Electronic Supplementary Material (ESI) for ChemComm.

Enantioconvergent alkylation of ketones with racemic secondary alcohols *via* hydrogen borrowing catalysis

Supplementary Information

Contents

1. General Experimental

Reactions were carried out in flame-dried glassware under an atmosphere of nitrogen unless stated otherwise. Room temperature (r.t.) refers to 20-25 °C. Temperatures of 0 °C were obtained using an ice/water bath. Temperatures of –17 °C were obtained using a salt/ice bath. Temperatures of –78 °C were obtained using a dry ice/acetone bath. Heating was achieved using an oil bath equipped with a contact thermometer.

Diethyl ether, CH_2Cl_2 and tetrahydrofuran were purified by filtration through activated alumina columns employing the method of Grubbs *et al*.[1] All other solvents and reagents were used as supplied without prior purification. All other reagents were used directly as supplied by major chemical suppliers, or following purification procedures described by Perrin and Armarego.[2]

Thin layer chromatography was performed on Merck Kieselgel 60 F_{254} 0.25 mm pre-coated aluminium plates. Product spots were visualized under UV light (λ = 254 nm) and/or by staining with potassium permanganate solution. Flash chromatography was performed using VWR silica gel 60 (40-63 μm particle size) using head pressure by means of a nitrogen line.

NMR spectroscopy was carried out using a Bruker 400 MHz spectrometer in the deuterated solvent stated, using the residual non-deuterated solvent signal as an internal reference. Chemical shifts are quoted in ppm with signal splittings recorded as singlet (s), doublet (d), triplet (t), quartet (q), quintet (qn), sextet (sext), septet (sept), octet (oct), nonet (non) and multiplet (m). The abbreviation br denotes broad. Coupling constants, *J*, are measured to the nearest 0.1 Hz and are presented as observed.

Infrared spectra were recorded neat on a Bruker Tensor 27 spectrometer equipped with an attenuated total reflectance attachment with internal calibration. Absorption maxima (λ_{max}) are quoted in wavenumbers (cm^{-1}). The abbreviation br denotes broad.

Electrospray ionisation (ESI) HRMS were recorded on a Thermo Exactive orbitrap spectrometer equipped with a Waters Equity LC system, with a flow rate of 0.2 mL/min using water:methanol:formic acid (10:89.9:0.1) as eluent. The system uses a heated electrospray ionisation (HESI-II) probe for ESI^+ and has a resolution of 50,000 FWHM under conditions for maximum sensitivity, with an accuracy of better than 5 ppm for 24 h following external calibration on the day of analysis. The mass reported is that containing the most abundant isotopes, with each value rounded to 4 decimal places and within 5 ppm of the calculated mass. Electron impact ionisation (EI) HRMS were performed on an Agilent 7200 quadrupole time of flight (Q-ToF) instrument equipped with a direct insertion probe supplied by Scientific Instrument Manufacturer (SIM) GmbH. Instrument control and data processing were performed using Agilent MassHunter software. The mass reported is that containing the most abundant isotopes, with each value to 4 decimal places and within 5 ppm of the calculated mass.

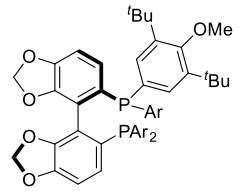
Optical rotations were recorded on a Schmidt Haensch Unipol L2000 polarimeter in a cell with a path length of 1 dm (using the sodium D line, 589 nm). Concentrations are reported in g/100 mL. Temperatures are reported in °C.

Chiral normal phase HPLC was performed on an Agilent 1260 Series HPLC unit equipped with UV-vis diode-array detector, fitted with the appropriate Daicel Chiralpak column (dimensions: 0.46 cm ø x 25 cm) along with the corresponding guard column (0.4 cm ø x 1 cm). Wavelengths (λ) are reported in nm, retention times (t_R) are reported in minutes and solvent flow rates are reported in mL min^{-1}.

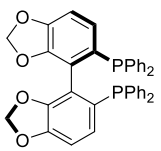
Reverse phase HPLC was performed on a Dionex UltiMate 3000 system equipped with UV-vis variable wavelength detector, fitted with an Agilent InfinityLab Poroshell 120 EC-C18 column (0.46 cm ø x 150 mm, 4 µm pore size).

2. Optimisation

2.1 Index of Ligands



(*R*)-DTBM-SEGPHOS



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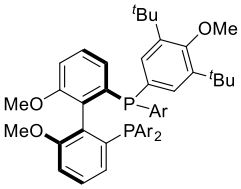
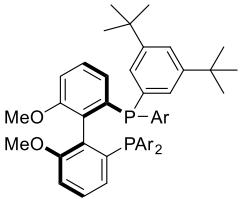
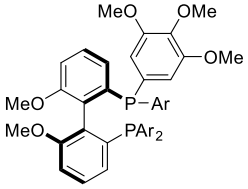


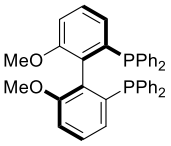
(*R*)-DTBM-MeOBIPHEP



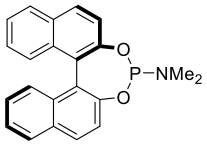
(*R*)-3,5-^{t}Bu-MeOBIPHEP



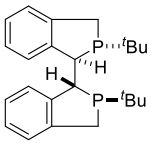
(*R*)-3,4,5-OMe-MeOBIPHEP



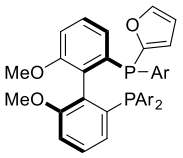
(*R*)-MeO-BIPHEP



(*R*)-MonoPhos



DuanPhos



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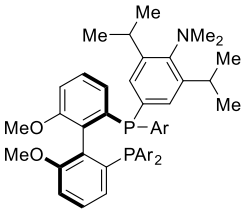

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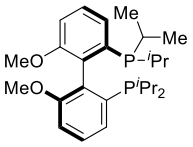

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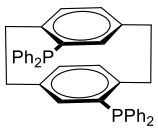
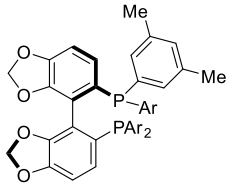
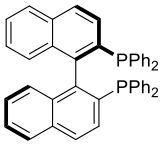


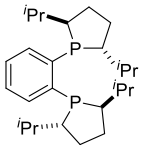
(*S*)-PHANEPHOS



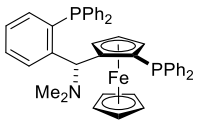
(*R*)-DM-SEGPHOS



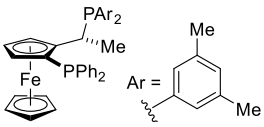
(*R*)-BINAP



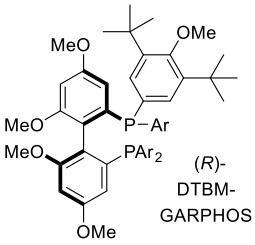
(*R*,*R*)-^{i}Pr-DUPHOS



(R_P,*R*)-TANIAPHOS

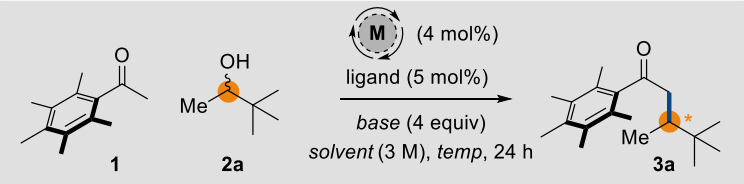


sl-j005



(*R*)-DTBM-GARPHOS

2.2 Extended Optimisation Table



To a 2–5 mL Biotage® microwave vial equipped with a stirrer bar was added commercially available 3,3-dimethyl-2-butanol (0.60 mmol, 2 equiv), 2',3',4',5',6'-Pentamethylacetophenone (0.30 mmol, 1 equiv), *ligand* (5 mol%), *precatalyst* (4 mol%), *solvent* (0.1 mL, 3 M) and *base* (1.20 mmol, 4 equiv) sequentially in the open atmosphere. The reaction vessel was sealed with a microwave vial cap (containing a Reseal™ septum) and heated to the *indicated temperature* in a preheated oil bath for 24 h. The mixture was cooled to r.t., diluted with Et_2O (4 mL), quenched with 3 M HCl (2 mL) and extracted with Et_2O (3 x 4 mL) and the combined organics were dried ($MgSO_4$), filtered and concentrated *in vacuo*. The residue was dissolved in MeCN (50 mL) and durene (40 mg, 0.30 mmol) was added as an internal standard. The yield was determined by calibrated reverse phase HPLC analysis (Agilent InfinityLab Poroshell 120 EC-C18 column with guard, 75% MeCN, 25% H_2O, 1.0 mL/min, 25 °C, λ = 254 nm, 5 µL injection). Small scale preparative TLC (95:5 pentane/Et_2O) was used to obtain an analytical sample of **3a** (~1 mg) and the enantioselectivity was determined by normal phase HPLC analysis (Chiralpak OD column with guard, 0.3 % IPA, 99.7 % hexane, 0.5 mL/min, 25 °C, λ = 254 nm, 10 µL injection).

Entry	[M][a]	Ligand	Base	Solvent	T/°C	Yield 3a[b]	e.r.[c]
1	Ir(cod)acac	(*R*)-DTBM-SEGPHOS	NaO^{t}Bu	^{t}BuOH	110	91	90:10
2	Ir(cod)acac	(*R*)-SEGPHOS	NaO^{t}Bu	^{t}BuOH	110	16	59:41
3	Ir(cod)acac	(*R*)-DTBM-MeOBIPHEP	NaO^{t}Bu	^{t}BuOH	110	88	81:19
4	Ir(cod)acac	(*R*)-3,5-tBu-MeOBIPHEP	NaO^{t}Bu	^{t}BuOH	110	93	68:32
5	Ir(cod)acac	(*R*)-3,4,5-OMe-MeOBIPHEP	NaO^{t}Bu	^{t}BuOH	110	64	79:21
6	Ir(cod)acac	(*R*)-MeO-BIPHEP	NaO^{t}Bu	^{t}BuOH	110	45	50:50
7	Ir(cod)acac	(*R*)-MonoPhos	NaO^{t}Bu	^{t}BuOH	110	13	58:42
8	Ir(cod)acac	DuanPhos	NaO^{t}Bu	^{t}BuOH	110	21	62:38
9	Ir(cod)acac	(*R*)-furyl-MeOBIPHEP	NaO^{t}Bu	^{t}BuOH	110	8	52:48
10	Ir(cod)acac	(*R*)-amino-MeOBIPHEP	NaO^{t}Bu	^{t}BuOH	110	62	61:39
11	Ir(cod)acac	(*R*)-^{i}Pr-MeOBIPHEP	NaO^{t}Bu	^{t}BuOH	110	5	50:50
12	Ir(cod)acac	(*S*)-PHANEPHOS	NaO^{t}Bu	^{t}BuOH	110	20	73:27
13	Ir(cod)acac	(*R*)-DM-SEGPHOS	NaO^{t}Bu	^{t}BuOH	110	47	54:46
14	Ir(cod)acac	(*R*)-BINAP	NaO^{t}Bu	^{t}BuOH	110	16	56:44
15	Ir(cod)acac	(*R*,*R*)-^{i}Pr-DUPHOS	NaO^{t}Bu	^{t}BuOH	110	17	54:46
16	Ir(cod)acac	(R_P,*R*)-TANIAPHOS	NaO^{t}Bu	^{t}BuOH	110	27	77:23
17	Ir(cod)acac	sl-j005	NaO^{t}Bu	^{t}BuOH	110	32	55:45
18	Ir(cod)acac	(*R*)-DTBM-GARPHOS	NaO^{t}Bu	^{t}BuOH	110	90	83:17
19	$[Rh(cod)Cl]_2$	(*R*)-DTBM-SEGPHOS	NaO^{t}Bu	^{t}BuOH	110	44	50:50

20	$[Ru(cod)Cl]_n$	(*R*)-DTBM-SEGPHOS	NaO^{t}Bu	^{t}BuOH	110	62	77:23
21	$[Ir(cod)Cl]_2$	(*R*)-DTBM-SEGPHOS	NaO^{t}Bu	^{t}BuOH	110	89	84:16
22	$[Ir(coe)Cl]_2$	(*R*)-DTBM-SEGPHOS	NaO^{t}Bu	^{t}BuOH	110	75	83:17
23	$Ru(acac)_3$	(*R*)-DTBM-SEGPHOS	NaO^{t}Bu	^{t}BuOH	110	70	65:35
24	Ir(cod)acac	(*R*)-DTBM-SEGPHOS	NaOH	^{t}BuOH	110	0	-
25	Ir(cod)acac	(*R*)-DTBM-SEGPHOS	KOH	^{t}BuOH	110	16	78:22
26	Ir(cod)acac	(*R*)-DTBM-SEGPHOS	KO^{t}Bu	^{t}BuOH	110	19	90:10
27	Ir(cod)acac	(*R*)-DTBM-SEGPHOS	KHMDS	^{t}BuOH	110	0	-
28	Ir(cod)acac	(*R*)-DTBM-SEGPHOS	NaO^{t}Bu	^{t}BuOH	90	73	75:25
29	Ir(cod)acac	(*R*)-DTBM-SEGPHOS	NaO^{t}Bu	PhMe	110	86	87:13

[a] Loading refers to mol% metal after dissociation of precursors. [b] Determined by reverse phase HPLC analysis *vs* durene as an internal standard. [c] Determined by normal phase HPLC analysis using a chiral stationary phase.

3. General procedures

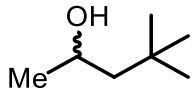
3.1 General Procedure A: Enantioconvergent Hydrogen Borrowing Alkylation

To a 2–5 mL Biotage® microwave vial equipped with a stirrer bar was added the appropriate alcohol (0.60 mmol, 2 equiv), 2',3',4',5',6'-Pentamethylacetophenone (0.30 mmol, 1 equiv), (*R*)-DTBM-SEGPHOS (5 mol%), Ir(cod)acac (4 mol%), ^{t}BuOH (0.1 mL, 3 M) and NaO^{t}Bu (1.20 mmol, 4.0 equiv) sequentially in the open atmosphere. The reaction vessel was sealed with a microwave vial cap (containing a Reseal™ septum) and stirred at 110 °C in a preheated oil bath for 24 h. The mixture was cooled to r.t., diluted with Et_2O (4 mL), quenched with 3 M aq. HCl (2 mL) and extracted with Et_2O (3 x 4 mL) and the combined organics were dried ($MgSO_4$), filtered and concentrated *in vacuo*. For ease of purification, residual (*R*)-DTBM-SEGPHOS was removed by treatment of the crude product in Et_2O (~40 mL) with *tert*-butyl hydroperoxide (5-6 M in decane, 50 µL, ~0.28 mmol), swirled and allowed to stand at r.t. for 10 min. The resulting solution was then concentrated and purified by column chromatography (see experimental methods section for details). Racemic cyclohexane products were obtained using our previously reported procedure.[3]

4. Experimental Procedures and Characterization Data

4.1 Synthesis of Alcohols

4,4-Dimethylpentan-2-ol, 2b



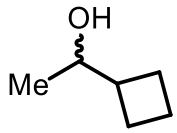
A solution of 3,3-dimethylbutanal (1.26 mL, 10.0 mmol) in Et_2O (30 mL) was cooled to -78 °C and MeMgBr (3 M in Et_2O, 6.7 mL, 20 mmol) was added dropwise. The resulting reaction mixture was stirred at -15 °C for 2 h. The reaction mixture was quenched with sat. aq. NH_4Cl (30 mL) and extracted with Et_2O (3 x 40 mL). The combined organic layers were washed with brine, dried ($MgSO_4$) and concentrated *in vacuo.* Purification by column chromatography (Pentane:Et_2O, 80:20) afforded the title compound **2b** as a transparent oil (550 mg, 48%).

The spectral data matched that previously reported in the literature.[4]

^{1}H NMR (400 MHz, $CDCl_3$) δ_H 3.94 (1H, dqd, *J*=7.7, 6.2, 3.4 Hz), 1.46 (1H, br s, O*H*), 1.39 (1H, dd, *J*=14.4, 7.7 Hz), 1.31 (1H, dd, *J*=14.4, 3.4 Hz), 1.17 (3H, d, *J*=6.2 Hz), 0.93 (9H, s).

^{13}C NMR (101 MHz, $CDCl_3$) δ_C 66.0, 53.2, 30.3, 30.2, 26.1.

1-Cyclobutylethan-1-ol, 2e



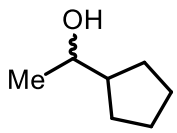
A solution of cyclobutanecarbaldehyde (841 mg, 10.0 mmol) in Et_2O (30 mL) was cooled to -78 °C and MeMgBr (6.7 mL, 3 M in Et_2O, 20 mmol) was added dropwise. The resulting reaction mixture was stirred at -15 °C for 1 h. The reaction mixture was quenched with sat. aq. NH_4Cl (15 mL) and extracted with Et_2O (3 x 20 mL). The combined organic layers were washed with brine, dried ($MgSO_4$) and concentrated *in vacuo.* Purification by column chromatography (Pentane:Et_2O, 80:20) afforded the title compound **2e** as a transparent oil (537 mg, 54%).

The spectral data matched that previously reported in the literature.[5]

^{1}H NMR (400 MHz, $CDCl_3$) δ_H 3.67 (1H, dq, *J*=7.7, 6.2 Hz), 2.33 – 2.18 (1H, m), 2.09 – 1.62 (6H, m), 1.50 (1H, br s, O*H*), 1.06 (3H, d, *J*=6.2 Hz).

^{13}C NMR (101 MHz, $CDCl_3$) δ_C 72.2, 43.0, 24.4, 24.3, 20.3, 17.8.

1-Cyclopentylethan-1-ol, 2f



To a stirred solution of $LiAlH_4$ (266 mg, 7.00 mmol) in Et_2O (40 mL) at 0 °C, was added a solution of 1-cyclopentylethan-1-one (713 mg, 6.40 mmol) in Et_2O (10 mL) slowly. The reaction was slowly warmed to r.t.

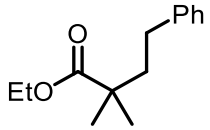
over 3 h. After this time, the reaction was quenched by sequential dropwise addition of H_2O (0.3 mL), aq. NaOH (15% w/v, 0.3 mL) and H_2O (0.9 mL) at 0 °C. The reaction mixture was diluted with Et_2O (10 mL) and $MgSO_4$ was added. The mixture was stirred vigorously for 15 min then filtered and concentrated *in vacuo*. Purification by column chromatography (Pentane:Et_2O, 80:20) afforded the title compound **2f** as a transparent oil (327 mg, 45%).

The spectral data matched that previously reported in the literature.[6]

^{1}H NMR (400 MHz, $CDCl_3$) δ_H 3.67 – 3.50 (1H, m), 1.91 – 1.75 (2H, m), 1.74 – 1.46 (5H, m), 1.46 – 1.27 (2H, m), 1.20 – 1.13 (4H, m).

^{13}C NMR (101 MHz, $CDCl_3$) δ_C 72.5, 48.2, 29.3, 29.0, 25.9, 25.8, 22.4.

Ethyl 2,2-dimethyl-4-phenylbutanoate, S1



A stirred solution of diisopropylamine (5.90 mL, 42.1 mmol) in THF (200 mL) was cooled to –78 °C and *n*-butyllithium (1.6 M in hexanes, 26.0 mL, 41.6 mmol) was added dropwise. The resulting solution was warmed to 0 °C and stirred for 15 min and then cooled to –78 °C and ethyl isobutyrate (5.00 mL, 37.2 mmol) was added dropwise. The resulting solution was stirred at –78 °C for 2 h and then (2-bromoethyl)benzene (4.60 mL, 33.6 mmol) was added dropwise. The resulting solution was stirred at –78 °C for 30 min and then warmed to r.t. and stirred for 16 h. After this time, the reaction mixture was quenched with sat. aq. NH_4Cl (250 mL) and extracted with Et_2O (3 x 200 mL). The combined organic layers were dried ($MgSO_4$) and concentrated *in vacuo.* Purification by column chromatography (Pentane:Et_2O, 95:5) afforded the title compound **S1** as a transparent oil (6.93 g, 94%).

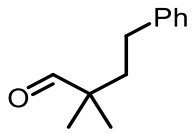
^{1}H NMR (400 MHz, $CDCl_3$) δ_H 7.32 – 7.26 (2H, m), 7.22 – 7.16 (3H, m), 4.15 (2H, q, *J* = 7.1 Hz), 2.62 – 2.48 (2H, m), 1.91 – 1.79 (2H, m), 1.28 (3H, t, *J* = 7.1 Hz), 1.25 (6H, s).

^{13}C NMR (101 MHz, $CDCl_3$) δ_C 177.8, 142.4, 128.5, 128.4, 125.9, 60.5, 42.9, 42.4, 31.7, 25.3, 14.4.

HRMS (ESI$^+$) m/z calcd. for $C_{14}H_{20}O_2Na$ $[M+Na]^+$ 243.1356; found at 243.1357, Δ 0.6 ppm.

FTIR (neat) v/cm^{-1} = 3027, 1726, 1474, 1454, 1177, 1152, 1128, 746, 699.

2,2-Dimethyl-4-phenylbutanal, S2



To a stirred solution of $LiAlH_4$ (1.72 g, 45.4 mmol) in Et_2O (100 mL) at 0 °C, was added a solution of 2,2-dimethyl-4-phenylbutanal **S1** (5.00 g, 22.7 mmol) in Et_2O (40 mL) slowly. The reaction was warmed to r.t. and stirred for 3 h. After this time, the reaction was quenched by sequential dropwise addition of H_2O (1.7 mL), aq. NaOH (15% w/v, 1.7 mL) and H_2O (5.2 mL) at 0 °C. The reaction mixture was diluted with Et_2O (150 mL) and $MgSO_4$ was added. The mixture was stirred vigorously for 15 min then filtered and concentrated *in vacuo* to

afford crude 2,2-dimethyl-4-phenylbutan-1-ol (3.99 g) which was used in the next step without further purification.

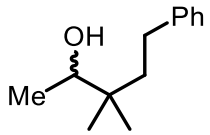
A stirred solution of oxalyl chloride (1.42 mL, 16.8 mmol) in CH_2Cl_2 (30 mL) was cooled to –78 °C and DMSO (2.38 mL, 33.6 mmol) was added dropwise. The resulting solution was stirred at –78 °C for 15 min and then a solution of crude 2,2-dimethyl-4-phenylbutan-1-ol (2.00 g) in CH_2Cl_2 (12 mL) was added dropwise. The resulting solution was stirred at –78 °C for 1 h and then triethylamine (11 mL, 78 mmol) was added dropwise. The resulting solution was stirred at –78 °C for 30 min and then warmed to r.t. and stirred for 15 min. After this time, the reaction mixture was quenched with water (100 mL) and the layers were separated. The aqueous layer was extracted with CH_2Cl_2 (2 x 200 mL). The combined organic layers were dried ($MgSO_4$) and concentrated *in vacuo.* Purification by column chromatography (Pentane:Et_2O, 95:5) afforded the title compound **S2** as a transparent oil (1.85 g, 94% over 2 steps).

The spectral data matched that previously reported in the literature.[7]

^{1}H NMR (400 MHz, $CDCl_3$) δ_H 9.49 (1H, s), 7.32 – 7.26 (2H, m), 7.22 – 7.16 (3H, m), 2.57 – 2.50 (2H, m), 1.87 – 1.75 (2H, m), 1.14 (6H, s).

^{13}C NMR (101 MHz, $CDCl_3$) δ_C 206.1, 142.0, 128.6, 128.4, 126.1, 46.1, 39.4, 30.9, 21.5.

3,3-Dimethyl-5-phenylpentan-2-ol, 2h



A stirred solution of 2,2-dimethyl-4-phenylbutanal **S2** (1.79 g, 10.2 mmol) in THF (50 mL) was cooled to 0 °C and MeMgBr (3 M in Et_2O, 4.20 mL, 12.7 mmol) was added dropwise. The resulting reaction mixture was warmed to r.t. and stirred for 30 min. The reaction mixture was then cooled to 0 °C and quenched with sat. aq. NH_4Cl (50 mL) and the layers were separated. The aqueous layer was extracted with CH_2Cl_2 (2 x 50 mL) and the combined organic layers were dried ($MgSO_4$) and concentrated *in vacuo.* Purification by column chromatography (Pentane:Et_2O, 75:25) afforded the title compound **2h** as a transparent oil (1.78 g, 91%).

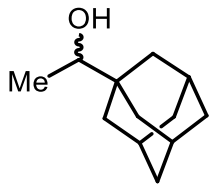
^{1}H NMR (400 MHz, $CDCl_3$) δ_H 7.31 – 7.26 (2H, m), 7.22 – 7.16 (3H, m), 3.65 – 3.58 (1H, m), 2.68 – 2.52 (2H, m), 1.64 (1H, ddd, *J* = 13.6, 12.1, 5.6 Hz), 1.52 (1H, ddd, *J* = 13.5, 12.1, 5.4 Hz), 1.34 (1H, br s, O*H*), 1.16 (3H, d, *J* = 6.4 Hz), 0.96 (3H, s), 0.95 (3H, s).

^{13}C NMR (101 MHz, $CDCl_3$) δ_C 143.4, 128.5, 128.4, 125.8, 74.5, 41.2, 37.7, 30.6, 22.7, 22.6, 17.9.

HRMS (EI$^+$) m/z calcd. for $C_{13}H_{20}O$ $[M]^+$ 192.1509; found at 192.1514, Δ 2.6 ppm.

FTIR (neat) ν/cm^{-1} = 3383 (br), 3026, 1454, 1373, 1082, 913, 753, 720, 698.

1-(Adamantan-1-yl)ethan-1-ol, 2i



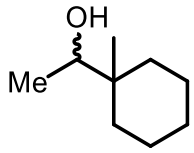
To a stirred solution of $LiAlH_4$ (228 mg, 6.60 mmol) in Et_2O (30 mL) at 0 °C, was added a solution of 1-adamantyl methyl ketone (1.07 g, 6.00 mmol) in Et_2O (10 mL) slowly. The reaction was warmed to r.t. and stirred for 1 h. After this time, the reaction was cooled to 0 °C and quenched by sequential dropwise addition of H_2O (0.23 mL), aq. NaOH (15% w/v, 0.23 mL) and H_2O (0.69 mL). The reaction mixture was diluted with Et_2O (40 mL) and $MgSO_4$ was added. The mixture was stirred vigorously for 15 min then filtered and concentrated *in vacuo*. Purification by column chromatography (Pentane:Et_2O, 80:20) afforded the title compound **2i** as a white solid (1.03 g, 95%).

The spectral data matched that previously reported in the literature.[8]

^{1}H NMR (400 MHz, $CDCl_3$) δ_H 3.28 (1H, p, *J* = 6.3 Hz), 2.03 – 1.95 (3H, m), 1.76 – 1.54 (9H, m), 1.51 – 1.43 (3H, m), 1.33 (1H, d, *J* = 5.2 Hz, O*H*), 1.09 (3H, d, *J* = 6.5 Hz).

