Facile One-pot Synthesis of Unsymmetrical Ureas, Carbamates, and Thiocarbamates from Cbz-protected Amines

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Supporting Information

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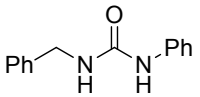
General Information

Reactions were performed in a well-dried flask under argon atmosphere unless noted otherwise. Solvents used as reaction media were dried over pre-dried molecular sieves (4 Å) in a microwave oven. Solvents for extraction and chromatography were reagent grade and used as received. Reagents were purified prior to use unless otherwise stated following the guidelines of Perrin and Armarego.[1] Column chromatography was performed with silica gel 60 (70−230 mesh) using a mixture of EtOAc/hexane as eluent. ^{1}H and ^{13}C NMR spectra were, respectively, recorded on a 400 or 600 MHz (^{1}H NMR), 100 or 150 MHz (^{13}C NMR) spectrometer in deuterated chloroform ($CDCl_3$) with tetramethylsilane(TMS) as an internal reference. Data are reported as (ap = apparent, s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, br = broad; coupling constant(s) in Hz, integration). High-resolution mass spectroscopy was performed using a magnetic sector analyzer. All of the new compounds were identified by ^{1}H and ^{13}C NMR, IR, and high resolution mass spectroscopy. The identity of the known compounds was established by the comparison of their ^{1}H and ^{13}C NMR peaks with the authentic values.

[1] D. D. Perrin, W. L. Armarego, *Purification of Laboratory Chemicals;* 3rd Ed., Pergamon Press, Oxford. 1988.

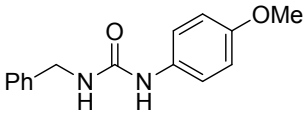
1. General procedure for the one-pot synthesis of unsymmetrical ureas

Cbz-protected amine **1** (0.5 mmol) and 2-Cl-pyridine (1.5 mmol) were dissolved in dry dichloromethane (10 mL, 0.05 M). Tf_2O (0.75 mmol) was added dropwise over 5 min. After stirring for 1 hour at room temperature, amine **3** (1.5 mmol) was added to the resulting mixture. After additional stirring for 1 hour, the mixture was diluted with dichloromethane and water, the mixture was extracted with dichloromethane (3 x 10 mL) and the combined organic layer was washed with brine and water, dried over $MgSO_4$, filtered and concentrated under reduced pressure. Purification by flash chromatography with EtOAc/hexane afforded the corresponding ureas.



3a

1-Benzyl-3-phenylurea (3a): Prepared according to the general procedure using Cbz-protected benzylamine (benzyl benzylcarbamate, **1a**) and aniline. The reaction mixture was purified by flash chromatography using 20% EtOAc/hexane to afford 98 mg (87% yield) of product as a yellowish solid. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.33-7.20 (m, 10H), 7.10 (t, J = 7.2 Hz, 1H), 6.51 (s, 1H), 4.41 (s, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 156.0, 139.0, 138.2, 129.0, 128.5, 127.1, 127.0, 123.8, 121.0, 44.0; HRMS (ESI) m/z $(M+H)^+$ calcd for $C_{14}H_{15}N_2O$ = 227.1179, found 227.1175. The analytical data were identical in all respects to those previously reported.[2,3]

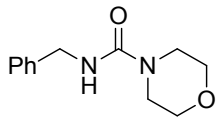


3b

1-Benzyl-3-(4-methoxyphenyl)urea (3b): Prepared according to the general procedure using Cbz-protected benzylamine (benzyl benzylcarbamate, **1a**) and 4-methoxyaniline. The reaction mixture was purified by flash chromatography using 20% EtOAc/hexane to afford 108 mg (84%

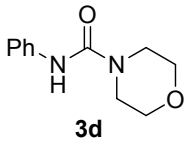
[2] H. K. Oh, J. E. Park, D. D. Sung , I. Lee, *J. Org. Chem.* **2004**, *69*, 3150.
[3] S. L. Peterson, S. M. Stucka, C. J. Dinsmore, *Org. Lett.* **2010**, *12*, 1340.

yield) of product as a yellowish solid. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.36 – 7.11 (m, 7H), 6.84 (d, *J* = 8.8 Hz, 2H), 6.29 (s, 1H), 5.04 (s, 1H), 4.40 (d, *J* = 5.6 Hz, 2H), 3.77 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 157.1, 138.9, 130.6, 128.6, 127.3, 125.1, 114.6, 55.5, 44.2; HRMS (ESI) m/z $(M+H)^+$ calcd for $C_{15}H_{17}N_2O_2$ = 257.1280, found 257.1278. The analytical data were identical in all respects to those previously reported.[4]



3c

***N*-Benzylmorpholine-4-carboxamide (3c):** Prepared according to the general procedure using Cbz-protected benzylamine (benzyl benzylcarbamate, **1a**) and morpholine. The reaction mixture was purified by flash chromatography using 50% EtOAc/hexane to afford 93 mg (84% yield) of product as a white solid. mp 138−140°C; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.34–7.25 (m, 5H), 4.71 (s, 1H), 4.42 (d, *J* = 5.4 Hz, 2H), 3.67 (t, *J* = 4.8 Hz, 4H), 3.35 (t, *J* = 4.8 Hz, 4H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 157.7, 139.2, 128.8, 127.9, 127.5, 66.6, 45.1, 44.1; HRMS (ESI) m/z $(M+H)^+$ calcd for $C_{12}H_{17}N_2O_2$ = 221.1290, found 221.1287. The analytical data were identical in all respects to those previously reported.[5]

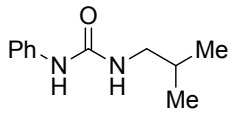


3d

***N*-Phenylmorpholine-4-carboxamide (3d)**: Prepared according to the general procedure using Cbz-protected phenylamine (benzyl phenylcarbamate, **1b**) and morpholine. The reaction mixture was purified by flash chromatography using 20% EtOAc/hexane to afford 72 mg (70% yield) of product as a yellowish solid. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.39 – 7.20 (m, 4H), 7.03 (t, *J* = 7.3 Hz, 1H), 6.75 (s, 1H), 3.71 – 3.59 (m, 4H), 3.48 – 3.34 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 155.3, 138.8, 128.8, 123.3, 120.4, 66.5, 44.2; HRMS (ESI) m/z $(M+H)^+$ calcd for $C_{11}H_{15}N_2O_2$ =

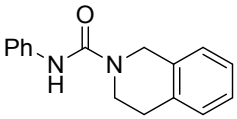
[4] G. M. Viana, L. C. S. Aguiar, J. A. Ferrao, A. B. C. Simas, M. G. Vasconcelos, *Tetrahedron Lett.* **2013**, *54*, 936.
[5] S. L. Peterson, S. M. Stucka, C. J. Dinsmore, *Org. Lett.* **2010**, *12*, 1340.

207.1128, found 207.1121. The analytical data were identical in all respects to those previously reported.[6]



3e

1-Isobutyl-3-phenylurea (3e): Prepared according to the general procedure using Cbz-protected phenylamine (benzyl phenylcarbamate, **1b**) and 2-methyl-1-propanol. The reaction mixture was purified by flash chromatography using 30% EtOAc/hexane to afford 83 mg (86% yield) of product as a white solid. mp152−153°C; IR; 3386, 3257, 2965, 2922, 2869, 1642, 1551, 1441, 1310, 1238 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$): δ 7.27 – 7.23 (m, 4H), 7.03 (s, 1H), 7.01 (t, *J* = 7.2 Hz, 1H), 5.41 (s, 1H), 3.01 (t, *J* = 6.0 Hz, 2H), 1.70 (m, 1H), 0.87 (d, *J* = 8.4 Hz, 6H); ^{13}C NMR (150 MHz, $CDCl_3$): δ 156.5, 138.9, 129.2 (2C), 123.5, 120.8, 47.7, 28.9, 20.1 (2C); HRMS (ESI) m/z $(M+H)^+$ calcd for $C_{11}H_{17}N_2O$ = 193.1341, found 193.1342.



3f

***N*-Phenyl-3,4-dihydroisoquinoline-2(1*H*)-carboxamide (3f)**: Prepared according to the general procedure using Cbz-protected phenylamine (benzyl phenylcarbamate, **1b**) and 1,2,3,4-tetrahydroisoquinoline. The reaction mixture was purified by flash chromatography using 20% EtOAc/hexane to afford 90 mg (71% yield) of product as a white solid. mp 145−147°C; IR 3252, 2913, 1631 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$): δ 7.39 (m, 2H), 7.29 (m, 2H), 7.11 (m, 4H), 7.03 (t, *J* = 6.6 Hz, 1H), 6.38 (s, 1H), 4.66 (s, 2H), 3.72 (t, *J* = 6.0 Hz, 2H), 2.94 (t, *J* = 5.4 Hz, 2H); ^{13}C NMR (150 MHz, $CDCl_3$): δ 154.9, 139.2, 135.1, 133.3, 128.9, 128.5, 126.9, 126.6, 126.4, 123.2, 120.1, 45.8, 41.7, 29.1; HRMS (ESI) m/z $(M+H)^+$ calcd for $C_{16}H_{17}N_2O$ = 253.1341, found 253.1346. The analytical data were identical in all respects to those previously reported.[7]

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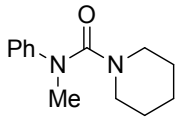
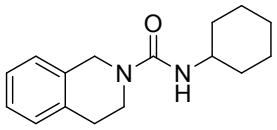
[6] B. Gabriele, G. Salerno, R. Mancuso, M. Costa, *J. Org. Chem.* **2004**, *69*, 3150.
[7] S. L. Peterson, S. M. Stucka, C. J. Dinsmore, *Org. Lett.* **2010**, *12*, 1340.



3g

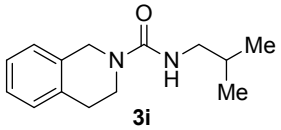
***N*-Methyl-*N*-phenylpiperidine-1-carboxamide (3g)**: Prepared according to the general procedure using Cbz-protected *N*-methylaniline (benzyl (methyl)phenylcarbamate, **1c**) and piperidine. The reaction mixture was purified by flash chromatography using 25% EtOAc/hexane to afford 76 mg (70% yield) of product as a colorless oil. ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.27 – 7.24 (m, 2H), 7.03 – 7.01 (m, 3H), 3.15 (s, 3H), 3.11 – 3.07 (m, 4H), 1.41 – 1.39 (m, 2H), 1.30 – 1.27 (m, 4H); ^{13}C NMR (150 MHz, $CDCl_3$): δ 161.3, 147.3, 129.3, 129.1, 124.1, 123.5, 48.2, 46.7, 41.9, 39.5, 25.8, 25.4, 24.5; HRMS (ESI) m/z $(M+H)^+$ calcd for $C_{13}H_{19}N_2O$ = 219.1490, found 219.1494. The analytical data were identical in all respects to those previously reported.[8]



3h

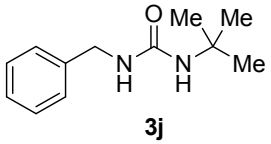
***N*-Cyclohexyl-3,4-dihydroisoquinoline-2(1*H*)-carboxamide (3h)**: Prepared according to the general procedure using Cbz-protected 1,2,3,4-tetrahydroisoquinoline (benzyl 3,4-dihydroisoquinoline-2(1*H*)-carboxylate, **1d**) and cyclohexylamine. The reaction mixture was purified by flash chromatography using 92% EtOAc/hexane to afford 119 mg (70% yield) of product as a white solid. mp 122−123°C; IR 3282, 2925, 2851, 1616, 1531, 1415, 1250 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.18 – 7.11 (m, 4H), 4.51 (s, 2H), 4.28 (d, *J* = 5.4 Hz, 1H), 3.69 (m, 1H), 3.59 (t, *J* = 6.0 Hz, 2H), 2.86 (t, *J* = 6.0 Hz, 2H), 1.96 (dd, *J* = 3.6, 6.6 Hz, 2H), 1.69 (m, 3H), 1.37 (m, 2H), 1.12 (m, 3H); ^{13}C NMR (150 MHz, $CDCl_3$): δ 156.9, 135.3, 133.6, 128.4 (2C), 126.7, 126.4, 120.4, 49.5 (2C), 45.5, 41.1, 34.2 (2C), 29.2, 25.8, 25.2; HRMS (ESI) m/z $(M+H)^+$ calcd for $C_{16}H_{23}N_2O$ = 259.1810, found 259.1813.

[8] S.-H. Lee, H. Matsushita, B. Clapham, K. D. Janda, *Tetrahedron* **2004**, *60*, 3439.



3i

***N*-Isobutyl-3,4-dihydroisoquinoline-2(1*H*)-carboxamide (3i)**: Prepared according to the general procedure using Cbz-protected 1,2,3,4-tetrahydroisoquinoline ((benzyl 3,4-dihydroisoquinoline-2(1*H*)-carboxylate, **1d**) and 2-methyl-1-propanol. The reaction mixture was purified by flash chromatography using 30% EtOAc/hexane to afford 109 mg (94% yield) of product as a white solid. mp 77−79°C; IR 3325, 2923, 1623, 1551, 1265, 1237 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$): δ 7.17 – 7.10 (m, 4H), 4.52 (m, 3H), 3.60 (t, *J* = 6.0 Hz, 2H), 3.08 (t, *J* = 6.0 Hz, 2H), 2.86 (t, *J* = 6.0 Hz, 2H), 1.77 (m, 1H), 0.91 (d, *J* = 7.2 Hz, 6H); ^{13}C NMR (150 MHz, $CDCl_3$): δ 157.7, 135.3, 133.6, 128.5, 126.7, 126.4(2C), 120.4, 48.4, 45.6, 41.2, 29.1, 28.9, 20.2(2); HRMS (ESI) m/z $(M+H)^+$ calcd for $C_{14}H_{21}N_2O$ = 233.1654, found 233.1656.

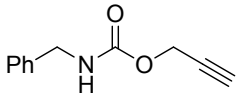


3j

1-Benzyl-3-*tert*-butylurea (3j). Prepared according to the general procedure using Cbz-protected benzylamine (benzyl benzylcarbamate, **1a**) and *tert*-butylamine. The reaction mixture was purified by flash chromatography using 20% EtOAc/hexane to afford 67 mg (65% yield) of product as a white solid. mp 109−111°C; ^1H NMR (600 MHz, $CDCl_3$): δ 7.29–7.26 (m, 2H), 7.24–7.22 (m, 3H), 4.78 (s, 1H), 4.49 (s, 1H), 4.25(s, 2H), 1.28 (s, 9H); ^{13}C NMR (150 MHz, $CDCl_3$): δ 157.6, 138.6, 128.6, 127.5, 127.2, 50.5, 44.4, 29.6 ; LRMS (EI); Mass calcd for $C_{12}H_{19}N_2O$ [M+H]+: 207.1; found 207.1. The analytical data were identical in all respects to those previously reported.[7]

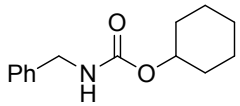
2. General procedure of the one-pot synthesis of carbamates

Cbz-protected amine **1** (0.5 mmol) and 2-Cl-pyridine (1.5 mmol) were dissolved in dry dichloromethane (10 mL, 0.05 M). Tf_2O (0.75 mmol) was added dropwise over 5 min. After stirring for 1 hour at room temperature, alcohol **5** (1.5 mmol) and triethylamine (1.5 mmol) were added to the resulting mixture. After additional stirring for 1 hour, the mixture was diluted with dichloromethane and water, the mixture was extracted with dichloromethane (3 x 10 mL) and the combined organic layer was washed with brine and water, dried over $MgSO_4$, filtered and concentrated under reduced pressure. Purification by flash chromatography with EtOAc/hexane afforded the corresponding carbamates.



5a

Prop-2-ynyl benzylcarbamate (5a): Prepared according to the general procedure using Cbz-protected benzylamine (benzyl benzylcarbamate, **1a**) and propargyl alcohol. The reaction mixture was purified by flash chromatography using 20% EtOAc/hexane to afford 85 mg (90% yield) of product as a colorless oil. ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.34 – 7.25 (m, 5H), 5.12 (s, 1H), 4.70 (d, *J* = 3.0 Hz, 2H), 4.37 (d, *J* = 5.4 Hz, 2H), 2.46 (t, *J* = 3.6 Hz, 1 H); ^{13}C NMR (150 MHz, $CDCl_3$): δ 155.5, 138.1, 128.9, 128.8, 127.7, 127.6, 127.3, 78.3, 74.7, 52.6, 45.2; HRMS (ESI) m/z $(M+H)^+$ calcd for $C_{11}H_{12}NO_2$ = 190.0868, found 190.0865. The analytical data were identical in all respects to those previously reported.[9]

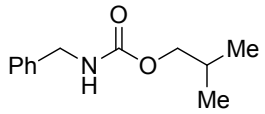


5b

Cyclohexyl benzylcarbamate (5b): Prepared according to the general procedure using Cbz-protected benzylamine (benzyl benzylcarbamate, **1a**) and cyclohexanol. The reaction mixture was purified by flash chromatography using 20% EtOAc/hexane to afford 101 mg (87% yield) of

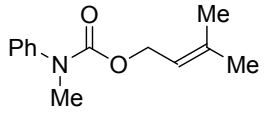
[9] R. Martnez, D. J. Ram, M. Yus, *Adv. Synth. Catal.* **2008**, *350*, 1235.

product as a white solid. mp 80−82°C; ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.33 – 7.26 (m, 5H), 4.91 (s, 1H), 4.66 (s, 1H) 4.35 (d, *J* = 6.0 Hz, 2H), 1.87 (s, 2H), 1.70 (s, 2H), 1.51 (s, 1H), 1.41 – 1.21 (m, 4H), 1.22 (s, 1H); ^{13}C NMR (150 MHz, $CDCl_3$): δ 156.3, 138.8, 128.7 (2C), 127.6, 127.5 (2C), 73.3, 45.0, 32.1 (2C), 25.5, 23.9 (2C); HRMS (ESI) m/z $(M+H)^+$ calcd for $C_{14}H_{20}NO_2$ = 234.1494, found 234.1495. The analytical data were identical in all respects to those previously reported.[10]



5c

Isobutyl benzylcarbamate (5c): **)**: Prepared according to the general procedure using Cbz-protected benzylamine (benzyl benzylcarbamate, **1a**) and isobutanol. The reaction mixture was purified by flash chromatography using 20% EtOAc/hexane. White solid, 94 mg, 91% yield. mp 37−39°C; ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.33 – 7.24 (m, 5H), 4.95 (s, 1H), 4.35 (d, *J* = 6.6 Hz, 2H), 3.86 (d, *J* = 6.6 Hz, 2H), 1.90 (m, 1H), 0.91 (d, *J* = 7.2 Hz, 6H); ^{13}C NMR (150 MHz, $CDCl_3$): δ 156.9, 138.7, 128.7, 127.6, 127.5, 71.2, 45.1, 28.1, 19.2, 19.1; HRMS (ESI) m/z $(M+H)^+$ calcd for $C_{12}H_{18}NO_2$ = 208.1338, found 208.1335.

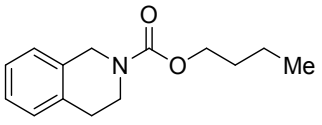


5d

3-Methylbut-2-enyl methyl(phenyl)carbamate (5d): Prepared according to the general procedure using Cbz-protected *N*-methylaniline (benzyl (methyl)phenylcarbamate, **1c**) and 3-methyl-2-buten-1-ol. The reaction mixture was purified by flash chromatography using 20% EtOAc/hexane to afford 91 mg (83% yield) of product as a colorless oil. ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.26 – 7.24 (m, 2H), 6.77 – 6.72 (m, 3H), 5.24 (t, *J* = 1.2 Hz, 1H), 3.91 (d, *J* = 6.0 Hz, 2H), 2.91 (s, 3H), 1.75 (s, 6H); ^{13}C NMR (150 MHz, $CDCl_3$): δ 149.9, 134.6, 129.2, 121.0 (2C), 116.5, 113.0 (2C), 50.6, 38.0, 25.8, 18.0; HRMS (ESI) m/z $(M+H)^+$ calcd for $C_{13}H_{18}NO_2$ =

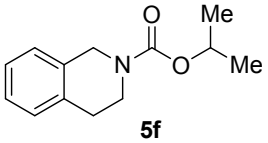
[10] M. Hatano, S. Kamiya, K. Moriyama, K. Ishihara, *Org. Lett.* **2011**, *13*, 430.

220.1338, found 220.1334. The analytical data were identical in all respects to those previously reported.[11]



5e

Butyl 3,4-dihydroisoquinoline-2(1*H*)-carboxylate (5e): Prepared according to the general procedure using Cbz-protected 1,2,3,4-tetrahydroisoquinoline (benzyl 3,4-dihydroisoquinoline-2(1*H*)-carboxylate, **1c**) and butanol. The reaction mixture was purified by flash chromatography using 20% EtOAc/hexane to afford 108 mg (93% yield) of product as a colorless oil. IR 2959, 1700, 1429, 1295, 1228, 1121 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$): δ 7.25 – 7.11 (m, 4H), 4.62 (s, 2H), 4.14 (t, *J* = 5.4 Hz, 2H), 3.69 (s, 2H), 2.85 (s, 2H), 1.65 (m, 2H), 1.43 (m, 2H), 0.95 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$): δ 155.9, 134.7, 133.6, 128.9, 128.3, 126.5, 126.3, 63.4, 45.7, 41.5, 31.2, 29.0, 19.2, 13.8; HRMS (ESI) m/z $(M+H)^+$ calcd for $C_{14}H_{20}NO_2$ = 234.1494, found 234.1492.



5f

Isopropyl 3,4-dihydroisoquinoline-2(1*H*)-carboxylate (5f): Prepared according to the general procedure using Cbz-protected 1,2,3,4-tetrahydroisoquinoline (benzyl 3,4-dihydroisoquinoline-2(1*H*)-carboxylate, **1a**) and 2-propanol. The reaction mixture was purified by flash chromatography using 20% EtOAc/hexane to afford 94 mg (86% yield) of product as a colorless oil. ^1H NMR (600 MHz, $CDCl_3$): δ 7.17 – 7.09 (m, 4H), 4.96 (m, 1H), 4.59 (s, 2H), 3.67 (s, 2H), 2.83 (s, 2H), 1.26 (d, *J* = 6.6 Hz, 6H); ^{13}C NMR (150 MHz, $CDCl_3$): δ 155.4, 134.8, 133.9, 128.9, 128.5, 126.5, 126.3, 68.7, 45.7, 41.5, 29.0, 22.4 (2C); HRMS (ESI) m/z $(M+H)^+$ calcd for $C_{13}H_{18}NO_2$ = 220.1338, found 220.1340. The analytical data were identical in all respects to those previously reported.[12]

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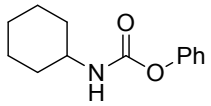
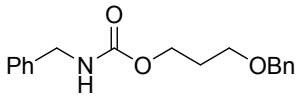
[11] J. A. Grzyb, M. Shen, C. Yoshina-Ishii, W. Chi, R. S. Brown, R. A. Batey, *Tetrahedron* **2005**, *61*, 7135.
[12] S. L. Peterson, S. M. Stucka, C. J. Dinsmore, *Org. Lett.* **2010**, *12*, 1340.



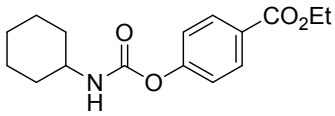
5g

Phenyl cyclohexylcarbamate (5g): Prepared according to the general procedure using Cbz-protected cyclohexylamine (benzyl cyclohexylcarbamate, **1e**) and phenol. The reaction mixture was purified by flash chromatography using 20% EtOAc/hexane to afford 90 mg (82% yield) of product as a white solid. mp: 134-136 °C. ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.35 – 7.32 (m, 2H), 7.18 – 7.01 (m, 3H), 4.87 (s, 1H), 3.55 (m, 1H), 2.00 (m, 2H), 1.73 (m, 2H), 1.62 (m, 1H), 1.37 (m, 2H), 1.20 (m, 3H); ^{13}C NMR (150 MHz, $CDCl_3$): δ 155.7, 151.2, 129.3 (2C), 125.1, 121.7 (2C), 50.1, 33.3 (2C), 25.5, 24.8 (2C); HRMS (ESI) m/z $(M+H)^+$ calcd for $C_{13}H_{18}NO_2$ = 220.1338, found 220.1334. The analytical data were identical in all respects to those previously reported.[13]



5h

3-(Benzyloxy)propyl benzylcarbamate (5h): Prepared according to the general procedure using Cbz-protected benzylamine (benzyl benzylcarbamate, **1a**) and 3-(benzyloxy)propan-1-ol. The reaction mixture was purified by flash chromatography using 20% EtOAc/hexane to afford 120 mg (80% yield) of product as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.31 - 7.24 (m, 10H), 7.14 (s, 1H), 4.43 – 4.24 (m, 4H), 4.43 (s, 2H), 3.46 (t, *J* = 6.3 Hz, 2H), 1.96 – 1.93 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ156.8, 128.6, 128.3, 127.5, 77.3, 76.9, 76.7, 66.7, 62.9, 29.6; LRMS (EI); Mass calcd for $C_{18}H_{22}NO_3$ [M+H]+: 300.1; found 300.1.



5i

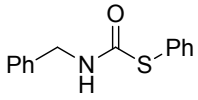
Ethyl 4-(cyclohexylcarbamoyloxy)benzoate (5i): Prepared according to the general procedure using Cbz-protected cyclohexylamine (benzyl cyclohexylcarbamate, **1e**) and ethyl 4-

[13] A. A. Wilson, A. Garcis, S. Houle, O. Sadovski, N. Vasdev, *Chem. Eur. J.* **2011**, *17*, 259.

hydroxybenzoate. The reaction mixture was purified by flash chromatography using 20% EtOAc/hexane to afford 106 mg (73% yield) of product as a white solid. White solid; mp 108−110°C; ^{1}H NMR (600 MHz, $CDCl_3$): δ 8.02 (d, *J* = 8.4 Hz, 2H), 7.06 (d, *J* = 9.0 Hz, 2H), 4.98 (s, 1H), 4.33 (m, 2H), 3.54 (m, 1H), 1.98 (m, 2H), 1.72 (m, 2H), 1.61 (m, 1H), 1.35 (m, 5H), 1.17 (m, 3H); ^{13}C NMR (150 MHz, $CDCl_3$): δ 166.1, 154.8, 152.9, 131.0, 127.2, 121.3, 61.1, 50.3, 33.3, 25.5, 24.8, 14.4; LRMS (EI); Mass calcd for $C_{16}H_{22}NO_4$ [M+H]+: 292.1; found 292.1.

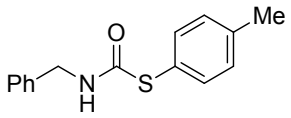
3. General procedure of the one-pot synthesis of thiocarbamates

Cbz-protected amine **1**(0.5 mmol) and 2-Cl-pyridine (1.5 mmol) were dissolved in dry dichloromethane (10 mL, 0.05 M). Tf_2O (0.75 mmol) was added dropwise over 5 min. After stirring for 1 hour at room temperature, thiol **6** was added to the resulting mixture. After additional stirring for 1 hour, the mixture was diluted with dichloromethane and water, the mixture was extracted with dichloromethane (3 x 10 mL) and the combined organic layer was washed with brine and water, dried over $MgSO_4$, filtered and concentrated under reduced pressure. Purification by flash chromatography with EtOAc/hexane afforded the corresponding thiocarbamates.



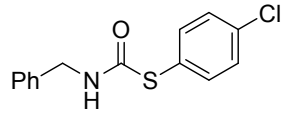
7a

***S*-Phenyl benzylcarbamothioate (7a)**: Prepared according to the general procedure using Cbz-protected benzylamine (benzyl benzylcarbamate, **1a**) and benzenethiol. The reaction mixture was purified by flash chromatography using 20% EtOAc/hexane to afford 90 mg (74% yield) of product as a yellow solid. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.56-7.54 (m, 2H), 7.40-7.21 (m, 8H), 5.76 (s, 1H), 4.42 (d, *J* = 5.7 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.2, 149.8, 138.7, 137.5, 135.5, 129.7, 129.4, 128.7, 127.6, 124.5, 122.3, 45.3, 29.7; LRMS (EI); Mass calcd for $C_{13}H_{14}NOS$ $[M+H]^+$: 244.1, found 244.0. The analytical data were identical in all respects to those previously reported.[14]



7b

***S-p*-Tolyl benzylcarbamothioate** (**7b**): Prepared according to the general procedure using Cbz-protected benzylamine (benzyl benzylcarbamate, **1a**) and 4-methylbenzenethiol. The reaction mixture was purified by flash chromatography using 20% EtOAc/hexane to afford 109 mg (74% yield) of product as a yellow solid. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.45 (d, J = 8.0 Hz, 2H), 7.26 (ddd, J = 27.6, 13.9, 7.6 Hz, 7H), 5.64 (s, 1H), 4.44 (d, J = 5.7 Hz, 2H), 2.36 (s, 3H); HRMS (ESI) m/z $(M+H)^+$ calcd for $C_{15}H_{16}NOS$ = 258.0934, found 258.0932. ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.6, 140.2, 135.5, 130.5, 130.1, 128.9, 128.6, 127.8, 127.4, 45.5, 44.9, 21.4, 21.2; LRMS (EI); Mass calcd for $C_{15}H_{16}NOS$ $[M+H]^+$: 258.1; found 258.0. The analytical data were identical in all respects to those previously reported.[5]



7c

***S*-(4-Chlorophenyl) benzylcarbamothioate** (**7c**): Prepared according to the general procedure using Cbz-protected benzylamine (benzyl benzylcarbamate, **1a**) and 4-chlorobenzenethiol. The reaction mixture was purified by flash chromatography using 20% EtOAc/hexane to afford 111 mg (80% yield) of product as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.48 (d, J = 8.5 Hz, 2H), 7.43 – 7.19 (m, 7H), 5.67 (s, 1H), 4.46 (d, J = 5.7 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 165.4, 136.6, 129.5, 128.8, 127.8 (d, J = 8.7 Hz), 45.5; LRMS (EI); Mass calcd for $C_{14}H_{13}ClNOS$ $[M+H]^+$: 278.0; found 278.0. The analytical data were identical in all respects to those previously reported.[5]

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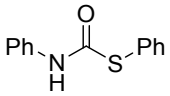
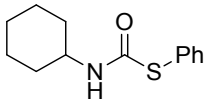
[14] J. W. K. Su, J. P. Zhang, X. R. Liang, *Organic Preparations and Procedures International* **2006**, *38*, 404.



