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Electronic Supplementary Information

Synergistic Gold and Enamine Catalysis: Intermolecular α-Alkylation of Aldehydes with Allenamides

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CONTENTS

General Procedures

Dry solvents were freshly distilled under argon from an appropriate drying agent before use. Gold complexes were prepared according to previously reported methods[1,2] or purchased from Aldrich. 3-(Propa-1,2-dien-1-yl)oxazolidin-2-one (**1a**),[3] 1-(propa-1,2-dien-1-yl)pyrrolidin-2-one (**1b**),[3] 4-methyl-*N*-phenyl-*N*-(propa-1,2-dien-1-yl)benzenesulfonamide (**1c**), [4] 4-methyl-*N*-bencyl-*N*-(propa-1,2-dien-1-yl)benzenesulfonamide (**1d**), [5] are known compounds and were synthesized according to the reported procedures. All other aldehydes used are known compounds[6] and were synthesized according to the reported procedures.[7] Chiral organocatalyst **C1**, **C2**, **C3, C4, C8, C 9** and **C10** were purchased from Aldrich. Organocatalyst **C5**,[8] **C6,**[8] **C7**,[9] **C11-12**,[10] **C13-15,**[11] and **C16**[12] are known compounds and were synthesized according to the reported procedures. All other reagents used were bought from Aldrich, Alfa Aesar, TCI or Acros and used without further purification.

Reactions were conducted in dry solvents under argon atmosphere unless otherwise stated. The abbreviation "rt" refers to reactions carried out approximately at 23 °C. Reaction mixtures were stirred using Teflon-coated magnetic stirring bars. Reaction temperatures were maintained using Thermowatch-controlled silicone oil baths. Thin-layer chromatography (TLC) was performed on silica gel plates and components were visualized by observation under UV light, and / or by treating the plates with *p*-anisaldehyde or cerium nitrate solutions, followed by heating. Flash chromatography was carried out on silica gel unless otherwise stated. Dryings were performed with anhydrous Na_2SO_4 or $MgSO_4$. Concentration refers to the removal of volatile solvents via distillation using a Büchi rotary evaporator followed by residual solvent removal under high vacuum. NMR spectra were recorded in $CDCl_3$, at 300 MHz (Varian) or 500 MHz (Varian). Carbon types and structure assignments were determined from DEPT-NMR. NMR spectra were analyzed using MestreNova© NMR data processing software (www.mestrelab.com). 1,3,5-Trimethoxybenzene was used as internal standard. The following abbreviations are used to indicate signal multiplicity: s, singlet; d, doublet; t, triplet; q, quartet; dd, double doublet; ddd, doublet of doublet of doublets; td, triple doublet; dt, doublet of triplets; dq, doublet of quartet; m, multiplet; br, broad. Mass spectra (ESI-MS) were acquired using IT-MS Bruker AmaZon SL at CIQUS and also using chemical ionization (CI) electron impact (EI), or electrospray ionization (ESI) at the CACTUS facility of the University of Santiago de Compostela. The reactions were monitored by TLC. Enantioselectivities were determined in an Agilent HPLC 1100 Series with Chiralpak IA, IB, IC, IA3 or OZ-H analytical columns.

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[1] C. H. M. Amijs, V. López-Carrillo, M. Raducan, P. Pérez-Galán, C. Ferrer and A. M. Echavarren, *J. Org. Chem.* 2008, **73**, 7721.

[2] P. de Frémont, N. Marion and S. P. Nolan, *J. Organomet. Chem.* 2009, **694**, 551.

[3] L. Wei, J. A. Mulder, C. A. Zificsak, C. J. Douglas and R. P. Hsung, *Tetrahedron*. 2001, **57**, 459.

[4] A. González-Gómez, G. Domínguez and J. Pérez-Castells, *Eur. J. Org. Chem.* 2009, 5057

[5] S. Suárez-Pantiga, C. Hernández-Díaz, M. Piedrafita, E. Rubio and J. M. González, *Adv. Synth. Catal.* 2012, **354**, 1651–1657.

[6] a) S. Hoffmann, M. Nicoletti and B. List, *J. Am. Chem. Soc.* 2006, **128**, 13074–5. b) P. Swamy, M. M. Reddy, M. Naresh, M. A. Kumar, K. Srujana, C. Durgaiah and N. Narender, *Adv. Synth. Catal.* 2015, **357**, 1125–1130. c) P. J. Deuss, M. Scott, F. Tran, N. J. Westwood, J. G. de Vries and K. Barta, *J. Am. Chem. Soc.* 2015, **137**, 7456–7467.

[7] D. S. Ermolat'ev, J. B. Bariwal, H. P. L. Steenackers, S. C. J. De Keersmaecker and E. V. Van der Eycken, *Angew. Chemie Int. Ed.* 2010, **49**, 9465–9468.

[8] Y. Hayashi, H. Gotoh, T. Hayashi and M. Shoji, *Angew. Chemie Int. Ed.* 2005, **44**, 4212–4215.

[9] A. Landa, A. Lizarraga, A. Mielgo, M. Oiarbide and C. Palomo, *Chem. Sci.* 2011, **2**, 353–357.

[10] C. Palomo, A. Landa, A. Mielgo, M. Oiarbide, S. Vera, *Angew. Chemie Int. Ed.* 2007, **46**, 8431–8435.

[11] D. Sánchez, D. Bastida, J. Burés, C. Isart, O. Pineda, J. Vilarrasa *Org. Lett*., 2009, **14**, 4635–4638.

[12] E. Gómez-Bengoa, J. Jiménez, I. Lapuerta, A. Mielgo, M.I Oiarbide, I. Otazo, I. Velilla, S. Vera, C. Palomo, *Chem. Sci.* 2013, **3**, 2949-2957.

General procedure for the alkylation of aldehydes with allenamides

Method A (racemic protocol):

To a solution of $Ph_3PAuNTf_2$ (2:1) toluene adduct (12,55 mg, 0.008 mmol), 2,2'-bipyridine (4.99 mg, 0.032 mmol) and benzoic acid (3.90 mg, 0.032 mmol) in Toluene (0.5 ml) in a dried Schlenk tube, was sequentially added a solution of the corresponding aldehyde **2** (0.320 mmol) and pyrrolidine (3.97 µl, 0.048 mmol) in Toluene (0.5 ml) and another of the corresponding allenamide **1** (0.160 mmol) in Toluene (0.5 ml; dropwise addition). The mixture was stirred under Argon atmospher at 60 ºC until the allenamide was consumed (the progress of the reaction was easily monitored by *tlc*) and filtered through a short pad of florisil, eluting with EtOAc. The solvent was removed and the crude residue was dissolved in 0.6 ml of a 1,3,5-trimethoxybenzene 0.0887 M solution in $CDCl_3$ for ^{1}H-NMR analysis. The crude mixture was then purified on column chromatography (hexanes/EtOAc 10-40%). All the reported yields are isolated yields.

Method A´ (racemic protocol followed by in situ reduction with $NaBH_4$):

Same conditions than Method A but once the allenamide was consumed (the progress of the reaction was easily monitored by *tlc*) the reaction was quenched by the addition of a solution of $NaBH_4$ (24.21 mg, 0.640 mmol) in MeOH (2 mL), stirred for 30 minutes and filtered through a short pad of florisil, eluting with EtOAc. The solvent was removed and the crude residue was dissolved in 0.6 ml of a 1,3,5-trimethoxybenzene 0.0887 M solution in $CDCl_3$ for ^{1}H-NMR analysis. The crude mixture was purified on column chromatography (hexanes / EtOAc 40-80% and 10% DCM). All the reported yields are isolated yields.

Method B (asymmetric protocol):

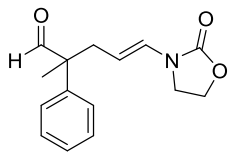
To a solution of $IPrAuNTf_2$ (13.84 mg, 0.016 mmol), 2,2'-bipyridine (4.99 mg, 0.032 mmol) and benzoic acid (3.90 mg, 0.032 mmol) in Toluene (0.5 ml) in a dried Schlenk tube, was sequentially added a solution of the corresponding aldehyde **2** (0.320 mmol) and chiral organocatalyst (0.032 mmol) in Toluene (0.5 ml) and another solution of the corresponding allenamide **1** (0.160 mmol) in Toluene (0.5 ml; dropwise adition). The mixture was stirred under Argon atmospher at 60 ºC until all the allenamide was consumed (the progress of the reaction was easily monitored by *tlc*) and filtered through a short pad of florisil, eluting with EtOAc. The solvent was removed and the crude residue was dissolved in 0.6 ml of a 1,3,5-trimethoxybenzene 0.0887 M solution in $CDCl_3$ for ^{1}H-NMR analysis. The crude mixture was then purified on column chromatography (hexanes/EtOAc 10-40%). All the reported yields are isolated yields.

Method B´(asymmetric protocol followed by in situ reduction with $NaBH_4$):

Same conditions than Method B but once the allenamide was consumed (the progress of the reaction was easily monitored by *tlc*) the reaction was quenched with the addition of a solution of $NaBH_4$ (24.21 mg, 0.640 mmol) in MeOH (2 mL), stirred for 30 minutes and filtered through a short pad of florisil, eluting with EtOAc. The solvent was removed and the crude residue was dissolved in 0.6 ml of a 1,3,5-trimethoxybenzene 0.0887 M solution in $CDCl_3$ for ^{1}H-NMR analysis. The crude mixture was purified on column chromatography (hexanes/EtOAc 40-80% and 10% DCM). All the reported yields are isolated yields.

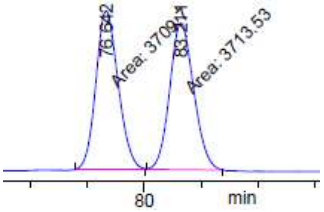
Characterization data

(E)-2-Methyl-5-(2-oxooxazolidin-3-yl)-2-phenylpent-4-enal (3aa)



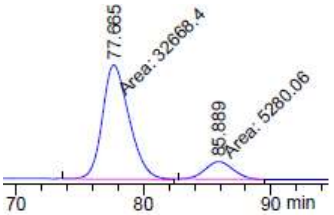
Method A: 83% yield. **Method B:** 66% yield (72% ee). **^{1}H NMR** (300 MHz, $CDCl_3$) δ 9.51 (s, 1H), 7.46 – 7.20 (m, 5H), 6.64 (d, *J* = 14.3 Hz, 1H), 4.50 (dt, *J* = 14.3, 7.6 Hz, 1H), 4.42 – 4.30 (m, 2H), 3.63 – 3.47 (m, 2H), 2.64 (d, *J* = 7.6 Hz, 1H), 1.43 (s, 3H). **^{13}C NMR** (75 MHz, $CDCl_3$) δ 201.97 (CH), 155.33 (C), 139.37 (C), 129.03 (CH), 127.55 (CH), 127.12 (CH), 126.67 (CH), 105.19 (CH), 62.18 (CH_2), 54.13 (C), 42.58 (CH_2), 36.99 (CH_2), 18.90 (CH_3). **LRMS** (m/z, ESI): 282.11 $(M+Na)^+$, 258.11, 201.04, 126.05. **HRMS** Calculated for $C_{15}H_{17}NNaO_3$: 282.1101, found 282.1103. **HPLC** Enantioselectivity was determined by chiral HPLC analysis on Chiralpak OZ-H at rt, (Hexane : iPrOH = 90:10, 1 ml/min).

Racemic sample:



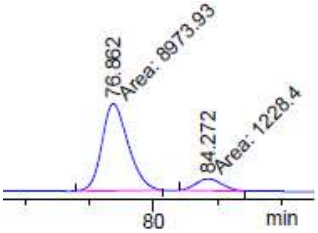
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	76.642	MM	2.2606	3709.70435	27.35040	49.9742
2	83.211	MM	2.4434	3713.52856	25.33021	50.0258

Table 3, entry 5; ee = 72%:



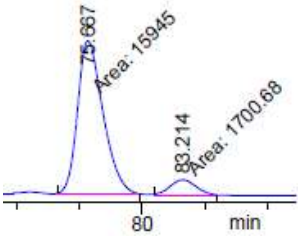
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	77.665	MM	2.4446	3.26684e4	222.72377	86.0862
2	85.889	MM	2.5720	5280.05957	34.21497	13.9138

Table 3, entry 6; ee = 75%:



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	76.862	MM	2.3916	8973.92969	62.53777	87.9596
2	84.272	MM	2.3898	1228.39978	8.56696	12.0404

Table 3, entry 7; ee = 81%:



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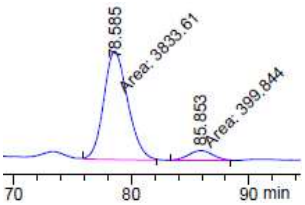
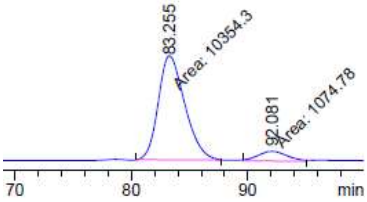
1	75.667	MM	2.3665	1.59450e4	112.29541	90.3621
2	83.214	MM	2.4663	1700.67651	11.49292	9.6379

Table 3, entry 8; ee = 81%:



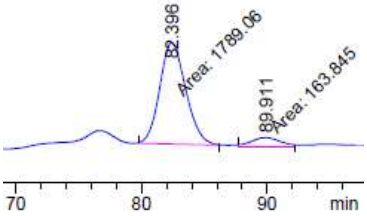
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	78.585	MM	2.3639	3833.61157	27.02897	90.5551
2	85.853	MM	2.5659	399.84354	2.59717	9.4449

Table 3, entry 9: ee = 81% :



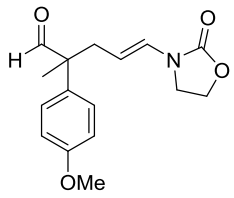
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	83.255	MM	2.6416	1.03543e4	65.32811	90.5961
2	92.081	MM	2.9054	1074.77539	6.16533	9.4039

Table 3, entry 10; ee = 83%:



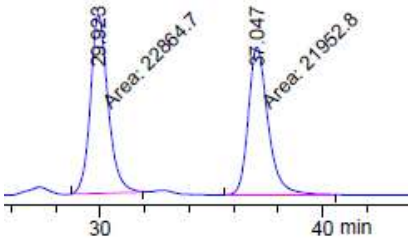
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	82.396	MM	2.3961	1789.06104	12.44428	91.6102
2	89.911	MM	2.5801	163.84546	1.05840	8.3898

(E)-2-(4-Methoxyphenyl)-2-methyl-5-(2-oxooxazolidin-3-yl)pent-4-enal (3ab)



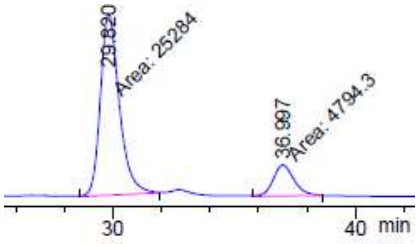
Method A: 75% yield. **Method B:** 40% yield (68% ee). **^{1}H NMR** (300 MHz, $CDCl_3$) δ 9.46 (s, 1H), 7.15 (d, *J* = 8.9 Hz, 2H), 6.91 (d, *J* = 8.9 Hz, 2H), 6.65 (d, *J* = 14.3 Hz, 1H), 4.59 – 4.42 (m, 1H), 4.45 – 4.29 (m, 2H), 3.81 (s, 3H), 3.64 – 3.50 (m, 2H), 2.62 (d, *J* = 6.7 Hz, 2H), 1.41 (s, 3H). **^{13}C NMR** (75 MHz, $CDCl_3$) δ 201.93 (CH), 159.01 (C), 155.39 (C), 131.15 (C), 128.35 (CH), 126.66 (CH), 114.50 (CH), 105.44 (CH), 62.21 (CH_2), 55.42 (CH_3), 53.48 (C), 42.67 (CH_2), 37.03 (CH_2), 19.02 (CH_3). **LRMS** (m/z, ESI): 312.12 $(M+Na)^+$, 185.09, 175.10, 159.08, 144.05, 126.05. **HRMS** Calculated for $C_{16}H_{19}NNaO_4$: 312.1206, found 312.1210. **HPLC** Enantioselectivity was determined by chiral HPLC analysis on Chiralpak IA at rt, (Hexane : iPrOH = 80:20, 1 ml/min).

Racemic sample:



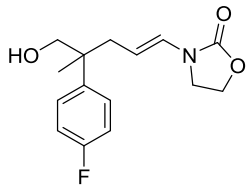
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	29.923	MM	0.9165	2.28647e4	415.78238	51.0174
2	37.047	MM	1.0549	2.19528e4	346.83911	48.9826

Table 3, entry 11; ee = 68%:



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	29.820	MM	0.9028	2.52840e4	466.77127	84.0606
2	36.997	MM	0.9983	4794.30225	80.03907	15.9394

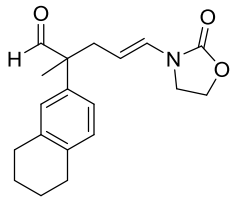
(E)-3-(4-(4-Fluorophenyl)-5-hydroxy-4-methylpent-1-en-1-yl)oxazolidin-2-one (3ac´)



Method A´: 40% yield. **^{1}H NMR** (300 MHz, $CDCl_3$) δ 7.37 – 7.27 (m, 2H), 7.03 (t, *J* = 8.8 Hz, 2H), 6.65 (d, *J* = 14.3 Hz, 1H), 4.48 (ddd, *J* = 14.3, 8.1, 6.9 Hz, 1H), 4.42 – 4.30 (m, 2H), 3.72 (d, *J* = 10.9 Hz, 1H), 3.63 – 3.47 (m, 3H), 2.61 – 2.47 (m, 1H), 2.34 (ddd, *J* = 14.1, 8.2, 1.1 Hz, 1H), 1.59 (br, 1H), 1.31 (s, 3H). **^{13}C NMR** (75 MHz, $CDCl_3$) δ 161.49 (d, *J* = 245.6 Hz, C), 155.43 (C), 140.25

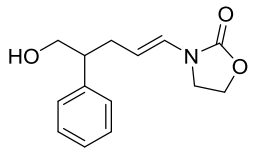
(C), 128.39 (d, *J* = 7.8 Hz, CH), 126.20 (CH), 115.39 (d, *J* = 20.8 Hz, CH), 106.12 (CH), 71.69 (CH_2), 62.19 (CH_2), 43.34 (C), 42.69 (CH_2), 39.16 (CH_2), 22.17 (CH_3). **LRMS** (m/z, ESI): 302.11 $(M+Na)^+$. 193.10, 175.09, 149.08. **HRMS** Calculated for $C_{15}H_{18}FNNaO_3$: 302.1163, found 302.1169.

(E)-2-Methyl-5-(2-oxooxazolidin-3-yl)-2-(5,6,7,8-tetrahydronaphthalen-2-yl)pent-4-enal (3ad)



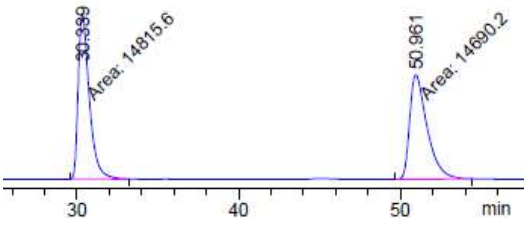
Method A: 47% yield. **^{1}H NMR** (300 MHz, $CDCl_3$) δ 9.47 (s, 1H), 7.08 (d, *J* = 8.0 Hz, 1H), 6.95 (dd, *J* = 8.0, 2.1 Hz, 1H), 6.90 (s, 1H), 6.66 (d, *J* = 14.3 Hz, 1H), 4.56 (dt, *J* = 14.3, 7.6 Hz, 1H), 4.44 – 4.32 (m, 2H), 3.66 – 3.49 (m, 2H), 2.80 – 2.70 (m, 4H), 2.63 (ddd, *J* = 7.3, 6.0, 1.2 Hz, 2H), 1.85 – 1.74 (m, 4H), 1.40 (s, 3H). **^{13}C NMR** (75 MHz, $CDCl_3$) δ 202.13 (CH), 155.39 (C), 137.89 (C), 136.67 (C), 136.40 (C), 129.83 (CH), 127.87 (CH), 126.60 (CH), 124.17 (CH), 105.62 (CH), 62.22 (CH_2), 53.78 (CH), 42.71 (CH_2), 36.92 (CH_2), 30.46 (C), 29.70 (CH_2), 29.09 (CH_2), 23.22 (CH_2), 18.99 (CH_3). **LRMS** (m/z, ESI): 336.15 $(M+Na)^+$, 209.13, 199.12, 149.05, 141.07. **HRMS** Calculated for $C_{19}H_{23}NNaO_3$: 336.1570, found 336.1575.

