Supporting Information

Phosphine-Promoted [3 + 3] Annulations of Aziridines With Allenoates: Facile Entry Into Highly Functionalized Tetrahydropyridines

Hongchao Guo, Qihai Xu, and Ohyun Kwon

Department of Chemistry and Biochemistry, University of California, Los Angeles, California 90095-1569

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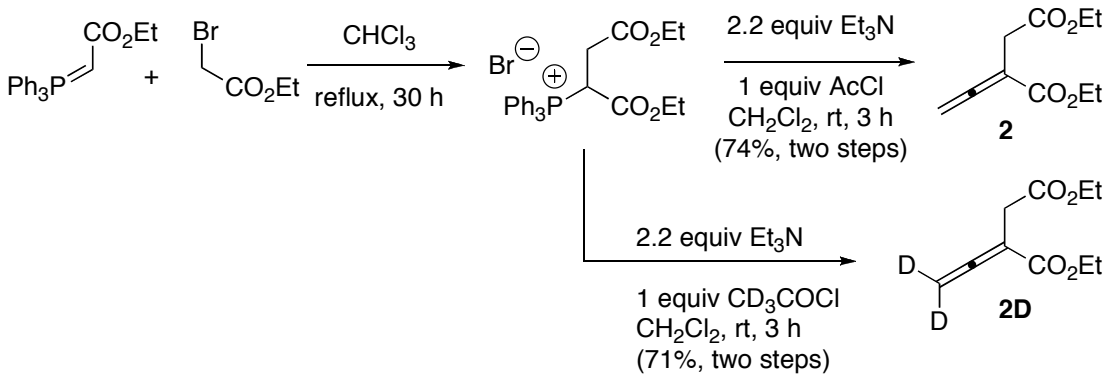
General Information

All reactions were performed under argon atmospheres in oven-dried glassware with magnetic stirring. Unless otherwise stated, all reagents were purchased from commercial suppliers and used without further purification. Dichloromethane was freshly distilled from CaH_2. Organic solutions were concentrated under reduced pressure on a rotary evaporator or an oil pump. Reactions were monitored through thin layer chromatography (TLC) on silica gel-precoated glass plates (0.25 mm thickness, SiliCycle silica gel). Chromatograms were visualized through fluorescence quenching with UV light at 254 nm. Flash column chromatography was performed using SiliCycle Silica-P Flash silica gel (60 Å pore size, 40–63 μm). Infrared spectra were recorded using a Perkin–Elmer Spectrum One FT-IR spectrometer. ^{1}H and ^{13}C NMR spectra were recorded in $CDCl_3$ on Bruker Avance 500, ARX-500, or ARX-400 spectrometers, as indicated. Chemical shifts (δ ppm) are provided relative to tetramethylsilane (TMS), with the resonance of the undeuterated solvent or TMS as the internal standard. ^{1}H NMR spectral data are reported as follows: chemical shift, multiplicity (s = singlet; d = doublet; t = triplet; q = quartet; m = multiplet), coupling constant(s) (Hz), integration. ^{13}C NMR spectral data are reported in terms of chemical shift. Accurate mass determinations were obtained on a Spec Ultima 7T FTICR (ESI-MS) spectrometer using samples dissolved in MeOH. High-performance liquid chromatography (HPLC) was performed on a Shimadzu LC-20AB HPLC system equipped with a spectrophotometric detector (monitoring at 254 nm). X-ray crystallographic data were collected using a Bruker SMART CCD-based diffractometer equipped with a low-temperature apparatus operated at 100 K.

Preparation of Diethyl 2-Vinylidenesuccinate (2) and the Deuterium-Labeled 2-Vinylidenesuccinate (2D)[1]

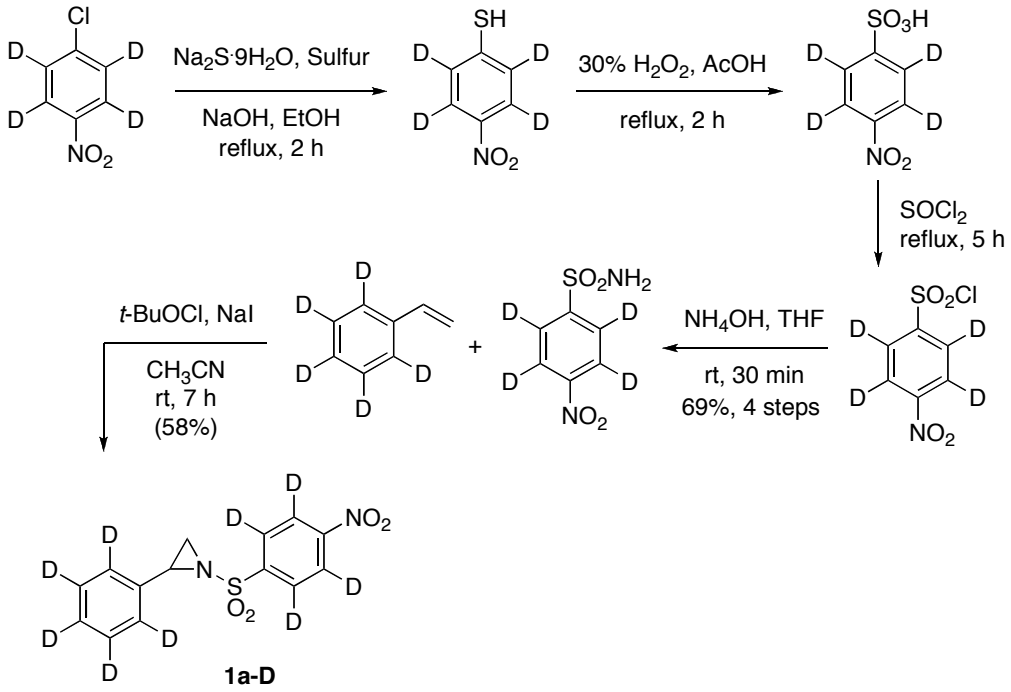
[1] Lang, R. W.; Hansen, H. J. *Org. Syn.* **1984**, *62*, 202.



Ethyl 2-bromoacetate (18.04 g, 108 mmol) was added at room temperature to a stirred solution of (ethoxycarbonylmethylene)triphenylphosphorane (13.92 g, 40 mmol) in $CHCl_3$ (120 mL). The reaction mixture was stirred for 30 h under reflux and then concentrated to give the phosphonium bromide as a brown solid. After drying under high vacuum for 2 h, the crude solid was dissolved in CH_2Cl_2 (80 mL), triethylamine (12.2 mL, 88 mmol) was added dropwise over 5 min, and then the mixture was stirred for 1 h. Acetyl chloride (2.84 mL, 40 mmol) was added dropwise via a syringe pump over 1 h and the resulting mixture was stirred for 2 h at room temperature and then concentrated. The residue was diluted with ether (100 mL) and the solid was filtered off under reduced pressure through a pad of Celite, which was washed with ether (3 × 20 mL). The combined ether solution was concentrated and the residue was purified by distillation to afford the product as a colorless oil (5.85 g, 74%). IR (neat) ν_{max} 3066, 2984, 1971, 1942, 1739, 1712, 1368, 1264, 1263 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ 1.22–1.30 (m, 6H), 3.24–3.26 (m, 2H), 4.13–4.25 (m, 4H), 5.20–5.22 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.18, 14.19, 34.8, 61.0, 61.4, 79.5, 94.6, 166.3, 170.5, 214.5; HRMS (EI) calculated for $C_{10}H_{14}O_4$ $[M]^+$ 198.0892, found 198.0889. When deuterium-labeled acetyl chloride was used, the corresponding deuterium-labeled diethyl 2-vinylidenesuccinate was obtained as a colorless oil (5.67 g, 71%). IR (neat) ν_{max} 2983, 2938, 2907, 2214, 1937, 1732, 1713, 1465, 1447, 1393, 1369, 1275, 1182, 1109, 1032, 920, 860, 776, 686, 652, 570 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ 1.19–1.29 (m, 6H), 3.21 (s, 2H), 4.08–4.25 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.1, 34.7, 60.9, 61.3, 94.8, 129.0, 166.2, 170.4, 214.6; MS (EI): 59, 69, 94, 107, 117, 122, 183, 186, 201 $[M + H]^+$.

Preparation of the Aziridines 1a–o and (*S*)-1a.[2] 1-(4-Nitrobenzenesulfonyl) aziridine,[2a] 2-methyl-1-(4-nitrobenzenesulfonyl) aziridine,[2b] the 2-aryl-1-(4-nitrobenzenesulfonyl) aziridines,[2c] and (*S*)-1-(4-nitrobenzenesulfonyl)-2-phenyl aziridine[2b] were prepared according to procedures described previously in the literature.

Preparation of the Deuterium-Labeled Aziridine 1a-D



A mixture of *p*-chloronitrobenzene-d_4 (2.052 g, 12.700 mmol), sulfur (0.297 g, 9.256 mmol, 0.729 equiv), $Na_2S{\cdot}9H_2O$ (2.196 g, 9.144 mmol, 0.720 equiv), and NaOH (0.508 g, 12.700 mmol, 1.0 equiv) in ethanol (50 mL) was heated under reflux for 2 h. The reaction was monitored (TLC) using the known non-labeled compound as the standard. The reaction was quenched with aqueous 10% HCl solution (20 mL) and diluted with ethyl acetate (150 mL). The organic layer was washed with aqueous 10% HCl solution, dried (anhydrous Na_2SO_4), filtered, and concentrated. The product *p*-nitrobenzenethiol-d_4 (yellow solid, 2.045 g) was used directly in the following step

[2] (a) Skerlj, R. T.; Nan, S.; Zhou, Y.; Bridger, G. J. *Tetrahedron Lett.* **2002**, *43*, 7569. (b) Farràs, J.; Ginesta, X.; Sutton, P. W.; Taltavull, J.; Egeler, F; Romea, P.; Urpí, F.; Vilarrasa, J. *Tetrahedron* **2001**, *57*, 7665. (c) Ryan, D.; McMorn, P.; Bethell, D.; Hutchings, G. *Org. Biomol. Chem.* **2004**, *2*, 3566.

without purification. ^{1}H NMR (300 MHz, $CDCl_3$): δ 3.79 (br s, 2H).

A mixture of *p*-nitrobenzenethiol-d_4 (2.040 g, 12.700 mmol), acetic acid (20 mL, 349.25 mmol, 27.5 equiv), and 30% H_2O_2 (10 mL, 97.79 mmol, 7.7 equiv) was heated under reflux for 2 h. The reaction was monitored (TLC) using the known non-labeled compound as the standard. The volatile materials were evaporated under reduced pressure and the residue was dried under high vacuum. The product *p*-nitrobenzenesulfonic acid-d_4 (yellowish solid, 2.703 g) was used directly in the following reaction.

A mixture of *p*-nitrobenzenesulfonic acid-d_4 (2.703 g, 12.70 mmol) and $SOCl_2$ (5 mL, 68.58 mmol, 5.4 equiv) was heated under reflux for 5 h. The reaction was monitored (TLC) using the known non-labeled compound as the standard. The excess $SOCl_2$ was evaporated under reduced pressure. The sticky oily residue was used directly in the following step.

Ammonium hydroxide (10 mL, 77.47 mmol, 6.1 equiv) was added slowly to a solution of *p*-nitrobenzenesulfonyl chloride-d_4 (crude product, 12.70 mmol) in THF (20 mL). The reaction was monitored (TLC) using the known non-labeled compound as the standard. After stirring for 0.5 h at rt, no sulfonyl chloride was detectable in the mixture. Saturated aqueous NaCl (50 mL) and ethyl acetate (200 mL) were added and then the separated organic layer was washed with saturated aqueous NaCl solution, dried (anhydrous Na_2SO_4), filtered, and concentrated. The solid was dissolved in ethyl acetate (100 mL) and then hexane (150 mL) was added slowly. The yellow solid was collected and dried to give 1.810 g (69.1%) of the deuterium-labeled sulfonamide, which was pure enough for further use. ^{1}H NMR (400 MHz, CD_3COCD_3): δ 6.96 (br s, 2H); ^{13}C NMR (100 MHz, CD_3COCD_3) 124.5, 124.8, 125.1, 127.8, 128.1, 128.4, 150.2, 150.6; MS (ESI): *m/z* calcd for $C_6H_3D_4N_2O_4S$ [M + H]: 207.03, found: 207.0, $C_6H_3D_4N_2NaO_4S$ [M + Na]: 229.02, found: 229.2.

With the deuterium labeled sulfonamide and styrene-d_5 in hand, the labeled aziridine **1a-D** was furnished in 57.6% yield using a previously described procedure.[3]

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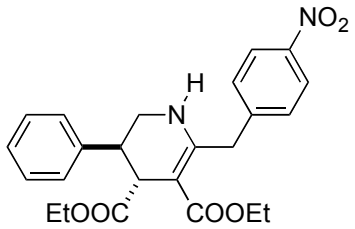
[3] Minakata, S.; Morino, Y.; Oderaotoshi, Y.; Komatsu, M. *Chem. Commun.* **2006**, 3337.

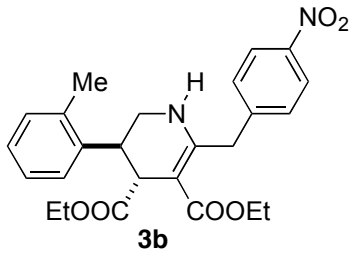
^{1}H NMR (400 MHz, $CDCl_3$): δ 2.52 (d, J = 4.4 Hz, 1H), 3.13 (d, J = 7.2 Hz, 1H), 3.91 (dd, J = 7.2, 4.4 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) 36.6, 41.8, 123.8, 124.0, 124.3, 125.8, 126.1, 126.3, 128.0, 128.3, 128.5, 128.6, 128.8, 129.1, 134.0, 143.8, 150.6; MS (ESI): *m/z* calcd for $C_{14}H_4D_9N_2O_4S$ [M + Na]: 314.11, found: 314.1.

General Procedure for the [3 + 3] Allene/Aziridine Annulation. An oven-dried 50-mL flask was charged with triphenylphosphine (0.097 mmol), the *N*-4-nitrobenzenesulfonyl-protected aziridine (0.097 mmol), and CH_2Cl_2 (10 mL) at room temperature. After adding diethyl 2-vinylidenesuccinate (0.233 mmol) to this solution, the mixture was stirred at room temperature for 36 h and then another charge of diethyl 2-vinylidenesuccinate (0.233 mmol) was added and the resulting mixture stirred for an additional 36 h. The reaction mixture was concentrated and the residue purified through flash column chromatography (EtOAc/hexane, 1:3) to afford the tetrahydropyridine product.



3a

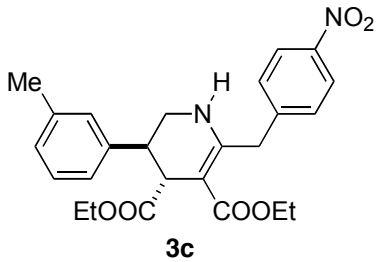
***trans*-Diethyl 2-(4-Nitrobenzyl)-5-phenyl-1,4,5,6-tetrahydropyridine-3,4-dicarboxylate (3a)**: 73%; yellow solid; IR (film) ν_{max} 3396, 2982, 2918, 2850, 1732, 1682, 1599, 1520, 1368, 1346, 1179, 1108, 1028, 858, 759, 736, 701 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.14–1.18 (m, 6H), 3.27–3.33 (m, 2H), 3.48–3.52 (m, 1H), 3.87 (d, J = 4.0 Hz, 1H), 4.00–4.13 (m, 4H), 4.20 (AB d, J = 16.0 Hz, 1H), 4.32 (AB d, J = 16.0 Hz, 1H), 4.44 (s, 1H), 7.18–7.20 (m, 2H), 7.20–7.31 (m, 3H), 7.36–7.40 (m, 2H), 8.08–8.12 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.2, 14.3, 38.9, 39.4, 44.6, 45.1, 59.4, 60.7, 93.5, 123.7, 127.1, 127.2, 128.5, 129.3, 141.4, 145.8, 146.7, 153.5, 167.4, 175.3; MS (ESI): *m/z* calcd for $C_{24}H_{26}N_2NaO_6$ [M + Na]: 461.17, found: 461.16.



3b

***trans*-Diethyl**

2-(4-Nitrobenzyl)-5-*o*-tolyl-1,4,5,6-tetrahydropyridine-3,4-dicarboxylate (3b): 88%; yellow solid; IR (film) ν_{max} 3395, 2981, 2917, 2850, 1732, 1682, 1601, 1521, 1369, 1346, 1179, 1109, 1017, 856, 756, 727 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ 1.12–1.17 (m, 6H), 2.35 (s, 3H), 3.17–3.23 (m, 1H), 3.43–3.48 (m, 2H), 3.75 (d, *J* = 4.4 Hz, 1H), 3.99–4.15 (m, 4H), 4.26 (AB d, *J* = 16.0 Hz, 1H), 4.36 (AB d, *J* = 16.0 Hz, 1H), 4.50 (s, 1H), 7.10–7.16 (m, 4H), 7.46 (d, *J* = 8.8 Hz, 2H), 8.14 (d, *J* = 8.8 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.1, 14.2, 19.6, 35.6, 39.0, 43.7, 45.3, 59.4, 60.6, 93.8, 123.7, 126.0, 126.3, 126.9, 129.5, 130.5, 135.5, 139.8, 145.8, 146.8, 153.5, 167.4, 175.4; MS (ESI): *m/z* calcd for $C_{25}H_{28}N_2NaO_6$ [M + Na]: 475.18, found: 475.22.

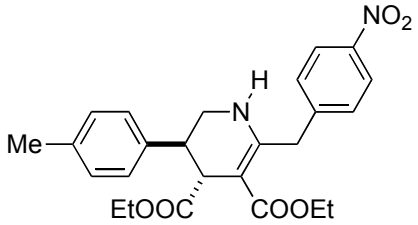


3c

***trans*-Diethyl**

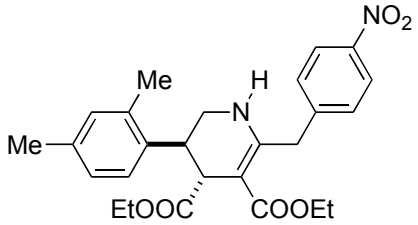
2-(4-Nitrobenzyl)-5-*m*-tolyl-1,4,5,6-tetrahydropyridine-3,4-dicarboxylate (3c): 82%; yellow solid; IR (film) ν_{max} 3393, 2981, 2918, 2850, 1732, 1686, 1600, 1521, 1346, 1255, 1231, 1203, 1180, 1108, 1030, 857, 783, 737, 703 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ 1.18 (apparent t, 6H), 3.23 (s, 3H), 3.24–3.31 (m, 2H), 3.49 (d, *J* = 12.0 Hz, 1H), 3.85 (d, *J* = 3.6 Hz, 1H), 4.01–4.13 (m, 4H), 4.24 (AB d, *J* = 15.6 Hz, 1H), 4.29 (AB d, *J* = 15.6 Hz, 1H), 4.44 (s, 1H), 6.99 (d, *J* = 6.8 Hz, 2H), 7.06 (d, *J* = 6.8 Hz, 1H), 7.17 (t, *J* = 7.2 Hz, 1H), 7.38 (d, *J* = 8.4 Hz, 2H), 8.11 (d, *J* = 8.4 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.2, 14.3, 21.5, 39.0, 39.5, 44.6, 45.3, 59.4,

60.6, 93.6, 123.7, 127.8, 128.0, 128.4, 129.3, 130.1, 138.1, 141.4, 145.8, 146.7, 153.5, 167.5, 175.4; MS (ESI): *m/z* calcd for $C_{25}H_{28}N_2NaO_6$ [M + Na]: 475.18, found: 475.23.



3d

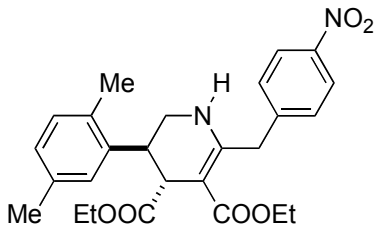
***trans*-Diethyl 2-(4-Nitrobenzyl)-5-*p*-tolyl-1,4,5,6-tetrahydropyridine-3,4-dicarboxylate (3d)**: 64%; yellow solid; IR (film) ν_{max} 3391, 2981, 2919, 2850, 1732, 1683, 1590, 1520, 1368, 1345, 1263, 1176, 1108, 1080, 1030, 858, 813, 775, 737 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ 1.14–1.19 (m, 6H), 2.33 (s, 3H), 3.25–3.30 (m, 2H), 3.47–3.50 (m, 1H), 3.85 (d, *J* = 2.8 Hz, 1H), 4.00–4.13 (m, 4H), 4.17 (AB d, *J* = 15.6 Hz, 1H), 4.35 (AB d, *J* = 15.6 Hz, 1H), 4.41 (s, 1H), 7.01 (s, 4H), 7.39 (d, *J* = 8.8 Hz, 2H), 8.11 (d, *J* = 8.8 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.2, 14.3, 21.0, 38.9, 39.0, 44.7, 45.2, 59.4, 60.7, 93.5, 123.7, 127.1, 129.2, 129.3, 136.7, 138.4, 145.8, 146.7, 153.5, 167.5, 175.3; MS (ESI): *m/z* calcd for $C_{25}H_{28}N_2NaO_6$ [M + Na]: 475.18, found: 475.17.



