Enantioselective dearomatization of isoquinolines by anion-binding catalysis en route to cyclic α-aminophosphonates

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SUPPORTING INFORMATION: PART A

General information: Unless stated otherwise, all reactions were carried out with distilled and dried solvents under an atmosphere of N_2 or argon, oven (120 °C) dried glassware with standard vacuum line techniques were used. Organic solvents used for carrying out reactions were dried using standard methods. All work up and purification were carried out with reagent grade solvents in air. Organometallic reagents were titrated using standard procedure[1] to determine their concentration. Thin-layer chromatography was performed using Merck silica gel 60 F_{254} pre-coated plates (0.25 mm). Column chromatography was performed using silica gel (230-400 or 100-200 mesh). Infrared (FT-IR) spectra were recorded on a Perkin Elmer Spectrum BX spectrophotometer in cm^{-1} and the bands are characterized as broad (br), strong (s), medium (m), and weak (w). NMR spectra were recorded on Bruker Ultrashield spectrometer at 400MHz (^1H) and 100 MHz (^{13}C). Chemical shifts are reported in ppm from tetramethylsilane with the solvent resonance as internal standard ($CDCl_3$: δ 7.26 for ^1H-NMR and $CDCl_3$: δ 77.0 for ^{13}C NMR). For ^1H NMR, data are reported as follows: chemical shift, multiplicity (s = singlet, d = doublet, dd = double doublet, t = triplet, q = quartet, br = broad, m = multiplet), coupling constants (Hz) and integration. High-resolution mass spectrometry was performed on Micromass Q-TOF Micro instrument. Optical rotations were measured on JASCO P-2000 polarimeter. Melting points were measured using ANALAB μ-Thermocal 10 melting point apparatus. All melting points were measured in open glass capillary and values are uncorrected. Enantiomeric ratios were determined by HPLC analysis using chiral columns in comparison with authentic racemic materials. Racemic products were prepared by the reaction of isoquinolines, TrocCl and silyl phosphites at r.t. without any catalyst. Trimethylsilyl chloride was distilled from anh. calcium hydride prior using. Triethyl amine and hexamethyldisilazane (HMDS) was distilled from KOH and stored over 4 Å MS. Isoquinolines **1a**, **1f**, **1l** were obtained from commercial source and used without any purification. Other isoquinolines were prepared as described below. Silyl phosphites were prepared according to the reported literature procedure.[2]

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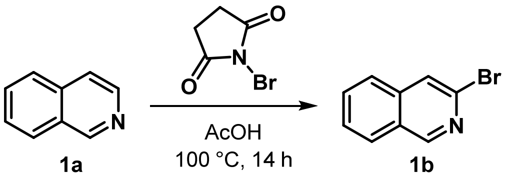
[1] J. Leonard, B. Lygo and G. Procter, *Advanced Practical Organic Chemistry*, 3rd ed.; CRC Press, 2010.

[2] J. Guin, Q. Wang, M. van Gemmeren and B. List, *Angew. Chem., Int. Ed.*, 2015, **54**, 355-358.

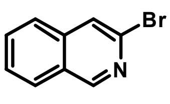
A. Procedure for the synthesis of isoquinolines:

Procedure for the synthesis of 3-bromoisoquinoline (1b):

3-Bromoisoquinoline (**1b**) was prepared according to the modified literature procedure.[3]



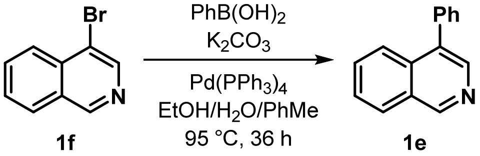
In an oven-dried round-bottom flask equipped with a reflux condenser, isoquinoline **1a** (5.0 g, 38.71 mmol, 1.0 equiv.) was taken in 10 mL glacial acetic acid and *N*-bromo succinimide (7.579 g, 42.58 mmol, 1.1 equiv.) was added portion wise at r.t. The resulting mixture was stirred at 100 °C for 14 h. The reaction mixture was then cooled to r.t. and acetic acid was evaporated in vacuo to obtain a black residue which was taken in $CHCl_3$, washed with water, sat. $NaHCO_3$ solution and sat. $Na_2S_2O_3$ solution. The organic layer was dried over anh. Na_2SO_4, concentrated in vacuo to obtain a red oil which was purified by silica gel column chromatography using 10% EtOAc in petroleum ether as eluent to obtain 3-bromoisoquinoline **1b** as a yellow oil.


1b

Purification by silica gel (100-200 mesh) column chromatography (10% EtOAc in petroleum ether) afforded pure **1b** as a yellow oil (520 mg, 2.499 mmol; 6% yield); **^{1}H-NMR (400 MHz, $CDCl_3$):** δ 9.16 (s; 1H), 8.72 (s; 1H), 8.15 (d, *J* = 8.4 Hz; 1H), 7.97 (d, *J* = 8.1 Hz; 1H), 7.82 (t, *J* = 7.9 Hz; 1H), 7.68 (t, *J* = 7.9 Hz; 1H); **^{13}C-NMR (100 MHz, $CDCl_3$):** δ 151.7, 144.7, 134.7, 131.7, 129.7, 128.2, 127.8, 125.9, 119.6; **HRMS (ESI+):** Calculated for C_9H_6BrNH ($[M + H]^+$): 207.9762, found: 207.9763.

Representative procedure for the synthesis of arylisoquinolines: Preparation of 4-phenylisoquinoline 1e:

4-Phenylisoquinoline **1e** was prepared according to the modified literature procedure.[4]



In an oven-dried round-bottom flask, 4-bromoisoquinoline **1f** (500 mg, 2.403 mmol, 1.0 equiv.) was taken in a mixture of 2.5 mL EtOH, 5 mL water and 10 mL toluene and degassed for

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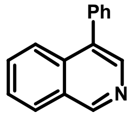
[3] S. A. Kulkarni, *Patent* WO2012090179, 2012.

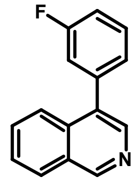
[4] R. B. Miller and J. J. Svoboda, *Synthetic Commun.*, 1994, **24**, 1187-1193.

20 min. To the resulting mixture, phenylboronic acid (440 mg, 3.605 mmol, 1.5 equiv.), K_2CO_3 (1.328 g, 9.612 mmol, 4.0 equiv.) and $Pd(PPh_3)_4$ (139 mg, 0.120 mmol, 0.05 equiv.) were added successively at r.t. The resulting mixture was stirred at 95 °C under positive argon pressure for 36 h. The reaction mixture was cooled to r.t., quenched with sat. NH_4Cl solution, extracted with CH_2Cl_2. The combined organic layer was dried over anh. Na_2SO_4, concentrated in vacuo to obtain a black oil which was purified by silica gel column chromatography using 20-40% EtOAc in petroleum ether as eluent to obtain 4-phenylisoquinoline **1e** as a yellow oil.



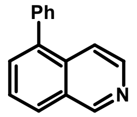
1e

Purification by silica gel (100-200 mesh) column chromatography (20-40% EtOAc in petroleum ether) afforded pure **1e** as a yellow oil (450 mg, 2.192 mmol; 91% yield); **^{1}H-NMR (400 MHz, $CDCl_3$):** δ 9.26 (s; 1H), 8.50 (s; 1H), 8.05 (d, *J* = 8.0 Hz; 1H), 7.92 (d, *J* = 8.0 Hz; 1H), 7.61-7.69 (m; 2H), 7.46-7.56 (m; 5H); **^{13}C-NMR (100 MHz, $CDCl_3$):** δ 151.9, 142.7, 136.9, 134.1, 133.2, 130.5, 130.0, 128.5, 128.4, 127.9, 127.8, 127.1, 124.7; **HRMS (ESI+):** Calculated for $C_{15}H_{11}NH$ ($[M + H]^+$): 206.0970, found: 206.0975.



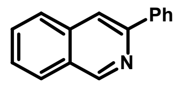
1h

Purification by silica gel (100-200 mesh) column chromatography (50% EtOAc in petroleum ether) afforded pure **1h** as a light yellow oil (300 mg, 1.344 mmol; 93% yield); **^{1}H-NMR (400 MHz, $CDCl_3$):** δ 9.28 (s; 1H), 8.48 (s; 1H), 8.05 (d, *J* = 8.0 Hz; 1H), 7.89 (d, *J* = 8.3 Hz; 1H), 7.63-7.72 (m; 2H), 7.49 (q, *J* = 7.4 Hz; 1H), 7.30 (d, *J* = 7.4 Hz; 1H), 7.23 (d, *J* = 9.7 Hz; 1H), 7.16-7.20 (m; 1H); ^{13}C**-NMR (100 MHz, $CDCl_3$):** δ 164.0, 161.6, 152.4, 142.8, 139.2 (d, *J* = 7.6 Hz), 133.9, 130.8, 130.2 (d, *J* = 8.6 Hz), 128.4, 128.0, 127.3, 125.8 (d, *J* = 2.9 Hz), 124.4, 117.1 (d, *J* = 21.6 Hz), 115.0, 114.8; **HRMS (ESI+):** Calculated for $C_{15}H_{10}FNH$ ($[M + H]^+$): 224.0876, found: 224.0878.



1n

Purification by silica gel (100-200 mesh) column chromatography (20-40% EtOAc in petroleum ether) afforded pure **1n** as a yellow oil (245 mg, 1.194 mmol; 83% yield); **^{1}H-NMR (400 MHz, $CDCl_3$):** δ 9.29 (s; 1H), 8.47 (d, *J* = 6.0 Hz; 1H), 7.92-7.95 (m; 1H), 7.70 (d, *J* = 6.0 Hz; 1H), 7.60-7.61 (m; 2H), 7.43-7.50 (m; 5H); **^{13}C-NMR (100 MHz, $CDCl_3$):** δ 152.7, 143.1, 139.0, 138.8, 133.9, 130.7, 129.7, 128.8, 128.4, 127.6, 127.0, 126.6, 118.3; **HRMS (ESI+):** Calculated for $C_{15}H_{11}NH$ ($[M + H]^+$): 206.0970, found: 206.0968.



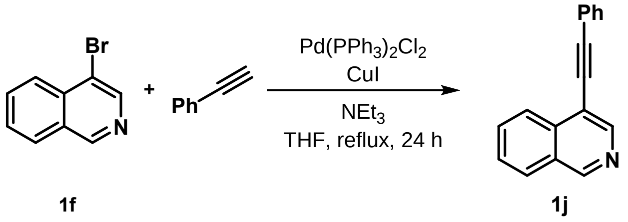
1c

Purification by silica gel (100-200 mesh) column chromatography (15-20% EtOAc in petroleum ether) afforded pure **1c** as a red oil (160 mg, 0.779 mmol; 78% yield); **^{1}H-NMR (400 MHz, $CDCl_3$):** δ 9.26 (s; 1H), 8.50 (s; 1H), 8.03 (d, *J* = 7.9 Hz; 1H), 7.91 (d, *J* = 8.3 Hz; 1H), 7.59-7.67 (m; 2H), 7.45-7.54 (m; 5H); **^{13}C-NMR (100 MHz,**

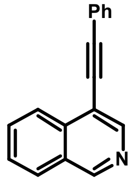
$CDCl_3$): δ 151.9, 142.8, 136.9, 134.1, 133.2, 128.5, 128.3, 127.84, 127.78, 127.1, 124.7; **HRMS (ESI+):** Calculated for $C_{15}H_{11}NH$ ($[M + H]^+$): 206.0970, found: 206.0970.

Representative procedure for the synthesis of phenylethynylisoquinoline: Preparation of 4-(phenylethynyl)isoquinoline 1j:

4- (Phenylethynyl)isoquinoline **1j** was prepared according to the modified literature procedure.[5]



In an oven-dried 2-neck round-bottom flask equipped with a reflux condenser and an argon inlet, 4-bromoisoquinoline **1f** (300 mg, 1.442 mmol, 1.0 equiv.), $Pd(PPh_3)_2Cl_2$ (20.2 mg, 0.028 mmol, 0.02 equiv.) and copper (I) iodide (2.7 mg, 0.014 mmol, 0.01 equiv.) were taken in 3 mL THF and degassed for 20 min. To the resulting mixture, triethyl amine (1.2 mL, 8.652 mmol, 6.0 equiv.) was added and the resulting mixture was allowed to reflux. Phenylacetylene (0.16 mL, 1.442 mmol, 1.0 equiv.) in 3 mL THF was added while refluxing and refluxing was continued for another 24 h. The reaction mixture was then cooled to r.t., diluted with Et_2O, washed with sat. aqueous $NaHCO_3$ solution. The combined organic layer was dried over anh. Na_2SO_4, concentrated in vacuo to obtain a brown oil which was purified by silica gel column chromatography using 15% EtOAc in petroleum ether as eluent to obtain 4-(phenylethynyl)isoquinoline **1j** as a red oil.



1j

Purification by silica gel (100-200 mesh) column chromatography (15% EtOAc in petroleum ether) afforded pure **1j** as a red oil (200 mg, 0.872 mmol; 60% yield); **^{1}H-NMR (400 MHz, $CDCl_3$):** δ 9.20 (s; 1H), 8.77 (s; 1H), 8.34 (d, *J* = 8.5 Hz; 1H), 8.00 (d, *J* = 8.1 Hz; 1H), 7.79-7.83 (m; 1H), 7.65-7.69 (m; 3H), 7.40-7.42 (m; 3H); **^{13}C-NMR (100 MHz, $CDCl_3$):** δ 151.9, 146.4, 135.6, 131.7, 131.1, 128.8, 128.5, 127.91, 127.87, 127.80, 125.1, 122.8, 116.0; **HRMS (ESI+):** Calculated for $C_{17}H_{11}NH$ ($[M + H]^+$): 230.0970, found: 230.0967.

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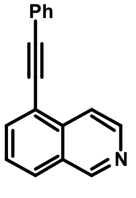
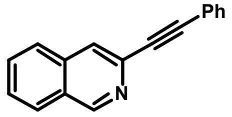
[5] M. Annapurna, T. Parsharamulu, P. Vishnuvardhan Reddy, M. Suresh, P. R. Likhar and M. Lakshmi Kantam, *Appl. Organomet. Chem.*, 2015, **29**, 234-239.



1p

Purification by silica gel (100-200 mesh) column chromatography (20-30% EtOAc in petroleum ether) afforded pure **1p** as a red oil (229 mg, 0.999 mmol; 100% yield); **^{1}H-NMR (400 MHz, CDCl$_3$):** δ 9.28 (s; 1H), 8.64 (d, *J* = 5.6 Hz; 1H), 8.19 (d, *J* = 5.9 Hz; 1H), 7.94-7.98 (m; 2H), 7.64-7.66 (m; 2H), 7.60 (t, *J* = 7.8 Hz; 1H), 7.41-7.43 (m; 3H); **^{13}C-NMR (100 MHz, CDCl$_3$):** δ 152.7, 143.9, 136.0, 134.0, 131.7, 128.8, 128.5, 128.0, 127.7, 126.8, 122.8, 120.3, 118.9, 95.5, 85.8; **HRMS (ESI+):** Calculated for $C_{17}H_{11}NH$ ([M + H]$^+$): 230.0970, found: 230.0975.

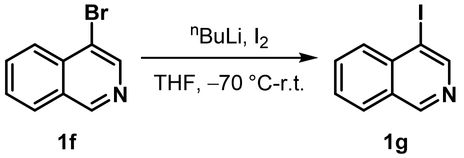


1d

Purification by silica gel (100-200 mesh) column chromatography (10% EtOAc in petroleum ether) afforded pure **1d** as a red oil (100 mg, 0.436 mmol; 44% yield); **^{1}H-NMR (400 MHz, CDCl$_3$):** δ 9.16 (s; 1H), 8.76 (s; 1H), 8.29 (d, *J* = 8.4 Hz; 1H), 7.93 (d, *J* = 8.2 Hz; 1H), 7.73-7.77 (m; 1H), 7.58-7.65 (m; 3H), 7.37-7.41 (m; 3H); **^{13}C-NMR (100 MHz, CDCl$_3$):** δ 151.8, 146.3, 135.3, 131.6, 130.9, 128.7, 128.3, 127.71, 127.69, 127.59, 124.9, 122.6, 115.8, 96.6, 84.4; **HRMS (ESI+):** Calculated for $C_{17}H_{11}NH$ ([M + H]$^+$): 230.0970, found: 230.0969.

Representative procedure for the synthesis of iodoisoquinoline: Preparation of 4-iodoisoquinoline 1g:

4-Iodoisoquinoline **1g** was prepared according to the modified literature procedure.[6]



In an oven-dried 25 mL 2-neck round-bottom flask equipped with an argon inlet, 2.2 M ^{n}BuLi in cyclohexane (2 mL, 4.4 mmol, 2.2 equiv.) was taken in 2 mL THF under positive argon pressure and cooled to -70 °C. 4-Bromoisoquinoline **1f** (416 mg, 2.0 mmol, 1.0 equiv.) in 3 mL THF was added dropwise at -70 °C and the resulting mixture was stirred at -70 °C for 30 min. Then iodine (1.117 g, 4.4 mmol, 2.2 equiv.) in 5 mL THF was added to it at -70 °C and the resulting mixture was stirred at -70 °C for 30 min and then at r.t. for 3 h. The reaction mixture was then diluted with Et_2O, washed with sat. $Na_2S_2O_5$ solution, dried over anh. Na_2SO_4, concentrated in vacuo to obtain a red oil which was purified by silica gel column chromatography using 30% EtOAc in petroleum ether as eluent to obtain 4-iodoisoquinoline **1g** as a yellow solid.

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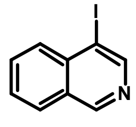
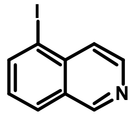
[6] J. A. Zoltewicz, N. M. Maier, S. Lavieri, I. Ghiviriga, K. A. Abboud and W. M. F. Fabian, *Tetrahedron*, 1997, **53**, 5379-5388.



1g

Purification by silica gel (100-200 mesh) column chromatography (30% EtOAc in petroleum ether) afforded pure **1g** as a yellow solid (260 mg, 1.019 mmol; 51% yield); **^{1}H-NMR (400 MHz, CDCl$_3$):** δ 9.14 (s; 1H), 8.94 (s; 1H), 8.00 (d, *J* = 8.6 Hz; 1H), 7.90 (d, *J* = 8.2 Hz; 1H), 7.78-7.81 (m; 1H), 7.65-7.69 (m; 1H); **^{13}C-NMR (100 MHz, CDCl$_3$):** δ 152.6, 151.0, 137.1, 132.0, 130.7, 129.7, 128.3, 128.2, 96.8; **HRMS (ESI+):** Calculated for C_9H_6INH ($[M + H]^+$): 255.9623, found: 255.9625.

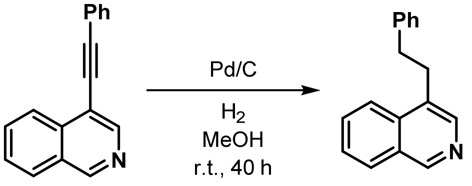


1m

Purification by silica gel (100-200 mesh) column chromatography (25% EtOAc in petroleum ether) afforded pure **1m** as a red solid (170 mg, 0.667 mmol; 46% yield); **^{1}H-NMR (400 MHz, CDCl$_3$):** δ 9.13 (s; 1H), 8.63 (d, *J* = 5.9 Hz; 1H), 8.26 (d, *J* = 7.2 Hz; 1H), 7.97 (d, *J* = 8.2 Hz; 1H), 7.83 (d, *J* = 5.9 Hz; 7.34 (t, *J* = 7.8 Hz; 1H); **^{13}C-NMR (100 MHz, CDCl$_3$):** δ 153.0, 144.9, 141.3, 137.5, 129.4, 128.4, 128.3, 124.1, 97.6; **HRMS (ESI+):** Calculated for C_9H_6INH ($[M + H]^+$): 255.9623, found: 255.9628.

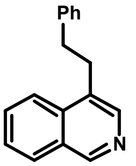
Representative procedure for the synthesis of phenethylisoquinoline: Preparation of 4-phenethylisoquinoline 1i:

4-Phenethylisoquinoline **1i** was prepared according to the modified literature procedure.[7]



1j 1i

In an oven-dried 2-neck round-bottom flask, 4- (phenylethynyl)isoquinoline **1j** (190 mg, 0.829 mmol, 1.0 equiv.) was taken in 3.3 mL MeOH along with 10% Pd/C (88.2 mg, 0.083 mmol, 0.1 equiv.) and stirred at r.t. under positive H_2 pressure for 40 h. Then the reaction mixture was filtered through a celite pad, washed with MeOH and the filtrate was concentrated in vacuo to obtain a yellow oil which was purified by silica gel column chromatography using 20% EtOAc in petroleum ether as eluent to obtain 4-phenethylisoquinoline **1i** as a light yellow oil.



1i

Purification by silica gel (100-200 mesh) column chromatography (20% EtOAc in petroleum ether) afforded pure **1i** as a light yellow oil (110 mg, 0.471 mmol; 90% yield); **^{1}H-NMR (400 MHz, CDCl$_3$):** δ 9.14 (s; 1H), 8.34 (s; 1H), 7.98-8.04 (m; 2H), 7.74 (t, *J* = 7.8 Hz; 1H), 7.61 (t, *J* = 7.7 Hz; 1H), 7.29-7.33 (m; 2H), 7.21-7.24 (m; 3H), 3.33 (t, *J* = 7.5 Hz; 2H), 3.05 (t, *J* = 7.5 Hz; 2H); **^{13}C-NMR (100 MHz,**

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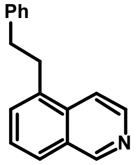
[7] D. E. Minter and M. A. Re, *J. Org. Chem.*, 1988, **53**, 2653-2655.

$CDCl_3$): δ 151.3, 142.7, 141.3, 134.5, 130.6, 130.3, 128.5, 128.39, 128.35, 128.33, 126.8, 126.2, 122.7, 36.8, 32.1; **HRMS (ESI+):** Calculated for $C_{17}H_{15}NH$ ($[M + H]^+$): 234.1283, found: 234.1282.

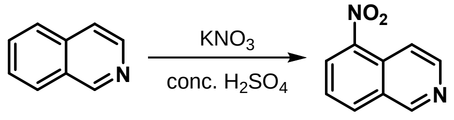


1o

Purification by silica gel (100-200 mesh) column chromatography (20% EtOAc in petroleum ether) afforded pure **1o** as a light yellow oil (120 mg, 0.515 mmol; 62% yield); **^{1}H-NMR (400 MHz, $CDCl_3$):** δ 9.26 (s; 1H), 8.56 (d, *J* = 6.0 Hz; 1H), 7.81-7.86 (m; 2H), 7.47-7.53 (m; 2H), 7.28-7.32 (m; 2H), 7.19-7.24 (m; 3H), 3.35 (t, *J* = 7.6 Hz; 2H), 3.04 (t, *J* = 7.6 Hz; 2H); **^{13}C-NMR (100 MHz, $CDCl_3$):** δ 153.3, 143.1, 141.3, 137.0, 134.5, 130.1, 129.0, 128.5, 128.4, 126.9, 126.20, 126.18, 116.6, 36.9, 34.2; **HRMS (ESI+):** Calculated for $C_{17}H_{15}NH$ ($[M + H]^+$): 234.1283, found: 234.1286.

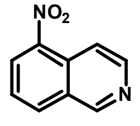
Representative procedure for the synthesis of nitroisoquinoline: Preparation of 5-nitroisoquinoline 1k:

5-Nitroisoquinoline **1k** was prepared according to the modified literature procedure.[8]



1a **1k**

In an oven-dried 50 mL round-bottom flask, isoquinoline **1a** (2 mL, 17.018 mmol, 1.0 equiv.) was taken in 10 mL conc. sulfuric acid at 0 °C and potassium nitrate (1.807 g, 17.869 mmol, 1.05 equiv.) in 10 mL conc. sulfuric acid was added dropwise at 0 °C. The resulting solution was allowed to attain r.t. and stirred at r.t. for 18 h. The reaction mixture was then poured onto ice and basified by the addition of solid NaOH until pH = 9. The resulting solid was filtered off, recrystalized from EtOH to obtain 5-nitroisoquinoline **1k** as a green solid.



1k

Purification by recrytalization from EtOH afforded pure **1k** as a green solid (2.0 g, 11.484 mmol; 67% yield); **^{1}H-NMR (400 MHz, $CDCl_3$):** δ 9.37 (s; 1H), 8.74 (d, *J* = 6.0 Hz; 1H), 8.55 (d, *J* = 7.6 Hz; 1H), 8.47 (d, *J* = 6.0 Hz; 1H), 8.29 (d, *J* = 8.3 Hz; 1H), 7.72 (t, *J* = 8.0 Hz; 1H); **^{13}C-NMR (100 MHz, $CDCl_3$):** δ 153.0, 146.6, 144.5, 134.9, 129.0, 128.4, 128.2, 125.8, 115.8; **HRMS (ESI+):** Calculated for $C_9H_6N_2O_2H$ ($[M + H]^+$): 175.0508, found: 175.0506.

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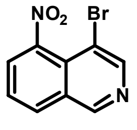
[8] Y. Cheng, L.-K. An, N. Wu, X.-D. Wang, X.-Z. Bu, Z.-S. Huang and L.-Q. Gu, *Bioor. Med. Chem.*, 2008, **16**, 4617-4625.

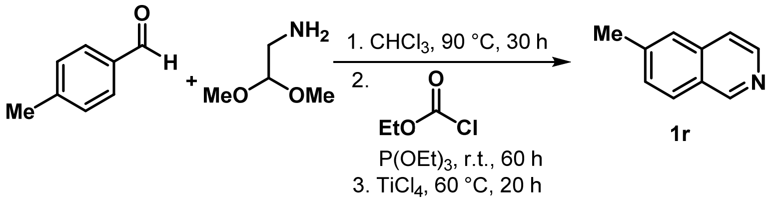


1w

Purification by silica gel (100-200 mesh) column chromatography (40% EtOAc in petroleum ether) afforded pure **1w** as a off-white solid (560 mg, 2.213 mmol; 92% yield); **^{1}H-NMR (400 MHz, CDCl$_3$):** δ 9.27 (s; 1H), 8.86 (s; 1H), 8.21 (d, *J* = 8.4 Hz; 1H), 7.96 (d, *J* = 7.6 Hz; 1H), 7.73 (t, *J* = 7.9 Hz; 1H); **^{13}C-NMR (100 MHz, CDCl$_3$):** δ 152.0, 149.5, 132.1, 130.4, 127.1, 127.0, 125.4, 113.2; **HRMS (ESI+):** Calculated for $C_9H_5BrN_2O_2H$ ($[M + H]^+$): 252.9613, found: 252.9614.

Representative procedure for the synthesis of isoquinolines: Preparation of 6-methylisoquinoline 1r:

6-Methylisoquinoline **1r** was prepared according to the modified literature procedure.[9]



In an oven-dried 25 mL 2-neck round-bottom flask equipped with a reflux condenser and an argon inlet, 4-methylbenzaldehyde (460 mg, 3.824 mmol, 1.0 equiv.) and aminoacetaldehyde dimethyl acetal (0.5 mL, 4.589 mmol, 1.2 equiv.) was taken in 9 mL $CHCl_3$ under positive argon pressure and refluxed at 90 °C for 30 h. Then the resulting mixture was cooled to 0 °C and ethyl chloroformate (0.44 mL, 4.589 mmol, 1.2 equiv.) was added followed by the addition of triethyl phosphite (0.92 mL, 5.354 mmol, 1.4 equiv.) at 0 °C. The resulting solution was allowed to attain r.t. and stirred at r.t. for 60 h. Then the resulting mixture was cooled to 0 °C and 1 M $TiCl_4$ solution in CH_2Cl_2 (16.06 mL, 16.061 mmol, 4.2 equiv.) was added dropwise over a period of 15 min at 0 °C. The resulting mixture was refluxed for 20 h. The reaction mixture was cooled to 0 °C and quenched by the careful addition of ice-water. The organic layer was discarded and the aqueous layer was washed with CH_2Cl_2. The aqueous layer was basified with sat. aqueous solution of NaK-tartarate until pH = 8 and extracted with CH_2Cl_2. The combined organic layer was dried over anh. Na_2SO_4, concentrated in vacuo to obtain 6-methylisoquinoline **1r** as a brown solid.

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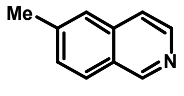
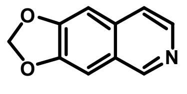
[9] A. L. Smith, F. F. DeMorin, N. A. Paras, Q. Huang, J. K. Petkus, E. M. Doherty, T. Nixey, J. L. Kim, D. A. Whittington, L. F. Epstein, M. R. Lee, M. J. Rose, C. Babij, M. Fernando, K. Hess, Q. Le, P. Beltran and J. Carnahan, *J. Med. Chem.*, 2009, **52**, 6189-6192.



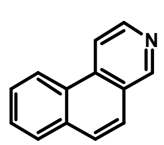
1r

Obtained as a brown solid (300 mg, 2.095 mmol; 55% yield) which was used for catalytic reaction without further purification; **^{1}H-NMR (400 MHz, CDCl$_3$):** δ 9.19 (s; 1H), 8.47 (d, *J* = 5.7 Hz; 1H), 7.87 (d, *J* = 8.3 Hz; 1H), 7.59 (s; 1H), 7.56 (d, *J* = 5.7 Hz; 1H), 7.44 (d, *J* = 8.3 Hz; 1H), 2.55 (s; 3H); **^{13}C-NMR (100 MHz, CDCl$_3$)**: δ 152.0, 142.9, 140.8, 136.1, 129.5, 127.4, 125.3, 120.0, 22.0; **HRMS (ESI+):** Calculated for $C_{10}H_9NH$ ([M + H]$^+$): 144.0813, found: 144.0813.



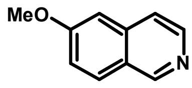
1x

Obtained as a yellow solid (50 mg, 0.289 mmol; 8% yield) which was used for catalytic reaction without further purification; **^{1}H-NMR (400 MHz, CDCl$_3$):** δ 8.99 (s; 1H), 8.36 (d, *J* = 5.5 Hz; 1H), 7.48 (d, *J* = 5.5 Hz; 1H), 7.19 (s; 1H), 7.07 (s; 1H), 6.10 (s; 2H); **^{13}C-NMR (100 MHz, CDCl$_3$):** δ 150.9, 150.2, 148.3, 142.1, 134.2, 125.9, 120.0, 103.1, 102.4, 101.5; **HRMS (ESI+):** Calculated for $C_{10}H_7NO_2H$ ([M + H]$^+$): 174.0555, found: 174.0558.



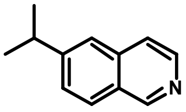
1v

Obtained as a black oil (70 mg, 0.391 mmol; 10% yield) which was used for catalytic reaction without further purification; **^{1}H-NMR (400 MHz, CDCl$_3$):** δ 10.06 (s; 1H), 8.81 (d, *J* = 8.3 Hz; 1H), 8.71 (d, *J* = 4.7 Hz; 1H), 7.94-7.96 (m; 2H), 7.66-7.77 (m; 4H); **^{13}C-NMR (100 MHz, CDCl$_3$):** δ 146.6, 144.9, 135.8, 132.1, 131.6, 129.2, 128.8, 127.8, 124.7, 121.9, 121.1; **HRMS (ESI+):** Calculated for $C_{13}H_9NH$ ([M + H]$^+$): 180.0813, found: 180.0813.



1q

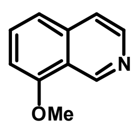
Obtained as a red viscous oil (440 mg, 2.764 mmol; 72% yield) which was used for catalytic reaction without further purification; **^{1}H-NMR (400 MHz, CDCl$_3$):** δ 9.10 (s; 1H), 8.44 (d, *J* = 5.8 Hz; 1H), 7.85 (d, *J* = 8.9 Hz; 1H), 7.54 (d, *J* = 5.8 Hz; 1H), 7.21-7.24 (m; 1H), 7.05-7.06 (m; 1H), 3.95 (s; 3H); **^{13}C-NMR (100 MHz, CDCl$_3$):** δ 160.9, 151.6, 143.5, 137.7, 129.3, 124.5, 120.3, 119.7, 104.0, 55.4; **HRMS (ESI+):** Calculated for $C_{10}H_9NOH$ ([M + H]$^+$): 160.0762, found: 160.0761.



1s

Obtained as a red viscous oil (120 mg, 0.701 mmol; 18% yield) which was used for catalytic reaction without further purification; **^{1}H-NMR (400 MHz, CDCl$_3$):** δ 9.19 (s; 1H), 8.48 (d, *J* = 5.8 Hz; 1H), 7.90 (d, *J* = 8.5 Hz; 1H), 7.61 (s; 1H), 7.59 (d, *J* = 5.8 Hz; 1H), 7.51 (d, *J* = 8.5 Hz; 1H), 3.06-3.13 (m; 1H), 1.35 (d, *J* = 6.9 Hz; 6H); **^{13}C-NMR (100 MHz, CDCl$_3$):** δ 152.0, 151.3, 143.0, 136.2, 127.6, 127.2, 122.6, 120.3, 34.5, 23.6; **HRMS (ESI+):** Calculated for $C_{12}H_{13}NH$ ([M + H]$^+$): 172.1126, found: 172.1120.

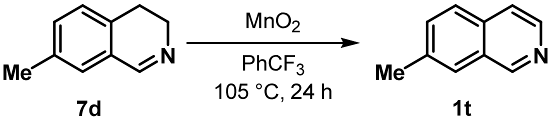
Obtained as a red oil (370 mg, 2.324 mmol; 53% yield) which was used for catalytic reaction without further purification; **^{1}H-NMR (400 MHz, CDCl$_3$):** δ 9.62 (s; 1H), 8.52 (d, *J* = 5.7 Hz; 1H), 7.55-7.59 (m; 2H), 7.35 (d, *J* = 8.4 Hz; 1H), 6.88 (d, *J* = 7.9 Hz; 1H), 4.02 (s; 3H); **^{13}C-NMR (100 MHz, CDCl$_3$):** δ 156.4, 147.6, 143.6, 136.9, 130.9, 120.8, 119.8, 118.4, 105.1, 55.6; **HRMS (ESI+):** Calculated for $C_{10}H_9NOH$ ([M + H]$^+$): 160.0762, found: 160.0761.



1u

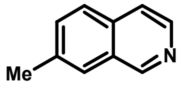
Representative procedure for the synthesis of 7-substituted isoquinolines: Preparation of 7-methylisoquinoline 1t:

7-Methylisoquinoline **1t** was prepared according to the modified literature procedure.[10]



In an oven-dried 10 mL round-bottom flask equipped with a reflux condenser and an argon inlet, 7-methyl-3,4-dihydroisoquinoline **7d** (110 mg, 0.758 mmol, 1.0 equiv.) was taken in 8.8 mL PhCF$_3$ and MnO$_2$ (659 mg, 7.58 mmol, 10.0 equiv.) was added. The resulting heterogeneous mixture was stirred at 105 °C for 24 h and the reaction mixture was then cooled to r.t., filtered through a celite pad, washed with CH$_2$Cl$_2$. The combined filtrate was dried over anh. Na$_2$SO$_4$, concentrated in vacuo to obtain a yellow oil which was purified by silica gel column chromatography using 20% EtOAc in petroleum ether as eluent to obtain 7-methylisoquinoline **1t** as a light yellow oil.

Purification by silica gel (100-200 mesh) column chromatography (20% EtOAc in petroleum ether) afforded pure **1t** as a light yellow oil (29 mg, 0.203 mmol; 27% yield); **^{1}H-NMR (400 MHz, CDCl$_3$):** δ 9.16 (s; 1H), 8.50 (d, *J* = 5.7 Hz; 1H), 7.69-7.70 (m; 2H), 7.58 (d, *J* = 5.7 Hz; 1H), 7.50 (d, *J* = 8.5 Hz; 1H), 2.53 (s; 3H); **^{13}C-NMR (100 MHz, CDCl$_3$):** δ 151.8, 142.2, 137.1, 134.0, 132.5, 128.8, 126.3, 126.2, 120.1, 21.7; **HRMS (ESI+):** Calculated for $C_{10}H_9NH$ ([M + H]$^+$): 144.0813, found: 144.0812.



1t

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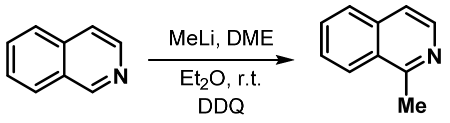
[10] J. Shi, G. Manolikakes, C.-H. Yeh, C. A. Guerrero, R. A. Shenvi, H. Shigehisa and P. S. Baran, *J. Am. Chem. Soc.*, 2011, **133**, 8014-8027.

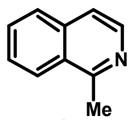
Representative procedure for the synthesis of 1-substituted isoquinolines: Preparation of 1-methylnitroisoquinoline 1y:

1-Methylisoquinoline **1y** was prepared according to the modified literature procedure.[11]



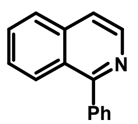
1a **1y**

In an oven-dried 100 mL 2-neck round-bottom flask equipped with an argon inlet, isoquinoline **1a** (1 mL, 8.50 mmol, 1.0 equiv.) and dimethoxyethane (0.89 mL, 8.50 mmol, 1.0 equiv.) was taken in 40 mL Et_2O and 3 M MeLi solution in diethoxymethane (3.4 mL, 10.21 mmol, 1.2 equiv.) was added. The resulting orange colored solution was stirred at r.t. for 3.5 h and MeOH (0.69 mL, 17.0 mmol, 2.0 equiv.) was added. DDQ (1.930 g, 8.50 mmol, 1.0 equiv.) was then added and the resulting mixture was stirred as r.t. for 14 h. To the reaction mixture, 40 mL water was added and extracted with Et_2O. The combined organic layer was dried over anh. Na_2SO_4, concentrated in vacuo to obtain a red oil which was purified by silica gel column chromatography using EtOAc as eluent to obtain 1-methylisoquinoline **1y** as a brown oil.



1y

Purification by silica gel (100-200 mesh) column chromatography (EtOAc) afforded pure **1y** as a brown oil (375 mg, 2.619 mmol; 31% yield); **^{1}H-NMR (400 MHz, $CDCl_3$):** δ 8.38 (d, *J* = 5.8 Hz; 1H), 8.10 (d, *J* = 8.4 Hz; 1H), 7.79 (d, *J* = 8.2 Hz; 1H), 7.64-7.68 (m; 1H), 7.56-7.60 (m; 1H), 7.49 (d, *J* = 5.8 Hz; 1H), 2.96 (s; 3H); **^{13}C-NMR (100 MHz, $CDCl_3$):** δ 158.5, 141.7, 135.8, 129.9, 127.4, 127.1, 127.0, 125.6, 119.2, 22.4; **HRMS (ESI+):** Calculated for $C_{10}H_9NH$ ($[M + H]^+$): 144.0813, found: 144.0815.



1z

Purification by silica gel (100-200 mesh) column chromatography (EtOAc) afforded pure **1z** as a yellow solid (720 mg, 3.508 mmol; 41% yield); **^{1}H-NMR (400 MHz, $CDCl_3$):** δ 8.62 (d, *J* = 5.7 Hz; 1H), 8.11 (d, *J* = 8.5 Hz; 1H), 7.88 (d, *J* = 8.2 Hz; 1H), 7.64-7.72 (m; 4H), 7.48-7.56 (m; 4H); **^{13}C-NMR (100 MHz, $CDCl_3$):** δ 160.7, 142.2, 139.6, 136.8, 130.0, 129.9, 128.5, 128.3, 127.5, 127.1, 127.0, 126.7, 119.9; **HRMS (ESI+):** Calculated for $C_{15}H_{11}NH$ ($[M + H]^+$): 205.0891, found: 205.0890.

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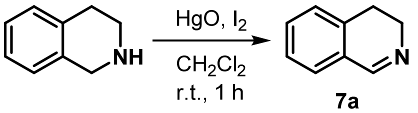
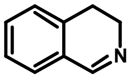
[11] F. Louërat, Y. Fort and V. Mamane, *Tetrahedron Lett.*, 2009, **50**, 5716-5718.

Representative procedure for the synthesis of dihydroisoquinoline: Preparation of 3,4-dihydroisoquinoline 7a:

3,4-Dihydroisoquinoline **7a** was prepared according to the modified literature procedure.[12]

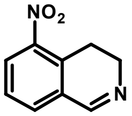


In an oven-dried 100 mL round-bottom flask equipped with an argon inlet, tetrahydroisoquinoline (500 mg, 3.754 mmol, 1.0 equiv.), iodine (1.429 g, 5.631 mmol, 1.5 equiv.) and mercuric oxide (1.220 g, 5.631 mmol, 1.5 equiv.) was taken in 38 mL CH_2Cl_2 under positive argon pressure and stirred at r.t. for 1 h. The reaction mixture was then filtered through a Whatmann filter paper and washed with CH_2Cl_2. The combined filtrate was washed with water, dried over anh. Na_2SO_4, concentrated in vacuo to obtain a brown oil which was purified by silica gel column chromatography using 80% EtOAc in petroleum ether as eluent to obtain 3,4-dihydroisoquinoline **7a** as a brown oil.



7a

Purification by silica gel (100-200 mesh) column chromatography (80% EtOAc in petroleum ether) afforded pure **7a** as a brown oil (456 mg, 3.476 mmol; 93% yield). **^{1}H-NMR (400 MHz, $CDCl_3$):** δ 8.34 (s; 1H), 7.34-7.37 (m; 1H), 7.26-7.32 (m; 2H), 7.16 (d, J = 7.3 Hz; 1H), 3.75-3.80 (m; 2H), 2.75 (t, J = 7.6 Hz; 2H); **^{13}C-NMR (100 MHz, $CDCl_3$):** δ 160.3, 136.3, 131.0, 128.5, 127.4, 127.2, 127.0, 47.3, 25.0; **HRMS (ESI+):** Calculated for C_9H_9NH ($[M + H]^+$): 132.0813, found: 132.0813.



7b

Purification by silica gel (100-200 mesh) column chromatography (60% EtOAc in petroleum ether) afforded pure **7b** as an orange viscous oil (100 mg, 0.568 mmol; 28% yield); **^{1}H-NMR (400 MHz, $CDCl_3$):** δ 8.41 (s; 1H), 8.03 (d; J = 8.0 Hz; 1H), 7.55 (d, J = 7.4 Hz; 1H), 7.47 (t, J = 8.0 Hz; 1H), 3.78-3.83 (m; 2H), 3.09 (t, J = 7.7 Hz; 2H); **^{13}C-NMR (100 MHz, $CDCl_3$):** δ 158.6, 147.6, 131.9, 129.8, 127.6, 126.6, 46.2, 21.4; **HRMS (ESI+):** Calculated for $C_9H_8N_2O_2H$ ($[M + H]^+$): 177.0664, found: 177.0663.

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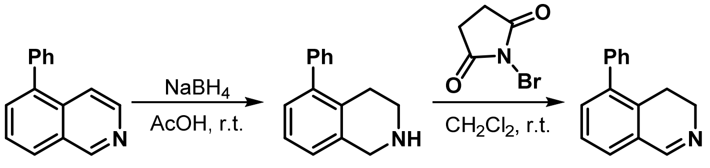
[12] K. Orito, T. Hatakeyama, M. Takeo, S. Uchiito, M. Tokuda and H. Suginome, *Tetrahedron*, 1998, **54**, 8403-8410.

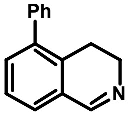
Preparation of 5-phenyl-3,4-dihydroisoquinoline 7c:

5-Phenyl-3,4-dihydroisoquinoline **7c** was prepared according to the modified literature procedure.[13,14]



7c

In an oven-dried 25 mL round-bottom flask, 5-phenylisoquinoline **1n** (410 mg, 2.0 mmol, 1.0 equiv.) was taken in 8 mL glacial acetic acid and $NaBH_4$ (303 mg, 8.0 mmol, 4.0 equiv.) was added portion wise over a period of 20 min. The resulting mixture was stirred at r.t. for 18 h. The reaction mixture was then poured onto ice, basified with solid NaOH, extracted with $CHCl_3$. The combined organic layer was dried over anh. Na_2SO_4, concentrated in vacuo to obtain a yellow oil which was taken in an oven-dried 25 mL round-bottom flask and 3.5 mL CH_2Cl_2 was added under positive argon pressure. *N*-Bromosuccinimide (391 mg, 2.2 mmol, 1.1 equiv.) was added portion wise and the resulting mixture was stirred at r.t. for 3 h. To the reaction mixture, 1 mL 30% aqueous NaOH solution was added and stirred at r.t. for another 3 h. The organic layer was collected and the aqueous layer was extracted with $CHCl_3$. The combined organic layer was dried over anh. Na_2SO_4, concentrated in vacuo to obtain a red oil which was purified by silica gel column chromatography to obtain 5-phenyl-3,4-dihydroisoquinoline **7c** as an orange oil.



7c

Purification by silica gel (100-200 mesh) column chromatography (50% EtOAc in petroleum ether) afforded pure **7c** as a orange oil (170 mg, 0.820 mmol; 41% yield); **^{1}H-NMR (400 MHz, $CDCl_3$):** δ 8.41 (s; 1H), 7.42-7.46 (m; 2H), 7.36-7.39 (m; 3H), 7.30-7.32 (m; 3H), 3.68 (t, *J* = 7.7 Hz; 2H), 2.71 (t, *J* = 7.7 Hz; 2H); **^{13}C-NMR (100 MHz, $CDCl_3$):** δ 160.8, 140.4, 139.6, 133.7, 132.6, 129.1, 128.7, 128.2, 127.3, 126.7, 126.5, 47.6, 23.0; **HRMS (ESI+):** Calculated for $C_{15}H_{13}NH$ ($[M + H]^+$): 208.1126, found: 208.1126.

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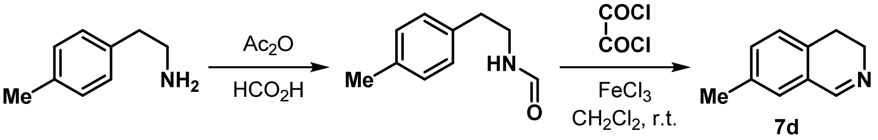
[13] M. G. Kelly, *Patent* WO2007109182, 2007.

[14] G. Lahm, J.-G. Deichmann, A. L. Rauen and T. Opatz, *J. Org. Chem.*, 2015, **80**, 2010-2016.

Preparation of 7-methyl-3,4-dihydroisoquinoline 7d:

7-Methyl-3,4-dihydroisoquinoline **7d** was prepared according to the modified literature procedure.[15]



In an oven-dried 25 mL round-bottom flask equipped with an argon inlet, 2-(p-tolyl)ethan-1-amine (620 mg, 4.596 mmol, 1.0 equiv.) was taken and cooled to 0 °C. To this solution, 4.3 mL formic acid was added at 0 °C followed by the addition of acetic anhydride (1.36 mL, 14.41 mmol, 6.3 equiv.) at 0 °C. The resulting mixture was allowed to come to r.t. and stir at r.t. for 2 h. The reaction mixture was then quenched with water, extracted with CH_2Cl_2. The combined organic layer was washed with sat. $NaHCO_3$ solution, brine and dried over anh. Na_2SO_4, concentrated in vacuo to obtain *N*-(4-methylphenethyl)formamide (380 mg, 2.328 mmol, 51% yield) as a red oil which was used for subsequent step without further purification. **^{1}H-NMR (400 MHz, CDCl$_3$):** δ 8.11 (s; 1H), 7.08-7.19 (m; 4H), 3.53-3.58 (m; 2H), 2.80 (t, *J* = 6.9 Hz; 2H), 2.32 (s; 3H); **^{13}C-NMR (100 MHz, CDCl$_3$):** δ 161.1, 136.2, 135.3, 129.5, 129.4, 128.7, 128.6, 39.2, 35.0, 21.0.

In an oven-dried 50 mL round-bottom flask equipped with an argon inlet, *N*-(4-methylphenethyl)formamide (380 mg, 2.328 mmol, 1.0 equiv.) was taken in 23.3 mL CH_2Cl_2 and oxalyl chloride (0.23 mL, 2.677 mmol, 1.15 equiv.) was added. The resulting mixture was stirred at r.t. for 1 h and then cooled to 0 °C. Ferric chloride (585 mg, 3.608 mmol, 1.55 equiv.) was added at 0 °C and the resulting solution was stirred at r.t. for 34 h. The reaction mixture was then quenched by the addition of 1 M HCl solution and stirred at r.t. for 1 h. The organic layer was collected, washed with brine, dried over anh. Na_2SO_4, concentrated in vacuo to obtain a black residue which was taken in a mixture of 19 mL MeOH and 1 mL conc. sulfuric acid and refluxed at 80 °C for 2 h. The resulting mixture was cooled to r.t. and solvent was evaporated in vacuo to obtain a red oil which was dissolved in EtOAc and extracted with 1 M aqueous HCl solution. The combined aqueous layer was basified with solid NaOH until pH = 11, extracted with CH_2Cl_2. The combined organic layer was dried over anh. Na_2SO_4, concentrated in vacuo to obtain a red oil which was purified by silica gel column chromatography using 60% EtOAc in petroleum ether as eluent to obtain 7-methyl-3,4-dihydroisoquinoline **7d** as a yellow oil.

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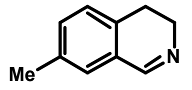
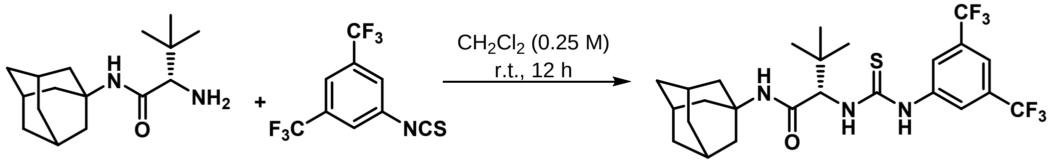
[15] M. Boehringer, D. Hunziker, B. Kuhn, B. M. Loeffler, F. Ricklin and H. P. Wessel, *Patent* US20060116393, 2006.



7d

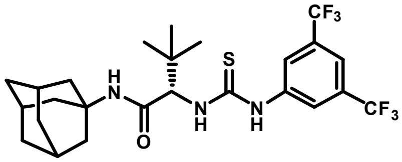
Purification by silica gel (100-200 mesh) column chromatography (60% EtOAc in petroleum ether) afforded pure **7d** as a yellow oil (69 mg, 0.475 mmol; 20% yield); **^{1}H-NMR (400 MHz, CDCl$_3$):** δ 8.27 (s; 1H), 7.14 (d, *J* = 7.7 Hz; 1H), 7.05 (s; 1H), 7.01 (d, *J* = 7.7 Hz; 1H), 3.72 (t, *J* = 7.8 Hz; 2H), 2.67 (t, *J* =7.8 Hz; 2H), 2.33 (s; 3H); **^{13}C-NMR (100 MHz, CDCl$_3$):** δ 160.3, 136.5, 133.1, 131.5, 128.2, 127.7, 127.1, 47.4, 24.5, 20.8; **HRMS (ESI+):** Calculated for $C_{10}H_{11}NH$ ($[M + H]^+$): 146.0970, found: 146.0971.

B. Representative procedure for the preparation of catalysts: Synthesis of catalyst I:



I

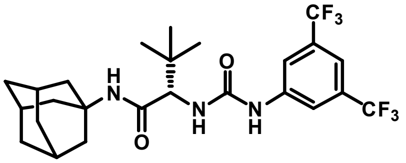
In an oven dried 10 mL round-bottom flask under positive argon pressure, (*S*)-*N*-((3*R*,5*R*,7*R*)-adamantan-1-yl)-2-amino-3,3-dimethylbutanamide (200 mg, 0.756 mmol., 1.0 equiv.) and 3,5-bis(trifluoromethyl)phenyl isothiocyanate (246 mg, 0.908 mmol., 1.2 equiv.) was taken in 3.0 mL CH_2Cl_2 and stirred at r.t. for 12 h. The product was purified by silica gel (230-400 mesh) column chromatography using 15% EtOAc in petroleum ether as eluent to obtain **I** as a white solid.



I

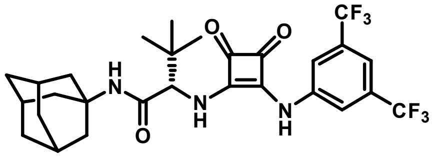
I: Purification by silica gel (230-400 mesh) column chromatography (15% EtOAc in petroleum ether) afforded pure **I** as a white solid (270 mg, 0.504 mmol; 67% yield). **R$_f$** = 0.40 (20% EtOAc in petroleum ether). **M. P.** = 157-160 °C. **FT-IR (neat):** ν 3310 (w), 2909 (m), 1645 (m), 1527 (s), 1272 (s), 1128 (s), 772 (s) cm^{-1}; **^{1}H-NMR (400 MHz, CDCl$_3$):** δ 8.82 (br s; 1H), 8.12 (d, *J* = 8.8 Hz; 1H), 7.93 (s; 2H), 7.54 (s; 1H), 5.67 (br s; 1H), 4.89 (d, *J* = 9.0 Hz; 1H), 2.02 (s; 3H), 1.99 (s; 6H), 1.59-1.68 (m; 6H), 1.11 (s; 9H); **^{13}C-NMR (100 MHz, CDCl$_3$):** δ 181.70, 171.35, 140.03, 131.52 (q, *J* = 33.5 Hz), 127.86, 124.00, 122.96 (q, *J* = 272.9 Hz), 120.04, 118.19, 66.94, 53.40, 41.69, 36.08, 34.81, 29.26, 27.43; **HRMS (ESI+):** Calculated for $C_{25}H_{21}F_6N_3OSNa$ ($[M + Na]^+$): 558.1990, found: 558.1989; **$[\alpha]_D^{22}$** –46.3 (*c* 1.00, CHCl$_3$).

II: Purification by silica gel (230-400 mesh) column chromatography (15% EtOAc in petroleum ether) afforded pure **II** as a white solid (340 mg, 0.654 mmol; 58% yield). **R_f** = 0.30 (20% EtOAc in petroleum ether). **M. P.** = 188-190 °C. **FT-IR (neat):** ν 3320 (w), 2911 (w), 1631 (m), 1567 (m), 1375 (m), 1273 (s), 1128 (s), 881 (m) cm^{-1}; **^{1}H-NMR (400 MHz, CDCl$_3$):** δ 7.88 (br s; 1H), 7.72 (s; 1H), 7.59 (s; 2H), 7.27 (s; 1H), 6.84 (d, J = 9.4 Hz; 1H), 5.71 (s; 1H), 4.13 (d, J = 9.5 Hz; 1H), 2.03 (s; 9H), 1.60-1.68 (m; 6H), 1.09 (s; 9H); **^{13}C-NMR (100 MHz, CDCl$_3$):** δ 172.26, 155.37, 140.27, 131.59 (q, J = 33.3 Hz), 131.39, 123.15 (q, J = 272.9 Hz), 118.96, 118.28, 115.33, 62.98, 53.21, 41.76, 36.11, 34.14, 29.30, 27.32; **HRMS (ESI+):** Calculated for $C_{25}H_{31}F_6N_3O_2Na$ ([M + Na]$^+$): 542.2218, found: 542.2216; **$[\alpha]_D^{22}$** +14.0 (*c* 0.50, CHCl$_3$).



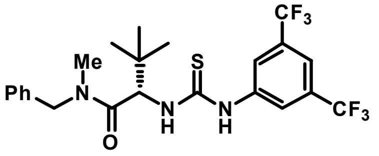
II

III: Reaction was done in MeOH for 3 d. Purification by filtration afforded pure **III** as a white solid (210 mg, 0.367 mmol; 32% yield). **R_f** = 0.30 (20% EtOAc in petroleum ether). **M. P.** = 197-199 °C. **FT-IR (neat):** ν 3231 (w), 2914 (w), 1674 (s), 1575 (s), 1449 (m), 1367 (s), 1278 (s), 1175 (s), 1126 (s), 696 (m) cm^{-1}; **^{1}H-NMR (400 MHz, DMSO-d$_6$):** δ 10.40 (s; 1H), 8.05 (d, J = 9.9 Hz; 1H), 7.91 (s; 2H), 7.77 (s; 1H), 7.45 (s; 1H), 4.31 (d, J = 9.8 Hz; 1H), 4.22 (s; 1H), 1.82 (s; 3H), 1.79 (s; 6H), 1.43 (s; 6H), 0.77 (s; 9H); **^{13}C-NMR (100 MHz, DMSO-d$_6$):** δ 183.88, 180.44, 169.11, 167.92, 162.38, 141.26, 131.36 (q, J = 33.0 Hz), 123.11 (q, J = 272.8 Hz), 119.29, 117.94, 114.49, 63.98, 60.88, 51.50, 40.82, 38.18, 35.39, 28.78, 26.03; **HRMS (ESI+):** Calculated for $C_{28}H_{31}F_6N_3O_3Na$ ([M + Na]$^+$): 594.2167, found: 594.2164; **$[\alpha]_D^{22}$** +15.8 (*c* 0.50, CHCl$_3$).

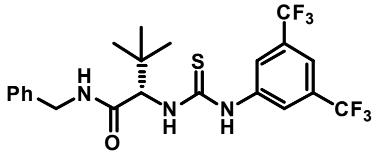


III

IV: Purification by silica gel (230-400 mesh) column chromatography (15% EtOAc in petroleum ether) afforded pure **IV** as a white solid (760 mg, 1.503 mmol; 59% yield). **R_f** = 0.30 (20% EtOAc in petroleum ether). **M. P.** = 52-55 °C. **FT-IR (neat):** ν 3318 (w), 2965 (w), 1610 (m), 1528 (m), 1379 (s), 1272 (s), 1124 (s), 772 (s) cm^{-1}; **^{1}H-NMR (400 MHz, CDCl$_3$):** δ 9.07 (s; 1H), 7.97 (d, J = 3.3 Hz; 1H), 7.86 (s; 2H), 7.55 (s; 1H), 7.28 (s; 1H), 7.16-7.22 (m; 4H), 5.69 (d, J = 9.3 Hz; 1H), 4.97 (d, J = 14.4 Hz; 1H), 4.22 (d, J = 14.4 Hz; 1H), 3.26 (s; 3H), 1.15 (s; 9H); **^{13}C-NMR (100 MHz, CDCl$_3$):** δ 181.71, 173.67, 140.00, 135.58, 131.66 (q, J = 33.7 Hz), 128.69, 128.05, 127.80, 124.03, 123.14 (q, J = 274.5 Hz), 118.30, 61.11, 51.85, 36.48, 36.12, 27.17; **HRMS (ESI+):** Calculated for $C_{23}H_{25}F_6N_3OSNa$ ([M + Na]$^+$): 528.1520, found: 528.1520; **$[\alpha]_D^{22}$** –54.0 (*c* 1.00, CHCl$_3$).

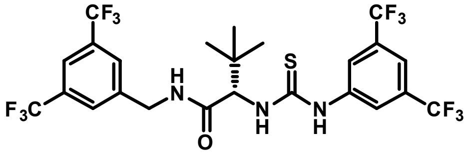


IV



V

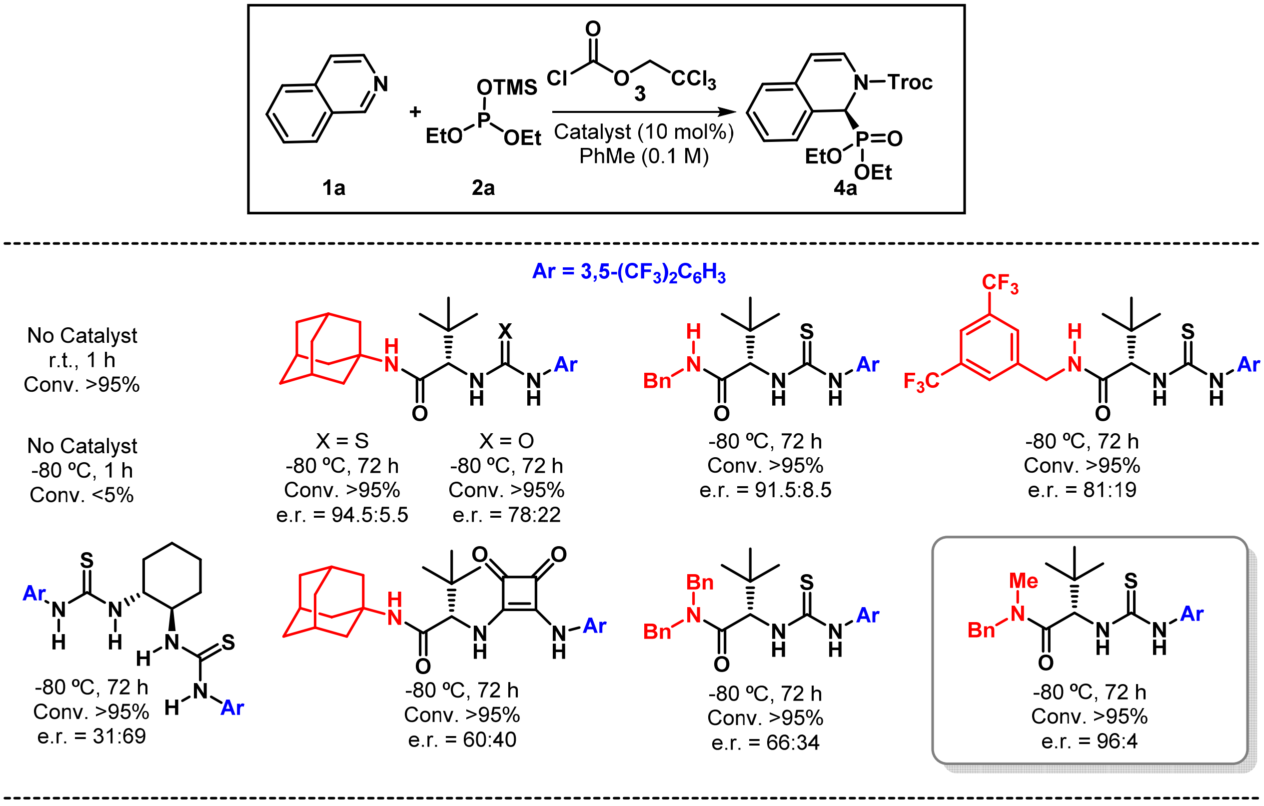
V: Purification by silica gel (230-400 mesh) column chromatography (15% EtOAc in petroleum ether) afforded pure **V** as a white solid (340 mg, 0.654 mmol; 58% yield). **R_f** = 0.35 (20% EtOAc in petroleum ether). **M. P**. = 78-80 °C. **FT-IR (neat):** ν 3308 (w), 2963 (w), 1647 (m), 1530 (s), 1378 (s), 1272 (s), 1175 (s), 1130 (s), 959 (m) cm^{-1}; **^{1}H-NMR (400 MHz, $CDCl_3$):** δ 9.05 (br s; 1H), 7.93 (d, *J* = 8.9 Hz; 1H), 7.89 (s; 2H), 7.58 (s; 1H), 7.16-7.24 (m; 5H), 6.42 (br s; 1H), 5.08 (d, *J* = 8.6 Hz; 1H), 4.48 (dd, *J* = 6.0, 14.6 Hz; 1H), 4.27 (dd, *J* = 4.8, 14.6 Hz; 1H), 1.13 (s; 9H); **^{13}C-NMR (100 MHz, $CDCl_3$):** δ 181.96, 172.13, 139.86, 136.18, 131.75 (q, *J* = 33.7 Hz), 128.83, 127.94, 127.66, 124.32, 123.03 (q, *J* = 272.6 Hz), 66.42, 44.19, 35.14, 27.22; **HRMS (ESI+):** Calculated for $C_{22}H_{23}F_6N_3OSNa$ ($[M + Na]^+$): 514.1364, found: 514.1361; **$[\alpha]_D^{22}$** –13.9 (*c* 1.00, $CHCl_3$).



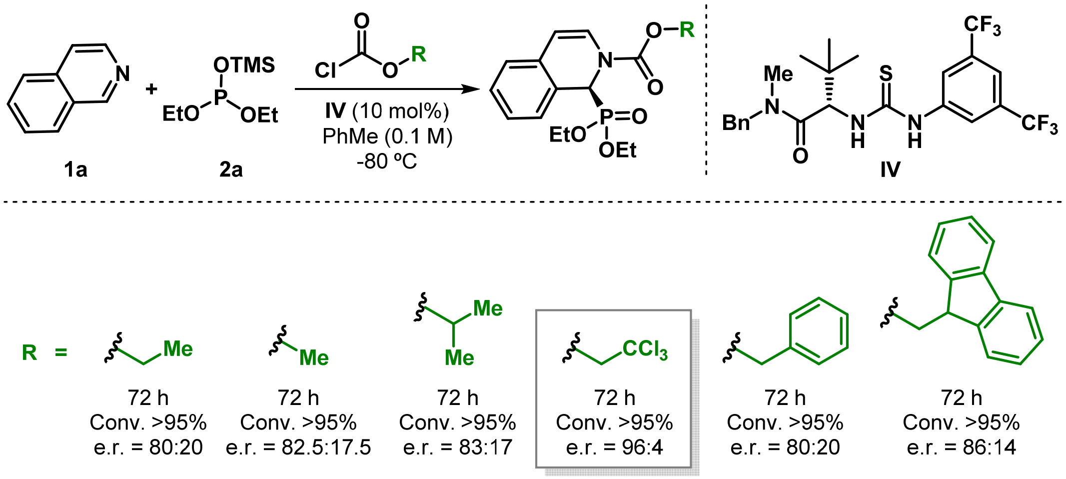
Purification by silica gel (230-400 mesh) column chromatography (15% EtOAc in petroleum ether) afforded a white solid (140 mg, 0.223 mmol; 53% yield). **R_f** = 0.45 (20% EtOAc in petroleum ether). **M. P.** = 131-133 °C. **FT-IR (neat):** ν 3298 (w), 2964 (w), 1658 (m), 1530 (m), 1378 (m), 1275 (s), 1167 (m), 1122 (s), 679 (m) cm^{-1}; **^{1}H-NMR (400 MHz, $CDCl_3$):** δ 9.36 (s; 1H), 7.90 (s; 2H), 7.60-7.69 (m; 5H), 7.04 (br s; 1H), 4.93 (d, *J* = 9.1 Hz; 1H), 4.52 (dd, *J* = 6.2, 15.7 Hz; 1H), 4.41 (dd, *J* = 5.9, 15.7 Hz; 1H), 1.11 (s; 9H); **^{13}C-NMR (100 MHz, $CDCl_3$):** δ 181.05, 171.81, 139.83, 139.31, 132.27 (q, J = 33.7 Hz), 132.25 (q, J = 33.4 Hz), 127.40, 123.18, 122.85 (q, J = 272.2 Hz), 122.60 (q, J = 273.3 Hz), 66.67, 42.68, 34.90, 26.94; **HRMS (ESI+):** Calculated for $C_{24}H_{21}F_6N_3OSNa$ ($[M + Na]^+$): 650.1111, found: 650.1110; **$[\alpha]_D^{22}$** –11.7 (*c* 1.00, $CHCl_3$).

C. Catalyst and reaction conditions optimization for the enantioselective dearomatization of isoquinolines:

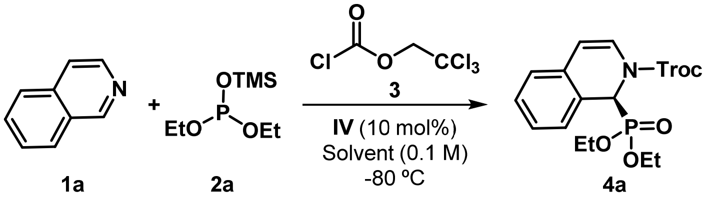
Catalyst Screening



Evaluation of Acylating Reagent



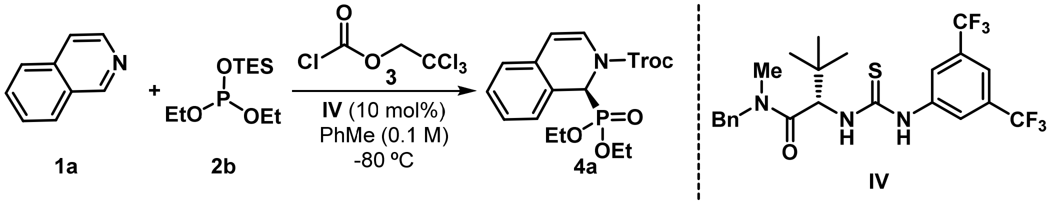
Solvent Optimization



Entry	Solvent	Time (h)	Conv.	e.r.
1	CH_2Cl_2	48	>95%	62:38
2	Et_2O	72	10%	80:20
3	THF	72	>95%	81:19
4	*n*-Pentane	72	N.R.	
5	2-MeTHF	72	40%	90:10
6	MeOH	72	10%	50:50
7	TBME	72	40	89.5:10.5
8	$PhMe:PhCF_3$	72	70	92.5:7.5
9	PhMe	72	>95%	96:4

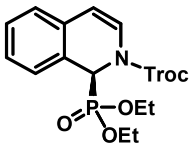
D. Catalytic enantioselective dearomatization of isoquinolines:

Representative procedure for the dearomatization of isoquinoline **1a** with diethyl triethylsilyl phosphite **2b**:



In an oven-dried reaction tube under positive argon pressure, isoquinoline **1a** (12 µL, 0.1 mmol., 1.0 equiv.) was taken in 0.4 mL PhMe and 2,2,2-trichloroethyl chloroformate **3** (18 µL, 0.13 mmol., 1.3 equiv.) was added at r.t. The resulting mixture was stirred at r.t. for 30 min and then cooled to -80 °C. After 15 min at -80 °C, a solution of **IV** (5.1 mg, 0.01 mmol., 0.1 equiv.) in 0.3 mL PhMe was added and the resulting mixture was allowed to stir at -80 °C for 15 min, followed by dropwise addition of a solution diethyl triethylsilyl phosphite **2b** (25.2 mg, 0.1 mmol., 1.0 equiv.) in 0.3 mL PhMe. The resulting solution was stirred at -80 °C for 72 h and then quenched by the addition of 1 mL water. The reaction mixture was allowed to attain r.t. and extracted with EtOAc. The combined organic layer was dried over anh. Na_2SO_4, concentrated in vacuo to obtain a light yellow oil which was purified by silica gel (100-200 mesh) column chromatography using 30% EtOAc in petroleum ether as eluent to obtain pure **4a** as a colorless oil (41 mg, 0.093 mmol; 93% yield).

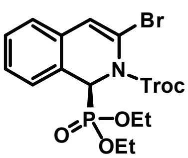
2,2,2-Trichloroethyl (*S*)-1-(diethoxyphosphoryl)isoquinoline-2(1*H*)-carboxylate 4a:



4a

Purification by silica gel (100-200 mesh) column chromatography (30% EtOAc in petroleum ether) afforded pure **4a** as a colorless oil (41 mg, 0.093 mmol; 93% yield). **R$_f$** = 0.40 (50% EtOAc in petroleum ether). **FT-IR (neat):** ν 2984 (s), 1727 (s), 1637 (s), 1453 (s), 1240 (s), 1128 (s), 1017 (s), 929 (s) cm^{-1}; **^{1}H-NMR (400 MHz, CDCl$_3$):** The compound exists as a 2.5:1 mixture of carbamate rotamers. Signals corresponding to the major rotamer: δ 7.18-7.25 (m; 3H), 7.06 (d, *J* = 7.2 Hz; 1H), 6.92 (d, *J* = 8.0 Hz; 1H), 5.93 (d, *J* = 8.0 Hz; 1H), 5.83 (d, *J* = 16.3 Hz; 1H), 4.89 (d, *J* = 11.9 Hz; 1H), 4.78 (d, *J* = 11.9 Hz; 1H), 3.86-4.10 (m; 4H), 1.19 (t, *J* = 7.0 Hz; 3H), 1.14 (t, *J* = 7.0 Hz; 3H); Representative signals corresponding to the minor rotamer: δ 6.96 (d, *J* = 8.0 Hz; 1H), 6.00 (d, *J* = 8.0 Hz; 1H), 5.77 (d, *J* = 16.3 Hz; 1H), 5.01 (d, *J* = 11.9 Hz; 1H), 4.68 (d, *J* = 11.9 Hz; 1H), 3.73-3.84 (m; 4H); **^{13}C-NMR (100 MHz, CDCl$_3$):** Signals corresponding to both rotamers: δ 151.29, 150.88, 130.95 (d, *J* = 4.2 Hz), 130.65 (d, *J* = 4.2 Hz), 128.85 (d, *J* = 3.4 Hz), 128.67 (d, *J* = 3.4 Hz), 128.57 (d, *J* = 2.8 Hz), 127.51 (d, *J* = 5.2 Hz), 127.43 (d, *J* = 2.8 Hz), 127.38 (d, *J* = 5.2 Hz), 125.47 (d, *J* = 2.2 Hz), 125.33 (d, *J* = 2.7 Hz), 125.16 (d, *J* = 2.9 Hz), 125.09 (d, *J* = 3.0 Hz), 125.04, 123.96, 111.13, 110.99, 94.75, 94.61, 75.62, 75.59, 63.20 (d, *J* = 7.4 Hz), 63.06 (d, *J* = 7.4 Hz), 62.98 (d, *J* = 7.4 Hz), 62.76 (d, *J* = 7.4 Hz), 54.68 (d, *J* = 151.5 Hz), 53.85 (d, *J* = 151.5 Hz), 16.35, 16.26 (d, *J* = 5.8 Hz); **^{31}P-NMR (162 MHz, CDCl$_3$):** δ 18.59 (for major rotamer), 18.37 (for minor rotamer); **HRMS (ESI+):** Calculated for $C_{19}H_{19}Cl_3NO_5PNa$ ($[M + Na]^+$): 463.9964, found: 463.9962; **$[\alpha]_D^{22}$** +174.7 (*c* 1.00, $CHCl_3$) for an enantiomerically enriched sample with 96:4 e.r. Enantiomeric ratio was determined by HPLC analysis (Daicel Chiralpak IE column, 254 nm, ^{n}Hexane/EtOH = 90:10, 1.0 mL min^{-1}, τ_{major} = 14.90 min, τ_{minor} = 26.65 min). Absolute stereochemistry of **4a** is assigned in analogy with **4w**.

2,2,2-Trichloroethyl (*S*)-3-bromo-1-(diethoxyphosphoryl)isoquinoline-2(1*H*)-carboxylate 4b:

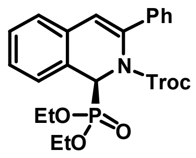


4b

Purification by silica gel (100-200 mesh) column chromatography (25% EtOAc in petroleum ether) afforded pure **4b** as a colorless oil (48 mg, 0.092 mmol; 92% yield). **R$_f$** = 0.60 (50% EtOAc in petroleum ether). **FT-IR (neat):** ν 2982 (w), 1729 (s), 1623 (w), 1391 (s), 1319 (s), 1234 (m), 1131 (s), 1019 (s) cm^{-1}; **^{1}H-NMR (400 MHz, CDCl$_3$):** The compound exists as a 2.4:1 mixture of carbamate rotamers. Signals corresponding to the major rotamer: δ 7.50-7.53 (m; 1H), 7.35-

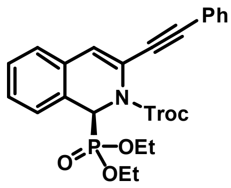
7.38 (m; 1H), 7.32-7.33 (m; 1H), 7.28-7.32 (m; 1H), 7.24 (s; 1H), 5.82 (d, *J* = 16.6 Hz; 1H), 4.96 (d, *J* = 11.8 Hz; 1H), 4.78 (d, *J* = 11.8 Hz; 1H), 3.75-4.14 (m; 4H), 1.22-1.26 (m; 3H), 1.15 (t, *J* = 7.0 Hz; 3H); Representative signals corresponding to the minor rotamer: δ 5.75 (d, *J* = 16.6 Hz; 1H), 5.03 (d, *J* = 11.8 Hz; 1H), 4.70 (d, *J* = 11.8 Hz; 1H); **^{13}C-NMR (100 MHz, CDCl$_3$):** Signals corresponding to both rotamers: δ 150.63, 150.22, 130.41 (d, *J* = 3.8 Hz), 130.13 (d, *J* = 3.8 Hz), 129.20 (d, *J* = 3.5 Hz), 129.01 (d, *J* = 3.1 Hz), 128.83 (d, *J* = 2.8 Hz), 127.41 (d, *J* = 5.3 Hz), 127.28 (d, *J* = 5.3 Hz), 126.17 (d, *J* = 2.3 Hz), 125.73, 125.38 (d, *J* = 2.7 Hz), 124.57, 106.90, 106.70, 94.60, 94.47, 75.82, 75.72, 63.54 (d, *J* = 7.2 Hz), 63.30 (d, *J* = 7.2 Hz), 63.23 (d, *J* = 7.2 Hz), 63.03 (d, *J* = 7.2 Hz), 54.88 (d, *J* = 150.7 Hz), 53.94 (d, *J* = 150.7 Hz), 16.33 (d, *J* = 6.0 Hz), 16.23 (d, *J* = 6.0 Hz); **^{31}P-NMR (162 MHz, CDCl$_3$):** δ 17.74 (for major rotamer), 17.47 (for minor rotamer); **HRMS (ESI+):** Calculated for $C_{16}H_{18}BrCl_3NO_5PNa$ ([M + Na]$^+$): 541.9069, found: 541.9069; **$[\alpha]_D^{22}$** +252.4 (c 1.00, CHCl$_3$) for an enantiomerically enriched sample with 96:4 e.r. Enantiomeric ratio was determined by HPLC analysis (Daicel Chiralpak AD-H column, 254 nm, ^{n}Hexane/EtOH = 90:10, 1.0 mL min^{-1}, τ_{major} = 7.98 min, τ_{minor} = 11.35 min). Absolute stereochemistry of **4b** is assigned in analogy with **4w**.

2,2,2-Trichloroethyl (*S*)-1-(diethoxyphosphoryl)-3-phenylisoquinoline-2(1*H*)-carboxylate 4c: Purification by silica gel (100-200 mesh) column chromatography (25% EtOAc in petroleum ether) afforded pure **4c** as a colorless oil (49 mg, 0.094 mmol; 94% yield). **R$_f$** = 0.55 (50% EtOAc in petroleum ether). **FT-IR (neat):** ν 2984 (w), 1727 (s), 1633 (m), 1450 (m), 1395 (s), 1265 (s), 1126 (s), 1053 (s), 1020 (s), 969 (s) cm^{-1}; **^{1}H-NMR (400 MHz, CDCl$_3$):** The compound exists as a 2.4:1 mixture of carbamate rotamers. Signals corresponding to the major rotamer: δ 7.35-7.44 (m; 6H), 7.21-7.30 (m; 2H), 7.09 (d, *J* = 7.6 Hz; 1H), 6.97 (s; 1H), 5.88 (d, *J* = 16.1 Hz; 1H), 4.95 (d, *J* = 11.7 Hz; 1H), 4.82 (d, *J* = 11.7 Hz; 1H), 3.83-4.19 (m; 4H), 1.24 (t, *J* = 7.0 Hz; 3H), 1.19 (t, *J* = 7.0 Hz; 3H); Representative signals corresponding to the minor rotamer: δ 7.12 (d, *J* = 7.6 Hz; 1H), 7.02 (s; 1H), 5.82 (d, *J* = 16.1 Hz; 1H), 5.07 (d, *J* = 11.7 Hz; 1H), 4.71 (d, *J* = 11.7 Hz; 1H); **^{13}C-NMR (100 MHz, CDCl$_3$):** Signals corresponding to both rotamers: δ 151.37, 151.07 (d, *J* = 1.5 Hz), 136.63, 136.42, 132.07 (d, *J* = 3.7 Hz), 131.81 (d, *J* = 3.7 Hz), 128.97, 128.94, 128.63, 128.56, 128.40 (d, *J* = 3.5 Hz), 127.90 (d, *J* = 2.5 Hz), 127.73 (d, *J* = 5.3 Hz), 127.67, 127.61 (d, *J* = 6.1 Hz), 126.61 (d, *J* = 1.9 Hz), 126.44 (d, *J* = 1.9 Hz), 125.09, 124.93, 124.63 (d, *J* = 2.9 Hz), 123.15, 122.02, 94.83, 94.67, 75.69, 75.62, 63.18 (d, *J* = 6.6 Hz), 63.02 (d, *J* = 6.6 Hz), 62.91 (d, *J* = 6.6 Hz), 62.80 (d, *J* = 6.6 Hz), 55.01 (d, *J* = 150.9 Hz), 54.03 (d, *J* = 150.9 Hz), 16.37 (d, *J* = 6.2 Hz), 16.26 (d, *J* = 6.2 Hz); **^{31}P-NMR (162 MHz, CDCl$_3$):** δ 18.77 (for major rotamer), 18.50 (for minor rotamer); **HRMS (ESI+):** Calculated for $C_{22}H_{23}Cl_3NO_5PNa$ ([M + Na]$^+$): 540.0277, found: 540.0273; **$[\alpha]_D^{22}$** +293.6 (*c* 1.00, CHCl$_3$) for an enantiomerically enriched sample with 92:8 e.r. Enantiomeric ratio was determined by HPLC



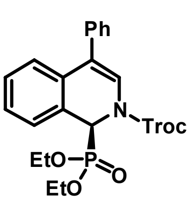
4c

analysis (Daicel Chiralpak AD-H column, 254 nm, ^{n}Hexane/EtOH = 90:10, 1.0 mL min^{-1}, τ_{major} = 6.93 min, τ_{minor} = 7.76 min). Absolute stereochemistry of **4c** is assigned in analogy with **4w**.



4d

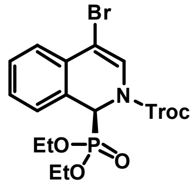
2,2,2-Trichloroethyl (*S*)-1-(diethoxyphosphoryl)-3-(phenylethynyl)isoquinoline-2(1*H*)-carboxylate 4d: Purification by silica gel (100-200 mesh) column chromatography (20% EtOAc in petroleum ether) afforded pure **4d** as a colorless oil (52 mg, 0.096 mmol; 96% yield). **R$_f$** = 0.60 (50% EtOAc in petroleum ether). **FT-IR (neat):** ν 3065 (w), 2983 (w), 1731 (s), 1620 (w), 1392 (s), 1235 (s), 1133 (m), 1020 (m) cm^{-1}; **^{1}H-NMR (400 MHz, CDCl$_3$):** The compound exists as a 2.3:1 mixture of carbamate rotamers. <u>Signals corresponding to the major rotamer</u>: δ 7.66 (d, *J* = 7.9 Hz; 1H), 7.53-7.55 (m; 2H), 7.30-7.45 (m; 7H), 5.87 (d, *J* = 15.9 Hz; 1H), 4.98 (d, *J* = 12.1 Hz; 1H), 4.82 (d, *J* = 12.1 Hz; 1H), 3.86-4.18 (m; 4H), 1.21-1.25 (m; 3H), 1.16 (t, *J* = 6.9 Hz; 3H); <u>Representative signals corresponding to the minor rotamer</u>: δ 5.80 (d, *J* = 15.9 Hz; 1H), 5.06 (d, *J* = 12.1 Hz; 1H), 4.71 (d, *J* = 12.1 Hz; 1H), 3.69-3.84 (m; 4H); **^{13}C-NMR (100 MHz, CDCl$_3$):** <u>Signals corresponding to both rotamers</u>: δ 150.79, 150.41, 131.47, 131.41, 129.97 (d, *J* = 3.8 Hz), 129.88, 129.09 (d, *J* = 3.4 Hz), 128.91 (d, *J* = 3.5 Hz), 128.56, 128.39, 128.35, 128.29, 128.22, 127.39 (d, *J* = 5.2 Hz), 127.31 (d, *J* = 5.2 Hz), 125.18 (d, *J* = 2.4 Hz), 125.01 (d, *J* = 2.4 Hz), 124.36 (d, *J* = 2.9 Hz), 124.30 (d, *J* = 2.9 Hz), 123.13, 123.05, 106.42, 106.28, 94.58, 94.44, 92.32, 92.06, 84.33, 84.14, 75.90, 75.80, 63.60 (d, *J* = 7.3 Hz), 63.38 (d, *J* = 7.3 Hz), 63.19 (d, *J* = 7.3 Hz), 62.99 (d, *J* = 7.3 Hz), 54.82 (d, *J* = 151.5 Hz), 53.94 (d, *J* = 151.5 Hz), 16.31 (d, *J* = 6.1 Hz), 16.22 (d, *J* = 6.1 Hz); **^{31}P-NMR (162 MHz, CDCl$_3$):** δ 17.88 (for major rotamer), 17.58 (for minor rotamer); **HRMS (ESI+):** Calculated for $C_{24}H_{23}Cl_3NO_5PNa$ ([M + Na]$^+$): 564.0277, found: 564.0275; **$[\alpha]_D^{22}$** +308.5 (*c* 0.50, CHCl$_3$) for an enantiomerically enriched sample with 90:10 e.r. Enantiomeric ratio was determined by HPLC analysis (Daicel Chiralpak IE column, 254 nm, ^{n}Hexane/EtOH = 90:10, 1.0 mL min^{-1}, τ_{major} = 12.88 min, τ_{minor} = 15.66 min). Absolute stereochemistry of **4d** is assigned in analogy with **4w**.



4e

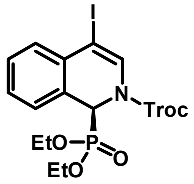
2,2,2-Trichloroethyl (*S*)-1-(diethoxyphosphoryl)-4-phenylisoquinoline-2(1*H*)-carboxylate 4e: Purification by silica gel (100-200 mesh) column chromatography (40% EtOAc in petroleum ether) afforded pure **4e** as a colorless oil (44 mg, 0.085 mmol; 85% yield). **R$_f$** = 0.60 (50% EtOAc in petroleum ether). **FT-IR (neat):** ν 2982 (m), 1727 (s), 1633 (s), 1450 (s), 1395 (s), 1265 (s), 1126 (s), 1052 (s), 1021 (s), 969 (s) cm^{-1}; **^{1}H-NMR (400 MHz, CDCl$_3$):** The compound exists as a 2.4:1 mixture of carbamate rotamers. <u>Signals corresponding to the major rotamer</u>: δ 7.35-7.44 (m; 6H), 7.20-7.29 (m; 2H), 7.09 (d, *J* = 7.6 Hz; 1H), 6.97 (s; 1H), 5.88 (d, *J* = 16.2 Hz; 1H), 4.95 (d, *J* = 11.9 Hz; 1H), 4.82 (d, *J* = 11.9 Hz; 1H), 3.98-4.16 (m; 4H), 1.17-

1.25 (m; 6H); Representative signals corresponding to the minor rotamer: δ 7.12 (d, J = 7.6 Hz; 1H), 7.02 (s; 1H), 5.82 (d, J = 16.2 Hz; 1H), 5.07 (d, J = 11.9 Hz; 1H), 4.71 (d, J = 11.9 Hz; 1H), 3.85-3.96 (m; 4H); **^{13}C-NMR (100 MHz, $CDCl_3$):** Signals corresponding to both rotamers: δ 151.40 (d, J = 1.3 Hz), 151.11 (d, J = 1.3 Hz), 136.65, 136.45, 132.10 (d, J = 3.8 Hz), 131.84 (d, J = 3.8 Hz), 129.01, 128.98, 128.66, 128.59, 128.40 (d, J = 3.5 Hz), 127.93 (d, J = 2.6 Hz), 127.76 (d, J = 5.4 Hz), 127.69, 127.61, 126.63 (d, J = 1.9 Hz), 126.46 (d, J = 2.2 Hz), 125.13, 124.96, 124.66 (d, J = 2.9 Hz), 123.18, 122.04, 94.85, 94.69, 75.73, 75.66, 63.23 (d, J = 7.4 Hz), 63.07 (d, J = 7.4 Hz), 62.96 (d, J = 7.4 Hz), 62.85 (d, J = 7.4 Hz), 54.97 (d, J = 150.1 Hz), 54.00 (d, J = 150.1 Hz), 16.49, 16.40 (d, J = 6.1 Hz); **^{31}P-NMR (162 MHz, $CDCl_3$):** δ 18.77 (for major rotamer), 18.48 (for minor rotamer); **HRMS (ESI+):** Calculated for $C_{22}H_{23}Cl_3NO_5PNa$ ([M + Na]$^+$): 540.0277, found: 540.0276; **$[\alpha]_D^{22}$** +136.7 (*c* 0.50, $CHCl_3$) for an enantiomerically enriched sample with 90.5:9.5 e.r. Enantiomeric ratio was determined by HPLC analysis (Daicel Chiralpak IE column, 254 nm, ^{n}Hexane/IPA = 80:20, 1.0 mL min^{-1}, τ_{major} = 12.12 min, τ_{minor} = 13.21 min). Absolute stereochemistry of **4e** is assigned in analogy with **4w**.



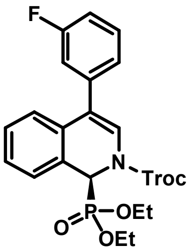
4f

2,2,2-Trichloroethyl (*S*)-4-bromo-1-(diethoxyphosphoryl)isoquinoline-2(1*H*)-carboxylate 4f: Purification by silica gel (100-200 mesh) column chromatography (40% EtOAc in petroleum ether) afforded pure **4f** as a colorless oil (47 mg, 0.090 mmol; 90% yield). **R$_f$** = 0.45 (50% EtOAc in petroleum ether). **FT-IR (neat):** ν 2923 (m), 1730 (m), 1626 (m), 1590 (m), 1391 (m), 1129 (m), 1021 (s) cm^{-1}; **^{1}H-NMR (400 MHz, $CDCl_3$):** The compound exists as a 2.3:1 mixture of carbamate rotamers. Signals corresponding to the major rotamer: δ 7.48-7.50 (m; 1H), 7.30-7.37 (m; 2H), 7.23-7.27 (m; 2H), 5.81 (d, J = 16.5 Hz; 1H), 4.94 (d, J = 12.0 Hz; 1H), 4.77 (d, J = 12.0 Hz; 1H), 3.86-4.14 (m; 4H), 1.20-1.24 (m; 3H), 1.14 (t, J = 7.1 Hz; 3H); Representative signals corresponding to the minor rotamer: δ 5.79 (d, J = 16.0 Hz; 1H), 5.02 (d, J = 12.0 Hz; 1H), 4.69 (d, J = 12.0 Hz; 1H), 3.74-3.82 (m; 4H); **^{13}C-NMR (100 MHz, $CDCl_3$):** Signals corresponding to both rotamers: δ 150.61, 150.18, 130.38 (d, J = 3.7 Hz), 130.11 (d, J = 4.1 Hz), 129.17 (d, J = 3.6 Hz), 129.00 (d, J = 1.1 Hz), 128.97, 128.81 (d, J = 2.9 Hz), 127.39 (d, J = 5.4 Hz), 127.26 (d, J = 5.7 Hz), 126.15 (d, J = 1.6 Hz), 125.72, 125.35 (d, J = 3.0 Hz), 124.55, 106.87, 106.68, 94.58, 94.46, 75.80, 75.70, 63.52 (d, J = 7.4 Hz), 63.28 (d, J = 7.4 Hz), 63.21 (d, J = 7.4 Hz), 63.00 (d, J = 7.4 Hz), 54.87 (d, J = 150.9 Hz), 53.90 (d, J = 150.9 Hz), 16.31 (d, J = 6.1 Hz), 16.21 (d, J = 6.1 Hz); **^{31}P-NMR (162 MHz, $CDCl_3$):** δ 17.74 (for major rotamer), 17.47 (for minor rotamer); **HRMS (ESI+):** Calculated for $C_{16}H_{18}BrCl_3NO_5PNa$ ([M + Na]$^+$): 541.9069, found: 541.9064; **$[\alpha]_D^{22}$** +203.4 (*c* 1.00, $CHCl_3$) for an enantiomerically enriched sample with 94.5:5.5 e.r. Enantiomeric ratio was determined by HPLC analysis (Daicel Chiralpak IE column, 254 nm, ^{n}Hexane/IPA = 80:20, 1.0 mL min^{-1}, τ_{major} = 11.23 min, τ_{minor} = 13.01 min). Absolute stereochemistry of **4f** is assigned in analogy with **4w**.



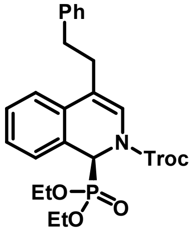
4g

2,2,2-Trichloroethyl (*S*)-1-(diethoxyphosphoryl)-4-iodoisoquinoline-2(1*H*)-carboxylate 4g: Purification by silica gel (100-200 mesh) column chromatography (30% EtOAc in petroleum ether) afforded pure **4g** as a colorless oil (52 mg, 0.091 mmol; 91% yield). $\mathbf{R_f}$ = 0.55 (50% EtOAc in petroleum ether). **FT-IR (neat):** ν 3066 (w), 2922 (w), 1728 (s), 1608 (w), 1449 (m), 1390 (s), 1316 (s), 1130 (m), 1019 (s) cm^{-1}; ^{1}**H-NMR (400 MHz, $CDCl_3$):** The compound exists as a 2.2:1 mixture of carbamate rotamers. Signals corresponding to the major rotamer: δ 7.18-7.47 (m; 5H), 5.80 (d, *J* = 16.3 Hz; 1H), 4.94 (d, *J* = 11.7 Hz; 1H), 4.77 (d, *J* = 11.7 Hz; 1H), 3.85-4.14 (m; 4H), 1.20-1.24 (m; 3H), 1.14 (t, *J* = 7.0 Hz; 3H); Representative signals corresponding to the minor rotamer: δ 5.73 (d, *J* = 16.3 Hz; 1H), 5.01 (d, *J* = 11.7 Hz; 1H), 4.68 (d, *J* = 11.7 Hz; 1H), 3.69-3.82 (m; 4H); ^{13}**C-NMR (100 MHz, $CDCl_3$):** Signals corresponding to both rotamers: δ 150.38, 149.88, 131.58, 131.47 (d, *J* = 4.2 Hz), 131.24 (d, *J* = 3.8 Hz), 130.47, 129.50, 129.45 (d, *J* = 3.0 Hz), 129.35 (d, *J* = 3.3 Hz), 129.17 (d, *J* = 3.6 Hz), 128.95 (d, *J* = 2.7 Hz), 128.76 (d, *J* = 2.6 Hz), 127.46 (d, *J* = 5.4 Hz), 127.33 (d, *J* = 5.6 Hz), 125.81 (d, *J* = 1.9 Hz), 125.58 (d, *J* = 1.9 Hz), 94.57, 94.44, 79.64, 79.47, 75.75, 75.66, 63.52 (d, *J* = 7.3 Hz), 63.24 (d, *J* = 7.8 Hz), 63.23 (d, *J* = 7.8 Hz), 63.01 (d, *J* = 7.2 Hz), 54.82 (d, *J* = 151.0 Hz), 53.92 (d, *J* = 151.0 Hz), 16.44 (d, *J* = 5.7 Hz), 16.35 (d, *J* = 4.0 Hz), 16.29 (d, *J* = 3.9 Hz); ^{31}**P-NMR (162 MHz, $CDCl_3$):** δ 17.97 (for major rotamer), 17.65 (for minor rotamer); **HRMS (ESI+):** Calculated for $C_{16}H_{18}Cl_3INO_5PNa$ ($[M + Na]^+$): 589.8931, found: 589.8932; $\mathbf{[\alpha]_D^{22}}$ +188.0 (*c* 1.00, $CHCl_3$) for an enantiomerically enriched sample with 93:7 e.r. Enantiomeric ratio was determined by HPLC analysis (Daicel Chiralpak IE column, 254 nm, ^{n}Hexane/IPA = 80:20, 1.0 mL min^{-1}, τ_{major} = 12.19 min, τ_{minor} = 13.79 min). Absolute stereochemistry of **4g** is assigned in analogy with **4w**.

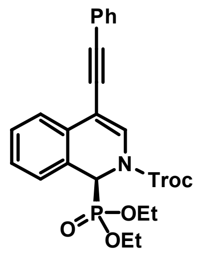


4h

2,2,2-Trichloroethyl (*S*)-1-(diethoxyphosphoryl)-4-(3-fluorophenyl)isoquinoline-2(1*H*)-carboxylate 4h: Purification by silica gel (100-200 mesh) column chromatography (30% EtOAc in petroleum ether) afforded pure **4h** as a colorless oil (49 mg, 0.091 mmol; 91% yield). $\mathbf{R_f}$ = 0.55 (50% EtOAc in petroleum ether). **FT-IR (neat):** ν 2983 (w), 1727 (s), 1579 (w), 1393 (s), 1279 (m), 1020 (s) cm^{-1}; ^{1}**H-NMR (400 MHz, $CDCl_3$):** The compound exists as a 2.3:1 mixture of carbamate rotamers. Signals corresponding to the major rotamer: δ 7.35-7.39 (m; 2H), 6.97-7.30 (m; 7H), 5.86 (d, *J* = 16.2 Hz; 1H), 4.94 (d, *J* = 11.9 Hz; 1H), 4.82 (d, *J* = 11.9 Hz; 1H), 3.87-4.14 (m; 4H), 1.16-1.25 (m; 6H); Representative signals corresponding to the minor rotamer: δ 5.80 (d, *J* = 16.2 Hz; 1H), 5.06 (d, *J* = 11.9 Hz; 1H), 4.71 (d, *J* = 11.9 Hz; 1H); ^{13}**C-NMR (100 MHz, $CDCl_3$):** Signals corresponding to both rotamers: δ 164.09, 161.60, 151.36, 151.01 (d, *J* = 1.4 Hz), 138.89 (d, *J* = 8.0 Hz), 138.69 (d, *J* = 8.0 Hz), 131.64 (d, *J* = 3.8 Hz), 131.38 (d, *J* = 4.0 Hz), 130.26, 130.14 (d, *J* = 7.0 Hz), 128.71 (d, *J* = 3.3 Hz), 128.53 (d, *J* = 3.3 Hz), 128.11 (d, *J* = 2.8 Hz), 127.94 (d, *J* = 2.8 Hz), 127.83 (d, *J* = 5.4 Hz), 127.70 (d, *J* = 5.6 Hz), 126.61 (d, *J* = 1.5 Hz), 126.43 (d, *J* = 2.1 Hz), 124.66, 124.61 (d, *J* = 2.9 Hz), 124.42 (d, *J* = 2.9 Hz), 124.07 (d, *J* = 2.0 Hz), 123.93 (d, *J* = 1.8 Hz), 123.66, 122.51, 94.78, 94.62, 75.75, 75.66, 63.23 (d, *J* = 6.6 Hz), 63.09 (d, *J* = 6.6 Hz), 62.94 (d, *J* = 6.6 Hz), 62.87 (d, *J* = 6.6 Hz), 55.04 (d, *J* = 151.4 Hz), 53.98 (d, *J* = 151.4 Hz), 16.47, 16.36 (d, *J* = 6.0 Hz); **^{31}P-NMR (162 MHz, CDCl$_3$):** δ 18.59 (for major rotamer), 18.32 (for minor rotamer); **HRMS (ESI+):** Calculated for $C_{22}H_{22}Cl_3FNO_5PNa$ ([M + Na]$^+$): 558.0183, found: 558.0182; **[α]$_D^{22}$** +271.3 (*c* 2.00, CHCl$_3$) for an enantiomerically enriched sample with 92:8 e.r. Enantiomeric ratio was determined by HPLC analysis (Daicel Chiralpak IE column, 254 nm, ^{n}Hexane/IPA = 80:20, 1.0 mL min^{-1}, τ_{major} = 11.02 min, τ_{minor} = 12.04 min). Absolute stereochemistry of **4h** is assigned in analogy with **4w**.

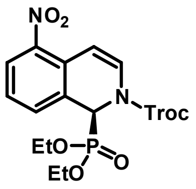

4i

2,2,2-Trichloroethyl (*S*)-1-(diethoxyphosphoryl)-4-phenethylisoquinoline-2(1*H*)-carboxylate 4i: Purification by silica gel (100-200 mesh) column chromatography (30% EtOAc in petroleum ether) afforded pure **4i** as a colorless oil (51 mg, 0.093 mmol; 93% yield). **R$_f$** = 0.55 (50% EtOAc in petroleum ether). **FT-IR (neat):** ν 2924 (w), 1724 (s), 1644 (w), 1398 (s), 1256 (s), 1020 (s) cm^{-1}; **^{1}H-NMR (400 MHz, CDCl$_3$):** The compound exists as a 2.2:1 mixture of carbamate rotamers. Signals corresponding to the major rotamer: δ 7.20-7.34 (m; 9H), 6.82 (s; 1H), 5.83 (d, *J* = 16.6 Hz; 1H), 4.94 (d, *J* = 11.9 Hz; 1H), 4.76 (d, *J* = 11.9 Hz; 1H), 3.91-4.15 (m; 4H), 2.67-2.99 (m; 4H), 1.14-1.26 (m; 6H); Representative signals corresponding to the minor rotamer: δ 6.89 (s; 1H), 5.77 (d, *J* = 16.6 Hz; 1H), 5.03 (d, *J* = 11.9 Hz; 1H), 4.70 (d, *J* = 11.9 Hz; 1H), 3.73-3.89 (m; 4H); **^{13}C-NMR (100 MHz, CDCl$_3$):** Signals corresponding to both rotamers: δ 151.28, 151.00 (d, *J* = 1.5 Hz), 141.61, 141.54, 131.84 (d, *J* = 3.9 Hz), 131.53 (d, *J* = 4.3 Hz), 128.83 (d, *J* = 3.6 Hz), 128.65 (d, *J* = 3.4 Hz), 128.49, 128.26, 127.72 (d, *J* = 5.8 Hz), 127.65 (d, *J* = 3.0 Hz), 127.52 (d, *J* = 2.9 Hz), 126.72 (d, *J* = 1.8 Hz), 126.55 (d, *J* = 1.8 Hz), 126.10, 122.15 (d, *J* = 3.1 Hz), 121.77, 121.36, 120.99, 120.66, 94.93, 94.78, 75.63, 75.57, 63.13 (d, *J* = 7.4 Hz), 62.95 (d, *J* = 7.4 Hz), 62.92 (d, *J* = 7.4 Hz), 62.70 (d, *J* = 7.4 Hz), 54.92 (d, *J* = 151.3 Hz), 54.03 (d, *J* = 151.3 Hz), 35.00, 34.85, 31.87, 16.37 (d. *J* = 5.3 Hz), 16.35 (d, *J* = 5.3 Hz); **^{31}P-NMR (162 MHz, CDCl$_3$):** δ 19.03 (for major rotamer), 18.64 (for minor rotamer); **HRMS (ESI+):** Calculated for $C_{24}H_{27}Cl_3NO_5PNa$ ([M + Na]$^+$): 568.0590, found: 568.0594; **[α]$_D^{22}$** +227.6 (*c* 1.00, CHCl$_3$) for an enantiomerically enriched sample with 91:9 e.r. Enantiomeric ratio was determined by HPLC analysis (Daicel Chiralpak AD-H column, 254 nm, ^{n}Hexane/EtOH = 80:20, 1.0 mL min^{-1}, τ_{major} = 5.91 min, τ_{minor} = 7.68 min). Absolute stereochemistry of **4i** is assigned in analogy with **4w**.



4j

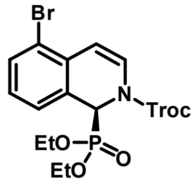
2,2,2-Trichloroethyl (*S*)-1-(diethoxyphosphoryl)-4-(phenylethynyl)isoquinoline-2(1*H*)-carboxylate 4j: Purification by silica gel (100-200 mesh) column chromatography (30% EtOAc in petroleum ether) afforded pure **4j** as a colorless oil (52 mg, 0.096 mmol; 96% yield). **R_f** = 0.55 (50% EtOAc in petroleum ether). **FT-IR (neat):** ν 2925 (w), 1728 (s), 1598 (w), 1391 (m), 1238 (m), 1021 (m) cm^{-1}; **^{1}H-NMR (400 MHz, $CDCl_3$):** The compound exists as a 2.2:1 mixture of carbamate rotamers. Signals corresponding to the major rotamer: δ 7.66 (d, *J* = 7.6 Hz; 1H), 7.52-7.55 (m; 2H), 7.30-7.45 (m; 7H), 5.88 (d, *J* = 15.8 Hz; 1H), 4.98 (d, *J* = 12.0 Hz; 1H), 4.82 (d, *J* = 12.0 Hz; 1H), 3.86-4.14 (m; 4H), 1.14-1.25 (m; 6H); Representative signals corresponding to the minor rotamer: δ 5.81 (d, *J* = 15.8 Hz; 1H), 5.06 (d, *J* = 12.0 Hz; 1H), 4.71 (d, *J* = 12.0 Hz; 1H), 3.72-3.82 (m; 4H); **^{13}C-NMR (100 MHz, $CDCl_3$):** Signals corresponding to both rotamers: δ 150.79, 150.43, 131.47, 131.42, 129.97 (d, *J* = 3.9 Hz), 129.86, 129.11 (d, *J* = 3.6 Hz), 128.93 (d, *J* = 3.5 Hz), 128.55, 128.40, 128.38, 128.35, 128.30, 128.22, 127.41 (d, *J* = 5.3 Hz), 127.33 (d, *J* = 5.3 Hz), 125.14 (d, *J* = 2.2 Hz), 124.96 (d, *J* = 2.8 Hz), 124.37 (d, *J* = 2.9 Hz), 124.31 (d, *J* = 2.9 Hz), 123.12, 123.04, 106.43, 106.30, 94.58, 94.43, 92.34, 92.07, 84.32, 84.13, 75.91, 75.81, 63.68 (d, *J* = 7.3 Hz), 63.45 (d, *J* = 7.3 Hz), 63.24 (d, *J* = 7.3 Hz), 63.06 (d, *J* = 7.3 Hz), 54.68 (d, *J* = 150.5 Hz), 53.90 (d, *J* = 150.5 Hz), 16.29 (d, *J* = 6.2 Hz), 16.21 (d, *J* = 6.2 Hz); **^{31}P-NMR (162 MHz, $CDCl_3$):** δ 17.90 (for major rotamer), 17.60 (for minor rotamer); **HRMS (ESI+):** Calculated for $C_{24}H_{23}Cl_3NO_5PNa$ ($[M + Na]^+$): 564.0277, found: 564.0267; **$[\alpha]_D^{22}$** +58.1 (*c* 1.00, $CHCl_3$) for an enantiomerically enriched sample with 94.5:5.5 e.r. Enantiomeric ratio was determined by HPLC analysis (Daicel Chiralpak IE column, 254 nm, ^{n}Hexane/IPA = 80:20, 1.0 mL min^{-1}, τ_{major} = 12.22 min, τ_{minor} = 14.67 min). Absolute stereochemistry of **4j** is assigned in analogy with **4w**.



4k

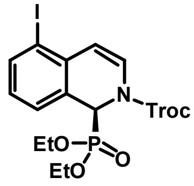
2,2,2-Trichloroethyl (*S*)-1-(diethoxyphosphoryl)-5-nitroisoquinoline-2(1*H*)-carboxylate 4k: Purification by silica gel (100-200 mesh) column chromatography (40% EtOAc in petroleum ether) afforded pure **4k** as a yellow oil (45 mg, 0.092 mmol; 92% yield). **R_f** = 0.30 (50% EtOAc in petroleum ether). **FT-IR (neat):** ν 2922 (m), 2852 (w), 1734 (m), 1629 (m), 1387 (m), 1274 (m), 1123 (w), 1019 (s) cm^{-1}; **^{1}H-NMR (400 MHz, $CDCl_3$):** The compound exists as a 3.3:1 mixture of carbamate rotamers. Signals corresponding to the major rotamer: δ 7.91 (d, *J* = 8.3 Hz; 1H), 7.48-7.50 (m; 1H), 7.31-7.35 (m; 1H), 7.14 (d, *J* = 8.3 Hz; 1H), 6.66 (d, *J* = 8.3 Hz; 1H), 5.88 (d, *J* = 16.9 Hz; 1H), 4.92 (d, *J* = 11.9 Hz; 1H), 4.82 (d, *J* = 11.9 Hz; 1H), 3.86-4.14 (m; 4H), 1.23 (t, *J* = 7.1 Hz; 3H), 1.18 (t, *J* = 7.1 Hz; 3H); Representative signals corresponding to the minor rotamer: δ 7.19 (d, *J* = 8.3 Hz; 1H), 6.72 (d, *J* = 8.3 Hz; 1H), 5.81 (d, *J* = 16.9 Hz; 1H), 5.03 (d, *J* = 11.9 Hz; 1H), 4.71 (d, *J* = 11.9 Hz; 1H); **^{13}C-NMR (100 MHz, $CDCl_3$):** Signals corresponding to both rotamers: δ 150.78, 150.49, 144.86 (d, *J* = 3.2 Hz), 132.37 (d, *J* = 5.4 Hz), 132.15 (d, *J* = 5.7 Hz), 129.41, 128.46 (d, *J* = 2.0 Hz), 128.29 (d, *J* = 2.0 Hz), 128.18, 127.34 (d, *J* = 2.9 Hz), 127.20 (d, *J* = 2.8 Hz), 126.04 (d, *J* = 3.6 Hz), 125.67 (d, *J* = 3.5 Hz), 125.15 (d, *J* = 3.4 Hz), 125.01 (d, *J* = 3.6 Hz), 105.21, 105.14, 94.46, 94.36, 75.84, 75.78, 63.50 (d, *J* = 7.5 Hz), 63.39 (d, *J* = 7.5 Hz), 63.30 (d, *J* = 7.5 Hz), 63.21 (d, *J* = 7.5 Hz), 54.76 (d, *J* = 153.0 Hz), 53.79 (d, *J* = 153.0 Hz), 16.28 (d, *J* = 5.8 Hz), 16.26 (d, *J* = 5.8 Hz); **^{31}P-NMR (162 MHz, CDCl$_3$):** δ 17.37 (for major rotamer), 17.21 (for minor rotamer); **HRMS (ESI+):** Calculated for $C_{16}H_{18}Cl_3N_2O_7PNa$ ($[M + Na]^+$): 508.9815, found: 508.9814; **$[\alpha]_D^{22}$** +118.4 (*c* 1.00, CHCl$_3$) for an enantiomerically enriched sample with 93:7 e.r. Enantiomeric ratio was determined by HPLC analysis (Phenomenex Lux Cellulose-1 column, 254 nm, ^{n}Hexane/IPA = 80:20, 1.0 mL min^{-1}, τ_{major} = 7.71 min, τ_{minor} = 8.57 min). Absolute stereochemistry of **4k** is assigned in analogy with **4w**.

2,2,2-Trichloroethyl (*S*)-5-bromo-1-(diethoxyphosphoryl)isoquinoline-2(1*H*)-carboxylate 4l:



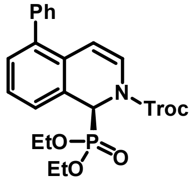
4l

Purification by silica gel (100-200 mesh) column chromatography (40% EtOAc in petroleum ether) afforded pure **4l** as a colorless oil (36 mg, 0.069 mmol; 69% yield). **R$_f$** = 0.45 (50% EtOAc in petroleum ether). **FT-IR (neat):** ν 2917 (m), 1729 (s), 1631 (m), 1387 (m), 1274 (m), 1117 (s), 1018 (s) cm^{-1}; **^{1}H-NMR (400 MHz, CDCl$_3$):** The compound exists as a 2.7:1 mixture of carbamate rotamers. <u>Signals corresponding to the major rotamer</u>: δ 7.46-7.48 (m; 1H), 7.18-7.20 (m; 1H), 7.00-7.08 (m; 2H), 6.30 (d, *J* = 8.1 Hz; 1H), 5.80 (d, *J* = 16.6 Hz; 1H), 4.90 (d, *J* = 11.6 Hz; 1H), 4.81 (d, *J* = 11.6 Hz; 1H), 3.89-4.13 (m; 4H), 1.15-1.24 (m; 6H); <u>Representative signals corresponding to the minor rotamer</u>: δ 6.36 (d, *J* = 8.1 Hz; 1H), 5.74 (d, *J* = 16.6 Hz; 1H), 5.02 (d, *J* = 11.6 Hz; 1H), 4.69 (d, *J* = 11.6 Hz; 1H), 3.76-3.88 (m; 4H); **^{13}C-NMR (100 MHz, CDCl$_3$):** <u>Signals corresponding to both rotamers</u>: δ 151.14, 150.76, 132.97 (d, *J* = 3.6 Hz), 132.81 (d, *J* = 3.6 Hz), 130.71 (d, *J* = 3.9 Hz), 130.42 (d, *J* = 3.9 Hz), 128.46 (d, *J* = 2.9 Hz), 128.31 (d, *J* = 2.9 Hz), 127.63 (d, *J* = 2.1 Hz), 127.48 (d, *J* = 2.1 Hz), 126.81 (d, *J* = 5.4 Hz), 126.66 (d, *J* = 5.4 Hz), 125.74, 120.77 (d, *J* = 3.8 Hz), 120.69 (d, *J* = 3.6 Hz), 109.81, 109.71, 94.67, 94.55, 75.78, 75.74, 63.43 (d, *J* = 7.4 Hz), 63.27 (d, *J* = 7.4 Hz), 63.20 (d, *J* = 7.4 Hz), 63.00 (d, *J* = 7.4 Hz), 54.75 (d, *J* = 151.5 Hz), 54.02 (d, *J* = 151.2 Hz), 16.33 (d, *J* = 2.4 Hz), 16.28 (d, *J* = 2.1 Hz); **^{31}P-NMR (162 MHz, CDCl$_3$):** δ 18.08 (for major rotamer), 17.88 (for minor rotamer); **HRMS (ESI+):** Calculated for $C_{16}H_{18}Cl_3NO_5PNa$ ($[M + Na]^+$): 541.9069, found: 541.9068; **$[\alpha]_D^{22}$** +137.3 (*c* 1.00, CHCl$_3$) for an enantiomerically enriched sample with 96:4 e.r. Enantiomeric ratio was determined by HPLC analysis (Daicel Chiralpak IE column, 254 nm, ^{n}Hexane/IPA = 80:20, 1.0 mL min^{-1}, τ_{major} = 13.42 min, τ_{minor} = 15.46 min). Absolute stereochemistry of **4l** is assigned in analogy with **4w**.



2,2,2-Trichloroethyl (*S*)-1-(diethoxyphosphoryl)-5-iodoisoquinoline-2(1*H*)-carboxylate 4m: Purification by silica gel (100-200 mesh) column chromatography (30% EtOAc in petroleum ether) afforded pure **4m** as a colorless oil (48 mg, 0.084 mmol; 84% yield). $\mathbf{R_f}$ = 0.55 (50% EtOAc in petroleum ether). **FT-IR (neat):** ν 2984 (m), 1731 (s), 1630 (s), 1444 (s), 1390 (s), 1339 (s), 1277 (s), 1139 (m), 1016 (s), 935 (s) cm^{-1}; **^{1}H-NMR (400 MHz, $CDCl_3$):** The compound exists as a 2.8:1 mixture of carbamate rotamers. Signals corresponding to the major rotamer: δ 7.74-7.76 (m; 1H), 7.21-7.23 (m; 1H), 6.98 (d, *J* = 8.0 Hz; 1H), 6.91 (t, *J* = 7.7 Hz; 1H), 6.19 (d, *J* = 8.0 Hz; 1H), 5.77 (d, *J* = 16.8 Hz; 1H), 4.91 (d, *J* = 12.2 Hz; 1H), 4.81 (d, *J* = 12.2 Hz; 1H), 3.82-4.09 (m; 4H), 1.15-1.24 (m; 6H); Representative signals corresponding to the minor rotamer: δ 7.02 (d, *J* = 8.0 Hz; 1H), 6.25 (d, *J* = 8.0 Hz; 1H), 5.70 (d, *J* = 16.8 Hz; 1H), 5.03 (d, *J* = 12.2 Hz; 1H), 4.70 (d, *J* = 12.2 Hz; 1H); **^{13}C-NMR (100 MHz, $CDCl_3$):** Signals corresponding to both rotamers: δ 151.03, 150.63 (d, *J* = 1.2 Hz), 144.73, 141.25, 139.57 (d, *J* = 3.5 Hz), 139.41 (d, *J* = 3.6 Hz), 133.75 (d, *J* = 3.5 Hz), 133.44 (d, *J* = 3.6 Hz), 128.72 (d, *J* = 2.8 Hz), 128.57 (d, *J* = 2.6 Hz), 128.34, 127.73 (d, *J* = 5.4 Hz), 127.58 (d, *J* = 5.7 Hz), 127.13, 126.90 (d, *J* = 2.1 Hz), 126.75 (d, *J* = 2.3 Hz), 125.99, 114.63, 114.50, 96.37 (d, *J* = 3.7 Hz), 96.29 (d, *J* = 3.7 Hz), 94.62, 94.50, 75.71, 75.67, 63.38 (d, *J* = 6.7 Hz), 63.21 (d, *J* = 6.7 Hz), 63.13 (d, *J* = 6.7 Hz), 62.93 (d, *J* = 6.7 Hz), 55.04 (d, *J* = 152.1 Hz), 54.15 (d, *J* = 152.1 Hz), 16.36 (d, *J* = 3.7 Hz), 16.27 (d, *J* = 5.8 Hz), 16.26 (d, *J* = 5.8 Hz); **^{31}P-NMR (162 MHz, $CDCl_3$):** δ 18.10 (for major rotamer), 17.89 (for minor rotamer); **HRMS (ESI+):** Calculated for $C_{16}H_{18}Cl_3INO_5PNa$ ($[M + Na]^+$): 589.8931, found: 589.8931; $[\boldsymbol{\alpha}]_D^{22}$ +179.9 (*c* 1.00, $CHCl_3$) for an enantiomerically enriched sample with 90.5:9.5 e.r. Enantiomeric ratio was determined by HPLC analysis (Daicel Chiralpak IE column, 254 nm, ^{n}Hexane/IPA = 80:20, 1.0 mL min^{-1}, τ_{major} = 13.88 min, τ_{minor} = 15.34 min). Absolute stereochemistry of **4m** is assigned in analogy with **4w**.

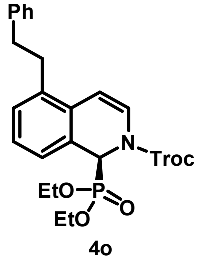
4m



2,2,2-Trichloroethyl (*S*)-1-(diethoxyphosphoryl)-5-phenylisoquinoline-2(1*H*)-carboxylate 4n: Purification by silica gel (100-200 mesh) column chromatography (30% EtOAc in petroleum ether) afforded pure **4n** as a colorless oil (45 mg, 0.087 mmol; 87% yield). $\mathbf{R_f}$ = 0.60 (50% EtOAc in petroleum ether). **FT-IR (neat):** ν 2925 (w), 1728 (s), 1634 (m), 1386 (s), 1231 (m), 1128 (s), 1020 (s) cm^{-1}; **^{1}H-NMR (400 MHz, $CDCl_3$):** The compound exists as a 2.6:1 mixture of carbamate rotamers. Signals corresponding to the major rotamer: δ 7.22-7.43 (m; 8H), 6.88 (d, *J* = 8.1 Hz; 1H), 5.99 (d, *J* = 8.1 Hz; 1H), 5.89 (d, *J* = 16.6 Hz; 1H), 4.90 (d, *J* = 11.8 Hz; 1H), 4.79 (d, *J* = 11.8 Hz; 1H), 3.94-4.12 (m; 4H), 1.15-1.25 (m; 6H); Representative signals corresponding to the minor rotamer: δ 6.91 (d, *J* = 8.1 Hz; 1H), 6.06 (d, *J* = 8.1 Hz; 1H), 5.84 (d, *J* = 16.6 Hz; 1H), 5.03 (d, *J* = 11.8 Hz; 1H), 4.70 (d, *J* = 11.8 Hz; 1H), 3.80-3.92 (m; 4H); **^{13}C-NMR (100 MHz, $CDCl_3$):** Signals corresponding to both rotamers: δ 151.24, 150.85

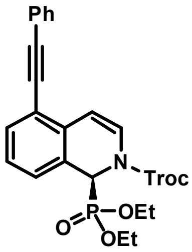
4n

(d, *J* = 1.3 Hz), 139.63, 139.53, 138.46 (d, *J* = 3.0 Hz), 138.36 (d, *J* = 3.0 Hz), 130.27 (d, *J* = 3.5 Hz), 130.11 (d, *J* = 3.3 Hz), 129.45, 129.42, 128.21, 128.19, 128.13 (d, *J* = 3.8 Hz), 127.30, 127.28, 127.25, 127.17 (d, *J* = 2.8 Hz), 126.73 (d, *J* = 5.2 Hz), 126.58 (d, *J* = 5.2 Hz), 126.24 (d, *J* = 2.1 Hz), 126.18 (d, *J* = 2.1 Hz), 125.10, 124.03, 109.49, 109.21, 94.74, 94.64, 75.62, 75.59, 63.22 (d, *J* = 7.4 Hz), 63.06 (d, *J* = 7.4 Hz), 62.97 (d, *J* = 7.4 Hz), 62.76 (d, *J* = 7.4 Hz), 55.10 (d, *J* = 150.7 Hz), 54.18 (d, *J* = 150.7 Hz), 16.36, 16.28 (d, *J* = 5.8 Hz); **^{31}P-NMR (162 MHz, $CDCl_3$):** δ 18.86 (for major rotamer), 18.59 (for minor rotamer); **HRMS (ESI+):** Calculated for $C_{22}H_{23}Cl_3NO_5PNa$ ([M + Na]$^+$): 540.0277, found: 540.0277; **[α]$_D^{22}$** +191.4 (*c* 1.00, $CHCl_3$) for an enantiomerically enriched sample with 93.5:6.5 e.r. Enantiomeric ratio was determined by HPLC analysis (Daicel Chiralpak IE column, 254 nm, ^{n}Hexane/IPA = 80:20, 1.0 mL min^{-1}, τ_{major} = 13.16 min, τ_{minor} = 15.24 min). Absolute stereochemistry of **4n** is assigned in analogy with **4w**.


