Electronic Supplementary Material (ESI) for Chemical Communications

Enantioselective synthesis of *anti*- and *syn*-*β*-hydroxy-*α*-phenyl carboxylates via boron-mediated asymmetric aldol reaction

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Supporting Information

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General Information

All reactions were conducted under an inert atmosphere. Dichloromethane, carbon tetrachloride, toluene, and pentane were freshly distilled from calcium hydride. Diethyl ether and tetrahydrofuran were distilled from sodium/benzophenone. All other chemicals were purchased

from Aldrich Chemical Co. and used without further purification, unless otherwise noted. Reaction-flasks were dried in oven at 100 ^{o}C for 12 h followed by cooling to room temperature under nitrogen atmosphere. Flash column chromatography was performed using silica gel (Particle size: 40-63μm (230×400 mesh), Sorbent technologies) with hexane-ethyl acetate mixture as eluent. TLC analysis was performed using aluminum-backed, Thin-Layer Silica Gel chromatography plates (Dynamic Absorbent Inc., 200 μm thickness, F-254 Indicator). ^{1}H and ^{13}C NMR spectra were recorded on Varian Inova-300 MHz spectrometer. Chemical shift (δ) values are reported in parts per million, and are referenced to tetramethylsilane. Data are reported as: δ value (multiplicity, *J*-value, integration, where s=singlet, d=doublet, t=triplet, m=multiplet, br=broad). Optical rotations were measured from an automatic polarimeter Autopol® III at the Na D-line (λ = 589 nm) using a 1 dm cell.

Phenylacetic acid and methyl phenylacetate (**2**) were purchased from Aldrich Chemical Co; Ethyl- (**3**),[1] isopropyl- (**4**),[1] and *t*-butyl- (**5**)[2] phenylacetates were prepared according to literature procedures. Diastereomeric ratios (*syn*:*anti* ratios) were determined by either ^{1}H NMR or ^{13}C NMR of a crude reaction mixture. Enantiomeric ratios (er) of both *syn*- and *anti*-isomers were determined by ^{1}H NMR analysis of either menthyl carbonate or dimenthyl carbonate derivatives of diols derived from corresponding aldol products. (-)-(1*R*)-menthyl chloroformate was reacted with the diol in the presence of 4-(dimethylamino)pyridine to produce the required menthyl carbonate or dimenthyl carbonate.

General Procedure for the *Anti*-Selective Aldol Reaction

Freshly-prepared diisopinocampheyl borane [(-)Ipc$_2$BH, (-)-**1**][3] [0.429 g, 1.5 mmol] was transferred to an oven-dried 50 mL round-bottom flask, under nitrogen, crushed into fine powder and suspended in pentane (3 mL). Trifluoromethanesulfonic acid (TfOH) (0.15 mL, 1.69 mmol) was added, dropwise, at 0 ^{o}C. The reaction mixture was stirred at the same temperature for 1-1.5 h until a clear solution of (-)-**1** was obtained. This was then cooled to -78 ^{o}C (Caution: Careful further agitation requires if magnetic stirrer bar does not move at this temperature).

1 . Kazemi, F.; Kiasat, A. R.; Mombaini, B. *Phosphorus, Sulfur, and Silicon* **2004**, *179*, 1187.
2 . Harker, W. R. R.; Carswell, E. L.; Carbery, D. R. *Org. Lett.* **2010**, *12*, 3712.
3 . H. C. Brown, N. N. Joshi, *J. Org. Chem.* **1988**, *53*, 4059.

Triethylamine (0.30 mL, 2.2 mmol) was then added, dropwise, to the cooled (-)-**1**, follwed by a pre-cooled (0 ^{o}C) solution of isopropyl phenylacetate (**4**, 1 mmol in 1 mL pentane). Stirring was continued for 2 h at -78 ^{o}C. Aldehyde (**6**, 1.5 mmol) dissolved in pentane (1 mL) was cooled to -78 ^{o}C and added, dropwise, to the solution of the enolate (Aldehydes, which were insoluble in pentane at this temperature, were added without cooling). The reaction was stirred for 3 h at the same temperature (-78 ^{o}C), quenched by the addition of *p*H 7 buffer solution (2 mL), diluted with MeOH (2 mL), followed by slow addition of 30% hydrogen peroxide (2 mL). The reaction was then warmed to room temperature and stirred for 4 h. The pentane layer was separated and washed with saturated brine solution (2 mL). The aqueous layer was extracted with dichloromethane (3 × 10 mL) and washed with brine (5 mL). Finally, the combined layers of pentane and dichloromethane were dried (anhydrous Na_2SO_4), filtered, concentrated *in vacuo*, and purified by silica gel column chromatography to obtain pure *anti*-aldol product (**9**) (Major *anti*-isomers were easily separated from minor *syn*-isomers by column chromatography. However, careful silica gel column chromatography was performed to separate the major *anti*-isomers from isopinocampheol byproduct).

General Procedure for the *Syn*-Selective Aldol Reaction

(-)-**1** (1.5 mmol) was preapred from (-)-diisopinocampheylborane[3] (freshly prepared) in dichloromethane as described above. Ethyl phenylacetate (**3**, 1 mmol), dissolved in 1 mL dichloromethane, was added at 0 ^{o}C, followed by the dropwise addition of triethylamine (0.30 mL, 2.2 mmol) and stirred for 2 h at 0 ^{o}C. The reaction mixture was then cooled to -78 ^{o}C and aldehyde (**6**, 1.5 mmol) was added, dropwise, to the solution of the enolate. The reaction was stirred for 3 h at the same temperature (-78 ^{o}C), quenched by the addition of *p*H 7 buffer solution (2 mL), diluted with MeOH (2 mL), followed by slow addition of 30% hydrogen peroxide (2 mL). The reaction was then warmed to room temperature and stirred for 4 h. The organic layer was separated and the aqueous layer was extracted with dichloromethane (3 × 10 mL) and the combined organic layers were washed with aqueous saturated brine (5 mL), dried over anhydrous Na_2SO_4, filtered, concentrated *in vacuo*, and purified by silica gel column chromatography to obtain pure *syn*-aldol product (**8**). (Major *syn*-isomers were easily separated from minor *anti*-isomers by column chromatography. However, careful silica gel column

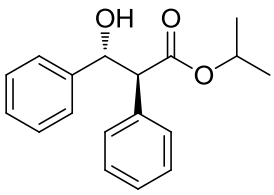
chromatography was performed to separate the major *syn*- isomers from isopinocampheol byproduct).

General Procedure for the Preparation of Mono- or dimenthyl Carbonate Derivatives

The diol obtained from the LAH reduction of aldol product (0.13 mmol) and 4-(dimethylamino)pyridine (from 1.5 equiv. to 3 equiv.) were dissolved in dry dichloromethane (1 mL) under an inert atmosphere and (-)-(*1R*)-menthyl chloroformate (from 1.5 equiv. to 3 equiv.) was added dropwise at 0 ^{o}C. The reaction mixture was then stirred until the reaction was complete by TLC analysis. Reaction was quenched by the addition of a few drops of water. The reaction mixture was diluted with 5 mL of dichloromethane, and then washed with 3 mL of saturated ammonium chloride solution. The organic layer was then separated, and the aqueous layer was extracted with (3 × 5 mL) of dichloromethane. Finally, the combined organic layers were washed with brine solution (5 mL), dried over anhydrous Na_2SO_4, filtered, concentrated *in vacuo*, and passed through a short silica gel column chromatography by using 5% ethyl acetate in hexane. During this chromatography, precaution was taken so that two diastereomeres were not separated. In all cases both diastereomeres were collected together after column chromatography, which was confirmed by analyzing menthyl carbonate derivative of the product obtained from racemic aldols. Both the racemic and chiral menthyl carbonate derivatives were prepared under similar conditions. The enantiomeric ratio (er) of the pure *anti*-diastereomers was determined by ^{1}H NMR analysis of either the secondary alcohol (2^{o} –OH) of the menthyl carbonate or the methyl protons of the menthyl group of the dimenthyl carbonate derivatives of the diols derived from the LAH reduction of *anti*-**9a**-**9i**. Similarly, the er of the pure *syn*-diastereomers was determined by ^{1}H NMR analysis of the methyl protons of the menthyl group of either mono- or dimenthyl carbonate derivatives of diols derived from the LAH reduction of *syn*-**8a**-**8h**.

