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Enantioselective H-bond-directed vinylogous iminium ion strategy for the functionalization of vinyl-substituted heteroaryl aldehydes

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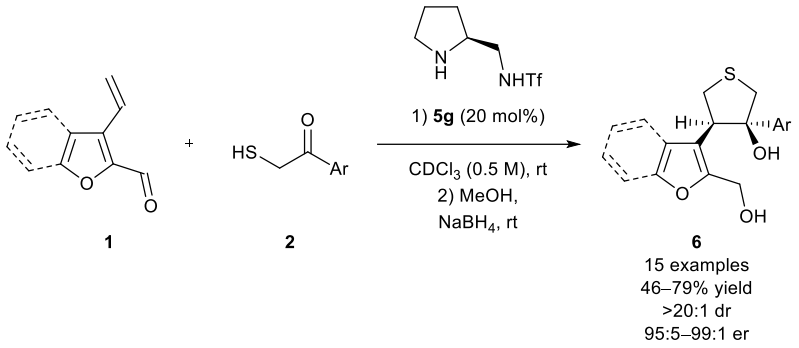
Contents

1. General methods

NMR spectra were acquired on a Bruker Ultra Shield 700 instrument, running at 700 MHz for ^{1}H and 176 MHz for ^{13}C, respectively. Chemical shifts (δ) are reported in ppm relative to residual solvent signals ($CDCl_3$: 7.26 ppm for ^{1}H NMR, 77.16 ppm for ^{13}C NMR). Mass spectra were recorded on a Bruker Maxis Impact spectrometer using electrospray (ES+) ionization referenced to the mass of the charged species. Optical rotations were measured on a Perkin-Elmer 241 polarimeter and $[\alpha]_D$ values are given in deg•cm•g^{-1}•dm^{-1}; concentration *c* is listed in g•(100 mL)$^{-1}$. Analytical thin layer chromatography (TLC) was performed using pre-coated aluminum-backed plates (Merck Kieselgel 60 F254) and visualized by ultraviolet irradiation or Hanessian's stain. The enantiomeric ratio (er) of the products was determined by chiral stationary phase UPC^2 or HPLC (Daicel Chiralpak IA and IG column). The racemic samples of products **6** for chiral UPC^2 separation studies were prepared using equimolar mixture of (*S)* and (*R*)-diphenyl-2-pyrrolidinemethanol trimethylsilyl ether as catalyst. Unless otherwise noted, analytical grade solvents and commercially available reagents were used without further purification. For flash chromatography (FC) silica gel (60, 35-70 μm, Merck KGaA). Vinyl-substituted heteroaromatic aldehydes **1** and α-mercaptocarbonyl compounds **2** were obtained using literature procedures.[1,2]

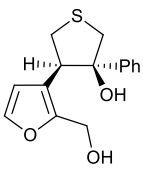
1. A. Przydacz, R. Kowalczyk and Ł. Albrecht, *Org. Biomol. Chem.*, 2017, **15**, 9566–9569.
2. X.-Y. Gao, R.-J. Yan, B.-X. Xiao, Ł. Albrecht and Y.-C. Chen, *Org. Lett.*, 2019, **21**, 9628–9632.

2. Organocatalytic synthesis of 6 – general procedure



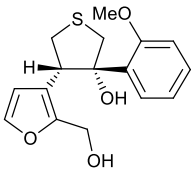
In an ordinary 4 mL glass vial, equipped with a Teflon-coated magnetic stirring bar and a screw cap, aldehyde **1** (1.0 equiv., 0.1 mmol), catalyst **5g** (0.2 equiv., 0.02 mmol, 4.6 mg) and corresponding α-mercaptocarbonyl compound **2** (1.2 equiv., 0.12 mmol) were dissolved in $CDCl_3$ (0.2 mL). The reaction mixture was stirred at ambient temperature for 20 h. After full conversion of the starting material **1** (as confirmed by ^{1}H NMR of a crude reaction mixture), MeOH (0.1 mL) and $NaBH_4$ (4 equiv., 0.4 mmol, 15.2 mg) were added. After 30 min. the reaction mixture was directly subjected to flash chromatography on silica gel (eluent: hexanes/ethyl acetate 85:15 to 70:30) to obtain pure product **6**.

(3*R*,4*R*)-4-(2-(Hydroxymethyl)furan-3-yl)-3-phenyltetrahydrothiophen-3-ol (6a)



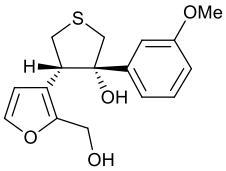
Following the general procedure product **6a** (>20:1 dr in a crude reaction mixture) was isolated in 75% yield as light-yellow oil. Catalyst **5g** (*S* configuration) was used in the reaction. ^{1}H NMR (700MHz, $CDCl_3$) δ 7.42 – 7.40 (m, 2H), 7.36 – 7.33 (m, 2H), 7.28 – 7.26 (m, 2H), 6.45 (d, *J* = 1.9 Hz, 1H), 4.18 (d, *J* = 13.5 Hz, 1H), 4.10 (d, *J* = 13.5 Hz, 1H), 3.66 (d, *J* = 12.0 Hz, 1H), 3.55 (dd, *J* = 11.0, 7.4 Hz, 1H), 3.34 (t, *J* = 10.9 Hz, 1H), 3.20 (dd, *J* = 10.8, 7.4 Hz, 1H), 3.13 (d, *J* = 12.0 Hz, 1H), 2.58 (bs, 1H). ^{13}C NMR (176 MHz, $CDCl_3$) δ 151.1, 142.3, 141.9, 128.6 (2C), 127.7, 125.2 (2C), 117.9, 111.5, 84.5, 55.4, 51.3, 45.4, 34.3. The er was determined by UPC^2 using a chiral Chiralpack IA column gradient from 100% CO_2 up to 40%; *i*-PrOH, 2.5 mL/min; τ_{major} = 3.92 min, τ_{minor} = 4.00 min, (99:1 er). $[\alpha]_D^{21}$ = 14.8 (c = 1.0, $CHCl_3$). HRMS calculated for [$C_{156}H_{18}O_3S$+Na]: 299.0718; found: 299.0717.

(3*S*,4*S*)-4-(2-(Hydroxymethyl)furan-3-yl)-3-(2-methoxyphenyl)tetrahydrothiophen-3-ol (6b)



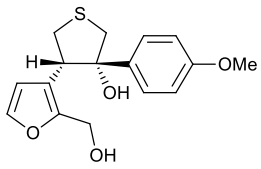
Following the general procedure product **6b** (>20:1 dr in a crude reaction mixture) was isolated in 79% yield as light-yellow oil. Catalyst *ent*-**5g** (*R* configuration) was used in the reaction. ^{1}H NMR (700MHz, $CDCl_3$) δ 7.44 (dd, *J* = 7.7, 1.7 Hz, 1H), 7.27-7.25 (m, 2H), 6.95 – 6.90 (m, 2H), 6.49 (d, *J* = 1.9 Hz, 1H), 4.28 (d, *J* = 13.4 Hz, 1H), 4.18 (d, *J* = 13.4 Hz, 1H), 4.09 (dd, *J* = 10.8, 7.2 Hz, 1H), 3.91 (s, 3H), 3.87 (d, *J* = 11.5 Hz, 1H), 3.33 (t, J = 10.6 Hz, 2H), 3.33 (bs, 1H), 3.09 (dd, *J* = 10.4, 7.2 Hz, 1H), 3.01 (d, *J* = 11.5 Hz, 1H). ^{13}C NMR (176 MHz, $CDCl_3$) δ 156.1, 151.2, 141.9, 129.6, 129.3, 127.9, 121.3, 118.9, 111.6, 111.3, 84.5, 55.5 (2C), 46.7, 42.4, 34.3. The er was determined by UPC^2 using a chiral Chiralpack IA column gradient from 100% CO_2 up to 40%; *i*-PrOH, 2.5 mL/min; τ_{major} = 4.29 min, τ_{minor} = 4.40 min, (98:2 er); $[\alpha]_D^{21}$ = –57.3 (c = 1.0, $CHCl_3$). HRMS calculated for [$C_{16}H_{18}O_4S$+Na]: 329.0822; found: 313.0823.

(3*S*,4*S*)-4-(2-(Hydroxymethyl)furan-3-yl)-3-(3-methoxyphenyl)tetrahydrothiophen-3-ol (6c)



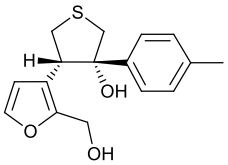
Following the general procedure product **6c** (>20:1 dr in a crude reaction mixture) was isolated in 64% yield as light-yellow oil. Catalyst *ent*-**5g** (*R* configuration) was used in the reaction. ^{1}H NMR (700MHz, $CDCl_3$) δ 7.28 – 7.22 (m, 2H), 7.00 – 6.95 (m, 2H), 6.77 (dd, *J* = 8.3, 2.4 Hz, 1H), 6.43 (d, *J* = 1.9 Hz, 1H), 4.21 (d, *J* = 13.5 Hz, 1H), 4.15 (d, *J* = 13.5 Hz, 1H), 3.75 (s, 3H), 3.60 (d, *J* = 12 Hz, 1H), 3.55 (dd, *J* = 11.1, 7.4 Hz, 1H), 3.32 (t, *J* = 10.9 Hz, 1H), 3.10 (d, *J* = 12.0 Hz, 1H), 2.75 (bs, 1H). ^{13}C NMR (176 MHz, $CDCl_3$) δ 159.9, 151.1, 144.1, 142.0, 129.5 (2C), 117.9, 117.1, 112.6, 111.9, 111.5, 84.5, 55.5, 55.4, 51.1, 45.5, 34.3. The er was determined by UPC^2 using a chiral Chiralpack IG column gradient from 100% CO_2 up to 40%; *i*-PrOH, 2.5 mL/min; τ_{major} = 4.47 min, τ_{minor} = 4.22 min, (99:1 er); $[\alpha]_D^{21}$ = –23.1 (c = 1.0, $CHCl_3$). HRMS calculated for [$C_{16}H_{18}O_4S$+Na]: 329.0823; found: 313.0822.

(3*S*,4*S*)-4-(2-(Hydroxymethyl)furan-3-yl)-3-(4-methoxyphenyl)tetrahydrothiophen-3-ol (6d)



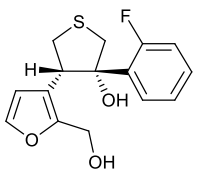
Following the general procedure product **6d** (>20:1 dr in a crude reaction mixture) was isolated in 64% yield as light-yellow oil. Catalyst *ent*-**5g** (*R* configuration) was used in the reaction. ^{1}H NMR (700 MHz, $CDCl_3$) δ 7.33 – 7.30 (m, 2H), 7.28 (d, *J* = 1.9 Hz, 1H), 6.87 – 6.83 (m, 2H), 6.44 (d, J = 1.9 Hz, 1H), 4.23 – 4.15 (m, 2H), 3.77 (s, 3H), 3.59 (d, *J* = 12.0 Hz, 1H), 3.51 (dd, J = 10.9, 7.4 Hz, 1H), 3.31 (t, *J* = 10.8 Hz, 1H), 3.18 (dd, *J* = 10.7, 7.4 Hz, 1H), 3.08 (d, *J* = 12.0 Hz, 1H), 2.60 (s, 1H). ^{13}C NMR (176 MHz, $CDCl_3$) δ 159.0, 151.2, 142.0, 134.1, 126.4 (2C), 118.1, 113.9 (2C), 111.6, 84.4, 55.6, 55.4, 50.9, 45.4, 34.2. The er was determined by UPC^2 using a chiral Chiralpack IG column gradient from 100% CO_2 up to 40%; *i*-PrOH, 2.5 mL/min; τ_{major} = 4.49 min, τ_{minor} = 4.33 min, (98:2 er); $[\alpha]_D^{21}$ = –48.0 (c = 1.0, $CHCl_3$). HRMS calculated for [$C_{16}H_{18}O_4S$+Na]: 329.0823; found: 313.0822.

(3*S*,4*S*)-4-(2-(Hydroxymethyl)furan-3-yl)-3-(*p*-tolyl)tetrahydrothiophen-3-ol (6e)



Following the general procedure product **6e** (>20:1 dr in a crude reaction mixture) was isolated in 68% yield as light-yellow oil. Catalyst *ent*-**5g** (*R* configuration) was used in the reaction. ^{1}H NMR (700 MHz, $CDCl_3$) δ 7.29 (d, *J* = 1.9 Hz, 1H), 7.29 – 7.27 (m, 2H), 7.16 – 7.13 (m, 2H), 6.44 (d, *J* = 1.9 Hz, 1H), 4.18 (d, *J* = 13.5 Hz, 1H), 4.11 (d, *J* = 13.5 Hz, 1H), 3.62 (d, J = 12.0 Hz, 1H), 3.52 (dd, *J* = 11.0, 7.4 Hz, 1H), 3.33 (t, *J* = 10.9 Hz, 1H), 3.17 (dd, *J* = 10.7, 7.4 Hz, 1H), 3.09 (d, *J* = 12.0 Hz, 1H), 2.62 (s, 1H), 2.30 (s, 3H). ^{13}C NMR (176 MHz, $CDCl_3$) δ 151.1, 142.0, 139.3, 137.5, 129.3 (2C), 125.1 (2C), 118.0, 111.5, 84.6, 55.4, 51.2, 45.5, 34.3, 21.0. The er was determined by UPC^2 using a chiral Chiralpack IG column gradient from 100% CO_2 up to 40%; *i*-PrOH, 2.5 mL/min; flow rate 1.0 mL/min; τ_{major} = 4.45 min, τ_{minor} = 4.18 min, (98:2 er); $[\alpha]_D^{21}$ = –18.5 (c = 1.0, $CHCl_3$). HRMS calculated for [$C_{16}H_{18}O_3S$+Na]: 313.0874; found: 313.0877.

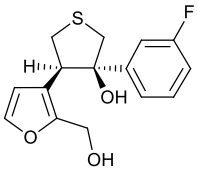
(3*S*,4*S*)-3-(2-Fluorophenyl)-4-(2-(hydroxymethyl)furan-3-yl)tetrahydrothiophen-3-ol (6f)



Following the general procedure product **6f** (>20:1 dr in a crude reaction mixture) was isolated in 61% yield as light-yellow oil. Catalyst *ent*-**5g** (*R* configuration) was used in the reaction. ^{1}H NMR (700MHz, $CDCl_3$) δ 7.50 (td, *J* = 8.2, 1.9 Hz, 1H), 7.29 – 7.21 (m, 2H), 7.11 – 7.05 (m, 2H), 6.41 (d, *J*

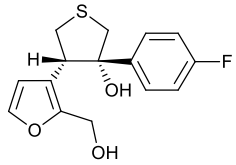
= 1.9 Hz, 1H), 4.33 (d, *J* = 13.4 Hz, 1H), 4.23 (d, *J* = 13.4 Hz, 1H), 3.96 (dd, *J* = 11.0, 7.5 Hz, 1H), 3.82 (d, *J* = 11.7 Hz, 1H), 3.33 (td, *J* = 10.8, 1.0 Hz, 1H), 3.17 (dd, *J* = 10.6, 7.4 Hz, 1H), 2.99 (dd, *J* = 11.8, 1.6 Hz, 1H), 2.88 (s, 1H). ^{13}C NMR (176 MHz, $CDCl_3$) δ 159.2 (d, *J* = 245.2 Hz), 151.2, 142.0, 129.8 (d, *J* = 8.5 Hz), 128.9 (d, *J* = 3.8 Hz), 124.6 (d, *J* = 3.4 Hz), 118.0, 116.2, 116.1, 111.6, 83.2 (d, *J* = 5.3 Hz), 55.4, 47.7 (d, *J* = 5.2 Hz), 43.2 (d, *J* = 5.2 Hz), 33.9. The er was determined by UPC^2 using a chiral Chiralpack IA column gradient from 100% CO_2 up to 40%; *i*-PrOH, 2.5 mL/min; τ_{major} = 3.73 min, τ_{minor} = 3.64 min, (96:4 er); $[\alpha]_D^{21}$ = –27.5 (c = 1.0, $CHCl_3$). HRMS calculated for [$C_{15}H_{15}O_3SF$+Na]: 317.0624; found: 317.0622.

(3*R*,4*R*)-3-(3-Fluorophenyl)-4-(2-(hydroxymethyl)furan-3-yl)tetrahydrothiophen-3-ol (6g)



Following the general procedure product **6g** (>20:1 dr in a crude reaction mixture) was isolated in 61% yield as light-yellow oil. Catalyst **5g** (*S* configuration) was used in the reaction. ^{1}H NMR (700MHz, $CDCl_3$) δ 7.30 (td, *J* = 8.0, 5.9 Hz, 1H), 7.26 (d, *J* = 2.0 Hz, 1H), 7.19 – 7.12 (m, 2H), 6.94 (tdd, *J* = 8.0, 2.6, 1.0 Hz, 1H), 6.42 (d, *J* = 2.0 Hz, 1H), 4.26 (d, *J* = 13.4 Hz, 1H), 4.22 (d, *J* = 13.4 Hz, 1H), 3.56 (d, *J* = 12.0 Hz, 1H), 3.56 (dd, *J* = 10.7, 7.5 Hz, 1H), 3.30 (dd, *J* = 10.8, 10.7 Hz, 1H), 3.20 (dd, *J* = 10.7, 7.5 Hz, 1H), 3.10 (d, *J* = 12.0 Hz, 1H), 2.78 (bs, 1H). ^{13}C NMR (176 MHz, $CDCl_3$) δ 163.5 (d, *J* = 246.7 Hz), 151.1, 145.1 (d, *J* = 6.9 Hz), 142.1, 130.0 (d, *J* = 8.2 Hz), 120.6 (d, *J* = 3.0 Hz), 117.7, 114.6 (d, *J* = 21.0 Hz), 113.0 (d, *J* = 22.9 Hz), 111.6, 84.1, 55.6, 50.9, 45.6, 34.2. The er was determined by UPC^2 using a chiral Chiralpack IA column gradient from 100% CO_2 up to 40%; *i*-PrOH, 2.5 mL/min; τ_{major} = 3.72 min, τ_{minor} = 3.89 min, (95:5 er); $[\alpha]_D^{21}$ = +30.5 (c = 1.0, $CHCl_3$). HRMS calculated for [$C_{15}H_{15}O_3SF$+Na]: 317.0624; found: 317.0624.

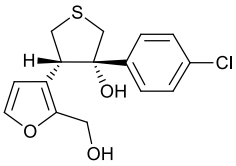
(3*S*,4*S*)-3-(4-Fluorophenyl)-4-(2-(hydroxymethyl)furan-3-yl)tetrahydrothiophen-3-ol (6h)



Following the general procedure product **6h** (>20:1 dr in a crude reaction mixture) was isolated in 60% yield as light-yellow oil. Catalyst *ent*-**5g** (*R* configuration) was used in the reaction. ^{1}H NMR (700MHz, $CDCl_3$) δ 7.41 – 7.36 (m, 2H), 7.27 – 7.24 (m, 1H), 7.07 – 6.97 (m, 2H), 6.41 (d, *J* = 1.9 Hz, 1H), 4.24 (d, *J* = 13.5 Hz, 1H), 4.21 (d, *J* = 13.5 Hz, 1H), 3.56 (d, *J* = 12.0 Hz, 1H), 3.53 (dd, J = 10.8, 7.5 Hz, 1H), 3.29 (t, *J* = 10.7 Hz, 1H), 3.19 (dd, *J* = 10.8, 7.5 Hz, 1H), 3.07 (d, *J*

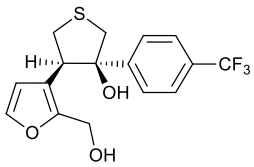
= 12.0 Hz, 1H), 2.85 (bs, 1H).^{13}C NMR (176 MHz, $CDCl_3$) δ 162.0 (d, *J* = 247.1 Hz), 151.0, 141.8, 137.7 (d, *J* = 3.1 Hz), 126.9 (d, *J* = 7.9 Hz, 2C), 117.8, 115.3 (d, *J* = 21.2 Hz), 111.6, 84.0, 55.5, 50.6, 45.4, 34.0. The er was determined by UPC^2 using a chiral Chiralpack IG column gradient from 100% CO_2 up to 40%; *i*-PrOH, 2.5 mL/min; τ_{major} = 3.95 min, τ_{minor} = 3.71 min, (96:4 er); $[\alpha]_D^{21}$ = –16.1 (c = 1.0, $CHCl_3$). HRMS calculated for [$C_{15}H_{15}O_3SF$+Na]: 317.0624; found: 317.0624.

(3*S*,4*S*)-3-(4-Chlorophenyl)-4-(2-(hydroxymethyl)furan-3-yl)tetrahydrothiophen-3-ol (6i)



Following the general procedure product **6i** (>20:1 dr in a crude reaction mixture) was isolated in 60% yield as light-yellow oil. Catalyst *ent*-**5g** (*R* configuration) was used in the reaction. ^{1}H NMR (700MHz, $CDCl_3$) δ 7.37 – 7.33 (m, 2H), 7.30 – 7.27 (m, 2H), 7.25 (dd, *J* = 1.9, 0.5 Hz, 1H), 6.41 (d, *J* = 1.9 Hz, 1H), 4.26 (d, *J* = 13.4 Hz, 1H), 4.22 (d, *J* = 13.4 Hz, 1H), 3.54 (d, *J* = 11.0 Hz, 1H), 3.53 (dd, *J* = 11.0, 7.7 Hz, 1H), 3.28 (dd, *J* = 11.0, 10.7 Hz, 1H), 3.19 (dd, *J* = 10.7, 7.7 Hz, 1H), 3.07 (d, *J* = 11.0 Hz, 1H), 2.88 (bs, 1H). ^{13}C NMR (176 MHz, $CDCl_3$) δ 151.1, 142.0, 140.7, 133.6, 128.7 (2C), 126.8 (2C), 117.8, 111.7, 84.1, 55.7, 50.7, 45.5, 34.1. The er was determined by UPC^2 using a chiral Chiralpack IG column gradient from 100% CO_2 up to 40%; *i*-PrOH, 2.5 mL/min; τ_{major} = 4.37 min, τ_{minor} = 4.04 min, (96:4 er); $[\alpha]_D^{21}$ = –43.5 (c = 1.0, $CHCl_3$). HRMS calculated for [$C_{15}H_{15}O_3SCl$+Na]: 333.0328; found: 333.0325.

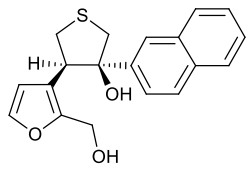
(3*R*,4*R*)-4-(2-(Hydroxymethyl)furan-3-yl)-3-(4-(trifluoromethyl)phenyl) tetrahydrothiophen-3-ol (6j)



Following the general procedure product **6j** (>20:1 dr in a crude reaction mixture) was isolated in 50% yield as light-yellow oil. Catalyst **5g** (*S* configuration) was used in the reaction. ^{1}H NMR (700 MHz, $CDCl_3$) δ 7.59 – 7.55 (m, 4H), 7.25 (d, *J* = 1.9 Hz, 1H), 6.42 (d, *J* = 1.9 Hz, 1H), 4.28 – 4.21 (m, 2H), 3.62 (dd, *J* = 10.8, 7.5 Hz, 1H), 3.57 (d, *J* = 12.0 Hz, 1H), 3.30 (t, *J* = 10.8 Hz, 1H), 3.23 (dd, *J* = 10.8, 7.6 Hz, 1H), 3.10 (d, *J* = 12.0 Hz, 1H), 2.87 (bs, 1H). ^{13}C NMR (176 MHz, $CDCl_3$) δ 151.1, 146.2, 142.0, 129.9 (q, *J* = 32.6 Hz), 125.8 (2C), 125.5 (q, *J* = 3.8 Hz, 2C), 124.1 (q, *J* = 272.7 Hz), 117.7, 111.7, 84.2, 55.7, 50.7, 45.7, 34.2. The er was determined by UPC^2 using a chiral Chiralpack IG column gradient from 100% CO_2 up to 40%;

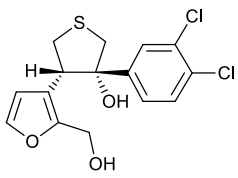
i-PrOH, 2.5 mL/min; τ_{major} = 3.13 min, τ_{minor} = 3.45 min, (97:3 er); $[\alpha]_D^{21}$ = –29.1 (c = 1.0, $CHCl_3$). HRMS calculated for [$C_{16}H_{15}O_3SF_3$+Na]: 367.0592; found: 367.0593.

(3*R*,4*R*)-4-(2-(Hydroxymethyl)furan-3-yl)-3-(naphthalen-2-yl)tetrahydrothiophen-3-ol (6k)



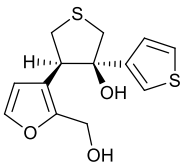
Following the general procedure product **6k** (>20:1 dr in a crude reaction mixture) was isolated in 55% yield as light-yellow oil. Catalyst **5g** (*S* configuration) was used in the reaction. ^{1}H NMR (700 MHz, $CDCl_3$) δ 7.91 (d, *J* = 1.9 Hz, 1H), 7.83 (d, *J* = 8.6 Hz, 1H), 7.81 – 7.77 (m, 2H), 7.51 (dd, *J* = 8.6, 1.9 Hz, 1H), 7.49 – 7.45 (m, 2H), 7.23 (d, *J* = 1.9 Hz, 1H), 6.46 (d, *J* = 1.9 Hz, 1H), 4.20 (d, *J* = 13.4 Hz, 1H), 4.12 (d, *J* = 13.4 Hz, 1H), 3.74 (dd, *J* = 10.8, 7.4 Hz, 1H), 3.69 (d, *J* = 12.0 Hz, 1H), 3.38 (t, *J* = 10.8 Hz, 1H), 3.23 (dd, *J* = 10.8, 7.4 Hz, 1H), 3.16 (d, *J* = 12.0 Hz, 1H), 2.87 (bs, 1H). ^{13}C NMR (176 MHz, $CDCl_3$) δ 151.1, 142.0, 139.4, 133.1, 132.5, 128.3 (2C), 127.6, 126.7, 126.5, 124.6, 122.9, 117.9, 111.6, 84.7, 55.5, 50.7, 45.8, 34.4. The er was determined by UPC^2 using a chiral Chiralpack IB. column gradient from 100% CO_2 up to 40%; *i*-PrOH, 2.5 mL/min; τ_{major} = 4.63 min, τ_{minor} = 4.84 min, (96:4 er); $[\alpha]_D^{21}$ = –44.1 (c = 1.0, $CHCl_3$). HRMS calculated for [$C_{19}H_{18}O_3S$+Na]: 349.0874; found: 349.0877.

(3*S*,4*S*)-3-(3,4-Dichlorophenyl)-4-(2-(hydroxymethyl)furan-3-yl)tetrahydrothiophen-3-ol (6l)



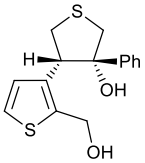
Following the general procedure product **6l** (>20:1 dr in a crude reaction mixture) was isolated in 58% yield as light-yellow oil. Catalyst *ent*-**5g** (*R* configuration) was used in the reaction. ^{1}H NMR (700MHz, $CDCl_3$) δ 7.58 (d, *J* = 2.2 Hz, 1H), 7.40 (d, *J* = 8.4 Hz, 1H), 7.29 – 7.27 (m, 2H), 6.43 (d, *J* = 1.9 Hz, 1H), 4.35 (d, *J* = 0.8 Hz, 2H), 3.60 (dd, *J* = 10.7, 7.5 Hz, 1H), 3.49 (d, *J* = 11.9 Hz, 1H), 3.29 (t, *J* = 10.7 Hz, 1H), 3.22 (dd, *J* = 10.8, 7.6 Hz, 1H), 3.08 (d, *J* = 12.0 Hz, 1H). ^{13}C NMR (176 MHz, $CDCl_3$) δ 151.1, 142.5, 142.0, 132.8, 131.7, 130.4, 127.8, 124.7, 117.7, 111.7, 83.6, 55.8, 50.3, 45.7, 34.0. The er was determined by UPC^2 using a chiral Chiralpack IG column gradient from 100% CO_2 up to 40%; *i*-PrOH, 2.5 mL/min; τ_{major} = 4.30 min, τ_{minor} = 3.95 min, (96:4 er); $[\alpha]_D^{21}$ = –35.8 (c = 1.0, $CHCl_3$). HRMS calculated for [$C_{14}H_{15}O_3SCl_2$+Na]: 366.9938; found: 366.9931.