4o

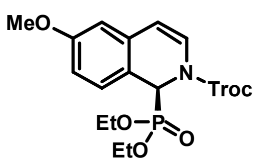
2,2,2-Trichloroethyl (*S*)-1-(diethoxyphosphoryl)-5-phenethylisoquinoline-2(1*H*)-carboxylate 4o: Purification by silica gel (100-200 mesh) column chromatography (30% EtOAc in petroleum ether) afforded pure **4o** as a colorless oil (48 mg, 0.088 mmol; 88% yield). **R$_f$** = 0.55 (50% EtOAc in petroleum ether). **FT-IR (neat):** ν 2923 (w), 1727 (s), 1635 (m), 1387 (m), 1231 (m), 1126 (m), 1020 (m) cm^{-1}; **^{1}H-NMR (400 MHz, $CDCl_3$):** The compound exists as a 2.5:1 mixture of carbamate rotamers. <u>Signals corresponding to the major rotamer</u>: δ 7.27-7.31 (m; 2H), 7.14-7.23 (m; 5H), 7.06-7.08 (m; 1H), 6.98 (d, *J* = 8.1 Hz; 1H), 6.16 (d, *J* = 8.1 Hz; 1H), 5.82 (d, *J* = 16.3 Hz; 1H), 4.93 (d, *J* = 11.9 Hz; 1H), 4.81 (d, *J* = 11.9 Hz; 1H), 3.90-4.11 (m; 4H), 2.93-2.97 (m; 2H), 2.83-2.87 (m; 2H), 1.15-1.26 (m; 6H); <u>Representative signals corresponding to the minor rotamer</u>: δ 7.02 (d, *J* = 8.1 Hz; 1H), 6.25 (d, *J* = 8.1 Hz; 1H), 5.77 (d, *J* = 16.3 Hz; 1H), 5.04 (d, *J* = 11.9 Hz; 1H), 4.71 (d, *J* = 11.9 Hz; 1H), 3.74-3.88 (m; 4H); **^{13}C-NMR (100 MHz, $CDCl_3$):** <u>Signals corresponding to both rotamers</u>: δ 150.88 (d, *J* = 1.4 Hz), 141.26, 141.24, 136.56 (d, *J* = 3.1 Hz), 136.45 (d, *J* = 3.1 Hz), 129.89 (d, *J* = 3.5 Hz), 129.73 (d, *J* = 3.3 Hz), 128.81 (d, *J* = 3.9 Hz), 128.56 (d, *J* = 4.1 Hz), 128.40, 128.30, 127.47 (d, *J* = 2.7 Hz), 127.33 (d, *J* = 2.7 Hz), 126.09, 126.05 (d, *J* = 2.1 Hz), 125.95 (d, *J* = 2.2 Hz), 125.84 (d, *J* = 5.3 Hz), 125.72 (d, *J* = 5.3 Hz), 125.26, 124.16, 107.95, 107.72, 94.81, 94.66, 75.68, 75.65, 63.18 (d, *J* = 7.3 Hz), 63.05 (d, *J* = 7.3 Hz), 62.98 (d, *J* = 7.3 Hz), 62.78 (d, *J* = 7.3 Hz), 55.08 (d, *J* = 151.4 Hz), 54.23 (d, *J* = 151.4 Hz), 37.33, 37.29, 34.70, 34.64, 16.37 (d, *J* = 5.4 Hz), 16.35 (d, *J* = 5.4 Hz); **^{31}P-NMR (162 MHz, $CDCl_3$):** δ 18.87 (for major rotamer), 18.64 (for minor rotamer); **HRMS (ESI+):** Calculated for $C_{25}H_{27}Cl_3NO_5PNa$ ([M + Na]$^+$): 568.0590, found: 5680590; **[α]$_D^{22}$** +195.1 (*c* 1.00, $CHCl_3$) for an enantiomerically enriched sample with 93:7 e.r. Enantiomeric ratio was determined by HPLC analysis (Daicel Chiralpak IE column, 254 nm, ^{n}Hexane/EtOH = 80:20, 1.0

mL min^{-1}, τ_{major} = 9.52 min, τ_{minor} = 10.30 min). Absolute stereochemistry of **4o** is assigned in analogy with **4w**.



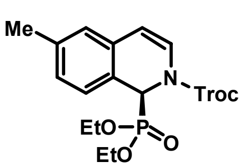
4p

2,2,2-Trichloroethyl (*S*)-1-(diethoxyphosphoryl)-5-(phenylethynyl)isoquinoline-2(1*H*)-carboxylate 4p: Purification by silica gel (100-200 mesh) column chromatography (30% EtOAc in petroleum ether) afforded pure **4p** as a colorless oil (49 mg, 0.090 mmol; 90% yield). **R$_f$** = 0.50 (50% EtOAc in petroleum ether). **FT-IR (neat):** ν 2925 (w), 1729 (s), 1635 (s), 1386 (m), 1232 (m), 1125 (m), 1020 (m) cm^{-1}; **^{1}H-NMR (400 MHz, CDCl$_3$):** The compound exists as a 2.9:1 mixture of carbamate rotamers. <u>Signals corresponding to the major rotamer</u>: δ 7.53-7.56 (m; 2H), 7.44-7.47 (m; 1H), 7.35-7.37 (m; 3H), 7.19-7.23 (m; 2H), 7.05 (d, *J* = 8.0 Hz; 1H), 6.52 (d, *J* = 8.0 Hz; 1H), 5.85 (d, *J* = 16.3 Hz; 1H), 4.91 (d, *J* = 11.8 Hz; 1H), 4.83 (d, *J* = 11.8 Hz; 1H), 3.83-4.13 (m; 4H), 1.16-1.25 (m; 6H); <u>Representative signals corresponding to the minor rotamer</u>: δ 7.09 (d, *J* = 8.0 Hz; 1H), 6.57 (d, *J* = 8.0 Hz; 1H), 5.79 (d, *J* = 16.3 Hz; 1H), 5.04 (d, *J* = 11.8 Hz; 1H), 4.71 (d, *J* = 11.8 Hz; 1H); **^{13}C-NMR (100 MHz, CDCl$_3$):** <u>Signals corresponding to both rotamers</u>: δ150.84, 132.33 (d, J = 3.4 Hz), 132.17 (d, J = 3.5 Hz), 132.10 (d, J = 3.5 Hz), 131.58, 128.55, 128.41, 127.58 (d, J = 5.4 Hz), 127.42 (d, J = 5.6 Hz), 127.25 (d, J = 2.8 Hz), 127.10 (d, J = 3.2 Hz), 126.14, 125.86 (d, J = 1.7 Hz), 125.05, 122.87, 119.04 (d, J = 3.0 Hz), 109.30, 109.19, 94.71, 94.59, 94.26, 94.13, 86.52, 86.40, 75.72, 75.70, 63.44 (d, J = 7.3 Hz), 63.29 (d, J = 7.3 Hz), 63.18 (d, J = 7.3 Hz), 62.96 (d, J = 7.3 Hz), 54.74 (d, J = 152.7 Hz), 53.97 (d, J = 152.7 Hz), 16.30 (d, J = 5.7 Hz); **^{31}P-NMR (162 MHz, CDCl$_3$):** δ 18.37 (for major rotamer), 18.14 (for minor rotamer); **HRMS (ESI+):** Calculated for $C_{24}H_{23}Cl_3NO_5PNa$ ($[M + Na]^+$): 564.0277, found: 564.0283; **$[\alpha]_D^{22}$** +111.3 (*c* 1.00, CHCl$_3$) for an enantiomerically enriched sample with 95:5 e.r. Enantiomeric ratio was determined by HPLC analysis (Daicel Chiralpak IE column, 254 nm, ^{n}Hexane/IPA = 80:20, 1.0 mL min^{-1}, τ_{major} = 14.12 min, τ_{minor} = 15.80 min). Absolute stereochemistry of **4p** is assigned in analogy with **4w**.



4q

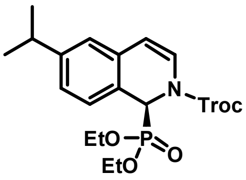
2,2,2-Trichloroethyl (*S*)-1-(diethoxyphosphoryl)-6-methoxyisoquinoline-2(1*H*)-carboxylate 4q: Purification by silica gel (100-200 mesh) column chromatography (30% EtOAc in petroleum ether) afforded pure **4q** as a colorless oil (39 mg, 0.083 mmol; 83% yield). **R$_f$** = 0.60 (50% EtOAc in petroleum ether). **FT-IR (neat):** ν 1642 (s), 1389 (w), 1256 (w), 1114 (w), 1021 (w) cm^{-1}; **^{1}H-NMR (400 MHz, CDCl$_3$):** The compound exists as a 2.4:1 mixture of carbamate rotamers. <u>Signals corresponding to the major rotamer</u>: δ 7.17-7.19 (m; 1H), 6.94 (d, *J* = 7.8 Hz; 1H), 6.75-6.78 (m; 1H), 6.62-6.63 (m; 1H), 5.89 (d, *J* = 8.1 Hz; 1H), 5.79 (d, *J* = 15.6 Hz; 1H), 4.91 (d, *J* = 11.7 Hz; 1H), 4.79 (d, *J* = 11.9 Hz; 1H), 3.87-5.04 (m; 4H), 3.80 (s; 3H), 1.15-1.25 (m; 6H); Representative signals corresponding to the minor rotamer: δ 6.98 (d, *J* = 7.8 Hz; 1H), 5.96 (d, *J* = 8.1 Hz; 1H), 5.73 (d, *J* = 15.6 Hz; 1H), 5.03 (d, *J* = 11.7 Hz; 1H), 4.68 (d, *J* = 11.9 Hz; 1H); **^{13}C-NMR (100 MHz, CDCl$_3$):** Signals corresponding to both rotamers: δ 160.07 (d, *J* = 3.1 Hz), 159.93 (d, *J* = 3.1 Hz), 151.41, 150.93, 132.26 (d, *J* = 3.9 Hz), 131.91 (d, *J* = 3.9 Hz), 128.61 (d, *J* = 5.1 Hz), 128.49 (d, *J* = 5.1 Hz), 125.50, 124.43, 117.57 (d, *J* = 2.2 Hz), 117.42 (d, *J* = 2.2 Hz), 112.80 (d, *J* = 2.4 Hz), 112.64 (d, *J* = 2.4 Hz), 111.12, 110.99, 110.80, 110.77, 94.82, 94.67, 75.71, 75.67, 63.24 (d, *J* = 7.1 Hz), 63.10 (d, *J* = 7.1 Hz), 62.97 (d, *J* = 7.1 Hz), 62.75 (d, *J* = 7.1 Hz), 55.31, 54.03 (d, *J* = 153.4 Hz), 53.33 (d, *J* = 153.4 Hz), 16.41 (d, *J* = 2.2 Hz), 16.35 (d, *J* = 2.7 Hz); **^{31}P-NMR (162 MHz, CDCl$_3$):** δ 18.82 (for major rotamer), 18.55 (for minor rotamer); **HRMS (ESI+):** Calculated for $C_{17}H_{21}Cl_3NO_6PNa$ ([M + Na]$^+$): 494.0070, found: 492.0073; **$[\alpha]_D^{22}$** +145.8 (*c* 0.50, CHCl$_3$) for an enantiomerically enriched sample with 87.5:12.5 e.r. Enantiomeric ratio was determined by HPLC analysis (Daicel Chiralpak IE column, 254 nm, ^{n}Hexane/IPA = 80:20, 1.0 mL min^{-1}, τ_{major} = 24.57 min, τ_{minor} = 45.48 min). Absolute stereochemistry of **4q** is assigned in analogy with **4w**.



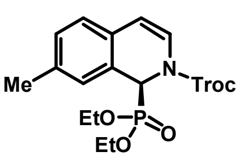
4r

2,2,2-Trichloroethyl (*S*)-1-(diethoxyphosphoryl)-6-methylisoquinoline-2(1*H*)-carboxylate 4r: Purification by silica gel (100-200 mesh) column chromatography (30% EtOAc in petroleum ether) afforded pure **4r** as a colorless oil (38 mg, 0.083 mmol; 83% yield). **R$_f$** = 0.40 (50% EtOAc in petroleum ether). **FT-IR (neat):** ν 2920 (s), 2850 (m), 1728 (s), 1638 (m), 1464 (m), 1388 (m), 1262 (m), 1115 (m), 1020 (s) cm^{-1}; **^{1}H-NMR (400 MHz, CDCl$_3$):** The compound exists as a 2.5:1 mixture of carbamate rotamers. Signals corresponding to the major rotamer: δ 7.14 (d, *J* = 7.7 Hz; 1H), 7.03 (d, *J* = 7.7 Hz; 1H), 6.91 (d, *J* = 8.2 Hz; 1H), 6.89 (s; 1H), 5.89 (d, *J* = 7.9 Hz; 1H), 5.80 (d, *J* = 16.0 Hz; 1H), 4.90 (d, *J* = 12.0 Hz; 1H), 4.79 (d, *J* = 12.0 Hz; 1H), 3.88-4.11 (m; 4H), 2.30 (s; 3H), 1.15-1.24 (m; 6H); Representative signals corresponding to the minor rotamer: δ 6.95 (d, *J* = 8.2 Hz; 1H), 5.96 (d, *J* = 7.9 Hz; 1H), 5.74 (d, *J* = 16.0 Hz; 1H), 5.02 (d, *J* = 12.0 Hz; 1H), 4.67 (d, *J* = 12.0 Hz; 1H), 3.73-3.87 (m; 4H); **^{13}C-NMR (100 MHz, CDCl$_3$):** Signals corresponding to both rotamers: δ 151.36, 150.94 (d, *J* = 1.4 Hz), 138.70 (d, *J* = 3.6 Hz), 138.49 (d, *J* = 3.6 Hz), 130.79 (d, *J* = 4.3 Hz), 130.49 (d, *J* = 4.3 Hz), 128.31 (d, *J* = 2.8 Hz), 128.16 (d, *J* = 2.8 Hz), 127.36 (d, *J* = 5.2 Hz), 127.24 (d, *J* = 5.2 Hz), 125.92 (d, *J* = 3.0 Hz), 125.84 (d, *J* = 3.0 Hz), 124.97, 123.90, 122.52 (d, *J* = 2.3 Hz), 122.39 (d, *J* = 2.3 Hz), 111.29, 111.14, 94.80, 94.66, 75.63, 75.60, 63.18 (d, *J* = 7.3 Hz), 63.05 (d, *J* = 7.3 Hz), 62.94 (d, *J* = 6.5 Hz), 62.72 (d, *J* = 6.5 Hz), 54.25 (d, *J* = 152.4 Hz), 53.64 (d, *J* = 152.4 Hz), 21.11, 16.43, 16.33 (d, *J* = 5.8 Hz); **^{31}P-NMR (162 MHz, CDCl$_3$):** δ 18.77 (for major rotamer), 18.55 (for minor rotamer); **HRMS (ESI+):** Calculated for $C_{17}H_{21}Cl_3NO_5PNa$ ([M + Na]$^+$): 478.0121, found: 478.0122; **$[\alpha]_D^{22}$** +190.5 (*c* 1.00, CHCl$_3$) for an enantiomerically enriched sample with 93.5:6.5 e.r. Enantiomeric ratio was determined by HPLC analysis (Daicel

Chiralpak IE column, 254 nm, ^{n}Hexane/IPA = 80:20, 1.0 mL min^{-1}, τ_{major} = 19.50 min, τ_{minor} = 28.31 min). Absolute stereochemistry of **4r** is assigned in analogy with **4w**.

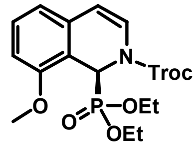

4s

2,2,2-Trichloroethyl (*S*)-1-(diethoxyphosphoryl)-6-isopropylisoquinoline-2(1*H*)-carboxylate 4s: Purification by silica gel (100-200 mesh) column chromatography (30% EtOAc in petroleum ether) afforded pure **4s** as a colorless oil (42 mg, 0.087 mmol; 87% yield). **R$_f$** = 0.50 (50% EtOAc in petroleum ether). **FT-IR (neat):** ν 2962 (m), 1728 (s), 1637 (s), 1390 (s), 1314 (m), 1241 (s), 1132 (m), 1053 (s), 1021 (s) cm^{-1}; **^{1}H-NMR (400 MHz, CDCl$_3$):** The compound exists as a 2.5:1 mixture of carbamate rotamers. Signals corresponding to the major rotamer: δ 7.17-7.19 (m; 1H), 7.09 (d, *J* = 7.8 Hz; 1H), 6.91-6.96 (m; 2H), 5.93 (d, *J* = 7.9 Hz; 1H), 5.81 (d, *J* = 16.3 Hz; 1H), 4.89 (d, *J* = 12.1 Hz; 1H), 4.79 (d, *J* = 12.1 Hz; 1H), 3.88-4.13 (m; 4H), 2.82-2.89 (m; 1H), 1.12-1.24 (m; 12H); Representative signals corresponding to the minor rotamer: δ 5.99 (d, *J* = 7.9 Hz; 1H), 5.76 (d, *J* = 16.3 Hz; 1H), 5.02 (d, *J* = 12.1 Hz; 1H), 4.66 (d, *J* = 12.1 Hz; 1H), 3.71-3.85 (m; 4H); **^{13}C-NMR (100 MHz, CDCl$_3$):** Signals corresponding to both rotamers: δ 151.38, 150.97 (d, *J* = 1.4 Hz), 149.85 (d, *J* = 3.7 Hz), 149.62 (d, *J* = 3.6 Hz), 130.87 (d, *J* = 3.9 Hz), 130.55 (d, *J* = 3.9 Hz), 127.47 (d, *J* = 5.2 Hz), 127.37 (d, *J* = 5.2 Hz), 125.83 (d, *J* = 2.7 Hz), 125.66 (d, *J* = 2.7 Hz), 124.92, 123.85, 123.40 (d, *J* = 3.0 Hz), 123.31 (d, *J* = 3.0 Hz), 122.91 (d, *J* = 2.2 Hz), 122.77 (d, *J* = 2.2 Hz), 111.51, 111.38, 94.83, 94.68, 75.64, 75.62, 63.23 (d, *J* = 6.6 Hz), 63.08 (d, *J* = 6.6 Hz), 62.96 (d, *J* = 6.6 Hz), 62.73 (d, *J* = 6.6 Hz), 54.53 (d, *J* = 152.1 Hz), 53.67 (d, *J* = 152.1 Hz), 33.81, 23.81, 23.80, 16.39 (d, *J* = 5.7 Hz), 16.30 (d, *J* = 5.7 Hz); **^{31}P-NMR (162 MHz, CDCl$_3$):** δ 18.86 (for major rotamer), 18.58 (for minor rotamer); **HRMS (ESI+):** Calculated for $C_{19}H_{25}Cl_3NO_5PNa$ ([M + Na]$^+$): 506.0434, found: 506.0432; **$[\alpha]_D^{22}$** +170.7 (*c* 2.00, CHCl$_3$) for an enantiomerically enriched sample with 88.5:11.5 e.r. Enantiomeric ratio was determined by HPLC analysis (Daicel Chiralpak IE column, 254 nm, ^{n}Hexane/IPA = 80:20, 1.0 mL min^{-1}, τ_{major} = 16.26 min, τ_{minor} = 24.69 min). Absolute stereochemistry of **4s** is assigned in analogy with **4w**.


4t

2,2,2-Trichloroethyl (*S*)-1-(diethoxyphosphoryl)-7-methylisoquinoline-2(1*H*)-carboxylate 4t: Purification by silica gel (100-200 mesh) column chromatography (20% EtOAc in petroleum ether) afforded pure **4t** as a colorless oil (43 mg, 0.094 mmol; 94% yield). **R$_f$** = 0.45 (50% EtOAc in petroleum ether). **FT-IR (neat):** ν 3109 (w), 2925 (m), 1727 (s), 1638 (m), 1387 (s), 1237 (s), 1135 (s), 1021 (s) cm^{-1}; **^{1}H-NMR (400 MHz, CDCl$_3$):** The compound exists as a 2.4:1 mixture of carbamate rotamers. Signals corresponding to the major rotamer: δ 7.05-7.09 (m; 2H), 6.97 (d; *J* = 7.6 Hz; 1H), 6.88 (d, *J* = 7.6 Hz; 1H), 5.92 (d, *J* = 7.6 Hz; 1H), 5.80 (d, *J* = 16.6 Hz; 1H), 4.90 (d, *J* = 11.8 Hz; 1H), 4.79 (d, *J* = 11.8 Hz; 1H), 3.90-4.14 (m;

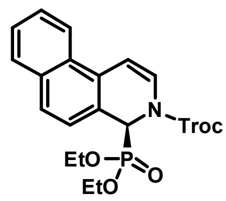
4H), 2.33 (s; 3H), 1.14-1.25 (m; 6H); Representative signals corresponding to the minor rotamer: δ 6.92 (d, *J* = 7.6 Hz; 1H), 5.99 (d, *J* = 7.6 Hz; 1H), 5.74 (d, *J* = 16.6 Hz; 1H), 5.03 (d, *J* = 11.8 Hz; 1H), 4.67 (d, *J* = 11.8 Hz; 1H), 3.69-3.88 (m; 4H); **^{13}C-NMR (100 MHz, CDCl$_3$):** Signals corresponding to both rotamers: δ 151.40, 151.04, 137.66 (d, *J* = 2.8 Hz), 129.56 (d, *J* = 3.7 Hz), 129.39 (d, *J* = 3.3 Hz), 128.30 (d, *J* = 5.2 Hz), 128.18 (d, *J* = 5.2 Hz), 128.02 (d, *J* = 4.2 Hz), 125.51 (d, *J* = 2.1 Hz), 125.35 (d, *J* = 2.1 Hz), 125.16 (d, *J* = 3.7 Hz), 125.08 (d, *J* = 3.0 Hz), 124.21, 123.14, 111.28, 111.13, 94.86, 94.71, 75.67, 75.63, 63.27 (d, *J* = 7.4 Hz), 63.13 (d, *J* = 7.4 Hz), 63.01 (d, *J* = 7.4 Hz), 62.77 (d, *J* = 7.4 Hz), 54.71 (d, *J* = 151.4 Hz), 53.92 (d, *J* = 151.4 Hz), 21.26, 21.23, 16.46 (d, *J* = 6.3 Hz), 16.33 (d, *J* = 6.3 Hz); **^{31}P-NMR (162 MHz, CDCl$_3$):** δ 18.77 (for major rotamer), 18.50 (for minor rotamer); **HRMS (ESI+):** Calculated for $C_{17}H_{21}Cl_3NO_5PNa$ ([M + Na]$^+$): 478.0121, found: 478.0127; **[α]$_D$^{22}** +156.7 (*c* 0.50, CHCl$_3$) for an enantiomerically enriched sample with 97:3 e.r. Enantiomeric ratio was determined by HPLC analysis (Daicel Chiralpak AD-H column, 254 nm, ^{n}Hexane/EtOH = 90:10, 1.0 mL min^{-1}, τ_{major} = 8.05 min, τ_{minor} = 11.47 min). Absolute stereochemistry of **4t** is assigned in analogy with **4w**.



4u

2,2,2-Trichloroethyl (*S*)-1-(diethoxyphosphoryl)-8-methoxyisoquinoline-2(1*H*)-carboxylate 4u: Purification by silica gel (100-200 mesh) column chromatography (40% EtOAc in petroleum ether) afforded pure **4u** as a colorless oil (39 mg, 0.083 mmol; 83% yield). **R$_f$** = 0.35 (50% EtOAc in petroleum ether). **FT-IR (neat):** ν 2925 (m), 1727 (s), 1637 (m), 1386 (s), 1262 (s), 1128 (m), 1020 (m) cm^{-1}; **^{1}H-NMR (400 MHz, CDCl$_3$):** The compound exists as a 2.7:1 mixture of carbamate rotamers. Signals corresponding to the major rotamer: δ 7.19-7.21 (m; 1H), 6.95-6.99 (m; 1H), 6.78-6.80 (m; 1H), 6.69-6.72 (m; 1H), 6.25 (d, *J* = 15.9 Hz; 1H), 5.93 (d, *J* = 7.7 Hz; 1H), 4.85 (s; 2H), 3.89-4.11 (m; 4H), 3.86 (s; 3H), 1.22-1.27 (m; 3H), 1.10-1.16 (m; 3H); Representative signals corresponding to the minor rotamer: δ 6.26 (d, *J* = 15.9 Hz; 1H), 6.01 (d, *J* = 7.7 Hz; 1H), 5.03 (d, *J* = 11.8 Hz; 1H), 4.72 (d, *J* = 11.8 Hz; 1H); **^{13}C-NMR (100 MHz, CDCl$_3$):** Signals corresponding to both rotamers: δ 155.37 (d, *J* = 4.8 Hz), 155.30 (d, *J* = 4.8 Hz), 151.42, 150.92 (d, *J* = 1.4 Hz), 132.31 (d, *J* = 3.9 Hz), 131.90 (d, *J* = 3.9 Hz), 129.41 (d, *J* = 3.6 Hz), 129.32 (d, *J* = 3.6 Hz), 125.84, 124.85, 117.71 (d, *J* = 3.0 Hz), 117.56 (d, *J* = 3.0 Hz), 113.93, 113.75, 111.51, 111.03, 110.19, 110.15 (d, *J* = 2.9 Hz), 94.82, 75.66, 75.62, 62.68 (d, *J* = 6.9 Hz), 62.66 (d, *J* = 6.9 Hz), 55.75, 55.61, 48.64 (d, *J* = 152.3 Hz), 48.54 (d, *J* = 152.3 Hz), 16.35 (d, *J* = 6.0 Hz), 16.20 (d, *J* = 6.0 Hz); **^{31}P-NMR (162 MHz, CDCl$_3$):** δ 19.59 (for major rotamer), 19.36 (for minor rotamer); **HRMS (ESI+):** Calculated for $C_{17}H_{21}Cl_3NO_6PNa$ ([M + Na]$^+$): 494.0070, found: 494.0068; **[α]$_D$^{22}** -42.2 (*c* 1.0, CHCl$_3$) for an enantiomerically enriched sample with 65.5:34.5 e.r. Enantiomeric ratio was determined by HPLC analysis (Phenomenex C-2 column, 254 nm, ^{n}Hexane/EtOH = 90:10, 1.0 mL min^{-1}, τ_{minor} = 9.81 min, τ_{major} = 10.85 min). Absolute stereochemistry of **4u** is assigned in analogy with **4w**.

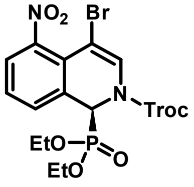
2,2,2-Trichloroethyl (*S*)-4-(diethoxyphosphoryl)benzo[f]isoquinoline-3(4*H*)-carboxylate 4v:



4v

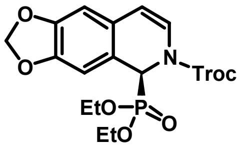
Purification by silica gel (100-200 mesh) column chromatography (30% EtOAc in petroleum ether) afforded pure **4v** as a colorless oil (38 mg, 0.077 mmol; 77% yield). **R$_f$** = 0.50 (50% EtOAc in petroleum ether). **FT-IR (neat):** ν 3062 (w), 2921 (m), 1726 (s), 1592 (w), 1386 (m), 1262 (s), 1127 (s), 1020 (s) cm^{-1}; **^{1}H-NMR (400 MHz, CDCl$_3$):** The compound exists as a 2.6:1 mixture of carbamate rotamers. Signals corresponding to the major rotamer: δ 8.03-8.05 (m; 1H), 7.80 (d, *J* = 7.8 Hz; 1H), 7.73 (d, *J* = 8.5 Hz; 1H), 7.46-7.54 (m; 2H), 7.35-7.39 (m; 1H), 7.12 (d, *J* = 8.0 Hz; 1H), 6.68 (d, *J* = 8.0 Hz; 1H), 5.98 (d, *J* = 16.4 Hz; 1H), 4.94 (d, *J* = 11.9 Hz; 1H), 4.82 (d, *J* = 11.9 Hz; 1H), 3.88-4.15 (m; 4H), 1.10-1.20 (m; 6H); Representative signals corresponding to the minor rotamer: δ 7.16 (d, *J* = 8.0 Hz; 1H), 6.75 (d, *J* = 8.0 Hz; 1H), 5.92 (d, *J* = 16.4 Hz; 1H), 5.05 (d, *J* = 11.9 Hz; 1H), 4.73 (d, *J* = 11.9 Hz; 1H), 3.71-3.86 (m; 4H); **^{13}C-NMR (100 MHz, CDCl$_3$):** Signals corresponding to both rotamers: δ 151.36, 150.92 (d, *J* = 1.3 Hz), 133.50 (d, *J* = 2.3 Hz), 133.44 (d, *J* = 2.3 Hz), 128.57 (d, *J* = 2.0 Hz), 128.53 (d, *J* = 2.0 Hz), 128.15 (d, *J* = 3.6 Hz), 127.78 (d, *J* = 2.2 Hz), 127.67 (d, *J* = 3.4 Hz), 126.98 (d, *J* = 5.7 Hz), 126.70 (d, *J* = 1.5 Hz), 126.66, 126.58, 126.23 (d, *J* = 1.3 Hz), 126.14 (d, *J* = 1.2 Hz), 125.90, 125.24 (d, *J* = 4.3 Hz), 125.10 (d, *J* = 4.3 Hz), 124.78, 122.93 (d, *J* = 2.3 Hz), 122.65 (d, *J* = 2.7 Hz), 122.49, 107.07, 106.95, 94.76, 94.62, 75.67, 75.63, 63.20 (d, *J* = 6.6 Hz), 63.10 (d, *J* = 6.6 Hz), 62.98 (d, *J* = 6.6 Hz), 62.79 (d, *J* = 6.6 Hz), 55.41 (d, *J* = 151.3 Hz), 54.55 (d, *J* = 151.3 Hz), 16.38 (d, *J* = 5.7 Hz), 16.29 (d, *J* = 5.7 Hz); **^{31}P-NMR (162 MHz, CDCl$_3$):** δ 18.50 (for major rotamer), 18.35 (for minor rotamer); **HRMS (ESI+):** Calculated for $C_{20}H_{21}Cl_3NO_5PNa$ ([M + Na]$^+$): 514.0121, found: 514.0121; **$[\alpha]_D^{22}$** +102.0 (*c* 1.00, CHCl$_3$) for an enantiomerically enriched sample with 87:13 e.r. Enantiomeric ratio was determined by HPLC analysis (Daicel Chiralpak IE column, 254 nm, ^{n}Hexane/IPA = 90:10, 1.0 mL min^{-1}, τ_{major} = 26.80 min, τ_{minor} = 44.76 min). Absolute stereochemistry of **4v** is assigned in analogy with **4w**.

2,2,2-Trichloroethyl (*S*)-4-bromo-1-(diethoxyphosphoryl)-5-nitroisoquinoline-2(1*H*)-carboxylate 4w:



4w

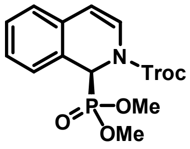
Purification by silica gel (100-200 mesh) column chromatography (50% EtOAc in petroleum ether) afforded pure **4w** as a yellow solid (54 mg, 0.095 mmol; 95% yield). **R$_f$** = 0.25 (50% EtOAc in petroleum ether). **M.P.** = 77-80 °C; **FT-IR (neat):** ν 2986 (w), 1736 (s), 1612 (m), 1535 (s), 1392 (s), 1320 (s), 1267 (s), 1231 (m), 1128 (s), 1019 (s) cm^{-1}; **^{1}H-NMR (400 MHz, CDCl$_3$):** The compound exists as a 3.3:1 mixture of carbamate rotamers. Signals corresponding to the major rotamer: δ 7.60-7.62 (m; 1H), 7.49-7.54 (m; 1H), 7.41-7.45 (m; 1H), 7.28-7.31 (m; 1H), 5.79 (d, J = 18.0 Hz; 1H), 5.00-5.07 (m; 1H), 4.74-4.77 (m; 1H), 3.91-4.22 (m; 4H), 1.21-1.40 (m; 6H); Representative signals corresponding to the minor rotamer: δ 5.71 (d, *J* = 18.0 Hz; 1H); **^{13}C-NMR (100 MHz, CDCl$_3$):** Signals corresponding to both rotamers: δ 150.14, 147.80, 133.14, 131.08, 130.43 (d, *J* = 5.8 Hz), 130.18 (d, *J* = 6.2 Hz), 129.85, 128.94 (d, *J* = 2.8 Hz), 128.81 (d, *J* = 2.8 Hz), 124.61 (d, *J* = 2.6 Hz), 124.50 (d, *J* = 3.5 Hz), 123.87 (d, *J* = 3.7 Hz), 101.47, 94.36, 75.96, 75.84, 63.70 (d, *J* = 6.3 Hz), 63.40 (d, *J* = 6.3 Hz), 55.04 (d, *J* = 149.8 Hz), 53.92 (d, *J* = 149.8 Hz), 16.34 (d, *J* = 6.0 Hz), 16.24 (d, *J* = 6.0 Hz); **^{31}P-NMR (162 MHz, CDCl$_3$):** δ 16.69 (for major rotamer), 16.49 (for minor rotamer); **HRMS (ESI+):** Calculated for $C_{16}H_{17}BrCl3N_2O_7PNa$ ([M + Na]$^+$): 586.8920, found: 586.8917; **[α]$_D^{22}$** +438.9 (*c* 1.00, CHCl$_3$) for an enantiomerically enriched sample with 90:10 e.r. Enantiomeric ratio was determined by HPLC analysis (Daicel Chiralpak IC column, 254 nm, ^{n}Hexane/EtOH = 90:10, 1.0 mL min^{-1}, τ_{minor} = 12.74 min, τ_{major} = 17.88 min). Absolute stereochemistry of **4w** is assigned by single crystal X-ray diffraction analysis.



4x

2,2,2-Trichloroethyl (*S*)-5-(diethoxyphosphoryl)-[1,3]dioxolo[4,5-g]isoquinoline-6(5*H*)-carboxylate 4x: Purification by silica gel (100-200 mesh) column chromatography (30% EtOAc in petroleum ether) afforded pure **4x** as a colorless oil (44 mg, 0.090 mmol; 90% yield). **R$_f$** = 0.40 (50% EtOAc in petroleum ether). **FT-IR (neat):** ν 3117 (w), 2984 (w), 1725 (s), 1645 (w), 1391 (s), 1338 (s), 1253 (s), 1125 (m), 1030 (s) cm^{-1}; **^{1}H-NMR (400 MHz, CDCl$_3$):** The compound exists as a 2.7:1 mixture of carbamate rotamers. Signals corresponding to the major rotamer: δ 6.83 (d, *J* = 7.8 Hz; 1H), 6.75 (s; 1H), 6.56 (s; 1H), 5.95 (s; 2H), 5.82 (d, *J* = 7.8 Hz; 1H), 5.72 (d, *J* = 15.9 Hz; 1H), 4.90 (d, *J* = 11.8 Hz; 1H), 4.77 (d, *J* = 11.8 Hz; 1H), 3.93-4.16 (m; 4H), 1.17-1.25 (m; 6H); Representative signals corresponding to the minor rotamer: δ 6.86 (d, *J* = 7.8 Hz; 1H), 6.76 (s; 1H), 6.57 (s; 1H), 5.94 (s; 2H), 5.89 (d, *J* = 7.8 Hz; 1H), 5.66 (d, *J* = 15.9 Hz; 1H), 5.00 (d, *J* = 11.8 Hz; 1H), 4.68 (d, *J* = 11.8 Hz; 1H), 3.82-3.90 (m; 4H); **^{13}C-NMR (100 MHz, CDCl$_3$):** Signals corresponding to both rotamers: δ 151.32, 150.99 (d, *J* = 2.0 Hz), 148.05 (d, *J* = 3.6 Hz), 147.93 (d, *J* = 3.6 Hz), 147.01 (d, *J* = 2.5 Hz), 146.94 (d, *J* = 2.8 Hz), 125.49 (d, *J* = 4.9 Hz), 125.15 (d, *J* = 4.6 Hz), 123.52, 122.42, 119.00 (d, *J* = 2.2 Hz), 118.78 (d, *J* = 2.6 Hz), 111.35, 111.17, 108.35 (d, *J* = 4.5 Hz), 108.24 (d, *J* = 4.8 Hz), 105.76 (d, *J* = 3.7 Hz), 105.69 (d, *J* = 3.7 Hz), 101.35, 101.30, 94.80, 94.66, 75.65, 75.62, 63.23 (d, *J* = 7.3 Hz), 63.10 (d, *J* = 7.3 Hz), 62.93 (d, *J* = 7.3 Hz), 62.72 (d, *J* = 7.3 Hz), 54.66 (d, *J* = 153.8 Hz), 53.81 (d, *J* = 153.8 Hz), 16.39 (d, *J* = 5.3 Hz), 16.27 (d, *J* = 5.3 Hz); **^{31}P-NMR (162 MHz, CDCl$_3$):** δ 18.68 (for major rotamer), 18.51 (for minor rotamer); **HRMS (ESI+):** Calculated for $C_{17}H_{19}Cl_3NO_7PNa$ ([M + Na]$^+$): 507.9862, found: 507.9863; **[α]$_D^{22}$** +109.1 (*c* 0.25, CHCl$_3$) for an enantiomerically enriched sample with 87.5:12.5 e.r. Enantiomeric ratio was determined by HPLC analysis (Phenomenex C-2 column, 254 nm, ^{n}Hexane/EtOH = 90:10, 1.0 mL min^{-1}, τ_{minor} = 15.88 min, τ_{major} = 19.03 min). Absolute stereochemistry of **4x** is assigned in analogy with **4w**.

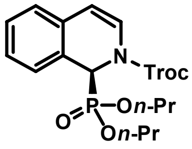
2,2,2-Trichloroethyl (*S*)-1-(dimethoxyphosphoryl)isoquinoline-2(1*H*)-carboxylate 6a:



6a

Purification by silica gel (100-200 mesh) column chromatography (30% EtOAc in petroleum ether) afforded pure **6a** as a colorless oil (38 mg, 0.092 mmol; 92% yield). **R$_f$** = 0.30 (50% EtOAc in petroleum ether). **FT-IR (neat):** ν 3073 (w), 2955 (m), 1726 (s), 1637 (m), 1385 (m), 1342 (m), 1239 (s), 1128 (s), 1027 (s) cm^{-1}; **^{1}H-NMR (400 MHz, CDCl$_3$):** The compound exists as a 2.6:1 mixture of carbamate rotamers. Signals corresponding to the major rotamer: δ 7.21-7.28 (m; 3H), 7.08-7.09 (m; 1H), 6.93 (d, *J* = 7.8 Hz; 1H), 5.96 (d, *J* = 7.8 Hz; 1H), 5.87 (d, *J* = 16.6 Hz; 1H), 4.95 (d, *J* = 11.9 Hz; 1H), 4.78 (d, *J* = 12.3 Hz; 1H), 3.67 (d, *J* = 10.7 Hz; 3H), 3.54 (d, *J* = 10.7 Hz; 3H); Representative signals corresponding to the minor rotamer: δ 6.97 (d, J = 7.8 Hz; 1H), 6.04 (d, *J* = 7.8 Hz; 1H), 5.81 (d, *J* = 16.6 Hz; 1H), 4.93 (d, *J* = 11.9 Hz; 1H), 4.82 (d, *J* = 12.3 Hz; 1H), 3.64 (d, *J* = 10.7 Hz; 3H), 3.49 (d, *J* = 10.7 Hz; 3H); **^{13}C-NMR (100 MHz, CDCl$_3$):** Signals corresponding to both rotamers: δ 151.22, 150.98, 130.95 (d, *J* = 3.8 Hz), 130.62 (d, *J* = 3.8 Hz), 129.07 (d, *J* = 3.6 Hz), 128.88 (d, *J* = 3.6 Hz), 127.78 (d, *J* = 2.8 Hz), 127.65, 127.59 (d, *J* = 5.6 Hz), 127.47 (d, *J* = 5.3 Hz), 125.32 (d, *J* = 3.1 Hz), 125.27 (d, *J* = 3.0 Hz), 125.18 (d, *J* = 2.2 Hz), 125.12, 125.03 (d, *J* = 2.7 Hz), 123.96, 111.16, 110.94, 94.83, 94.68, 75.68, 75.63, 55.09, 53.75 (d, *J* = 7.3 Hz), 53.60 (d, *J* = 7.3 Hz), 53.50 (d, *J* = 7.3 Hz), 53.49 (d, *J* = 152.1 Hz), 53.31 (d, *J* = 7.3 Hz); **^{31}P-NMR (162 MHz, CDCl$_3$):** δ 21.26 (for major rotamer), 20.66 (for minor rotamer); **HRMS (ESI+):** Calculated for $C_{14}H_{15}Cl_3NO_5PNa$ ($[M + Na]^+$): 435.9651, found: 435.9648; **$[\alpha]_D^{22}$** +312.3 (*c* 0.50, CHCl$_3$) for an enantiomerically enriched sample with 87.5:12.5 e.r. Enantiomeric ratio was determined by HPLC analysis (Daicel Chiralpak AD-H column, 254 nm, ^{n}Hexane/EtOH = 90:10, 1.0 mL min^{-1}, τ_{major} = 20.56 min, τ_{minor} = 23.27 min). Absolute stereochemistry of **6a** is assigned in analogy with **4w**.

2,2,2-Trichloroethyl (*S*)-1-(dipropoxyphosphoryl)isoquinoline-2(1*H*)-carboxylate 6b:

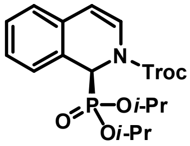


6b

Purification by silica gel (100-200 mesh) column chromatography (20% EtOAc in petroleum ether) afforded pure **6b** as a colorless oil (45 mg, 0.096 mmol; 96% yield). **R$_f$** = 0.60 (50% EtOAc in petroleum ether). **FT-IR (neat):** ν 2967 (s), 1728 (s), 1638 (m), 1385 (m), 1243 (s), 1128 (s), 996 (s) cm^{-1}; **^{1}H-NMR (400 MHz, CDCl$_3$):** The compound exists as a 2.8:1 mixture of carbamate rotamers. Signals corresponding to the major rotamer: δ 7.22-7.29 (m; 3H), 7.09-7.10 (m; 1H), 6.96 (d, *J* = 7.8 Hz; 1H), 5.96 (d, *J* = 7.8 Hz; 1H), 5.88 (d, *J* = 16.5 Hz; 1H), 4.90 (d, *J* = 12.0 Hz; 1H), 4.84 (d, *J* = 12.0 Hz; 1H), 3.70-4.00 (m; 4H), 1.52-1.62 (m; 4H), 0.84-0.90 (m; 6H); Representative signals corresponding to the minor rotamer: δ 7.10 (d, *J* = 7.8 Hz; 1H), 6.03 (d, *J* = 7.8 Hz; 1H), 5.82 (d, *J* = 16.5 Hz; 1H), 5.09 (d, *J* = 12.0 Hz; 1H), 4.67 (d, *J* = 12.0 Hz; 1H); **^{13}C-NMR (100 MHz, CDCl$_3$):** Signals corresponding to both rotamers: δ 151.35, 150.92

(d, *J* = 1.3 Hz), 131.01 (d, *J* = 4.2 Hz), 130.71 (d, *J* = 4.2 Hz), 128.85 (d, *J* = 3.6 Hz), 128.67 (d, *J* = 3.4 Hz), 127.61 (d, *J* = 2.7 Hz), 127.53 (d, *J* = 5.3 Hz), 127.48 (d, *J* = 2.7 Hz), 127.38 (d, *J* = 5.3 Hz), 125.63 (d, *J* = 2.2 Hz), 125.53 (d, *J* = 2.4 Hz), 125.21 (d, *J* = 3.1 Hz), 125.13 (d, *J* = 3.0 Hz), 125.05, 123.98, 111.21, 111.06, 94.77, 94.67, 75.68, 75.66, 68.60 (d, *J* = 7.0 Hz), 68.34 (d, *J* = 7.0 Hz), 68.30 (d, *J* = 7.0 Hz), 68.12 (d, *J* = 7.0 Hz), 54.72 (d, *J* = 151.8 Hz), 53.84 (d, *J* = 151.8 Hz), 23.84, 23.78 (d, *J* = 5.9 Hz), 9.88; **^{31}P-NMR (162 MHz, CDCl$_3$):** δ 18.73 (for major rotamer), 18.39 (for minor rotamer); **HRMS (ESI+):** Calculated for $C_{18}H_{23}Cl_3NO_5PNa$ ([M + Na]$^+$): 492.0277, found: 492.0280; **$[\alpha]_D^{22}$** +256.5 (*c* 1.00, CHCl$_3$) for an enantiomerically enriched sample with 95:5 e.r. Enantiomeric ratio was determined by HPLC analysis (Daicel Chiralpak AD-H column, 254 nm, ^{n}Hexane/EtOH = 90:10, 1.0 mL min^{-1}, τ_{major} = 9.16 min, τ_{minor} = 10.12 min). Absolute stereochemistry of **6b** is assigned in analogy with **4w**.

2,2,2-Trichloroethyl (*S*)-1-(diisopropoxyphosphoryl)isoquinoline-2(1*H*)-carboxylate 6c:

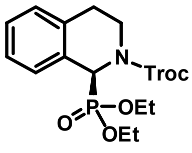


6c

Purification by silica gel (100-200 mesh) column chromatography (20% EtOAc in petroleum ether) afforded pure **6c** as a colorless oil (45 mg, 0.096 mmol; 96% yield). **R$_f$** = 0.65 (50% EtOAc in petroleum ether). **FT-IR (neat):** ν 2980 (w), 1728 (m), 1639 (m), 1384 (m), 1341 (w), 1130 (w), 1104 (w), 988 (m) cm^{-1}; **^{1}H-NMR (400 MHz, CDCl$_3$):** The compound exists as a 2.2:1 mixture of carbamate rotamers. Signals corresponding to the major rotamer: δ 7.18-7.24 (m; 3H), 7.06-7.08 (m; 1H), 6.93 (d, *J* = 7.8 Hz; 1H), 5.92 (d, *J* = 7.8 Hz; 1H), 5.80 (d, *J* = 17.1 Hz; 1H), 4.83 (s; 2H), 4.44-4.75 (m; 4H), 1.34-1.36 (m; 3H), 1.23-1.26 (m; 3H), 1.15-1.17 (m; 3H), 1.05-1.08 (m; 3H); Representative signals corresponding to the minor rotamer: δ 6.97 (d, *J* = 7.8 Hz; 1H), 5.98 (d, *J* = 7.8 Hz; 1H), 5.73 (d, *J* = 17.1 Hz; 1H), 5.09 (d, *J* = 11.8 Hz; 2H); **^{13}C-NMR (100 MHz, CDCl$_3$):** Signals corresponding to both rotamers: δ 150.93 (d, *J* = 1.4 Hz), 131.12 (d, *J* = 3.8 Hz), 130.83 (d, *J* = 3.8 Hz), 128.72 (d, *J* = 3.4 Hz), 128.55 (d, *J* = 3.4 Hz), 127.54 (d, *J* = 5.3 Hz), 127.46 (d, *J* = 2.8 Hz), 127.40, 127.33 (d, *J* = 2.9 Hz), 126.01 (d, *J* = 1.9 Hz), 125.89 (d, *J* = 2.7 Hz), 125.23 (d, *J* = 3.0 Hz), 125.11 (d, *J* = 3.2 Hz), 125.07, 124.09, 111.38, 111.33, 94.77, 94.68, 75.72, 75.69, 72.13 (d, *J* = 7.9 Hz), 72.02 (d, *J* = 7.9 Hz), 71.82 (d, *J* = 7.9 Hz), 71.57 (d, *J* = 7.9 Hz), 70.85 (d, *J* = 5.6 Hz), 55.14 (d, *J* = 154.9 Hz), 54.71 (d, *J* = 154.9 Hz), 24.28 (d, *J* = 2.9 Hz), 24.15 (d, *J* = 2.9 Hz), 24.06 (d, *J* = 3.1 Hz), 23.99 (d, *J* = 4.3 Hz), 23.87, 23.79 (d, *J* = 5.1 Hz), 23.70 (d, *J* = 5.9 Hz), 23.52, 23.45 (d, *J* = 5.3 Hz); **^{31}P-NMR (162 MHz, CDCl$_3$):** δ 16.71; **HRMS (ESI+):** Calculated for $C_{18}H_{23}Cl_3NO_5PNa$ ([M + Na]$^+$): 492.0277, found: 492.0279; **$[\alpha]_D^{22}$** +284.1 (*c* 0.50, CHCl$_3$) for an enantiomerically enriched sample with 97:3 e.r. Enantiomeric ratio was determined by HPLC analysis (Daicel Chiralpak IE column, 254 nm, ^{n}Hexane/EtOH = 80:20, 1.0 mL min^{-1}, τ_{major} = 7.91 min, τ_{minor} = 9.54 min). Absolute stereochemistry of **6c** is assigned in analogy with **4w**.

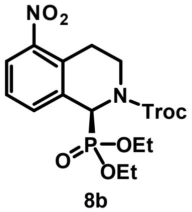
E. Catalytic enantioselective phosphonylation of dihydroisoquinolines:

Similar procedure as that of the preparation of **4a** described above was followed.



8a

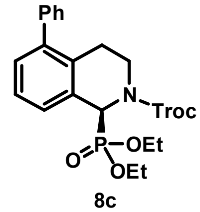
2,2,2-Trichloroethyl (*S*)-1-(diethoxyphosphoryl)-3,4-dihydroisoquinoline-2(1*H*)-carboxylate 8a: Purification by silica gel (100-200 mesh) column chromatography (30% EtOAc in petroleum ether) afforded pure **8a** as a colorless oil (40 mg, 0.090 mmol; 90% yield). **R$_f$** = 0.45 (50% EtOAc in petroleum ether). **FT-IR (neat):** ν 2984 (m), 1717 (s), 1428 (s), 1249 (m), 1229 (s), 1222 (s) cm^{-1}; **^{1}H-NMR (400 MHz, CDCl$_3$):** The compound exists as a 1.9:1 mixture of carbamate rotamers. Signals corresponding to the major rotamer: δ 7.44-7.45 (m; 1H), 7.19-7.22 (m; 2H), 7.14-7.17 (m; 1H), 5.67 (d, *J* = 20.2 Hz; 1H), 4.71-4.86 (m; 2H), 3.67-4.32 (m; 6H), 2.88-2.96 (m; 2H), 1.25-1.31 (m; 3H), 1.13-1.20 (m; 3H); Representative signals corresponding to the minor rotamer: δ 5.62 (d, *J* = 20.2 Hz; 1H); **^{13}C-NMR (100 MHz, CDCl$_3$):** Signals corresponding to both rotamers: δ 153.66 (d, *J* = 3.7 Hz), 153.31 (d, *J* = 3.7 Hz), 134.54 (d, *J* = 5.9 Hz), 129.36 (d, *J* = 2.0 Hz), 129.03 (d, *J* = 2.4 Hz), 128.95, 128.57, 128.05 (d, *J* = 4.2 Hz), 127.81 (d, *J* = 4.0 Hz), 127.74 (d, *J* = 3.5 Hz), 127.60 (d, *J* = 3.1 Hz), 126.26 (d, *J* = 3.0 Hz), 126.19, 95.42, 95.19, 75.49, 75.37, 63.36 (d, *J* = 6.8 Hz), 63.16 (d, *J* = 6.8 Hz), 62.95 (d, *J* = 6.8 Hz), 62.72 (d, *J* = 6.8 Hz), 53.54 (d, *J* = 153.2 Hz), 53.26 (d, *J* = 153.2 Hz), 40.18, 39.68, 28.14, 27.62, 16.42 (d, *J* = 5.9 Hz), 16.32 (d, *J* = 5.9 Hz); **^{31}P-NMR (162 MHz, CDCl$_3$):** δ 20.84 (for major rotamer), 20.48 (for minor rotamer); **HRMS (ESI+):** Calculated for $C_{16}H_{21}Cl_3NO_5PNa$ ([M + Na]$^+$): 466.0121, found: 466.0120; **[α]$_D^{22}$** +18.6 (*c* 2.0, CHCl$_3$) for an enantiomerically enriched sample with 95:5 e.r. Enantiomeric ratio was determined by HPLC analysis (Daicel Chiralpak IE column, 254 nm, ^{n}Hexane/IPA = 80:20, 1.0 mL min^{-1}, τ_{major} = 17.06 min, τ_{minor} = 21.42 min). Absolute stereochemistry of **8a** is assigned in analogy with **4w**.



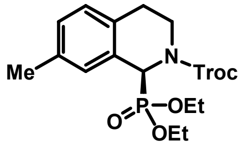
8b

2,2,2-Trichloroethyl (*S*)-1-(diethoxyphosphoryl)-5-nitro-3,4-dihydroisoquinoline-2(1*H*)-carboxylate 8b: Purification by silica gel (100-200 mesh) column chromatography (35% EtOAc in petroleum ether) afforded pure **8b** as a colorless oil (44 mg, 0.090 mmol; 90% yield). **R$_f$** = 0.30 (50% EtOAc in petroleum ether). **FT-IR (neat):** ν 2987 (s), 1718 (s), 1530 (s), 1430 (s), 1354 (m), 1288 (s), 1250 (s), 1220 (s), 1123 (s), 1049 (s), 970 (s) cm^{-1}; **^{1}H-NMR (400 MHz, CDCl$_3$):** The compound exists as a 2.7:1 mixture of carbamate rotamers. Signals corresponding to the major rotamer: δ 7.85-7.87 (m; 1H), 7.74-7.79 (m; 1H), 7.36-7.40 (m; 1H), 5.72 (d, *J* = 21.4 Hz; 1H), 4.81 (s; 2H), 4.28-4.40 (m; 1H), 3.93-4.21 (m; 4H), 3.60-3.82 (m; 1H), 3.09-3.29 (m; 2H), 1.28-1.33 (m; 3H), 1.16-1.24 (m; 3H); Representative signals corresponding to the minor rotamer: δ 5.66 (d, *J* = 21.8 Hz; 1H), 4.85 (d, *J* = 11.9 Hz; 1H), 4.73 (d, *J* = 11.9 Hz; 1H); **^{13}C-NMR (100 MHz, CDCl$_3$):** Signals corresponding to both rotamers: δ 153.36 (d, *J* = 3.6 Hz), 152.86 (d, *J* = 2.7 Hz), 149.70 (d, *J* = 2.1 Hz), 149.51 (d, *J* = 2.2 Hz), 132.90 (d, *J* = 3.6 Hz), 132.55 (d, *J* = 4.3 Hz), 132.02, 131.71, 129.84 (d, *J* = 6.0 Hz), 126.67 (d, *J* = 2.6 Hz), 124.06 (d, *J* = 3.0 Hz), 123.94 (d, *J* = 3.0 Hz), 95.16, 95.01, 75.54, 75.42, 63.64 (d, *J* = 7.8 Hz), 63.36 (d, *J* = 7.8 Hz), 63.28 (d, *J* = 7.8 Hz), 63.03 (d, *J* = 7.8 Hz), 53.46 (d, *J* = 153.7 Hz), 53.04 (d, *J* = 153.7 Hz), 38.93, 38.49, 25.39, 24.87, 16.30 (d, *J* = 4.9 Hz), 16.27; **^{31}P-NMR (162 MHz, CDCl$_3$):** δ 19.89 (for major rotamer), 19.53 (for minor rotamer); **HRMS (ESI+):** Calculated for $C_{16}H_{20}Cl_3N_2O_7PNa$ ([M + Na]$^+$): 510.9971, found: 510.9969; **[α]$_D^{22}$** +133.0 (*c* 3.00, CHCl$_3$) for an enantiomerically enriched sample with 78.5:21.5 e.r. Enantiomeric ratio was determined by HPLC analysis (Daicel Chiralpak AD-H column, 254 nm, ^{n}Hexane/EtOH = 90:10, 1.0 mL min^{-1}, τ_{major} = 22.15 min, τ_{minor} = 28.10 min). Absolute stereochemistry of **8b** is assigned in analogy with **4w**.

2,2,2-Trichloroethyl (*S*)-1-(diethoxyphosphoryl)-5-phenyl-3,4-dihydroisoquinoline-2(1*H*)-carboxylate 8c: Purification by silica gel (100-200 mesh) column chromatography (20% EtOAc in petroleum ether) afforded pure **8c** as a colorless oil (43 mg, 0.083 mmol; 83% yield). **R$_f$** = 0.55 (50% EtOAc in petroleum ether). **FT-IR (neat):** ν 2983 (m), 1718 (s), 1429 (m), 1291 (m), 1124 (s), 1020 (s), 964 (s) cm^{-1}; **^{1}H-NMR (400 MHz, CDCl$_3$):** The compound exists as a 2.2:1 mixture of carbamate rotamers. Signals corresponding to the major rotamer: δ 7.35-7.46 (m; 4H), 7.26-7.30 (m; 3H), 7.18-7.20 (m; 1H), 5.72 (d, *J* = 20.0 Hz; 1H), 4.80 (s; 2H), 3.60-4.18 (m; 6H), 2.79-2.93 (m; 2H), 1.16-1.34 (m; 6H); Representative signals corresponding to the minor rotamer: δ 5.68 (d, *J* = 20.0 Hz; 1H), 4.86 (d, *J* = 11.8 Hz; 1H), 4.74 (d, *J* = 11.8 Hz; 1H); **^{13}C-NMR (100 MHz, CDCl$_3$):** Signals corresponding to both rotamers: δ 153.70 (d, *J* = 3.5 Hz), 153.24 (d, *J* = 2.5 Hz), 142.01 (d, *J* = 2.8 Hz), 140.68, 140.62, 132.59 (d, *J* = 5.7 Hz), 129.48, 129.31 (d, *J* = 3.5 Hz), 129.21 (d, *J* = 3.5 Hz), 129.11, 129.04, 128.22, 127.34 (d, *J* = 4.3 Hz), 127.22, 127.16, 127.05 (d, *J* = 3.9 Hz), 125.99 (d, *J* = 3.0 Hz), 95.39, 95.22, 75.49, 75.37, 63.39 (d, *J* = 7.0 Hz), 63.21 (d, *J* = 7.0 Hz), 62.97 (d, *J* = 7.0 Hz), 62.76 (d, *J* = 7.0 Hz), 54.06 (d, *J* = 154.6 Hz), 53.82 (d, *J* = 154.6 Hz), 40.66, 40.11, 26.58, 26.37, 16.37 (d, *J* = 6.1 Hz), 16.34 (d, *J* = 6.1 Hz); **^{31}P-NMR (162 MHz, CDCl$_3$):** δ 20.83 (for major rotamer), 20.52 (for minor rotamer); **HRMS (ESI+):** Calculated for $C_{22}H_{25}Cl_3NO_5PNa$ ([M + Na]$^+$): 542.0434, found: 542.0438; **[α]$_D^{22}$** +15.5 (*c* 1.0, CHCl$_3$) for an enantiomerically enriched sample with 81:19 e.r. Enantiomeric ratio was determined by HPLC analysis (Daicel Chiralpak AD-H column, 254 nm, ^{n}Hexane/EtOH = 90:10, 1.0 mL min^{-1}, τ_{major} = 7.76 min, τ_{minor} = 9.02 min). Absolute stereochemistry of **8c** is assigned in analogy with **4w**.



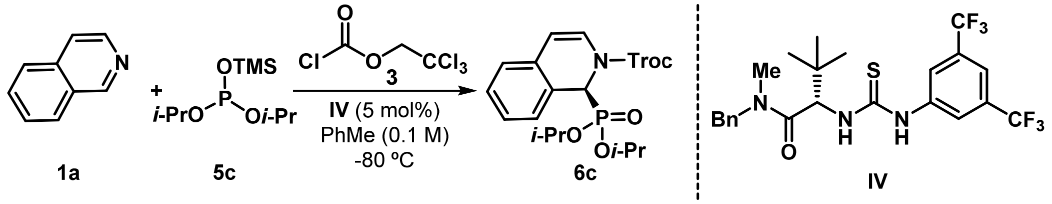
8c



8d

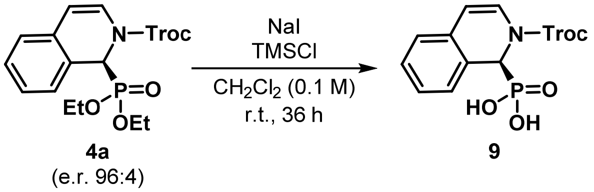
2,2,2-Trichloroethyl (*S*)-1-(diethoxyphosphoryl)-7-methyl-3,4-dihydroisoquinoline-2(1*H*)-carboxylate 8d: Purification by silica gel (100-200 mesh) column chromatography (20% EtOAc in petroleum ether) afforded pure **8d** as a colorless oil (44 mg, 0.096 mmol; 96% yield). **R$_f$** = 0.50 (50% EtOAc in petroleum ether). **FT-IR (neat):** ν 2986 (m), 2929 (m), 1717 (s), 1428 (s), 1298 (s), 1248 (s), 1051 (s), 1023 (s) cm^{-1}; **^{1}H-NMR (400 MHz, CDCl$_3$):** The compound exists as a 2.4:1 mixture of carbamate rotamers. <u>Signals corresponding to the major rotamer</u>: δ 7.25-7.26 (m; 1H), 7.02-7.04 (m; 2H), 5.54-5.65 (m; 1H), 4.82 (d, *J* = 12.0 Hz; 1H), 4.75 (d, *J* = 21.5 Hz; 1H), 3.65-4.30 (m; 6H), 2.82-2.97 (m; 2H), 2.31 (s; 3H), 1.24-1.31 (m; 3H), 1.13-1.20 (m; 3H); <u>Representative signals corresponding to the minor rotamer</u>: δ 4.83 (d, *J* = 12.0 Hz; 1H), 4.72 (d, *J* = 21.5 Hz; 1H); **^{13}C-NMR (100 MHz, CDCl$_3$):** <u>Signals corresponding to both rotamers</u>: δ 153.63 (d, *J* = 3.7 Hz), 153.25 (d, *J* = 3.7 Hz), 135.75 (d, *J* = 2.8 Hz), 131.39 (d, *J* = 5.7 Hz), 129.12 (d, *J* = 2.5 Hz), 128.81 (d, *J* = 2.5 Hz), 128.63, 128.59 (d, *J* = 3.2 Hz), 128.46 (d, *J* = 3.1 Hz), 128.42, 128.24, 128.19 (d, *J* = 3.8 Hz), 95.41, 95.17, 75.44, 75.30, 63.26 (d, *J* = 7.3 Hz), 63.06 (d, *J* = 7.3 Hz), 62.87 (d, *J* = 7.3 Hz), 62.65 (d, *J* = 7.3 Hz), 53.50 (d, *J* = 152.6 Hz), 53.17 (d, *J* = 152.6 Hz), 40.28, 39.80, 27.69, 27.18, 20.99, 16.28 (d, *J* = 5.8 Hz); **^{31}P-NMR (162 MHz, CDCl$_3$):** δ 20.97 (for major rotamer), 20.57 (for minor rotamer); **HRMS (ESI+):** Calculated for $C_{17}H_{23}Cl_3NO_5PNa$ ($[M + Na]^+$): 480.0277, found: 480.0276; **$[\alpha]_D^{22}$** +53.1 (*c* 3.00, CHCl$_3$) for an enantiomerically enriched sample with 93.5:6.5 e.r. Enantiomeric ratio was determined by HPLC analysis (Daicel Chiralpak AD-H column, 254 nm, ^{n}Hexane/EtOH = 90:10, 1.0 mL min^{-1}, τ_{major} = 7.66 min, τ_{minor} = 11.93 min). Absolute stereochemistry of **8d** is assigned in analogy with **4w**.

F. Large scale reaction: procedure for the dearomatization of isoquinoline 1a with diisopropyl trimethylsilyl phosphite 5c:

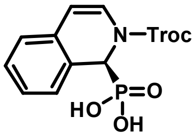


In an oven-dried reaction tube under positive argon pressure, isoquinoline **1a** (120 μL, 1.0 mmol., 1.0 equiv.) was taken in 4.0 mL toluene and 2,2,2-trichloroethyl chloroformate **3** (180 μL, 1.3 mmol., 1.3 equiv.) was added at r.t. The resulting mixture was stirred at r.t. for 30 min and then cooled to –80 °C. After 15 min at –80 °C, a solution of **IV** (25.5 mg, 0.05 mmol., 0.05 equiv.) in 3.0 mL toluene was added and the resulting mixture was allowed to stir at –80 °C for 15 min, followed by dropwise addition of a solution diisopropyl trimethylsilyl phosphite **5c** (149.2 mg, 1.0 mmol., 1.0 equiv.) in 3.0 mL toluene. The resulting solution was stirred at –80 °C for 104 h and then quenched by the addition of 10 mL water. The reaction mixture was allowed to attain r.t. and extracted with EtOAc. The combined organic layer was dried over anh. Na_2SO_4, concentrated in vacuo to obtain a light yellow oil which was purified by silica gel (100-200 mesh) column chromatography using 30% EtOAc in petroleum ether as eluent to obtain pure **6c** as a colorless oil (438 mg, 0.93 mmol; 93% yield). Catalyst **IV** was obtained as an off-white solid (24.2 mg, 0.0475 mmol., 95% yield) using 15% EtOAc in petroleum ether as eluent.

G. Procedure for hydrolysis of 2,2,2-trichloroethyl (*S*)-1-(diethoxyphosphoryl)isoquinoline-2(1*H*)-carboxylate 4a:



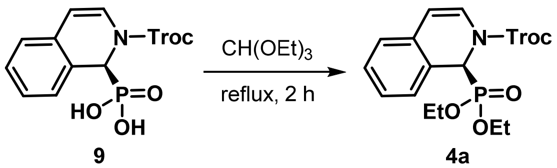
In an oven-dried 10 mL round-bottom flask under positive argon pressure, 2,2,2-trichloroethyl (*S*)-1-(diethoxyphosphoryl)isoquinoline-2(1*H*)-carboxylate **4a** (177.1 mg, 0.4 mmol, 1.0 equiv.) was taken in 4 mL CH_2Cl_2 at r.t. and sodium iodide (359.7 mg, 2.4 mmol, 6.0 equiv.) was added in one portion followed by the addition of trimethylsilyl chloride (0.31 mL, 2.4 mmol, 6.0 equiv.). The resulting solution was stirred at r.t. for 36 h and the product was purified by silica gel (100-200 mesh) column chromatography using 10% MeOH in CH_2Cl_2 as eluent to obtain pure **9** as colorless oil.



9

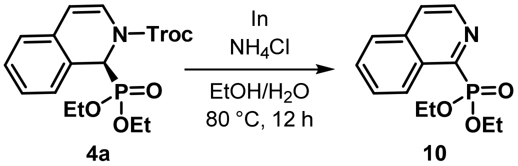
(*S*)-(2-((2,2,2-Trichloroethoxy)carbonyl)-1,2-dihydroisoquinolin-1-yl)phosphonic acid 9: Purification by silica gel (100-200 mesh) column chromatography (10% MeOH in CH_2Cl_2) afforded pure **9** as a colorless oil (101 mg, 0.261 mmol; 65% yield). **R$_f$** = 0.20 (10% MeOH in CH_2Cl_2). **FT-IR (neat):** ν 3446 (br s), 2980 (w), 2251 (m), 1660 (m), 1236 (m), 1054 (s) cm^{-1}; **^{1}H-NMR (400 MHz, $CDCl_3$):** The compound exists as a 2.6:1 mixture of carbamate rotamers. Signals corresponding to the major rotamer: δ 7.46 (br s; 2H), 7.28-7.29 (m; 1H), 7.14-7.19 (m; 2H), 7.06 (d, *J* = 7.4 Hz; 1H), 6.88 (d, *J* = 7.6 Hz; 1H), 5.95 (d, *J* = 7.8 Hz; 1H), 5.79 (d, *J* = 17.3 Hz; 1H), 4.98 (d, *J* = 12.1 Hz; 1H), 4.92 (d, *J* = 12.1 Hz; 1H); Representative signals corresponding to the minor rotamer: δ 5.98 (d, *J* = 7.8 Hz; 1H), 5.73 (d, *J* = 17.3 Hz; 1H), 5.14 (d, *J* = 12.1 Hz; 1H), 4.71 (d, *J* = 12.1 Hz; 1H); **^{13}C-NMR (100 MHz, $CDCl_3$):** Signals corresponding to both rotamers: δ 151.29, 150.88, 130.95 (d, *J* = 4.2 Hz), 130.65 (d, *J* = 4.2 Hz), 128.85 (d, *J* = 3.4 Hz), 128.67 (d, *J* = 3.4 Hz), 128.57 (d, *J* = 2.8 Hz), 127.51 (d, *J* = 5.2 Hz), 127.43 (d, *J* = 2.8 Hz), 127.38 (d, *J* = 5.2 Hz), 125.47 (d, *J* = 2.2 Hz), 125.33 (d, *J* = 2.7 Hz), 125.16 (d, *J* = 2.9 Hz), 125.09 (d, *J* = 3.0 Hz), 125.04, 123.96, 111.13, 110.99, 94.75, 94.61, 75.62, 75.59, 54.68 (d, *J* = 151.5 Hz), 53.85 (d, *J* = 151.5 Hz); **^{31}P-NMR (162 MHz, $CDCl_3$):** δ 18.29; **HRMS (ESI+):**

Calculated for $C_{12}H_{11}Cl_3NO_5PNa$ ([M + Na]$^+$): 407.9338, found: 407.9339; **$[\alpha]_D^{22}$** +222.2 (*c* 1.00, $CHCl_3$) for an enantiomerically enriched sample with 96:4 e.r. Enantiomeric ratio was determined by converting **9** to **4a** by triethyl orthoformate.



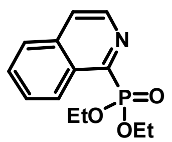
In an oven-dried 5 mL round-bottom flask equipped with a reflux condenser and an argon inlet, (*S*)-(2-((2,2,2-trichloroethoxy)carbonyl)-1,2-dihydroisoquinolin-1-yl)phosphonic acid **9** (50 mg, 0.129 mmol, 1.0 equiv.) was taken along with 1.3 mL $CH(OEt)_3$ and refluxed for 2 h. The reaction mixture was cooled to r.t. and solvent was evaporated in vacuo to obtain a brown oil which was taken in EtOAc, washed with brine, concentrated in vacuo to obtain a light yellow oil which was purified by silica gel (100-200 mesh) column chromatography to obtain pure **4a** as a colorless oil. HPLC analysis showed 96:4 e.r. (Daicel Chiralpak IE column, 254 nm, ^{n}Hexane/EtOH = 90:10, 1.0 mL min^{-1}, τ_{major} = 14.76 min, τ_{minor} = 26.18 min).

H. Procedure for the preparation of diethyl isoquinolin-1-ylphosphonate 10:



In a 10 mL round-bottom flask equipped with a glass stopper, 2,2,2-trichloroethyl (*S*)-1-(diethoxyphosphoryl)isoquinoline-2(1*H*)-carboxylate **4a** (88.5 mg, 0.2 mmol, 1.0 equiv.) was taken in 1:1 EtOH/H_2O mixture along with indium ingots (45.9 mg, 0.4 mmol, 2.0 equiv.) and NH_4Cl (32.1 mg, 0.6 mmol, 3.0 equiv.). The resulting solution was stirred at 80 °C for 12 h and then cooled to r.t. The reaction mixture was diluted with EtOAc, filtered through a Whatmann filter paper. The filtrate was dried over anh. Na_2SO_4, concentrated in vacuo to obtain a colorless oil which was purified by silica gel (100-200 mesh) column chromatography using 50% EtOAC in petroleum ether as eluent to obtain pure **10** as a colorless oil.

Diethyl isoquinolin-1-ylphosphonate 10: Purification by silica gel (100-200 mesh) column chromatography (50% EtOAc in petroleum ether) afforded pure **10** as a colorless oil (37 mg, 0.139 mmol; 70% yield). **R_f** = 0.20 (50% EtOAc in petroleum ether). **FT-IR (neat):** ν 3109 (w), 1638 (m), 1387 (s), 1237 (s), 1135 (s), 1021 (s) cm^{-1}; **^{1}H-NMR (400 MHz, $CDCl_3$):** δ 8.95 (d, *J* = 8.3 Hz; 1H), 8.70 (d, *J* = 5.6 Hz; 1H), 7.88 (d, *J* = 7.9 Hz; 1H), 7.79-7.80 (m; 1H), 7.68-7.76 (m; 2H), 4.29-4.33 (m; 4H), 1.38 (t,

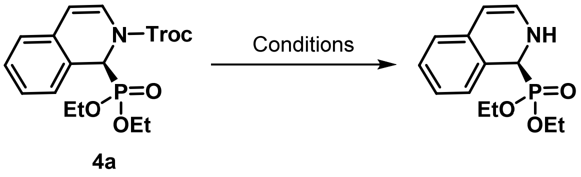


10

J = 7.0 Hz; 6H); **^{13}C-NMR (100 MHz, CDCl$_3$):** δ 152.44 (d, *J* = 226.7 Hz), 142.23, 141.98, 136.07 (d, *J* = 10.4 Hz), 130.54, 129.92 (d, *J* = 28.9 Hz), 128.40, 127.25 (d, *J* = 2.8 Hz), 127.14, 123.65 (d, *J* = 4.0 Hz), 63.22 (d, *J* = 6.1 Hz), 16.38 (d, J = 6.2 Hz); **^{31}P-NMR (162 MHz, CDCl$_3$):** δ 10.52; **HRMS (ESI+):** Calculated for $C_{13}H_{16}NO_3PNa$ ([M + Na]$^+$): 288.0766, found: 288.0766.

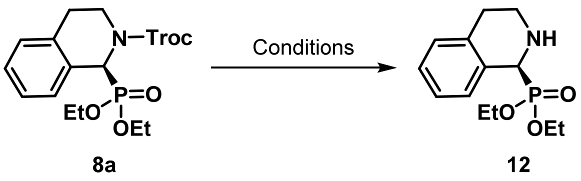
I. Unsuccessful attempts for the removal of Troc:

Table 1. Attempts to remove Troc from **4a**



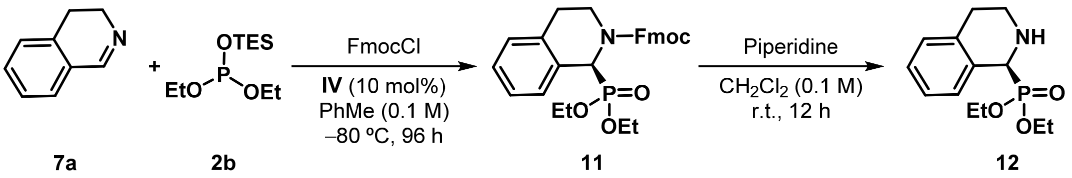
Entry	Conditions	Outcome
1	Zn (5.0 equiv.), AcOH (5.2 equiv.) THF/H_2O (1:1), 25 °C, 36 h	No reaction
2	Zn (8.0 equiv.) AcOH/CH_2Cl_2 (4:1), 60 °C, 1 h	Decomposed to isoquinoline **1a**
3	Zn (5.0 equiv.), imidazole (5.0 equiv.) THF/H_2O (1:1), 25 °C, 36 h	No reaction
4	Zn (2.0 equiv.) THF/H_2O (1:1), 25 °C, 36 h	No reaction
5	Zn (5.0 equiv.), AcOH (5.2 equiv.) THF/H_2O (1:1), 80 °C, 6 h	Complex reaction mixture
6	In (2.0 equiv.), NH_4Cl (3.0 equiv.) EtOH/H_2O (3:2), 25 °C, 24 h	No reaction
7	In (2.0 equiv.), NH_4Cl (3.0 equiv.) EtOH/H_2O (3:2), 80 °C, 12 h	Formed aromatic compound **10**

Table 2. Attempts to remove Troc from **8a**



Entry	Conditions	Outcome
1	Zn (5.0 equiv.), AcOH (5.2 equiv.) THF/H_2O (1:1), 25 °C, 36 h	No reaction
2	Zn (8.0 equiv.) AcOH/CH_2Cl_2 (4:1), 60 °C, 1 h	No reaction
3	Zn (5.0 equiv.), imidazole (5.0 equiv.) THF/H_2O (1:1), 25 °C, 36 h	No reaction
4	Zn (5.0 equiv.), AcOH (5.2 equiv.) THF/H_2O (1:1), 80 °C, 6 h	No reaction
5	In (2.0 equiv.), NH_4Cl (3.0 equiv.) EtOH/H_2O (3:2), 80 °C, 12 h	No reaction

J. Procedure for the preparation of diethyl (*S*)-(1,2,3,4-tetrahydroisoquinolin-1-yl)phosphonate:

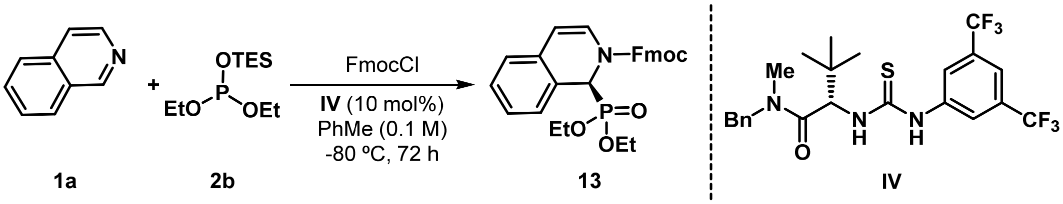


In an oven-dried reaction tube under positive argon pressure, dihydroisoquinoline **7a** (13 mg, 0.1 mmol, 1.0 equiv.) was taken in 0.4 mL toluene and FmocCl (22.2 mg, 0.13 mmol, 1.3 equiv.) was added at 25 °C. The resulting mixture was stirred at 25 °C for 30 min and then cooled to –80 °C. After 15 min at –80 °C, a solution of **IV** (5.1 mg, 0.01 mmol, 0.1 equiv.) in 0.3 mL toluene was added and the resulting mixture was allowed to stir at –80 °C for 15 min, followed by dropwise addition of a solution diethyl triethylsilyl phosphite **2b** (25.2 mg, 0.1 mmol, 1.0 equiv.) in 0.3 mL toluene. The resulting solution was stirred at –80 °C for 96 h and then quenched by the addition of 1 mL water. The reaction mixture was allowed to attain 25 °C and extracted with EtOAc. The combined organic layer was dried over anh. Na_2SO_4, concentrated in vacuo to obtain a light yellow oil which was purified by silica gel (100-200 mesh) column chromatography using 50% EtOAc in petroleum ether as eluent to obtain pure **11** as a colorless oil (36 mg, 0.073 mmol; 73% yield). **R$_f$** = 0.40 (50% EtOAc in petroleum ether). **FT-IR (neat):** ν 2984 (s), 1727 (s), 1637 (s), 1453 (s), 1240 (s), 1128 (s) cm^{-1}; **^{1}H-NMR (400 MHz, CDCl$_3$):** The compound exists as a 1.4:1 mixture of carbamate rotamers. Signals corresponding to the major rotamer: δ 7.57-7.81 (m; 4H), 7.17-7.47 (m; 8H), 5.75 (d, *J* = 20.8 Hz; 1H), 4.25-4.69 (m; 2H), 3.61-4.17 (m; 6H), 2.82-2.98 (m; 1H), 2.06 (s; 2H), 1.26-1.30 (m; 3H), 1.19 (t, *J* = 7.0 Hz; 3H); Representative signals corresponding to the minor rotamer: δ 5.40 (d, *J* = 20.8 Hz; 1H), 1.11 (t, *J* = 7.0 Hz; 3H); **^{13}C-NMR (100 MHz, CDCl$_3$):** Signals corresponding to both rotamers: δ 171.04, 155.24 (d, *J* = 3.8 Hz), 154.94 (d, *J* = 3.8 Hz), 143.86 (d, *J* = 2.0 Hz), 143.70, 143.50, 141.25, 141.15, 134.77 (d, *J* = 6.0 Hz), 134.63 (d, *J* = 6.0 Hz), 129.32 (d, *J* = 2.4 Hz), 129.26, 128.91 (d, *J* = 2.5 Hz), 128.77, 128.00 (d, *J* = 3.7 Hz), 127.66, 127.55, 127.49 (d, *J* = 3.2 Hz), 127.39 (d, *J* = 3.2 Hz), 127.01, 126.92, 126.09 (d, *J* = 2.7 Hz), 125.92 (d, *J* = 2.7 Hz), 125.10, 124.85, 124.76, 119.95, 119.81, 67.82, 63.24 (d, *J* = 7.3 Hz), 63.00 (d, *J* = 7.3 Hz), 62.74 (d, *J* = 7.3 Hz), 62.34 (d, *J* = 7.3 Hz), 60.29, 53.30 (d, *J* = 152.2 Hz), 52.78 (d, *J* = 152.2 Hz), 47.34, 47.12, 39.86, 39.13, 28.01, 27.54, 20.95, 16.29 (d, *J* = 5.2 Hz), 14.11; **^{31}P-NMR (162 MHz, CDCl$_3$):** δ 21.42 (for major rotamer), 20.82 (for minor rotamer); **HRMS (ESI+):** Calculated for $C_{28}H_{30}NO_5PNa$ ($[M + Na]^+$): 514.1759, found: 514.1759; **$[\alpha]_D^{22}$** +17.7 (*c* 1.00, CHCl$_3$) for an enantiomerically enriched sample with 88:12 e.r. Enantiomeric ratio was determined by HPLC analysis (Phenomenex C-1 column, 210 nm, ^{n}Hexane/IPA = 90:10, 1.0 mL min^{-1}, τ_{major} = 17.05 min, τ_{minor} = 19.23 min). Absolute stereochemistry of **11** is assigned in analogy with **4w**.

In an oven-dried 10 mL round-bottom flask equipped with an argon inlet, **11** (30 mg, 0.061 mmol, 1.0 equiv.) was taken in 0.4 mL CH_2Cl_2 at 25 °C. To this solution, piperidine (5.4 mg, 0.064 mmol, 1.05 equiv.) was added and the resulting solution was stirred at 25 °C for 12 h. The reaction mixture was quenched by the addition of sat. aqueous NH_4Cl solution, extracted with EtOAc. The combined organic layer was dried over anh. Na_2SO_4, concentrated in vacuo to obtain a colorless oil which was purified by silica gel (100-200 mesh) column chromatography using 100:5 CH_2Cl_2/MeOH as eluent to obtain pure **12** as a colorless oil (15 mg, 0.056 mmol; 91% yield). **R$_f$** = 0.20 (5% MeOH in CH_2Cl_2). **FT-IR (neat):** ν 2984 (s), 1240 (s), 1128 (s) cm^{-1}; **^{1}H-NMR (400 MHz, CDCl$_3$):** δ 7.48-7.50 (m; 1H), 7.09-7.16 (m; 3H), 4.48 (d, *J* = 16.4 Hz; 1H), 3.97-4.14 (m; 3H), 3.85-3.93 (m; 1H), 3.38-3.44 (m; 1H), 2.99-3.05 (m; 1H), 2.82-2.85 (m; 1H), 2.38 (br s; 1H), 1.28 (t, *J* = 7.1 Hz; 3H), 1.15 (t, *J* = 7.1 Hz; 3H); **^{13}C-NMR (100 MHz, CDCl$_3$):** δ 135.60 (d, *J* = 7.0 Hz), 129.80 (d, *J* = 3.9 Hz), 129.39 (d, *J* = 2.1 Hz), 127.97 (d, *J* = 4.0 Hz), 126.87 (d, *J* = 3.1 Hz), 125.63 (d, *J* = 3.1 Hz), 62.96 (d, *J* = 7.1 Hz), 62.23 (d, *J* = 7.4 Hz), 54.33 (d, *J* = 145.3 Hz), 40.80 (d, *J* = 5.7 Hz), 29.26, 16.39 (d, *J* = 5.9 Hz), 16.31 (d, *J* = 5.9 Hz); **^{31}P-NMR (162 MHz, CDCl$_3$):** δ 24.44; **HRMS (ESI+):** Calculated for $C_{13}H_{20}NO_3PNa$

($[M + Na]^+$): 292.1079, found: 292.1082; **$[\alpha]_D^{22}$** +19.3 (*c* 1.00, $CHCl_3$) for an enantiomerically enriched sample with 87.5:12.5 e.r. Enantiomeric ratio was determined by HPLC analysis (Phenomenex C-1 column, 210 nm, ^{n}Hexane/IPA = 90:10, 1.0 mL min^{-1}, τ_{major} = 9.21 min, τ_{minor} = 13.92 min). Absolute stereochemistry of **12** is assigned in analogy with **4w**.

K. Procedure for catalytic dearomatization of isoquinoline using FmocCl as acylating agent:



In an oven-dried reaction tube under positive argon pressure, isoquinoline **1a** (12 µL, 0.1 mmol, 1.0 equiv.) was taken in 0.4 mL toluene and FmocCl (22.2 mg, 0.13 mmol, 1.3 equiv.) was added at 25 °C. The resulting mixture was stirred at 25 °C for 30 min and then cooled to –80 °C. After 15 min at –80 °C, a solution of **IV** (5.1 mg, 0.01 mmol, 0.1 equiv.) in 0.3 mL toluene was added and the resulting mixture was allowed to stir at –80 °C for 15 min, followed by dropwise addition of a solution diethyl triethylsilyl phosphite **2b** (25.2 mg, 0.1 mmol, 1.0 equiv.) in 0.3 mL PhMe. The resulting solution was stirred at –80 °C for 72 h and then quenched by the addition of 1 mL water. The reaction mixture was allowed to attain 25 °C and extracted with EtOAc. The combined organic layer was dried over anh. Na_2SO_4, concentrated in vacuo to obtain a light yellow oil which was purified by silica gel (100-200 mesh) column chromatography using 50% EtOAc in petroleum ether as eluent to obtain pure **13** as a colorless oil (42 mg, 0.086 mmol; 86% yield). **R_f** = 0.35 (50% EtOAc in petroleum ether). **FT-IR (neat):** ν 2984 (s), 1727 (s), 1637 (s), 1453 (s), 1240 (s), 1128 (s), 1017 (s), 929 (s) cm^{-1}; **^{1}H-NMR (400 MHz, $CDCl_3$):** The compound exists as a 2.0:1 mixture of carbamate rotamers. <u>Signals corresponding to the major rotamer</u>: δ 7.78-7.82 (m; 2H), 7.60-7.73 (m; 2H), 7.41-7.45 (m; 2H), 7.25-7.36 (m; 5H), 7.11 (d, *J* = 6.6 Hz; 1H), 6.93 (d, *J* = 7.8 Hz; 1H), 5.95 (d, *J* = 7.7 Hz; 1H), 5.94 (d, *J* = 15.7 Hz; 1H), 4.32-4.68 (m; 2H), 3.66-4.17 (m; 4H), 2.06 (s; 1H), 1.10-1.26 (m; 6H); <u>Representative signals corresponding to the minor rotamer</u>: δ 7.04 (d, *J* = 7.8 Hz; 1H), 5.99 (d, *J* = 7.7 Hz; 1H), 5.71 (d, *J* = 15.7 Hz; 1H); **^{13}C-NMR (100 MHz, $CDCl_3$):** <u>Signals corresponding to both rotamers</u>: δ 152.86, 152.45, 143.64, 143.44 (d, *J* = 8.9 Hz), 143.42, 141.27, 141.22, 130.98 (d, *J* = 4.0 Hz), 128.77 (d, *J* = 3.3 Hz), 128.55 (d, *J* = 3.3 Hz), 127.77, 127.53 (d, *J* = 5.2 Hz), 127.40 (d, *J* = 2.5 Hz), 127.27 (d, *J* = 5.5 Hz), 127.10, 125.67, 125.49, 125.14, 124.95, 124.93, 124.90, 124.51, 120.00, 110.21, 110.16, 68.65, 63.15 (d, *J* = 7.3 Hz), 62.96 (d, *J* = 7.3 Hz), 62.89 (d, *J* = 7.3 Hz), 62.54 (d, *J* = 7.3 Hz), 60.30, 54.65 (d, *J* = 151.1 Hz), 53.58 (d, *J* = 151.1 Hz), 47.01, 46.86, 20.96, 16.31 (d, *J* = 5.2 Hz), 16.29, 16.24; **^{31}P-NMR (162 MHz, CDCl$_3$):** δ 19.20 (for major rotamer), 18.59 (for minor rotamer); **HRMS (ESI+):** Calculated for $C_{28}H_{28}NO_5PNa$ ([M + Na]$^+$): 512.1603, found: 512.1606; **$[\alpha]_D^{22}$** +174.7 (*c* 1.00, CHCl$_3$) for an enantiomerically enriched sample with 86:14 e.r. Enantiomeric ratio was determined by HPLC analysis (Phenomenex C-1 column, 254 nm, ^{n}Hexane/EtOH = 90:10, 1.0 mL min^{-1}, τ_{major} = 16.22 min, τ_{minor} = 19.38 min). Absolute stereochemistry of **13** is assigned in analogy with **4w**.

L. Unsuccessful attempts for the removal of Fmoc:

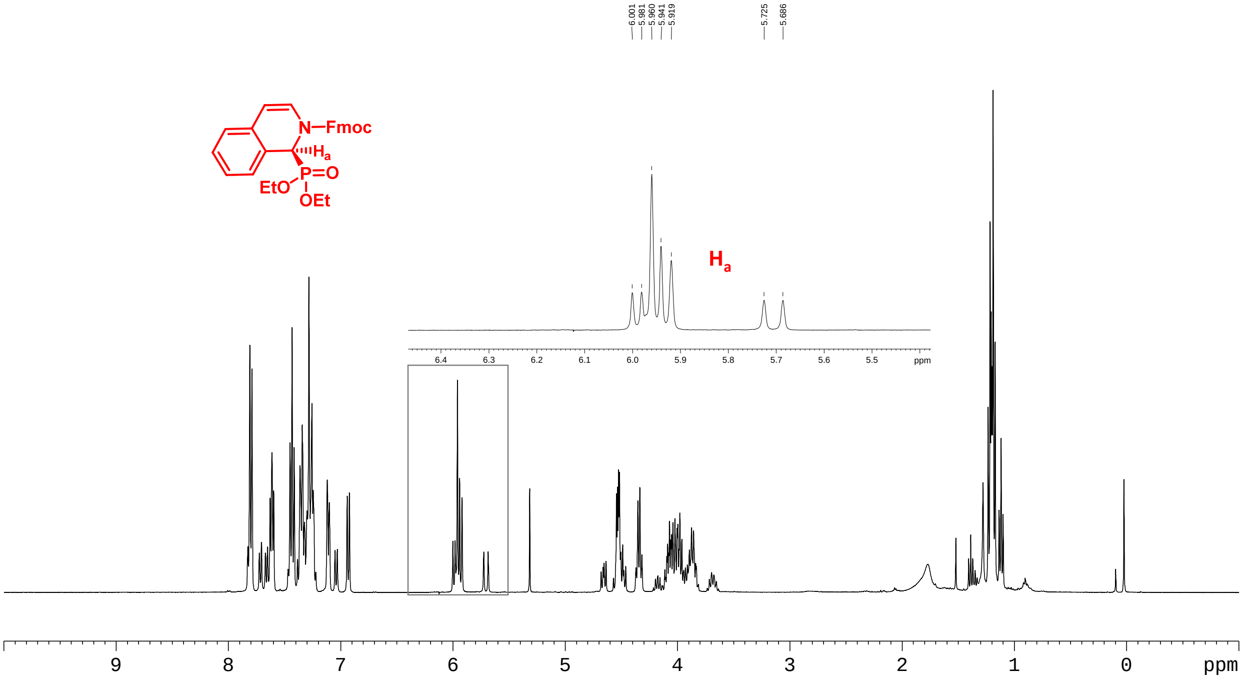
Table 3. Attempts to remove Fmoc from **13**

13

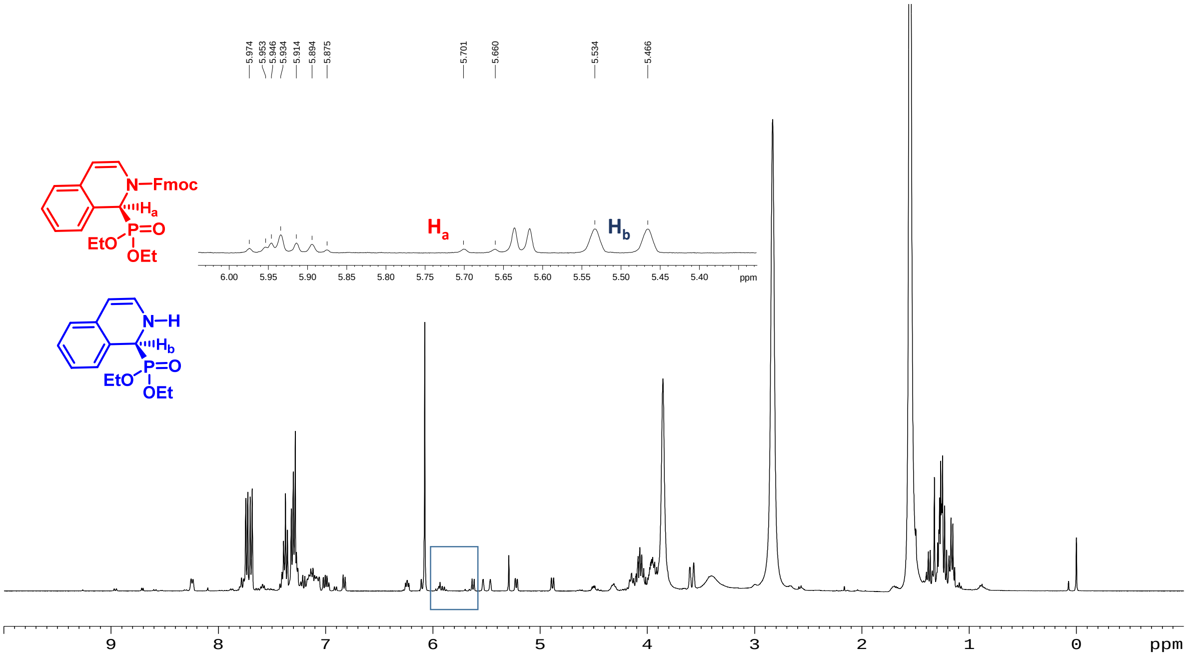
Entry	Conditions	Outcome
1	Piperidine (1.5 equiv.) CH$_2$Cl$_2$ (0.1 M), 25 °C, 1 h	Formed aromatic compound **10**
2	Piperidine (1.05 equiv.) CH$_2$Cl$_2$ (0.1 M), 25 °C, 6 h	Formed aromatic compound **10**
3	Piperidine (3.0 equiv.) CH$_2$Cl$_2$ (0.1 M), 25 °C, 30 min	Formed aromatic compound **10** during the work-up
4	Piperidine (1.05 equiv.) CH$_3$CN (0.1 M), 25 °C, <5 min	Formed aromatic compound **10** during the work-up
5	Piperidine (3.0 equiv.) CH$_2$Cl$_2$ (0.1 M), 25 °C, 30 min then Boc$_2$O (5.0 equiv.), 25 °C, 2 h	Formed aromatic compound **10**
6	Piperidine (3.0 equiv.) CH$_2$Cl$_2$ (0.1 M), 25 °C, 30 min then Boc$_2$O (5.0 equiv.), DMAP (0.5 equiv.) 25 °C, 2 h	Formed aromatic compound **10**

M. Reaction monitoring of Fmoc removal from 13 by ^{1}H-NMR

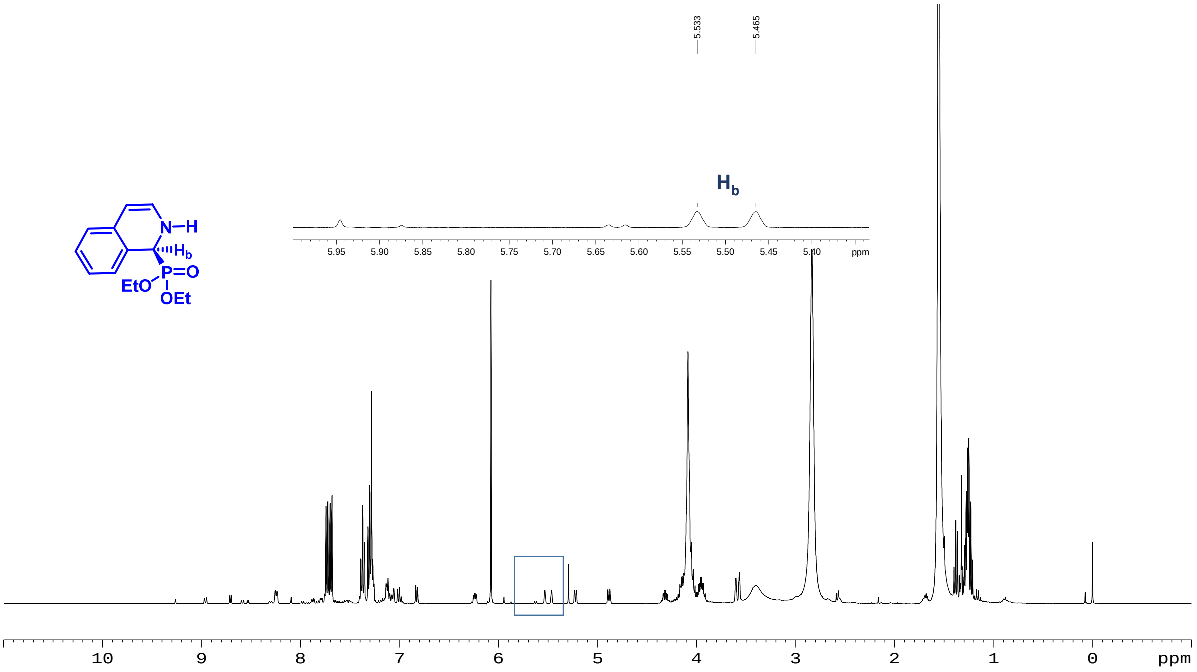
Before the addition of piperidine



After 1.5 h of the addition of piperidine

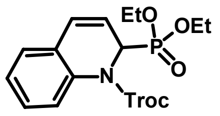


After 3.5 h of the addition of piperidine



N. Catalytic enantioselective dearomatization of quinoline:

Similar procedure as that of the preparation of **4a** described above was followed using catalyst **V**.



15

2,2,2-Trichloroethyl 2-(diethoxyphosphoryl)quinoline-1(2*H*)-carboxylate 15: Purification by silica gel (100-200 mesh) column chromatography (50% EtOAc in petroleum ether) afforded pure **15** as a colorless oil (31 mg, 0.070 mmol; 70% yield). **R$_f$** = 0.35 (50% EtOAc in petroleum ether). **FT-IR (neat):** ν 3446 (br s), 2980 (w), 2251 (m), 1660 (m), 1236 (m), 1054 (s) cm^{-1}; **^{1}H-NMR (400 MHz, CDCl$_3$):** Signals corresponding to the both rotamer: δ 7.40-8.19 (m; 2H), 7.07-7.26 (m; 2H), 6.62 (dd, J = 5.5, 9.2 Hz; 1H), 6.12 (br s; 1H), 5.63-5.67 (m; 2H), 3.80-4.18 (m; 6H), 1.17-1.38 (m; 6H); **^{13}C-NMR (100 MHz, CDCl$_3$):** Signals corresponding to both rotamers: δ 151.29, 150.88, 130.95 (d, *J* = 4.2 Hz), 130.65 (d, *J* = 4.2 Hz), 128.85 (d, *J* = 3.4 Hz), 128.67 (d, *J* = 3.4 Hz), 128.57 (d, *J* = 2.8 Hz), 127.51 (d, *J* = 5.2 Hz), 127.43 (d, *J* = 2.8 Hz), 127.38 (d, *J* = 5.2 Hz), 125.47 (d, *J* = 2.2 Hz), 125.33 (d, *J* = 2.7 Hz), 125.16 (d, *J* = 2.9 Hz), 125.09 (d, *J* = 3.0 Hz), 125.04, 123.96, 111.13, 110.99, 94.75, 94.61, 75.62, 75.59, 63.20 (d, *J* = 7.4 Hz), 63.06 (d, *J* = 7.4 Hz), 62.98 (d, *J* = 7.4 Hz), 62.76 (d, *J* = 7.4 Hz), 54.68 (d, *J* = 151.5 Hz), 53.85 (d, *J* = 151.5 Hz), 16.35, 16.26 (d, *J* = 5.8 Hz); **^{31}P-NMR (162 MHz, CDCl$_3$):** δ 18.86 (for major rotamer), 18.58 (for minor rotamer); **HRMS (ESI+):** Calculated for $C_{16}H_{19}Cl_3NO_5PNa$ ([M + Na]$^+$): 463.9964, found: 463.9961; **$[\alpha]_D^{22}$** +121.7 (*c* 1.00, CHCl$_3$) for an enantiomerically enriched sample with 81:19 e.r. Enantiomeric ratio was determined by HPLC analysis (Daicel

Chiralpak IE column, 254 nm, ^{n}Hexane/IPA = 80:20, 1.0 mL min^{-1}, τ_{major} = 28.94 min, τ_{minor} = 31.15 min).

