Supporting Information

Highly enantioselective Biginelli reaction catalyzed by SPINOL-phosphoric acids

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CONTENTS

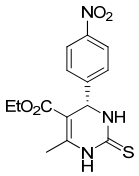
1. General Information

Unless otherwise noted, all reagents were purchased from commercial supplies and used without further purification. Solvents were used without dryness. ^{1}H NMR spectra were recorded on 400 MHz spectrometer. The chemical shifts were reported relative to internal standard TMS (0) in $CDCl_3$ or 2.5 in DMSO-d_6. The following abbreviations were used to describe peak patterns where appropriate: br=broad, s=singlet, d=doublet, t=triplet, q=quartet, m=multiplet. Coupling constants were reported in Hertz (Hz). ^{13}C NMR spectra were recorded on 100 MHz spectrometer, referred to the internal solvent signals (77.0 for $CDCl_3$ or 40.0 for DMSO-d_6). Optical rotations were determined using a Perkin Elmer Model 341 polarimeter at 20 ^{o}C. The enantiomeric excesses (ee) were determined by chiral HPLC analysis on Daicel Chiralpak AS-H or AD-H columns.

2. General Procedure for the Enantioselective Biginelli Reaction

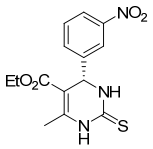
Under nitrogen atmosphere, aldehyde **2** (0.1 mmol), thiourea **3a** (0.12 mmol) and catalyst (*S*)-**1f** (0.005 mmol) were dissolved in 1 mL xylene. After being stirred at room temperature for 2 hours, acetoacetate **4** (0.3 mmol) was added, and the resulting mixture was stirred at 50 °C for 3 days as monitored by TLC. Then the reaction was cooled to room temperature, diluted with ethyl acetate and added some silica gel. The organic solvents were removed under vacuum and the residue was purified by flash column chromatography on silica gel (ethyl acetate / petroleum ether = 1/4 – 1/2) to afford the corresponding DHPM product.

(*S*)-ethyl-6-methyl-4-(4-nitrophenyl)-2-thioxo-1,2,3,4-tetrahydropyrimidine-5-carboxylate (5a):



This product was obtained in 92% yield after chromatography and 94% ee as determined by HPLC [Daicel Chiralpak AS-H, *n*-hexane / *i*-propanol = 70 / 30, 1.0 mL/min, λ = 254 nm, t (minor) = 17.84 min, t (major) = 22.50 min]. $[\alpha]_D^{20}$ = +223.6° (c = 0.6, EtOAc); ^{1}H NMR (400 MHz, DMSO-d_6) δ 1.12 (t, *J* = 6.8 Hz, 3H), 2.33 (s, 3H), 4.03 (q, *J* = 6.8 Hz, 2H), 5.33 (d, *J* = 3.6 Hz, 1H), 7.51 (d, *J* = 9.2 Hz, 2H), 8.25 (d, *J* = 8.8 Hz, 2H), 9.76 (s, 1H), 10.49 (s, 1H); ^{13}C NMR (100 MHz, DMSO-d_6) δ 14.4, 17.7, 54.1, 60.2, 100.2, 124.4, 128.3, 146.4, 147.4, 150.8, 165.3, 175.0; MS (ESI) *m/z* 320.1 ($[M-H]^-$).

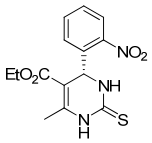
(*S*)-ethyl-6-methyl-4-(3-nitrophenyl)-2-thioxo-1,2,3,4-tetrahydropyrimidine-5-carboxylate (5b):



This product was obtained in 86% yield after chromatography and 97% ee as determined by HPLC [Daicel Chiralpak AD-H, *n*-hexane / *i*-propanol = 80 / 20, 1.0 mL/min, λ = 254 nm, t (minor) = 17.40 min, t (major) = 23.02 min]. $[\alpha]_D^{20}$ = +125.3° (c = 0.44, EtOAc); ^{1}H NMR (400 MHz, DMSO-d_6) δ

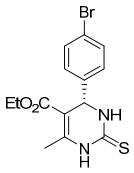
1.12 (t, *J* = 6.4 Hz, 3H), 2.34 (s, 3H), 4.00-4.08 (m, 2H), 5.36 (d, *J* = 3.6 Hz, 1H), 7.69-7.72 (m, 2H), 8.10 (s, 1H), 8.16-8.19 (m, 1H), 9.77 (d, *J* = 1.6 Hz, 1H), 10.51 (s, 1H); ^{13}C NMR (100 MHz, DMSO-d_6) δ 14.4, 17.7, 54.0, 60.2, 100.3, 121.6, 123.2, 130.9, 133.5, 146.0, 146.5, 148.3, 165.3, 175.0; MS (ESI) *m/z* 320.1 ([M-H]$^-$).

(*S*)-ethyl-6-methyl-4-(2-nitrophenyl)-2-thioxo-1,2,3,4-tetrahydropyrimidine-5-carboxylate (5c):



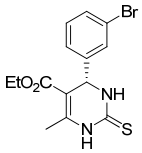
This product was obtained in 81% yield after chromatography and 99% ee as determined by HPLC [Daicel Chiralpak AD-H, *n*-hexane / *i*-propanol = 90 / 10, 1.0 mL/min, λ = 254 nm, t (major) = 19.68 min, t (minor) = 29.28 min]. $[\alpha]_D^{20}$ = +304.8° (c = 0.34, EtOAc); ^{1}H NMR (400 MHz, DMSO-d_6) δ 0.94 (t, *J* = 6.8 Hz, 3H), 2.32 (s, 3H), 3.84-3.92 (m, 2H), 5.97 (d, *J* = 2.4 Hz, 1H), 7.52-7.57 (m, 2H), 7.76 (t, *J* = 7.6 Hz, 1H), 7.94 (d, *J* = 8.0 Hz, 1H), 9.58 (s, 1H), 10.46 (s, 1H); ^{13}C NMR (100 MHz, DMSO-d_6) δ 14.4, 17.7, 54.1, 60.2, 100.2, 124.4, 128.3, 146.4, 147.4, 150.8, 165.3, 175.0; MS (ESI) *m/z* 320.1 ([M-H]$^-$).

(*S*)-ethyl-6-methyl-4-(4-bromophenyl)-2-thioxo-1,2,3,4-tetrahydropyrimidine-5-carboxylate (5d):



This product was obtained in 92% yield after chromatography and 90% ee as determined by HPLC [Daicel Chiralpak AD-H, *n*-hexane / *i*-propanol = 80 / 20, 1.0 mL/min, λ = 254 nm, t (minor) = 9.07 min, t (major) = 12.04 min]. $[\alpha]_D^{20}$ = +137.4° (c = 0.66, EtOAc); ^{1}H NMR (400 MHz, DMSO-d_6) δ 1.10 (t, *J* = 6.8 Hz, 3H), 2.30 (s, 3H), 4.01 (q, *J* = 7.2 Hz, 2H), 5.16 (d, *J* = 3.2 Hz, 1H), 7.18 (d, *J* = 8.4 Hz, 2H), 7.56 (d, *J* = 8.4 Hz, 2H), 9.68 (d, *J* = 1.6 Hz, 1H), 10.40 (s, 1H); ^{13}C NMR (100 MHz, DMSO-d_6) δ 14.5, 17.7, 54.0, 60.2, 100.7, 121.3, 129.2, 132.0, 143.3, 145.9, 165.5, 174.8; MS (ESI) *m/z* 355.0 ([M+H]$^+$).

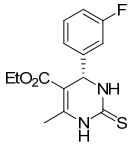
(*S*)-ethyl-6-methyl-4-(3-bromophenyl)-2-thioxo-1,2,3,4-tetrahydropyrimidine-5-carboxylate (5e):



This product was obtained in 82% yield after chromatography and 92% ee as determined by HPLC [Daicel Chiralpak AS-H, *n*-hexane / *i*-propanol = 70 / 30, 1.0 mL/min, λ = 254 nm, t (minor) = 12.39 min, t (major) = 15.85 min]. $[\alpha]_D^{20}$ = +105.0° (c = 0.48, EtOAc); ^{1}H NMR (400 MHz, DMSO-d_6) δ 1.11 (t, *J* = 6.8 Hz, 3H), 2.30 (s, 3H), 3.98-4.07 (m, 2H), 5.18 (d, *J* = 3.2 Hz, 1H), 7.22 (d, *J* = 8.0 Hz, 1H), 7.32-7.38 (m, 2H), 7.49 (d, *J* = 8.0 Hz, 1H), 9.67 (s, 1H), 10.40 (s, 1H); ^{13}C NMR (100 MHz,

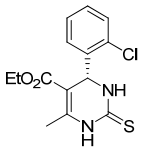
DMSO-d_6) δ 14.4, 17.7, 54.0, 60.1, 100.6, 122.1, 125.8, 129.7, 131.0, 131.4, 146.0, 146.5, 165.4, 174.8; MS (ESI) *m/z* 354.9 ($[M+H]^+$).

(*S*)-ethyl-6-methyl-4-(3-fluorophenyl)-2-thioxo-1,2,3,4-tetrahydropyrimidine-5-carboxylate (5f):



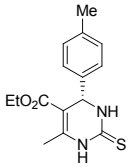
This product was obtained in 89% yield after chromatography and 94% ee as determined by HPLC [Daicel Chiralpak AD-H, *n*-hexane / *i*-propanol = 90 / 10, 0.6 mL/min, λ = 254 nm, t (major) = 32.42 min, t (minor) = 36.94 min]. $[\alpha]_D^{20}$ = +86.5° (c = 0.47, EtOAc); ^{1}H NMR (400 MHz, DMSO-d_6) δ 1.11 (t, *J* = 5.2 Hz, 3H), 2.31 (s, 3H), 4.00-4.07 (m, 2H), 5.21 (d, *J* = 2.8 Hz, 1H), 6.99 (d, *J* = 7.6 Hz, 1H), 7.07-7.15 (m, 2H), 7.39-7.44 (m, 1H), 9.71 (s, 1H), 10.43 (s, 1H); ^{13}C NMR (100 MHz, DMSO-d_6) δ 14.5, 17.7, 54.0, 60.2, 100.7, 113.6, 115.0, 122.9, 131.2, 146.1, 146.7, 162.6, 165.5, 174.9; MS (ESI) *m/z* 295.2 ($[M+H]^+$).

(*S*)-ethyl-6-methyl-4-(2-chlorophenyl)-2-thioxo-1,2,3,4-tetrahydropyrimidine-5-carboxylate (5g):



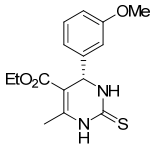
This product was obtained in 88% yield after chromatography and 97% ee as determined by HPLC [Daicel Chiralpak AS-H, *n*-hexane / *i*-propanol = 85 / 15, 1.0 mL/min, λ = 254 nm, t (minor) = 15.98 min, t (major) = 21.62 min]. $[\alpha]_D^{20}$ = +59.5° (c = 0.6, EtOAc); ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.06 (t, *J* = 6.8 Hz, 3H), 2.44 (s, 3H), 4.02 (q, *J* = 7.6 Hz, 2H), 5.90 (d, *J* = 2.8 Hz, 1H), 7.21-7.25 (m, 3H), 7.36-7.39 (m, 1H), 7.57 (s, 1H), 8.66 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 13.8, 17.8, 52.6, 60.3, 100.7, 127.6, 128.5, 129.6, 129.8, 132.6, 138.5, 144.6, 164.8, 174.1; MS (ESI) *m/z* 311.1 ($[M+H]^+$).

(*S*)-ethyl-6-methyl-2-thioxo-4-p-tolyl-1,2,3,4-tetrahydropyrimidine-5-carboxylate (5h):



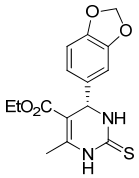
This product was obtained in 96% yield after chromatography and 91% ee as determined by HPLC [Daicel Chiralpak AS-H, *n*-hexane / *i*-propanol = 70 / 30, 1.0 mL/min, λ = 254 nm, t (minor) = 12.93 min, t (major) = 15.91 min]. $[\alpha]_D^{20}$ = +77.6° (c = 0.71, MeOH); ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.17 (t, *J* = 6.8 Hz, 3H), 2.31 (s, 3H), 2.34 (s, 3H), 4.05-4.11 (m, 2H), 5.34 (d, *J* = 2.8 Hz, 1H), 7.10 (d, *J* = 7.6 Hz, 2H), 7.17 (d, *J* = 8.0 Hz, 2H), 7.86 (s, 1H), 8.50 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 14.0, 18.1, 21.1, 55.7, 60.3, 103.0, 126.6, 129.4, 138.0, 139.5, 142.8, 165.3, 174.1; MS (ESI) *m/z* 290.9 ($[M+H]^+$).

(*S*)-ethyl-4-(3-methoxyphenyl)-6-methyl-2-thioxo-1,2,3,4-tetrahydropyrimidine-5-carboxylate (5i):



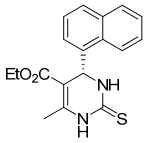
This product was obtained in 90% yield after chromatography and 94% ee as determined by HPLC [Daicel Chiralpak AS-H, *n*-hexane / *i*-propanol = 70 / 30, 1.0 mL/min, λ = 254 nm, t (minor) = 13.97 min, t (major) = 19.77 min]. $[\alpha]_D^{20}$ = +71.7° (c = 0.38, MeOH); ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.17 (t, *J* = 6.8 Hz, 3H), 2.35 (s, 3H), 3.77 (s, 3H), 4.06-4.14 (m, 2H), 5.36 (d, *J* = 3.2 Hz, 1H), 6.79-6.82 (m, 2H), 6.87 (d, *J* = 7.6 Hz, 1H), 7.22 (t, *J* = 7.6 Hz, 1H), 7.87 (s, 1H), 8.46 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 14.1, 18.1, 55.2, 55.9, 60.3, 102.7, 112.7, 113.4, 118.9, 129.9, 143.0, 143.8, 159.9, 165.2, 174.3; MS (ESI) *m/z* 307.0 ($[M+H]^+$).

(*S*)-ethyl-4-(benzo[*d*][1,3]dioxol-5-yl)-6-methyl-2-thioxo-1,2,3,4-tetrahydropyrimidine-5-carboxylate (5j):



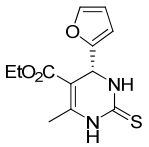
This product was obtained in 84% yield after chromatography and 94% ee as determined by HPLC [Daicel Chiralpak AS-H, *n*-hexane / *i*-propanol = 70 / 30, 1.0 mL/min, λ = 254 nm, t (minor) = 24.00 min, t (major) = 28.17 min]. $[\alpha]_D^{20}$ = +85.2° (c = 0.41, EtOAc); ^{1}H NMR (400 MHz, DMSO-d_6) δ 1.11 (t, *J* = 6.4 Hz, 3H), 2.29 (s, 3H), 4.02 (q, *J* = 6.8 Hz, 2H), 5.10 (d, *J* = 4.0 Hz, 1H), 6.00 (s, 2H), 6.67-6.73 (m, 2H), 6.87 (d, *J* = 8.0 Hz, 1H), 9.59 (d, *J* = 2.0 Hz, 1H), 10.31 (s, 1H); ^{13}C NMR (100 MHz, DMSO-d_6) δ 14.5, 17.6, 54.2, 60.1, 101.2, 101.6, 107.2, 108.6, 120.1, 138.0, 145.5, 147.2, 147.9, 165.6, 174.6; MS (ESI) *m/z* 321.0 ($[M+H]^+$).

(*S*)-ethyl-6-methyl-4-(naphthalen-1-yl)-2-thioxo-1,2,3,4-tetrahydropyrimidine-5-carboxylate (5k):



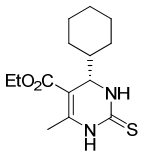
This product was obtained in 98% yield after chromatography and 99% ee as determined by HPLC [Daicel Chiralpak AS-H, *n*-hexane / *i*-propanol = 70 / 30, 1.0 mL/min, λ = 254 nm, t (minor) = 18.99 min, t (major) = 27.21 min]. $[\alpha]_D^{20}$ = +0.6° (c = 0.44, EtOAc); ^{1}H NMR (400 MHz, DMSO-d_6) δ 0.82 (t, *J* = 6.8 Hz, 3H), 2.40 (s, 3H), 3.78-3.88 (m, 2H), 6.08 (d, *J* = 4.0 Hz, 1H), 7.39 (d, *J* = 8.4 Hz, 1H), 7.48-7.62 (m, 3H), 7.88 (d, *J* = 8.4 Hz, 1H), 7.95 (d, *J* = 8.4 Hz, 1H), 8.38 (d, *J* = 8.4 Hz, 1H), 9.65 (s, 1H), 10.38 (s, 1H); ^{13}C NMR (100 MHz, DMSO-d_6) δ 14.3, 17.7, 50.2, 60.0, 101.3, 124.3, 125.4, 126.3, 126.4, 126.7, 128.9, 128.9, 130.5, 133.9, 139.7, 145.9, 165.6, 174.2; MS (ESI) *m/z* 327.0 ($[M+H]^+$).

(*R*)-ethyl-4-(furan-2-yl)-6-methyl-2-thioxo-1,2,3,4-tetrahydropyrimidine-5-carboxylate (5l):



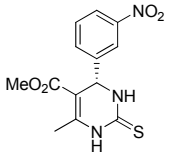
This product was obtained in 80% yield after chromatography and 90% ee as determined by HPLC [Daicel Chiralpak AD-H, *n*-hexane / *i*-propanol = 80 / 20, 0.7 mL/min, λ = 254 nm, t (minor) = 14.71 min, t (major) = 18.09 min]. $[\alpha]_D^{20}$ = -40.9° (c = 0.6, EtOAc); ^{1}H NMR (400 MHz, DMSO-d_6) δ 1.14 (t, *J* = 5.6 Hz, 3H), 2.28 (s, 3H), 4.03-4.06 (m, 2H), 5.24 (d, *J* = 2.0 Hz, 1H), 6.14-6.15 (m, 1H), 6.38 (s, 1H), 7.59 (s, 1H), 9.66 (s, 1H), 10.42 (s, 1H); ^{13}C NMR (100 MHz, DMSO-d_6) δ 14.6, 17.6, 48.2, 60.1, 98.7, 106.8, 111.0, 143.2, 146.5, 155.1, 165.3, 175.4; MS (ESI) *m/z* 265.1 ($[M-H]^-$).

(*S*)-ethyl-4-cyclohexyl-6-methyl-2-thioxo-1,2,3,4-tetrahydropyrimidine-5-carboxylate (5m):



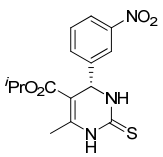
This product was obtained in 40% yield after chromatography and 84% ee as determined by HPLC [Daicel Chiralpak AS-H, *n*-hexane / *i*-propanol = 85 / 15, 1.0 mL/min, λ = 254 nm, t (major) = 14.46 min, t (minor) = 18.62 min]. $[\alpha]_D^{20}$ = +203.4° (c = 0.54, EtOAc); ^{1}H NMR (400 MHz, $CDCl_3$) δ 0.97-1.02 (m, 1H), 1.12-1.19 (m, 4H), 1.29 (t, *J* = 6.8 Hz, 3H), 1.50-1.75 (m, 6H), 2.34 (s, 3H), 4.16-4.24 (m, 3H), 8.07 (s, 1H), 8.58 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 14.2, 17.9, 25.8, 26.0, 26.1, 26.6, 28.5, 44.8, 57.0, 60.2, 101.6, 143.9, 165.8, 175.5; MS (ESI) *m/z* 283.1 ($[M+H]^+$).

(*S*)-methyl-6-methyl-4-(3-nitrophenyl)-2-thioxo-1,2,3,4-tetrahydropyrimidine-5-carboxylate (5n):



This product was obtained in 94% yield after chromatography and 91% ee as determined by HPLC [Daicel Chiralpak AD-H, *n*-hexane / *i*-propanol = 75 / 25, 1.0 mL/min, λ = 254 nm, t (minor) = 12.55 min, t (major) = 19.46 min]. $[\alpha]_D^{20}$ = +100.3° (c = 0.48, EtOAc); ^{1}H NMR (400 MHz, DMSO-d_6) δ 2.34 (s, 3H), 3.58 (s, 3H) , 5.35 (d, *J* = 3.6 Hz, 1H), 7.68-7.72 (m, 2H), 8.09 (s, 1H), 8.16-8.19 (m, 1H), 9.83 (s, 1H), 10.56 (s, 1H); ^{13}C NMR (100 MHz, DMSO-d_6) δ 17.8, 51.8, 53.8, 100.1, 121.6, 123.3, 131.0, 133.5, 145.7, 146.8, 148.4, 165.9, 175.0; MS (ESI) *m/z* 306.1 ($[M-H]^-$).

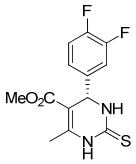
(*S*)-isopropyl-6-methyl-4-(3-nitrophenyl)-2-thioxo-1,2,3,4-tetrahydropyrimidine-5-carboxylate (5o):



This product was obtained in 94% yield after chromatography and 95% ee as determined by HPLC

[Daicel Chiralpak AD-H, *n*-hexane / *i*-propanol = 80 / 20, 1.0 mL/min, λ = 254 nm, t (minor) = 13.27 min, t (major) = 21.39 min]. $[\alpha]_D^{20}$ = +112.9° (c = 0.5, EtOAc); ^{1}H NMR (400 MHz, DMSO-d_6) δ 1.01 (d, *J* = 4.8 Hz, 3H), 1.19 (d, *J* = 5.2 Hz, 3H), 2.32 (s, 3H), 4.83-4.88 (m, 1H), 5.33 (d, *J* = 2.4 Hz, 1H), 7.67-7.72 (m, 2H), 8.08 (s, 1H), 8.18 (d, *J* = 6.4 Hz, 1H), 9.77 (s, 1H), 10.50 (s, 1H); ^{13}C NMR (100 MHz, DMSO-d_6) δ 17.7, 21.9, 22.1, 54.1, 67.6, 100.6, 121.7, 123.2, 130.9, 133.5, 146.2, 146.3, 148.2, 164.8, 175.0; MS (ESI) *m/z* 334.1 ($[M-H]^-$).

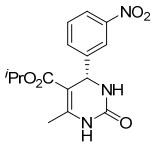
(*S*)-methyl-4-(3,4-difluorophenyl)-6-methyl-2-thioxo-1,2,3,4-tetrahydropyrimidine-5-carboxylate (5p):



This product was obtained in 90% yield after chromatography and 93% ee as determined by HPLC [Daicel Chiralpak AD-H, *n*-hexane / *i*-propanol = 90 / 10, 1.0 mL/min, λ = 254 nm, t (minor) = 21.90 min, t (major) = 28.21 min]. $[\alpha]_D^{20}$ = +60.9° (c = 0.6, EtOAc); ^{1}H NMR (400 MHz, DMSO-d_6) δ 2.32 (s, 3H), 3.58 (s, 3H), 5.21 (d, *J* = 3.2 Hz, 1H), 7.07-7.10 (m, 1H), 7.20-7.25 (m, 1H), 7.40-7.47 (m, 1H), 9.73 (d, *J* = 1.6 Hz, 1H), 10.47 (s, 1H); ^{13}C NMR (100 MHz, DMSO-d_6) δ 17.7, 51.6, 53.5, 100.3, 115.9, 118.2, 123.5, 141.4, 146.5, 149.6, 166.0, 174.9; MS (ESI) *m/z* 299.1 ($[M+H]^+$).

