Organocatalytic enantioselective allylic alkylation of MBH-carbonates with β-ketoesters

M. Kamlar,[a] S. Hybelbauerová[b] I. Císařová[c] and J. Veselý[a]

[a] Department of Organic Chemistry, Faculty of Science, Charles University in Prague, Hlavova 2030, 128 43 Praha 2, Czech Republic, e-mail: jxvesely@natur.cuni.cz, fax: +42-221951226.

[b] Department of Chemical Education, Faculty of Science, Charles University in Prague, Hlavova 2030, 128 43 Praha 2, Czech Republic.

[c] Department of Inorganic Chemistry, Faculty of Science, Charles University in Prague, Hlavova 2030, 128 43 Praha 2, Czech Republic.

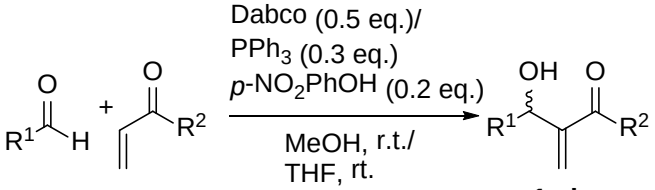
1 General procedure

Chemicals and solvents were either purchased (puriss p.A.) from commercial suppliers or purified by standard techniques. For thin-layer chromatography (TLC), silica gel plates Merck 60 F254 were used, and compounds were visualized by irradiation with UV light and/or by treatment with a solution of phosphomolybdenic acid (25 g), $Ce(SO_4)_2 \cdot H_2O$ (10 g), conc. H_2SO_4 (60 mL), and H_2O (940 mL) followed by heating or by treatment with a solution of p-anisaldehyde (23 mL), conc. H_2SO_4 (35 mL), acetic acid (10 mL), and ethanol (900 mL) followed by heating.

Flash chromatography was performed by using silica gel Merck 60 (particle size 0.040–0.063 mm). ^1H and ^{13}C NMR spectra were measured on FT-NMR spectrometer Bruker AVANCE III 600 MHz. Chemical shifts are given in ppm relative and coupling constants J are given in Hz. The spectra were recorded in $CDCl_3$ as solvent at room temperature and served as internal standard (δ = 7.26 ppm) for ^1H NMR and (δ = 77.0 ppm) for ^{13}C NMR. IR DRIFT spectras were recorded with Nicolet AVATAR 370 FT-IR in cm^{-1}. Chiral HPLC was carried out using a LC20AD Shimadzu liquid chromatograph with SPD-M20A diode array detector with columns Daicel Chiralpak® IA, Daicel Chiralpak® IB, Daicel Chiralpak® AD. High-resolution mass spectroscopic data were obtained at Institute of Organic Chemistry and Biochemistry, Academy of Science, v.v.i.

2 Preparation of Reagents and Substrates

2.1 Preparation of MBH alcohols

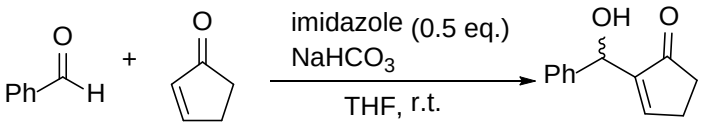


a) R^1 = Ph, R^2 = OMe b) R^1 = *p*-ClPh, R^2 = OMe
c) *p*-BrPh, R^2 = OMe d) *o*-BrPh, R^2 = OMe
e) *p*-MeOPh, R^2 = OMe f) *p*-MePh, R^2 = OMe
g) 1-thienyl, R^2 = OMe h) *p*-NO_2Ph, R^2 = OMe
i) 1-naphthy, R^2 = OMe j) Ph, R^2 = Me
k) E-styryl, R^2 = OMe

Following the reported procedure in case of esters,[1] to a stirred solution of arylaldehyde (1 eq.) in methanol was added methyl acrylate (1.2 eq.) and then 1,4-diaza-bicyclo[2.2.2]octane (0.5 eq.). The solution was stirred at room temperature 48-120 hours. The crude reaction mixture was purified by column chromatography (Hex/EtOAc mixtures) affording products **1**. NMR spectra fit with data published in literature.

Following the reported procedure in case of methylvinyl ketone,[2] to stirred solution of benzaldehyde (1 eq.) PPh_3 (0.2 eq.) and *p*-NO_2PhOH (0.3 eq.) in THF was added methylvinyl ketone at room temperature. The crude reaction mixture was purified by column chromatography (Hex/EtOAc mixture) afforting product **1l**. NMR spectra fit with data published in the literature.

[1] D. J. V. C. van Steenis, T. Marcelli, M. Lutz, A. L. Spek, J. H. van Maarseveen and H. Hiemstra, *Adv. Synth. Catal.* **2007**, 349, 281-286.
[2] Y.-H. Liu, and M. Shi, *Org. Biomol. Chem.* 2006, **4**, 1468-1470.

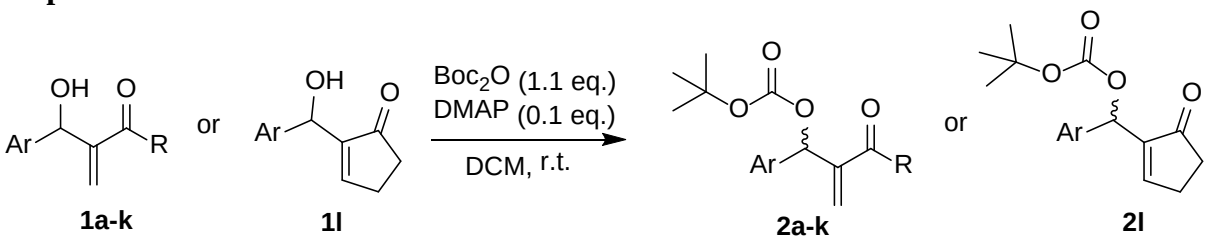


1l

Following the reported procedure,[3] to solution of benzaldehyde, imidazole and 1M water solution of $NaHCO_3$ in THF was added cyclopentenone at room temperature. After full conversion was reaction quenched by 1M HCl and washed with EtOAc. Organic phase was dried over Na_2SO_4. Reaction mixture was purified by column chromatography (Hex/EtOAc) affording prouct **1l**. NMR spectra correspond with data published in the literature.

2.1.1 Preparation of MBH carbonates and ester

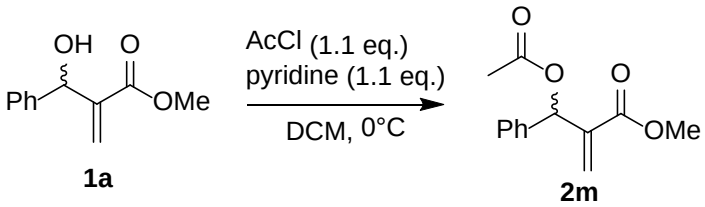
Preparation of MBH carbonates



1a-k **1l** **2a-k** **2l**

Following the reported procedure, to a solution of MBH alcohol **1** (1 eq.) in DCM was added Boc_2O (1.1 eq.) and 4-dimethylaminopyridine (0.1 eq.). The solution was monitored by TLC analysis and after full conversion (cca 3 hours) the solvent was removed and crude mixture was purified by column chromatography (Hex/EtOAc mixtures) affording compounds **2**. NMR data correspond with data published in the literature.

Preparation of MBH ester



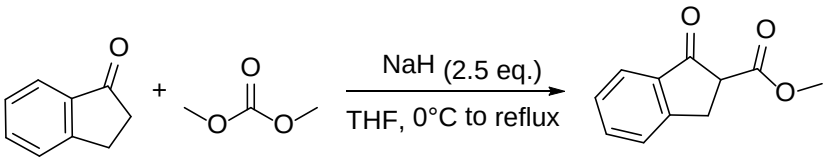
1a **2m**

methyl 2-(acetoxy(phenyl)methyl)acrylate (2m). Following the reported procedure,[4] to a solution of MBH alcohol **1a** (1 eq.) in DCM was added pyridine (1.1 eq.) and AcCl (1.1 eq.) at 0 °C. After full conversion (TLC monitoring) was reaction mixture quenched by addition of 1M HCl, extracted with DCM. Organic layer was washed with brine, dried over MgSO4, filtered and puriffied on silica gel affording desired product 2n in 85% yield as colorless oil. NMR data fit with data published in the literature.

2.1.2 Preparation of β-ketoesters

Preparation of methyl 2,3-dihydro-1-oxo-1H-indene-2-carboxylate

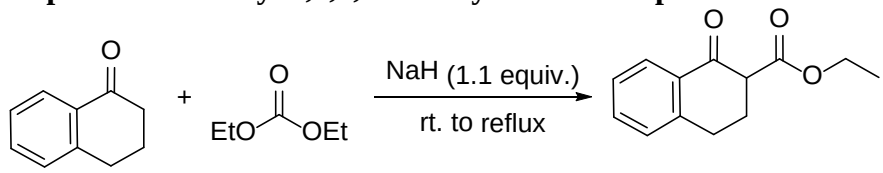
[3] K. Itoh and T. Makino, *J. Org. Chem*. 2004, **69**, 395-405.
[4] R.Annunziata, M. Benaglia, M. Cinquini, F. Cozzi and L. Raimondi, *J. Org. Chem.*, 1995, **60**, 4697-4706.



3h

According a reported procedure,[5] to a stirred solution of NaH (2.5 eq.) in dry toluene under argon was added dimethyl carbonate (6 eq.) and the mixture was warmed to 60 °C followed by dropwise addition of 1-indanone (1 eq.) during 1 hour. After additional stirring for 1 hour at 60 °C the reaction was cooled to room temperature and quenched by addition of acetic acid and 1M HCl. The aqueous phase was extracted by toluene and combined organic layer was washed with water, $NaHCO_3$ and brine, dried over $MgSO_4$ and concentrated in vacuo. The crude oil was purified by destilation under reduced pressure affording pure product **3h** (60 % yield) as collorless oil, which solidified on standing. NMR data fit with data published in the literature.

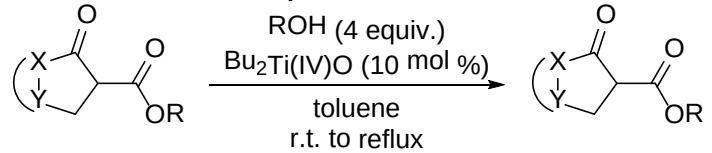
Preparation of Ethyl 1,2,3,4-tetrahydro-1-oxonaphthalene-2-carboxylate



3j

According a reported procedure,[6] 1-Tetralon (1 equiv.) was added to the suspension of NaH (1.1 equiv.) in diethyl carbonate (10 equiv.). The mixture was refluxed under Ar atmosphere for 2 h. The crude mixture was quenched by addition of 1M aqueous HCl at rt and then extracted with Et_2O. Organic phase was then treated with brine and dried over anhydrous $MgSO_4$, filtered and concentrated by distillation under reduced pressure. The residue was separated on silica gel using Hex:EtOAc (15:1)obtaining ketoester **3j** as yellow oil in 69% yield. NMR spectra correspondes with data published in literature.

Preparation of other β-oxoesters



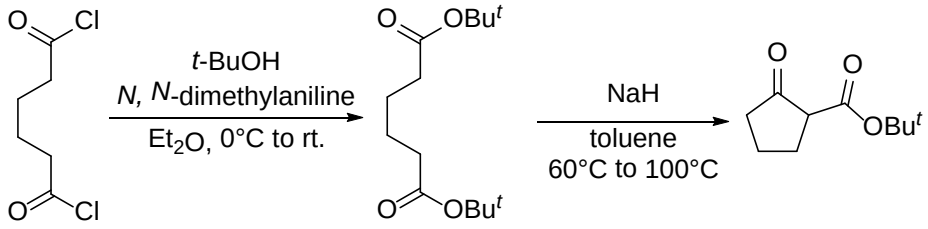
3a (X-Y = C_2H_4, R = Et)
3h (X-Y = C_6H_4, R = Me)

3b (X-Y = C_2H_4, R = *i*-Pr)
3e (X-Y = C_6H_4, R = 1-adamantyl)
3f (X-Y = C_6H_4, R = *i*-Pr)
3g (X-Y = C_6H_4, R = Et)

According a reported procedure,[7] oxoester **3a/3h** (1 eq.), appropriate alcohol (5 eq.) and dibutyltin oxide (0.1 eq.) was refluxed in toluene. After full conversion was the reaction mixture purified by column chromatography affording corresponding oxoester. NMR data of corresponding oxoesters fit to data published in the literature.

Preparation of *tert*-Butyl 2-oxocyclopentane-1-carboxylate (3c)

[5] A. M. Smith, D. Billen and K. K. Hii, *Chem. Commun.* 2009, 3925-3927.
[6] H. Tsuchida, M. Tamura and E. Hasegawa; *J. Org. Chem.* 2009, **74**, 2467-2475.
[7] A. M. R. Smith, H. S. Rzepa, A. J. P. White, D. Billen and K. K. Hii, *J. Org. Chem.* 2010, **75**, 3085-3096.

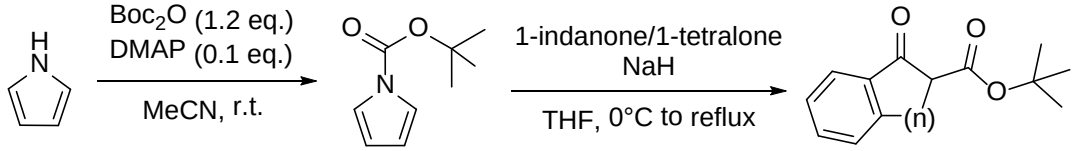


3c

di-*tert*-Butyl adipate. According a reported procedure,[8] to a vigorously stirred solution of *tert*-butanol (3 eq.) and N,N-dimethylaniline (3 eq.) in diehtylether at 0 °C was dropwise added solution of adipoyl chloride (1 eq.) in diethylether. The mixture was stirred overnight at rt. and the mixture was then washed with water. Organic layer was washed with 1M HCl, $NaHCO_3$, brine and then dried over $MgSO_4$. After filtration and concentration in vacuo was obtained appropriate compound as colorless oil (72%), which crystalized on standing. NMR data of di-tert-Butyl adipate correspond with data published in the literature.

***tert*-Butyl 2-oxocyclopentane-1-carboxylate (3c).** According a reported procedure, sodium hydride (1 eq.) was suspended in in dry toluene and the mixture heated to 60 °C for 30 minutes. Then after was added solution of di-*tert*-butyl adipate (0.1 eq.) in tert-butanol (1 mL). After additional 30 minutes was added remained di-*tert* butyl adipate dissolved in toluene. Reacion mixture was then stirred for 3 hours at 100 °C. After cooling in ice bath was the reaction mixture quenched by addition of MeOH, H_2O a NH_4Cl. Organic layer was separated and water layer was extracted by toluene. Combined organic layer was dried over $MgSO_4$, filtered, concentrated in vacuo and desired compound **3c** was obtained by distillation under reduced pressure in 45% yeild. NMR data **3c** correspond with data published in the literature.

Preparation of *tert*-butyl β-ketoester derivatives containing indene and tetralone moiety



3d (n = CH_2)
3i (n = C_2H_4)

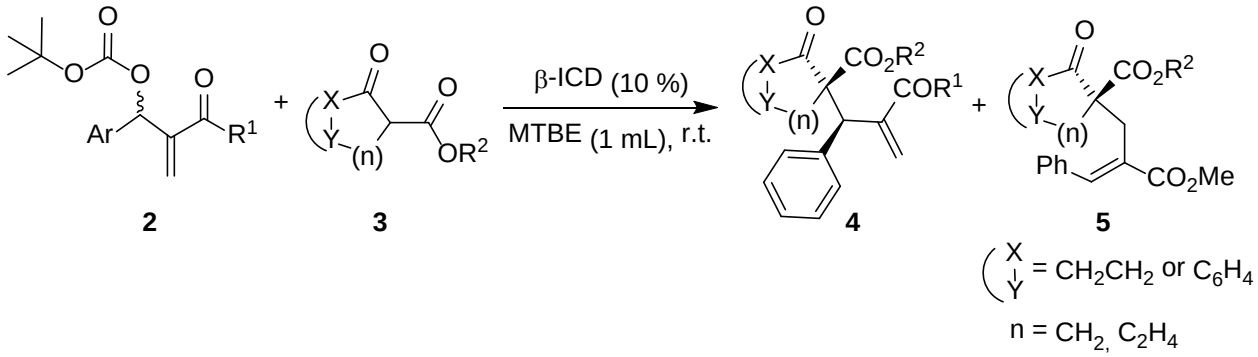
***tert*-Butyl 1H-pyrrole-1-carboxylate.** Following the slightly modified procedure,[9] to the solution of pyrrole (1 eq.) in acetonitrile was added Boc_2O (1.2 eq.) and 4-dimethylaminopyridine (0.1 eq.) and the solution was stirred overnight. The reaction mixture was then diluted with Et_2O, washed with $NaHCO_3$ and brine. Organic layer was dried over $MgSO_4$, filtered and concentrated under reduced pressure. The crude product was purified by column chromatography (Hex/EtOAc) yielding the title compound as colorless oil (85 %). NMR data of title compound fit with data published in the literature.

***tert*-Butyl 1-oxo-2,3-dihydro-1*H*-indene-2-carboxylate (3d).** According a reported procedure,[10] to a stirred solution of NaH (2 eq.) in dry THF was added 1-indanone (1 eq.) at room temperature. The solution was then warm to reflux and tert-butyl 1H-pyrrole-1-carboxylate (2 eq) in dry THF was added dropwise and the solution was stirred at reflux after full conversion. After cooling to 0°C was the reaction mixture acidified with 1M HCl and

[8] M. E. Bunnage, S. G. Davies, R. M. Parkin, P. M. Roberts, A. D. Smith, J. M. Withey, *Org. Biomol. Chem.* 2004, **2**, 3337-3354.
[9] J. E. Taylor, M. D. Jones, J. M. J. Williams and S. D. Bull, *Org. Lett.* 2010, **12**, 5740-5743.
[10] T. A. Moss, D. R. Fenwick and D. J. Dixon, *J. Am. Chem.Soc.*, 2008, **130**, 10076-10077.

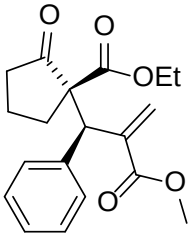
then extracted with EtOAc and the organic layer was washed with brine, dried with Na_2SO_4, concentrated and purified on silica (Hex/EtOAc) affording compound **3d** (72 %) as violet oil.
***tert*-Butyl 1,2,3,4-tetrahydro-1-oxonaphthalene-2-carboxylate (3i)**. According a reported procedure,[10] to a stirred solution of NaH (2 eq.) in dry THF was added 1-indanone (1 eq.) at room temperature. The solution was then warm to reflux and tert-butyl 1H-pyrrole-1-carboxylate (2 eq) in dry THF was added dropwise and the solution was stirred at reflux after full conversion. After cooling to 0°C was the reaction mixture acidified with 1M HCl and then extracted with EtOAc and the organic layer was washed with brine, dried with Na_2SO_4, concentrated and purified on silica (Hex/EtOAc) affording compound **3i** (40 %) as yellow oil. NMR data of **3d** and **3i** fit with data published in the literature.

2.2 Asymmetric allylic alkylation



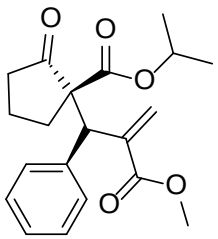
To a stirred solution of β-ICD (0.010 mmol) and MBH carbonate **2** (0.11 mmol) in *tert*-butylmethyl ether (1 mL) was added appropriate β-ketoester **3** (0.1 mmol) at room temperature. After completion of the reaction the crude reaction mixture was purified by column chromatography (Hex/EtOAc mixtures) affording compound **4**.

Ethyl (*R*)-1-((*R*)-2-(methoxycarbonyl)-1-phenylallyl)-2-oxocyclopentane-1-carboxylate


4aa

Yellowish oil, yield 45 %, 58 % ee. The ee was determined by HPLC analysis using Chiralpak AD column (98/2 heptane/*i*-PrOH, flow rate 1.0mL/min; λ = 190 nm, t_{major} = 9.8 min., t_{minor} = 11.0 min); ^{1}H NMR (600 MHz, $CDCl_3$): δ = 7.26–7.23 (m, 2H), 7.21-7.19 (m, 1H), 7.14-7.13 (m, 2H), 6.40 (s, 1H), 5.70 (d, *J* = 0.9 Hz, 1H), 5.22 (s, 1H), 4.19 (dq, *J* = 10.8 Hz, *J´* = 7.2 Hz, 1H), 4.09 (dq, *J* = 10.8 Hz, *J´* = 7.1 Hz, 1H), 3.61 (s, 3H), 2.86 (ddd, *J* = 13.2 Hz, *J´* = 4.3 Hz, *J´´* = 7.2 Hz, 1H), 2.19 (ddd, *J* = 18.2 Hz, *J´* = 8.3 Hz, *J´´* = 4.7 Hz, 1H), 2.11 (ddd, *J* = 13.3 Hz, *J´* = 8.5 Hz, *J´´* = 8.5 Hz, 1H), 1.84–1.79 (m, 1H), 1.62–1.54 (m, 1H), 1.34–1.28 (m, 1H), 1.20 (t, *J* = 7.1Hz, 3H) ppm; ^{13}C NMR (151 MHz, $CDCl_3$): δ = 213.14, 168.74, 166.80, 140.73, 136.92, 129.84 (2C), 128.41 (2C), 127.30, 124.80, 65.15, 61.92, 52.06, 49.78, 38.32, 28.46, 19.66, 13.89 ppm; $[\alpha]_D$ = -153.7° (c = 0.40, $CHCl_3$); IR (KBr): *ν* = 3084, 3060, 3025, 2983, 2947, 2899, 1748, 1721, 1625, 1491, 1464, 1452, 1431, 1401,1365, 1284, 1227, 1162, 1138, 713 cm^{-1}; HRMS (ESI) m/z calcd for $C_{19}H_{22}O_5Na$ $[M+Na]^+$ = 353.1359, found = 353.1359.

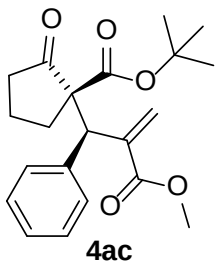
Isopropyl (*R*)-1-((*R*)-2-(methoxycarbonyl)-1-phenylallyl)-2-oxocyclopentane-1-carboxylate


4ab

Collorless oil, yield 36 %, 77 % ee. The ee was determined by HPLC analysis using Chiralpak AD column (99/1 heptane/*i*-PrOH, flow rate 1.0mL/min; λ = 190 nm, t_{major} = 9.3 min., t_{minor} = 11.4 min); ^{1}H NMR (600 MHz, $CDCl_3$): δ = 7.25–7.18 (m, 3H), 7.14-7.12 (m, 2H), 6.40 (s, 1H), 5.71 (d, *J* = 1.2 Hz, 1H), 5.21 (s, 1H), 4.97–4.93 (m, 1H), 3.60 (s, 3H), 2.85–2.82 (m, 1H), 2.20–2.15 (m, 1H), 2.11–2.06 (m, 1H), 1.85–1.77 (m, 1H), 1.61–1.54 (m, 1H), 1.33–1.28 (m, 1H), 1.22 (d, *J* = 6.2 Hz, 3H), 1.14 (d, *J* = 6.2 Hz, 3H) ppm; ^{13}C NMR (151 MHz, $CDCl_3$): δ = 213.01, 168.17, 166.82, 140.77, 136.99, 129.83 (2C), 128.36 (2C), 127.22, 124.82, 69.42, 65.17, 52.02, 49.59, 38.24, 28.45,21.53, 21.17, 19.66 ppm; $[\alpha]_D$ = -139.3° (c = 0.42, $CHCl_3$); IR (KBr): *ν* = 3093, 3060, 3025, 2986, 2950, 2923, 2884, 1963, 1909, 1745,

1715, 1625, 1500, 1443, 1368, 1284, 1224, 1186, 1132, 1108, 955, 707 cm^{-1} ; HRMS (ESI) m/z calcd for $C_{20}H_{24}O_5Na$ [M+Na]+ = 367.1516, found = 367.1515.

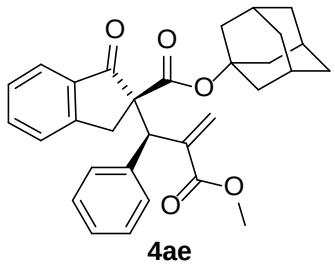
tert-Butyl (_R_)-1-((_R_)-2-(methoxycarbonyl)-1-phenylallyl)-2-oxocyclopentane-1-carboxylate



4ac

Yellow oil, yield 47 %, 81 % ee. The ee was determined by HPLC analysis using Chiralpak IB column (98/2 heptane/*i*-PrOH, flow rate 1.0 mL/min; λ = 190 nm, t_{minor} = 5.2 min., t_{major} = 5.4 min); ^{1}H NMR (600 MHz, $CDCl_3$): δ = 7.25–7.22 (m, 2H), 7.20-7.17 (m, 1H), 7.14-7.12 (m, 2H) 6.41 (s, 1H), 5.72 (d, *J* = 1.1 Hz, 1H), 5.16 (s, 1H), 3.62 (s, 3H), 2.81–2.77 (m, 1H), 2.21–2.15 (m, 1H), 2.09–2.04 (m, 1H), 1.85–1.77 (m, 1H), 1.60–1.52 (m, 1H), 1.39 (s, 9H), 1.32–1.28 (m, 1H) ppm; ^{13}C NMR (151 MHz, $CDCl_3$): δ = 213.37, 167.69, 167.00, 140.96, 137.21, 129.86 (2C), 128.35 (2C), 127.17, 124.81, 82.16, 65.78, 52.03, 49.64, 38.23, 28.54, 27.61(3C), 19.66 ppm; $[\alpha]_D$ = -107.8° (c = 0.45, $CHCl_3$); IR (KBr): *ν* = 3087, 3055, 3031, 2977, 2950, 2929, 2881, 1751, 1721, 1682, 1631, 1494, 1452, 1437, 1392, 1368, 1284, 1242, 1150, 707 cm^{-1}; HRMS (ESI) m/z calcd for $C_{21}H_{26}O_5Na$ $[M+Na]^+$ = 381.1673, found = 381.1672.

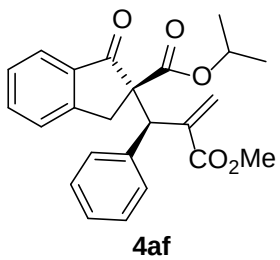
(3_S_,5_S_,7_S_)-adamantan-1-yl (_R_)-2-((_R_)-2-(tert-butoxycarbonyl)-1-phenylallyl)-1-oxo-2,3-dihydro-1_H_-indene-2-carboxylate



4ae

Off-white semisolid, yield 50 %, 85 % ee. The ee was determined by HPLC analysis using Chiralpak IB column (98/2 heptane/*i*-PrOH, flow rate 1.0mL/min; λ = 190 nm, t_{minor} = 6.7 min., t_{major} = 8.2 min); 1H NMR (600 MHz, CDCl3): δ = 7.60 – 7.59 (m, 1H), 7.43 – 7.41 (m, 1H), 7.28 – 7.27 (m, 1H), 7.22 – 7.19 (m, 1H). 7.15 – 7.14 (m, 2H), 7.08 – 7.05 (m, 2H), 7.01 – 6.98 (m, 1H), 6.49 (s, 1H), 5.79 (s, 1H), 5.42 (s, 1H), 3.97 (d, J=17.7 Hz, 1H), 3.64 (s, 3H), 3.27 (d, J=16.7 Hz, 1H), 2.12 (bs, 3H), 2.06 – 2.00 (m, 6H), 1.61 (s, 6H) ppm; 13C NMR (151 MHz, CDCl3): δ= 200.84, 167.51, 167.01, 153.94, 141.35, 136.46, 135.10, 134.45, 129.58 (2C), 128.08 (2C), 127.29, 127.02, 125.84, 124.71, 124.47, 82.48, 66.63, 52.10, 49.34, 40.81 (3C), 36.08 (3C), 32.91, 30.80 (3C) ppm; $[\alpha]_D$ = -255.7° (c = 0.87, $CHCl_3$); IR (KBr): *ν* = 3025, 2950, 2914, 2854, 1721, 1706, 1631, 1607, 1455, 1431, 1356, 1275, 1233, 1210, 1156, 1060 cm^{-1}; HRMS (ESI) m/z calcd for $C_{31}H_{32}O_5Na$ $[M+Na]^+$ = 507.2142, found = 507.2140.

Isopropyl (_R_)-2-((_R_)-2-(methoxycarbonyl)-1-phenylallyl)-1-oxo-2,3-dihydro-1_H_-indene-2-carboxylate

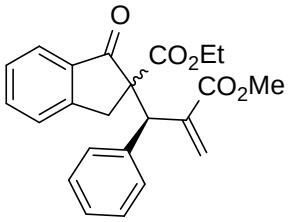


4af

Off-white semisolid, yield 40 %, 69 % ee. The ee was determined by HPLC analysis using Chiralpak AD column (95/5 heptane/*i*-PrOH, flow rate 1.0mL/min; λ = 190 nm, t_{major} = 12.1 min., t_{minor} = 13.9 min); ^{1}H NMR (600 MHz, $CDCl_3$): δ = 7.60-7.59 (m, 1H), 7.44-7.41 (m, 1H), 7.29-7.27 (m, 1H), 7.22-7.19 (m, 1H), 7.16-7.14 (m, 2H), 7.08-7.05 (m, 2H), 7.01-6.98 (m, 1H), 6.48 (s, 1H), 5.77 (d, J=1.0 Hz, 1H), 5.47 (s, 1H), 5.00-4.93 (m, 1H), 4.04 (d, J=17.8 Hz, 1H), 3.32 (d, J=16.1 Hz, 1H). 1.24 (d, J=6.3 Hz, 3H), 1.14 (d,J=6.3 Hz, 3H) ppm; ^{13}C NMR (151 MHz, $CDCl_3$): δ = 200.48, 168.46, 166.81, 153.79, 141.18, 136.14, 135.20, 134.35, 129.53 (2C), 128.09 (2C), 127.37, 127.11, 125.88, 124.67, 124.51, 69.80, 65.73, 52.09, 49.38, 32.86, 21.53, 21.19 ppm; $[\alpha]_D$ = -231.3° (c = 0.8, $CHCl_3$); IR (KBr): *ν* = 3090,

3066, 3019, 2974, 2929, 1712, 1607, 1497, 1479, 1272, 1236, 1207, 1171, 1102 cm^{-1}; HRMS (ESI) m/z calcd for $C_{24}H_{24}O_5Na$ $[M+Na]^+$ = 415.1516, found = 415.1515.

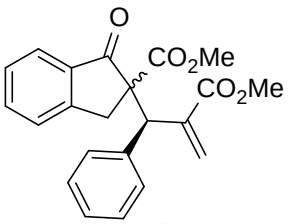
Ethyl 2-((*R*)-2-(methoxycarbonyl)-1-phenylallyl)-1-oxo-2,3-dihydro-1*H*-indene-2-carboxylate



4ag

Yellowish oil, yield 61 %, dr: 3:1, 65/71 % ee. The ee was determined by HPLC analysis using Chiralpak AD column (95/5 heptane/i-PrOH, flow rate 1.0 mL/min, λ = 190 nm, t_{1major} = 17.8 min., t_{1minor} = 20.9 min., t_{2minor} = 18.9 min., t_{2major} = 30.3 min.); ^{1}H NMR (600 MHz, $CDCl_3$): major diastereomer: δ = 7.61-7.59 (m, 1H), 7.45-7.42 (m, 1H), 7.30-7.28 (m, 1H), 7.23-7.20 (m, 1H), 7.16-7.14 (m, 2H), 7.08-7.05 (m, 2H), 7.02-6.99 (m, 1H), 6.48 (s, 1H), 5.76 (d, *J* = 1.4 Hz, 1H), 5.47 (d, *J* = 0.5 Hz, 1H), 4.19 (q, *J* = 7.1 Hz, 1H), 4.14 (q, *J* = 7.2 Hz, 1H), 4.06 (d, *J* = 16.8 Hz, 1H), 3.63 (s, 3H), 3.35 (d, *J* = 16.8 Hz), 1.21 (t, *J* = 7.2 Hz, 3H) ppm; ^{13}C NMR (151 MHz, $CDCl_3$): major diastereomer: δ = 200.49, 169.05, 166.79, 153.77, 141.13, 136.07, 135.31, 134.32, 129.54 (2C), 128.13 (2C), 127.44, 127.16, 125.92, 124.68, 124.58, 65.61, 62.22, 52.12, 49.55, 32.87, 13.92 ppm; ^{1}H NMR (600 MHz, $CDCl_3$): minor diastereomer: δ = 7.73-7.71 (m, 1H), 7.60-7.57 (m, 1H), 7.46-7.44 (m, 1H), 7.37-7.34 (m, 1H), 7.27-7.25 (m, 4H), 7.21-7.18 (m, 1H), 6.18 (s, 1H), 5.46 (d, *J* = 1.3 Hz, 1H), 5.31 (d, *J* = 0.9 Hz, 1H), 4.12 (q, *J* = 7.2 Hz, 1H), 4.04 (q, *J* = 7.1 Hz, 1H), 3.86 (d, *J* = 17.6 Hz, 1H), 3.59 (d, *J* = 17.2 Hz), 3.54 (s, 3H), 1.06 (t, *J* = 7.2 Hz, 3H) ppm; ^{13}C NMR (151 MHz, $CDCl_3$): minor diastereomer: δ = 200.12, 169.36, 167.05, 152.79, 140.38, 138.93, 135.55, 135.44, 128.89 (2C), 128.36 (2C), 127.74, 127.07, 126.99, 126.29, 124.61, 65.43, 62.16, 51.94, 49.60, 34.59, 13.73 ppm; $[\alpha]_D$ = -161.7° (c = 0.47, $CHCl_3$); IR (KBr): *ν* = 3060, 3034, 2980, 2950, 2899, 1957, 1894, 1742, 1718, 1628, 1604, 1589, 1497,1470, 1452, 1434, 1272, 1254, 1239, 1201, 1159, 707 cm^{-1}; HRMS (ESI) m/z calcd for $C_{23}H_{22}O_5Na$ $[M+Na]^+$ = 401.1359, found = 401.1359.

Methyl 2-((*R*)-2-(methoxycarbonyl)-1-phenylallyl)-1-oxo-2,3-dihydro-1*H*-indene-2-carboxylate

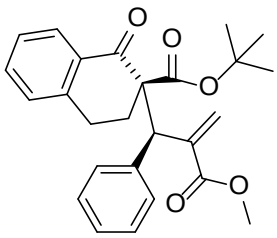


4ah

Colorless oil, yield 81 %, dr: 3:2, 56/64 % ee. The ee was determined by HPLC analysis using Chiralpak AD column (95/5 heptane/*i*-PrOH, flow rate 1.0 mL/min; λ = 190 nm, t_{1major} = 17.5 min., t_{1minor} = 28.6 min, t_{2minor} = 20.5 min., t_{2major} = 47.6 min); ^{1}H NMR (600 MHz, $CDCl_3$) major diastereomer: δ = 7.73–7.72 (m, 2H), 7.61-7.59 (m, 1H), 7.47-7.44 (m, 1H), 7.38–7.35 (m, 2H), 7.27–7.25 (m, 4H), 7.23–7.22 (m, 1H), 6.19 (s, 1H), 5.43 (d, *J* = 1.3 Hz, 1H), 5.34 (d, *J* = 0.9 Hz, 1H), 3.83 (d, *J* = 17.5 Hz, 1H), 3.61 (s, 3H), 3.59 (d, *J* = 17.0 Hz, 1H), 3.55 (s, 3H), ppm; ^{13}C NMR (151 MHz, $CDCl_3$) major diastereomer: δ = 199.97, 169.85, 166.96, 152.66, 140.18, 138.67, 135.51, 128.75 (2C), 128.41 (2C), 127.80, 127.13, 126.51, 126.33, 124.66, 53.08, 51.95, 49.43, 34.41 ppm; ^{1}H NMR (600 MHz, $CDCl_3$) minor diastereomer: δ = 7.59–7.58 (m, 1H), 7.44-7.43 (m, 1H), 7.30-7.29 (m, 1H), 7.21–7.19 (m, 1H), 7.15–7.14 (m, 2H), 7.08–7.06 (m, 2H), 7.02–7.00 (m, 1H), 6.48 (d, *J* = 0.4 Hz, 1H), 5.75 (d, *J* = 1.4 Hz, 1H), 5.45 (d, *J* = 0.7 Hz, 1H), 4.08 (d, *J* = 17.0 Hz, 1H), 3.71 (s, 3H), 3.62 (s, 3H), 3.37 (d, *J* = 17.0 Hz, 1H) ppm; ^{13}C NMR (151 MHz, $CDCl_3$) minor diastereomer: δ = 200.41, 169.67, 166.69, 153.68, 141.12, 135.96, 135.36, 134.24, 129.49 (2C), 128.11 (2C), 127.47, 127.17, 125.91, 124.54, 124.48, 65.40, 53.31, 52.09, 49.48, 32.85 ppm; $[\alpha]_D$ = -12.5° (c = 1.48, $CHCl_3$); IR (KBr): *ν* = 3052, 3028, 2995,

2953, 2836, 1748, 1718, 1631,1604, 1586, 1491, 1464, 1455, 1434, 1278, 1236, 1162, 770, 710 cm^{-1}; HRMS (ESI) m/z calcd for $C_{22}H_{20}O_5Na$ $[M+Na]^+$ = 387.1203, found = 387.1202.

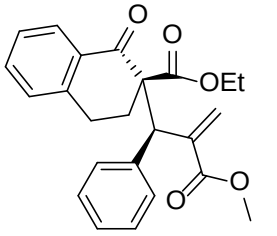
***tert*-Butyl (*R*)-2-((*R*)-2-(methoxycarbonyl)-1-phenylallyl)-1-oxo-1,2,3,4-tetrahydronaphthalene-2-carboxylate**



4ai

Off-white semisolid, yield 40 %, 84 % ee. The ee was determined by HPLC analysis using Chiralpak AD column (90/10 heptane/*i*-PrOH, flow rate 1.0mL/min; λ = 190 nm, t_{minor} = 7.1 min., t_{major} = 8.2 min); ^{1}H NMR (600 MHz, $CDCl_3$): δ = 8.00 (dd, *J* = 7.9 Hz, *J´* = 1.2 Hz, 1H), 7.48 – 7.46 (m, 2H), 7.42 – 7.40 (m, 1H), 7.27 – 7.22 (m, 3H), 7.19 – 7.16 (m, 1H), 7.15 – 7.14 (m, 1H), 6.47 (s, 1H), 6.00 (s, 1H), 5.18 (s, 1H), 3.71 (s, 3H), 3.23 (ddd, *J* = 17.3 Hz, *J´* = 12.4 Hz, *J´´* = 4.8 Hz, 1H), 2.82 (ddd, *J* = 17.6 Hz, *J´* = 4.9 Hz, *J´´* = 2.6 Hz, 1H), 2.57 (ddd, *J* = 13.8 Hz, *J´* = 4.9 Hz, *J´´* = 3.0 Hz, 1H), 2.11 (ddd, *J* = 13.8 Hz, *J´* = 12.4 Hz, *J´´* = 5.0 Hz, 1H), 1.18 (s, 9H) ppm; ^{13}C NMR (151 MHz, $CDCl_3$): δ = 193.82, 169.20, 167.93, 142.38, 140.32, 138.92, 133.05 (2C), 130.78 (2C), 128.34, 128.00, 127.84 (2C), 127.72, 126.74, 126.45, 82.54, 62.06, 49.17, 31.31, 27.44 (3C), 26.22 ppm; $[\alpha]_D$ = -52.9° (c = 0.6, $CHCl_3$); IR (KBr): *ν* = 3060, 3025, 2977, 2947, 2929, 2848, 1954, 1888, 1721, 1691, 1628, 1598, 1458, 1434, 1368, 1272, 1248, 1192, 1153 cm^{-1}; HRMS (ESI) m/z calcd for $C_{26}H_{28}O_5Na$ $[M+Na]^+$ = 443.1829, found = 443.1829.

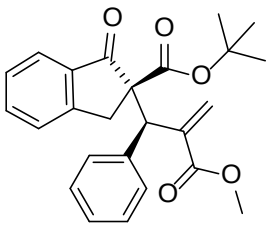
Ethyl (*R*)-2-((*R*)-2-(methoxycarbonyl)-1-phenylallyl)-1-oxo-1,2,3,4-tetrahydronaphthalene-2-carboxylate



4aj

Off-white semisolid, yield 64 %, 79 % ee. The ee was determined by HPLC analysis using Chiralpak IC column (90/10 heptane/*i*-PrOH, flow rate 1.0mL/min; λ = 190 nm, t_{minor} = 25.2 min., t_{major} = 45.5 min); ^{1}H NMR (600 MHz, $CDCl_3$): δ = 8.04 (dd, *J* = 7.9 Hz, *J´* = 1.2 Hz, 1H), 7.45 – 7.42 (m, 3H), 7.29 – 7.23 (m, 3H), 7.20 – 7.17 (m, 1H), 7.16 – 7.15 (m, 1H), 6.49 (s, 1H), 5.96 (d, *J* = 0.6 Hz, 1H), 5.39 (s, 1H), 4.10 – 3.99 (m, 2H), 3.71 (s, 3H), 3.31 (ddd, *J* = 17.2 Hz, *J´* = 12.2 Hz, *J´´* = 4.7 Hz, 1H), 2.84 (ddd, *J* = 17.4 Hz, *J´* = 4.8 Hz, *J´´* = 3.2 Hz, 1H), 2.67 (ddd, *J* = 13.8 Hz, *J´* = 4.6 Hz, *J´´* = 2.9 Hz, 1H), 2.14 (ddd, *J* = 13.8 Hz, *J´* = 12.3 Hz, *J´´* = 5.0 Hz, 1H), 1.06 (t, *J* = 7.2 Hz. 3H) ppm; ^{13}C NMR (151 MHz, $CDCl_3$): δ = 193.08, 169.84, 167.63, 142.80, 140.27, 138.35, 133.42, 132.35, 130.61 (2C), 128.49, 128.37, 127.93 (2C), 127.05, 126.89, 126.53, 61.53 (2C), 52.17, 48.80, 30.16, 26.07, 13.72 ppm; $[\alpha]_D$ = -113.0° (c = 0.35, $CHCl_3$); IR (KBr): *ν* = 3052, 3025, 2998, 2977, 2950, 2920, 1724, 1679, 1595, 1464,1443, 1248, 1269, 1230, 1207, 1189, 1159 cm^{-1}; HRMS (ESI) m/z calcd for $C_{24}H_{24}O_5Na$ $[M+Na]^+$ = 415.1516, found = 415.1514.

***tert*-Butyl (*R*)-2-((*R*)-2-(methoxycarbonyl)-1-phenylallyl)-1-oxo-2,3-dihydro-1*H*-indene-2-carboxylate**

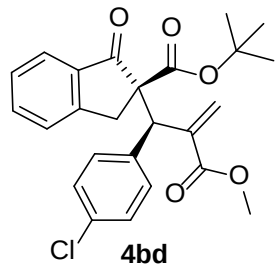


4ad

Off-white semisolid, yield 70 %, 90 % ee. The ee was determined by HPLC analysis using Chiralpak AD column (95/5 heptane/*i*-PrOH, flow rate 1.0mL/min; λ = 190 nm, t_{major} = 7.8 min., t_{minor} = 9.8 min); ^{1}H NMR (600 MHz, $CDCl_3$): δ = 7.60 (d, *J* = 7.6 Hz, 1H), 7.43-7.41 (m, 1H), 7.27 (d, *J* = 7.7 Hz, 1H), 7.22-7.19 (m, 1H), 7.15 (d, J = 7.6 Hz, 2H), = 7.10-7.05 (m, 2H), δ = 7.01-6.98 (m, 1H), δ = 6.49 (s, 1H), δ = 5.78 (d, *J* = 1.26 Hz, 1H), δ = 5.42 (s, 1H), δ = 3.98 (d, *J* = 16.7 Hz, 1H), 3.64 (s, 3H), δ = 3.28 (d, J = 16.7 Hz, 1H), δ = 1.39 (s, 9H);

^{13}C NMR (151 MHz, $CDCl_3$): δ = 200.79, 167.83, 166.95, 153.90, 141.37, 136.37, 135.11, 134.42, 129.55 (2C), 128.07 (2C), 127.30, 127.04, 125.85, 124.62, 124.45, 82.44, 66.49, 52.08, 49.37, 32.88, 27.58 (3C); $[\alpha]_D$ = -305° (c = 0.7, $CHCl_3$); IR (KBr): *v* = 3060, 3028, 2977, 2947, 2929, 1718, 1361, 1604, 1589, 1494, 1479, 1371, 1278, 1248, 1153, 767, 743, 704 cm^{-1}; HRMS (ESI) m/z calcd for $C_{25}H2_6O_5$ $[M+Na]^+$ = 429.16725, found = 429.1671̃2.

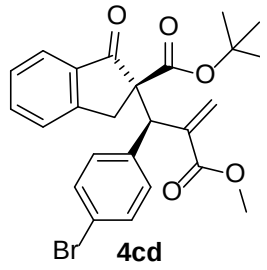
***tert*-Butyl (*R*)-2-((*R*)-1-(4-chlorophenyl)-2-(methoxycarbonyl)allyl)-1-oxo-2,3-dihydro-1*H*-indene-2-carboxylate**



4bd

Off-white semisolid, yield 60 %, 88 % ee. The ee was determined by HPLC analysis using Chiralpak AD column (98/2 heptane/*i*-PrOH, flow rate 1.0mL/min; λ = 190 nm, t_{major} = 9.3 min., t_{minor} = 13.0 min); ^{1}H NMR (600 MHz, $CDCl_3$): δ = 7.61 (d, *J* = 7.8 Hz, 1H), 7.48-7.46 (m, 1H), 7.31 (d, *J* = 8.0 Hz, 1H), 7.25-7.24 (m, 1H), 7.10 (d, *J* = 8.6 Hz, 2H), 7.05 (d, *J* = 8.6 Hz, 2H), 6.49 (s, 1H), 5.79 (d, *J* = 1.1 Hz, 1H), 5.40 (s, 1H), 3.99 (d, *J* = 16.7 Hz, 1H), 3.65 (s, 3H), 3.21 (d, J = 16.7 Hz, 1H), 1.38 (s, 9H) ppm; ^{13}C NMR (151 MHz, $CDCl_3$): δ = 200.57, 167.55, 166.74, 153.74, 141.10, 135.41, 135.15, 134.28, 133.00, 130.93 (2C), 128.33 (2C), 127.55, 125.94, 124.92, 124.56, 82.65, 66.34, 52.17, 48.71, 32.81, 27.57 (3C) ppm; $[\alpha]_D$ = -255.7° (c = 0.7, $CHCl_3$); IR (KBr): *v* = 3066, 3000, 2978, 2952,2926, 1721, 1634, 1610, 1592, 1491, 1467,1410,1368, 1269, 1245, 1153 cm^{-1}; HRMS (ESI) m/z calcd for $C_{25}H_{25}O_5ClNa$ $[M+Na]^+$ = 463.1283, found = 463.1281.

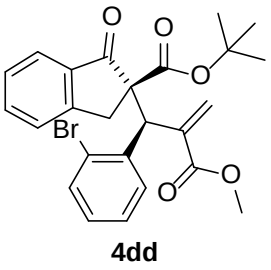
***tert*-Butyl (*R*)-2-((*R*)-1-(4-bromophenyl)-2-(methoxycarbonyl)allyl)-1-oxo-2,3-dihydro-1*H*-indene-2-carboxylate**



4cd

Off-white semisolid, yield 60 %, 93 % ee. The ee was determined by HPLC analysis using Chiralpak AD column (95/5 heptane/*i*-PrOH, flow rate 1.0mL/min; λ = 190 nm, t_{major} = 9.7 min., t_{major} = 13.9 min); ^{1}H NMR (600 MHz, $CDCl_3$): δ = 7.61 (d, *J* = 7.7 Hz, 1H), 7.49-7.46 (m, 1H), 7.31 (d, *J* = 7.3 Hz, 1H), 7.26-7.25 (m, 1H), 7.21-7.20 (m, 2H), 7.04-7.03 (m, 2H), 6.49 (s, 1H), 5.78 (d, *J* = 1.26 Hz, 1H), 5.38 (s, 1H), 3.99 (d, *J* = 16.7 Hz, 1H), 3.65 (s, 1H), 3.20 (d, *J* = 16.7 Hz, 1H), 1.37 (s, 9H); ^{13}C NMR (151 MHz, $CDCl_3$): δ = 200.52, 167.51, 166.72, 153.73, 141.02, 135.70, 135.43, 134.25, 131.30 (2C), 131.29 (2C), 127.56, 125.95, 124.97, 124.57, 121.26, 82.65, 66.30, 52.18, 48.73, 32.80, 27.59 (3C); $[\alpha]_D$ = -241.7° (c = 0.76, $CHCl_3$); IR (KBr): *v* = 3058, 3037, 3001, 2980, 5950, 2929, 1733, 1715, 1628, 1604, 1589, 1488, 1464, 1443, 1368, 1272, 1251, 1150 cm^{-1}; HRMS (ESI) m/z calcd for $C_{25}H_{25}O_5Br$ $[M+Na]^+$ = 507.07776, found = 507.07783.

***tert*-Butyl (*R*)-2-((*R*)-1-(2-bromophenyl)-2-(methoxycarbonyl)allyl)-1-oxo-2,3-dihydro-1*H*-indene-2-carboxylate**

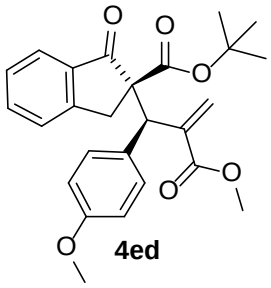


4dd

Colorless oil, yield 21 %, 78 % ee. The ee was determined by HPLC analysis using Chiralpak AD column (95/5 heptane/*i*-PrOH, flow rate 1.0mL/min; λ = 190 nm, t_{major} = 8.1 min., t_{major} = 9.1 min); ^{1}H NMR (600 MHz, $CDCl_3$): δ = 7.70 (*br* d, *J*= 7.1 Hz, 1H), 7.61 (*br* d, *J* = 7.6 Hz, 1H), 7.48 (td, *J* = 7.6 Hz, *J´* = 1.1 Hz 1H), 7.43 (dd, *J* = 8.2, *J´* = 1.3 Hz, 1H), 7.32 (*br* d, *J* = 7.5 Hz, 1H), 7.27 – 7.24 (m, 1H), 7.11 (td, *J* = 7.5 Hz, *J´* = 1.4 Hz 1H), 6.92 (td, *J* = 7.8 Hz, *J´* = 1.7 Hz 1H), 6.34 (s, 1H), 5.63 – 5.62 (m, 2H), 3.87 (d, *J* = 16.9 Hz, 1H), 3.73 (d, *J* = 17.8 Hz, 1H), 3.61 (s, 3H), 1.32 (s, 9H) ppm; ^{13}C NMR (151 MHz, $CDCl_3$): δ = 200.25,

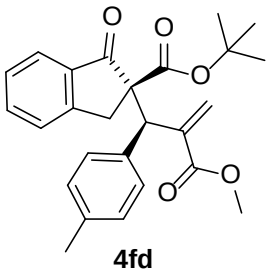
169.21, 167.13, 152.10, 140.24, 138.70, 135.63, 134.96, 133.48, 130.40, 128.28, 128.06, 127.52, 126.99, 125.74, 125.65, 124.41, 82.36, 64.84, 52.05, 48.55, 36.34, 27.54 (3 C), ppm; $[\alpha]_D$ = -37.1° (c = 0.35, $CHCl_3$); IR (KBr): *v* = 3055, 3037, 3010, 2998, 2971, 2926, 2851, 1730, 1706, 1628, 1607, 1470, 1443, 1278, 1251, 1153 cm^{-1}; HRMS (ESI) m/z calcd for $C_{25}H_{25}O_5BrNa$ $[M+Na]^+$ = 507.0780, found = 507.0780.

***tert*-Butyl (*R*)-2-((*R*)-2-(methoxycarbonyl)-1-(4-methoxyphenyl)allyl)-1-oxo-2,3-dihydro-1*H*-indene-2-carboxylate**


4ed

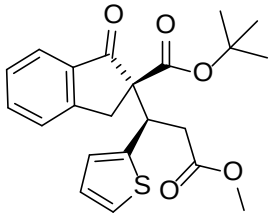
Off-white semisolid, yield 82 %, 91 % ee. The ee was determined by HPLC analysis using Chiralpak AD column (95/5 heptane/i-PrOH, flow rate 1.0mL/min; λ = 190 nm, t_{major} = 10.8 min., t_{minor} = 17.6 min); ^1H NMR (600 MHz, $CDCl_3$): δ = 7.61 (d, *J* = 7.6 Hz, 1H), 7.44-7.43 (m, 1H), 7.30 (d, *J* = 8.1 Hz, 1H), 7.23–7.22 (m, 1H), 7.06 (d, *J* = 4.7 Hz, 2H), 6.60 (d, *J* = 4.7 Hz, 2H), 6.45 (s, 1H), 5.75 (d, *J* = 1.2 Hz, 1H), 5.39 (s, 1H), 3.97 (d, *J* = 16.6 Hz, 1H), 3.65 (s, 3H), 3.63 (s, 3H), 3.27 (d, *J* = 16.7 Hz, 1H), 1.38 (s, 9H) ppm; ^{13}C NMR (151 MHz, $CDCl_3$): δ = 200.86, 167.86, 167.04, 158.39, 154.01, 141.66, 135.14, 134.45, 130.66 (2C), 128.35, 127.31, 125.91, 124.47, 124.18, 113.50, 82.37, 66.70, 54.98, 52.08, 48.61, 32.87, 27.58 (3C) ppm; $[\alpha]_D$ = -182.1° (c = 0.7, $CHCl_3$); IR (KBr): *v* = 3072, 3034, 2980, 2950, 2938, 2902, 2833,1718,1628, 1607, 1589, 1515, 1461, 1434, 1398, 1348, 1272, 1251, 1153 cm^{-1}; HRMS (ESI) m/z calcd for $C_{26}H_{28}O_6Na$ $[M+Na]^+$ = 459.1778, found = 459.1777.