O. Single crystal X-ray diffraction analysis of 4w:

A single crystal of **4w** (recrystallized from MeOH at 25 °C) was mounted and the diffraction data were collected at 110 K on a Bruker D8 Quest CMOS diffractometer using SMART/SAINT software. Intensity data were collected using graphite-monochromatized Mo-Ka radiation (0.71073 Å) at 110 K. The structures were solved by direct methods using the SHELX-97 and refined by full-matrix leastsquareson F^2. Empirical absorption corrections were applied with SADABS. All Non-hydrogen atoms were refined anisotropically, and hydrogen atoms were included in geometric positions. Structure was drawn using ORTEP-3. The crystallographic refinement parameters are given below:

Crystal data and structure refinement for 4w:

Identification code	**4w**	
Empirical formula	$C_{16}H_{11}BrCl_3N_2O_7P$	
Formula weight	560.50	
Temperature	293(2) K	
Wavelength	0.71073 Å	
Crystal system	orthorhombic	
Space group	P 21	
Unit cell dimensions	a = 5.5852(4) Å	α = 90°
	b = 15.8761(11) Å	β = 90°
	c = 24.5341(16) Å	γ = 90°
Volume	2175.5(3) Å^3	
Z	4	
Density (calculated)	1.711 Mg/m^3	
Absorption coefficient	2.372 mm^{-1}	
F(000)	1112	
Theta range for data collection	3.06 to 25.50°	
Index ranges	$-6 \leq h \leq 6$, $-19 \leq k \leq 19$, $-29 \leq l \leq 29$	
Reflections collected	38489	
Independent reflections	4038 [R_{int} = 0.0748]	
Completeness to Θ = 25.02°	99.7 %	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	4038 / 0 / 290	

Goodness-of-fit on F^2	1.043
Final R indices [I > 2σ (I)]	$R1 = 0.0377$, $\omega R2 = 0.0831$
R indices (all data)	$R1 = 0.0478$, $\omega R2 = 0.0868$
Absolute structure parameter	0.023(9)
Largest diff. peak and hole	0.615 and –0.749 e.Å^{-3}

Atomic coordinates (× 10^4) and equivalent isotropic displacement parameters (Å^2 × 10^3) for 4w. U(eq) is defined as one third of the trace of the orthogonalized U^{ij} tensor.

	x	y	z	U(eq)
C(13)	-2914(10)	3730(3)	9527(2)	34(1)
C(16)	1697(10)	-961(3)	7950(2)	40(1)
C(17)	-3609(11)	-1028(3)	9645(2)	42(2)
C(15)	1820(16)	-560(6)	8428(4)	24(2)
C(20)	-39(14)	-153(5)	7940(3)	14(2)
O(7)	-990(12)	-21(2)	8424(2)	81(2)
C(18)	-3922(15)	-279(6)	9332(4)	24(2)
C(19)	-1851(18)	-344(6)	9648(4)	27(2)
O(8)	-5402(10)	780(3)	7706(2)	84(2)
Br(1)	2894(1)	3379(1)	8132(1)	24(1)
Cl(1)	-2329(2)	2265(1)	6010(1)	26(1)
P(3)	-891(2)	696(1)	8858(1)	26(1)
Cl(2)	-6621(2)	2534(1)	6623(1)	58(1)
O(6)	-2864(7)	1425(2)	7115(1)	36(1)
N(1)	-2458(6)	1640(2)	8010(1)	19(1)
N(2)	-402(8)	4438(2)	8880(2)	31(1)
C(4)	12(6)	2782(3)	8261(2)	13(1)
C(12)	-4857(8)	1765(3)	6283(2)	26(1)
O(2)	-2243(7)	346(2)	9370(1)	37(1)
C(6)	-1545(8)	3663(3)	9061(2)	23(1)
O(4)	958(8)	4789(2)	9200(2)	49(1)
Cl(3)	-6551(2)	1313(1)	5745(1)	38(1)
C(3)	-1436(7)	2923(3)	8748(2)	16(1)
C(9)	-4427(8)	2346(3)	9367(2)	29(1)
C(5)	-558(7)	2181(3)	7904(2)	17(1)
O(5)	-920(7)	4714(2)	8431(1)	38(1)

O(1)	1467(6)	1024(2)	8989(2)	43(1)
C(8)	-4359(10)	3066(4)	9682(2)	38(1)
C(1)	-3001(8)	1467(3)	8581(2)	22(1)
C(2)	-2967(7)	2270(3)	8911(2)	17(1)
C(10)	-3721(11)	1237(4)	7617(2)	42(2)
C(11)	-4165(11)	1071(4)	6661(2)	46(2)

Bond lengths [Å] and angles [°] for 4w

C(13)-C(6)	1.380(6)
C(13)-C(8)	1.381(8)
C(16)-C(15)	1.337(10)
C(16)-C(20)	1.608(10)
C(17)-C(18)	1.426(10)
C(17)-C(19)	1.464(11)
C(15)-O(7)	1.788(10)
C(20)-O(7)	1.317(9)
O(7)-P(3)	1.561(4)
C(18)-O(2)	1.368(9)
C(19)-O(2)	1.307(9)
O(8)-C(10)	1.207(6)
Br(1)-C(4)	1.895(4)
Cl(1)-C(12)	1.753(5)
P(3)-O(1)	1.452(4)
P(3)-O(2)	1.569(3)
P(3)-C(1)	1.829(5)
Cl(2)-C(12)	1.777(5)
O(6)-C(10)	1.354(5)
O(6)-C(11)	1.444(5)
N(1)-C(10)	1.355(6)
N(1)-C(5)	1.390(5)
N(1)-C(1)	1.460(5)
N(2)-O(5)	1.220(5)
N(2)-O(4)	1.226(5)
N(2)-C(6)	1.455(6)
C(4)-C(5)	1.332(6)
C(4)-C(3)	1.460(6)

C(12)-C(11)	1.492(8)
C(12)-Cl(3)	1.773(4)
C(6)-C(3)	1.404(6)
C(3)-C(2)	1.402(6)
C(9)-C(8)	1.380(7)
C(9)-C(2)	1.390(6)
C(1)-C(2)	1.511(6)

C(6)-C(13)-C(8)	119.6(4)
C(15)-C(16)-C(20)	70.4(5)
C(18)-C(17)-C(19)	57.7(5)
C(16)-C(15)-O(7)	100.2(6)
O(7)-C(20)-C(16)	110.9(6)
C(20)-O(7)-P(3)	135.8(5)
C(20)-O(7)-C(15)	64.9(5)
P(3)-O(7)-C(15)	108.3(4)
O(2)-C(18)-C(17)	119.0(7)
O(2)-C(19)-C(17)	120.5(7)
O(1)-P(3)-O(7)	116.4(3)
O(1)-P(3)-O(2)	112.7(2)
O(7)-P(3)-O(2)	105.7(2)
O(1)-P(3)-C(1)	115.3(2)
O(7)-P(3)-C(1)	102.2(2)
O(2)-P(3)-C(1)	103.0(2)
C(10)-O(6)-C(11)	116.0(4)
C(10)-N(1)-C(5)	123.8(3)
C(10)-N(1)-C(1)	119.1(3)
C(5)-N(1)-C(1)	117.0(3)
O(5)-N(2)-O(4)	124.2(4)
O(5)-N(2)-C(6)	118.3(4)
O(4)-N(2)-C(6)	117.4(4)
C(5)-C(4)-C(3)	121.0(4)
C(5)-C(4)-Br(1)	116.8(3)
C(3)-C(4)-Br(1)	122.0(3)
C(11)-C(12)-Cl(1)	111.3(4)
C(11)-C(12)-Cl(3)	107.6(3)
Cl(1)-C(12)-Cl(3)	109.2(2)

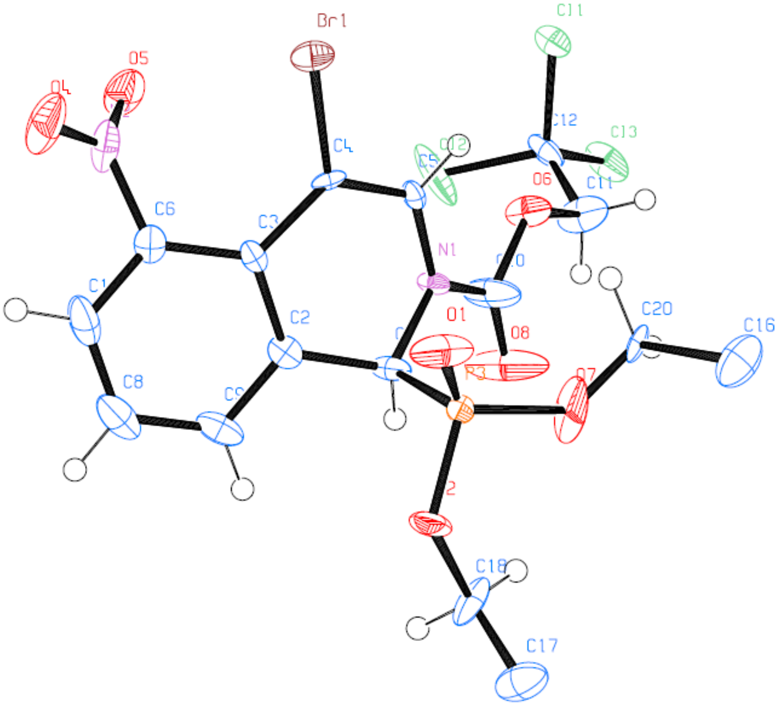
C(11)-C(12)-Cl(2)	111.0(3)
Cl(1)-C(12)-Cl(2)	108.3(3)
Cl(3)-C(12)-Cl(2)	109.3(2)
C(19)-O(2)-C(18)	62.8(6)
C(19)-O(2)-P(3)	129.3(5)
C(18)-O(2)-P(3)	122.2(4)
C(13)-C(6)-C(3)	122.8(4)
C(13)-C(6)-N(2)	115.5(4)
C(3)-C(6)-N(2)	121.4(4)
C(2)-C(3)-C(6)	115.8(4)
C(2)-C(3)-C(4)	117.2(4)
C(6)-C(3)-C(4)	126.9(4)
C(8)-C(9)-C(2)	120.4(5)
C(4)-C(5)-N(1)	120.2(4)
C(9)-C(8)-C(13)	119.6(4)
N(1)-C(1)-C(2)	110.6(3)
N(1)-C(1)-P(3)	110.4(3)
C(2)-C(1)-P(3)	111.0(3)
C(9)-C(2)-C(3)	121.5(4)
C(9)-C(2)-C(1)	119.8(4)
C(3)-C(2)-C(1)	118.7(4)
O(8)-C(10)-O(6)	124.9(4)
O(8)-C(10)-N(1)	124.1(4)
O(6)-C(10)-N(1)	111.1(4)
O(6)-C(11)-C(12)	108.9(4)

Symmetry transformations used to generate equivalent atoms:

Anisotropic displacement parameters ($Å^2 \times 10^3$) for 4w. The anisotropic displacement factor exponent takes the form: $-2p^2[h^2a^{*2}U^{11} + ... + 2 h k a^* b^* U^{12}]$

	U11	U22	U33	U23	U13	U12
C(13)	48(3)	37(3)	16(2)	-9(2)	-3(2)	21(3)
C(16)	45(3)	30(3)	46(3)	4(2)	-12(3)	5(3)
C(17)	59(4)	24(3)	42(3)	8(2)	-11(3)	-16(3)
C(15)	17(4)	23(5)	32(5)	12(4)	-6(4)	3(4)

C(20)	13(4)	18(5)	11(4)	0(3)	-6(3)	2(3)
O(7)	206(6)	20(2)	17(2)	-4(2)	1(3)	22(3)
C(18)	10(4)	35(6)	26(5)	8(4)	-1(4)	-3(4)
C(19)	34(5)	29(5)	19(5)	4(4)	-4(4)	5(5)
O(8)	117(4)	119(4)	17(2)	7(2)	-13(2)	-103(4)
Br(1)	18(1)	28(1)	26(1)	6(1)	-3(1)	-7(1)
Cl(1)	20(1)	37(1)	21(1)	-2(1)	2(1)	-2(1)
P(3)	46(1)	14(1)	17(1)	0(1)	12(1)	1(1)
Cl(2)	18(1)	114(1)	42(1)	-45(1)	1(1)	10(1)
O(6)	54(2)	42(2)	11(1)	-1(1)	-5(2)	-27(2)
N(1)	24(2)	24(2)	9(2)	2(1)	-1(1)	-13(2)
N(2)	47(3)	22(2)	25(2)	-9(2)	-12(2)	10(2)
C(4)	9(2)	13(2)	18(2)	9(2)	-4(2)	-1(2)
C(12)	20(2)	46(3)	14(2)	-10(2)	2(2)	-9(2)
O(2)	65(3)	30(2)	17(2)	2(1)	12(2)	-19(2)
C(6)	27(3)	21(2)	22(2)	0(2)	-7(2)	7(2)
O(4)	78(3)	29(2)	39(2)	-10(2)	-22(2)	-8(2)
Cl(3)	25(1)	71(1)	19(1)	-16(1)	-3(1)	-13(1)
C(3)	17(2)	23(2)	9(2)	-2(2)	-3(2)	5(2)
C(9)	21(2)	48(3)	18(2)	9(2)	1(2)	3(2)
C(5)	22(2)	18(2)	10(2)	-2(2)	1(2)	3(2)
O(5)	63(2)	21(2)	29(2)	2(2)	-13(2)	9(2)
O(1)	20(2)	41(2)	67(3)	31(2)	12(2)	13(2)
C(8)	39(3)	56(4)	19(3)	0(3)	7(2)	23(3)
C(1)	20(2)	36(3)	9(2)	2(2)	1(2)	-12(2)
C(2)	11(2)	27(2)	13(2)	2(2)	-3(2)	2(2)
C(10)	62(4)	53(3)	11(2)	3(2)	-4(2)	-34(3)
C(11)	71(4)	51(3)	14(2)	-1(2)	-9(3)	-38(3)



ORTEP representation of the X-ray structure of (*S*)-**4w** (thermal ellipsoids at 50% probability)

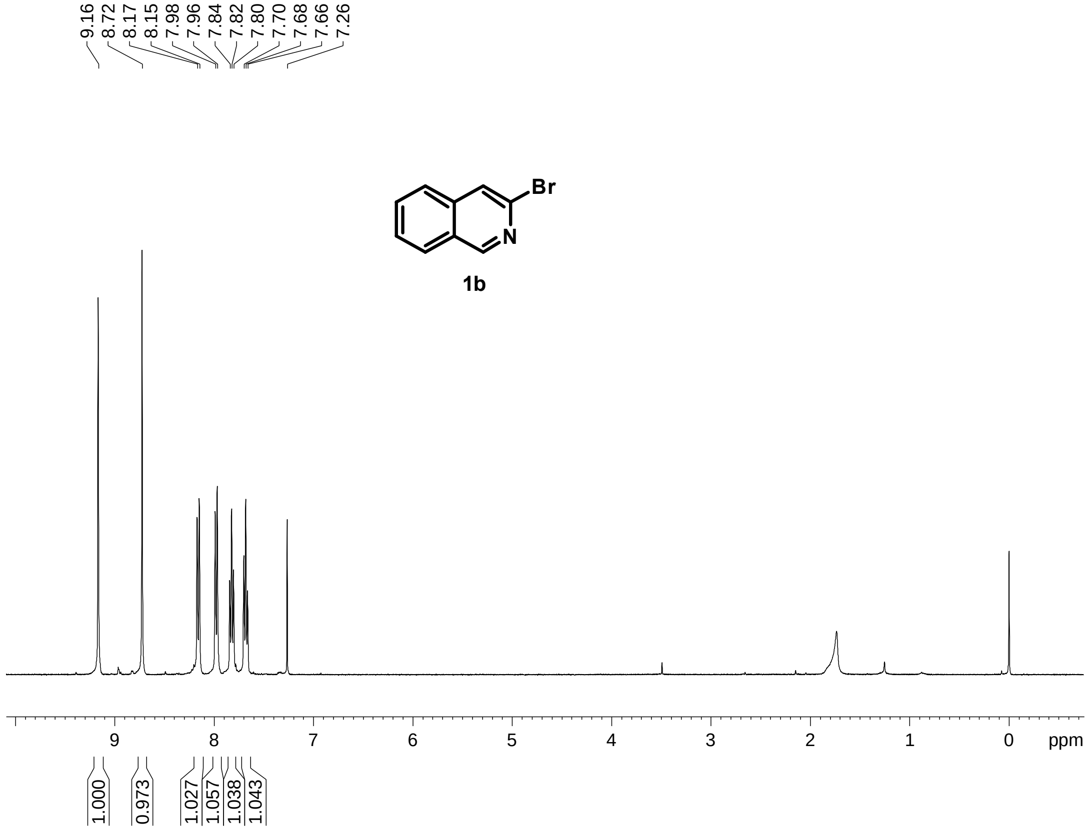
Enantioselective dearomatization of isoquinolines by anion-binding catalysis en route to cyclic α-aminophosphonates

Abhijnan Ray Choudhury and Santanu Mukherjee*

Department of Organic Chemistry, Indian Institute of Science, Bangalore 560 012, INDIA

sm@orgchem.iisc.ernet.in

SUPPORTING INFORMATION: PART B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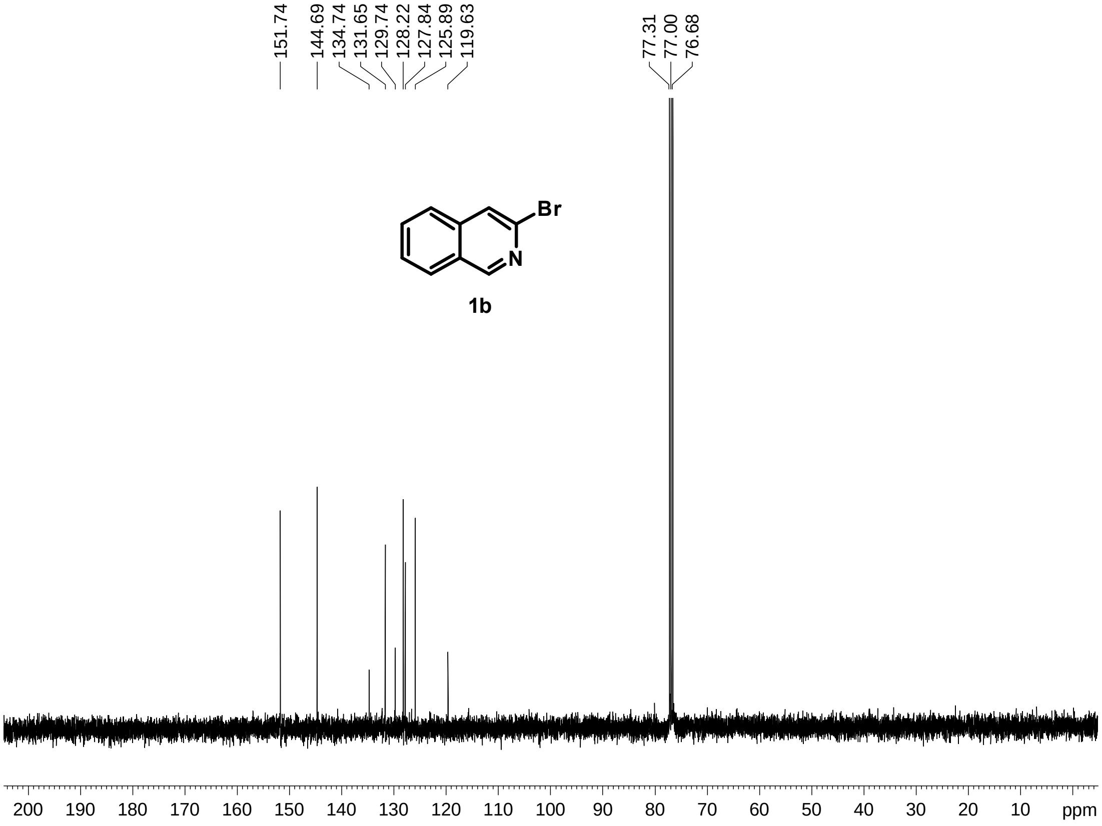
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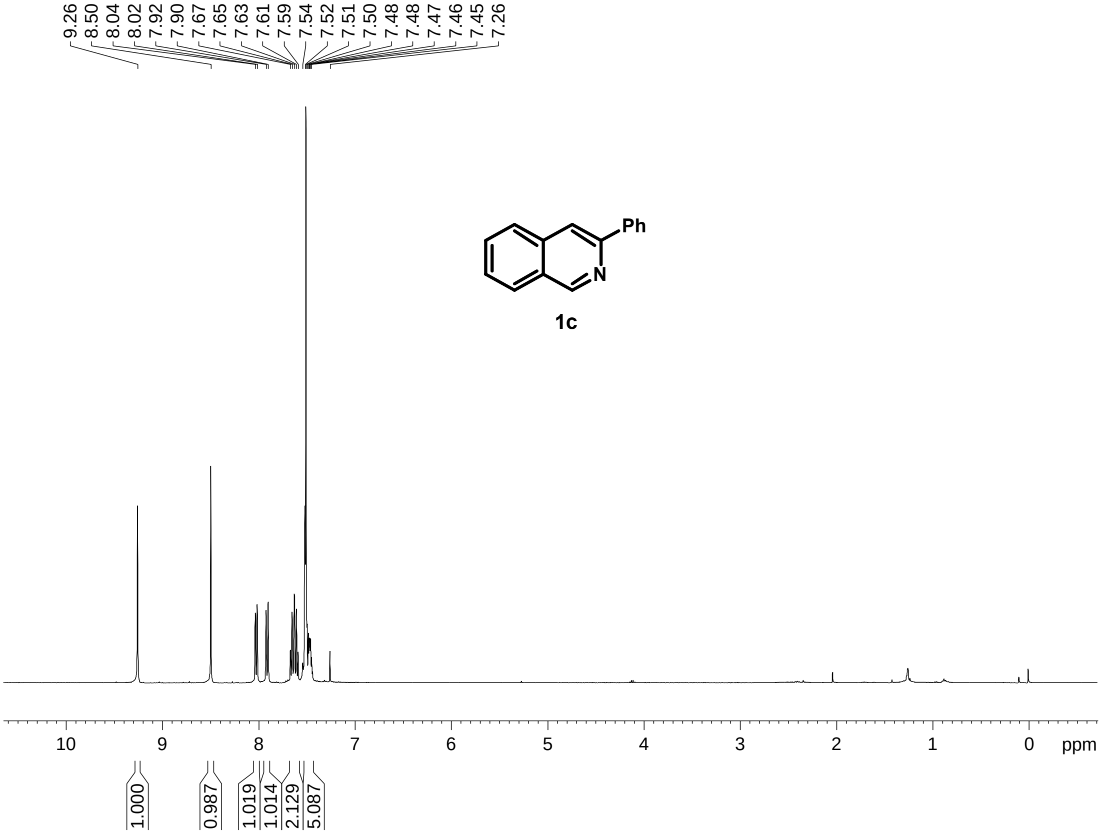
1b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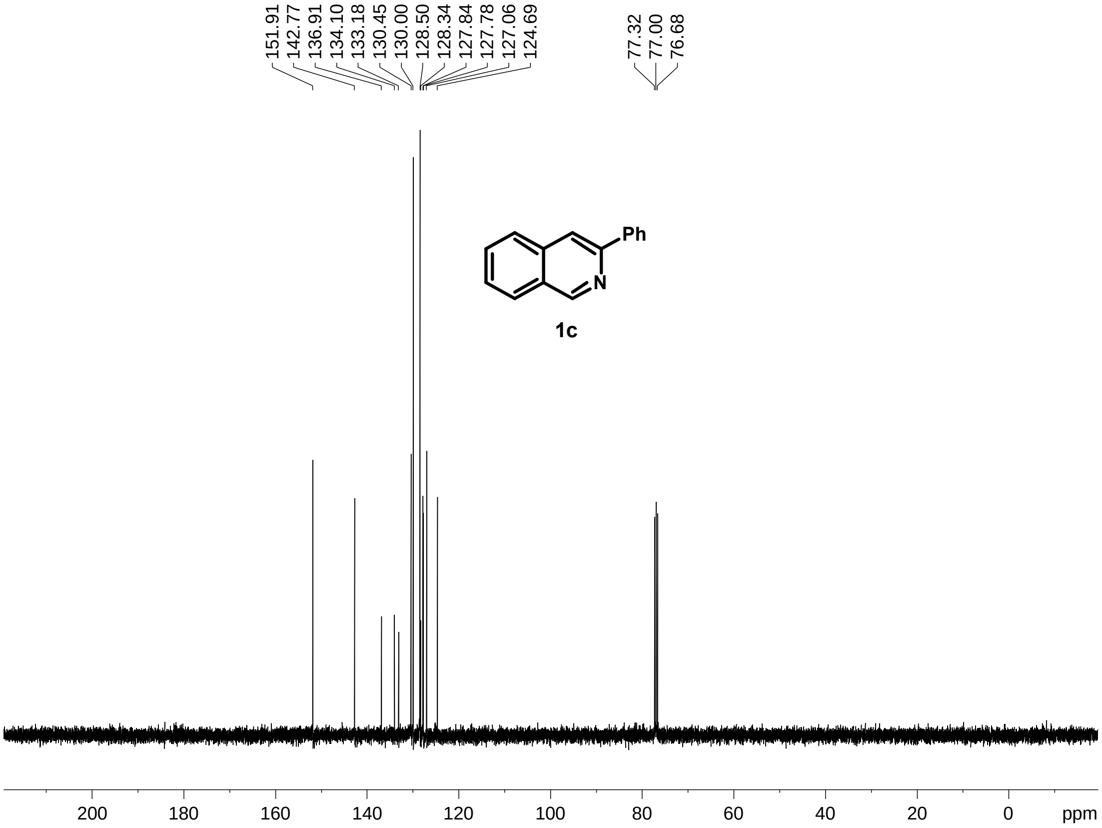
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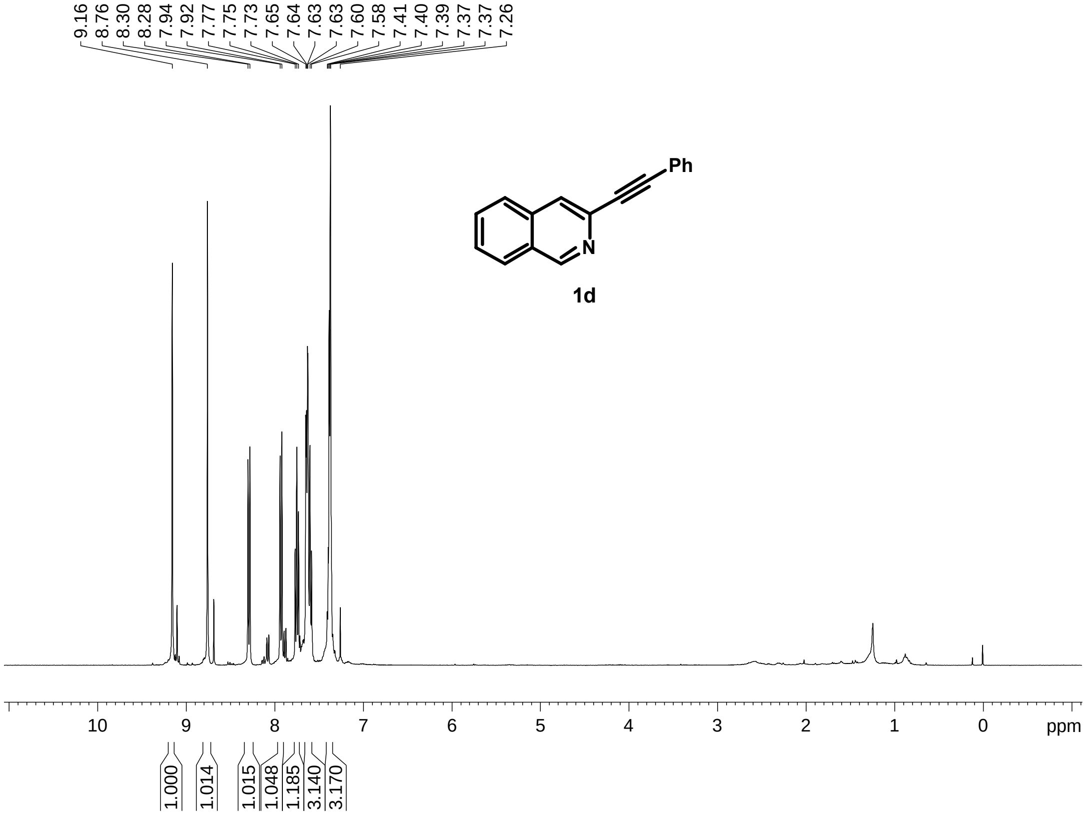
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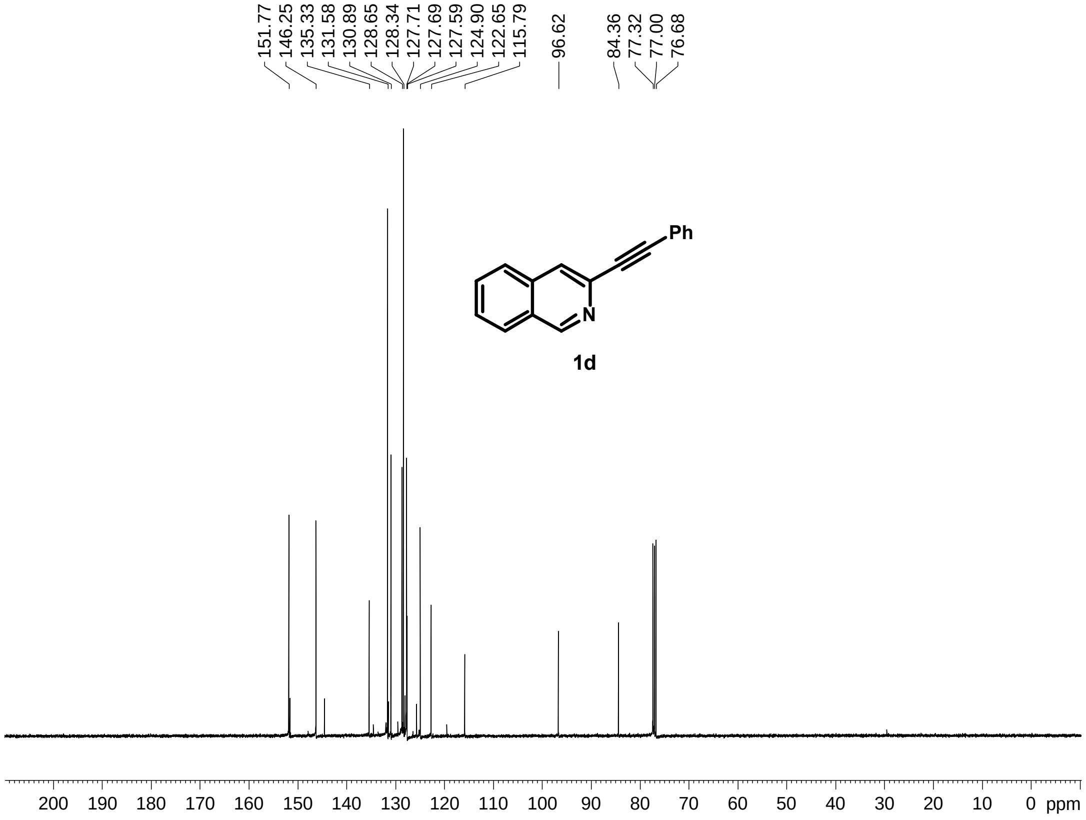
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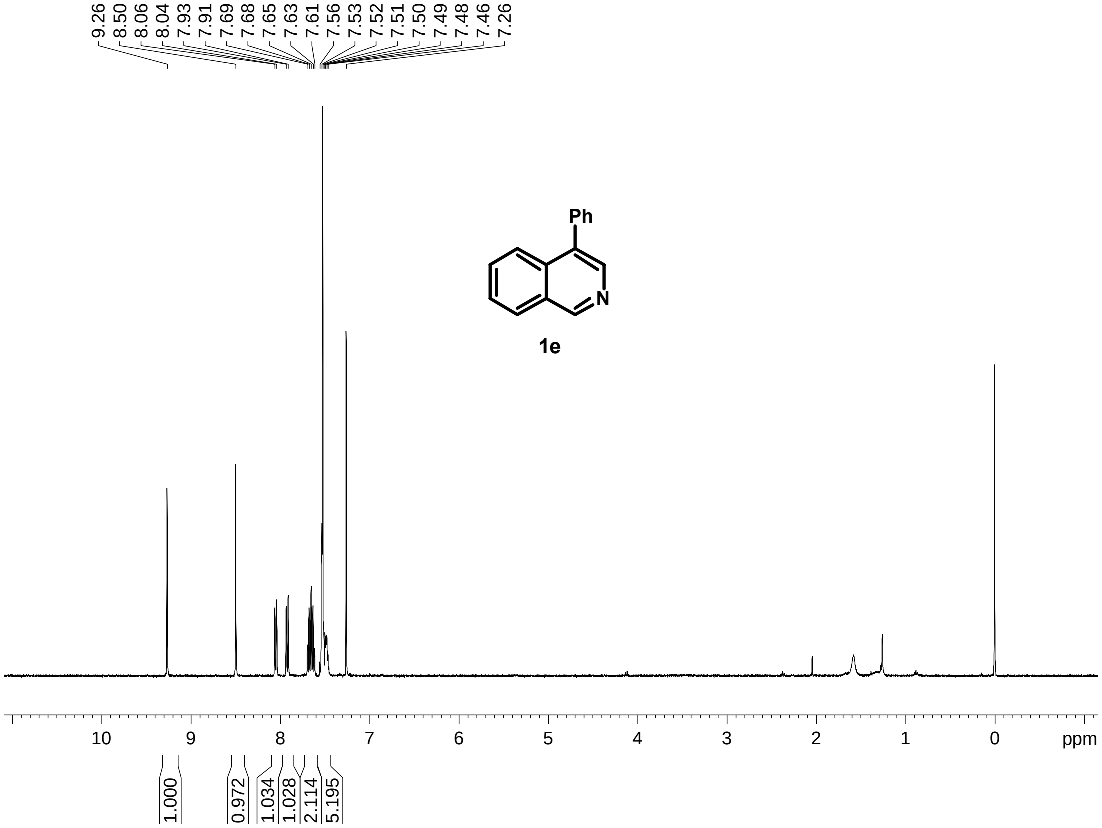
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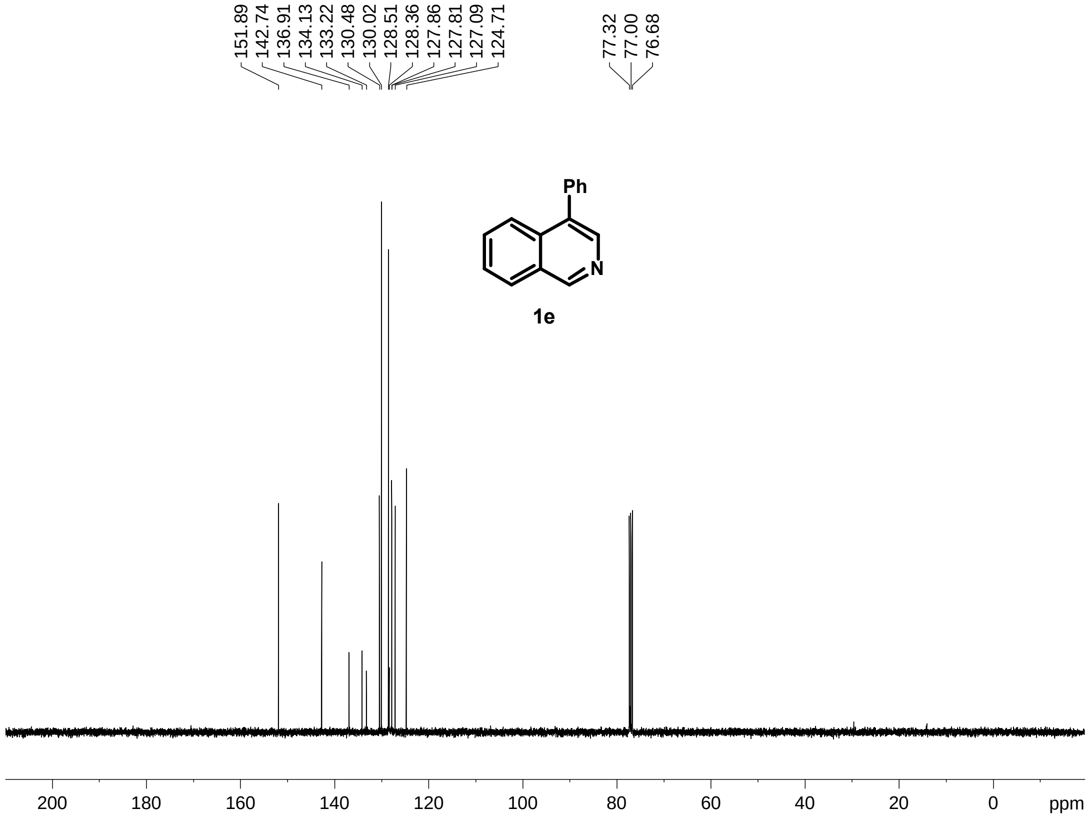
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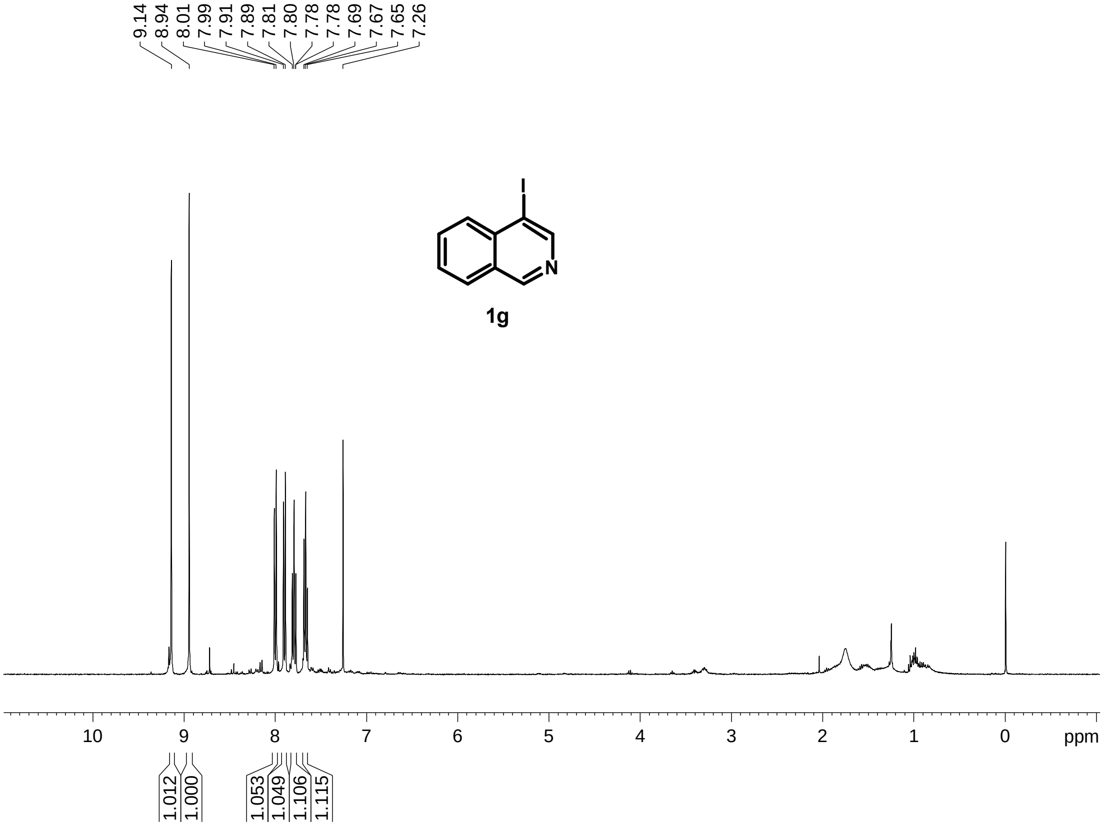
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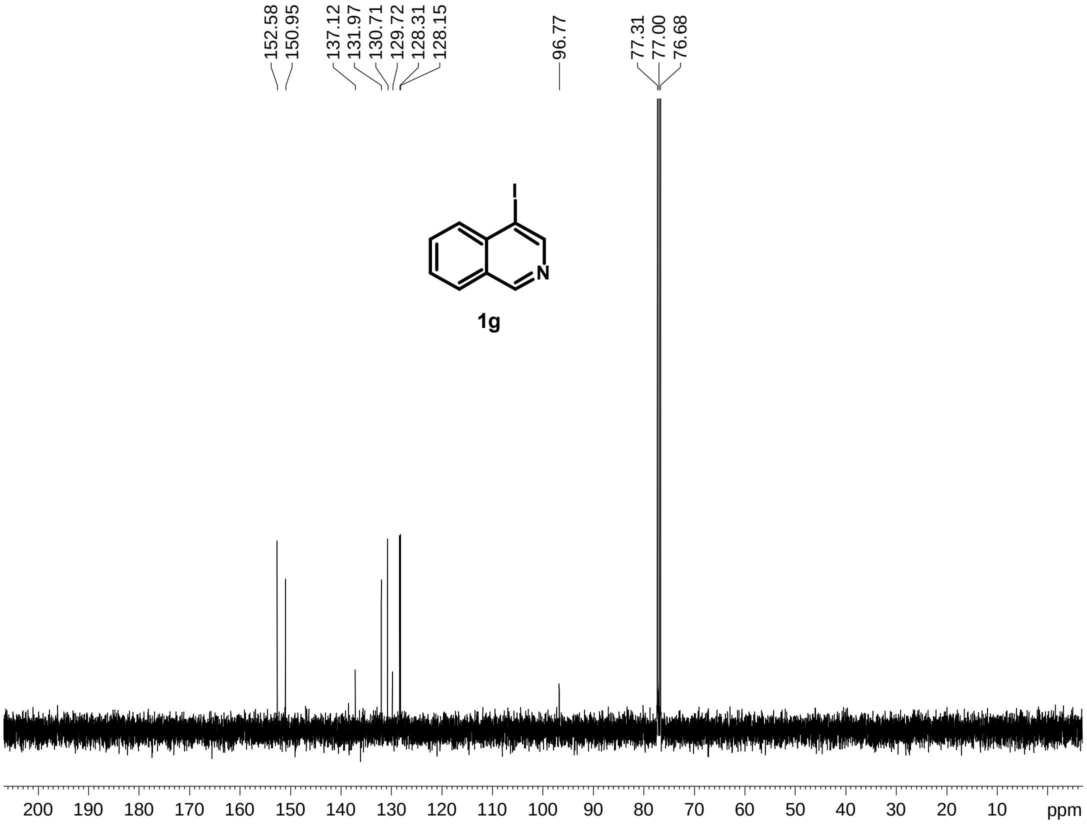
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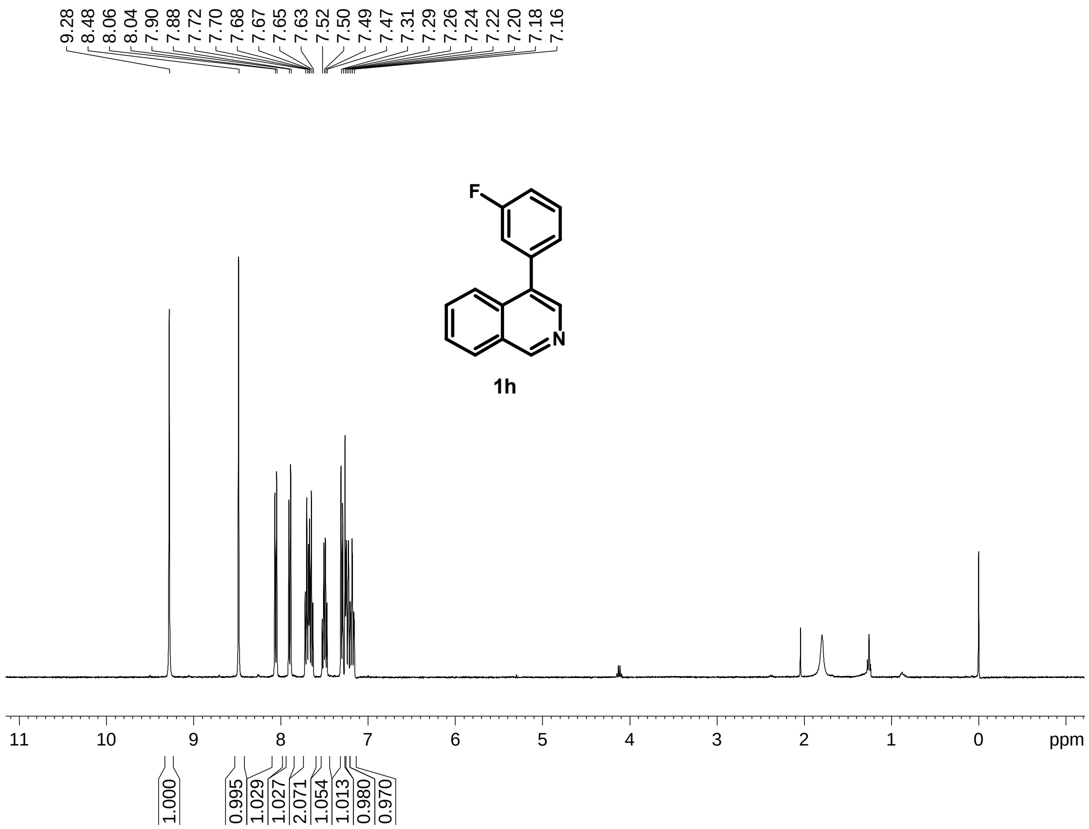
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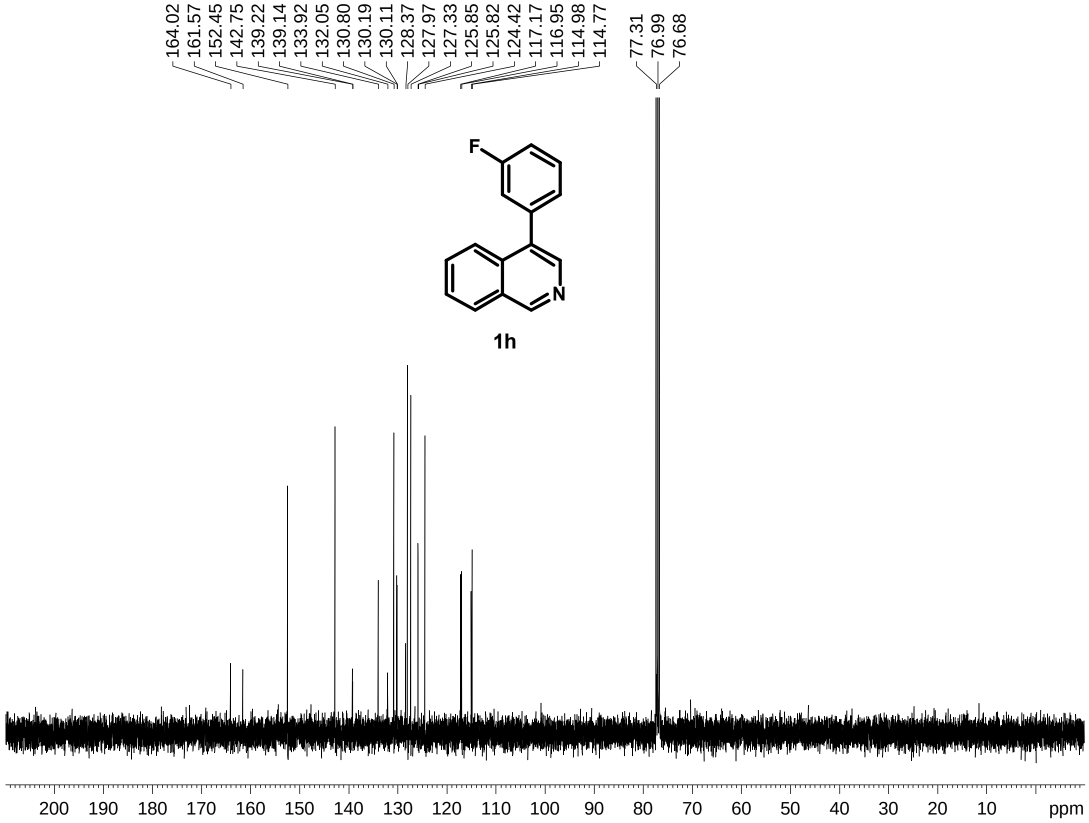
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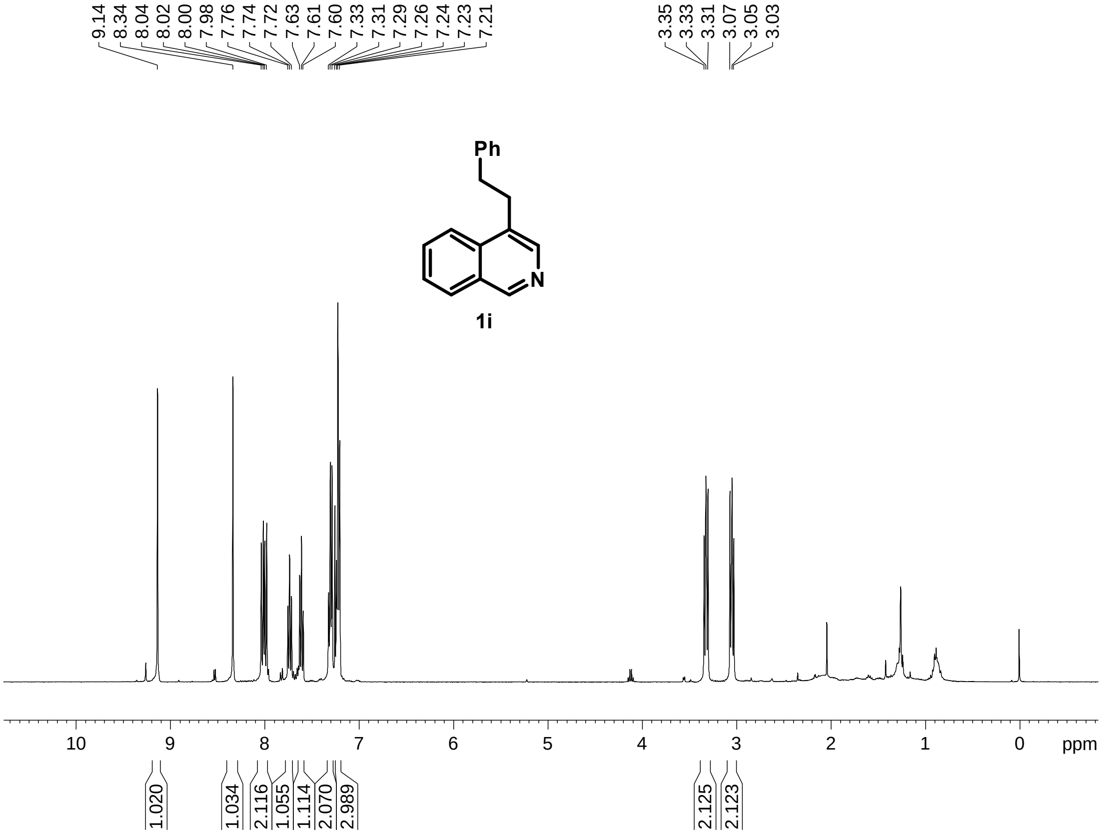
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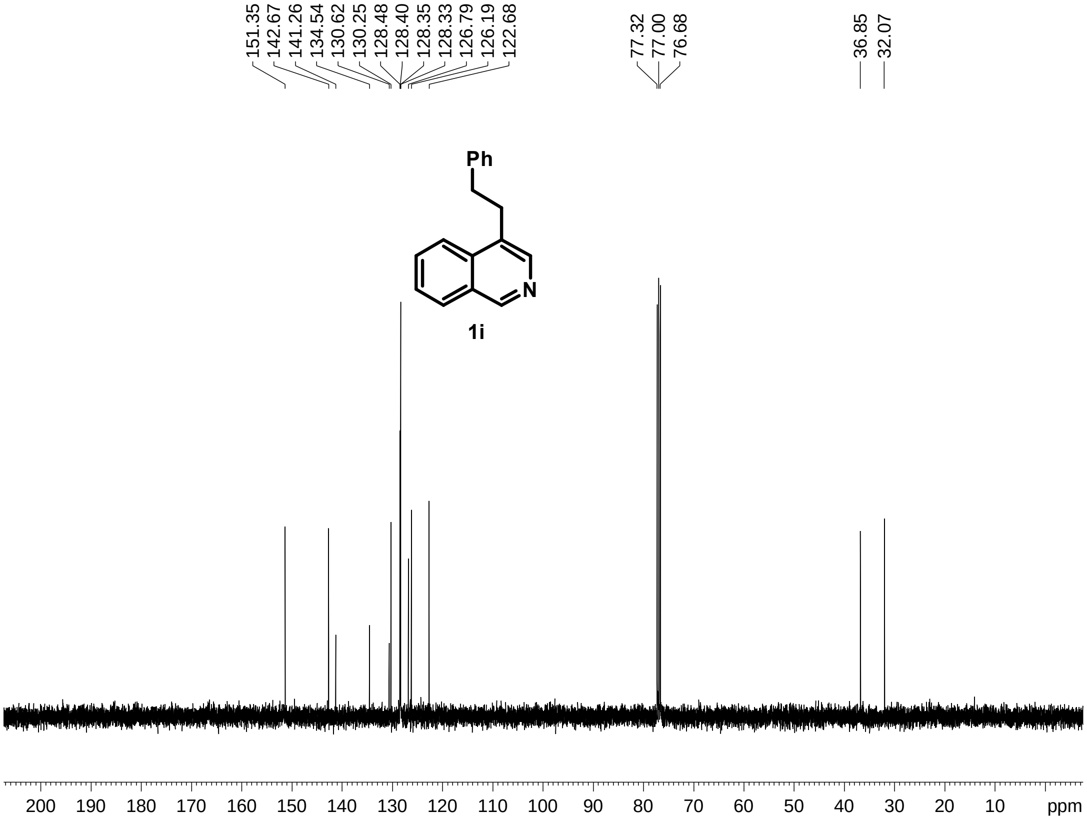
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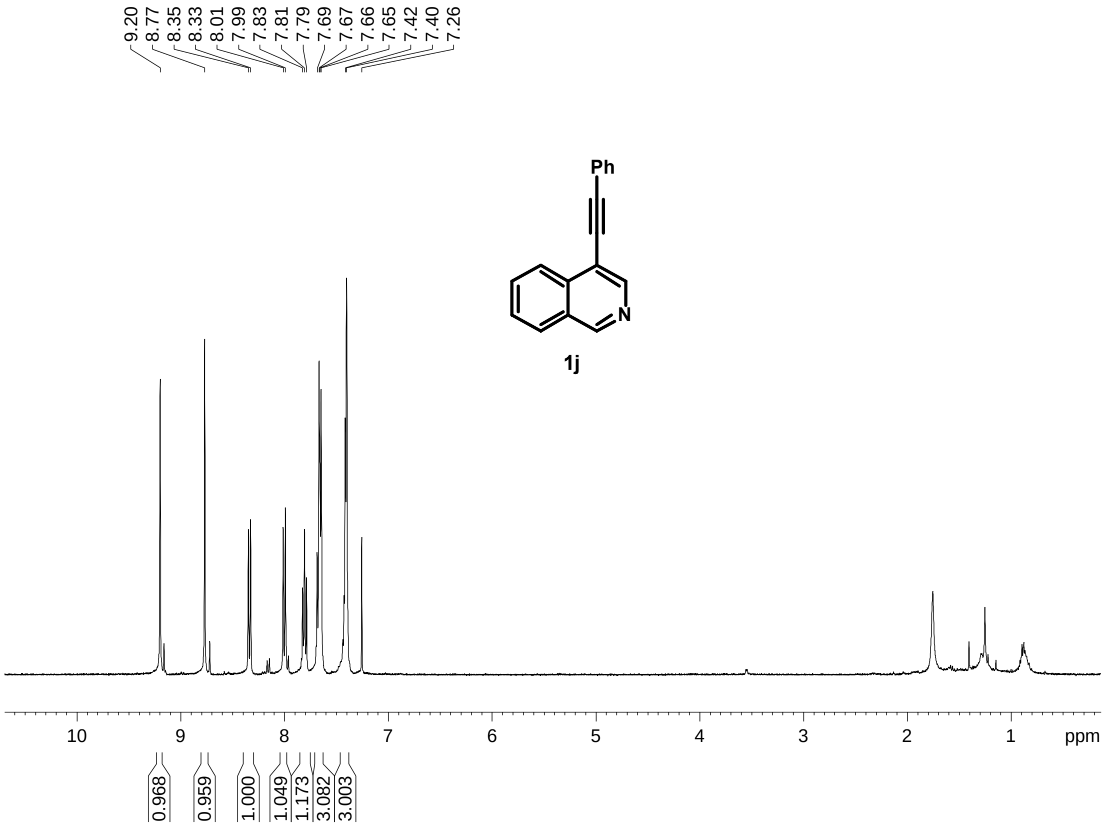
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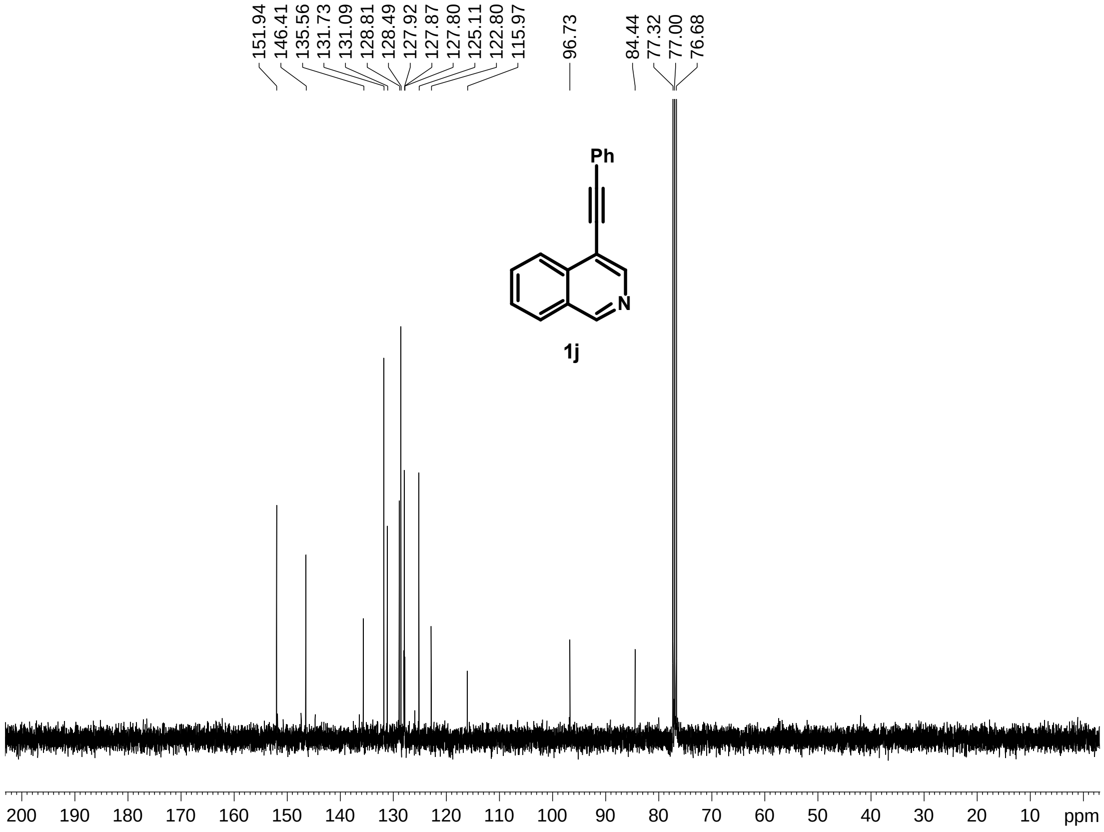
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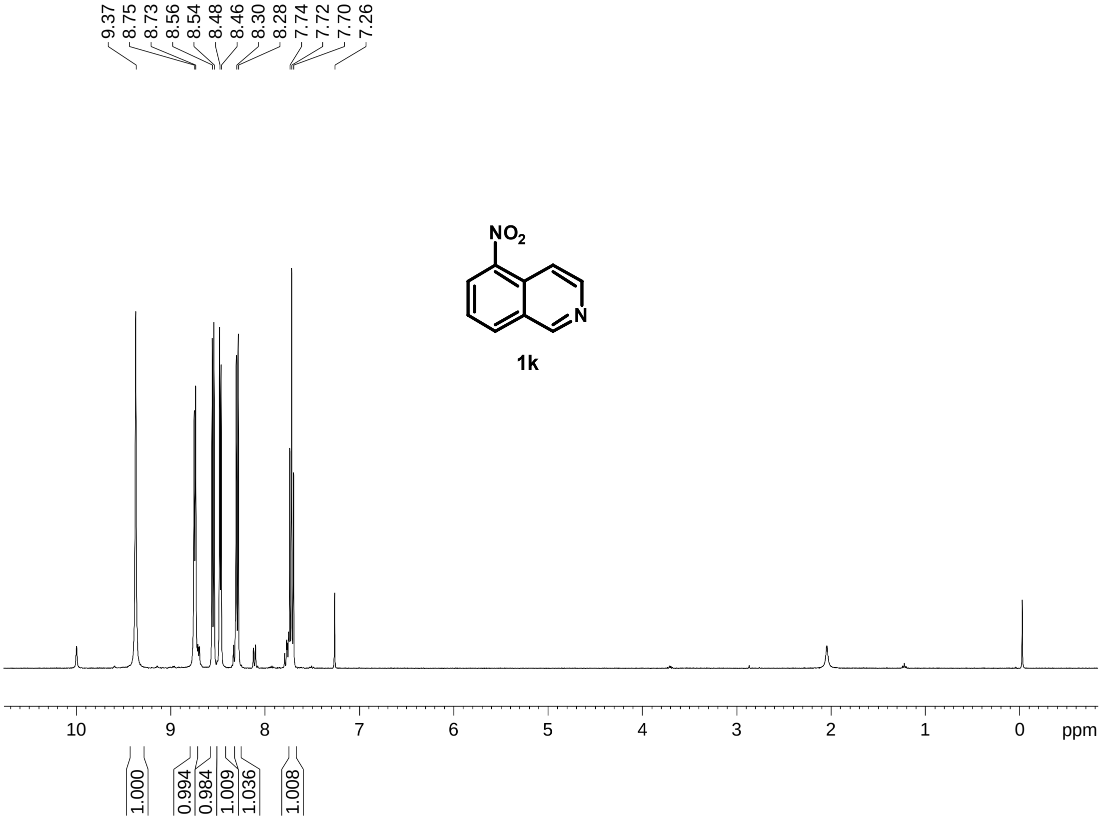
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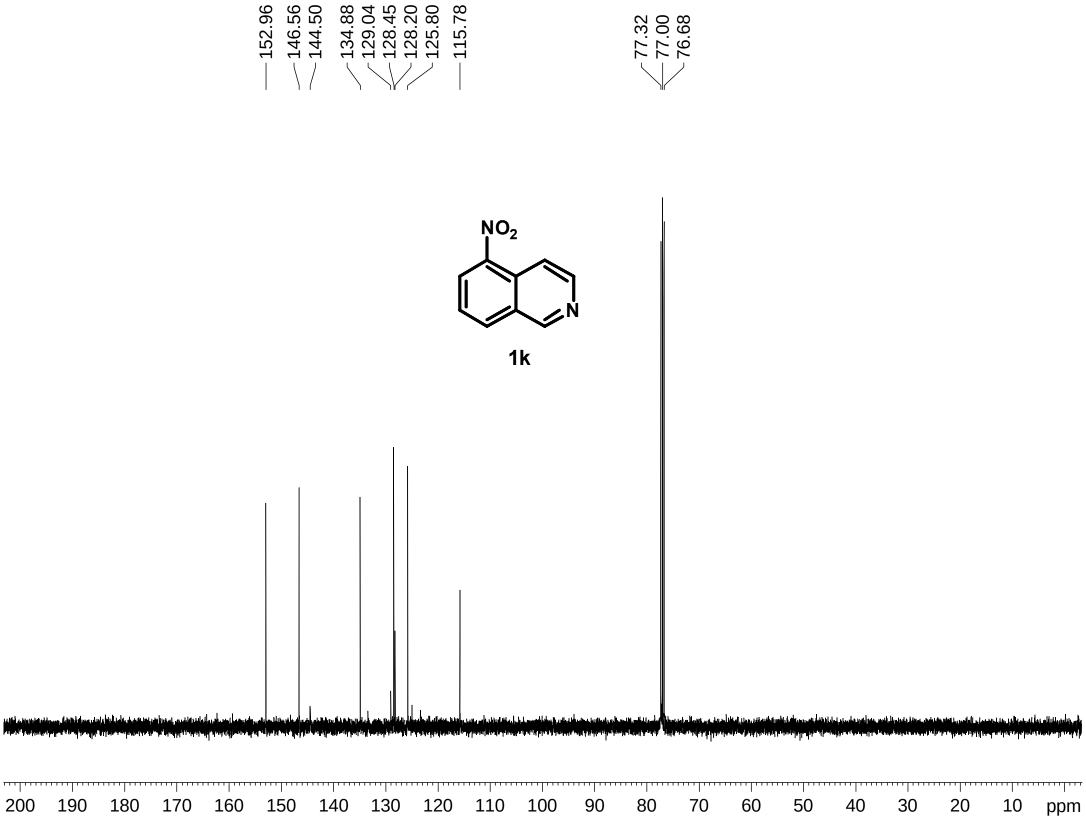
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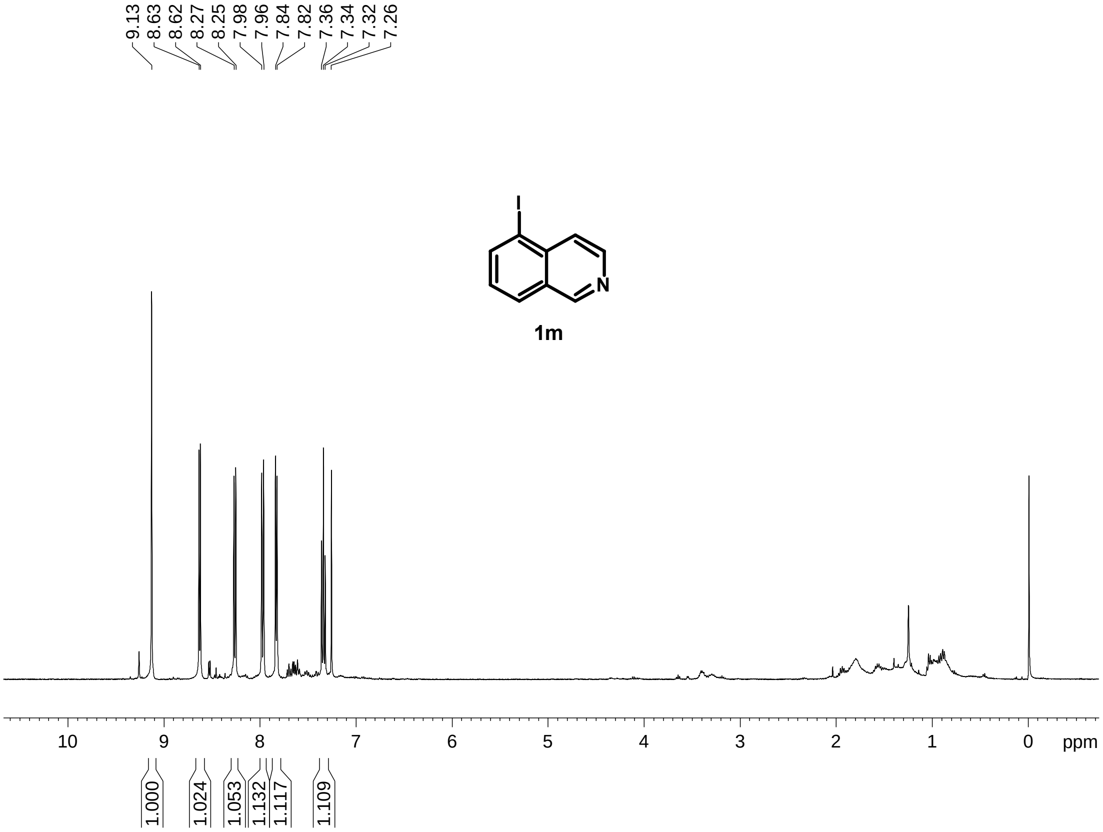
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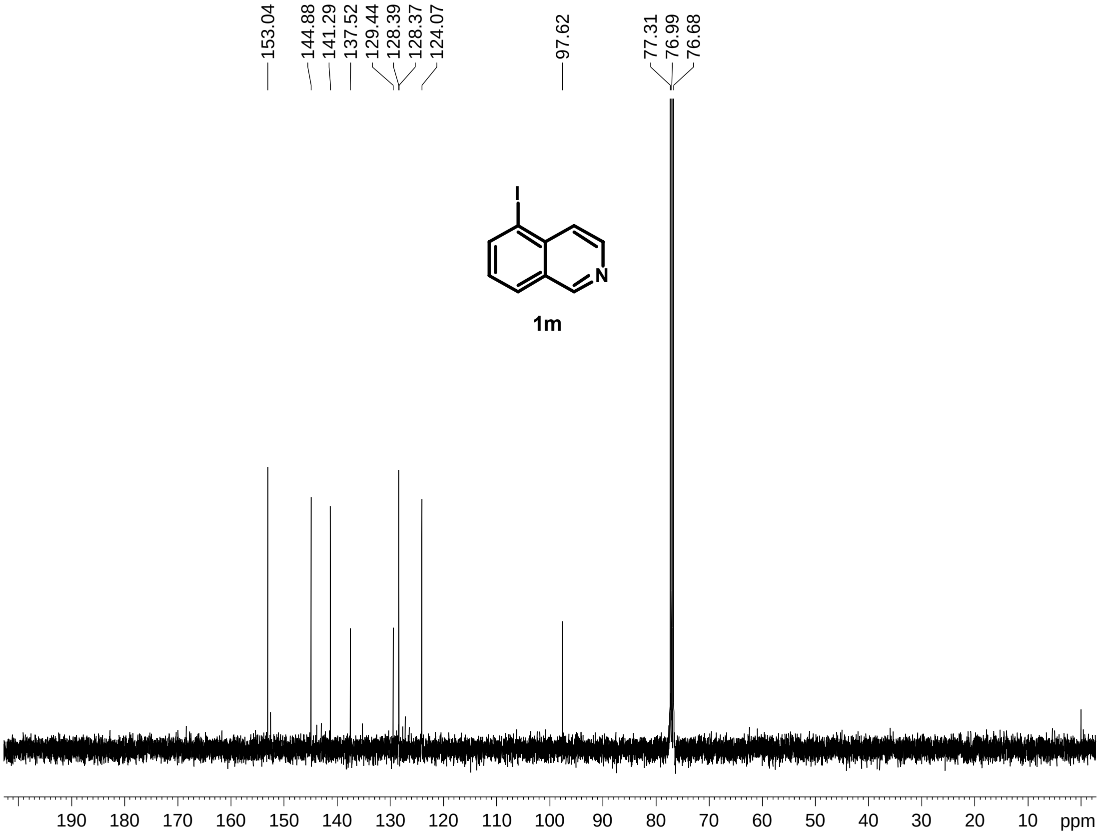
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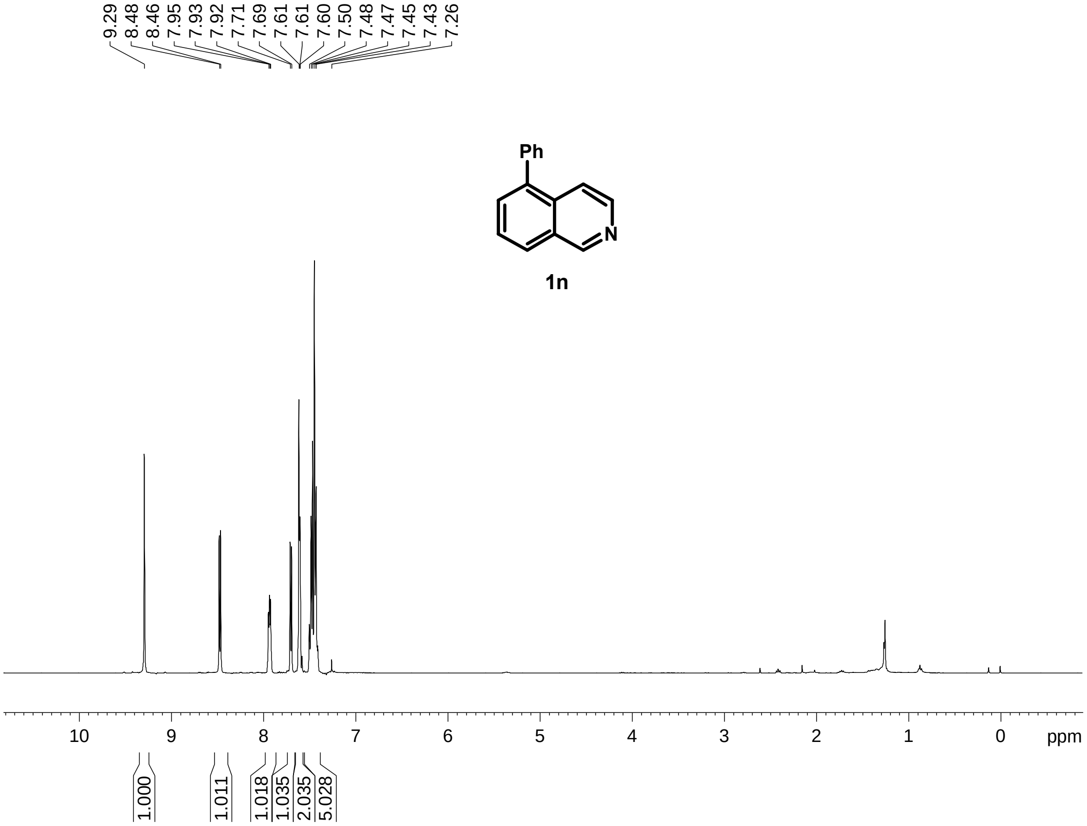
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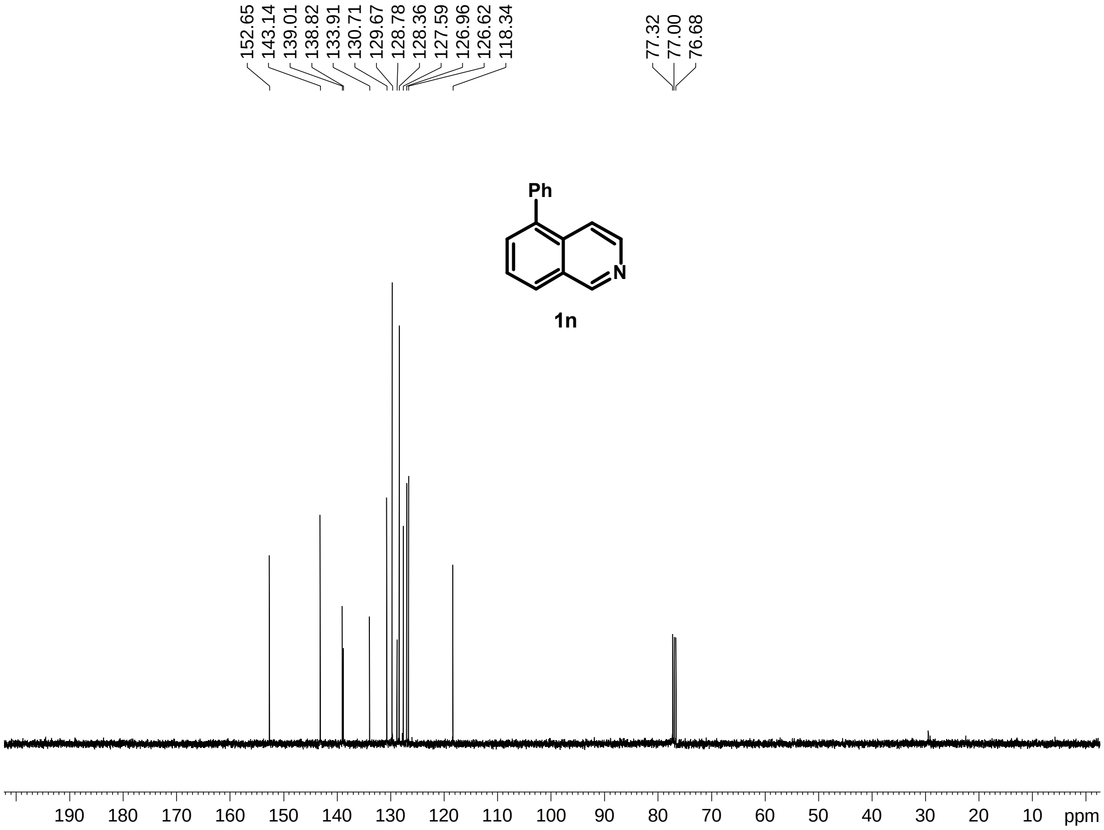
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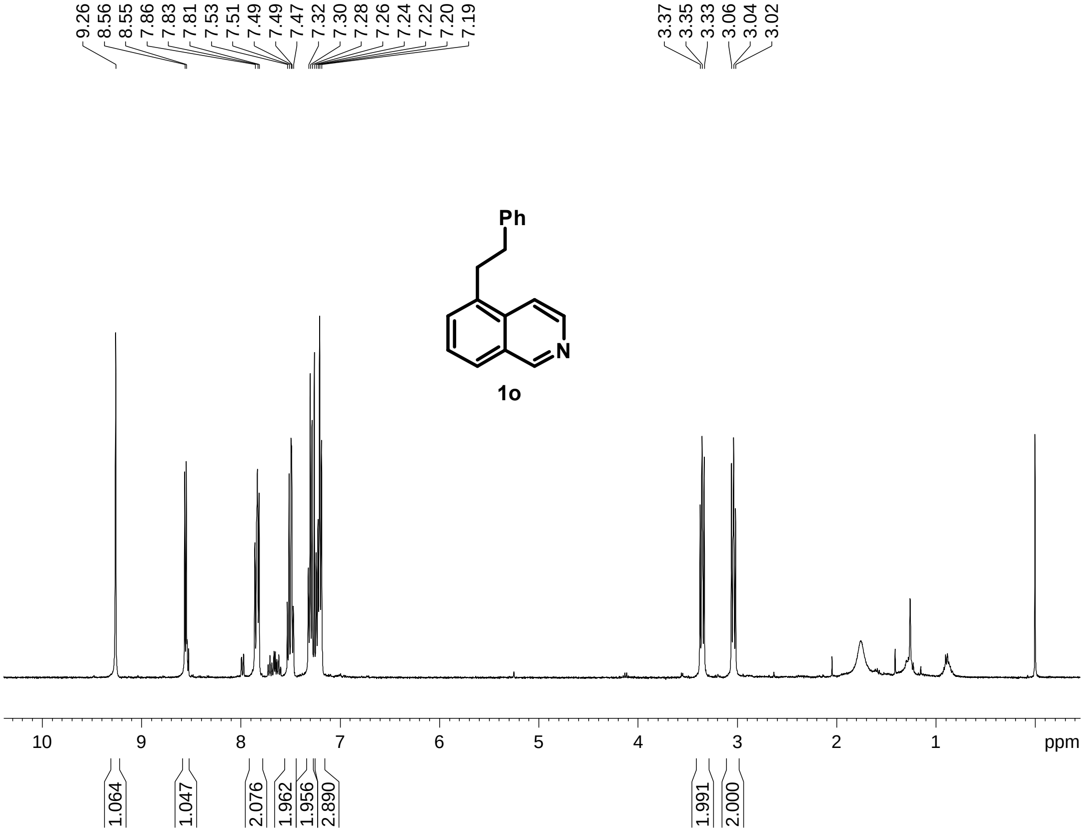
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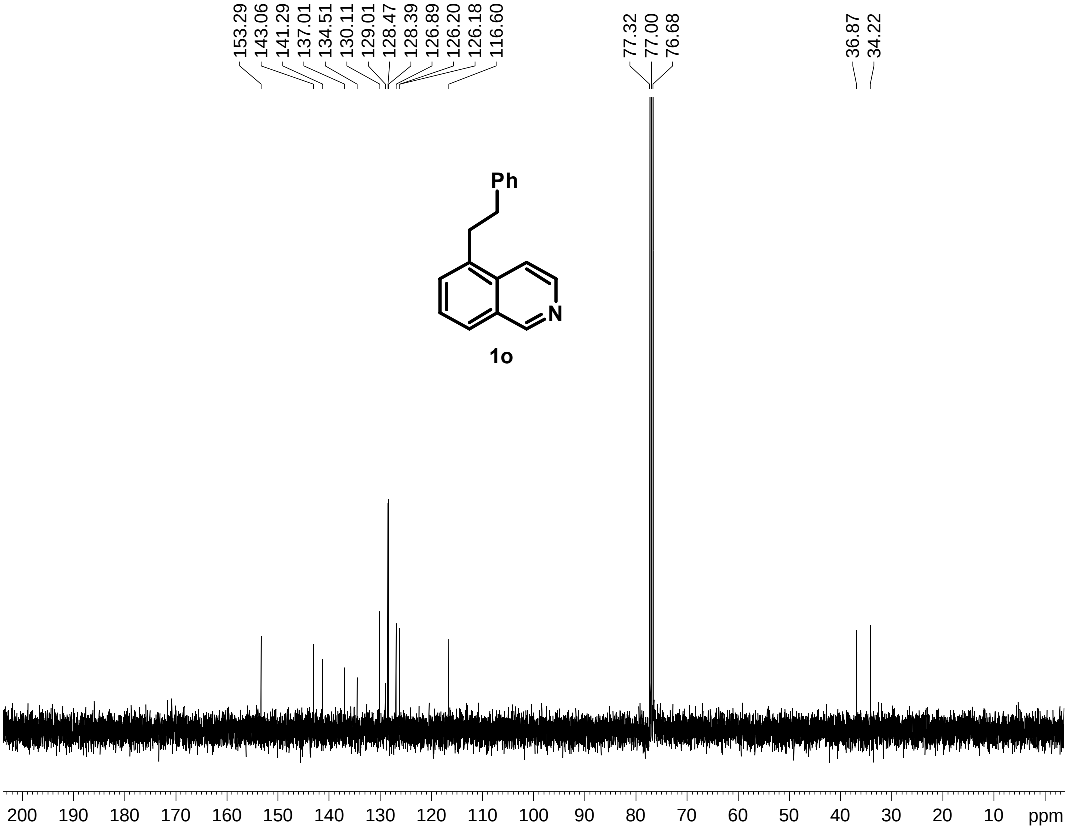
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77.00
76.68
36.87
34.22
Ph
N
200
190
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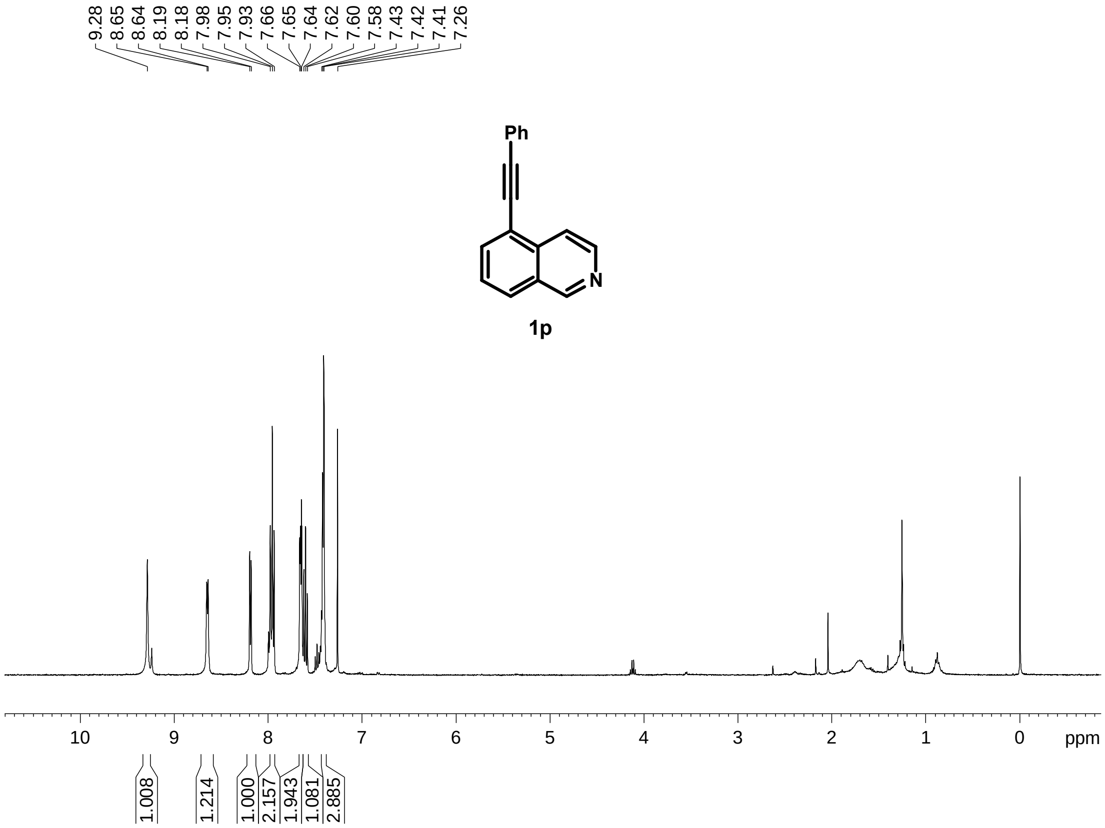
ppm

1o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7.64
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7.60
7.58
7.43
7.42
7.41
7.26
Ph
N
1p
10
9
8
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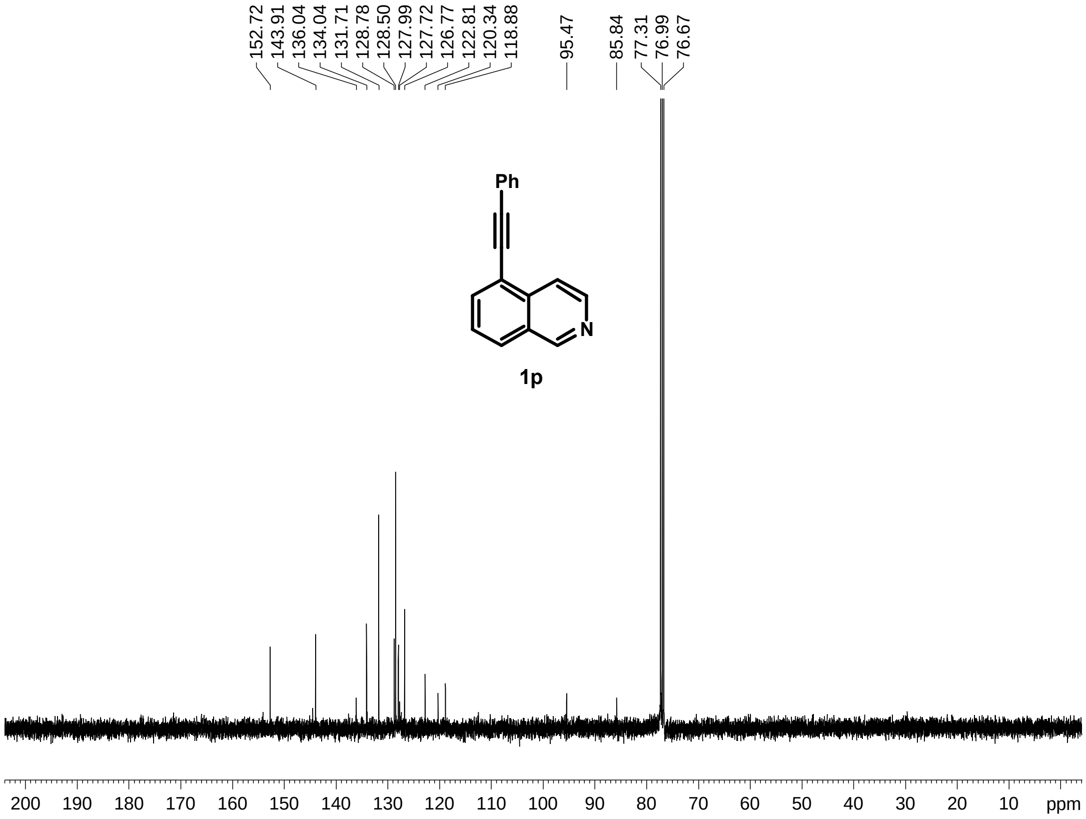
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126.77
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120.34
118.88
95.47
85.84
77.31
76.99
76.67
Ph
N
1p
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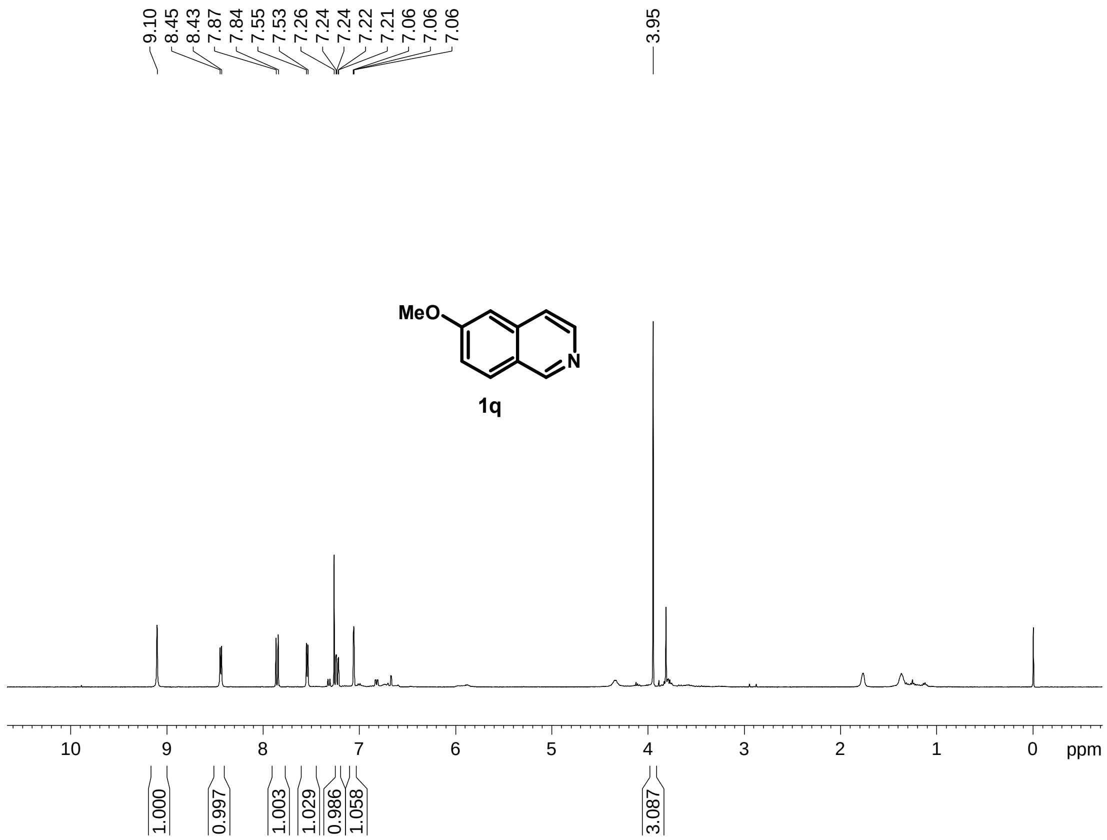
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7.06
7.06
7.06
3.95
MeO
N
1q
10
9
8
7
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2
1
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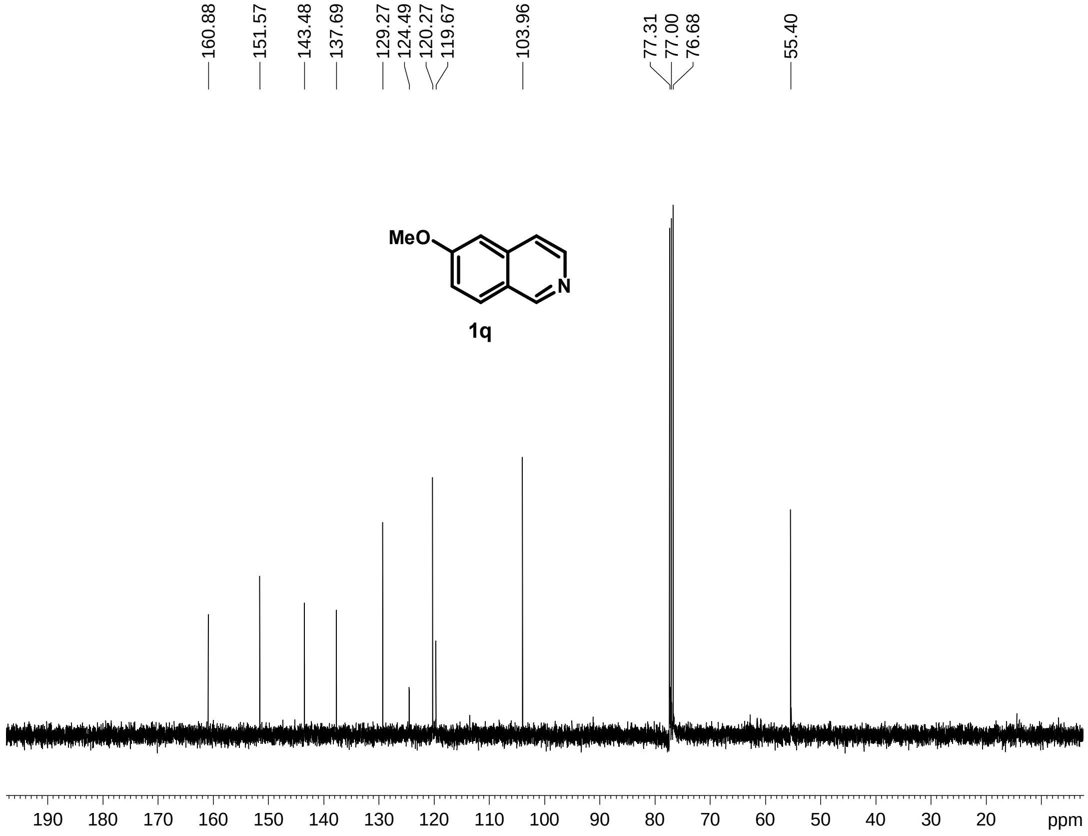
1.058
3.087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N
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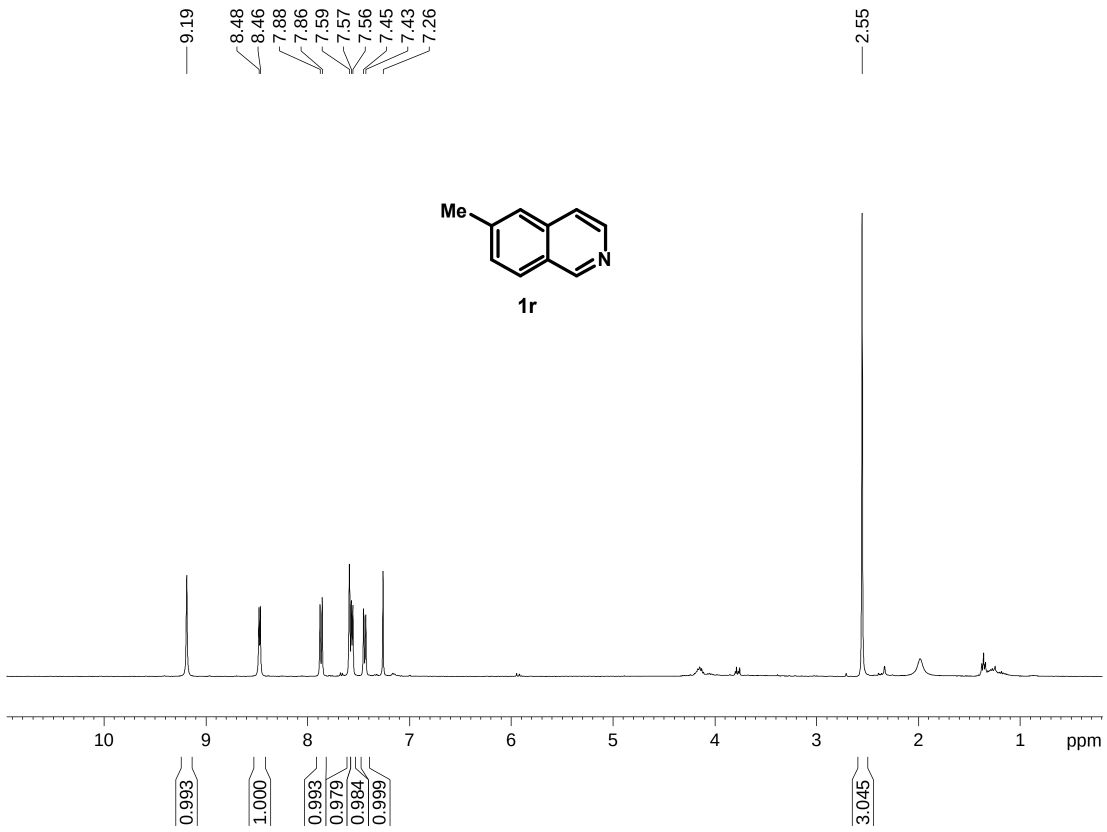
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7.59
7.57
7.56
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7.43
7.26
2.55
Me
N
1r
10
9
8
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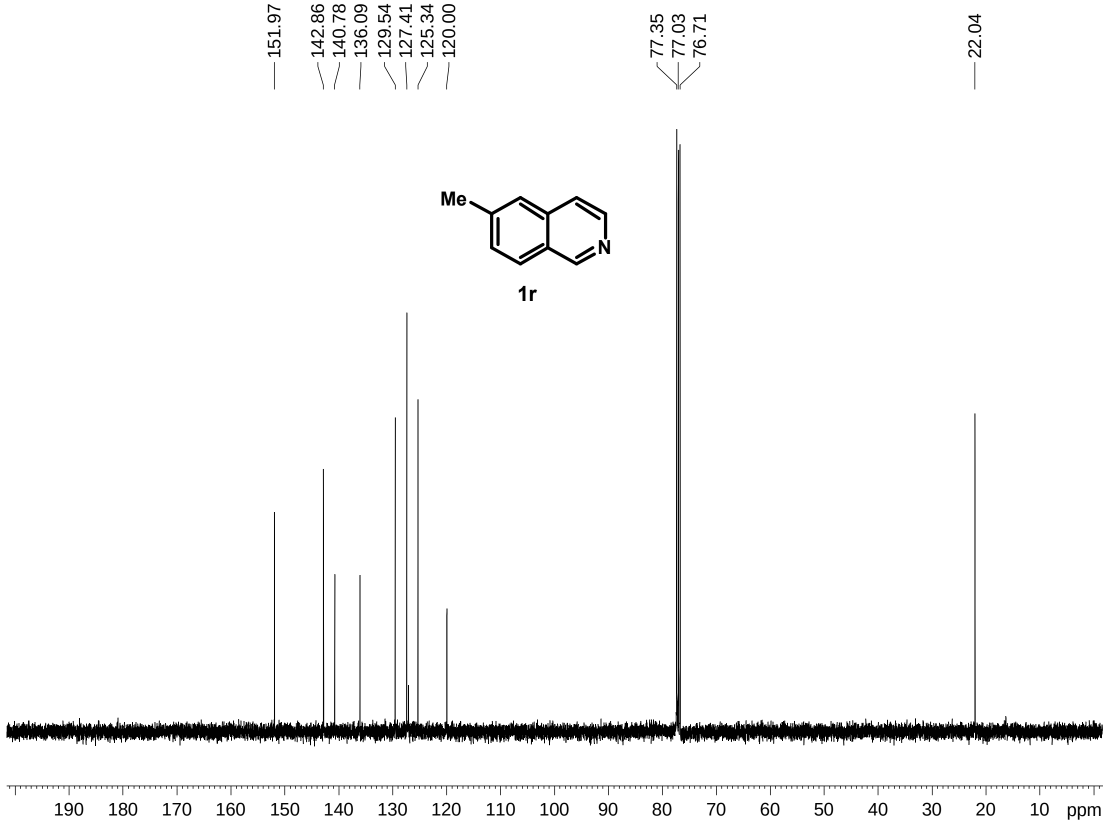
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1r
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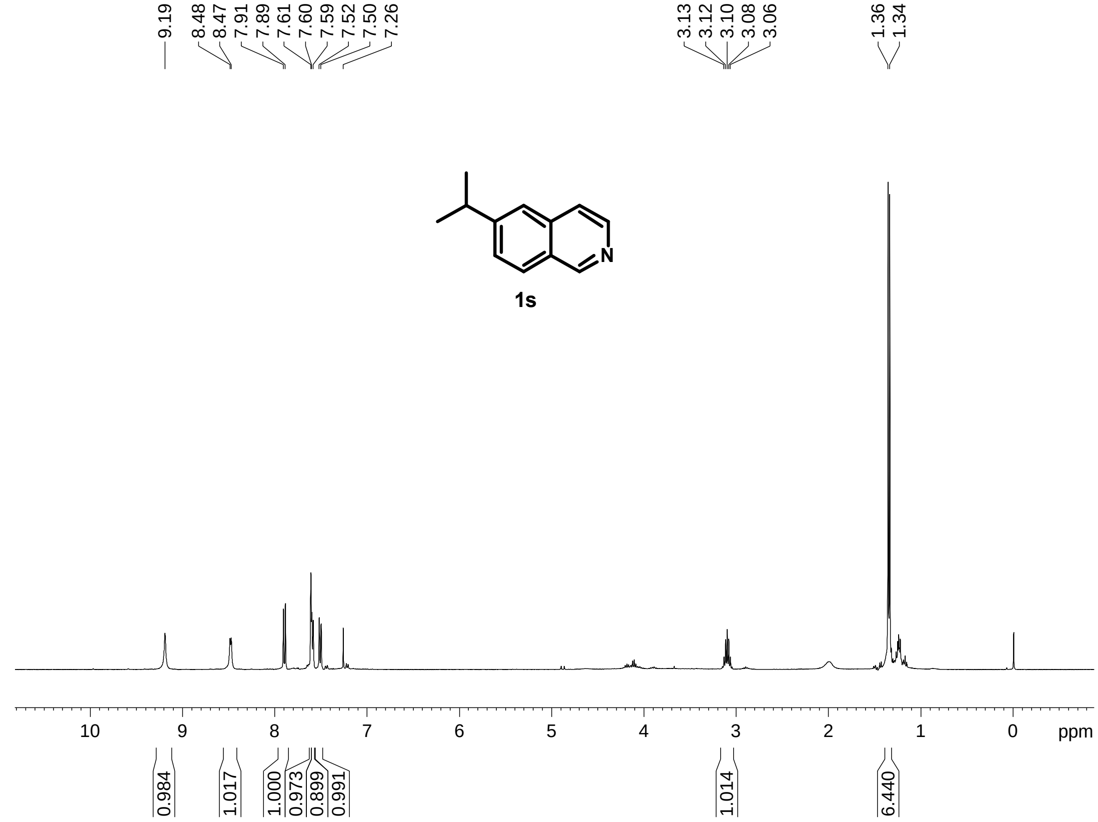
10
ppm



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7.26
3.13
3.12
3.10
3.08
3.06
1.36
1.34
N
1s
10
9
8
7
6
5
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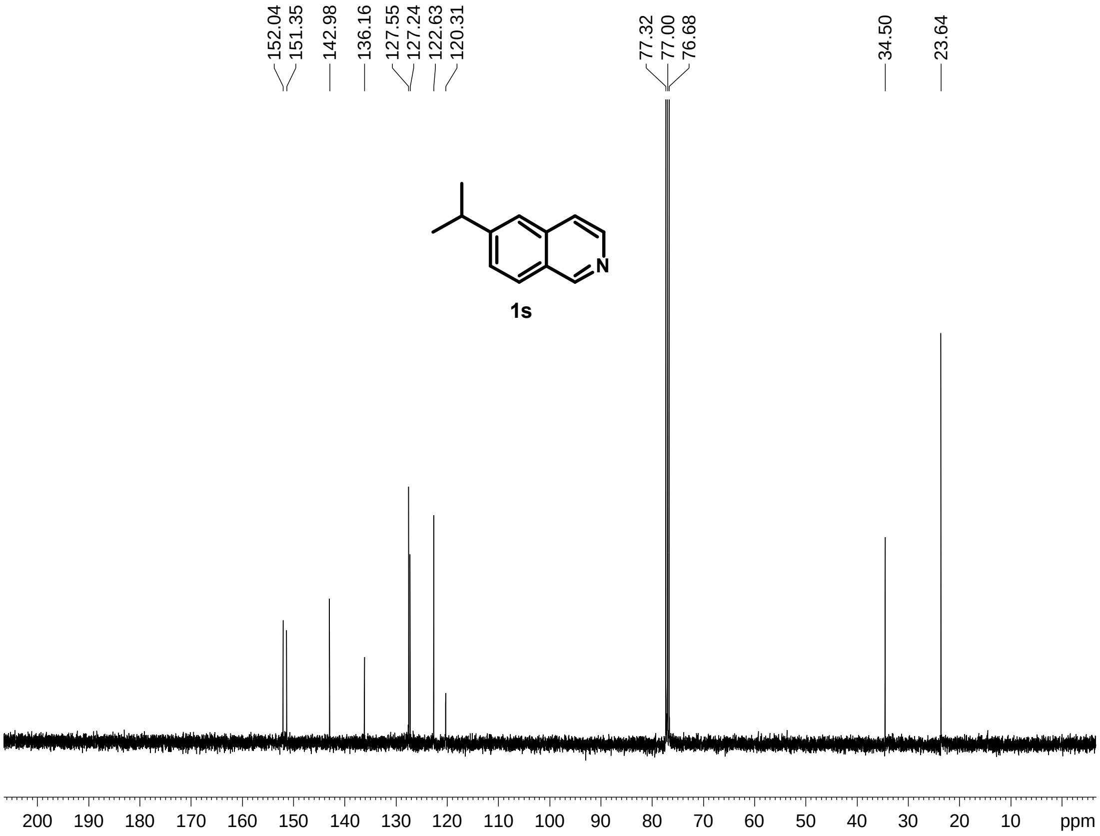
6.440



