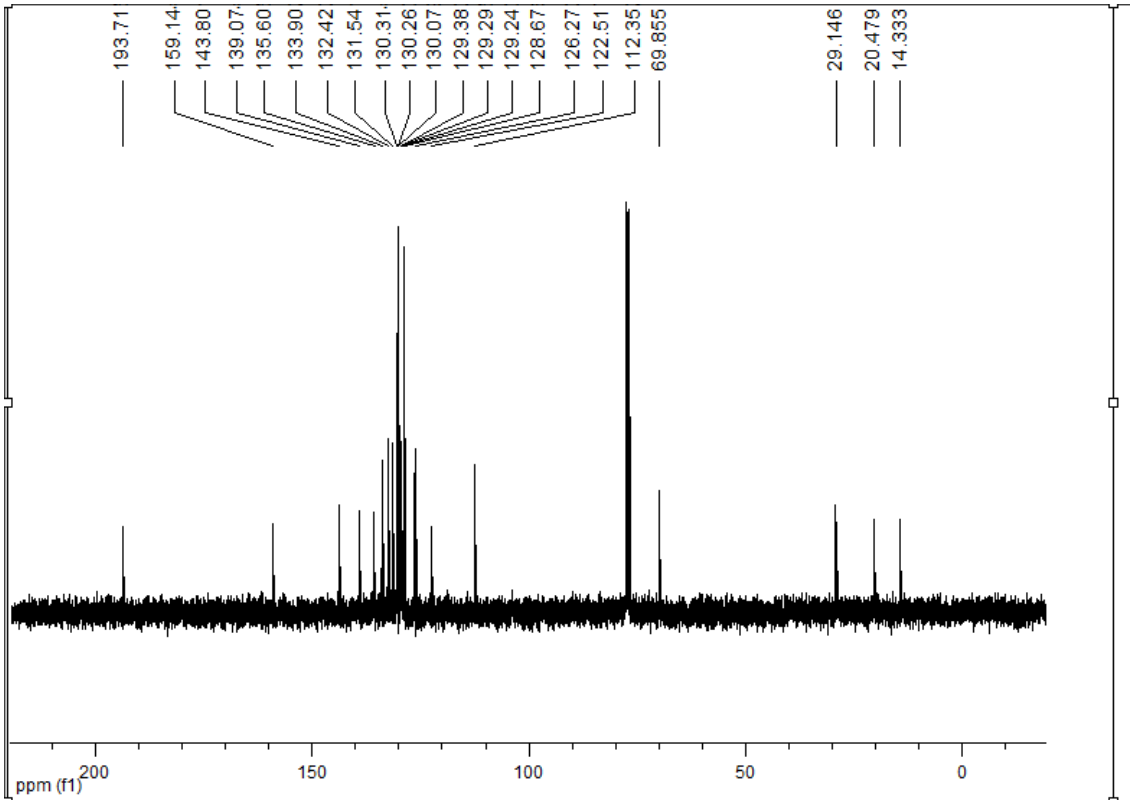
5c


7.445
7.409
7.356
7.335
7.299
6.855
5.340
3.810
2.503
O
H3CO
O
S
O
Ph
O
Ph
3.00
7.06
0.97
1.00
3.04
3.00
10.0
5.0
0.0
ppm (f1)

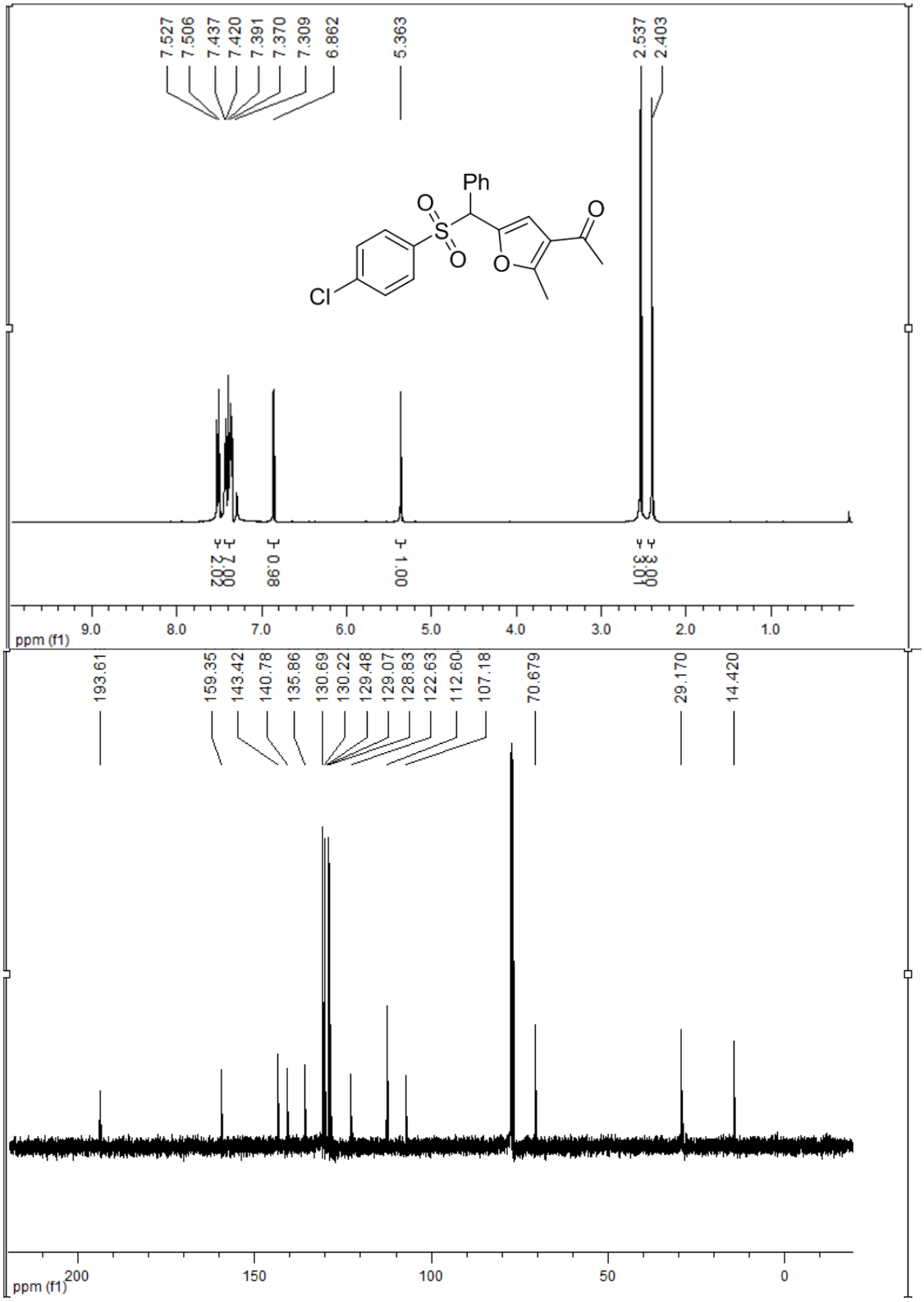

163.92
160.05
143.86
137.51
133.83
130.28
129.25
128.71
128.68
128.19
114.70
112.75
70.613
51.426
13.732
200
150
100
50
0
ppm (f1)

5d

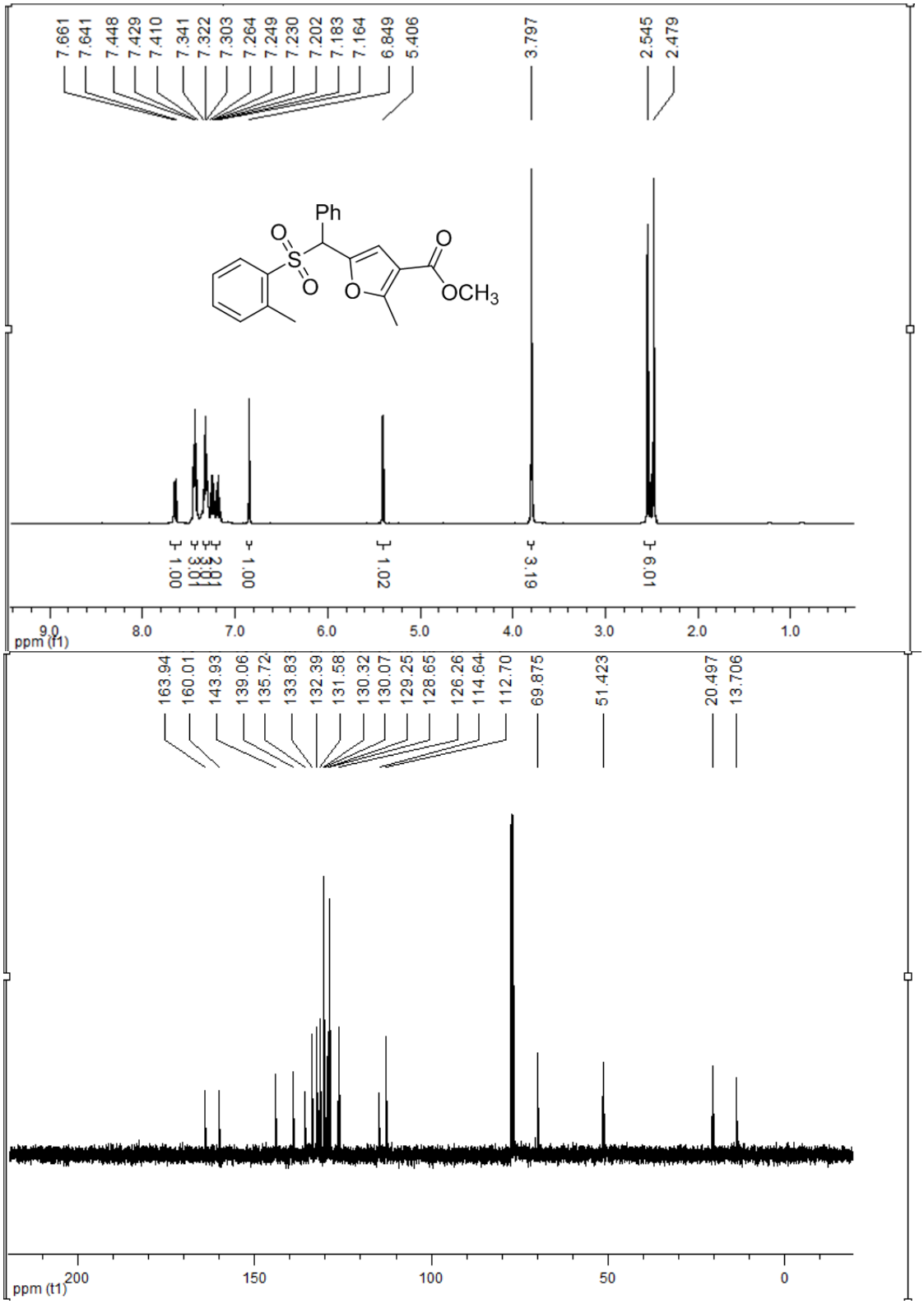

7.473
7.453
7.436
7.418
7.341
7.301
7.253
7.200
7.163
2.542
2.495
2.379
Ph
O
S
O
O
O
1.00
3.02
5.07
1.00
1.00
3.06
3.03
ppm (f1)
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0


193.71
159.14
143.80
139.07
135.60
133.90
132.42
131.54
130.31
130.26
130.07
129.38
129.29
129.24
128.67
126.27
122.51
112.35
69.855
29.146
20.479
14.333
ppm (f1)
200
150
100
50
0