***tert*-Butyl (*R*)-2-((*R*)-2-(methoxycarbonyl)-1-(p-tolyl)allyl)-1-oxo-2,3-dihydro-1*H*-indene-2-carboxylate**


4fd

Colorless oil, yield 50 %, 88 % ee. The ee was determined by HPLC analysis using Chiralpak AD column (95/5 heptane/i-PrOH, flow rate 1.0mL/min; λ = 190 nm, t_{major} = 8.7 min., t_{minor} = 11.0 min); ^1H NMR (600 MHz, $CDCl_3$): δ = 7.61 (*br* d, *J*= 7.7 Hz, 1H), 7.43 (dt, *J* = 7.6 Hz, *J´* = 1.2 Hz, 1H), 7.29 (*br* d, *J* = 7.7 Hz, 1H), 7.22 (dt, *J* = 7.6 Hz, *J´* = 0.6 Hz, 1H), 7.03 (br d, *J*=8.2 Hz, 2H), 6.87 (*br* d, *J* = 7.9 Hz, 2H), 6.46 (s, 1H), 5.76 (d, *J* = 1.2 Hz, 1H), 5.41 (s, 1H), 3.96 (d, *J* = 17.7 Hz, 1H), 3.65 (s, 3H), 3.28 (d, *J* = 17.1 Hz, 1H), 2.13 (s, 3H), 1.38 (s, 9H) ppm; ^{13}C NMR (151 MHz, $CDCl_3$): δ = 200.76, 167.86, 167.03, 154.03, 141.55, 136.55, 135.07, 134.44, 133.29, 129.46 (2 × C), 128.86 (2 C), 127.27, 125.91, 124.48, 124.41, 82.38, 66.73, 52.07, 48.89, 32.91, 27.58 (3 C), 20.84 ppm; $[\alpha]_D$ = -334.3° (c = 0.69, $CHCl_3$); IR (KBr): *v* = 3001, 2986, 2944, 2926, 2866, 1730, 1718, 1607, 1431, 1365, 1272, 1251, 1222, 1153 1117 cm^{-1}; HRMS (ESI) m/z calcd for $C_{26}H_{28}O_5Na$ $[M+Na]^+$ = 443.1829, found = 443.1828.

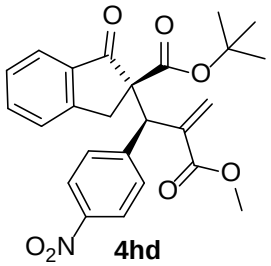
***tert*-Butyl (*R*)-2-((*R*)-3-methoxy-3-oxo-1-(thiophen-2-yl)propyl)-1-oxo-2,3-dihydro-1*H*-indene-2-carboxylate**


4gd

Off-white semisolid, yield 70 %, 83 % ee. The ee was determined by HPLC analysis using Chiralpak IB column (95/5 heptane/*i*-PrOH, flow rate 1.0mL/min; λ = 190 nm, t_{minor} = 5.8 min., t_{major} = 6.8 min); ^1H NMR (600 MHz, $CDCl_3$): δ = 7.69 (d, *J* = 7.7 Hz, 1H), 7.51-7.49 (m, 1H), 7.37 (d, *J* = 7.6 Hz, 1H), 7.30–7.27 (m, 1H), 6.97 (dd, *J* = 4.9 Hz, *J´* = 1.5 Hz, 1H), 6.74–6.72 (m, 2H), 6.46 (s, 1H), 5.83 (d, *J* = 1.0 Hz, 1H), 5.70 (s, 1H), 3.98 (d, *J* = 16.6 Hz, 1H), 3.72 (s, 3H), 3.36 (d, *J* = 16.6 Hz, 1H), 1.36 (s, 9H) ppm; ^{13}C NMR (151 MHz, $CDCl_3$): δ = 200.50, 167.18, 166.77, 154.25, 141.57, 140.38, 135.25, 134.40, 127.47, 127.05, 126.71,

126.05, 124.93, 124.86, 124.67, 82.68, 67.12, 52.25, 44.38, 33.54, 27.56 (3C) ppm; $[\alpha]_D$ = -256.6° (c = 0.73, $CHCl_3$); IR (KBr): *v* = 3117, 3102, 3063, 3007, 2980, 2947, 2929, 1715, 1625, 1604, 1589,1479, 1464, 1437, 1392,1368, 1275, 1245, 1153 cm^{-1}; HRMS (ESI) m/z calcd for $C_{23}H_{24}O_5NaS$ $[M+Na]^+$ = 435.1237, found = 435.1236.

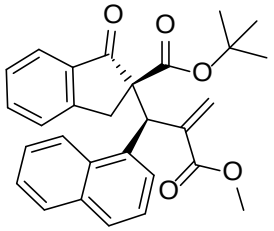
***tert*-Butyl (*R*)-2-((*R*)-2-(methoxycarbonyl)-1-(4-nitrophenyl)allyl)-1-oxo-2,3-dihydro-1*H*-indene-2-carboxylate**



4hd

Yellow oil, yield 70 %, 71 % ee. The ee was determined by HPLC analysis using Chiralpak AD column (95/5 heptane/i-PrOH, flow rate 1.0mL/min; λ = 190 nm, t_{major} = 18.5 min., t_{minor} = 24.2 min); ^1H NMR (600 MHz, $CDCl_3$): δ = 7.95–7.93 (m, 2H), 7.61 (d, *J* = 7.7 Hz, 1H), 7.48-7.46 (m, 1H), 7.36-7.34 (m, 2H), 7.30 (d, *J* = 7.9 Hz, 1H), 7.26-7.24 (m, 1H), 6.57 (s, 1H), 5.87 (d, *J* = 1.1 Hz, 1H), 5.49 (s, 1H), 4.05 (d, *J* = 16.9 Hz, 1H), 3.65 (s, 3H), 3.18 (d, *J* = 16.8 Hz, 1H), 1.39 (s, 9H) ppm; ^{13}C NMR (151 MHz, $CDCl_3$): δ = 200.24, 167.15, 166.41, 153.38, 152.57, 147.25, 146.96, 144.52, 140.36, 139.24, 135.71, 134.08, 130.45 (2C), 127.80, 125.95, 125.84, 124.66, 123.41, 123.30 (2C), 83.03, 65.97, 52.30, 49.14, 32.80, 27.56 (3C) ppm; $[\alpha]_D$ = -170.9° (c = 0.90, $CHCl_3$); IR (KBr): *v* = 3108, 3072, 3034, 2977, 2950, 2929, 1721, 1631, 1607, 1521, 1476, 1464, 1440, 1371, 1344, 1272, 1245, 1156 cm^{-1}; HRMS (ESI) m/z calcd for $C_{25}H_{25}O_7NNa$ $[M+Na]^+$ = 474.1523, found = 474.1522.

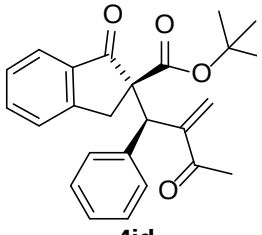
***tert*-Butyl (*R*)-2-((*R*)-2-(methoxycarbonyl)-1-(naphthalen-1-yl)allyl)-1-oxo-2,3-dihydro-1*H*-indene-2-carboxylate**



4id

Off-white semisolid, yield 42 %, 95 % ee. The ee was determined by HPLC analysis using Chiralpak AD column (95/5 heptane/*i*-PrOH, flow rate 1.0mL/min; λ = 190 nm, t_{major} = 7.2 min., t_{minor} = 8.2 min); ^1H NMR (600 MHz, $CDCl_3$): δ = 8.48 (d, *J* = 8.7 Hz, 1H), 7.61 (d, *J* = 8.0 Hz, 1H), 7.57-7.54 (m, 1H), 7.50 (d, *J* = 8.2 Hz, 1H), 7.43 (d, *J* = 7.2 Hz, 1H), 7.40–7.37 (m, 1H), 7.34–7.31 (m, 1H), 7.22–7.17 (m, 3H), 7.02–6.99 (m, 1H), 6.43 (s, 1H), 6.20 (s, 1H), 5.81 (d, *J* = 1.0 Hz, 1H), 4.04 (d, *J* = 17.0 Hz, 1H), 3.66 (d, J = 16.9 Hz, 1H), 3.53 (s, 3H), 1.42 (s, 9H) ppm; ^{13}C NMR (151 MHz, $CDCl_3$): δ = 200.37, 168.71, 167.17, 152.84, 142.34, 134.80, 134.68, 133.83, 133.65, 131.77, 128.02, 127.98, 127.06, 126.72, 125.90, 125.47 (2C), 124.88, 124.77, 124.24, 123.97, 82.39, 65.50, 52.06, 43.77, 34.08, 27.63 (3C) ppm; $[\alpha]_D$ = -151.5° (c = 0.52, $CHCl_3$); IR (KBr): *v* = 3046, 3004, 2977, 2947, 2929, 1721, 1631, 1607, 1589,1506,1467, 1434, 1395, 1368, 1275, 1248, 1156, 782 cm^{-1}; HRMS (ESI) m/z calcd for $C_{29}H_{28}O_5Na$ $[M+Na]^+$ = 479.1829, found = 479.1829.

***tert*-Butyl (*R*)-2-((*R*)-2-methylene-3-oxo-1-phenylbutyl)-1-oxo-2,3-dihydro-1*H*-indene-2-carboxylate – major diastereomer**

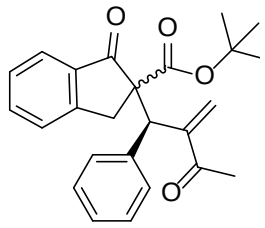


4jd

Colorless oil, yield 26 %, 91 % ee. The ee was determined by HPLC analysis using Chiralpak IB column (98/2 heptane/*i*-PrOH, flow rate 1.0 mL/min; λ = 190 nm, t_{major} = 15.6 min., t_{minor} = 18.4 min.); ^1H NMR (600 MHz, $CDCl_3$) major diastereomer: δ = 7.61–7.59 (m, 1H), 7.44–7.41 (m, 1H), 7.28–7.20 (m, 2H), 7.15-7.13 (m, 2H), 7.07-7.05 (m, 2H), 7.00-6.98 (m, 1H), 6.29 (s, 1H), 5.91 (s, 1H), 5.48 (s, 1H), 4.00 (d, *J* = 16.8 Hz, 1H), 3.30 (d, *J* = 16.7 Hz, 1H), 2.27 (s, 3H), 1.37 (s,3H) ppm; ^{13}C NMR (151 MHz, $CDCl_3$) major diastereomer: δ = 200.86, 198.41, 167.96, 153.79, 149.31, 136.52, 135.11, 134.50, 129.61 (2C), 128.16 (2C),

127.33, 127.08, 125.86, 124.46, 123.65, 82.36, 66.34, 48.55, 33.07, 27.62 (3C), 26.47 ppm; $[\alpha]_D$ = -293.3° (c = 0.3, $CHCl_3$); IR (KBr): *ν* = 3081, 3058, 3031, 3001, 2977, 2929, 1739, 1709, 1679, 1601, 1365, 1272, 1242, 1147, 1021 cm^{-1}; HRMS (ESI) m/z calcd for $C_{25}H_{26}O_4Na$ $[M+Na]^+$ = 413.1723, found = 413.1722.

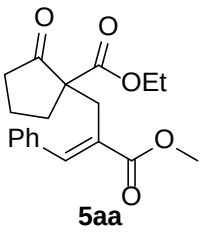
***tert*-Butyl 2-((*R*)-2-methylene-3-oxo-1-phenylbutyl)-1-oxo-2,3-dihydro-1*H*-indene-2-carboxylate – mixture of diastereomers**



4jd

Colorless oil, yield 46 % (mixture of diastereomers in 3:2 ratio), 91/ 95 % ee. The ee was determined by HPLC analysis using Chiralpak IB column (98/2 heptane/*i*-PrOH, flow rate 1.0 mL/min; λ = 190 nm, t_{1major} = 15.6 min., t_{1minor} = 18.4 min., t_{2minor} = 25.2 min., t_{2major} = 27.5 min); ^{1}H NMR (600 MHz, $CDCl_3$) major diastereomer: δ = 7.61–7.59 (m, 1H), 7.44–7.41 (m, 1H), 7.28–7.20 (m, 2H), 7.15-7.13 (m, 2H), 7.07-7.05 (m, 2H), 7.00-6.98 (m, 1H), 6.29 (s, 1H), 5.91 (s, 1H), 5.48 (s, 1H), 4.00 (d, *J* = 16.8 Hz, 1H), 3.30 (d, *J* = 16.7 Hz, 1H), 2.27 (s, 3H), 1.37 (s,3H) ppm; ^{13}C NMR (151 MHz, $CDCl_3$) major diastereomer: δ = 200.86, 198.41, 167.96, 153.79, 149.31, 136.52, 135.11, 134.50, 129.61 (2C), 128.16 (2C), 127.33, 127.08, 125.86, 124.46, 123.65, 82.36, 66.34, 48.55, 33.07, 27.62 (3C), 26.47 ppm; ^{1}H NMR (600 MHz, $CDCl_3$) minor diastereomer: δ = 7.68 – 7.67 (m, 1H), 7.56 – 7.54 (m, 1H), 7.43 – 7.40 (m, 1H), 7.34 – 7.31 (m, 1H), 7.27 – 7.16 (m, 5H, overlapped signal with signals of major diastereomer), 6.00 (s, 1H), 5.82 (s, 1H), 5.28 (s, 1H), 3.86 (d, *J* = 16.6 Hz, 1H), 3.53 (d, *J* = 16.6 Hz, 1H), 2.00 (s, 3H), 1.23 (s, 9H) ppm; ^{13}C NMR (151 MHz, $CDCl_3$) minor diastereomer: δ = 200.78, 198.86, 168.60, 152.74, 149.39, 139.83, 135.78, 135.19, 128.99 (2C), 128.27 (2C), 127.62, 127.04, 126.74, 126.03, 124.54, 82.34, 65.41, 48.61, 35.35, 27.45, 26.13 ppm; IR (KBr): *ν* = 3081, 3058, 3031, 3001, 2977, 2929, 1739, 1709, 1679, 1601, 1365, 1272, 1242, 1147, 1021 cm^{-1}; HRMS (ESI) m/z calcd for $C_{25}H_{26}O_4Na$ $[M+Na]^+$ = 413.1723, found = 413.1722.

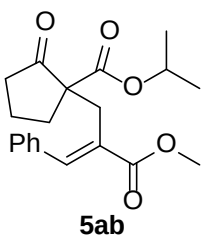
Ethyl 1-((*E*)-2-(methoxycarbonyl)-3-phenylallyl)-2-oxocyclopentane-1-carboxylate



5aa

Colorless oil, yield 13 %. ^{1}H NMR (600 MHz, $CDCl_3$): δ = 7.77 (s, 1H), 7.40-7.31 (m, 4H), 4.06 (dq, *J* = 10.7 Hz, *J´* = 7.1 Hz, 1H), 3.97 (dq, *J* = 10.8 Hz, *J´* = 7.0 Hz, 1H), 3.77 (s, 3H), 3.45 (dd, *J* = 14.6 Hz, *J´* = 0.5 Hz, 1H), 3.02 (dd, *J* = 14.5 Hz, *J´* = 0.4 Hz, 1H), 2.41-2.39 (m, 1H), 2.37-2.32 (m, 1H), 2.16-2.11 (m, 1H), 1.84-1.75 (m, 3H), 1.15 (t, *J* = 7.1 Hz, 3H) ppm; ^{13}C NMR (151 MHz, $CDCl_3$): δ = 213.87, 170.69, 168.73, 142.07, 135.13, 129.24 (2C), 129.10, 128.61, 128.58 (2C), 61.56, 60.06, 51.97, 37.13, 32.85, 30.25, 19.45, 13.90 ppm; IR (KBr): *ν* = 3055, 3022, 2980, 2950, 2899, 1757, 1718, 1625, 1500, 1449, 1437, 1368, 1254, 1230, 1204, 1147, 1120, 770 cm^{-1}; HRMS (ESI) m/z calcd for $C_{19}H_{22}O_5Na$ [M+Na]+ = 353.1359, found = 353.1359.

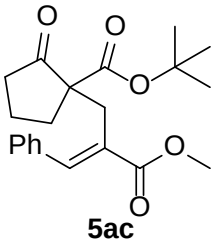
Isopropyl (*E*)-1-(2-(methoxycarbonyl)-3-phenylallyl)-2-oxocyclopentane-1-carboxylate



5ab

Colorless oil, yield 57 %. ^{1}H NMR (600 MHz, $CDCl_3$): δ = 7.76 (s, 1H), 7.39 – 7.31 (m, 5H), 4.95-4.89 (m, 1H), 3.76 (s, 3H), 3.44 (dd, J_1=14.6, J_2=0.5 Hz, 1H), 3.02 (dd, J_1=14.6, J_2=0.6 Hz, 1H), 2.42-2.33 (m, 2H), 2.17-2.11 (m, 1H), 1.89-1.76 (m, 3H), 1.17 (d, J=6.4 Hz, 3H), 1.15 (d, J=6.3 Hz, 3H) ppm; ^{13}C NMR (151 MHz, $CDCl_3$): δ = 214.00, 170.47, 168.77, 142.04, 135.09, 129.33 (2C), 129.17, 128.64, 128.55 (2C), 69.22, 59.90, 51.90, 37.06, 33.04, 30.19, 21.52, 21.40, 19.52 ppm; IR (KBr): *ν* = 3058, 3022, 2980, 2953, 2878, 1754, 1715, 1446, 1434, 1251, 1227, 1147, 1105, 764 cm^{-1}; HRMS (ESI) m/z calcd for $C_{20}H_{24}O_5Na$ [M+Na]+ = 367.1516, found = 367.1516.

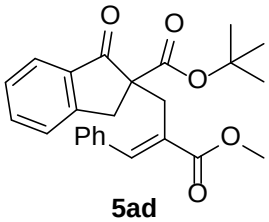
***Tert*-butyl 1-(*E*)-2-(methoxycarbonyl)-3-phenylallyl)-2-oxocyclopentane-1-carboxylate**



5ac

Colorless oil, yield 11 %. ^{1}H NMR (600 MHz, $CDCl_3$): δ = 7.74 (s, 1H), 7.41–7.31 (m, 5H), 3.77 (s, 3H), 3.45 (d, *J* = 14.2 Hz, 1H), 2.99 (d, *J* = 14.2 Hz, 1H), 2.40–2.34 (m, 2H), 2.16–2.10 (m, 1H), 1.88–1.76 (m, 3H), 1.37 (s, 9H) ppm; ^{13}C NMR (151 MHz, $CDCl_3$): δ = 214.22, 170.15, 168.92, 141.76, 135.10, 129.47 (2C), 129.37, 128.66, 128.54 (2C), 82.13, 60.55, 51.90, 37.01, 33.45, 30.10, 27.73 (3C) 19.57 ppm; IR (KBr): *v* = 3055, 3022, 2977, 2947, 2881, 1751, 1718, 1625, 1494, 1452, 1432, 1392, 1368, 1257, 1204, 1144, 1117, 770 cm^{-1}; HRMS (ESI) m/z calcd for $C_{21}H_{26}O_5Na$ $[M+Na]^+$ = 381.1673, found = 381.1672.

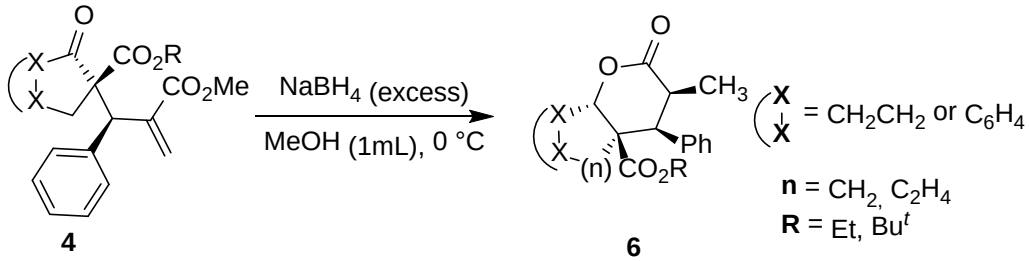
***Tert*-butyl 2-((*E*)-2-(methoxycarbonyl)-3-phenylallyl)-1-oxo-2,3-dihydro-1*H*-indene-2-carboxylate (u multipletů region od – do a ne jednotné číslo)**



5ad

Yellow oil, yield 19 %. ^{1}H NMR (600 MHz, $CDCl_3$): δ = 7.73-7.71 (m, 1H), 7.69 (s, 1H), 7.56 (td, *J* = 7.6 Hz, 1H), 7.40-7.34 (m, 7H), 3.65 (dd, *J* = 14.8 Hz, *J´* = 0.4 Hz, 1H), 3.54 (d, *J* = 16.7 Hz, 1H), 3.51 (s, 3H), 3.3 (dd, *J* = 14.8 Hz, *J´* = 0.7 Hz, 1H), 3.11 (d, *J* = 17.3 Hz, 1H), 1.35 (s, 9H) ppm; ^{13}C NMR (151 MHz, $CDCl_3$): δ = 202.44, 170.08, 168.46, 152.90, 142.16, 135.33, 134.95, 134.88, 129.47 (2C), 129.21, 128.78, 128.62 (2C), 127.46, 126.09, 124.25, 82.07, 60.61, 51.58, 36.37, 30.93, 27.71 (3C) ppm; IR (KBr): *v* = 3055, 3028, 2980, 2950, 2929, 1715, 1628, 1604, 1586, 1497, 1467, 1449, 1431, 1368, 1269, 1251, 1153, 845, 770, 746, 701 cm^{-1}; HRMS (ESI) m/z calcd for $C_{25}H_{26}O_5Na$ $[M+Na]^+$ = 429.1673, found = 429.1671.

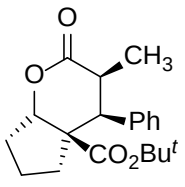
Preparation of lactone derivatives



4 **6**

At stirring compound **4** in cooled MeOH (1 mL, 0°C) was added excess of solid $NaBH_4$ in one portion. Reaction was monitored by TLC analysis and after completion the solution was poured in the cooled mixture of EtOAc/sat. NH_4Cl (0°C). The water layer was extracted with EtOAc and combined organics were dried over $MgSO_4$, filtered and concentrated in vacuo. The residue were purified by chromatography to get desired lactone derivative **5**.

(3*S*,4*R*,4a*R*,7a*S*)-*tert*-butyl octahydro-3-methyl-2-oxo-4-phenylcyclopenta[b]pyran-4a-carboxylate

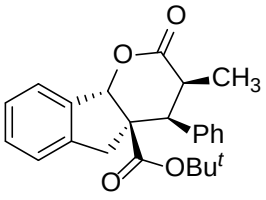


6a

Off-white semisolid, yield 45 %, 82 % ee. The ee was determined by HPLC analysis using Chiralpak AD column (98/2 heptane/*i*-PrOH, flow rate 1.0 mL/min; λ = 190 nm, t_{minor} = 12.3 min., t_{major} = 14.5 min); 1H NMR (600 MHz, CDCl3): δ = 7.28 - 7.25 (m, 2H), 7.23 – 7.21 (m, 2H), 7.12 – 7.10 (m, 2H), 5.66 (dd, *J* = 6.3 Hz, *J´* = 5.4 Hz, 1H), 3.32 (d, *J* = 5.3 Hz, 1H), 2.99 – 2.95 (m, 1H), 2.36 – 2.27 (m, 2H), 2.16 (dt, *J* =14.0 Hz, *J ´*= 7.9 Hz, 1H), 1.97 – 1.91 (m, 1H), 1.84 – 1.80 (m, 1H), 1.64 – 1.57 (m, 1H), 1.04 (s, 9H), 0.99 (d, *J* = 6.8 Hz, 3H) ppm; 13C NMR (151 MHz, CDCl3): δ = 172.96, 172.62, 137.80,

129.06 (2C), 128.62 (2C), 127.44, 83.42, 81.26, 55.57, 52.74, 39.00, 35.97, 35.24, 27.26 (3C), 22.72, 14.11 ppm; $[\alpha]_D$ = +49.2° (c = 0.31, $CHCl_3$); IR (KBr): ν = 3031, 3001,2974, 2959, 2875, 1742, 1706, 1455, 1368, 1263, 1165, 1153, 1111, 1069 cm^{-1}; HRMS (TOF) m/z calcd for $C_{20}H_{26}O_4$ $[M+H]^+$ = 331.1909, found = 331.1906.

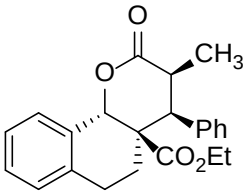
***Tert*-butyl 3-methyl-2-oxo-4-phenyl-3,4,5,9b-tetrahydroindeno[1,2-b]pyran-4a(2*H*)-carboxylate**



6b

Off-white semisolid, yield 48 %., 91 % ee. The ee was determined by HPLC analysis using Chiralpak AD column (90/10 heptane/*i*-PrOH, flow rate 1.0 mL/min; λ = 190 nm, t_{major} = 7.9 min., t_{minor} = 11.2 min); ^{1}H NMR (600 MHz, CDCl3): δ = 7.55–7.53 (m, 1H), 7.37-7.21 (m, 8H), 6.77 (s, 1H), 3.72 (d, J = 17.8 Hz, 1H), 3.48 (d, *J* = 17.8 Hz, 1H), 3.44 (d, *J* = 4.5 Hz, 1H), 2.53 (dd, J_1 = 6.9 Hz, J_2 = 4.7 Hz, 1H), 1.00 (s, 9H), 0.94 (d, *J* = 6.8 Hz, 3H) ppm; ^{13}C NMR (151 MHz, CDCl3): δ = 173.23, 172.19, 140.27, 139.49, 137.38, 129.75, 128.58 (4C), 128.15, 127.55, 125.79, 123.86, 84.25, 81.60, 56.20, 55.63, 47.30, 36.99, 27.11, 13.83 ppm; $[\alpha]_D$ = +50° (c = 0.19, $CHCl_3$); IR (KBr): ν = 3090, 3066, 3031, 2980, 2929, 2878, 1760, 1712, 1598, 1497, 1458, 1368, 1257, 1156, 1111, 1015, 848, 746, 701 cm^{-1}; HRMS (ESI) m/z calcd for $C_{24}H_{26}O_4Na$ $[M+Na]^+$ = 401.1723, found = 401.1719.

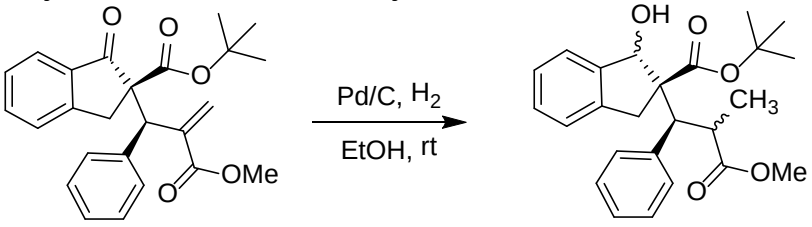
(3*S*,4*R*,4a*R*,10b*S*)-ethyl 3,4,4a,5,6,10b-hexahydro-3-methyl-2-oxo-4-phenyl-2*H*-benzo[h]chromene-4a-carboxylate



6c

Off-white semisolid, yield 50 %, 83 % ee. The ee was determined by HPLC analysis using Chiralpak AD column (95/5 heptane/*i*-PrOH, flow rate 1.0 mL/min; λ = 190 nm, t_{minor} = 15.6 min., t_{major} = 18.3 min); ^{1}H NMR (600 MHz, $CDCl_3$): δ = 7.49 – 7.47 (m, 1H), 7.36 – 7.33 (m, 2H), 7.31 – 7.28 (m, 1H), 7.24 – 7.22 (m, 2H), 7.18 – 7.17 (m, 2H), 7.11 – 7.08 (m, 1H), 5.89 (s, 1H), 3.79 – 3.70 (m, 2H), 3.46 (d, *J* = 6.5 Hz, 1H), 3.21 – 3.17 (m, 1H), 2.96 (ddd, *J* = 17.1 Hz, *J´* = 4.6 Hz, *J´* = 2.5 Hz, 1H), 2.74 (ddd, *J* = 17.5 Hz, *J´* = 11.8 Hz, *J´´* = 6.1 Hz, 1H), 2.42 – 2.34 (m, 2H), 1.09 (d, *J* = 6.6 Hz, 3H), 0.87 (t, *J* = 7.0 Hz, 3H) ppm; ^{13}C NMR (151 MHz, $CDCl_3$): δ = 172.89, 171,42, 136.34, 135.19, 132.83, 131.03, 128.91 (*br* s, 2C), 128.79 (2C), 128.73, 128.46, 127.90, 126.69, 76.78 (overlapped with solvent), 60.88, 52.93, 49.42, 34.31, 27.55, 26.75, 14.01, 13.60 ppm; $[\alpha]_D$ = +10.8° (c = 0.33, $CHCl_3$); IR (KBr): ν = 3081, 3025, 2935, 2869, 2851, 1724, 1500, 1458, 1377, 1251, 1216, 1180 cm^{-1}; HRMS (ESI) m/z calcd for $C_{23}H_{24}O_4Na$ $[M+Na]^+$ = 387.1567, found = 387.1568.

Preparation of *tert*-butyl 1-hydroxy-2-(3-methoxy-2-methyl-3-oxo-1-phenylpropyl)-2,3-dihydro-1*H*-indene-2-carboxylate

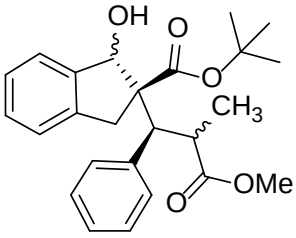


4ad **7a**

In stirring solution of compound **4ad** (0.18 mmol) in EtOH (2 mL) at room temperature was added 10% Pd/C (20% w/w). The reaction mixture was purged with H_2 from a balloon filled

with H_2 gas. Reaction was monitored by TLC analysis and after completion the mixture was subjected directly to column (Hex/EtOAc mixture) affording compound **7a**.

***Tert*-butyl (2*R*)-1-hydroxy-2-((1*S*)-3-methoxy-2-methyl-3-oxo-1-phenylpropyl)-2,3-dihydro-1*H*-indene-2-carboxylate**



7a

Colorless oil, yield 35 %, 90 % ee. The ee was determined by HPLC analysis using Chiralpak AD column (90/10 heptane/*i*-PrOH, flow rate 1.0 mL/min; λ = 190 nm, t_{major} = 12.0 min., t_{minor} = 21.8 min); ^{1}H NMR (600 MHz, $CDCl_3$): δ = 7.25–7.08 (m, 9H), 4.75 (d, J = 6.0 Hz, 1H), 3.76 (d, J = 10.5 Hz, 1H), 3.41 (d, J = 15.4 Hz, 1H), 3.34 (s, 3H), 3.22 (dq, J_1 = 10.5, J_2 = 7.0 Hz, 1H), 2.98 (d, J = 15.4 Hz, 1H), 1.36 (d, J = 7.2 Hz, 3H), 1.26 (s, 9H), ppm; ^{13}C NMR (151 MHz, $CDCl_3$): δ = 175.60, 174.82, 142.60, 140.36, 139.35, 129.82 (2C), 127.98 (2C), 127.80, 127.04, 126.50, 123.74, 123.18, 82.58, 80.15, 64.01, 51.35, 51.16, 43.90, 34.39, 27.54, 17.06 ppm; $[\alpha]_D$ = -19.0° (c = 0.21, $CHCl_3$); IR (KBr): ν = 3450, 3060, 3028, 2980, 2947, 2929, 2848, 1730, 1607, 1532, 1497, 1458, 1431, 1392, 1371, 1251, 1159, 1060, 848, 752 cm^{-1}; HRMS (ESI) m/z calcd for $C_{25}H_{30}O_5Na$ [M+Na]+ = 433.1986, found = 433.1985.

2.3 X-ray diffraction data

Single-crystal X-ray diffraction data for **4cd** and **6b** were obtained from Nonius KappaCCD difractometer equipped with Bruker ApexII detector by monochromatized MoKα radiation (λ = 0.71073 Å) at 150(2)K. The structures were solved by direct methods (SHELXS, Sheldrik, 2008) and refined by full-matrix least squares based on F^2 (SHELXL97). The hydrogen atoms were fixed into idealised positions (riding model) and assigned temperature factors H_{iso}(H) = 1.2 U_{eq}(pivot atom).[11]

The determination of absolute configuration of corresponding derivatives were based on anomalous dispersion of bromine atoms.

Crystal data for **4cd**: $C_{25}H_{25}BrO_5$, M = 485.36, Triclinic, *P*1 (No 1), *a* = 6.4597 (4) Å, *b* = 9.7895 (6) Å, *c* = 10.0741 (5) Å, α = 70.729 (2)°, β = 76.156 (2)°, γ = 79.307 (2)°, *V* = 579.93 (6) Å^3, Z = 1, D_x = 1.390 Mg m^{-3}, colourless crystal of dimensions 0.43 × 0.24 × 0.18 mm, numerical absorption correction (μ = 1.81 mm^{-1}) T_{min} = 0.513, T_{max} = 0.732; a total of 10226 measured reflections (θ_{max}= 27.5˚), from which 5195 were unique (R_{int} = 0.016) and 4911 observed according to the $I > 2\sigma(I)$ criterion. The refinement converged (Δ/σ_{max}< 0.001) to *R* = 0.025 for observed reflections and $wR(F^2)$ = 0.052, *GOF* = 1.05 for 284 parameters and all 5195 reflections. The final difference map displayed no peaks of chemical significance ($\Delta\rho_{max}$ = 0.36, $\Delta\rho_{min}$ −0.34 e.Å^{-3}). Chirality parameter −0.005 (4).

Crystal data for **6b**: $C_{24}H_{26}O_4$, M = 378.45, Monoclinic, *P* 2_1 (No 4), *a* = 9.6739 (3) Å, *b* = 8.7077 (3) Å, *c* = 12.2435 (4) Å, β = 99.6610 (10)°, *V* = 1016.73 (6) Å^3, Z = 2, D_x = 1.236 Mg m^{-3}, colourless crystal of dimensions 0.48 × 0.33 × 0.28 mm, multi-scan absorption correction (μ = 0.08 mm^{-1}) T_{min} = 0.961, T_{max} = 0.977; a total of 15240 measured reflections (θ_{max}= 27.5˚), from which 4680 were unique (R_{int} = 0.023) and 4263 observed according to the $I > 2\sigma(I)$ criterion. The refinement converged (Δ/σ_{max}< 0.001) to *R* = 0.037 for observed reflections and $wR(F^2)$ = 0.094, *GOF* = 1.05 for 257 parameters and all 4680 reflections. The final difference map displayed no peaks of chemical significance ($\Delta\rho_{max}$ = 0.23, $\Delta\rho_{min}$ −0.24.Å^{-3}). The absolute configuration has been assigned by reference to an unchanging chiral centre in the synthetic procedure. (Chirality parameter −0.5 (8))

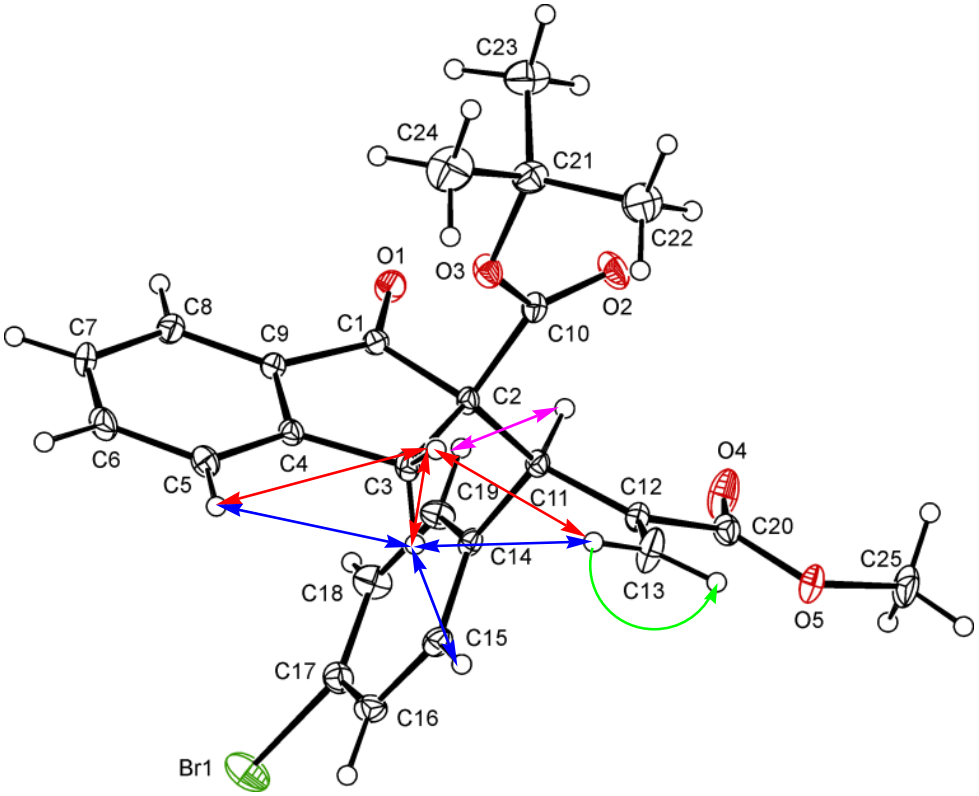
Crystallographic data (excluding structure factors) for the structures have been deposited with the Cambridge Crystallographic Data Centre with CCDC numbers 953269 and 953270

[11] G. M. Sheldrick, *Acta Cryst*., 2008, **A64**, 112-122.

for **4cd** and **6b**: respectively. Copies of the data can be obtained, free of charge, on application to Cambridge Crystallographic Data Centre, 12 Union Road, Cambridge CB2 1EZ, UK, (fax: +44-(0)1223-336033 or e-mail: deposit@ccdc.cam.ac.Uk).

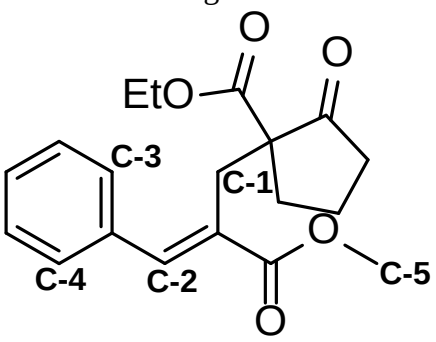
2.4 Relative configuration of compound 4ad from 1D gNOESY experiments

1D gNOESY experiments were necessary for dertermination of relative configuration **4cd**. In 1D gNOESY spectra were observed the correlations between protons H-3a and H-3b, H-5, H-13b; H-3b and H-5, H-13b, H-15; H-11 and H-19. Each of these crosspeaks corresponds to the X-ray structure of (C2,C11-R,R)-4f. Both aryl rings are in syn-configuration.

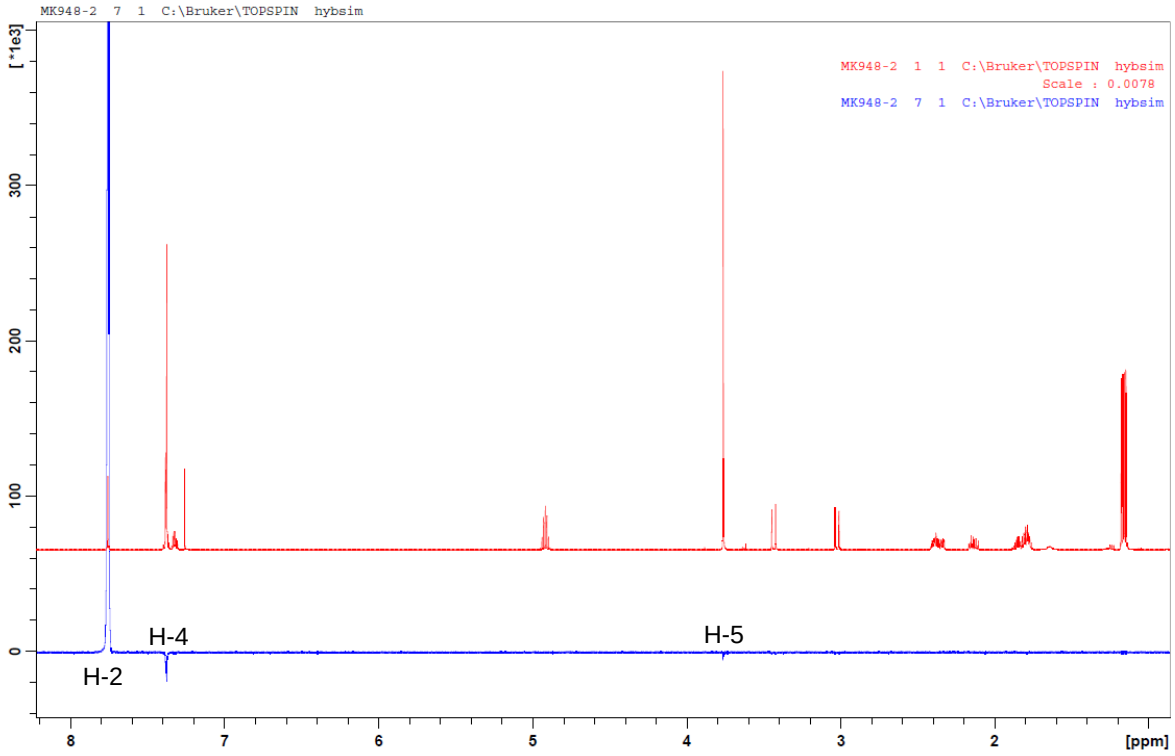


2.5 Determination of the double bond configuration of 5aa

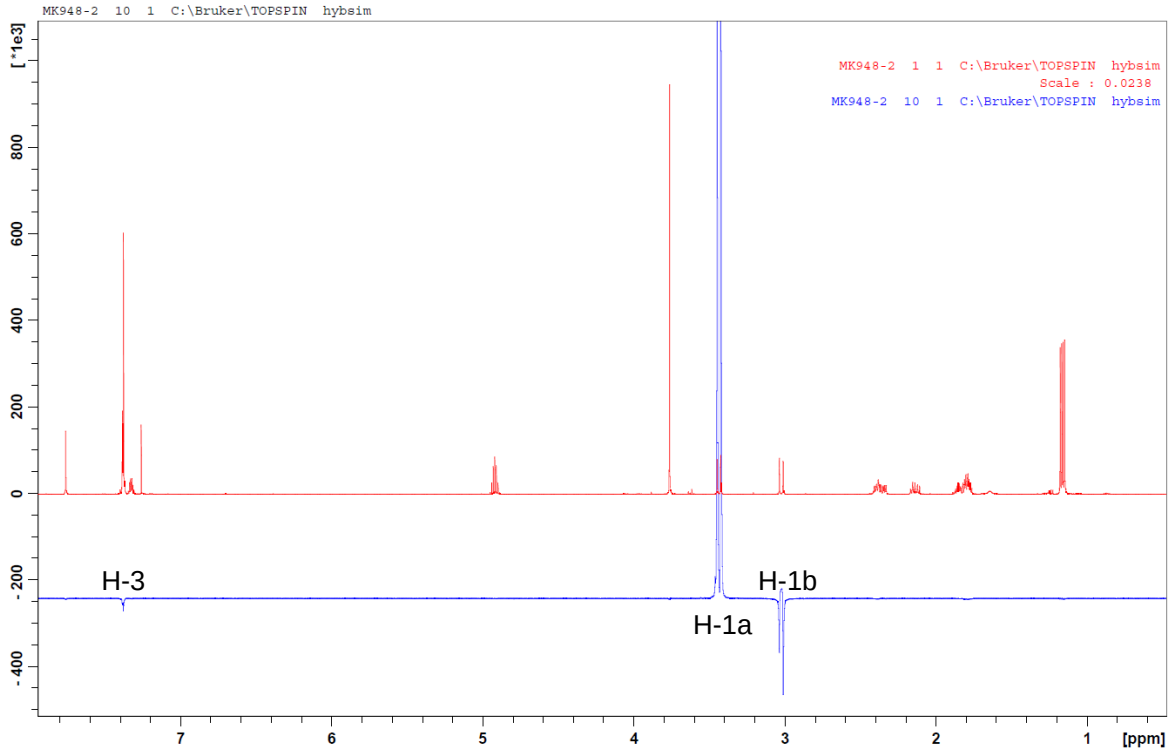
Determination of a configuration of double bond was able due to 1D gNOESY experiments. The interaction among proton atoms in 1D NMR gNOESY spectra of **5aa** are shown below. In NMR spectra there is no interaction between H-1a and H-2, H-1b and H-2. In 1D gNOESY NMR spectra we can see interaction among protons: H-1a and H-1b, H-1a and H-3, H-1b and H-4 and weak interaction between H-2 and H-5. All crospeaks in 1D gNOESY NMR spectra show to *E*-configuration of double bond.



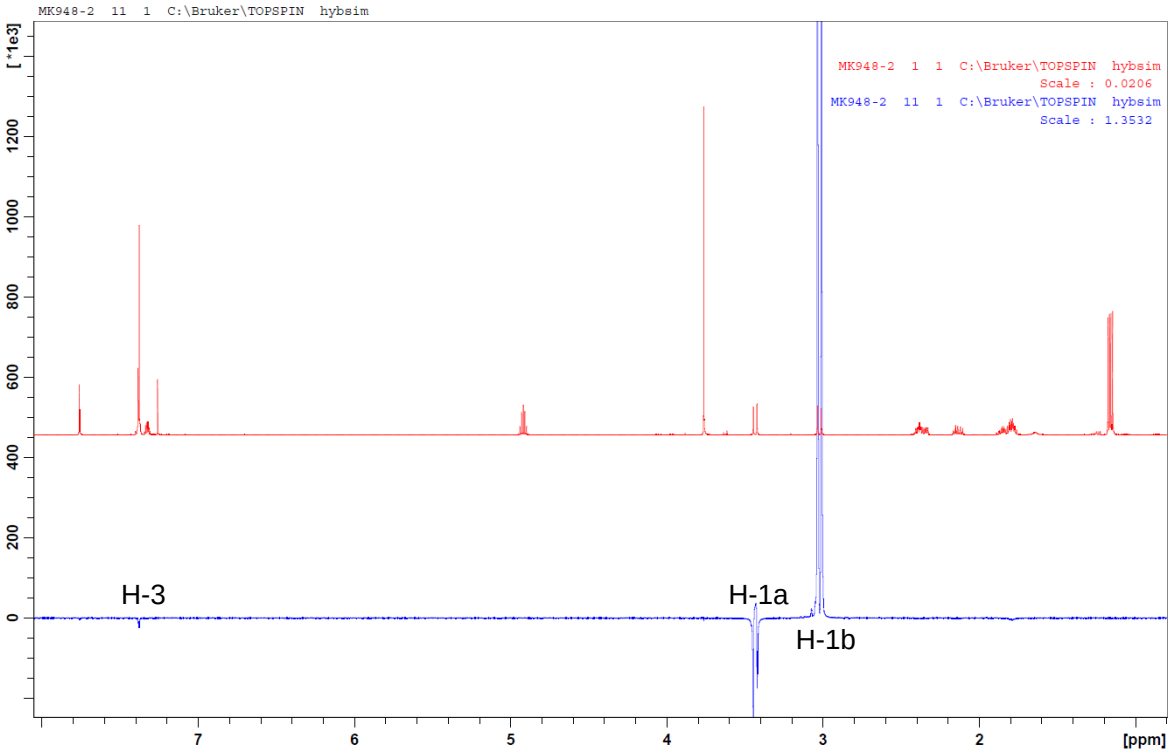
1D gNOESY NMR spectrum of H-2



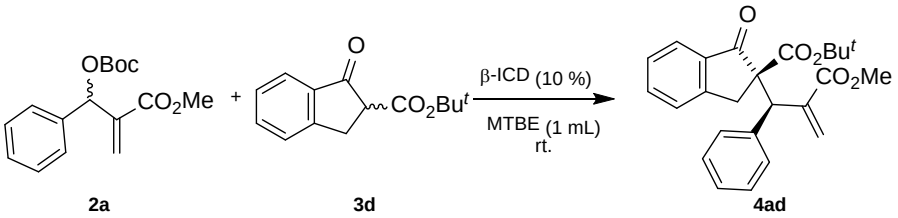
1D gNOESY NMR spectrum of H-1a



1D gNOESY NMR spectrum of H-1b



2.6 Kinetic resolution of the MBH-carbonate



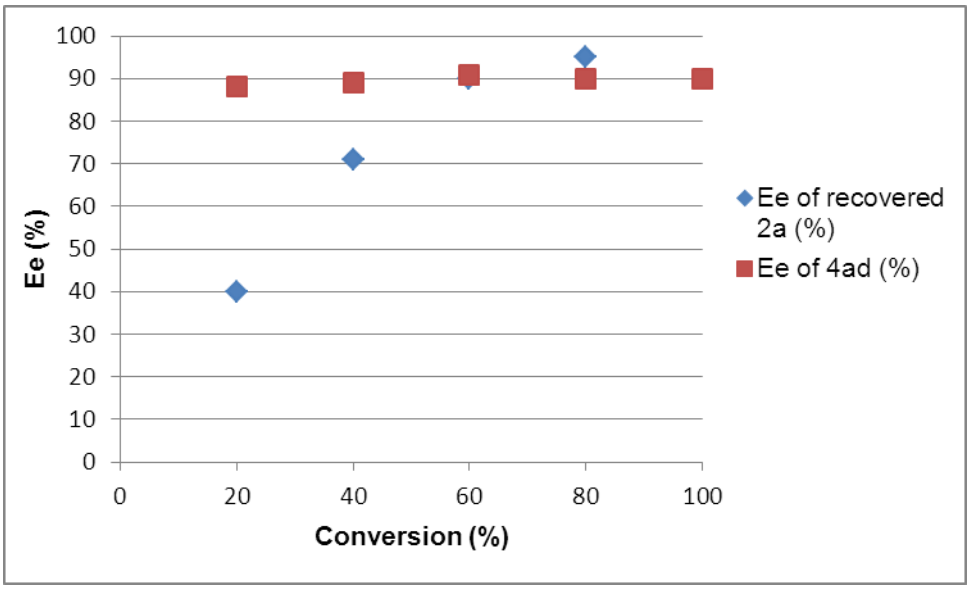
2a 3d 4ad

Entry	Ratio of 2a:3d	Time (h)	dr[a]	Yield of 4ad/recovered 2a (%)	ee of 4ad (%)[b]	ee of recovered 2a (%)[b]
1	5:1	3	5:1	12/48	88	40
2	5:2	4	5:1	25/34	89	71
3	5:3	7	5:1	27/27	91	90
4	5:4	16	5:1	40/14	90	95
5	1:1	21	5:1	70/-	90	-

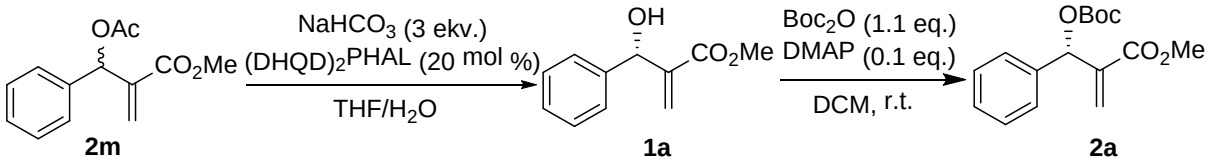
[a] determined by ^{1}H NMR

[b] determined by HPLC (Chiral AD 95:5 Hept:*i*PrOH, 1mL)

Kinetic resolution of MBH carbonate **2a**



Preparation of enantioenriched MBH carbonate 2a



2m **1a** (ee 77%) **2a** (ee = 77%)

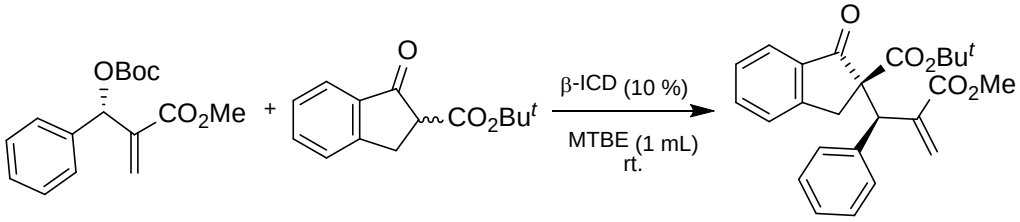
Methyl (*S*)-2-(hydroxy(phenyl)methyl)acrylate (**1a**). According a reported procedure,[12] to a stirred solution of the Baylis–Hillman acetate **2m** (234 mg, 1.0 mmol) and $(DHQD)_2PHAL$ (156 mg, 0.2 mmol) in aqueous THF (10mL, H_2O/THF = 1:2) was added sodium bicarbonate (252 mg, 3.0 mmol). The reaction mixture was stirred at 45 °C for 3.5 days. Reaction mixture

[12] J. N. Kim, H. J. Lee and J. H. Gong, *Tetrahedron Lett.* 2002, **43**, 9141-9146.

was then extracted with DCM and organic phase was dried over Na_2SO_4 , filtered concentrated in vacuo. Crude material was separated on column chromatography (Hex:EtOAc mixture) obtaining MBH alcohol **1a** (35% yield, 77% ee). NMR data of **1a** correspond with data published in the literature.