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77.00
76.68
34.50
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N
1s
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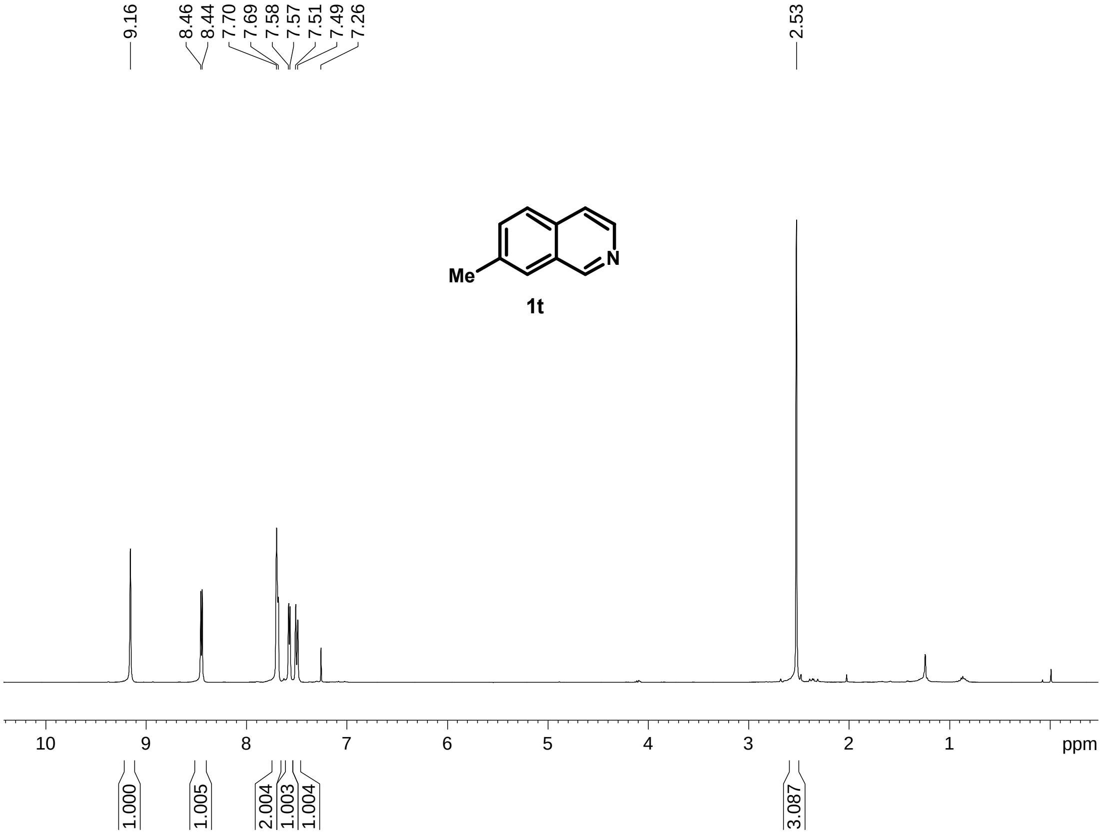
10
ppm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7.26
2.53
Me
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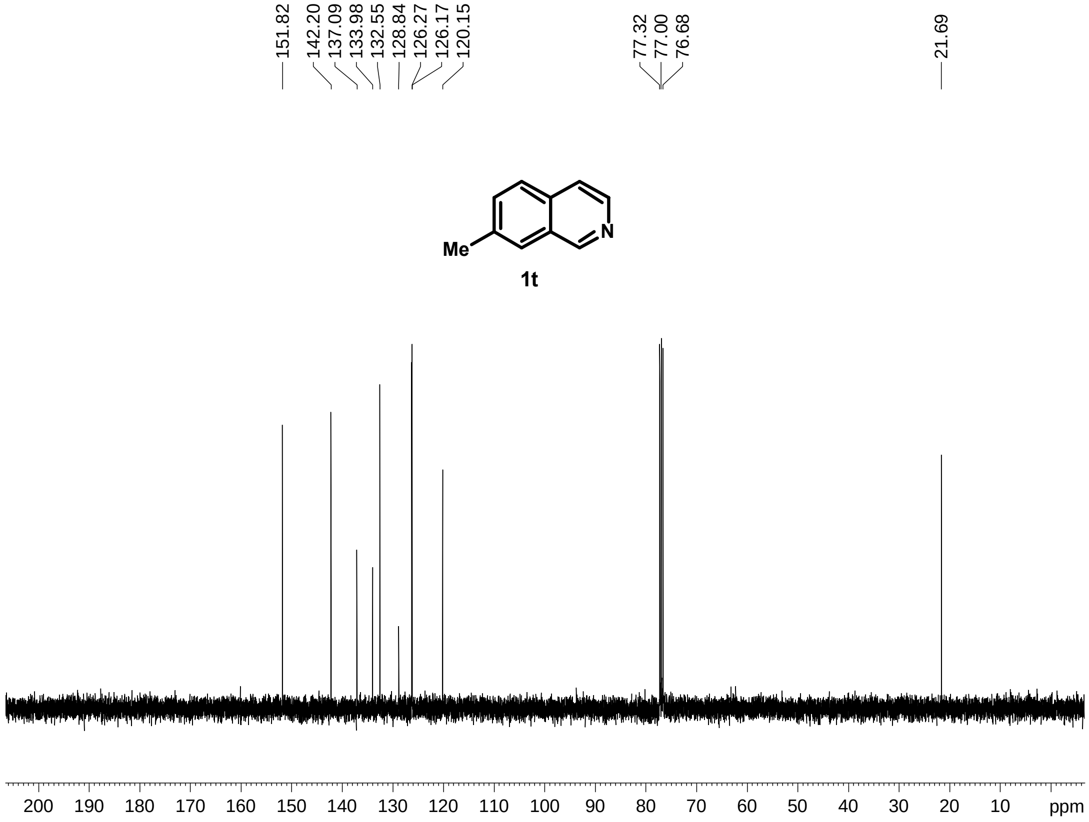
2.004
1.003
1.004
3.087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77.00
76.68
21.69
Me
N
1t
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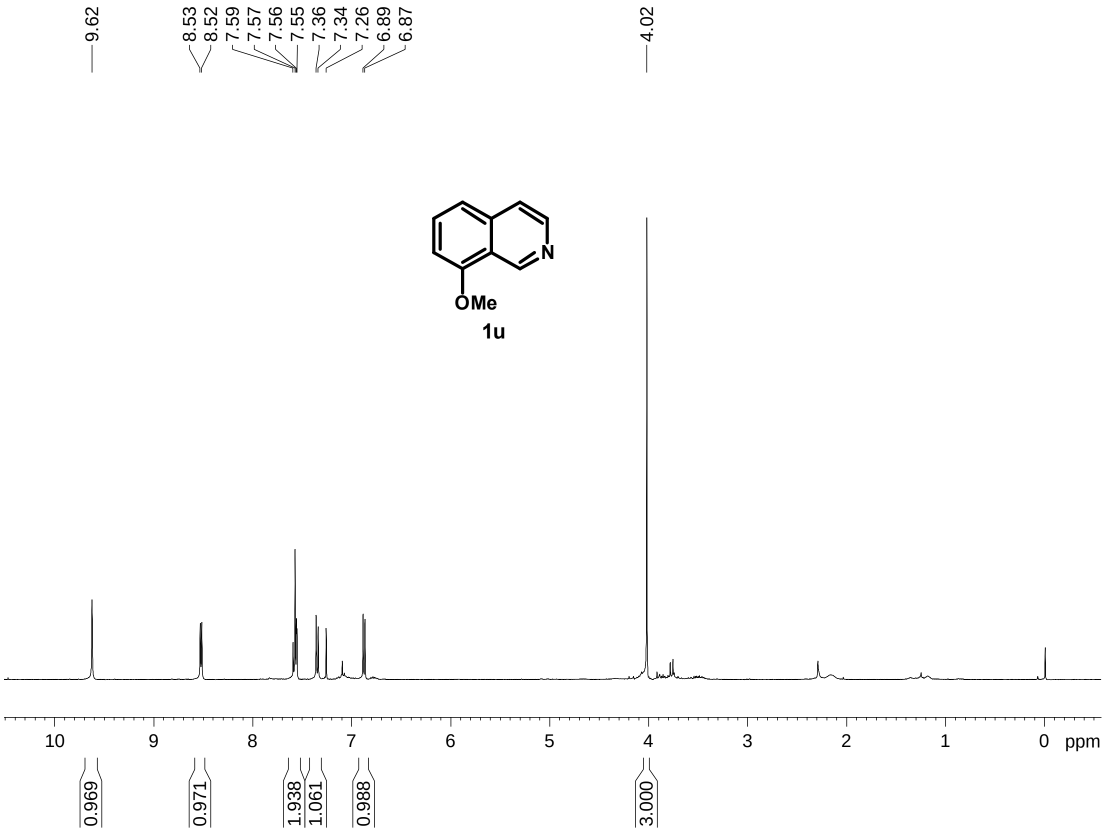
10
ppm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7.56
7.55
7.36
7.34
7.26
6.89
6.87
4.02
N
OMe
1u
10
9
8
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3
2
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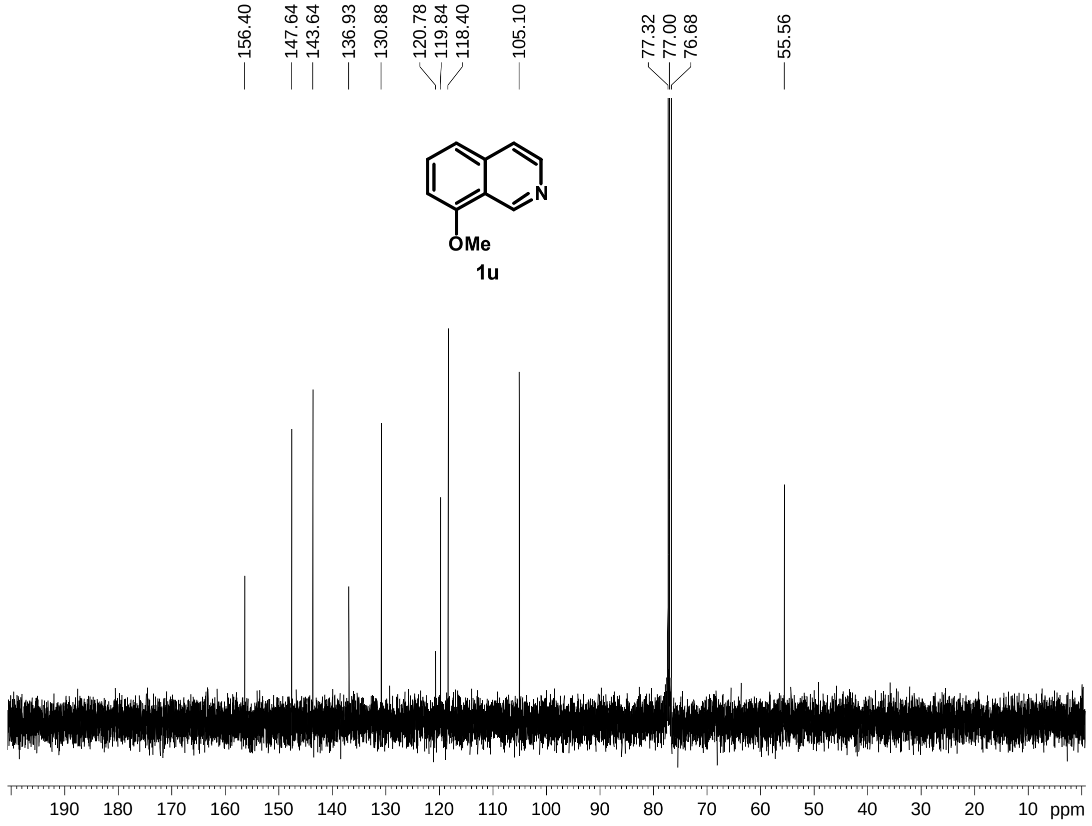
1.061
0.988
3.000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119.84
118.40
105.10
77.32
77.00
76.68
55.56
N
OMe
1u
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180
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150
140
130
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100
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70
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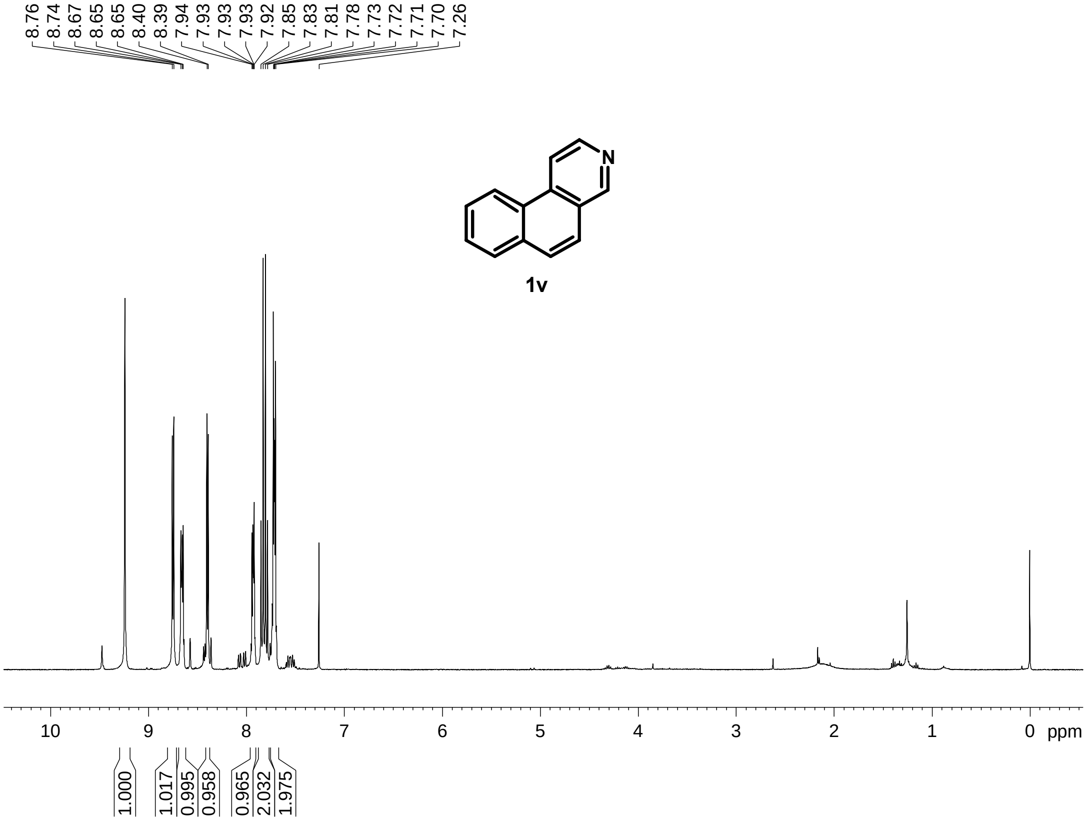
30
20
10
ppm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8.74
8.67
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8.65
8.40
8.39
7.94
7.93
7.93
7.93
7.92
7.85
7.83
7.81
7.78
7.73
7.72
7.71
7.70
7.26
N
1v
10
9
8
7
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0
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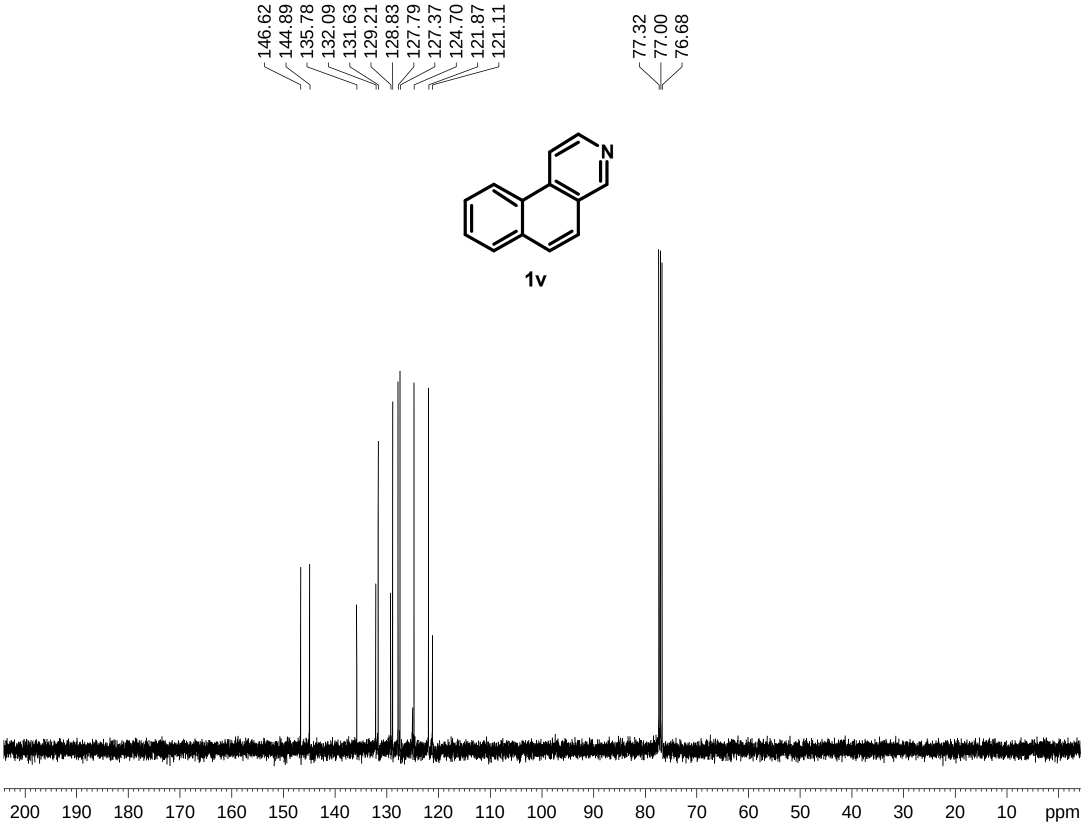
2.032
1.975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131.63
129.21
128.83
127.79
127.37
124.70
121.87
121.11
77.32
77.00
76.68
N
1v
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150
140
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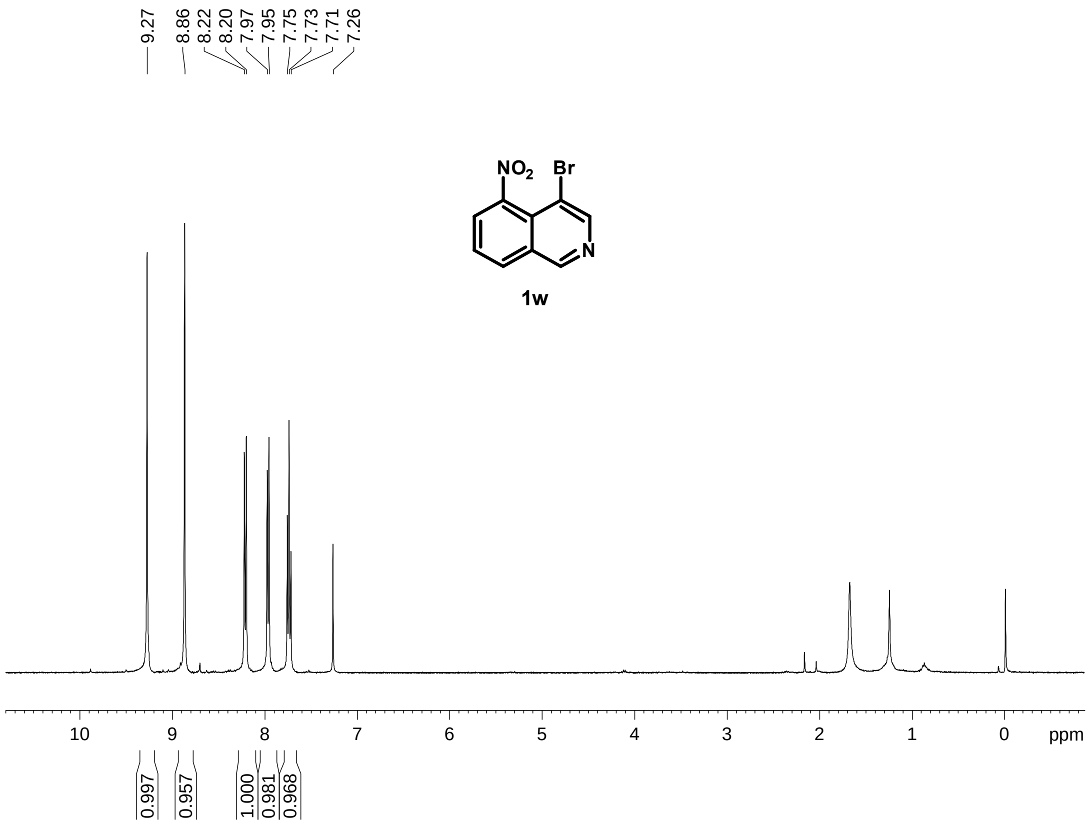
10
ppm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7.95
7.75
7.73
7.71
7.26
NO2
Br
N
1w
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5
4
3
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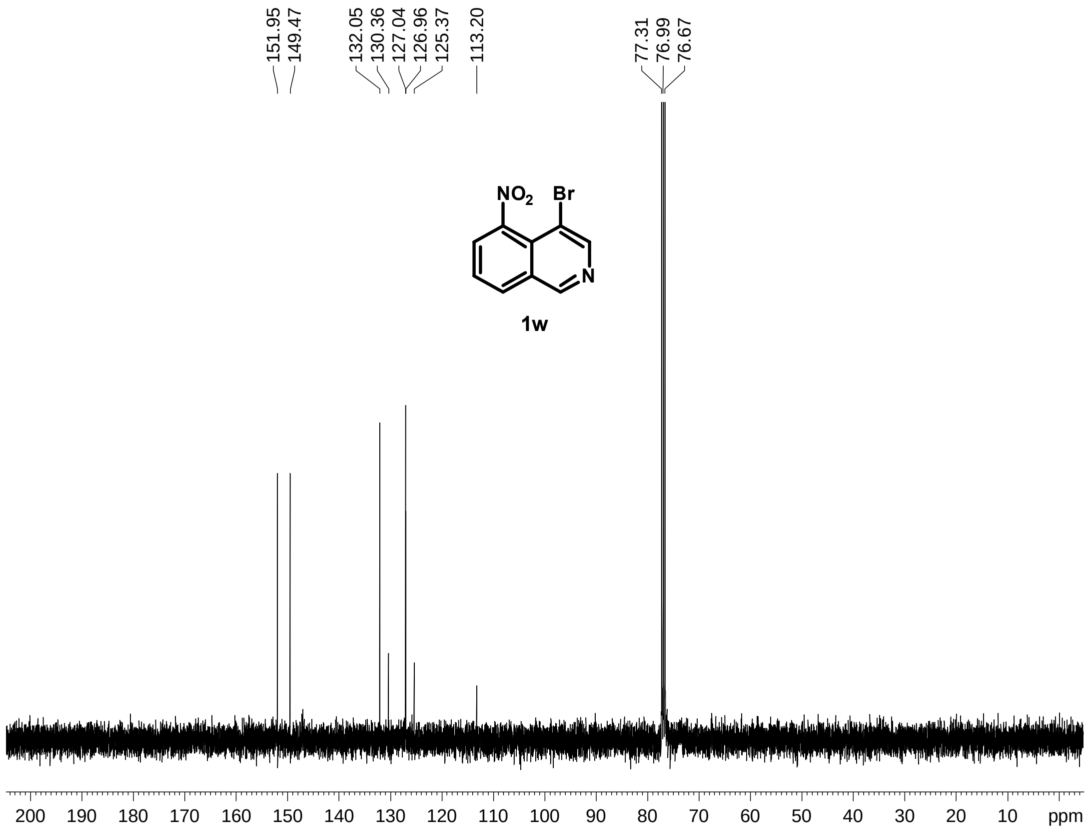
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132.05
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127.04
126.96
125.37
113.20
77.31
76.99
76.67
NO2
Br
N
1w
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180
170
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150
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130
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100
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30
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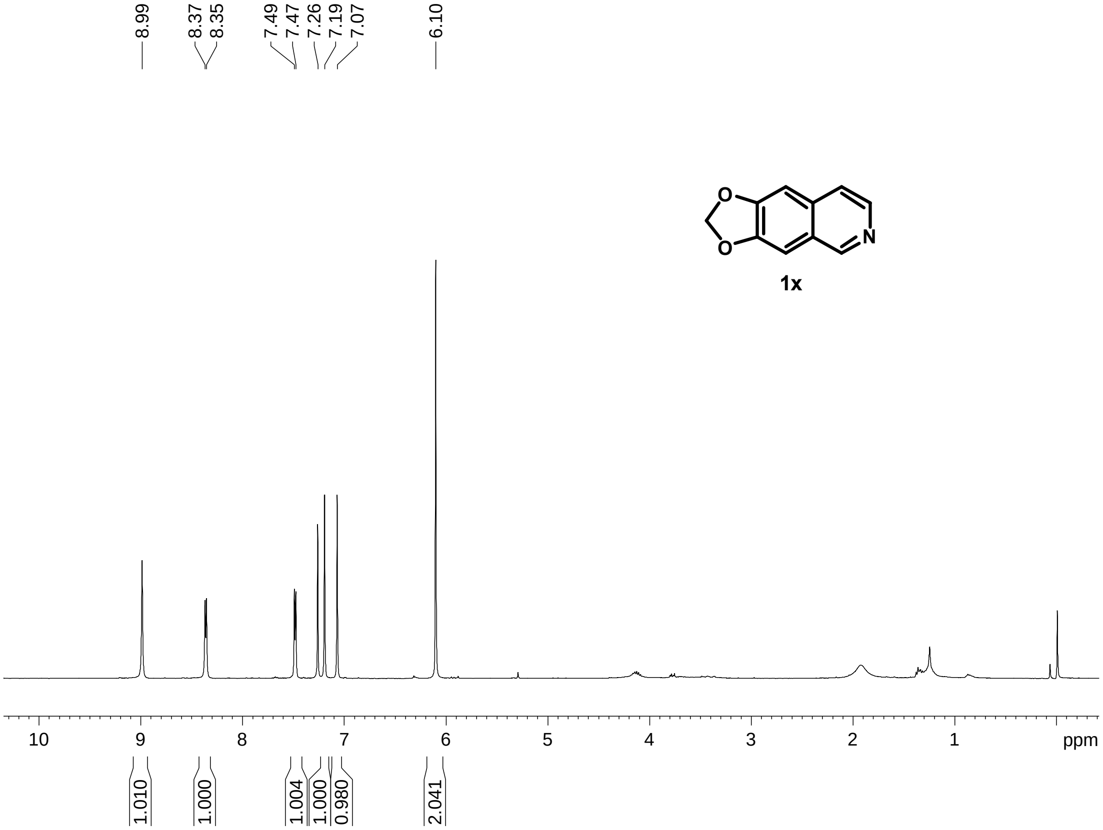
10
ppm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7.47
7.26
7.19
7.07
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1x
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8
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6
5
4
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ppm
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1.000
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1.000
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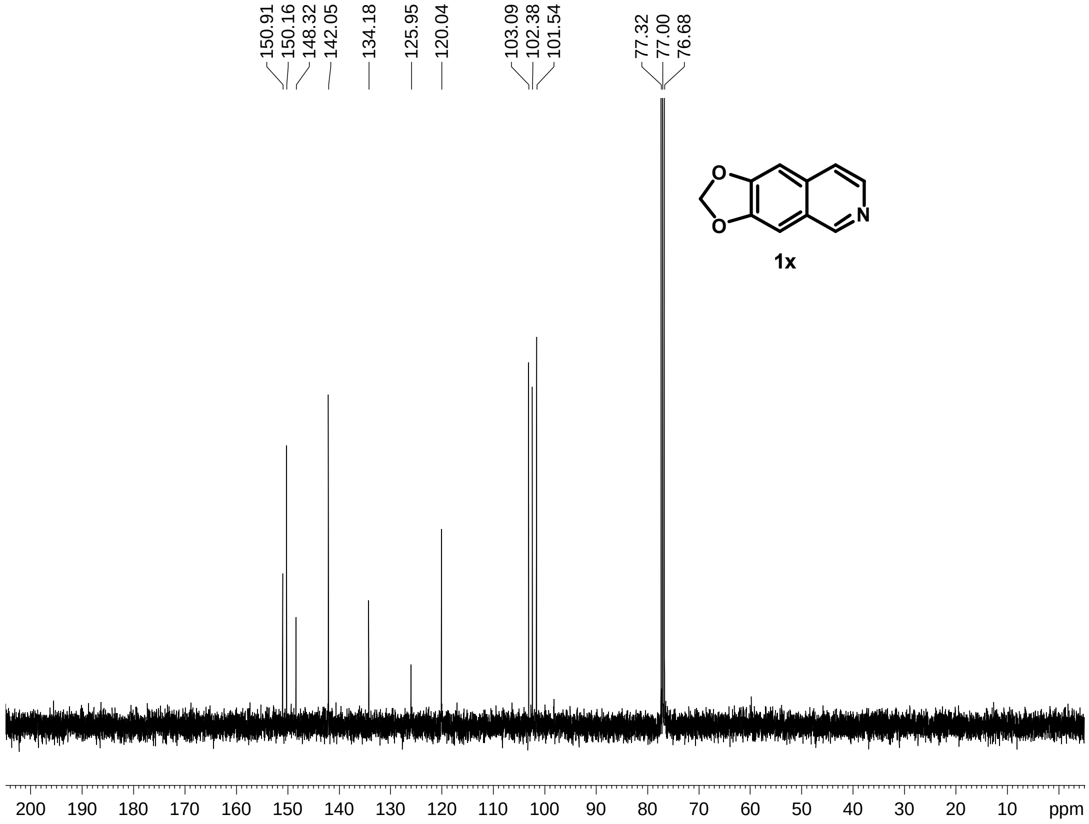
2.041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150.16
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125.95
120.04
103.09
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101.54
77.32
77.00
76.68
1x
200
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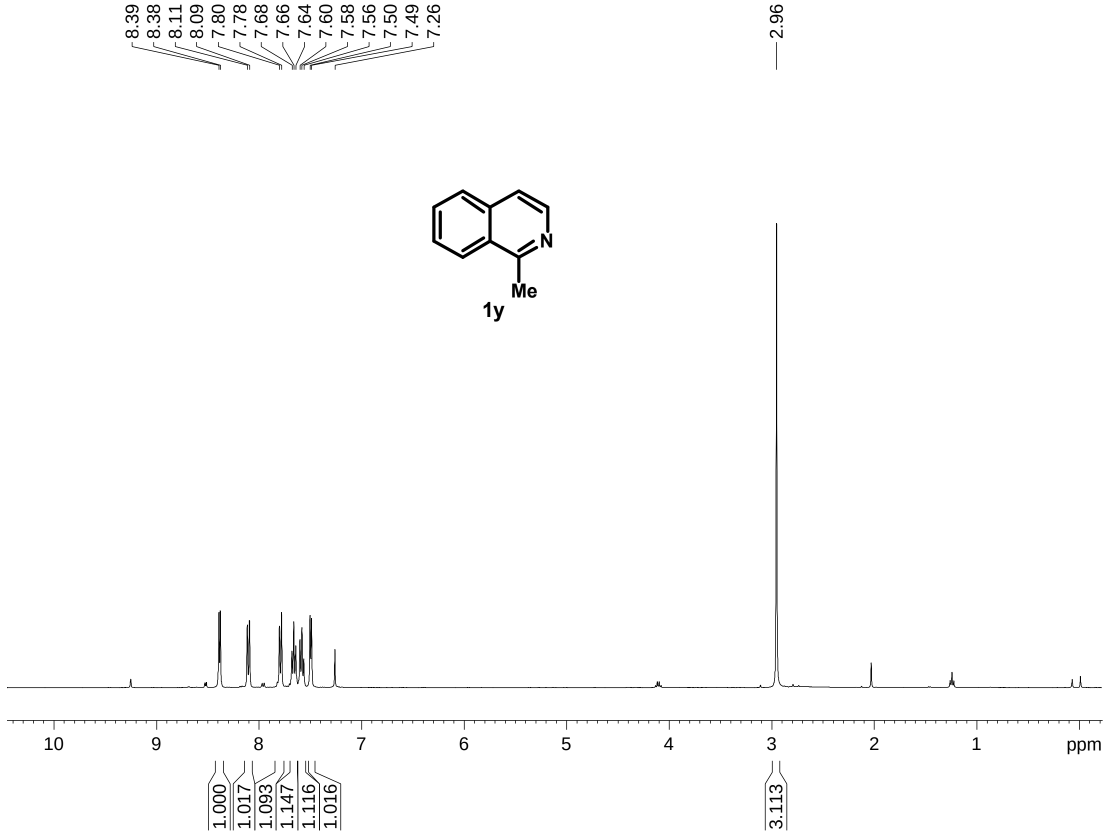
10
ppm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7.60
7.58
7.56
7.50
7.49
7.26
2.96
N
Me
1y
10
9
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6
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2
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1.093
1.147
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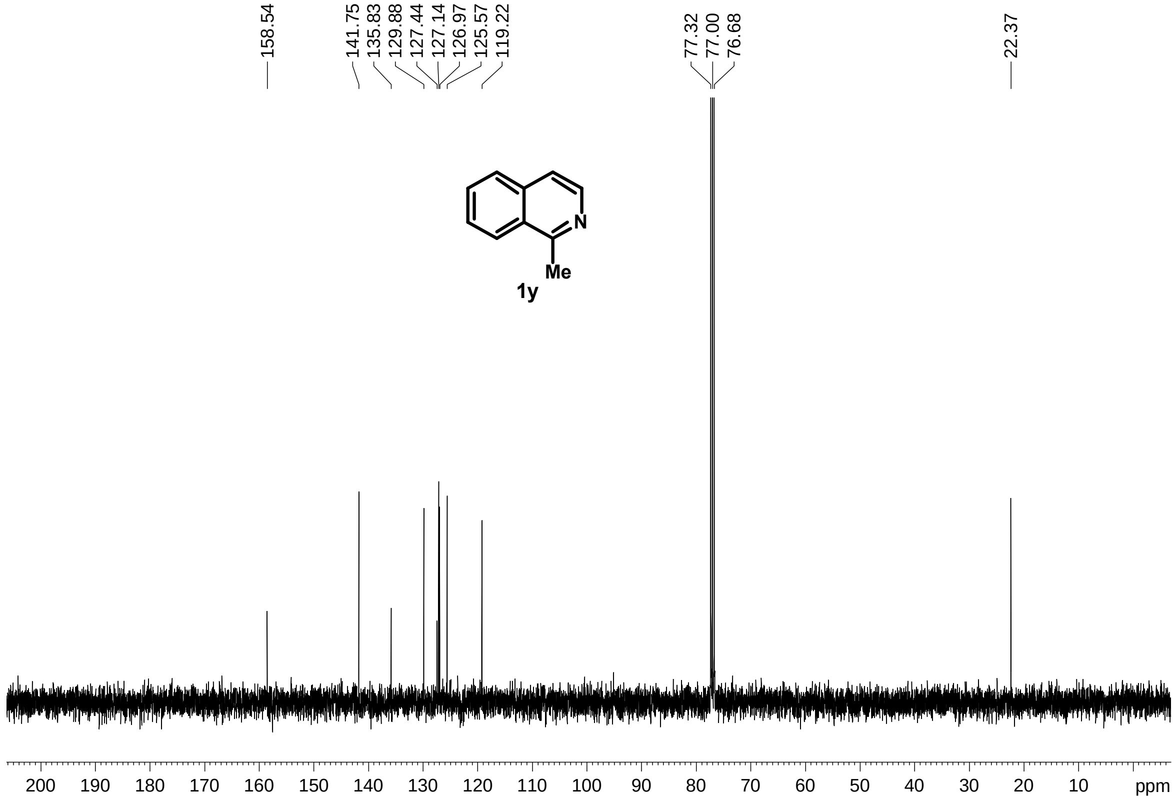
1.016
3.113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77.32
77.00
76.68
22.37
N
Me
1y
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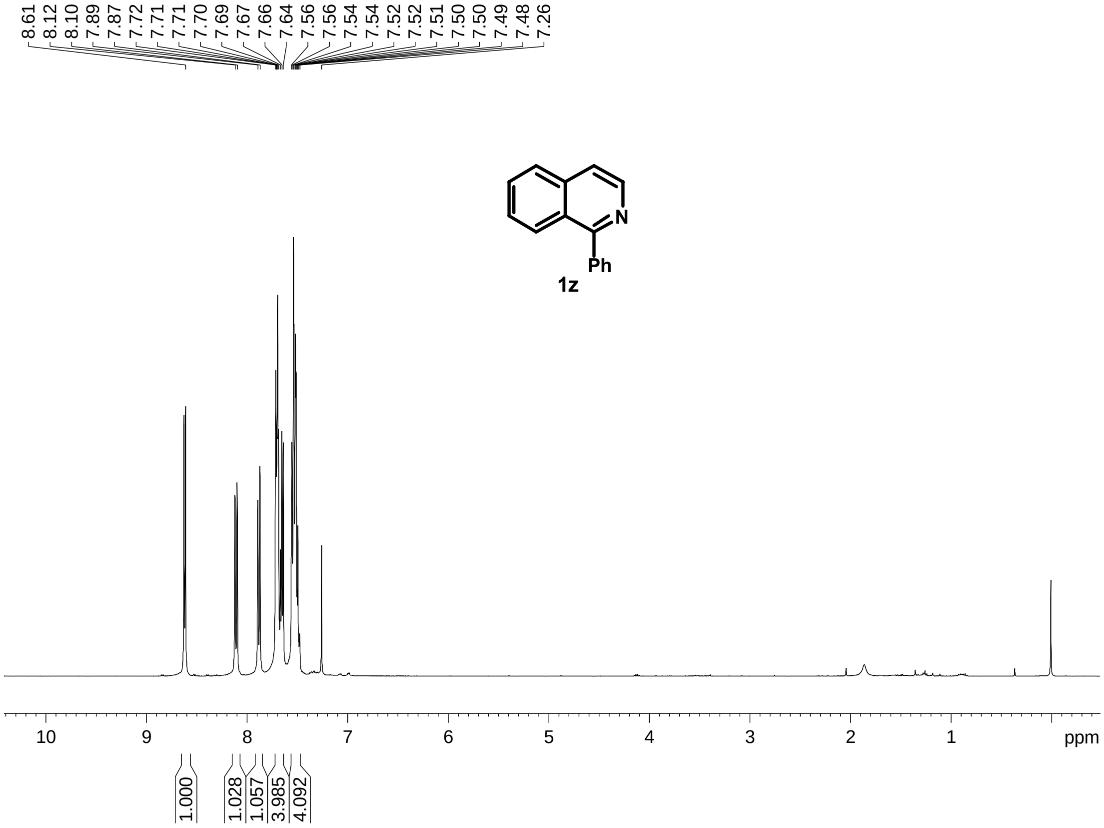
ppm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7.64
7.56
7.56
7.54
7.54
7.52
7.52
7.51
7.50
7.50
7.49
7.48
7.26
N
Ph
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6
5
4
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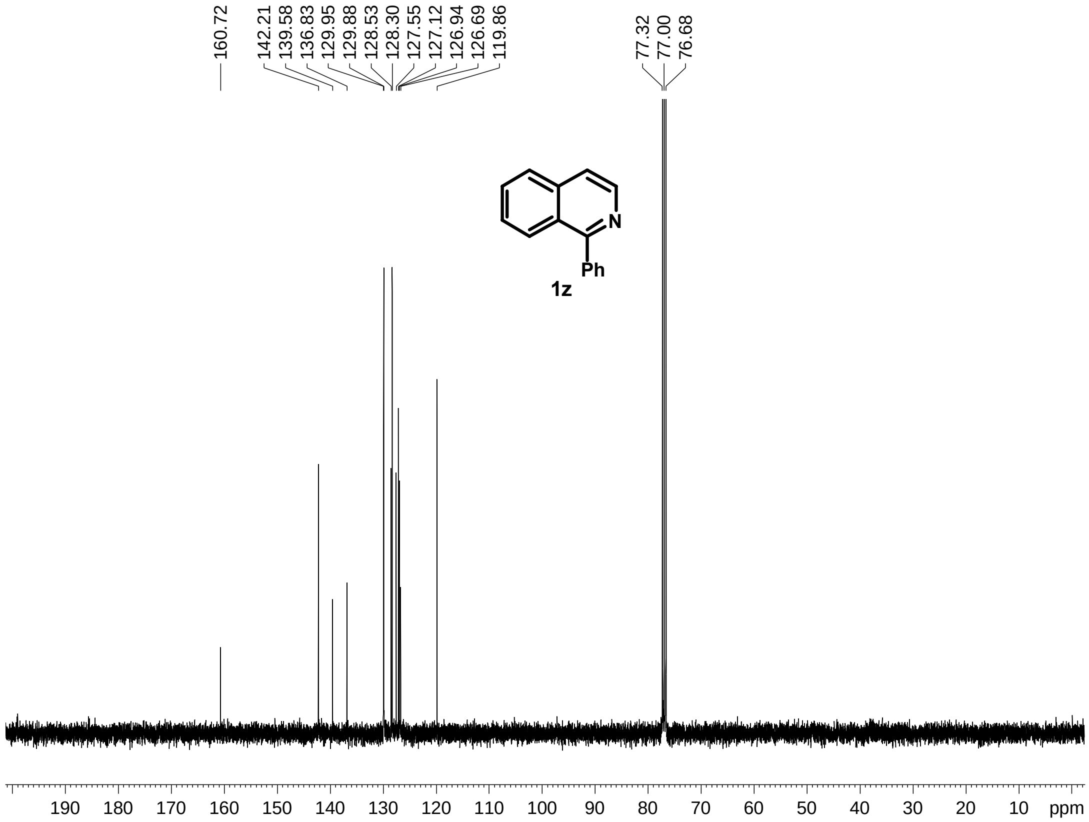
3.985
4.092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127.12
126.94
126.69
119.86
77.32
77.00
76.68
N
Ph
1z
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150
140
130
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110
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70
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30
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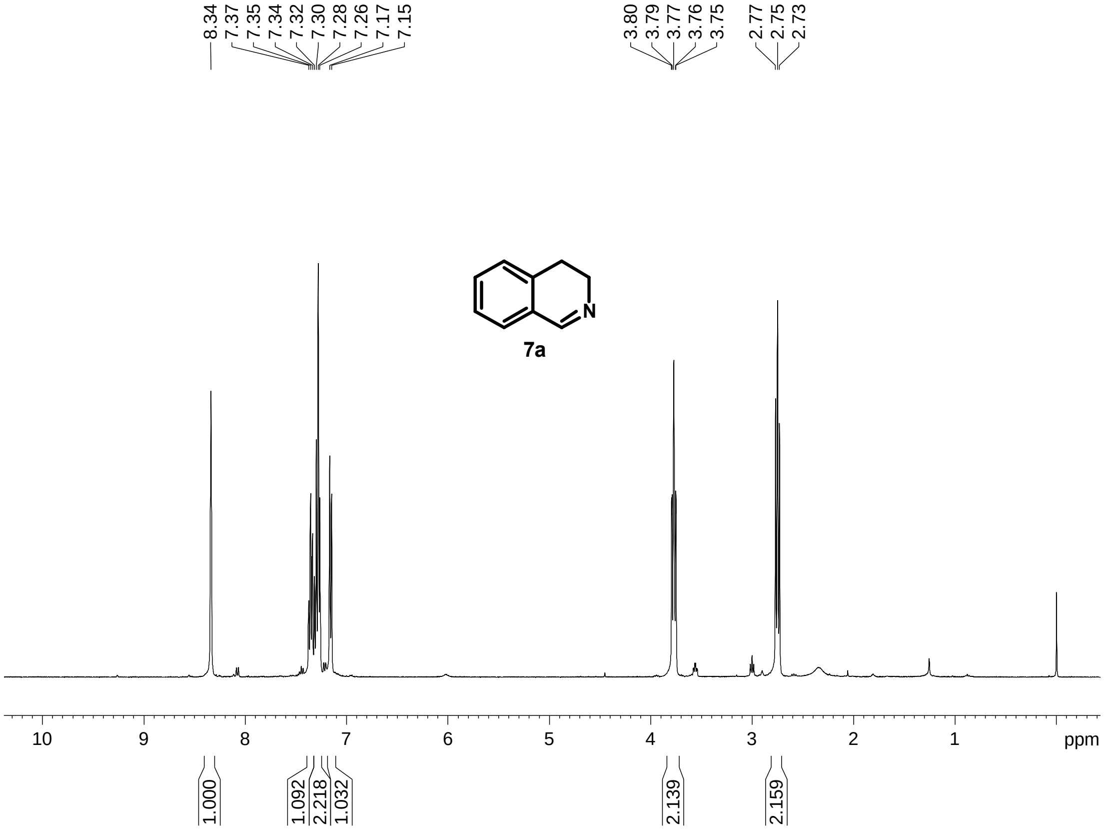
10
ppm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7.15
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3.79
3.77
3.76
3.75
2.77
2.75
2.73
N
7a
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5
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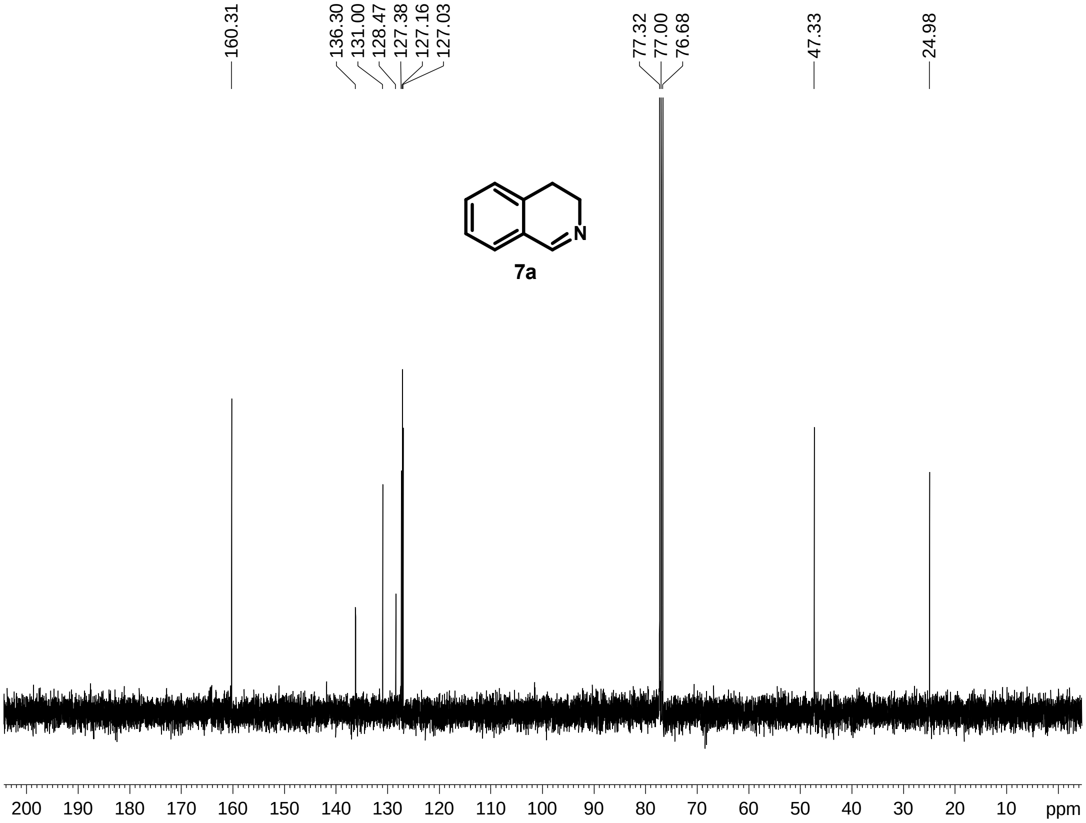
2.159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77.00
76.68
47.33
24.98
N
7a
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150
140
130
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110
100
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80
70
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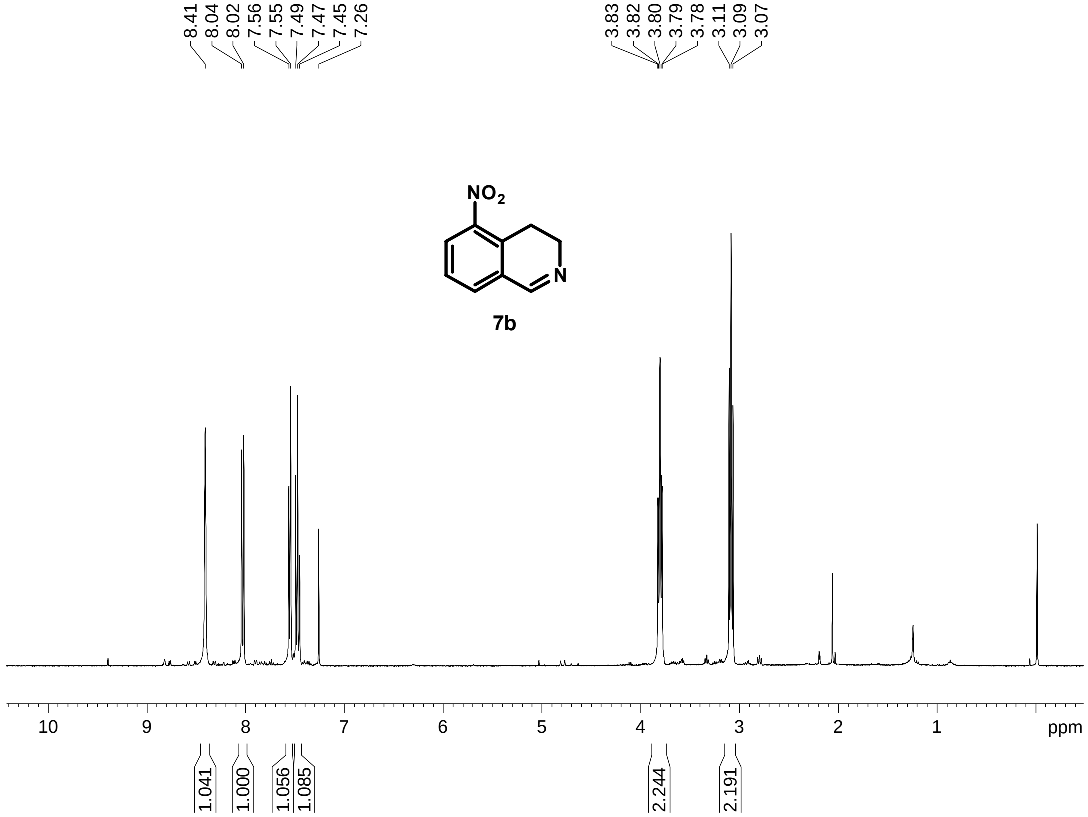
40
30
20
10
ppm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7.45
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3.82
3.80
3.79
3.78
3.11
3.09
3.07
NO2
N
7b
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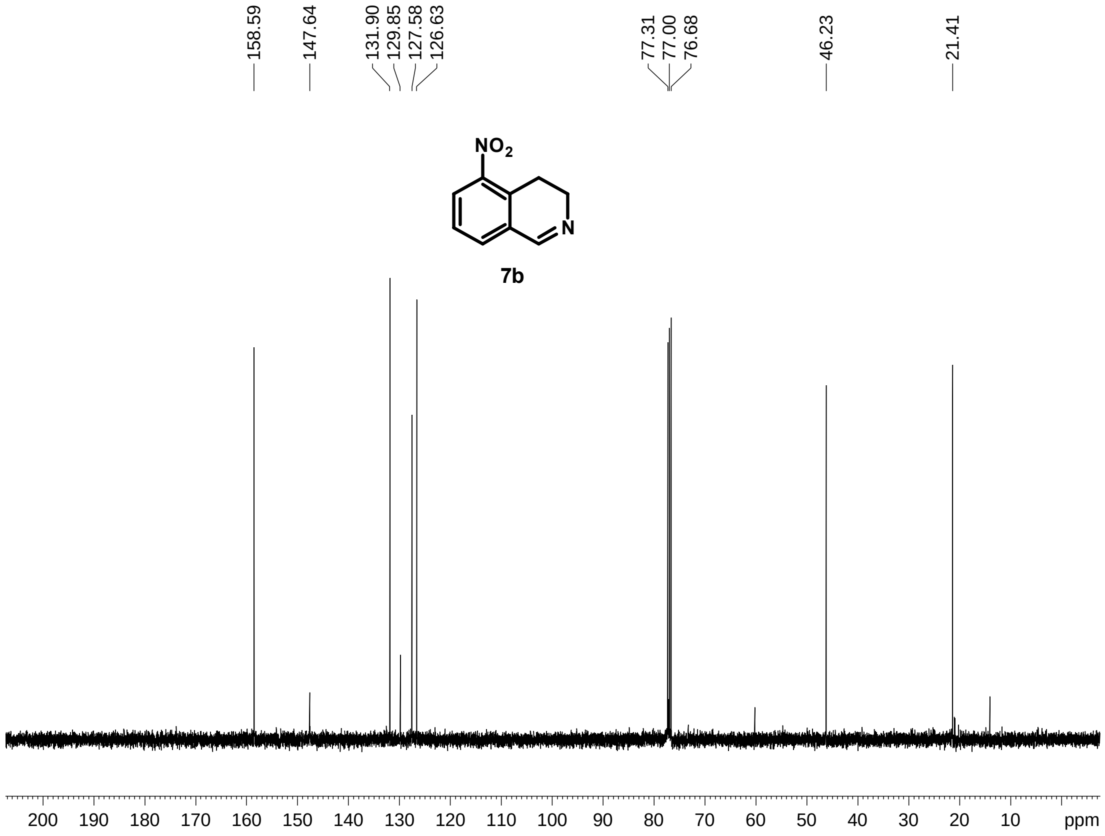
2.191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76.68
46.23
21.41
NO2
N
7b
200
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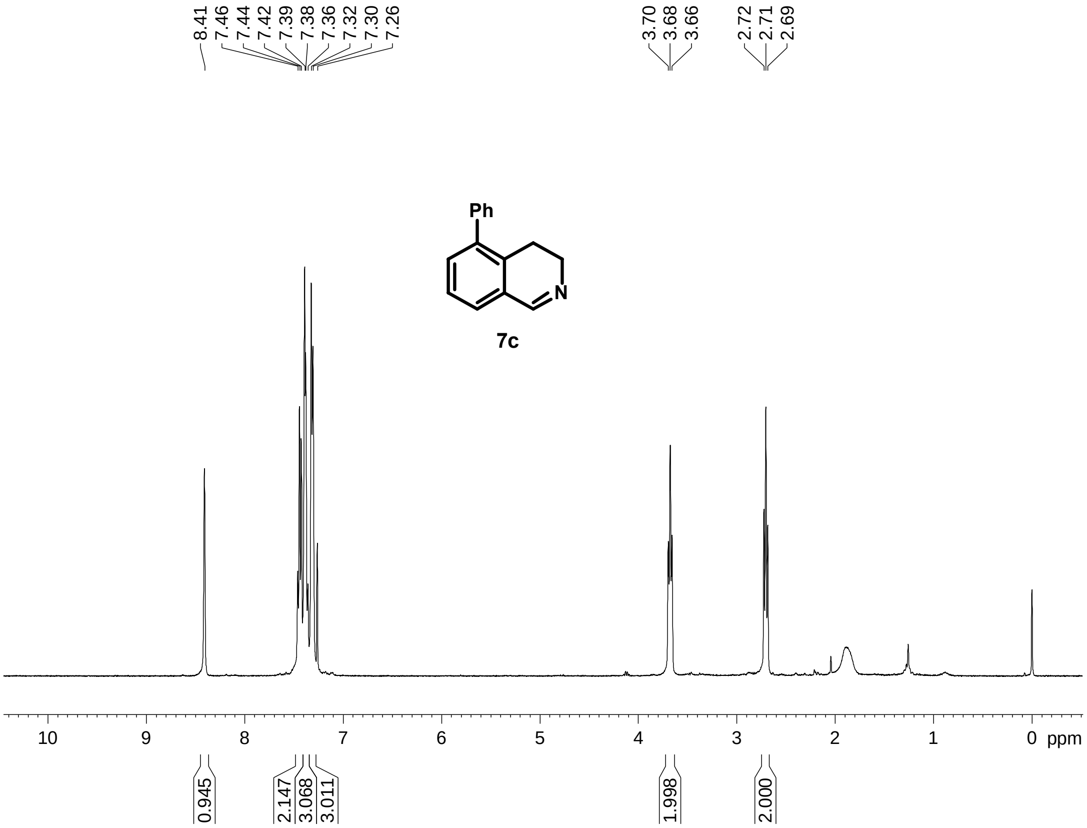
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm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7.30
7.26
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3.68
3.66
2.72
2.71
2.69
Ph
N
7c
10
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4
3
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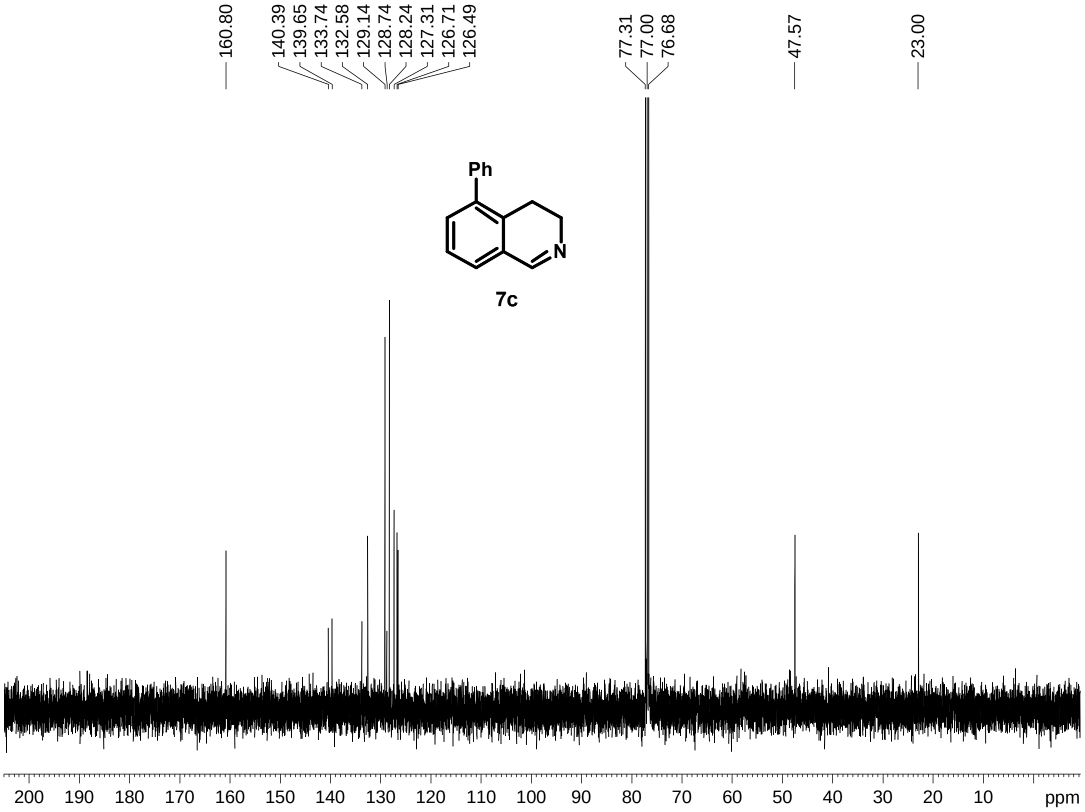
2.000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126.71
126.49
77.31
77.00
76.68
47.57
23.00
Ph
N
7c
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140
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100
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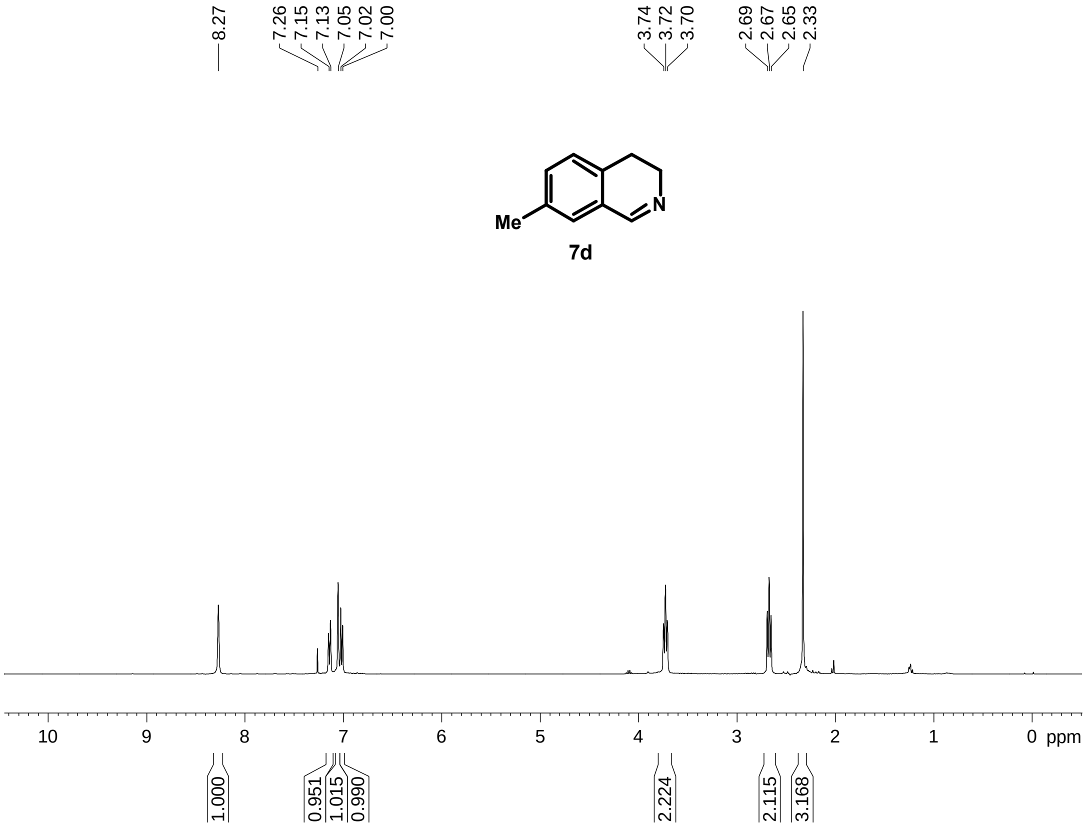
ppm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Me
N
7d
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9
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3
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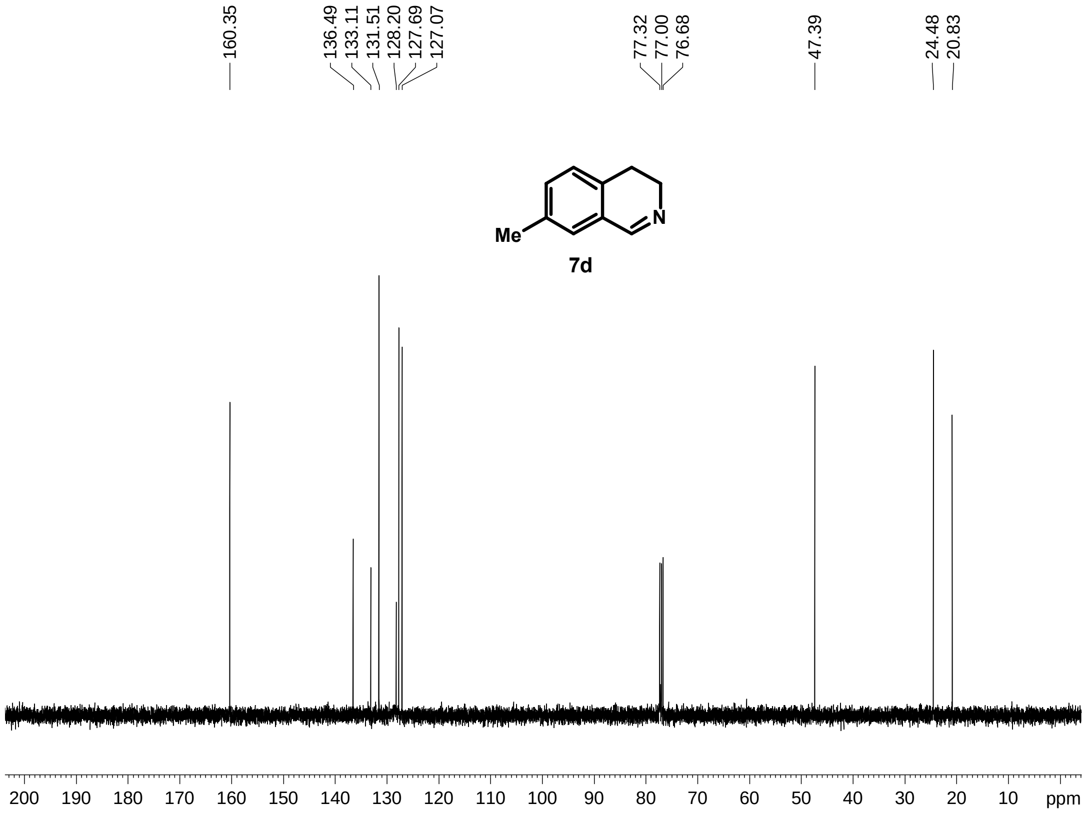
3.168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136.49
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127.07
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77.00
76.68
47.39
24.48
20.83
Me
N
7d
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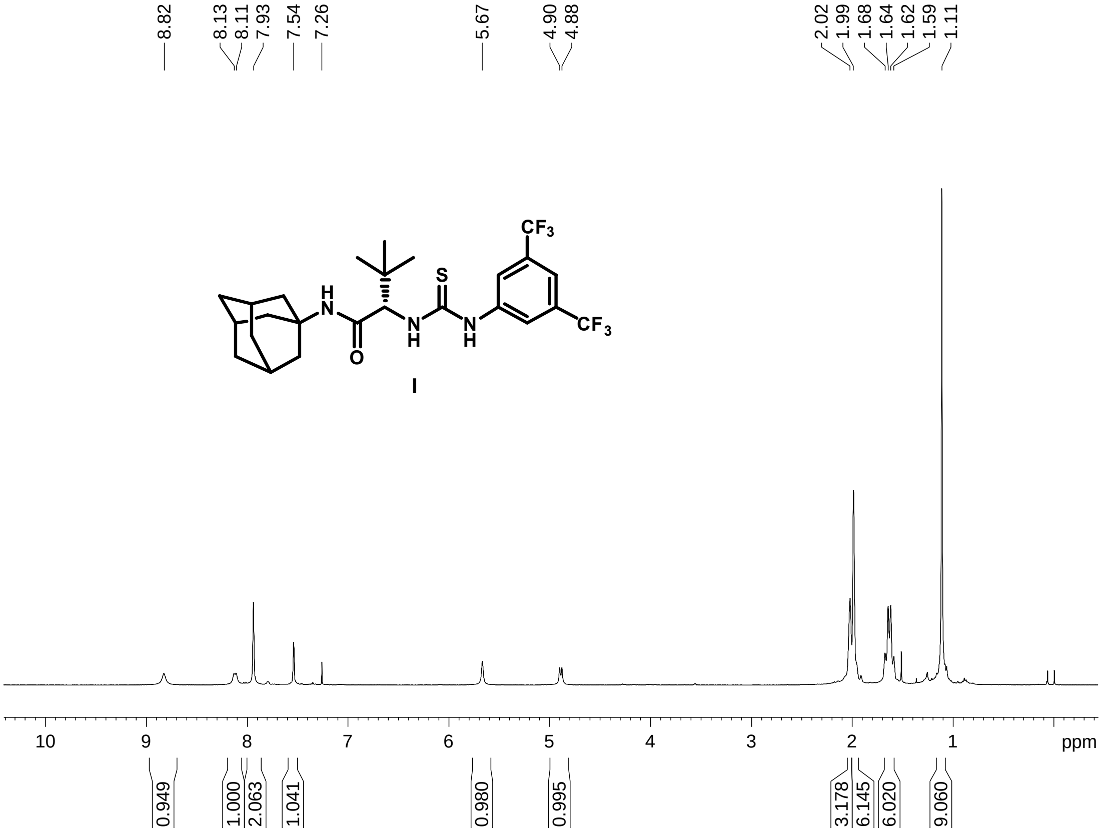
10
ppm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8.13
8.11
7.93
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7.26
5.67
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1.99
1.68
1.64
1.62
1.59
1.11
CF3
CF3
S
H
N
N
H
N
H
O
I
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8
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6
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4
3
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ppm
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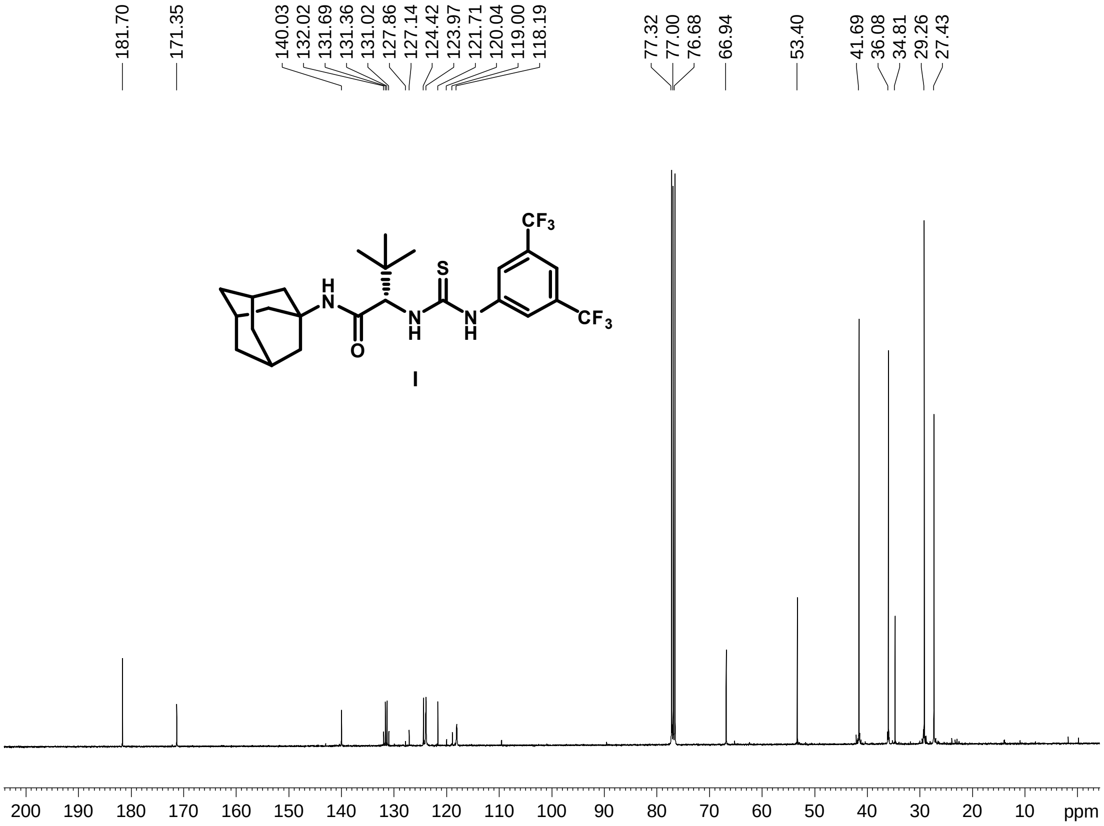
0.980
0.995
3.178
6.145
6.020
9.060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171.35
140.03
132.02
131.69
131.36
131.02
127.86
127.14
124.42
123.97
121.71
120.04
119.00
118.19
77.32
77.00
76.68
66.94
53.40
41.69
36.08
34.81
29.26
27.43
CF3
CF3
S
H
N
N
H
N
H
O
I
200
190
180
170
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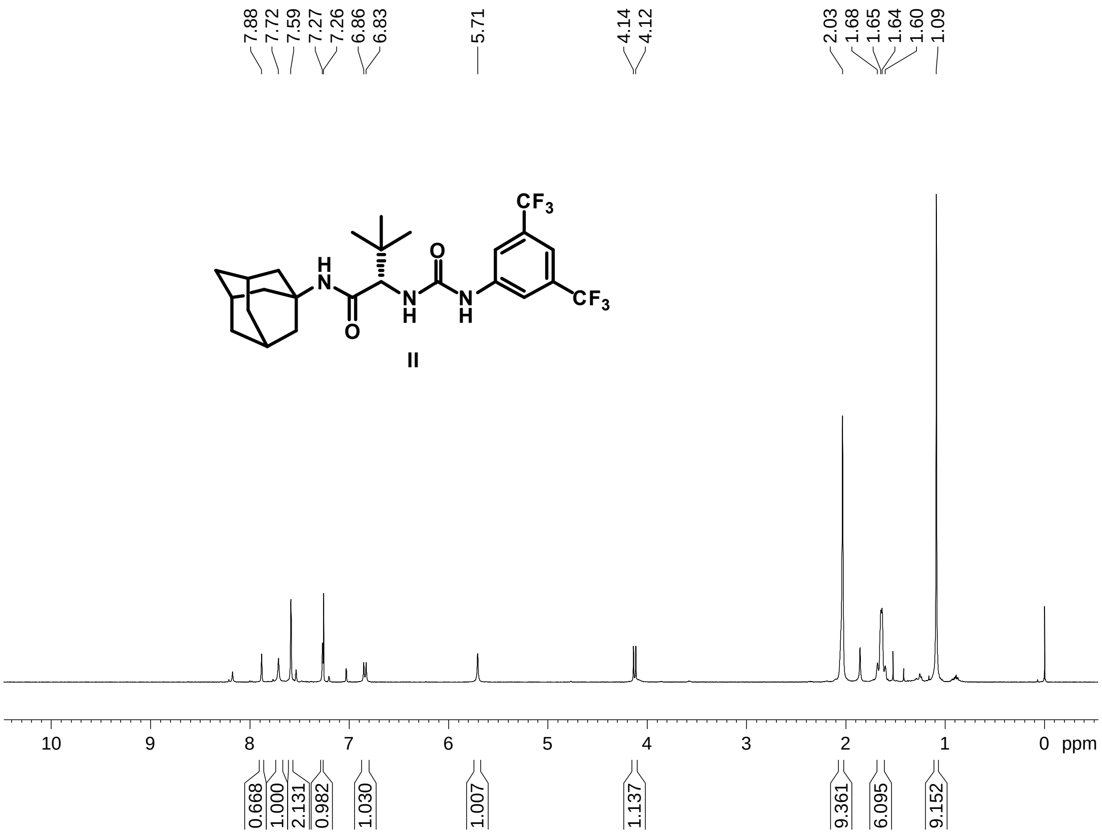
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm


7.88
7.72
7.59
7.27
7.26
6.86
6.83
5.71
4.14
4.12
2.03
1.68
1.65
1.64
1.60
1.09
CF3
CF3
H
N
O
N
H
N
H
O
II
10
9
8
7
6
5
4
3
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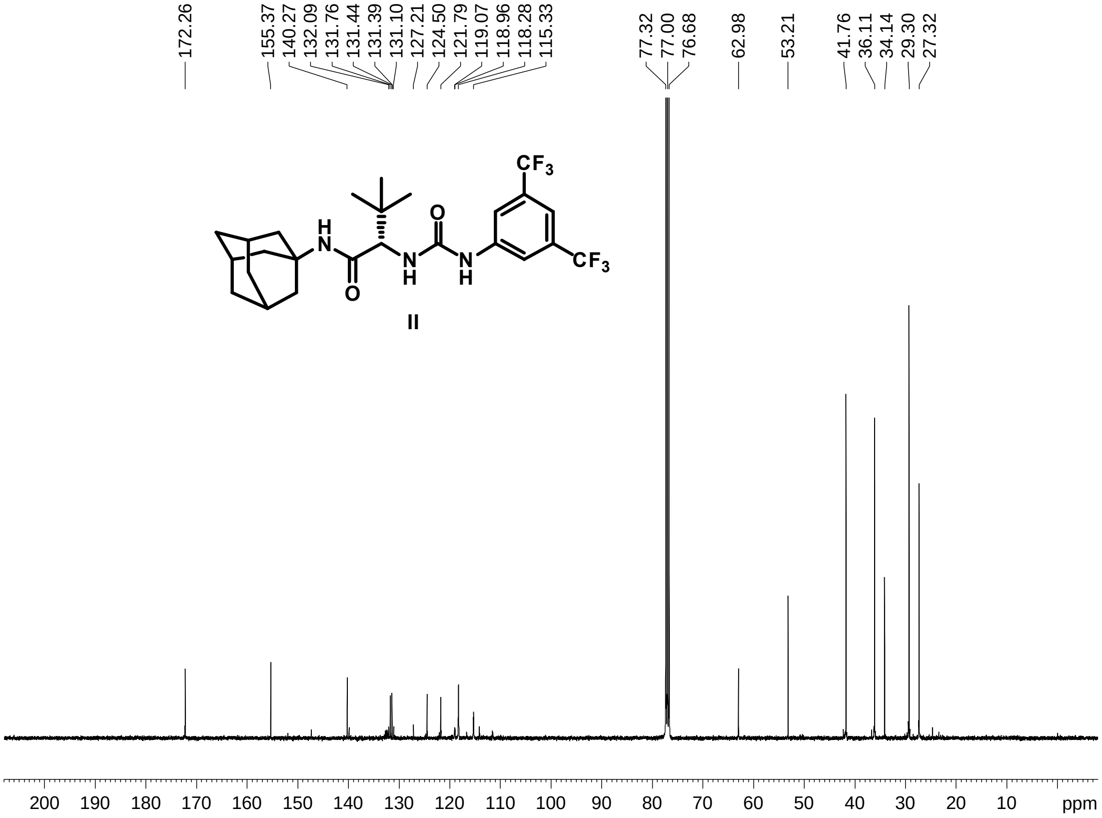
6.095
9.152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124.50
121.79
119.07
118.96
118.28
115.33
77.32
77.00
76.68
62.98
53.21
41.76
36.11
34.14
29.30
27.32
CF3
CF3
H
N
O
N
H
N
H
O
II
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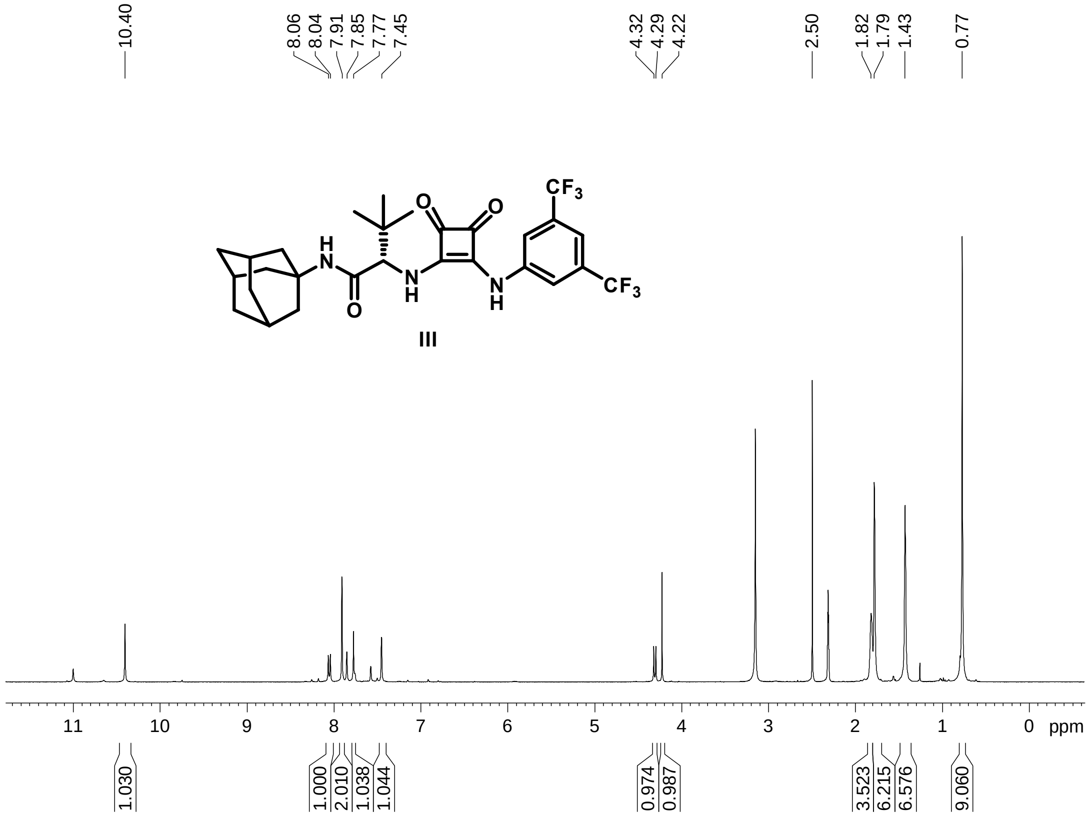
ppm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8.06
8.04
7.91
7.85
7.77
7.45
4.32
4.29
4.22
2.50
1.82
1.79
1.43
0.77
CF3
CF3
O
O
H
N
N
H
N
H
O
III
11
10
9
8
7
6
5
4
3
2
1
0
ppm
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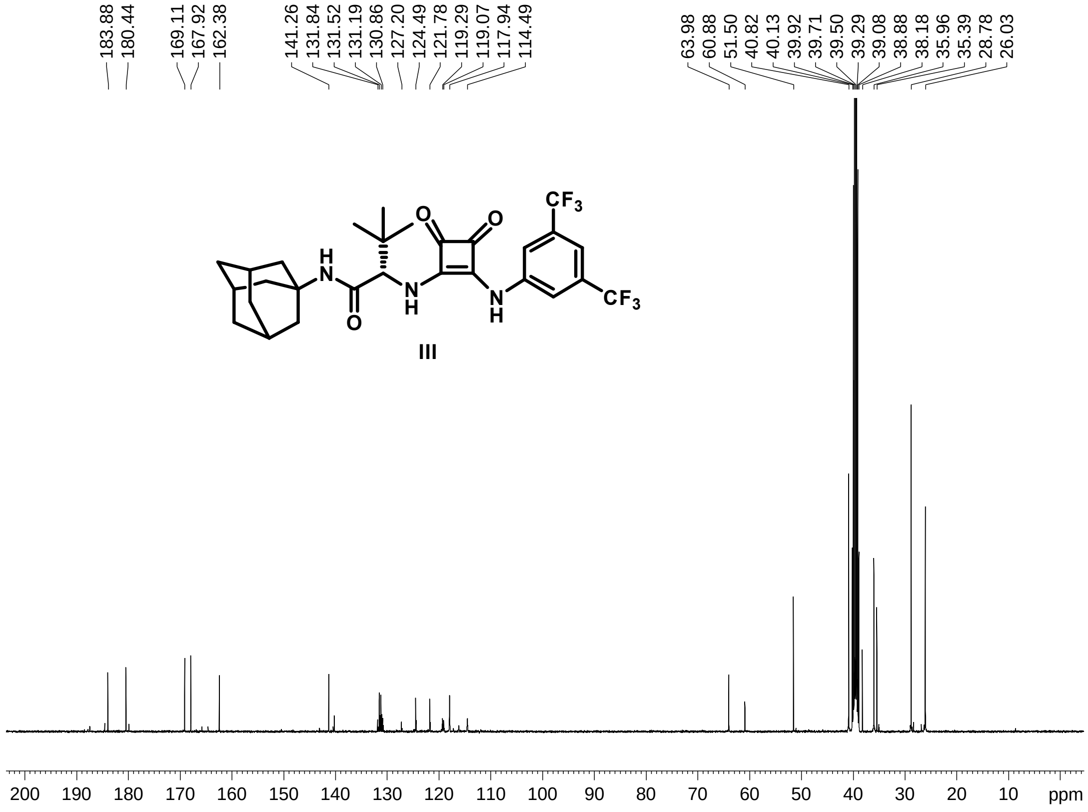
2.010
1.038
1.044
0.974
0.987
3.523
6.215
6.576
9.060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167.92
162.38
141.26
131.84
131.52
131.19
130.86
127.20
124.49
121.78
119.29
119.07
117.94
114.49
63.98
60.88
51.50
40.82
40.13
39.92
39.71
39.50
39.29
39.08
38.88
38.18
35.96
35.39
28.78
26.03
CF3
CF3
O
O
H
N
N
H
N
H
O
III
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180
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160
150
140
130
120
110
100
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80
70
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30
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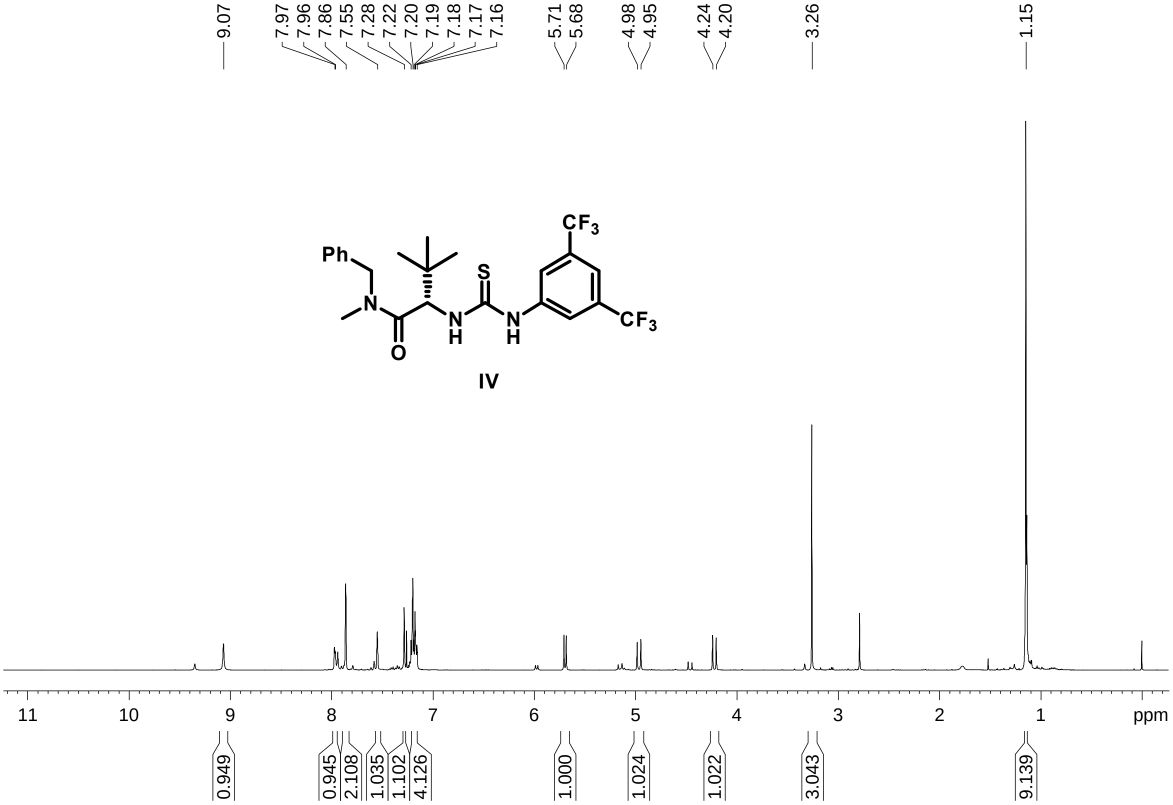
10
ppm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7.96
7.86
7.55
7.28
7.22
7.20
7.19
7.18
7.17
7.16
5.71
5.68
4.98
4.95
4.24
4.20
3.26
1.15
Ph
N
O
H
N
S
H
N
CF3
CF3
IV
11
10
9
8
7
6
5
4
3
2
1
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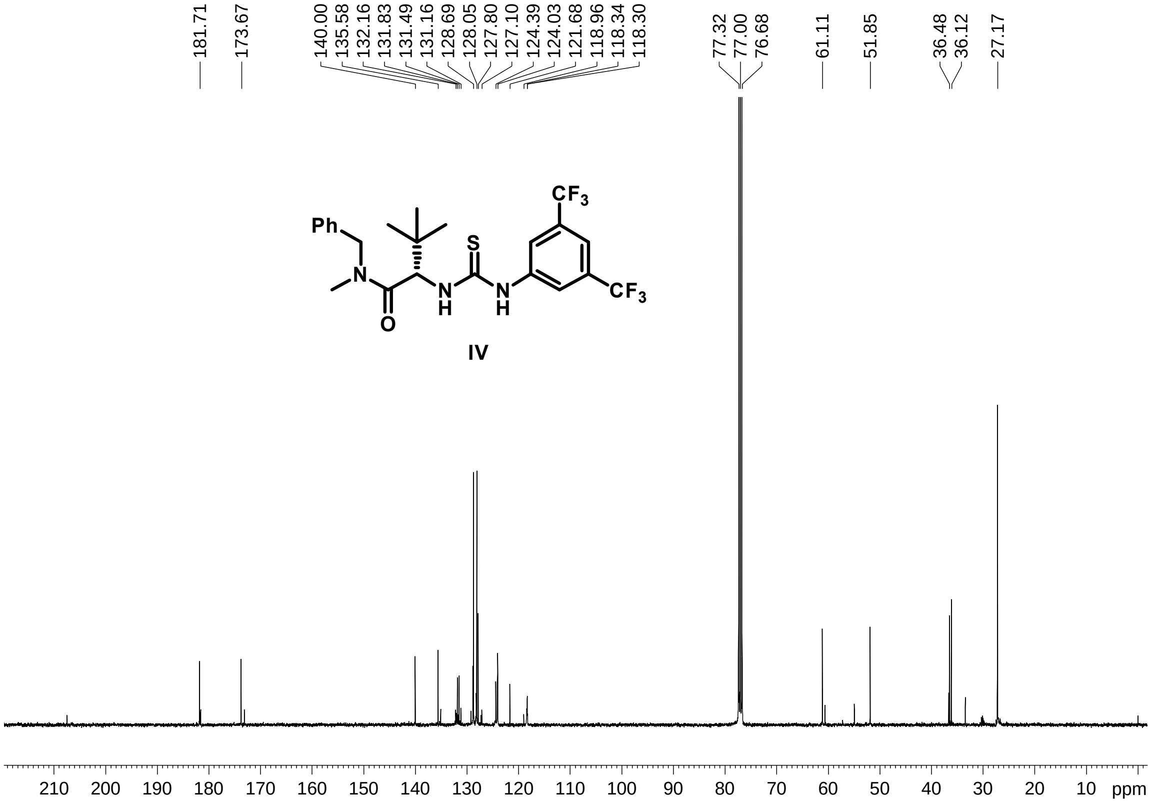
2.108
1.035
1.102
4.126
1.000
1.024
1.022
3.043
9.139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131.83
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131.16
128.69
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127.80
127.10
124.39
124.03
121.68
118.96
118.34
118.30
77.32
77.00
76.68
61.11
51.85
36.48
36.12
27.17
Ph
N
O
H
N
S
H
N
CF3
CF3
IV
210
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180
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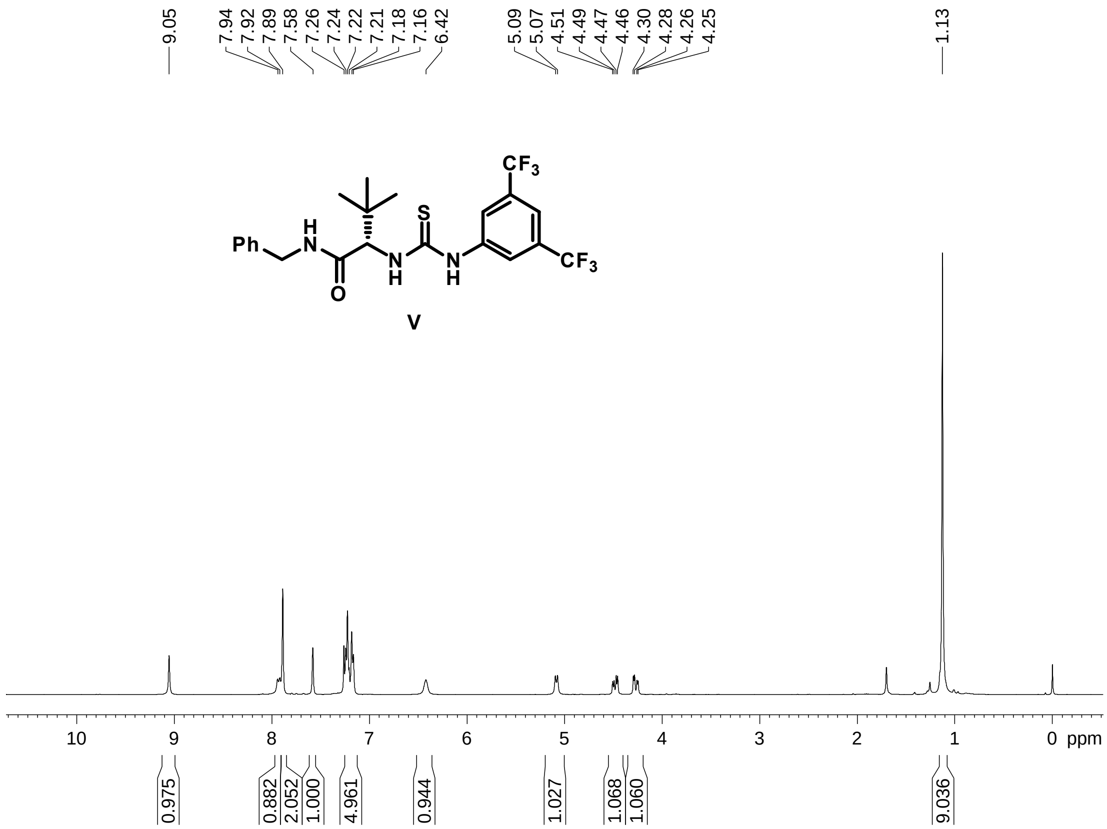
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm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7.92
7.89
7.58
7.26
7.24
7.22
7.21
7.18
7.16
6.42
5.09
5.07
4.51
4.49
4.47
4.46
4.30
4.28
4.26
4.25
1.13
CF3
S
H
Ph
N
N
H
N
H
O
CF3
V
10
9
8
7
6
5
4
3
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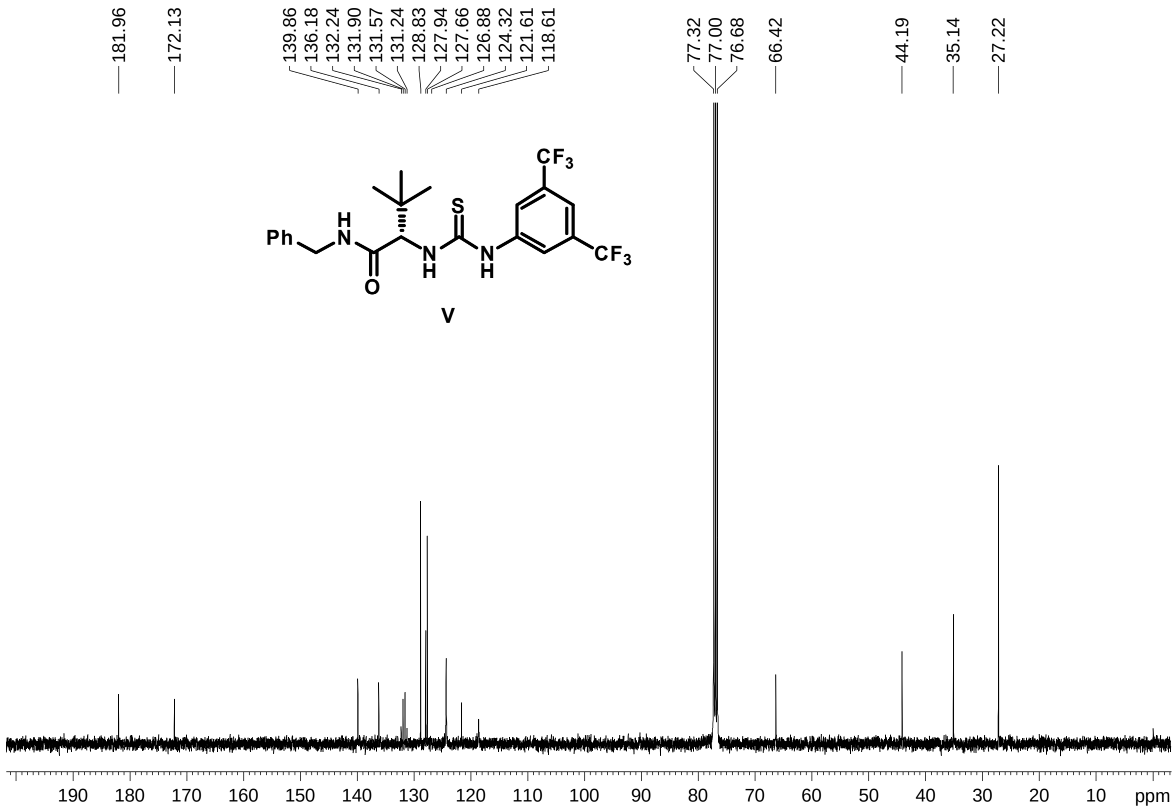
2.052
1.000
4.961
0.944
1.027
1.068
1.060
9.036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172.13
139.86
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132.24
131.90
131.57
131.24
128.83
127.94
127.66
126.88
124.32
121.61
118.61
77.32
77.00
76.68
66.42
44.19
35.14
27.22
CF3
S
H
Ph
N
N
H
N
H
O
CF3
V
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180
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150
140
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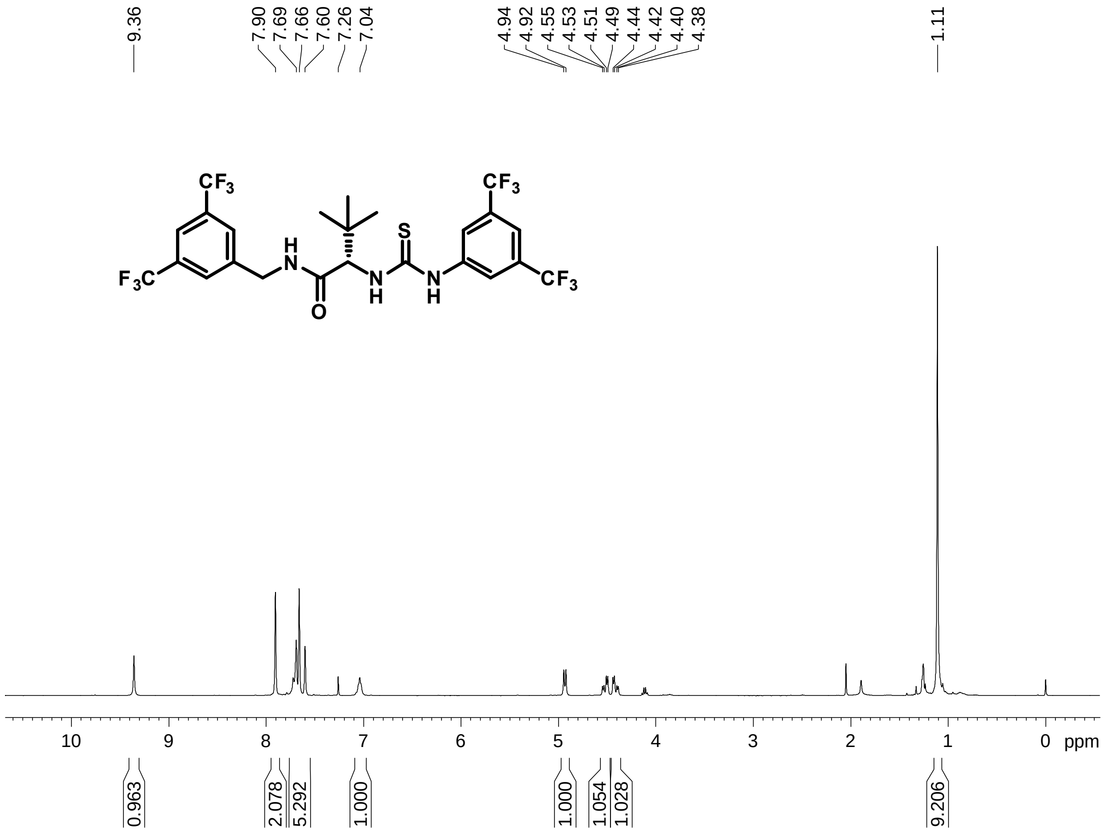
30
20
10
ppm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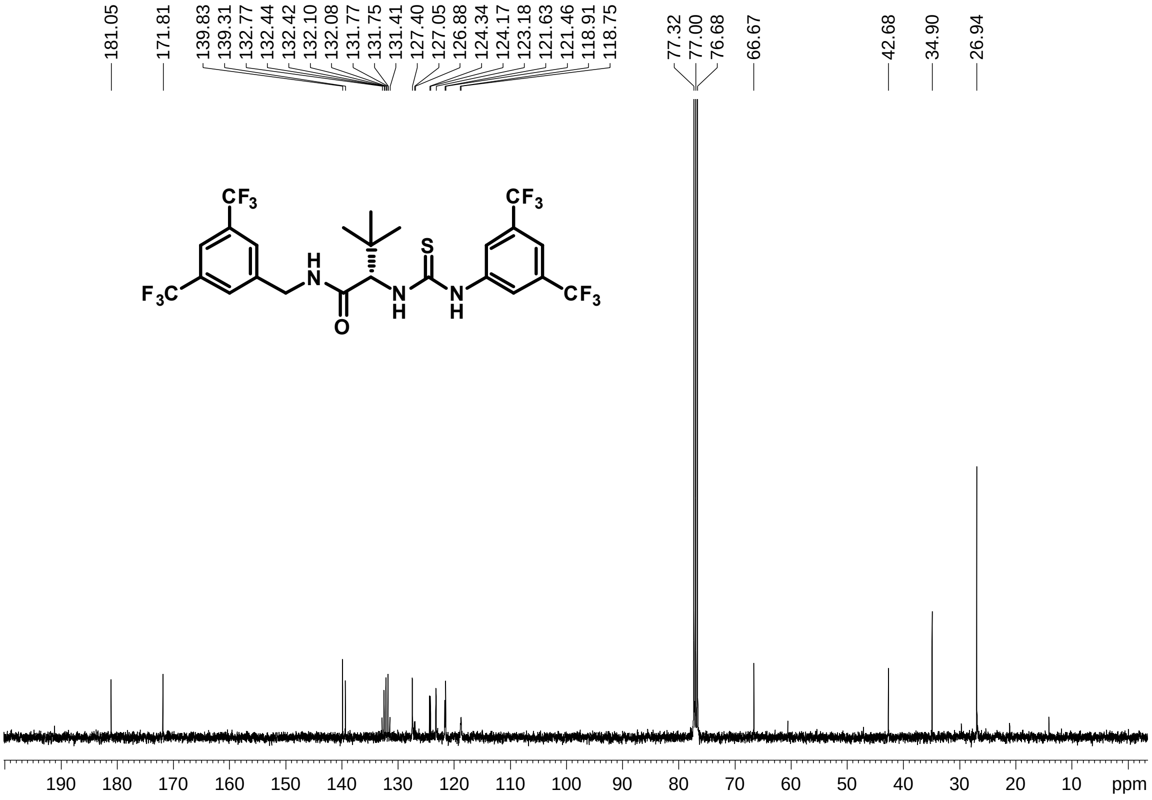
7.04
4.94
4.92
4.55
4.53
4.51
4.49
4.44
4.42
4.40
4.38
1.11
CF3
CF3
F3C
CF3
H
N
O
S
N
H
N
H
0.963
2.078
5.292
1.000
1.000
1.054
1.028
9.206
10
9
8
7
6
5
4
3
2
1
0
ppm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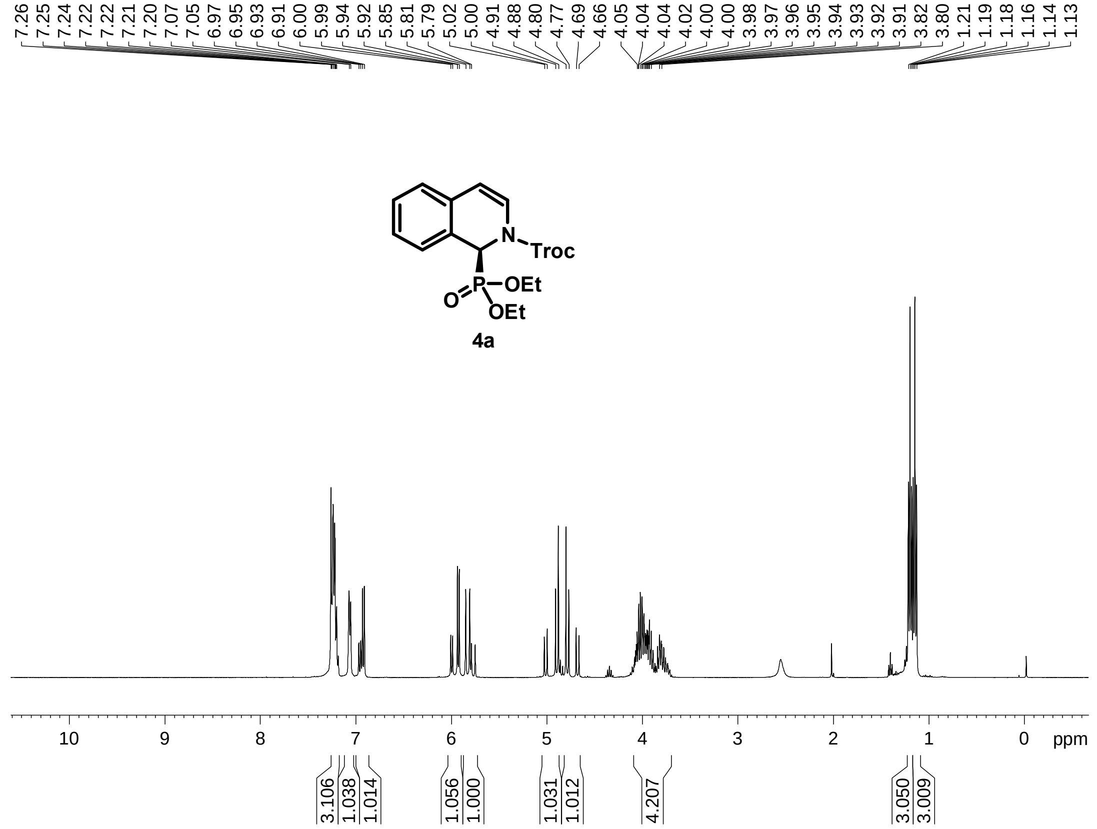
139.83
139.31
132.77
132.44
132.42
132.10
132.08
131.77
131.75
131.41
127.40
127.05
126.88
124.34
124.17
123.18
121.63
121.46
118.91
118.75
77.32
77.00
76.68
66.67
42.68
34.90
26.94
CF3
CF3
F3C
CF3
H
N
O
S
N
H
N
H
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm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7.25
7.24
7.22
7.22
7.21
7.20
7.07
7.05
6.97
6.95
6.93
6.91
6.00
5.99
5.94
5.92
5.85
5.81
5.79
5.02
5.00
4.91
4.88
4.80
4.77
4.69
4.66
4.05
4.04
4.04
4.02
4.00
4.00
3.98
3.97
3.96
3.95
3.94
3.93
3.92
3.91
3.82
3.80
1.21
1.19
1.18
1.16
1.14
1.13
N
Troc
P
O
OEt
OEt
4a
10
9
8
7
6
5
4
3
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0
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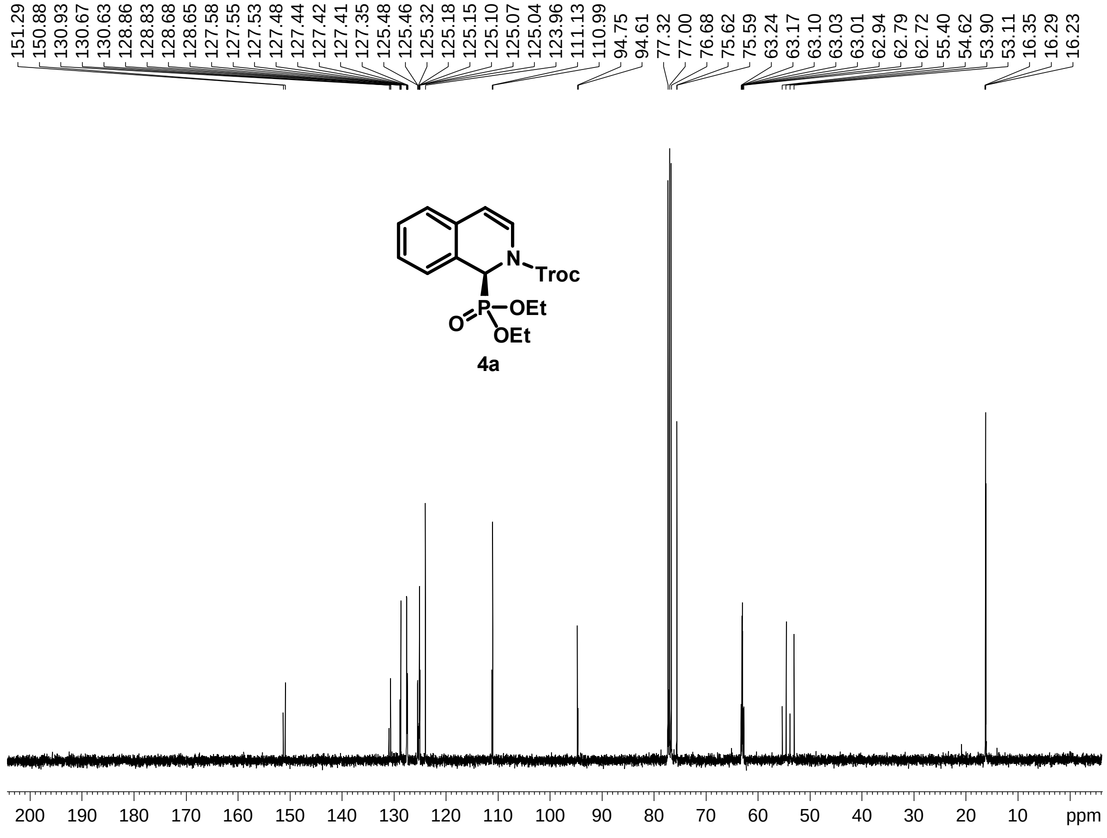
1.038
1.014
1.056
1.000
1.031
1.012
4.207
3.050
3.009


151.29
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130.63
128.86
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128.68
128.65
127.58
127.55
127.53
127.48
127.44
127.42
127.41
127.35
125.48
125.46
125.32
125.18
125.15
125.10
125.07
125.04
123.96
111.13
110.99
94.75
94.61
77.32
77.00
76.68
75.62
75.59
63.24
63.17
63.10
63.03
63.01
62.94
62.79
62.72
55.40
54.62
53.90
53.11
16.35
16.29
16.23
N
Troc
P
O
OEt
OEt
4a
200
190
180
170
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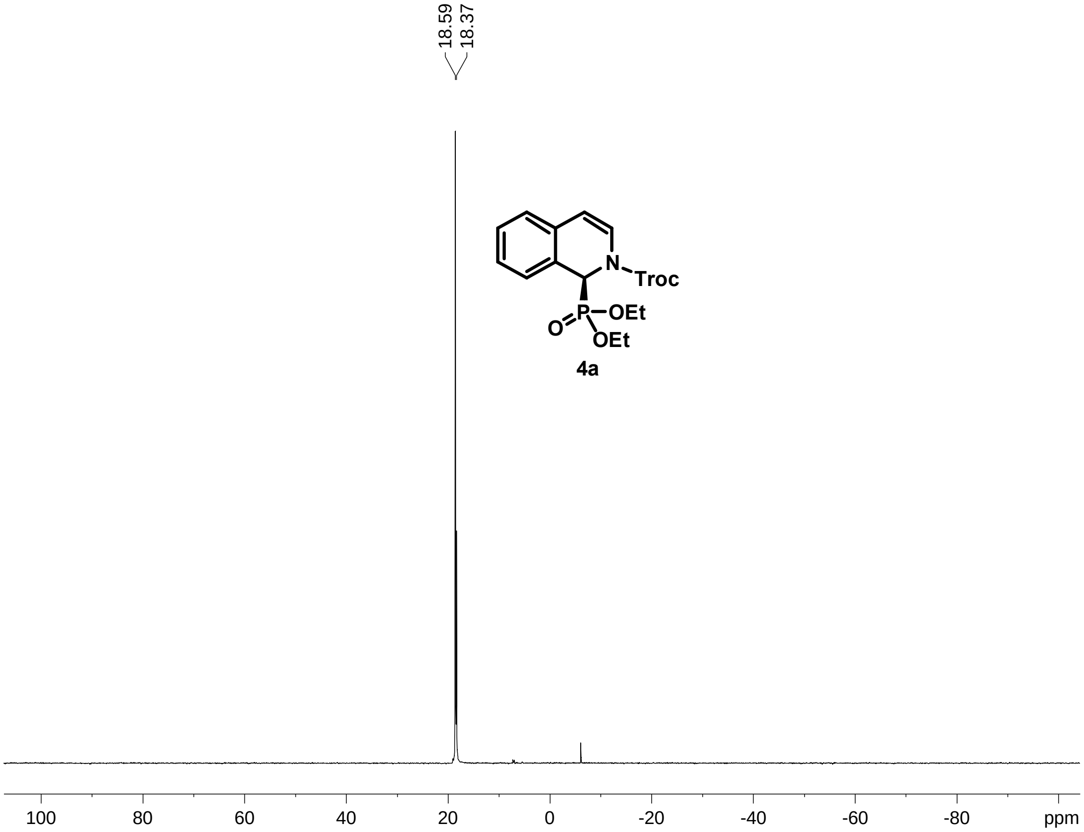
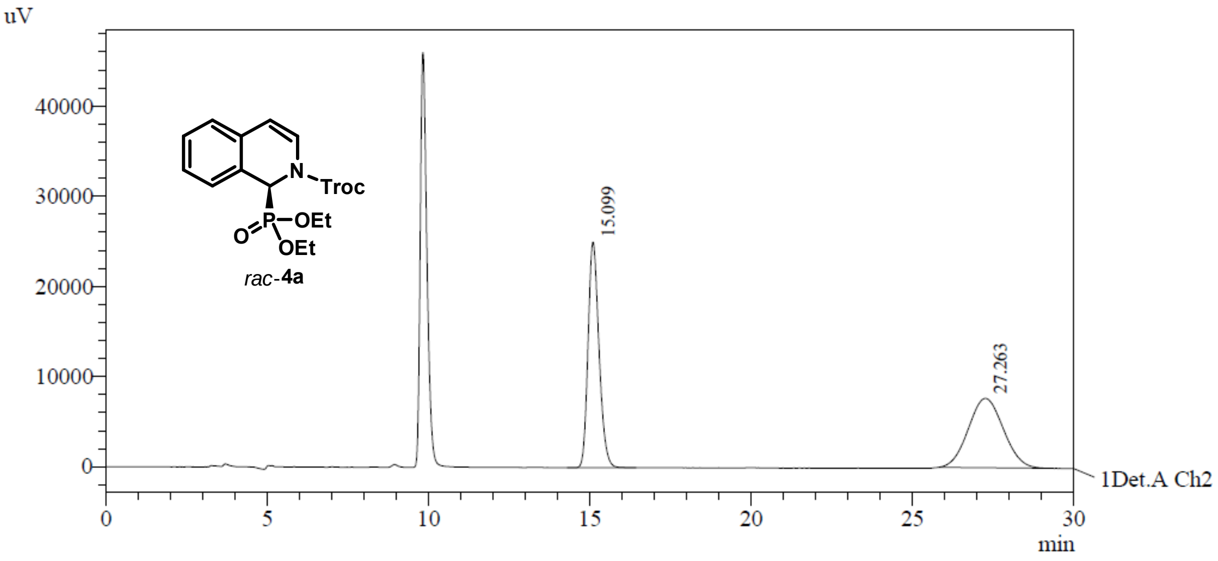
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm



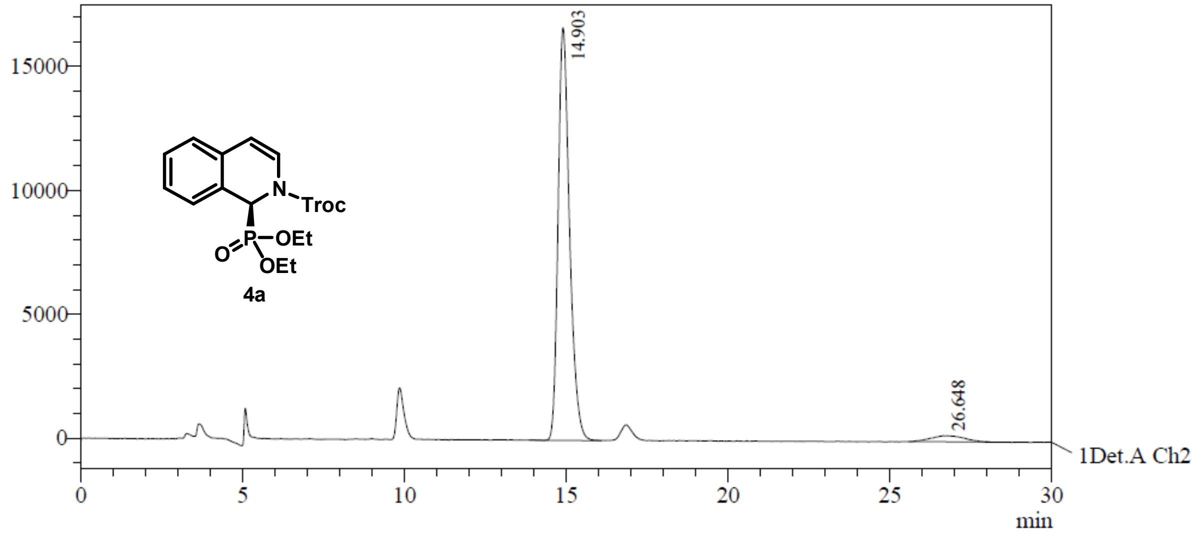
4a



PeakTable

Detector A Ch2 254nm

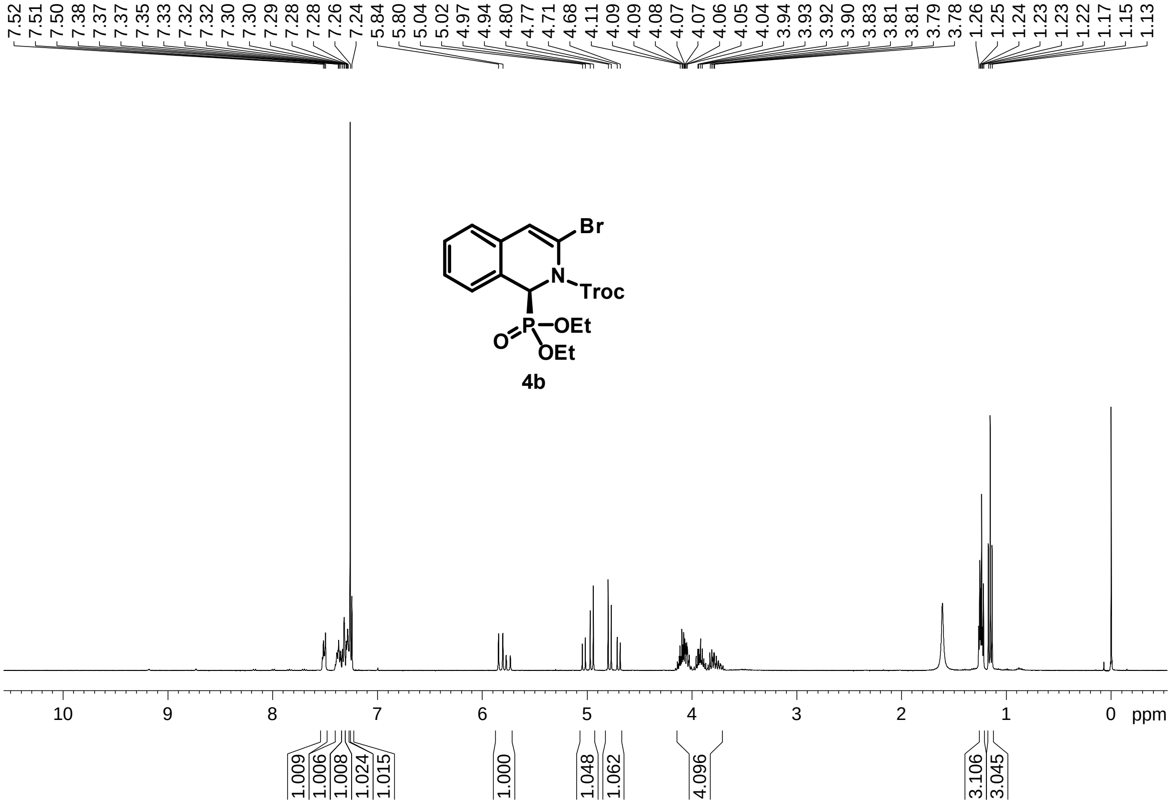
Peak#	Ret. Time	Area	Area %
1	15.099	590024	50.411
2	27.263	580394	49.589
Total		1170418	100.000



PeakTable

Detector A Ch2 254nm

Peak#	Ret. Time	Area	Area %
1	14.903	411042	95.953
2	26.648	17337	4.047
Total		428379	100.000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7.51
7.50
7.38
7.37
7.37
7.35
7.33
7.32
7.32
7.30
7.30
7.29
7.28
7.28
7.26
7.24
5.84
5.80
5.04
5.02
4.97
4.94
4.80
4.77
4.71
4.68
4.11
4.09
4.09
4.08
4.07
4.07
4.06
4.05
4.04
3.94
3.93
3.92
3.90
3.83
3.81
3.81
3.79
3.78
1.26
1.25
1.24
1.23
1.23
1.22
1.17
1.15
1.13
Br
N
Troc
O
P
OEt
OEt
4b
10
9
8
7
6
5
4
3
2
1
0
ppm
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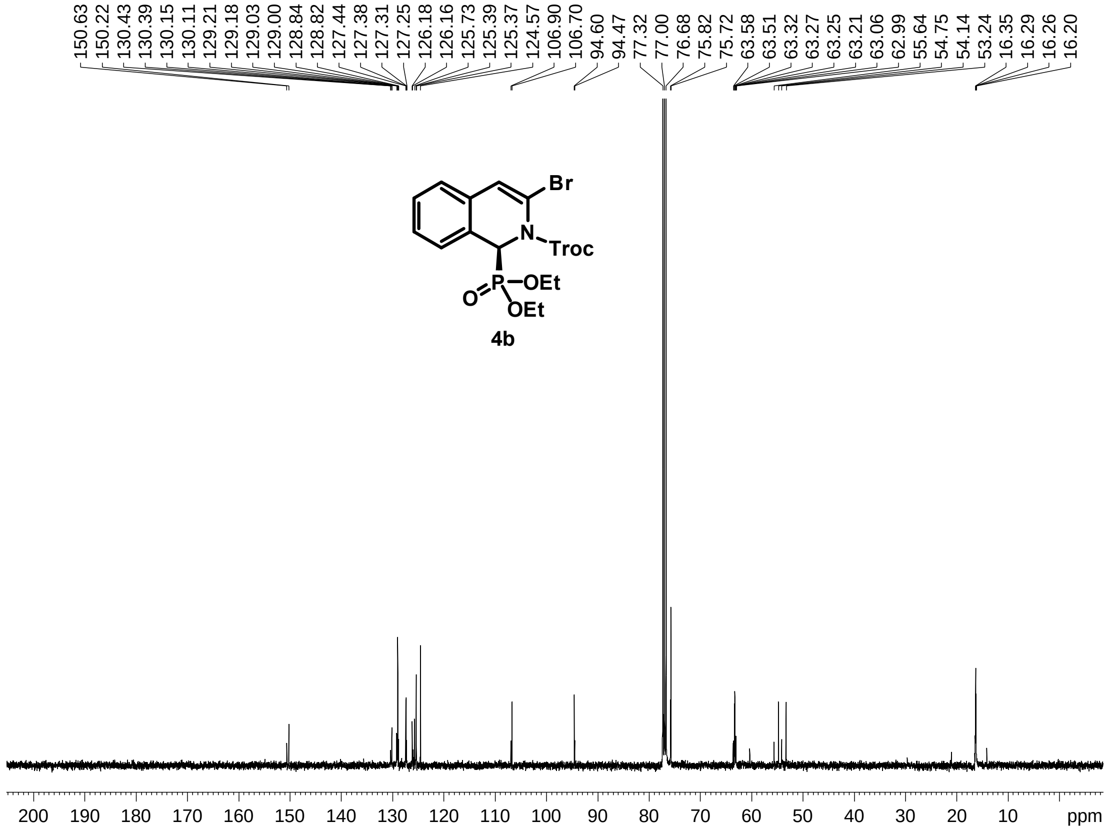
1.006
1.008
1.024
1.015
1.000
1.048
1.062
4.096
3.106
3.045


150.63
150.22
130.43
130.39
130.15
130.11
129.21
129.18
129.03
129.00
128.84
128.82
127.44
127.38
127.31
127.25
126.18
126.16
125.73
125.39
125.37
124.57
106.90
106.70
94.60
94.47
77.32
77.00
76.68
75.82
75.72
63.58
63.51
63.32
63.27
63.25
63.21
63.06
62.99
55.64
54.75
54.14
53.24
16.35
16.29
16.26
16.20
Br
N
Troc
O
P
OEt
OEt
4b
200
190
180
170
160
150
140
130
120
110
100
90
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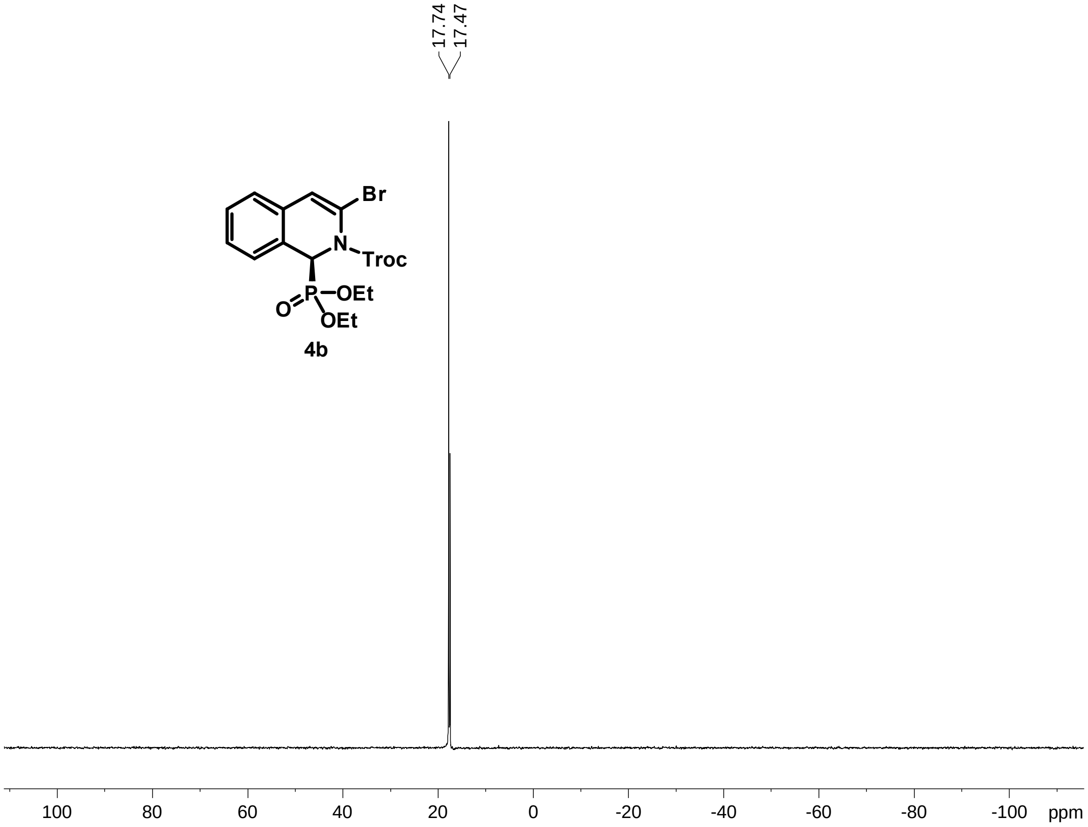
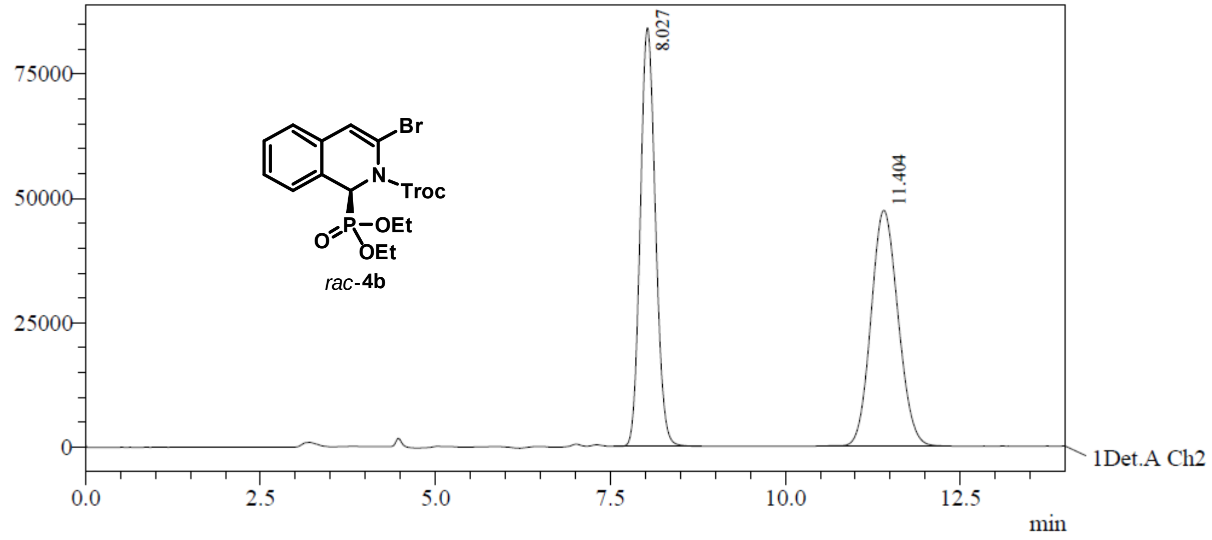
50
40
30
20
10
ppm



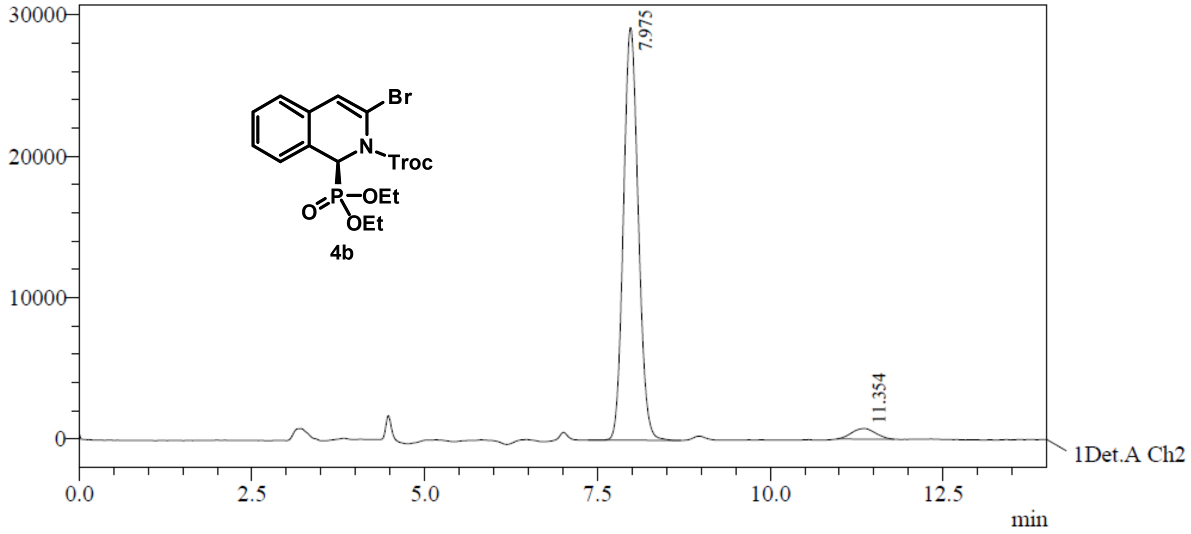
4b



PeakTable

Detector A Ch2 254nm

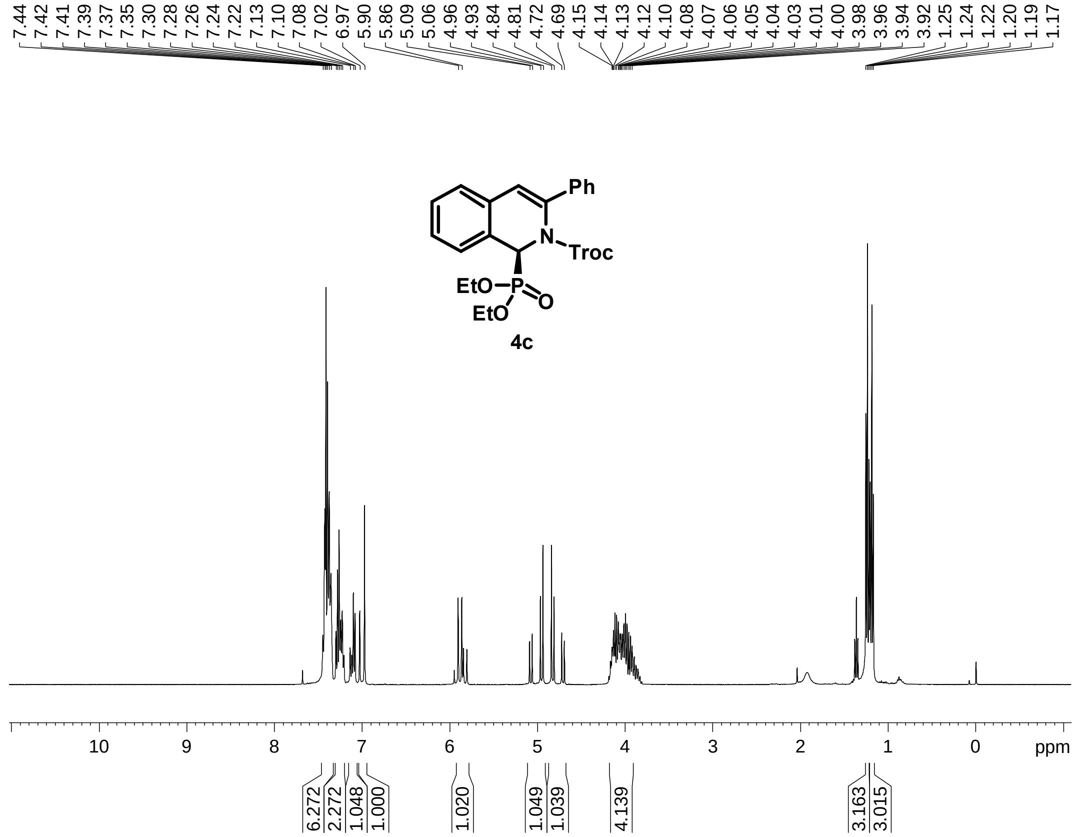
Peak#	Ret. Time	Area	Area %
1	8.027	1271264	49.932
2	11.404	1274708	50.068
Total		2545972	100.000



PeakTable

Detector A Ch2 254nm

Peak#	Ret. Time	Area	Area %
1	7.975	435546	95.975
2	11.354	18264	4.025
Total		453810	100.000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7.39
7.37
7.35
7.30
7.28
7.26
7.24
7.22
7.13
7.10
7.08
7.02
6.97
5.90
5.86
5.09
5.06
4.96
4.93
4.84
4.81
4.72
4.69
4.15
4.14
4.13
4.12
4.10
4.08
4.07
4.06
4.05
4.04
4.03
4.01
4.00
3.98
3.96
3.94
3.92
1.25
1.24
1.22
1.20
1.19
1.17
Ph
N
Troc
EtO
P
O
EtO
4c
10
9
8
7
6
5
4
3
2
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0
ppm
6.272
2.272
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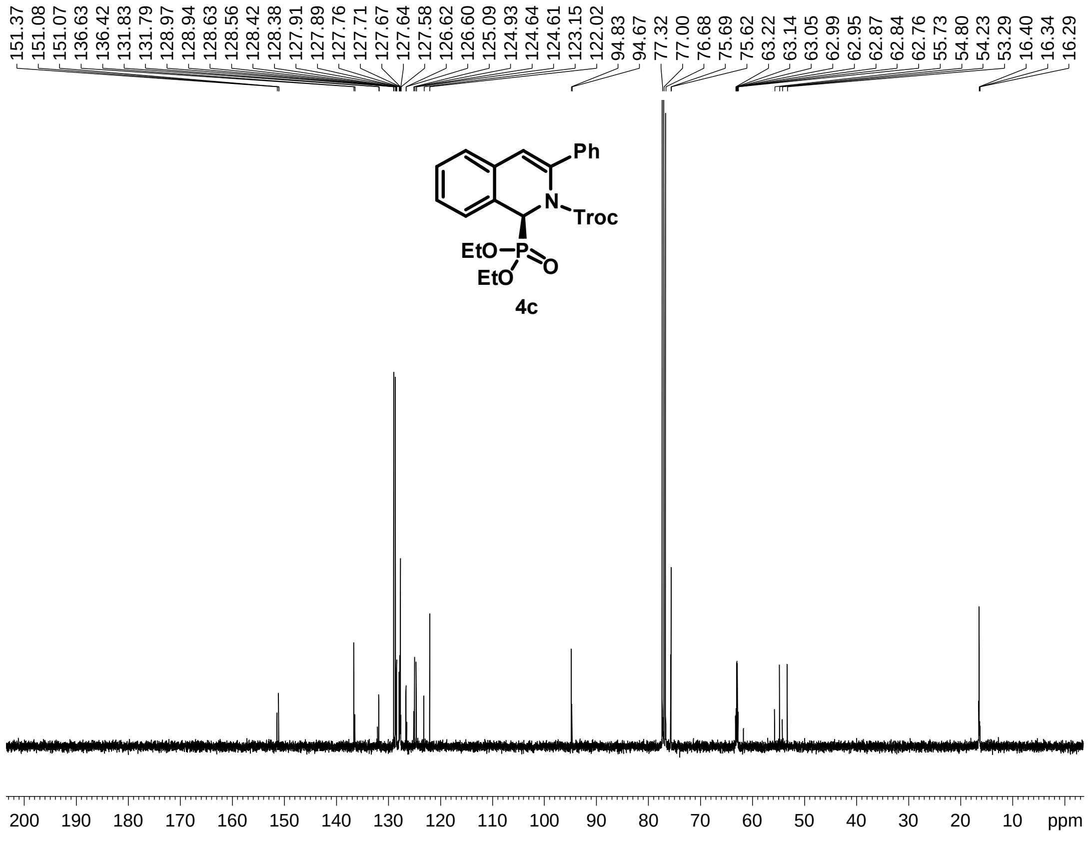
1.000
1.020
1.049
1.039
4.139
3.163
3.015


151.37
151.08
151.07
136.63
136.42
131.83
131.79
128.97
128.94
128.63
128.56
128.42
128.38
127.91
127.89
127.76
127.71
127.67
127.64
127.58
126.62
126.60
125.09
124.93
124.64
124.61
123.15
122.02
94.83
94.67
77.32
77.00
76.68
75.69
75.62
63.22
63.14
63.05
62.99
62.95
62.87
62.84
62.76
55.73
54.80
54.23
53.29
16.40
16.34
16.29
Ph
N
Troc
EtO
P
O
EtO
4c
200
190
180
170
160
150
140
130
120
110
100
90
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70
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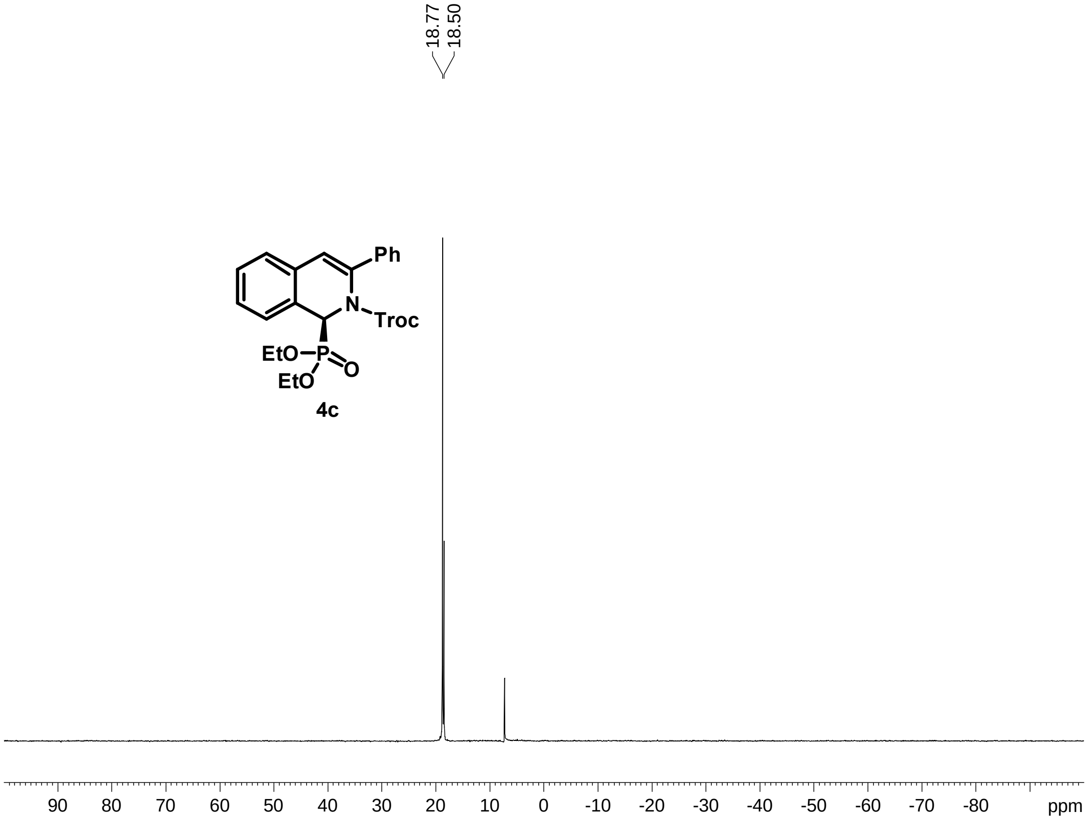
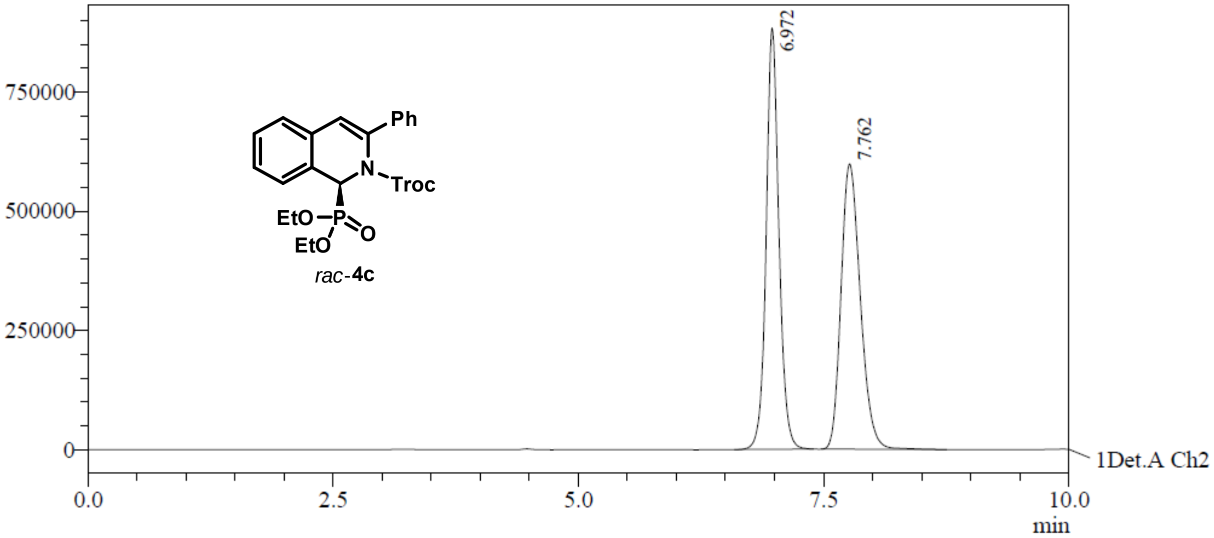
50
40
30
20
10
ppm

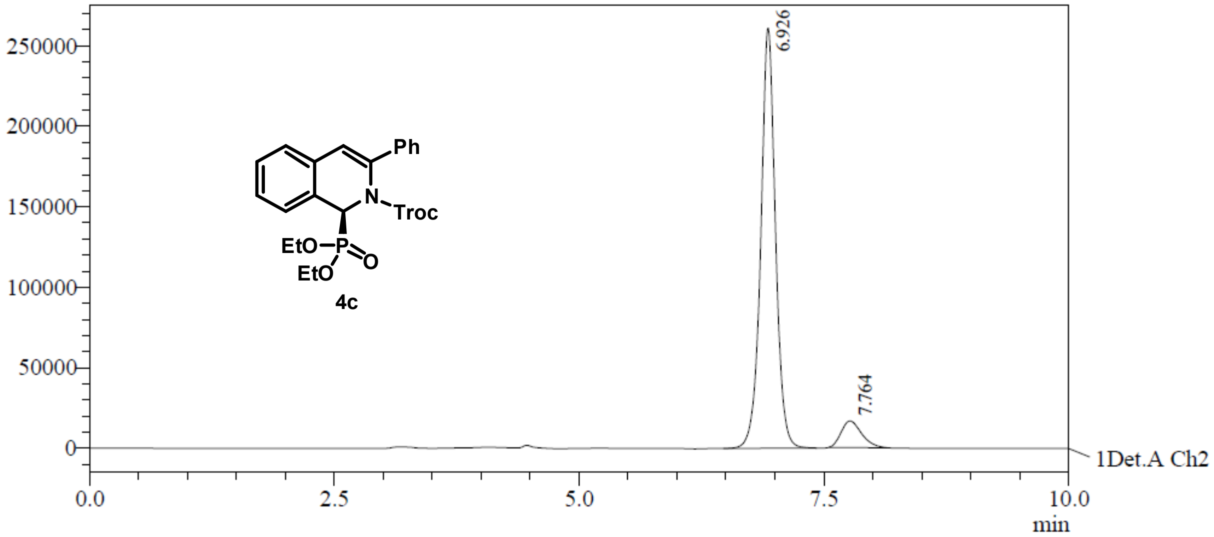

18.77
18.50
Ph
N
Troc
EtO
P
O
EtO
4c
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
ppm



PeakTable

Detector A Ch2 254nm

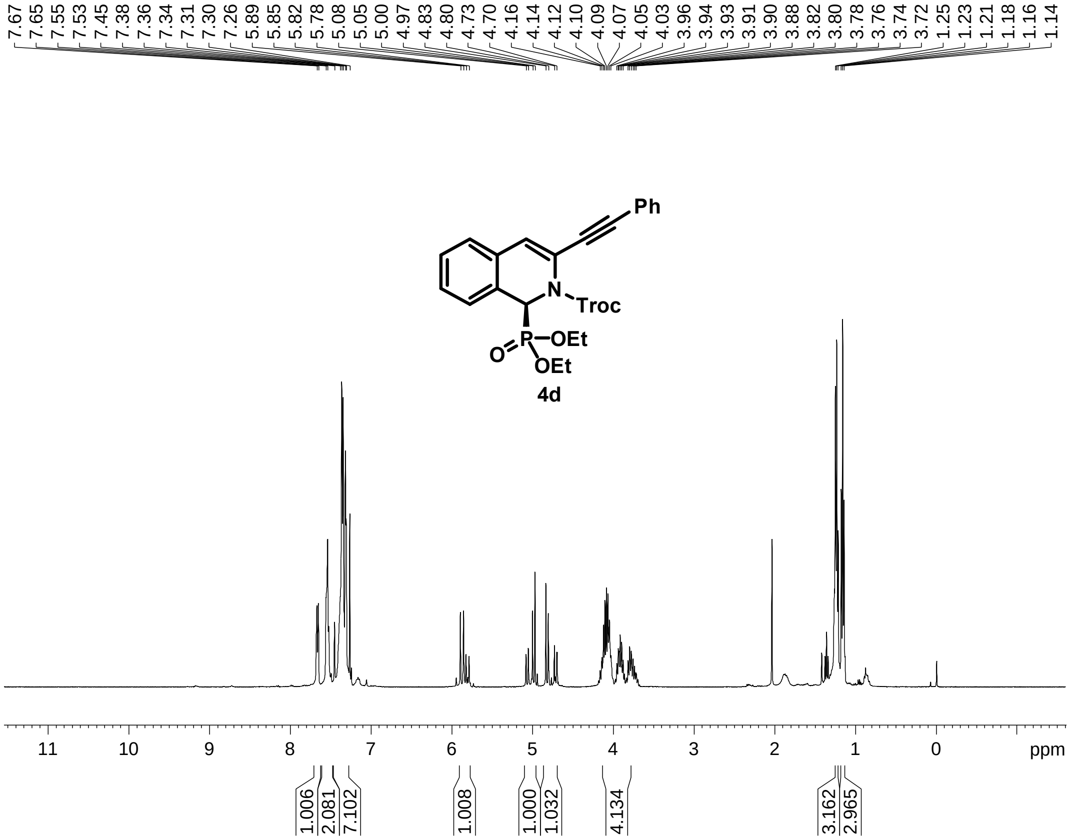
Peak#	Ret. Time	Area	Area %
1	6.972	8023936	49.499
2	7.762	8186288	50.501
Total		16210224	100.000



PeakTable

Detector A Ch2 254nm

Peak#	Ret. Time	Area	Area %
1	6.926	2728684	91.893
2	7.764	240727	8.107
Total		2969410	100.000