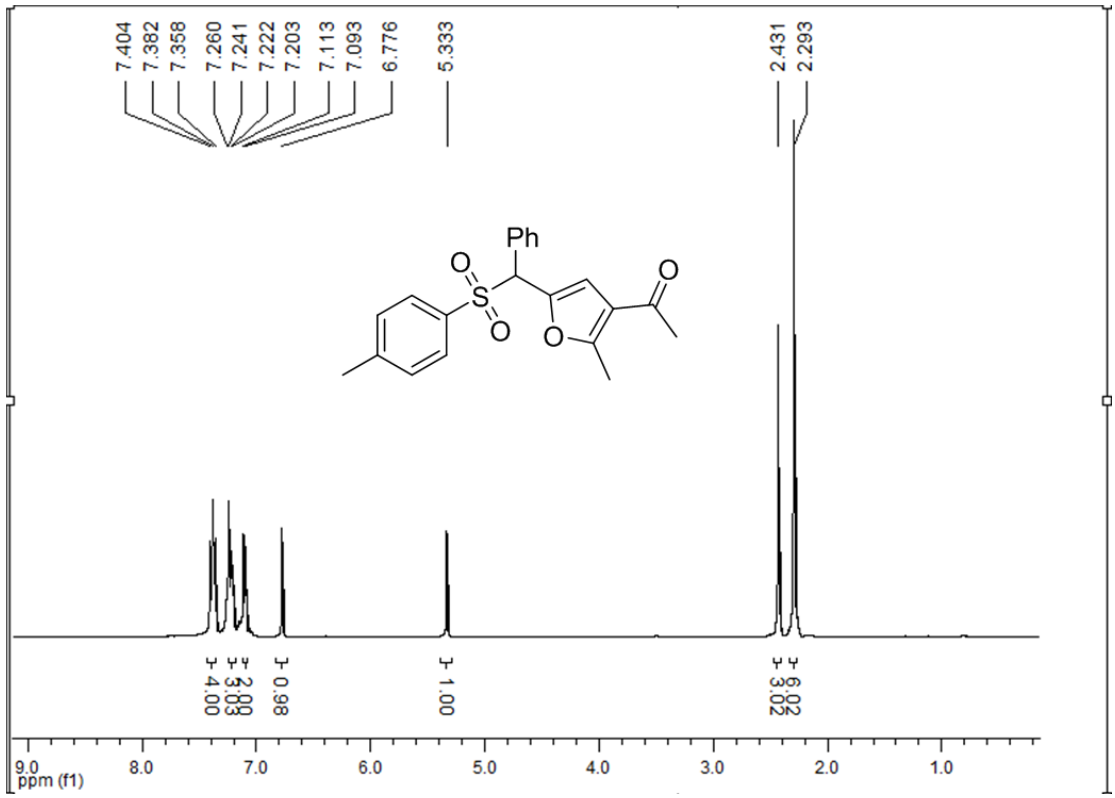
5e

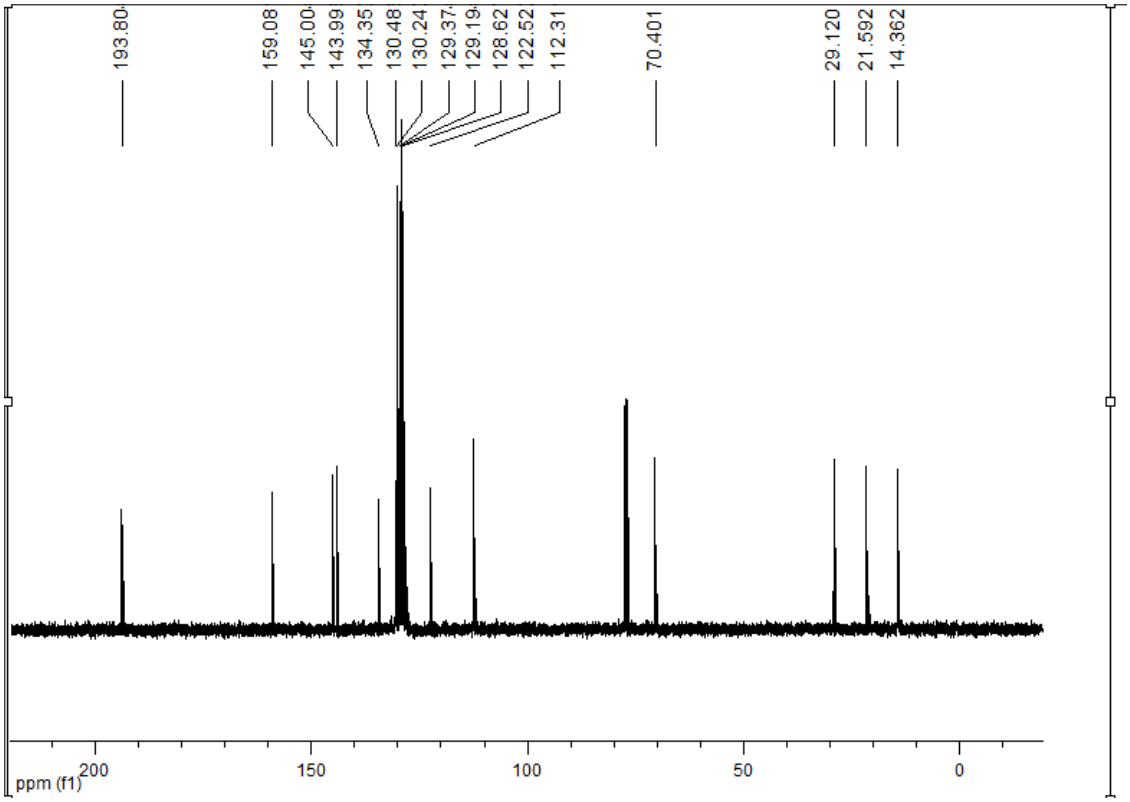

7.527
7.506
7.437
7.420
7.391
7.370
7.309
6.862
5.363
2.537
2.403
Ph
O
S
O
O
O
Cl
2.88
0.98
1.00
3.00
ppm (f1)
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
193.61
159.35
143.42
140.78
135.86
130.69
130.22
129.48
129.07
128.83
122.63
112.60
107.18
70.679
29.170
14.420
ppm (f1)
200
150
100
50
0

5f

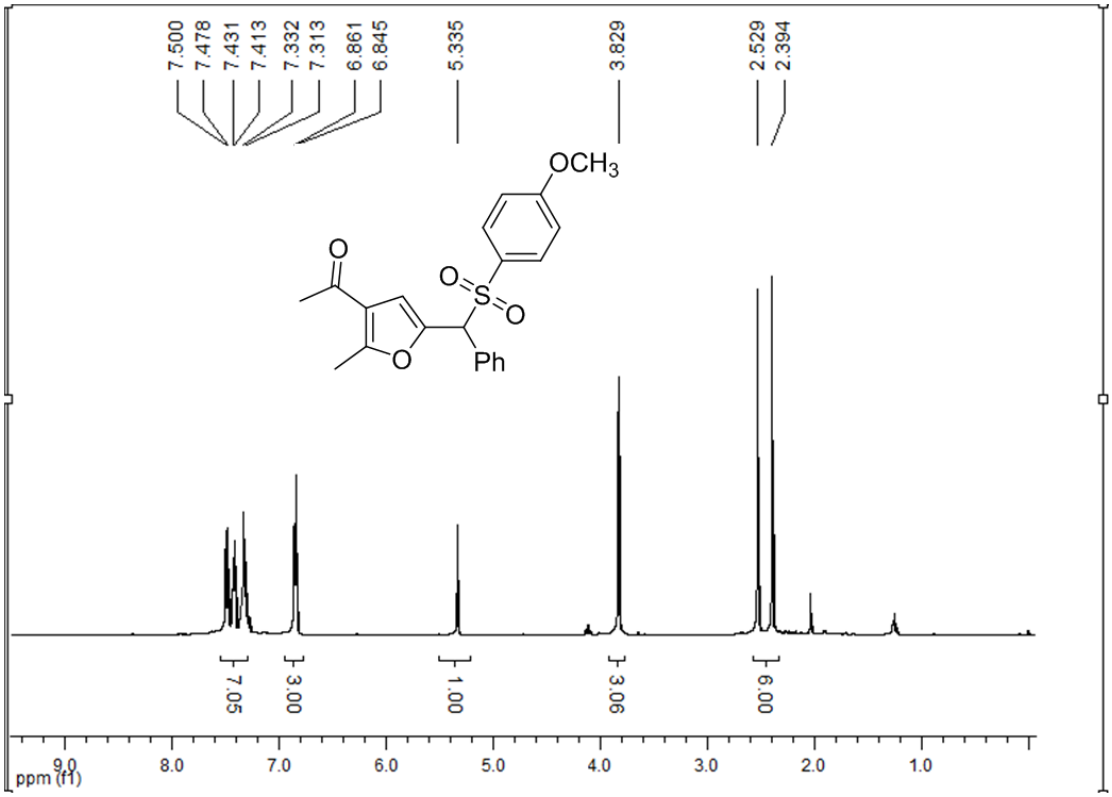

7.661
7.641
7.448
7.429
7.410
7.341
7.322
7.303
7.264
7.249
7.230
7.202
7.183
7.164
6.849
5.406
3.797
2.545
2.479
Ph
O
S
O
O
O
OCH3
1.00
1.00
1.02
3.19
6.01
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
ppm (f1)
163.94
160.01
143.93
139.06
135.72
133.83
132.39
131.58
130.32
130.07
129.25
128.65
126.26
114.64
112.70
69.875
51.423
20.497
13.706
200
150
100
50
0
ppm (t1)

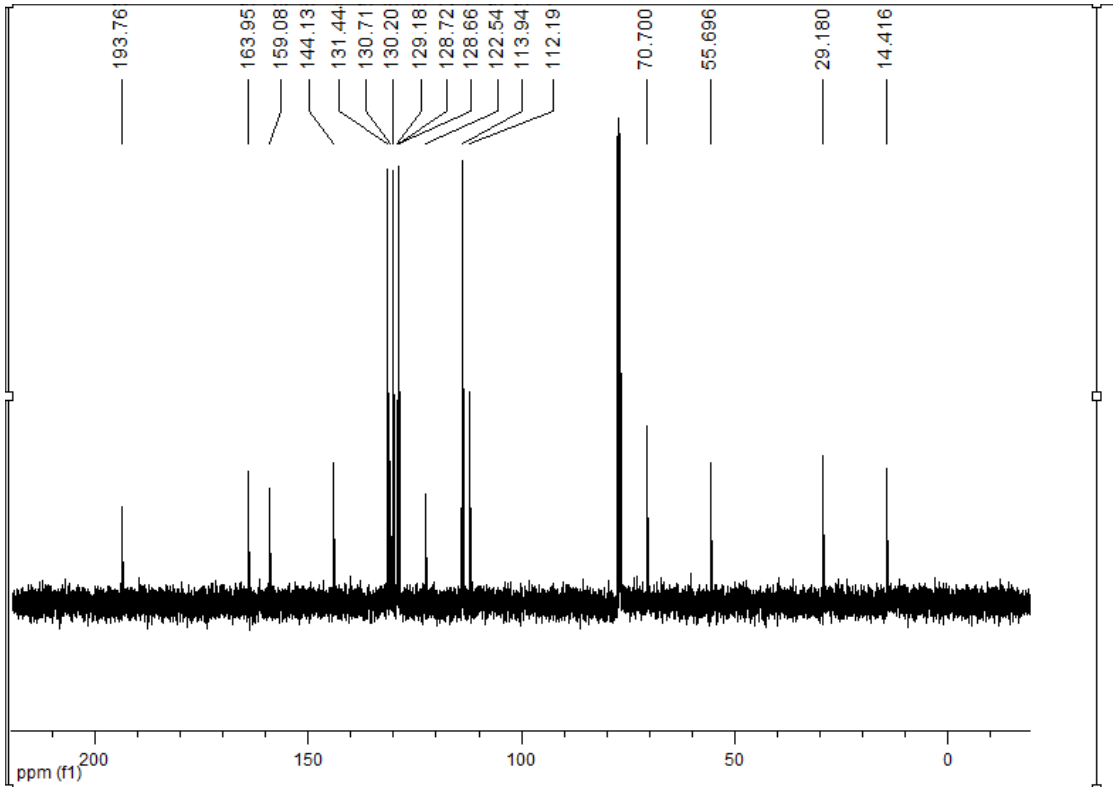
5g


7.404
7.382
7.358
7.260
7.241
7.222
7.203
7.113
7.093
6.776
5.333
2.431
2.293
Ph
O
S
O
O
O
4.00
3.03
2.00
0.98
1.00
3.02
6.02
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
ppm (f1)