(E)-3-(5-Hydroxy-4-phenylpent-1-en-1-yl)oxazolidin-2-one (3ae´)



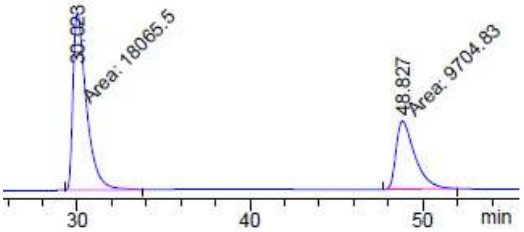
Method A´: 98% yield. **Method B´:** 99% yield (30% ee). **^{1}H NMR** (300 MHz, $CDCl_3$) δ 7.36 – 7.16 (m, 5H), 6.64 (d, *J* = 14.3 Hz, 1H), 4.66 (dt, *J* = 14.8, 7.4 Hz, 1H), 4.36 (t, *J* = 8.3 Hz, 2H), 3.86 – 3.67 (m, 2H), 3.56 (t, *J* = 8.7 Hz, 2H), 2.83 (dt, *J* = 13.2, 6.8 Hz, 1H), 2.51 (ddd, *J* = 14.3, 7.8, 6.5 Hz, 1H), 2.47 – 2.30 (m, 1H), 1.58 (br s, 1H). **^{13}C NMR** (75 MHz, $CDCl_3$) δ 155.47 (C), 141.72 (C), 128.81 (CH), 128.09 (CH), 127.01 (CH), 125.24 (CH), 108.57 (CH), 66.83 (CH_2), 62.21 (CH_2), 49.24 (CH), 42.64 (CH_2), 32.70 (CH_2). **LRMS** (m/z, ESI): 270.10 $(M+Na)^+$, 236.14, 230.11, 143.08. **HRMS** Calculated for $C_{14}H_{17}NNaO_3$: 270.1101, found 270.1100. **HPLC** Enantioselectivity was determined by chiral HPLC analysis on Chiralpak IA3 at rt, (Hexane : iPrOH = 85:15, 1 ml/min).

Racemic sample:



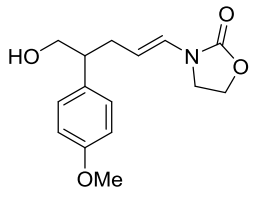
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	30.339	MM	0.7974	1.48156e4	309.66888	50.2126
2	50.961	MM	1.2468	1.46902e4	196.36877	49.7874

Table 3, entry 14; ee = 30%:



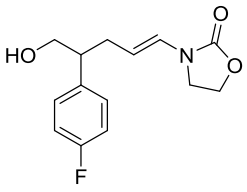
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	30.023	MM	0.8983	1.80655e4	335.16611	65.0532
2	48.827	MM	1.2547	9704.83496	128.91800	34.9468

(E)-3-(5-Hydroxy-4-(4-methoxyphenyl)pent-1-en-1-yl)oxazolidin-2-one (3af´)



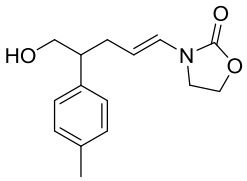
Method A´: 99% yield. **^{1}H NMR** (300 MHz, $CDCl_3$) δ 7.11 (d, *J* = 8.6 Hz, 2H), 6.87 (d, *J* = 8.8 Hz, 2H), 6.64 (d, *J* = 14.3 Hz, 1H), 4.65 (dt, *J* = 14.4, 7.4 Hz, 1H), 4.37 (t, *J* = 8.2 Hz, 2H), 3.79 (s, 3H), 3.81 – 3.63 (m, 2H), 3.64 – 3.41 (m, 2H), 2.79 (p, *J* = 6.8 Hz, 1H), 2.56 – 2.39 (m, 1H), 2.43 – 2.26 (m, 1H), 1.45 (br s, 1H). **^{13}C NMR** (75 MHz, $CDCl_3$) δ 158.64 (C), 155.45 (C), 133.52 (C), 129.03 (CH), 125.23 (CH), 114.29 (CH), 108.63 (CH), 67.05 (CH_2), 62.19 (CH_2), 55.38 (CH_3), 48.45 (CH), 42.67 (CH_2), 32.88 (CH_2). **LRMS** (m/z, ESI): 300.12 $(M+Na)^+$, 173.09, 158.08, 147.08, 121.06. **HRMS** Calculated for $C_{15}H_{19}NNaO_4$: 300.1206, found 300.1206.

(E)-3-(4-(4-Fluorophenyl)-5-hydroxypent-1-en-1-yl)oxazolidin-2-one (3ag')



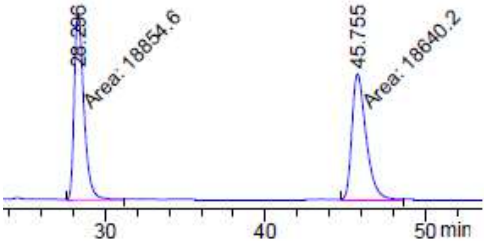
Method A´: 99% yield. **^{1}H NMR** (300 MHz, $CDCl_3$) δ 7.19 – 7.10 (m, 2H), 7.05 – 6.96 (m, 2H), 6.63 (d, *J* = 14.3 Hz, 1H), 4.62 (ddd, *J* = 14.5, 7.8, 6.9 Hz, 1H), 4.37 (t, *J* = 8.2 Hz, 2H), 3.85 – 3.66 (m, 2H), 3.66 – 3.47 (m, 2H), 2.81 (dq, *J* = 8.4, 6.4 Hz, 1H), 2.50 (dddd, *J* = 14.2, 7.7, 6.3, 1.2 Hz, 1H), 2.34 (dddd, *J* = 14.3, 8.4, 6.9, 1.4 Hz, 1H), 1.68 (br, 1H). **^{13}C NMR** (75 MHz, $CDCl_3$) δ 161.70 (d, *J* = 244.6 Hz, C), 155.33 (C), 137.34 (d, *J* = 3.5 Hz, C), 129.35 (d, *J* = 7.9 Hz, CH), 125.25 (CH), 115.45 (d, *J* = 21.1 Hz, CH), 108.15 (CH), 66.62 (CH_2), 62.09 (CH_2), 48.35 (CH), 42.50 (CH_2), 32.66 (CH_2). **LRMS** (m/z, ESI): 288.10 $(M+Na)^+$., 279.09, 135.06, 109.04 **HRMS** Calculated for $C_{14}H_{16}FNNaO_3$: 288.1006, found 288.1008.

(E)-3-(5-Hydroxy-4-(p-tolyl)pent-1-en-1-yl)oxazolidin-2-one (3ah´)



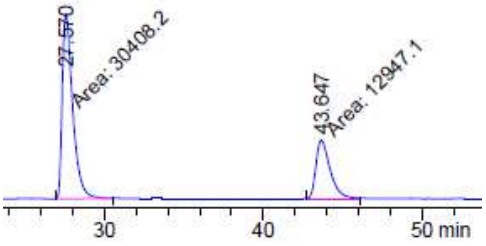
Method A´: 99% yield. **Method B´:** 96% yield (40% ee). **^{1}H NMR** (300 MHz, $CDCl_3$) δ 7.13 (d, *J* = 8.5 Hz, 2H), 7.07 (d, *J* = 8.2 Hz, 2H), 6.63 (d, *J* = 14.3 Hz, 1H), 4.74 – 4.58 (m, 1H), 4.36 (t, *J* = 8.3 Hz, 2H), 3.81 – 3.64 (m, 2H), 3.57 (td, *J* = 7.8, 1.9 Hz, 2H), 2.88 – 2.70 (m, 1H), 2.59 – 2.40 (m, 1H), 2.44 – 2.32 (m, 1H), 2.32 (s, 3H), 1.62 (br, 1H). **^{13}C NMR** (75 MHz, $CDCl_3$) δ 155.48 (C), 138.54 (C), 136.51 (C), 129.50 (CH), 127.93 (CH), 125.12 (CH), 108.73 (CH), 66.89 (CH_2), 62.20 (CH_2), 48.79 (CH), 42.65 (CH_2), 32.74 (CH_2), 21.12 (CH_3). **LRMS** (m/z, ESI): 284.12 $(M+Na)^+$, 175.11, 157.10, 142.07, 131.08. **HRMS** Calculated for $C_{15}H_{19}NNaO_3$: 284.1257, found 284.1257. **HPLC** Enantioselectivity was determined by chiral HPLC analysis on Chiralpak IA3 at rt, (Hexane : iPrOH = 85:15, 1 ml/min).

Racemic sample:



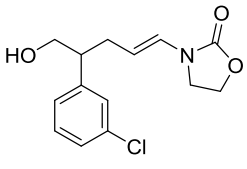
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	28.296	MM	0.7015	1.88546e4	447.98538	50.2859
2	45.755	MM	1.0272	1.86402e4	302.43173	49.7141

Table 3, entry 15; ee = 40%:



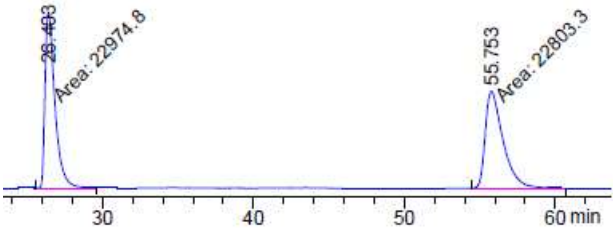
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	27.570	MM	0.7638	3.04082e4	663.51196	70.1372
2	43.647	MM	1.0301	1.29471e4	209.47125	29.8628

(E)-3-(4-(3-Chlorophenyl)-5-hydroxypent-1-en-1-yl)oxazolidin-2-one (3ai´)



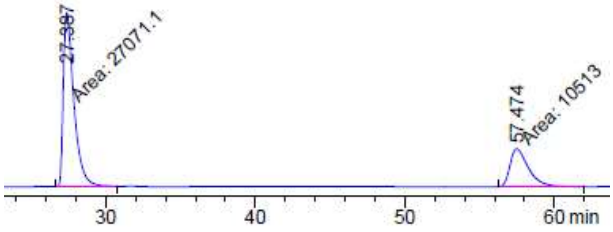
Method A´: 99% yield. **Method B´:** 99% yield (44% ee). **^{1}H NMR** (300 MHz, $CDCl_3$) δ 7.29 – 7.14 (m, 3H), 7.13 – 7.03 (m, 1H), 6.63 (d, *J* = 14.3 Hz, 1H), 4.62 (dt, *J* = 14.5, 7.3 Hz, 1H), 4.37 (t, *J* = 8.4 Hz, 2H), 3.84 – 3.65 (m, 2H), 3.63 – 3.50 (m, 2H), 2.88 – 2.71 (m, 1H), 2.58 – 2.41 (m, 1H), 2.43 – 2.26 (m, 1H), 1.87 (br, 1H). **^{13}C NMR** (75 MHz, $CDCl_3$) δ 155.39 (C), 144.04 (C), 134.38 (C), 129.89 (CH), 128.15 (CH), 126.99 (CH), 126.16 (CH), 125.34 (CH), 108.00 (CH), 66.26 (CH_2), 62.15 (CH_2), 48.85 (CH), 42.52 (CH_2), 32.43 (CH_2). **LRMS** (m/z, ESI): 306.06, 304.07 $(M+Na)^+$, 151.03, 125.01. **HRMS** Calculated for $C_{14}H_{16}ClNNaO_3$: 304.0711, found 304.0712. **HPLC** Enantioselectivity was determined by chiral HPLC analysis on Chiralpak IA3 at rt, (Hexane : iPrOH = 85:15, 1 ml/min).

Racemic sample:



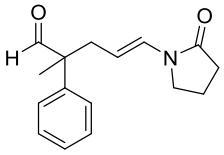
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	26.403	MM	0.7587	2.29748e4	504.66431	50.1873
2	55.753	MM	1.3648	2.28032e4	278.46661	49.8127

Table 3, entry 16; ee = 44%:



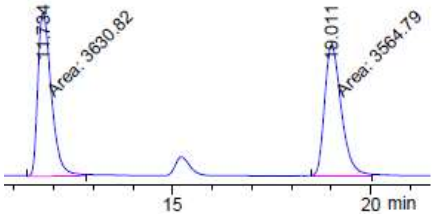
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	27.397	MM	0.8231	2.70711e4	548.14404	72.0280
2	57.474	MM	1.4547	1.05130e4	120.44840	27.9720

(E)-2-Methyl-5-(2-oxopyrrolidin-1-yl)-2-phenylpent-4-enal (3ba)



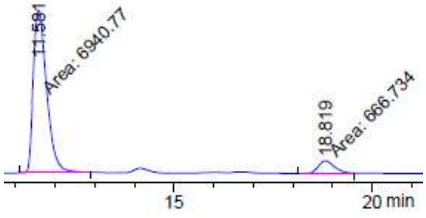
Method A: 52% yield. **Method B:** 52% yield (82% ee).**^{1}H NMR** (500 MHz, $CDCl_3$) δ 9.51 (s, 1H), 7.40 – 7.35 (m, 2H), 7.31 – 7.27 (m, 1H), 7.23 (dd, *J* = 8.3, 1.3 Hz, 2H), 6.88 (d, *J* = 14.4 Hz, 1H), 4.62 (dt, *J* = 14.7, 7.6 Hz, 1H), 3.39 – 3.33 (m, 2H), 2.66 (dd, *J* = 7.5, 1.2 Hz, 2H), 2.48 – 2.41 (m, 2H), 2.09 – 1.99 (m, 2H), 1.43 (s, 3H). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 202.12 (CH), 173.04 (C), 139.57 (C), 129.04 (CH), 127.53 (CH), 127.17 (CH), 126.48 (CH), 106.22 (CH), 54.20 (C), 45.31 (CH_2), 37.30 (CH_2), 31.29 (CH_2), 19.01 (CH_3), 17.44 (CH_2). **LRMS** (m/z, ESI): 280.13 $(M+Na)^+$, 230.13, 147.06, 124.07. **HRMS** Calculated for $C_{16}H_{19}NNaO_2$: 280.1308, found 280.1311. **HPLC** Enantioselectivity was determined by chiral HPLC analysis on Chiralpak IA3 at rt, (Hexane : iPrOH = 85:15, 1 ml/min).

Racemic sample



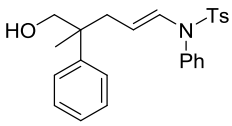
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	11.734	MM	0.3953	3630.82056	153.09007	50.4588
2	19.011	MM	0.4863	3564.79321	122.16275	49.5412

Table 3, entry 12, ee = 82%



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	11.581	MM	0.3933	6940.77100	294.10605	91.2358
2	18.819	MM	0.4873	666.73438	22.80306	8.7642

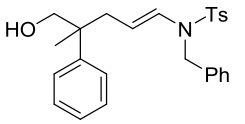
(E)-N-(5-Hydroxy-4-methyl-4-phenylpent-1-en-1-yl)-4-methyl-N-phenylbenzenesulfonamide (3ca')



Method A´: 47% yield. **^{1}H NMR** (300 MHz, $CDCl_3$) δ 7.42 (d, *J* = 8.3 Hz, 2H), 7.34 – 7.12 (m, 10H), 6.89 – 6.70 (m, 3H), 4.20 (dt, *J* = 14.0, 7.8 Hz, 1H), 3.68 (d, *J* = 10.9 Hz, 1H), 3.51 (d, *J* = 10.9 Hz, 1H), 2.44 (s, 3H), 2.31 (qdd, *J* = 13.8, 7.8, 1.2 Hz, 2H), 1.57 (br s, 1H), 1.20 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$) δ 144.53 (C), 143.80 (C), 137.03 (C), 136.00 (C), 131.13 (CH), 130.04 (CH), 129.65

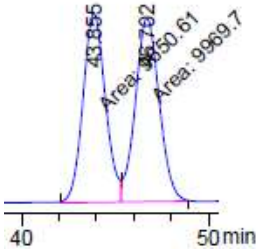
(CH), 129.40 (CH), 128.85 (CH), 128.53 (CH), 127.55 (CH), 126.68 (CH), 126.34 (CH), 108.35 (CH), 71.35 (CH_2), 43.95 (C), 39.27 (CH_2), 21.81 (CH_3), 21.75 (CH_3). **LRMS** (m/z, ESI): 422.17 $(M+H)^+$, 266.14, 157.07. **HRMS** Calculated for $C_{25}H_{28}NO_3S$: 422.1784, found 422.1786.

(E)-N-Benzyl-N-(5-hydroxy-4-methyl-4-phenylpent-1-en-1-yl)-4-methylbenzenesulfonamide (3da´)



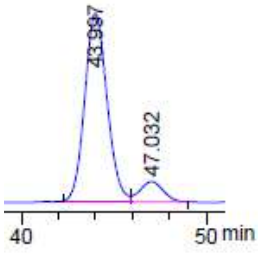
Method A´: 51% yield. **Method B´:** 50% yield (80% ee). **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.62 (d, *J* = 8.2 Hz, 2H), 7.33 – 7.24 (m, 7H), 7.24 – 7.17 (m, 1H), 7.17 – 7.06 (m, 4H), 6.59 (d, *J* = 14.2 Hz, 1H), 4.48 – 4.38 (m, 2H), 4.31 (d, *J* = 15.6 Hz, 1H), 3.55 (d, *J* = 10.9 Hz, 1H), 3.41 (d, *J* = 10.9 Hz, 1H), 2.45 (s, 3H), 2.36 (ddd, *J* = 13.9, 7.1, 1.2 Hz, 1H), 2.20 (ddd, *J* = 13.9, 8.1, 1.0 Hz, 1H), 1.13 (br s, 1H), 1.05 (s, 3H). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 144.30 (C), 143.80 (C), 136.04 (C), 135.54 (C), 129.90 (CH), 128.64 (CH), 128.51 (CH), 127.47 (CH), 127.41 (CH), 127.15 (CH), 127.04 (CH), 126.64 (CH), 126.27 (CH), 109.50 (CH), 71.26 (CH_2), 49.45 (CH_2), 43.64 (C), 39.75 (CH_2), 21.70 (CH_3), 21.59 (CH_3). **LRMS** (m/z, ESI): 458.17 $(M+Na)^+$, 168.05. **HRMS** Calculated for $C_{26}H_{29}NNaO_3S$: 458.1760, found 458.1768. **HPLC** Enantioselectivity was determined by chiral HPLC analysis on Chiralpak OZ-H at rt, (Hexane : iPrOH = 90:10, 0.5 ml/min).

Racemic sample



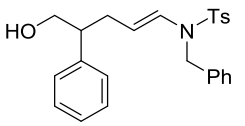
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	43.855	MF	1.3876	9650.60547	115.91866	49.1868
2	46.702	FM	1.4827	9969.70312	112.06666	50.8132

Table 3, entry 13; ee = 80%:



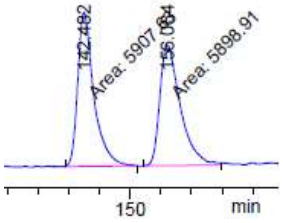
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	43.997	BV	1.2742	1.39488e4	166.36559	89.8699
2	47.032	VB	1.0708	1572.30286	17.86444	10.1301

(E)-N-Benzyl-N-(5-hydroxy-4-phenylpent-1-en-1-yl)-4-methylbenzenesulfonamide (3de´)



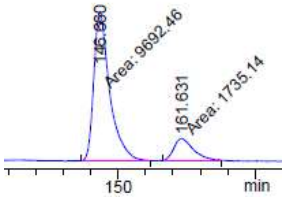
Method A: 99% yield. **Method B:** 99% yield (70% ee). **^{1}H NMR** (300 MHz, $CDCl_3$) δ 7.55 (d, *J* = 8.3 Hz, 2H), 7.29 – 7.21 (m, 8H), 7.19 – 7.14 (m, 2H), 6.99 – 6.92 (m, 2H), 6.60 (d, *J* = 14.1 Hz, 1H), 4.55 (dt, *J* = 14.4, 7.3 Hz, 1H), 4.37 (d, *J* = 3.2 Hz, 2H), 3.58 (s, 2H), 2.69 – 2.56 (m, 1H), 2.43 (s, 3H), 2.39 – 2.28 (m, 1H), 2.30 – 2.13 (m, 1H), 1.26 (br, 1H). **^{13}C NMR** (75 MHz, $CDCl_3$) δ 143.75 (C), 141.52 (C), 136.07 (C), 135.62 (C), 129.89 (CH), 128.70 (CH), 128.63 (CH), 128.07 (CH), 127.46 (CH), 127.08 (CH), 127.00 (CH), 126.79 (CH), 110.76 (CH), 66.49 (CH_2), 49.50 (CH_2), 48.96 (CH), 33.31 (CH_2), 21.68 (CH_3). **LRMS** (m/z, ESI): 422.17 $(M+H)^+$, 300.10, 279.08. **HRMS** Calculated for $C_{25}H_{28}NO_3S$: 422.1784, found 422.1787. **HPLC** Enantioselectivity was determined by chiral HPLC analysis on Chiralpak IA3 at rt, (Hexane : iPrOH = 95:5, 1 ml/min).