7.67
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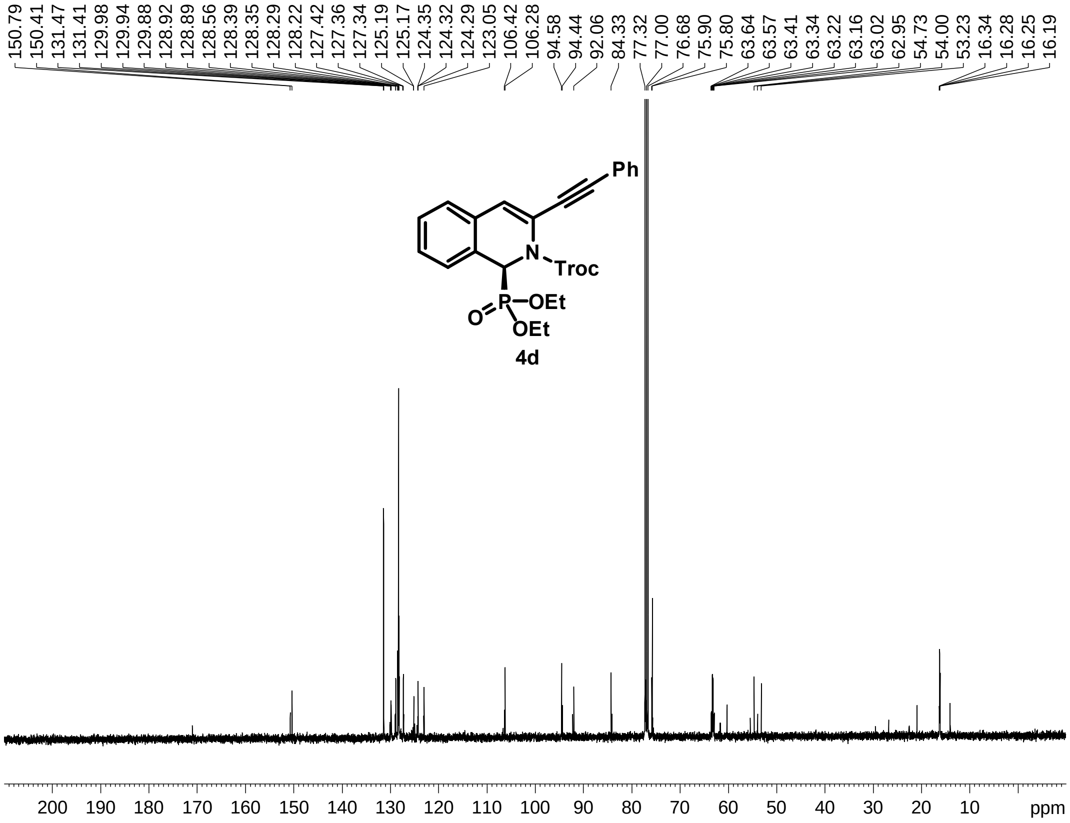
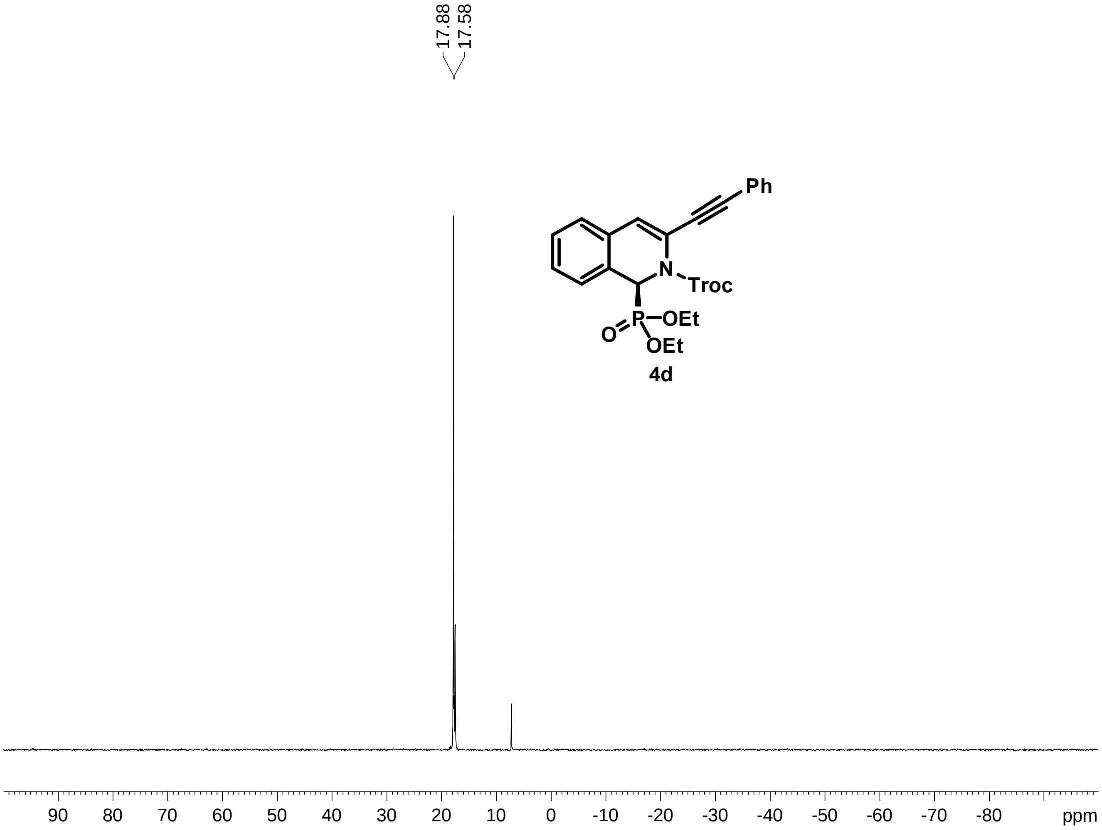
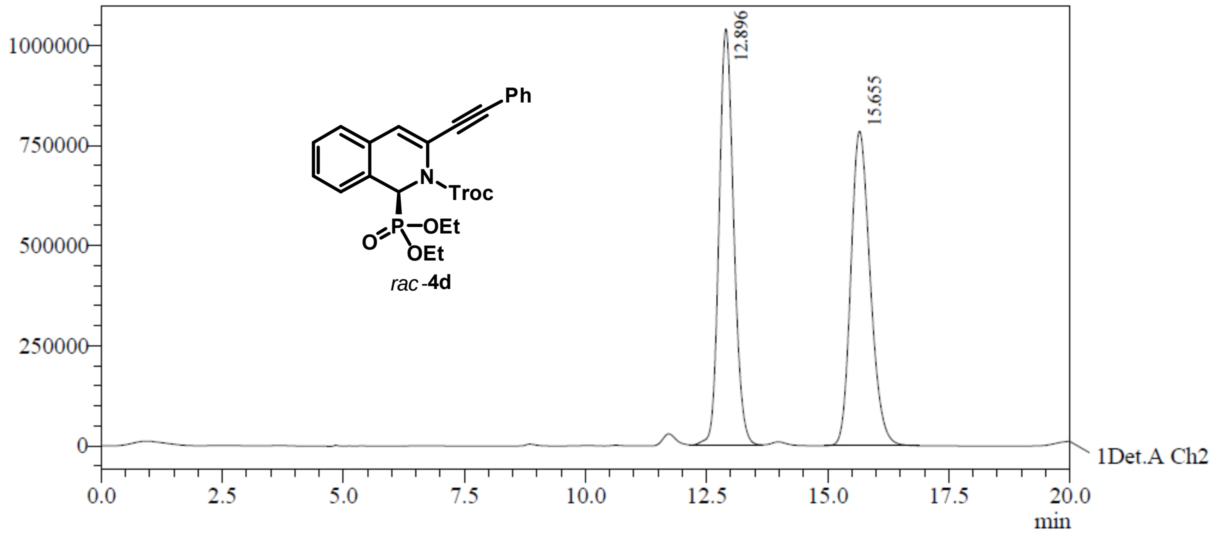
7.53
7.45
7.38
7.36
7.34
7.31
7.30
7.26
5.89
5.85
5.82
5.78
5.08
5.05
5.00
4.97
4.83
4.80
4.73
4.70
4.16
4.14
4.12
4.10
4.09
4.07
4.05
4.03
3.96
3.94
3.93
3.91
3.90
3.88
3.82
3.80
3.78
3.76
3.74
3.72
1.25
1.23
1.21
1.18
1.16
1.14
Ph
N
Troc
P
OEt
O
OEt
4d
11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.006
2.081
7.102
1.008
1.000
1.032
4.134
3.162
2.965


150.79
150.41
131.47
131.41
129.98
129.94
129.88
128.92
128.89
128.56
128.39
128.35
128.29
128.22
127.42
127.36
127.34
125.19
125.17
124.35
124.32
124.29
123.05
106.42
106.28
94.58
94.44
92.06
84.33
77.32
77.00
76.68
75.90
75.80
63.64
63.57
63.41
63.34
63.22
63.16
63.02
62.95
54.73
54.00
53.23
16.34
16.28
16.25
16.19
Ph
N
Troc
P
OEt
O
OEt
4d
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm


17.88
17.58
Ph
N
Troc
P
OEt
O
OEt
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
ppm

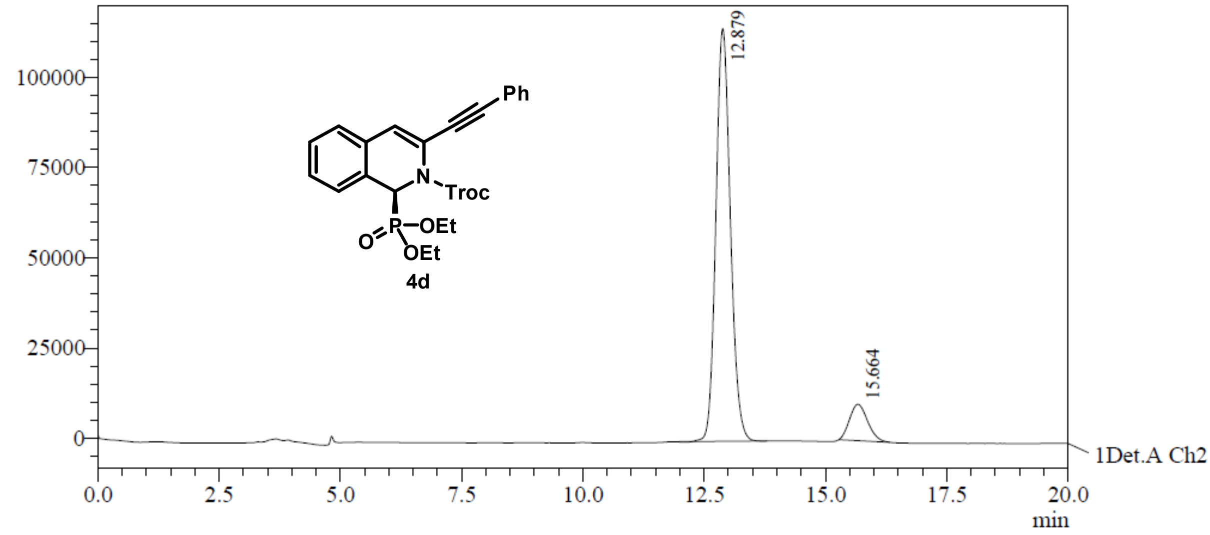
4d



PeakTable

Detector A Ch2 254nm

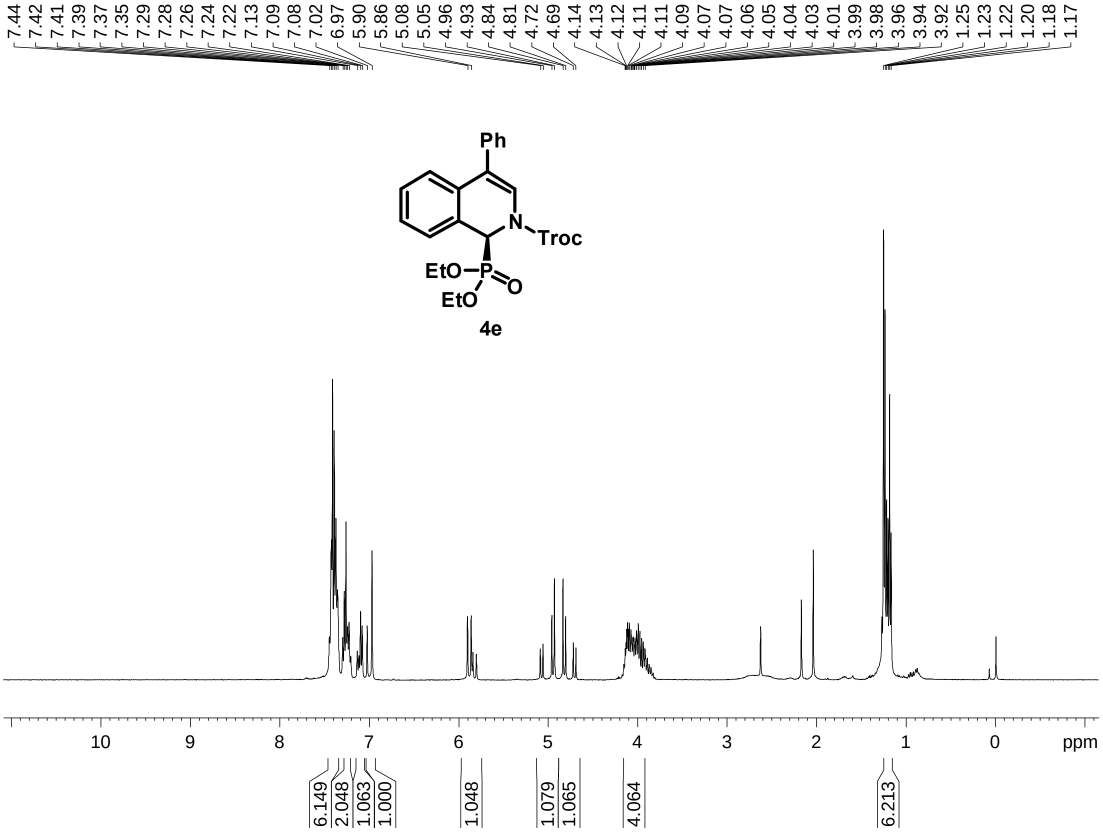
Peak#	Ret. Time	Area	Area %
1	12.896	21833570	49.965
2	15.655	21863733	50.035
Total		43697303	100.000



PeakTable

Detector A Ch2 254nm

Peak#	Ret. Time	Area	Area %
1	12.879	2380178	90.098
2	15.664	261580	9.902
Total		2641758	100.000


7.44
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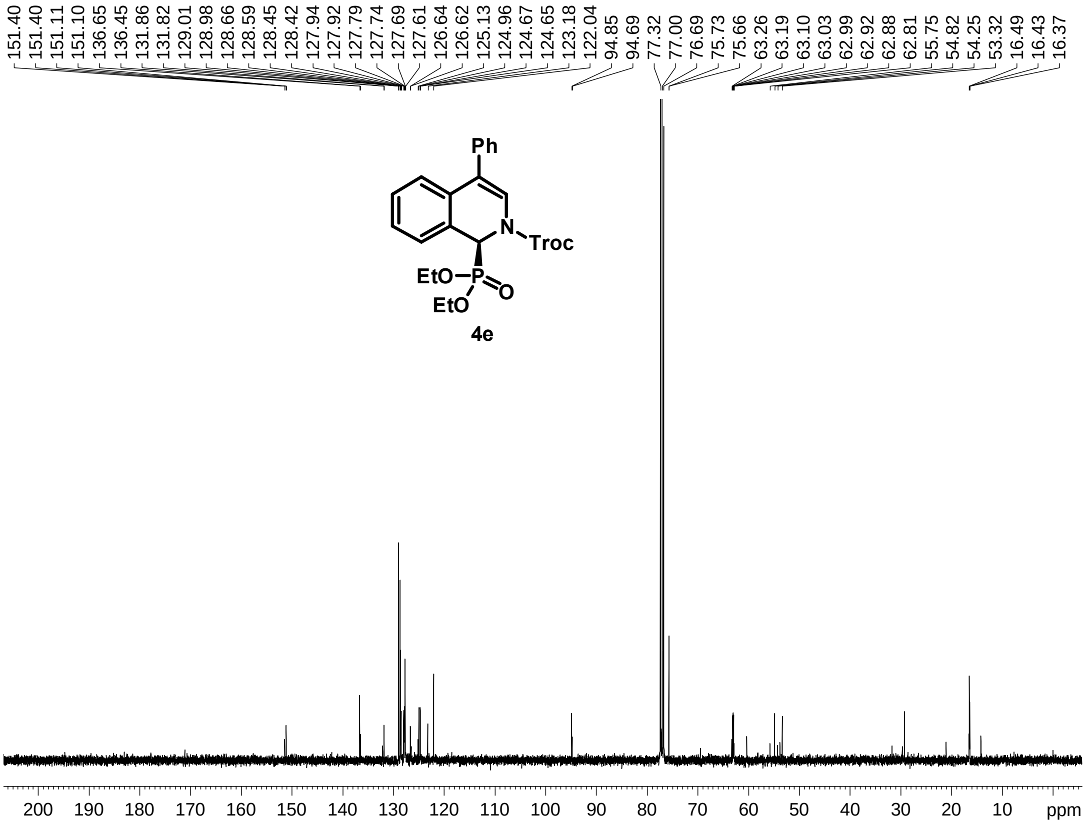
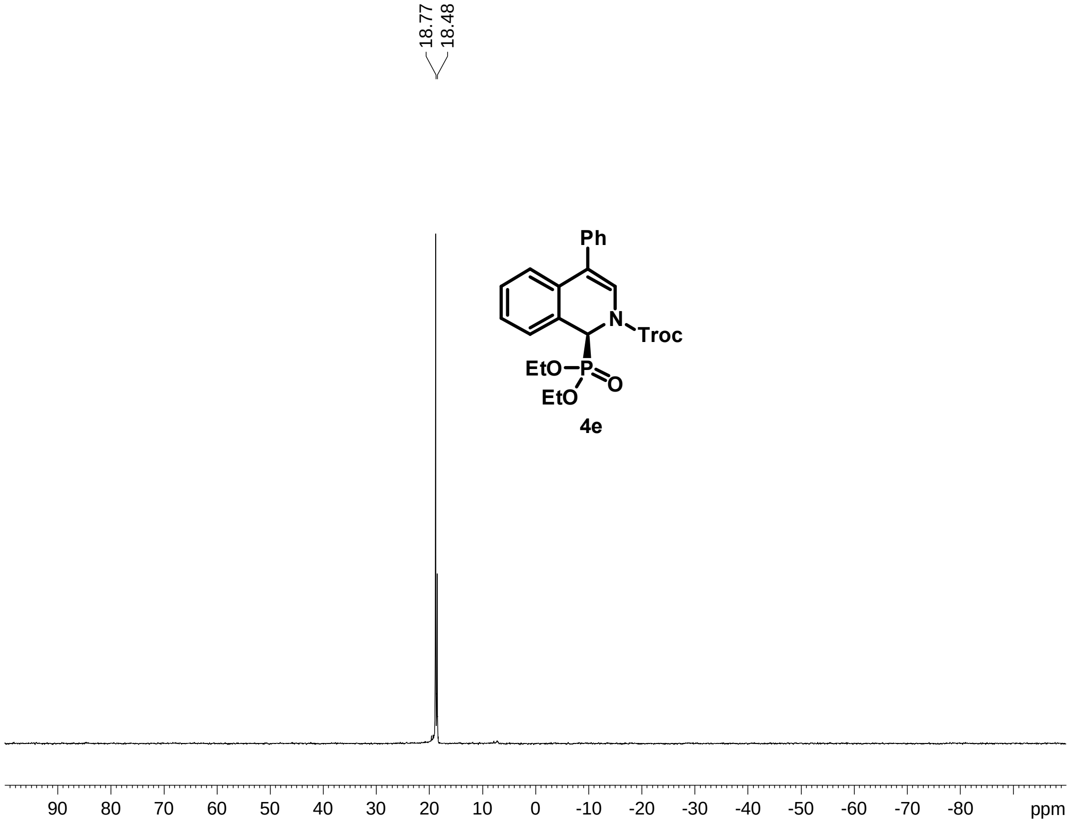
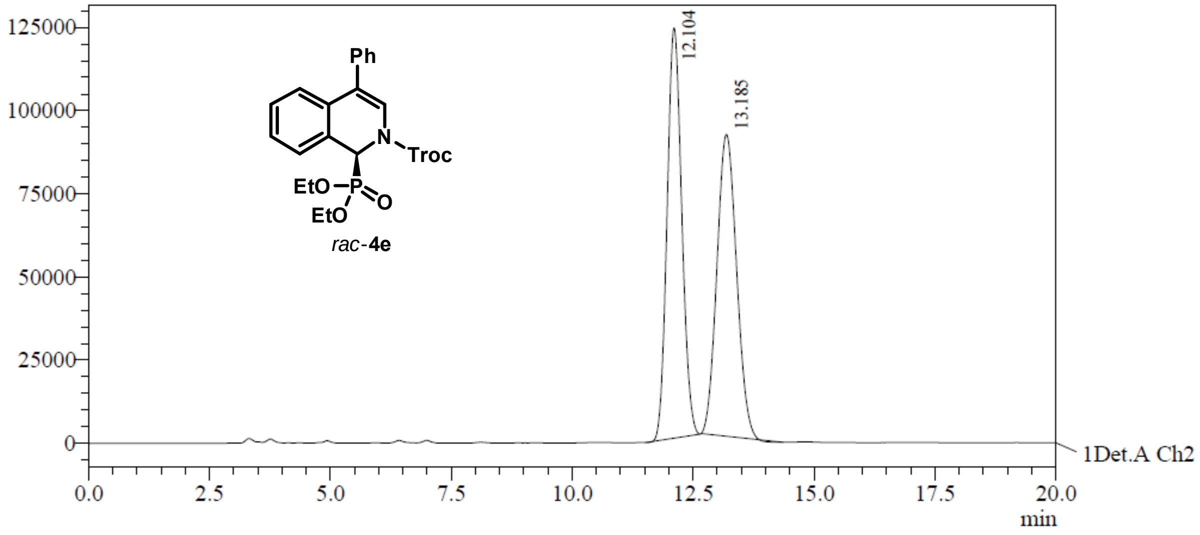
7.41
7.39
7.37
7.35
7.29
7.28
7.26
7.24
7.22
7.13
7.09
7.08
7.02
6.97
5.90
5.86
5.08
5.05
4.96
4.93
4.84
4.81
4.72
4.69
4.14
4.13
4.12
4.11
4.11
4.09
4.07
4.07
4.06
4.05
4.04
4.03
4.01
3.99
3.98
3.96
3.94
3.92
1.25
1.23
1.22
1.20
1.18
1.17
Ph
N
Troc
EtO
P
O
EtO
4e
10
9
8
7
6
5
4
3
2
1
0
ppm
6.149
2.048
1.063
1.000
1.048
1.079
1.065
4.064
6.213


151.40
151.40
151.11
151.10
136.65
136.45
131.86
131.82
129.01
128.98
128.66
128.59
128.45
128.42
127.94
127.92
127.79
127.74
127.69
127.61
126.64
126.62
125.13
124.96
124.67
124.65
123.18
122.04
94.85
94.69
77.32
77.00
76.69
75.73
75.66
63.26
63.19
63.10
63.03
62.99
62.92
62.88
62.81
55.75
54.82
54.25
53.32
16.49
16.43
16.37
Ph
N
Troc
EtO
P
O
EtO
4e
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

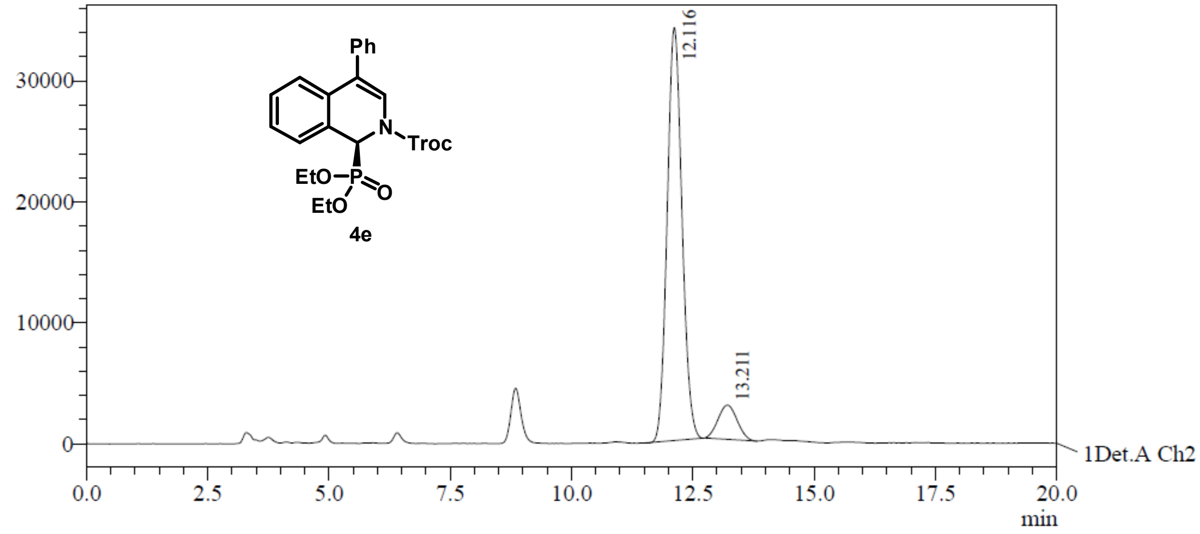

18.77
18.48
Ph
N
Troc
EtO
P
O
EtO
4e
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
ppm



PeakTable

Detector A Ch2 254nm

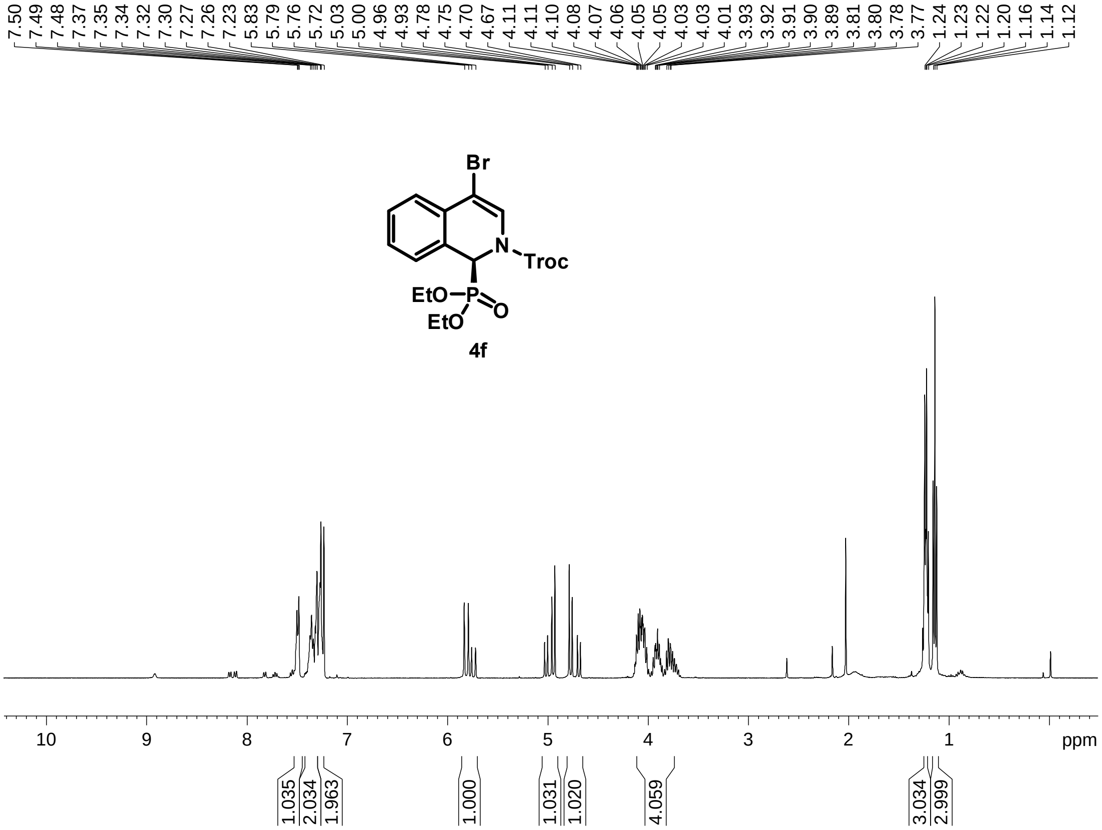
Peak#	Ret. Time	Area	Area %
1	12.104	2600570	50.407
2	13.185	2558581	49.593
Total		5159151	100.000

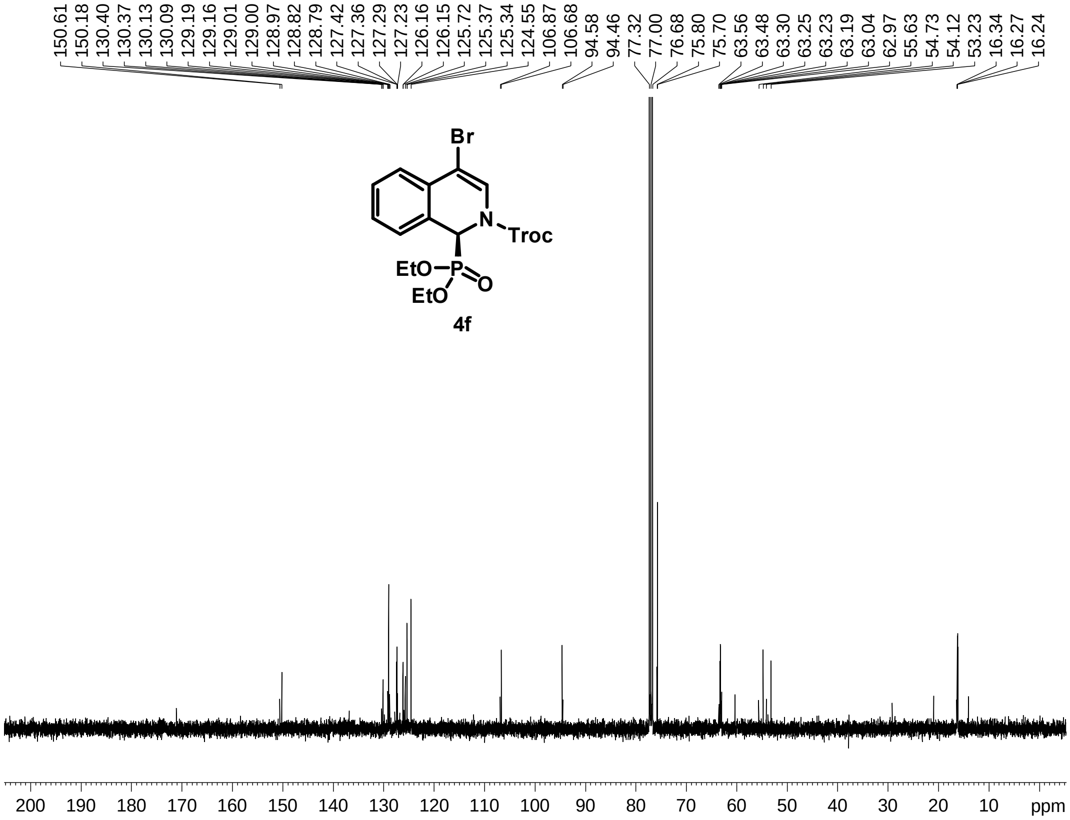


PeakTable

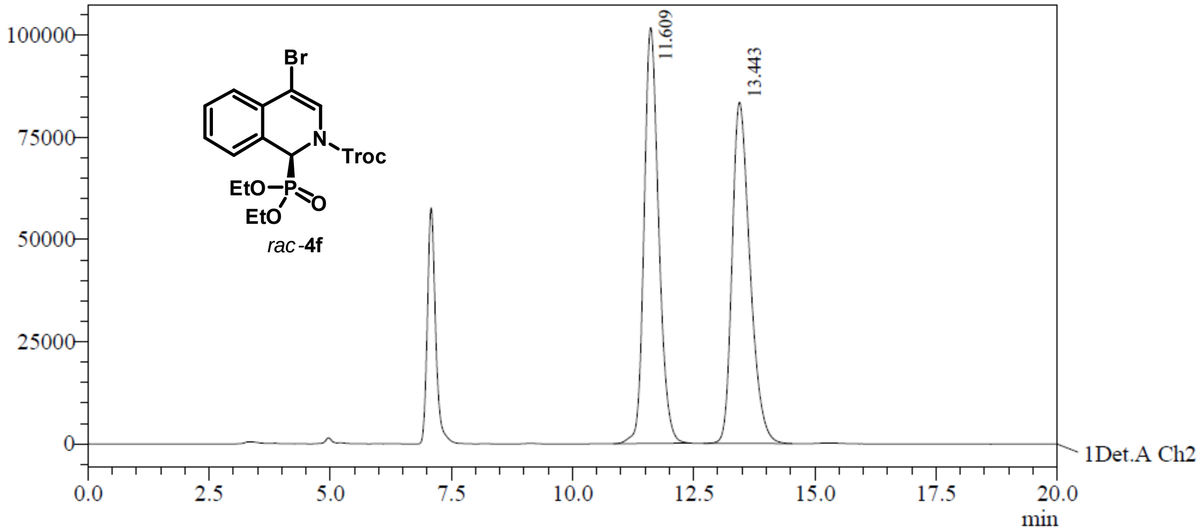
Detector A Ch2 254nm

Peak#	Ret. Time	Area	Area %
1	12.116	726292	90.382
2	13.211	77289	9.618
Total		803581	100.000


7.50
7.49
7.48
7.37
7.35
7.34
7.32
7.30
7.27
7.26
7.23
5.83
5.79
5.76
5.72
5.03
5.00
4.96
4.93
4.78
4.75
4.70
4.67
4.11
4.11
4.10
4.08
4.07
4.06
4.05
4.05
4.03
4.03
4.01
3.93
3.92
3.91
3.90
3.89
3.81
3.80
3.78
3.77
1.24
1.23
1.22
1.20
1.16
1.14
1.12
Br
N
Troc
EtO
P
O
EtO
4f
10
9
8
7
6
5
4
3
2
1
ppm
1.035
2.034
1.963
1.000
1.031
1.020
4.059
3.034
2.999


150.61
150.18
130.40
130.37
130.13
130.09
129.19
129.16
129.01
129.00
128.97
128.82
128.79
127.42
127.36
127.29
127.23
126.16
126.15
125.72
125.37
125.34
124.55
106.87
106.68
94.58
94.46
77.32
77.00
76.68
75.80
75.70
63.56
63.48
63.30
63.25
63.23
63.19
63.04
62.97
55.63
54.73
54.12
53.23
16.34
16.27
16.24
Br
N
Troc
EtO
P
O
EtO
4f
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

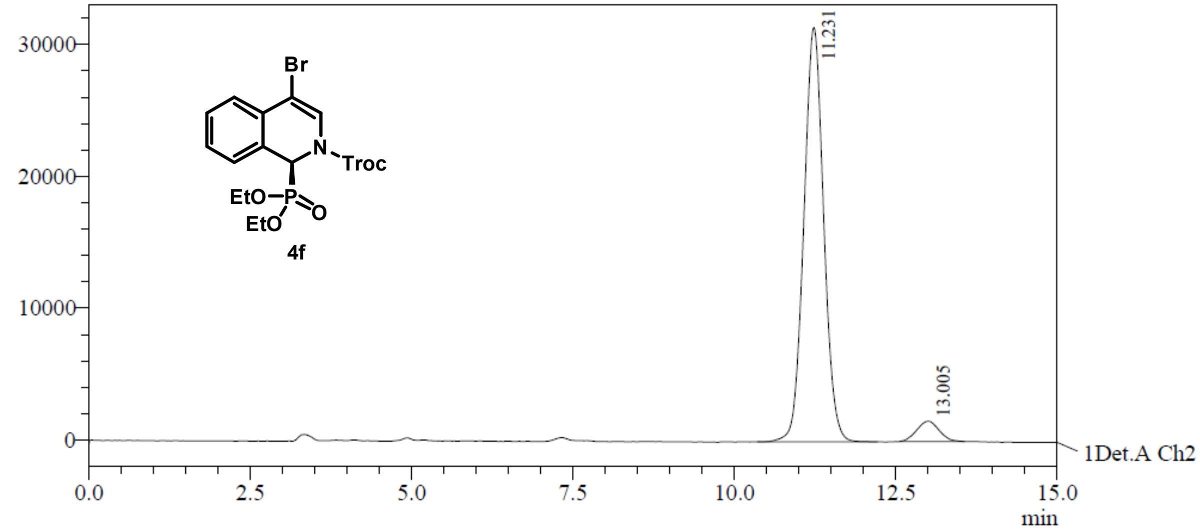

17.74
17.47
Br
N
Troc
EtO
P
O
EtO
4f
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
ppm



PeakTable

Detector A Ch2 254nm

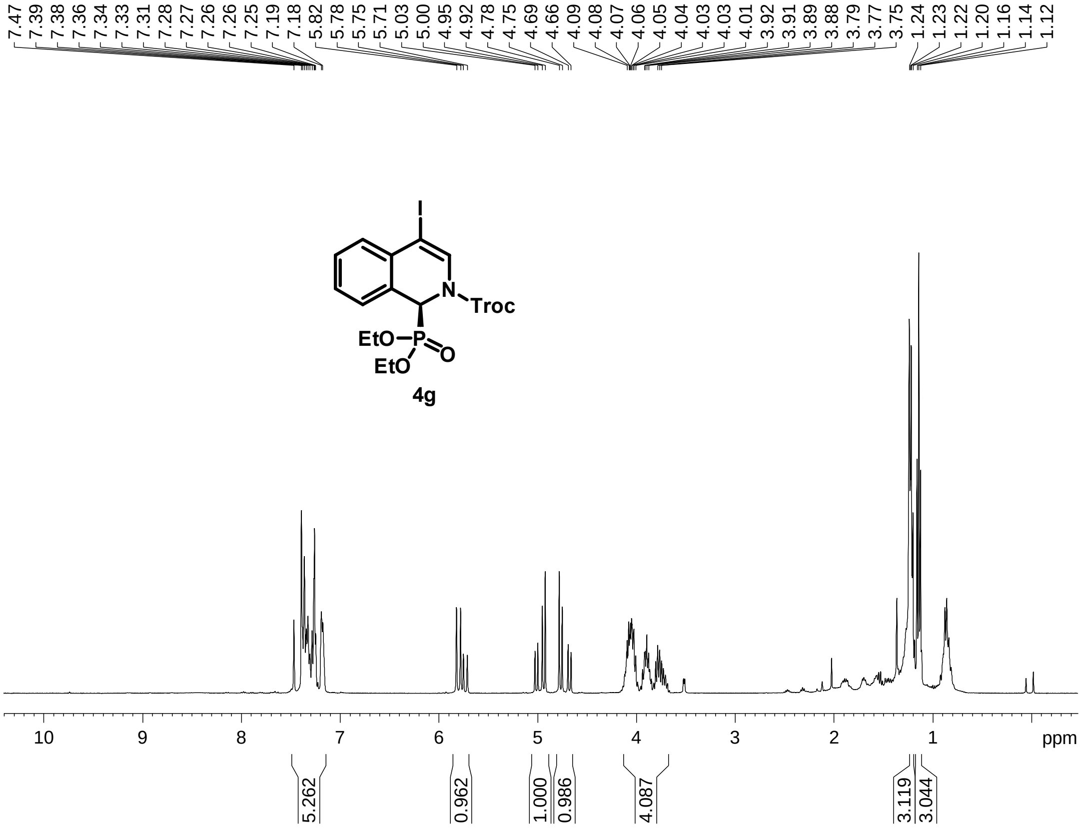
Peak#	Ret. Time	Area	Area %
1	11.609	2131623	49.871
2	13.443	2142623	50.129
Total		4274246	100.000

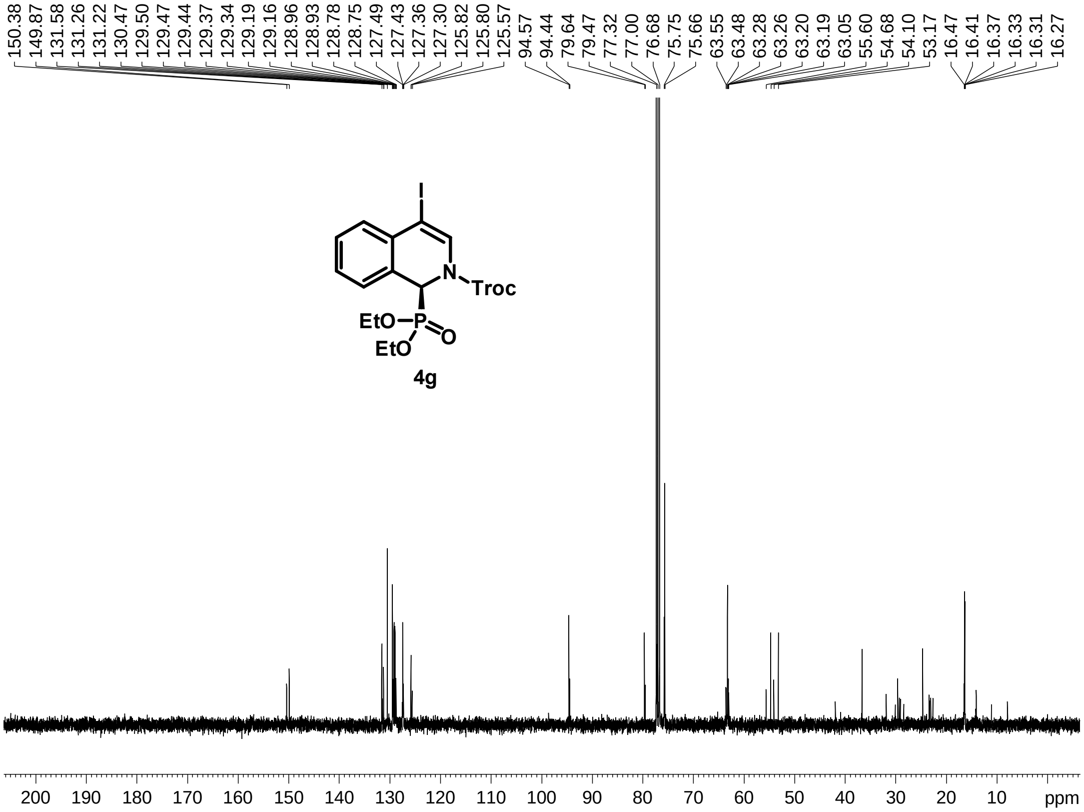


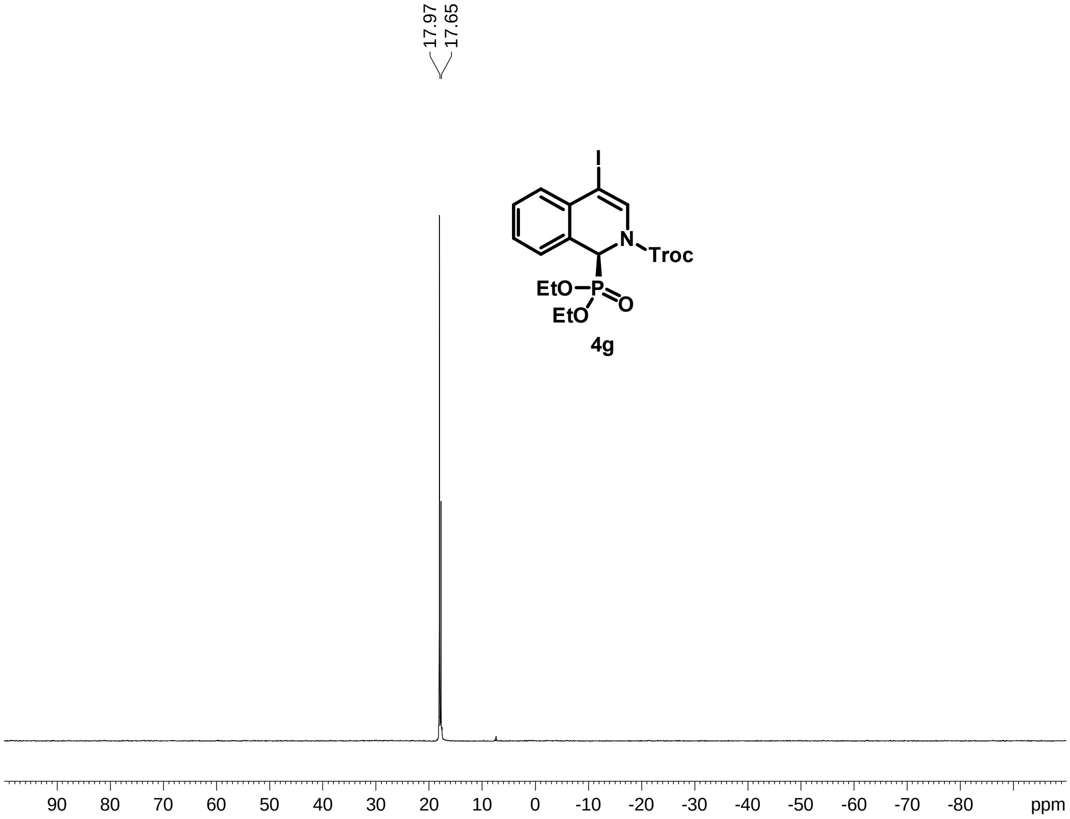
PeakTable

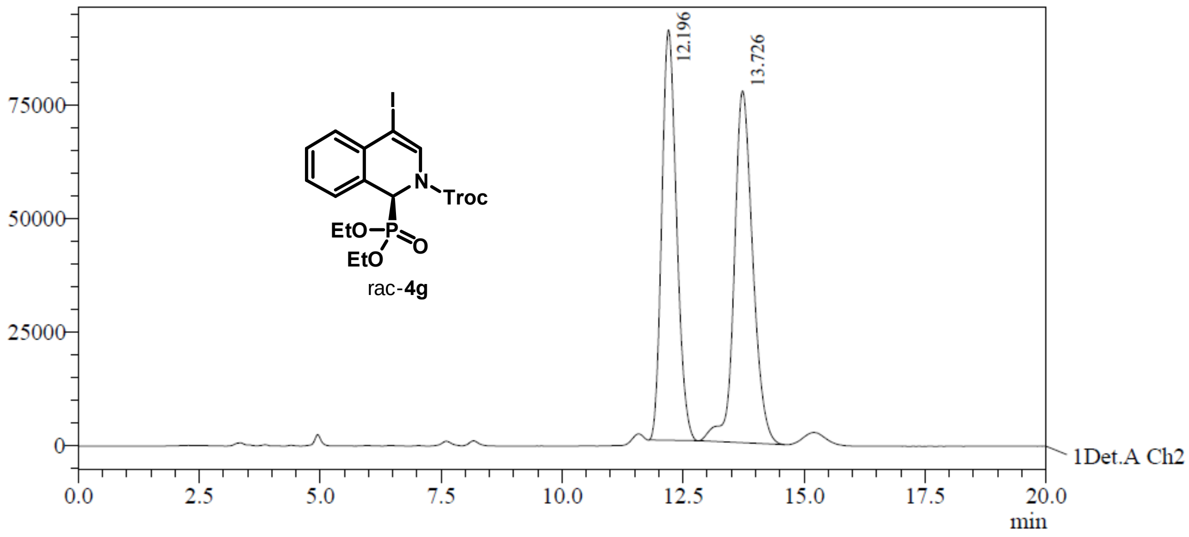
Detector A Ch2 254nm

Peak#	Ret. Time	Area	Area %
1	11.231	672603	94.776
2	13.005	37074	5.224
Total		709677	100.000


7.47
7.39
7.38
7.36
7.34
7.33
7.31
7.28
7.27
7.26
7.26
7.25
7.19
7.18
5.82
5.78
5.75
5.71
5.03
5.00
4.95
4.92
4.78
4.75
4.69
4.66
4.09
4.08
4.07
4.06
4.05
4.04
4.03
4.03
4.01
3.92
3.91
3.89
3.88
3.79
3.77
3.75
1.24
1.23
1.22
1.20
1.16
1.14
1.12
I
N
Troc
EtO
P
O
EtO
4g
10
9
8
7
6
5
4
3
2
1
ppm
5.262
0.962
1.000
0.986
4.087
3.119
3.044


150.38
149.87
131.58
131.26
131.22
130.47
129.50
129.47
129.44
129.37
129.34
129.19
129.16
128.96
128.93
128.78
128.75
127.49
127.43
127.36
127.30
125.82
125.80
125.57
94.57
94.44
79.64
79.47
77.32
77.00
76.68
75.75
75.66
63.55
63.48
63.28
63.26
63.20
63.19
63.05
55.60
54.68
54.10
53.17
16.47
16.41
16.37
16.33
16.31
16.27
I
N
Troc
EtO
P
O
EtO
4g
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

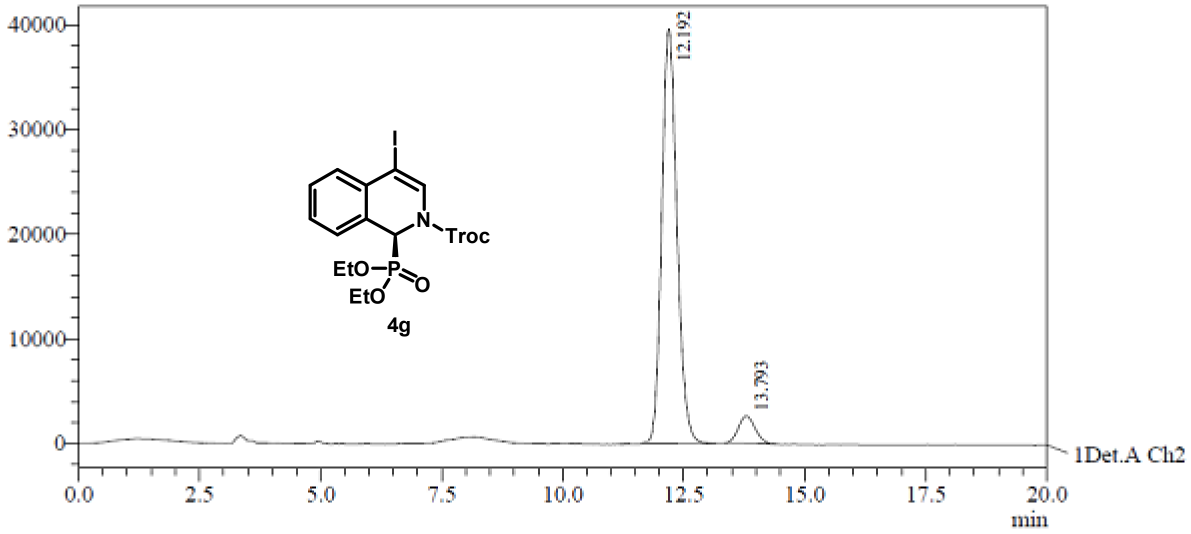

17.97
17.65
I
N
Troc
EtO
P
O
EtO
4g
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
ppm



PeakTable

Detector A Ch2 254nm

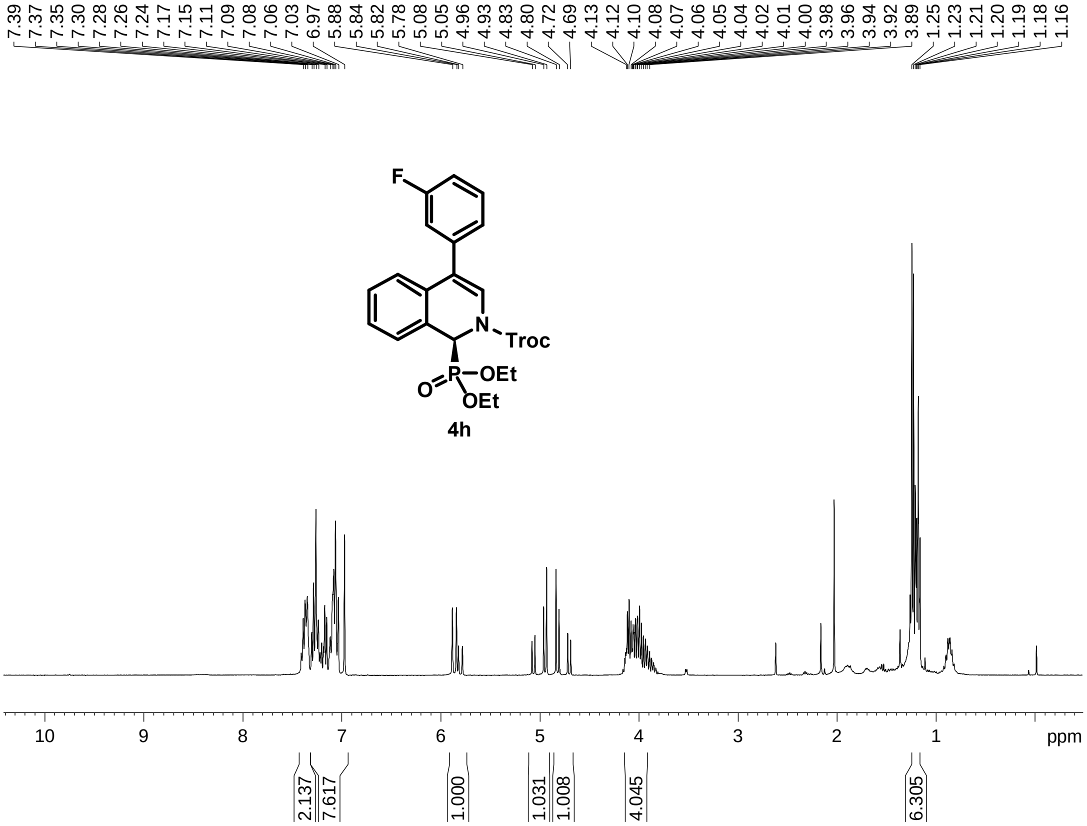
Peak#	Ret. Time	Area	Area %
1	12.196	1917090	48.053
2	13.726	2072434	51.947
Total		3989524	100.000

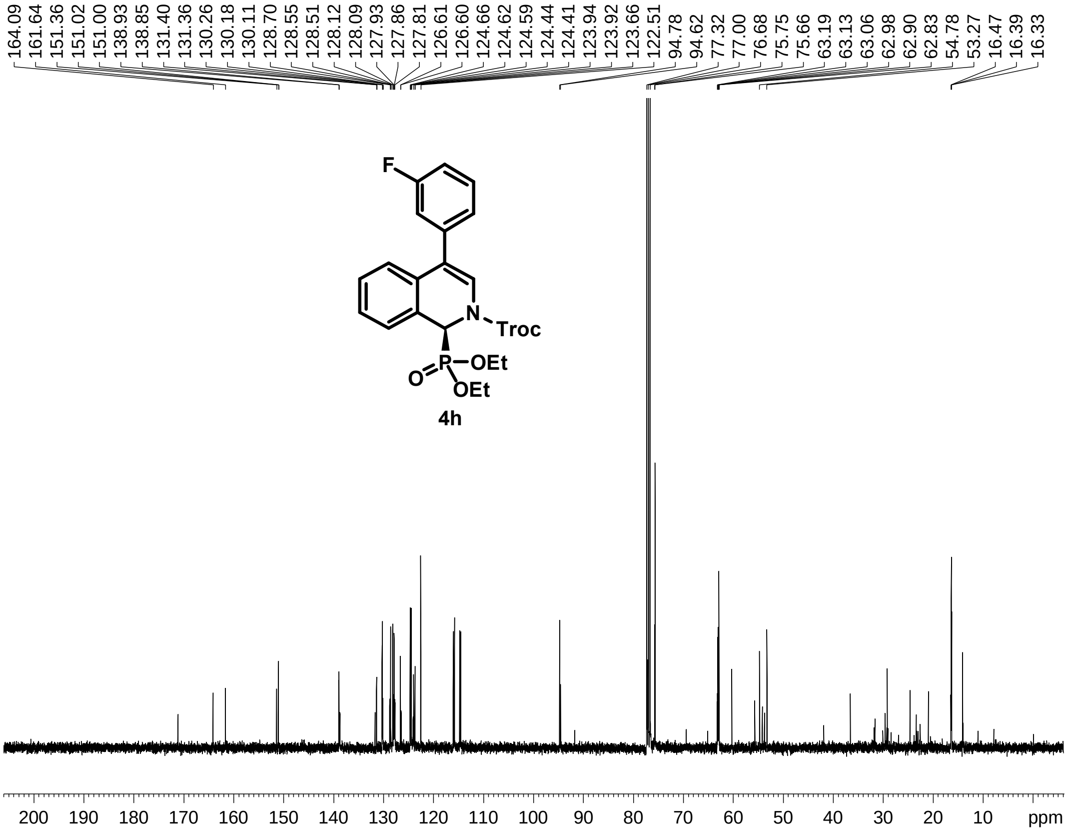


PeakTable

Detector A Ch2 254nm

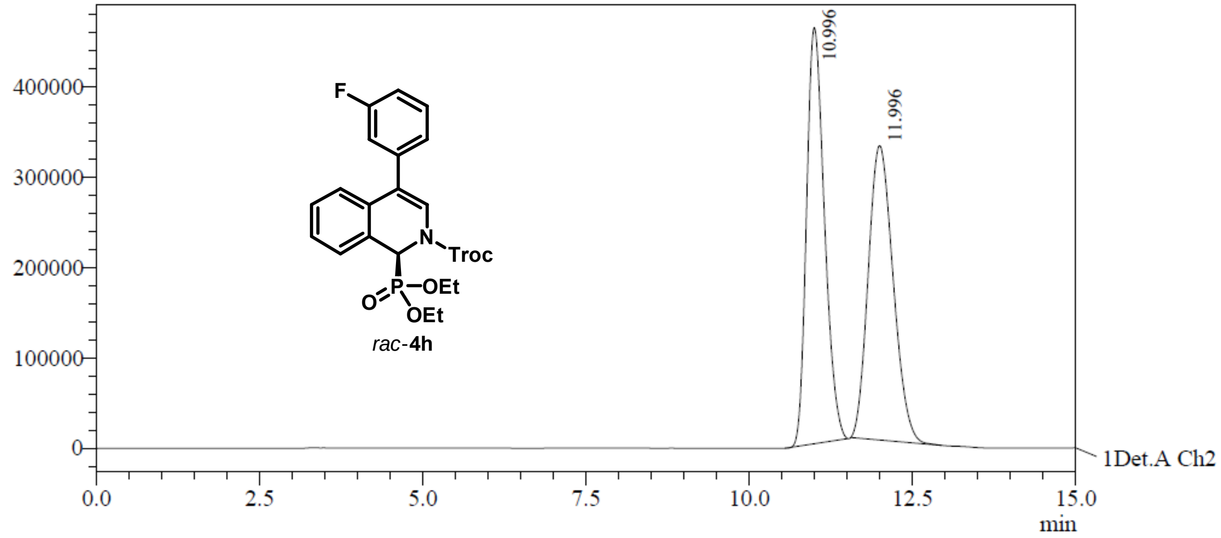
Peak#	Ret. Time	Area	Area %
1	12.192	876047	93.186
2	13.793	64059	6.814
Total		940106	100.000


7.39
7.37
7.35
7.30
7.28
7.26
7.24
7.17
7.15
7.11
7.09
7.08
7.06
7.03
6.97
5.88
5.84
5.82
5.78
5.08
5.05
4.96
4.93
4.83
4.80
4.72
4.69
4.13
4.12
4.10
4.08
4.07
4.06
4.05
4.04
4.02
4.01
4.00
3.98
3.96
3.94
3.92
3.89
1.25
1.23
1.21
1.20
1.19
1.18
1.16
F
N
Troc
P
OEt
O
OEt
4h
10
9
8
7
6
5
4
3
2
1
ppm
2.137
7.617
1.000
1.031
1.008
4.045
6.305


164.09
161.64
151.36
151.02
151.00
138.93
138.85
131.40
131.36
130.26
130.18
130.11
128.70
128.55
128.51
128.12
128.09
127.93
127.86
127.81
126.61
126.60
124.66
124.62
124.59
124.44
124.41
123.94
123.92
123.66
122.51
94.78
94.62
77.32
77.00
76.68
75.75
75.66
63.19
63.13
63.06
62.98
62.90
62.83
54.78
53.27
16.47
16.39
16.33
F
N
Troc
P
OEt
O
OEt
4h
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm


18.59
18.32
F
N
Troc
P
OEt
O
OEt
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
ppm

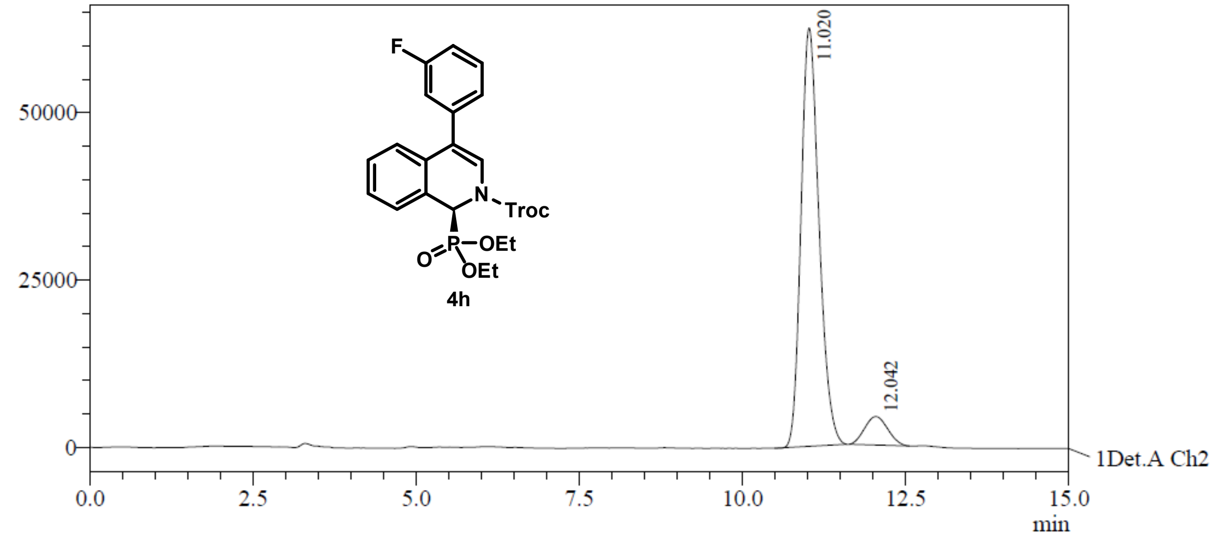
4h


rac-**4h**

PeakTable

Detector A Ch2 254nm

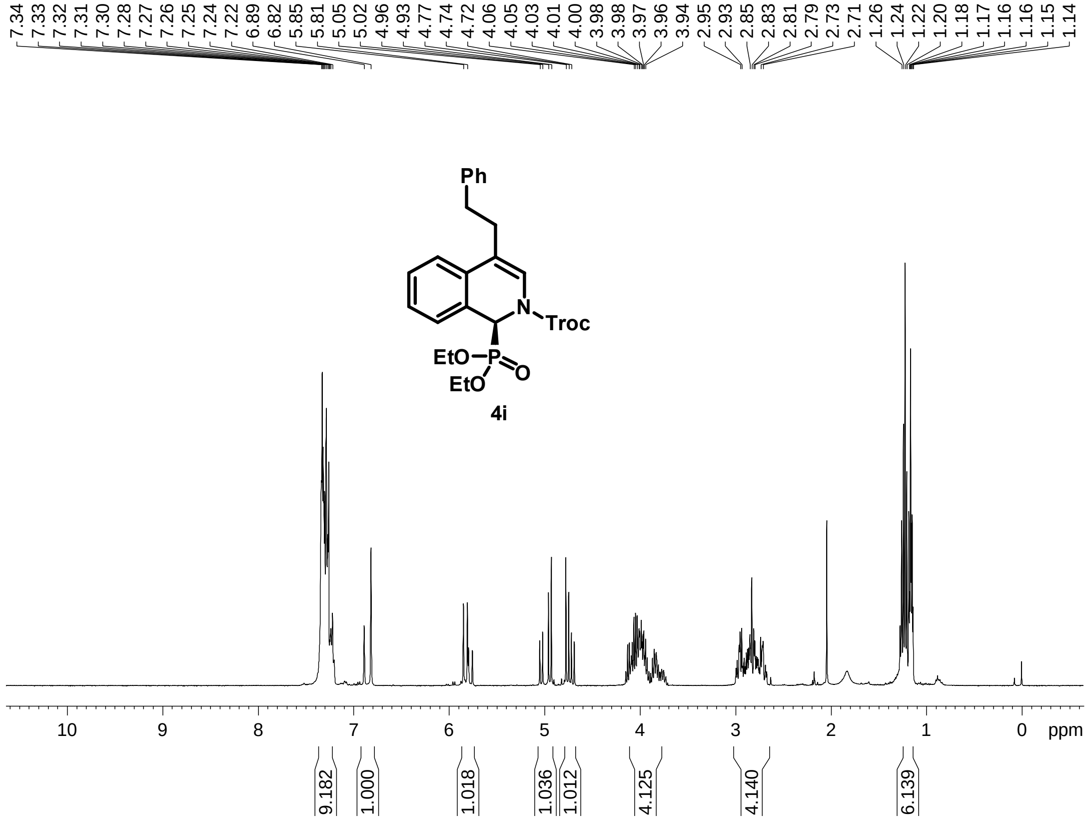
Peak#	Ret. Time	Area	Area %
1	10.996	8779995	50.364
2	11.996	8653227	49.636
Total		17433221	100.000


4h

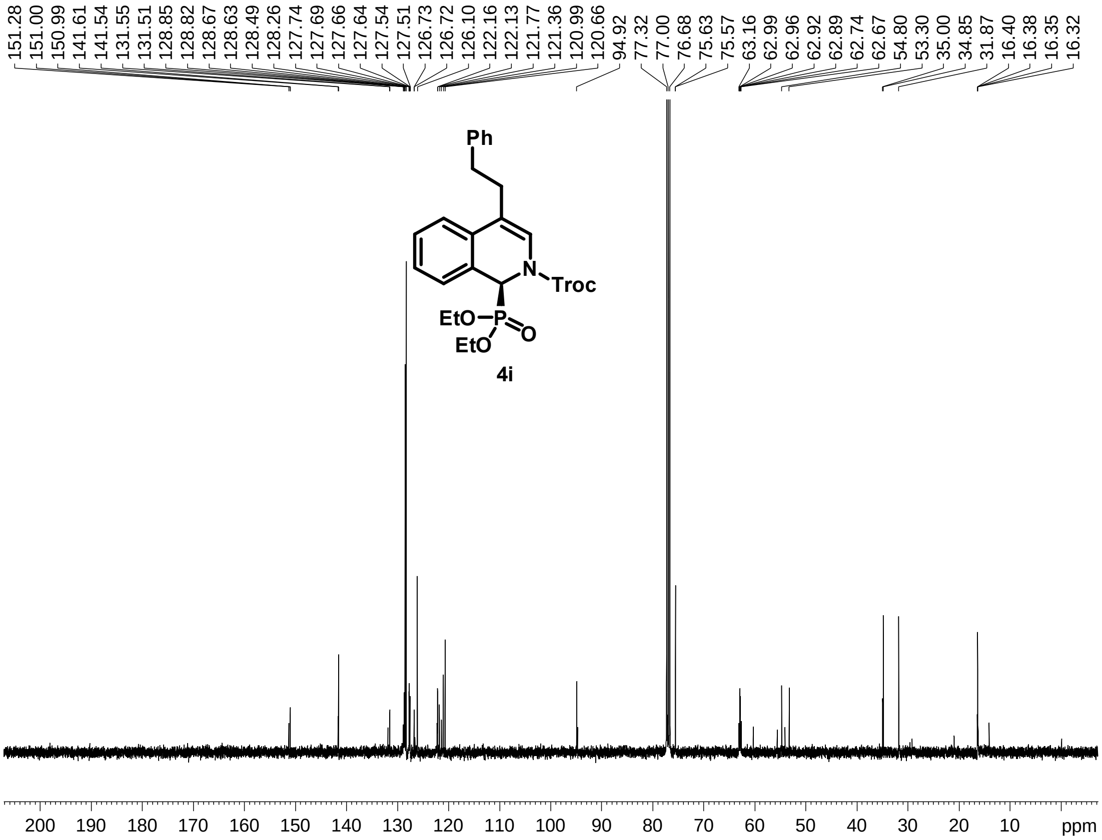
PeakTable

Detector A Ch2 254nm

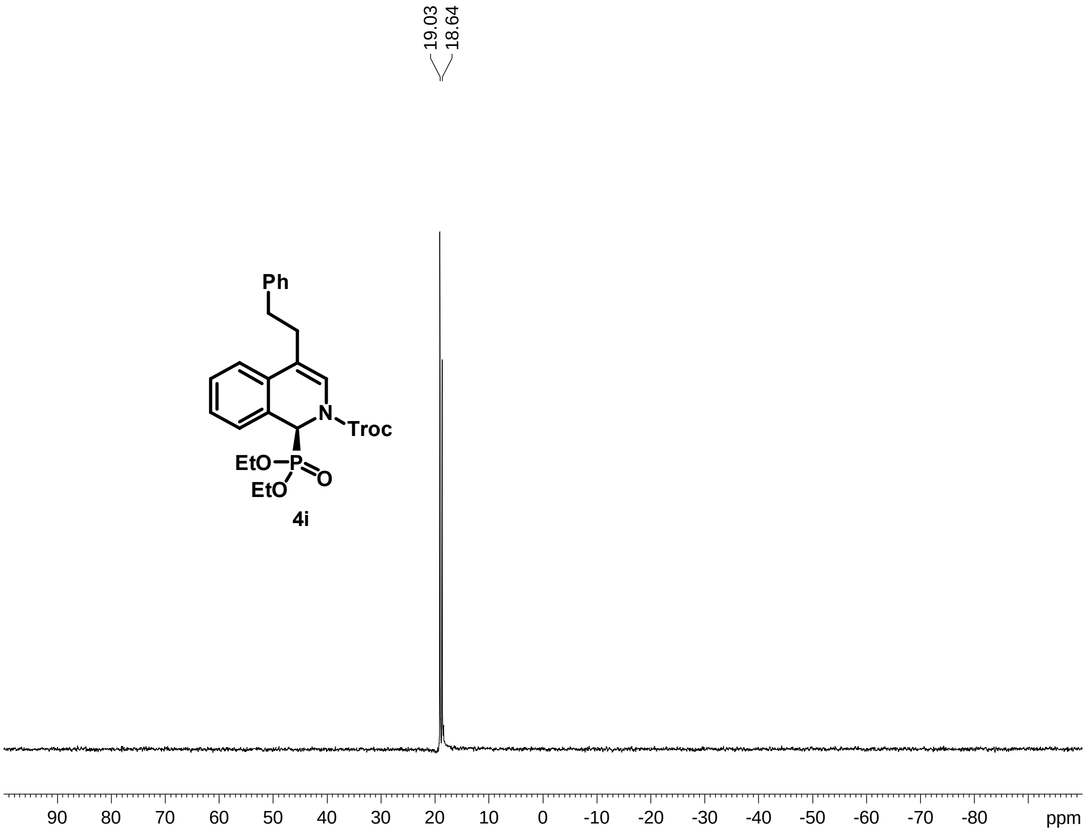
Peak#	Ret. Time	Area	Area %
1	11.020	1200494	91.991
2	12.042	104520	8.009
Total		1305014	100.000


7.34
7.33
7.32
7.31
7.30
7.28
7.27
7.26
7.25
7.24
7.22
6.89
6.82
5.85
5.81
5.05
5.02
4.96
4.93
4.77
4.74
4.72
4.06
4.05
4.03
4.01
4.00
3.98
3.98
3.97
3.96
3.94
2.95
2.93
2.85
2.83
2.81
2.79
2.73
2.71
1.26
1.24
1.22
1.20
1.18
1.17
1.16
1.16
1.15
1.14
Ph
N
Troc
EtO
P
O
EtO
10
9
8
7
6
5
4
3
2
1
0
ppm
9.182
1.000
1.018
1.036
1.012
4.125
4.140
6.139

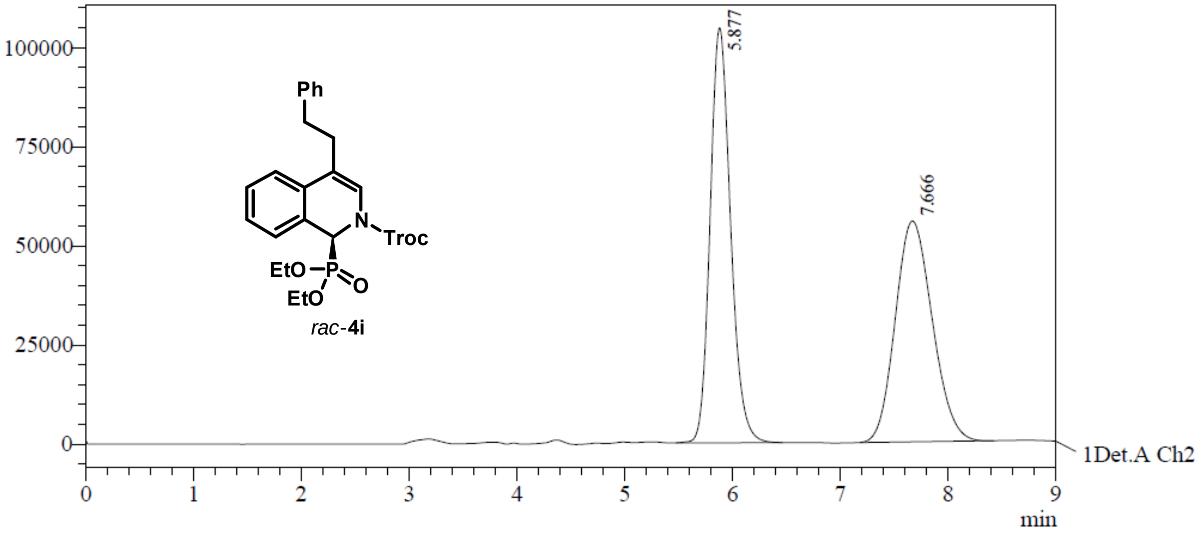
4i


151.28
151.00
150.99
141.61
141.54
131.55
131.51
128.85
128.82
128.67
128.63
128.49
128.26
127.74
127.69
127.66
127.64
127.54
127.51
126.73
126.72
126.10
122.16
122.13
121.77
121.36
120.99
120.66
94.92
77.32
77.00
76.68
75.63
75.57
63.16
62.99
62.96
62.92
62.89
62.74
62.67
54.80
53.30
35.00
34.85
31.87
16.40
16.38
16.35
16.32
Ph
N
Troc
EtO
P
O
EtO
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

4i


19.03
18.64
Ph
N
Troc
EtO
P
O
EtO
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
ppm

4i

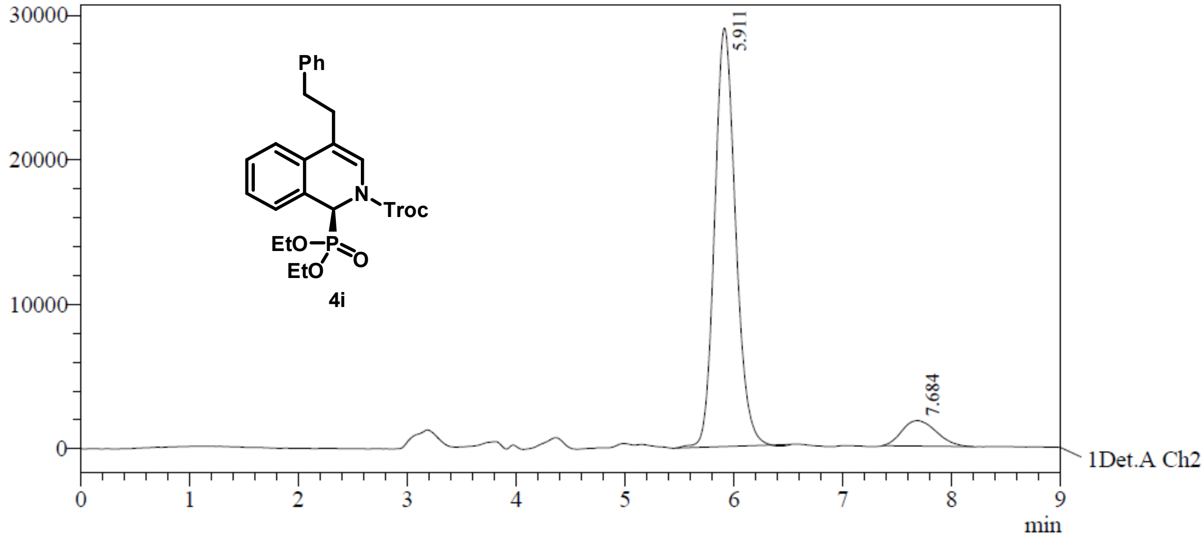


rac-**4i**

PeakTable

Detector A Ch2 254nm

Peak#	Ret. Time	Area	Area %
1	5.877	1383867	50.995
2	7.666	1329839	49.005
Total		2713705	100.000

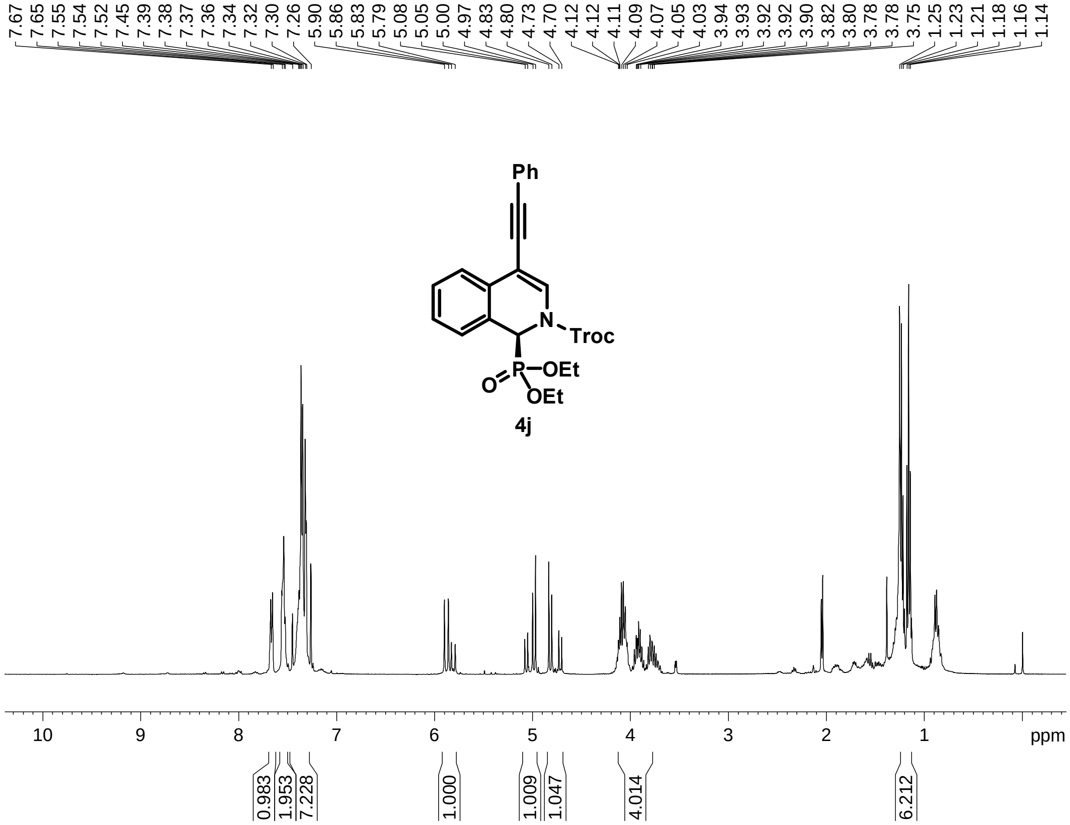


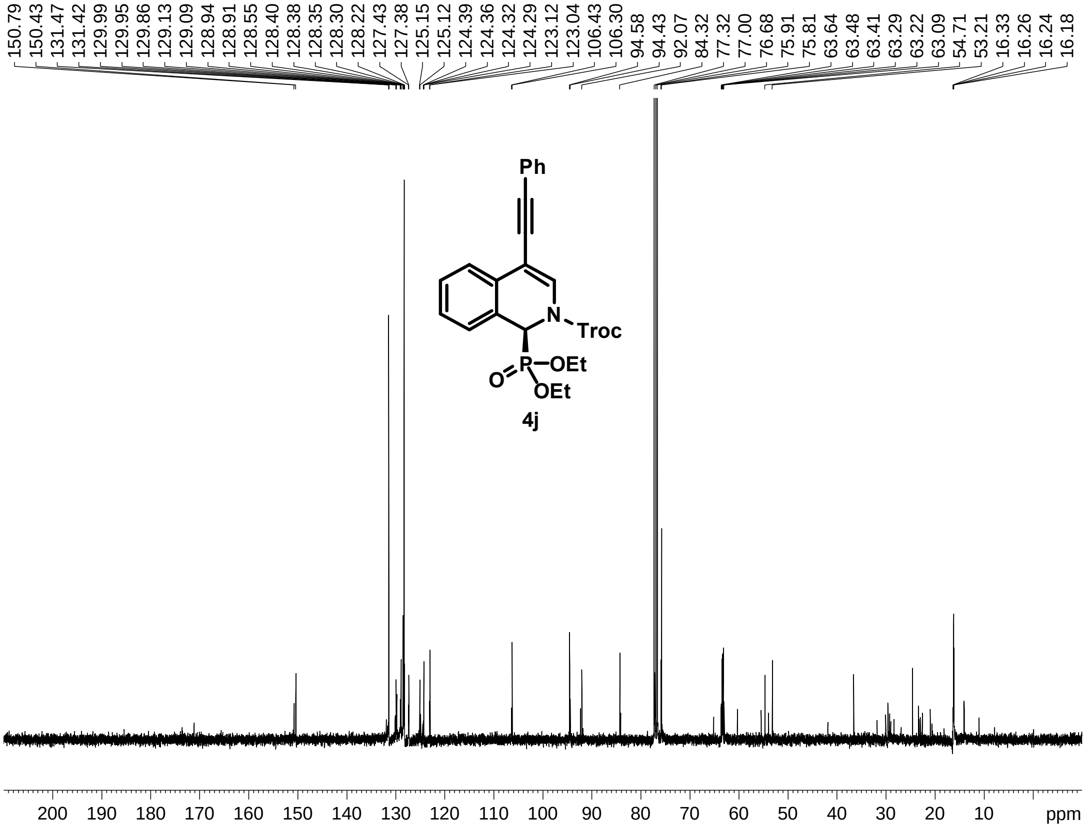
4i

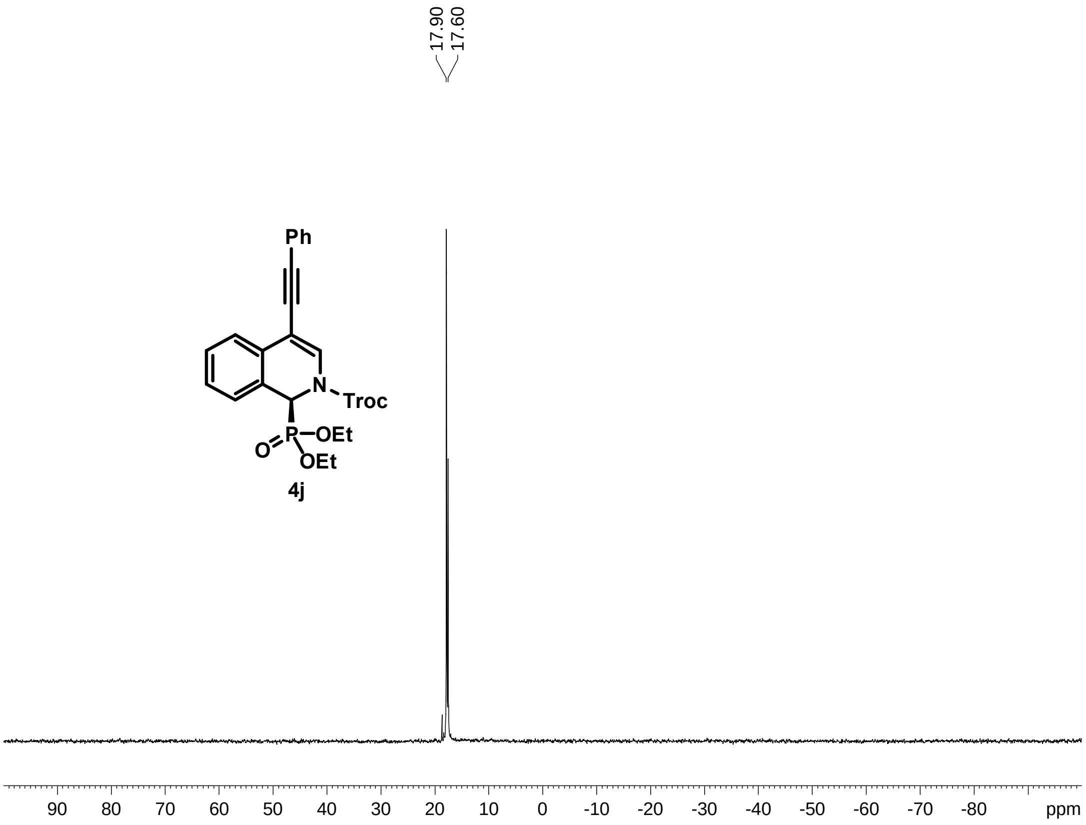
PeakTable

Detector A Ch2 254nm

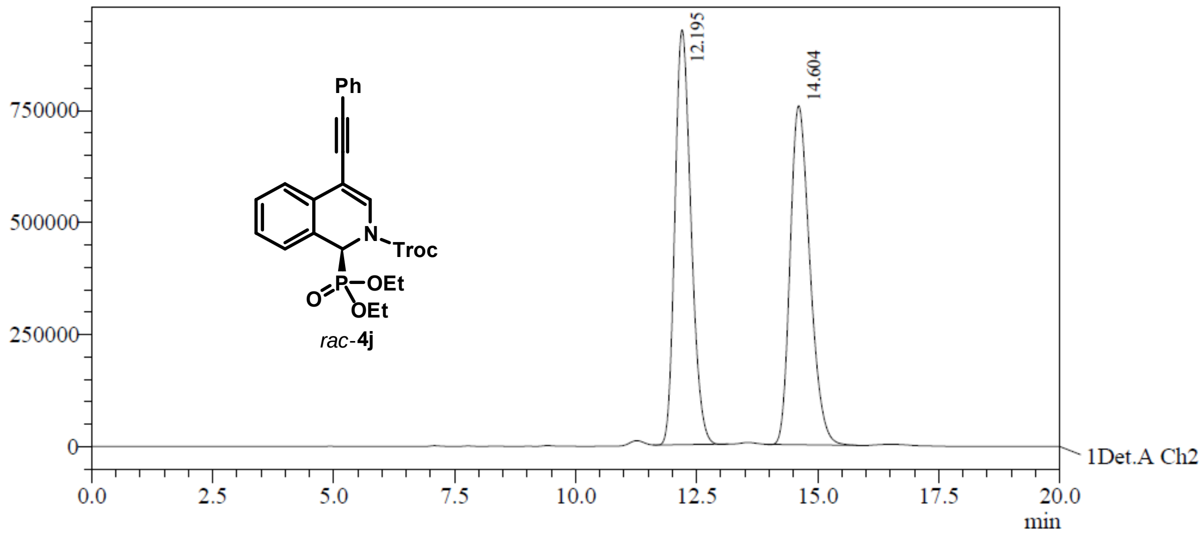
Peak#	Ret. Time	Area	Area %
1	5.911	387283	90.880
2	7.684	38866	9.120
Total		426149	100.000


7.67
7.65
7.55
7.54
7.52
7.45
7.39
7.38
7.37
7.36
7.34
7.32
7.30
7.26
5.90
5.86
5.83
5.79
5.08
5.05
5.00
4.97
4.83
4.80
4.73
4.70
4.12
4.12
4.11
4.09
4.07
4.05
4.03
3.94
3.93
3.92
3.92
3.90
3.82
3.80
3.78
3.78
3.75
1.25
1.23
1.21
1.18
1.16
1.14
Ph
N
Troc
P
OEt
O
OEt
4j
10
9
8
7
6
5
4
3
2
1
ppm
0.983
1.953
7.228
1.000
1.009
1.047
4.014
6.212


150.79
150.43
131.47
131.42
129.99
129.95
129.86
129.13
129.09
128.94
128.91
128.55
128.40
128.38
128.35
128.30
128.22
127.43
127.38
125.15
125.12
124.39
124.36
124.32
124.29
123.12
123.04
106.43
106.30
94.58
94.43
92.07
84.32
77.32
77.00
76.68
75.91
75.81
63.64
63.48
63.41
63.29
63.22
63.09
54.71
53.21
16.33
16.26
16.24
16.18
Ph
N
Troc
P
OEt
O
OEt
4j
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm


17.90
17.60
Ph
N
Troc
P
OEt
O
OEt
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
ppm

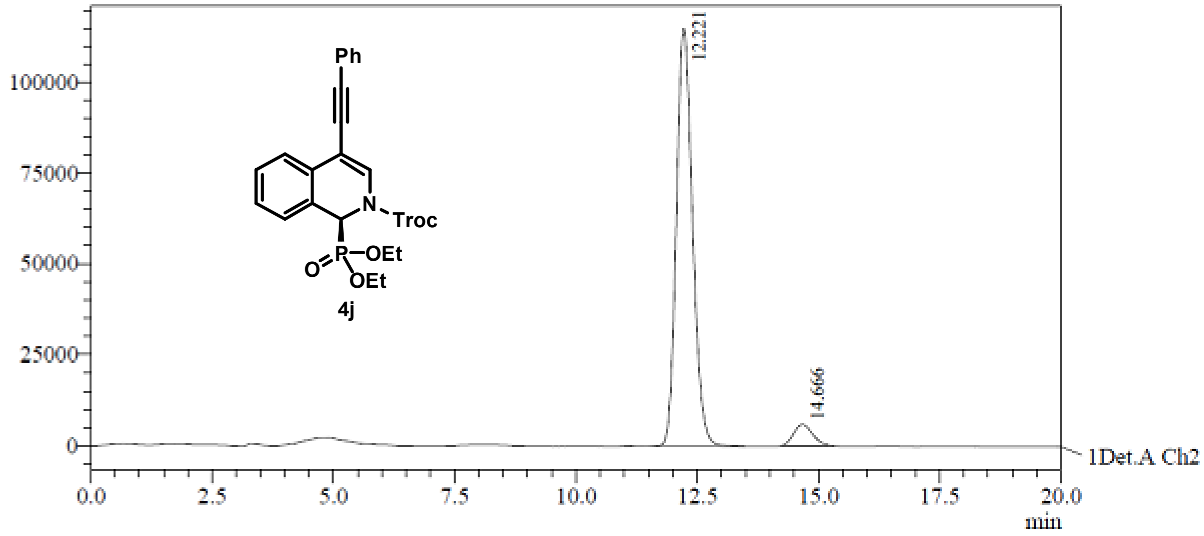
4j



PeakTable

Detector A Ch2 254nm

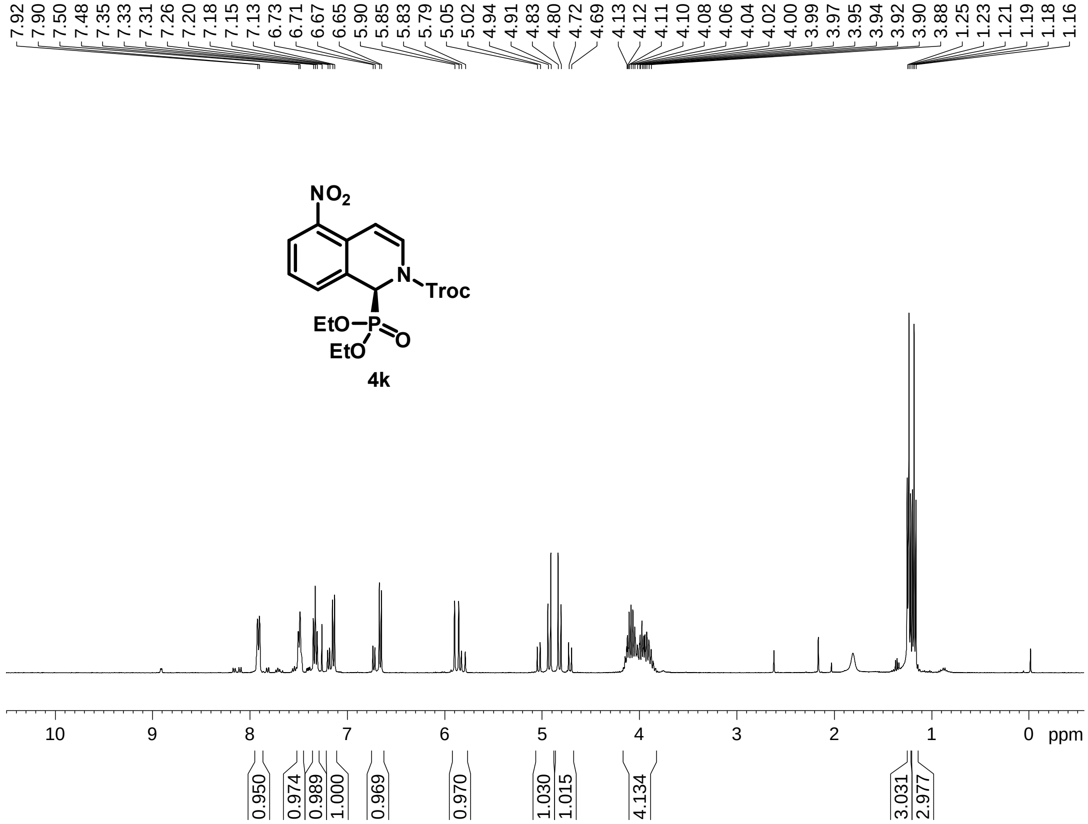
Peak#	Ret. Time	Area	Area %
1	12.195	21480086	49.956
2	14.604	21518110	50.044
Total		42998196	100.000

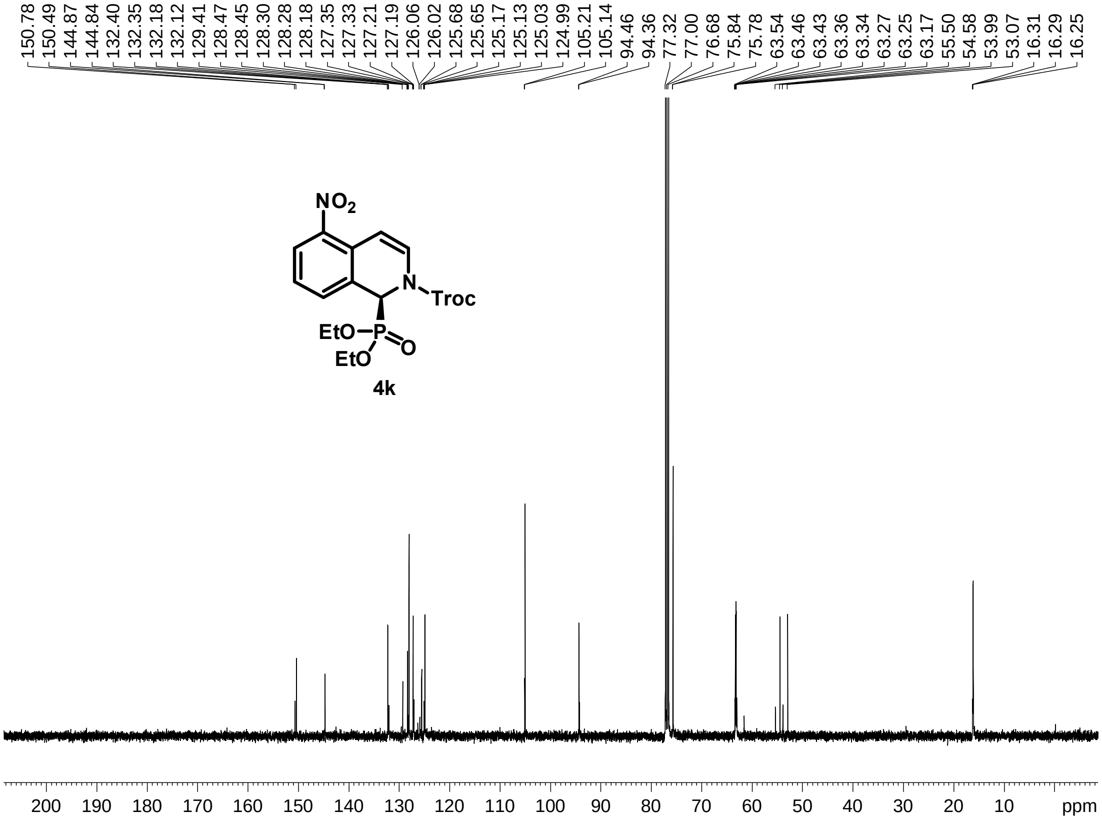


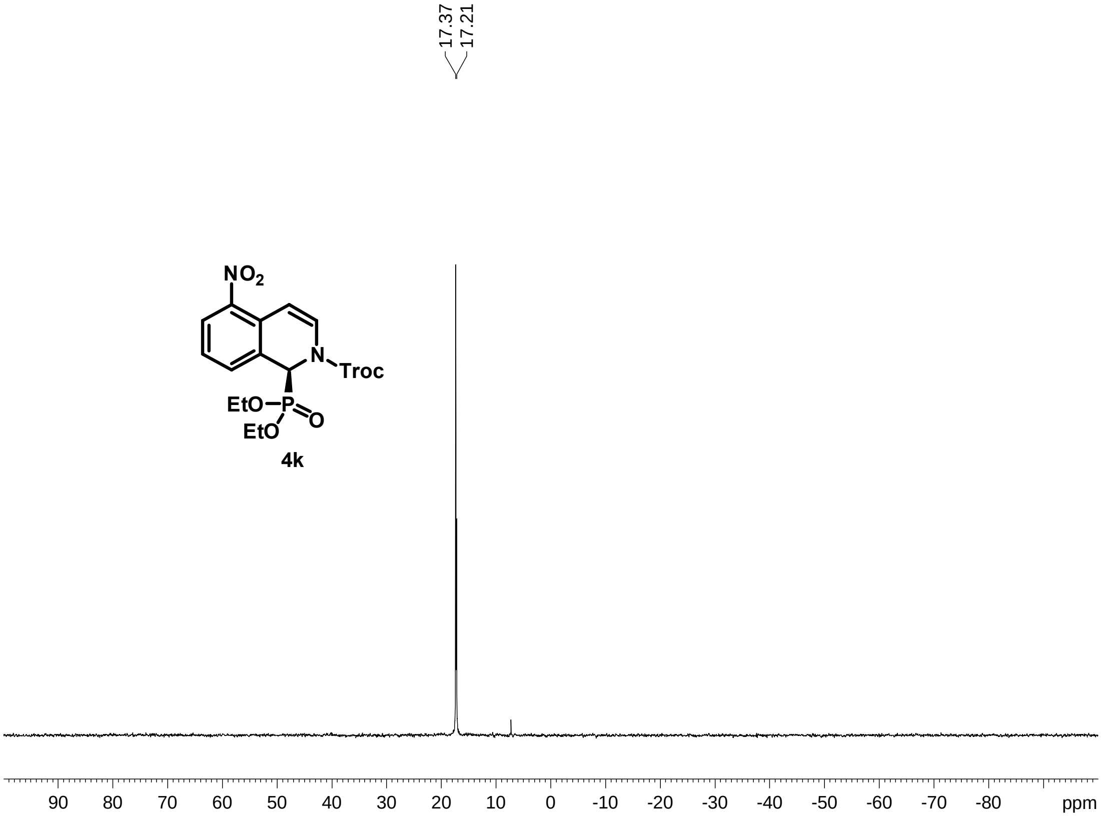
PeakTable

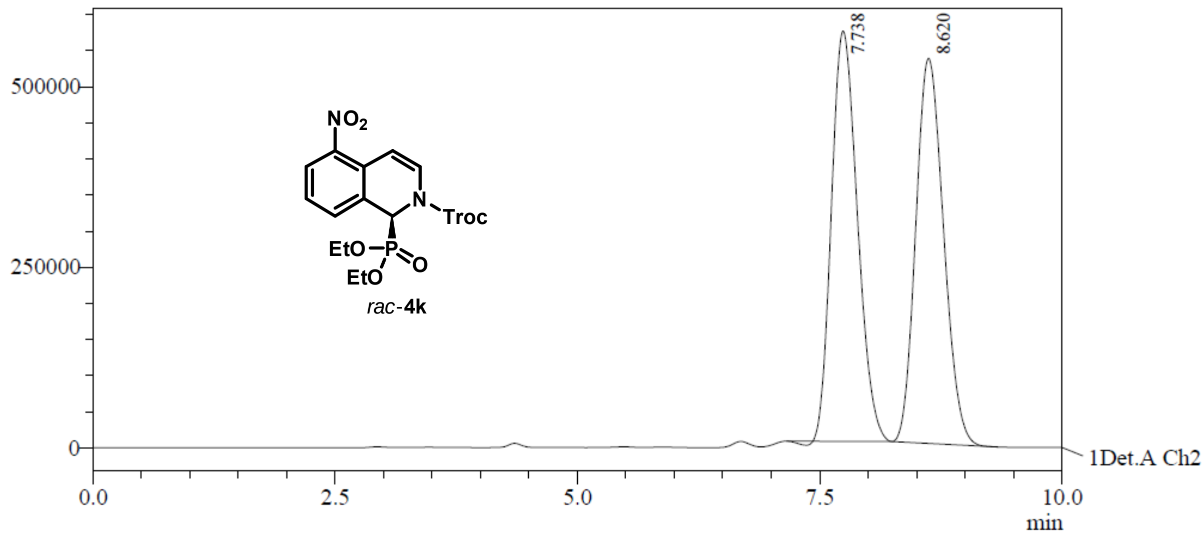
Detector A Ch2 254nm

Peak#	Ret. Time	Area	Area %
1	12.221	2687048	94.358
2	14.666	160655	5.642
Total		2847703	100.000


7.92
7.90
7.50
7.48
7.35
7.33
7.31
7.26
7.20
7.18
7.15
7.13
6.73
6.71
6.67
6.65
5.90
5.85
5.83
5.79
5.05
5.02
4.94
4.91
4.83
4.80
4.72
4.69
4.13
4.12
4.11
4.10
4.08
4.06
4.04
4.02
4.00
3.99
3.97
3.95
3.94
3.92
3.90
3.88
1.25
1.23
1.21
1.19
1.18
1.16
NO2
N
Troc
EtO
P
O
EtO
4k
10
9
8
7
6
5
4
3
2
1
0
ppm
0.950
0.974
0.989
1.000
0.969
0.970
1.030
1.015
4.134
3.031
2.977


150.78
150.49
144.87
144.84
132.40
132.35
132.18
132.12
129.41
128.47
128.45
128.30
128.28
128.18
127.35
127.33
127.21
127.19
126.06
126.02
125.68
125.65
125.17
125.13
125.03
124.99
105.21
105.14
94.46
94.36
77.32
77.00
76.68
75.84
75.78
63.54
63.46
63.43
63.36
63.34
63.27
63.25
63.17
55.50
54.58
53.99
53.07
16.31
16.29
16.25
NO2
N
Troc
EtO
P
O
EtO
4k
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

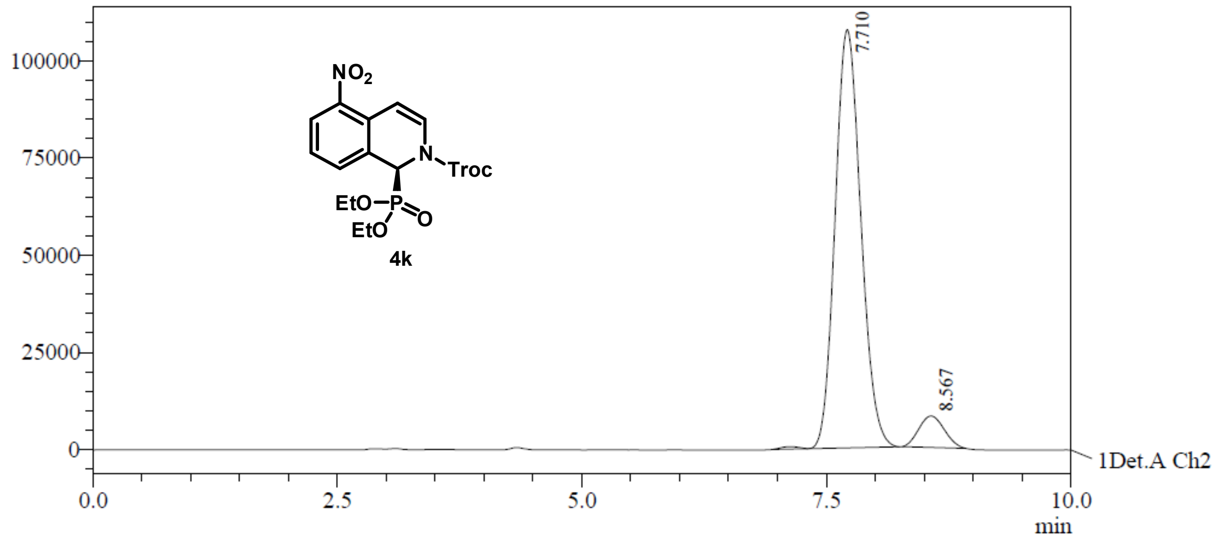

17.37
17.21
NO2
N
Troc
EtO
P
O
EtO
4k
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
ppm



PeakTable

Detector A Ch2 254nm

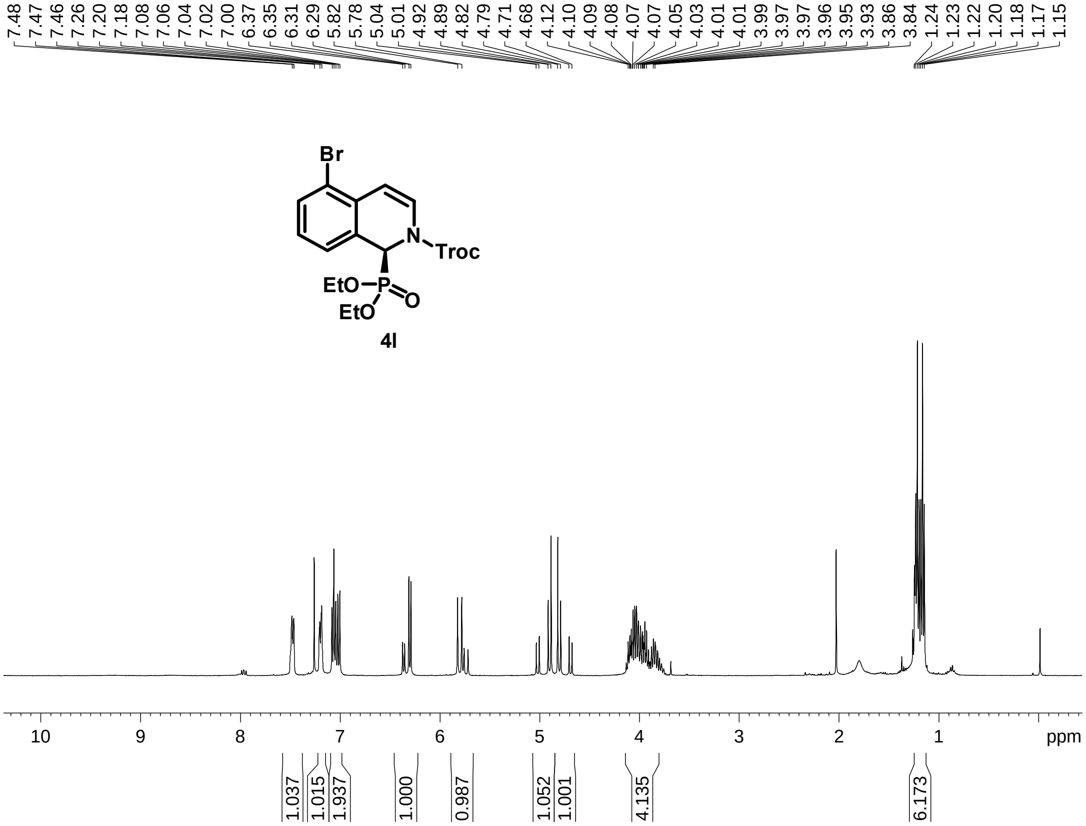
Peak#	Ret. Time	Area	Area %
1	7.738	10566882	49.813
2	8.620	10646122	50.187
Total		21213004	100.000

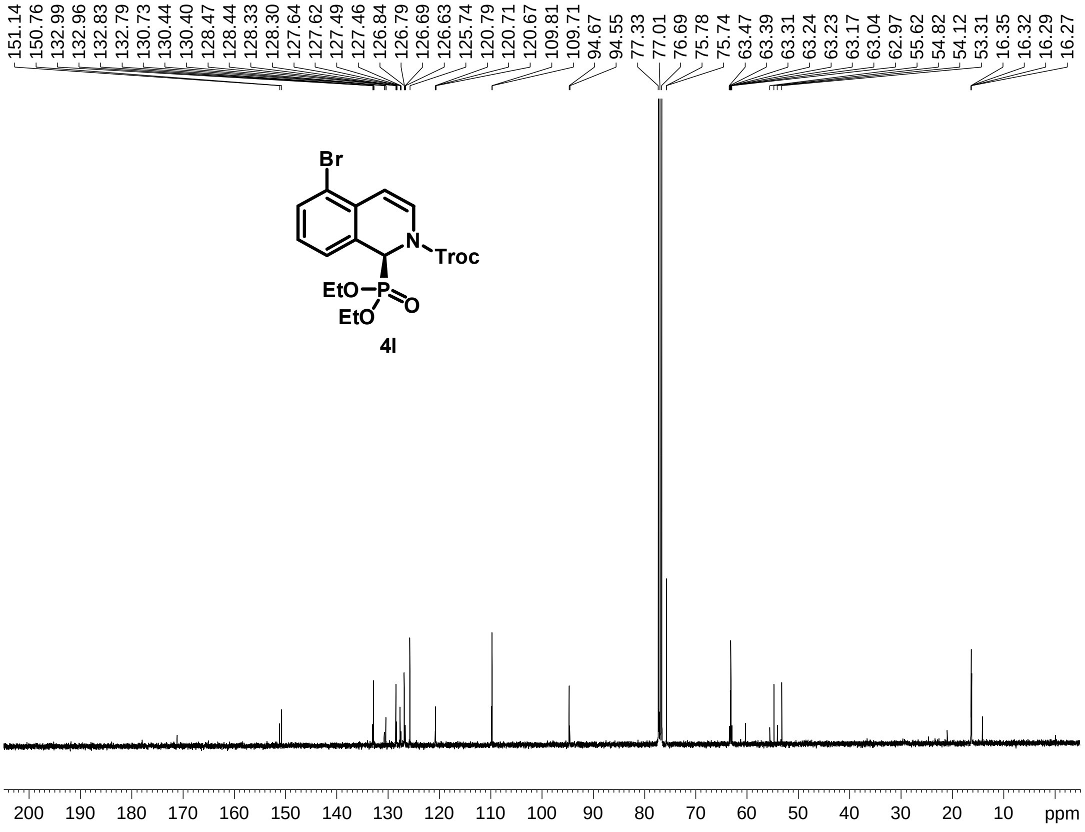


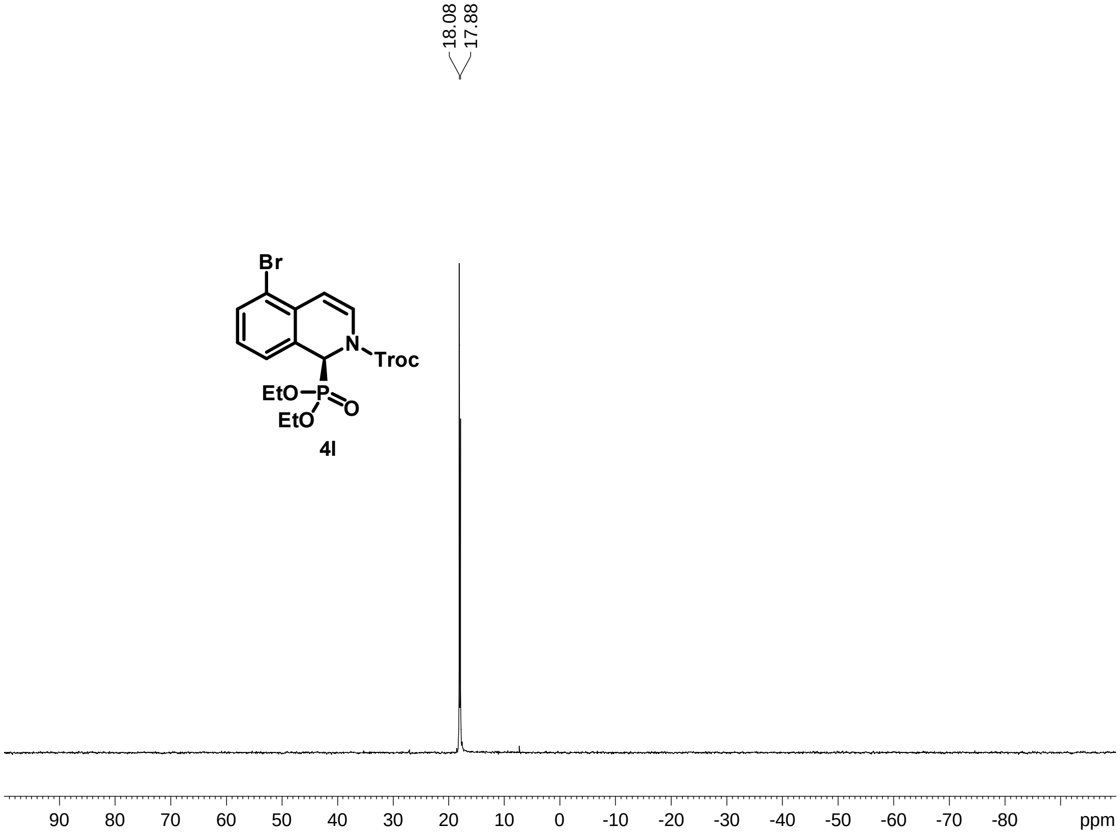
PeakTable

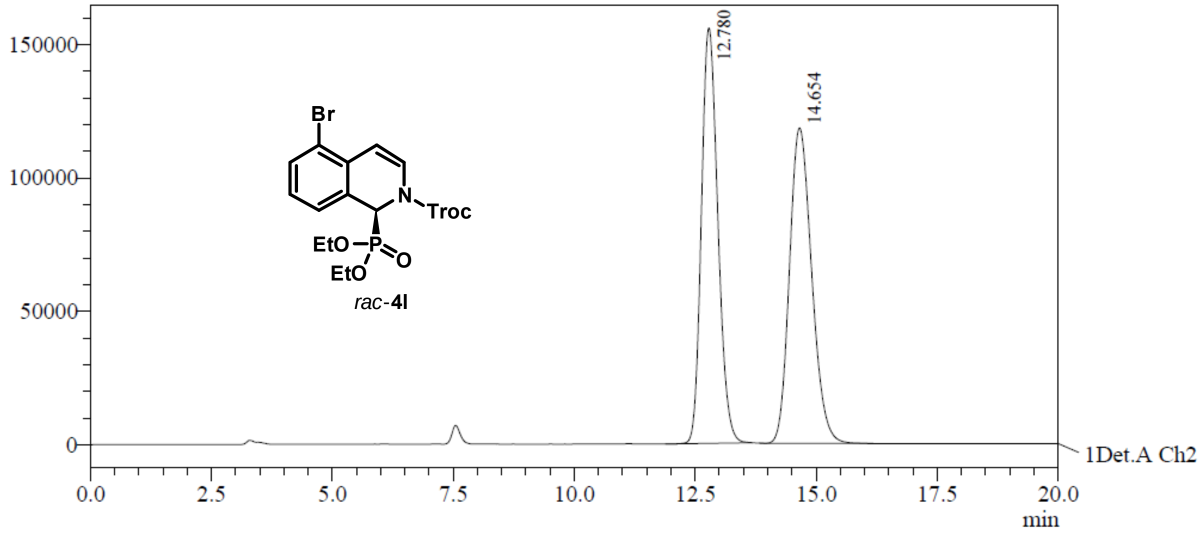
Detector A Ch2 254nm

Peak#	Ret. Time	Area	Area %
1	7.710	1979345	93.090
2	8.567	146933	6.910
Total		2126278	100.000


7.48
7.47
7.46
7.26
7.20
7.18
7.08
7.06
7.04
7.02
7.00
6.37
6.35
6.31
6.29
5.82
5.78
5.04
5.01
4.92
4.89
4.82
4.79
4.71
4.68
4.12
4.10
4.09
4.08
4.07
4.07
4.05
4.03
4.01
4.01
3.99
3.97
3.97
3.96
3.95
3.93
3.86
3.84
1.24
1.23
1.22
1.20
1.18
1.17
1.15
Br
N
Troc
EtO
P
O
EtO
4l
10
9
8
7
6
5
4
3
2
1
ppm
1.037
1.015
1.937
1.000
0.987
1.052
1.001
4.135
6.173


151.14
150.76
132.99
132.96
132.83
132.79
130.73
130.44
130.40
128.47
128.44
128.33
128.30
127.64
127.62
127.49
127.46
126.84
126.79
126.69
126.63
125.74
120.79
120.71
120.67
109.81
109.71
94.67
94.55
77.33
77.01
76.69
75.78
75.74
63.47
63.39
63.31
63.24
63.23
63.17
63.04
62.97
55.62
54.82
54.12
53.31
16.35
16.32
16.29
16.27
Br
N
Troc
EtO
P
O
EtO
4l
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

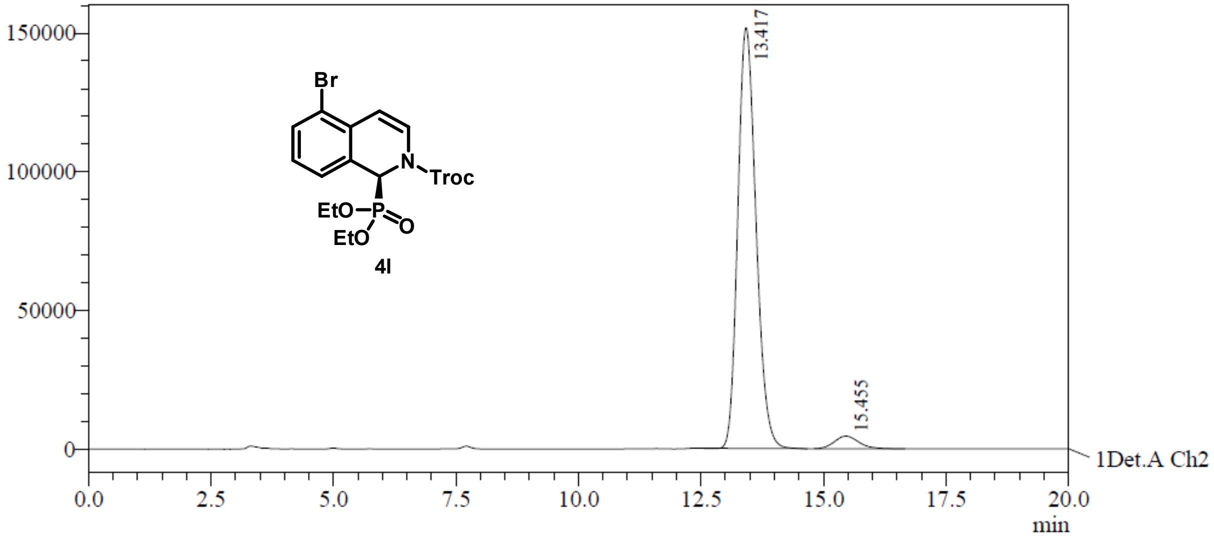

18.08
17.88
Br
N
Troc
EtO
P
O
EtO
4l
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
ppm