3e

***trans*-Diethyl 5-(2,4-Dimethylphenyl)-2-(4-nitrobenzyl)-1,4,5,6-tetrahydropyridine-3,4-dicarboxylate (3e)**: 82%; yellow solid; IR (film) ν_{max} 2919, 1729, 1600, 1520, 1342, 1181, 1106, 1015, 857 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ 1.13–1.17 (m, 6H), 2.28 (s, 3H), 2.31 (s, 3H), 3.15–3.21 (m, 1H), 3.40–3.46 (m, 2H), 3.72 (d, *J* = 4.4 Hz, 1H), 3.99–4.15 (m, 4H), 4.23 (AB d, *J* = 15.6 Hz, 1H), 4.38 (AB d, *J* = 15.6 Hz, 1H), 4.47 (s, 1H), 6.91–7.03 (m, 3H), 7.45–7.48 (m, 2H), 8.13–8.16 (m, 2H); ^{13}C NMR (100

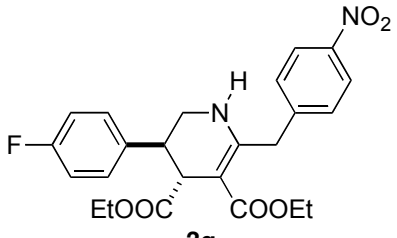
MHz, $CDCl_3$): δ 14.15, 14.24, 19.5, 20.9, 35.3, 39.0, 43.8, 45.4, 59.4, 60.6, 93.8, 123.7, 125.9, 126.9, 129.5, 131.3, 135.3, 136.5, 136.9, 145.8, 146.7, 153.4, 167.5, 175.5; MS (ESI): *m/z* calcd for $C_{26}H_{30}N_2NaO_6$ [M + Na]: 489.20, found: 489.22.



3f

***trans*-Diethyl**

5-(2,5-Dimethylphenyl)-2-(4-nitrobenzyl)-1,4,5,6-tetrahydropyridine-3,4-dicarboxylate (3f): 98%; yellow solid; IR (film) ν_{max} 3392, 2920, 2849, 1730, 1592, 1520, 1444, 1367, 1345, 1178, 1107, 1028, 856, 812, 735 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ 1.12–1.17 (m, 6H), 2.21 (s, 3H), 2.30 (s, 3H), 3.19–3.22 (m, 1H), 3.40–3.46 (m, 2H), 3.73 (d, *J* = 4.0 Hz, 1H), 4.00–4.13 (m, 4H), 4.25 (AB d, *J* = 12.4 Hz, 1H), 4.39 (AB d, *J* = 12.4 Hz, 1H), 4.50 (s, 1H), 6.92–6.95 (m, 2H), 7.04 (d, *J* = 6.0 Hz, 1H), 7.47 (d, *J* = 6.8 Hz, 2H), 8.14 (d, *J* = 7.2 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.0, 14.1, 19.0, 21.1, 35.7, 38.9, 43.8, 45.3, 59.2, 60.4, 93.8, 123.7, 126.6, 127.4, 129.3, 130.3, 132.2, 135.6, 139.5, 145.7, 146.6, 153.3, 167.3, 175.4; MS (ESI): *m/z* calcd for $C_{26}H_{30}N_2NaO_6$ [M + Na]: 489.20, found: 489.22.

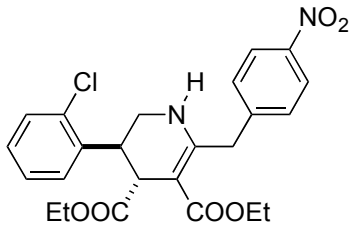


3g

***trans*-Diethyl**

5-(4-Fluorophenyl)-2-(4-nitrobenzyl)-1,4,5,6-tetrahydropyridine-3,4-dicarboxylate (3g): 76%; yellow solid; IR (film) ν_{max} 3387, 2981, 2918, 2850, 1732, 1664, 1600, 1512, 1368, 1345, 1224, 1178, 1162, 1108, 1016, 858, 833, 776, 736 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ (apparent t, 6H), 3.23–3.29 (m, 2H), 3.46–3.49 (m, 1H), 3.82 (d,

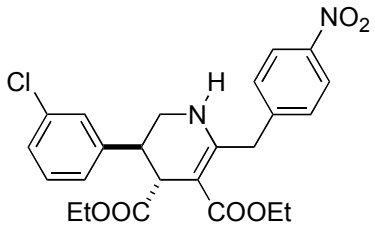
J = 4.0 Hz, 1H), 4.01–4.15 (m, 5H), 4.42 (apparent AB d, 2H), 6.95–7.00 (m, 2H), 7.15–7.18 (m, 2H), 7.40 (d, *J* = 8.4 Hz, 2H), 8.13 (d, *J* = 8.4 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.2, 14.3, 38.89, 38.94, 44.7, 45.4, 59.4, 60.8, 93.5, 115.2, 115.4, 123.7, 128.7, 128.8, 129.3, 145.7, 146.8, 153.5, 167.4, 175.1; MS (ESI): *m/z* calcd for $C_{24}H_{25}FN_2NaO_6$ [M + Na]: 479.16, found: 479.11.



3h

***trans*-Diethyl**

5-(2-Chlorophenyl)-2-(4-nitrobenzyl)-1,4,5,6-tetrahydropyridine-3,4-dicarboxylate (3h): 46%; yellow solid; IR (film) ν_{max} 3395, 2982, 2917, 2850, 1733, 1683, 1598, 1521, 1368, 1346, 1244, 1180, 1109, 1034, 858, 758, 735, 706 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.16–1.23 (m, 6H), 3.31–3.35 (m, 1H), 3.48–3.53 (m, 1H), 3.74–3.77 (m, 1H), 3.83 (d, *J* = 2.8 Hz, 1H), 4.03–4.23 (m, 5H), 4.36 (apparent AB d, 2H), 7.13–7.21 (m, 3H), 7.36–7.38 (m, 1H), 7.43 (d, *J* = 8.8 Hz, 2H), 8.13 (d, *J* = 6.8 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.2, 14.3, 35.7, 38.9, 42.8, 44.0, 59.5, 60.9, 93.4, 123.7, 127.0, 127.8, 128.3, 129.4, 129.7, 133.5, 138.9, 145.6, 146.8, 153.7, 167.4, 174.9; MS (ESI): *m/z* calcd for $C_{24}H_{25}ClN_2NaO_6$ [M + Na]: 495.13, found: 495.04.

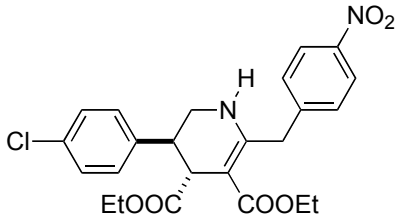


3i

***trans*-Diethyl**

5-(3-Chlorophenyl)-2-(4-nitrobenzyl)-1,4,5,6-tetrahydropyridine-3,4-dicarboxylate (3i): 86%; yellow solid; IR (film) ν_{max} 3396, 2981, 2918, 2850, 1732, 1682, 1597,

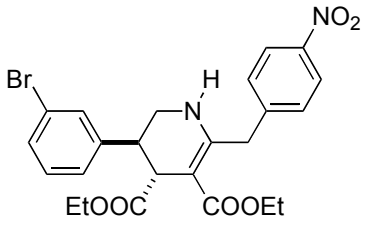
1521, 1369, 1346, 1261, 1180, 1108, 1018, 858, 786, 735, 695 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ 1.15–1.21 (m, 6H), 3.26–3.30 (m, 2H), 3.48–3.52 (m, 1H), 3.83 (d, *J* = 3.6, 1H), 4.02–4.15 (m, 4H), 4.24 (AB d, *J* = 15.6 Hz, 1H), 4.31 (AB d, *J* = 15.6 Hz, 1H), 4.45 (s, 1H), 7.07–7.10 (m, 1H), 7.17–7.22 (m, 3H), 7.39 (d, *J* = 8.8 Hz, 2H), 8.11 (d, *J* = 6.8 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.2, 14.3, 38.87, 38.93, 44.2, 45.0, 59.5, 60.8, 93.2, 123.8, 125.5, 127.2, 127.3, 129.3, 129.8, 134.4, 143.6, 145.6, 146.8, 153.5, 167.4, 174.9; MS (ESI): *m/z* calcd for $C_{24}H_{25}ClN_2NaO_6$ [M + Na]: 495.13, found: 495.18.



3j

***trans*-Diethyl**

5-(4-Chlorophenyl)-2-(4-nitrobenzyl)-1,4,5,6-tetrahydropyridine-3,4-dicarboxylate (3j): 84%; yellow solid; IR (film) ν_{max} 3391, 2981, 2918, 2850, 1732, 1683, 1598, 1521, 1494, 1368, 1346, 1261, 1179, 1108, 1094, 1030, 1015, 912, 858, 805, 734 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ 1.08–1.12 (m, 6H), 3.16–3.22 (m, 2H), 3.22–3.42 (m, 1H), 3.75 (d, *J* = 3.2 Hz, 1H), 3.94–4.08 (m, 5H), 4.35 (apparent AB d, 2H), 7.06 (d, *J* = 8.8 Hz, 2H), 7.18 (dd, *J* = 2, 6.8 Hz, 2H), 7.32 (d, 8.4 Hz, 2H), 8.05 (d, *J* = 8.4 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.2, 14.3, 38.9, 44.5, 45.1, 59.5, 60.8, 93.4, 123.7, 128.6, 128.7, 129.3, 132.8, 139.9, 145.6, 146.8, 153.4, 167.4, 175.0; MS (ESI): *m/z* calcd for $C_{24}H_{25}ClN_2NaO_6$ [M + Na]: 495.13, found: 495.17.

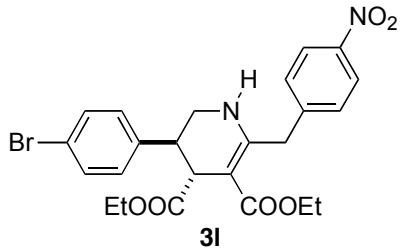


3k

***trans*-Diethyl**

5-(3-Bromophenyl)-2-(4-nitrobenzyl)-1,4,5,6-tetrahydropyridine-3,4-dicarboxyla

te (3k): 58%; yellow solid; IR (film) ν_{max} 3379, 2980, 2918, 2850, 1732, 1683, 1594, 1520, 1368, 1346, 1261, 1178, 1109, 1077, 1029, 859, 783, 736, 695 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ 1.16–1.21 (m, 6H), 3.26–3.29 (m, 2H), 3.48–3.53 (m, 1H), 3.83 (d, *J* = 4.0 Hz, 1H), 4.02–4.15 (m, 4H), 4.24 (AB d, *J* = 15.6 Hz, 1H), 4.32 (AB d, *J* = 15.6 Hz, 1H), 4.40 (s, 1H), 7.12–7.18 (m, 2H), 7.37 (apparent t, 4H), 8.13 (d, *J* = 8.8 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.2, 14.3, 38.9, 44.2, 45.0, 59.5, 60.9, 93.2, 122.6, 123.8, 126.0, 129.1, 129.3, 130.1, 130.2, 130.3, 143.8, 145.5, 146.8, 153.5, 167.3, 174.9; MS (ESI): *m/z* calcd for $C_{24}H_{25}BrN_2NaO_6$ [M + Na]: 539.08, found: 539.13.

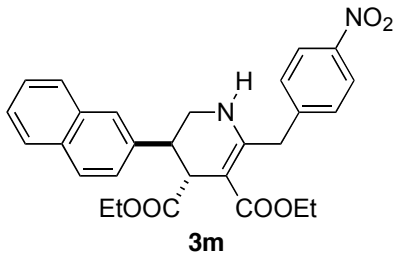


3l

***trans*-Diethyl**

5-(4-Bromophenyl)-2-(4-nitrobenzyl)-1,4,5,6-tetrahydropyridine-3,4-dicarboxyla

te (3n): 75%; yellow solid; IR (film) ν_{max} 3376, 2980, 2918, 2850, 1732, 1683, 1591, 1521, 1491, 1368, 1346, 1262, 1179, 1109, 1076, 1011, 858, 820, 777, 736 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ 1.13–1.21 (m, 6H), 3.22–3.28 (m, 2H), 3.45–3.51 (m, 1H), 3.82 (d, *J* = 4.0 Hz, 1H), 3.99–4.14 (m, 5H), 4.42 (apparent AB d, 2H), 7.08 (d, *J* = 8.4 Hz, 2H), 7.38–7.42 (m, 4H), 8.12 (d, *J* = 8.4 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.2, 14.3, 38.8, 38.9, 44.4, 45.0, 59.5, 60.8, 93.4, 120.9, 123.8, 129.0, 129.3, 131.6, 140.4, 145.6, 146.8, 153.4, 167.3, 174.9; MS (ESI): *m/z* calcd for $C_{24}H_{25}BrN_2NaO_6$ [M + Na]: 539.08, found: 539.13.

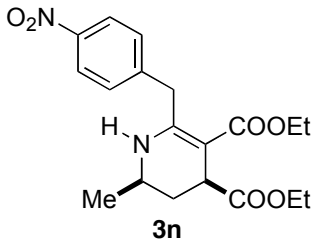


3m

***trans*-Diethyl**

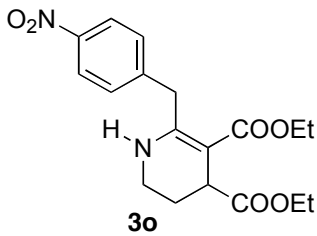
5-(Naphth-2-yl)-2-(4-nitrobenzyl)-1,4,5,6-tetrahydropyridine-3,4-dicarboxylate

(3m): 84%; yellow solid; IR (film) ν_{max} 3391, 2980, 2918, 2850, 1731, 1682, 1599, 1520, 1368, 1345, 1270, 1181, 1107, 1079, 1018, 858, 818, 774, 749, 718 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ 1.14–1.19 (m, 6H), 3.41–3.49 (m, 2H), 3.56–3.60 (m, 1H), 4.01–4.20 (m, 6H), 4.34 (AB d, *J* = 15.2 Hz, 1H), 4.50 (s, 1H), 7.32–7.36 (m, 3H), 7.44–7.48 (m, 2H), 7.58 (s, 1H), 7.63–7.66 (m, 1H), 7.77–7.82 (m, 2H), 7.99–8.02 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.2, 14.3, 39.0, 39.2, 44.3, 45.0, 59.4, 60.8, 93.2, 123.7, 125.5, 125.7, 125.9, 126.2, 127.5, 127.7, 128.2, 129.3, 132.4, 133.2, 138.7, 145.8, 146.6, 153.6, 167.5, 175.3; MS (ESI): *m/z* calcd for $C_{28}H_{28}N_2NaO_6$ [M + Na]: 511.18, found: 511.22.



3n

***cis*-Diethyl 6-Methyl-2-(4-nitrobenzyl)-1,4,5,6-tetrahydropyridine-3,4-dicarboxylate (3n)**: 66%; yellow solid; IR (film) ν_{max} 3379, 2981, 2918, 2850, 1732, 1683, 1591, 1521, 1369, 1346, 1261, 1178, 1107, 1030, 859, 736 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ 1.16 (t, *J* = 7.2 Hz, 3H), 1.27 (t, *J* = 7.2 Hz, 3H), 1.67–1.75 (m, 1H), 2.15–2.21 (m, 1H), 3.32–3.37 (m, 1H), 3.64 (dd, *J* = 6.8, 10.4 Hz, 1H), 3.96 (s, 1H), 4.00–4.19 (m, 5H), 4.38 (AB d, *J* = 15.6 Hz, 1H), 7.44–7.46 (m, 2H), 8.14–8.18 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.24, 14.27, 21.1, 34.1, 39.0, 40.9, 46.2, 59.3, 60.5, 94.6, 123.8, 129.1, 146.0, 146.7, 153.1, 167.3, 175.6; MS (ESI): *m/z* calcd for $C_{19}H_{24}N_2NaO_6$ [M + Na]: 399.15, found: 399.18.

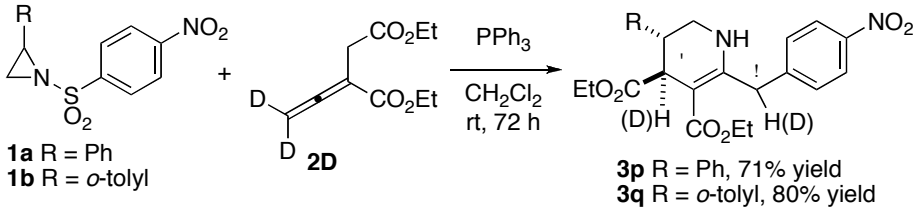


3o

Diethyl 2-(4-Nitrobenzyl)-1,4,5,6-tetrahydropyridine-3,4-dicarboxylate (3o): 37%;

yellow solid; IR (film) ν_{max} 3391, 2982, 2933, 2850, 1732, 1683, 1589, 1520, 1368, 1346, 1253, 1181, 1109, 859 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ 1.17 (t, *J* = 7.2 Hz, 3H), 1.27 (t, *J* = 6.4 Hz, 3H); 1.84–1.93 (m, 1H), 2.10–2.14 (m, 1H), 3.18–3.24 (m, 2H), 3.74 (d, *J* = 3.2 Hz, 1H), 4.00–4.20 (m, 5H), 4.30 (s, 1H), 4.46 (AB d, *J* = 16.4 Hz, 1H), 7.45 (d, *J* = 8.8 Hz, 2H), 8.14 (d, *J* = 8.8 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.4, 24.1, 38.6, 38.9, 39.0, 59.2, 60.6, 93.2, 123.8, 129.2, 146.1, 146.7, 153.2, 167.5, 175.5; MS (ESI): *m/z* calcd for $C_{18}H_{22}N_2NaO_6$ [M + Na]: 385.14, found: 385.16.

[3 + 3] Annulation of the Deuterium-Labeled Allenoate 2D

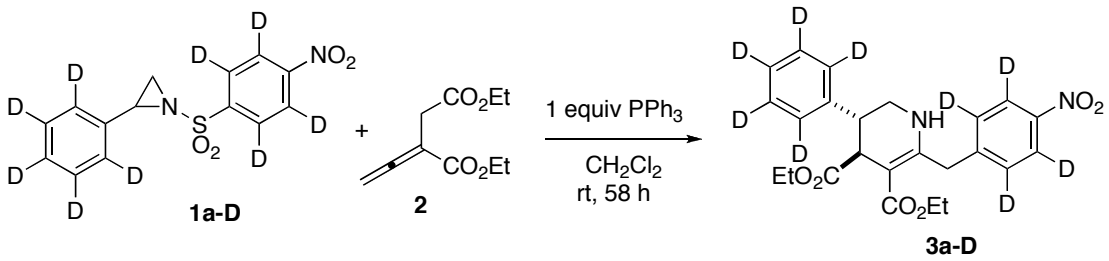


An oven-dried 50-mL flask was charged with triphenylphosphine (0.097 mmol), the *N*-4-nitrobenzenesulfonyl-protected aziridine (0.097 mmol), and CH_2Cl_2 (10 mL) at room temperature. The deuterium-labeled diethyl 2-vinylidenesuccinate **2D** (0.233 mmol) was added to the resulting solution and the mixture was stirred at room temperature. After 36 h, another charge of diethyl 2-vinylidenesuccinate **2D** (0.233 mmol) was added; the resulting mixture was stirred for an additional 36 h and then concentrated. The residue was purified through flash column chromatography (EtOAc/hexane = 1:3) to afford the corresponding tetrahydropyridine product. With the aziridine **1a** as the starting material, the corresponding tetrahydropyridine **3p** was obtained as a yellow solid (trans-isomer, 30.5 mg, 71.4% yield; trans:cis = 9:1). When the aziridine **1b** was used, the corresponding product **3q** was obtained as a yellow solid (trans-isomer, 35.3 mg, 80.2% yield; trans:cis = 9:1). See pages S36 and S37 for the ^1H NMR spectra of the partially labeled products **3p** and **3q**. We suspect that the deuterium atom on the enamine nitrogen atom (in compounds **3p** and **3q**) is exchanged to a hydrogen atom in the solvent used for NMR spectroscopy and performed an enamine H/D exchange experiment; see page S19 for the

hydrogen/deuterium exchange experiments on the tetrahydropyridine **3a**. Another possible mechanism explaining the loss of the enamine deuterium atom is enamine/imine tautomerization. The solid state structure of **3a** reveals that the ring $C(sp^2)$–N and C=C bond distances were 1.343 and 1.378 Å, respectively; i.e., they deviate from typical values, indicating a potential enamine/imine mixture. Typical $C(sp^2)$–N, C=N, C=C, and $C(sp^3)$–$C(sp^2)$ bond distances are 1.416, 1.279, 1.322, and 1.507 Å, respectively; see: *CRC Handbook of Chemistry and Physics*, 78th ed.; Lide, D. R., Ed.; CRC Press: Boca Raton, NY, 1997; Section 9.

[3 + 3] Annulation of the Enantiomerically Pure Aziridine (*S*)-1a. An oven-dried 10-mL flask was charged with triphenylphosphine (30 mg, 0.115 mmol), (*S*)-**1a** (35 mg, 0.115 mmol), and CH_2Cl_2 (3 mL) at room temperature. Diethyl 2-vinylidenesuccinate (109 mg, 0.552 mmol) was added to the resulting solution and the mixture was stirred at room temperature for 24 h before being concentrated. The residue was purified through flash column chromatography (EtOAc/hexane = 1:3) to afford the tetrahydropyridine product as a single enantiomer [63.5% yield; >99% ee, determined through SFC analysis (AS-H, MeOH 30%, CO_2 70%; flow rate: 1.5 mL/min)]; $[\alpha]_D^{20}$ −72.0° (*c* = 1.4, $CHCl_3$). See pages S38–41 for HPLC chromatograms of the aziridines **1a** and (*S*)-**1a** and the tetrahydropyridines **3a** and (−)-**3a**.