^{13}C NMR (101 MHz, $CDCl_3$) δ_C 76.0, 37.8, 37.4, 36.7, 28.5, 16.6.

1-(1-Methylcyclohexyl)ethan-1-ol, 2j



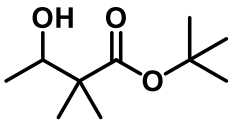
A solution of 1-(1-methylcyclohexyl)ethan-1-one (640 mg, 4.56 mmol) in Et_2O (10 mL) was slowly added to a stirred solution of $LiAlH_4$ (194 mg, 5.11 mmol) in Et_2O (30 mL) at 0 °C. The reaction mixture was slowly warmed to r.t. over 2 h. After this time, the reaction was quenched by sequential dropwise addition of water (0.19 mL), aq. NaOH (15% w/v, 0.19 mL) and water (0.57 mL). The reaction mixture was diluted with Et_2O (10 mL) and $MgSO_4$ was added. The mixture was stirred vigorously for 15 min then filtered and concentrated *in vacuo*. Purification by column chromatography (Pentane:Et_2O, 85:15) afforded the title compound **2j** as a pale yellow oil (499 mg, 76%).

The spectral data matched that previously reported in the literature.[8]

^{1}H NMR (400 MHz, $CDCl_3$) δ_H 3.51 (1H, q, *J*=6.4 Hz), 1.63 – 1.12 (10H, m), 1.10 (3H, d, *J*=6.5 Hz), 0.84 (3H, s).

^{13}C NMR (101 MHz, $CDCl_3$) δ_C 75.6, 37.3, 34.4, 33.8, 26.5, 21.9, 21.9, 17.7, 17.1.

***tert*-Butyl 3-hydroxy-2,2-dimethylbutanoate, 2o**



A solution of *tert*-butyl acetoacetate (1.86 g, 10.0 mmol) in MeOH (25 mL) was cooled to 0 °C and $NaBH_4$ (0.57 g, 10 mmol) was added portion wise. The reaction was slowly warmed to r.t. over 2 h. After this time, the reaction was quenched with saturated sat. aq. NH_4Cl (50 mL) and extracted with Et_2O (3 x 60 mL). The combined organic layers were washed with brine, dried ($MgSO_4$) and concentrated *in vacuo.* Purification by column chromatography (Pentane:Et_2O, 80:20) afforded the title compound **2o** (1.35 g, 72%) as a transparent oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ_H 3.75 (1H, p, *J*=6.4 Hz), 2.85 (1H, d, *J*=6.3 Hz, O*H*), 1.41 (9H, s), 1.09 (9H, m).

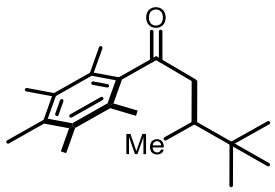
^{13}C NMR (101 MHz, $CDCl_3$) δ_C 177.2, 80.9, 72.6, 47.5, 28.1, 22.3, 20.2, 17.9.

HRMS (ESI$^+$) m/z calcd. for $C_{10}H_{20}O_3Na$ $[M+Na]^+$ 211.1310; found at 211.1306, Δ 0.56 ppm

FTIR (neat) ν/cm^{-1} = 3436, 2977, 1713, 1459, 1392, 1368, 1278, 1256, 1138, 1098, 1036, 909, 849

4.2 Enantioconvergent Hydrogen Borrowing Catalysis

(*S*)-3,4,4-Trimethyl-1-(2,3,4,5,6-pentamethylphenyl)pentan-1-one, 3a



0.3 mmol scale reaction: Pentamethylacetophenone **1** (57 mg, 0.30 mmol)[9], commercially available 3,3-dimethyl-2-butanol (75 µL, 0.60 mmol), (*R*)-DTBM-SEGPHOS (18 mg, 5 mol%), Ir(cod)acac (4.8 mg, 4 mol%) and NaO^{t}Bu (115 mg, 1.20 mmol) were subjected to **General Procedure A**. Purification by column chromatography (Penane:Et_2O, 98:2) afforded the title compound **3a** as a white solid (75 mg, 91%, 90:10 e.r.).

Gram scale hydrogen borrowing: To a 100 mL ACE pressure tube equipped with a stirrer bar was added commercially available 3,3-dimethyl-2-butanol (1.25 mL, 10.0 mmol), pentamethylacetophenone **1** (952 mg, 5.00 mmol), (*R*)-DTBM-SEGPHOS (295 mg, 5 mol%), Ir(cod)acac (80 mg, 4 mol%), ^{t}BuOH (1.7 mL, 3 M) and NaO^{t}Bu (1.92 g, 20.0 mmol) sequentially in an air atmosphere. The reaction vessel was sealed and stirred at 110 °C in a preheated oil bath for 24 h. The mixture was cooled to r.t., diluted with Et_2O (20 mL), quenched with 3 M HCl (15 mL) and extracted with Et_2O (3 x 20 mL). The combined organics were dried ($MgSO_4$), filtered and concentrated *in vacuo*. For ease of purification, residual (*R*)-DTBM-SEGPHOS was removed by treatment of the crude product in Et_2O (~80 mL) with *tert*-butyl hydroperoxide (5-6 M in decane, 0.50 mL, ~2.8 mmol), swirled and allowed to stand at r.t. for 10 min. Purification by column chromatography (Pentane:Et_2O, 98:2) afforded the title compound **3a** as a white solid (1.17 g, 85%, 92:8 e.r.). Recrystallization from boiling methanol afforded the title compound **3a** as white needles (834 mg, 71% recovery, 97:3 e.r.).

^{1}H NMR (400 MHz, $CDCl_3$) δ_H 2.86 (1H, dd, *J*=19.3, 0.8 Hz), 2.40 (1H, dd, *J*=19.3, 10.4 Hz), 2.24 (3H, s), 2.19 (6H, s), 2.13 – 2.02 (7H, m), 1.02 (3H, dd, *J*=6.7, 0.8 Hz), 0.87 (9H, s).

^{13}C NMR (101 MHz, $CDCl_3$) δ_C 211.7, 141.1, 135.4, 133.2, 127.4, 48.9, 37.2, 32.6, 27.3, 17.1, 16.8, 16.1, 15.7

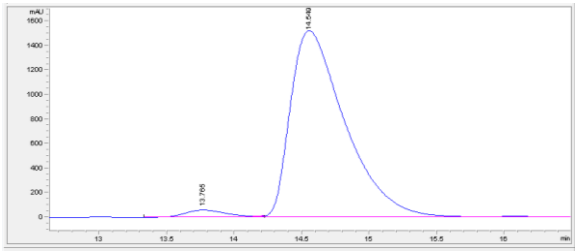
HRMS (ESI$^+$) m/z calcd. for $C_{19}H_{31}O$ $[M+H]^+$ 275.2375; found at 275.2370, Δ 0.1 ppm.

FTIR (neat) ν/cm^{-1} = 2959, 1703, 1467, 1404, 1365, 1308, 1119, 1054, 989, 912, 803, 676.

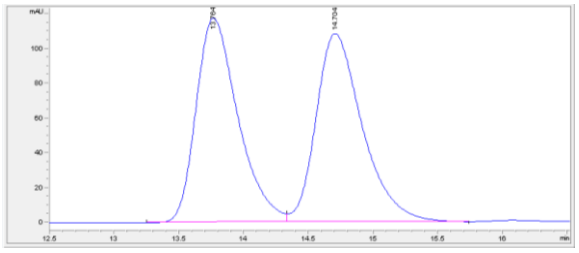
m.p. = 93-95 °C.

[α]$_D^{25}$ -29.1 (c = 0.43, $CHCl_3$).

Chiral HPLC: Chiralpak OD with guard, 0.3 % IPA, 99.7 % hexane, 0.5 mL/min, 25 °C, λ = 254 nm, 10 µL injection

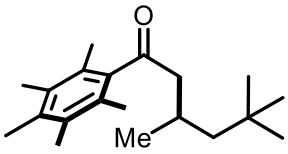


#	Time	Type	Area	Height	Width	Area%	Symmetry
1	13.765	BV E	1228.5	58.3	0.3239	2.784	0.721
2	14.549	VV R	42904.5	1522.5	0.4234	97.216	0.566



#	Time	Type	Area	Height	Width	Area%	Symmetry
1	13.764	BV	2641.5	117.3	0.3427	49.479	0.665
2	14.704	VB	2697.1	108.2	0.3787	50.521	0.665

(*R*)-3,5,5-Trimethyl-1-(2,3,4,5,6-pentamethylphenyl)hexan-1-one, 3b



Pentamethylacetophenone **1** (57 mg, 0.30 mmol), 4,4-dimethylpentan-2-ol **2b** (70 mg, 0.60 mmol), (*R*)-DTBM-SEGPHOS (18 mg, 5 mol%), Ir(cod)acac (4.8 mg, 4 mol%) and NaO^{t}Bu (115 mg, 1.20 mmol) were subjected to **General Procedure A**. Purification by column chromatography (Pentane:Et_2O, 98:2) afforded the title compound **3b** as a white solid (60 mg, 69%, 63:37 e.r.).

^{1}H NMR (400 MHz, $CDCl_3$) δ_H 2.73 (1H, dd, J=19.2, 3.9 Hz), 2.57 (1H, dd, J=19.2, 8.7 Hz), 2.42 – 2.27 (1H, m), 2.24 (3H, s), 2.19 (6H, s), 2.11 (6H, s), 1.28 (1H, dd, J=14.0, 5.1 Hz), 1.16 (1H, dd, J=14.0, 5.6 Hz), 1.10 (3H, d, J=6.6 Hz), 0.95 (9H, s).

^{13}C NMR (101 MHz, $CDCl_3$) δ_C 211.2, 140.9, 135.3, 133.2, 127.4, 55.4, 51.2, 31.4, 30.1, 24.6, 23.1, 17.1, 16.8, 16.0.

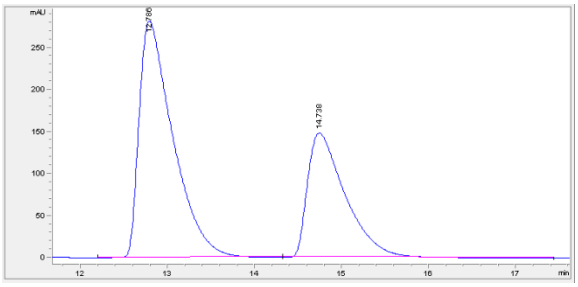
HRMS (ESI^+) m/z calcd. for $C_{20}H_{33}O$ $[M+H]^+$ 289.2531; found at 289.2526, Δ 0.11 ppm.

FTIR (neat) ν/cm^{-1} = 3658, 2980, 2956, 1702, 1464, 1381, 1251, 1150, 1113, 1072, 943.

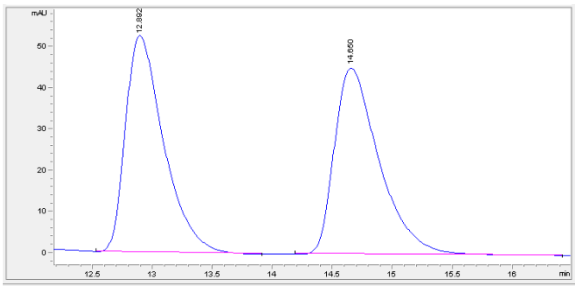
m.p. = 85-86 °C.

$[\alpha]_D^{25}$ –6.2 (c = 1.00, $CHCl_3$).

Chiral HPLC : Chiralpak IA with guard, 0.3 % IPA, 99.7 % hexane, 1 mL/min, 25 °C, λ = 254 nm, 10 µL injection

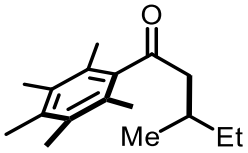


#	Time	Type	Area	Height	Width	Area%	Symmetry
1	12.786	BB	7640.5	282.3	0.4018	63.046	0.405
2	14.738	BB	4478.5	148.4	0.4481	36.954	0.423



#	Time	Type	Area	Height	Width	Area%	Symmetry
1	12.892	BB	1165.9	52.6	0.3364	49.817	0.562
2	14.65	BB	1174.5	45.2	0.3912	50.183	0.553

(*R*)-3-Methyl-1-(2,3,4,5,6-pentamethylphenyl)pentan-1-one, 3c



Pentamethylacetophenone **1** (57 mg, 0.30 mmol), commercially available 2-butanol (45 mg, 0.60 mmol), (*R*)-DTBM-SEGPHOS (18 mg, 5 mol%), Ir(cod)acac (4.8 mg, 4 mol%) and NaO^{t}Bu (115 mg, 1.20 mmol) were subjected to **General Procedure A**. Purification by column chromatography (Pentane:Et_2O, 98:2) afforded the title compound **3c** as a white solid (40 mg, 54%, 58:42 e.r.).

^{1}H NMR (400 MHz, $CDCl_3$) δ_H 2.68 (1H, dd, *J* = 18.8, 5.0 Hz), 2.51 (1H, dd, *J* = 18.8, 7.8 Hz), 2.23 (3H, s), 2.18 (6H, s), 2.14 – 2.08 (7H, m), 1.53 – 1.39 (1H, m), 1.32 – 1.18 (1H, m), 1.02 (3H, d, *J* = 6.6 Hz), 0.91 (3H, t, *J* = 7.4 Hz).

^{13}C NMR (101 MHz, $CDCl_3$) δ_C 211.5, 141.0, 135.4, 133.2, 127.4, 52.7, 29.6, 19.7, 17.2, 16.8, 16.1, 11.5. [N.B. the peak at d = 29.6 ppm corresponds to two overlapping signals].

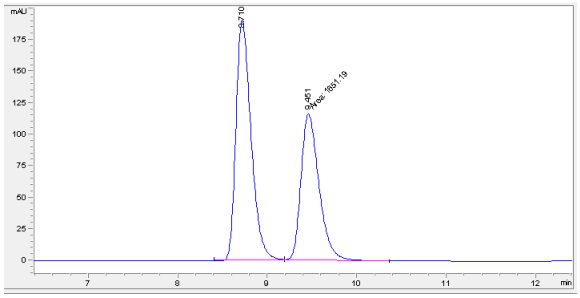
HRMS (ESI^+) m/z calcd. for $C_{17}H_{27}O$ $[M+H]^+$ 247.2056; found at 247.2057, Δ –0.19 ppm.

FTIR (neat) ν/cm^{-1} = 2958, 2924, 2874, 1699, 1459, 1401, 1378, 1360, 1303, 1144, 1096, 999.

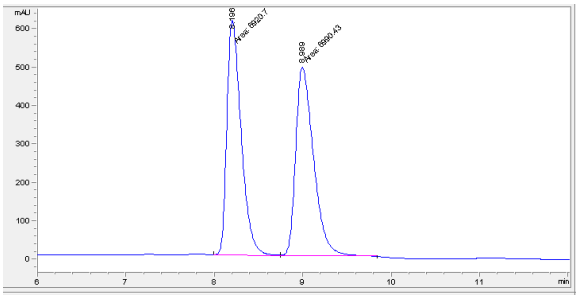
m.p. = 40–41 °C.

$[\alpha]_D^{25}$ –2.9 (c = 1.00, $CHCl_3$).

Chiral HPLC: Chiralpak IA with guard, 0.3 % IPA, 99.7 % hexane, 1 mL/min, 25 °C, λ = 210 nm, 10 µL injection

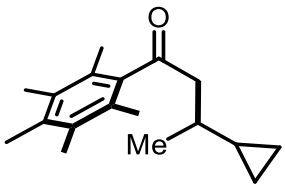


#	Time	Type	Area	Height	Width	Area%	Symmetry
1	8.71	BV	2251.9	191.4	0.1813	57.695	0.641
2	9.451	MF	1651.2	116.8	0.2355	42.305	0.68



#	Time	Type	Area	Height	Width	Area%	Symmetry
1	8.196	MF	6920.7	612.3	0.1884	49.749	0.587
2	8.989	FM	6990.4	491.9	0.2369	50.251	0.582

(*S*)-3-Cyclopropyl-1-(2,3,4,5,6-pentamethylphenyl)butan-1-one, 3d



Pentamethylacetophenone **1** (57 mg, 0.30 mmol), commercially available 1-cyclopropylethanol (59 µl, 0.60 mmol), (*R*)-DTBM-SEGPHOS (18 mg, 5 mol%), Ir(cod)acac (4.8 mg, 4 mol%) and NaO^{t}Bu (115 mg, 1.20 mmol) were subjected to **General Procedure A**. Purification by column chromatography (Pentane:Et_2O, 98:2) afforded the title compound **3d** as a white solid (57 mg, 73%, 72:28 e.r.).

^{1}H NMR (400 MHz, $CDCl_3$) δ_H 2.88 (1H, dd, *J*=19.0, 4.2 Hz), 2.64 (1H, dd, *J*=19.0, 8.3 Hz), 2.23 (3H, s), 2.19 (6H, s), 2.12 (6H, s), 1.53 – 1.42 (1H, m), 1.13 (3H, d, *J*=6.7 Hz), 0.64 (1H, dtt, *J*=9.6, 8.0, 5.0 Hz), 0.51 – 0.31 (2H, m), 0.24 – 0.10 (2H, m).

^{13}C NMR (101 MHz, $CDCl_3$) δ_C 211.2, 141.0, 135.4, 133.2, 127.4, 53.1, 33.5, 20.1, 18.3, 17.1, 16.8, 16.1, 4.3, 4.1.

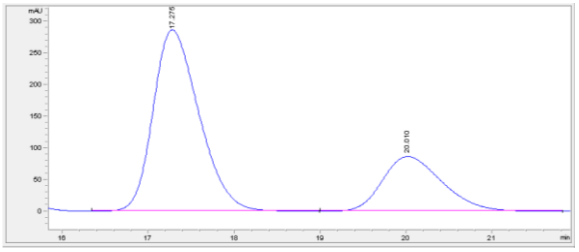
HRMS (ESI^+) m/z calcd. for $C_{18}H_{27}O$ $[M+H]^+$ 259.2062; found at 259.2058, Δ 0.41 ppm.

FTIR (neat) ν/cm^{-1} = 2927, 1701, 1457, 1401, 1351, 1313, 1129, 1016, 821.

m.p. = 43-44 °C.

$[\alpha]_D^{25}$ -13.6 (c = 1.00, $CHCl_3$).

Chiral HPLC: Chiralpak IG with guard, 0.9 % IPA, 99.1 % hexane, 1 mL/min, 25 °C, λ = 210 nm, 10 µL injection



#	Time	Type	Area	Height	Width	Area%	Symmetry
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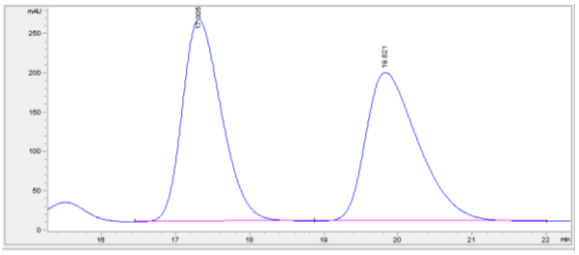
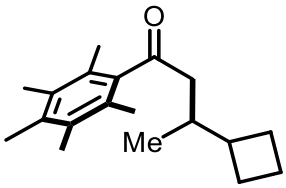
2	20.01	BB	4142.2	86.3	0.7402	28.064	0.701



#	Time	Type	Area	Height	Width	Area%	Symmetry
1	17.305	BB	9489.7	258.4	0.5685	50.432	0.694
2	19.821	BB	9327	190	0.7508	49.568	0.566

(*S*)-3-Cyclobutyl-1-(2,3,4,5,6-pentamethylphenyl)butan-1-one, 3e



Pentamethylacetophenone **1** (57 mg, 0.30 mmol), 1-cyclobutylethan-1-ol **2e** (60 mg, 0.60 mmol), (*R*)-DTBM-SEGPHOS (18 mg, 5 mol%), Ir(cod)acac (4.8 mg, 4 mol%) and NaO^{t}Bu (115 mg, 1.20 mmol) were subjected to **General Procedure A**. Purification by column chromatography (Pentane:Et_2O, 98:2) afforded the title compound **3e** as a white solid (65 mg, 80%, 78:22 e.r.).

^{1}H NMR (400 MHz, $CDCl_3$) δ_H 2.65 (1H, dd, *J*=18.8, 2.2 Hz), 2.40 – 2.29 (1H, m), 2.23 (3H, s), 2.18 (6H, s), 2.15 – 1.89 (10H, m) 1.89 – 1.55 (4H, m), 0.97 (3H, d, *J*=6.1 Hz).

^{13}C NMR (101 MHz, $CDCl_3$) δ_C 211.6, 141.1, 135.4, 133.2, 127.4, 49.9, 41.9, 34.7, 26.8, 26.7, 17.4, 17.2, 17.1, 16.8, 16.1.

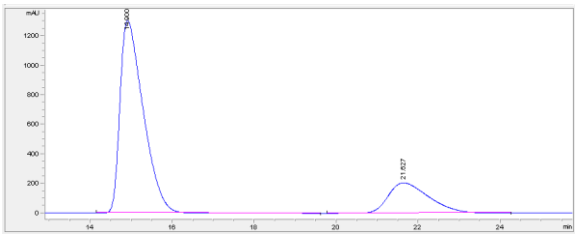
HRMS (ESI$^+$) m/z calcd. for $C_{19}H_{29}O$ $[M+H]^+$ 273.2218; found at 273.2213, Δ -0.03 ppm.

FTIR (neat) v/cm^{-1} = 3657, 2980, 2923, 1703, 1462, 1380, 1252, 1153, 1072, 955.

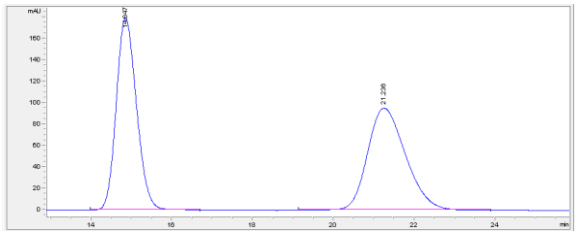
m.p. = 69-70 °C.

$[\alpha]_D^{25}$ -20.5 (c = 1.00, $CHCl_3$).

Chiral HPLC: (Chiralpak IG with guard, 0.9 % IPA, 99.1 % hexane, 1 mL/min, 25 °C, λ = 210 nm, 10 µL injection)

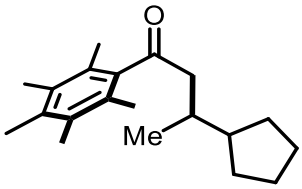


#	Time	Type	Area	Height	Width	Area%	Symmetry
1	14.9	BB	51704.1	1312.7	0.5995	78.369	0.457
2	21.627	BB	14270.9	206.5	1.0541	21.631	0.577



#	Time	Type	Area	Height	Width	Area%	Symmetry
1	14.847	BB	6232.6	179.6	0.5388	49.985	0.8
2	21.236	BB	6236.4	95.5	1.006	50.015	0.735

(*S*)-3-Cyclopentyl-1-(2,3,4,5,6-pentamethylphenyl)butan-1-one, 3f



Pentamethylacetophenone **1** (57 mg, 0.30 mmol), 1-cyclopentylethan-1-ol **2f** (60 mg, 0.60 mmol), (*R*)-DTBM-SEGPHOS (18 mg, 5 mol%), Ir(cod)acac (4.8 mg, 4 mol%) and NaO^{t}Bu (115 mg, 1.20 mmol) were subjected to **General Procedure A**. Purification by column chromatography (Pentane:Et_2O, 98:2) afforded the title compound **3f** as a white solid (59 mg, 69%, 84:16 e.r.).

^{1}H NMR (400 MHz, $CDCl_3$) δ_H 2.80 (1H, dd, *J*=19.0, 2.8 Hz), 2.51 (1H, dd, *J*=19.0, 9.5 Hz), 2.24 (3H, s), 2.19 (6H, s), 2.15 – 2.04 (7H, m) 1.84 – 1.45 (7H, m), 1.30 – 1.10 (2H, m), 1.07 (3H, d, *J*=6.6 Hz).

^{13}C NMR (101 MHz, $CDCl_3$) δ_C 211.5, 141.1, 135.4, 133.2, 127.4, 51.9, 45.9, 33.0, 30.7, 30.2, 25.8, 25.6, 18.9, 17.1, 16.8, 16.1.

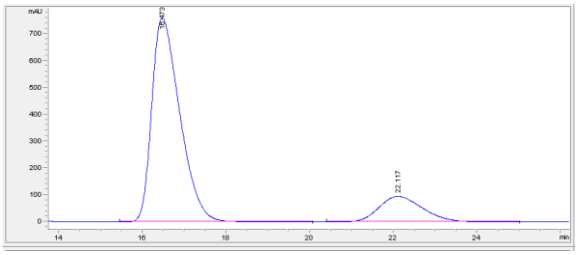
HRMS (ESI$^+$) m/z calcd. for $C_{20}H_{31}O$ $[M+H]^+$ 287.2369; found at 287.2370, Δ 0.12 ppm.

FTIR (neat) ν/cm^{-1} = 2949, 2868, 1701, 1451, 1401, 1307, 1099, 934.

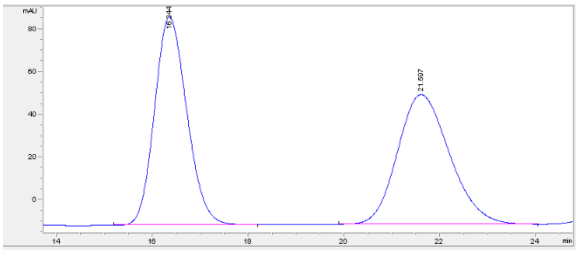
m.p. = 60-61 °C.

$[\alpha]_D^{25}$ -21.1 (c = 1.00, $CHCl_3$).

Chiral HPLC: (Chiralpak IG with guard, 0.9 % IPA, 99.1 % hexane, 1 mL/min, 25 °C, λ = 210 nm, 10 µL injection)

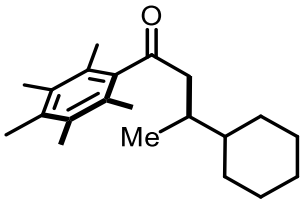


#	Time	Type	Area	Height	Width	Area%	Symmetry
1	16.473	BB	35406.5	759	0.7162	83.525	0.563
2	22.117	BB	6983.7	95.2	1.1343	16.475	0.747



#	Time	Type	Area	Height	Width	Area%	Symmetry
1	16.344	BB	4547.8	97	0.7251	49.935	0.823
2	21.597	BB	4559.6	60.3	1.1536	50.065	0.792

(*S*)-3-Cyclohexyl-1-(2,3,4,5,6-pentamethylphenyl)butan-1-one, 3g



Pentamethylacetophenone **1** (57 mg, 0.30 mmol), commercially available 1-cyclohexylethanol (77 mg, 0.60 mmol), (*R*)-DTBM-SEGPHOS (18 mg, 5 mol%), Ir(cod)acac (4.8 mg, 4 mol%) and NaO^{t}Bu (115 mg, 1.20 mmol) were subjected to **General Procedure A**. Purification by column chromatography (Pentane:Et_2O, 98:2) afforded the title compound **3g** as a white solid (73 mg, 81%, 82:18 e.r.).