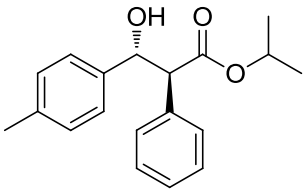
Characterization of the compounds

Isopropyl (2*S*,3*R*)-3-hydroxy-2,3-diphenylpropanoate (9a)



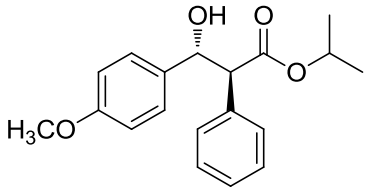
^{1}H NMR (300 MHz, $CDCl_3$): δ 7.19 – 7.07 (m, 10H), 5.17 – 5.04 (m, 2H), 3.84 (d, *J* = 9.0 Hz, 1H), 3.29 (d, *J* = 4.5 Hz, 1H), 1.23 (d, *J* = 6.3 Hz, 3H), 1.12 (d, *J* = 6.3 Hz, 3H); **^{13}C NMR (75 MHz, $CDCl_3$):** δ 173.1, 141.0, 135.6, 128.6, 128.5, 128.1, 127.8, 127.4, 126.7, 76.7, 68.8, 60.1, 21.8, 21.5. **HRMS-EI** $C_{18}H_{20}O_3$ calc. 284.1412, found 284.1399. **$[\alpha]_D^{24}$** = –88.04 (*c* 1.65, $CHCl_3$). Yield: 83%; *Syn*:*anti* – 8:92; er – 87:13 (Determined by ^{1}H NMR analysis of menthyl carbonate derivative of diol obtained by reduction of **9a**).

Isopropyl (2*S*,3*R*)-3-hydroxy-2-phenyl-3-(*p*-tolyl)propanoate (9b)



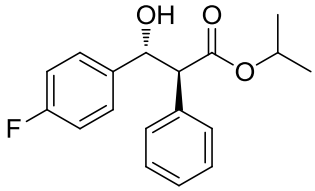
^{1}H NMR (300 MHz, $CDCl_3$): δ 7.19 – 7.08 (m, 5H), 6.99 (s, 4H), 5.14 – 5.03 (m, 2H), 3.83 (d, *J* = 9.0 Hz, 1H), 3.24– 3. 21 (m, 1H), 2.25 (s, 3H), 1.23 (d, *J* = 6.3 Hz, 3H), 1.12 (d, *J* = 6.3 Hz, 3H); **^{13}C NMR (75 MHz, $CDCl_3$):** δ 173.1, 138.0, 137.4, 135.7, 128.9, 128.6, 128.5, 127.4, 126.6, 76.6, 68.7, 60.1, 21.8, 21.6, 21.2. **HRMS-EI** $C_{19}H_{22}O_3$ calc. 298.1569, found 298.1574. **$[\alpha]_D^{25}$** = –88.44 (*c* 1.6, $CHCl_3$). Yield: 90%; *Syn*:*anti* – 11:89; er – 81:19 (Determined by ^{1}H NMR analysis of dimenthyl carbonate derivative of diol obtained by reduction of **9b**).

Isopropyl (2*S*,3*R*)-3-hydroxy -3-(4-methoxyphenyl)-2-phenylpropanoate (9c)



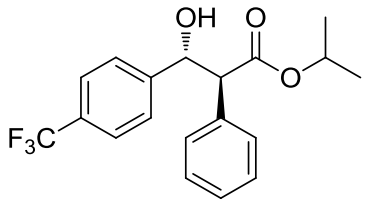
^{1}H NMR (300 MHz, $CDCl_3$): δ 7.18 – 7.00 (m, 7H), 6.70 (d, *J* = 8.7 Hz, 2H), 5.12 – 5.03 (m, 2H), 3.81 (d, *J* = 9.3 Hz, 1H), 3.71 (s, 3H), 3.23 (d, *J* = 3.3 Hz, 1H), 1.24 (d, *J* = 6.3 Hz, 3H), 1.12 (d, *J* = 6.3 Hz, 3H); **^{13}C NMR (75 MHz, $CDCl_3$):** δ 173.1, 159.0, 135.6, 133.2, 128.6, 128.4, 127.9, 127.3, 113.4, 76.2, 68.7, 60.2, 55.1, 21.8, 21.5. **HRMS-EI** $C_{19}H_{22}O_4$ calc. 314.1518, found 314.1526. **$[\alpha]_D^{25}$** = –83.38 (*c* 2.8, $CHCl_3$). Yield: 76%; *Syn*:*anti* – 6:94; er – 81:19 (Determined by ^{1}H NMR analysis of menthyl carbonate derivative of diol obtained by reduction of **9c**).

Isopropyl (2*S*,3*R*)-3-(4-fluorophenyl)-3-hydroxy-2-phenylpropanoate (9d)



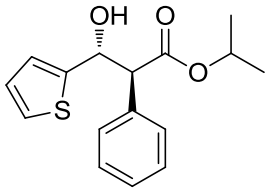
^{1}H NMR (300 MHz, $CDCl_3$): δ 7.26 – 7.16 (m, 3H), 7.08 – 6.88 (m, 4H), 6.84 (t, *J* = 6.9 Hz, 2H), 5.15 – 5.04 (m, 2H), 3.77 (d, *J* = 9.3 Hz, 1H), 3.38 (br, 1H), 1.24 (d, *J* = 6.3 Hz, 3H), 1.12 (d, *J* = 6.3 Hz, 3H); **^{13}C NMR (75 MHz, $CDCl_3$):** δ 173.1, 162.3 ($J_{C\text{-}F}$ = 244.4 Hz), 136.8, 135.4, 128.6, 128.4, 128.3, 127.6, 115.0 ($J_{C\text{-}F}$ = 20.9 Hz), 76.1, 68.9, 60.4, 21.8, 21.5. **HRMS-EI** $C_{18}H_{19}FO_3$ calc. 302.1318, found 302.1325. **$[\alpha]_D^{25}$** = –85.42 (*c* 1.6, $CHCl_3$). Yield: 80%; *Syn*:*anti* – 10:90; er – 80:20 (Determined by ^{1}H NMR analysis of dimenthyl carbonate derivative of diol obtained by reduction of **9d**).

Isopropyl (2*S*,3*R*)-3-hydroxy-2-phenyl-3-(4-(trifluoromethyl)phenyl)propanoate (9e)



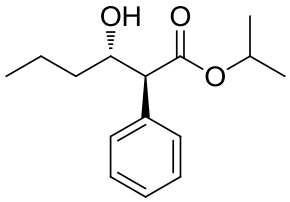
^{1}H NMR (300 MHz, $CDCl_3$): δ 7.43 (d, *J* = 8.1 Hz, 2H), 7.21 – 7.18 (m, 5H), 7.07 – 7.04 (m, 2H), 5.20 (dd, *J* = 3.6, 9.0 Hz, 2H), 5.12 – 5.03 (m, 1H), 3.78 (d, *J* = 9.0 Hz, 1H), 3.55 (br, 1H), 1.22 (d, *J* = 6.3 Hz, 3H), 1.11 (d, *J* = 6.0 Hz, 3H); **^{13}C NMR (75 MHz, $CDCl_3$):** δ 172.9, 145.0, 135.1, 128.7, 128.6, 127.8, 127.1, 125.0, 76.1, 69.1, 60.1, 21.8, 21.5. **HRMS-EI** $C_{19}H_{19}F_3O_3$ calc. 352.1286, found 352.1290. **$[\alpha]_D^{20}$** = –83.46 (*c* 2.7, $CHCl_3$). Yield: 70%; *Syn*:*anti* – 13:87; er – 80:20 (Determined by ^{1}H NMR analysis of dimenthyl carbonate derivative of diol obtained by reduction of **9e**).

