Synthesis of chiloglottones – semiochemicals from sexually deceptive orchids and their pollinators

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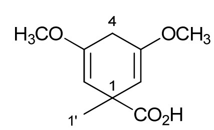
Supporting Information Index

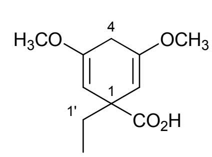
Representative Procedure for preparation of 2. Reductive alkylations were performed with adaptations to published procedures.[1,2] To a solution of 3,5-dimethoxybenzoic acid (1 equiv.) in dry THF (2 mL/mmol) liquid NH_3 (approx. 5 mL/mmol) was condensed. Lithium (2.2 equiv.) was added in portions at -33°C until a deep blue color persisted. The appropriate alkyl halide (1.2 equiv.) was added dropwise, causing an immediate reversion of the color change through orange to colorless. NH_3 was evaporated under a stream of N_2 overnight. The residue was partitioned between Et_2O and H_2O, the aqueous layer chilled to 0°C and acidified to pH 3-4 with careful addition of 2*N* HCl. The aqueous layer was reextracted (EtOAc), the organic phase washed (H_2O), dried ($MgSO_4$) and concentrated *in vacuo*. The solid residue was recrystallized from CH_2Cl_2 to return the diene acid **2**.

3,5-dimethoxy-1-methylcyclohexa-2,5-dienecarboxylic acid (2b)



Yield = 79% as colorless prisms. IR (neat): br. 3430, 1724, 1600 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$): δ 4.71 (2H, *dd*, ^4J = 1.5, ^4J = 1.5, H-2,6), 3.59 (6H, *s*, 3,5–OCH_3), 2.82 (1H, *dt*, ^2J = 20.7, ^4J = 1.5, H-4a), 2.73 (1H, *dt*, ^2J = 20.7, ^4J = 1.5, H-4b), 1.41 (3H, *s*, H-1′); ^{13}C APT NMR (75 MHz, $CDCl_3$): δ 172.2 (C, 1-CO_2H), 152.7 (C, C-3,5), 96.4 (CH, C-2,6), 54.4 (CH_3, 3,5–OCH_3), 45.8 (C, C-1), 30.9 (CH_2, C-4), 29.0 (CH_3, C-1′); *m/z* (ESI) 199.0963 [$(M+H)^+$ $C_{10}H_{15}O_4$ requires 199.0970 (Δ = 3.6 ppm)].

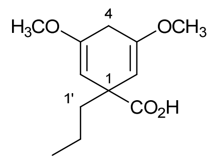
3,5-dimethoxy-1-ethylcyclohexa-2,5-dienecarboxylic acid (2c)



Yield = 78 % as colorless prisms. IR (neat): v. br. 3400, 2090, 1640 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$): δ 4.65 (2H, *dd*, ^4J = 1.2, ^4J = 1.2, H-2,6), 3.60 (6H, *s*, 3,5–OCH_3), 2.77-2.66 (2H, *m*, H-4), 1.75 (2H, *q*,

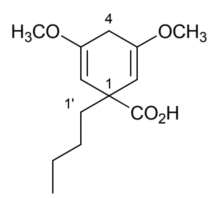
^3J = 7.5, H-1′), 0.82 (3H, *t*, ^3J = 7.5, H-2′); ^{13}C APT NMR (75 MHz, $CDCl_3$): δ 182.5 (C, 1-*C*O_2H), 153.4 (C, C-3,5), 94.4 (CH, C-2,6), 54.4 (CH_3, 3,5–O*C*H_3), 50.3 (C, C-1), 33.7 (CH_2, C-1′), 31.1 (CH_2, C-4), 8.6 (CH_3, C-2′); *m/z* (ESI) 213.1121 [$(M+H)^+$ $C_{11}H_{17}O_4$ requires 213.1127 (Δ = 2.8 ppm)].

3,5-dimethoxy-1-propylcyclohexa-2,5-dienecarboxylic acid (2d)



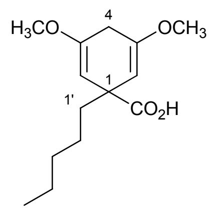
Yield = 99% as colorless prisms. IR (neat): v. br. 3400, 2090, 1643 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$): δ 4.68 (2H, *s*, H-2,6), 3.60 (6H, *s*, 3,5–OC*H*$_3$), 2.75 (2H, *s*, H-4), 1.73-1.67 (2H, *m*, H-1′), 1.31-1.20 (2H, *m*, H-2′), 0.90 (3H, *t*, ^3J = 7.2, H-3′); ^{13}C APT NMR (75 MHz, $CDCl_3$): δ 182.8 (C, *C*O_2H), 153.0 (C, C-3,5), 94.8 (CH, C-2,6), 54.4 (CH_3, 3,5–O*C*H_3), 49.9 (C, C-1), 43.4 (CH_2, C-1′), 31.1 (CH_2, C-4), 17.6 (CH_2, C-2′), 14.2 (CH_3, C-3′); *m/z* (ESI) 227.1289 [$(M+H)^+$ $C_{12}H_{19}O_4$ requires 227.1283 (Δ = 2.8 ppm)].

3,5-dimethoxy-1-butylcyclohexa-2,5-dienecarboxylic acid (2e)



Yield = 77% as colorless prisms. IR (neat): v. br. 3400, 2090, 1640 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$): δ 4.68 (2H, *s*, H-2,6), 3.60 (6H, *s*, 3,5–OC*H*$_3$), 2.76 (2H, *s*, H-4), 1.74-1.68 (2H, *m*, H-1′), 1.32-1.16 (4H, *m*, H-2′ and H-3′), 1.70 (3H, *t*, ^4J = 7.2, H-4′); ^{13}C APT NMR (75 MHz, $CDCl_3$): δ 182.8 (C, *C*O_2H), 153.1 (C, C-3,5), 94.9 (CH, C-2,6), 54.4 (CH_3, 3,5–O*C*H_3), 49.9 (C, C-1), 40.9 (CH_2, C-1′), 31.1 (CH_2, C-4), 26.4 (CH_2, C-2′), 22.9 (CH_2, C-3′), 14.0 (CH_3, C-4′); *m/z* (ESI) 241.1437 [$(M+H)^+$ $C_{13}H_{21}O_4$ requires 241.1440 (Δ = 1.2 ppm)].

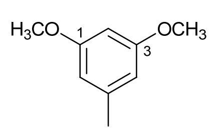
3,5-dimethoxy-1-pentylcyclohexa-2,5-dienecarboxylic acid (2f)



Yield = 44% as colorless prisms. IR (neat): v. br. 3400, 2090, 1643 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ 4.67 (2H, *s*, H-2,6), 3.60 (6H, *s*, 3,5–OC*H*$_3$), 2.76 (2H, *s*, H-4), 1.73-1.68 (2H, *m*, H-1′), 1.32-1.15 (6H, *m*, H-2′, H-3′ and H-4′), 0.86 (3H, *t*, $^3J = 7.2$, H-5′); ^{13}C APT NMR (75 MHz, $CDCl_3$): δ 182.8 (C, 1-*C*O$_2$H), 153.1 (C, C-3,5), 94.9 (CH, C-2,6), 54.4 (CH_3, 3,5–O*C*H$_3$), 49.9 (C, C-1), 41.0 (CH_2, C-1′), 32.0 (CH_2, C-3′), 31.1 (CH_2, C-4), 23.9 and 22.5 (CH_2, C-2′ and C-4′), 14.0 (CH_3, C-5′); *m/z* (ESI) 255.1596 [$(M+H)^+$ $C_{14}H_{23}O_4$ requires 255.1596 ($\Delta = 0.0$ ppm)].

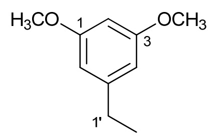
Representative Procedure for synthesis of 3: Following a published account with minor modifications;[1] to a rapidly stirred solution of **2** (1 equiv.) in benzene (20 mL/mmol) was added $Pb(OAc)_4$ (1.3 equiv.). After 30-40 min, by which time the mixture had become colorless, H_2O (approx. equivolume to benzene) was added and the mixture filtered under vacuum through a plug of silica. The aqueous phase was extracted with Et_2O and the combined organic extracts washed (sat. aqueous $NaHCO_3$ solution), dried ($MgSO_4$) and the solvents removed *in vacuo* to give **3** as a pale mobile oil.

1,3-dimethoxy-5-methylbenzene (3b)



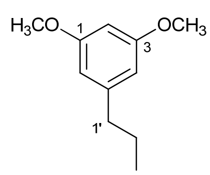
Yield = 91% as pale yellow oil: IR (neat): 2997, 2940, 2835, s. 1597, 1462, 1204, 1150, 829 cm^{-1}; ^{1}H NMR: (300 MHz, CDCl$_3$): δ 6.35 (2H, *d*, ^{4}J = 2.1, H-4,6), 6.30 (1H, *t*, ^{4}J = 2.1, H-2), 3.78 (6H, *s*, 1,3–OC*H*$_3$), 2.31 (3H, *s*, H-1′); ^{13}C NMR: (75 MHz, CDCl$_3$): δ 160.7 (C, C-1,3), 140.2 (C, C-5), 107.0 (CH, C-4,6), 97.5 (CH, C-2), 55.2 (CH$_3$, 1,3–O*C*H$_3$), 21.8 (CH$_3$, C-1′); *m/z* (EI) 152.0833 [M$^{+\bullet}$ $C_9H_{12}O_2$ requires 152.0837 (Δ = 2.8 ppm)].

1,3-dimethoxy-5-ethylbenzene (3c)



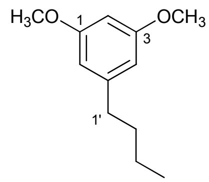
Yield = 94% as pale yellow oil: IR (neat): 2997, 2943, 2835, s. 1598, 1462, 1204, 1145, 829 cm^{-1}; ^{1}H NMR (300 MHz, CDCl$_3$): δ 6.37 (2H, *d*, ^{4}J = 2.1, H-4,6), 6.30 (1H, *t*, ^{4}J = 2.1, H-2), 3.79 (6H, *s*, 1,3–OC*H*$_3$), 2.60 (2H, *q*, ^{3}J = 7.5, H-1′), 1.23 (3H, *t*, ^{3}J = 7.5, H-2′); ^{13}C APT NMR (75 MHz, CDCl$_3$): δ 160.7 (C, C-1,3), 146.7 (C, C-5), 105.9 (CH, C-4,6), 97.5 (CH, C-2), 55.2 (CH$_3$, 1,3–O*C*H$_3$), 29.2 (CH$_2$, C-1′), 15.4 (CH$_3$, C-2′); *m/z* (EI) 166.0992 [M$^{+\bullet}$ $C_{10}H_{14}O_2$ requires 166.0994 (Δ = 1.1 ppm)].

1,3-dimethoxy-5-propylbenzene (3d)



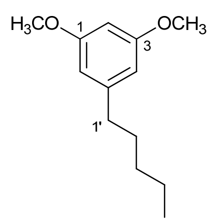
Yield = 99% as a pale yellow oil: IR (neat): 2997, 2959, 2832, s. 1597, 1462, 1204, 1150, 829 cm^{-1}; ^{1}H NMR (300 MHz, CDCl$_3$): δ 6.35 (2H, *d*, ^{4}J = 2.1, H-4,6), 6.30 (1H, *t*, ^{4}J = 2.1, H-2), 3.78 (6H, *s*, 1,3–OC*H*$_3$), 2.53 (2H, *t*, ^{3}J = 7.5, H-1′), 1.63 (2H, *tq*, ^{3}J = 7.5, ^{3}J = 7.5, H-2′), 1.23 (3H, *t*, ^{3}J = 7.5, H-3′); ^{13}C NMR APT NMR (75 MHz, CDCl$_3$): δ 160.6 (C, C-1,3), 145.1 (C, C-5), 106.5 (CH, C-4,6), 97.5 (CH, C-2), 55.2 (CH$_3$, 1,3–O*C*H$_3$), 38.4 (CH$_2$, C-1′), 24.3 (CH$_2$, C-2′), 13.9 (CH$_3$, C-3′); *m/z* (EI) 180.1149 [M$^{+\bullet}$ $C_{11}H_{16}O_2$ requires 180.1150 (Δ = 0.7 ppm)].

1,3-dimethoxy-5-butylbenzene (3e)



Yield = 88% as a pale yellow oil: IR (neat): 2995, 2950, 2835, s. 1595, 1462, 1205, 1150, 829 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$): δ 6.35 (2H, *d*, $^{4}J = 2.1$, H-4,6), 6.30 (1H, *t*, $^{4}J = 2.1$, H-2), 3.78 (6H, *s*, 1,3–OCH_3), 2.55 (2H, *t*, $^{3}J = 7.5$, H-1′), 1.59 (2H, *tt*, $^{3}J = 7.5$, $^{3}J = 7.5$, H-2′), 1.23 (2H, *tq*, $^{3}J = 7.5$, $^{3}J = 7.2$, H-3′), 0.93 (2H, *t*, $^{3}J = 7.2$, H-4′); ^{13}C NMR APT NMR (75 MHz, $CDCl_3$): δ 160.6 (C, C-1,3), 145.4 (C, C-5), 106.4 (CH, C-4,6), 97.5 (CH, C-2), 55.2 (CH_3, 1,3–OCH_3), 36.0 (CH_2, C-1′), 33.4 (CH_2, C-2′), 22.4 (CH_2, C-3′), 13.9 (CH_3, C-4′); *m/z* (EI) 194.1307 [$M^{+\bullet}$ $C_{12}H_{18}O_2$ requires 194.1307 ($\Delta = 0.1$ ppm)].

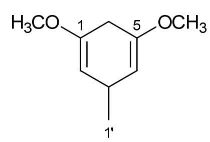
1,3-dimethoxy-5-pentylbenzene (3f)



Yield = 84% as a clear colourless oil: IR (neat): 2997, 2959, 2835, s. 1602, 1462, 1198, 1149, 829 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$): δ 6.35 (2H, *d*, $^{4}J = 2.4$, H-4,6), 6.30 (1H, *t*, $^{4}J = 2.4$, H-2), 3.79 (6H, *s*, 1,3–OCH_3), 2.55 (2H, *t*, $^{3}J = 7.5$, H-1′), 1.61 (2H, *tt*, $^{3}J = 7.5$, $^{3}J = 7.5$, H-2′), 1.35-1.30 (4H, *m*, H-3′ and H-4′), 0.93 (2H, *t*, $^{3}J = 7.2$, H-5′); ^{13}C NMR APT NMR (75 MHz, $CDCl_3$): δ 160.6 (C, C-1,3), 145.4 (C, C-5), 106.5 (CH, C-4,6), 97.5 (CH, C-2), 55.2 (1,3–OCH_3), 36.3 (CH_2, C-1′), 31.5 and 30.9 (CH_2, C-2′ and C-3′), 22.5 (CH_2, C-4′), 14.0 (CH_3, C-5′); *m/z* (EI) 208.1460 [$M^{+\bullet}$ $C_{13}H_{20}O_2$ requires 208.1463 ($\Delta =$ 1.7 ppm)].