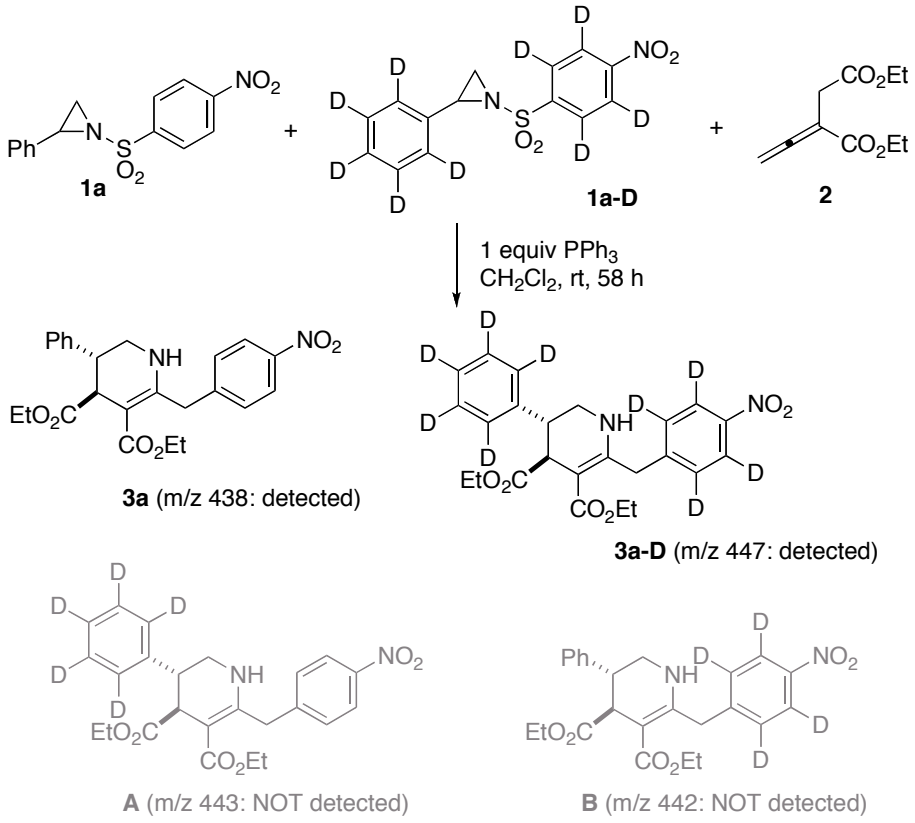
[3 + 3] Annulation of the Deuterium-Labeled Aziridine 1a-D



An oven-dried 10-mL flask was charged with triphenylphosphine (35 mg, 0.134 mmol), the deuterium-labeled aziridine **1a-D** (42 mg, 0.134 mmol), and CH_2Cl_2 (8 mL) at room temperature. Diethyl 2-vinylidenesuccinate **2** (128 mg, 0.643 mmol) was

added to the resulting solution and the mixture was stirred at room temperature for 58 h before being concentrated. The residue was purified through flash column chromatography (EtOAc/hexane = 1:3) to afford the corresponding deuterated tetrahydropyridine **3a-D** (13 mg, 21.7%). ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.08-1.12 (m, 6H), 3.22-3.27 (m, 2H), 3.42-3.47 (m, 1H), 3.82 (br d, *J*=2.8, 1H), 3.93-4.08 (m, 4H), 4.16 (AB d, *J*=16.0, 1H), 4.25 (AB d, *J*=16.0, 1H), 4.26 (br s, 1H); MS (ESI): *m/z* calcd for $C_{24}H_{18}D_9N_2O_6$ [M + H]: 448.53, found 448; calcd for $C_{24}H_{17}D_9N_2NaO_6$ [M + Na]: 470.52, found 470.

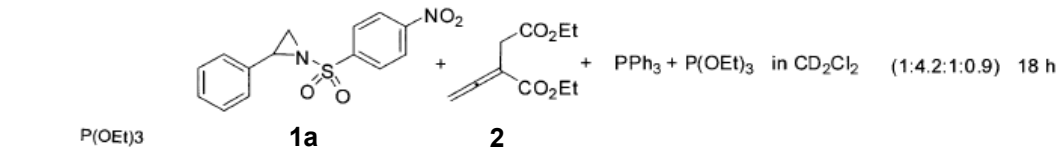
[3 + 3] Crossover Annulation of the Aziridine 1a and the Deuterium-Labeled Aziridine 1a-D



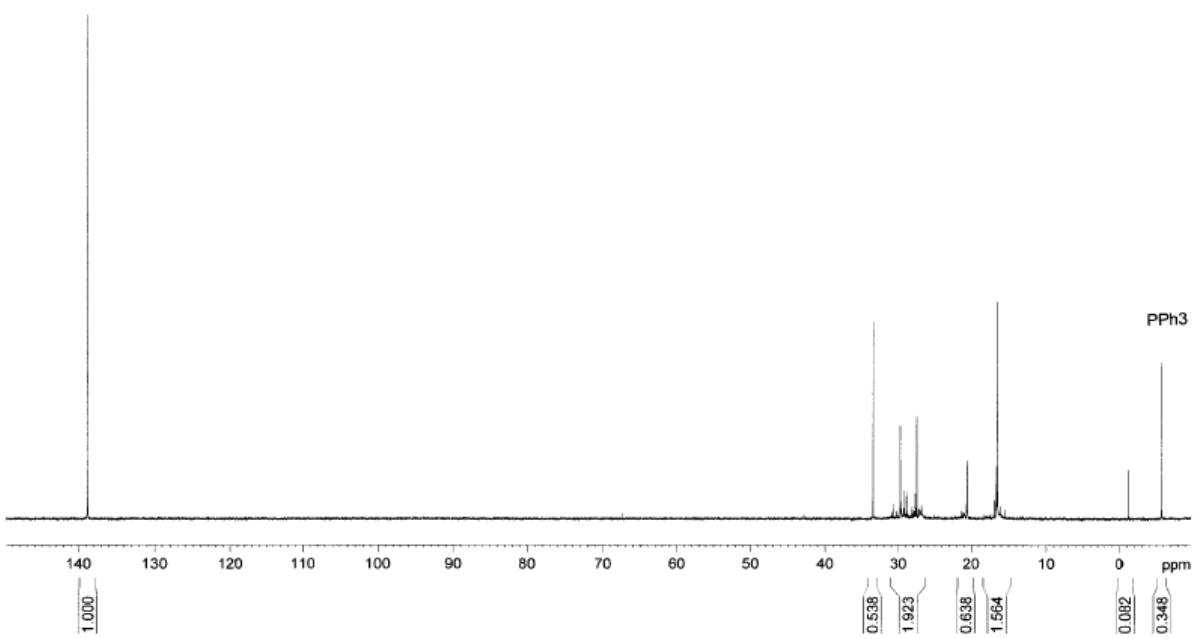
An oven-dried 10-mL flask was charged with triphenylphosphine (35 mg, 0.134 mmol), the *N*-4-nitrobenzenesulfonyl-protected aziridine **1a** (20.4 mg, 0.067 mmol), the deuterium-labeled *N*-4-nitrobenzenesulfonyl protected aziridine **1a-D** (21 mg, 0.067 mmol), and CH_2Cl_2 (4 mL) at room temperature. Diethyl 2-vinylidenesuccinate (**2**, 128 mg, 0.643 mmol) was added to the resulting solution and the mixture was

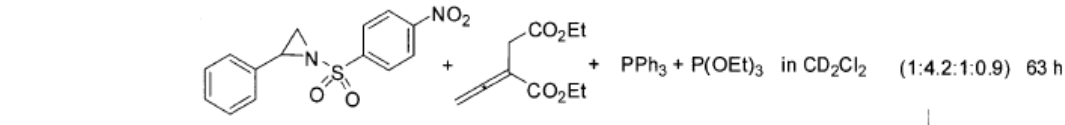
stirred at room temperature for 58 h before being concentrated. The residue was purified through flash column chromatography (EtOAc/hexane = 1:3) to afford the corresponding tetrahydropyridine mixture (26 mg). Mass spectrometric analysis indicated that the product mixture included the compounds **3a** and **3a-D**, but not compound **A** or **B**. The ^{1}H NMR spectrum indicated that the tetrahydropyridine product mixture contained **3a** and **3a-D** in a ratio of ca. 1:1. ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.13–1.25 (m, 12H), 3.28–3.32 (m, 4H), 3.48–3.52 (m, 2H), 3.86 (d, *J* = 3.3, 2H), 4.00–4.13 (m, 8H), 4.20 (AB d, *J* = 15.9 Hz, 2H), 4.32 (AB d, *J* = 15.9 Hz, 2H), 4.56 (br s, 2H), 7.18–7.31 (m, 5H), 7.36 (d, *J* = 7.2 Hz, 2H), 8.08 (d, *J* = 7.2 Hz, 2H). See page S42 for the ^{1}H NMR spectrum of a mixture of the tetrahydropyridines **3a** and **3a-D** and pages S43–45 for the mass spectrum of the mixture of **3a** and **3a-D** that did not contain compound **A** or **B**.

^{31}P NMR Spectrum Revealing Free PPh_3 in the [3 + 3] Annulation Mixture. An oven-dried NMR tube was charged with triphenylphosphine (17.2 mg, 0.066 mmol), the *N*-(*p*-nitrobenzenesulfonyl)aziridine **1a** (20 mg, 0.066 mmol), triethyl phosphite (10 uL, 0.058 mmol), and CD_2Cl_2 (0.5 mL) at room temperature. Diethyl 2-vinylidenesuccinate (**2**, 55 mg, 0.277 mmol) was added to the resulting solution and the mixture was analyzed using ^{31}P NMR spectroscopy. Signals representing PPh_3 were present in the spectra of the reaction mixture after even 63 h. Copies of the ^{31}P NMR spectra recorded after 18 and 63 h are presented on the following page (p S18).

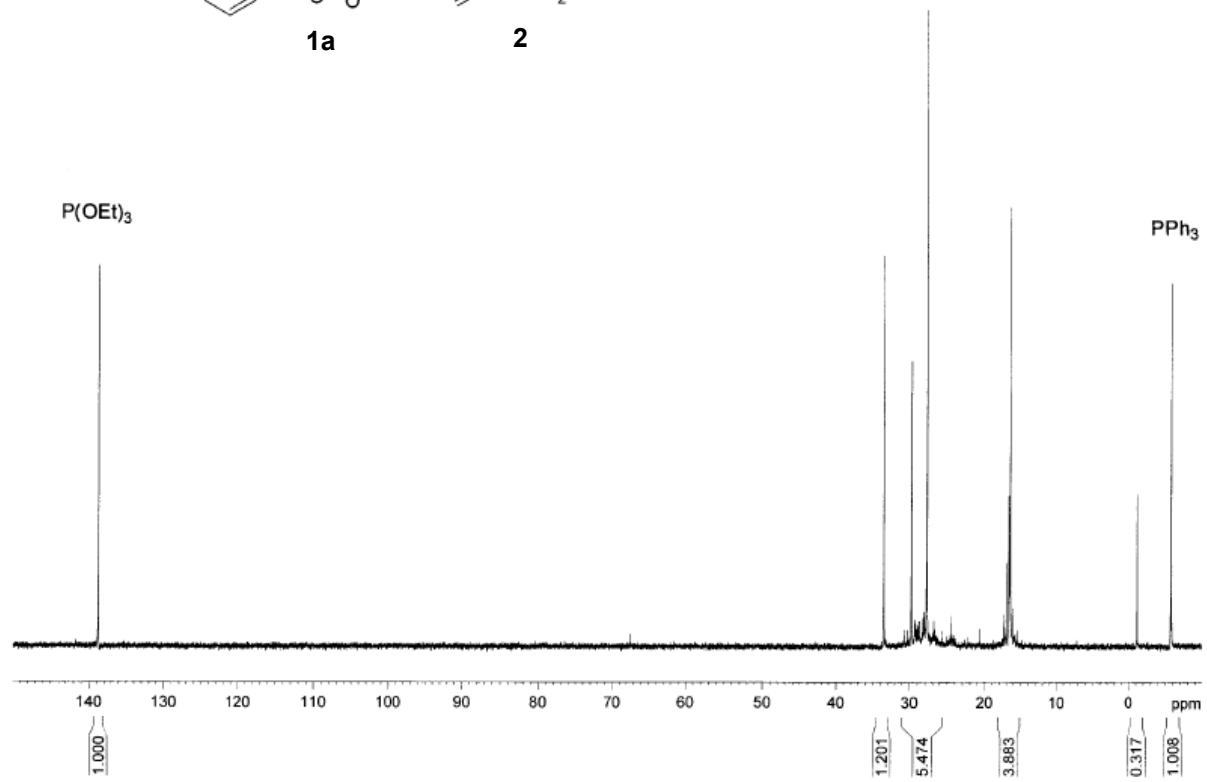

NO2
CO2Et
CO2Et
+
+ PPh3 + P(OEt)3 in CD2Cl2 (1:4.2:1:0.9) 18 h

1a **2**

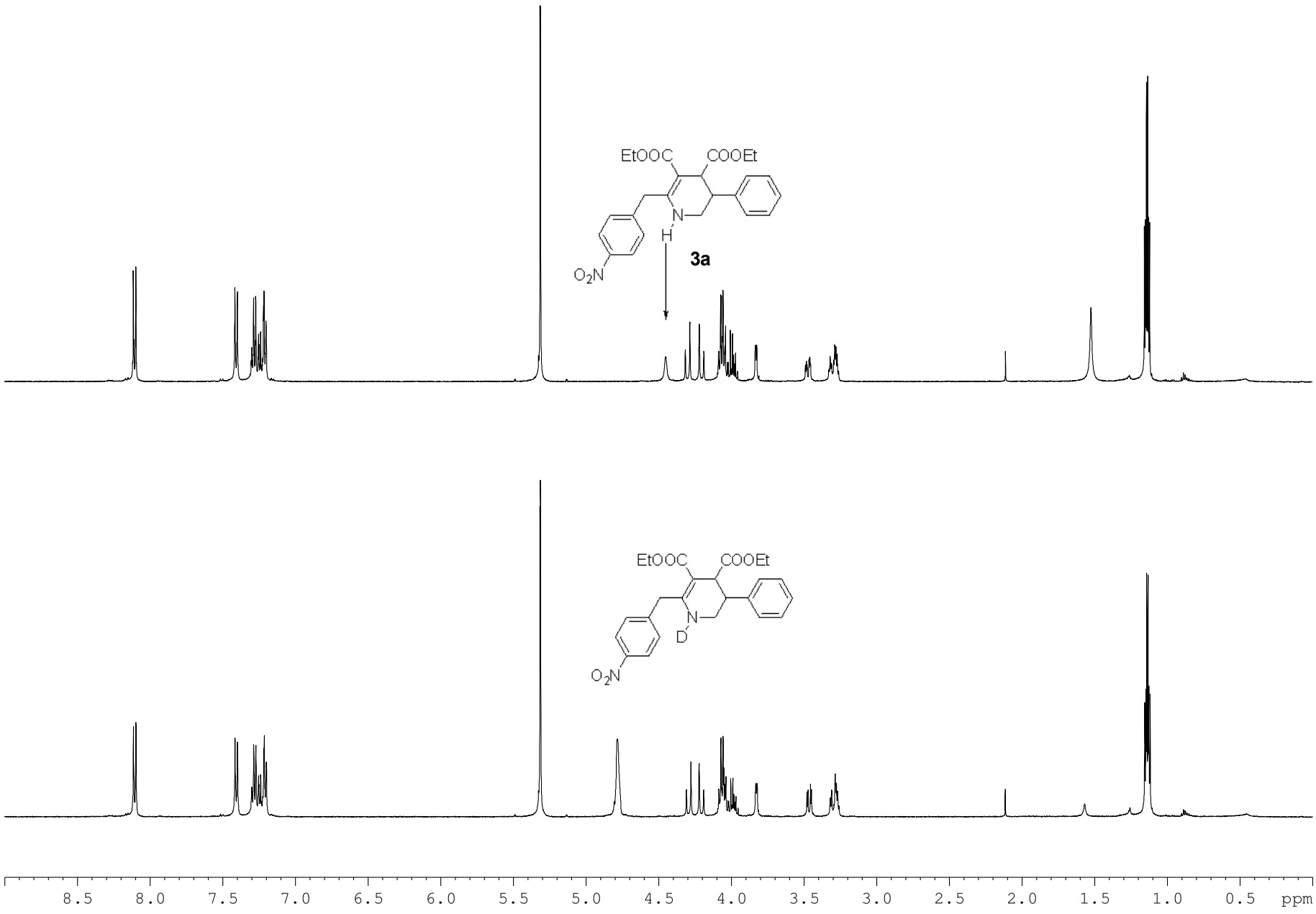

P(OEt)3
PPh3
140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm
1.000
0.538
1.923
0.638
1.564
0.082
0.348

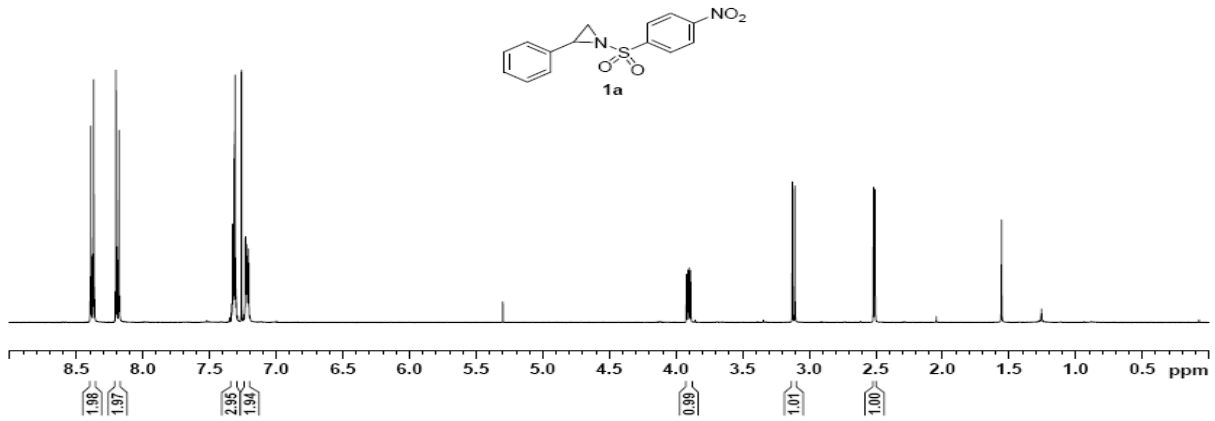

NO2
CO2Et
CO2Et
+
+ PPh3 + P(OEt)3 in CD2Cl2 (1:4.2:1:0.9) 63 h

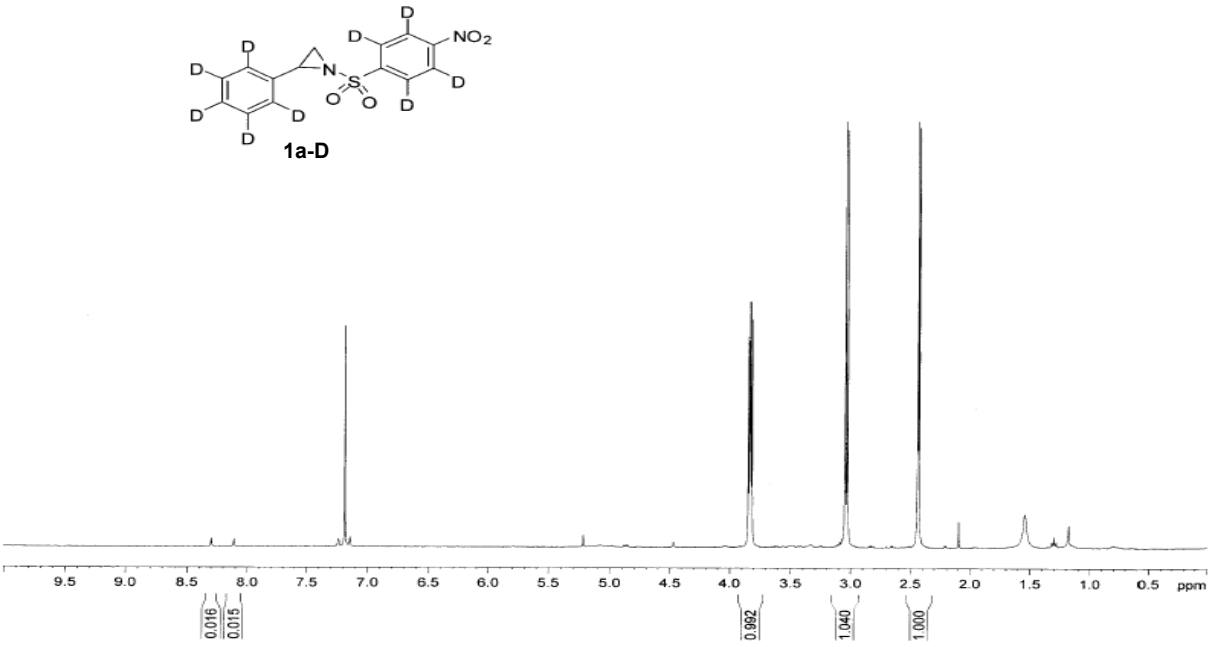
1a **2**

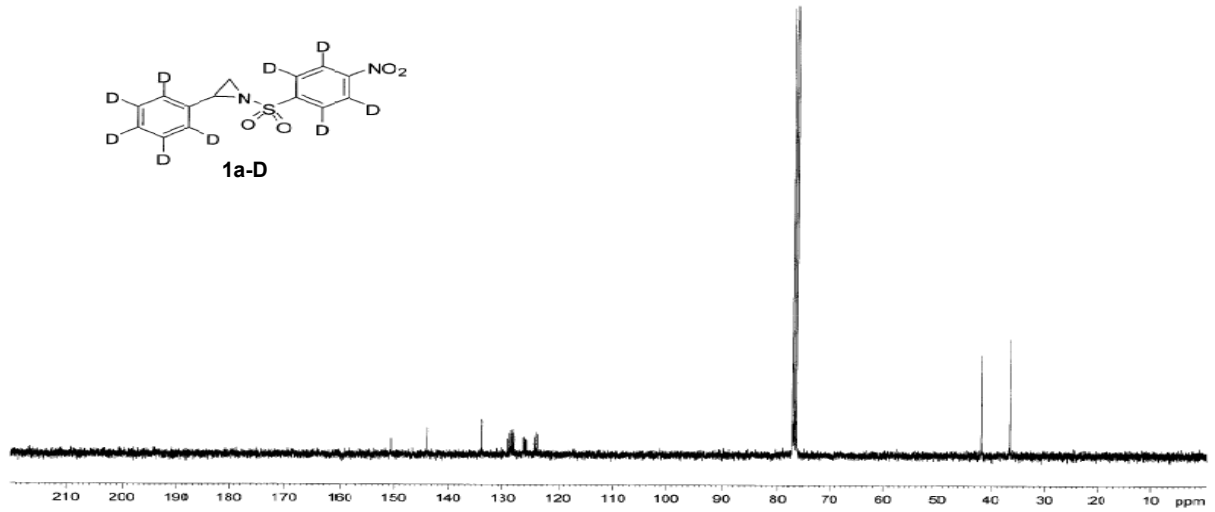

P(OEt)3
PPh3
140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm
1.000
1.201
5.474
3.883
0.317
1.008