PeakTable

Detector A Ch2 254nm

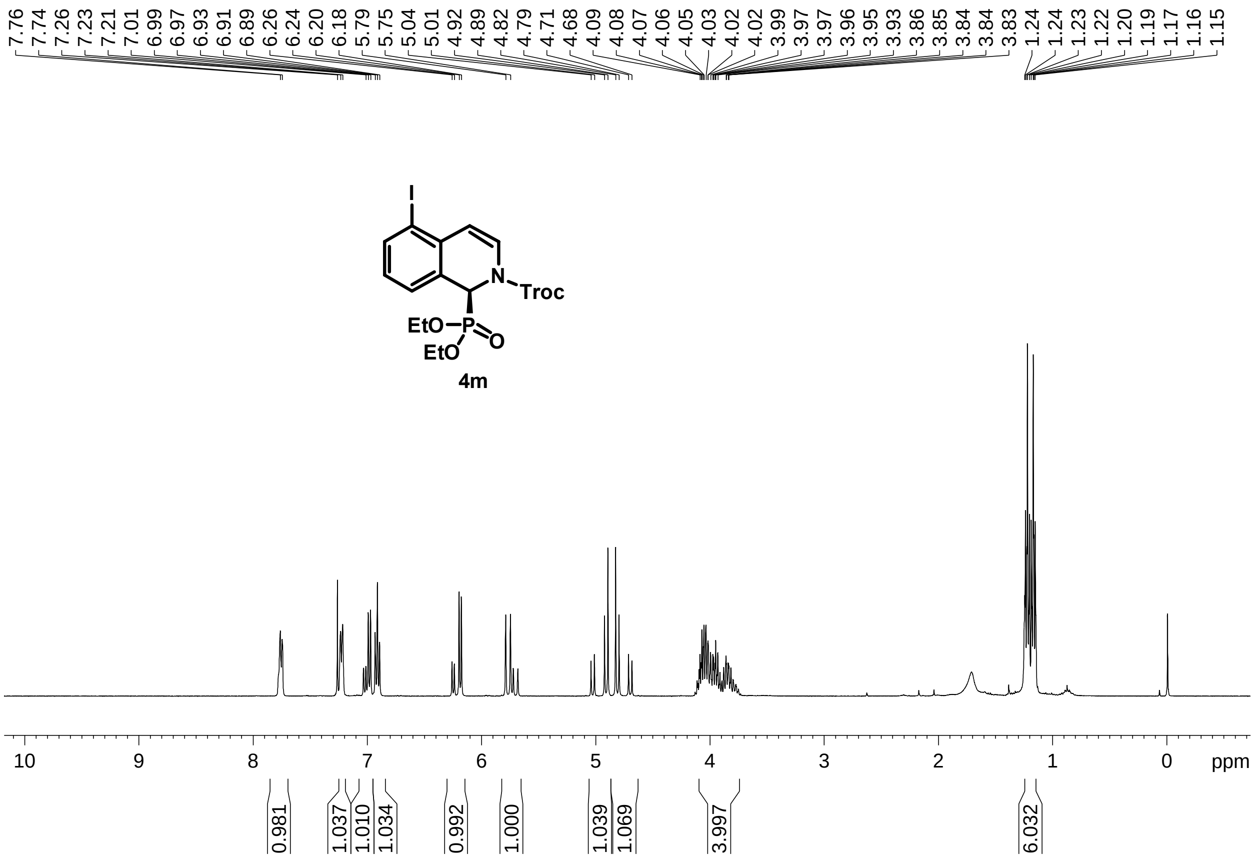
Peak#	Ret. Time	Area	Area %
1	12.780	3679931	49.340
2	14.654	3778402	50.660
Total		7458334	100.000

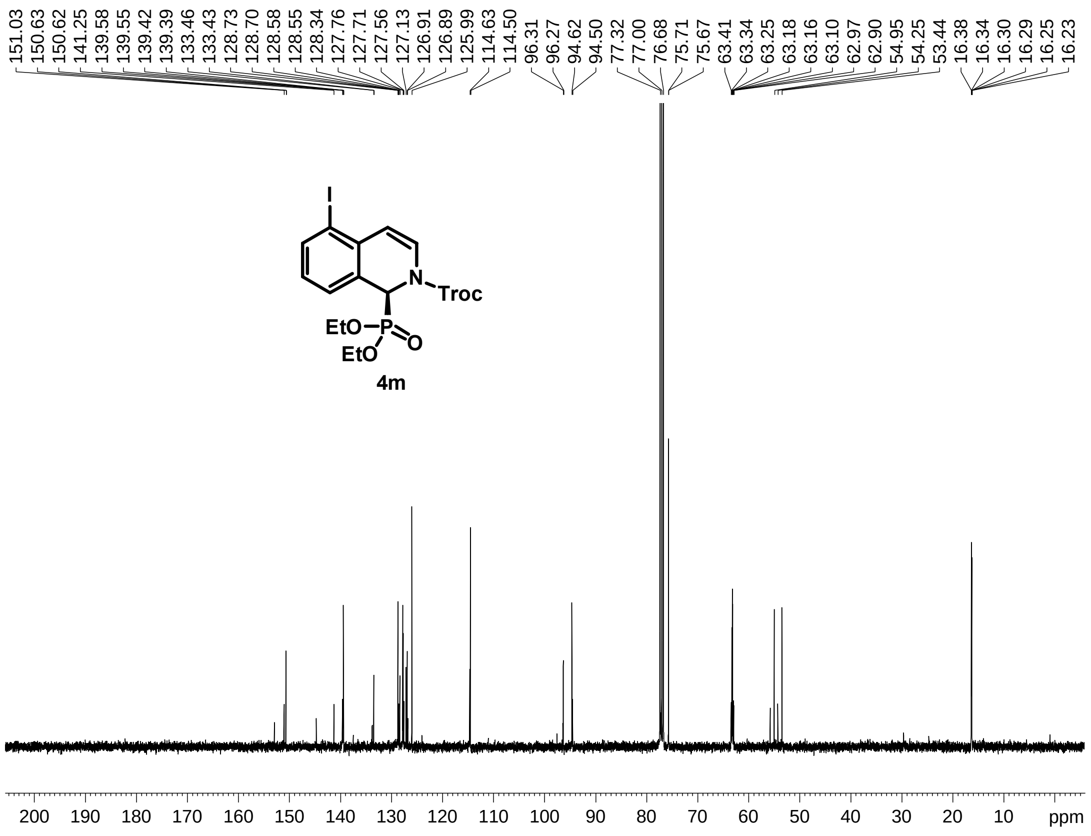


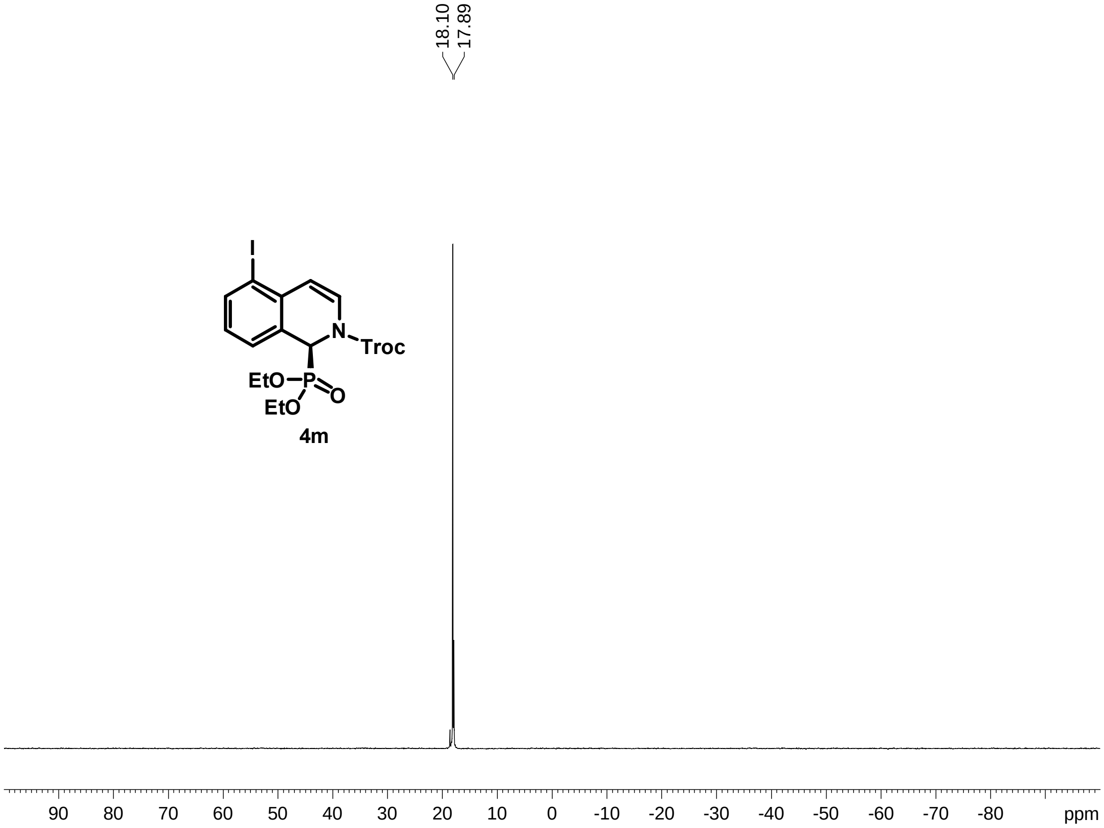
PeakTable

Detector A Ch2 254nm

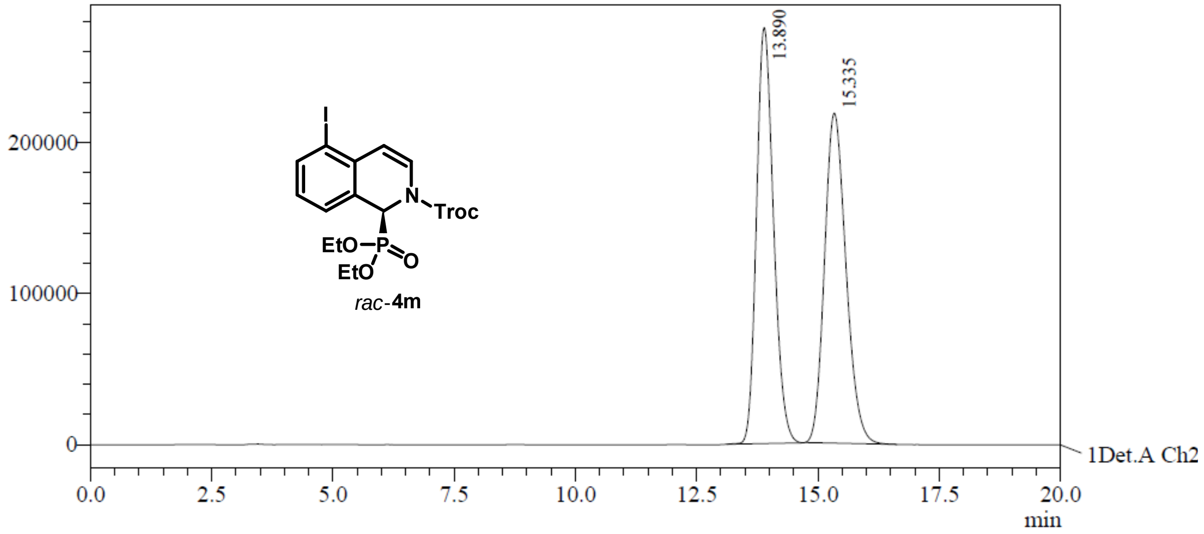
Peak#	Ret. Time	Area	Area %
1	13.417	3920271	96.184
2	15.455	155542	3.816
Total		4075813	100.000


7.76
7.74
7.26
7.23
7.21
7.01
6.99
6.97
6.93
6.91
6.89
6.26
6.24
6.20
6.18
5.79
5.75
5.04
5.01
4.92
4.89
4.82
4.79
4.71
4.68
4.09
4.08
4.07
4.06
4.05
4.03
4.02
4.02
3.99
3.97
3.97
3.96
3.95
3.93
3.86
3.85
3.84
3.84
3.83
1.24
1.24
1.23
1.22
1.20
1.19
1.17
1.16
1.15
I
N
Troc
EtO
P
O
EtO
4m
10
9
8
7
6
5
4
3
2
1
0
ppm
0.981
1.037
1.010
1.034
0.992
1.000
1.039
1.069
3.997
6.032


151.03
150.63
150.62
141.25
139.58
139.55
139.42
139.39
133.46
133.43
128.73
128.70
128.58
128.55
128.34
127.76
127.71
127.56
127.13
126.91
126.89
125.99
114.63
114.50
96.31
96.27
94.62
94.50
77.32
77.00
76.68
75.71
75.67
63.41
63.34
63.25
63.18
63.16
63.10
62.97
62.90
54.95
54.25
53.44
16.38
16.34
16.30
16.29
16.25
16.23
I
N
Troc
EtO
P
O
EtO
4m
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm


18.10
17.89
I
N
Troc
EtO
P
O
EtO
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
ppm

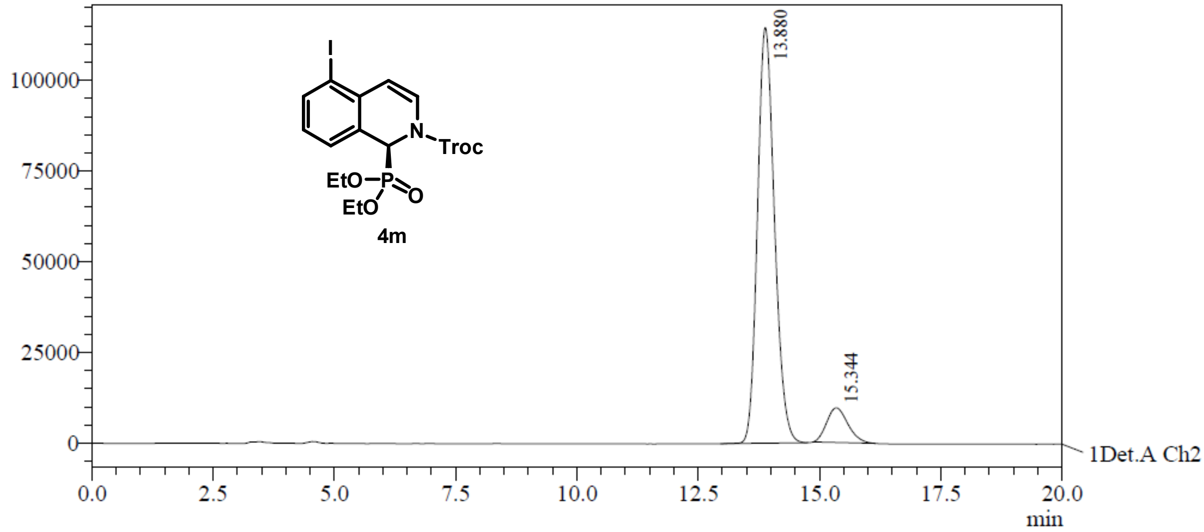
4m



PeakTable

Detector A Ch2 254nm

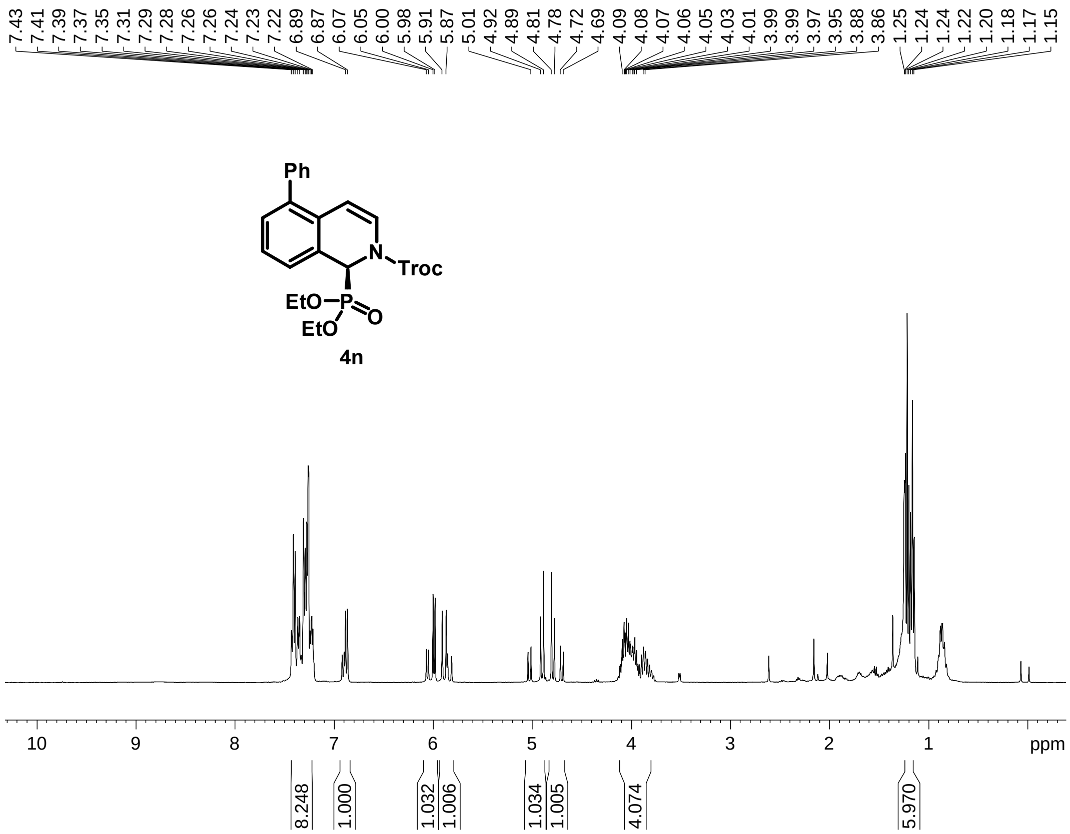
Peak#	Ret. Time	Area	Area %
1	13.890	6734073	50.033
2	15.335	6725119	49.967
Total		13459193	100.000

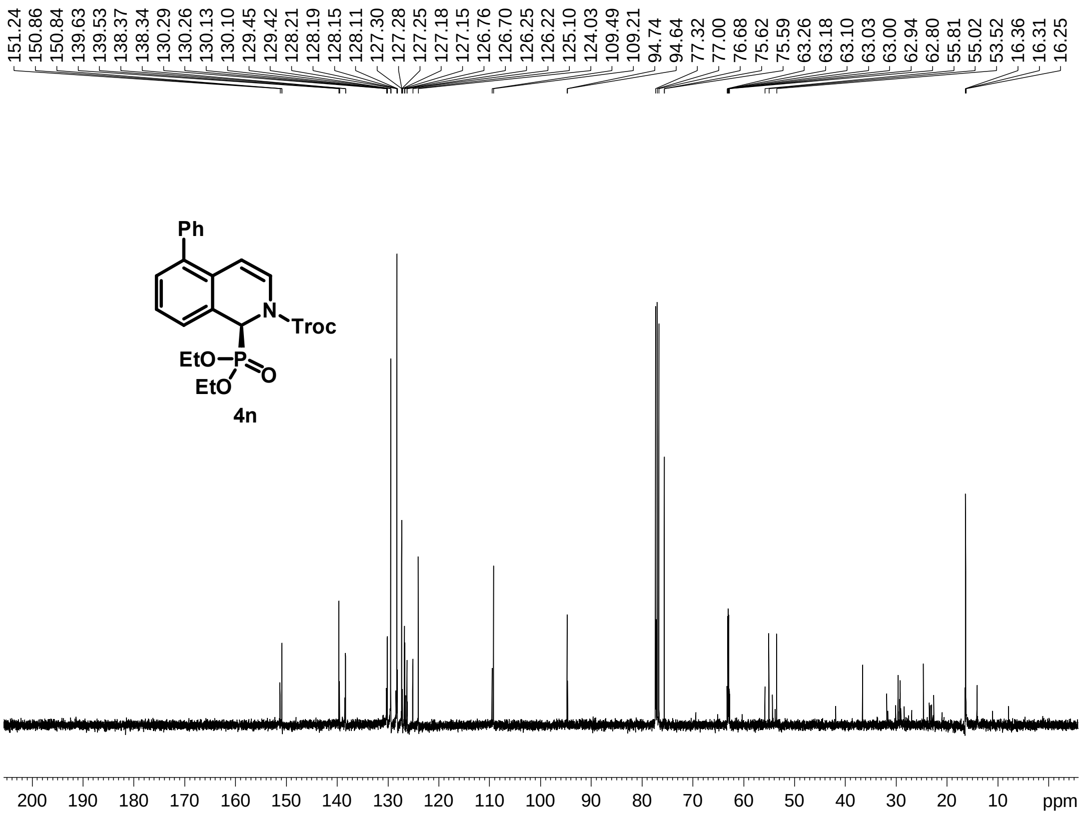


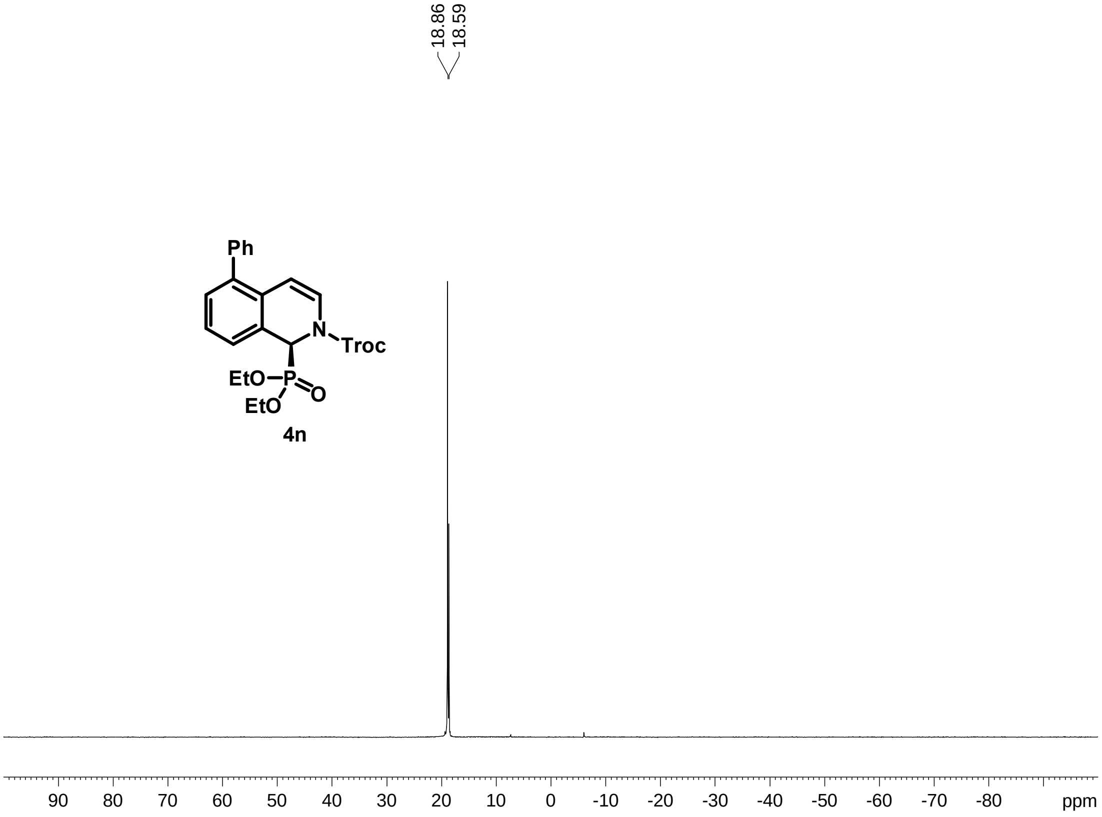
PeakTable

Detector A Ch2 254nm

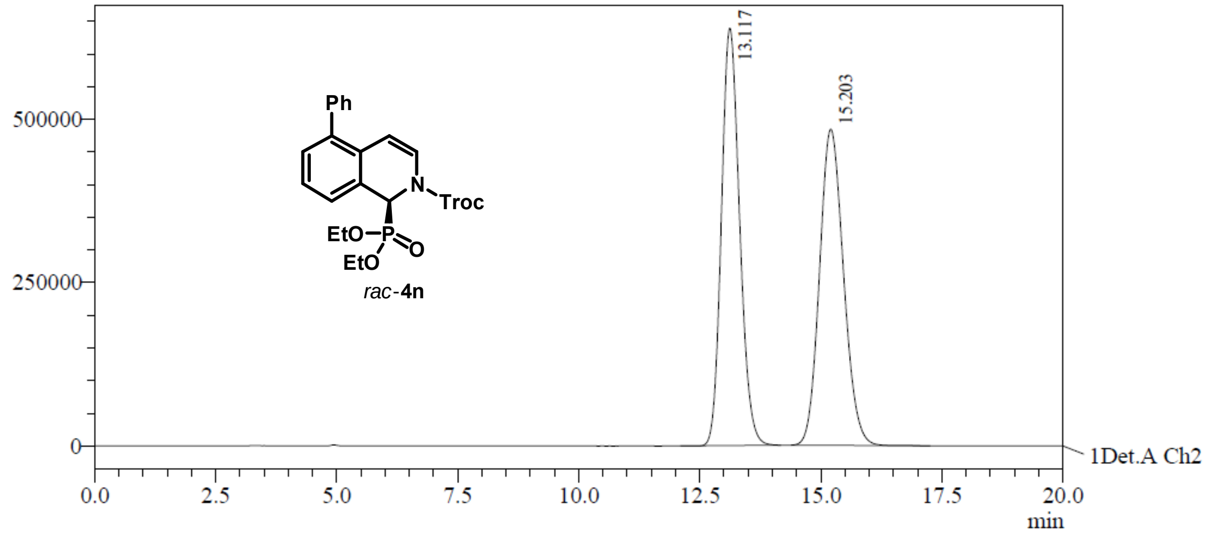
Peak#	Ret. Time	Area	Area %
1	13.880	2802849	90.589
2	15.344	291177	9.411
Total		3094027	100.000


7.43
7.41
7.39
7.37
7.35
7.31
7.29
7.28
7.26
7.26
7.24
7.23
7.22
6.89
6.87
6.07
6.05
6.00
5.98
5.91
5.87
5.01
4.92
4.89
4.81
4.78
4.72
4.69
4.09
4.08
4.07
4.06
4.05
4.03
4.01
3.99
3.99
3.97
3.95
3.88
3.86
1.25
1.24
1.24
1.22
1.20
1.18
1.17
1.15
Ph
N
Troc
EtO
P
O
EtO
4n
10
9
8
7
6
5
4
3
2
1
ppm
8.248
1.000
1.032
1.006
1.034
1.005
4.074
5.970


151.24
150.86
150.84
139.63
139.53
138.37
138.34
130.29
130.26
130.13
130.10
129.45
129.42
128.21
128.19
128.15
128.11
127.30
127.28
127.25
127.18
127.15
126.76
126.70
126.25
126.22
125.10
124.03
109.49
109.21
94.74
94.64
77.32
77.00
76.68
75.62
75.59
63.26
63.18
63.10
63.03
63.00
62.94
62.80
55.81
55.02
53.52
16.36
16.31
16.25
Ph
N
Troc
EtO
P
O
EtO
4n
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm


18.86
18.59
Ph
N
Troc
EtO
P
O
EtO
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
ppm

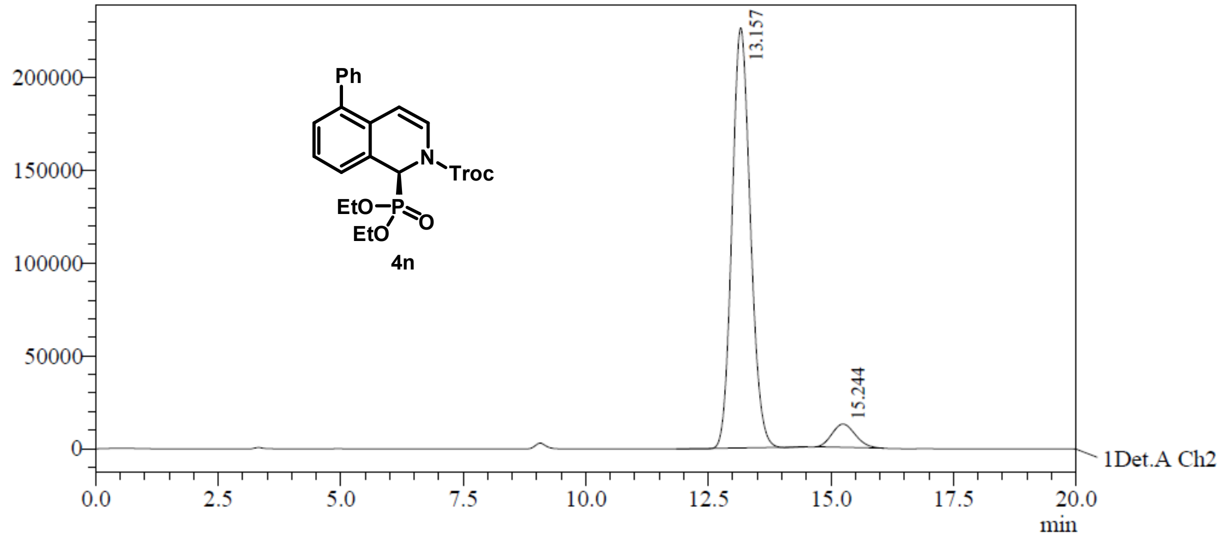
4n



PeakTable

Detector A Ch2 254nm

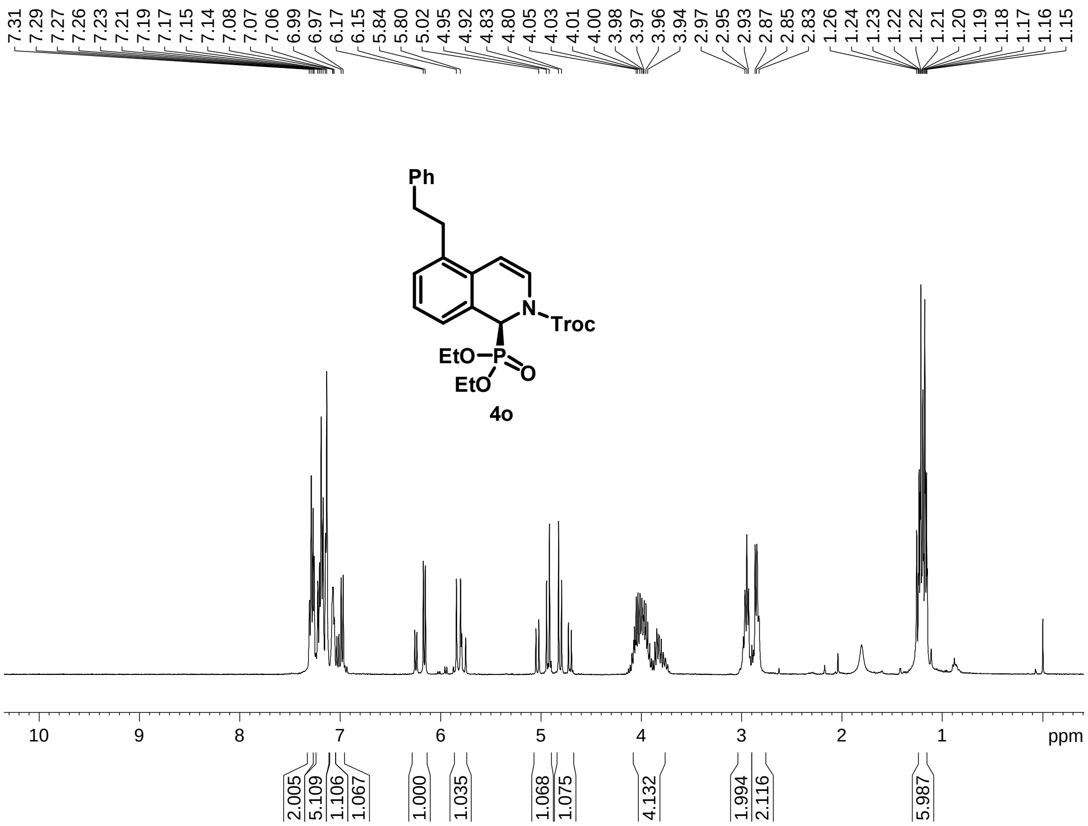
Peak#	Ret. Time	Area	Area %
1	13.117	16730044	50.059
2	15.203	16690302	49.941
Total		33420346	100.000

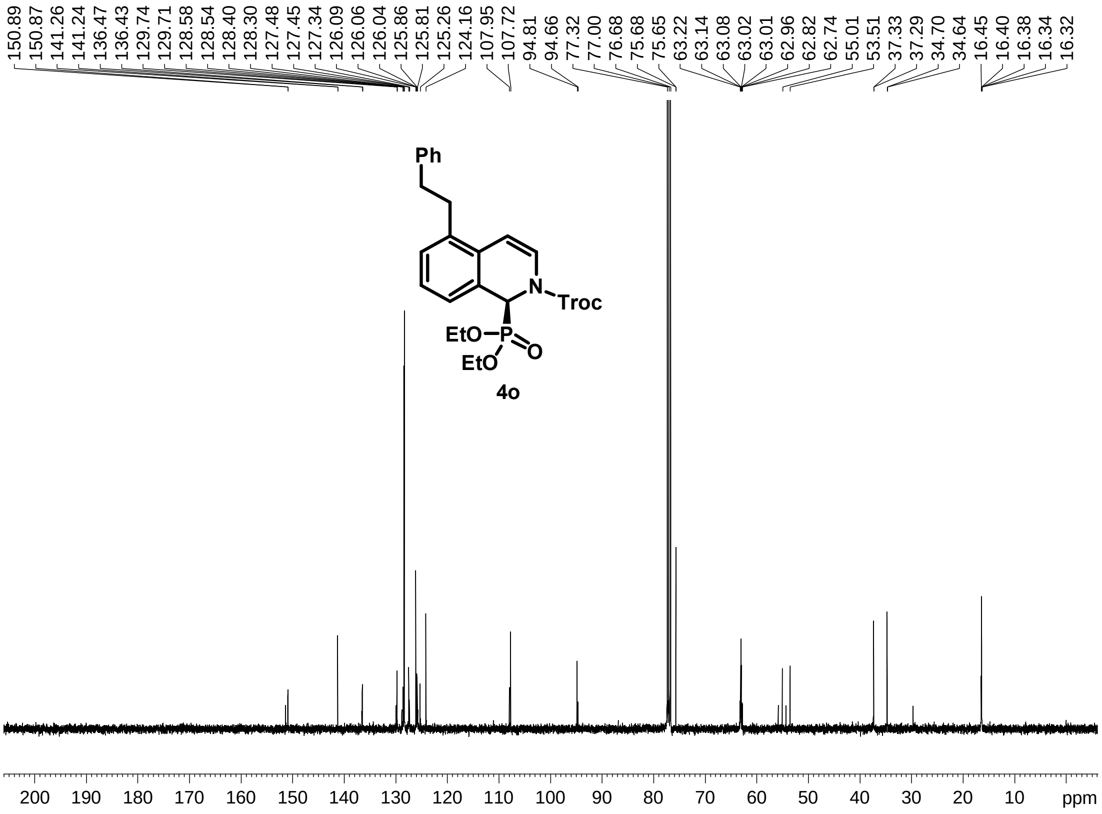


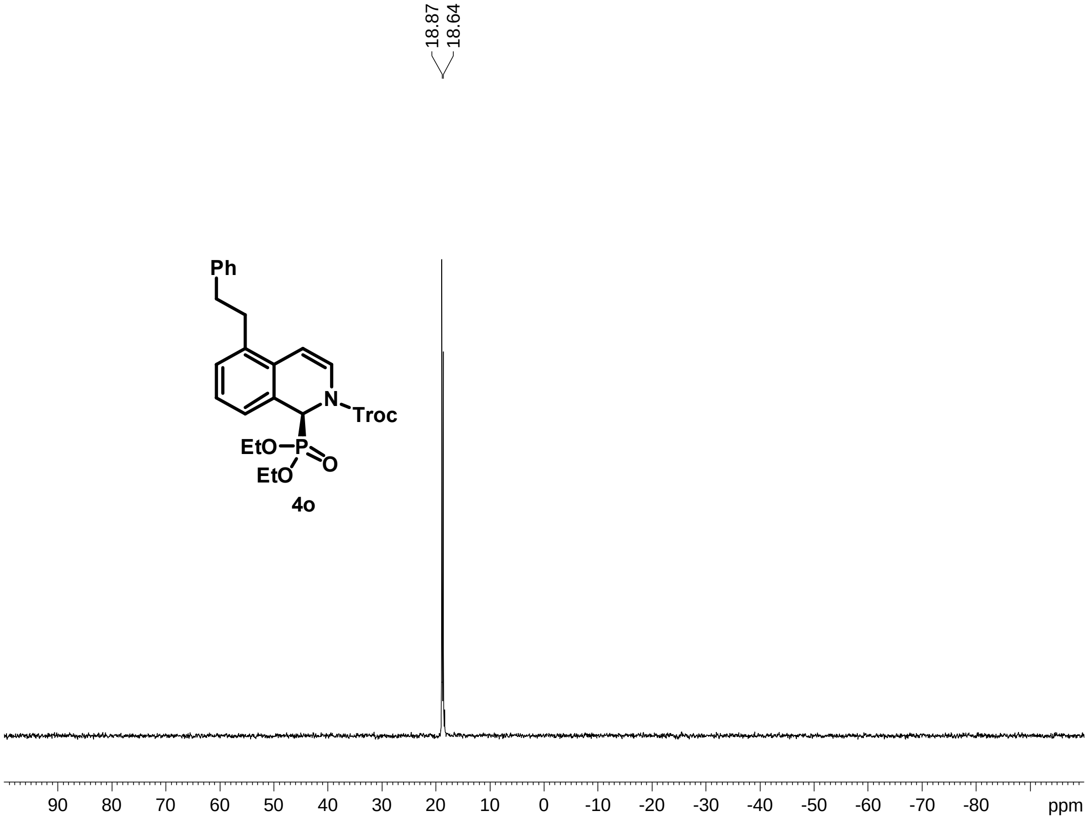
PeakTable

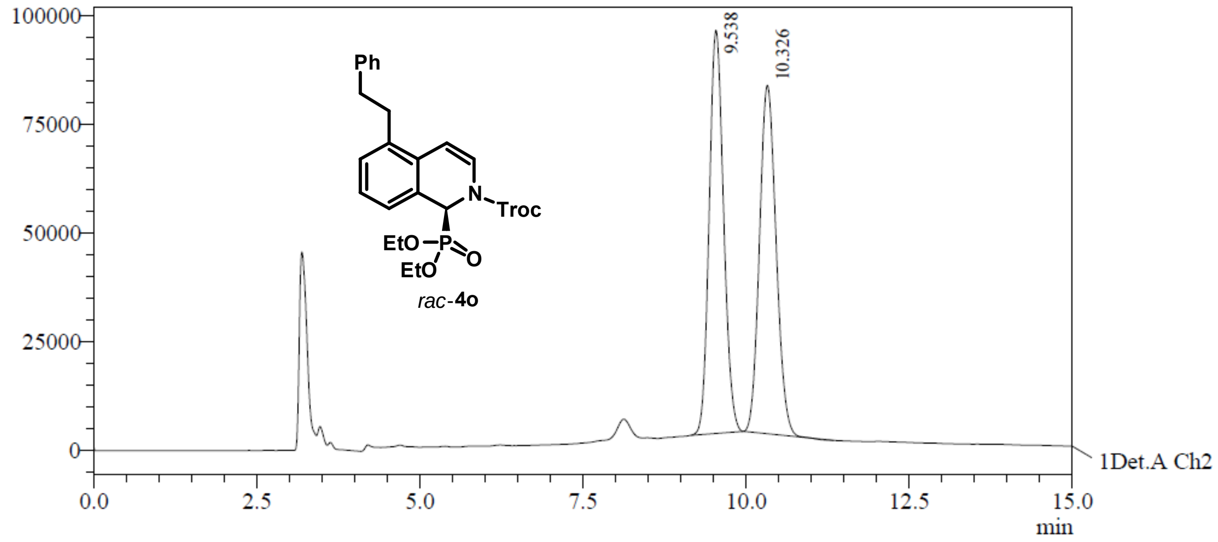
Detector A Ch2 254nm

Peak#	Ret. Time	Area	Area %
1	13.157	5896868	93.402
2	15.244	416549	6.598
Total		6313417	100.000


7.31 7.29 7.27 7.26 7.23 7.21 7.19 7.17 7.15 7.14 7.08 7.07 7.06 6.99 6.97 6.17 6.15 5.84 5.80 5.02 4.95 4.92 4.83 4.80 4.05 4.03 4.01 4.00 3.98 3.97 3.96 3.94 2.97 2.95 2.93 2.87 2.85 2.83 1.26 1.24 1.23 1.22 1.22 1.21 1.20 1.19 1.18 1.17 1.16 1.15
Ph
N
Troc
EtO
P
O
EtO
4o
10
9
8
7
6
5
4
3
2
1
ppm
2.005
5.109
1.106
1.067
1.000
1.035
1.068
1.075
4.132
1.994
2.116
5.987


150.89 150.87 141.26 141.24 136.47 136.43 129.74 129.71 128.58 128.54 128.40 128.30 127.48 127.45 127.34 126.09 126.06 126.04 125.86 125.81 125.26 124.16 107.95 107.72 94.81 94.66 77.32 77.00 76.68 75.68 75.65 63.22 63.14 63.08 63.02 63.01 62.96 62.82 62.74 55.01 53.51 37.33 37.29 34.70 34.64 16.45 16.40 16.38 16.34 16.32
Ph
N
Troc
EtO
P
O
EtO
4o
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm


18.87
18.64
Ph
N
Troc
EtO
P
O
EtO
4o
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
ppm

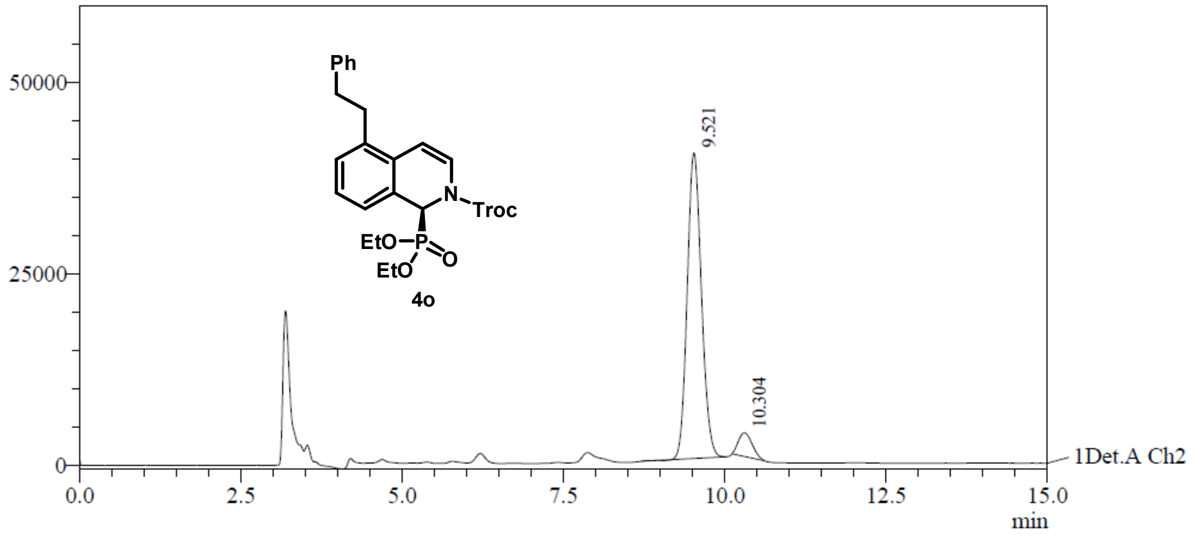


rac-**4o**

PeakTable

Detector A Ch2 254nm

Peak#	Ret. Time	Area	Area %
1	9.538	1426513	50.095
2	10.326	1421113	49.905
Total		2847626	100.000

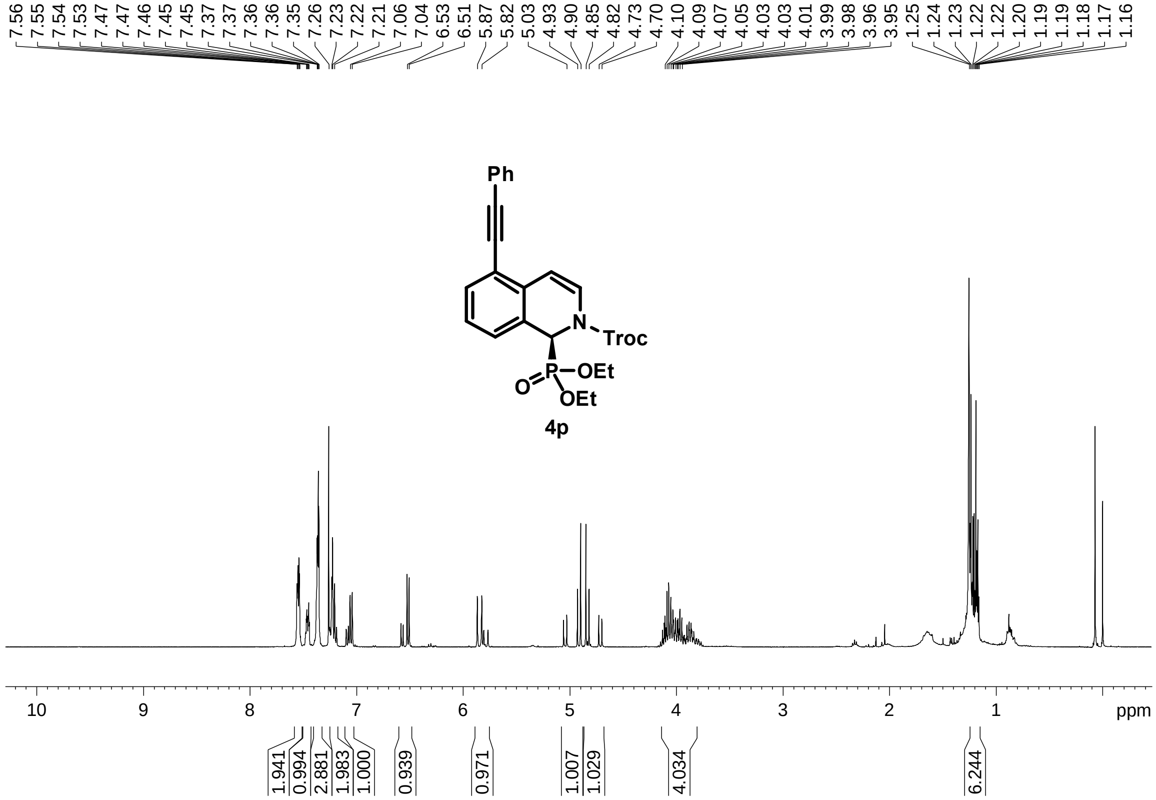


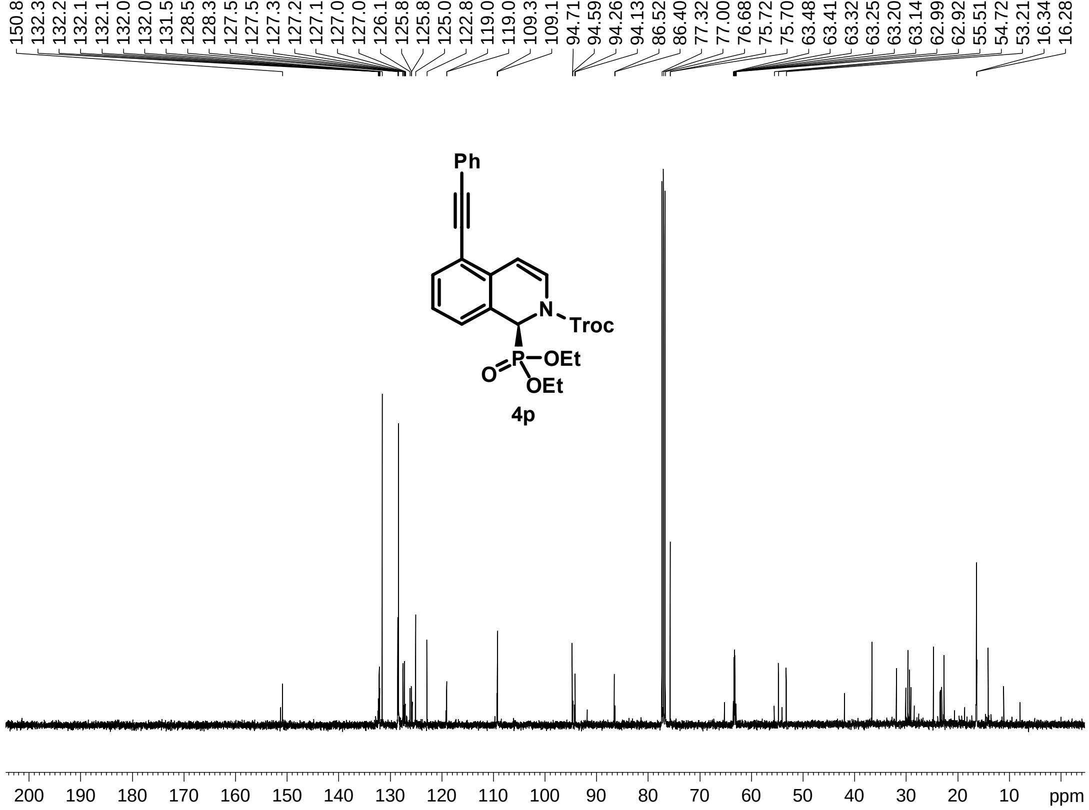
4o

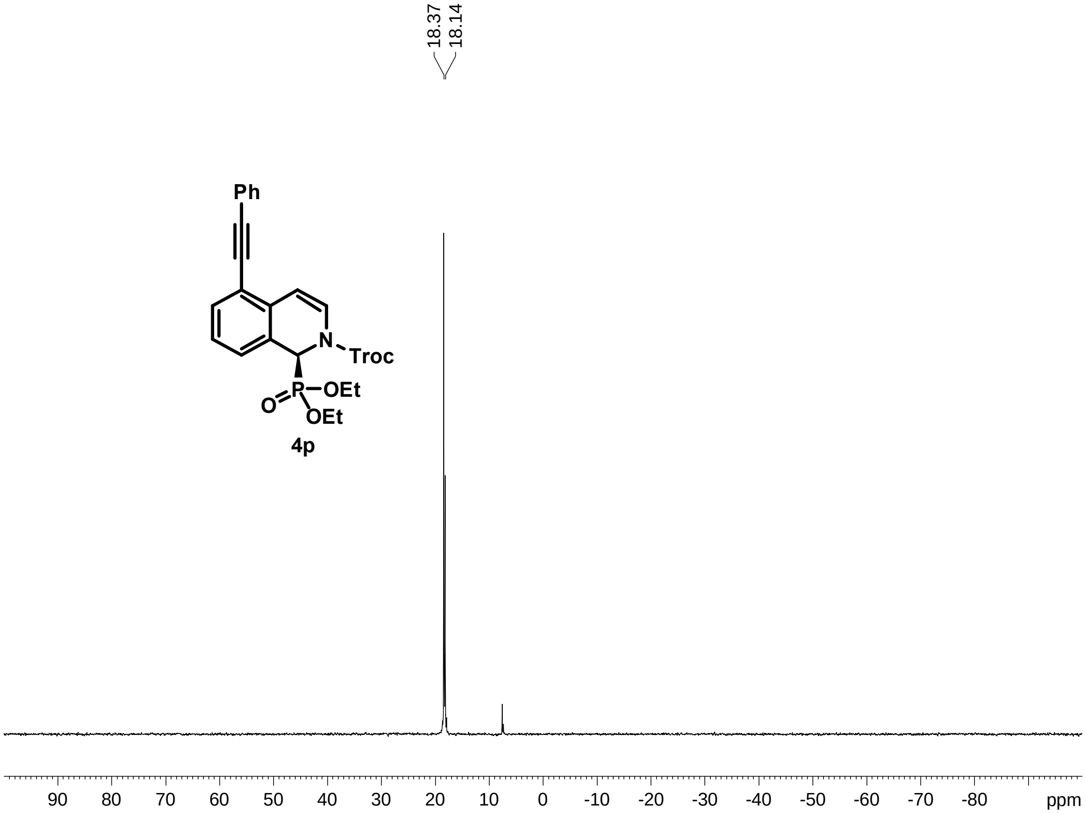
PeakTable

Detector A Ch2 254nm

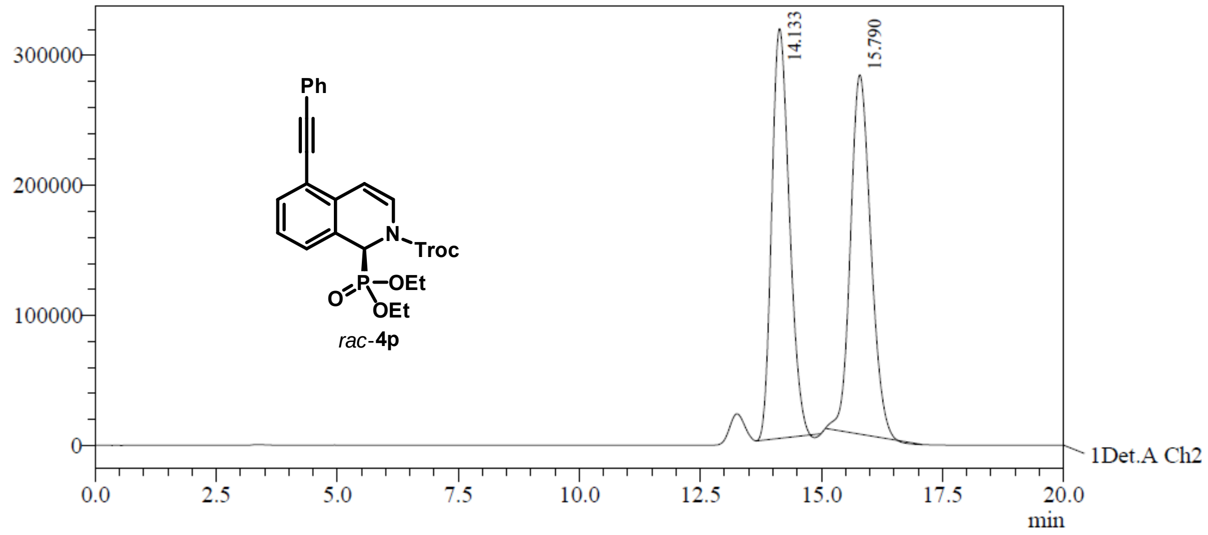
Peak#	Ret. Time	Area	Area %
1	9.521	611386	92.995
2	10.304	46053	7.005
Total		657439	100.000


7.56
7.55
7.54
7.53
7.47
7.47
7.46
7.45
7.45
7.37
7.37
7.36
7.36
7.35
7.26
7.23
7.22
7.21
7.06
7.04
6.53
6.51
5.87
5.82
5.03
4.93
4.90
4.85
4.82
4.73
4.70
4.10
4.09
4.07
4.05
4.03
4.03
4.01
3.99
3.98
3.96
3.95
1.25
1.24
1.23
1.22
1.22
1.20
1.19
1.19
1.18
1.17
1.16
Ph
N
Troc
P
OEt
O
OEt
4p
10
9
8
7
6
5
4
3
2
1
ppm
1.941
0.994
2.881
1.983
1.000
0.939
0.971
1.007
1.029
4.034
6.244


150.84
132.31
132.27
132.14
132.11
132.05
132.01
131.52
128.50
128.36
127.56
127.51
127.34
127.22
127.19
127.08
127.05
126.14
125.88
125.86
125.05
122.87
119.06
119.03
109.30
109.19
94.71
94.59
94.26
94.13
86.52
86.40
77.32
77.00
76.68
75.72
75.70
63.48
63.41
63.32
63.25
63.20
63.14
62.99
62.92
55.51
54.72
53.21
16.34
16.28
Ph
N
Troc
P
OEt
O
OEt
4p
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm


18.37
18.14
Ph
N
Troc
P
OEt
OEt
O
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
ppm

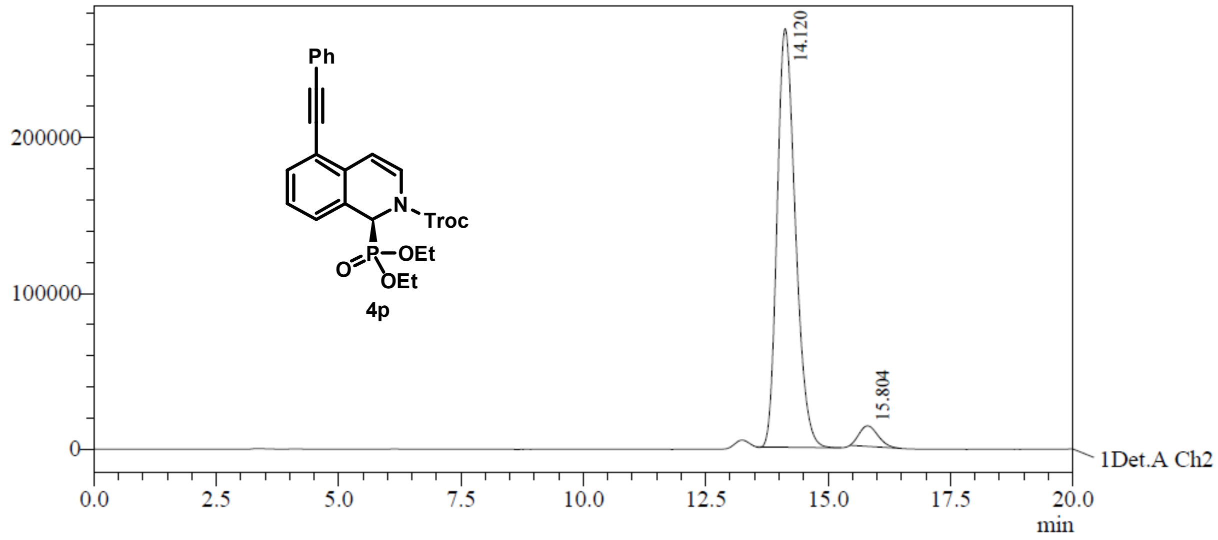
4p



PeakTable

Detector A Ch2 254nm

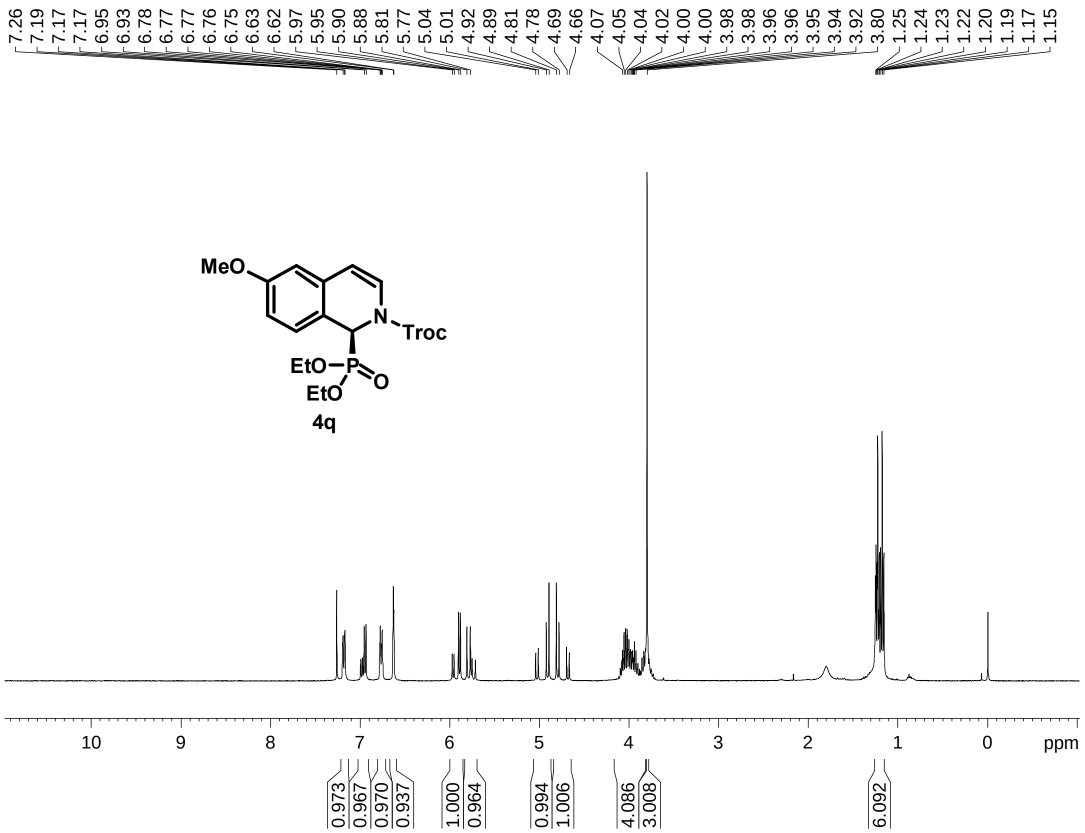
Peak#	Ret. Time	Area	Area %
1	14.133	7995621	49.764
2	15.790	8071519	50.236
Total		16067140	100.000

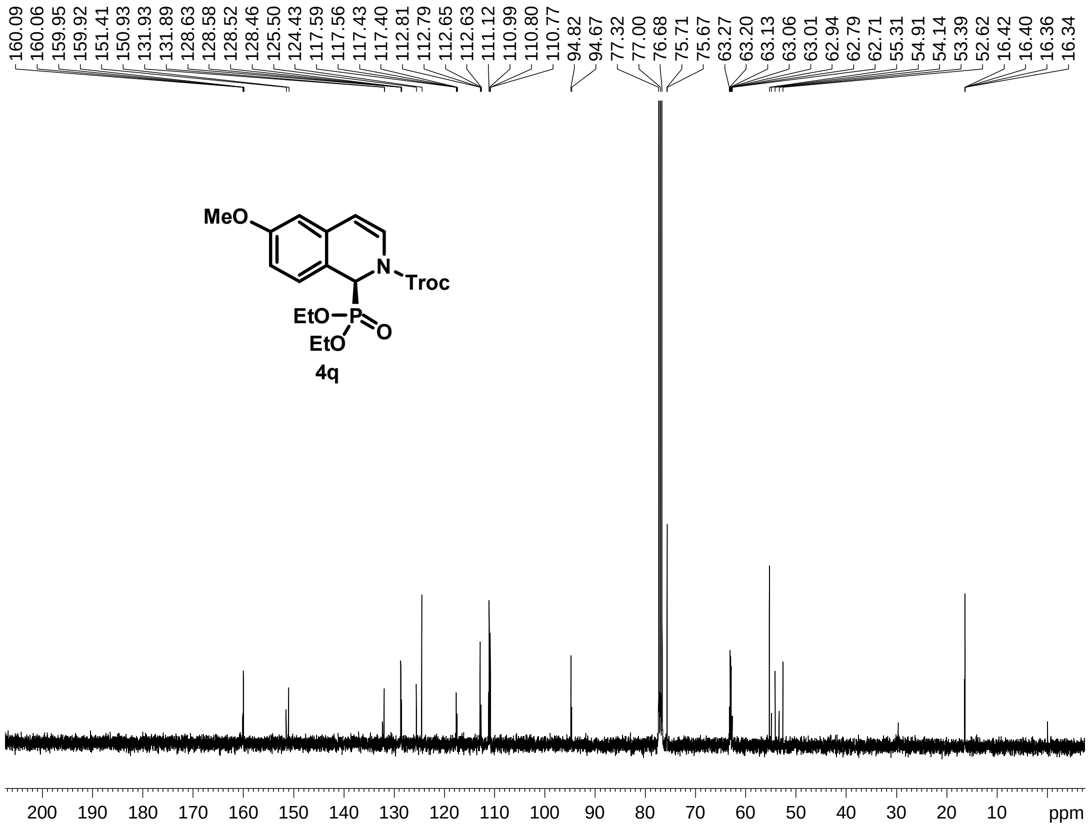


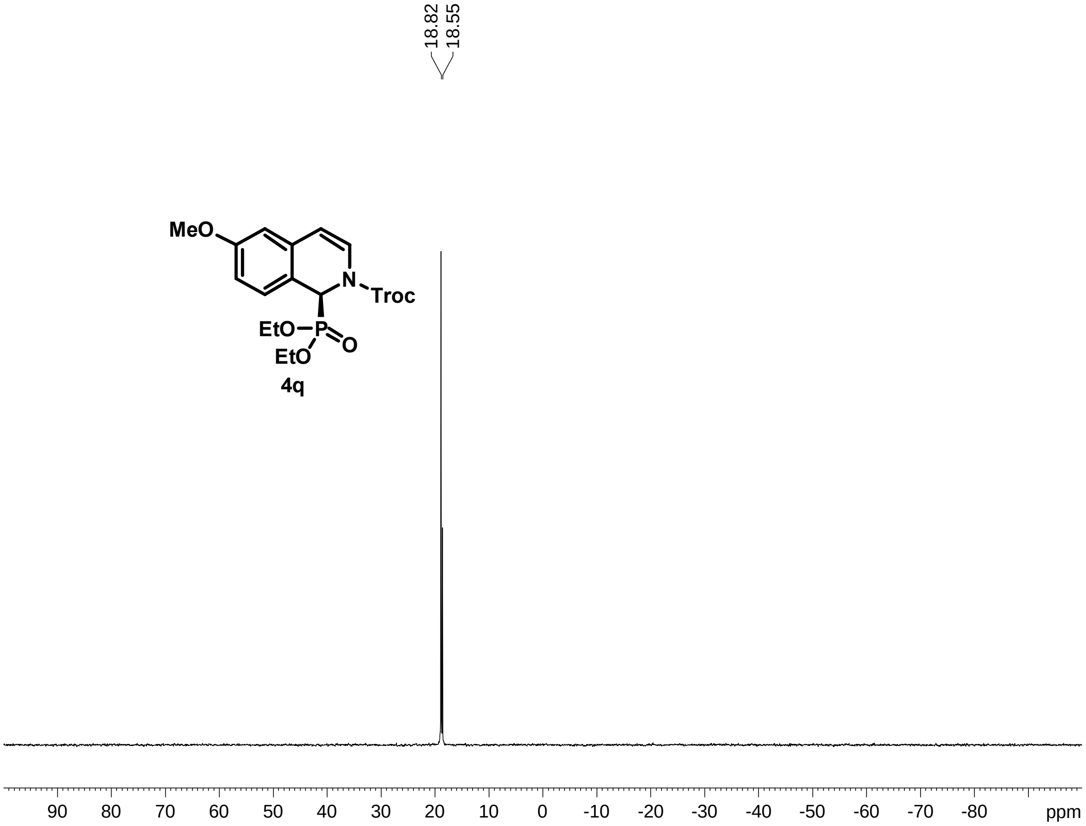
PeakTable

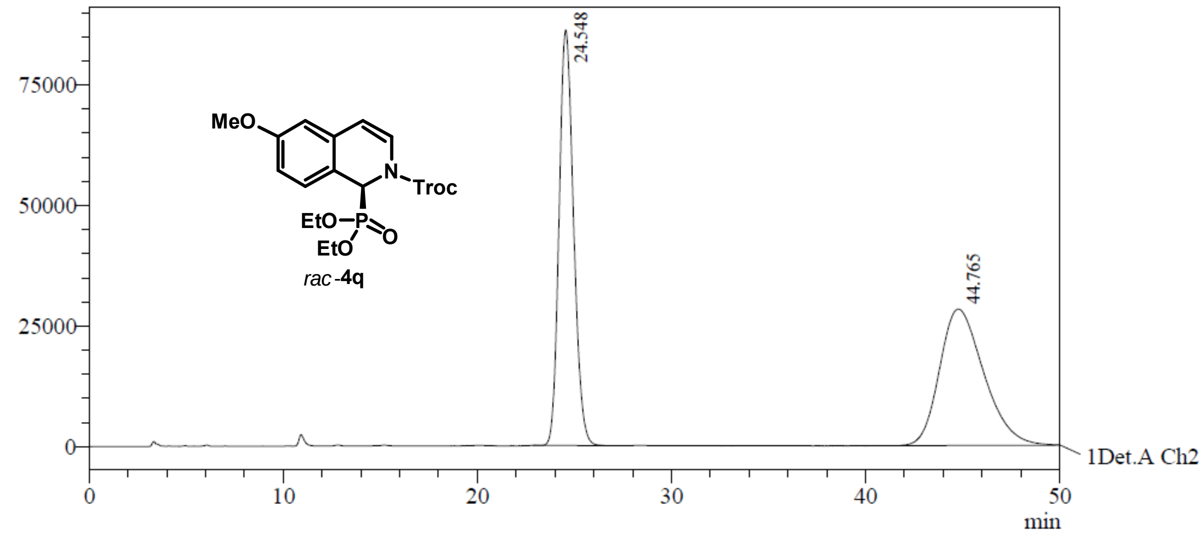
Detector A Ch2 254nm

Peak#	Ret. Time	Area	Area %
1	14.120	6992853	95.217
2	15.804	351291	4.783
Total		7344145	100.000


7.26
7.19
7.17
7.17
6.95
6.93
6.78
6.77
6.77
6.76
6.75
6.63
6.62
5.97
5.95
5.90
5.88
5.81
5.77
5.04
5.01
4.92
4.89
4.81
4.78
4.69
4.66
4.07
4.05
4.04
4.02
4.00
4.00
3.98
3.98
3.96
3.96
3.95
3.94
3.92
3.80
1.25
1.24
1.23
1.22
1.20
1.19
1.17
1.15
MeO
N
Troc
EtO
P
O
EtO
4q
10
9
8
7
6
5
4
3
2
1
0
ppm
0.973
0.967
0.970
0.937
1.000
0.964
0.994
1.006
4.086
3.008
6.092


160.09
160.06
159.95
159.92
151.41
150.93
131.93
131.89
128.63
128.58
128.52
128.46
125.50
124.43
117.59
117.56
117.43
117.40
112.81
112.79
112.65
112.63
111.12
110.99
110.80
110.77
94.82
94.67
77.32
77.00
76.68
75.71
75.67
63.27
63.20
63.13
63.06
63.01
62.94
62.79
62.71
55.31
54.91
54.14
53.39
52.62
16.42
16.40
16.36
16.34
MeO
N
Troc
EtO
P
O
EtO
4q
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

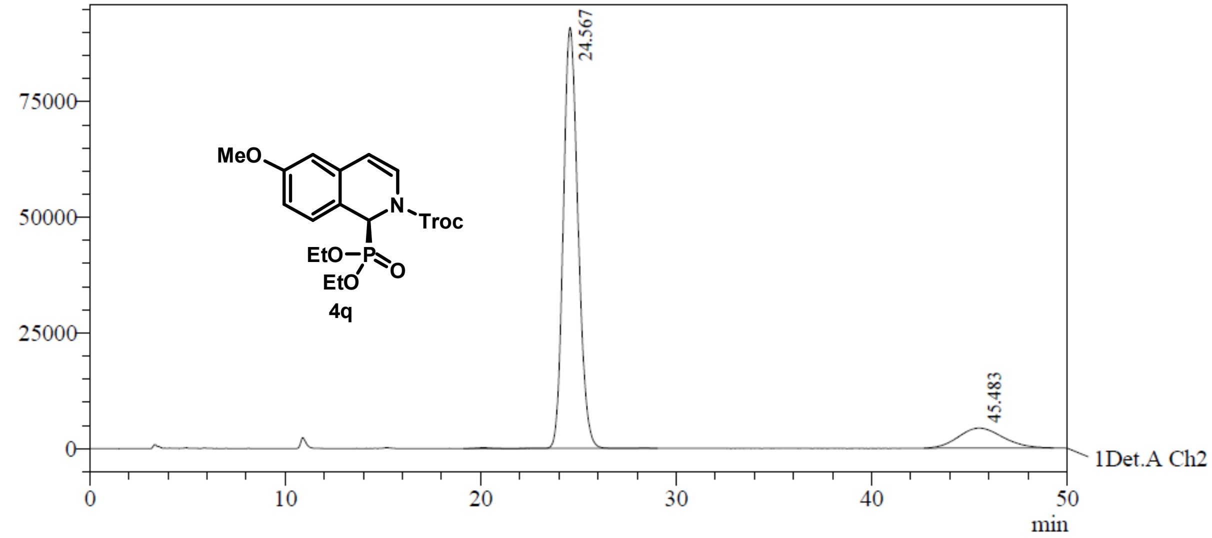

18.82
18.55
MeO
N
Troc
EtO
P
O
EtO
4q
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
ppm



PeakTable

Detector A Ch2 254nm

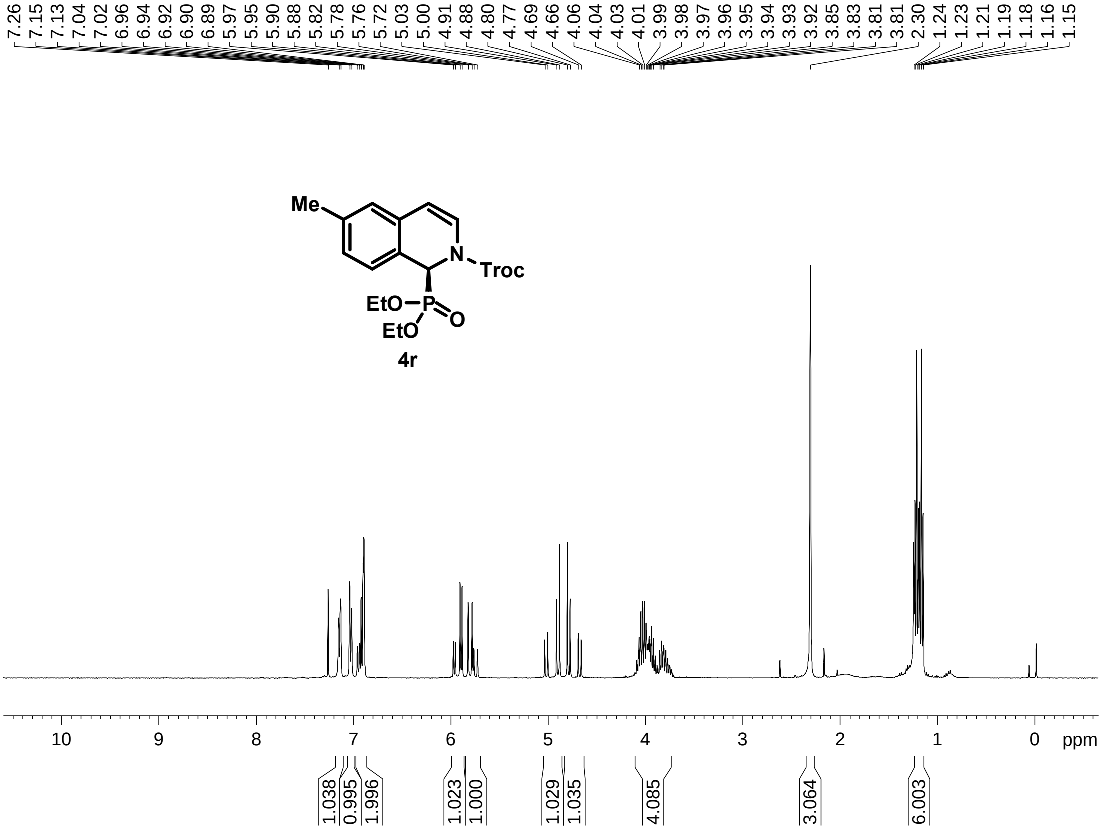
Peak#	Ret. Time	Area	Area %
1	24.548	4477321	49.967
2	44.765	4483204	50.033
Total		8960525	100.000

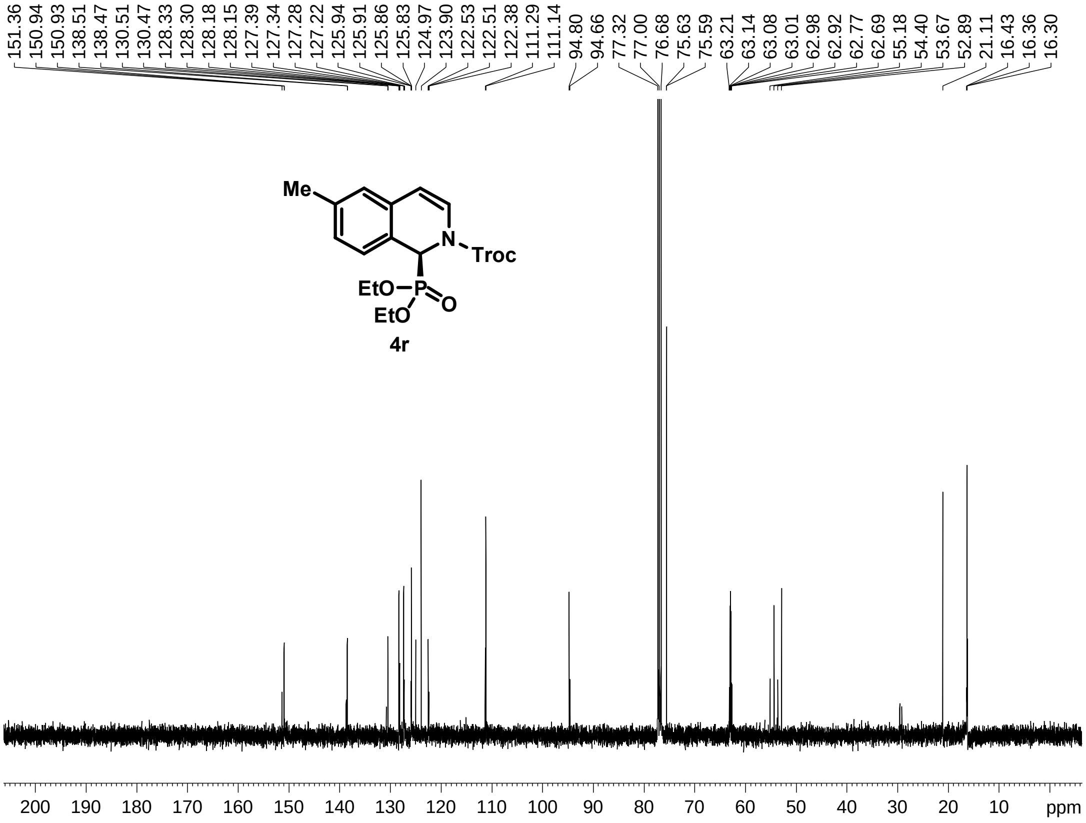


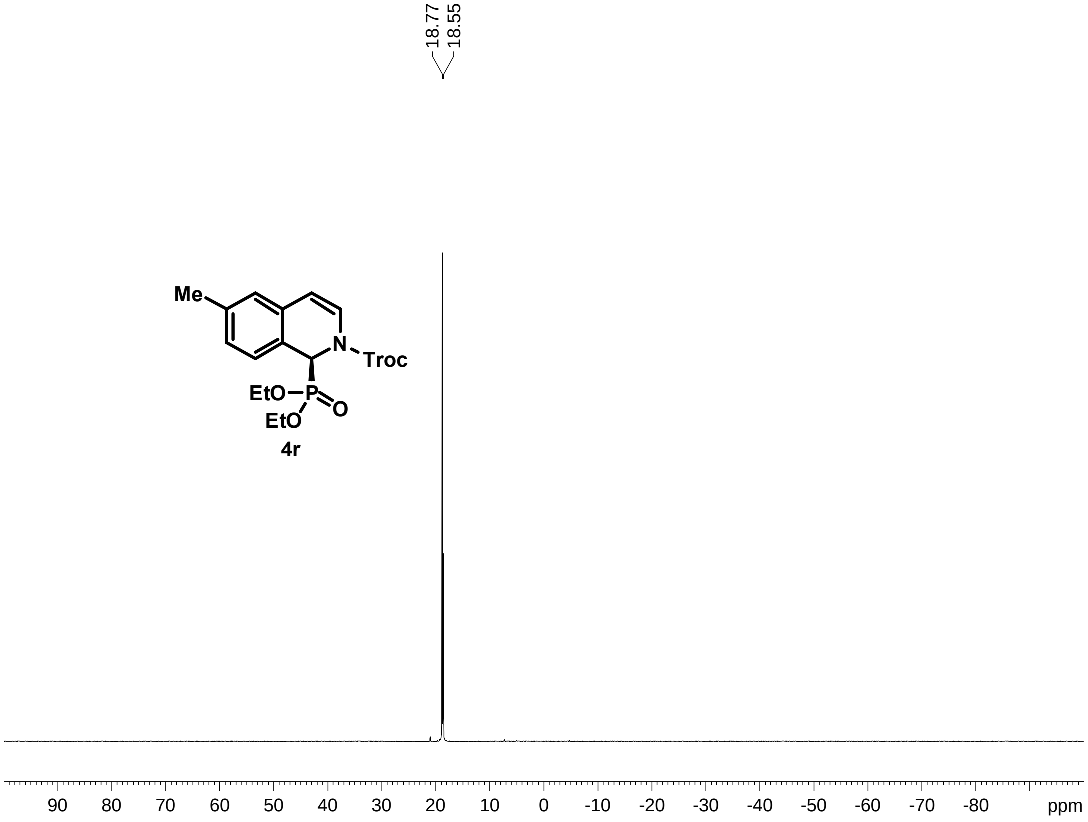
PeakTable

Detector A Ch2 254nm

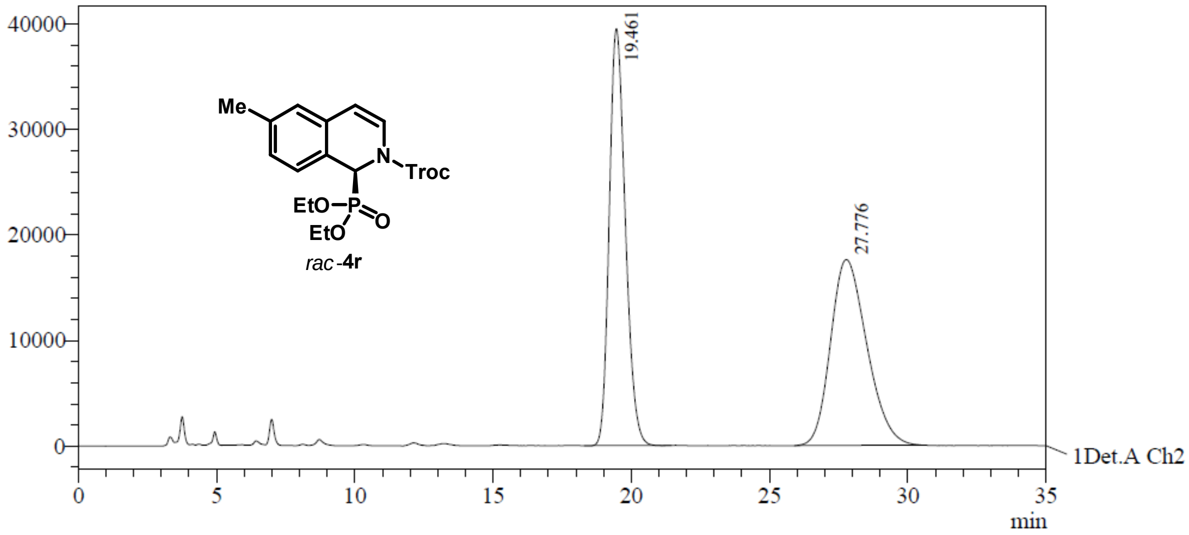
Peak#	Ret. Time	Area	Area %
1	24.567	4769892	87.506
2	45.483	681037	12.494
Total		5450929	100.000


7.26
7.15
7.13
7.04
7.02
6.96
6.94
6.92
6.90
6.89
5.97
5.95
5.90
5.88
5.82
5.78
5.76
5.72
5.03
5.00
4.91
4.88
4.80
4.77
4.69
4.66
4.06
4.04
4.03
4.01
3.99
3.98
3.97
3.96
3.95
3.94
3.93
3.92
3.85
3.83
3.81
3.81
2.30
1.24
1.23
1.21
1.19
1.18
1.16
1.15
Me
N
Troc
EtO
P
O
EtO
4r
10
9
8
7
6
5
4
3
2
1
0
ppm
1.038
0.995
1.996
1.023
1.000
1.029
1.035
4.085
3.064
6.003


151.36
150.94
150.93
138.51
138.47
130.51
130.47
128.33
128.30
128.18
128.15
127.39
127.34
127.28
127.22
125.94
125.91
125.86
125.83
124.97
123.90
122.53
122.51
122.38
111.29
111.14
94.80
94.66
77.32
77.00
76.68
75.63
75.59
63.21
63.14
63.08
63.01
62.98
62.92
62.77
62.69
55.18
54.40
53.67
52.89
21.11
16.43
16.36
16.30
Me
N
Troc
EtO
P
O
EtO
4r
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm


18.77
18.55
Me
N
Troc
EtO
P
O
EtO
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
ppm

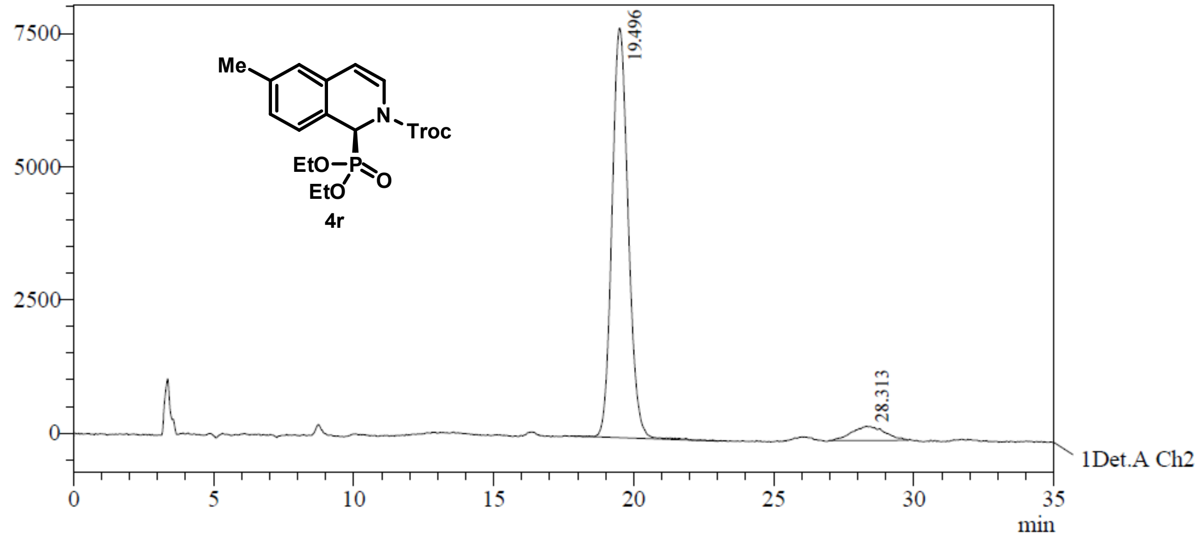
4r



PeakTable

Detector A Ch2 254nm

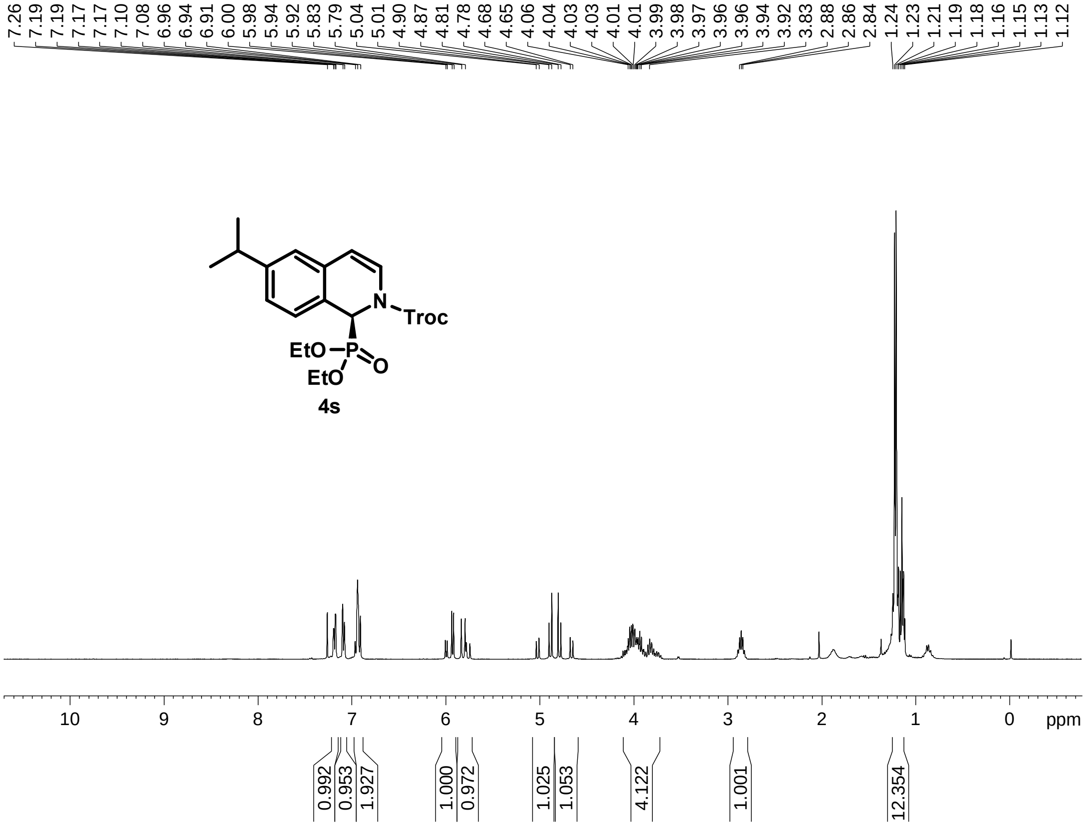
Peak#	Ret. Time	Area	Area %
1	19.461	1599866	49.892
2	27.776	1606801	50.108
Total		3206667	100.000

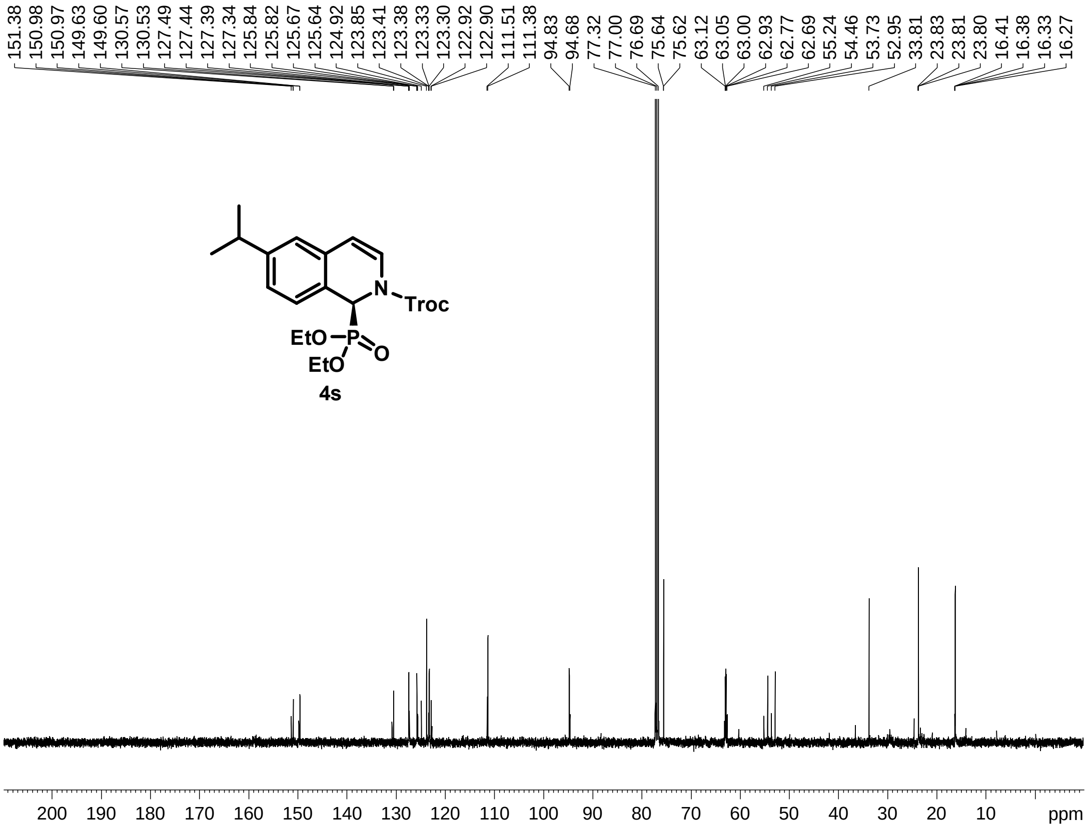


PeakTable

Detector A Ch2 254nm

Peak#	Ret. Time	Area	Area %
1	19.496	309932	93.506
2	28.313	21524	6.494
Total		331456	100.000


7.26
7.19
7.19
7.17
7.17
7.10
7.08
6.96
6.94
6.91
6.00
5.98
5.94
5.92
5.83
5.79
5.04
5.01
4.90
4.87
4.81
4.78
4.68
4.65
4.06
4.04
4.03
4.03
4.01
4.01
3.99
3.98
3.97
3.96
3.96
3.94
3.92
3.83
2.88
2.86
2.84
1.24
1.23
1.21
1.19
1.18
1.16
1.15
1.13
1.12
N
Troc
EtO
P
O
EtO
4s
10
9
8
7
6
5
4
3
2
1
0
ppm
0.992
0.953
1.927
1.000
0.972
1.025
1.053
4.122
1.001
12.354


151.38
150.98
150.97
149.63
149.60
130.57
130.53
127.49
127.44
127.39
127.34
125.84
125.82
125.67
125.64
124.92
123.85
123.41
123.38
123.33
123.30
122.92
122.90
111.51
111.38
94.83
94.68
77.32
77.00
76.69
75.64
75.62
63.12
63.05
63.00
62.93
62.77
62.69
55.24
54.46
53.73
52.95
33.81
23.83
23.81
23.80
16.41
16.38
16.33
16.27
N
Troc
EtO
P
O
EtO
4s
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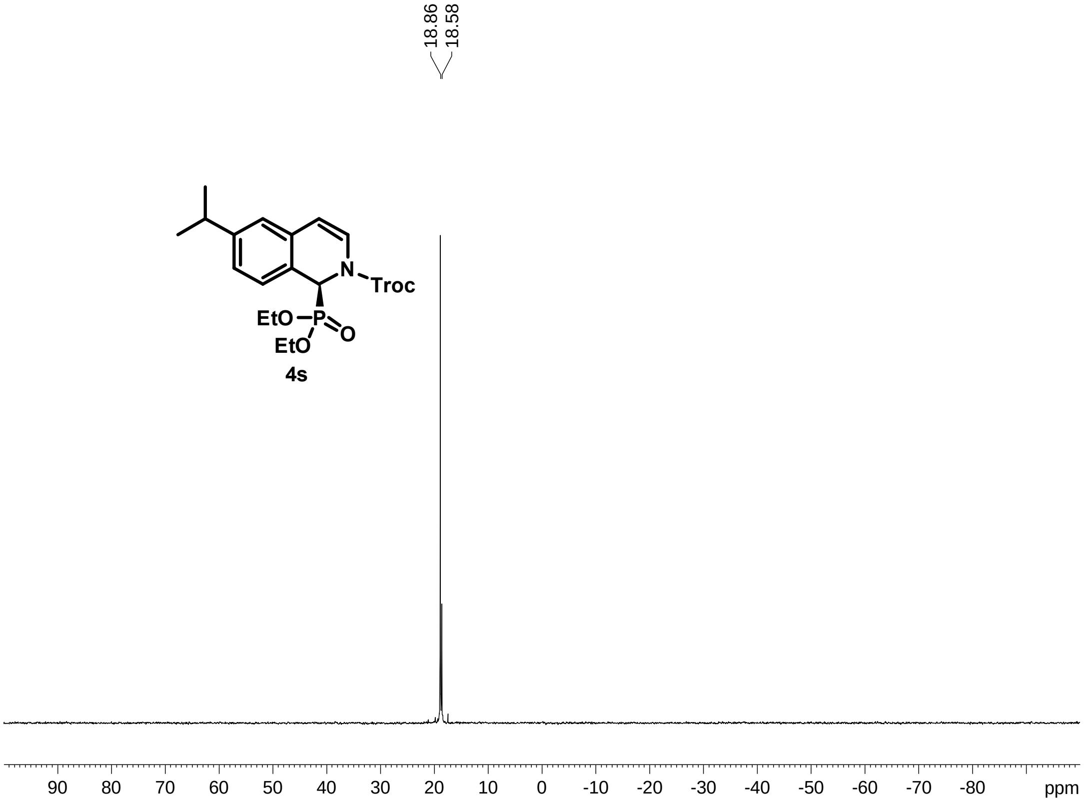
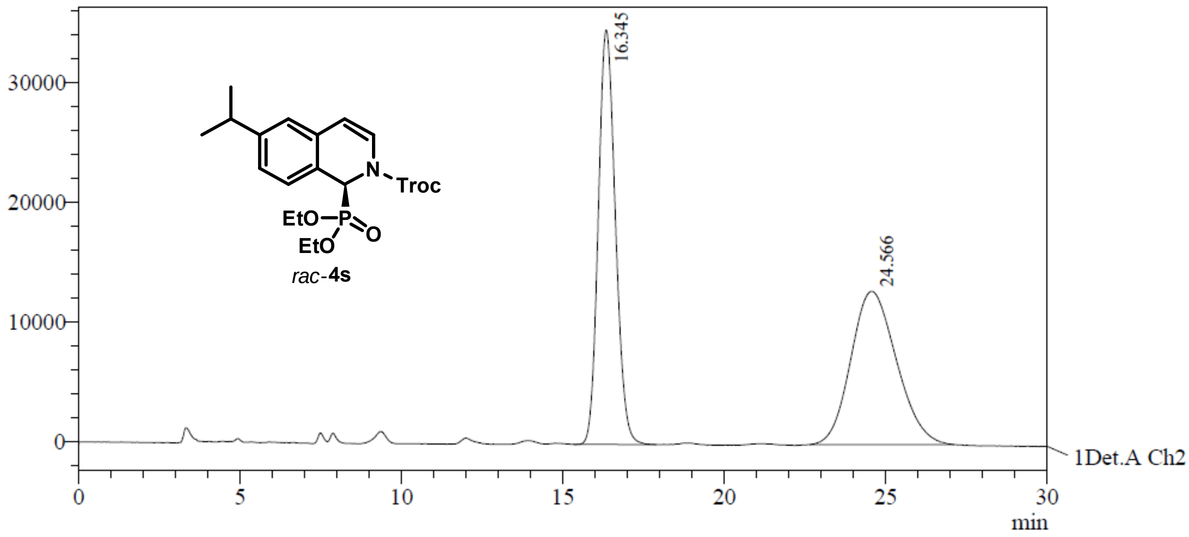
50
40
30
20
10
ppm

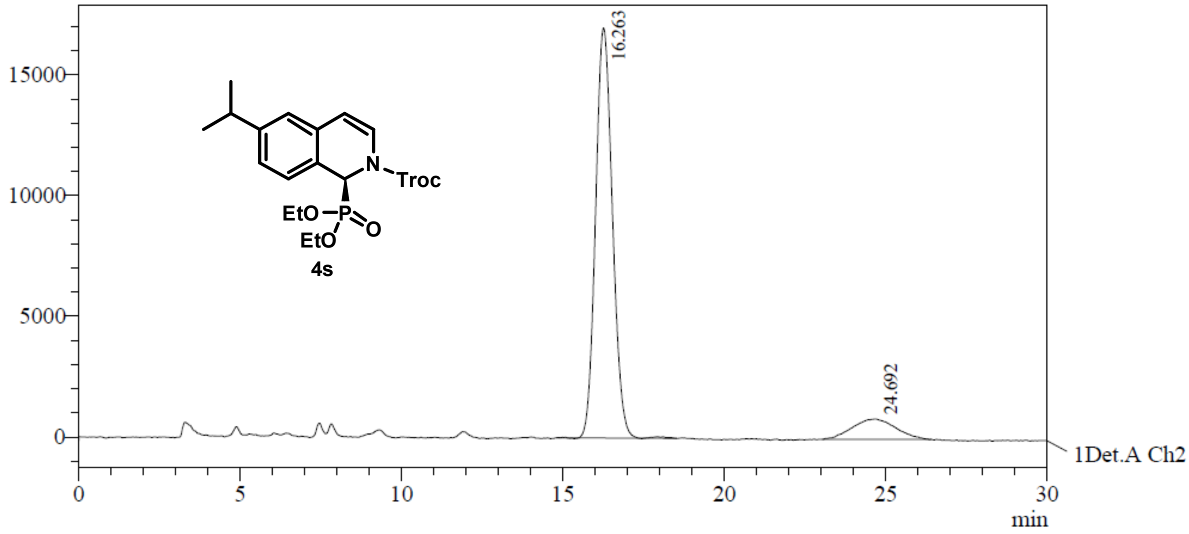

18.86
18.58
N
Troc
EtO
P
O
EtO
4s
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
ppm



PeakTable

Detector A Ch2 254nm

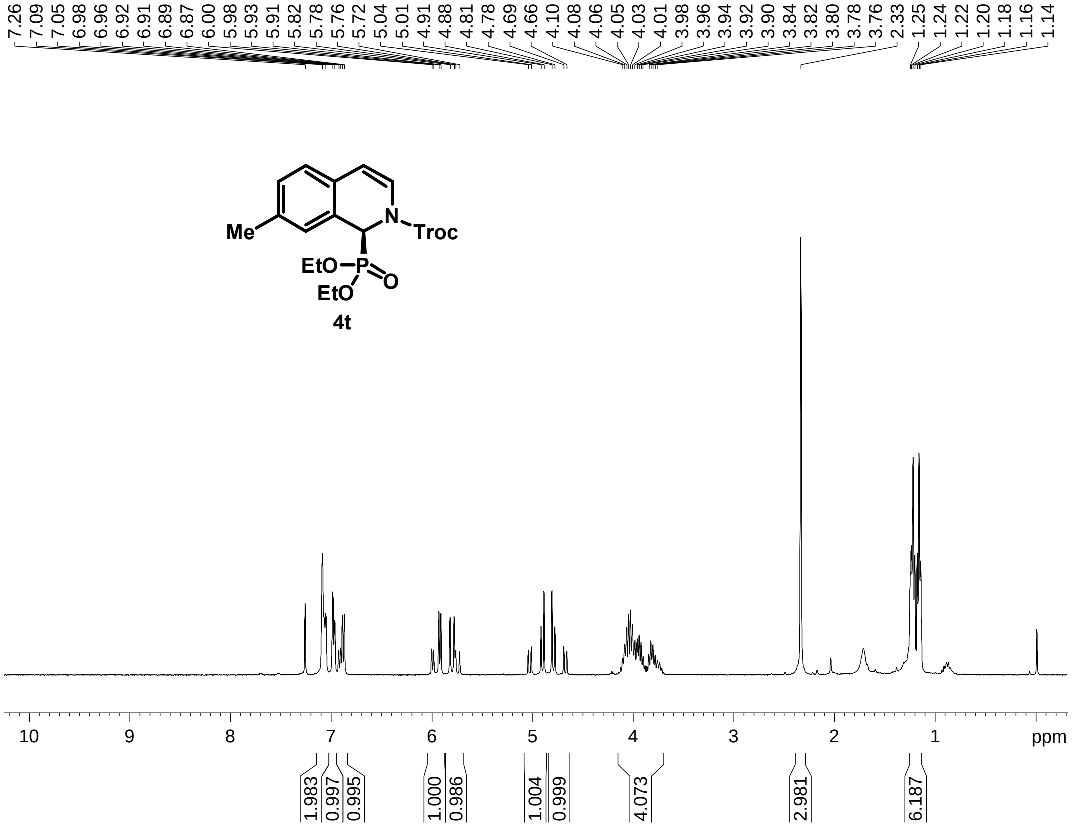
Peak#	Ret. Time	Area	Area %
1	16.345	1277609	50.391
2	24.566	1257779	49.609
Total		2535388	100.000

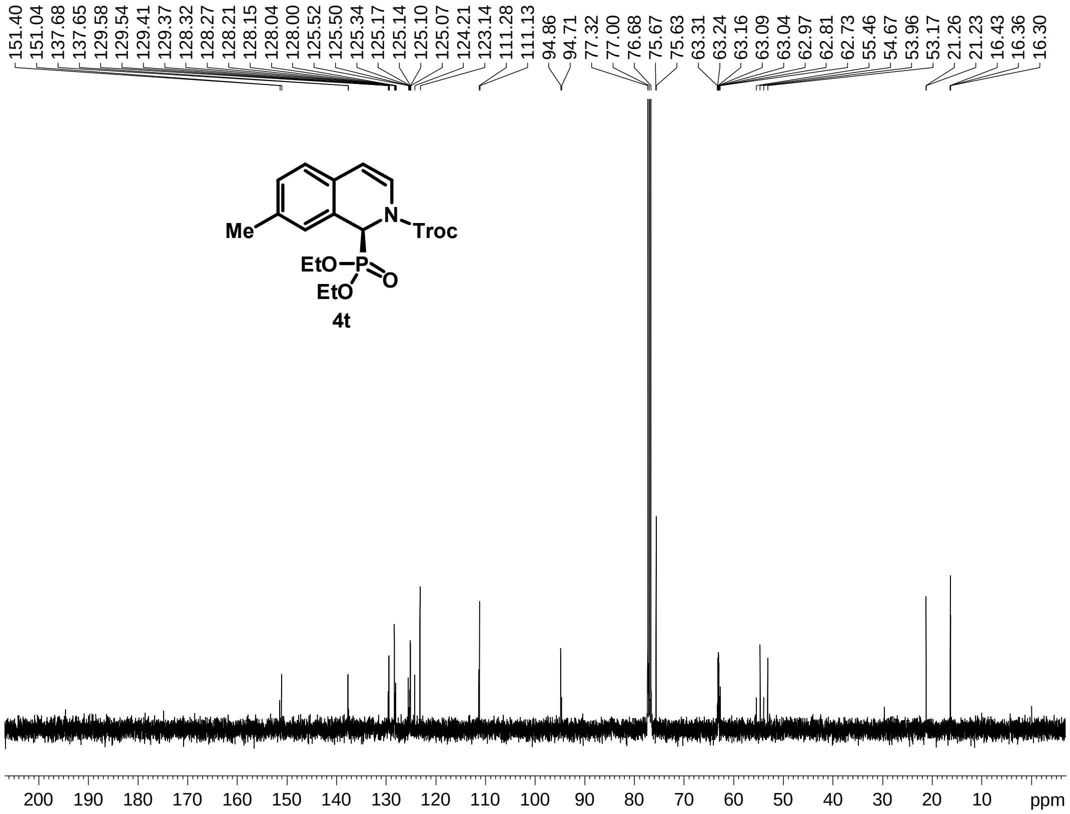


PeakTable

Detector A Ch2 254nm

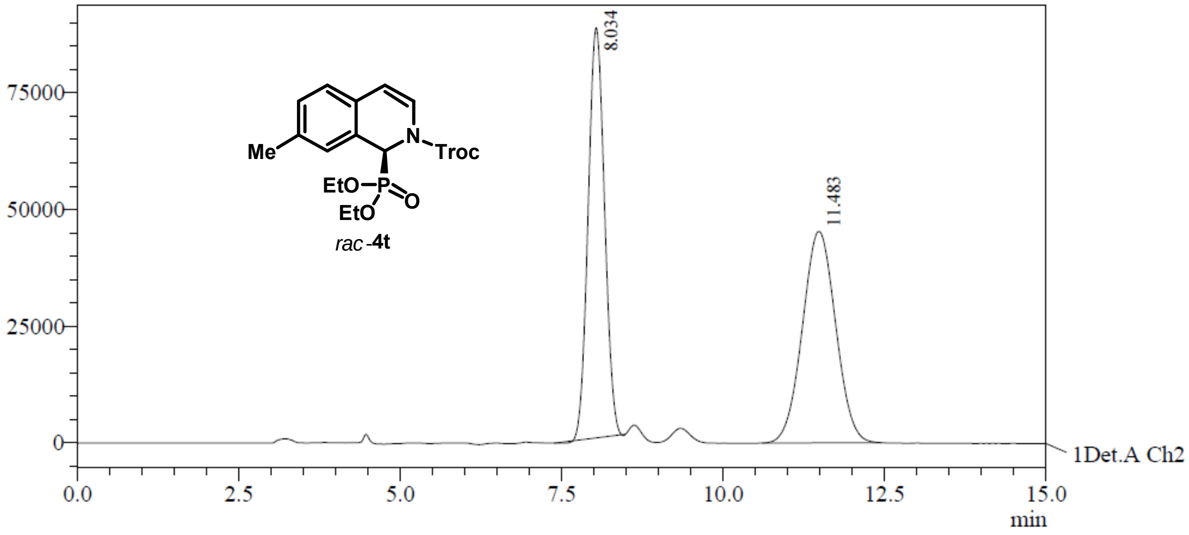
Peak#	Ret. Time	Area	Area %
1	16.263	617428	88.595
2	24.692	79483	11.405
Total		696910	100.000


7.26
7.09
7.05
6.98
6.96
6.92
6.91
6.89
6.87
6.00
5.98
5.93
5.91
5.82
5.78
5.76
5.72
5.04
5.01
4.91
4.88
4.81
4.78
4.69
4.66
4.10
4.08
4.06
4.05
4.03
4.01
3.98
3.96
3.94
3.92
3.90
3.84
3.82
3.80
3.78
3.76
2.33
1.25
1.24
1.22
1.20
1.18
1.16
1.14
Me
N
Troc
EtO
P
O
EtO
4t
10
9
8
7
6
5
4
3
2
1
ppm
1.983
0.997
0.995
1.000
0.986
1.004
0.999
4.073
2.981
6.187


151.40
151.04
137.68
137.65
129.58
129.54
129.41
129.37
128.32
128.27
128.21
128.15
128.04
128.00
125.52
125.50
125.34
125.17
125.14
125.10
125.07
124.21
123.14
111.28
111.13
94.86
94.71
77.32
77.00
76.68
75.67
75.63
63.31
63.24
63.16
63.09
63.04
62.97
62.81
62.73
55.46
54.67
53.96
53.17
21.26
21.23
16.43
16.36
16.30
Me
N
Troc
EtO
P
O
EtO
4t
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm


18.77
18.50
Me
N
Troc
EtO
P
O
EtO
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
ppm

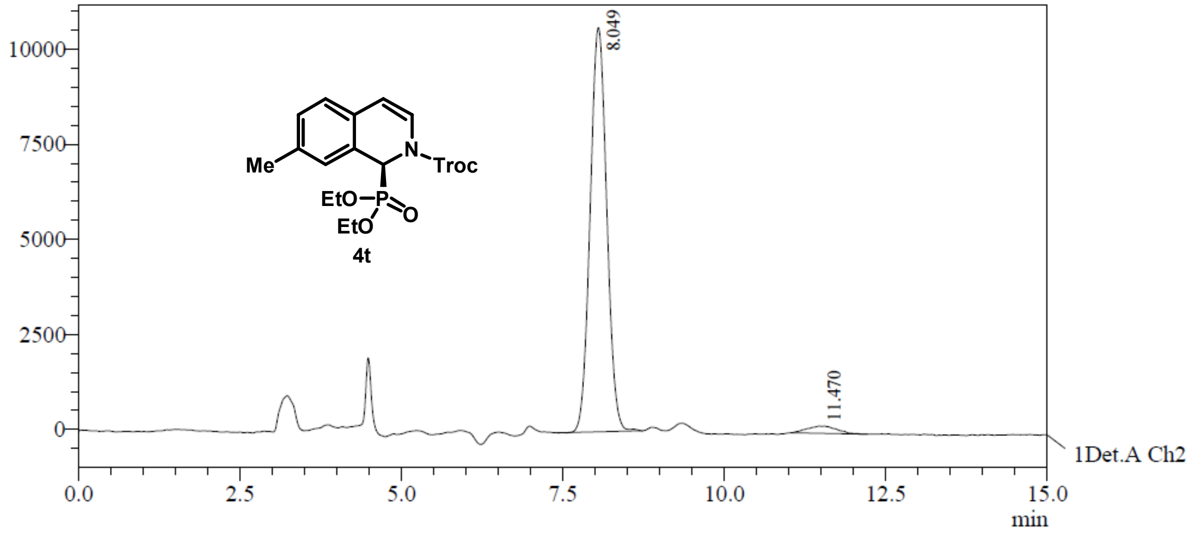
4t



PeakTable

Detector A Ch2 254nm

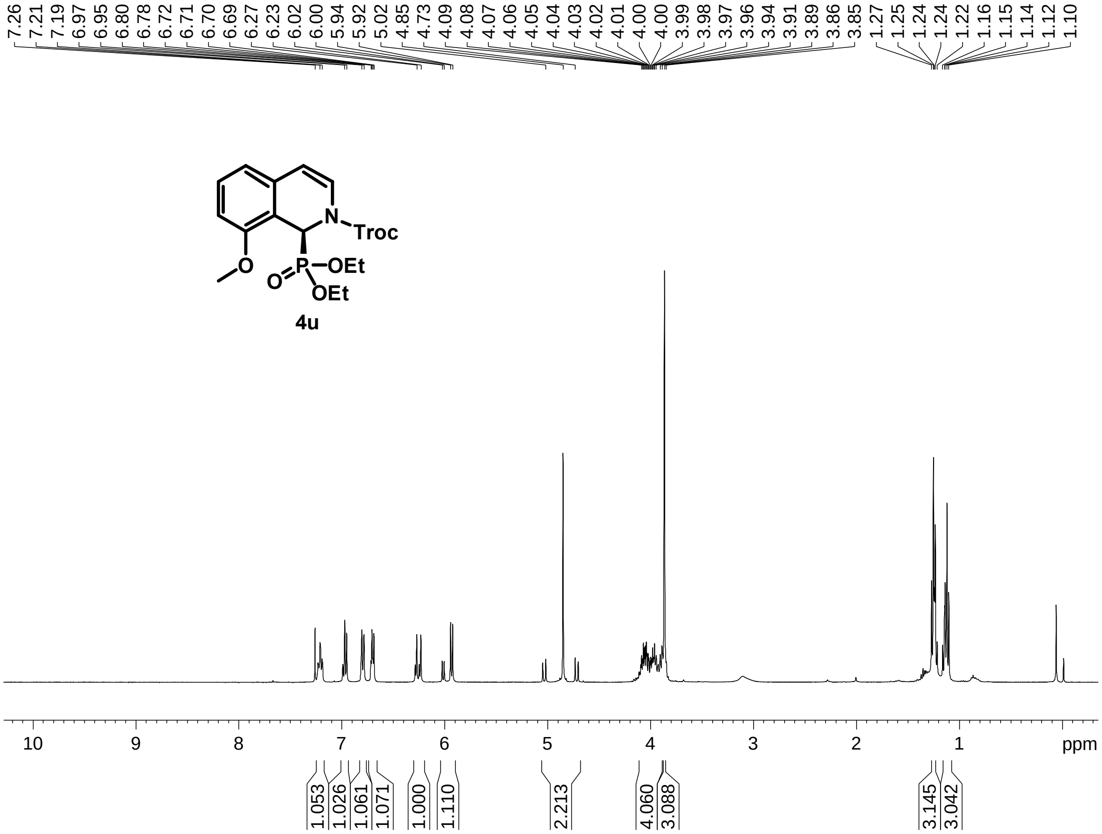
Peak#	Ret. Time	Area	Area %
1	8.034	1550362	48.816
2	11.483	1625575	51.184
Total		3175937	100.000