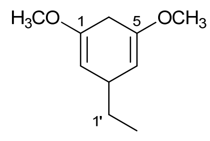
Representative Procedure for preparation of 4: To a solution of **3** (1 equiv.) in dry THF (approx. 4.5 mL/mmol) and *t*BuOH (approx. 4.5 mL/mmol), NH_3 (approx. 10-15 mL/mmol) was condensed. Lithium (17 equiv.) was added in portions at -33°C and the solution allowed to warm slowly to r.t. NH_3 was evaporated under a stream of N_2 and the residue partitioned between Et_2O and sat. aqueous NH_4Cl solution. The aqueous was reextracted (Et_2O), the combined organics dried ($MgSO_4$) and concentrated under vacuum to return the diene **4**.

1,5-dimethoxy-3-methylcyclohexa-1,4-diene (4b)



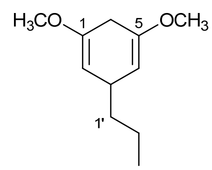
Yield = 61% as a pale yellow oil. IR (neat): 3000, 2955, 2865, s. 1600, 1382, 1205, 1150, 825 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ 4.57 (2H, *ddd*, $^3J = 3.3$, $^4J = 1.2$, $^4J = 1.2$, H-2,4), 3.56 (6H, *s*, 1,5–OCH_3), 3.04 (1H, *qtdd*, $^3J = 6.9$, $^3J = 3.3$, $^5J = 6.9$, $^5J = 6.9$, H-3), 2.81-2.71 (2H, *m*, H-6), 1.08 (3H, *d*, $^3J = 6.9$ H-1′); ^{13}C APT NMR (75 MHz, $CDCl_3$): δ 151.2 (C, C-1,5), 97.7 (CH, C-2,4), 54.1 (CH_3, 1,5–OCH_3), 31.0 (CH_2, C-6), 30.6 (CH, C-3), 24.5 (CH_3, C-1′); *m/z* (EI) 154.0994 [$M^{+\bullet}$ $C_9H_{14}O_2$ requires 154.0996 (Δ = 0.1 ppm)].

1,5-dimethoxy-3-ethylcyclohexa-1,4-diene (4c)



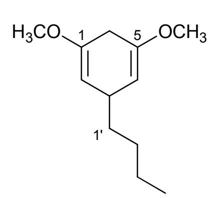
Yield = 83% as a clear colourless oil. b.p. 145°C @ 1.5mmHg; IR (neat): 3059, 2997, 2959, 2824, s. 1694, 1663, 1597, 1443, 1397, 1234, 1207, 1150 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$): δ 4.58-4.57 (2H, *m*, H-2,4), 3.57 (6H, *s*, 1,5–OCH_3), 2.94 (1H, *ttdd*, $^{3}J = 7.0$, $^{3}J = 3.3$, $^{5}J = 6.6$, $^{5}J = 6.6$, H-3), 2.77-2.76 (2H, *m* [apparent *d*], $J = 6.5$, H-6), 1.43 (2H, *dq*, $^{3}J = 7.0$, $^{3}J = 7.0$, H-1′), 0.87 (3H, *t*, $^{3}J = 7.0$, H-2′); ^{13}C APT NMR (75 MHz, $CDCl_3$): δ 151.9 (C, C-1,5), 65.7 (CH, C-2,4), 54.1 (CH_3, 1,5–OCH_3), 36.8 (C-3), 31.3 (CH_2, C-6), 30.7 (CH_2, C-1′), 10.4 (CH_3, C-2′); *m/z* (ESI) 169.1226 [$(M+H)^+$ $C_{10}H_{17}O_2$ requires 169.1229 (Δ = 1.7 ppm)].

1,5-dimethoxy-3-propylcyclohexa-1,4-diene (4d)



Yield = 88% as a pale yellow oil. IR (neat): 3059, 2997, 2955, 2870, 2839, s. 1693, 1659, 1609, 1462, 1204, 1150 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$): δ 4.60-4.59 (2H, *m*, H-2,4), 3.56 (6H, *s*, 1,5–OCH_3), 3.03-2.93 (1H, *m*, H-3), 2.77-2.75 (2H, *m* [apparent *d*], $J = 6.9$, H-6), 1.37-1.34 (4H, *m*, H-1′ and H-2’), 0.91 (3H, *t*, $^{3}J = 7.0$, H-3′); ^{13}C APT NMR (75 MHz, $CDCl_3$): δ 151.6 (C, C-1,5), 96.0 (CH, C-2,4), 54.1 (CH_3, 1,5–OCH_3), 40.6 (CH_2, C-1′), 35.4 (CH_2, C-3), 31.3 (CH_2, C-6), 19.4 (CH_2, C-2′), 14.3 (CH_3, C-3′); *m/z* (ESI) 183.1383 [$(M+H)^+$ $C_{11}H_{19}O_2$ requires 183.1385 (Δ = 1.1 ppm)].

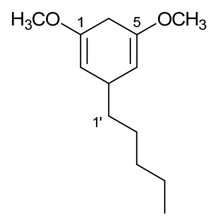
1,5-dimethoxy-3-butylcyclohexa-1,4-diene (4e)



Yield = 100% as a pale yellow oil: b.p. 150°C @ 0.7mmHg; IR (neat): 3059, 2997, 2955, 2928, 2855, 1693, 1663, 1609, 1462, 1397, 1207, 1150 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$): δ 4.60 (2H, *ddd*, $^{3}J = 3.3$,

$^{4}J = 1.2$, $^{4}J = 1.2$, H-2,4), 3.56 (6H, *s*, 1,5–OCH_3), 3.03-2.91 (1H, *m*, H-3), 2.76 (2H, *m*, H-6) 1.42-1.25 (6H, *m*, H-1′, H-2′ and H-3′), 0.90 (3H, *t*, $^{3}J = 7.2$, H-4′); ^{13}C APT NMR (75 MHz, $CDCl_3$): δ 151.6 (C, C-1,5), 96.1 (CH, C-2,4), 54.1 (CH_3, 1,5–OCH_3), 38.1 (CH_2, C-1′), 35.6 (CH, C-3), 31.3 (CH_2, C-6), 28.5 (CH_2, C-2′), 23.0 (CH_2, C3′), 14.1 (CH_3, C4′); *m/z* (EI) 196.1463 [$M^{+\bullet}$ $C_{12}H_{20}O_2$ requires 196.1460 (Δ = 1.9 ppm)].

1,5-dimethoxy-3-pentylcyclohexa-1,4-diene (4f)

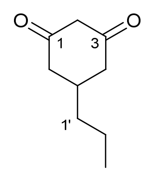


Yield = 85% as a pale yellow oil; IR (neat): 3059, 2997, 2955, 2928, 2870, s. 1695, 1663, 1610, 1443, 1204, 1150 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$): δ 4.59 (2H, *d*, $^{3}J = 3.6$, H-2,4), 3.56 (6H, *s*, 1,5-OCH_3), 2.96 (1H, *ttdd*, $^{3}J = 7.2$, $^{3}J = 3.6$, $^{5}J = 7.2$, $^{5}J = 7.2$, H-3), 2.78-2.75 (2H, *m*, [apparent *d*], $J = 7.2$, H-6) 1.4-1.25 (8H, *m*, H-1′, H-2′, H-3′ and H-4′), 0.89 (3H, *t*, $^{3}J = 6.9$, H-5′); ^{13}C APT NMR (75 MHz, $CDCl_3$): δ 151.6 (C, C-1,5), 96.1 (CH, C-2,4), 54.1 (CH_3, 1,5–OCH_3), 38.3 (CH_2, C-1′), 35.6 (CH, C-3), 31.3 (CH_2, C-6), 32.2 and 26.0 (CH_2, C-2′ and C-3′), 22.7 (CH_2, C-4′), 14.1 (CH_3, C-5′); *m/z* (ESI) 211.1696 [$(M+H)^+$ $C_{13}H_{23}O_2$ requires 211.1698 (Δ = 0.9 ppm)].

Representative Procedure for preparation of 5: Alkylations were achieved in a similar manner to previously reported methods.[3] A solution of **4** (1 equiv.) in dry THF (10 mL/mmol) was cooled to -78°C. *t*BuLi (1.1 equiv., 1.255 M in pentane) was added dropwise *via* syringe. The solution was stirred for 30 min at -78°C before dropwise addition of the required alkyl halide (1.6 equiv). After 10-15 min at -78°C the suspension was slowly warmed to r.t. and quenched with H_2O. The aqueous residue was extracted with Et_2O, the combined organic phases dried ($MgSO_4$) and the solvents removed *in vacuo*, returning **5**, which was immediately hydrolyzed to **1**, without separation of diastereomers.

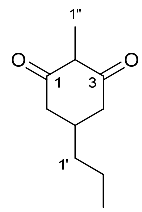
Representative Procedure for synthesis of 1: With modifications on a reported method,[4] crude **5** (1 equiv.) was dissolved in acetone (5 mL/mmol) and aq. 2*N* HCl (3 equiv.) added. The resulting solution was stirred overnight at r.t. The acetone was evaporated under reduced pressure and the residue diluted (H_2O), basified (aq. 1*N* NaOH) and washed with Et_2O. The aqueous layer was reacidified (pH 1-3 aq. 2*N* HCl) and extracted with EtOAc. The organic phase was dried ($MgSO_4$) and concentrated *in vacuo* to return **1** as a white solid.

5-propyl-1,3-cyclohexanedione (1da)



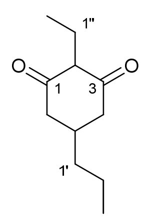
Yield = 88% as spreading colorless crystals: m.p. 95-99°C; IR (neat): br. 3310, 2957, 2930, 2872, br. 2550, 1572, 1232 cm^{-1}; ^1H NMR (500 MHz, CD_3OD): δ 2.40 (2H, *d*, ^2J = 12.5, H-4eq, 6eq), 2.12-2.09 (1H, *m*, H-5), 2.10 (2H, *d*, ^2J = 12.5, H-4ax, 6ax), 1.39-1.38 (4H, *m*, H-1′ and H-2′), 0.93 (3H, *t*, ^3J = 7.0, H-3′); ^{13}C APT NMR (125 MHz, CD_3OD): δ 104.3 (CH, C-2), 39.7 (br, CH_2, C-4,6), 38.8 (CH_2, C-1′), 34.9 (CH, C-5), 20.8 (CH_2, C-2′), 14.4 (CH_3, C-3′); *m/z* (EI) 154.0992 [$M^{+\bullet}$ $C_9H_{14}O_2$ requires 154.0994 (Δ = 0.9 ppm)], 154 (7%), 139 (1), 126 (3), 111 (23), 97 (100), 83 (82), 69 (28), 55 (83).

2-methyl-5-propyl-1,3-cyclohexanedione (1db)



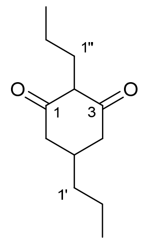
Yield = 92% over two steps. m.p. 111-115°C; IR (neat): br. 3060, 2955, 2930, 2872, br. 2650, 1572, 1383, 1242, 1088 cm^{-1}; ^{1}H NMR (500 MHz, CD_3OD): δ 2.44 (2H, *dd*, ^2J = 16.5, ^3J = 4.0, H-4eq, 6eq), 2.13 (2H, *dd*, ^2J = 16.5, ^3J = 11.0, H-4ax, 6ax), 2.06-2.01 (1H, *m*, H_5), 1.63 (3H, *s*, H-1″), 1.37-1.35 (4H, *m*, H-1′ and H-2′), 0.92 (3H, *t*, ^3J = 7.0, H-3′); ^{13}C APT NMR (125 MHz, CD_3OD): δ 111.5 (C, C-2), 38.9 (CH_2, C-1′), 34.5 (CH, C-5), 20.7 (CH_2, C-2′), 14.4 (CH_3, C-3′), 7.1 (CH_3, C-1″); *m/z* (EI) 168.1151 [$M^{+\bullet}$ $C_{10}H_{16}O_2$ requires 168.1150 (Δ = 0.3 ppm)], 168 (25%), 153 (<1), 140 (6), 125 (10), 111 (2), 97 (100), 83 (10), 70 (17), 55 (43).

2-ethyl-5-propyl-1,3-cyclohexanedione "Chiloglottone 1" (1dc)



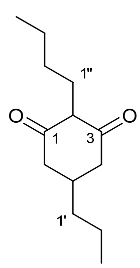
Yield = 82% over two steps. m.p. 124-126°C; IR (neat): 2957, 2928, 2872, br. 2640, 1557, 1383, 1263, 1244, 1105 cm^{-1}; ^{1}H NMR (500 MHz, CD_3OD): δ 2.46 (2H, *dd*, ^2J = 16.5, ^3J = 4.3, H-4eq, 6eq), 2.25 (2H, *q*, ^3J = 7.5, H-1″), 2.14 (2H, *dd*, ^2J = 16.5, ^3J = 11.3, H-4ax, 6ax), 2.07-2.01 (1H, *m*, H-5), 1.39-1.34 (4H, *m*, H-1′ and H-2′), 0.94 (3H, *t*, ^3J = 6.5, H-3′), 0.90 (3H, *t*, ^3J = 7.5, H-2″); ^{13}C APT NMR (125 MHz, CD_3OD): δ 176.5 (C, C-1,3), 118.5 (C, C-2), 39.3 (CH_2, C-4,6), 38.8 (CH_2, C-1′), 34.4 (CH, C-5), 20.7 (CH_2, C-2′), 16.0 (CH_2, C-1″), 14.4 and 13.6 (CH_3, C-2″, C-3′); *m/z* (EI) 182.1307 [$M^{+\bullet}$ $C_{11}H_{18}O_2$ requires 182.1307 (Δ = 0.1 ppm)], 182 (39%), 167 (5), 154 (6), 139 (17), 125 (42), 111 (30), 97 (100), 84 (35), 69 (39), 55 (78).