Methyl (*S*)-2-(((tert-butoxycarbonyl)oxy)(phenyl)methyl)acrylate (2a) Compound **2a** was prepared according above mentioned precedure for preparation MBH carbonates.[1]

Allylic alkylation with enantiomerically enriched MBH carbonate 2a



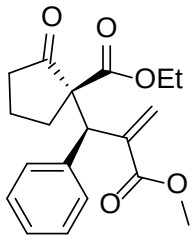
2a **3d** **4ad**

Entry	Ratio of 2a:3d	Time (h)	dr[a]	Yield of 4ad (%)	ee of starting 2a (%)[b]	ee of 4ad (%)[b]
1	1:1	46	5:1	60	77	89

[a] determined by ^{1}H NMR

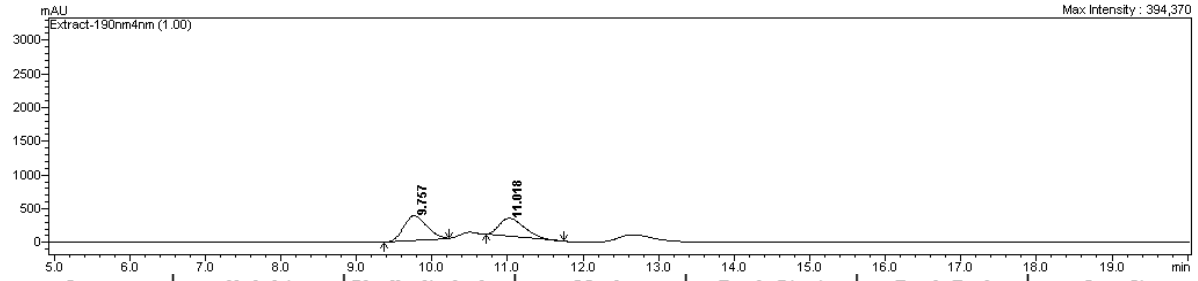
[b] determined by HPLC (Chiral AD 95:5 Hept:*i*PrOH, 1mL)

3 HPLC analysis

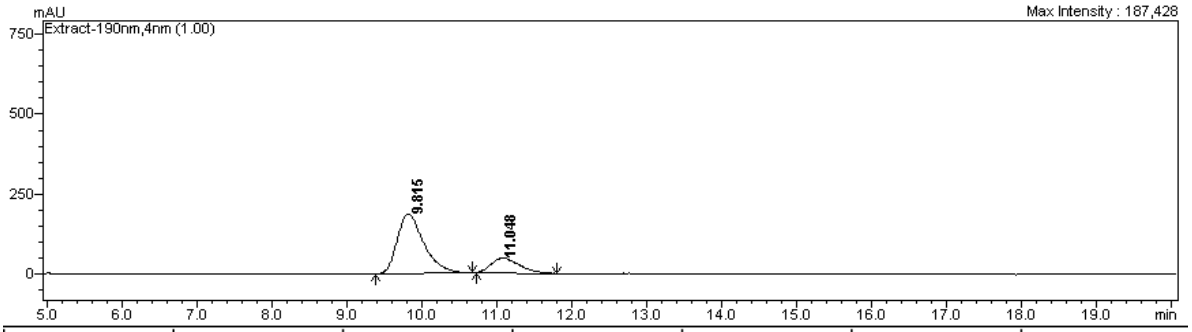


4aa

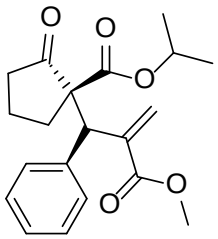
Conditions: Column AD (Heptane : isopropanol 95:5, flow: 1mL/min)



Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
6214103	327840	0.000000		9.440	10.069	49.4341
6356387	268973	0.000000		10.720	11.744	50.5659

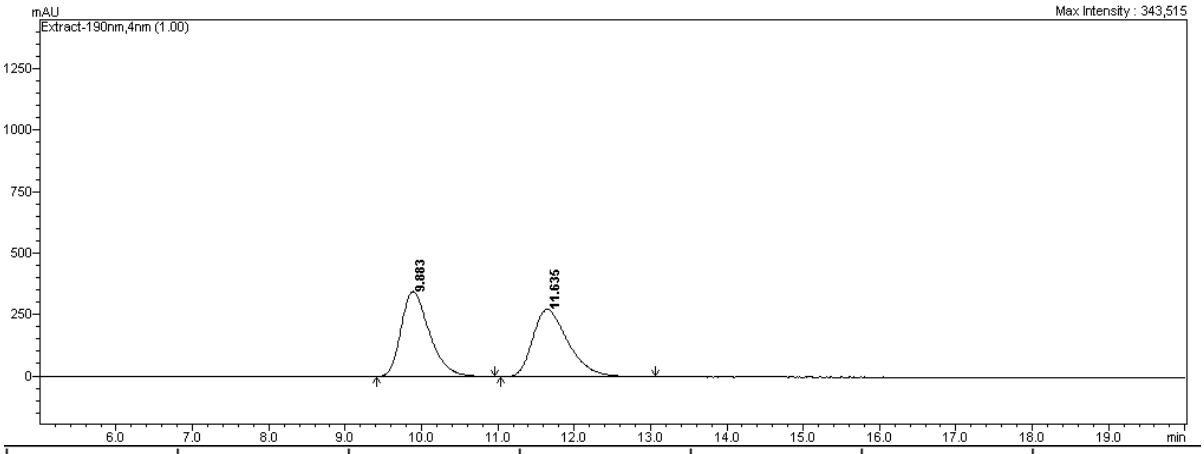


Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
4626372	186089	0.000000		9.387	10.667	78.9685
1232134	45815	0.000000		10.720	11.797	21.0315

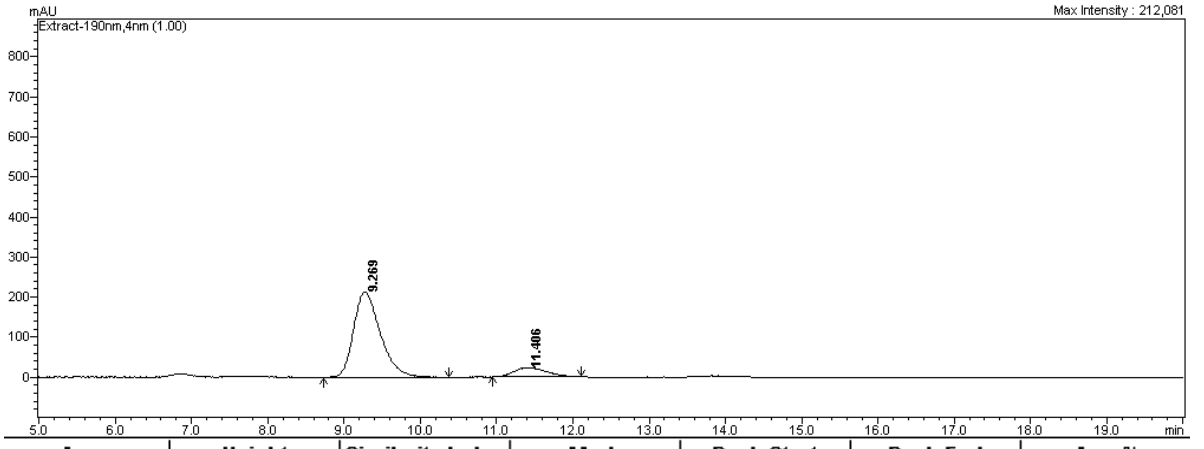


4ab

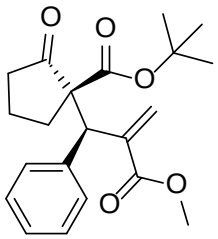
Conditions: Column AD (Heptane : isopropanol 99:1, flow: 1mL/min)



Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
8987341	346326	0.000000		9.408	10.965	50.4068
8842294	273828	0.000000		11.040	13.056	49.5932

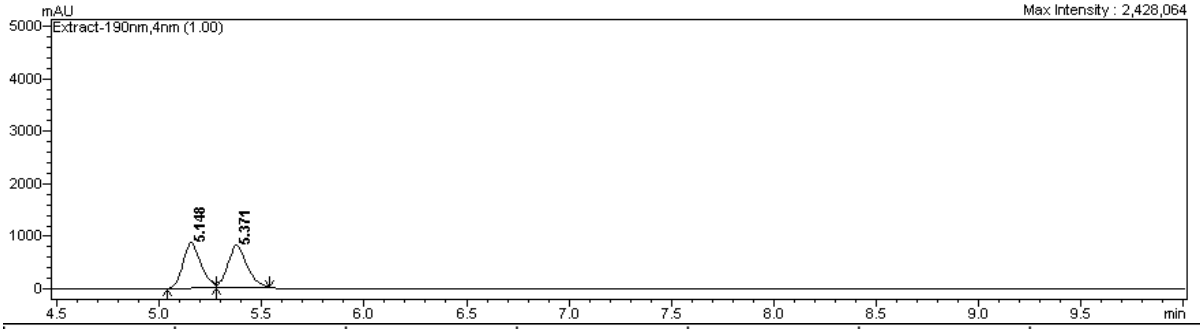


Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
5189843	212341	0.000000		8.736	10.368	88.4284
679134	23257	0.000000		10.955	12.107	11.5716

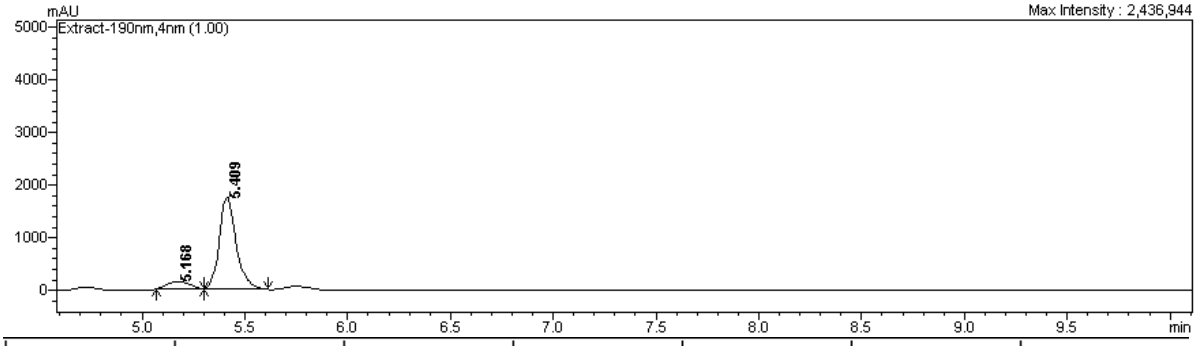


4ac

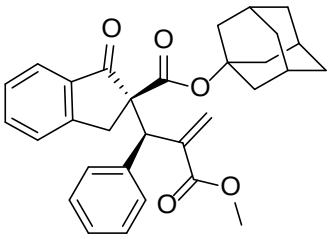
Conditions: Column IB (Heptane : isopropanol 95:5, flow: 1mL/min)



Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
5450611	882524	0.000000		5.035	5.280	50.7135
5297235	825292	0.000000	V	5.280	5.536	49.2865

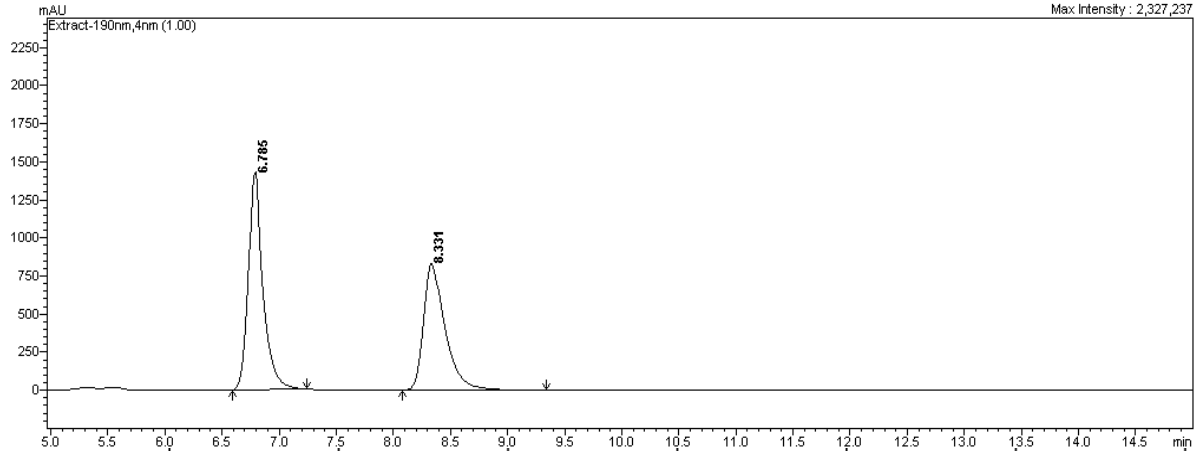


Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
972120	138054	0.000000		5.067	5.301	9.0169
9808930	1733604	0.000000		5.301	5.611	90.9831

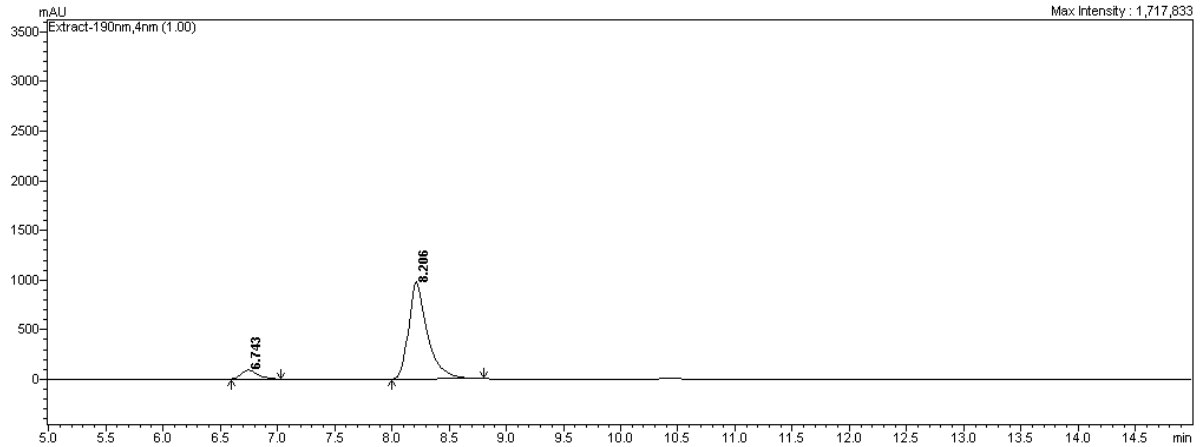


4ae

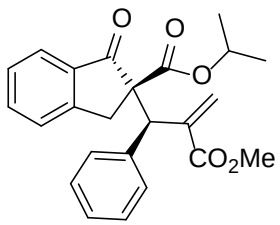
Conditions: Column IB (Heptane : isopropanol 98:2, flow: 1mL/min)



Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
12389519	1428201	0.000000		6.592	7.243	53.4634
10784304	829179	0.000000		8.075	9.344	46.5366

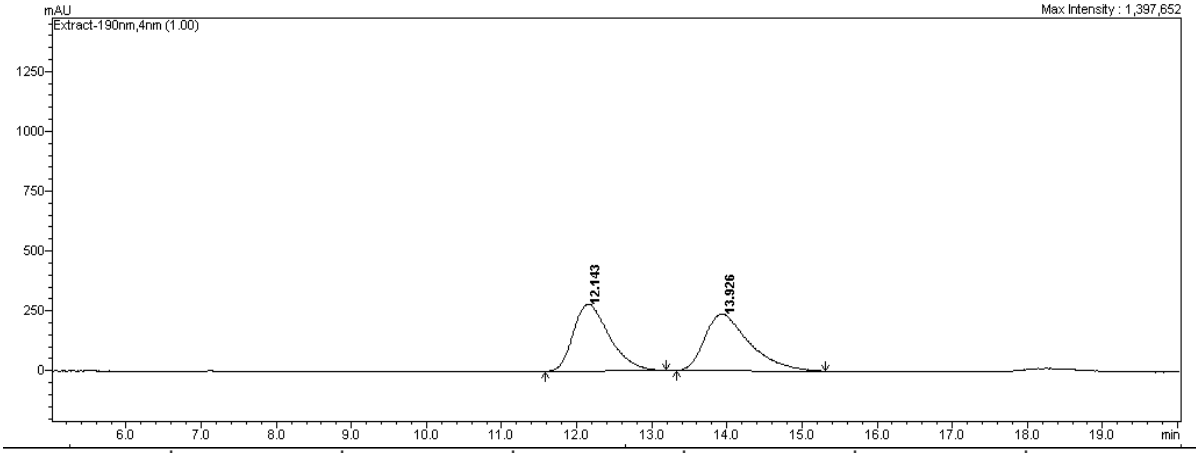


Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
929990	89705	0.000000		6.592	7.029	7.6627
11206558	982082	0.000000		8.000	8.800	92.3373

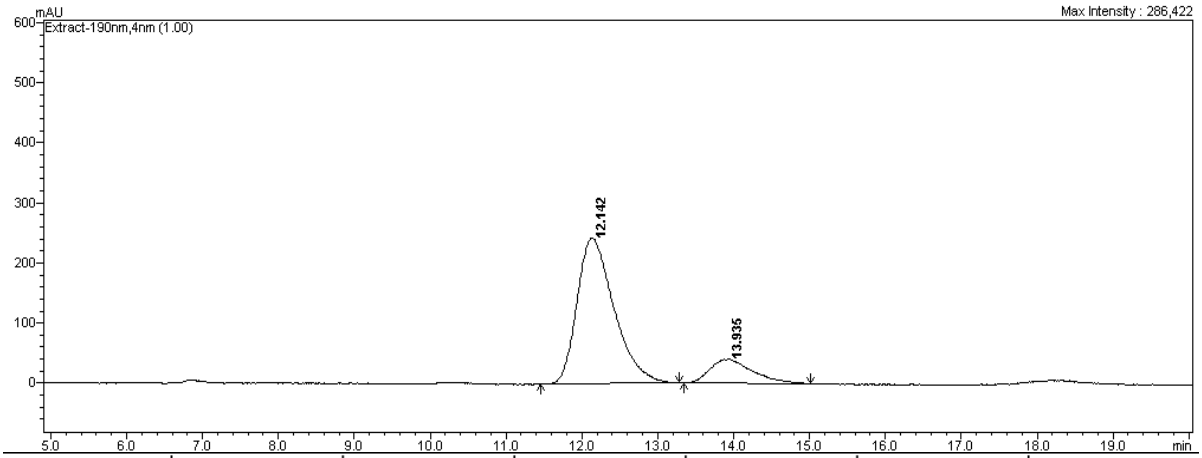


4af

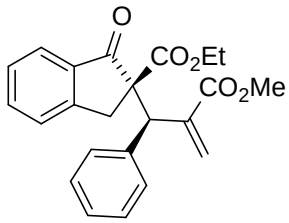
Conditions: Column AD (Heptane : isopropanol 95:5, flow: 1mL/min)



Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
9362136	280781	0.000000		11.584	13.195	48.9030
9782180	238475	0.000000		13.333	15.317	51.0970

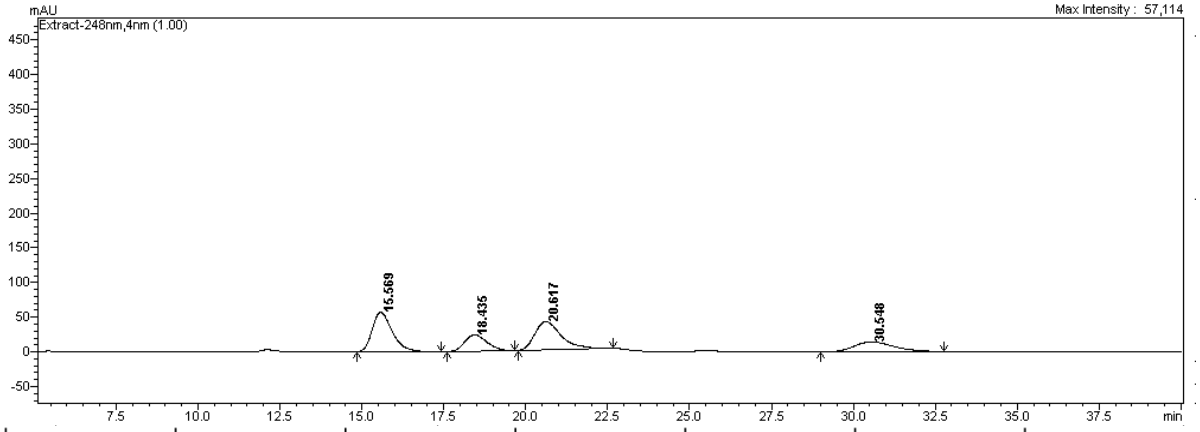


Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
8215349	242976	0.000000		11.456	13.280	84.4096
1517368	39746	0.000000		13.344	15.008	15.5904

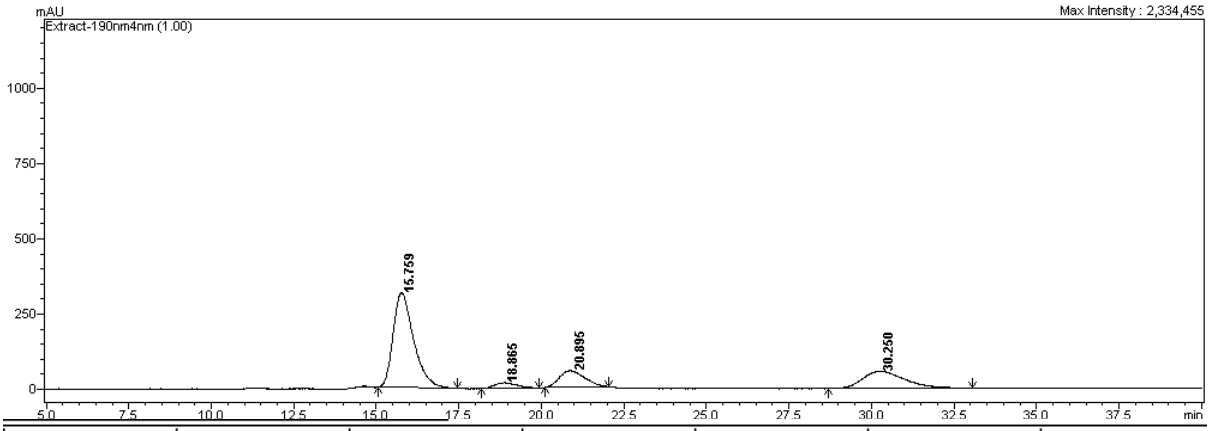


4ag

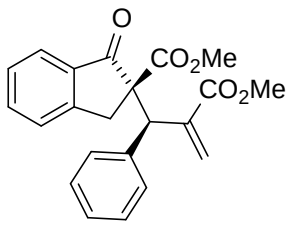
Conditions: Column AD (Heptane : isopropanol 95:5, flow: 1mL/min)



Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
2401656	56667	0.000000		14.859	17.408	34.2906
1143328	23811	0.000000		17.589	19.669	16.3243
2264186	40611	0.000000		19.787	22.667	32.3278
1194662	14264	0.000000		29.013	32.768	17.0573

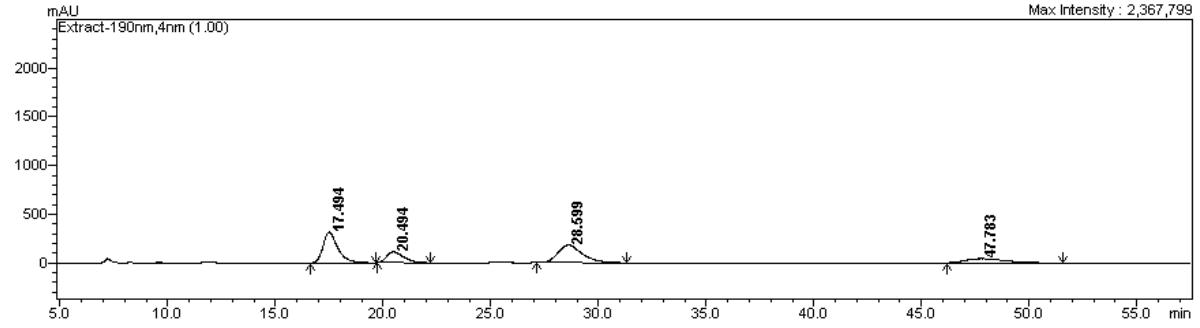


Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
13694936	316317	0.000000		15.061	17.440	60.6294
853554	18918	0.000000		18.197	19.936	3.7788
2949555	55400	0.000000		20.117	22.048	13.0581
5089904	56936	0.000000		28.715	33.045	22.5337

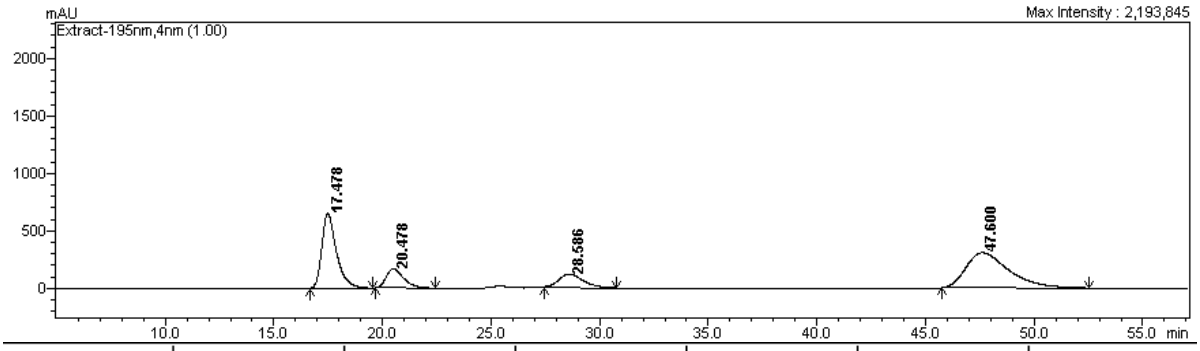


4ah

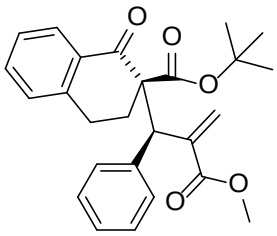
Conditions: Column AD (Heptane : isopropanol 95:5, flow: 1mL/min)



Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
14934526	316053	0.000000		16.608	19.648	36.5084
6084979	111780	0.000000		19.712	22.219	14.8751
14163616	178501	0.000000		27.115	31.296	34.6238
5724015	45053	0.000000		46.165	51.541	13.9927

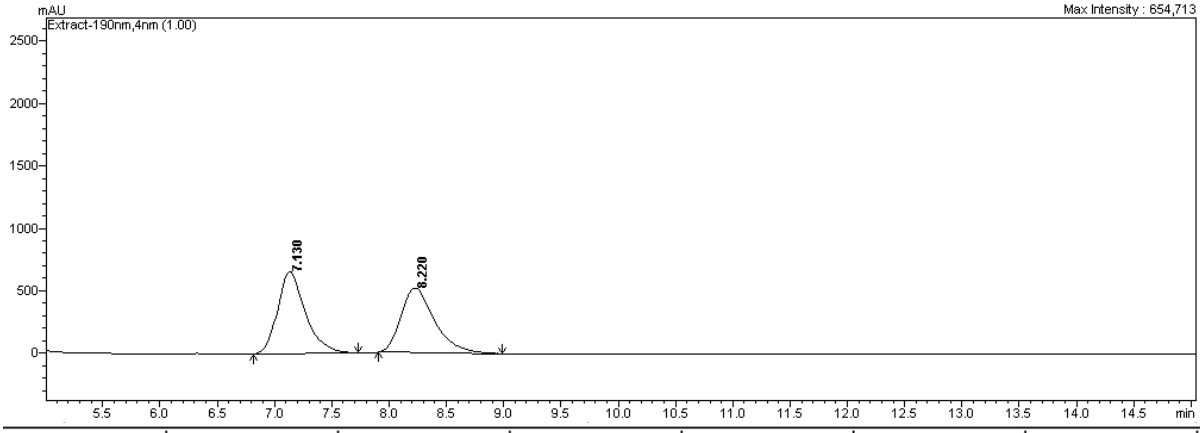


Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
30317247	654590	0.000000		16.651	19.573	33.5952
9199102	164845	0.000000		19.701	22.421	10.1937
8582856	113109	0.000000		27.467	30.752	9.5108
42143685	306474	0.000000		45.749	52.533	46.7003

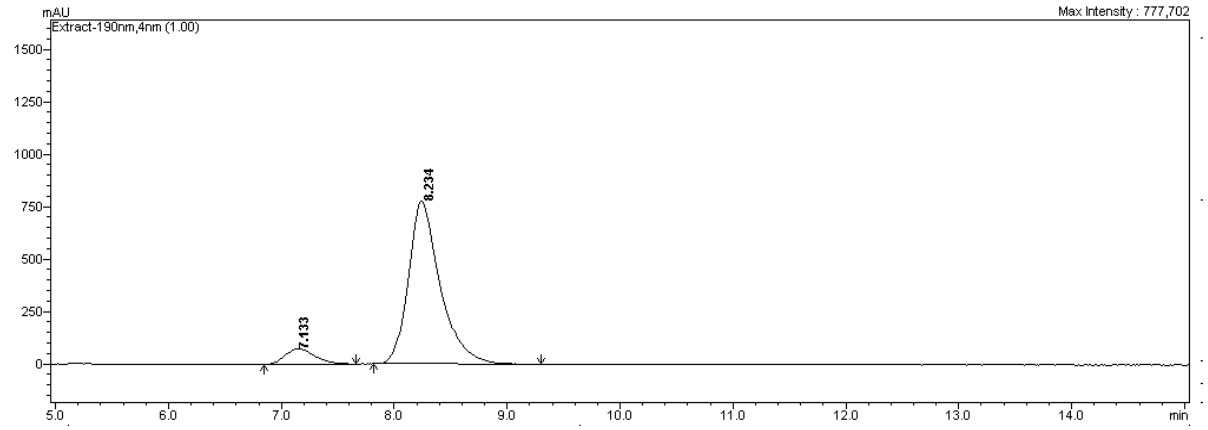


4ai

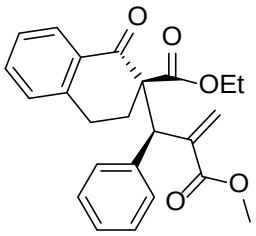
Conditions: Column AD (Heptane : isopropanol 90:10, flow: 1mL/min)



Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
11133560	657403	0.000000		6.816	7.733	51.5146
10478871	517247	0.000000		7.904	8.992	48.4854

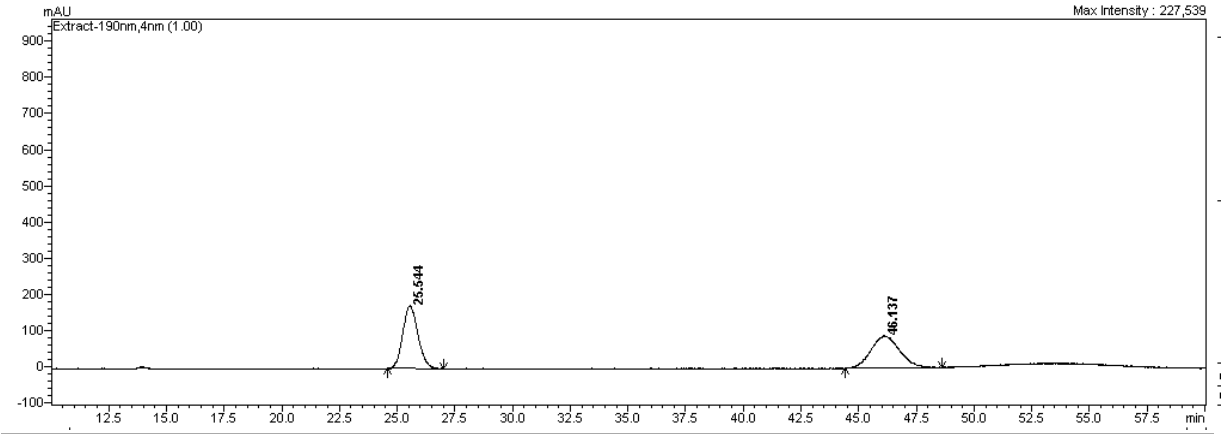


Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
1350055	74548	0.000000		6.848	7.659	8.0975
15322509	777330	0.000000		7.819	9.301	91.9025

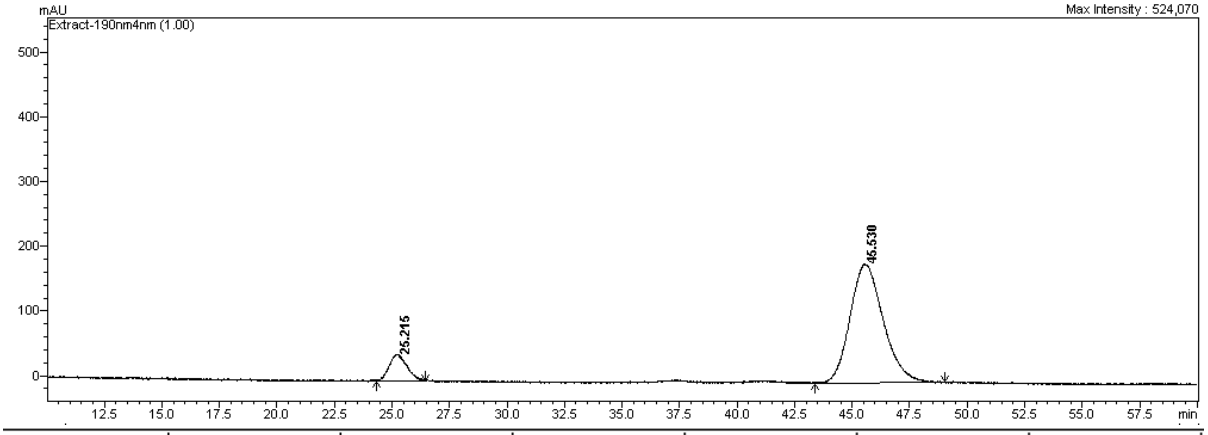


4aj

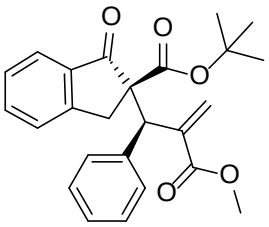
Conditions: Column IC (Heptane : isopropanol 90:10, flow: 1mL/min)



Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
7980101	173677	0.000000		24.576	27.029	51.2783
7582246	88600	0.000000		44.437	48.597	48.7217

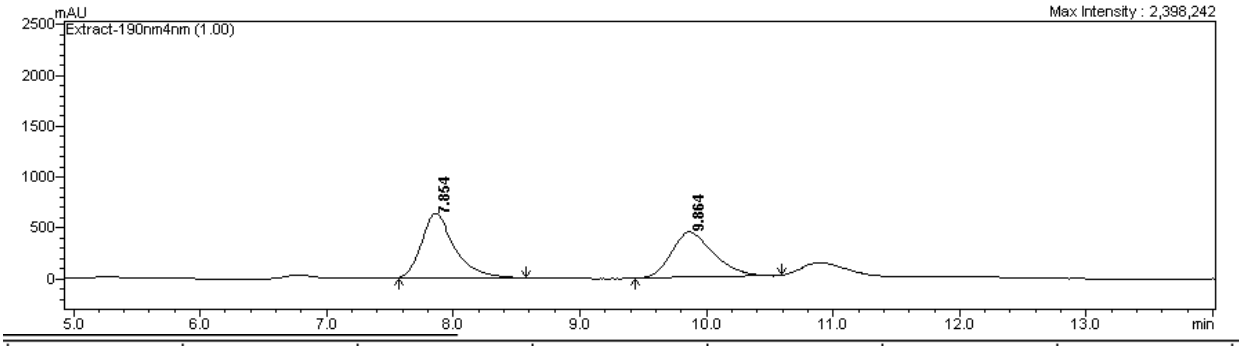


Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
2152766	40297	0.000000		24.352	26.432	10.2731
18802564	184405	0.000000		43.381	49.045	89.7269

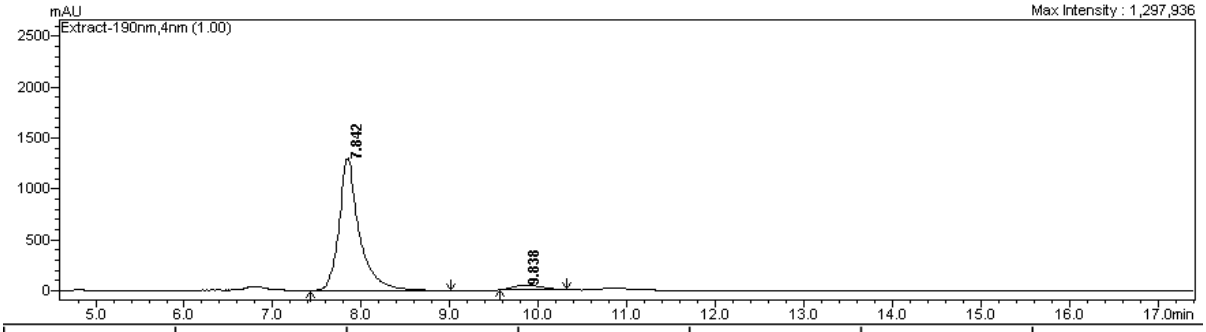


4ad

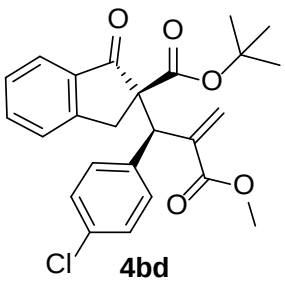
Conditions: Column AD (Heptane : isopropanol 95:5, flow: 1mL/min)



Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
11412788	632009	0.000000		7.573	8.576	52.7694
10214893	443310	0.000000		9.440	10.592	47.2306

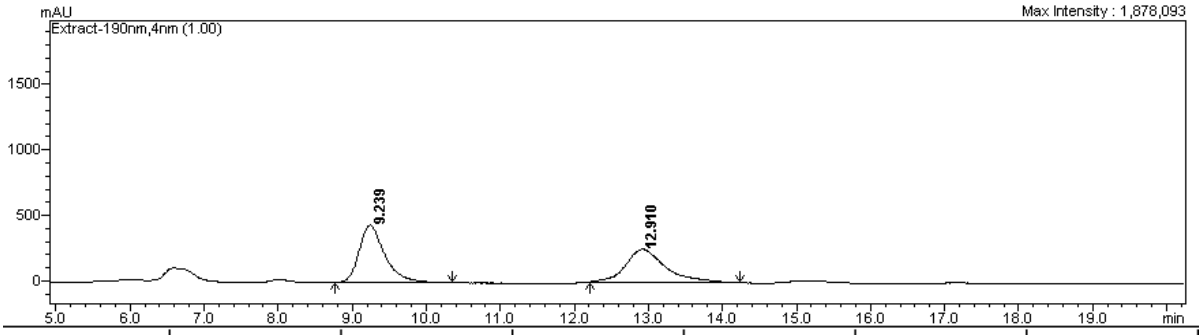


Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
20489457	1296452	0.000000		7.424	9.013	95.0587
1065072	48336	0.000000		9.568	10.315	4.9413

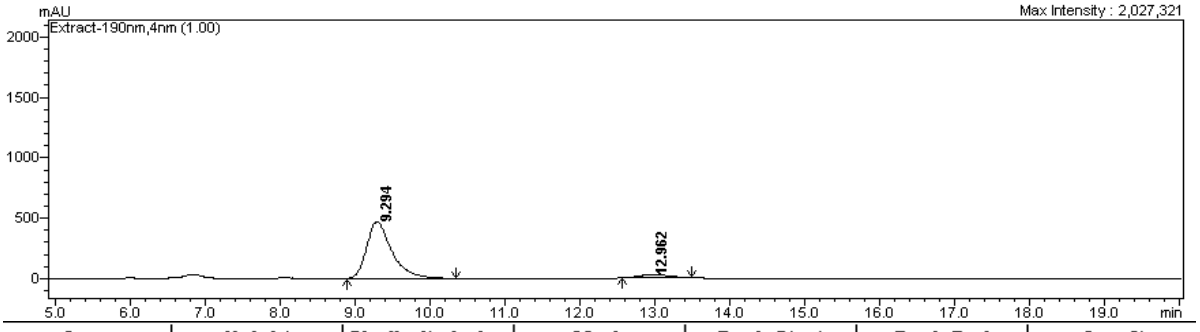


4bd

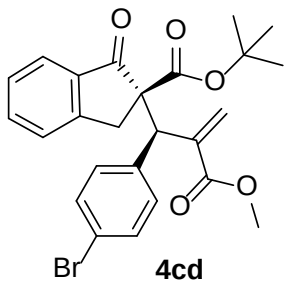
Conditions: Column AD (Heptane : isopropanol 95:5, flow: 1mL/min)



Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
10642101	438964	0.000000		8.768	10.347	53.2215
9353780	250466	0.000000		12.203	14.229	46.7785

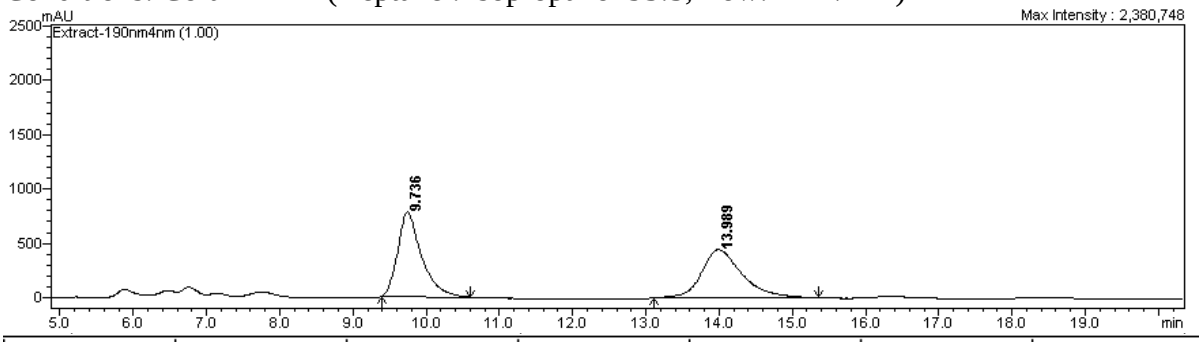


Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
11015534	469854	0.000000		8.885	10.347	93.6936
741438	26667	0.000000		12.565	13.493	6.3064

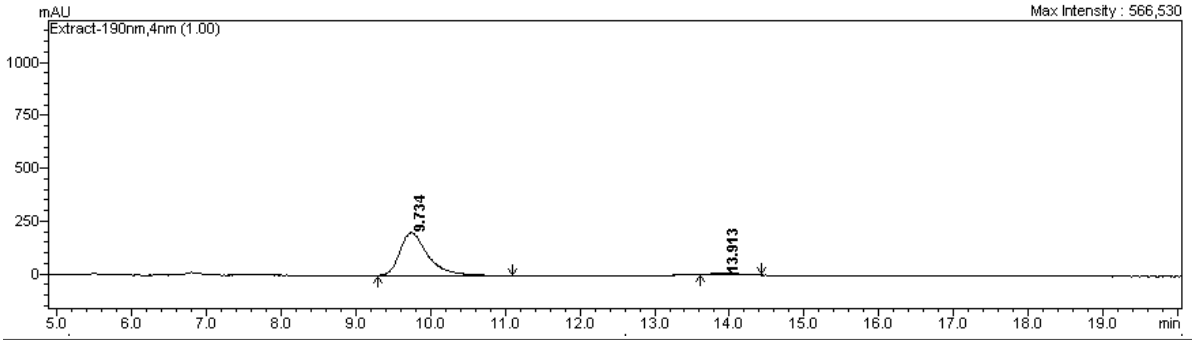


4cd

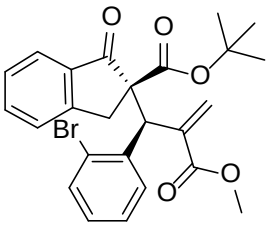
Conditions: Column AD (Heptane : isopropanol 95:5, flow: 1mL/min)



Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
17619077	781491	0.000000		9.387	10.603	50.6299
17180645	444536	0.000000		13.120	15.360	49.3701

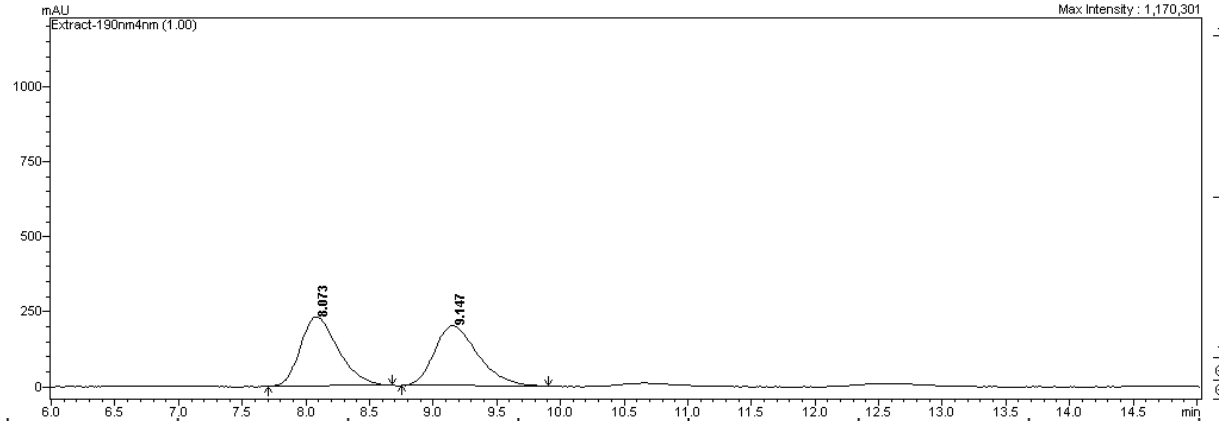


Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
5239680	202393	0.000000		9.301	11.093	96.4830
190997	7131	0.000000		13.611	14.421	3.5170

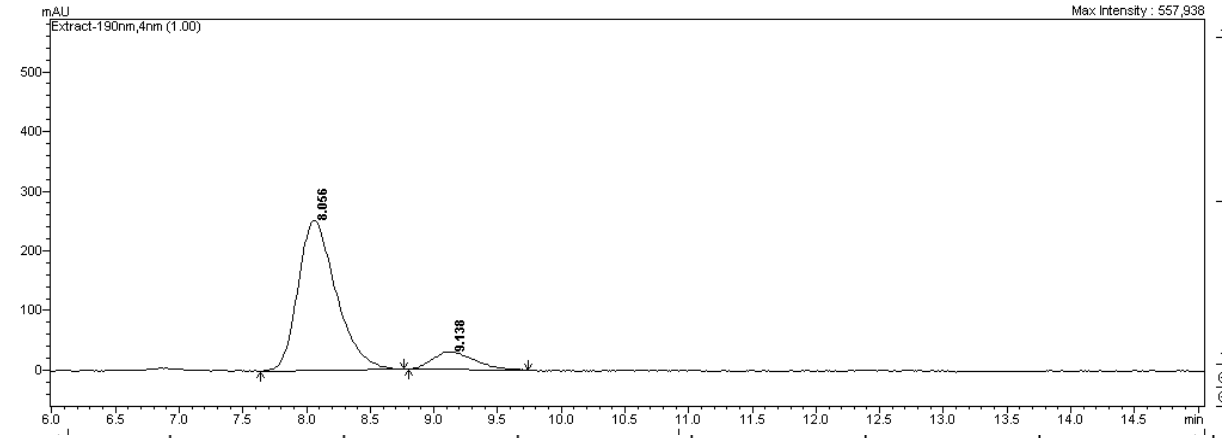


4dd

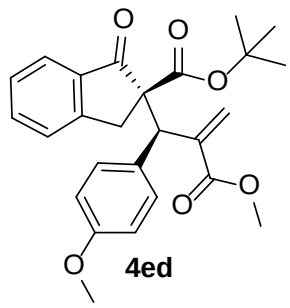
Conditions: Column AD (Heptane : isopropanol 95:5, flow: 1mL/min)



Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
4788022	230128	0.000000		7.701	8.683	50.2090
4748168	199072	0.000000		8.757	9.909	49.7910

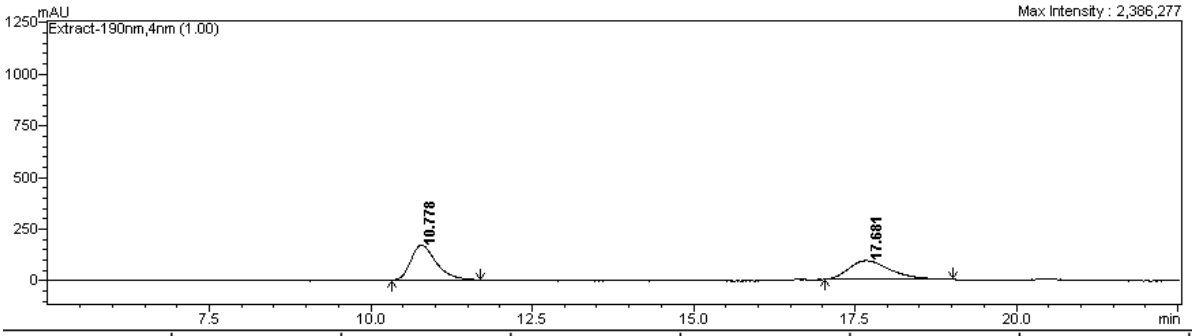


Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
5224749	250908	0.000000		7.637	8.768	89.0481
642586	28757	0.000000		8.800	9.739	10.9519

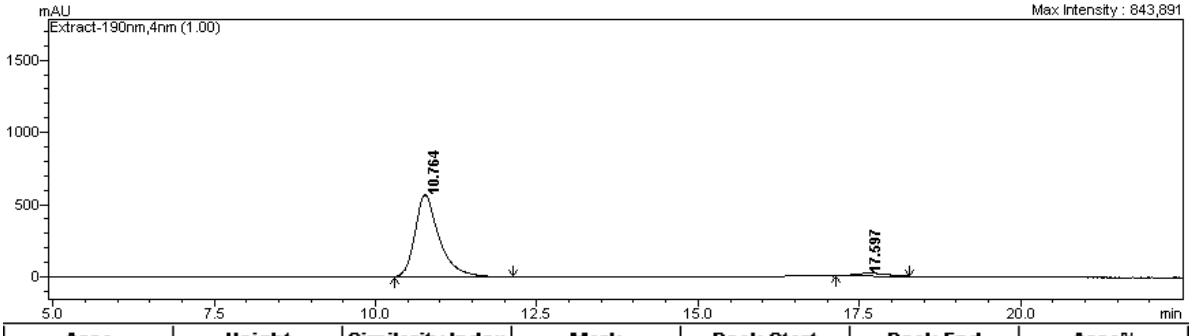


4ed

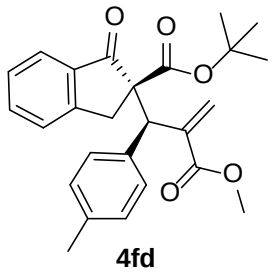
Conditions: Column AD (Heptane : isopropanol 95:5, flow: 1mL/min)



Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
4743869	172052	0.000000		10.336	11.691	53.4702
4128122	91242	0.000000		17.035	19.029	46.5298

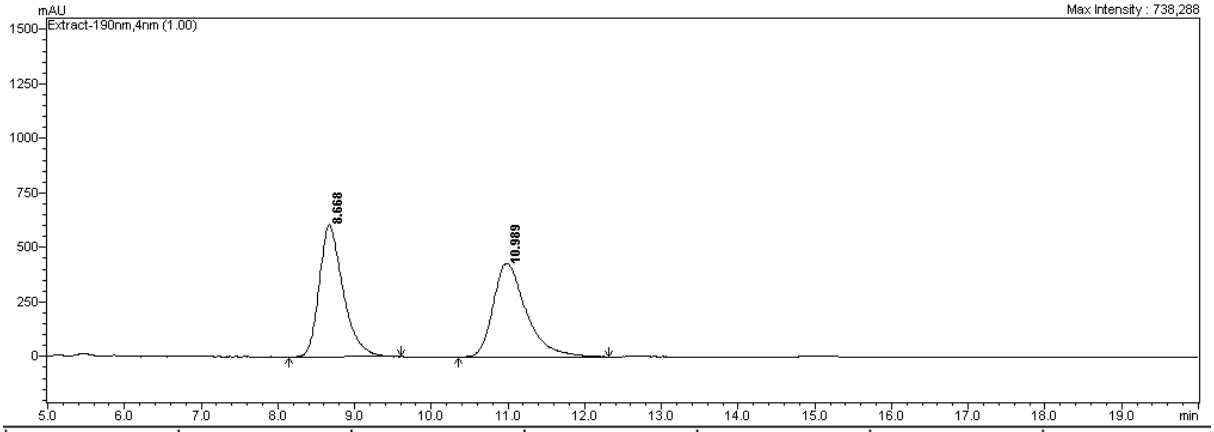


Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
14966169	567648	0.000000		10.304	12.128	95.3466
730417	20668	0.000000		17.131	18.272	4.6534

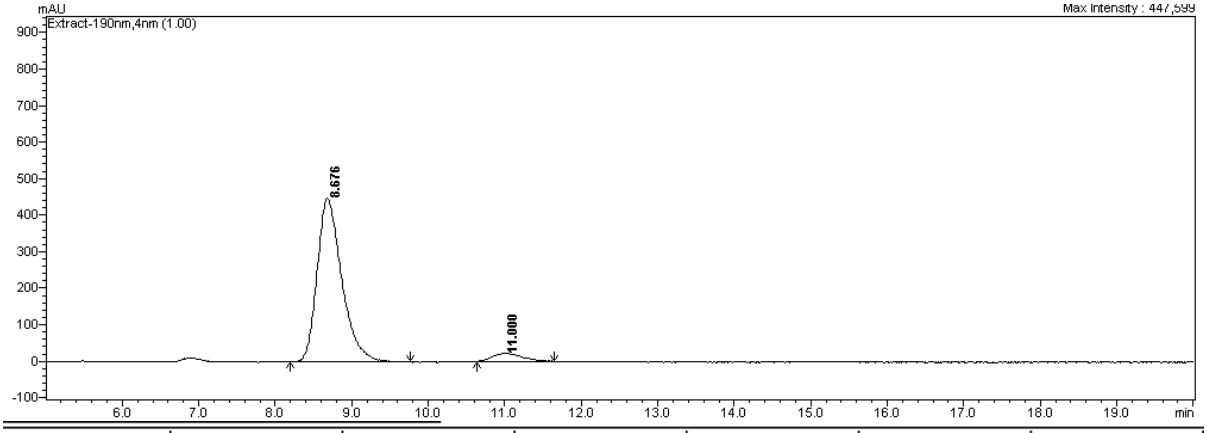


4fd

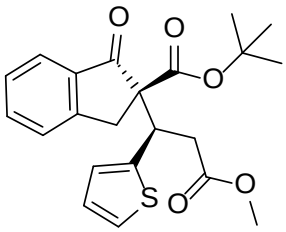
Conditions: Column AD (Heptane : isopropanol 95:5, flow: 1mL/min)



Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
13058734	605995	0.000000		8.149	9.611	50.3992
12851846	429274	0.000000		10.357	12.320	49.6008

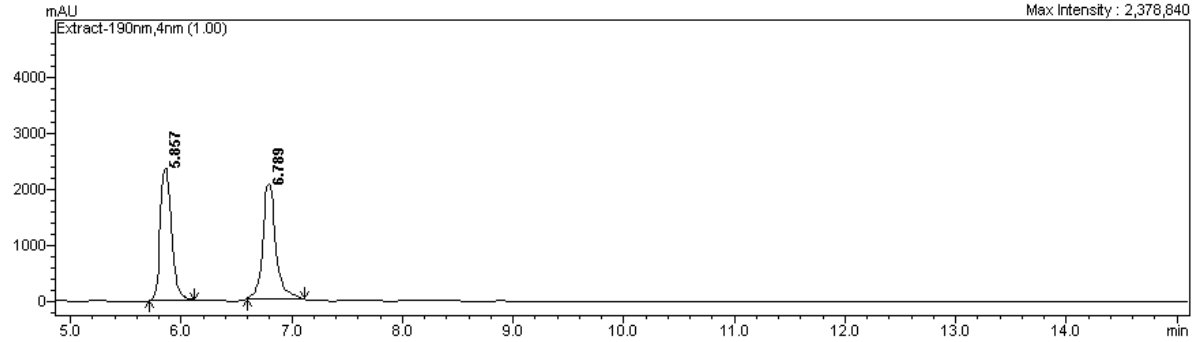


Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
10042833	449446	0.000000		8.192	9.760	94.1050
629108	22740	0.000000		10.635	11.648	5.8950

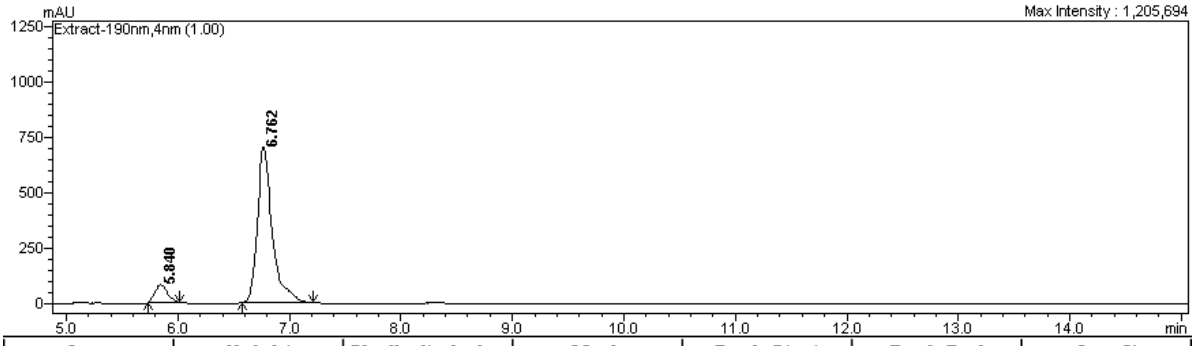


4gd

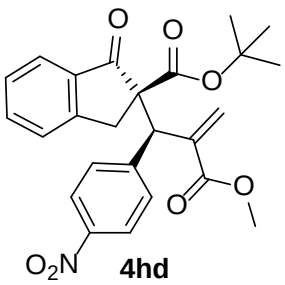
Conditions: Column IB (Heptane : isopropanol 95:5, flow: 1mL/min)



Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
16819975	2352813	0.000000		5.717	6.112	49.7066
17018571	2043858	0.000000		6.592	7.115	50.2934

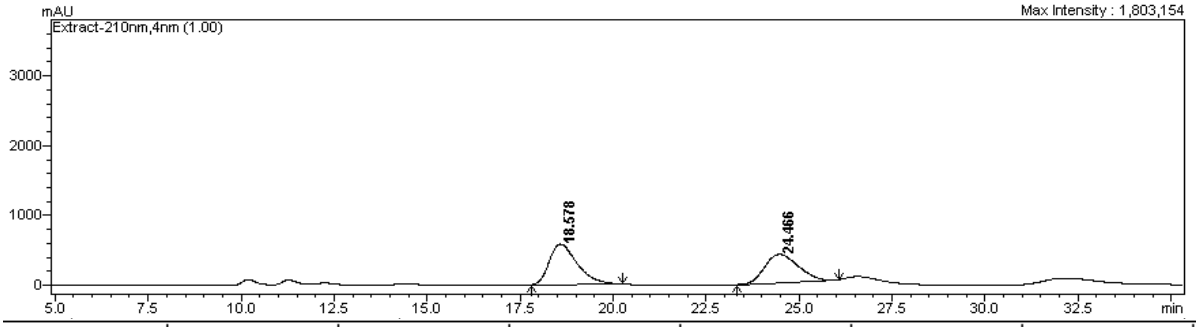


Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
596030	78165	0.000000		5.739	6.016	8.4500
6457540	700268	0.000000		6.581	7.211	91.5500

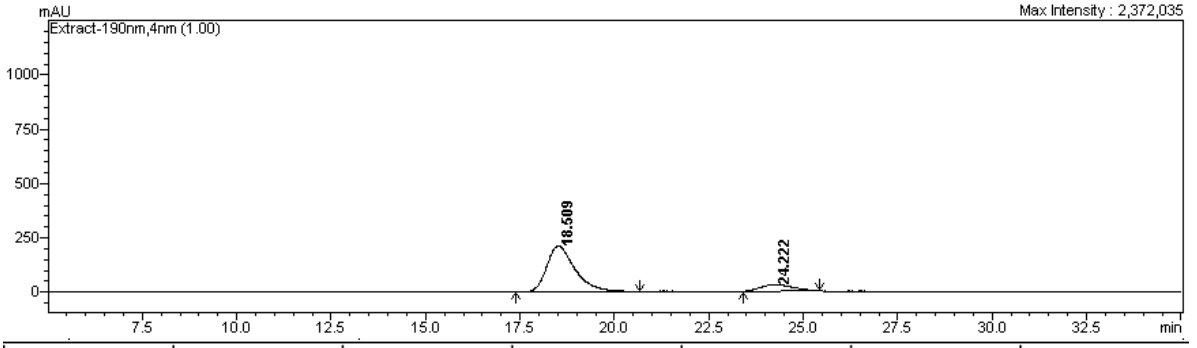


4hd

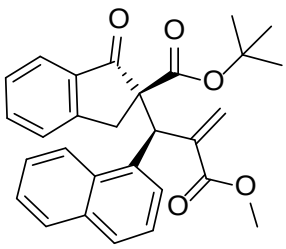
Conditions: Column AD (Heptane : isopropanol 95:5, flow: 1mL/min)



Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
30481670	580263	0.000000		17.792	20.267	54.9697
24970092	403609	0.000000		23.339	26.069	45.0303

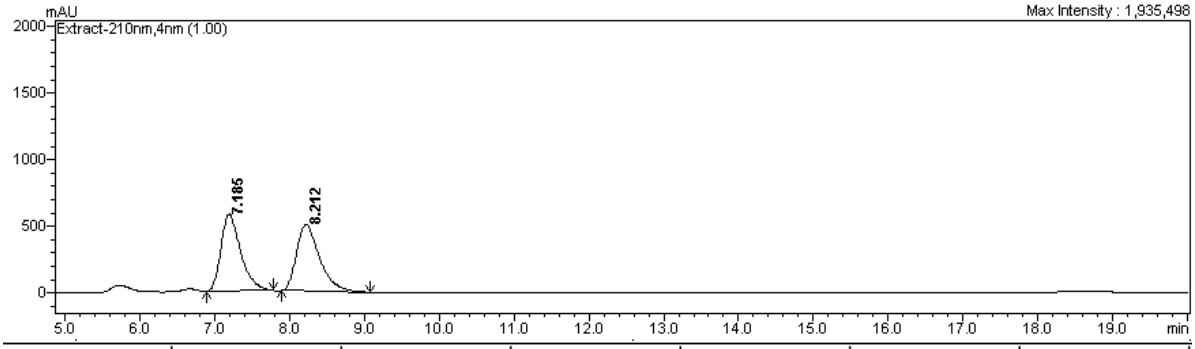


Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
10939998	211150	0.000000		17.397	20.672	85.9246
1792093	30572	0.000000		23.424	25.419	14.0754

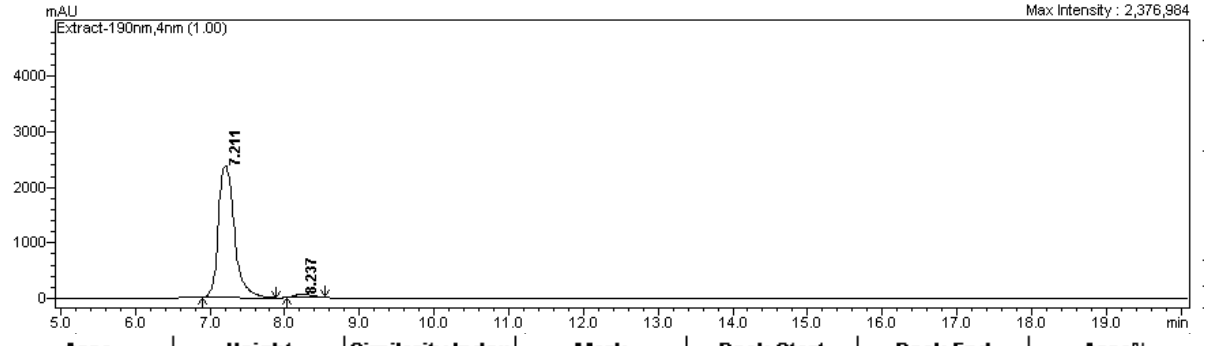


4id

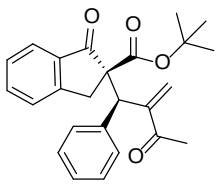
Conditions: Column AD (Heptane : isopropanol 95:5, flow: 1mL/min)



Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
10663949	576688	0.000000		6.880	7.787	49.8882
10711743	497787	0.000000		7.893	9.067	50.1118

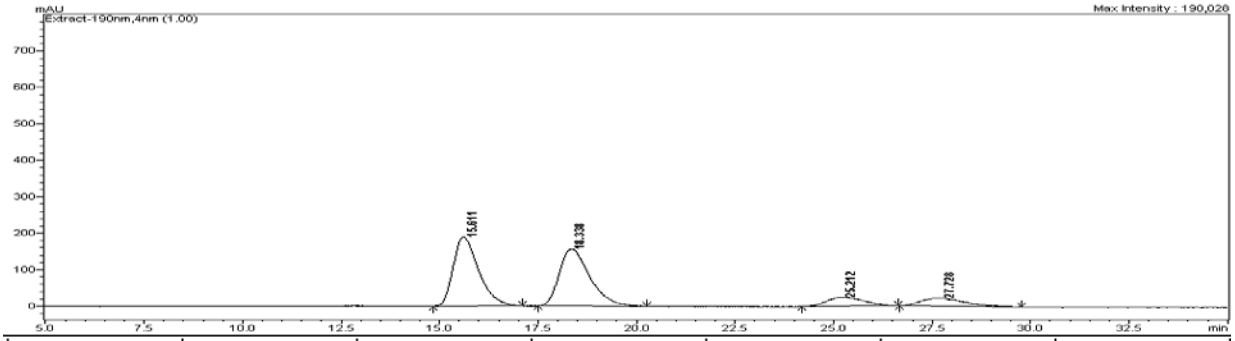


Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
35458286	2364546	0.000000		6.901	7.883	97.6400
857049	52461	0.000000		8.032	8.533	2.3600



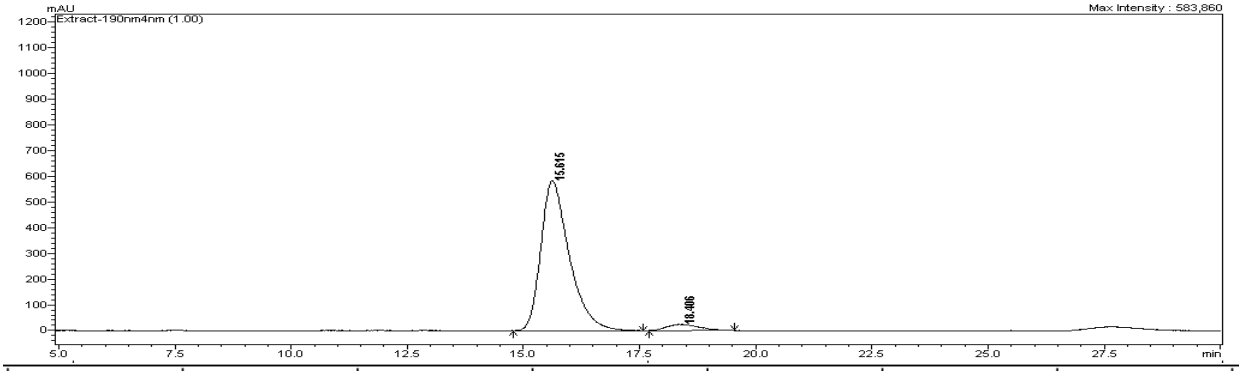
4jd

Conditions: Column AD (Heptane : isopropanol 98:2, flow: 1mL/min)



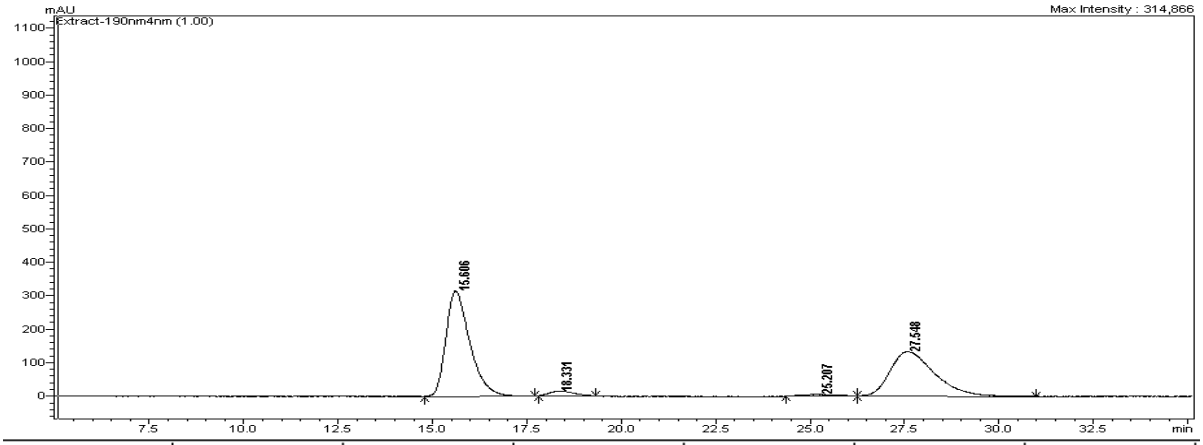
Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
8391036	188846	0.000000		14.827	17.109	42.2385
8340510	156444	0.000000		17.504	20.267	41.9841
1585337	24375	0.000000		24.181	26.645	7.9802
1548976	21221	0.000000		26.688	29.760	7.7972

single diastereomer

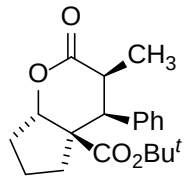


Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
24785551	584117	0.000000		14.795	17.589	95.4942
1169494	23977	0.000000		17.696	19.541	4.5058

mixture of diastereomers (3:2 ratio)

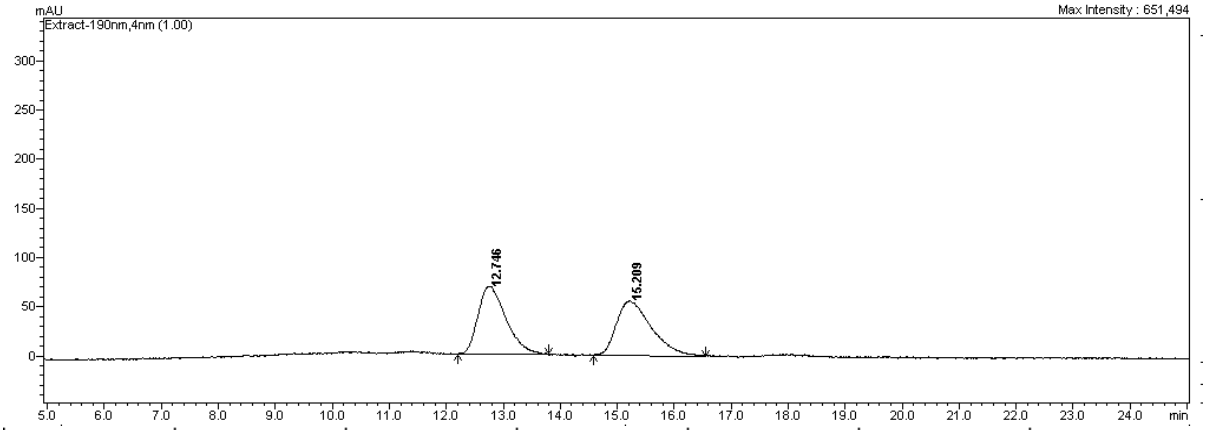


Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
13918306	315528	0.000000		14.805	17.696	54.1975
624410	14177	0.000000		17.813	19.317	2.4314
312443	5933	0.000000		24.373	26.261	1.2166
10825562	133609	0.000000		26.261	30.976	42.1544

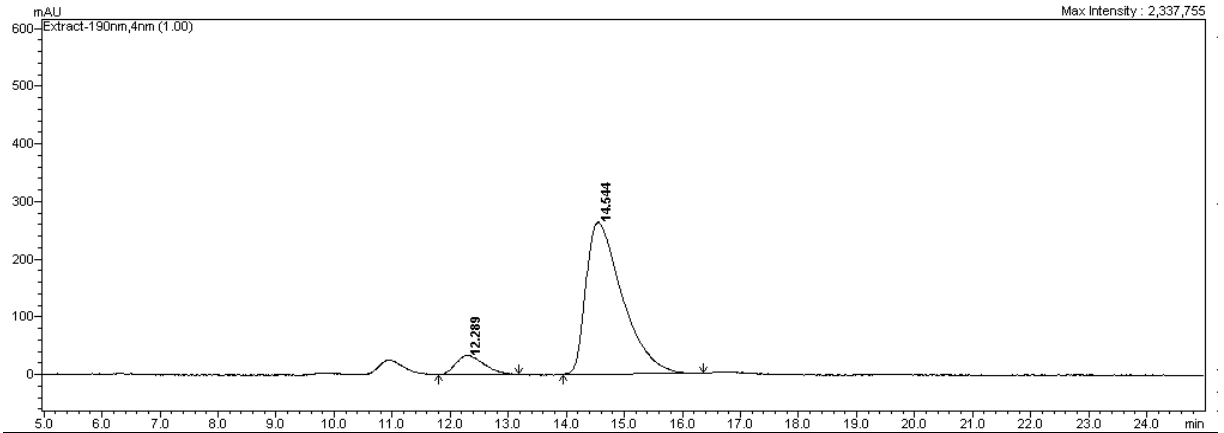


6a

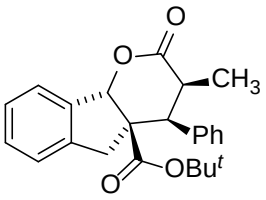
Conditions: Column AD (Heptane : isopropanol 98:2, flow: 1mL/min)



Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
2343418	68863	0.000000		12.203	13.803	50.0472
2338997	55228	0.000000		14.581	16.555	49.9528

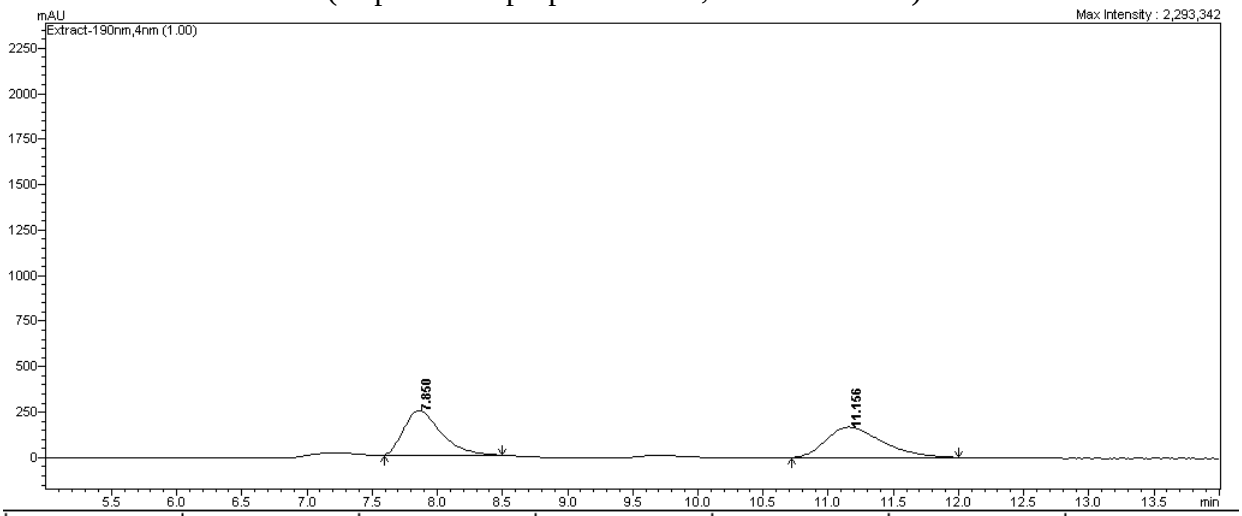


Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
1110143	33613	0.000000		11.797	13.184	8.8242
11470521	263634	0.000000		13.952	16.352	91.1758

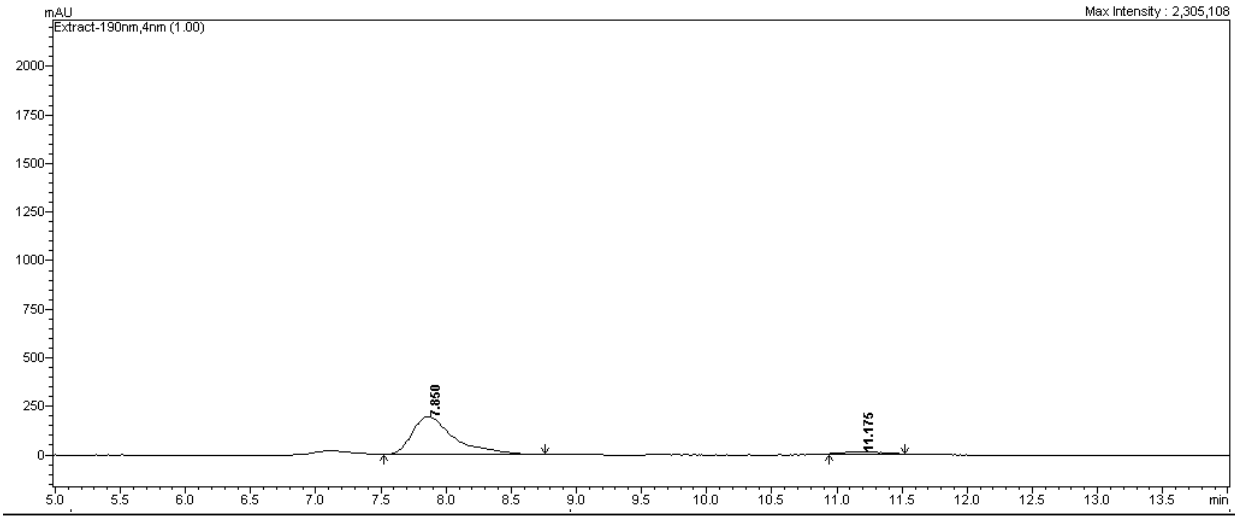


6b

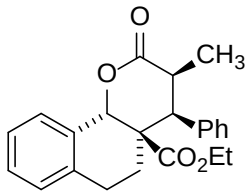
Conditions: Column AD (Heptane : isopropanol 90:10, flow: 1mL/min)



Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
4825934	245325	0.000000		7.595	8.501	49.0011
5022688	167571	0.000000		10.720	12.000	50.9989

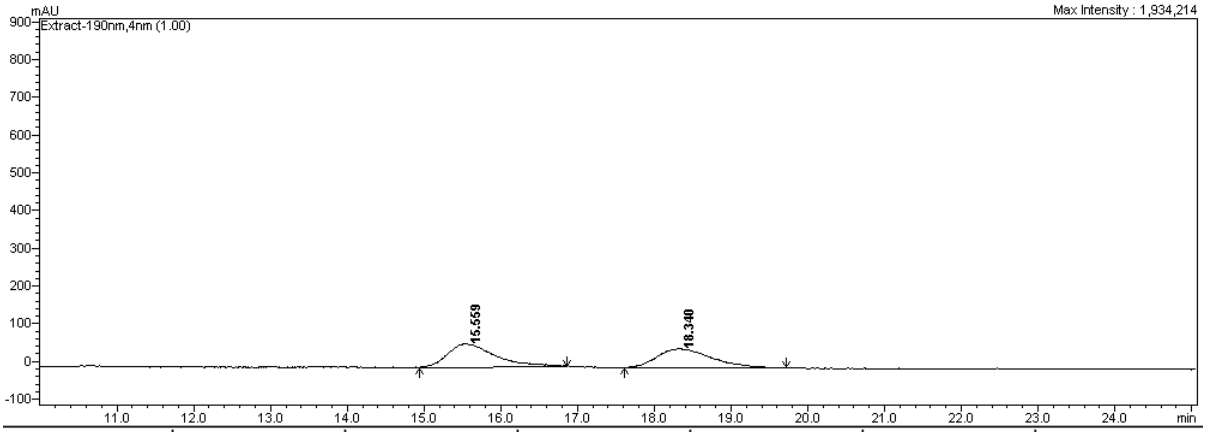


Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
4341068	193972	0.000000		7.520	8.757	95.5235
203433	10389	0.000000		10.944	11.520	4.4765

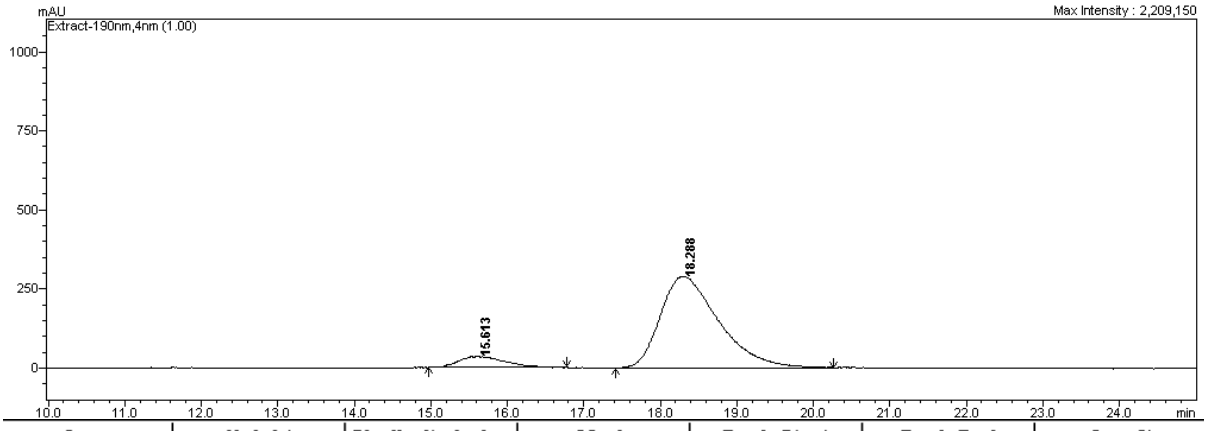


6c

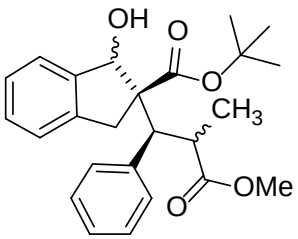
Conditions: Column AD (Heptane : isopropanol 95:5, flow: 1mL/min)



Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
2584991	61051	0.000000		14.933	16.864	50.8915
2494429	51097	0.000000		17.611	19.712	49.1085

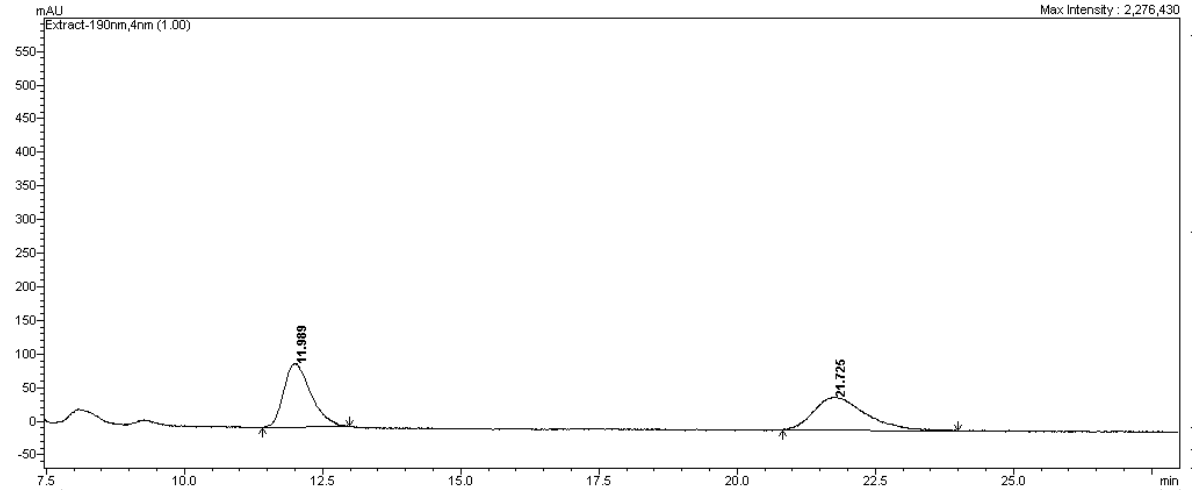


Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
1459006	35085	0.000000		14.965	16.779	8.7062
15299279	289324	0.000000		17.408	20.267	91.2938

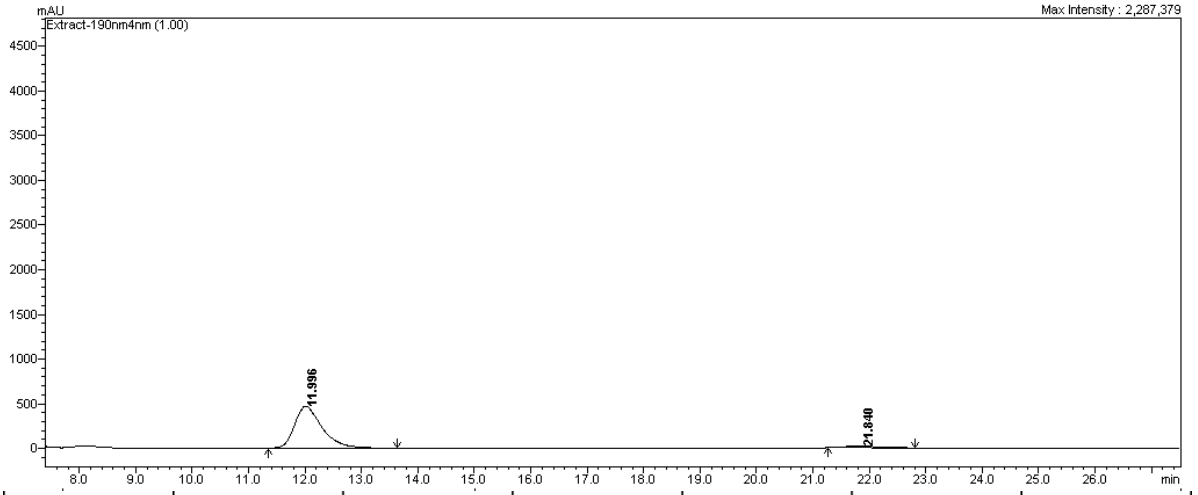


7a

Conditions: Column AD (Heptane : isopropanol 90:10, flow: 1mL/min)

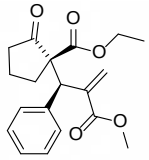


Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
3207925	94958	0.000000		11.413	12.992	50.4525
3150388	48623	0.000000		20.821	24.000	49.5475

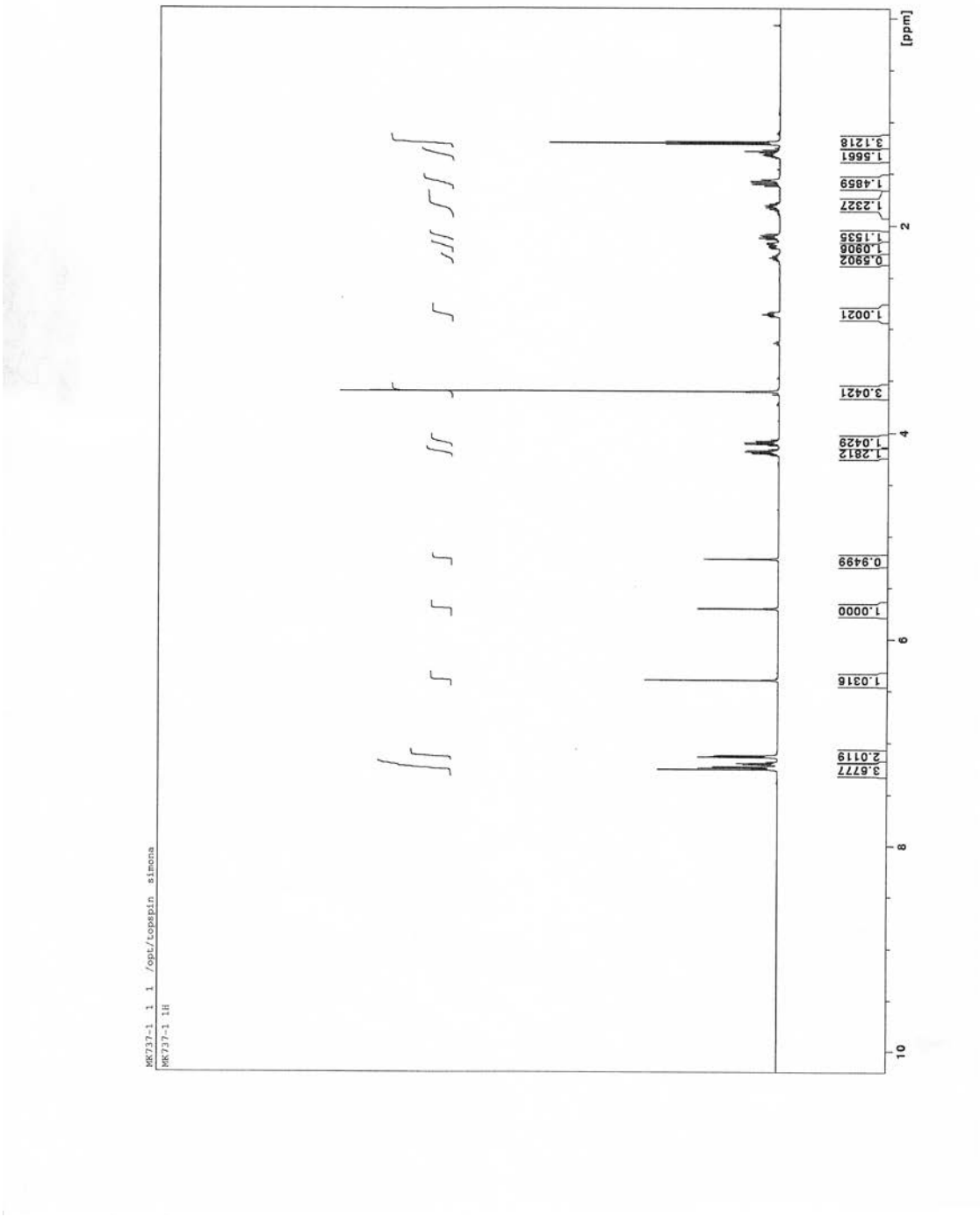


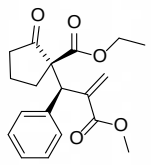
Area	Height	Similarity Index	Mark	Peak Start	Peak End	Area%
15752328	468242	0.000000		11.349	13.632	94.8399
857069	17702	0.000000		21.259	22.816	5.1601

4 NMR spectra

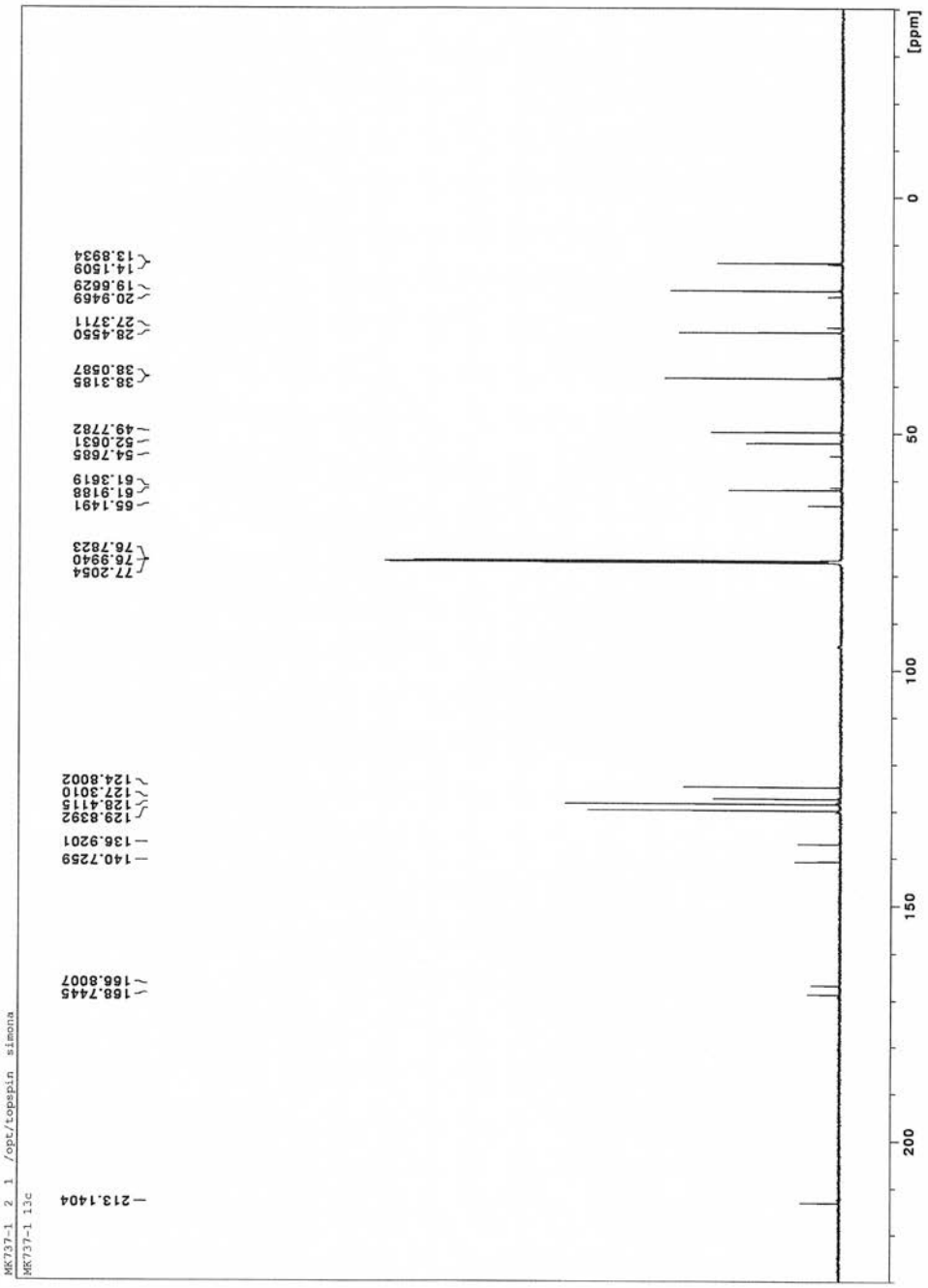


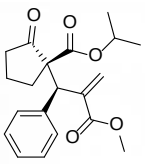
4aa



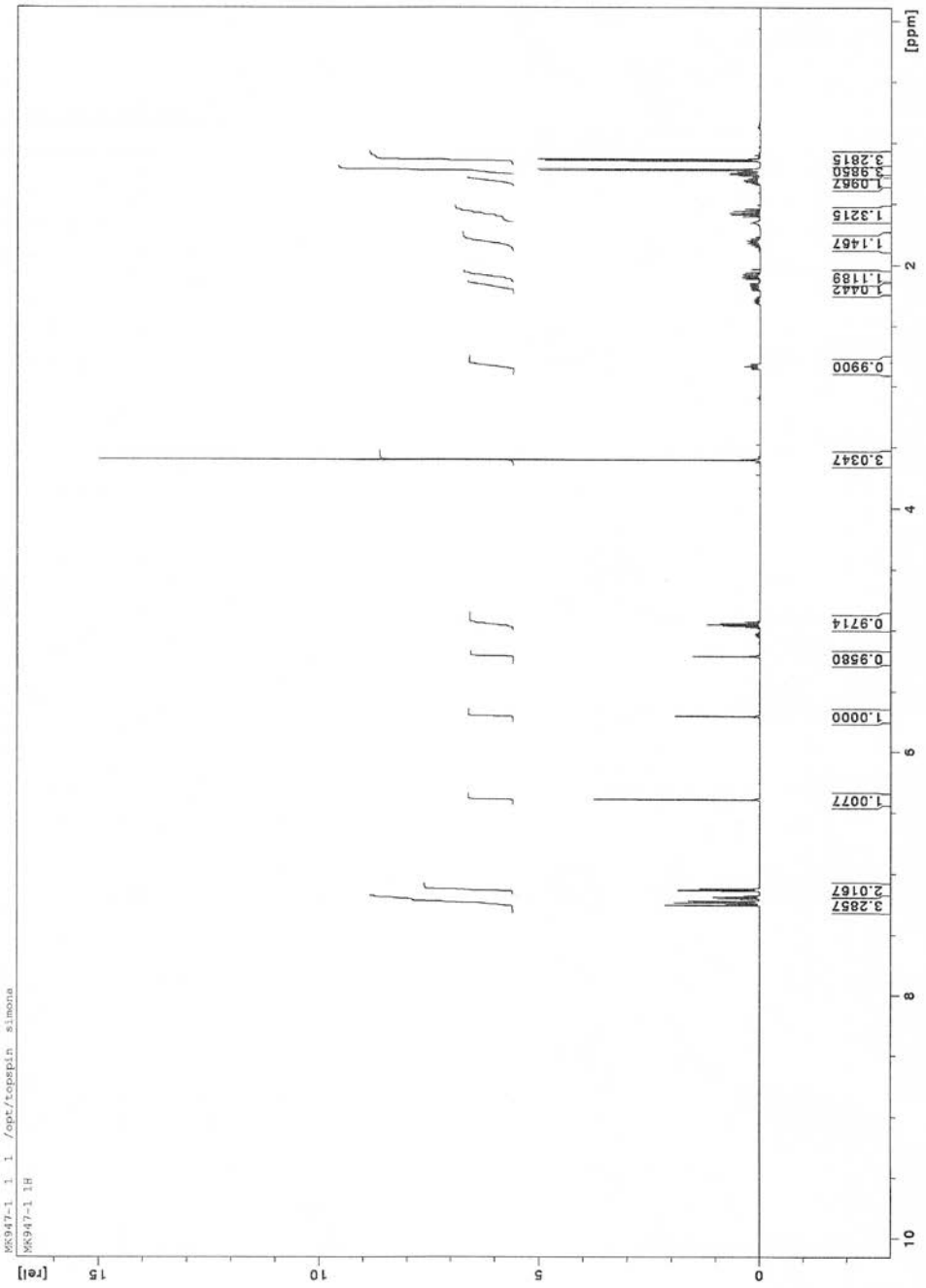


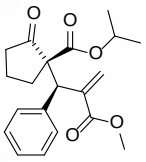
4aa


MK737-1 2 1 /opt/topspin simona
MK737-1 13c
213.1404
168.7445
166.8007
140.7259
136.9201
129.8392
128.4115
127.3010
124.8002
77.2054
76.9940
76.7823
65.1491
61.9188
61.3619
54.7685
52.0631
49.7782
38.3185
38.0587
28.4550
27.3711
20.9469
19.6629
14.1509
13.8934
[ppm]
0
50
100
150
200

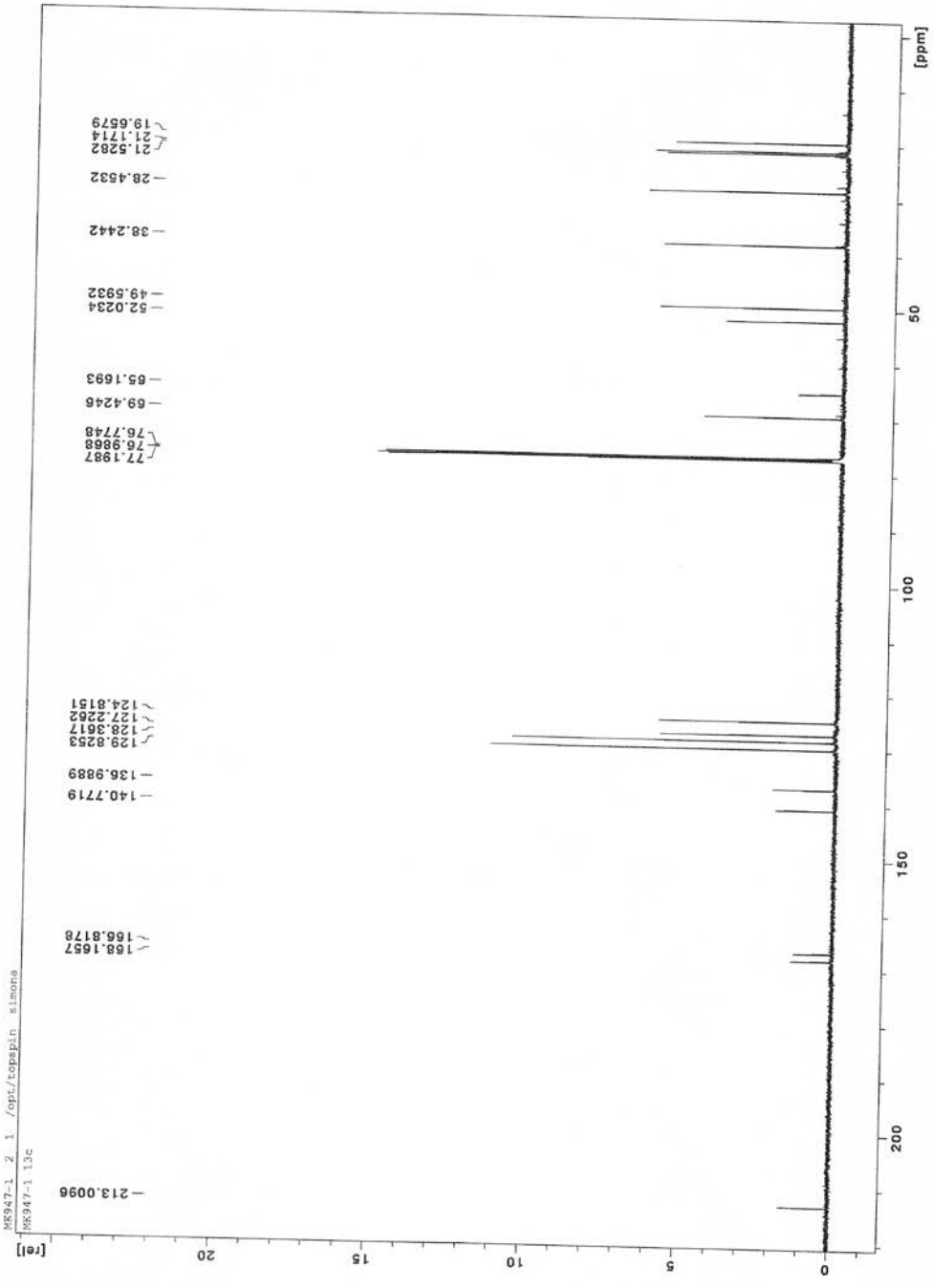


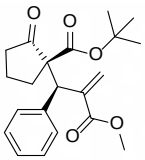
4ab


MK947-1 1 1 /opt/topspin simone
MK947-1 1H
[rel]
15
10
5
0
[ppm]
10
8
6
4
2
3.2857
2.0167
1.0077
1.0000
0.9580
0.9714
3.0347
0.9900
1.0442
1.1189
1.1467
1.3215
1.0967
3.9850
3.2815

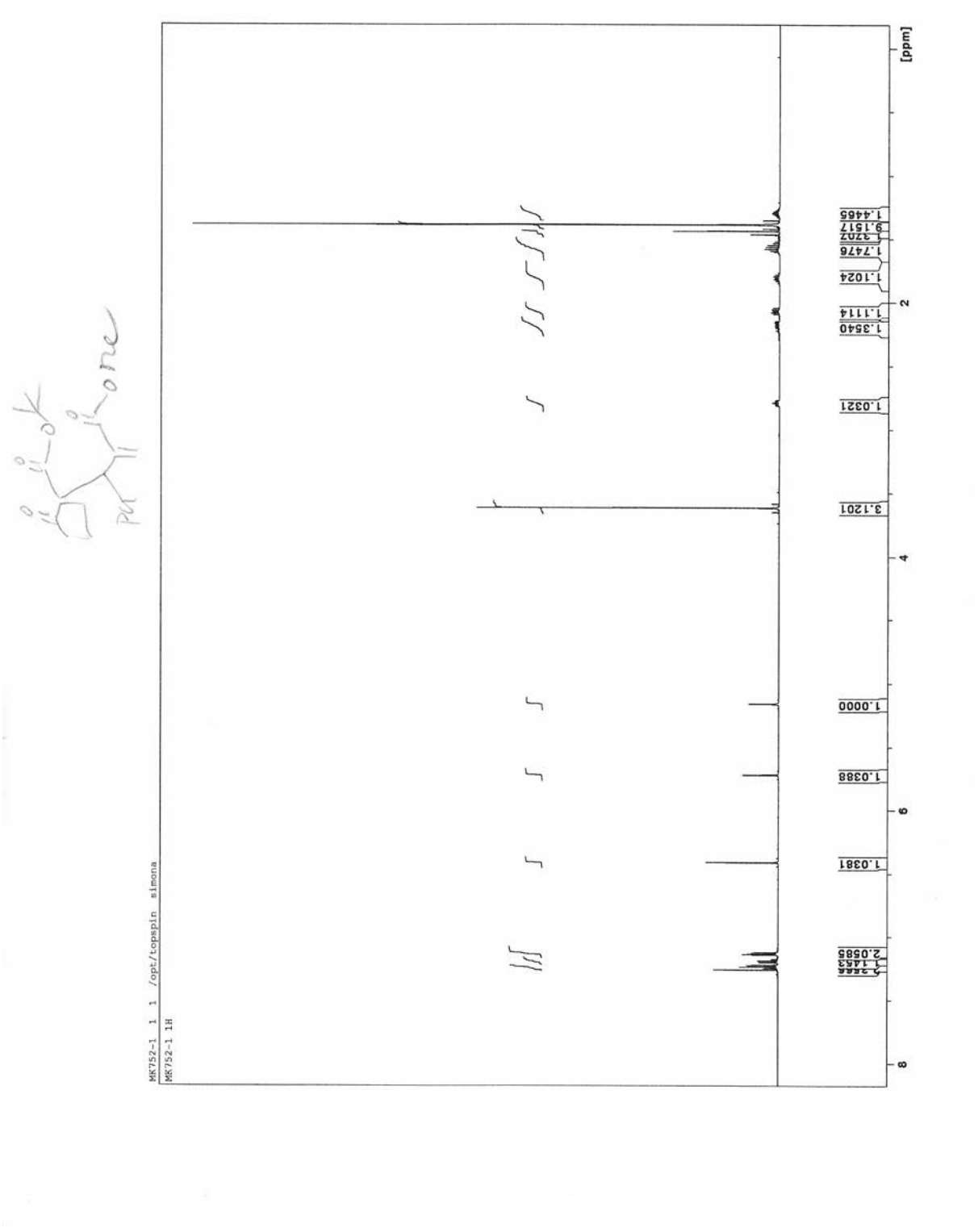


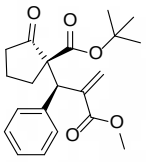
4ab


MK947-1 2 1 /opt/topspin simona
MK947-1 13c
[rel]
[ppm]
213.0096
168.1657
166.8178
140.7719
136.9889
129.8253
128.3617
127.2262
124.8151
77.1987
76.9868
76.7748
69.4246
65.1693
52.0234
49.5932
38.2442
28.4532
21.5282
21.1714
19.6579