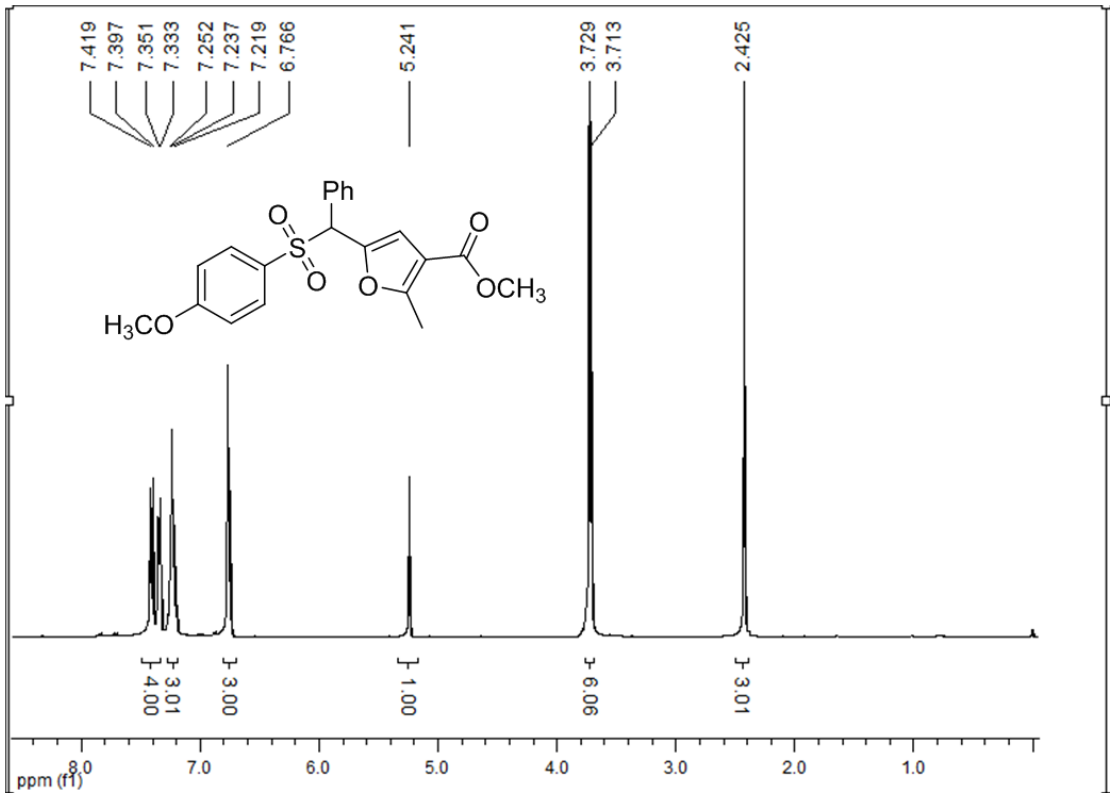

193.80
159.08
145.00
143.99
134.35
130.48
130.24
129.37
129.19
128.62
122.52
112.31
70.401
29.120
21.592
14.362
200
150
100
50
0
ppm (f1)

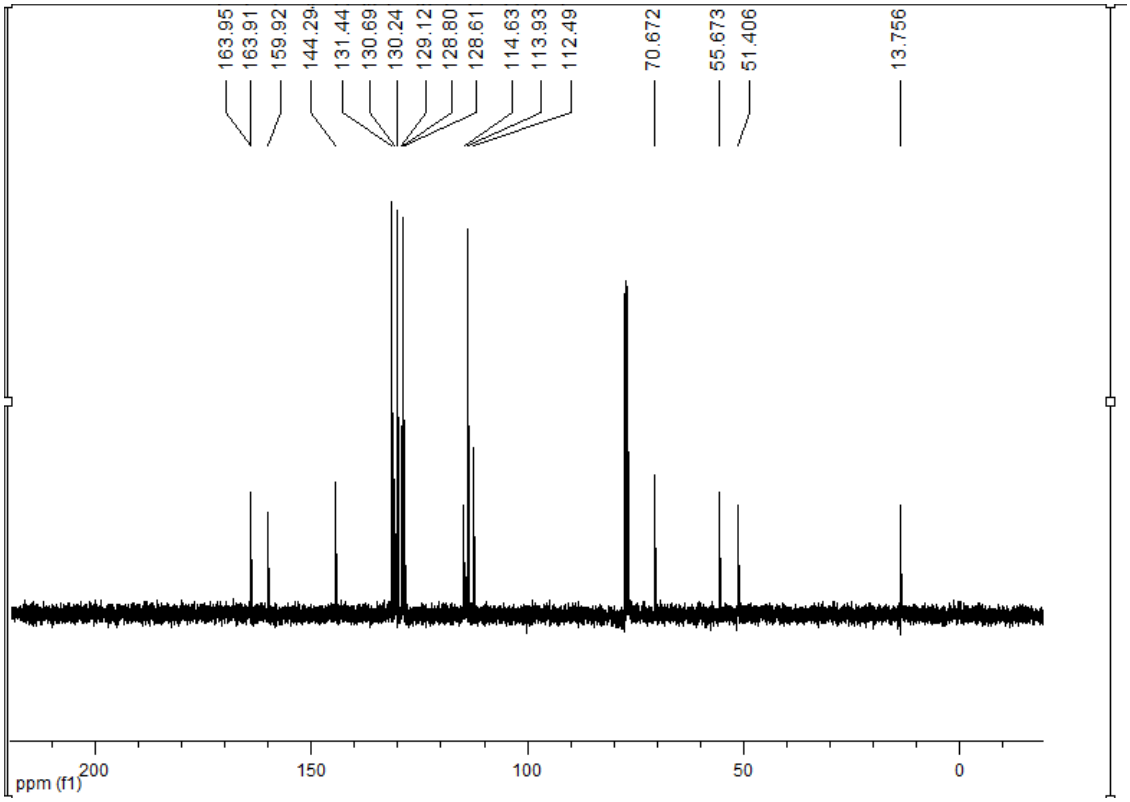
5h


7.500
7.478
7.431
7.413
7.332
7.313
6.861
6.845
5.335
3.829
2.529
2.394
OCH3
O
O
S
O
O
Ph
7.05
3.00
1.00
3.06
6.00
ppm (f1)
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0

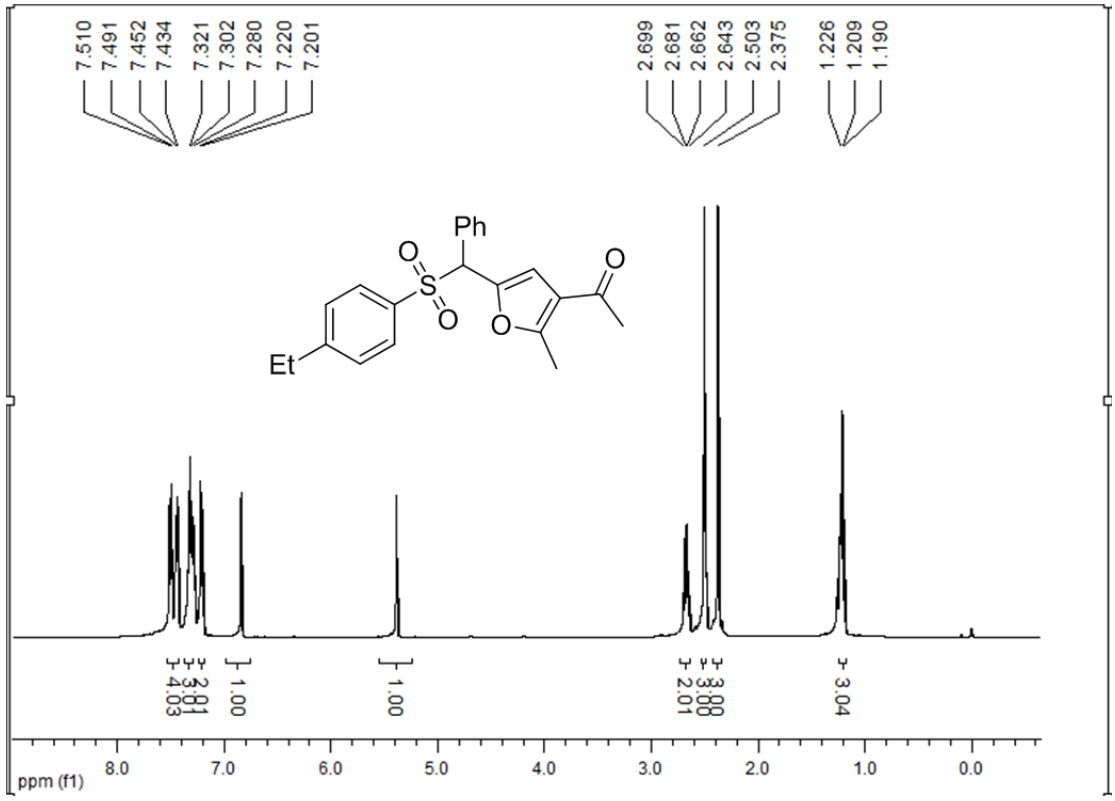

193.76
163.95
159.08
144.13
131.44
130.71
130.20
129.18
128.72
128.66
122.54
113.94
112.19
70.700
55.696
29.180
14.416
ppm (f1)
200
150
100
50
0

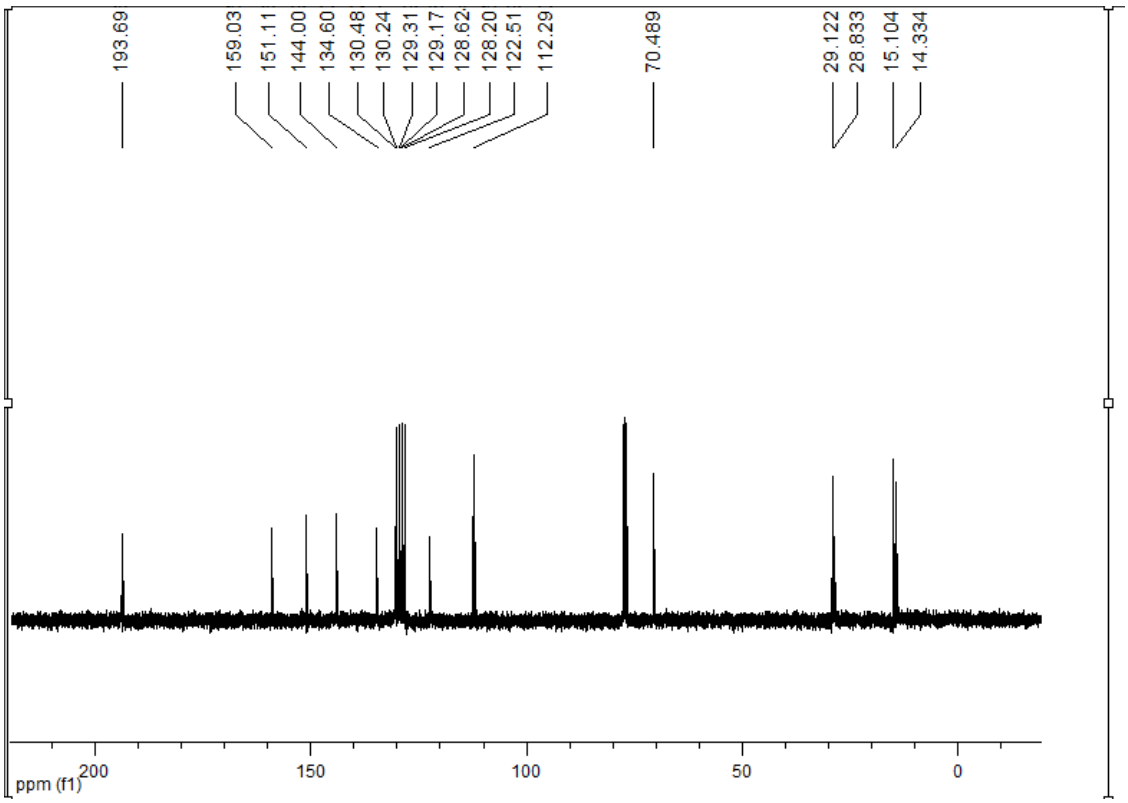
5i


7.419
7.397
7.351
7.333
7.252
7.237
7.219
6.766
5.241
3.729
3.713
2.425
Ph
O
S
O
O
O
OCH3
H3CO
4.00
3.01
3.00
1.00
6.06
3.01
ppm (f1)
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0