Isopropyl (2*S*,3*R*)-3-hydroxy-2-phenyl-3-(thiophen-2-yl)propanoate (9f)



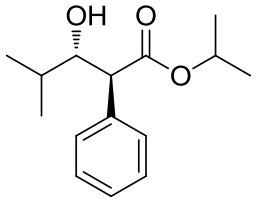
^{1}H NMR (300 MHz, $CDCl_3$): δ 7.26 – 7.16 (m, 6H), 6.79 (dd, *J* = 3.6, 5.1 Hz, 1H), 6.61 (dd, *J* = 0.6, 3.6 Hz, 1H), 5.43 (d, *J* = 8.4 Hz, 1H), 5.12 – 5.04 (m, 1H), 3.90 (d, *J* = 8.7 Hz, 1H), 3.50 (br, 1H), 1.25 (d, *J* = 6.3 Hz, 3H), 1.13 (d, *J* = 6.3 Hz, 3H); **^{13}C NMR (75 MHz, $CDCl_3$):** δ 172.8, 144.9, 135.5, 128.6, 127.7, 126.5, 125.0, 72.8, 69.1, 60.2, 21.8, 21.5. **HRMS-EI** $C_{16}H_{18}O_3S$ calc. 290.0977, found 290.0988. **$[\alpha]_D^{24}$** = –73.79 (*c* 0.6, $CHCl_3$). Yield: 64%; *Syn*:*anti* – 2:98; er – 88:12 (Determined by ^{1}H NMR analysis of menthyl carbonate derivative of diol obtained by reduction of **9f**).

Isopropyl (2*S*,3*S*)-3-hydroxy-2-phenylhexanoate (9g)



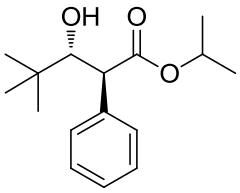
^{1}H NMR (300 MHz, $CDCl_3$): δ 7.32 – 7.26 (m, 5H), 5.10 – 4.98 (m, 1H), 4.16 – 4.12 (m, 1H), 3.52 (d, *J* = 9.0 Hz, 1H), 2.89 (br, 1H), 1.58 – 1.46 (m, 1H), 1.29 – 1.23 (m, 3H), 1.24 (d, *J* = 6.3 Hz, 3H), 1.09 (d, *J* = 6.3 Hz, 3H), 0.82 (t, *J* = 7.2 Hz, 3H); **^{13}C NMR (75 MHz, $CDCl_3$):** δ 173.3, 136.6, 128.8, 128.4, 127.5, 73.2, 68.5, 59.0, 36.2, 21.8, 21.5, 18.7, 14.0. **HRMS-EI** $C_{15}H_{22}O_3$ calc. 250.1569, found 250.1577. **$[\alpha]_D^{20}$** = –35.20 (*c* 2.5, $CHCl_3$). Yield: 68%; *Syn*:*anti* – 12:88; er – 88:12 (Determined by ^{1}H NMR analysis of menthyl carbonate derivative of diol obtained by reduction of **9g**).

Isopropyl (2*S*,3*S*)-3-hydroxy-4-methyl-2-phenylpentanoate (9h)



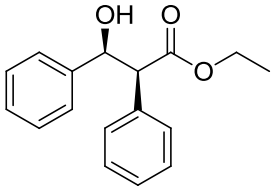
^{1}H NMR (300 MHz, $CDCl_3$): δ 7.32 – 7.25 (m, 5H), 5.07 – 4.98 (m, 1H), 4.07 – 4.01 (m, 1H), 3.69 (d, *J* = 9.3 Hz, 1H), 2.87 (d, *J* = 5.7 Hz, 1H), 1.51– 1.39 (m, 1H), 1.24 (d, *J* = 6.3 Hz, 3H), 1.09 (d, *J* = 6.3 Hz, 3H), 0.94 (d, *J* = 6.9 Hz, 3H), 0.88 (d, *J* = 6.9 Hz, 3H); **^{13}C NMR (75 MHz, $CDCl_3$):** δ 173.5, 136.6, 128.8, 128.4, 127.5, 76.7, 68.5, 56.1, 29.4, 21.8, 21.5, 20.4, 14.8. **HRMS-EI** $C_{15}H_{22}O_3$ calc. 250.1569, found 250.1579. **$[\alpha]_D^{20}$** = –29.00 (*c* 4.4, $CHCl_3$). Yield: 68%; *Syn*:*anti* – 12:88; er – 81:19 (Determined by ^{1}H NMR analysis of menthyl carbonate derivative of diol obtained by reduction of **9h**).

Isopropyl (2*S*,3*R*)-3-hydroxy-4,4-dimethyl-2-phenylpentanoate (9i)



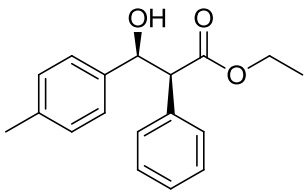
^{1}H NMR (300 MHz, $CDCl_3$): δ 7.44 (dd, *J* = 1.8, 8.4 Hz, 2H), 7.35 – 7.23 (m, 3H), 5.05 – 4.96 (m, 1H), 4.19 (d, *J* = 8.4 Hz, 1H), 3.79 (d, *J* = 3.6 Hz, 1H), 3.61 (dd, *J* = 3.6, 8.4 Hz, 1H), 1.26 (d, *J* = 6.3 Hz, 3H), 1.12 (d, *J* = 6.3 Hz, 3H); 0.92 (s, 9H) **^{13}C NMR (75 MHz, $CDCl_3$):** δ 174.3, 138.5, 128.7, 128.3, 127.4, 82.5, 68.7, 51.1, 36.5, 26.5, 21.6, . **HRMS-EI** $C_{16}H_{24}O_3$ calc. 264.1725, found 264.1736. **$[\alpha]_D^{24}$** = –14.2 (*c* 1.7, $CHCl_3$). Yield: 70%; *Syn*:*anti* – 3:97; er – 78:22 (Determined by ^{1}H NMR analysis of menthyl carbonate derivative of diol obtained by reduction of **9i**).

Ethyl (2*S*,3*S*)-3-hydroxy-2,3-diphenylpropanoate (8a)



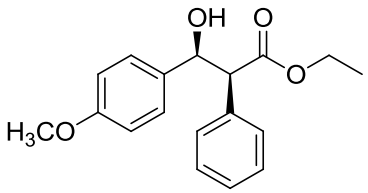
^{1}H NMR (300 MHz, $CDCl_3$): δ 7.37 – 7.25 (m, 10H), 5.26 (dd, *J* = 2.1, 7.8 Hz, 1H), 4.06–3.88 (m, 2H) 3.85 (d, *J* = 7.8 Hz, 1H), 2.61 (br, 1H), 1.02 (t, *J* = 7.2 Hz, 3H); **^{13}C NMR (75 MHz, $CDCl_3$):** δ 172.4, 141.0, 135.0, 129.2, 128.7, 128.3, 128.1, 128.0, 126.9, 75.3, 61.0, 59.9, 14.0. **HRMS-EI** $C_{17}H_{18}O_3$ calc. 270.1256, found 270.1260. **$[\alpha]_D^{24}$** = –103.73 (*c* 2.2, $CHCl_3$). Yield: 75%; *Syn*:*anti* – 83:17; er – >99:<1 (Determined by ^{1}H NMR analysis of menthyl carbonate derivative of diol obtained by reduction of **8a**).

