Supporting Information

Boron-Catalyzed Dehydrative Allylation of 1,3-Diketones and β-Ketone Esters with 1,3-DiarylAllyl Alcohols in Water

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CONTENT

General Information.

All reagents and solvents were purchased from Adamas Reagent, Energy Chemical, Alfa Aesa Chemical Co., Aladdin Industrial Corp., Macklin Biochemical Co., Acors Organics, Bide Pharmatech Ltd., and so forth. All chemicals are without purification unless otherwise stated. All heating was done in an oil bath. Thin-layer chromatography (TLC) for analysis was performed on Schleicher&Schuell F1400/LS 254 silica gel plates observed under UV light (λ = 254 nm). ^{1}H-NMR spectra were recorded at 300 MHz or 400 MHz, and carbon NMR (^{13}C {^{1}H}) were recorded at 101 MHz. $CDCl_3$ was used as a solvent as an internal standard (0.00 ppm) unless otherwise stated. High-resolution mass spectra were recorded using a Q-TOF time-of-flight mass spectrometer. Coupling constants (J) were reported in Hertz (Hz). Infrared (IR) spectra were recorded on a Jasco ATR MIRacle spectrophotometer. Samples were scanned in the 400-4000cm-1 region with KBr pellet.

1. The synthesis of the substrates

1.1 The synthesis of β-diketone or β-keto ester.

These compounds can be synthesized by Claisen condensation reaction, in which the appropriate ketone was reacted with the ester of without α-hydrogen under the NaH to produce β-diketone. And the ketone were reacted with dimethyl carbonate under the NaH to form β-keto ester[1]. The Compounds **1b**, **1c**, **1e-1h, 1k-1s** can be synthesized by this method. **1i**, **1t** and **1u** can be synthesized by selectively reducing the double bond of conjugated unsaturated ketones in the presence of triethyl silane and HFIP catalyzed by $B(C_6F_5)_3$[2].

1.2 The synthesis of 1,3-diarylallyl alcohols.

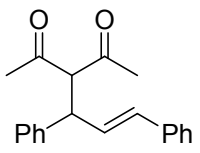
The allyl alcohol could be easily prepared according to literature[3].

2. General experimental procedure and data

General Process of the allylation of 1,3-diketone and β-keto ester compounds with allyl alcohol.

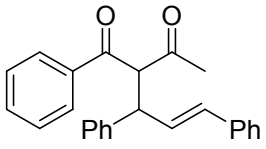
1,3-diketone and β-keto ester (0.3 mmol), allyl alcohol (0.3 mmol), $B(C_6F_5)_3$ (3 mol%), H_2O (1.5 mL) were added to the reaction tube and the reaction mixture was stirred at 100 °C in oil bath for 1 h. The reaction was monitored by TLC. When the reaction was finished, the mixture was cooled to RT and extracted with ethyl acetate three times (5 mL each). The organic phase was merged and dried with anhydrous $MgSO_4$, and vacuum evaporated. Further purification was carried out via silica gel column chromatography and eluted with ethyl acetate and petroleum ether.

(E)-3-(1,3-diphenylallyl)pentane-2,4-dione (3aa) [4a].



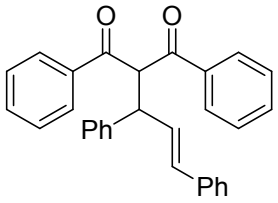
Yield: 78 mg, 89% yield; white solid; m.p.100.5-101.7 °C; Rf: 0.5 (petroleum ether/EtOAc = 7/1). **IR (KBr):** 3028, 2964, 1724, 1701, 1359, 1263, 1095, 1026, 972, 804, 746, 700 cm^{-1}. **^{1}H NMR (300 MHz, $CDCl_3$)** δ 7.39-7.15 (m, 10H), 6.45 (d, *J* = 15.8 Hz, 1H), 6.29-6.12 (m, 1H), 4.62-4.09 (m, 2H), 2.26 (s, 3H), 1.94 (s, 3H). **^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ 202.8, 202.7, 140.1, 136.6, 131.7, 129.3, 129.0, 128.5, 127.9, 127.7, 127.3, 126.4, 74.5, 49.2, 30.0, 29.7.

(E)-2-(1,3-diphenylallyl)-1-phenylbutane-1,3-dione (3ba)[4b].



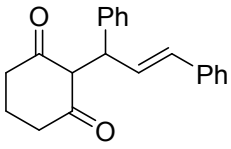
Yield: 88 mg, 83% yield; colorless liquid; Rf: 0.5 (petroleum ether/EtOAc = 7/1). **IR (KBr):** 3061, 3028, 1713, 1676, 1448, 1358, 1254, 970, 750, 696 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.99 (dd, *J* = 77.4, 7.1 Hz, 2H), 7.66-7.03 (m, 13H), 6.64 -6.07 (m, 2H), 5.23 (dd, *J* = 17.9, 11.2 Hz, 1H), 4.63 (dd, *J* = 11.2, 8.7 Hz, 1H), 2.14 (d, *J* = 103.2 Hz, 3H). . **^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ 203.0, 194.3, 140.7, 140.0, 137.2, 136.9, 136.8, 136.6, 133.8, 133.6, 131.7, 131.6, 130.0, 129.4, 129.0, 128.9, 128.9, 128.7, 128.7, 128.6, 128.5, 128.4, 128.3, 127.9, 127.7, 127.4, 127.3, 127.0, 126.9, 126.4, 126.3, 69.5, 68.7, 49.5, 49.3, 28.1, 27.8.

(E)-2-(1,3-diphenylallyl)-1,3-diphenylpropane-1,3-dione (3ca)[4b].



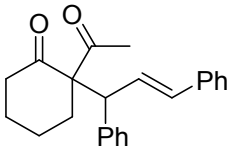
Yield: 88 mg, 83% yield; white solid, m.p.112.1-113.0 °C; Rf: 0.5 (petroleum ether/EtOAc = 7/1). **IR (KBr):** 3063, 3028, 2926, 1693, 1659, 1448, 1284, 1257, 991, 964, 746, 692 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$)** δ 8.12-8.04 (m, 2H), 7.90-7.83 (m, 2H), 7.57-7.53 (m, 1H), 7.48-7.30 (m, 7H), 7.28-7.08 (m, 8H), 6.44-6.30 (m, 2H), 6.04 (d, *J* = 10.5 Hz, 1H), 4.86 (ddd, *J* = 10.5, 6.1, 1.3 Hz, 1H)**. ^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ 194.5, 193.8, 141.0, 137.3, 136.9, 136.9, 133.5, 133.3, 131.9, 130.0, 128.9, 128.8, 128.7, 128.6, 128.5, 128.3, 127.4, 126.9, 126.3, 62.5, 50.1.

(E)-2-(1,3-diphenylallyl)cyclohexane-1,3-dione (3da)[4c].



Yield: 68 mg, 75% yield; white solid, m.p.107.5-108.4 °C; Rf: 0.5 (petroleum ether/EtOAc = 7/1). **IR (KBr):** 3026, 2951, 1771, 1599, 1562, 1493, 1369, 1275, 1192, 1082, 976, 746, 698 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.48-7.16 (m, 10H), 6.94 (dd, *J* = 15.9, 8.1 Hz, 1H), 6.52 (d, *J* = 15.9 Hz, 1H), 5.24 (d, *J* = 8.1 Hz, 1H), 2.41 (t, *J* = 6.0 Hz, 4H), 1.91 (p, *J* = 6.5 Hz, 2H). **^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ 142.2, 137.1, 131.8, 130.6, 128.5, 128.5, 127.8, 127.4, 126.4, 126.3, 117.4, 41.9, 20.6.

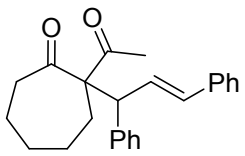
(E)-2-acetyl-2-(1,3-diphenylallyl)cyclohexan-1-one (3ea).



Yield: 85 mg, total yield 86% yield; and **3ea (A)** as a white solid, m.p.80.5-81.4°C; Rf: 0.5 (petroleum ether/EtOAc = 7/1). **IR (KBr):** 3028, 2951, 1695, 1599, 1495, 1452, 1356, 1174, 1126, 972, 748, 700 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.43-7.15 (m, 10H), 6.51-6.46 (m, 2H), 4.44 (dd, *J* = 5.7, 3.6 Hz, 1H), 2.62-2.44 (m, 2H), 2.20 (ddd, *J* = 14.9, 12.9, 6.0 Hz, 1H), 2.04 (s, 3H), 1.88 (dddd, *J* = 12.0, 6.0, 4.3, 2.6 Hz, 1H), 1.81-1.58 (m, 4H). **^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ: 208.3, 205.0, 139.6, 136.9, 132.7, 129.6, 128.4, 128.1, 127.7, 127.5, 126.7, 126.4, 72.1, 52.06, 42.68, 31.0, 27.3, 25.7, 20.8.

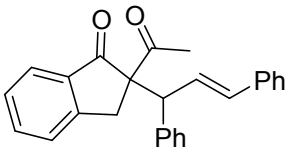
And a colorless liquid **3ea (B)**; Rf: 0.4 (petroleum ether/EtOAc = 7/1). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.30 (s, 10H), 6.59 (dd, *J* = 15.8, 7.9 Hz, 1H), 6.42-6.33 (m, 1H), 4.42 (dd, *J* = 7.9, 1.2 Hz, 1H), 2.72-2.64 (m, 1H), 2.53 (ddq, *J* = 15.0, 3.5, 1.6 Hz, 1H), 2.30-2.17 (m, 1H), 1.98 (s, 3H), 1.97-1.74 (m, 3H), 1.65-1.60 (m, 2H). **^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ: 208.3, 205.0, 139.6, 136.9, 132.7, 129.6, 128.4, 128.1, 127.7, 127.5, 126.7, 126.4, 72.1, 52.0, 42.6, 31.2, 27.3, 25.7, 20.8. **HRMS (ESI) m/z (M+Na)$^+$** calcd for $C_{24}H_{26}O_2Na$: 369.1830; Found: 369.1832.

(E)-2-acetyl-2-(1,3-diphenylallyl)cycloheptan-1-one (3fa).



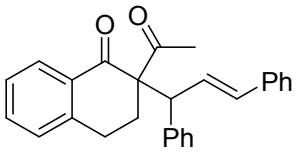
Yield: 81 mg, 78% yield; colorless liquid; Rf: 0.5 (petroleum ether/EtOAc = 7/1). **IR (KBr):** 2929, 2858, 1695, 1601, 1493, 1454, 1356, 1163, 970, 748, 698 cm^{-1}. **^{1}H NMR (300 MHz, $CDCl_3$)** δ 7.40-7.15 (m, 10H), 6.83-6.29 (m, 2H), 4.55-4.01 (m, 1H), 2.48-2.23 (m, 2H), 2.20 (s, 4H), 2.00 (dd, *J* = 15.0, 10.2 Hz, 1H), 1.69-1.29 (m, 6H). **^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ: 212.5, 211.3, 208.6, 206.2, 139.9, 139.2, 137.2, 136.8, 132.9, 132.2, 129.7, 129.3, 129.0, 128.5, 128.5, 128.4, 128.3, 127.6, 127.5, 127.3, 127.3, 127.0, 126.4, 74.6, 73.4, 56.2, 52.9, 45.3, 43.6, 32.2, 30.3, 28.6, 28.3, 26.2, 25.6, 25.4, 25.4. **HRMS (ESI) m/z (M+Na)$^+$** calcd for $C_{23}H_{24}O_2Na$: 355.1674; Found: 355.1684.

(E)-2-acetyl-2-(1,3-diphenylallyl)-2,3-dihydro-1H-inden-1-one (3ga).



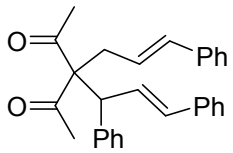
Yield: 91 mg, 83% yield; colorless liquid; Rf: 0.5 (petroleum ether/EtOAc = 7/1). **IR (KBr):** 3030, 2926, 1699, 1605, 1495, 1456, 1356, 1273, 1176, 968, 768, 700 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.85-6.92 (m, 14H), 6.65-6.02 (m, 2H), 4.98-4.91 (m, 1H), 4.20 (dd, *J* = 39.4, 17.1 Hz, 1H), 3.36 (dd, *J* = 85.5, 17.2 Hz, 1H), 2.37 (d, *J* = 107.0 Hz, 3H). **^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ: 202.7, 202.3, 202.0, 201.9, 154.3, 153.9, 139.1, 138.7, 136.7, 136.6, 135.6, 135.2, 135.1, 134.8, 133.5, 133.1, 129.4, 128.9, 128.7, 128.6, 128.3, 128.2, 128.2, 127.9, 127.7, 127.5, 127.5, 127.3, 127.1, 126.4, 126.4, 126.3, 126.1, 124.5, 124.2, 74.3, 73.5, 53.4, 51.2, 32.0, 29.9, 26.2, 26.0. **HRMS (ESI) m/z (M+Na)$^+$** calcd for $C_{26}H_{22}O_2Na$: 389.1517; Found: 389.1525.

(E)-2-acetyl-2-(1,3-diphenylallyl)-3,4-dihydronaphthalen-1(2H)-one (3ha).



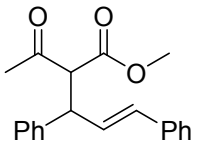
Yield: 100 mg, 88% yield); colorless liquid; Rf: 0.5 (petroleum ether/EtOAc = 7/1). **IR (KBr):** 3028, 2931, 1707, 1674, 1599, 1493, 1450, 1358, 1230, 1173, 970, 748, 700 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$)** δ 8.11 (ddd, *J* = 23.1, 7.9, 1.5 Hz, 1H), 7.49-7.10 (m, 13H), 6.99-6.39 (m, 2H), 4.63 (dd, *J* = 195.7, 8.9 Hz, 1H), 3.10 (dddd, *J* = 83.7, 17.2, 12.6, 4.6 Hz, 1H), 2.87-2.68 (m, 2H), 2.25 (s, 1H), 2.09 (d, *J* = 7.8 Hz, 3H). **^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ: 205.2, 202.8, 197.6, 195.9, 143.8, 143.4, 140.2, 139.3, 137.2, 136.9, 133.9, 133.8, 133.0, 133.0, 132.6, 132.5, 131.9, 130.0, 129.6, 129.3, 128.8, 128.7, 128.5, 128.5, 128.4, 128.2, 128.0, 127.9, 127.6, 127.5, 127.4, 127.2, 127.1, 126.8, 126.8, 126.8, 126.5, 126.5, 126.4, 125.8, 69.4, 67.5, 55.2, 50.4, 29.0, 28.2, 27.5, 26.9, 26.6, 26.2, 26.0, 23.2. **HRMS (ESI) m/z (M+H)$^+$** calcd for $C_{27}H_{25}O_2$: 381.1874; Found: 381.1855.

3-cinnamyl-3-((E)-1,3-diphenylallyl)pentane-2,4-dione (3ia).



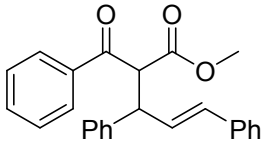
Yield: 62 mg, 51% yield; colorless liquid; Rf: 0.5 (petroleum ether/EtOAc = 7/1). **IR (KBr):** 3028, 2922, 1724, 1701, 1601, 1495, 1360, 1271, 1140, 972, 744, 698, cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.38-7.15 (m, 15H), 6.61 (dd, *J* = 15.8, 8.5 Hz, 1H), 6.43-6.32 (m, 2H), 5.88 (dt, *J* = 15.7, 7.2 Hz, 1H), 4.46 (dd, *J* = 8.6, 1.1 Hz, 1H), 2.91 (ddd, *J* = 15.3, 7.3, 1.5 Hz, 1H), 2.81 (ddd, J = 15.3, 7.2, 1.6 Hz, 1H), 2.22 (s, 3H), 2.05 (s, 3H). **^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ: 206.6, 206.1, 139.1, 137.0, 136.8, 133.7, 132.6, 129.6, 128.9, 128.5, 128.5, 128.4, 127.5, 127.3, 126.3, 126.1, 124.3, 74.1, 51.4, 36.1, 30.3, 29.5. **HRMS (ESI) m/z (M+Na)$^+$** calcd for $C_{29}H_{28}O_2Na$: 431.1987; Found: 431.1995.

Methyl (E)-2-acetyl-3,5-diphenylpent-4-enoate (3ja) [4a].



Yield: 64 mg, 69% yield; colorless liquid; Rf: 0.4 (petroleum ether/EtOAc = 7/1). **IR (KBr):** 3028, 2953, 1741, 1714, 1601, 1495, 1450, 1358, 1157, 970, 746, 698 cm^{-1}. **^{1}H NMR (300 MHz, $CDCl_3$)** δ 7.40-7.14 (m, 10H), 6.46 (dd, *J* = 15.8, 9.1 Hz, 1H), 6.28 (ddd, *J* = 15.9, 14.0, 8.2 Hz, 1H), 4.31 (ddd, *J* = 10.8, 8.1, 2.4 Hz, 1H), 4.13 (dd, *J* = 11.2, 6.9 Hz, 1H), 3.60 (d, *J* = 64.6 Hz, 3H), 2.17 (d, *J* = 81.3 Hz, 3H). **^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ 201.6, 201.4, 168.4, 168.1, 140.4, 140.1, 136.8, 136.6, 132.0, 131.6, 129.5, 129.1, 128.9, 128.8, 128.5, 128.0, 127.9, 127.7, 127.6, 127.2, 127.1, 126.4, 65.4, 65.1, 52.6, 52.4, 49.0, 48.8, 30.1, 30.0.

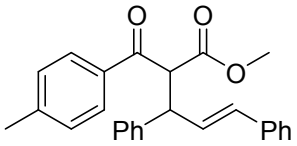
Methyl (E)-2-benzoyl-3,5-diphenylpent-4-enoate (3ka)[4b].



Yield: 99 mg, 86% yield; white solid; m.p.112.1-113.0 °C; Rf: 0.4 (petroleum ether/EtOAc = 7/1). **IR (KBr):** 3028, 2951, 1736, 1680, 1599, 1495, 1450, 1261, 1157, 970, 744, 698 cm^{-1}. **^{1}H NMR (300 MHz, $CDCl_3$)** δ 8.15-8.06 (m, 1H),

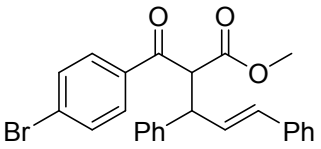
7.99 -7.90 (m, 1H), 7.70-7.04 (m, 13H), 6.63-6.14 (m, 2H), 5.06 (dd, *J* = 10.9, 6.1 Hz, 1H), 4.62 (td, *J* = 10.8, 10.3, 8.1 Hz, 1H), 3.56 (d, *J* = 67.8 Hz, 3H). **^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ 193.2, 192.6, 168.5, 168.0, 140.7, 140.4, 137.0, 136.9, 136.8, 136.6, 133.7, 133.6, 131.9, 131.7, 129.7, 129.7, 128.9, 128.8, 128.7, 128.5, 128.5, 128.3, 128.3, 128.0, 127.5, 127.4, 127.2, 126.9, 126.4, 126.3, 59.7, 59.5, 52.7, 52.5, 49.0, 48.9.

Methyl (E)-2-(4-methylbenzoyl)-3,5-diphenylpent-4-enoate (3la).



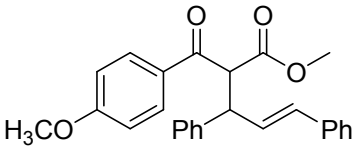
Yield: 92 mg, 79% yield; colorless liquid; Rf: 0.4 (petroleum ether/EtOAc = 7/1). **IR (KBr):** 3028, 2956, 1736, 1672, 1605, 1452, 1288, 1261, 1186, 1159, 968, 748, 698 cm^{-1}. **^{1}H NMR (400 MHz,$CDCl_3$)** δ 8.02-7.95 (m, 1H), 7.87-7.80 (m, 1H), 7.41-7.26 (m, 6H), 7.25-7.08 (m, 6H), 6.57-6.17 (m, 2H), 5.00 (td, *J* = 11.0, 0.9 Hz, 1H), 4.65-4.50 (m, 1H), 3.54 (d, *J* = 91.6 Hz, 3H), 2.40 (d, *J* = 14.9 Hz, 3H). **^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ: 192.5, 192.0, 168.5, 168.1, 144.7, 144.5, 140.7, 140.4, 137.0, 136.9, 134.3, 134.0, 131.7, 131.5, 129.8, 129.7, 129.5, 129.3, 128.9, 128.6, 128.6, 128.4, 128.3, 128.3, 127.9, 127.4, 127.3, 127.1, 126.7, 126.3, 126.2, 59.9, 59.0, 52.6, 52.3, 48.9, 48.0, 21.6, 21.6. **HRMS (ESI) m/z (M+Na)$^{+}$** calcd for $C_{26}H_{24}O_3Na$: 407.1623; Found: 407.1624.

Methyl (E)-2-(4-bromobenzoyl)-3,5-diphenylpent-4-enoate (3ma).



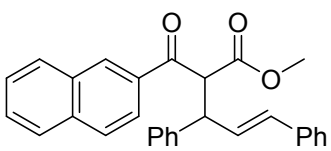
Yield: 114 mg, 85% yield; colorless liquid; Rf: 0.4 (petroleum ether/EtOAc = 7/1). **IR (KBr):** 3028, 2951, 1736, 1684, 1585, 1493, 1450, 1259, 1290, 1157, 968, 748, 698 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.97-7.89 (m, 1H), 7.83-7.73 (m, 1H), 7.62 (dq, *J* = 9.1, 2.2 Hz, 1H), 7.58-7.51 (m, 1H), 7.40-7.08 (m, 10H), 6.57-6.16 (m, 2H), 4.95 (t, *J* = 11.1 Hz, 1H), 4.62-4.49 (m, 1H), 3.55 (d, *J* = 92.9 Hz, 3H). **^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ: 192.1, 191.2, 168.1, 167.7, 140.4, 139.6, 136.8, 136.7, 135.5, 135.2, 132.1, 132.0, 131.7, 130.2, 129.9, 129.4, 129.3, 129.1, 128.9, 128.7, 128.7, 128.5, 128.3, 128.2, 127.9, 127.5, 127.4, 127.2, 126.6, 126.3, 126.2, 60.3, 59.6, 52.8, 52.5, 49.7, 48.1. **HRMS (ESI) m/z (M+Na)$^{+}$** calcd for $C_{25}H_{21}O_3NaBr$: 471.0572; Found: 471.0578.

Methyl (E)-2-(4-methoxybenzoyl)-3,5-diphenylpent-4-enoate (3na).



Yield: 98 mg, 82% yield; colorless liquid; Rf: 0.4 (petroleum ether/EtOAc = 7/1). **IR (KBr):** 3028, 2955, 1741, 1676, 1599, 1454, 1261, 1174, 1026, 970, 748, 698, 580 cm^{-1}. **^{1}H NMR (400 MHz,$CDCl_3$)** δ 8.15-7.90 (m, 2H), 7.43-7.26 (m, 5H), 7.24-7.08 (m, 5H), 6.99-6.83 (m, 2H), 6.57-6.15 (m, 2H), 4.98 (t, *J* = 11.2 Hz, 1H), 4.65-4.52 (m, 1H), 3.85 (d, *J* = 12.1 Hz, 3H), 3.54 (d, *J* = 92.9 Hz, 3H). **^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ: 192.1, 189.9, 168.7, 167.2, 164.0, 163.9, 141.4, 140.5, 137.0, 136.9, 131.6, 131.5, 131.2, 130.9, 129.9, 129.8, 129.8, 129.5, 128.6, 128.4, 128.3, 128.3, 127.9, 127.4, 127.3, 127.0, 126.7, 126.3, 126.2, 114.0, 113.8, 59.2, 58.7, 55.5, 55.4, 52.6, 52.3, 48.8, 48.7. **HRMS (ESI) m/z (M+Na)$^{+}$** calcd for $C_{26}H_{24}O_4Na$: 423.1572; Found: 423.1591.

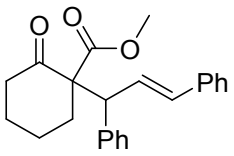
Methyl (E)-2-(2-naphthoyl)-3,5-diphenylpent-4-enoate (3oa).



Yield: 108 mg, 86% yield; colorless liquid; Rf: 0.4 (petroleum ether/EtOAc = 7/1). **IR (KBr):** 3028, 2953, 1734, 1678, 1628, 1495, 1452, 1358, 1296, 1153, 968, 748, 698 cm^{-1}. **^{1}H NMR (400 MHz,$CDCl_3$)** δ 8.62 (dd, *J* = 53.9, 1.8 Hz, 1H), 8.16-7.94 (m, 2H), 7.93-7.81 (m, 2H), 7.66-7.60 (m, 1H), 7.59-7.53 (m, 1H), 7.49-7.07 (m, 10H), 5.24 (dd, *J* = 12.7, 10.9 Hz, 1H), 4.76-4.63 (m, 1H),

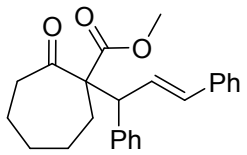
3.58 (d, *J* = 91.3 Hz, 3H). **^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ: 193.8, 192.4, 168.5, 167.7, 140.7, 140.4, 137.0, 136.8, 135.8, 135.7, 134.2, 133.9, 132.5, 132.0, 131.9, 131.7, 130.8, 130.6, 129.8, 129.8, 129.8, 129.7, 128.9, 128.8, 128.8, 128.7, 128.7, 128.6, 128.5, 128.3, 128.3, 127.9, 127.8, 127.7, 127.5, 127.3, 127.2, 126.9, 126.9, 126.4, 126.3, 124.1, 124.0, 59.7, 59.6, 52.8, 52.5, 49.1, 48.9. **HRMS (ESI) m/z (M+Na)$^+$** calcd for $C_{29}H_{24}O_3Na$: 443.1623; Found: 443.1619.

Methyl (E)-1-(1,3-diphenylallyl)-2-oxocyclohexane-1-carboxylate (3pa).



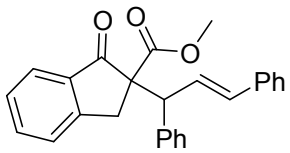
Yield: 80 mg, 76% yield; colorless liquid; Rf: 0.4 (petroleum ether/EtOAc = 7/1). **IR (KBr):** 3027, 2931, 1710, 1645, 1496, 1452, 1357, 1234, 970, 748, 700 cm^{-1}. **^{1}H NMR (400 MHz,$CDCl_3$)** δ 7.44-7.16 (m, 10H), 6.78-6.63 (m, 1H), 6.43 (dd, *J* = 15.7, 3.1 Hz, 1H), 4.22 (dd, *J* = 59.7, 9.1 Hz, 1H), 3.54 (d, *J* = 11.5 Hz, 3H), 2.63 (dq, *J* = 12.3, 2.7 Hz, 1H), 2.53-2.35 (m, 2H), 1.95 (tdd, *J* = 9.5, 4.8, 2.3 Hz, 1H), 1.84-1.47 (m, 4H). **^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ: 206.9, 205.0, 171.6, 171.1, 139.9, 138.9, 137.3, 136.7, 132.4, 130.0, 129.7, 129.1, 128.8, 128.4, 128.4, 128.1, 128.0, 127.3, 127.3, 127.0, 126.8, 126.3, 126.3, 66.2, 66.0, 53.5, 52.2, 52.1, 51.6, 42.0, 34.8, 33.4, 26.9, 26.6, 21.7. **HRMS (ESI) m/z (M+Na)$^+$** calcd for $C_{23}H_{24}O_3Na$: 371.1623; Found: 371.1621.

Methyl (E)-1-(1,3-diphenylallyl)-2-oxocycloheptane-1-carboxylate (3qa).



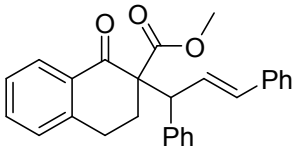
Yield: 92 mg, 85% yield; colorless liquid; Rf: 0.4 (petroleum ether/EtOAc = 7/1). **IR (KBr):** 3028, 2937, 1736, 1711, 1599, 1495, 1452, 1223, 1147, 968, 748, 700 cm^{-1}. **^{1}H NMR (400 MHz,$CDCl_3$)** δ 7.41-7.15 (m, 10H), 6.73 (ddd, *J* = 15.7, 12.3, 9.5 Hz, 1H), 6.42 (dd, *J* = 15.7, 5.5 Hz, 1H), 4.22 (dd, *J* = 31.1, 9.4 Hz, 1H), 3.63 (d, *J* = 20.9 Hz, 3H), 2.56-2.40 (m, 1H), 2.40-2.15 (m, 1H), 2.11-1.87 (m, 2H), 1.69-1.35 (m, 6H). **^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ: 208.8, 208.2, 172.2, 171.8, 139.6, 137.4, 137.2, 132.3, 132.0, 129.7, 129.5, 129.3, 128.8, 128.4, 128.4, 128.2, 128.2, 127.3, 127.2, 127.1, 127.0, 126.3, 68.1, 67.7, 55.5, 54.9, 52.1, 52.0, 44.3, 42.3, 32.9, 31.8, 30.0, 29.8, 25.8, 25.4, 25.3, 25.1. **HRMS (ESI) m/z (M+Na)$^+$** calcd for $C_{24}H_{26}O_3Na$: 385.1780; Found: 385.1786.

Methyl (E)-2-(1,3-diphenylallyl)-1-oxo-2,3-dihydro-1H-indene-2-carboxylate (3ra).



Yield: 102 mg, 88% yield; colorless liquid; Rf: 0.4 (petroleum ether/EtOAc = 7/1). **IR (KBr):** 3030, 2928, 1741, 1713, 1606, 1495, 1456, 1277, 1236, 1163, 968, 752, 700 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.80-7.01 (m, 14H), 6.66-6.48 (m, 1H), 6.45-6.12 (m, 1H), 4.91-4.81 (m, 1H), 4.07-3.97 (m, 1H), 3.74-3.44 (m, 4H). **^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ: 201.1, 200.1, 169.9, 169.6, 153.4, 153.2, 139.7, 138.3, 137.0, 136.8, 135.5, 135.2, 135.2, 135.1, 133.9, 132.9, 129.4, 128.7, 128.6, 128.6, 128.5, 128.5, 128.3, 128.1, 127.9, 127.7, 127.6, 127.4, 127.4, 127.1, 127.1, 126.4, 126.3, 126.3, 126.0, 124.7, 124.5, 66.4, 65.7, 53.1, 52.9, 52.6, 50.4, 33.6, 32.6. **HRMS (ESI) m/z (M+Na)$^+$** calcd for $C_{26}H_{22}O_3Na$: 405.1467; Found: 405.1488.

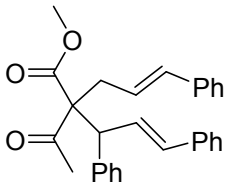
Methyl (E)-2-(1,3-diphenylallyl)-1-oxo-1,2,3,4-tetrahydronaphthalene-2 -carboxylate (3sa).



Yield: 92 mg, 79% yield; colorless liquid; Rf: 0.4 (petroleum ether/EtOAc = 7/1). **IR (KBr):** 3028, 2949, 1732, 1687, 1601, 1450, 1238, 1215, 972, 746, 700 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$)** δ 8.12 (dd, *J* = 7.9, 1.4 Hz, 1H), 7.53-7.11 (m, 13H), 7.05-6.70 (m, 1H), 6.53 (dd, *J* = 19.4, 15.7 Hz, 1H), 4.53 (dd, *J* = 103.9, 9.6 Hz, 1H), 3.53 (d, *J* = 4.9 Hz, 3H), 3.37-3.03 (m, 1H), 2.90 (dddd, *J* = 17.5, 10.1, 4.8, 2.8 Hz, 1H), 2.69 (tdd, *J* = 13.5, 4.5, 2.7 Hz, 1H), 2.30-2.11 (m, 1H). **^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ: 194.1, 193.1,

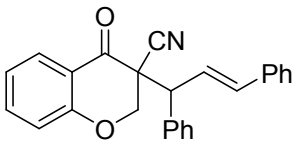
170.8, 169.9, 143.0, 142.9, 139.9, 139.4, 137.3, 137.1, 133.5, 133.4, 132.8, 132.4, 132.4, 130.0, 129.9, 129.5, 128.7, 128.4, 128.5, 128.4, 128.3, 128.3, 128.1, 128.1, 127.9, 127.5, 127.3, 127.2, 126.8, 126.7, 126.6, 126.4, 126.4, 63.5, 62.0, 55.4, 53.0, 52.5, 52.4, 30.3, 29.0, 26.9, 26.5, 25.4. **HRMS (ESI) m/z (M+Na)$^+$** calcd for $C_{27}H_{24}O_3Na$: 419.1623; Found: 419.1628.

Methyl (E)-2-acetyl-2-cinnamyl-3,5-diphenylpent-4-enoate (3ta).



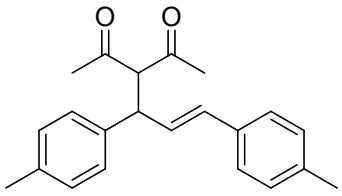
Yield: 30 mg, 23% yield; colorless liquid; Rf: 0.4 (petroleum ether/EtOAc = 7/1). **IR (KBr):** 3028, 2951, 1738, 1709, 1601, 1454, 1495, 1448, 1356, 1213, 968, 746, 698 cm^{-1}. **^{1}H NMR (400 MHz, CDCl$_3$)** δ 7.39-7.15 (m, 15H), 6.68 (ddd, *J* = 15.7, 9.0, 1.5 Hz, 1H), 6.50-6.29 (m, 2H), 6.07-5.92 (m, 1H), 4.27 (dd, *J* = 8.8, 1.0 Hz, 1H), 3.73 (d, *J* = 55.2 Hz, 3H), 2.92-2.64 (m, 2H), 2.11 (d, *J* = 41.3 Hz, 3H). **^{13}C {^{1}H} NMR (101 MHz, CDCl$_3$)** δ: 205.1, 204.7, 171.9, 171.5, 139.5, 139.3, 137.3, 137.0, 137.0, 133.8, 133.7, 132.8, 132.4, 129.3, 129.2, 129.0, 128.6, 128.5, 128.4, 128.4, 128.3, 127.5, 127.3, 127.3, 127.3, 127.3, 127.1, 126.3, 126.3, 126.1, 124.2, 68.4, 67.7, 53.4, 52.7, 52.0, 51.3, 38.2, 37.8, 30.4, 30.1. **HRMS (ESI) m/z (M+Na)$^+$** calcd for $C_{29}H_{28}O_3Na$: 447.1936; Found: 447.1935.

(E)-3-(1,3-diphenylallyl)-4-oxochromane-3-carbonitrile (3ua).



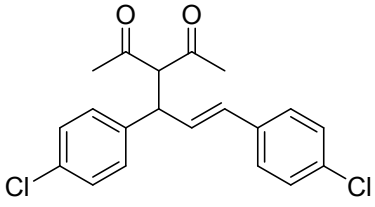
Yield: 88 mg, 80% yield; colorless liquid; Rf: 0.4 (petroleum ether/EtOAc = 7/1). **IR (KBr):** 3030, 2924, 2249, 1701, 1606, 1471, 1458, 1302, 1215, 1138, 974, 748, 696 cm^{-1}. **^{1}H NMR (400 MHz, CDCl$_3$)** δ 7.88 (dd, *J* = 60.0, 7.7 Hz, 1H), 7.66-7.50 (m, 2H), 7.44 (dt, *J* = 21.0, 8.3 Hz, 3H), 7.26 (s, 4H), 7.24 (d, *J* = 6.3 Hz, 2H), 7.13 (dt, *J* = 9.3, 4.9 Hz, 2H), 6.82- 6.20 (m, 2H), 4.88-4.24 (m, 2H), 4.11 (dd, *J* = 39.4, 9.1 Hz, 1H). **^{13}C {^{1}H} NMR (101 MHz, CDCl$_3$)** δ 184.6, 184.3, 160.1, 159.9, 137.2, 137.1, 136.8, 136.6, 136.3, 136.0, 136.0, 134.4, 129.2, 129.0, 128.9, 128.7, 128.6, 128.5, 128.5, 128.4, 128.3, 128.3, 128.0, 126.7, 126.7, 125.0, 124.4, 123.0, 123.0, 119.0, 118.3, 117.9, 117.9, 115.5, 115.4, 69.5, 69.3, 54.1, 54.0, 49.6, 48.7. **HRMS (ESI) m/z (M+Na)$^+$** calcd for $C_{25}H_{19}NO_2Na$: 388.1313; Found: 388.1305.

(E)-3-(1,3-di-p-tolylallyl)pentane-2,4-dione (3ab)[4d].



Yield: 74 mg, 75% yield; white solid; m.p.70.1-71.3 °C; Rf: 0.5 (petroleum ether/EtOAc = 10/1). **IR (KBr):** 3028, 2922, 1728, 1699, 1645, 1514, 1417, 1360, 1169, 972, 802 cm^{-1}. **^{1}H NMR (400 MHz, CDCl$_3$)** δ 7.22-7.11 (m, 6H), 7.12-7.03 (m, 2H), 6.39 (d, *J* = 15.8 Hz, 1H), 6.18-6.08 (m, 1H), 2.31 (s, 6H), 2.25 (s, 3H), 1.94 (s, 3H). **^{13}C {^{1}H} NMR (101 MHz, CDCl$_3$)** δ 203.1, 202.9, 137.5, 137.1, 136.8, 133.8, 131.3, 129.7, 129.2, 128.4, 127.8, 126.2, 74.6, 48.9, 30.0, 29.8, 21.1, 21.0.

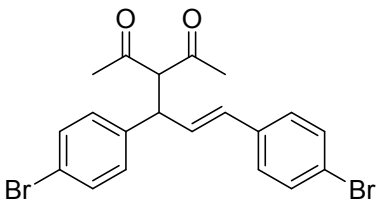
(E)-3-(1,3-bis(4-chlorophenyl)allyl)pentane-2,4-dione (3ac)[4d].



Yield: 78 mg, 73% yield; white solid; m.p. 83.5-84.0 °C; Rf: 0.5 (petroleum ether/EtOAc = 10/1). **IR (KBr):** 3032, 2922, 1730, 1699, 1491, 144, 1358, 1282, 1147, 1092, 972, 820, 675 cm^{-1}. **^{1}H NMR (400 MHz, CDCl$_3$)** δ 7.47-7.41 (m, 2H), 7.41-7.35 (m, 2H), 7.22-6.97 (m, 4H), 6.33 (d, *J* = 15.8 Hz, 1H), 6.12 (ddd, *J* = 15.8, 6.1, 1.8 Hz, 1H), 4.29 (d, *J* = 5.8 Hz, 2H), 2.23 (s, 3H), 1.95 (s,

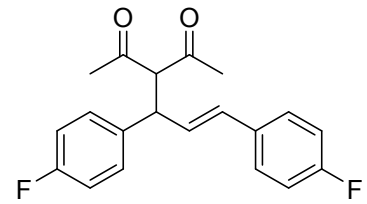
3H). **^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ 202.2, 202.0, 138.9, 135.2, 132.2, 131.8, 131.8, 131.7, 131.0, 129.6, 129.4, 129.0, 127.9, 121.7, 121.3, 74.2, 48.2, 30.0, 29.7.

(E)-3-(1,3-bis(4-bromophenyl)allyl)pentane-2,4-dione (3ad)[4d].



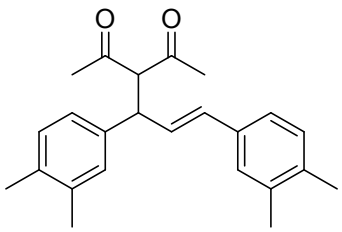
Yield: 107 mg, 80% yield; white solid; m.p. 78.5-79.3 °C; (petroleum ether/EtOAc = 7/1). **IR (KBr):** 3030, 1726, 1699, 1487, 1412, 1360, 1269, 1142, 972, 810, 658 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.46-7.42 (m, 2H), 7.40-7.35 (m, 2H), 7.18-7.08 (m, 4H), 6.33 (d, *J* = 15.8 Hz, 1H), 6.12 (ddd, *J* = 15.8, 6.1, 1.8 Hz, 1H), 4.29 (d, *J* = 5.8 Hz, 2H), 2.23 (s, 3H), 1.95 (s, 3H). **^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ 202.2, 202.0, 138.9, 135.2, 132.2, 131.7, 131.0, 129.6, 129.4, 127.9, 121.7, 121.3, 74.3, 48.2, 30.0, 29.7.

(E)-3-(1,3-bis(4-fluorophenyl)allyl)pentane-2,4-dione (3ae)[4d].



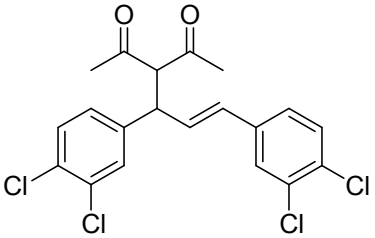
Yield: 74 mg, 76% yield; white solid; m.p. 92.1-93.5 °C; Rf: 0.5 (petroleum ether/EtOAc = 7/1). **IR (KBr):** 3041, 2924, 1730, 1699, 1603, 1510, 1454, 1358, 1227, 1159, 970, 839, 754, 675 cm^{-1}. **^{1}H NMR (300 MHz, $CDCl_3$)** δ 7.36-7.16 (m, 4H), 6.98 (dddd, *J* = 17.2, 8.7, 6.8, 2.1 Hz, 4H), 6.36 (d, *J* = 15.8 Hz, 1H), 6.14-6.00 (m, 1H), 4.31 (d, *J* = 7.3 Hz, 2H), 2.24 (s, 3H), 1.93 (s, 3H). **^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ 202.5, 202.3, 163.6, 163.0, 161.1, 160.6, 135.9, 135.8, 132.6, 132.6, 130.6, 129.5, 129.4, 128.8, 128.8, 127.9, 127.9, 116.0, 115.8, 115.6, 115.3, 74.5, 48.1, 30.0, 29.7. **^{19}F NMR ($CDCl_3$, 376MHz):** δ -114.0, -114.9.

(E)-3-(1,3-bis(3,4-dimethylphenyl)allyl)pentane-2,4-dione (3af).



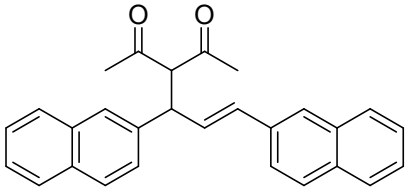
Yield: 42 mg, 41% yield; colorless liquid.; Rf: 0.5 (petroleum ether/EtOAc = 7/1). **IR (KBr):** 3009, 2922, 1728, 1699, 1605, 1508, 1352, 1153, 970, 818, 742, 675 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.15-6.94 (m, 6H), 6.37 (d, *J* = 15.8 Hz, 1H), 6.12 (dd, *J* = 15.8, 8.1 Hz, 1H), 4.48-4.15 (m, 2H), 2.26-2.20 (m, 15H), 1.95 (s, 3H). **^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ: 203.2, 203.0, 137.6, 137.1, 136.5, 136.1, 135.4, 134.3, 131.2, 130.1, 129.7, 129.1, 128.3, 127.5, 124.6, 123.8, 74.5, 48.9, 31.3, 29.8, 19.8, 19.6, 19.4, 19.3. **HRMS (ESI) m/z (M+H)$^{+}$** calcd for $C_{24}H_{29}O_2$: 349.2168; Found: 349.2166.

(E)-3-(1,3-bis(3,4-dichlorophenyl)allyl)pentane-2,4-dione (3ag).



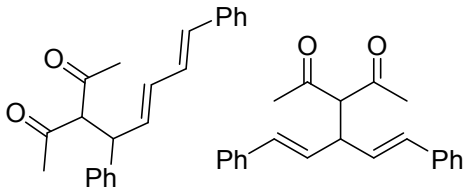
Yield: 70 mg, 54% yield; colorless liquid.; Rf: 0.5 (petroleum ether/EtOAc = 10/1). **IR (KBr):** 3010, 2924, 1732, 1701, 1591, 1556, 1471, 1358, 1263, 1136, 1030, 968, 883, 816, 708, 673, 621, 577 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.40 (d, *J* = 8.3 Hz, 1H), 7.37-7.31 (m, 3H), 7.15-7.05 (m, 2H), 6.31 (d, *J* = 15.8 Hz, 1H), 6.14-6.07 (m, 1H), 4.36-4.23 (m, 2H), 2.23 (s, 3H), 2.00 (s, 3H). **^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ: 201.6, 201.4, 139.9, 136.1, 133.1, 132.7, 131.7, 131.6, 131.4, 130.5, 130.3, 130.0, 129.8, 128.0, 127.2, 125.6, 73.4, 47.6, 30.4, 29.6. **HRMS (ESI) m/z (M+H)$^{+}$** calcd for $C_{20}H_{17}Cl_2O_2$:428.9973; Found: 428.9966.

(E)-3-(1,3-di(naphthalen-2-yl)allyl)pentane-2,4-dione (3ah)[4d].



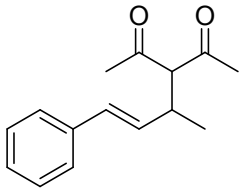
Yield: 75 mg, 64% yield; white solid; m.p. 93.5-94.8 °C; Rf: 0.6 (petroleum ether/EtOAc = 7/1). **IR (KBr):** 3053, 2924, 1726, 1699, 1628, 1599, 1417, 1358, 1269, 1149, 966, 895, 860, 816, 748, 621 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.84-7.71 (m, 7H), 7.65 (s, 1H), 7.53-7.37 (m, 6H), 6.62 (d, *J* = 15.8 Hz, 1H), 6.39 (dd, *J* = 15.8, 7.6 Hz, 1H), 4.63-4.48 (m, 2H), 2.31 (s, 3H), 1.95 (s, 3H). **^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ 202.8, 202.6, 137.5, 133.9, 133.6, 133.5, 133.0, 132.6, 132.1, 129.5, 128.9, 128.2, 127.9, 127.8, 127.7, 127.6, 126.7, 126.4, 126.4, 126.3, 126.0, 126.0, 125.9, 123.4, 74.5, 49.2, 30.0, 29.9.

3-((2E,4E)-1,5-diphenylpenta-2,4-dien-1-yl)pentane-2,4-dione (3ai)[4e].



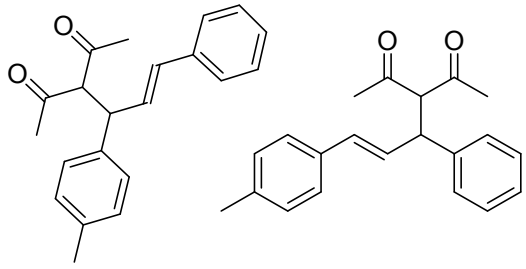
Yield: 51 mg, 59% yield; yellow liquid; Rf: 0.6 (petroleum ether/EtOAc = 10/1). **IR (KBr):** 3028, 2926, 1726, 1699, 1628, 1599, 1493, 1540, 1419, 1358, 1186, 1153, 972, 754, 700, 623 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.37-7.23 (m, 10H), 6.71-6.46 (m, 2H), 6.28-5.79 (m, 2H), 4.35-3.95 (m, 2H), 2.32-1.91 (m, 6H). **^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ 202.9, 202.7, 140.0, 137.0, 133.2, 132.8, 132.3, 132.2, 129.0, 128.6, 128.1, 127.9, 127.8, 127.7, 127.6, 127.3, 126.3, 126.3, 74.5, 73.8, 49.0, 46.4, 30.0, 29.7.

(E)-3-(4-phenylbut-3-en-2-yl)pentane-2,4-dione (3aj) [4d].



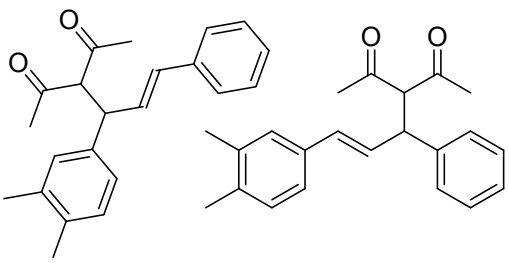
Yield: 14 mg, 20% yield; colorless liquid; Rf: 0.6 (petroleum ether/EtOAc = 7/1). **IR (KBr):** 3026, 2968, 2929, 2875, 1697, 1599, 1547, 1493, 1452, 1421, 1358, 1273, 1190, 1156, 970, 750, 696 cm^{-1}. **^{1}H NMR (300 MHz,$CDCl_3$)** δ 7.34-7.23 (m, 6H), 6.44 (dd, *J* = 15.9, 0.9 Hz, 1H), 6.00 (dd, *J* = 15.9, 8.5 Hz, 1H), 3.69 (d, *J* = 10.4 Hz, 1H), 3.28-3.14 (m, 1H), 2.23 (s, 3H), 2.13 (s, 3H), 1.09 (d, *J* = 6.7 Hz, 3H). **^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ 203.6, 203.5, 136.8, 131.0, 130.9, 128.6, 128.5, 127.6, 126.2, 75.6, 37.9, 30.0, 29.7, 18.8.

(E)-3-(3-phenyl-1-(p-tolyl)allyl)pentane-2,4-dione (3ak)[4d].



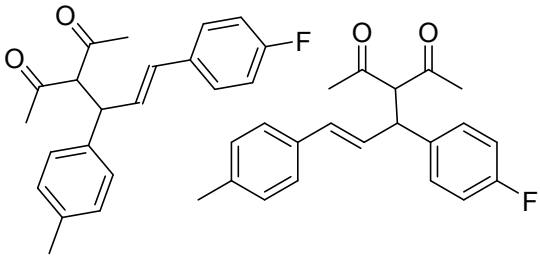
Yield: 70 mg, 80% yield; white solid mixture; Rf: 0.5 (petroleum ether/EtOAc = 7/1). **IR (KBr):** 3028, 2949, 2920, 1726, 1701, 1601, 1514, 1417, 1360, 1275, 1171, 1142, 972, 816, 860, 816, 764, 739, 698, 623 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.34-7.27 (m, 3H), 7.25-7.11 (m, 5H), 7.08 (d, *J* = 7.9 Hz, 1H), 6.41 (dd, *J* = 15.8, 6.8 Hz, 1H), 6.24-6.09 (m, 1H), 4.32 (t, *J* = 6.4 Hz, 2H), 2.31 (s, 3H), 2.25 (s, 3H), 1.93 (d, *J* = 5.1 Hz, 3H). **^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ: 203.0, 202.9, 202.8, 202.8, 140.2, 137.5, 136.9, 136.9, 136.6, 133.7, 131.5, 131.4, 129.7, 129.4, 129.1, 129.0, 128.5, 128.3, 128.1, 127.9, 127.76, 127.6, 127.2, 126.3, 126.2, 125.9, 74.5, 49.2, 48.8, 30.0, 30.0, 29.7, 29.7, 21.1, 21.0.

(E)-3-(1-(3,4-dimethylphenyl)-3-phenylallyl)pentane-2,4-dione (3al).



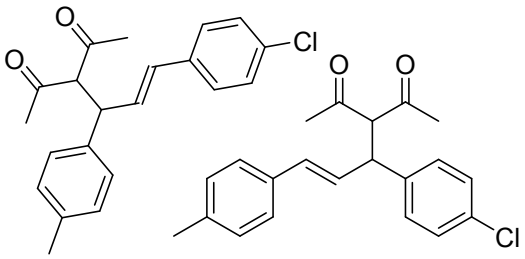
Yield: 59 mg, 61% yield; colorless liquid; Rf: 0.4 (petroleum ether/EtOAc = 7/1). **IR (KBr):** 3026, 2924, 1728, 1699, 1603, 1498, 1450, 1356, 1269, 1153, 968, 822, 762, 698, 617 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.42-7.18 (m, 5H), 7.18-6.99 (m, 3H), 6.44 (t, *J* = 16.3 Hz, 1H), 6.27-6.13 (m, 1H), 4.43-4.26 (m, 2H), 2.25 (dd, 9H), 1.97 (d, *J* = 11.4 Hz, 3H). **^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ: 203.0, 202.9, 202.8, 202.8, 140.3, 137.5, 137.2, 136.7, 136.6, 136.2, 135.5, 134.2, 131.6, 131.3, 130.2, 129.8, 129.7, 129.2, 129.0, 128.5, 128.0, 127.9, 127.6, 127.6, 127.2, 126.3, 125.1, 123.9, 74.6, 74.4, 49.2, 48.1, 30.0, 30.0, 29.8, 29.7, 19.9, 19.7, 19.5, 19.3. **HRMS (ESI) m/z (M+Na)$^+$** calcd for $C_{22}H_{24}O_2Na$: 343.1674; Found: 343.1678.

(E)-3-(3-(4-fluorophenyl)-1-(p-tolyl)allyl)pentane-2,4-dione (3am).



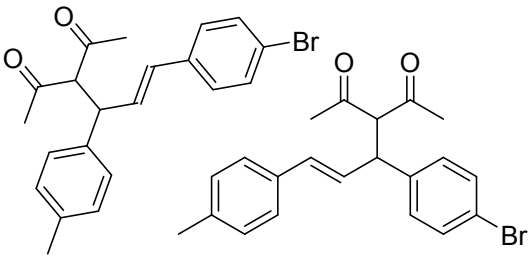
Yield: 80 mg, 82% yield; colorless liquid; Rf: 0.4 (petroleum ether/EtOAc = 7/1). **IR (KBr):** 3026, 2924, 1730, 1699, 1603, 1510, 1419, 1358, 1227, 1157, 970, 835, 812, 750, 723, 619 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.24-7.07 (m, 6H), 7.00 (dd, *J* = 16.5, 7.9 Hz, 2H), 6.39 (dd, *J* = 15.8, 3.5 Hz, 1H), 6.13 (dt, *J* = 15.4, 7.1 Hz, 1H), 4.39-4.26 (m, 2H), 2.31 (s, 3H), 2.25 (d, *J* = 2.4 Hz, 3H), 1.94 (s, 3H). **^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ: 202.9, 202.7, 202.6, 202.5, 163.5, 163.0, 161.0, 160.5, 137.7, 136.9, 136.1, 136.0, 133.6, 132.8, 132.8, 131.6, 130.2, 129.8, 129.7, 129.5, 129.4, 129.3, 129.2, 129.1, 127.9, 127.9, 127.8, 127.7, 126.2, 125.8, 115.9, 115.7, 115.5, 115.3, 115.1, 114.9, 74.6, 74.4, 48.4, 48.2, 29.8, 29.6, 21.1, 21.0. **^{19}F NMR ($CDCl_3$, 376MHz)**: δ -114.2, -115.0. **HRMS (ESI) m/z (M+Na)$^+$** calcd for $C_{21}H_{21}O_2NaF$: 347.1423; Found: 347.1426.

(E)-3-(3-(4-chlorophenyl)-1-(p-tolyl)allyl)pentane-2,4-dione (3an)[4d].



Yield: 82 mg, 81% yield; white solid mixture; Rf: 0.4 (petroleum ether/EtOAc = 7/1). **IR (KBr):** 3028, 2924, 1730, 1699, 1512, 1491, 1358, 1282, 1149, 972, 812, 723, 636 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.34-7.07 (m, 8H), 6.39 (dd, *J* = 15.8, 8.5 Hz, 1H), 6.14 (dddd, *J* = 25.0, 15.7, 6.7, 1.2 Hz, 1H), 4.38-4.26 (m, 2H), 2.33 (s, 3H), 2.26 (s, 3H), 1.96 (d, *J* = 6.8 Hz, 3H). **^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ: 202.8, 202.6, 202.5, 202.3, 138.8, 137.7, 137.0, 136.7, 135.0, 133.5, 133.2, 132.9, 131.9, 130.2, 130.1, 129.7, 129.2, 129.2, 129.1, 128.6, 127.7, 127.5, 126.2, 74.5, 74.4, 48.6, 48.3, 30.0, 29.9, 29.8, 29.6, 21.1, 21.0.

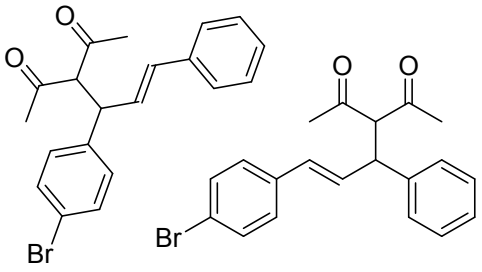
(E)-3-(3-(4-bromophenyl)-1-(p-tolyl)allyl)pentane-2,4-dione (3ao).



Yield: 99 mg, 86% yield; white solid mixture; Rf: 0.4 (petroleum ether/EtOAc = 7/1). **IR (KBr):** 3020, 2920, 1730, 1699, 1512, 1485, 1417, 1358, 1284, 1146, 1070, 1009, 972, 810, 721, 663, 629 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.50-7.26 (m, 2H),

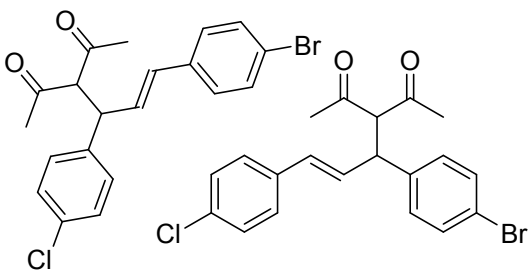
7.23-7.07 (m, 6H), 6.38 (t, *J* = 15.5 Hz, 1H), 6.25-6.06 (m, 1H), 4.39-4.26 (m, 2H), 2.33 (s, 3H), 2.26 (d, *J* = 1.7 Hz, 3H), 1.96 (d, *J* = 7.7 Hz, 3H). **^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ: 202.8, 202.5, 202.4, 202.3, 139.3, 137.7, 137.0, 136.6, 135.5, 133.5, 132.0, 131.9, 131.5, 130.3, 130.2, 129.7, 129.6, 129.2, 127.8, 127.7, 127.4, 126.2, 121.4, 121.0, 74.4, 74.4, 48.7, 48.4, 30.0, 29.9, 29.8, 29.6, 21.1, 21.0. **HRMS (ESI) m/z (M+Na)$^+$** calcd for $C_{21}H_{21}O_2NaBr$: 407.0623; Found: 407.0620.

(E)-3-(1-(4-bromophenyl)-3-phenylallyl)pentane-2,4-dione (3ap).



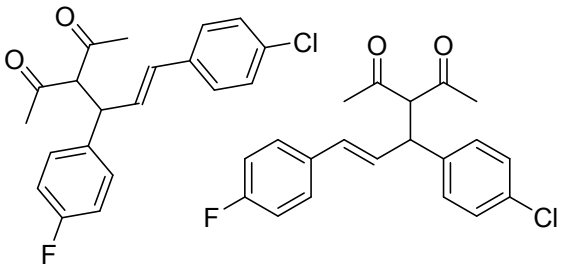
Yield: 88 mg, 82% yield; white solid mixture; Rf: 0.5 (petroleum ether/EtOAc = 7/1). **IR (KBr):** 3028, 2918, 1724, 1699, 1489, 1360, 1273, 1173, 1140, 1072, 1009, 972, 818, 762, 702 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.49-7.18 (m, 7H), 7.13 (d, *J* = 8.5 Hz, 2H), 6.39 (dd, *J* = 22.8, 15.8 Hz, 1H), 6.24-6.09 (m, 1H), 4.39-4.26 (m, 2H), 2.24 (d, *J* = 1.8 Hz, 3H), 1.94 (d, *J* = 12.6 Hz, 3H). **^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ: 202.6, 202.4, 202.3, 202.2, 139.7, 139.2, 136.3, 135.4, 132.1, 132.0, 131.6, 130.5, 130.1, 129.6, 129.1, 128.5, 128.5, 127.9, 127.9, 127.3, 126.3, 121.4, 74.3, 74.3, 49.0, 48.3, 30.1, 30.0, 29.8, 29.6. **HRMS (ESI) m/z (M+Na)$^+$** calcd for $C_{20}H_{19}O_2NaBr$: 393.0466; Found: 393.0464.

(E)-3-(3-(4-bromophenyl)-1-(4-chlorophenyl)allyl)pentane-2,4-dione (3aq).



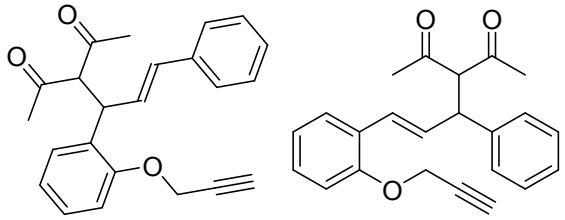
Yield: 90 mg, 75% yield; white solid mixture; Rf: 0.4 (petroleum ether/EtOAc = 7/1). **IR (KBr):** 3030, 2924, 1730, 1489, 1412, 1358, 1282, 1146, 1090, 1011, 970, 818, 717, 629 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.42 (dd, *J* = 25.3, 8.4 Hz, 2H), 7.30 (d, *J* = 8.4 Hz, 1H), 7.27-7.17 (m, 3H), 7.14 (dd, *J* = 8.6, 2.0 Hz, 2H), 6.36 (dd, *J* = 15.8, 6.2 Hz, 1H), 6.14 (dt, *J* = 15.8, 8.2 Hz, 1H), 4.33 (d, *J* = 6.4 Hz, 2H), 2.24 (s, 3H), 1.96 (s, 3H). **^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ: 202.2, 202.0, 138.9, 138.3, 135.2, 134.8, 133.4, 133.1, 132.1, 131.6, 130.9, 130.8, 129.6, 129.4, 129.3, 129.2, 129.2, 128.7, 127.9, 127.5, 121.6, 121.2, 74.2, 74.2, 48.2, 48.1, 30.0, 29.7. **HRMS (ESI) m/z (M+Na)$^+$** calcd for $C_{20}H_{18}O_2NaClBr$: 427.0076; Found: 427.0074.