2,5-dipropyl-1,3-cyclohexanedione (1dd)



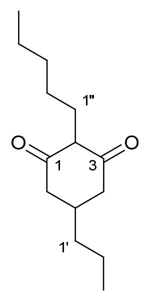
Yield = 75% over two steps. m.p. 133-138°C; IR (neat): br. 3425, 2957, 2928, 2872, br. 2640, 1566, 1383, 1240, 1233, 1113 cm^{-1}; ^{1}H NMR (500 MHz, CD_3OD): δ 2.44 (2H, *dd*, ^{2}J = 14.0, ^{3}J = 3.0, H-4eq, 6eq), 2.19 (2H, *t*, ^{3}J = 7.5, H-1″), 2.13 (2H, *dd*, ^{2}J = 14.0, ^{3}J = 11.0, H-4ax, 6ax), 2.06-2.00 (1H, *m*, H-5), 1.38-1.35 (4H, *m*, H-1′ and H-2′), 1.33 (2H, *tq* [apparent *hex*], ^{3}J = 7.5, ^{3}J = 7.0, H-2″), 0.93 (3H, *t*, ^{3}J = 7.0, H-3′), 0.85 (3H, *t*, ^{3}J = 7.0, H-3″); ^{13}C APT NMR (125 MHz, CD_3OD): δ 116.6 (C, C-2), 38.9 (CH_2, C-1′), 34.5 (CH, C-5), 24.7 (CH_2, C-1″), 22.8 (CH_2, C-2″), 20.8 (CH_2, C-2′), 14.43 and 14.38 (CH_3, C-3′ and C-3″); *m/z* (EI) 196.1457 [$M^{+\bullet}$ $C_{12}H_{20}O_2$ requires 196.1463 (Δ = 3.3 ppm)], 196 (33%), 181 (32), 167 (32), 154 (14), 139 (29), 125 (30), 111 (67), 97 (100), 84 (40), 69 (22), 55 (82).

2-butyl-5-propyl-1,3-cyclohexanedione (1de)



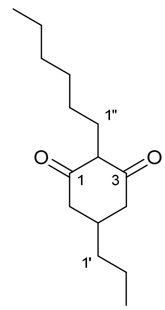
Yield = 81% over two steps. m.p. 141-146 °C; IR (neat): br. 3050, 2957, 2926, 2872, br. 2621, 1568, 1383, 1242, 1115 cm^{-1}; ^{1}H NMR (500 MHz, CD_3OD): δ 2.44 (2H, *dd*, ^{2}J = 16.5, ^{3}J = 4.0, H-4eq, 6eq), 2.21 (2H, *t*, ^{3}J = 7.0, H-1″), 2.13 (2H, *dd*, ^{2}J = 16.5, ^{3}J = 11.0, H-4ax, 6ax), 2.06-2.00 (1H, *m*, H-5), 1.37-1.35 (4H, *m*, H-1′ and H-2′), 1.29-1.26 (4H, *m*, H-2″ and H-3″), 0.93 (3H, *t*, ^{3}J = 7.0, H-3′), 0.88 (3H, *t*, ^{3}J = 7.0, H-4″); ^{13}C APT NMR (125 MHz, CD_3OD): δ 116.8 (C, C-2), 40.5 (br, CH_2, C-4,6), 38.9 (CH_2, C-1′), 34.5 (CH, C-5), 32.0 (CH_2, C-2″), 23.8 (CH_2, C-3″), 22.4 (CH_2, C-1″), 20.8 (CH_2, C-2′), 14.5 and 14.4 (CH_3, C-3′ and C-4″); *m/z* (EI) 210.1618 [$M^{+\bullet}$ $C_{13}H_{22}O_2$ requires 210.1620 (Δ = 0.6 ppm)], 210 (19%), 195 (6), 181 (38), 167 (34), 155 (28), 139 (27), 125 (37), 111 (56), 97 (100), 84 (37), 69 (25), 55 (67).

2-pentyl-5-propyl-1,3-cyclohexanedione (1df)



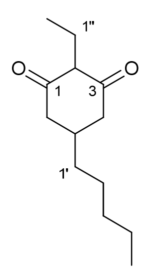
Yield = 69% over two steps. m.p. 139-143°C; IR (neat): br. 3450, 2957, 2928, 2872, br. 2633, 1568, 1385, 1242, 1115 cm^{-1}; ^{1}H NMR (500 MHz, CD_3OD): δ 2.44 (2H, *dd*, ^{2}J = 16.5, ^{3}J = 3.5, H-4eq, 6eq), 2.20 (2H, *t*, ^{3}J = 7.0, H-1″), 2.13 (2H, *dd*, ^{2}J = 16.5, ^{3}J = 11.0, H-4ax, 6ax), 2.05-2.00 (1H, *m*, H-5), 1.37-1.35 (4H, *m*, H-1′, and H-2′), 1.32-1.22 (6H, *m*, H-2″, H-3″ and H-4″), 0.93 (3H, *t*, ^{3}J = 7.0, H-3′), 0.87 (3H, *t*, ^{3}J = 7.0, H-5″); ^{13}C APT NMR (125 MHz, CD_3OD): δ 116.8 (C, C-2), 38.8 (CH_2, C-1′), 34.5 (CH, C-5), 33.0 (CH_2, C-3″), 29.4 (CH_2, C-2″), 23.7 and 22.6 (CH_2, C-1″ and C-4″), 20.8 (CH_2, C-2′), 14.5 and 14.4 (CH_3, C-3′ and C-5″); *m/z* (EI) 224.1776 [$M^{+\bullet}$ $C_{14}H_{24}O_2$ requires 224.1776 (Δ = 0.0 ppm)], 224 (17%), 209 (5), 195 (16), 181 (50), 168 (19), 155 (46), 139 (24), 125 (23), 111 (63), 97 (100), 84 (40), 69 (23), 55 (68).

2-hexyl-5-propyl-1,3-cyclohexanedione (1dg)



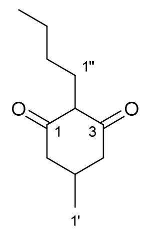
Yield = 66% over two steps. m.p. 133-136°C; IR (neat): br. 3055, 2957, 2926, 2872, br. 2645, 1568, 1383, 1242, 1117 cm^{-1}; ^{1}H NMR (500 MHz, CD_3OD): δ 2.44 (2H, *dd*, ^{2}J = 16.5, ^{3}J = 4.0, H-4eq, 6eq), 2.20 (2H, *t*, ^{3}J = 7.0, H-1″), 2.13 (2H, *dd*, ^{2}J = 16.5, ^{3}J = 11.0, H-4ax, 6ax), 2.06-2.00 (1H, *m*, H-5), 1.37-1.35 (4H, *m*, H-1′ and H-2′), 1.30-1.24 (8H, *m*, H-2″, H-3″, H-4″ and H-5″), 0.92 (3H, *t*, ^{3}J = 7.0, H-3′), 0.88 (3H, *t*, ^{3}J = 7.0, H-6″); ^{13}C APT NMR (125 MHz, CD_3OD): δ 116.8 (C, C-2), 38.8 (CH_2, C-1′), 34.5 (CH, C-5), 33.0 and 30.4 (CH_2, C-3″ and C-4″), 29.7 (CH_2, C-2″), 23.8 and 22.7 (CH_2, C-1″ and C-5″), 20.8 (CH_2, C-2′), 14.5 and 14.4 (CH_3, C-3′ and C-6″); *m/z* (EI) 238.1936 [$M^{+\bullet}$ $C_{15}H_{26}O_2$ requires 238.1933 (Δ = 1.2 ppm)], 238 (31%), 223 (<1), 209 (6), 195 (35), 181 (41), 168 (31), 155 (76), 139 (21), 125 (27), 111 (71), 97 (100), 84 (41), 69 (23), 55 (75).

2-ethyl-5-pentyl-1,3-cyclohexanedione "Chiloglottone 2" (1fc)



Yield = 72% over two steps. IR (neat): br. 3448, 2957, 2928, 2872, br. 2639, 1560, 1385, 1242, 1108 cm^{-1}; ^{1}H NMR (500 MHz, CD_3OD): δ 2.44 (2H, *dd*, ^{2}J = 16.5, ^{3}J = 4.0, H-4eq, 6eq), 2.25 (2H, *q*, ^{3}J = 7.5, H-1″), 2.13 (2H, *dd*, ^{2}J = 16.5, ^{3}J = 11.0, H-4ax, 6ax), 2.05-1.98 (1H, *m*, H-5), 1.38-1.24 (8H, *m*, H-1′, H-2′, H-3′ and H-4′), 0.94 and 0.90 (3H, *t*, ^{3}J = 6.5, H-5′ and 3H, *t*, ^{3}J = 7.5, H-2″); ^{13}C APT NMR (125 MHz, CD_3OD): δ 118.2 (C, C-2), 36.6 and 33.1 (CH_2, C-1′ and CH_2, C-3′), 34.8 (CH, C-5), 27.4 (CH_2, C-2′), 23.7 (CH_2, C-4′), 16.0 (CH_2, C-1″), 14.5 and 13.6 (CH_3, C-2″ and C-5′); *m/z* (EI) 210.1618 [$M^{+\bullet}$ $C_{13}H_{22}O_2$ requires 210.1620 (Δ = 1.9 ppm)], 210 (36%), 183 (12), 169 (9), 153 (27), 139 (43), 125 (82), 112 (50), 111 (35), 97 (35), 84 (45), 69 (52), 55 (100), 43 (47), 41 (50).

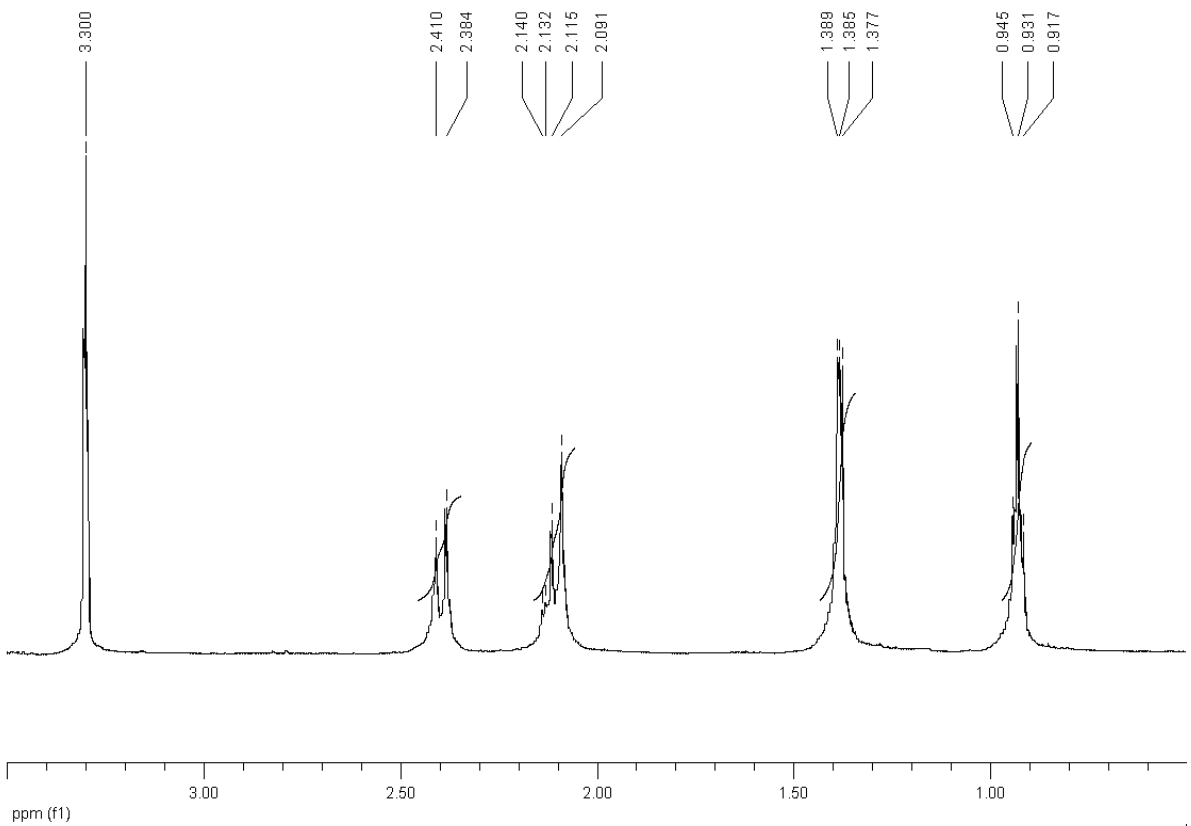
2-ethyl-5-pentyl-1,3-cyclohexanedione "Chiloglottone 3" (1be)



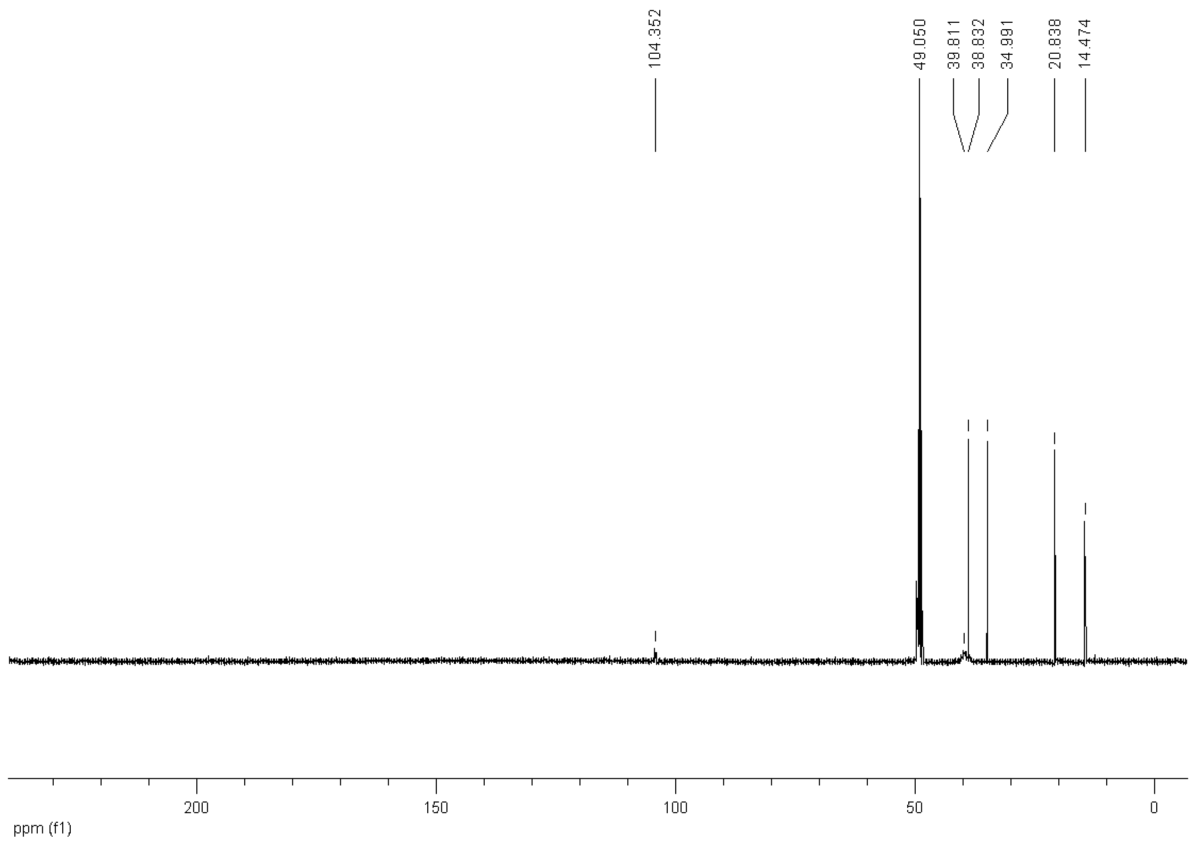
Yield = 55% over two steps: IR (neat): 2955, 2930, 2870, br. 2640, 1555, 1383, 1260, 1095 cm^{-1}; ^1H NMR (500 MHz, CD_3OD): δ 2.42 (2H, *d*, ^2J = 13.5, H-4eq, 6eq), 2.24 (2H, *q*, ^3J = 7.0, H-1″), 2.17-2.09 (3H, *m*, H-4ax, 6ax and H-5), 1.33-1.24 (4H, *m*, H-2″ and H-3″), 1.07 (3H, *d*, ^3J = 4.5, H-1′), 0.90 (3H, *t*, ^3J = 7.0, H-4″); ^{13}C APT NMR (125 MHz, CD_3OD): δ 116.7 (C, C-2), 32.1 (CH_2, C-2″), 29.9 (CH, C-5), 23.8 (CH_2, C-3″), 22.5 (CH_2, C-1″), 21.2 (CH_3, C-1′), 14.5 (CH_3, C-4″); *m/z* (EI) 182.1310 [$M^{+\bullet}$ $C_{11}H_{18}O_2$ requires 182.1307 (Δ = 1.81 ppm)], 182 (4%), 165 (3), 153 (16), 140 (18), 126 (20), 111 (27), 98 (30), 84 (48), 69 (85), 55 (92), 41 (100).