(3*R*,4*R*)-4-(2-(Hydroxymethyl)furan-3-yl)-3-(thiophen-3-yl)tetrahydrothiophen-3-ol (6m)



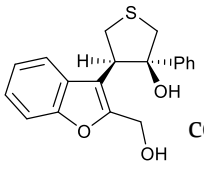
Following the general procedure product **6m** (>20:1 dr in a crude reaction mixture) was isolated in 52% yield as light-yellow oil. Catalyst **5g** (*S* configuration) was used in the reaction. ^{1}H NMR (700 MHz, $CDCl_3$) δ 7.34 – 7.30 (m, 2H), 7.17 (dd, *J* = 3.1, 1.4 Hz, 1H), 7.01 (dd, *J* = 5.0, 1.4 Hz, 1H), 6.46 (d, *J* = 1.9 Hz, 1H), 4.29 – 4.17 (m, 2H), 3.57 (d, *J* = 11.8 Hz, 1H), 3.47 (dd, *J* = 10.8, 7.4 Hz, 1H), 3.30 (t, *J* = 10.7 Hz, 1H), 3.16 (dd, *J* = 10.7, 7.4 Hz, 1H), 3.12 (d, *J* = 11.9 Hz, 1H), 2.68 (bs, 1H), 1.26 (s, 1H). ^{13}C NMR (176 MHz, $CDCl_3$) δ 151.2, 144.3, 142.0, 126.6, 125.1, 121.7, 118.0, 111.5, 83.5, 55.5, 50.6, 44.8, 34.0. The er was determined by UPC^2 using a chiral Chiralpack IA column gradient from 100% CO_2 up to 40%; MeOH, 2.5 mL/min; τ_{major} = 3.88 min, τ_{minor} = 4.10 min, (98:2 er); $[\alpha]_D^{21}$ = +14.1 (c = 1.0, $CHCl_3$). HRMS calculated for [$C_{13}H_{14}O_3S$+Na]: 349.0874; found: 349.0877.

(3*S*,4*S*)-4-(2-(Hydroxymethyl)thiophen-3-yl)-3-phenyltetrahydrothiophen-3-ol (6n)



Following the general procedure product **6n** (>20:1 dr in a crude reaction mixture) was isolated in 46% yield as light-yellow solid. The reaction was carried out at 40 ^{o}C. Catalyst *ent*-**5g** (*R* configuration) was used in the reaction. ^{1}H NMR (700 MHz, $CDCl_3$) δ 7.42 – 7.39 (m, 2H), 7.31 (m, 2H), 7.29 (d, *J* = 5.3 Hz, 1H), 7.27 – 7.23 (m, 1H), 7.20 (d, *J* = 5.3 Hz, 1H), 4.33 (d, *J* = 13.2 Hz, 1H), 4.23 (d, *J* = 13.2 Hz, 1H), 3.78 – 3.71 (m, 2H), 3.36 (t, *J* = 10.7 Hz, 1H), 3.21 (dd, *J* = 10.7, 7.4 Hz, 1H), 3.13 (d, *J* = 11.9 Hz, 1H), 2.66 (bs, 1H). ^{13}C NMR (176 MHz, $CDCl_3$) δ 142.3, 140.3, 134.4, 128.6 (2C), 128.5, 127.8, 125.2 (2C), 124.4, 84.52, 57.4, 53.5, 45.0, 34.8. The er was determined by UPC^2 using a chiral Chiralpack IG column gradient from 100% CO_2 up to 40%; *i*-PrOH, 2.5 mL/min; τ_{major} = 4.47 min, τ_{minor} = 4.66 min, (98:2 er); $[\alpha]_D^{23}$ = +12.9 (c = 1.0, $CHCl_3$). HRMS calculated for [$C_{15}H_{16}O_3S_2$+Na]: 315.0489; found: 315.0491.

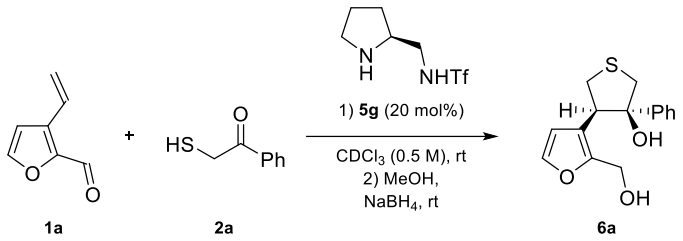
(3*R*,4*R*)-4-(2-(hydroxymethyl)benzofuran-3-yl)-3-phenyltetrahydrothiophen-3-ol (6o)



Following the general procedure product **6o** (>20:1 dr in a crude reaction mixture) was isolated in 55% yield as light-yellow solid/oil. Catalyst **5g** (*S* configuration) was used in the reaction. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.72 (dd, *J* = 7.8, 1.6 Hz, 1H), 7.41–7.34 (m, 3H), 7.31–7.15 (m, 5H), 4.42 (d, *J* = 13.6 Hz, 1H), 4.30 (d, *J* = 13.6 Hz, 1H), 3.88–3.75 (m, 3H), 3.31–3.21 (m, 1H), 3.19 (d, *J* = 12.2 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 154.2, 153.6, 141.9, 128.5, 128.4, 127.7, 125.1, 124.6, 122.48, 121.8,

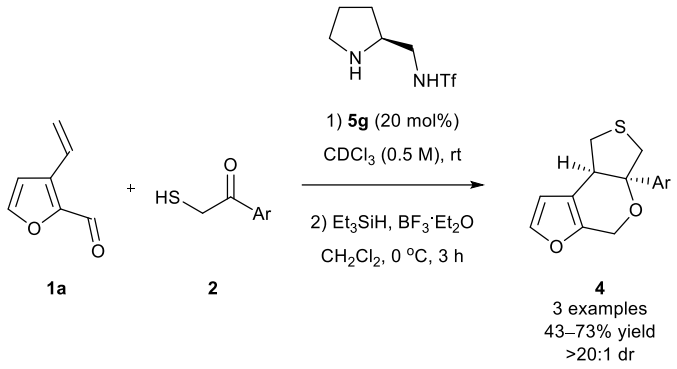
112.5, 111.4, 85.3, 56.3, 52.2, 45.6, 32.8. The er was determined by HPLC analysis using a chiral Daicel Chiralpack IC column gradient from 100% CO_2 up to 40%; *i*-PrOH, 1.0 mL/min; τ_{major} = 6.71 min, τ_{minor} = 7.53 min, (95:5 er); $[\alpha]_D^{25}$ = –44 (c = 0.5, $CHCl_3$). HRMS calculated for [$C_{15}H_{16}O_3S_2$+Na]: 349.0869; found: 349.0868.

3. Enantioselective synthesis of (3*R*,4*R*)-4-(2-(hydroxymethyl)furan-3-yl)-3-phenyltetrahydrothiophen-3-ol 6a on a 1 g scale



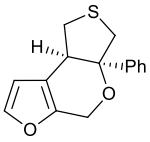
In an ordinary 4 mL glass vial, equipped with a Teflon-coated magnetic stirring bar and a screw cap, aldehyde **1a** (1.0 equiv., 8.19 mmol), catalyst **5g** (0.2 equiv., 1.64 mmol) and α-mercaptoacetophenone **2a** (1.2 equiv., 9.83 mmol) were dissolved in $CDCl_3$ (16.4 mL). The reaction mixture was stirred at ambient temperature for 20 h. After full conversion of the starting material **1a** (as confirmed by ^1H NMR of a crude reaction mixture), MeOH (8.2 mL) and $NaBH_4$ (4 equiv., 32.76 mmol) were added. After 30 min. the reaction mixture was directly subjected to flash chromatography on silica gel (eluent: hexane/ethyl acetate 85:15 to 70:30) to obtain pure product **6a** in 69% yield as light-yellow oil.

4. Synthesis of tricyclic furan derivatives 4 – general procedure



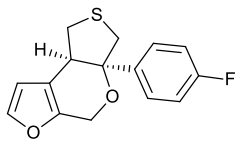
In an ordinary 4 mL glass vial, equipped with a Teflon-coated magnetic stirring bar and a screw cap, aldehyde **1** (1.0 equiv., 0.1 mmol), catalyst **5g** (0.2 equiv., 0.02 mmol, 4.6 mg) and corresponding α-mercaptocarbonyl compound **2** (1.2 equiv., 0.12 mmol) were dissolved in $CDCl_3$ (0.2 mL). The reaction mixture was stirred at ambient temperature for 20 h. After full conversion of the starting material **1** (as confirmed by ^{1}H NMR of a crude reaction mixture), the crude product was diluted with CH_2Cl_2 (1 mL), then Et_3SiH (3.0 equiv, 0.3 mmol) and $BF_3{\cdot}Et_2O$ (3.3 equiv., 0.33 mmol) were added in that order at 0 °C. The mixture was stirred for 3 h and directly subjected to flash chromatography on silica gel (eluent: hexane/diethyl ether 80:20) to obtain pure product **4**.

(3a*R*,8b*R*)-3a-Phenyl-3,3a,5,8b-tetrahydro-1*H*-furo[3,2-*d*]thieno[3,4-*b*]pyran (4a)



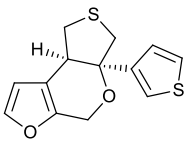
Following the general procedure product **4a** (>20:1 dr in a crude reaction mixture) was isolated in 73% yield as light yellow oil. ^{1}H NMR (700 MHz, $CDCl_3$) δ 7.39 – 7.37 (m, 2H), 7.32 – 7.29 (m, 2H), 7.28 – 7.26 (m, 1H), 7.26 – 7.24 (m, 1H), 6.37 (d, *J* = 1.9 Hz, 1H), 4.64 (d, *J* = 15.0 Hz, 1H), 4.19 (ddd, *J* = 15.0, 1.2 Hz, 1H), 3.81 (ddd, *J* = 10.5, 7.2, 1.2 Hz, 1H), 3.43 (d, *J* = 12.3 Hz, 1H), 3.30 (dd, *J* = 10.5, 7.2 Hz, 1H), 3.14 (d, *J* = 12.3 Hz, 1H), 3.08 (t, *J* = 10.5 Hz, 1H). ^{13}C NMR (176 MHz, $CDCl_3$) δ 146.6, 141.8, 139.4, 128.6 (2C), 128.1, 126.5 (2C), 116.8, 109.4, 87.7, 60.4, 43.7, 43.6, 36.7. HRMS calculated for [$C_{15}H_{14}O_2S$+Na]: 258.0715; found: 257.0634.

(3a*R*,8b*R*)-3a-(4-Fluorophenyl)-3,3a,5,8b-tetrahydro-1*H*-furo[3,2-*d*]thieno[3,4-*b*]pyran (4b)



Following the general procedure product **4b** (>20:1 dr in a crude reaction mixture) was isolated in 51% yield as yellow oil. ^{1}H NMR (700 MHz, $CDCl_3$) δ 7.38 – 7.32 (m, 2H), 7.27 – 7.24 (m, 1H), 7.02 – 6.96 (m, 2H), 6.37 (d, *J* = 1.9 Hz, 1H), 4.64 (d, *J* = 15.0 Hz, 1H), 4.15 (dt, *J* = 15.1, 1.3 Hz, 1H), 3.75 (ddd, *J* = 10.2, 7.2, 1.6 Hz, 1H), 3.41 (d, *J* = 12.3 Hz, 1H), 3.29 (dd, *J* = 10.6, 7.2 Hz, 1H), 3.11 (d, *J* = 12.3 Hz, 1H), 3.07 (t, *J* = 10.4 Hz, 1H). ^{13}C NMR (176 MHz, $CDCl_3$) δ 162.4 (d, *J* = 247.3 Hz), 146.5, 142.0, 135.2 (d, *J* = 3.1 Hz), 128.4 (d, *J* = 8.0 Hz), 116.7, 115.6 (d, *J* = 21.2 Hz), 109.4, 87.2, 60.3, 43.8, 43.6, 36.7. HRMS calculated for [$C_{15}H_{13}O_2S_F$+Na]: 276.0620; found: 275.9634.

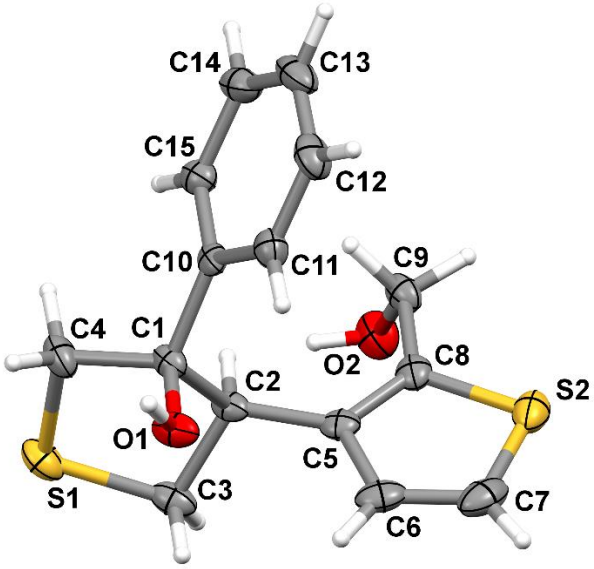
(3a*R*,8b*R*)-3a-(Thiophen-3-yl)-3,3a,5,8b-tetrahydro-1*H*-furo[3,2-*d*]thieno[3,4-*b*]pyran (6c)



Following the general procedure product **4c** (>20:1 dr in a crude reaction mixture) was isolated in 43% yield as yellow oil. ^{1}H NMR (700 MHz, $CDCl_3$) δ 7.29 – 7.25 (m, 2H), 7.11 (dd, *J* = 5.0, 1.4 Hz, 1H), 7.07 (dd, *J* = 2.9, 1.4 Hz, 1H), 6.36 (d, *J* = 1.9 Hz, 1H), 4.63 (d, *J* = 14.7 Hz, 1H), 4.20 (ddd, *J* = 14.9, 1.7, 1.0 Hz, 1H), 3.65 (ddd, *J* = 10.0, 7.2, 1.6 Hz, 1H), 3.44 (d, *J* = 12.2 Hz, 1H), 3.27 (dd, *J* = 10.7, 7.3 Hz, 1H), 3.20 (d, *J* = 12.2 Hz, 1H), 3.02 (dd, *J* = 10.7, 10.1 Hz, 1H). ^{13}C NMR (176 MHz, $CDCl_3$) δ 146.7, 141.9, 141.1, 126. 7, 126.1, 122.5, 116.8, 109.4, 85.6, 60.4, 45.3, 43.2, 36.8. HRMS calculated for [$C_{14}H_{12}O_2S_2$+Na]: 264.0279; found: 264.0283.

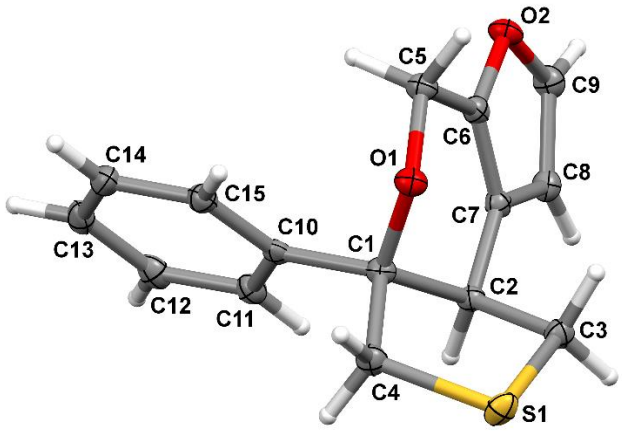
5. Crystal and X-ray data

The compound **6n** ($C_{15}H_{16}O_2S_2$) crystallizes in the non-centrosymmetric triclinic space group *P*1 (Z = 2) and the crystal structure consists of two crystallographically independent formula units in the unit cell.



A view of one of the two unique molecules present in the asymmetric unit of **6n**, with the atom-numbering scheme. Displacement ellipsoids drawn at the 50% probability level. Hydrogen atoms are drawn with an arbitrary radius

Single-crystal X-ray diffraction data were collected at temperature of 100 K. The compound **4a** ($C_{15}H_{14}O_2S$) crystallizes in the non-centrosymmetric monoclinic space group $P2_1$ (Z = 2) and the crystal structure consists of one crystallographically independent formula unit in the unit cell.



A view of the molecule of **4a** with displacement ellipsoids drawn at the 50% probability level. Hydrogen atoms are drawn with an arbitrary radius

Single crystal X-ray diffraction data were collected at 100 K by the ω-scan technique using a RIGAKU XtaLAB Synergy, Dualflex, Pilatus 300K diffractometer[3] with PhotonJet micro-focus X-ray Source Cu-Kα (λ = 1.54184 Å). Data collection, cell refinement, data reduction and absorption correction were performed using CrysAlis PRO software.[3] The crystal structure was solved by using direct methods with the SHELXT 2018/2 program.[4] Atomic scattering factors were taken from the International Tables for X-ray Crystallography. Positional parameters of non-H-atoms were refined by a full-matrix least-squares method on F^2 with anisotropic thermal parameters by using the SHELXL 2018/3 program.[5] All hydrogen atoms were placed in calculated positions (O–H = 0.84 Å, C–H = 0.95–1.00 Å) and included as riding contributions with isotropic displacement parameters set to 1.2-1.5 times the U_{eq} of the parent atom.

6n: Formula $C_{15}H_{16}O_2S_2$, monoclinic, space group *P*1, *Z* = 2, unit cell constants *a* = 8.0197(1), *b* = 9.6836(1), *c* = 10.1550(2) Å, a = 63.873(2), b = 83.678(1), g = 84.070(1)°, *V* = 702.42(2) $Å^3$. The integration of the data yielded a total of 15510 reflections with θ angles in the range of 4.86 to 69.99 of which 4979 reflections were unique (R_{int} = 1.40%), and 4973 were greater than $2\sigma(F^2)$. The final anisotropic full-matrix least-squares refinement on F^2 with 346 parameters converged to R_1 = 2.93% and wR_2 = 7.38% for all data. The goodness-of-fit was 1.047. The largest peak in the final difference electron density synthesis was 0.40 e $Å^{-3}$ and the largest hole was -0.46 e $Å^{-3}$. The absolute configuration was determined from anomalous scattering, by calculating the x Flack parameter[6] of 0.001(6) using 2325 quotients.

4a: Formula $C_{15}H_{14}O_2S$, monoclinic, space group *P*2_1, *Z* = 2, unit cell constants *a* = 7.3707(1), *b* = 10.3546(1), *c* = 8.6086(1) Å, b = 108.874(1)°, *V* = 621.688(13) $Å^3$. The integration of the data yielded a total of 21876 reflections with θ angles in the range of 6.35 to 66.58 of which 2177 were independent (R_{int} = 2.05%), and all were greater than $2\sigma(F^2)$. The final anisotropic full-matrix least-squares refinement on F^2 with 163 parameters converged to R_1 = 1.94% and wR_2 = 5.11% for all data. The goodness-of-fit was 1.054. The largest peak in the final difference electron density synthesis was 0.19 e $Å^{-3}$ and the largest hole was -0.15 e $Å^{-3}$. The absolute configuration was determined from anomalous scattering, by calculating the x Flack parameter[6] of 0.003(7) using 1020 quotients.

CCDC 2024877 (**6n**) and 2024876 (**4a**) contain the supplementary crystallographic data for this paper. These data can be obtained free of charge from The Cambridge Crystallographic Data Centre via www.ccdc.cam.ac.uk/structures.

3. Rigaku OD. CrysAlis PRO. Rigaku Oxford Diffraction Ltd, Yarnton, Oxfordshire, England, 2019.

4. G. M. Sheldrick, *Acta Cryst.* 2015, **A71**, 3-8.

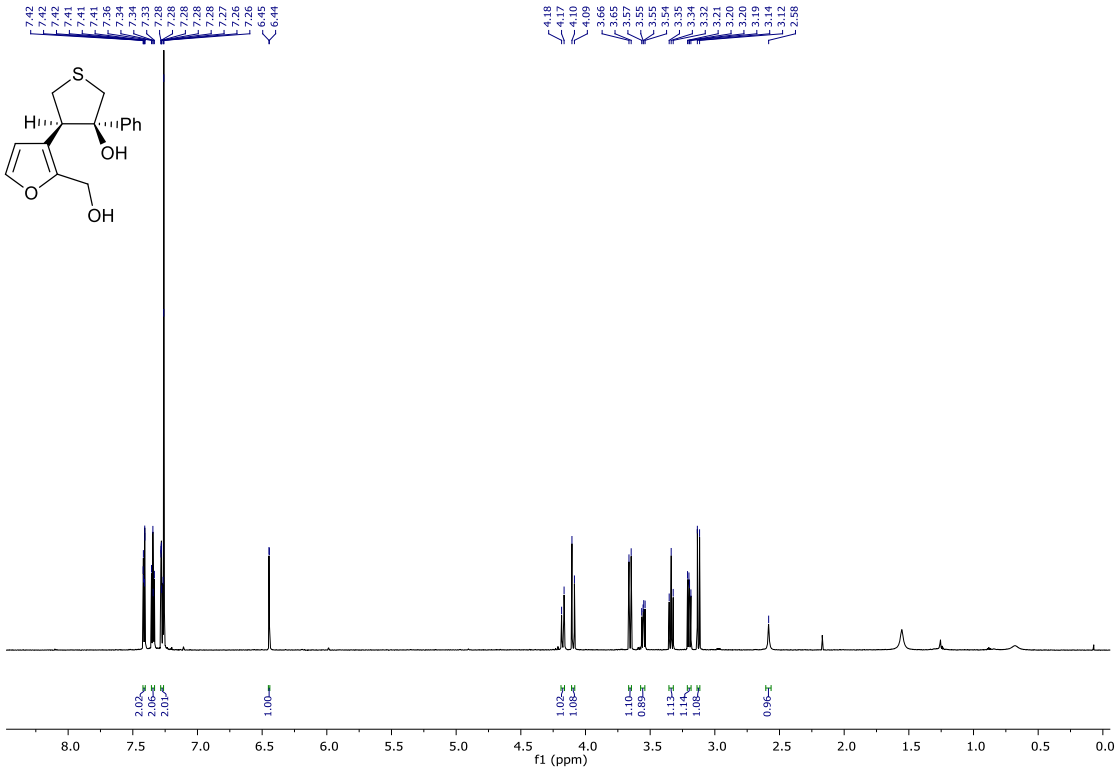
5. G. M. Sheldrick, *Acta Cryst.* 2015, **C71**, 3-8.

6. S. Parsons, H. D. Flack, T. Wagner, *Acta Cryst.* 2013, **B69**, 249-259.

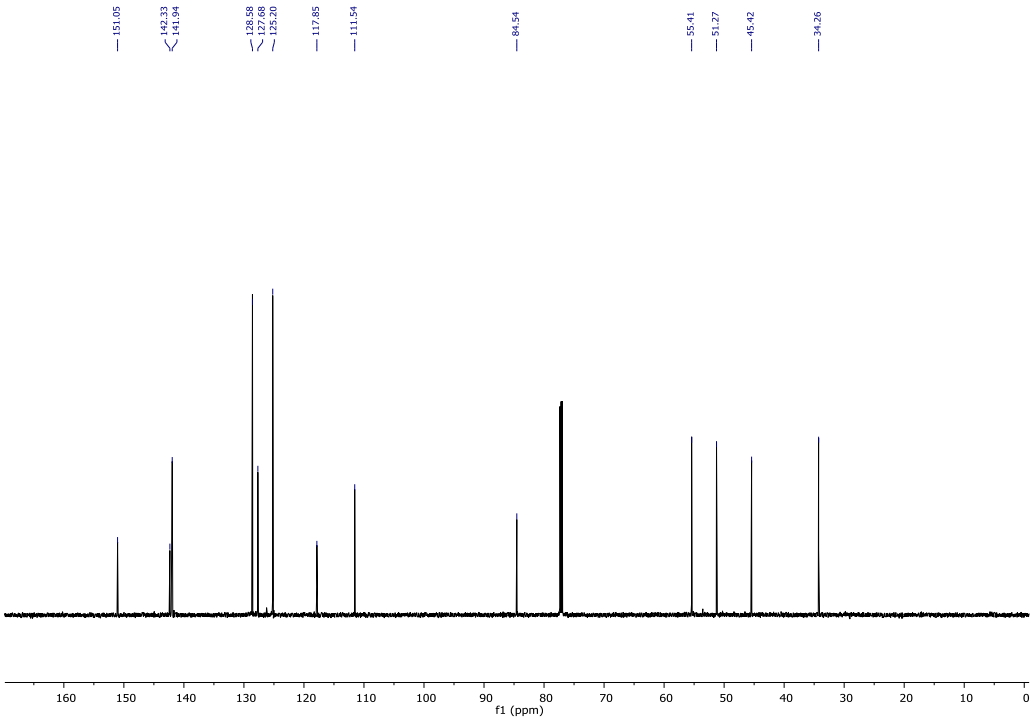
6. NMR data

(3*R*,4*R*)-4-(2-(Hydroxymethyl)furan-3-yl)-3-phenyltetrahydrothiophen-3-ol (6a)

^{1}H NMR

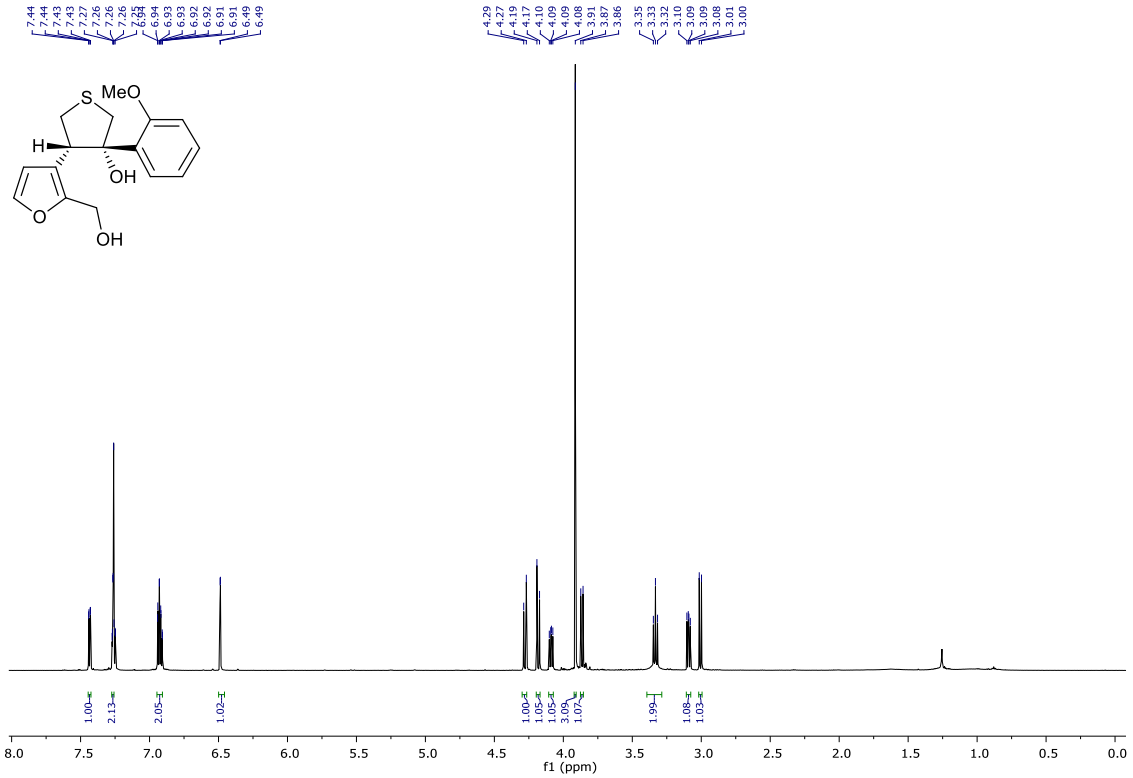


^{13}C NMR

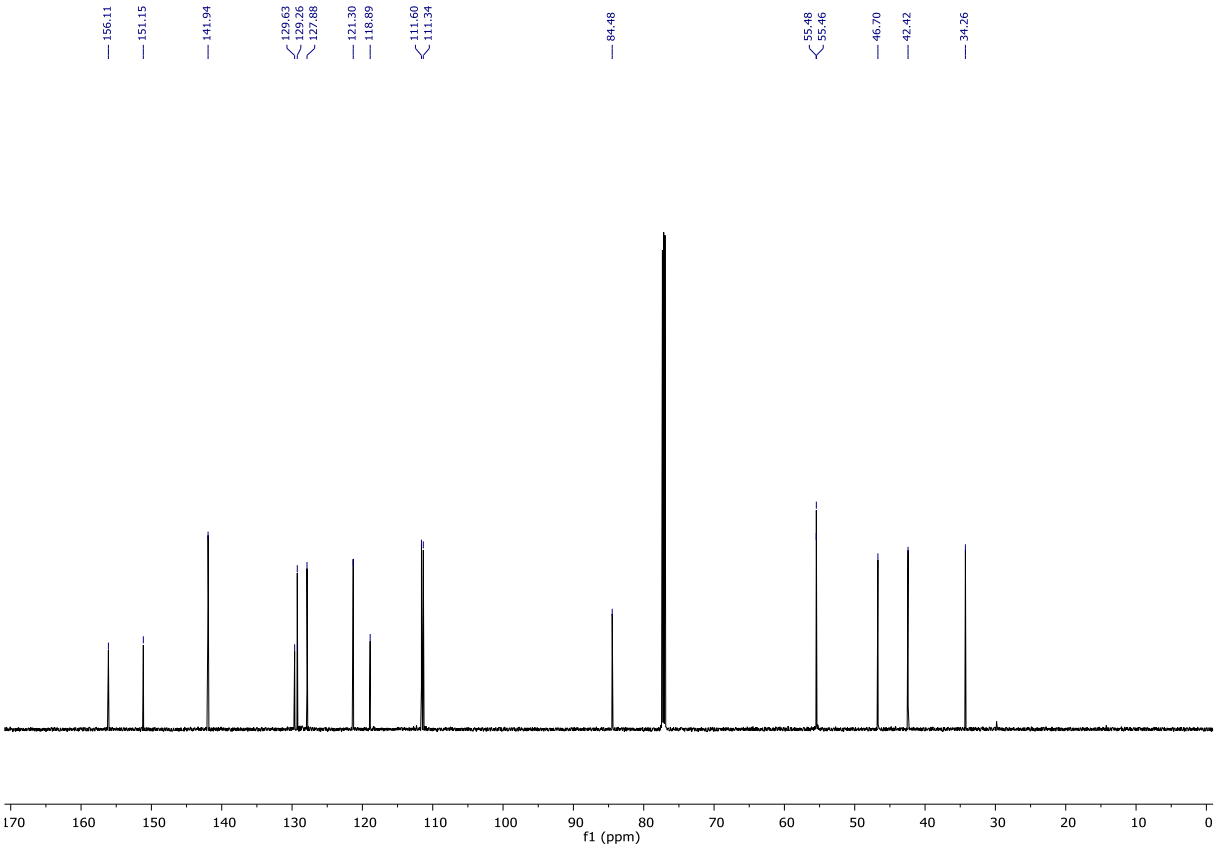


(3*S*,4*S*)-4-(2-(Hydroxymethyl)furan-3-yl)-3-(2-methoxyphenyl)tetrahydrothiophen-3-ol (6b)