(E)-3-(3-(4-chlorophenyl)-1-(4-fluorophenyl)allyl)pentane-2,4-dione (3ar).



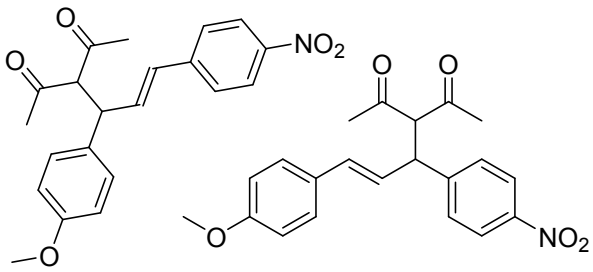
Yield: 85 mg, 83% yield; white solid mixture; Rf: 0.4 (petroleum ether/EtOAc = 7/1). **IR (KBr):** 1730, 1701, 1601, 1510, 1416, 1358, 1281, 1225, 1159, 1090, 1011, 974, 823, 764, 600 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.33-7.17 (m, 6H), 7.09-6.93 (m, 2H), 6.38 (dd, *J* = 15.8, 7.0 Hz, 1H), 6.20-6.03 (m, 1H), 4.40-4.27 (m, 2H), 2.25 (s, 3H), 1.96 (d, *J* = 4.9 Hz, 3H). **^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ: 202.4, 202.3, 202.2, 202.1, 138.5, 135.6, 135.5, 134.8, 133.4, 133.1, 132.4, 130.8, 130.6, 129.6, 129.5, 129.4, 129.2, 129.2, 128.7, 128.4, 128.3, 127.9, 127.8, 127.5, 116.0, 115.8, 115.6, 115.3, 74.5, 74.4, 48.2, 48.1, 30.0, 29.9, 29.6, 29.6. **^{19}F NMR ($CDCl_3$, 376MHz)**: δ -113.8, -114.8. **HRMS (ESI) m/z (M+Na)$^+$** calcd for $C_{20}H_{18}O_2NaClF$: 367.0877; Found: 367.0876.

(E)-3-(3-phenyl-1-(2-(prop-2-yn-1-ylxoy)phenyl)pentane-2.4-dione (3as).



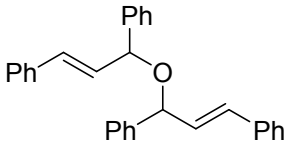
Yield: 77 mg, 75% yield; colorless liquid; Rf: 0.4 (petroleum ether/EtOAc = 5/1). **IR (KBr):** 3294, 3030, 2924, 2121, 1724, 1699, 1601, 1491, 1452, 1360, 1271, 1219, 1142, 1024, 980, 924, 756, 694, 631 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.47-7.15 (m, 7H), 7.04-6.93 (m, 2H), 6.58 (dd, 1H), 6.37-6.24 (m, 1H), 4.76 (dd, *J* = 43.0, 2.4 Hz, 2H), 4.70-4.35 (m, 2H), 2.54 (t, *J* = 2.4 Hz, 1H), 2.27 (s, 3H), 1.98 (d, *J* = 19.7 Hz, 3H). **^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ: 203.3, 202.9, 154.8, 154.7, 140.3, 136.8, 131.8, 130.1, 129.5, 128.9, 128.7, 128.5, 128.4, 128.2, 127.9, 127.4, 127.1 126.9, 126.3, 126.1, 122.0, 121.6, 112.8, 112.7, 78.5, 78.4, 75.6, 75.6, 74.6, 72.6, 56.3, 56.0, 48.9, 44.4, 30.5, 30.2, 29.6, 29.1. **HRMS (ESI) m/z (M+Na)$^+$** calcd for $C_{23}H_{22}O_3Na$: 369.1467; Found: 369.1467.

(E)-3-(1-(4-methoxyphenyl)-3-(4-nitrophenyl)allyl)pentane-2,4-dione (3at)[4f].



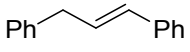
Yield: 93 mg, 85% yield; yellow liquid; Rf: 0.5 (petroleum ether/EtOAc = 3/1). **IR (KBr)**: 3003, 2935, 2839, 1728, 1699, 1643, 1601, 1516, 1419, 1344, 1254, 1180, 1153, 1111, 1032, 972, 831, 741, 694 cm^{-1}. **^{1}H NMR (300 MHz, $CDCl_3$)** δ 8.25-8.04 (m, 2H), 7.38 (d, *J* = 8.9 Hz, 2H), 7.16 (d, *J* = 8.7 Hz, 2H), 6.85 (d, *J* = 8.7 Hz, 2H), 6.50-6.26 (m, 2H), 4.33 (d, *J* = 3.3 Hz, 3H), 2.24 (s, 3H), 1.93 (d, 3H). **^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ: 202.5, 202.2, 201.8, 201.6, 158.8, 158.7, 148.2, 146.8, 143.1, 143.1, 134.6, 134.3, 130.9, 129.7, 129.3, 129.1, 129.1, 129.0, 128.8, 128.6, 128.6, 128.5, 128.2, 127.6, 126.8, 125.0, 124.1, 124.0, 123.9, 123.7, 123.6, 74.1, 55.2, 55.2, 48.5, 48.1, 30.1, 29.9, 29.8, 29.6.

bis(1,3-diphenylallyl) ether (4aa)[4g].



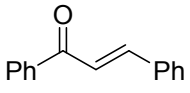
The target compound was obtained according to general procedure, but the reaction temperature is 30 °C, and the crude product was purified by silica gel chromatography using petroleum ether/EtOAc = 100/1 as an eluent to give pure product **4aa** (30 mg, 26% yield) as a yellow liquid; Rf: 0.5 (petroleum ether/EtOAc = 70/1). **IR (KBr):** 3055, 2924, 1591, 1479, 1433, 1090, 854, 744, 696 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.49-7.26 (m, 20H), 6.63 (dd, *J* = 15.7, 4.2 Hz, 2H), 6.38 (ddd, *J* = 20.9, 15.9, 7.0 Hz, 2H), 5.13 (t, *J* = 7.7 Hz, 2H). **^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ 141.3, 141.2, 136.6, 136.6, 131.6, 131.4, 130.5, 130.3, 128.6, 128.5, 127.8, 127.7, 127.7, 127.1, 126.7, 126.6, 126.6, 79.2, 79.1.

(E)-prop-1-ene-1,3-diyldibenzene (5aa)[4g].



Compound **4aa** (0.3 mmol), $B(C_6F_5)_3$ (3 mol%), H_2O (1.5 mL) were added to the reaction tube and the reaction mixture was stirred at 100 °C in oil bath for 1 h. and the crude product was purified by silica gel chromatography using petroleum ether/EtOAc = 200/1 as an eluent to give pure product **5aa** (20 mg, 26% yield) as a colorless liquid; Rf: 0.4 (petroleum ether/EtOAc = 100/1). **IR (KBr):** 3028, 1603, 1498, 1450, 1227, 966, 742, 696 cm^{-1}. **^{1}H NMR (300 MHz, $CDCl_3$)** δ 7.46-7.20 (m, 10H), 6.58-6.34 (m, 2H), 3.61 (d, *J* = 6.3 Hz, 2H). **^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ 140.2, 137.6, 133.4, 131.2, 129.3, 128.8, 128.6, 127.2, 126.3, 126.2, 39.4.

(E)-chalcone (6aa)[4g].

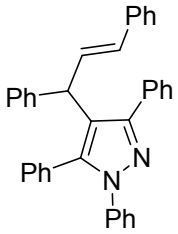


Compound **4aa** (0.3 mmol), $B(C_6F_5)_3$ (3 mol%), H_2O (1.5 mL) were added to the reaction tube and the reaction mixture was stirred at 100 °C in oil bath for 1 h. and the crude product was purified by silica gel chromatography using petroleum ether/EtOAc = 100/1 as an eluent to give pure product **6aa** (12 mg, 20% yield) as a yellow solid; Rf: 0.4 (petroleum ether/EtOAc = 50/1). **IR (KBr):** 3061, 1664, 1605, 1448, 1336, 1215, 1016, 982, 787, 748, 690 cm^{-1}. **^{1}H NMR (300 MHz, $CDCl_3$)** δ 8.07-7.98 (m, 2H), 7.82 (d, *J* = 15.7 Hz, 1H), 7.70-7.48 (m, 6H), 7.47-7.38 (m, 3H). **^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ 190.5, 144.8, 138.2, 134.9, 132.8, 130.6, 129.0, 128.6, 128.5, 128.5, 122.1.

Scale-up of the Transformation on a 10 mmol Scale.

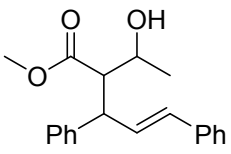
Acetylacetone (1 mol), allyl alcohol (1 mol), $B(C_6F_5)_3$ (3 mol%), H_2O (20 mL) were added to the reaction tube and the reaction mixture was stirred at 100 °C in oil bath for 1 h. The reaction was monitored by TLC. When the reaction was finished, cooled to room temperature, extraction with ethyl acetate was done three times, the organic phase was merged and dried with anhydrous $MgSO_4$, and vacuum evaporated. Further purification was carried out via silica gel column chromatography and eluted with ethyl acetate and petroleum ether.

Synthesis of 4 according to the Following Procedure.



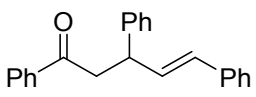
3ca (0.3 mmol) and phenylhydrazine (1.2 eq) in acetic acid (1.5 mL) at 100 °C for one hour. And the crude product was purified by silica gel chromatography using petroleum ether/EtOAc = 100/1 as an eluent to give pure product **4** (101 mg, 69% yield) as a colorless liquid; Rf: 0.5 (petroleum ether/EtOAc = 50/1). **IR (KBr):** 3059, 2928, 1597, 1497, 1448, 1358, 1155, 1072, 968, 744, 696 cm^{-1}. **^{1}H NMR (300 MHz, $CDCl_3$)** δ 7.58 (dd, *J* = 6.6, 3.0 Hz, 2H), 7.39-7.08 (m, 23H), 6.47-6.28 (m, 2H), 5.05 (d, *J* = 6.3 Hz, 1H). **^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ: 151.8, 143.9, 141.7, 140.0, 137.3, 133.8, 131.5, 131.4, 131.0, 130.6, 129.0, 128.6, 128.4, 128.4, 128.3, 128.2, 128.2, 128.1, 127.8, 127.2, 126.8, 126.2, 126.1, 124.8, 120.6, 44.2. **HRMS (ESI) m/z (M+Na)$^+$** calcd for $C_{36}H_{28}N_2Na$: 511.2150; Found: 511.2143.

Synthesis of 5 according to the Following Procedure.



3ja (0.2 mmol) and $NaBH_4$ (0.5 eq) in MeOH (1.5 mL) at 0 °C for one hour. And the crude product was purified by silica gel chromatography using petroleum ether/EtOAc = 7/1 as an eluent to give pure product **5** (31 mg, 51% yield) as a colorless liquid; Rf: 0.5 (petroleum ether/EtOAc = 50/1). **IR (KBr):** 3028, 2968, 1718, 1601, 1495, 1452, 1267, 1201, 1165, 1130, 1032, 968, 748, 698 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.42-7.18 (m, 10H), 6.75-6.22 (m, 2H), 4.18-3.99 (m, 2H), 3.54 (d, *J* = 109.8 Hz, 3H), 2.87 (ddd, *J* = 11.2, 5.2, 2.9 Hz, 1H), 1.22 (dd, *J* = 43.7, 6.5 Hz, 3H). **^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ: 174.8, 173.7, 142.0, 141.0, 137.1, 136.9, 132.3, 130.9, 130.5, 129.8, 128.9, 128.5, 128.4, 128.4, 127.9, 127.8, 127.5, 127.4, 126.9, 126.8, 126.3, 126.2, 77.3, 77.0, 76.7, 65.9, 65.5, 57.5, 56.4, 51.6, 50.7, 49.0, 22.6, 22.4. **HRMS (ESI) m/z (M+H)$^+$** calcd for $C_{20}H_{23}O_3$: 311.1640; Found: 311.1647.

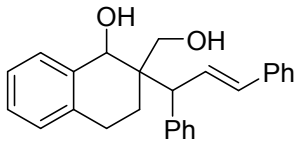
Synthesis of 6[4h] according to the Following Procedur.



3ka (0.2 mmol) in 20% NaOH (3 mL) at 100 °C for 5 h. And the crude product was purified by silica gel chromatography using petroleum ether/EtOAc = 30/1 as an eluent to give pure product **6** (34 mg, 56% yield) as a yellow liquid; Rf:

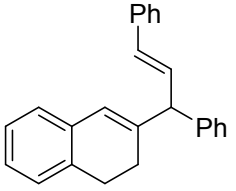
0.5 (petroleum ether/EtOAc = 15/1). **IR (KBr):** 3030, 1678, 1597, 1493, 1448, 1417, 1230, 968, 750, 692, cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$)** δ 8.00-7.93 (m, 2H), 7.58 (t, *J* = 7.4 Hz, 1H), 7.47 (t, *J* = 7.5 Hz, 2H), 7.38-7.14 (m, 10H), 6.42 (d, 2H), 4.33 (td, *J* = 6.8, 4.5 Hz, 1H), 3.61-3.45 (m, 2H). **^{13}C NMR (101 MHz, $CDCl_3$)** δ 198.2, 143.3, 137.2, 137.2, 133.1, 132.6, 130.1, 128.7, 128.6, 128.4, 128.1, 127.8, 127.2, 126.6, 126.2, 44.5, 43.9.

Synthesis of 7 according to the Following Procedure.



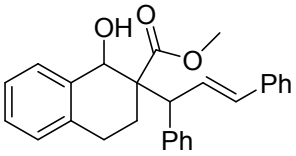
3sa (0.5 mmol) and diisobutylaluminium hydride (4 eq) in THF (5 mL) at -20 °C for 12 hour. And the crude product was purified by silica gel chromatography using petroleum ether/EtOAc = 7/1 as an eluent to give pure product **7** (151 mg, 82% yield) as a white solid; m.p.82.5-83.6 °C; Rf: 0.5 (petroleum ether/EtOAc = 3/1). **IR (KBr):** 1703, 1635, 1103, 804, 746, 698 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.48 (dd, *J* = 27.7, 5.9 Hz, 2H), 7.40-7.13 (m, 12H), 6.78 (dd, *J* = 15.0, 9.3 Hz, 1H), 6.35 (dd, *J* = 40.6, 15.7 Hz, 1H), 4.58 (d, *J* = 122.8 Hz, 1H), 4.02 (dd, *J* = 133.5, 10.1 Hz, 1H), 3.65-3.48 (m, 2H), 3.04-2.91 (m, 1H), 2.78 (ddt, *J* = 26.1, 17.4, 8.2 Hz, 1H), 2.06 (d, *J* = 71.7 Hz, 1H), 1.86 (dt, *J* = 10.1, 5.5 Hz, 1H), 1.69 (s, 1H), 1.54 (dd, *J* = 13.1, 6.9 Hz, 1H). **^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ: 141.5, 141.0, 137.8, 137.3, 135.9, 135.6, 132.6, 131.5, 131.4, 131.2, 129.6, 129.5, 128.8, 128.5, 128.4, 128.3, 128.3, 127.8, 127.7, 127.4, 127.2, 127.0, 126.6, 126.5, 126.4, 126.3, 126.3, 126.2, 73.4, 72.7, 65.6, 65.1, 53.4, 50.8, 45.0, 25.8, 25.4, 24.4, 24.4. **HRMS (ESI) m/z (M+Na)$^+$** calcd for $C_{26}H_{26}O_2Na$: 393.1830; Found: 393.1831.

Synthesis of 8 according to the Following Procedure.



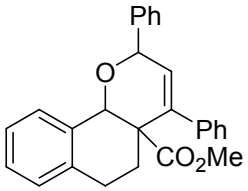
7 (0.2 mmol) and *p*-TsOH (1 eq) in toluene (2 mL) and DMSO (0.3 mL) at 80 °C for 12 hour. And the crude product was purified by silica gel chromatography using petroleum ether/EtOAc = 150/1 as an eluent to give pure product **8** (48 mg, 75% yield) as a colorless liquid; Rf: 0.5 (petroleum ether/EtOAc = 25/1). **IR (KBr):** 3059, 3026, 2929, 1599, 1491, 1450, 1072, 1030, 970, 750, 698 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.49-7.26 (m, 10H), 7.21-7.05 (m, 4H), 6.62 (dd, *J* = 15.9, 7.4 Hz, 1H), 6.50-6.40 (m, 2H), 4.38 (d, *J* = 7.3 Hz, 1H), 2.83 (t, *J* = 7.2 Hz, 2H), 2.26 (t, *J* = 8.1 Hz, 2H). **^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ: 143.0, 141.8, 137.7, 134.6, 134.5, 131.4, 131.0, 128.6, 128.5, 128.5, 127.3, 127.2, 126.6, 126.6, 126.4, 126.3, 126.0, 124.3, 55.6, 28.3, 26.7. **HRMS (ESI) m/z (M+H)$^+$** calcd for $C_{25}H_{23}$: 323.1800; Found: 323.1800.

Synthesis of 9 according to the Following Procedure.



3sa (0.5 mmol) and diisobutylaluminium hydride (2 eq) in THF (5 mL) at -20 °C for 2 hour. And the crude product was purified by silica gel chromatography using petroleum ether/EtOAc = 20/1 as an eluent to give pure product **9** (151 mg, 76% yield) as a white solid; m.p.123.4-124.1 °C; Rf: 0.3 (petroleum ether/EtOAc = 7/1). **IR (KBr):** 3730, 3508, 3028, 2931, 1703, 1601, 1510, 1452, 1356, 1225, 1016, 970, 810, 746, 698 cm^{-1}. **^{1}H NMR (300 MHz, $CDCl_3$)** δ 7.45 (t, *J* = 7.3 Hz, 2H), 7.37-7.30 (m, 5H), 7.29-7.15 (m, 6H), 7.09 (d, *J* = 7.3 Hz, 1H), 6.92 (ddd, *J* = 31.7, 15.6, 10.3 Hz, 1H), 6.70-6.49 (m, 1H), 4.92 (d, *J* = 127.8 Hz, 1H), 4.08 (dd, *J* = 66.4, 10.3 Hz, 1H), 3.48 (s, 3H), 2.89-2.74 (m, 2H), 2.48-1.98 (m, 2H), 1.64 (s, 1H). **^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ 173.2, 173.0, 140.6, 140.3, 138.0, 137.4, 137.3, 137.0, 135.9, 135.3, 132.4, 132.2, 130.1, 129.8, 129.2, 129.1, 129.0, 128.9, 128.6, 128.5, 128.4, 128.3, 128.2, 128.1, 128.0, 127.3, 127.2, 126.9, 126.8, 126.4, 126.3, 126.3, 126.1, 69.9, 68.5, 55.1, 54.6, 54.0, 52.6, 51.2, 26.2, 26.0, 24.8, 23.5. **HRMS (ESI) m/z (M+H)$^+$** calcd for $C_{27}H_{27}O_3$: 399.1960; Found: 399.1966.

Synthesis of 10 according to the Following Procedure.



Compound **9** (0.2 mmol) and DDQ (1.2 eq) and 80 mg 4 Å MS in CH_2Cl_2 (10 mL) at rt for 12 hour. And the crude product was purified by silica gel chromatography using petroleum ether/EtOAc = 200/1 as an eluent to give pure product **10** (36 mg, 46% yield) as a colorless liquid; Rf: 0.3 (petroleum ether/EtOAc = 25/1). **IR (KBr):** 3028, 2924, 1732, 1493, 1441, 1381, 1244, 1217, 974, 933, 823, 746, 698 cm^{-1}. **^{1}H NMR (300 MHz, $CDCl_3$)** δ 7.49 (dd, *J* = 12.8, 7.9 Hz, 3H), 7.43-7.35 (m, 4H), 7.33-7.21 (m, 7H), 7.11 (t, *J* = 4.3 Hz, 1H), 7.02 (d, *J* = 15.7 Hz, 1H), 6.58 (d, *J* = 15.7 Hz, 1H), 6.07 (s, 1H), 3.76 (s, 4H), 2.68 (ddd, *J* = 15.0, 11.0, 4.0 Hz, 1H), 2.44-2.34 (m, 1H), 2.26 (dt, *J* = 14.0, 4.5 Hz, 1H), 1.79-1.63 (m, 1H). **^{13}C {^{1}H} NMR (101 MHz, $CDCl_3$)** δ: 172.9, 140.5, 139.5, 136.6, 133.4, 131.3, 129.5, 129.2, 128.5, 128.5, 128.2, 128.1, 127.6, 127.1, 126.8, 126.5, 124.6, 87.5, 76.1, 56.9, 52.1, 27.6, 26.3. **HRMS (ESI) m/z $(M+H)^+$** calcd for $C_{27}H_{25}O_3$: 397.1804; Found: 397.1805.

3. Reference

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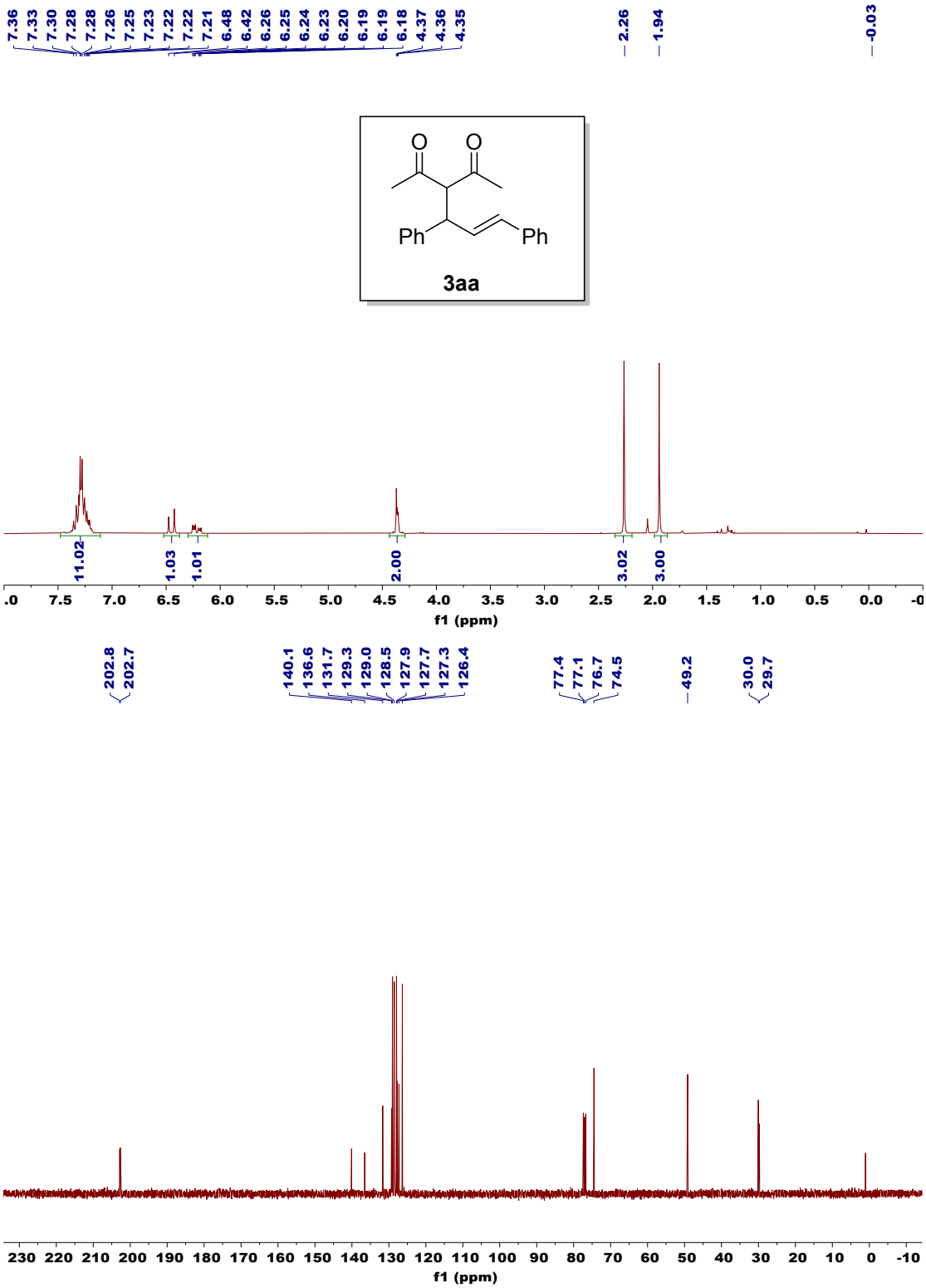
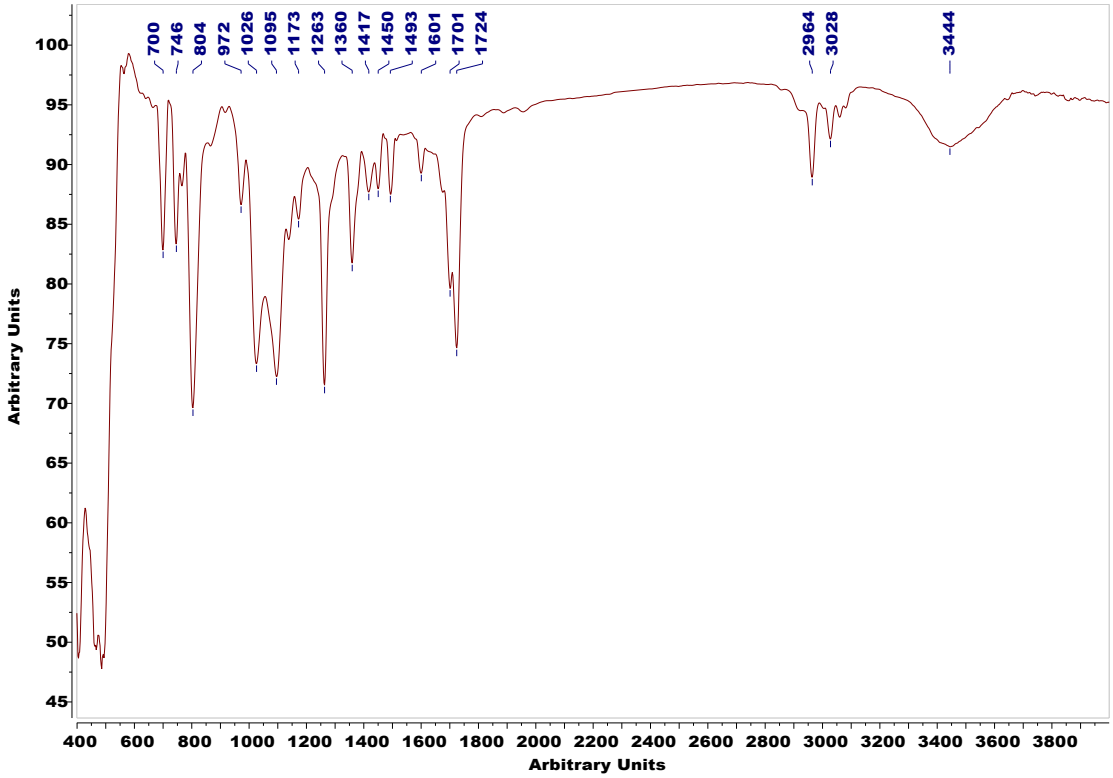
4 ^{1}HNMR, ^{13}CNMR and IR




700
746
804
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1263
1360
1417
1450
1493
1601
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Arbitrary Units


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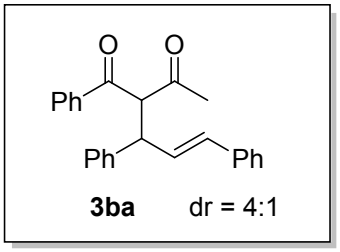
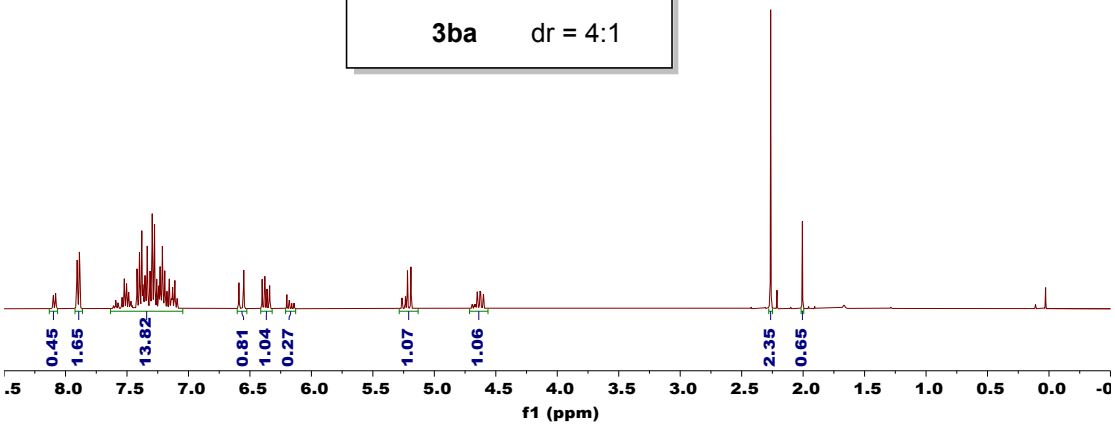
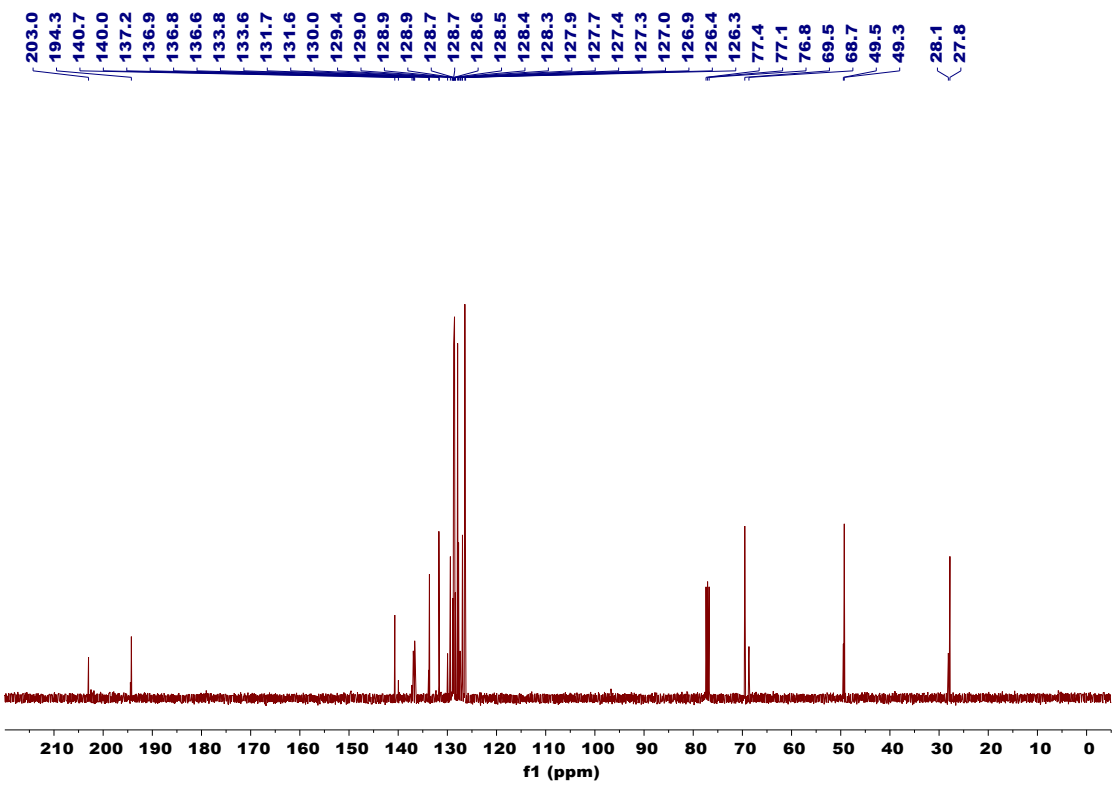
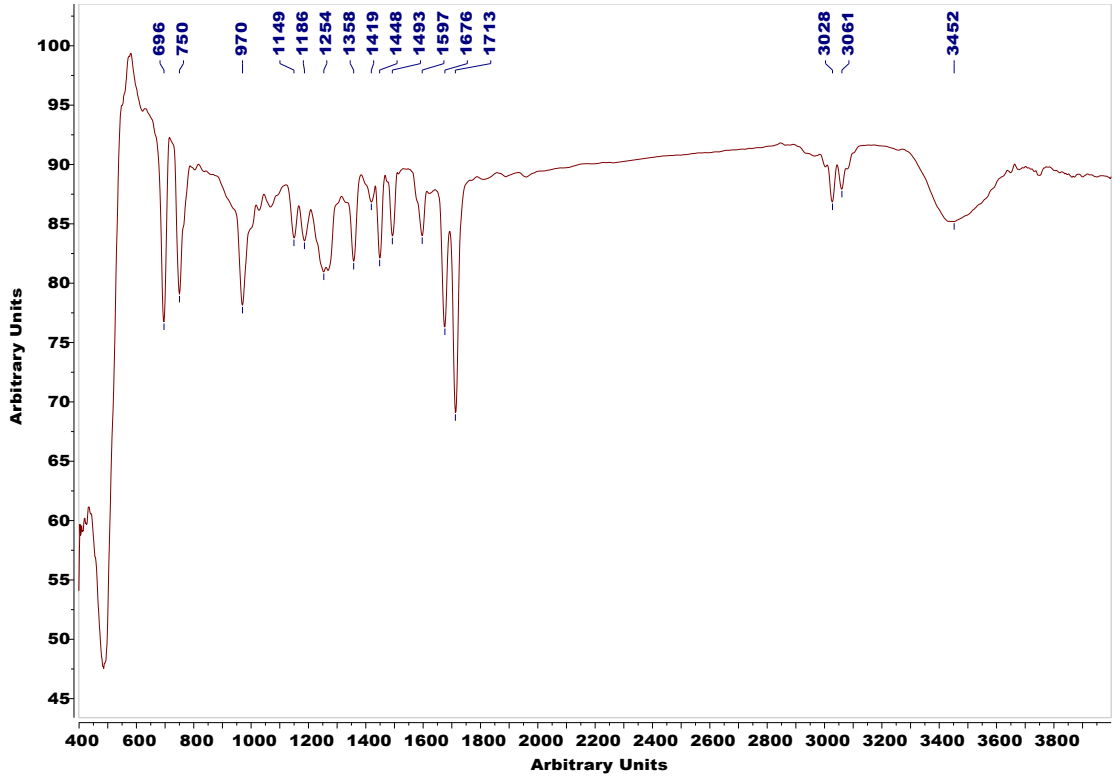
7.28
7.26
7.24
7.23
7.21
7.19
7.18
7.16
7.15
7.13
7.11
6.59
6.55
6.40
6.38
6.38
6.36
6.34
6.34
6.20
5.26
5.23
5.22
5.19
4.65
4.63
4.62
4.60
2.26
2.01
0.03


O
O
Ph
Ph
Ph

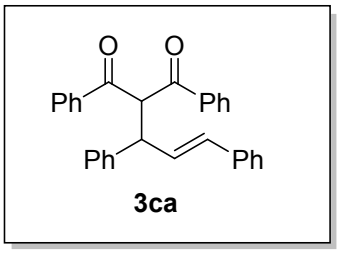
3ba dr = 4:1


0.45
1.65
13.82
0.81
1.04
0.27
1.07
1.06
2.35
0.65
f1 (ppm)

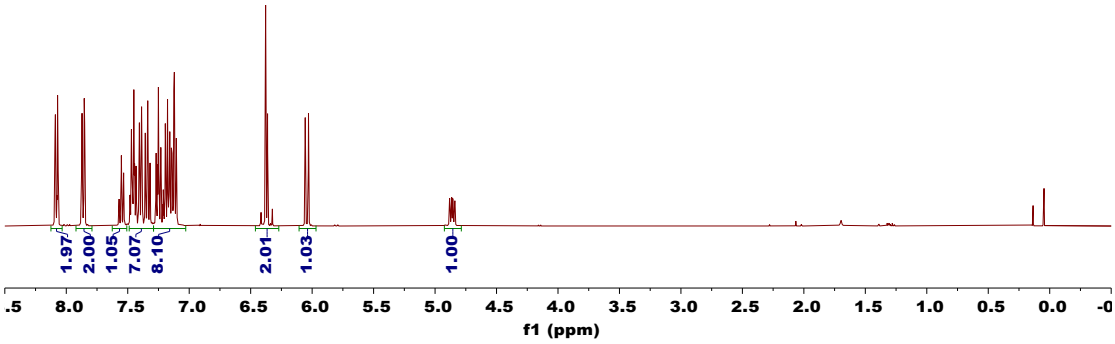

203.0
194.3
140.7
140.0
137.2
136.9
136.8
136.6
133.8
133.6
131.7
131.6
130.0
129.4
129.0
128.9
128.9
128.7
128.7
128.6
128.5
128.4
128.3
127.9
127.7
127.4
127.3
127.0
126.9
126.4
126.3
77.4
77.1
76.8
69.5
68.7
49.5
49.3
28.1
27.8
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

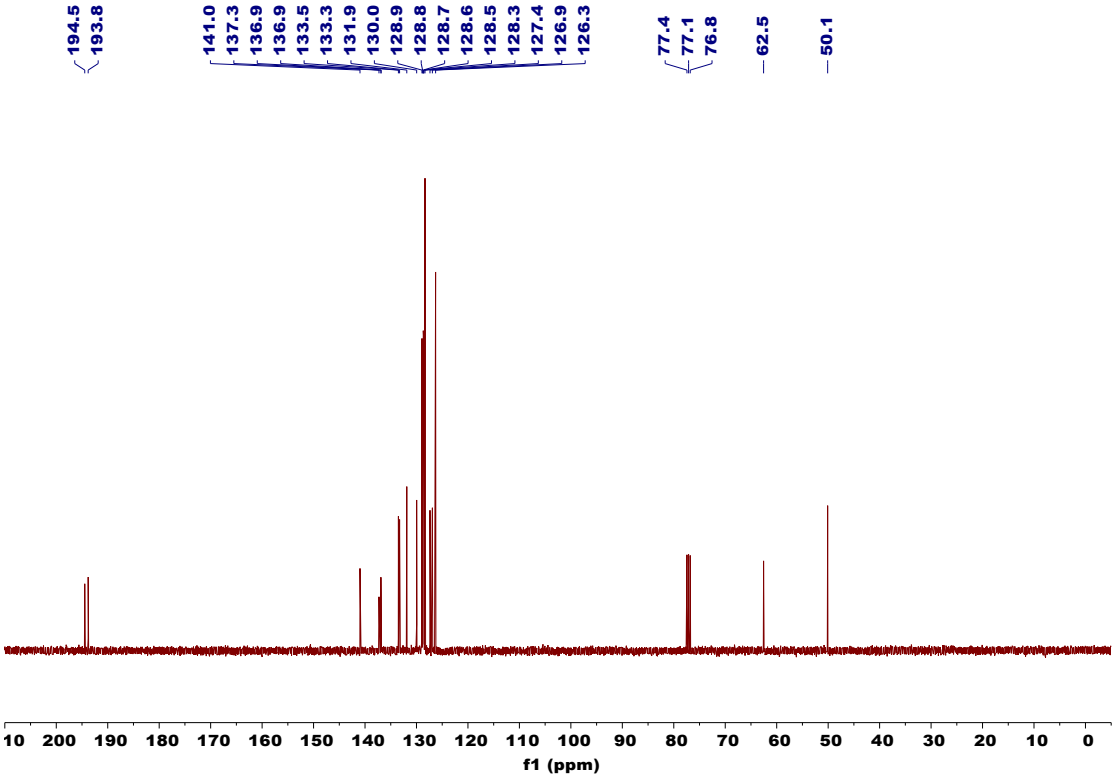

696
750
970
1149
1186
1254
1358
1419
1448
1493
1597
1676
1713
3028
3061
3452
Arbitrary Units
100 95 90 85 80 75 70 65 60 55 50 45
400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 2800 3000 3200 3400 3600 3800
Arbitrary Units

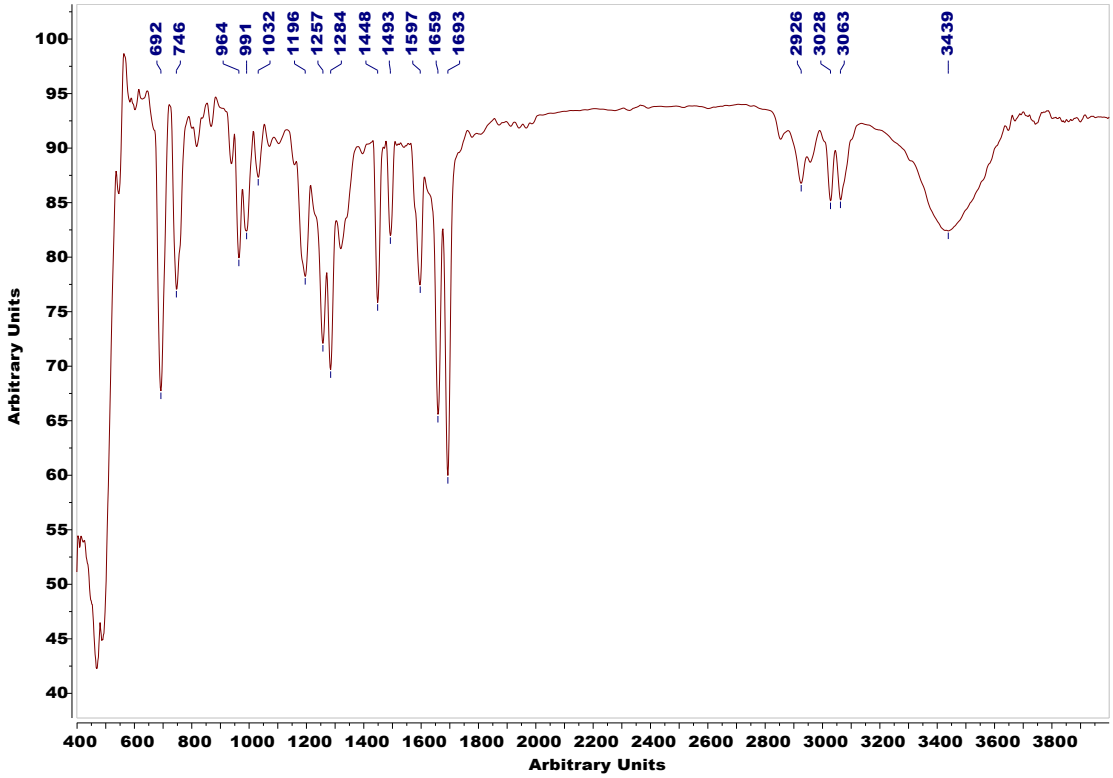

8.09 8.09 8.07 8.07 7.87 7.87 7.85 7.85 7.57 7.55 7.54 7.53 7.53 7.48 7.47 7.46 7.45 7.43 7.41 7.39 7.36 7.34 7.32 7.27 7.25 7.23 7.19 7.18 7.16 7.16 7.15 7.14 7.13 7.12 7.10 6.38 6.38 6.36 6.06 6.03 4.88 4.88 4.87 4.86 4.86 4.85 4.84


O
O
Ph
Ph
Ph
Ph

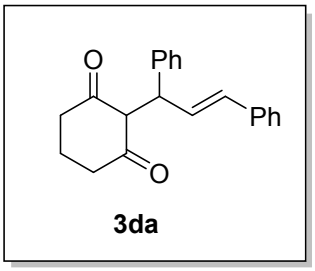
3ca


1.97
2.00
1.05
7.07
8.10
2.01
1.03
1.00
.5 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 -0
f1 (ppm)

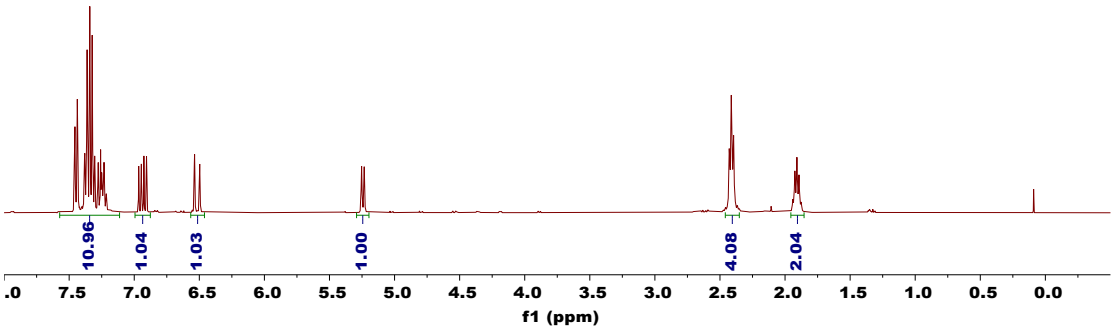

194.5 193.8
141.0 137.3 136.9 136.9 133.5 133.3 131.9 130.0 128.9 128.8 128.7 128.6 128.5 128.3 127.4 126.9 126.3
77.4 77.1 76.8
62.5
50.1
10 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

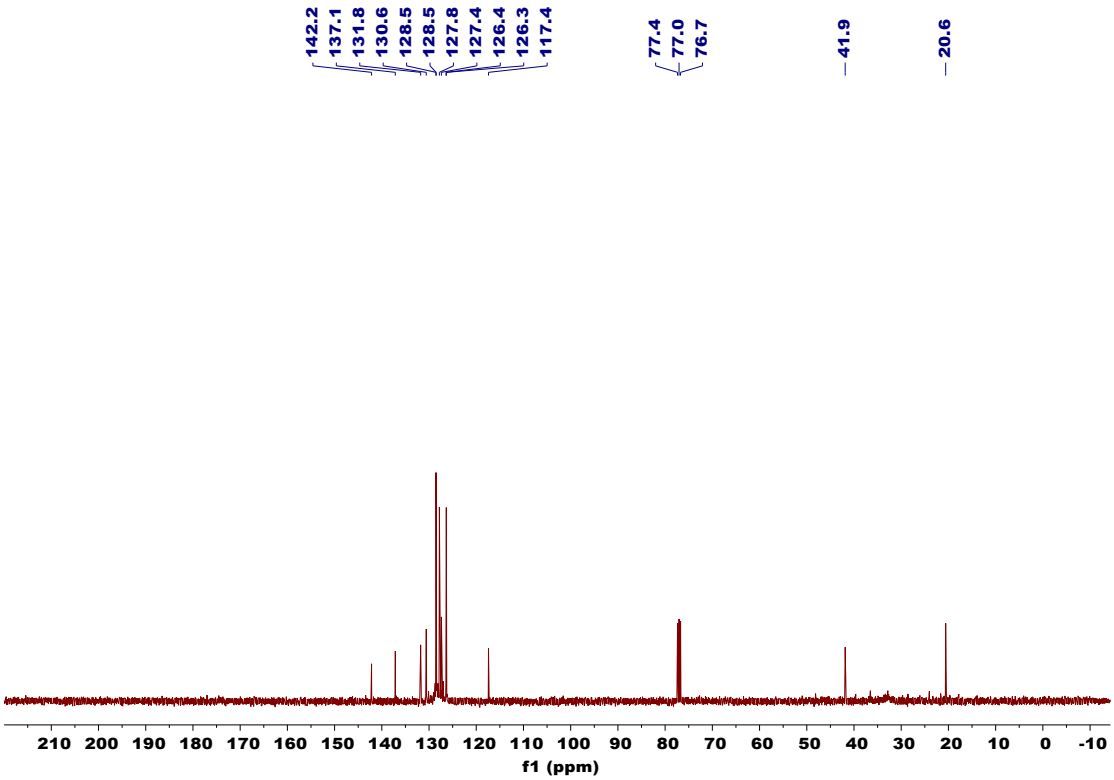

692
746
964
991
1032
1196
1257
1284
1448
1493
1597
1659
1693
2926
3028
3063
3439
Arbitrary Units
Arbitrary Units

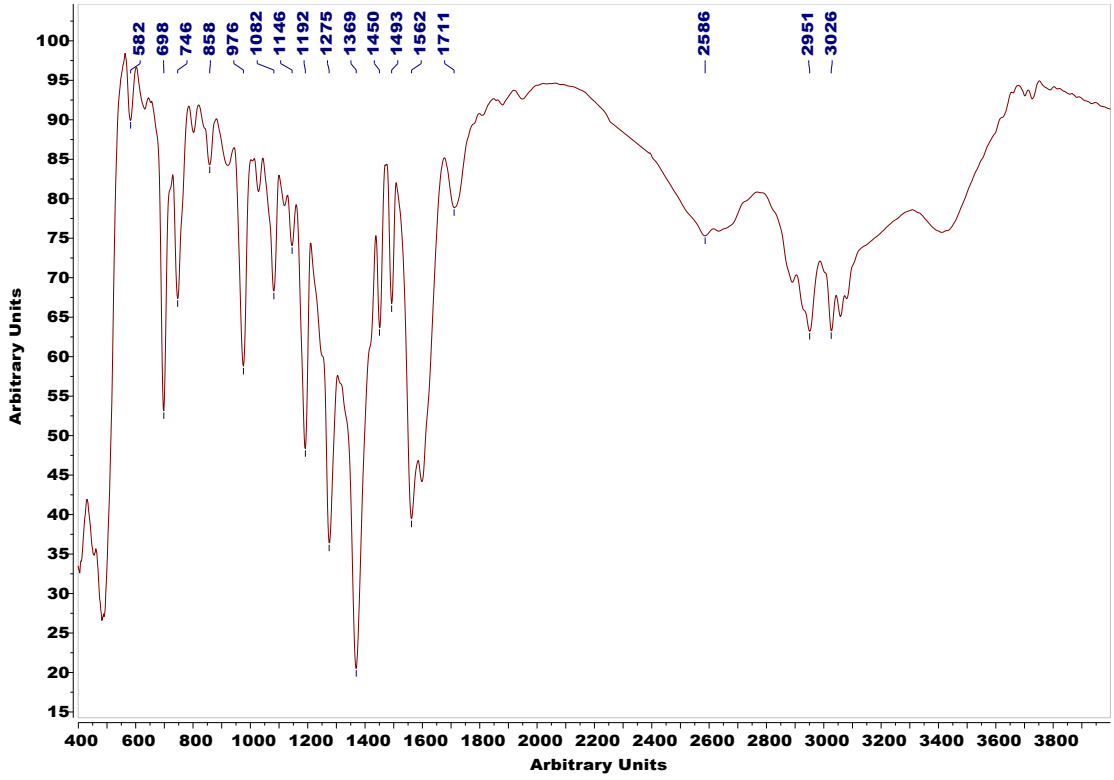

7.46
7.46
7.43
7.38
7.36
7.34
7.32
7.30
7.28
7.28
7.26
7.26
7.25
7.25
7.24
7.24
7.23
7.23
7.22
7.21
7.21
6.97
6.95
6.93
6.91
6.54
6.50
5.25
5.23
2.43
2.41
2.40
1.94
1.92
1.91
1.89
1.88
0.09

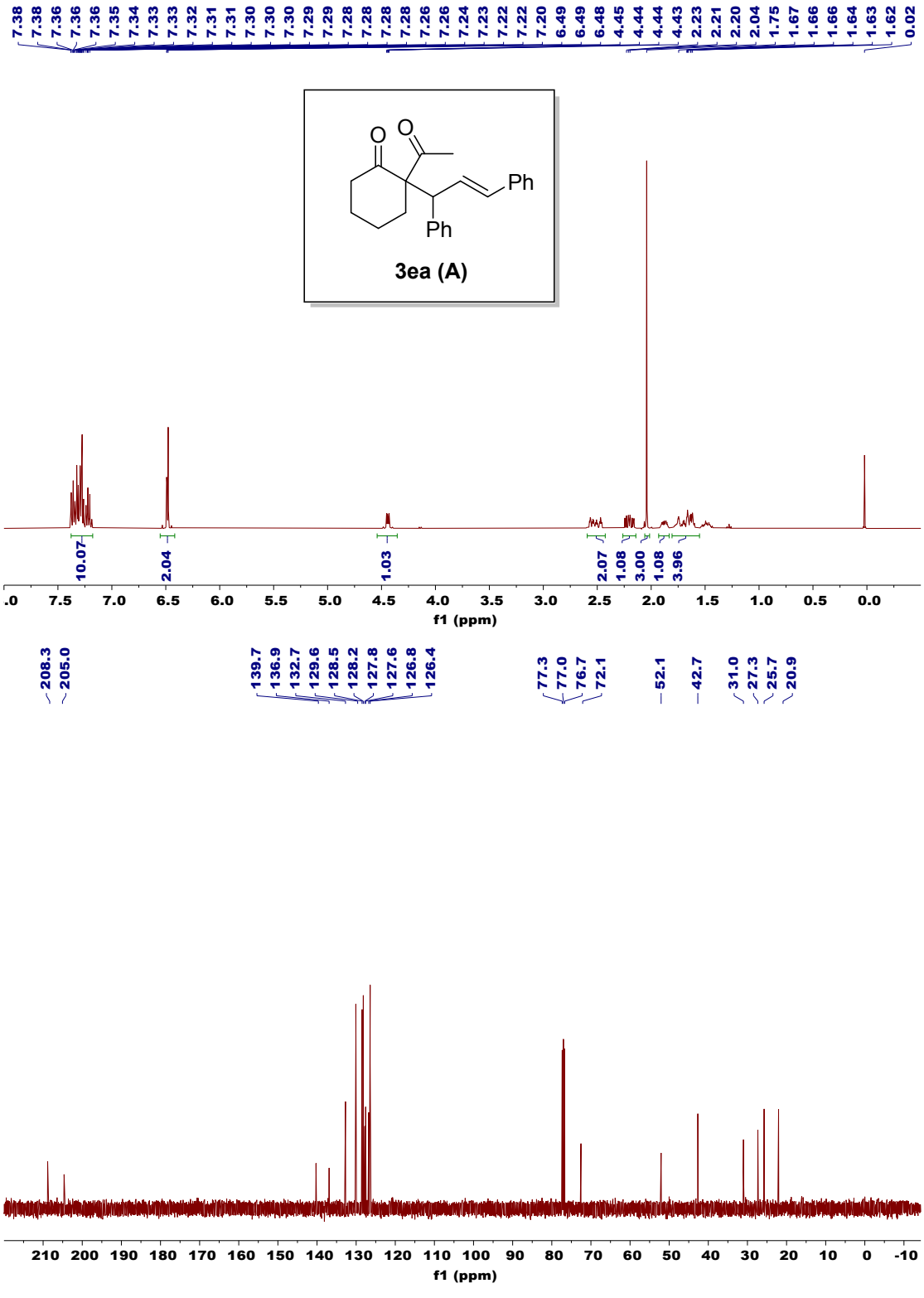

O
Ph
Ph
O

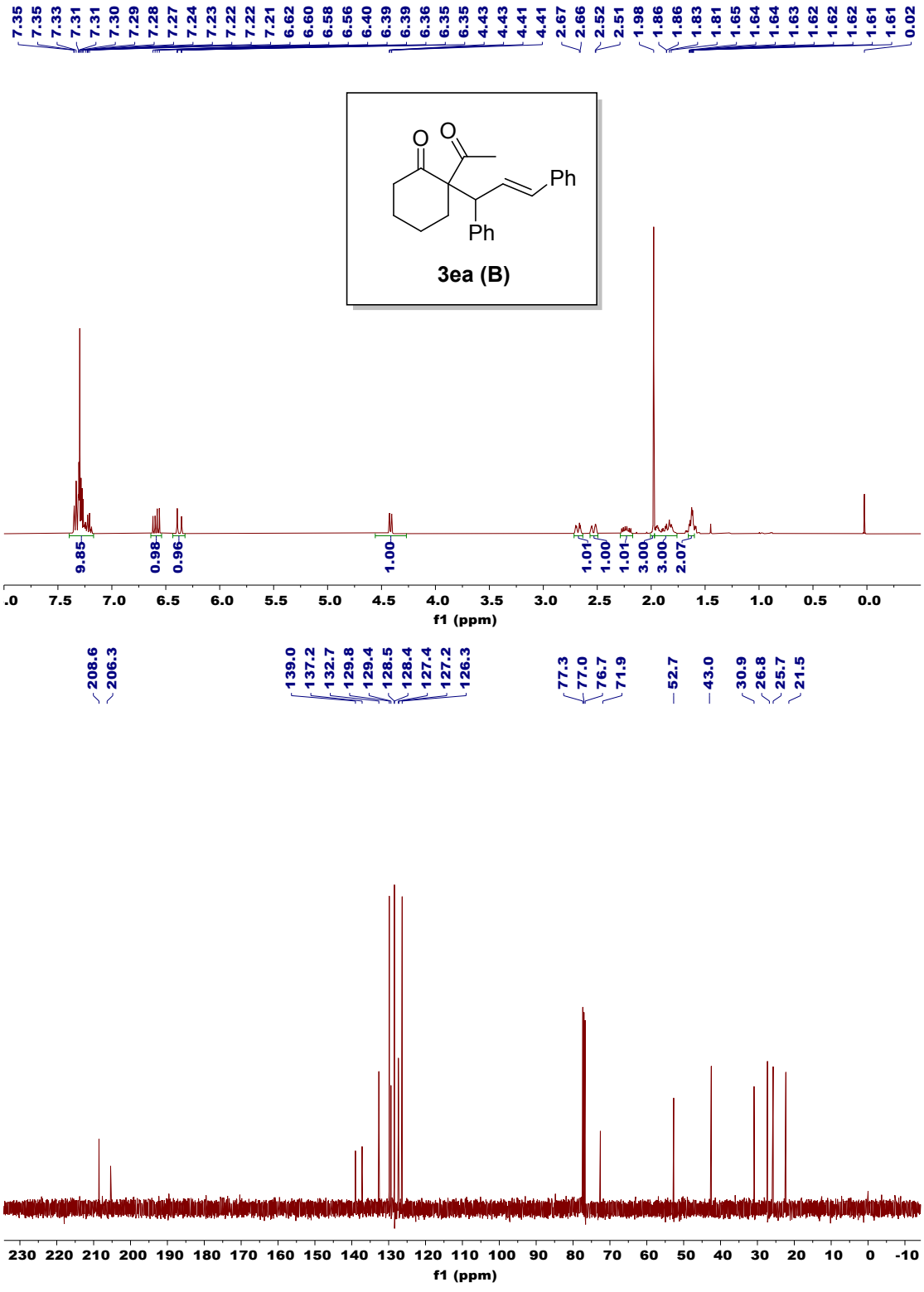
3da

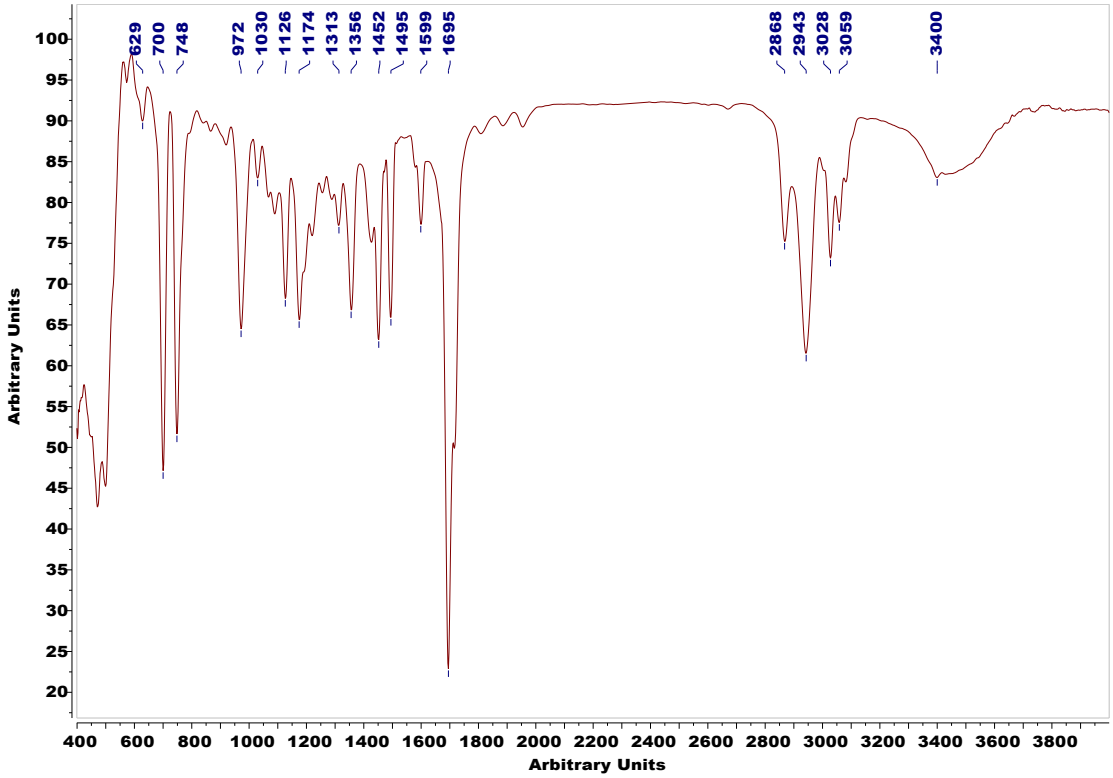

10.96
1.04
1.03
1.00
4.08
2.04
f1 (ppm)