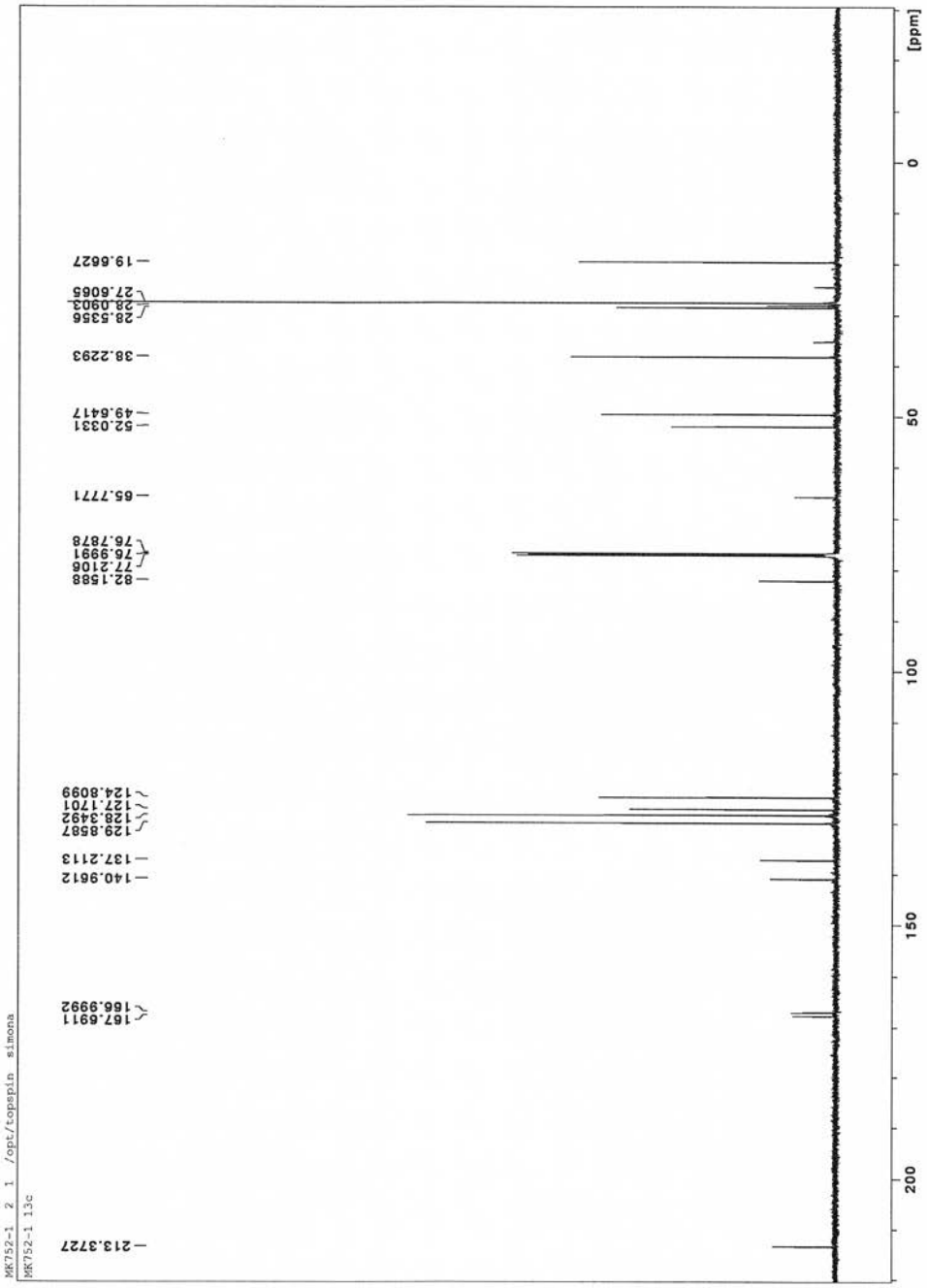


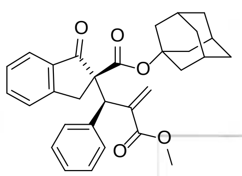
4ac


MK752-1 1 1 /opt/topspin simona
MK752-1 1H
[ppm]
1.4455
9.1517
3202
1.7476
1.1024
1.1114
1.3540
1.0321
3.1201
1.0000
1.0388
1.0381
2.0585
2.2644
1.1453

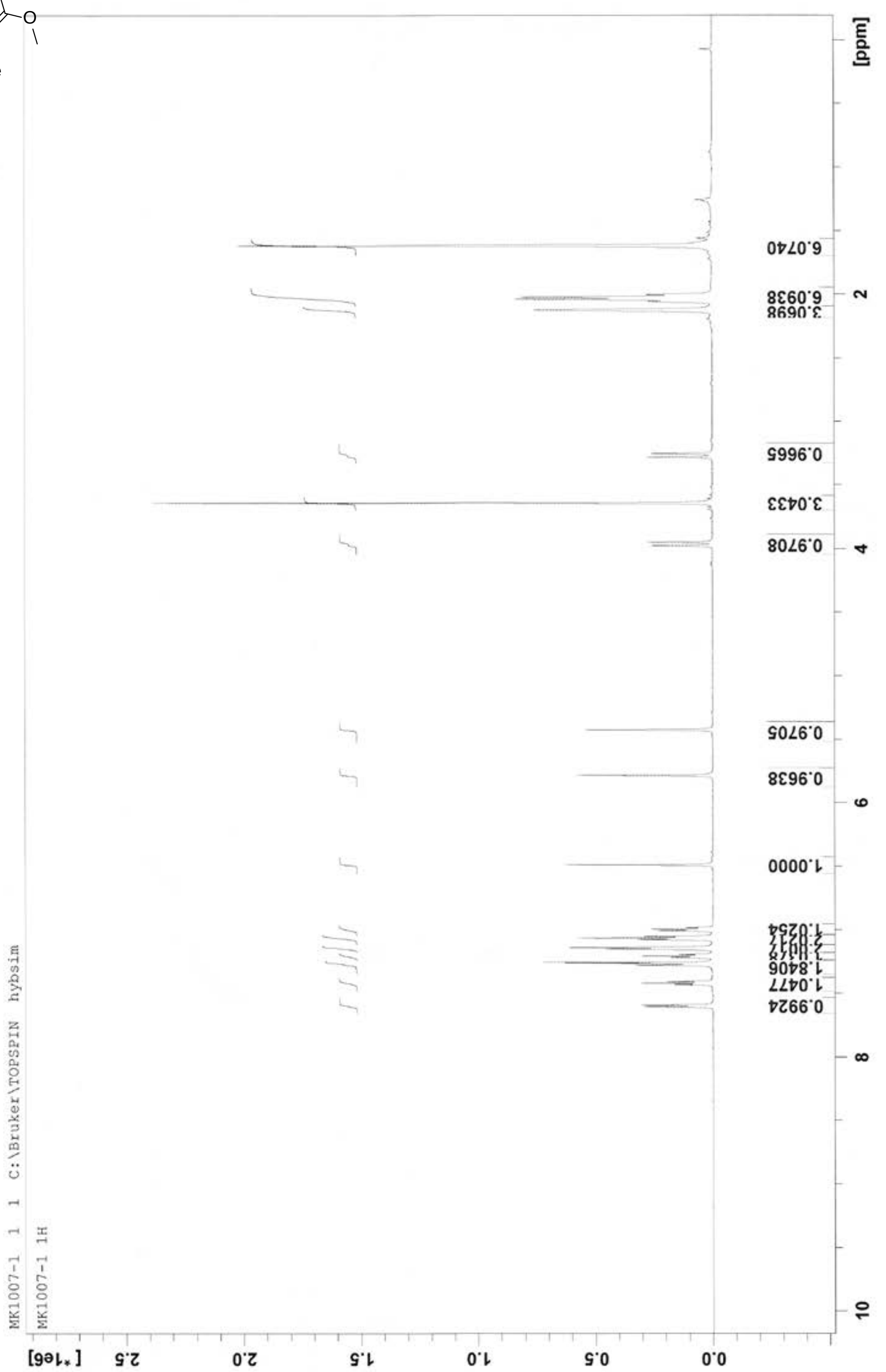


4ac

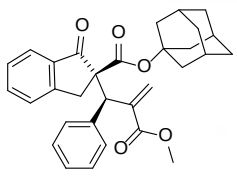

MK752-1 2 1 /opt/topspin simona
MK752-1 13c
213.3727
167.6911
166.9992
140.9612
137.2113
129.8587
128.3492
127.1701
124.8099
82.1588
77.2106
76.9991
76.7878
65.7771
52.0331
49.6417
38.2293
28.5356
28.0903
27.6065
19.6627
[ppm]
0
50
100
150
200



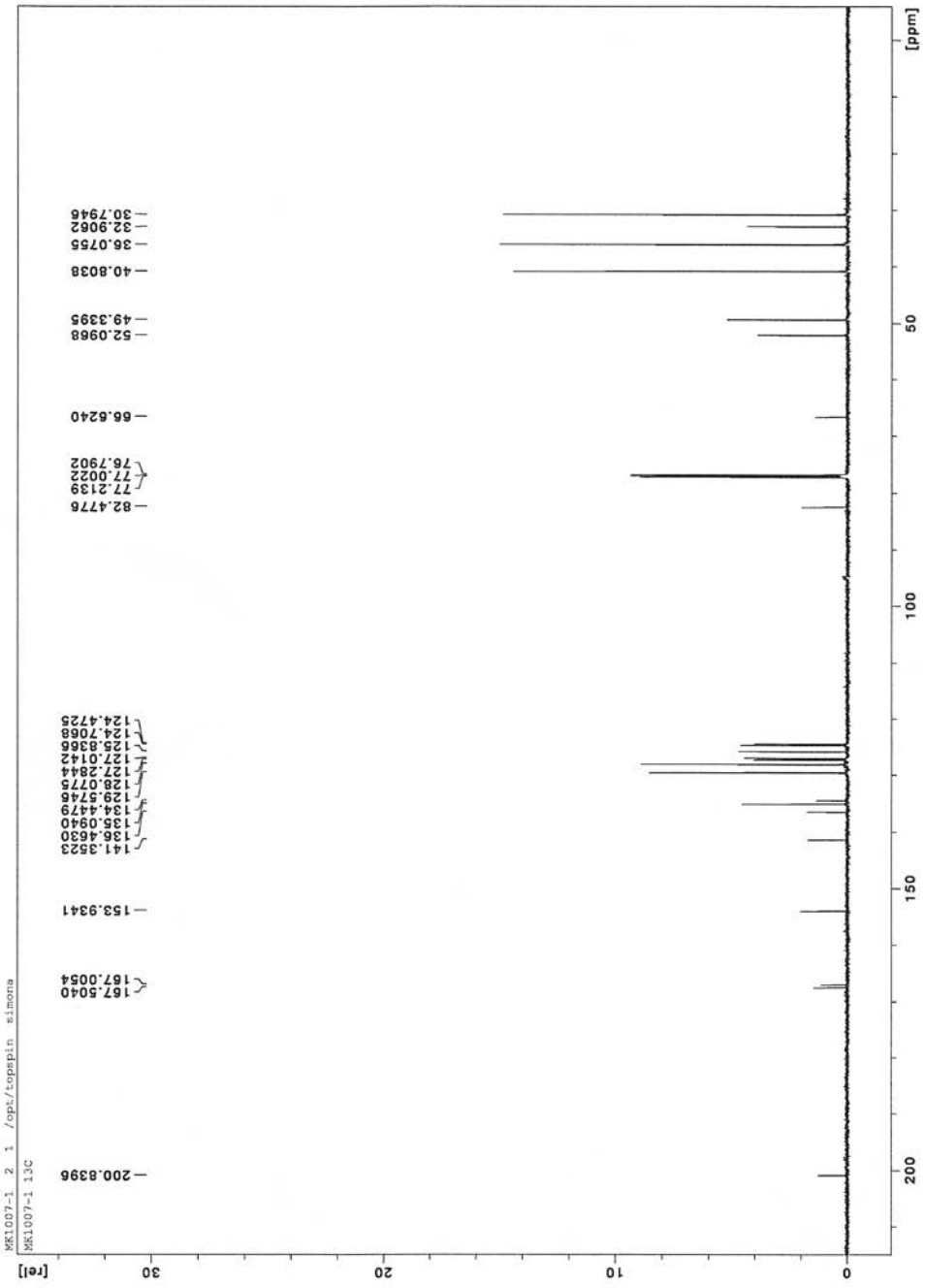
4ae

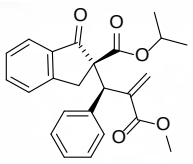


MK1007-1 1 1 C:\Bruker\TOPSPIN hybsim
MK1007-1 1H
[ppm]
6.0740
6.0938
3.0698
0.9665
3.0433
0.9708
0.9705
0.9638
1.0000
1.0254
1.8406
1.0477
0.9924
[*1e6]

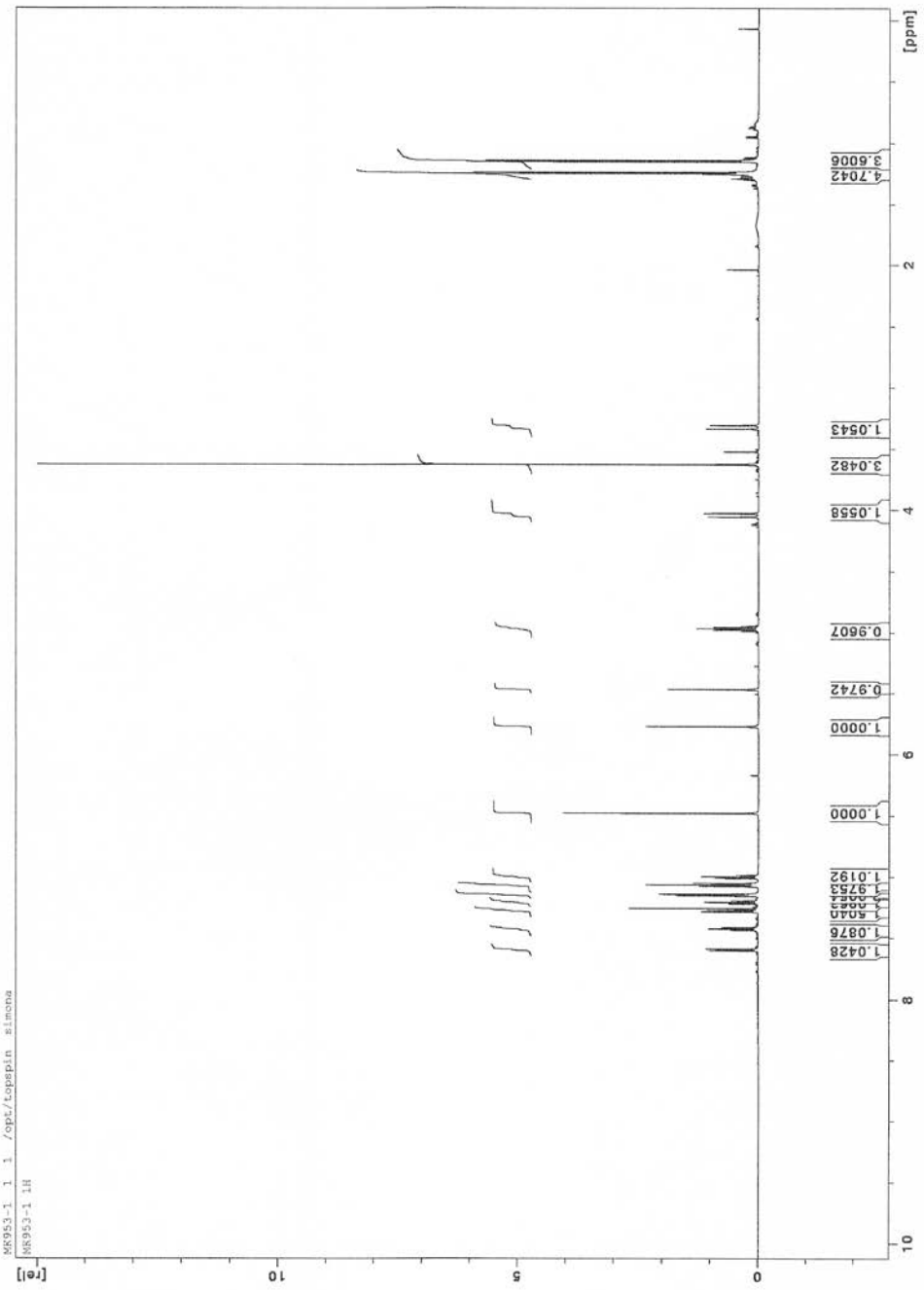


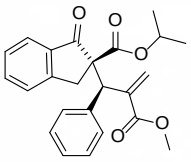
4ae


MK1007-1 2 1 /opt/topspin simona
MK1007-1 13C
200.8396
167.5040
167.0054
153.9341
141.3523
136.4630
135.0940
134.4479
129.5746
128.0775
127.2844
127.0142
125.8366
124.7068
124.4725
82.4776
77.2139
77.0022
76.7902
66.6240
52.0968
49.3395
40.8038
36.0755
32.9062
30.7946
[rel]
30
20
10
0
[ppm]
200
150
100
50

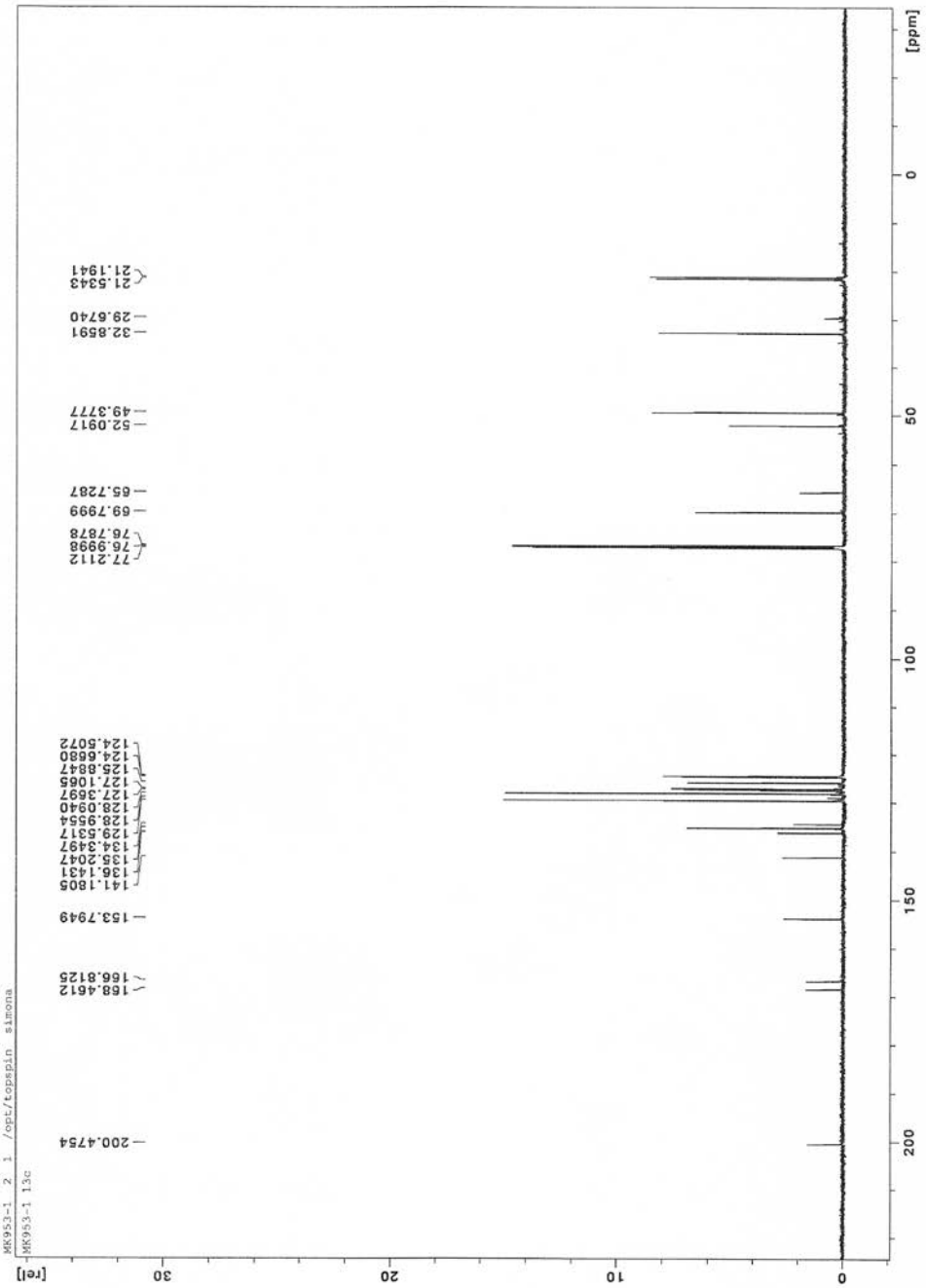


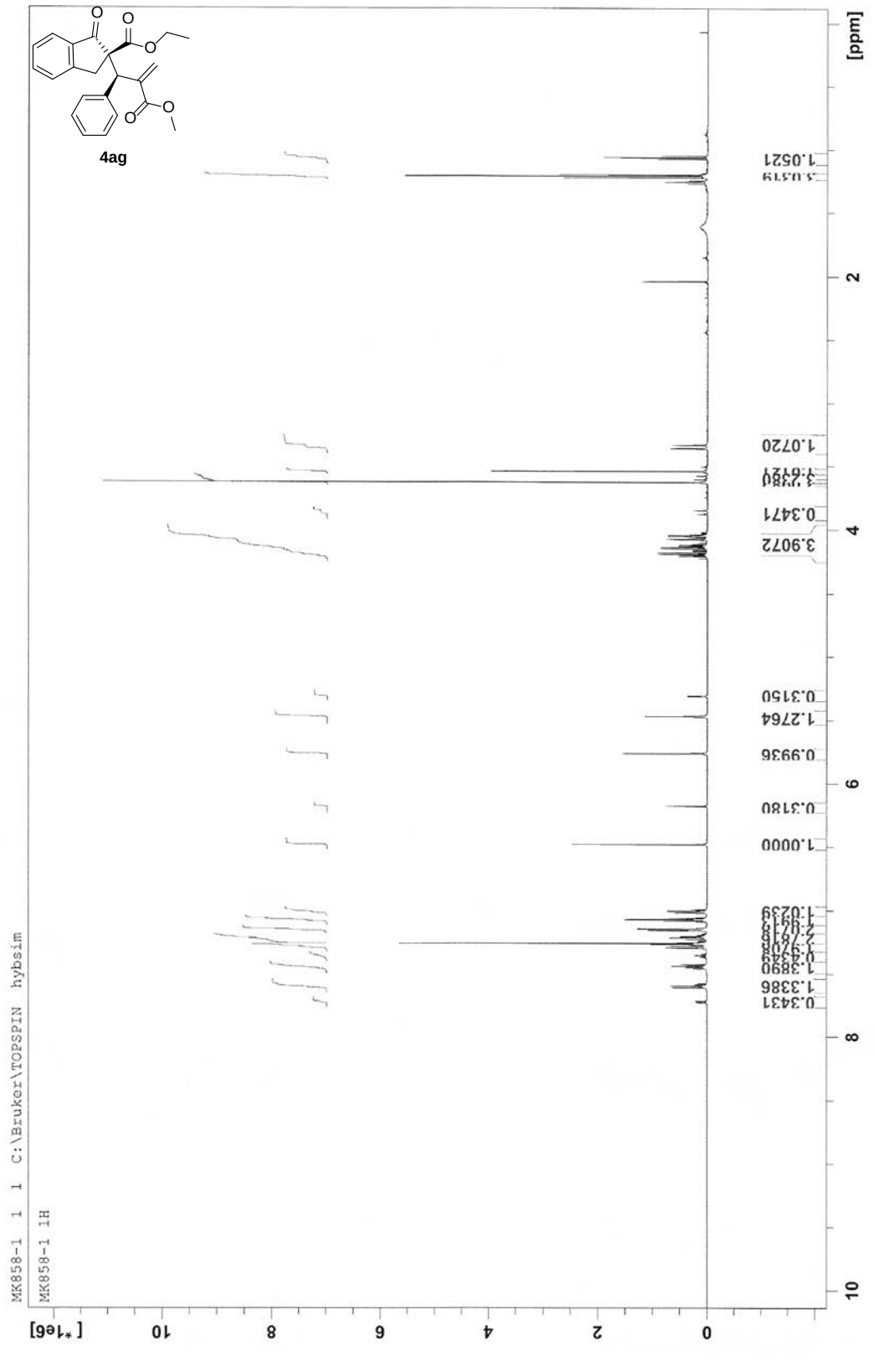
4af

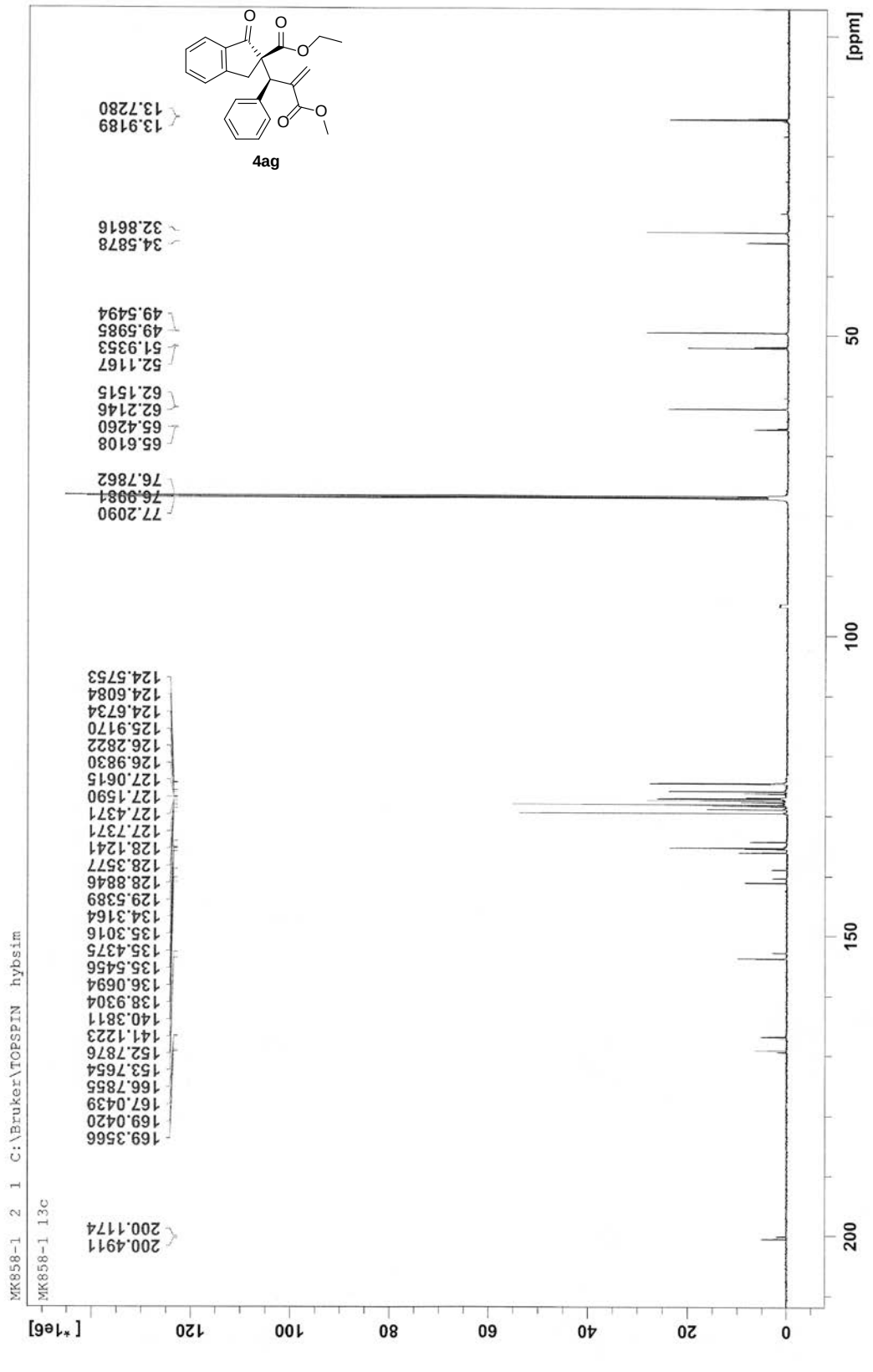

MR953-1 1 1 /opt/topspin simona
MR953-1 1H
[rel]
10
5
0
[ppm]
10
8
6
4
2
1.0428
1.0876
1.0192
1.0000
1.0000
0.9742
0.9607
1.0558
3.0482
1.0543
4.7042
3.6006

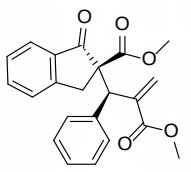


4af

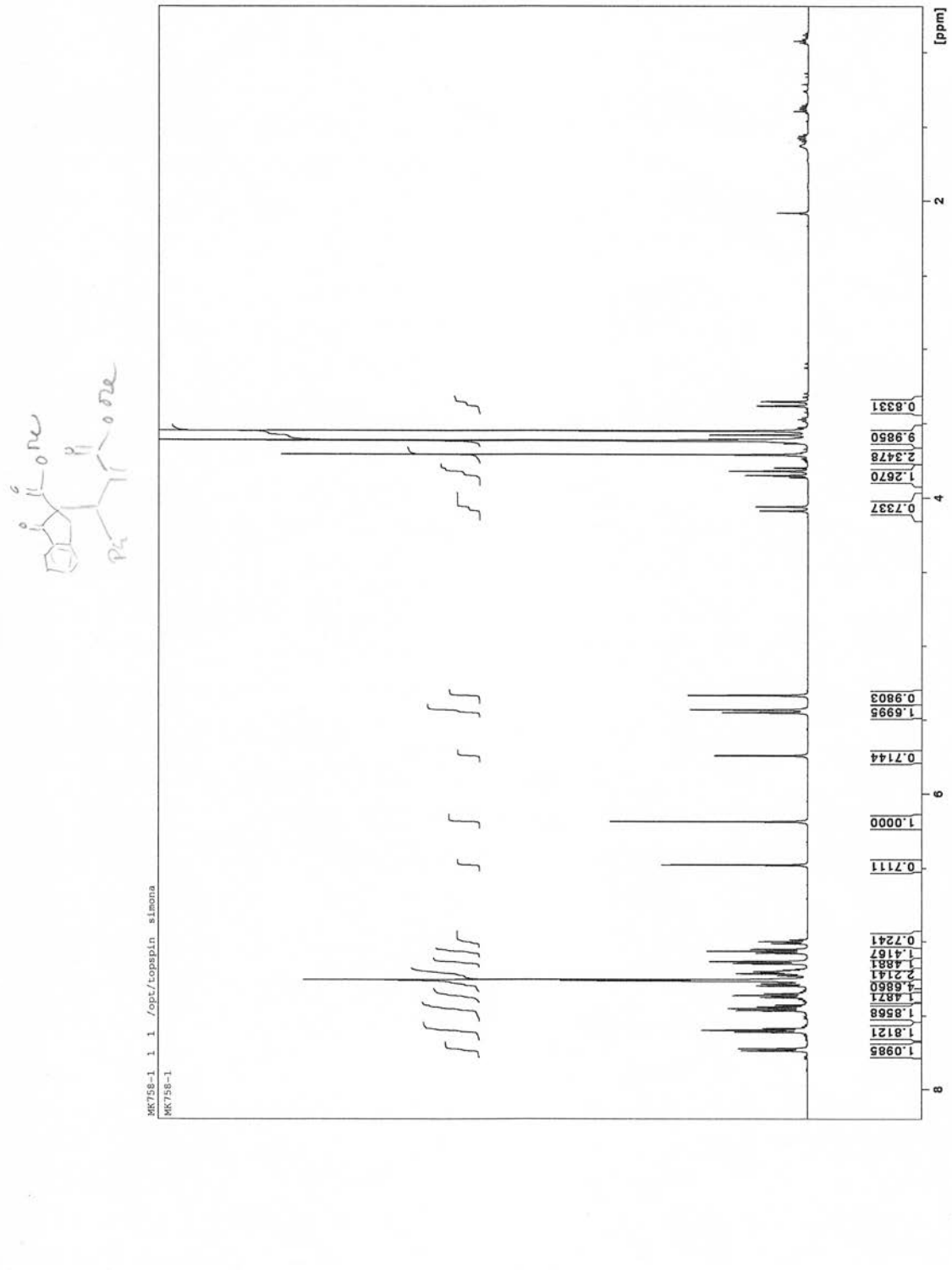

MK953-1 2 1 /opt/topspin simona
MK953-1 13c
[rel]
[ppm]
200.4754
168.4612
166.8125
153.7949
141.1805
136.1431
135.2047
134.3497
129.5317
128.9554
128.0940
127.3697
127.1065
125.8847
124.6680
124.5072
77.2112
76.9998
76.7878
69.7999
65.7287
52.0917
49.3777
32.8591
29.6740
21.5343
21.1941

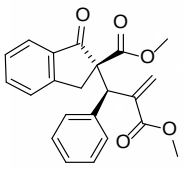

4ag
MK858-1 1 1 C:\Bruker\TOPSPIN hybsim
MK858-1 1H
[*1e6]
[ppm]
1.0521
1.0720
3.9072
0.3471
0.3150
1.2764
0.9936
0.3180
1.0000
1.0239
0.3431
1.3386
1.3890
0.4329


4ag
MK858-1 2 1 C:\Bruker\TOPSPIN hybsim
MK858-1 13c
[*1e6]
[ppm]
200.4911
200.1174
169.3566
169.0420
167.0439
166.7855
153.7654
152.7876
141.1223
140.3811
138.9304
136.0694
135.5456
135.4375
135.3016
134.3164
129.5389
128.8846
128.3577
128.1241
127.7371
127.4371
127.1590
127.0615
126.9830
126.2822
125.9170
124.6734
124.6084
124.5753
77.2090
76.9981
76.7862
65.6108
65.4260
62.2146
62.1515
52.1167
51.9353
49.5985
49.5494
34.5878
32.8616
13.9189
13.7280

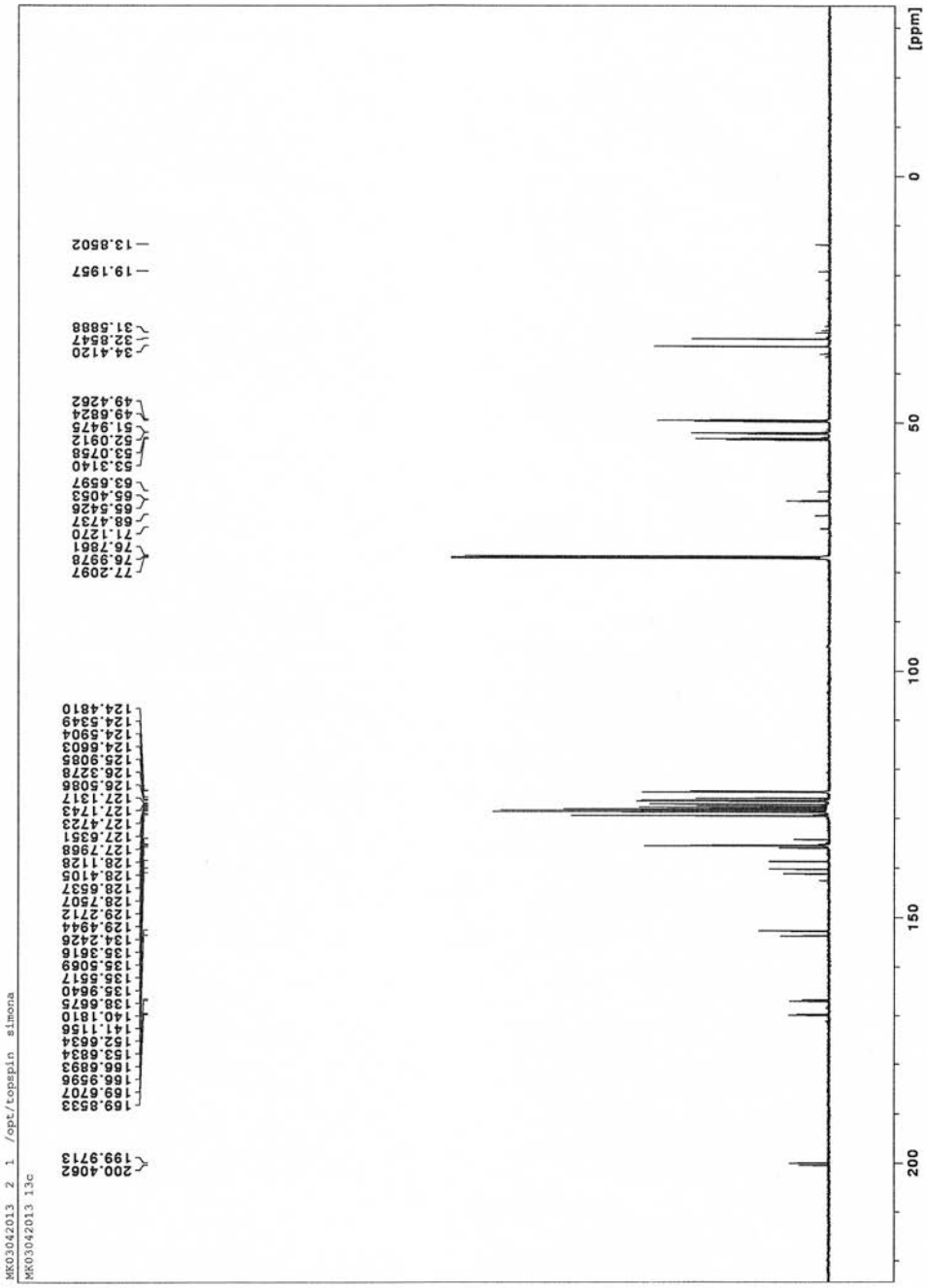


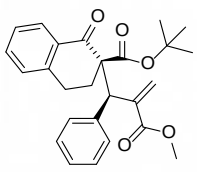
4ah


MK758-1 1 1 /opt/topspin simona
MK758-1
[ppm]
8
6
4
2
1.0985
1.8121
1.8568
1.4871
4.6860
2.2141
1.4881
1.4167
0.7241
0.7111
1.0000
0.7144
0.9803
1.6995
0.7337
1.2670
2.3478
9.9850
0.8331

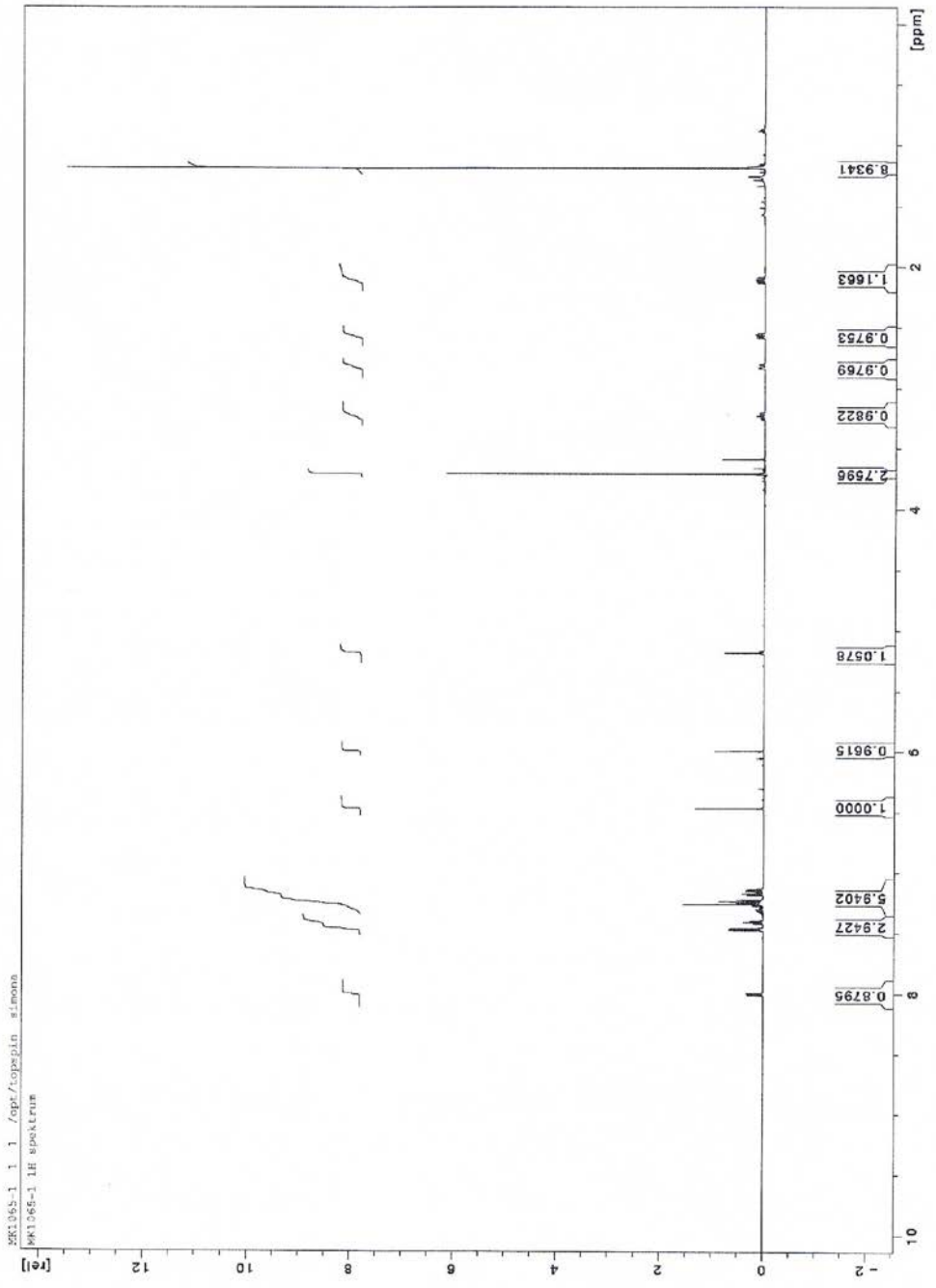


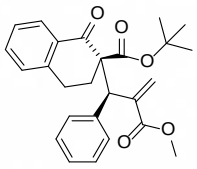
4ah


MK03042013 2 1 /opt/topspin simona
MK03042013 13c
200.4062
199.9713
169.8533
169.6707
166.9596
166.6893
153.6834
152.6634
141.1156
140.1810
138.6675
135.9640
135.5517
135.5069
135.3616
134.2426
129.4944
129.2712
128.7507
128.6537
128.4105
128.1128
127.7968
127.6351
127.4723
127.1743
127.1317
126.5086
126.3278
125.9085
124.6603
124.5904
124.5349
124.4810
77.2097
76.9978
76.7861
71.1270
68.4737
65.5426
65.4053
63.6597
53.3140
53.0758
52.0912
51.9475
49.6824
49.4262
34.4120
32.8547
31.5888
19.1957
13.8502
[ppm]
0
50
100
150
200

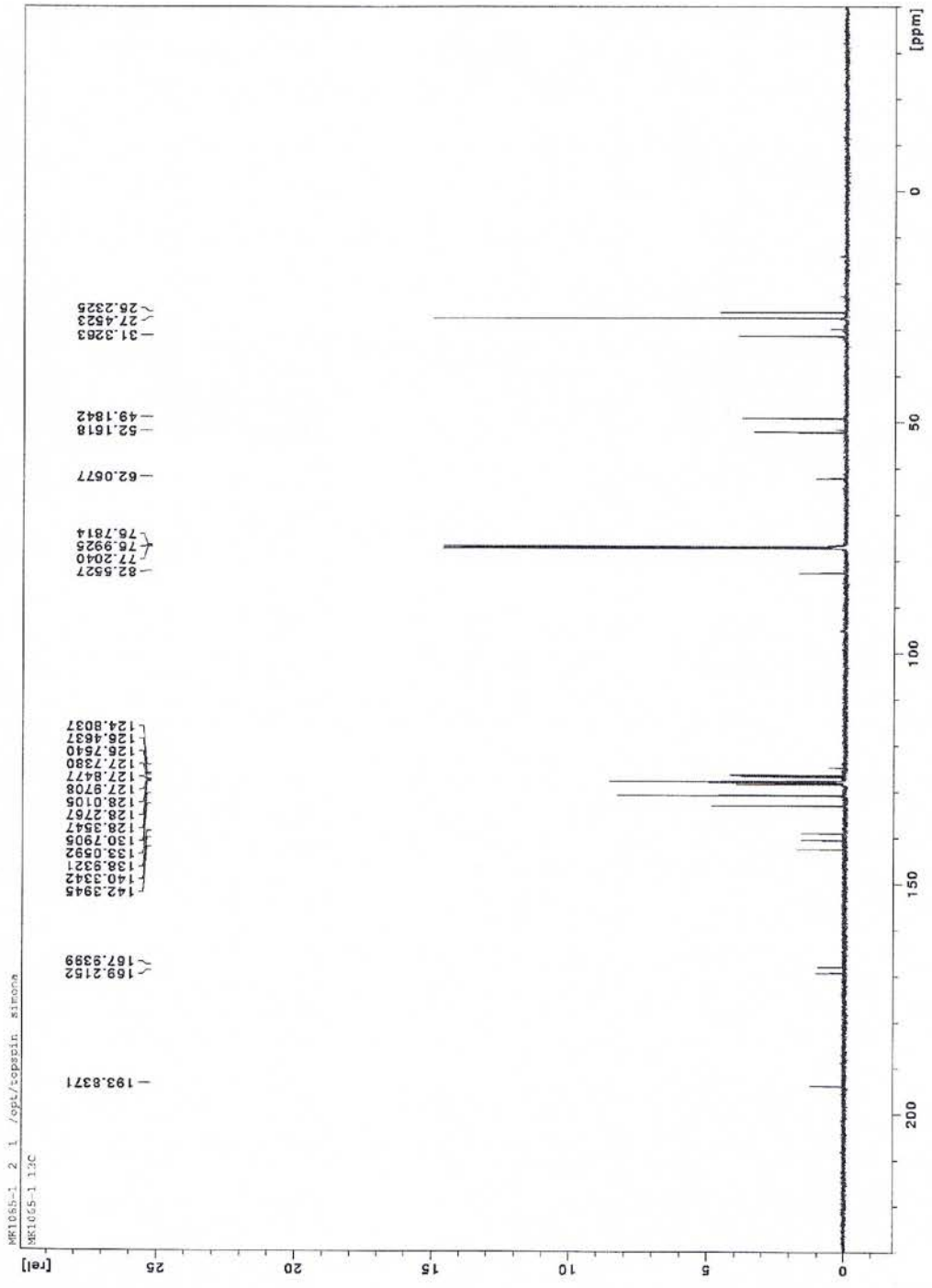


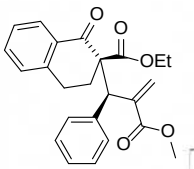
4ai


MK1065-1 1 1 /opt/topspin simona
MK1065-1 1H spektrum
[rel]
[ppm]
8.9341
1.1663
0.9753
0.9769
0.9822
2.7596
1.0578
0.9615
1.0000
5.9402
2.9427
0.8795

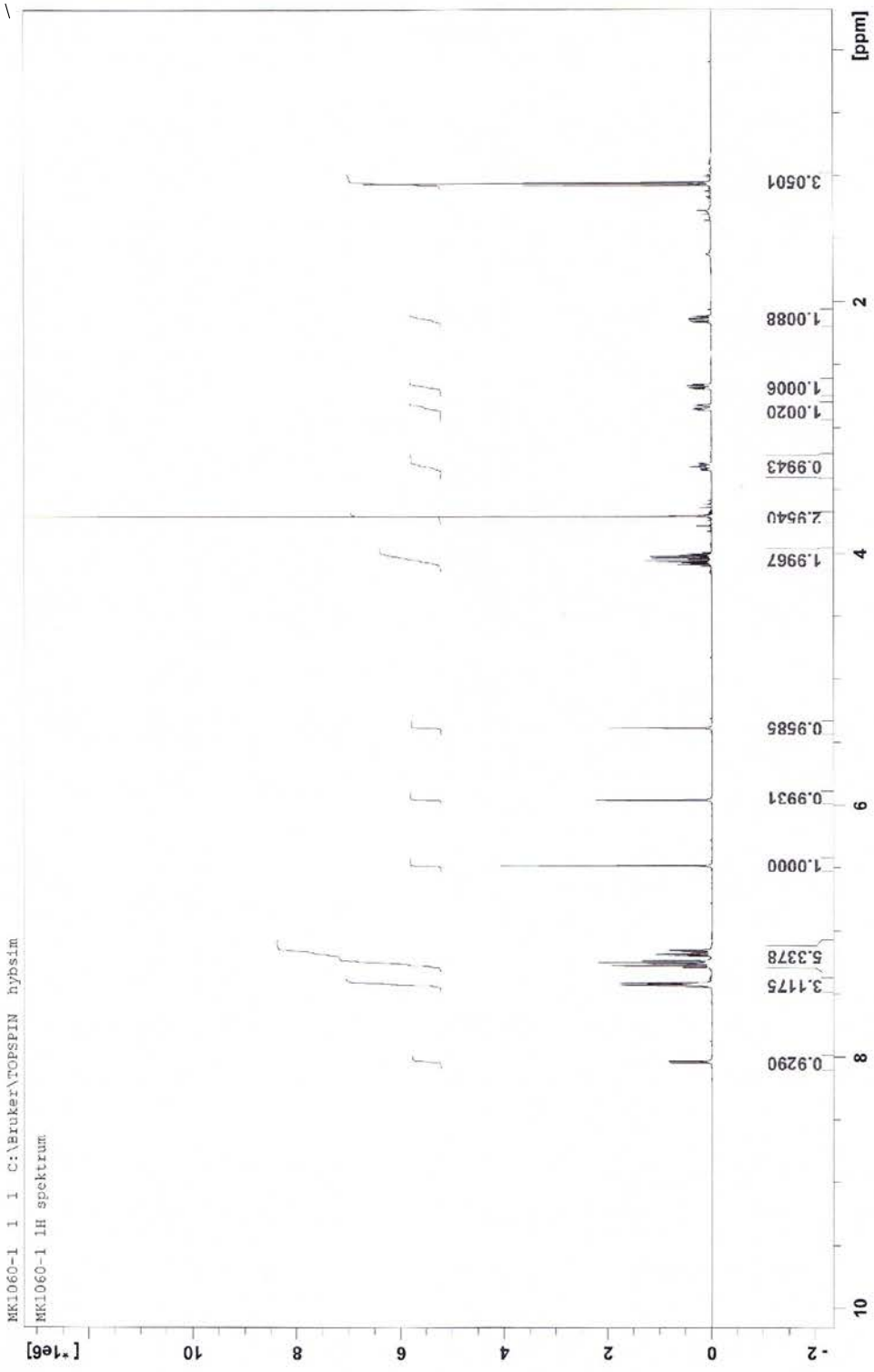


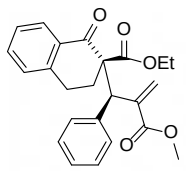
4ai


MR1055-1 2 1 /opt/topspin simona
MR1055-1 13C
193.8371
169.2152
167.9399
142.3945
140.3342
138.9321
133.0592
130.7905
128.3547
128.2767
128.0105
127.9708
127.8477
127.7380
126.7540
126.4637
124.8037
82.5527
77.2040
76.9925
76.7814
62.0677
52.1618
49.1842
31.3263
27.4523
26.2325
[rel]
[ppm]