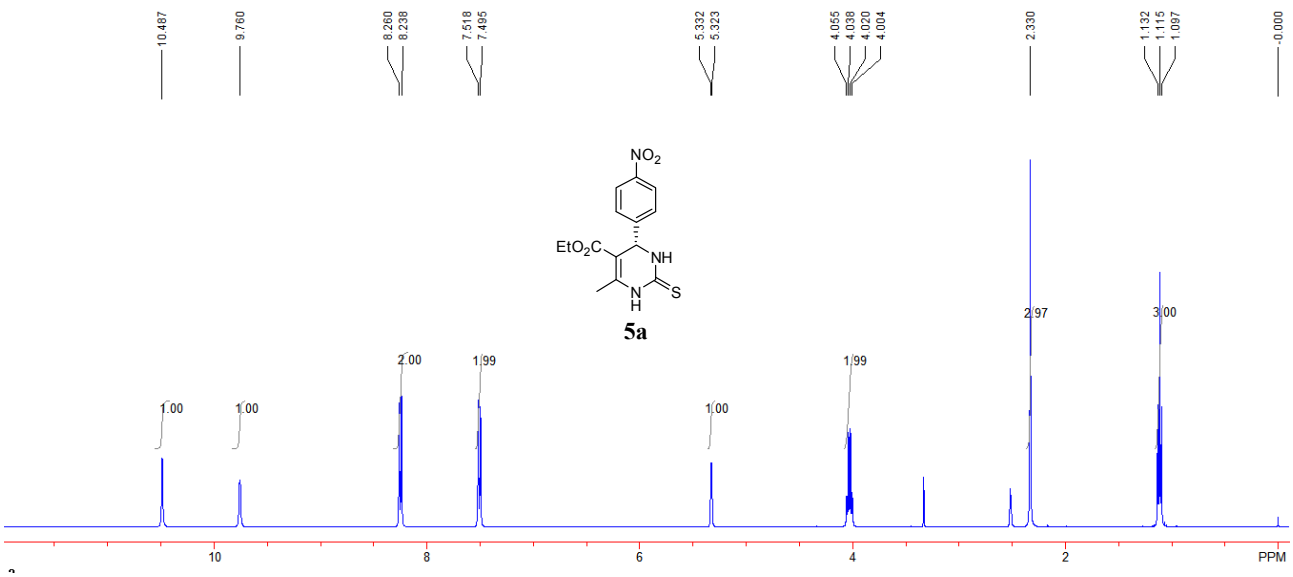
3. Synthesis of dihydropyrimidinone 5q

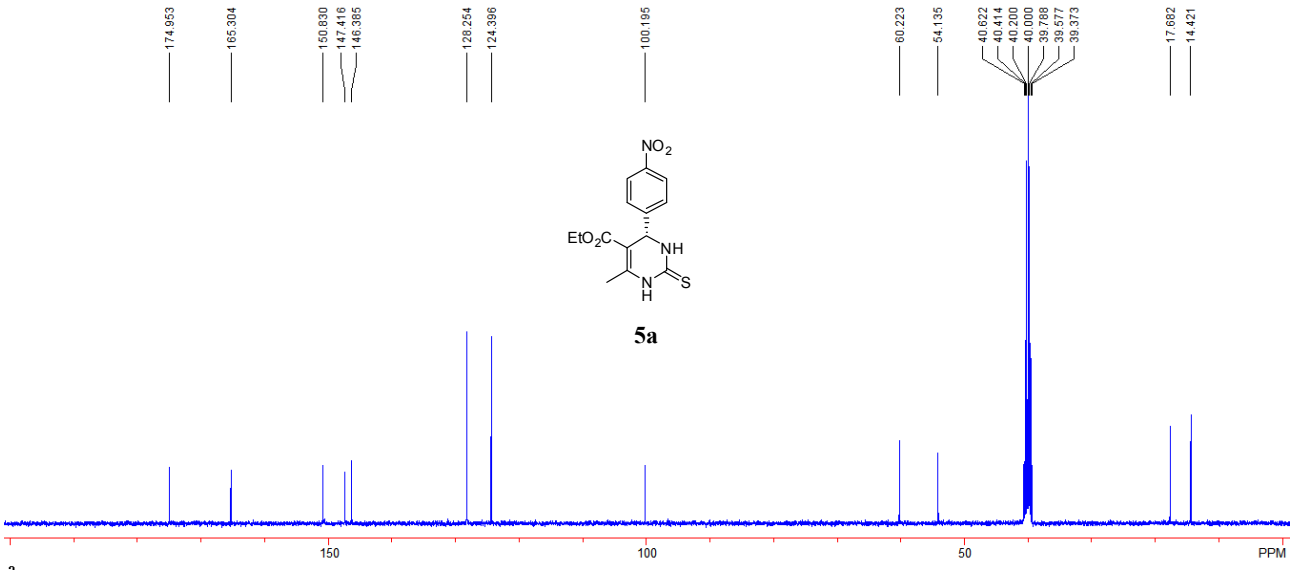
(*S*)-isopropyl-6-methyl-4-(3-nitrophenyl)-2-oxo-1,2,3,4-tetrahydropyrimidine-5-carboxylate (5q):

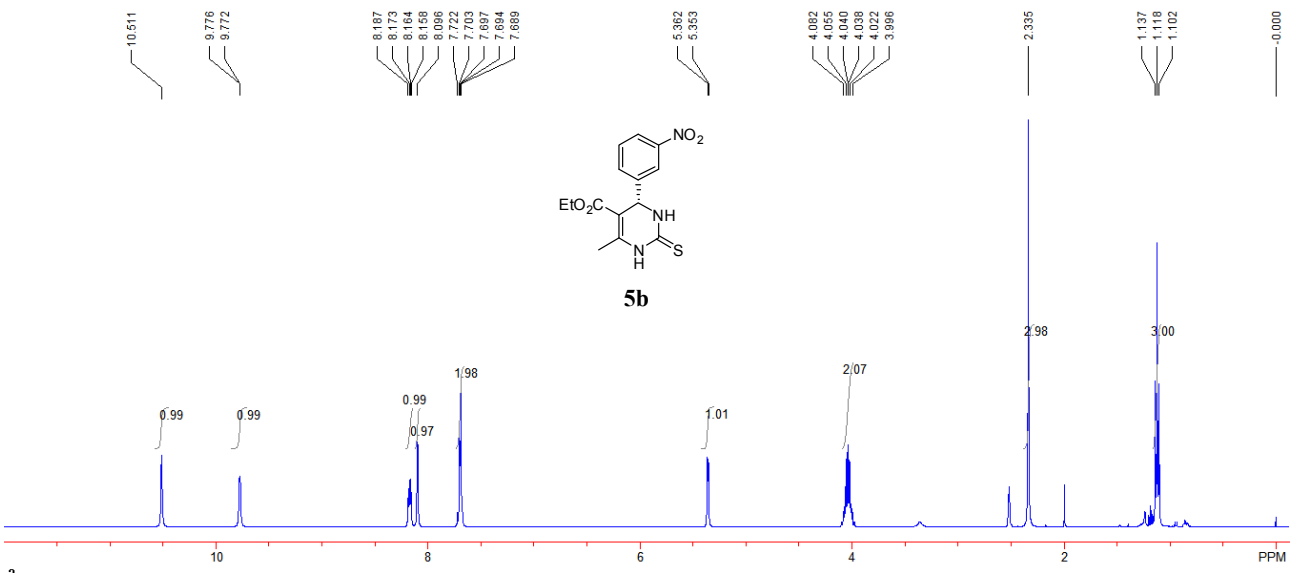


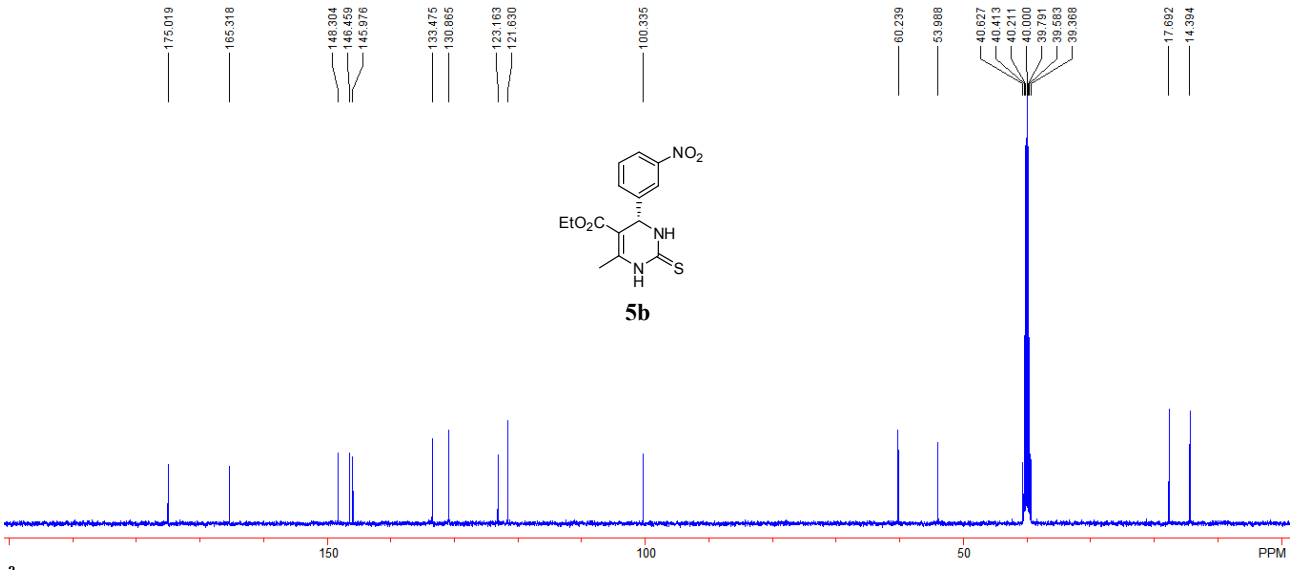
To a solution of **5o** (28.9 mg, 0.086 mmol) in ethyl acetate (1.6 mL) was added ammonia (0.7 mL) and 30% aqueous H_2O_2 (0.7 mL). After stirred at 50 °C for 1 hour open to air, the reaction mixture was quenched with 1 mL water and extracted with ethyl acetate. The organic layer was dried over Na_2SO_4, concentrated in vacuo, and the residue was purified by silica gel column chromatography (ethyl acetate / petroleum ether = 2/1). The product **5q** was obtained in 81% yield and 95% ee as determined by HPLC [Daicel Chiralpak AD-H, *n*-hexane / *i*-propanol = 80 / 20, 1.0 mL/min, λ = 254 nm, t (minor) = 9.30 min, t (major) = 13.19 min]. $[\alpha]_D^{20}$ = +90.8° (c = 0.6, EtOAc); ^{1}H NMR (400 MHz, DMSO-d_6) δ 1.00 (d, *J* = 6.4 Hz, 3H), 1.19 (d, *J* = 6.4 Hz, 3H), 2.30 (s, 3H), 4.81-4.88 (m, 1H), 5.32 (s, 1H), 7.66-7.74 (m, 2H), 7.91 (s, 1H), 8.11-8.16 (m, 2H), 9.37 (s, 1H); ^{13}C NMR (100 MHz, DMSO-d_6) δ 18.3, 21.9, 22.2, 54.2, 67.1, 99.1, 121.6, 122.7, 130.6, 133.5, 147.6, 148.2, 149.7, 152.3, 165.0; MS (ESI) *m/z* 317.9 ($[M-H]^-$).