142.2
137.1
131.8
130.6
128.5
128.5
127.8
127.4
126.4
126.3
117.4
77.4
77.0
76.7
41.9
20.6
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

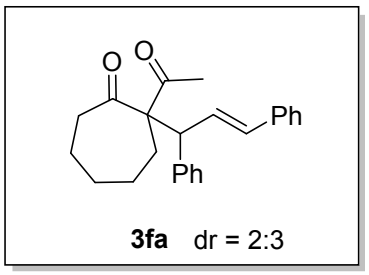

582
698
746
858
976
1082
1146
1192
1275
1369
1450
1493
1562
1711
2586
2951
3026
Arbitrary Units
100 95 90 85 80 75 70 65 60 55 50 45 40 35 30 25 20 15
400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 2800 3000 3200 3400 3600 3800
Arbitrary Units


7.38 7.38 7.36 7.36 7.36 7.35 7.34 7.33 7.33 7.32 7.31 7.31 7.30 7.30 7.30 7.29 7.29 7.28 7.28 7.28 7.28 7.26 7.26 7.24 7.23 7.22 7.22 7.20 6.49 6.49 6.48 4.45 4.44 4.44 4.43 2.23 2.21 2.20 2.04 1.75 1.67 1.66 1.66 1.64 1.63 1.62 0.02
O
O
Ph
Ph
3ea (A)
10.07
2.04
1.03
2.07
1.08
3.00
1.08
3.96
f1 (ppm)
208.3
205.0
139.7
136.9
132.7
129.6
128.5
128.2
127.8
127.6
126.8
126.4
77.3
77.0
76.7
72.1
52.1
42.7
31.0
27.3
25.7
20.9
f1 (ppm)

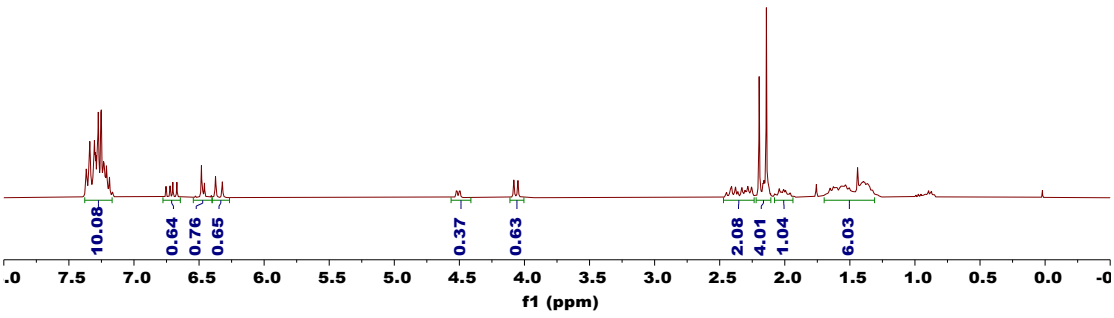

7.35 7.35 7.33 7.31 7.31 7.30 7.29 7.28 7.27 7.24 7.23 7.22 7.22 7.21 6.62 6.60 6.58 6.56 6.40 6.39 6.39 6.36 6.35 6.35 4.43 4.43 4.41 4.41 2.67 2.66 2.52 2.51 1.98 1.86 1.86 1.83 1.81 1.65 1.64 1.64 1.63 1.62 1.62 1.62 1.61 1.61 0.02
O
O
Ph
Ph
3ea (B)
9.85 0.98 0.96 1.00 1.01 1.00 1.01 3.00 3.00 2.07
f1 (ppm)
208.6 206.3 139.0 137.2 132.7 129.8 129.4 128.5 128.4 127.4 127.2 126.3 77.3 77.0 76.7 71.9 52.7 43.0 30.9 26.8 25.7 21.5
f1 (ppm)

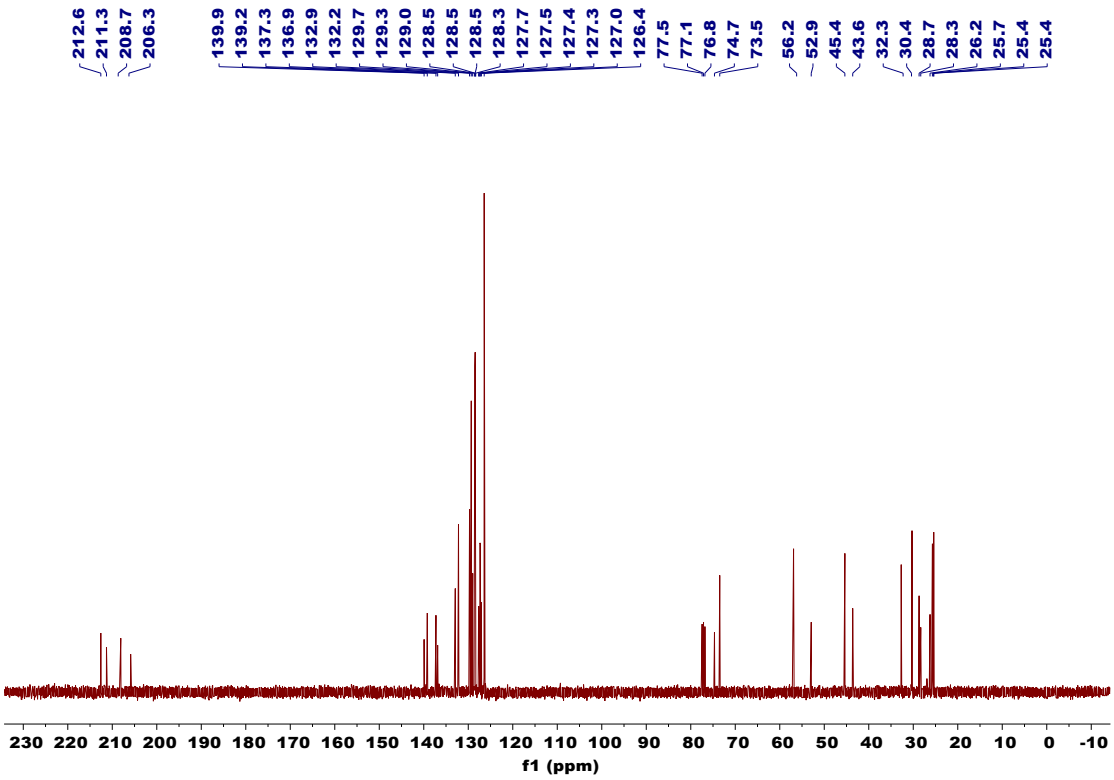

629
700
748
972
1030
1126
1174
1313
1356
1452
1495
1599
1695
2868
2943
3028
3059
3400
Arbitrary Units
Arbitrary Units

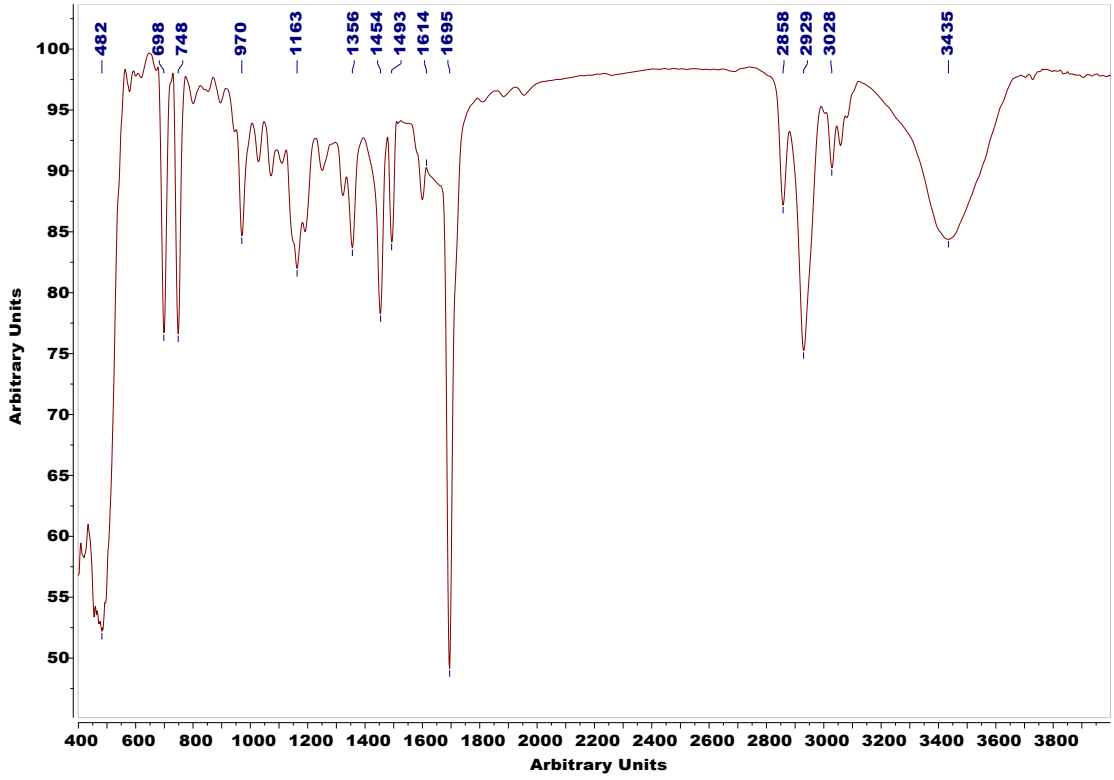

7.37
7.34
7.31
7.30
7.30
7.28
7.27
7.25
7.23
7.21
7.19
6.75
6.72
6.70
6.67
6.48
6.46
6.37
6.32
4.52
4.52
4.50
4.49
4.08
4.05
2.41
2.33
2.31
2.28
2.26
2.20
2.04
2.01
1.99
1.76
1.65
1.63
1.60
1.53
1.51
1.44
1.41
1.40
1.37
1.33
0.89
0.02


O
O
Ph
Ph

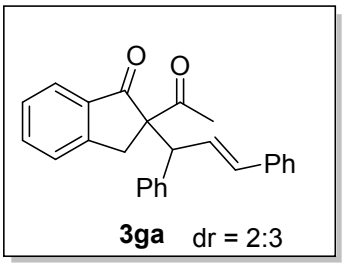
3fa dr = 2:3


10.08
0.64
0.76
0.65
0.37
0.63
2.08
4.01
1.04
6.03
f1 (ppm)

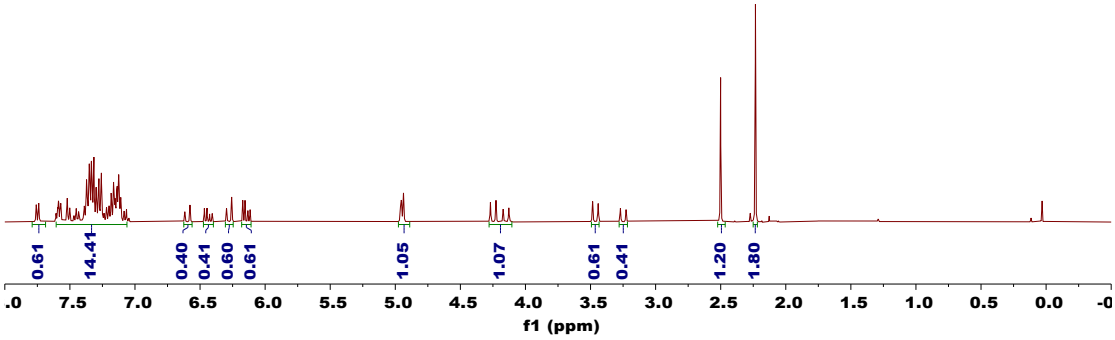

212.6
211.3
208.7
206.3
139.9
139.2
137.3
136.9
132.9
132.2
129.7
129.3
129.0
128.5
128.5
128.5
128.3
127.7
127.5
127.4
127.3
127.0
126.4
77.5
77.1
76.8
74.7
73.5
56.2
52.9
45.4
43.6
32.3
30.4
28.7
28.3
26.2
25.7
25.4
25.4
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


482
698
748
970
1163
1356
1454
1493
1614
1695
2858
2929
3028
3435
Arbitrary Units
100
95
90
85
80
75
70
65
60
55
50
400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 2800 3000 3200 3400 3600 3800
Arbitrary Units

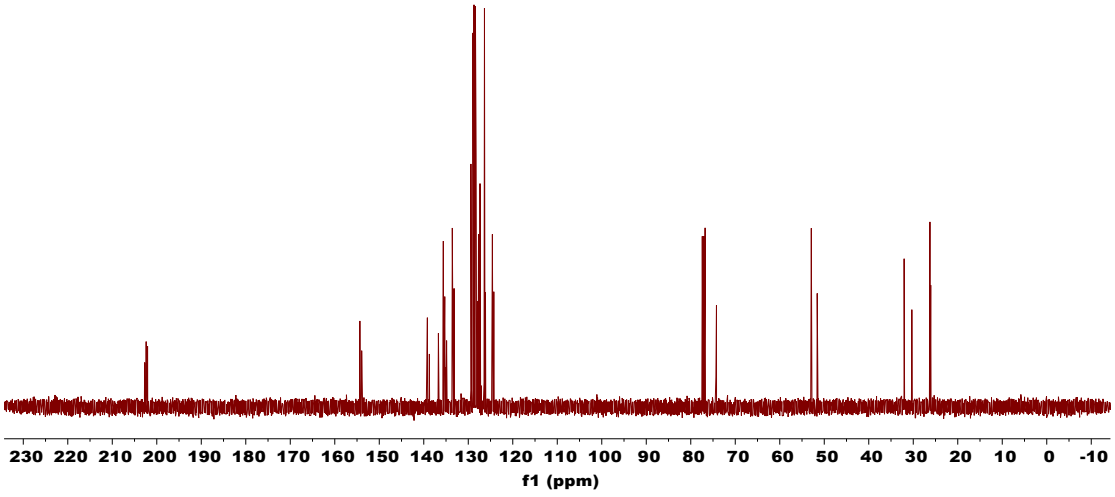

7.76 7.74 7.57 7.57 7.52 7.50 7.45 7.39 7.37 7.35 7.34 7.32 7.30 7.28 7.26 7.22 7.20 7.18 7.16 7.15 7.15 7.14 7.14 7.13 7.13 7.11 6.58 6.47 6.45 6.26 6.26 6.17 6.15 4.96 4.95 4.95 4.94 4.93 4.27 4.23 4.13 3.48 3.44 3.27 2.50 2.23 0.03

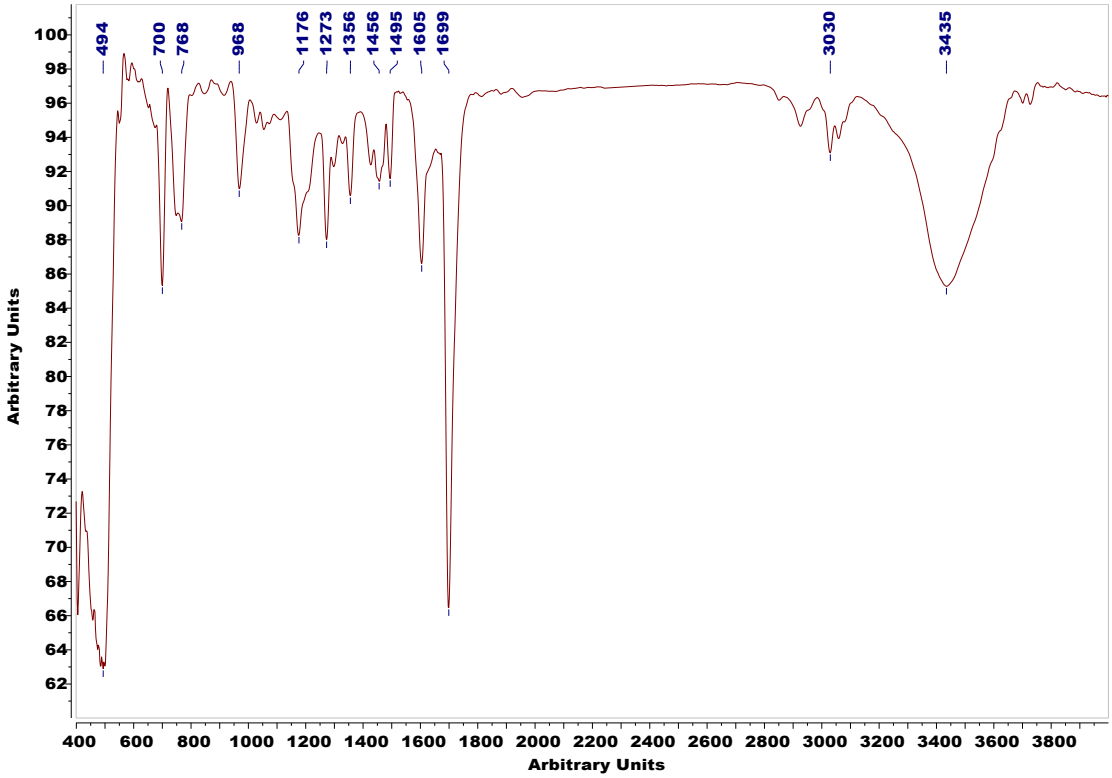

O
O
Ph
Ph

3ga dr = 2:3

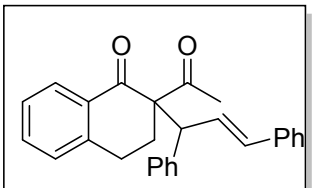

0.61 14.41 0.40 0.41 0.60 0.61 1.05 1.07 0.61 0.41 1.20 1.80
.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0
f1 (ppm)


202.7 202.4 202.1 201.9 154.4 153.9 139.2 138.7 136.7 136.6 135.6 135.3 135.1 134.9 133.6 133.2 129.4 128.9 128.7 128.6 128.4 128.3 128.2 127.9 127.7 127.6 127.5 127.4 127.2 126.4 126.4 126.4 126.1 124.6 124.3 77.4 77.1 76.8 74.3 73.6 53.4 51.2 32.0 29.9 26.3 26.1

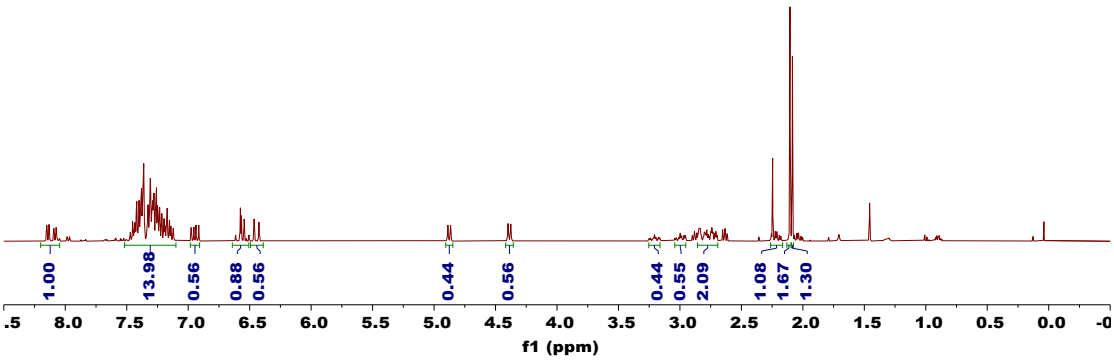

230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


494
700
768
968
1176
1273
1356
1456
1495
1605
1699
3030
3435
Arbitrary Units
Arbitrary Units

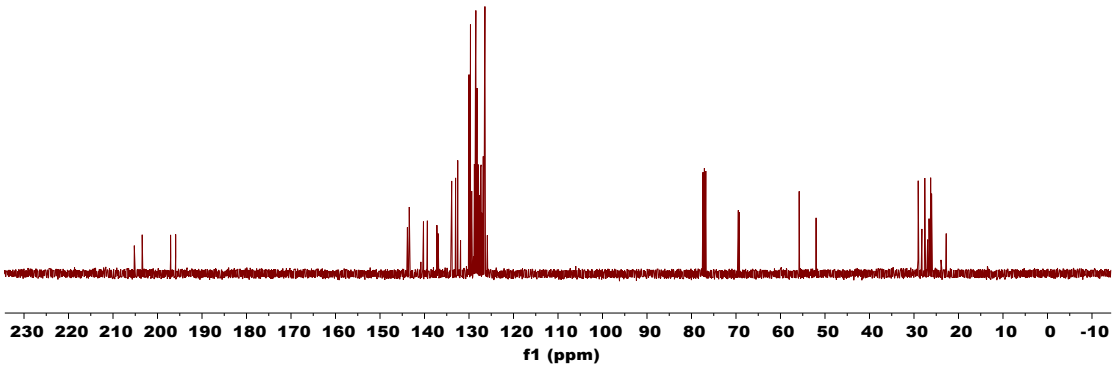

8.15
8.15
8.13
8.13
7.45
7.45
7.43
7.43
7.42
7.42
7.40
7.39
7.38
7.38
7.37
7.36
7.33
7.31
7.30
7.29
7.28
7.26
7.26
7.25
7.23
7.21
7.20
7.19
7.17
7.16
7.14
6.95
6.94
6.91
6.58
6.57
6.54
6.46
6.42
4.89
4.87
4.40
4.38
2.25
2.10
2.09
0.04

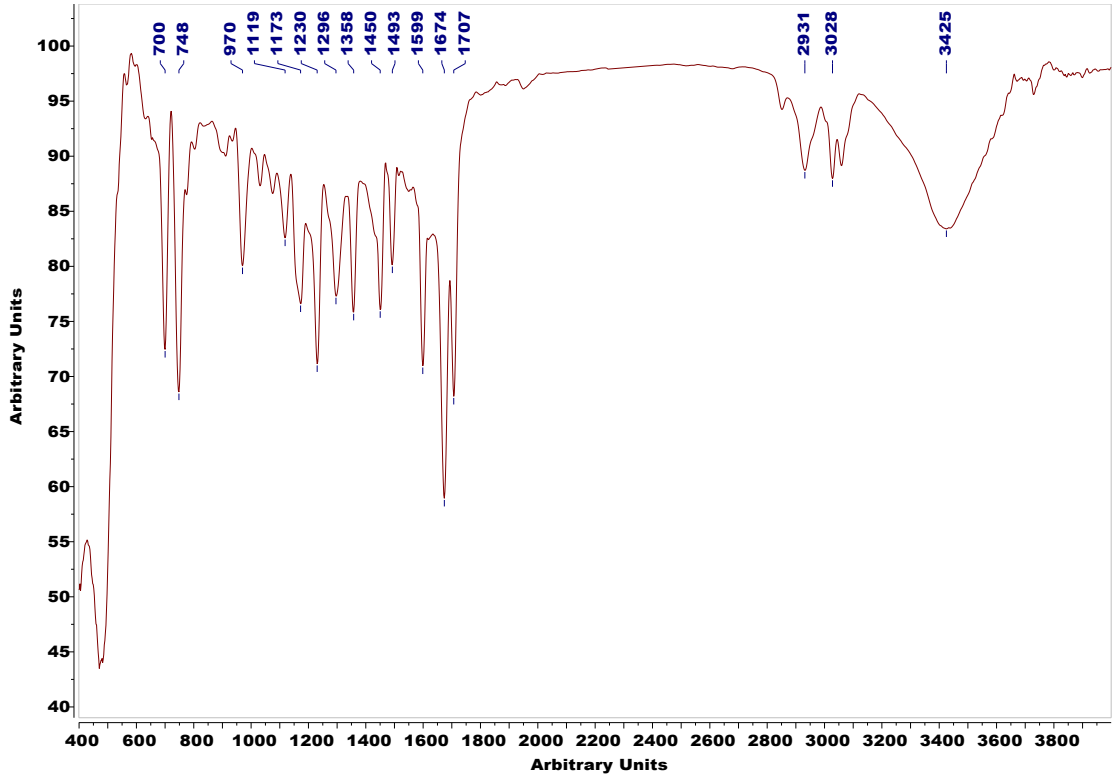

O
O
Ph
Ph

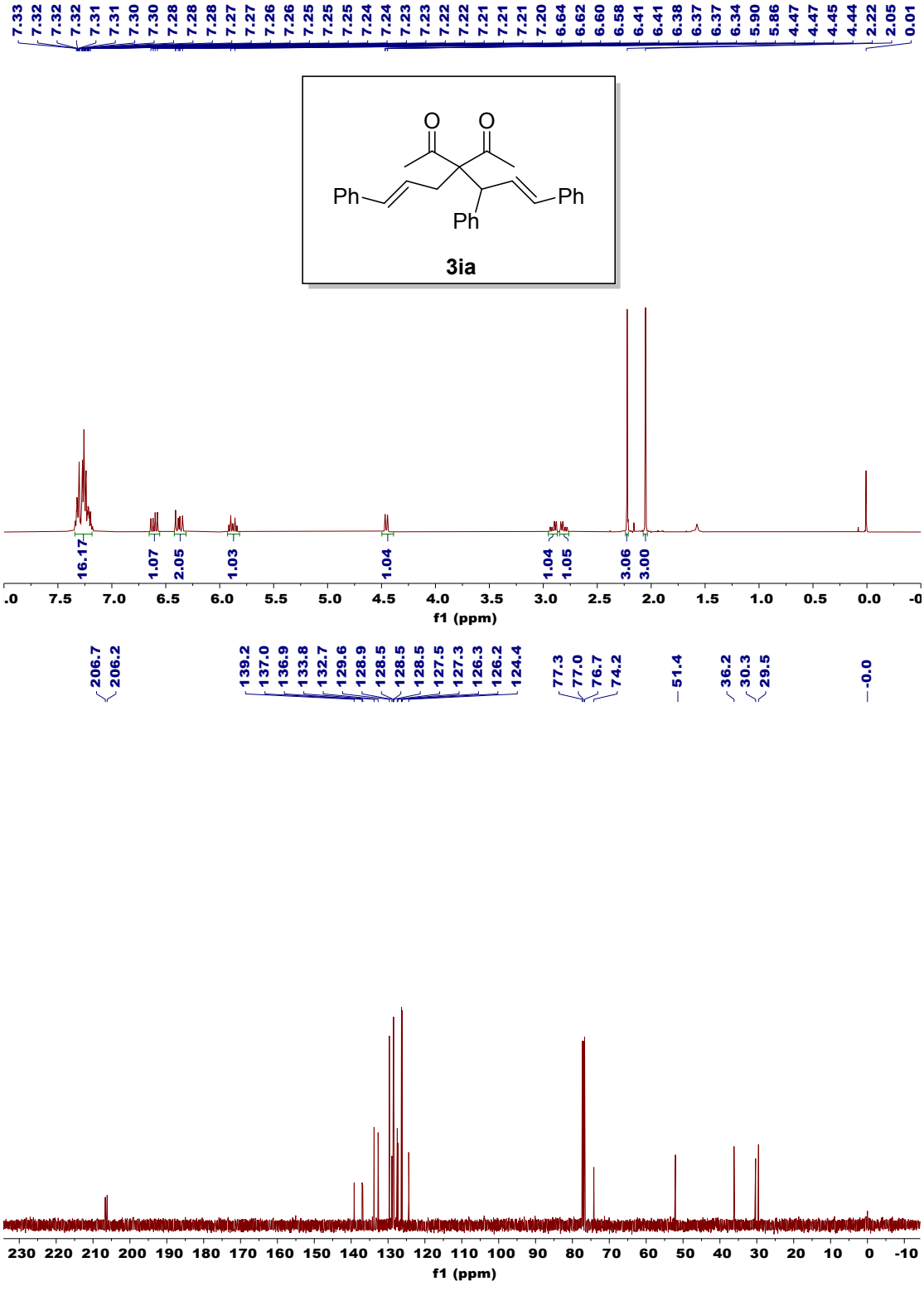
3ha dr = 2:3

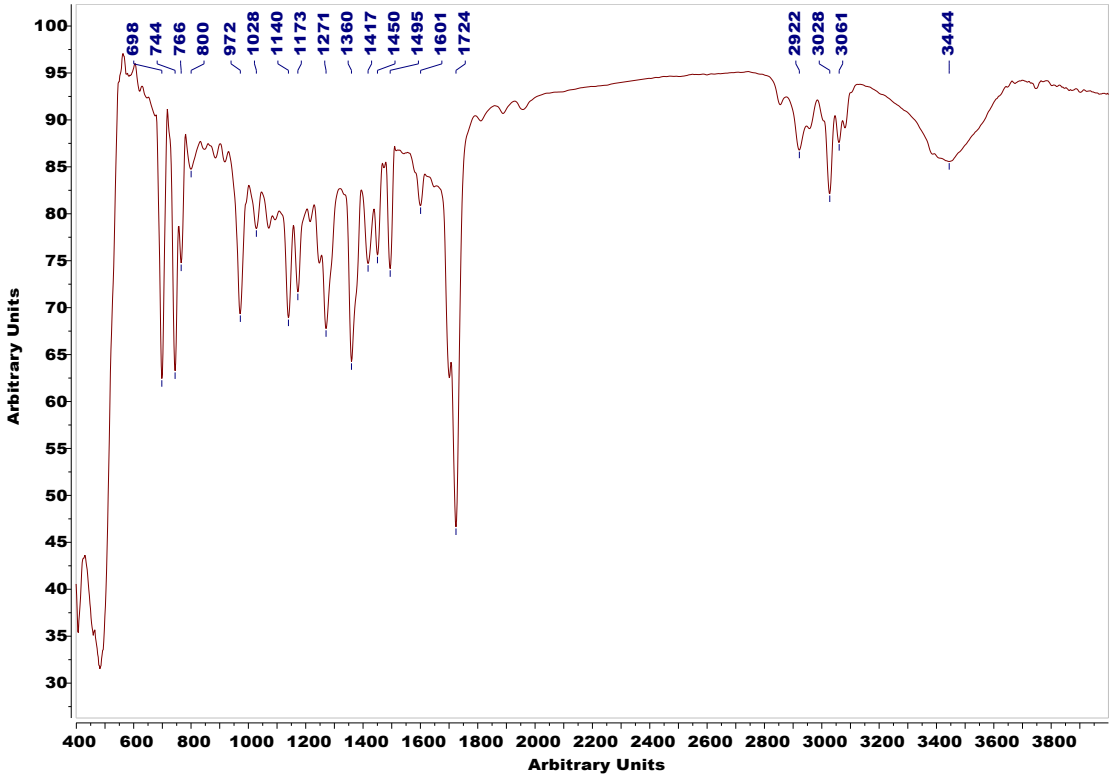

1.00
13.98
0.56
0.88
0.56
0.44
0.56
0.44
0.55
2.09
1.08
1.67
1.30
f1 (ppm)


205.2
202.8
197.6
195.9
143.8
143.4
140.2
139.4
137.2
136.9
133.9
133.9
133.0
133.0
132.6
132.5
131.9
130.0
129.7
129.4
128.9
128.8
128.5
128.5
128.5
128.2
128.0
128.0
127.7
127.6
127.4
127.3
127.1
126.9
126.9
126.8
126.5
126.5
126.4
125.9
69.5
67.5
55.2
50.5
29.1
28.2
27.6
26.9
26.6
26.3
26.0
23.2

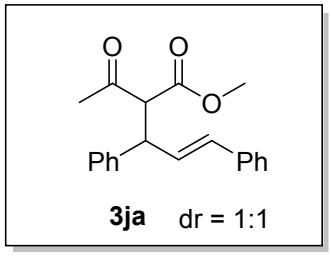

230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


700
748
970
1119
1173
1230
1296
1358
1450
1493
1599
1674
1707
2931
3028
3425
Arbitrary Units
100 95 90 85 80 75 70 65 60 55 50 45 40
400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 2800 3000 3200 3400 3600 3800
Arbitrary Units

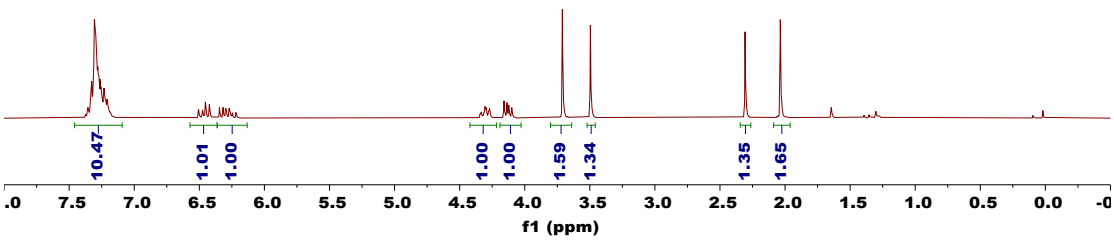

7.33 7.32 7.32 7.32 7.31 7.31 7.30 7.30 7.28 7.28 7.28 7.27 7.27 7.26 7.26 7.25 7.25 7.25 7.24 7.24 7.23 7.23 7.22 7.22 7.21 7.21 7.21 7.20 6.64 6.62 6.60 6.58 6.41 6.41 6.38 6.37 6.37 6.34 5.90 5.86 4.47 4.47 4.45 4.44 2.22 2.05 0.01
O
O
Ph
Ph
Ph
3ia
16.17 1.07 2.05 1.03 1.04 1.04 1.05 3.06 3.00
f1 (ppm)
206.7 206.2 139.2 137.0 136.9 133.8 132.7 129.6 128.9 128.5 128.5 128.5 127.5 127.3 126.3 126.2 124.4 77.3 77.0 76.7 74.2 51.4 36.2 30.3 29.5 -0.0
f1 (ppm)

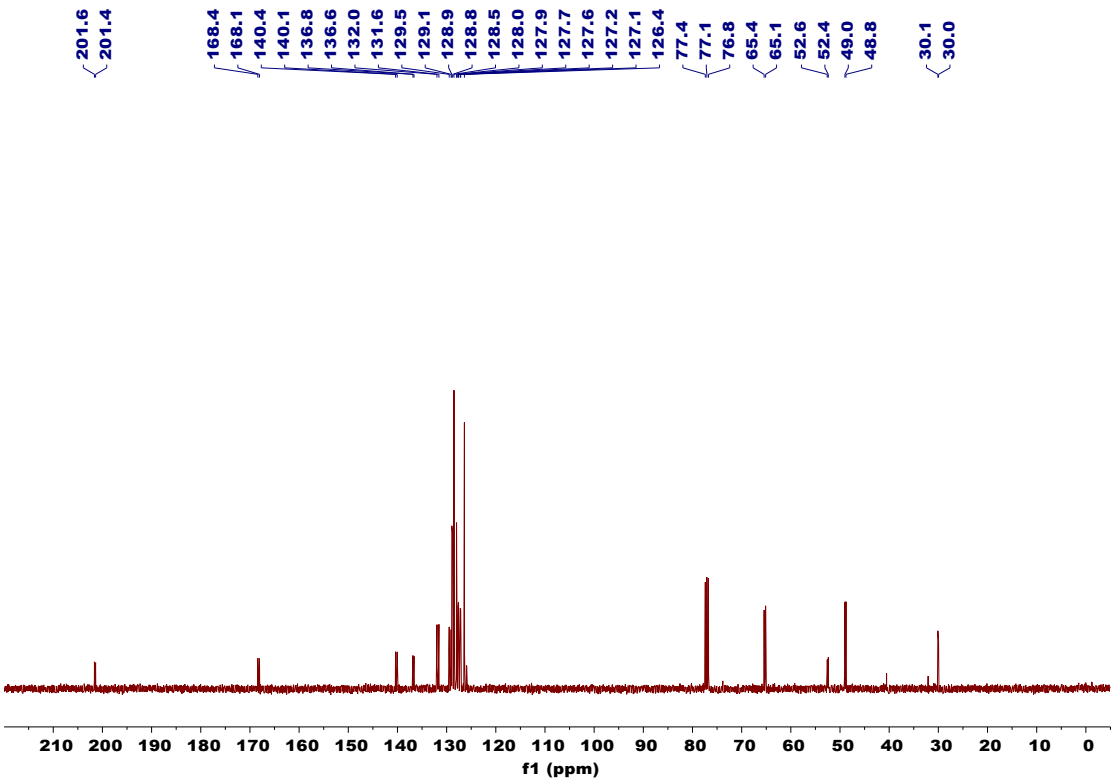

698
744
766
800
972
1028
1140
1173
1271
1360
1417
1450
1495
1601
1724
2922
3028
3061
3444
Arbitrary Units
Arbitrary Units

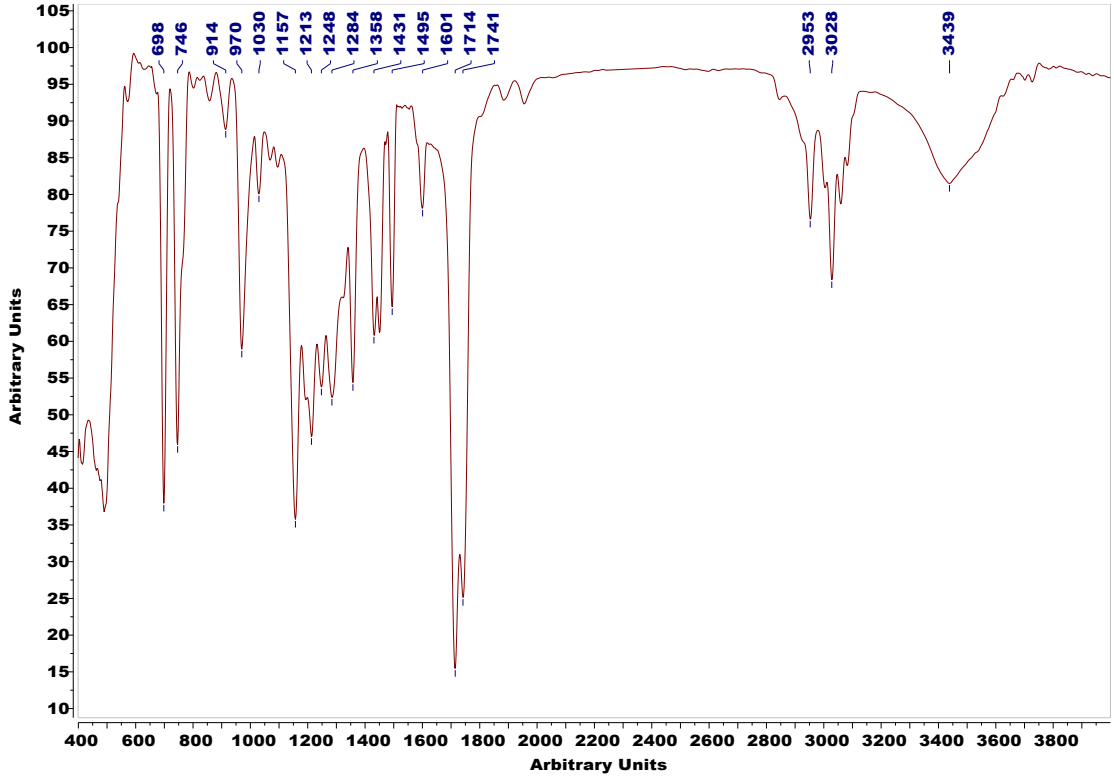

7.36
7.36
7.35
7.33
7.33
7.33
7.31
7.30
7.29
7.28
7.27
7.26
7.25
7.25
7.23
7.22
7.22
7.21
7.20
7.19
6.51
6.48
6.45
6.42
6.34
6.32
6.30
6.29
6.27
6.27
6.25
6.22
4.33
4.32
4.31
4.30
4.28
4.27
4.16
4.14
4.12
4.10
3.71
3.50
2.31
2.04
0.02


O
O
O
Ph
Ph

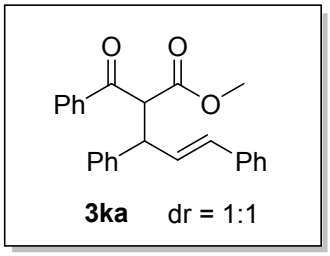
3ja dr = 1:1


10.47
1.01
1.00
1.00
1.00
1.59
1.34
1.35
1.65
f1 (ppm)

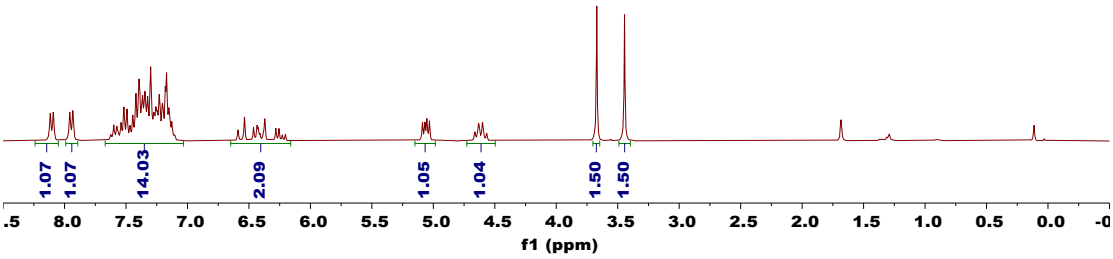

201.6
201.4
168.4
168.1
140.4
140.1
136.8
136.6
132.0
131.6
129.5
129.1
128.9
128.8
128.5
128.0
127.9
127.7
127.6
127.2
127.1
126.4
77.4
77.1
76.8
65.4
65.1
52.6
52.4
49.0
48.8
30.1
30.0
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


698
746
914
970
1030
1157
1213
1248
1284
1358
1431
1495
1601
1714
1741
2953
3028
3439
Arbitrary Units
105 100 95 90 85 80 75 70 65 60 55 50 45 40 35 30 25 20 15 10
400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 2800 3000 3200 3400 3600 3800
Arbitrary Units

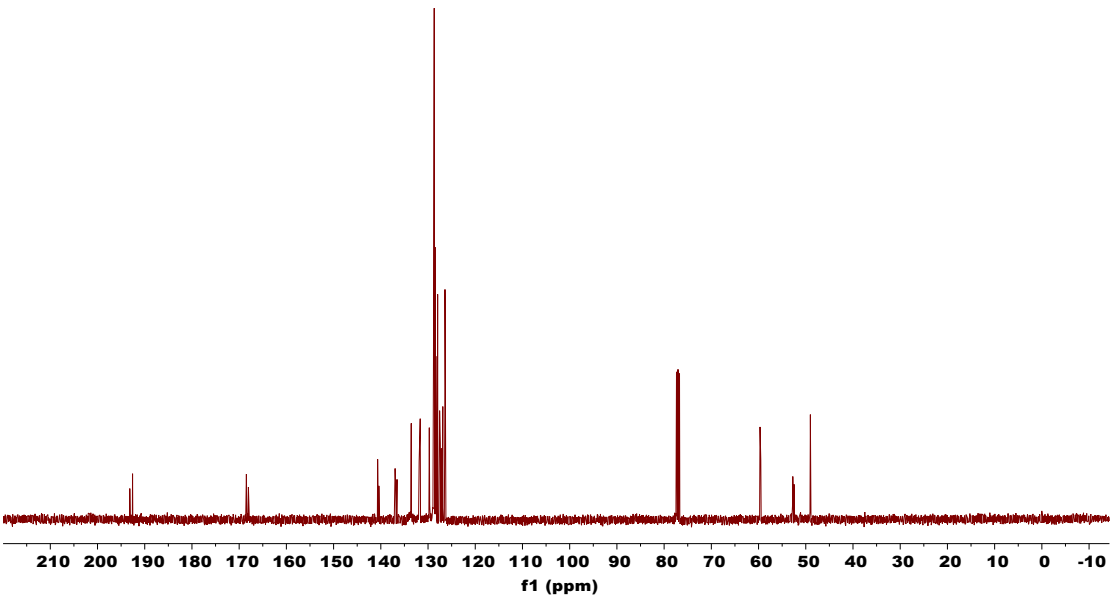

8.12 8.09 8.09 7.96 7.93 7.93 7.60 7.58 7.54 7.52 7.49 7.46 7.44 7.42 7.39 7.36 7.35 7.32 7.30 7.27 7.26 7.23 7.20 7.18 7.17 7.15 7.13 6.59 6.54 6.46 6.43 6.42 6.38 6.37 6.28 6.26 5.09 5.07 5.05 5.03 4.64 4.63 4.60 4.59 3.67 3.44 0.11

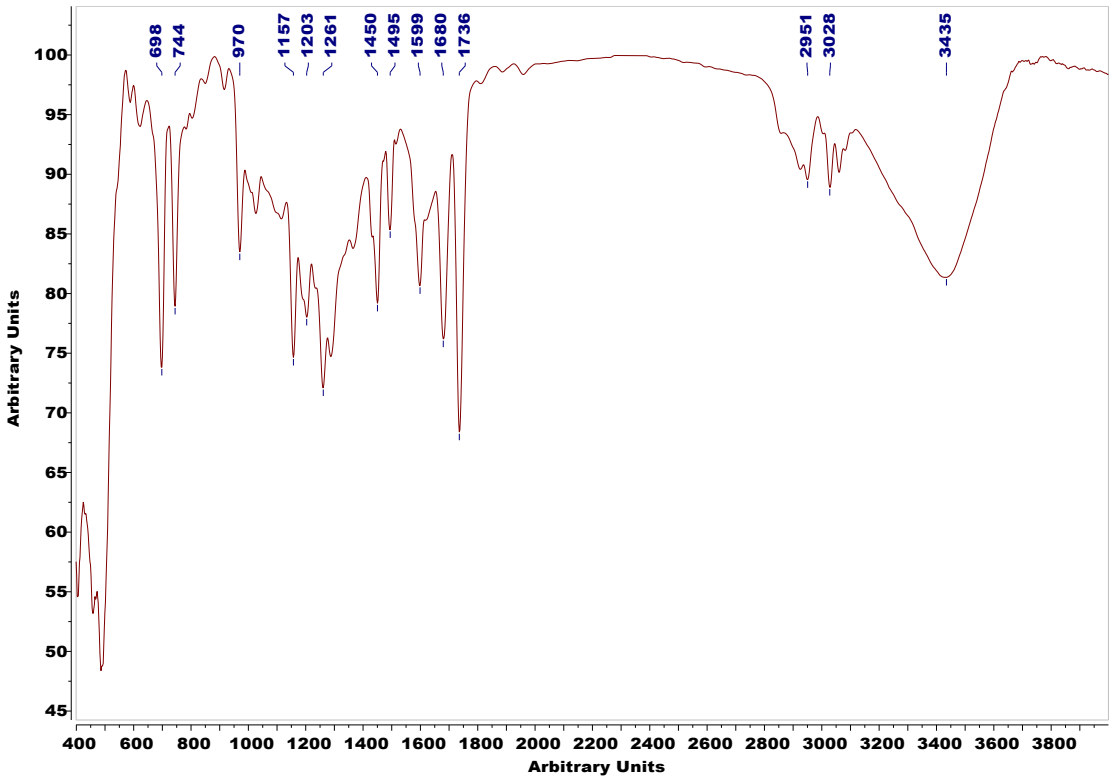

O
O
Ph
O
Ph
Ph

3ka dr = 1:1

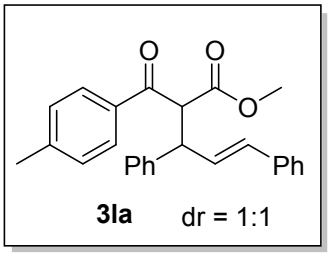

1.07 1.07 14.03 2.09 1.05 1.04 1.50 1.50
.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0
f1 (ppm)


193.2 192.6 168.5 168.0 140.7 140.4 137.0 136.9 136.8 136.6 133.7 133.6 131.9 131.7 129.7 129.7 128.9 128.8 128.7 128.5 128.5 128.3 128.3 128.0 127.5 127.4 127.2 126.9 126.4 126.3 77.4 77.1 76.7 59.7 59.5 52.7 52.5 49.0 48.9

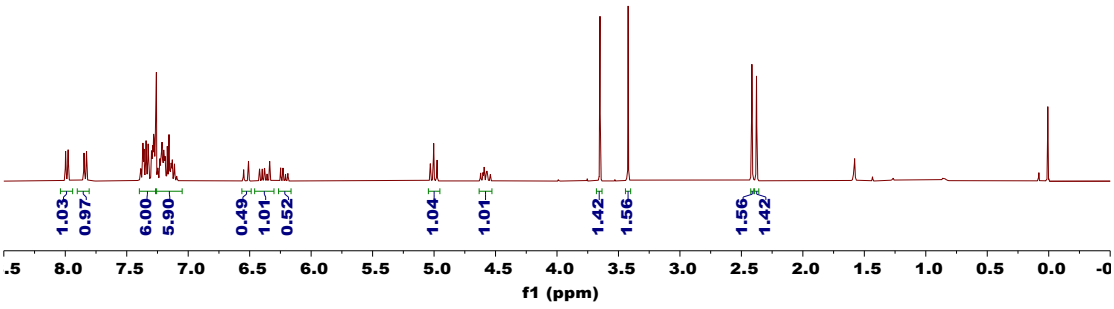

210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

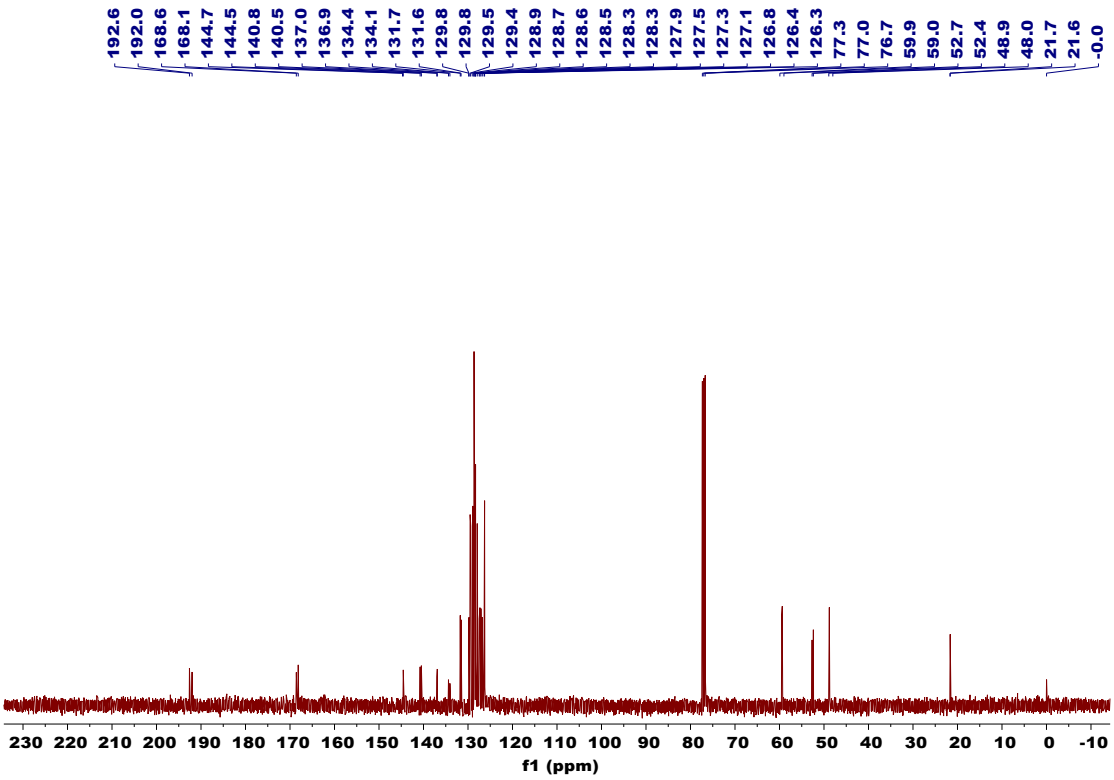

698
744
970
1157
1203
1261
1450
1495
1599
1680
1736
2951
3028
3435
Arbitrary Units
Arbitrary Units

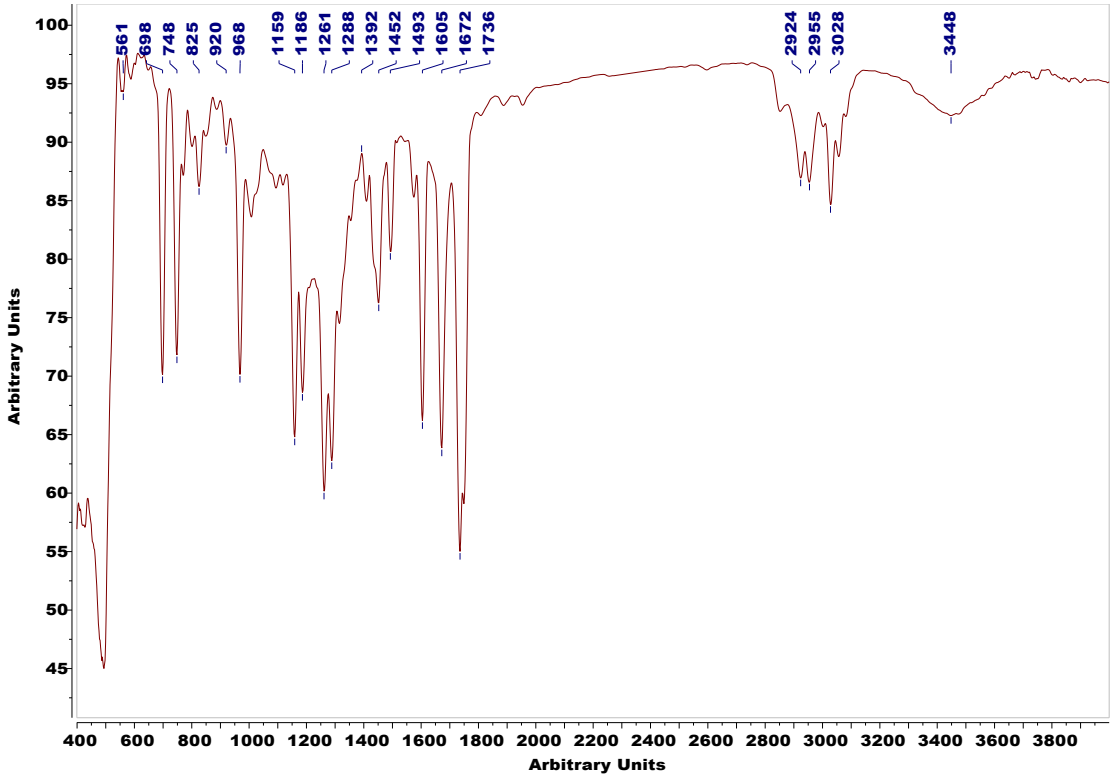

8.00
7.98
7.98
7.85
7.83
7.37
7.36
7.34
7.33
7.30
7.29
7.29
7.28
7.28
7.27
7.26
7.25
7.23
7.22
7.21
7.21
7.20
7.19
7.19
7.17
7.16
7.15
7.14
7.13
7.11
6.51
6.38
6.34
6.25
5.03
5.03
5.00
5.00
4.98
4.98
4.59
3.65
3.42
2.41
2.38
1.58
0.01


O
O
O
Ph
Ph

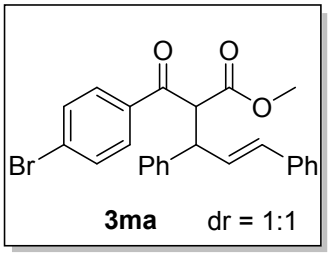
3la dr = 1:1


1.03
0.97
6.00
5.90
0.49
1.01
0.52
1.04
1.01
1.42
1.56
1.56
1.42
f1 (ppm)

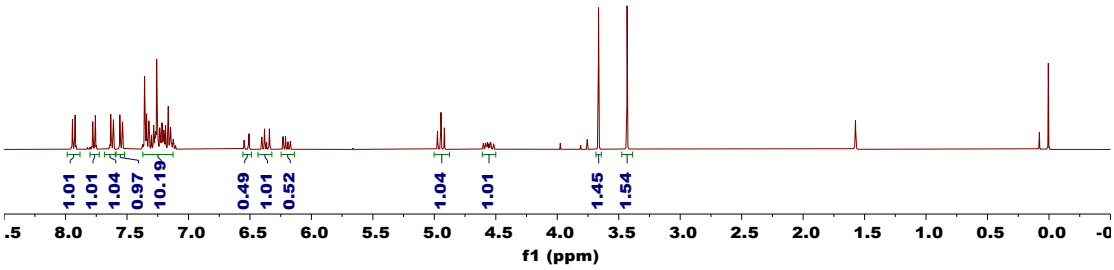

192.6
192.0
168.6
168.1
144.7
144.5
140.8
140.5
137.0
136.9
134.4
134.1
131.7
131.6
129.8
129.8
129.5
129.4
128.9
128.7
128.6
128.5
128.3
128.3
127.9
127.5
127.3
127.1
126.8
126.4
126.3
77.3
77.0
76.7
59.9
59.0
52.7
52.4
48.9
48.0
21.7
21.6
-0.0
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


561
698
748
825
920
968
1159
1186
1261
1288
1392
1452
1493
1605
1672
1736
2924
2955
3028
3448
Arbitrary Units
100 95 90 85 80 75 70 65 60 55 50 45
400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 2800 3000 3200 3400 3600 3800
Arbitrary Units

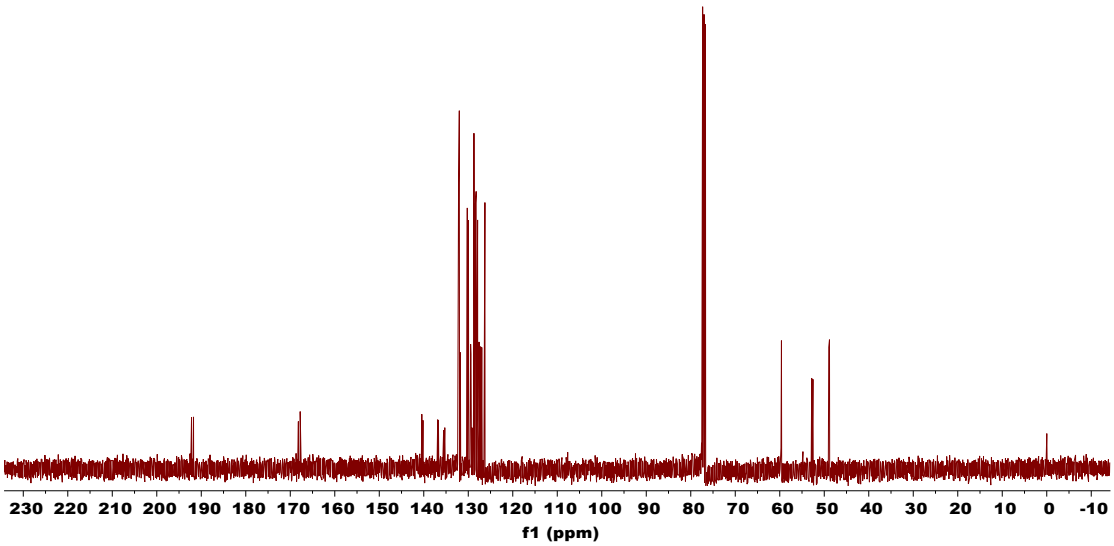

7.94 7.94 7.93 7.92 7.78 7.77 7.63 7.63 7.62 7.61 7.56 7.55 7.54 7.54 7.36 7.35 7.34 7.32 7.32 7.30 7.28 7.27 7.27 7.26 7.25 7.23 7.22 7.20 7.19 7.16 7.15 7.13 6.55 6.51 6.40 6.38 6.36 6.34 6.23 6.21 6.19 6.17 4.97 4.95 4.92 4.60 4.58 4.58 4.57 4.56 4.55 4.55 4.54 4.52 3.66 3.48 3.43 -0.00