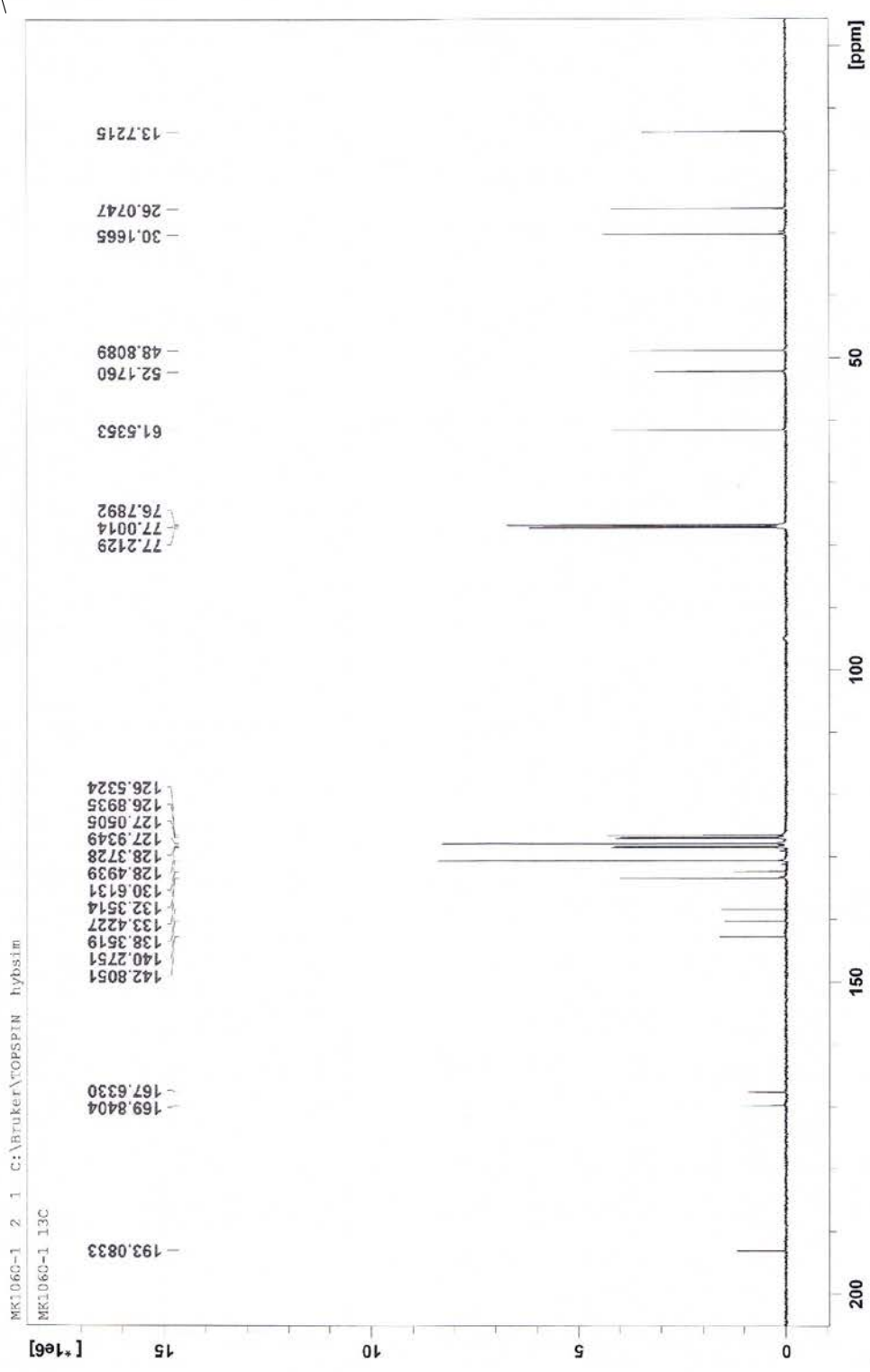

O
O
OEt
O
O

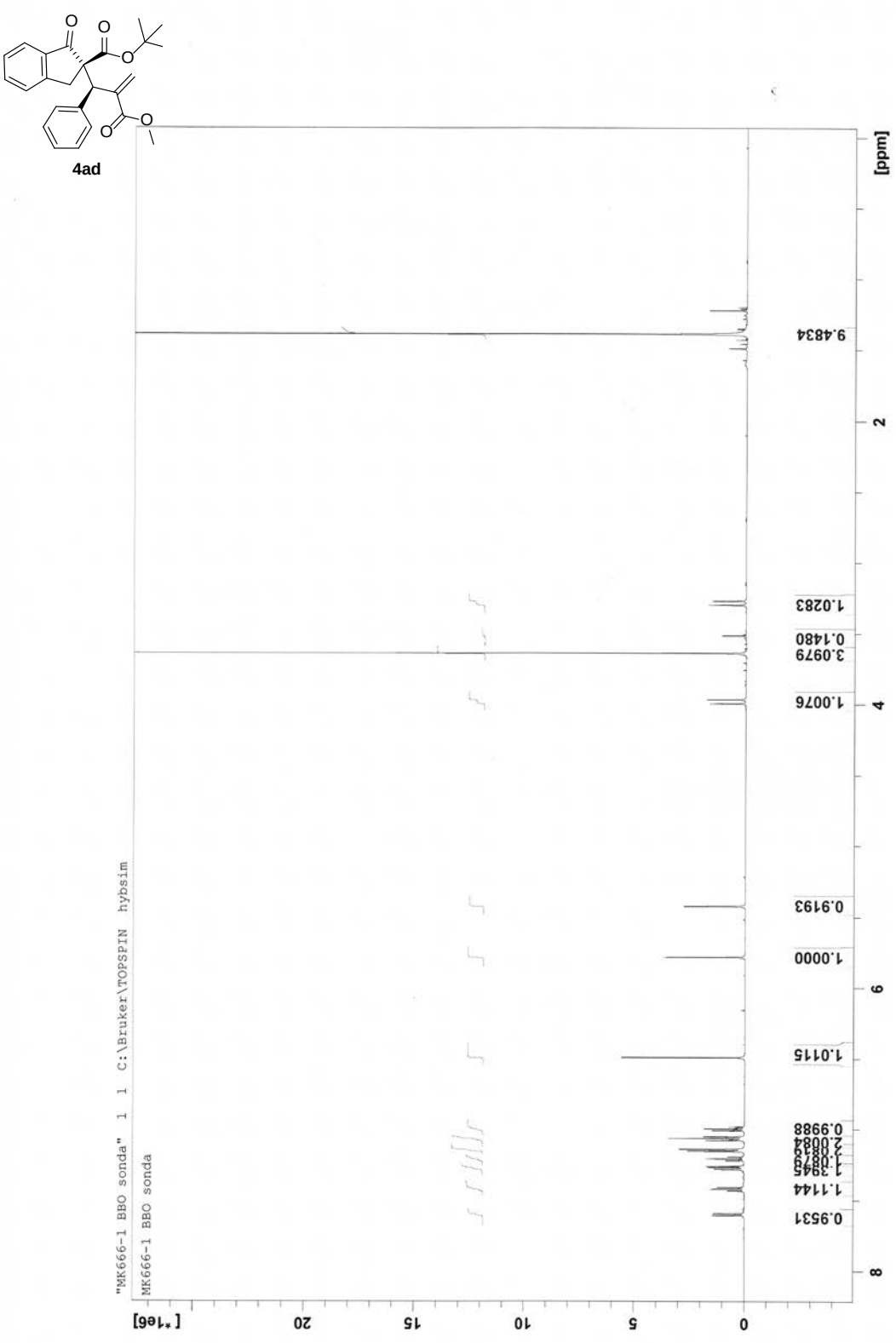
4aj

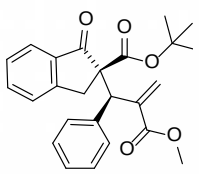

MK1060-1 1 1 C:\Bruker\TOPSPIN hybsim
MK1060-1 1H spektrum
[*1e6]
10
8
6
4
2
0
-2
[ppm]
2
4
6
8
10
3.0501
1.0088
1.0006
1.0020
0.9943
2.9540
1.9967
0.9585
0.9931
1.0000
5.3378
3.1175
0.9290


O
O
OEt
O
O

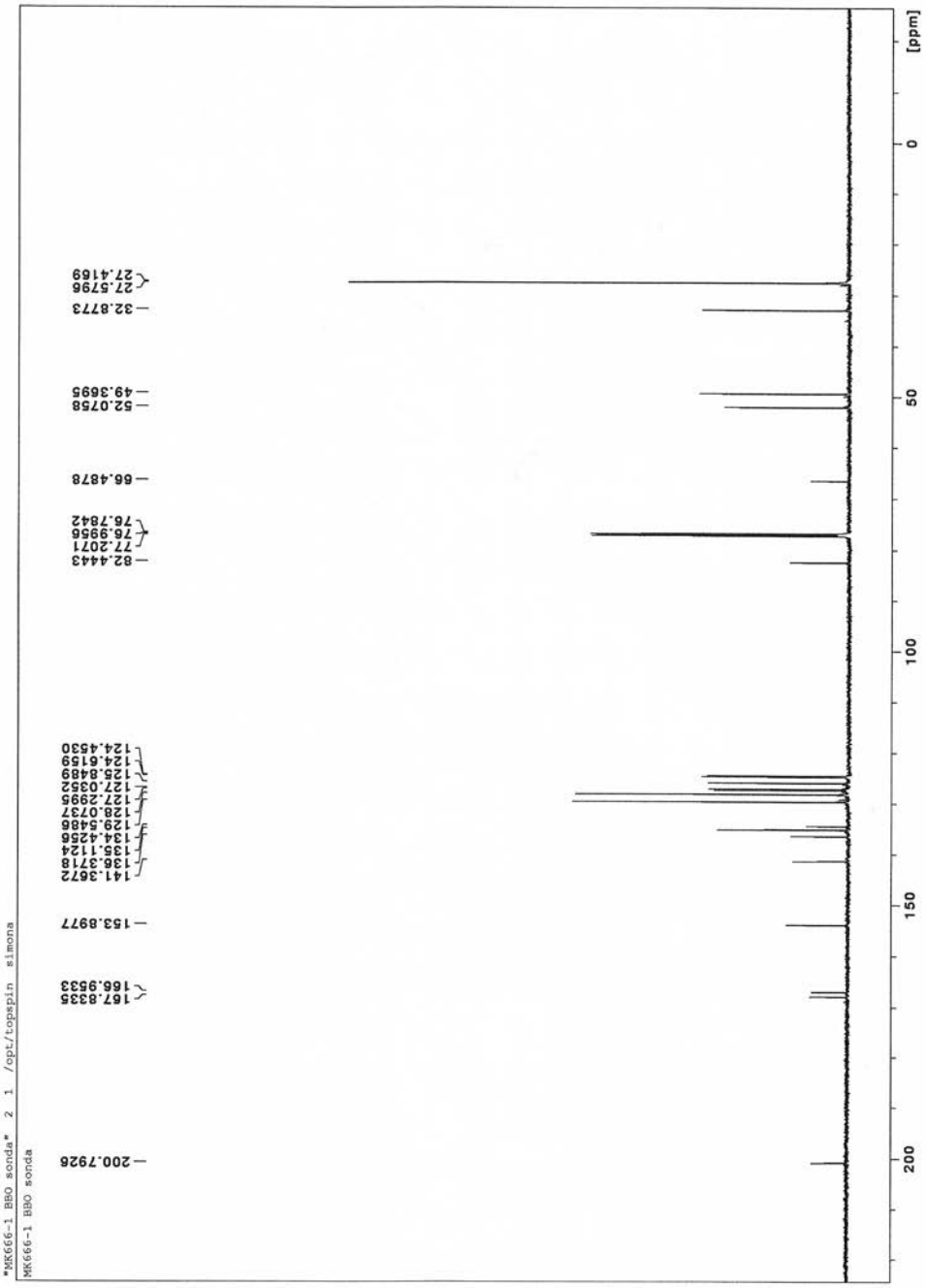
4aj

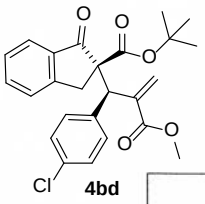

13.7215
26.0747
30.1665
48.8089
52.1760
61.5353
76.7892
77.0014
77.2129
126.5324
126.8935
127.0505
127.9349
128.3728
128.4939
130.6131
132.3514
133.4227
138.3519
140.2751
142.8051
167.6330
169.8404
193.0833
MK1060-1 2 1 C:\Bruker\TOPSPIN hybsim
MK1060-1 13C
[*1e6]
15
10
5
0
[ppm]
200
150
100
50


4ad
"MK666-1 BBO sonda" 1 1 C:\Bruker\TOPSPIN hybsim
MK666-1 BBO sonda
[ppm]
9.4834
1.0283
0.1480
3.0979
1.0076
0.9193
1.0000
1.0115
0.9988
2.0084
1.0870
1.3945
1.1144
0.9531

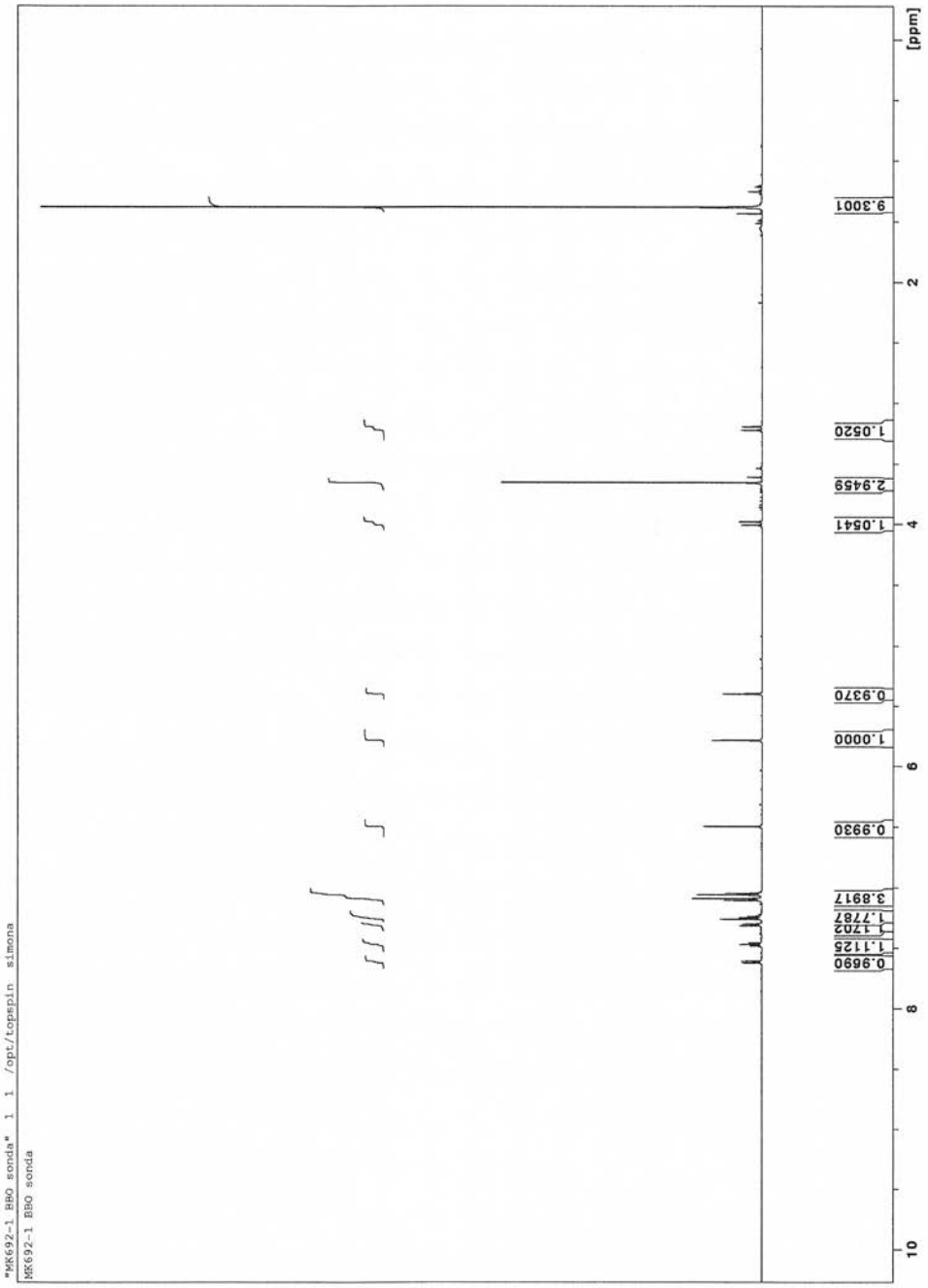


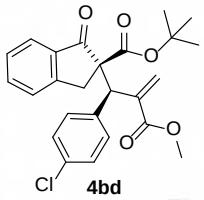
4ad


"MK666-1 BBO sonda" 2 1 /opt/topspin simona
MK666-1 BBO sonda
200.7926
167.8335
166.9533
153.8977
141.3672
136.3718
135.1124
134.4256
129.5486
128.0737
127.2995
127.0352
125.8489
124.6159
124.4530
82.4443
77.2071
76.9956
76.7842
66.4878
52.0758
49.3695
32.8773
27.5796
27.4169
[ppm]
0
50
100
150
200

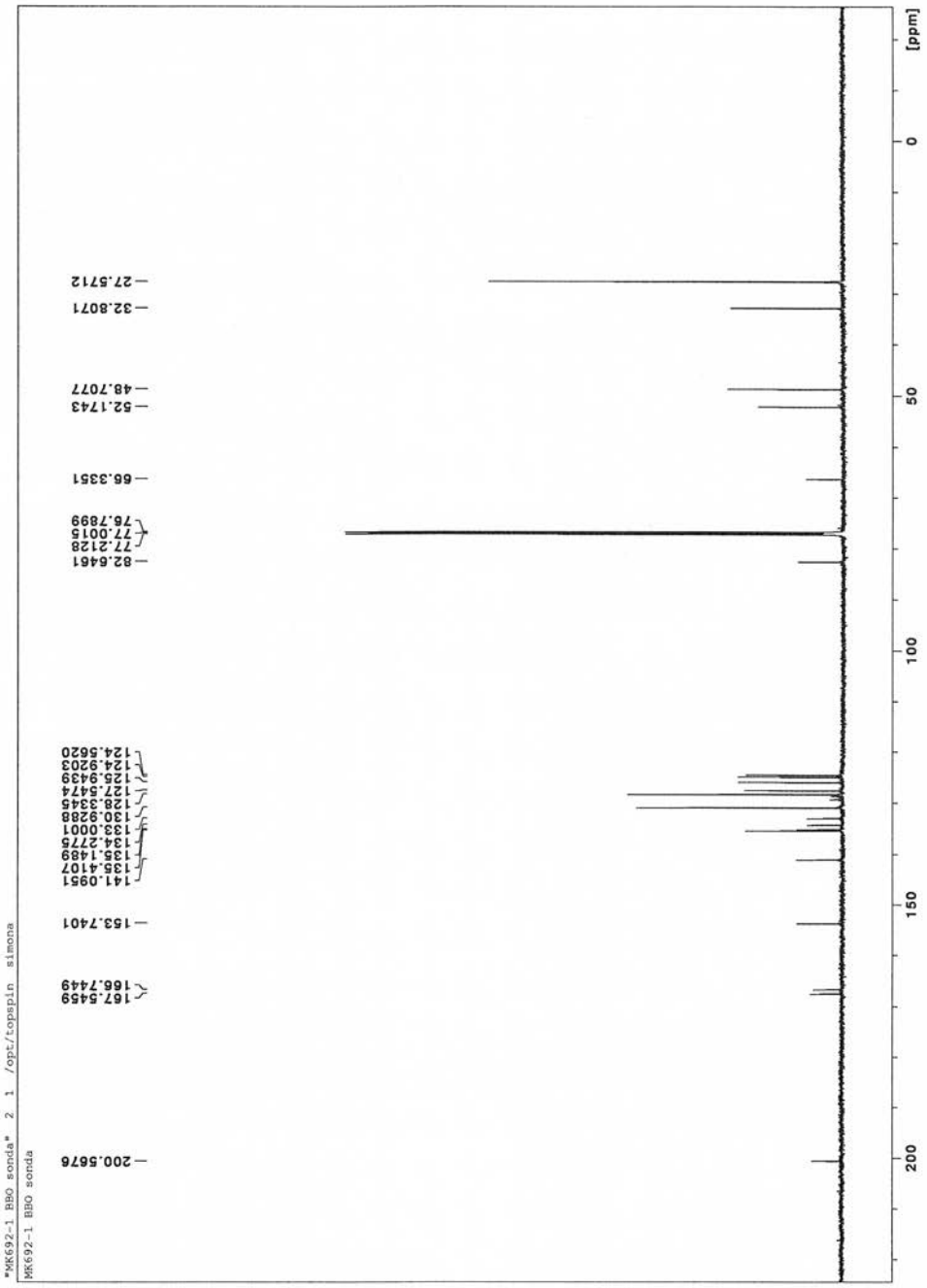

O
O
O
O
O
Cl

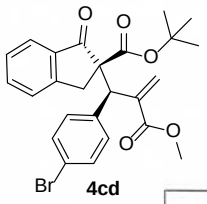
4bd


"MK692-1 BBO sonda" 1 1 /opt/topspin simona
MK692-1 BBO sonda
9.3001
1.0520
2.9459
1.0541
0.9370
1.0000
0.9930
3.8917
1.7787
1.1202
1.1125
0.9690
[ppm]

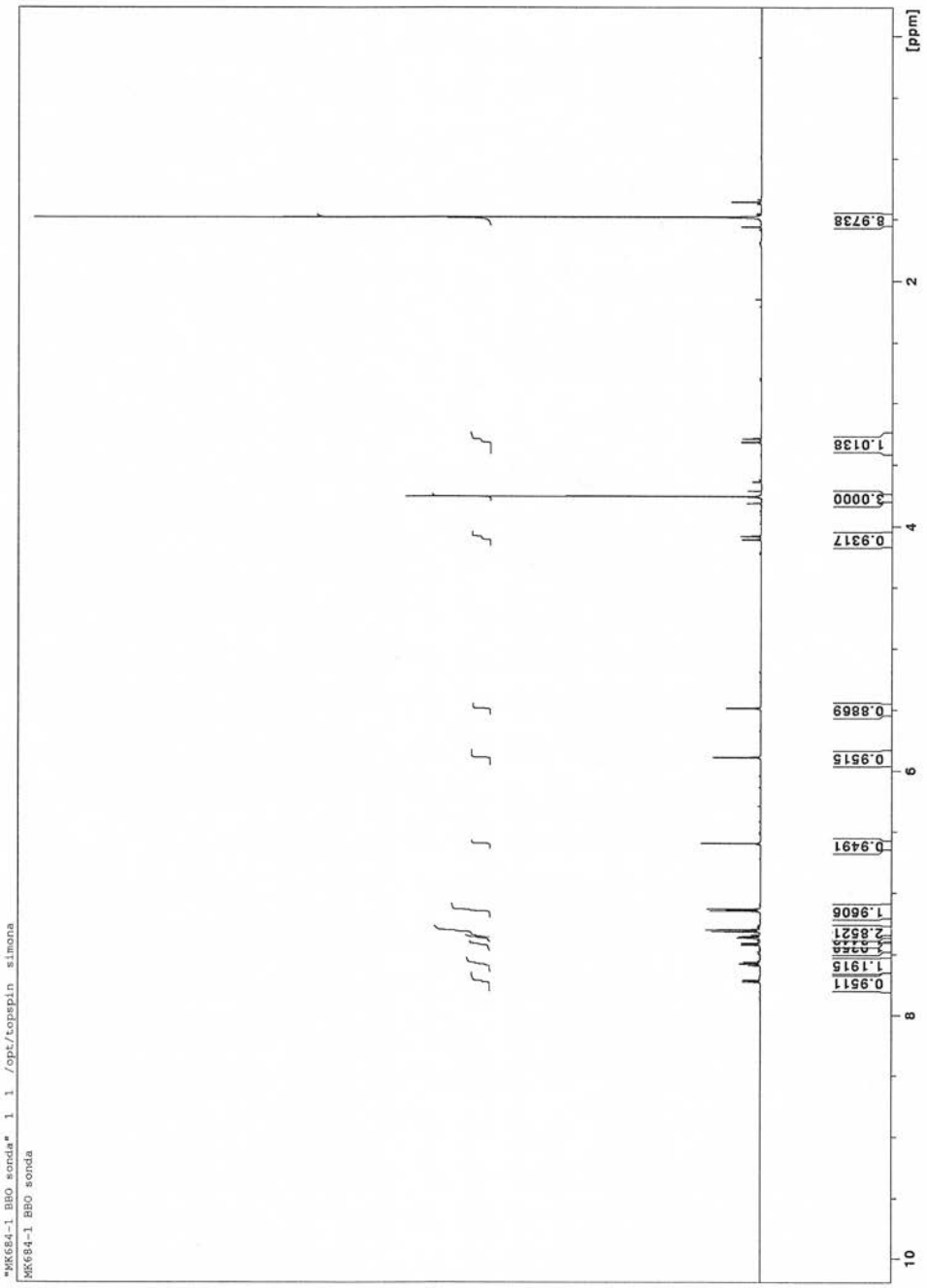

O
O
O
O
O
Cl

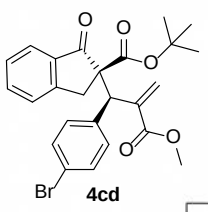
4bd


"MK692-1 BBO sonda" 2 1 /opt/topspin simona
MK692-1 BBO sonda
200.5676
167.5459
166.7449
153.7401
141.0951
135.4107
135.1489
134.2775
133.0001
130.9288
128.3345
127.5474
125.9439
124.9203
124.5620
82.6461
77.2128
77.0015
76.7899
66.3351
52.1743
48.7077
32.8071
27.5712
[ppm]
0
50
100
150
200

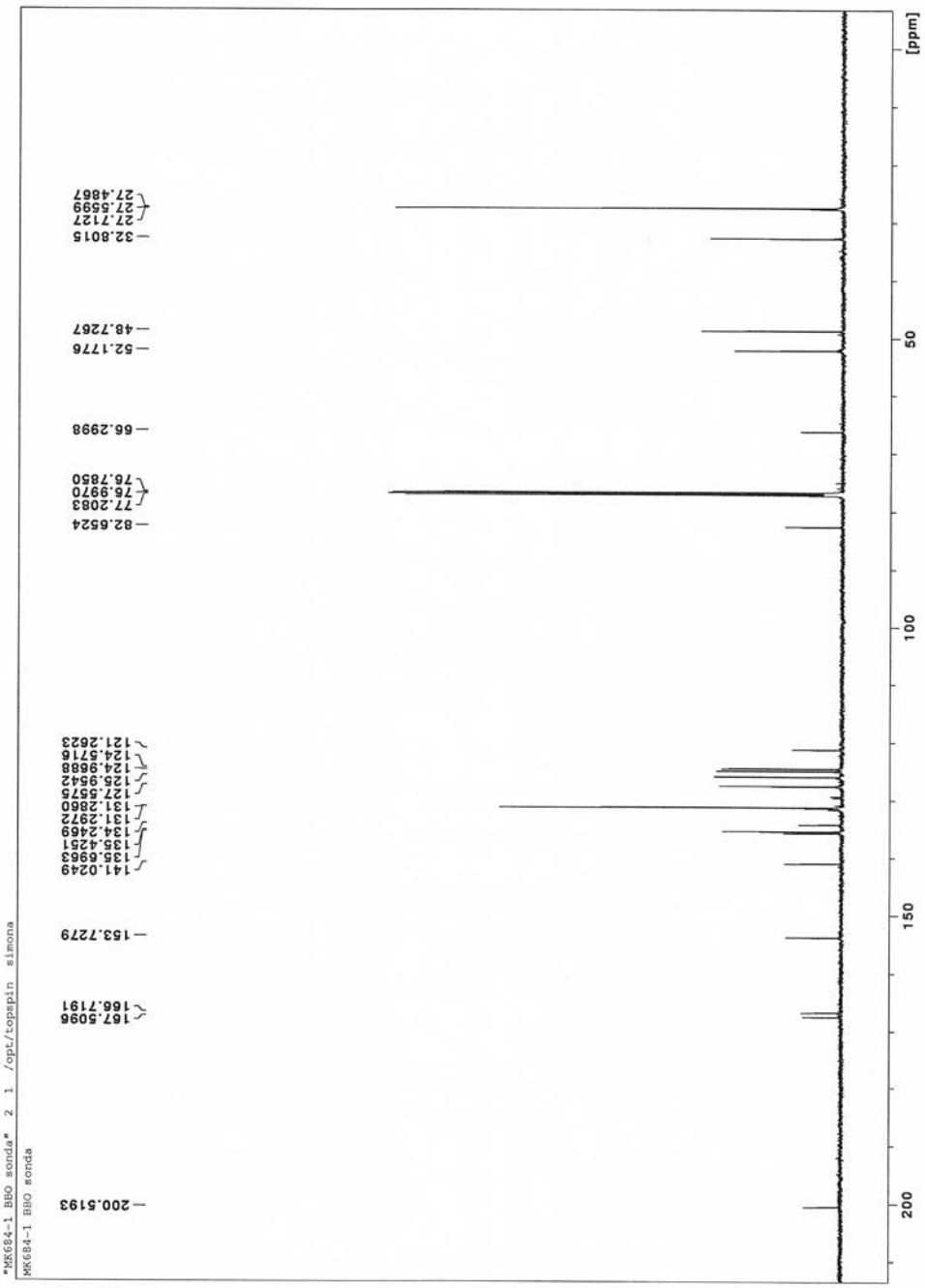

O
O
O
O
O
Br

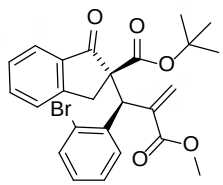
4cd


"MK684-1 BBO sonda" 1 1 /opt/topspin simona
MK684-1 BBO sonda
8.9738
1.0138
3.0000
0.9317
0.8869
0.9515
0.9491
1.9606
2.8521
0.9511
1.1915
[ppm]

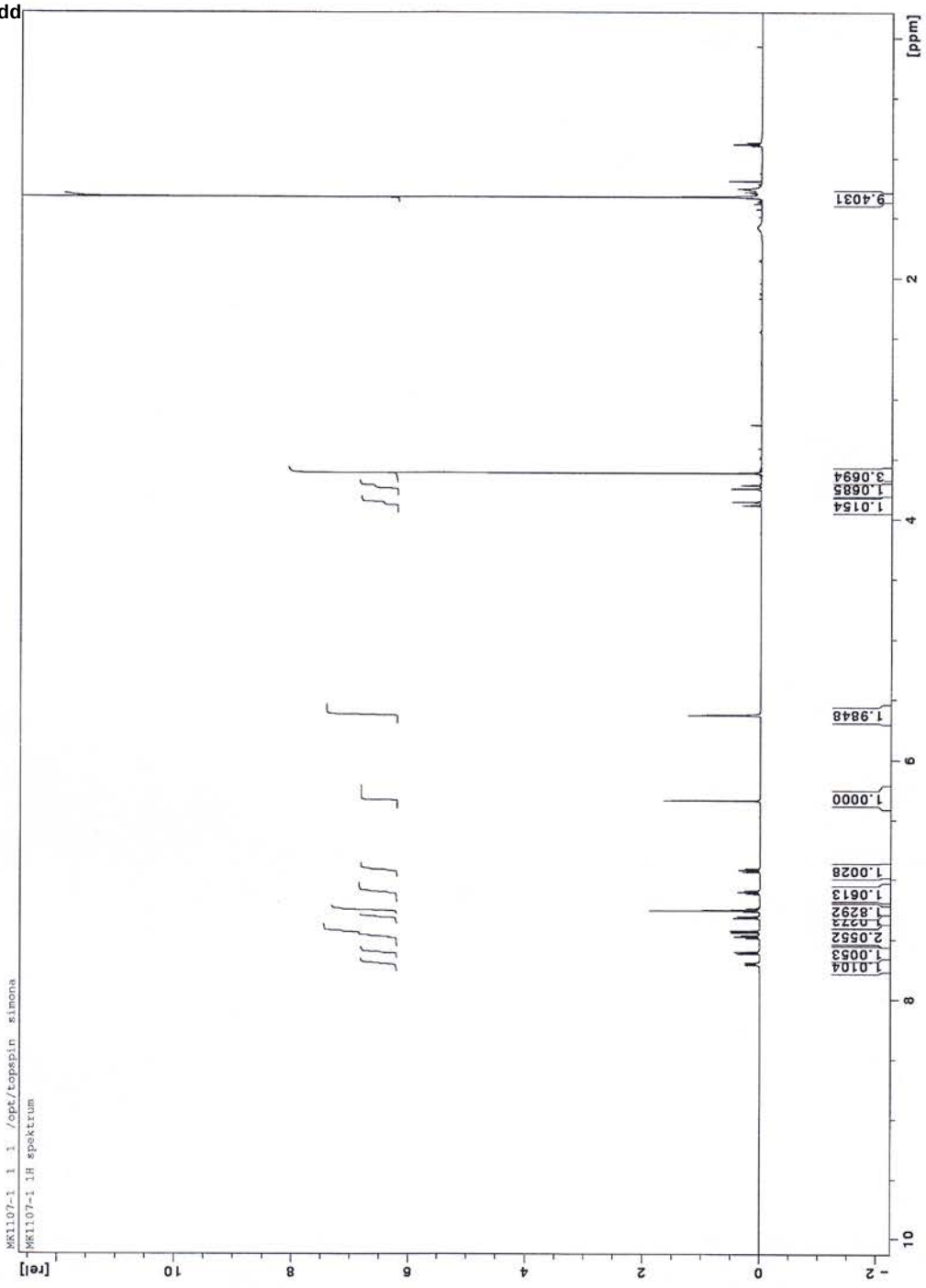

O
O
O
O
O
Br

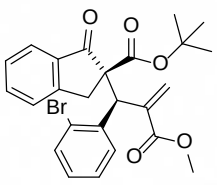
4cd


"MK684-1 BBO sonda" 2 1 /opt/topspin simona
MK684-1 BBO sonda
200.5193
167.5096
166.7191
153.7279
141.0249
135.6963
135.4251
134.2469
131.2972
131.2860
127.5575
126.9542
124.9688
124.3716
121.2623
82.6524
77.2083
76.9970
76.7850
66.2998
52.1776
48.7267
32.8015
27.7127
27.5599
27.4867
[ppm]
50
100
150
200

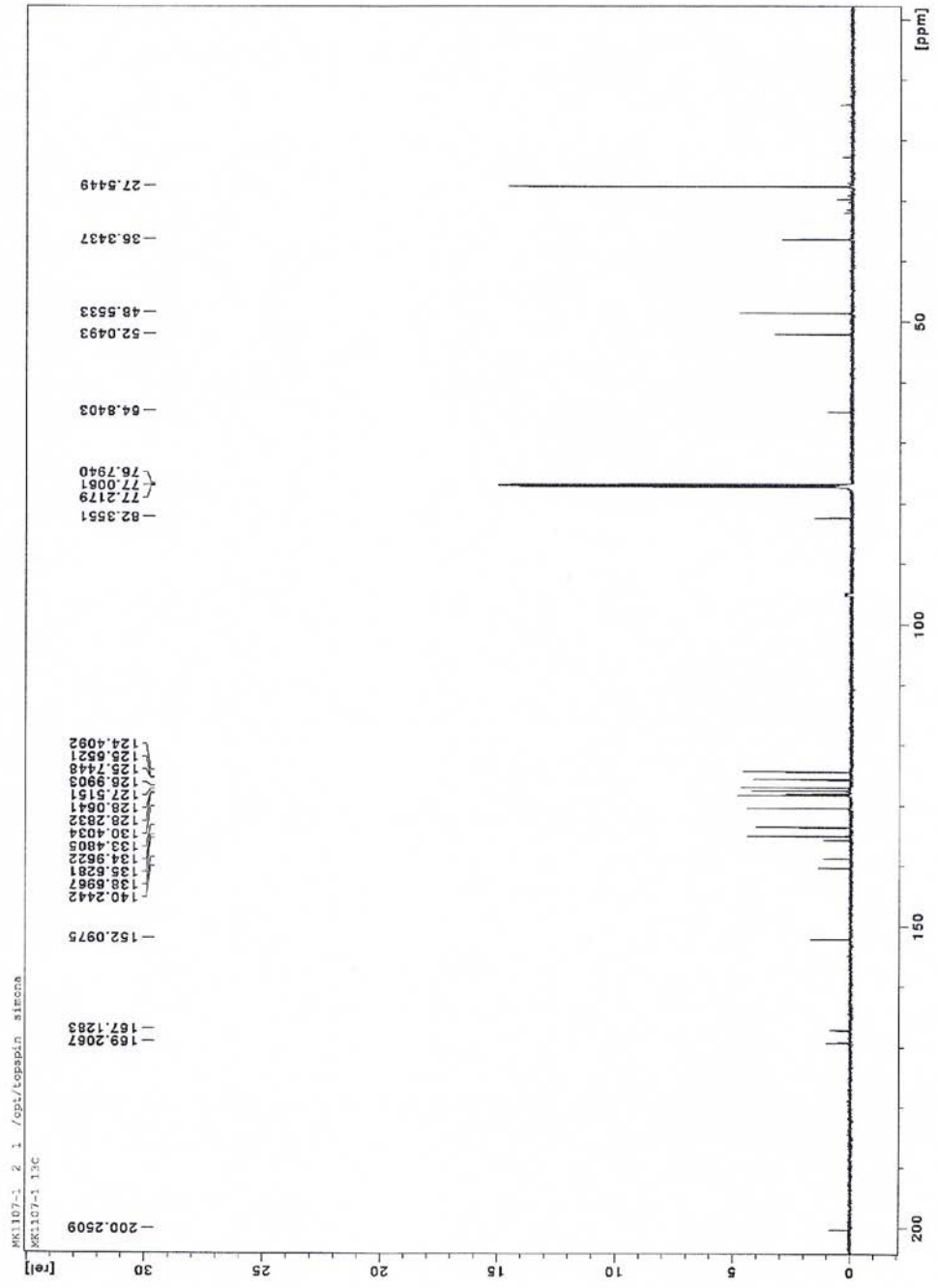

O
O
O
Br
O
O

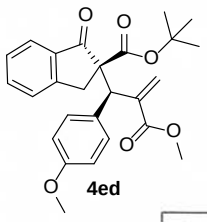
4dd


MK1107-1 1 1 /opt/topspin simona
MK1107-1 1H spektrum
[rel]
[ppm]
9.4031
3.0694
1.0685
1.0154
1.9848
1.0000
1.0028
1.0613
.8292
.0273
2.0552
1.0053
1.0104

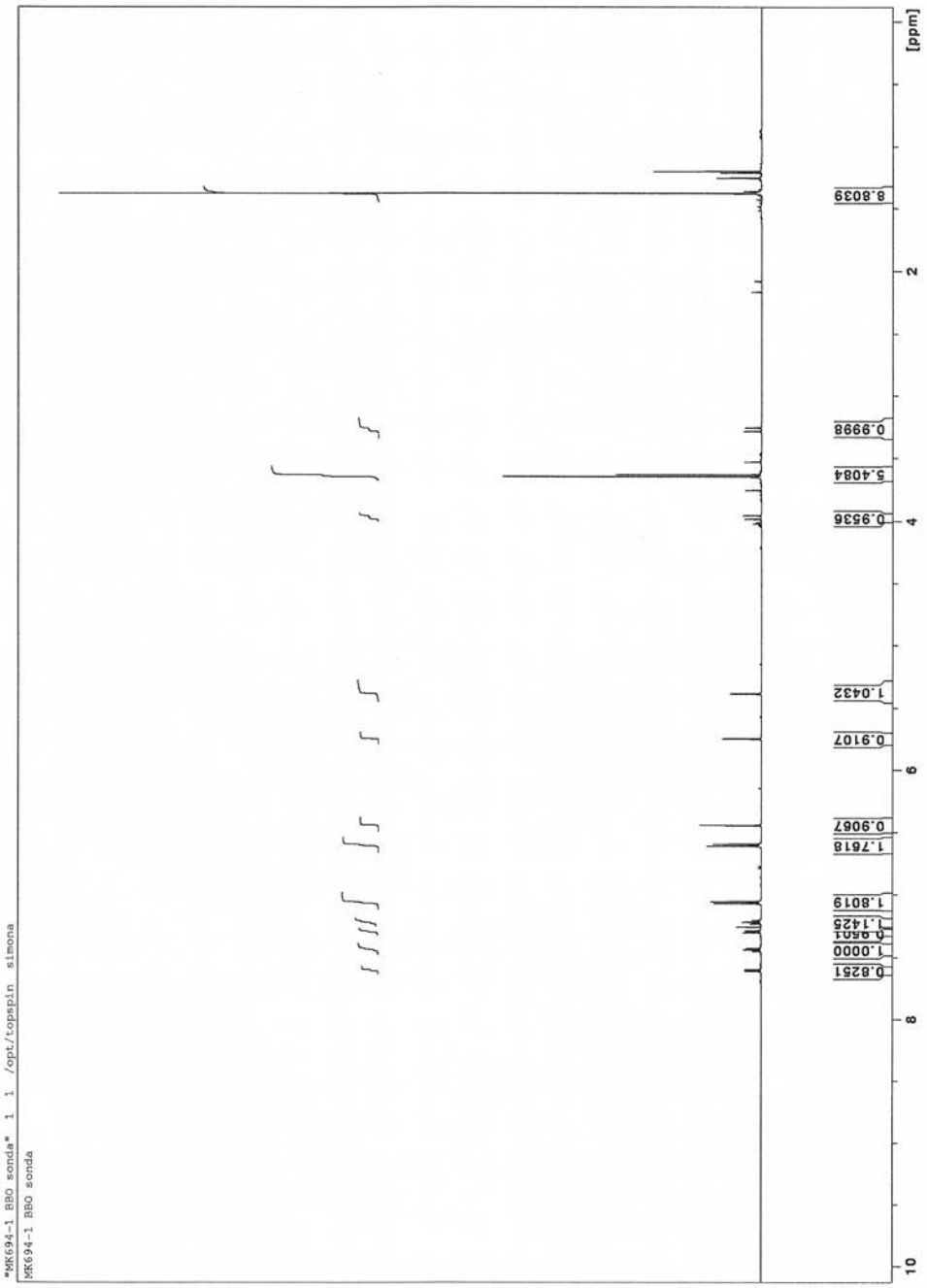

O
O
O
Br
O
O

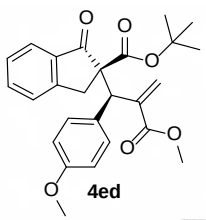
4dd


MK1107-1 2 1 /cpt/toppin simona
MK1107-1 13C
[rel]
30
25
20
15
10
5
0
[ppm]
200
150
100
50
200.2509
167.1283
169.2067
152.0975
140.2442
138.6967
135.6281
134.9622
133.4805
130.4034
128.2832
128.0641
127.5151
126.9903
125.7448
125.6521
124.4092
82.3551
77.2179
77.0061
76.7940
64.8403
52.0493
48.5533
36.3437
27.5449

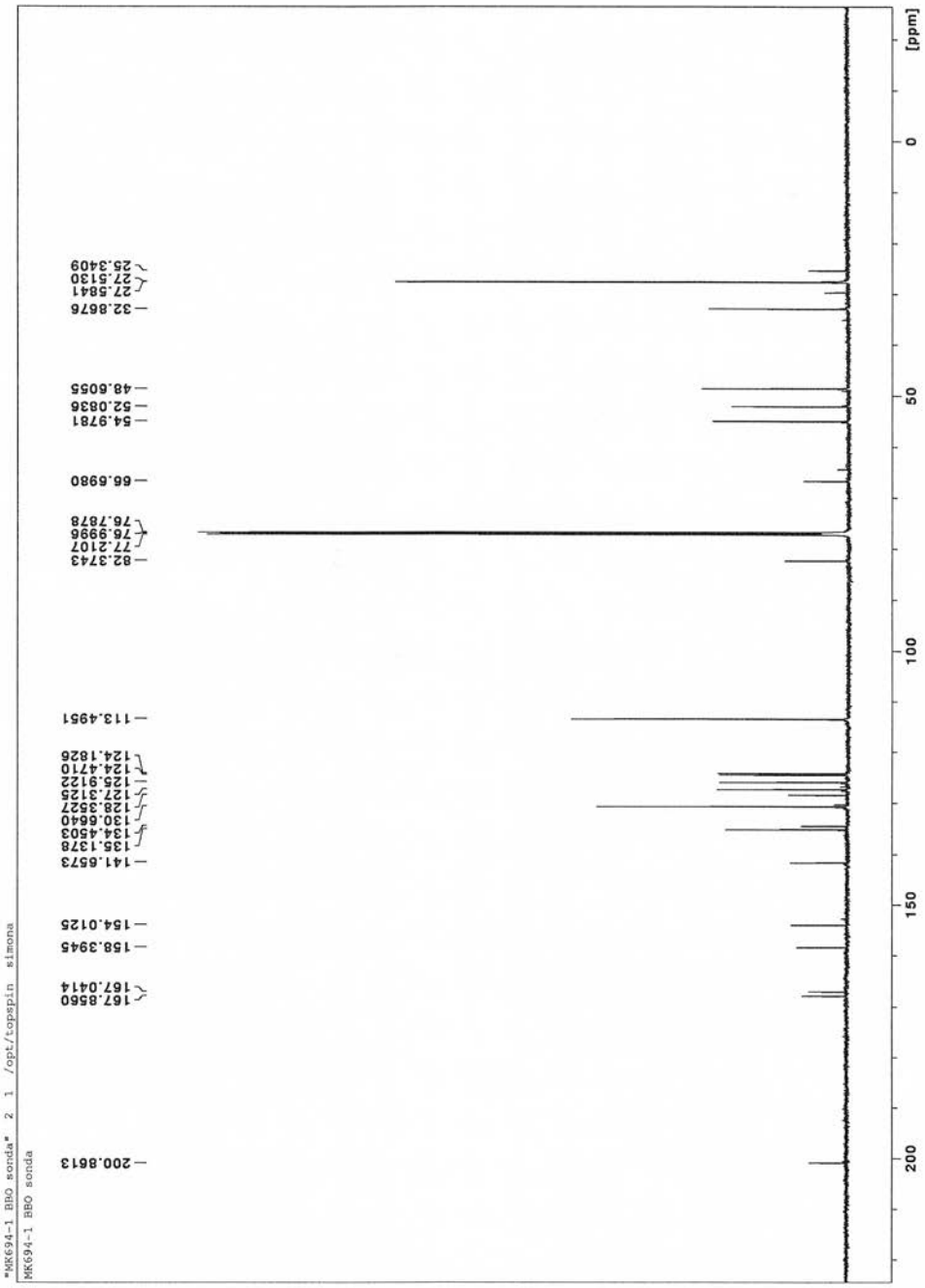


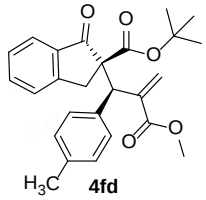
4ed


"MK694-1 BBO sonda" 1 1 /opt/topspin simona
MK694-1 BBO sonda
8.8039
0.9998
5.4084
0.9536
1.0432
0.9107
0.9067
1.7618
1.8019
1.1425
1.0000
0.8251
[ppm]

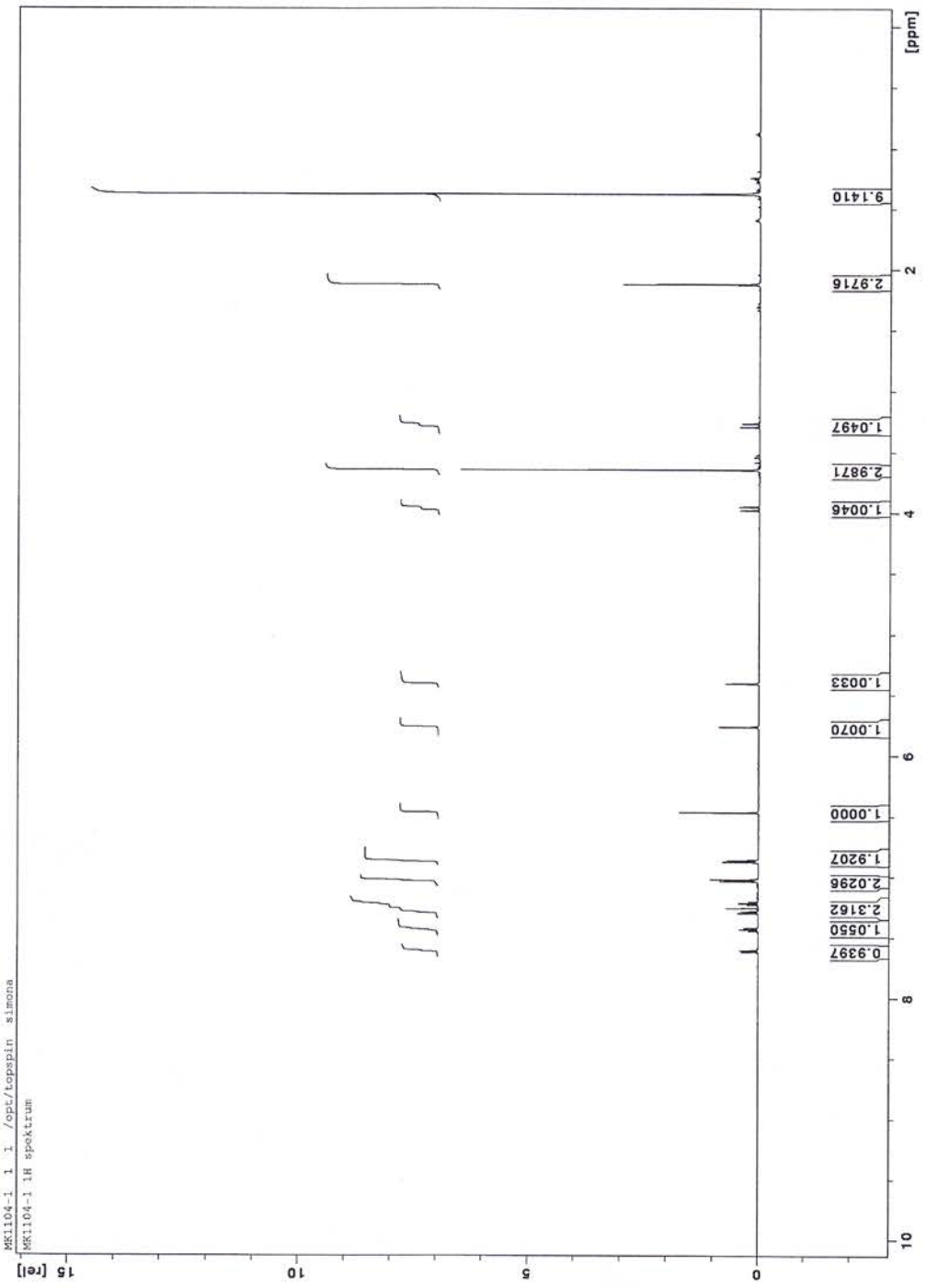


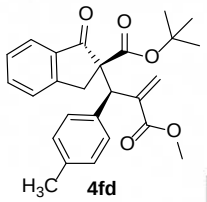
4ed


"MK694-1 BBO sonda" 2 1 /opt/topspin simona
MK694-1 BBO sonda
200.8613
167.8560
167.0414
158.3945
154.0125
141.6573
135.1378
134.4503
130.6640
128.3527
127.3125
125.9122
124.4710
124.1826
113.4951
82.3743
77.2107
76.9996
76.7878
66.6980
54.9781
52.0836
48.6055
32.8676
27.5841
27.5130
25.3409
[ppm]
0
50
100
150
200

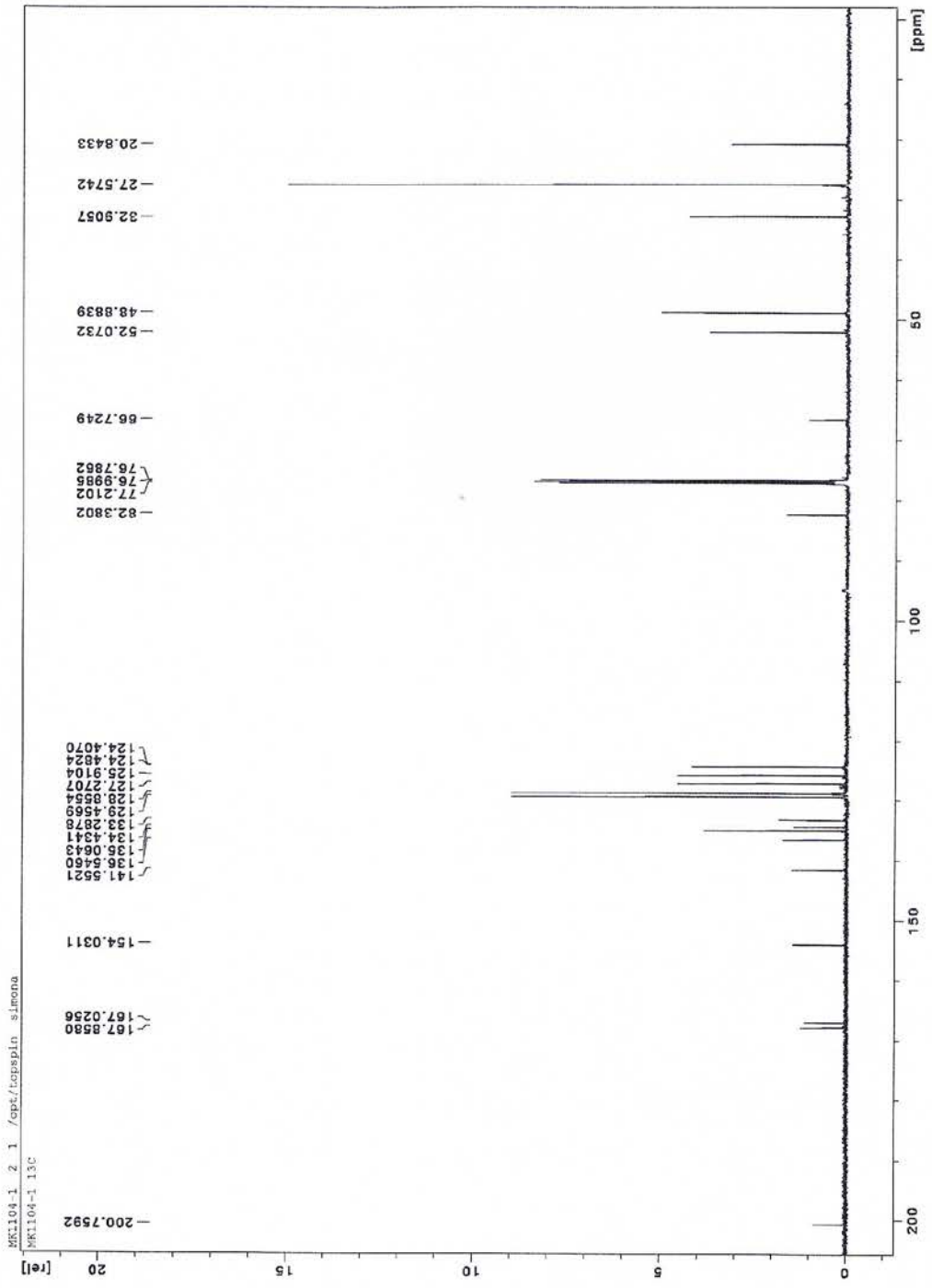

O
O
O
O
O
H3C

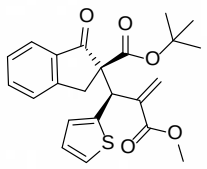
4fd


MK1104-1 1 1 /opt/topspin simona
MK1104-1 1H spektrum
[rel]
15
10
5
0
[ppm]
10
8
6
4
2
0.9397
1.0550
2.3162
2.0296
1.9207
1.0000
1.0070
1.0033
1.0046
2.9871
1.0497
2.9716
9.1410