^{1}H NMR (400 MHz, $CDCl_3$) δ_H 2.77 (1H, dd, *J* = 19.0, 3.5 Hz), 2.50 (1H, dd, *J* = 19.0, 9.2 Hz), 2.25 (3H, s), 2.20 (6H, s), 2.19 – 2.13 (1H, m), 2.12 (6H, s), 1.83 – 1.57 (5H, m), 1.34 – 0.95 (9H, m).

^{13}C NMR (101 MHz, $CDCl_3$) δ_H 211.7, 141.0, 135.3, 133.1, 127.3, 50.3, 42.8, 32.7, 30.3, 29.1, 26.9, 26.8, 26.8, 17.1, 16.9, 16.8, 16.0.

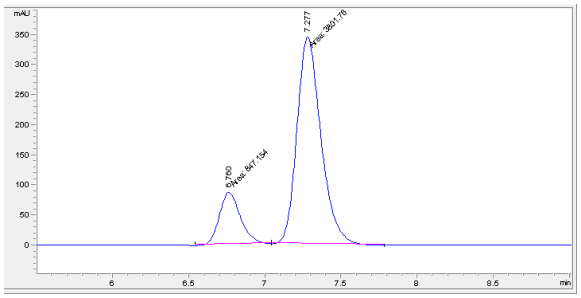
HRMS (ESI^+) m/z calcd. for $C_{21}H_{32}ONa$ $[M+Na]^+$ 323.2345; found at 323.2344, Δ –0.31 ppm.

FTIR (neat) v/cm^{-1} = 2922, 2851, 1702, 1448, 1402, 1379, 1352, 1311, 1276, 1111, 1070, 994.

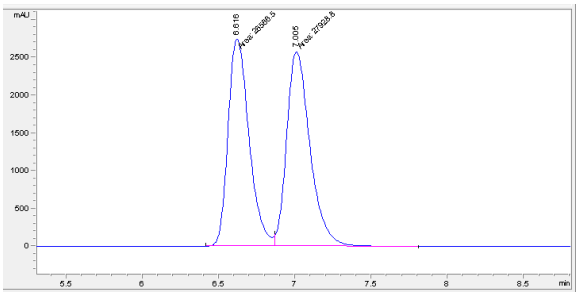
m.p. = 71–72 °C.

$[\alpha]_D^{25}$ –13.4 (c = 1.00, $CHCl_3$).

Chiral HPLC: Chiralpak IC with guard, 1 % IPA, 99 % hexane, 1 mL/min, 25 °C, λ = 210 nm, 10 µL injection

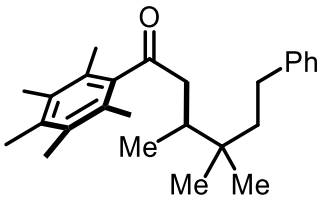


#	Time	Type	Area	Height	Width	Area%	Symmetry
1	6.76	MM	847.2	87.5	0.1614	18.223	0.798
2	7.277	MM	3801.8	345.6	0.1834	81.777	0.772



#	Time	Type	Area	Height	Width	Area%	Symmetry
1	6.616	MF	26566.5	2752.8	0.1608	48.750	0
2	7.005	FM	27928.8	2591.8	0.1796	51.250	0.676

(*S*)-3,4,4-Trimethyl-1-(2,3,4,5,6-pentamethylphenyl)-6-phenylhexan-1-one, 3h



Pentamethylacetophenone **1** (57 mg, 0.30 mmol), 3,3-dimethyl-5-phenylpentan-2-ol **2h** (115 mg, 0.60 mmol), (*R*)-DTBM-SEGPHOS (18 mg, 5 mol%), Ir(cod)acac (4.8 mg, 4 mol%) and NaO^{t}Bu (115 mg, 1.20 mmol) were subjected to **General Procedure A**. Purification by column chromatography (Pentane:Et_2O, 98:2) afforded the title compound **3h** as a white solid (61 mg, 56%, 82:18 e.r.).

^{1}H NMR (400 MHz, $CDCl_3$) δ_H 7.31 – 7.24 (2H, m), 7.21 – 7.12 (3H, m), 2.87 (1H, d, *J* = 19.0 Hz), 2.67 – 2.48 (2H, m), 2.45 (1H, dd, *J* = 19.1, 10.5 Hz), 2.36 – 2.23 (1H, m), 2.24 (3H, s), 2.20 (6H, s), 2.12 (6H, s), 1.63 – 1.43 (2H, m), 1.06 (3H, d, *J* = 6.6 Hz), 0.93 (3H, s), 0.93 (3H, s).

^{13}C NMR (101 MHz, $CDCl_3$) δ_C 211.6, 143.5, 141.0, 135.5, 133.3, 128.5, 128.4, 127.3, 125.7, 48.5, 42.8, 35.1, 34.7, 30.5, 24.8, 24.6, 17.2, 16.8, 16.1, 15.3.

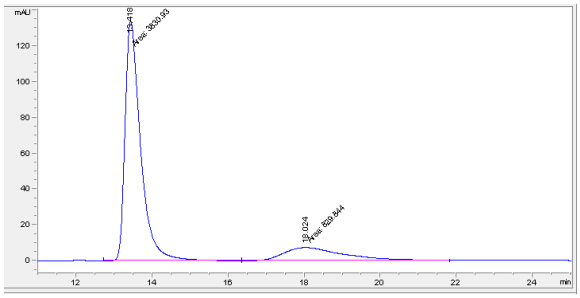
HRMS (ESI^+) m/z calcd. for $C_{26}H_{36}ONa$ $[M+Na]^+$ 387.2658; found at 387.2661, Δ 0.56 ppm.

FTIR (neat) v/cm^{-1} = 2960, 1702, 1454, 1374, 1308, 1114, 914, 755, 734, 699.

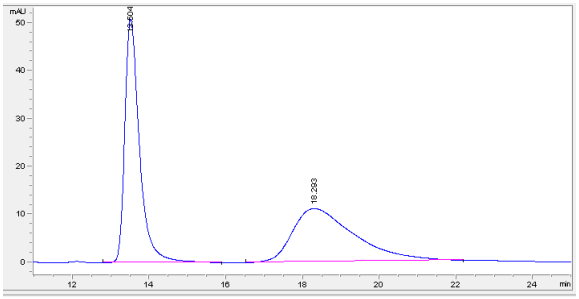
m.p. = 81-82 °C.

$[\alpha]_D^{25}$ –15.2 (c = 1.00, $CHCl_3$).

Chiral HPLC: Chiralpak IA with guard, 0.3 % IPA, 99.7 % hexane, 1 mL/min, 25 °C, λ = 210 nm, 10 µL injection

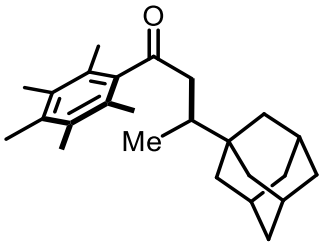


#	Time	Type	Area	Height	Width	Area%	Symmetry
1	13.418	MF	3830.9	134.1	0.476	82.195	0.541
2	18.024	FM	829.8	7.4	1.8746	17.805	0.546



#	Time	Type	Area	Height	Width	Area%	Symmetry
1	13.504	BB	1354.7	50.8	0.4034	52.067	0.585
2	18.293	BB	1247.2	11.1	1.4021	47.933	0.498

(*S*)-3-(Adamantan-1-yl)-1-(2,3,4,5,6-pentamethylphenyl)butan-1-one, 3i



Pentamethylacetophenone **1** (57 mg, 0.30 mmol), 1-(adamantan-1-yl)ethan-1-ol **2i** (108 mg, 0.60 mmol), (*R*)-DTBM-SEGPHOS (18 mg, 5 mol%), Ir(cod)acac (4.8 mg, 4 mol%) and NaO^{t}Bu (115 mg, 1.20 mmol) were subjected to **General Procedure A.** Purification by column chromatography (Pentane:Et_2O, 98:2) afforded the title compound **3i** as a white solid (85 mg, 81%, 85:15 e.r.).

^{1}H NMR (400 MHz, $CDCl_3$) δ_H 3.00 – 2.83 (1H, m), 2.35 (1H, dd, *J*=19.3, 10.4 Hz), 2.24 (3H, s), 2.19 (6H, s), 2.11 (6H, s), 2.00 – 1.93 (3H, m), 1.92 – 1.83 (1H, m), 1.79 – 1.41 (12H, m), 0.99 (3H, d, *J*=6.7 Hz).

^{13}C NMR (101 MHz, $CDCl_3$) δ_C 212.1, 141.2, 135.3, 133.2, 127.3, 47.3, 39.4, 37.4, 37.3, 34.2, 28.8, 17.2, 16.8, 16.1, 14.1.

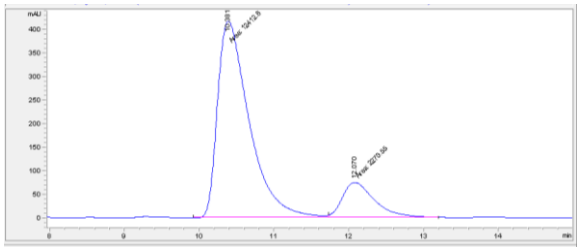
HRMS (ESI$^+$) m/z calcd. for $C_{25}H_{37}O$ $[M+H]^+$ 353.2844; found at 353.2840, Δ 0.17 ppm.

FTIR (neat) ν/cm^{-1} = 2901, 2847, 2360, 1703, 1447, 1403, 1379, 1356, 1308, 1123, 1102, 1021, 998, 914, 804, 732, 688, 647.

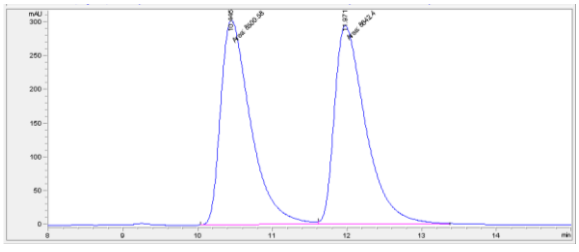
m.p. = 126–127 °C.

$[\alpha]_D^{25}$ -23.2 (c = 0.43, $CHCl_3$).

Chiral HPLC: (Chiralpak IA with guard, 0.3 % IPA, 99.7 % hexane, 1 mL/min, 25 °C, λ = 210 nm, 10 µL injection)

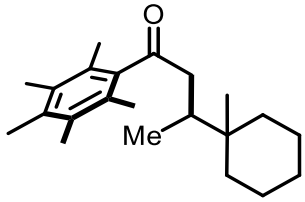


#	Time	Type	Area	Height	Width	Area%	Symmetry
1	10.381	MF	12412.6	419.9	0.4927	84.536	0
2	12.07	FM	2270.6	75.3	0.5024	15.464	0.589



#	Time	Type	Area	Height	Width	Area%	Symmetry
1	10.445	MF	8500.6	302.3	0.4686	49.586	0
2	11.971	MF	8642.4	294	0.4899	50.414	0.507

(*S*)-3-(1-Methylcyclohexyl)-1-(2,3,4,5,6-pentamethylphenyl)butan-1-one, 3j



Pentamethylacetophenone **1** (57 mg, 0.30 mmol), 1-(1-methylcyclohexyl)ethan-1-ol **2j** (85 mg, 0.60 mmol), (*R*)-DTBM-SEGPHOS (18 mg, 5 mol%), Ir(cod)acac (4.8 mg, 4 mol%) and NaO^{t}Bu (115 mg, 1.20 mmol) were subjected to **General Procedure A** with an extended reaction time (48 h). Purification by column chromatography (Pentane:Et_2O, 98:2) afforded the title compound **3j** as a white solid (55 mg, 52%, 78:22 e.r.).

^{1}H NMR (400 MHz, $CDCl_3$) δ_H 2.85 (1H, dt, *J*=19.2, 1.2 Hz), 2.38 (1H, dd, *J*=19.2, 10.3 Hz), 2.28 – 2.16 (10H, m), 2.11 (6H, s), 1.57 – 1.20 (10H, m), 0.99 (3H, d, *J*=6.7), 0.75 (3H, s).

^{13}C NMR (101 MHz, $CDCl_3$) δ_C 211.9, 141.2, 135.4, 133.2, 127.4, 48.1, 36.1, 35.9, 35.2, 34.7 26.5, 22.0, 21.9, 19.9, 17.1, 16.8, 16.1, 14.7.

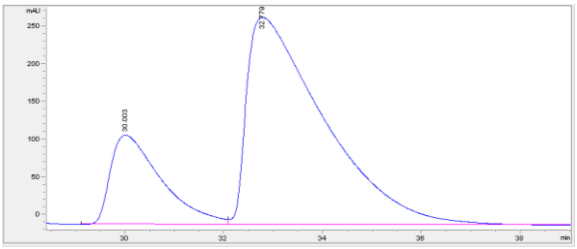
HRMS (ESI$^+$) m/z calcd. for $C_{22}H_{35}O$ $[M+H]^+$ 315.2688; found at 315.2682, Δ -0.01 ppm.

FTIR (neat) ν/cm^{-1} = 2923, 1702, 1459, 1381, 1309, 1114, 912.

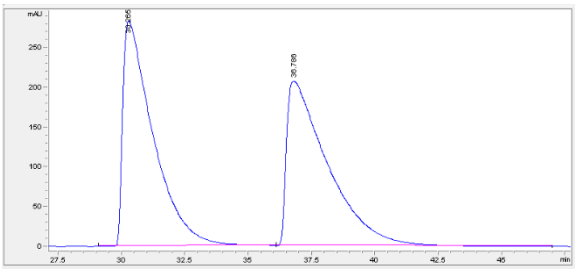
m.p. = 90-91 °C.

$[\alpha]_D^{25}$ -20.9 (c = 1.00, $CHCl_3$).

Chiral HPLC: Chiralpak IC with guard, 0.3 % IPA, 99.7 % hexane, 1 mL/min, 25 °C, λ = 210 nm, 10 µL injection

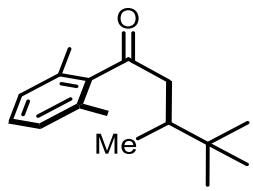


#	Time	Type	Area	Height	Width	Area%	Symmetry
1	30.003	BV	8468.4	118.2	1.0477	22.082	0.386
2	32.779	VB	29881.1	274.4	1.5546	77.918	0.237



#	Time	Type	Area	Height	Width	Area%	Symmetry
1	30.265	BB	23609	282.7	1.1924	50.267	0.223
2	36.786	BB	23358	206.7	1.5523	49.733	0.194

(*S*)-1-(2,6-Dimethylphenyl)-3,4,4-trimethylpentan-1-one, 3k



Commercially available 1-(2,6-Dimethylphenyl)ethan-1-one (45 mg, 0.30 mmol), commercially available 3,3-dimethyl-2-butanol (75 µL, 0.60 mmol), (*R*)-DTBM-SEGPHOS (18 mg, 5 mol%), Ir(cod)acac (4.8 mg, 4 mol%) and NaO^{t}Bu (115 mg, 1.20 mmol) were subjected to **General Procedure A**. Purification by column chromatography (Pentane:Et_2O, 98:2) afforded the title compound **3k** as a transparent oil (64 mg, 92%, 83:17 e.r.).

^{1}H NMR (400 MHz, $CDCl_3$) δ_H 7.18 – 7.15 (1H, m), 7.04 – 6.99 (2H, m), 2.86 (1H, dd, *J*=18.8, 1.6 Hz), 2.44 (1H, dd, *J*=18.8, 10.4 Hz), 2.23 (6H, s), 2.06 (1H, dqd, *J*=10.5, 6.7, 1.8 Hz), 1.00 (3H, dd, *J*=6.8, 0.8 Hz), 0.88 (9H, s).

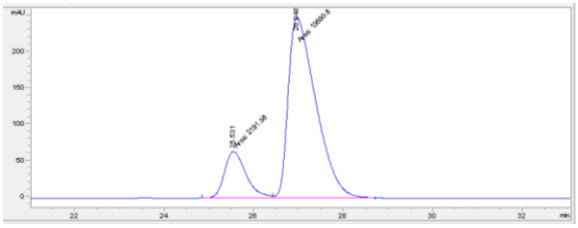
^{13}C NMR (101 MHz, $CDCl_3$) δ_C 210.4, 142.9, 132.5, 128.5, 127.9, 48.0, 37.3, 32.7, 27.3, 19.2, 15.7.

HRMS (ESI^+) m/z calcd. for $C_{16}H_{25}O$ $[M+H]^+$ 233.1905; found at 233.1903 Δ 1.09 ppm.

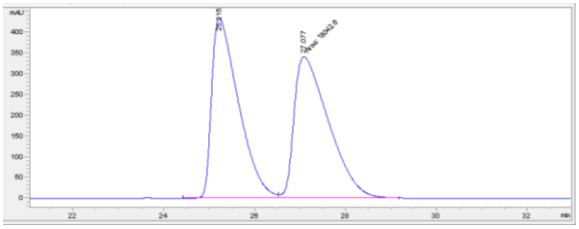
FTIR (neat) ν/cm^{-1} = 2959, 2871, 2361, 1703, 1596, 1464, 1403, 1365, 1295, 1247, 1212, 1113, 1034, 985, 920, 811, 770, 741, 686.

$[\alpha]_D^{25}$ -21.3 (c = 1.00, $CHCl_3$).

Chiral HPLC: (Chiralpak IG with guard, 0.3 % IPA, 99.7 % hexane, 0.5 mL/min, 25 °C, λ = 210 nm, 10 µL injection)

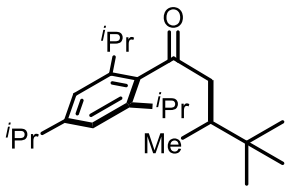


#	Time	Type	Area	Height	Width	Area%	Symmetry
1	25.531	FM	2191.6	64.4	0.5671	17.012	0.694
2	26.948	MF	10690.8	248.6	0.7168	82.988	0.45



#	Time	Type	Area	Height	Width	Area%	Symmetry
1	25.215	BV	17841.5	433.3	0.6264	49.720	0.377
2	27.077	MF	18042.6	340.2	0.8838	50.280	0.39

(*S*)-3,4,4-Trimethyl-1-(2,4,6-triisopropylphenyl)pentan-1-one, 3l



Commercially available 1-(2,4,6-triisopropylphenyl)ethan-1-one (74 mg, 0.30 mmol), commercially available 3,3-dimethyl-2-butanol (75 µL, 0.60 mmol), (*R*)-DTBM-SEGPHOS (18 mg, 5 mol%), Ir(cod)acac (4.8 mg, 4 mol%) and NaO^{t}Bu (115 mg, 1.20 mmol) were subjected to **General Procedure A**. Purification by column chromatography (Pentane:Et_2O, 98:2) afforded the title compound **3l** as a light yellow oil (60 mg, 60%, 88:12 e.r.).

^{1}H NMR (400 MHz, $CDCl_3$) δ_H 6.99 (2H, s), 2.98 – 2.78 (2H, m), 2.78 – 2.54 (2H, m, br), 2.44 (1H, dd, *J*=19.3, 10.4 Hz), 2.06 (1H, dqd, *J*=10.4, 6.7, 1.7 Hz), 1.25 (18H, br d, *J*=7.0 Hz), 1.00 (3H, d, *J*=6.7 Hz), 0.87 (9H, s).

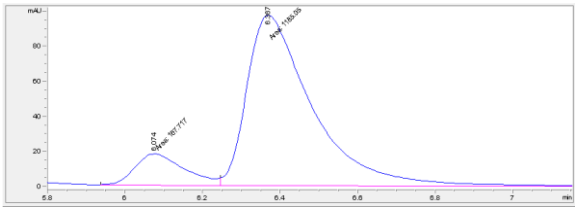
^{13}C NMR (101 MHz, $CDCl_3$) δ_C 210.9, 149.4, 143.5, 138.5, 121.2, 49.8, 37.3, 34.5, 32.5, 31.0 (br), 27.3, 24.7 (br), 24.1, 15.6.

HRMS (ESI^+) m/z calcd. for $C_{23}H_{39}O$ $[M+H]^+$ 331.3001; found at 331.2995 Δ -0.22 ppm.

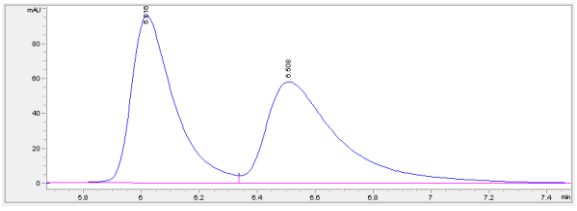
FTIR (neat) ν/cm^{-1} = 2960, 2871, 1703, 1607, 1461, 1404, 1364, 1293, 1245, 1215, 986, 877, 773, 654.

$[\alpha]_D^{25}$ -28.0 (c = 1.00, $CHCl_3$).

Chiral HPLC: (Chiralpak IA with guard, 0.1 % IPA, 99.9 % hexane, 1 mL/min, 25 °C, λ = 254 nm, 10 µL injection)



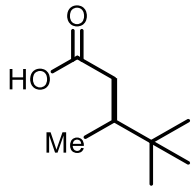
#	Time	Type	Area	Height	Width	Area%	Symmetry
1	6.074	MF	167.7	18.2	0.1533	12.398	3856.03
2	6.367	FM	1185	97.3	0.2029	87.602	0.438



#	Time	Type	Area	Height	Width	Area%	Symmetry
1	6.016	BV	1005.4	96.4	0.1536	49.234	0.529
2	6.508	VB	1036.7	58.6	0.2564	50.766	0.405

4.3 Derivatisation of Products

(S)-3,4,4-Trimethylpentanoic acid, 11



To a 2–5 mL Biotage® microwave vial equipped with a stirrer bar was added ketone **3a** (55 mg, 0.20 mmol, 97:3 e.r.), hexafluoroisopropanol (1.8 mL) and 37% aq. HCl (0.26 mL, 12 M) sequentially in the open atmosphere. The reaction vessel was sealed with a microwave vial cap (containing a Reseal™ septum) and stirred at 65 °C in a preheated oil bath for 24 h. The mixture was cooled to r.t., diluted with H_2O (10 mL) and extracted with CH_2Cl_2 (3 x 20 mL) and the combined organics were dried ($MgSO_4$), filtered and concentrated *in vacuo*. Purification by column chromatography (Pentane:Et_2O, 98:2) afforded the title compound **11** as a light yellow oil (27 mg, 93%).

The spectral data matched that previously reported in the literature.[10]

^{1}H NMR (400 MHz, $CDCl_3$) δ_H 10.97 (1H, br s, COO*H*), 2.55 (1H, dd, *J* = 15.0, 3.3 Hz), 1.99 (1H, dd, *J* = 14.9, 10.8 Hz), 1.84 – 1.75 (1H, m), 0.92 (3H, d, *J* = 6.8 Hz), 0.88 (9H, s).

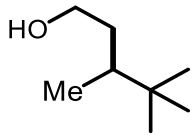
^{13}C NMR (101 MHz, $CDCl_3$) δ_C 180.9, 39.9, 37.4, 32.8, 27.2, 15.1.

HRMS (ESI^-) m/z calcd. for $C_8H_{15}O_2$ $[M–H]^-$ 143.1078; found at 143.1075, Δ –1.89 ppm.

FTIR (neat) ν/cm^{-1} = 2962, 1707, 1468, 1413, 1367, 1304, 1220, 1179, 1109, 940, 669.

[α]$_D^{20}$ -19.1 (c = 0.9, EtOH); Lit. $[\alpha]_D^{20}$ +19.6 (c = 0.9, EtOH) for the (*R*)-enantiomer.[11]

(*S*)-3,4,4-Trimethylpentan-1-ol, 12



A stirred solution of ketone **3a** (110 mg, 0.40 mmol, 97:3 e.r.) in CH_2Cl_2 (2 mL) was cooled to –17 °C (ice/NaCl bath). Br_2 (42 µL, 0.80 mmol) was added dropwise and the resulting solution was stirred at –17 °C for 15 min. The reaction mixture was then warmed to r.t. and the majority of the volatiles were removed under a stream of nitrogen and the resulting solid was dried *in vacuo* (0.2 mmHg) for 30 sec. The residue was dissolved in THF (4 mL) and the resulting stirred solution was cooled to 0 °C. $LiAlH_4$ (76 mg, 2.00 mmol) was added in a single portion and the reaction mixture was warmed to r.t. and stirred for 1 h. The resulting mixture was diluted with Et_2O (4 mL) and quenched by sequential dropwise addition of H_2O (76 µL), aq. NaOH (15% w/v, 76 µL) and H_2O (228 µL). $MgSO_4$ was added and the resulting suspension was stirred vigorously for 15 min and then filtered and concentrated *in vacuo.* Purification by column chromatography (Pentane:Et_2O, 70:30) afforded the title compound **12** as a transparent oil (48 mg, 92%).

^{1}H NMR (400 MHz, $CDCl_3$) δ_H 3.73 (1H, ddd, *J*=10.3, 8.2, 4.5 Hz), 3.60 (1H, ddd, *J*=10.3, 7.9, 7.1 Hz), 1.86 – 1.75 (1H, m), 1.42 (1H, s, O*H*), 1.31 – 1.12 (2H, m), 0.96 – 0.75 (12H, m).

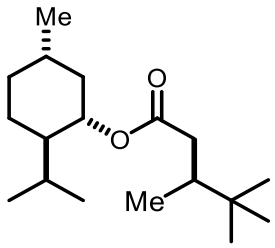
^{13}C NMR (101 MHz, $CDCl_3$) δ_C 62.5, 39.5, 35.1, 33.0, 27.3, 14.6.

HRMS (ESI^+) This compound could not be observed by ESI, APCI or EI analysis.

FTIR (neat) ν/cm^{-1} = 3319 (br), 2973, 2881, 1379, 1088, 1046, 880, 803.

$[\alpha]_D^{20}$ -14.9 (c = 3.32, EtOH).

(1*S*,2*R*,5*S*)-2-Isopropyl-5-methylcyclohexyl (*S*)-3,4,4-trimethylpentanoate, 13



Br_2 (21 µL, 0.40 mmol) was added dropwise to a cooled (–17 °C ice/NaCl bath) solution of ketone **3a** (55 mg, 0.20 mmol, 97:3 e.r.) in CH_2Cl_2 (1 mL). The resulting solution was stirred at –17 °C for 15 min followed by addition of D-Menthol (94 mg, 0.60 mmol). The reaction mixture was warmed to r.t. and stirred for 16 h. After this time, the mixture was diluted with Et_2O (10 mL) and H_2O (10 mL), then extracted with Et_2O (3 x 10 mL) and the combined organics were dried ($MgSO_4$), filtered and concentrated *in vacuo*. Purification by column chromatography (Pentane:Et_2O, 98:2) afforded the title compound **13** as a transparent oil (51 mg, 90%, >95:5 d.r.).