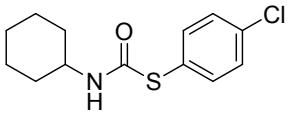
7d

***S*-(4-Chlorophenyl) benzylcarbamothioate** (**7d**): Prepared according to the general procedure using benzyl phenylcarbamate **1b** and benzenethiol. The reaction mixture was purified by flash chromatography using 20% EtOAc/hexane to afford 83 mg (72% yield) of product as a yellow solid. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.66 – 7.02 (m, 10H), 5.29 (d, J = 2.2 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 164.4, 137.5, 135.4, 129.9, 129.5, 129.2, 128.7, 128.4, 127.9, 119.6; LRMS (EI); Mass calcd for $C_{13}H_{12}NOS$ $[M+H]^+$: 230.1; found 230.0. The analytical data were identical in all respects to those previously reported.[15]



7e

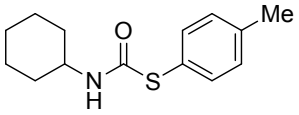
***S*-Phenyl cyclohexylcarbamothioate** (**7e**): Prepared according to the general procedure using benzyl cyclohexylcarbamate **1e** and benzenethiol. The reaction mixture was purified by flash chromatography using 20% EtOAc/hexane to afford 85 mg (72% yield) of product as a yellow solid. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.78 – 7.32 (m, 5H), 5.24 (s, 1H), 3.73 (s, 1H), 1.89 (d, J = 9.2 Hz, 2H), 1.62 (d, J = 9.2 Hz, 2H), 1.17 (ddd, J = 105.7, 59.1, 47.3 Hz, 6H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 164.9, 135.4, 129.4, 50.5, 25.3, 24.5; LRMS (EI); Mass calcd for $C_{13}H_{18}NOS$ $[M+H]^+$: 236.1; found 236.1. The analytical data were identical in all respects to those previously reported.[16]



7f

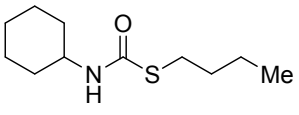
[15] M. Hutchby, C. E. Houlden, J. G. Ford, S. N. G. Tyler, M. R. Gagn, G. C. L-Jones, K. I. B-Milburn, *Angew. Chem. Int. Ed.***2009**, *48*, 8721.
[16] K. S. Jeong, H. K. Oh, *Bull. Korean Chem. Soc.* **2008**, *29*, 1621.

***S*-(4-chlorophenyl) cyclohexylcarbamothioate** (**7f**): Prepared according to the general procedure using benzyl cyclohexylcarbamate **1e** and 4-chlorobenzenethiol. The reaction mixture was purified by flash chromatography using 20% EtOAc/hexane to afford 94 mg (70% yield) of product as a yellow solid. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.57 – 7.13 (m, 4H), 5.34 (s, 1H), 3.72 (d, J = 6.6 Hz, 1H), 1.91 (d, J = 9.6 Hz, 2H), 1.81 – 1.48 (m, 3H), 1.48 – 1.01 (m, 5H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 164.2, 136.5, 135.7, 133.9, 130.1, 129.7, 129.3, 50.8, 29.7, 25.3, 24.6; LRMS (EI); Mass calcd for $C_{13}H_{17}ClNOS$ $[M+H]^+$: 270.1; found 270.0. The analytical data were identical in all respects to those previously reported.[7]



7g

***S*-*p*-Tolyl cyclohexylcarbamothioate** (**7g**): Prepared according to the general procedure using benzyl cyclohexylcarbamate **1e** and 4-methylbenzenethiol. The reaction mixture was purified by flash chromatography using 20% EtOAc/hexane to afford 90 mg (72% yield) of product as a yellow solid. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.43 (d, J = 8.0 Hz, 2H), 7.21 (d, J = 8.0 Hz, 2H), 5.24 (s, 1H), 3.72 (d, J = 3.4 Hz, 1H), 2.37 (s, 3H), 1.87 (d, J = 9.4 Hz, 2H), 1.78 – 1.47 (m, 3H), 1.29 (dd, J = 20.7, 8.7 Hz, 2H), 1.11 (dd, J = 19.7, 7.6 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ165.4, 139.9, 135.4, 130.2, 125.4, 50.4, 32.8, 25.3, 24.6, 21.3; LRMS (EI); Mass calcd for $C_{14}H_{20}NOS$ $[M+H]^+$: 250.1; found 250.1. The analytical data were identical in all respects to those previously reported.[7]

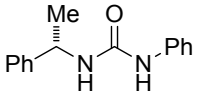


7h

***S*-Butyl cyclohexylcarbamothioate (7h)**: Prepared according to the general procedure using benzyl cyclohexylcarbamate **1e** and 1-butanethiol. The reaction mixture was purified by flash chromatography using 20% EtOAc/hexane to afford 92 mg (85% yield) of product as a pale yellow oil. **^{1}H NMR (400 MHz, $CDCl_3$):** δ 5.24, (s, 1H), 3.72 (s, 1H), 2.86 (t, J = 7.3 Hz, 2H),

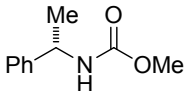
1.92 – 1.89 (m, 2H), 1.70 – 1.65 (m, 2H), 1.60-1.08 (m, 10H), 0.89 (t, J = 7.3 Hz, 3H); **^{13}C NMR (100 MHz, $CDCl_3$):** δ166.2, 50.4, 33.2, 32.5, 29.6, 25.4, 24.7, 21.9, 13.6; LRMS (EI); Mass calcd for $C_{11}H_{22}NOS$ [M+H]+: 215.1; found 215.1.[17]

4. Syntheses of enantioenriched urea 9 and carbamate 10



9

(*S*)-1-Phenyl-3-(1-phenylethyl)urea (9): Prepared according to the general procedure using Cbz-protected (S)-(-)-α-methylbenzylamine ((S)-(-)-α-benzyl 1-phenylethylcarbamate, **8)** and aniline. The reaction mixture was purified by flash chromatography using 20% EtOAc/hexane to afford 202.4 mg (82% yield) of product as a yellowish solid. mp: 148−150 °C; $[\alpha]_D^{20}$ −8.03 (*c* 1.00, $CHCl_3$); ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.17−7.34 (m, 10H), 6.97−6.99 (m, 1H), 5.82 (d, J = 6.6 Hz, 1H), 4.88 (m, 1H), 1.32 (d, J = 6.6 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$): δ 155.7, 144.2, 138.9, 129.1, 128.7, 127.2, 125.9, 123.2, 120.2, 49.9, 23.0; HRMS (ESI) m/z $(M+H)^+$ calcd for $C_{15}H_{17}N_2O$ = 241.1341, found 241.1345. Enantiomeric ratio was measured by chiral phase HPLC (Chiralpak AD-H, 30%, *i*-PrOH/Hexane, 0.8 mL/min, 360 nm), Rt_1 (major) = 7.6 min, Rt_2 (minor) = 4.7 min; e.r. > 99.5:0.5. The analytical data were identical in all respects to those previously reported.[18]



10

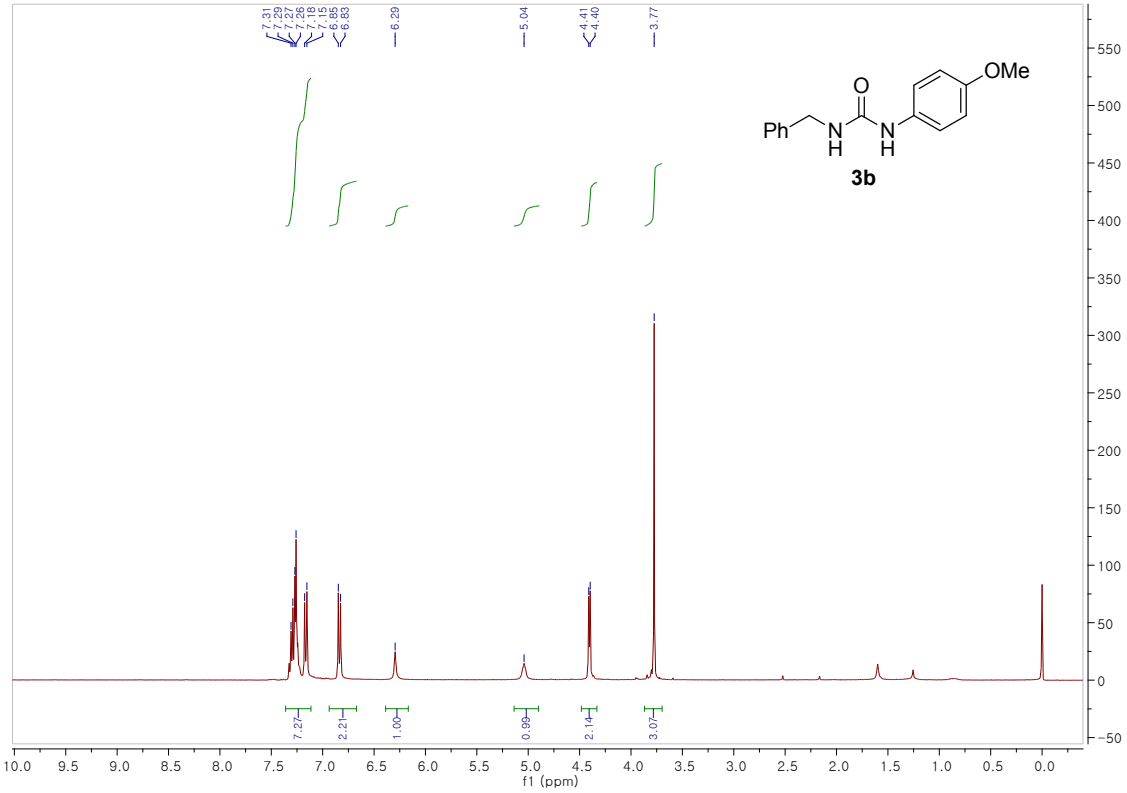
(*S*)-Methyl 1-phenylethylcarbamate (10). Prepared according to the general procedure using Cbz-protected (*S*)-(-)-α-methylbenzylamine ((*S*)-(-)-α-benzyl 1-phenylethylcarbamate, **8**) and methanol. The reaction mixture was purified by flash chromatography using 20% EtOAc/hexane to afford 145 mg (81% yield, 1.0 mmol scale) of product as a yellowish solid. mp 55−57°C; ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.34–7.23 (m, 5H), 4.99 (s, 1H), 4.84 (s, 1H), 3.64 (s, 3H), 1.47 (d, J = 6.6 Hz, 3H), 6.64(s, 1H); ^{13}C NMR (150 MHz, $CDCl_3$): δ 156.3, 143.6, 128.7, 127.3, 126.0,

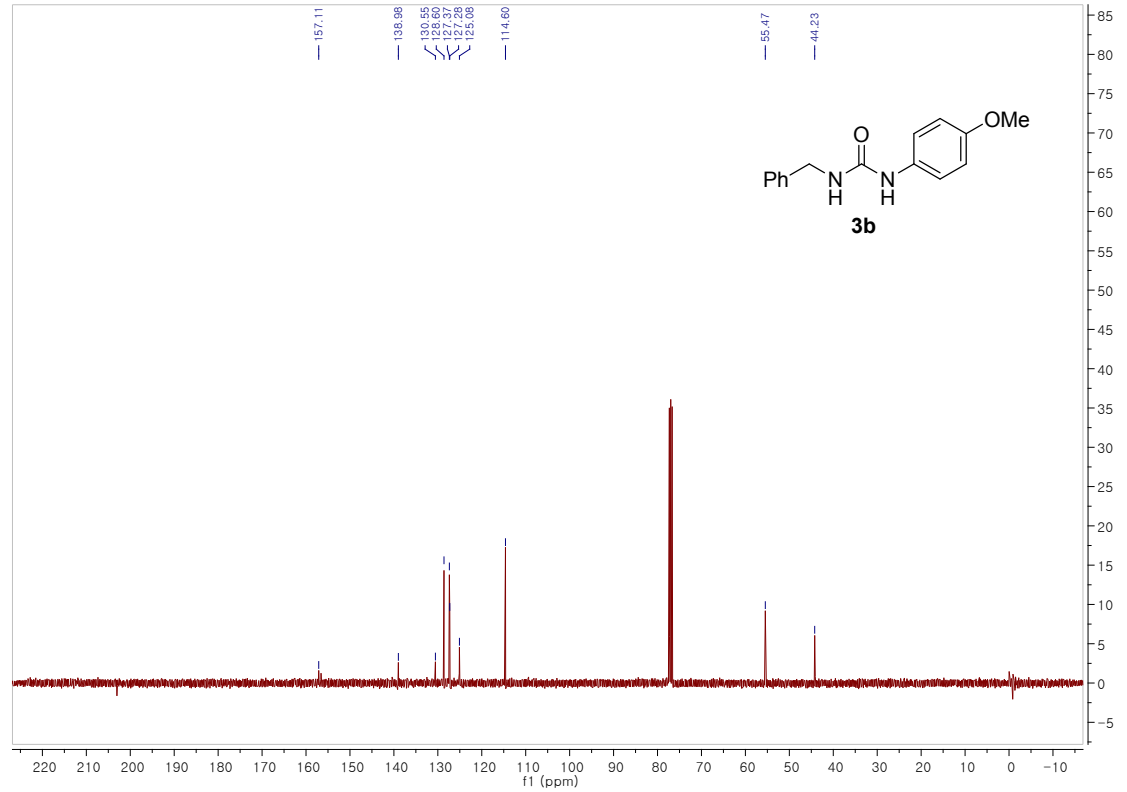
[17] K. Yoshida, M. Isobe, K. Yano, K. Nagamatsu, *Bull. Chem. Soc. Jpn.* **1985**, *58*, 2143.
[18] S.-Y. Moon, U. B. Kim, D.-B. Sung, W.-S. Kim, *J. Org. Chem.* **2015**, *80*, 1856.

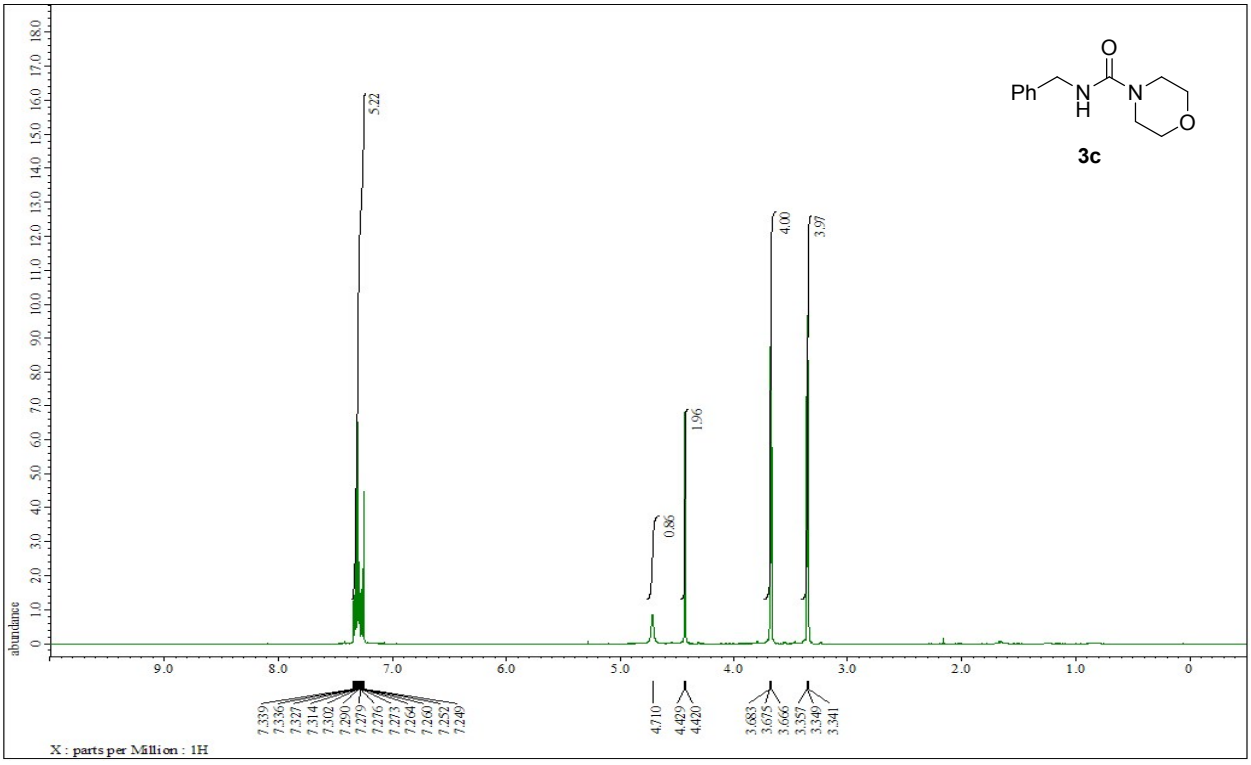
52.1, 50.7, 22.5; LRMS (EI); Mass calcd for $C_{10}H_{14}NO_2$ [M+H]+: 180.1; found 180.1. Enantiomeric ratio was measured by chiral phase HPLC (Chiralcel OD-H, 5%, *i*-PrOH/Hexane, 1.0 mL/min, 210 nm), R_{t1} (major) = 13.3 min, R_{t2} (minor) = 16.4 min; e.r. > 99.5:0.5. The analytical data were identical in all respects to those previously reported.[19]

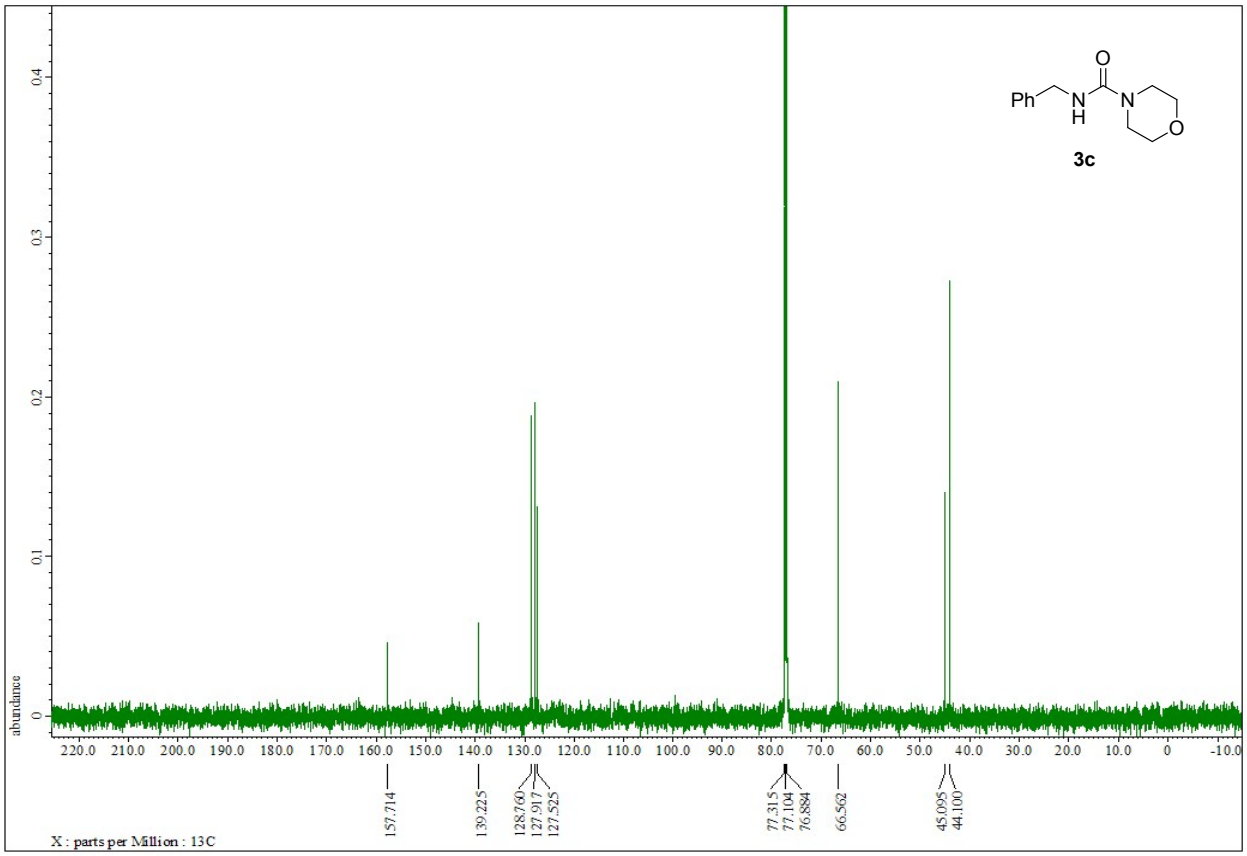
[19] S. H. Lee; I. S. Kim; R. Li; G. R. Dong; L. S. Jeong; Y. H. Jung *J. Org. Chem.* **2011**, *76*, 10011.