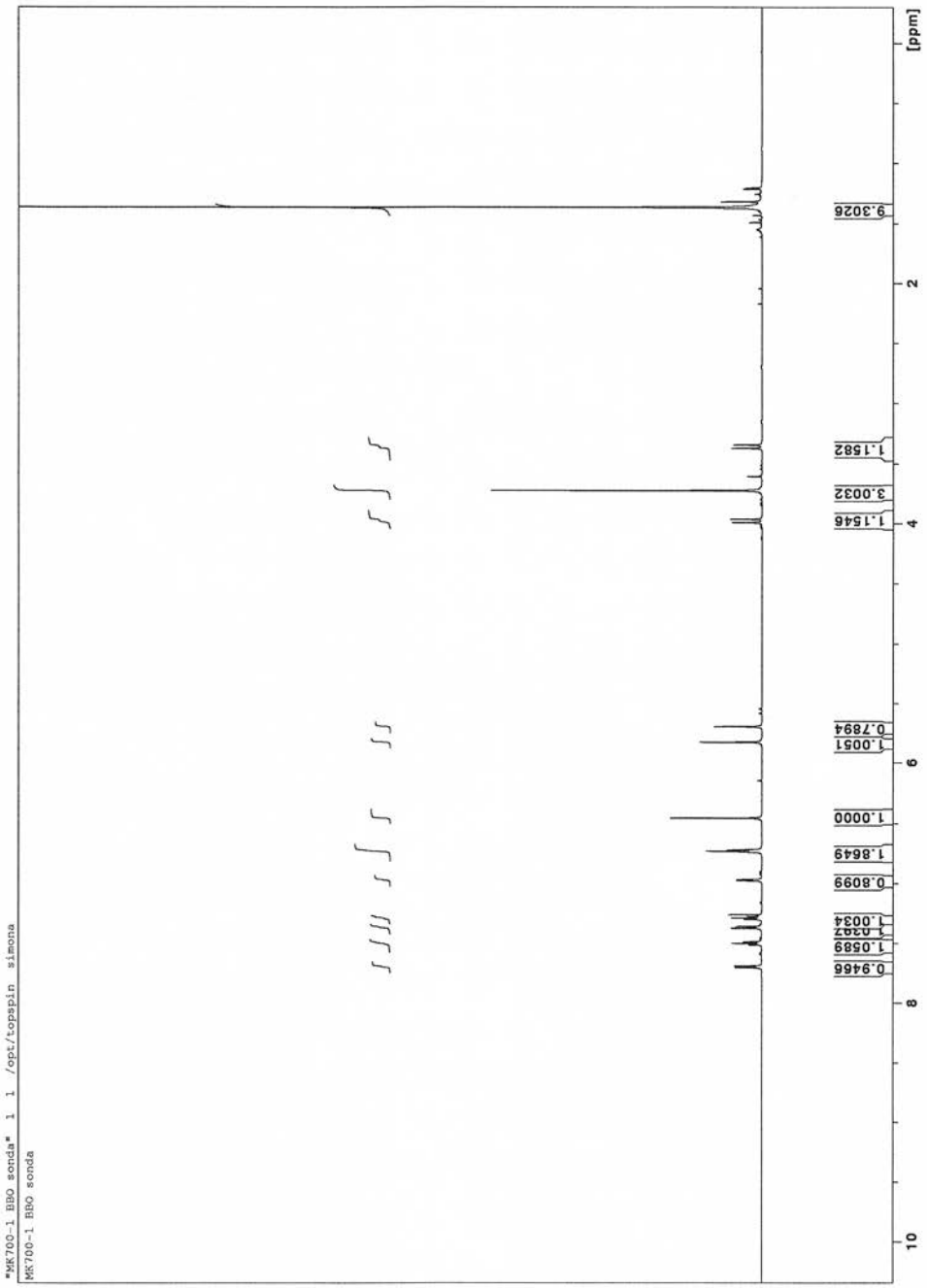

O
O
O
O
O
H_3C

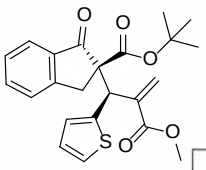
4fd


MK1104-1 2 1 /opt/topspin simona
MK1104-1 13C
[rel]
[ppm]
200.7592
167.8580
167.0256
154.0311
141.5521
136.5460
136.0643
134.4341
133.2878
129.4569
128.8554
127.2707
125.9104
124.4824
124.4070
82.3802
77.2102
76.9986
76.7862
66.7249
52.0732
48.8839
32.9057
27.5742
20.8433

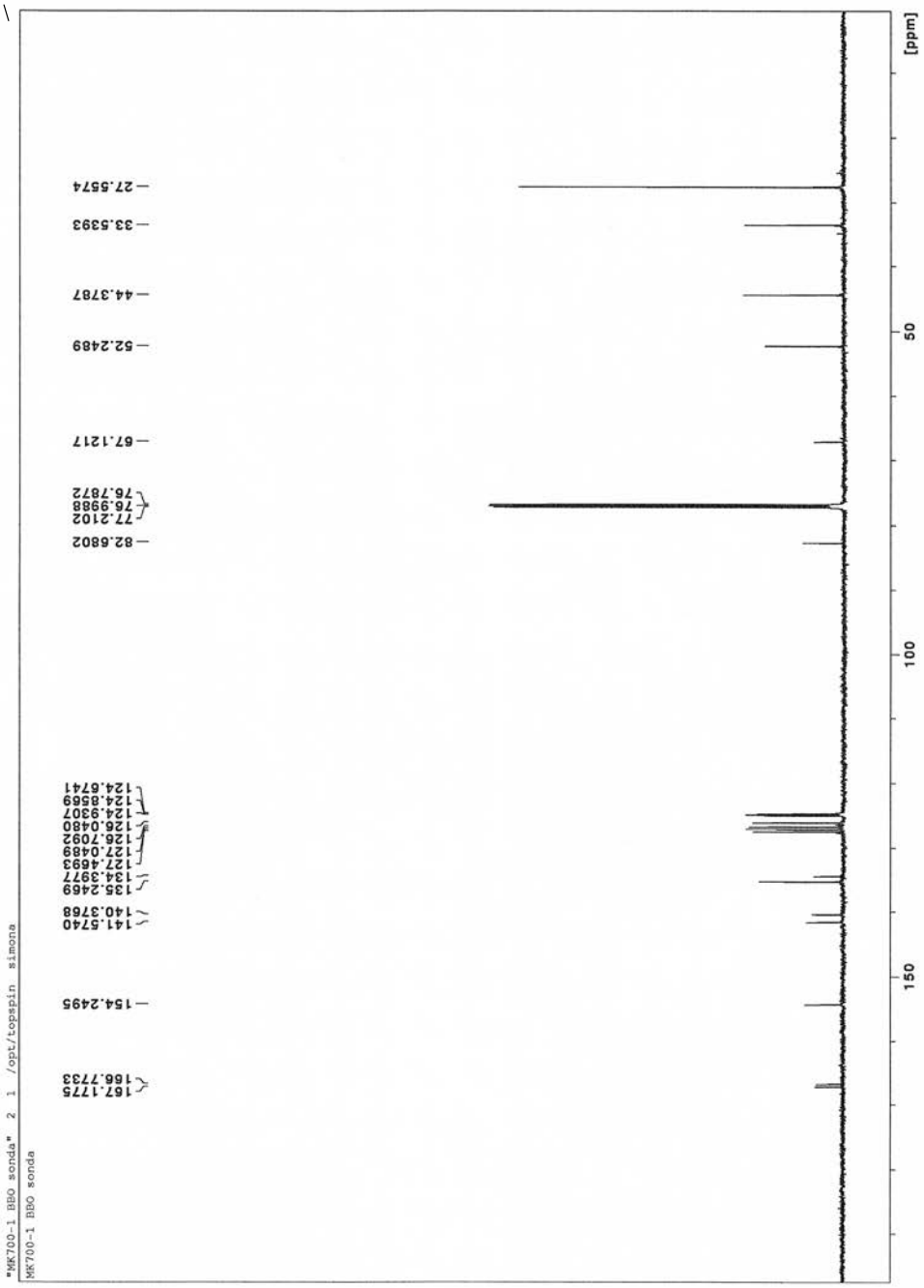


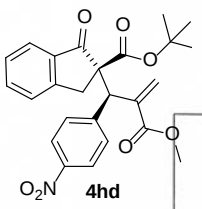
4gd


"MK700-1 BBO sonda" 1 1 /opt/topspin simona
MK700-1 BBO sonda
9.3026
1.1582
3.0032
1.1546
0.7894
1.0051
1.0000
1.8649
0.8099
1.0034
1.0427
1.0589
0.9466
[ppm]

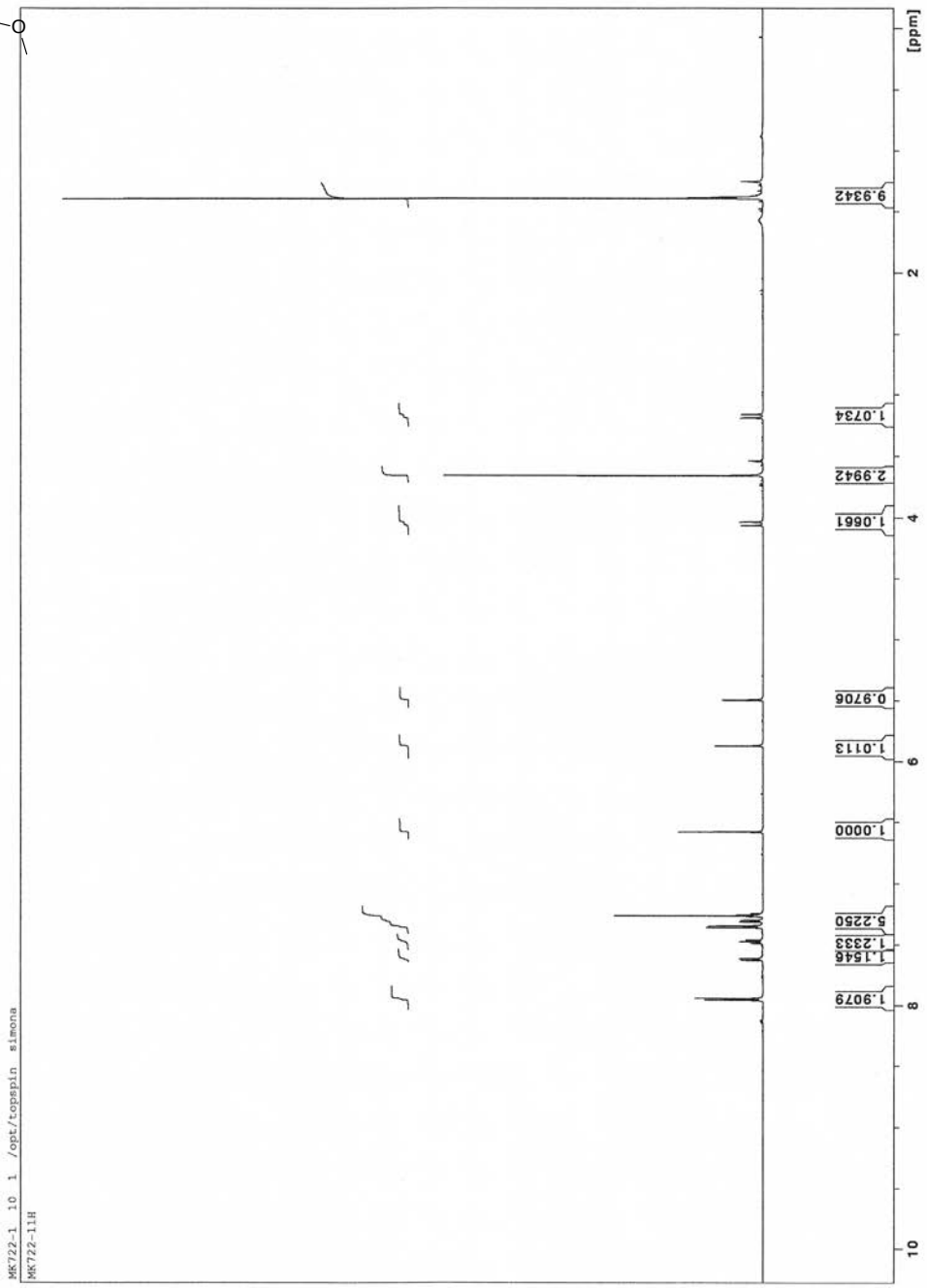


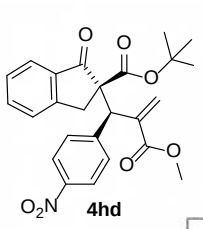
4gd


"MK700-1 BBO sonda" 2 1 /opt/topspin simona
MK700-1 BBO sonda
27.5574
33.5393
44.3787
52.2489
67.1217
76.7872
76.9988
77.2102
82.6802
124.6741
124.8569
124.9307
126.0480
126.7092
127.0489
127.4693
134.3977
135.2469
140.3768
141.5740
154.2495
166.7733
167.1775
[ppm]
50
100
150

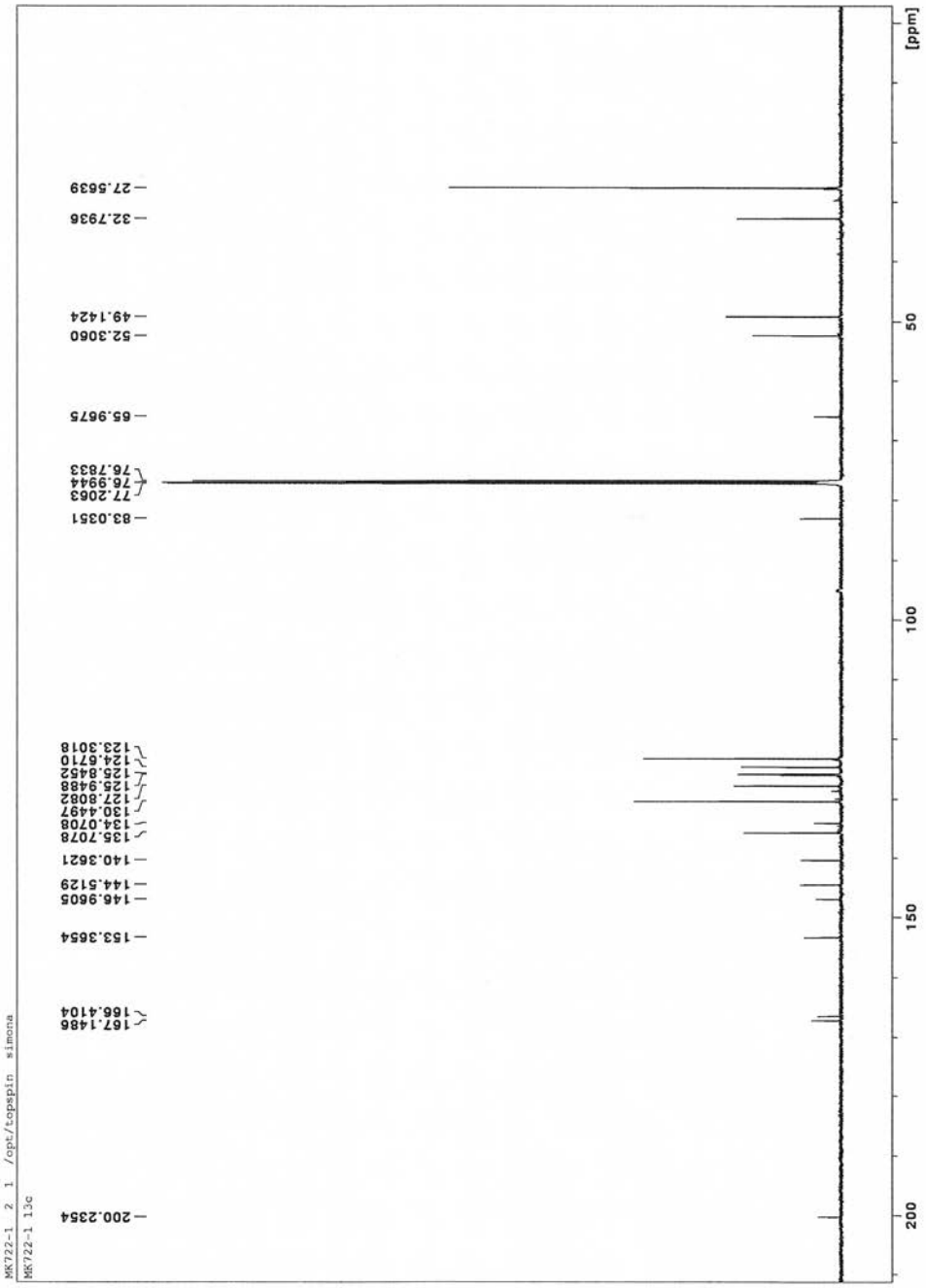

O
O
O
O
O
O_2N

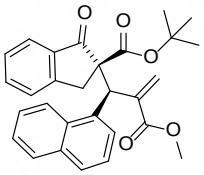
4hd


MK722-1 10 1 /opt/topspin simona
MK722-11H
9.9342
1.0734
2.9942
1.0661
0.9706
1.0113
1.0000
5.2250
1.2333
1.1546
1.9079
[ppm]

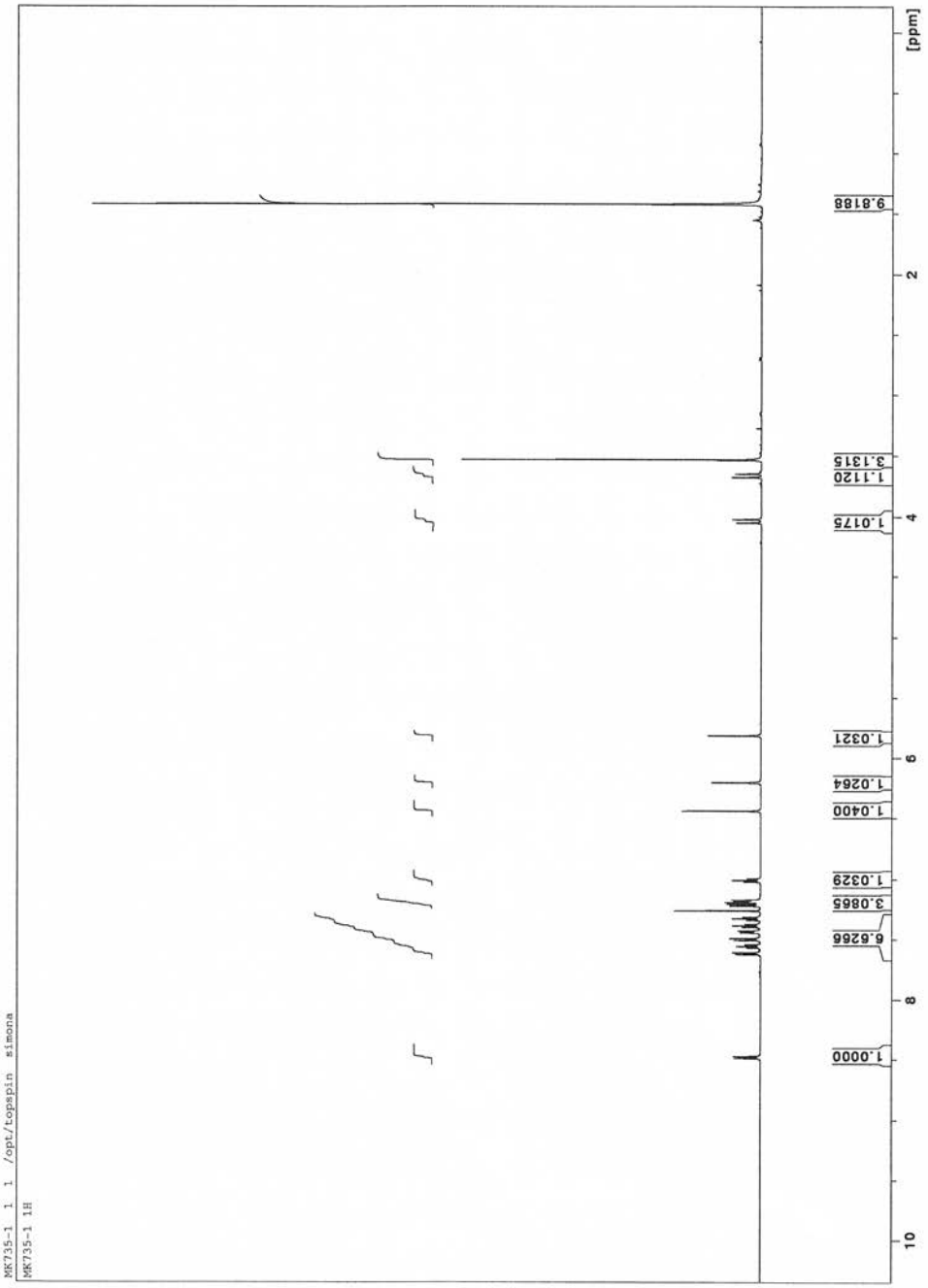


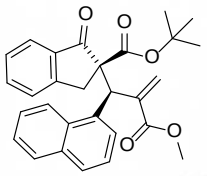
4hd


MK722-1 2 1 /opt/topspin simona
MK722-1 13c
200.2354
167.1486
166.4104
153.3654
146.9605
144.5129
140.3621
135.7078
134.0708
130.4497
127.8082
125.9488
125.8452
124.6710
123.3018
83.0351
77.2063
76.9944
76.7833
65.9675
52.3060
49.1424
32.7936
27.5639
[ppm]
200
150
100
50

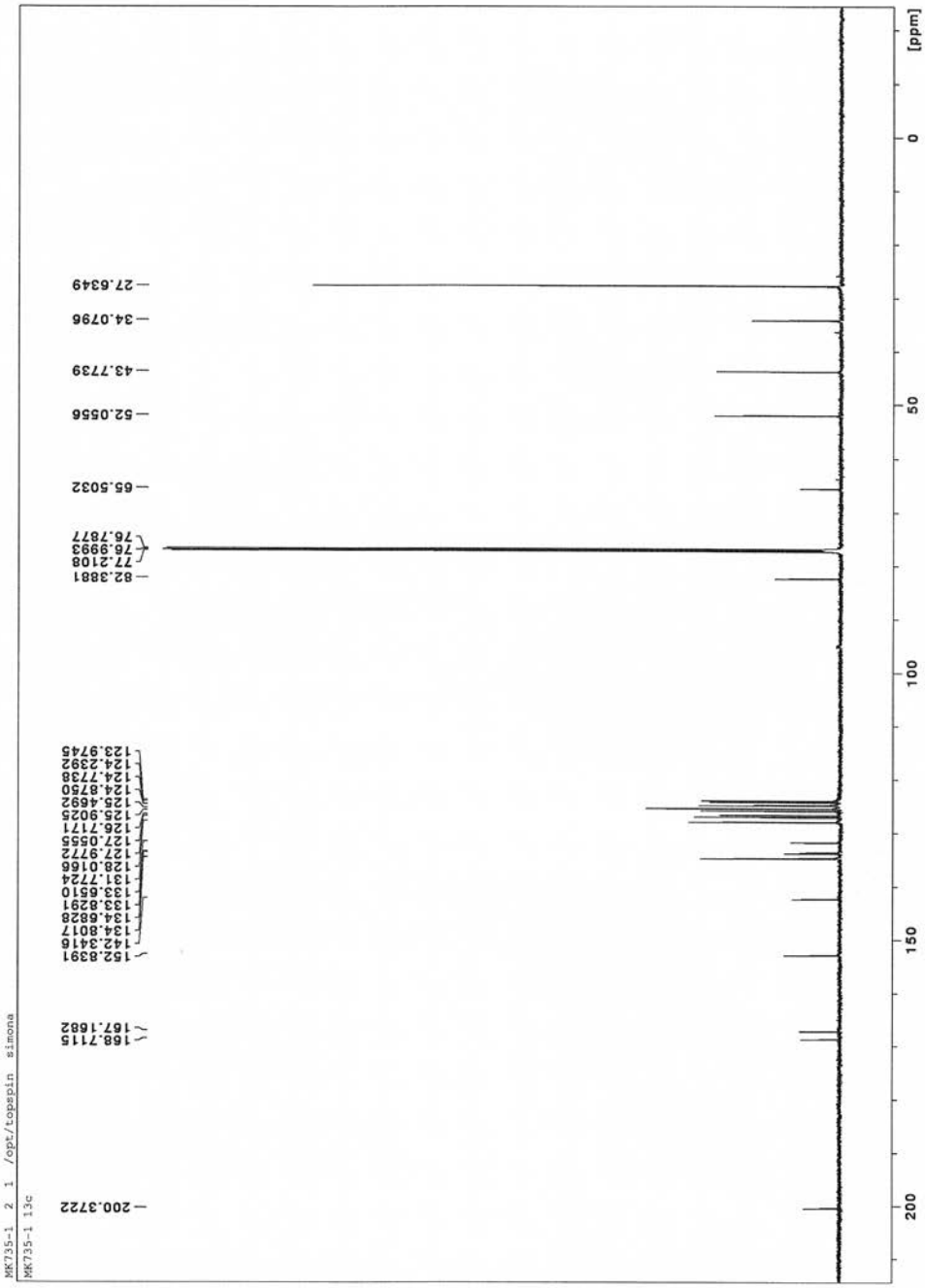


4id

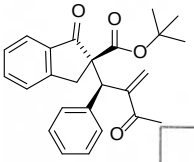

MK735-1 1 1 /opt/topspin simona
MK735-1 1H
9.8188
3.1315
1.1120
1.0175
1.0321
1.0264
1.0400
1.0329
3.0865
6.6266
1.0000
[ppm]



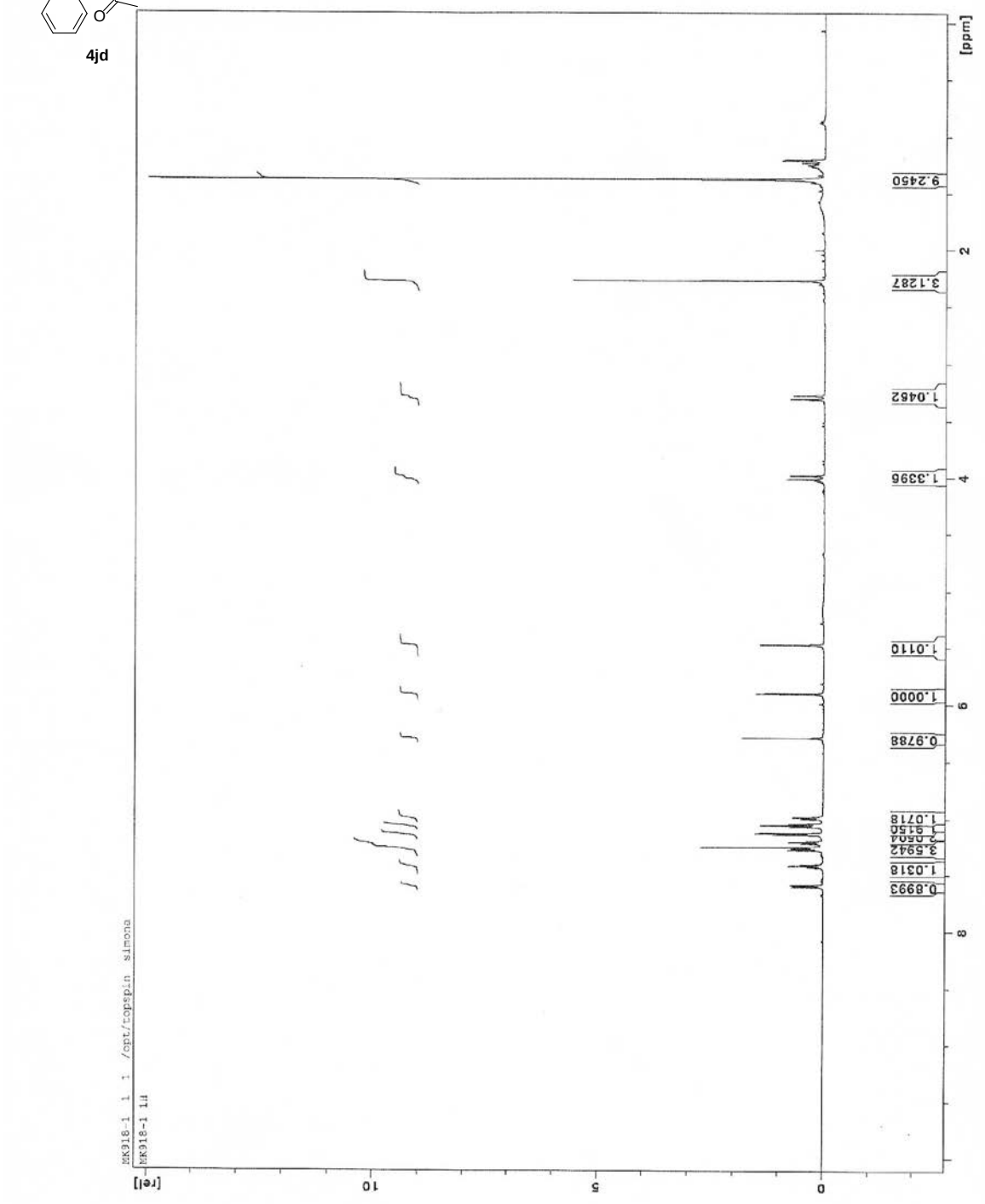
4id

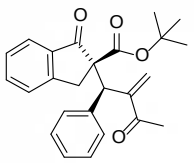

MK735-1 2 1 /opt/topspin simona
MK735-1 13c
200.3722
168.7115
167.1682
152.8391
142.3416
134.8017
134.6828
133.8291
133.6510
131.7724
128.0166
127.9772
127.0555
126.7171
125.9025
125.4692
124.8750
124.7738
124.2392
123.9745
82.3881
77.2108
76.9993
76.7877
65.5032
52.0556
43.7739
34.0796
27.6349
[ppm]
0
50
100
150
200

isolated single major diastereomer

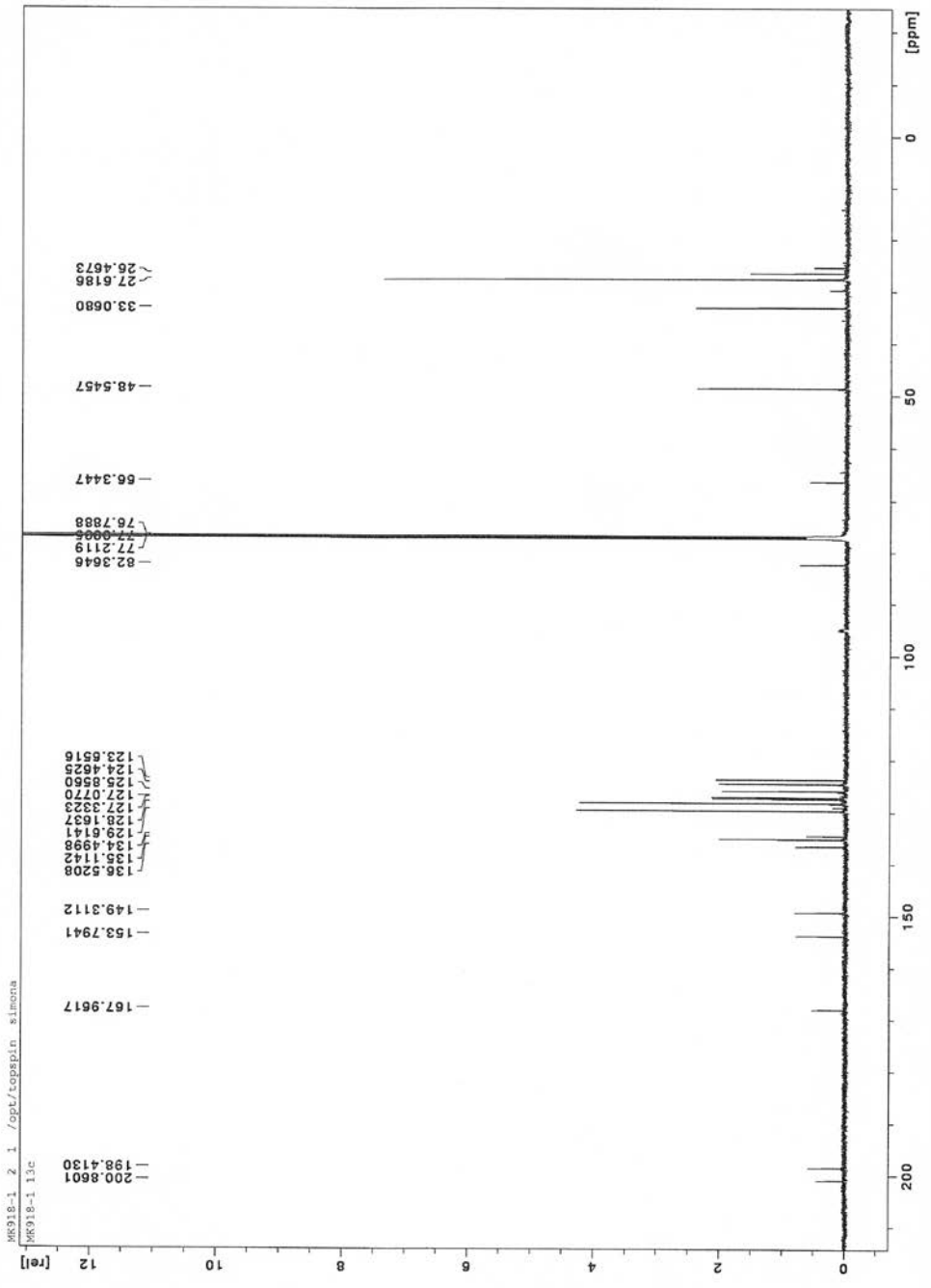


4jd

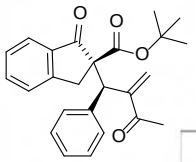




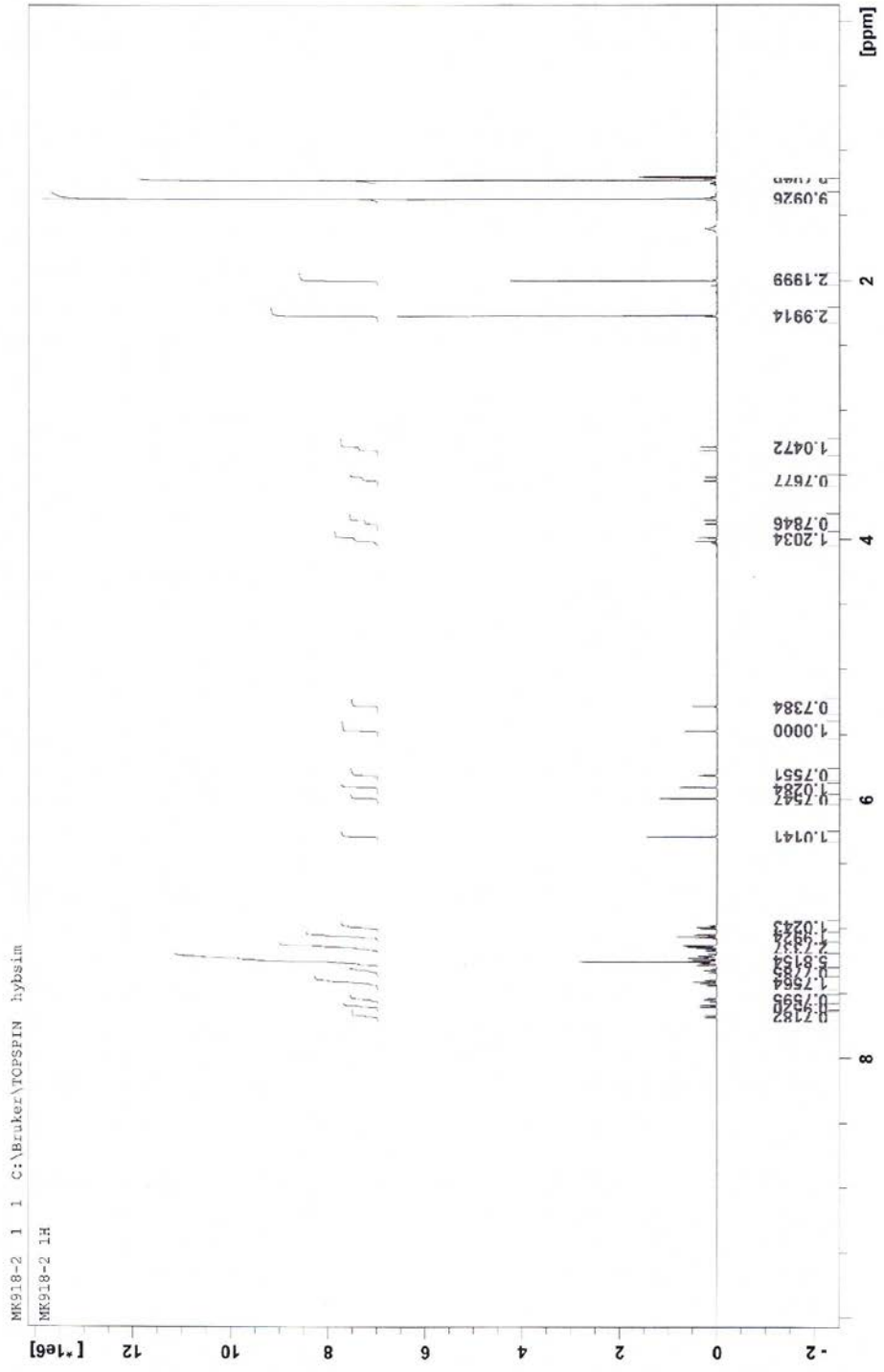
4jd

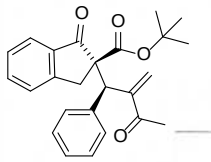

MK918-1 2 1 /opt/topspin simona
MK918-1 13c
[rel]
[ppm]
200.8601
198.4130
167.9617
153.7941
149.3112
136.5208
135.1142
134.4998
129.6141
128.1637
127.3323
127.0770
125.8560
124.4625
123.6516
82.3646
77.2119
76.7888
66.3447
48.5457
33.0680
27.6186
26.4673

isolated mixture of diastereomers (3:2 ratio)

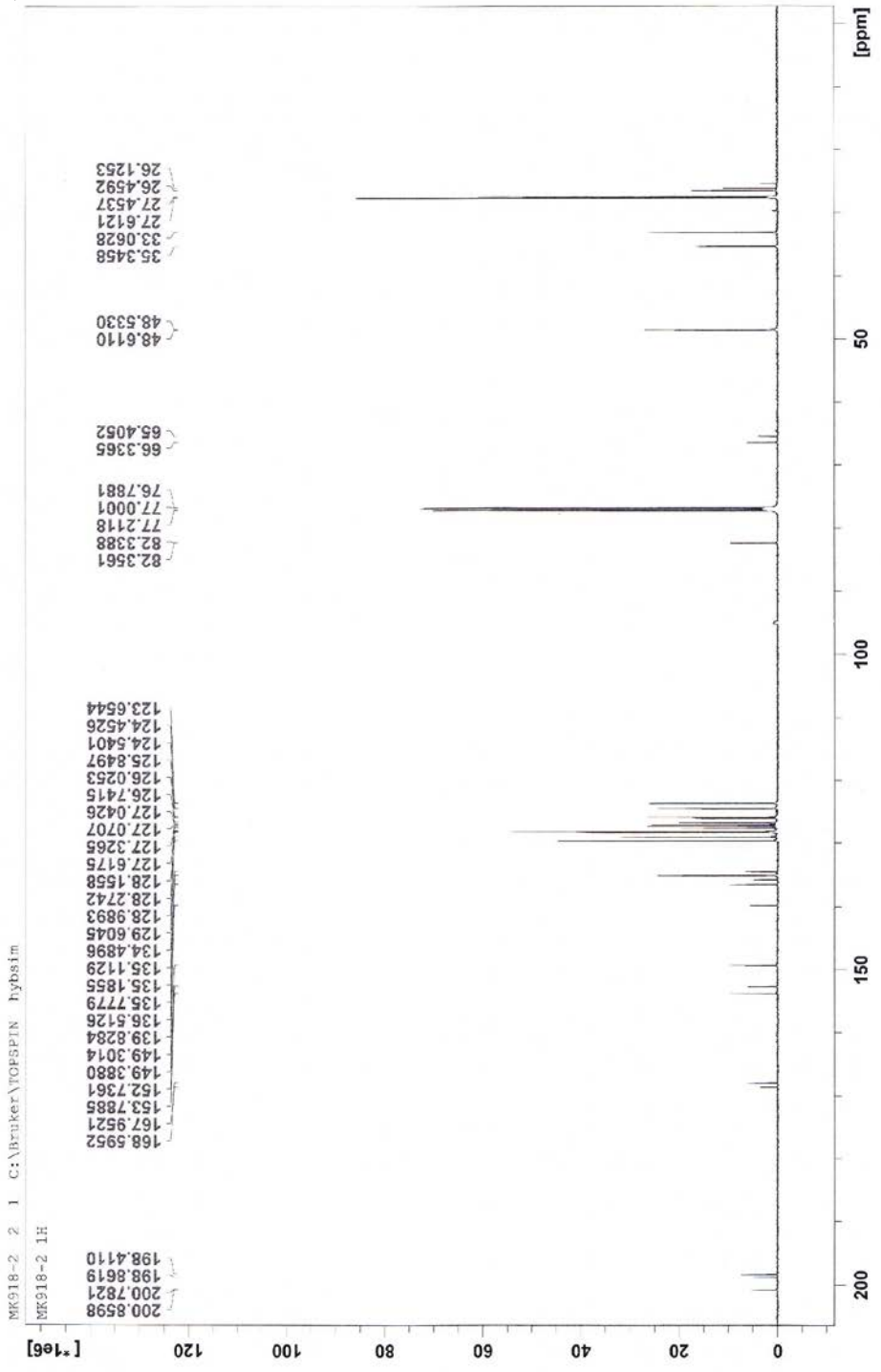


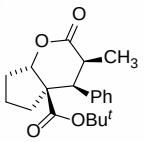
4jd



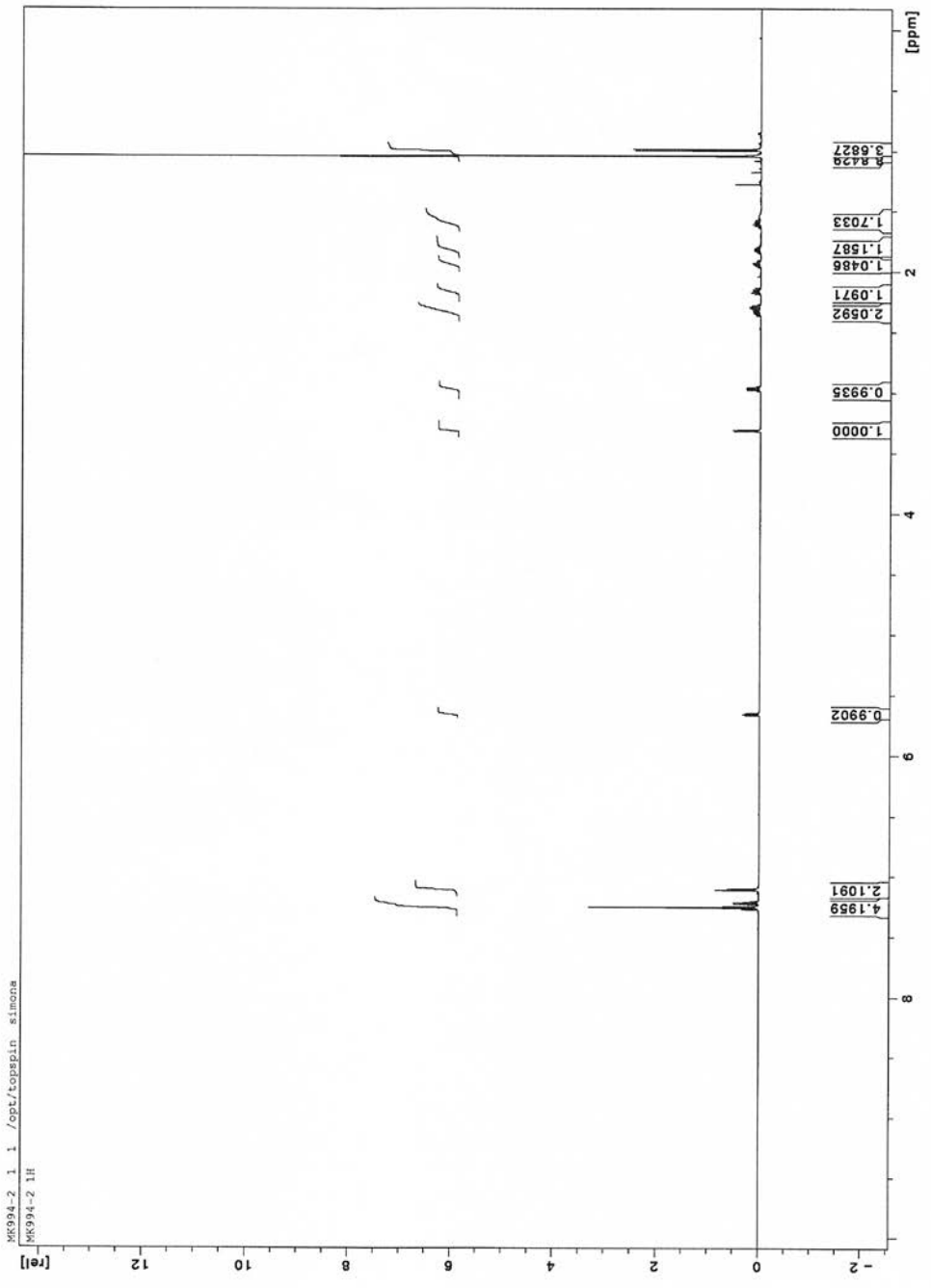


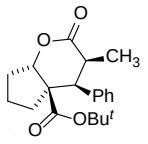
4jd


MK918-2 2 1 C:\Bruker\TOPSPIN hybsim
MK918-2 1H
198.4110
198.8619
200.7821
200.8598
168.5952
167.9521
153.7885
152.7361
149.3880
149.3014
139.8284
136.5126
135.7779
135.1855
135.1129
134.4896
129.6045
128.9893
128.2742
128.1558
127.6175
127.3265
127.0707
127.0426
126.7415
126.0253
125.8497
124.5401
124.4526
123.6544
82.3388
82.3561
77.2118
77.0001
76.7881
66.3365
65.4052
48.6110
48.5330
35.3458
33.0628
27.6121
27.4537
26.4592
26.1253
[ppm]
[*1e6]

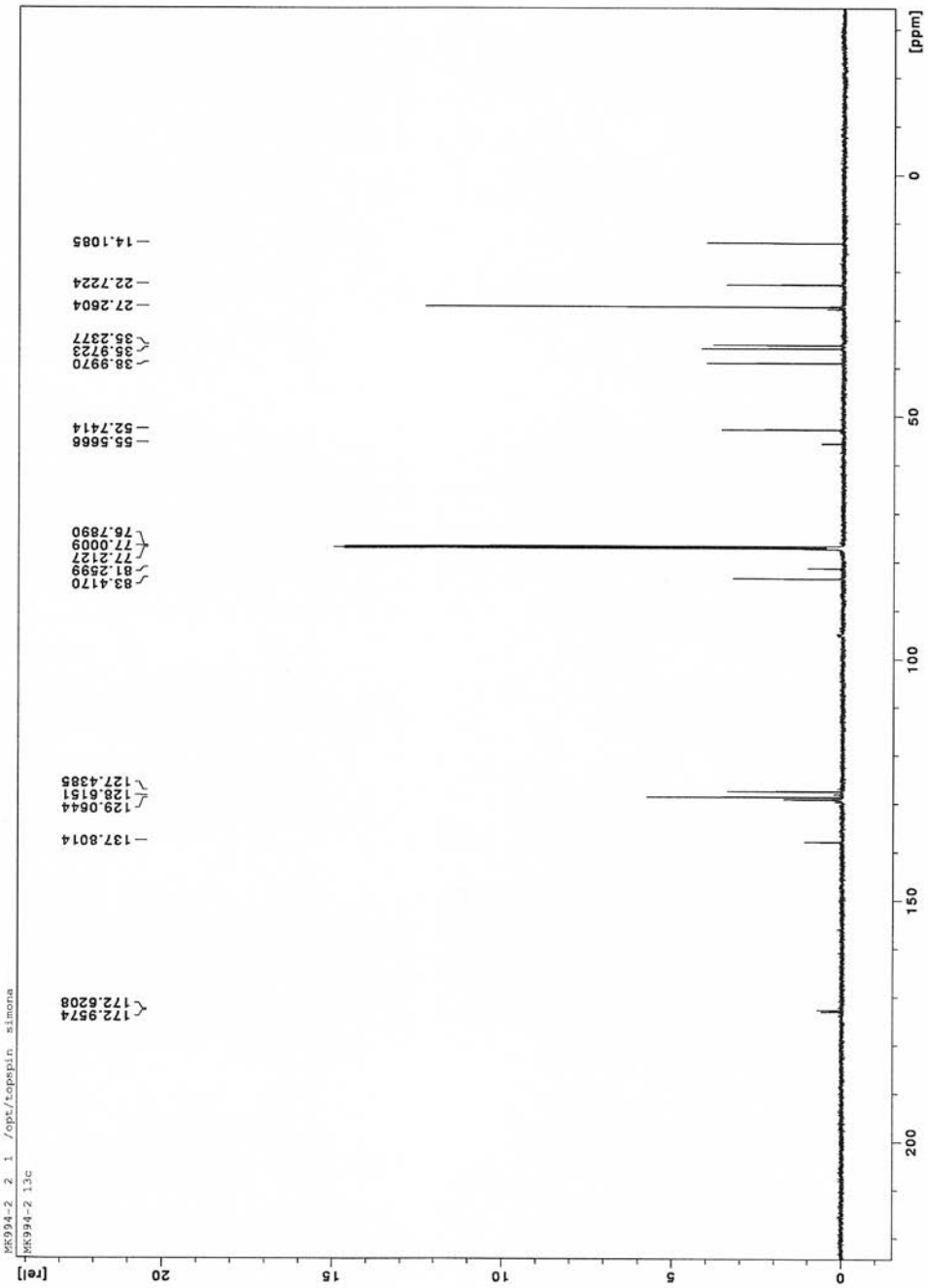

O
O
CH3
Ph
O
OBut

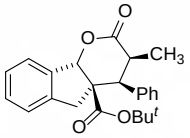
6a


MK994-2 1 1 /opt/topspin simona
MK994-2 1H
[rel]
[ppm]
3.8439
3.6827
1.7033
1.1587
1.0486
1.0971
2.0592
0.9935
1.0000
0.9902
2.1091
4.1959

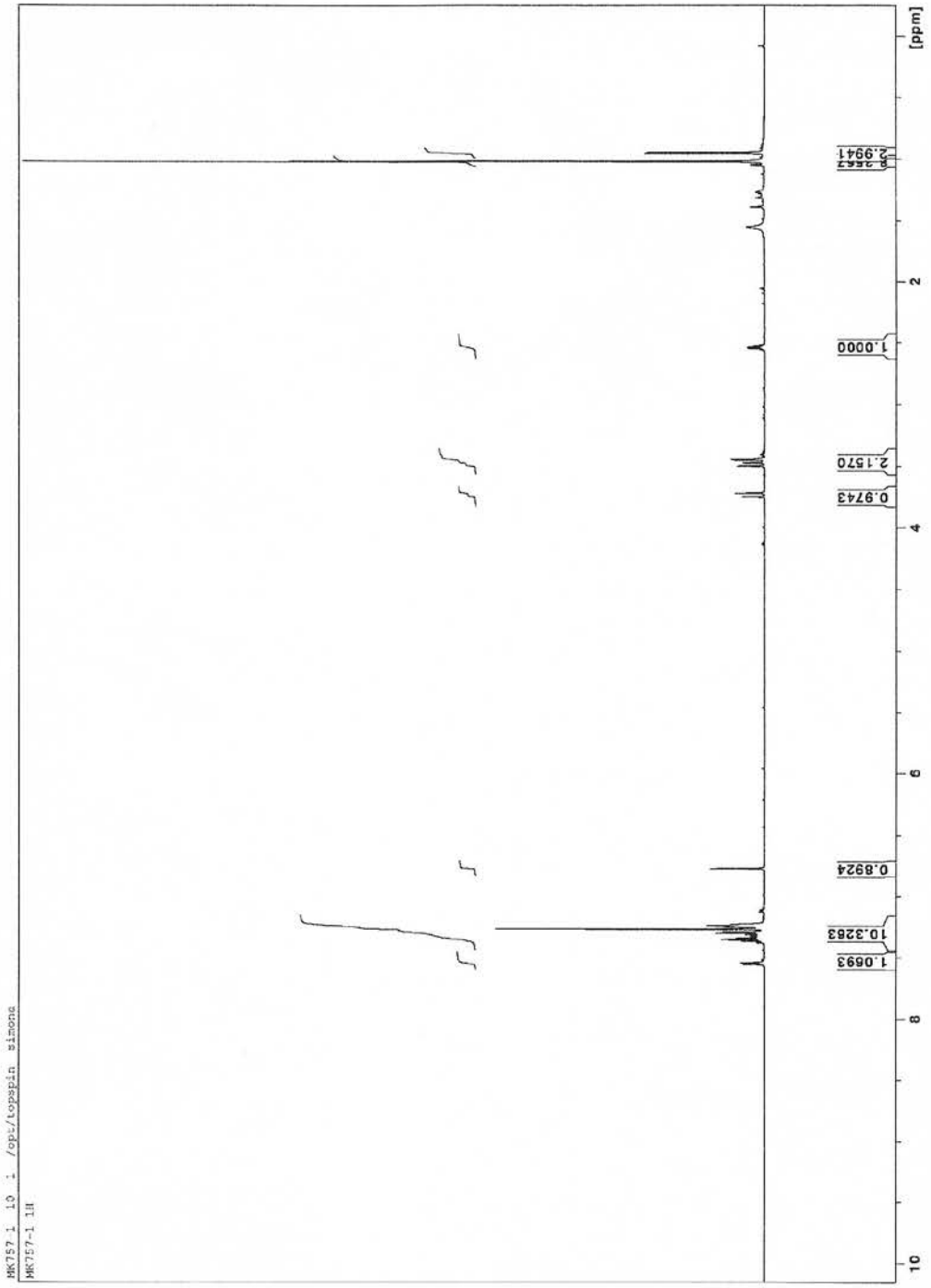

O
O
CH3
Ph
OBut
O

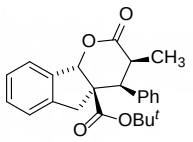
6a


14.1085
22.7224
27.2604
35.2377
35.9723
38.9970
52.7414
55.5666
76.7890
77.0009
77.2127
81.2599
83.4170
127.4385
128.6151
129.0644
137.8014
172.9574
172.8208
[ppm]
[rel]
MK994-2 2 1 /opt/topspin simona
MK994-2 13c