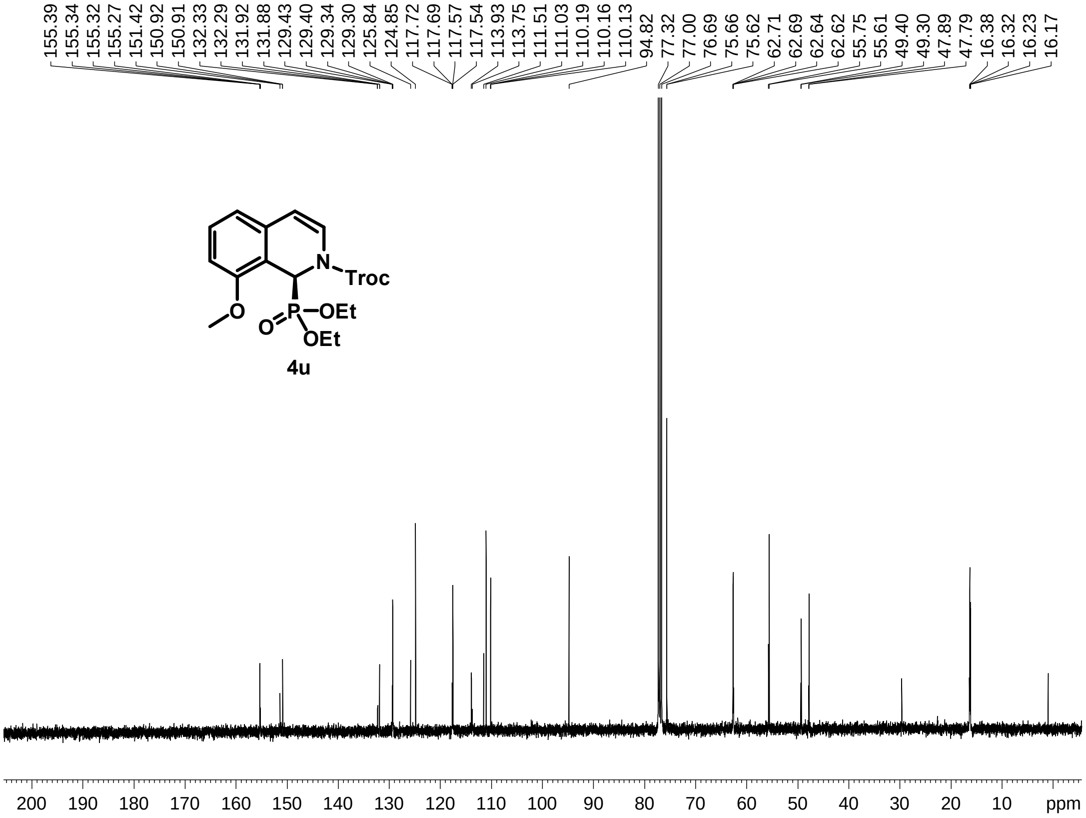


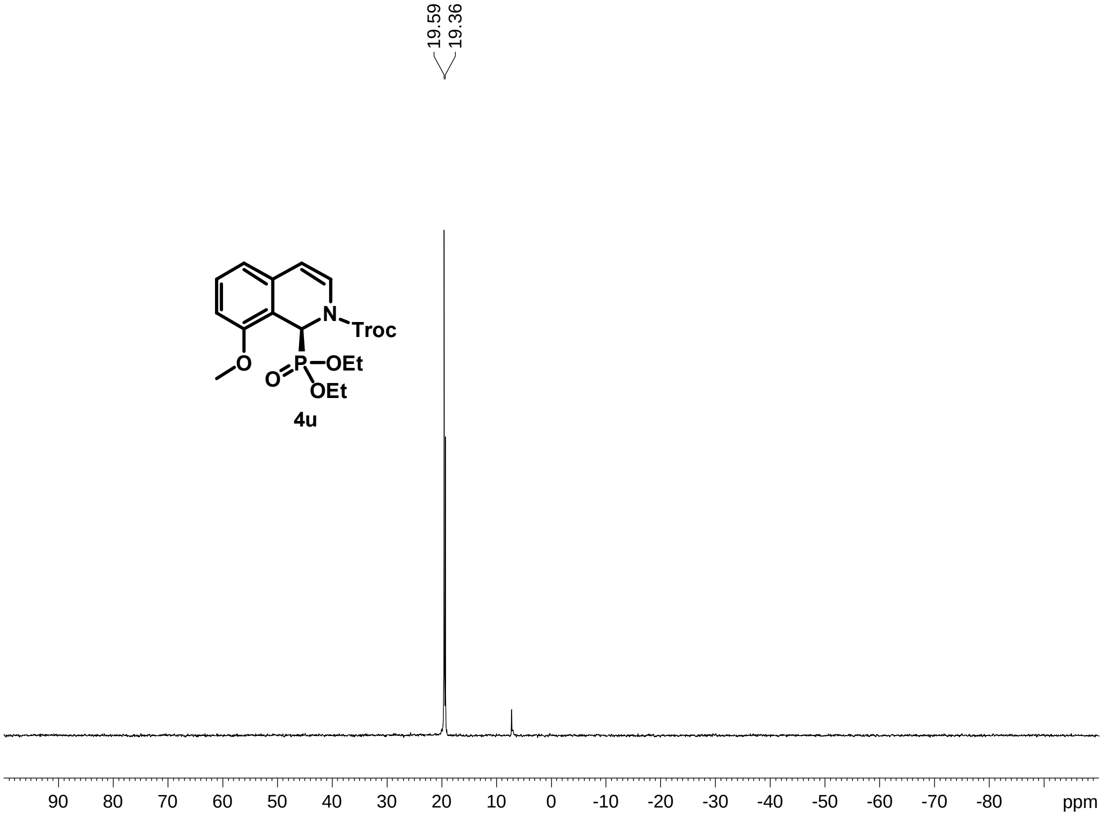
PeakTable

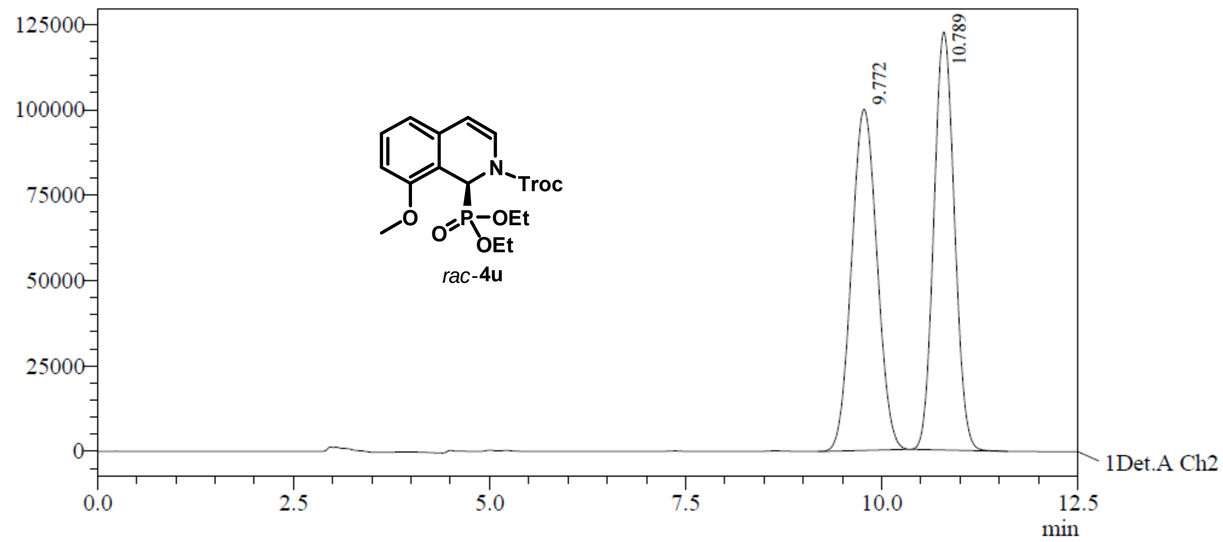
Detector A Ch2 254nm

Peak#	Ret. Time	Area	Area %
1	8.049	189962	96.889
2	11.470	6099	3.111
Total		196062	100.000


7.26
7.21
7.19
6.97
6.95
6.80
6.78
6.72
6.71
6.70
6.69
6.27
6.23
6.02
6.00
5.94
5.92
5.02
4.85
4.73
4.09
4.08
4.07
4.06
4.05
4.04
4.03
4.02
4.01
4.00
4.00
3.99
3.98
3.97
3.96
3.94
3.91
3.89
3.86
3.85
1.27
1.25
1.24
1.24
1.22
1.16
1.15
1.14
1.12
1.10
N
Troc
O
P
OEt
O
OEt
4u
10
9
8
7
6
5
4
3
2
1
ppm
1.053
1.026
1.061
1.071
1.000
1.110
2.213
4.060
3.088
3.145
3.042


155.39
155.34
155.32
155.27
151.42
150.92
150.91
132.33
132.29
131.92
131.88
129.43
129.40
129.34
129.30
125.84
124.85
117.72
117.69
117.57
117.54
113.93
113.75
111.51
111.03
110.19
110.16
110.13
94.82
77.32
77.00
76.69
75.66
75.62
62.71
62.69
62.64
62.62
55.75
55.61
49.40
49.30
47.89
47.79
16.38
16.32
16.23
16.17
N
Troc
O
P
OEt
O
OEt
4u
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

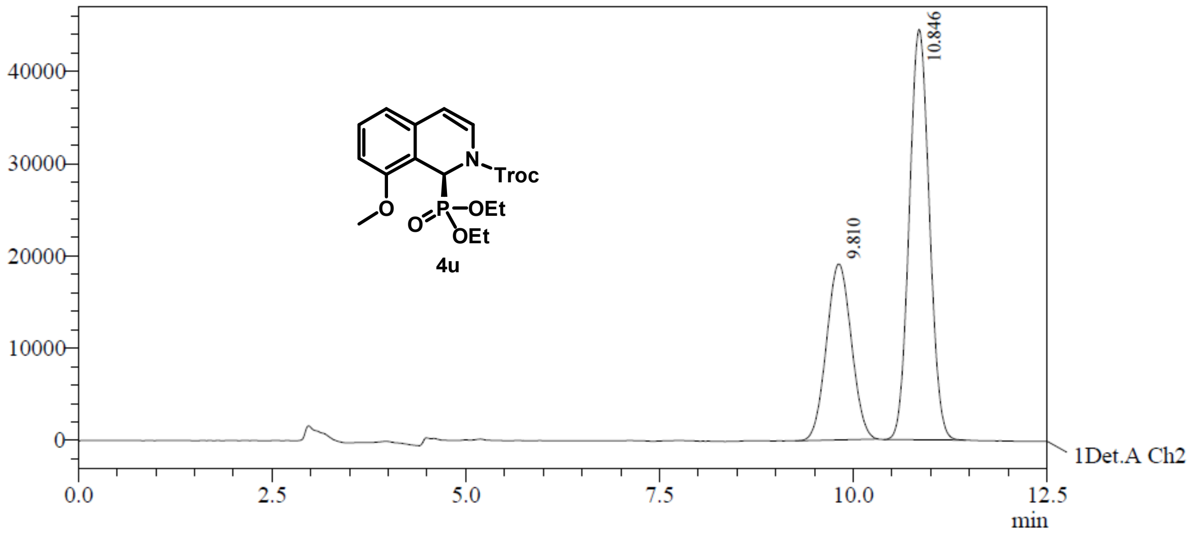

19.59
19.36
N
Troc
O
P
O
OEt
OEt
4u
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
ppm



PeakTable

Detector A Ch2 254nm

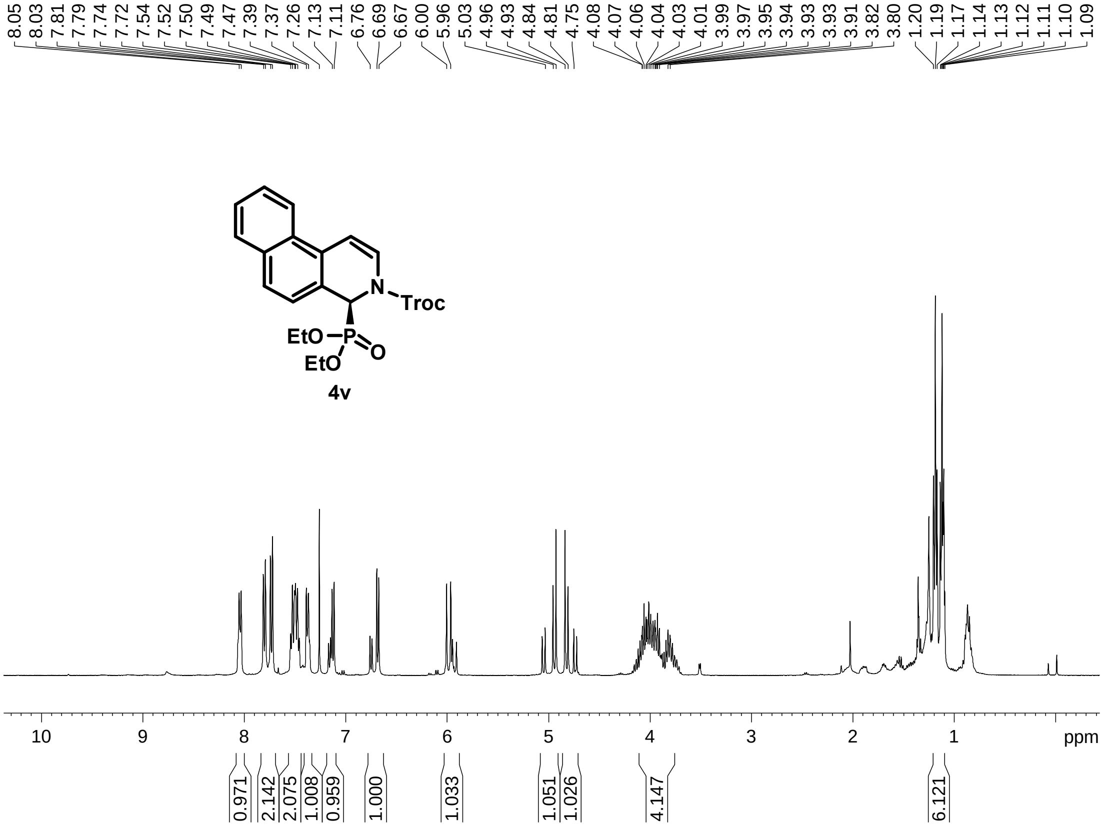
Peak#	Ret. Time	Area	Area %
1	9.772	2255306	50.239
2	10.789	2233875	49.761
Total		4489182	100.000

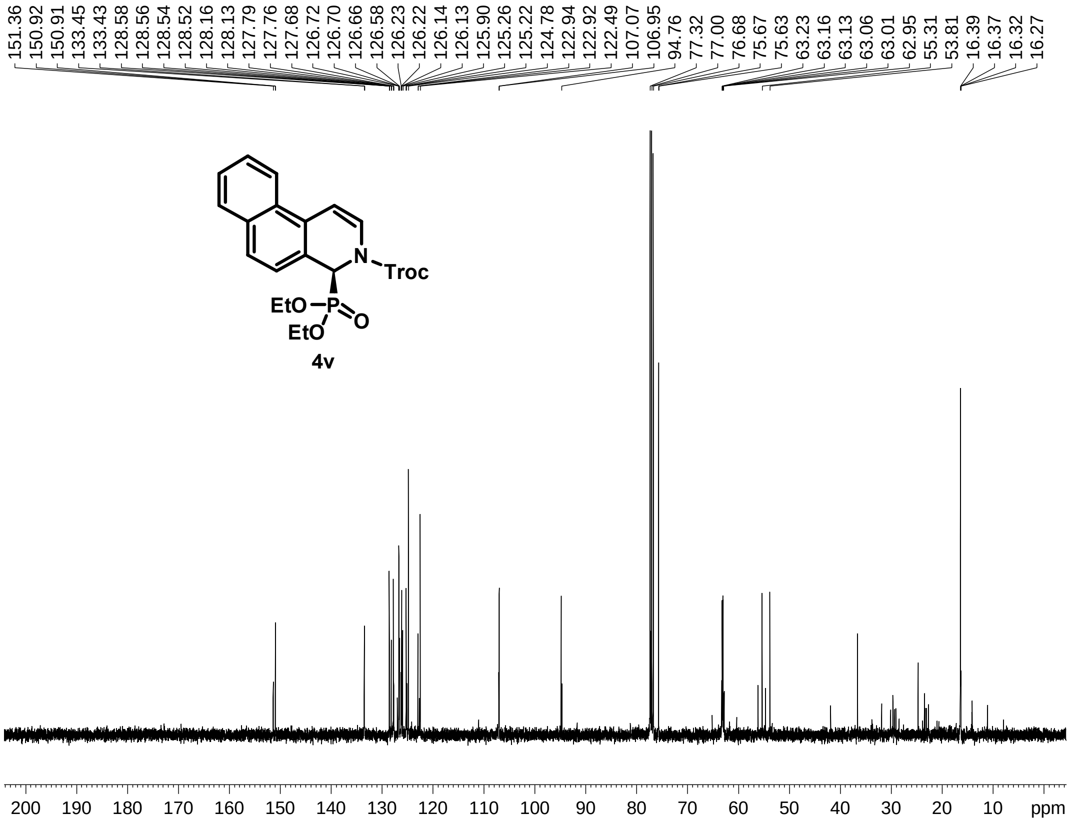


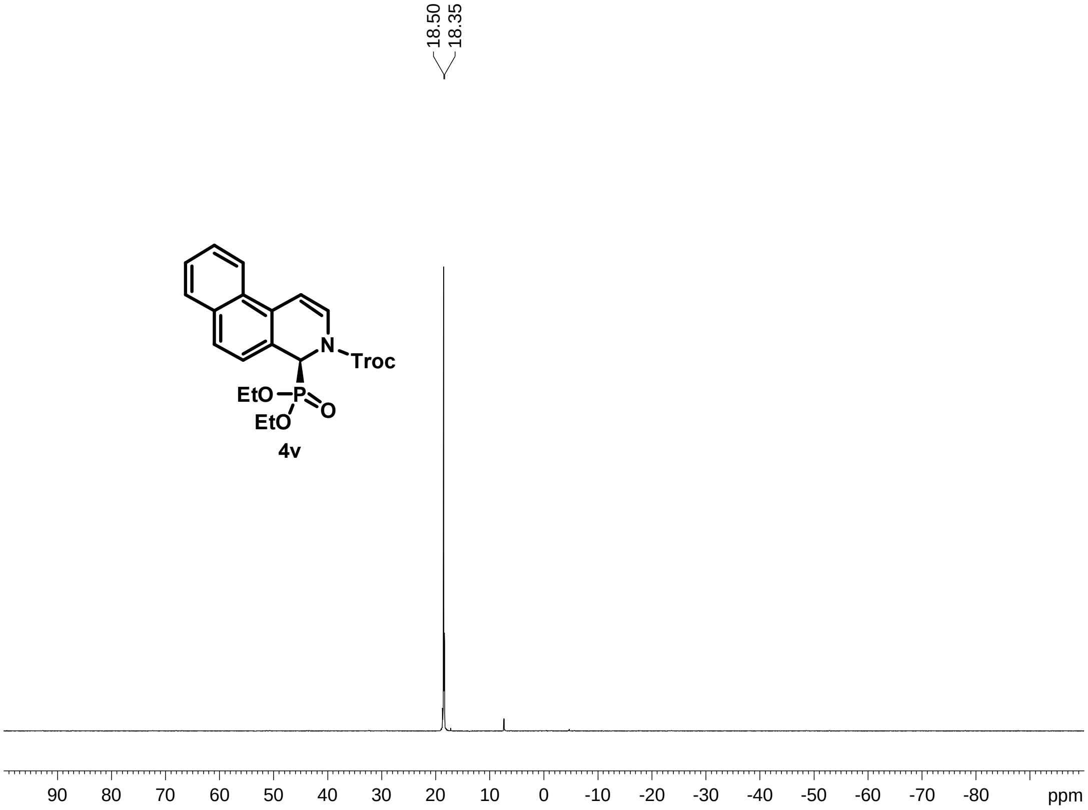
PeakTable

Detector A Ch2 254nm

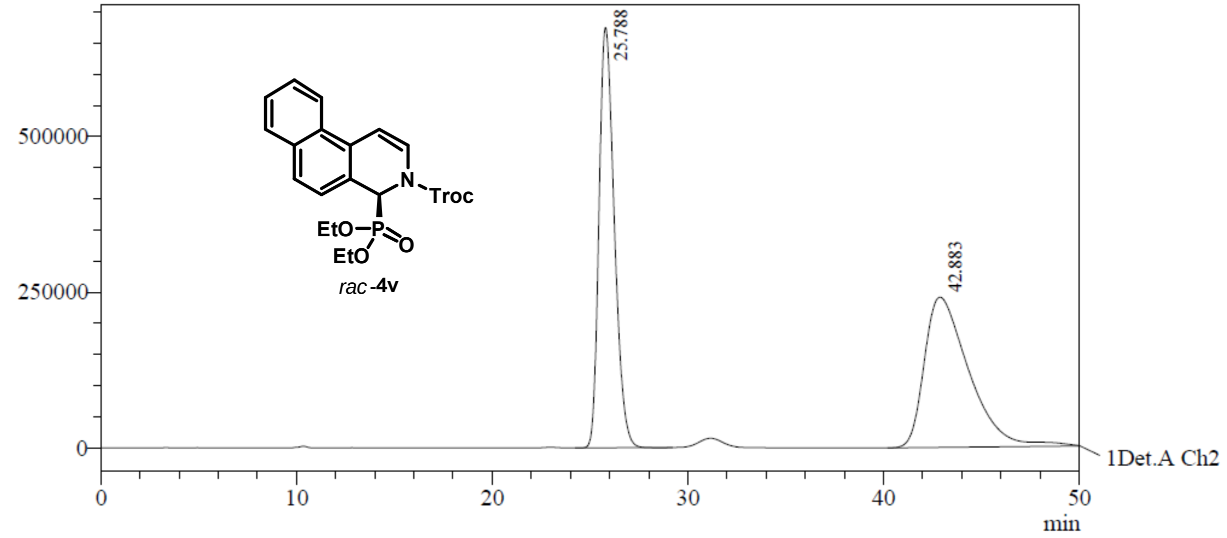
Peak#	Ret. Time	Area	Area %
1	9.810	425664	34.650
2	10.846	802793	65.350
Total		1228457	100.000


8.05
8.03
7.81
7.79
7.74
7.72
7.54
7.52
7.50
7.49
7.47
7.39
7.37
7.26
7.13
7.11
6.76
6.69
6.67
6.00
5.96
5.03
4.96
4.93
4.84
4.81
4.75
4.08
4.07
4.06
4.04
4.03
4.01
3.99
3.97
3.95
3.94
3.93
3.93
3.91
3.82
3.80
1.20
1.19
1.17
1.14
1.13
1.12
1.11
1.10
1.09
N
Troc
EtO
P
O
EtO
4v
10
9
8
7
6
5
4
3
2
1
ppm
0.971
2.142
2.075
1.008
0.959
1.000
1.033
1.051
1.026
4.147
6.121


151.36
150.92
150.91
133.45
133.43
128.58
128.56
128.54
128.52
128.16
128.13
127.79
127.76
127.68
126.72
126.70
126.66
126.58
126.23
126.22
126.14
126.13
125.90
125.26
125.22
124.78
122.94
122.92
122.49
107.07
106.95
94.76
77.32
77.00
76.68
75.67
75.63
63.23
63.16
63.13
63.06
63.01
62.95
55.31
53.81
16.39
16.37
16.32
16.27
N
Troc
EtO
P
O
EtO
4v
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm


18.50
18.35
N
Troc
EtO
P
O
EtO
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
ppm

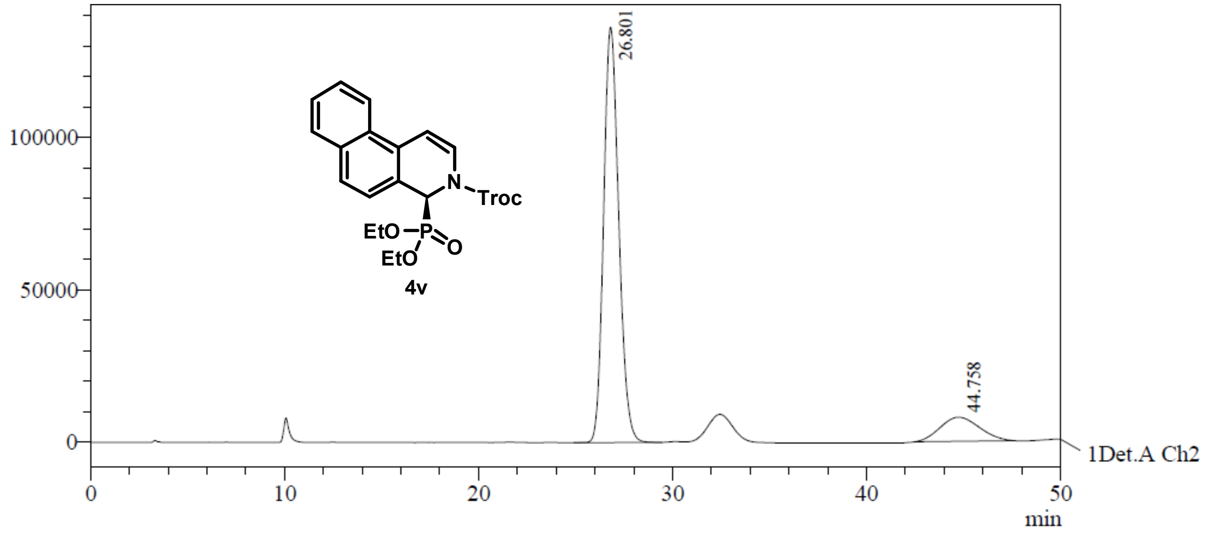
4v



PeakTable

Detector A Ch2 254nm

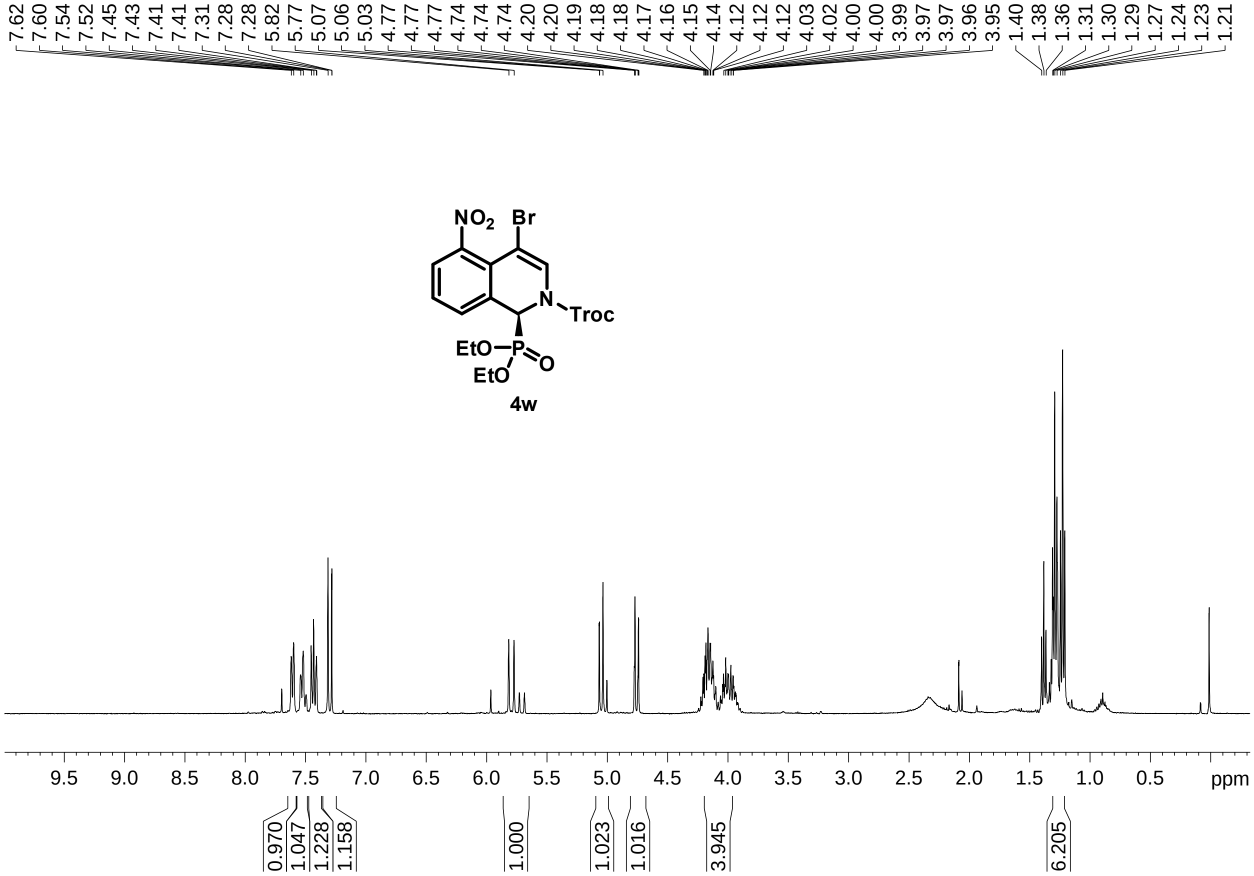
Peak#	Ret. Time	Area	Area %
1	25.788	36660948	48.923
2	42.883	38275728	51.077
Total		74936676	100.000

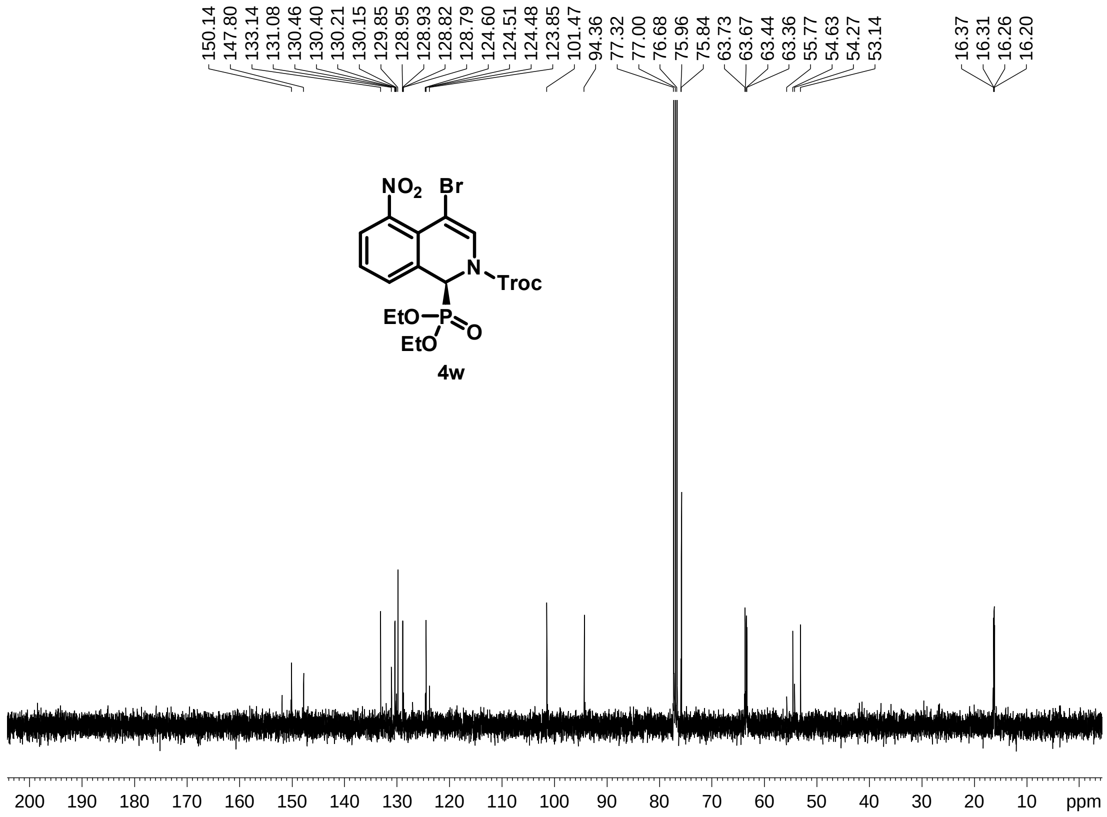


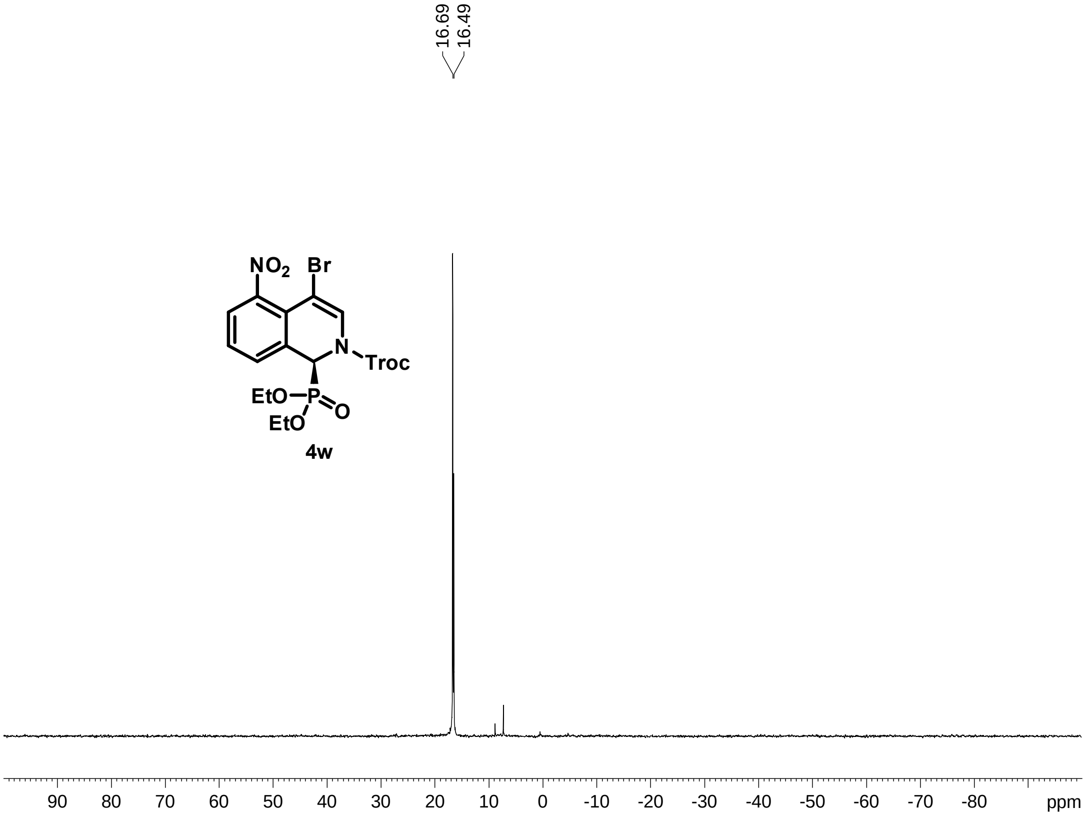
PeakTable

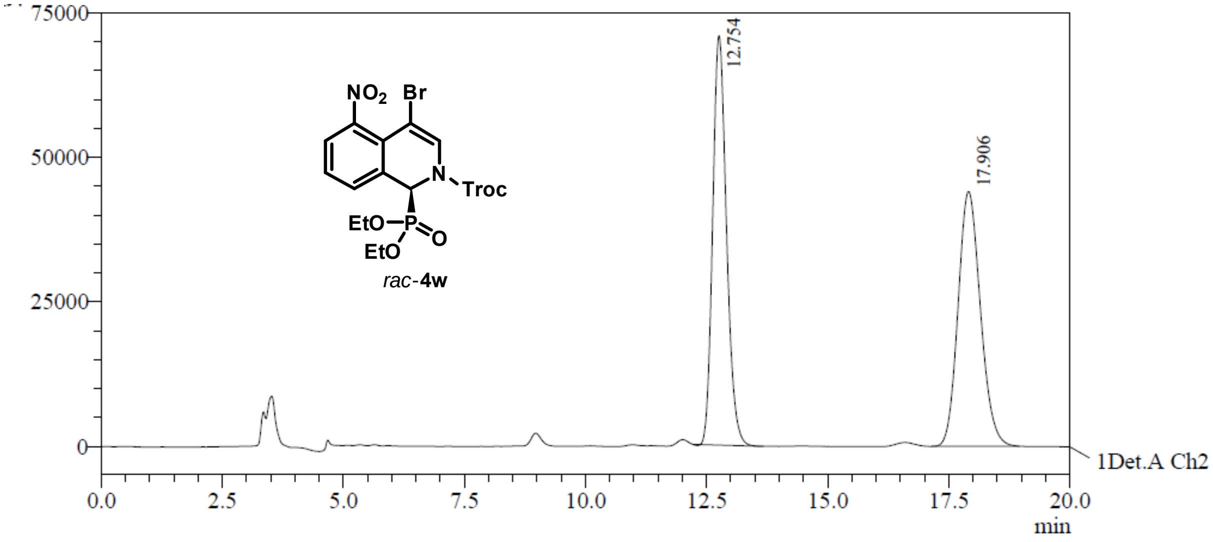
Detector A Ch2 254nm

Peak#	Ret. Time	Area	Area %
1	26.801	7397164	86.919
2	44.758	1113213	13.081
Total		8510377	100.000


7.62 7.60 7.54 7.52 7.45 7.43 7.41 7.41 7.31 7.28 7.28 5.82 5.77 5.07 5.06 5.03 4.77 4.77 4.77 4.74 4.74 4.74 4.20 4.20 4.19 4.18 4.18 4.17 4.16 4.15 4.14 4.12 4.12 4.12 4.03 4.02 4.00 4.00 3.99 3.97 3.97 3.96 3.95 1.40 1.38 1.36 1.31 1.30 1.29 1.27 1.24 1.23 1.21
NO2
Br
N
Troc
EtO
P
O
EtO
4w
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
0.970 1.047 1.228 1.158 1.000 1.023 1.016 3.945 6.205


150.14 147.80 133.14 131.08 130.46 130.40 130.21 130.15 129.85 128.95 128.93 128.82 128.79 124.60 124.51 124.48 123.85 101.47 94.36 77.32 77.00 76.68 75.96 75.84 63.73 63.67 63.44 63.36 55.77 54.63 54.27 53.14 16.37 16.31 16.26 16.20
NO2
Br
N
Troc
EtO
P
O
EtO
4w
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm

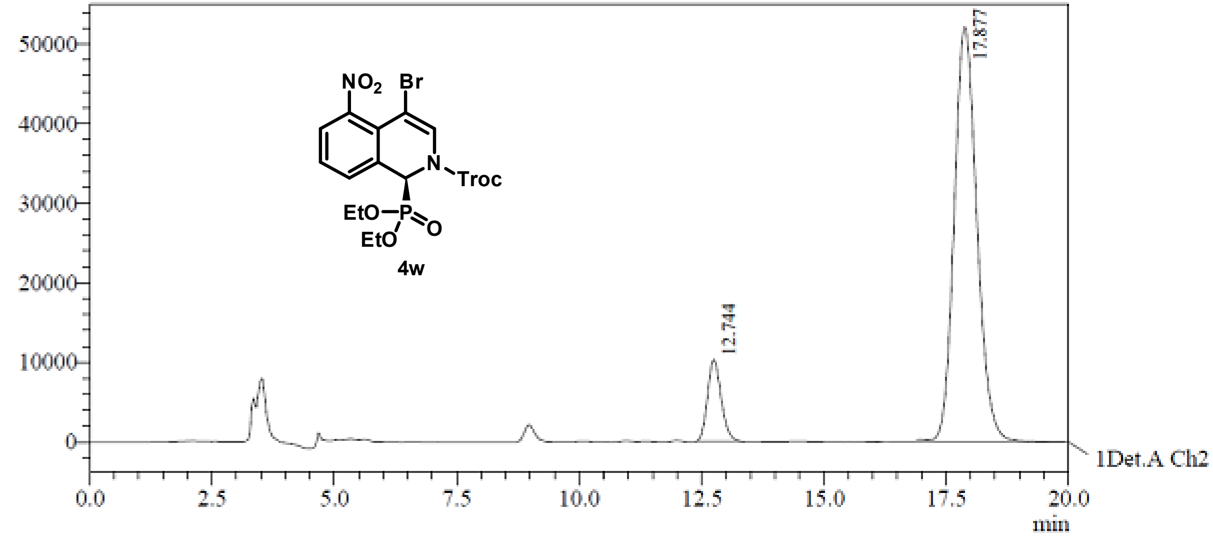

16.69
16.49
NO2
Br
N
Troc
EtO
P
O
EtO
4w
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
ppm



PeakTable

Detector A Ch2 254nm

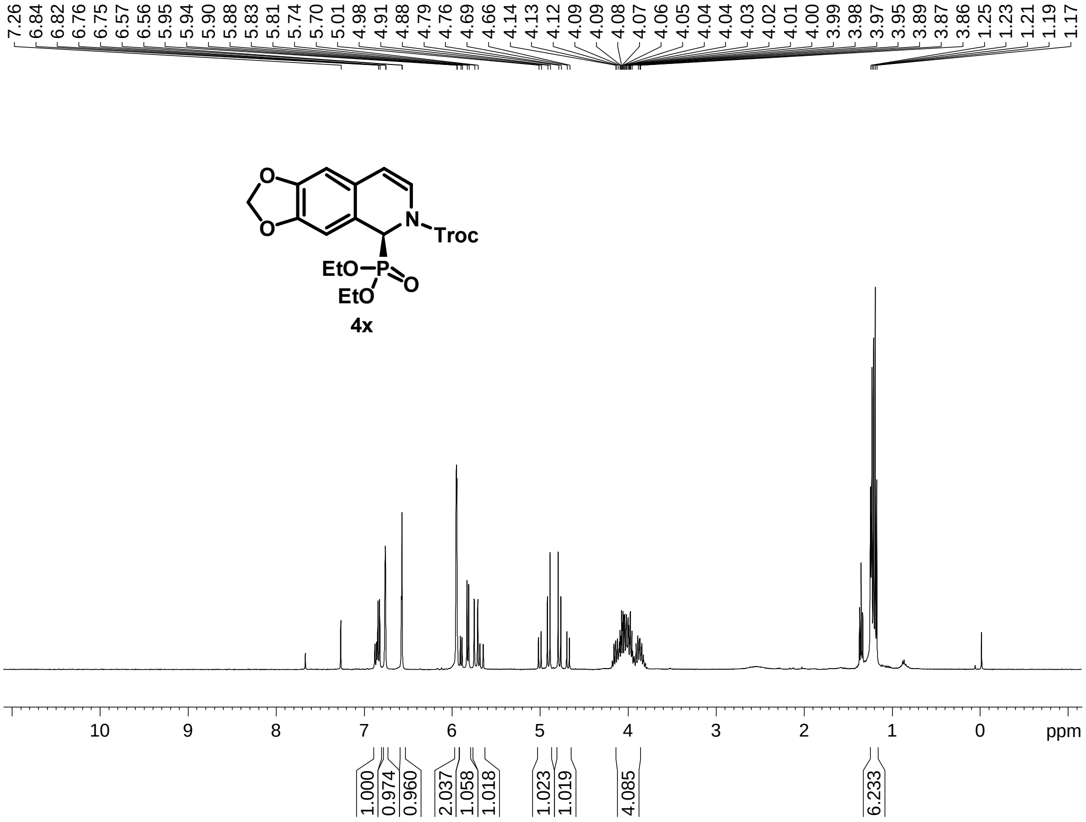
Peak#	Ret. Time	Area	Area %
1	12.754	1402409	49.784
2	17.906	1414587	50.216
Total		2816996	100.000

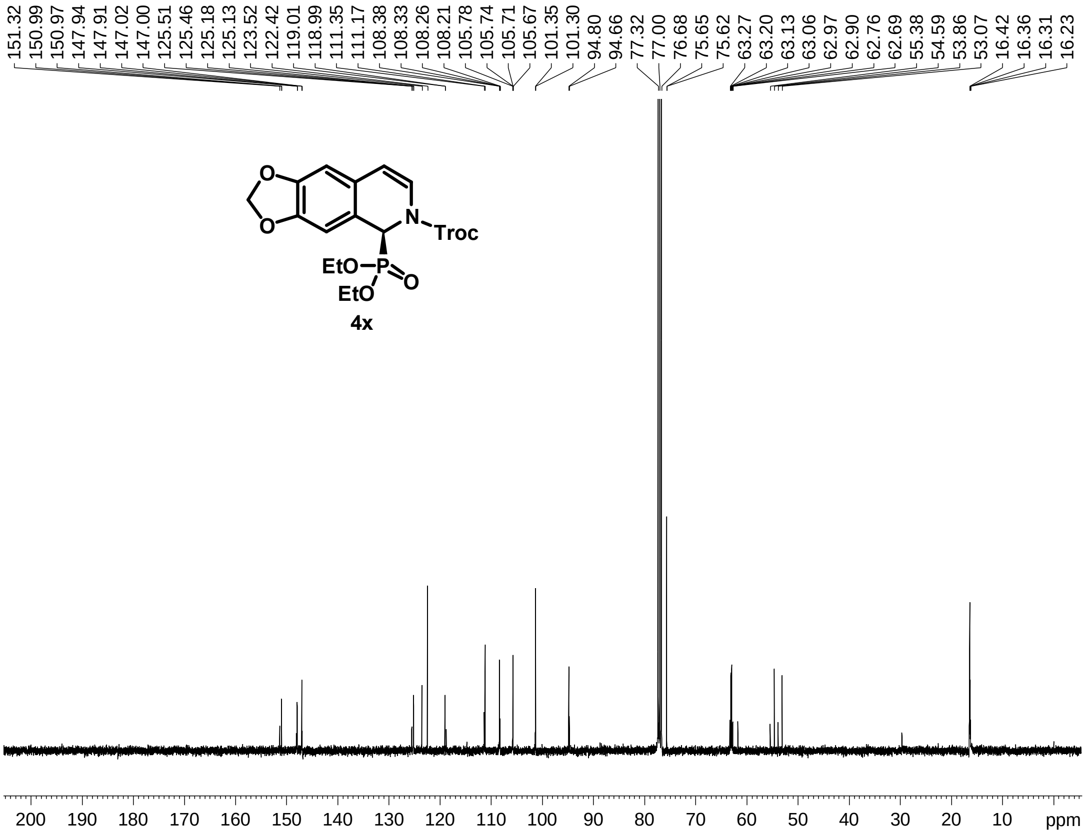


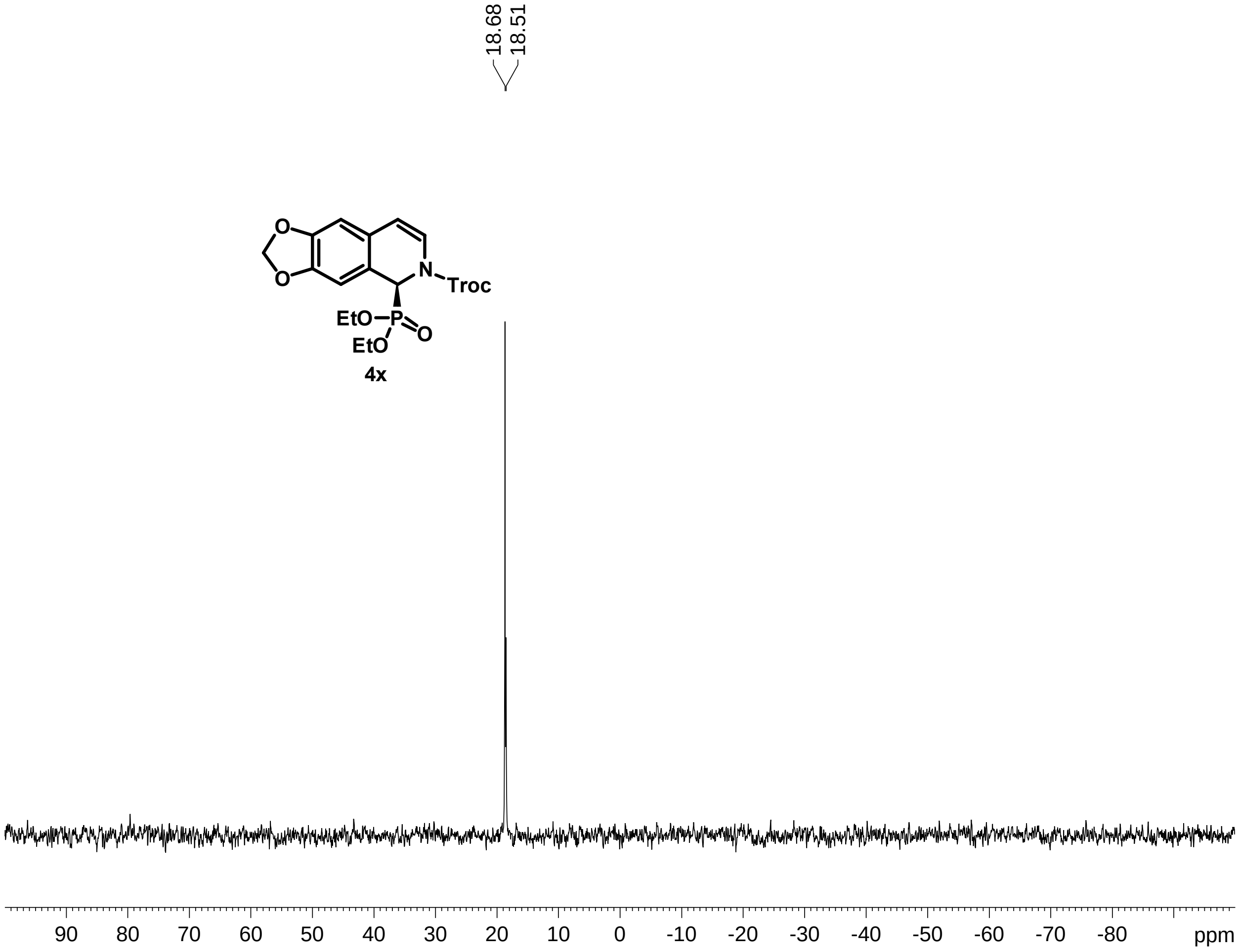
PeakTable

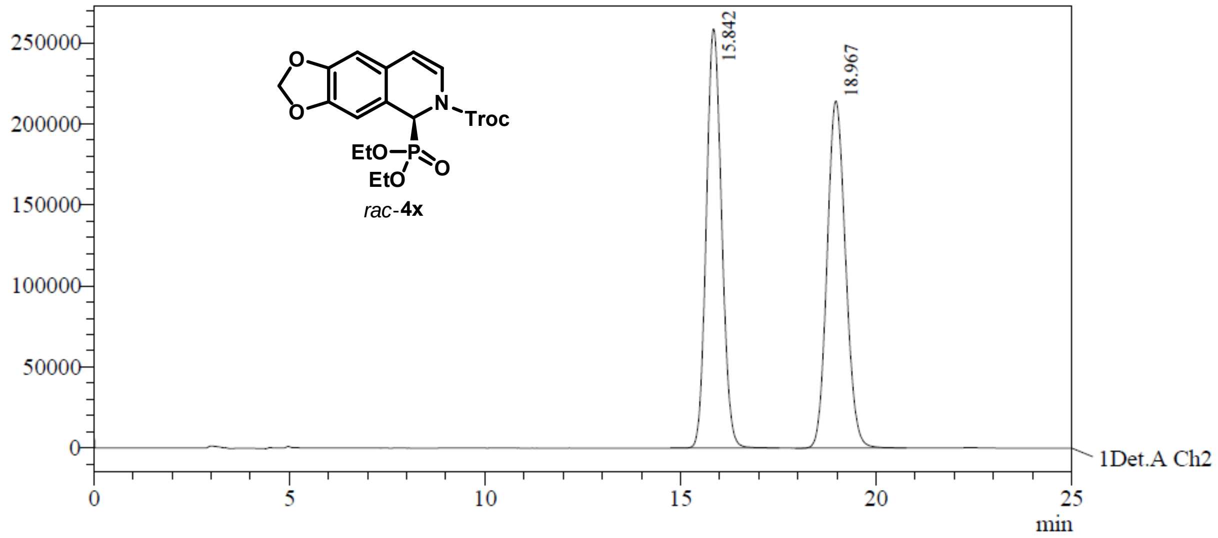
Detector A Ch2 254nm

Peak#	Ret. Time	Area	Area %
1	12.744	197265	10.305
2	17.877	1716997	89.695
Total		1914263	100.000


7.26
6.84
6.82
6.76
6.75
6.57
6.56
5.95
5.94
5.90
5.88
5.83
5.81
5.74
5.70
5.01
4.98
4.91
4.88
4.79
4.76
4.69
4.66
4.14
4.13
4.12
4.09
4.09
4.08
4.07
4.06
4.05
4.04
4.04
4.03
4.02
4.01
4.00
3.99
3.98
3.97
3.95
3.89
3.87
3.86
1.25
1.23
1.21
1.19
1.17
O
O
N
Troc
EtO
P
O
EtO
4x
10
9
8
7
6
5
4
3
2
1
0
ppm
1.000
0.974
0.960
2.037
1.058
1.018
1.023
1.019
4.085
6.233


151.32
150.99
150.97
147.94
147.91
147.02
147.00
125.51
125.46
125.18
125.13
123.52
122.42
119.01
118.99
111.35
111.17
108.38
108.33
108.26
108.21
105.78
105.74
105.71
105.67
101.35
101.30
94.80
94.66
77.32
77.00
76.68
75.65
75.62
63.27
63.20
63.13
63.06
62.97
62.90
62.76
62.69
55.38
54.59
53.86
53.07
16.42
16.36
16.31
16.23
O
O
N
Troc
EtO
P
O
EtO
4x
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

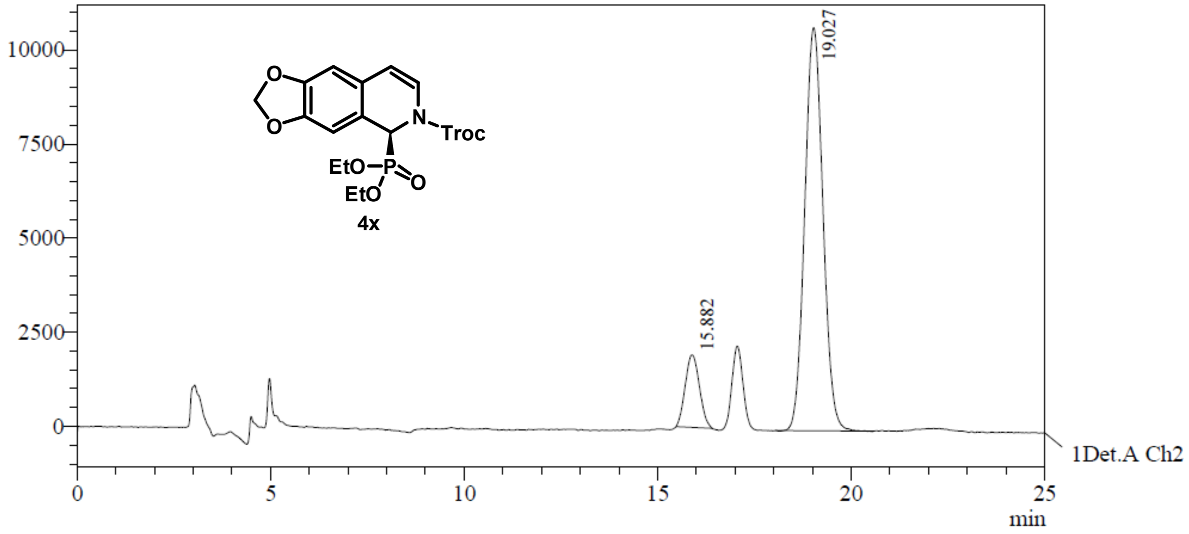

18.68
18.51
O
O
N
Troc
EtO
P
O
EtO
4x
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
ppm



PeakTable

Detector A Ch2 254nm

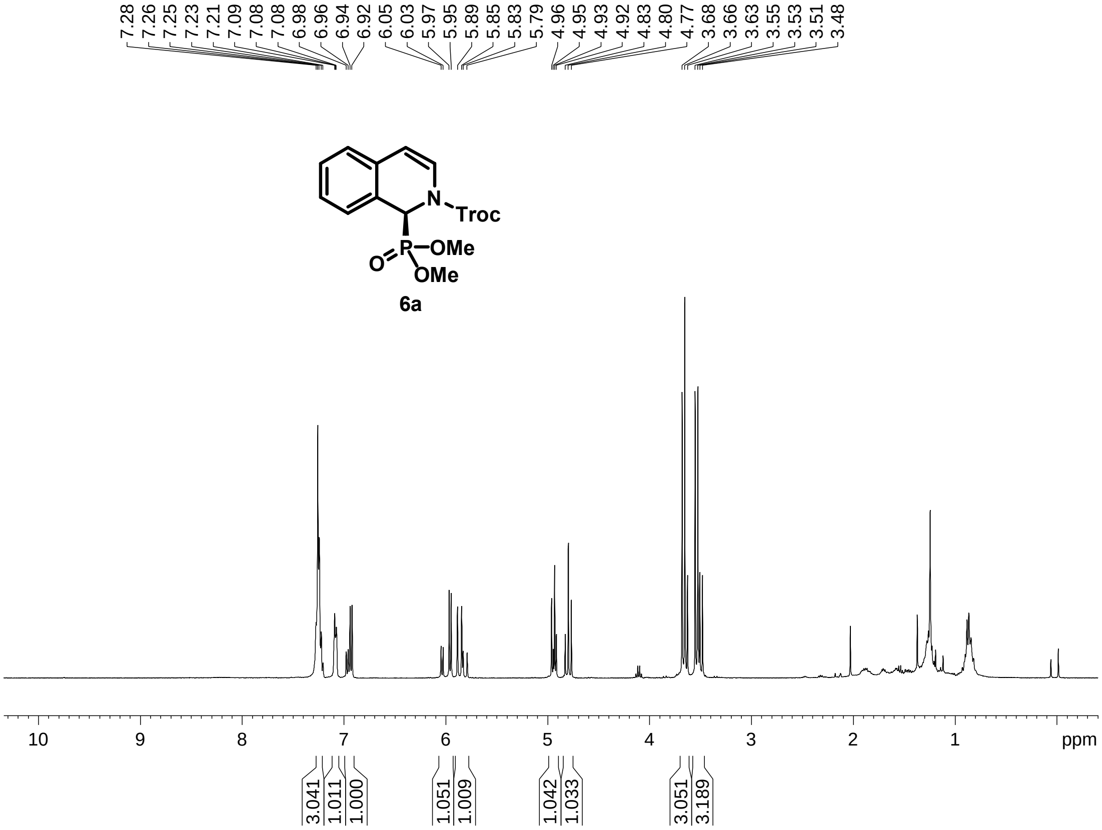
Peak#	Ret. Time	Area	Area %
1	15.842	7032636	50.037
2	18.967	7022274	49.963
Total		14054910	100.000

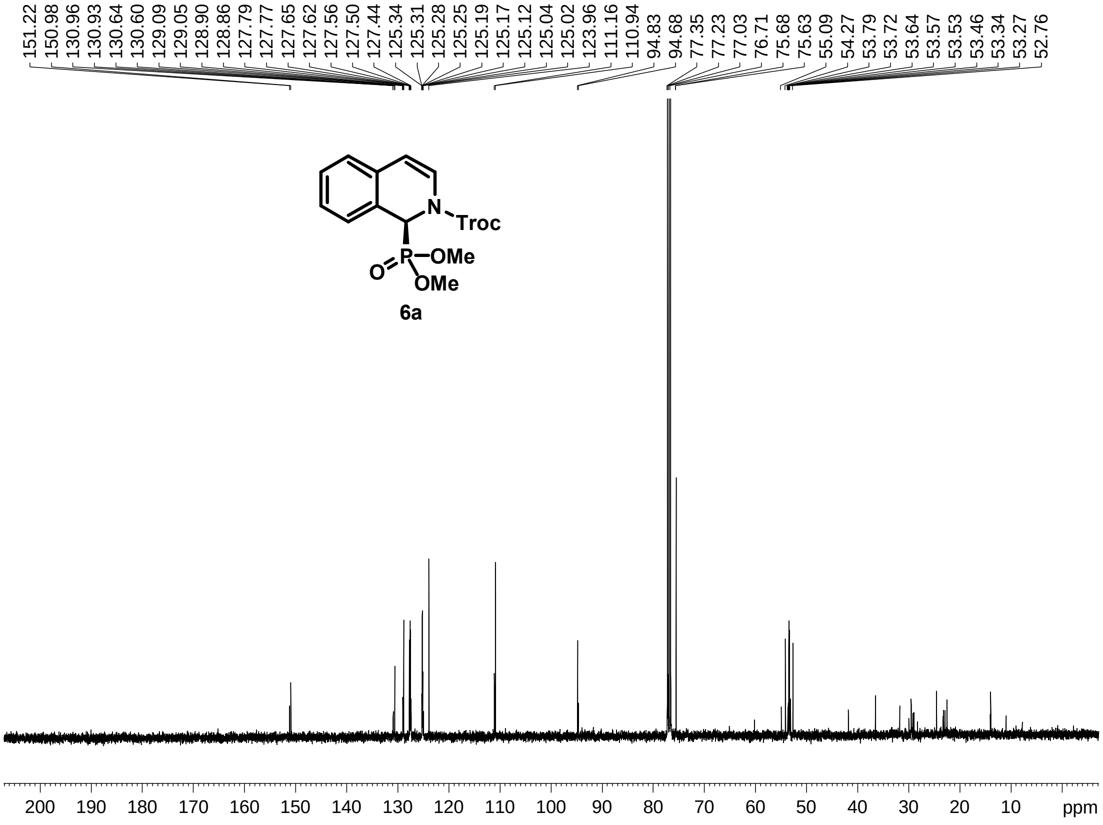


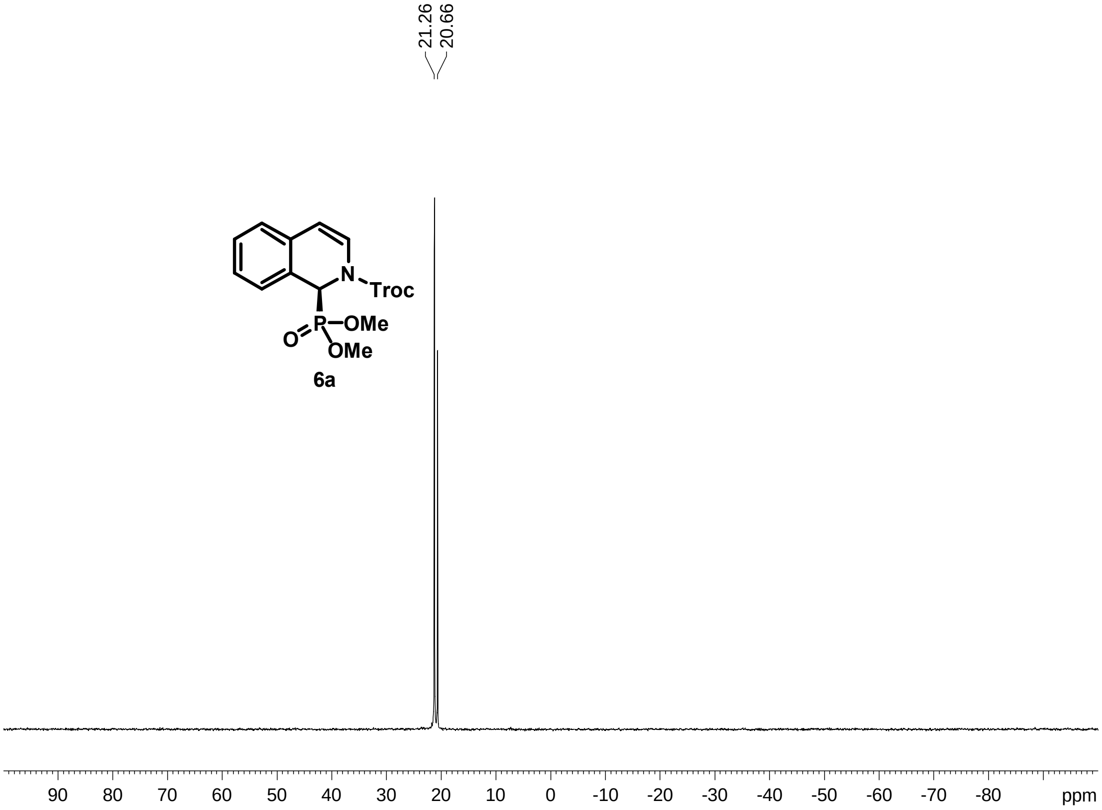
PeakTable

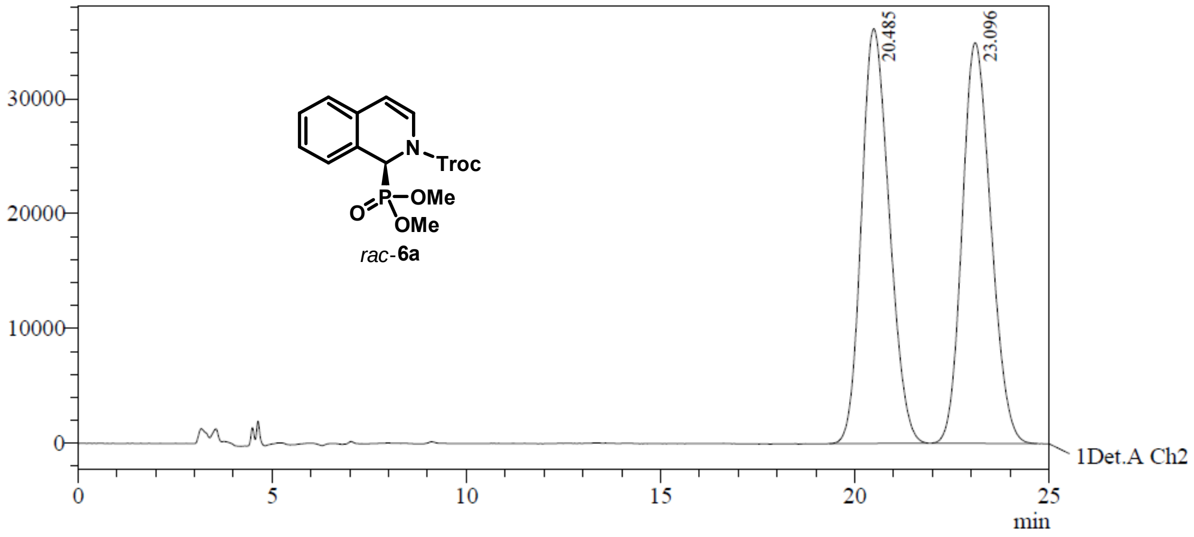
Detector A Ch2 254nm

Peak#	Ret. Time	Area	Area %
1	15.882	49216	12.300
2	19.027	350921	87.700
Total		400138	100.000


7.28
7.26
7.25
7.23
7.21
7.09
7.08
7.08
6.98
6.96
6.94
6.92
6.05
6.03
5.97
5.95
5.89
5.85
5.83
5.79
4.96
4.95
4.93
4.92
4.83
4.80
4.77
3.68
3.66
3.63
3.55
3.53
3.51
3.48
N
Troc
P
OMe
O
OMe
6a
10
9
8
7
6
5
4
3
2
1
ppm
3.041
1.011
1.000
1.051
1.009
1.042
1.033
3.051
3.189


151.22
150.98
130.96
130.93
130.64
130.60
129.09
129.05
128.90
128.86
127.79
127.77
127.65
127.62
127.56
127.50
127.44
125.34
125.31
125.28
125.25
125.19
125.17
125.12
125.04
125.02
123.96
111.16
110.94
94.83
94.68
77.35
77.23
77.03
76.71
75.68
75.63
55.09
54.27
53.79
53.72
53.64
53.57
53.53
53.46
53.34
53.27
52.76
N
Troc
P
OMe
O
OMe
6a
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

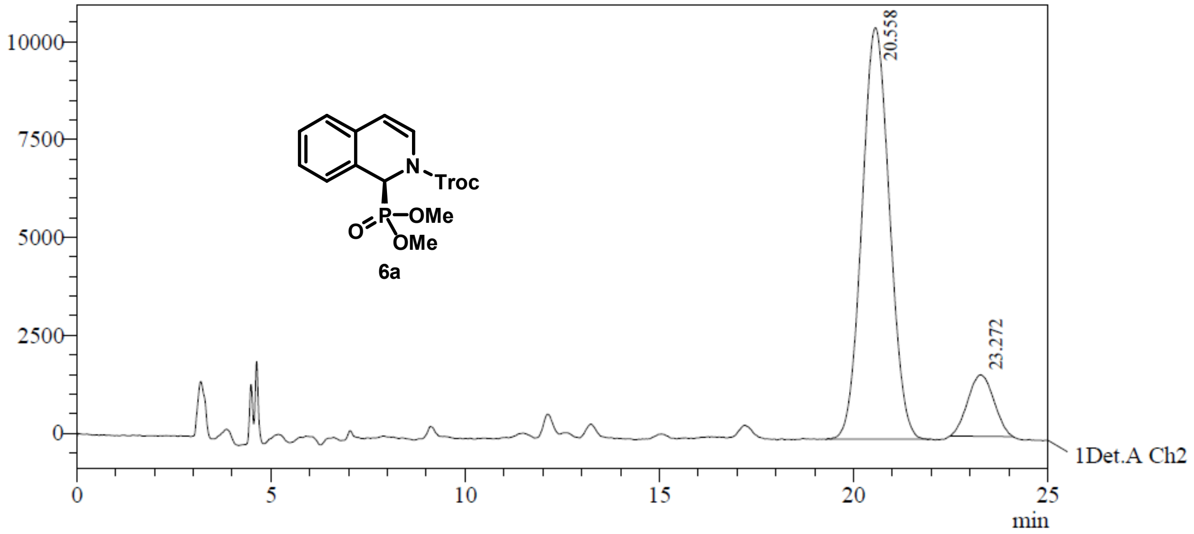

21.26
20.66
N
Troc
P
OMe
O
OMe
6a
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
ppm



PeakTable

Detector A Ch2 254nm

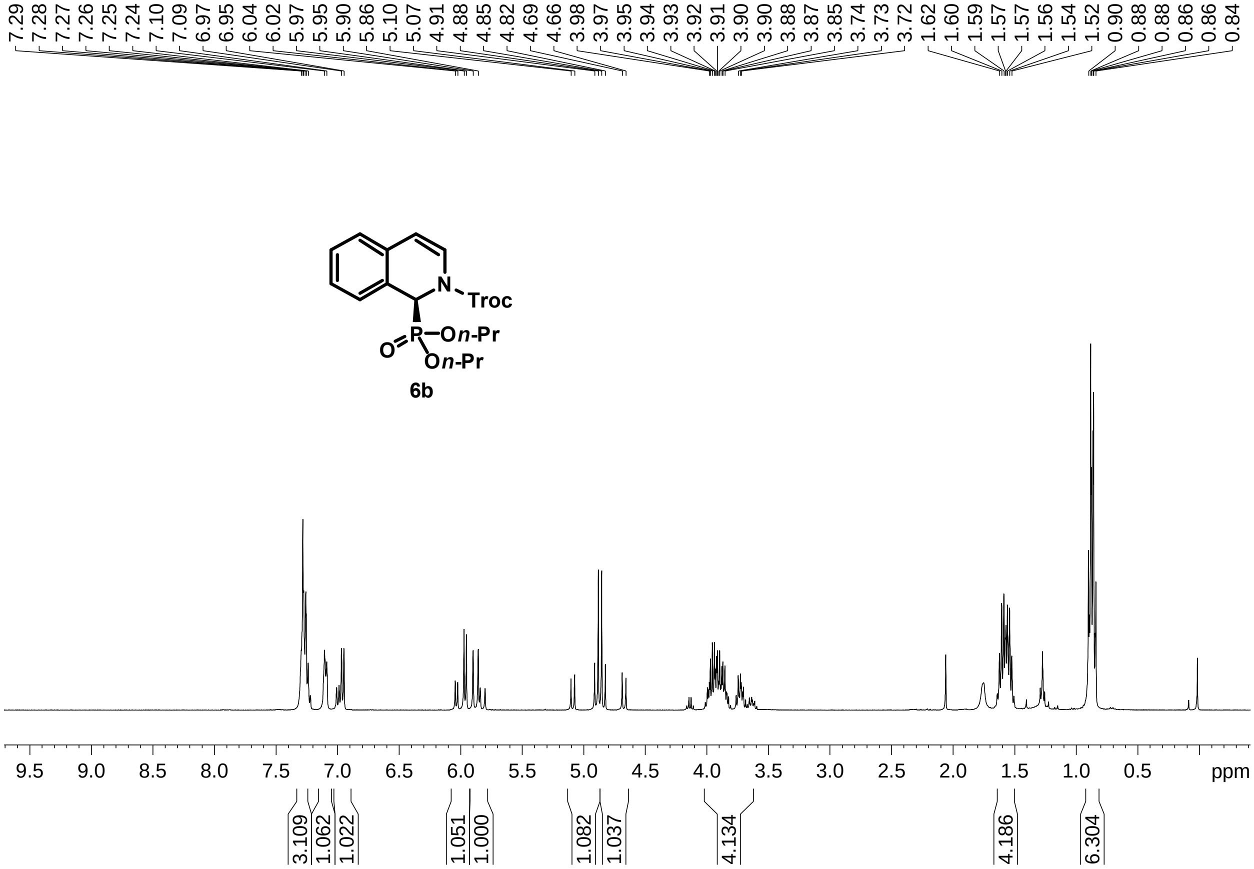
Peak#	Ret. Time	Area	Area %
1	20.485	1798257	49.994
2	23.096	1798694	50.006
Total		3596951	100.000

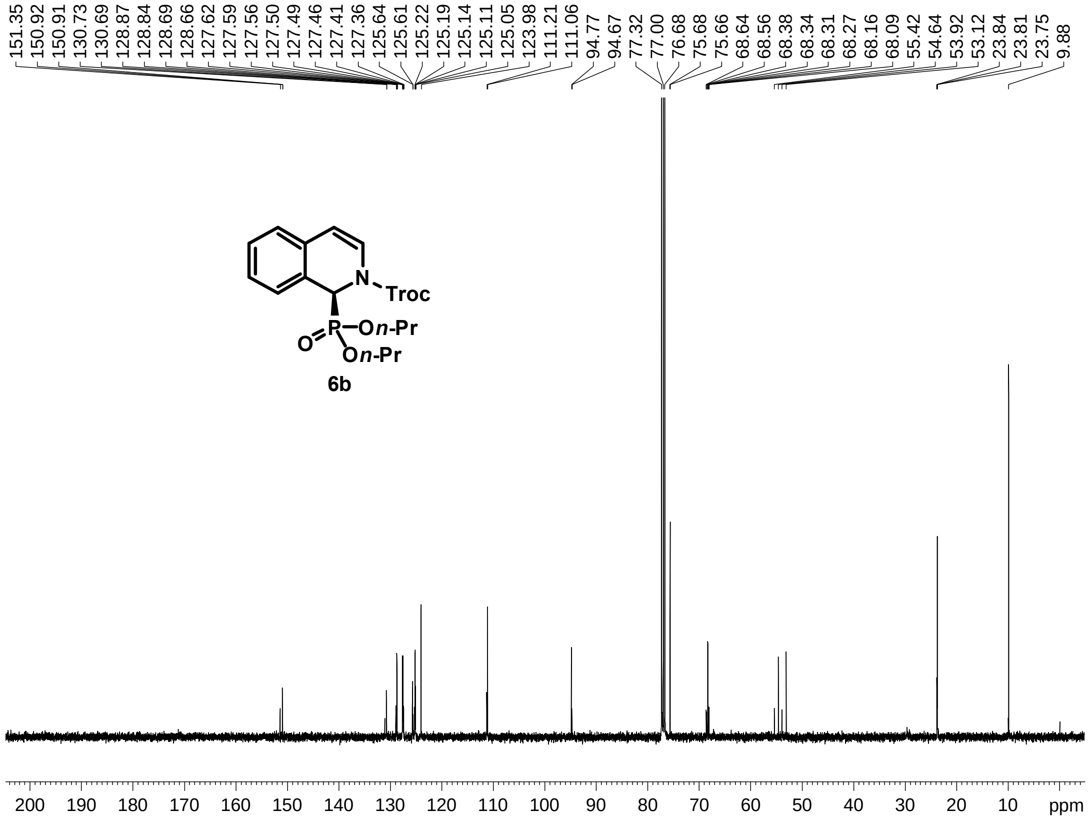


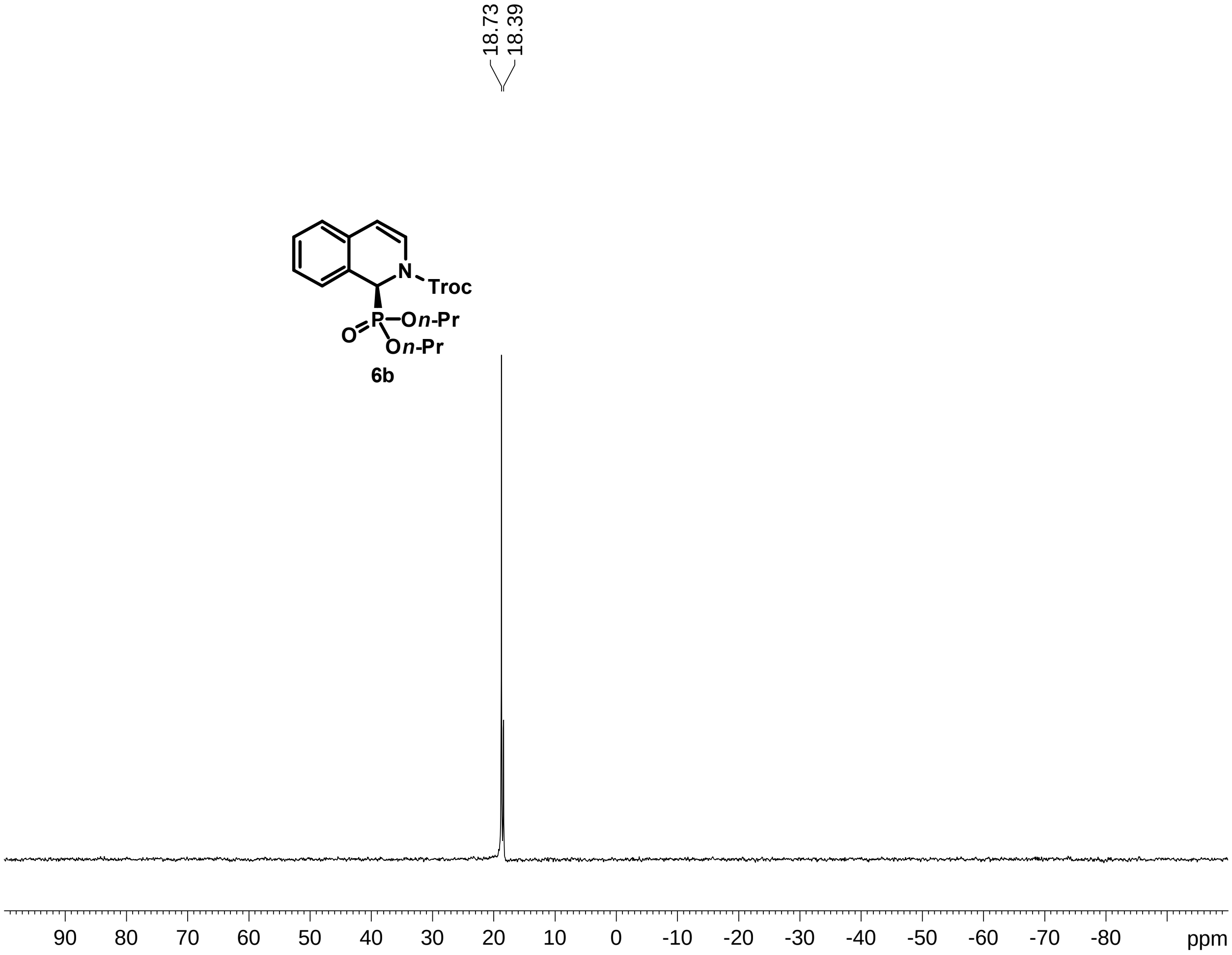
PeakTable

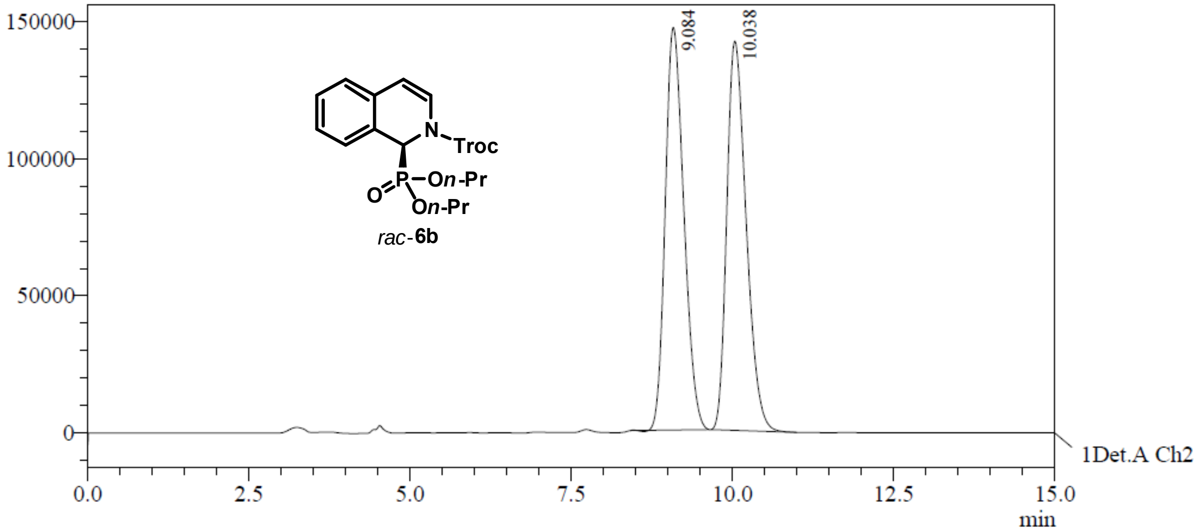
Detector A Ch2 254nm

Peak#	Ret. Time	Area	Area %
1	20.558	518286	87.560
2	23.272	73636	12.440
Total		591923	100.000


7.29
7.28
7.27
7.26
7.25
7.24
7.10
7.09
6.97
6.95
6.04
6.02
5.97
5.95
5.90
5.86
5.10
5.07
4.91
4.88
4.85
4.82
4.69
4.66
3.98
3.97
3.95
3.94
3.93
3.92
3.91
3.90
3.90
3.88
3.87
3.85
3.74
3.73
3.72
1.62
1.60
1.59
1.57
1.57
1.56
1.54
1.52
0.90
0.88
0.88
0.86
0.84
N
Troc
O
P
On-Pr
On-Pr
6b
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
3.109
1.062
1.022
1.051
1.000
1.082
1.037
4.134
4.186
6.304


151.35
150.92
130.91
130.73
130.69
128.87
128.84
128.69
128.66
127.62
127.59
127.56
127.50
127.49
127.46
127.41
127.36
125.64
125.61
125.22
125.19
125.14
125.11
125.05
123.98
111.21
111.06
94.77
94.67
77.32
77.00
76.68
75.66
68.64
68.56
68.38
68.34
68.31
68.27
68.16
68.09
55.42
54.64
53.92
53.12
23.84
23.81
23.75
9.88
N
Troc
O
P
On-Pr
On-Pr
6b
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

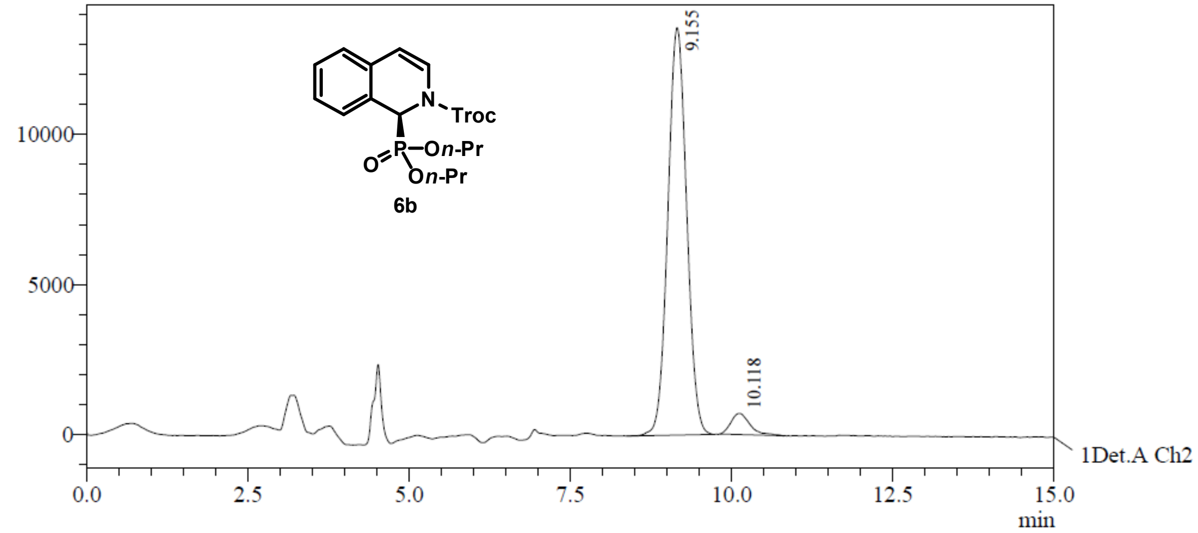

18.73
18.39
N
Troc
P
O
On-Pr
On-Pr
6b
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
ppm



PeakTable

Detector A Ch2 254nm

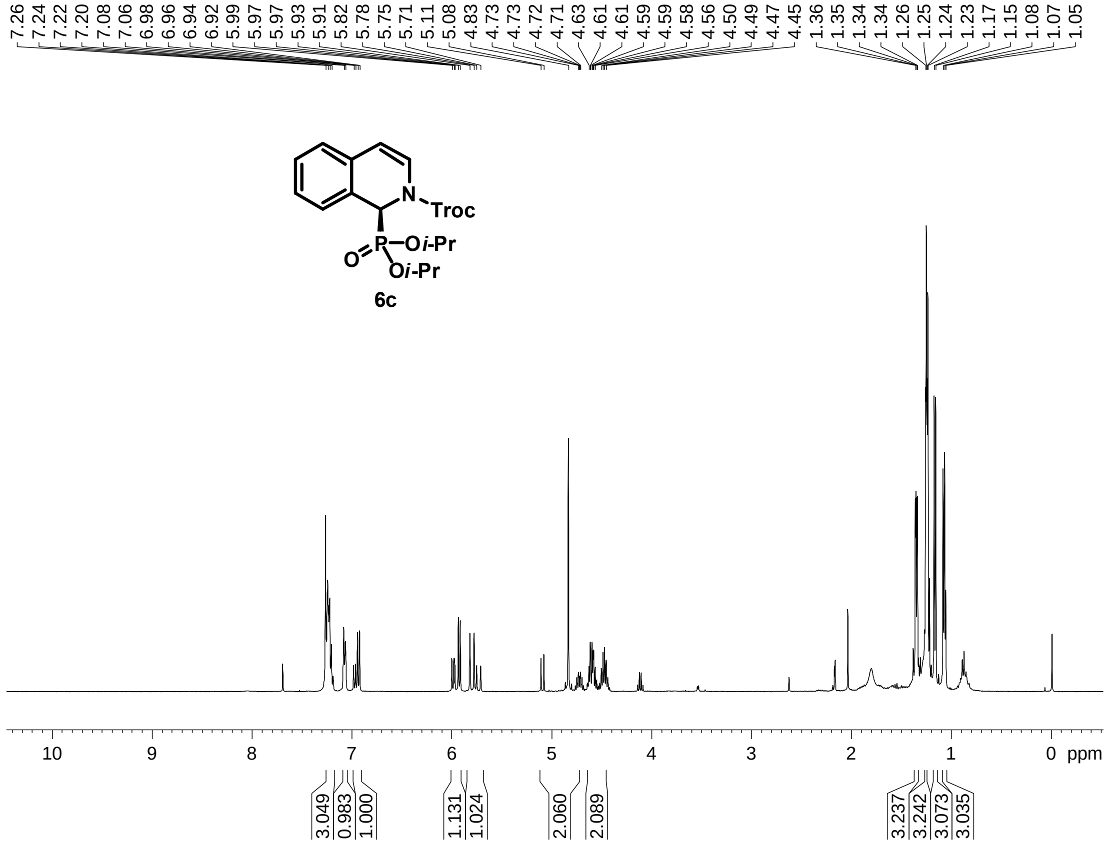
Peak#	Ret. Time	Area	Area %
1	9.084	2941800	49.759
2	10.038	2970301	50.241
Total		5912101	100.000

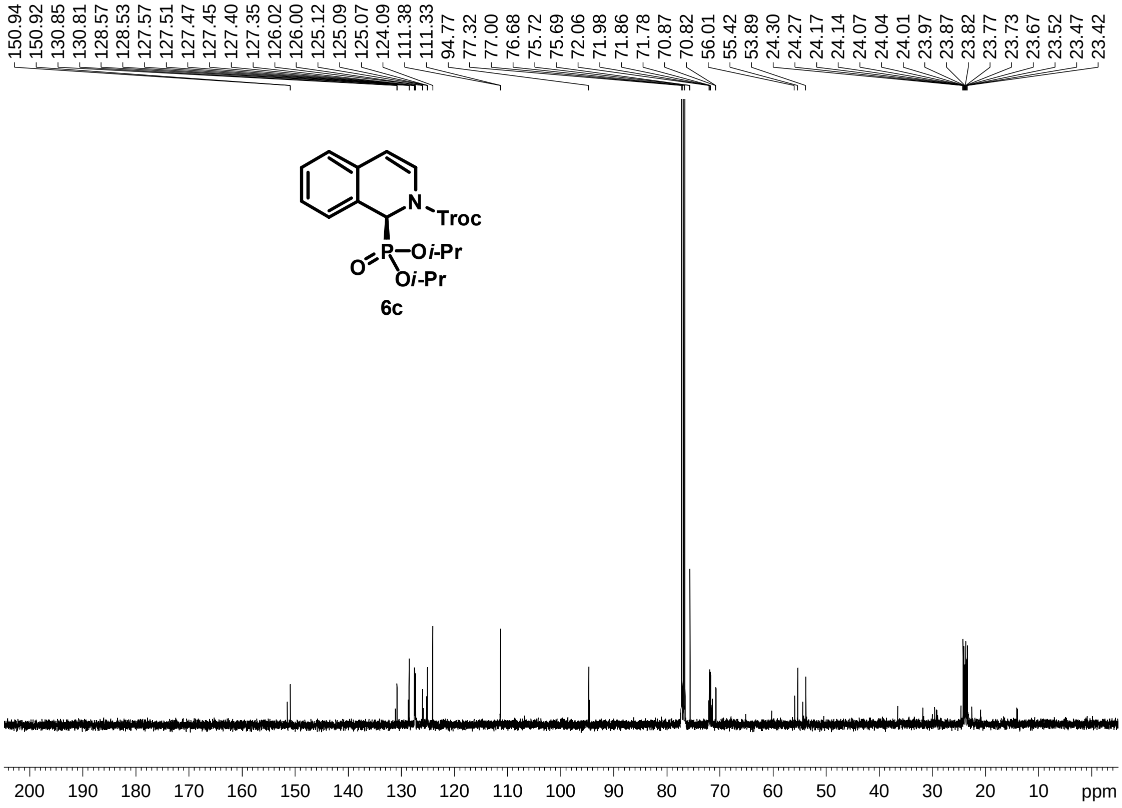


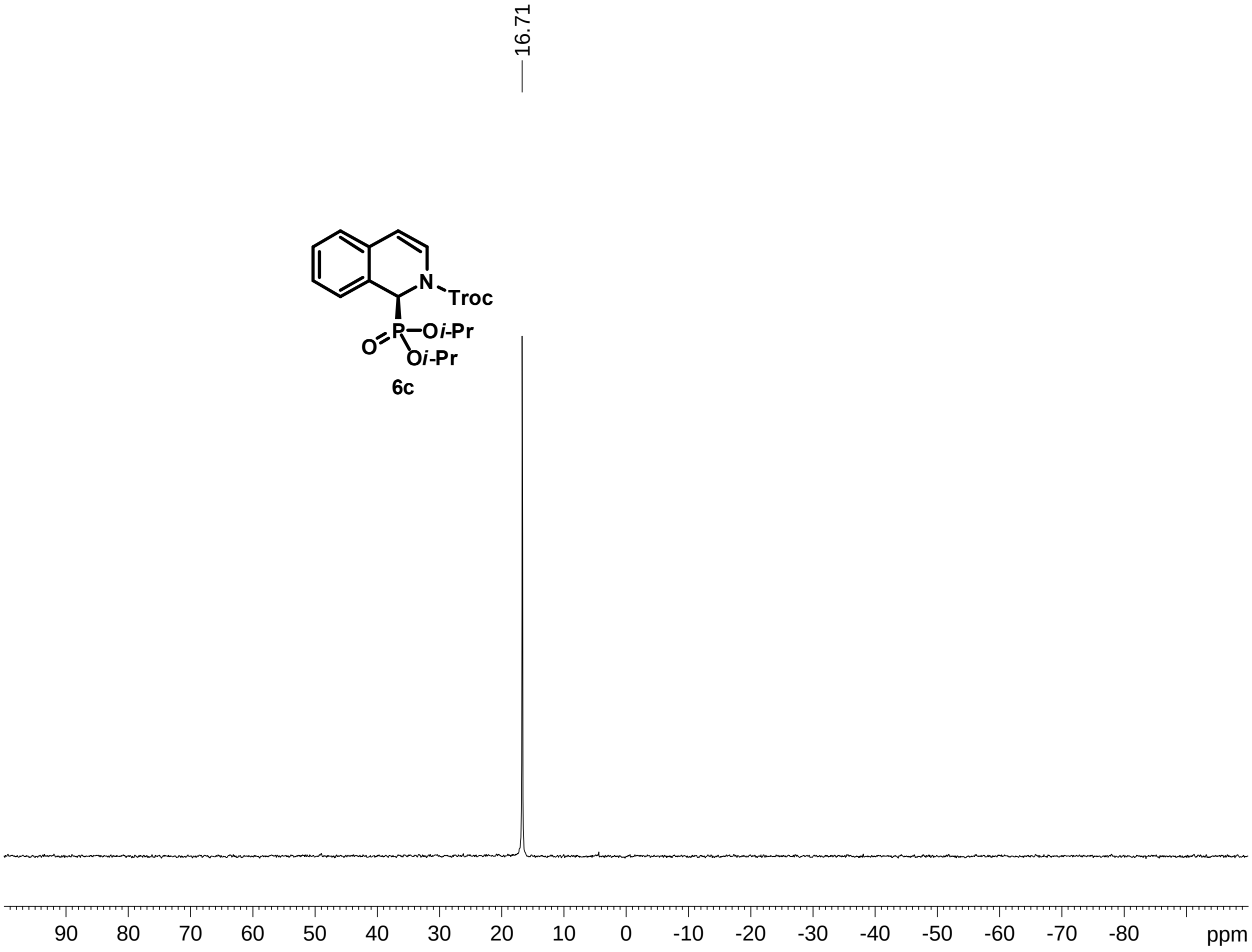
PeakTable

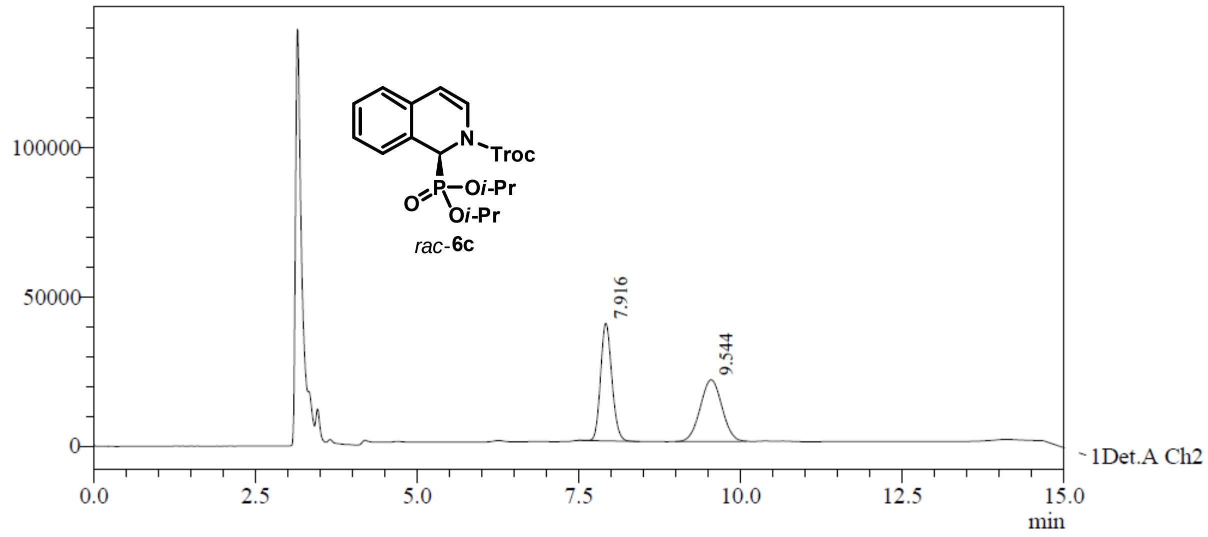
Detector A Ch2 254nm

Peak#	Ret. Time	Area	Area %
1	9.155	275106	94.980
2	10.118	14541	5.020
Total		289647	100.000


7.26
7.24
7.22
7.20
7.08
7.06
6.98
6.96
6.94
6.92
5.99
5.97
5.97
5.93
5.91
5.82
5.78
5.75
5.71
5.11
5.08
4.83
4.73
4.73
4.72
4.71
4.63
4.61
4.61
4.59
4.59
4.58
4.56
4.50
4.49
4.47
4.45
1.36
1.35
1.34
1.34
1.26
1.25
1.24
1.23
1.17
1.15
1.08
1.07
1.05
N
Troc
P
O
O*i*-Pr
O*i*-Pr
6c
10
9
8
7
6
5
4
3
2
1
0
ppm
3.049
0.983
1.000
1.131
1.024
2.060
2.089
3.237
3.242
3.073
3.035


150.94
150.92
130.85
130.81
128.57
128.53
127.57
127.51
127.47
127.45
127.40
127.35
126.02
126.00
125.12
125.09
125.07
124.09
111.38
111.33
94.77
77.32
77.00
76.68
75.72
75.69
72.06
71.98
71.86
71.78
70.87
70.82
56.01
55.42
53.89
24.30
24.27
24.17
24.14
24.07
24.04
24.01
23.97
23.87
23.82
23.77
23.73
23.67
23.52
23.47
23.42
N
Troc
P
O
O*i*-Pr
O*i*-Pr
6c
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

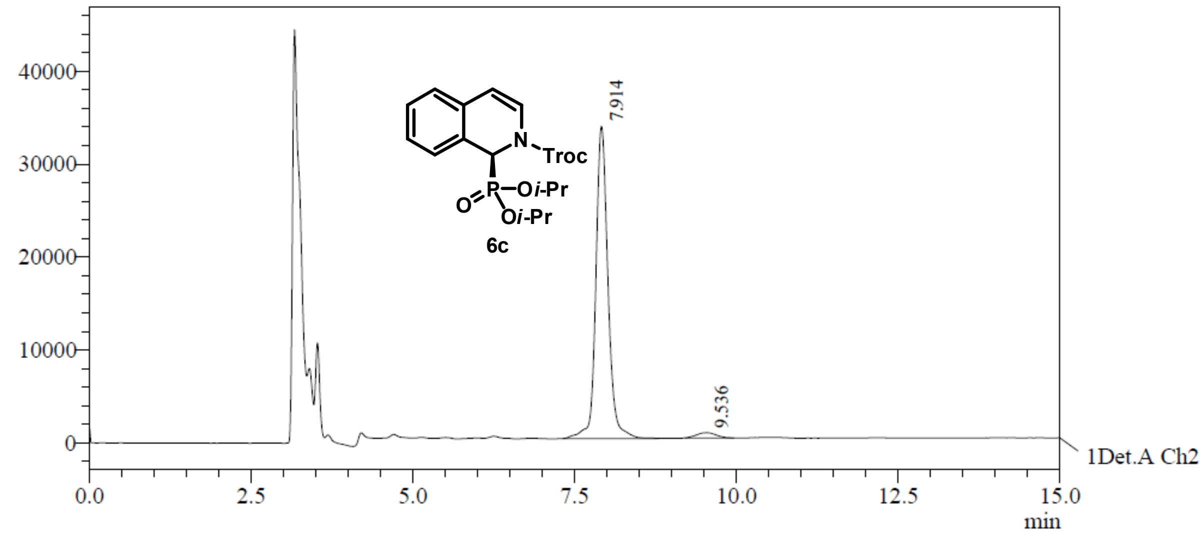

16.71
N
Troc
O
P
O*i*-Pr
O*i*-Pr
6c
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
ppm



PeakTable

Detector A Ch2 254nm

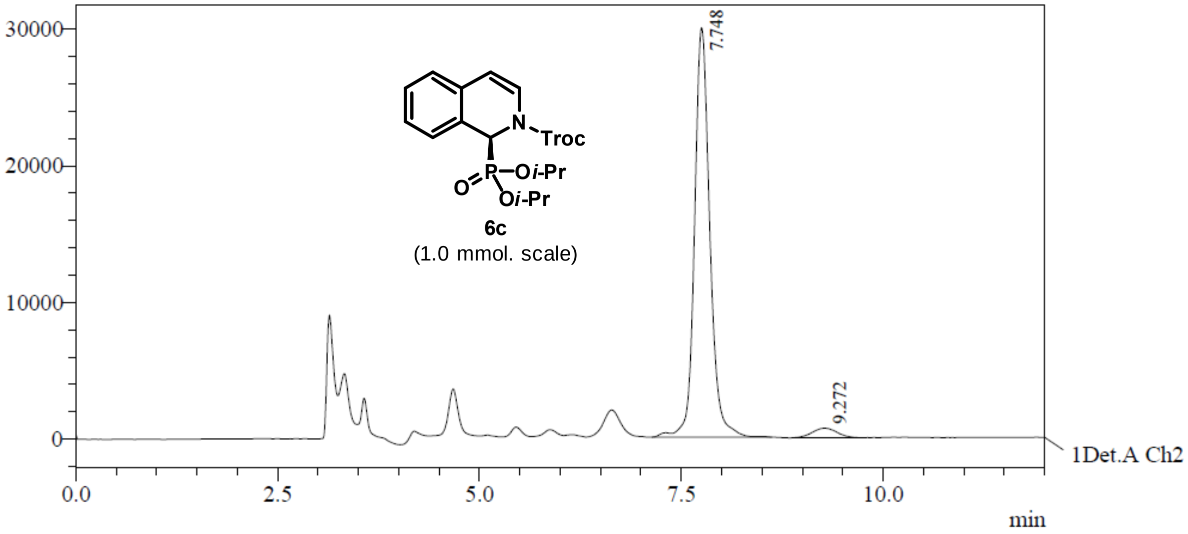
Peak#	Ret. Time	Area	Area %
1	7.916	480731	49.893
2	9.544	482788	50.107
Total		963519	100.000



PeakTable

Detector A Ch2 254nm

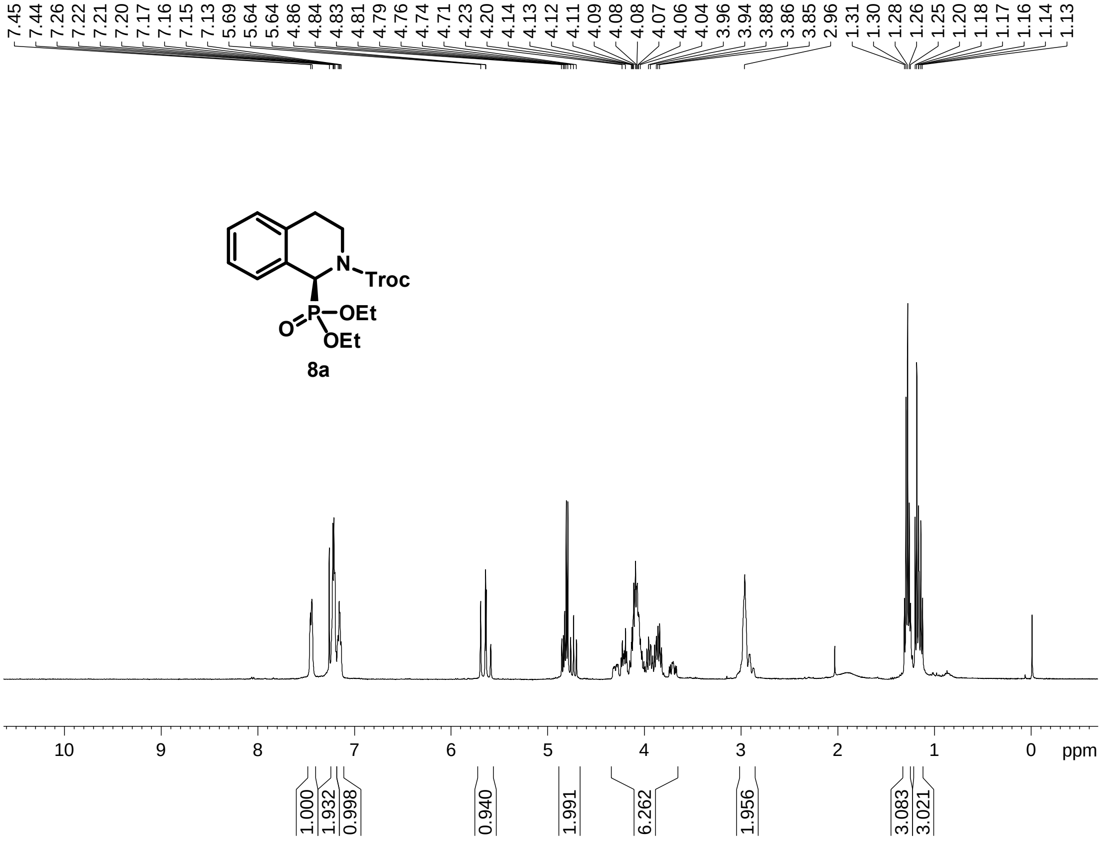
Peak#	Ret. Time	Area	Area %
1	7.914	439686	97.313
2	9.536	12140	2.687
Total		451826	100.000

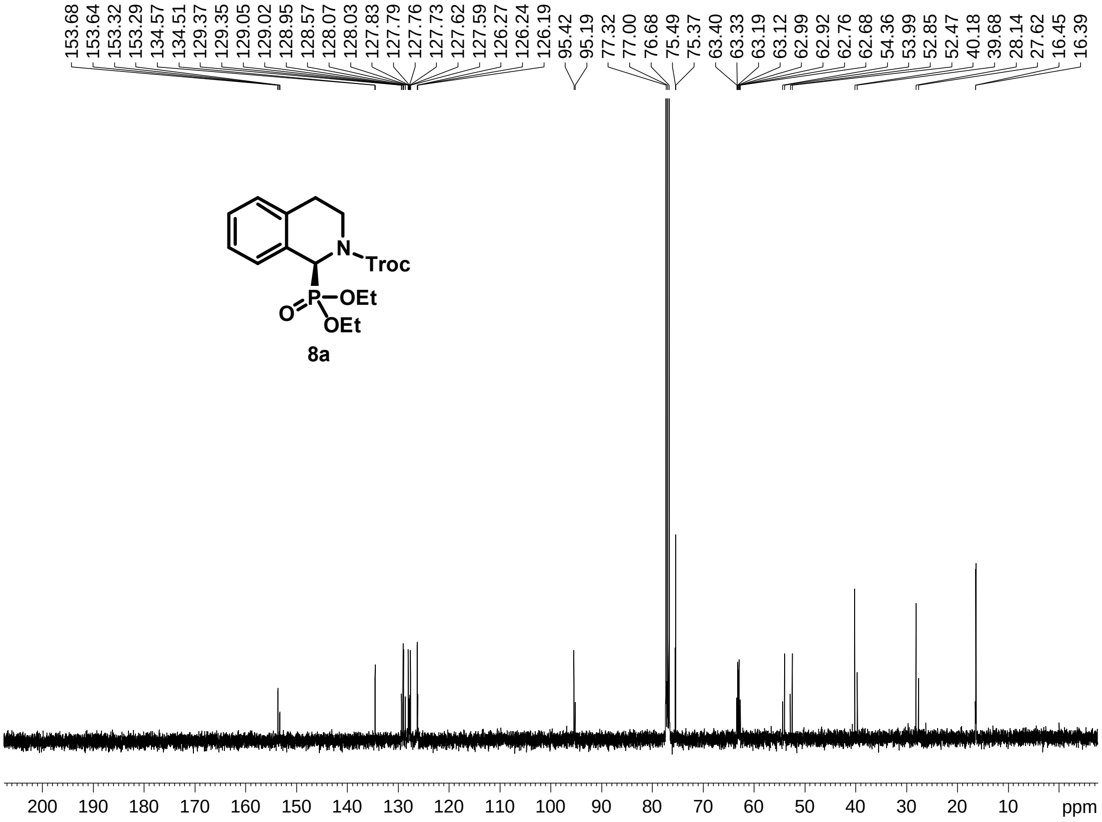


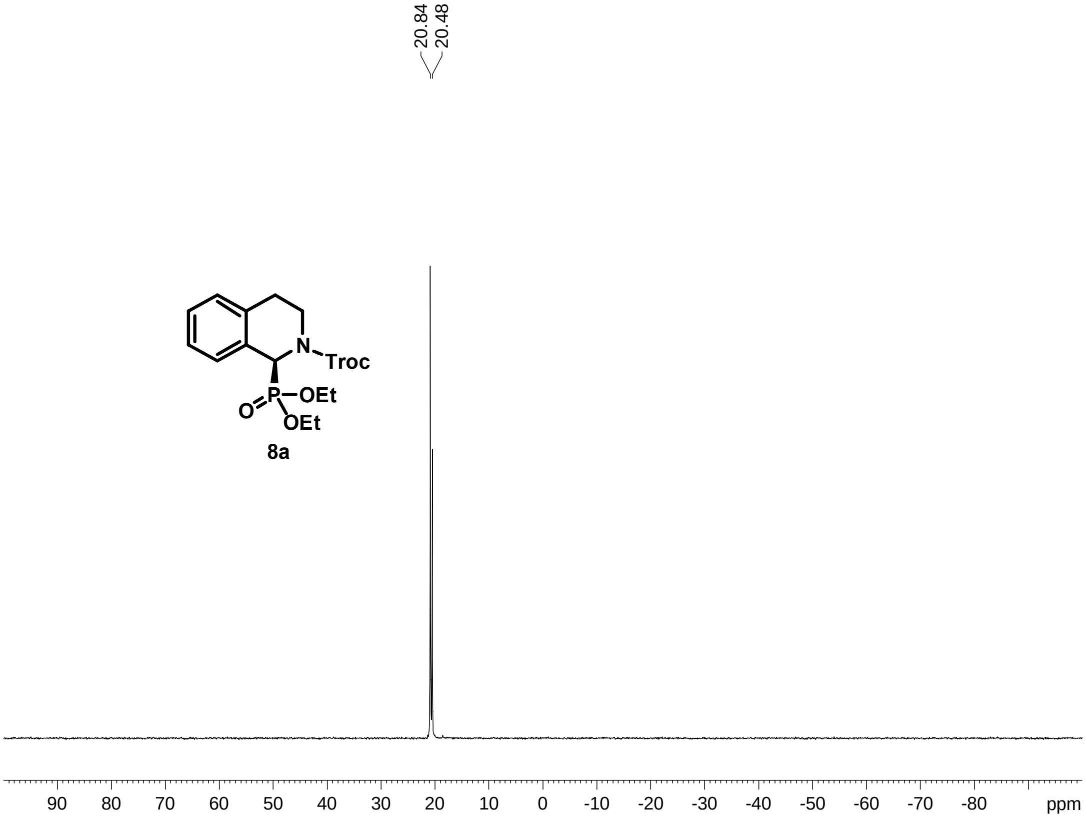
PeakTable

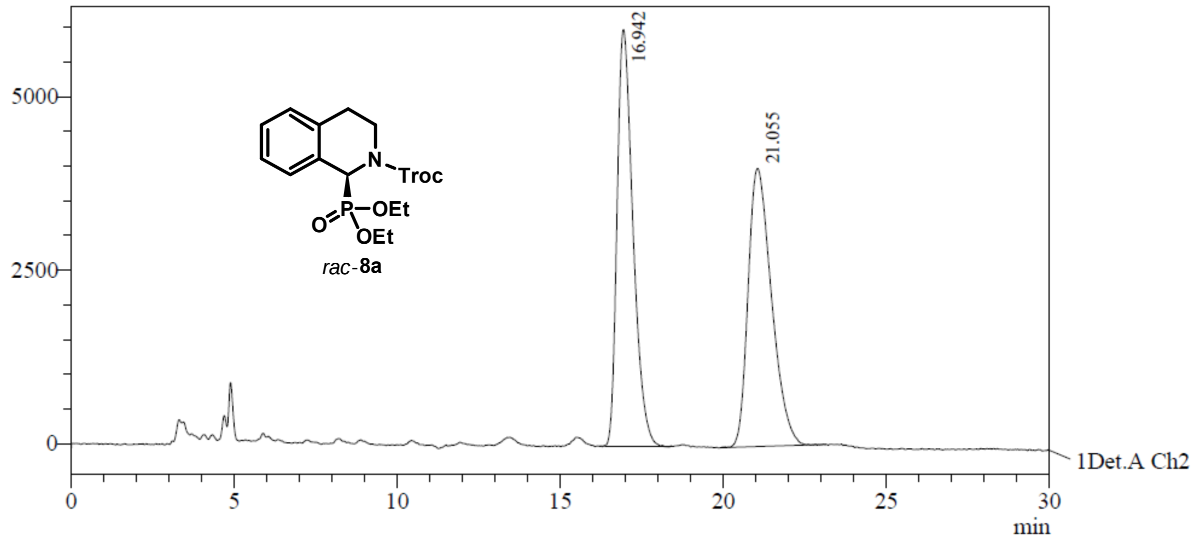
Detector A Ch2 254nm

Peak#	Ret. Time	Area	Area %
1	7.748	395353	96.440
2	9.272	14595	3.560
Total		409948	100.000


7.45
7.44
7.26
7.22
7.21
7.20
7.17
7.16
7.15
7.13
5.69
5.64
5.64
4.86
4.84
4.83
4.81
4.79
4.76
4.74
4.71
4.23
4.20
4.14
4.13
4.12
4.11
4.09
4.08
4.08
4.07
4.06
4.04
3.96
3.94
3.88
3.86
3.85
2.96
1.31
1.30
1.28
1.26
1.25
1.20
1.18
1.17
1.16
1.14
1.13
N
Troc
O
P
OEt
OEt
8a
10
9
8
7
6
5
4
3
2
1
0
ppm
1.000
1.932
0.998
0.940
1.991
6.262
1.956
3.083
3.021


153.68
153.64
153.32
153.29
134.57
134.51
129.37
129.35
129.05
129.02
128.95
128.57
128.07
128.03
127.83
127.79
127.76
127.73
127.62
127.59
126.27
126.24
126.19
95.42
95.19
77.32
77.00
76.68
75.49
75.37
63.40
63.33
63.19
63.12
62.99
62.92
62.76
62.68
54.36
53.99
52.85
52.47
40.18
39.68
28.14
27.62
16.45
16.39
N
Troc
O
P
OEt
OEt
8a
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

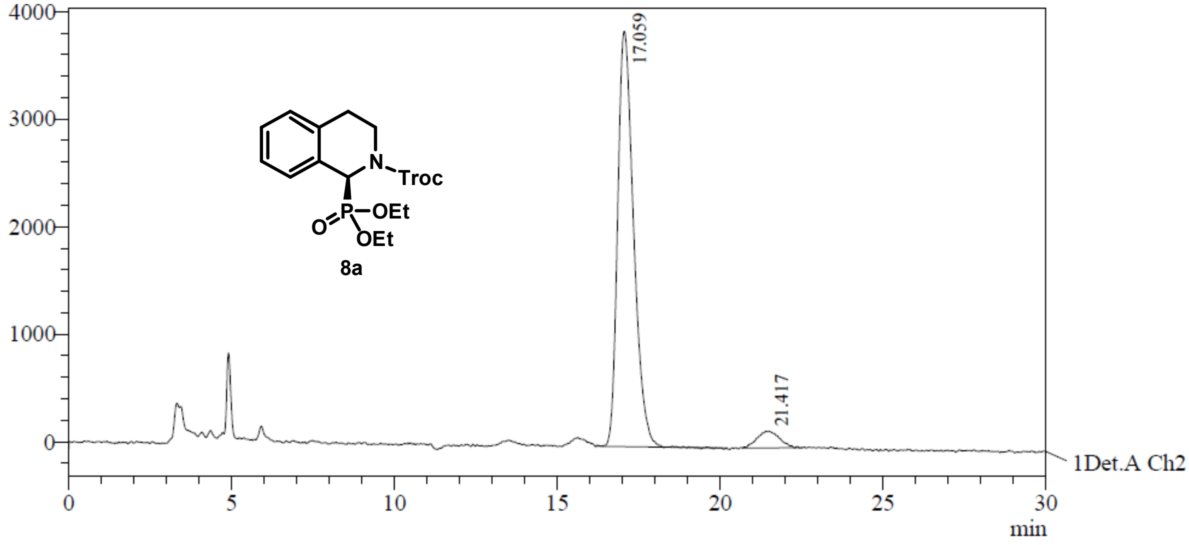

20.84
20.48
N
Troc
P
OEt
O
OEt
8a
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
ppm



PeakTable

Detector A Ch2 254nm

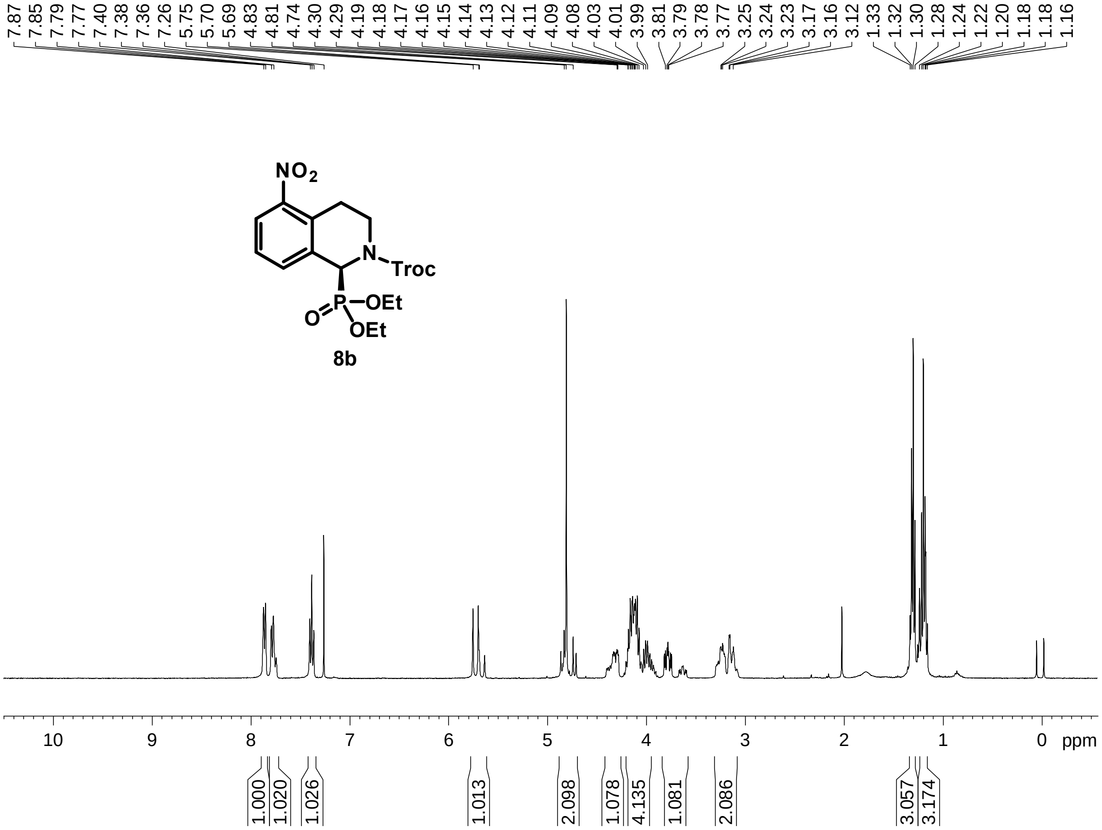
Peak#	Ret. Time	Area	Area %
1	16.942	203992	50.448
2	21.055	200368	49.552
Total		404360	100.000