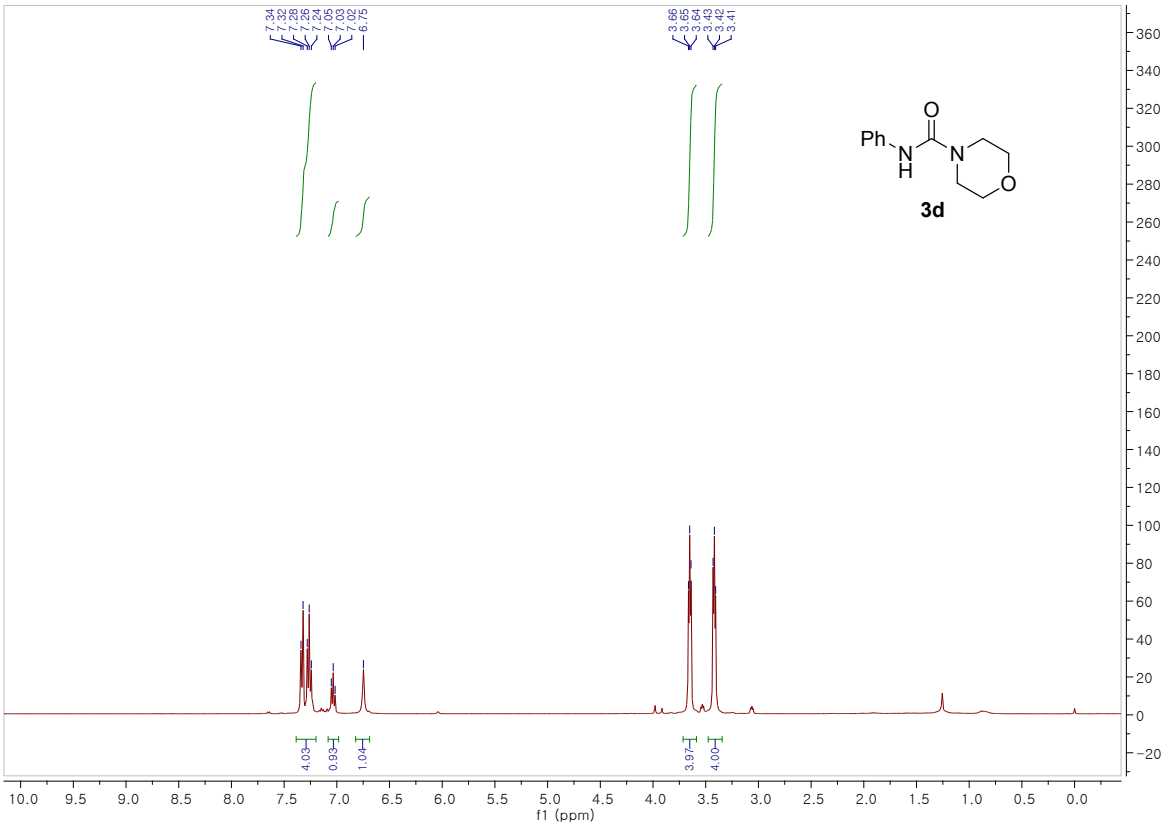
Selected NMR Spectra

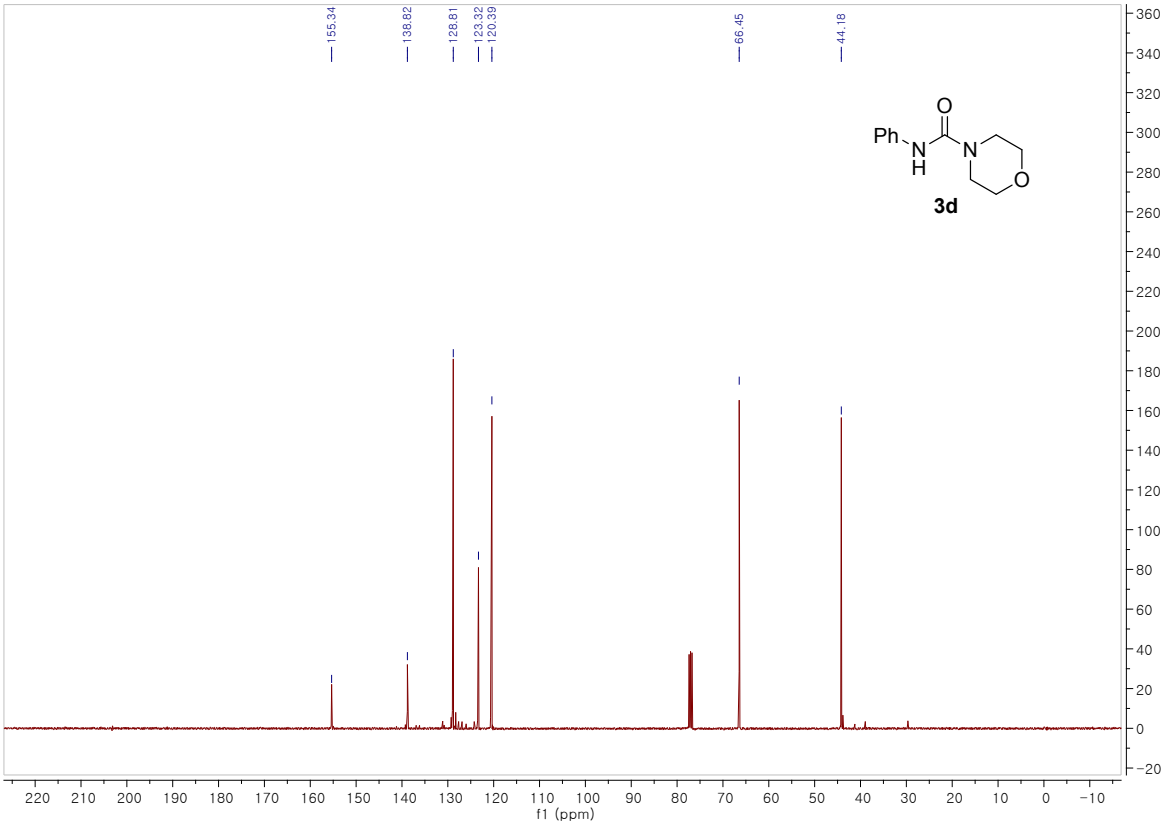


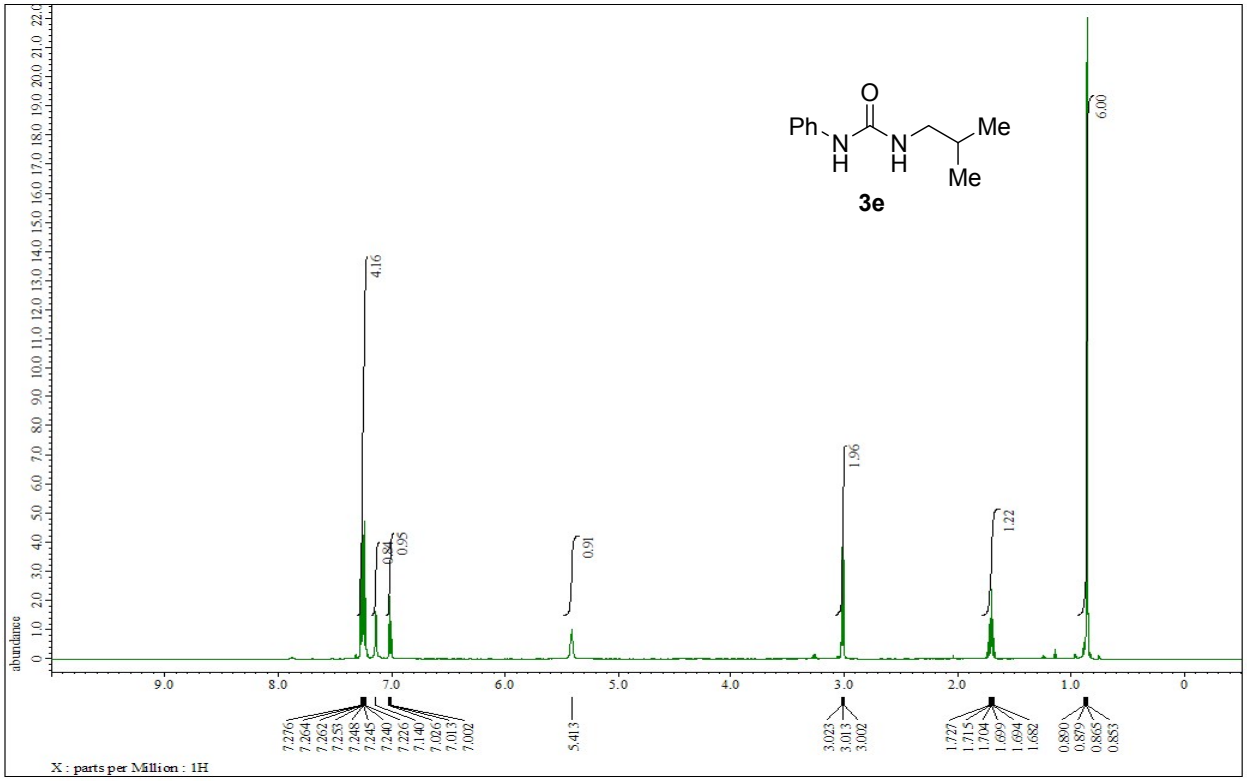


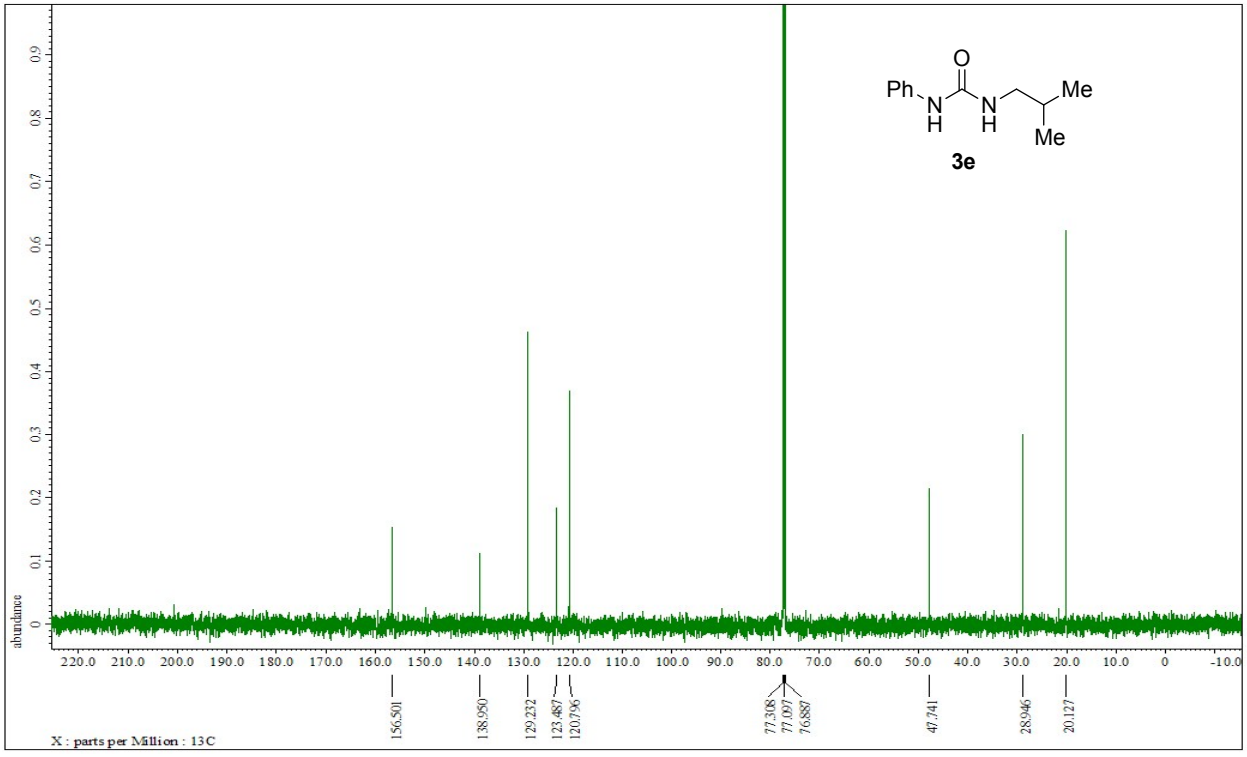

Ph
N
H
O
N
O
3c
5.22
0.86
1.96
4.00
3.97
abundance
X : parts per Million : 1H

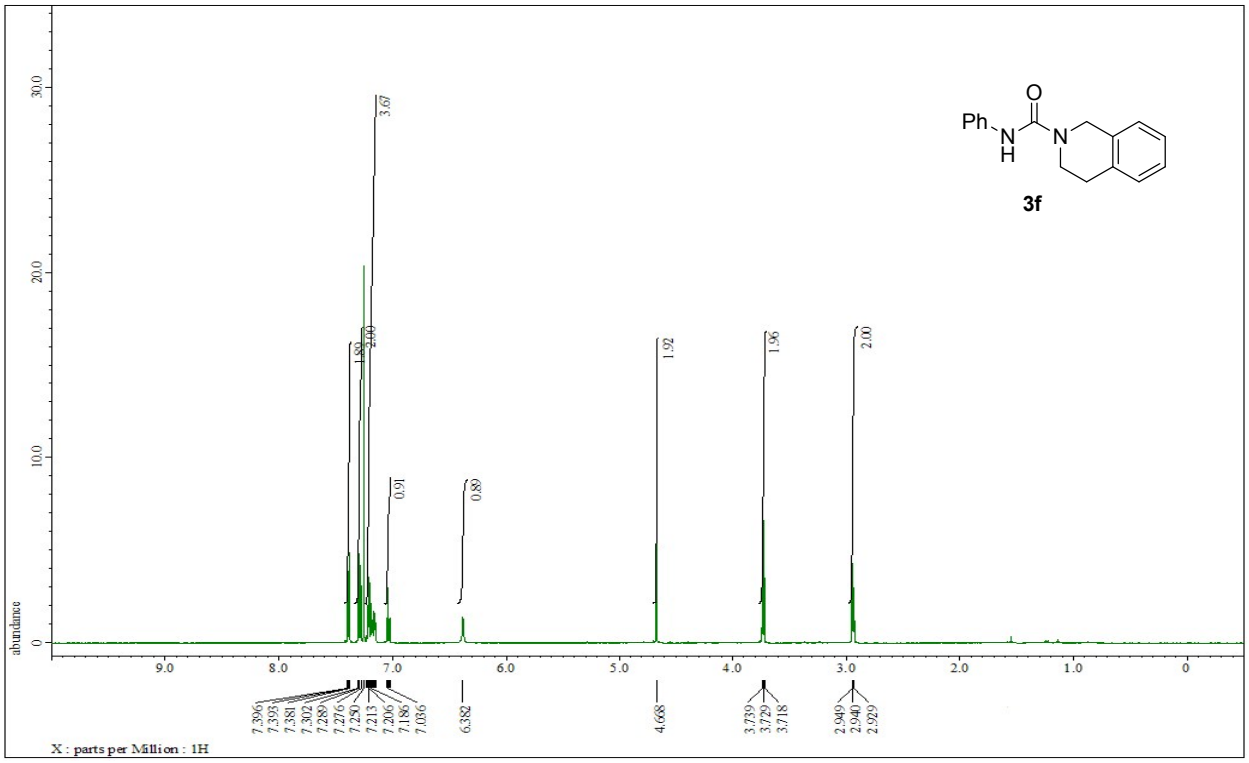

Ph
N
H
O
N
O
3c
abundance
157.714
139.225
128.760
127.917
127.525
77.315
77.104
76.884
66.562
45.095
44.100
X : parts per Million : 13C

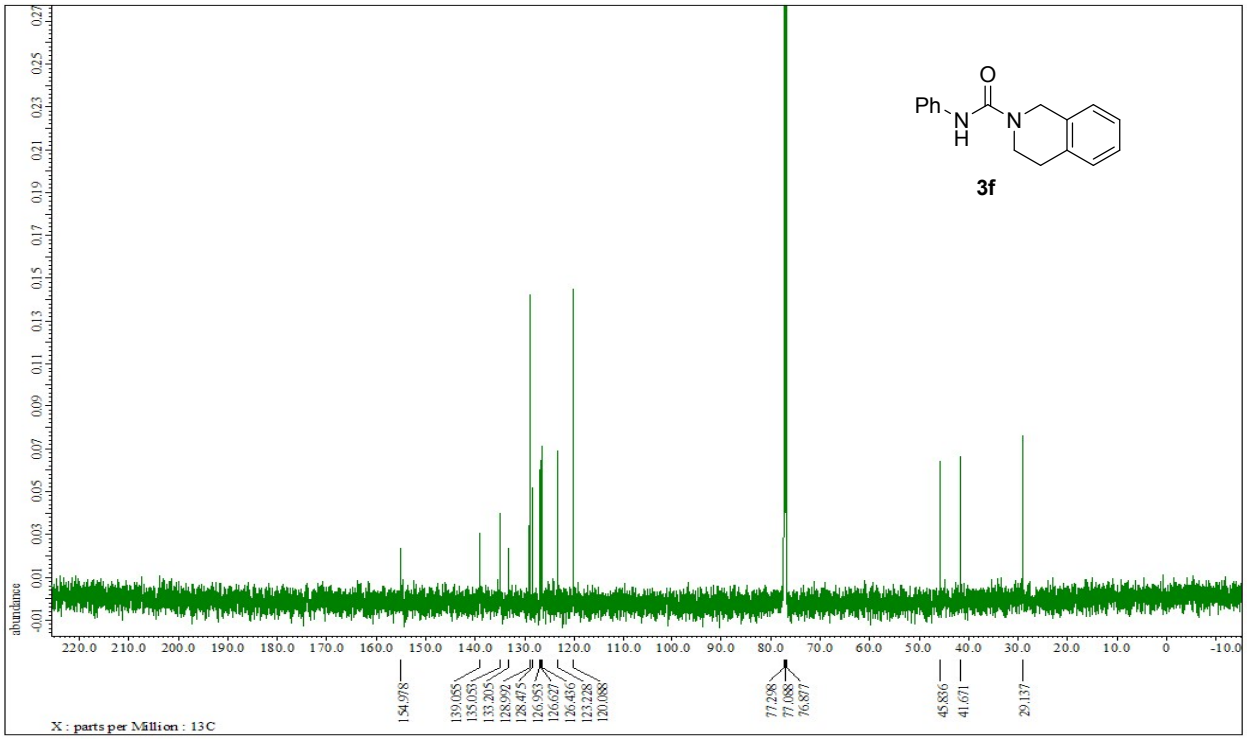

7.34
7.32
7.28
7.26
7.24
7.05
7.03
7.02
6.75
3.66
3.65
3.64
3.43
3.42
3.41
Ph
N
H
O
N
O
3d
4.03
0.93
1.04
3.97
4.00
f1 (ppm)

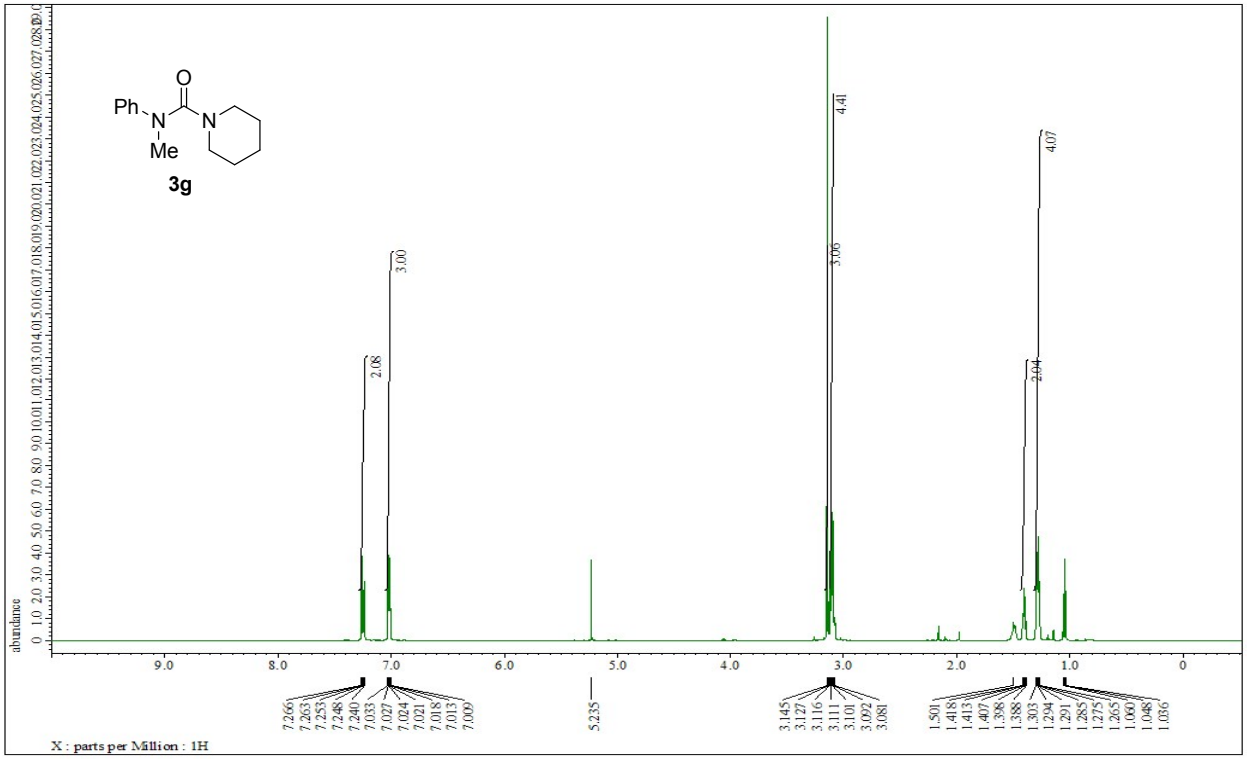

155.34
138.82
128.81
123.32
120.39
66.45
44.18
Ph
N
H
O
N
O
3d
f1 (ppm)

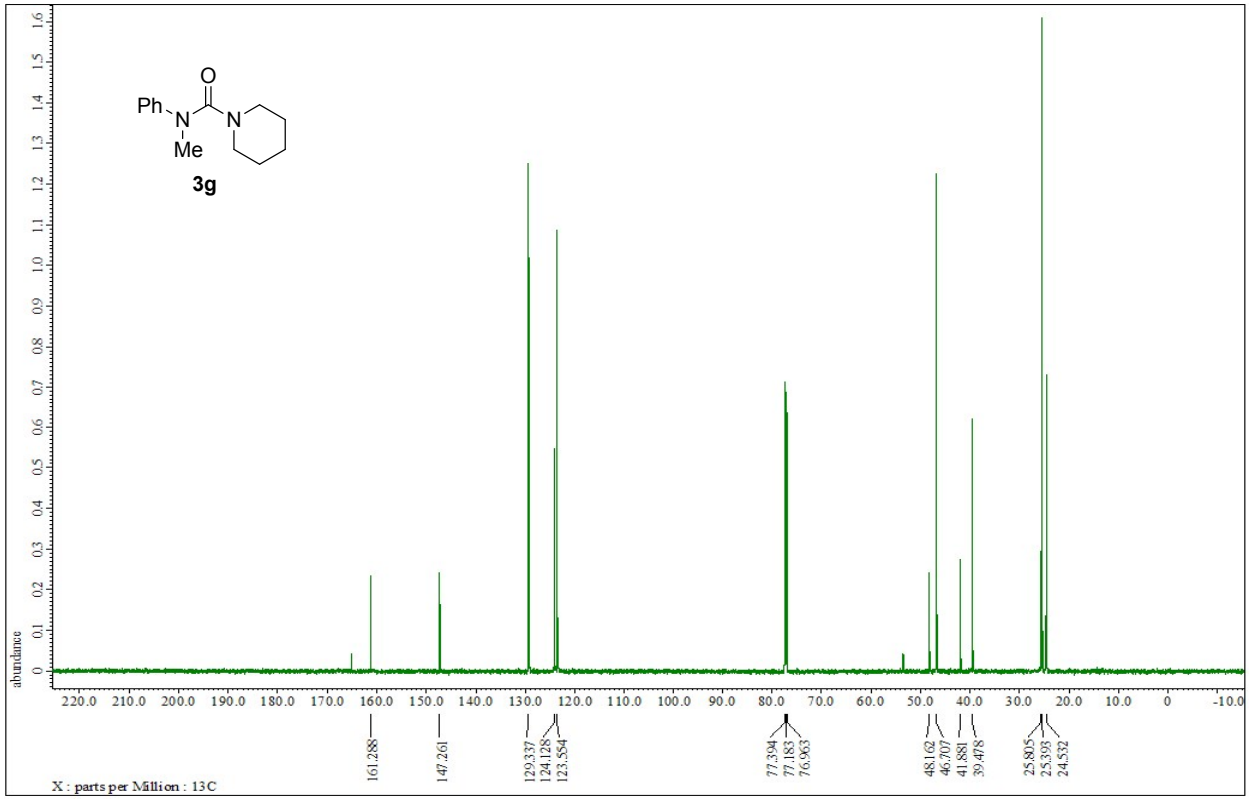

Ph
N
H
O
N
H
Me
Me
3e
4.16
0.84
0.95
0.91
1.96
1.22
6.00
abundance
X : parts per Million : 1H

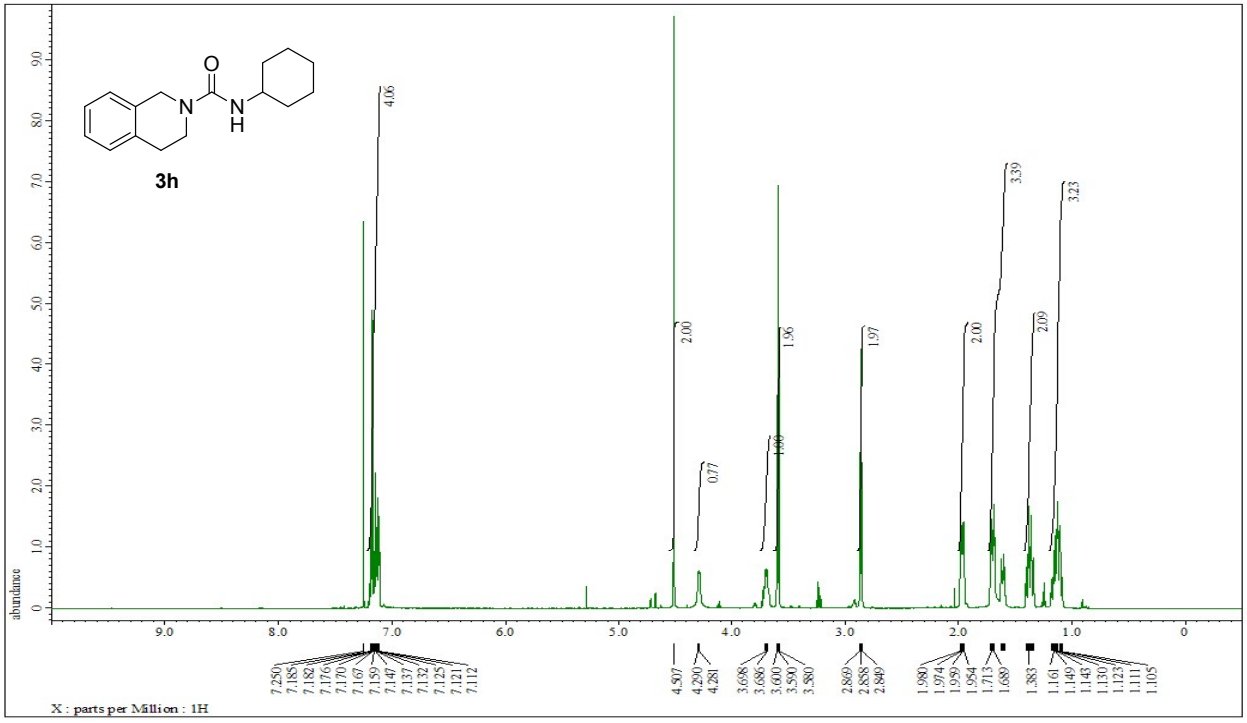

Ph
N
H
O
N
H
Me
Me
3e
abundance
X : parts per Million : 13C

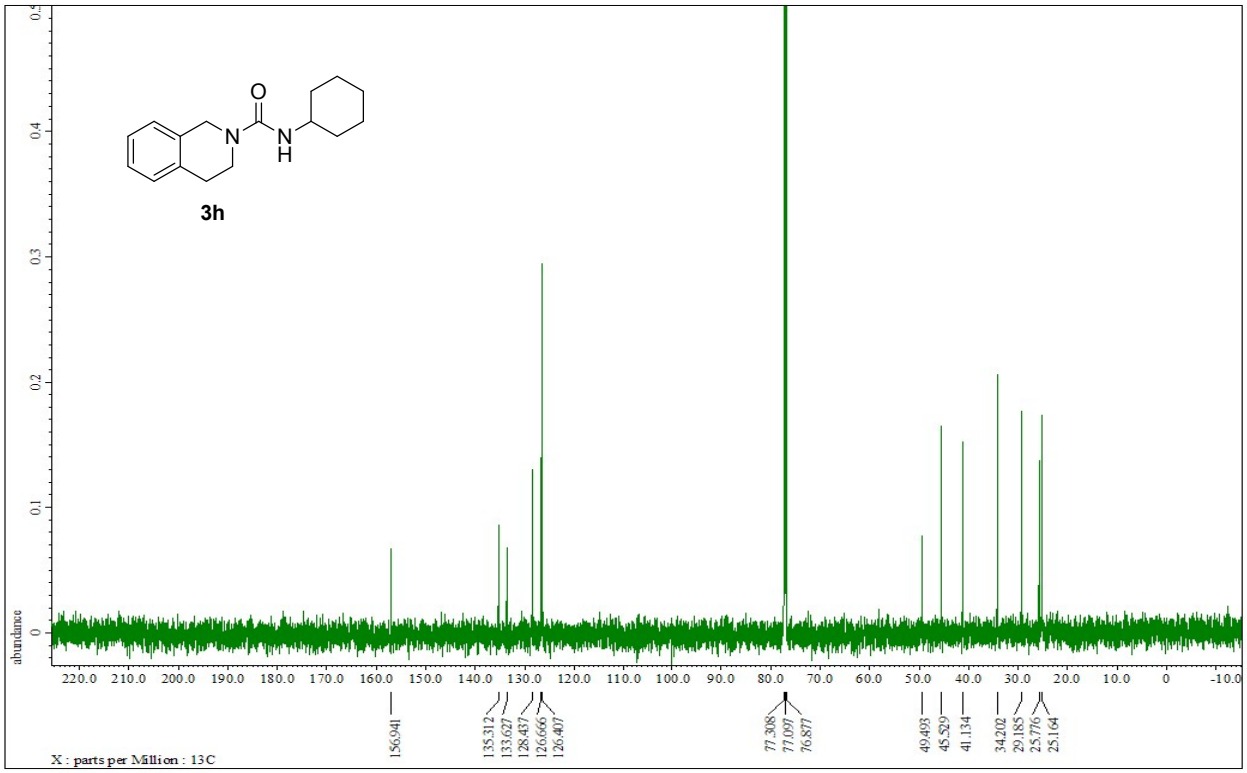

3f
abundance
X : parts per Million : 1H

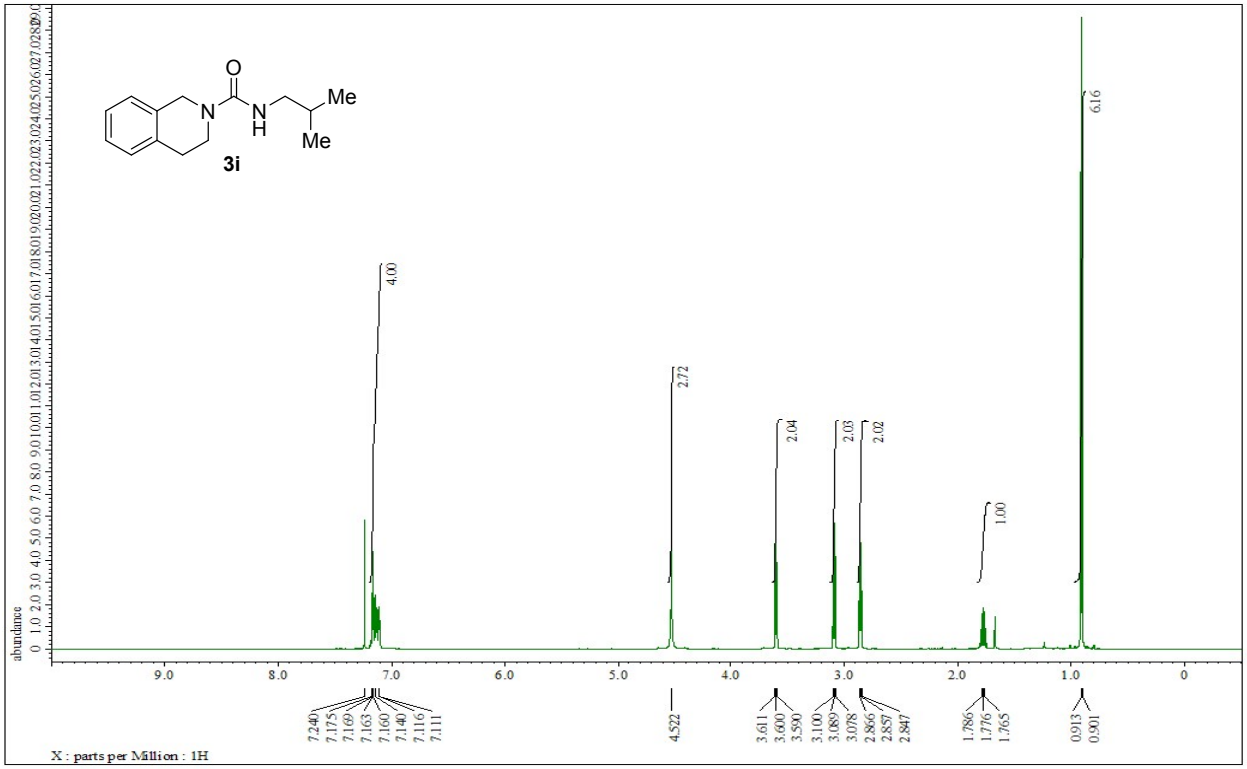

3f
abundance
X : parts per Million : 13C

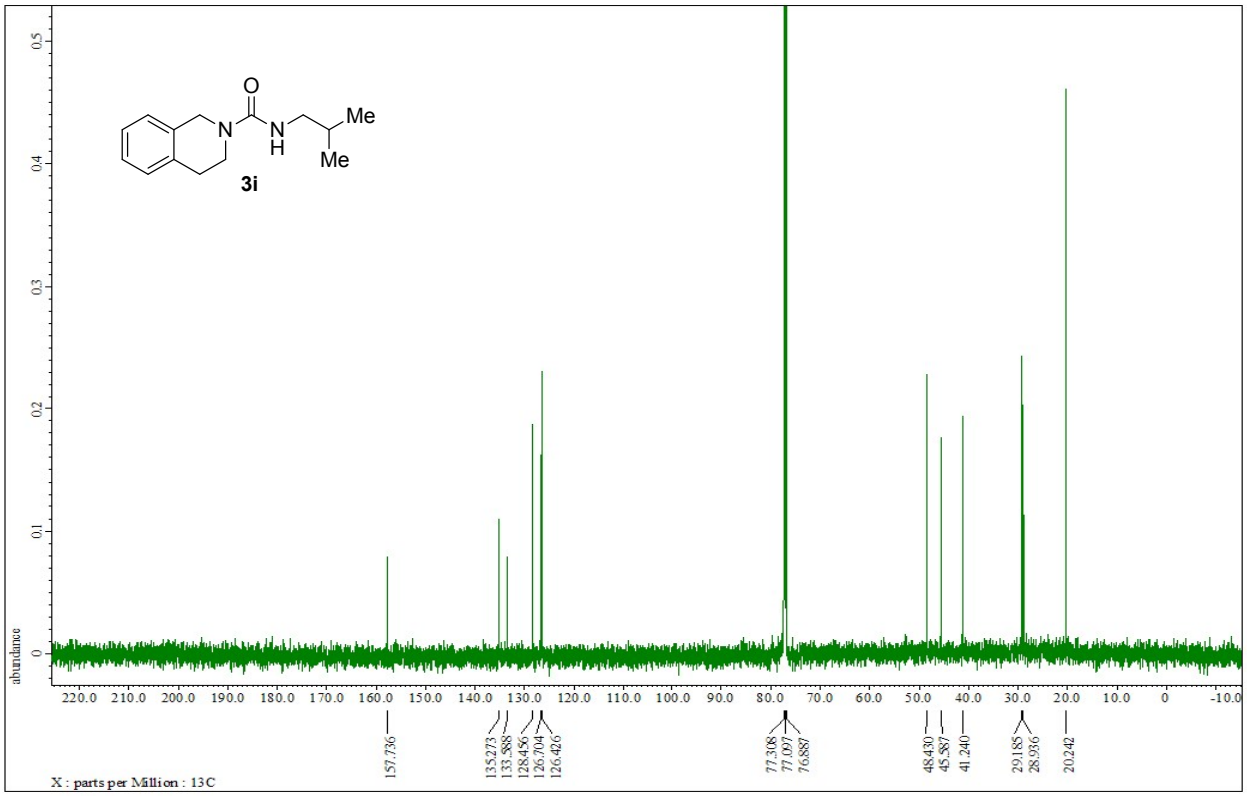

Ph
N
O
N
Me
3g
4.41
4.07
3.00
3.06
2.08
2.04
abundance
X : parts per Million : 1H