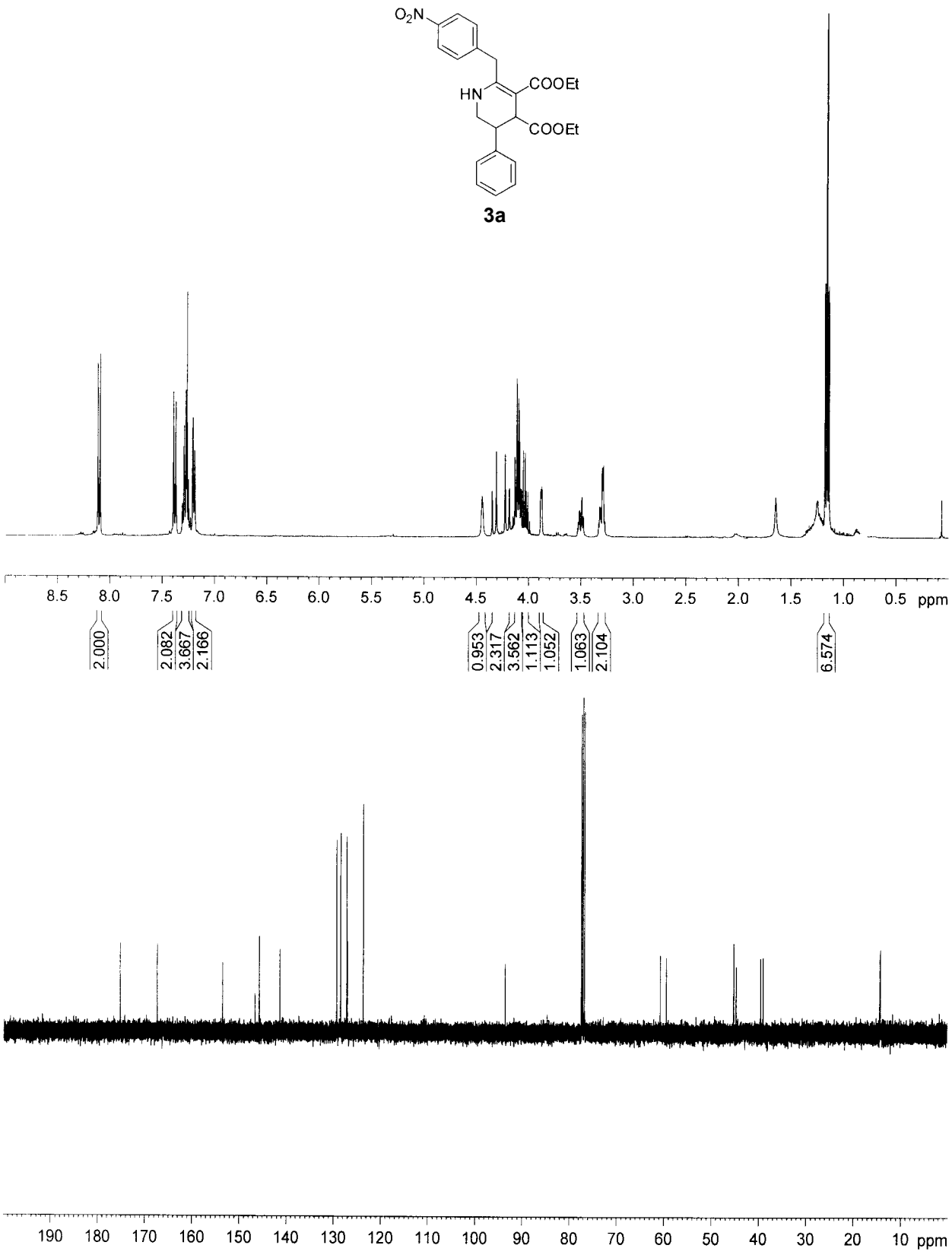
Deuterium Exchange in CD_2Cl_2 with D_2O

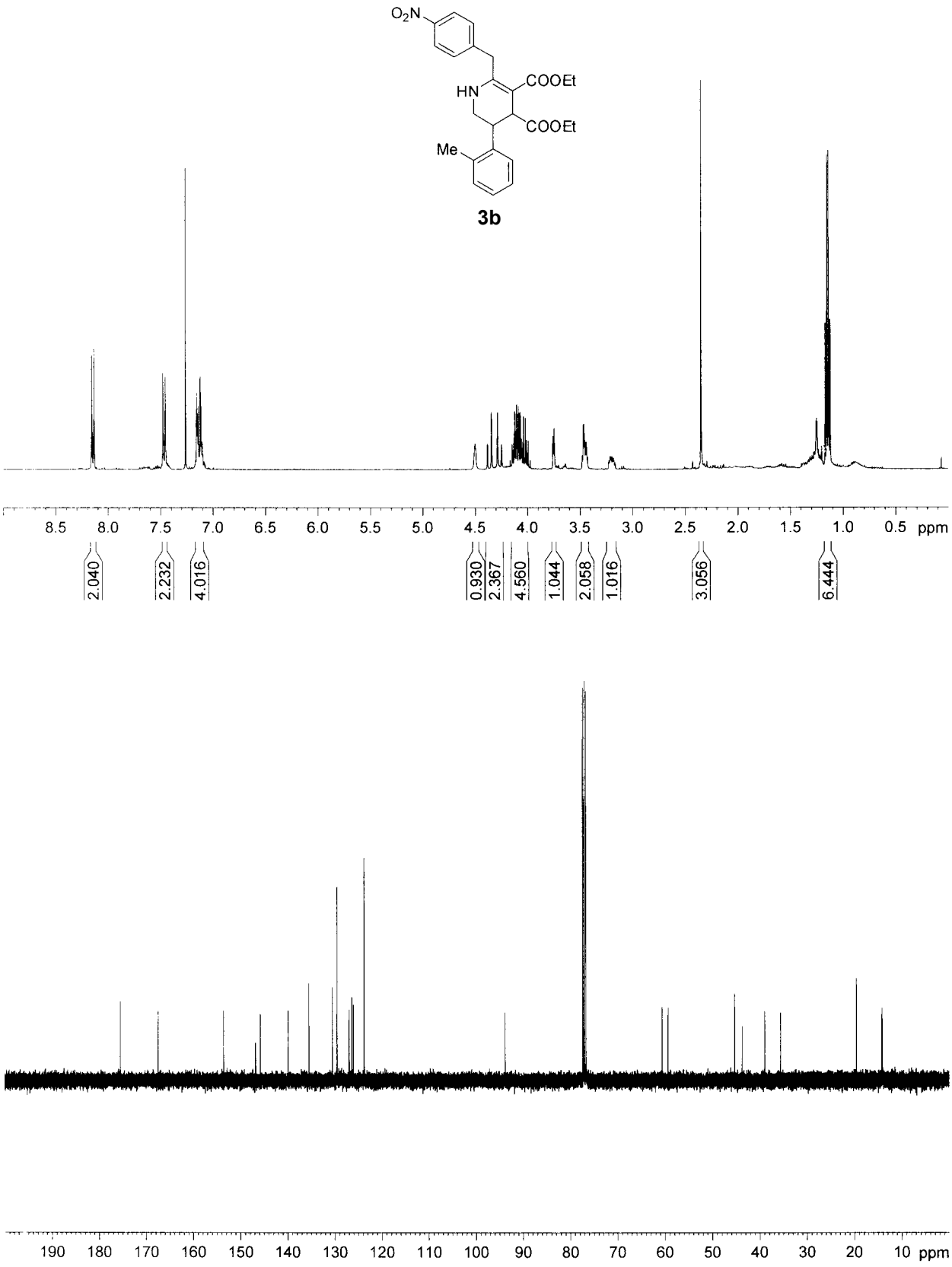


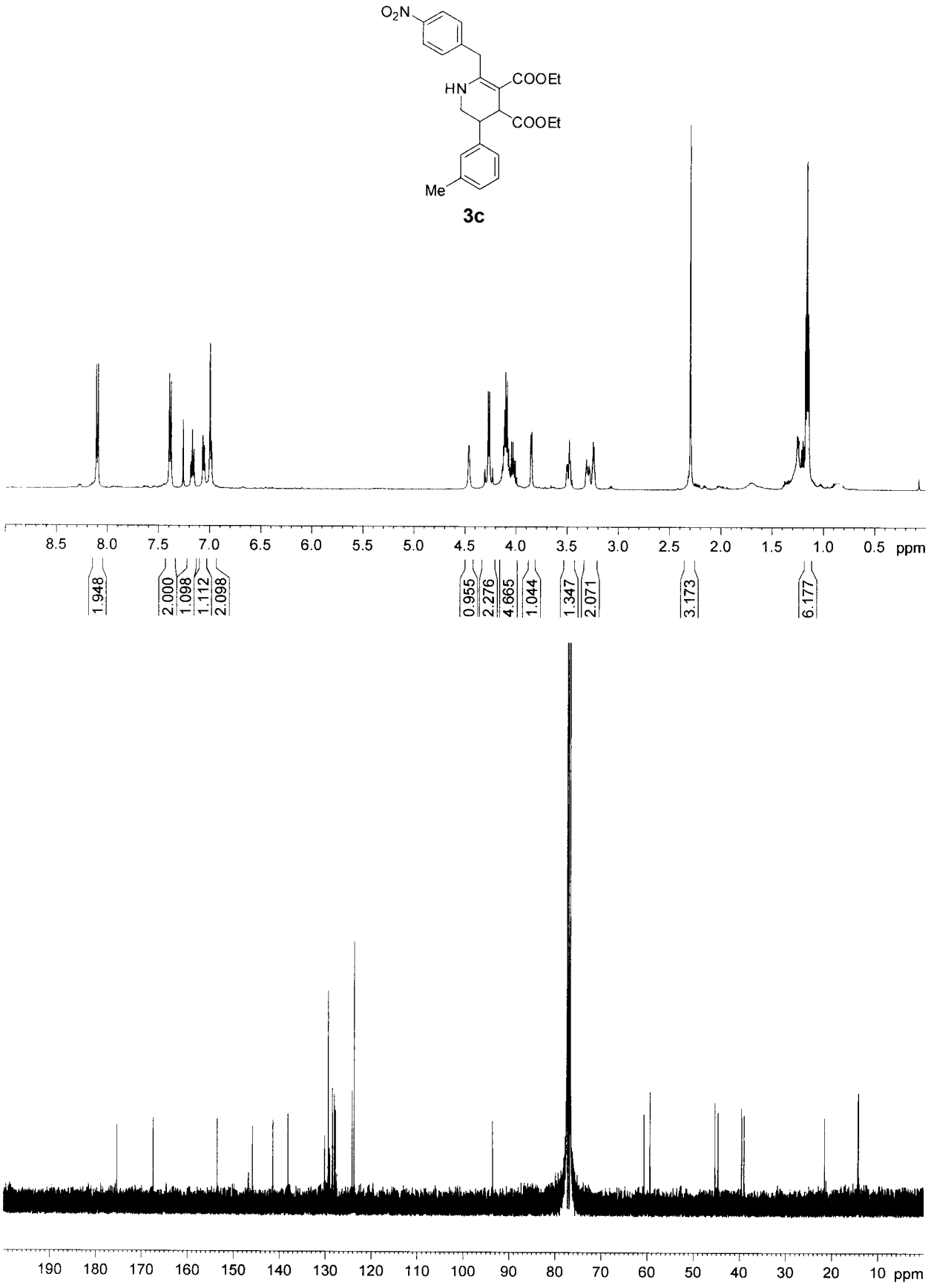

NO2
N
S
O
O
1a
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm
1.98 1.97 2.95 1.94 0.99 1.01 1.00

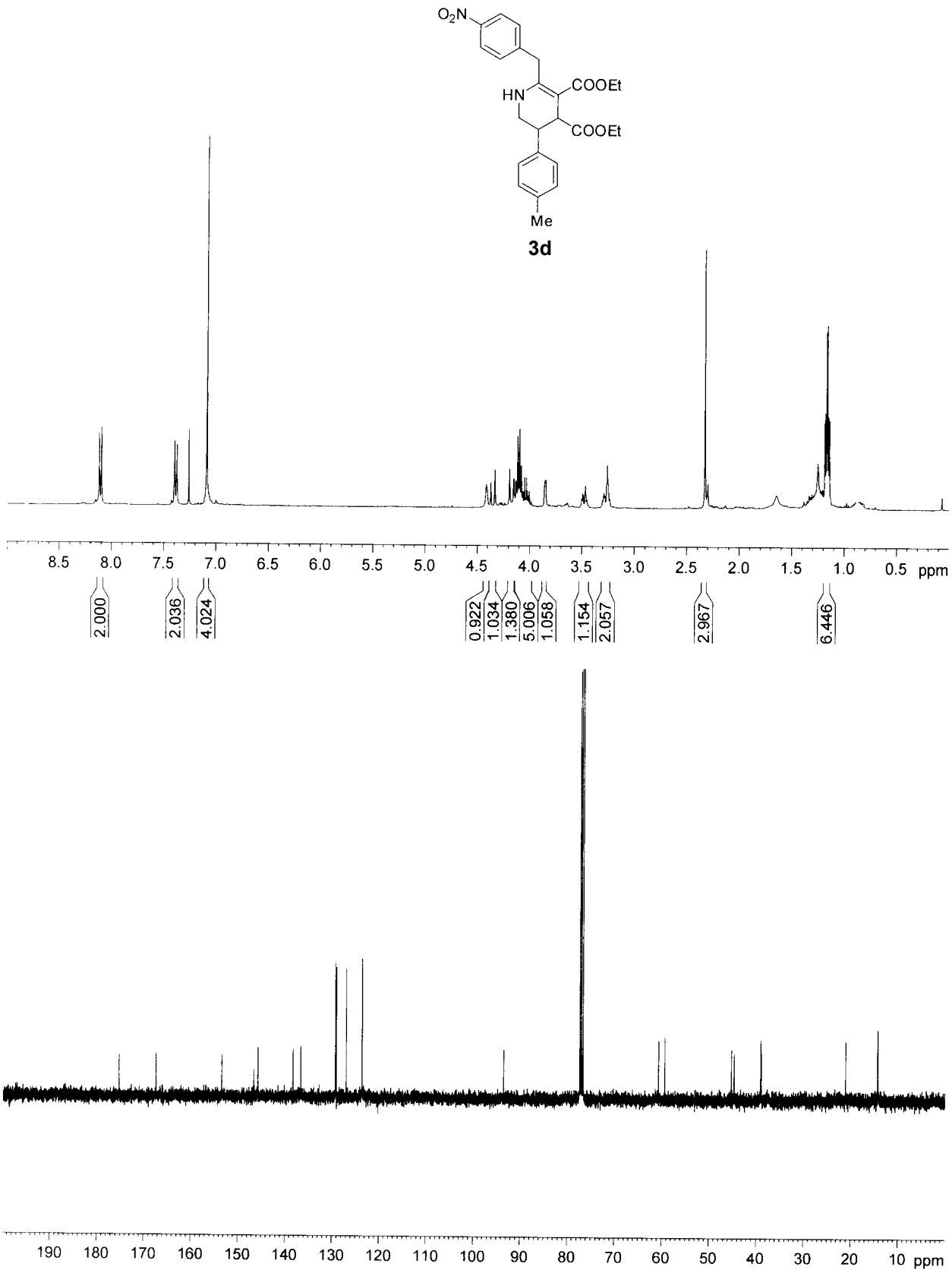

D
NO2
N
S
O
O
1a-D
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm
0.016 0.015 0.992 1.040 1.000