^{1}H NMR (400 MHz, $CDCl_3$) δ_H 4.68 (1H, td, *J*=10.9, 4.3 Hz), 2.46 (1H, ddd, *J*=14.2, 3.4, 0.8 Hz), 2.04 – 1.74 (4H, m), 1.72 – 1.62 (2H, m), 1.55 – 1.32 (2H, m), 1.20 – 0.79 (21H, m), 0.75 (3H, d, *J*=7.0 Hz).

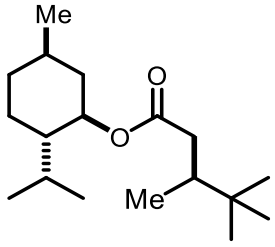
^{13}C NMR (101 MHz, $CDCl_3$) δ_C 174.0, 74.1, 47.2, 41.2, 40.3, 38.1, 34.5, 32.9, 31.6, 27.3, 26.4, 23.6, 22.2, 20.9, 16.4, 15.0.

HRMS (ESI^+) m/z calcd. for $C_{18}H_{35}O_2$ $[M+H]^+$ 283.2637; found at 283.2633, Δ 0.47 ppm.

FTIR (neat) ν/cm^{-1} = 2957, 2871, 1731, 1457, 1368, 1294, 1257, 1201, 1163, 1083, 1057, 1039, 1014, 987.

$[\alpha]_D^{25}$ +38.5 (c = 1.00, $CHCl_3$).

(1*R*,2*S*,5*R*)-2-Isopropyl-5-methylcyclohexyl (*S*)-3,4,4-trimethylpentanoate, 14



Br_2 (21 µL, 0.40 mmol) was added dropwise to a cooled (–17 °C ice/NaCl bath) solution of ketone **3a** (55 mg, 0.20 mmol, 97:3 e.r.) in CH_2Cl_2 (1 mL). The resulting solution was stirred at –17 °C for 15 min followed by addition of L-Menthol (94 mg, 0.60 mmol). The reaction mixture was warmed to r.t. and stirred for 16 h. After this time, the mixture was diluted with Et_2O (10 mL) and H_2O (10 mL), then extracted with Et_2O (3 x 10 mL) and the combined organics were dried ($MgSO_4$), filtered and concentrated *in vacuo*. Purification by column

chromatography (Pentane:Et_2O, 98:2) afforded the title compound **14** as a transparent oil (49 mg, 87%, >95:5 d.r.).

^{1}H NMR (400 MHz, $CDCl_3$) δ_H 4.68 (1H, td, *J*=10.9, 4.3 Hz), 2.46 (1H, ddd, *J*=14.2, 3.4, 0.8 Hz), 2.09 – 1.73 (4H, m), 1.73 – 1.63 (2H, m), 1.56 – 1.31 (2H, m), 1.18 – 0.79 (21H, m), 0.75 (3H, d, *J*=7.0 Hz).

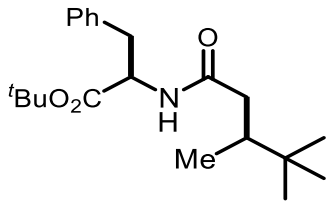
^{13}C NMR (101 MHz, $CDCl_3$) δ_C 173.9, 74.0, 47.2, 41.0, 40.0, 38.1, 34.5, 32.8, 31.5, 27.3, 26.5, 23.7, 22.2, 20.9, 16.5, 15.0.

HRMS (ESI^+) m/z calcd. for $C_{18}H_{34}NaO_2$ $[M+Na]^+$ 305.2457; found at 305.2452, Δ 0.31 ppm.

FTIR (neat) v/cm^{-1} = 2956, 2870, 1731, 1457, 1368, 1294, 1256, 1201, 1163, 1082, 1057, 1039, 1013, 987.

$[\alpha]_D^{25}$ -63.8 (c = 1.00, $CHCl_3$).

***tert*-Butyl ((*S*)-3,4,4-trimethylpentanoyl)-D-phenylalaninate, 15**



Br_2 (21 µL, 0.40 mmol) was added dropwise to a cooled (–17 °C ice/NaCl bath) solution of ketone **3a** (55 mg, 0.20 mmol, 97:3 e.r.) in CH_2Cl_2 (1 mL). The resulting solution was stirred at –17 °C for 15 min followed by addition of H-D-Phe-O^{t}Bu·HCl (103 mg, 0.40 mmol) and ^{i}Pr$_2$EtN (140 µL, 0.80 mmol). The reaction mixture was warmed to r.t. and stirred for 16 h. After this time, the mixture was diluted with Et_2O (10 mL) and washed successively with 1 M aq. HCl (10 mL) and sat. aq. $NaHCO_3$ (10 mL). The combined organics were dried ($MgSO_4$), filtered and concentrated *in vacuo*. Purification by column chromatography (Pentane:Et_2O, 80:20) afforded the title compound **15** as a pale yellow solid and a single diastereomer (62 mg, 89%, >95:5 d.r.).

^{1}H NMR (400 MHz, $CDCl_3$) δ_H 7.26 – 7.12 (3H, m), 7.12 – 7.05 (2H, m), 5.78 (1H, d, *J*=7.8 Hz, N*H*), 4.72 (1H, dt, *J*=7.8, 6.1 Hz), 3.01 (2H, d, *J*=6.1 Hz), 2.39 – 2.26 (1H, m), 1.73 – 1.59 (2H, m), 1.34 (9H, s), 0.80 – 0.76 (12H, s)

^{13}C NMR (101 MHz, $CDCl_3$) δ_C 173.0, 171.1, 136.5, 129.6, 128.5, 127.0, 82.4, 53.5, 40.5, 39.8, 38.3, 32.8, 28.1, 27.3, 14.9.

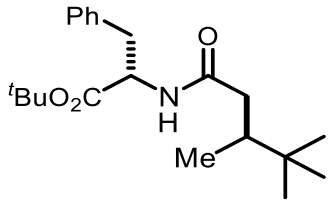
HRMS (ESI^+) m/z calcd. for $C_{21}H_{33}O_3NNa$ $[M+Na]^+$ 370.2353; found at 370.2355 Δ -0.01 ppm.

FTIR (neat) ν_{max}/cm^{-1} = 3291, 2964, 1732, 1644, 1546, 1498, 1456, 1367, 1255, 1155, 1104, 848, 740, 699.

m.p. = 105-106 °C.

$[\alpha]_D^{25}$ -59.7 (c = 1.00, $CHCl_3$).

***tert*-Butyl ((*S*)-3,4,4-trimethylpentanoyl)-L-phenylalaninate, 16**



Br_2 (21 µL, 0.40 mmol) was added dropwise to a cooled (–17 °C ice/NaCl bath) solution of ketone **3a** (55 mg, 0.20 mmol, 97:3 e.r.) in CH_2Cl_2 (1 mL). The resulting solution was stirred at –17 °C for 15 min followed by addition of H-L-Phe-O^{t}Bu·HCl (103 mg, 0.40 mmol) and ^{i}Pr$_2$EtN (140 µL, 0.80 mmol). The reaction mixture was warmed to r.t. and stirred for 16 h. After this time, the mixture was diluted with Et_2O (10 mL) and washed successively with 1 M aq. HCl (10 mL) and sat. aq. $NaHCO_3$ (10 mL). The combined organics were dried ($MgSO_4$), filtered and concentrated *in vacuo*. Purification by column chromatography (Pentane:Et_2O, 80:20) afforded the title compound **16** as a pale yellow solid and a single diastereomer (65 mg, 94%, >95:5 d.r.).

^{1}H NMR (400 MHz, $CDCl_3$) δ_H 7.34 – 7.02 (5H, m), 5.80 (1H, d, *J*=7.8 Hz, N*H*), 4.73 (1H, dt, *J*=7.8, 6.1 Hz), 3.01 (2H, d, *J*=6.1 Hz), 2.35 (1H, dd, *J*=13.6, 2.7 Hz), 1.77 – 1.58 (2H, m), 1.33 (9H, s), 0.78 (9H, s), 0.75 – 0.70 (3H, m).

^{13}C NMR (101 MHz, $CDCl_3$) δ_C 172.9, 171.1, 136.5, 129.6, 128.5, 127.0, 82.4, 53.6, 40.2, 39.8, 38.5, 32.8, 28.1, 27.3, 14.9.

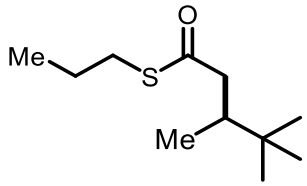
HRMS (ESI$^+$) m/z calcd. for $C_{21}H_{33}O_3NNa$ $[M+Na]^+$ 370.2353; found at 370.2353 Δ -0.01 ppm.

FTIR (neat) ν_{max}/cm^{-1} = 3292, 2965, 1735, 1646, 1543, 1498, 1456, 1367, 1226, 1155, 1102, 847, 740, 699.

m.p. = 89-91 °C.

[α]$_D^{25}$ +40.7 (c = 1.00, $CHCl_3$).

S-propyl (*S*)-3,4,4-trimethylpentanethioate, 17



Br_2 (21 µL, 0.40 mmol) was added dropwise to a cooled (–17 °C ice/NaCl bath) solution of ketone **3a** (55 mg, 0.20 mmol) in CH_2Cl_2 (1 mL). The resulting solution was stirred at –17 °C for 15 min followed by addition of 1-propanethiol (56 µL, 0.60 mmol). The reaction mixture was warmed to r.t. and stirred for 16 h. After this time, the mixture was diluted with CH_2Cl_2 (10 mL) and sat. aq. $Na_2S_2O_3$ (10 mL), then extracted with CH_2Cl_2 (3 x 10 mL) and the combined organics were dried ($MgSO_4$), filtered and concentrated *in vacuo*. Purification by column chrotography (Pentane:Et_2O, 98:2) afforded the title compound **17** as a pale yellow oil (37 mg, 93%).

^{1}H NMR (400 MHz, $CDCl_3$) δ_H 2.85 (2H, t, *J*=7.3 Hz), 2.69 (1H, dd, *J*=14.4, 3.2 Hz), 2.23 (1H, dd, *J*=14.4, 10.8 Hz), 1.85 (1H, dqd, *J*=10.8, 6.8, 3.2 Hz), 1.59 (2H, hex, *J*=7.3 Hz), 0.97 (3H, t, *J*=7.3 Hz), 0.91 – 0.82 (12H, m).

^{13}C NMR (101 MHz, $CDCl_3$) δ_C 200.4, 47.4, 40.8, 33.0, 31.0, 27.3, 23.2, 14.7, 13.5.

HRMS (ESI$^+$) m/z calcd. for $C_{11}H_{23}O_2S$ $[M+H]^+$ 203.1470; found at 203.1467, Δ 1.39 ppm.

FTIR (neat) ν_{max}/cm^{-1} = 2963, 2873, 2360, 2341, 1693, 1463, 1378, 1366, 1286, 1221, 1113, 1017, 986, 776, 692, 669.

[α]$_D^{25}$ -22.1 (c = 1.00, $CHCl_3$).

5. References

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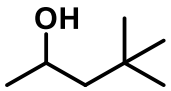
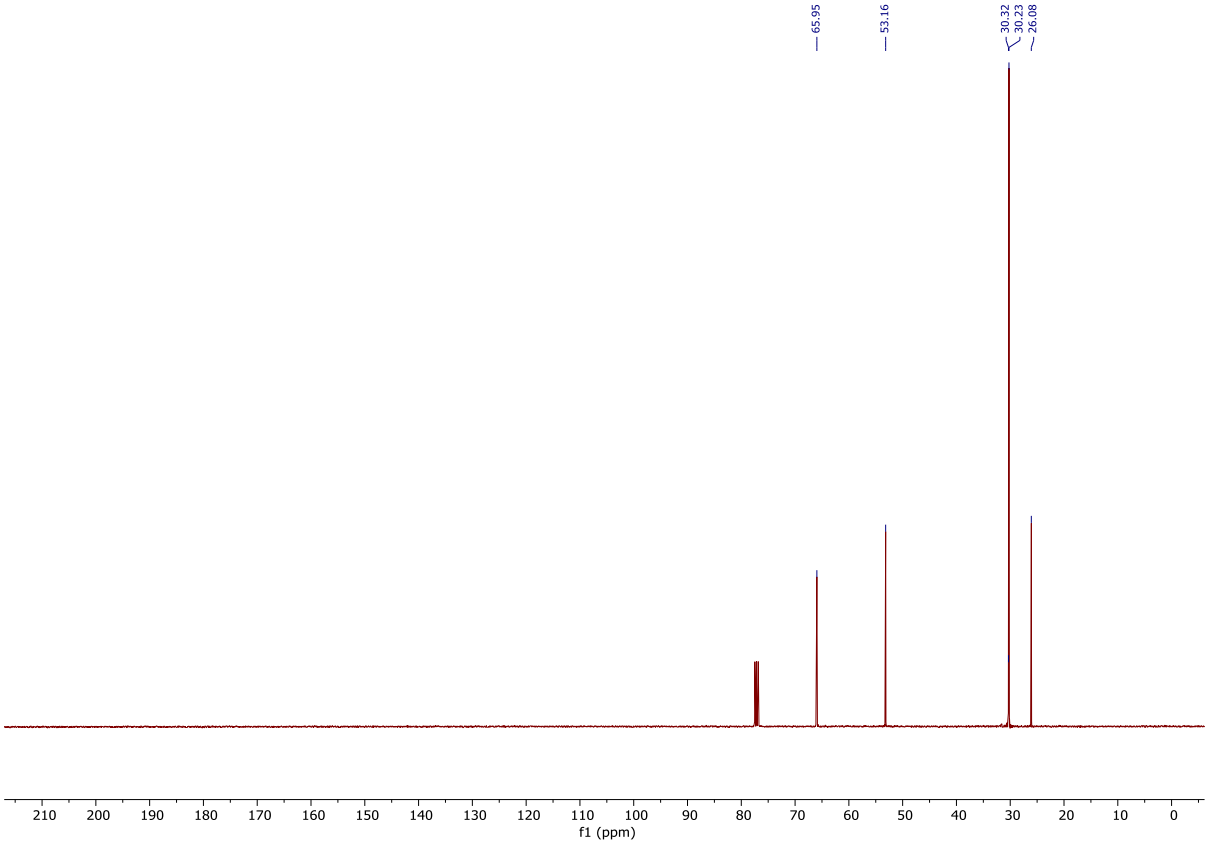
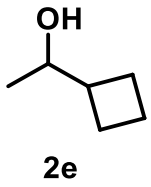
6. NMR Spectra



2b




OH

2e

1.00
1.00
6.65
0.95
3.39
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
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0.5
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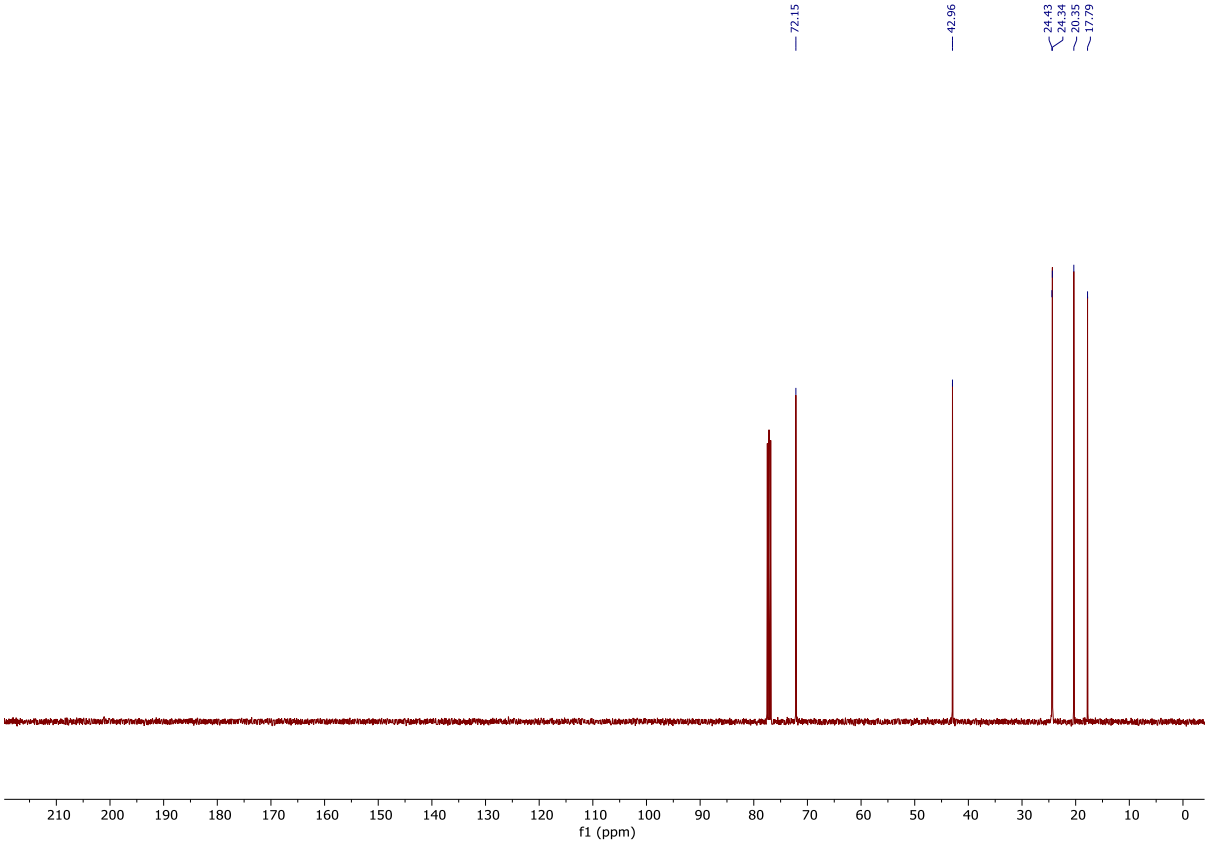
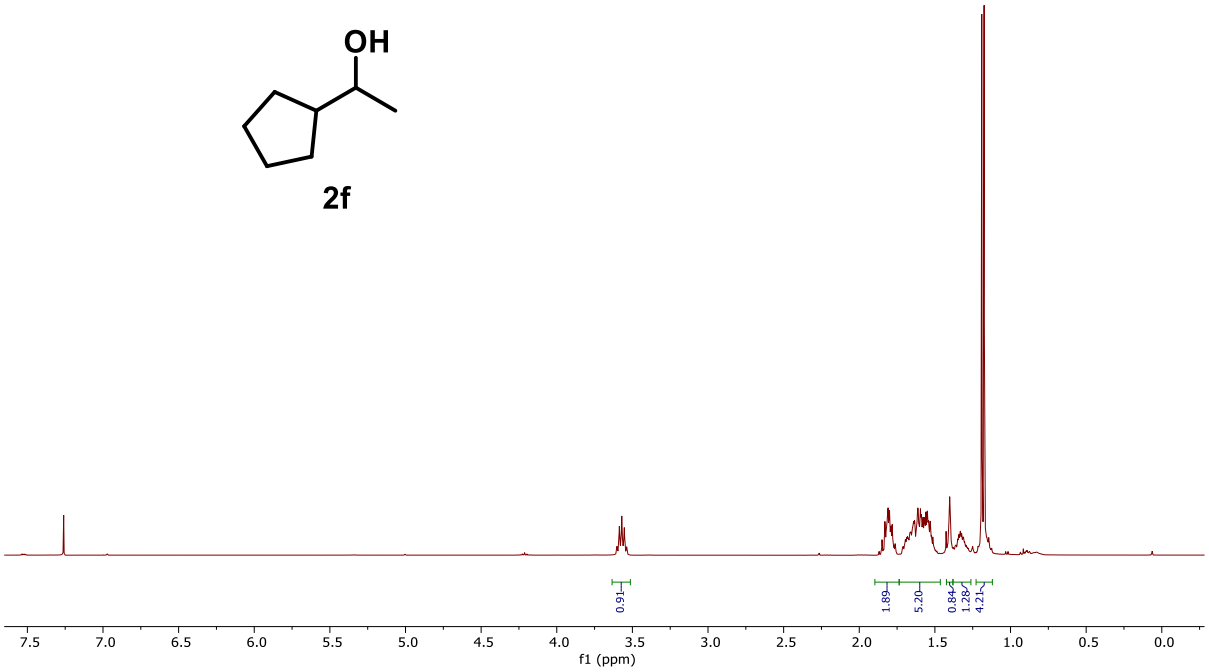
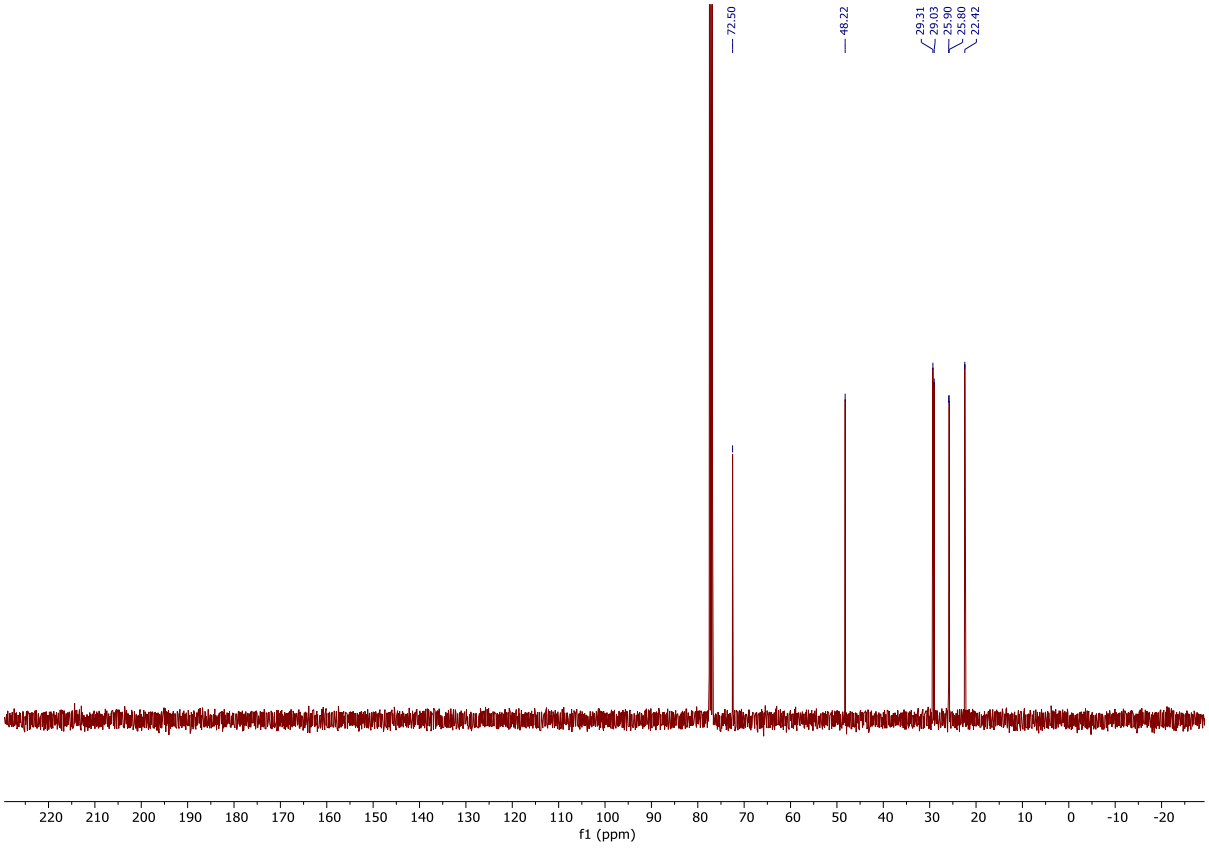
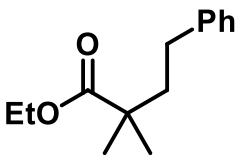
f1 (ppm)


72.15
42.96
24.43
24.34
20.35
17.79
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

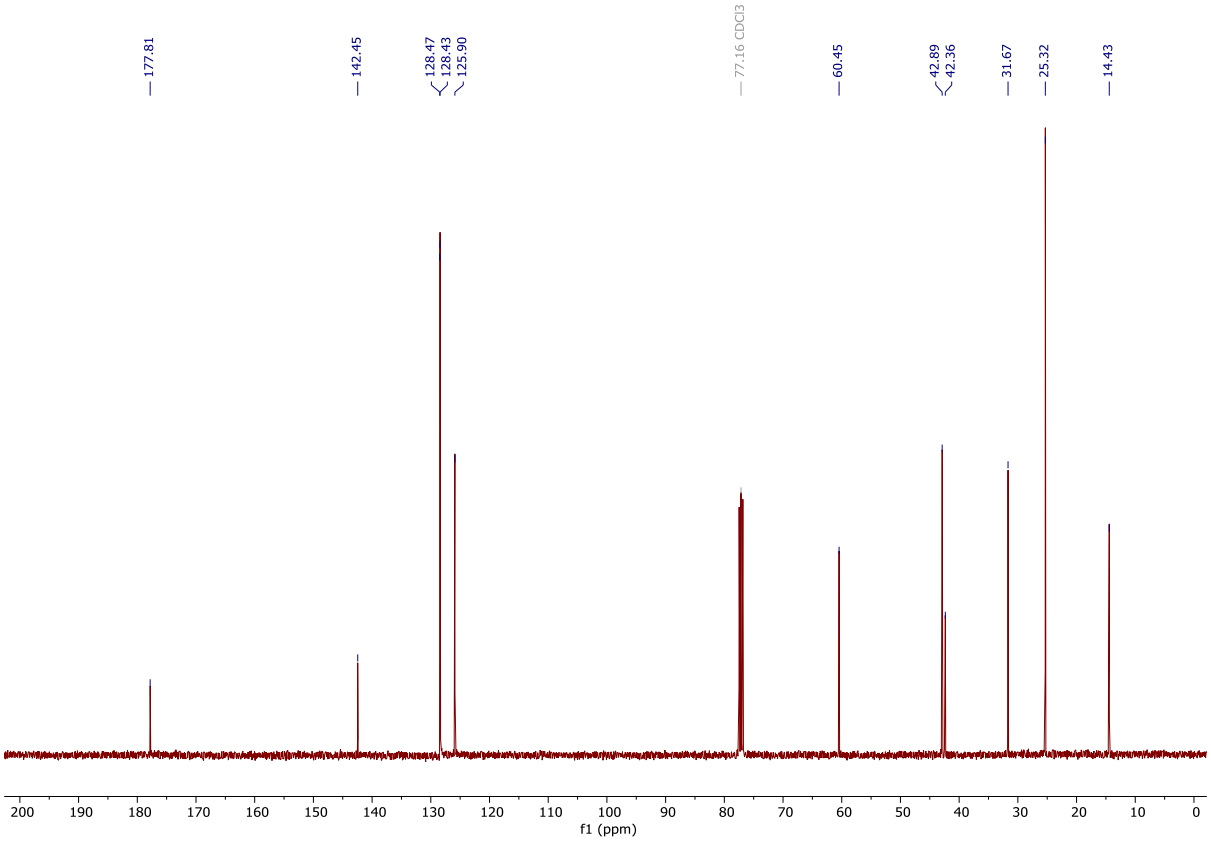

OH
2f
0.91
1.89
5.20
0.84
1.28
4.21
7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