Racemic sample:



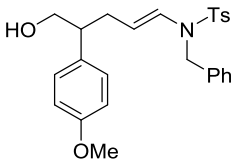
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	142.482	MM	3.0457	5907.63379	32.32792	50.0369
2	156.064	MM	3.8935	5898.90967	25.25123	49.9631

Table 3, entry 17, ee = 70%



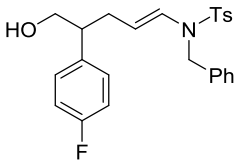
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	146.660	MM	3.3866	9692.46484	47.69967	84.8162
2	161.631	MM	4.0903	1735.14185	7.07009	15.1838

(E)-N-benzyl-N-(5-hydroxy-4-(4-methoxyphenyl)pent-1-en-1-yl)-4-methylbenzenesulfonamide (3df´)



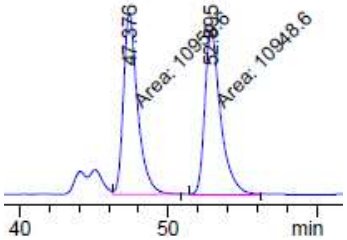
Method A´: 99% yield. **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.57 (d, *J* = 8.2 Hz, 2H), 7.30 – 7.25 (m, 5H), 7.19 (d, *J* = 6.0 Hz, 2H), 6.89 (d, *J* = 8.6 Hz, 2H), 6.84 – 6.78 (m, 2H), 6.61 (d, *J* = 14.5 Hz, 1H), 4.57 (dt, *J* = 14.4, 7.3 Hz, 1H), 4.39 (q, *J* = 15.8 Hz, 2H), 3.82 (s, 3H), 3.57 (dd, *J* = 6.9, 2.6 Hz, 2H), 2.66 – 2.55 (m, 1H), 2.44 (s, 3H), 2.40 – 2.28 (m, 1H), 2.20 (dt, *J* = 15.2, 8.0 Hz, 1H), 1.25 (d, *J* = 6.9 Hz, 1H). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 158.36 (C), 143.73 (C), 136.01 (C), 135.61 (C), 133.36 (C), 129.85, 128.97 (CH), 128.58 (CH), 127.41 (CH), 127.05 (CH), 126.99 (CH), 126.95 (CH), 114.08 (CH), 110.83 (CH), 66.61 (CH_2), 55.31 (CH_3), 49.42 (CH_2), 48.08 (CH), 33.40 (CH_2), 21.65 (CH_3). **LRMS** (m/z, ESI): 474.17 $(M+Na)^+$, 452.18 $(M+H)^+$, 353.26 **HRMS** Calculated for $C_{26}H_{30}NO_4S$: 452.1890, found 452.1892.

(E)-N-benzyl-N-(4-(4-fluorophenyl)-5-hydroxypent-1-en-1-yl)-4-methylbenzenesulfonamide (3dg´)



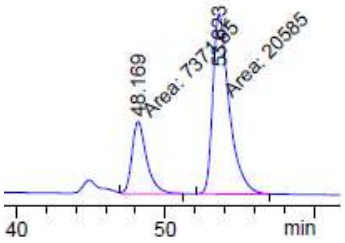
Method A´: 99% yield. **Method B´:** 99% yield (48% ee). **^{1}H NMR** (300 MHz, $CDCl_3$) δ 7.55 (d, *J* = 8.3 Hz, 2H), 7.34 – 7.18 (m, 5H), 7.18 – 7.10 (m, 2H), 7.03 – 6.80 (m, 4H), 6.57 (d, *J* = 14.2 Hz, 1H), 4.57 – 4.41 (m, 1H), 4.45 – 4.27 (m, 2H), 3.57 (dd, *J* = 6.8, 1.2 Hz, 2H), 2.69 – 2.51 (m, 1H), 2.43 (s, 3H), 2.40 – 2.30 (m, 1H), 2.30 – 2.07 (m, 1H), 1.26 (s, 1H).**^{13}C NMR** (75 MHz, $CDCl_3$) δ 161.67 (d, *J* = 244.4 Hz, C), 143.87 (C), 137.15 (d, *J* = 3.3 Hz, C), 136.03 (C), 135.58 (C), 129.90 (CH), 129.45 (d, *J* = 7.9 Hz, CH), 128.63 (CH), 127.48 (CH), 127.20 (CH), 127.00 (CH), 126.96 (CH), 115.42 (d, *J* = 21.0 Hz, CH), 110.25 (CH), 66.45 (CH_2), 49.48 (CH_2), 48.25 (CH), 33.44 (CH_2), 21.66 (CH_3). **LRMS** (m/z, ESI): 462.15 $(M+Na)^+$, 440.16 $(M+H)^+$, 420.14, 300.10. **HRMS** Calculated for $C_{25}H_{27}FNO_3S$: 440.1690, found 440.1680. **HPLC** Enantioselectivity was determined by chiral HPLC analysis on Chiralpak IA3 at rt, (Hexane : iPrOH = 90:10, 1 ml/min).

Racemic sample:



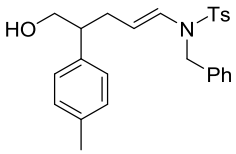
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	47.376	FM	1.1112	1.09596e4	164.37982	50.0251
2	52.895	MM	1.2291	1.09486e4	148.46262	49.9749

Table 3, entry 18: ee = 48%



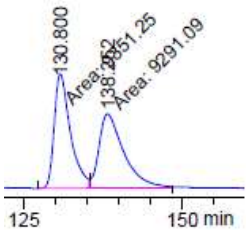
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	48.169	FM	1.1512	7371.64893	106.72400	26.3681
2	53.623	MM	1.2902	2.05850e4	265.91565	73.6319

(E)-N-benzyl-N-(5-hydroxy-4-(p-tolyl)pent-1-en-1-yl)-4-methylbenzenesulfonamide (3dh´)



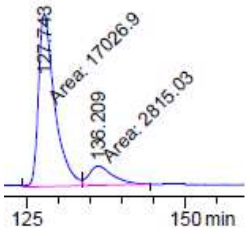
Method A': 99% yield. **Method B':** 99% yield (72% ee). **^{1}H NMR** (300 MHz, $CDCl_3$) δ 7.56 (d, *J* = 8.3 Hz, 2H), 7.31 – 7.22 (m, 5H), 7.20 – 7.13 (m, 2H), 7.06 (d, *J* = 7.6 Hz, 2H), 6.85 (d, *J* = 8.0 Hz, 2H), 6.60 (d, *J* = 14.2 Hz, 1H), 4.57 (dt, *J* = 14.5, 7.4 Hz, 1H), 4.38 (d, *J* = 3.0 Hz, 2H), 3.56 (d, *J* = 6.7 Hz, 2H), 2.68 – 2.49 (m, 1H), 2.43 (s, 3H), 2.33 (s, 3H), 2.41 – 2.26 (m, 1H), 2.32 – 2.12 (m, 1H), 1.27 (s, 1H). **^{13}C NMR** (75 MHz, $CDCl_3$) δ 143.72 (C), 138.37 (C), 136.23 (C), 136.06 (C), 135.61 (C), 129.85 (CH), 129.39 (CH), 128.59 (CH), 127.92 (CH), 127.44 (CH), 127.09 (CH), 127.01 (CH), 110.98 (CH), 66.57 (CH_2), 49.47 (CH_2), 48.50 (CH), 33.30 (CH_2), 21.67 (CH_3), 21.17 (CH_3). **LRMS** (m/z, ESI): 458.17 $(M+Na)^+$, 436.19 $(M+H)^+$, 300.10. **HRMS** Calculated for $C_{26}H_{29}NNaO_3S$: 458.1760, found 458.1766. **HPLC** Enantioselectivity was determined by chiral HPLC analysis on Chiralpak IA3 at rt, (Hexane : iPrOH = 95:5, 1 ml/min).

Racemic sample:



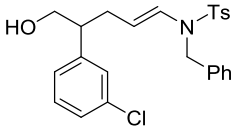
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	130.800	MF	2.9532	9351.25488	52.77546	50.1614
2	138.252	FM	4.5219	9291.09082	34.24477	49.8386

Table 3, entry 19: ee = 72%



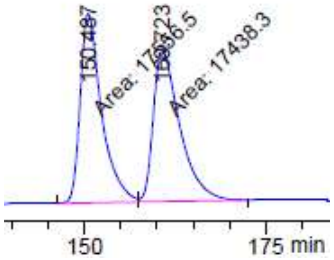
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	127.743	MF	2.9715	1.70269e4	95.50150	85.8127
2	136.209	FM	4.3724	2815.02905	10.73035	14.1873

(E)-N-Benzyl-N-(4-(3-chlorophenyl)-5-hydroxypent-1-en-1-yl)-4-methylbenzenesulfonamide (3di´)



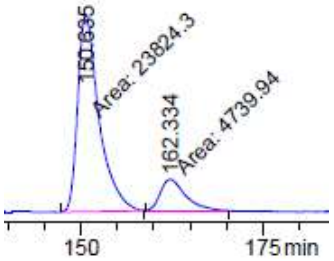
Method A': 99% yield. **Method B':** 99% yield (67% ee). **^{1}H NMR** (300 MHz, $CDCl_3$) δ 7.56 (d, *J* = 8.3 Hz, 2H), 7.32 – 7.11 (m, 9H), 6.99 (s, 1H), 6.82 (dt, *J* = 6.3, 1.9 Hz, 1H), 6.59 (d, *J* = 14.2 Hz, 1H), 4.58 – 4.42 (m, 1H), 4.43 – 4.28 (m, 2H), 3.56 (d, *J* = 6.6 Hz, 2H), 2.67 – 2.51 (m, 1H), 2.43 (s, 3H), 2.39 – 2.27 (m, 1H), 2.26 – 2.12 (m, 1H), 1.29 (s, 1H). **^{13}C NMR** (75 MHz, $CDCl_3$) δ 143.87 (C), 136.01 (C), 135.50 (C), 134.44 (C), 129.93 (CH), 128.67 (CH), 128.26 (CH), 127.52 (CH), 127.35 (CH), 127.01 (CH), 126.97 (CH), 126.26 (CH), 110.17 (CH), 66.30 (CH_2), 49.52 (CH_2), 48.80 (CH), 33.10 (CH_2), 21.69 (CH_3). **LRMS** (m/z, ESI): 478.12 $(M+Na)^+$, 456.14 $M+H)^+$, 311.03, 300.10. **HRMS** Calculated for $C_{25}H_{26}ClNNaO_3S$: 478.1214, found 478.1216. **HPLC** Enantioselectivity was determined by chiral HPLC analysis on Chiralpak IA3 at rt, (Hexane : iPrOH = 95:5, 1 ml/min).

Racemic sample:



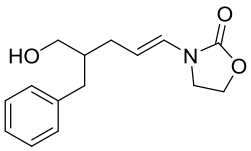
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	150.487	MF	3.4345	1.75565e4	85.19675	50.1688
2	160.723	FM	4.2543	1.74383e4	68.31705	49.8312

Table 3, entry 20: ee = 67%



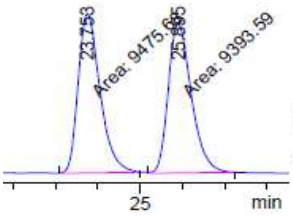
Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	150.635	MM	3.4080	2.38243e4	116.51218	83.4060
2	162.334	MM	4.1875	4739.93799	18.86543	16.5940

(E)-3-(4-Benzyl-5-hydroxypent-1-en-1-yl)oxazolidin-2-one (3aj´)



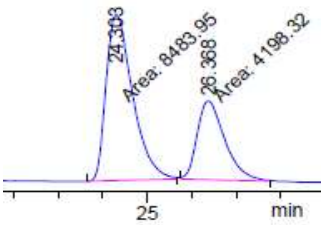
Reaction carried out in acetonitrile under otherwise identical conditions of **Method B':** 45% yield (34% ee). **^{1}H NMR** (300 MHz, $CDCl_3$) δ 7.36 – 7.12 (m, 5H), 6.67 (d, *J* = 14.3 Hz, 1H), 4.84 – 4.67 (m, 1H), 4.42 (dd, *J* = 8.5, 7.7 Hz, 2H), 3.64 (td, *J* = 7.7, 1.7 Hz, 2H), 3.59 – 3.52 (m, 2H), 2.64 (qd, *J* = 13.7, 7.2 Hz, 2H), 2.27 – 2.01 (m, 2H), 1.99 – 1.79 (m, 1H), 1.25 (s, 1H). **^{13}C NMR** (75 MHz, $CDCl_3$) δ 155.48 (C), 140.55 (C), 129.28 (CH), 128.54 (CH), 126.16 (CH), 125.42 (CH), 108.85 (CH), 64.75 (CH_2), 62.25 (CH_2), 43.39 (CH), 42.74 (CH_2), 37.54 (CH_2), 31.53 (CH_2). **LRMS** (m/z, ESI): 284.12 $(M+Na)^+$, 273.08, 236.14. **HRMS** Calculated for $C_{15}H_{19}NNaO_3$: 284.1257, found 284.1258. **HPLC** Enantioselectivity was determined by chiral HPLC analysis on Chiralpak IA3 at rt, (Hexane : iPrOH = 85:15, 1 ml/min).

Racemic sample



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	23.753	MM	0.5992	9475.68164	263.57043	50.2175
2	25.895	MM	0.6299	9393.59180	248.54149	49.7825

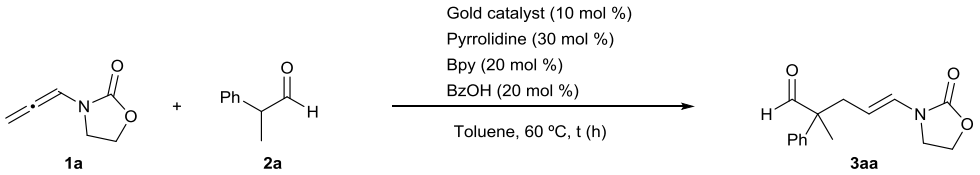
Asymmetric example (Reference 22, main manuscript; ee = 34%:



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	24.303	MM	0.6913	8483.95410	204.53790	66.8962
2	26.368	MM	0.7211	4198.32080	97.03584	33.1038

Additional data obtained in the optimization of the racemic alkylation of aldehydes

Table S1. Influence of the ancillary ligand and counterion of L-AuX [a]



Entry	gold catalyst (X mol %)	t (h)	yield (%)
1	none	46	0
2	**Au1** (10)	1	30
3	**Au2** (10)	3.5	88
4	**Au3** (10)	3	25
5	$Ph_3PAuNTf_2$ (5)	1.5	43
6	$Ph_3PAuNTf_2$ (10)	0.3	83
7	$Ph_3PAuCl/AgSbF_6$ (10)	18	23
8	$XPhosAuNTf_2$ (10)	0.5	5
9	$JohnPhosAuNTf_2$ (10)	0.5	6
10	$tBuXPhosAuNTf_2$ (10)	0.5	5
11	$RuPhosAuNTf_2$ (10)	1	10
12	$SPhosAuNTf_2$ (10)	0.7	12
13	$(tBu)_3PAuNTf_2$ (10)	0.5	14
14	$(pCF_3C_6H_4)_3PAuNTf_2$ (10)	0.7	73
15	$Ph_3PAu(TA)OTf$ (10)	6	63
16	$IMesAuNTf_2$ (10)	0.5	63
17	$IPrAuNTf_2$ (10)	3	68

[a] All reactions were carried out using conditions described in Method A. Yields determined by Internal Standard [1,3,5-$(MeO)_3C_6H_3$] unless otherwise noted.

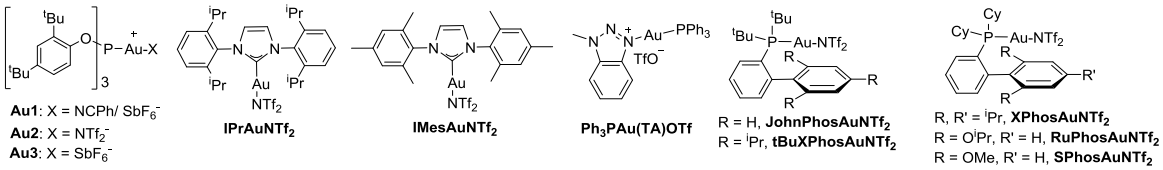
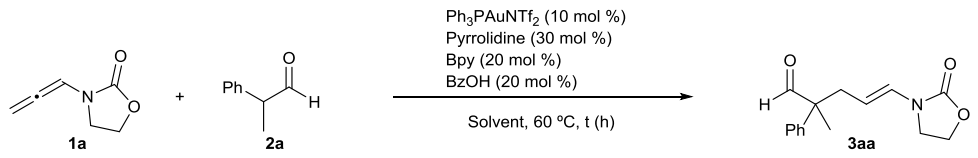


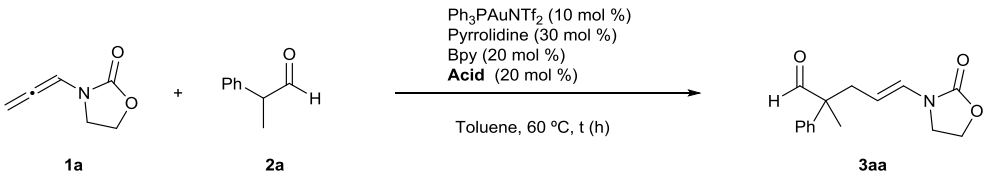
Table S2 Influence of the solvent.



Entry	Solvent	t (h)	yield (%)
1	Toluene	0.3	83
2	Tetrahydrofuran	0.5	10
3	1,4-Dioxane	0.5	15
4	Acetonitrile	0.3	39

All reactions were carried out using conditions described in Method A. Yields determined by Internal Standard [1,3,5-$(MeO)_3C_6H_3$] unless otherwise noted.

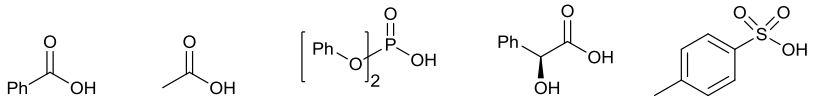
Table S3 Influence of the acid.



1a 2a 3aa

Entry	Acid	t (h)	yield (%)
1	none	0.5	25
2	**4a**	0.3	83
3	**4b**	0.5	41
4	**4c**	0.5	39
5	**4d**	0.3	43
6	**4e**	1	30

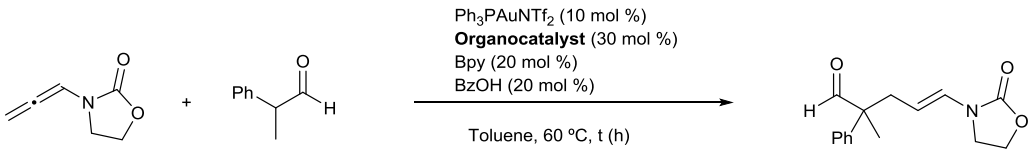
All reactions were carried out using conditions described in Method A. Yields determined by Internal Standard [1,3,5-$(MeO)_3C_6H_3$] unless otherwise noted



4a 4b 4c 4d 4e

Additional data obtained in the optimization of the asymmetric alkylation of aldehydes

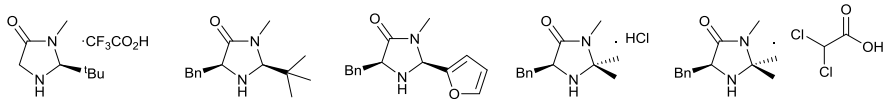
Table S4. Screening of MacMillan Organocatalysts



1a 2a 3aa

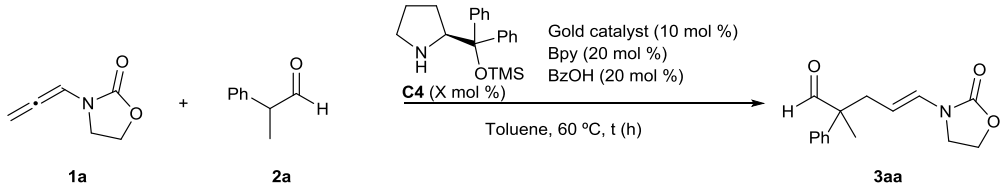
Entry	Organocatalyst (C)	t (h)	yield (%)	ee (%)
1[a]	**C1**	1	13	39
2	**C1b**	2	<5	-
3	**C1c**	2	-[b]	-
4[a]	**C1d**	2	-[b]	-
5[a]	**C1e**	2	-[b]	-

All reactions were carried out using conditions described in Method B. Yields determined by Internal Standard [1,3,5-$(MeO)_3C_6H_3$] unless otherwise noted. [a] benzoic acid was not added to the reaction. [b] Polymerization of **1a** was exclusively observed.



C1 C1b C1c C1d C1e

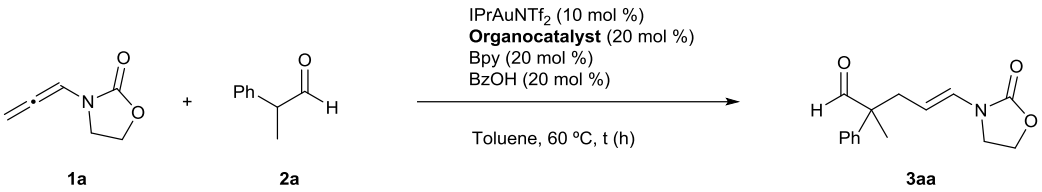
Table S5 **Screening of chiral Organocatalyst C4 with different gold catalysts**



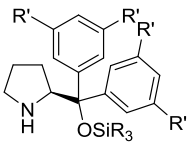
Entry	gold catalyst	Organocatalyst (Xmol%)	t (h)	yield (%)	ee (%)
1	$Ph_3PAuNTf_2$	**C4** (30)	0.5	68	59
2	$(pCF_3C_6H_4)_3PAuNTf_2$	**C4** (30)	0.7	71	48
3	$Ph_3PAu(TA)OTf$	**C4** (30)	1	53	67
4	$IMesAuNTf_2$	**C4** (30)	2.5	20	58
5	$IPrAuNTf_2$	**C4** (20)	0.5	66	72

All reactions were carried out using conditions described in Method B. Yields determined by Internal Standard [1,3,5-$(MeO)_3C_6H_3$] unless otherwise noted.