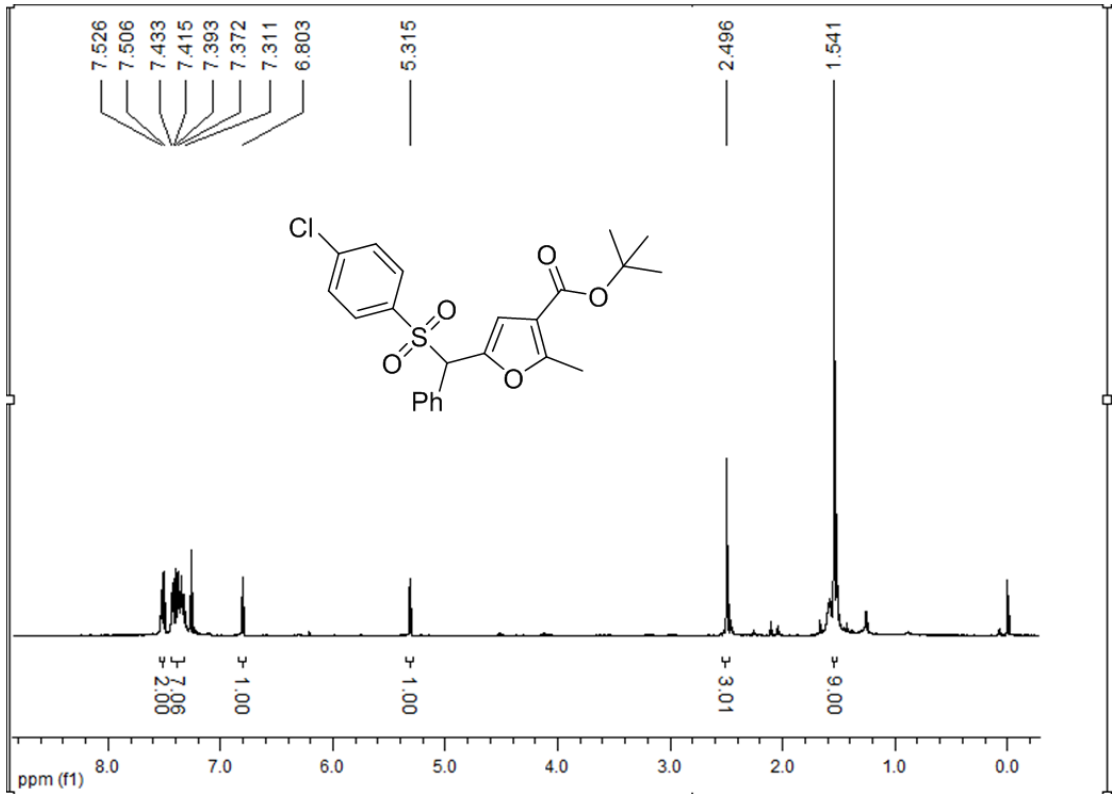

163.95
163.91
159.92
144.29
131.44
130.69
130.24
129.12
128.80
128.61
114.63
113.93
112.49
70.672
55.673
51.406
13.756
ppm (f1)
200
150
100
50
0

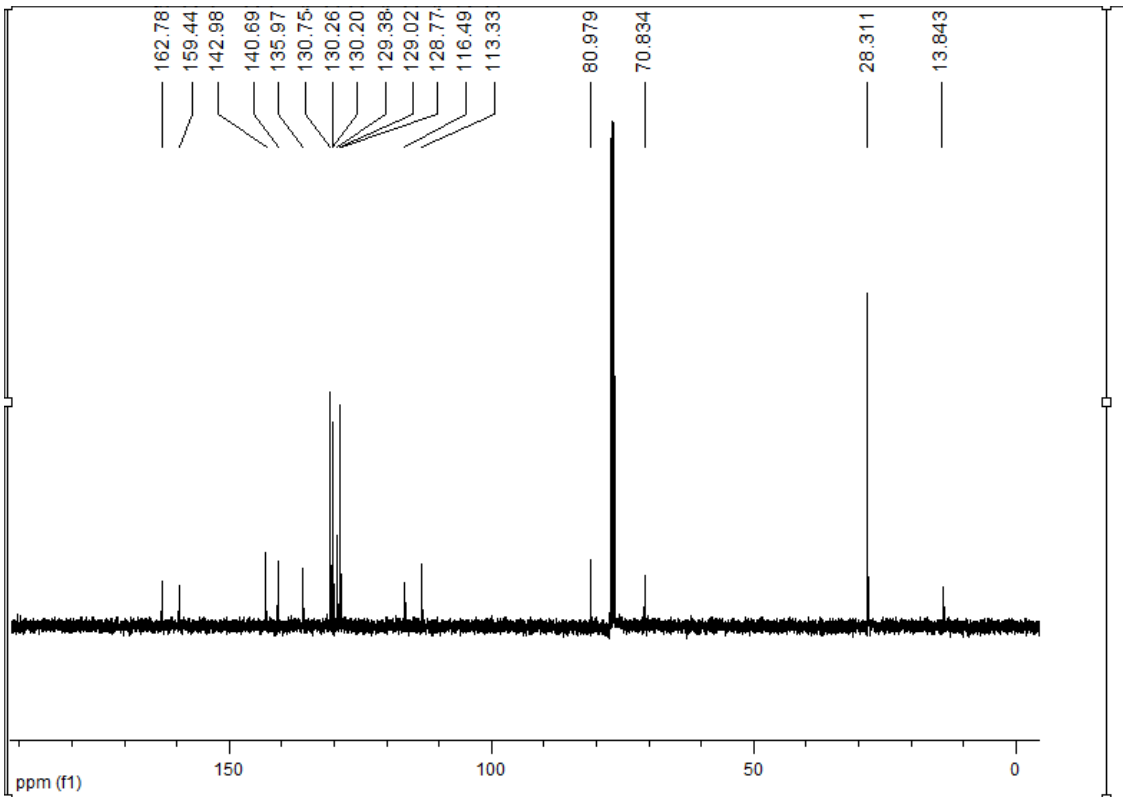
5j


7.510
7.491
7.452
7.434
7.321
7.302
7.280
7.220
7.201
2.699
2.681
2.662
2.643
2.503
2.375
1.226
1.209
1.190
Ph
O
S
O
O
O
Et
4.03
3.11
1.00
1.00
2.01
3.00
3.04
ppm (f1)
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0

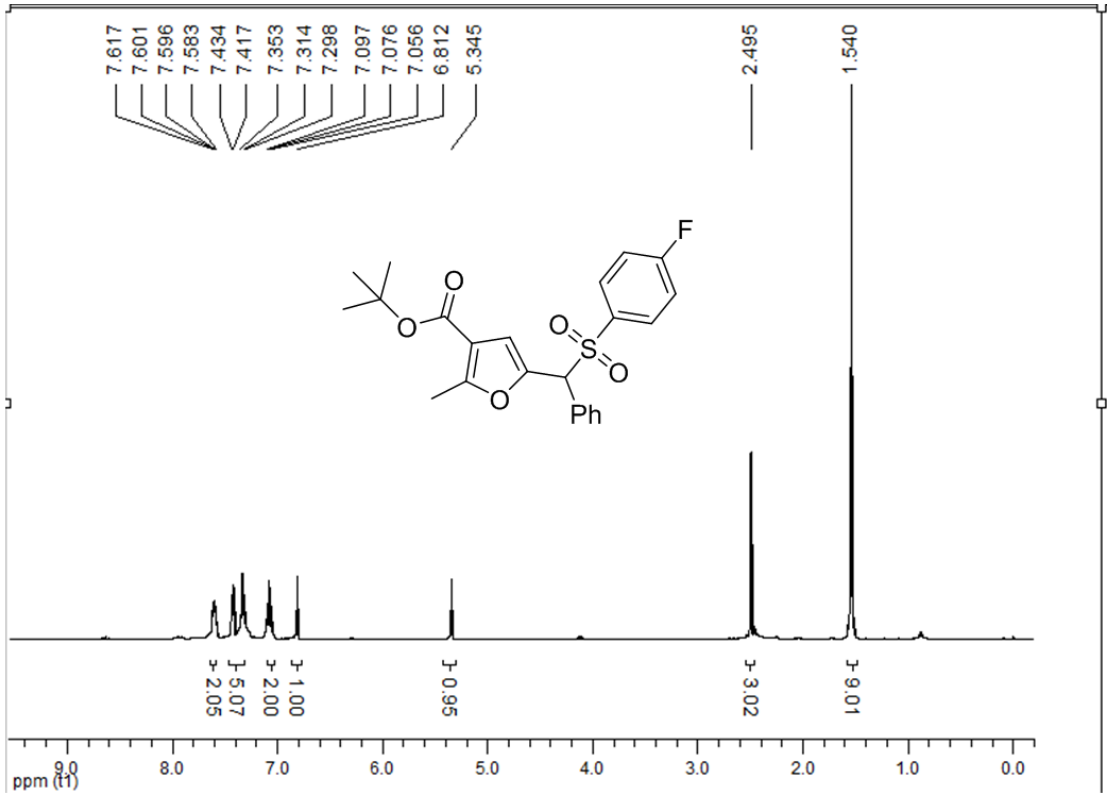

193.69
159.03
151.11
144.00
134.60
130.48
130.24
129.31
129.17
128.62
128.20
122.51
112.29
70.489
29.122
28.833
15.104
14.334
ppm (f1)
200
150
100
50
0

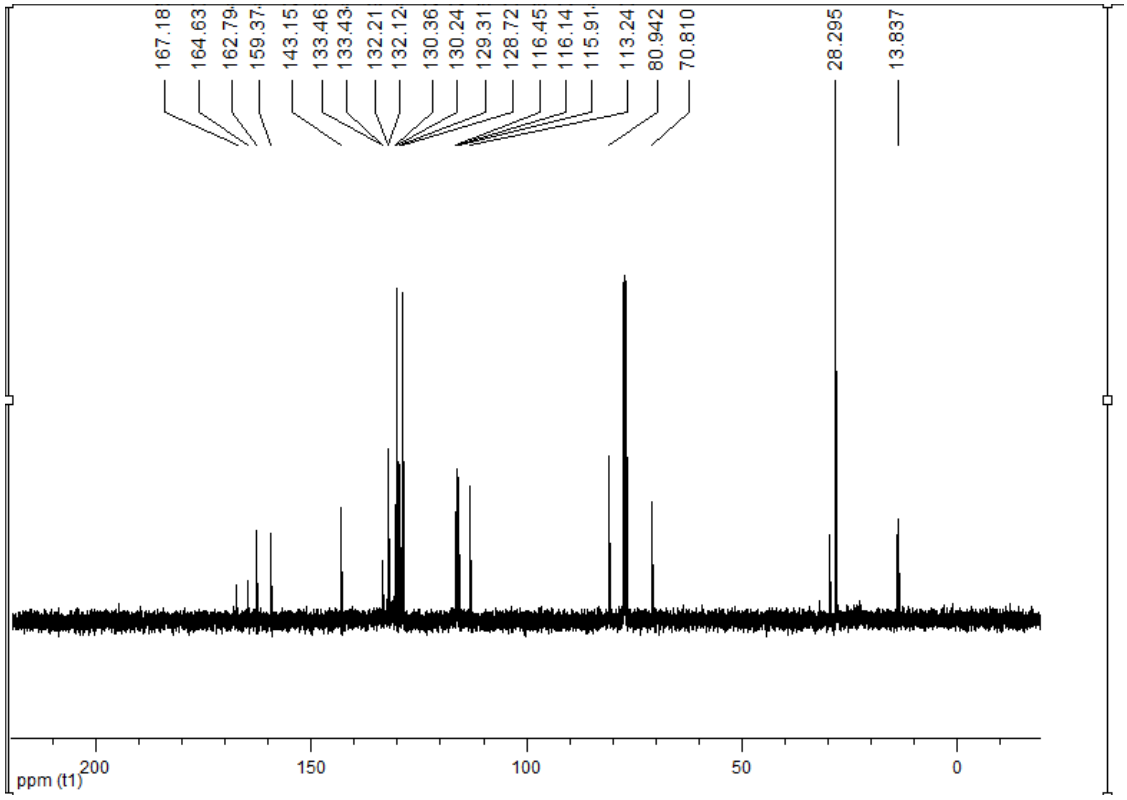
5k


7.526
7.506
7.433
7.415
7.393
7.372
7.311
6.803
5.315
2.496
1.541
Cl
O
O
S
O
O
Ph
O
O
7.06
2.00
1.00
1.00
3.01
9.00
ppm (f1)
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0