^{1}H NMR

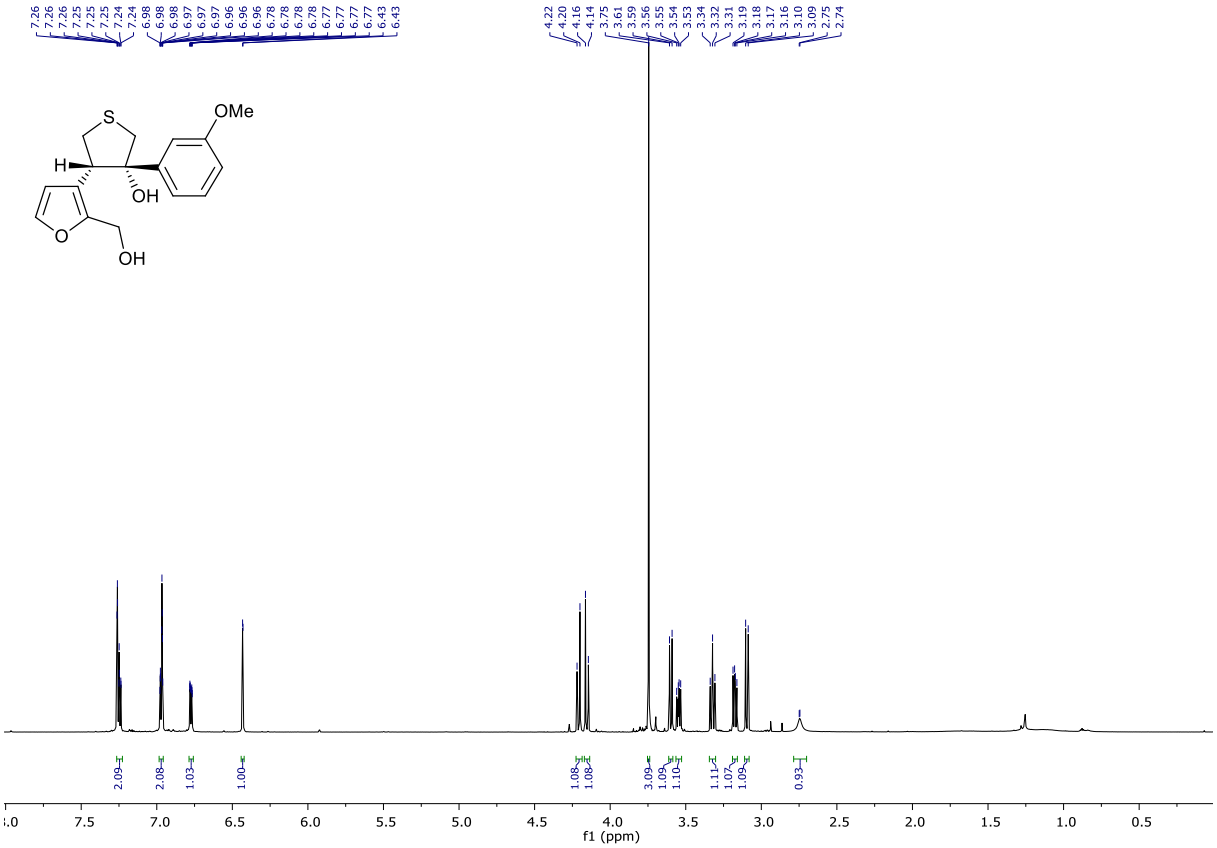


^{13}C NMR

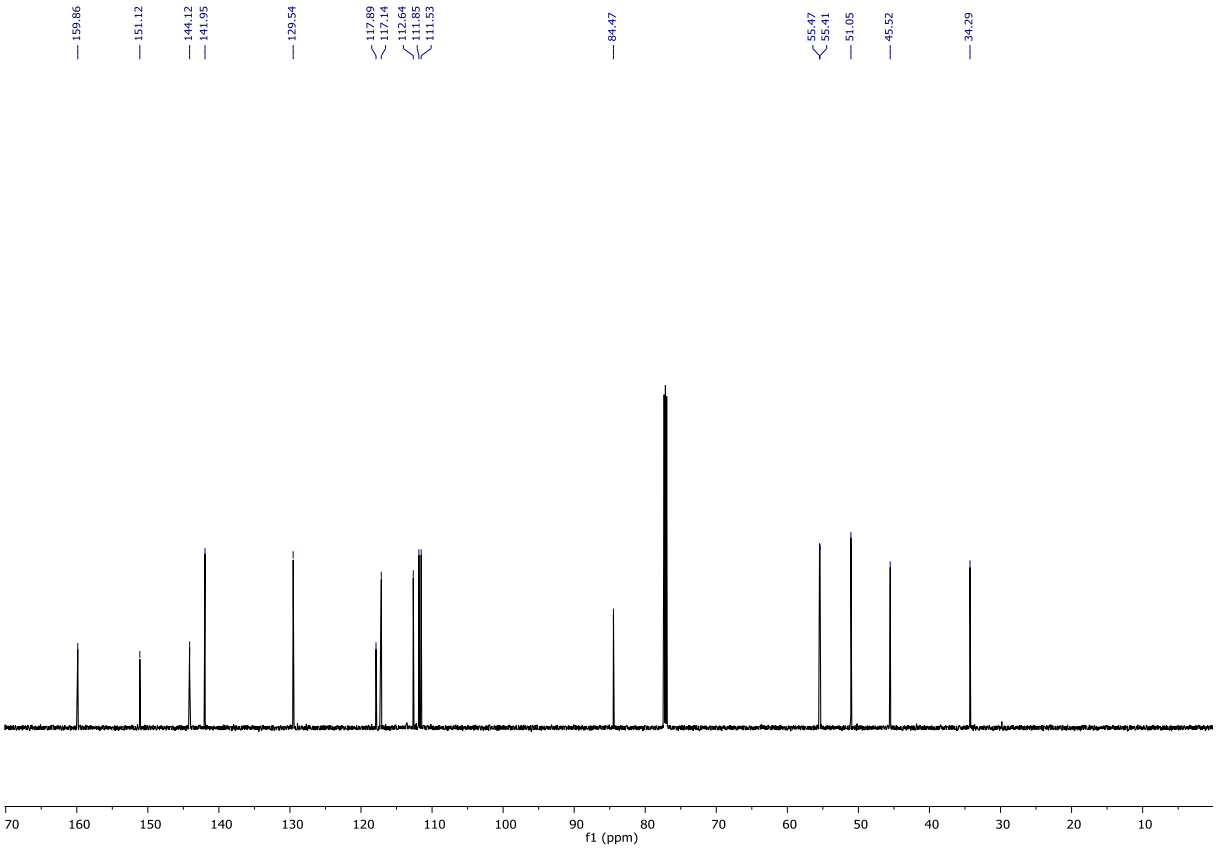


(3*S*,4*S*)-4-(2-(Hydroxymethyl)furan-3-yl)-3-(3-methoxyphenyl)tetrahydrothiophen-3-ol (6c)

^{1}H NMR

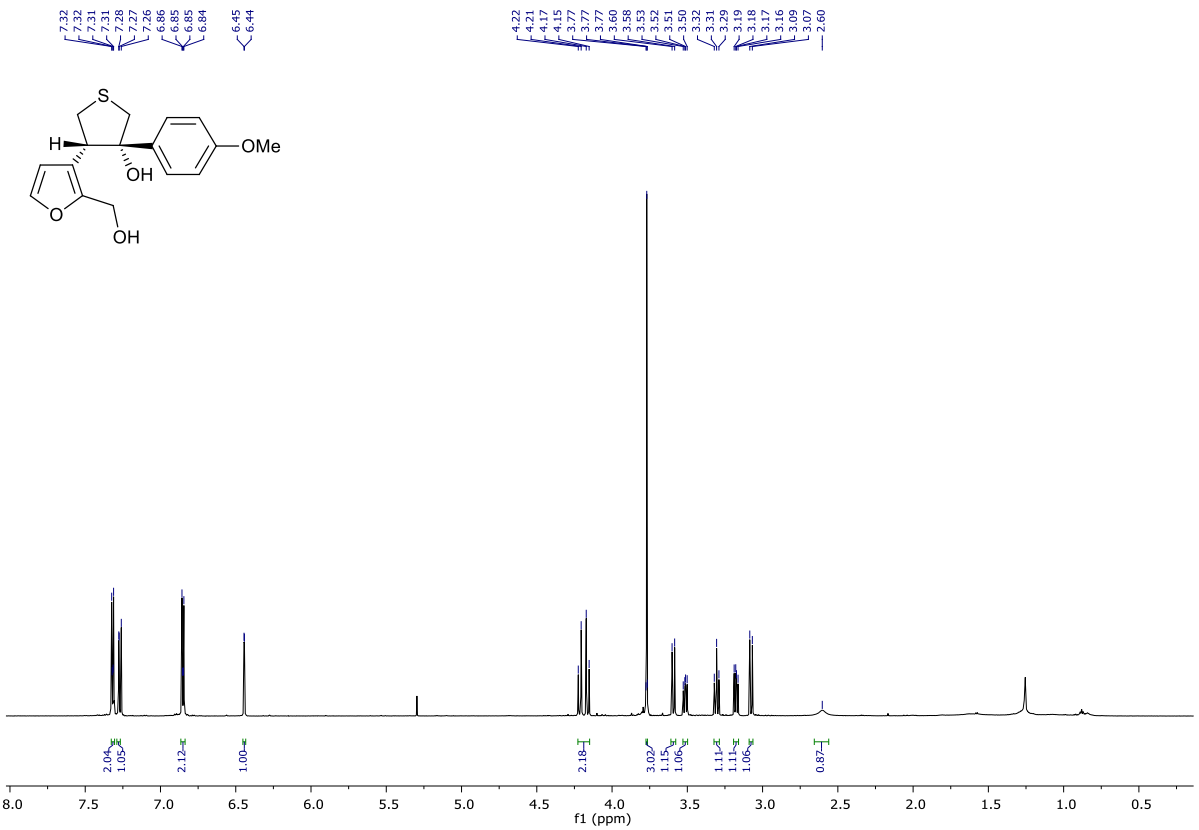


^{13}C NMR

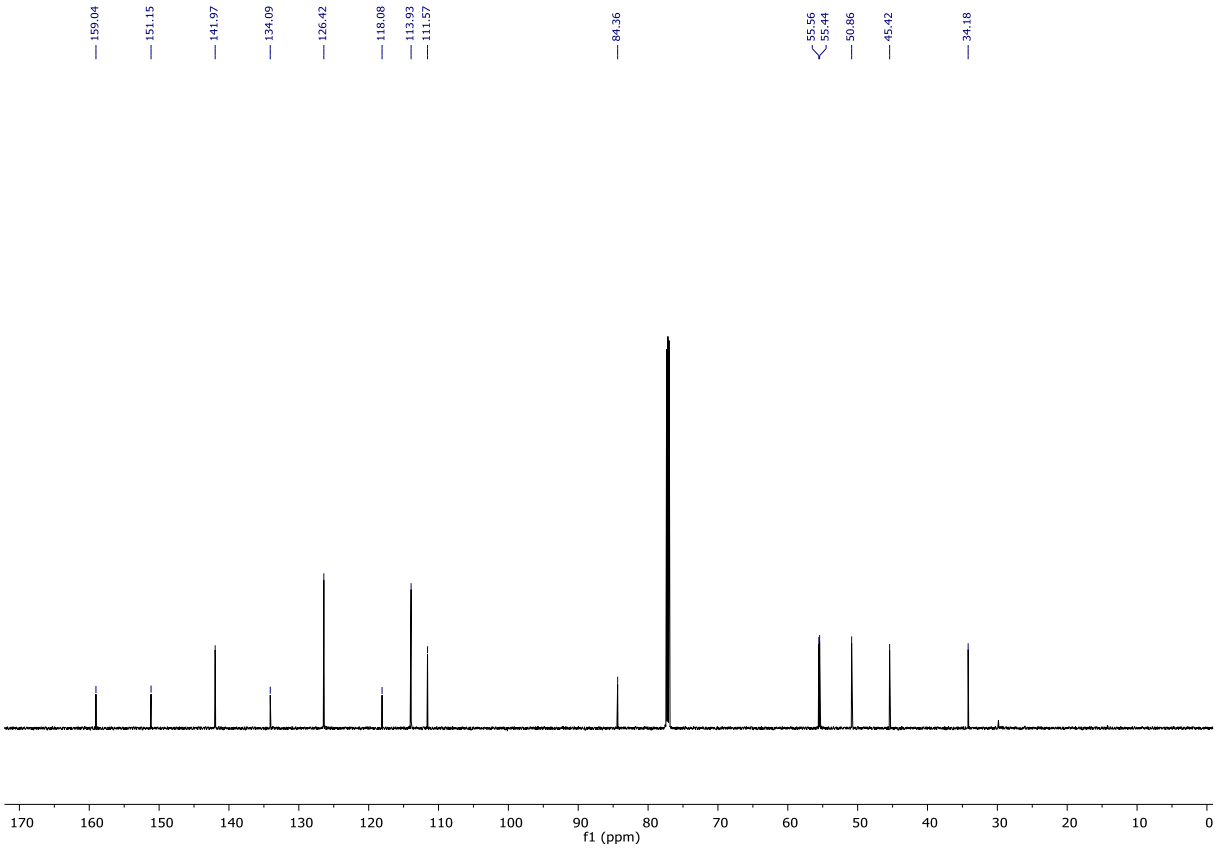


(3*S*,4*S*)-4-(2-(Hydroxymethyl)furan-3-yl)-3-(4-methoxyphenyl)tetrahydrothiophen-3-ol (6d)

^{1}H NMR

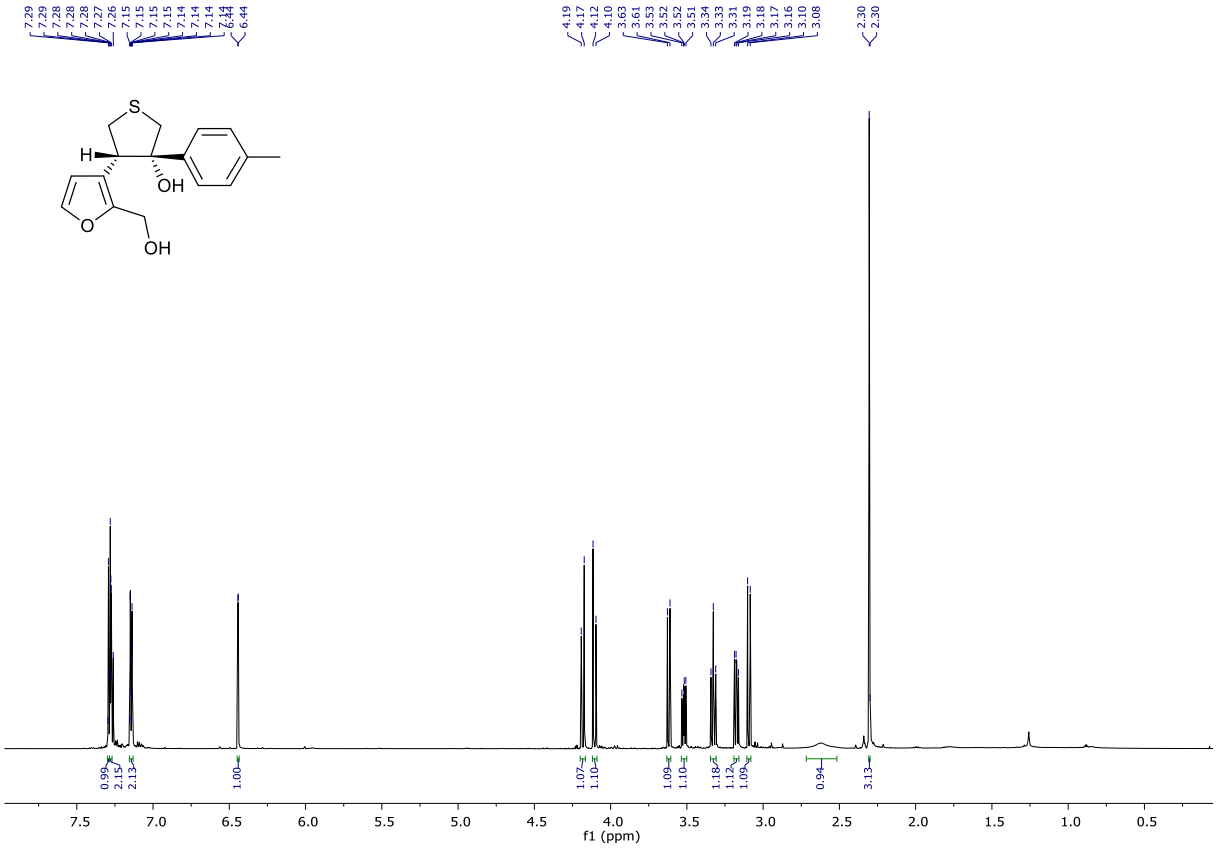


^{13}C NMR

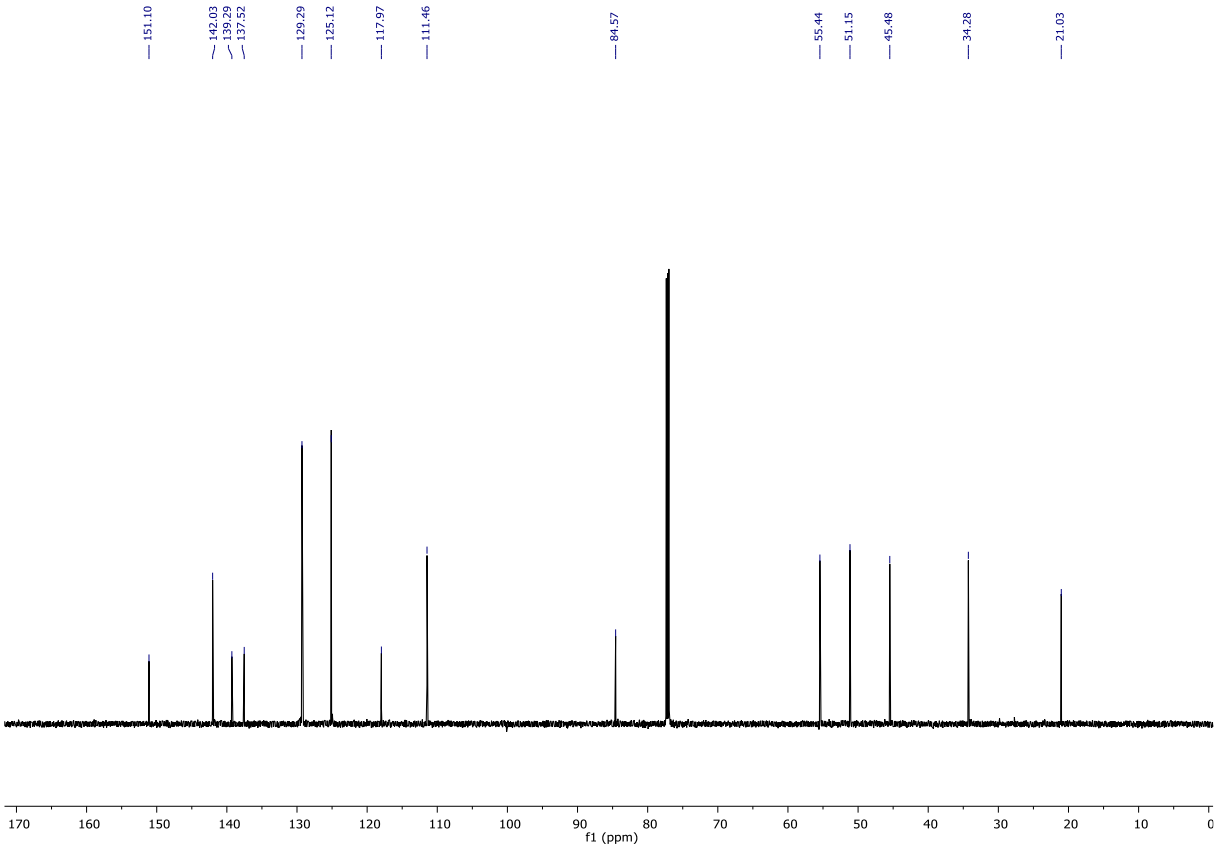


(3*S*,4*S*)-4-(2-(Hydroxymethyl)furan-3-yl)-3-(*p*-tolyl)tetrahydrothiophen-3-ol (6e)

^{1}H NMR

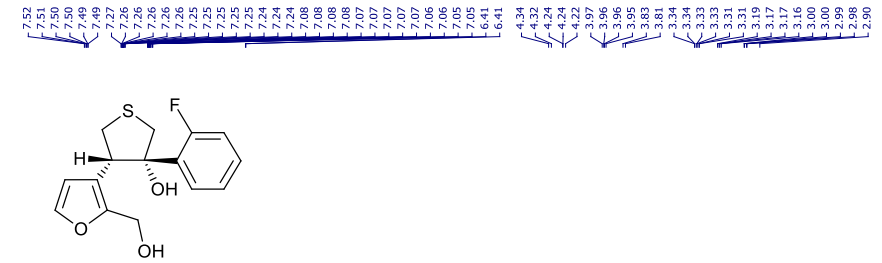


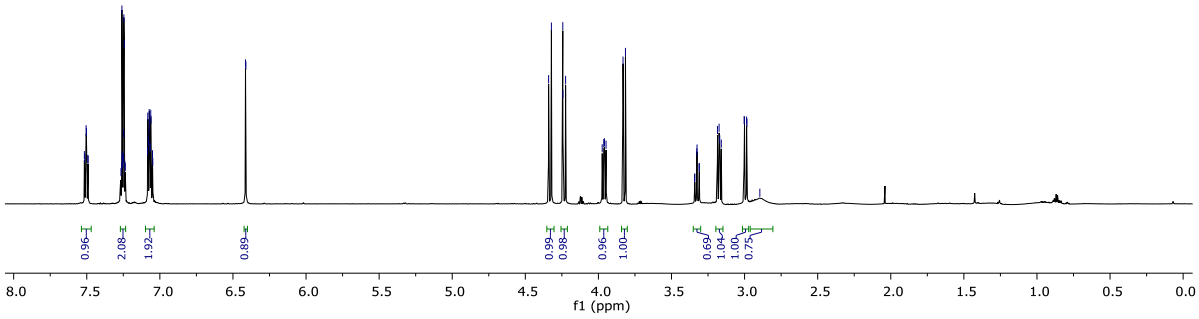
^{13}C NMR



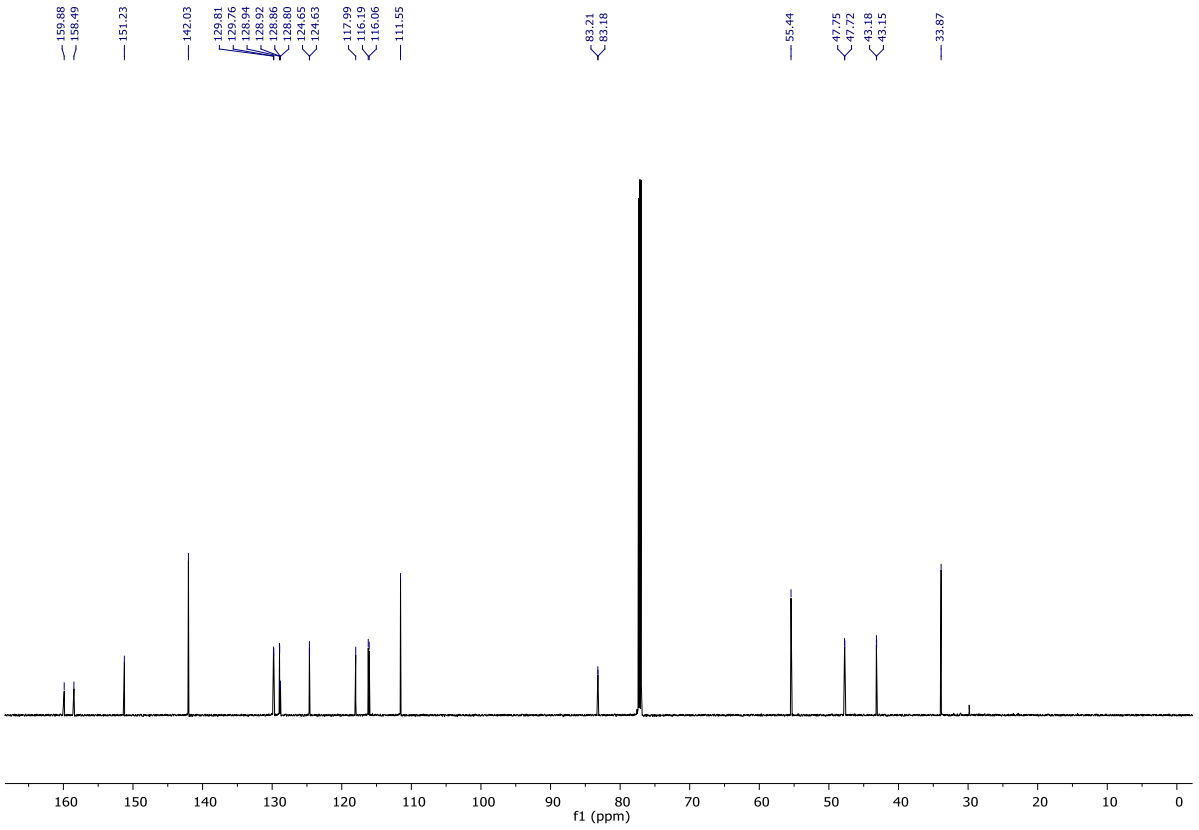
(3*S*,4*S*)-3-(2-Fluorophenyl)-4-(2-(hydroxymethyl)furan-3-yl)tetrahydrothiophen-3-ol (6f)