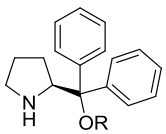
Table S6 **Influence of the structure of the Prolinol.**



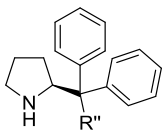
Entry	**organocatalyst**	t (h)	yield (%)	ee (%)
1	**C4**	0.5	66	72
2	**C5**	0.5	30	81
3	**C6**	0.7	25	81
4	**C7**	0.7	23	83
5	**C8**	1	35	61
6	**C9**	0.7	56	0
7	**C10**	0.7	15	44
8	**C11**	4	24	73
9	**C12**	0.7	26	65
10	**C13**	1	32	35
11	**C14**	0.7	33	48
12	**C15**	1	28	47
13	**C16**	0.5	11	60



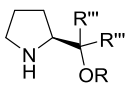
C4: R' = H, R = Me
C8: R' = Me, R = Me



C5: R =TBS
C6: R =TES
C7: R =TPS

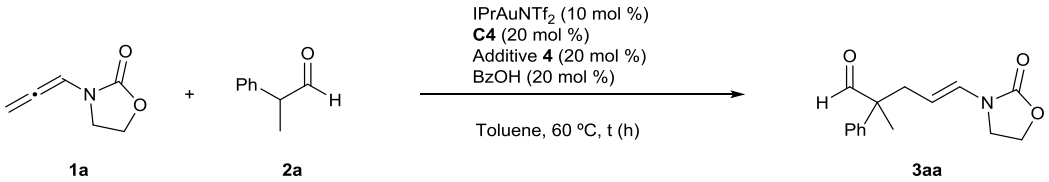


C9: R'' =H
C10: R'' =F



C11: R''' = Me, R =TMS
C12: R''' = Me, R =TBS
C13: R''' = H, R =TBS
C14: R''' = H, R =TIPS
C15: R''' = H, R =TBDPS
C16: R''' = iBu, R = TPS

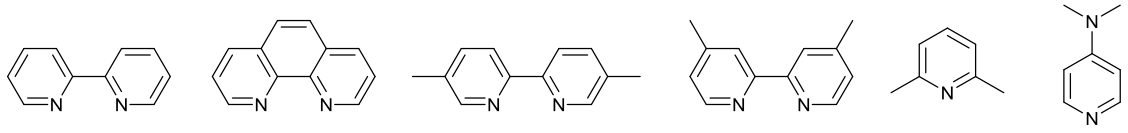
Table S7. Influence of the additive.



1a 2a 3aa

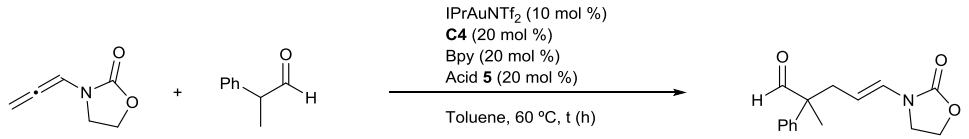
Entry	additive	t (h)	yield (%)	ee (%)
1	none	0.3	37	76
2	Bpy (**4a**)	0.5	66	72
3	**4b**	1	33	80
4	**4c**	0.5	55	73
5	**4d**	0.5	50	74
6	**4e**	2	66	70
7	**4f**	2	20	50

All reactions were carried out using conditions described in Method **B**. Yields determined by Internal Standard [1,3,5-$(MeO)_3C_6H_3$] unless otherwise noted**.**



4a (Bpy) **4b** **4c** **4d** **4e** **4f**

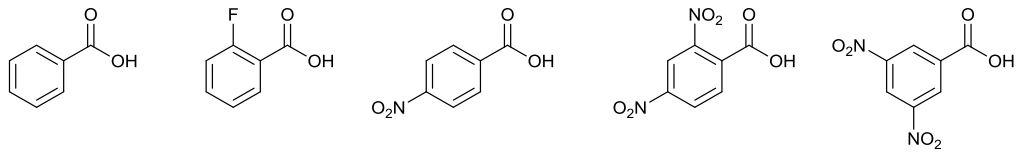
Table S8. Influence of the acid.



1a 2a 3aa

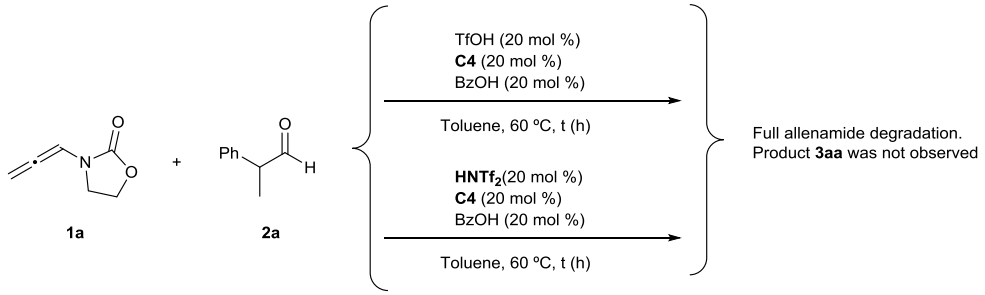
Entry	**Acid (5)**	t (h)	yield (%)	ee (%)
1	**5a**	0.5	66	72
2	**5b**	0.3	53	74
3	**5c**	0.5	50	73
4	**5d**	0.5	42	76
5	**5e**	0.7	67	69

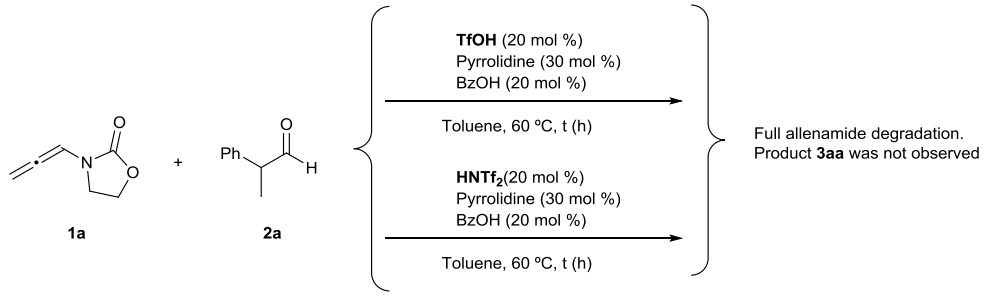
All reactions were carried out using conditions described in Method **B**. Yields determined by Internal Standard [1,3,5-$(MeO)_3C_6H_3$] unless otherwise noted



5a **5b** **5c** **5d** **5e**

Table S9. Control experiments by using Brönsted acids instead of gold catalysts.





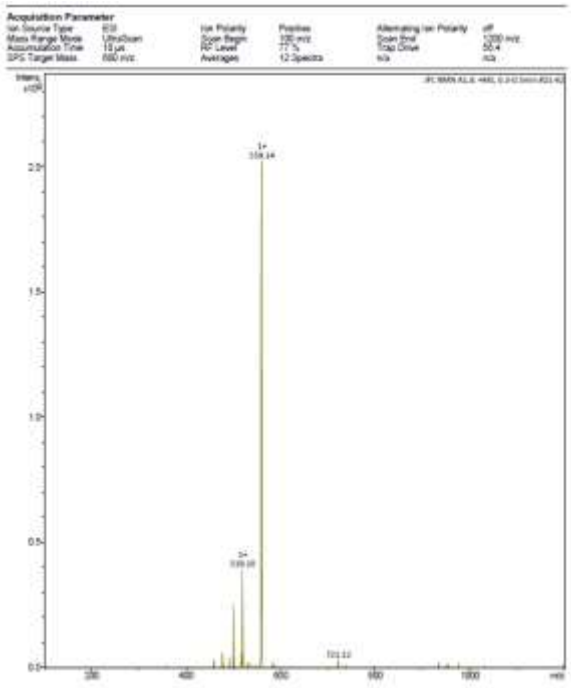
All reactions were analyzed by 1H-NMR using Internal Standard [1,3,5-$(MeO)_3C_6H_3$]

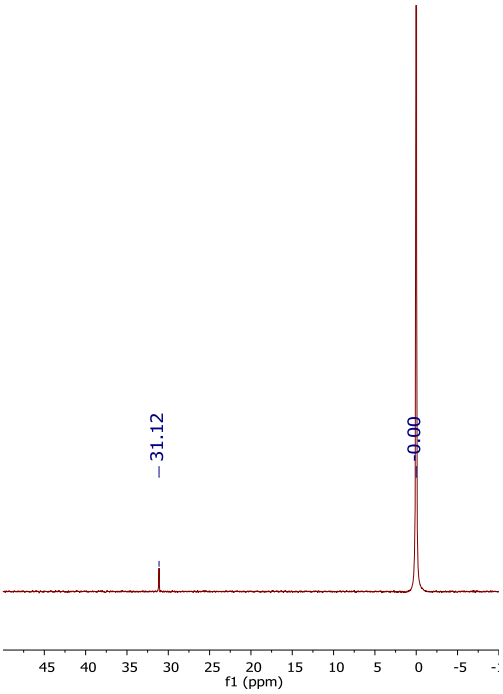
NMR and ESI-MS experiments

1. **$Ph_3PAuNTf_2$ (d8-toluene complex, 2:1)**

ESI-MS : M^+= 559.14,

^{31}P-NMR: 31.12 ppm

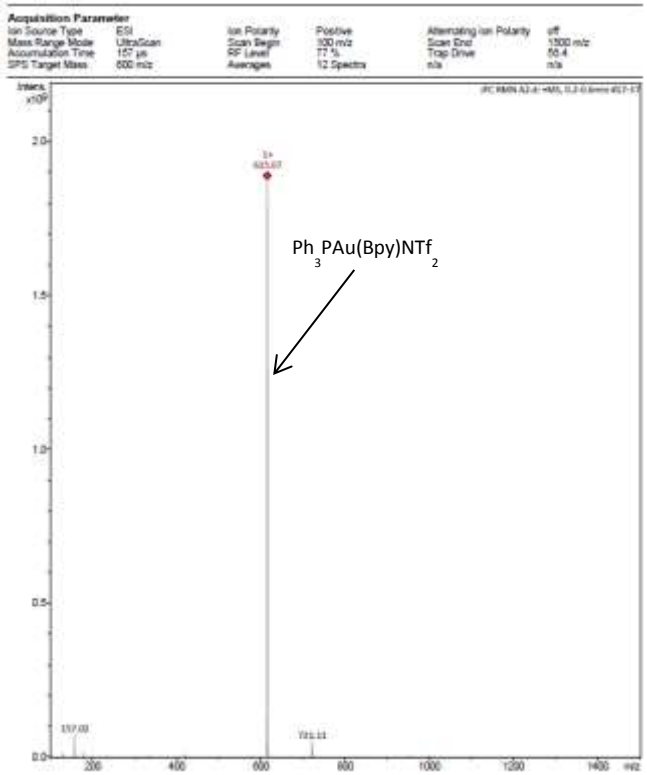


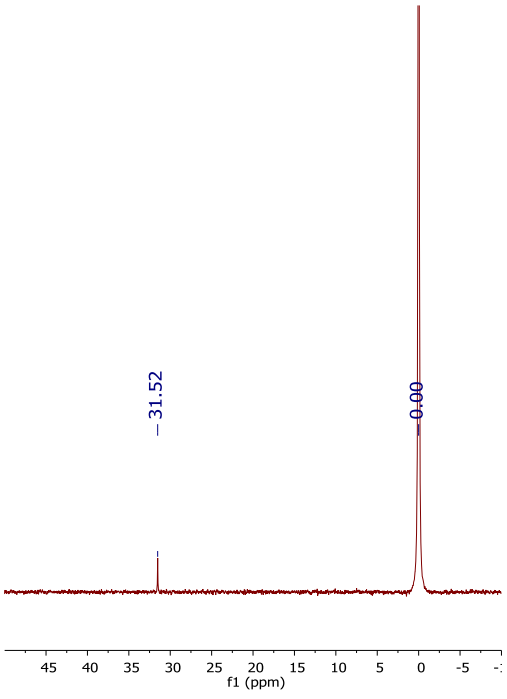


2. **$Ph_3PAu(Bpy)NTf_2$** (Prepared by mixing Bpy and $Ph_3PAuNTf_2$ (ratio 1:1)

ESI-MS : M^+= 615.17,

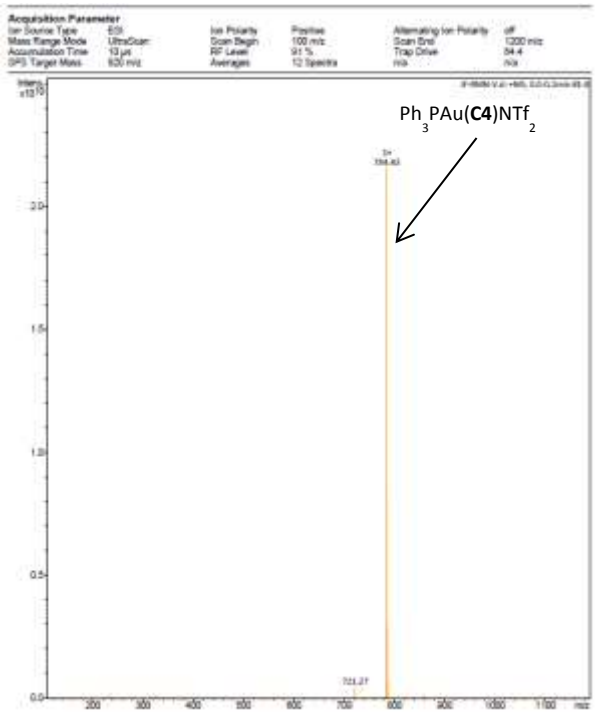
^{31}P-NMR: 31.52 ppm



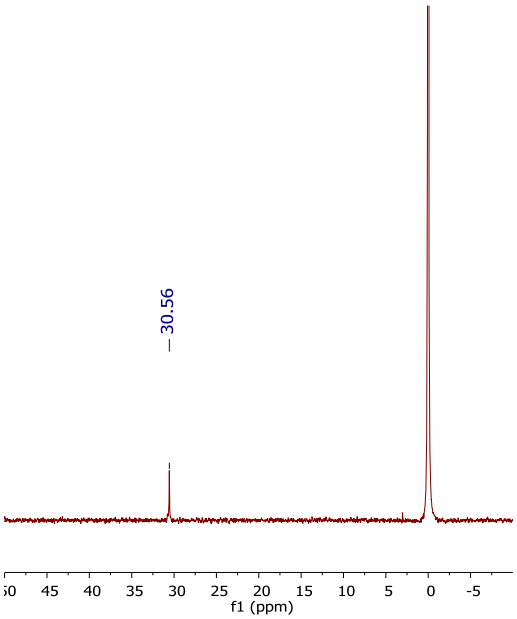


3. **$Ph_3PAu(C4)NTf_2$** (Prepared by mixing **C4** and $Ph_3PAuNTf_2$ (ratio 1:1)

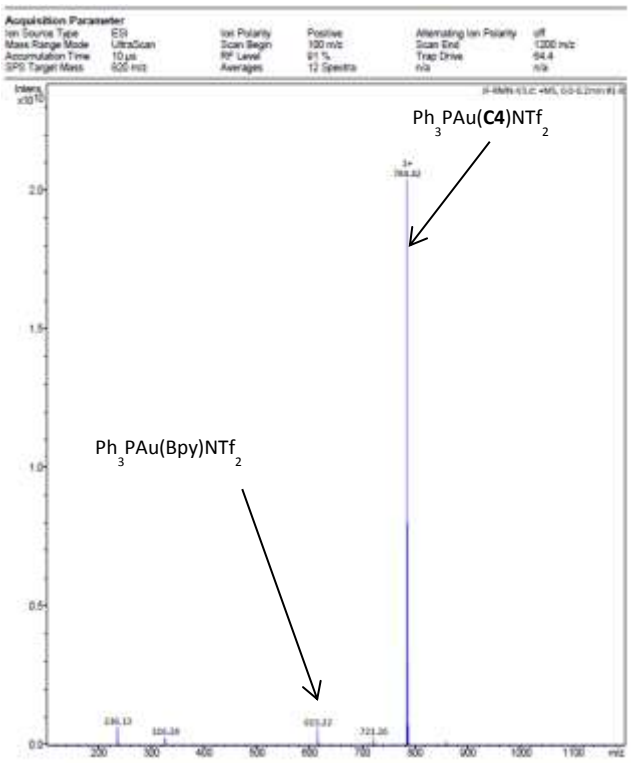
ESI-MS :M^+ = 784.43

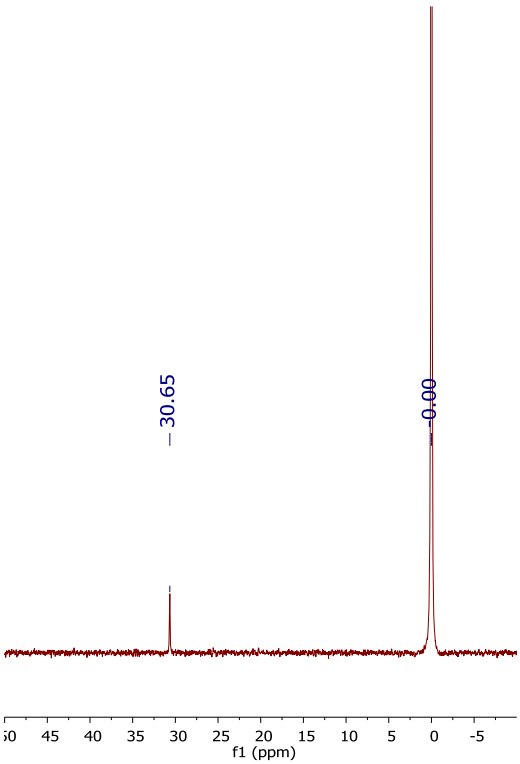


31P-NMR: 30.56 ppm

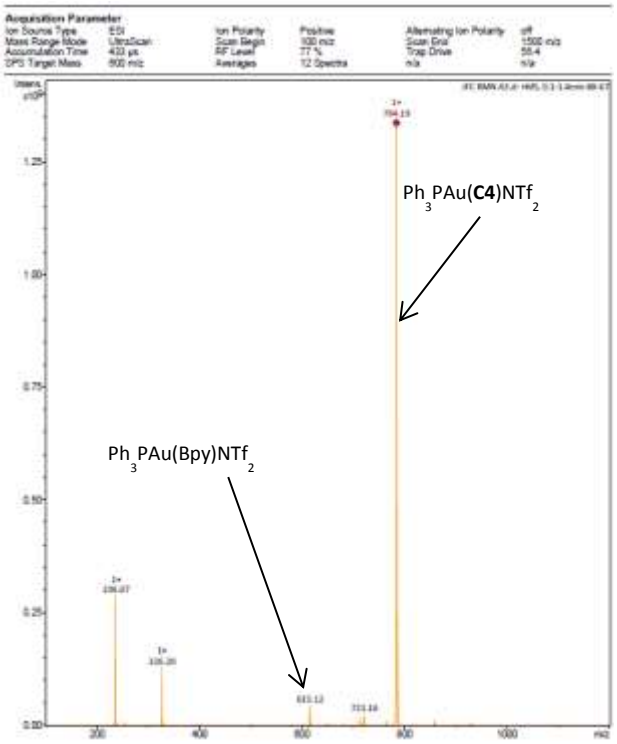


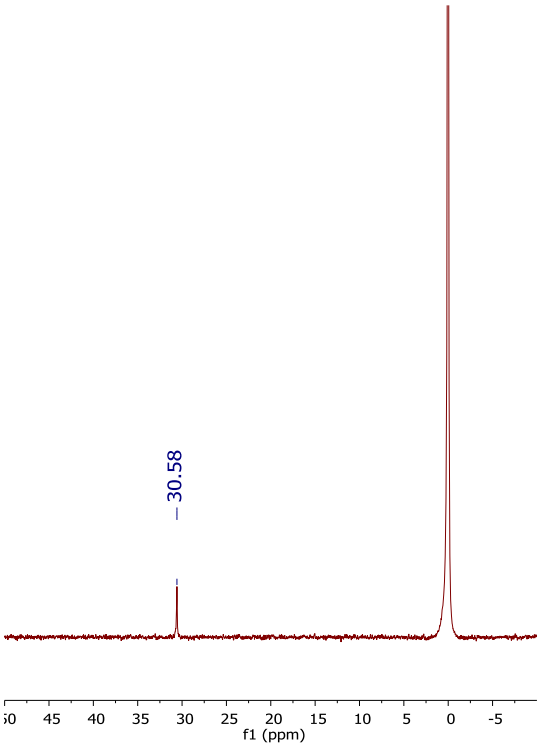
$Ph_3PAu(C4)NTf_2$ + Bpy (2 equiv)



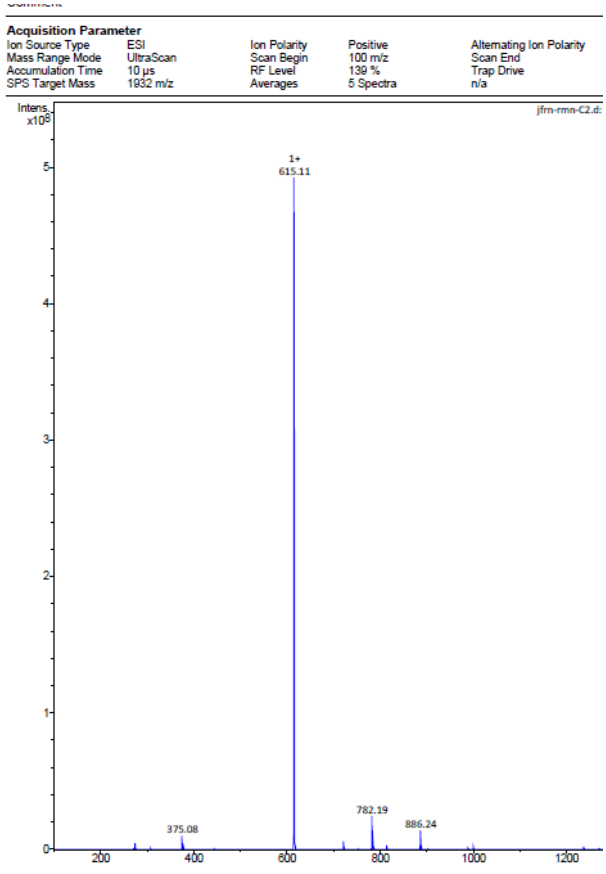


$Ph_3PAu(Bpy)NTf_2$ + C4 (1 equiv)