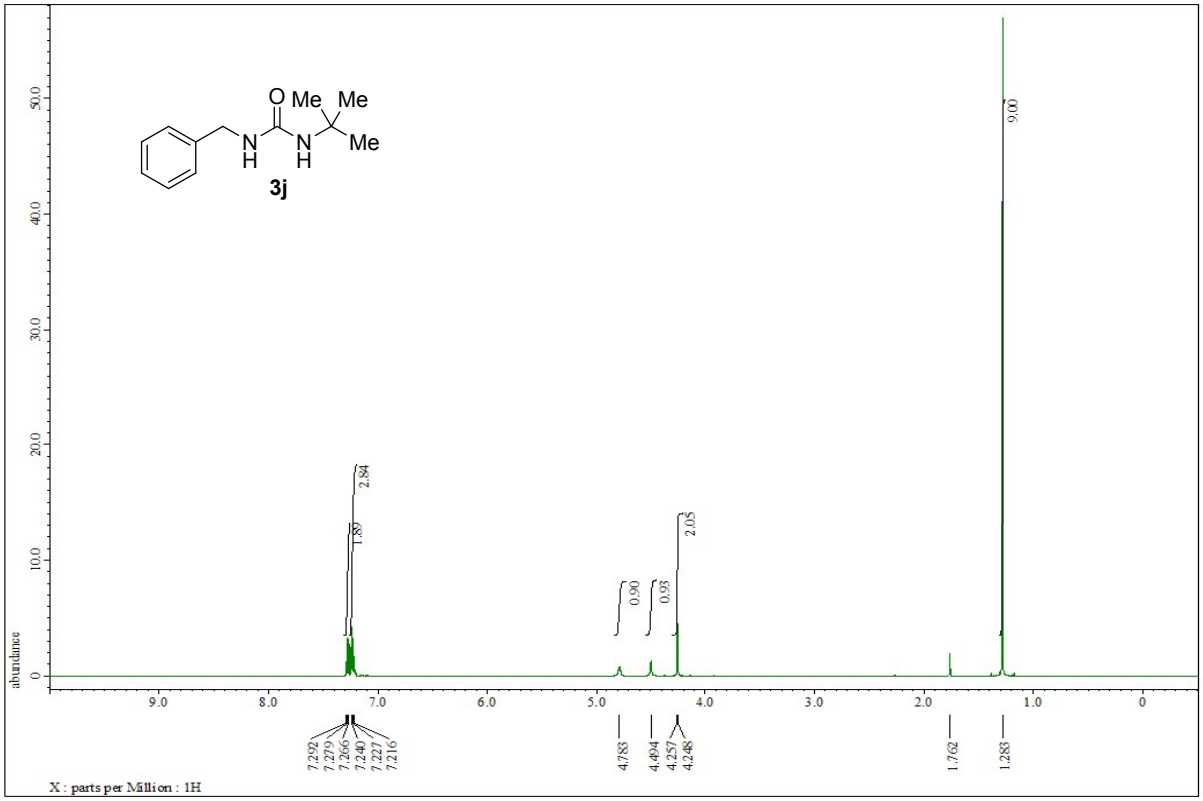

Ph
N
O
N
Me
3g
abundance
X : parts per Million : 13C

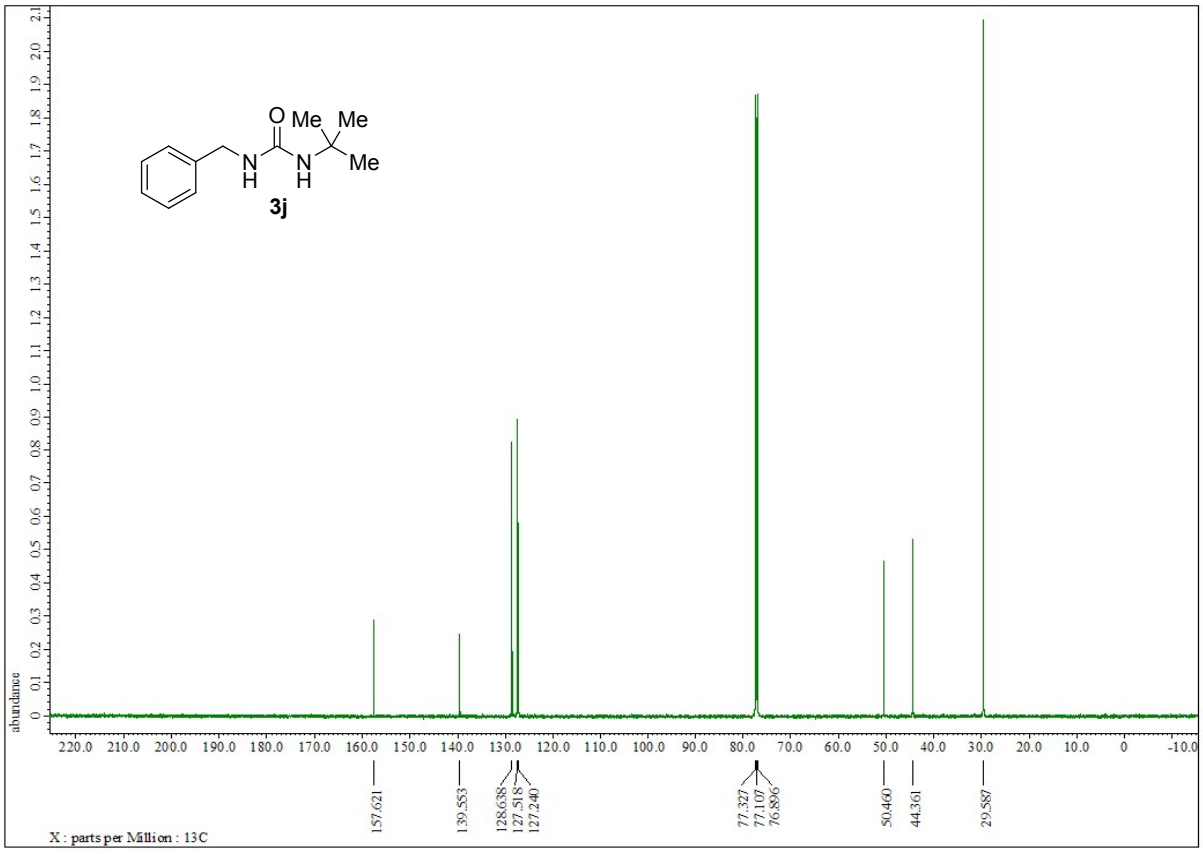

3h
4.06
2.00
0.77
1.96
1.88
1.97
2.00
3.39
2.09
3.23
abundance
X : parts per Million : 1H

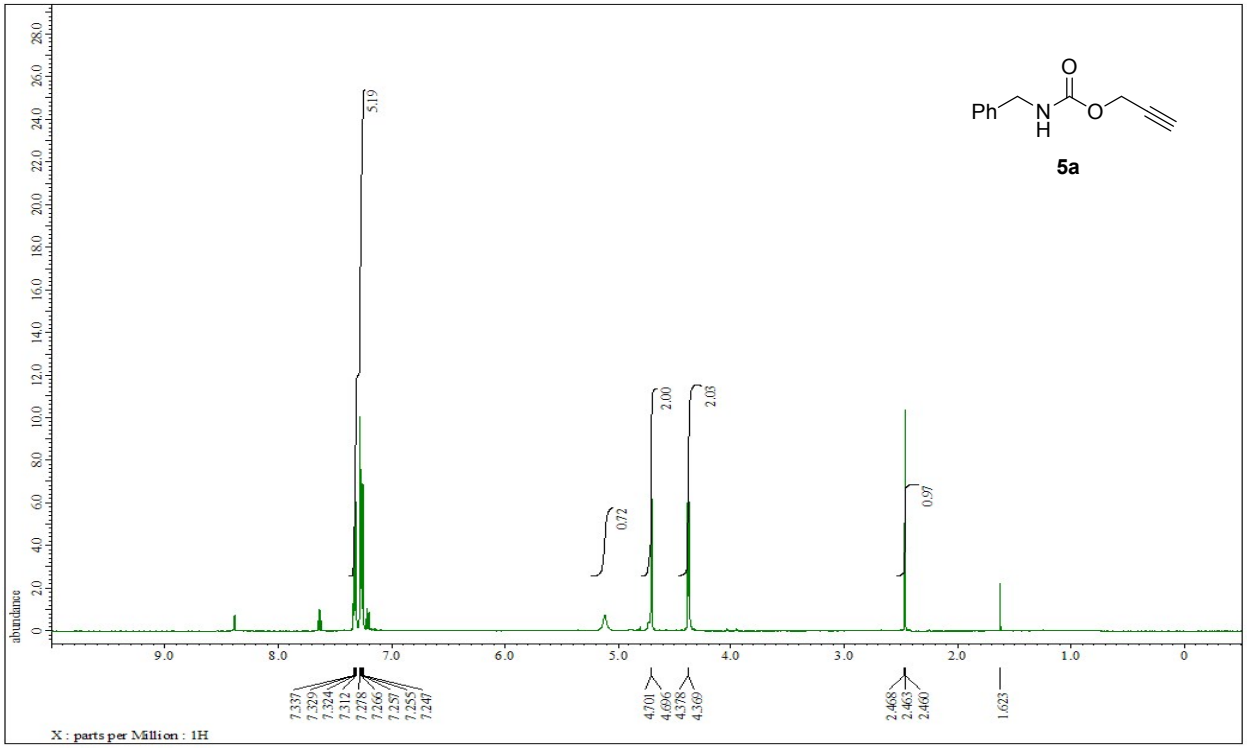

3h
abundance
156.941
135.312
133.627
128.457
126.666
126.407
77.308
77.097
76.877
49.493
45.529
41.134
34.202
29.185
25.776
25.164
X : parts per Million : 13C

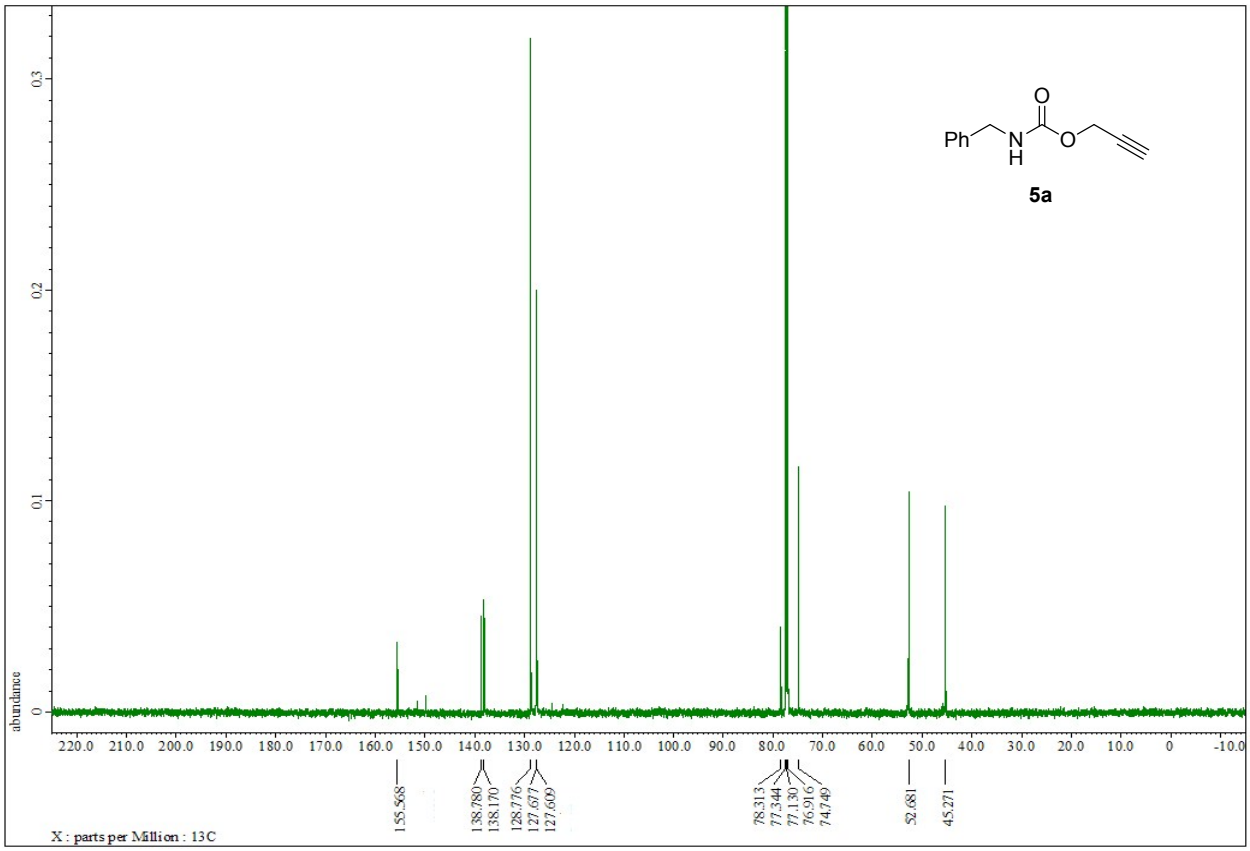

3i
abundance
X : parts per Million : 1H

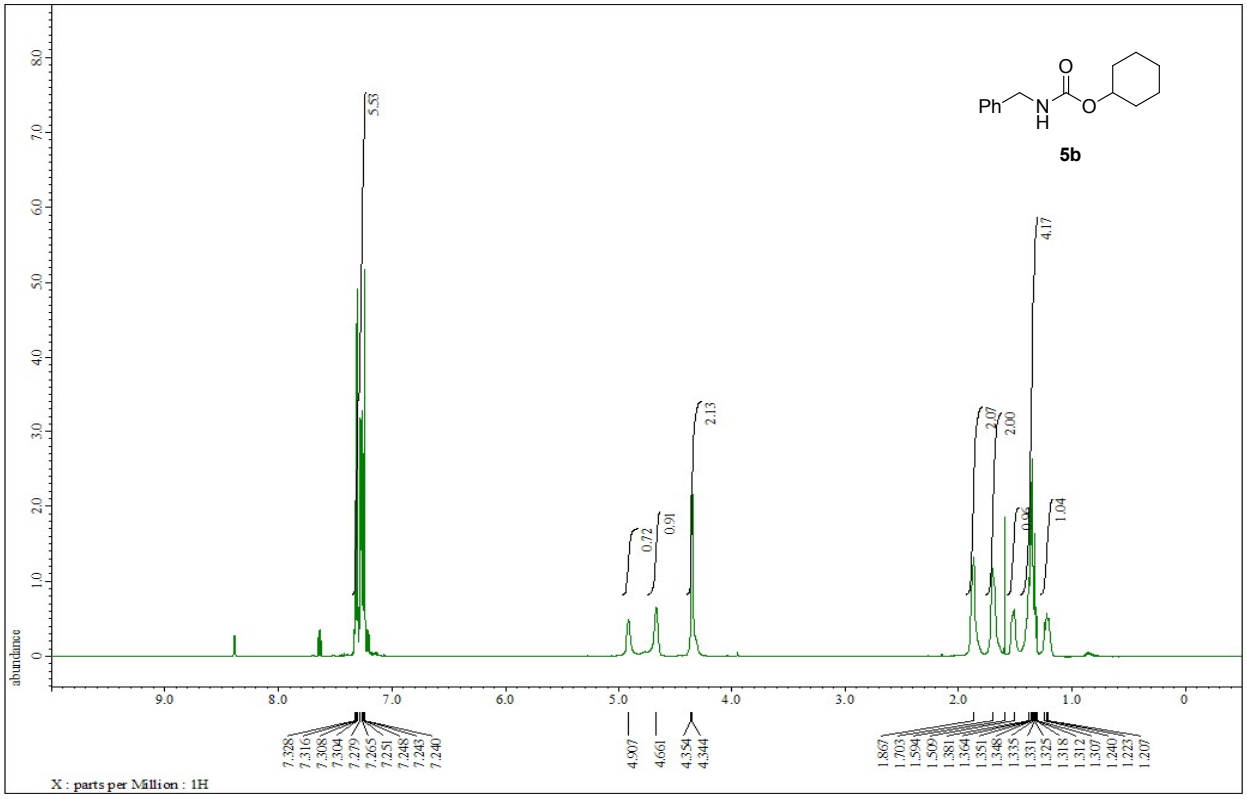

3i
abundance
X : parts per Million : 13C

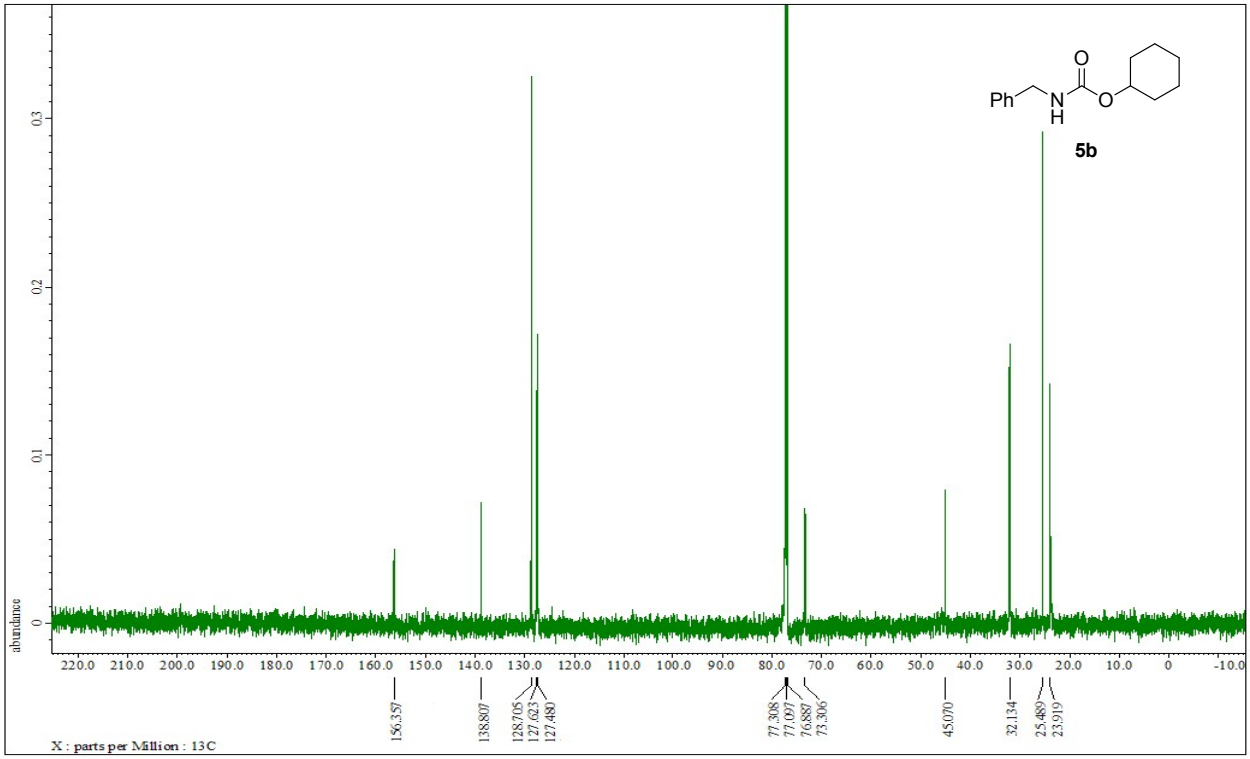

O Me Me
N H
N H
Me
3j
9.00
2.84
1.89
2.05
0.90
0.93
abundance
7.292
7.279
7.266
7.240
7.227
7.216
4.788
4.494
4.257
4.248
1.762
1.283
X : parts per Million : 1H

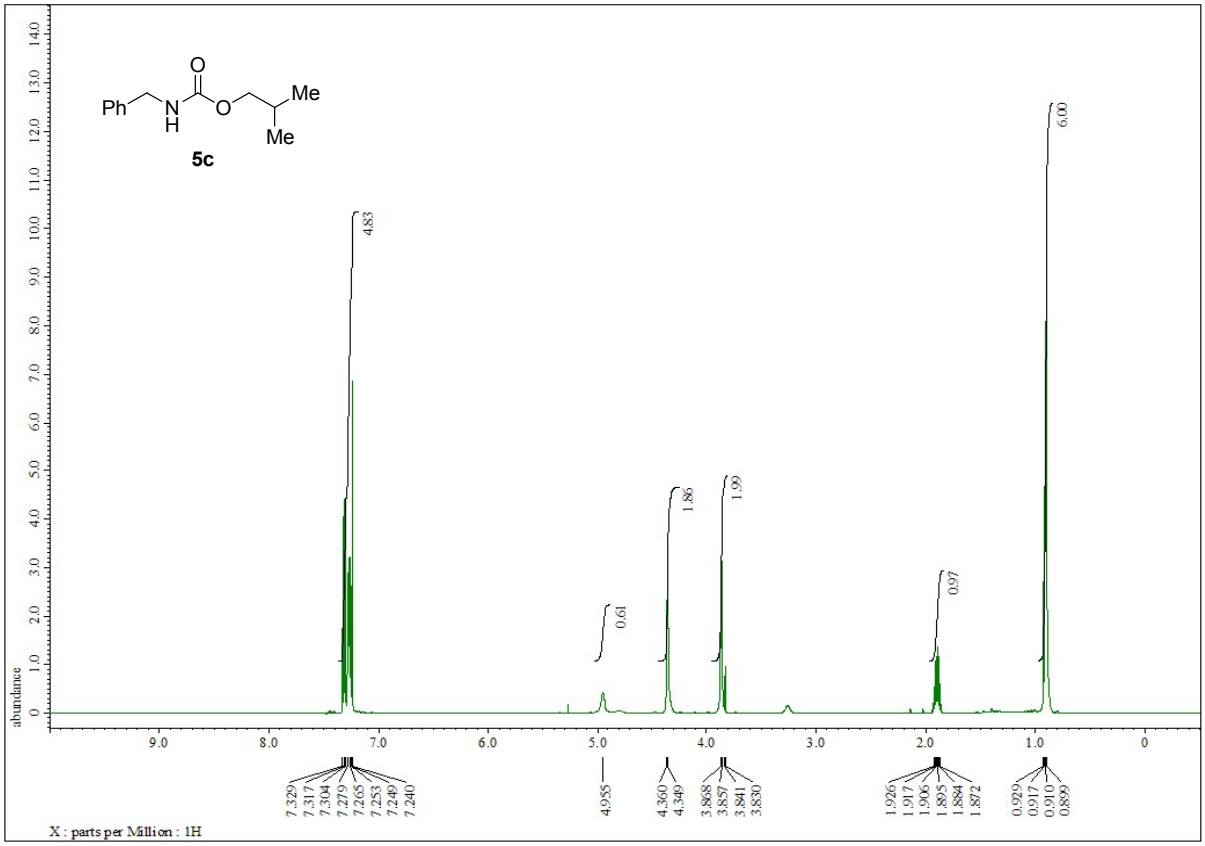

O Me Me
N H
N H
Me
3j
abundance
157.621
139.553
128.638
127.518
127.240
77.327
77.107
76.886
50.460
44.361
29.587
X : parts per Million : 13C

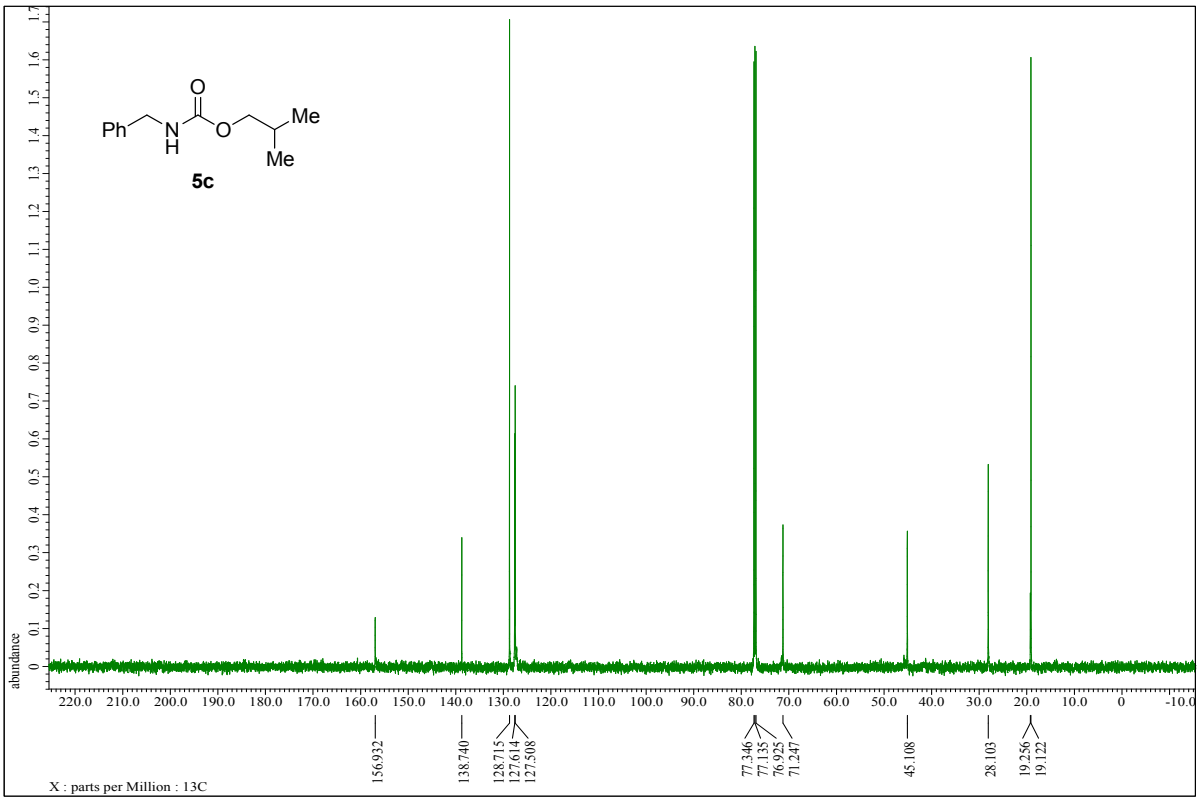

5.19
2.00
2.08
0.72
0.97
7.337
7.329
7.324
7.312
7.278
7.266
7.257
7.255
7.247
4.701
4.696
4.378
4.369
2.468
2.463
2.460
1.623
X : parts per Million : 1H
abundance
Ph
N
H
O
O
5a