Ethyl (2*S*,3*S*)-3-hydroxy-2-phenyl-3-(*p*-tolyl)propanoate (8b)



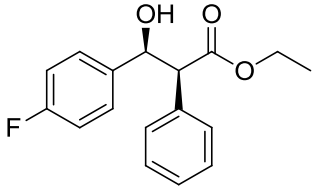
^{1}H NMR (300 MHz, $CDCl_3$): δ 7.39 – 7.29 (m, 5H), 7.21(d, *J* = 8.1 Hz, 2H), 7.10 (d, *J* = 8.1 Hz, 2H), 5.22 (dd, *J* = 2.1, 7.8 Hz, 1H), 4.05 – 3.88 (m, 2H), 3.85 (d, *J* = 8.1 Hz, 1H), 2.49 (d, *J* = 2.1 Hz, 1H), 2.32 (s, 3H), 1.03 (t, *J* = 7.2 Hz, 3H); **^{13}C NMR (75 MHz, $CDCl_3$):** δ 172.4, 138.0, 137.7, 135.2, 129.2, 129.0, 128.7, 127.9, 126.8, 75.2, 60.9, 59.9, 21.3, 14.0. **HRMS-EI** $C_{18}H_{20}O_3$ calc. 284.1412, found 284.1425. **$[\alpha]_D^{25}$** = –108.54 (*c* 0.55, $CHCl_3$). Yield: 73%; *Syn*:*anti* – 82:18; er – 93:7 (Determined by ^{1}H NMR analysis of menthyl carbonate derivative of diol obtained by reduction of **8b**).

Ethyl (2*S*,3*S*)-3-hydroxy-3-(4-methoxyphenyl)-2-phenylpropanoate (8c)



^{1}H NMR (300 MHz, $CDCl_3$): δ 7.37 – 7.21 (m, 7H), 6.80 (dd, *J* = 2.1, 6.9 Hz, 2H), 5.15 (d, *J* = 8.1 Hz, 1H), 4.00 – 3.85 (m, 2H), 3.81 (d, *J* = 8.1 Hz, 1H), 3.73 (s, 3H), 2.65 (s, 1H), 0.99 (t, *J* = 7.2 Hz, 3H); **^{13}C NMR (75 MHz, $CDCl_3$):** δ 172.2, 159.2, 135.3, 133.3, 129.1, 128.5, 128.0, 127.8, 113.5, 74.8, 60.8, 59.9, 55.1, 13.9. **HRMS-EI** $C_{18}H_{20}O_4$ calc. 300.1362, found 300.1368. **$[\alpha]_D^{25}$** = –98.30 (*c* 1.6, $CHCl_3$). Yield: 66%; *Syn*:*anti* – 86:14; er – 93:7 (Determined by ^{1}H NMR analysis of menthyl carbonate derivative of diol obtained by reduction of **8c**).

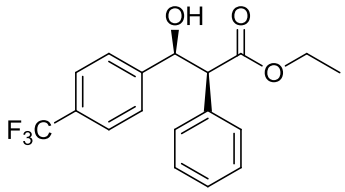
Ethyl (2*S*,3*S*)-3-(4-fluorophenyl)-3-hydroxy-2-phenylpropanoate (8d)



^{1}H NMR (300 MHz, $CDCl_3$): δ 7.32 (s, 5H), 7.29 – 7.25 (m, 2H), 6.98 (t, *J* = 8.7 Hz, 2H), 5.25 (dd, *J* = 2.1, 7.5 Hz, 1H), 4.09 – 3.90 (m, 2H), 3.80 (d, *J* = 7.5 Hz, 1H), 2.72 (d, *J* = 2.4 Hz, 1H), 1.05 (t, *J* = 7.2 Hz, 3H); **^{13}C NMR (75 MHz, $CDCl_3$):** δ 172.4, 162.5 ($J_{C\text{-}F}$ = 244.5 Hz), 136.7, 134.6, 129.2, 128.7, 128.6, 128.5, 128.1, 115.2 ($J_{C\text{-}F}$ = 21.1 Hz), 74.6, 61.1, 59.8, 14.0. **HRMS-**

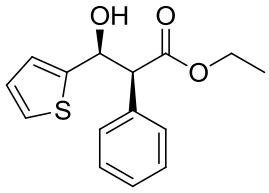
EI $C_{17}H_{17}FO_3$ calc. 288.1162, found 288.1175. $[\alpha]_D^{25}$ = –104.44 (*c* 1.6, $CHCl_3$). Yield: 67%; *Syn*:*anti* – 84:16; er – 96:4 (Determined by ^{1}H NMR analysis of dimenthyl carbonate derivative of diol obtained by reduction of **8d**).

Ethyl (2*S*,3*S*)-3-hydroxy-2-phenyl-3-(4-(trifluoromethyl)phenyl)propanoate (8e)



^{1}H NMR (300 MHz, $CDCl_3$): δ 7.54 (d, *J* = 8.1 Hz, 2H), 7.39 (d, *J* = 8.1 Hz, 2H), 7.32 – 7.24 (m, 5H), 5.32 (d, *J* = 6.9 Hz, 1H), 4.10 – 3.92 (m, 2H), 3.81 (d, *J* = 7.2 Hz, 1H), 2.96 (d, *J* = 2.1 Hz, 1H), 1.05 (t, *J* = 7.2 Hz, 3H); **^{13}C NMR (75 MHz, $CDCl_3$):** δ 172.5, 144.9, 134.2, 129.3, 128.7, 128.2, 127.2, 125.2, 74.5, 61.3, 59.4, 13.9. **HRMS-EI** $C_{18}H_{17}F_3O_3$ calc. 338.1130, found 338.1145. $[\alpha]_D^{24}$ = –102.66 (*c* 4.55, $CHCl_3$). Yield: 82%; *Syn*:*anti* – 84:16; er – >99:<1 (Determined by ^{1}H NMR analysis of dimenthyl carbonate derivative of diol obtained by reduction of **8e**).

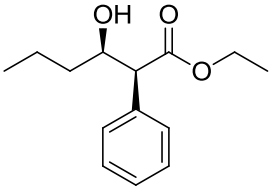
Ethyl (2*S*,3*S*)-3-hydroxy-2-phenyl-3-(thiophen-2-yl)propanoate (8f)



^{1}H NMR (300 MHz, $CDCl_3$): δ 7.43 – 7.32 (m, 5H), 7.24 (d, *J* = 6 Hz, 1H), 7.01 (d, *J* = 3 Hz, 1H), 6.94 (dd, *J* = 3.6, 5.1 Hz, 1H), 5.56 (dd, *J* = 2.7, 8.1 Hz, 1H), 4.12 – 3.97 (m, 2H), 3.92 (d, *J* = 8.1 Hz, 1H), 2.61 (d, *J* = 2.7 Hz, 1H), 1.1 (t, *J* = 7.2 Hz, 3H); **^{13}C NMR (75 MHz, $CDCl_3$):** δ 172.1, 144.6, 134.9, 129.2, 128.9, 128.2, 126.6, 125.2, 71.5, 61.2, 60.4, 14.0. **HRMS-EI** $C_{15}H_{16}O_3S$ calc. 276.0820, found 276.0833. $[\alpha]_D^{24}$ = –69.75 (*c* 1.0, $CHCl_3$). Yield: 81%; *Syn*:*anti*

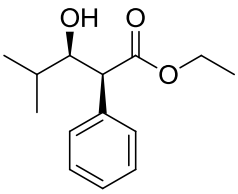
– 83:17; er – 96:4 (Determined by ^{1}H NMR analysis of dimenthyl carbonate derivative of diol obtained by reduction of **8f**).