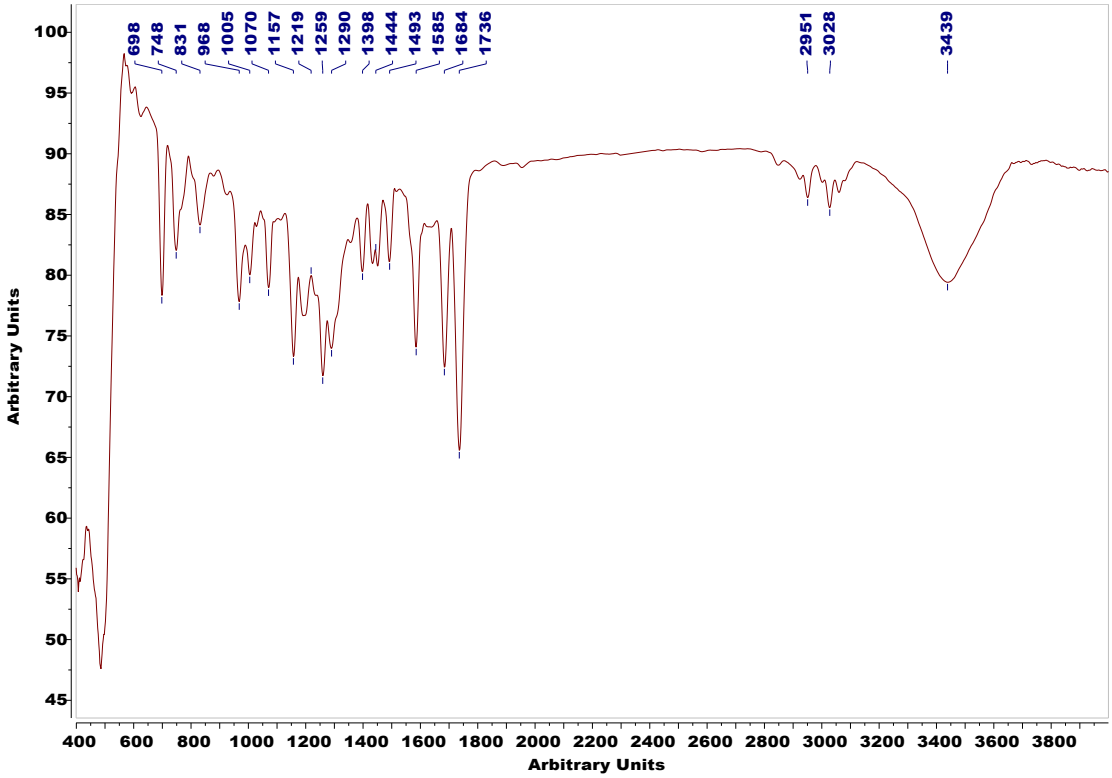

O
O
O
Br
Ph
Ph

3ma dr = 1:1

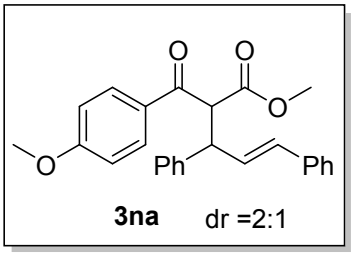

1.01 1.01 1.04 0.97 10.19 0.49 1.01 0.52 1.04 1.01 1.45 1.54
8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

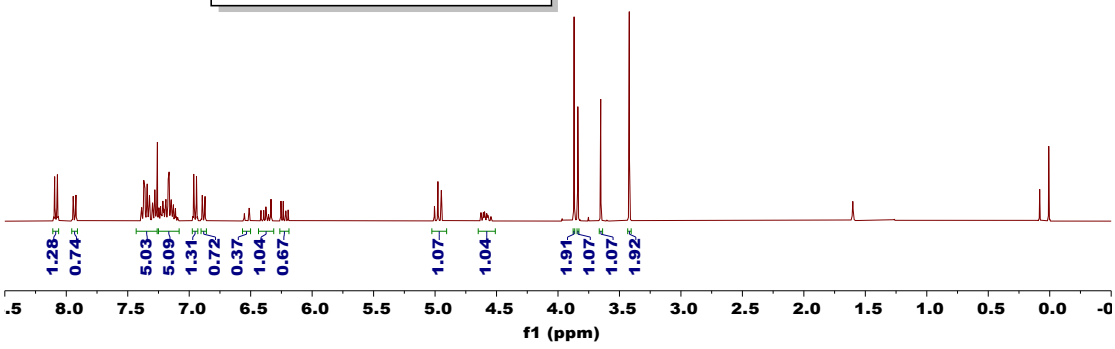

192.2 191.3 168.2 167.8 140.4 139.7 136.9 136.7 135.5 135.3 132.2 132.0 131.8 130.2 130.0 129.5 129.4 129.1 128.9 128.7 128.7 128.5 128.4 128.2 127.9 127.6 127.5 127.2 127.0 126.4 126.3 77.3 77.0 76.7 60.4 59.6 52.8 52.5 49.7 48.1 -0.0

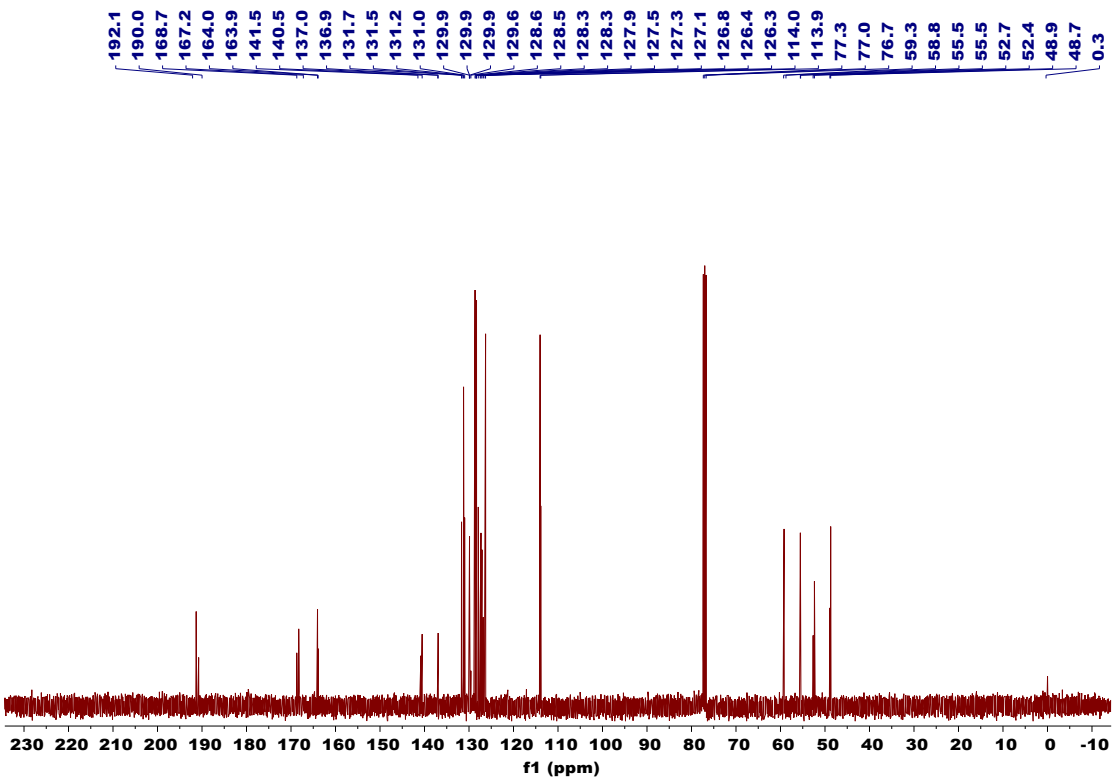

230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

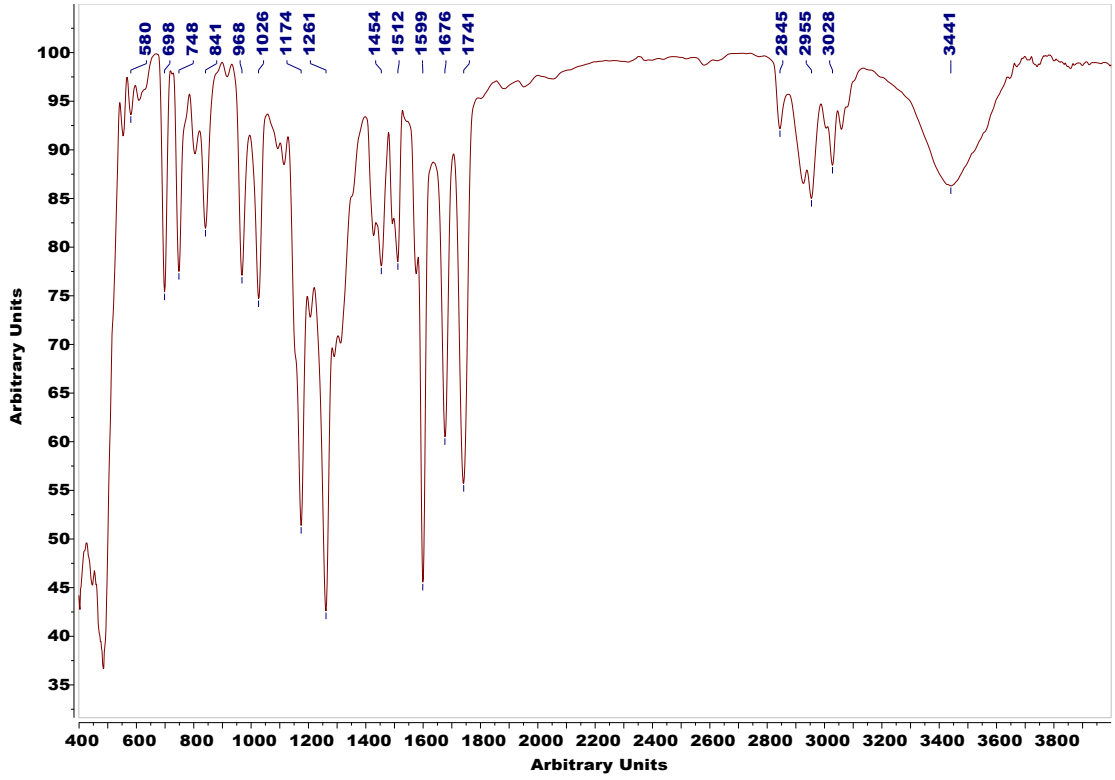

698
748
831
968
1005
1070
1157
1219
1259
1290
1398
1444
1493
1585
1684
1736
2951
3028
3439
Arbitrary Units
Arbitrary Units


8.09
8.09
8.08
8.07
7.94
7.92
7.39
7.37
7.37
7.36
7.34
7.33
7.32
7.30
7.28
7.26
7.25
7.23
7.21
7.21
7.19
7.19
7.19
7.17
7.16
7.15
7.15
7.13
7.11
6.96
6.96
6.94
6.89
6.87
6.51
6.38
6.33
6.25
6.23
5.01
4.98
4.95
3.87
3.84
3.65
3.42
0.01

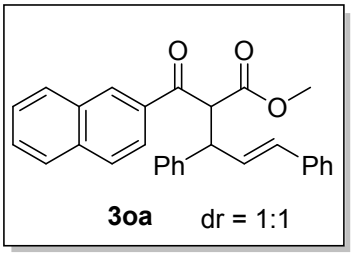

O
O
O
O
Ph
Ph
3na
dr =2:1


1.28
0.74
5.03
5.09
1.31
0.72
0.37
1.04
0.67
1.07
1.04
1.91
1.07
1.07
1.92
f1 (ppm)

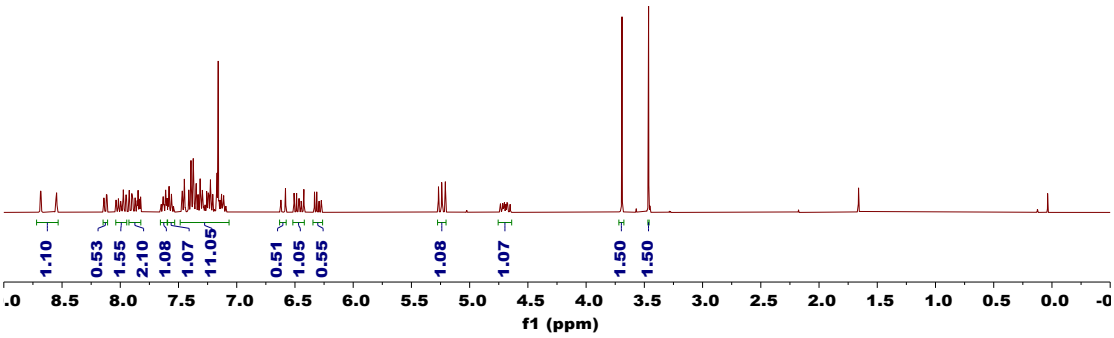

192.1
190.0
168.7
167.2
164.0
163.9
141.5
140.5
137.0
136.9
131.7
131.5
131.2
131.0
129.9
129.9
129.9
129.6
128.6
128.5
128.3
128.3
127.9
127.5
127.3
127.1
126.8
126.4
126.3
114.0
113.9
77.3
77.0
76.7
59.3
58.8
55.5
55.5
52.7
52.4
48.9
48.7
0.3
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


580
698
748
841
968
1026
1174
1261
1454
1512
1599
1676
1741
2845
2955
3028
3441
Arbitrary Units
100 95 90 85 80 75 70 65 60 55 50 45 40 35
400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 2800 3000 3200 3400 3600 3800
Arbitrary Units

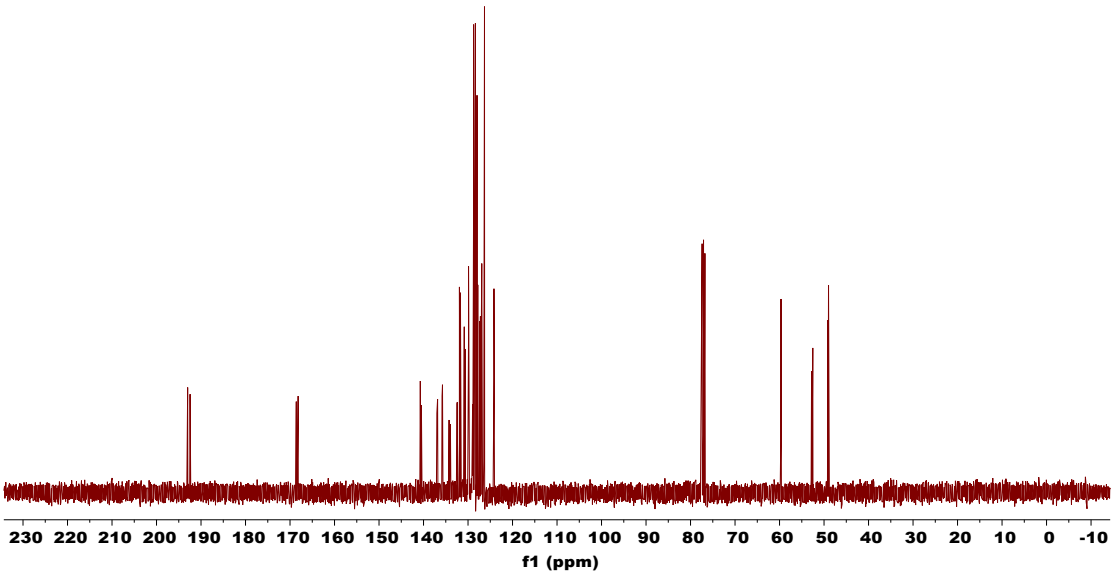

8.69 8.68 8.55 8.55 8.12 8.11 7.97 7.95 7.95 7.92 7.90 7.85 7.61 7.58 7.58 7.56 7.47 7.45 7.41 7.39 7.37 7.35 7.33 7.32 7.30 7.29 7.26 7.24 7.23 7.21 7.17 7.17 7.16 6.58 6.51 6.49 6.43 6.42 6.33 6.31 5.27 5.24 5.24 5.21 3.69 3.46 0.04

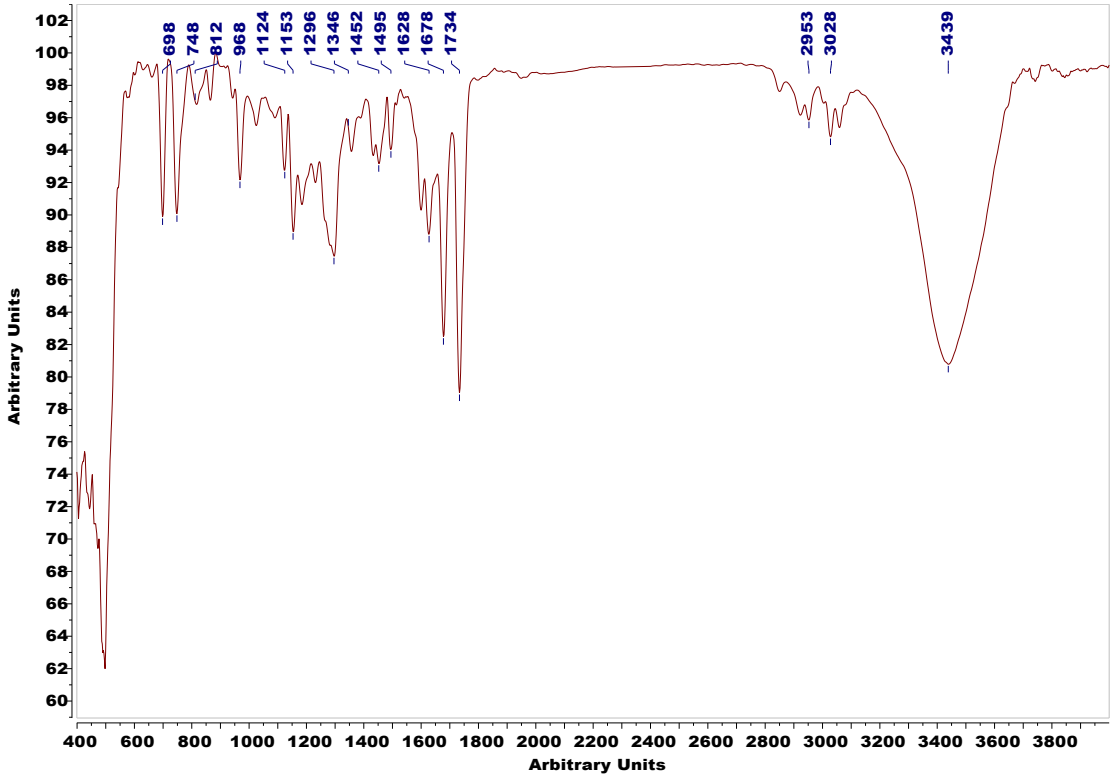

O
O
O
Ph
Ph

3oa dr = 1:1

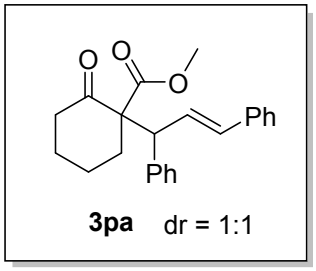

1.10 0.53 1.55 2.10 1.08 1.07 11.05 0.51 1.05 0.55 1.08 1.07 1.50 1.50
.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0
f1 (ppm)


192.5 168.6 140.7 140.5 136.8 135.8 135.7 132.5 132.4 131.9 131.7 130.8 130.6 129.9 129.8 129.8 129.7 129.0 128.9 128.8 128.7 128.7 128.6 128.5 128.4 128.3 128.0 127.8 127.8 127.6 127.4 127.2 127.0 126.9 126.4 126.3 124.2 124.0 77.4 77.1 76.8 59.7 59.7 52.8 52.5 49.1 49.0

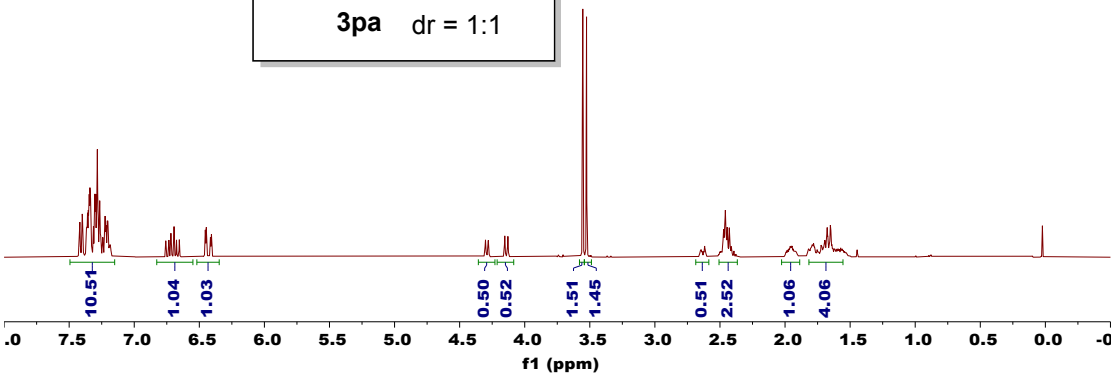

230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

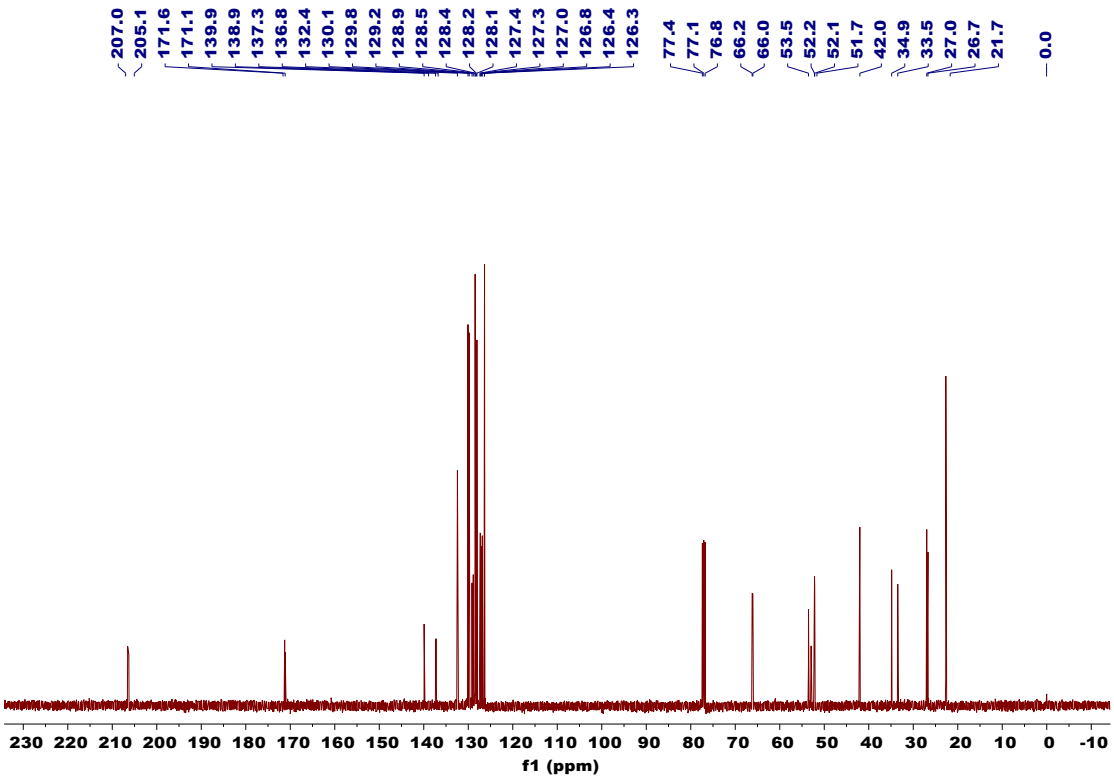

698
748
812
968
1124
1153
1296
1346
1452
1495
1628
1678
1734
2953
3028
3439
Arbitrary Units
Arbitrary Units

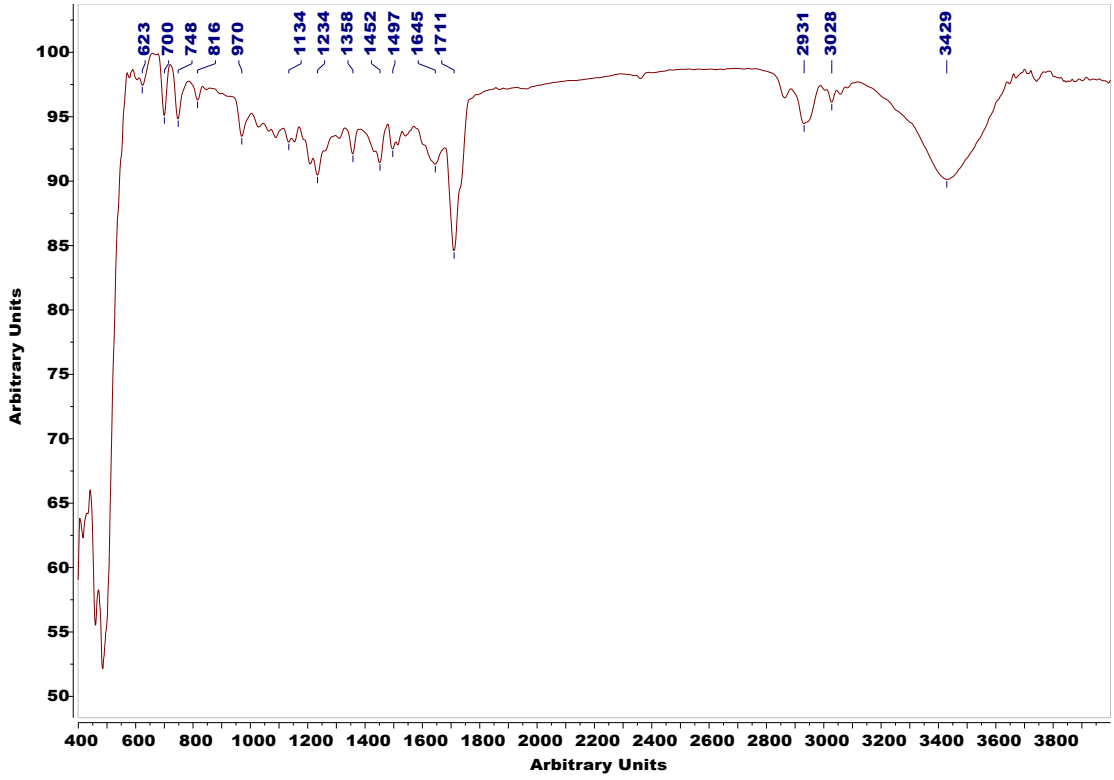

7.42
7.40
7.36
7.36
7.35
7.35
7.35
7.34
7.32
7.30
7.30
7.28
7.26
7.26
7.24
7.23
7.22
7.21
7.20
7.18
6.76
6.73
6.72
6.71
6.69
6.68
6.65
6.45
6.45
6.41
6.41
4.30
4.28
4.15
3.55
3.53
2.47
2.46
2.44
2.43
1.79
1.78
1.72
1.69
1.68
1.65
0.02

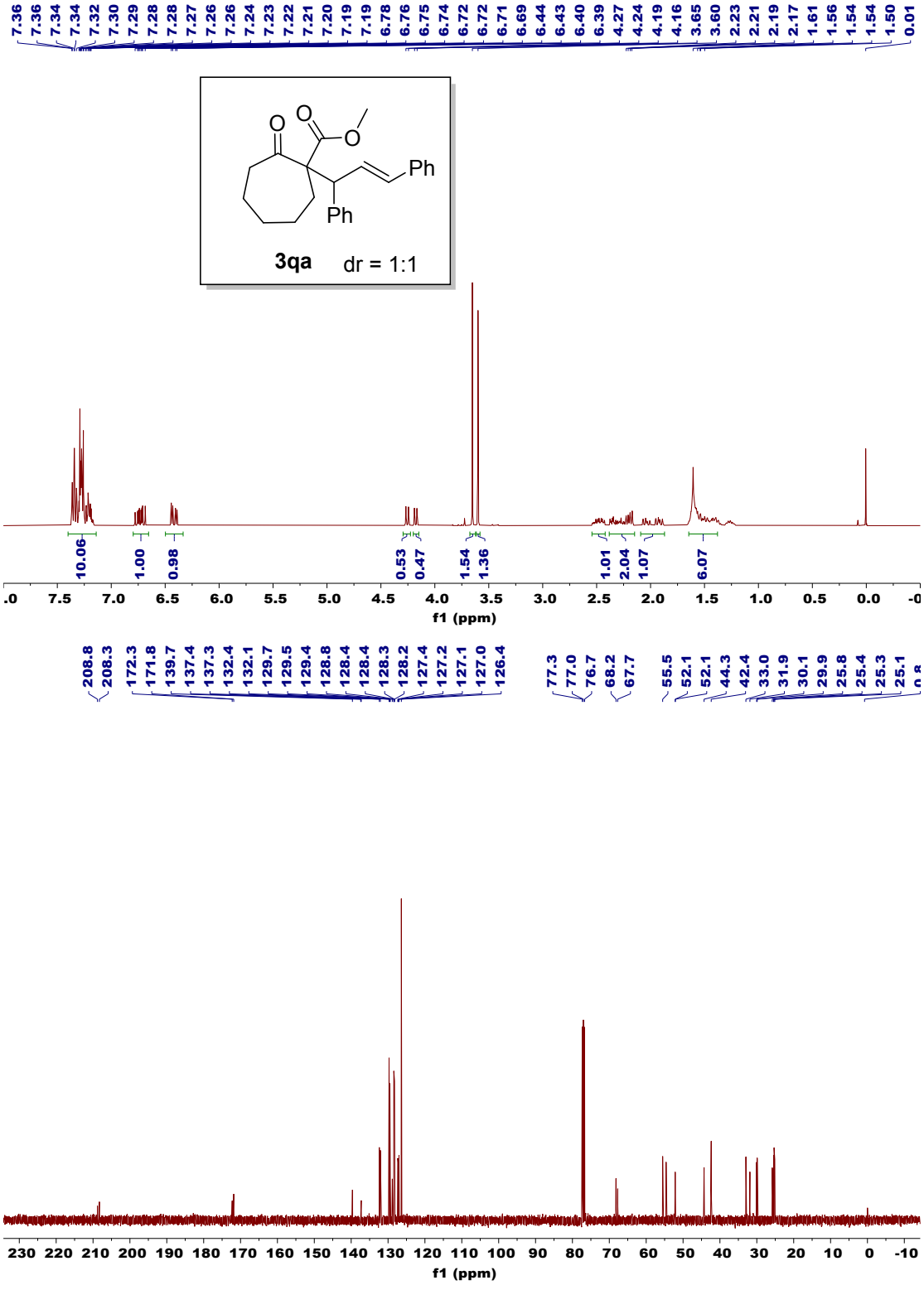

O
O
O
Ph
Ph

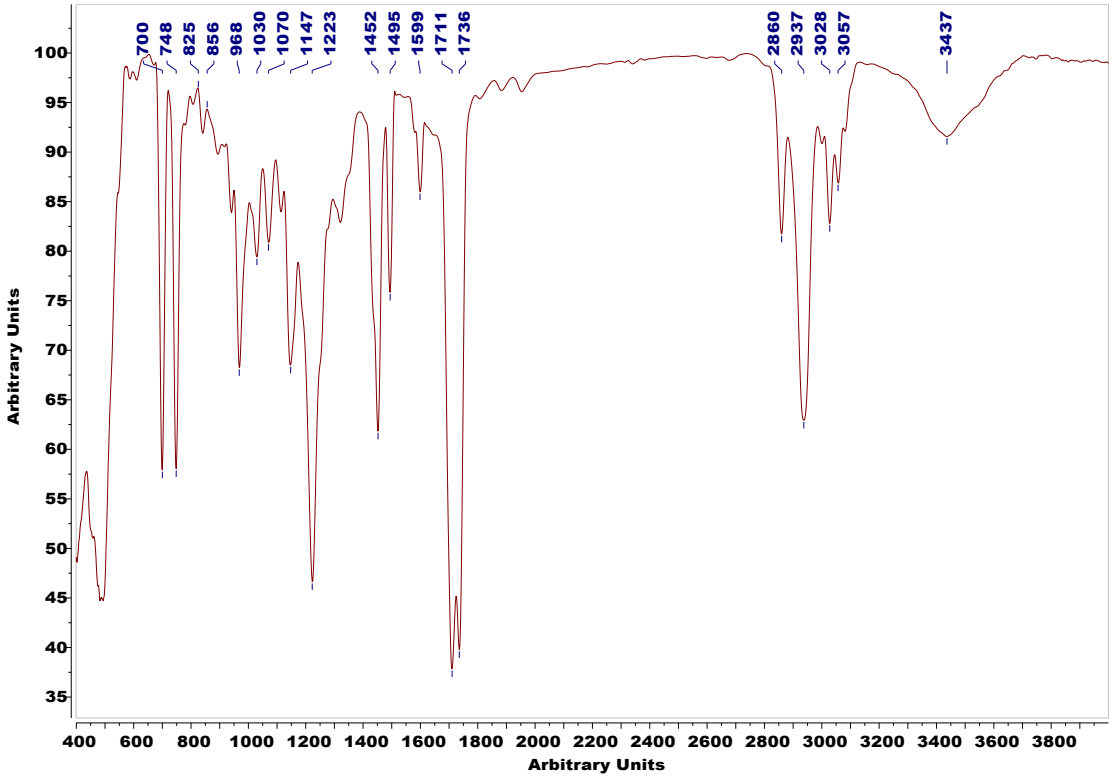
3pa dr = 1:1


10.51
1.04
1.03
0.50
0.52
1.51
1.45
0.51
2.52
1.06
4.06
f1 (ppm)

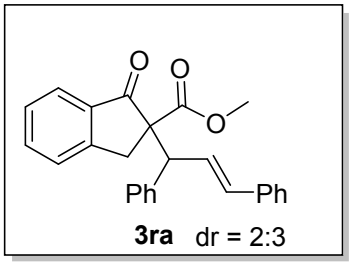

207.0
205.1
171.6
171.1
139.9
138.9
137.3
136.8
132.4
130.1
129.8
129.2
128.9
128.5
128.4
128.2
128.1
127.4
127.3
127.0
126.8
126.4
126.3
77.4
77.1
76.8
66.2
66.0
53.5
52.2
52.1
51.7
42.0
34.9
33.5
27.0
26.7
21.7
0.0
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


623
700
748
816
970
1134
1234
1358
1452
1497
1645
1711
2931
3028
3429
Arbitrary Units
100
95
90
85
80
75
70
65
60
55
50
400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 2800 3000 3200 3400 3600 3800
Arbitrary Units

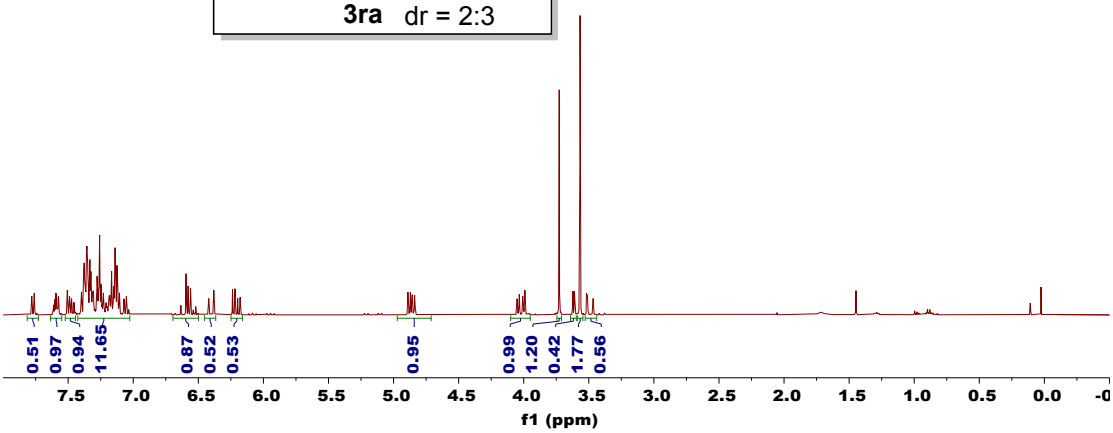

7.36 7.36 7.34 7.34 7.32 7.30 7.29 7.28 7.28 7.27 7.26 7.26 7.24 7.23 7.22 7.21 7.20 7.19 7.19 6.78 6.76 6.75 6.74 6.72 6.72 6.71 6.69 6.44 6.43 6.40 6.39 4.27 4.24 4.19 4.16 3.65 3.60 2.23 2.21 2.19 2.17 1.61 1.56 1.54 1.54 1.50 0.01
O
O
O
Ph
Ph
3qa dr = 1:1
10.06 1.00 0.98 0.53 0.47 1.54 1.36 1.01 2.04 1.07 6.07
f1 (ppm)
208.8 208.3 172.3 171.8 139.7 137.4 137.3 132.4 132.1 129.7 129.5 129.4 128.8 128.4 128.4 128.3 128.2 127.4 127.2 127.1 127.0 126.4 77.3 77.0 76.7 68.2 67.7 55.5 52.1 52.1 44.3 42.4 33.0 31.9 30.1 29.9 25.8 25.4 25.3 25.1
f1 (ppm)

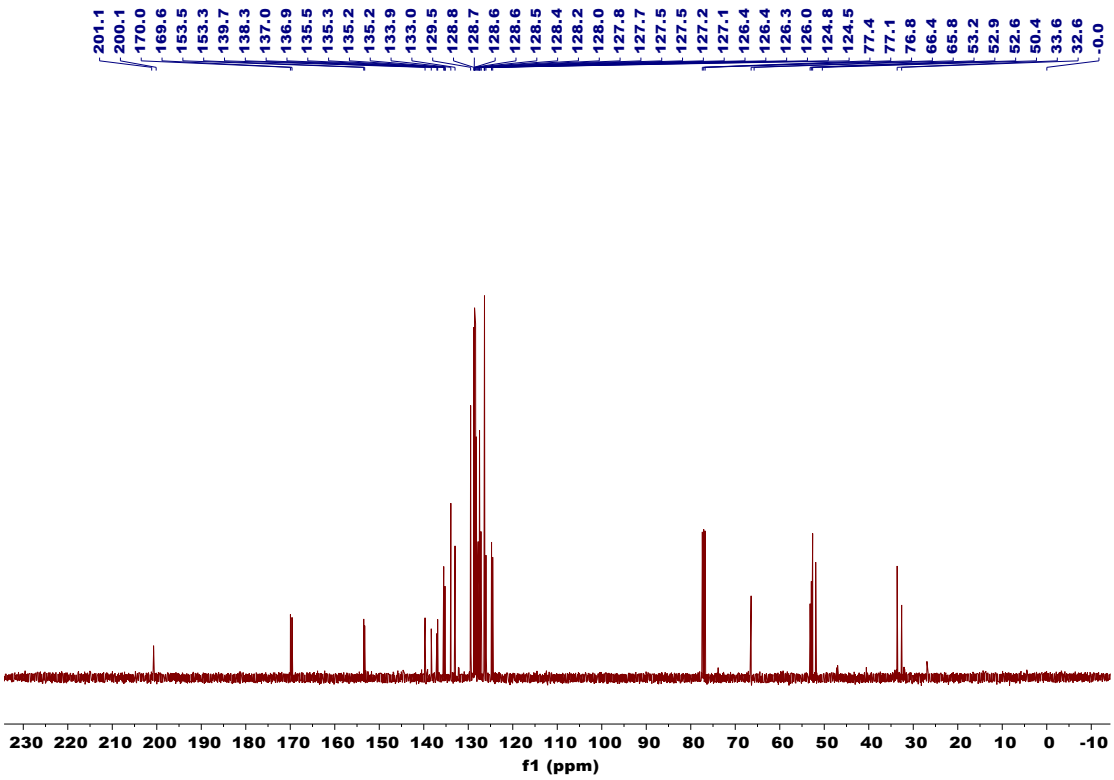

700
748
825
856
968
1030
1070
1147
1223
1452
1495
1599
1711
1736
2860
2937
3028
3057
3437
Arbitrary Units
Arbitrary Units

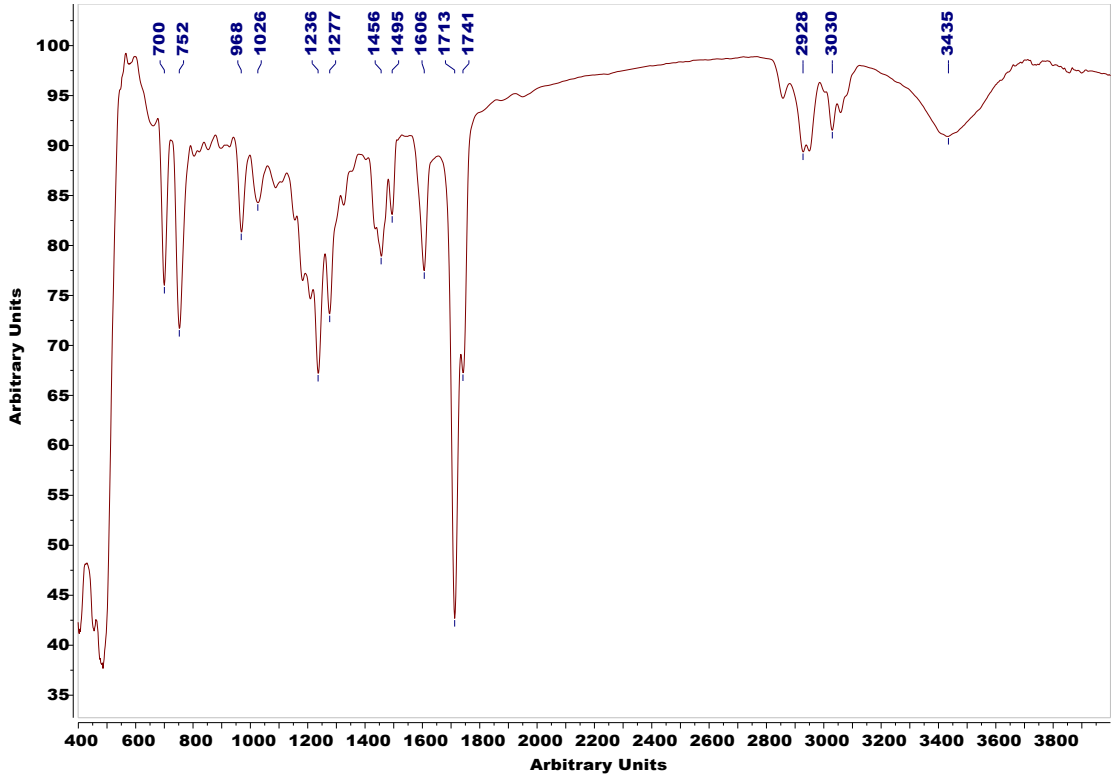

7.78
7.76
7.60
7.51
7.40
7.38
7.38
7.36
7.36
7.35
7.33
7.33
7.31
7.31
7.28
7.27
7.26
7.25
7.23
7.18
7.17
7.15
7.14
7.13
7.12
7.11
7.05
6.59
6.58
6.56
6.38
6.24
6.22
4.89
4.87
4.86
4.84
4.03
4.01
3.99
3.73
3.62
3.61
3.57
3.52
3.51
0.03

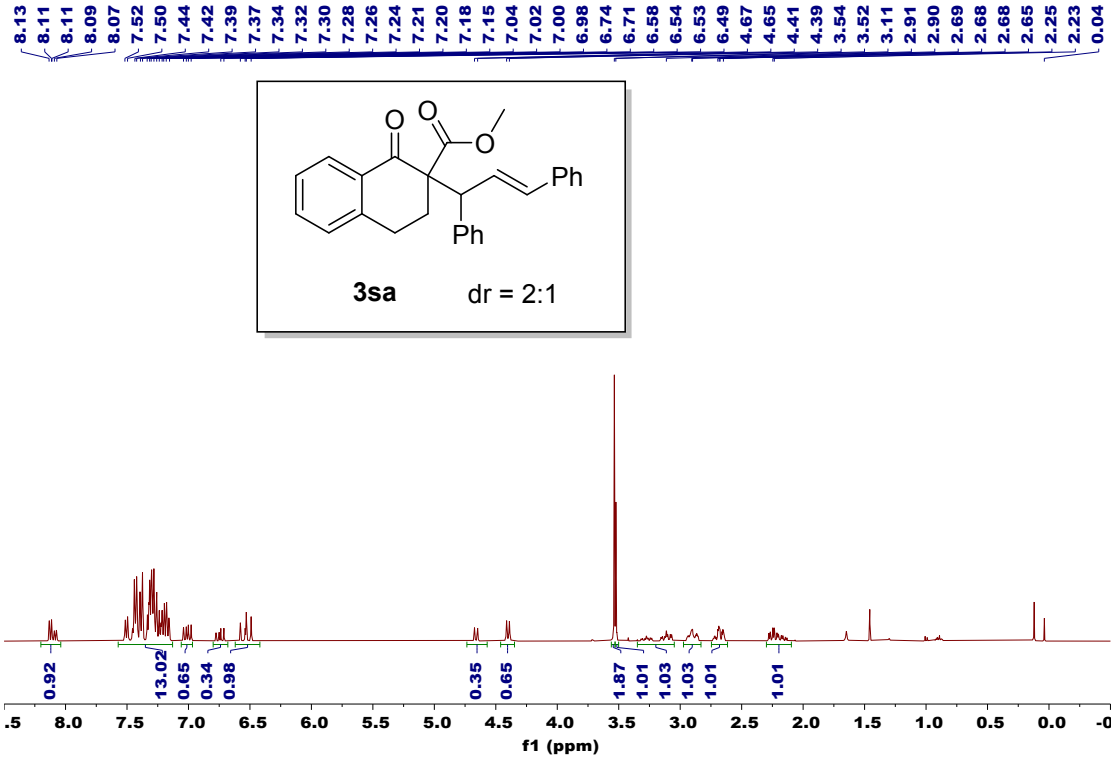

O
O
O
Ph
Ph

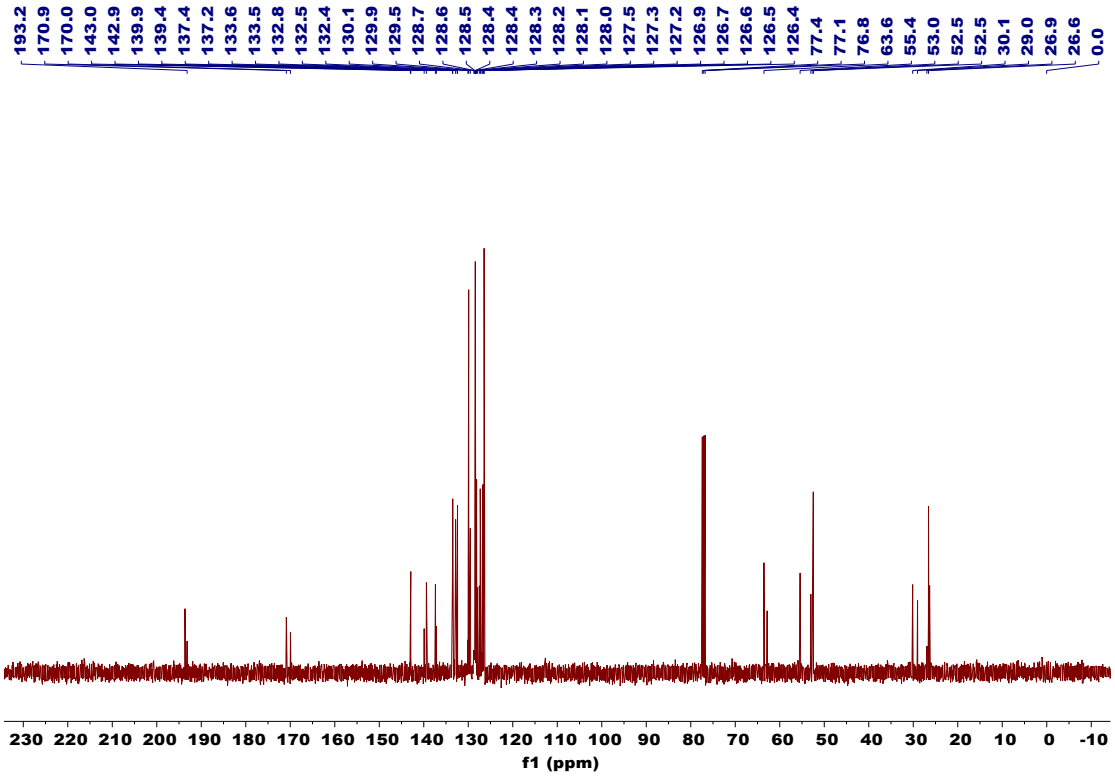
3ra dr = 2:3

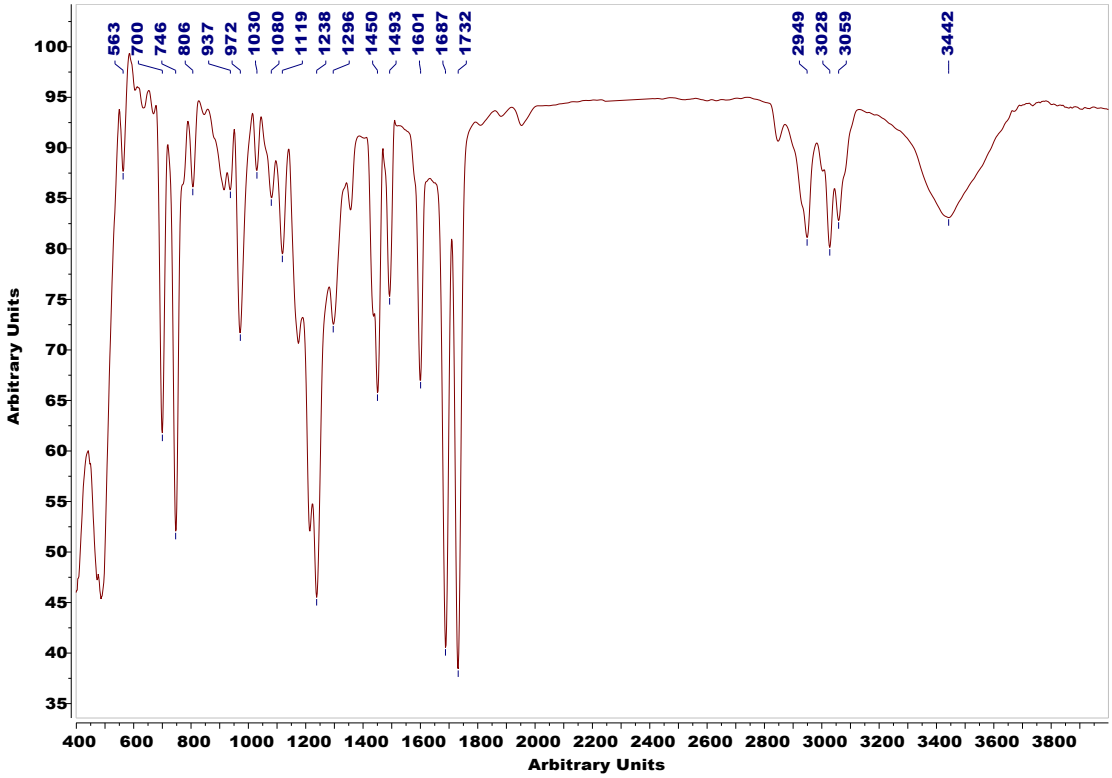

0.51
0.97
0.94
11.65
0.87
0.52
0.53
0.95
0.99
1.20
0.42
1.77
0.56
f1 (ppm)

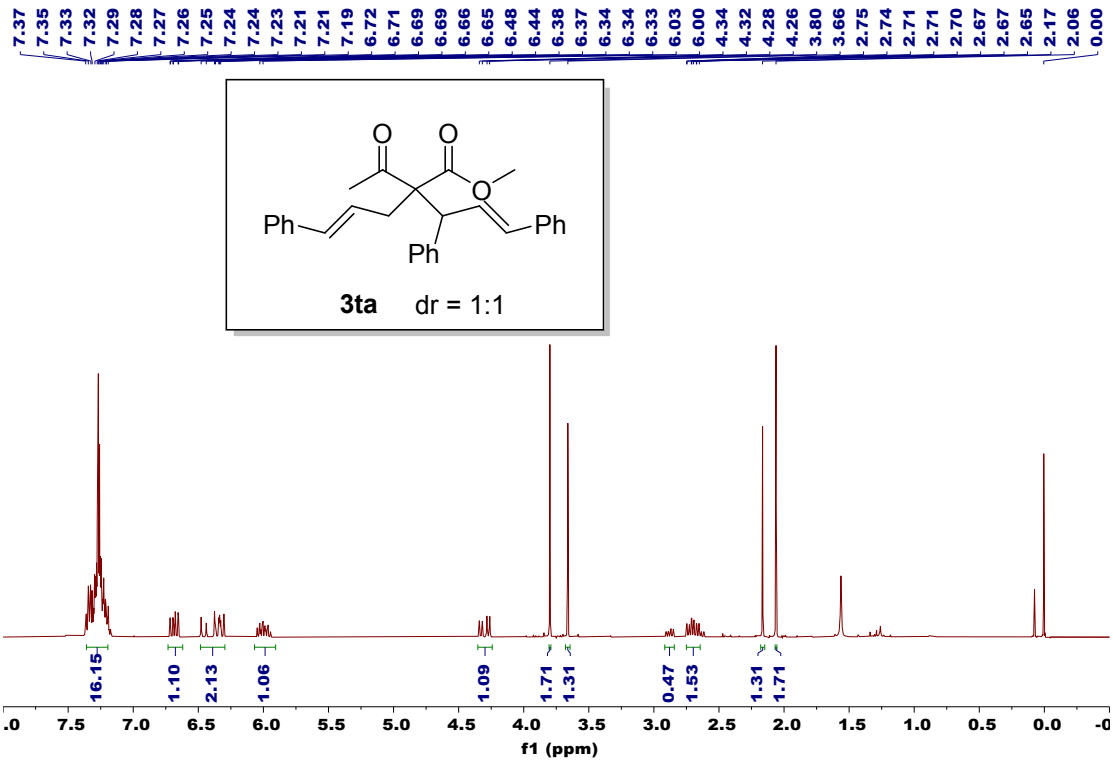

201.1
200.1
170.0
169.6
153.5
153.3
139.7
138.3
137.0
136.9
135.5
135.3
135.2
135.2
133.9
133.0
129.5
128.8
128.7
128.6
128.6
128.5
128.4
128.2
128.0
127.8
127.7
127.5
127.5
127.2
127.1
126.4
126.4
126.3
126.0
124.8
124.5
77.4
77.1
76.8
66.4
65.8
53.2
52.9
52.6
50.4
33.6
32.6
-0.0
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

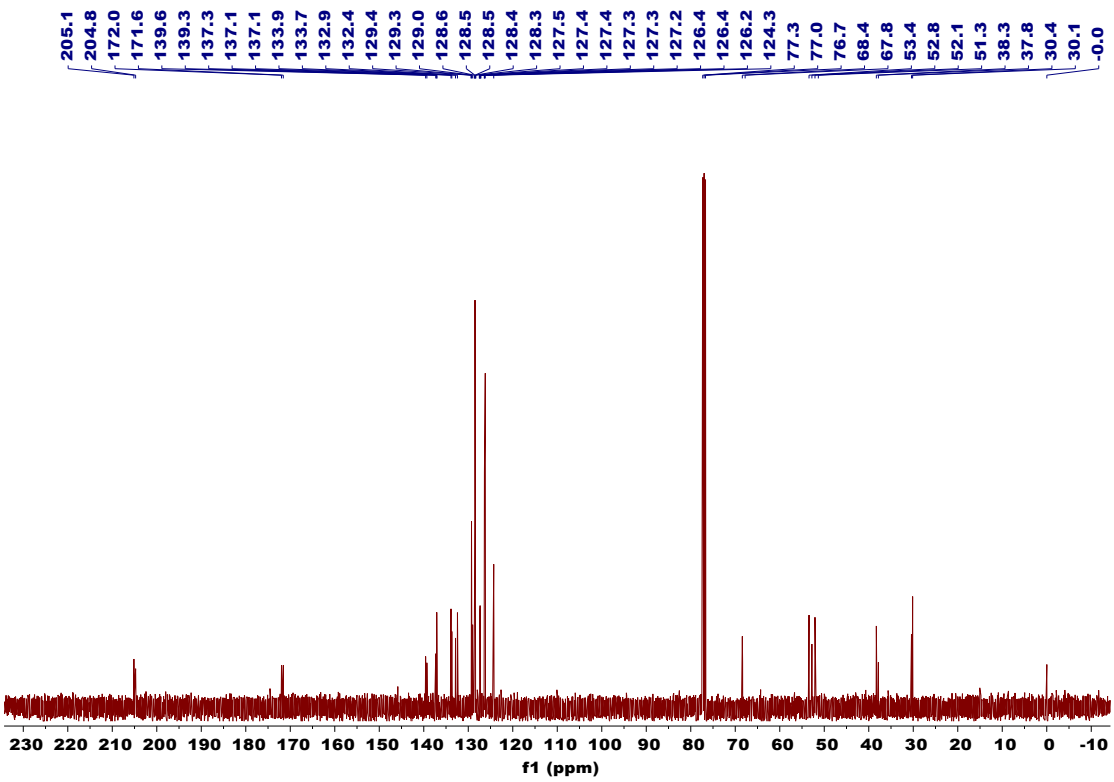

700
752
968
1026
1236
1277
1456
1495
1606
1713
1741
2928
3030
3435
Arbitrary Units
100 95 90 85 80 75 70 65 60 55 50 45 40 35
400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 2800 3000 3200 3400 3600 3800
Arbitrary Units

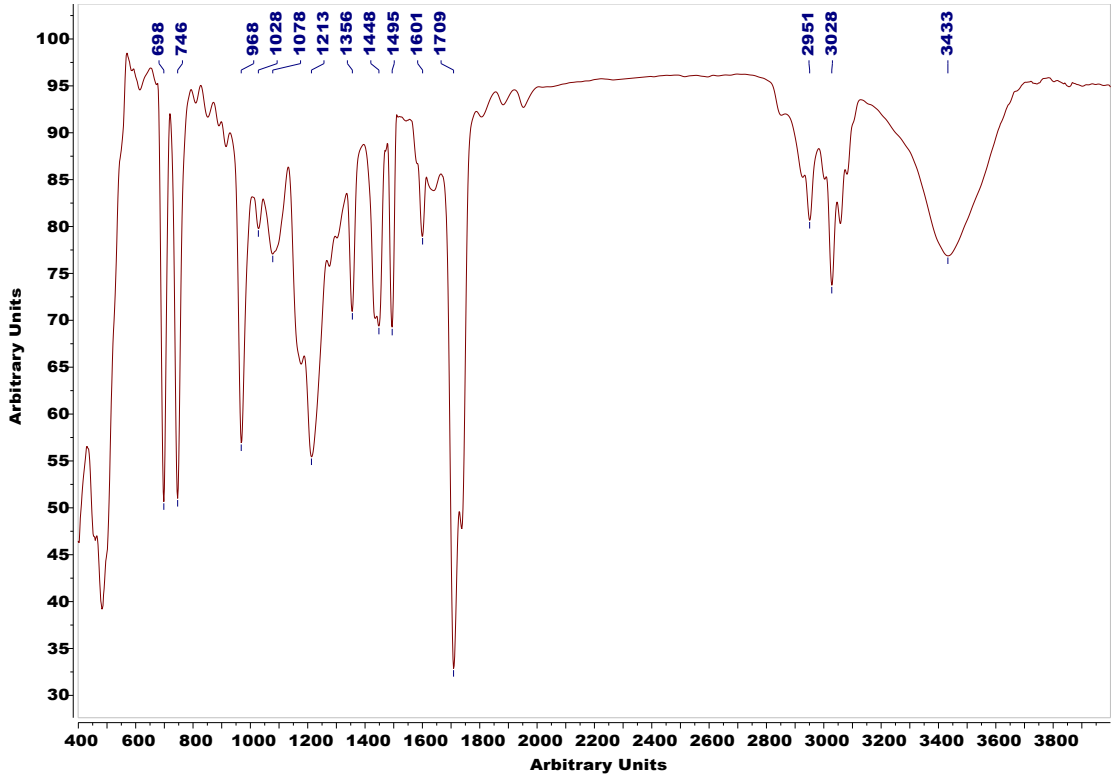

8.13 8.11 8.11 8.09 8.07 7.52 7.50 7.44 7.42 7.39 7.37 7.34 7.32 7.30 7.28 7.26 7.24 7.21 7.20 7.18 7.15 7.04 7.02 7.00 6.98 6.74 6.71 6.58 6.54 6.53 6.49 4.67 4.65 4.41 4.39 3.54 3.52 3.11 2.91 2.90 2.69 2.68 2.68 2.65 2.25 2.23 0.04
O
O
O
Ph
Ph
3sa
dr = 2:1
0.92 13.02 0.65 0.34 0.98 0.35 0.65 1.87 1.01 1.03 1.01 1.01
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)