^{1}H NMR



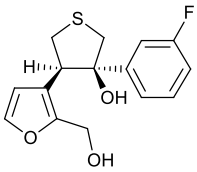


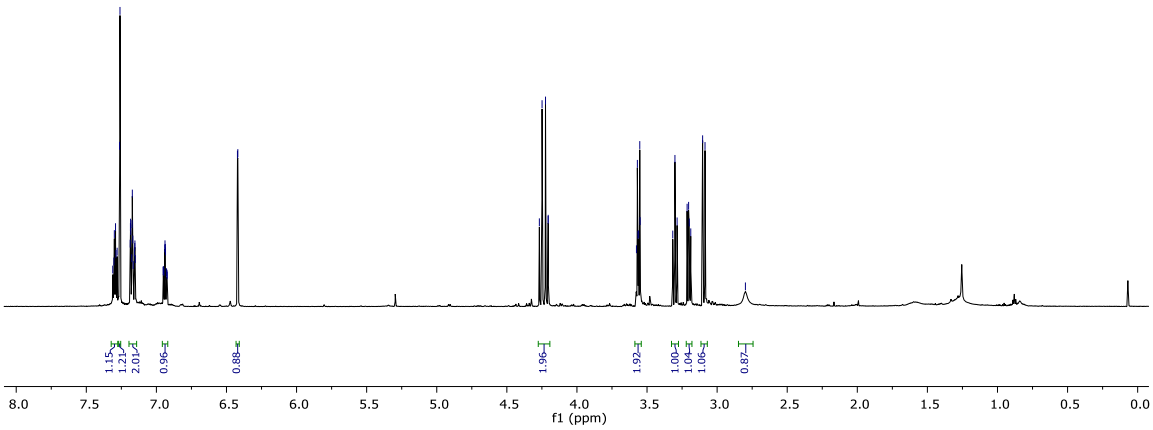
^{13}C NMR



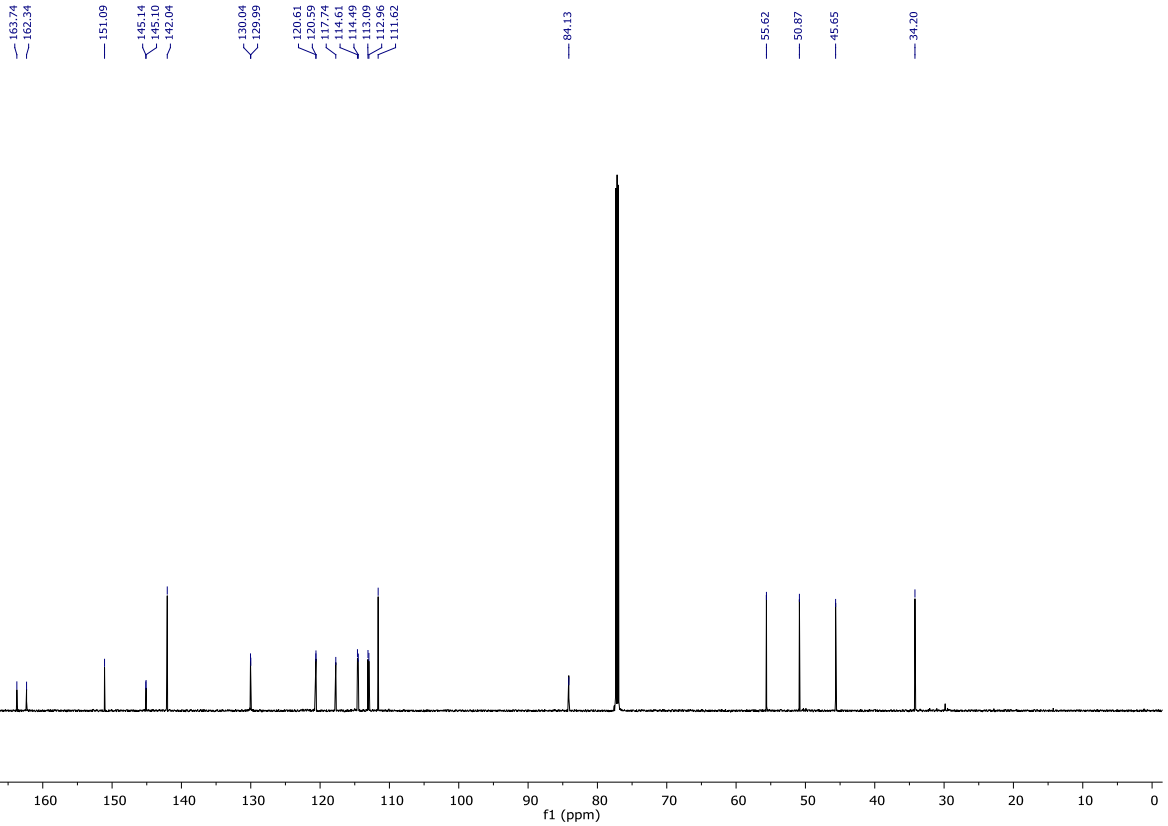
(3*R*,4*R*)-3-(3-Fluorophenyl)-4-(2-(hydroxymethyl)furan-3-yl)tetrahydrothiophen-3-ol (6g)

^{1}H NMR



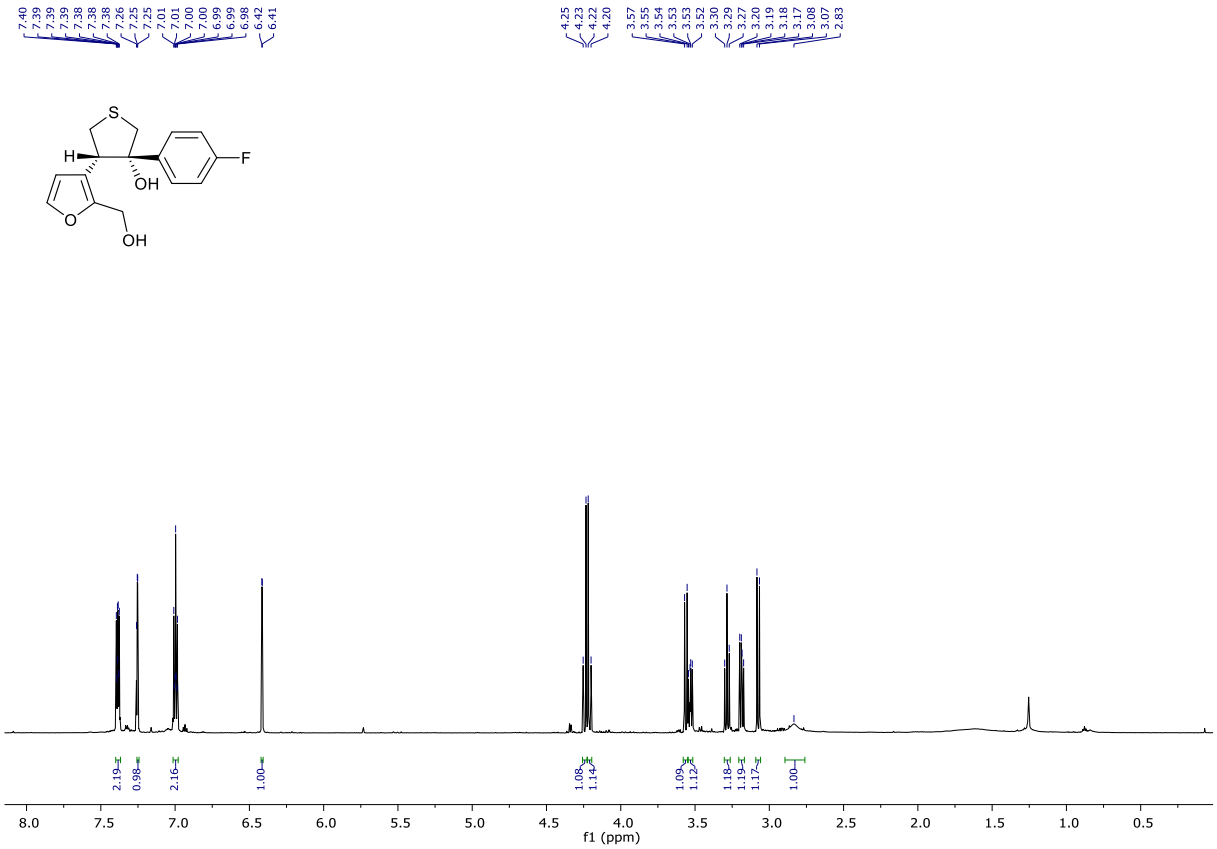


^{13}C NMR

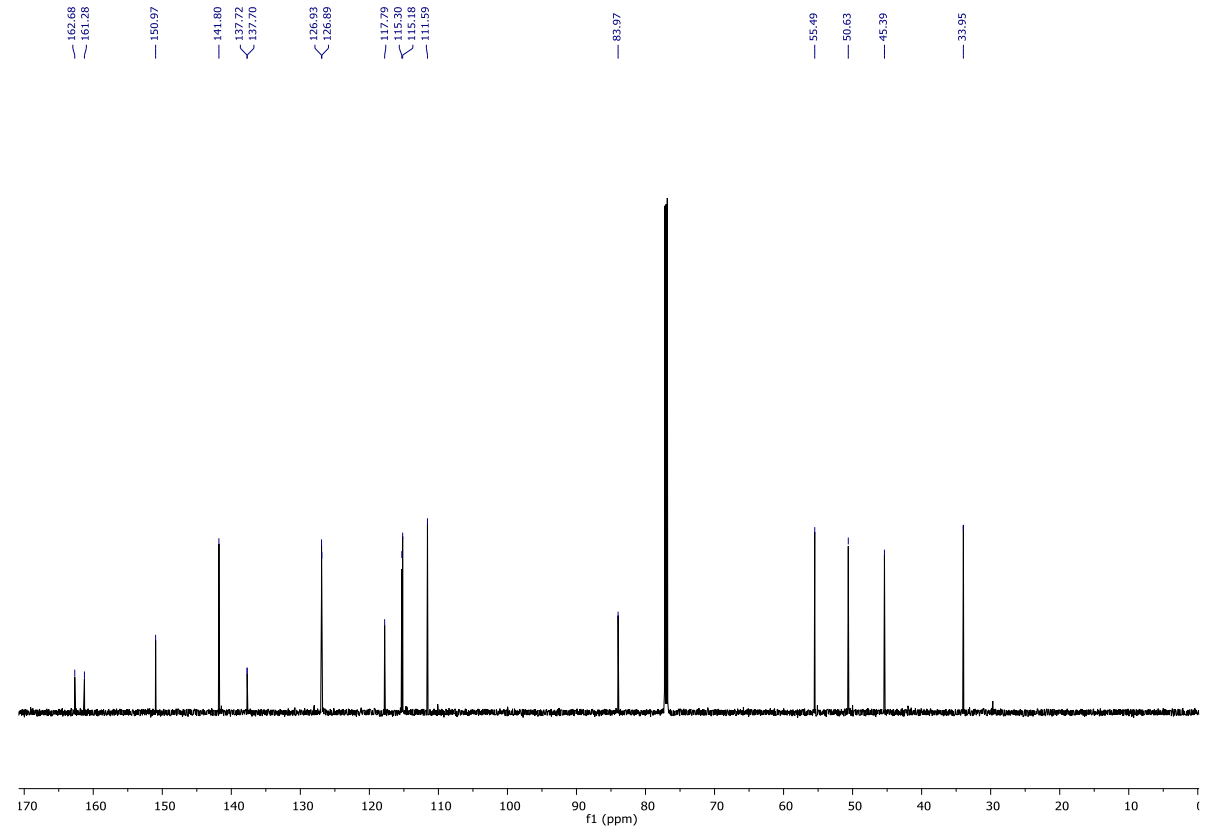


(3*S*,4*S*)-3-(4-Fluorophenyl)-4-(2-(hydroxymethyl)furan-3-yl)tetrahydrothiophen-3-ol (6h)

^{1}H NMR

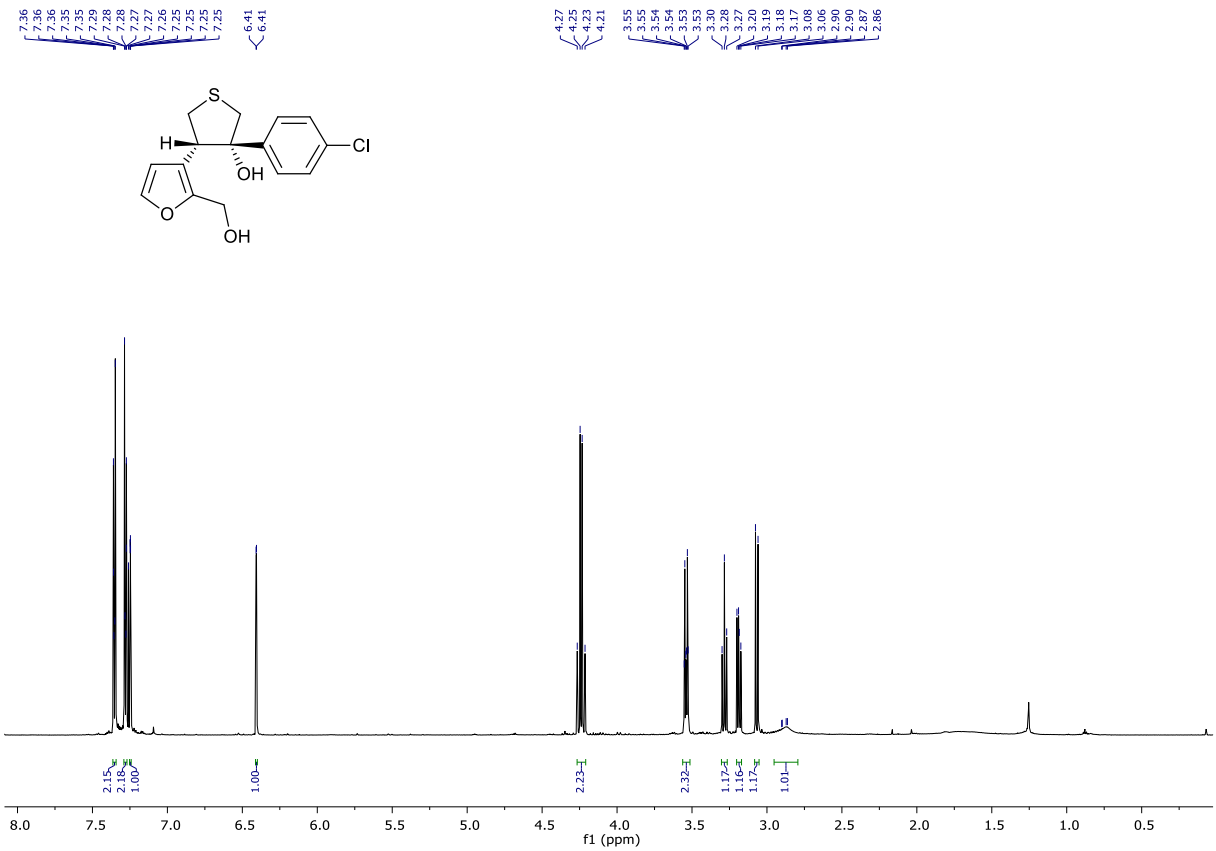


^{13}C NMR

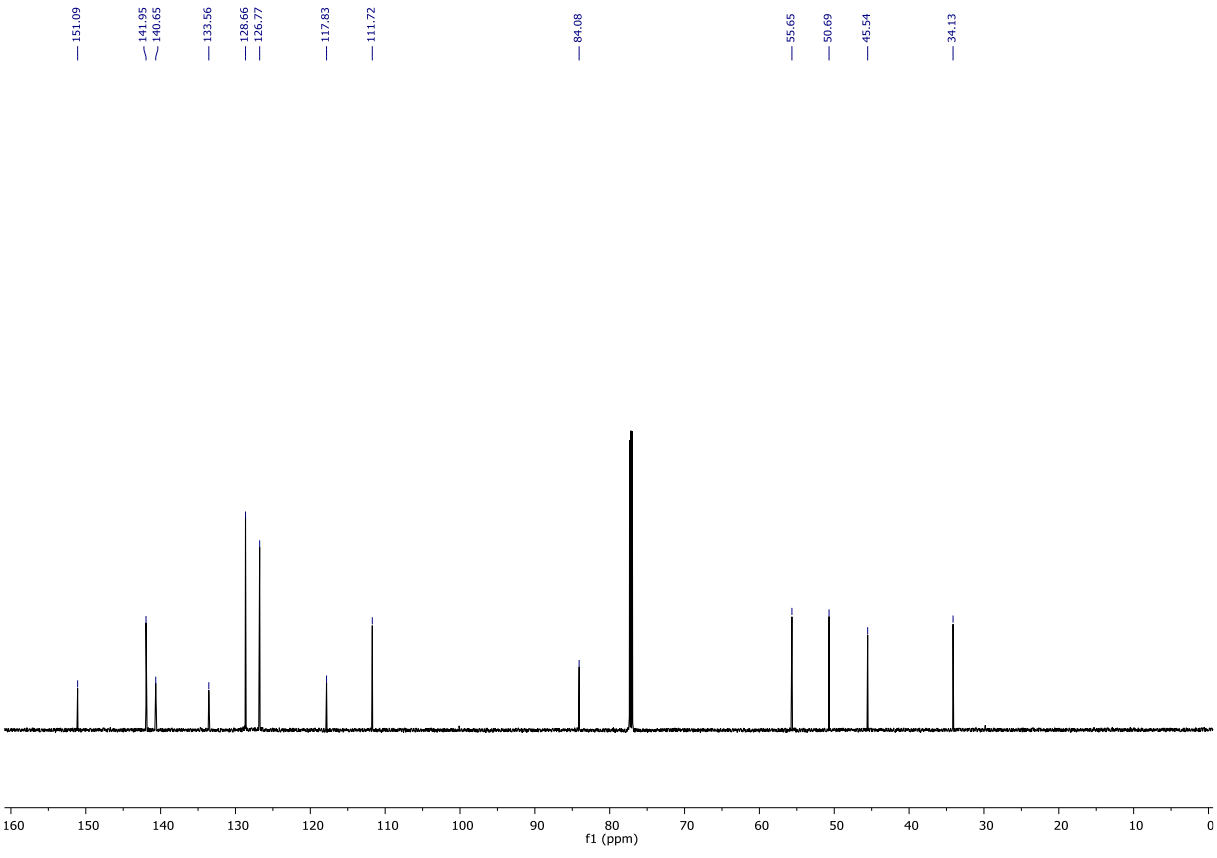


(3*S*,4*S*)-3-(4-Chlorophenyl)-4-(2-(hydroxymethyl)furan-3-yl)tetrahydrothiophen-3-ol (6i)

^{1}H NMR

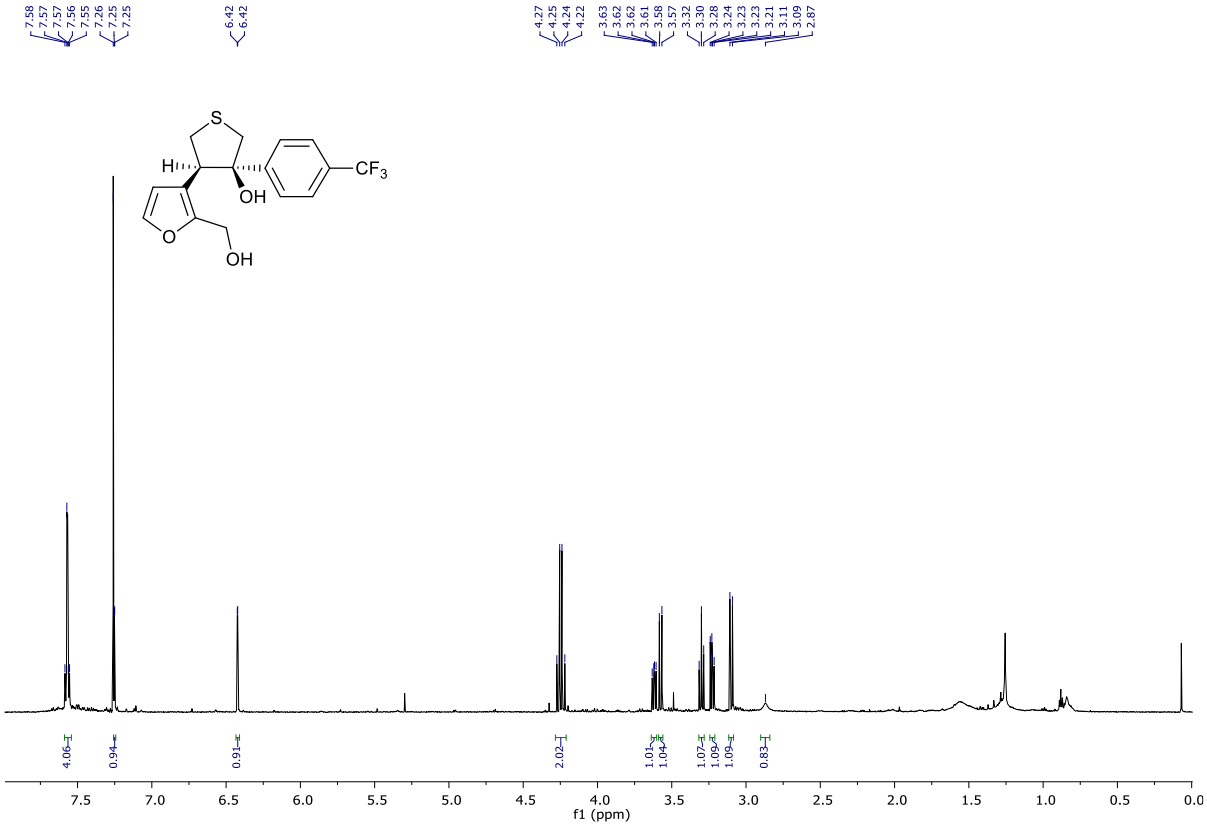


^{13}C NMR

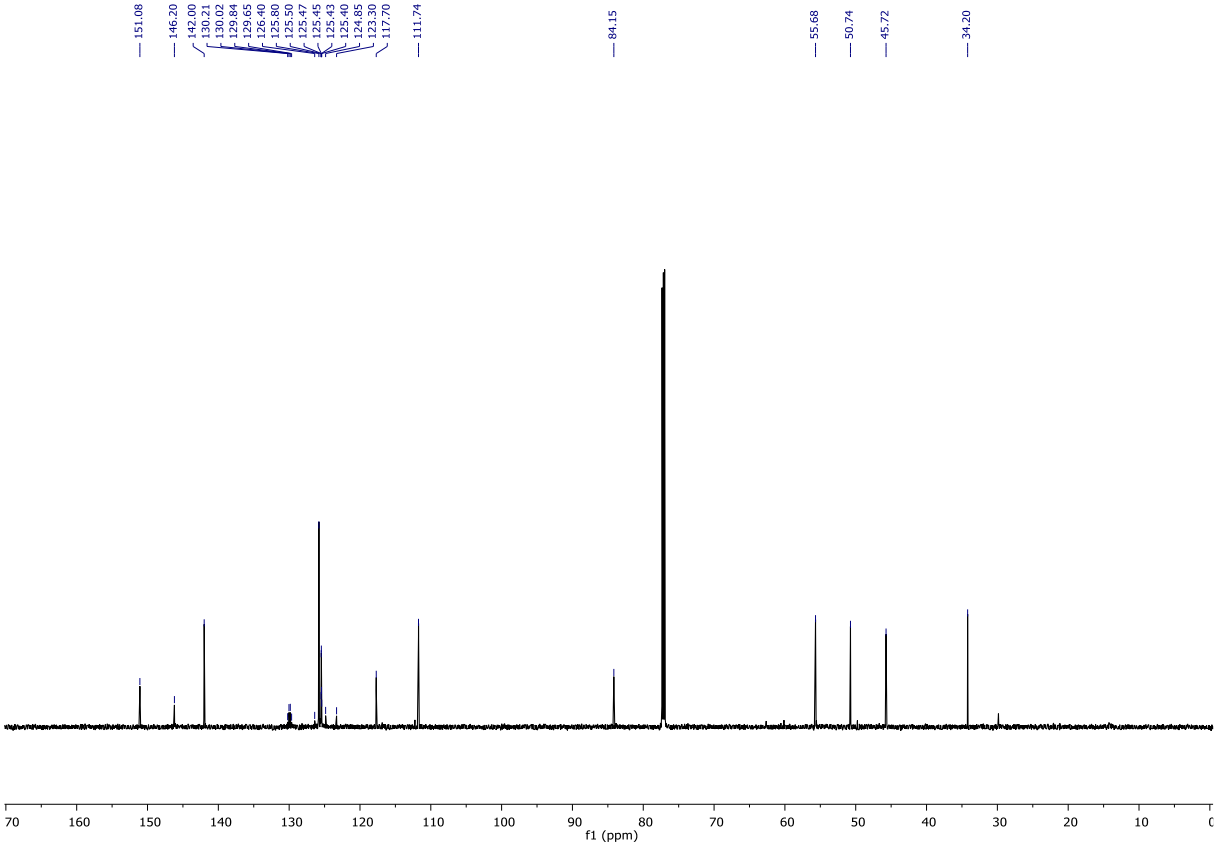


(3*R*,4*R*)-4-(2-(Hydroxymethyl)furan-3-yl)-3-(4-(trifluoromethyl)phenyl) tetrahydrothiophen-3-ol (6j)

^{1}H NMR

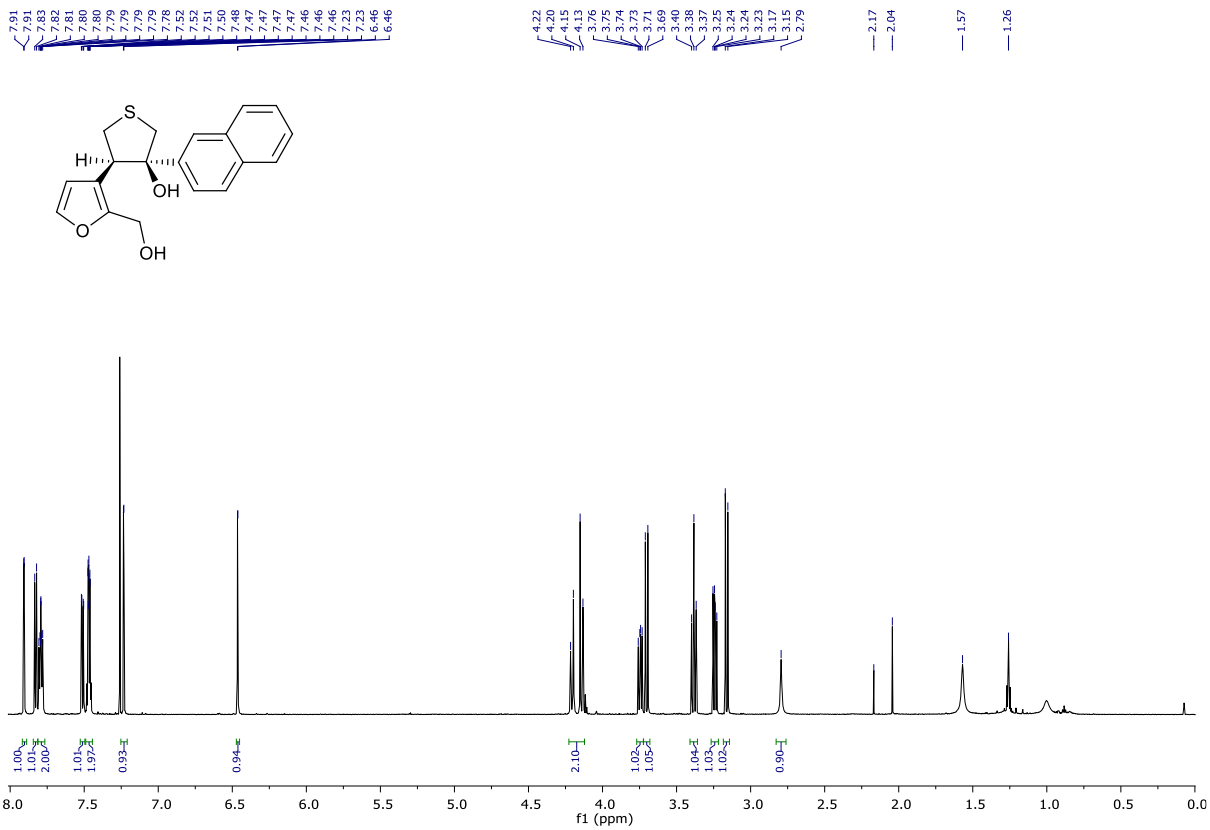


^{13}C NMR

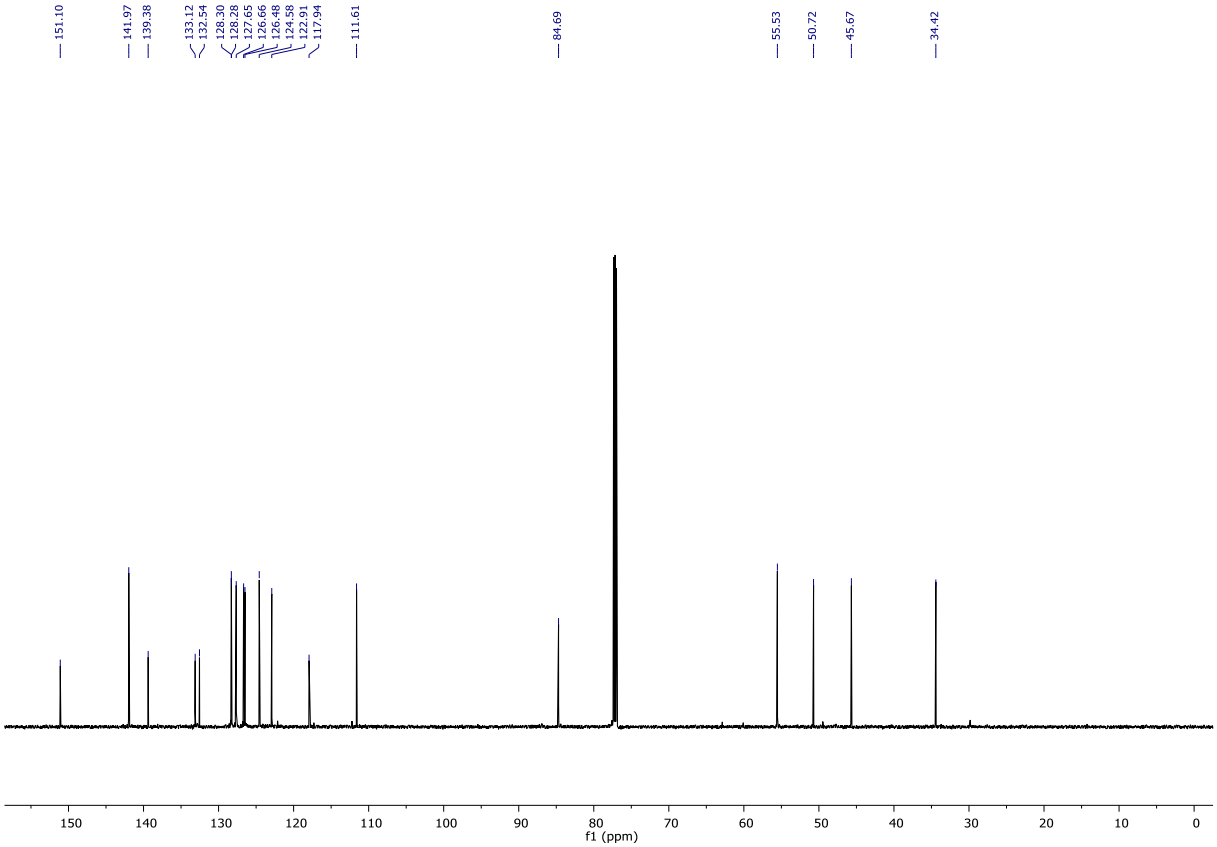


(3*R*,4*R*)-4-(2-(Hydroxymethyl)furan-3-yl)-3-(naphthalen-2-yl)tetrahydrothiophen-3-ol (6k)