Ethyl (2*S*,3*R*)-3-hydroxy-2-phenylhexanoate (8g)

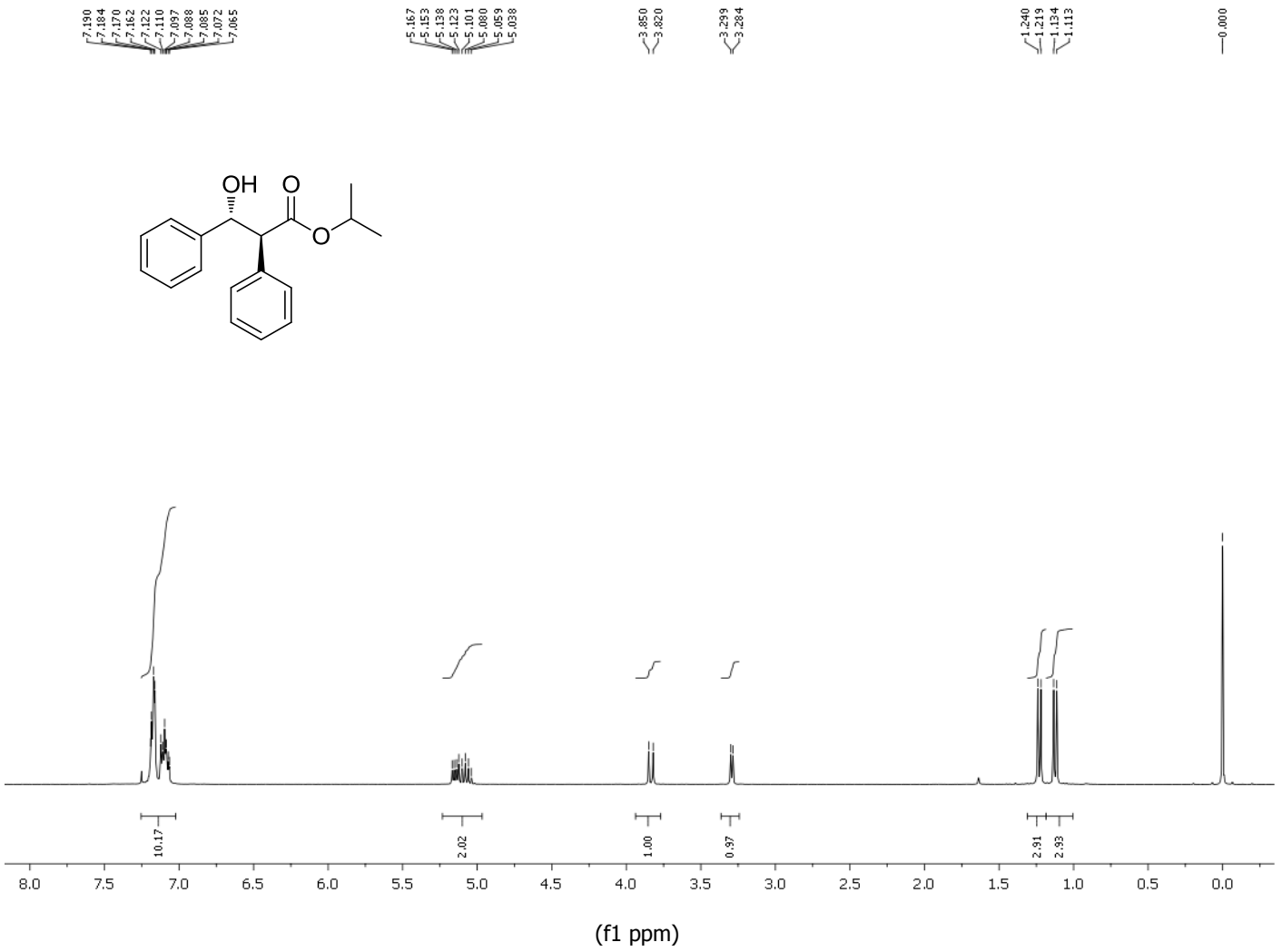


^{1}H NMR (300 MHz, $CDCl_3$): δ 7.37 – 7.25 (m, 5H), 4.21 – 4.03 (m, 3H), 3.54 (d, *J* = 6.6 Hz, 1H), 2.50 (d, *J* = 3.0 Hz, 1H), 1.55 – 1.36 (m, 4H), 1.20 (t, *J* = 6.9 Hz, 3H), 0.90 (t, *J* = 6.9 Hz, 3H); **^{13}C NMR (75 MHz, $CDCl_3$):** δ 173.3, 135.3, 129.2, 128.6, 127.7, 72.0, 61.0, 57.5, 36.7, 19.0, 14.0. **HRMS-EI** $C_{14}H_{20}O_3$ calc. 236.1412, found 236.1427. **$[\alpha]_D^{25}$** = –59.17 (*c* 1.9, $CHCl_3$). Yield: 72%; *Syn*:*anti* – 85:15; er – >99:<1 (Determined by ^{1}H NMR analysis of menthyl carbonate derivative of diol obtained by reduction of **8g**).

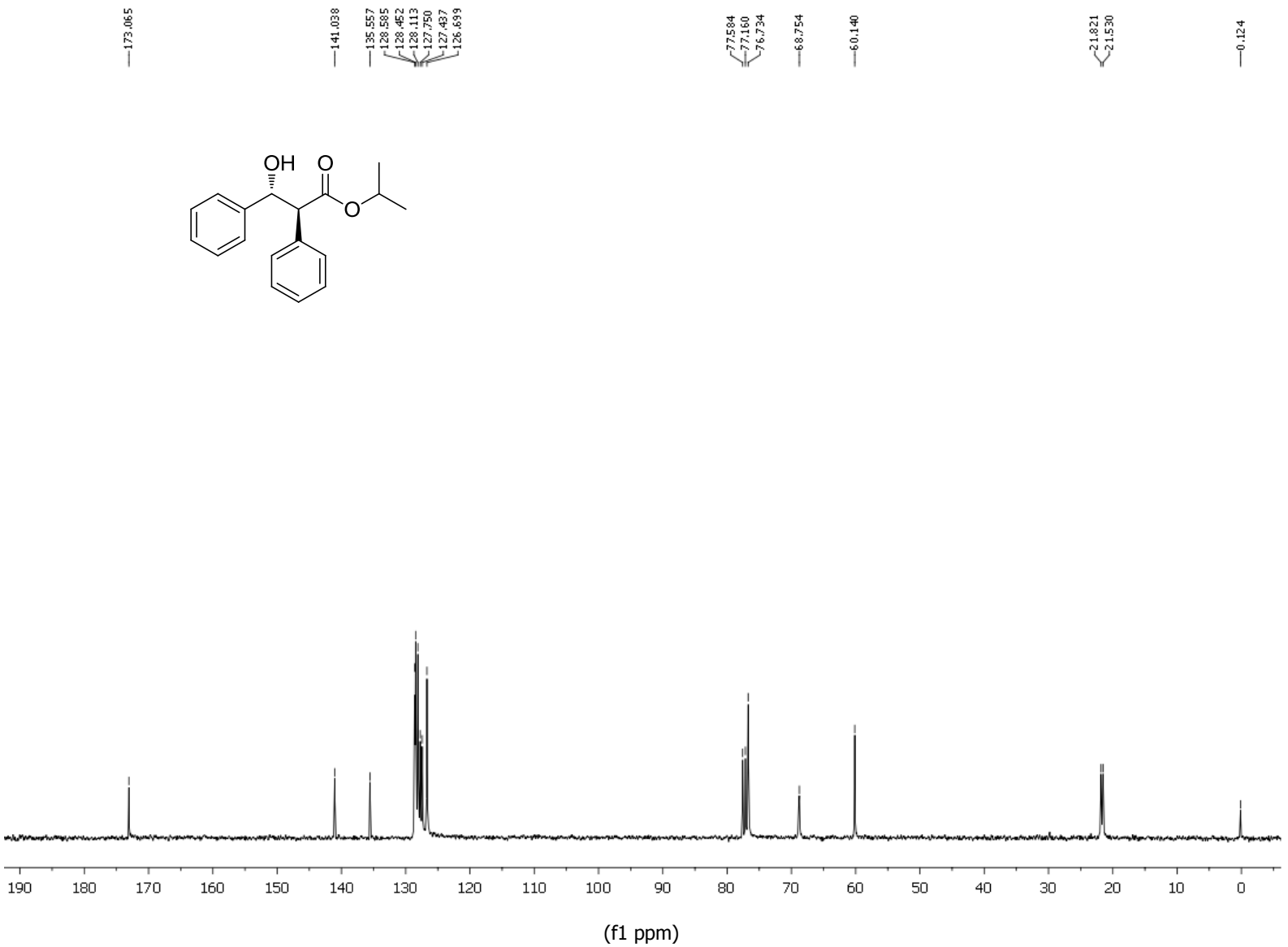
Ethyl (2*S*,3*R*)-3-hydroxy-4-methyl-2-phenylpentanoate (8h)