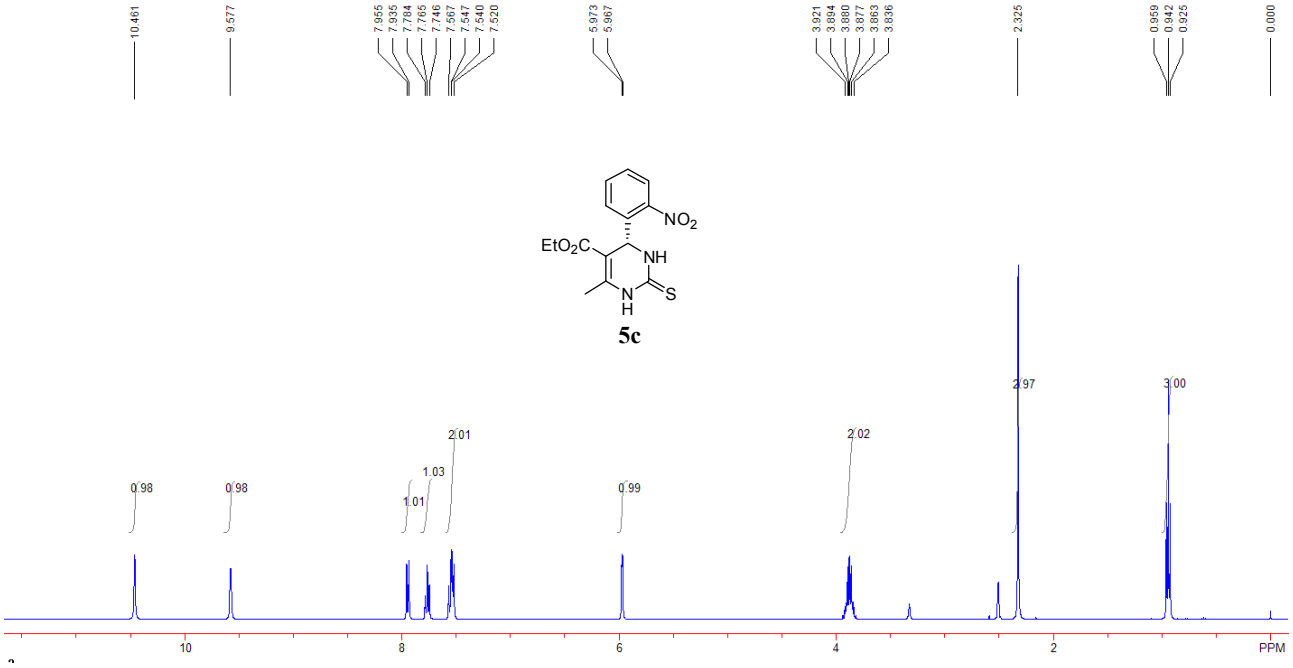
4. NMR spectra for compounds 5a-q

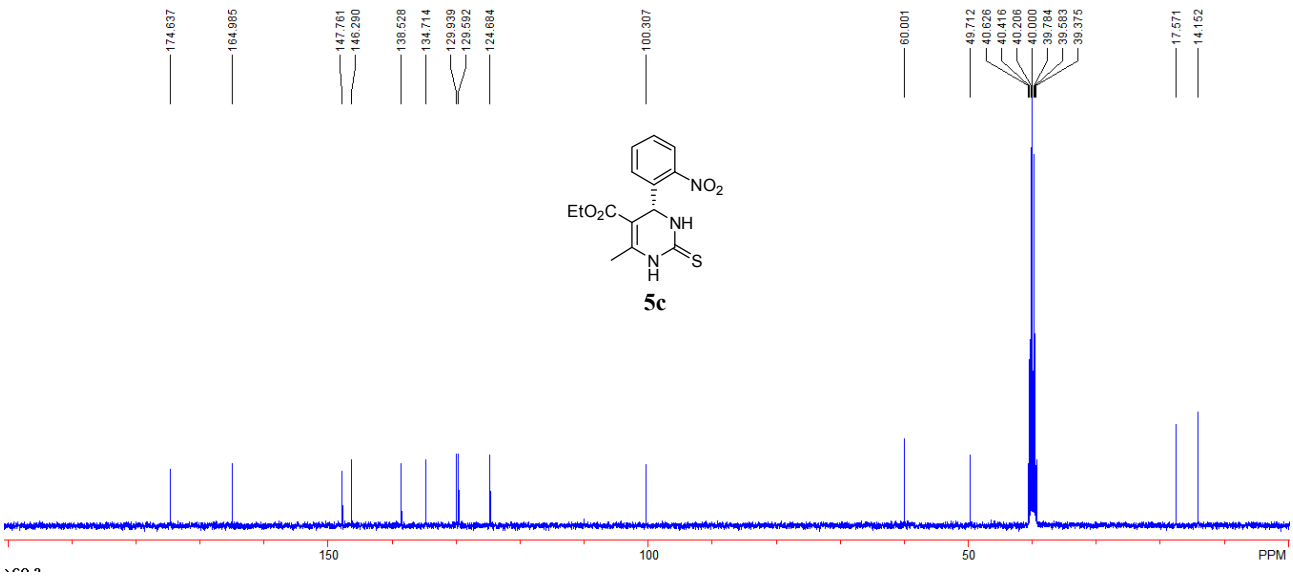


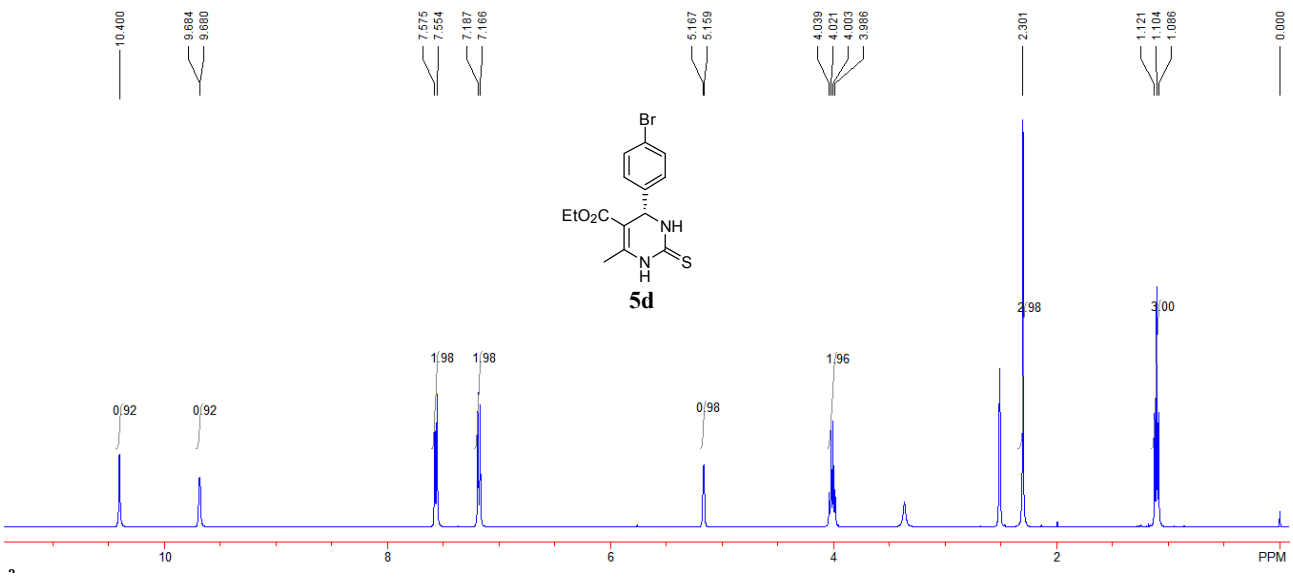


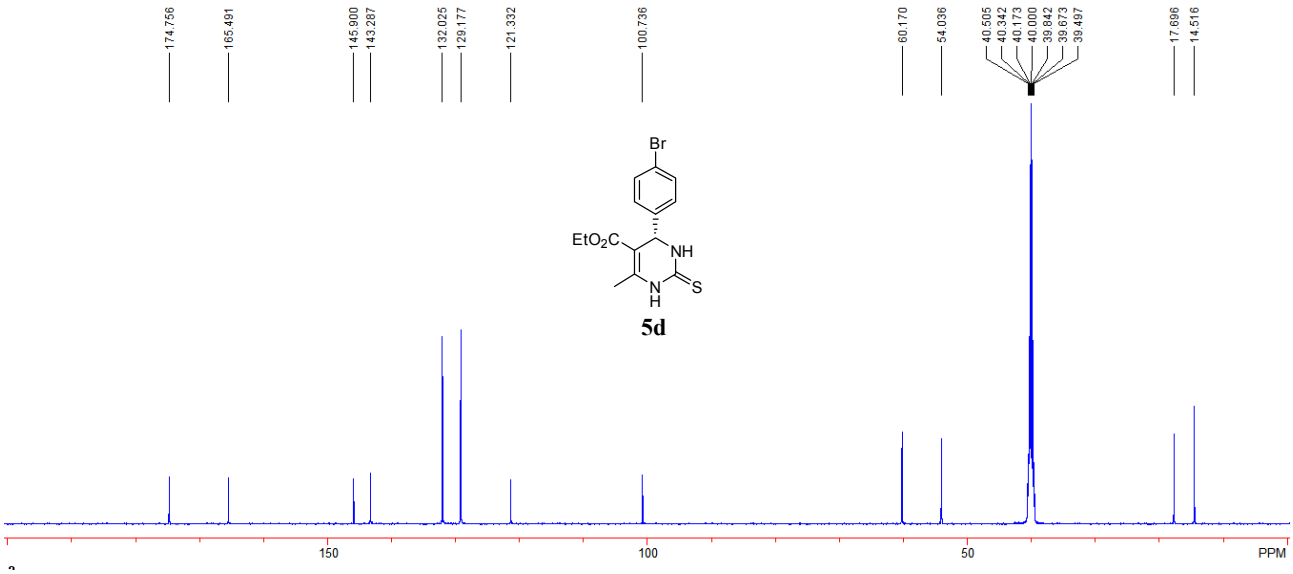


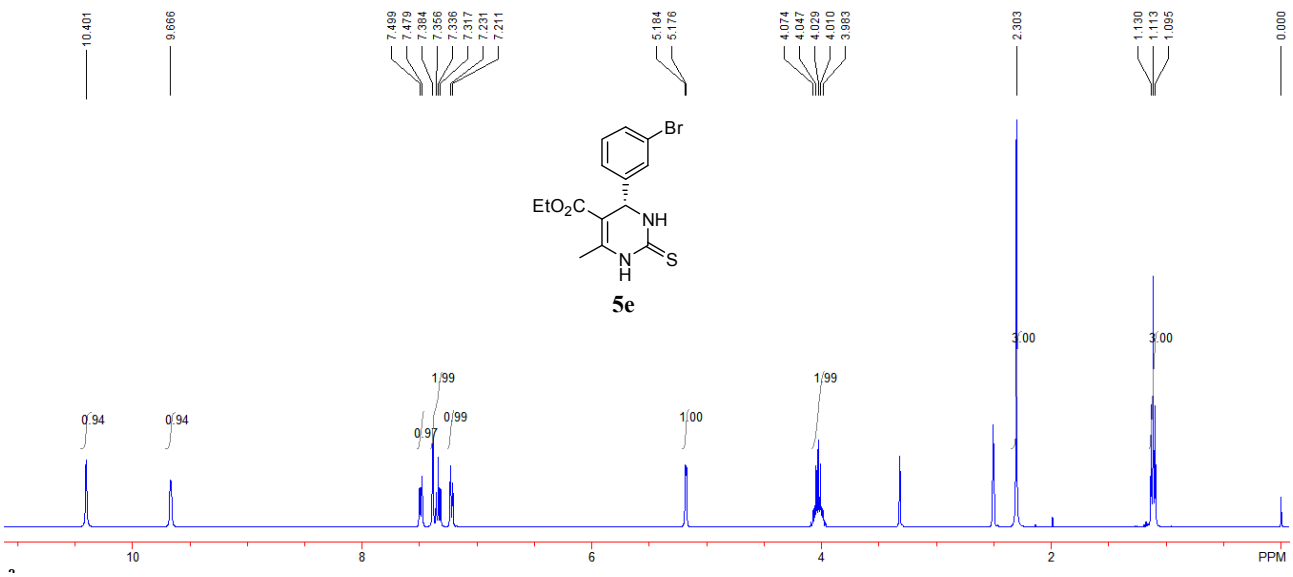


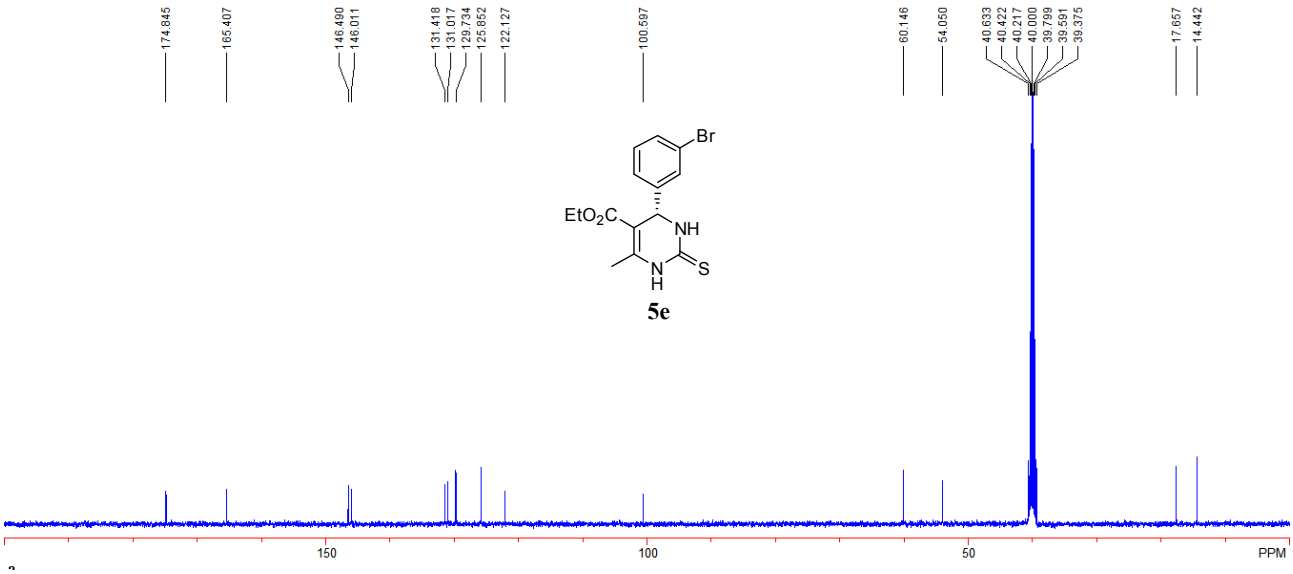


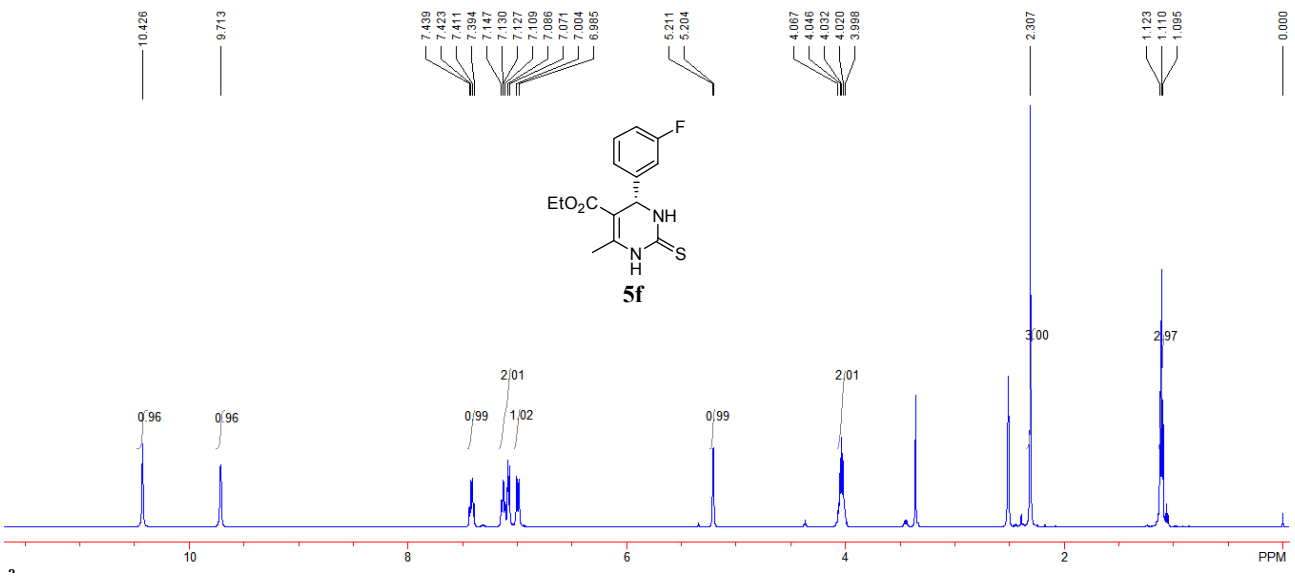


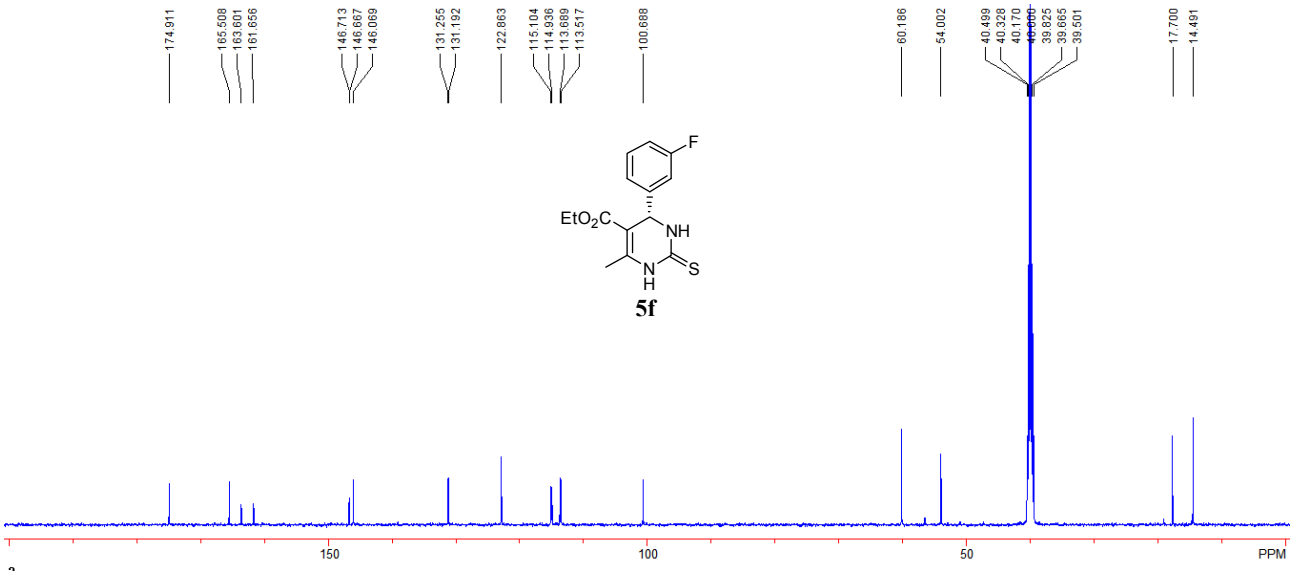


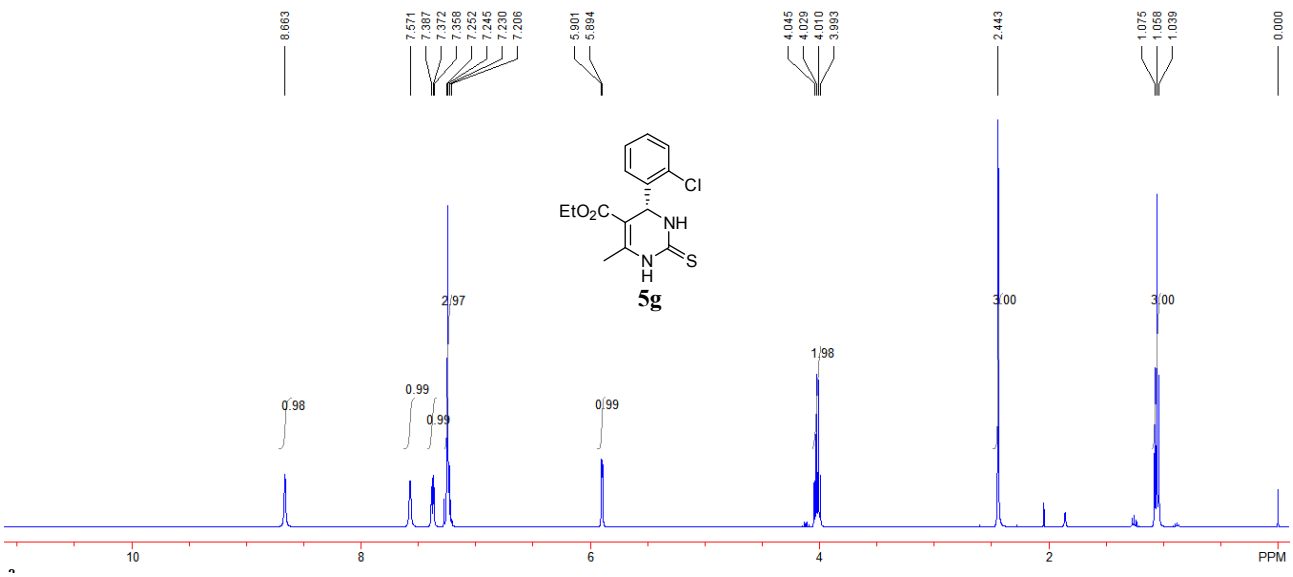








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7.387
7.372
7.358
7.252
7.245
7.230
7.206
5.901
5.894
4.045
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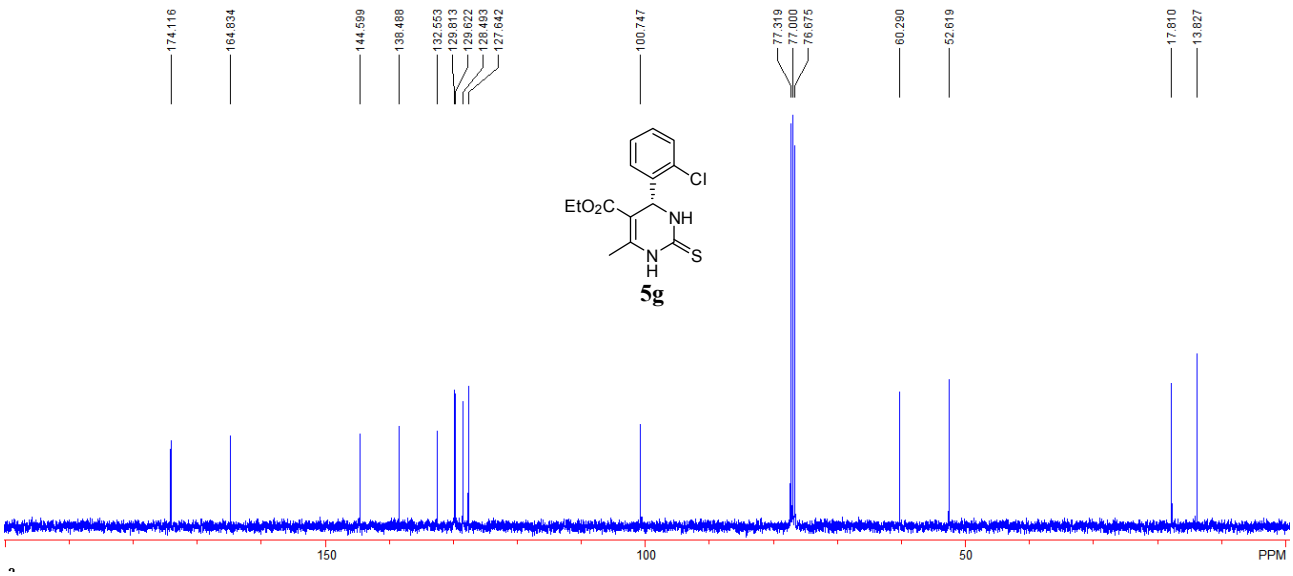
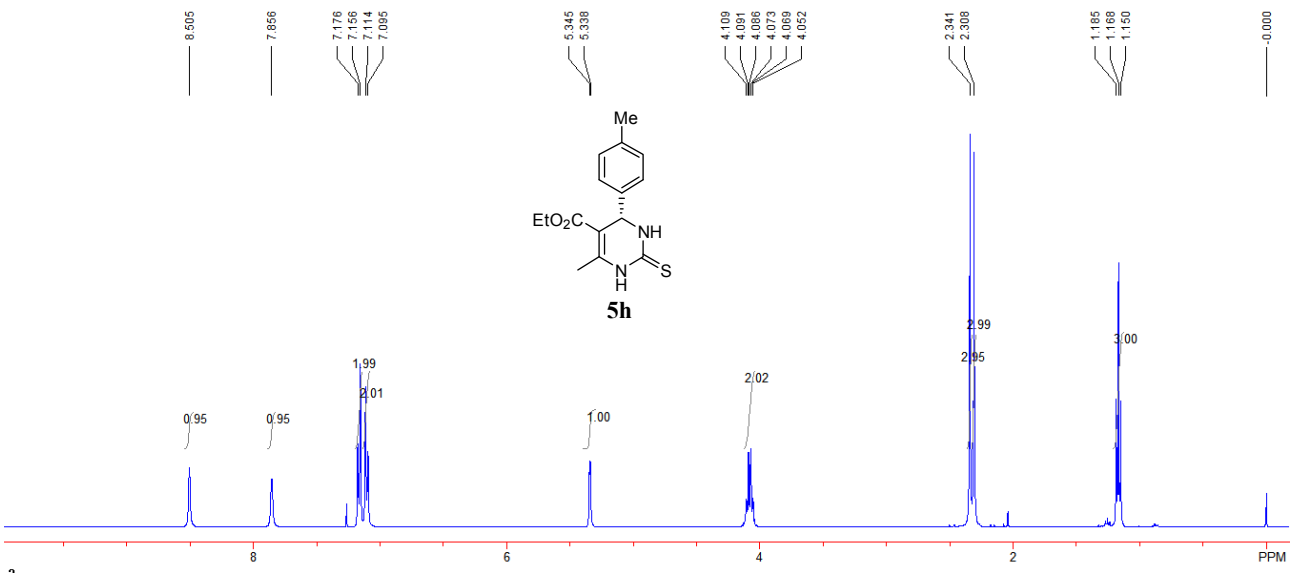
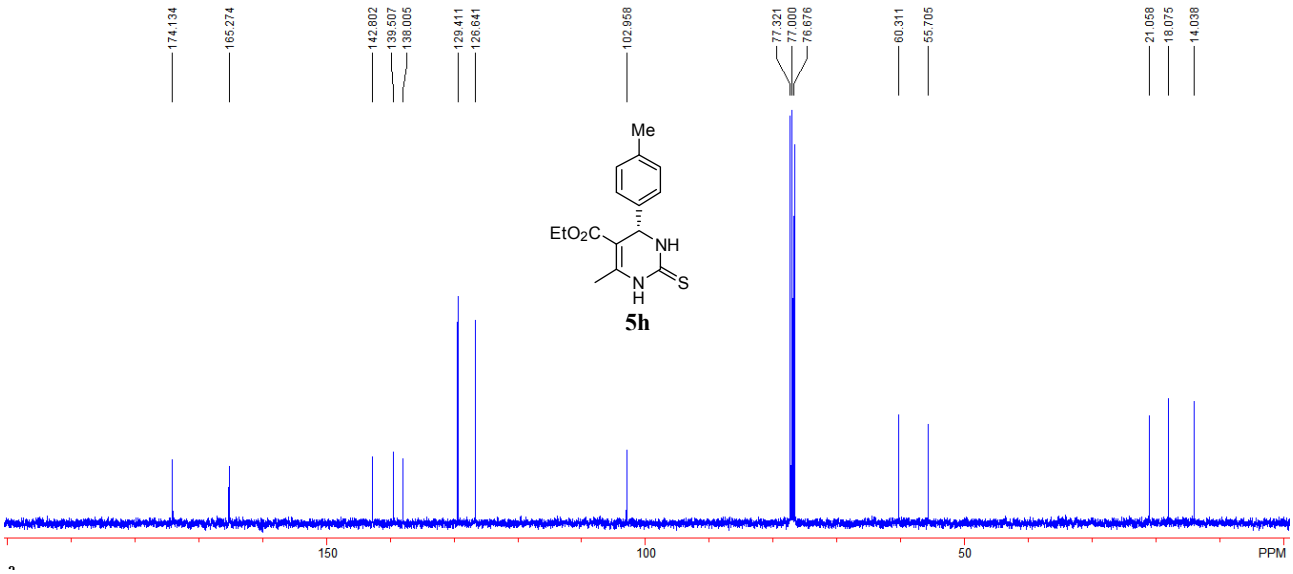
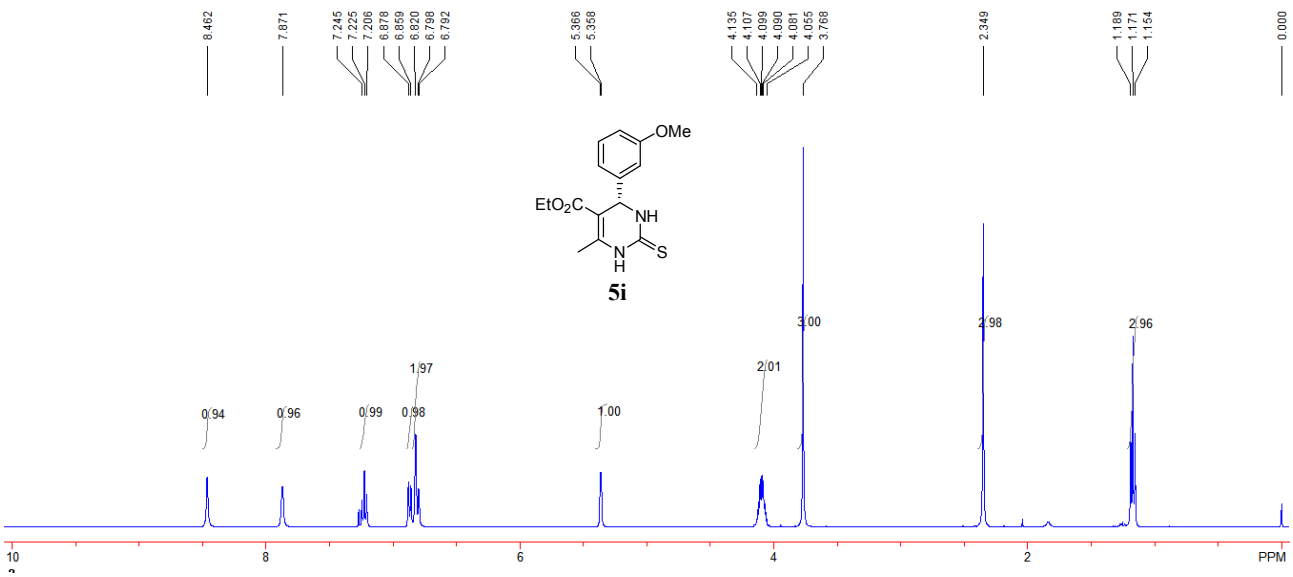
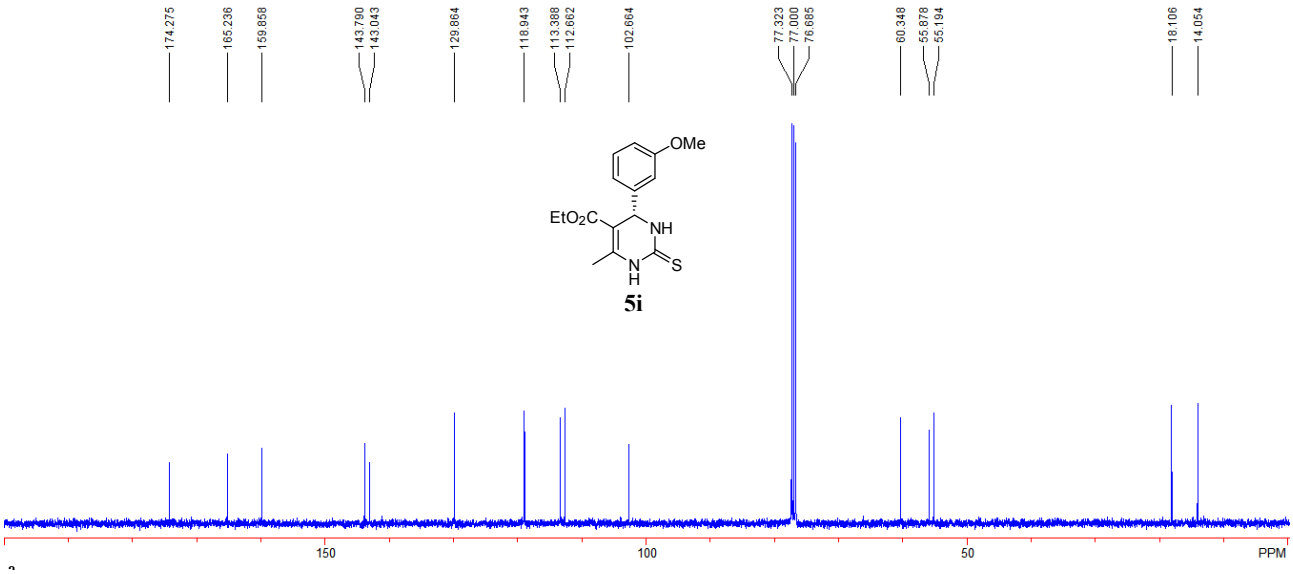
4.010
3.993
2.443
1.075
1.058
1.039
0.000
Cl
EtO2C
NH
N
H
S
5g
0.98
0.99
0.99
2.97
0.99
1.98
3.00
3.00
10
8
6
4
2
PPM

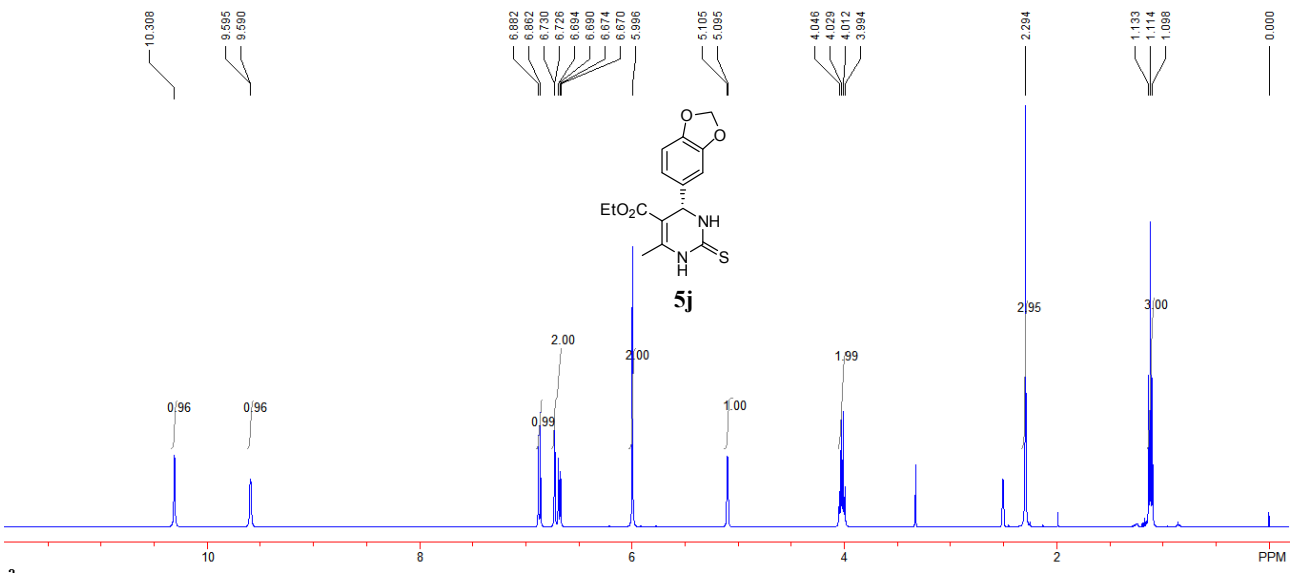

174.116
164.834
144.599
138.488
132.553
129.813
129.622
128.493
127.642
100.747
77.319
77.000
76.675
60.290
52.619
17.810
13.827
Cl
EtO2C
NH
N
H
S
5g
150
100
50
PPM