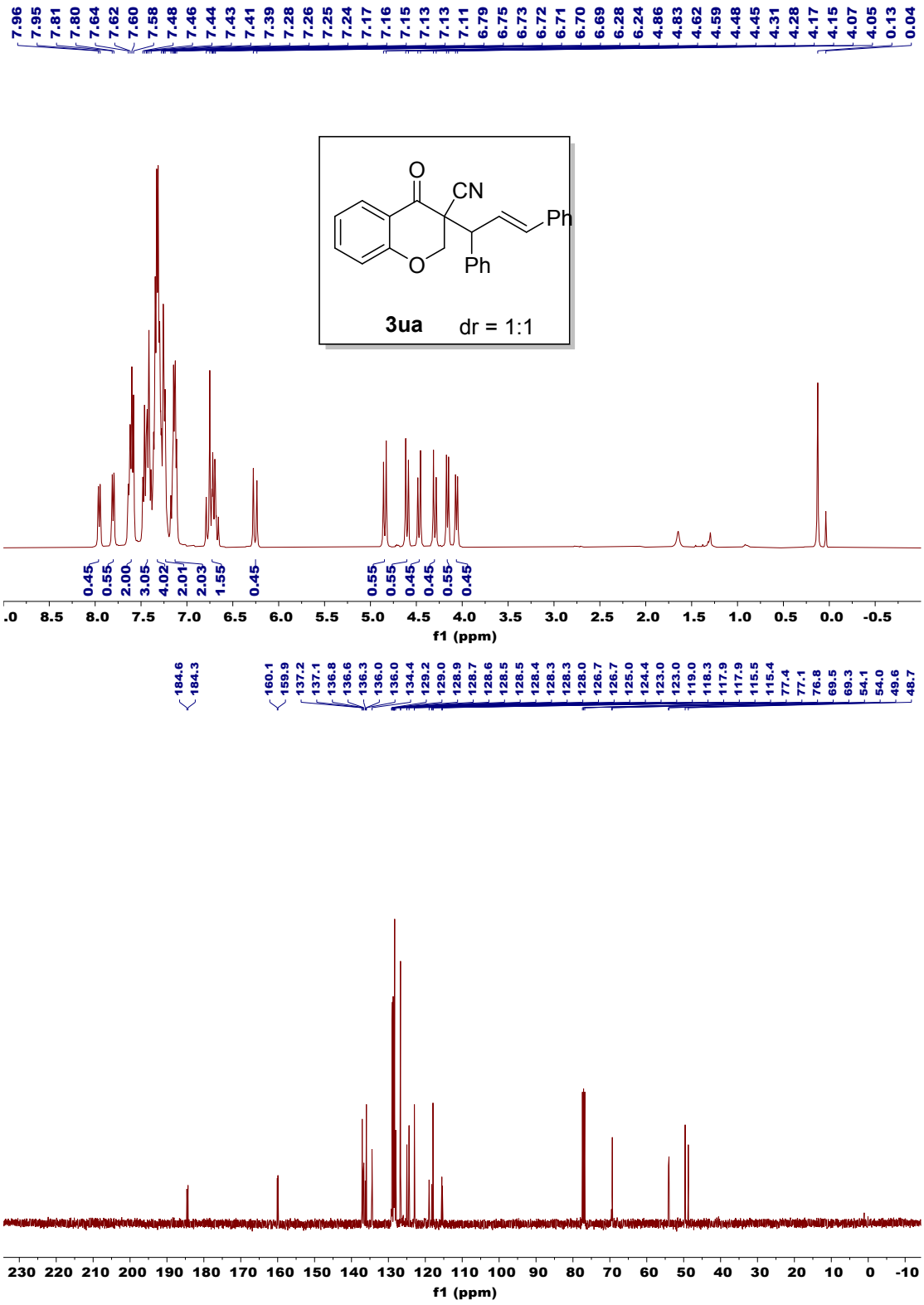

193.2 170.9 170.0 143.0 142.9 139.9 139.4 137.4 137.2 133.6 133.5 132.8 132.5 132.4 130.1 129.9 129.5 128.7 128.6 128.5 128.4 128.4 128.3 128.2 128.1 128.0 127.5 127.3 127.2 126.9 126.7 126.6 126.5 126.4 77.4 77.1 76.8 63.6 55.4 53.0 52.5 52.5 30.1 29.0 26.9 26.6 0.0
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

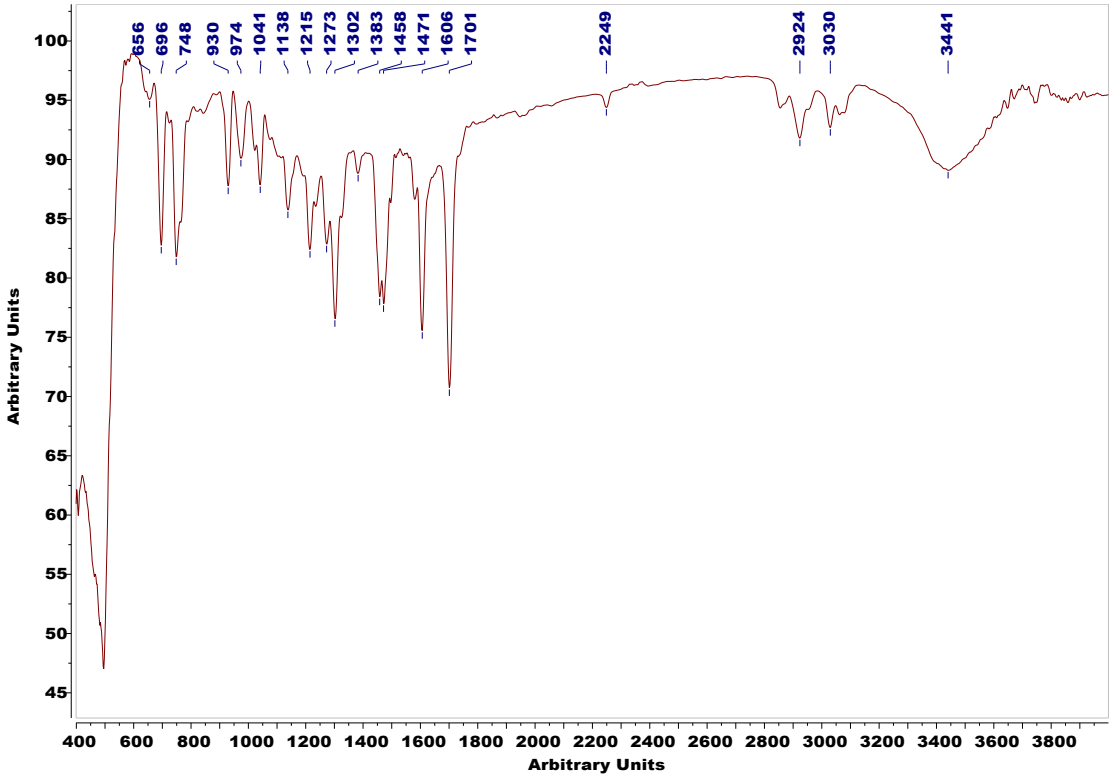

563
700
746
806
937
972
1030
1080
1119
1238
1296
1450
1493
1601
1687
1732
2949
3028
3059
3442
Arbitrary Units
Arbitrary Units


7.37
7.35
7.33
7.32
7.29
7.28
7.27
7.26
7.25
7.24
7.24
7.23
7.21
7.21
7.19
6.72
6.71
6.69
6.69
6.66
6.65
6.48
6.44
6.38
6.37
6.34
6.34
6.33
6.03
6.00
4.34
4.32
4.28
4.26
3.80
3.66
2.75
2.74
2.71
2.71
2.70
2.67
2.67
2.65
2.17
2.06
0.00
O
O
O
Ph
Ph
Ph
3ta dr = 1:1
16.15
1.10
2.13
1.06
1.09
1.71
1.31
0.47
1.53
1.31
1.71
f1 (ppm)

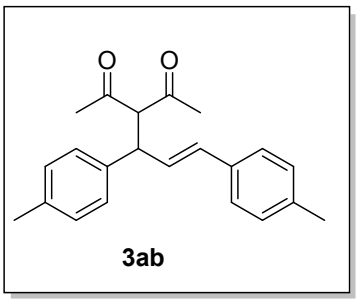

205.1
204.8
172.0
171.6
139.6
139.3
137.3
137.1
137.1
133.9
133.7
132.9
132.4
129.4
129.3
129.0
128.6
128.5
128.5
128.4
128.3
127.5
127.4
127.4
127.3
127.3
127.2
126.4
126.4
126.2
124.3
77.3
77.0
76.7
68.4
67.8
53.4
52.8
52.1
51.3
38.3
37.8
30.4
30.1
-0.0
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

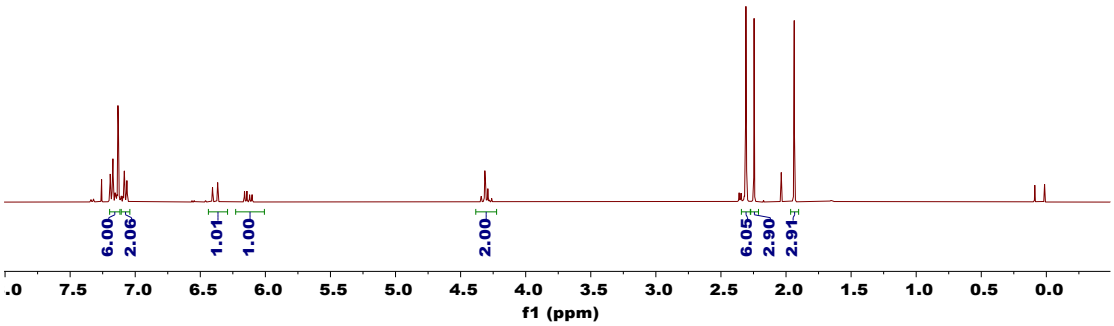

698
746
968
1028
1078
1213
1356
1448
1495
1601
1709
2951
3028
3433
Arbitrary Units
100 95 90 85 80 75 70 65 60 55 50 45 40 35 30
400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 2800 3000 3200 3400 3600 3800
Arbitrary Units

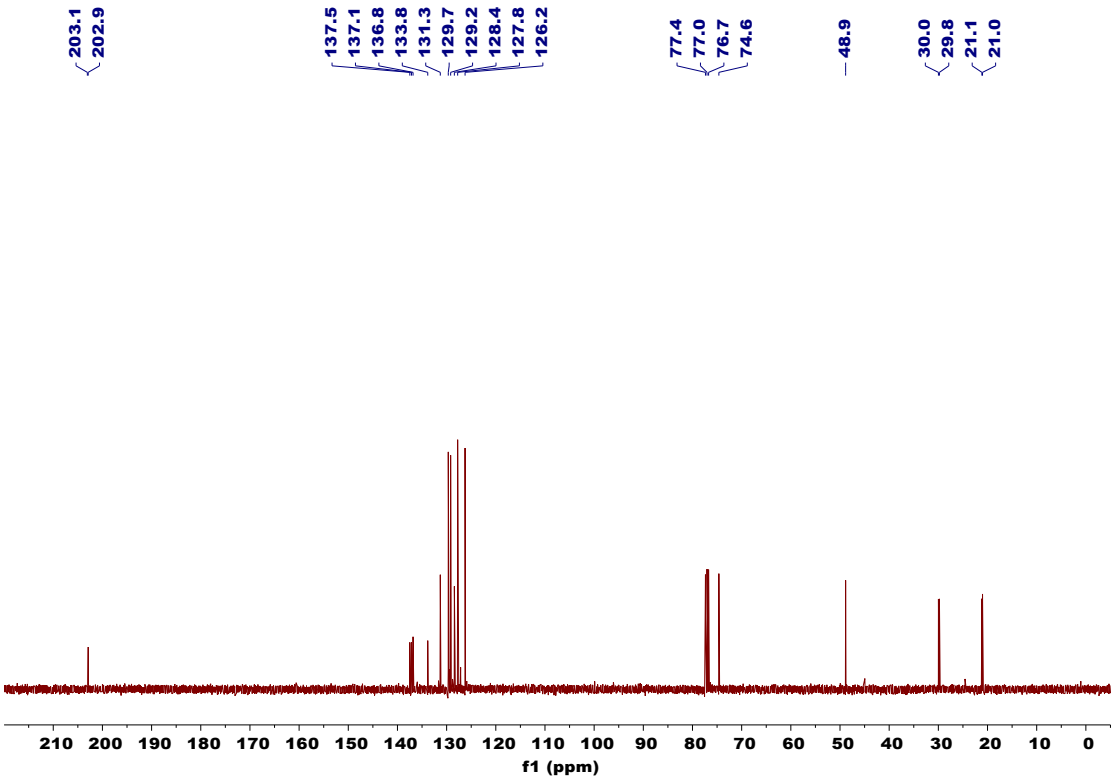

7.96 7.95 7.81 7.80 7.64 7.62 7.60 7.58 7.48 7.46 7.44 7.43 7.41 7.39 7.28 7.26 7.25 7.24 7.17 7.16 7.15 7.13 7.13 7.11 6.79 6.75 6.73 6.72 6.71 6.70 6.69 6.28 6.24 4.86 4.83 4.62 4.59 4.48 4.45 4.31 4.28 4.17 4.15 4.07 4.05 0.13 0.04
O
CN
Ph
O
Ph
3ua dr = 1:1
0.45 0.55 2.00 3.05 4.02 2.01 2.03 1.55 0.45 0.55 0.55 0.45 0.45 0.55 0.45
f1 (ppm)
184.6 184.3 160.1 159.9 137.2 137.1 136.8 136.6 136.3 136.0 136.0 134.4 129.2 129.0 128.9 128.7 128.6 128.5 128.5 128.4 128.3 128.3 128.0 126.7 126.7 125.0 124.4 123.0 123.0 119.0 118.3 117.9 117.9 115.5 115.4 77.4 77.1 76.8 69.5 69.3 54.1 54.0 49.6 48.7
f1 (ppm)

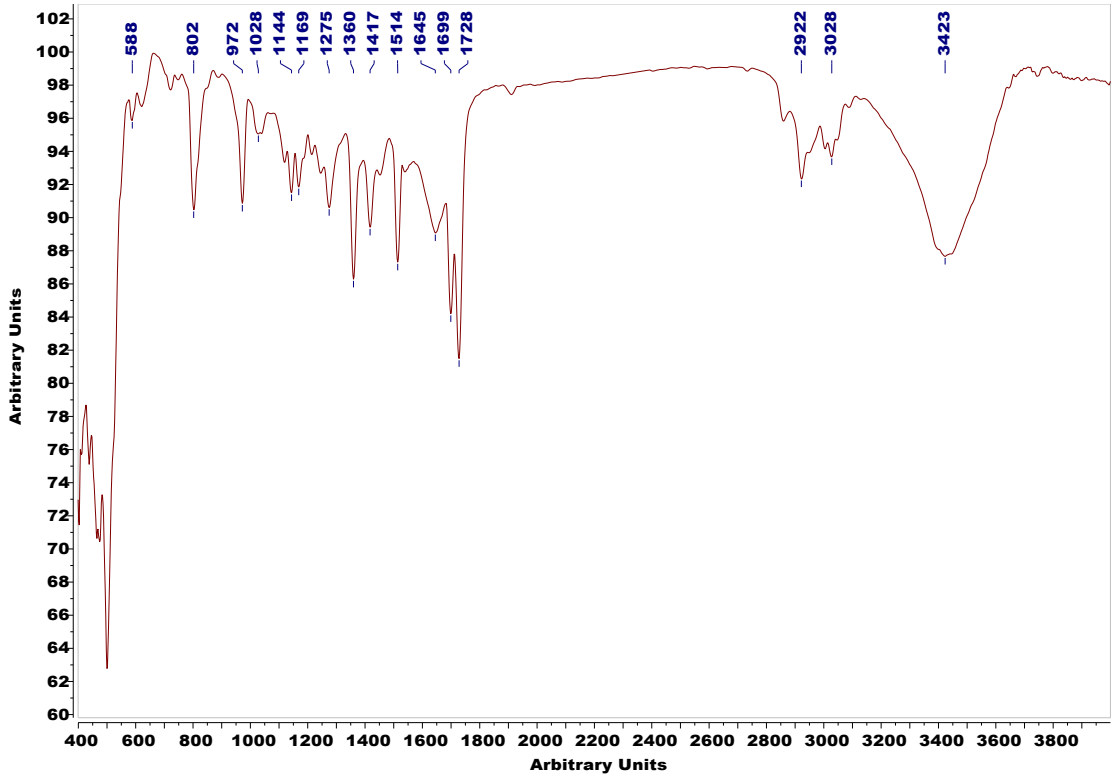

656
696
748
930
974
1041
1138
1215
1273
1302
1383
1458
1471
1606
1701
2249
2924
3030
3441
Arbitrary Units
Arbitrary Units

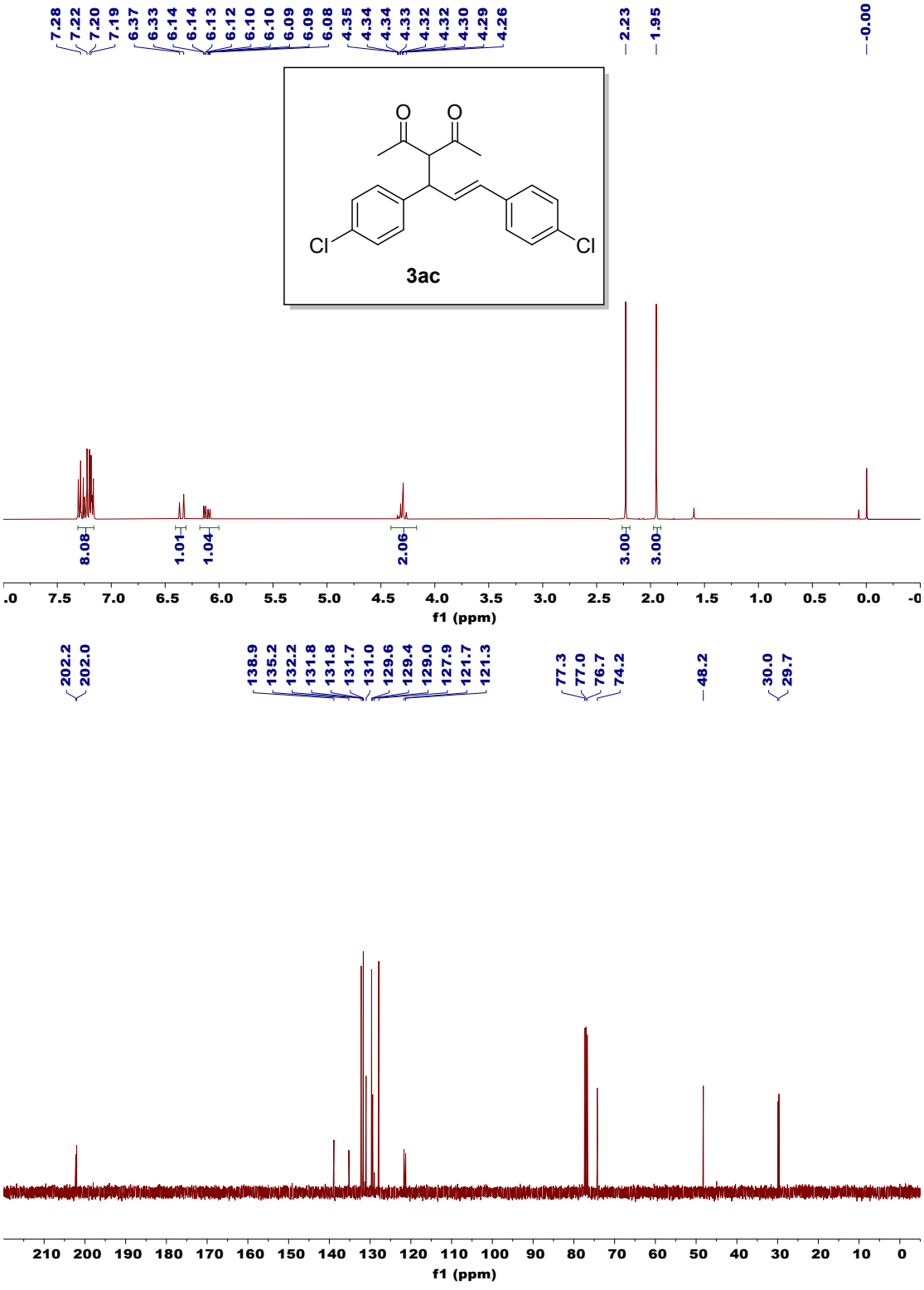

7.26
7.19
7.17
7.13
7.13
7.09
7.06
6.41
6.37
6.16
6.14
6.12
6.07
4.34
4.31
4.31
4.29
4.23
2.31
2.25
1.94
0.08
0.01

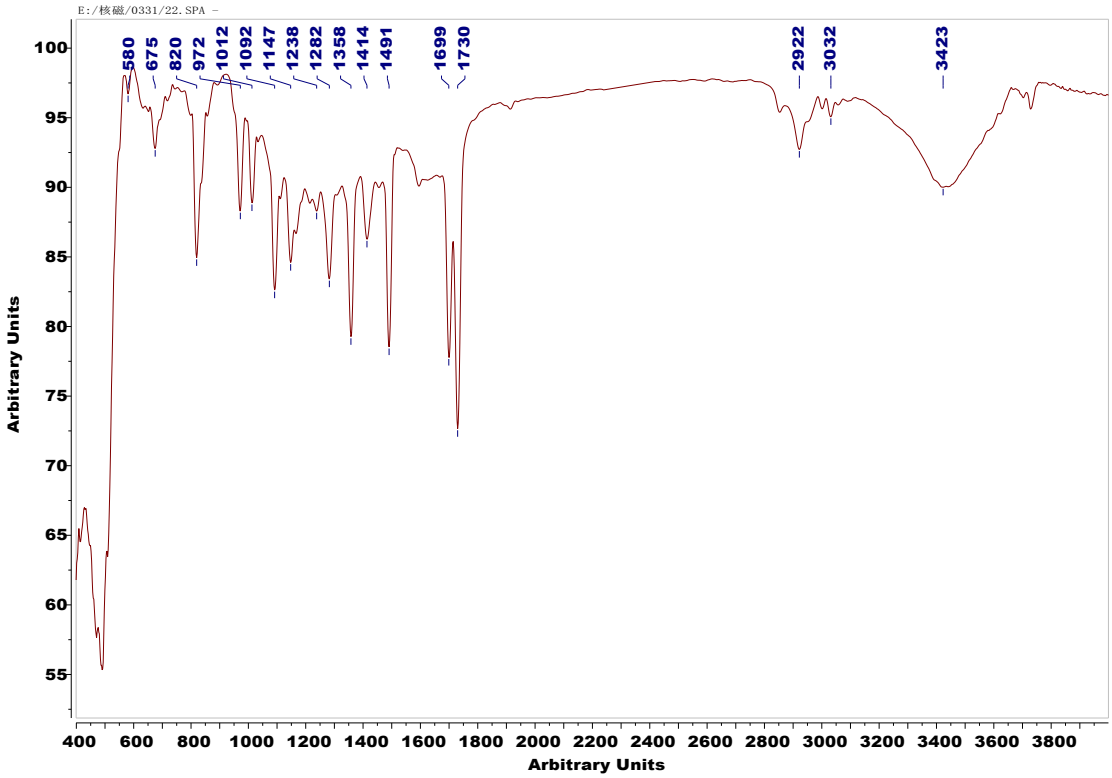

O
O
3ab


6.00
2.06
1.01
1.00
2.00
6.05
2.90
2.91
f1 (ppm)


203.1
202.9
137.5
137.1
136.8
133.8
131.3
129.7
129.2
128.4
127.8
126.2
77.4
77.0
76.7
74.6
48.9
30.0
29.8
21.1
21.0
f1 (ppm)


588
802
972
1028
1144
1169
1275
1360
1417
1514
1645
1699
1728
2922
3028
3423
Arbitrary Units
Arbitrary Units


7.28
7.22
7.20
7.19
6.37
6.33
6.14
6.14
6.13
6.12
6.10
6.10
6.09
6.09
6.08
4.35
4.34
4.34
4.33
4.32
4.32
4.30
4.29
4.26
2.23
1.95
-0.00
O
O
Cl
Cl
3ac
8.08
1.01
1.04
2.06
3.00
3.00
f1 (ppm)
202.2
202.0
138.9
135.2
132.2
131.8
131.8
131.7
131.0
129.6
129.4
129.0
127.9
121.7
121.3
77.3
77.0
76.7
74.2
48.2
30.0
29.7
f1 (ppm)


E:/核磁/0331/22.SPA -
Arbitrary Units
580
675
820
972
1012
1092
1147
1238
1282
1358
1414
1491
1699
1730
2922
3032
3423
Arbitrary Units


7.48
7.46
7.45
7.45
7.44
7.43
7.43
7.40
7.40
7.39
7.39
7.38
7.38
7.37
7.37
7.15
7.14
7.14
7.13
7.13
7.12
7.12
7.11
7.11
7.10
7.09
6.35
6.31
6.15
6.15
6.14
6.13
6.11
6.11
6.10
6.09
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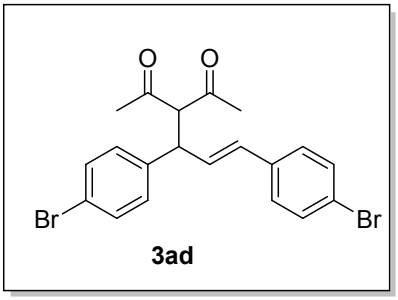
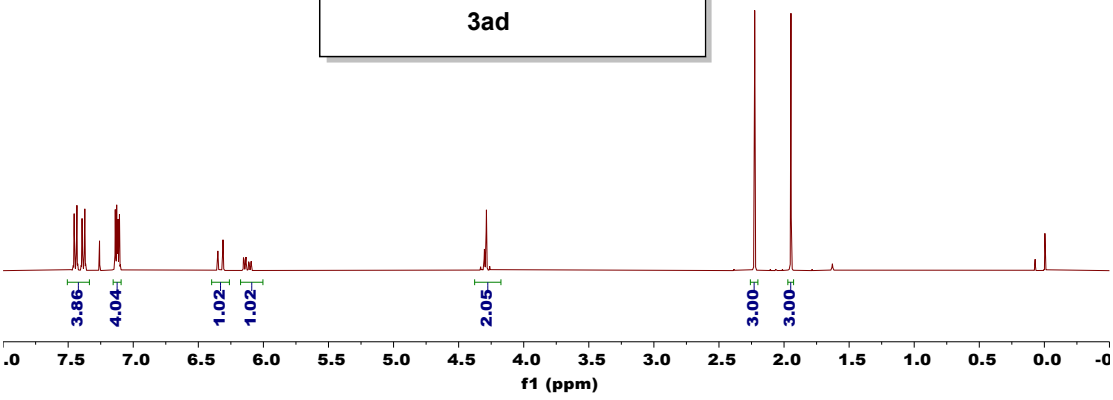
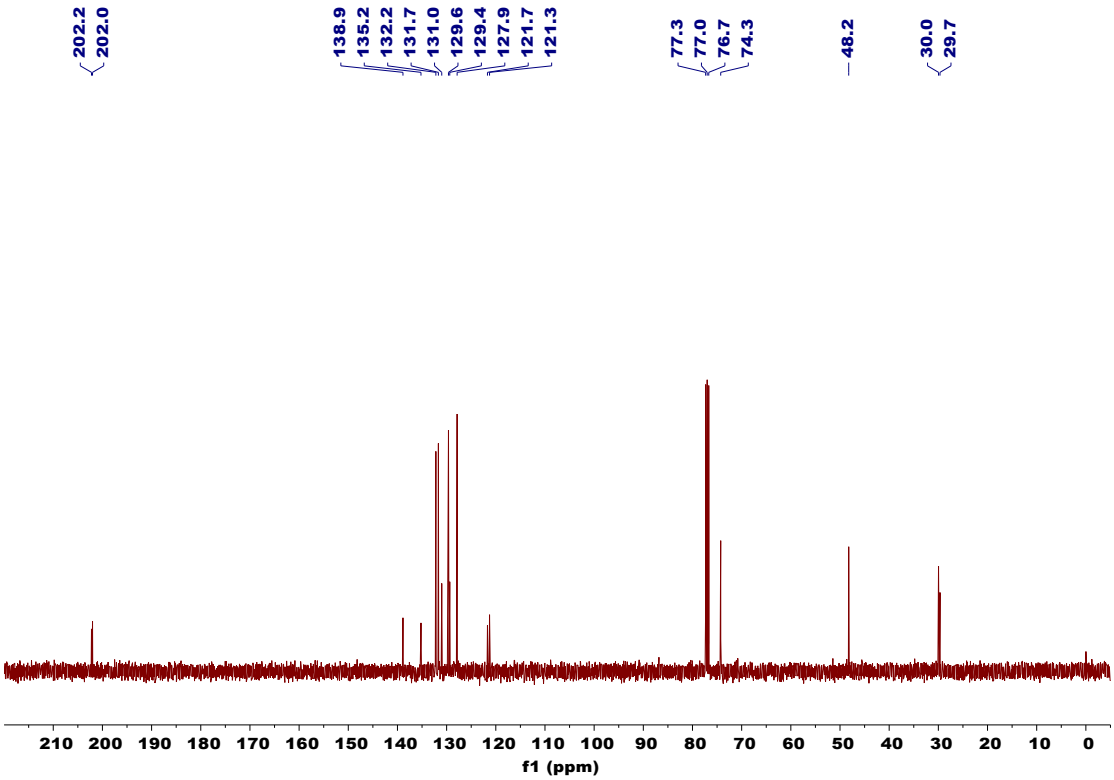
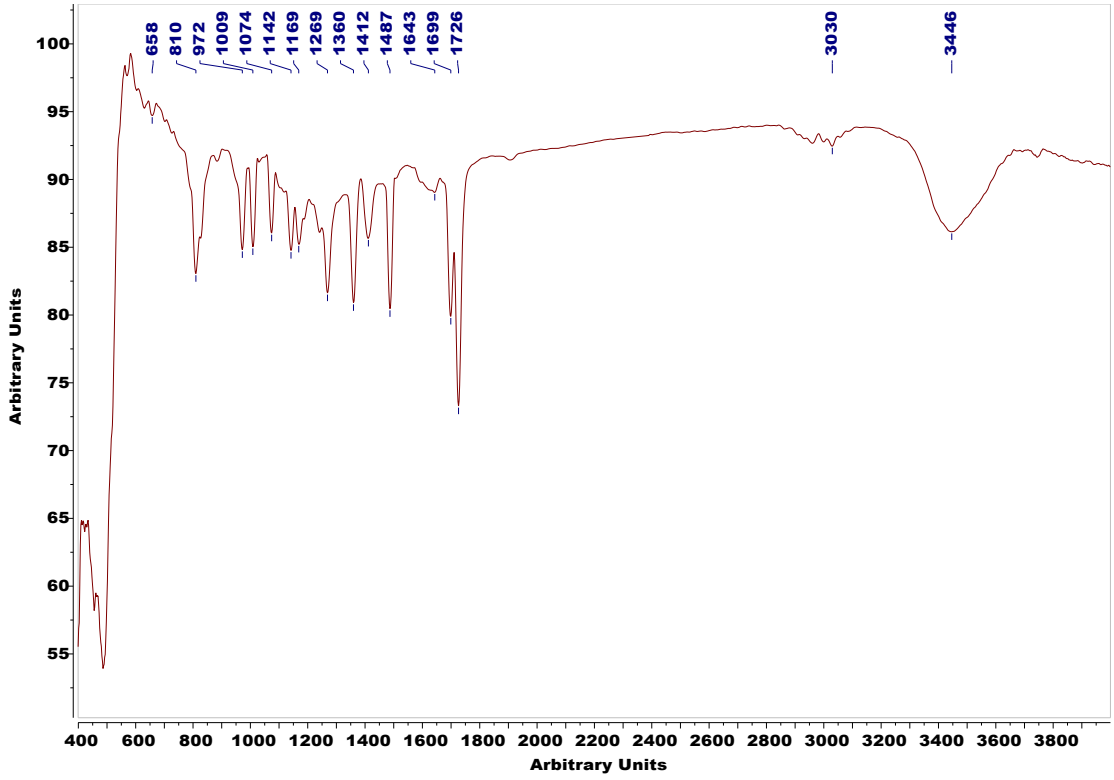
4.32
4.30
4.30
4.29
4.29
4.26
2.23
1.95
0.00

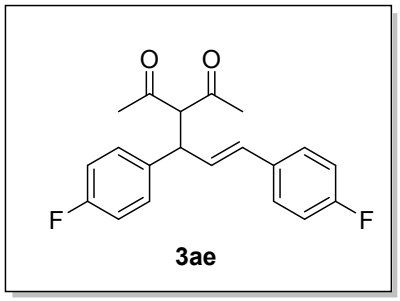

O
O
Br
Br
3ad


3.86
4.04
1.02
1.02
2.05
3.00
3.00
f1 (ppm)

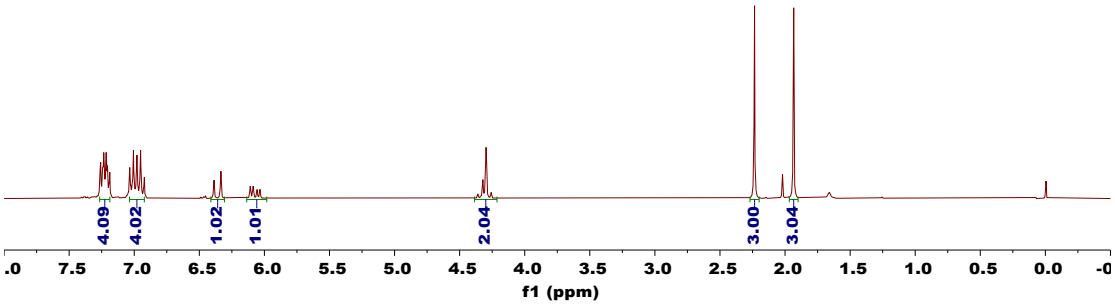

202.2
202.0
138.9
135.2
132.2
131.7
131.0
129.6
129.4
127.9
121.7
121.3
77.3
77.0
76.7
74.3
48.2
30.0
29.7
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


658
810
972
1009
1074
1142
1169
1269
1360
1412
1487
1643
1699
1726
3030
3446
Arbitrary Units
100 95 90 85 80 75 70 65 60 55
400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 2800 3000 3200 3400 3600 3800
Arbitrary Units

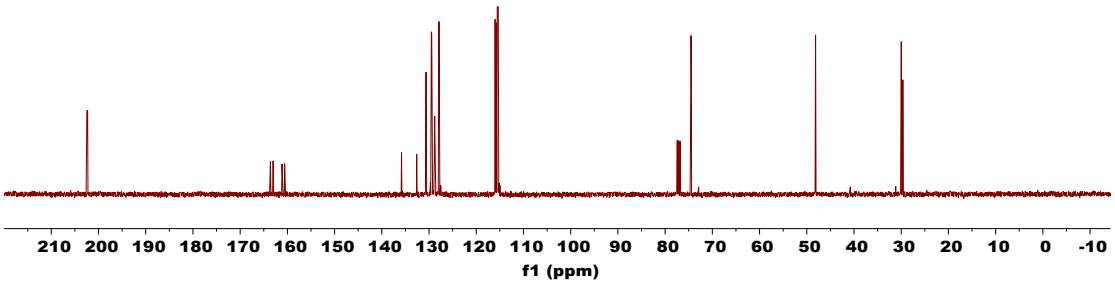

7.26
7.26
7.24
7.23
7.22
7.21
7.19
7.19
7.03
7.01
6.98
6.95
6.92
6.39
6.33
6.11
6.09
6.06
6.03
4.32
4.30
4.29
2.24
2.23
1.94
1.93
0.00

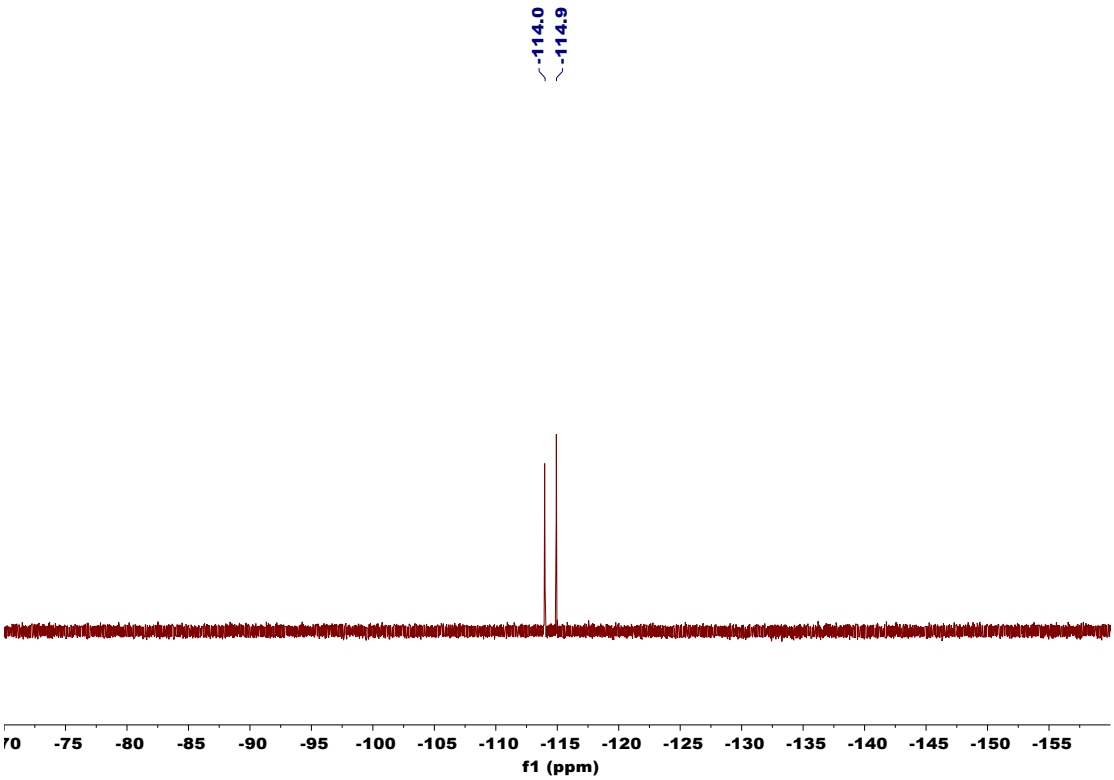

O
O
F
F

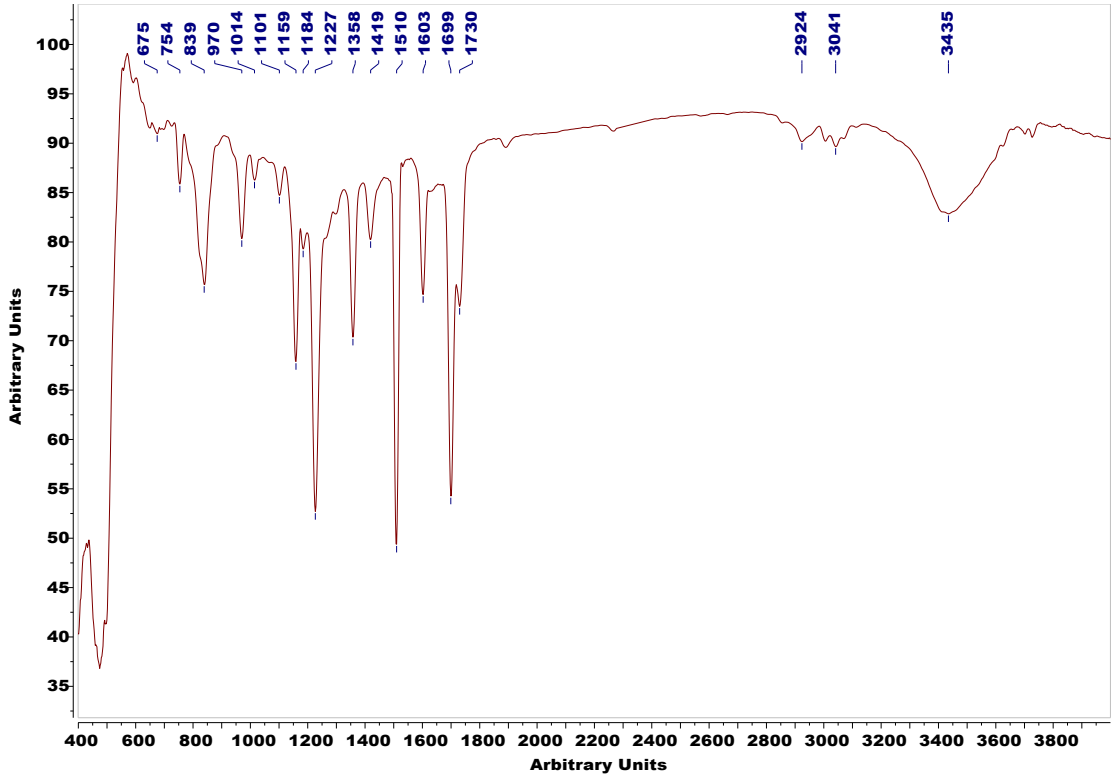
3ae

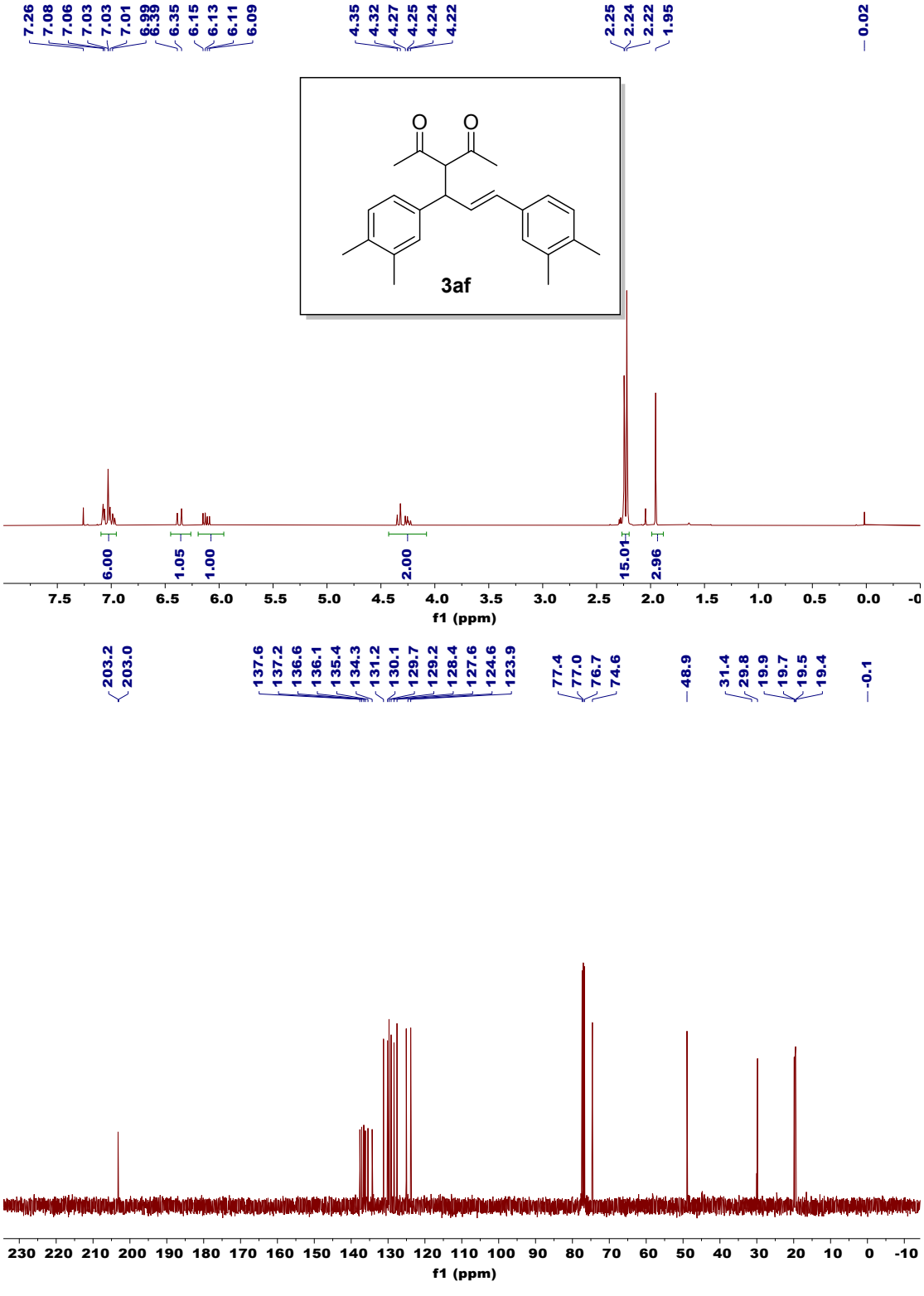

4.09
4.02
1.02
1.01
2.04
3.00
3.04
f1 (ppm)

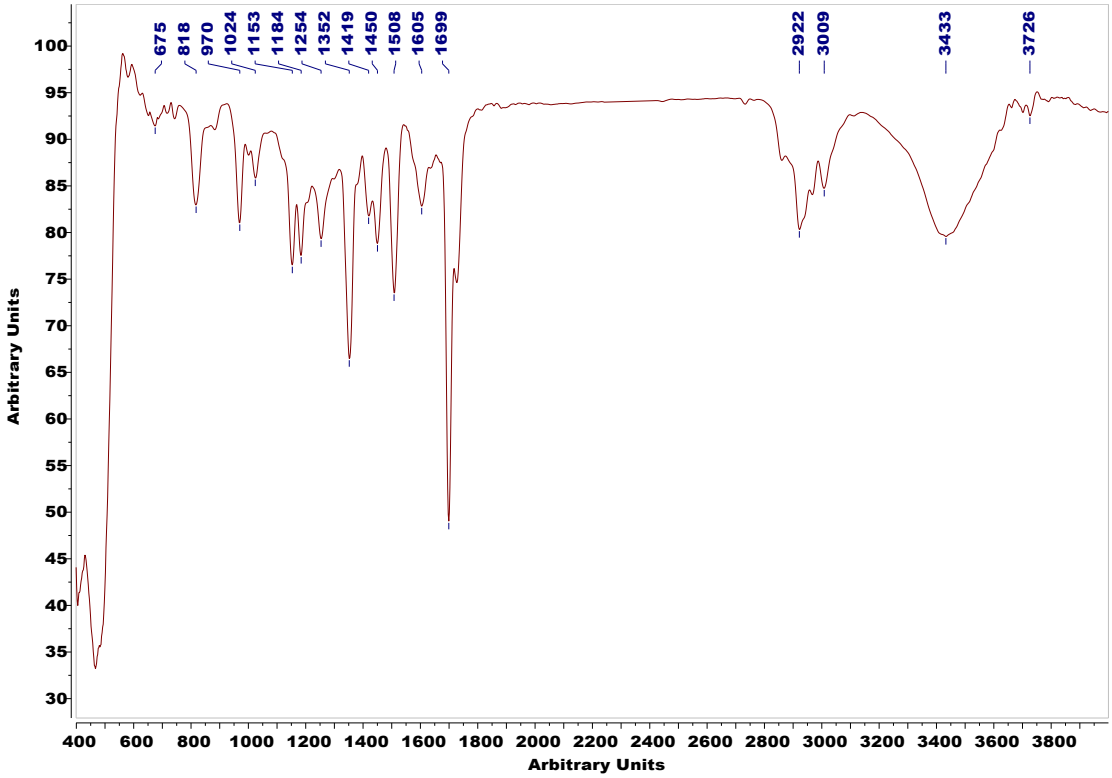

202.5
202.3
163.6
163.0
161.1
160.6
135.9
135.8
132.6
132.6
130.6
129.5
129.4
128.8
128.8
127.9
127.9
116.0
115.8
115.6
115.3
77.4
77.1
76.8
74.5
48.1
30.0
29.7


f1 (ppm)

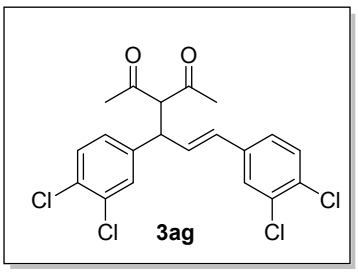

-114.0
-114.9
-75
-80
-85
-90
-95
-100
-105
-110
-115
-120
-125
-130
-135
-140
-145
-150
-155
f1 (ppm)

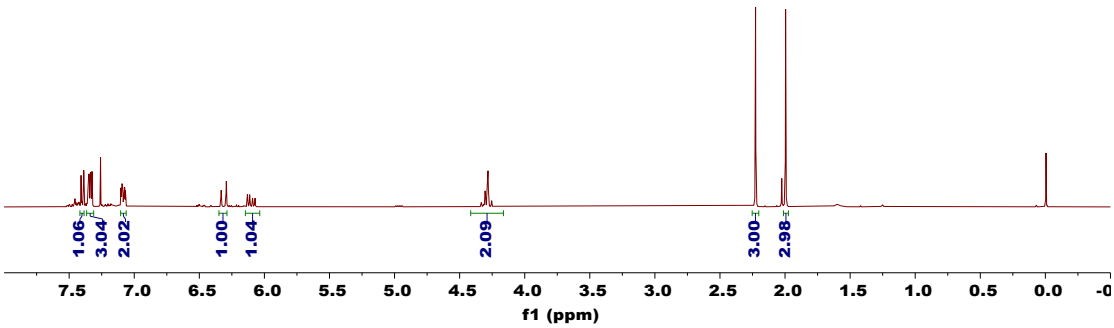

675
754
839
970
1014
1101
1159
1184
1227
1358
1419
1510
1603
1699
1730
2924
3041
3435
Arbitrary Units
Arbitrary Units

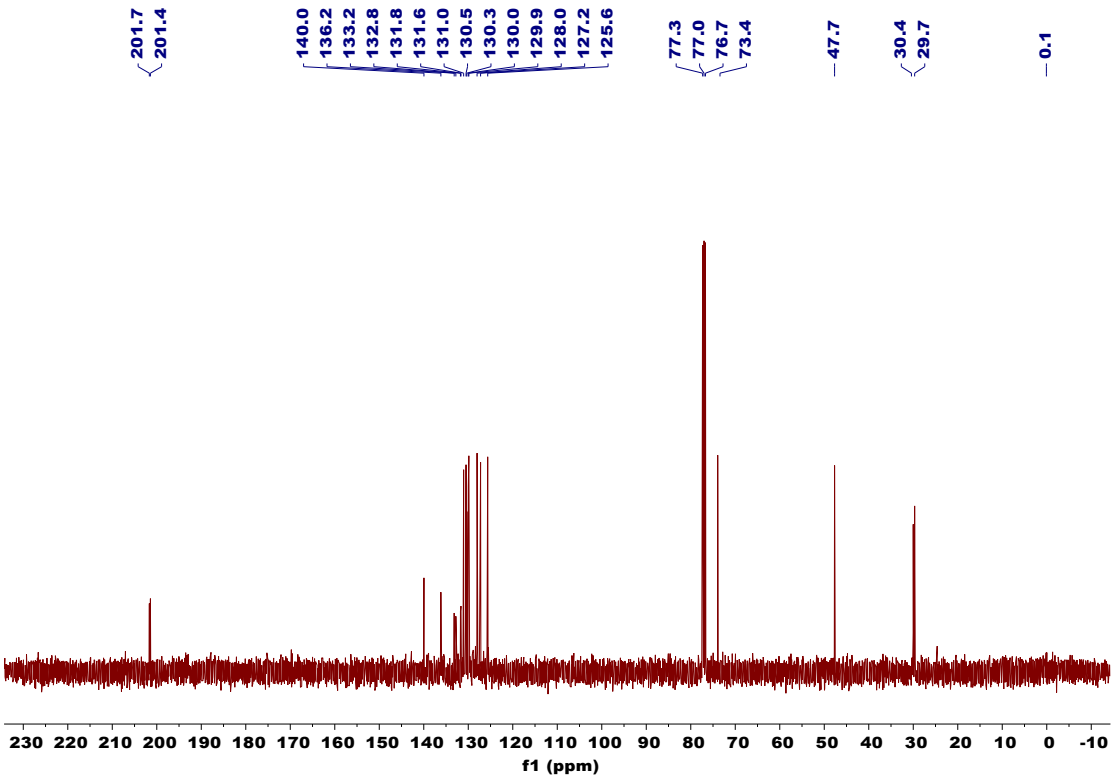

7.26
7.08
7.06
7.03
7.03
7.01
6.39
6.35
6.15
6.13
6.11
6.09
4.35
4.32
4.27
4.25
4.24
4.22
2.25
2.24
2.22
1.95
0.02
O
O
3af
6.00
1.05
1.00
2.00
15.01
2.96
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)
203.2
203.0
137.6
137.2
136.6
136.1
135.4
134.3
131.2
130.1
129.7
129.2
128.4
127.6
124.6
123.9
77.4
77.0
76.7
74.6
48.9
31.4
29.8
19.9
19.7
19.5
19.4
-0.1
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

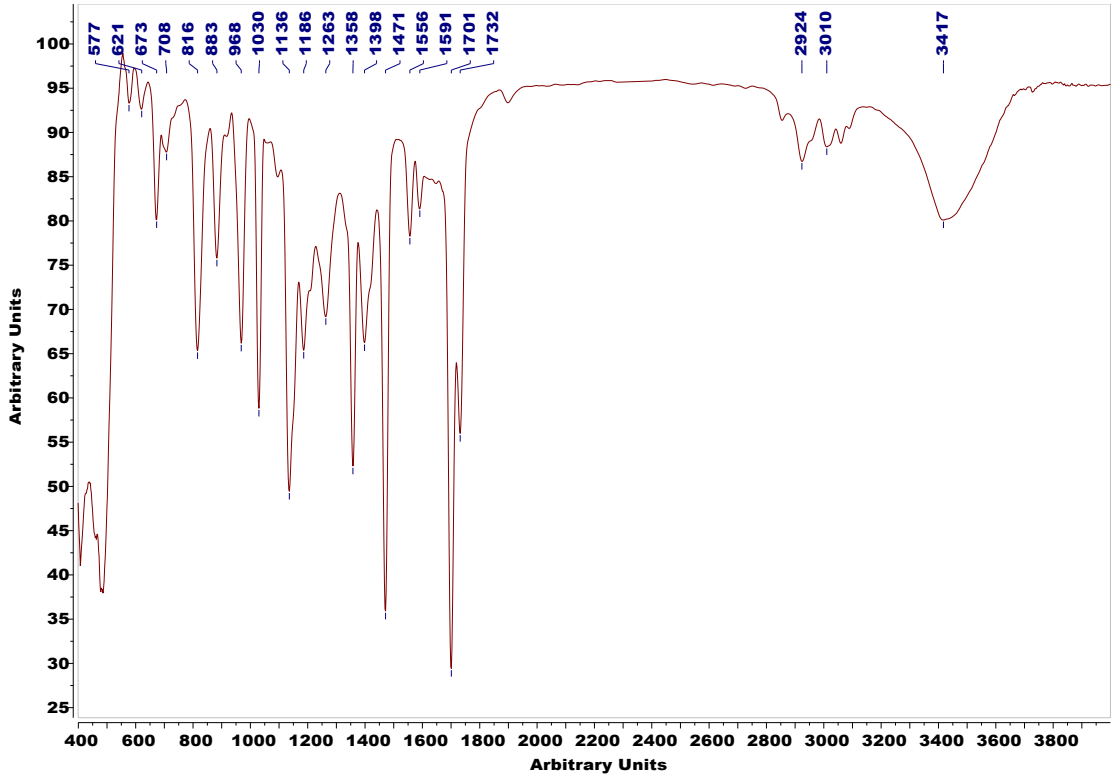

675
818
970
1024
1153
1184
1254
1352
1419
1450
1508
1605
1699
2922
3009
3433
3726
Arbitrary Units
Arbitrary Units

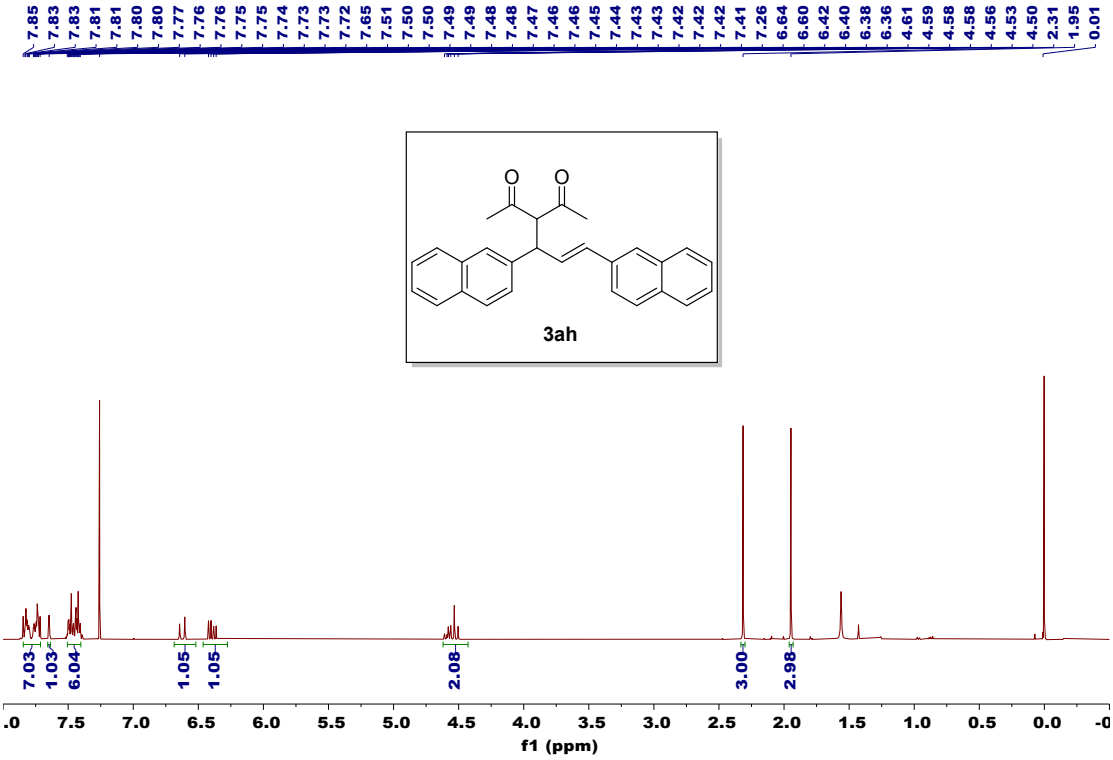

7.39
7.36
7.35
7.35
7.34
7.33
7.32
7.10
7.10
7.09
7.09
7.08
7.08
7.07
7.07
6.33
6.29
6.13
6.13
6.11
6.11
6.09
6.09
6.08
6.07
6.07
4.33
4.32
4.31
4.30
4.29
4.28
4.25
2.23
2.00
1.99
-0.00

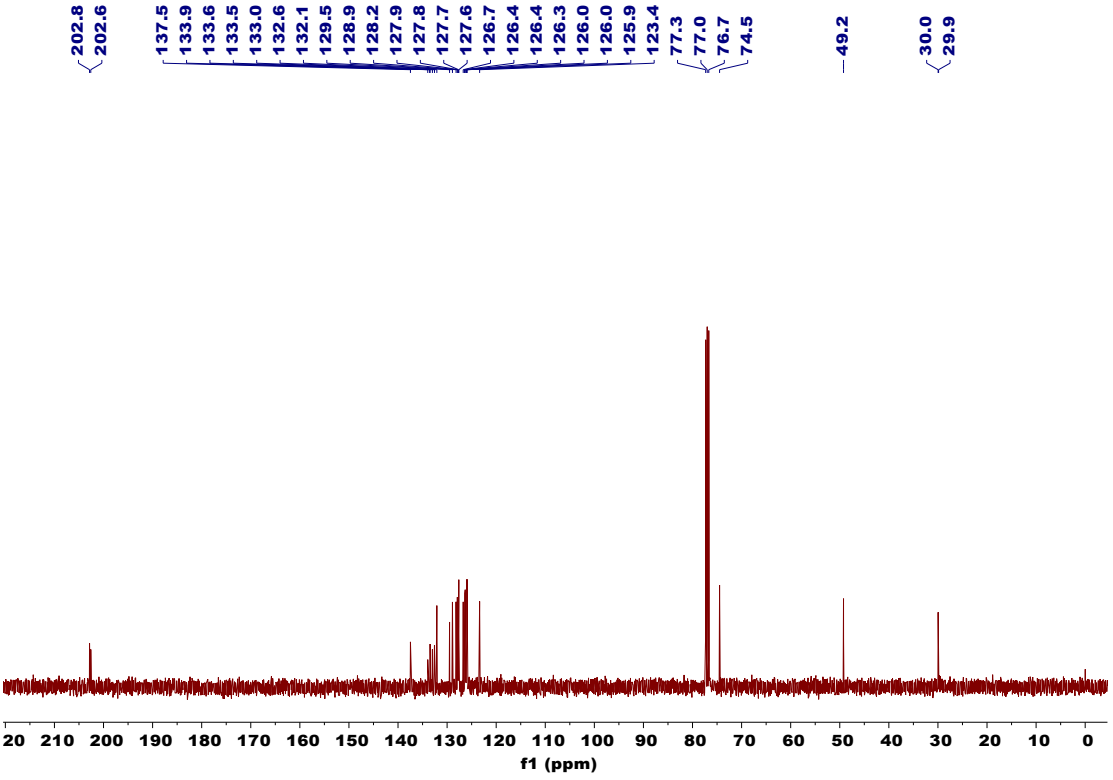

O
O
Cl
Cl
Cl
Cl
3ag

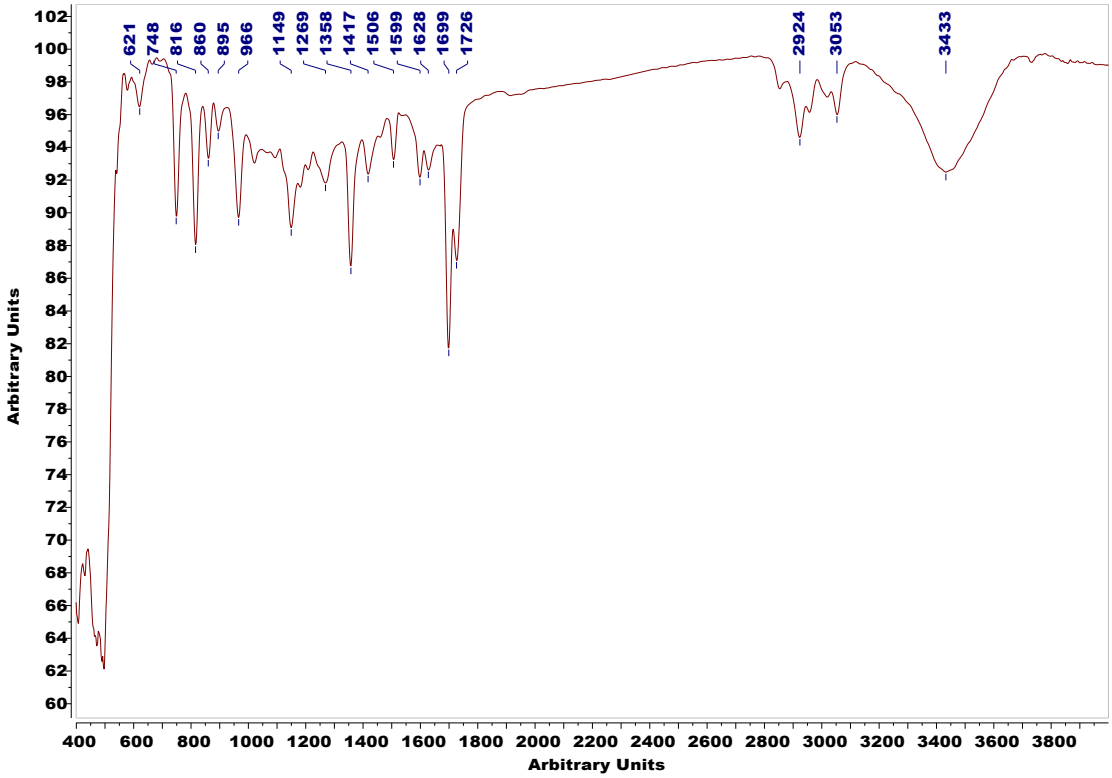

1.06
3.04
2.02
1.00
1.04
2.09
3.00
2.98
f1 (ppm)