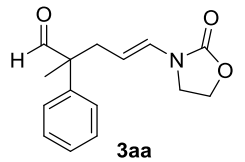




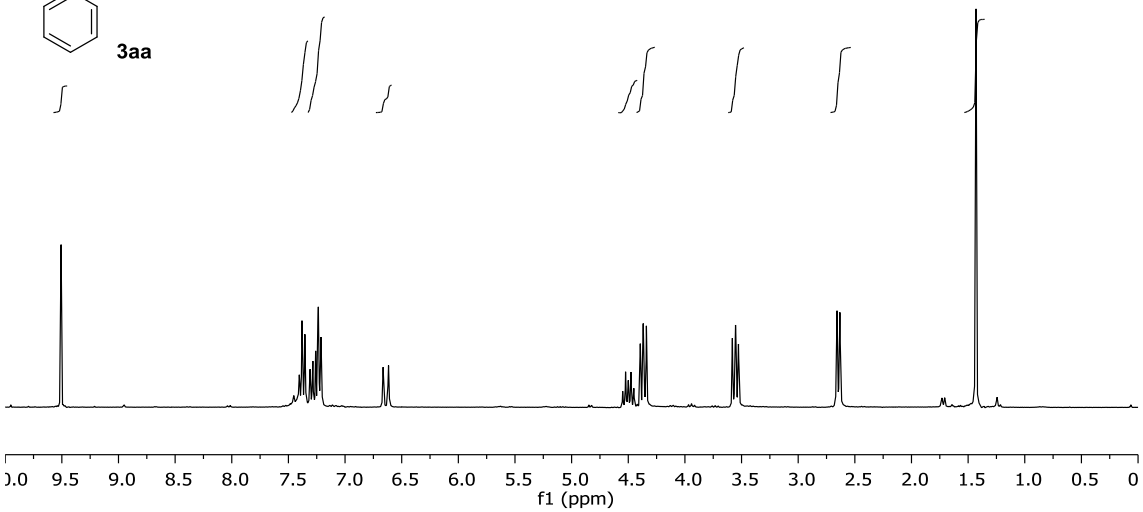
$Ph_3PAu(\mathbf{C4})NTf_2$ + Bpy + Phenylacetaldehyde

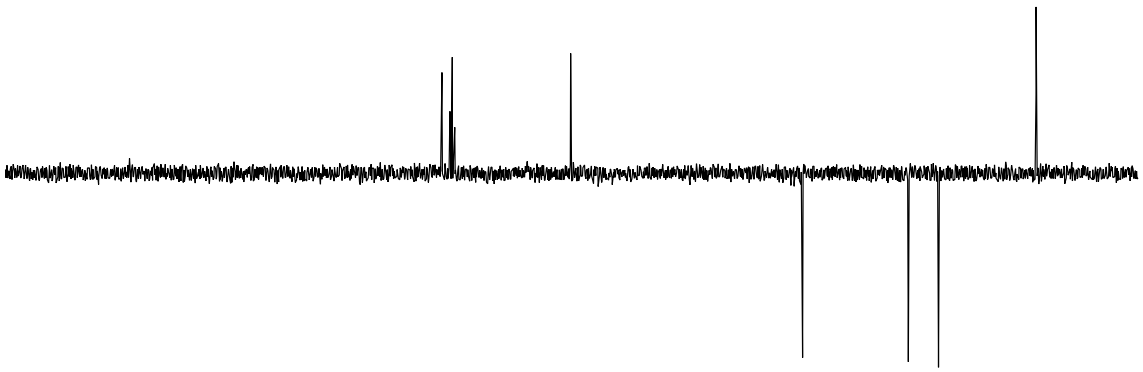


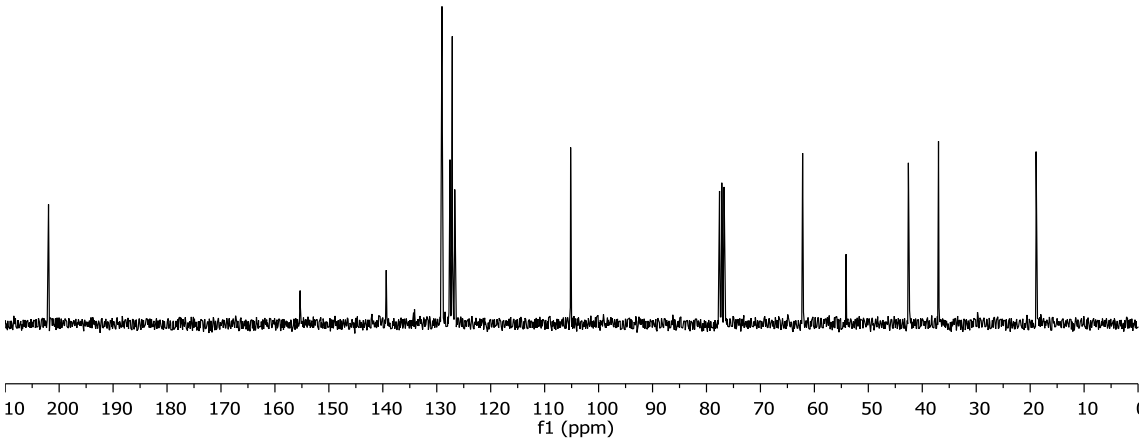
NMR Spectra

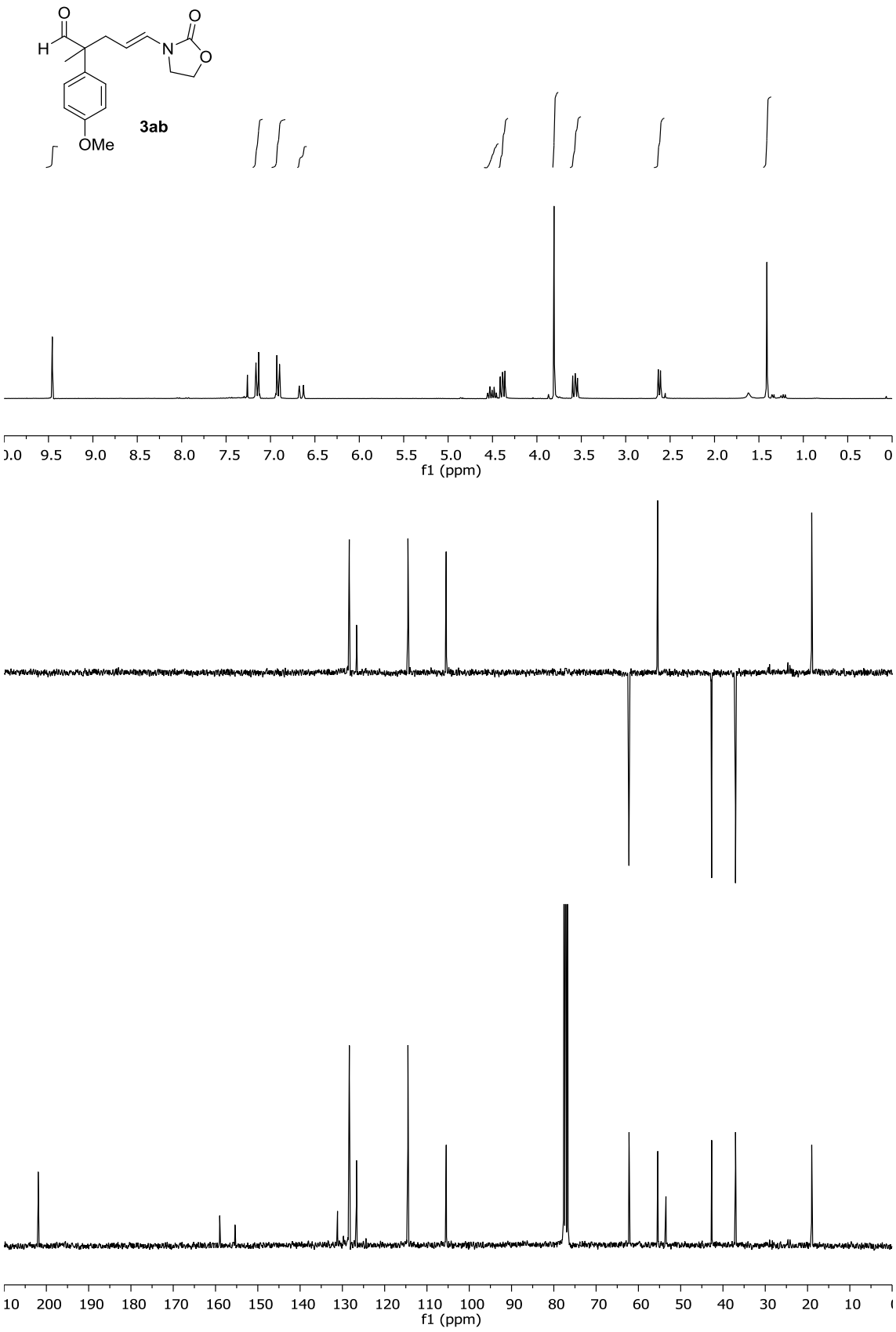


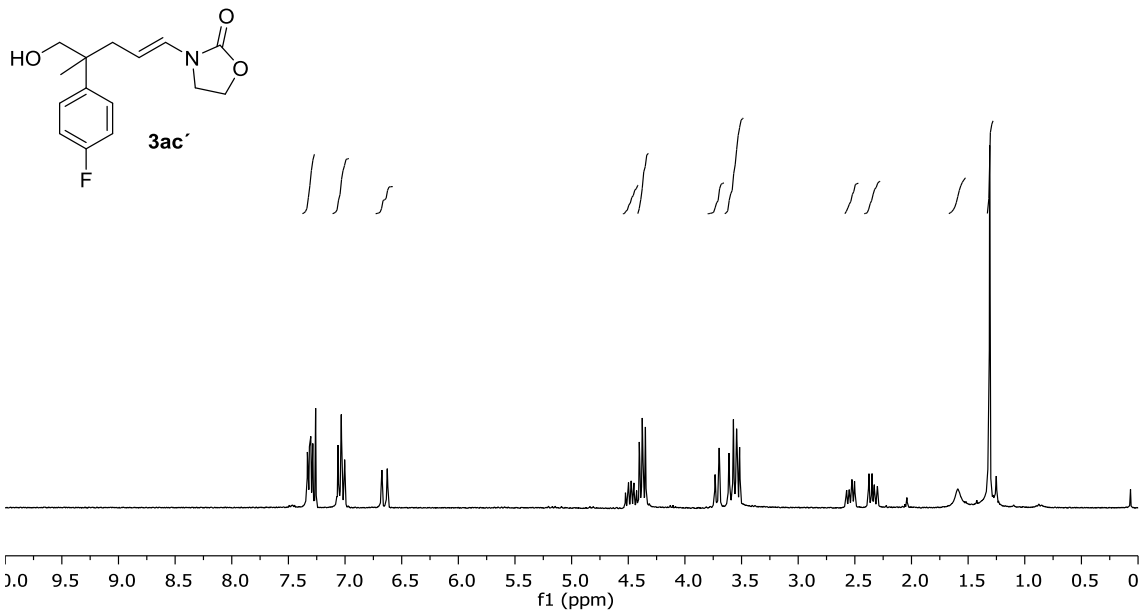
3aa

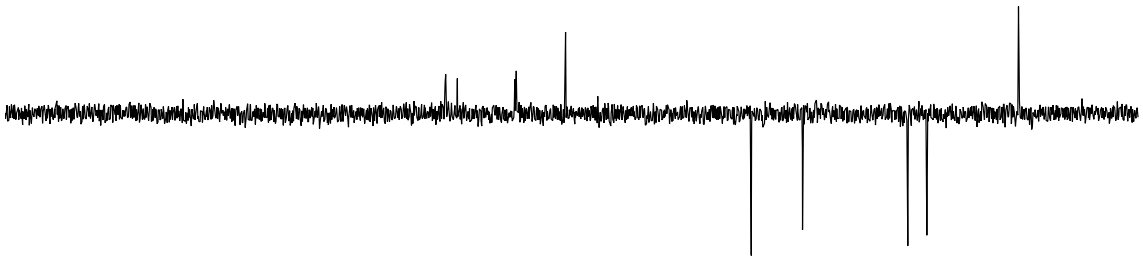


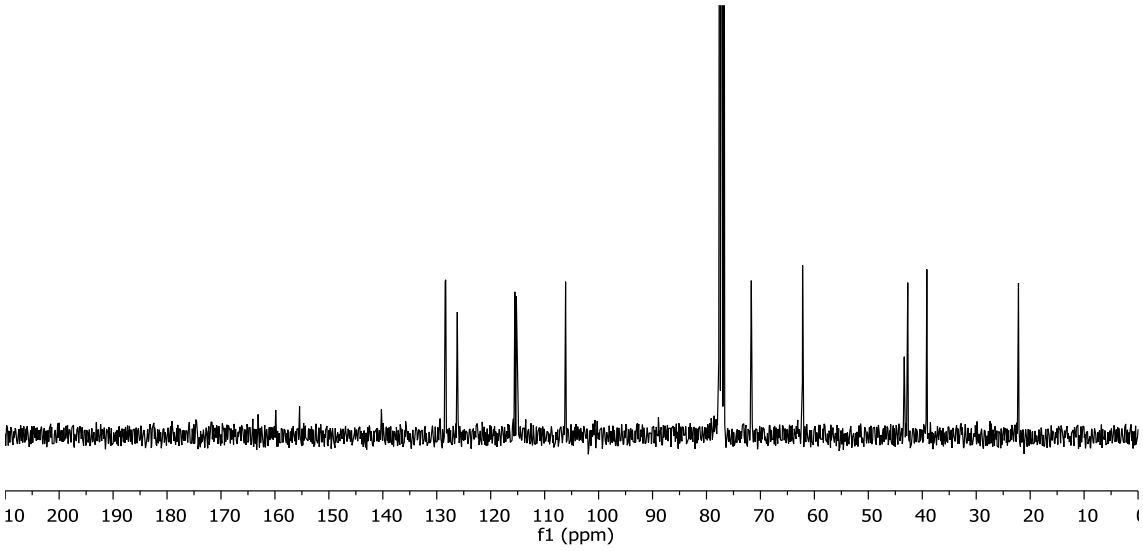


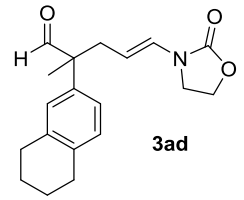



O
H
O
N
O
OMe
3ab
f1 (ppm)
f1 (ppm)

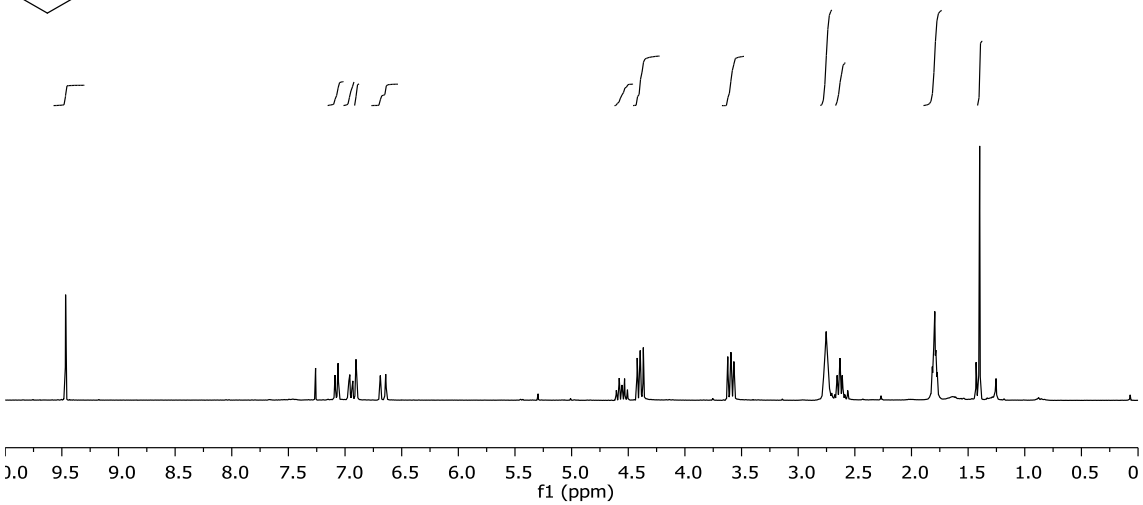

HO
O
N
O
F
3ac´
f1 (ppm)