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9.590
6.882
6.862
6.730
6.726
6.694
6.690
6.674
6.670
5.996
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5.095
4.046
4.029
4.012
3.994
2.294
1.133
1.114
1.098
0.000
EtO2C
NH
N
H
S
5j
0.96
0.96
0.99
2.00
2.00
1.00
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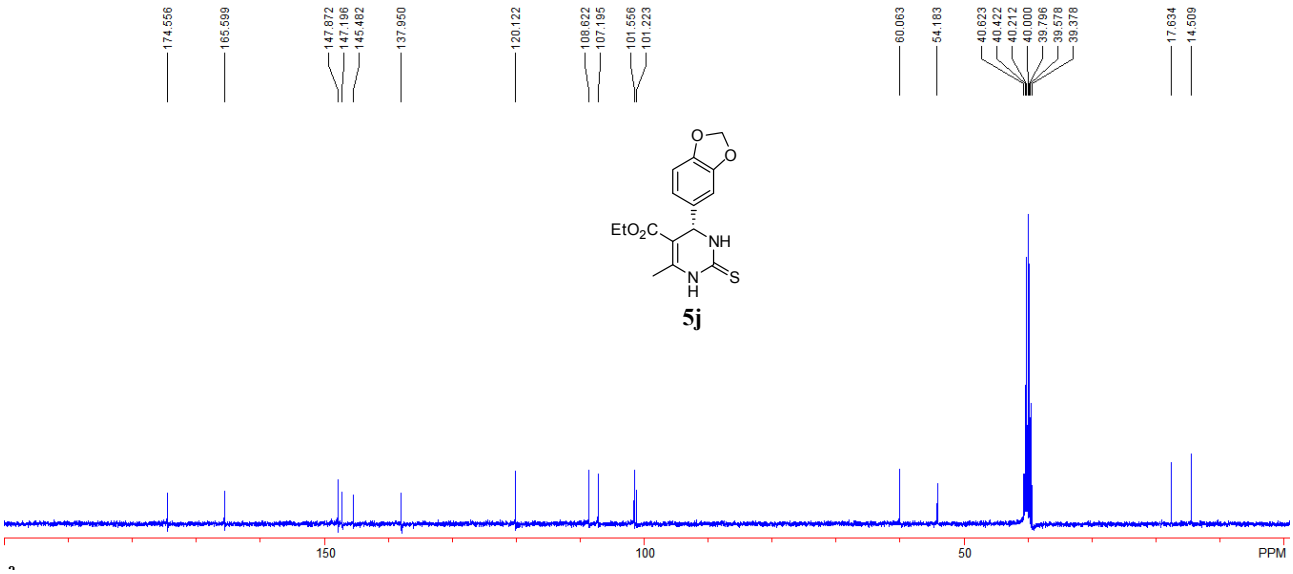
3.00
10
8
6
4
2
PPM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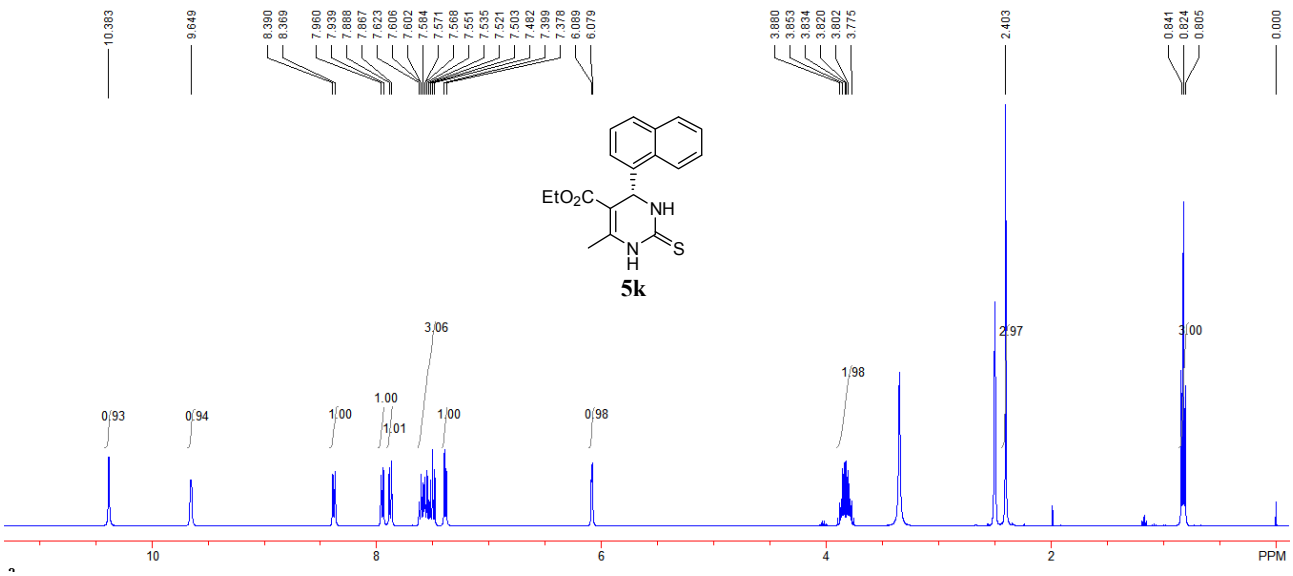
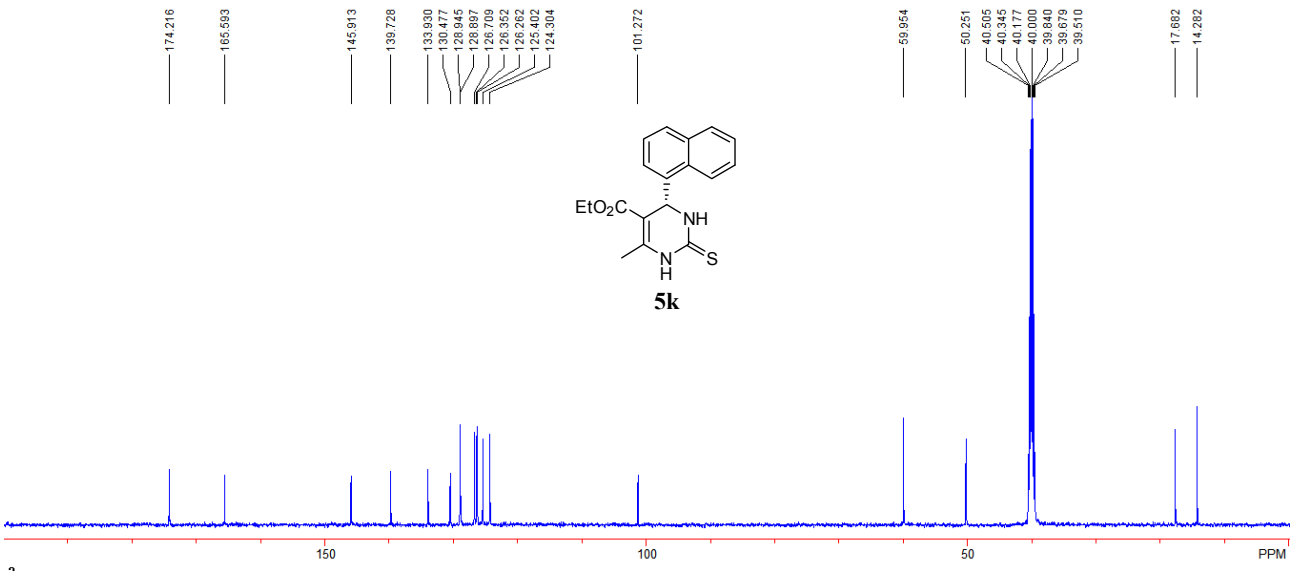
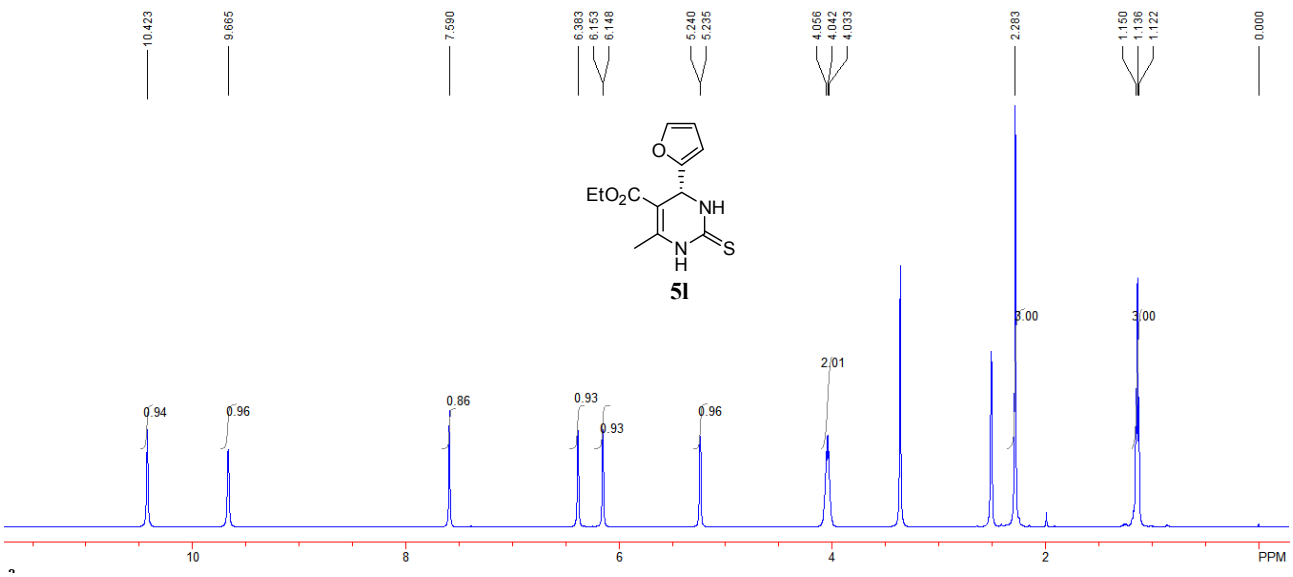
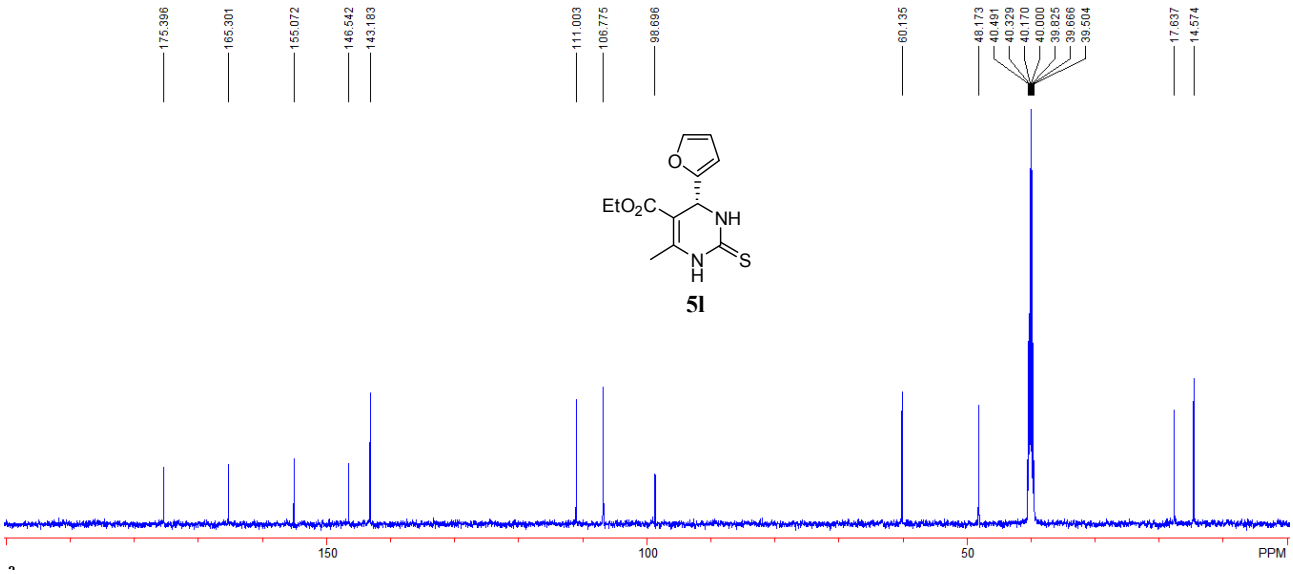
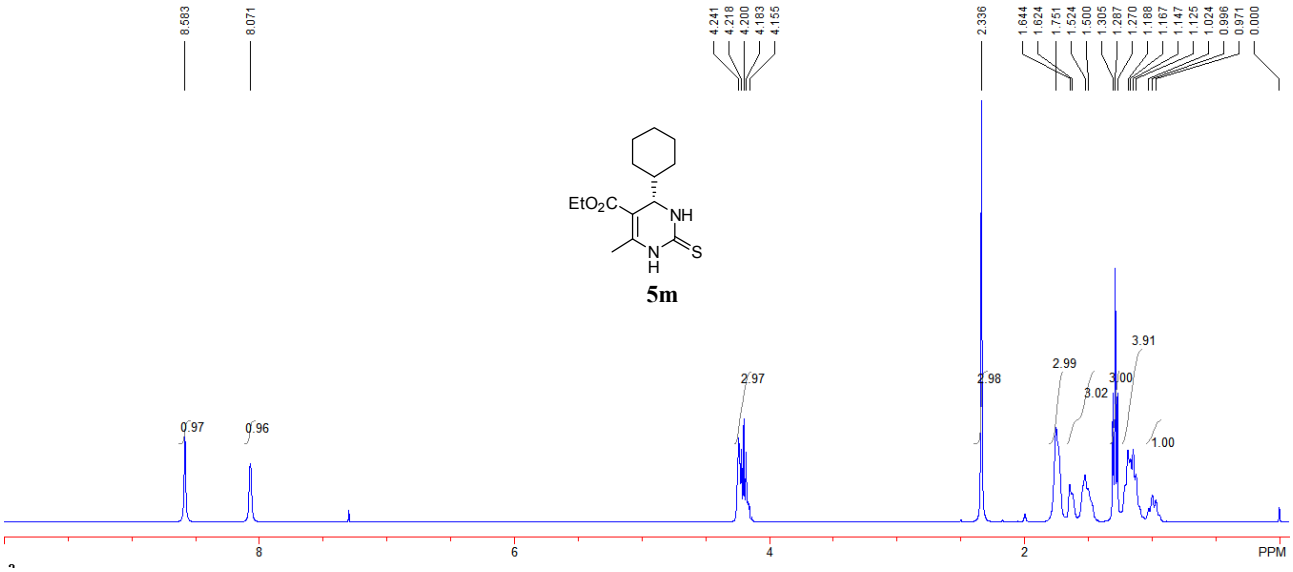
147.196
145.482
137.950
120.122
108.622
107.195
101.556
101.223
60.063
54.183
40.623
40.422
40.212
40.000
39.796
39.578
39.378
17.634
14.509
EtO2C
NH
N
H
S
5j
150
100
50
PPM

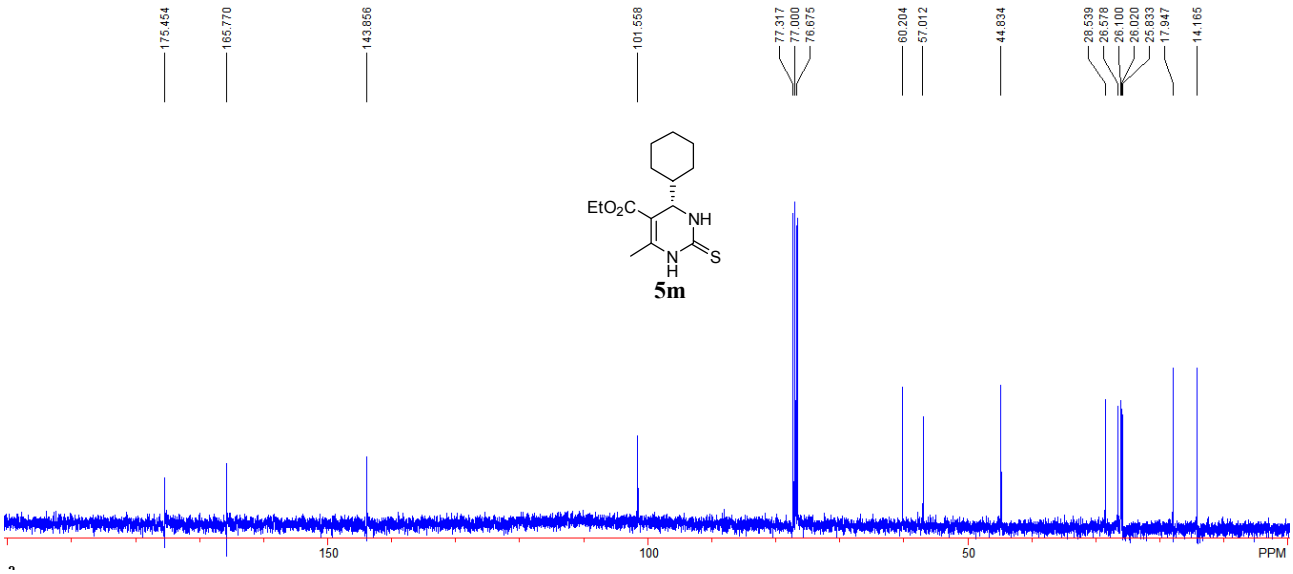


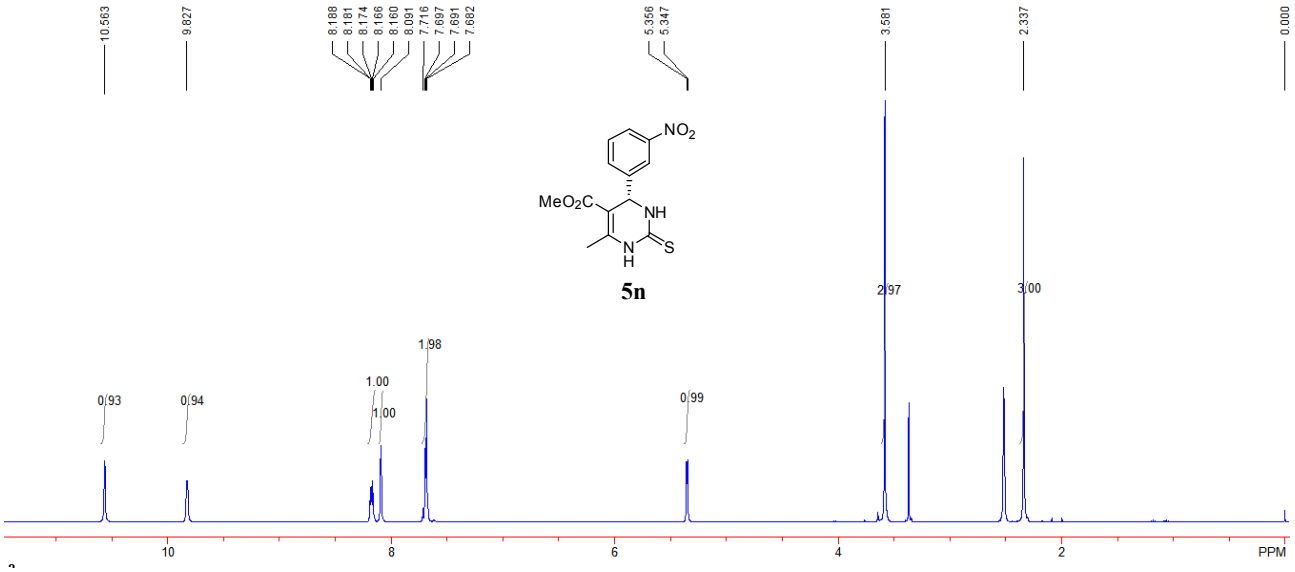








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5.347
3.581
2.337
0.000
NO2
MeO2C
NH
N
H
S
5n
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1.00
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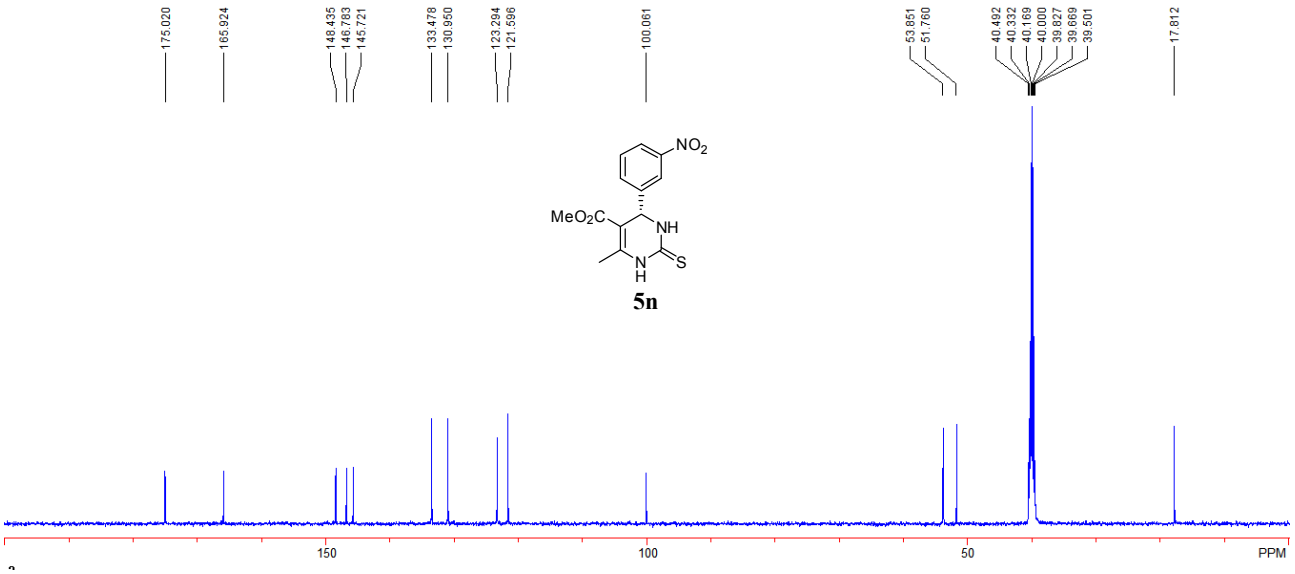
3.00
10
8
6
4
2
PPM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145.721
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100.061
53.851
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40.332
40.169
40.000
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NO2
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N
H
S
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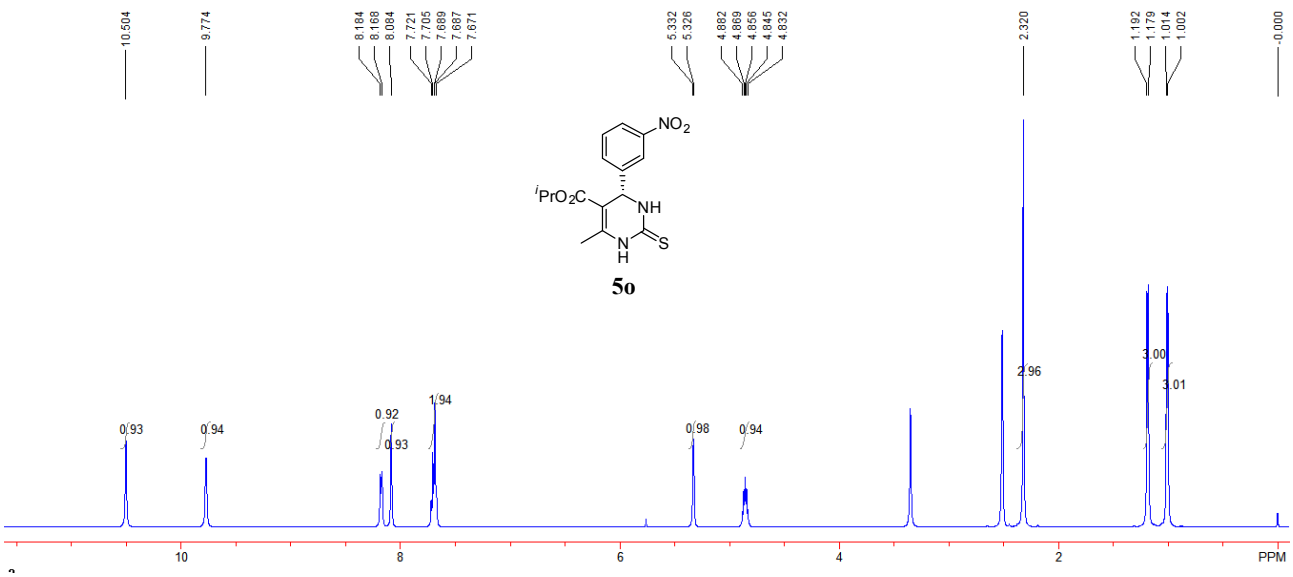
150
100
50
PPM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8.084
7.721
7.705
7.689
7.687
7.671
5.332
5.326
4.882
4.869
4.856
4.845
4.832
2.320
1.192
1.179
1.014
1.002
-0.000
NO2
iPrO2C
NH
N
H
S
0.93
0.94
0.92
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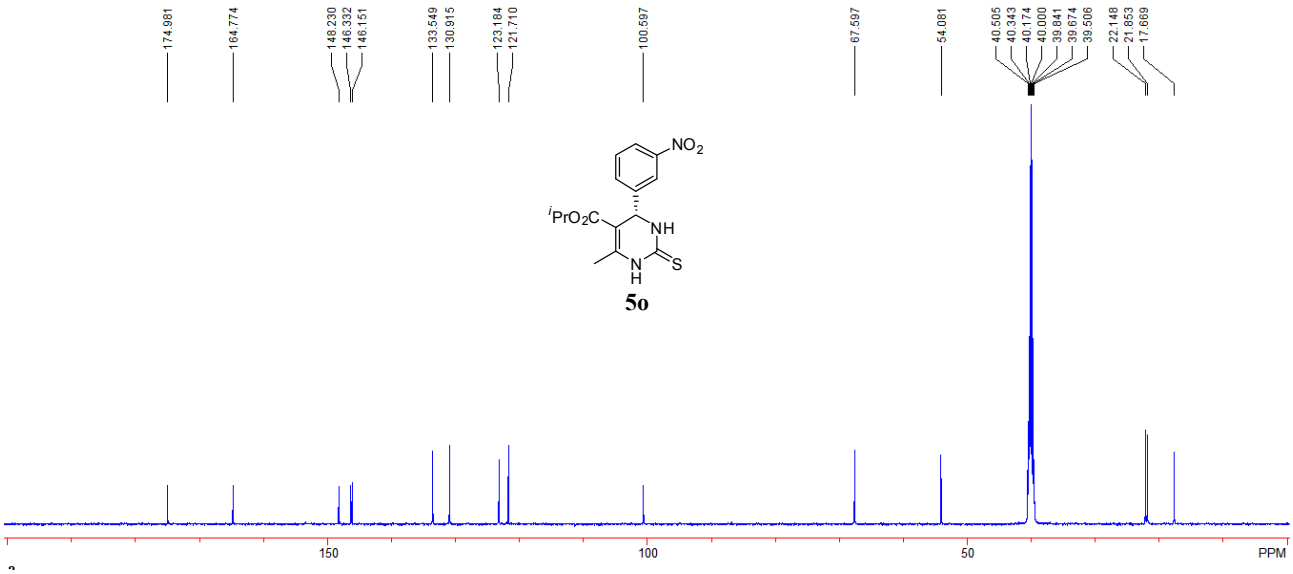
0.98
0.94
2.96
3.00
3.01
10
8
6
4
2
PPM