5-propyl-1,3-cyclohexanedione (1da)

^{1}H NMR, 500 MHz, CD_3OD

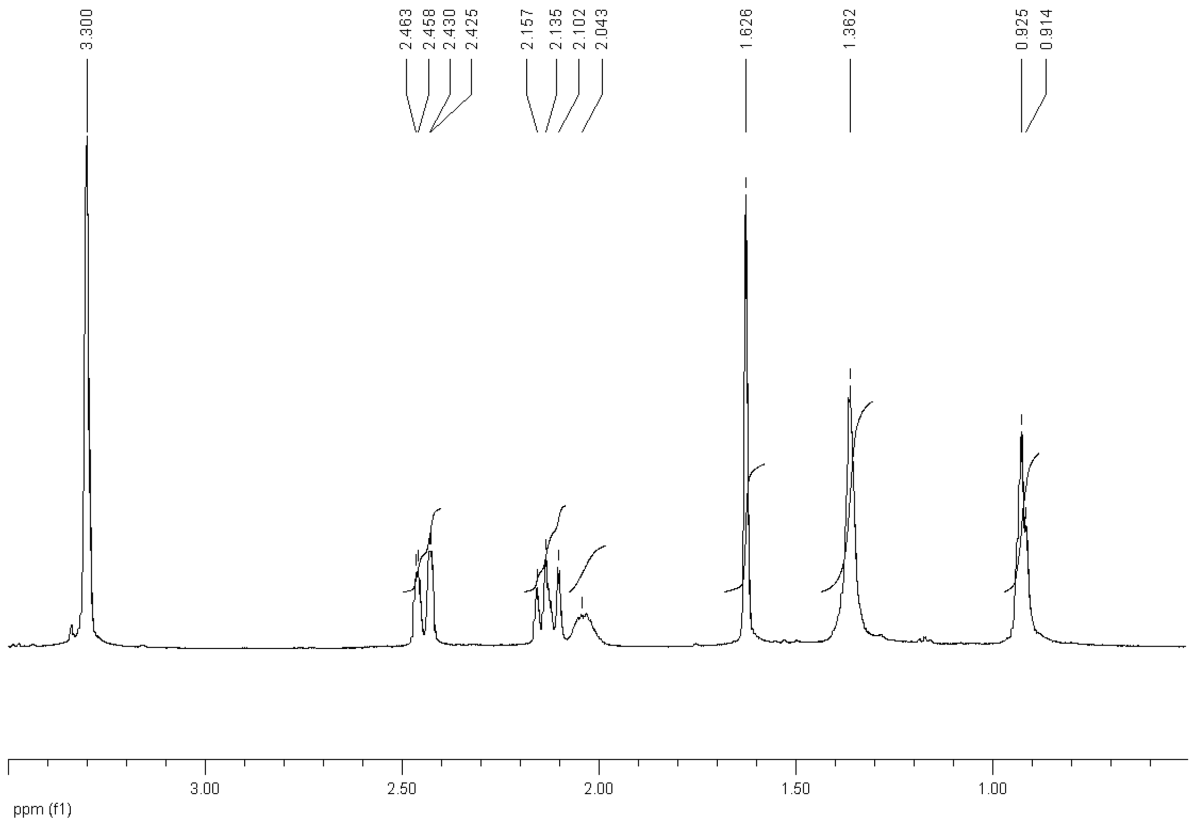


^{13}C NMR, 125 MHz, CD_3OD

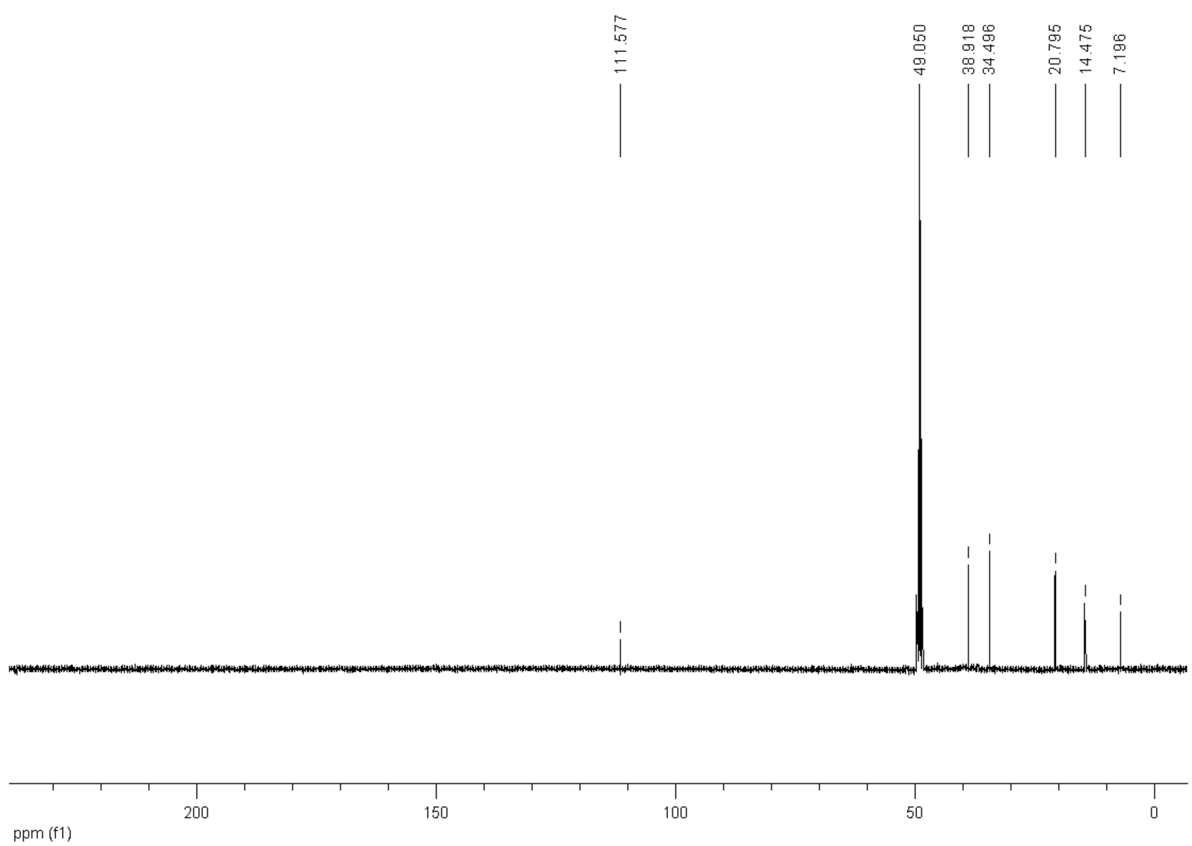


2-methyl-5-propyl-1,3-cyclohexanedione (1db)

^{1}H NMR, 500 MHz, CD_3OD

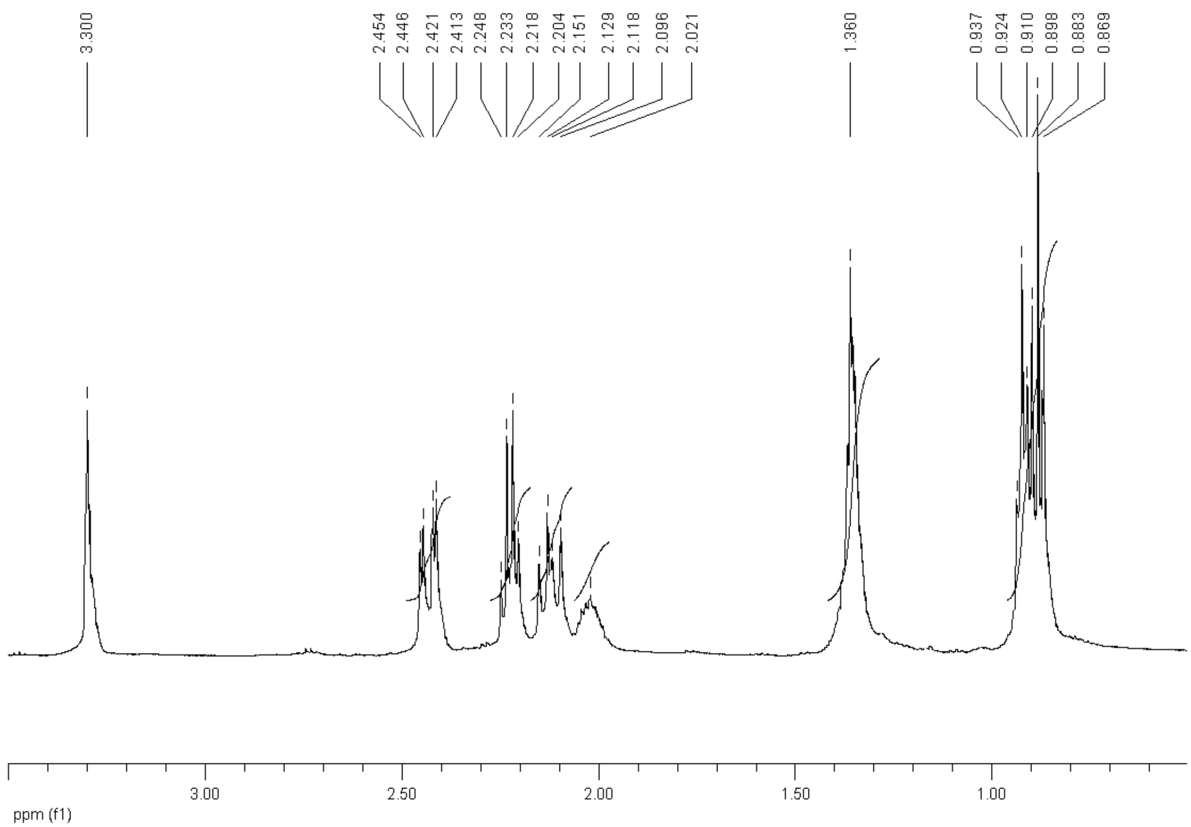


^{13}C NMR, 125 MHz, CD_3OD

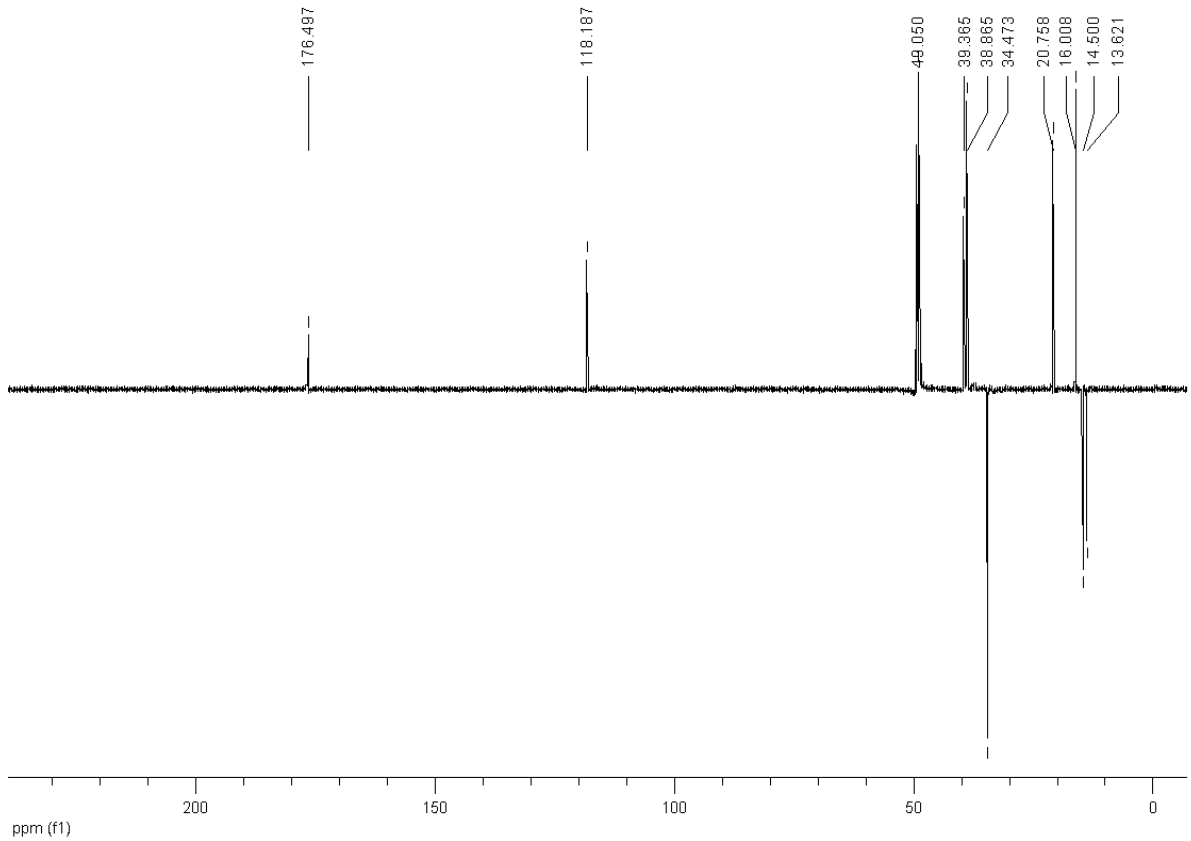


2-ethyl-5-propyl-1,3-cyclohexanedione "Chiloglottone 1" (1dc)