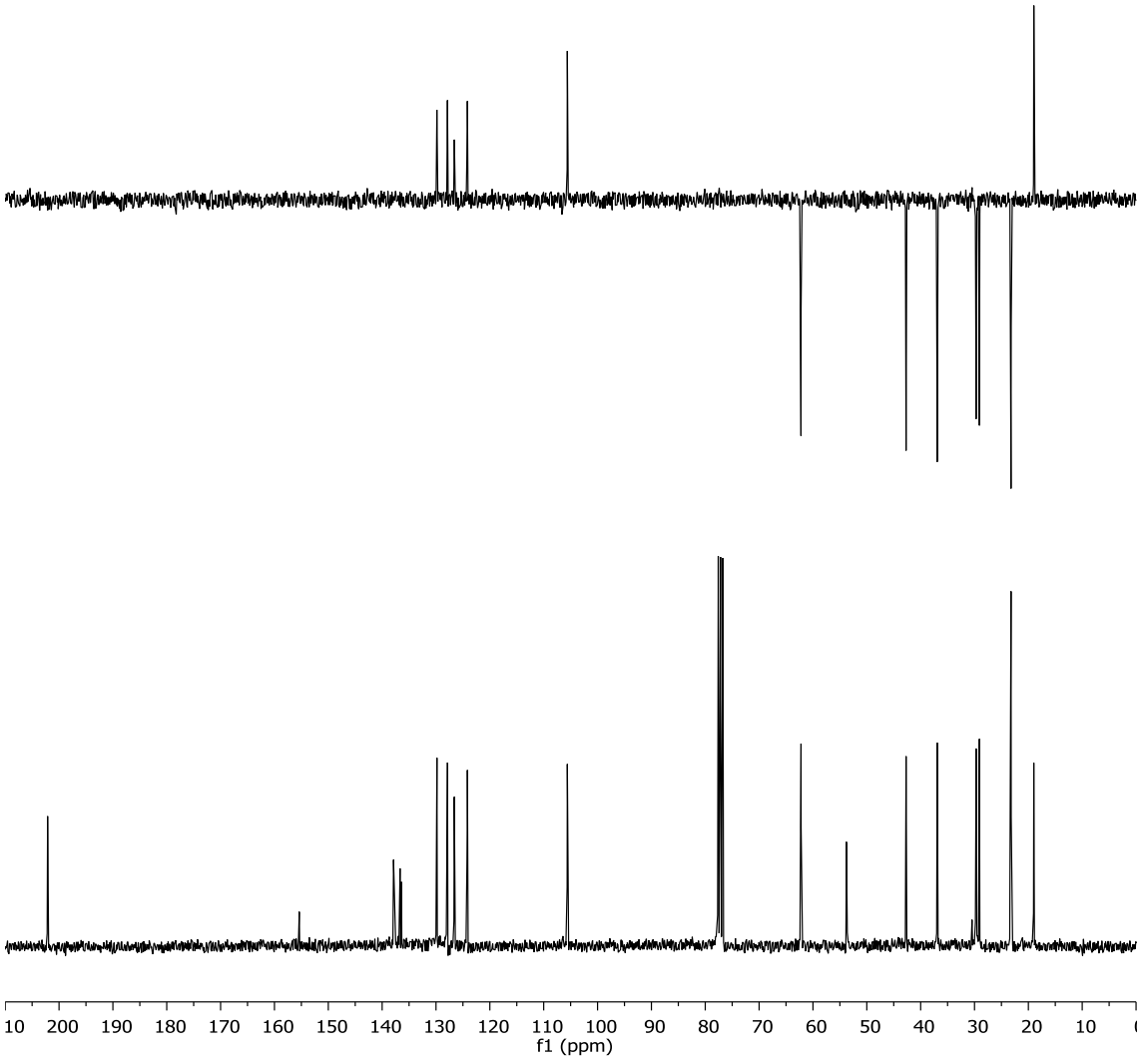


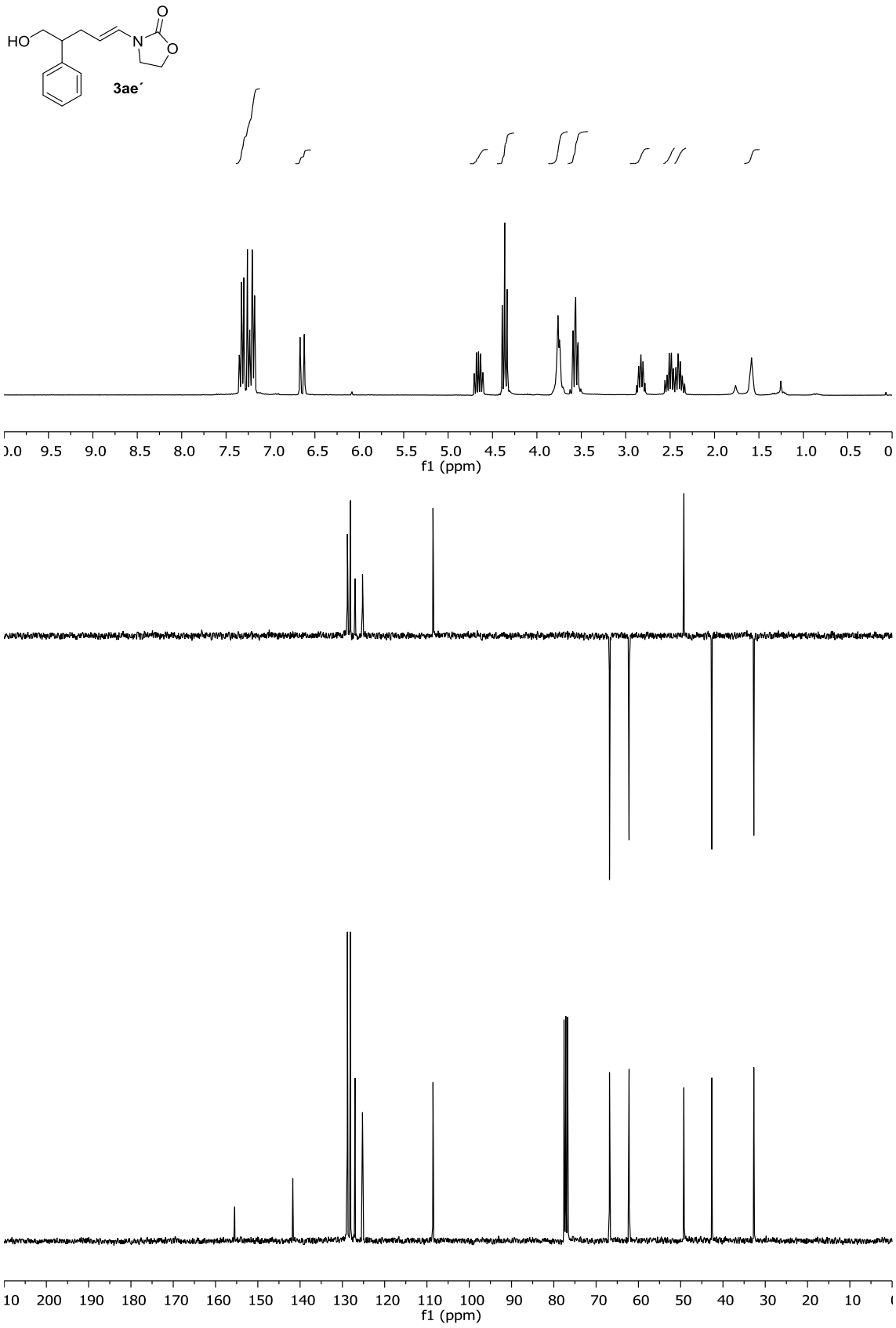

f1 (ppm)

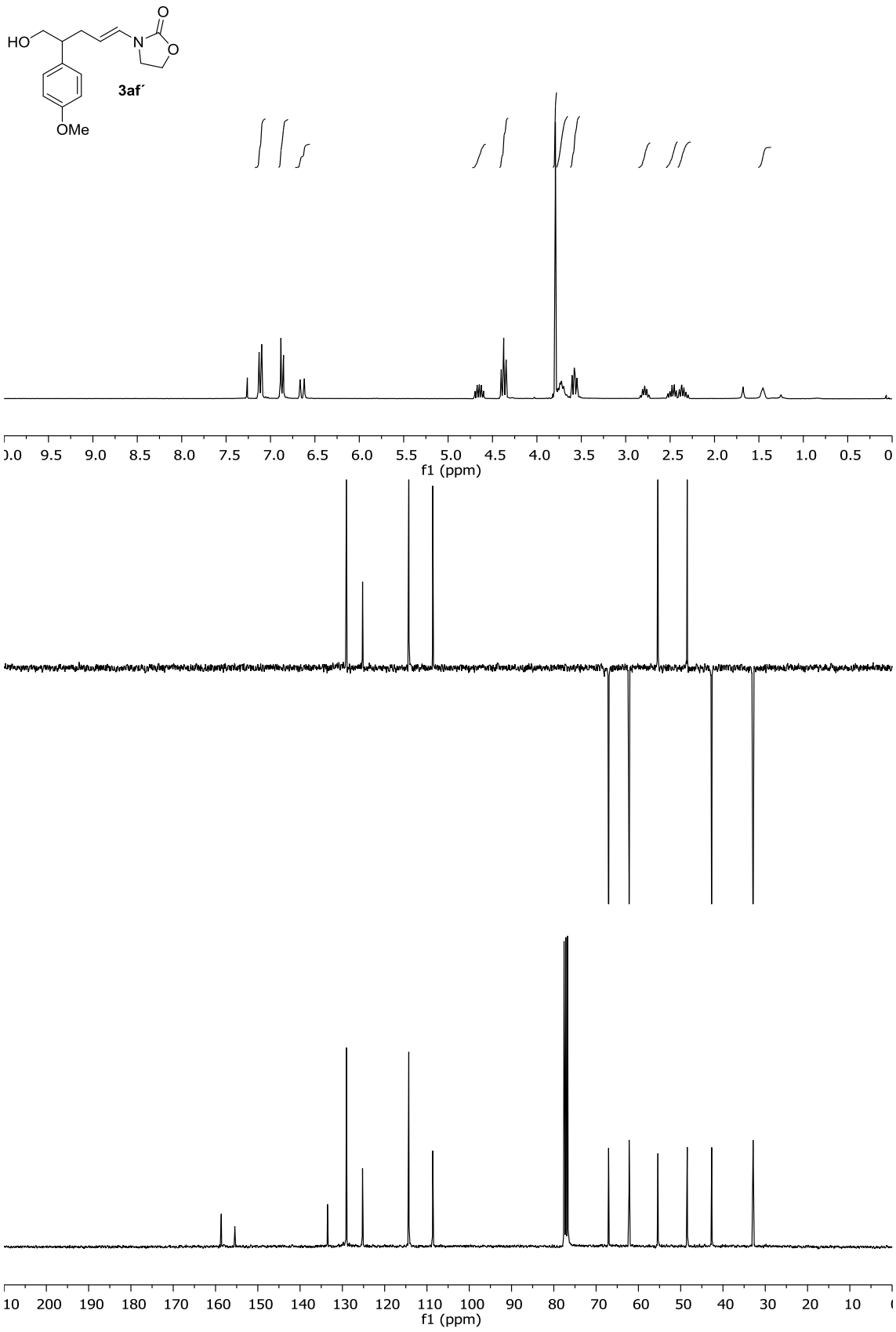

O
H
O
N
O

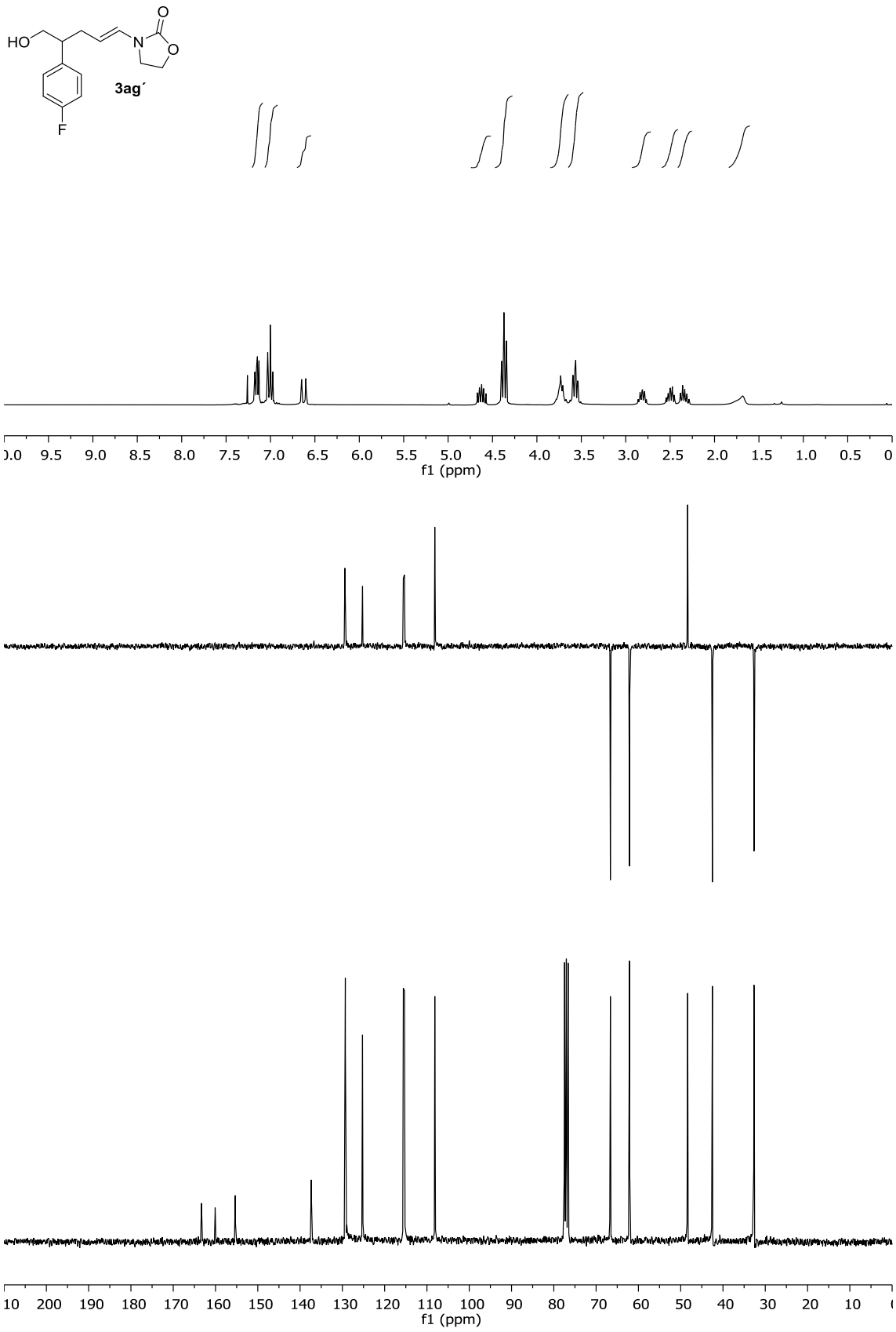
3ad

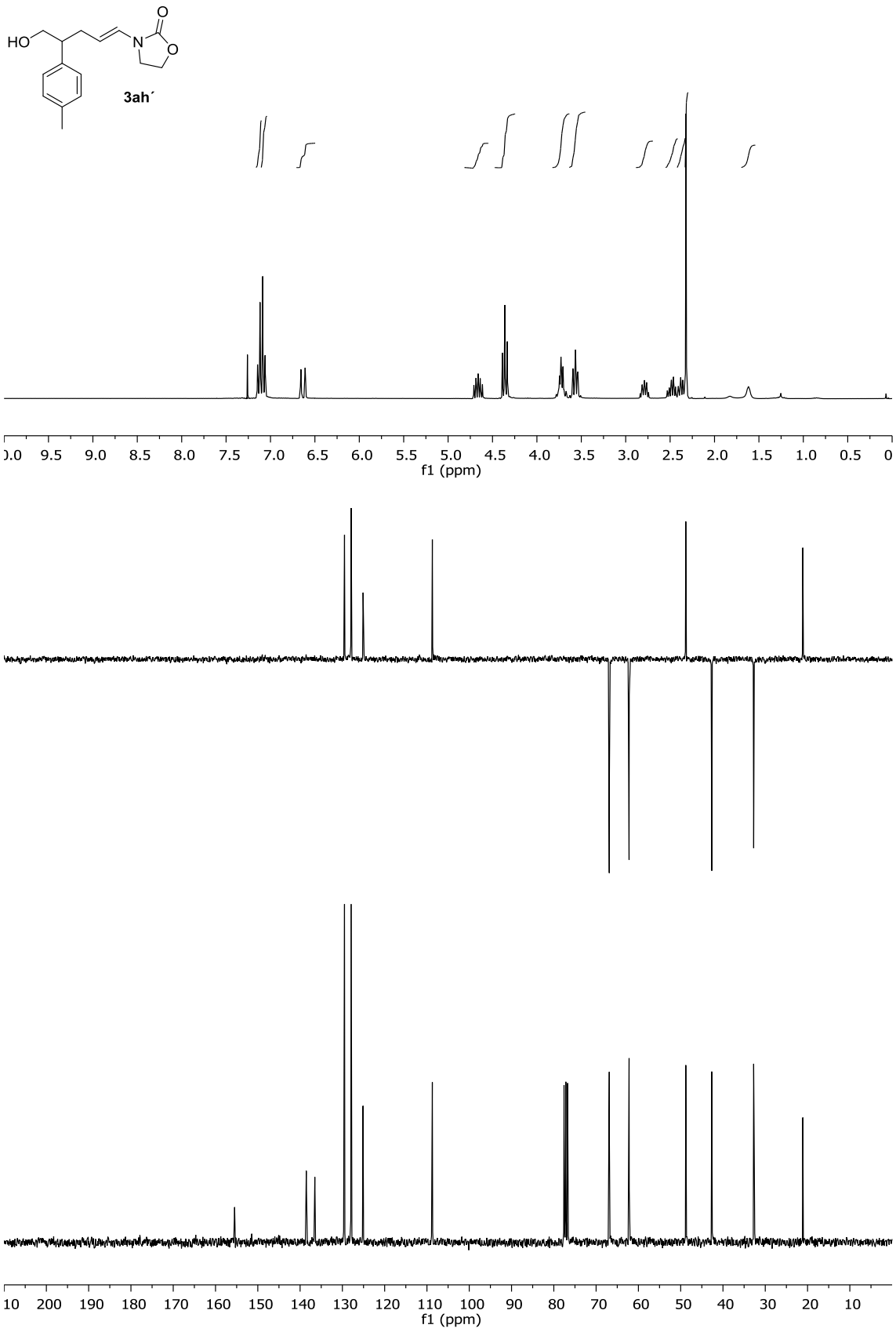

9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)

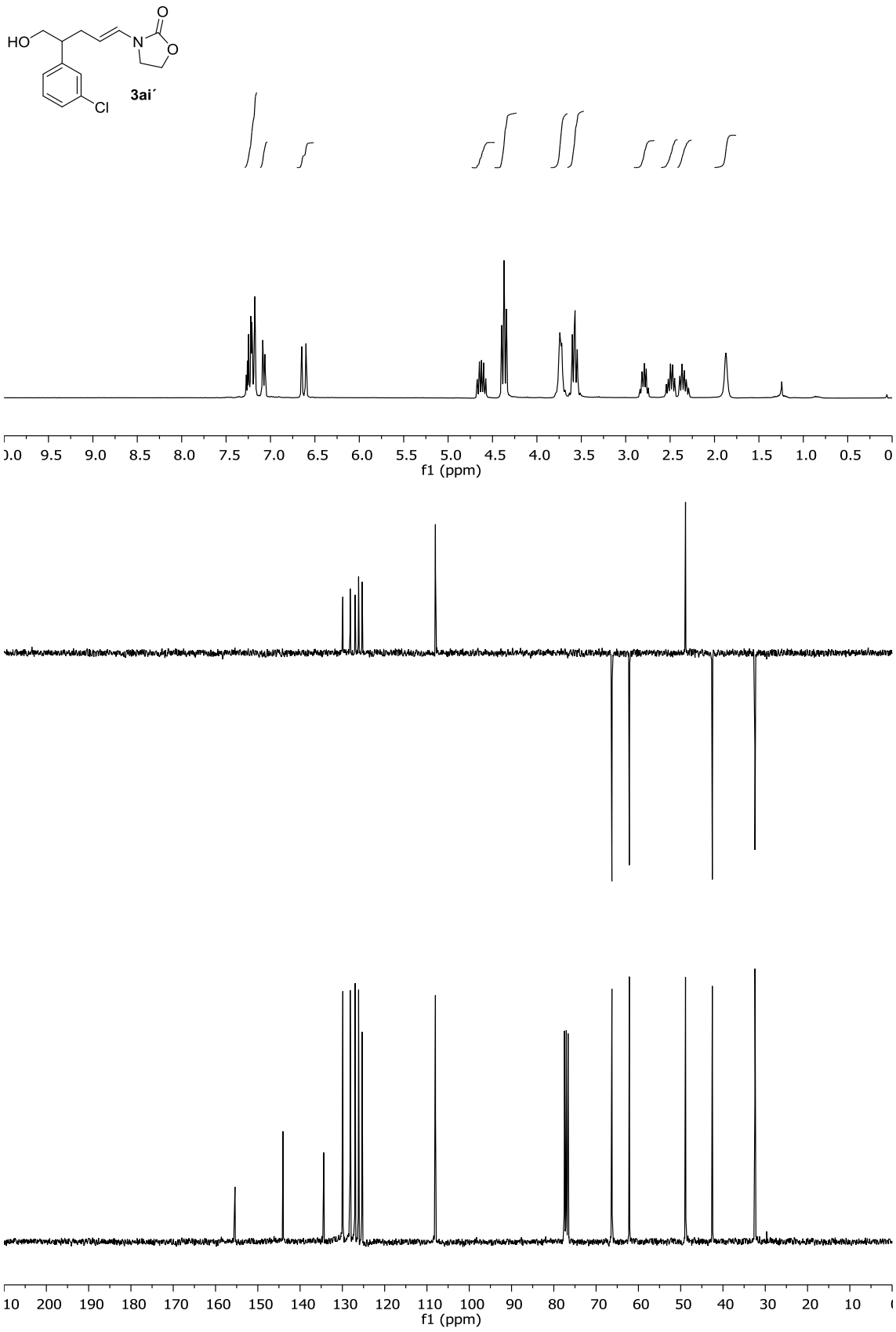

200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
f1 (ppm)

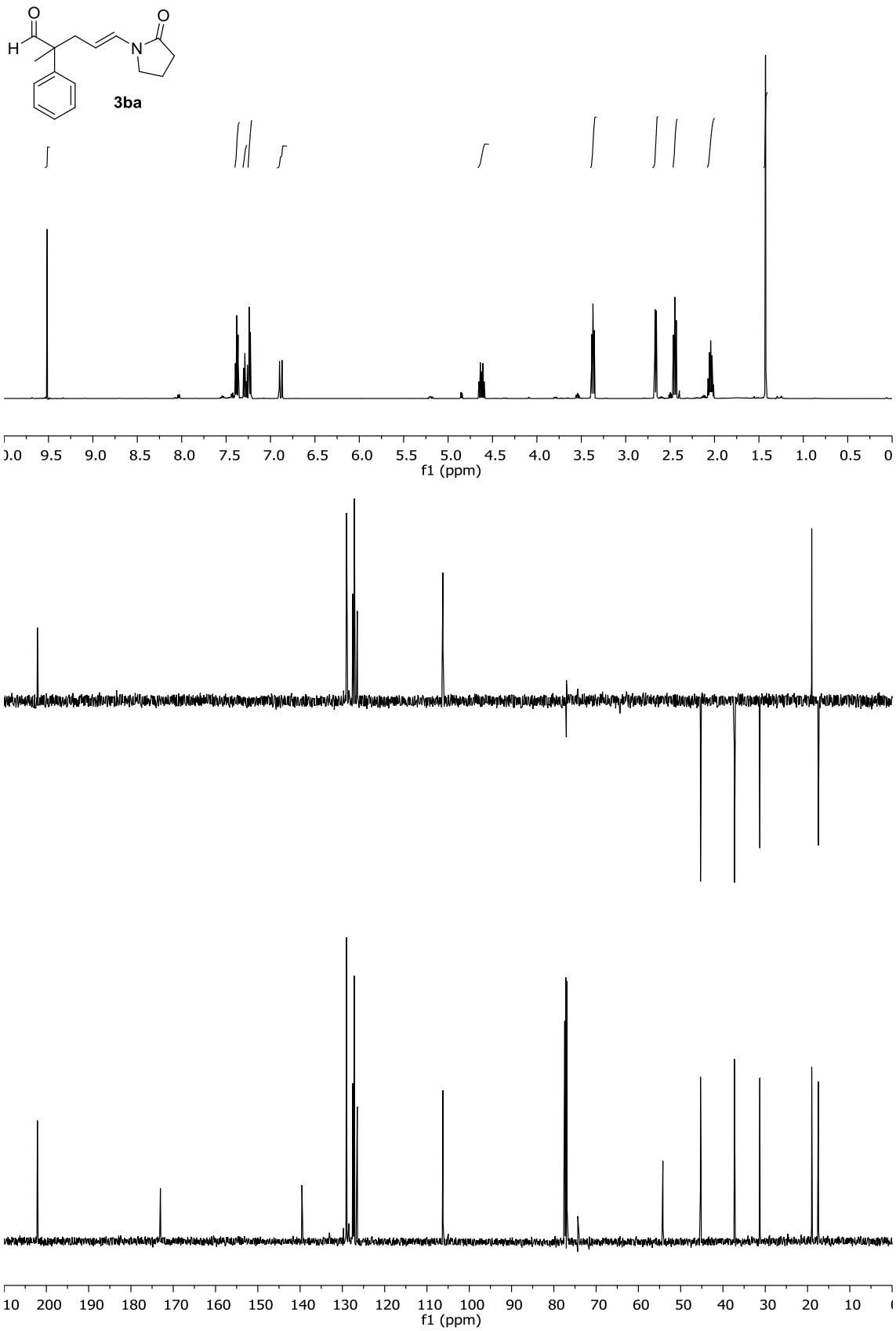

HO
O
N
O
3ae´
f1 (ppm)
f1 (ppm)