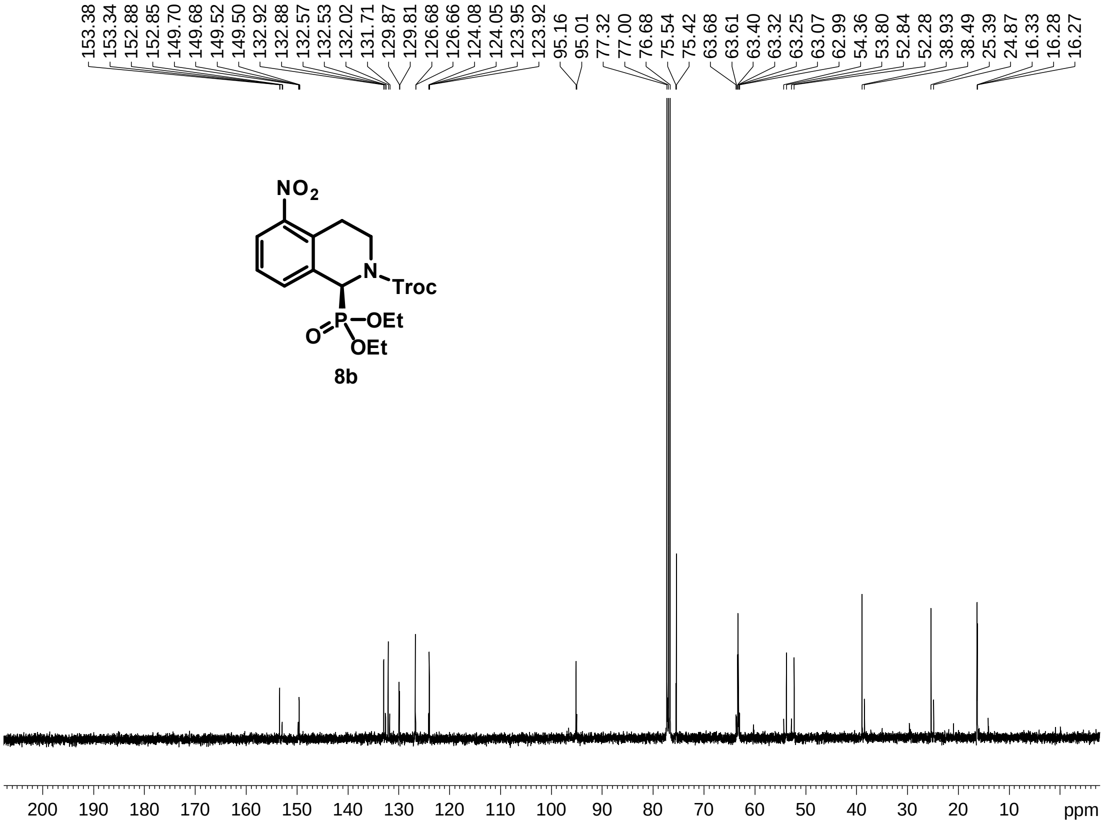


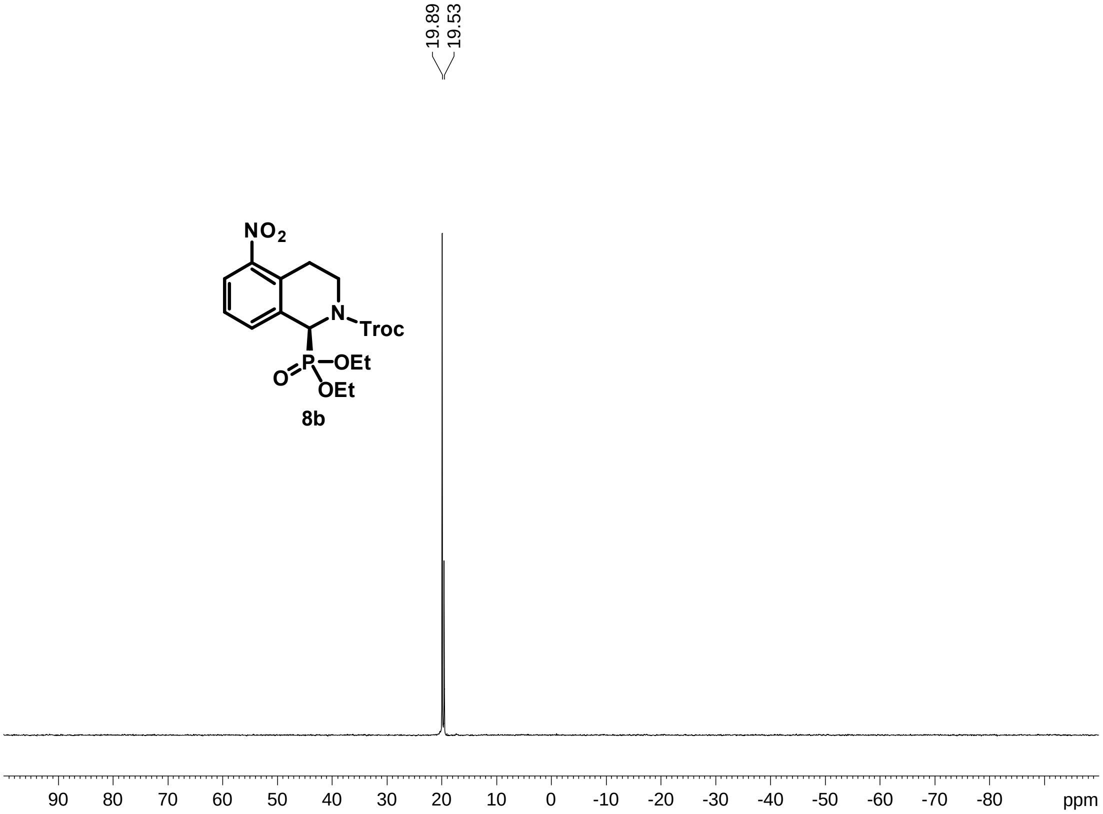
PeakTable

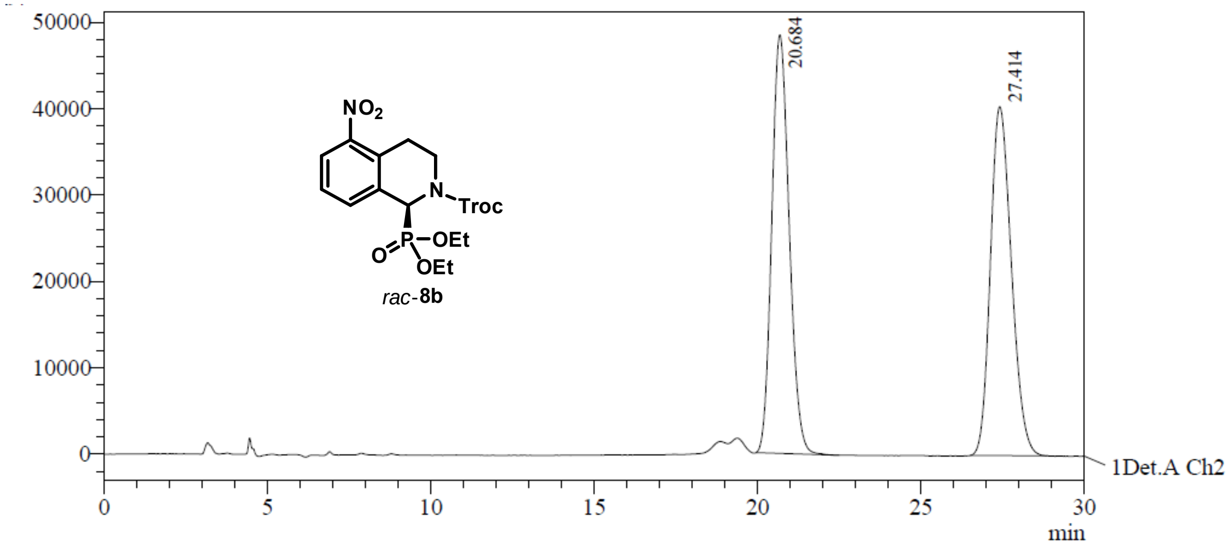
Detector A Ch2 254nm

Peak#	Ret. Time	Area	Area %
1	17.059	131116	94.655
2	21.417	7403	5.345
Total		138519	100.000


7.87
7.85
7.79
7.77
7.40
7.38
7.36
7.26
5.75
5.70
5.69
4.83
4.81
4.74
4.30
4.29
4.19
4.18
4.17
4.16
4.15
4.14
4.13
4.12
4.11
4.09
4.08
4.03
4.01
3.99
3.81
3.79
3.78
3.77
3.25
3.24
3.23
3.17
3.16
3.12
1.33
1.32
1.30
1.28
1.24
1.22
1.20
1.18
1.18
1.16
NO2
N
Troc
O
P
OEt
OEt
8b
10
9
8
7
6
5
4
3
2
1
0
ppm
1.000
1.020
1.026
1.013
2.098
1.078
4.135
1.081
2.086
3.057
3.174


153.38
153.34
152.88
152.85
149.70
149.68
149.52
149.50
132.92
132.88
132.57
132.53
132.02
131.71
129.87
129.81
126.68
126.66
124.08
124.05
123.95
123.92
95.16
95.01
77.32
77.00
76.68
75.54
75.42
63.68
63.61
63.40
63.32
63.25
63.07
62.99
54.36
53.80
52.84
52.28
38.93
38.49
25.39
24.87
16.33
16.28
16.27
NO2
N
Troc
O
P
OEt
OEt
8b
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm


19.89
19.53
NO2
N
Troc
P
O
OEt
OEt
8b
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
ppm

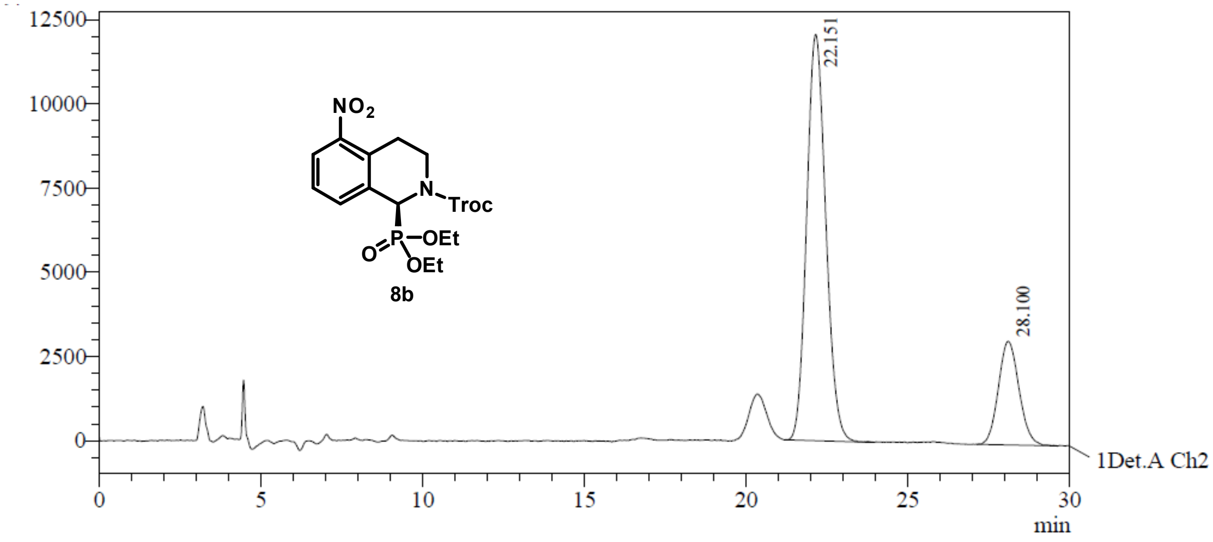


rac-**8b**

PeakTable

Detector A Ch2 254nm

Peak#	Ret. Time	Area	Area %
1	20.684	1799188	49.879
2	27.414	1807885	50.121
Total		3607074	100.000

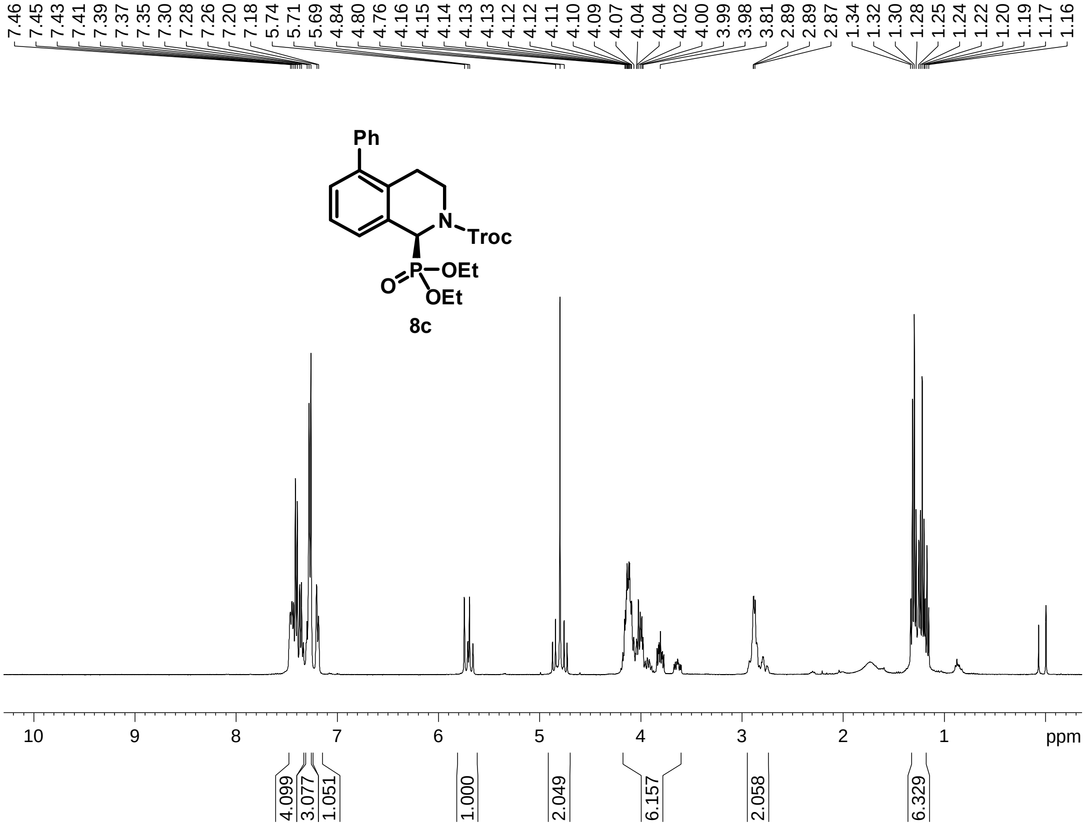


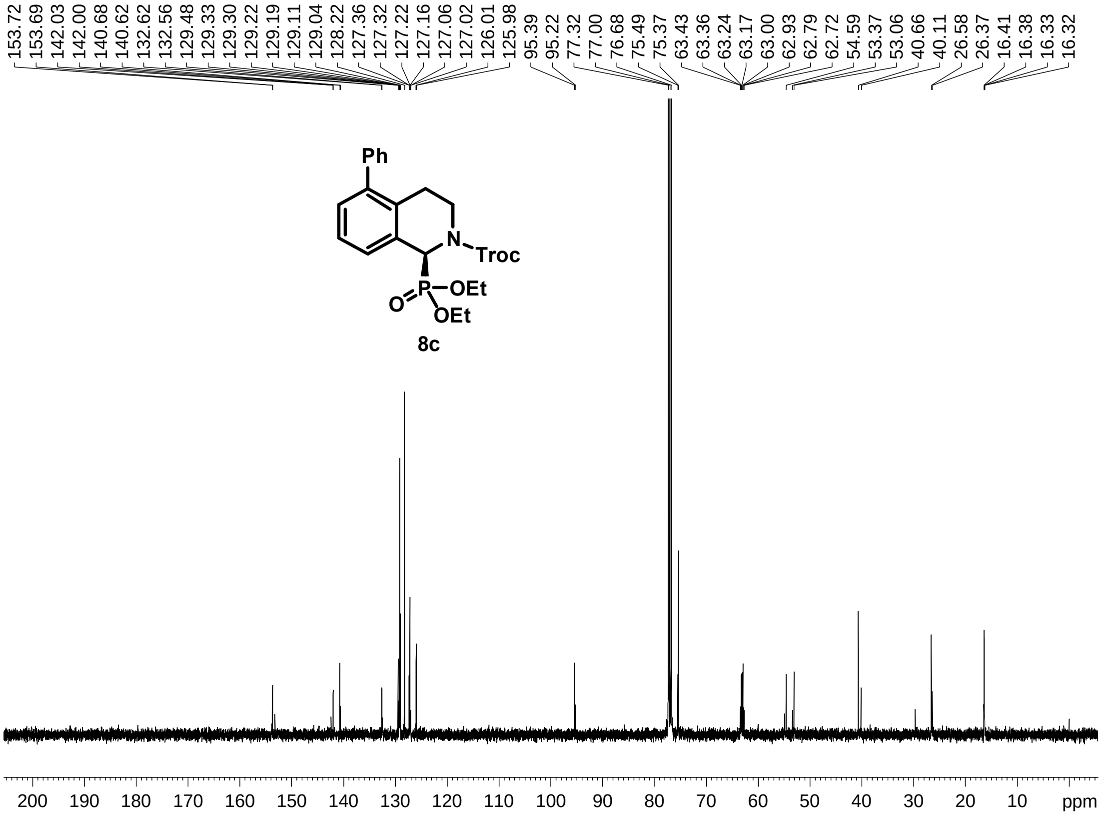
8b

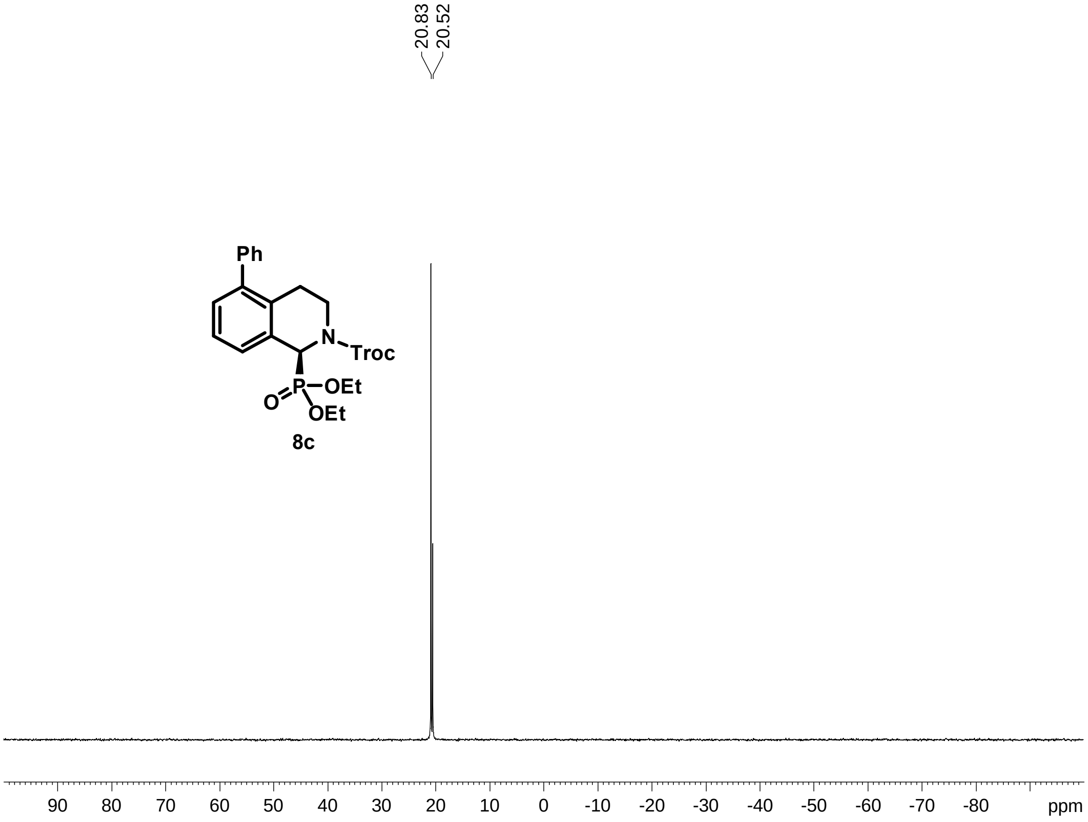
PeakTable

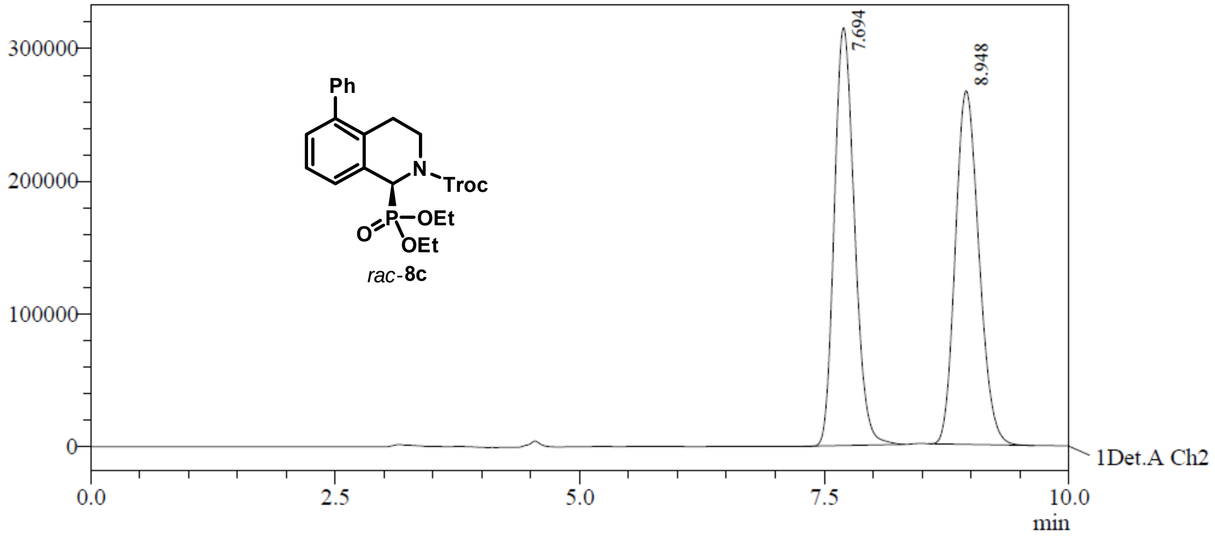
Detector A Ch2 254nm

Peak#	Ret. Time	Area	Area %
1	22.151	496351	78.402
2	28.100	136734	21.598
Total		633084	100.000


7.46
7.45
7.43
7.41
7.39
7.37
7.35
7.30
7.28
7.26
7.20
7.18
5.74
5.71
5.69
4.84
4.80
4.76
4.16
4.15
4.14
4.13
4.13
4.12
4.12
4.11
4.10
4.09
4.07
4.04
4.04
4.02
4.00
3.99
3.98
3.81
2.89
2.89
2.87
1.34
1.32
1.30
1.28
1.25
1.24
1.22
1.20
1.19
1.17
1.16
Ph
N
Troc
P
OEt
O
OEt
8c
10
9
8
7
6
5
4
3
2
1
ppm
4.099
3.077
1.051
1.000
2.049
6.157
2.058
6.329


153.72
153.69
142.03
142.00
140.68
140.62
132.62
132.56
129.48
129.33
129.30
129.22
129.19
129.11
129.04
128.22
127.36
127.32
127.22
127.16
127.06
127.02
126.01
125.98
95.39
95.22
77.32
77.00
76.68
75.49
75.37
63.43
63.36
63.24
63.17
63.00
62.93
62.79
62.72
54.59
53.37
53.06
40.66
40.11
26.58
26.37
16.41
16.38
16.33
16.32
Ph
N
Troc
P
OEt
O
OEt
8c
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

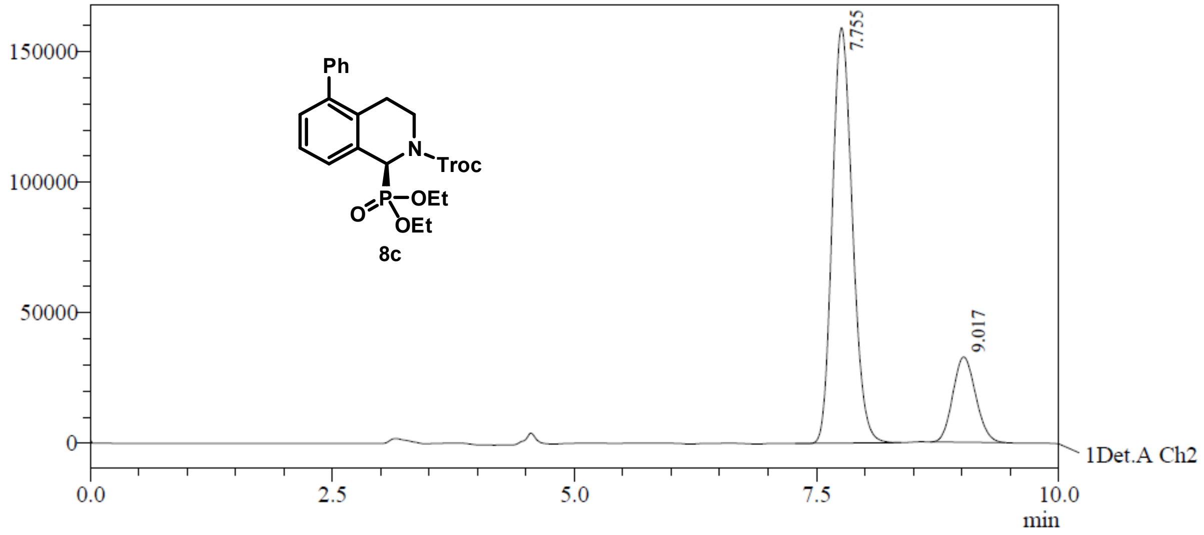

20.83
20.52
Ph
N
Troc
O
P
OEt
OEt
8c
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
ppm



PeakTable

Detector A Ch2 254nm

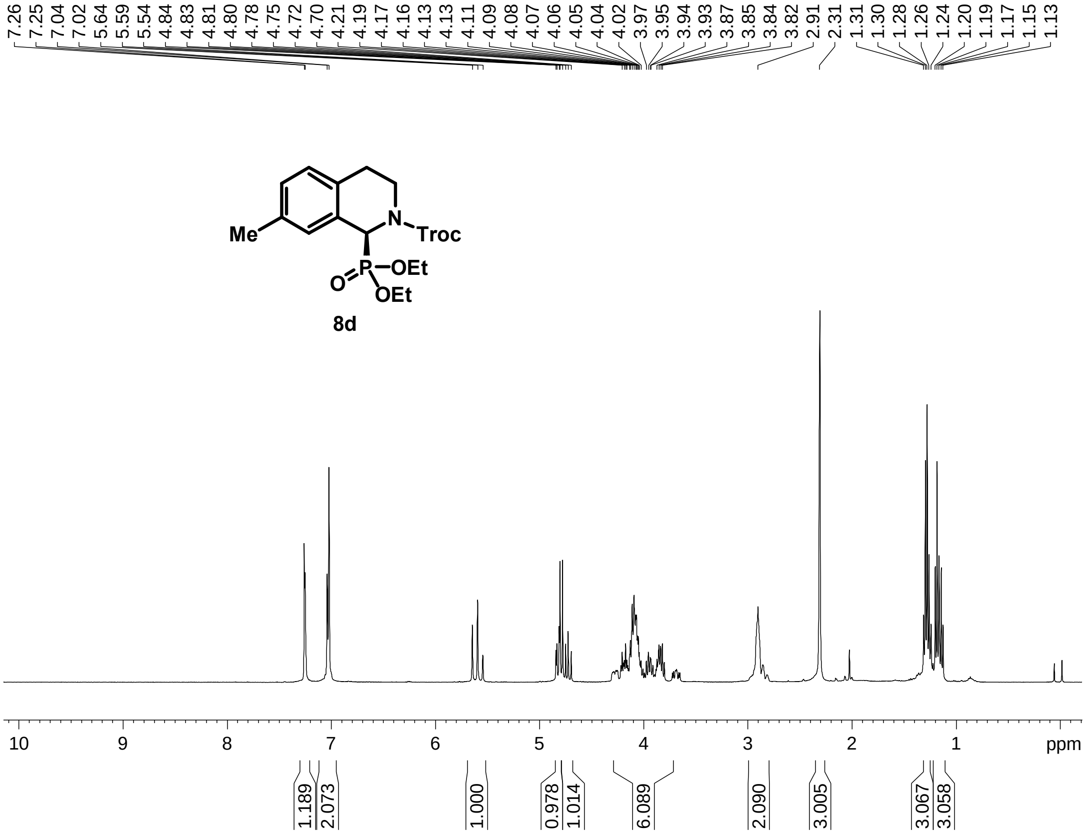
Peak#	Ret. Time	Area	Area %
1	7.694	4522018	50.176
2	8.948	4490235	49.824
Total		9012252	100.000

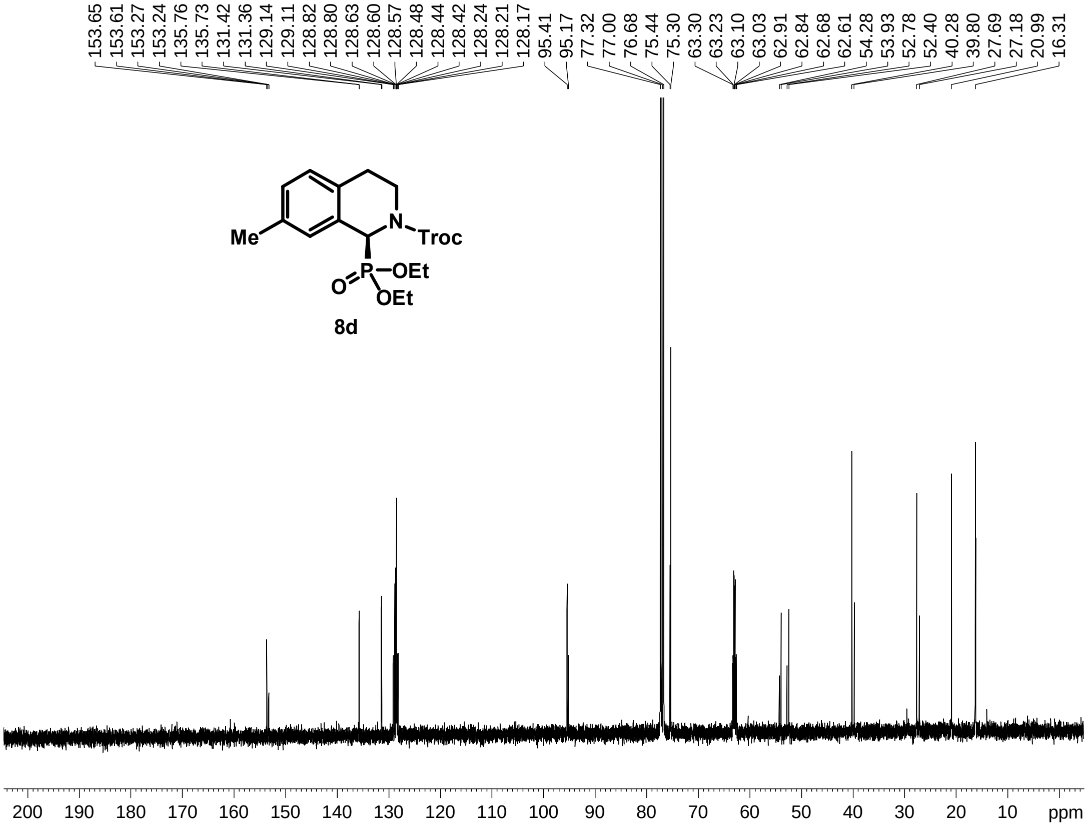


PeakTable

Detector A Ch2 254nm

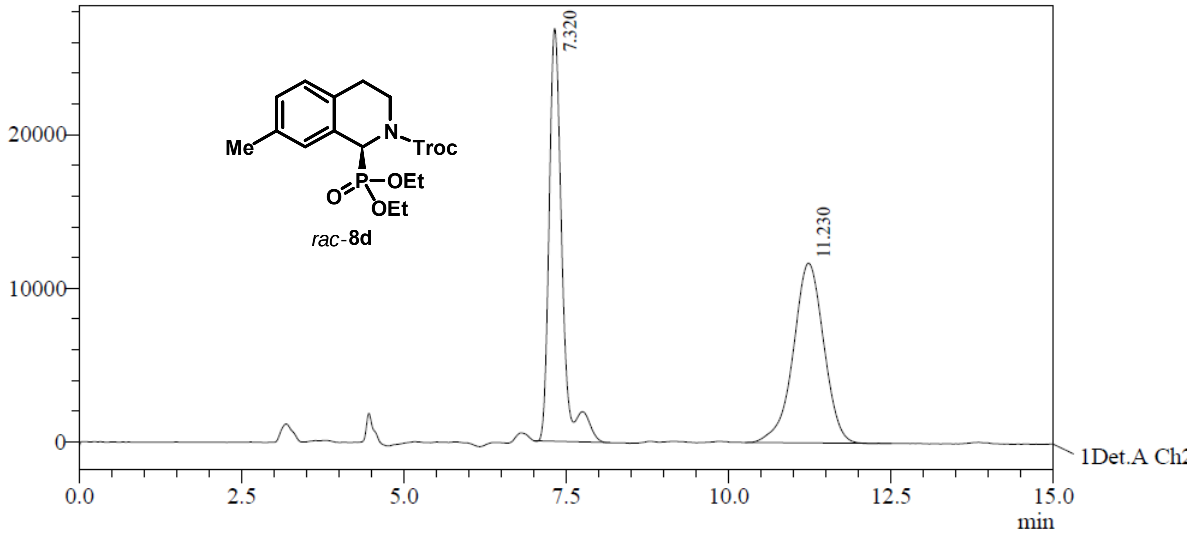
Peak#	Ret. Time	Area	Area %
1	7.755	2301552	81.097
2	9.017	536473	18.903
Total		2838025	100.000


7.26
7.25
7.04
7.02
5.64
5.59
5.54
4.84
4.83
4.81
4.80
4.78
4.75
4.72
4.70
4.21
4.19
4.17
4.16
4.13
4.13
4.11
4.09
4.08
4.07
4.06
4.05
4.04
4.02
3.97
3.95
3.94
3.93
3.87
3.85
3.84
3.82
2.91
2.31
1.31
1.30
1.28
1.26
1.24
1.20
1.19
1.17
1.15
1.13
Me
N
Troc
P
OEt
O
OEt
8d
10
9
8
7
6
5
4
3
2
1
ppm
1.189
2.073
1.000
0.978
1.014
6.089
2.090
3.005
3.067
3.058


153.65
153.61
153.27
153.24
135.76
135.73
131.42
131.36
129.14
129.11
128.82
128.80
128.63
128.60
128.57
128.48
128.44
128.42
128.24
128.21
128.17
95.41
95.17
77.32
77.00
76.68
75.44
75.30
63.30
63.23
63.10
63.03
62.91
62.84
62.68
62.61
54.28
53.93
52.78
52.40
40.28
39.80
27.69
27.18
20.99
16.31
Me
N
Troc
P
OEt
O
OEt
8d
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm


20.97
20.57
Me
N
Troc
O
P
OEt
OEt
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
ppm

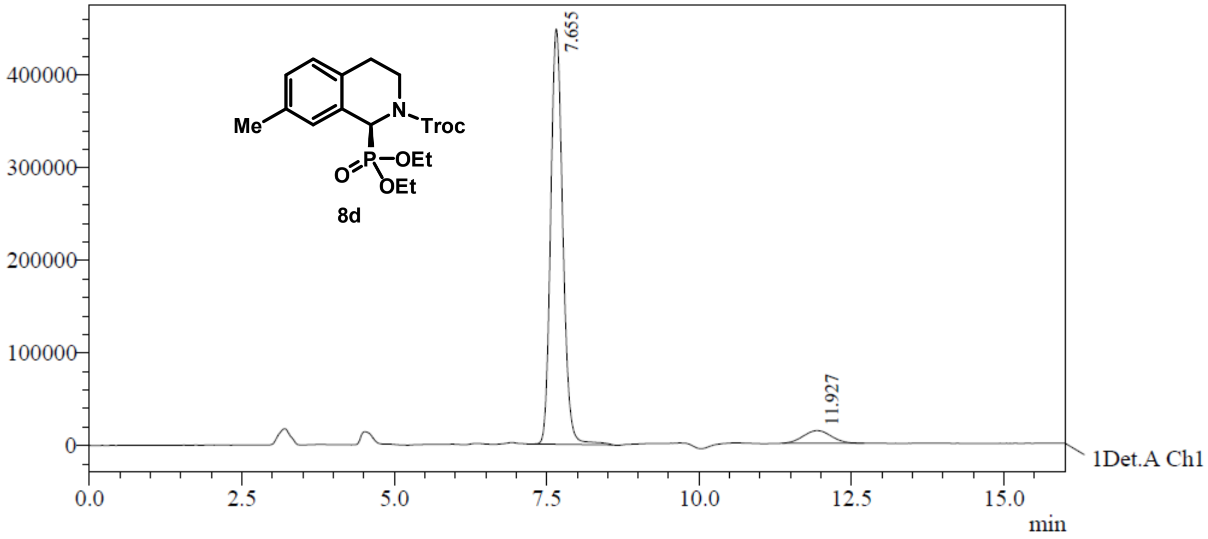
8d



PeakTable

Detector A Ch2 254nm

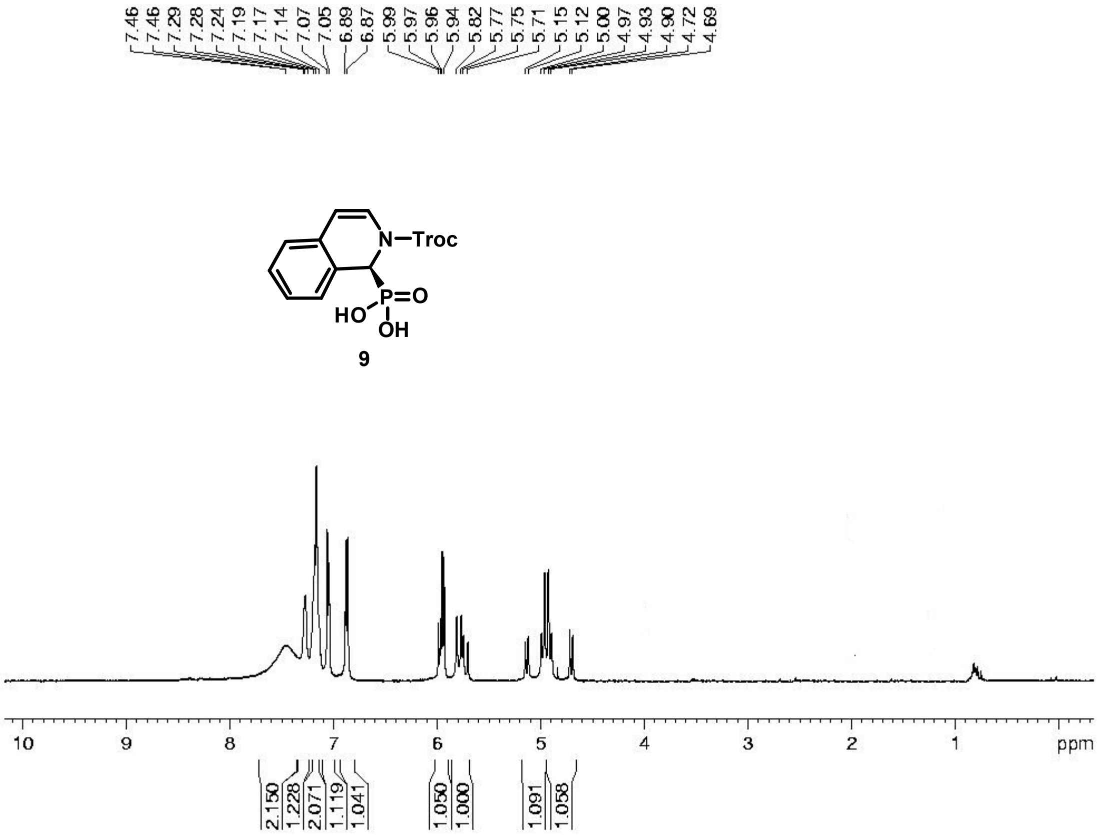
Peak#	Ret. Time	Area	Area %
1	7.320	374413	49.454
2	11.230	382677	50.546
Total		757089	100.000

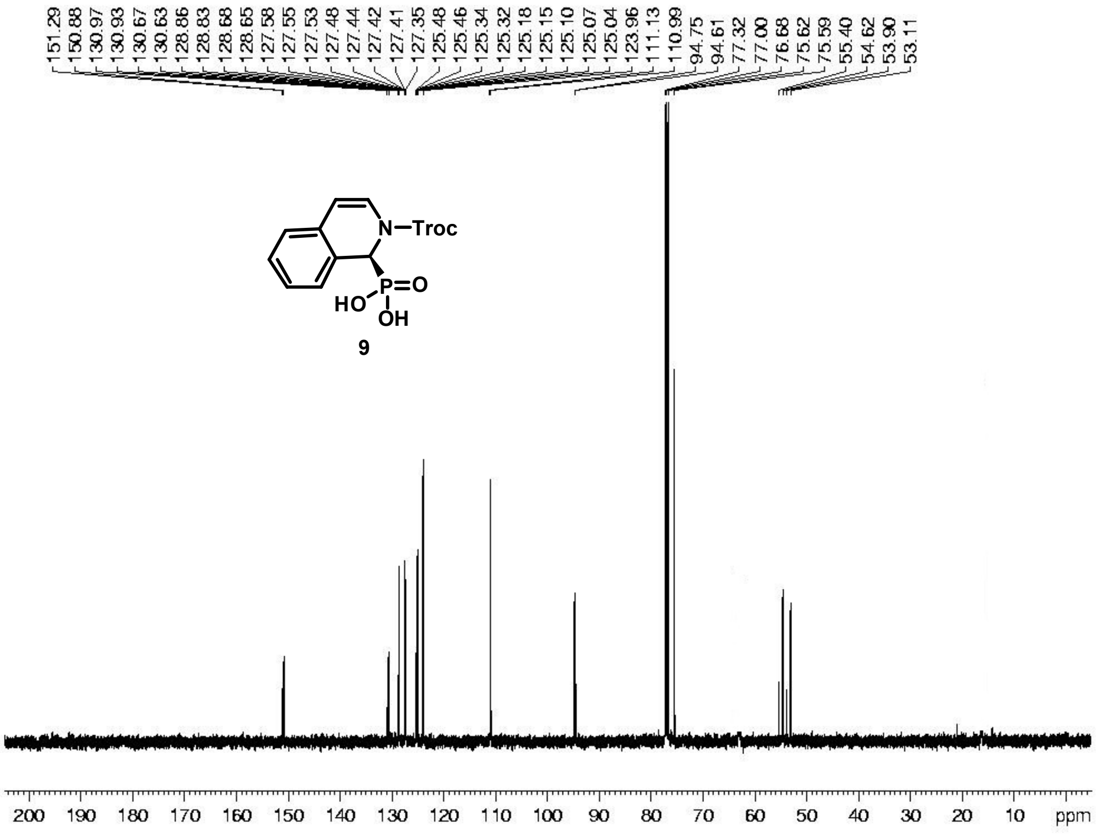


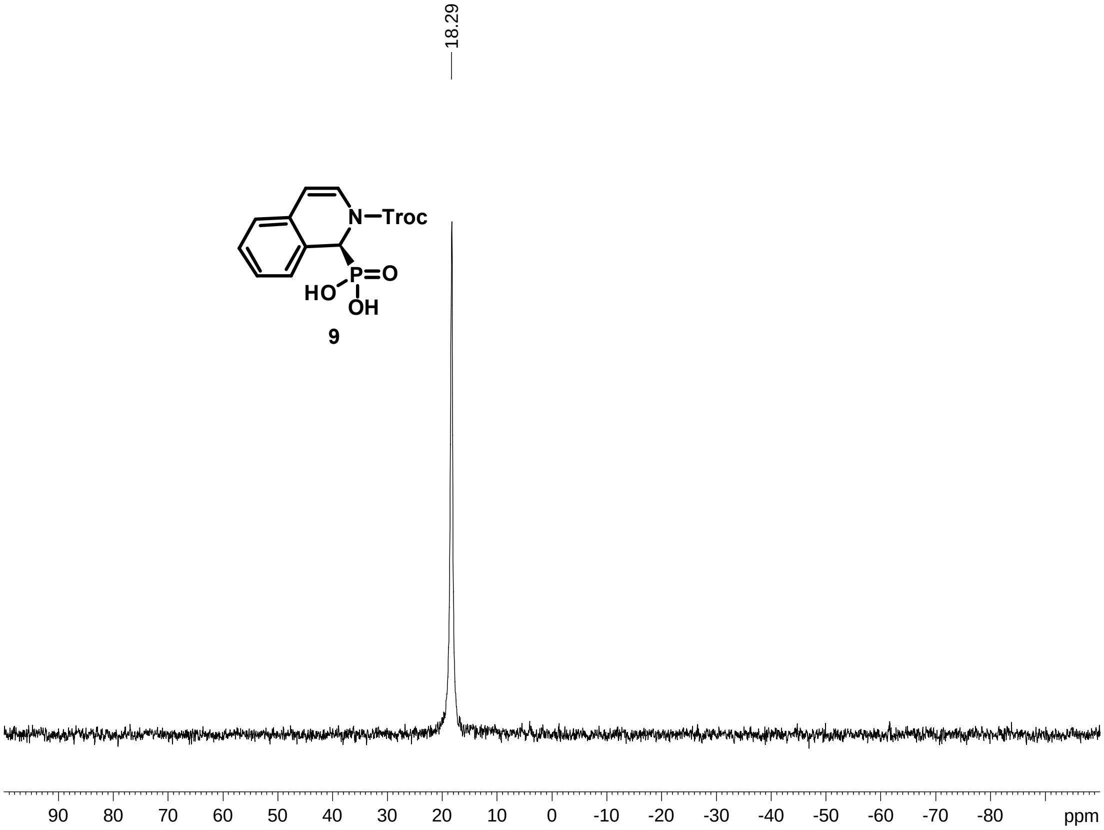
PeakTable

Detector A Ch1 210nm

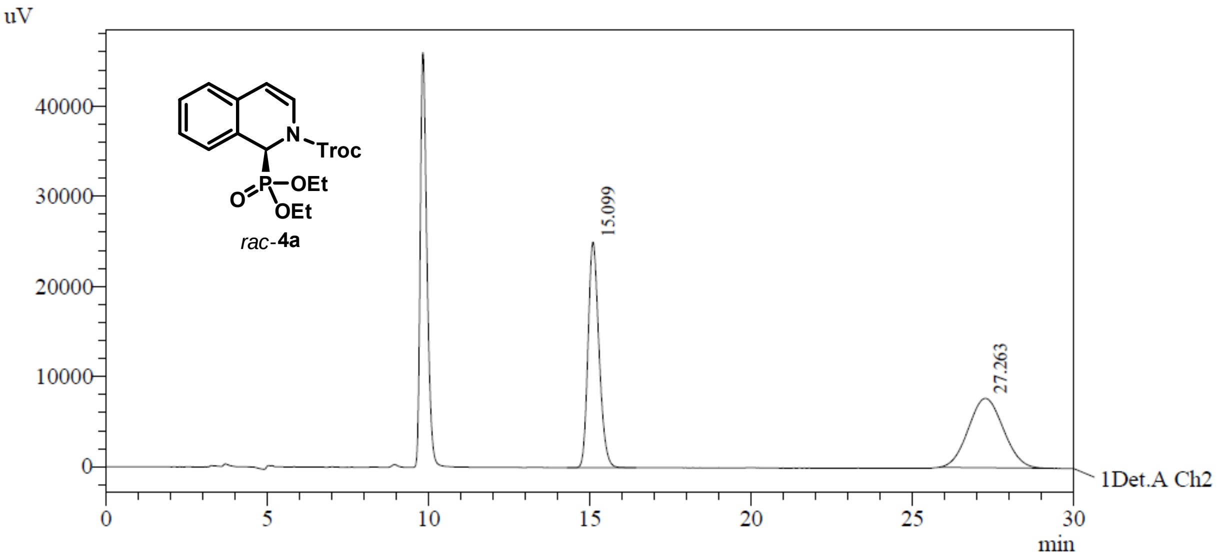
Peak#	Ret. Time	Area	Area %
1	7.655	6212412	93.362
2	11.927	441721	6.638
Total		6654133	100.000


7.46
7.46
7.29
7.28
7.24
7.19
7.17
7.14
7.07
7.05
6.89
6.87
5.99
5.97
5.96
5.94
5.82
5.77
5.75
5.71
5.15
5.12
5.00
4.97
4.93
4.90
4.72
4.69
N−Troc
P=O
HO
OH
9
10
9
8
7
6
5
4
3
2
1
ppm
2.150
1.228
2.071
1.119
1.041
1.050
1.000
1.091
1.058


151.29
150.88
130.97
130.93
130.67
130.63
128.86
128.83
128.68
128.65
127.58
127.55
127.53
127.48
127.44
127.42
127.41
127.35
125.48
125.46
125.34
125.32
125.18
125.15
125.10
125.07
125.04
123.96
111.13
110.99
94.75
94.61
77.32
77.00
76.68
75.62
75.59
55.40
54.62
53.90
53.11
N−Troc
P=O
HO
OH
9
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm


18.29
N
Troc
P
O
HO
OH
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
ppm

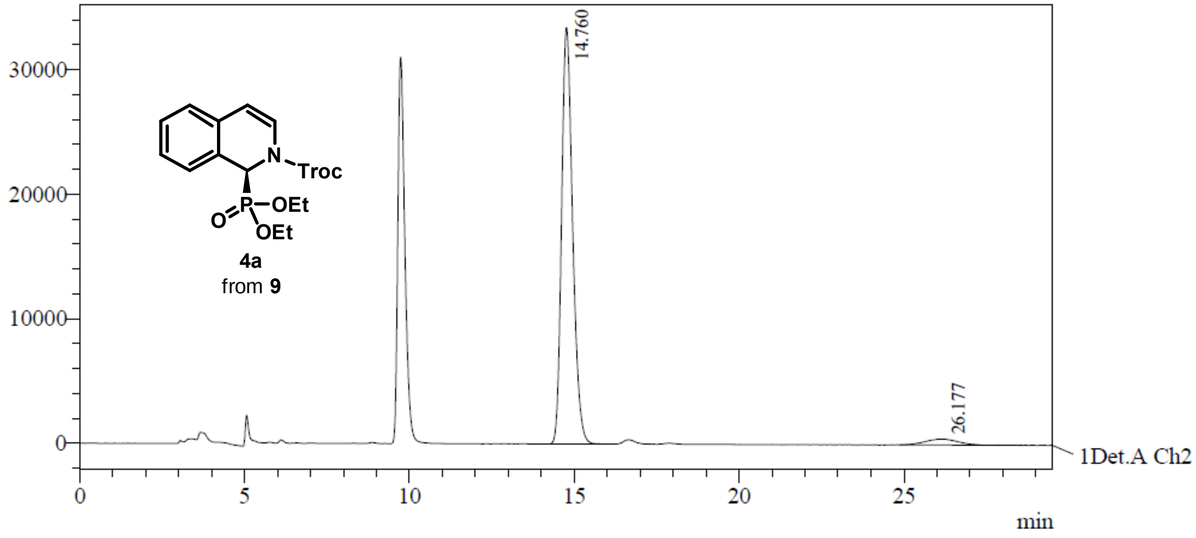
9



PeakTable

Detector A Ch2 254nm

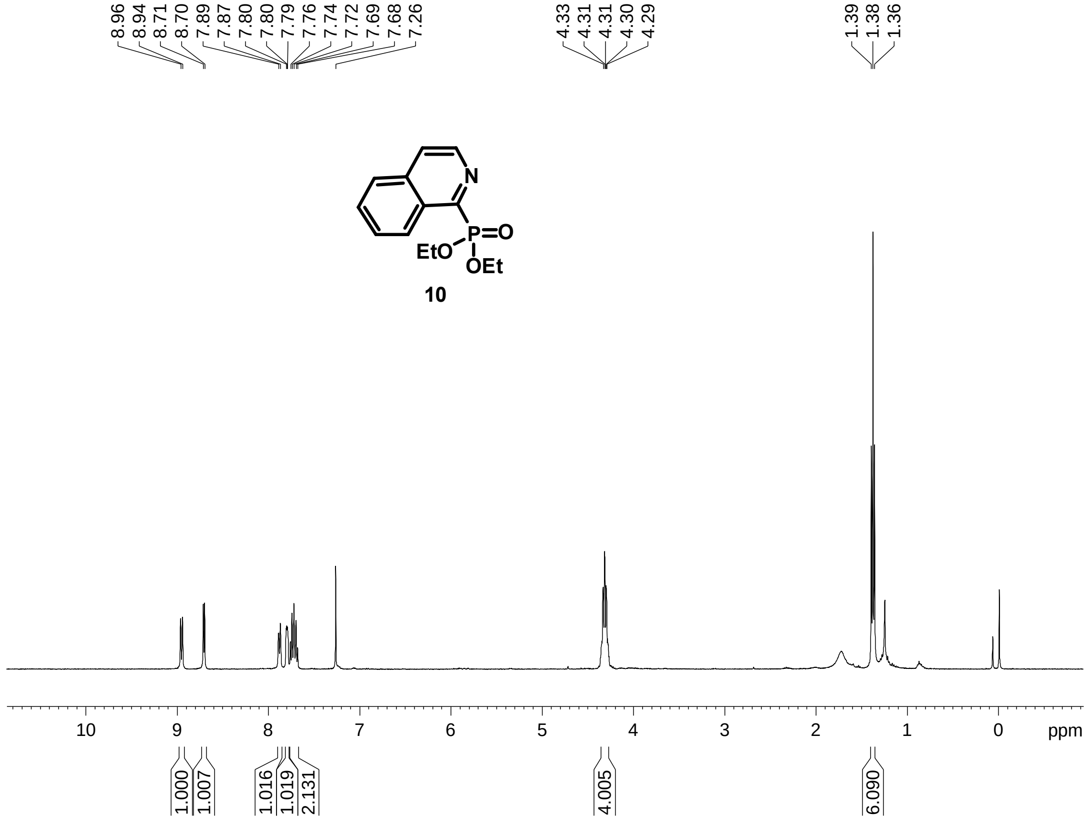
Peak#	Ret. Time	Area	Area %
1	15.099	590024	50.411
2	27.263	580394	49.589
Total		1170418	100.000

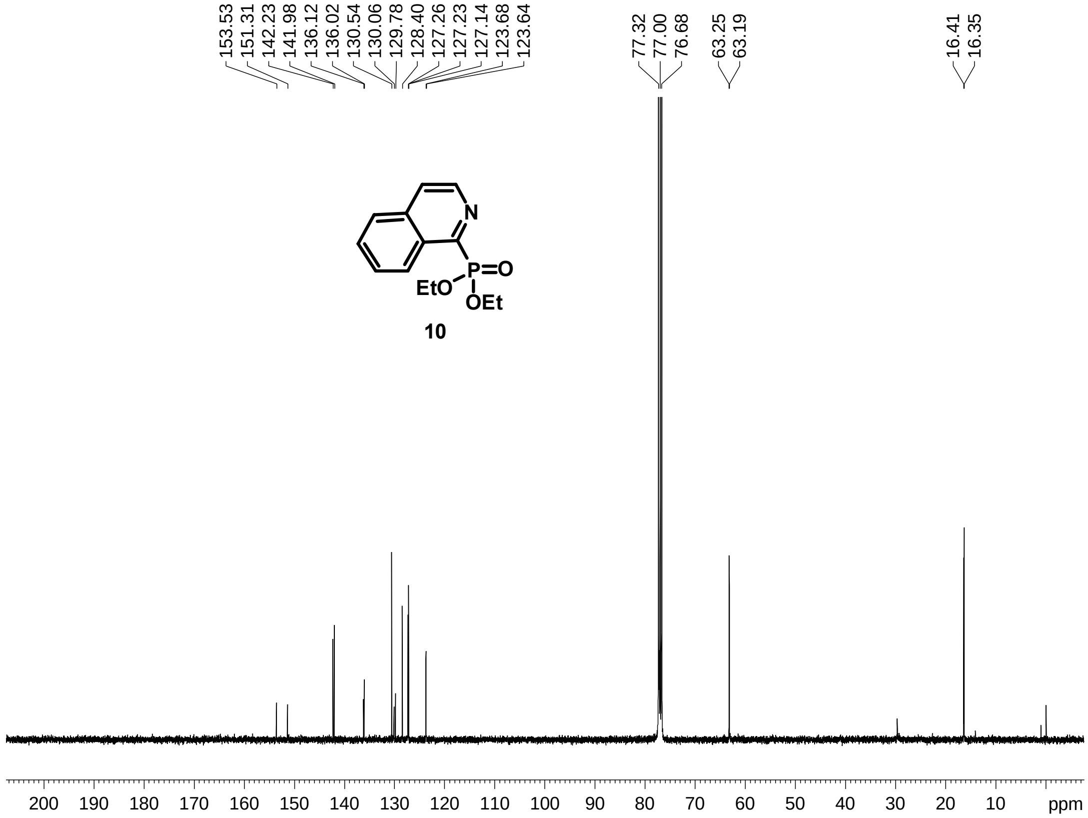


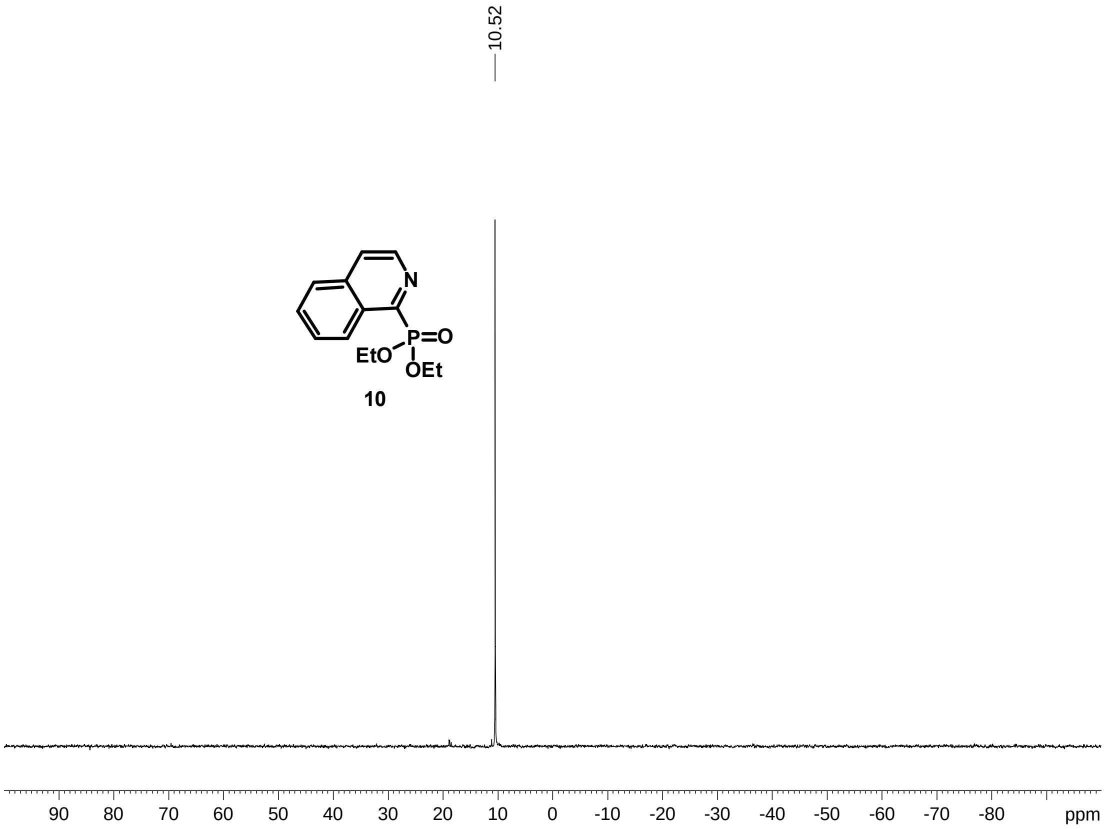
PeakTable

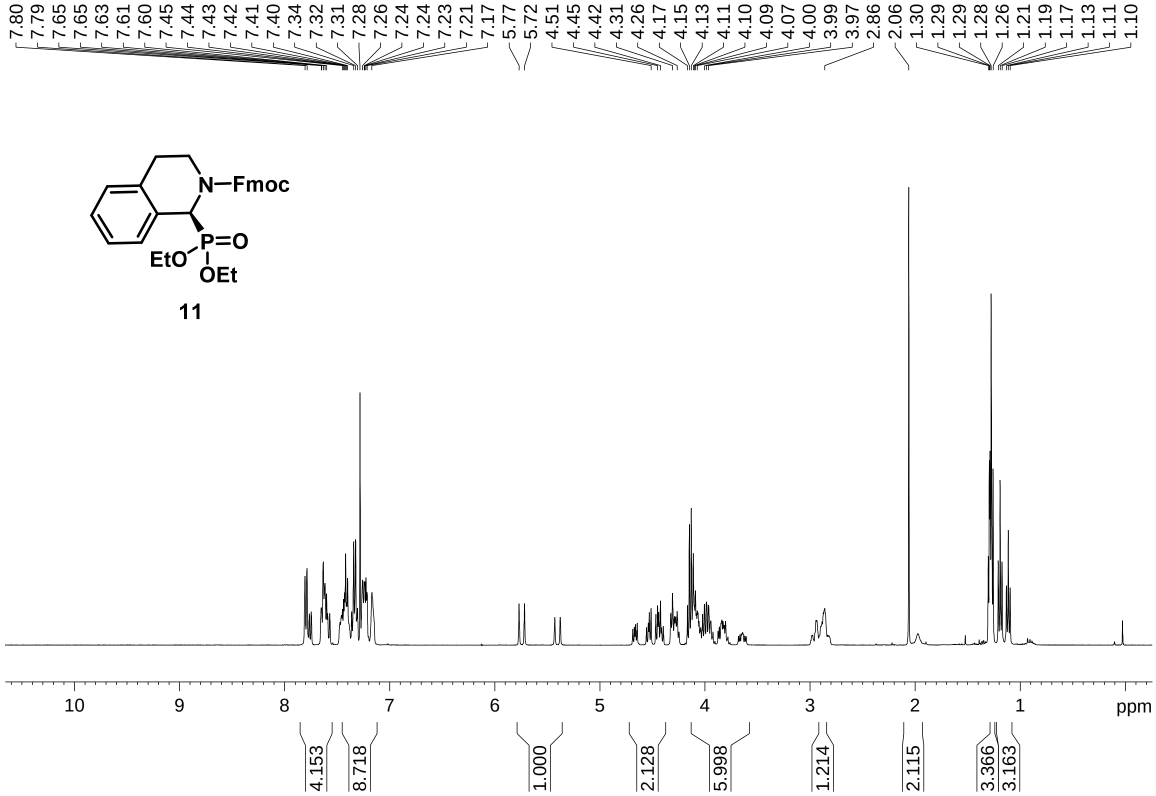
Detector A Ch2 254nm

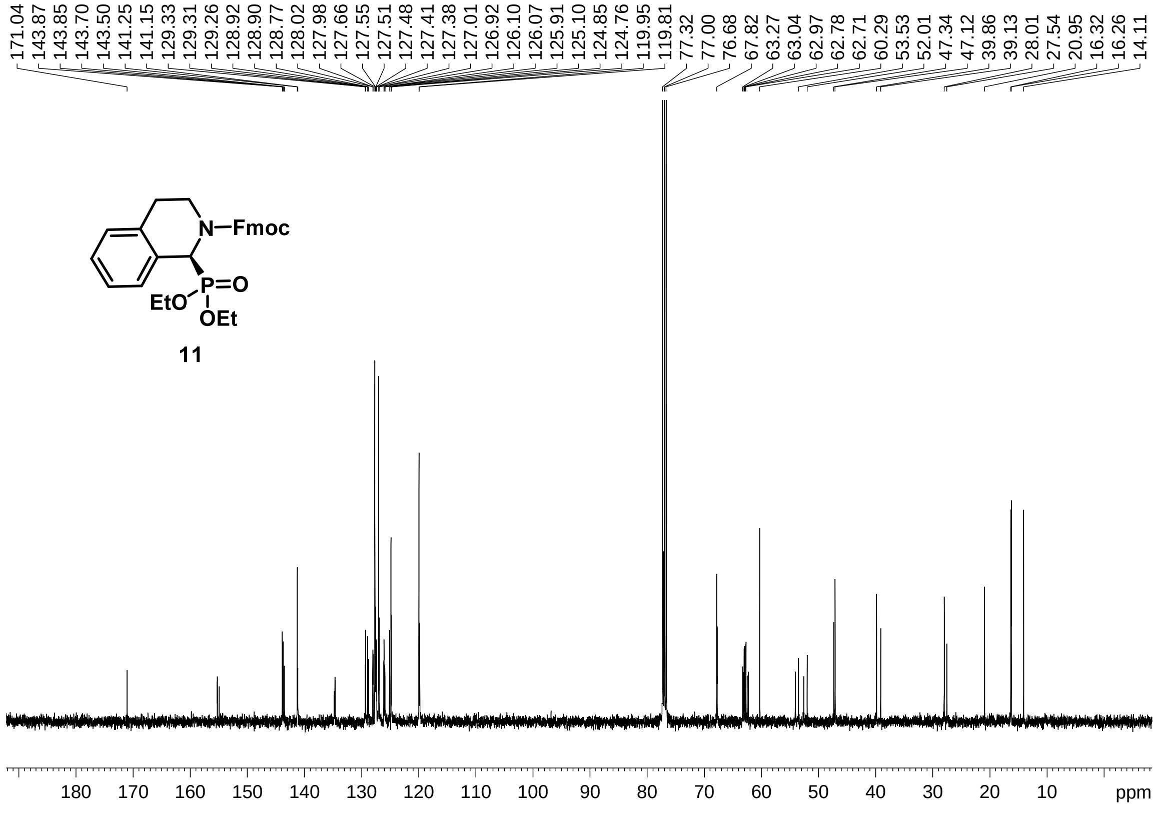
Peak#	Ret. Time	Area	Area %
1	14.760	780481	95.990
2	26.177	32601	4.010
Total		813082	100.000

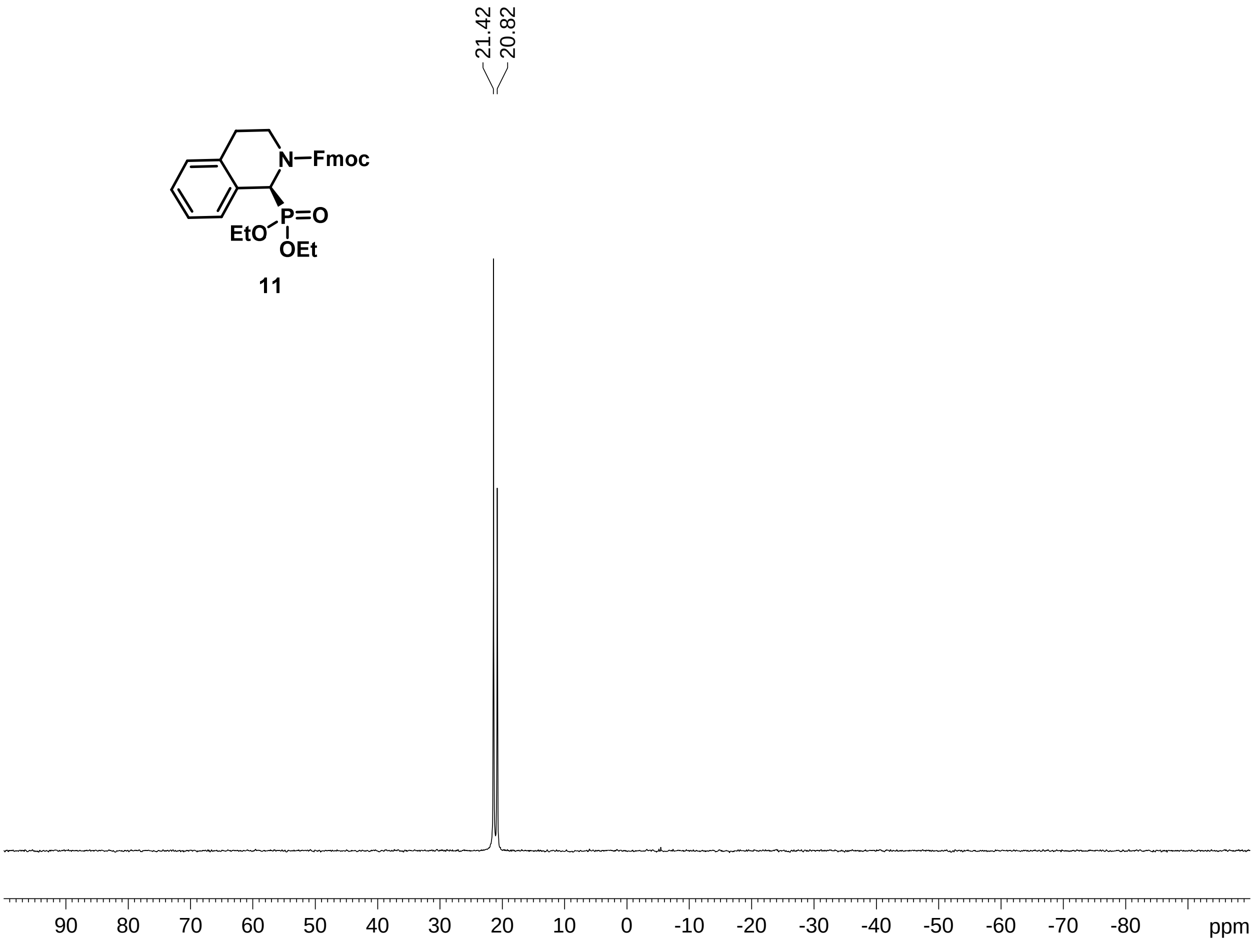

10
8.96
8.94
8.71
8.70
7.89
7.87
7.80
7.80
7.79
7.76
7.74
7.72
7.69
7.68
7.26
4.33
4.31
4.31
4.30
4.29
1.39
1.38
1.36
N
P=O
EtO
OEt
10
9
8
7
6
5
4
3
2
1
0
ppm
1.000
1.007
1.016
1.019
2.131
4.005
6.090

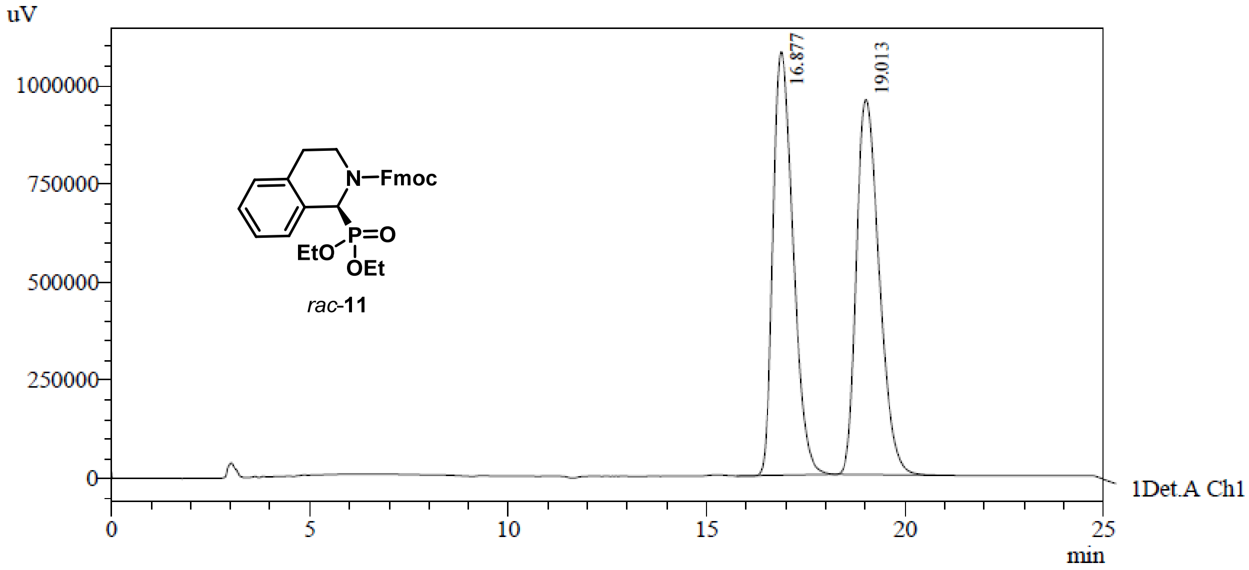

10
153.53
151.31
142.23
141.98
136.12
136.02
130.54
130.06
129.78
128.40
127.26
127.23
127.14
123.68
123.64
77.32
77.00
76.68
63.25
63.19
16.41
16.35
N
P=O
EtO
OEt
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm


10
10.52
N
P
O
EtO
OEt
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
ppm


7.80
7.79
7.65
7.65
7.63
7.61
7.60
7.45
7.44
7.43
7.42
7.41
7.40
7.34
7.32
7.31
7.28
7.26
7.24
7.24
7.23
7.21
7.17
5.77
5.72
4.51
4.45
4.42
4.31
4.26
4.17
4.15
4.13
4.11
4.10
4.09
4.07
4.00
3.99
3.97
2.86
2.06
1.30
1.29
1.29
1.28
1.26
1.21
1.19
1.17
1.13
1.11
1.10
N—Fmoc
P=O
EtO
OEt
11
10
9
8
7
6
5
4
3
2
1
ppm
4.153
8.718
1.000
2.128
5.998
1.214
2.115
3.366
3.163


171.04
143.87
143.85
143.70
143.50
141.25
141.15
129.33
129.31
129.26
128.92
128.90
128.77
128.02
127.98
127.66
127.55
127.51
127.48
127.41
127.38
127.01
126.92
126.10
126.07
125.91
125.10
124.85
124.76
119.95
119.81
77.32
77.00
76.68
67.82
63.27
63.04
62.97
62.78
62.71
60.29
53.53
52.01
47.34
47.12
39.86
39.13
28.01
27.54
20.95
16.32
16.26
14.11
N—Fmoc
P=O
EtO
OEt
11
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

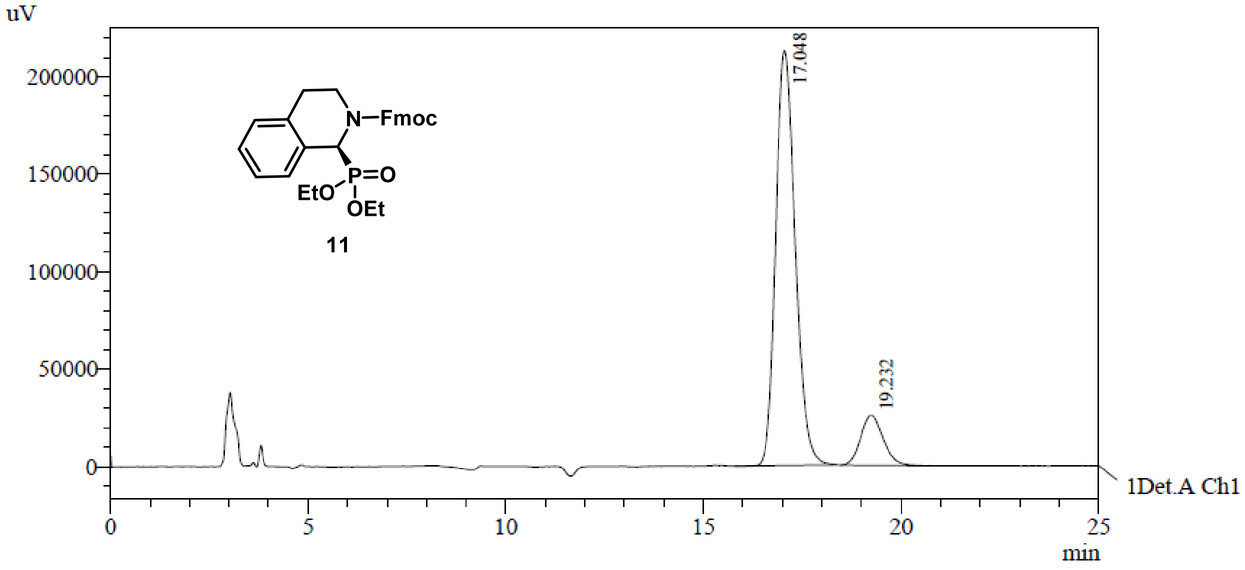

21.42
20.82
N—Fmoc
P=O
EtO
OEt
11
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
ppm



PeakTable

Detector A Ch1 210nm

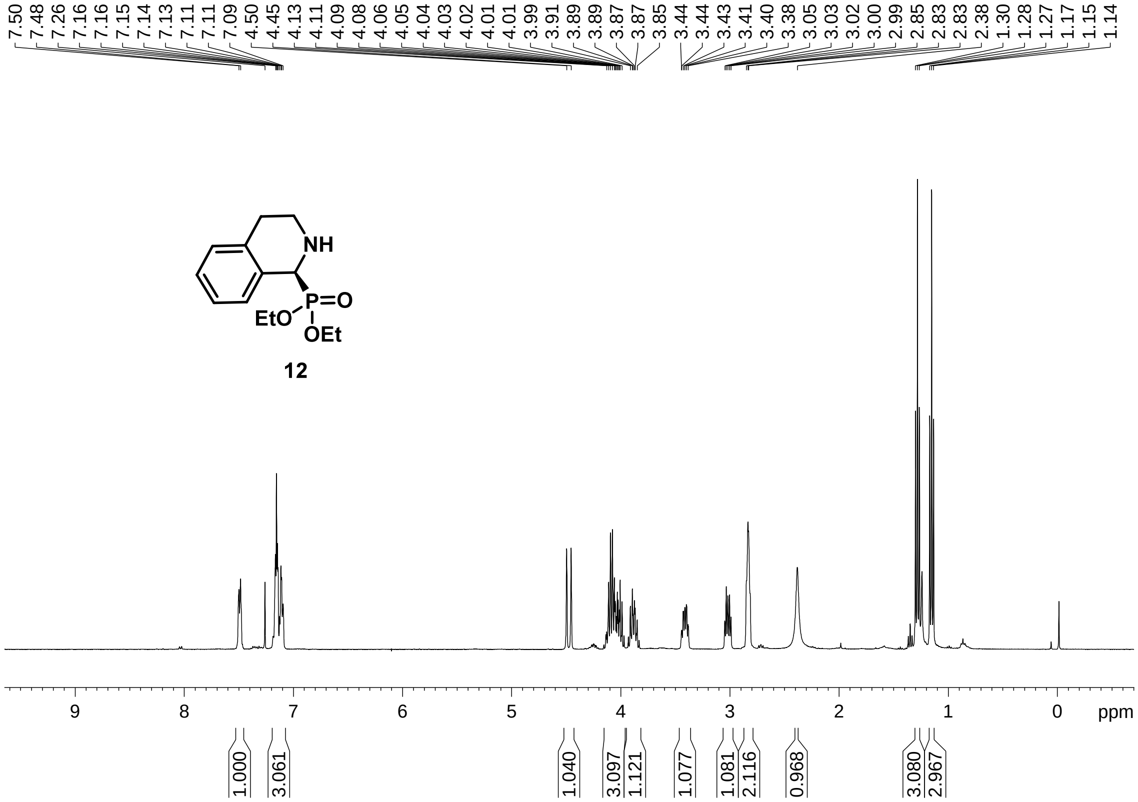
Peak#	Ret. Time	Area	Area %
1	16.877	38087252	49.800
2	19.013	38392493	50.200
Total		76479746	100.000

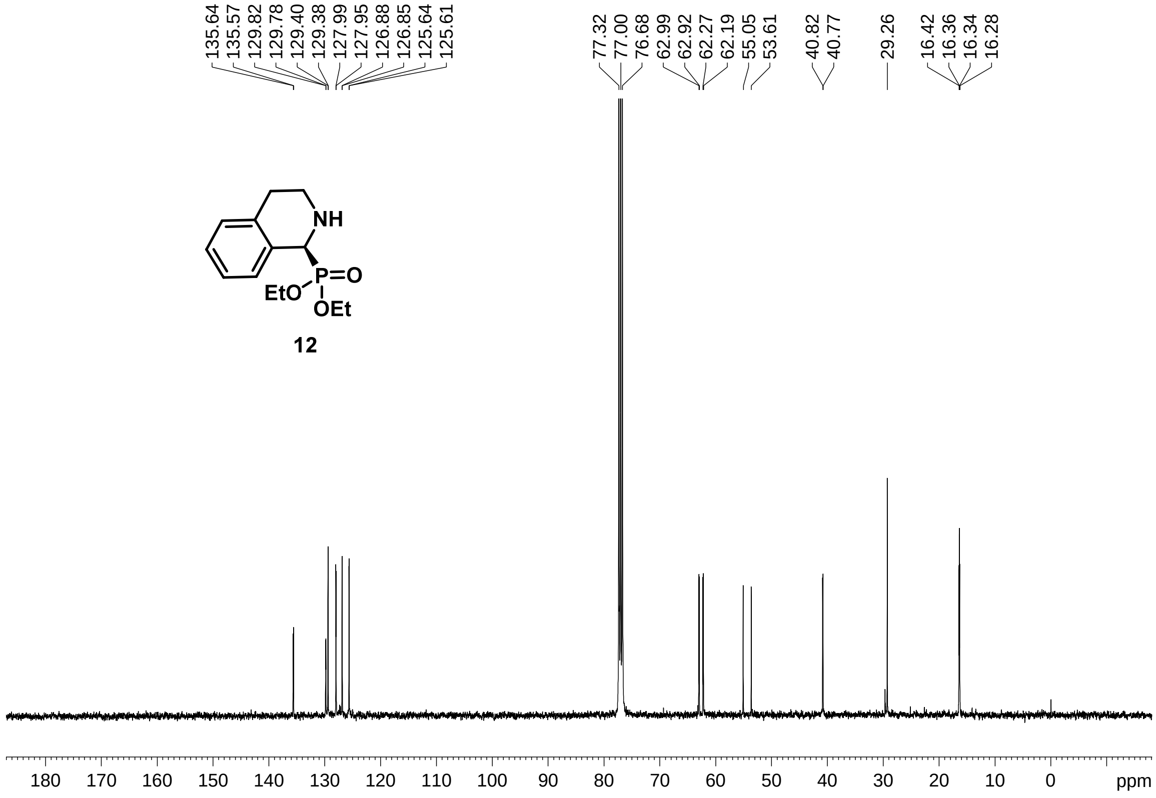


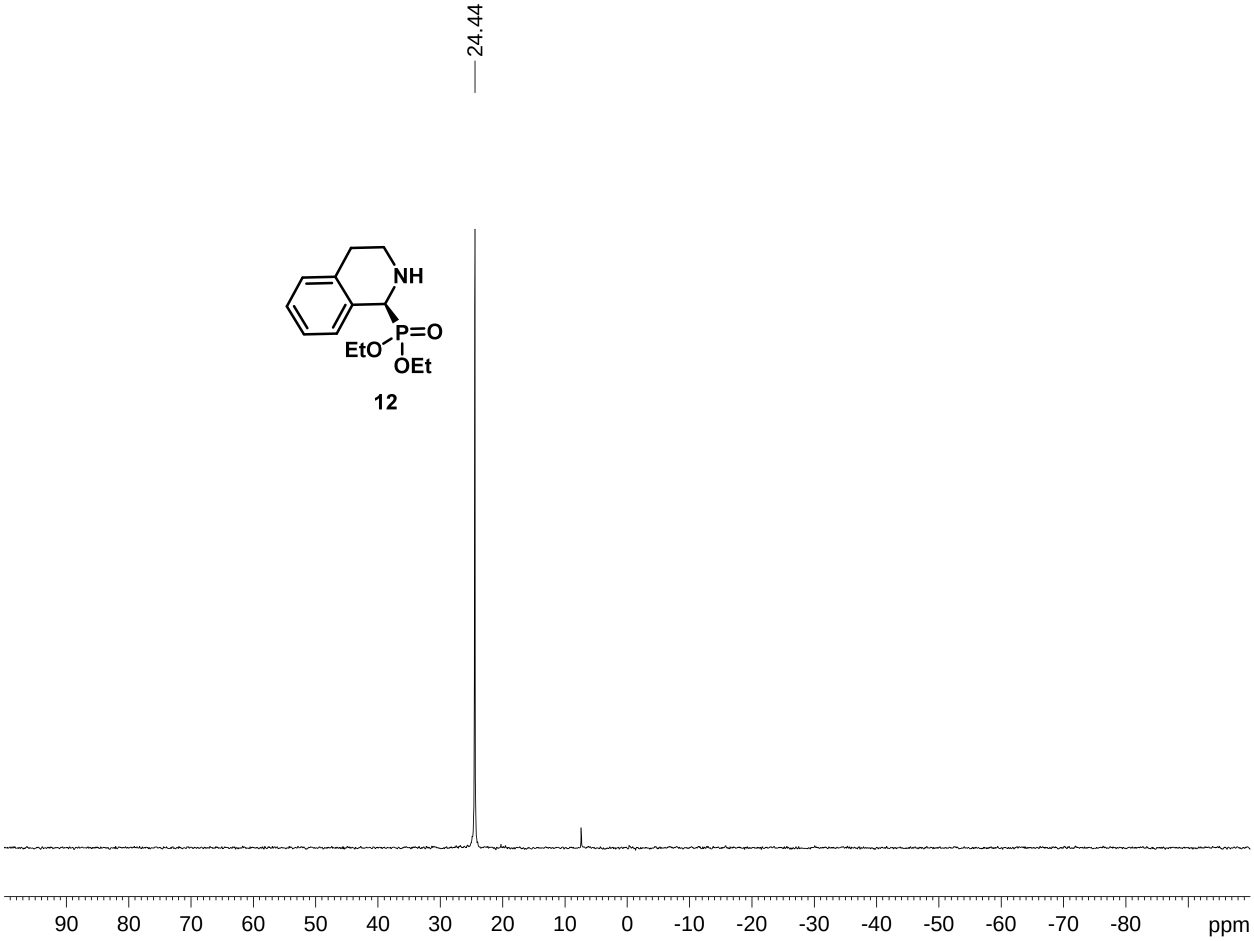
PeakTable

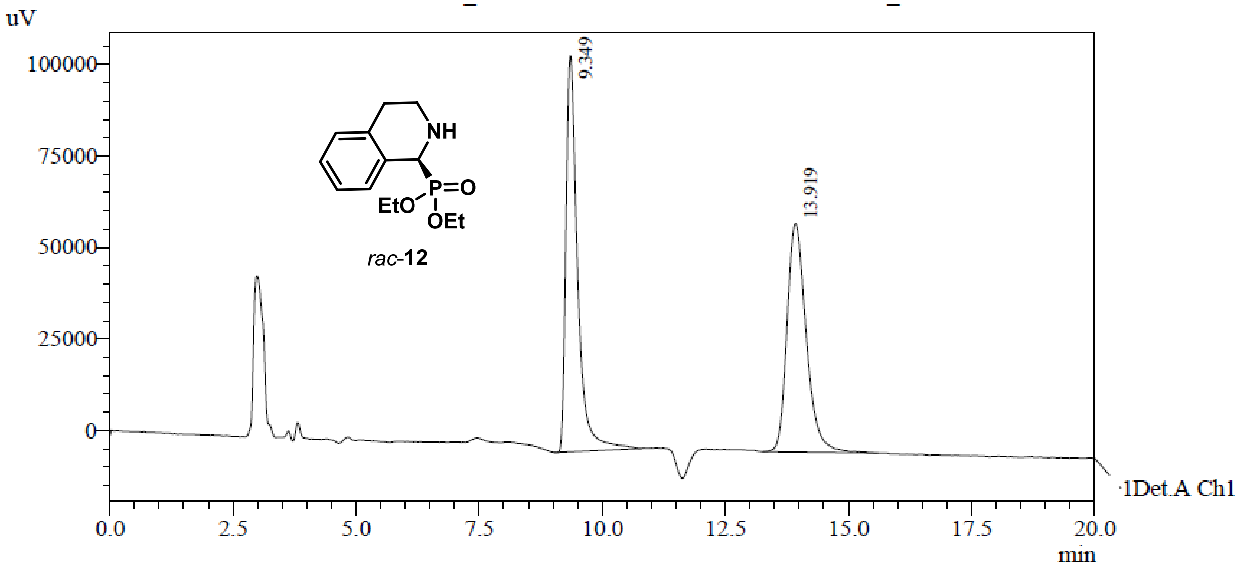
Detector A Ch1 210nm

Peak#	Ret. Time	Area	Area %
1	17.048	7307507	87.806
2	19.232	1014866	12.194
Total		8322373	100.000


7.50
7.48
7.26
7.16
7.16
7.15
7.14
7.13
7.11
7.11
7.09
4.50
4.45
4.13
4.11
4.09
4.08
4.06
4.05
4.04
4.03
4.02
4.01
4.01
3.99
3.91
3.89
3.89
3.87
3.87
3.85
3.44
3.44
3.43
3.41
3.40
3.38
3.05
3.03
3.02
3.00
2.99
2.85
2.83
2.83
2.38
1.30
1.28
1.27
1.17
1.15
1.14
NH
P=O
EtO
OEt
12
9
8
7
6
5
4
3
2
1
0
ppm
1.000
3.061
1.040
3.097
1.121
1.077
1.081
2.116
0.968
3.080
2.967


135.64
135.57
129.82
129.78
129.40
129.38
127.99
127.95
126.88
126.85
125.64
125.61
77.32
77.00
76.68
62.99
62.92
62.27
62.19
55.05
53.61
40.82
40.77
29.26
16.42
16.36
16.34
16.28
NH
P=O
EtO
OEt
12
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

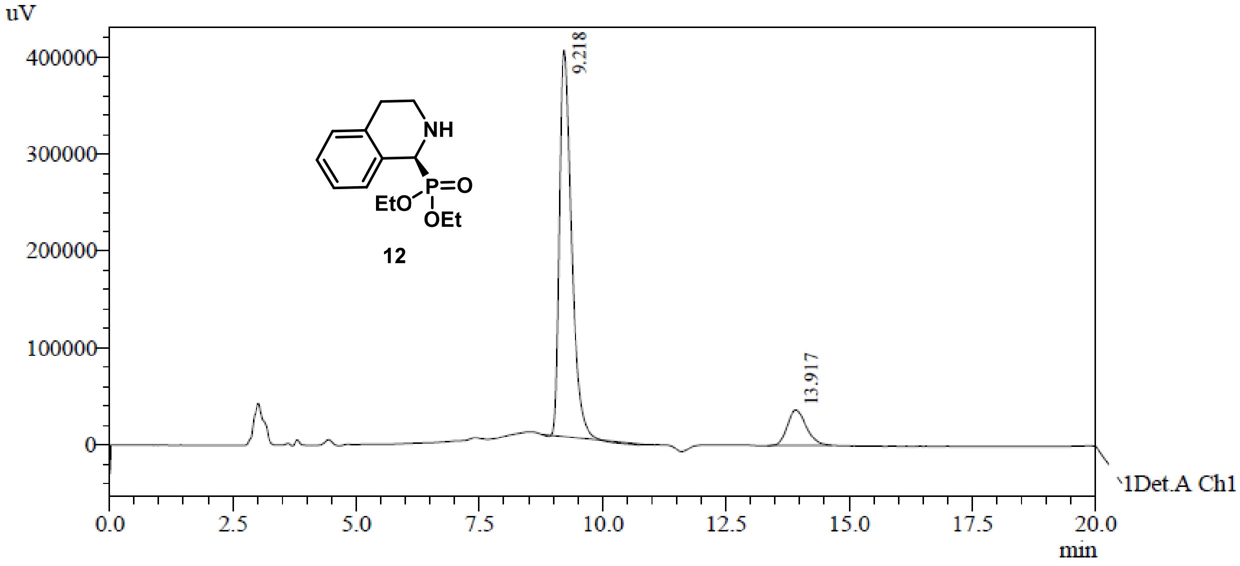

24.44
NH
P=O
EtO
OEt
12
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
ppm



PeakTable

Detector A Ch1 210nm

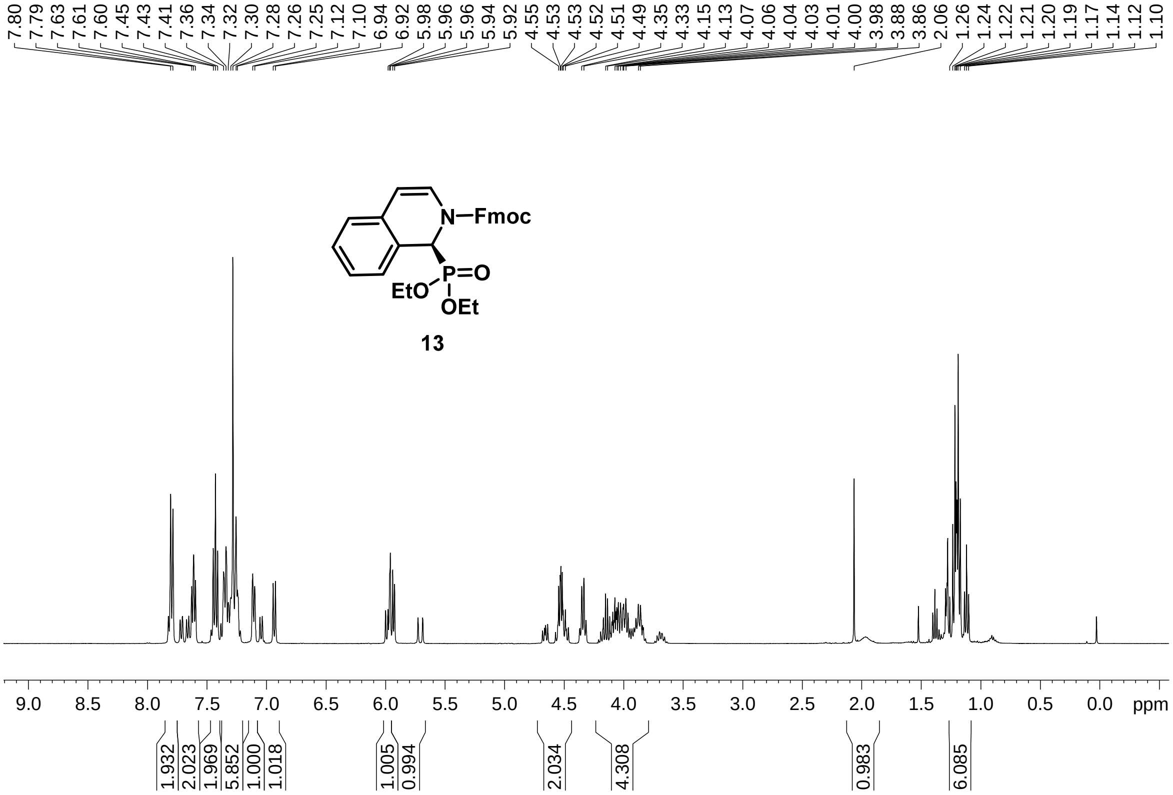
Peak#	Ret. Time	Area	Area %
1	9.349	1792888	51.268
2	13.919	1704218	48.732
Total		3497106	100.000

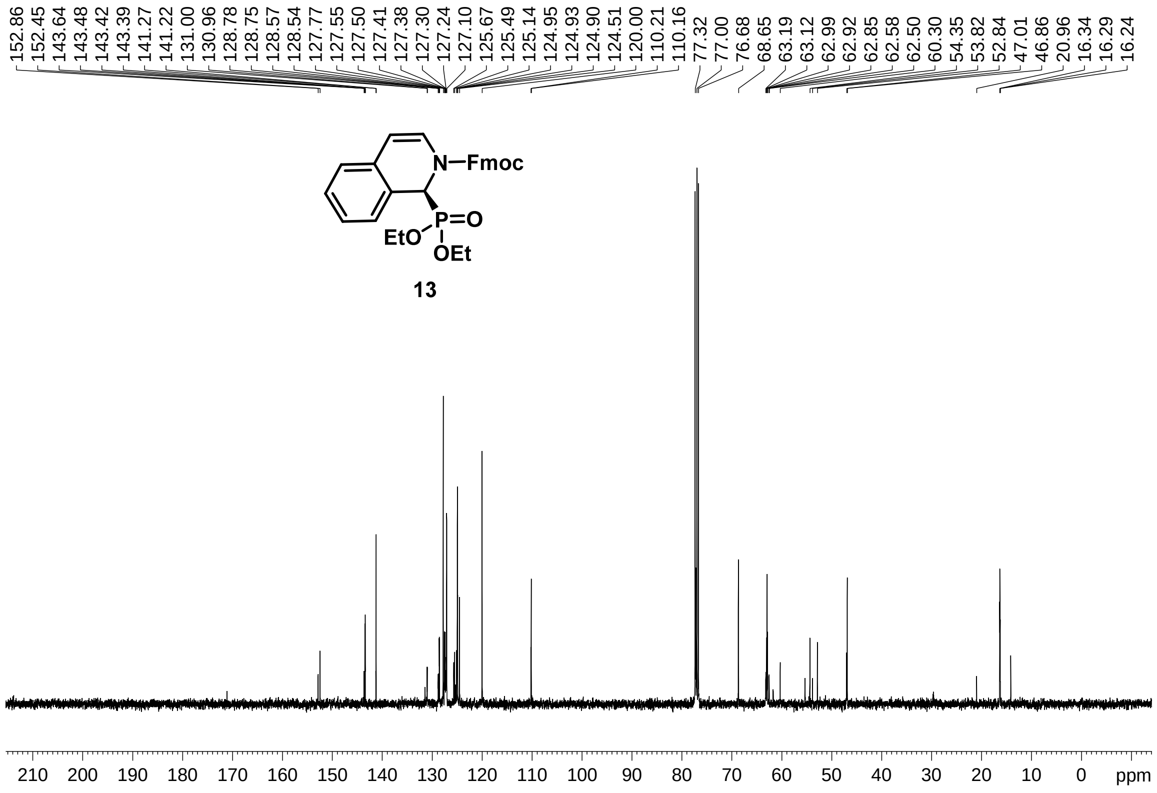


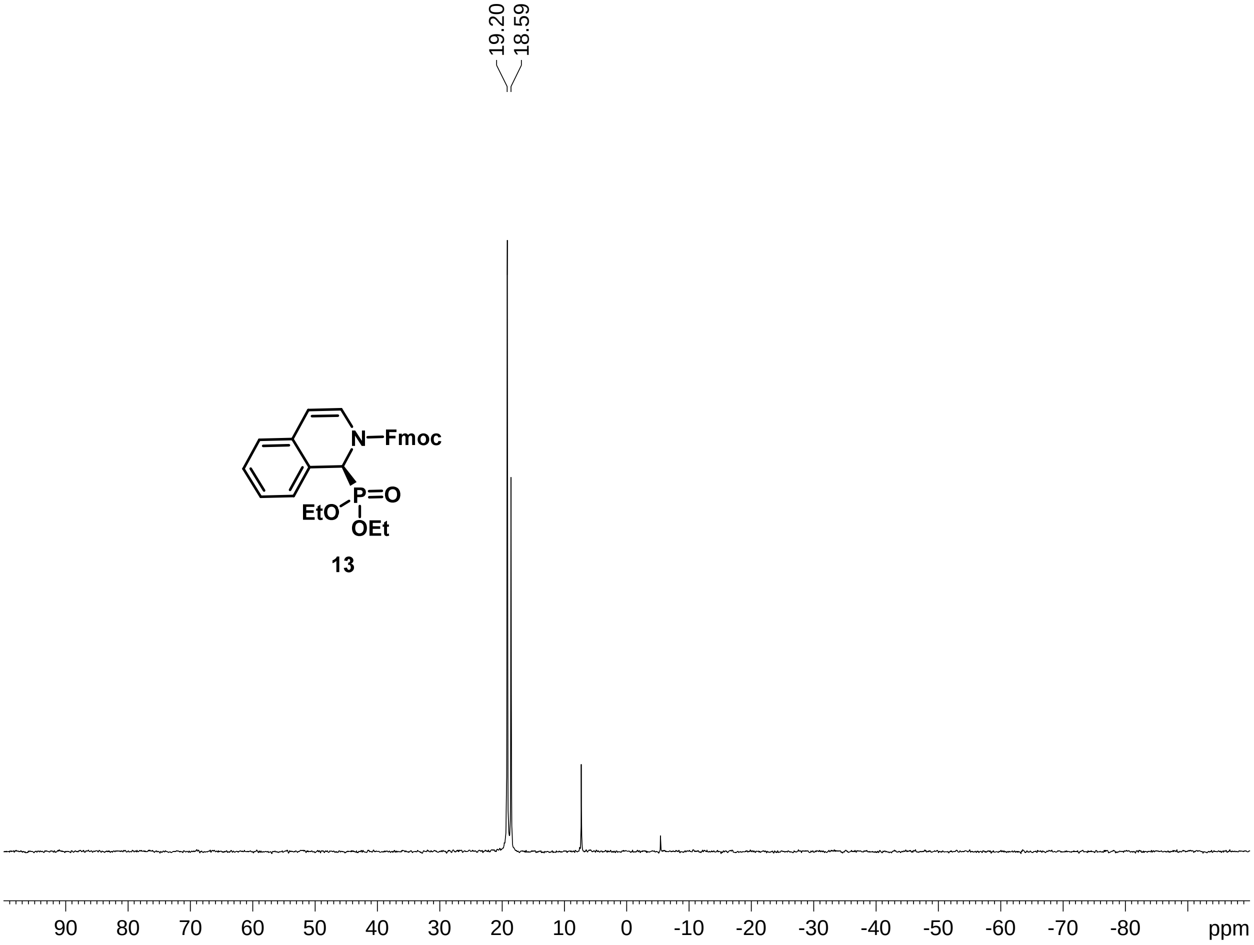
PeakTable

Detector A Ch1 210nm

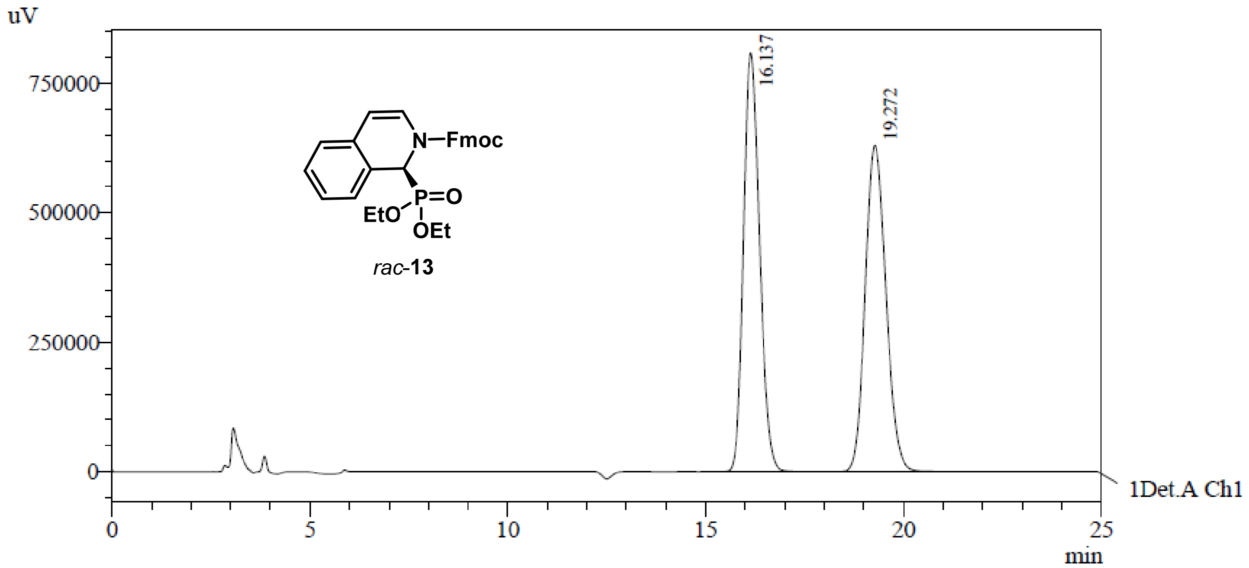
Peak#	Ret. Time	Area	Area %
1	9.218	6779973	87.473
2	13.917	970988	12.527
Total		7750961	100.000


7.80
7.79
7.63
7.61
7.60
7.45
7.43
7.41
7.36
7.34
7.32
7.30
7.28
7.26
7.25
7.12
7.10
6.94
6.92
5.98
5.96
5.96
5.94
5.92
4.55
4.53
4.53
4.52
4.51
4.49
4.35
4.33
4.15
4.13
4.07
4.06
4.04
4.03
4.01
4.00
3.98
3.88
3.86
2.06
1.26
1.24
1.22
1.21
1.20
1.19
1.17
1.14
1.12
1.10
N−Fmoc
P=O
EtO
OEt
13
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
1.932
2.023
1.969
5.852
1.000
1.018
1.005
0.994
2.034
4.308
0.983
6.085


152.86
152.45
143.64
143.48
143.42
143.39
141.27
141.22
131.00
130.96
128.78
128.75
128.57
128.54
127.77
127.55
127.50
127.41
127.38
127.30
127.24
127.10
125.67
125.49
125.14
124.95
124.93
124.90
124.51
120.00
110.21
110.16
77.32
77.00
76.68
68.65
63.19
63.12
62.99
62.92
62.85
62.58
62.50
60.30
54.35
53.82
52.84
47.01
46.86
20.96
16.34
16.29
16.24
N−Fmoc
P=O
EtO
OEt
13
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm


19.20
18.59
N—Fmoc
P=O
EtO
OEt
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
ppm

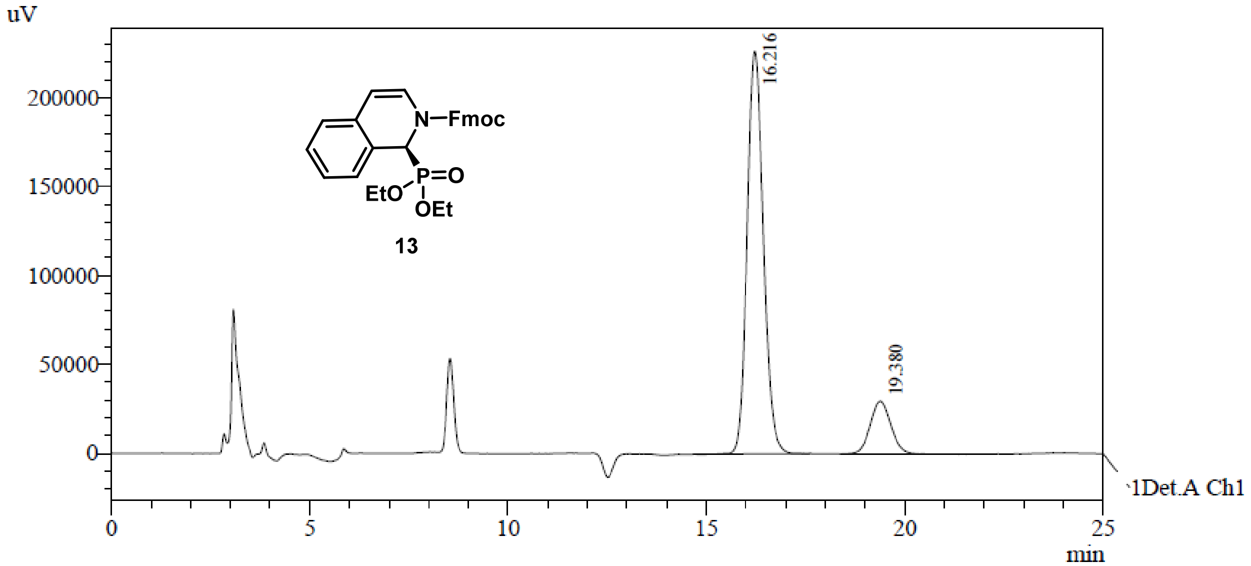
13



PeakTable

Detector A Ch1 210nm

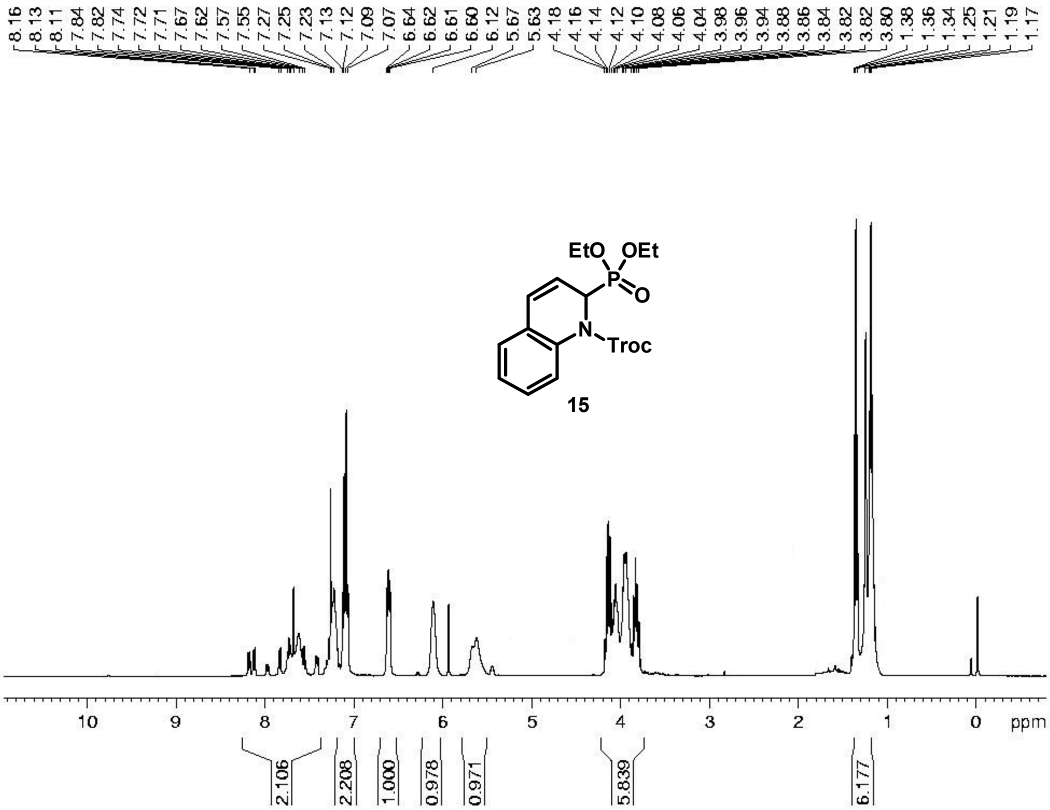
Peak#	Ret. Time	Area	Area %
1	16.137	22858918	49.951
2	19.272	22904157	50.049
Total		45763075	100.000

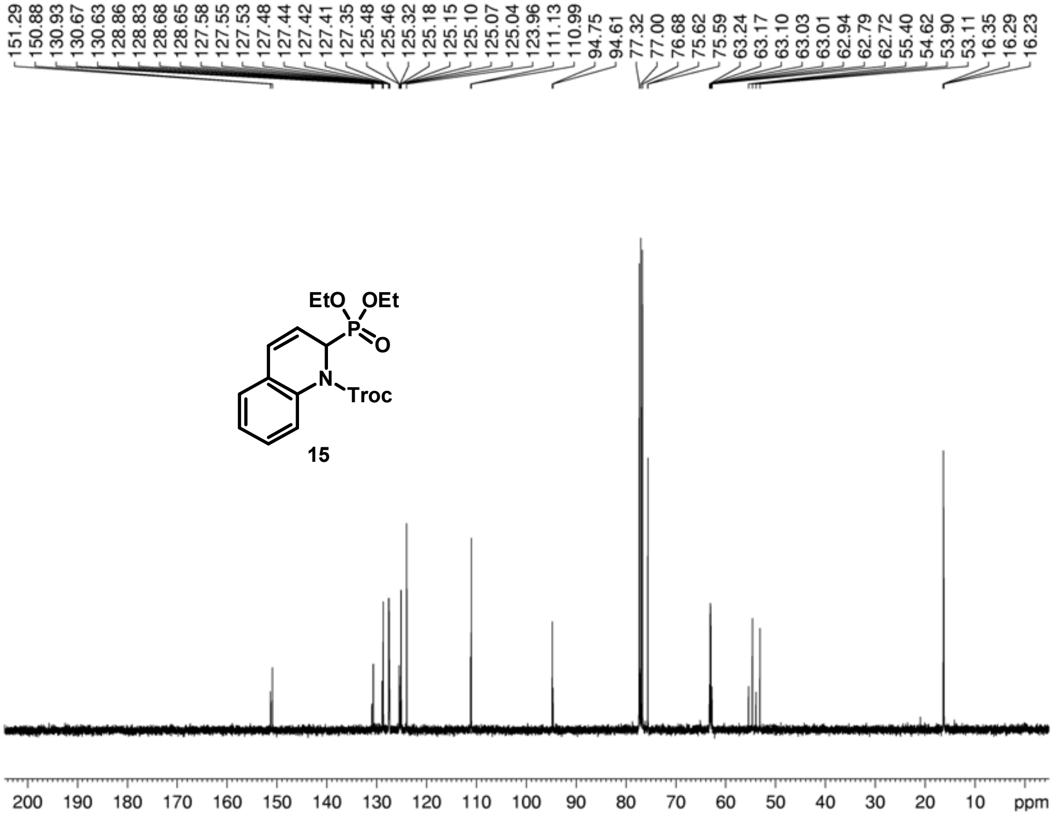


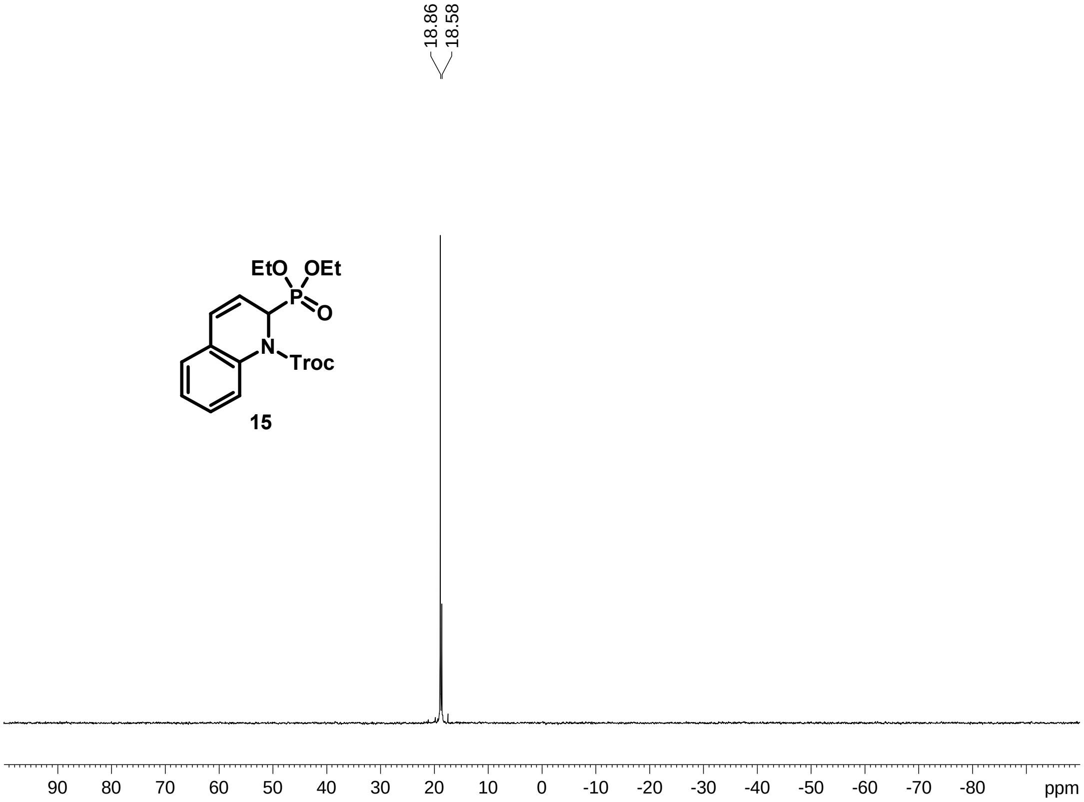
PeakTable

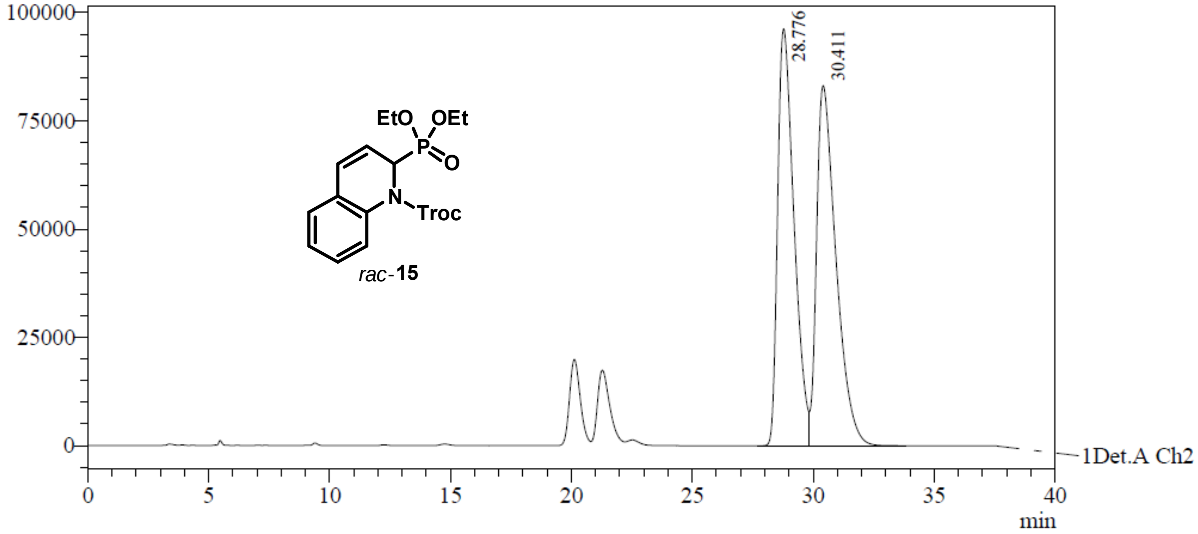
Detector A Ch1 210nm

Peak#	Ret. Time	Area	Area %
1	16.216	6455781	85.738
2	19.380	1073857	14.262
Total		7529638	100.000


8.16
8.13
8.11
7.84
7.82
7.74
7.72
7.71
7.67
7.62
7.57
7.55
7.27
7.25
7.23
7.13
7.12
7.09
7.07
6.64
6.62
6.61
6.60
6.12
5.67
5.63
4.18
4.16
4.14
4.12
4.10
4.08
4.06
4.04
3.98
3.96
3.94
3.88
3.86
3.84
3.82
3.82
3.80
1.38
1.36
1.34
1.25
1.21
1.19
1.17
EtO
OEt
P
O
N
Troc
15
10
9
8
7
6
5
4
3
2
1
0
ppm
2.106
2.208
1.000
0.978
0.971
5.839
6.177


151.29
150.88
130.93
130.67
130.63
128.86
128.83
128.68
128.65
127.58
127.55
127.53
127.48
127.44
127.42
127.41
127.35
125.48
125.46
125.32
125.18
125.15
125.10
125.07
125.04
123.96
111.13
110.99
94.75
94.61
77.32
77.00
76.68
75.62
75.59
63.24
63.17
63.10
63.03
63.01
62.94
62.79
62.72
55.40
54.62
53.90
53.11
16.35
16.29
16.23
EtO
OEt
P
O
N
Troc
15
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

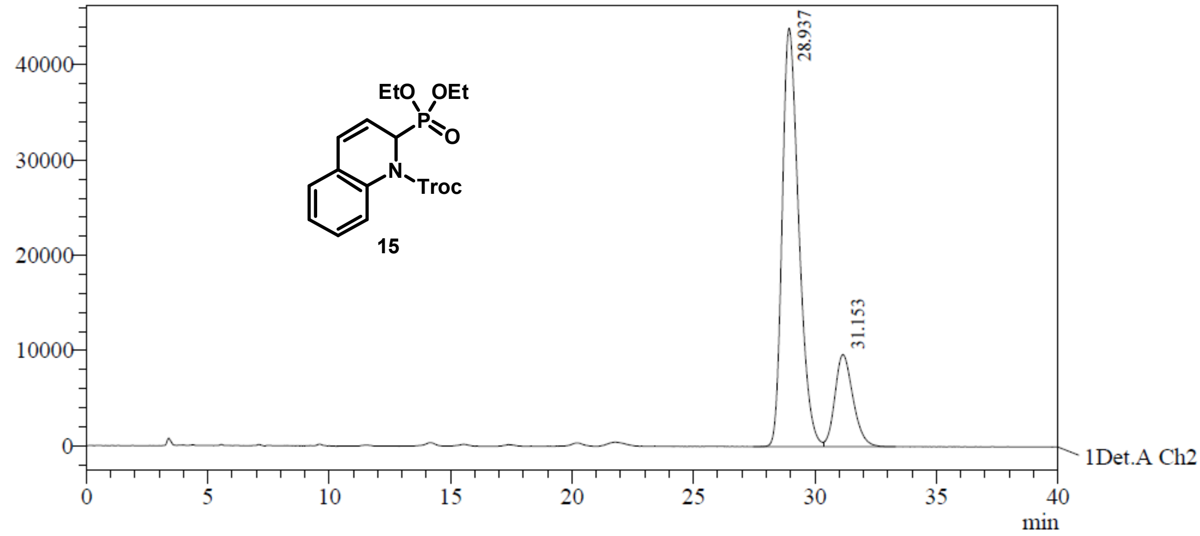

18.86
18.58
EtO
OEt
P
O
N
Troc
15
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
ppm



PeakTable

Detector A Ch2 254nm

Peak#	Ret. Time	Area	Area %
1	28.776	4530078	49.279
2	30.411	4662591	50.721
Total		9192669	100.000



PeakTable

Detector A Ch2 254nm

Peak#	Ret. Time	Area	Area %
1	28.937	2093188	80.637
2	31.153	502615	19.363
Total		2595803	100.000