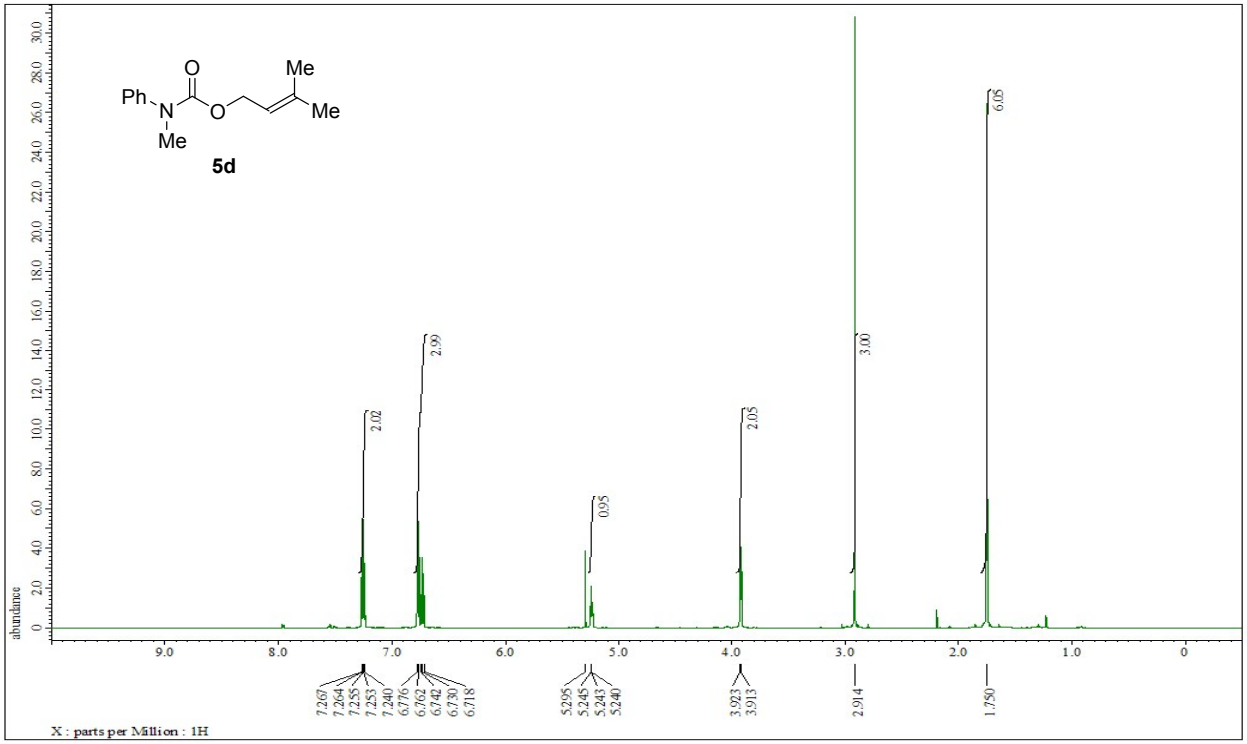

155.568
138.780
138.170
128.776
127.687
127.609
78.313
77.344
77.130
76.916
74.749
52.681
45.271
X : parts per Million : 13C
abundance
Ph
N
H
O
O
5a

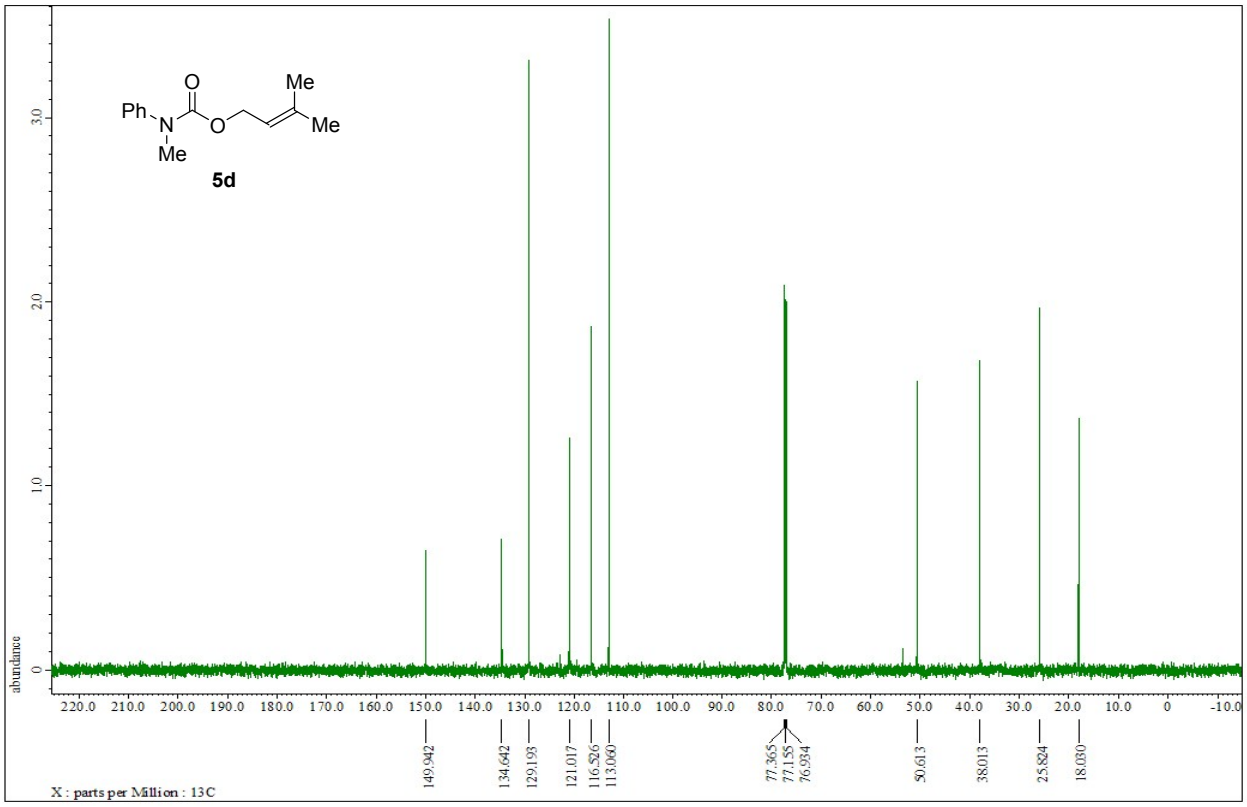

5b
5.53
0.72
0.91
2.13
4.17
2.07
2.00
0.96
1.04
abundance
X : parts per Million : 1H

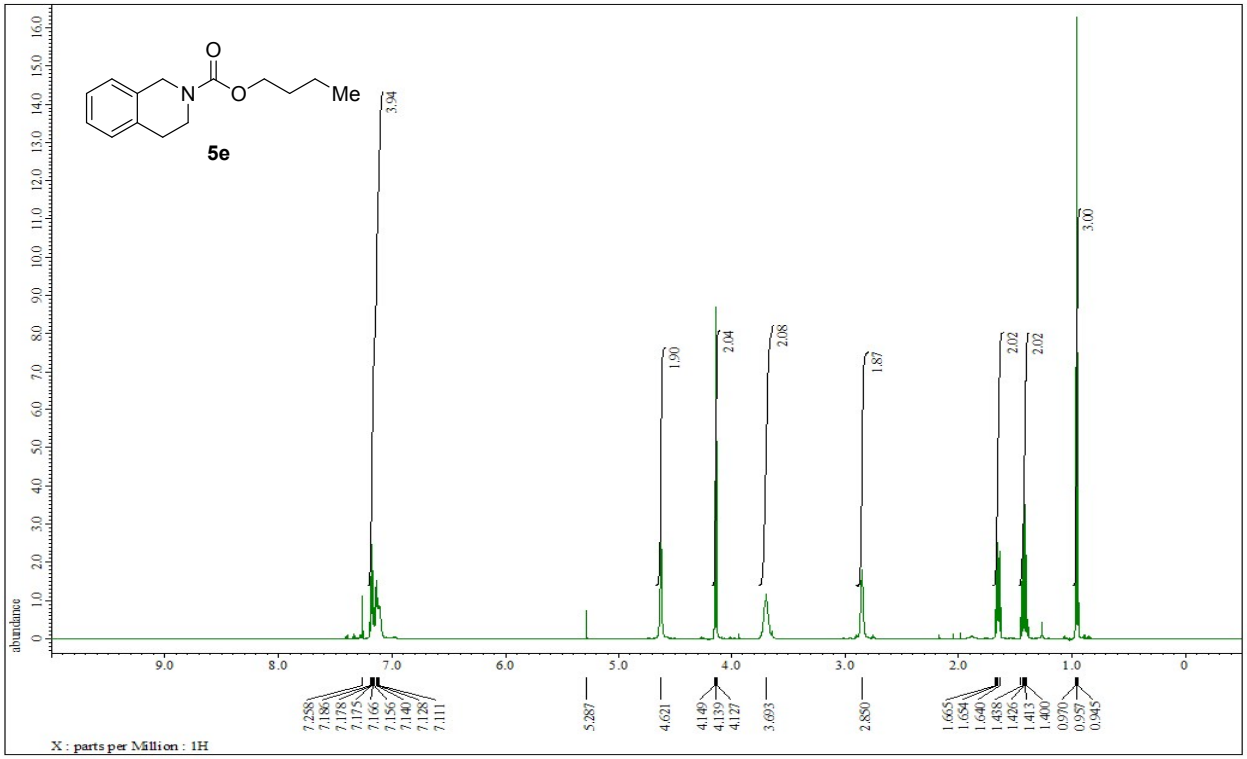

5b
abundance
X : parts per Million : 13C

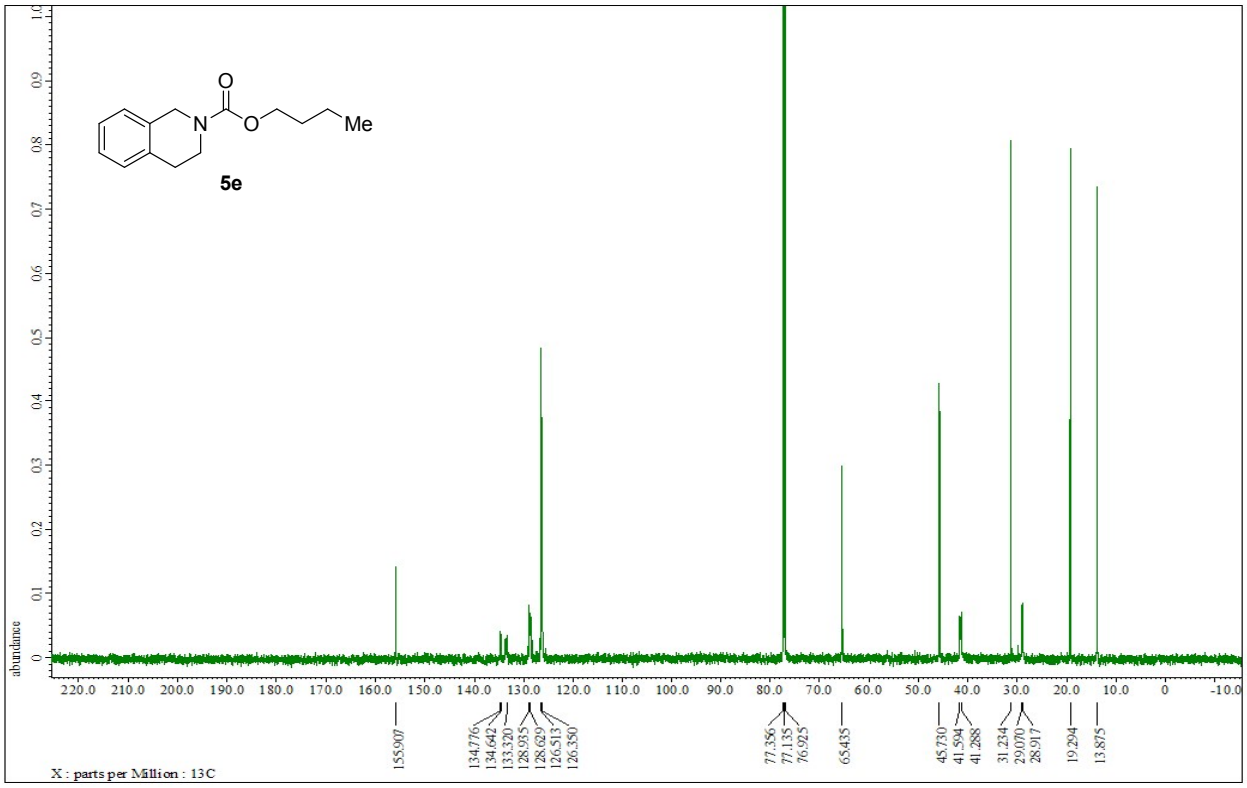

Ph
N
H
O
O
Me
Me
5c
4.83
0.61
1.86
1.99
0.97
6.00
abundance
X : parts per Million : 1H

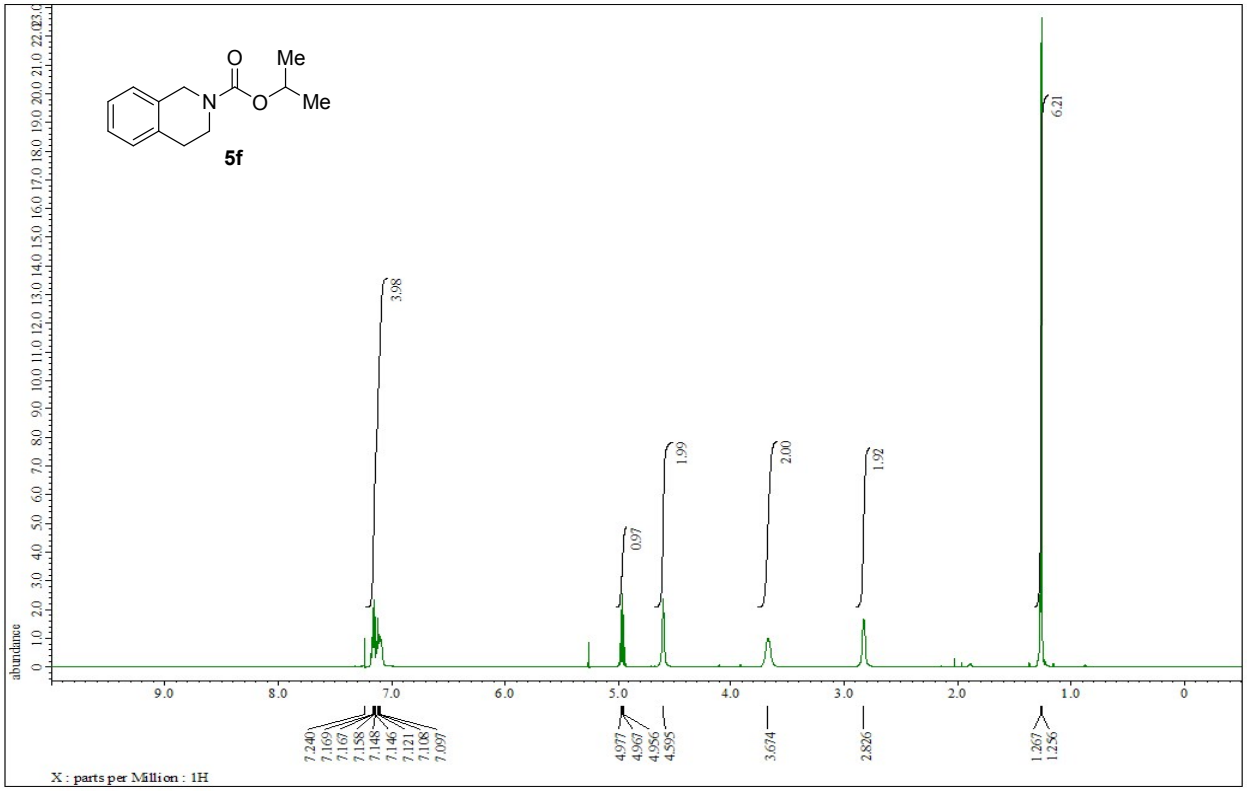

Ph
N
H
O
O
Me
Me
5c
abundance
X : parts per Million : 13C

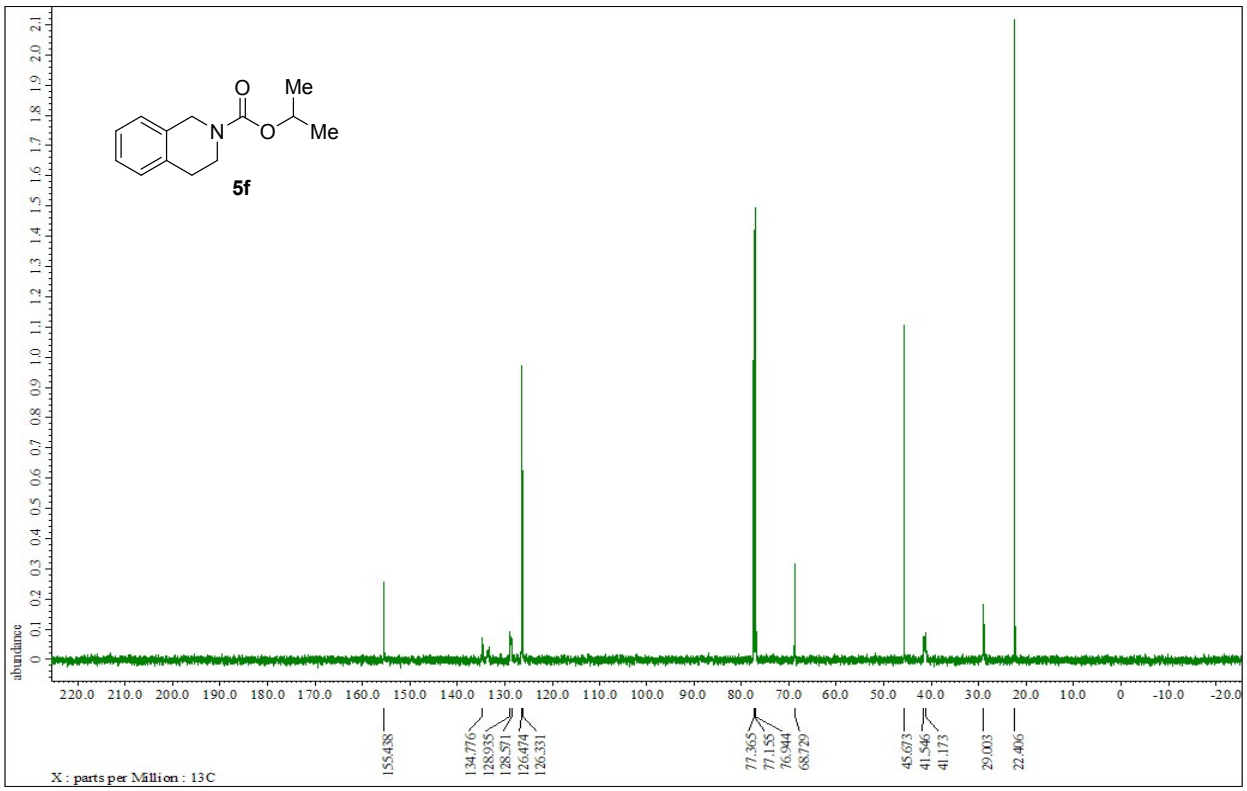

Ph
N
Me
O
O
Me
Me
5d
abundance
2.02
2.99
0.95
2.05
3.00
6.05
7.267
7.264
7.255
7.253
7.240
6.776
6.762
6.742
6.730
6.718
5.295
5.245
5.243
5.240
3.923
3.913
2.914
1.750
X : parts per Million : 1H

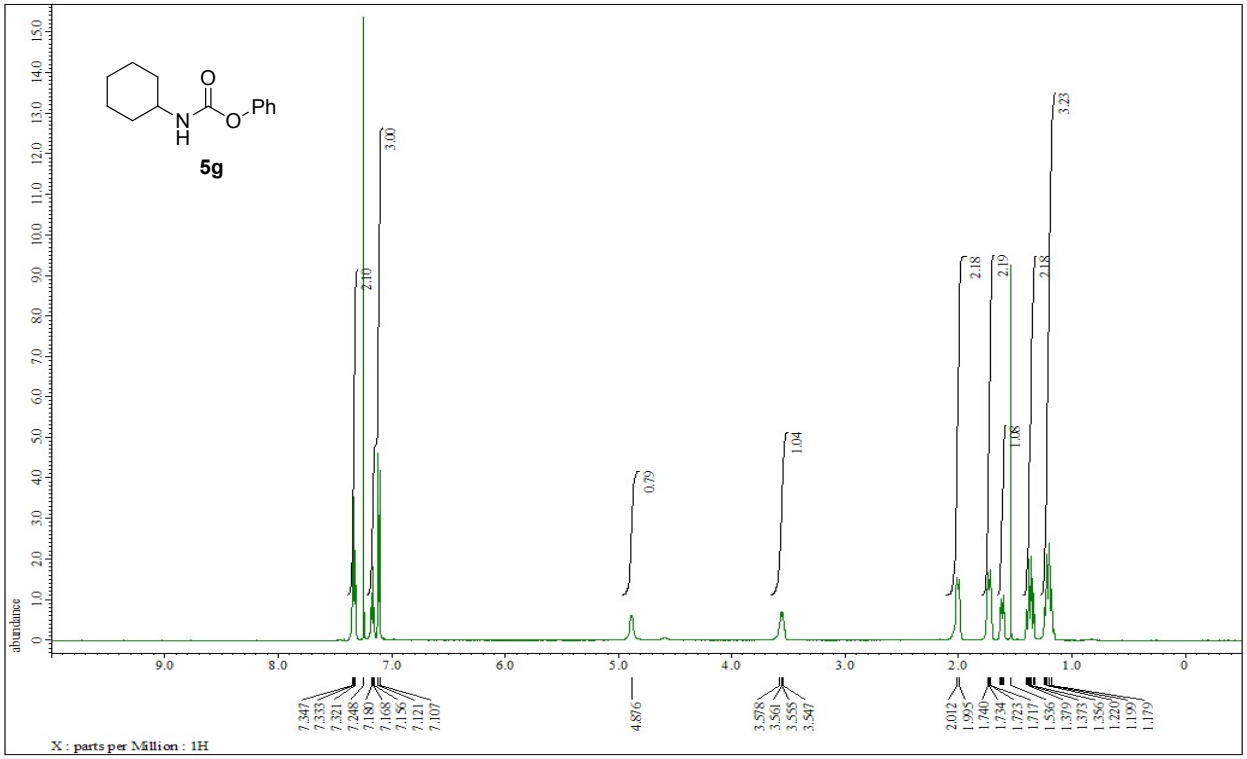

Ph
N
Me
O
O
Me
Me
5d
abundance
149.942
134.642
129.193
121.017
116.526
113.060
77.365
77.155
76.934
50.613
38.013
25.824
18.030
X : parts per Million : 13C

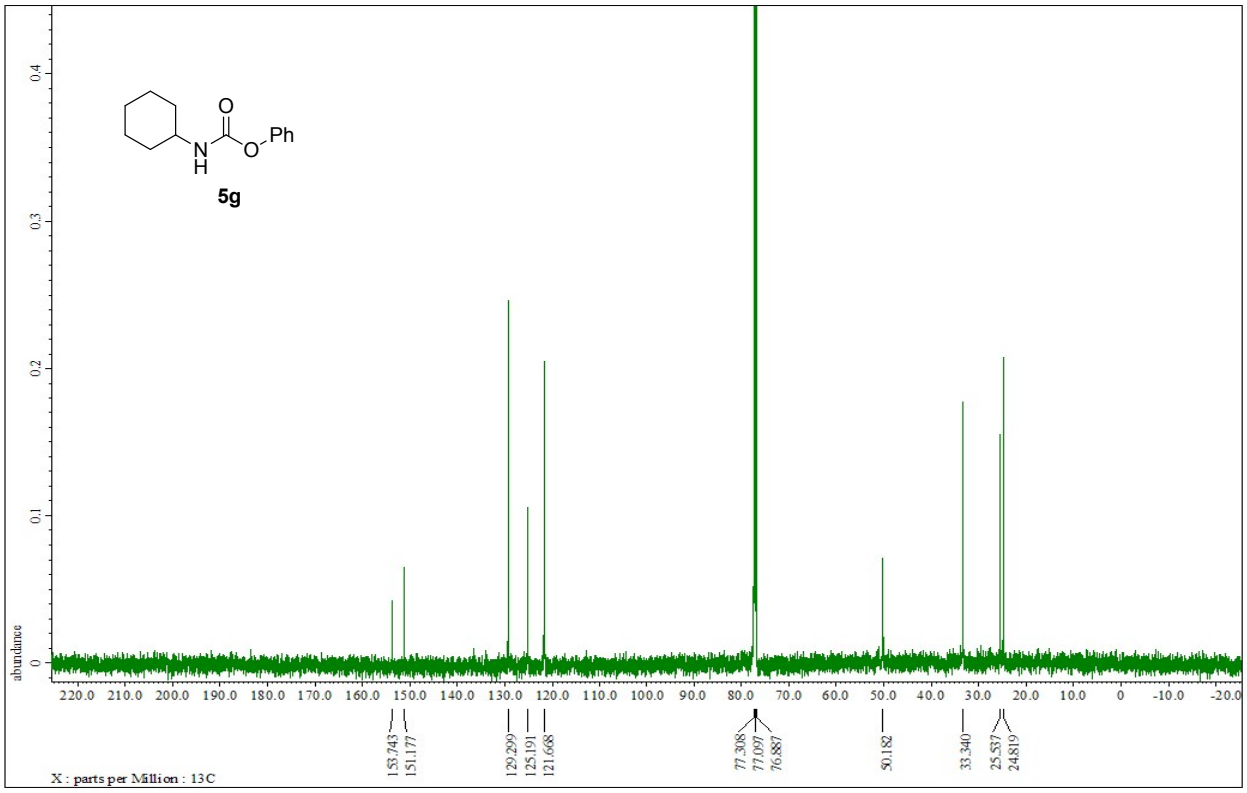

O
N
O
Me
5e
3.94
1.90
2.04
2.08
1.87
2.02
2.02
3.00
abundance
X : parts per Million : 1H

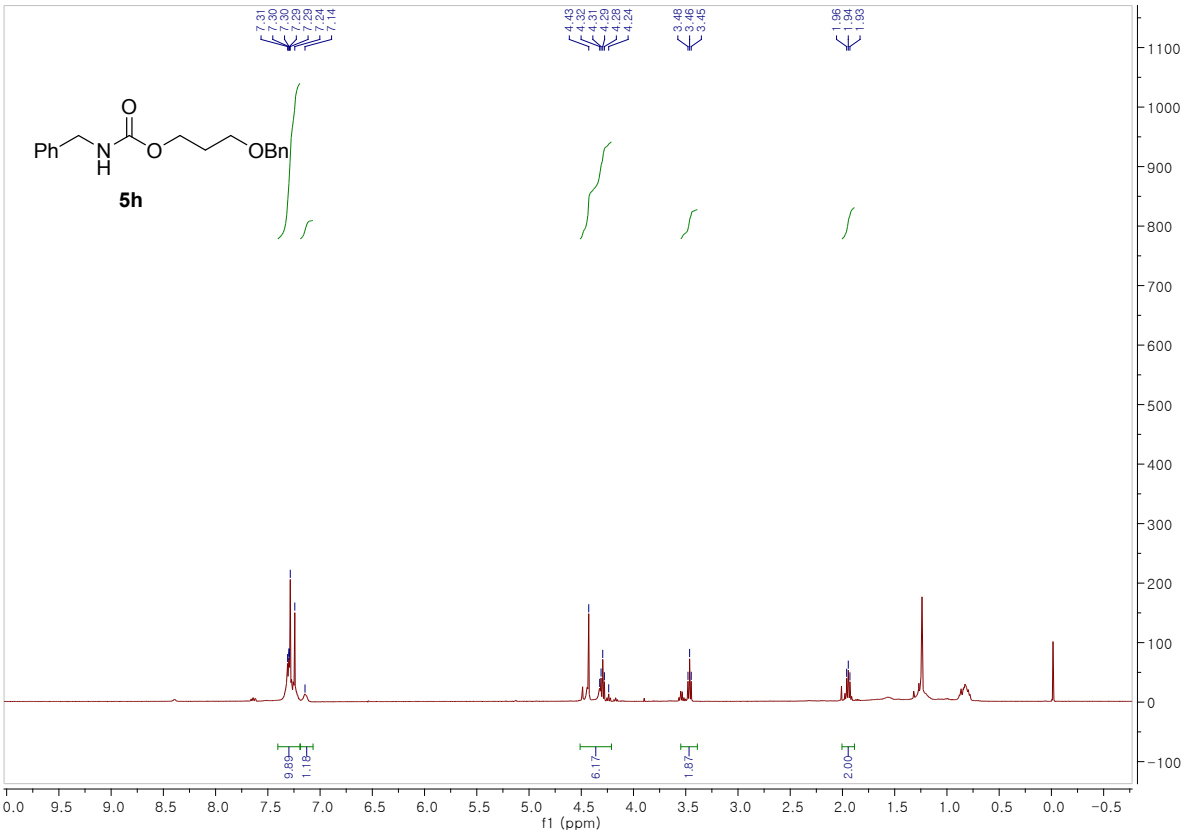

O
N
O
Me
5e
abundance
X : parts per Million : 13C

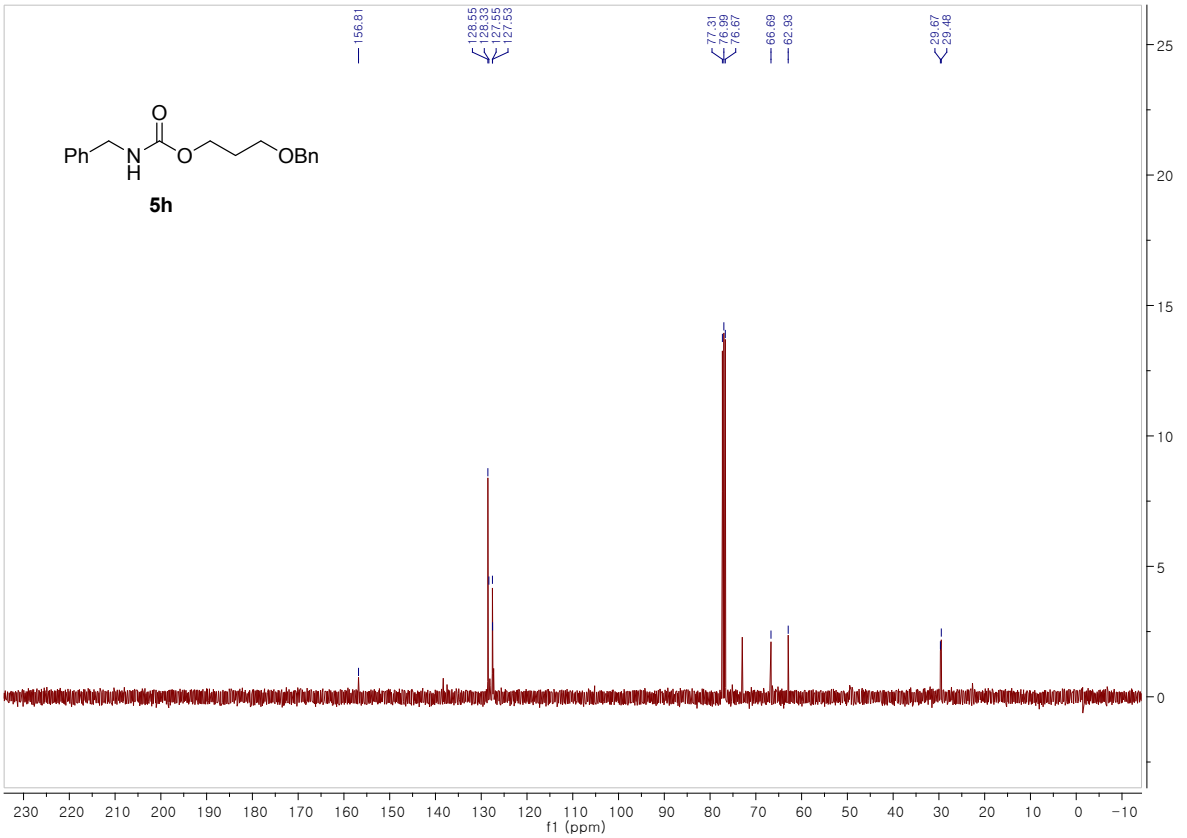

O
Me
N
O
Me
5f
3.98
0.97
1.99
2.00
1.92
6.21
abundance
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
7.240
7.169
7.167
7.158
7.148
7.146
7.121
7.108
7.097
4.977
4.967
4.956
4.595
3.674
2.826
1.267
1.256
X : parts per Million : 1H