5o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146.332
146.151
133.549
130.915
123.184
121.710
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67.597
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40.343
40.174
40.000
39.841
39.674
39.506
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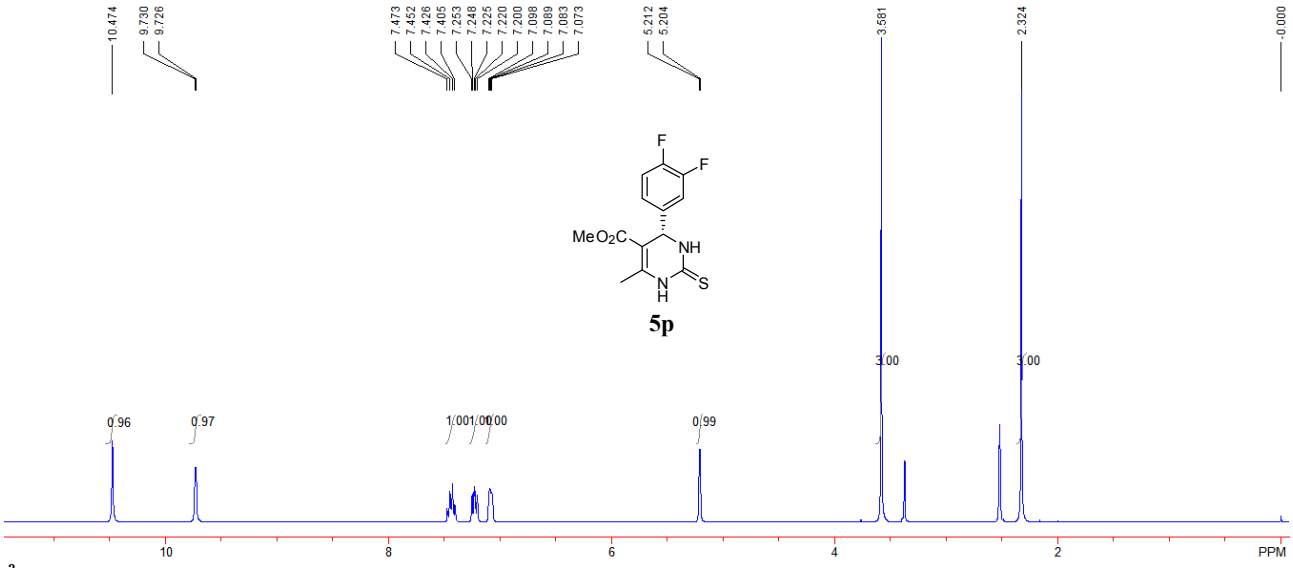
NO2
iPrO2C
NH
N
H
S
150
100
50
PPM

5o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7.452
7.426
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7.089
7.083
7.073
5.212
5.204
3.581
2.324
0.000
F
F
MeO2C
NH
N
H
S
5p
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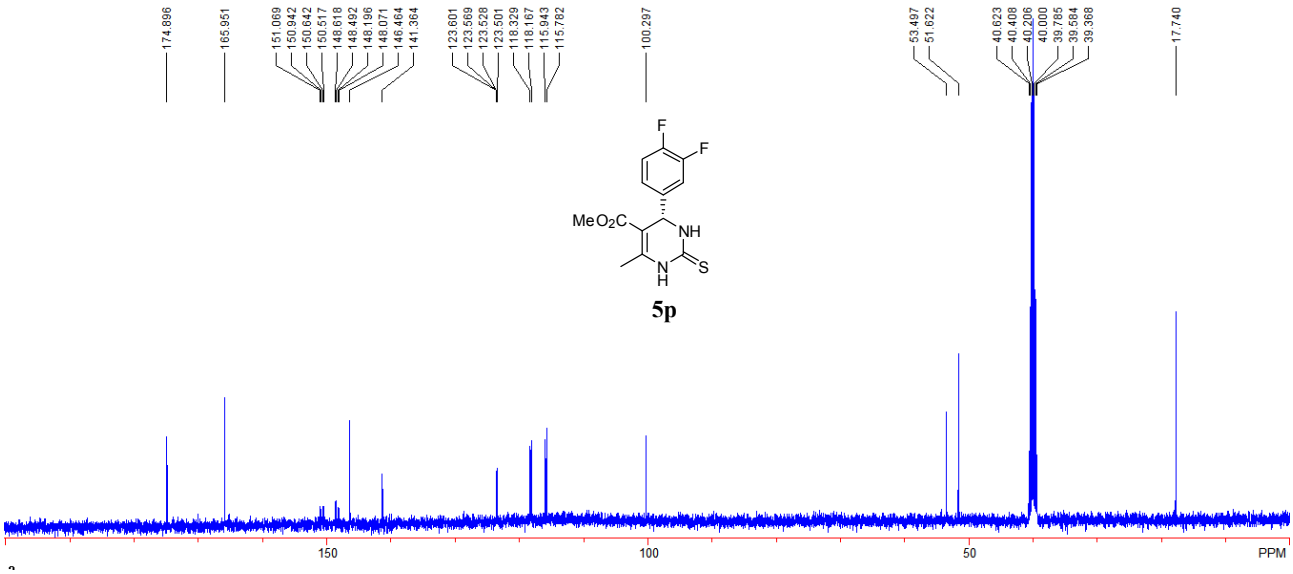
0.97
1.00
1.00
0.99
10
8
6
4
2
PPM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123.569
123.528
123.501
118.329
118.167
115.943
115.782
100.297
53.497
51.622
40.623
40.408
40.206
40.000
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F
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NH
N
H
S
5p
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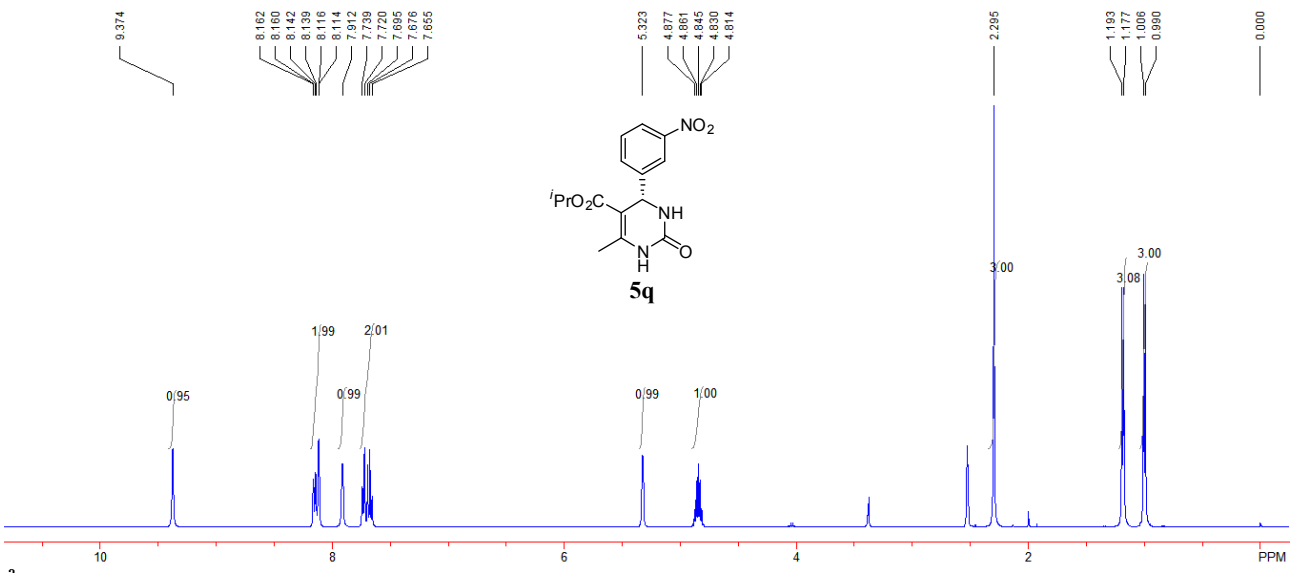
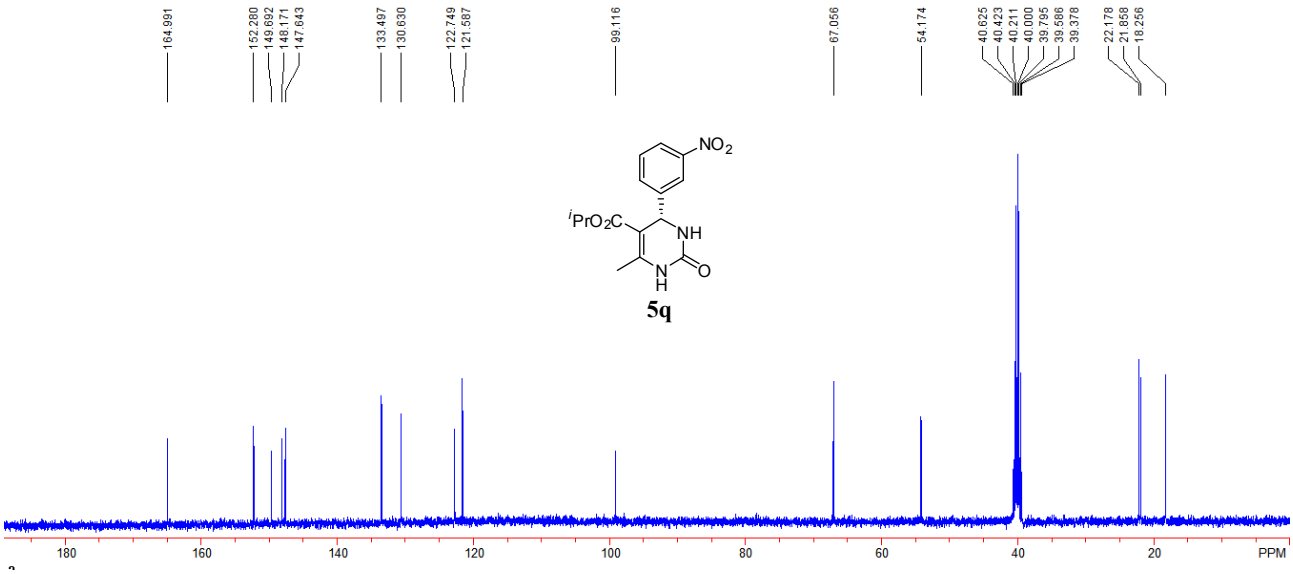
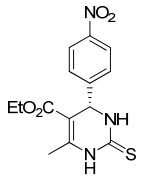
PPM



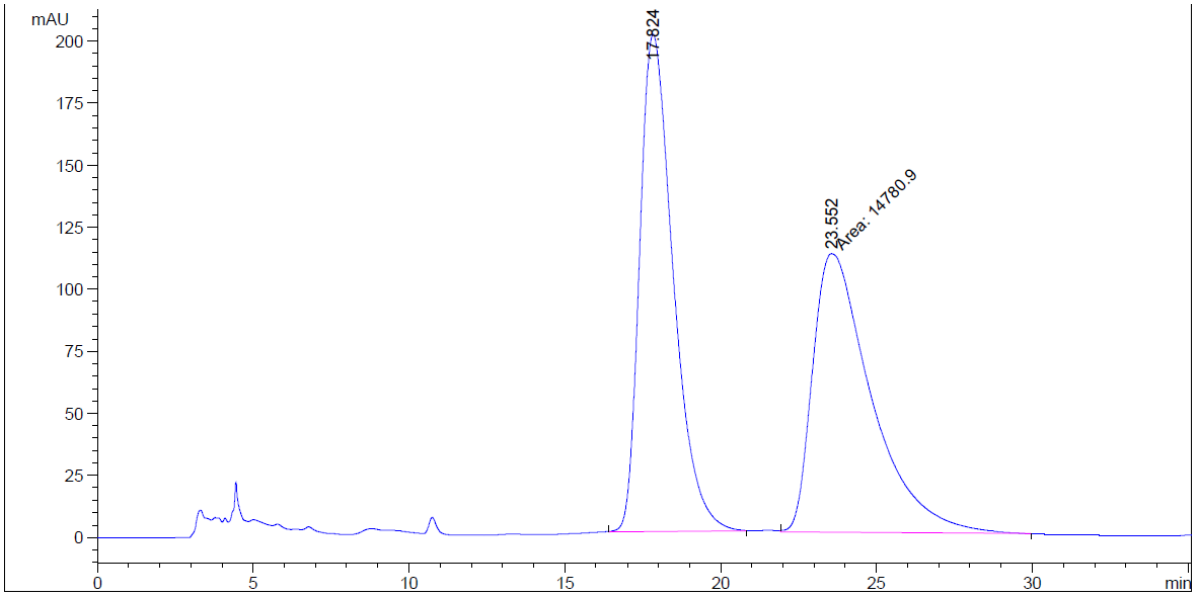


5. HPLC spectra for compounds 5a-q



5a

94% ee. [Daicel Chiralpak AS-H, *n*-hexane / *i*-propanol = 70 / 30, 1.0 mL/min, λ = 254 nm]



Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
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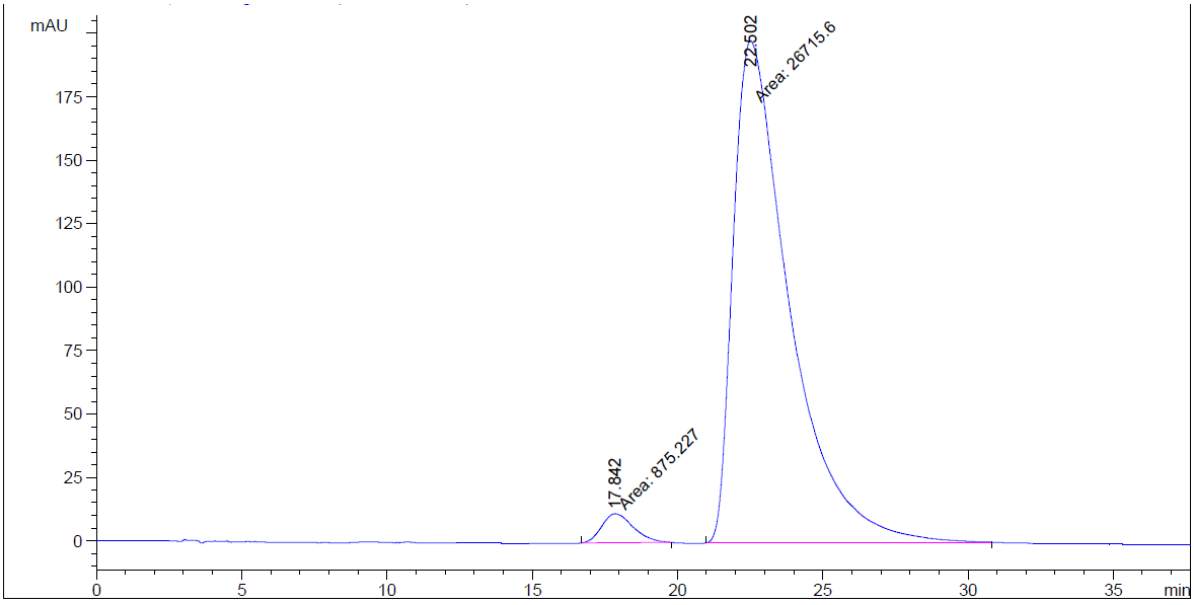
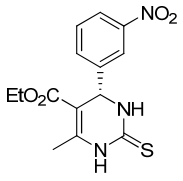
2	23.552	MM	2.1910	1.47809e4	112.43418	49.6205
Totals :				2.97880e4	312.93346	

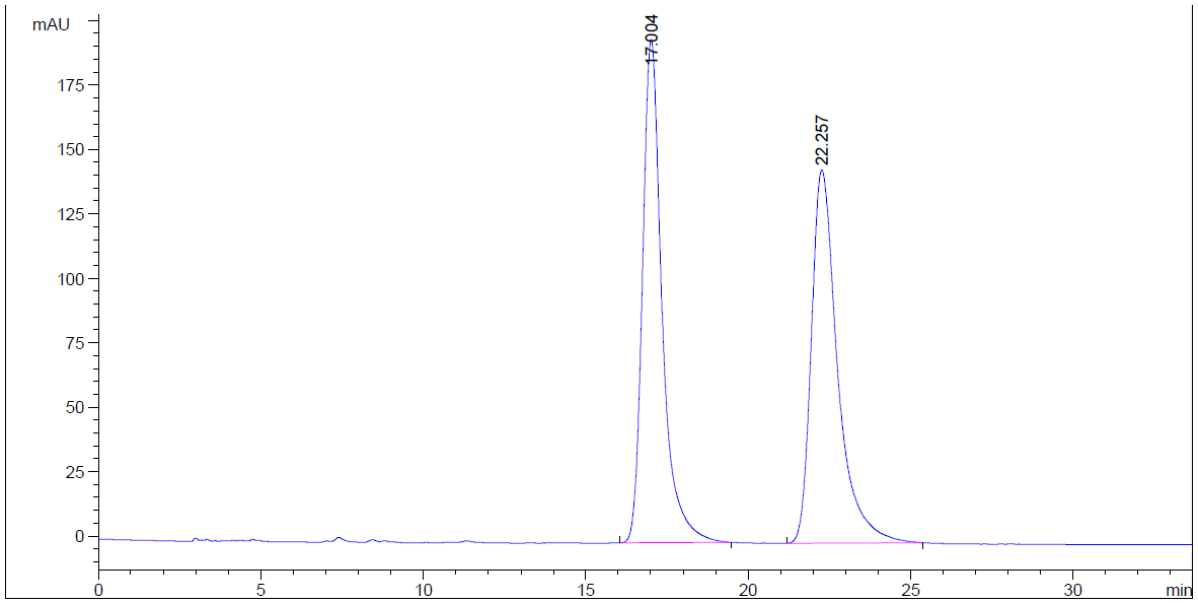


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	17.842	MM	1.2685	875.22687	11.49930	3.1722
2	22.502	MM	2.2492	2.67156e4	197.96330	96.8278
Totals :				2.75908e4	209.46260	

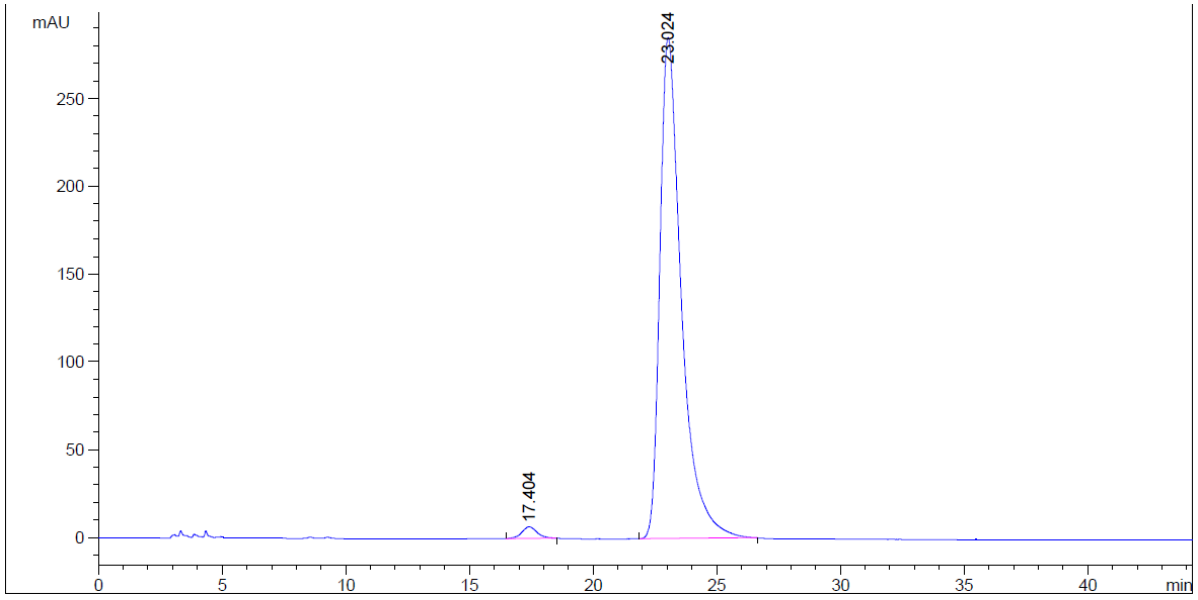


5b

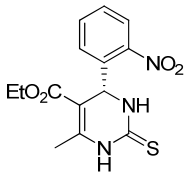
97% ee. [Daicel Chiralpak AD-H, *n*-hexane / *i*-propanol = 80 / 20, 1.0 mL/min, λ = 254 nm]



Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	17.004	BB	0.6296	8175.65186	195.32120	50.0611
2	22.257	BB	0.8465	8155.68408	144.78120	49.9389
Totals :				1.63313e4	340.10240	

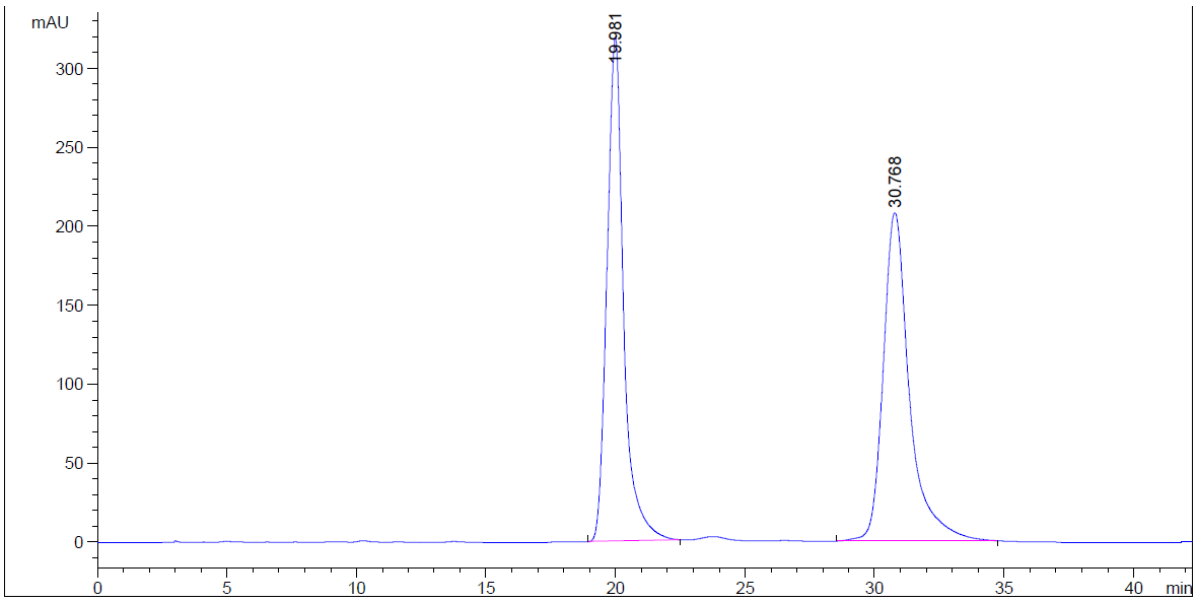


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	17.404	BB	0.6625	297.75690	6.70150	1.6942
2	23.024	BB	0.9010	1.72770e4	285.52570	98.3058
Totals :				1.75747e4	292.22720	

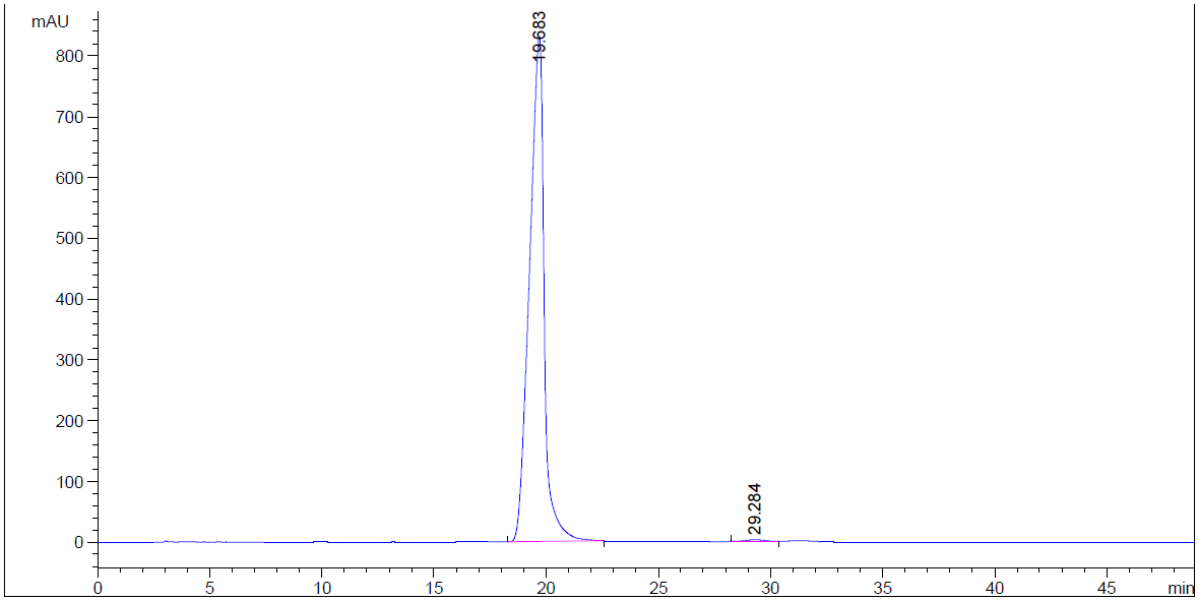


5c

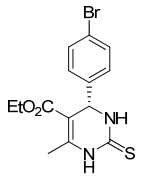
99% ee. [Daicel Chiralpak AD-H, *n*-hexane / *i*-propanol = 90 / 10, 1.0 mL/min, λ = 254 nm]



Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	19.981	PB	0.6755	1.42570e4	319.13693	49.3004
2	30.768	BB	1.0479	1.46616e4	208.03734	50.6996
Totals :				2.89186e4	527.17427	

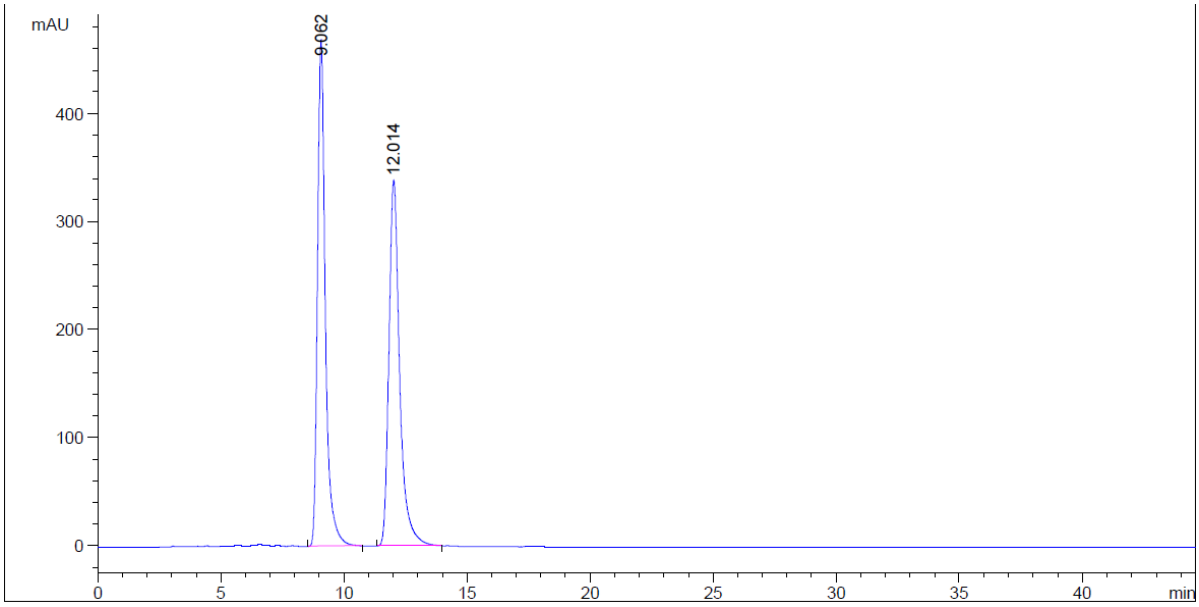


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	19.683	PB	0.6870	3.79402e4	831.03552	99.4516
2	29.284	BV	0.8822	209.19762	3.23646	0.5484
Totals :				3.81494e4	834.27198	

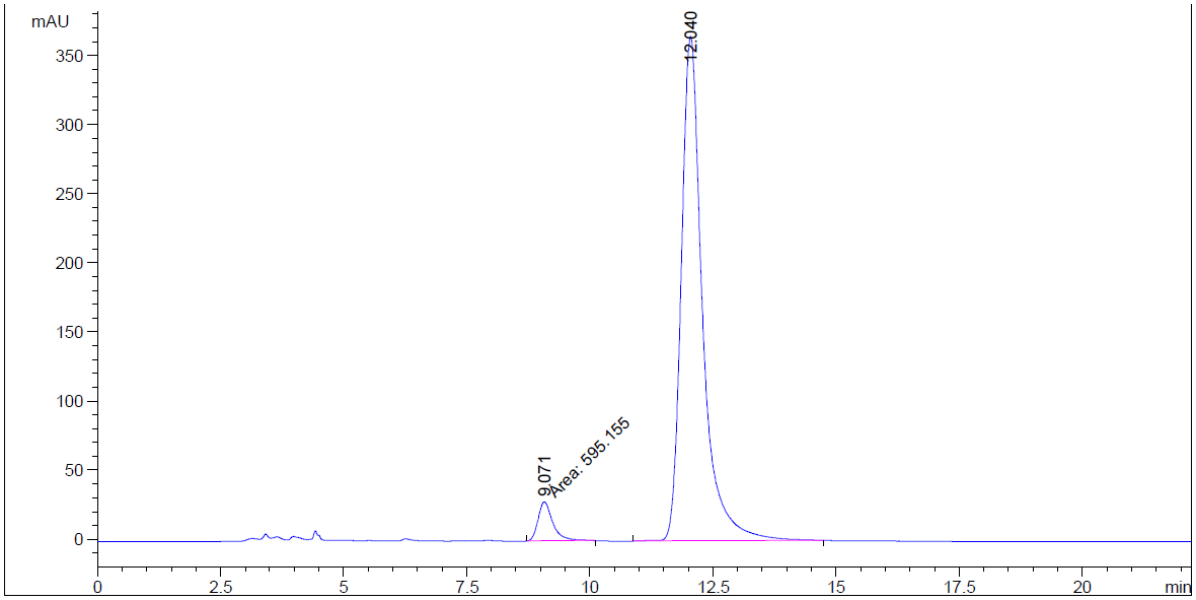


5d

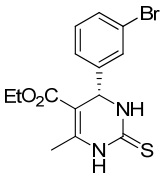
90% ee. [Daicel Chiralpak AD-H, *n*-hexane / *i*-propanol = 80 / 20, 1.0 mL/min, λ = 254 nm]



Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	9.062	BB	0.3318	1.03538e4	469.09305	50.0929
2	12.014	PB	0.4586	1.03154e4	338.79376	49.9071
Totals :				2.06692e4	807.88681	

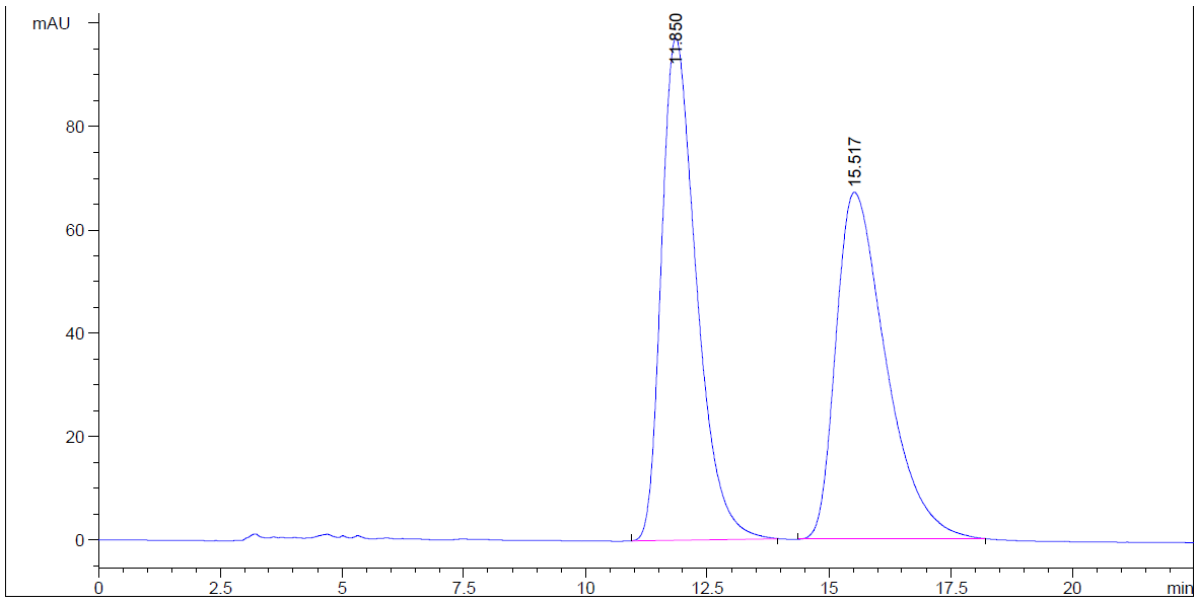


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	9.071	MM	0.3510	595.15515	28.26121	5.1358
2	12.040	BB	0.4519	1.09932e4	364.91504	94.8642
Totals :				1.15883e4	393.17625	

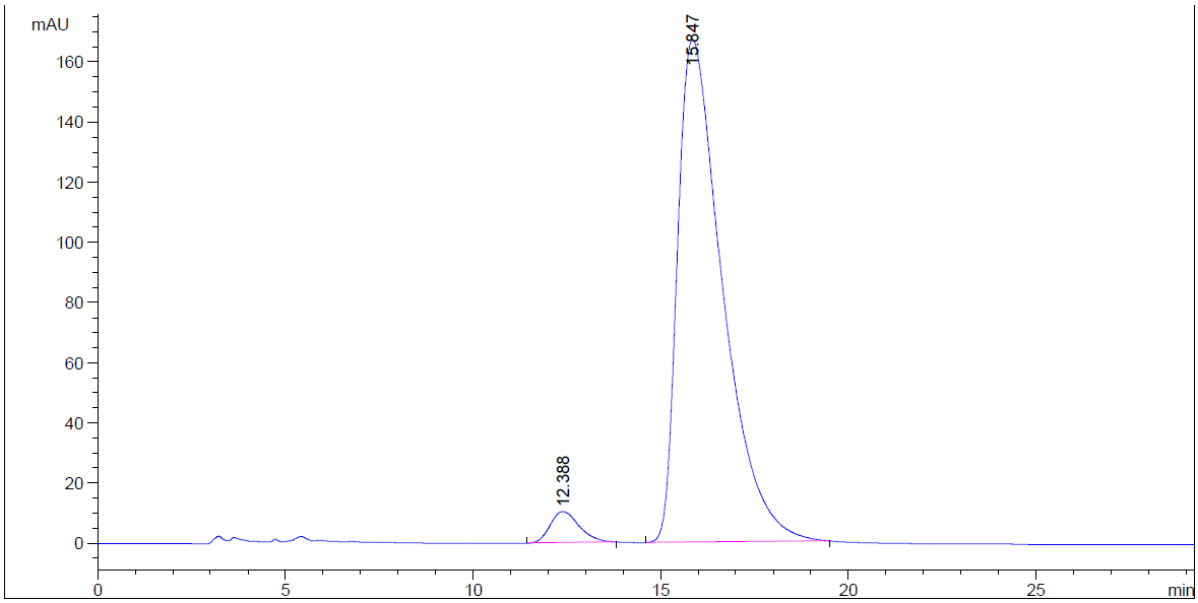


5e

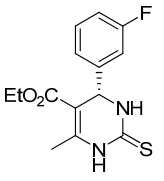
92% ee. [Daicel Chiralpak AS-H, *n*-hexane / *i*-propanol = 70 / 30, 1.0 mL/min, λ = 254 nm]



Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	11.850	BB	0.7621	4867.41748	97.15600	50.3150
2	15.517	PB	1.0654	4806.47607	67.12450	49.6850
Totals :				9673.89355	164.28049	

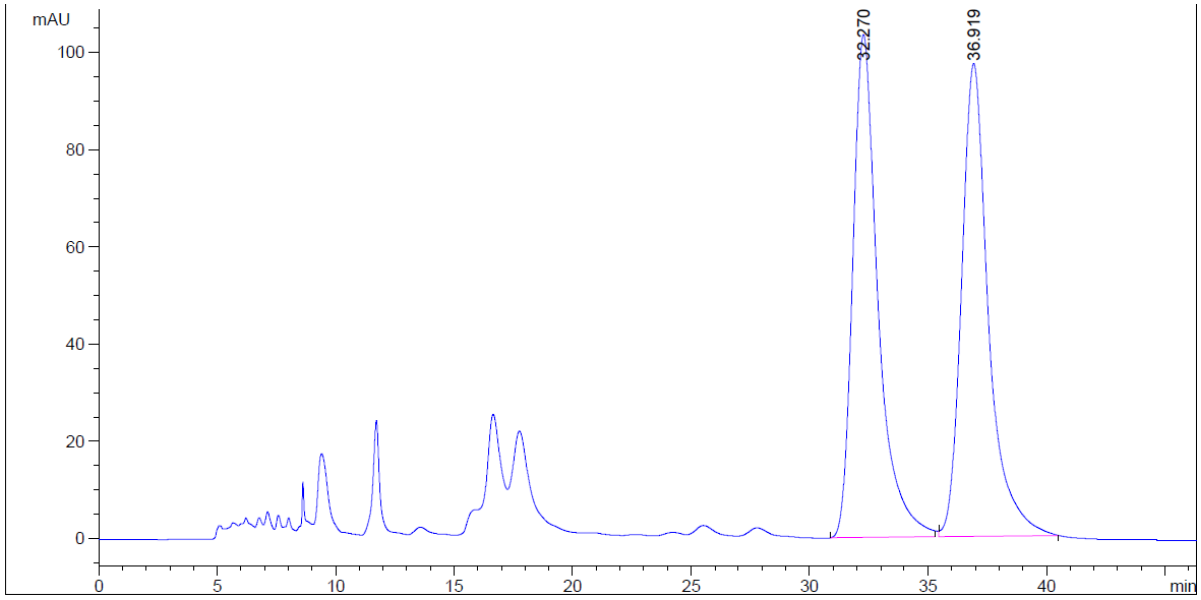


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	12.388	BB	0.8164	564.57837	10.40671	3.8921
2	15.847	BB	1.2499	1.39411e4	167.10834	96.1079
Totals :				1.45057e4	177.51505	

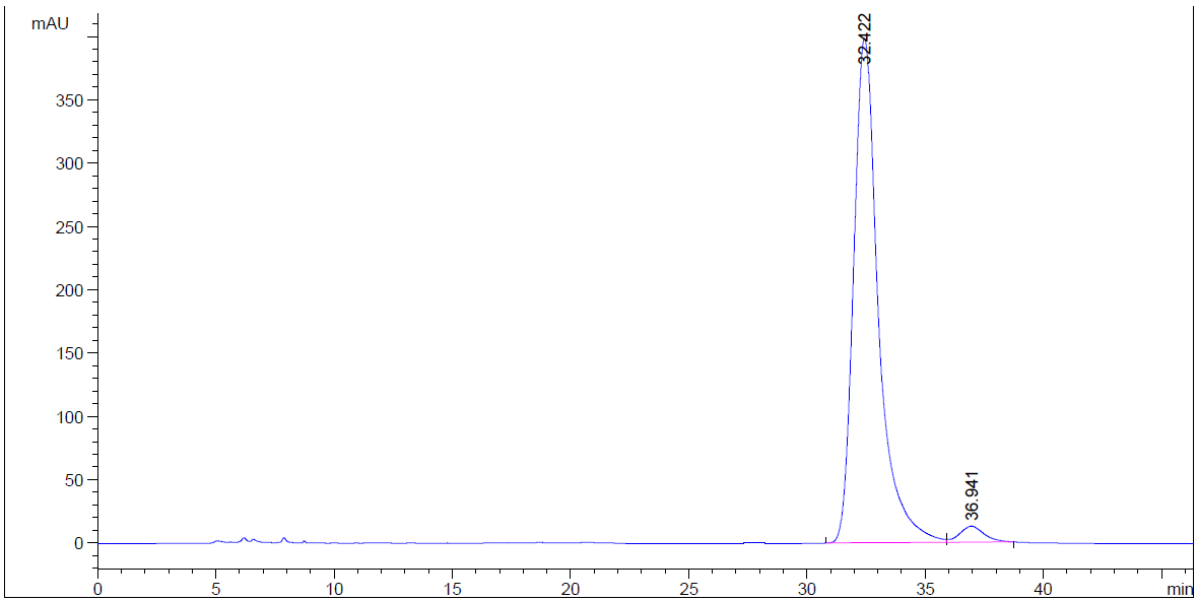


5f

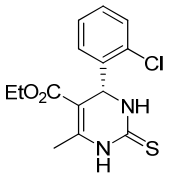
94% ee. [Daicel Chiralpak AD-H, *n*-hexane / *i*-propanol = 90 / 10, 0.6 mL/min, λ = 254 nm]



Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	32.270	BB	1.1124	7677.75098	103.57271	49.9219
2	36.919	BB	1.1833	7701.75928	97.38155	50.0781
Totals :				1.53795e4	200.95425	

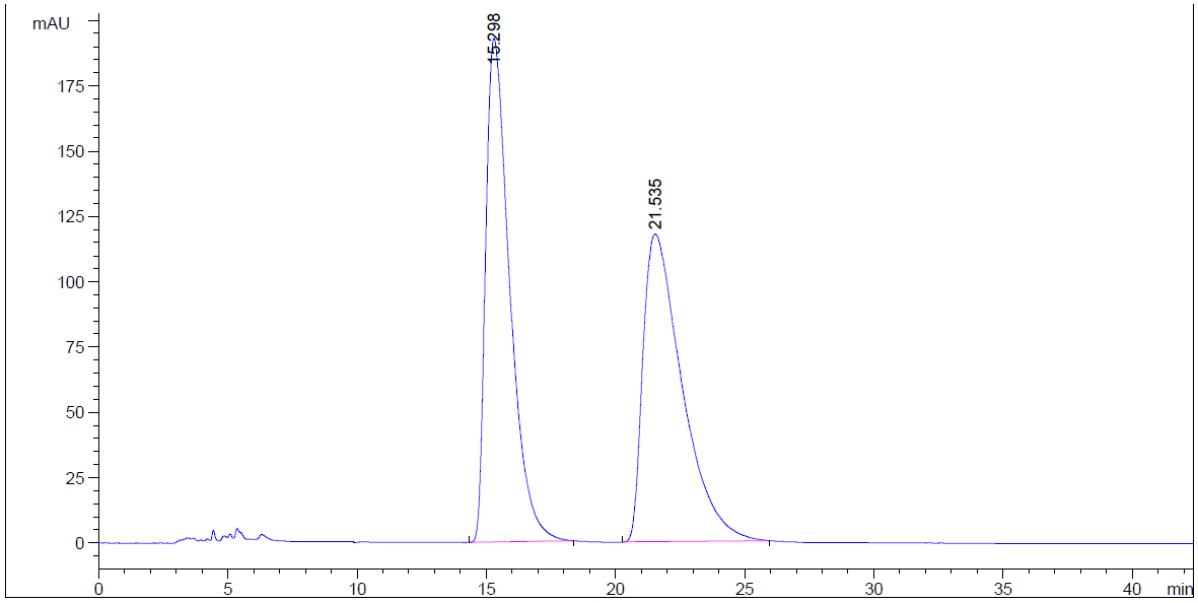


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	32.422	BB	1.0864	2.91055e4	398.57510	96.9355
2	36.941	BB	1.0575	920.15021	12.83832	3.0645
Totals :				3.00257e4	411.41342	

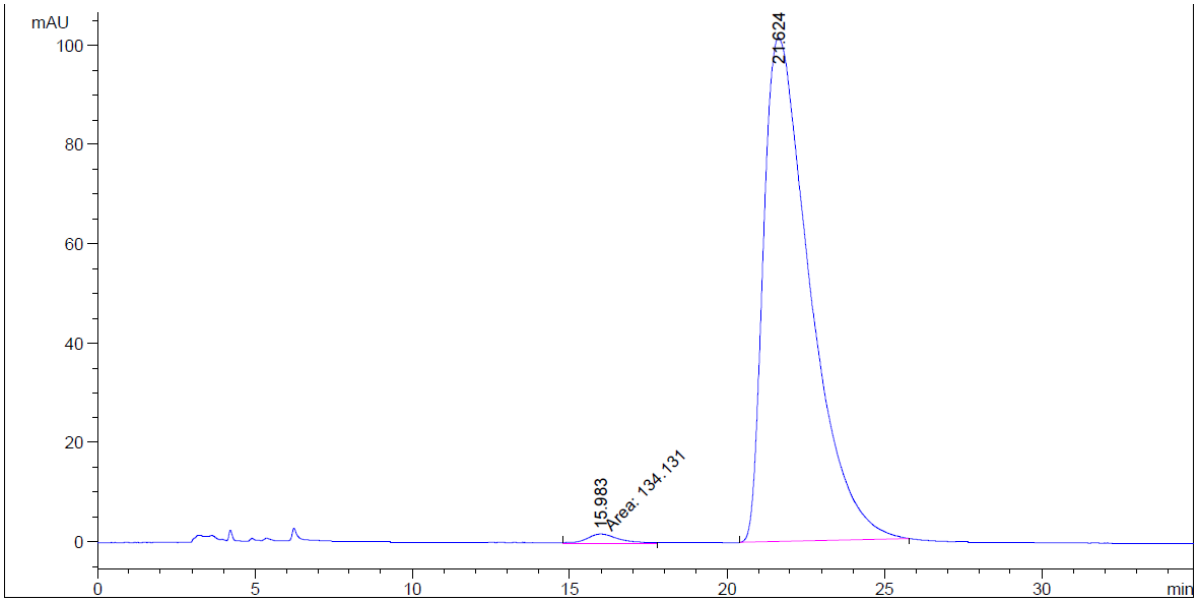


5g

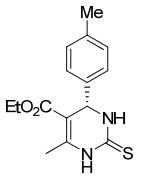
97% ee. [Daicel Chiralpak AS-H, *n*-hexane / *i*-propanol = 85 / 15, 1.0 mL/min, λ = 254 nm]



Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	15.298	BB	1.0028	1.24863e4	192.86852	50.1391
2	21.535	BB	1.4852	1.24170e4	117.87386	49.8609
Totals :				2.49033e4	310.74237	

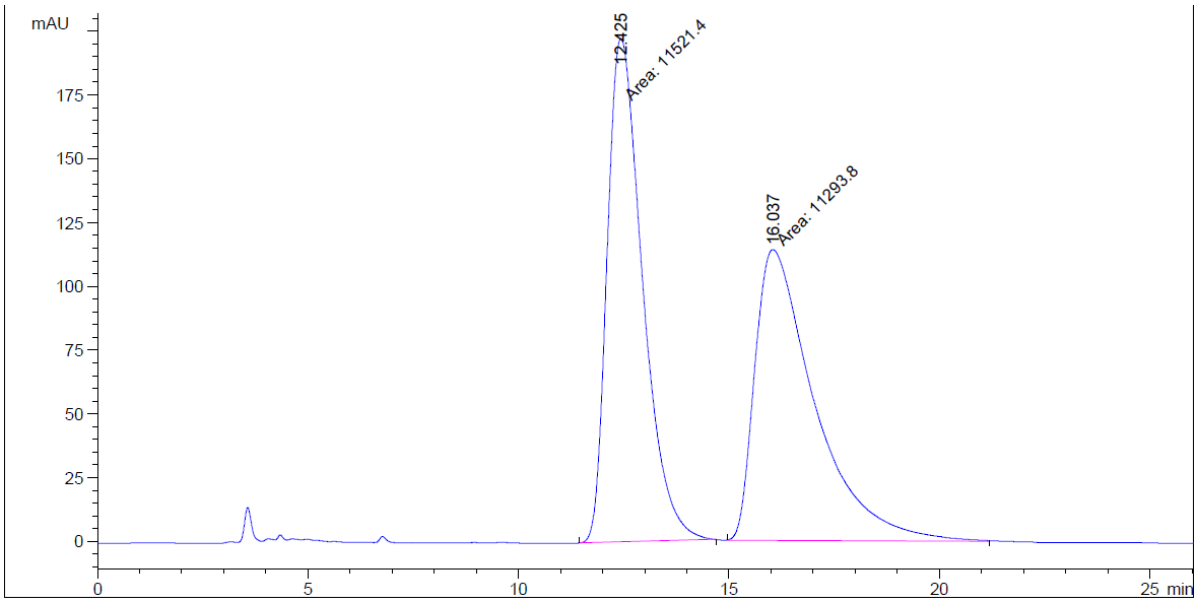


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	15.983	MM	1.2026	134.13109	1.85895	1.2716
2	21.624	BB	1.4639	1.04143e4	101.58916	98.7284
Totals :				1.05484e4	103.44811	