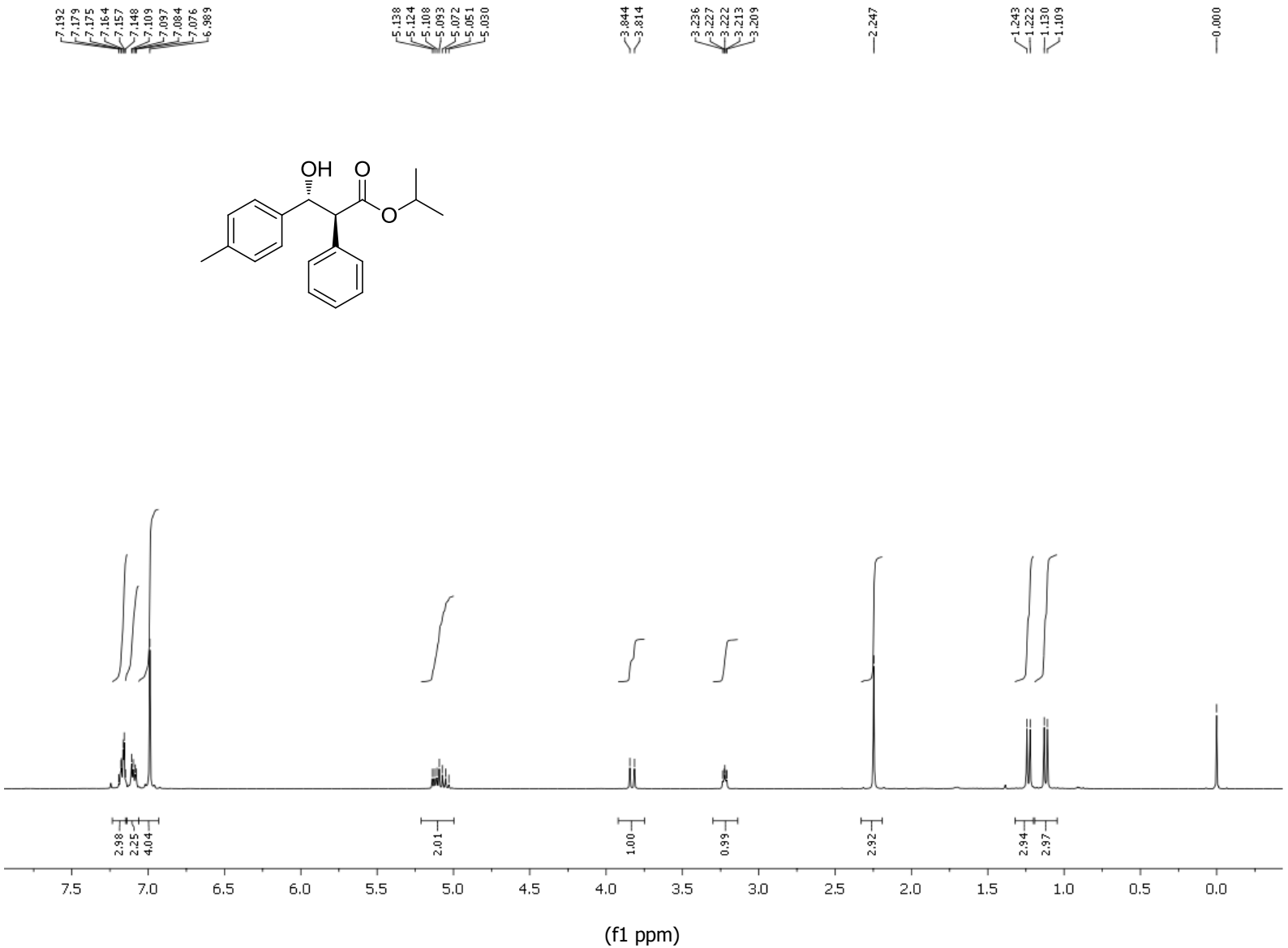
^{1}H NMR (300 MHz, $CDCl_3$): δ 7.44 – 7.26 (m, 5H), 4.23 – 4.03 (m, 2H), 3.99 – 3.94 (m, 1H), 3.72 (d, *J* = 6.9 Hz, 1H), 2.30 (d, *J* = 3.3 Hz, 1H), 1.70 – 1.59 (m, 1H), 1.21 (t, *J* = 7.2 Hz, 3H), 0.99 (dd, *J* = 3.9, 6.6 Hz, 6H); **^{13}C NMR (75 MHz, $CDCl_3$):** δ 173.4, 135.7, 129.3, 128.7, 127.7, 77.0, 61.0, 55.0, 30.8, 19.9, 16.7, 14.1. **HRMS-EI** $C_{14}H_{20}O_3$ calc. 236.1412, found 236.1423. **$[\alpha]_D^{25}$** = –65.93 (*c* 1.65, $CHCl_3$) Yield: 75%; *Syn*:*anti* – 85:15; er – >99:<1 (Determined by ^{1}H NMR analysis of menthyl carbonate derivative of diol obtained by reduction of **8h**)