^{1}H NMR, 500 MHz, CD_3OD

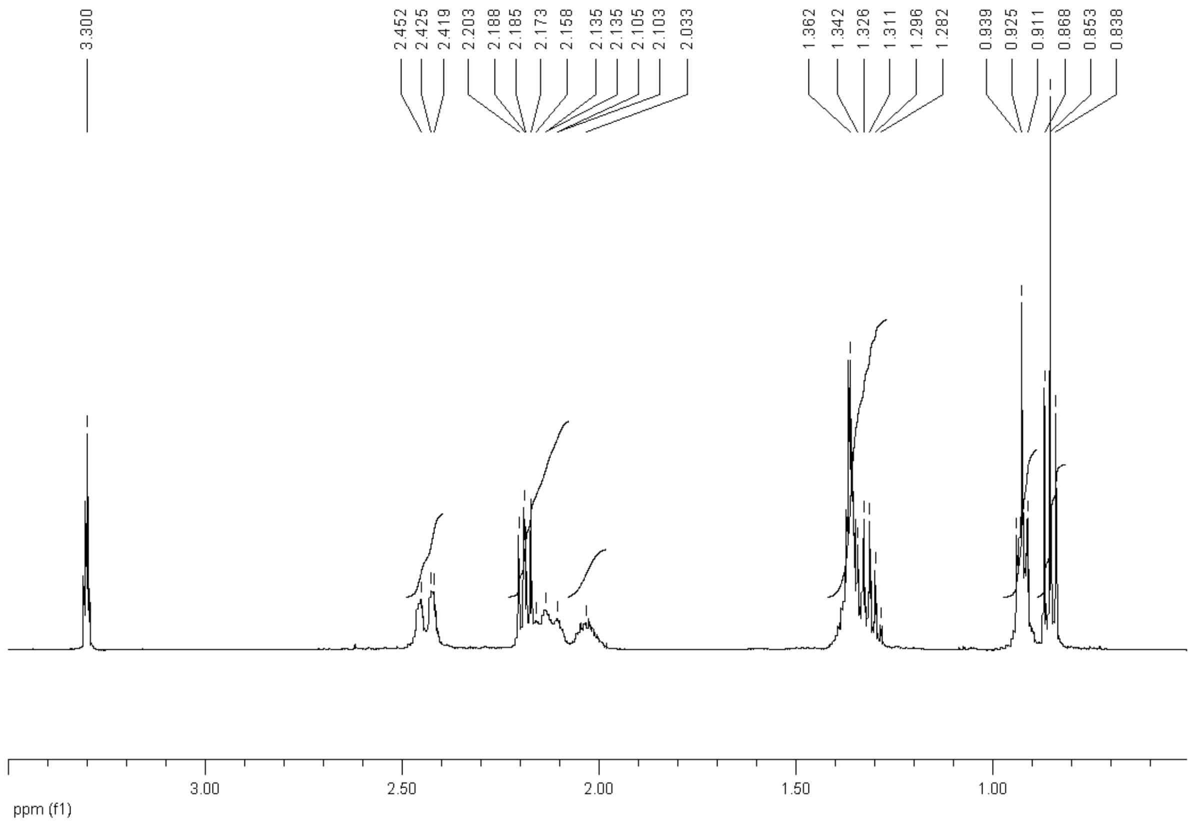


^{13}C APT NMR, 125 MHz, CD_3OD

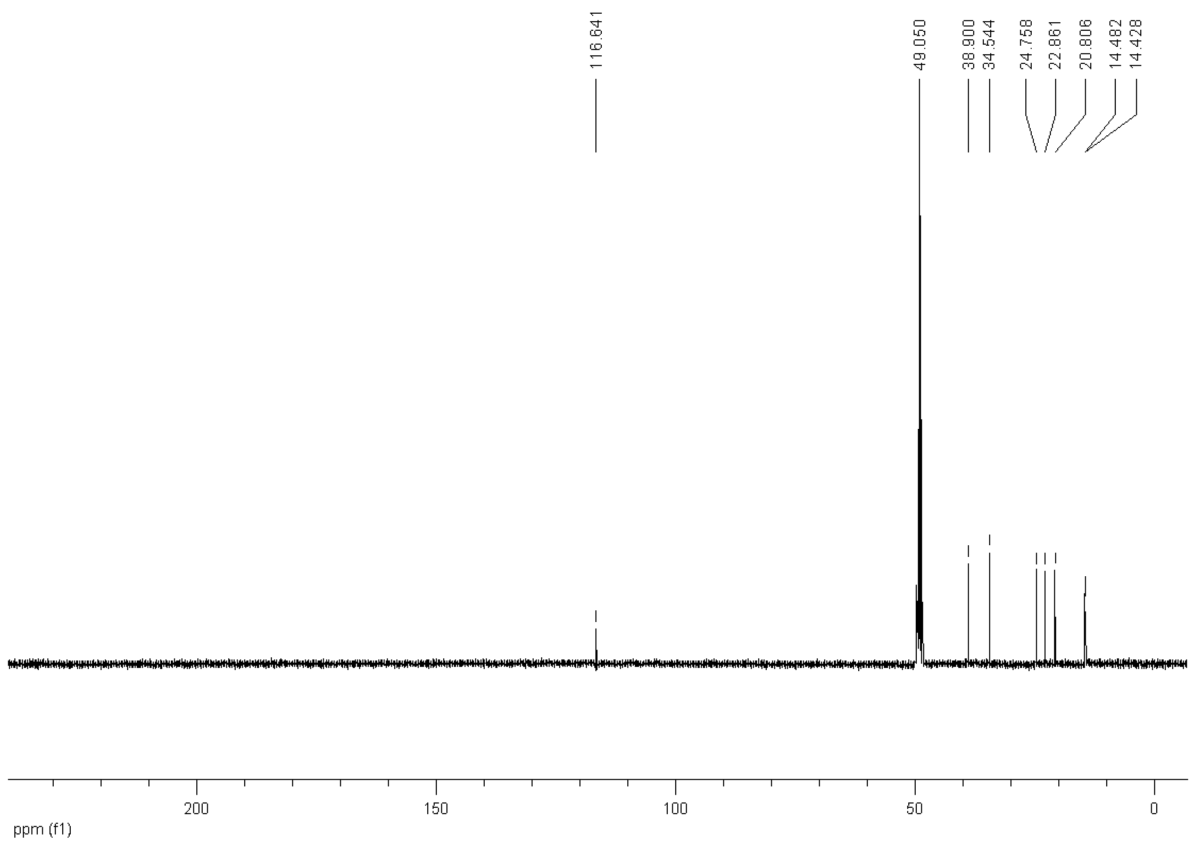


2,5-dipropyl-1,3-cyclohexanedione (1dd)

^{1}H NMR, 500 MHz, CD_3OD

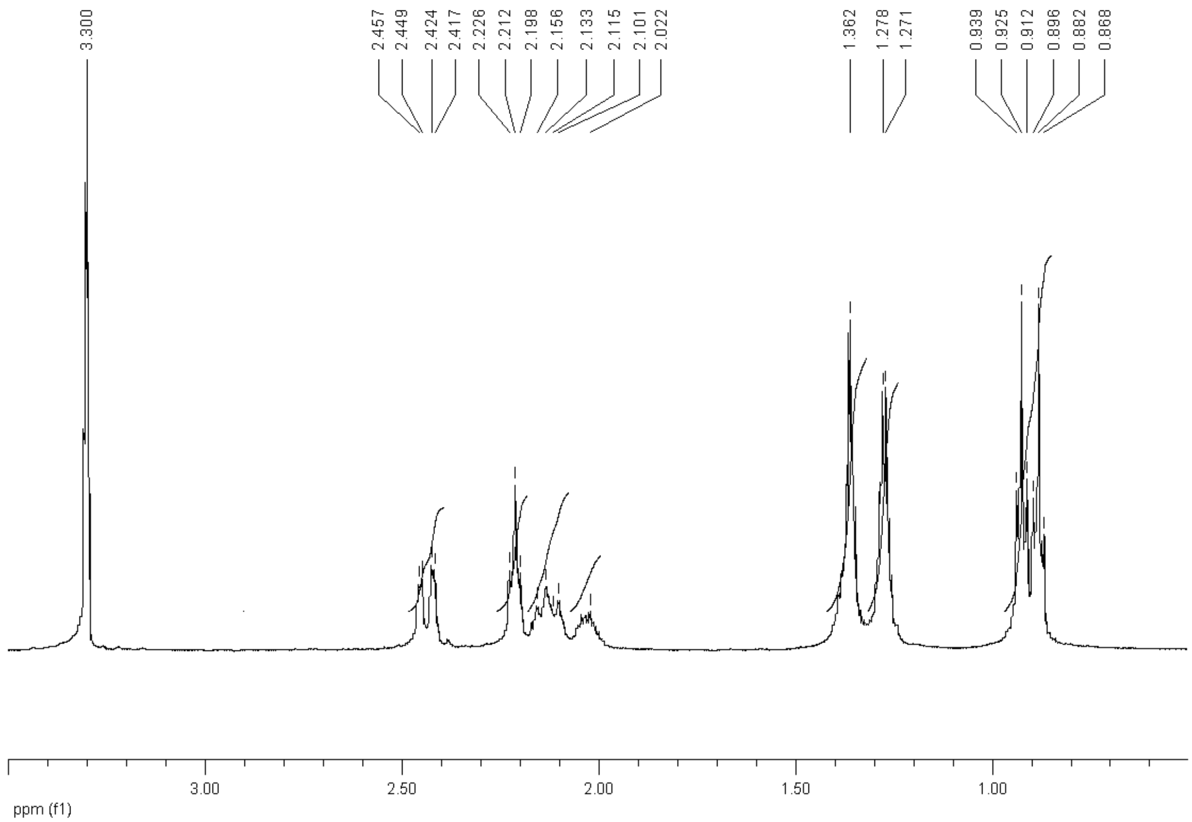


^{13}C NMR, 125 MHz, CD_3OD

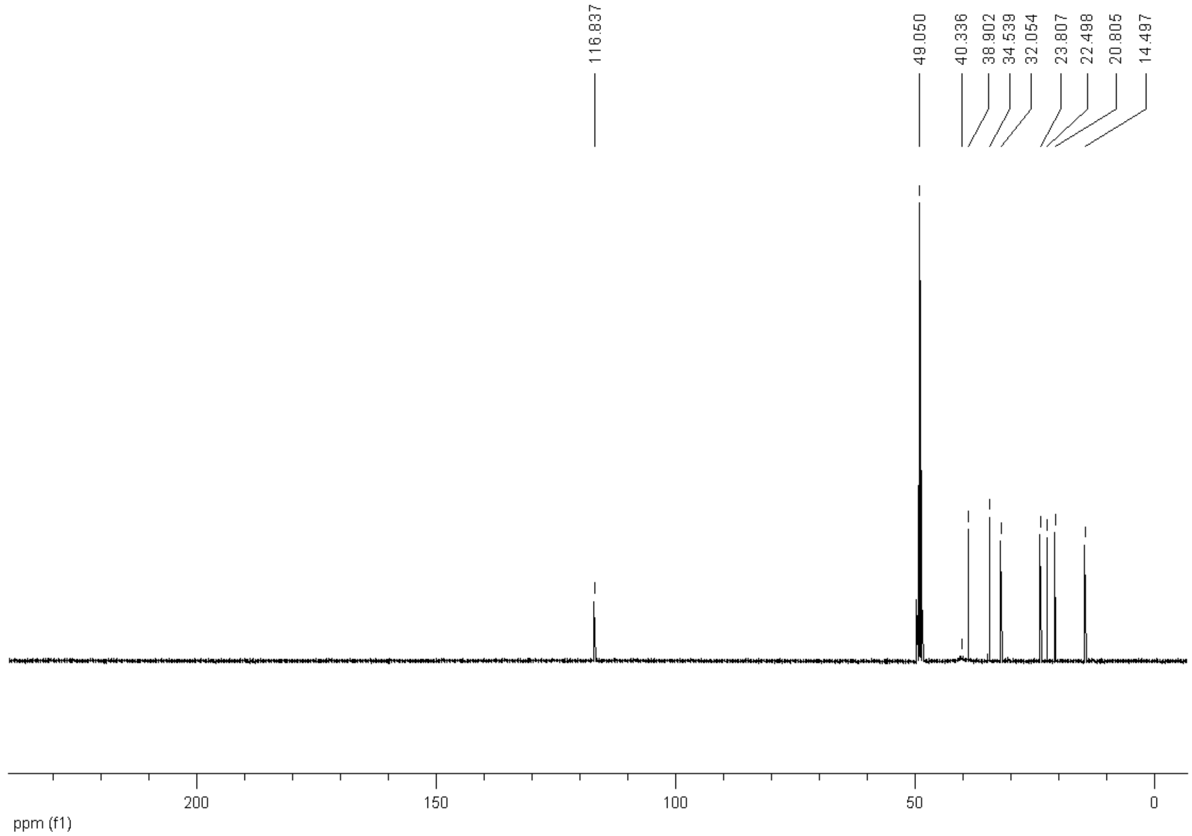


2-butyl-5-propyl-1,3-cyclohexanedione (1de)