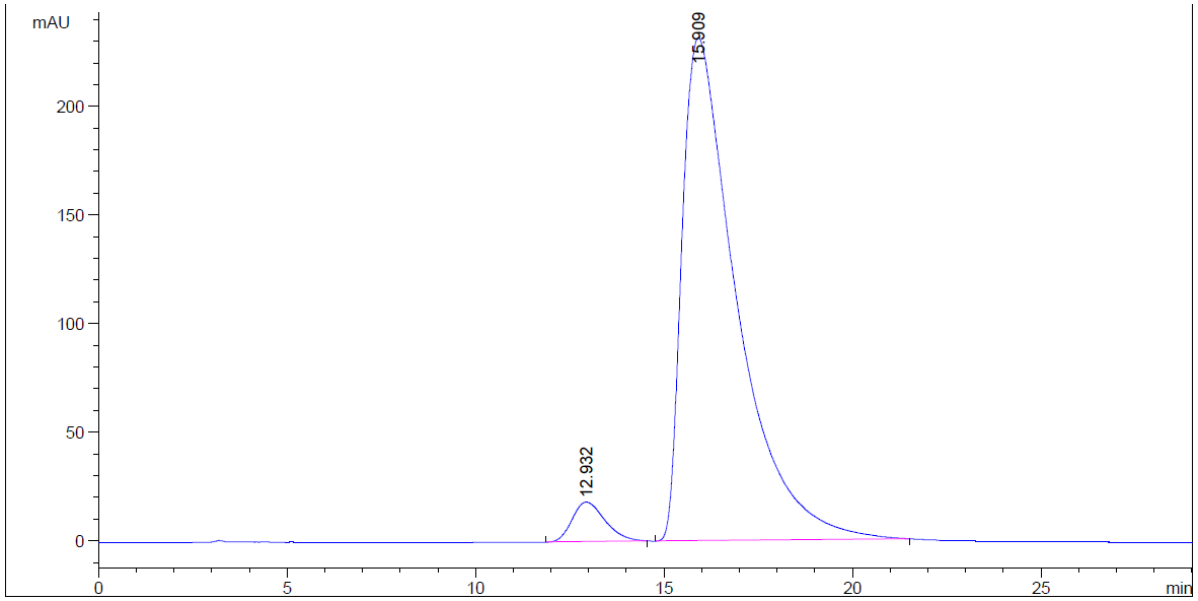


5h

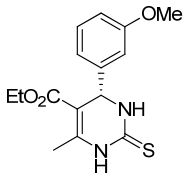
91% ee. [Daicel Chiralpak AS-H, *n*-hexane / *i*-propanol = 70 / 30, 1.0 mL/min, λ = 254 nm]



Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	12.425	MM	0.9727	1.15214e4	197.40623	50.4987
2	16.037	MM	1.6494	1.12938e4	114.11863	49.5013
Totals :				2.28152e4	311.52486	

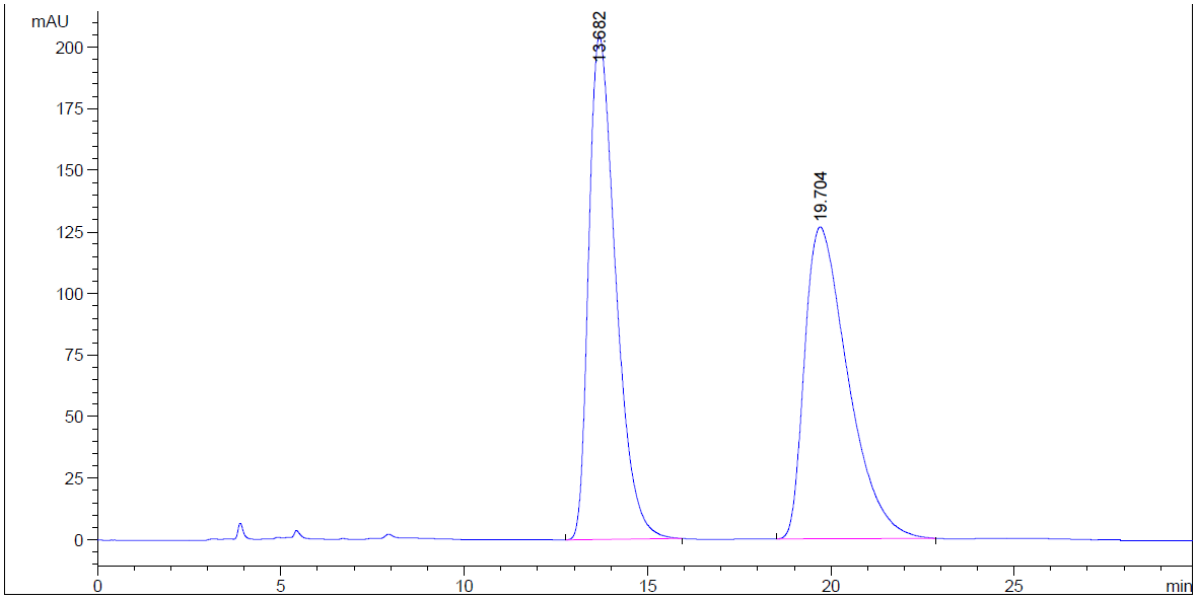


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	12.932	BB	0.9223	1117.75159	18.29885	4.5617
2	15.909	PB	1.5020	2.33854e4	231.73943	95.4383
Totals :				2.45031e4	250.03828	

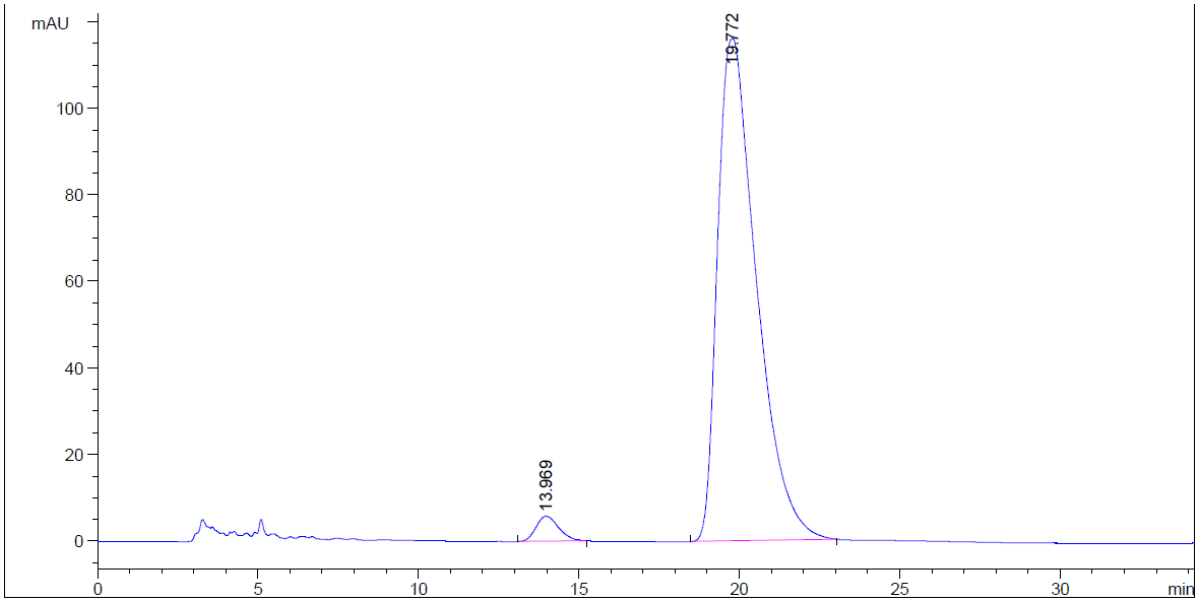


5i

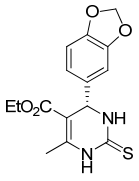
94% ee. [Daicel Chiralpak AS-H, *n*-hexane / *i*-propanol = 70 / 30, 1.0 mL/min, λ = 254 nm]



Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	13.682	BB	0.7879	1.04859e4	204.36339	50.1747
2	19.704	BB	1.2253	1.04129e4	126.69315	49.8253
Totals :				2.08989e4	331.05653	

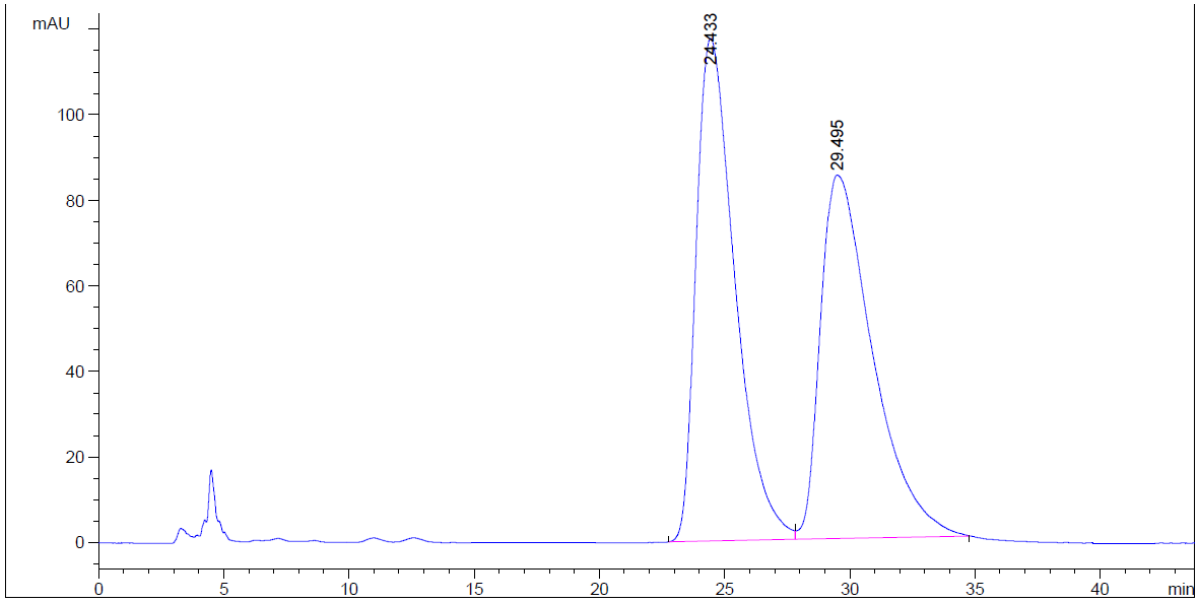


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	13.969	BB	0.7380	289.10699	5.83761	2.8662
2	19.772	BB	1.2604	9797.74805	116.18851	97.1338
Totals :				1.00869e4	122.02612	

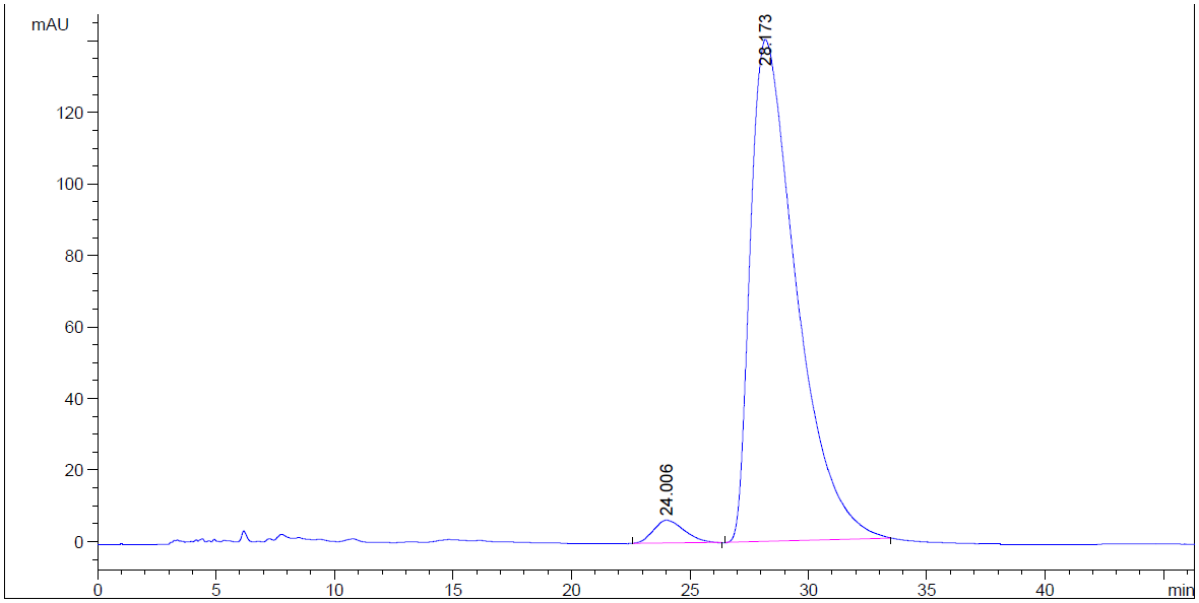


5j

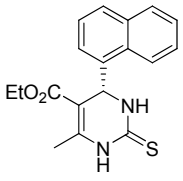
94% ee. [Daicel Chiralpak AS-H, *n*-hexane / *i*-propanol = 70 / 30, 1.0 mL/min, λ = 254 nm]



Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	24.433	BB	1.5728	1.27076e4	117.54663	50.6044
2	29.495	BB	2.0819	1.24041e4	85.03219	49.3956
Totals :				2.51117e4	202.57882	

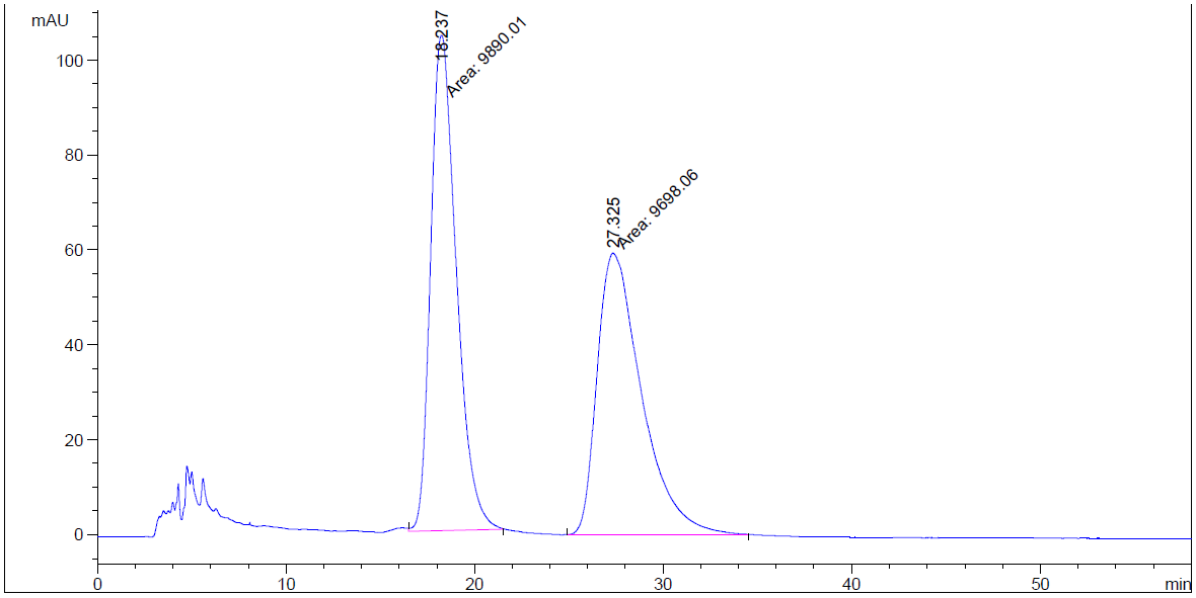


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	24.006	BP	1.1262	590.02887	6.44535	3.0202
2	28.173	BB	1.9155	1.89459e4	140.35837	96.9798
Totals :				1.95360e4	146.80372	

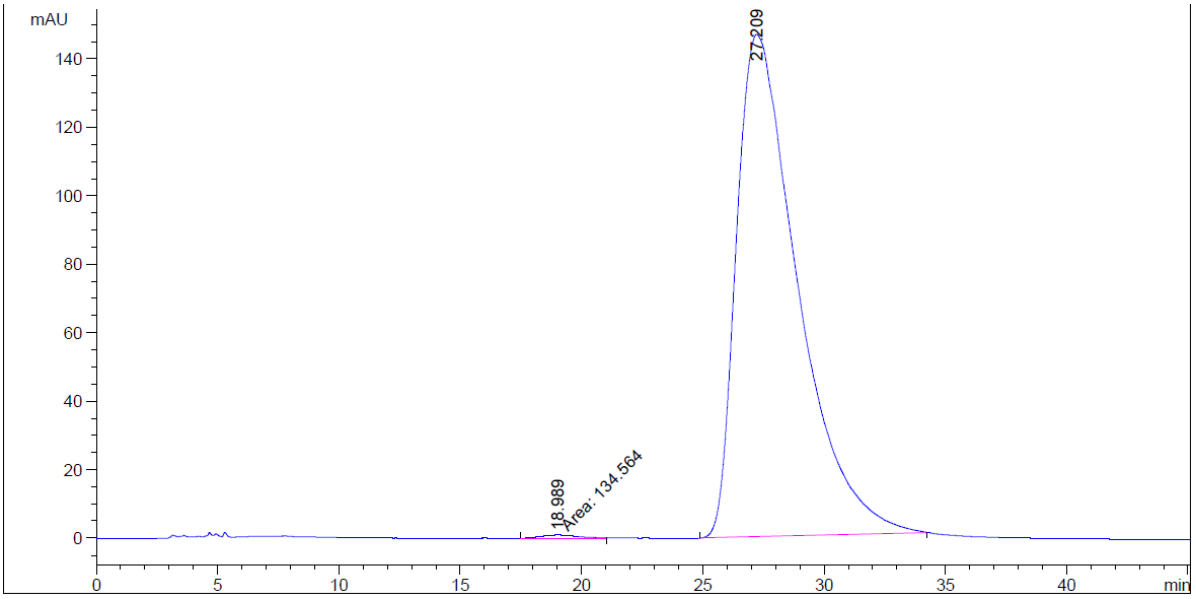


5k

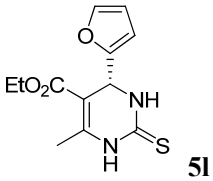
99% ee. [Daicel Chiralpak AS-H, *n*-hexane / *i*-propanol = 70 / 30, 1.0 mL/min, λ = 254 nm]



Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	18.237	FM	1.5780	9890.00879	104.45937	50.4900
2	27.325	MM	2.7247	9698.05566	59.32167	49.5100
Totals :				1.95881e4	163.78104	

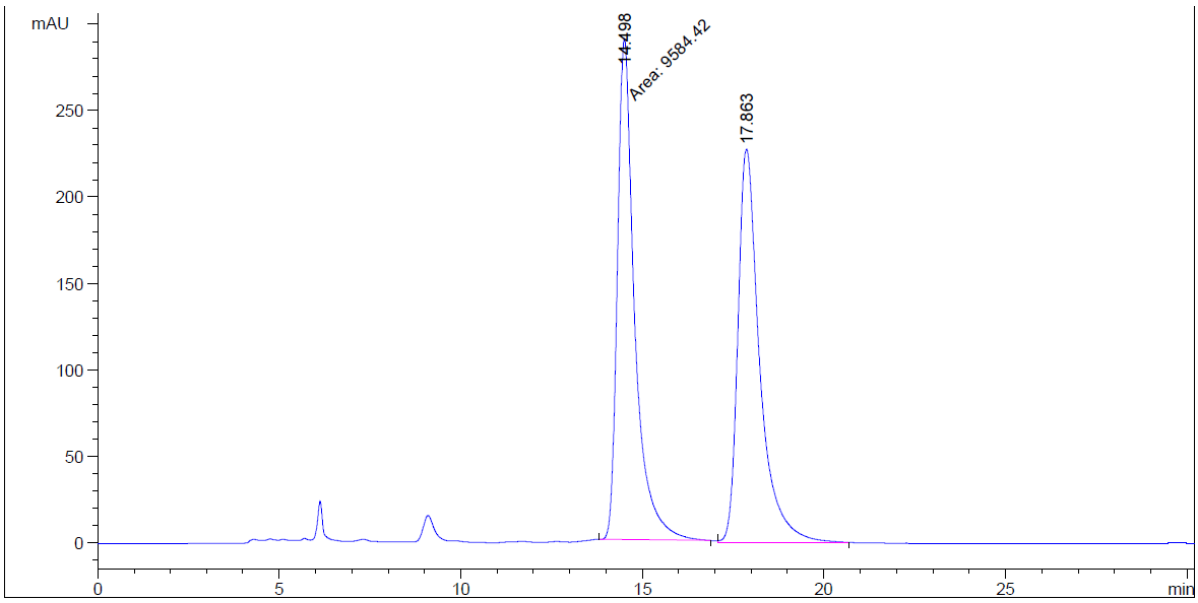


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	18.989	MM	1.9886	134.56404	1.12777	0.5206
2	27.209	BB	2.4423	2.57110e4	146.79988	99.4794
Totals :				2.58456e4	147.92765	

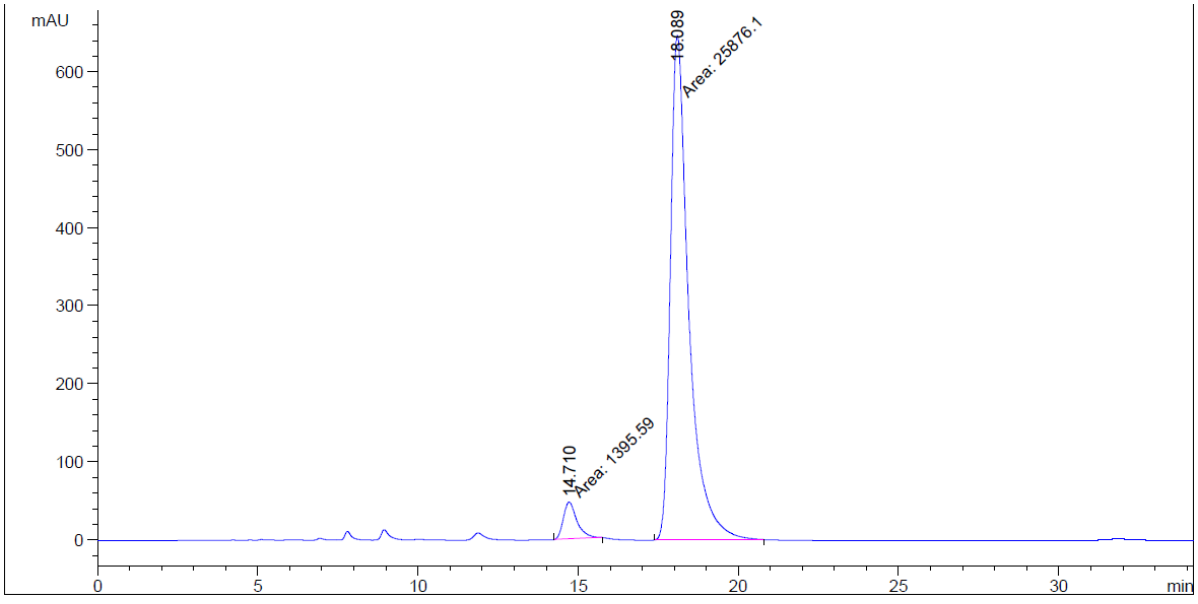


5l

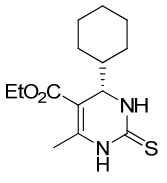
90% ee. [Daicel Chiralpak AD-H, *n*-hexane / *i*-propanol = 80 / 20, 0.7 mL/min, λ = 254 nm]



Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	14.498	MM	0.5508	9584.41992	290.01431	50.2016
2	17.863	BB	0.6214	9507.45410	227.53589	49.7984
Totals :				1.90919e4	517.55020	

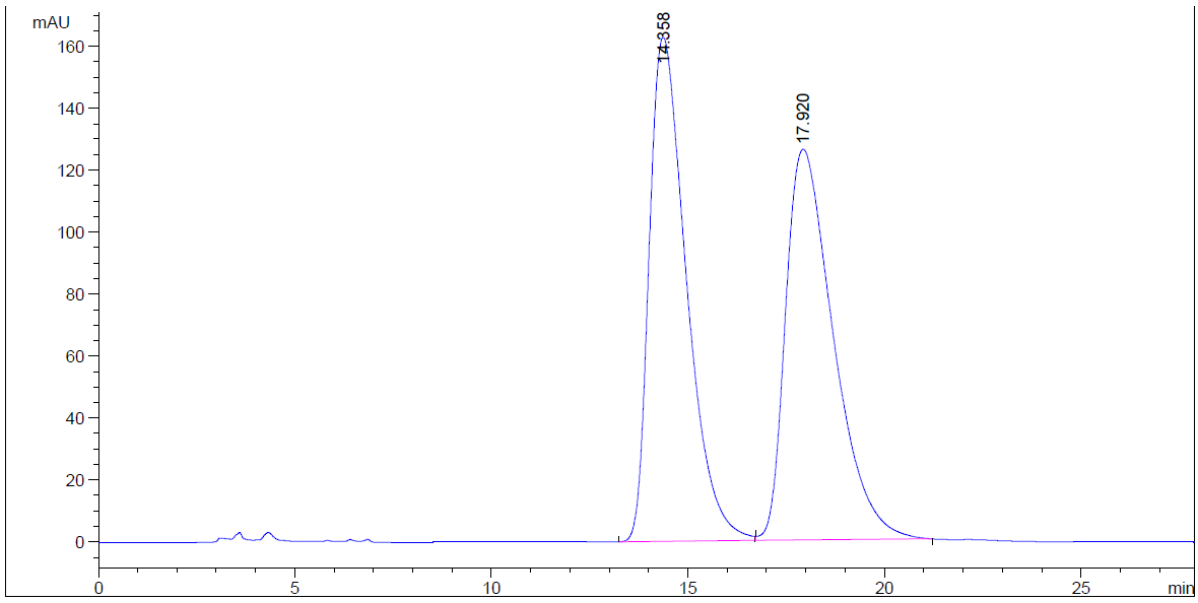


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	14.710	MM	0.4907	1395.59192	47.39988	5.1174
2	18.089	MM	0.6667	2.58761e4	646.89917	94.8826
Totals :				2.72717e4	694.29905	