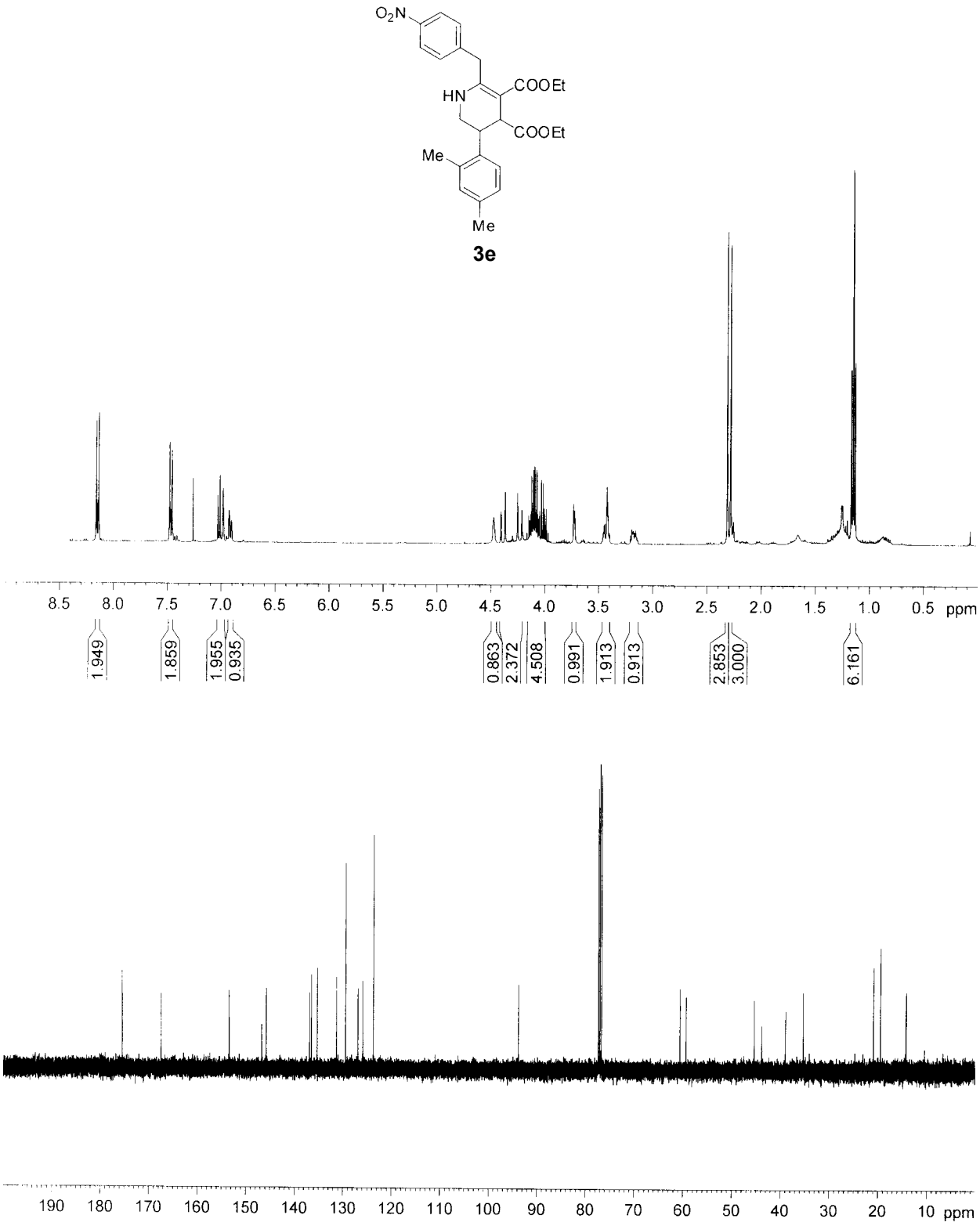

D
NO2
N
S
O
O
1a-D
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm

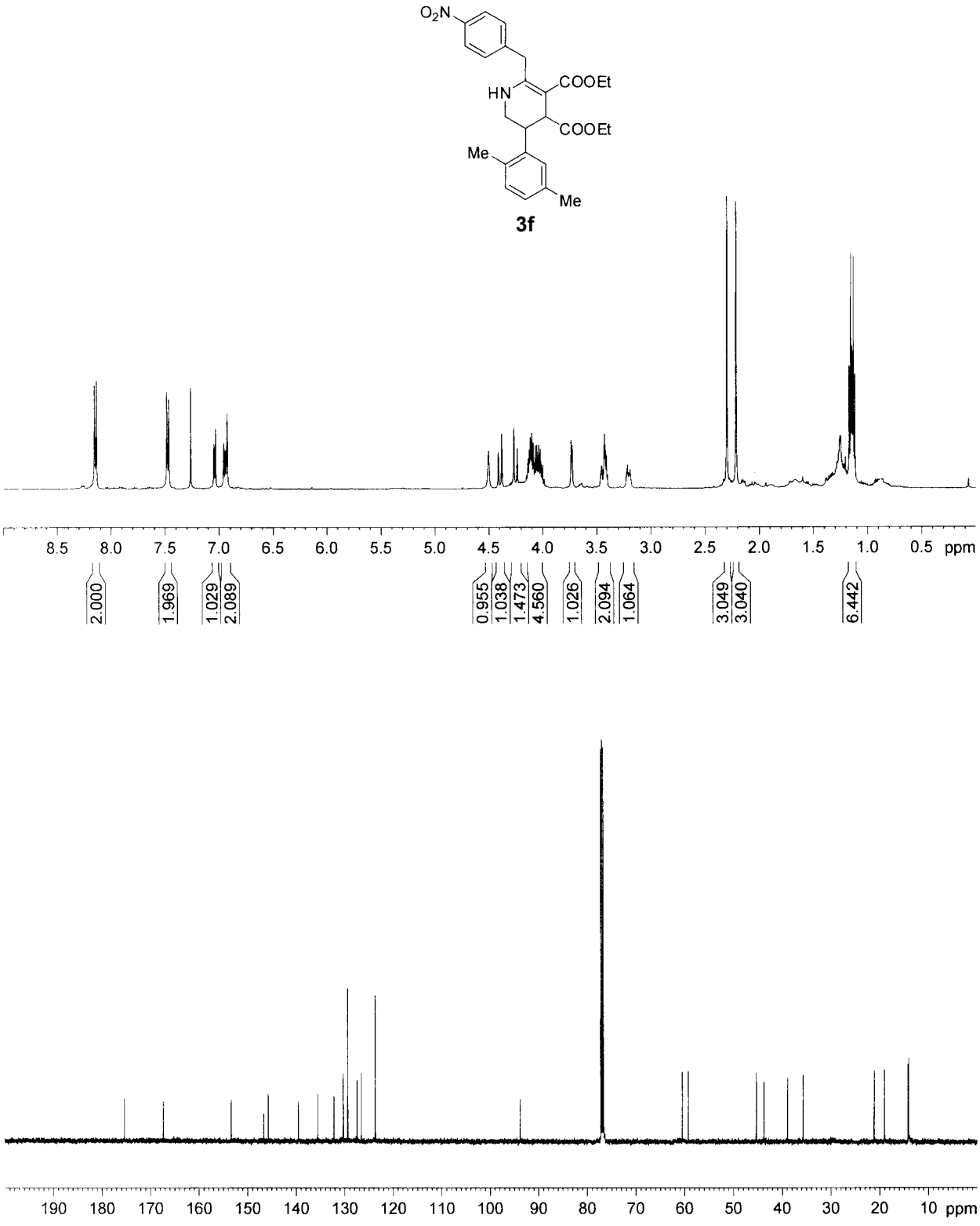

O2N
HN
COOEt
COOEt
3a
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm
2.000
2.082
3.667
2.166
0.953
2.317
3.562
1.113
1.052
1.063
2.104
6.574
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm

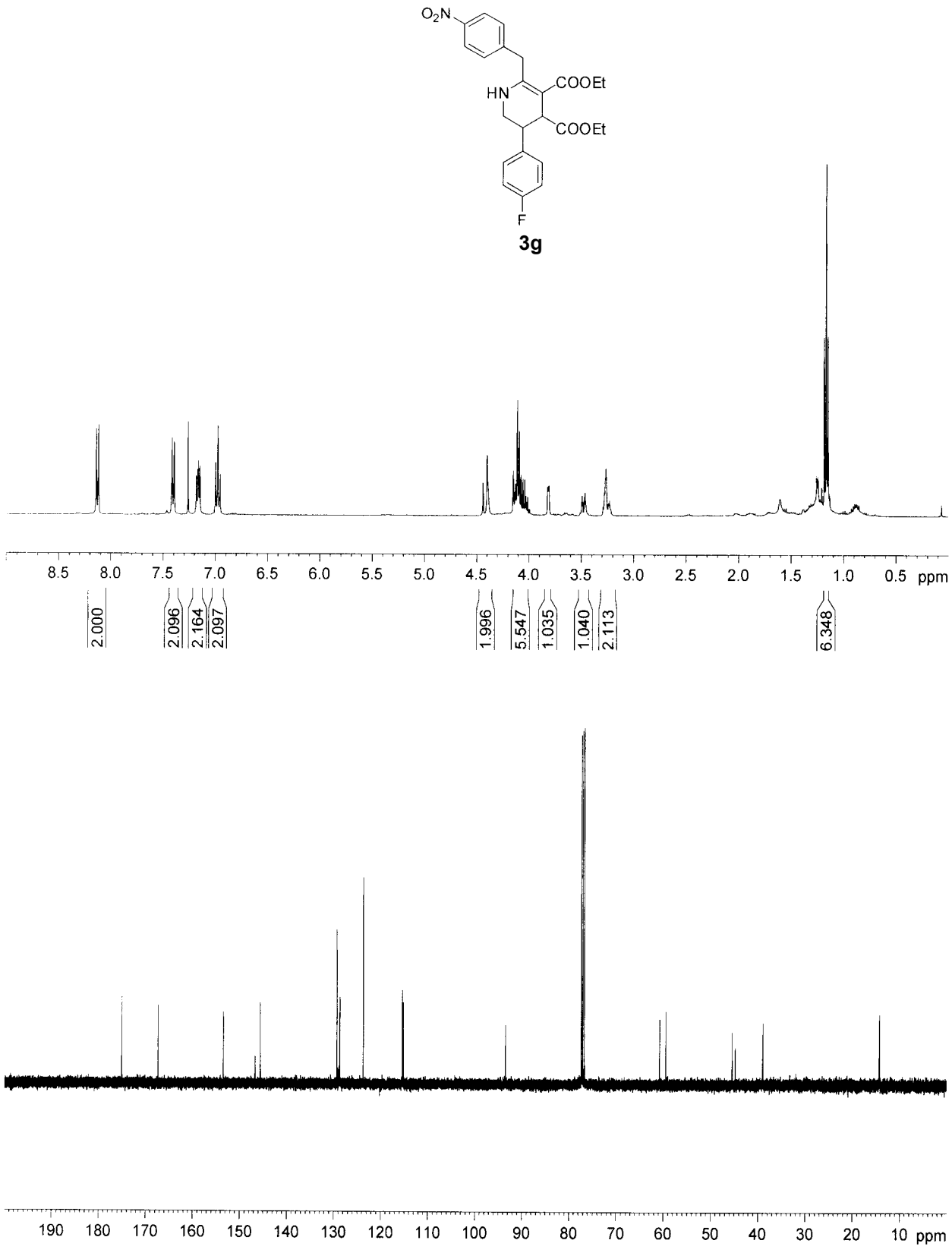

O2N
HN
COOEt
COOEt
Me
3b
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm
2.040
2.232
4.016
0.930
2.367
4.560
1.044
2.058
1.016
3.056
6.444
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm

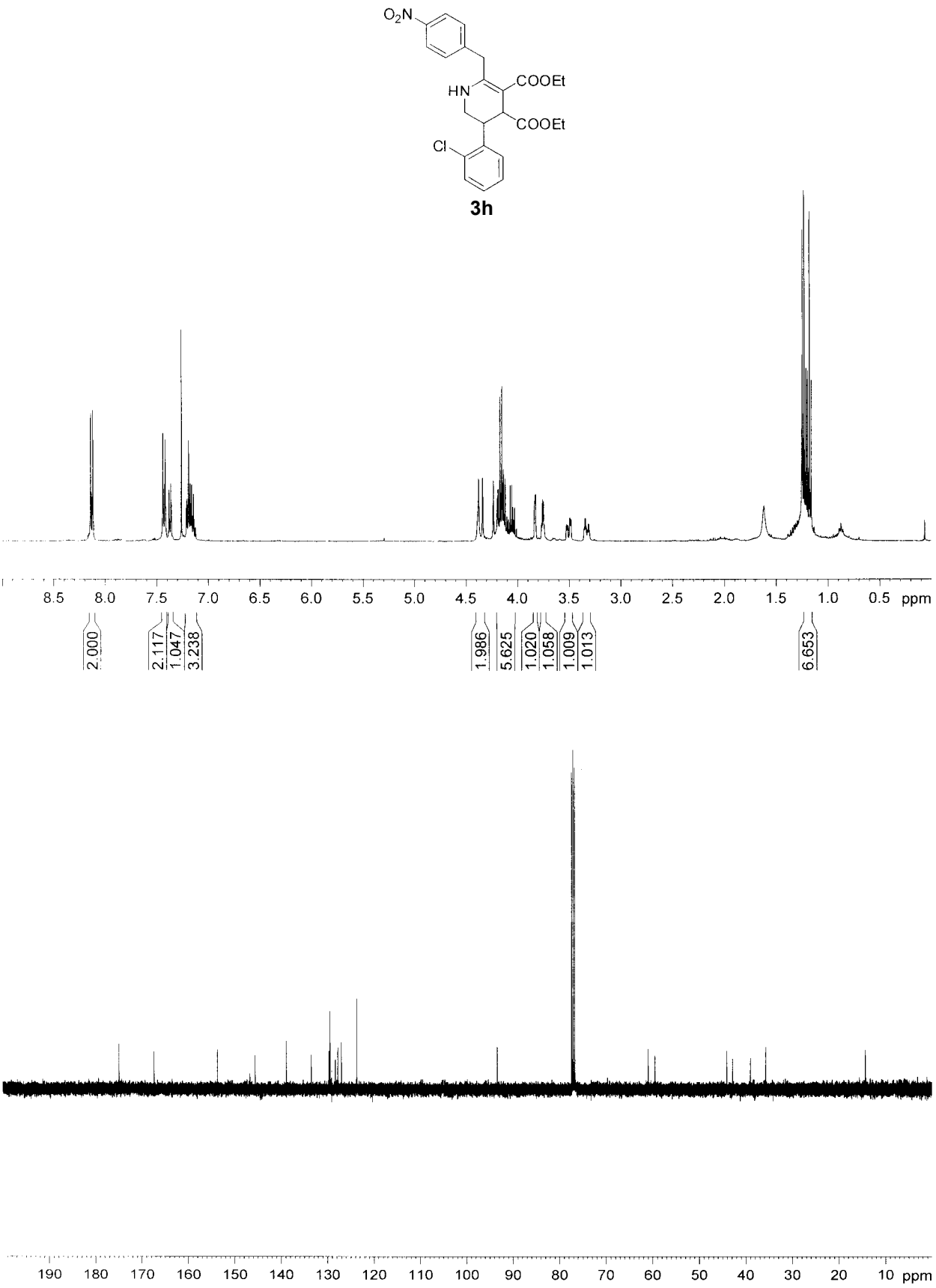

O2N
HN
COOEt
COOEt
Me
3c
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm
1.948
2.000
1.098
1.112
2.098
0.955
2.276
4.665
1.044
1.347
2.071
3.173
6.177
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm

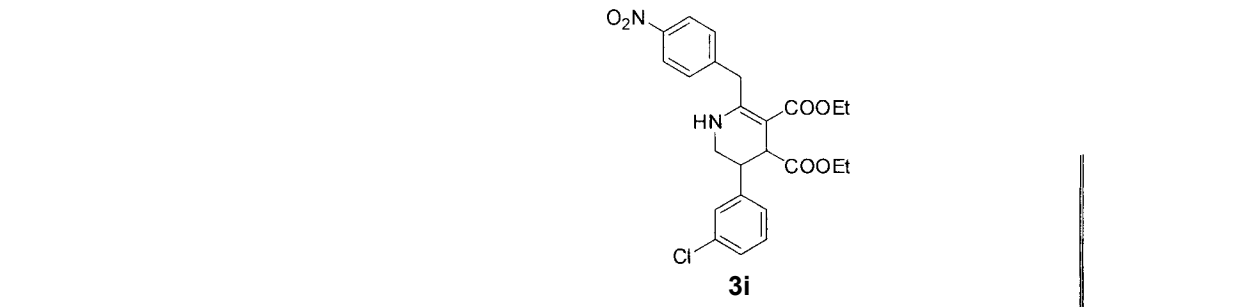

O2N
HN
COOEt
COOEt
Me
3d
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm
2.000
2.036
4.024
0.922
1.034
1.380
5.006
1.058
1.154
2.057
2.967
6.446
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm


O2N
HN
COOEt
COOEt
Me
Me
3e
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm
1.949
1.859
1.955
0.935
0.863
2.372
4.508
0.991
1.913
0.913
2.853
3.000
6.161
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm


O2N
HN
COOEt
COOEt
Me
Me
3f
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm
2.000
1.969
1.029
2.089
0.955
1.038
1.473
4.560
1.026
2.094
1.064
3.049
3.040
6.442
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm

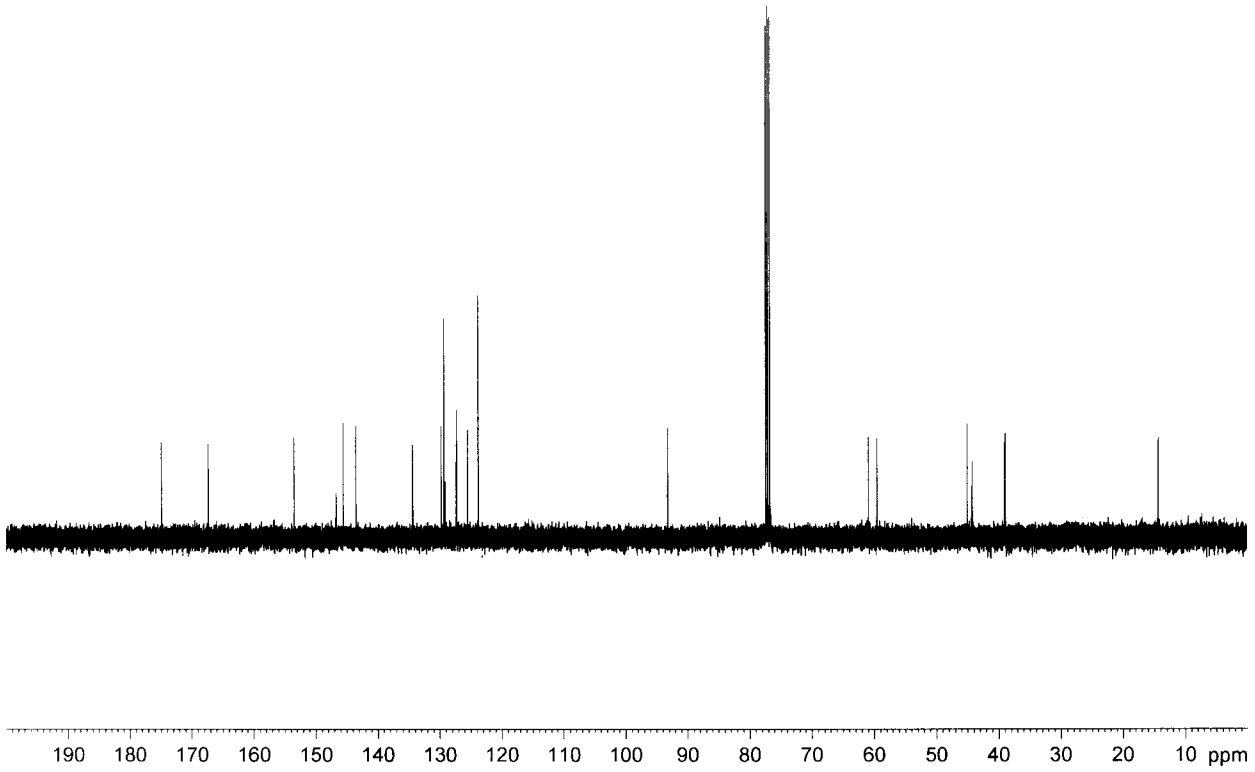

O2N
HN
COOEt
COOEt
F
3g
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm
2.000
2.096
2.164
2.097
1.996
5.547
1.035
1.040
2.113
6.348
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm

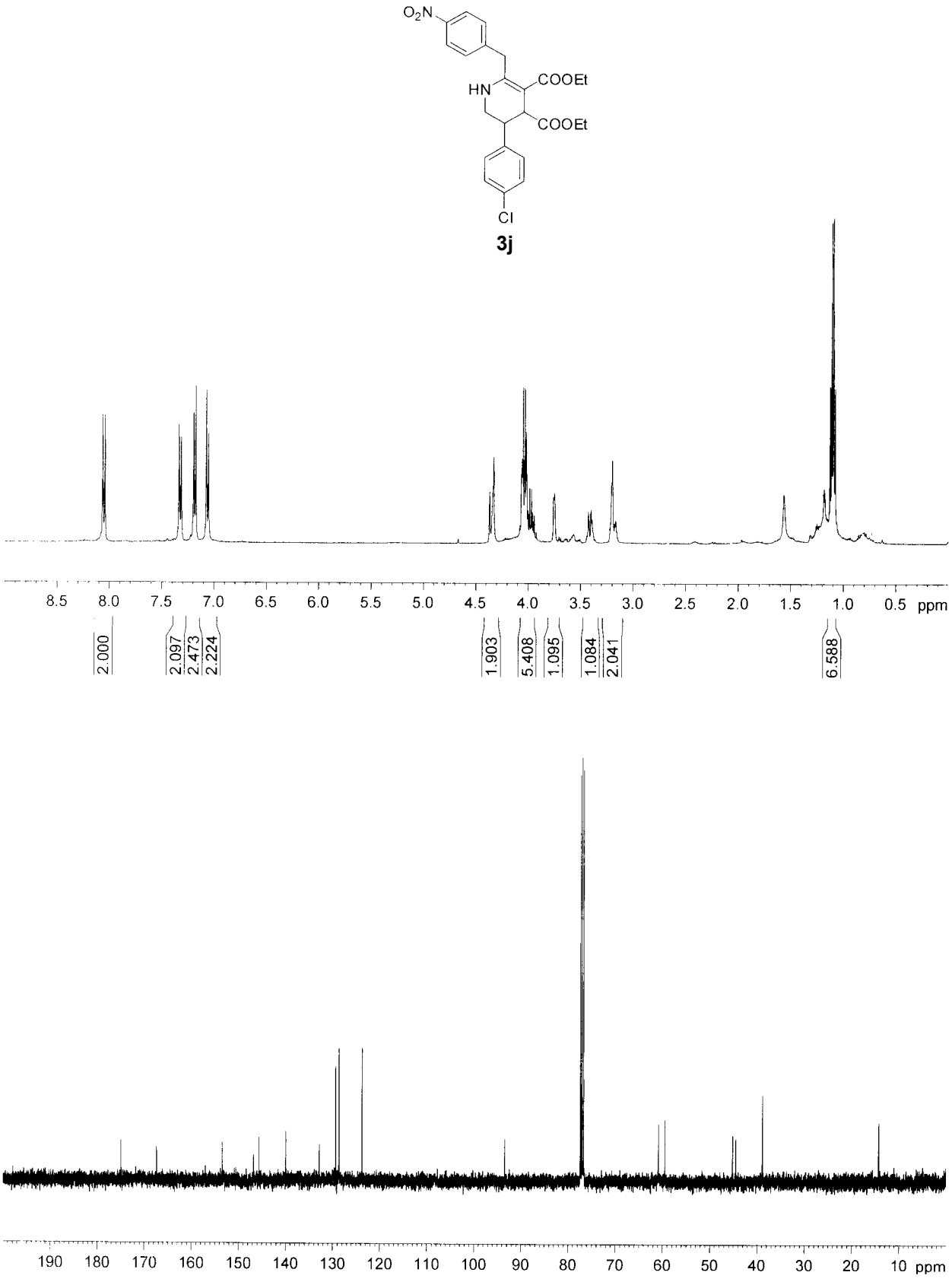

O2N
HN
COOEt
COOEt
Cl
3h
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm
2.000
2.117
1.047
3.238
1.986
5.625
1.020
1.058
1.009
1.013
6.653
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm

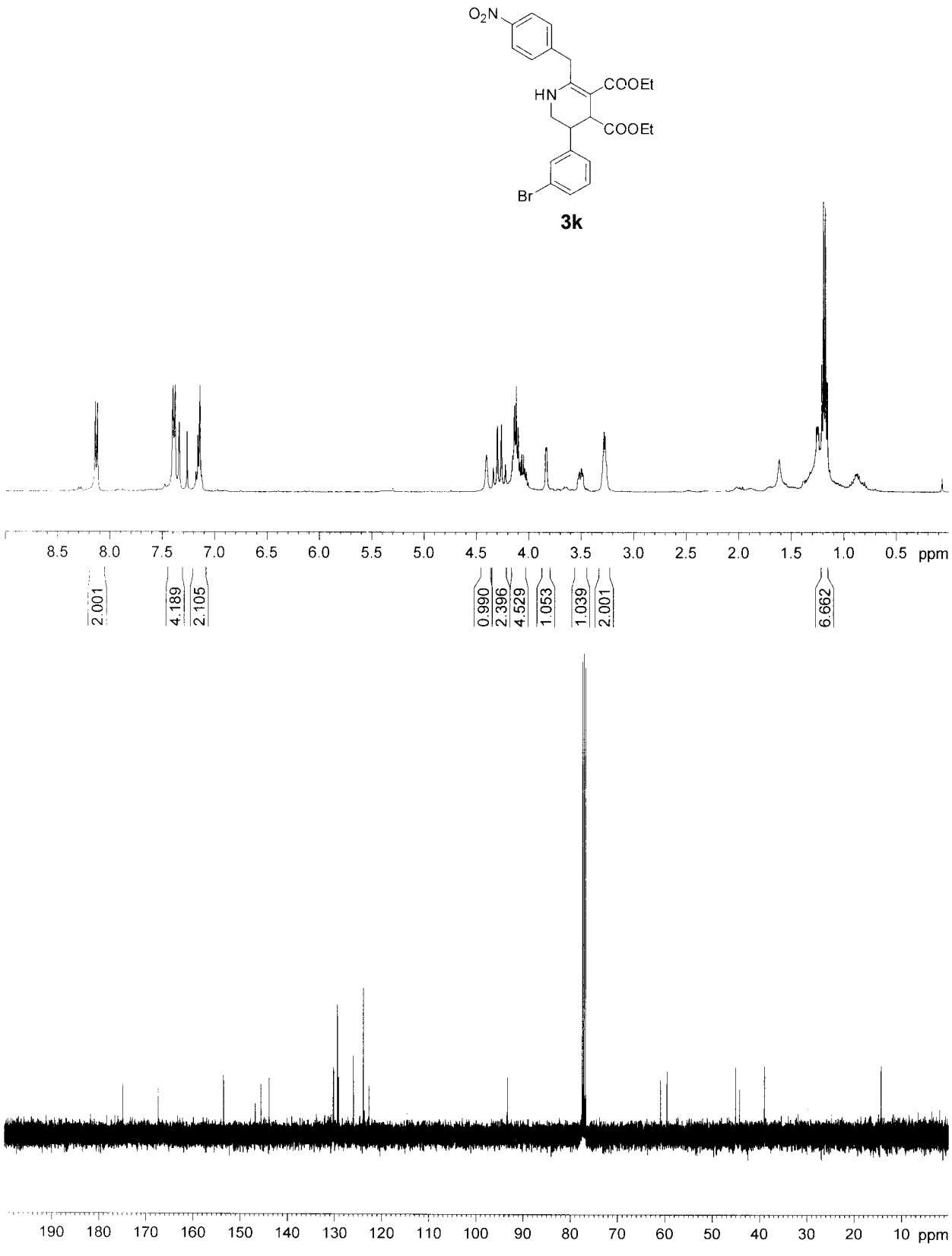

O2N
HN
COOEt
COOEt
Cl

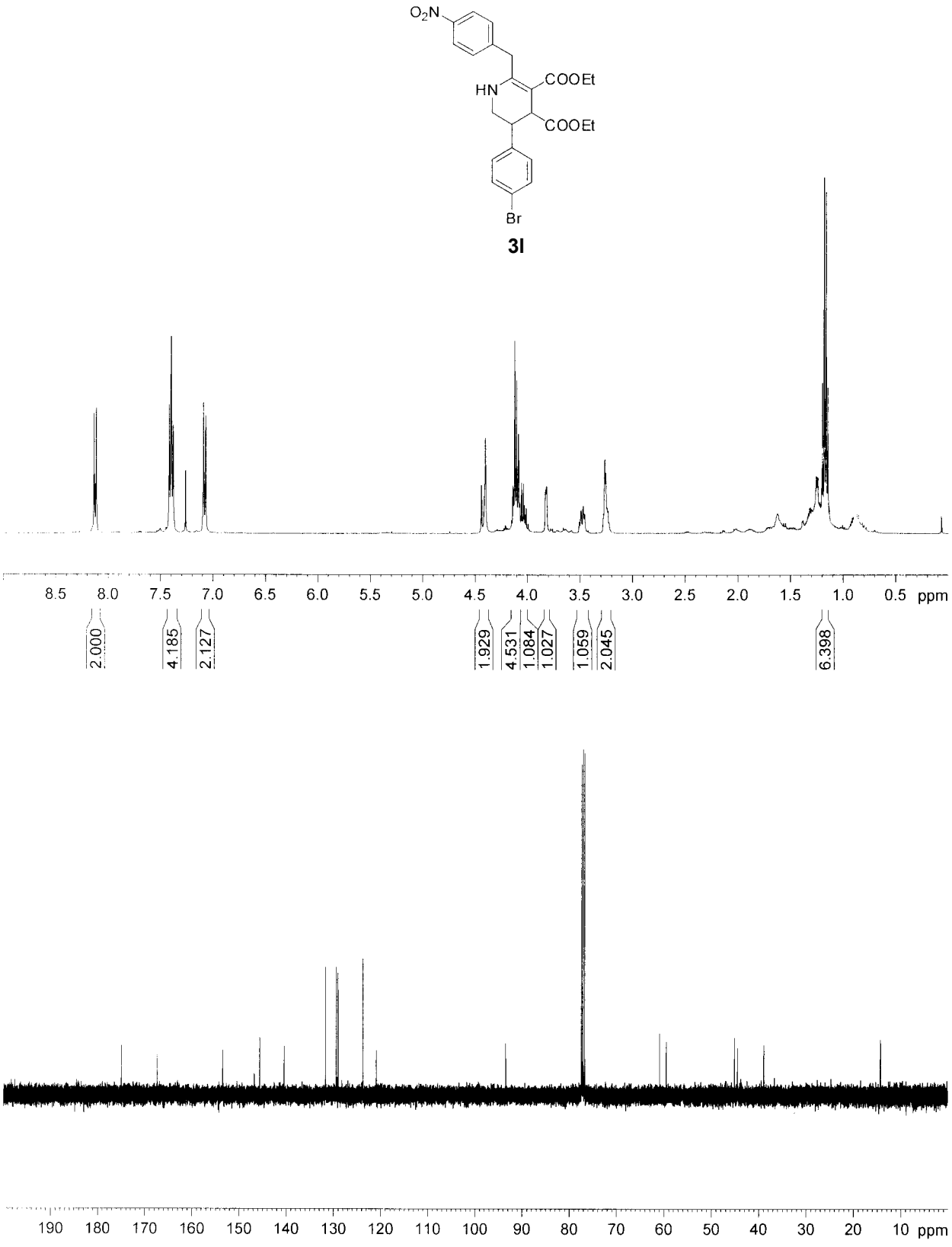
3i

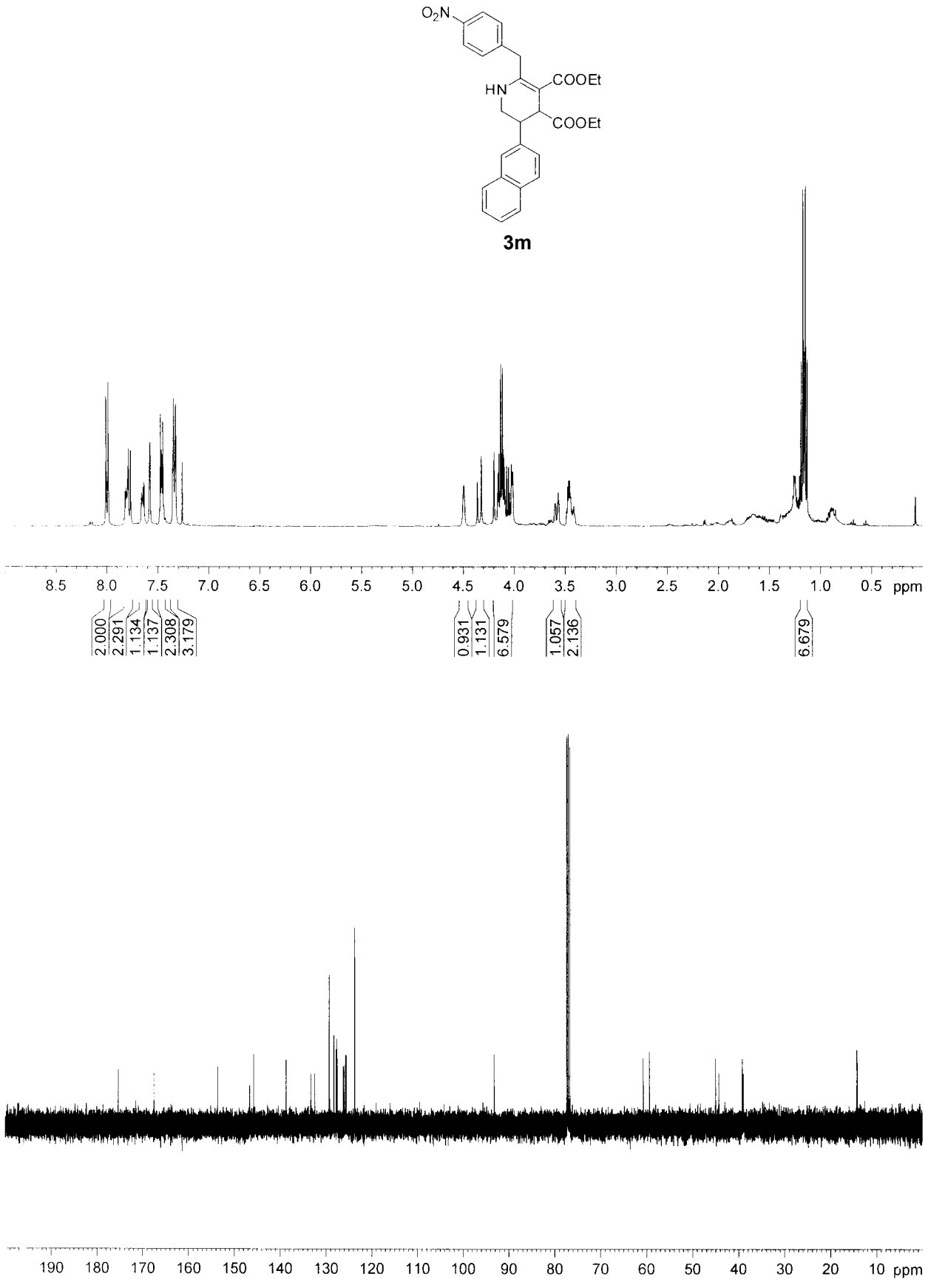
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm
2.000
2.107
3.085
1.092
0.952
2.403
4.628
1.068
1.113
2.091
6.711

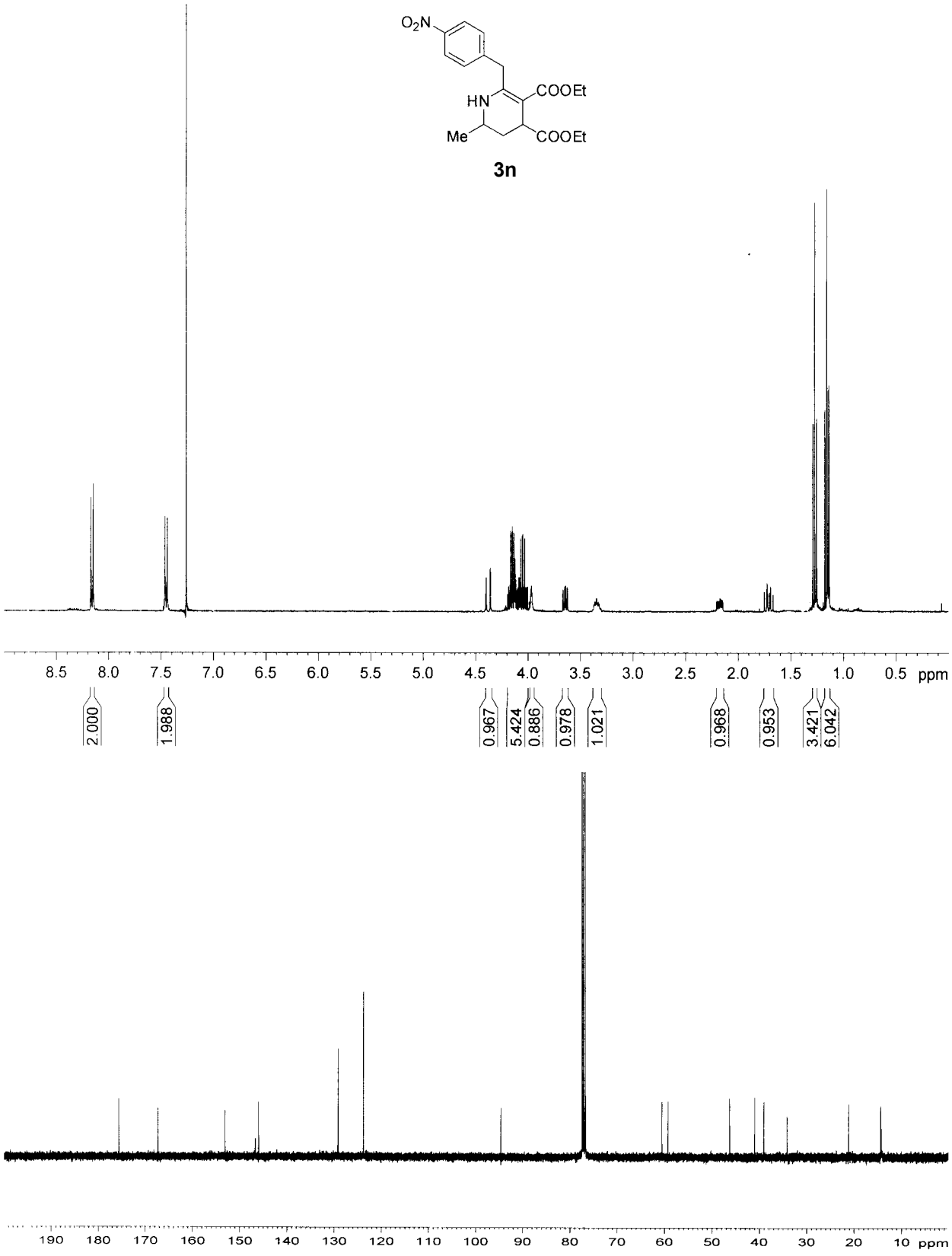

190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm

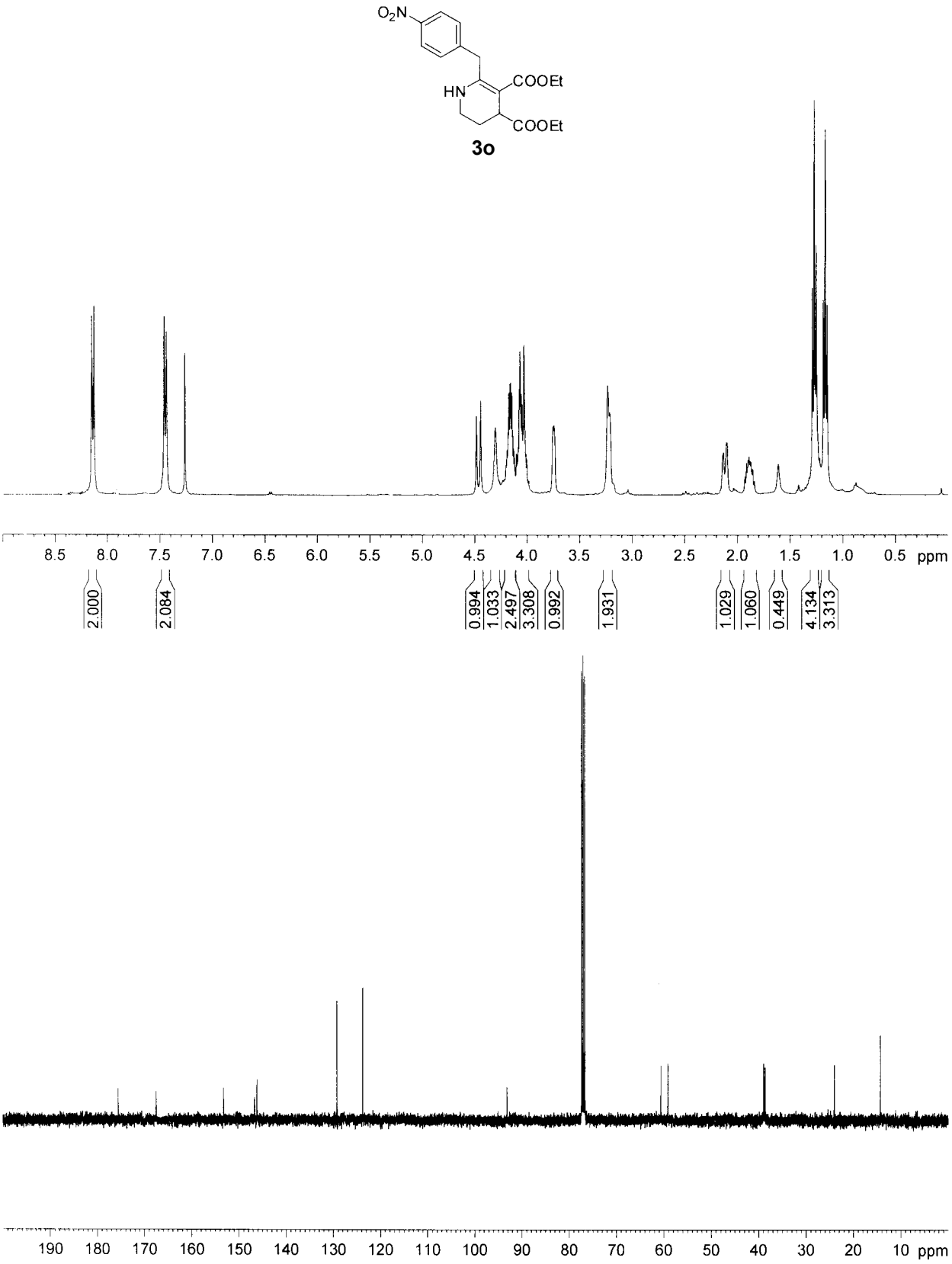

O2N
HN
COOEt
COOEt
Cl
3j
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm
2.000
2.097
2.473
2.224
1.903
5.408
1.095
1.084
2.041
6.588
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm

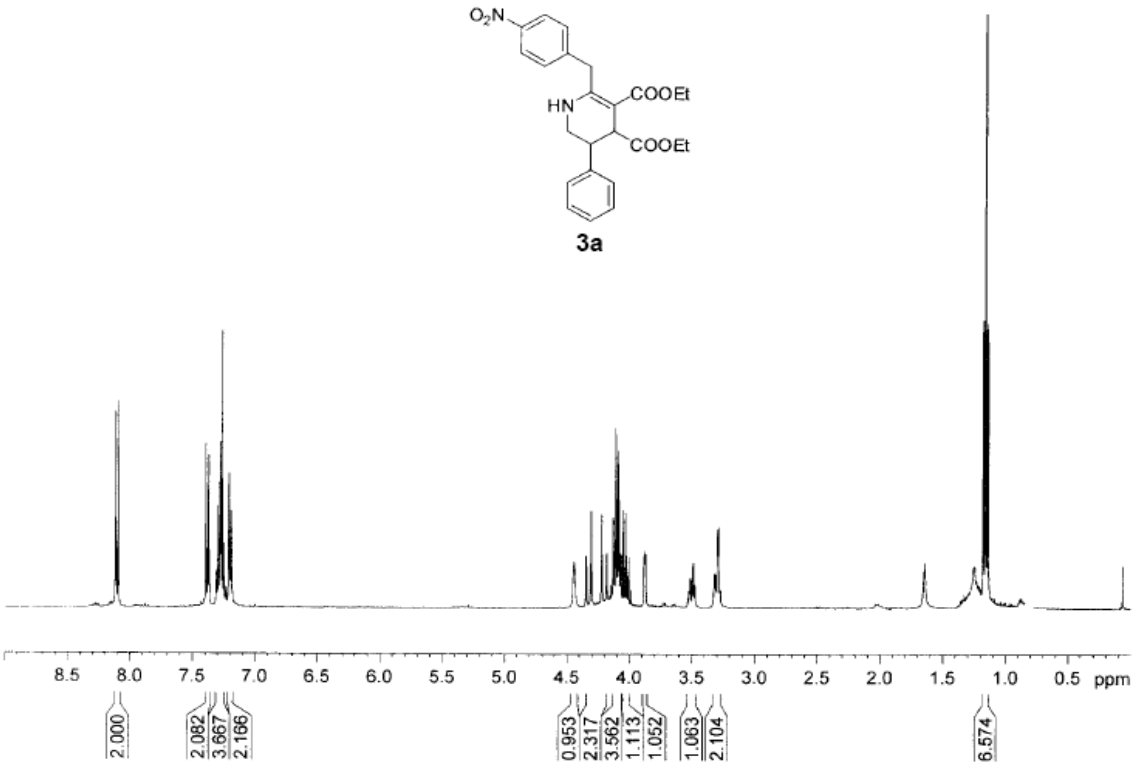

O2N
HN
COOEt
COOEt
Br
3k
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm
2.001
4.189
2.105
0.990
2.396
4.529
1.053
1.039
2.001
6.662
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm

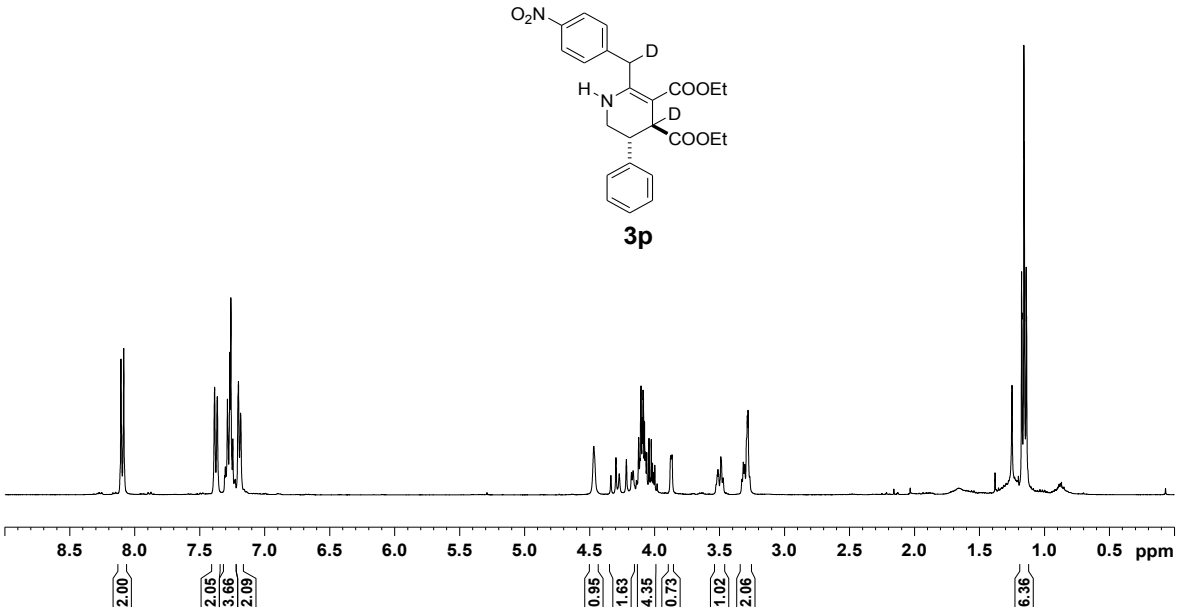

O2N
HN
COOEt
COOEt
Br
3l
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm
2.000
4.185
2.127
1.929
4.531
1.084
1.027
1.059
2.045
6.398
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm

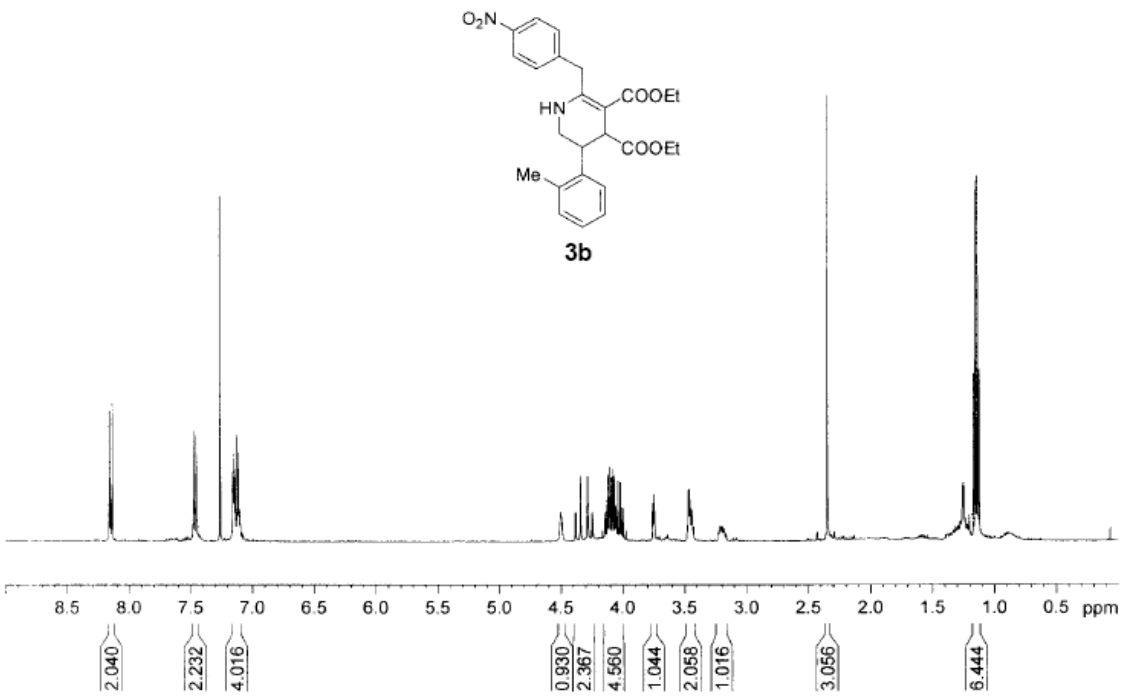

O2N
HN
COOEt
COOEt
3m
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm
2.000 2.291 1.134 1.137 2.308 3.179 0.931 1.131 6.579 1.057 2.136 6.679
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm

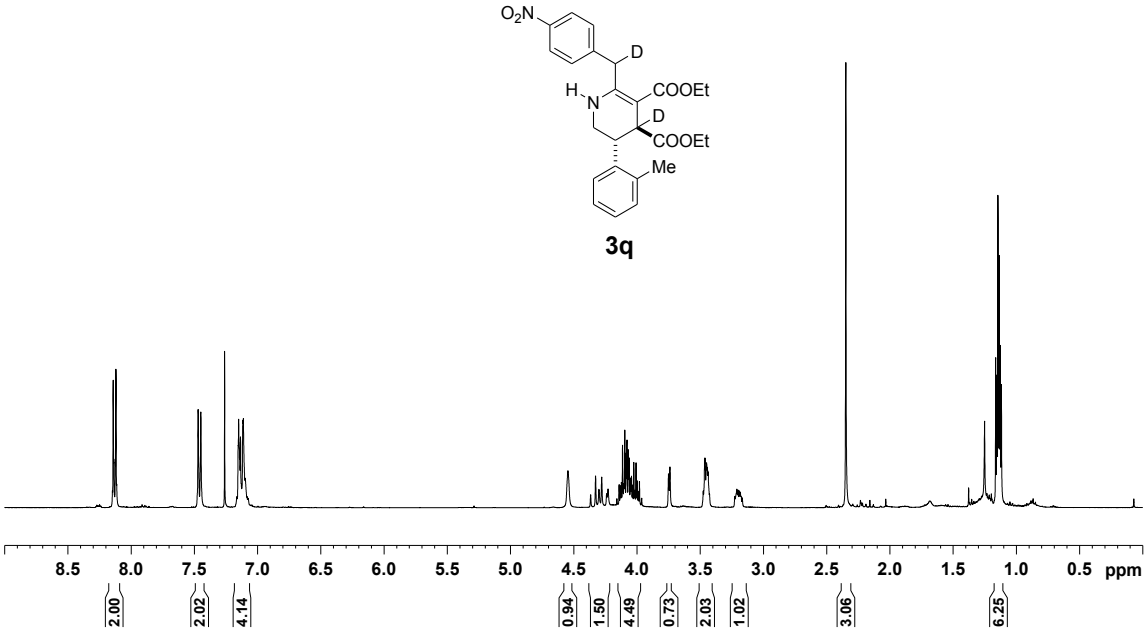

O2N
HN
Me
COOEt
COOEt
3n
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm
2.000
1.988
0.967
5.424
0.886
0.978
1.021
0.968
0.953
3.421
6.042
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm


O2N
HN
COOEt
COOEt
3o
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm
2.000
2.084
0.994
1.033
2.497
3.308
0.992
1.931
1.029
1.060
0.449
4.134
3.313
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm


O2N
HN
COOEt
COOEt
3a
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm
2.000
2.082
3.667
2.166
0.953
2.317
3.562
1.113
1.052
1.063
2.104
6.574

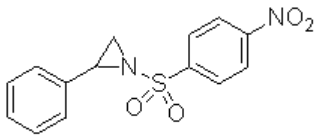

O2N
D
H
N
COOEt
D
COOEt
3p
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm
2.00
2.05
3.66
2.09
0.95
1.63
4.35
0.73
1.02
2.06
6.36


O2N
HN
COOEt
COOEt
Me
3b
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm
2.040
2.232
4.016
0.930
2.367
4.560
1.044
2.058
1.016
3.056
6.444

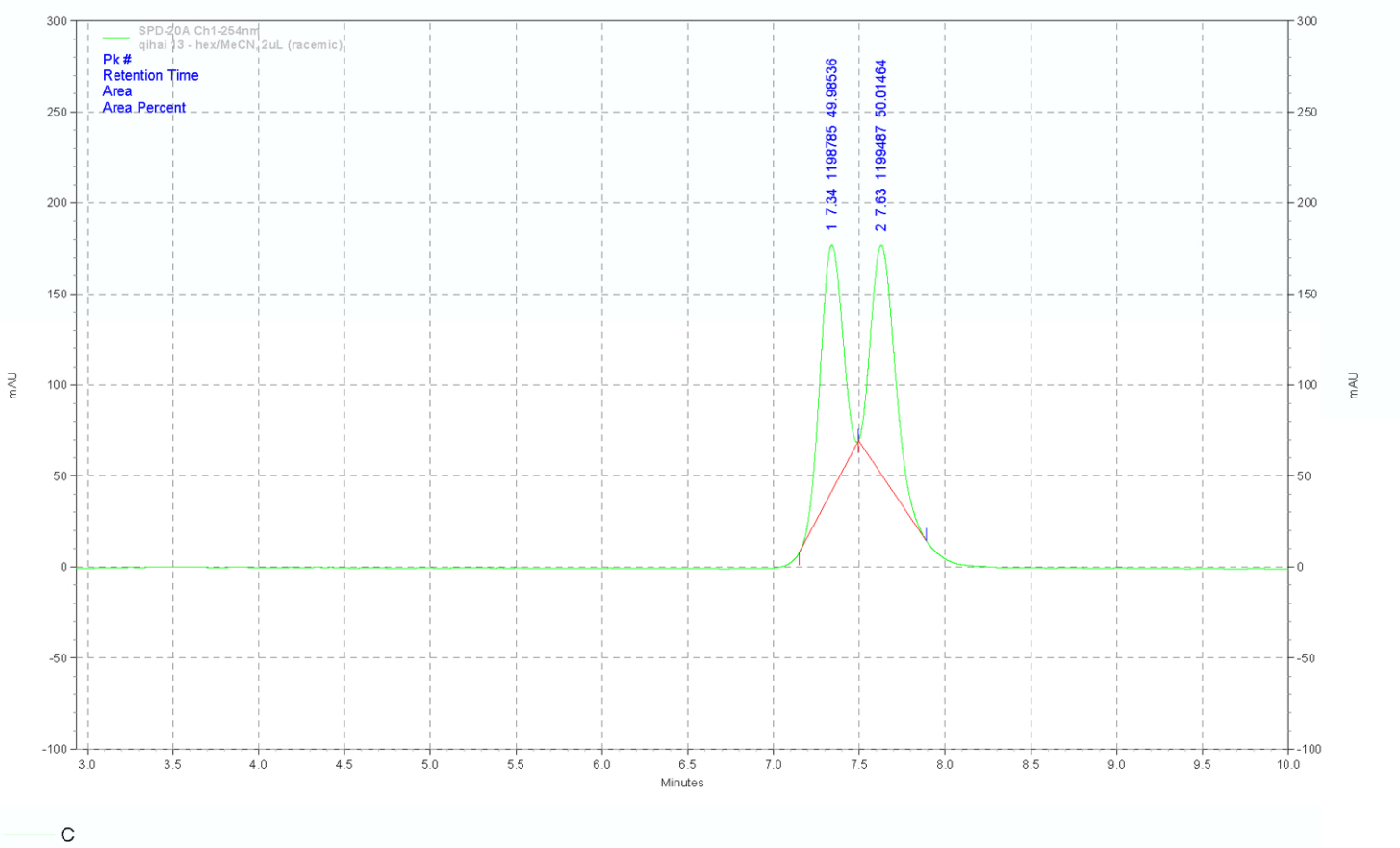

O2N
D
H
N
COOEt
D
COOEt
Me
3q
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 ppm
2.00
2.02
4.14
0.94
1.50
4.49
0.73
2.03
1.02
3.06
6.25

Area % Report

Method Name: C:\EZStart\Projects\Default\Method\qihai 13.met
Data: C:\EZStart\Projects\Default\Data\Qihai\qihai test 13.dat
User: System
Acquired: 3/10/2009 12:27:36 PM
Printed: 3/24/2009 9:39:24 PM



1a (racemic)

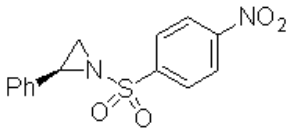


SPD-20A
Ch1-254nm
Results

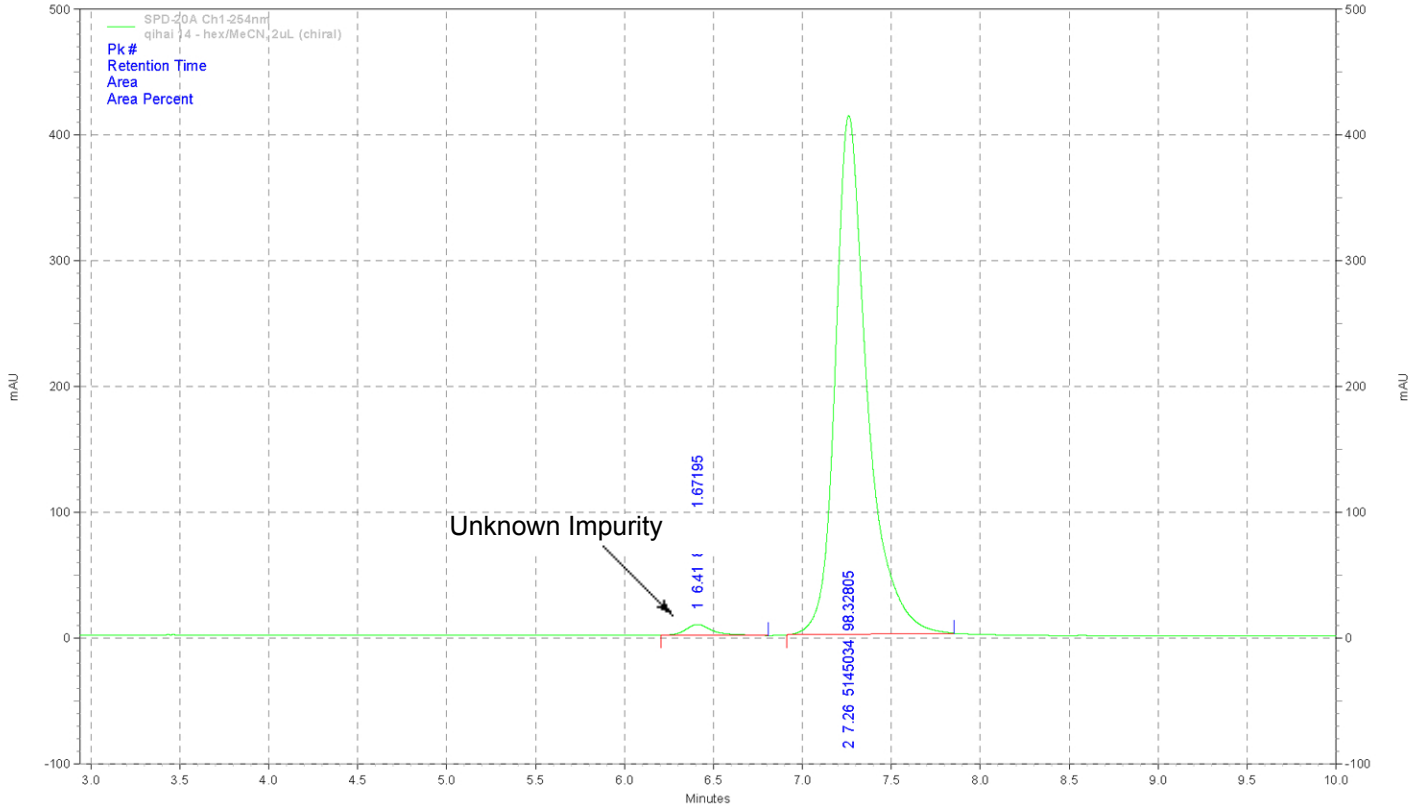
Retention Time	Area	Area %	Height	Height %
7.340	1198785	49.99	135104	51.90
7.627	1199487	50.01	125203	48.10
Totals	2398272	100.00	260307	100.00

Area % Report

Method Name: C:\EZStart\Projects\Default\Method\qihai 14.met
Data: C:\EZStart\Projects\Default\Data\Qihai\qihai test 14.dat
User: System
Acquired: 3/10/2009 12:44:38 PM
Printed: 3/24/2009 9:44:01 PM



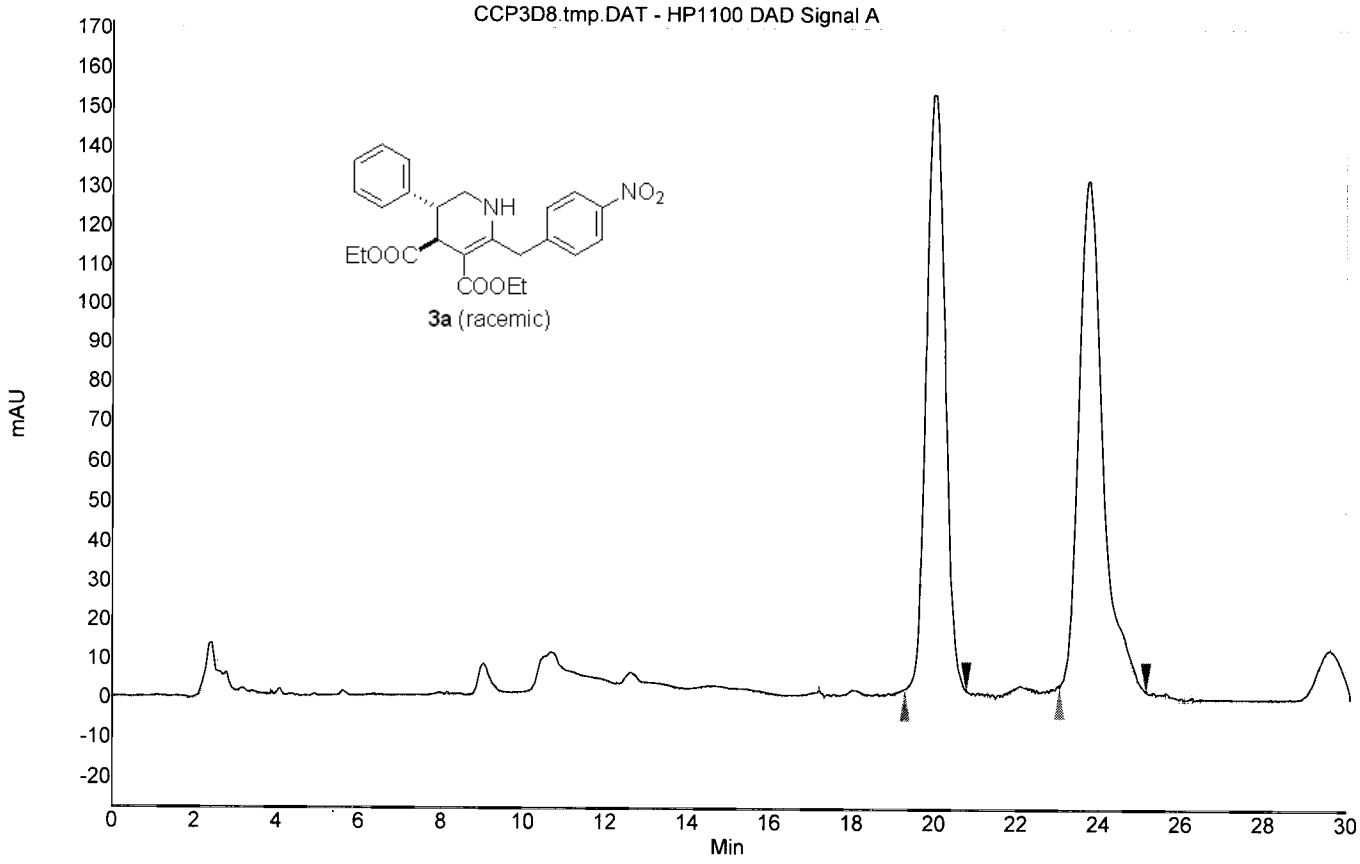
(S)-**1a**



SPD-20A
Ch1-254nm
Results

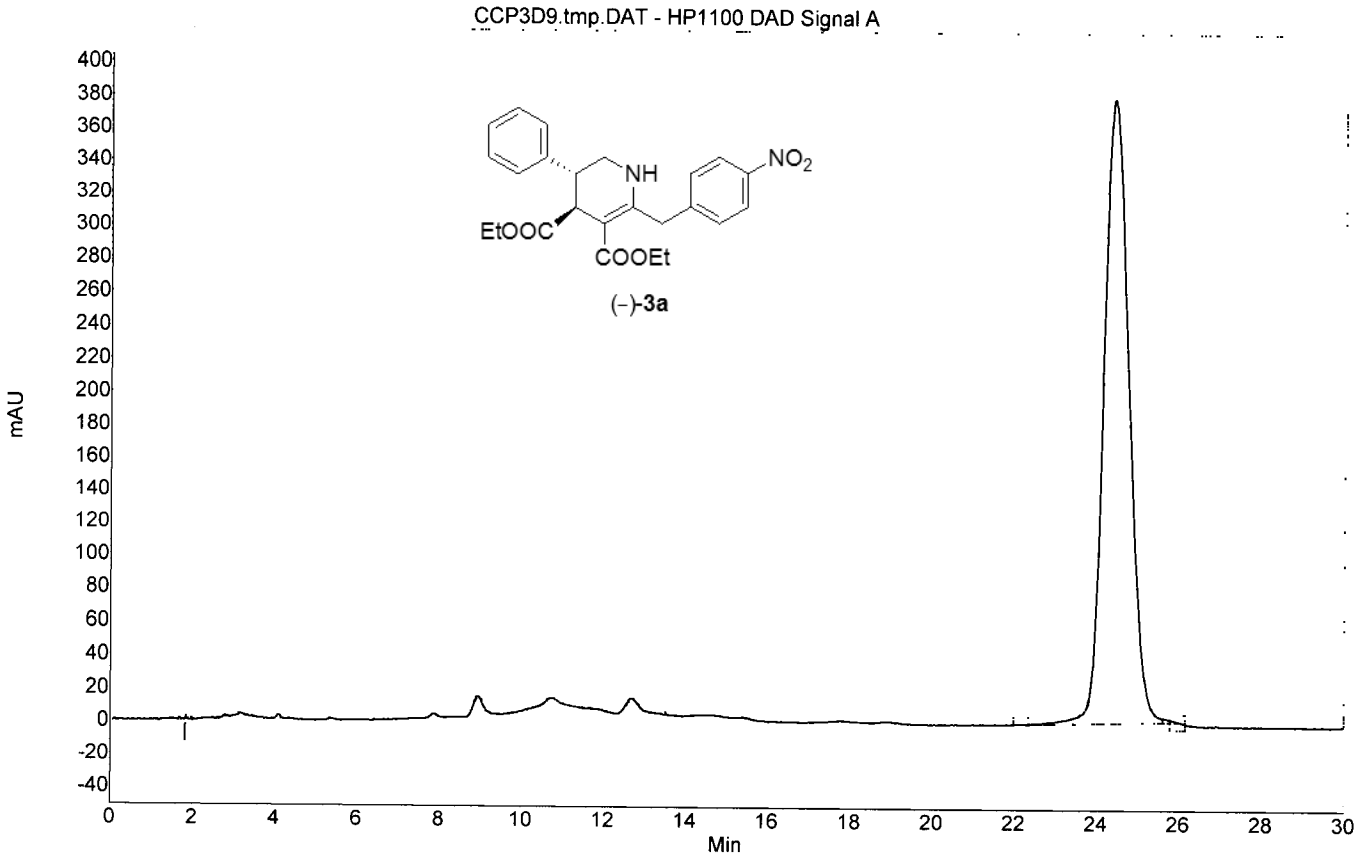
Retention Time	Area	Area %	Height	Height %
6.410	87485	1.67	8608	2.04
7.260	5145034	98.33	412611	97.96
Totals	5232519	100.00	421219	100.00

Date:3/24/2009
Sample:x-0-20
Method Name:zls-1
Run Info:N.A.