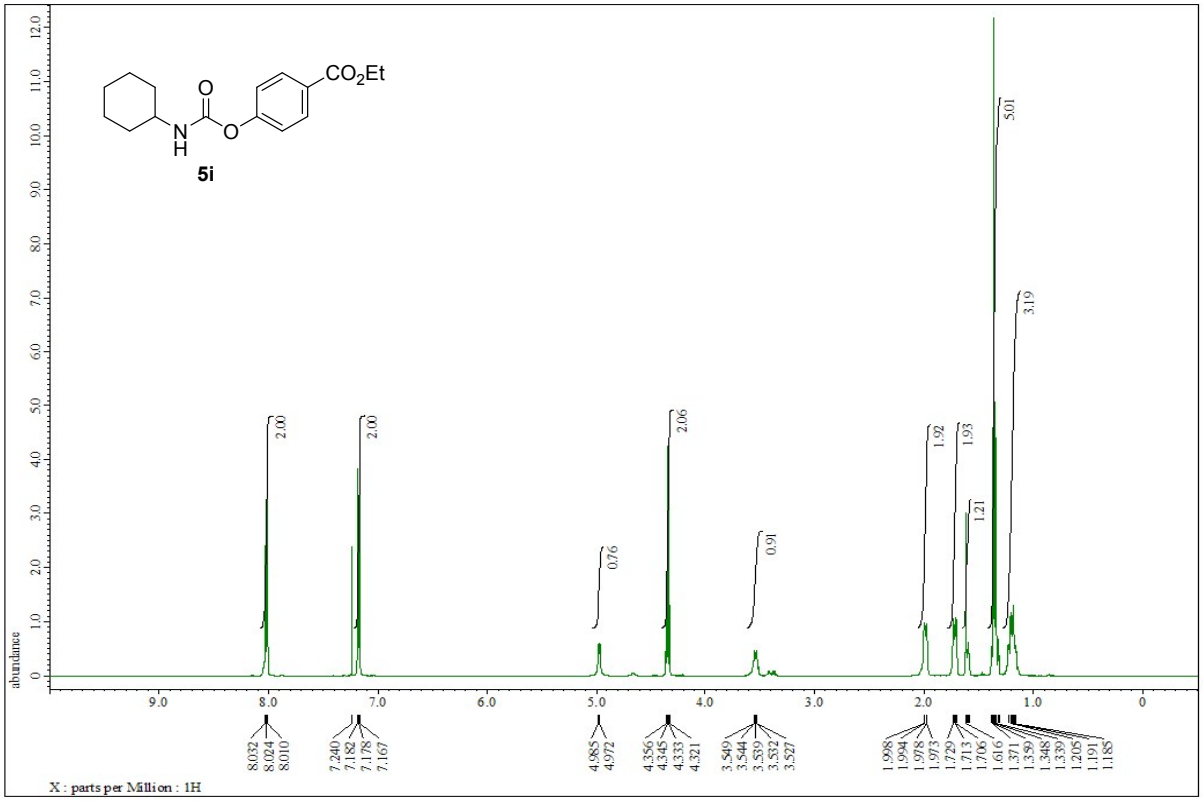

O
Me
N
O
Me
5f
abundance
220.0
210.0
200.0
190.0
180.0
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
-10.0
-20.0
155.438
134.776
128.935
128.571
126.474
126.331
77.365
77.155
76.944
68.729
45.673
41.546
41.173
29.003
22.406
X : parts per Million : 13C

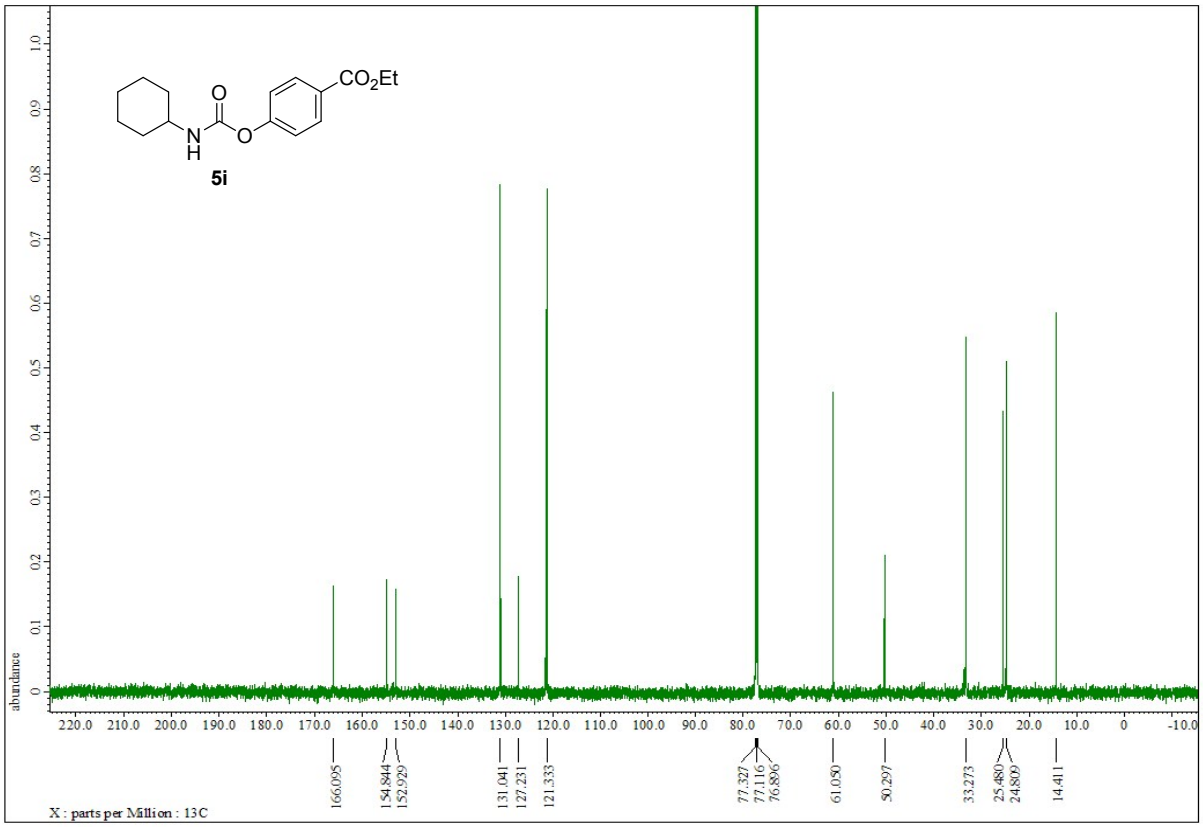

5g
abundance
X : parts per Million : 1H

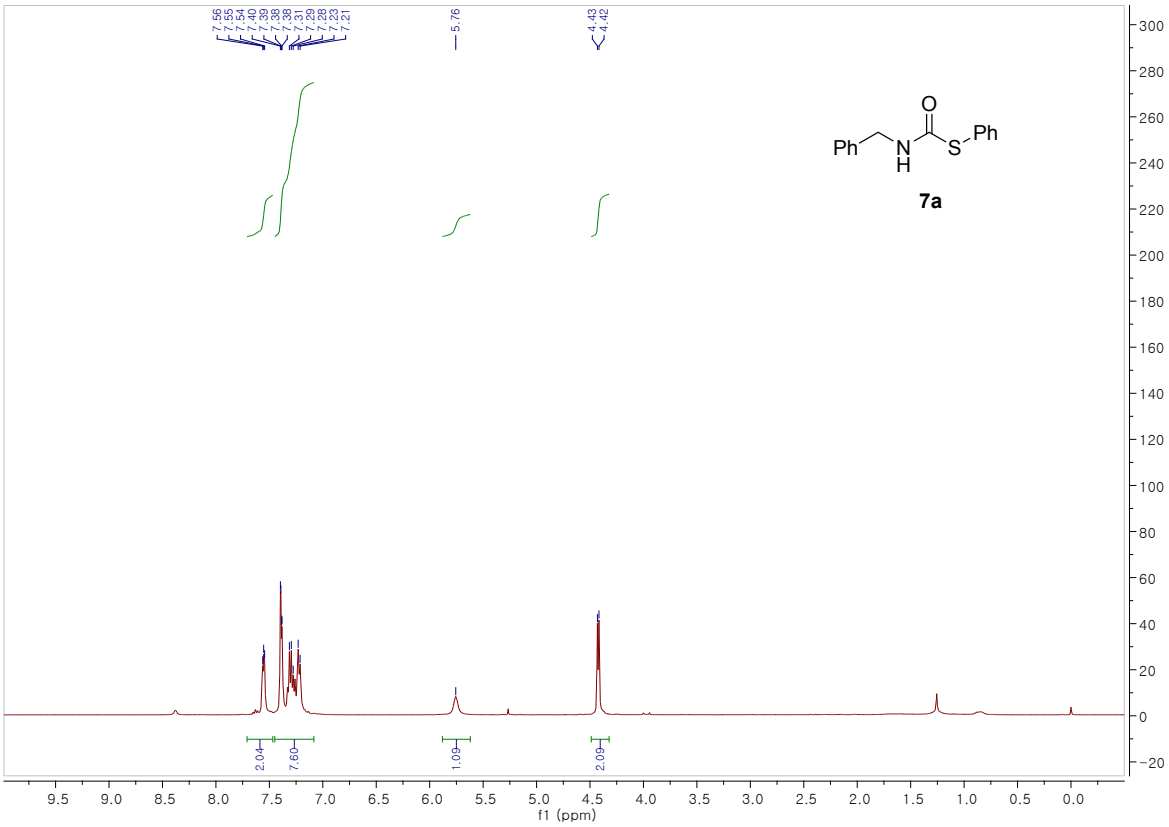

5g
abundance
X : parts per Million : 13C

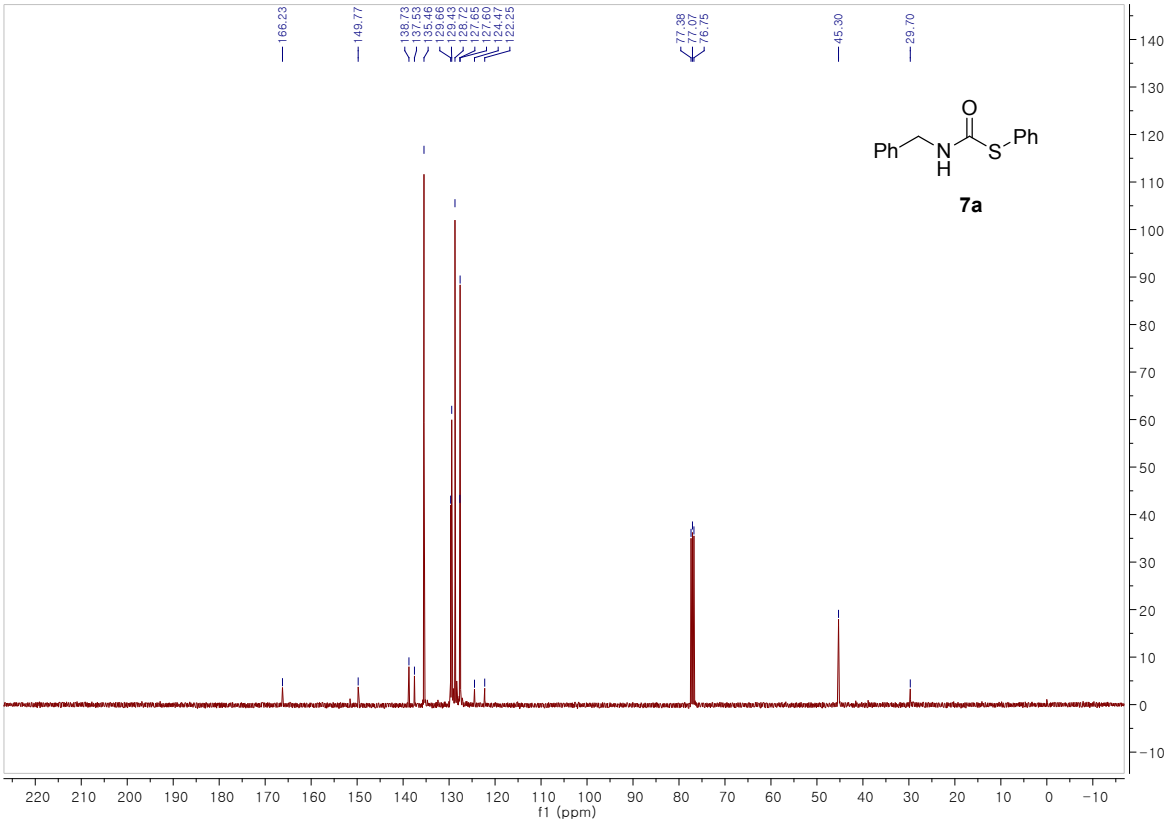

7.31
7.30
7.30
7.29
7.29
7.24
7.14
4.43
4.32
4.31
4.29
4.28
4.24
3.48
3.46
3.45
1.96
1.94
1.93
Ph
N
H
O
O
OBn
5h
9.89
1.18
6.17
1.87
2.00
f1 (ppm)


156.81
128.55
128.33
127.55
127.53
77.31
76.99
76.67
66.69
62.93
29.67
29.48
Ph
N
H
O
O
OBn
5h
f1 (ppm)

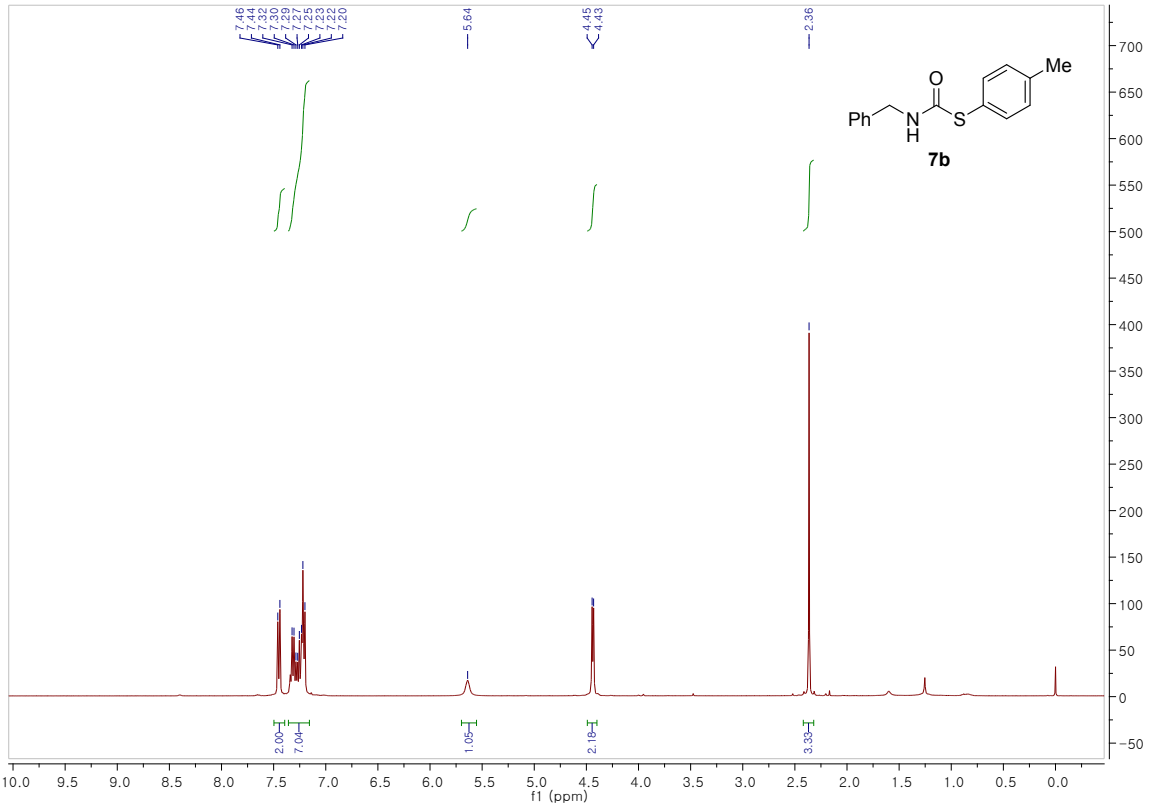

CO2Et
O
N
H
O
5i
abundance
X : parts per Million : 1H
2.00
2.00
0.76
2.06
0.91
1.92
1.93
1.21
5.01
3.19
8.032
8.024
8.010
7.240
7.182
7.178
7.167
4.985
4.972
4.356
4.345
4.333
4.321
3.549
3.544
3.539
3.532
3.527
1.998
1.994
1.978
1.973
1.729
1.713
1.706
1.616
1.371
1.359
1.348
1.339
1.205
1.191
1.185

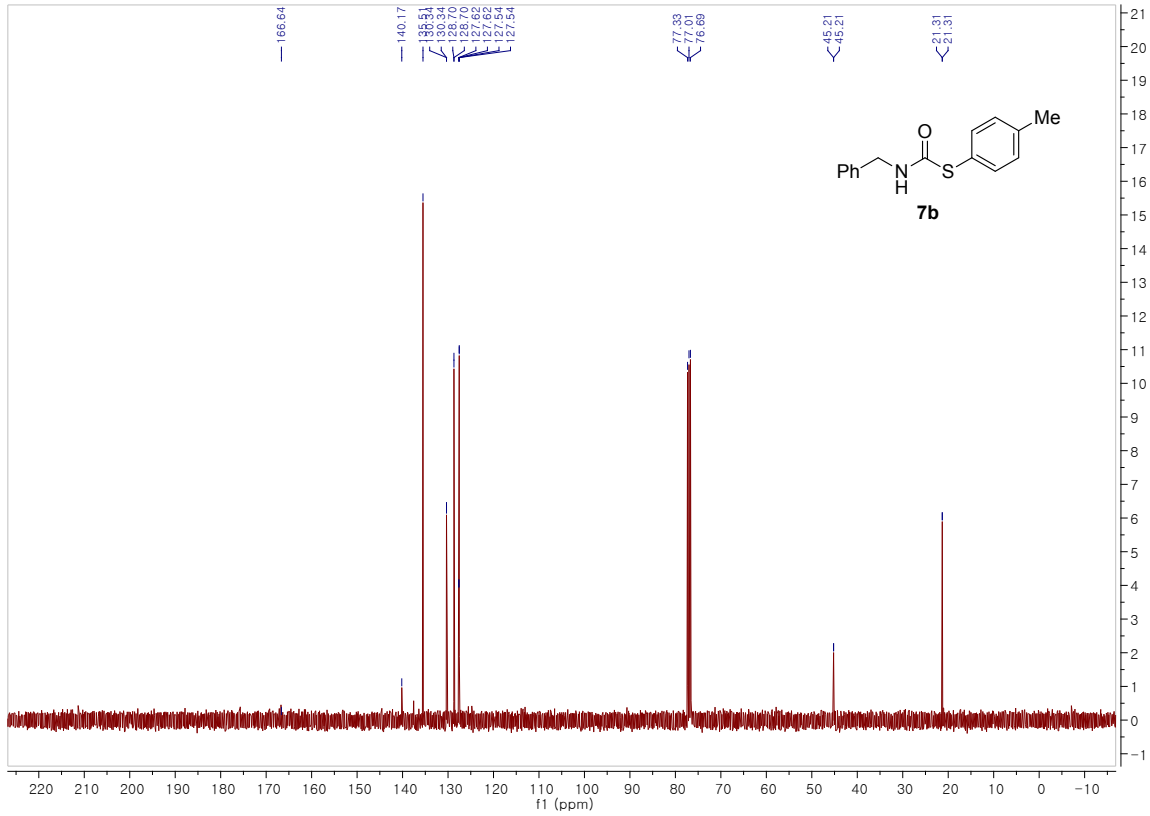

CO2Et
O
N
H
O
5i
abundance
X : parts per Million : 13C
166.095
154.844
152.929
131.041
127.231
121.333
77.327
77.116
76.896
61.050
50.297
33.273
25.480
24.809
14.411

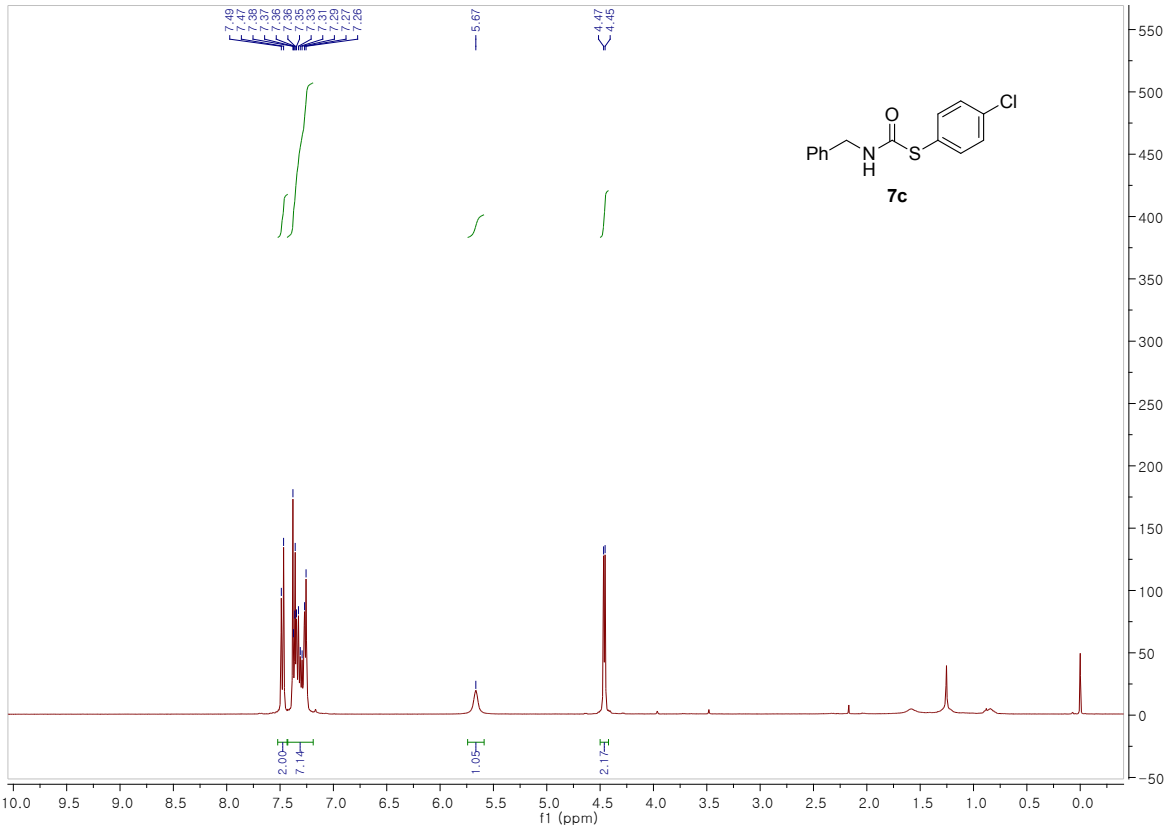

7.56
7.55
7.54
7.40
7.39
7.38
7.31
7.29
7.28
7.23
7.21
5.76
4.43
4.42
2.04
7.60
1.09
2.09
f1 (ppm)

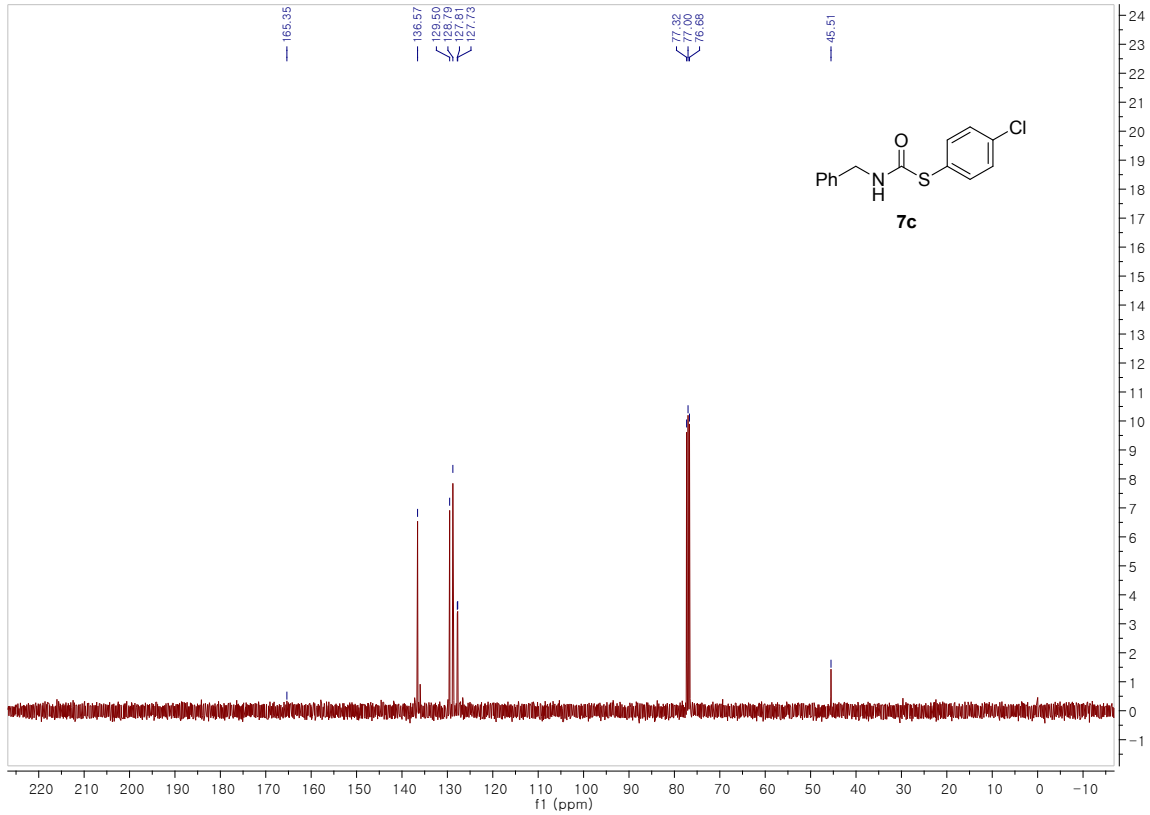

166.23
149.77
138.73
137.43
135.46
129.66
129.43
128.72
127.65
127.60
124.47
122.25
77.38
77.07
76.75
45.30
29.70
f1 (ppm)