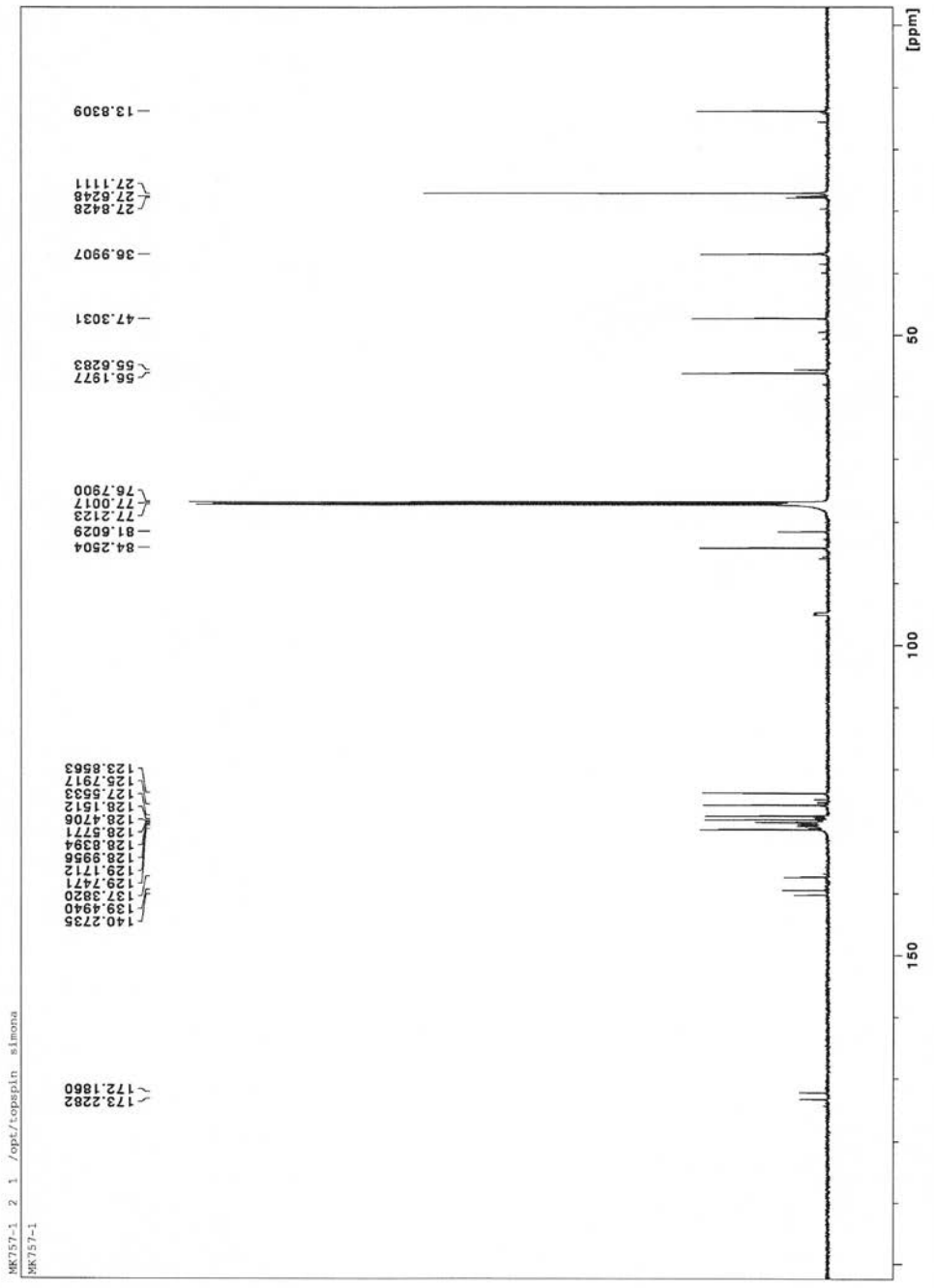

O
O
CH3
Ph
O
OBut

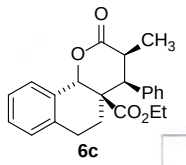
6b


MK757-1 1H
MK757 1 10 1 /opt/topspin simona
[ppm]
2.9941
1.0000
2.1570
0.9743
0.8924
10.3263
1.0693

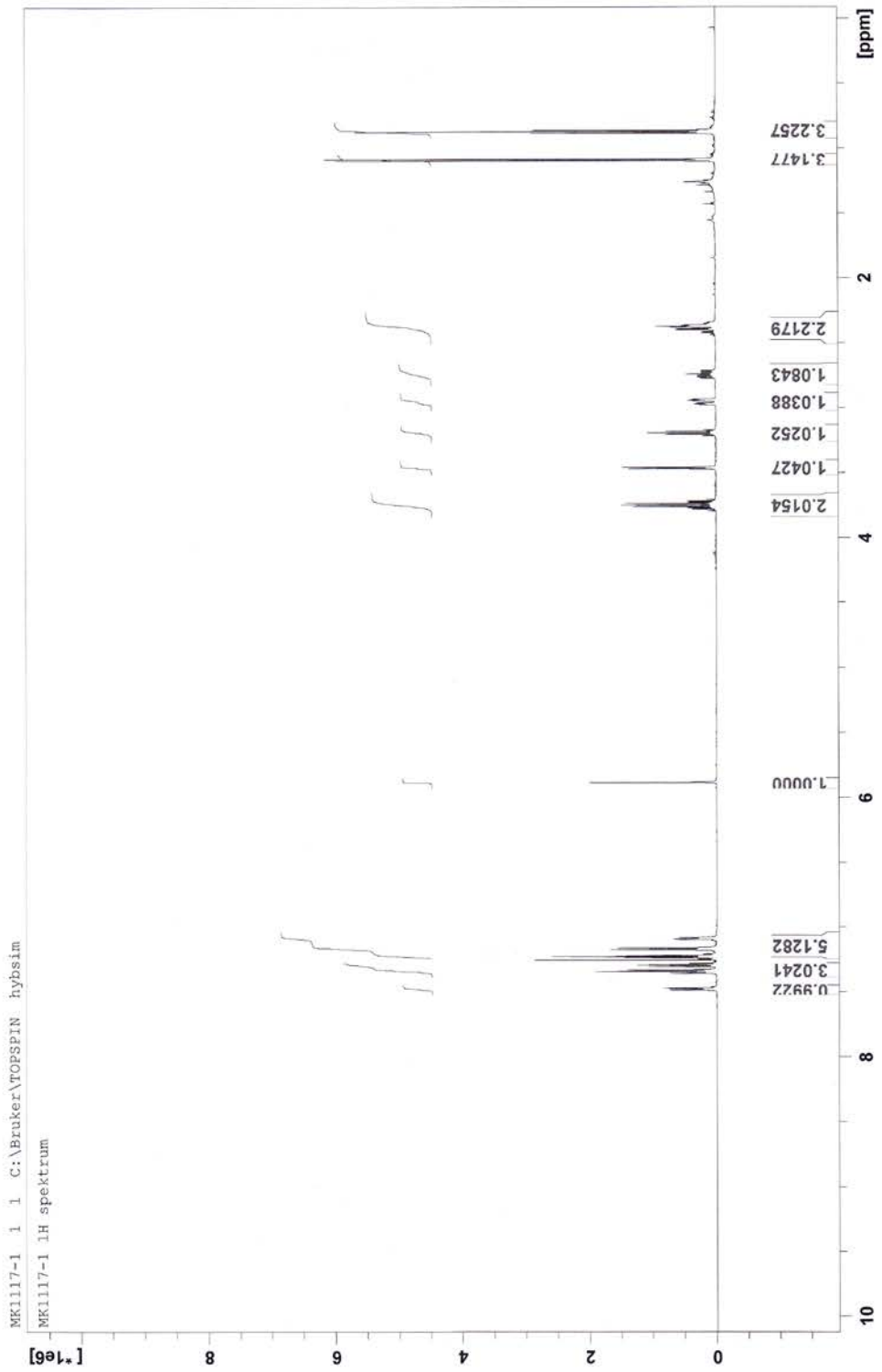

O
O
CH3
Ph
O
OBut

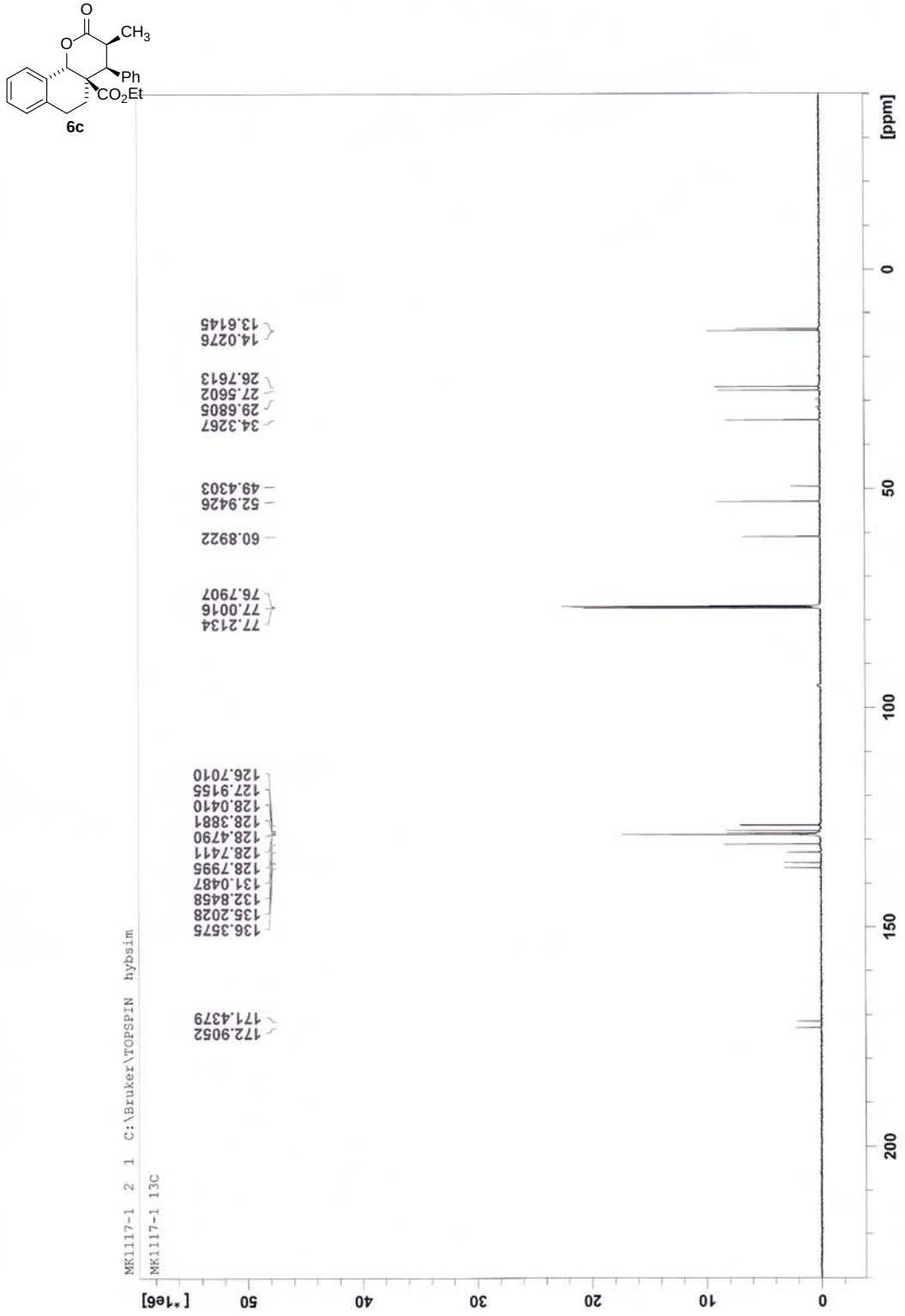
6b

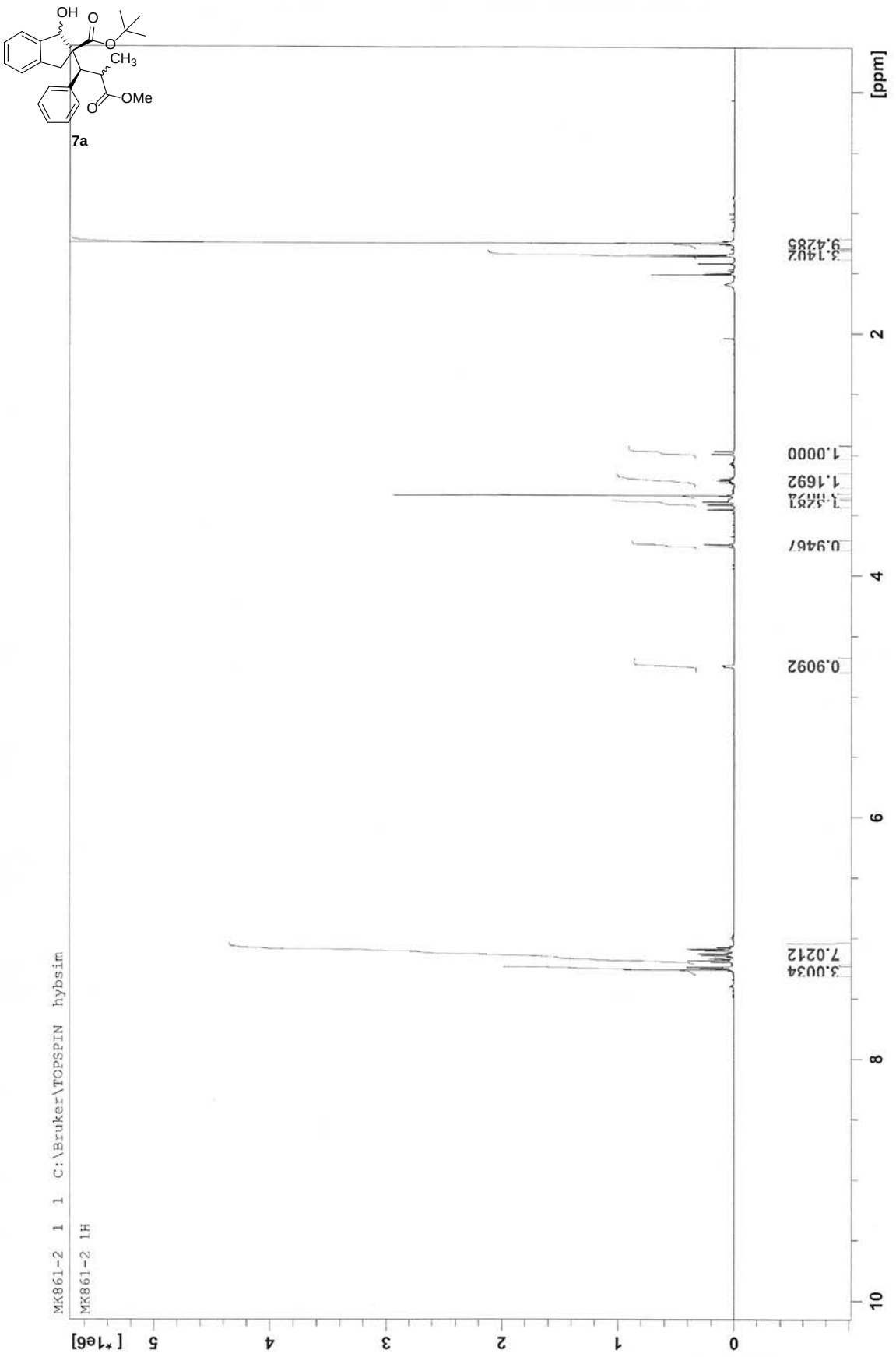

13.8309
27.1111
27.6248
27.8428
36.9907
47.3031
55.6283
56.1977
76.7900
77.0017
77.2123
81.6029
84.2504
123.8563
125.7917
127.5533
128.1512
128.4706
128.5771
128.8394
128.9956
129.1712
129.7471
137.3820
139.4940
140.2735
172.1860
173.2282
MK757-1 2 1 /opt/topspin simona
MK757-1
[ppm]
50
100
150

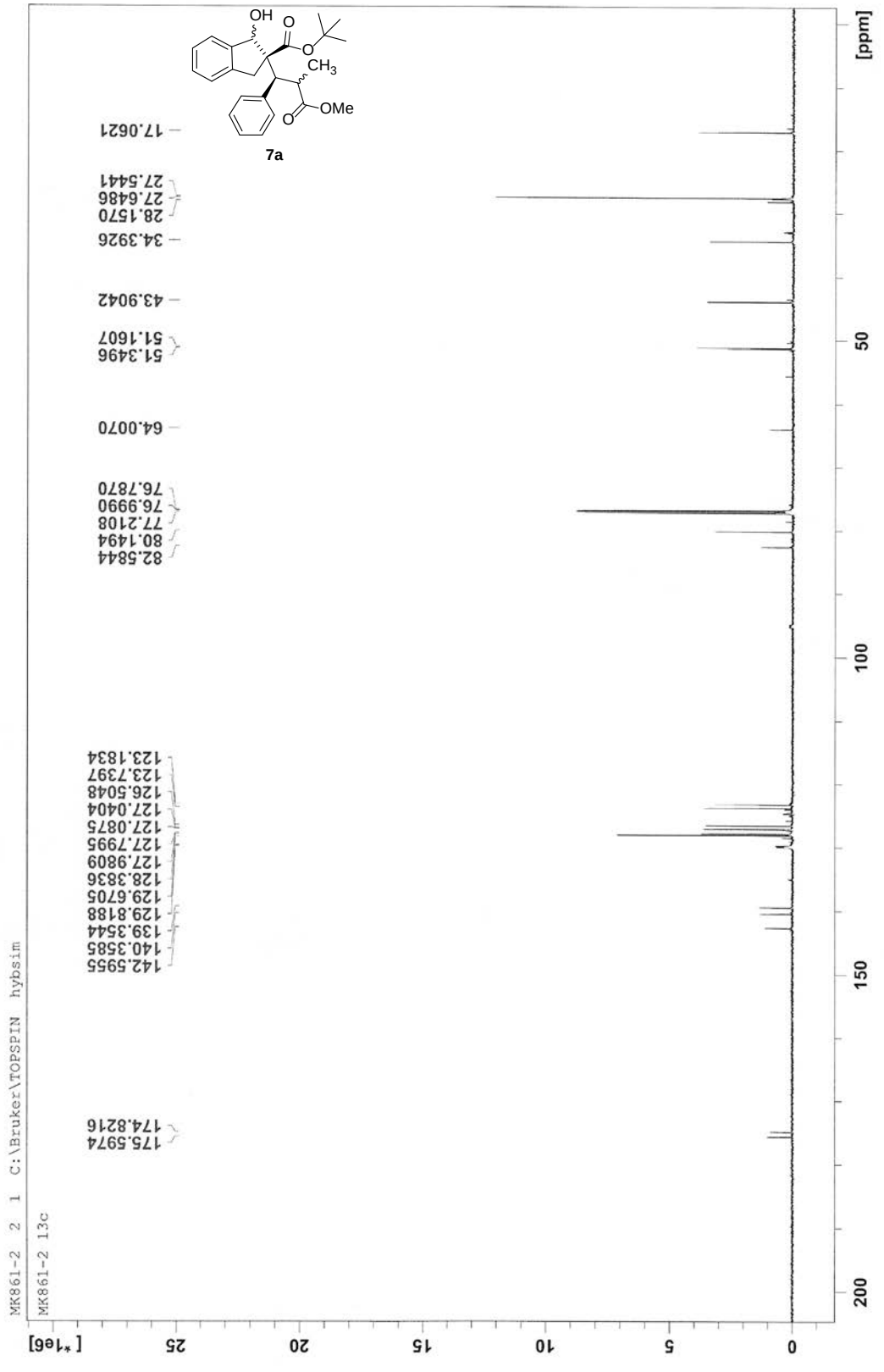

O
O
CH3
Ph
CO2Et

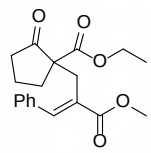
6c


MK1117-1 1 1 C:\Bruker\TOPSPIN hybsim
MK1117-1 1H spektrum
[*1e6]
0
2
4
6
8
[ppm]
10
8
6
4
2
3.2257
3.1477
2.2179
1.0843
1.0388
1.0252
1.0427
2.0154
1.0000
5.1282
3.0241
0.9922

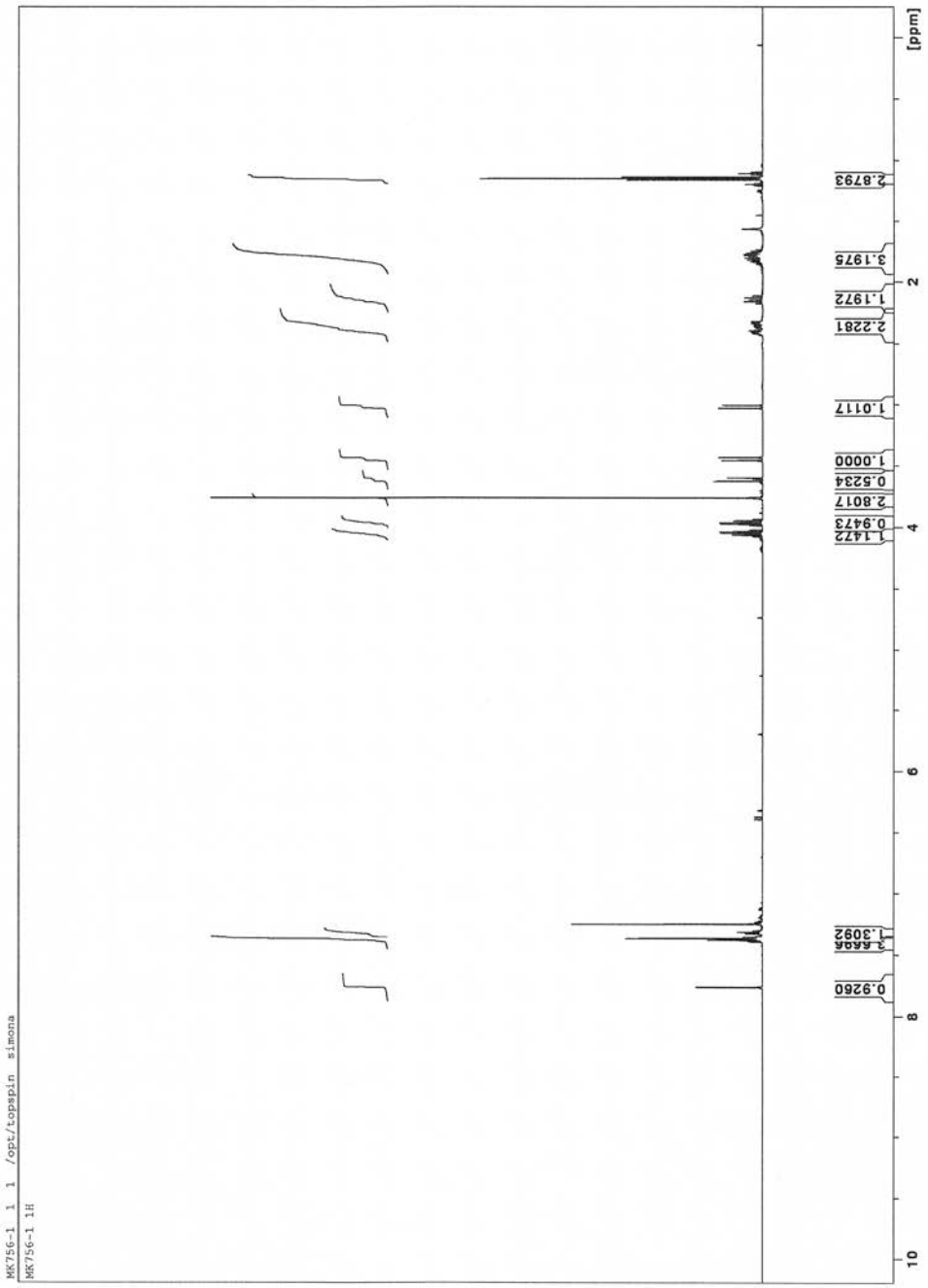

O
O
CH3
Ph
CO2Et
6c
13.6145
14.0276
26.7613
27.5602
29.6805
34.3267
49.4303
52.9426
60.8922
76.7907
77.0016
77.2134
126.7010
127.9155
128.0410
128.3881
128.4790
128.7411
128.7995
131.0487
132.8458
135.2028
136.3575
171.4379
172.9052
MK1117-1 2 1 C:\Bruker\TOPSPIN hybsim
MK1117-1 13C
[ppm]
[*1e6]

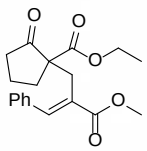

OH
O
O
CH3
OMe
O
7a
MK861-2 1 1 C:\Bruker\TOPSPIN hybsim
MK861-2 1H
[*1e6]
[ppm]
7.0212
3.0034
1.0000
1.1692
0.9092


OH
O
O
CH3
OMe
O
7a
17.0621
27.5441
27.6486
28.1570
34.3926
43.9042
51.1607
51.3496
64.0070
76.7870
76.9990
77.2108
80.1494
82.5844
123.1834
123.7397
126.5048
127.0404
127.0875
127.7995
127.9809
128.3836
129.6705
129.8188
139.3544
140.3585
142.5955
174.8216
175.5974
MK861-2 2 1 C:\Bruker\TOPSPIN hybsim
MK861-2 13c
[ppm]
[*1e6]

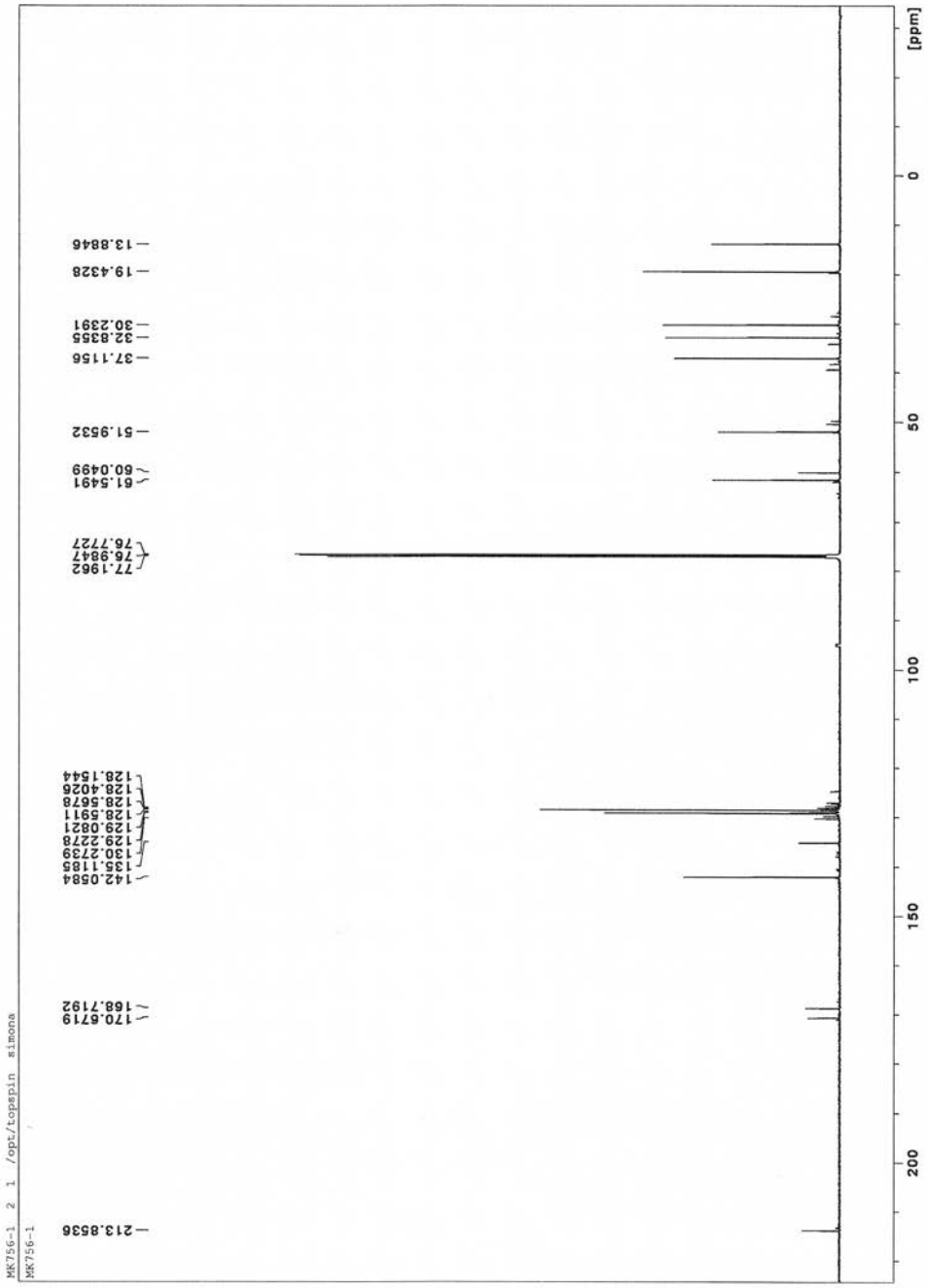

O
O
O
Ph
O
O

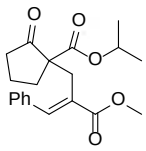
5aa


MK756-1 1 1 /opt/topspin simona
MK756-1 1H
[ppm]
2.8793
3.1975
1.1972
2.2281
1.0117
1.0000
0.5234
2.8017
0.9473
1.1472
1.3092
3.4848
0.9260

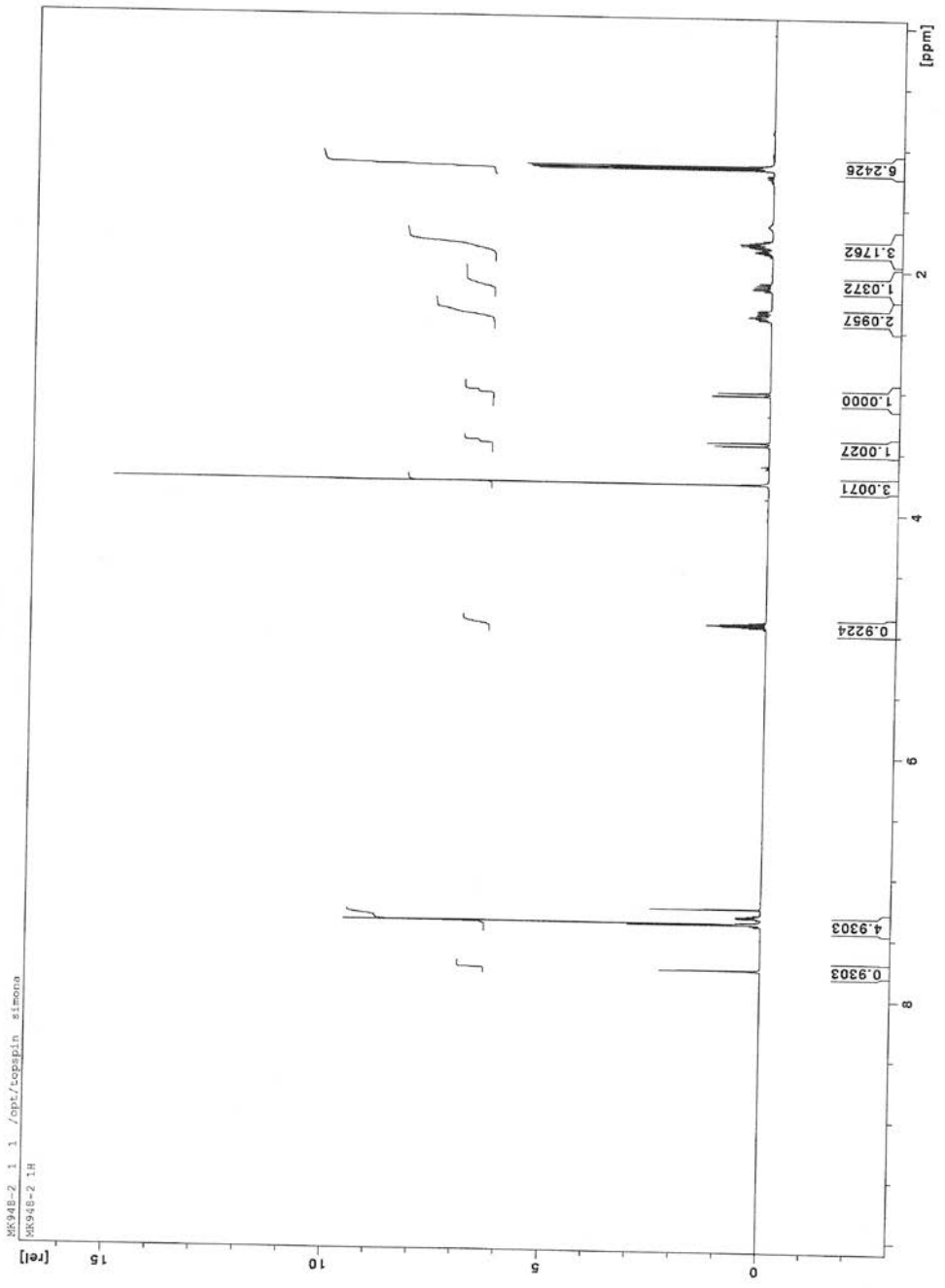

O
O
O
Ph
O
O

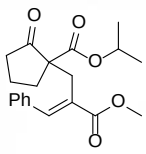
5aa


MK756-1 2 1 /opt/topspin simona
MK756-1
213.8536
170.6719
168.7192
142.0584
135.1185
130.2739
129.2278
129.0821
128.5911
128.5678
128.4026
128.1544
77.1962
76.9847
76.7727
61.5491
60.0499
51.9532
37.1156
32.8355
30.2391
19.4328
13.8846
[ppm]
0
50
100
150
200

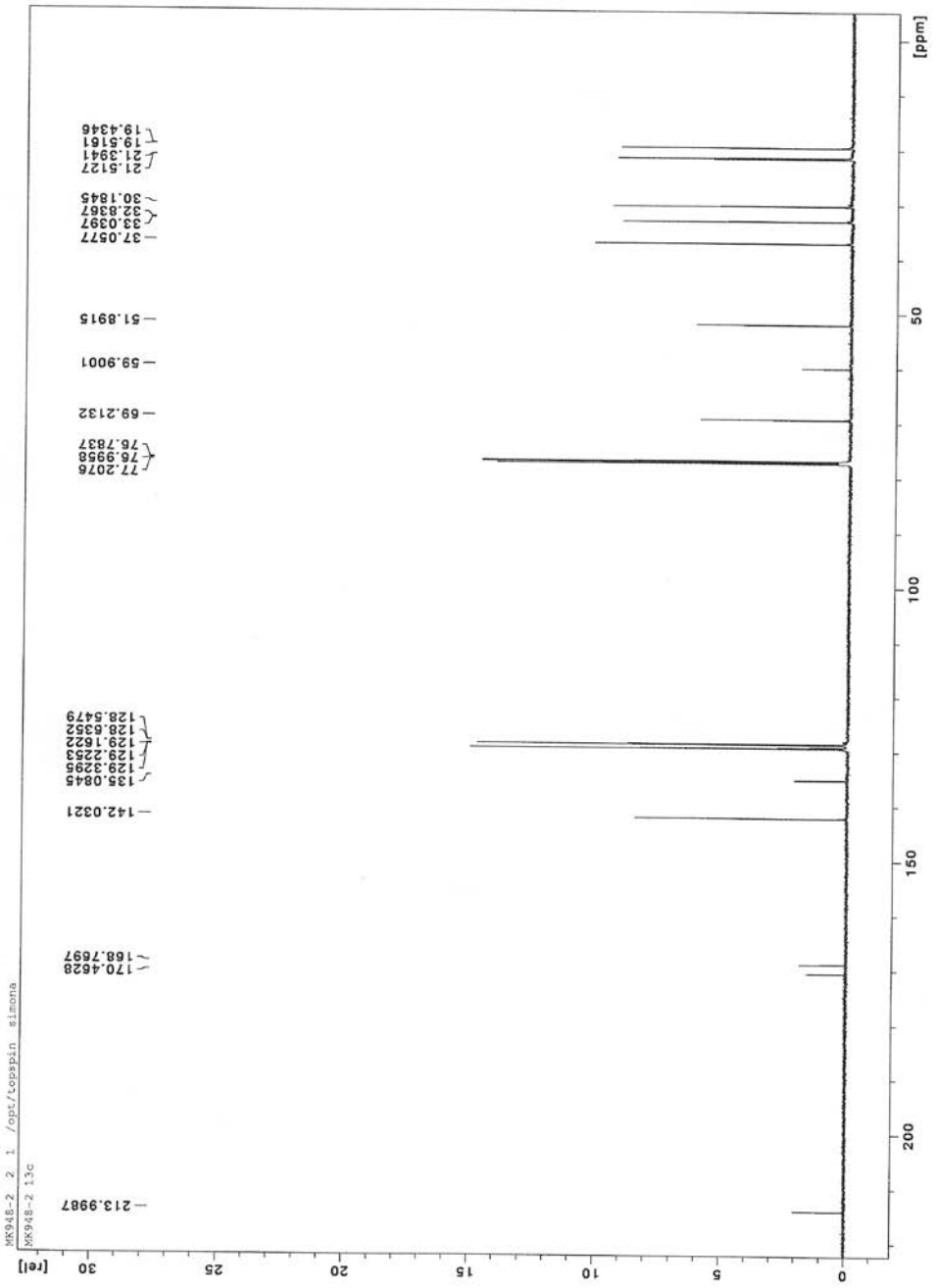

O
O
O
Ph
O
O

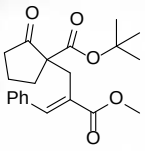
5ab


6.2426
3.1762
1.0372
2.0957
1.0000
1.0027
3.0071
0.9224
4.9303
0.9303
[ppm]
[rel]
MK948-2 1 1 /opt/topspin simona
MK948-2 1H

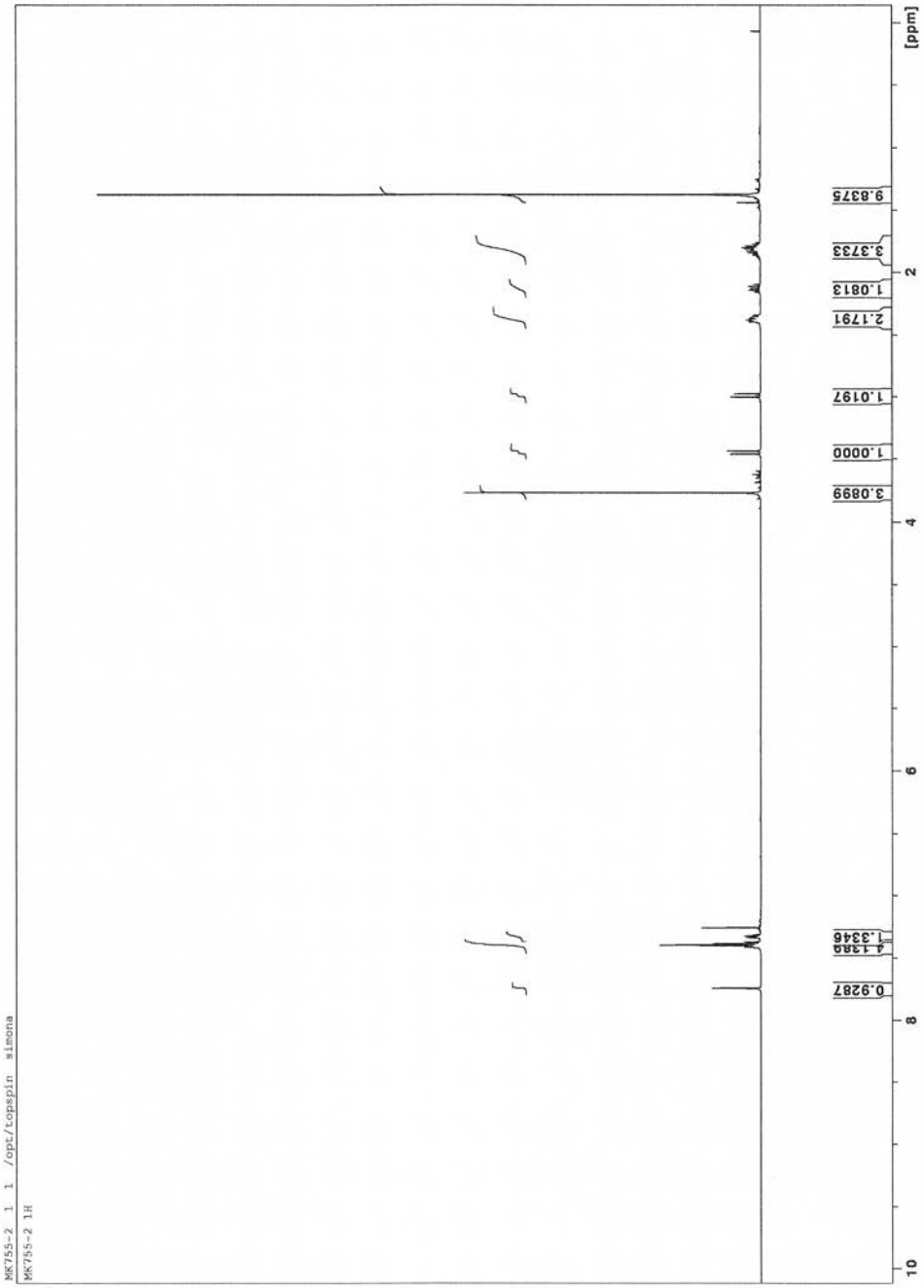

O
O
O
Ph
O
O

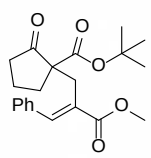
5ab


MK948-2 2 1 /opt/topspin simona
MK948-2 13c
213.9987
170.4628
168.7697
142.0321
135.0845
129.3295
129.2253
129.1622
128.6352
128.5479
77.2076
76.9958
76.7837
69.2132
59.9001
51.8915
37.0577
33.0397
32.8367
30.1845
21.5127
21.3941
19.5161
19.4346
[rel]
[ppm]

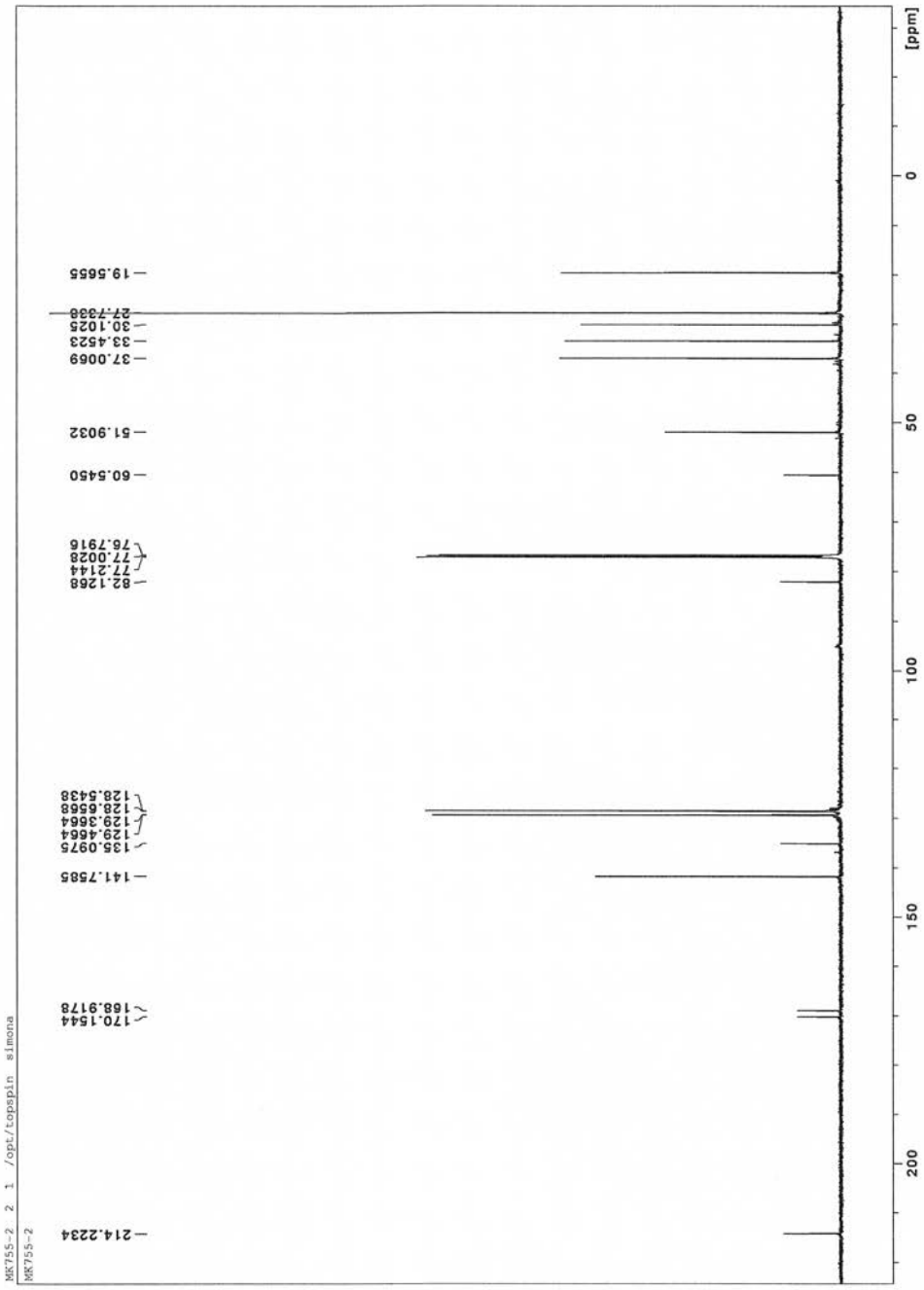

O
O
O
Ph
O
O

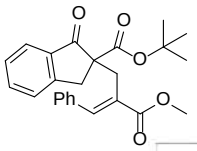
5ac


MK755-2 1 1 /opt/topspin simona
MK755-2 1H
9.8375
3.3733
1.0813
2.1791
1.0197
1.0000
3.0899
1.3346
4.1380
0.9287
[ppm]
2
4
6
8
10

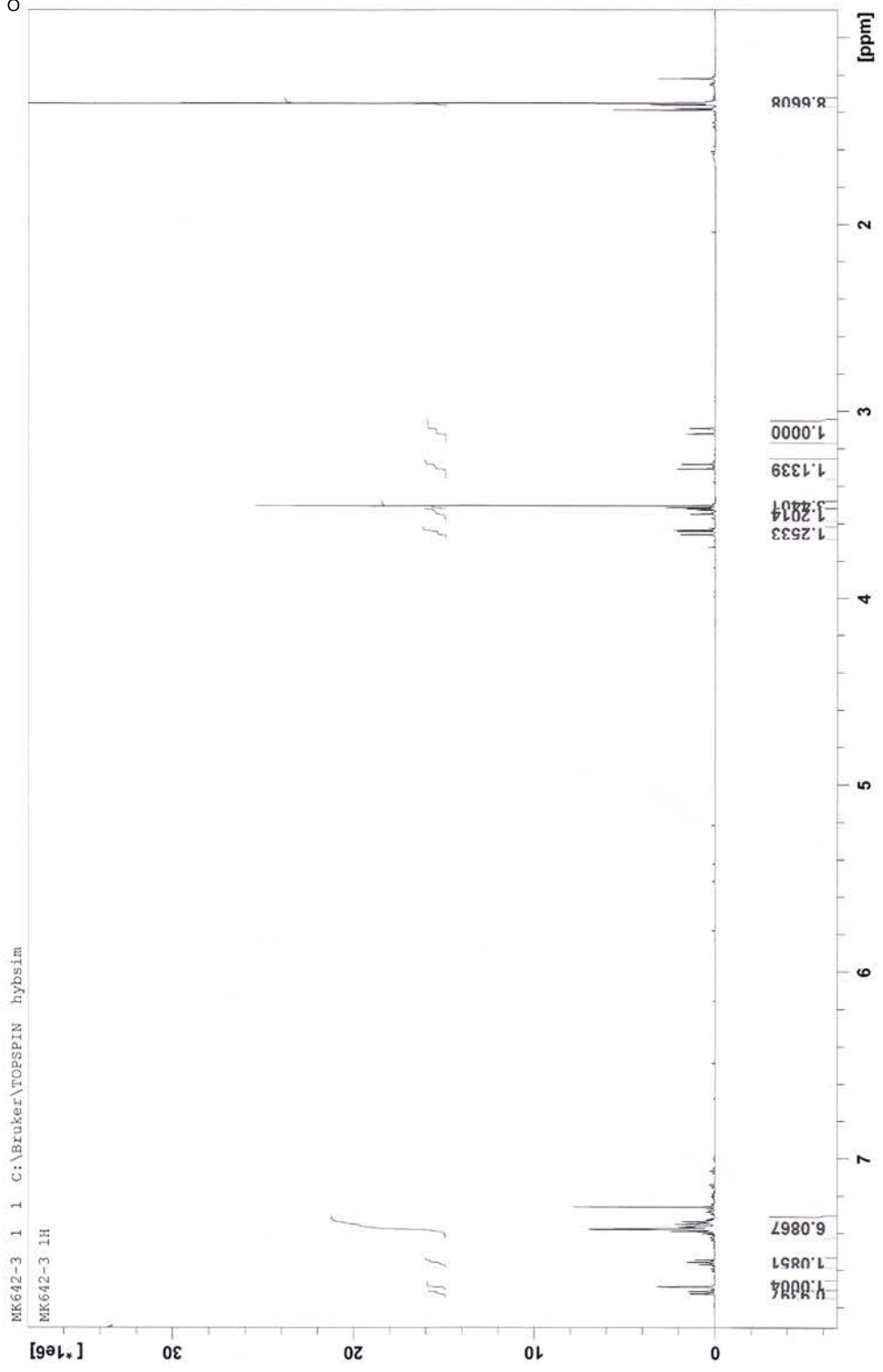

O
O
O
Ph
O
O

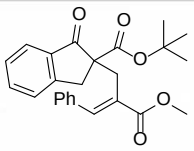
5ac


MK755-2 2 1 /opt/topspin simona
MK755-2
214.2234
170.1544
168.9178
141.7585
135.0975
129.4664
129.3664
128.6568
128.5438
82.1268
77.2144
77.0028
76.7916
60.5450
51.9032
37.0069
33.4523
30.1025
27.7338
19.5655
[ppm]
0
50
100
150
200

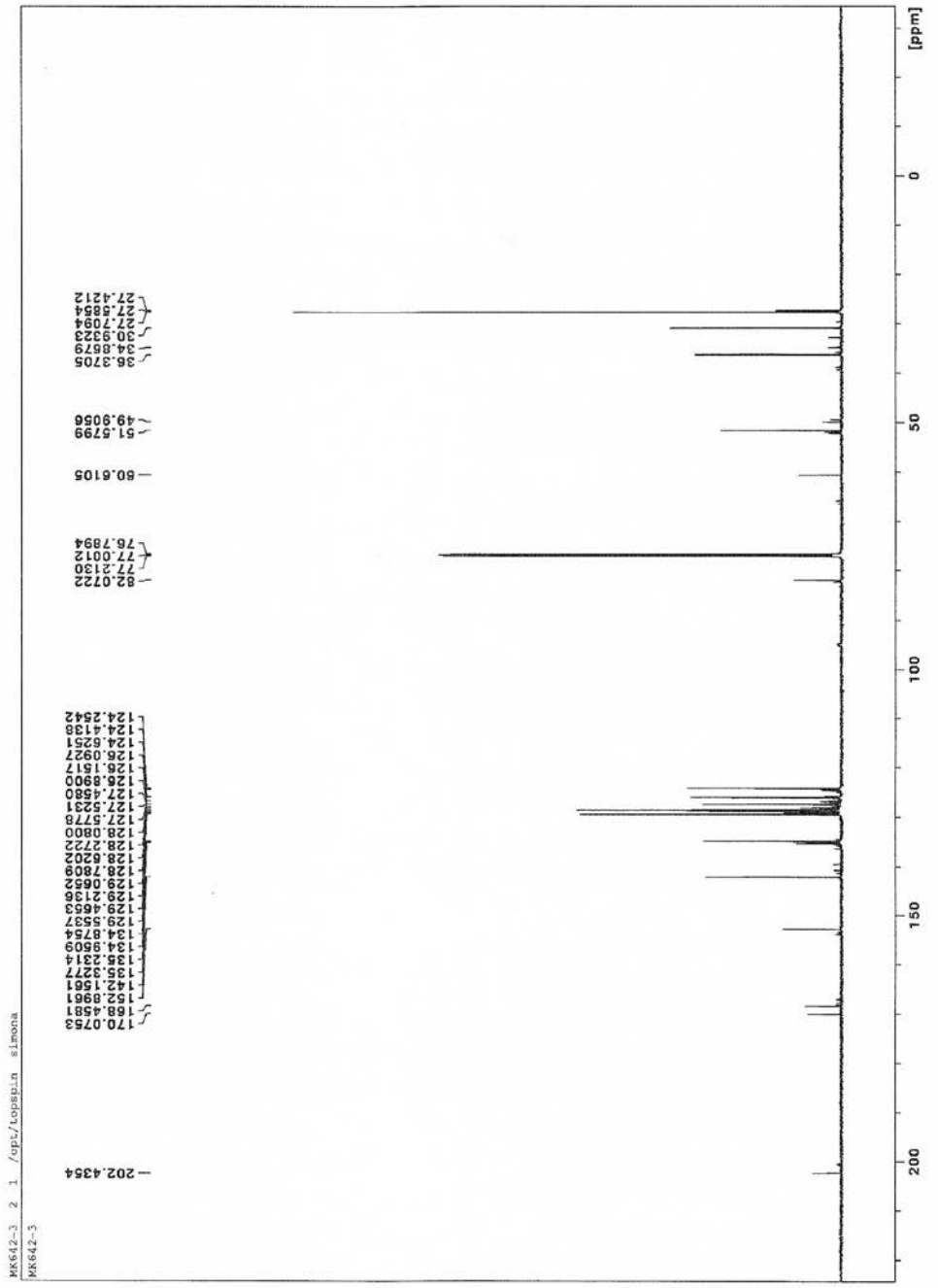

O
O
O
Ph
O
O

5ad


MK642-3 1 1 C:\Bruker\TOPSPIN hybsim
MK642-3 1H
[ppm]
8.6608
1.0000
1.1339
3.4401
1.2014
1.2533
6.0867
1.0857
1.0004
[*1e6]
30
20
10
0


O
O
O
Ph
O
O

5ad


MK642-3
2 1 /opt/topspin simona
MK642-3
202.4354
170.0753
168.4581
152.8961
142.1561
135.3277
135.2314
134.9509
134.8754
129.5537
129.4653
128.2136
128.0652
128.7809
128.6202
128.2722
128.0800
127.5778
127.5231
127.4580
126.8900
126.1517
126.0927
124.6251
124.4138
124.2542
82.0722
77.2130
77.0012
76.7894
60.6105
51.5799
49.9056
36.3705
34.8679
30.9323
27.7094
27.5854
27.4212
[ppm]
0
50
100
150
200