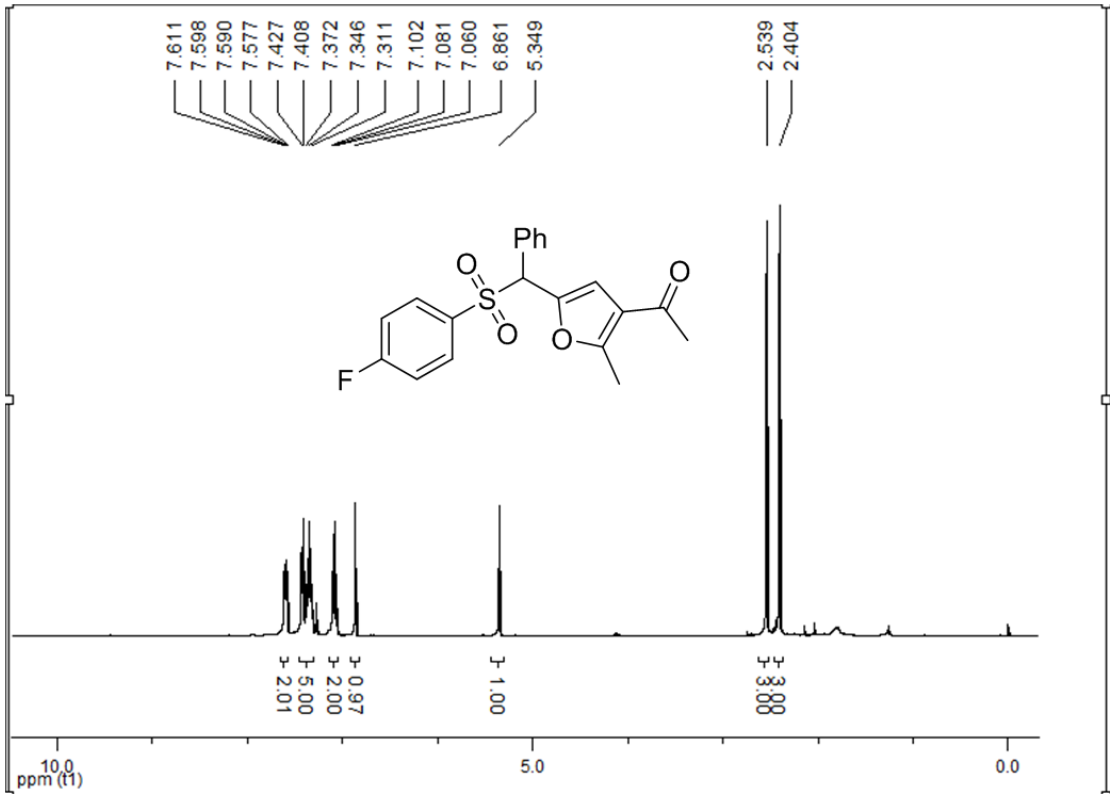

162.78
159.44
142.98
140.69
135.97
130.75
130.26
130.20
129.38
129.02
128.77
116.49
113.33
80.979
70.834
28.311
13.843
ppm (f1)
150
100
50
0

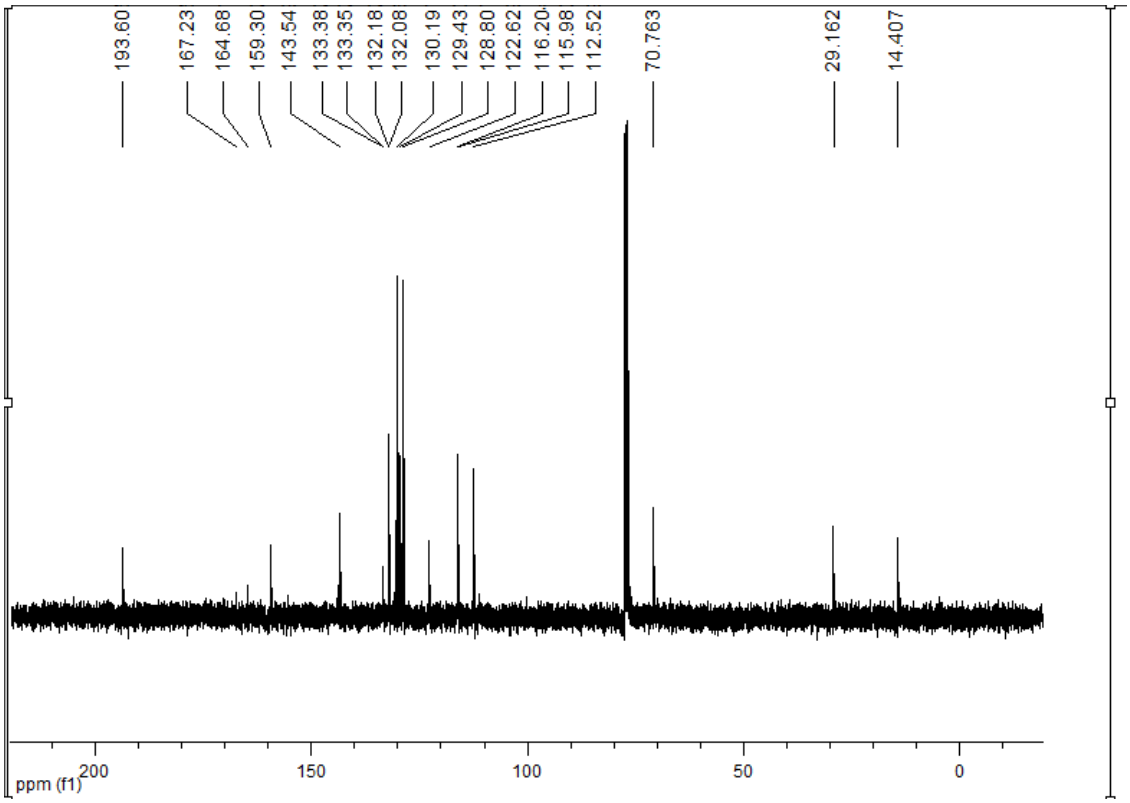
5l


7.617
7.601
7.596
7.583
7.434
7.417
7.353
7.314
7.298
7.097
7.076
7.056
6.812
5.345
2.495
1.540
F
O
O
O
S
O
O
Ph
2.05
5.07
2.00
1.00
0.95
3.02
9.01
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
ppm (t1)

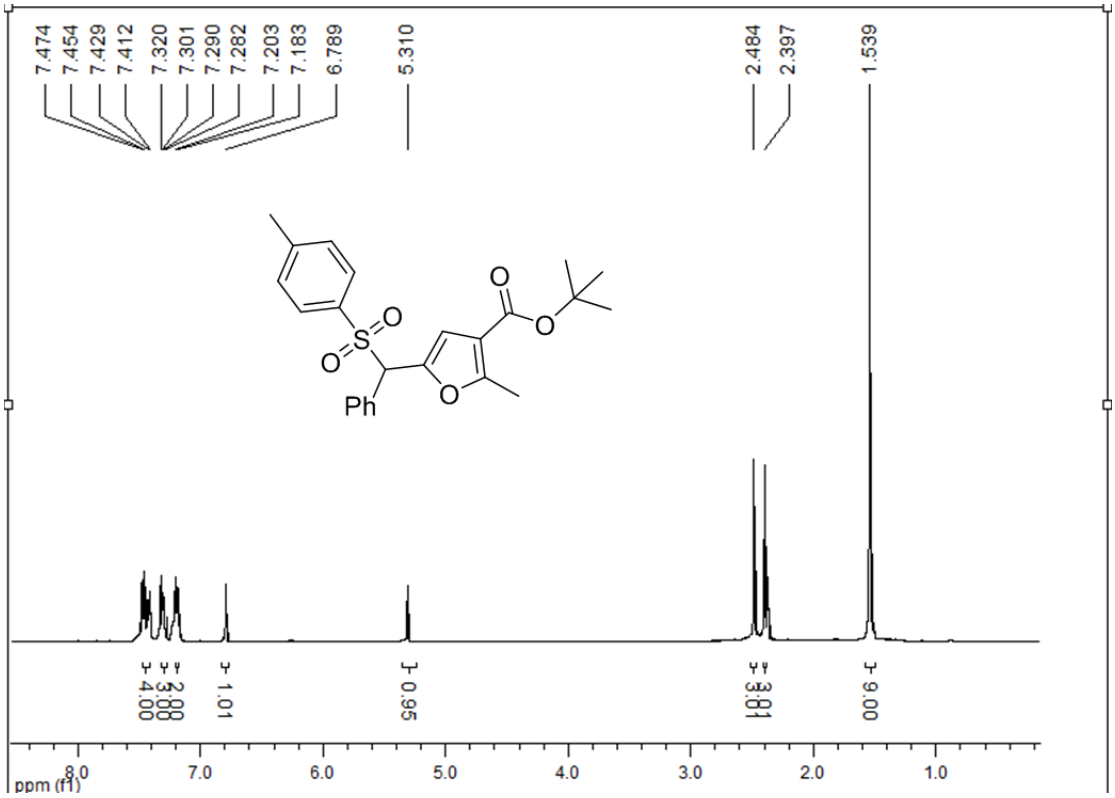

167.18
164.63
162.79
159.37
143.15
133.46
133.43
132.21
132.12
130.36
130.24
129.31
128.72
116.45
116.14
115.91
113.24
80.942
70.810
28.295
13.837
200
150
100
50
0
ppm (t1)

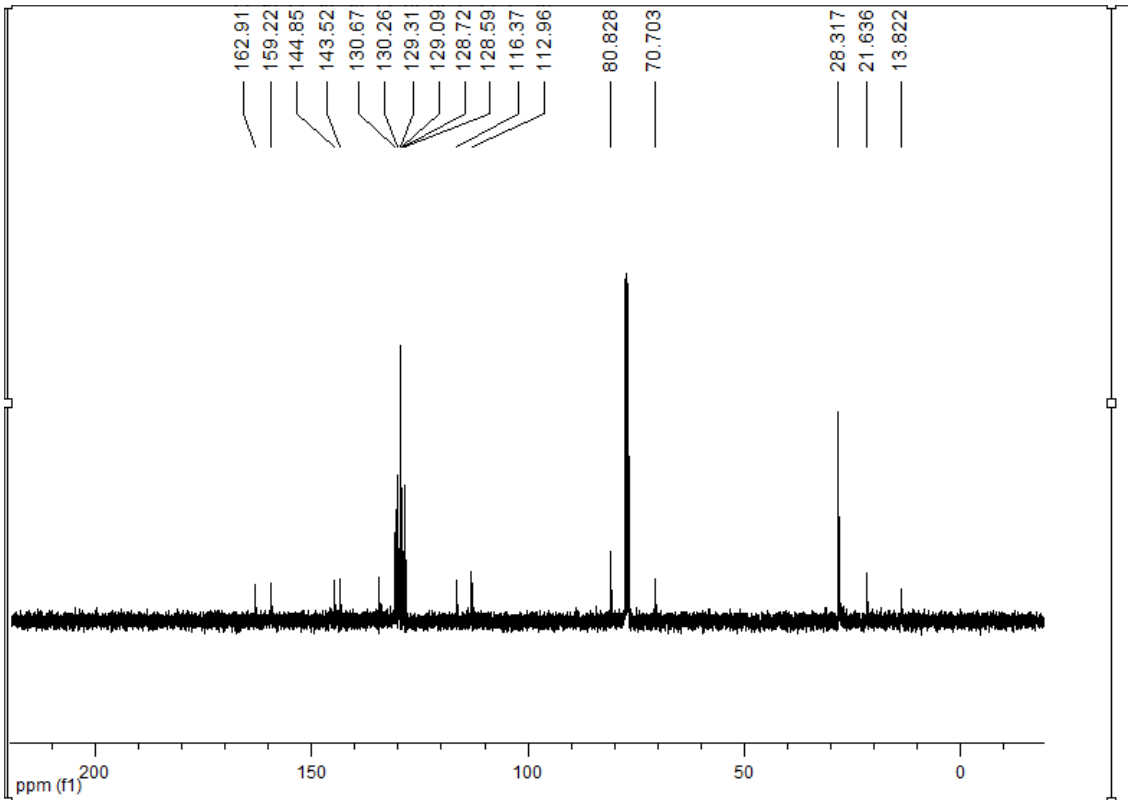
5m


7.611
7.598
7.590
7.577
7.427
7.408
7.372
7.346
7.311
7.102
7.081
7.060
6.861
5.349
2.539
2.404
Ph
O
S
O
O
O
F
2.01
5.00
2.00
0.97
1.00
3.00
3.00
10.0
ppm (f1)
5.0
0.0