^{1}H NMR

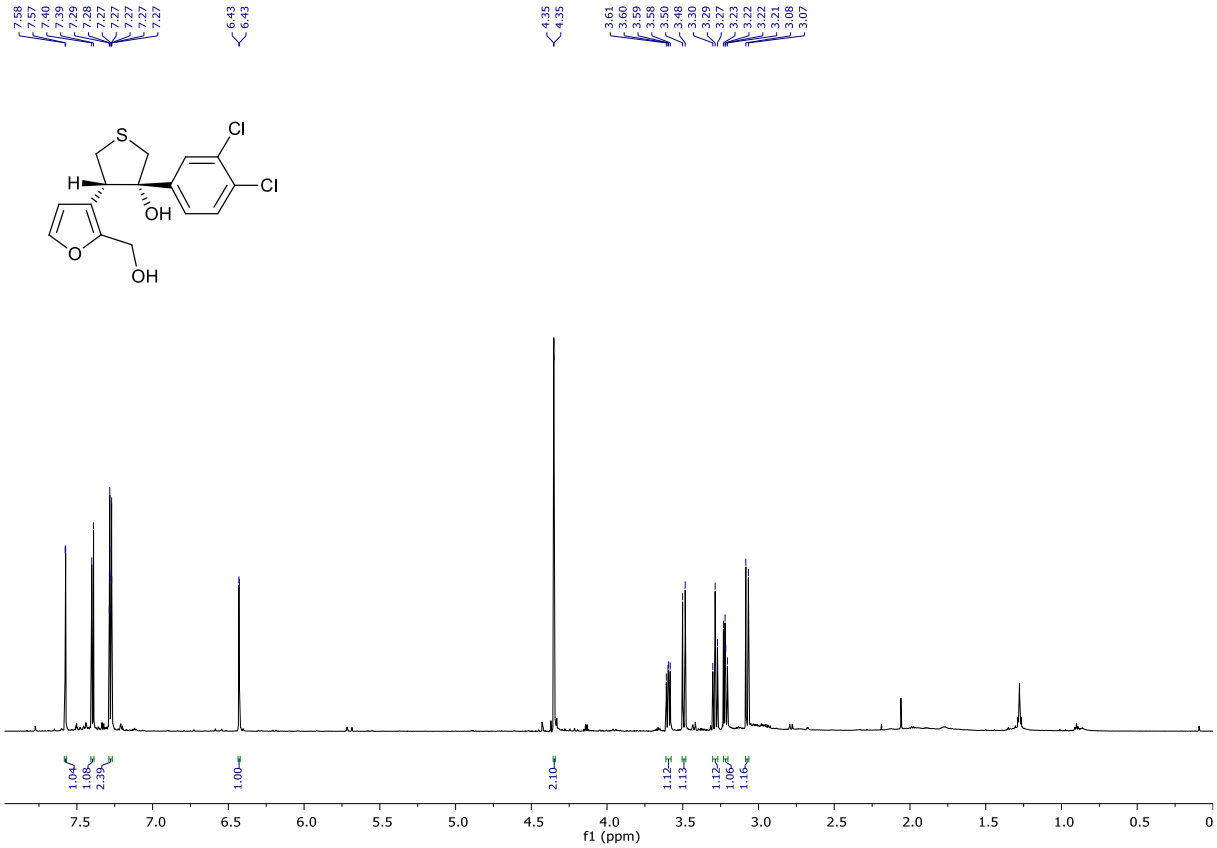


^{13}C NMR

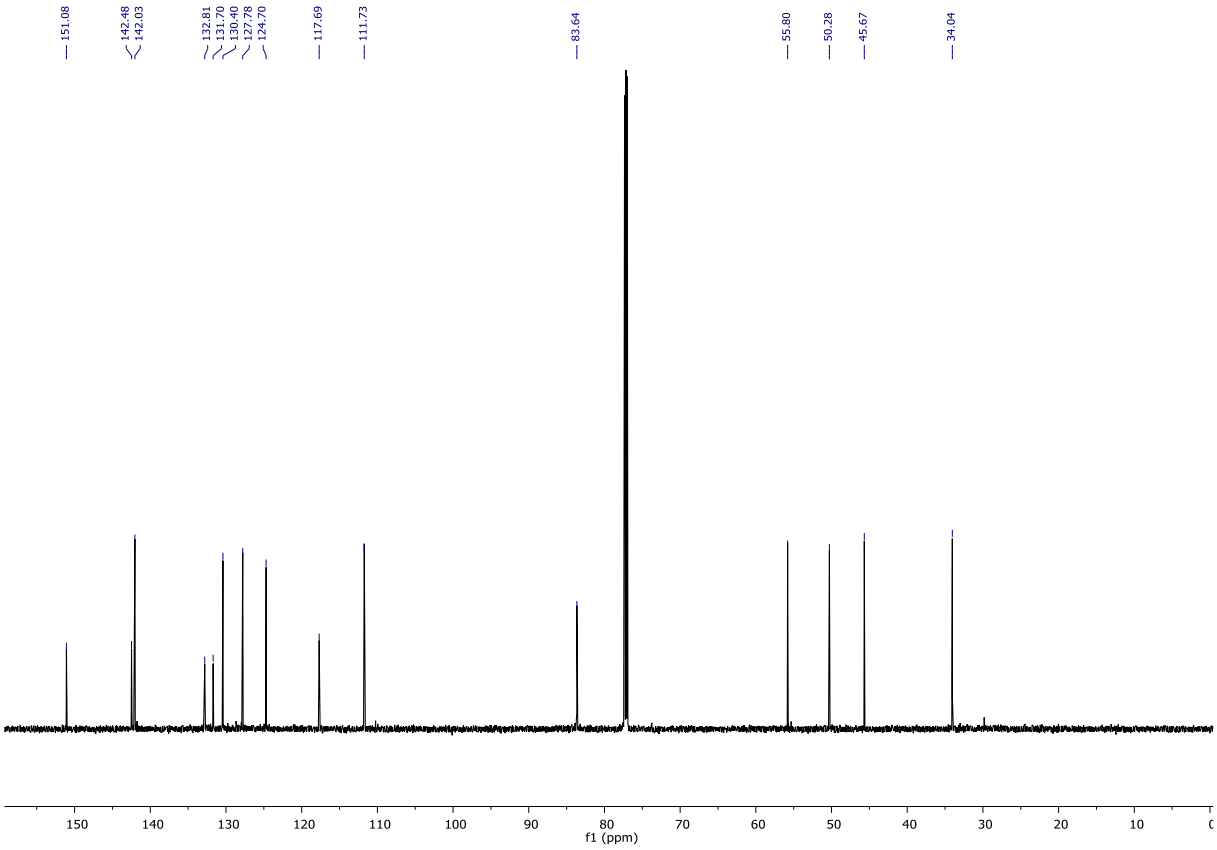


(3*S*,4*S*)-3-(3,4-Dichlorophenyl)-4-(2-(hydroxymethyl)furan-3-yl)tetrahydrothiophen-3-ol (6l)

^{1}H NMR

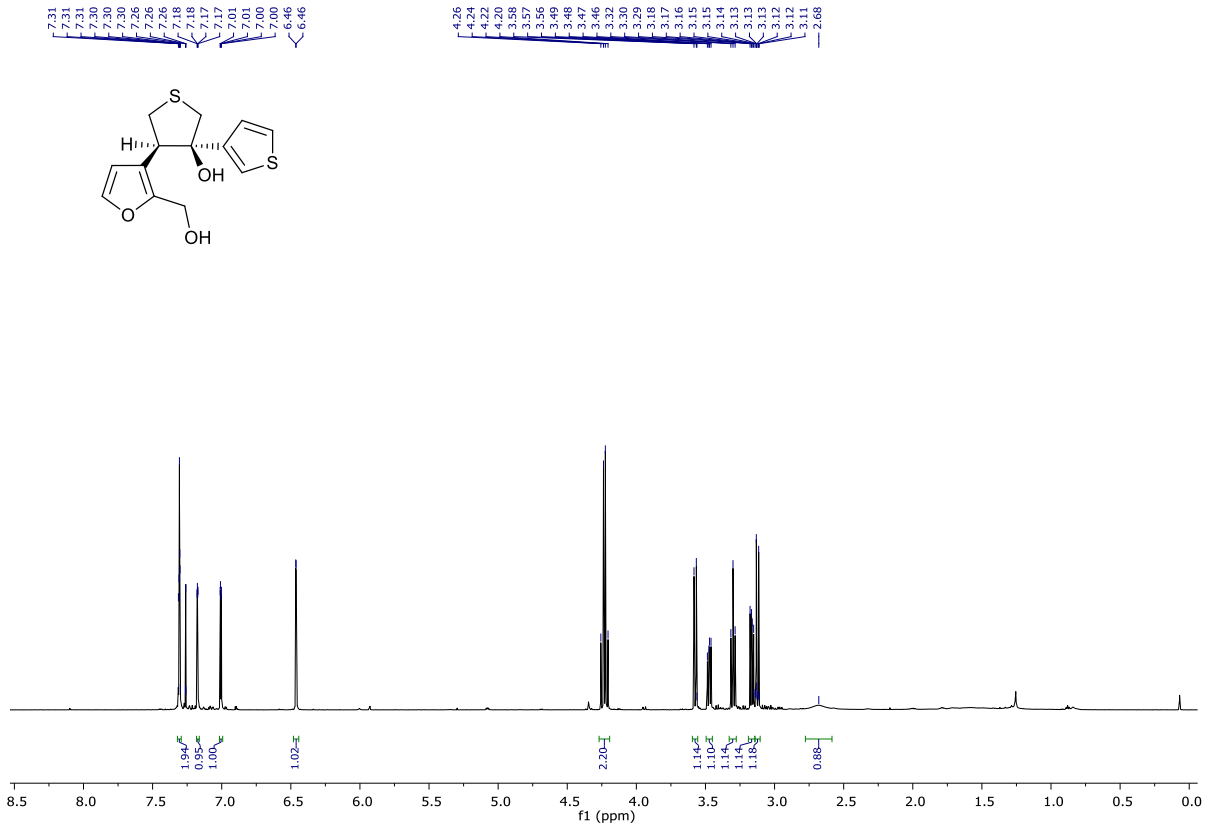


^{13}C NMR

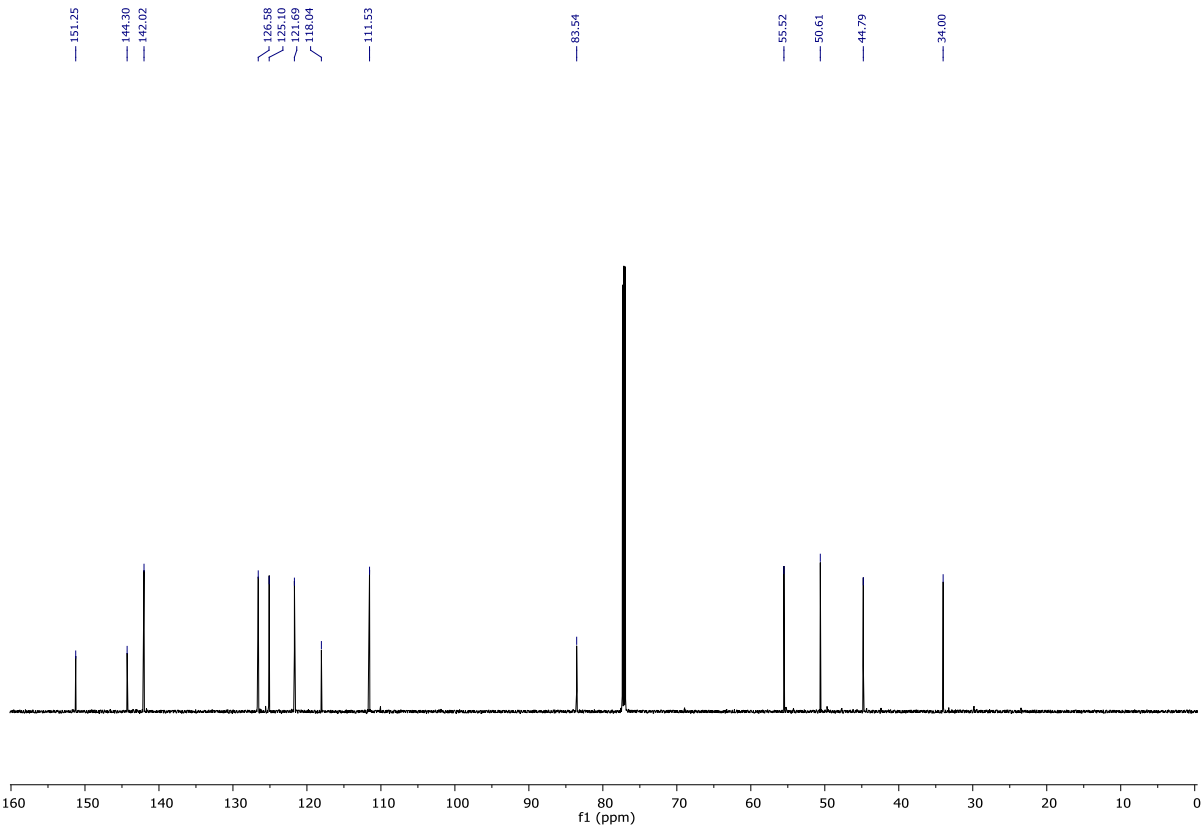


(3*R*,4*R*)-4-(2-(Hydroxymethyl)furan-3-yl)-3-(thiophen-3-yl)tetrahydrothiophen-3-ol (6m)

^{1}H NMR

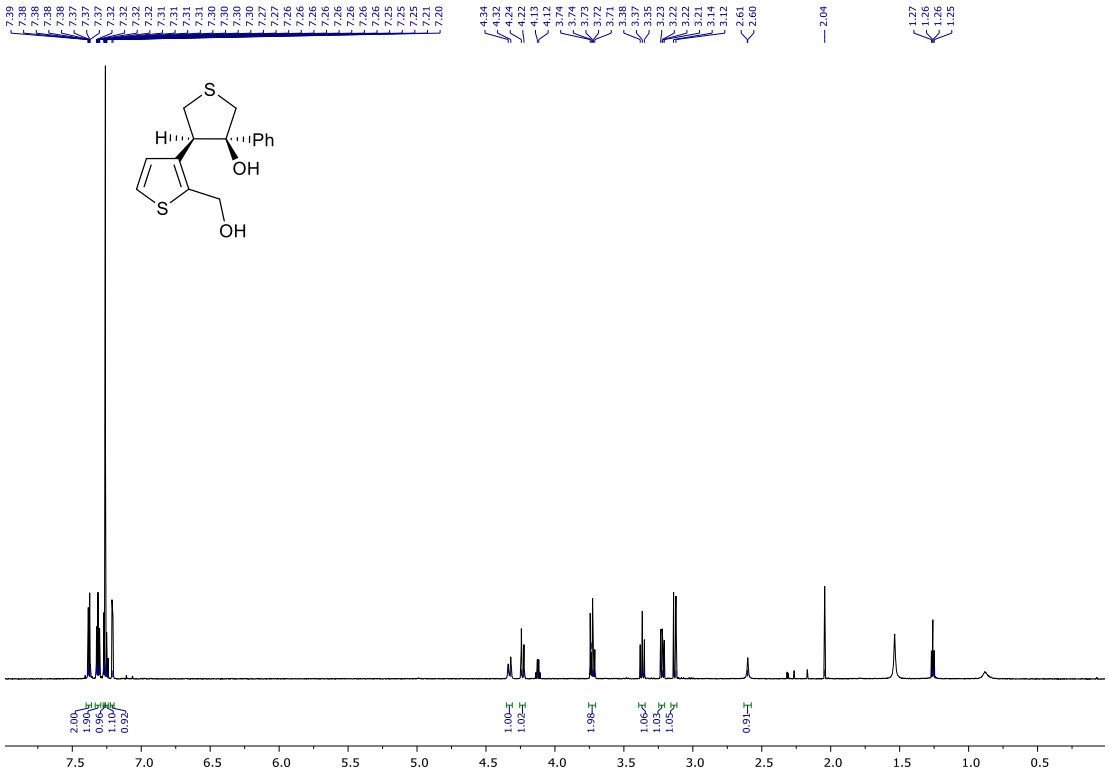


^{13}C NMR

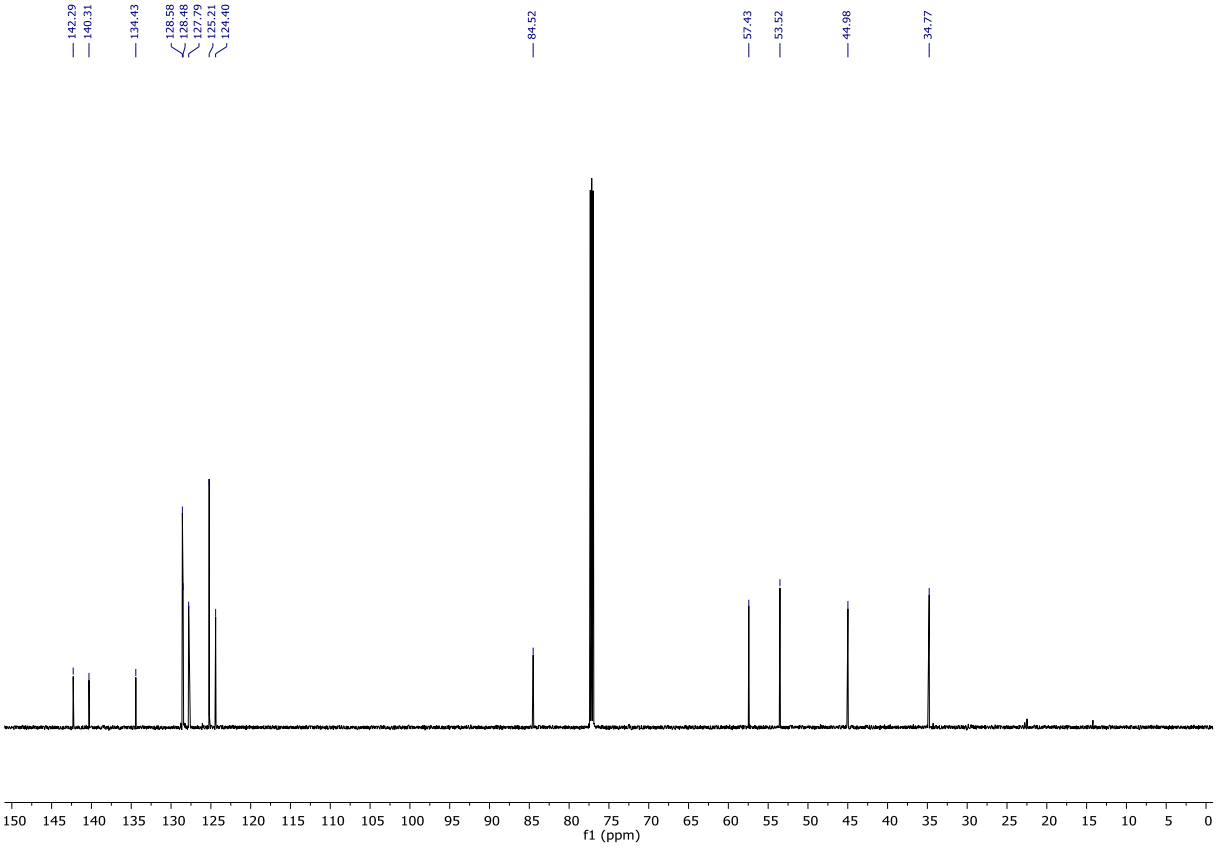


(3*R*,4*R*)-4-(2-(Hydroxymethyl)thiophen-3-yl)-3-phenyltetrahydrothiophen-3-ol (6n)

^{1}H NMR

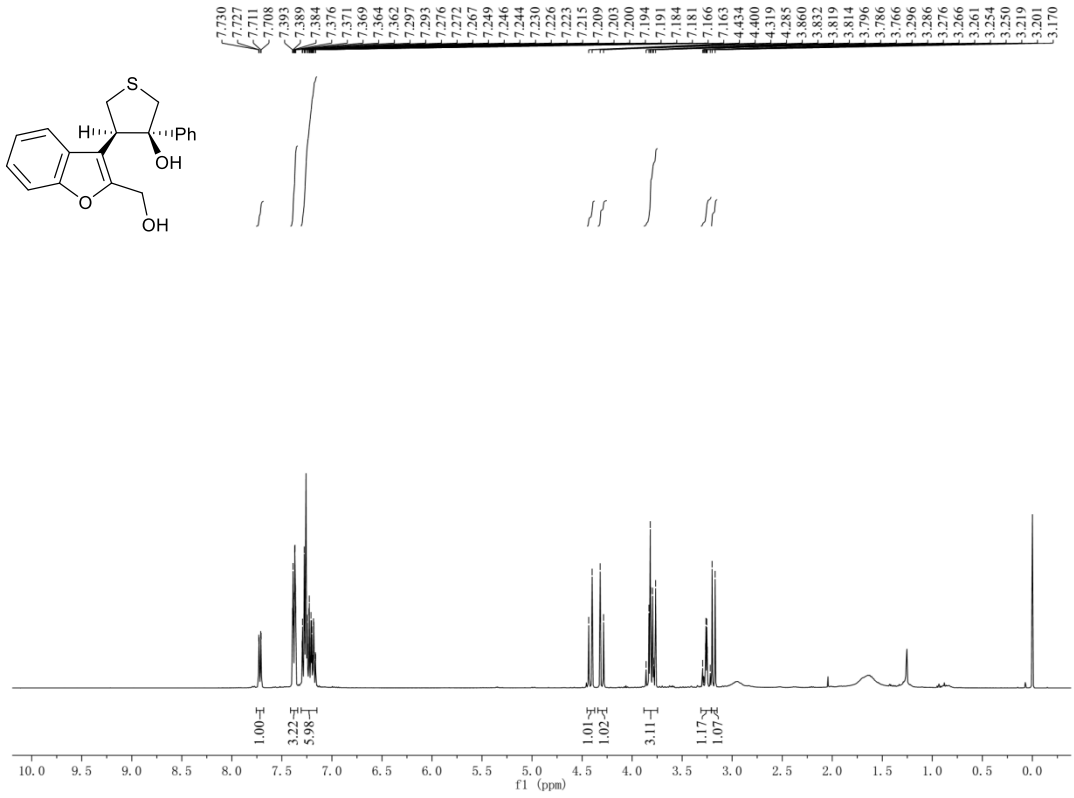


^{13}C NMR

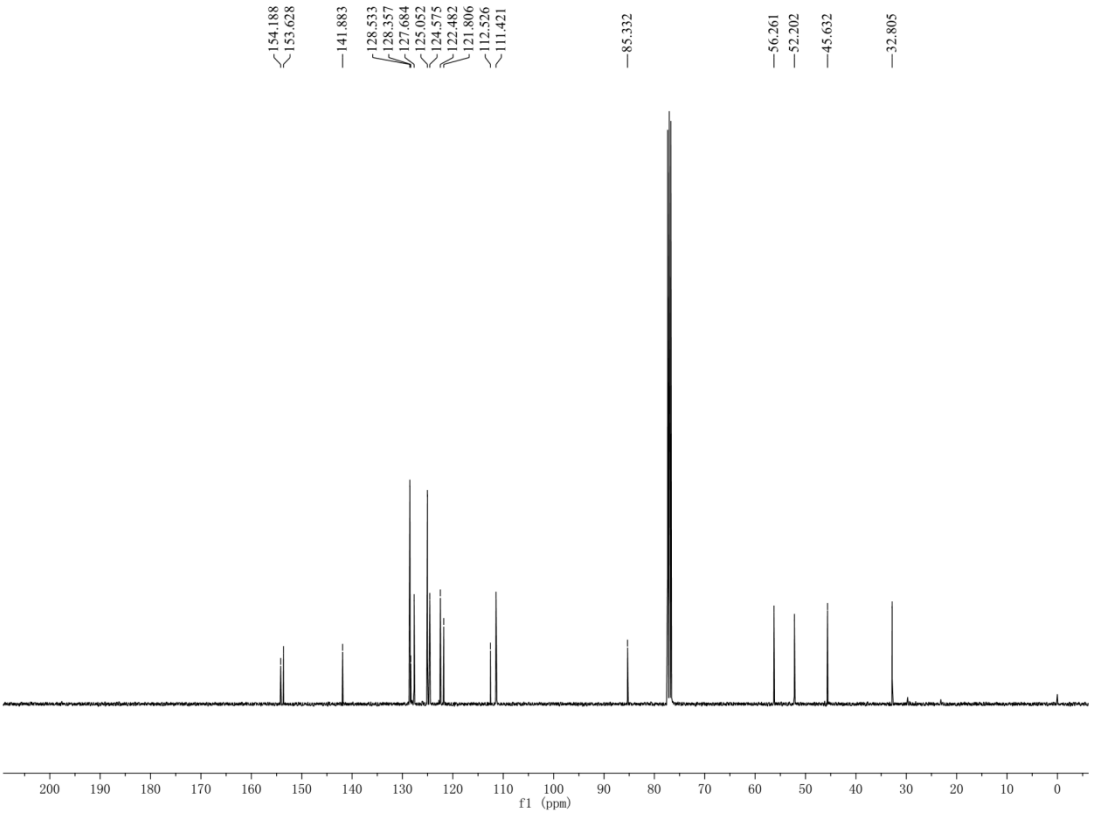


(3*R*,4*R*)-4-(2-(Hydroxymethyl)benzofuran-3-yl)-3-phenyltetrahydrothiophen-3-ol (6o)