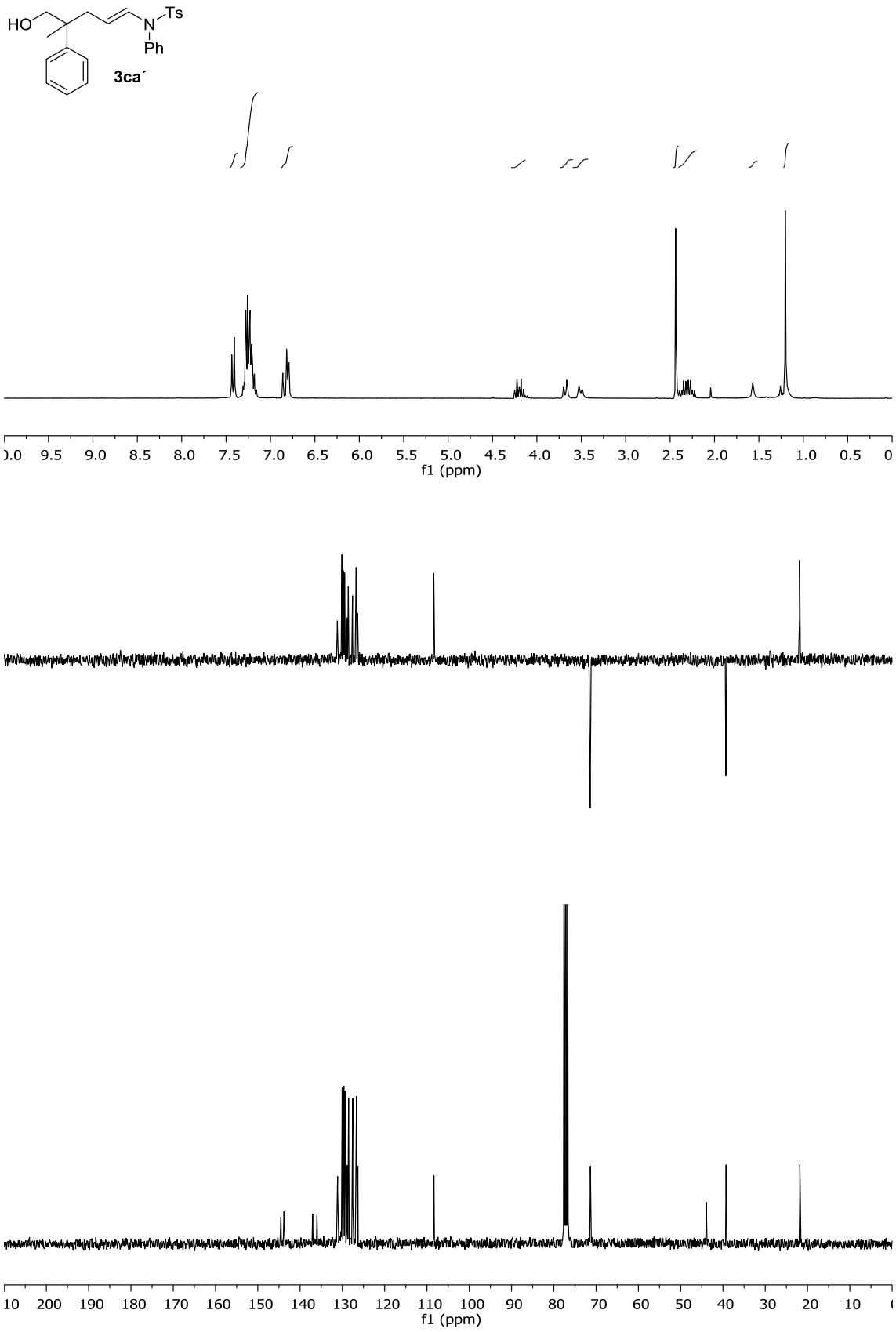

HO
O
N
O
OMe
3af´
f1 (ppm)
f1 (ppm)

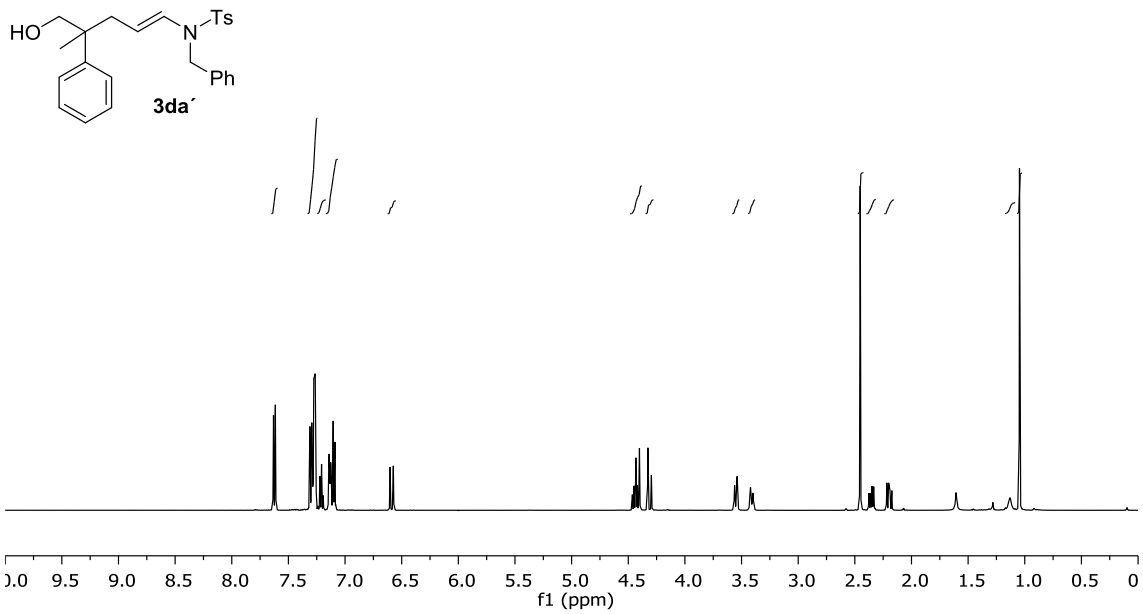

HO
O
N
O
F
3ag´
f1 (ppm)
f1 (ppm)

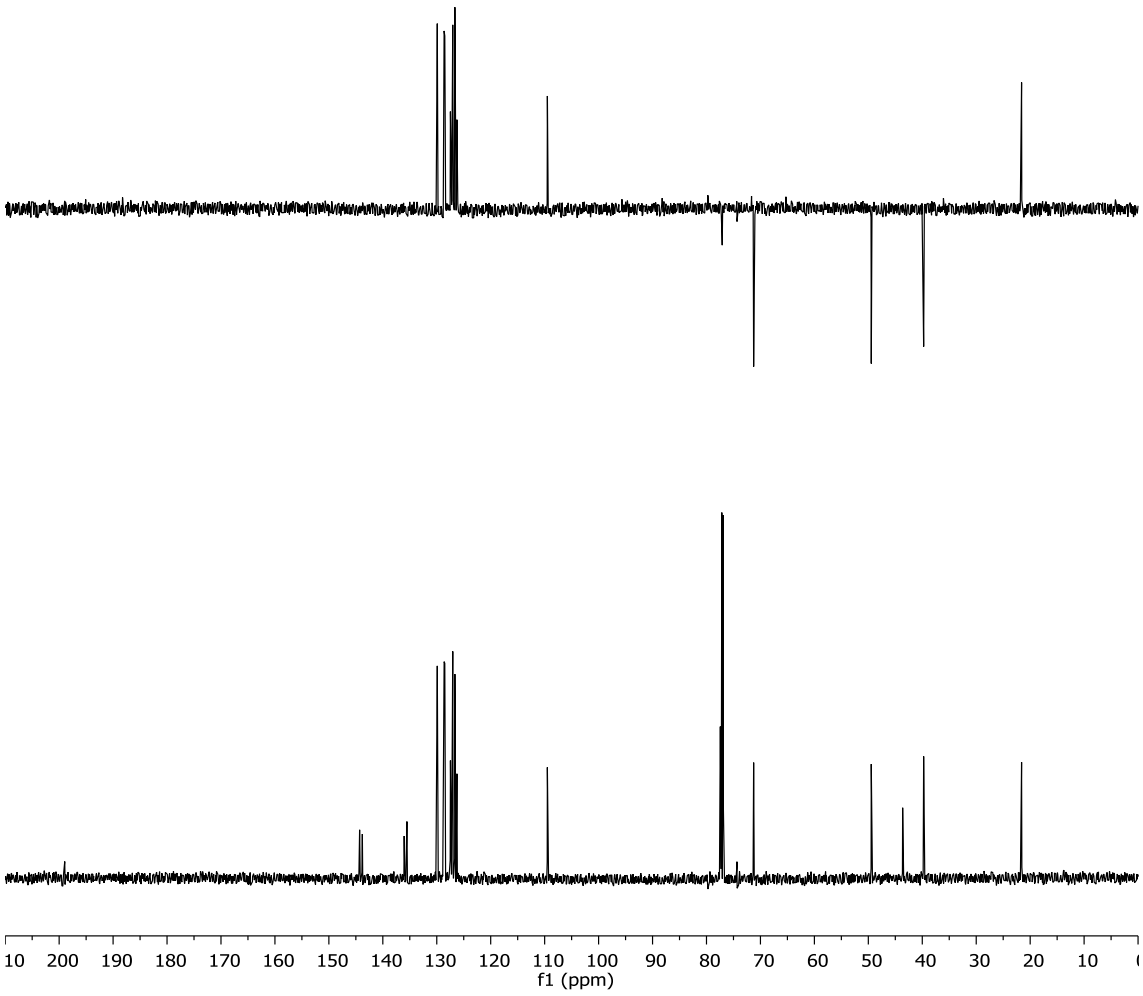

HO
O
N
O
3ah´
f1 (ppm)
f1 (ppm)

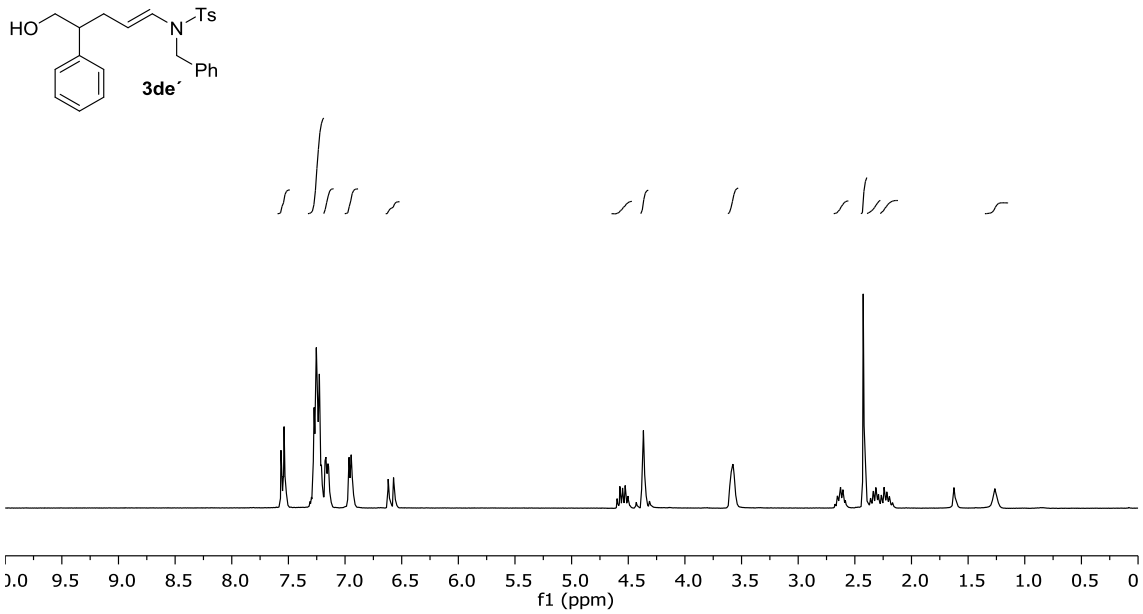

HO
O
N
O
Cl
3ai´
f1 (ppm)
f1 (ppm)

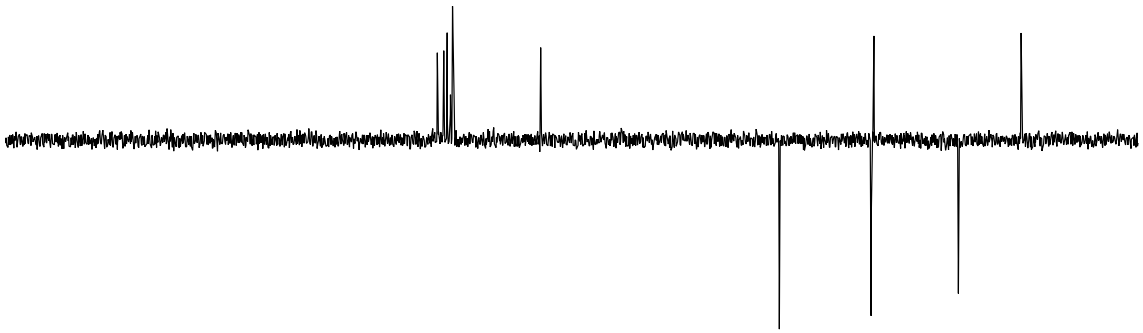

O
H
O
N
3ba
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0
f1 (ppm)
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
f1 (ppm)

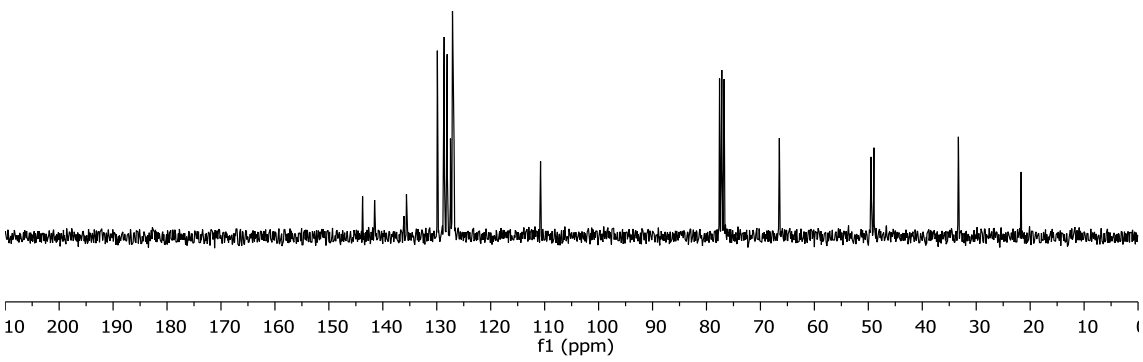

HO
Ts
N
Ph
3ca´
f1 (ppm)
f1 (ppm)

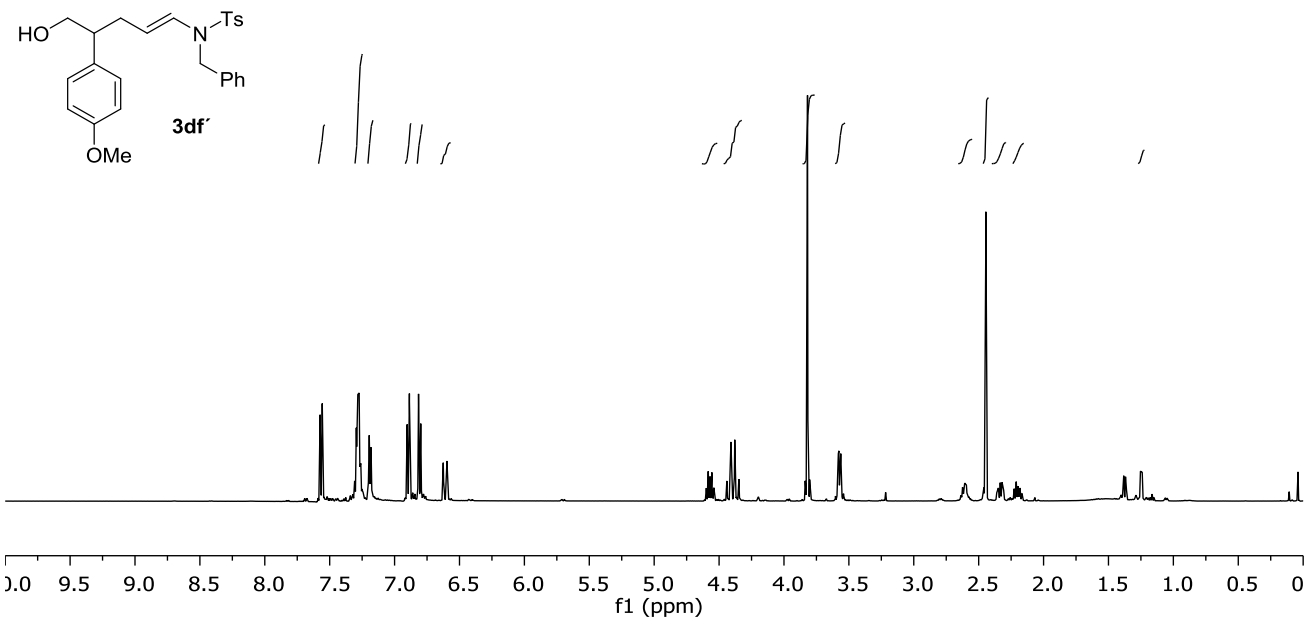

HO
N
Ts
Ph
3da´
f1 (ppm)

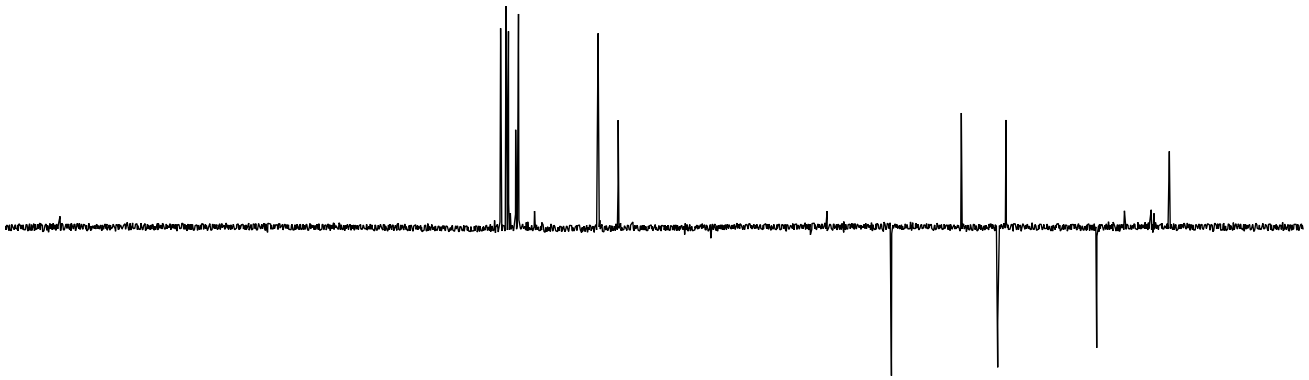

f1 (ppm)

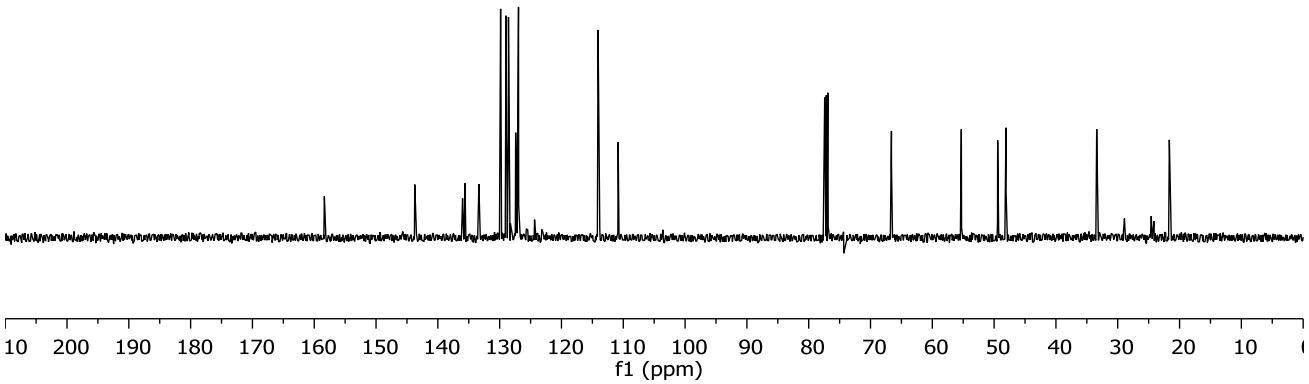

HO
Ts
N
Ph
3de´
f1 (ppm)