[1]H NMR, 500 MHz, CD_3OD

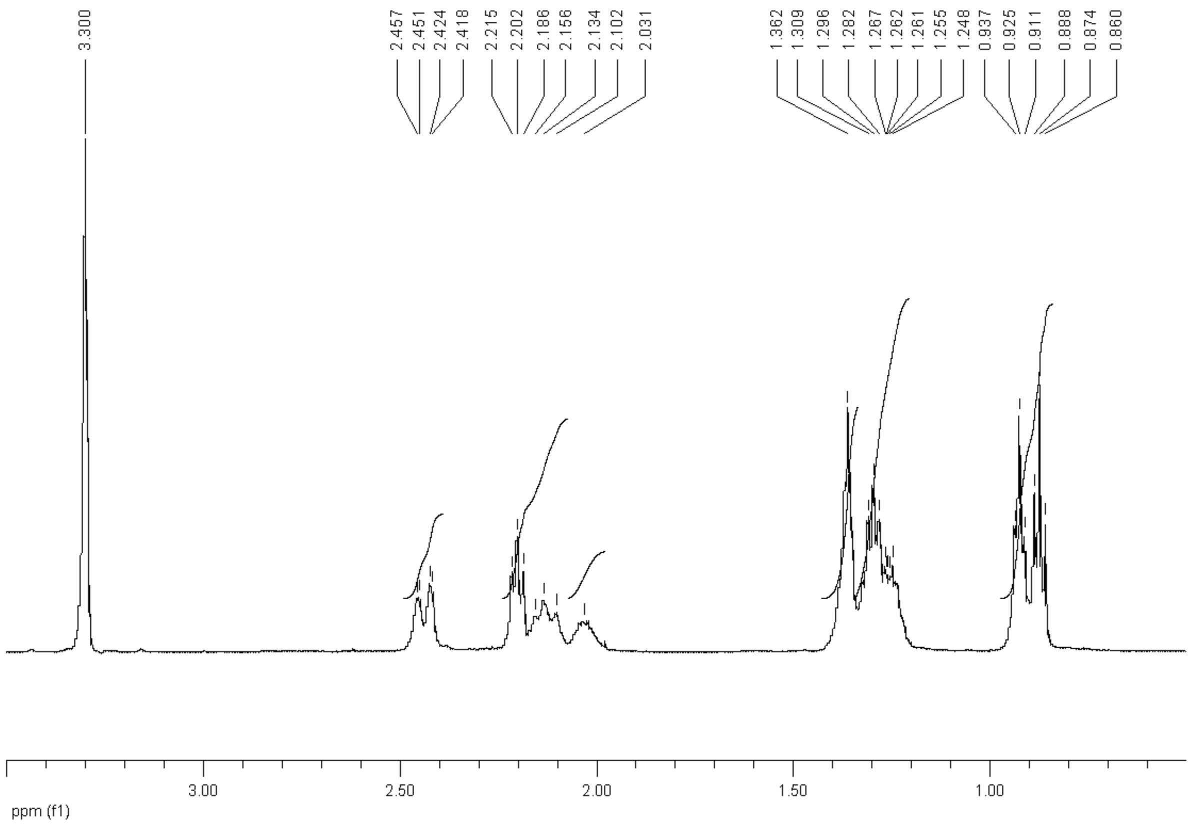


[13]C NMR, 125 MHz, CD_3OD

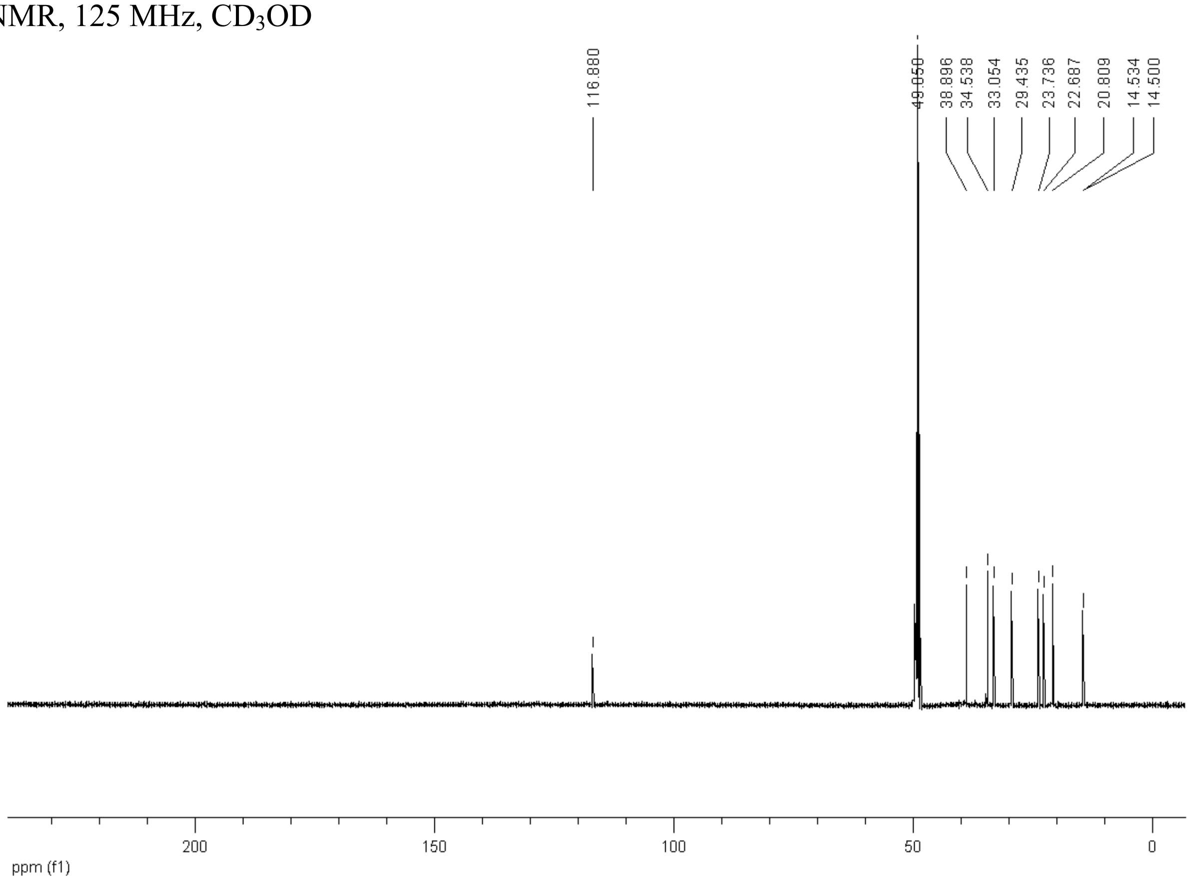


2-pentyl-5-propyl-1,3-cyclohexanedione (1df)

^{1}H NMR, 500 MHz, CD_3OD

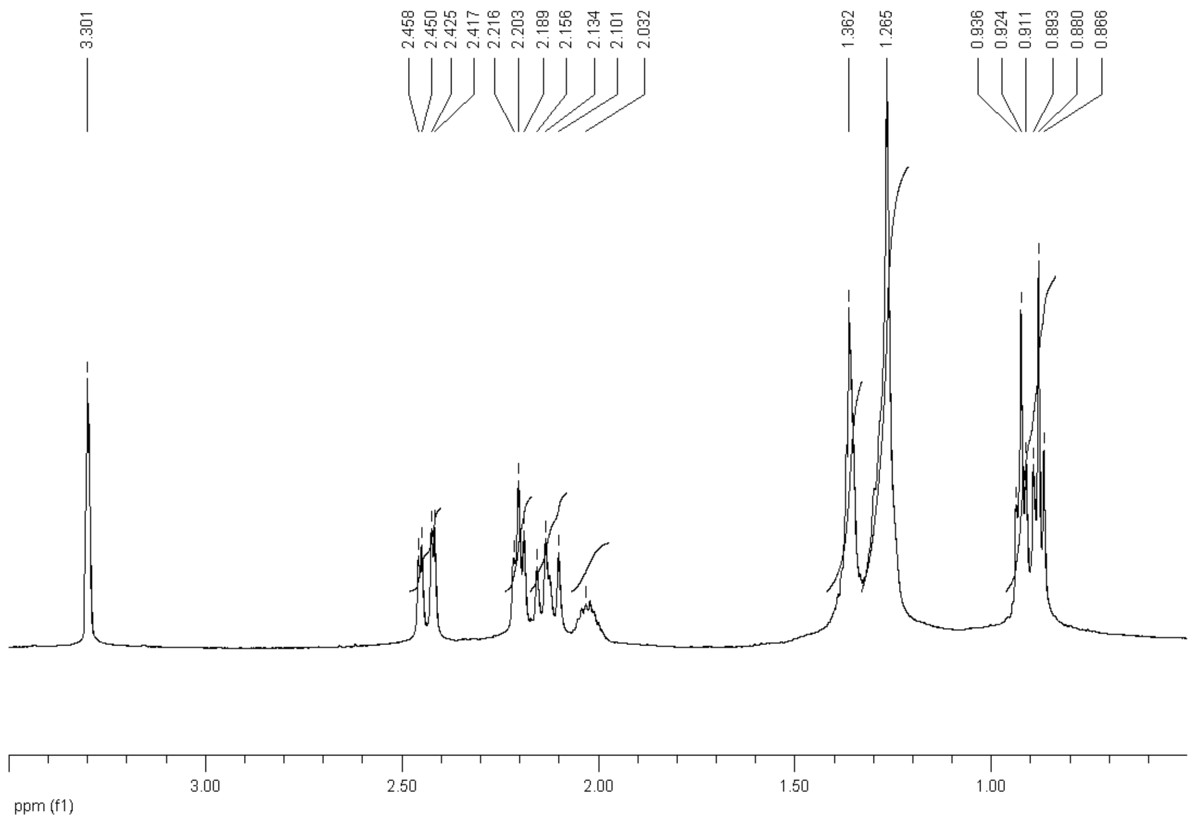


^{13}C NMR, 125 MHz, CD_3OD

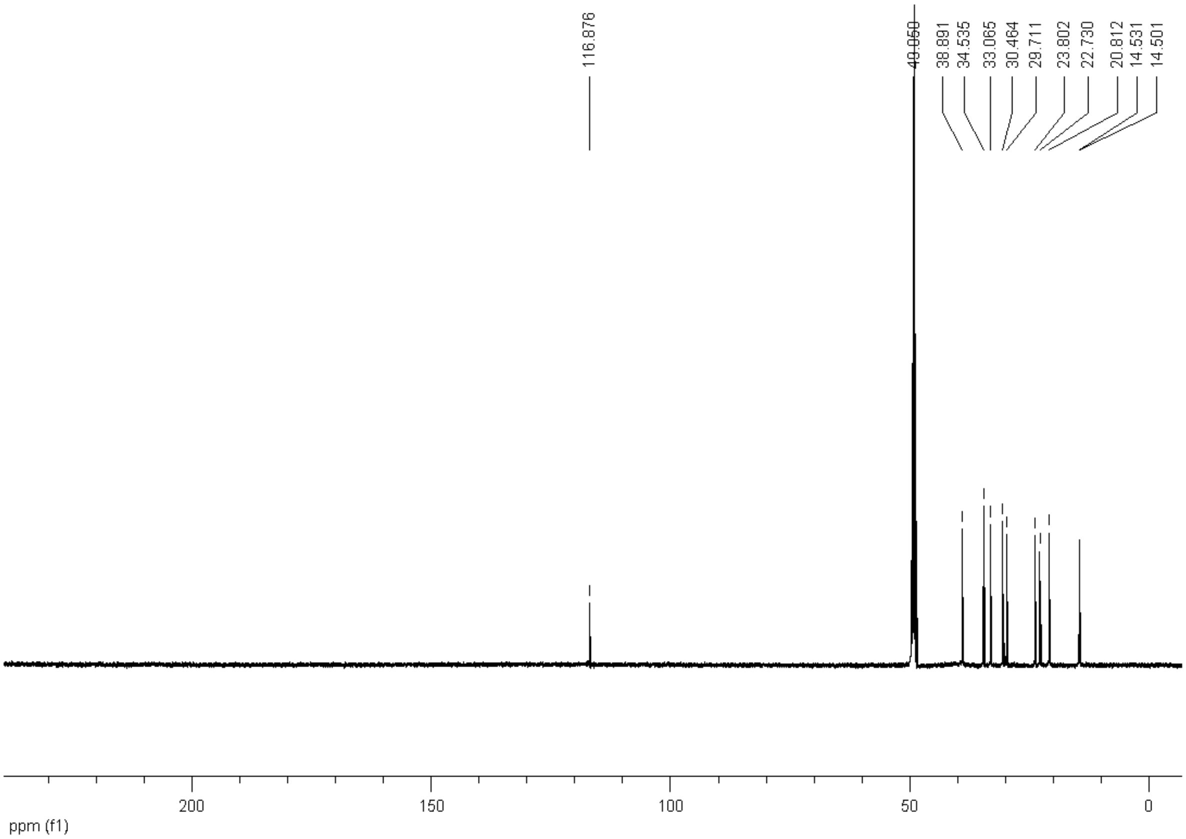


2-hexyl-5-propyl-1,3-cyclohexanedione (1dg)