^{1}H NMR

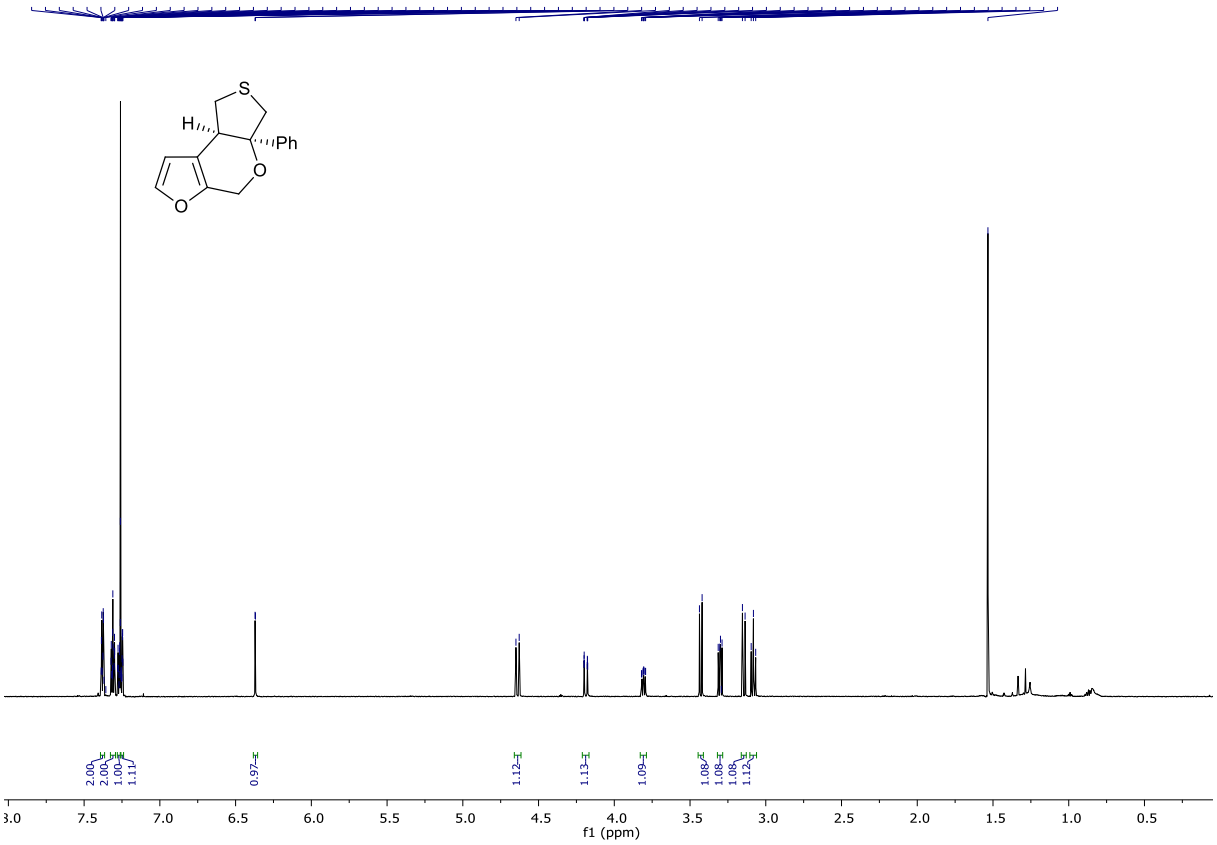


^{13}C NMR

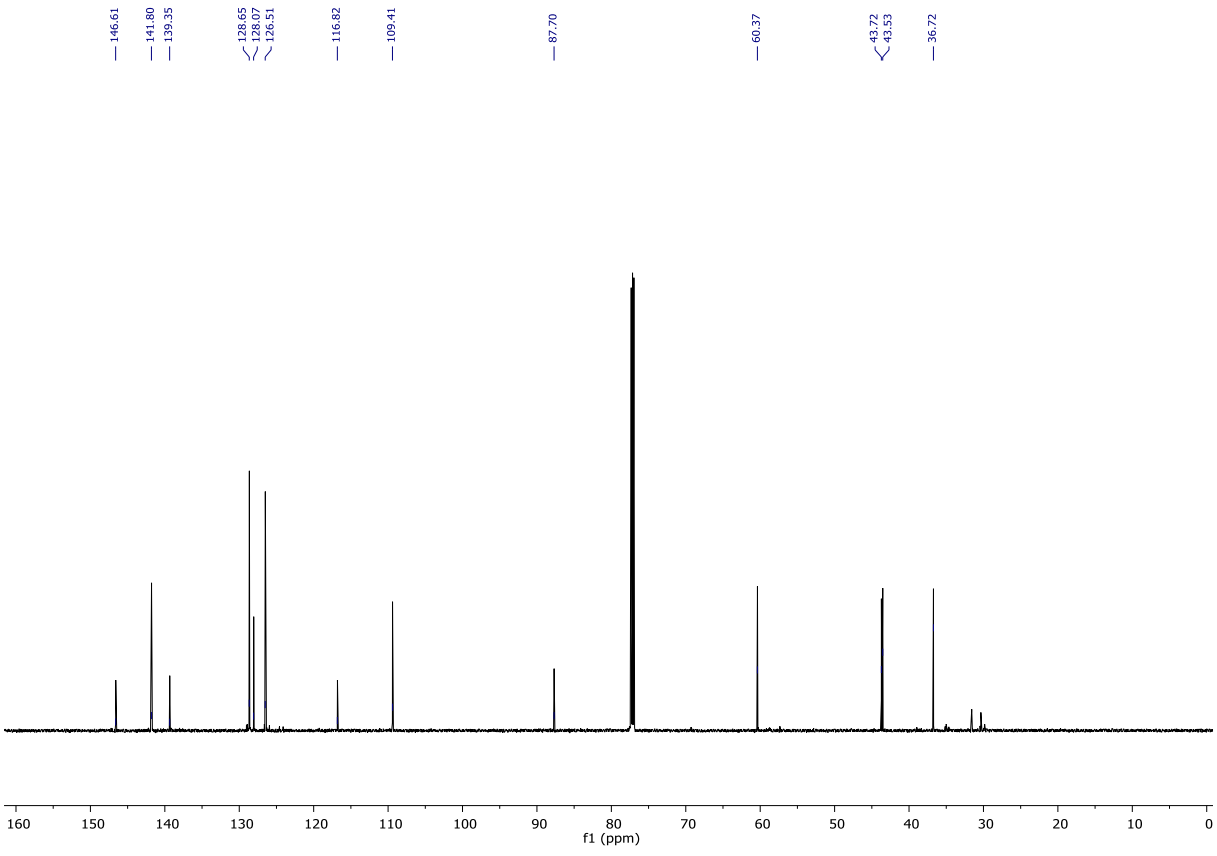


(3a*R*,8b*R*)-3a-Phenyl-3,3a,5,8b-tetrahydro-1*H*-furo[3,2-*d*]thieno[3,4-*b*]pyran (4a)

^{1}H NMR

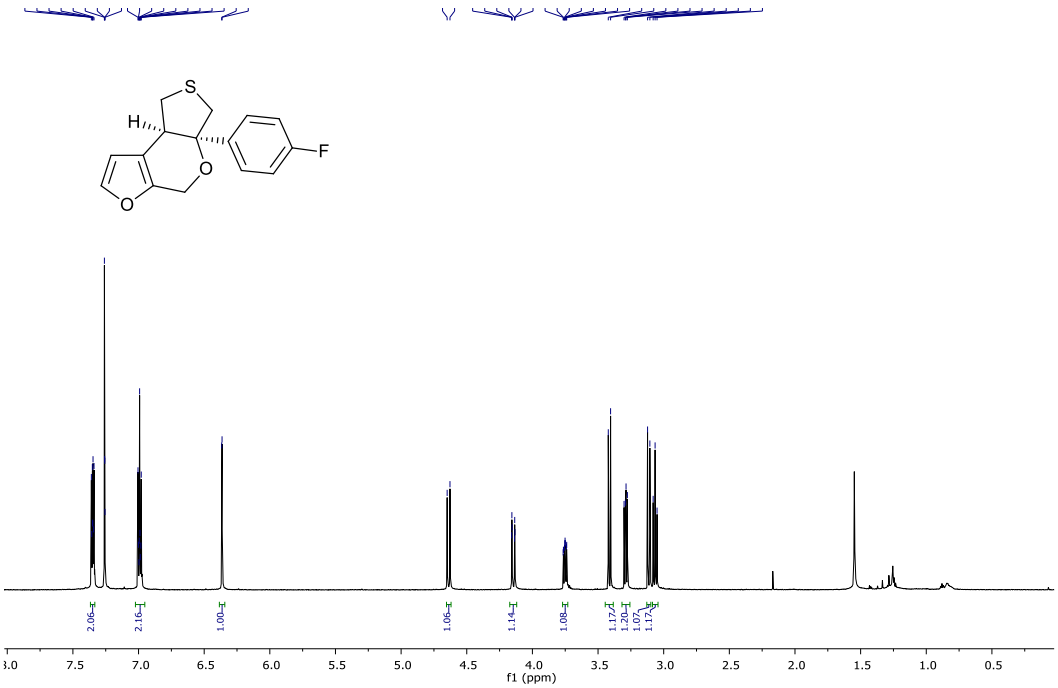


^{13}C NMR

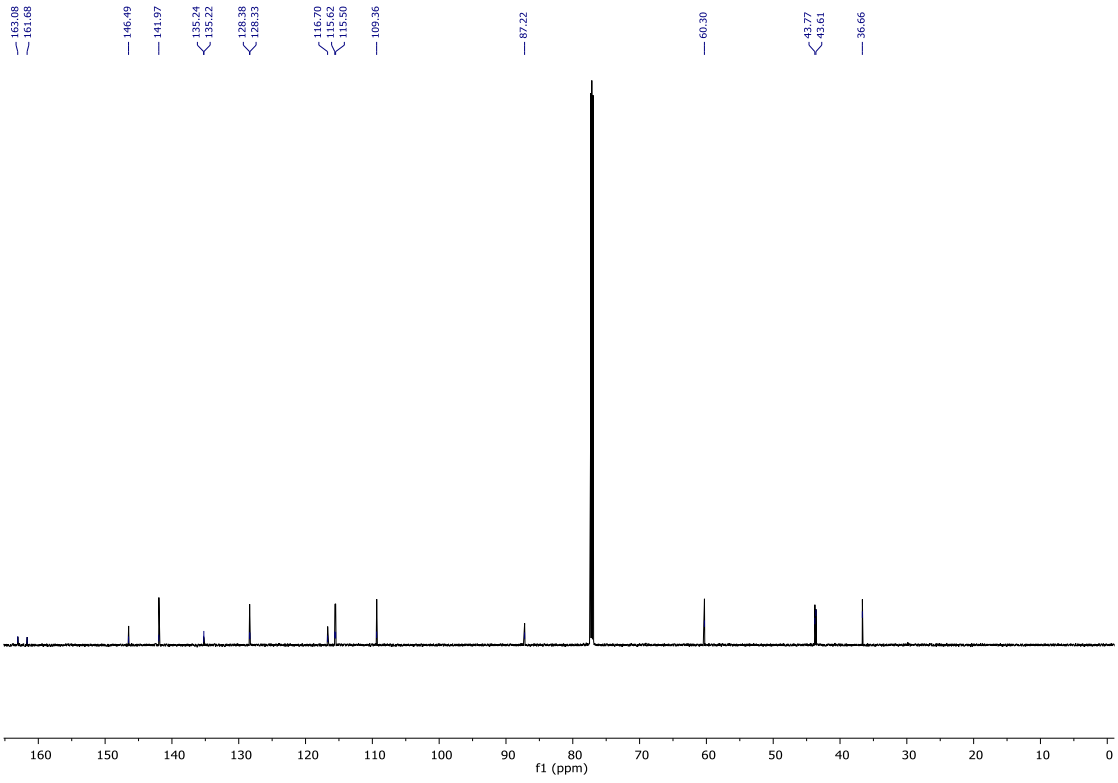


(3a*R*,8b*R*)-3a-(4-Fluorophenyl)-3,3a,5,8b-tetrahydro-1*H*-furo[3,2-*d*]thieno[3,4-*b*]pyran (4b)

^{1}H NMR

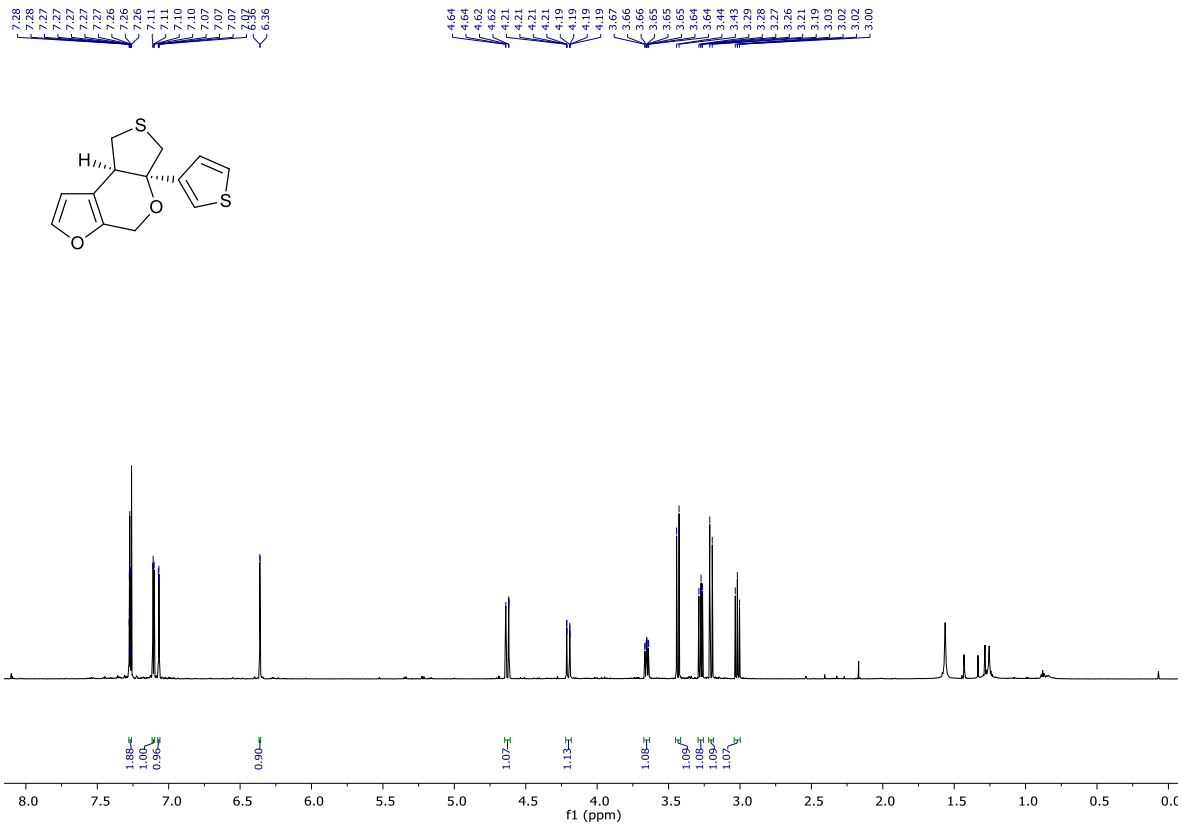


^{13}C NMR

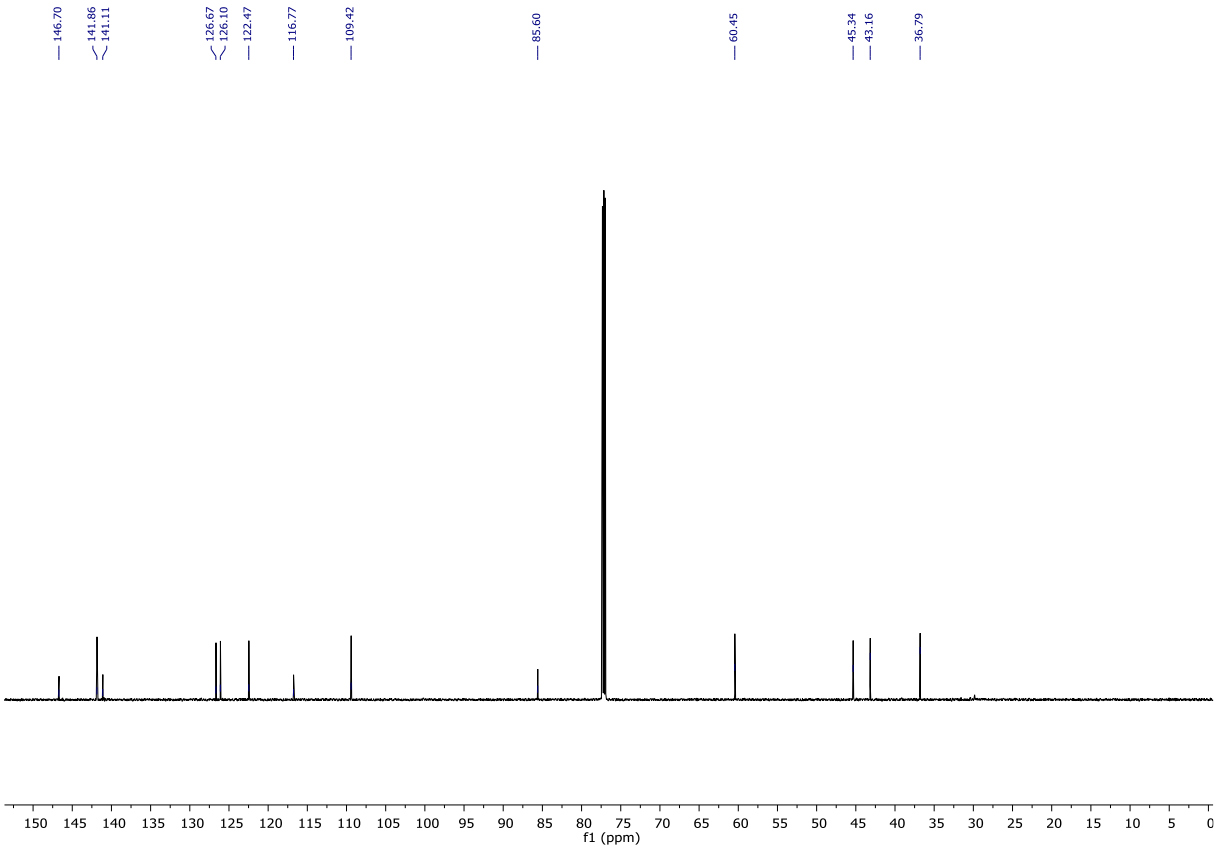


(3a*R*,8b*R*)-3a-(Thiophen-3-yl)-3,3a,5,8b-tetrahydro-1*H*-furo[3,2-*d*]thieno[3,4-*b*]pyran (4c)

^{1}H NMR



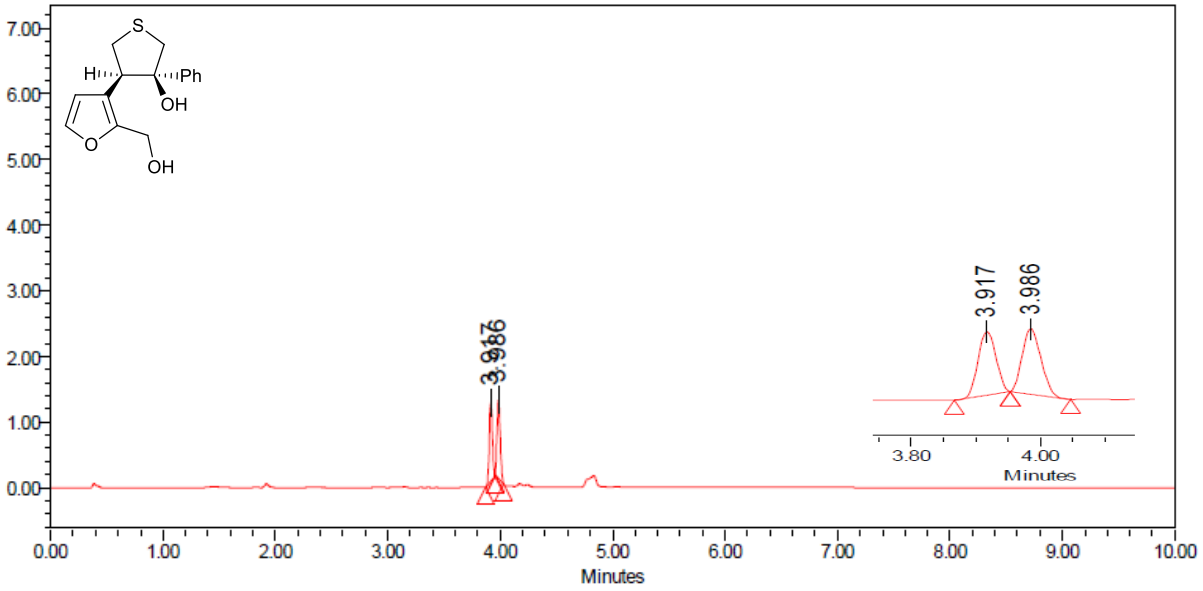
^{13}C NMR



7. UPC^2 traces

(3*R*,4*R*)-4-(2-(Hydroxymethyl)furan-3-yl)-3-phenyltetrahydrothiophen-3-ol (6a)

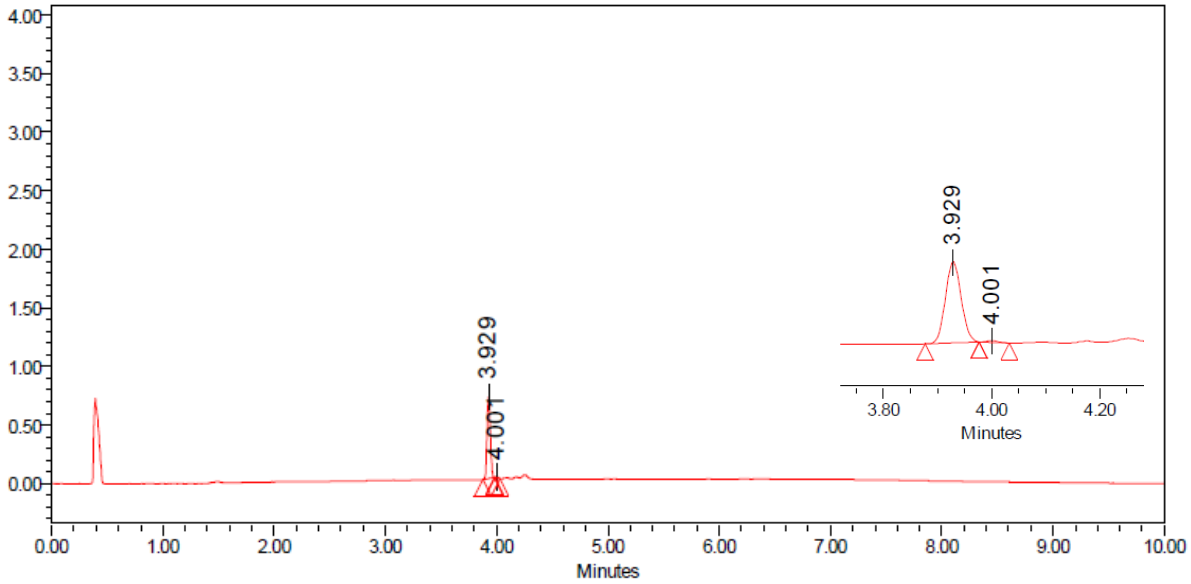
Racemic sample



Peak Results

	RT	% Area
1	3.917	49.03
2	3.986	50.97

Enantiomerically enriched sample

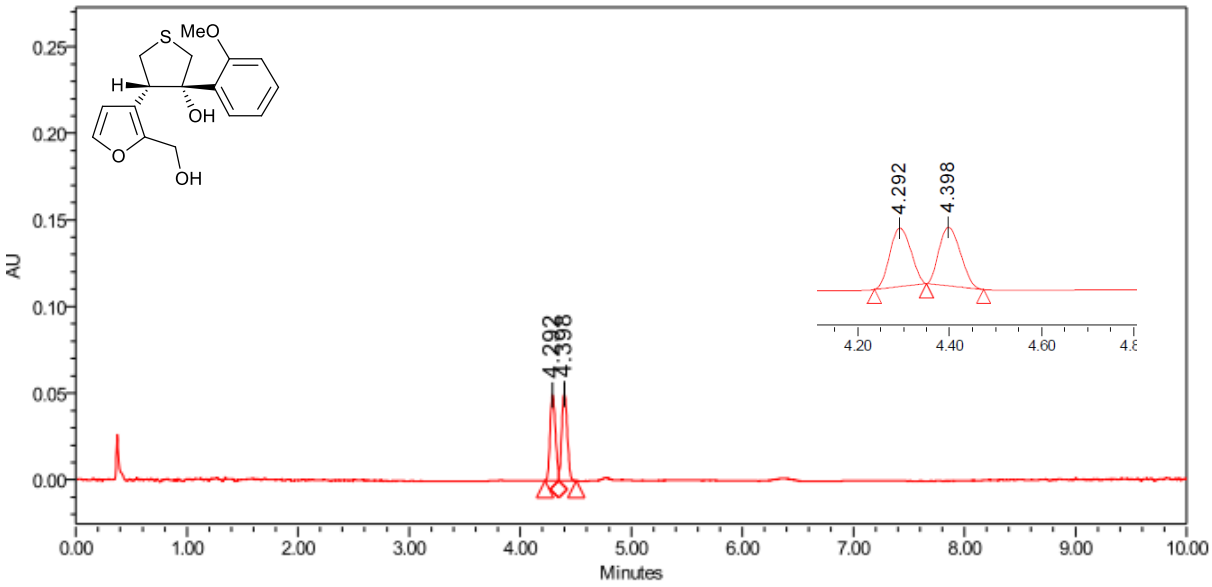


Peak Results

	RT	% Area
1	3.929	98.86
2	4.001	1.14

(3*S*,4*S*)-4-(2-(Hydroxymethyl)furan-3-yl)-3-(2-methoxyphenyl)tetrahydrothiophen-3-ol (6b)

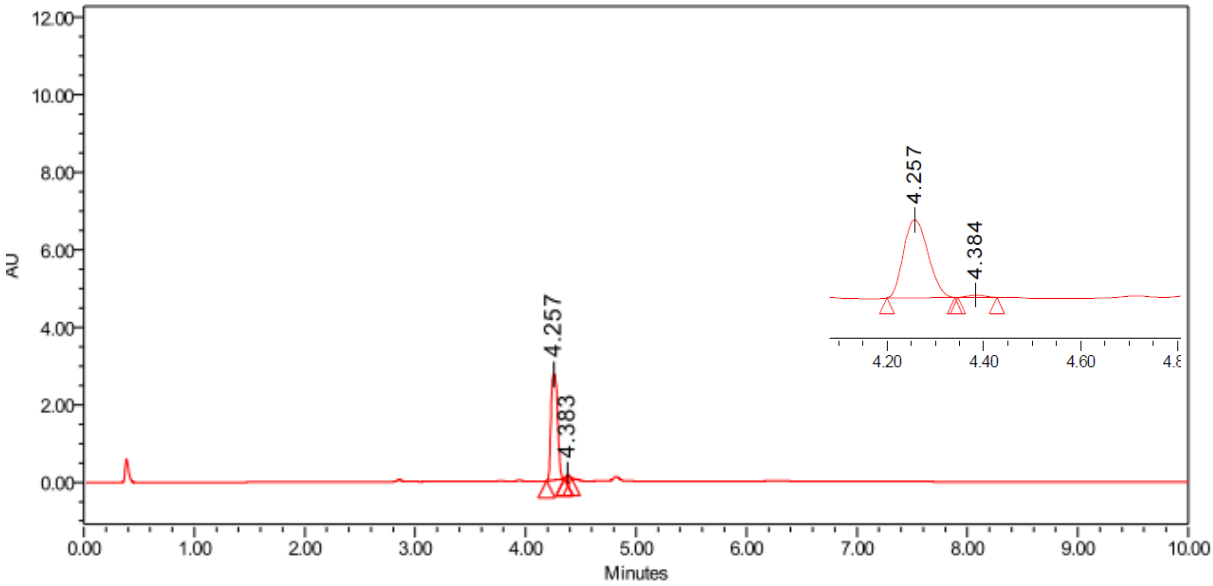
Racemic sample



Peak Results

	RT	% Area
1	4.292	49.28
2	4.398	50.72

Enantiomerically enriched sample

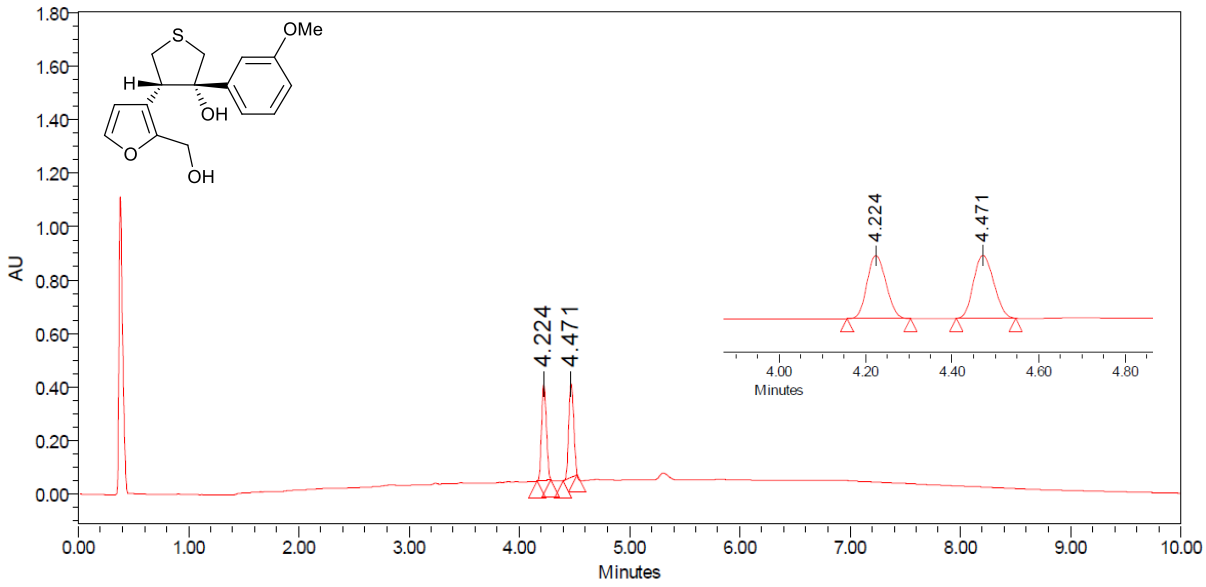


Peak Results

	RT	% Area
1	4.257	98.22
2	4.383	1.78

(3*S*,4*S*)-4-(2-(Hydroxymethyl)furan-3-yl)-3-(3-methoxyphenyl)tetrahydrothiophen-3-ol (6c)