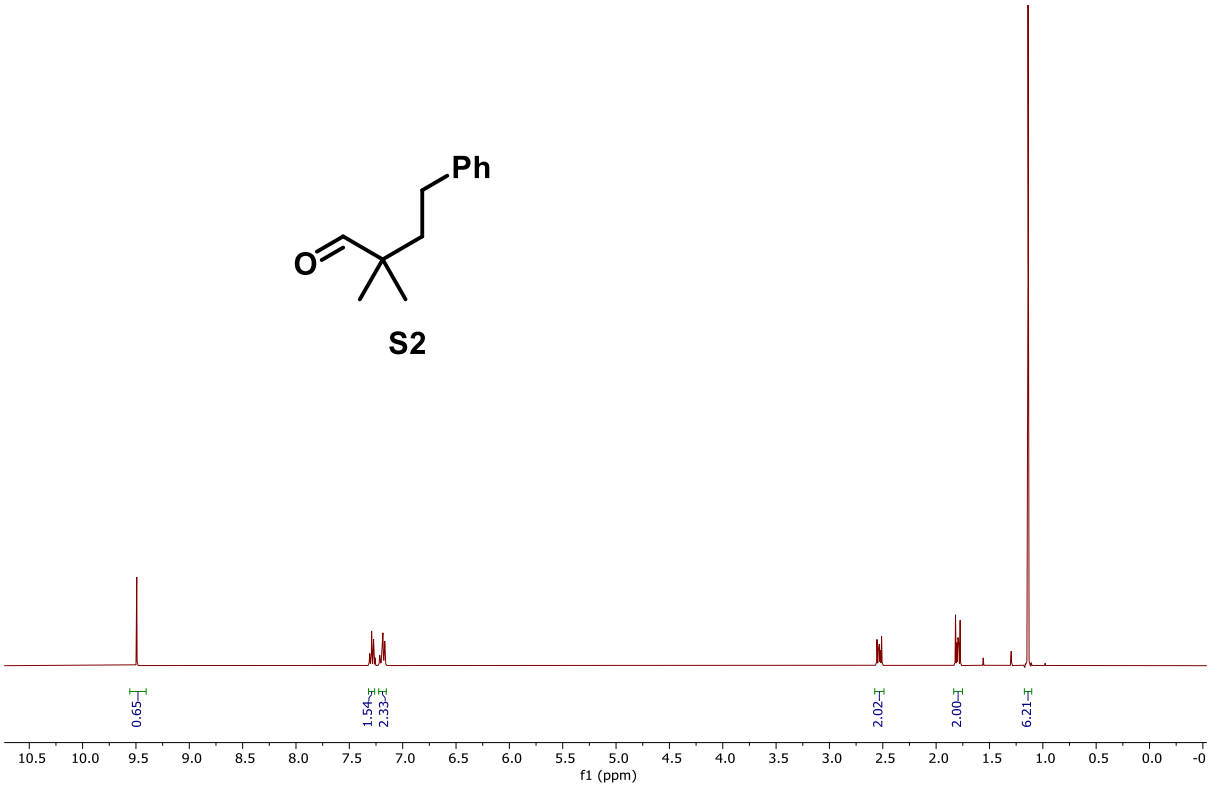

72.50
48.22
29.31
29.03
25.90
25.80
22.42
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20
f1 (ppm)

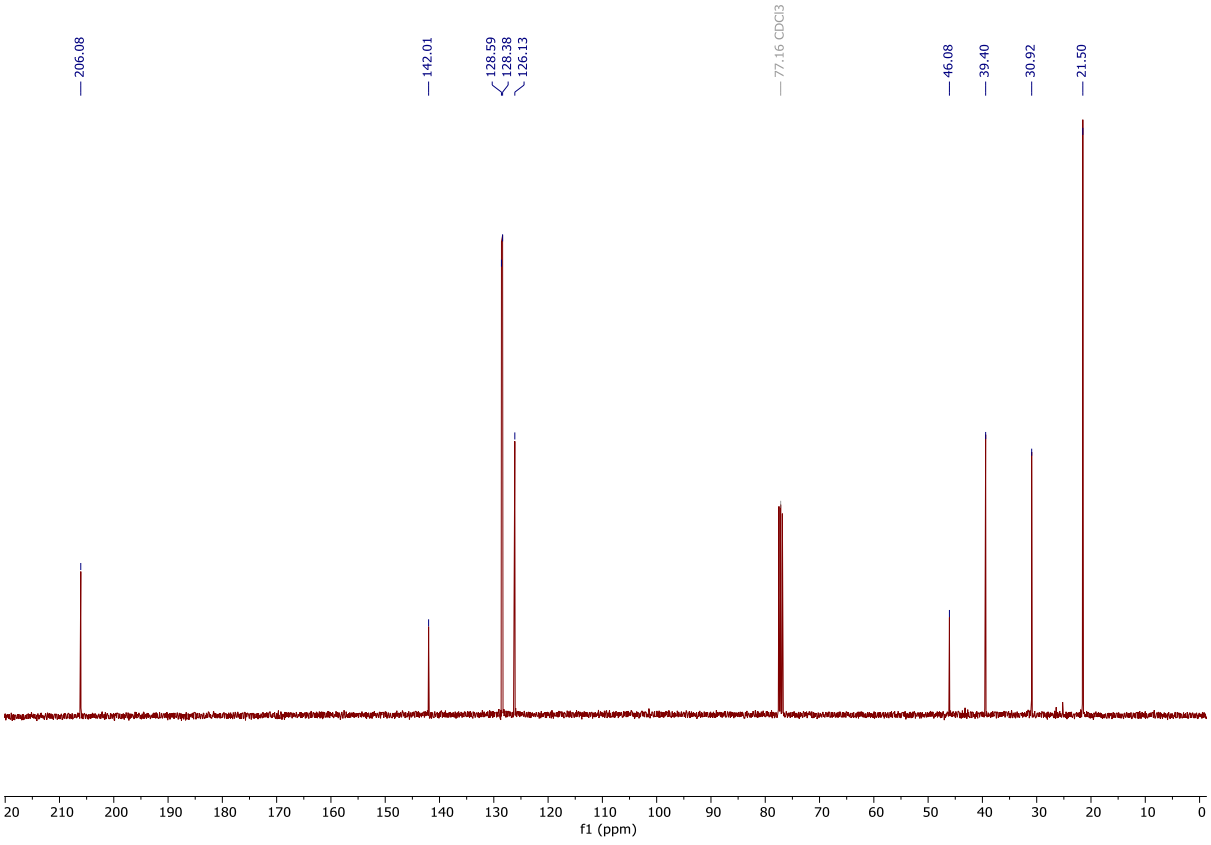

Ph
O
EtO

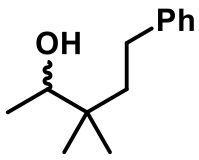
S1

1.96
2.86
2.02
2.16
2.18
3.50
5.99
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)


177.81
142.45
128.47
128.43
125.90
77.16 CDCl3
60.45
42.89
42.36
31.67
25.32
14.43
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

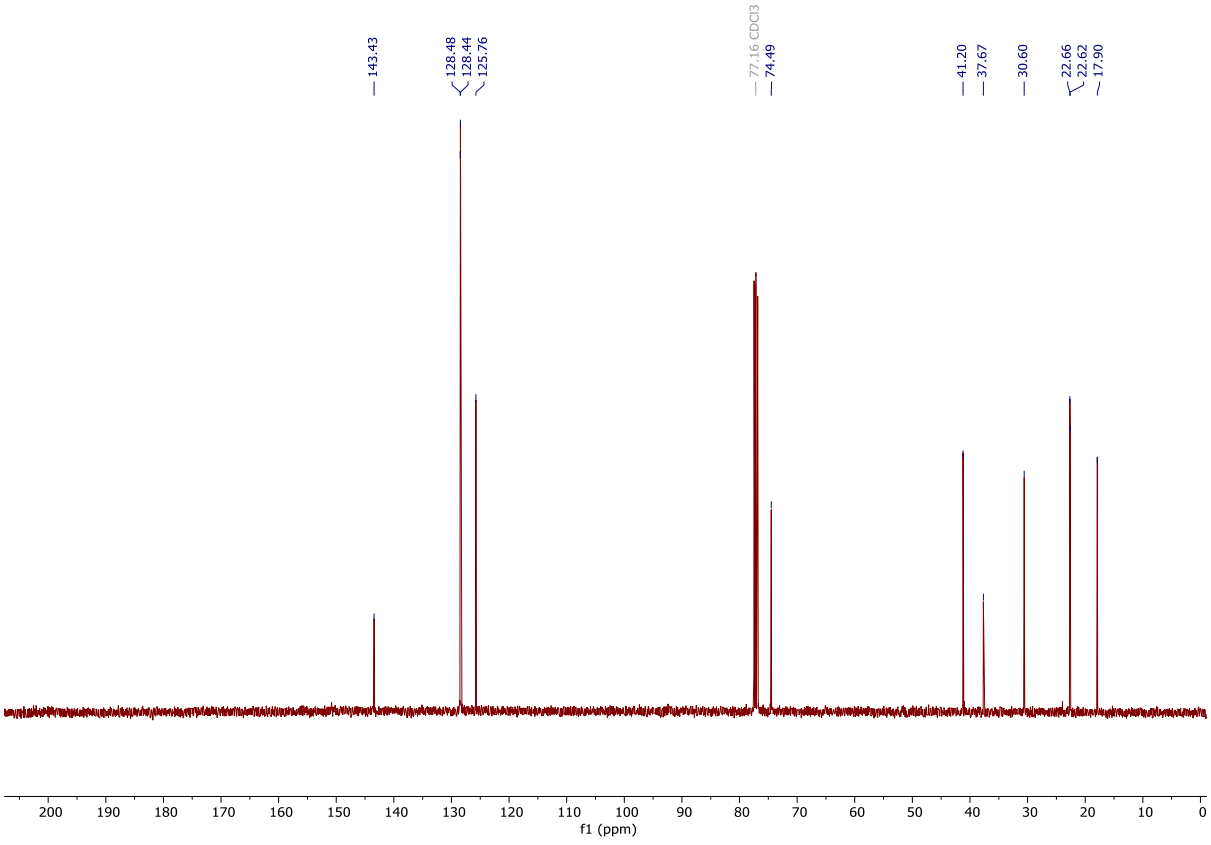

Ph
O
S2
0.65
1.54
2.33
2.02
2.00
6.21
f1 (ppm)

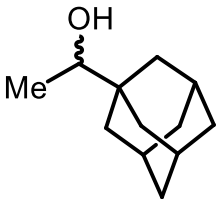

206.08
142.01
128.59
128.38
126.13
77.16 CDCl3
46.08
39.40
30.92
21.50
f1 (ppm)


OH
Ph

2h

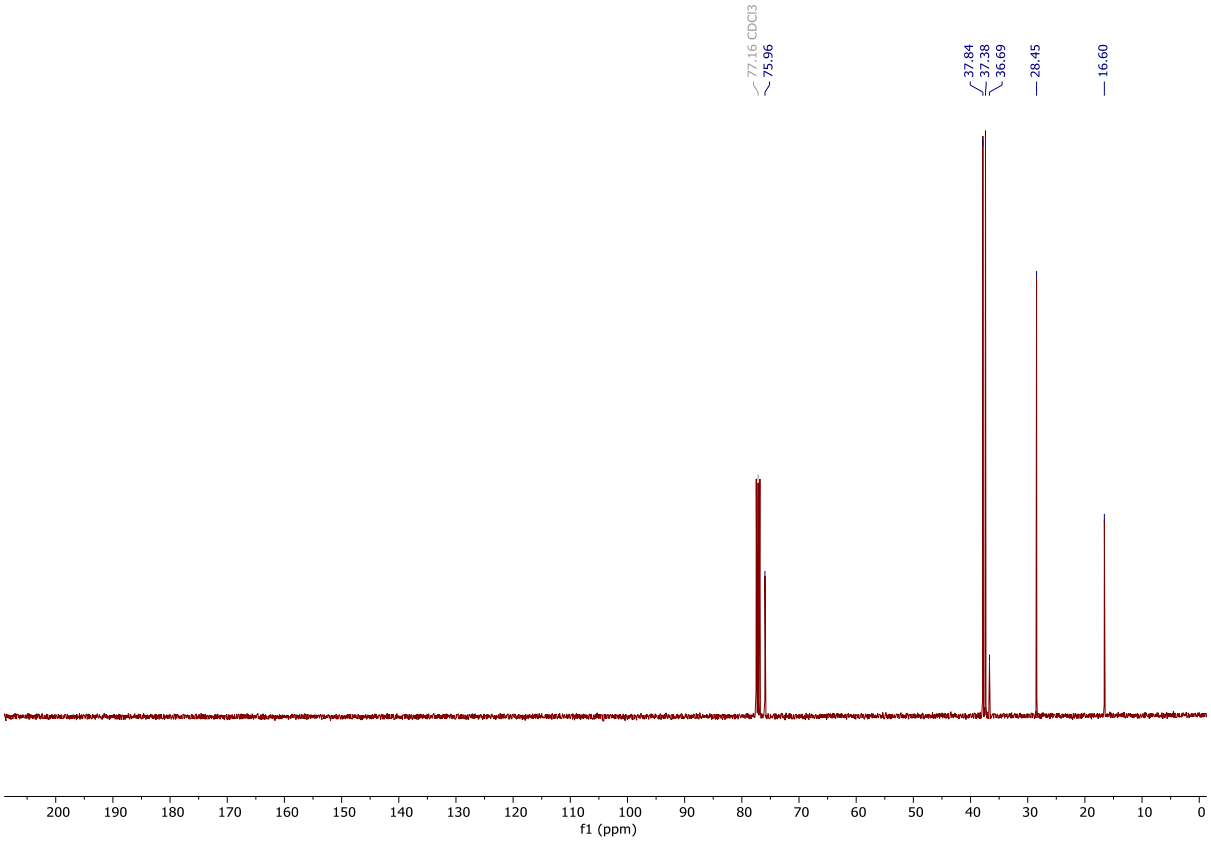
1.93
2.66
0.94
2.02
1.18
1.03
0.81
2.98
6.08
7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

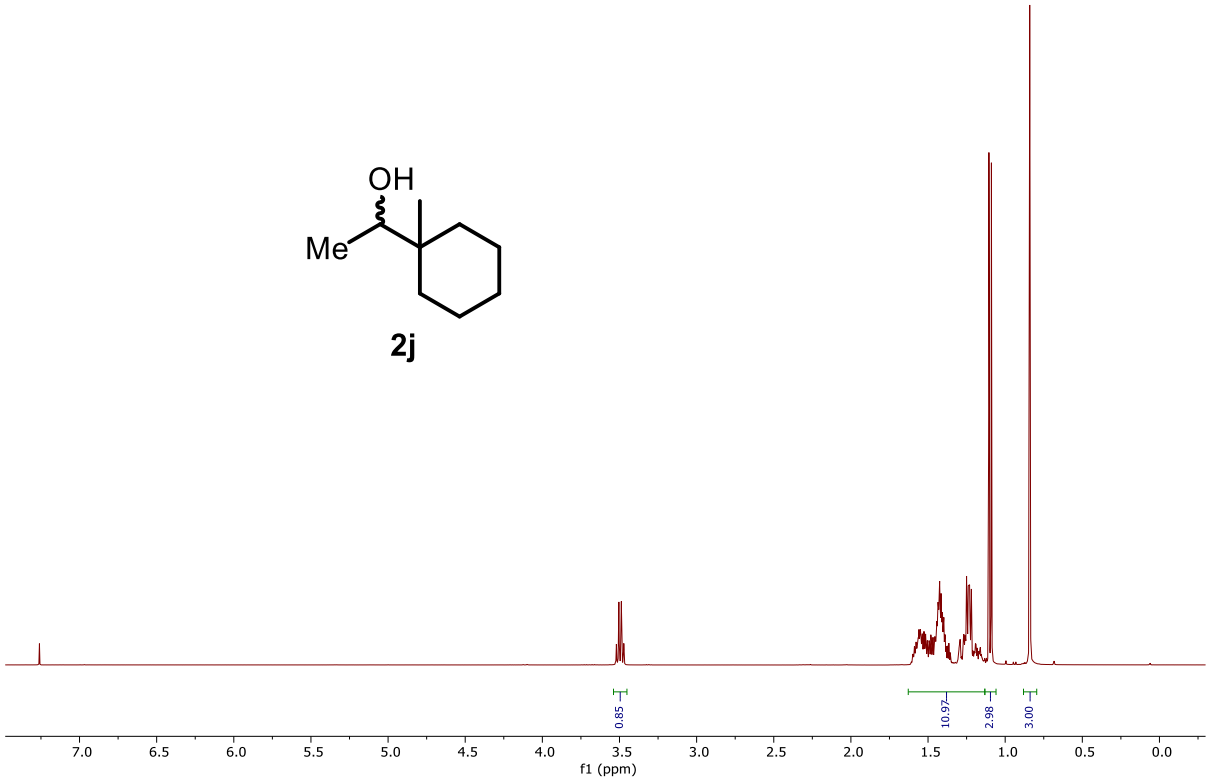

143.43
128.48
128.44
125.76
77.16 CDCl3
74.49
41.20
37.67
30.60
22.66
22.62
17.90
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

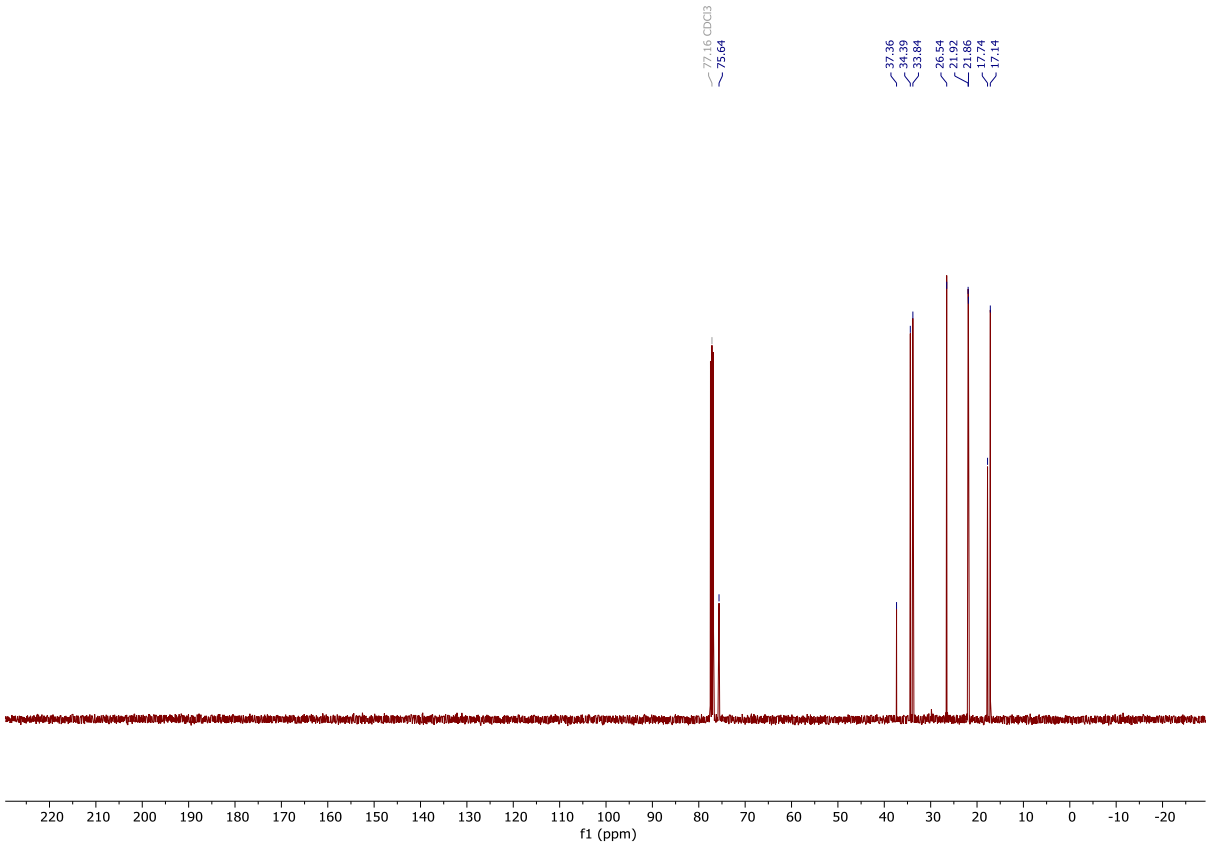

OH
Me

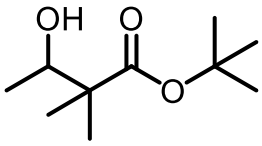
2i

0.90
2.77
9.23
3.00
0.92
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)


77.16 CDCl3
75.96
37.84
37.38
36.69
28.45
16.60
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

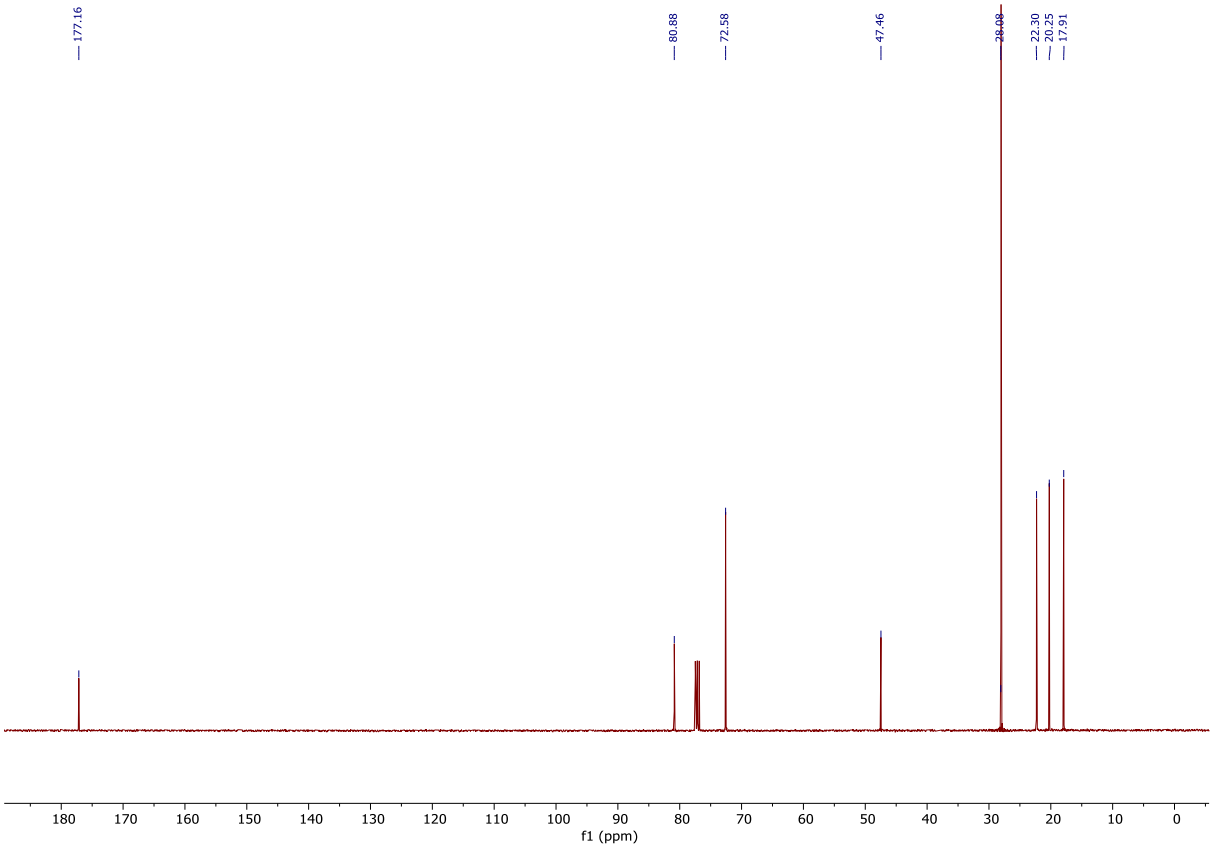

OH
Me
2j
0.85
10.97
2.98
3.00
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

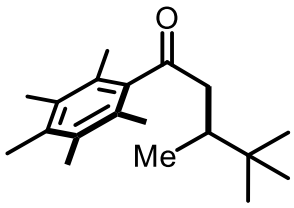

77.16 CDCl3
75.64
37.36
34.39
33.84
26.54
21.92
21.86
17.74
17.14
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
f1 (ppm)