201.7
201.4
140.0
136.2
133.2
132.8
131.8
131.6
131.0
130.5
130.3
130.0
129.9
128.0
127.2
125.6
77.3
77.0
76.7
73.4
47.7
30.4
29.7
0.1
f1 (ppm)

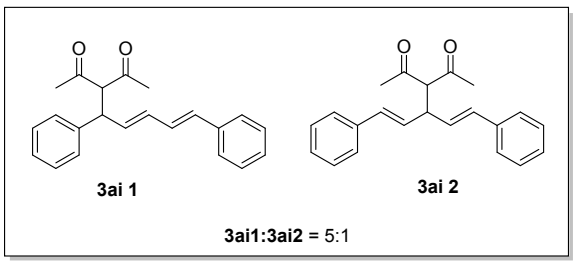

577
621
673
708
816
883
968
1030
1136
1186
1263
1358
1398
1471
1556
1591
1701
1732
2924
3010
3417
Arbitrary Units
Arbitrary Units


7.85 7.83 7.83 7.81 7.81 7.80 7.80 7.77 7.76 7.76 7.75 7.75 7.74 7.73 7.73 7.72 7.65 7.51 7.50 7.50 7.49 7.49 7.48 7.48 7.47 7.46 7.46 7.45 7.44 7.43 7.43 7.42 7.42 7.42 7.41 7.26 6.64 6.60 6.42 6.40 6.38 6.36 4.61 4.59 4.58 4.58 4.56 4.53 4.50 2.31 1.95 0.01
O
O
3ah
7.03 1.03 6.04 1.05 1.05 2.08 3.00 2.98
.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 -0
f1 (ppm)


202.8 202.6 137.5 133.9 133.6 133.5 133.0 132.6 132.1 129.5 128.9 128.2 127.9 127.8 127.7 127.6 126.7 126.4 126.4 126.3 126.0 126.0 125.9 123.4 77.3 77.0 76.7 74.5 49.2 30.0 29.9
20 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


621
748
816
860
895
966
1149
1269
1358
1417
1506
1599
1628
1699
1726
2924
3053
3433
Arbitrary Units
Arbitrary Units


7.37
7.36
7.35
7.34
7.33
7.32
7.31
7.29
7.27
7.27
7.25
7.25
7.23
6.71
6.68
6.67
6.64
6.55
6.52
6.51
6.48
6.27
6.25
6.23
6.21
6.13
6.11
6.09
6.08
5.85
5.83
5.81
5.80
4.34
4.31
4.29
4.26
4.03
4.00
3.98
3.96
2.28
2.23
1.94
0.03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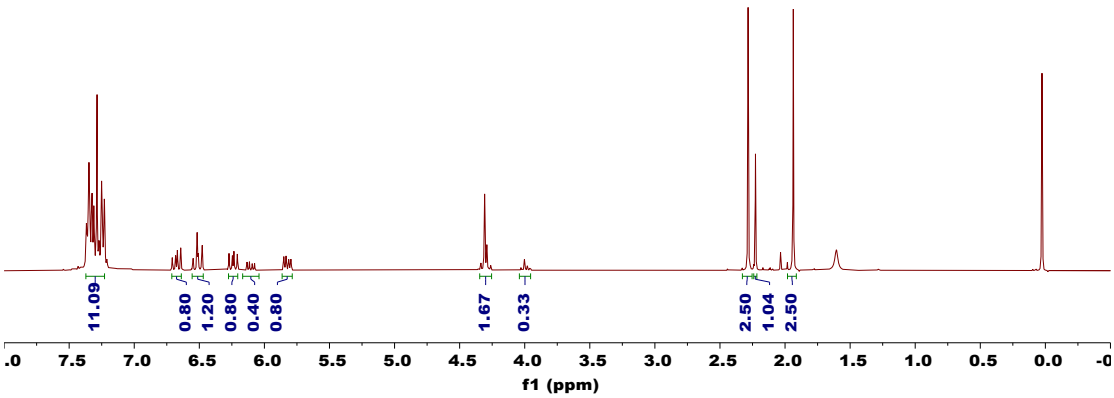
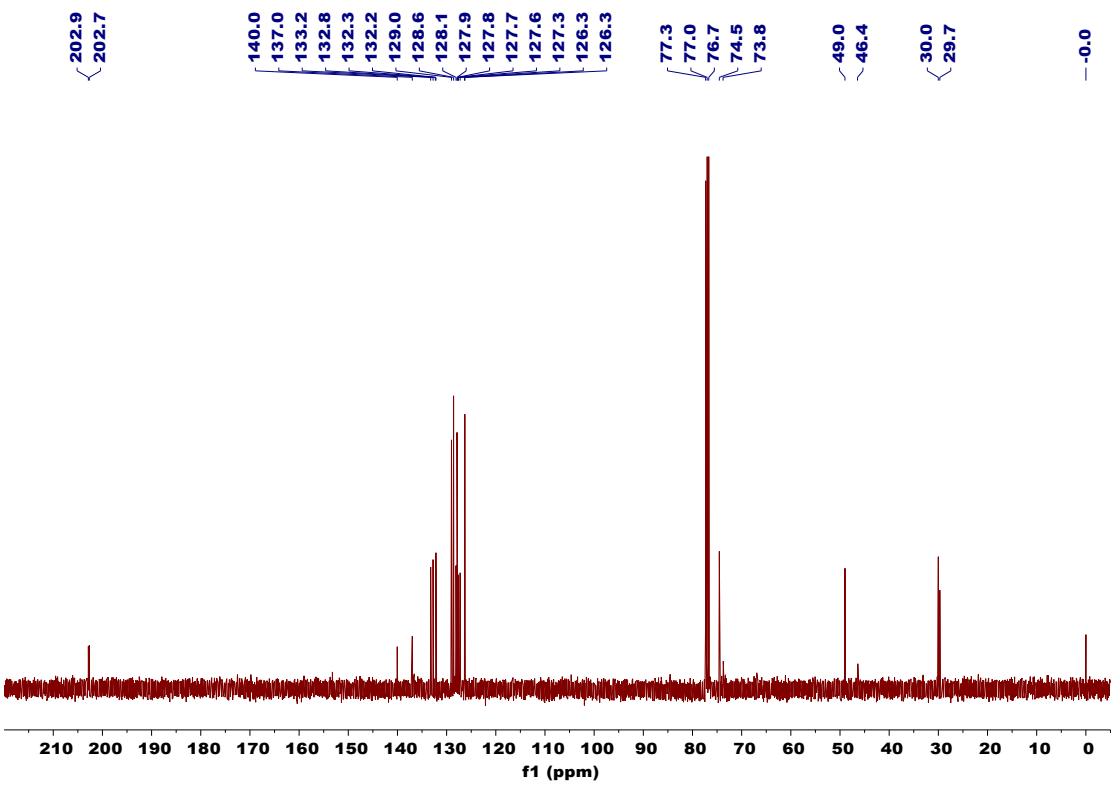
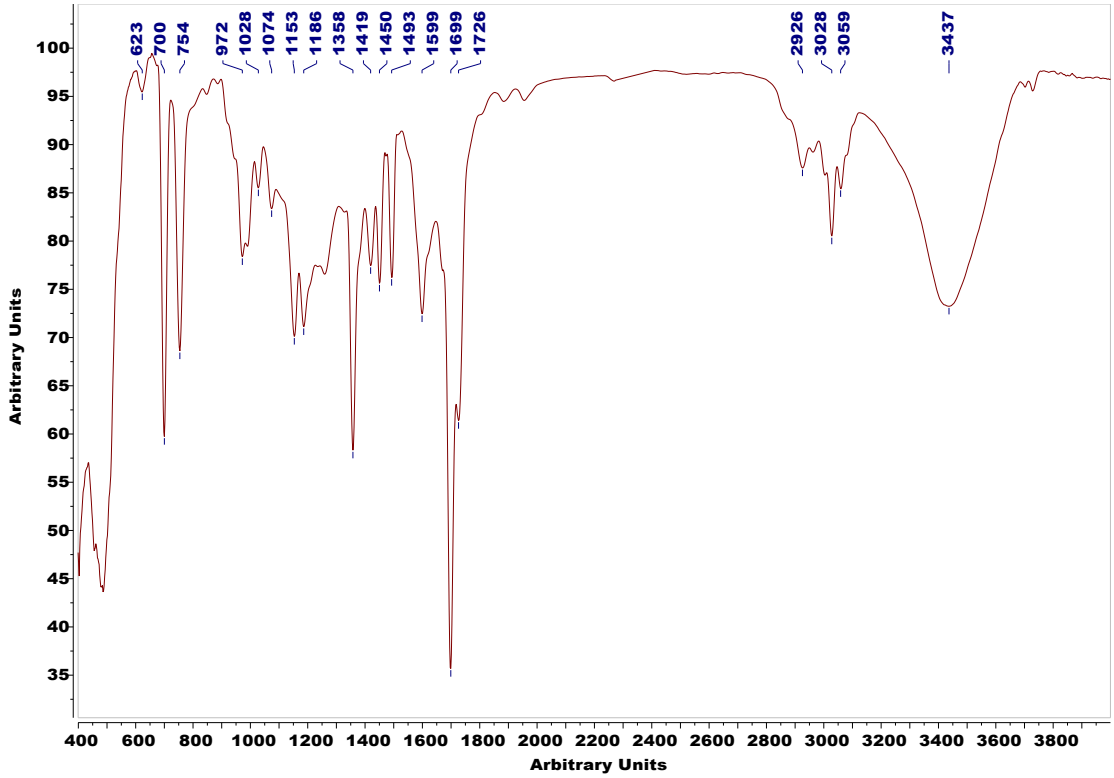
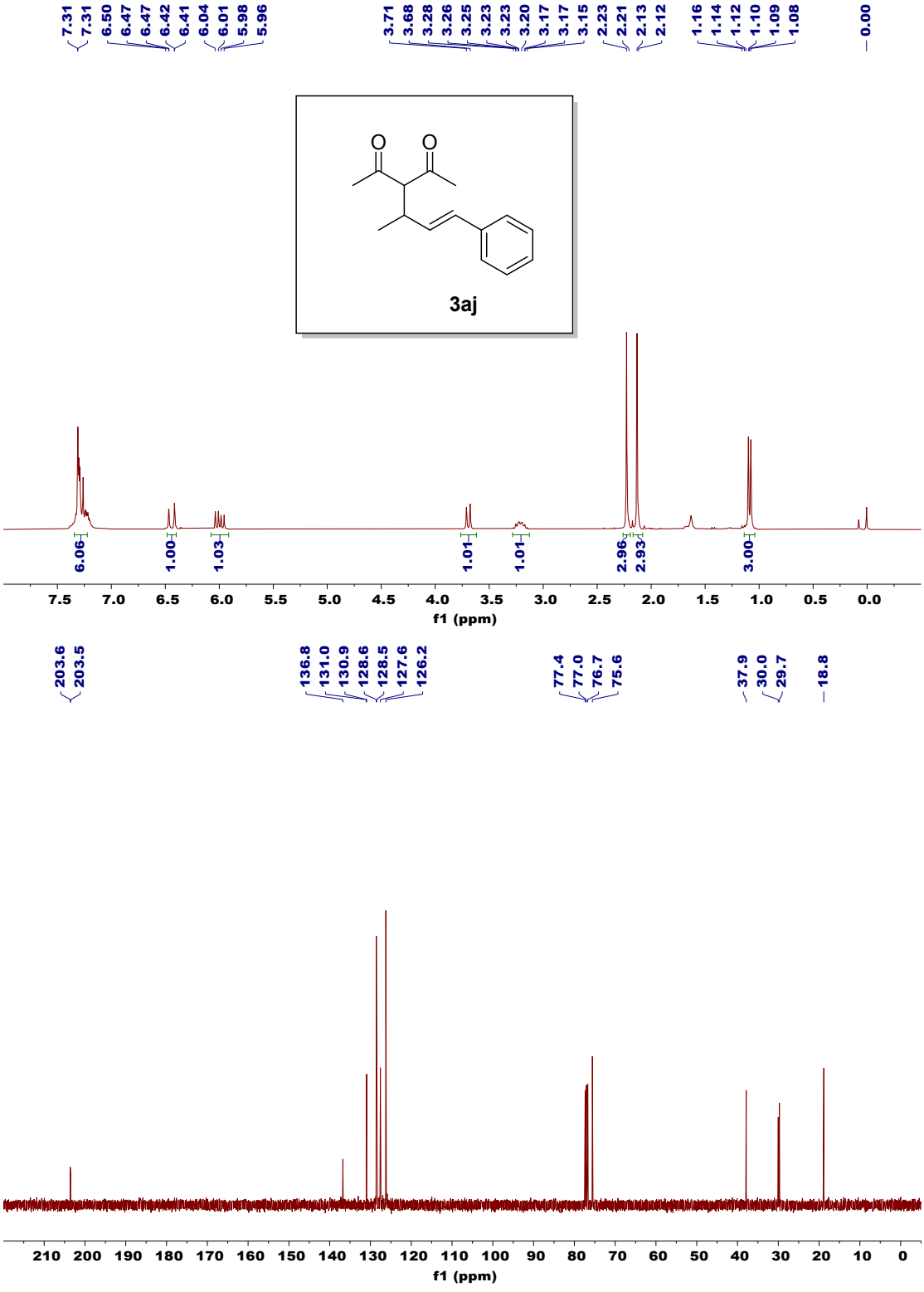
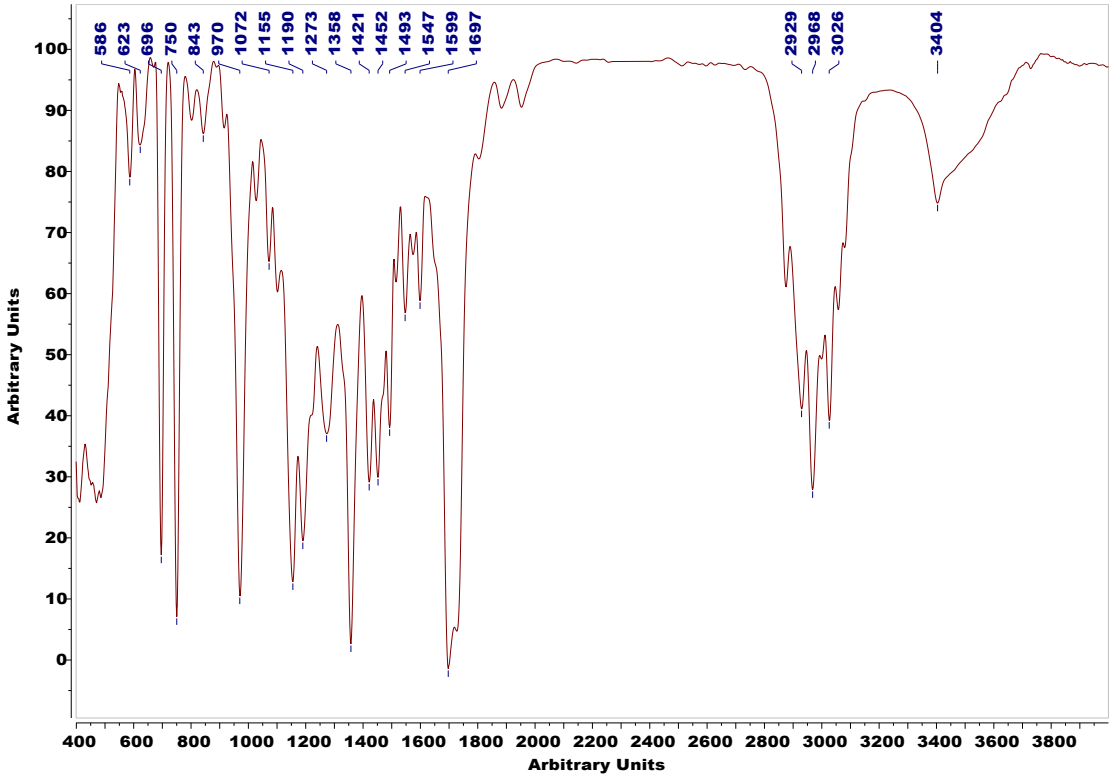
3ai 2
3ai1:3ai2 = 5:1

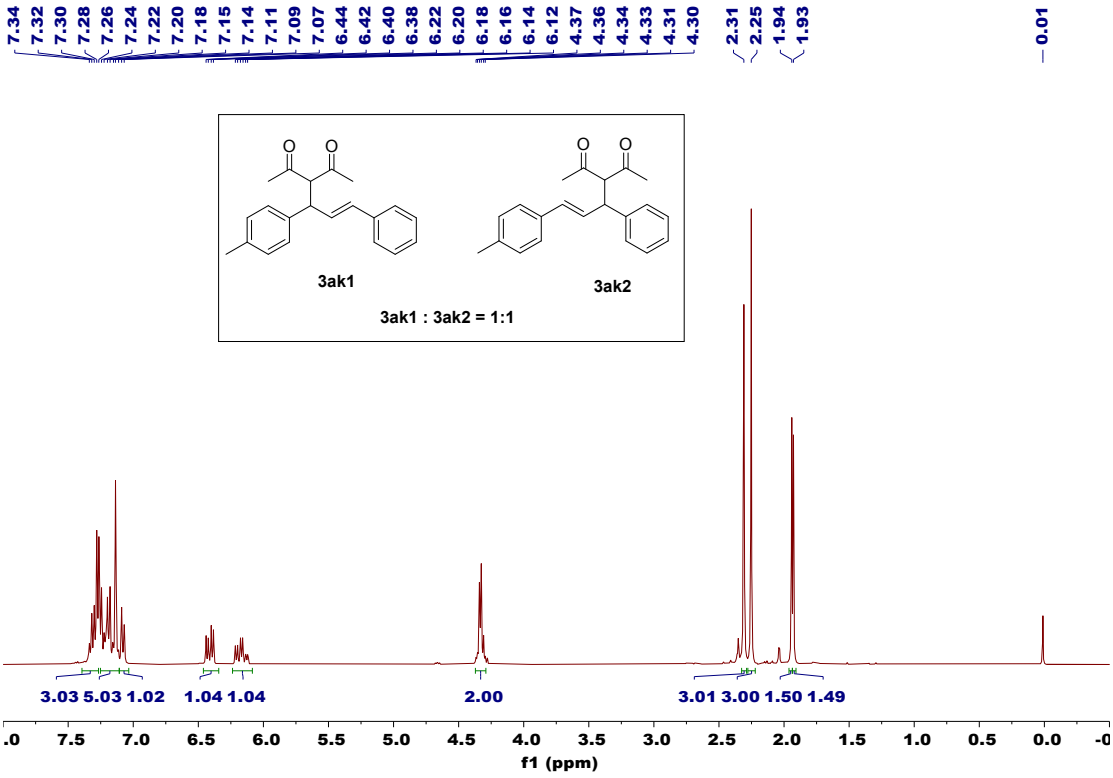

11.09
0.80
1.20
0.80
0.40
0.80
1.67
0.33
2.50
1.04
2.50
f1 (ppm)


202.9
202.7
140.0
137.0
133.2
132.8
132.3
132.2
129.0
128.6
128.1
127.9
127.8
127.7
127.6
127.3
126.3
126.3
77.3
77.0
76.7
74.5
73.8
49.0
46.4
30.0
29.7
-0.0
f1 (ppm)

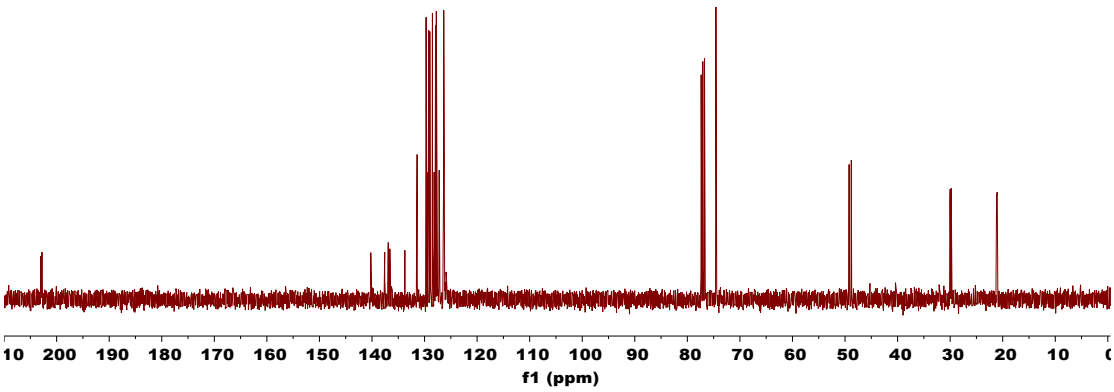

623
700
754
972
1028
1074
1153
1186
1358
1419
1450
1493
1599
1699
1726
2926
3028
3059
3437
Arbitrary Units
Arbitrary Units

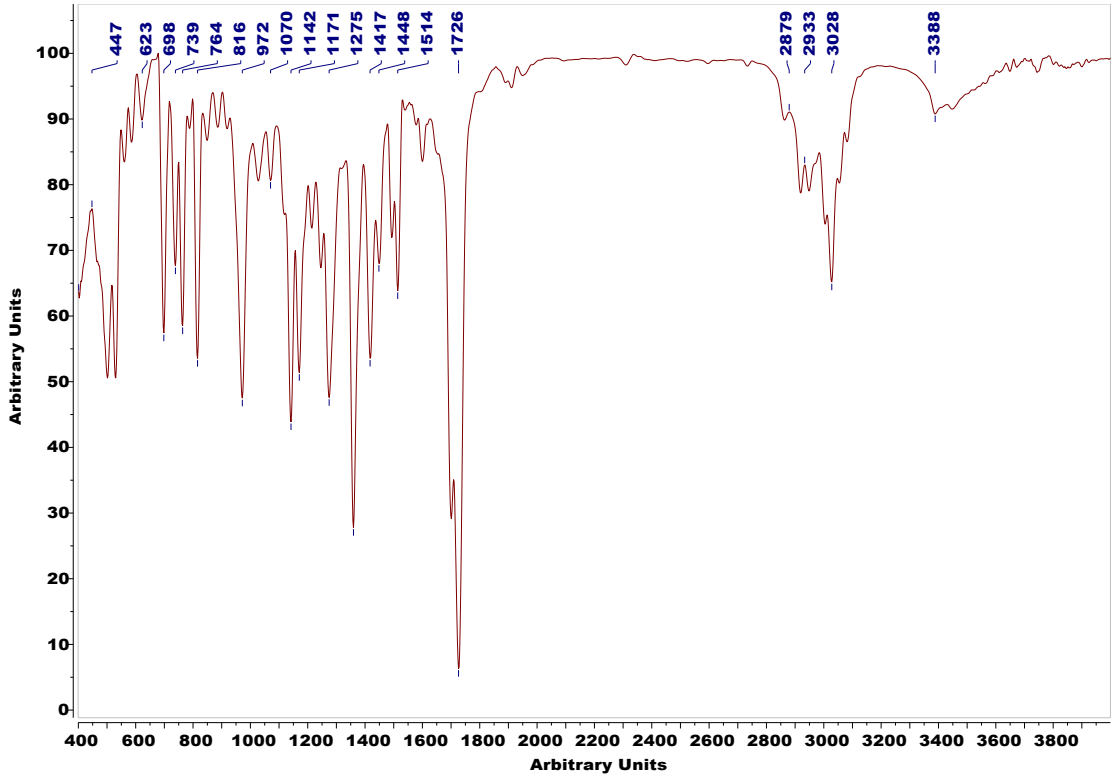

7.31
7.31
6.50
6.47
6.47
6.42
6.41
6.04
6.01
5.98
5.96
3.71
3.68
3.28
3.26
3.25
3.23
3.23
3.20
3.17
3.17
3.15
2.23
2.21
2.13
2.12
1.16
1.14
1.12
1.10
1.09
1.08
0.00
O
O
3aj
6.06
1.00
1.03
1.01
1.01
2.96
2.93
3.00
7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)
203.6
203.5
136.8
131.0
130.9
128.6
128.5
127.6
126.2
77.4
77.0
76.7
75.6
37.9
30.0
29.7
18.8
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


586
623
696
750
843
970
1072
1155
1190
1273
1358
1421
1452
1493
1547
1599
1697
2929
2968
3026
3404
Arbitrary Units
Arbitrary Units

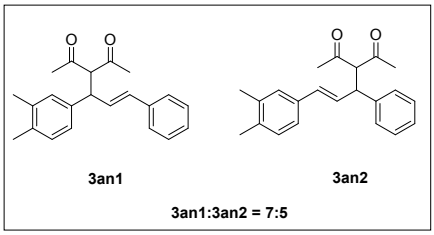

7.34
7.32
7.30
7.28
7.26
7.24
7.22
7.20
7.18
7.15
7.14
7.11
7.09
7.07
6.44
6.42
6.40
6.38
6.22
6.20
6.18
6.16
6.14
6.12
4.37
4.36
4.34
4.33
4.31
4.30
2.31
2.25
1.94
1.93
0.01
3ak1
3ak2
3ak1 : 3ak2 = 1:1
3.03 5.03 1.02
1.04 1.04
2.00
3.01 3.00 1.50 1.49
f1 (ppm)

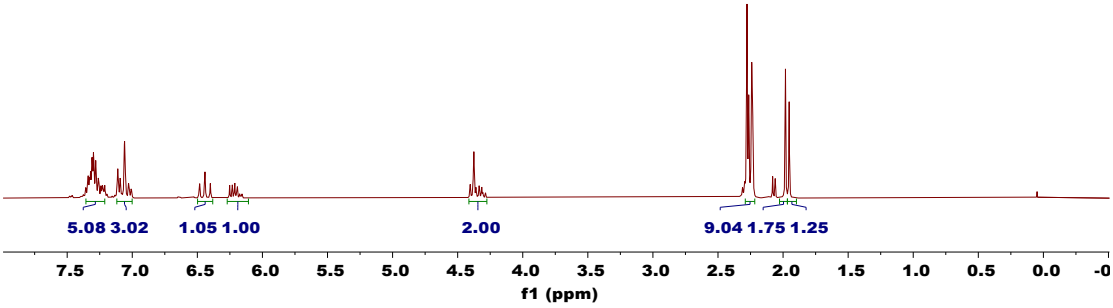

203.0
203.0
202.8
202.8
140.2
137.6
137.0
136.9
136.6
133.7
131.5
131.4
129.7
129.5
129.2
129.0
128.5
128.4
128.2
127.9
127.8
127.7
127.2
126.3
126.3
125.9
77.4
77.1
76.7
74.6
49.2
48.8
30.1
30.0
29.8
29.8
21.2
21.0


10 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
f1 (ppm)

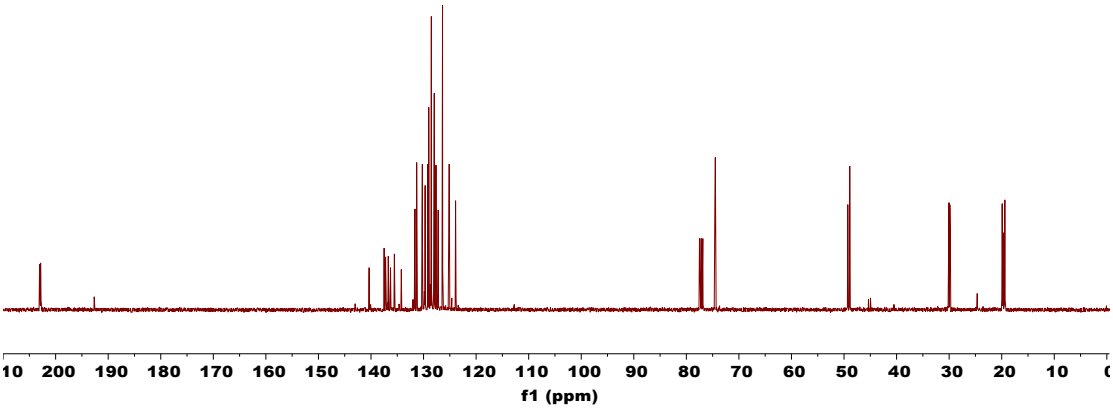

447
623
698
739
764
816
972
1070
1142
1171
1275
1417
1448
1514
1726
2879
2933
3028
3388
Arbitrary Units
100
90
80
70
60
50
40
30
20
10
0
400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 2800 3000 3200 3400 3600 3800
Arbitrary Units

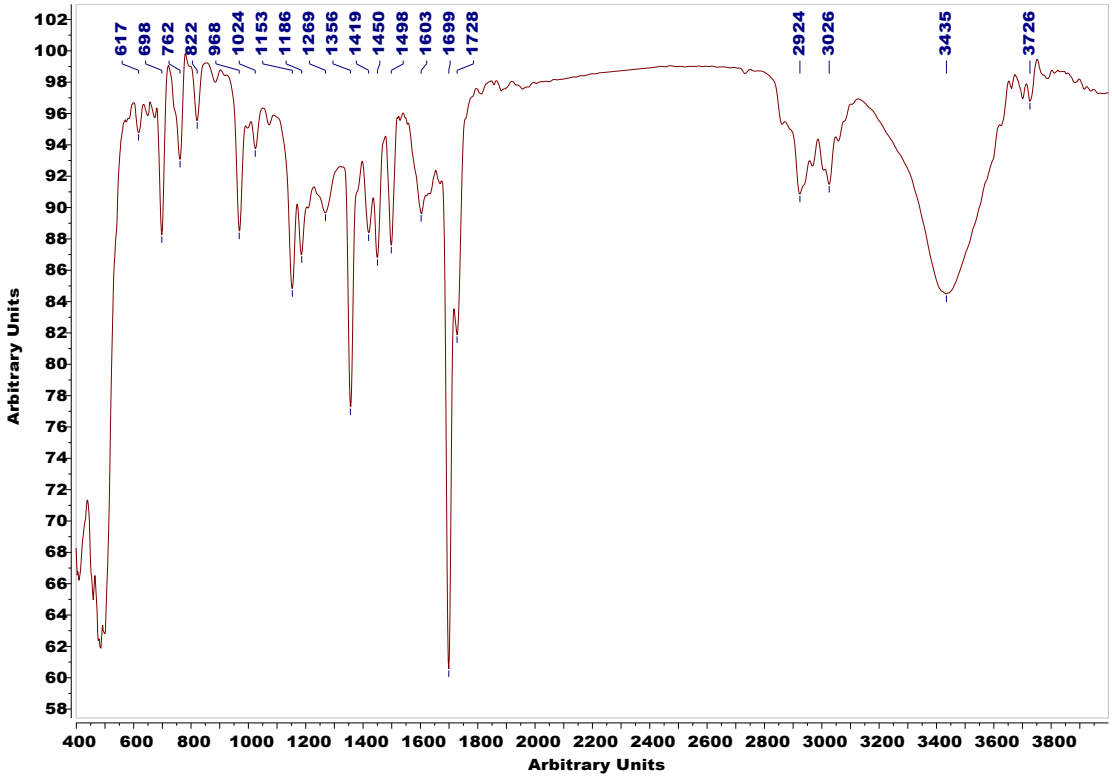

7.34 7.33 7.32 7.31 7.30 7.29 7.28 7.26 7.26 7.24 7.23 7.21 7.11 7.09 7.06 7.03 7.01 6.48 6.44 6.40 6.25 6.23 6.21 6.20 6.17 6.16 4.40 4.38 4.36 4.33 4.32 4.31 4.29 2.28 2.26 2.24 2.23 1.98 1.95
0.05


3an1
3an2
3an1:3an2 = 7:5

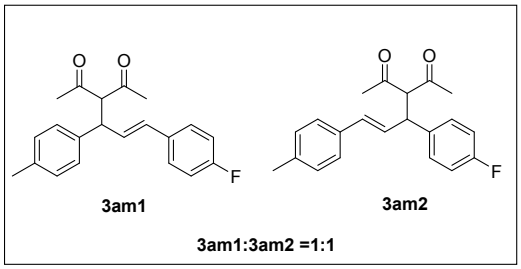

5.08 3.02
1.05 1.00
2.00
9.04 1.75 1.25
7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

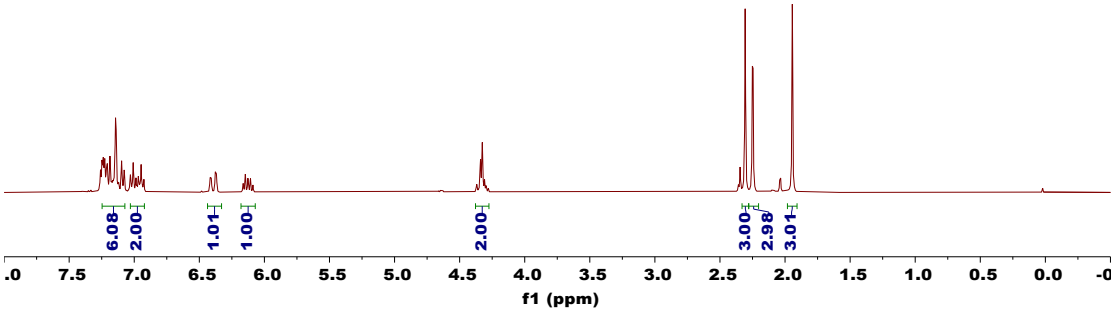

203.1 202.9 202.9 202.8 140.4 137.5 137.2 136.7 136.7 136.3 135.6 134.2 131.6 131.3 130.2 129.8 129.7 129.2 129.0 128.5 128.1 128.0 127.6 127.6 127.2 126.4 125.1 123.9 77.5 77.2 76.9 74.6 74.5 49.3 48.2 30.1 30.0 29.9 29.8 19.9 19.7 19.5 19.3

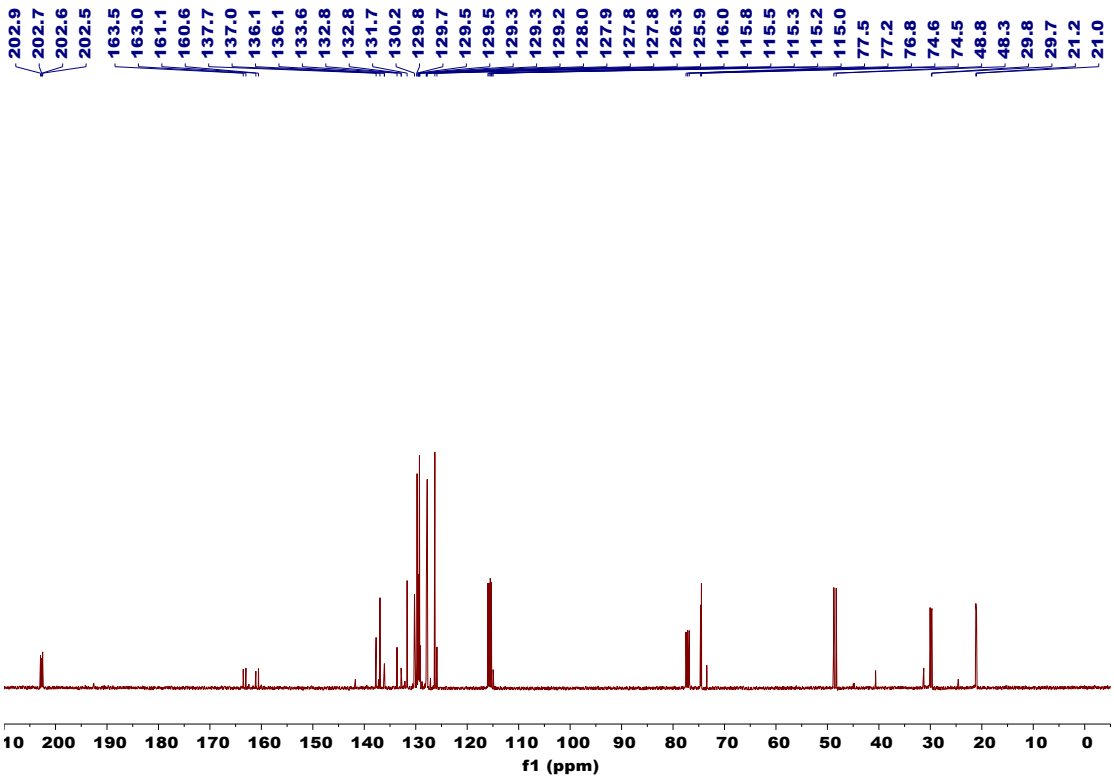

10 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
f1 (ppm)

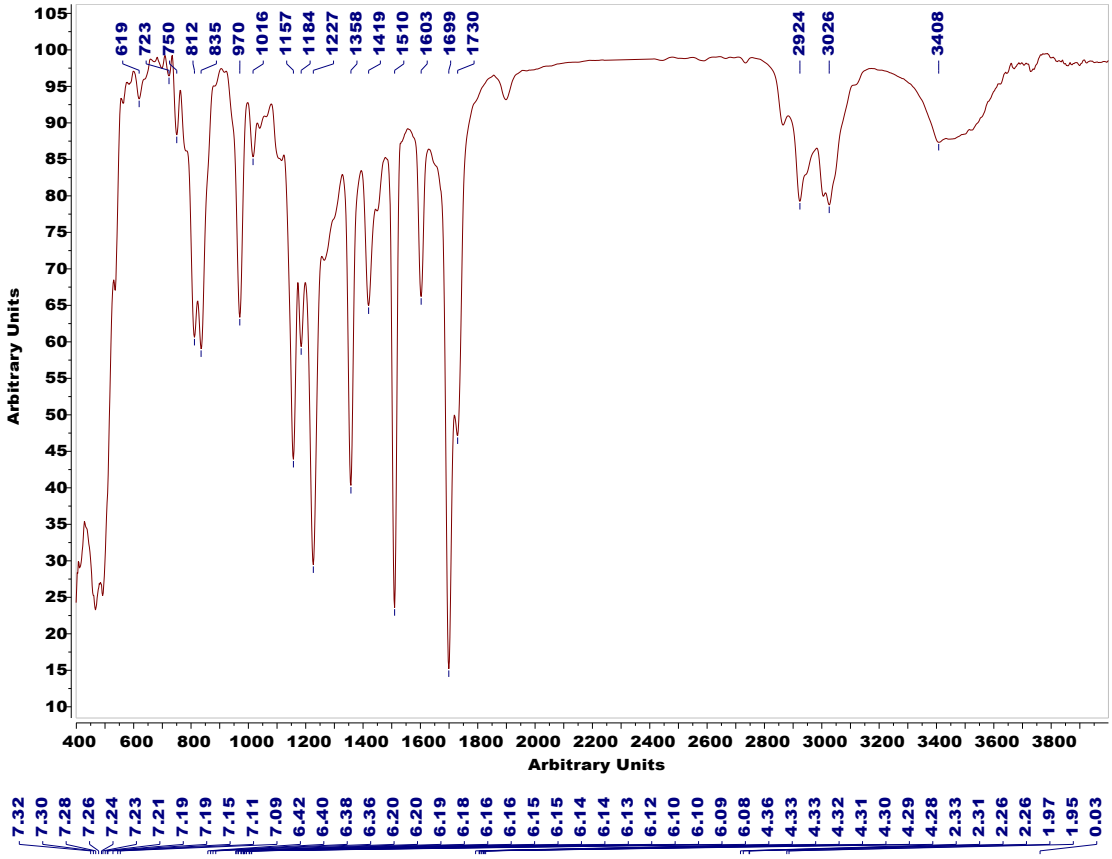

617
698
762
822
968
1024
1153
1186
1269
1356
1419
1450
1498
1603
1699
1728
2924
3026
3435
3726
Arbitrary Units
Arbitrary Units


7.26
7.25
7.24
7.23
7.21
7.21
7.19
7.14
7.12
7.10
7.08
7.03
7.01
6.99
6.97
6.94
6.92
6.42
6.41
6.38
6.37
6.16
6.15
6.13
6.11
6.09
4.37
4.34
4.33
4.31
4.30
4.28
2.31
2.25
2.25
1.94
0.02

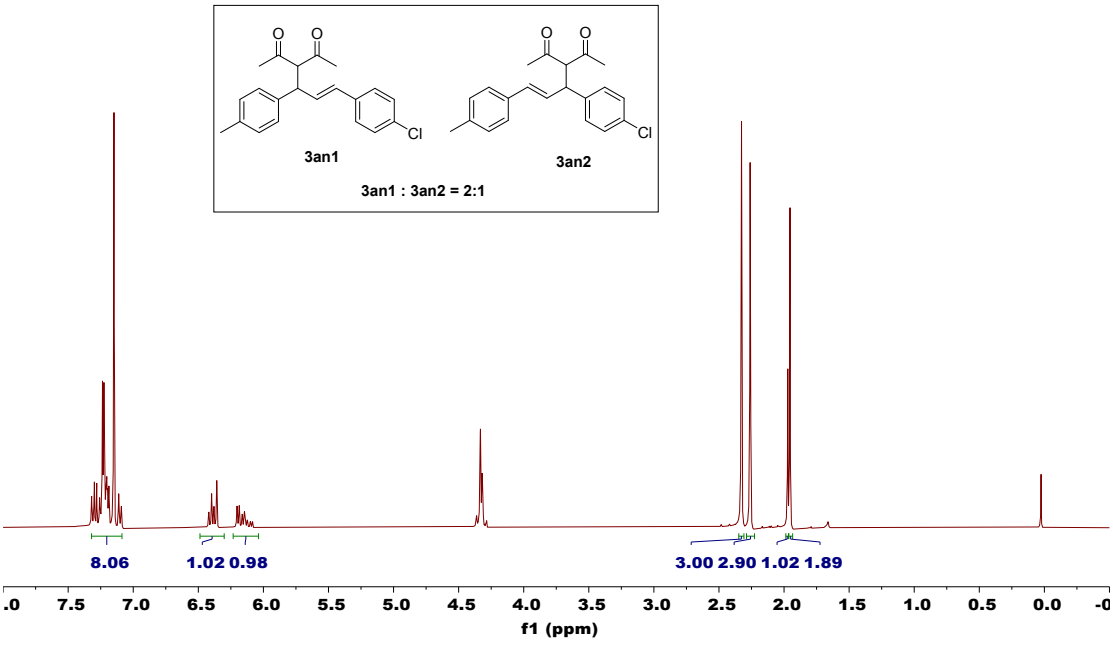

O
O
F
3am1
O
O
F
3am2
3am1:3am2 =1:1

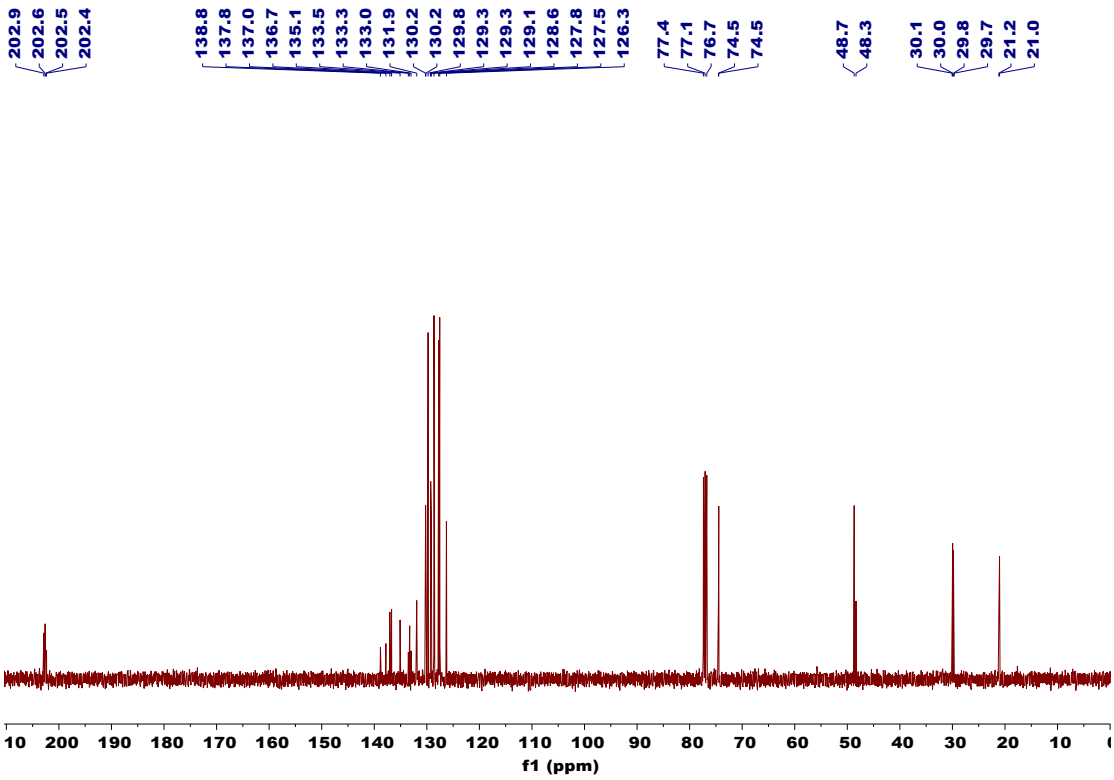

6.08
2.00
1.01
1.00
2.00
3.00
2.98
3.01
f1 (ppm)

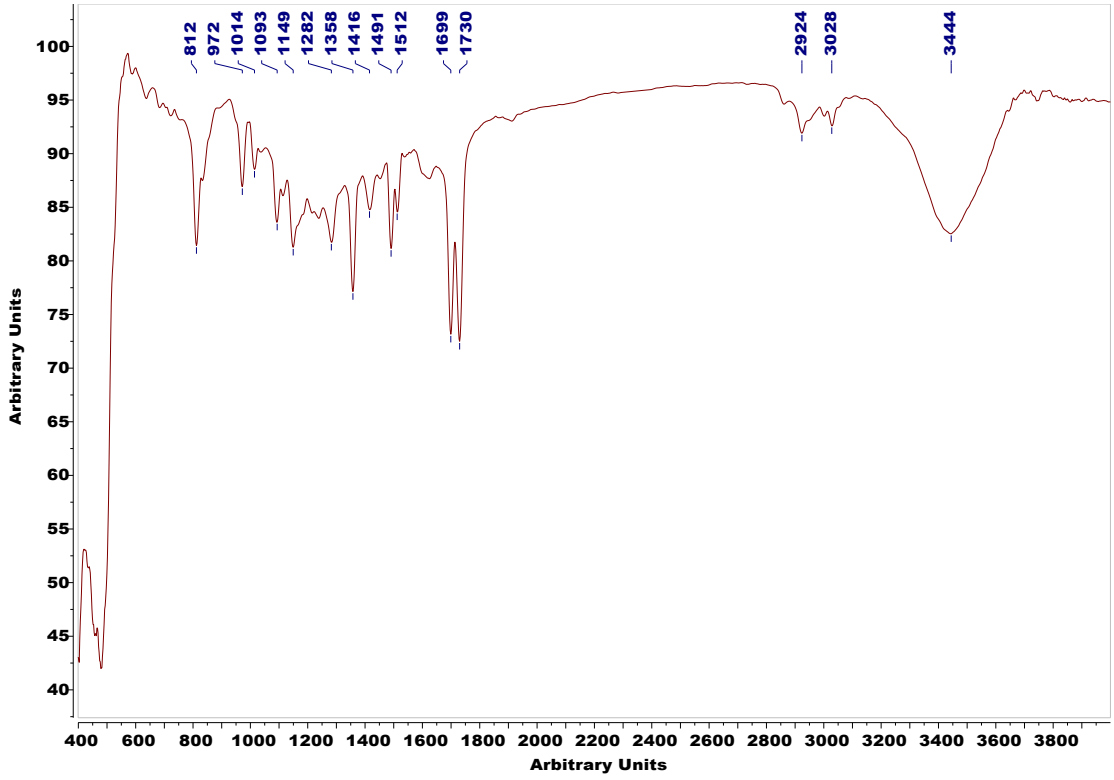

202.9
202.7
202.6
202.5
163.5
163.0
161.1
160.6
137.7
137.0
136.1
136.1
133.6
132.8
132.8
131.7
130.2
129.8
129.7
129.5
129.5
129.3
129.3
129.2
128.0
127.9
127.8
127.8
126.3
125.9
116.0
115.8
115.5
115.3
115.2
115.0
77.5
77.2
76.8
74.6
74.5
48.8
48.3
29.8
29.7
21.2
21.0
10 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)
-114.2
-115.0
-85 -90 -95 -100 -105 -110 -115 -120 -125 -130 -135 -1
f1 (ppm)

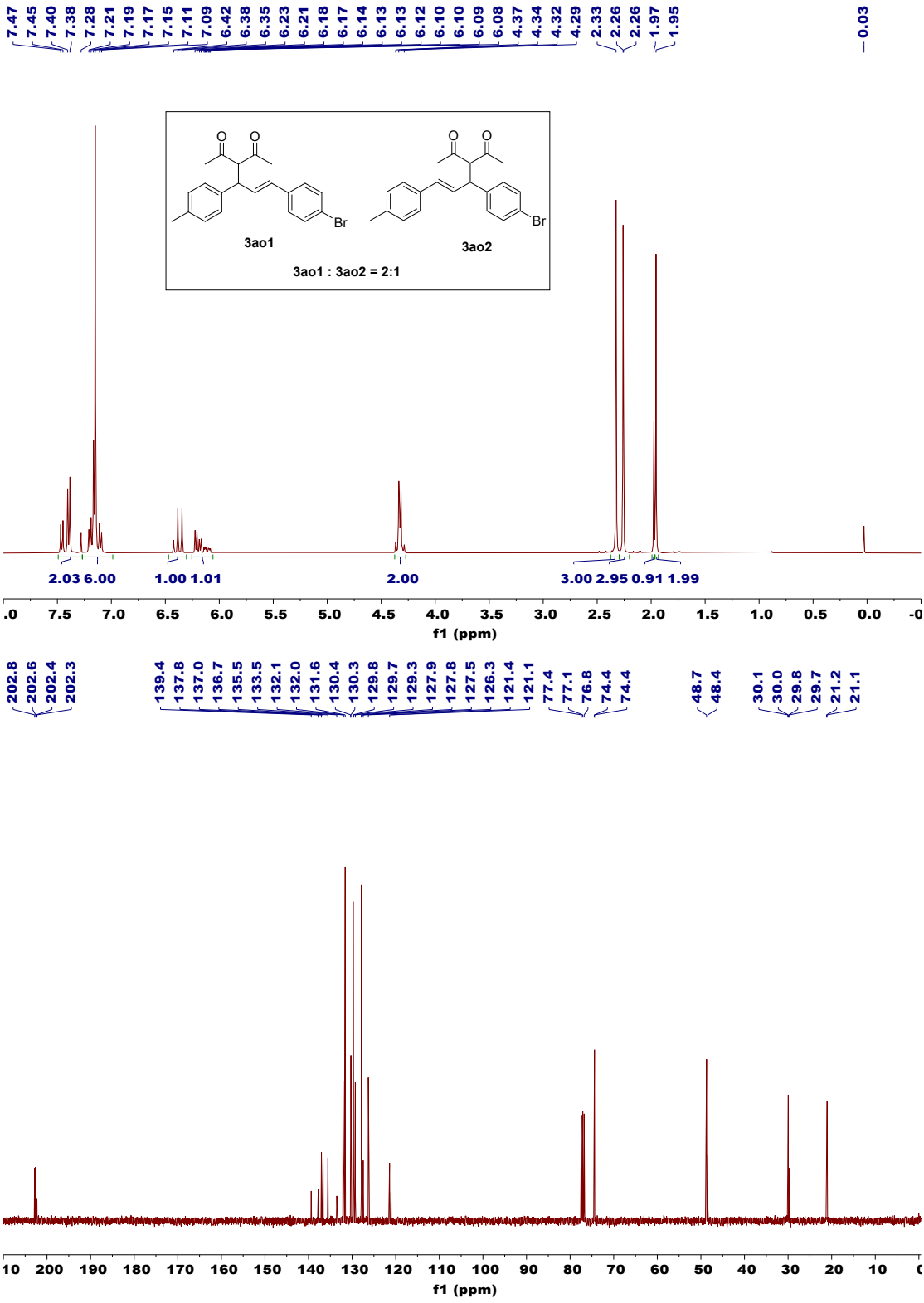

Arbitrary Units
619
723
750
812
835
970
1016
1157
1184
1227
1358
1419
1510
1603
1699
1730
2924
3026
3408
Arbitrary Units

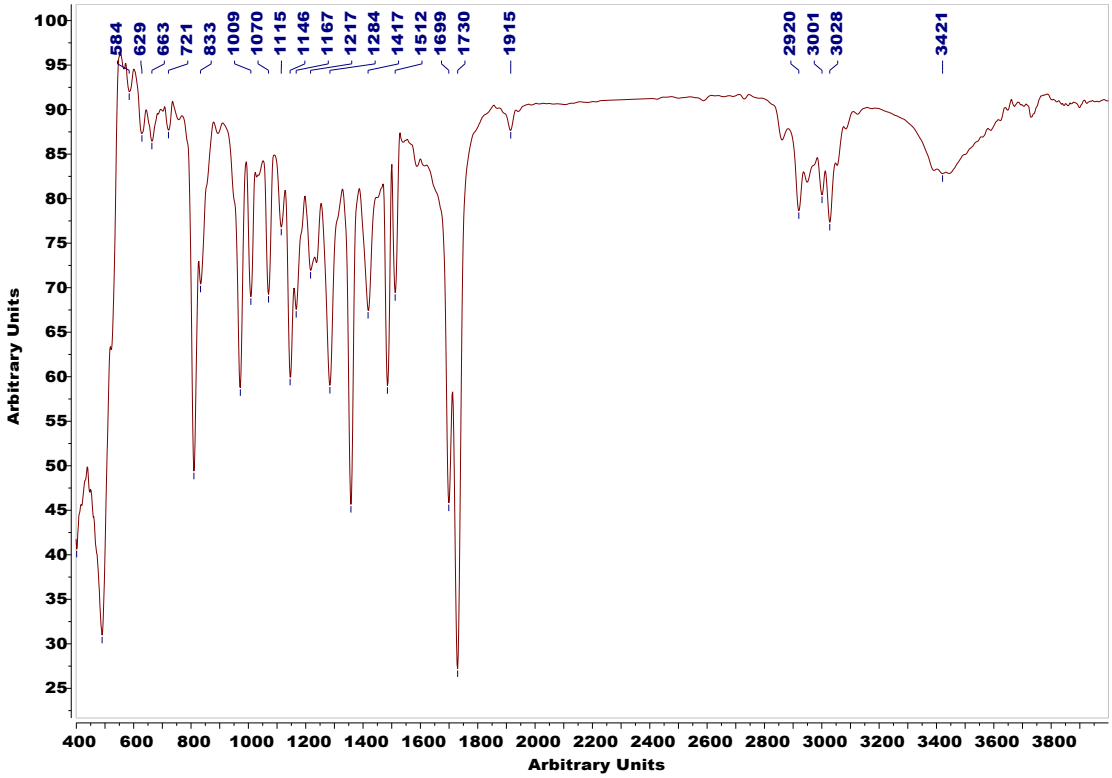
7.32 7.30 7.28 7.26 7.24 7.23 7.21 7.19 7.19 7.15 7.11 7.09 6.42 6.40 6.38 6.36 6.20 6.20 6.19 6.18 6.16 6.16 6.15 6.15 6.14 6.14 6.13 6.12 6.10 6.10 6.09 6.08 4.36 4.33 4.33 4.32 4.31 4.30 4.29 4.28 2.33 2.31 2.26 2.26 1.97 1.95 0.03


3an1
3an2
3an1 : 3an2 = 2:1
8.06
1.02 0.98
3.00 2.90 1.02 1.89
f1 (ppm)

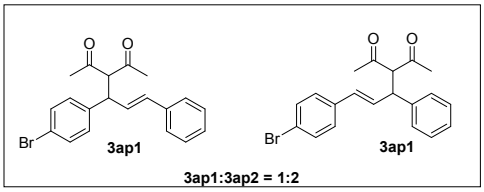

202.9
202.6
202.5
202.4
138.8
137.8
137.0
136.7
135.1
133.5
133.3
133.0
131.9
130.2
130.2
129.8
129.3
129.3
129.1
128.6
127.8
127.5
126.3
77.4
77.1
76.7
74.5
74.5
48.7
48.3
30.1
30.0
29.8
29.7
21.2
21.0
10 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
f1 (ppm)

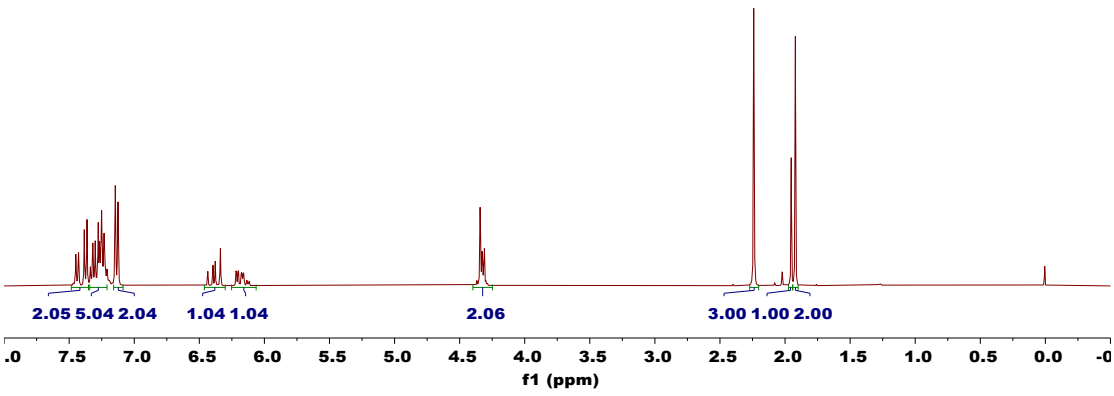

812
972
1014
1093
1149
1282
1358
1416
1491
1512
1699
1730
2924
3028
3444
Arbitrary Units
100 95 90 85 80 75 70 65 60 55 50 45 40
400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 2800 3000 3200 3400 3600 3800
Arbitrary Units