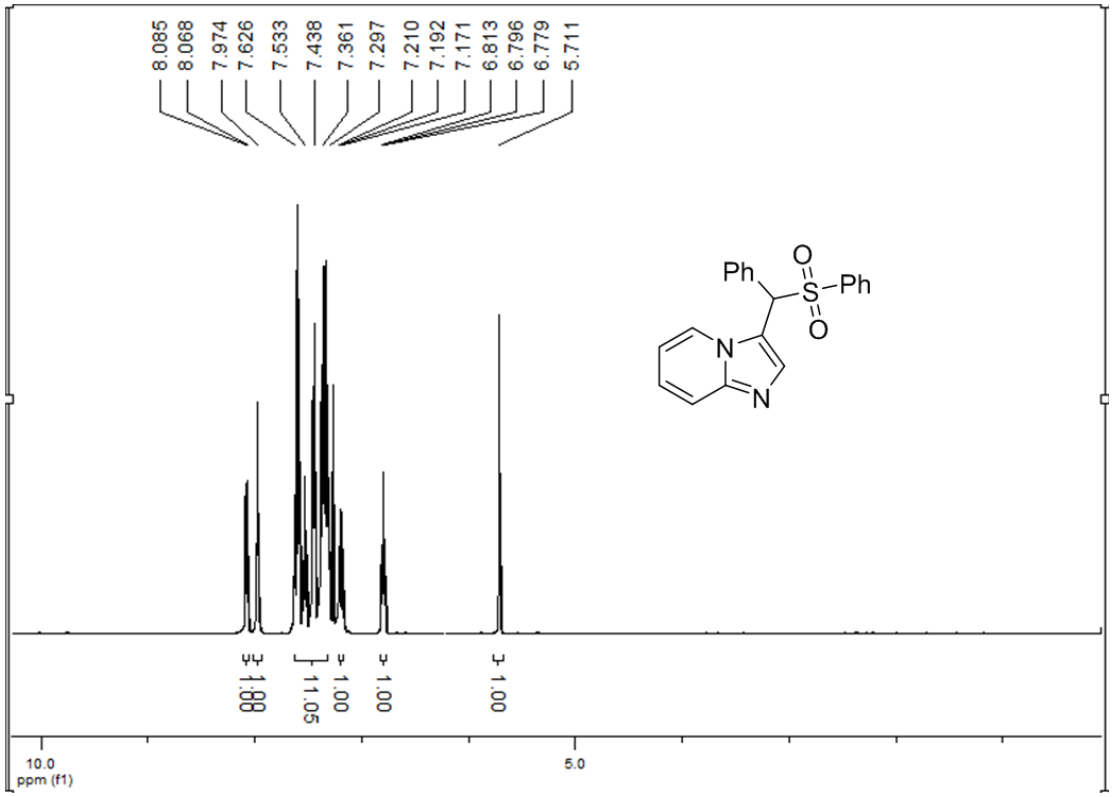

193.60
167.23
164.68
159.30
143.54
133.38
133.35
132.18
132.08
130.19
129.43
128.80
122.62
116.20
115.98
112.52
70.763
29.162
14.407
ppm (f1)
200
150
100
50
0

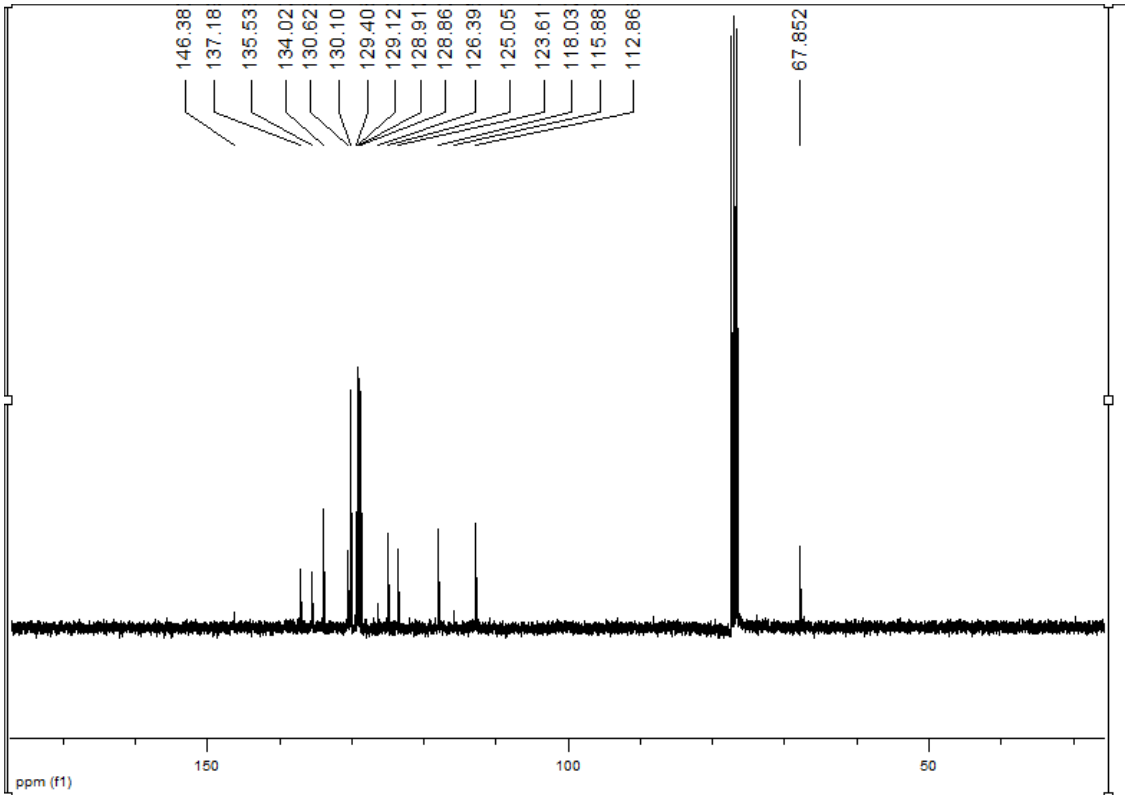
5n


7.474
7.454
7.429
7.412
7.320
7.301
7.290
7.282
7.203
7.183
6.789
5.310
2.484
2.397
1.539
Ph
4.00
3.00
2.00
1.01
0.95
3.01
3.01
9.00
ppm (f1)

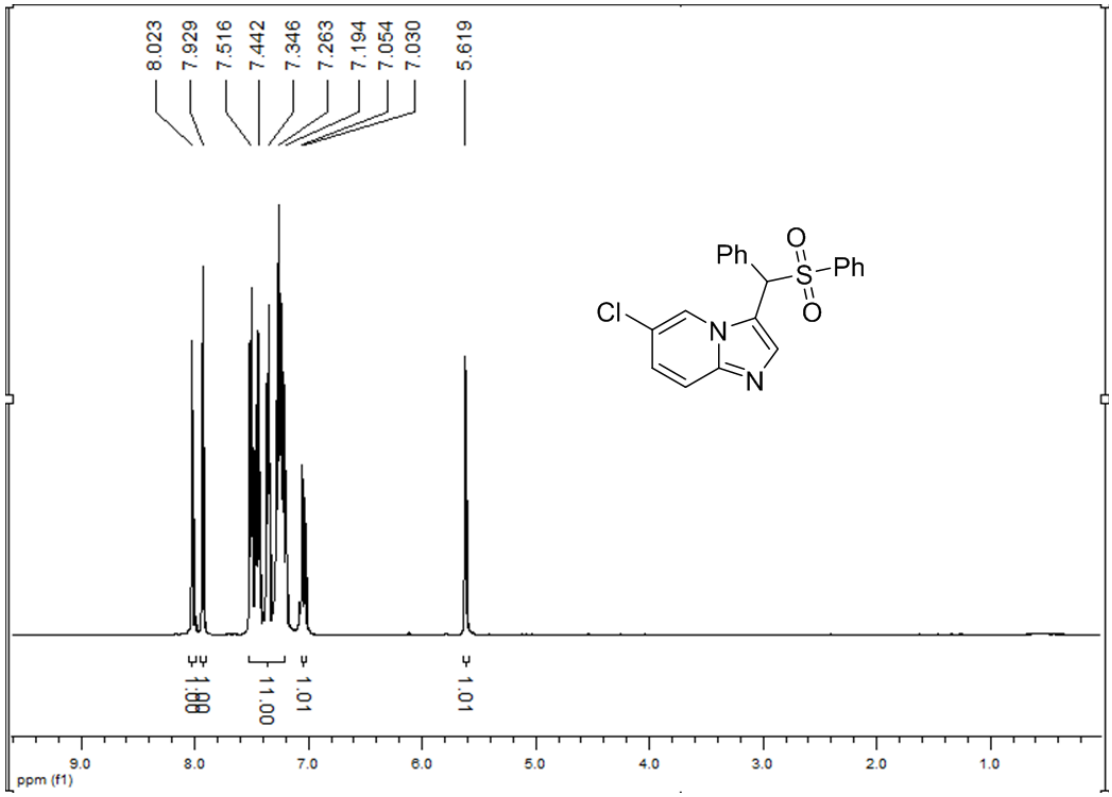

162.91
159.22
144.85
143.52
130.67
130.26
129.31
129.09
128.72
128.59
116.37
112.96
80.828
70.703
28.317
21.636
13.822
ppm (f1)

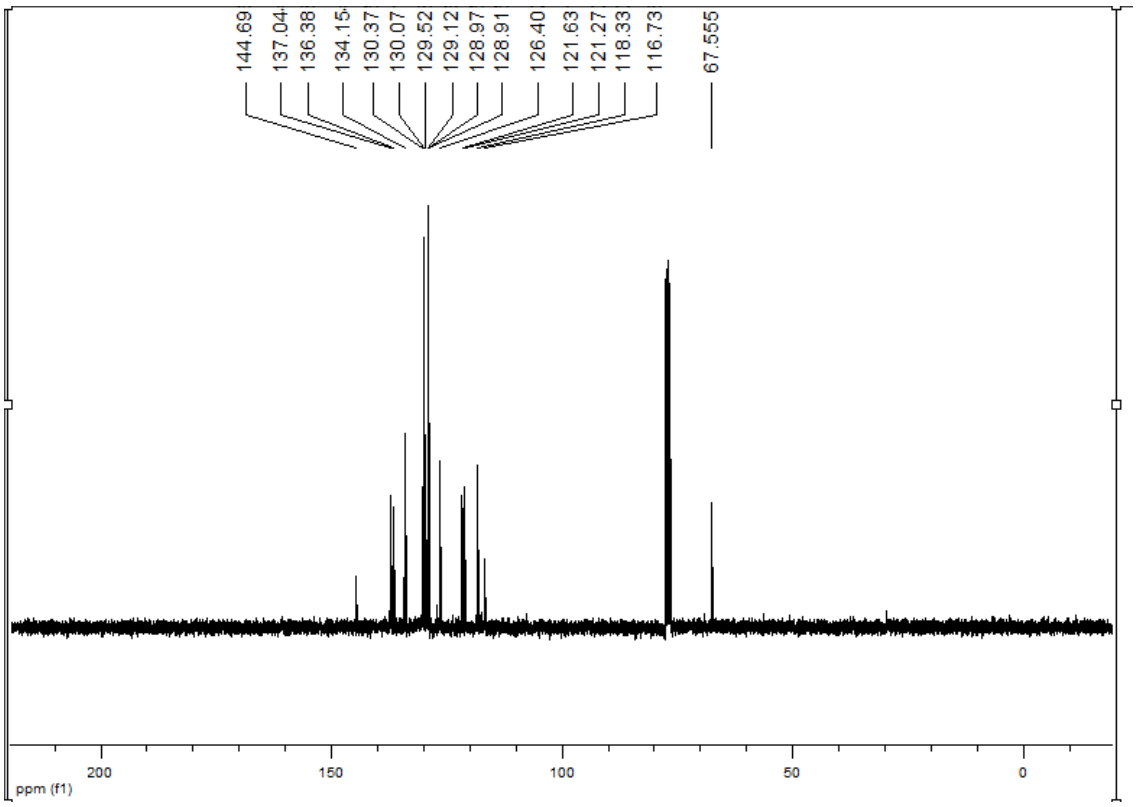
6a


8.085
8.068
7.974
7.626
7.533
7.438
7.361
7.297
7.210
7.192
7.171
6.813
6.796
6.779
5.711
1.00
1.00
11.05
1.00
1.00
10.0
ppm (f1)
5.0
Ph
O
S
Ph
O
N
N