OH
O
O

2o

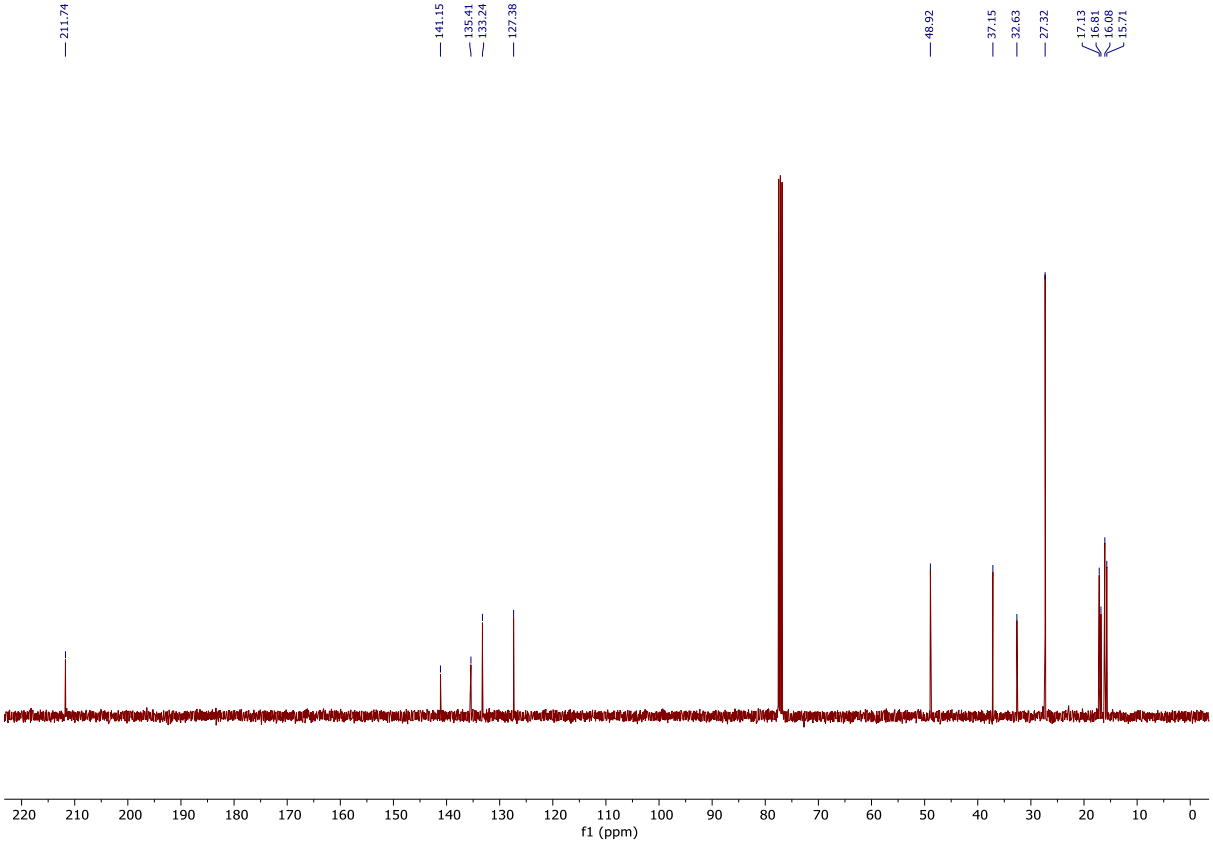
0.90
0.85
9.09
9.01
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

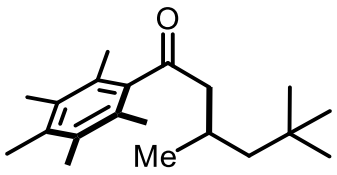

177.16
80.88
72.58
47.46
28.08
22.30
20.25
17.91
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


O
Me

3a

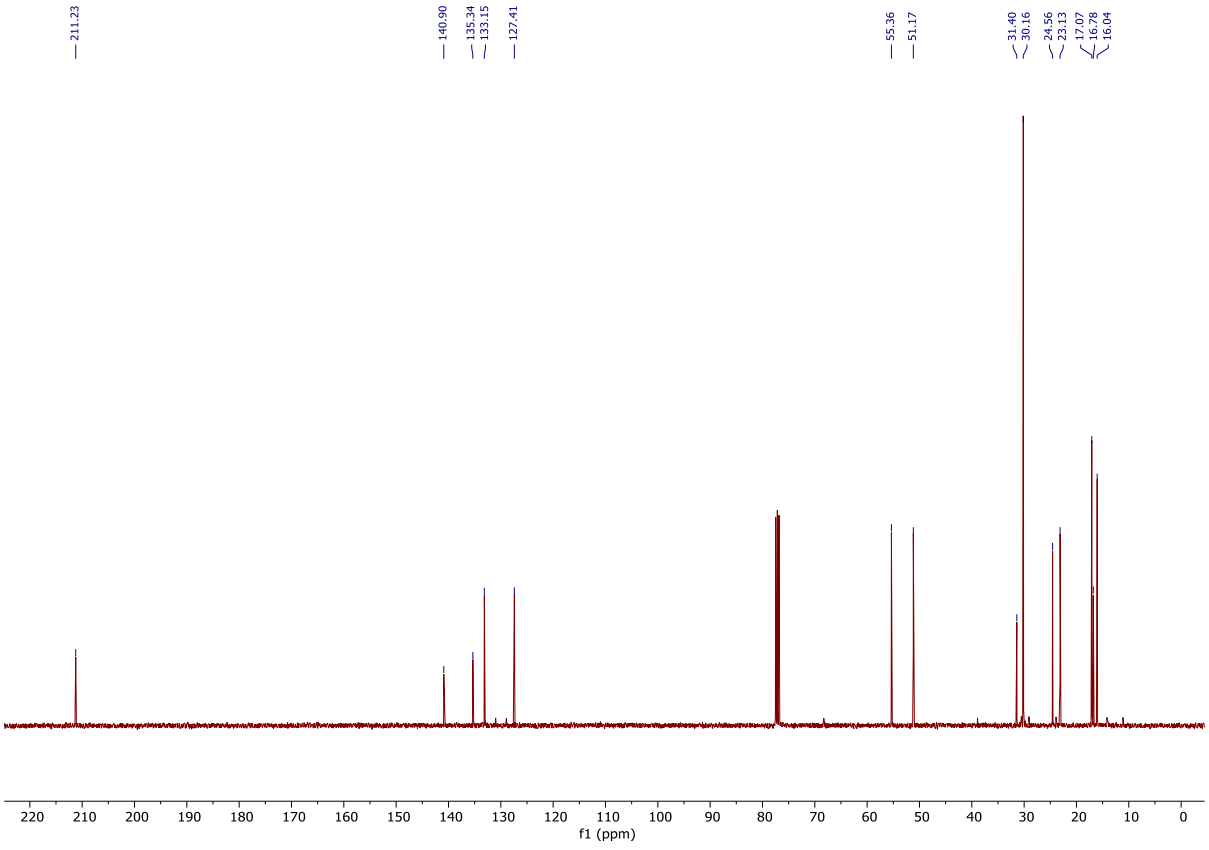
0.97
1.10
3.10
6.04
7.07
3.14
9.00
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

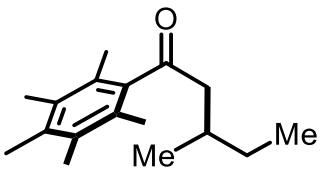

211.74
141.15
135.41
133.24
127.38
48.92
37.15
32.63
27.32
17.13
16.81
16.08
15.71
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


O
Me

3b

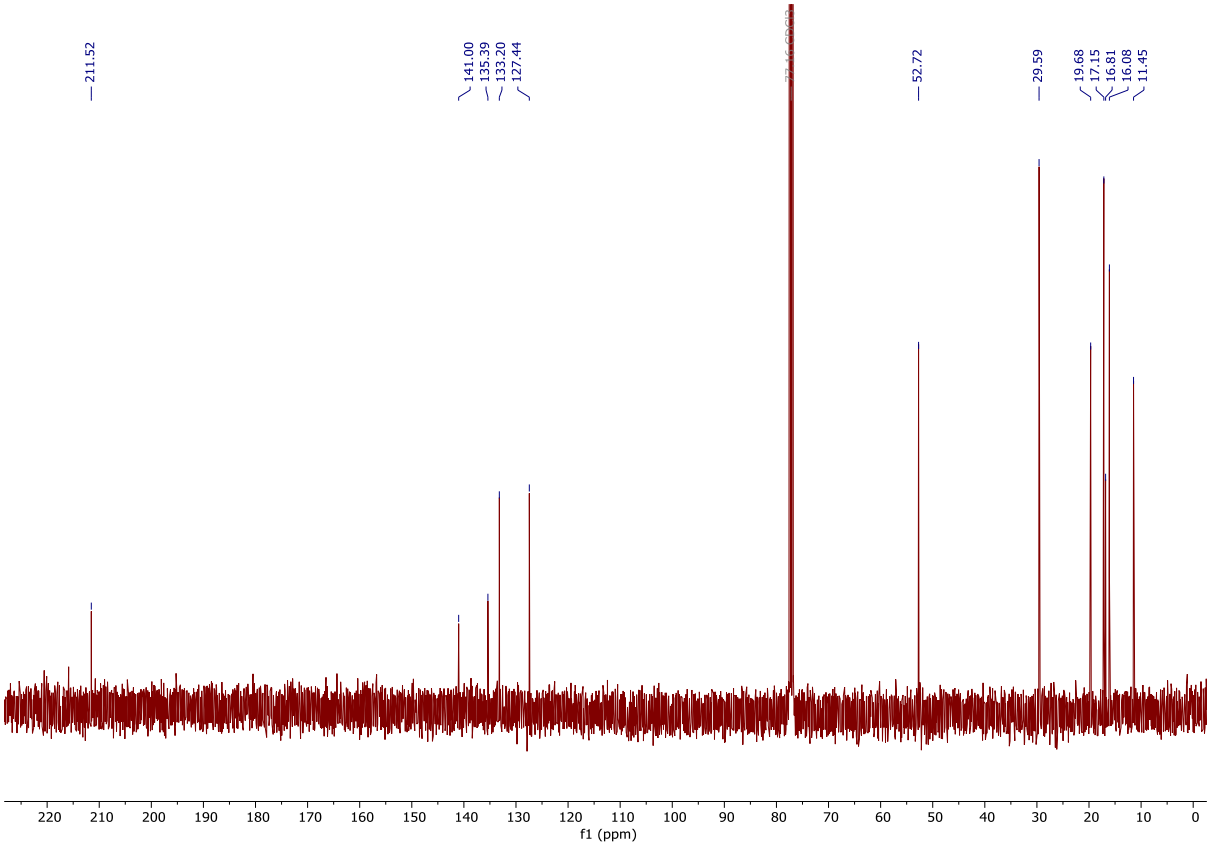
1.00
1.00
1.18
2.96
6.03
5.99
1.15
1.06
3.08
9.43
7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

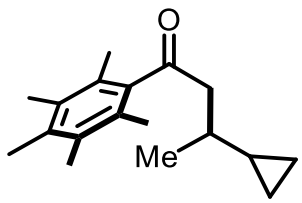

211.23
140.90
135.34
133.15
127.41
55.36
51.17
31.40
30.16
24.56
23.13
17.07
16.78
16.04
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


O
Me
Me

3c

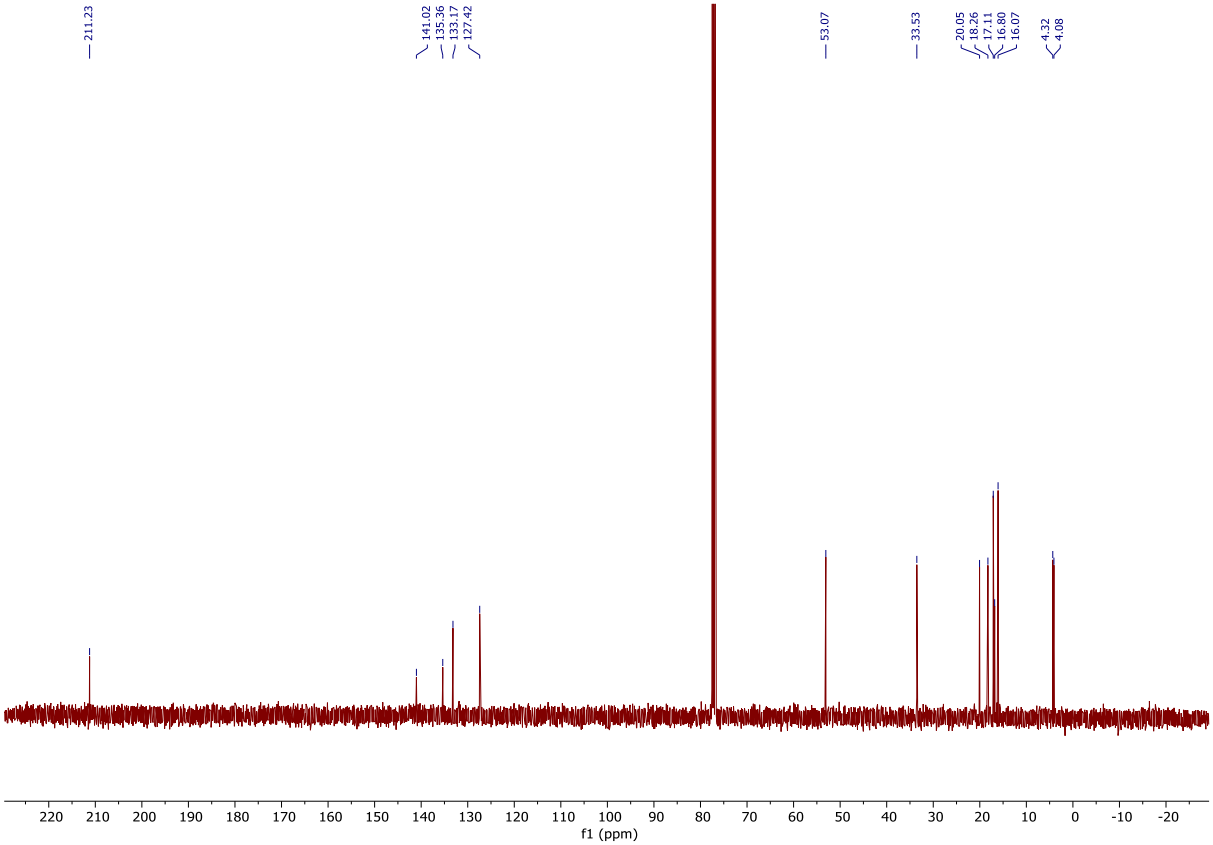
1.01
1.00
2.90
5.84
6.86
1.04
1.53
3.01
3.00
8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0
f1 (ppm)

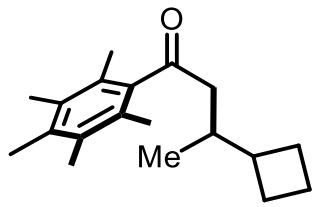

211.52
141.00
135.39
133.20
127.44
77.16 CDCl3
52.72
29.59
19.68
17.15
16.81
16.08
11.45
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


O
Me

3d

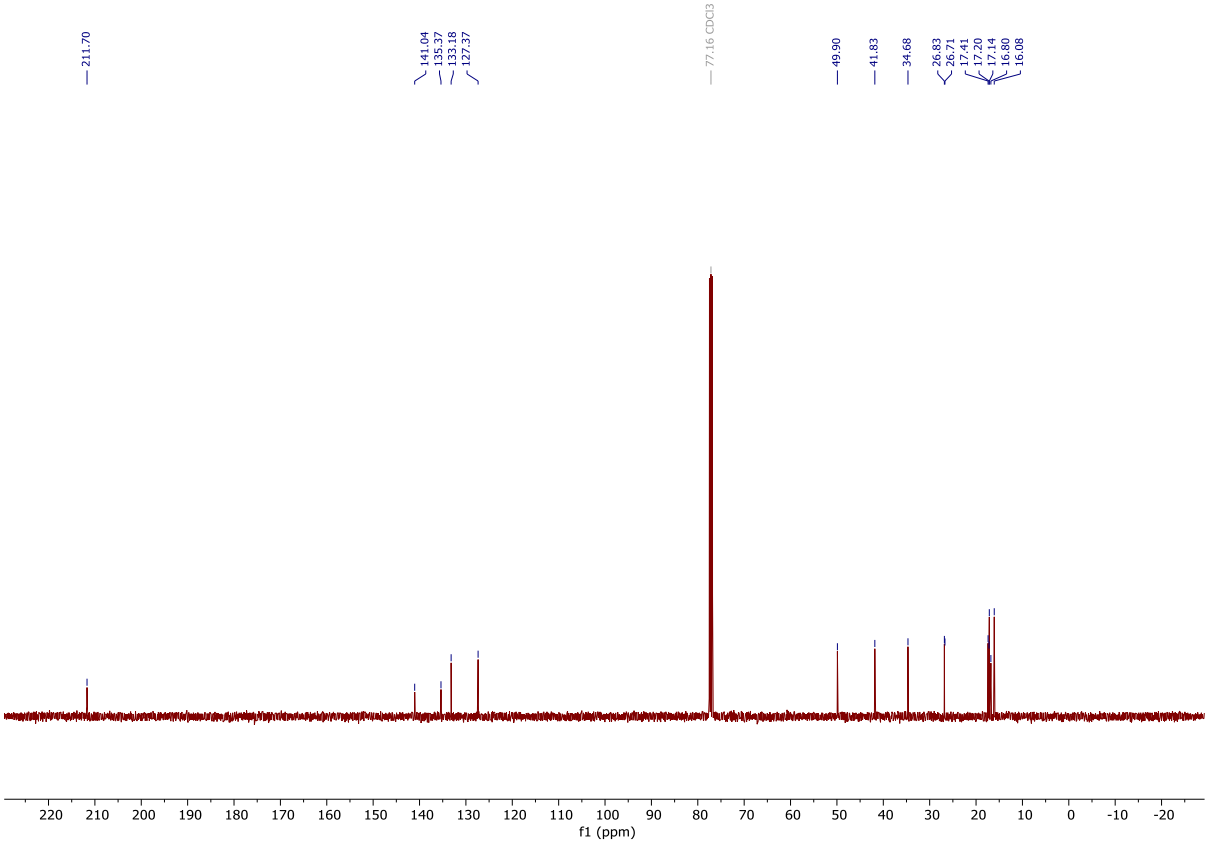
1.00
1.06
3.28
6.53
6.46
3.01
0.95
2.03
1.98
7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

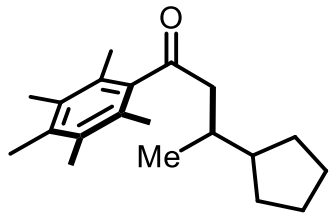

211.23
141.02
135.36
133.17
127.42
53.07
33.53
20.05
19.26
17.11
16.80
16.07
4.32
4.08
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20
f1 (ppm)


O
Me

3e

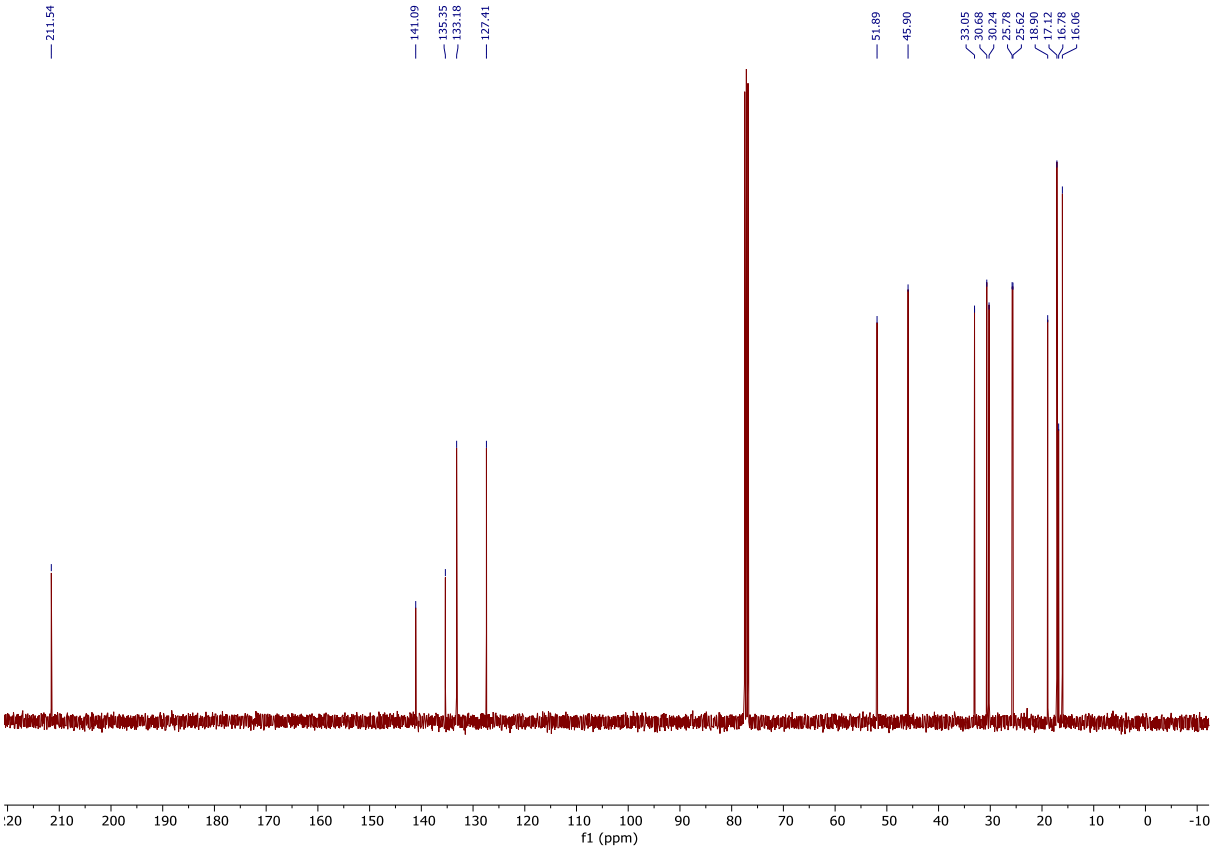
1.00
1.08
3.02
5.96
10.22
4.48
2.87
7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

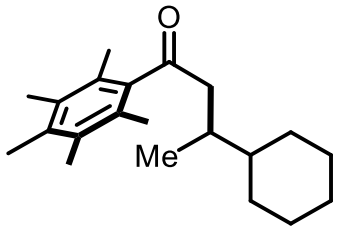

211.70
141.04
135.37
133.18
127.37
77.16 CDCl3
49.90
41.83
34.68
26.83
26.71
17.41
17.20
17.14
16.80
16.08
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20
f1 (ppm)


O
Me

3f

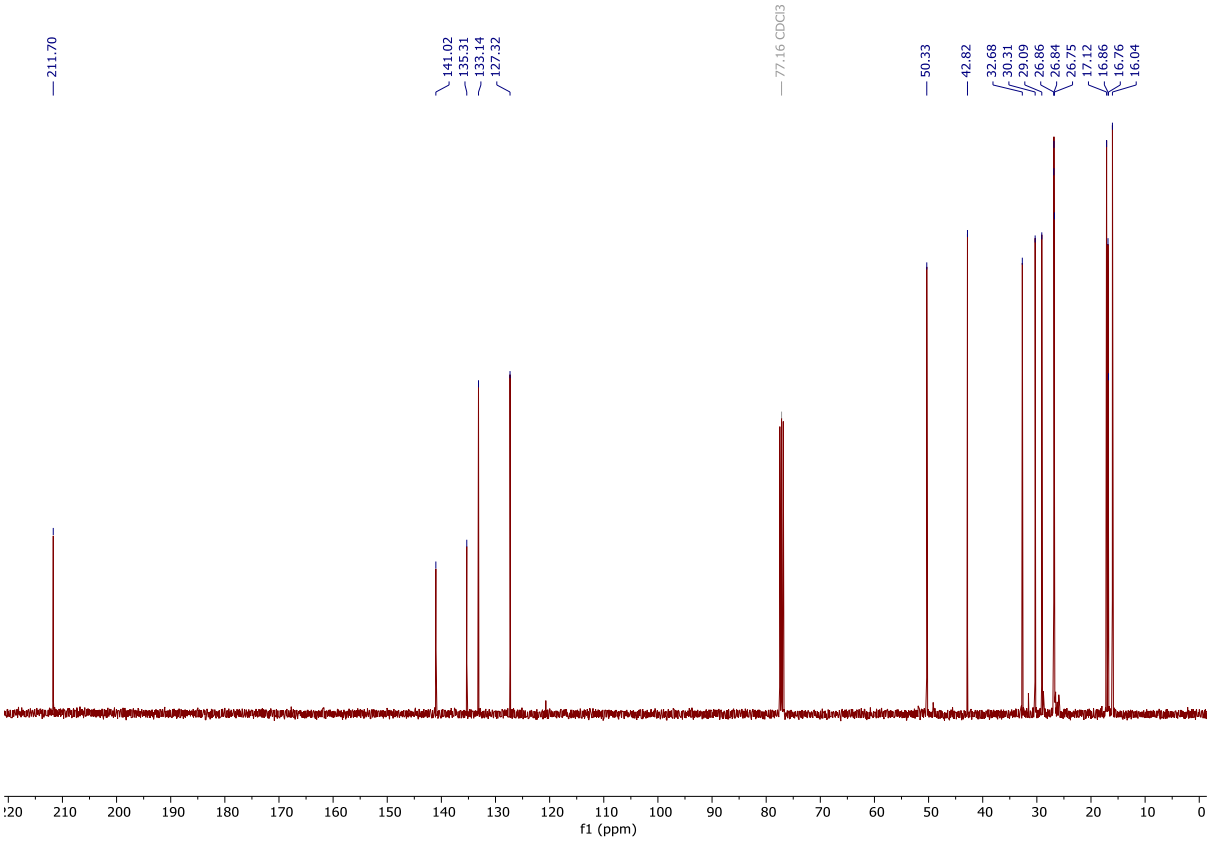
1.00
1.01
3.08
6.13
7.15
7.60
2.11
3.02
7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

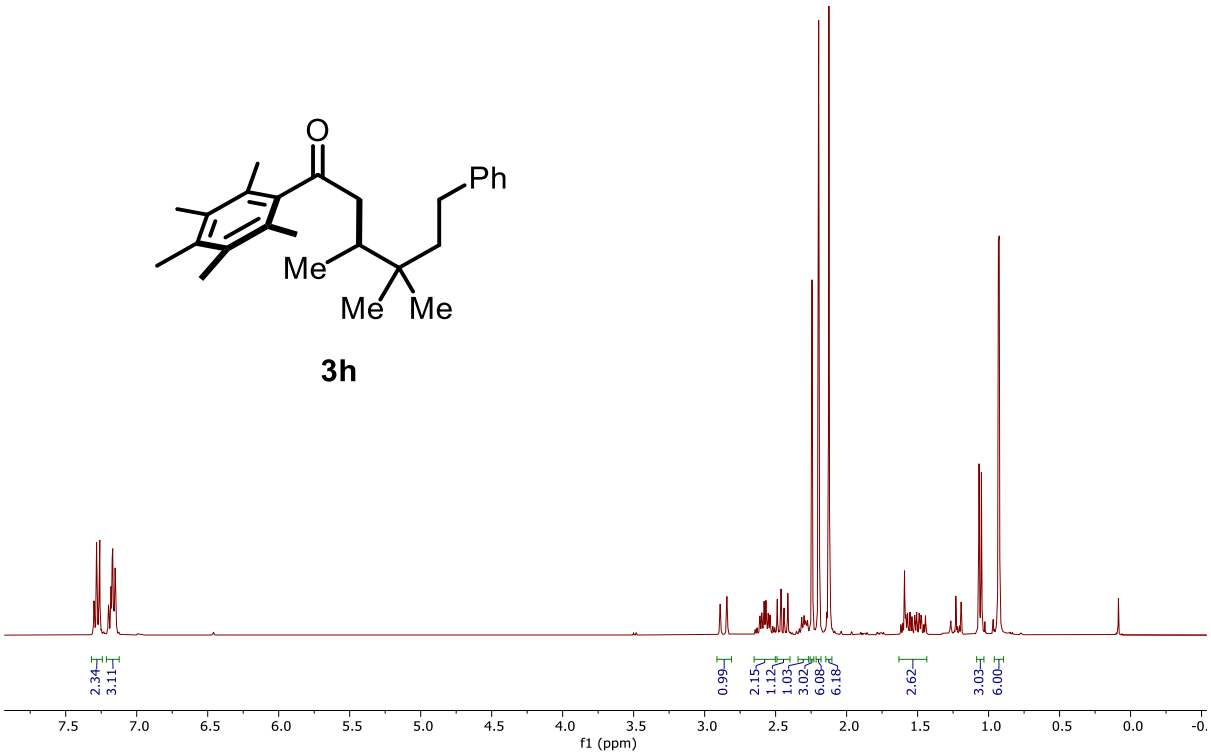

211.54
141.09
135.35
133.18
127.41
51.89
45.90
33.05
30.68
30.24
25.78
25.62
18.90
17.12
16.78
16.06
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