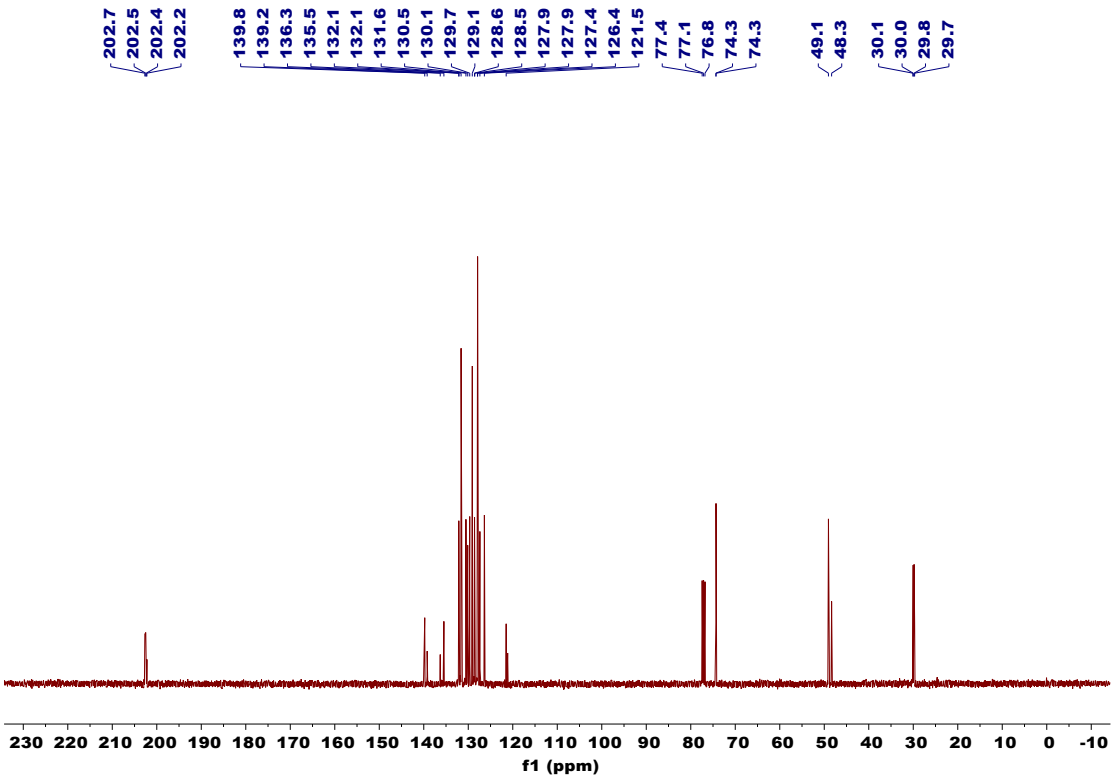

7.47 7.45 7.40 7.38 7.28 7.21 7.19 7.17 7.15 7.11 7.09 6.42 6.38 6.35 6.23 6.21 6.18 6.17 6.14 6.13 6.13 6.12 6.10 6.10 6.09 6.08 4.37 4.34 4.32 4.29 2.33 2.26 2.26 1.97 1.95
0.03
3ao1
3ao2
3ao1 : 3ao2 = 2:1
2.03 6.00 1.00 1.01 2.00 3.00 2.95 0.91 1.99
f1 (ppm)
202.8 202.6 202.4 202.3 139.4 137.8 137.0 136.7 135.5 133.5 132.1 132.0 131.6 130.4 130.3 129.8 129.7 129.3 127.9 127.8 127.5 126.3 121.4 121.1 77.4 77.1 76.8 74.4 74.4 48.7 48.4 30.1 30.0 29.8 29.7 21.2 21.1
f1 (ppm)

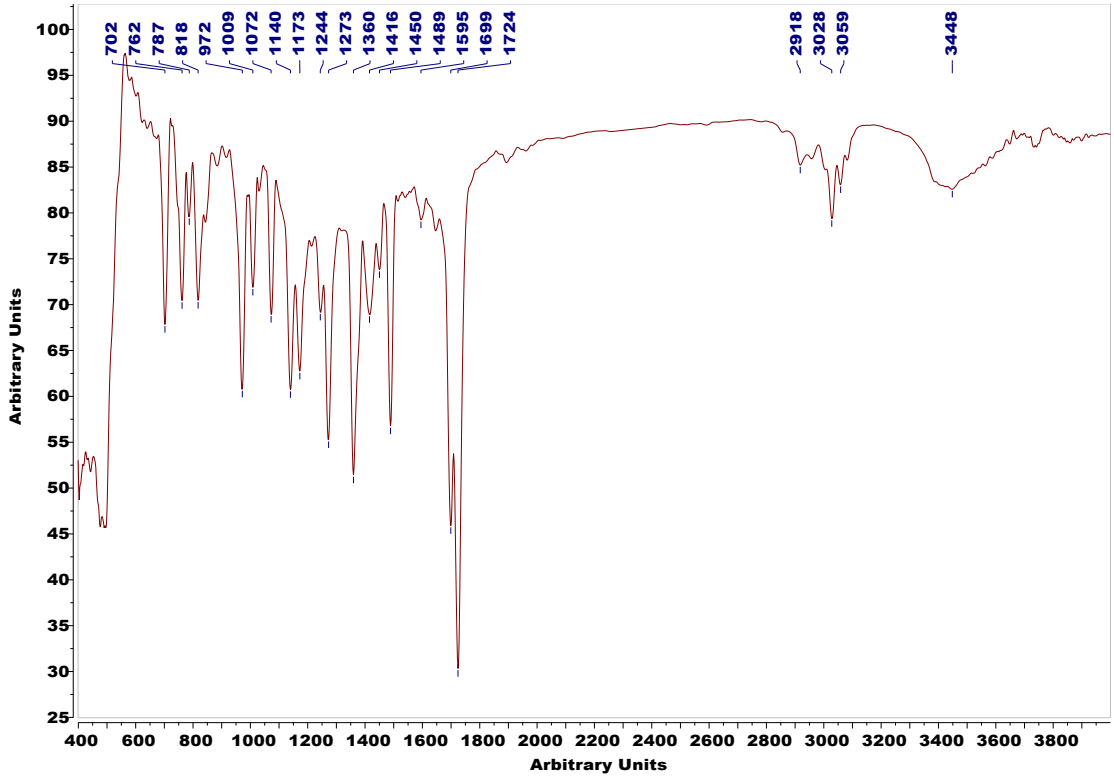

584
629
663
721
833
1009
1070
1115
1146
1167
1217
1284
1417
1512
1699
1730
1915
2920
3001
3028
3421
Arbitrary Units
Arbitrary Units

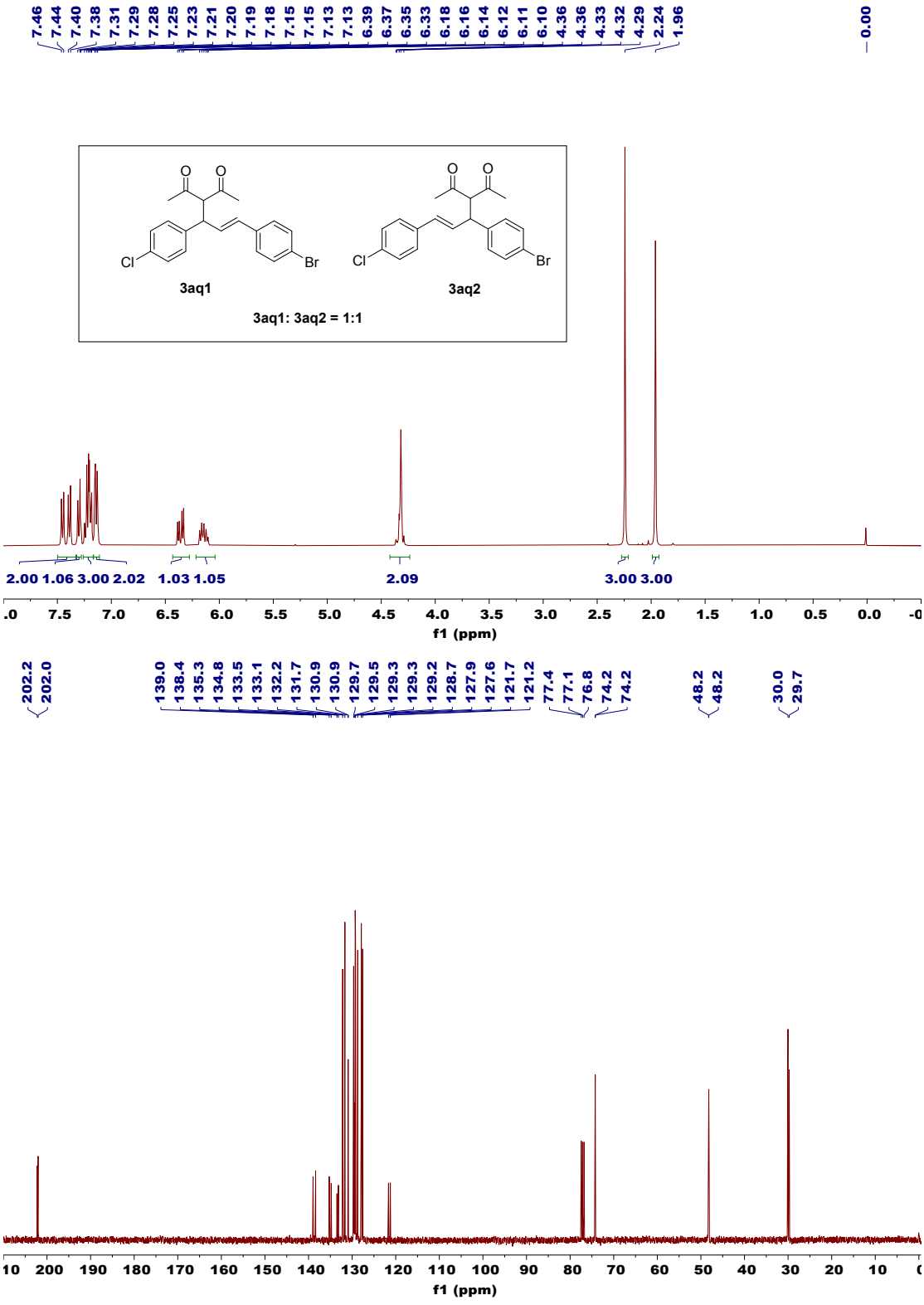

7.45
7.43
7.38
7.36
7.34
7.32
7.30
7.28
7.27
7.26
7.25
7.23
7.21
7.15
7.12
6.43
6.40
6.38
6.34
6.22
6.21
6.20
6.20
6.18
6.17
6.16
6.16
6.14
6.13
6.12
6.12
4.37
4.34
4.33
4.31
4.30
2.24
2.24
1.95
1.92
0.00

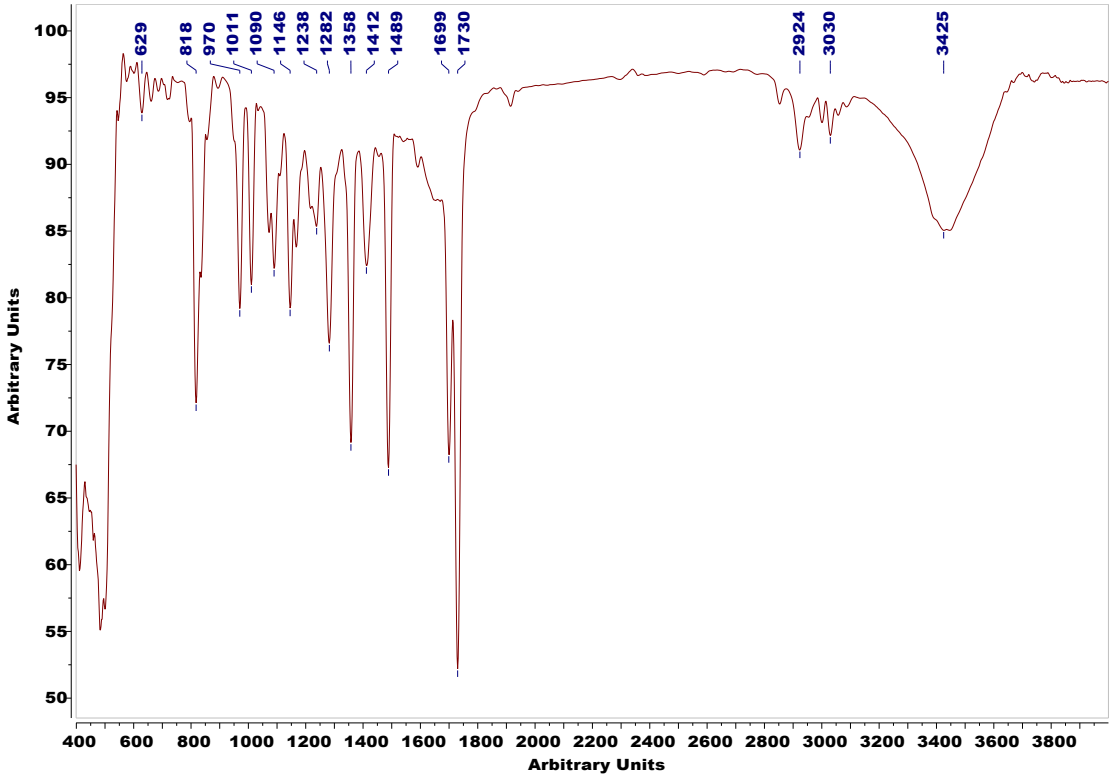

Br
3ap1
Br
3ap1
3ap1:3ap2 = 1:2


2.05 5.04 2.04
1.04 1.04
2.06
3.00 1.00 2.00
f1 (ppm)


202.7
202.5
202.4
202.2
139.8
139.2
136.3
135.5
132.1
132.1
131.6
130.5
130.1
129.7
129.1
128.6
128.5
127.9
127.9
127.4
126.4
121.5
77.4
77.1
76.8
74.3
74.3
49.1
48.3
30.1
30.0
29.8
29.7
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


702
762
787
818
972
1009
1072
1140
1173
1244
1273
1360
1416
1450
1489
1595
1699
1724
2918
3028
3059
3448
Arbitrary Units
100 95 90 85 80 75 70 65 60 55 50 45 40 35 30 25
400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 2800 3000 3200 3400 3600 3800
Arbitrary Units


7.46 7.44 7.40 7.38 7.31 7.29 7.28 7.25 7.23 7.21 7.20 7.19 7.18 7.15 7.15 7.13 7.13 6.39 6.37 6.35 6.33 6.18 6.16 6.14 6.12 6.11 6.10 4.36 4.36 4.33 4.32 4.29 2.24 1.96
0.00
Cl
Br
3aq1
3aq2
3aq1: 3aq2 = 1:1
2.00 1.06 3.00 2.02 1.03 1.05 2.09 3.00 3.00
f1 (ppm)
202.2 202.0 139.0 138.4 135.3 134.8 133.5 133.1 132.2 131.7 130.9 130.9 129.7 129.5 129.3 129.3 129.2 128.7 127.9 127.6 121.7 121.2 77.4 77.1 76.8 74.2 74.2 48.2 48.2 30.0 29.7
f1 (ppm)


629
818
970
1011
1090
1146
1238
1282
1358
1412
1489
1699
1730
2924
3030
3425
Arbitrary Units
Arbitrary Units


7.32
7.30
7.28
7.26
7.26
7.24
7.21
7.19
7.05
7.03
7.01
7.00
6.97
6.95
6.40
6.39
6.36
6.35
6.18
6.16
6.14
6.12
6.10
6.09
6.06
6.05
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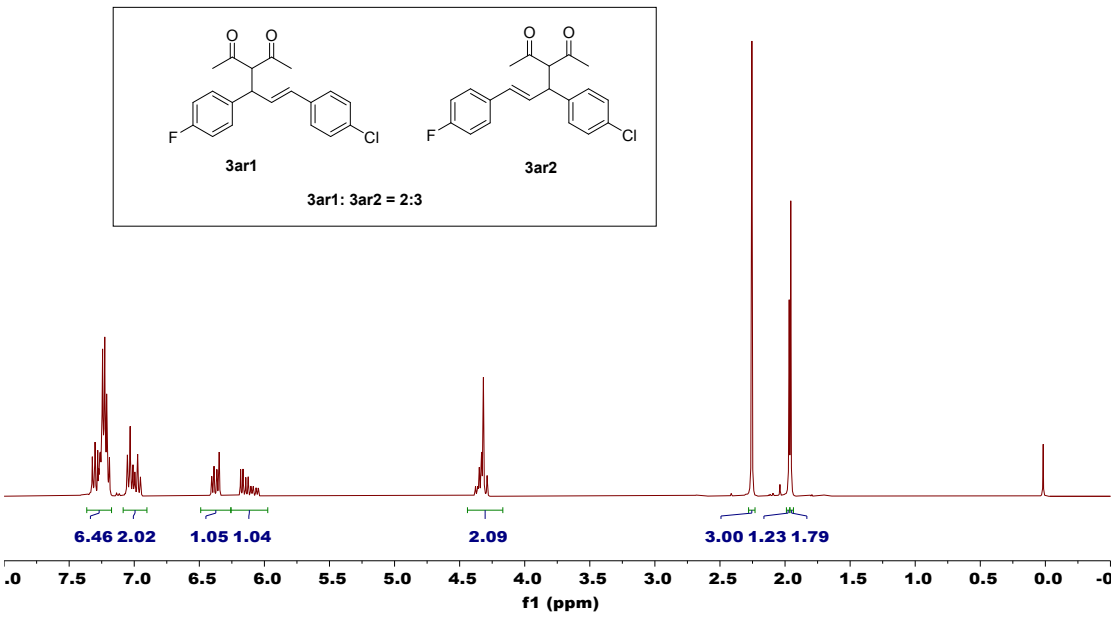
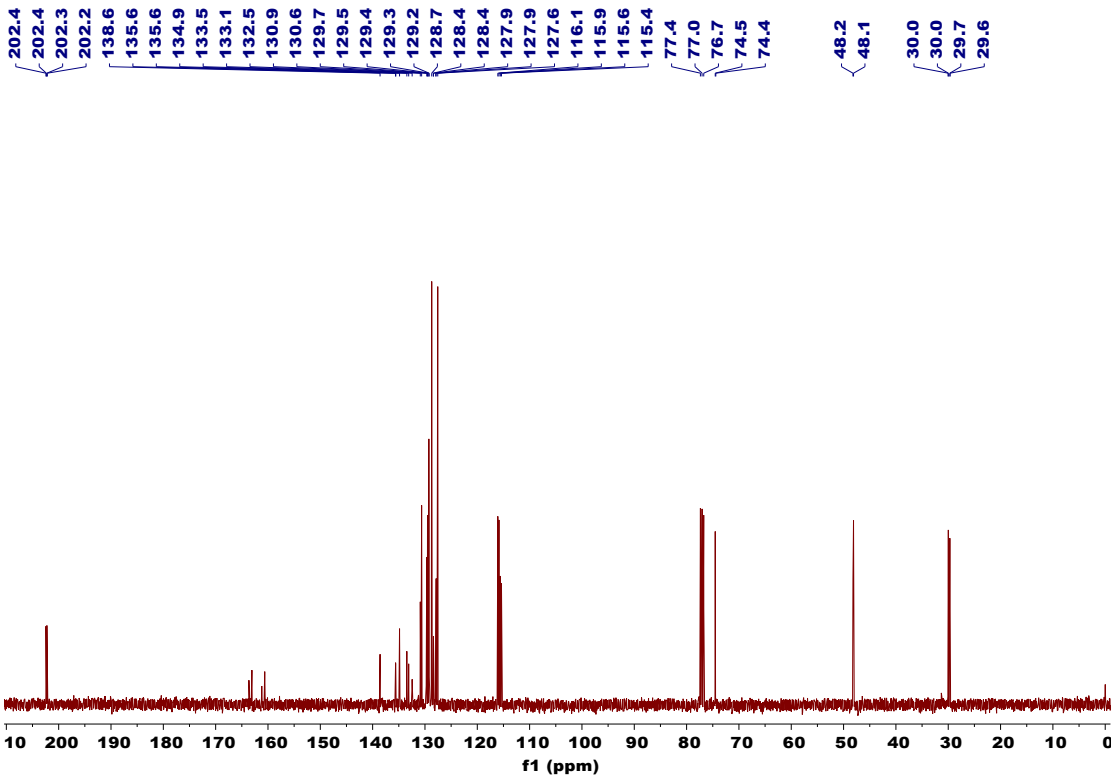
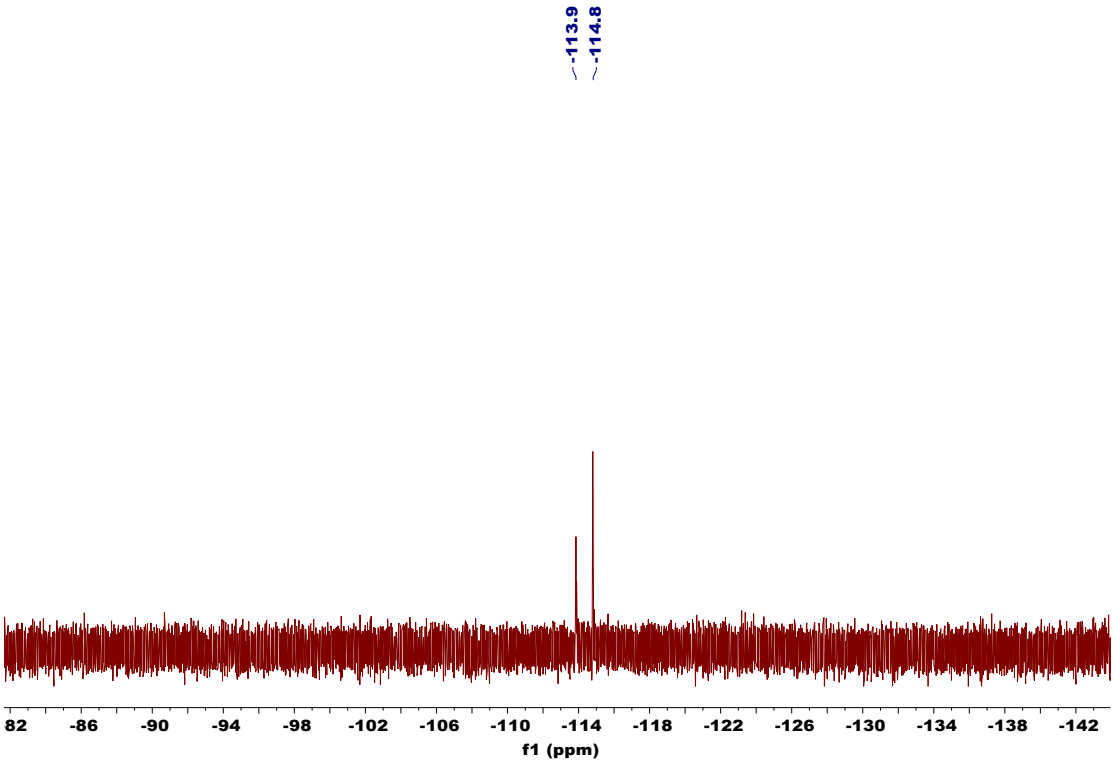
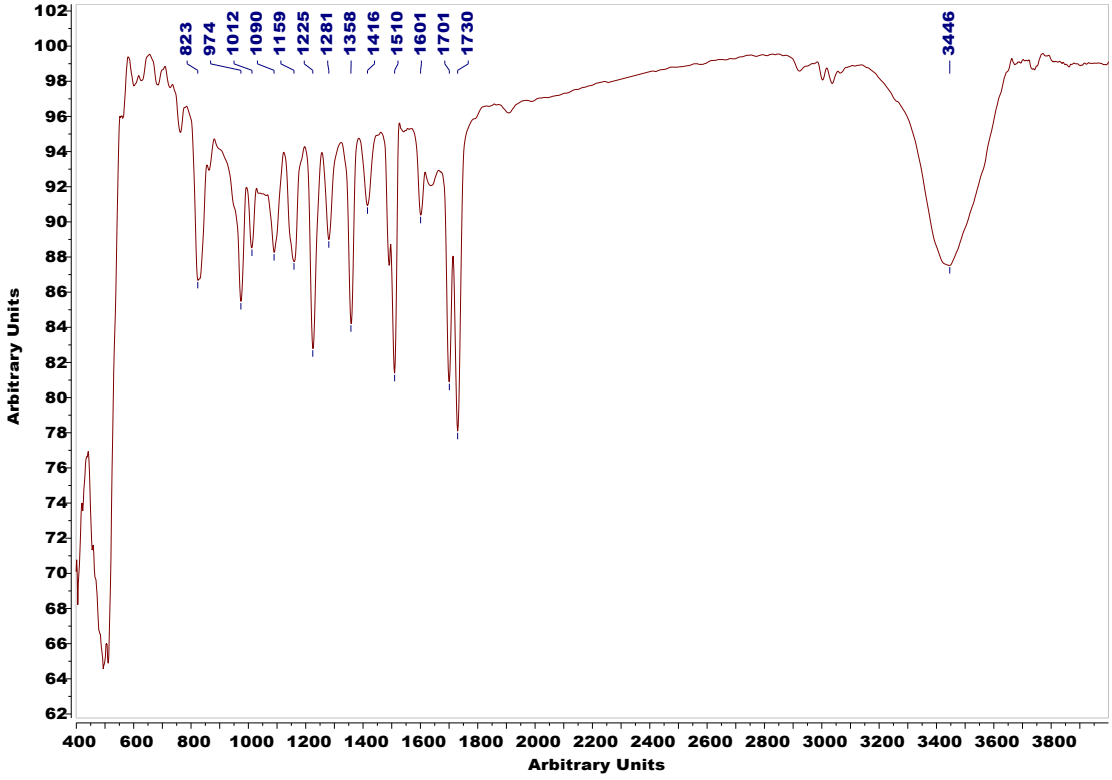
4.33
4.32
4.29
2.25
1.99
1.97
1.96
-0.05

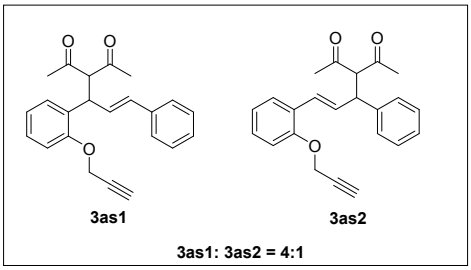

O
O
F
Cl
3ar1
O
O
F
Cl
3ar2
3ar1: 3ar2 = 2:3
6.46 2.02
1.05 1.04
2.09
3.00 1.23 1.79
f1 (ppm)

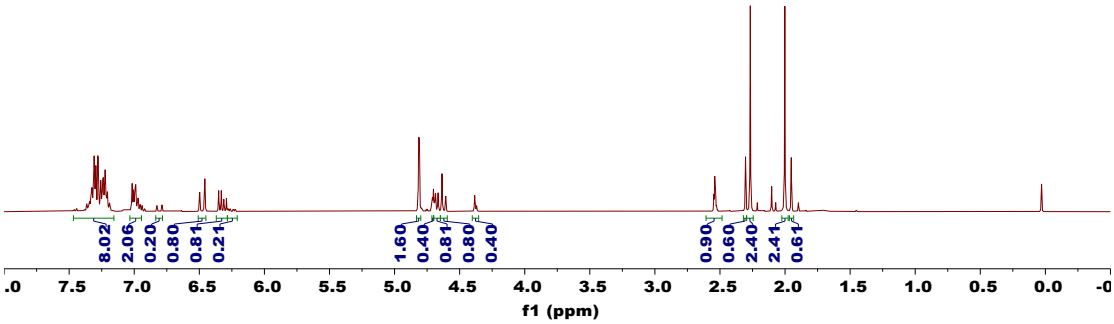

202.4
202.4
202.3
202.2
138.6
135.6
135.6
134.9
133.5
133.1
132.5
130.9
130.6
129.7
129.5
129.4
129.3
129.2
128.7
128.4
128.4
127.9
127.9
127.6
116.1
115.9
115.6
115.4
77.4
77.0
76.7
74.5
74.4
48.2
48.1
30.0
30.0
29.7
29.6
10 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

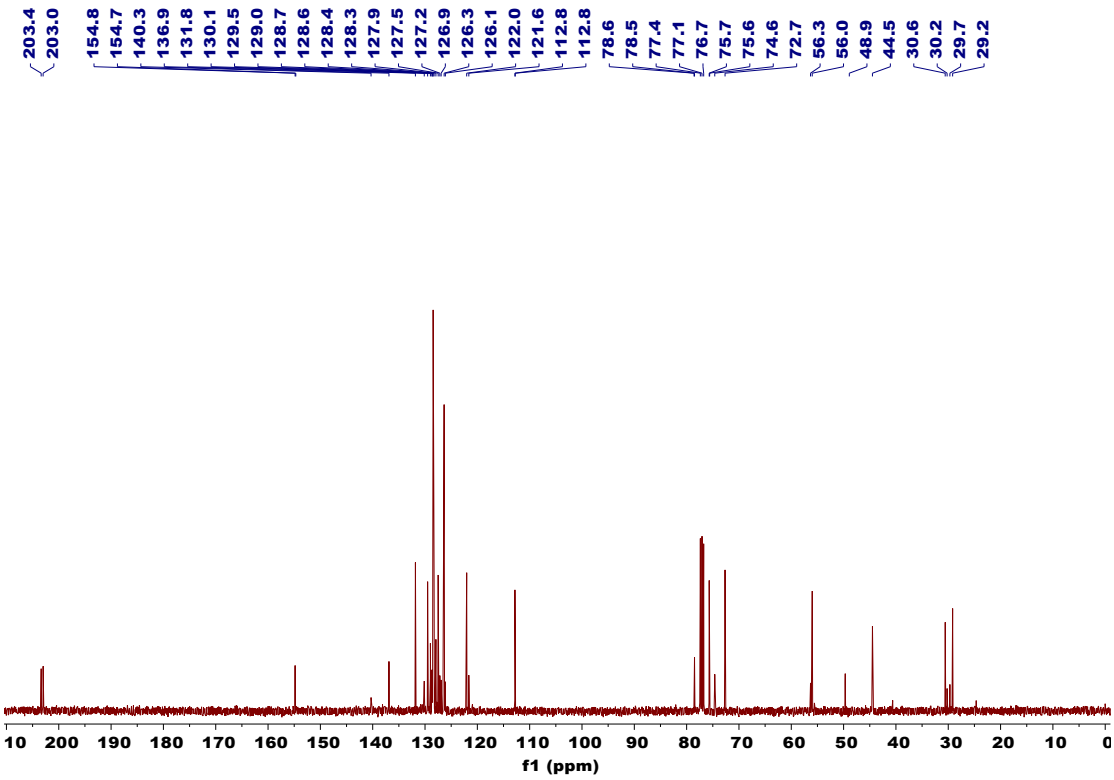

-113.9
-114.8
82 -86 -90 -94 -98 -102 -106 -110 -114 -118 -122 -126 -130 -134 -138 -142
f1 (ppm)

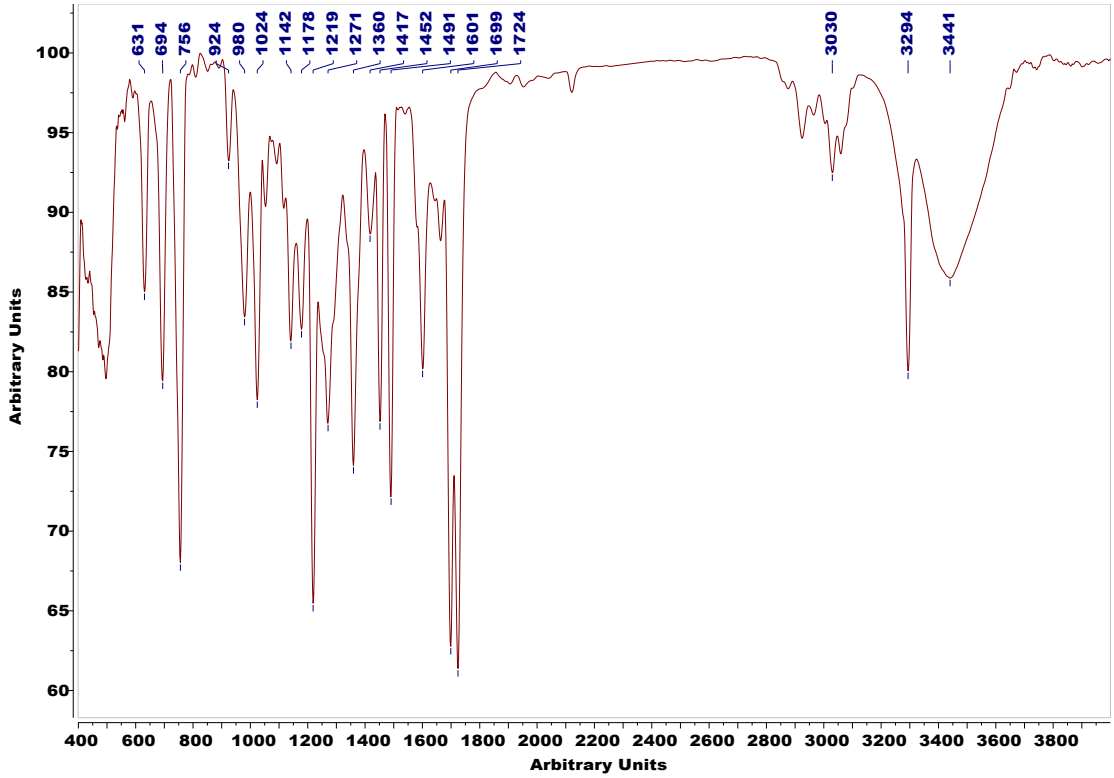

823
974
1012
1090
1159
1225
1281
1358
1416
1510
1601
1701
1730
3446
Arbitrary Units
Arbitrary Units

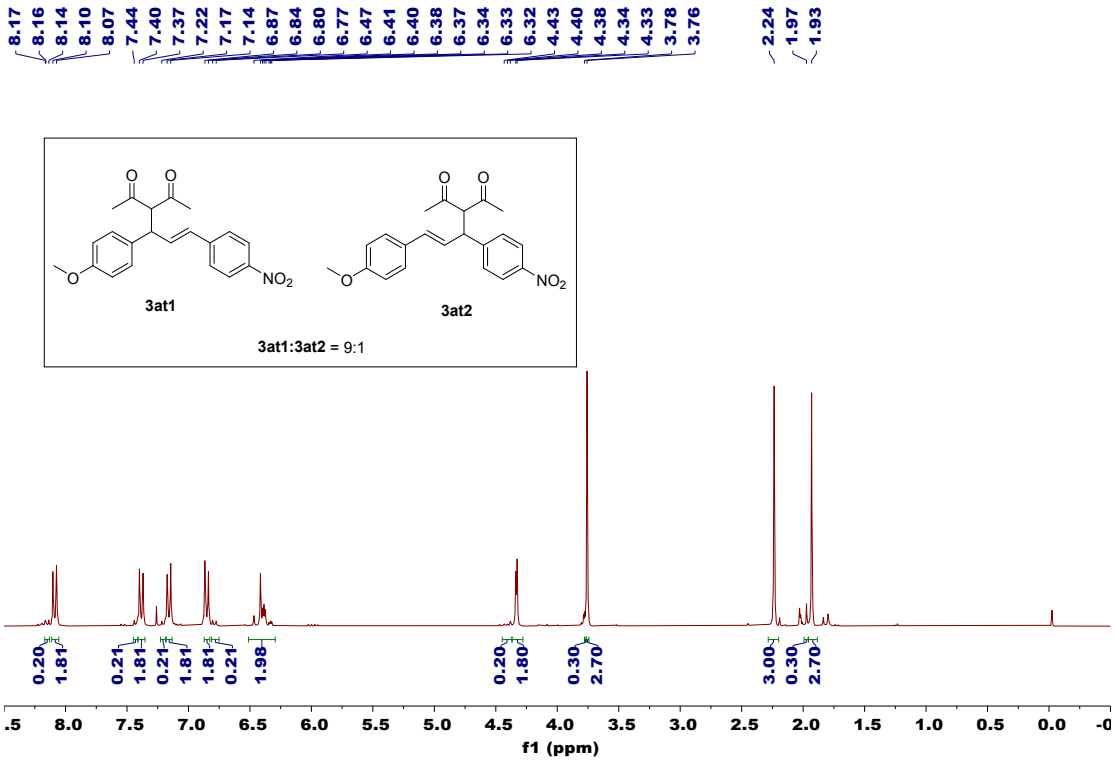

7.44 7.37 7.36 7.35 7.31 7.29 7.28 7.25 7.23 7.22 7.19 7.02 7.01 7.00 6.97 6.97 6.95 6.83 6.79 6.50 6.46 6.35 6.33 6.31 6.29 6.28 6.26 4.82 4.81 4.71 4.71 4.70 4.69 4.69 4.67 4.64 4.61 4.38 4.37 2.55 2.54 2.53 2.31 2.27 2.00 1.95 0.03

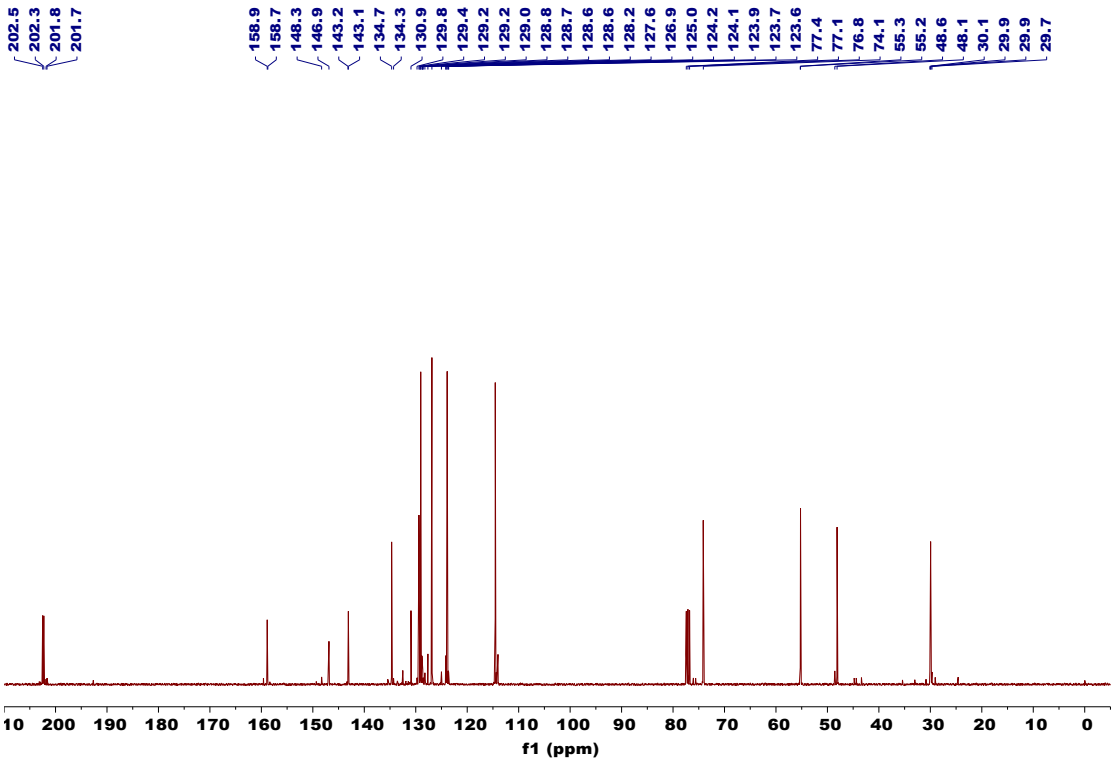

3as1
3as2
3as1: 3as2 = 4:1

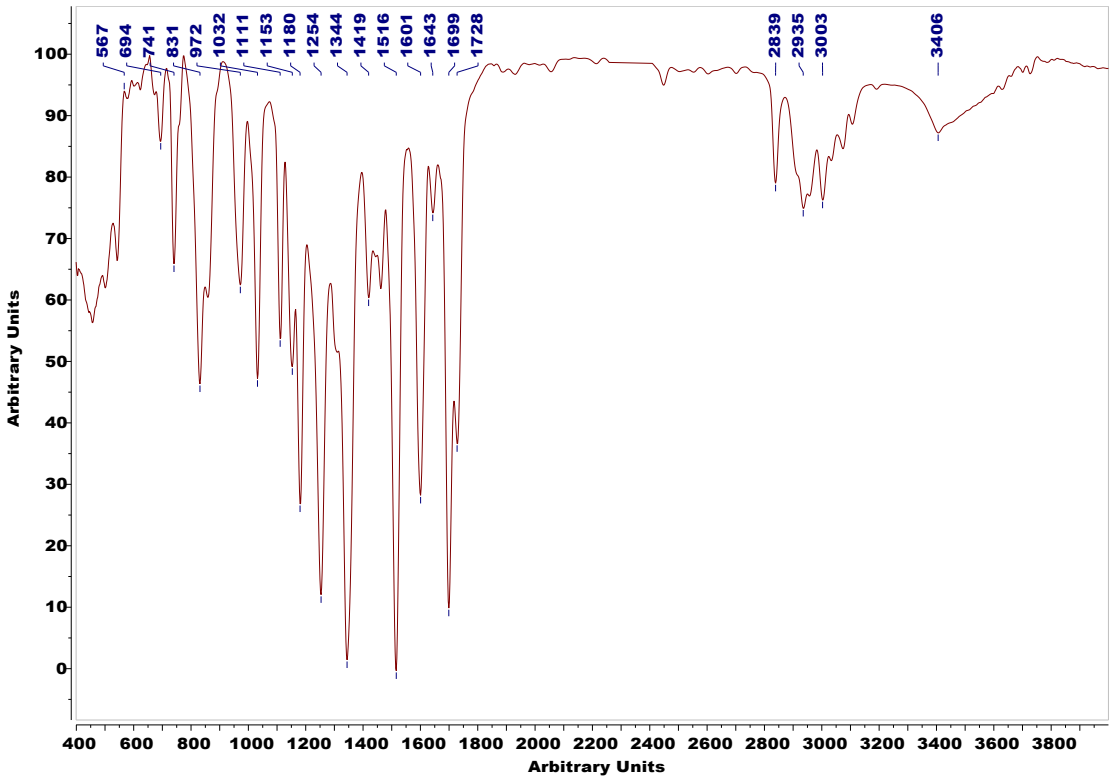

8.02 2.06 0.20 0.80 0.81 0.21 1.60 0.40 0.81 0.80 0.40 0.90 0.60 2.40 2.41 0.61
f1 (ppm)

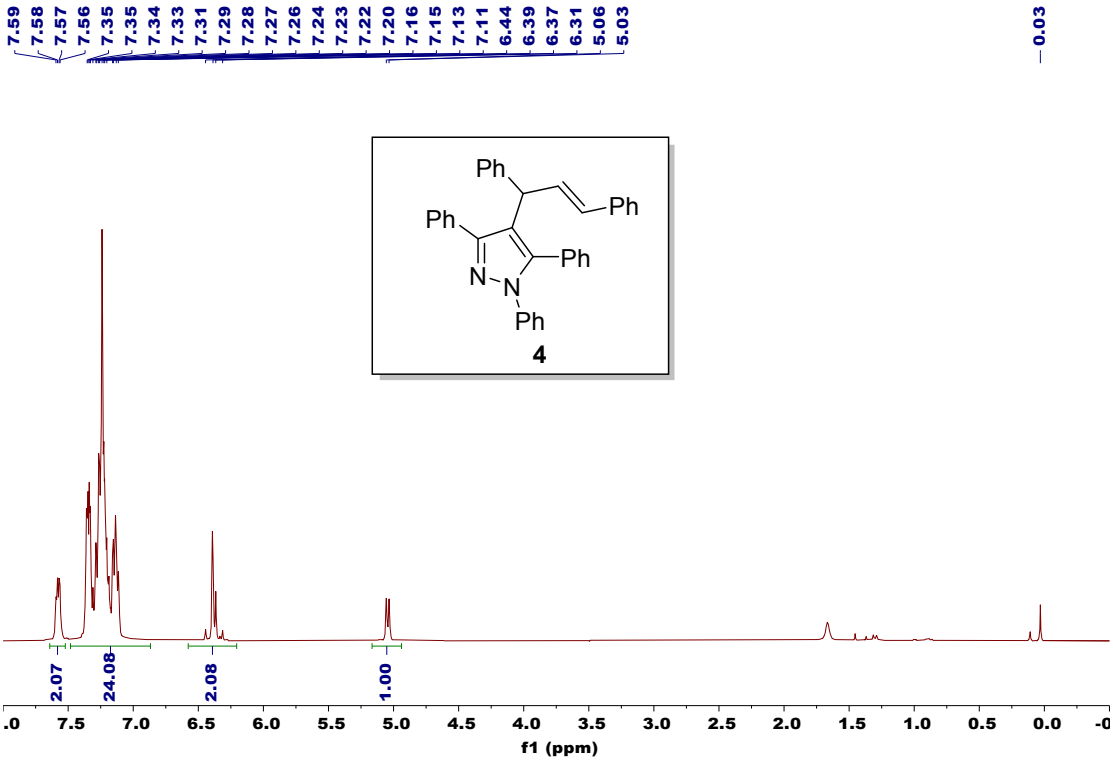

203.4
203.0
154.8
154.7
140.3
136.9
131.8
130.1
129.5
129.0
128.7
128.6
128.4
128.3
127.9
127.5
127.2
126.9
126.3
126.1
122.0
121.6
112.8
112.8
78.6
78.5
77.4
77.1
76.7
75.7
75.6
74.6
72.7
56.3
56.0
48.9
44.5
30.6
30.2
29.7
29.2
f1 (ppm)

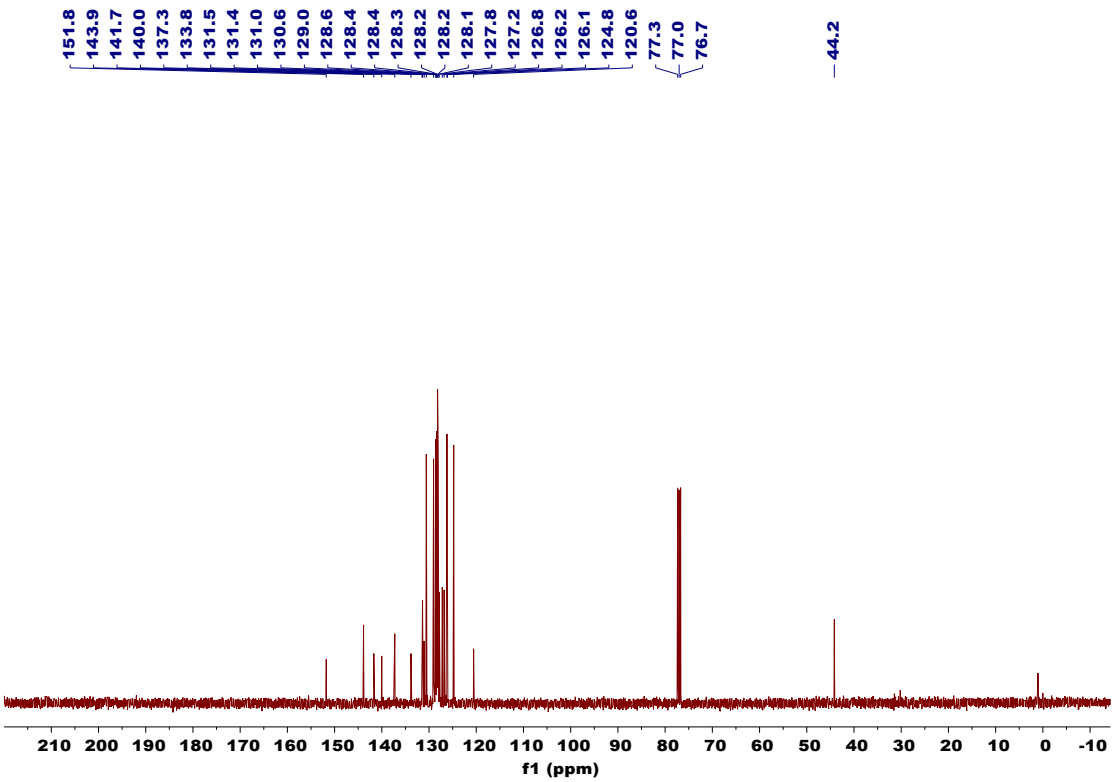

631
694
756
924
980
1024
1142
1178
1219
1271
1360
1417
1452
1491
1601
1699
1724
3030
3294
3441
Arbitrary Units
Arbitrary Units

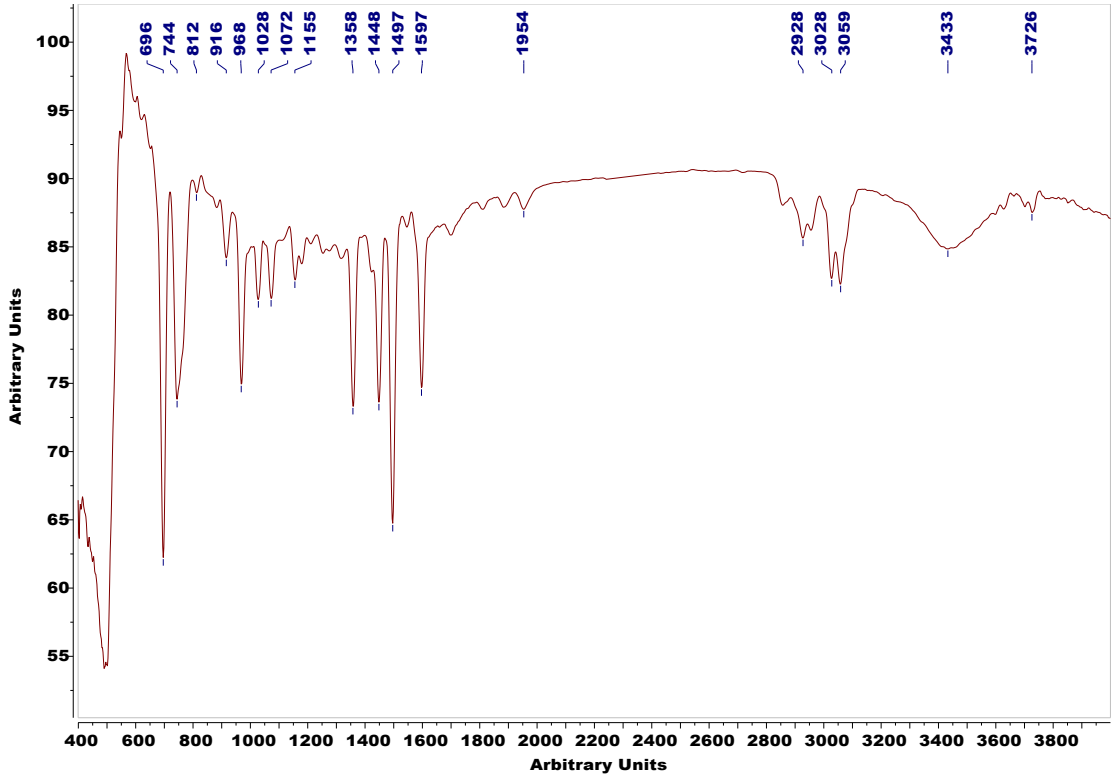

8.17 8.16 8.14 8.10 8.07 7.44 7.40 7.37 7.22 7.17 7.14 6.87 6.84 6.80 6.77 6.47 6.41 6.40 6.38 6.37 6.34 6.33 6.32 4.43 4.40 4.38 4.34 4.33 3.78 3.76 2.24 1.97 1.93
3at1
3at2
3at1:3at2 = 9:1
0.20 1.81 0.21 1.81 0.21 1.81 1.81 0.21 1.98 0.20 1.80 0.30 2.70 3.00 0.30 2.70
f1 (ppm)

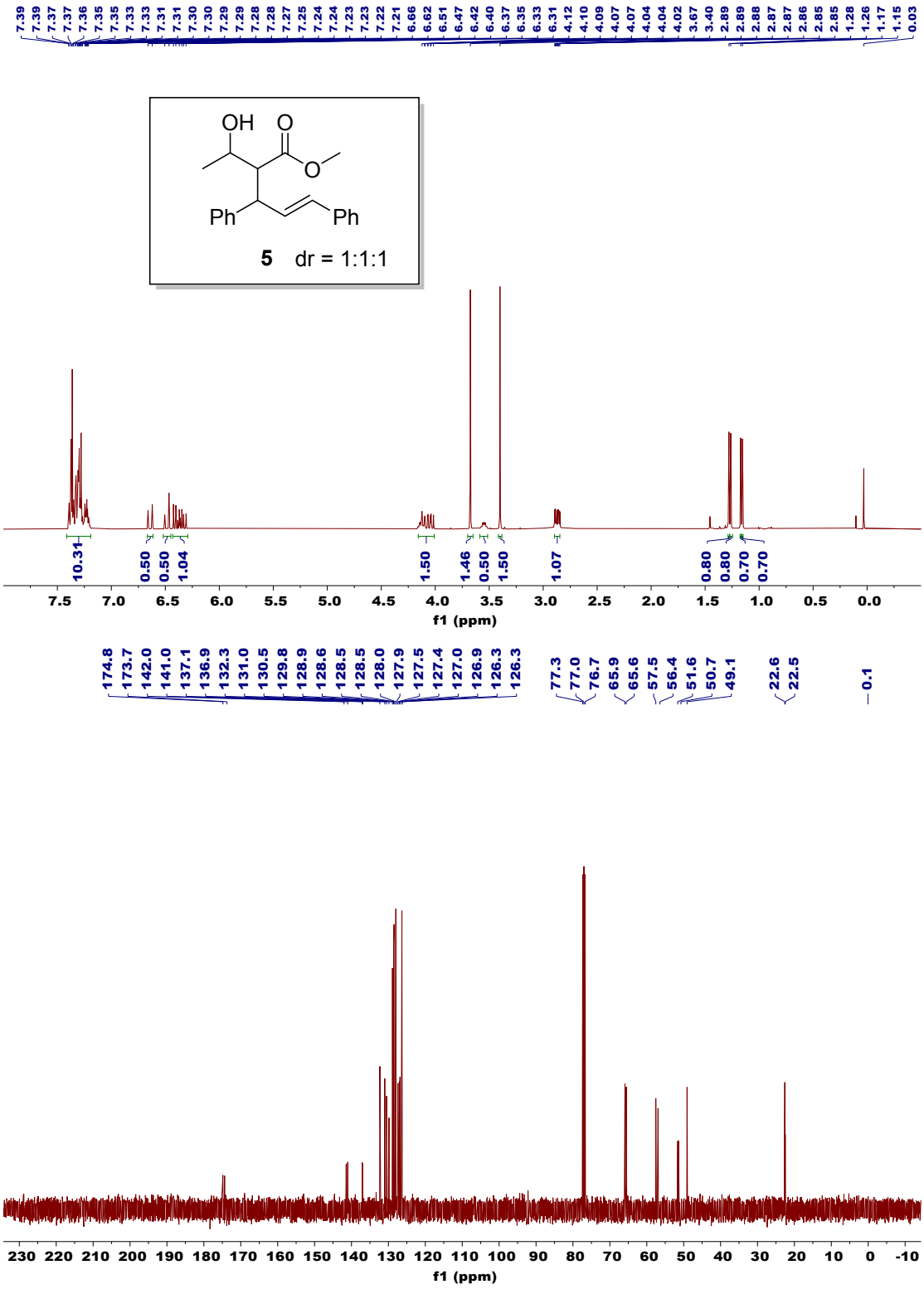

202.5 202.3 201.8 201.7 158.9 158.7 148.3 146.9 143.2 143.1 134.7 134.3 130.9 129.8 129.4 129.2 129.2 129.0 128.8 128.7 128.6 128.6 128.2 127.6 126.9 125.0 124.2 124.1 123.9 123.7 123.6 77.4 77.1 76.8 74.1 55.3 55.2 48.6 48.1 30.1 29.9 29.9 29.7
f1 (ppm)

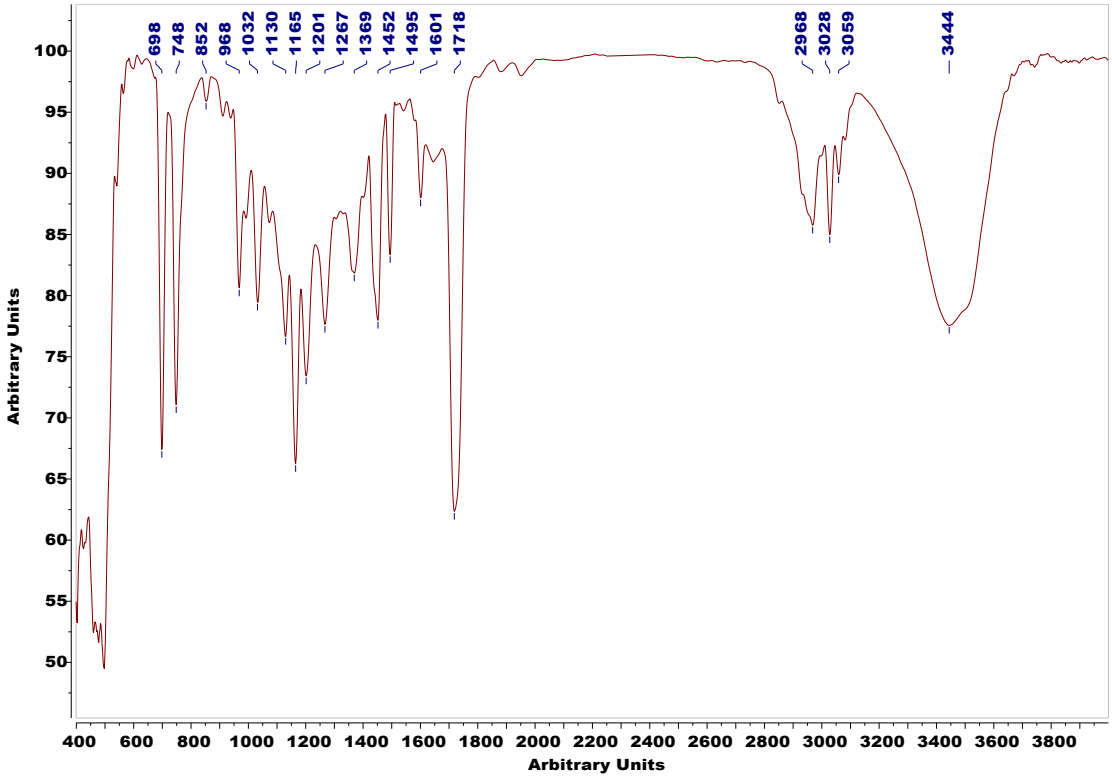

567
694
741
831
972
1032
1111
1153
1180
1254
1344
1419
1516
1601
1643
1699
1728
2839
2935
3003
3406
Arbitrary Units
Arbitrary Units


7.59
7.58
7.57
7.56
7.35
7.34
7.33
7.31
7.29
7.28
7.27
7.26
7.24
7.23
7.22
7.20
7.16
7.15
7.13
7.11
6.44
6.39
6.37
6.31
5.06
5.03
0.03
Ph
Ph
Ph
Ph
N
N
Ph
4
2.07
24.08
2.08
1.00
f1 (ppm)


151.8
143.9
141.7
140.0
137.3
133.8
131.5
131.4
131.0
130.6
129.0
128.6
128.4
128.4
128.3
128.2
128.2
128.1
127.8
127.2
126.8
126.2
126.1
124.8
120.6
77.3
77.0
76.7
44.2
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


696
744
812
916
968
1028
1072
1155
1358
1448
1497
1597
1954
2928
3028
3059
3433
3726
Arbitrary Units
100
95
90
85
80
75
70
65
60
55
400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 2800 3000 3200 3400 3600 3800
Arbitrary Units


OH
O
O
Ph
Ph
5 dr = 1:1:1
f1 (ppm)
f1 (ppm)


698
748
852
968
1032
1130
1165
1201
1267
1369
1452
1495
1601
1718
2968
3028
3059
3444
Arbitrary Units
Arbitrary Units