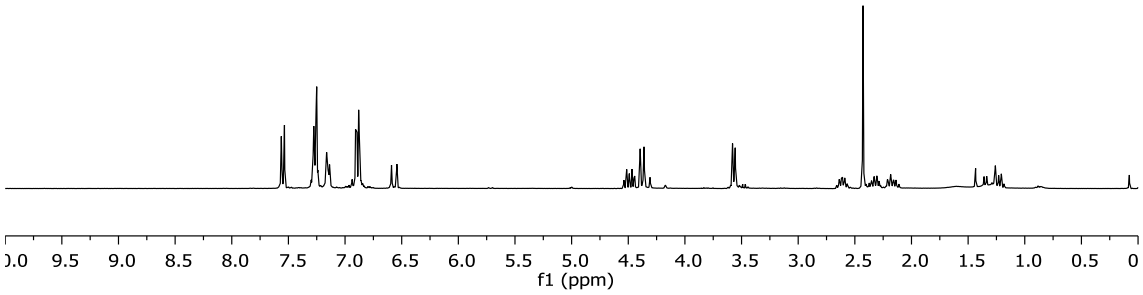

f1 (ppm)

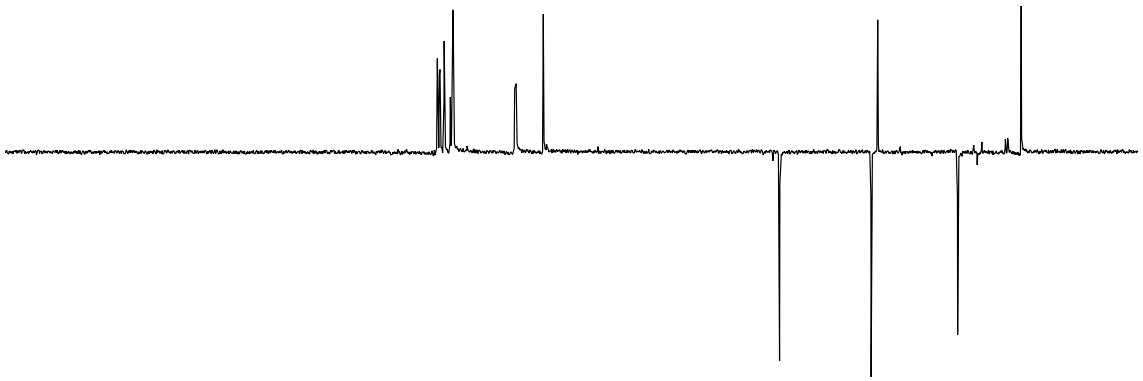

HO
N
Ts
Ph
OMe
3df´
f1 (ppm)

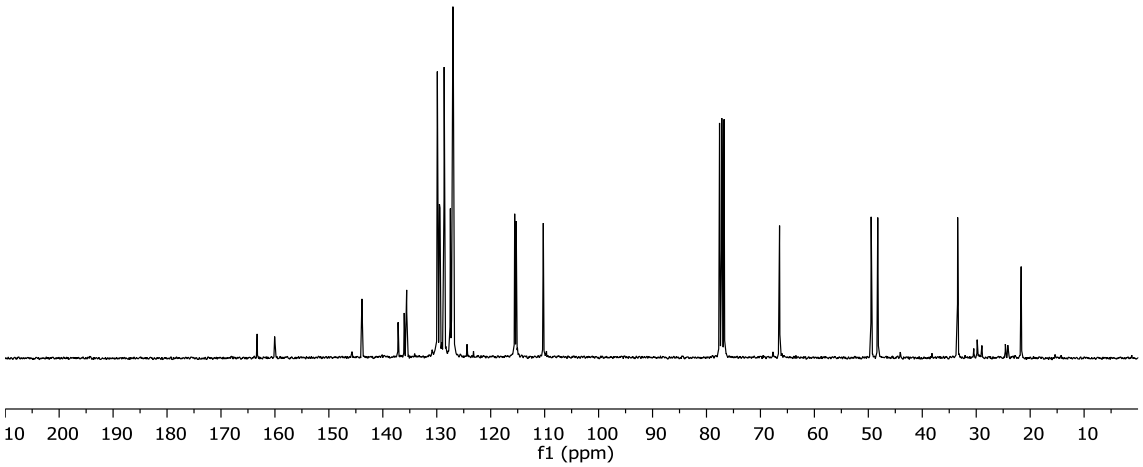


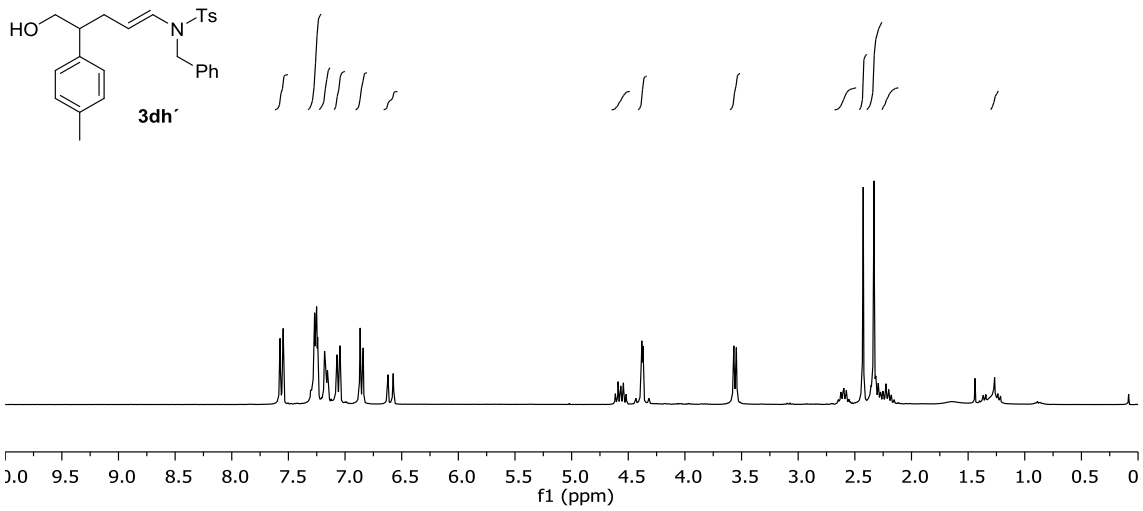

f1 (ppm)

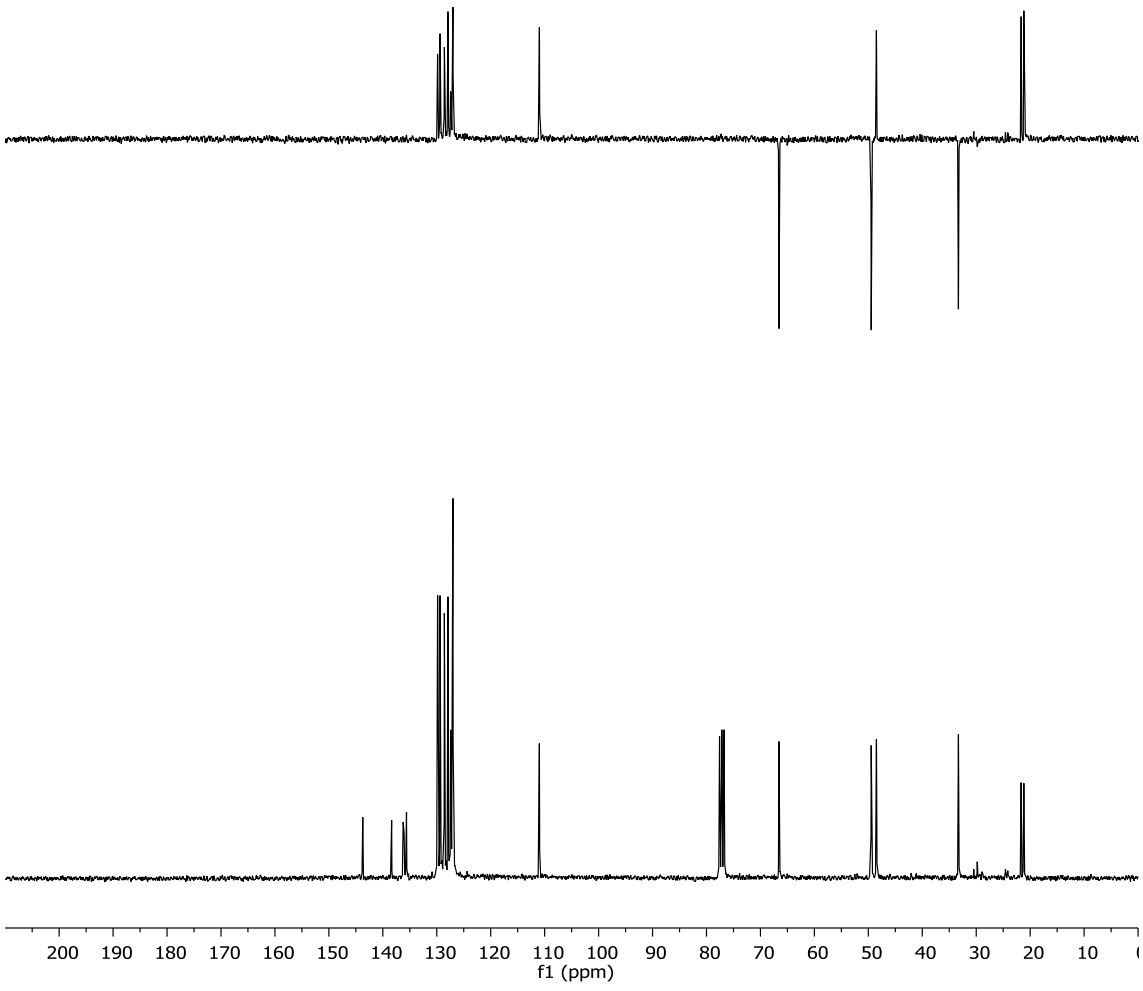

HO
Ts
N
Ph
F
3dg´

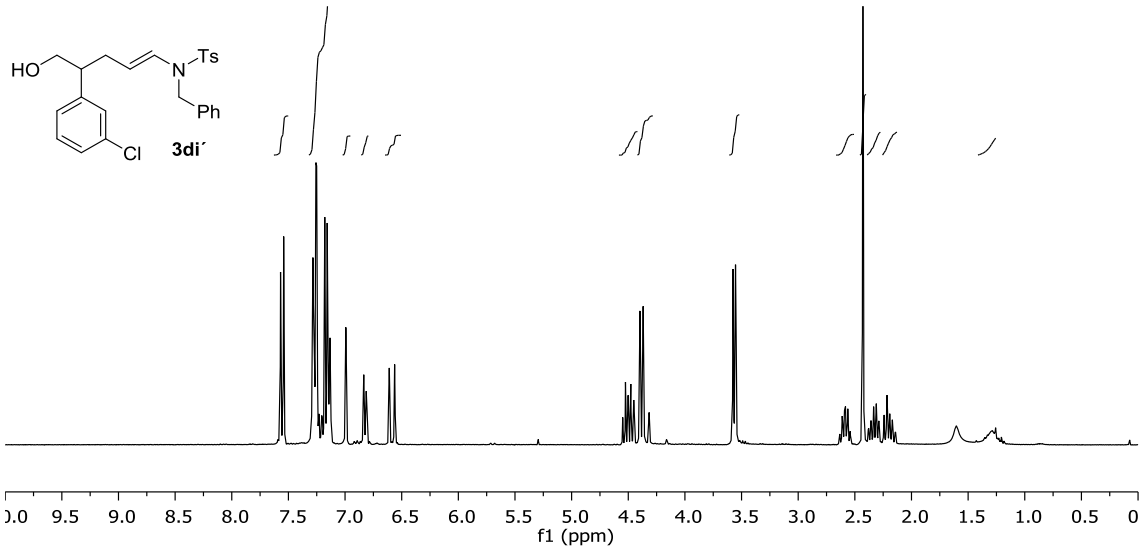

0.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0
f1 (ppm)

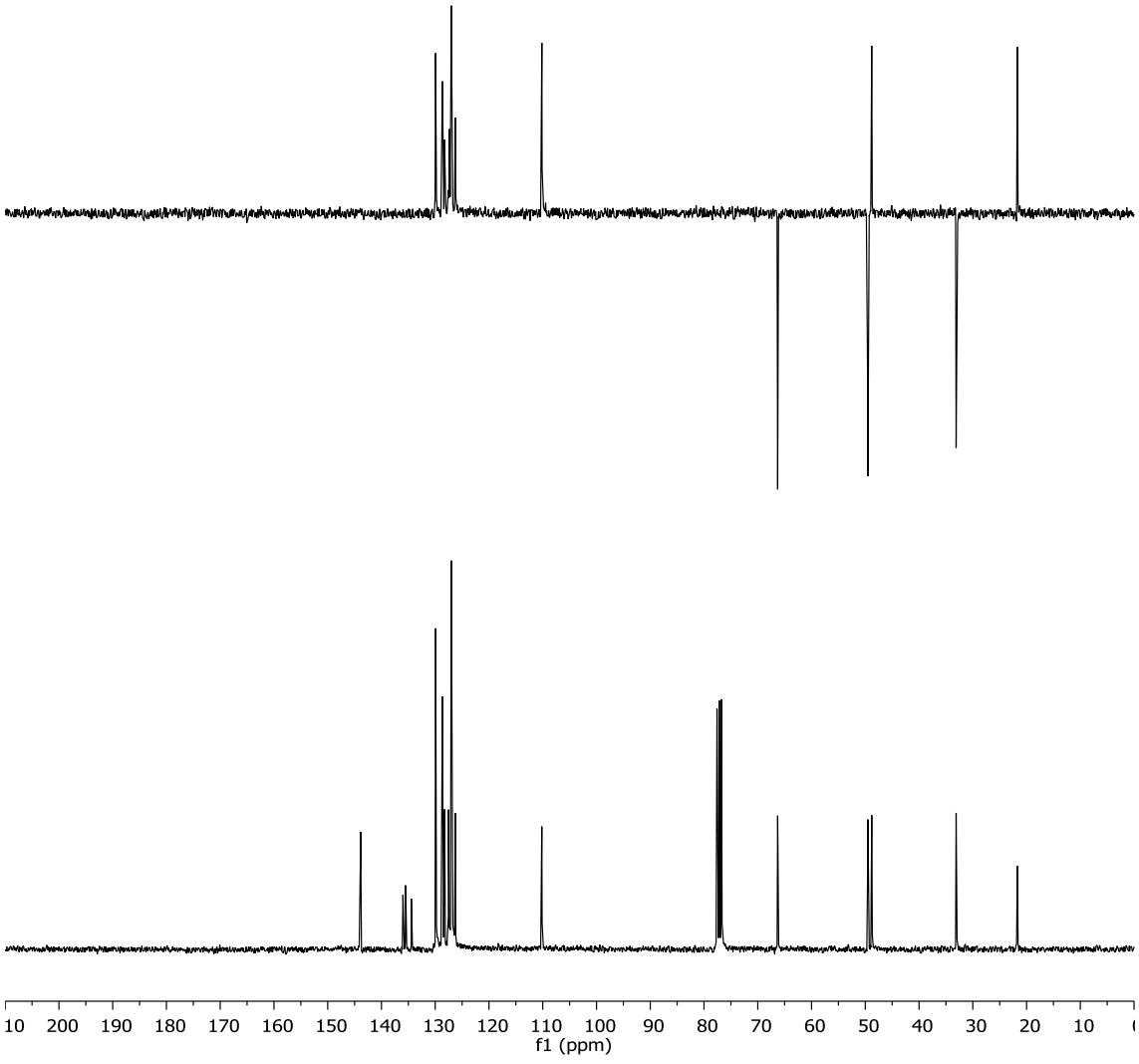


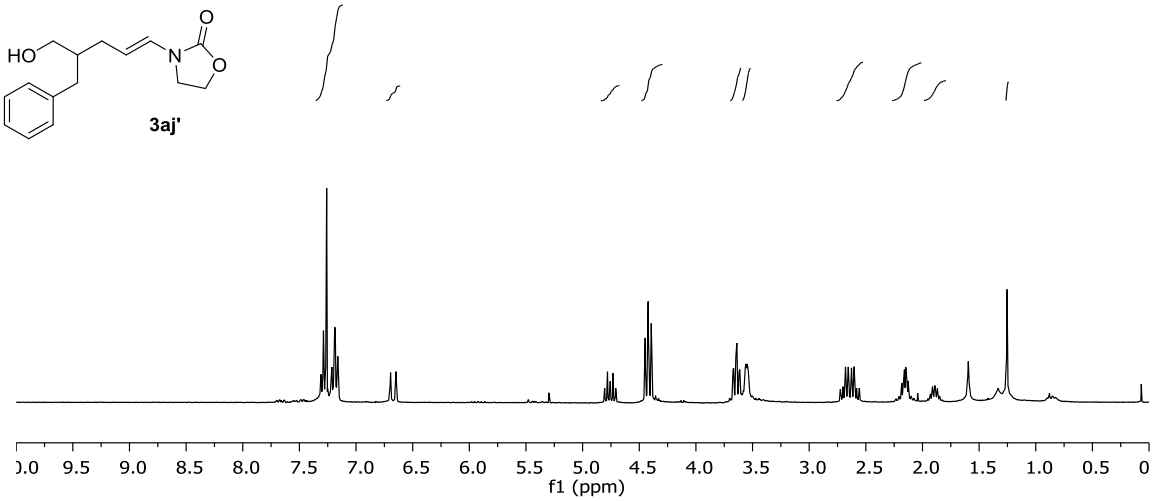

210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
f1 (ppm)

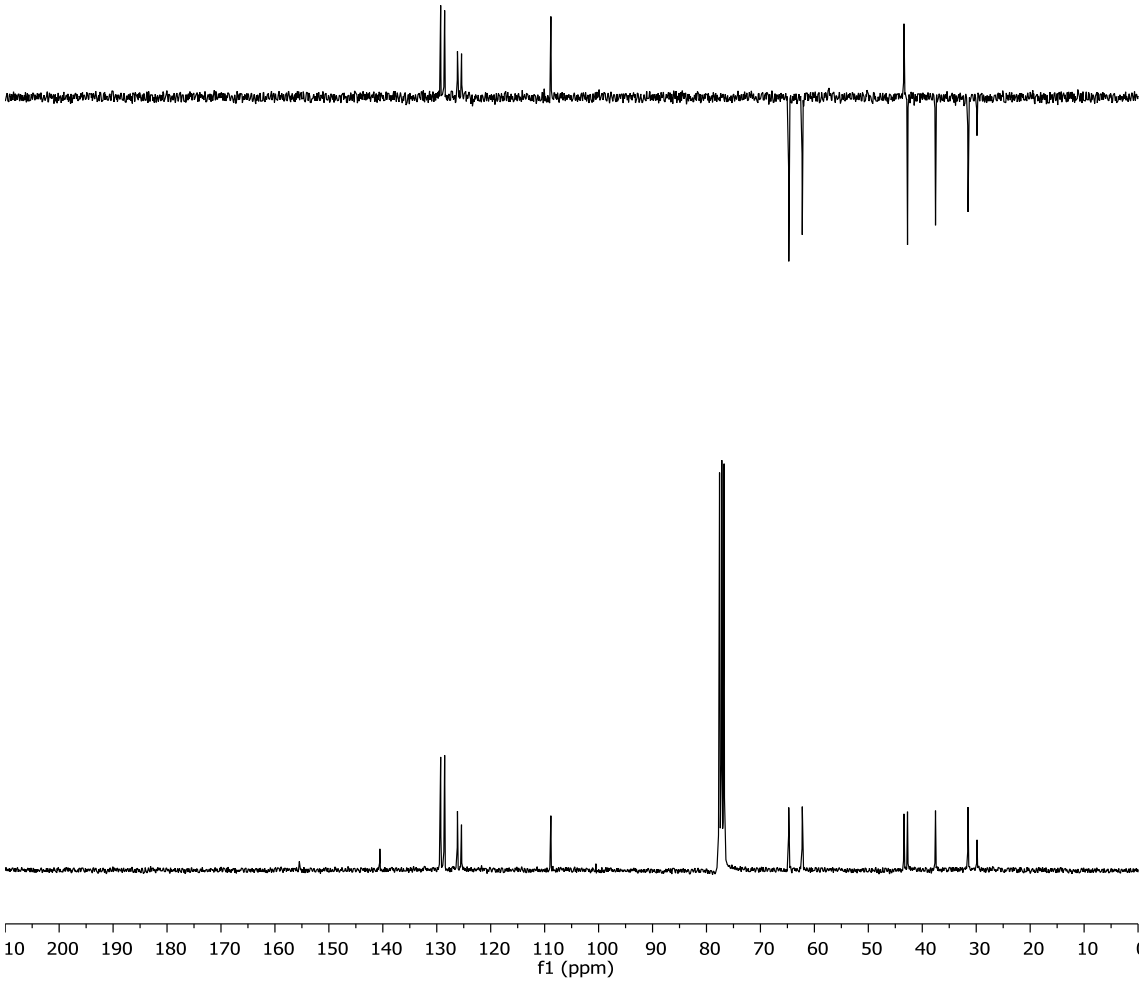

HO
Ts
N
Ph
3dh´
f1 (ppm)


f1 (ppm)


HO
Ts
N
Ph
Cl
3di´
f1 (ppm)


f1 (ppm)


HO
O
N
O
3aj'
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0
f1 (ppm)


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