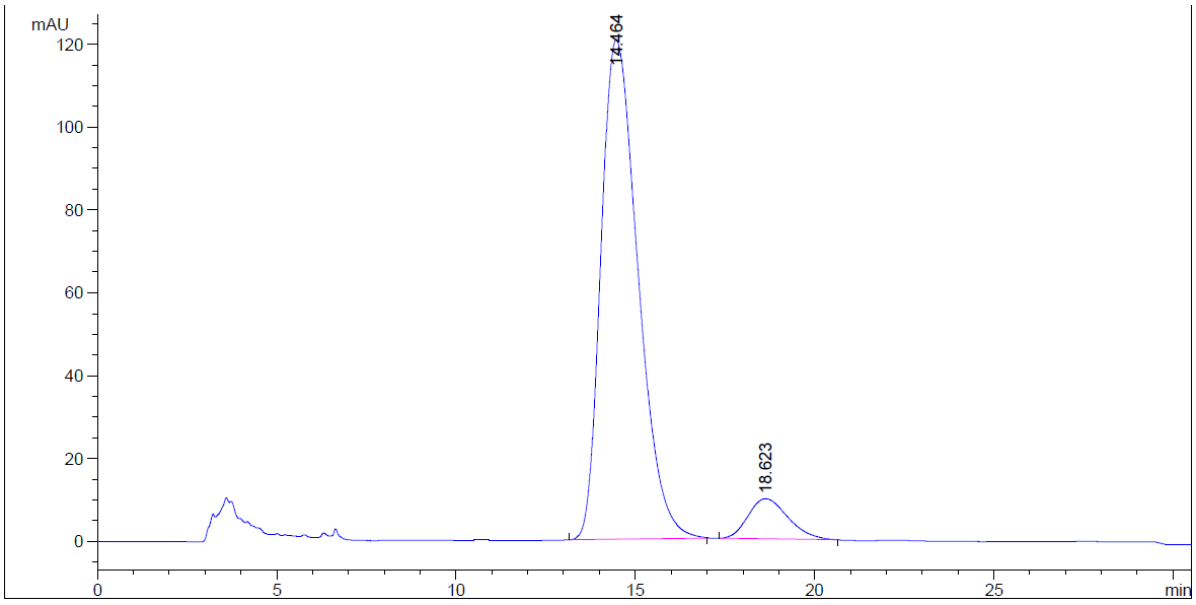


5m

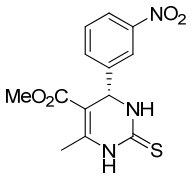
84% ee. [Daicel Chiralpak AS-H, *n*-hexane / *i*-propanol = 85 / 15, 1.0 mL/min, λ = 254 nm]



Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	14.358	BB	1.0205	1.07209e4	162.72295	50.0956
2	17.920	BB	1.2667	1.06799e4	126.22408	49.9044
Totals :				2.14008e4	288.94703	

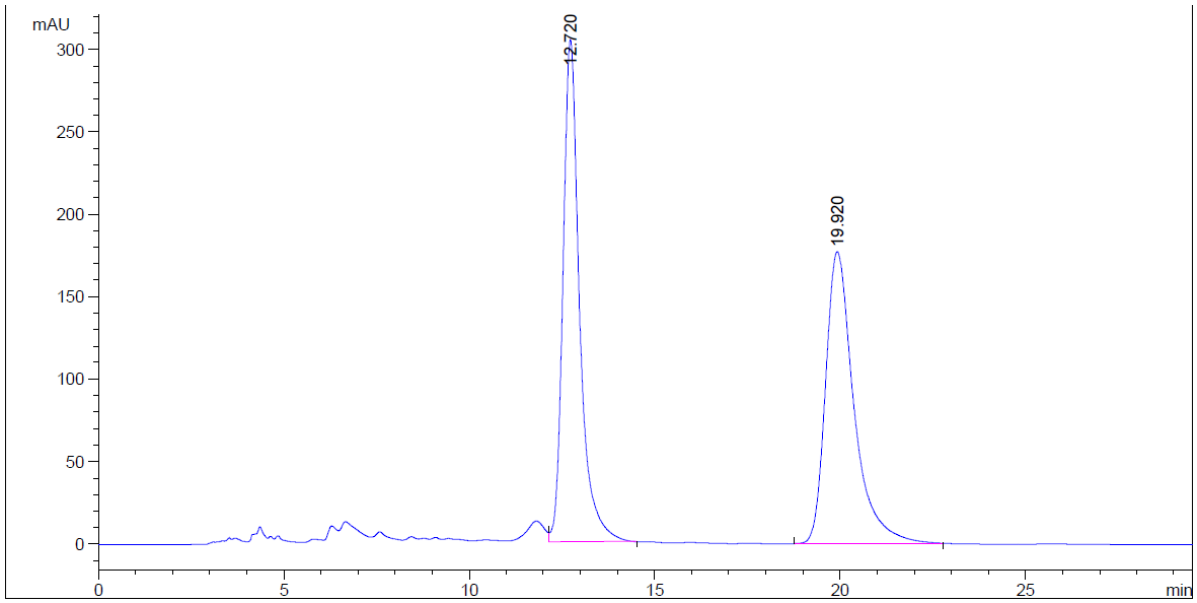


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	14.464	BB	1.1070	8649.51465	120.68172	91.9475
2	18.623	BB	1.1215	757.50275	9.75460	8.0525
Totals :				9407.01740	130.43632	

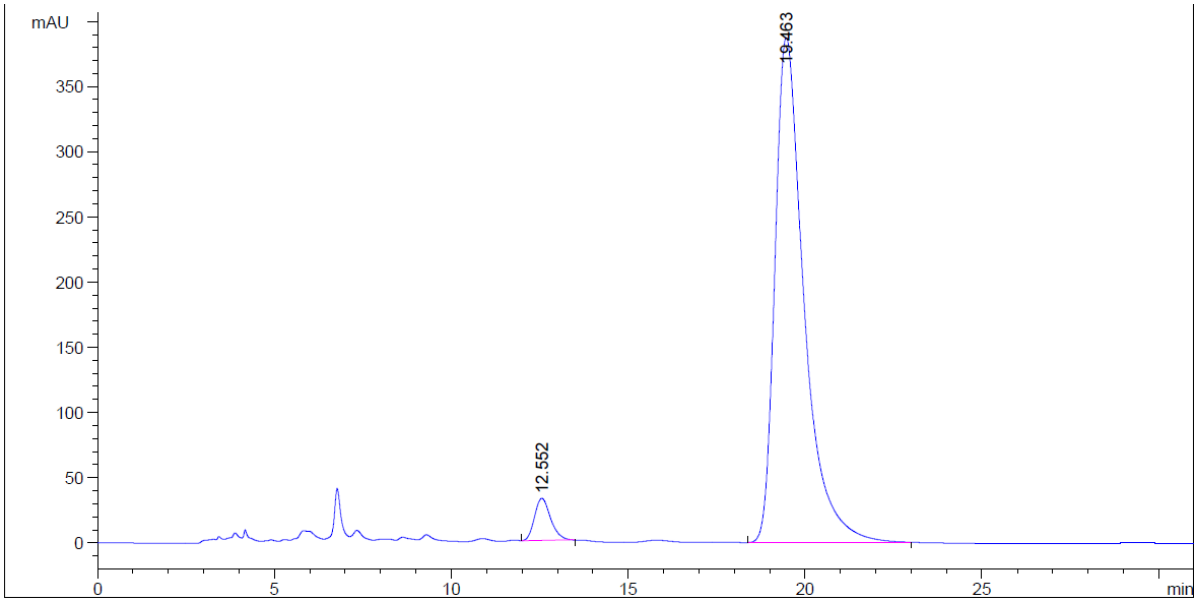


5n

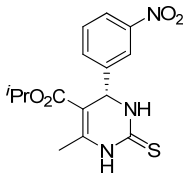
91% ee. [Daicel Chiralpak AD-H, *n*-hexane / *i*-propanol = 75 / 25, 1.0 mL/min, λ = 254 nm]



Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	12.720	VP	0.4653	9450.99707	304.65536	50.0849
2	19.920	BB	0.7947	9418.94629	177.23788	49.9151
Totals :				1.88699e4	481.89325	

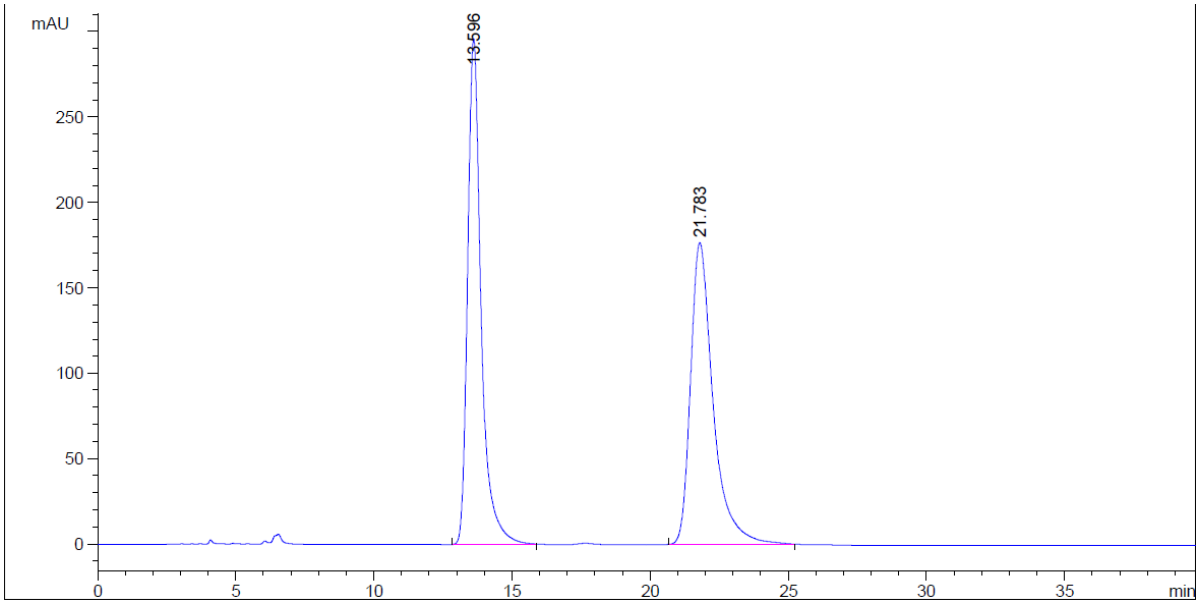


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	12.552	VB	0.4873	1035.40479	32.57830	4.4821
2	19.463	PB	0.8495	2.20654e4	387.33524	95.5179
Totals :				2.31008e4	419.91354	

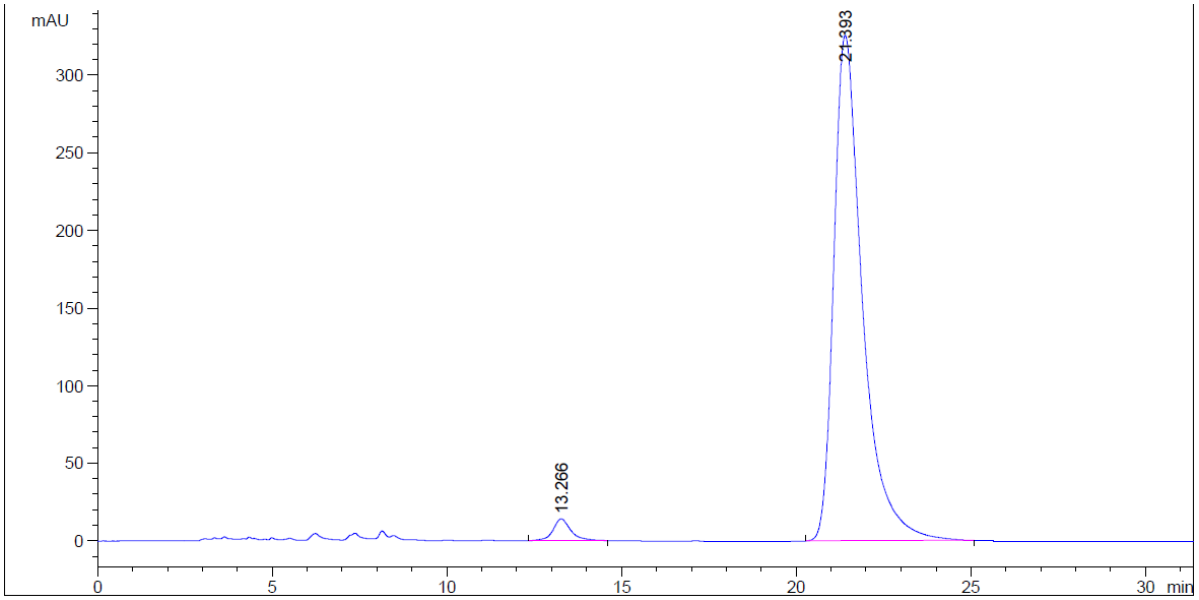


5o

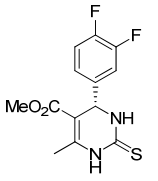
95% ee. [Daicel Chiralpak AD-H, *n*-hexane / *i*-propanol = 80 / 20, 1.0 mL/min, λ = 254 nm]



Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	13.596	BB	0.5100	1.00659e4	296.24277	50.0684
2	21.783	BB	0.8474	1.00384e4	176.78358	49.9316
Totals :				2.01043e4	473.02635	

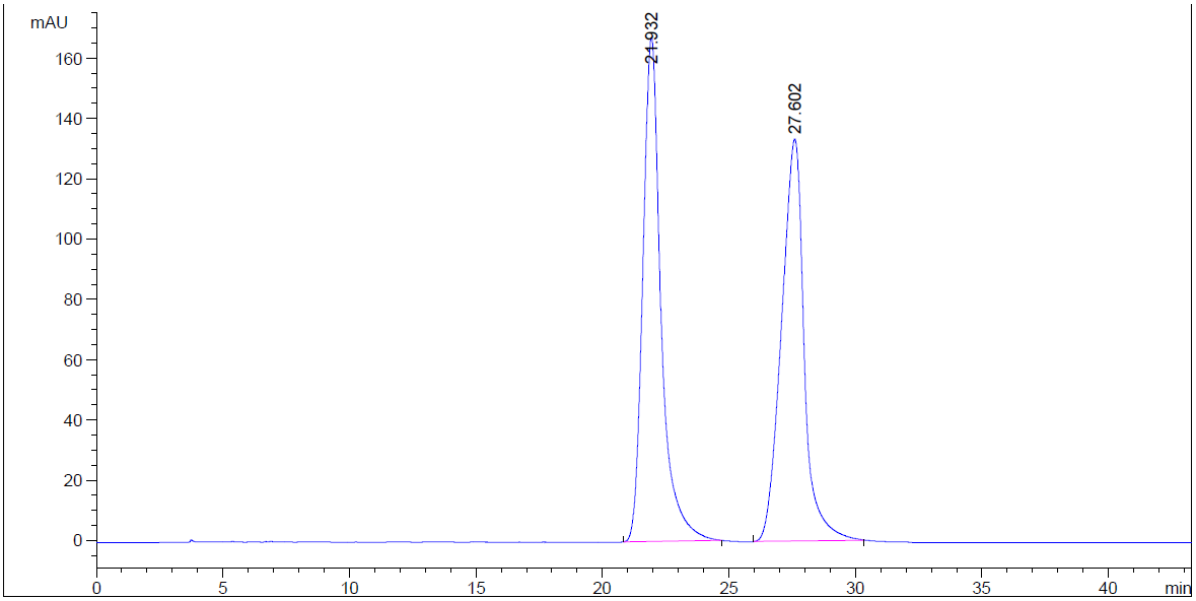


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	13.266	BB	0.5350	514.06219	14.13406	2.6845
2	21.393	BB	0.8509	1.86353e4	325.74194	97.3155
Totals :				1.91493e4	339.87600	

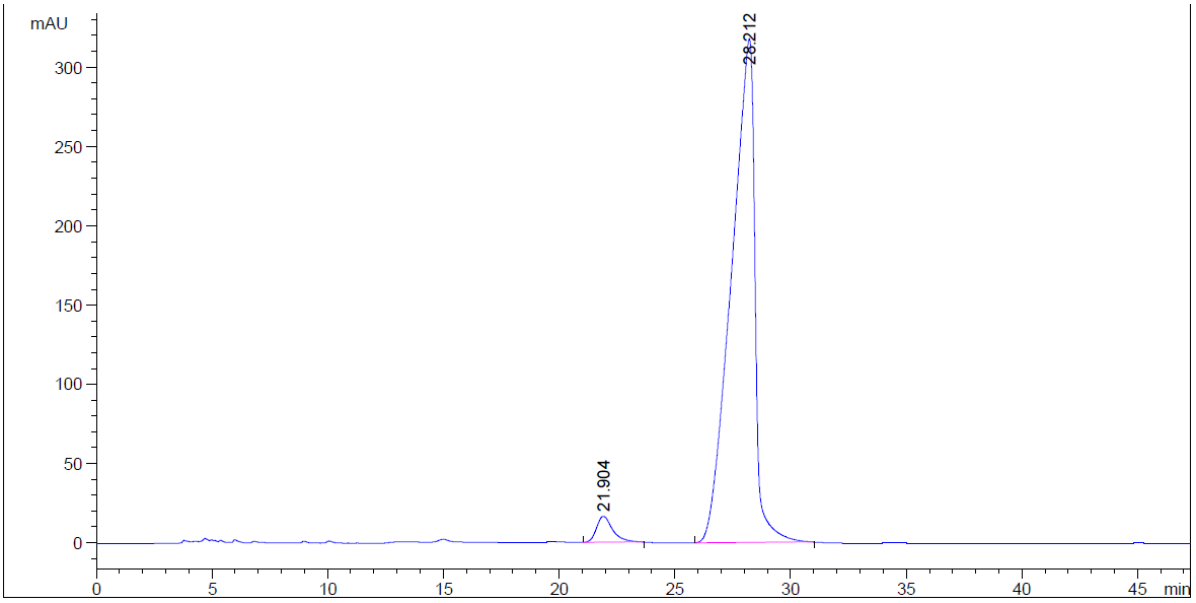


5p

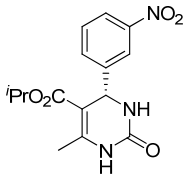
93% ee. [Daicel Chiralpak AD-H, *n*-hexane / *i*-propanol = 90 / 10, 1.0 mL/min, λ = 254 nm]



Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	21.932	BB	0.7515	8372.38770	167.23622	50.1335
2	27.602	BB	0.9597	8327.80664	133.42879	49.8665
Totals :				1.67002e4	300.66501	

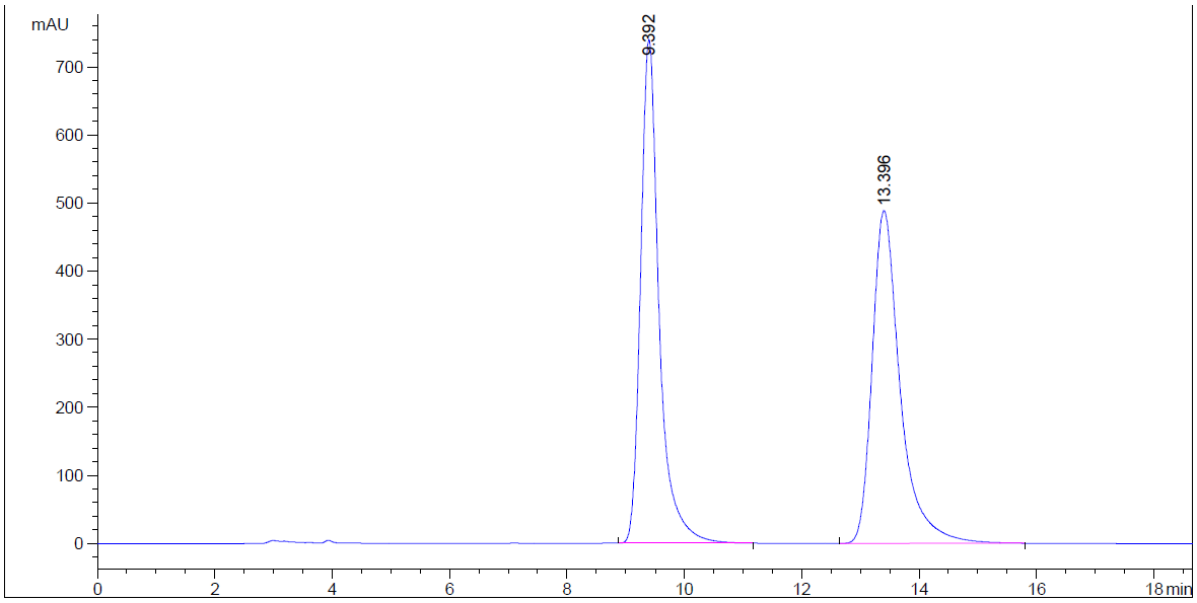


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	21.904	BB	0.7376	810.40900	16.45695	3.4744
2	28.212	BB	1.0338	2.25147e4	318.14581	96.5256
Totals :				2.33251e4	334.60276	

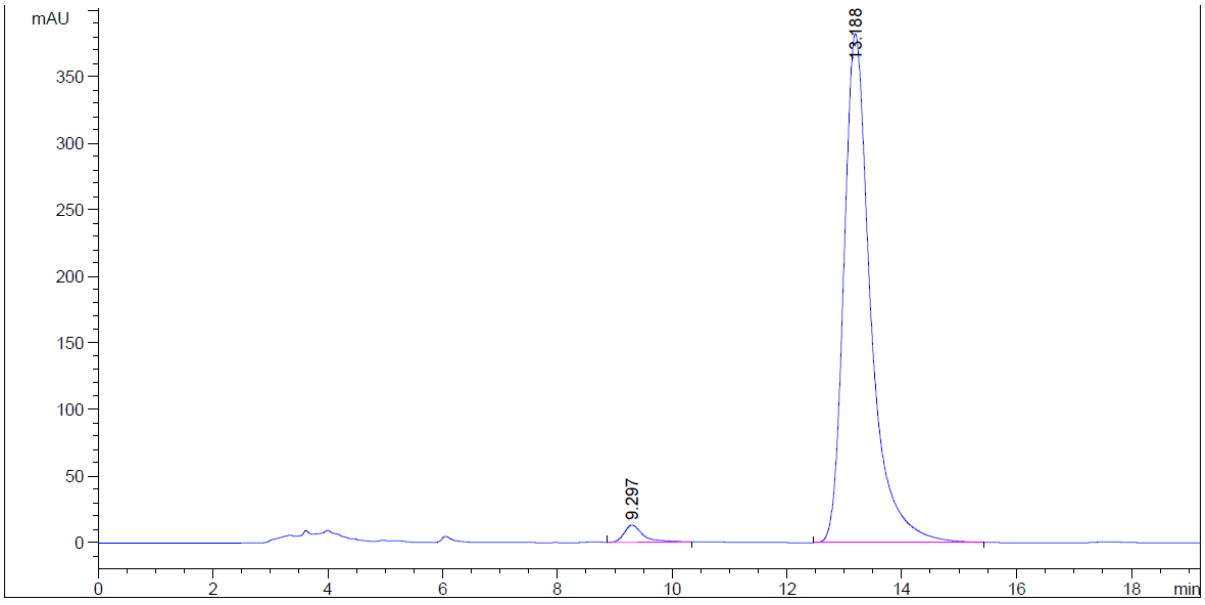


5q

95% ee. [Daicel Chiralpak AD-H, *n*-hexane / *i*-propanol = 80 / 20, 1.0 mL/min, λ = 254 nm]



Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	9.392	VB	0.3295	1.62881e4	740.33899	49.9841
2	13.396	BB	0.5010	1.62985e4	488.92944	50.0159
Totals :				3.25866e4	1229.26843	



Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	9.297	VB	0.3477	304.55817	12.99397	2.3957
2	13.188	BB	0.4862	1.24080e4	382.49643	97.6043
Totals :				1.27126e4	395.49040	