^{1}H NMR, 500 MHz, CD_3OD

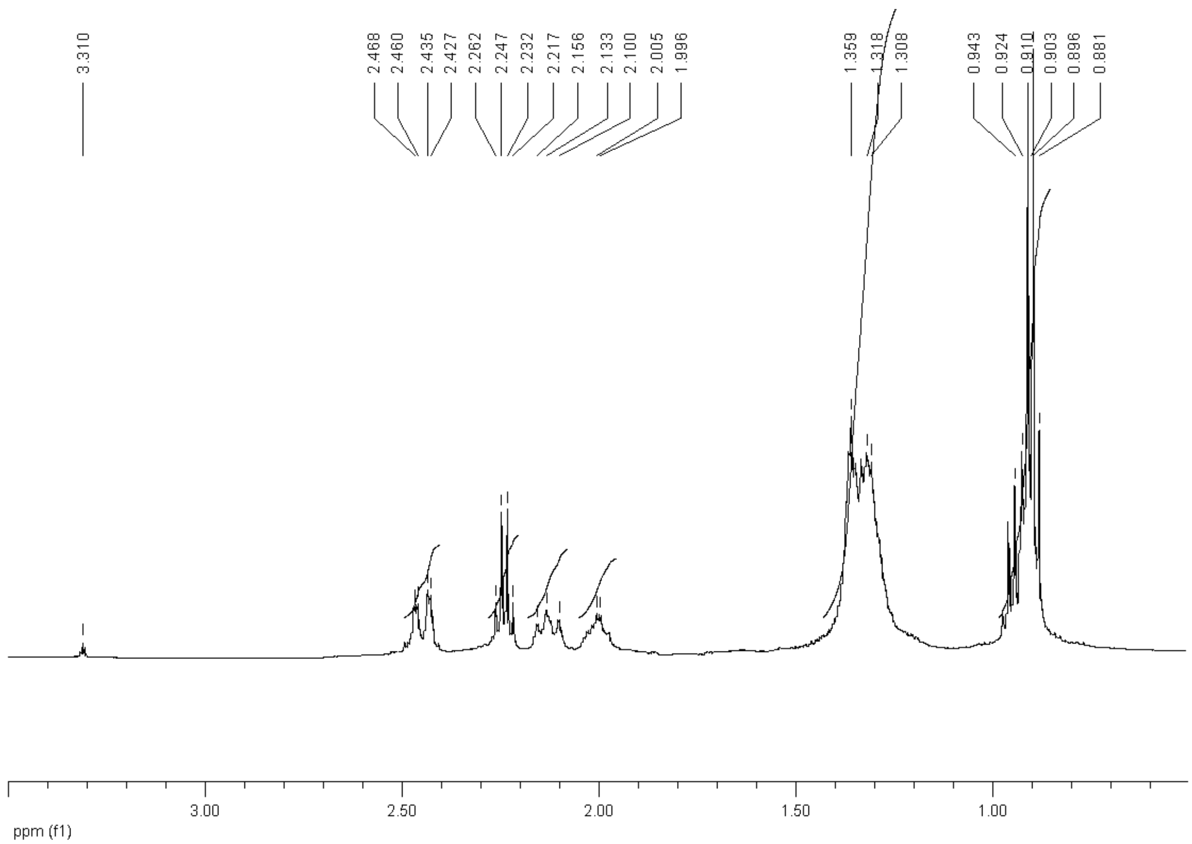


^{13}C NMR, 125 MHz, CD_3OD

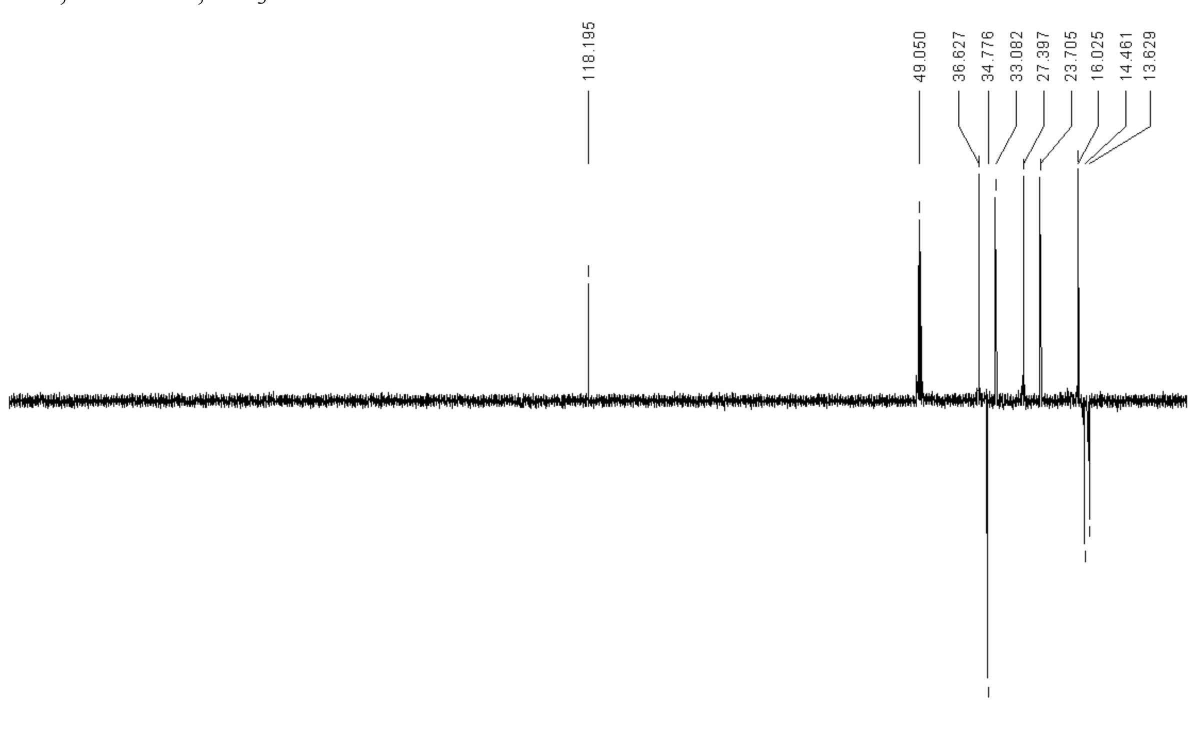


2-ethyl-5-pentyl-1,3-cyclohexanedione "Chiloglottone 2" (1fc)

^{1}H NMR, 500 MHz, CD_3OD

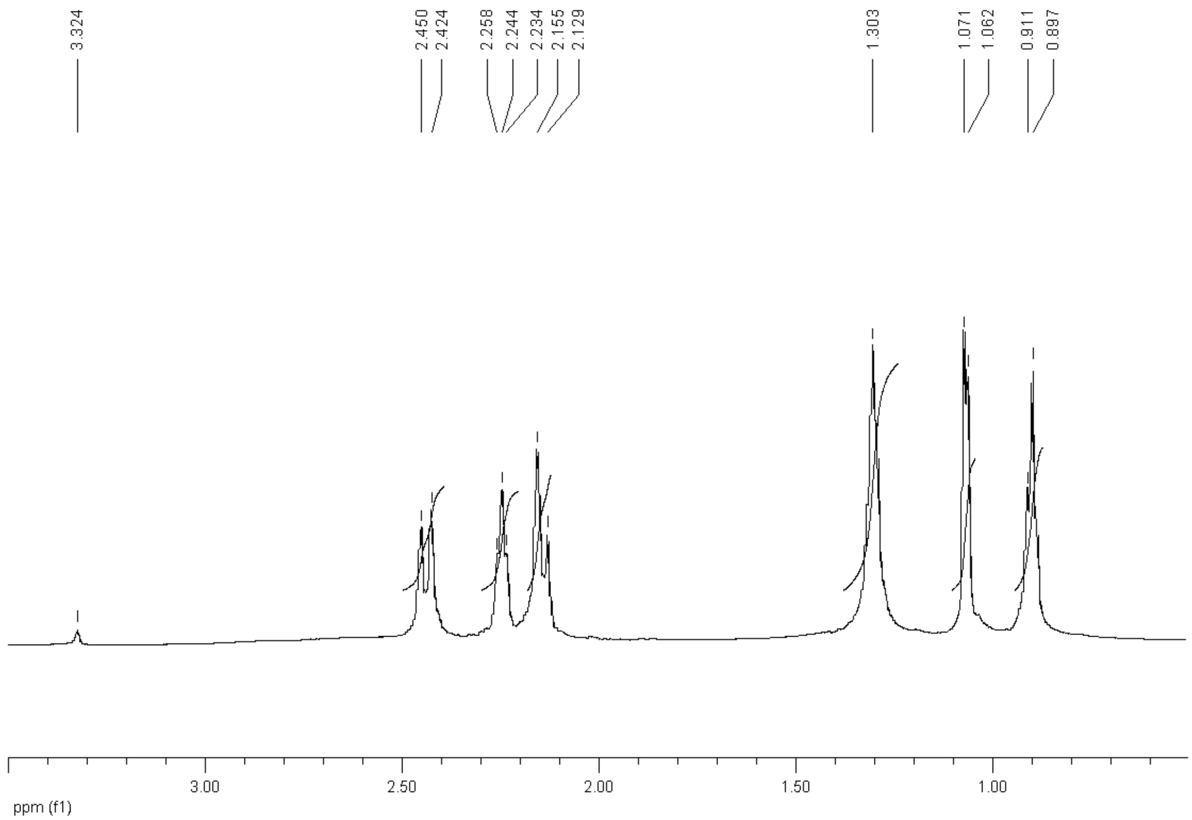


^{13}C NMR, 125 MHz, CD_3OD

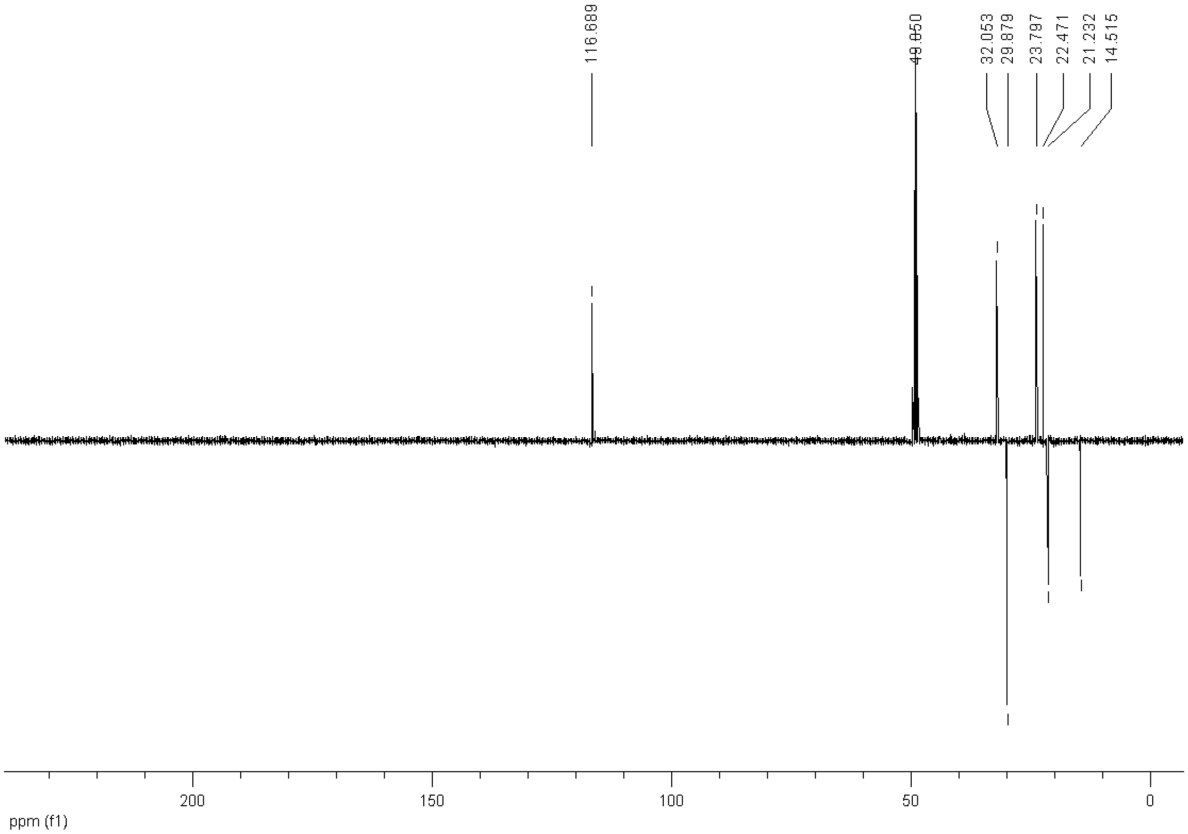


2-ethyl-5-pentyl-1,3-cyclohexanedione "Chiloglottone 3" (1be)

^{1}H NMR, 500 MHz, CD_3OD

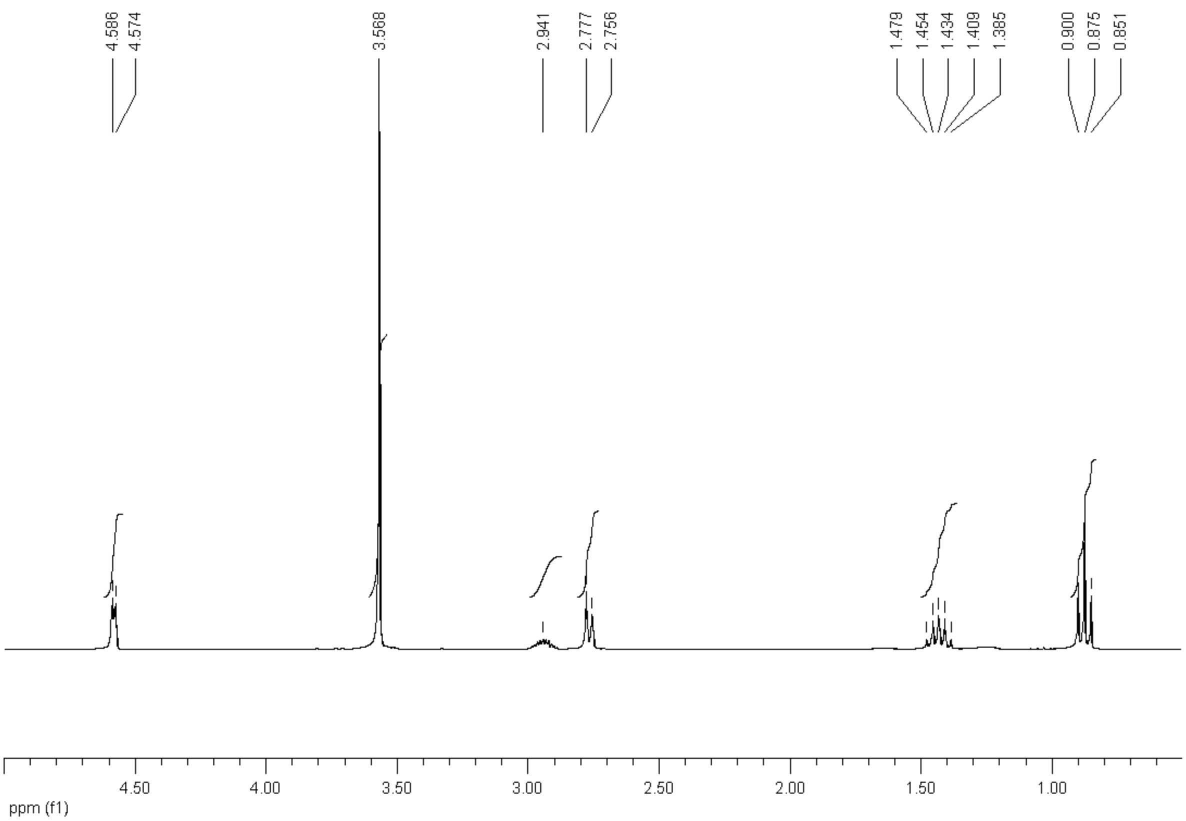


^{13}C NMR, 125 MHz, CD_3OD

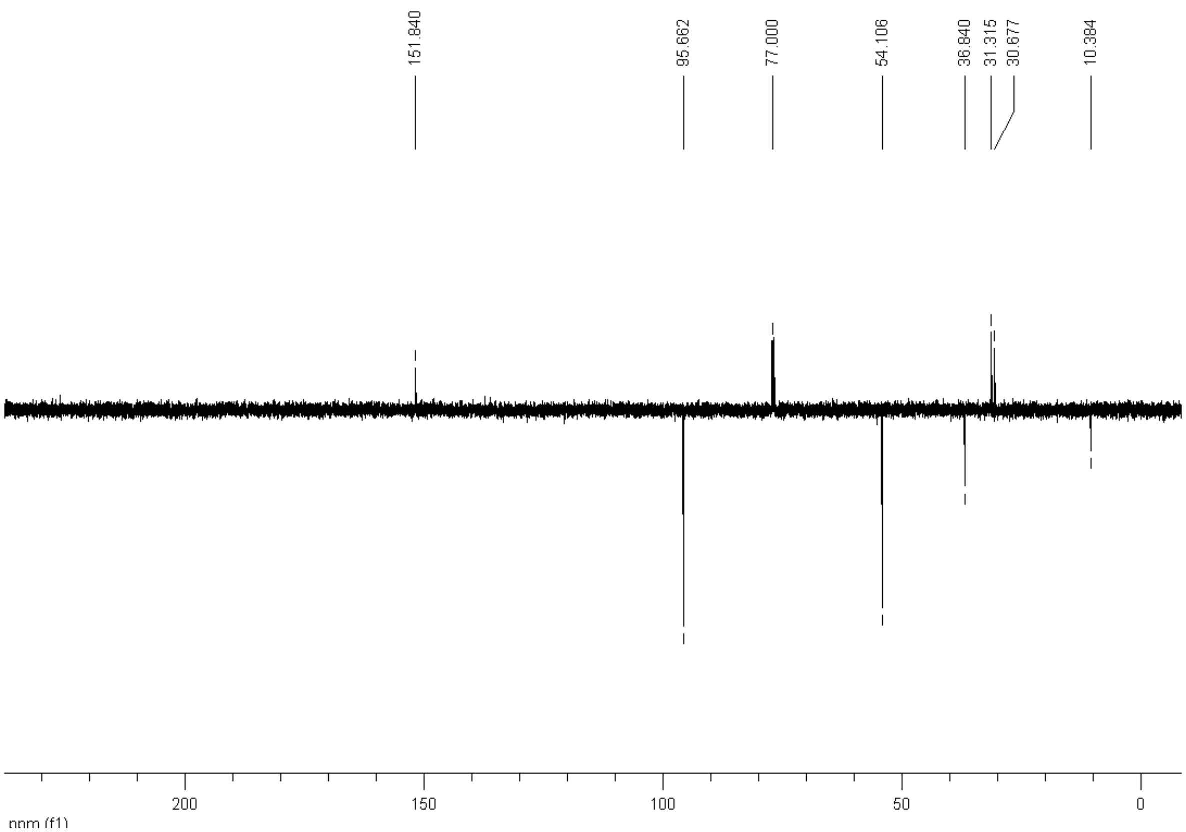


1,5-dimethoxy-3-ethylcyclohexa-1,4-diene (4c)