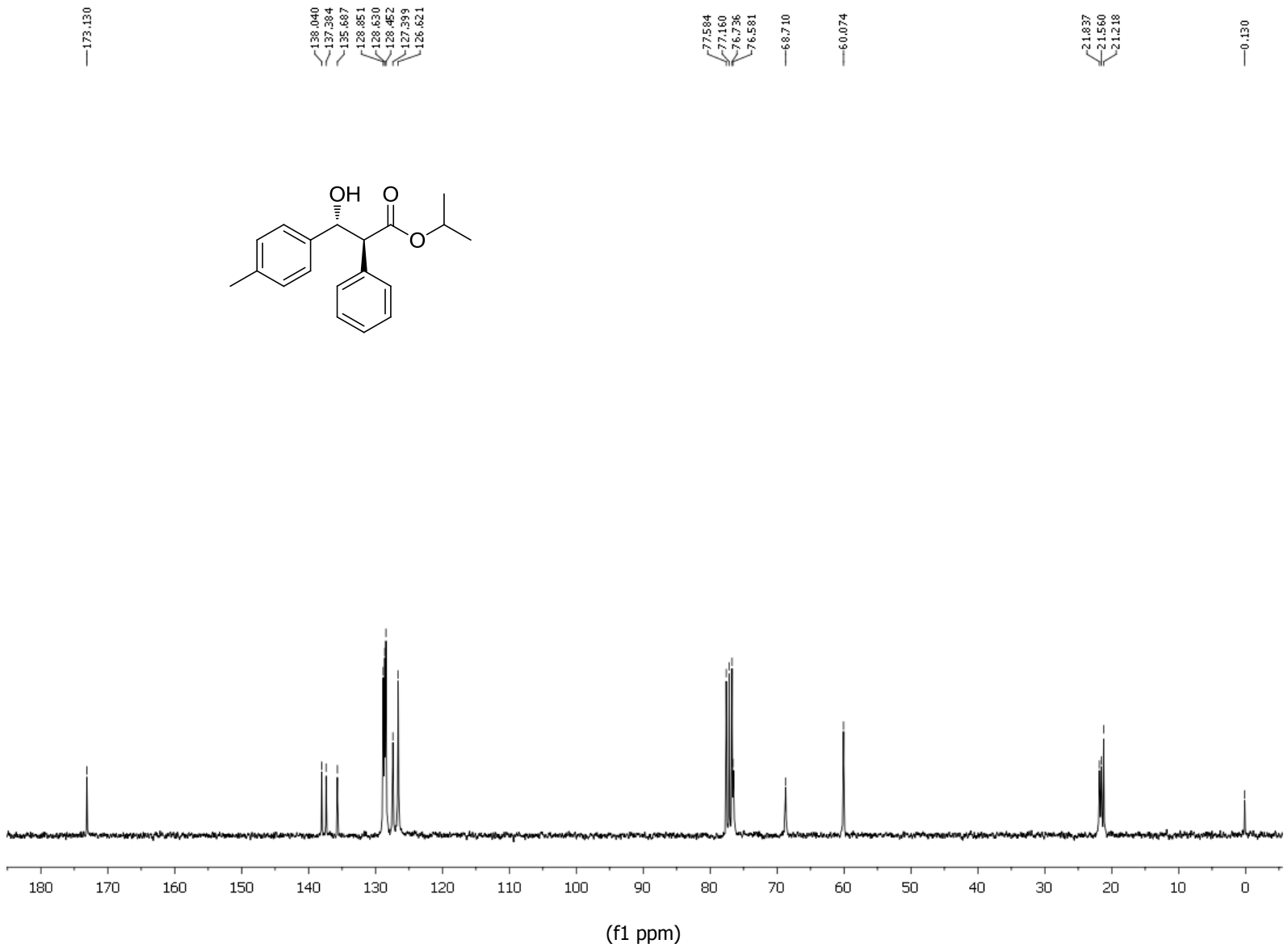
^{1}H NMR spectrum of isopropyl (2*S*,3*R*)-3-hydroxy-2,3-diphenylpropanoate (**9a**)



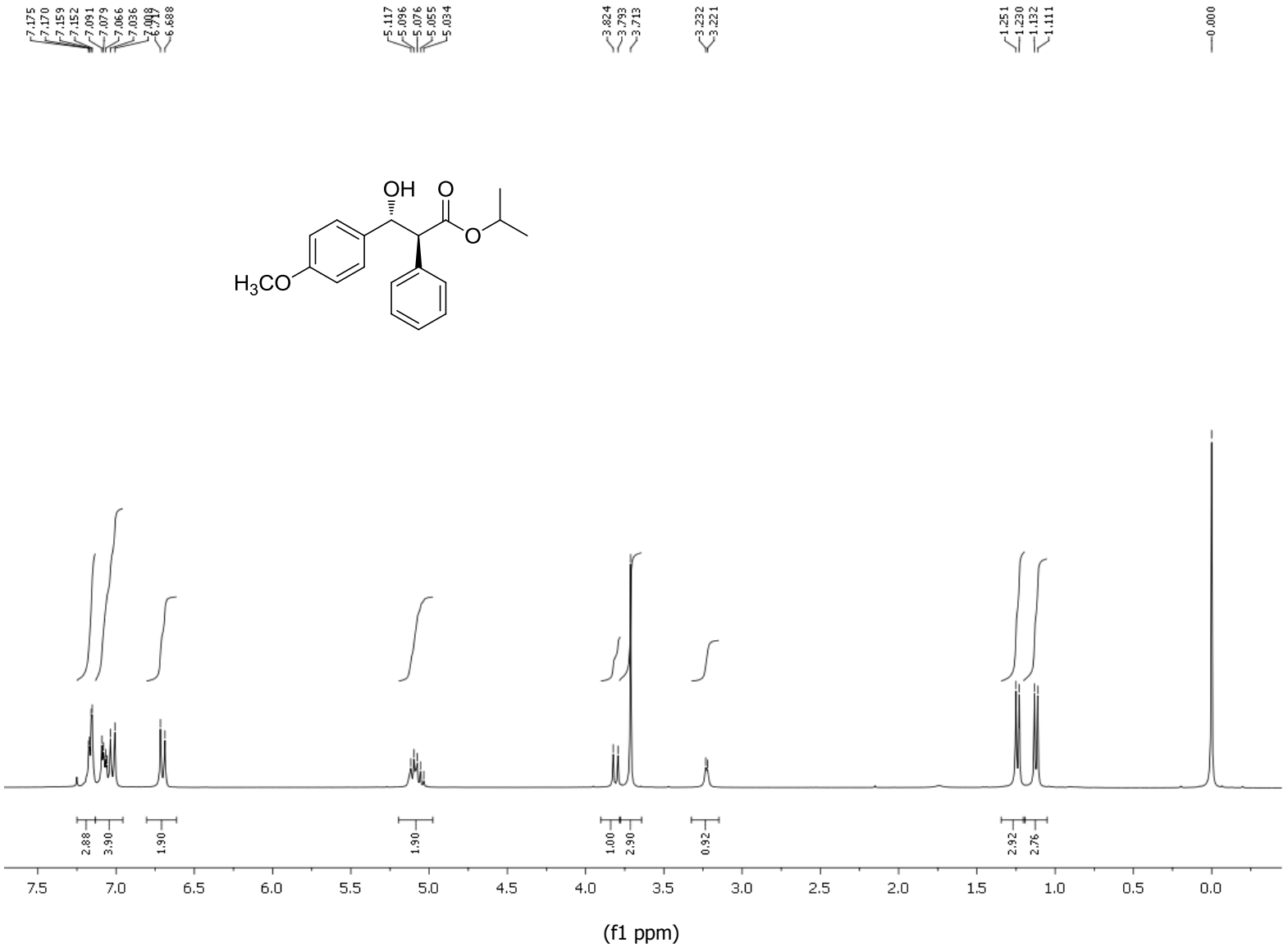
^{13}C NMR spectrum of isopropyl (2*S*,3*R*)-3-hydroxy-2,3-diphenylpropanoate (**9a)**