O
Me

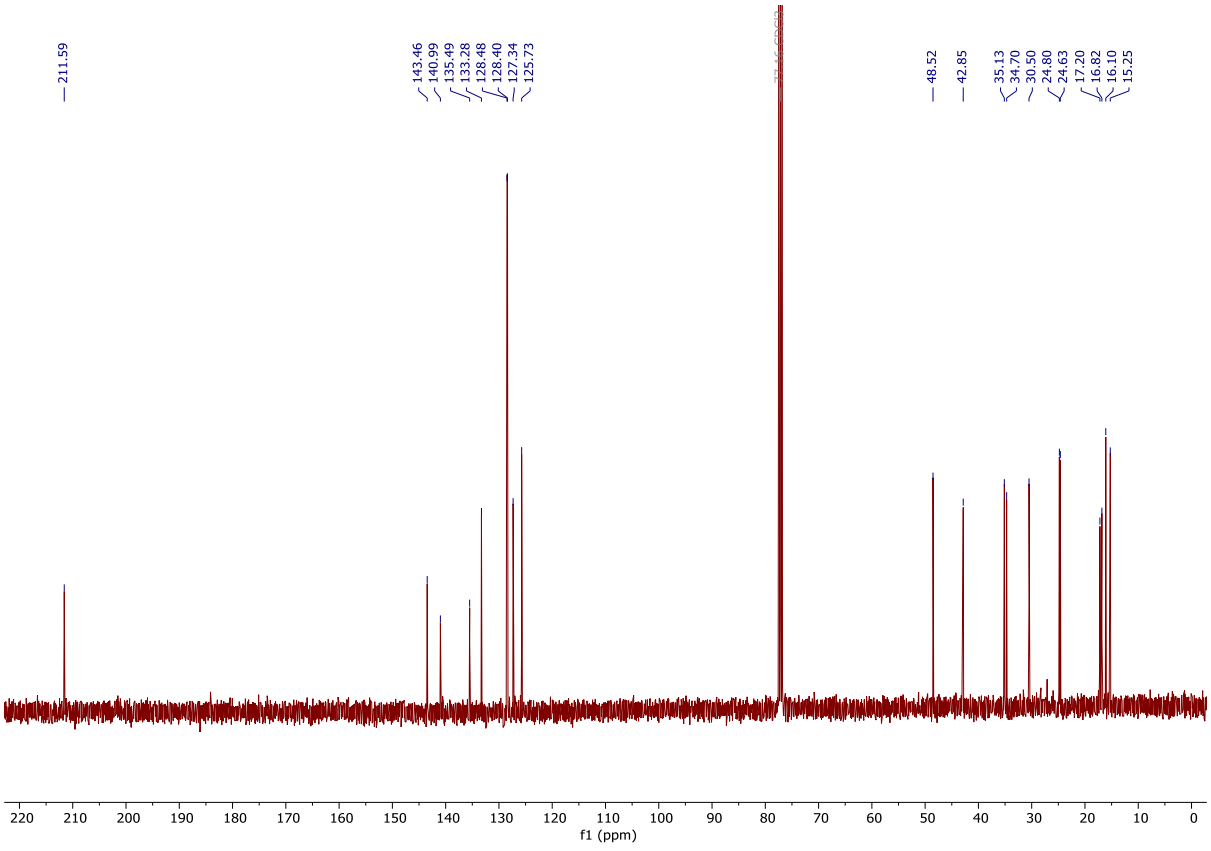
3g

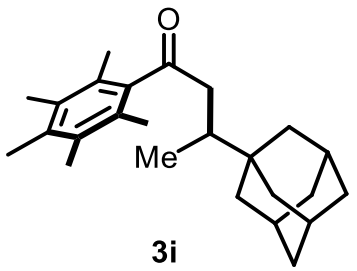
1.00
1.02
3.01
12.96
5.54
9.74
8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


211.70
141.02
135.31
133.14
127.32
77.16 CDCl3
50.33
42.82
32.68
30.31
29.09
26.86
26.84
26.75
17.12
16.86
16.76
16.04
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


O
Ph
Me
Me
Me
2.34
3.11
0.99
2.15
1.12
1.03
3.02
6.08
6.18
2.62
3.03
6.00
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)

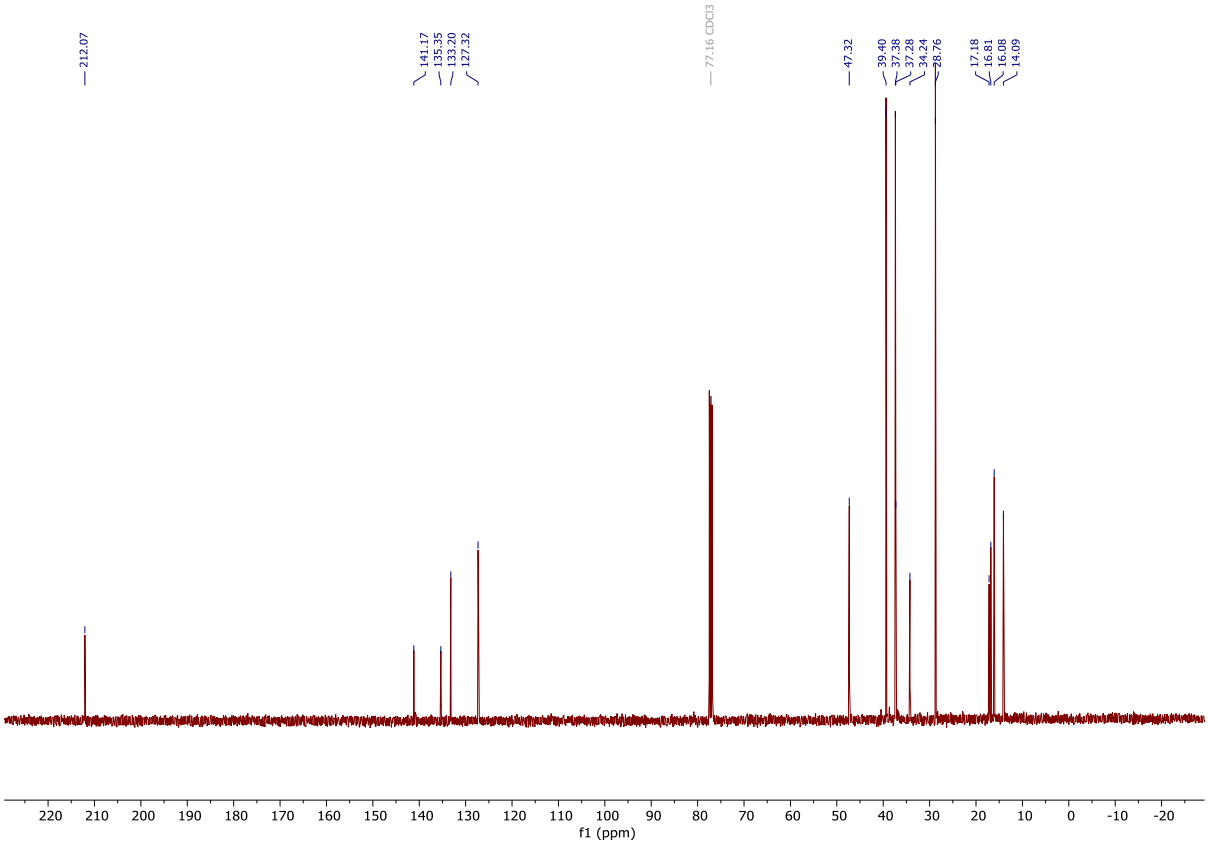
3h

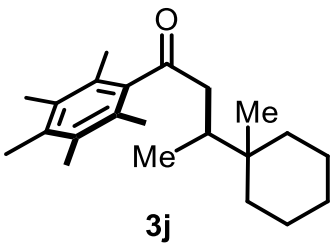

211.59
143.46
140.99
135.49
133.28
128.48
128.40
127.34
125.73
77.46
48.52
42.85
35.13
34.70
30.50
24.80
24.63
17.20
16.82
16.10
15.25
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


O
Me

3i

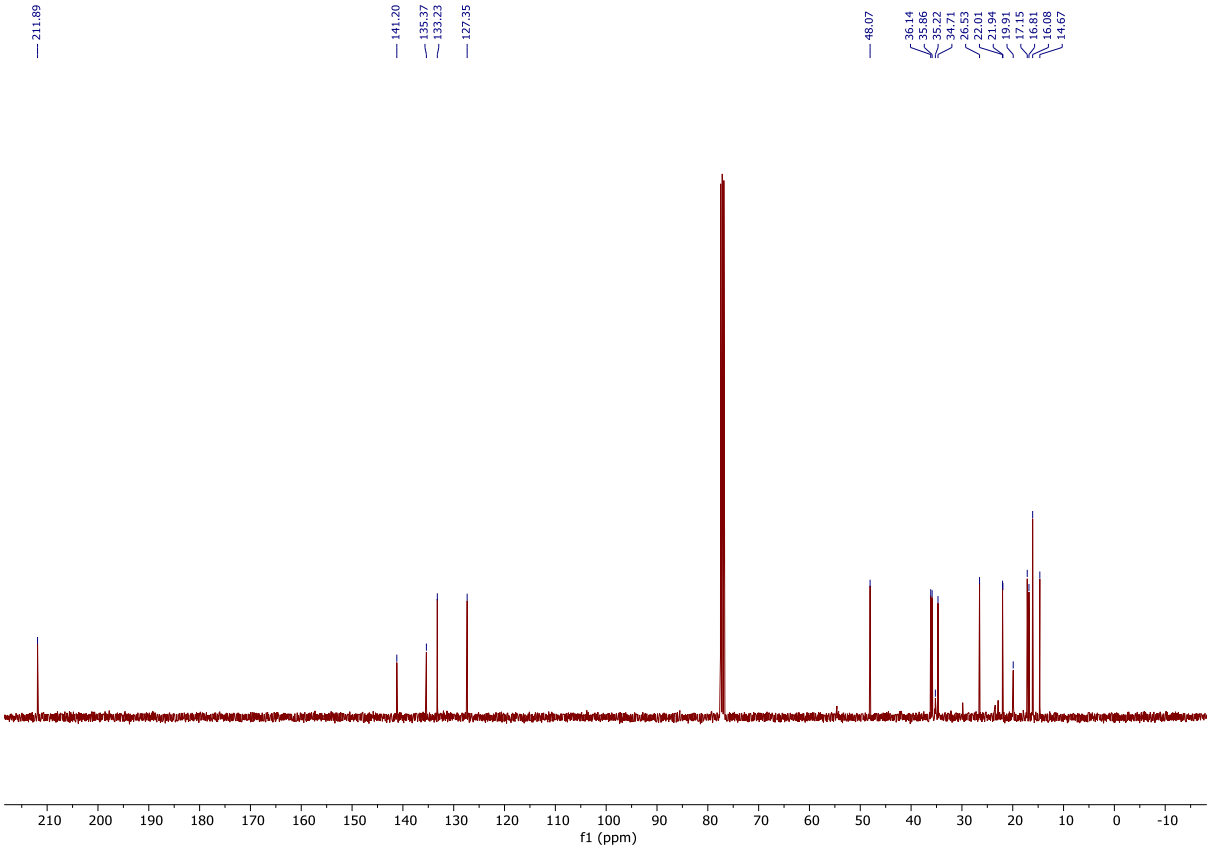
1.00
1.11
3.13
6.15
6.30
3.05
1.04
3.35
3.30
6.28
2.99
7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

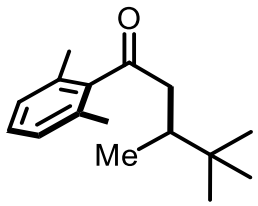

212.07
141.17
135.35
133.20
127.32
77.16 CDCl3
47.32
39.40
37.38
37.28
34.24
28.76
17.18
16.81
16.08
14.09
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20
f1 (ppm)


O
Me
Me

3j

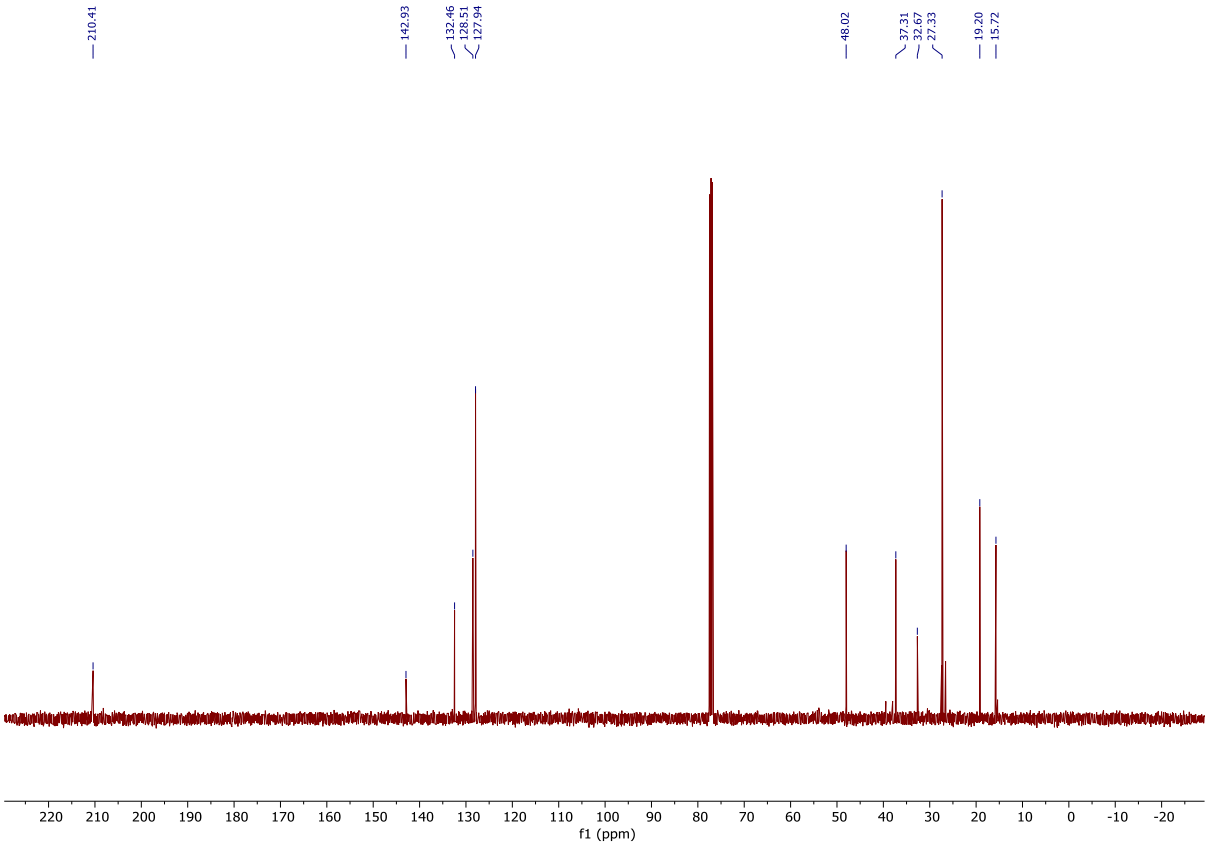
0.99
1.10
10.77
6.38
11.34
2.96
2.97
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

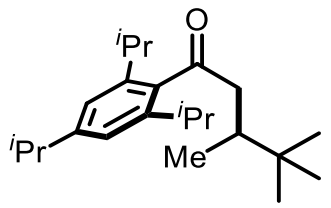

211.89
141.20
135.37
133.23
127.35
48.07
36.14
35.86
35.22
34.71
26.53
22.01
21.94
19.91
17.15
16.81
16.08
14.67
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)


O
Me

3k

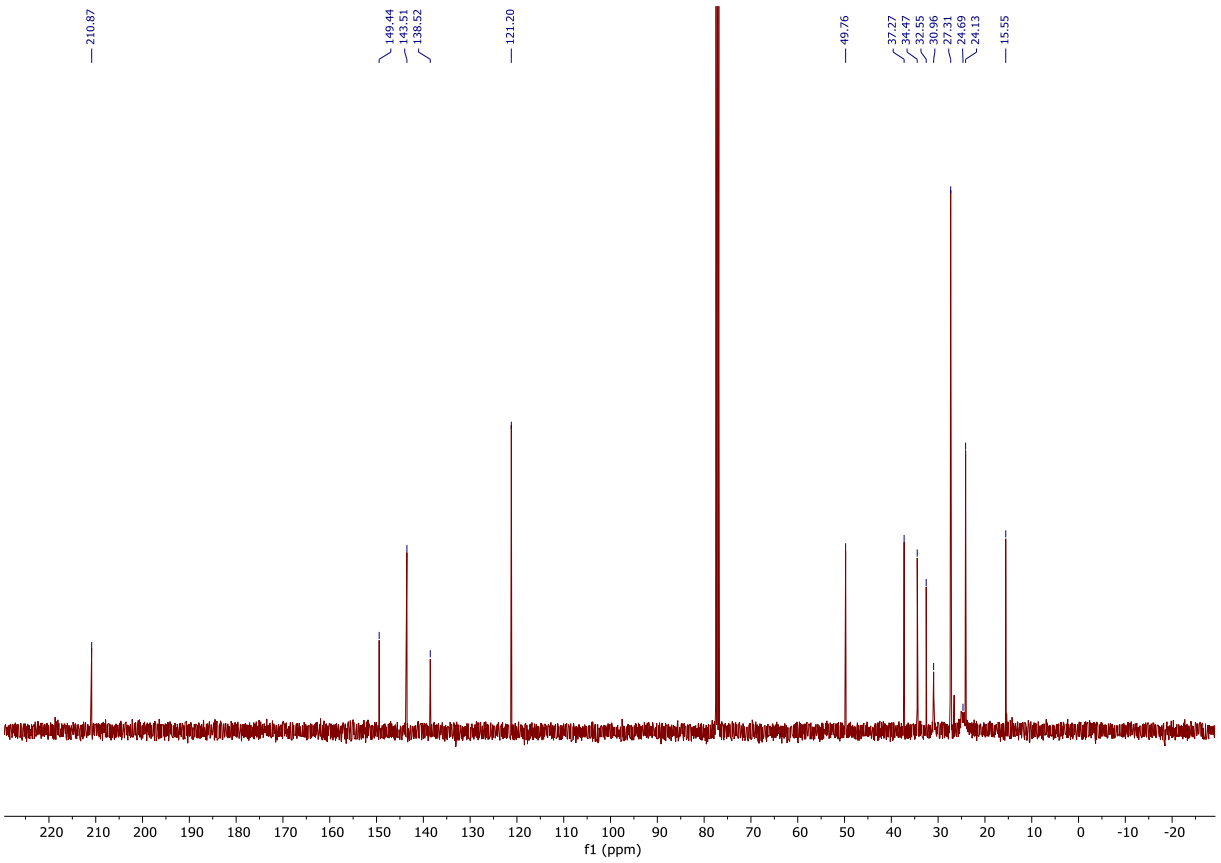
0.90
1.78
1.00
1.08
5.86
0.98
3.03
8.97
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

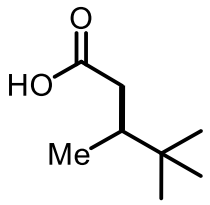

210.41
142.93
132.46
128.51
127.94
48.02
37.31
32.67
27.33
19.20
15.72
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
f1 (ppm)


O
iPr
iPr
iPr
Me

3l

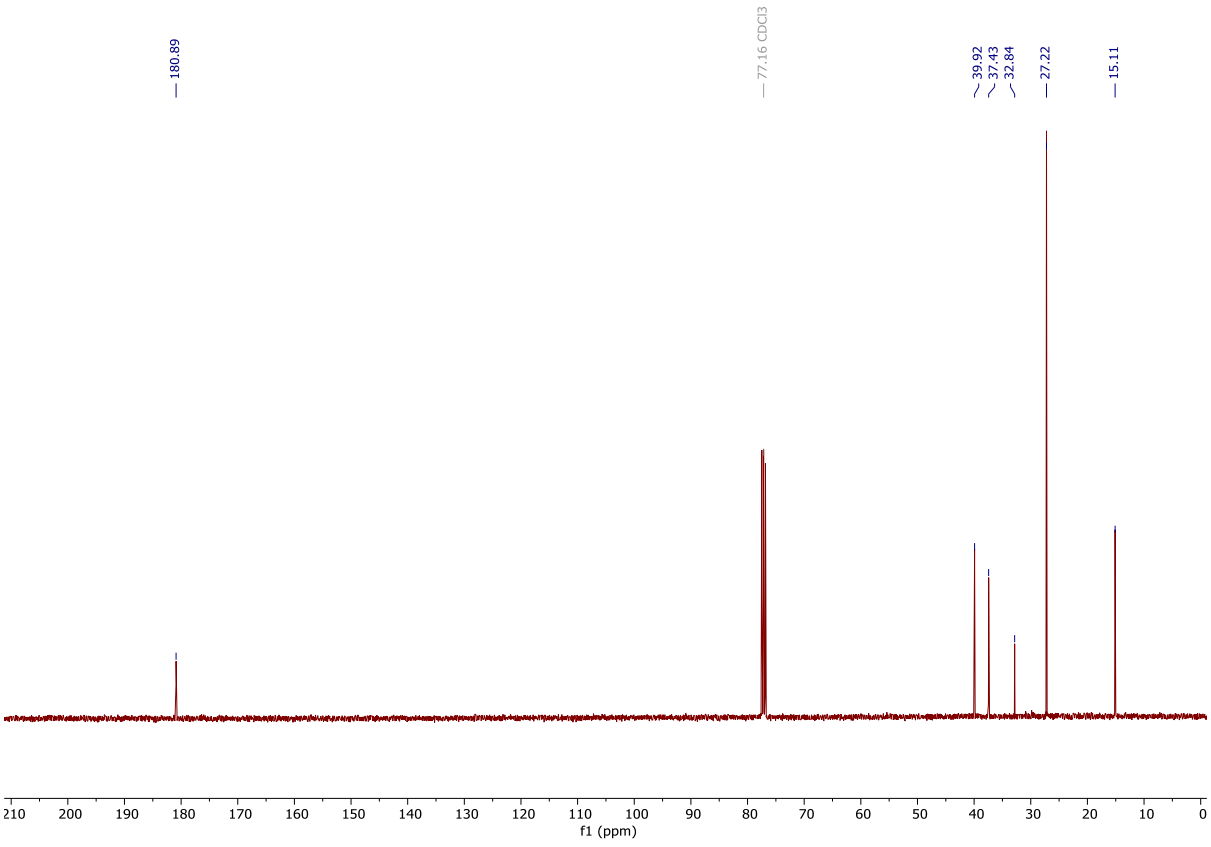
1.99
2.00
2.04
1.06
0.96
18.64
3.00
9.40
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

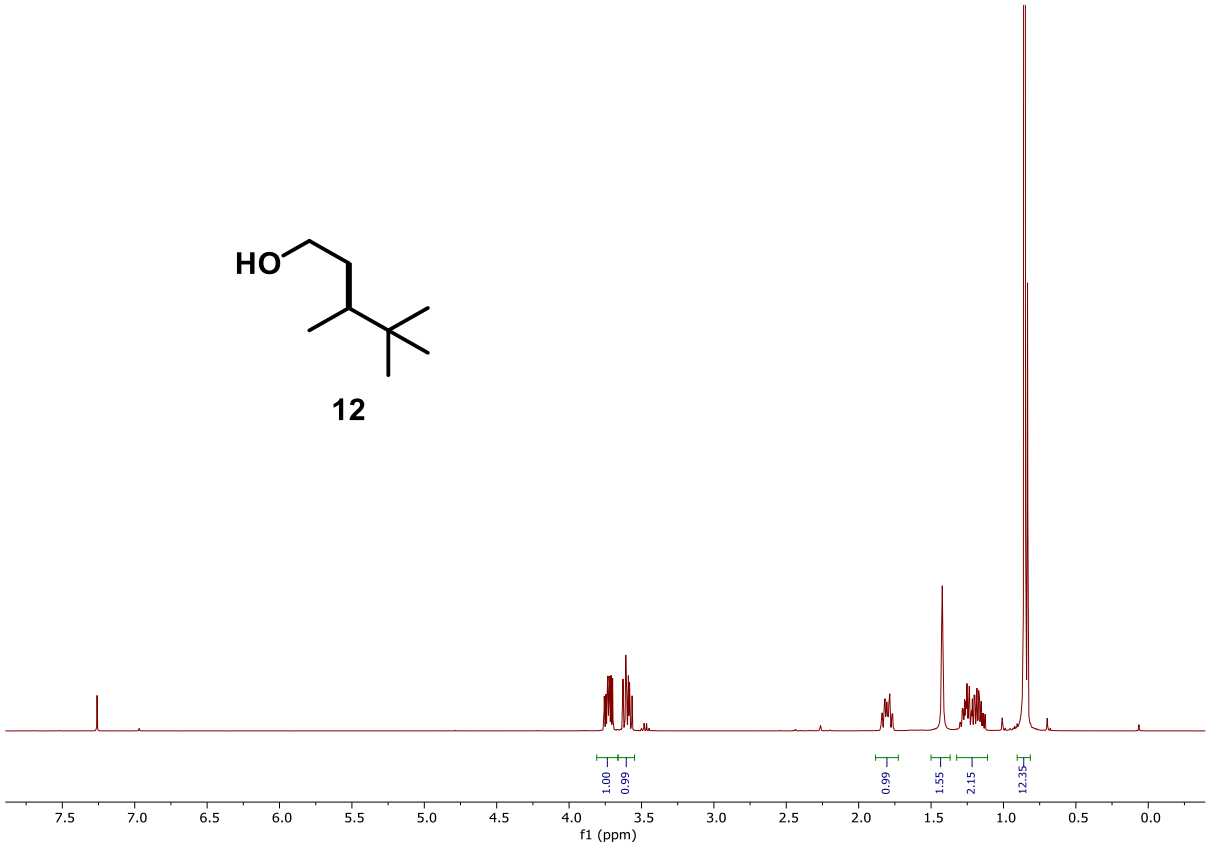

210.87
149.44
143.51
138.52
121.20
49.76
37.27
34.47
32.55
30.96
27.31
24.69
24.13
15.55
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
f1 (ppm)