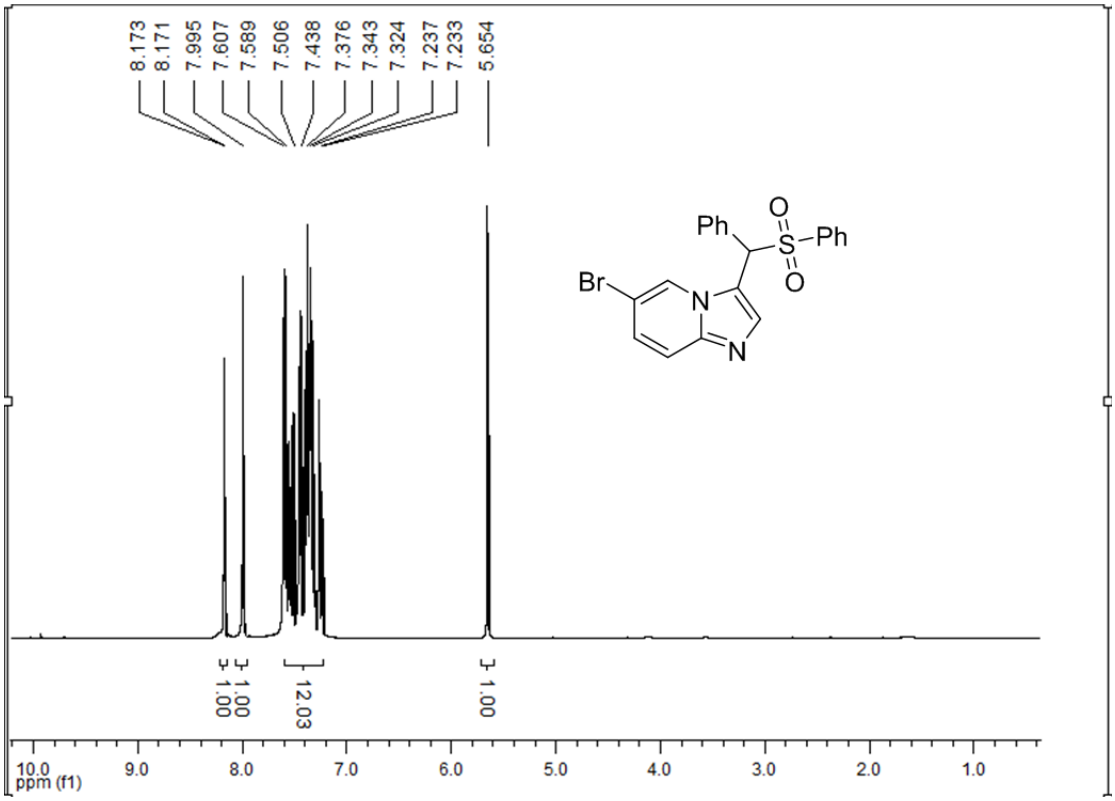

146.38
137.18
135.53
134.02
130.62
130.10
129.40
129.12
128.91
128.86
126.39
125.05
123.61
118.03
115.88
112.86
67.852
150
100
50
ppm (f1)

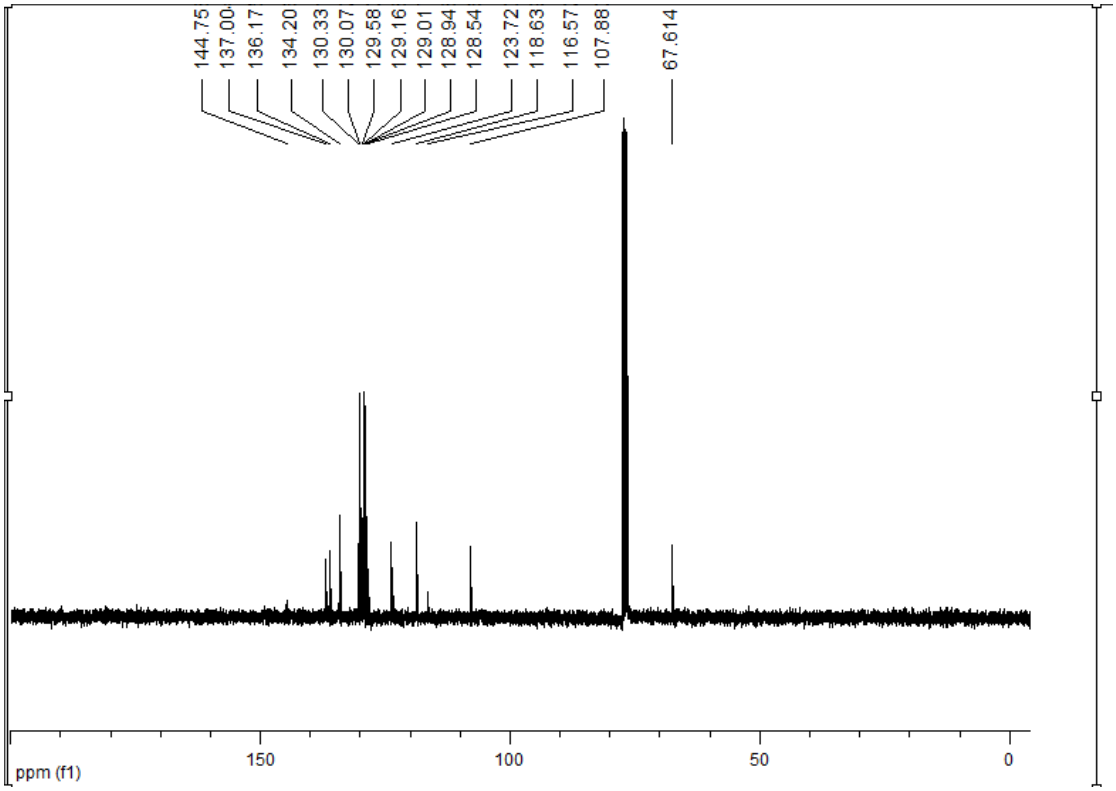
6b


8.023
7.929
7.516
7.442
7.346
7.263
7.194
7.054
7.030
5.619
Ph
O
S
Ph
O
Cl
N
N
1.00
1.00
11.00
1.01
1.01
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
ppm (f1)

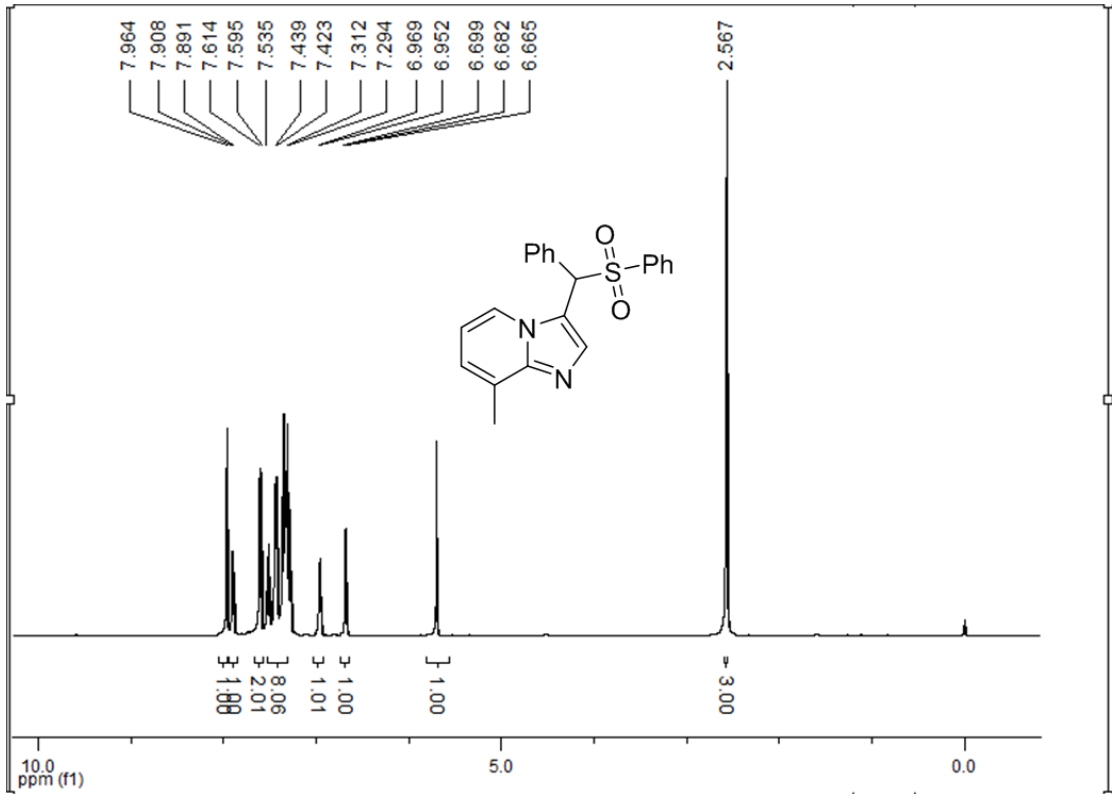

144.69
137.04
136.38
134.15
130.37
130.07
129.52
129.12
128.97
128.91
126.40
121.63
121.27
118.33
116.73
67.555
200
150
100
50
0
ppm (f1)

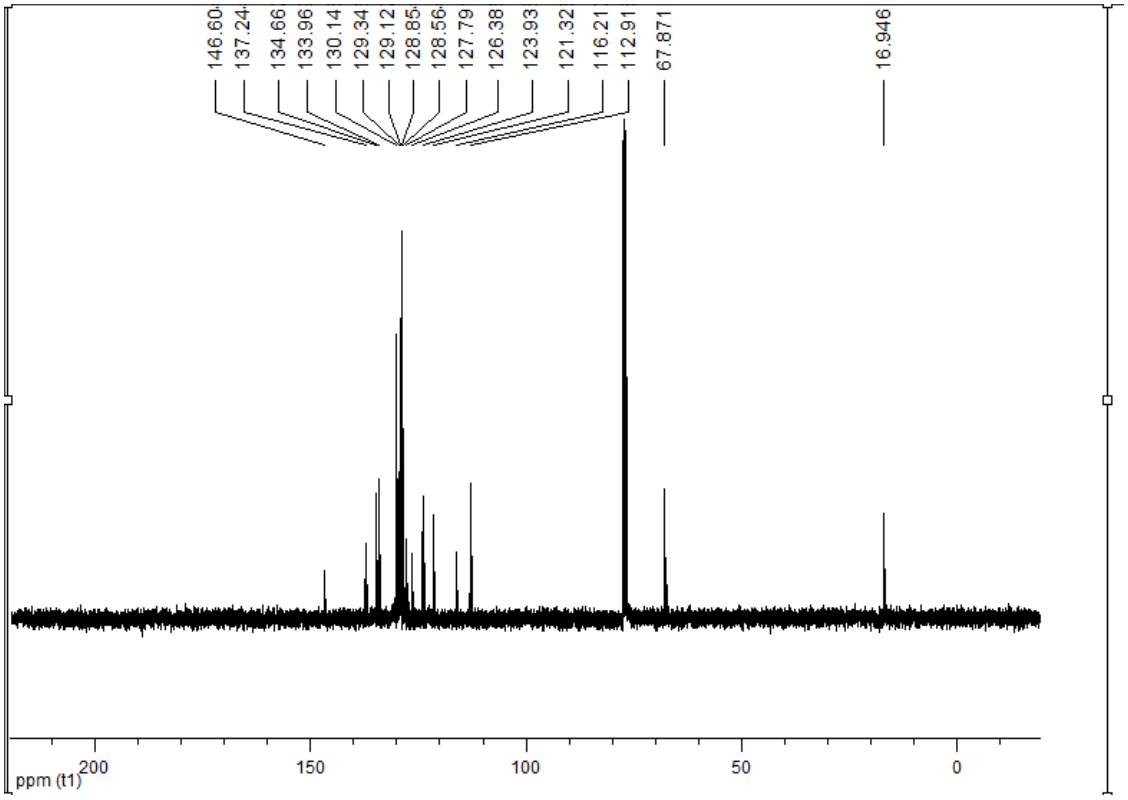
6c


8.173
8.171
7.995
7.607
7.589
7.506
7.438
7.376
7.343
7.324
7.237
7.233
5.654
Ph
O
S
Ph
O
Br
N
N
1.00
1.00
12.03
1.00
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
ppm (f1)