7.98
7.96
7.96
7.60
7.58
7.56
7.49
7.47
7.45
7.35
7.34
7.32
7.30
7.28
7.26
7.25
7.24
7.23
7.22
7.22
7.22
7.21
6.44
6.42
4.35
4.34
4.34
4.33
4.32
4.31
3.57
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3.53
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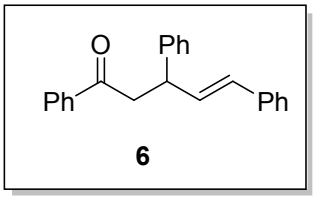
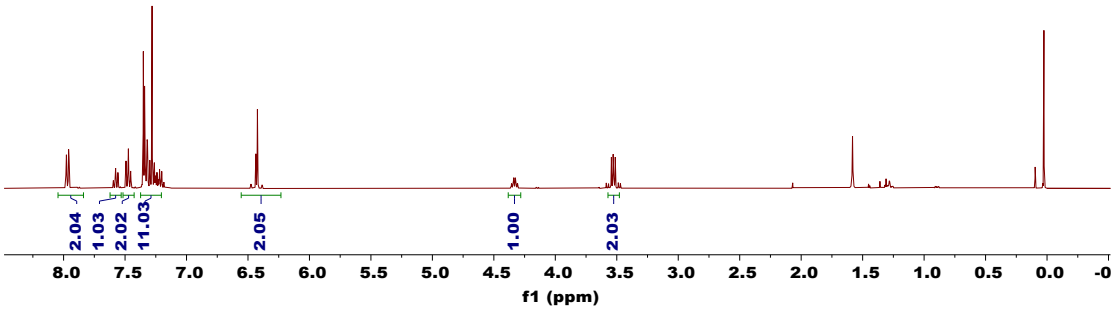
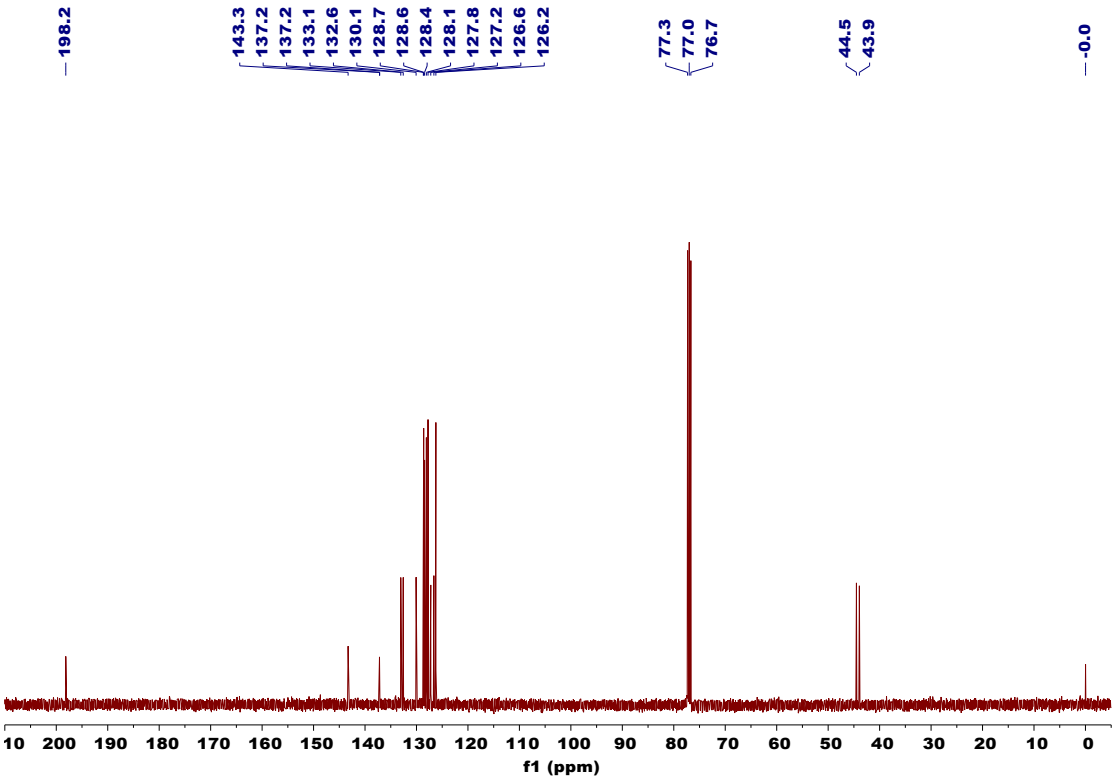
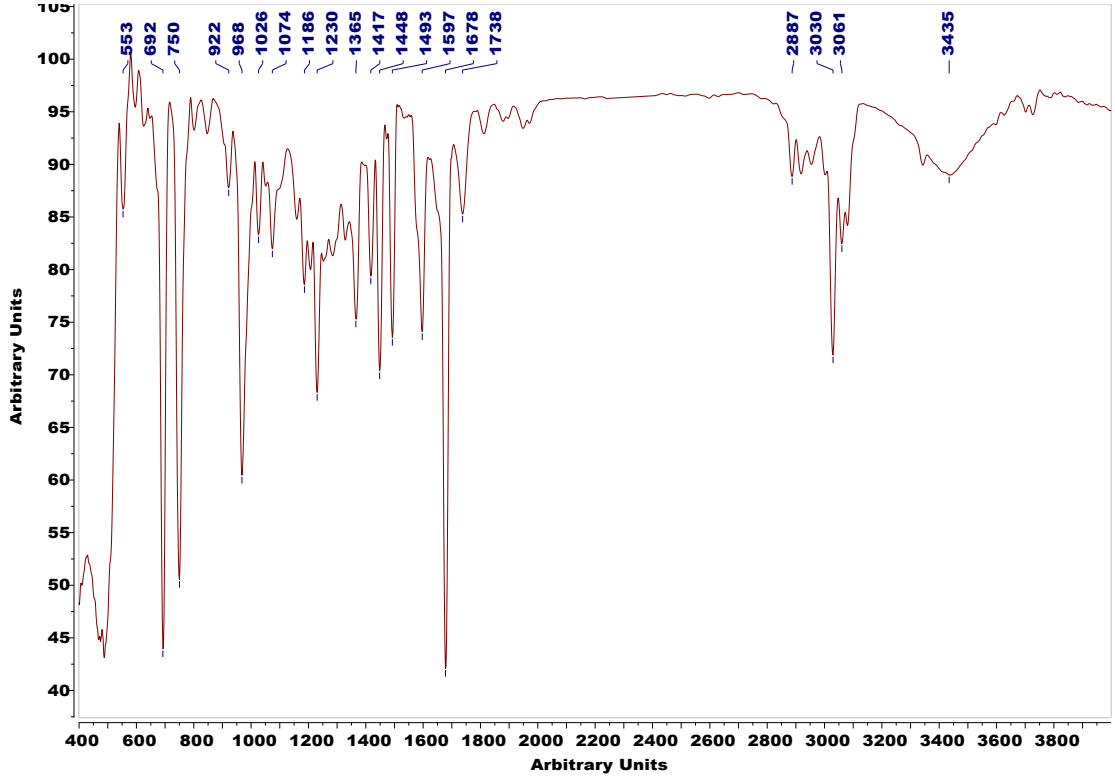
3.51
3.49
0.03

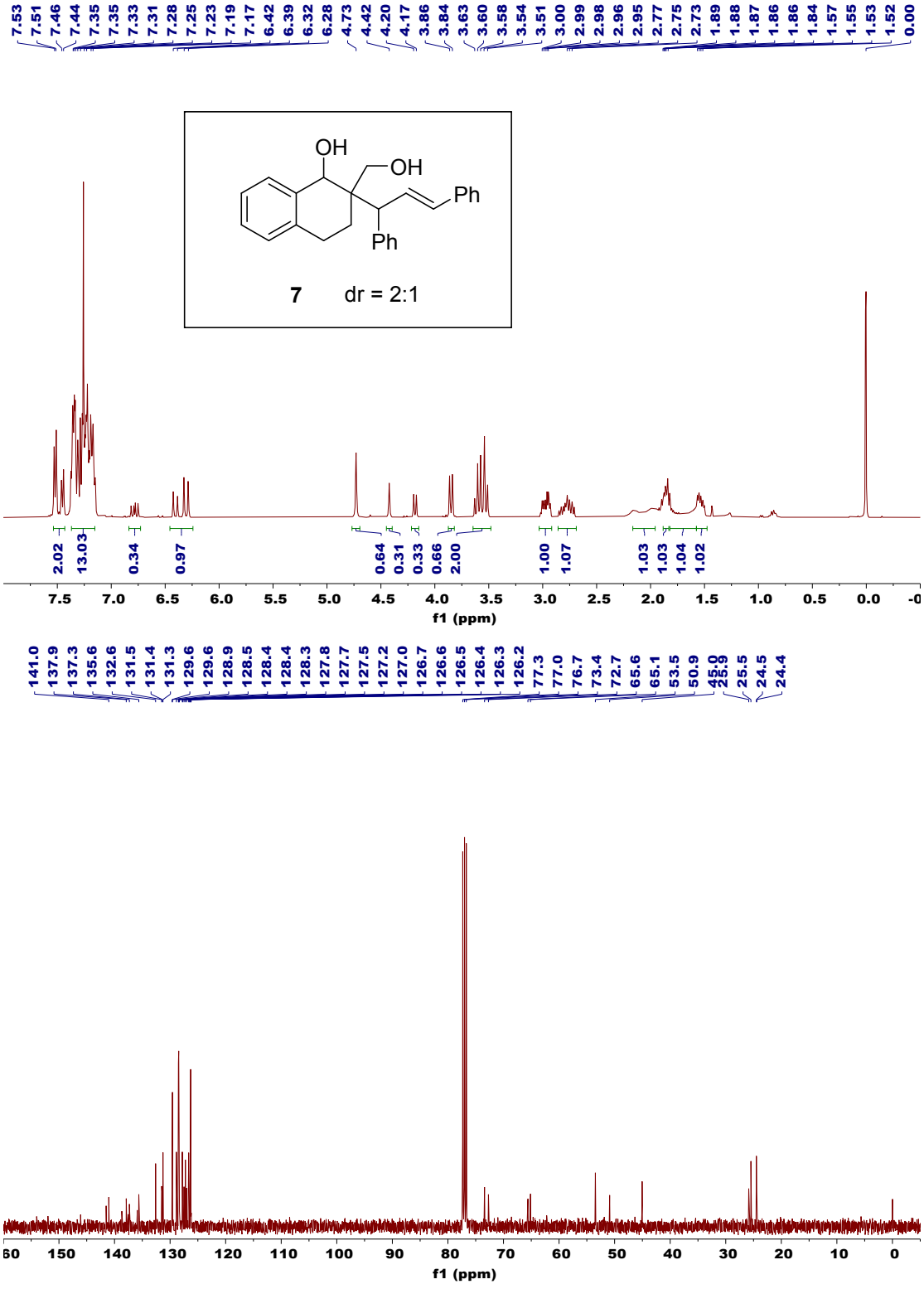

O
Ph
Ph
Ph

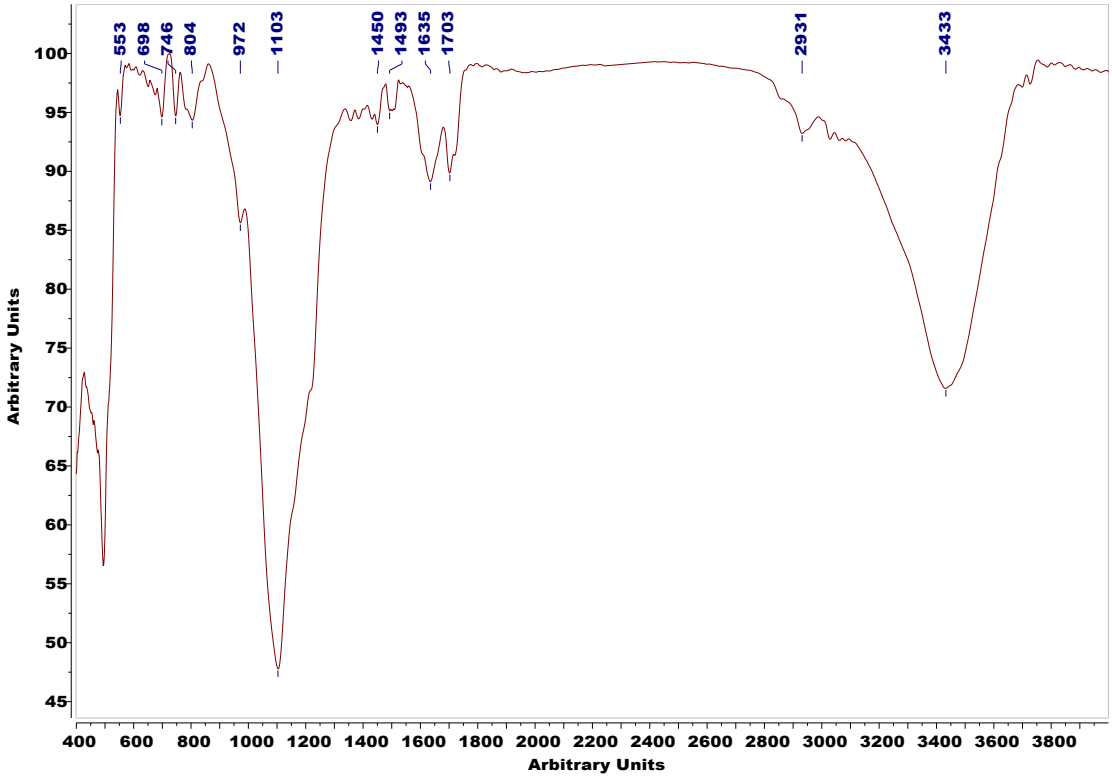
6


2.04
1.03
2.02
11.03
2.05
1.00
2.03
f1 (ppm)

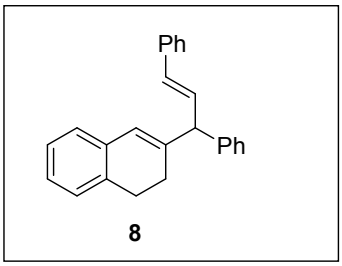

198.2
143.3
137.2
137.2
133.1
132.6
130.1
128.7
128.6
128.4
128.1
127.8
127.2
126.6
126.2
77.3
77.0
76.7
44.5
43.9
-0.0
f1 (ppm)


553
692
750
922
968
1026
1074
1186
1230
1365
1417
1448
1493
1597
1678
1738
2887
3030
3061
3435
Arbitrary Units
Arbitrary Units

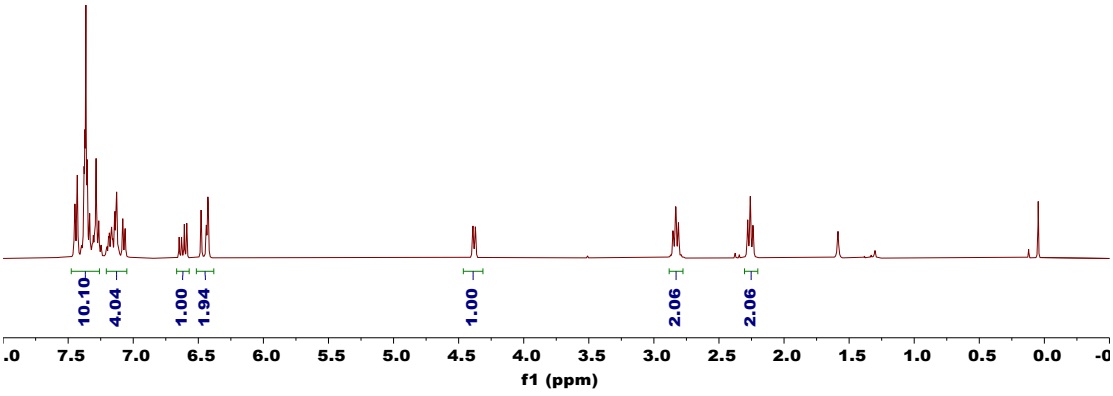

7.53 7.51 7.46 7.44 7.35 7.35 7.33 7.31 7.28 7.25 7.23 7.19 7.17 6.42 6.39 6.32 6.28 4.73 4.42 4.20 4.17 3.86 3.84 3.63 3.60 3.58 3.54 3.51 3.00 2.99 2.98 2.96 2.95 2.77 2.75 2.73 1.89 1.88 1.87 1.86 1.86 1.84 1.57 1.55 1.53 1.52 0.00
OH
OH
Ph
Ph
7 dr = 2:1
2.02 13.03 0.34 0.97 0.64 0.31 0.33 0.66 2.00 1.00 1.07 1.03 1.03 1.04 1.02
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)
141.0 137.9 137.3 135.6 132.6 131.5 131.4 131.3 129.6 129.6 128.9 128.5 128.4 128.4 128.3 127.8 127.7 127.5 127.2 127.0 126.7 126.6 126.5 126.4 126.3 126.2 77.3 77.0 76.7 73.4 72.7 65.6 65.1 53.5 50.9 45.0 25.9 25.5 24.5 24.4
150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

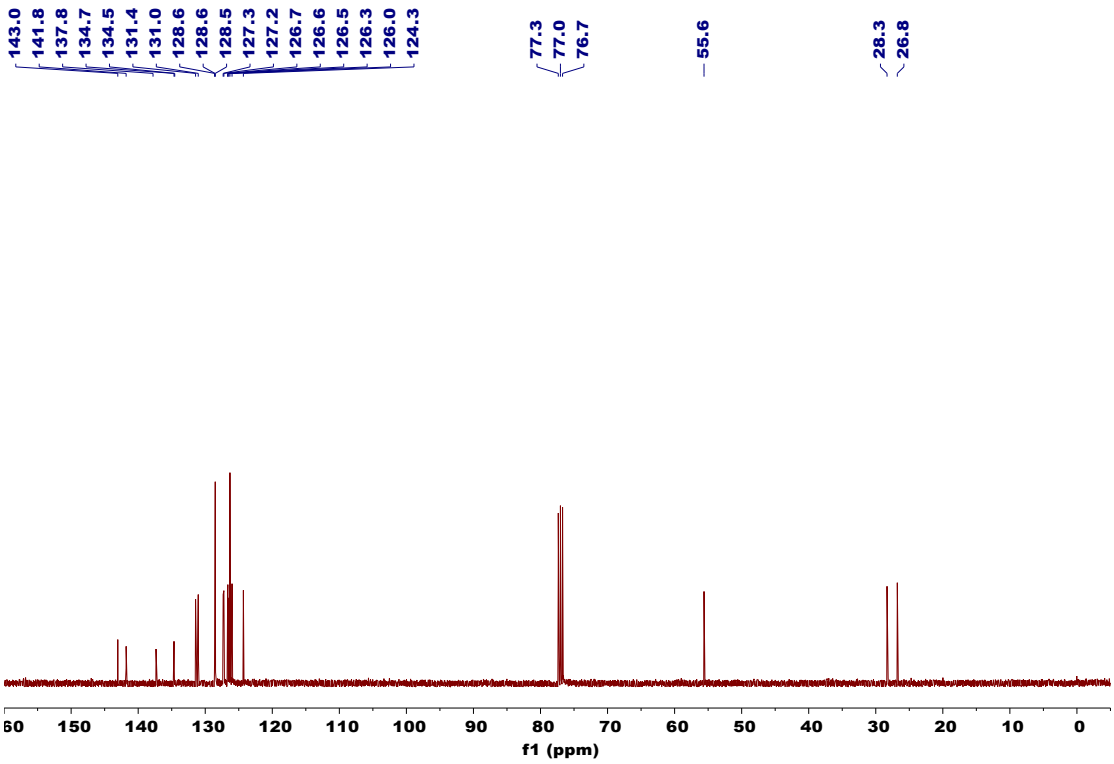

553
698
746
804
972
1103
1450
1493
1635
1703
2931
3433
Arbitrary Units
Arbitrary Units

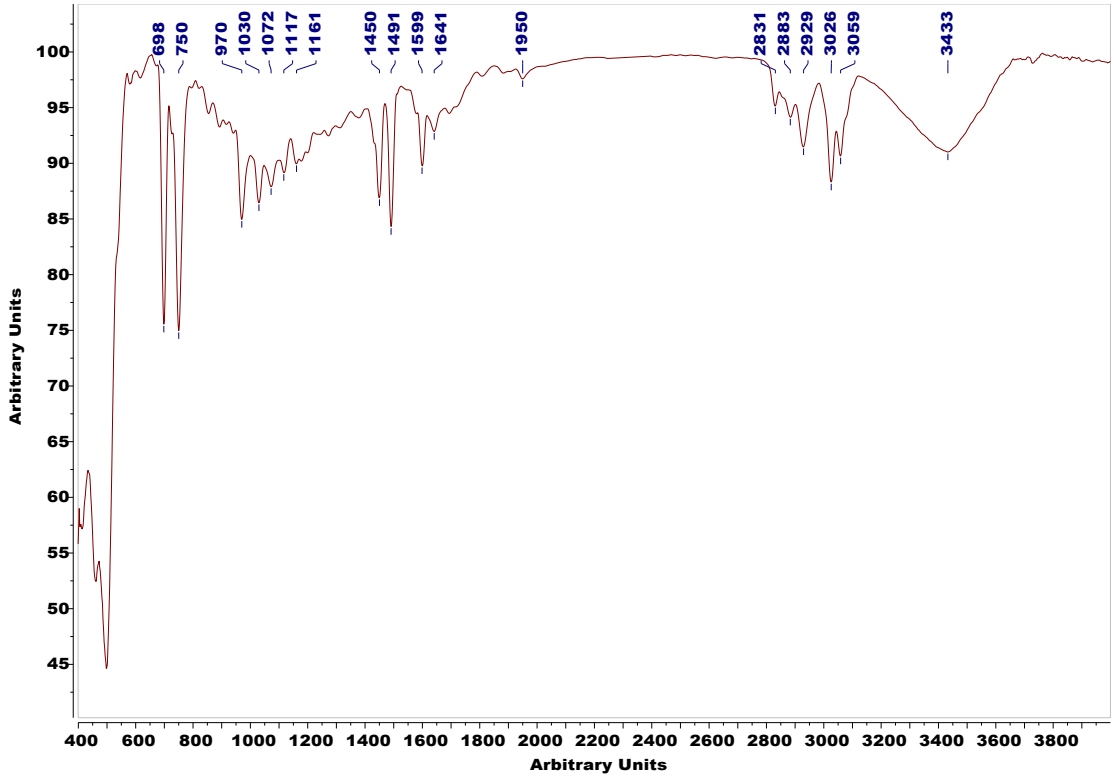

7.45
7.43
7.37
7.36
7.35
7.34
7.29
7.26
7.19
7.18
7.17
7.17
7.16
7.14
7.12
7.08
7.06
6.65
6.63
6.61
6.59
6.48
6.44
6.42
4.39
4.37
2.85
2.83
2.81
2.28
2.26
2.24
0.05

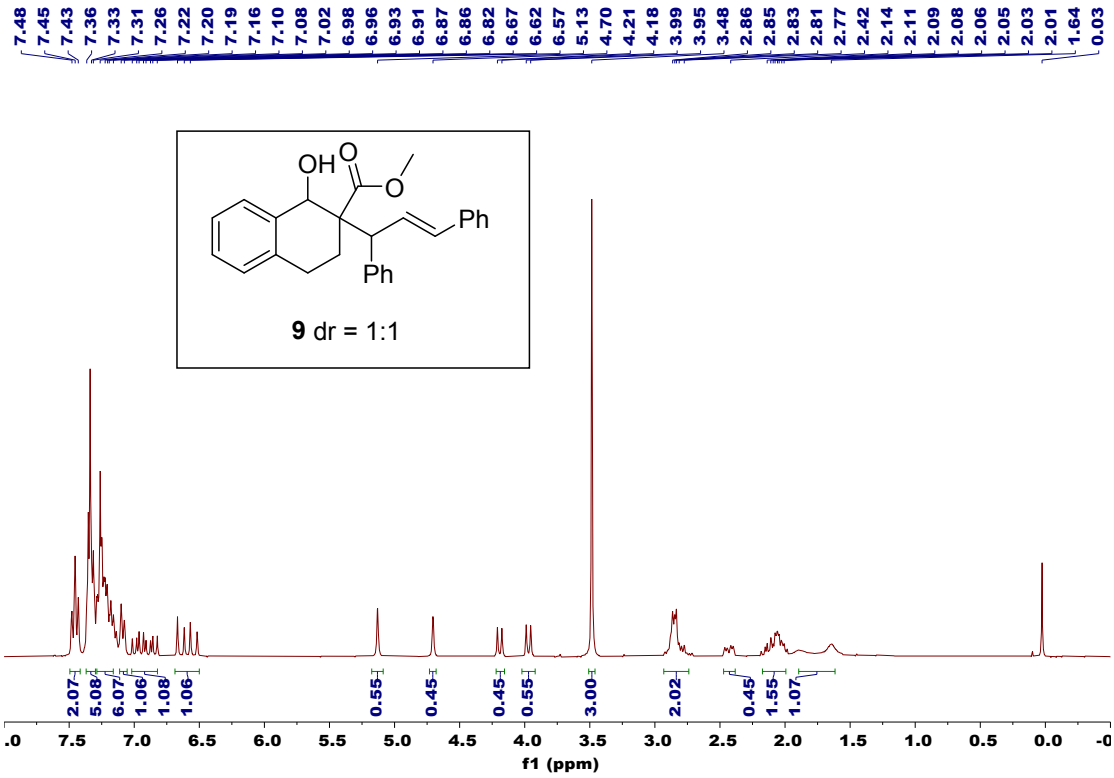

Ph
Ph

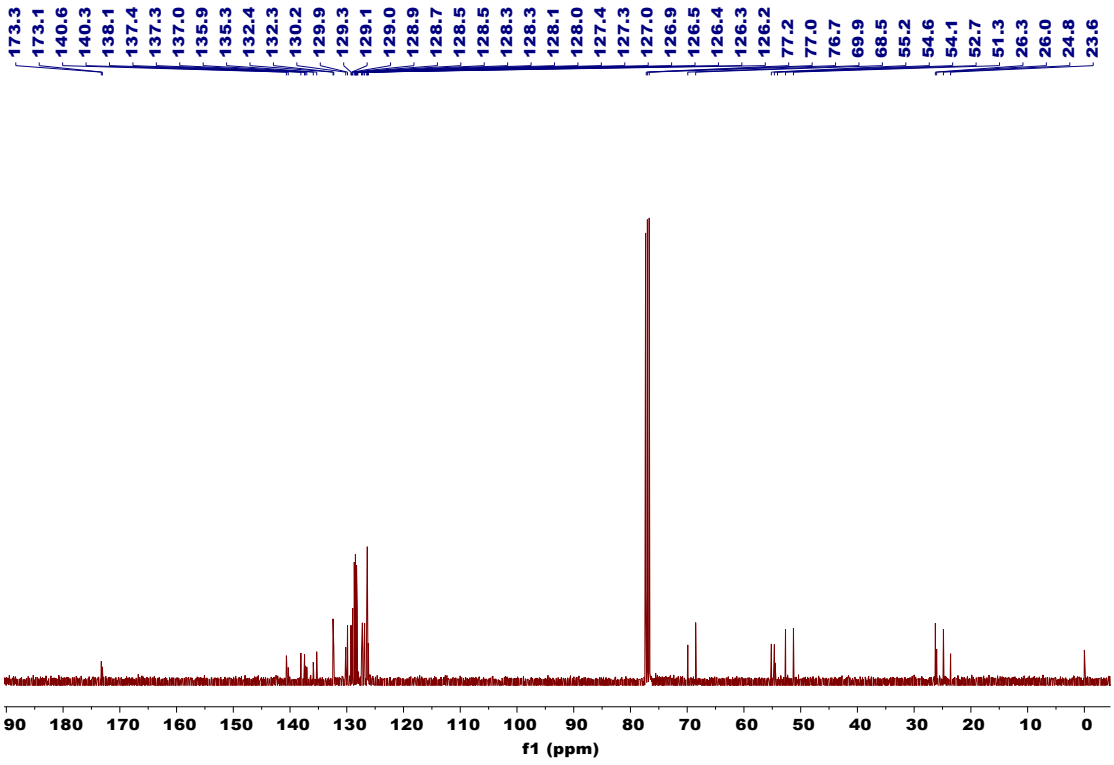
8

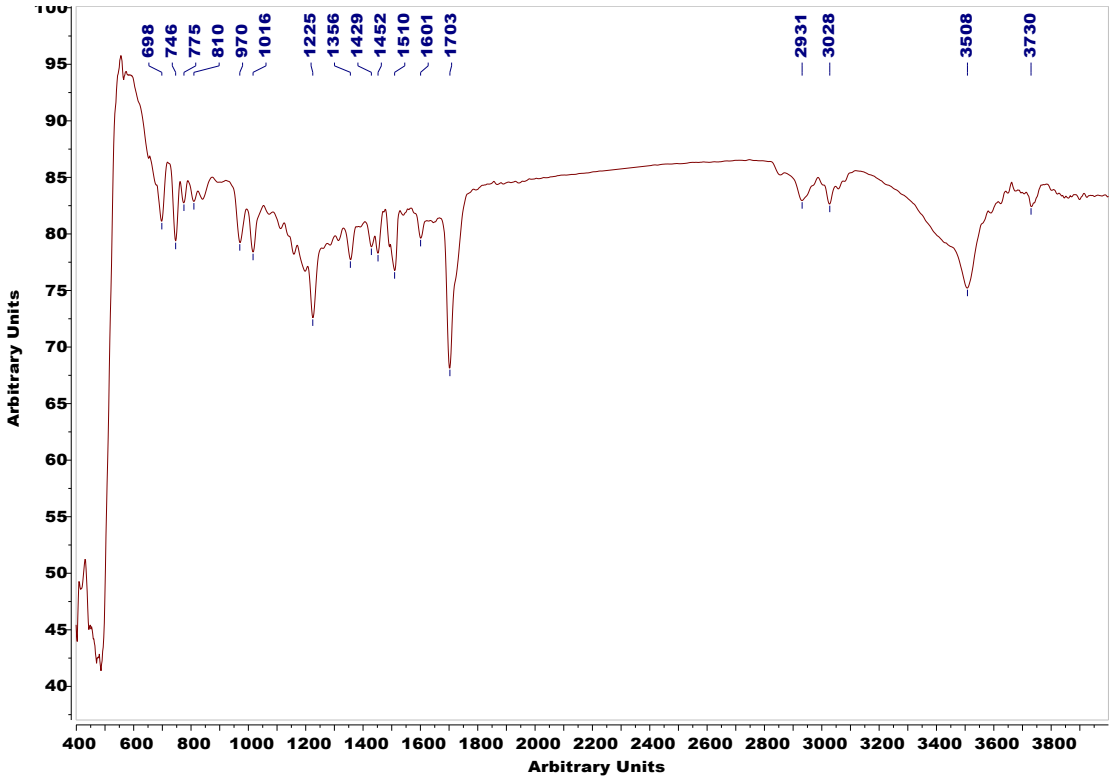

10.10
4.04
1.00
1.94
1.00
2.06
2.06
f1 (ppm)


143.0
141.8
137.8
134.7
134.5
131.4
131.0
128.6
128.6
128.5
127.3
127.2
126.7
126.6
126.5
126.3
126.0
124.3
77.3
77.0
76.7
55.6
28.3
26.8
f1 (ppm)

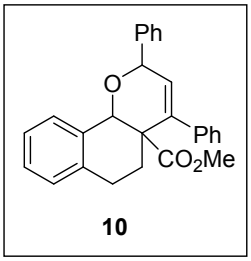

698
750
970
1030
1072
1117
1161
1450
1491
1599
1641
1950
2831
2883
2929
3026
3059
3433
Arbitrary Units
Arbitrary Units


7.48 7.45 7.43 7.36 7.33 7.31 7.26 7.22 7.20 7.19 7.16 7.10 7.08 7.02 6.98 6.96 6.93 6.91 6.87 6.86 6.82 6.67 6.62 6.57 5.13 4.70 4.21 4.18 3.99 3.95 3.48 2.86 2.85 2.83 2.81 2.77 2.42 2.14 2.11 2.09 2.08 2.06 2.05 2.03 2.01 1.64 0.03
OH
O
O
Ph
Ph
9 dr = 1:1
2.07 5.08 6.07 1.06 1.08 1.06 0.55 0.45 0.45 0.55 3.00 2.02 0.45 1.55 1.07
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)

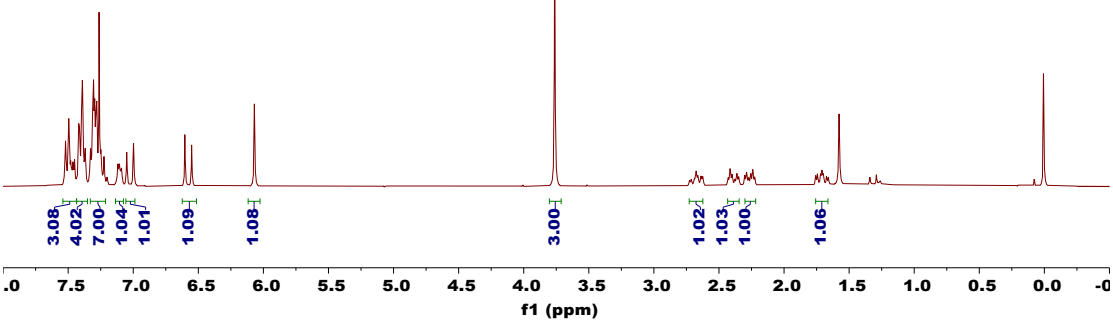

173.3 173.1 140.6 140.3 138.1 137.4 137.3 137.0 135.9 135.3 132.4 132.3 130.2 129.9 129.3 129.1 129.0 128.9 128.7 128.5 128.5 128.3 128.3 128.1 128.0 127.4 127.3 127.0 126.9 126.5 126.4 126.3 126.2 77.2 77.0 76.7 69.9 68.5 55.2 54.6 54.1 52.7 51.3 26.3 26.0 24.8 23.6
90 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

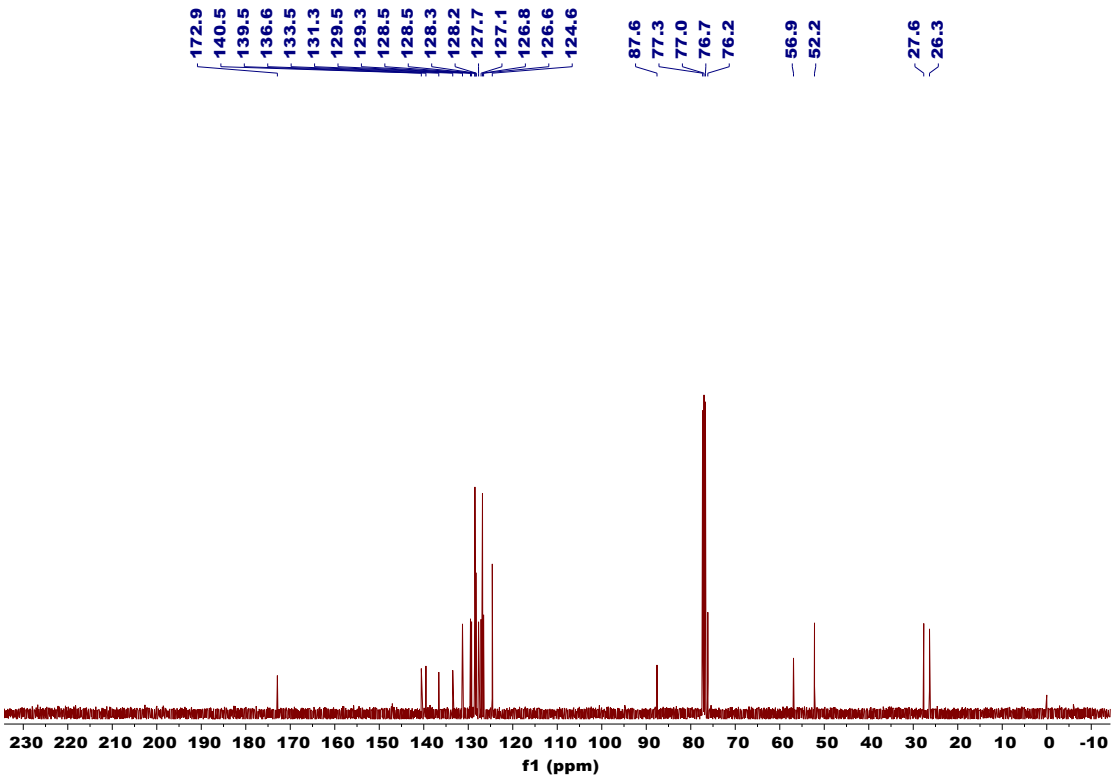

698
746
775
810
970
1016
1225
1356
1429
1452
1510
1601
1703
2931
3028
3508
3730
Arbitrary Units
Arbitrary Units

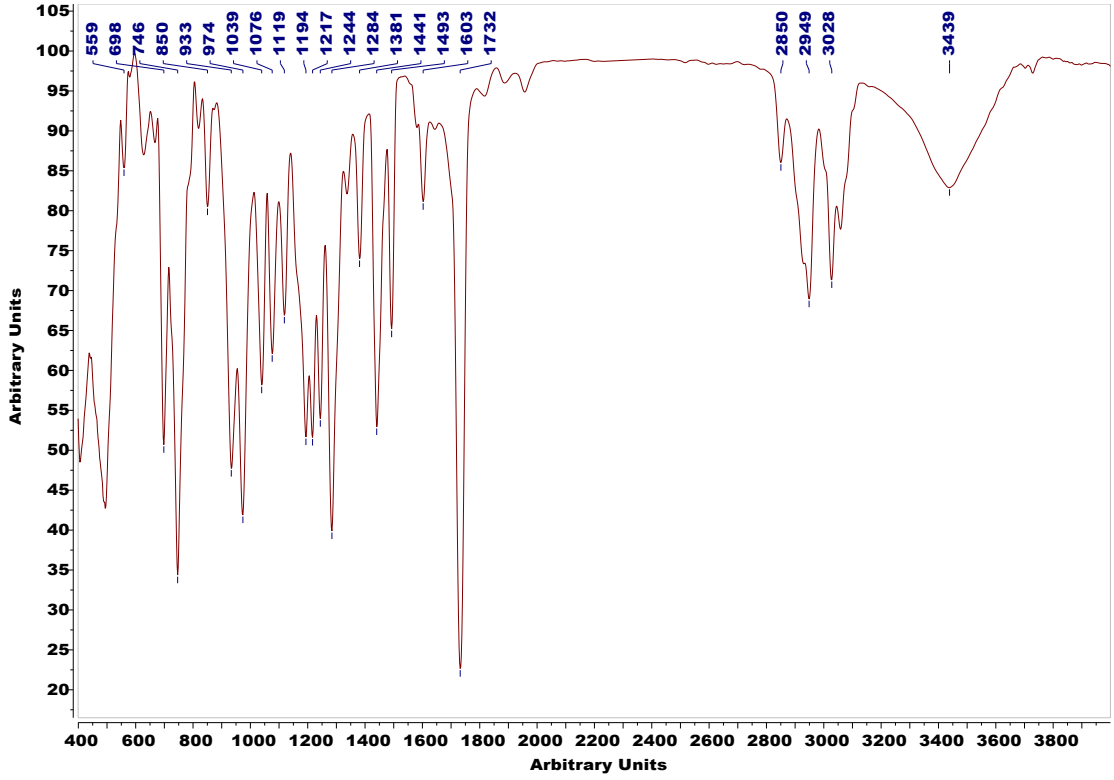

7.52
7.50
7.48
7.46
7.45
7.42
7.41
7.39
7.37
7.33
7.30
7.30
7.28
7.26
7.25
7.22
7.12
7.11
7.09
7.05
7.00
6.60
6.55
6.07
3.76
2.68
2.66
2.64
2.63
2.41
2.40
2.36
2.35
2.30
2.29
2.27
2.26
2.24
2.22
1.76
1.74
1.72
1.71
1.70
1.67
1.66
0.01


Ph
O
Ph
CO2Me

10


3.08
4.02
7.00
1.04
1.01
1.09
1.08
3.00
1.02
1.03
1.00
1.06
f1 (ppm)


172.9
140.5
139.5
136.6
133.5
131.3
129.5
129.3
128.5
128.5
128.3
128.2
127.7
127.1
126.8
126.6
124.6
87.6
77.3
77.0
76.7
76.2
56.9
52.2
27.6
26.3
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


559
698
746
850
933
974
1039
1076
1119
1194
1217
1244
1284
1381
1441
1493
1603
1732
2850
2949
3028
3439
Arbitrary Units
105 100 95 90 85 80 75 70 65 60 55 50 45 40 35 30 25 20
400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 2800 3000 3200 3400 3600 3800
Arbitrary Units


7.48
7.48
7.47
7.47
7.46
7.45
7.45
7.44
7.43
7.43
7.43
7.41
7.41
7.40
7.39
7.38
7.35
7.34
7.34
7.33
7.32
7.31
7.28
7.27
6.66
6.65
6.62
6.61
6.43
6.41
6.39
6.38
6.38
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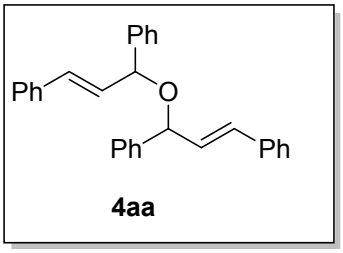
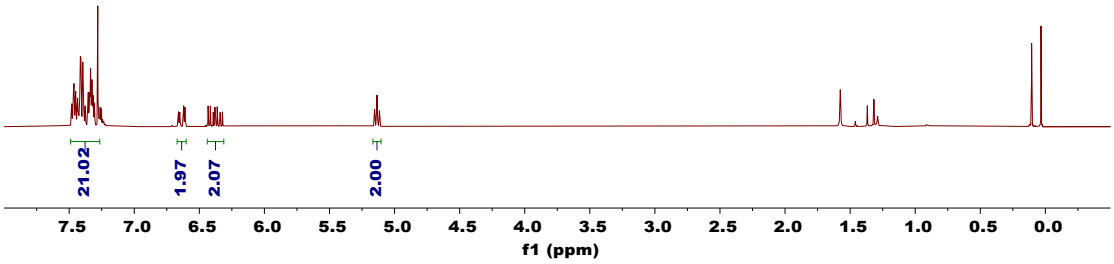
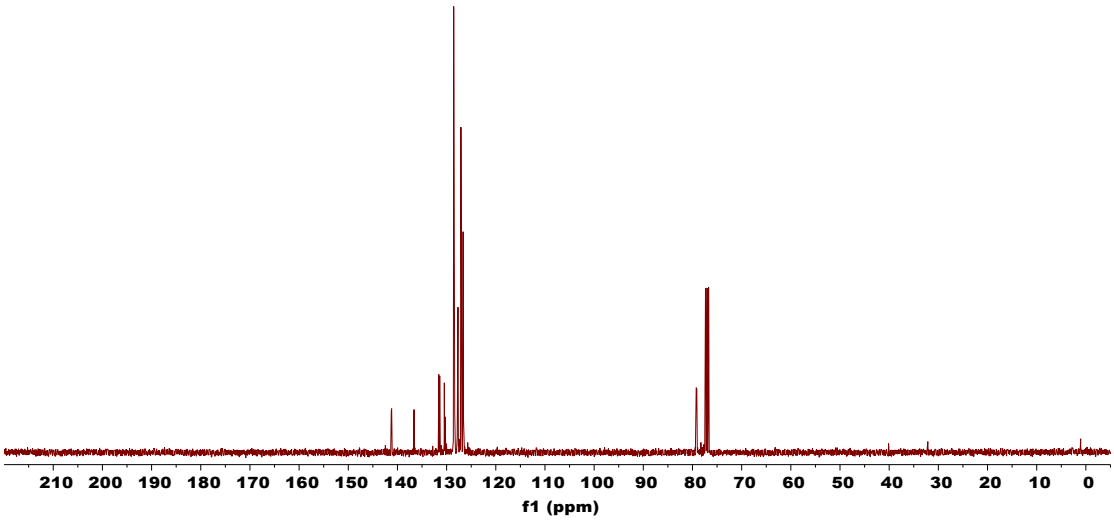
6.34
6.32
5.15
5.13
5.12
0.03

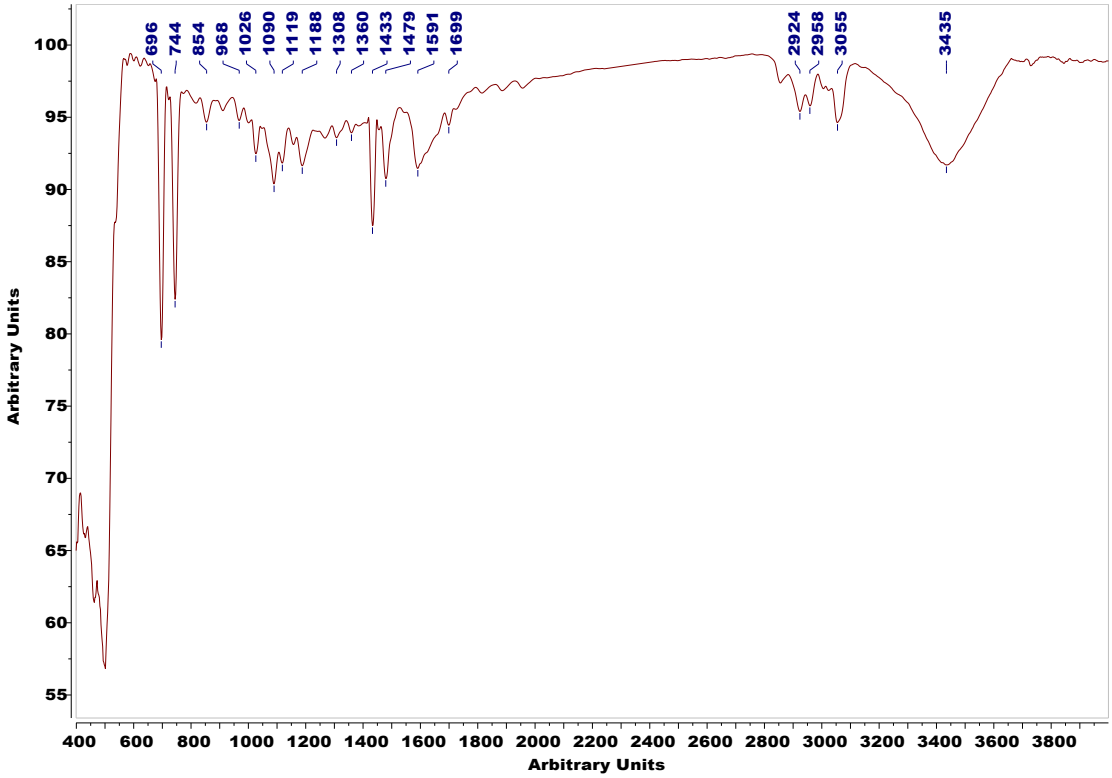

Ph
Ph
O
Ph
Ph

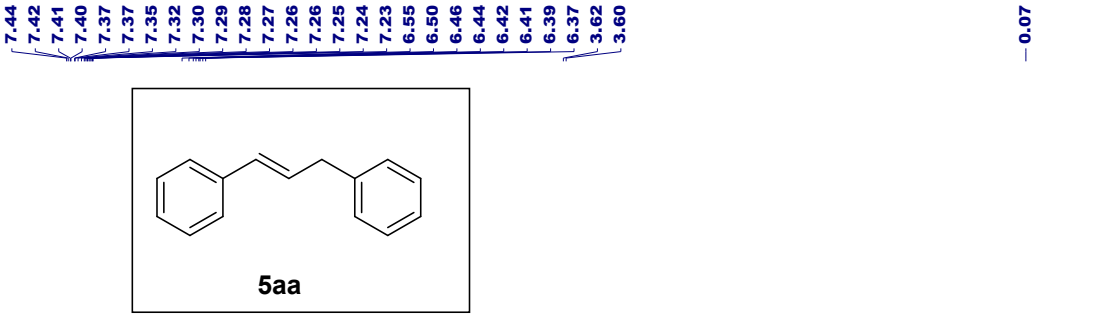
4aa


21.02
1.97
2.07
2.00
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)

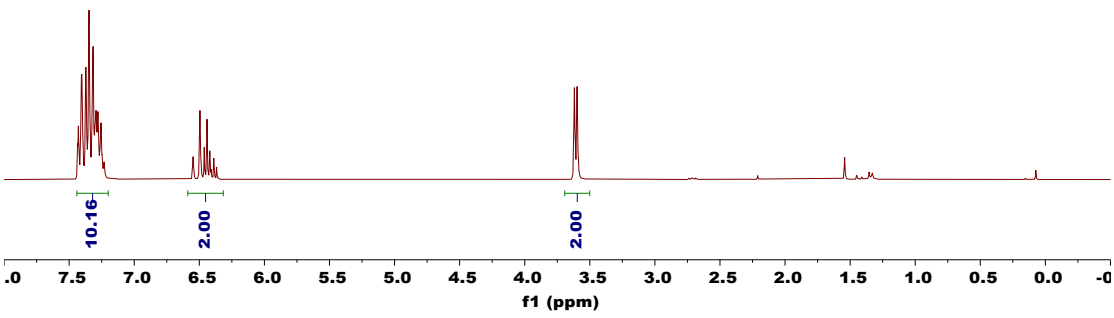

141.3
141.2
136.6
136.6
131.6
131.4
130.5
130.3
128.6
128.5
127.8
127.7
127.7
127.1
126.7
126.6
126.6
79.2
79.1
77.4
77.0
76.7

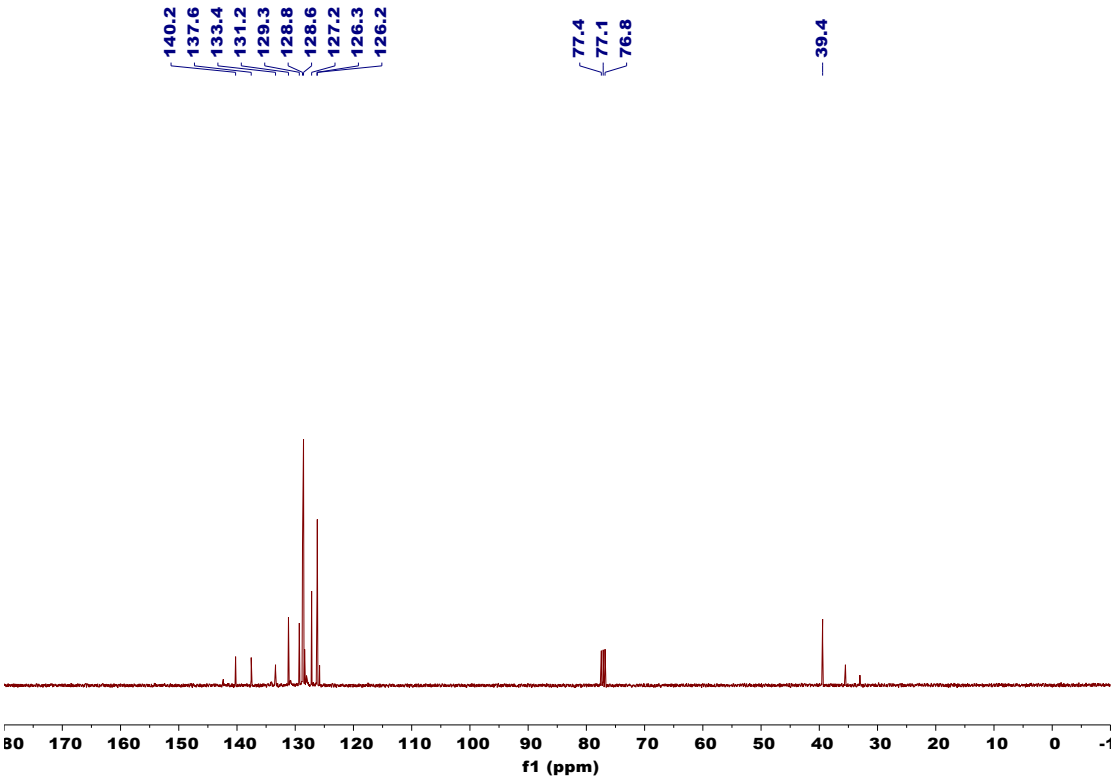

210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

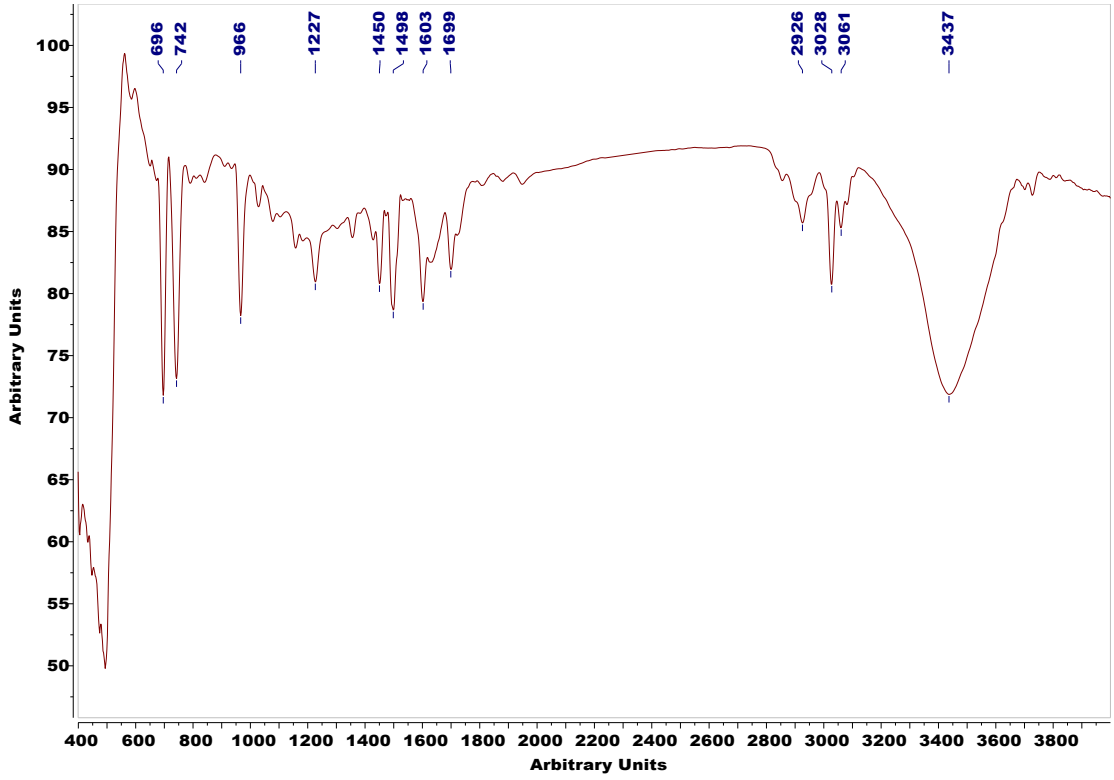

696
744
854
968
1026
1090
1119
1188
1308
1360
1433
1479
1591
1699
2924
2958
3055
3435
Arbitrary Units
Arbitrary Units

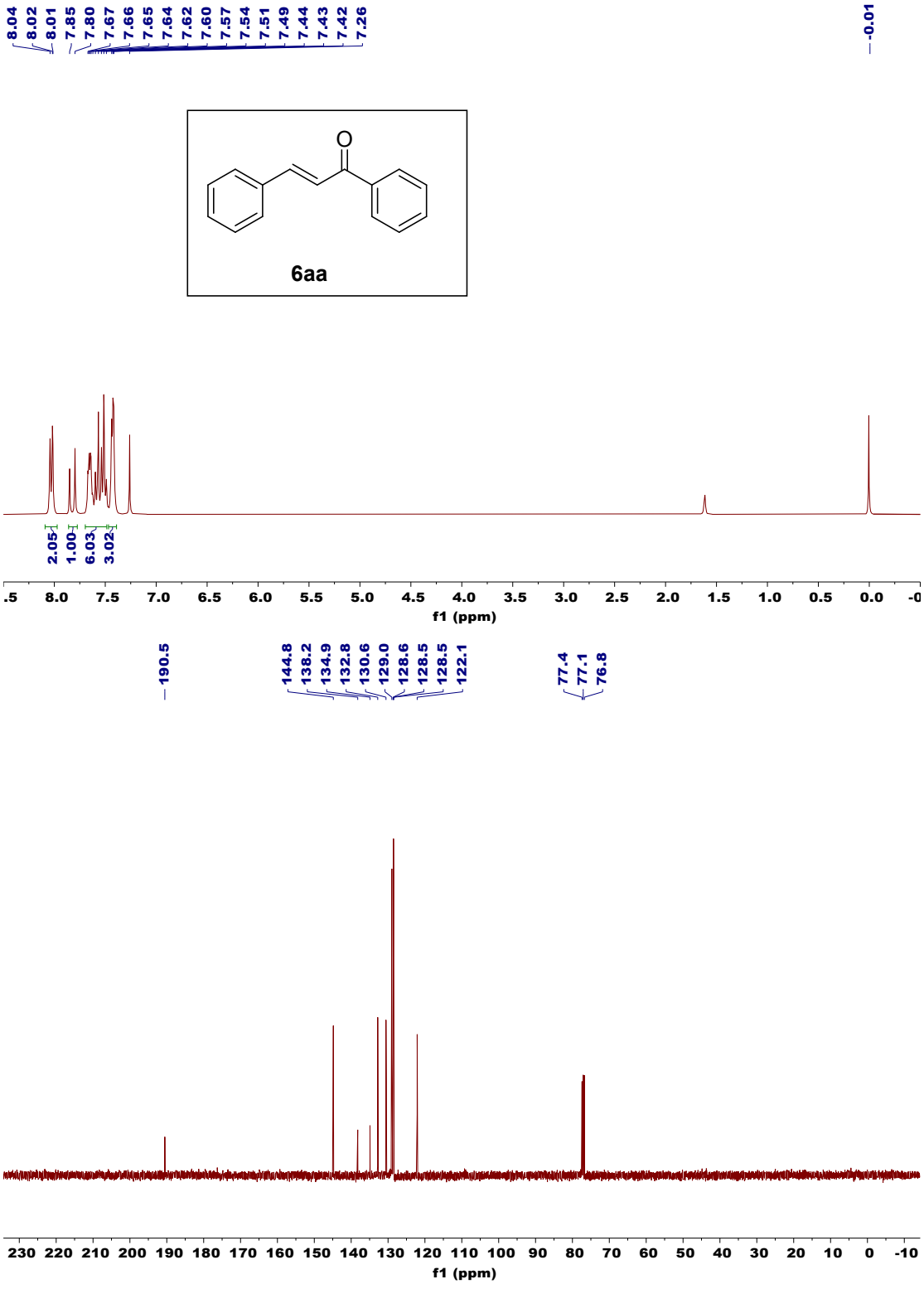

7.44
7.42
7.41
7.40
7.37
7.37
7.35
7.32
7.30
7.29
7.28
7.27
7.26
7.26
7.25
7.24
7.23
6.55
6.50
6.46
6.44
6.42
6.41
6.39
6.37
3.62
3.60
0.07

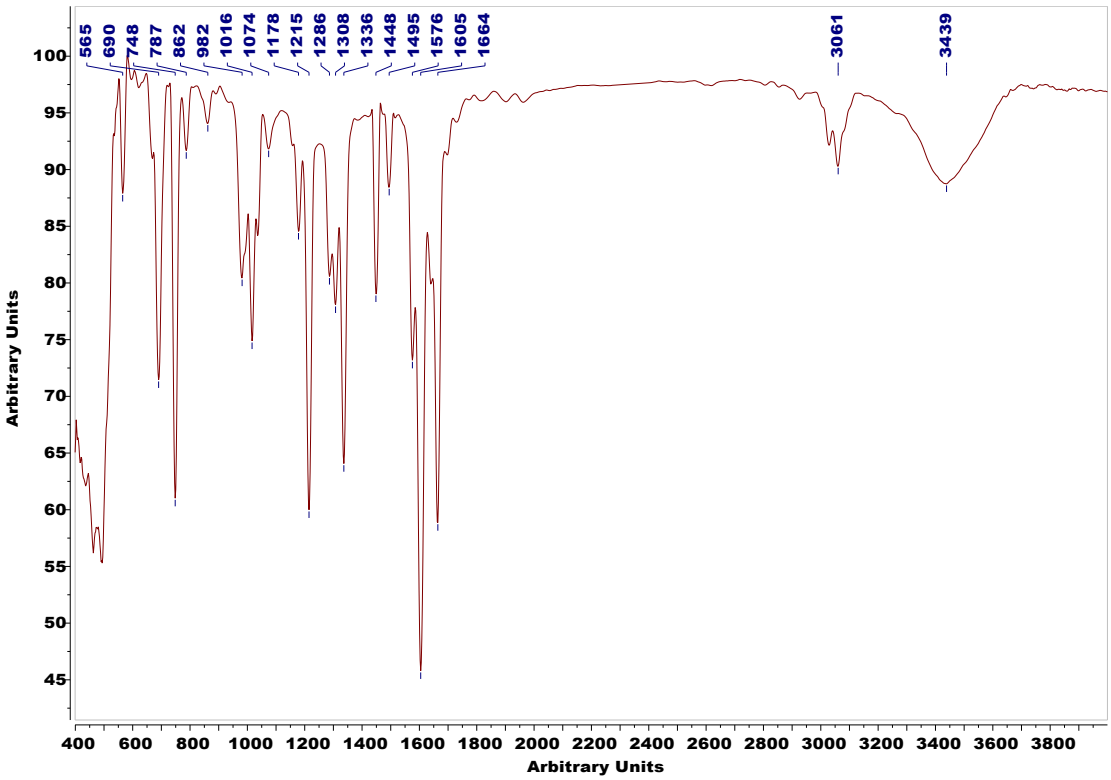
5aa


10.16
2.00
2.00
f1 (ppm)


140.2
137.6
133.4
131.2
129.3
128.8
128.6
127.2
126.3
126.2
77.4
77.1
76.8
39.4
f1 (ppm)


696
742
966
1227
1450
1498
1603
1699
2926
3028
3061
3437
Arbitrary Units
Arbitrary Units


8.04
8.02
8.01
7.85
7.80
7.67
7.66
7.65
7.64
7.62
7.60
7.57
7.54
7.51
7.49
7.44
7.43
7.42
7.26
-0.01
O
6aa
2.05
1.00
6.03
3.02
f1 (ppm)
190.5
144.8
138.2
134.9
132.8
130.6
129.0
128.6
128.5
128.5
122.1
77.4
77.1
76.8
f1 (ppm)


565
690
748
787
862
982
1016
1074
1178
1215
1286
1308
1336
1448
1495
1576
1605
1664
3061
3439
Arbitrary Units
100
95
90
85
80
75
70
65
60
55
50
45
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
3200
3400
3600
3800
Arbitrary Units