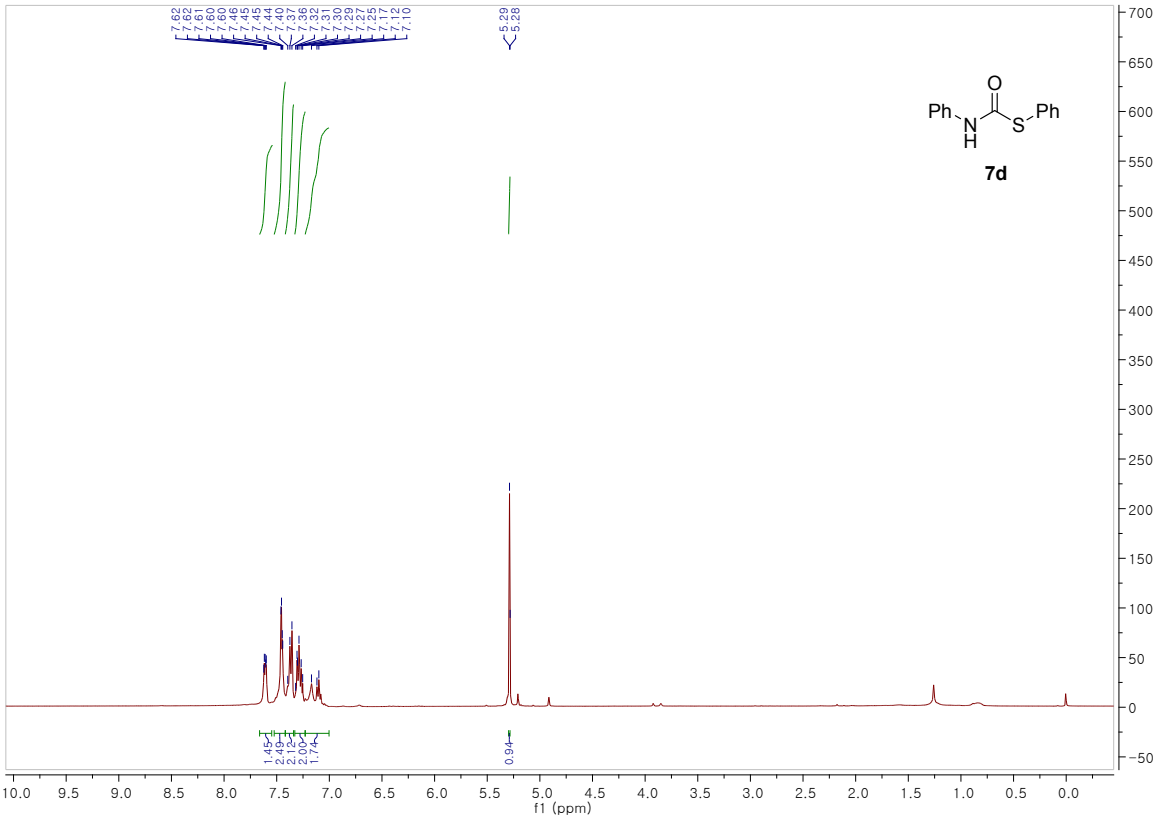
7a

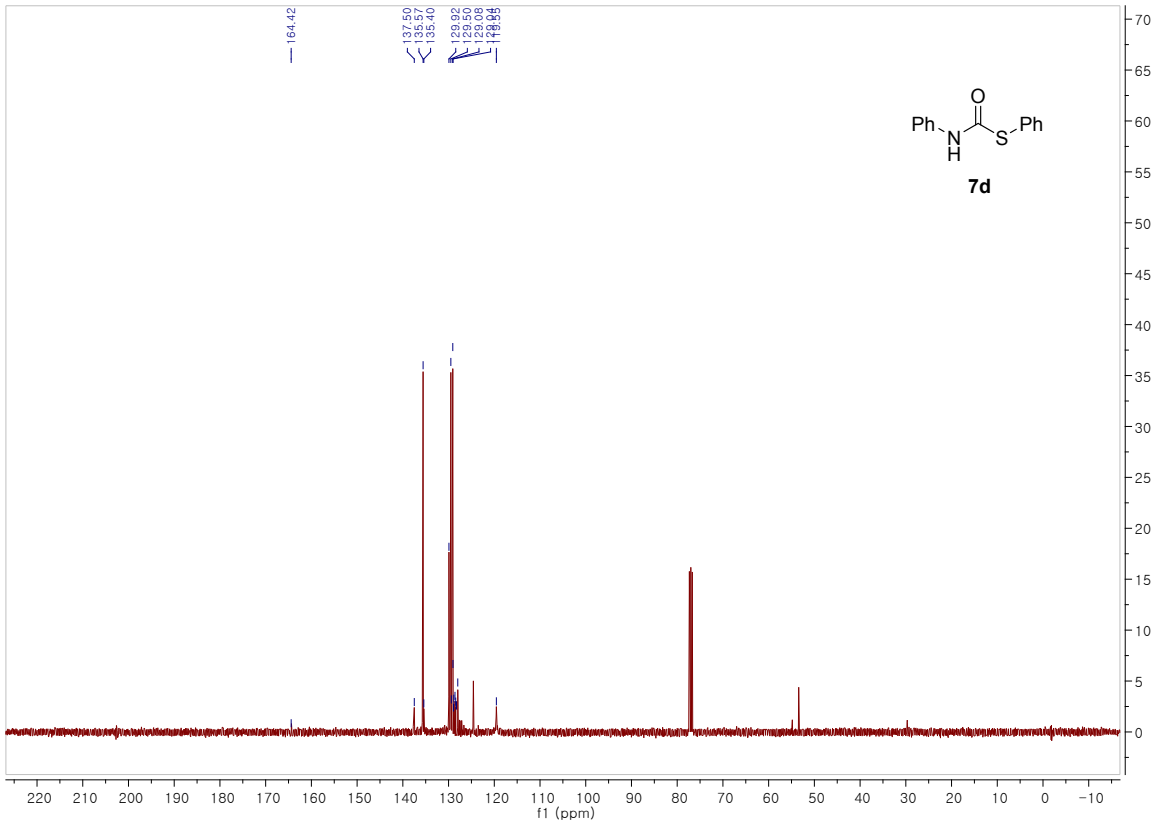

7.46
7.44
7.32
7.30
7.29
7.27
7.25
7.23
7.22
7.20
5.64
4.45
4.43
2.36
Ph
N
H
O
S
Me
7b
2.00
7.04
1.05
2.18
3.33
f1 (ppm)

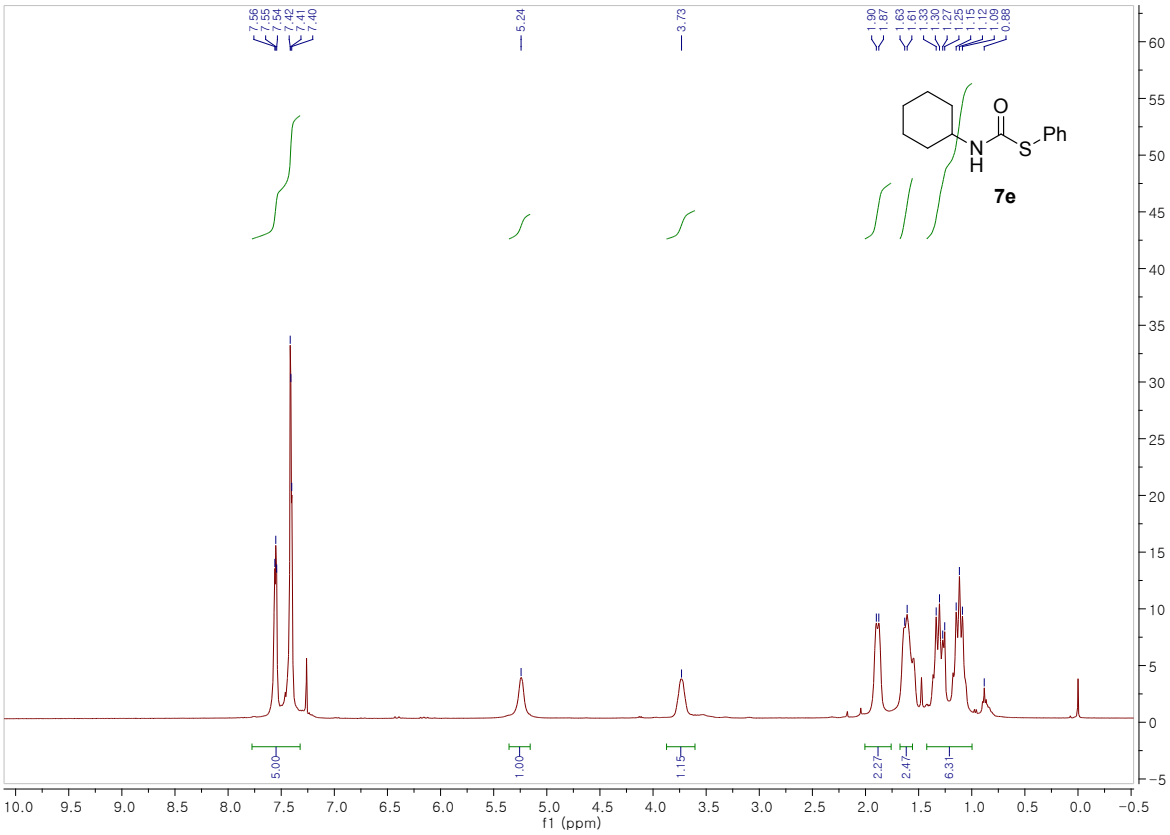

166.64
140.17
135.51
133.34
130.34
128.70
128.70
127.62
127.62
127.54
127.54
77.33
77.01
76.69
45.21
45.21
21.31
21.31
Ph
N
H
O
S
Me
7b
f1 (ppm)

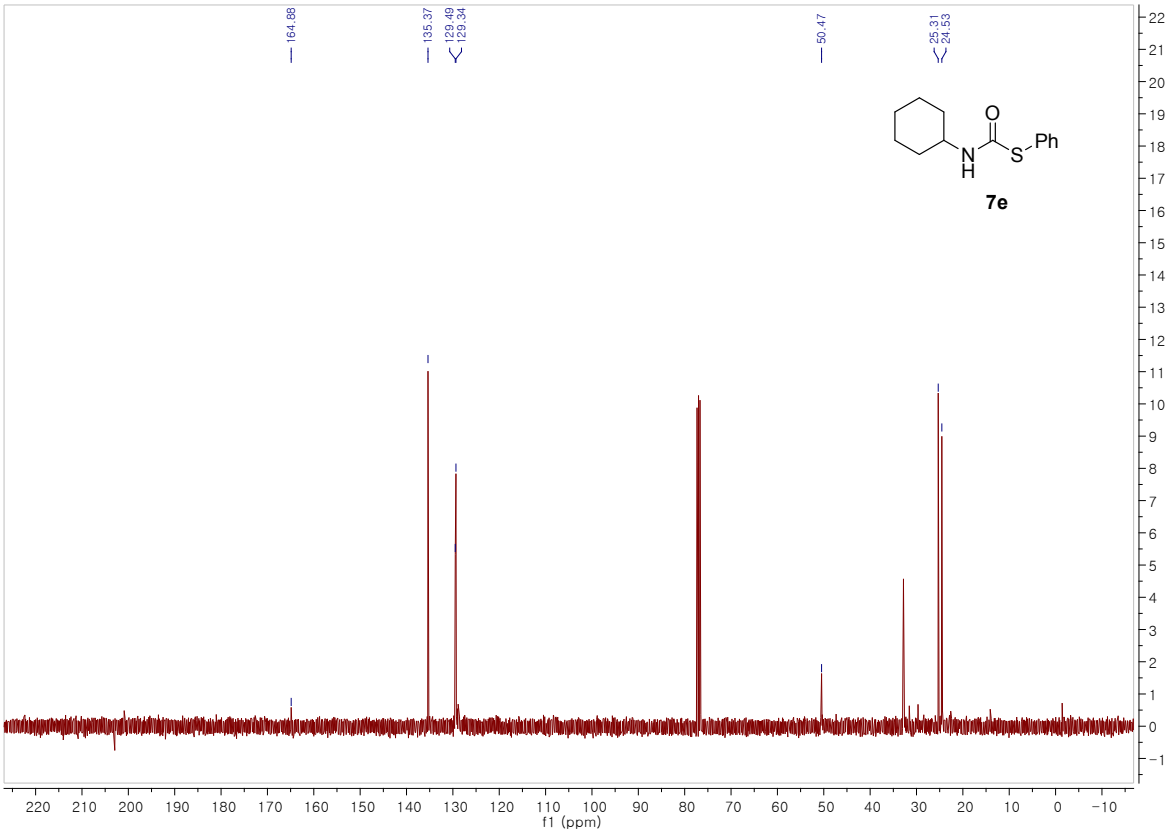

7.49
7.47
7.38
7.37
7.36
7.35
7.33
7.31
7.29
7.27
7.26
5.67
4.47
4.45
2.00
7.14
1.05
2.17
f1 (ppm)
Ph
N
H
O
S
Cl
7c

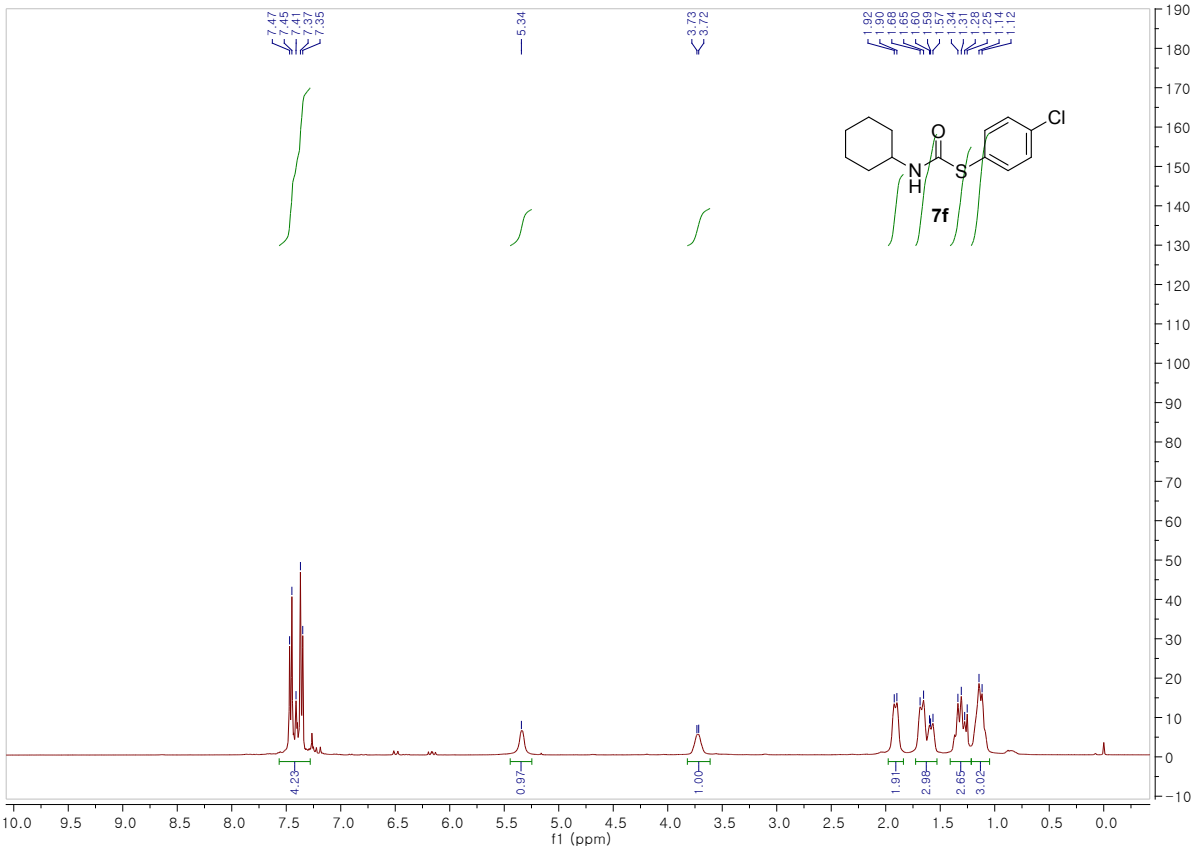

165.35
136.57
129.50
129.29
127.81
127.73
77.32
77.00
76.68
45.51
f1 (ppm)
Ph
N
H
O
S
Cl
7c

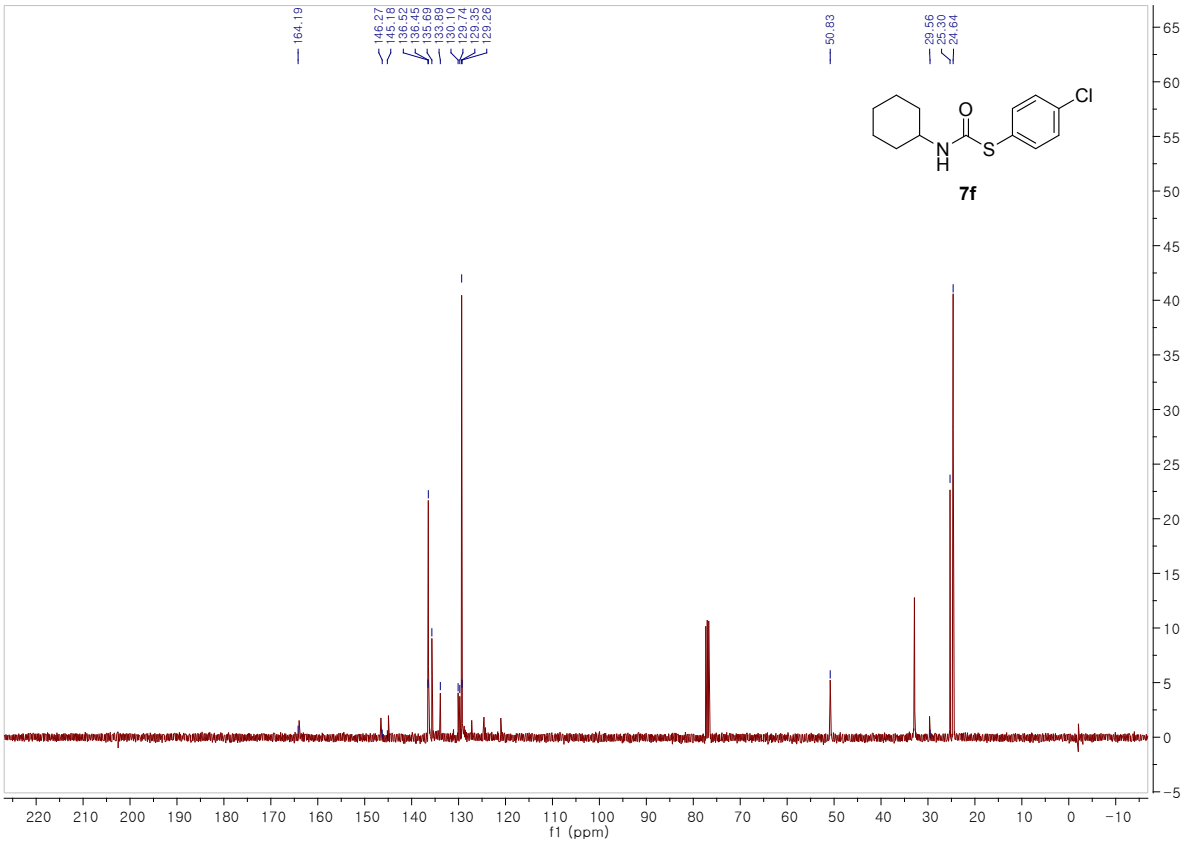

7.62
7.62
7.61
7.60
7.60
7.46
7.45
7.44
7.40
7.37
7.36
7.32
7.31
7.30
7.29
7.27
7.25
7.17
7.12
7.10
5.29
5.28
1.49
2.48
2.19
2.00
1.74
0.94
Ph
N
H
O
S
Ph
7d
f1 (ppm)

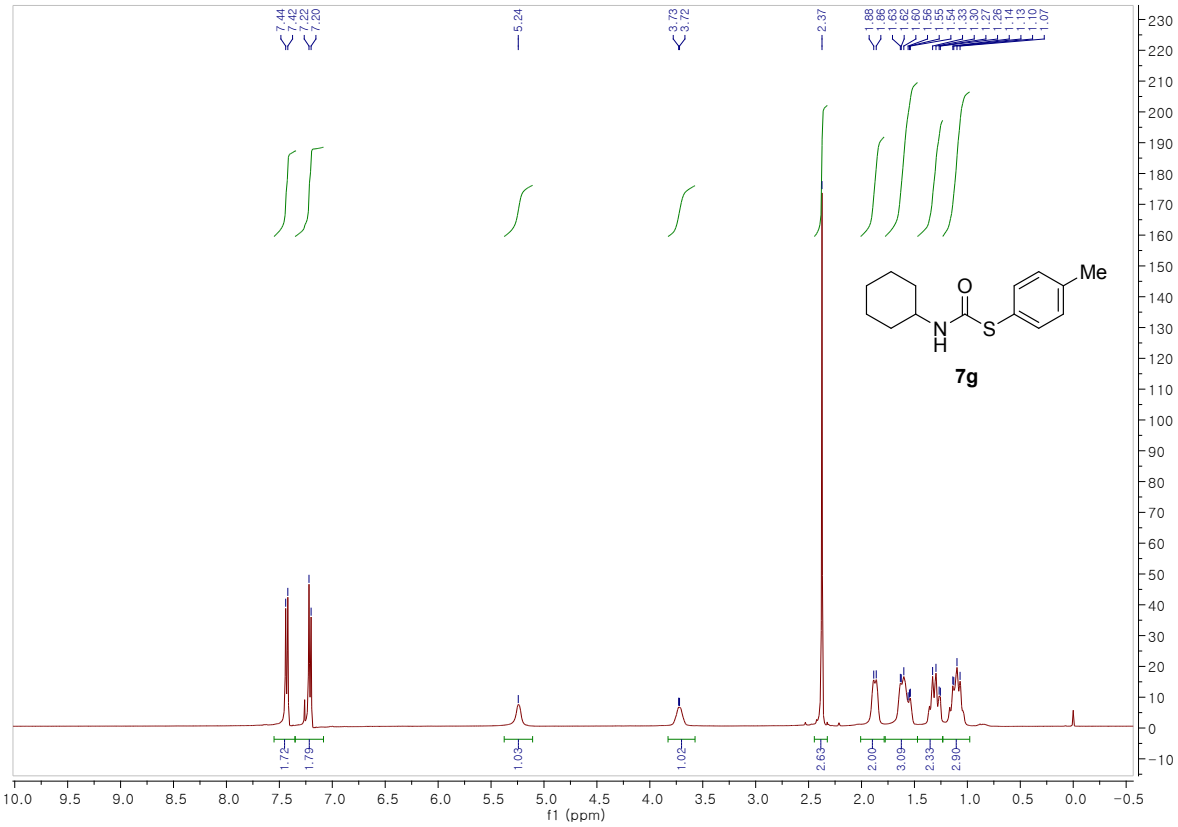

164.42
137.50
135.57
135.40
129.92
129.50
129.08
Ph
N
H
O
S
Ph
7d
f1 (ppm)

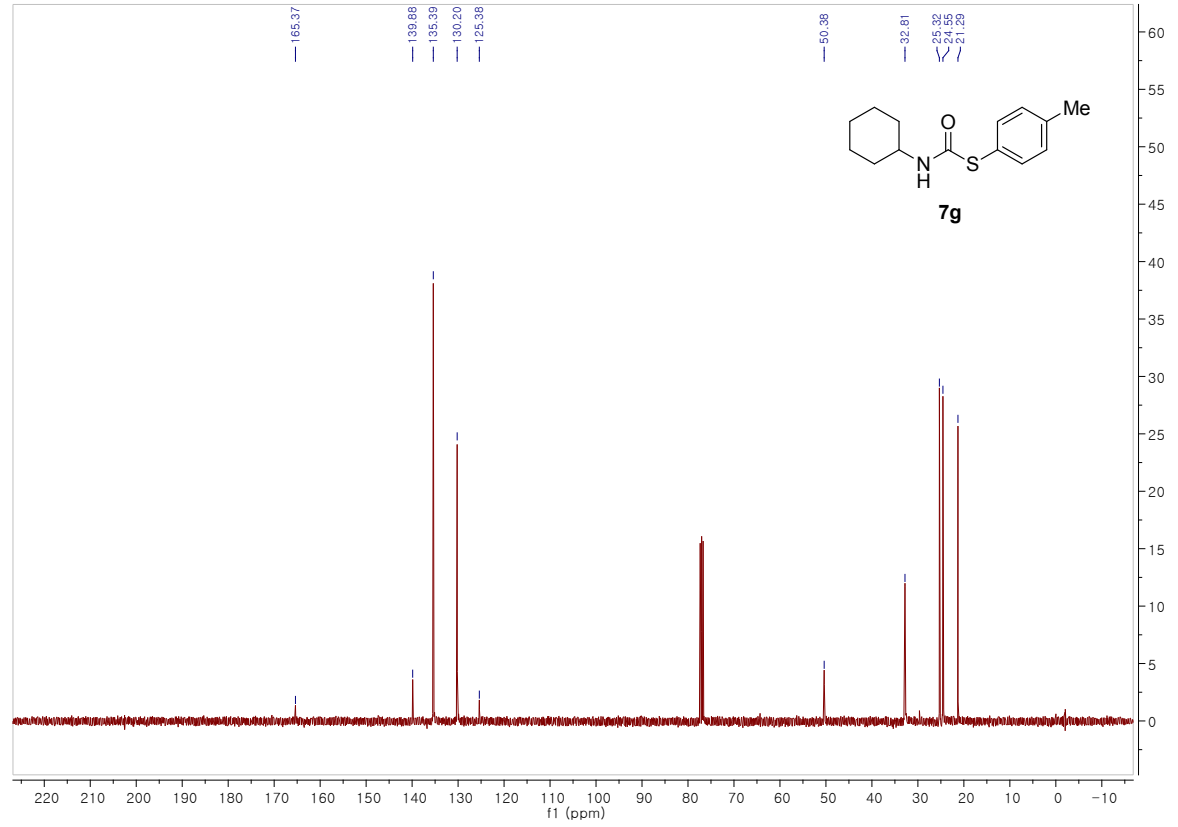

7.56
7.55
7.54
7.42
7.41
7.40
5.24
3.73
1.90
1.87
1.63
1.61
1.33
1.30
1.27
1.25
1.15
1.12
1.09
0.88
O
N
H
S
Ph
7e
5.00
1.00
1.15
2.27
2.47
6.31
f1 (ppm)

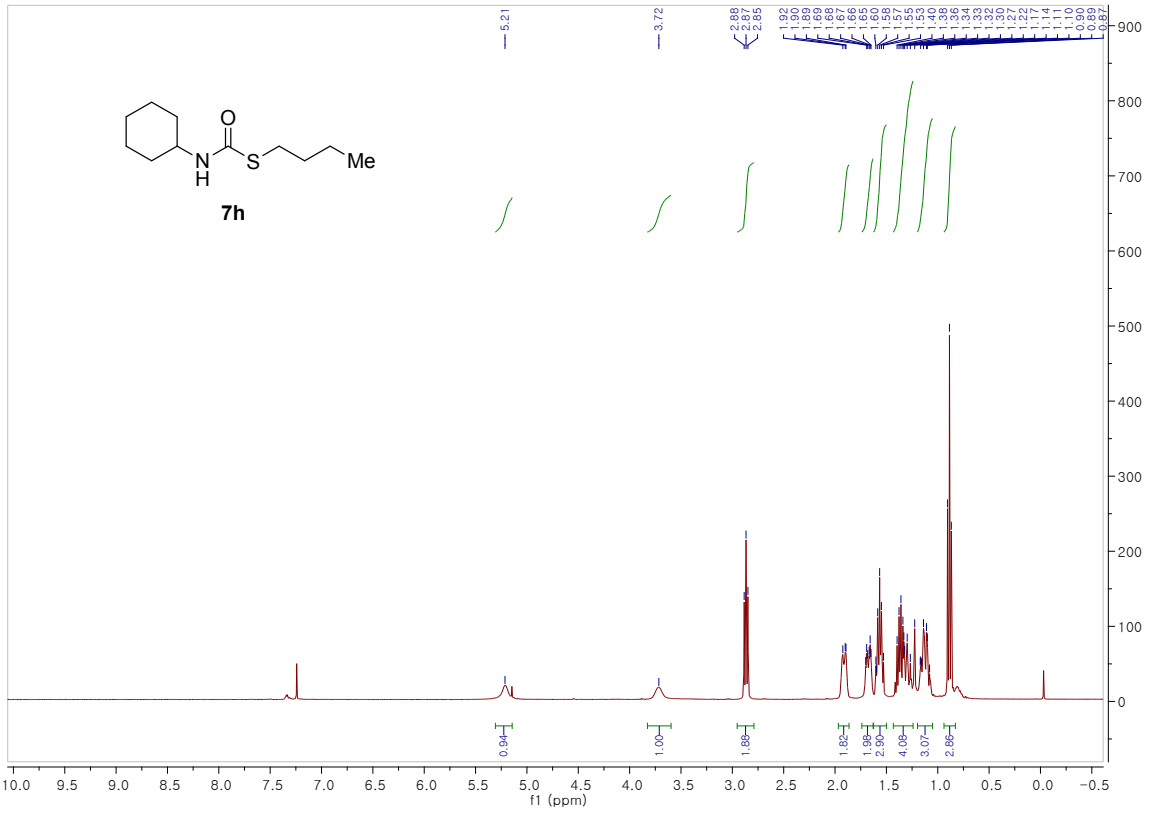

164.88
135.37
129.49
129.34
50.47
25.31
24.53
O
N
H
S
Ph
7e
f1 (ppm)