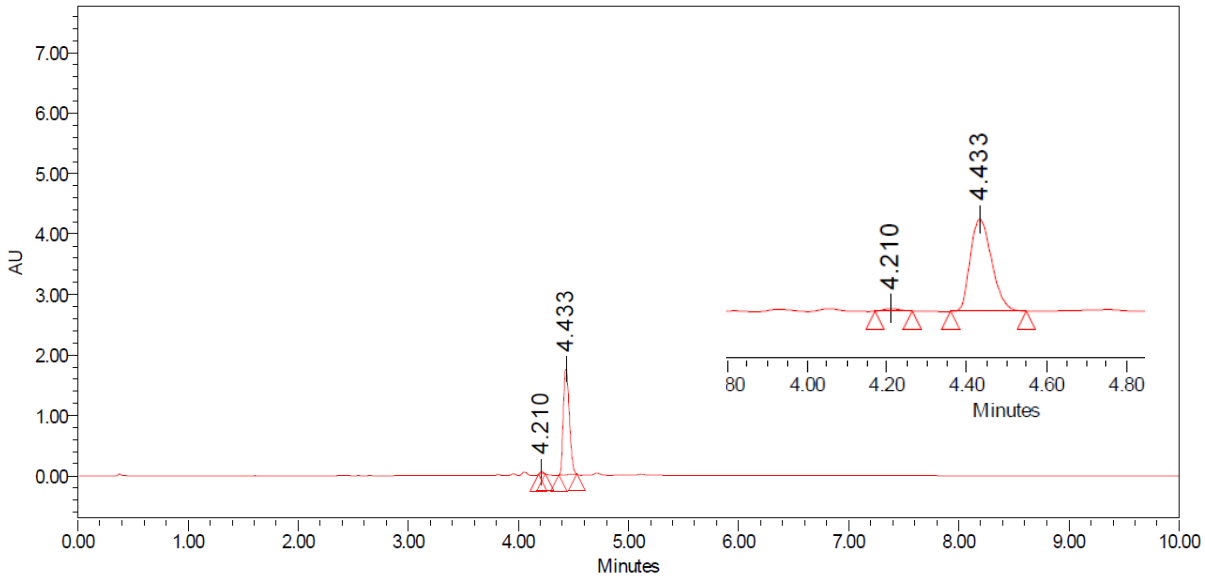
Racemic sample



Peak Results

	RT	% Area
1	4.224	49.79
2	4.471	50.21

Enantiomerically enriched sample

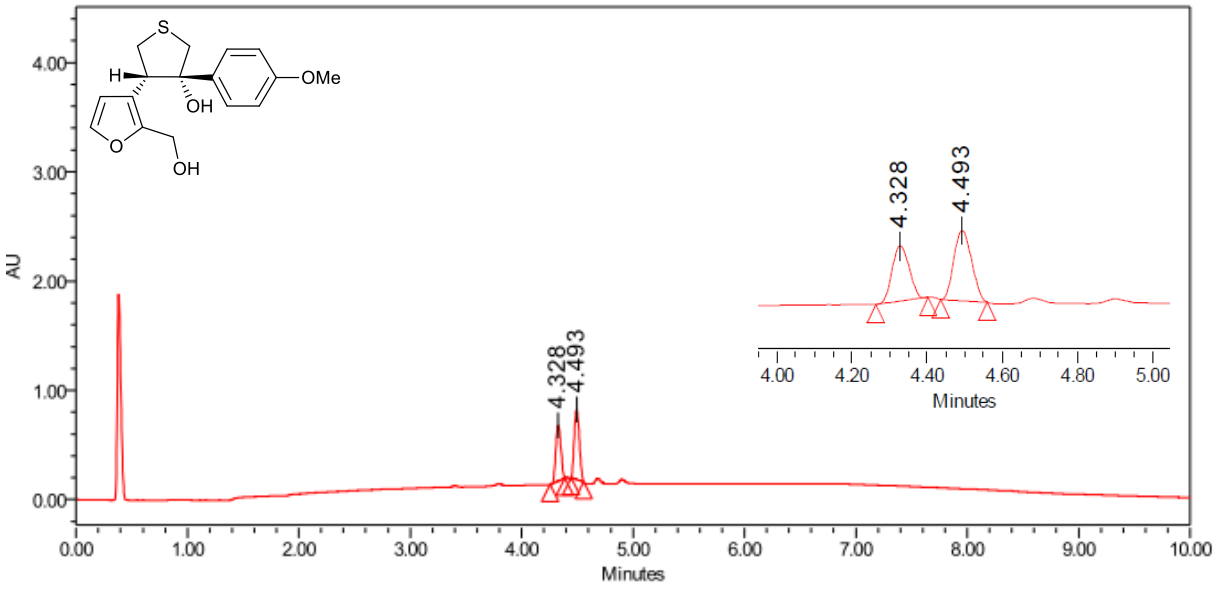


Peak Results

	RT	% Area
1	4.210	1.20
2	4.433	98.80

(3*S*,4*S*)-4-(2-(Hydroxymethyl)furan-3-yl)-3-(4-methoxyphenyl)tetrahydrothiophen-3-ol (6d)

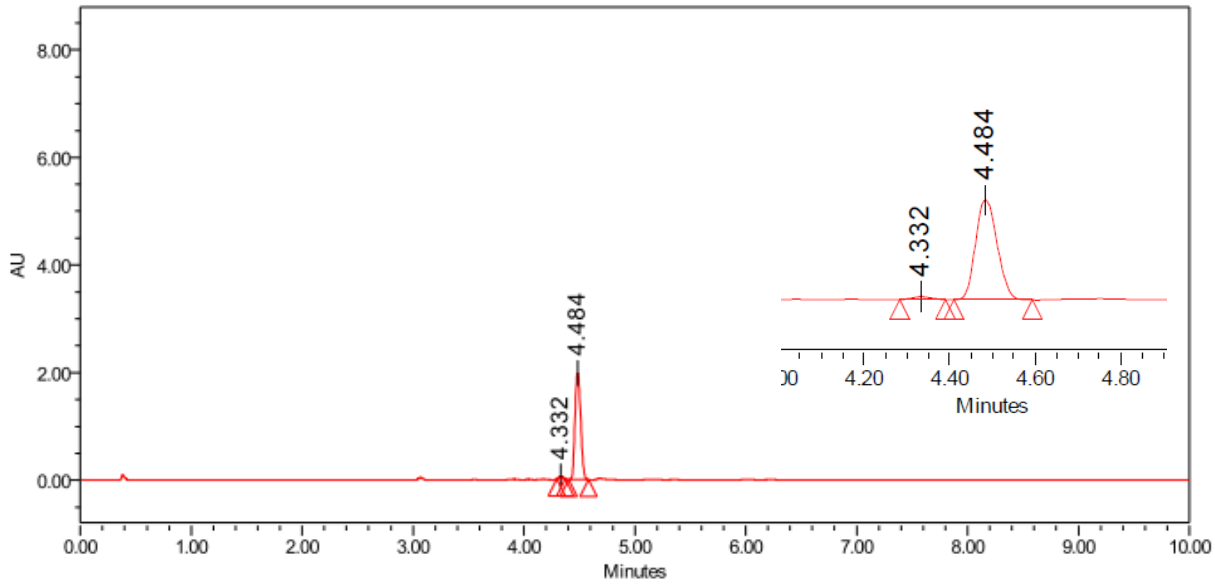
Racemic sample



Peak Results

	RT	% Area
1	4.328	43.99
2	4.493	56.01

Enantiomerically enriched sample

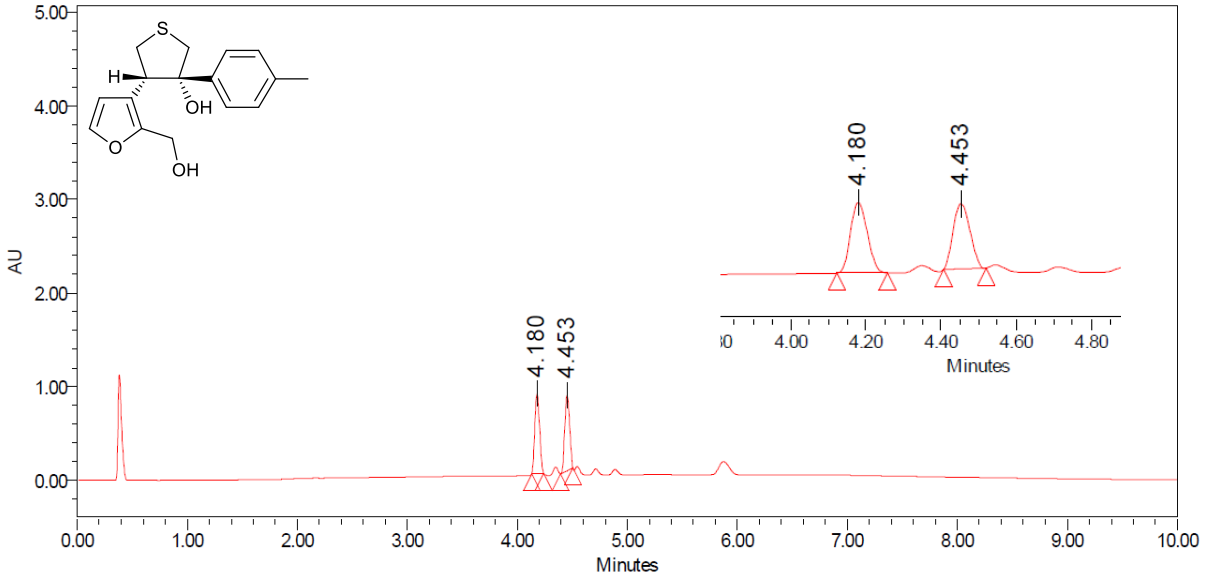


Peak Results

	RT	% Area
1	4.332	1.86
2	4.484	98.14

(3*S*,4*S*)-4-(2-(Hydroxymethyl)furan-3-yl)-3-(*p*-tolyl)tetrahydrothiophen-3-ol (6e)

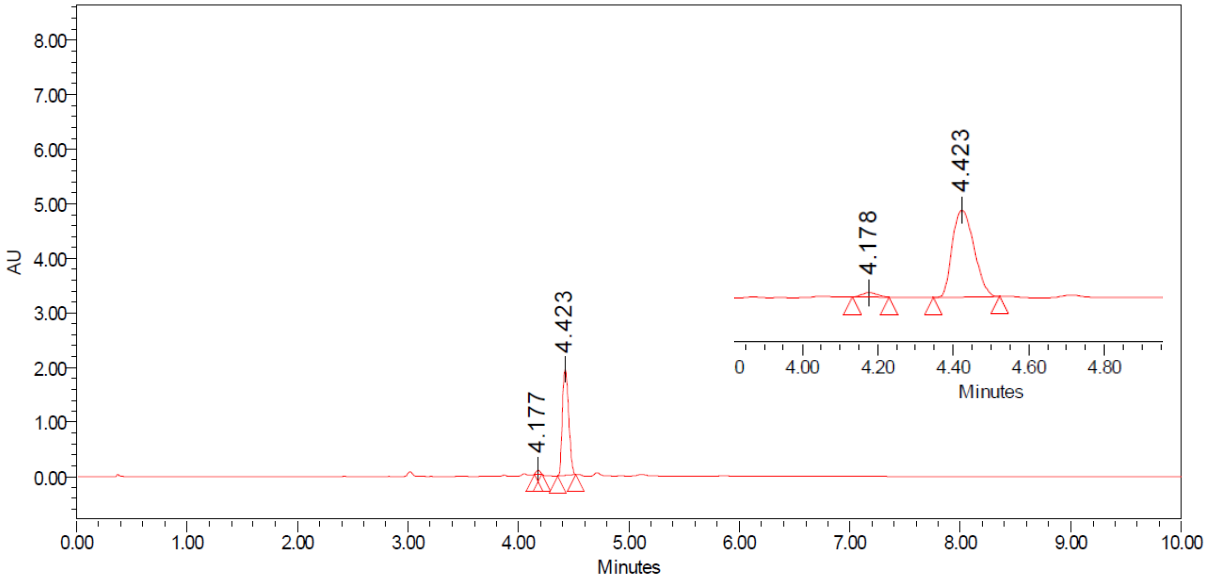
Racemic sample



Peak Results

	RT	% Area
1	4.180	51.02
2	4.453	48.98

Enantiomerically enriched sample

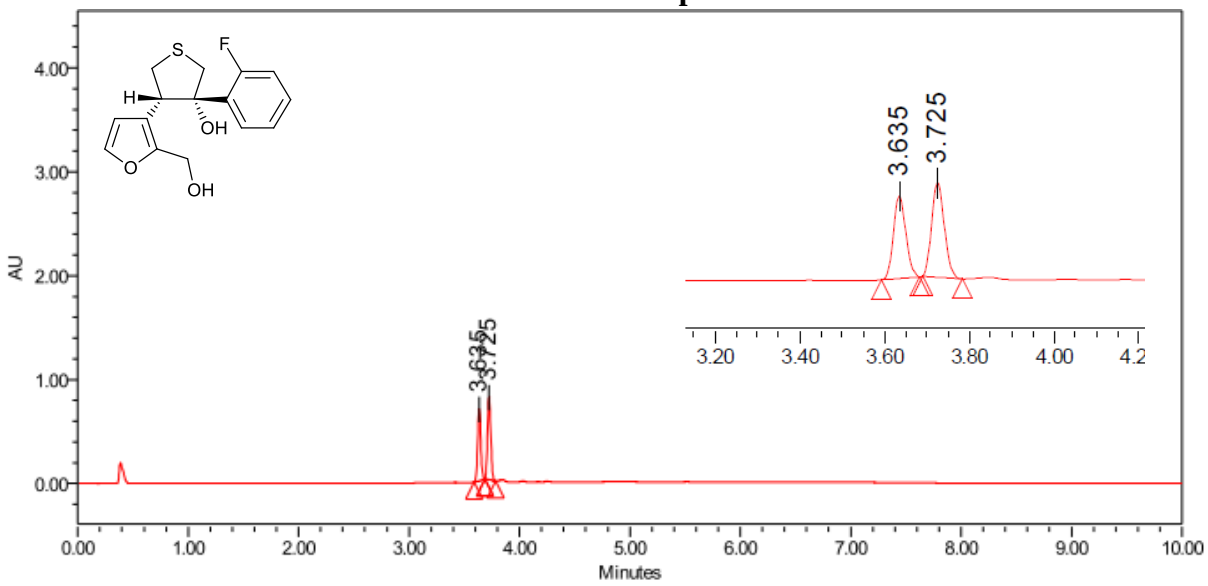


Peak Results

	RT	% Area
1	4.177	2.16
2	4.423	97.84

(3*S*,4*S*)-3-(2-Fluorophenyl)-4-(2-(hydroxymethyl)furan-3-yl)tetrahydrothiophen-3-ol (6f)

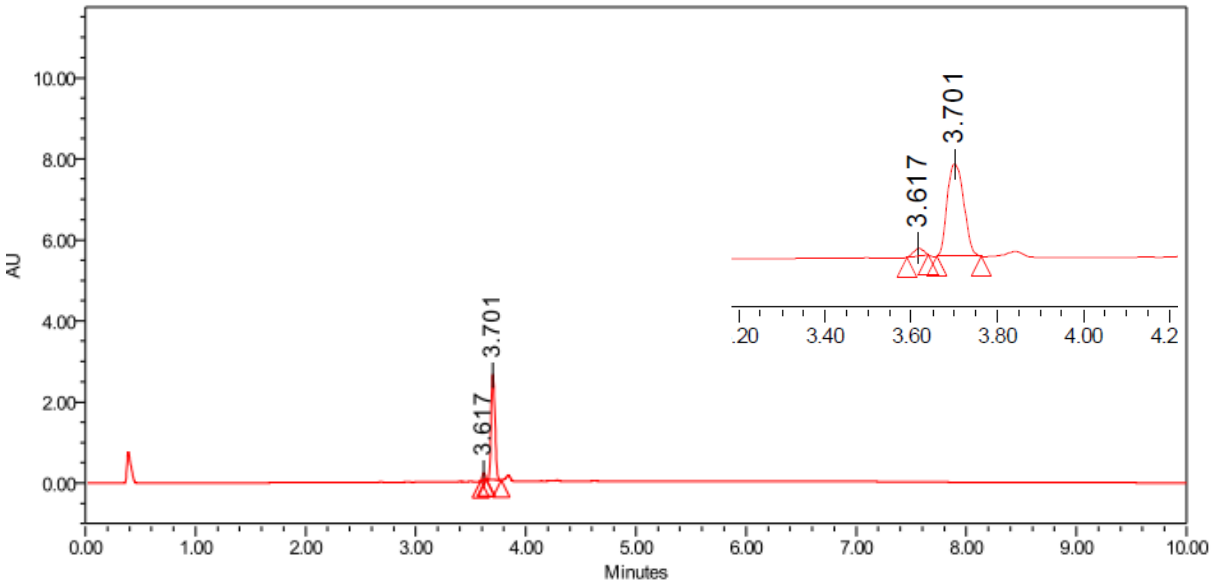
Racemic sample



Peak Results

	RT	% Area
1	3.635	46.07
2	3.725	53.93

Enantiomerically enriched sample

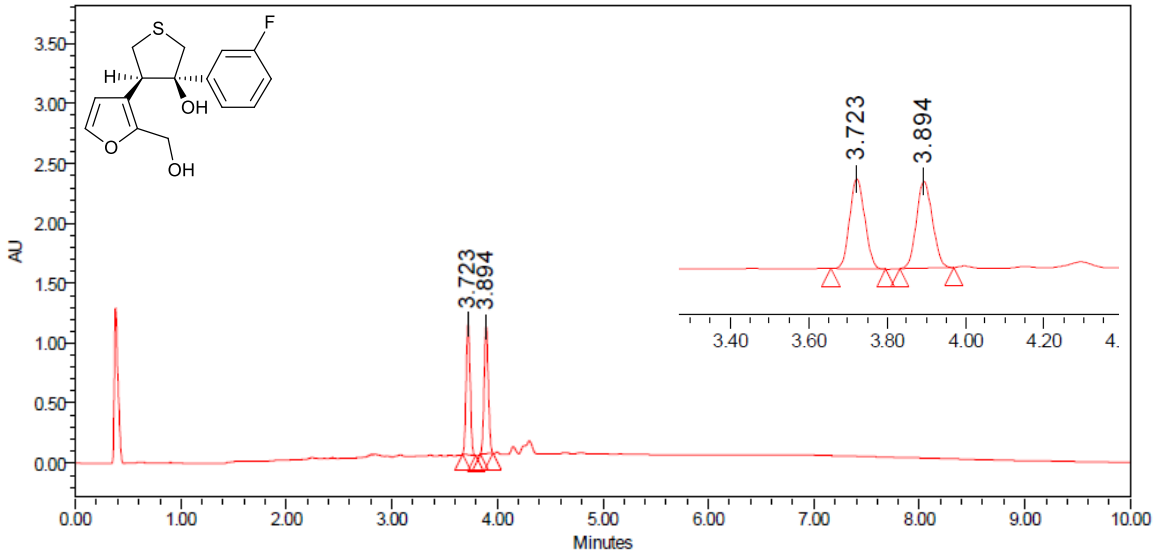


Peak Results

	RT	% Area
1	3.617	4.09
2	3.701	95.91

(3*R*,4*R*)-3-(3-Fluorophenyl)-4-(2-(hydroksymetyl)furan-3-yl)tetrahydro-tiofen-3-ol (6g)

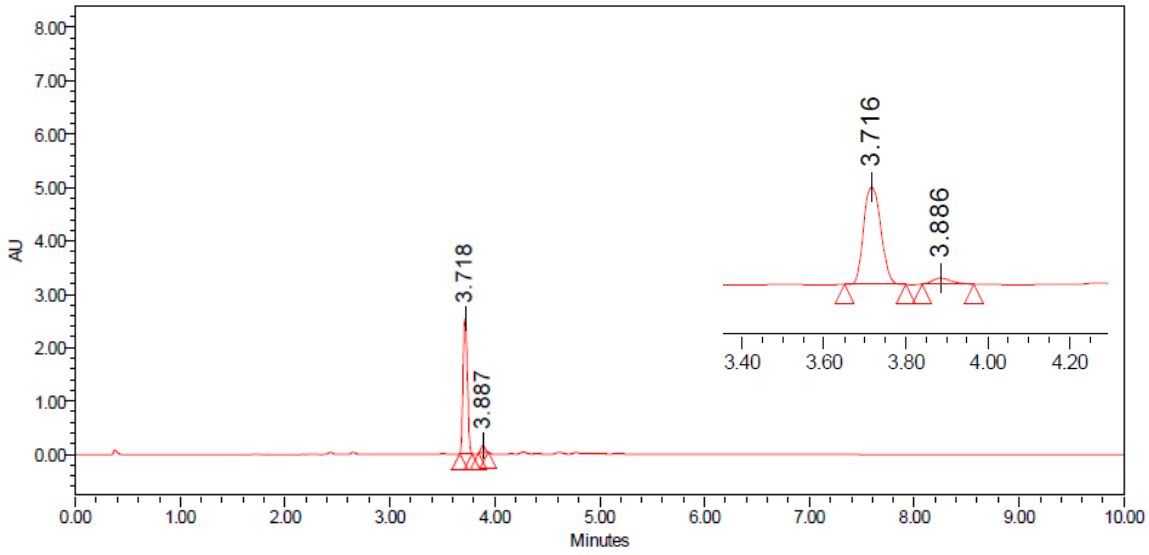
Racemic sample



Peak Results

	RT	% Area
1	3.723	49.48
2	3.894	50.52

Enantiomerically enriched sample

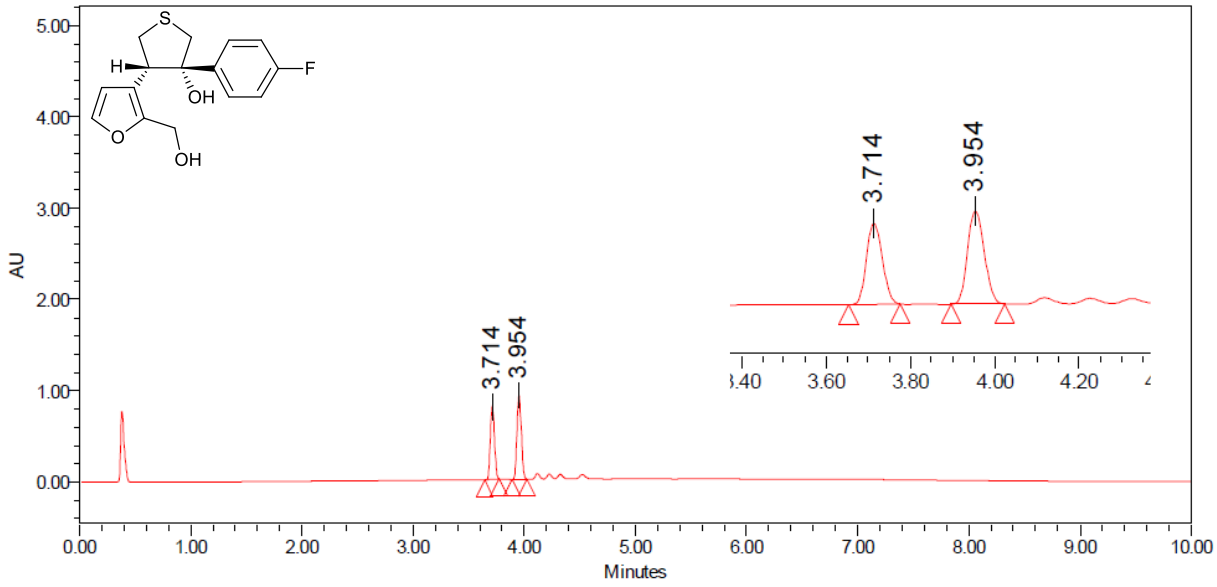


Peak Results

	RT	% Area
1	3.718	95.12
2	3.887	4.88

(3*S*,4*S*)-3-(4-Fluorophenyl)-4-(2-(hydroxymethyl)furan-3-yl)tetrahydrothiophen-3-ol (6h)

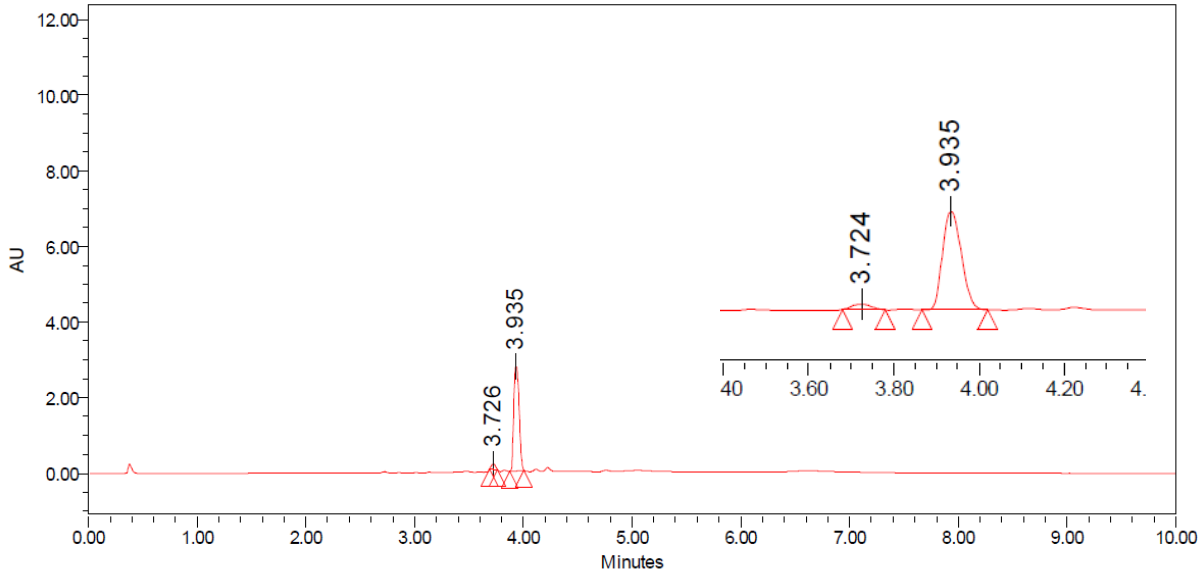
Racemic sample



Peak Results

	RT	% Area
1	3.714	45.01
2	3.954	54.99

Enantiomerically enriched sample

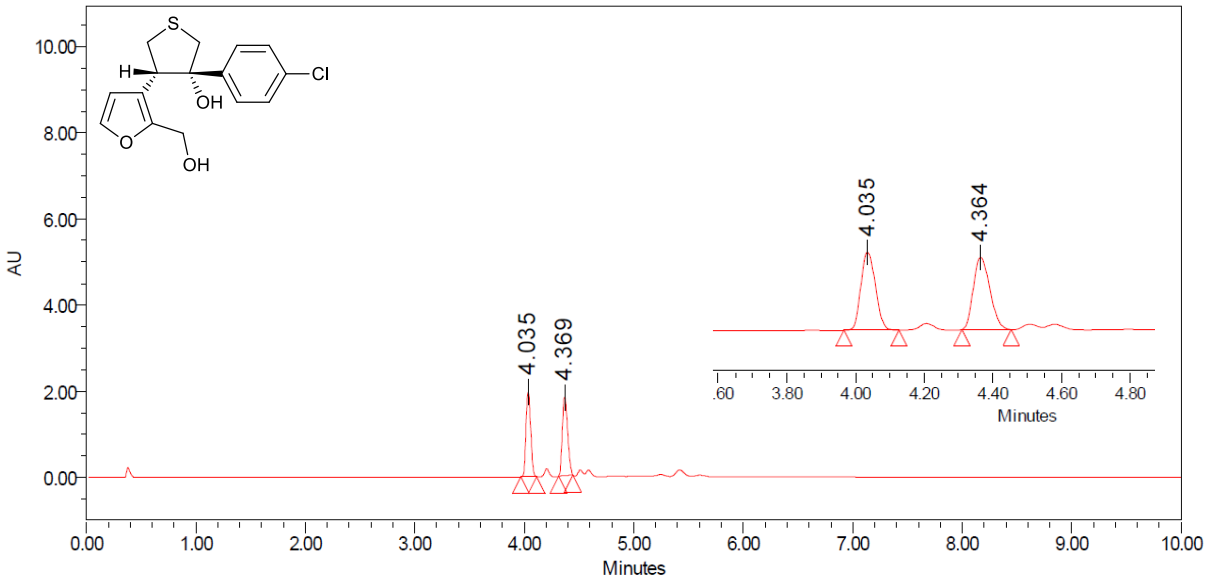


Peak Results

	RT	% Area
1	3.726	3.89
2	3.935	96.11

(3*S*,4*S*)-3-(4-Chlorophenyl)-4-(2-(hydroxymethyl)furan-3-yl)tetrahydrothiophen-3-ol (6i)