^{1}H NMR, 300 MHz, $CDCl_3$

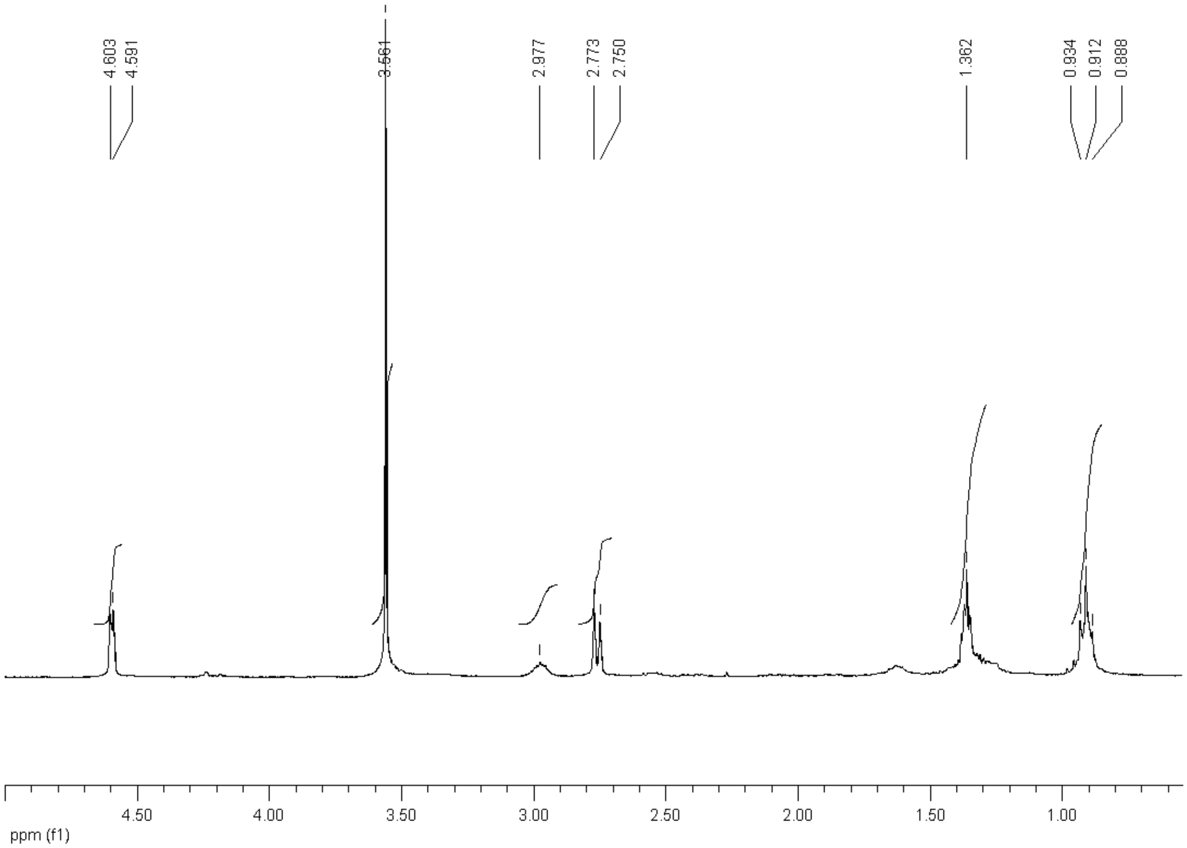


^{13}C APT NMR, 75 MHz, $CDCl_3$

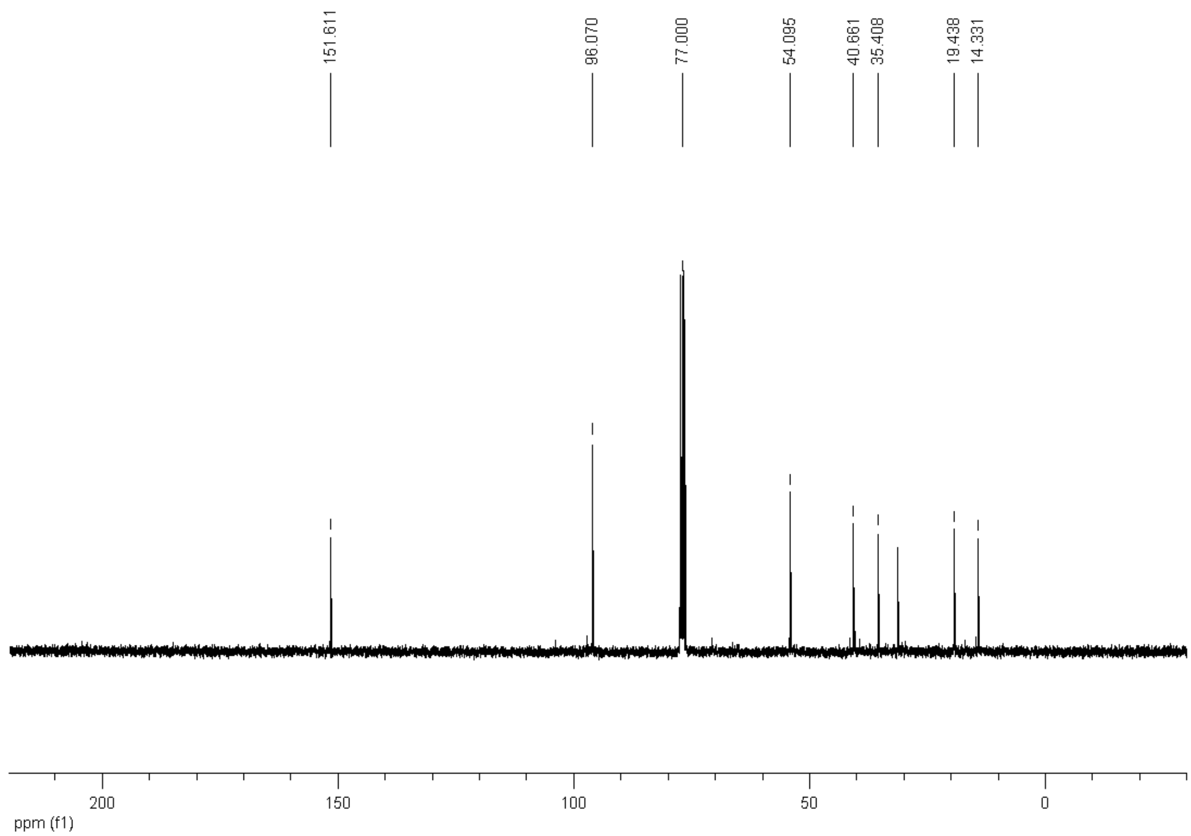


1,5-dimethoxy-3-propylcyclohexa-1,4-diene (4d)

^{1}H NMR, 300 MHz, $CDCl_3$

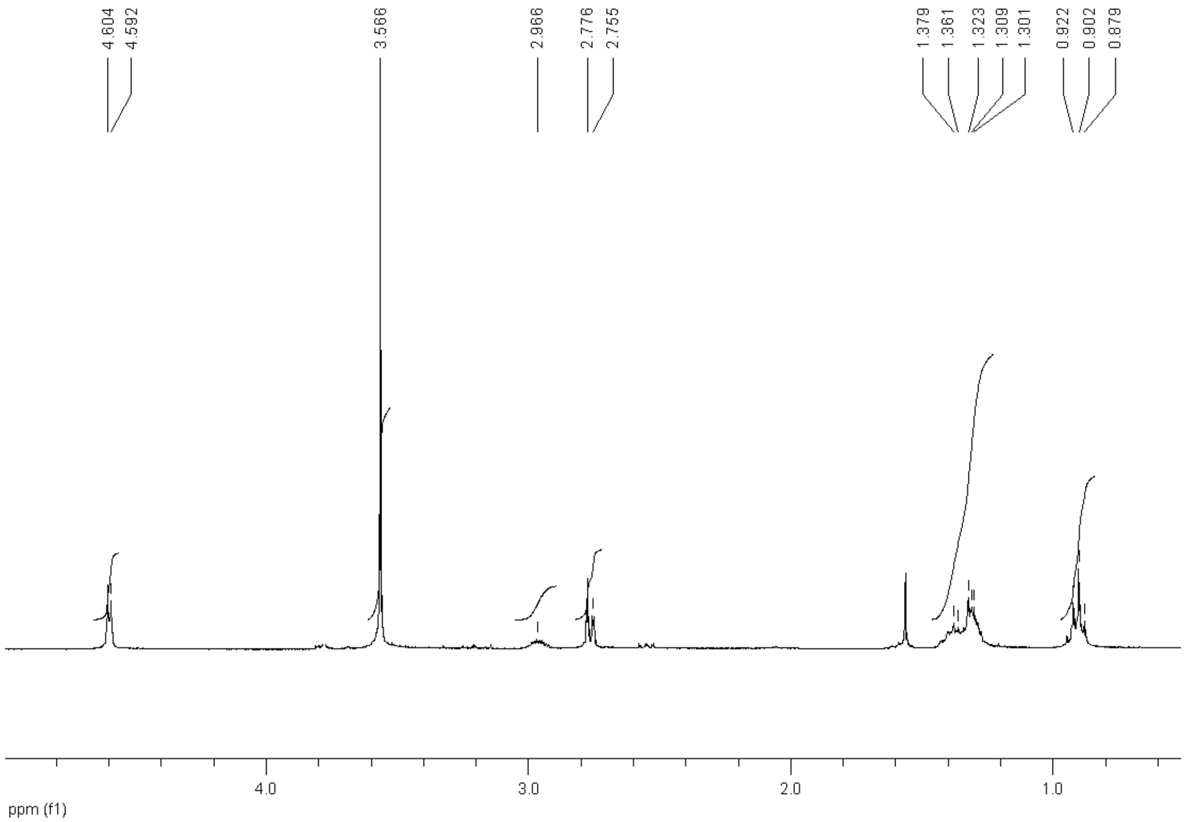


^{13}C NMR, 75 MHz, $CDCl_3$

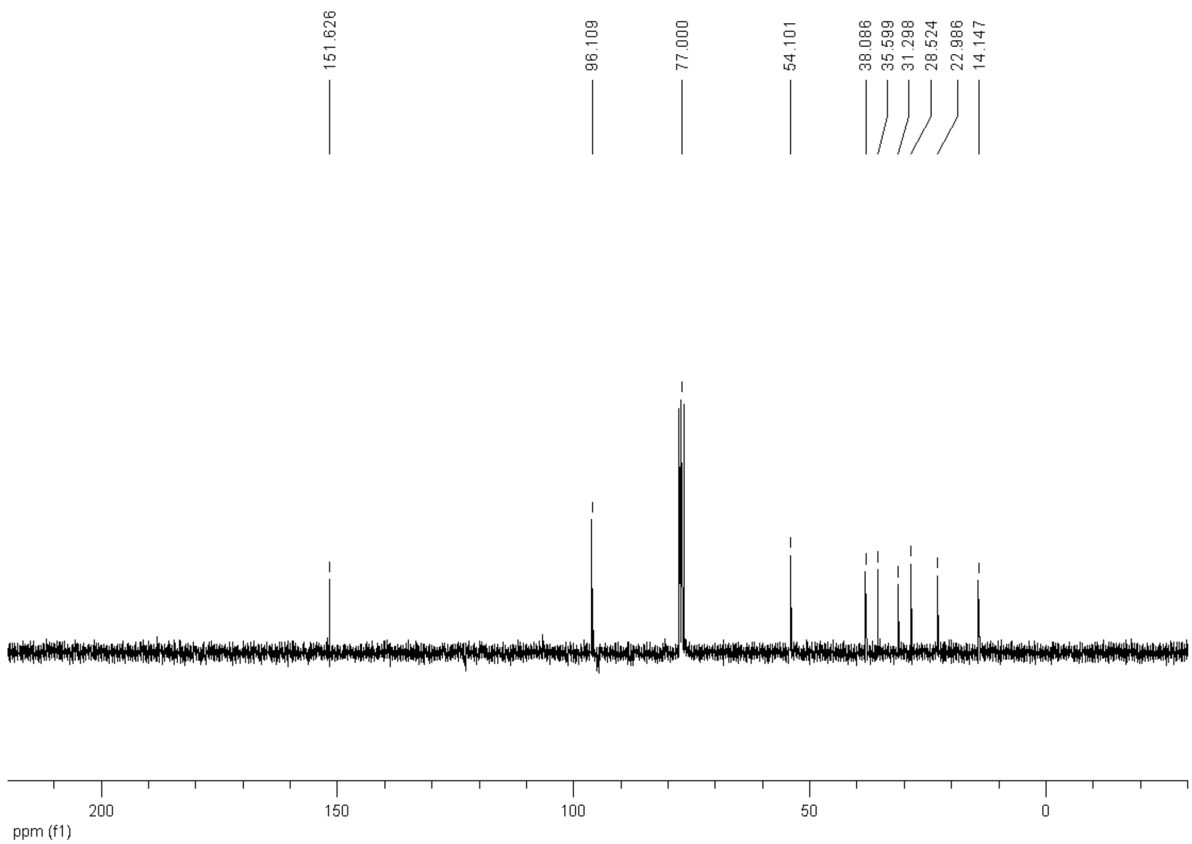


1,5-dimethoxy-3-butylcyclohexa-1,4-diene (4e)

^{1}H NMR, 300 MHz, $CDCl_3$



^{13}C NMR, 75 MHz, $CDCl_3$



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