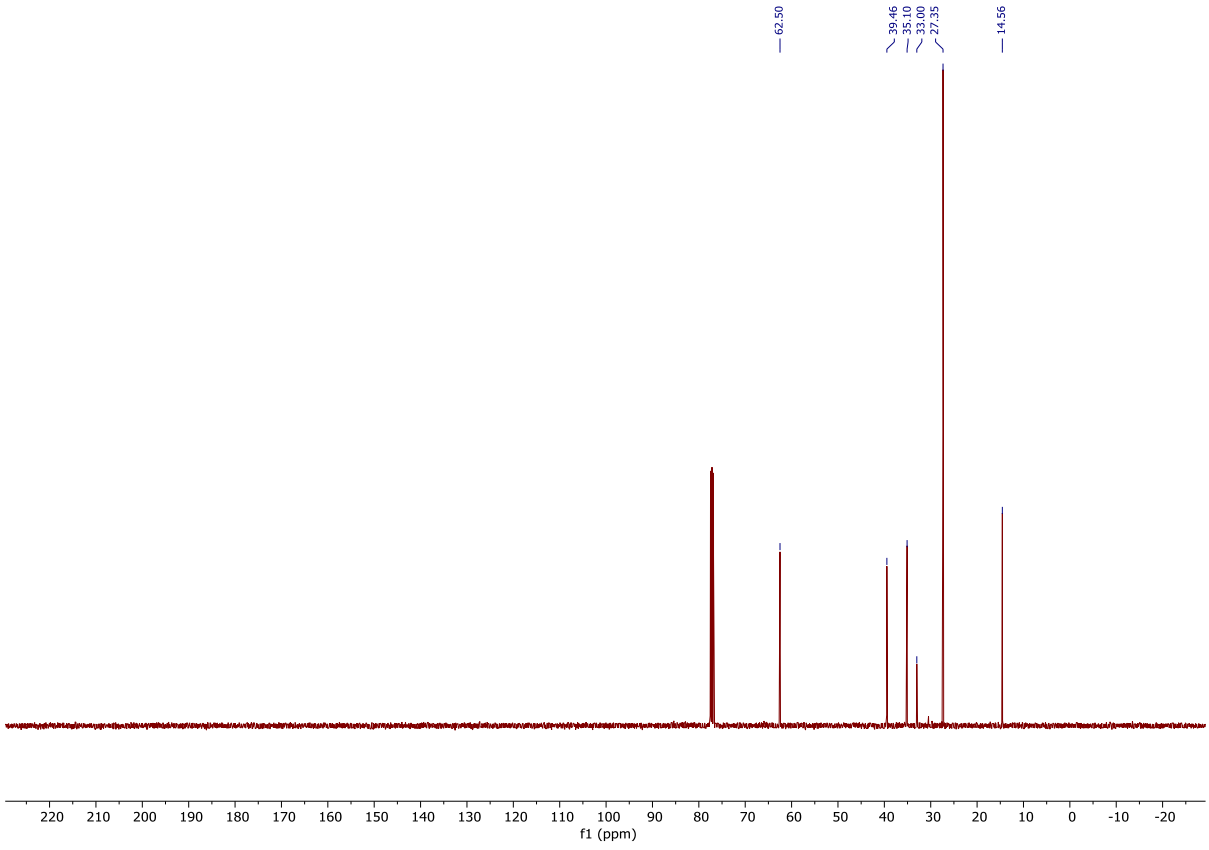

O
HO
Me

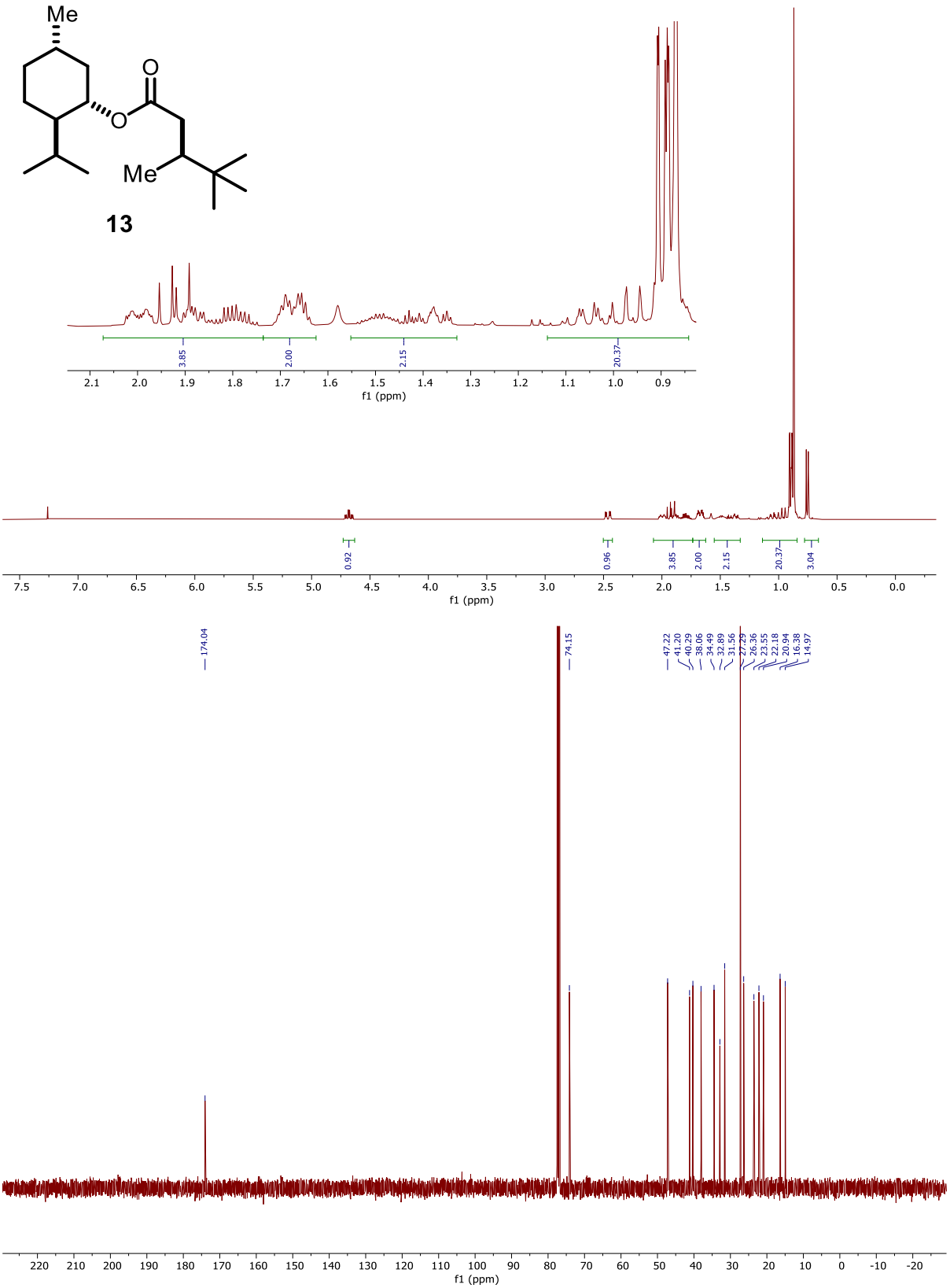
(S)-**11**

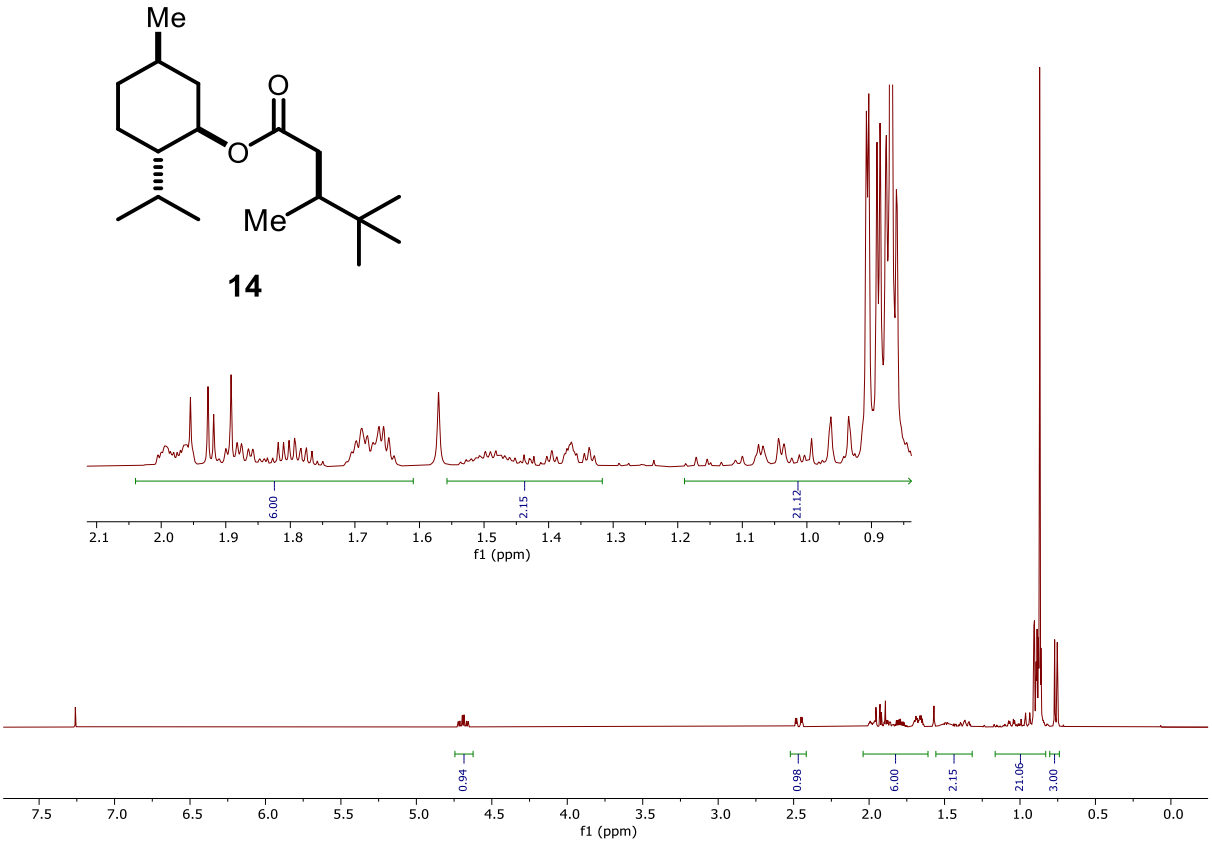
0.48
0.97
1.02
0.91
2.92
8.90
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
f1 (ppm)

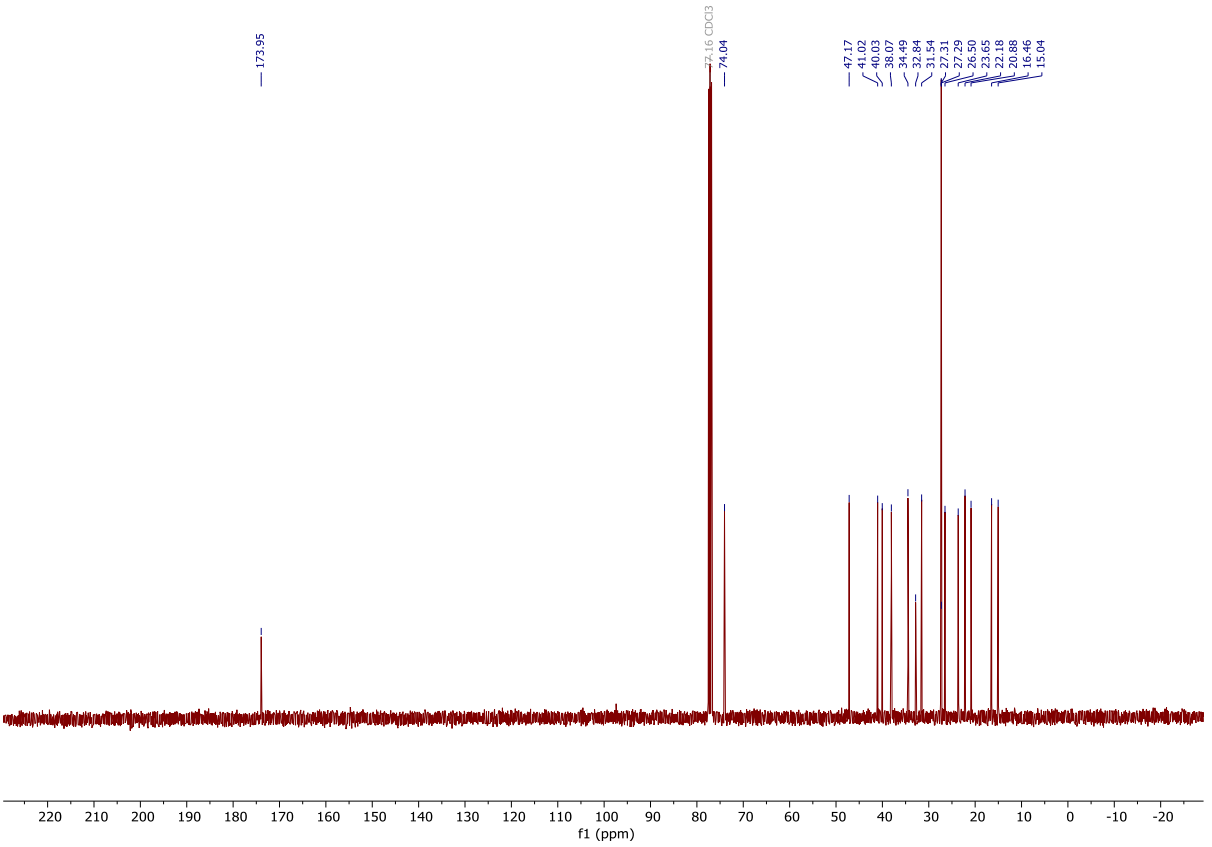

180.89
77.16 CDCl3
39.92
37.43
32.84
27.22
15.11
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

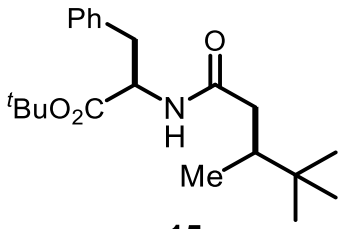

HO
12
1.00
0.99
0.99
1.55
2.15
12.35
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


62.50
39.46
35.10
33.00
27.35
14.56
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
f1 (ppm)


Me
O
O
Me
13
3.85
2.00
2.15
20.37
f1 (ppm)
0.92
0.96
3.85
2.00
2.15
20.37
3.04
f1 (ppm)
174.04
74.15
47.22
41.20
40.29
38.06
34.49
31.89
31.56
27.29
26.36
23.55
22.18
20.94
16.38
14.97
f1 (ppm)

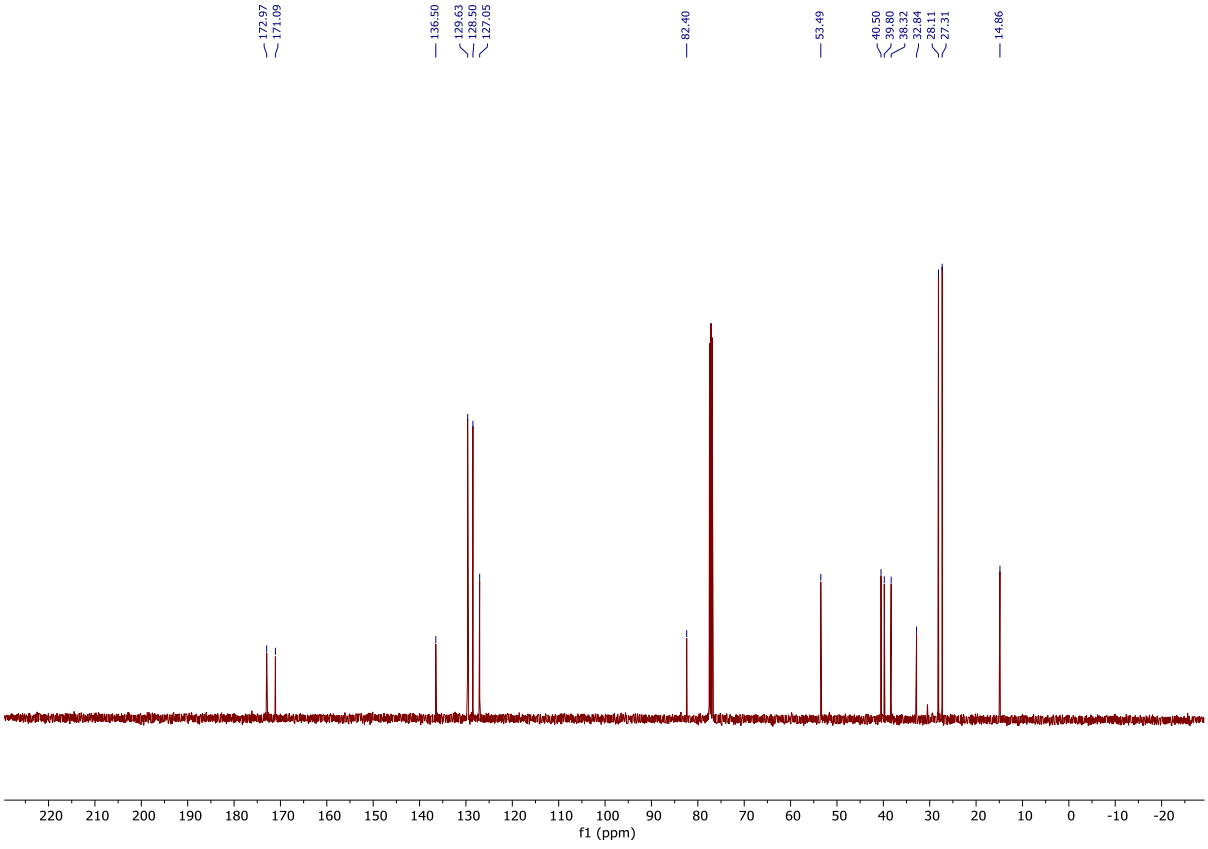

Me
O
O
Me
14
6.00
2.15
21.12
f1 (ppm)
0.94
0.98
6.00
2.15
21.06
3.00
f1 (ppm)

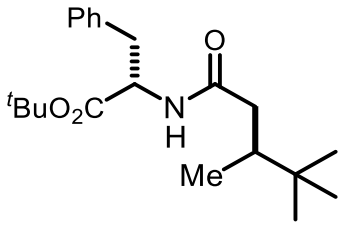

173.95
77.16 CDCl3
74.04
47.17
41.02
40.03
38.07
34.49
32.84
31.54
27.31
27.29
26.50
23.65
22.18
20.88
16.46
15.04
f1 (ppm)


Ph
O
tBuO2C
N
H
Me

15

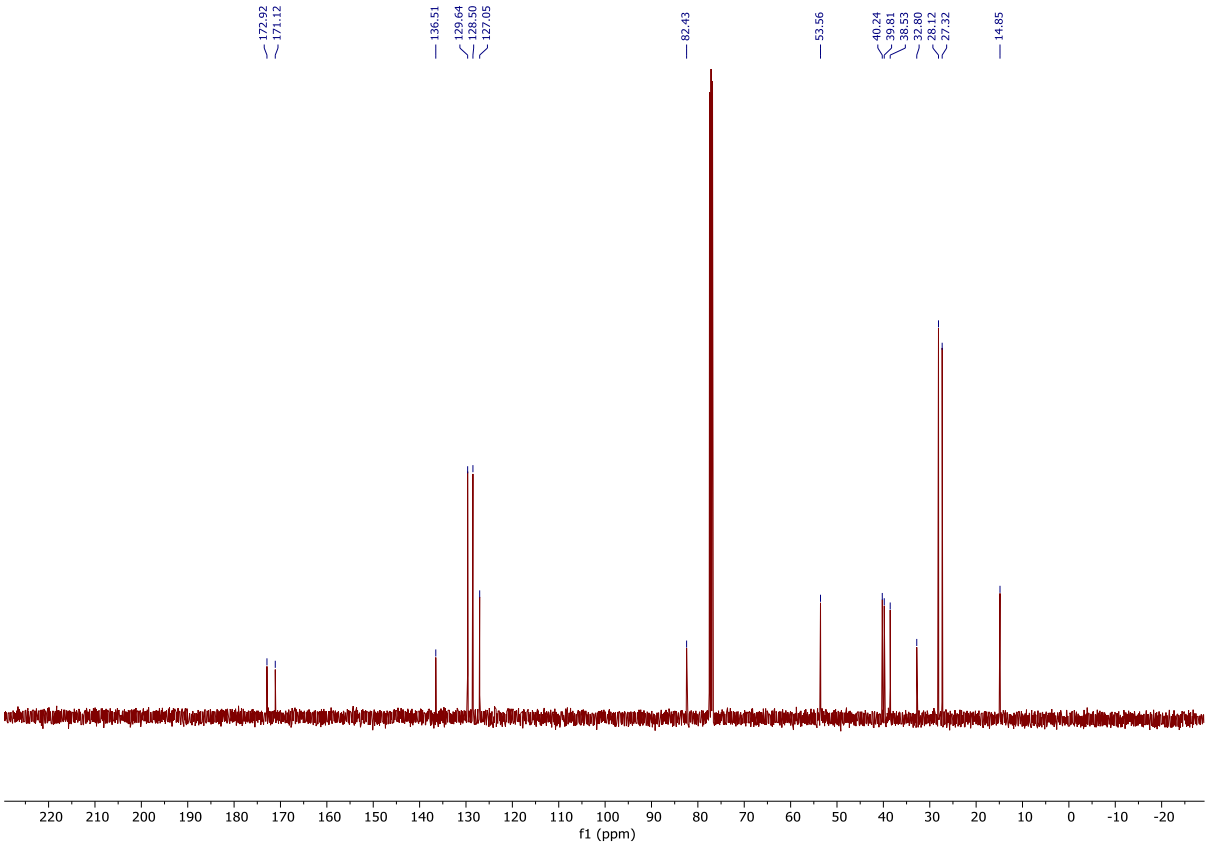
3.29
2.04
0.97
1.00
2.16
1.07
2.25
9.62
12.63
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

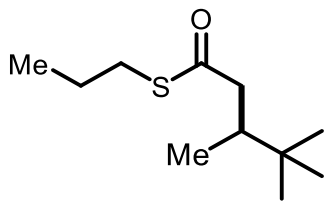

172.97
171.09
136.50
129.63
128.50
127.05
82.40
53.49
40.50
39.80
39.32
32.84
28.11
27.31
14.86
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
f1 (ppm)


Ph
O
^{t}BuO$_2$C
N
H
Me

16

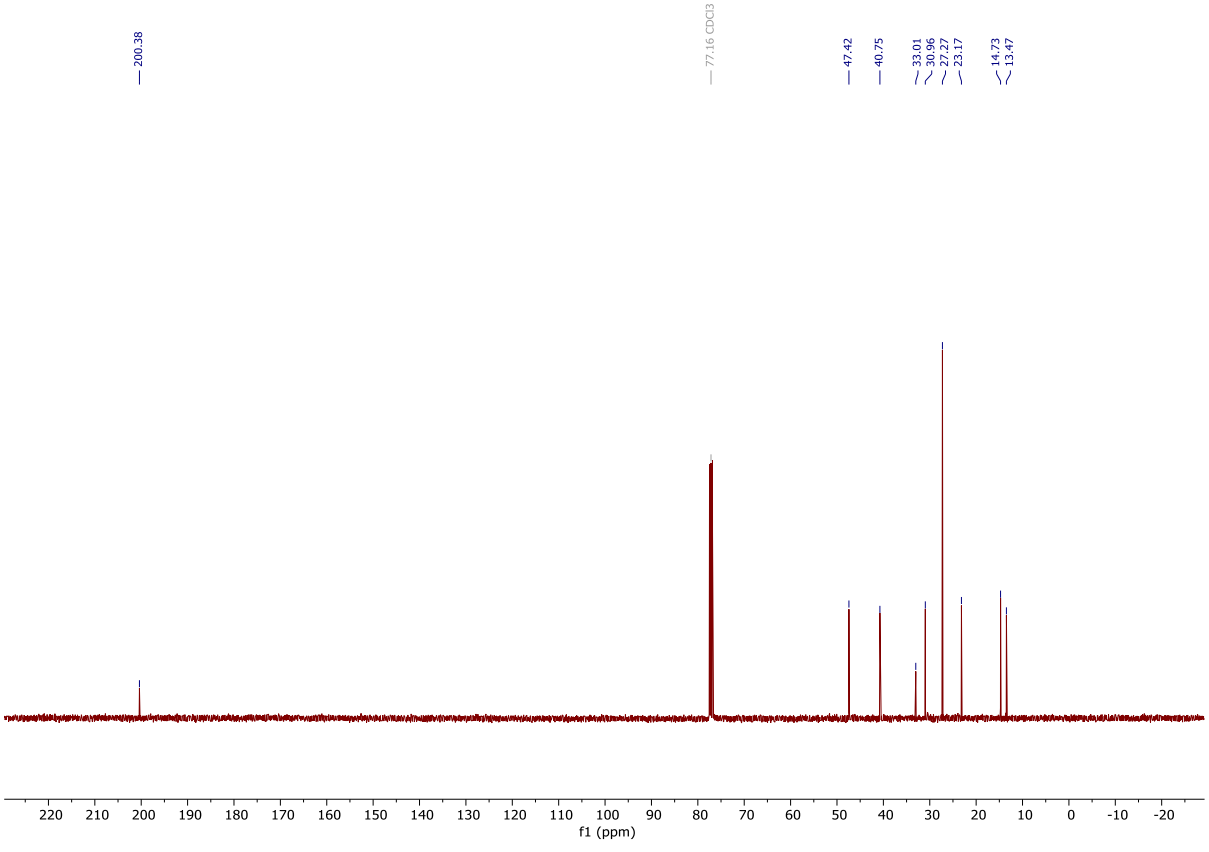
5.06
0.92
0.92
1.94
0.98
2.36
9.41
8.82
3.00
7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


172.92
171.12
136.51
129.64
128.50
127.05
82.43
53.56
40.24
39.81
38.53
32.80
29.12
27.32
14.85
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20
f1 (ppm)


Me
S
O
Me

17

1.83
1.00
1.02
0.88
2.24
2.95
12.12
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)


200.38
77.16 CDCl3
47.42
40.75
33.01
30.96
27.27
23.17
14.73
13.47
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20
f1 (ppm)