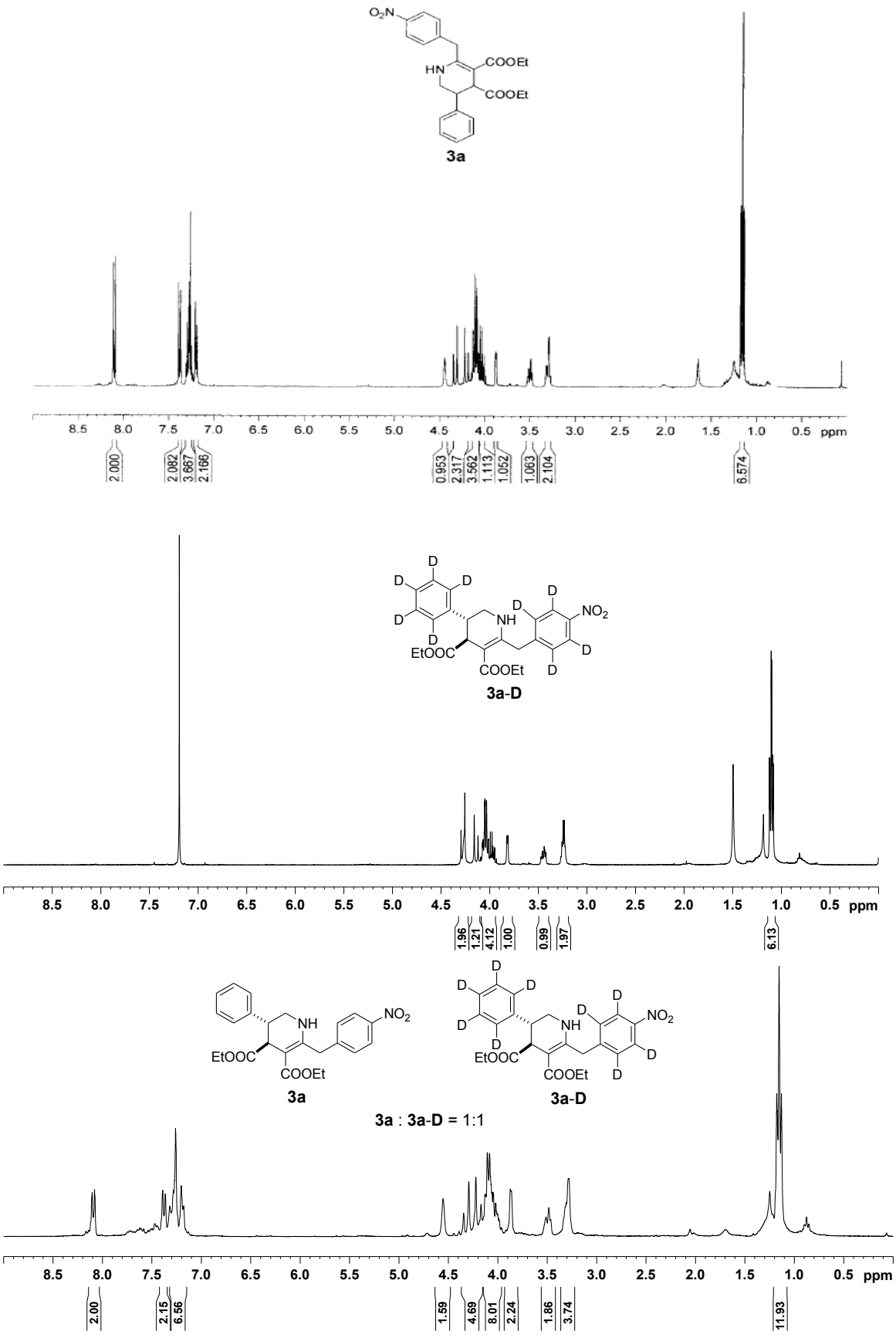


Index	Name	Start	Time	End	RT Offset	Quantity	Height	Area	Area
		[Min]	[Min]	[Min]	[Min]	[% Area]	[µV]	[µV.Min]	[%]
1	UNKNOWN	19.29	20.00	20.78	0.00	46.68	153.0	78.3	46.680
2	UNKNOWN	23.05	23.78	25.16	0.00	53.32	132.2	89.4	53.320
Total						100.00	285.2	167.7	100.000

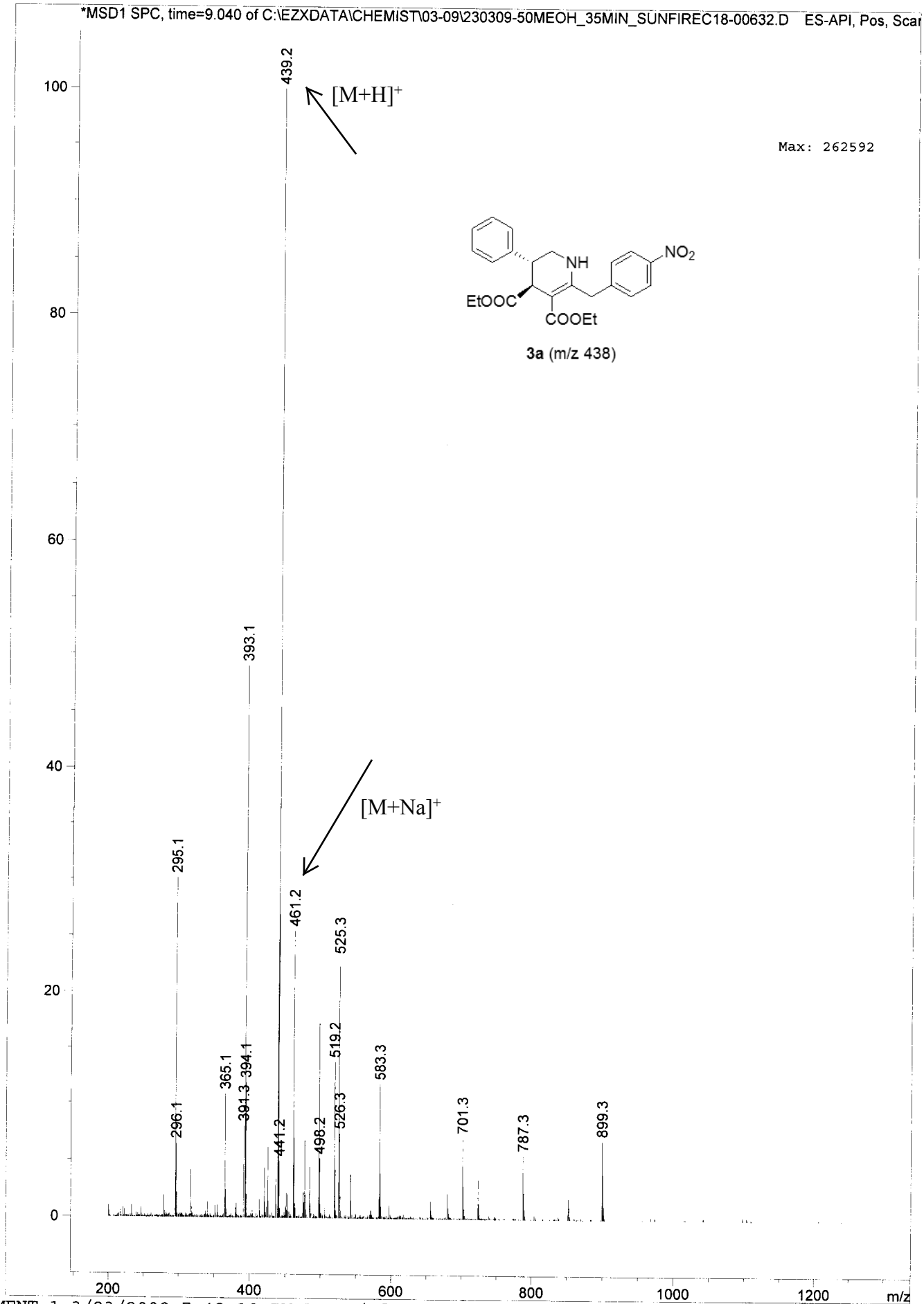
Date:3/24/2009
Sample:x-1-20
Method Name:zls-1
Run Info:N.A.



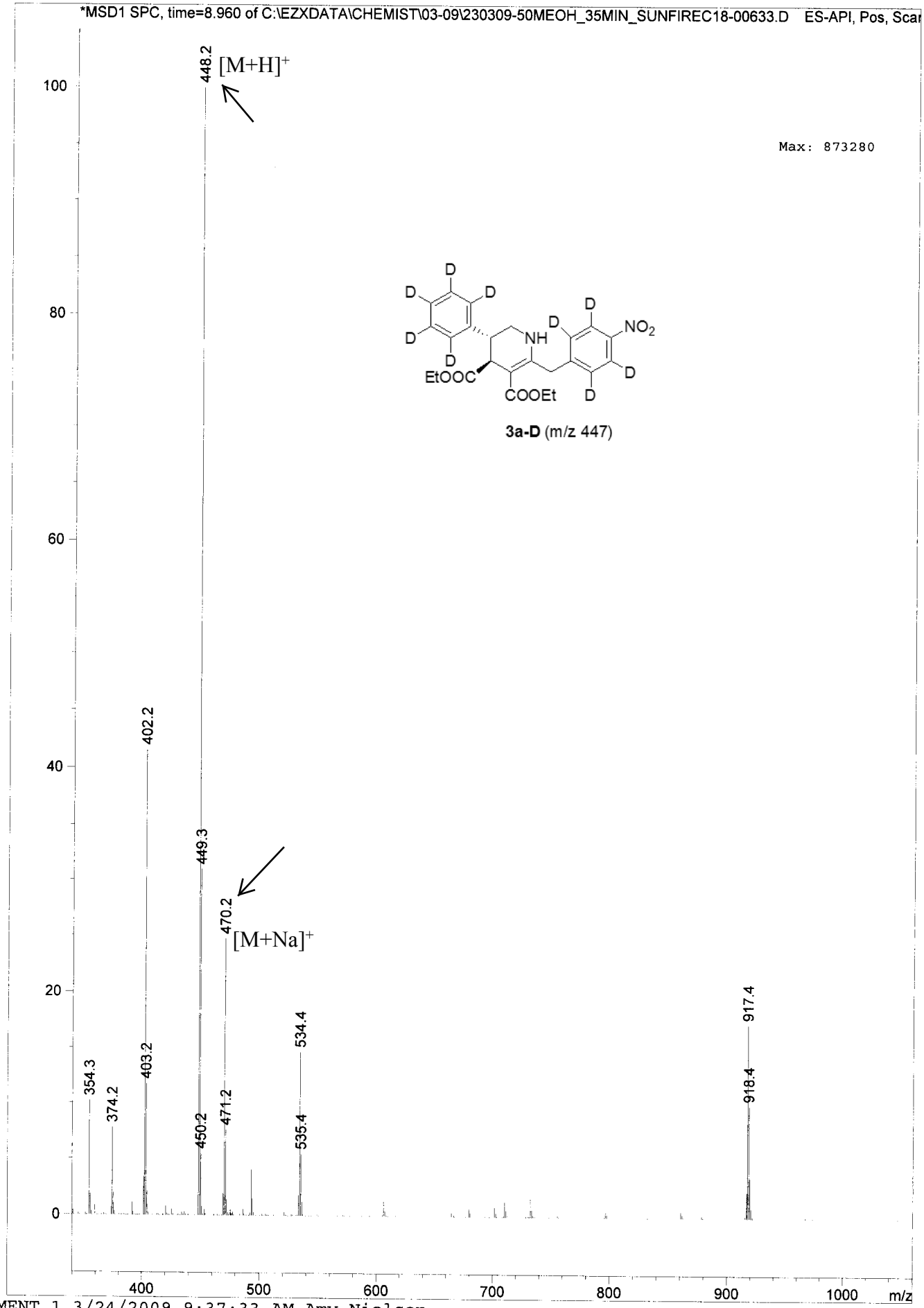
Index	Name	Start	Time	End	RT Offset	Quantity	Height	Area	Area
		[Min]	[Min]	[Min]	[Min]	[% Area]	[µV]	[µV.Min]	[%]
1	UNKNOWN	23.43	24.39	25.61	0.00	100.00	378.3	265.5	100.000
Total						100.00	378.3	265.5	100.000


3a
3a-D
3a : 3a-D = 1:1
ppm

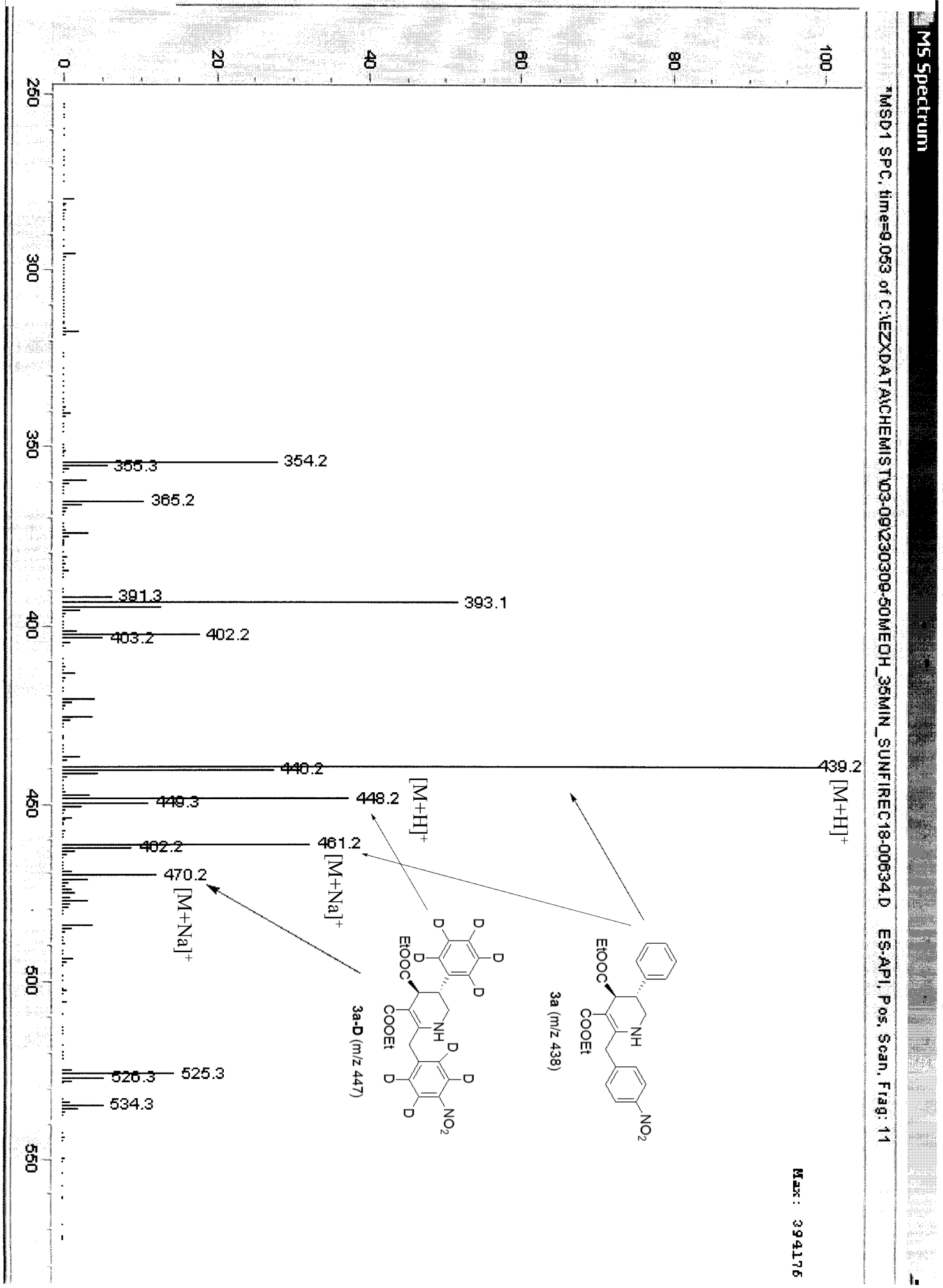
MS Spectrum


*MSD1 SPC, time=9.040 of C:\EZXDATA\CHEMIST\03-09\230309-50MEOH_35MIN_SUNFIREC18-00632.D ES-API, Pos, Scan
Max: 262592
439.2
[M+H]+
[M+Na]+
NH
NO2
EtOOC
COOEt
3a (m/z 438)
393.1
295.1
461.2
525.3
519.2
583.3
365.1
394.1
391.3
296.1
441.2
498.2
526.3
701.3
787.3
899.3
100
80
60
40
20
0
200
400
600
800
1000
1200
m/z

MS Spectrum

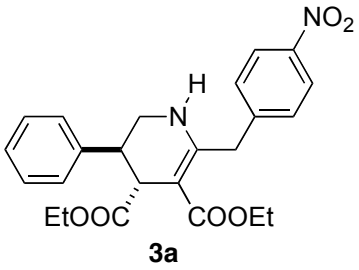


3a-D (m/z 447)

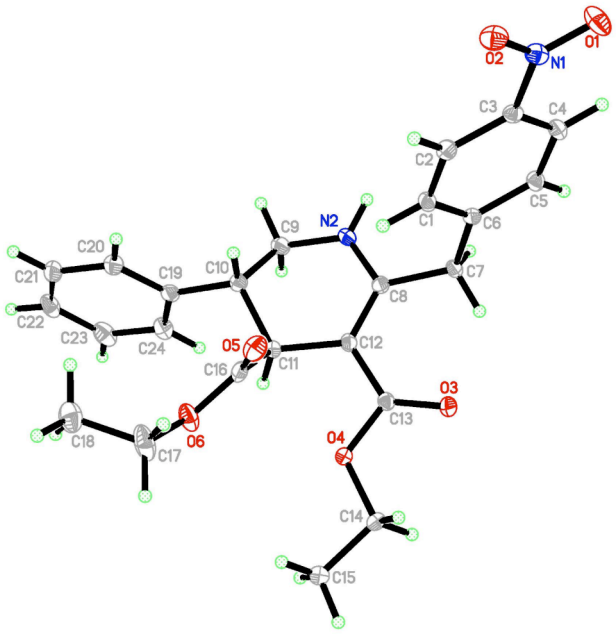

MS Spectrum
*MSD1 SPC, time=9.053 of C:\EZXDATA\CHEMISTRY\03-09\230309-50MEOH_35MIN_SUNFIREC18-00634.D ES-API, Pos, Scan, Frag: 11
Max: 3941176
354.2
355.3
365.2
391.3
393.1
402.2
403.2
439.2
440.2
448.2
449.3
461.2
462.2
470.2
525.3
526.3
534.3
[M+H]+
[M+Na]+
[M+H]+
[M+Na]+
3a (m/z 438)
3a-D (m/z 447)
EtOOC
COOEt
NH
NO2
D

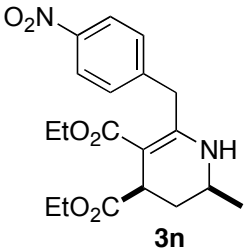
ORTEP Representations of Compounds 3a and 3n

Crystallographic data for **3a** and **3n** have been deposited with the Cambridge Crystallographic Data Centre as supplementary numbers CCDC-713484 and -713485. These data can be obtained online free of charge [or from the Cambridge Crystallographic Data Center, 12, Union Road, Cambridge CB2 1EZ, UK; fax: (+44) 1223-336-033; or deposit@ccdc.cam.ac.uk].



3a





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