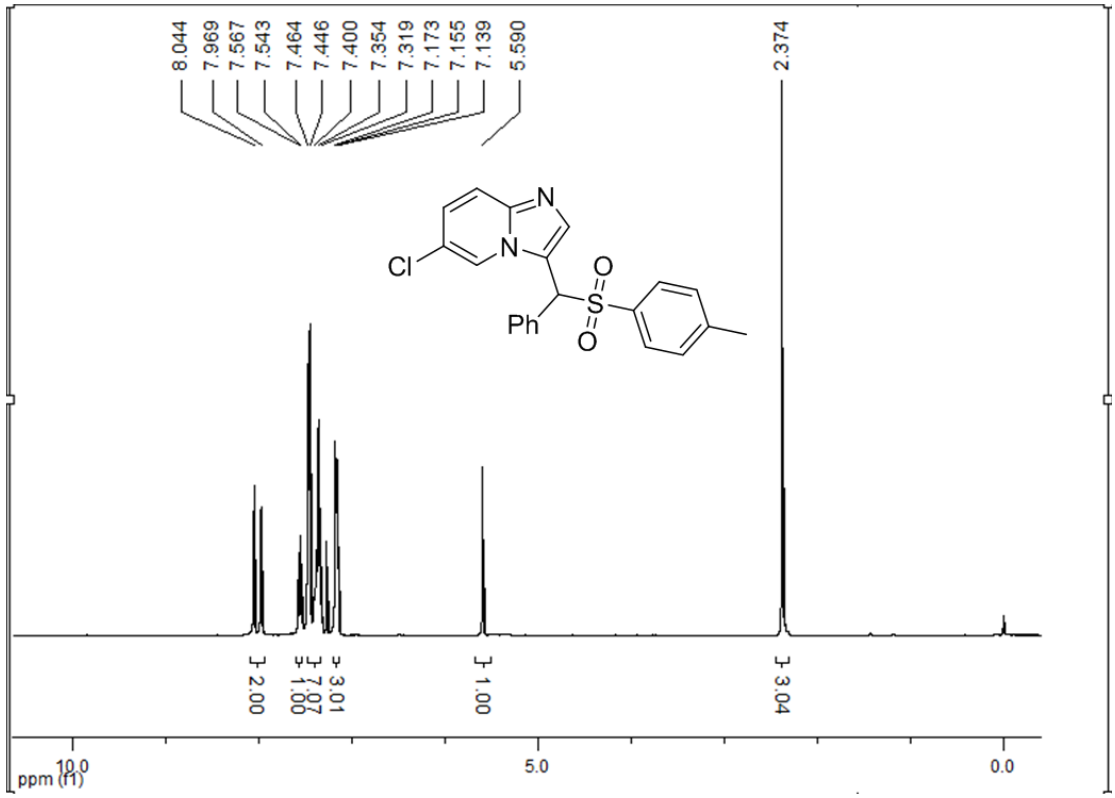

144.75
137.00
136.17
134.20
130.33
130.07
129.58
129.16
129.01
128.94
128.54
123.72
118.63
116.57
107.88
67.614
150
100
50
0
ppm (f1)

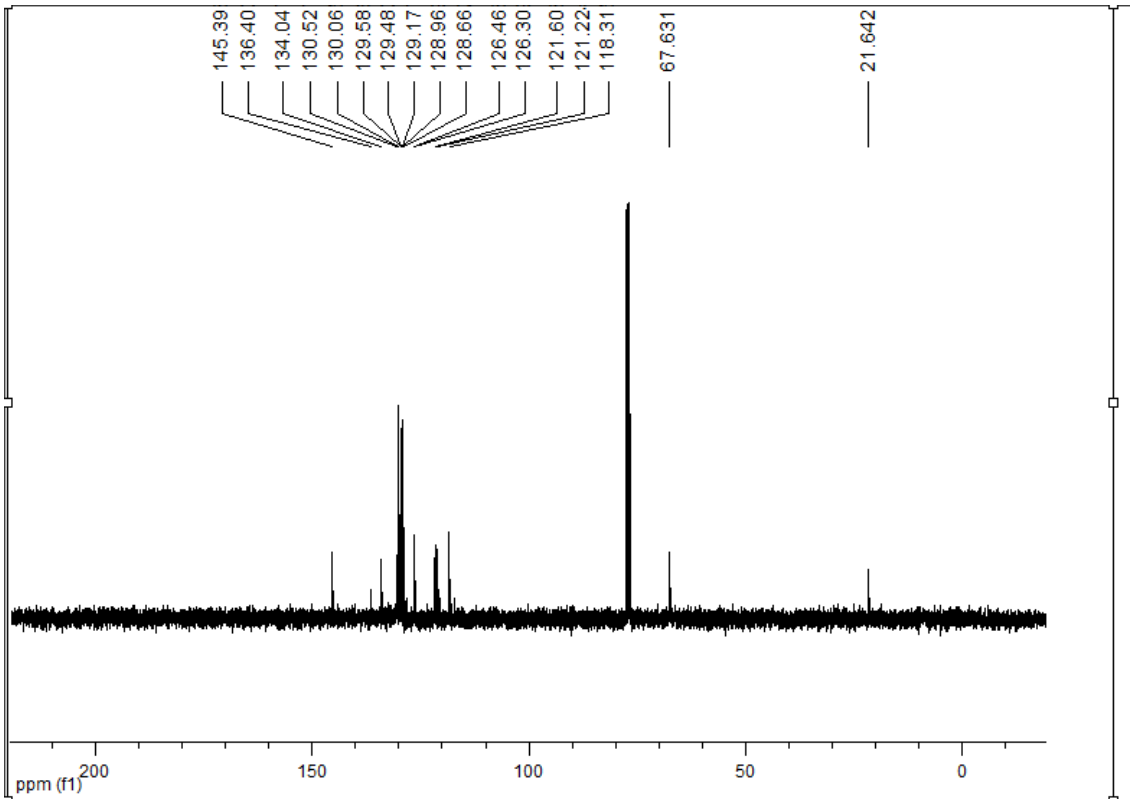
6d


7.964
7.908
7.891
7.614
7.595
7.535
7.439
7.423
7.312
7.294
6.969
6.952
6.699
6.682
6.665
2.567
Ph
Ph
S
O
O
N
N
1.00
8.06
2.01
1.01
1.00
1.00
3.00
10.0
ppm (f1)
5.0
0.0


146.60
137.24
134.66
133.96
130.14
129.34
129.12
128.85
128.56
127.79
126.38
123.93
121.32
116.21
112.91
67.871
16.946
ppm (t1)
200
150
100
50
0

6e


8.044
7.969
7.567
7.543
7.464
7.446
7.400
7.354
7.319
7.173
7.155
7.139
5.590
2.374
N
N
Cl
O
S
O
Ph
2.00
1.00
7.07
3.01
1.00
3.04
10.0
5.0
0.0
ppm (f1)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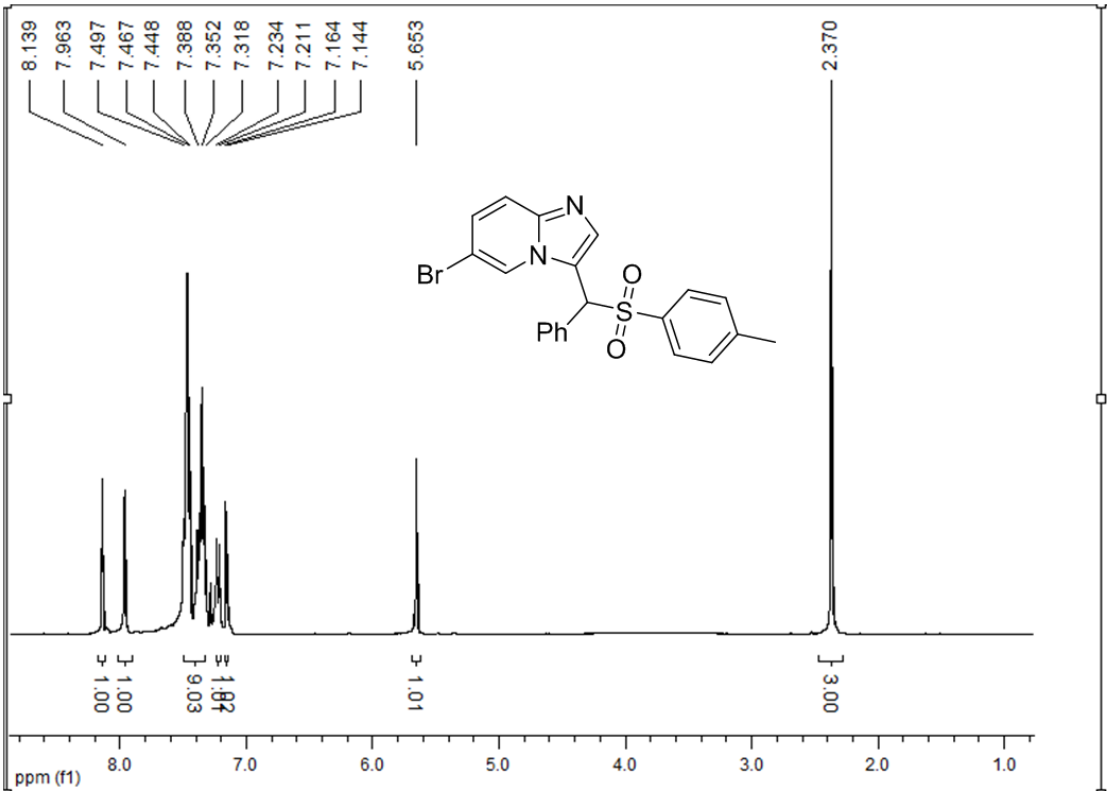
136.40
134.04
130.52
130.06
129.58
129.48
129.17
128.96
128.66
126.46
126.30
121.60
121.22
118.31
67.631
21.642
200
150
100
50
0
ppm (f1)

6f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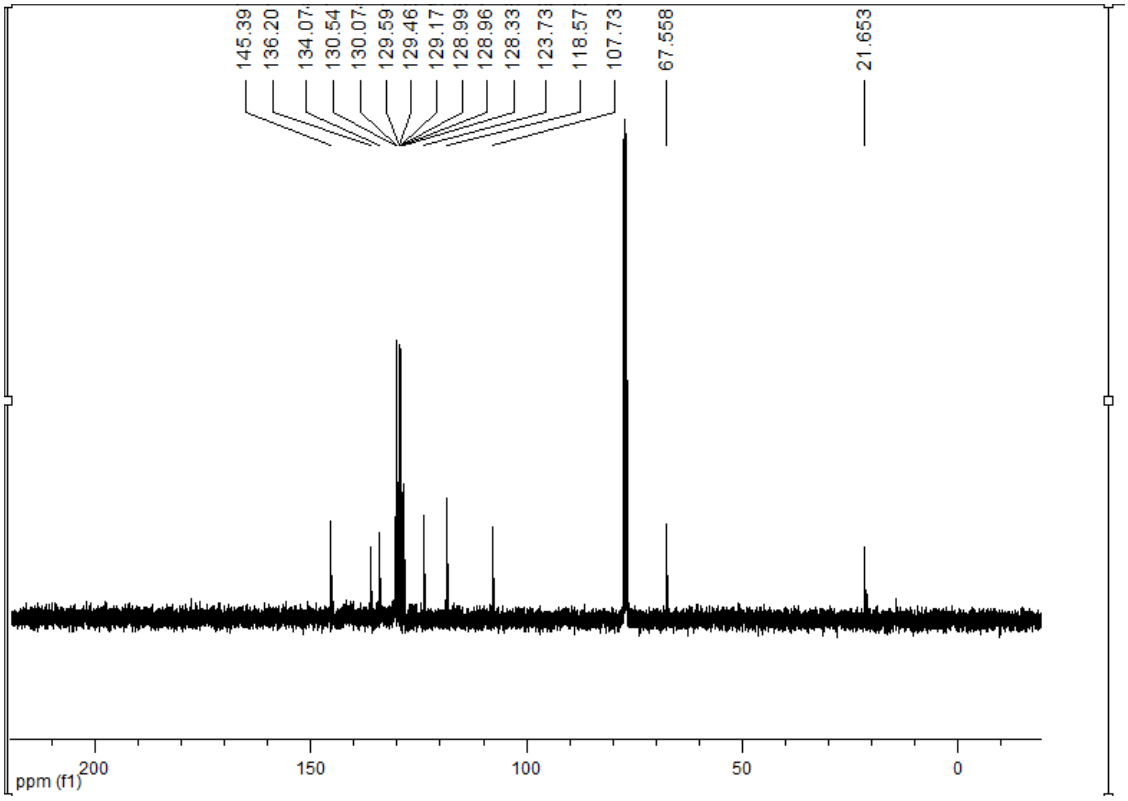
7.963
7.497
7.467
7.448
7.388
7.352
7.318
7.234
7.211
7.164
7.144
5.653
2.370
Br
N
N
O
S
O
Ph
1.00
1.00
9.03
1.01
3.00
ppm (f1)
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0


145.39
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134.07
130.54
130.07
129.59
129.46
129.17
128.99
128.96
128.33
123.73
118.57
107.73
67.558
21.653
ppm (f1)
200
150
100
50
0