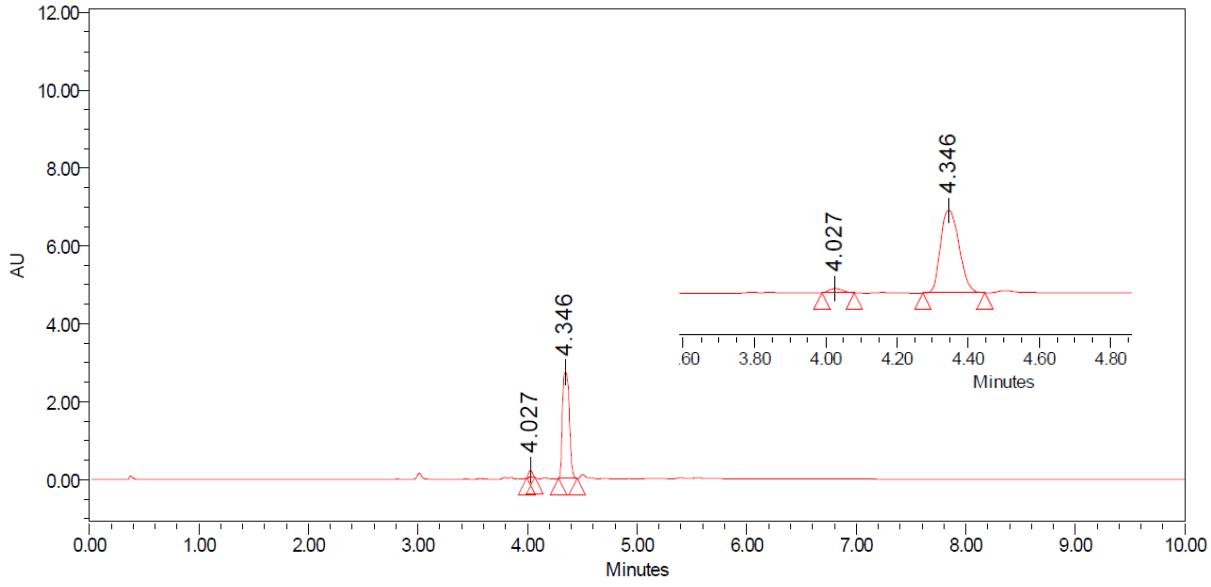
Racemic sample



Peak Results

	RT	% Area
1	4.035	48.82
2	4.369	51.18

Enantiomerically enriched sample

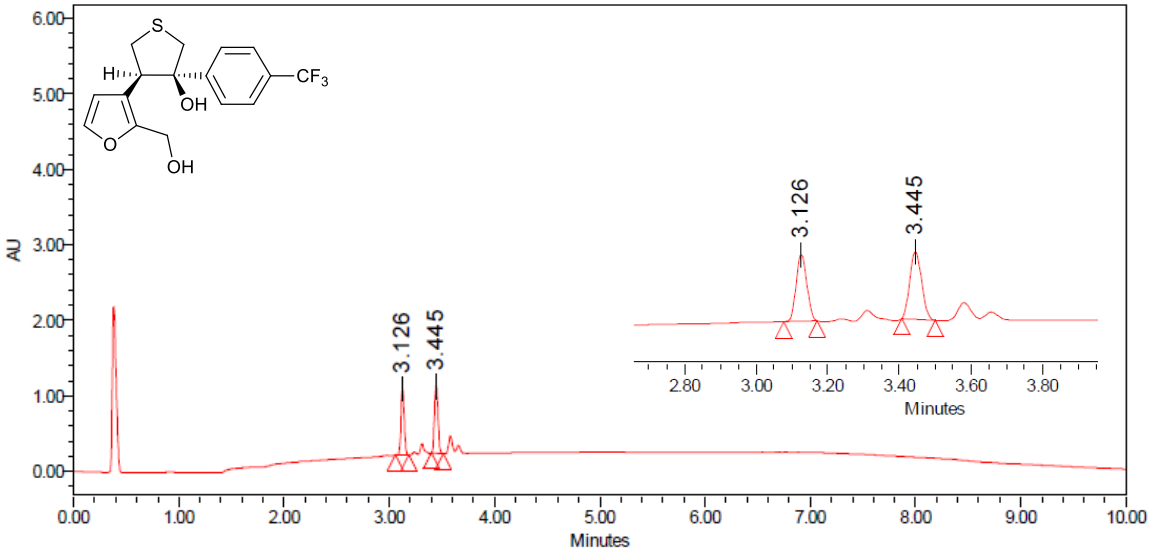


Peak Results

	RT	% Area
1	4.027	3.60
2	4.346	96.40

(3*R*,4*R*)-4-(2-(Hydroxymethyl)furan-3-yl)-3-(4-(trifluoromethyl)phenyl) tetrahydrothiophen-3-ol (6j)

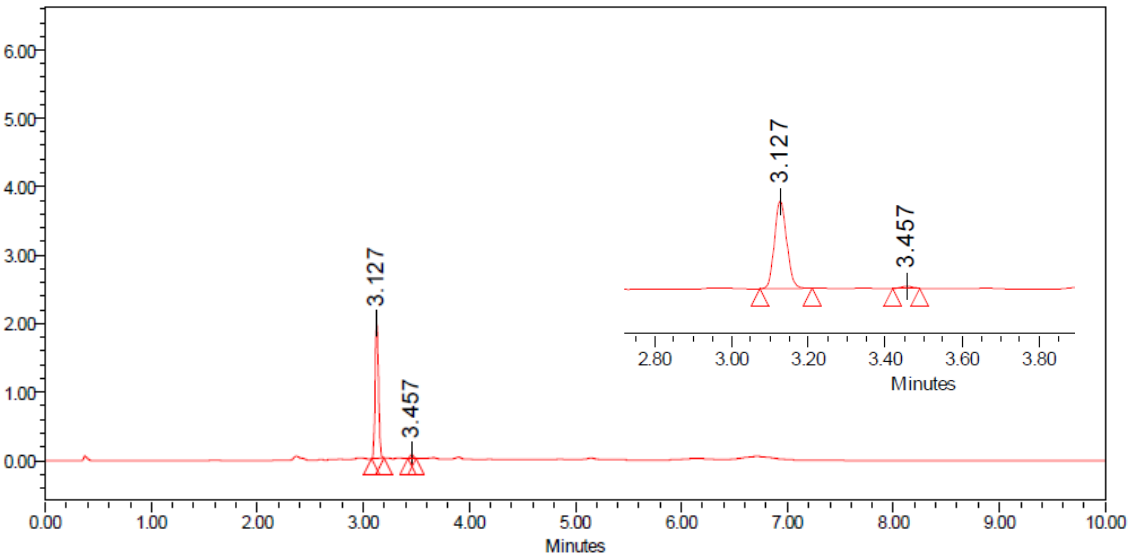
Racemic sample



Peak Results

	RT	% Area
1	3.126	46.92
2	3.445	53.08

Enantiomerically enriched sample

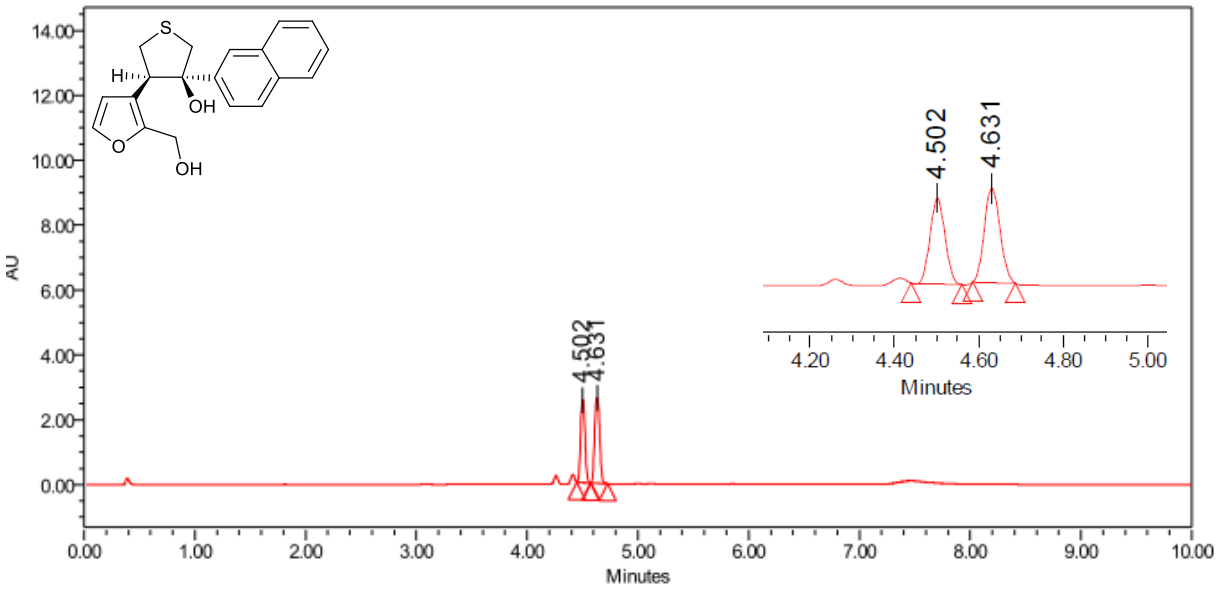


Peak Results

	RT	% Area
1	3.127	97.46
2	3.457	2.54

(3*R*,4*R*)-4-(2-(Hydroxymethyl)furan-3-yl)-3-(naphthalen-2-yl)tetrahydrothiophen-3-ol (6k)

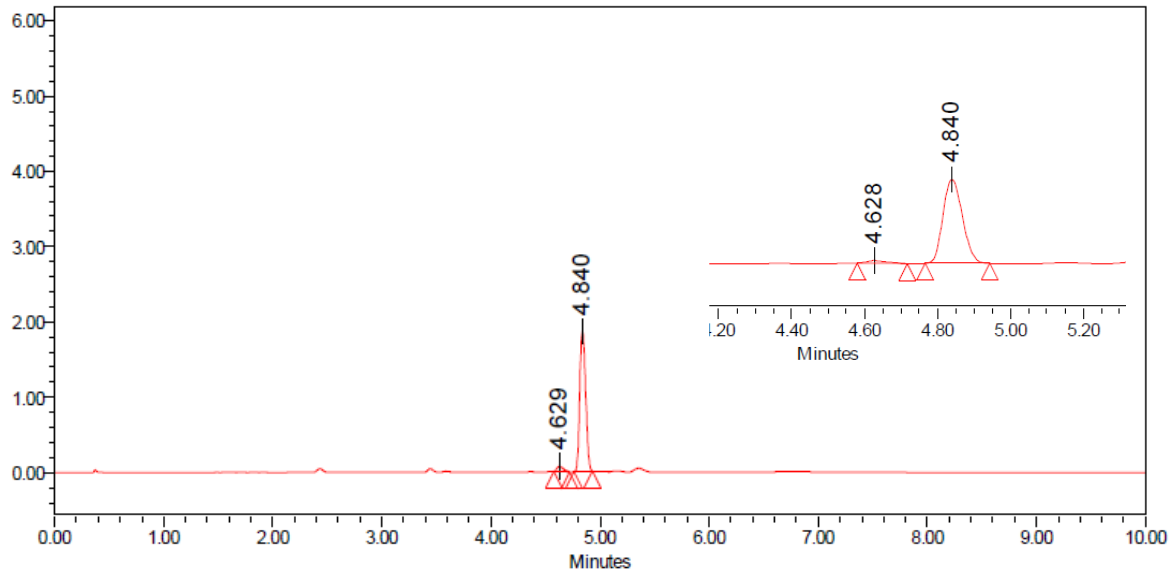
Racemic sample



Peak Results

	RT	% Area
1	4.502	46.28
2	4.631	53.72

Enantiomerically enriched sample

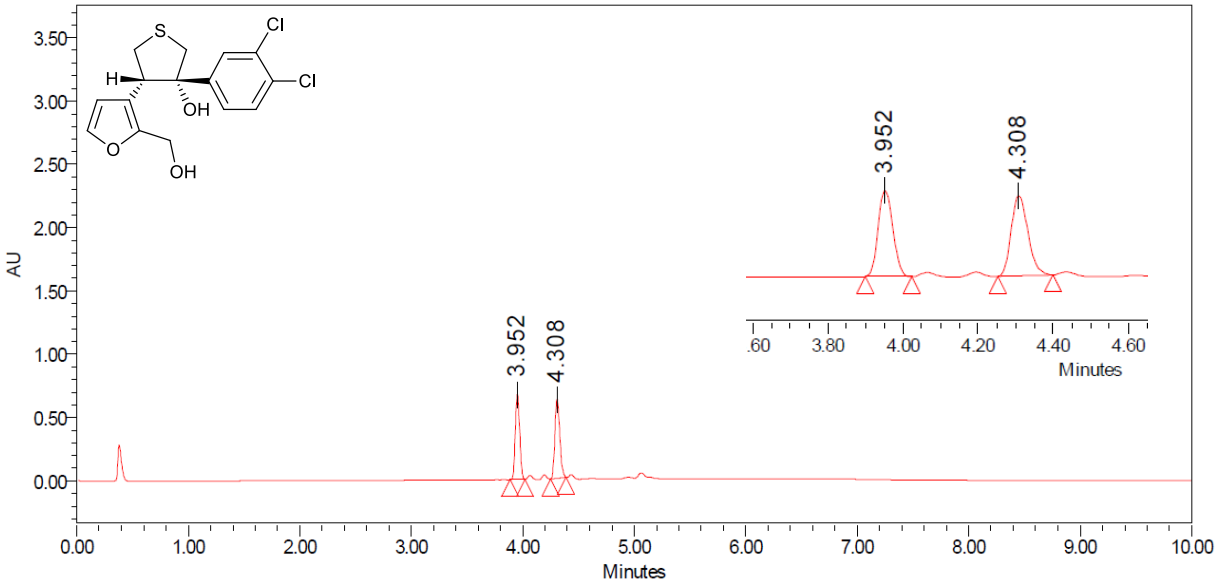


Peak Results

	RT	% Area
1	4.629	3.86
2	4.840	96.14

(3*S*,4*S*)-3-(3,4-Dichlorophenyl)-4-(2-(hydroxymethyl)furan-3-yl)tetrahydrothiophen-3-ol (6l)

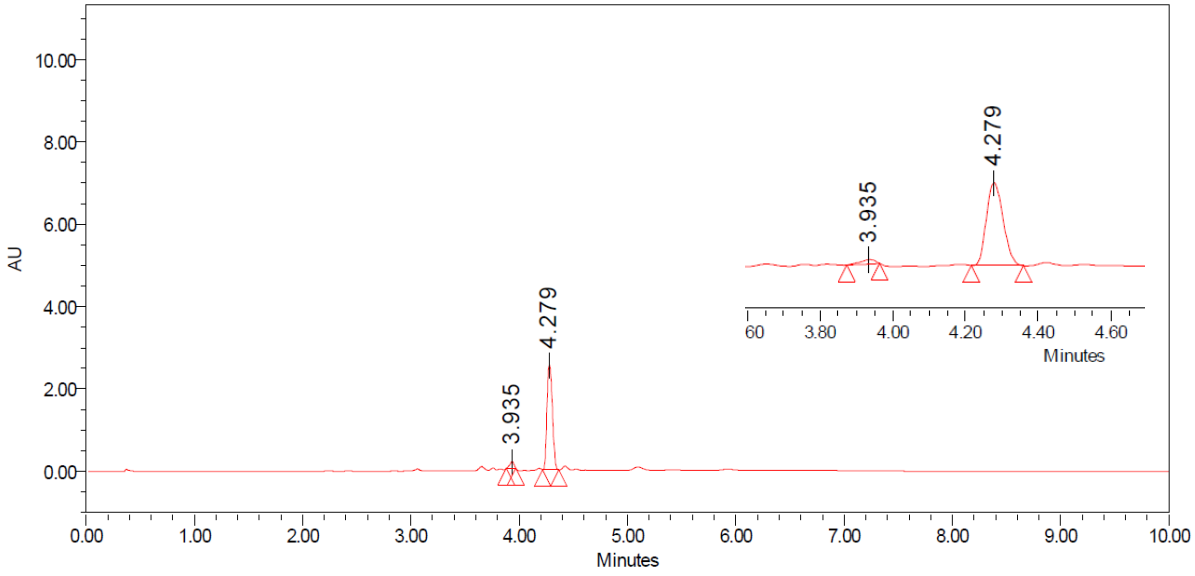
Racemic sample



Peak Results

	RT	% Area
1	3.952	48.94
2	4.308	51.06

Enantiomerically enriched sample

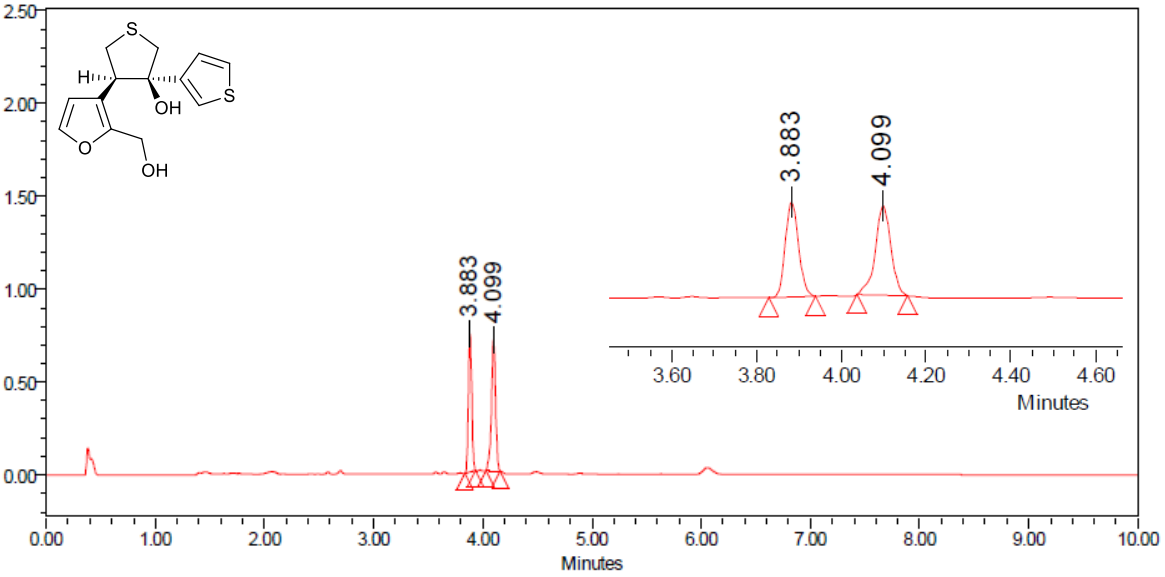


Peak Results

	RT	% Area
1	3.935	4.22
2	4.279	95.78

(3*R*,4*R*)-4-(2-(Hydroxymethyl)furan-3-yl)-3-(thiophen-3-yl)tetrahydrothiophen-3-ol (6m)

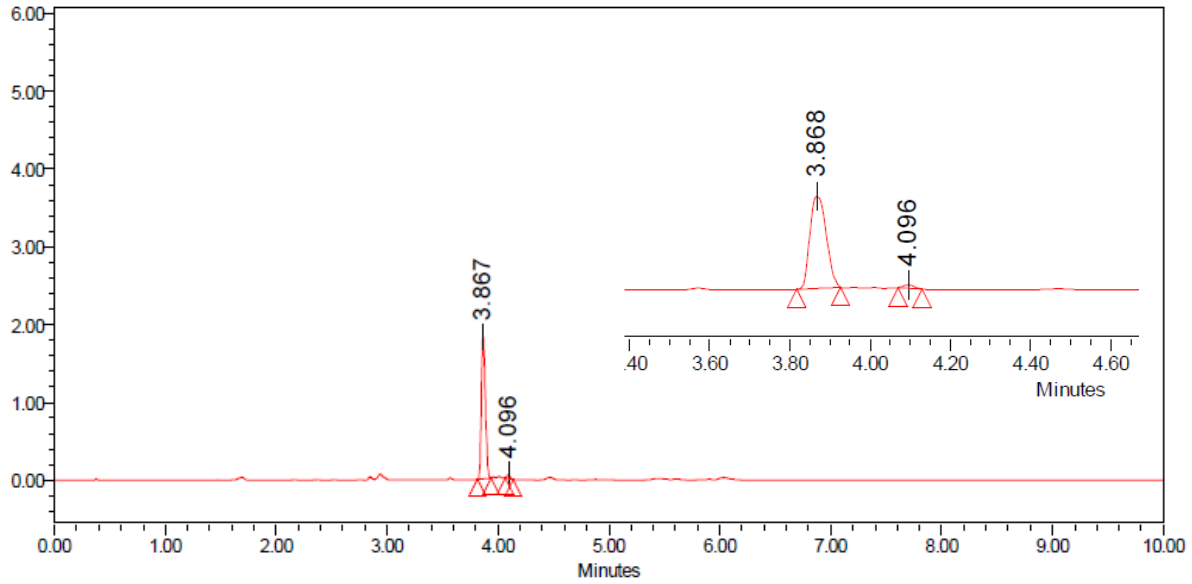
Racemic sample



Peak Results

	Retention Time (min)	% Area
1	3.883	46.50
2	4.099	53.50

Enantiomerically enriched sample

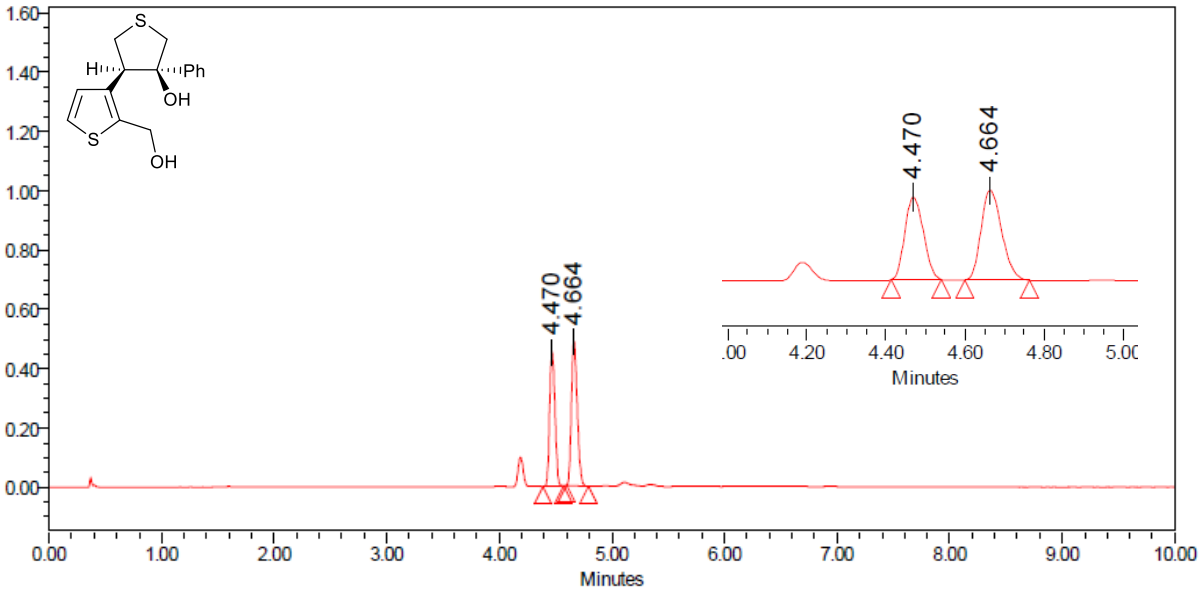


Peak Results

	RT	% Area
1	3.867	97.98
2	4.096	2.02

(3*S*,4*S*)-4-(2-(Hydroxymethyl)thiophen-3-yl)-3-phenyltetrahydrothiophen-3-ol (6n)

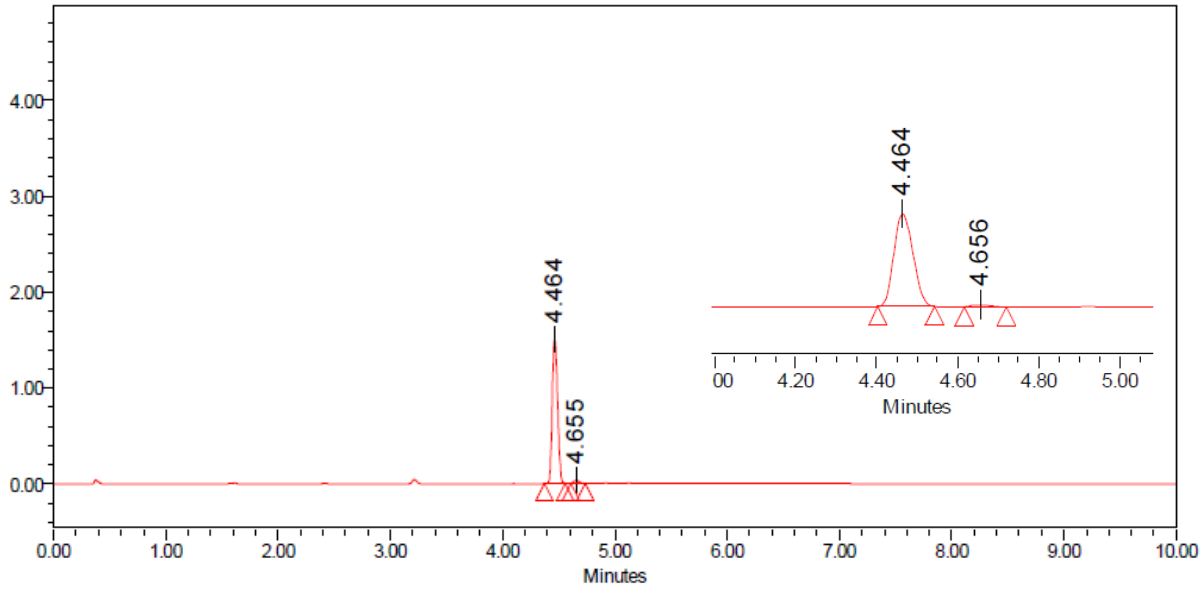
Racemic sample



Peak Results

	RT	% Area
1	4.470	45.71
2	4.664	54.29

Enantiomerically enriched sample

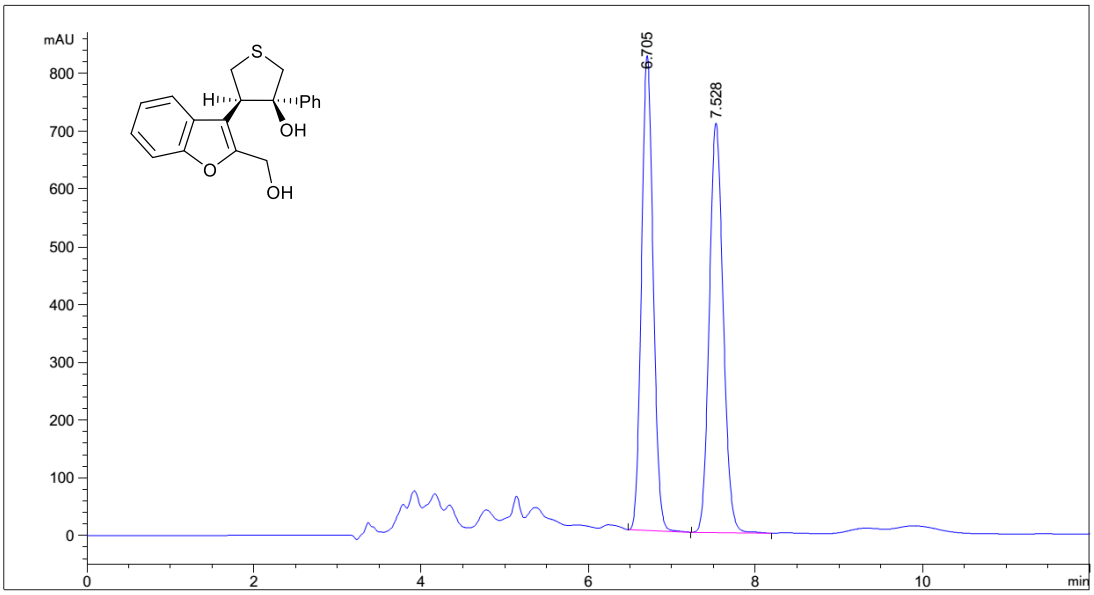


Peak Results

	RT	% Area
1	4.464	97.86
2	4.655	2.14

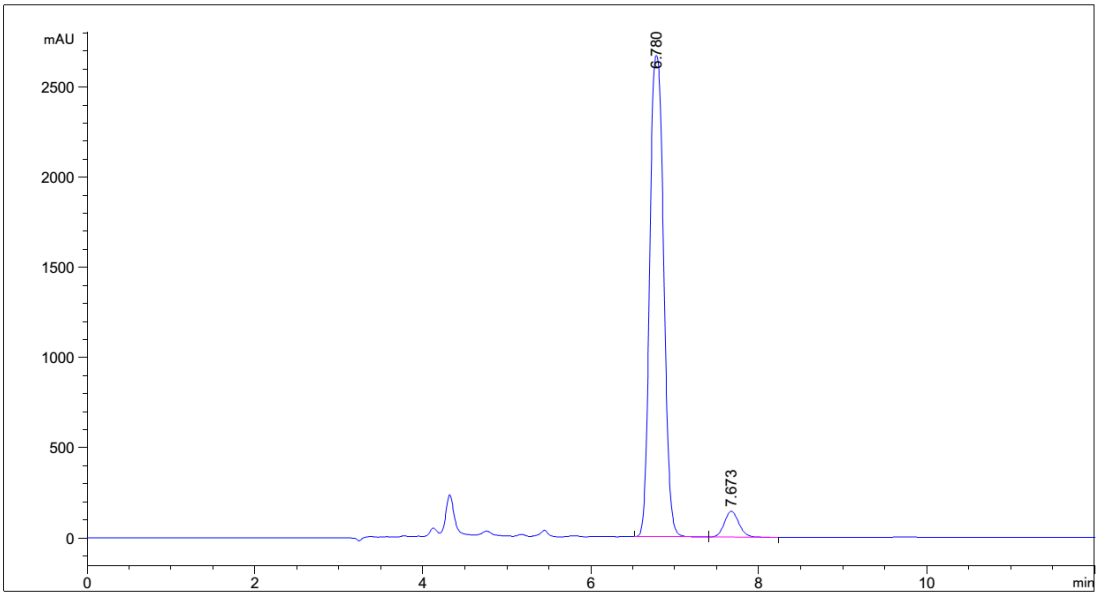
(3*R*,4*R*)-4-(2-(Hydroxymethyl)benzofuran-3-yl)-3-phenyltetrahydrothiophen-3-ol (6o)

Racemic sample



Peak No.	Ret Time	Width	Area	Height	Area [%]
#	[min]	[min]	[mAU*s]	[mAU]	%
1	6.705 BB	0.1511	7984.79883	822.44684	49.3921
2	7.528 BB	0.1797	8181.34375	709.24634	50.6079

Enantiomerically enriched sample



Peak No.	Ret Time	Width	Area	Height	Area [%]
#	[min]	[min]	[mAU*s]	[mAU]	%
1	6.780 VV	0.1831	3.05694e4	2668.82910	94.6400
2	7.673 VBA	0.1857	1731.31812	143.67699	5.3600