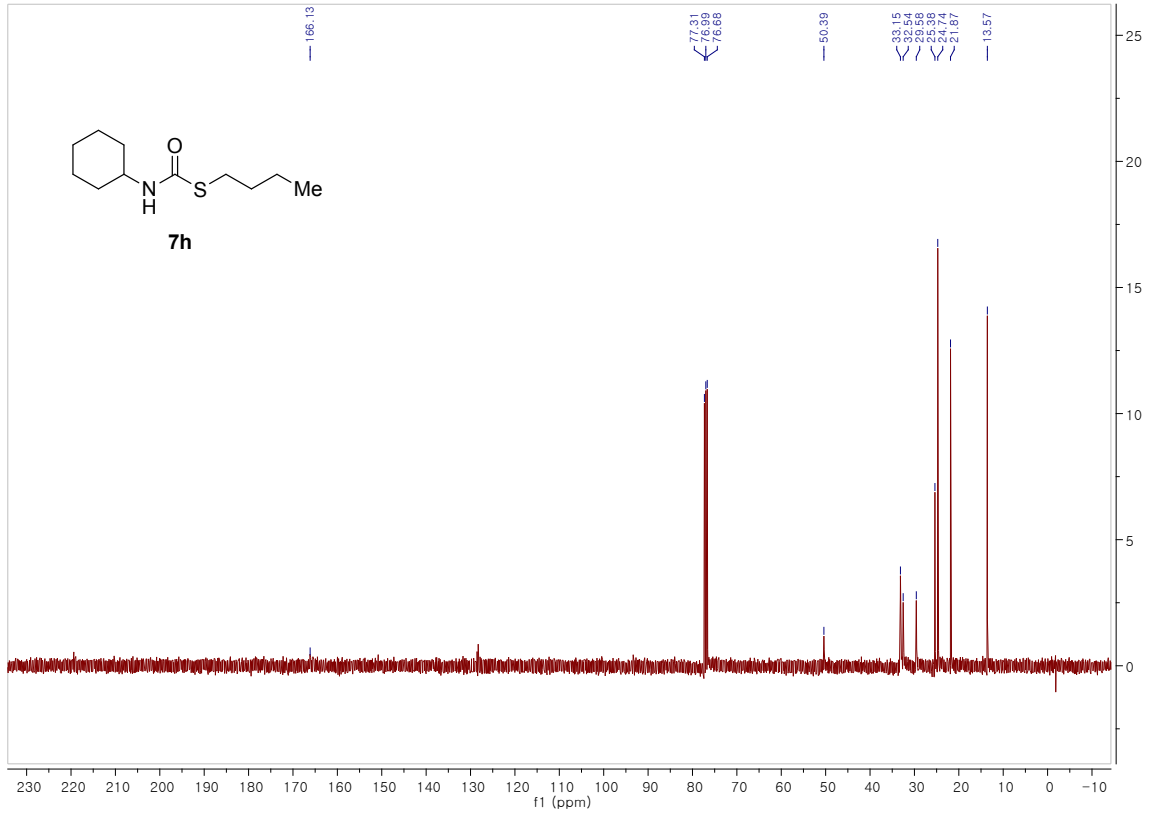

7.47
7.45
7.41
7.37
7.35
5.34
3.73
3.72
1.92
1.90
1.88
1.65
1.60
1.59
1.57
1.34
1.31
1.28
1.25
1.14
1.12
Cl
O
N
H
S
7f
4.23
0.97
1.00
1.91
2.98
2.65
3.02
f1 (ppm)

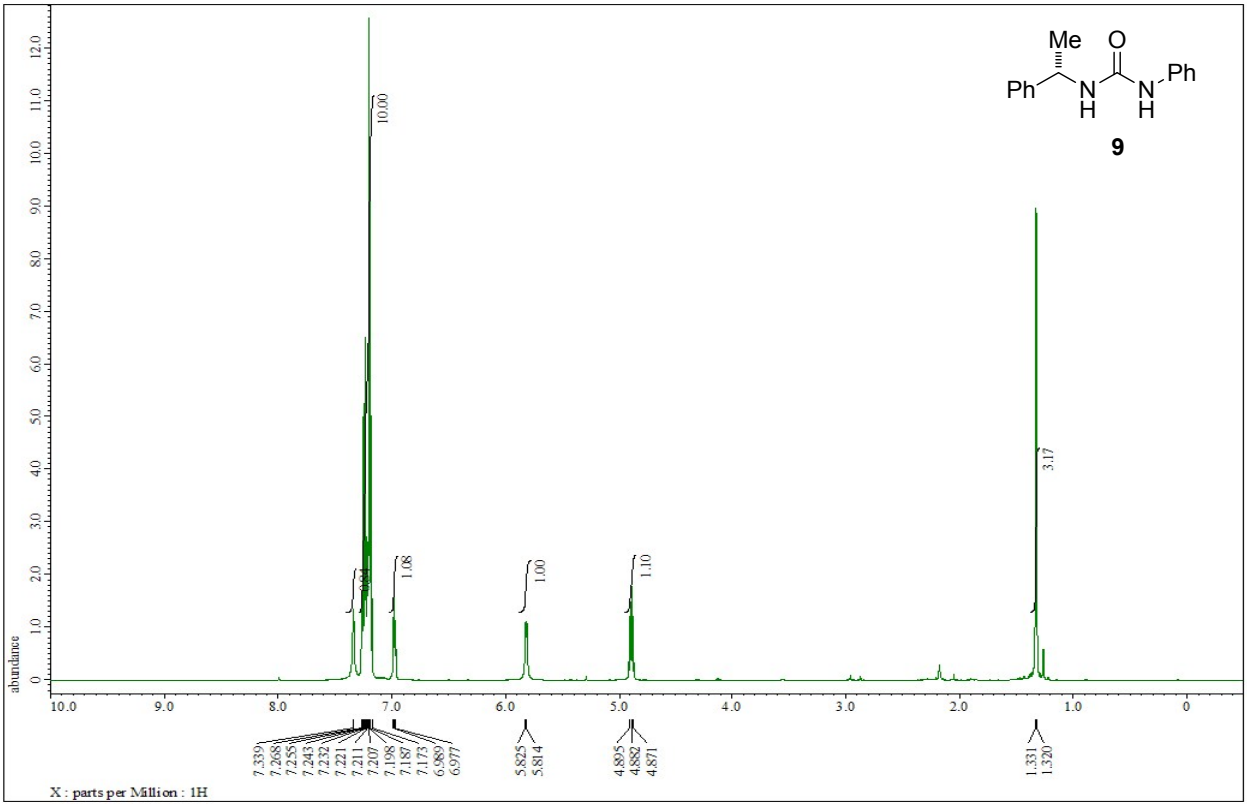

164.19
146.27
145.18
136.52
136.45
135.69
133.89
130.10
129.74
129.35
129.26
50.83
29.56
25.30
24.64
Cl
O
N
H
S
7f
f1 (ppm)

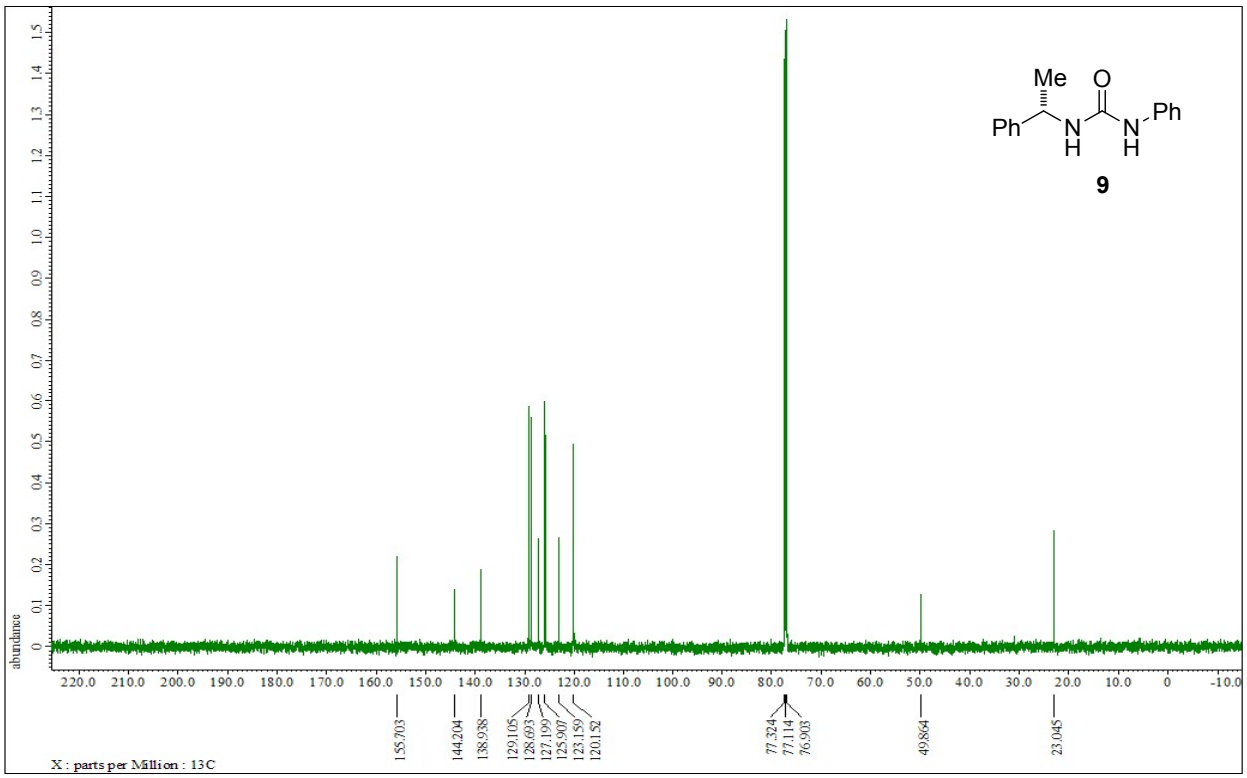

7.44
7.42
7.22
7.20
5.24
3.73
3.72
2.37
1.88
1.86
1.63
1.62
1.60
1.56
1.55
1.54
1.33
1.30
1.27
1.26
1.14
1.13
1.10
1.07
1.72
1.79
1.03
1.02
2.63
2.00
3.09
2.33
2.90
Me
O
N
H
S
7g
f1 (ppm)

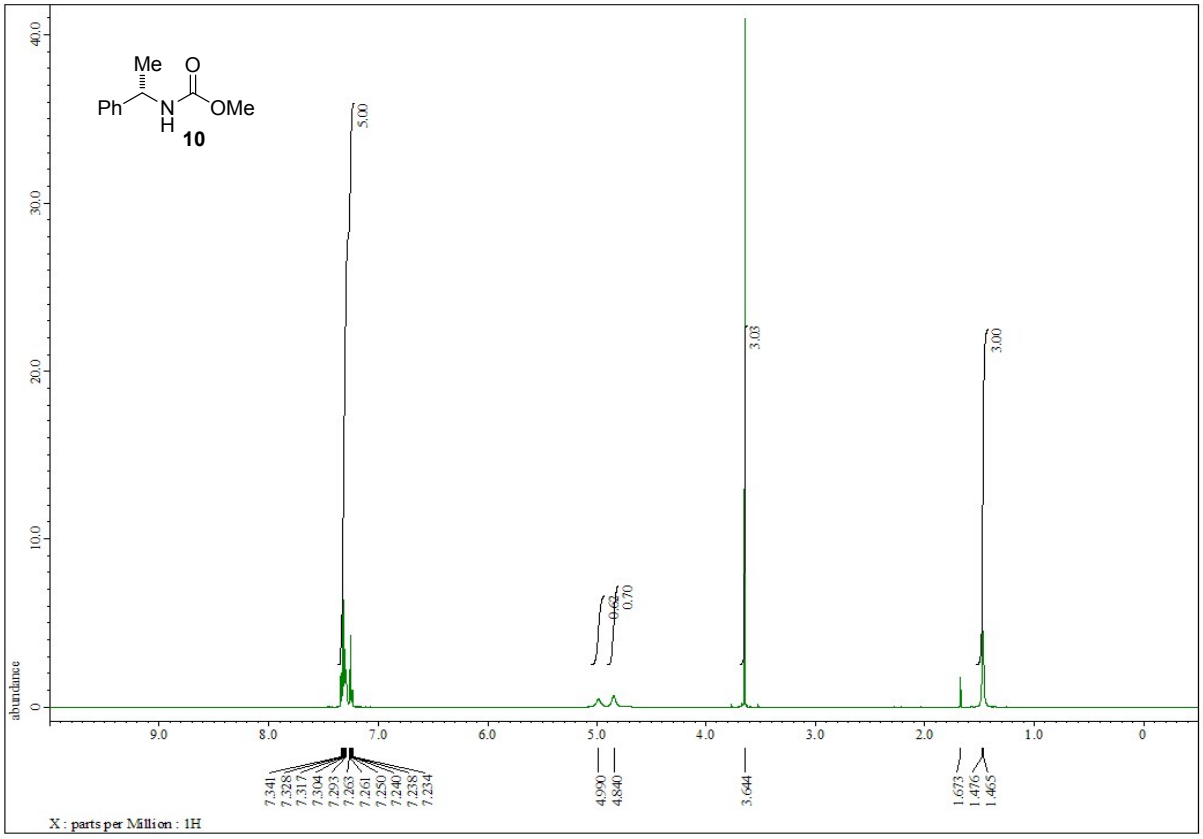

165.37
139.88
135.39
130.20
125.38
50.38
32.81
25.32
24.55
21.29
Me
O
N
H
S
7g
f1 (ppm)

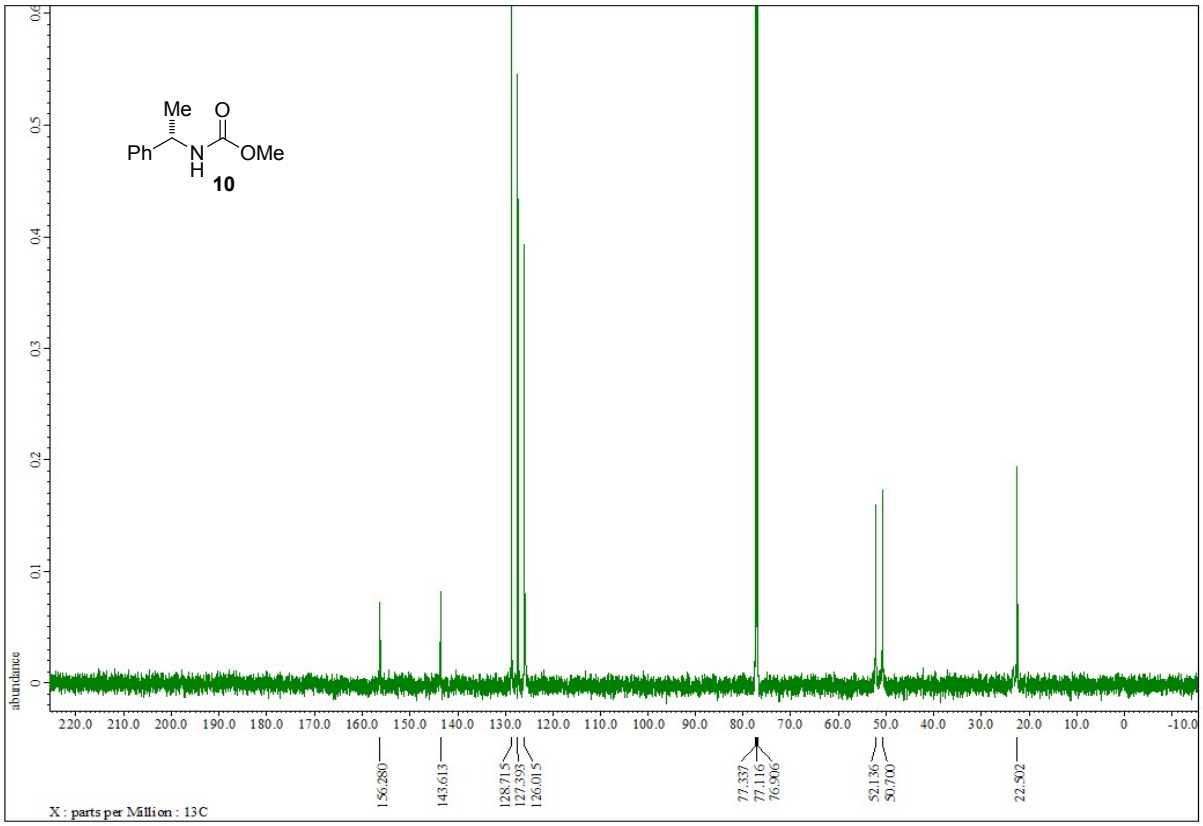

7h
5.21
3.72
2.88
2.87
2.85
0.94
1.00
1.89
1.82
1.98
2.90
4.08
3.07
2.86
f1 (ppm)


7h
166.13
77.31
76.99
76.68
50.39
33.15
32.54
29.58
25.38
24.74
21.87
13.57
f1 (ppm)


Me
O
Ph
N
H
N
H
Ph
9
abundance
10.00
1.08
1.00
1.10
3.17
7.339
7.268
7.255
7.243
7.232
7.221
7.211
7.207
7.198
7.187
7.173
6.989
6.977
5.825
5.814
4.895
4.882
4.871
1.331
1.320
X : parts per Million : 1H

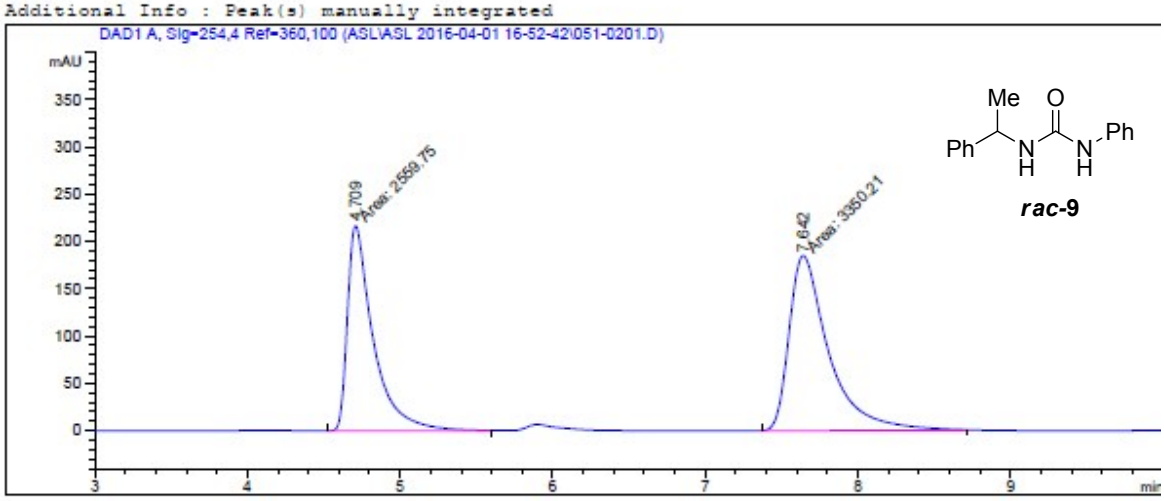

Me
O
Ph
N
H
N
H
Ph
9
abundance
155.703
144.204
138.938
129.105
128.693
127.199
125.907
123.159
120.152
77.324
77.114
76.903
49.864
23.045
X : parts per Million : 13C


Me
O
Ph
N
H
OMe
10
5.00
3.03
3.00
0.62
0.70
abundance
7.341
7.328
7.317
7.304
7.293
7.263
7.261
7.250
7.240
7.238
7.234
4.990
4.840
3.644
1.673
1.476
1.465
X : parts per Million : 1H


Me
O
Ph
N
H
OMe
10
abundance
156.280
143.613
128.715
127.393
126.015
77.337
77.116
76.906
52.136
50.700
22.502
X : parts per Million : 13C

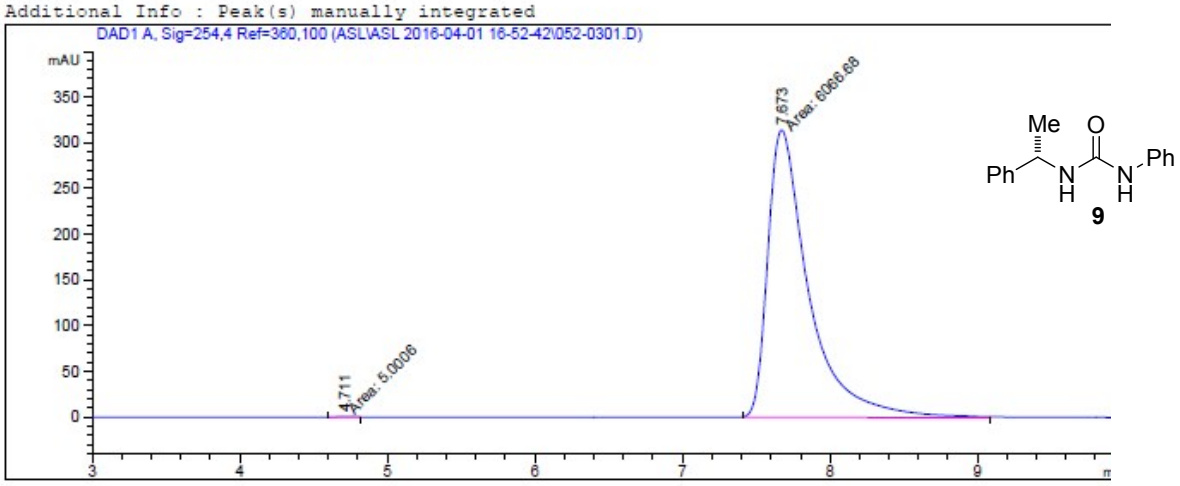
HPLC Traces of Racemic and Enantioenriched Compound 9 and 10

Additional Info : Peak(s) manually integrated

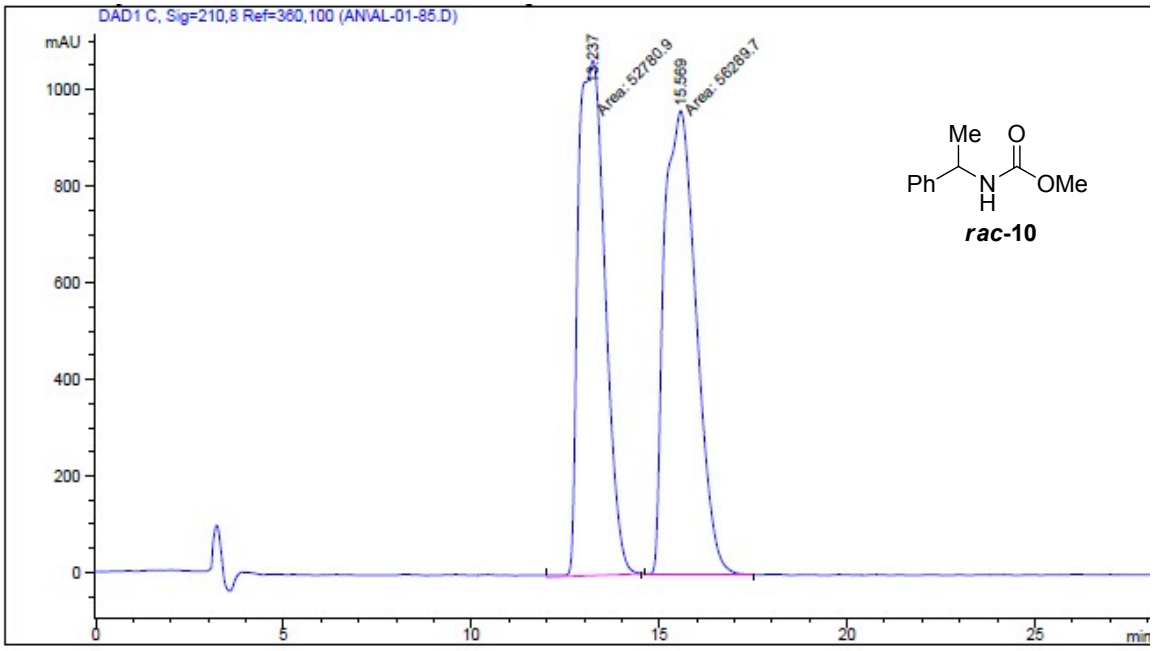



```
================================================================================
                          Area Percent Report
================================================================================

Sorted By             :      Signal
Multiplier:                   :      1.0000
Dilution:                     :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: DAD1 A, Sig=254,4 Ref=360,100

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]   [mAU*s]     [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1   4.709 MM    0.1964 2559.75464  217.24174  43.3125
   2   7.642 MM    0.3017 3350.21289  185.04453  56.6875

Totals :                  5909.96753  402.28627
```

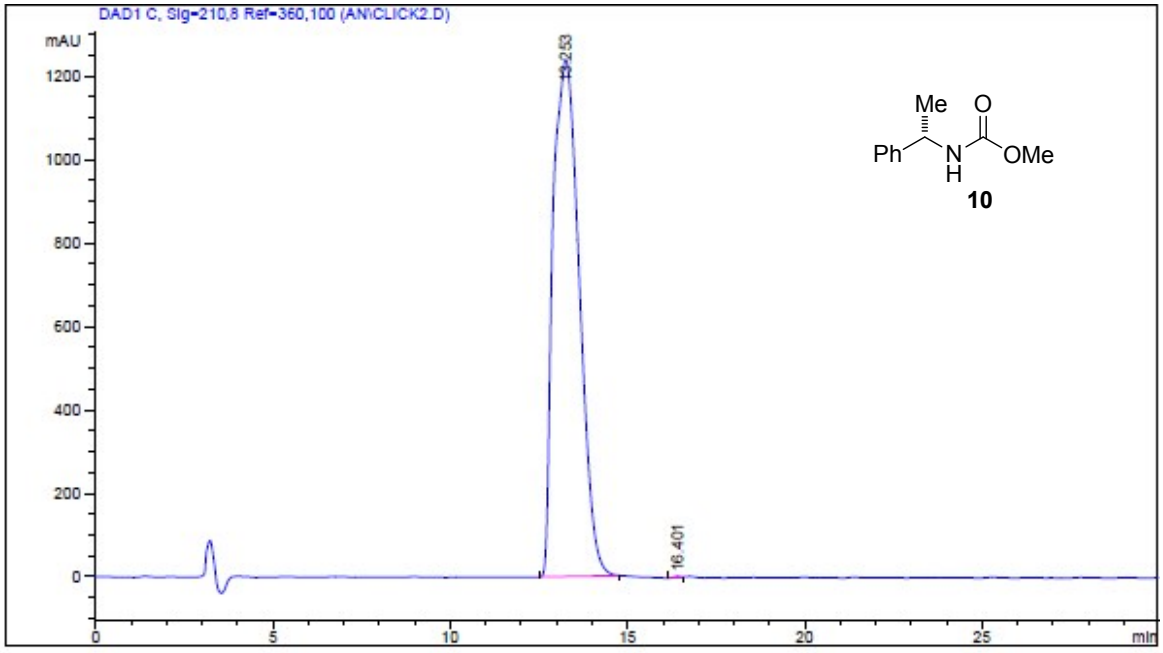
Additional Info : Peak(s) manually integrated




```
=====================================================================
                        Area Percent Report
=====================================================================

Sorted By             :      Signal
Multiplier:                   :      1.0000
Dilution:                     :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: DAD1 A, Sig=254,4 Ref=360,100

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]   [mAU*s]     [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1   4.711 MM    0.1237    5.00060 6.73716e-1   0.0824
   2   7.673 MM    0.3220 6066.67920  314.05862  99.9176

Totals :                  6071.67980  314.73234
```




```
=====================================================================
                    Area Percent Report
=====================================================================

Sorted By             :      Signal
Multiplier            :      1.0000
Dilution              :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: DAD1 C, Sig=210,8 Ref=360,100

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]   [mAU*s]     [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1  13.237 MM    0.8247 5.27809e4  1066.69104  48.3915
   2  15.569 MM    0.9787 5.62897e4   958.55536  51.6085

Totals :                  1.09071e5  2025.24640
```




```
================================================================================
                            Area Percent Report
================================================================================

Sorted By             :      Signal
Multiplier            :      1.0000
Dilution              :      1.0000
Sample Amount         :      5.00000  [ng/ul]    (not used in calc.)
Use Multiplier & Dilution Factor with ISTDs


Signal 1: DAD1 C, Sig=210,8 Ref=360,100

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]   [mAU*s]     [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1  13.253 PB    0.7003 6.35707e4  1239.61743  99.9062
   2  16.401 PV    0.2143   59.65941    4.08745   0.0938

Totals :                  6.36304e4  1243.70488
```