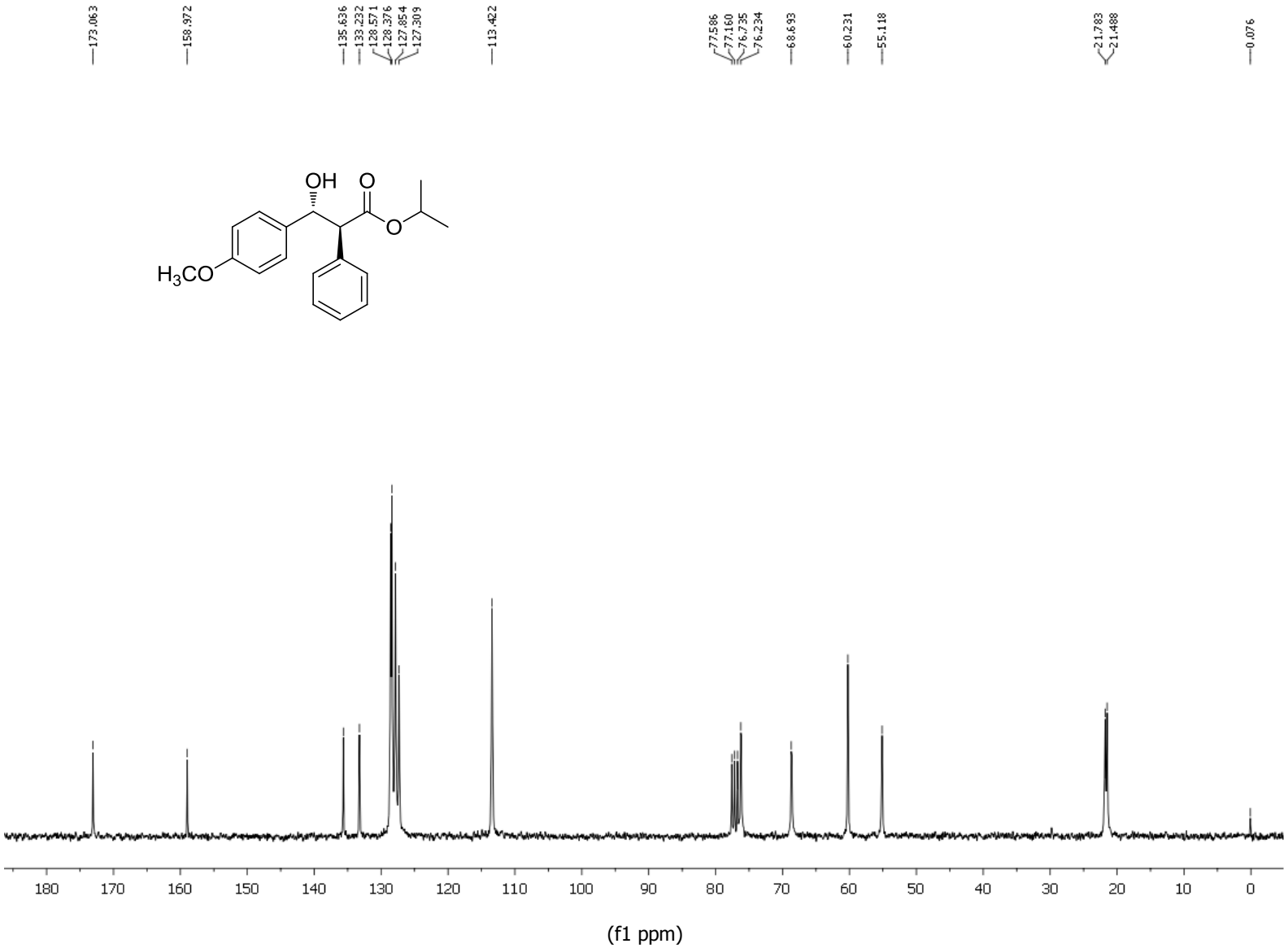
^{1}H NMR spectrum of isopropyl (2*S*,3*R*)-3-hydroxy-2-phenyl-3-(*p*-tolyl)propanoate (**9b**)



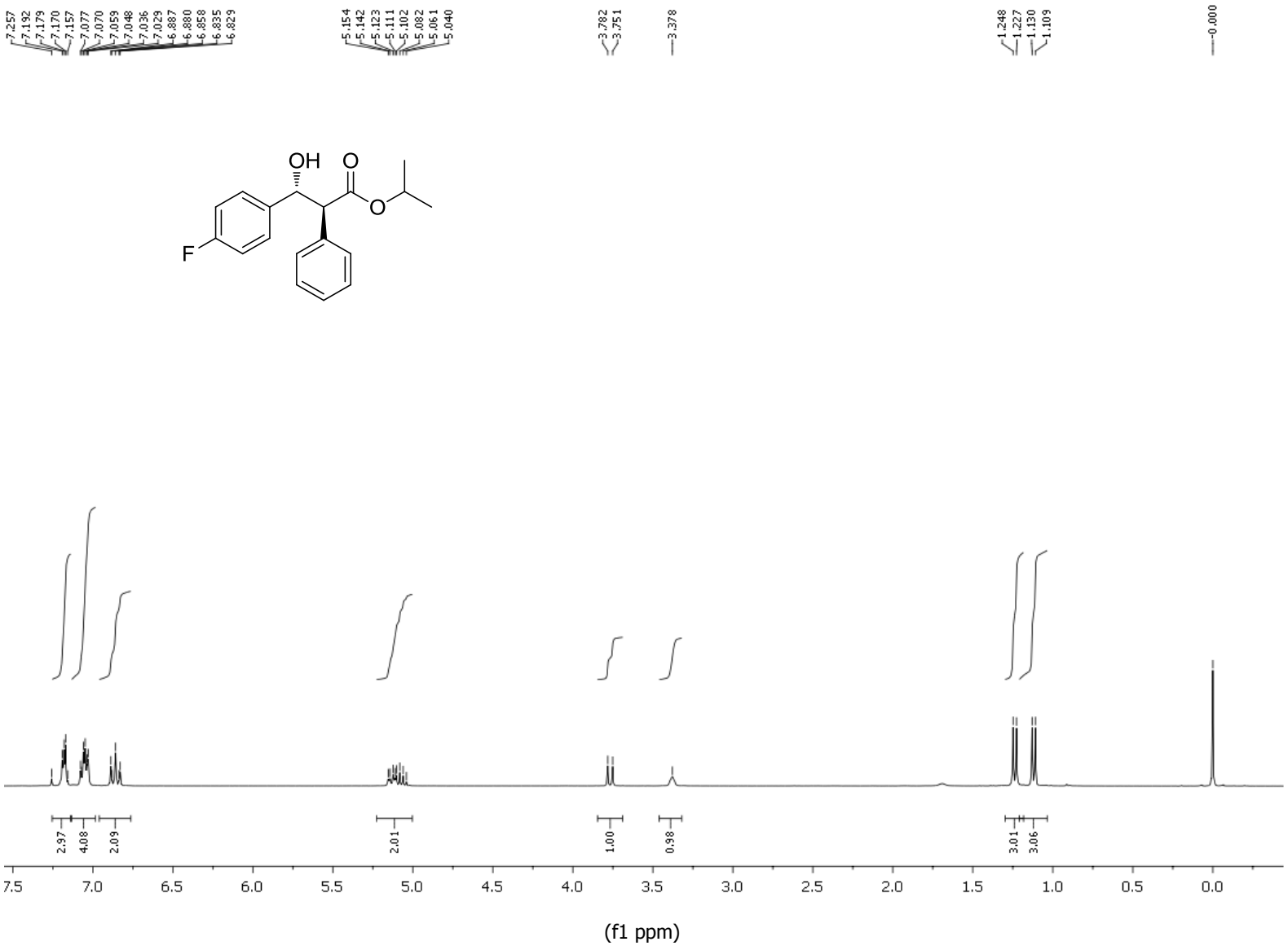
^{13}C NMR spectrum of isopropyl (2*S*,3*R*)-3-hydroxy-2-phenyl-3-(*p*-tolyl)propanoate (**9b**)



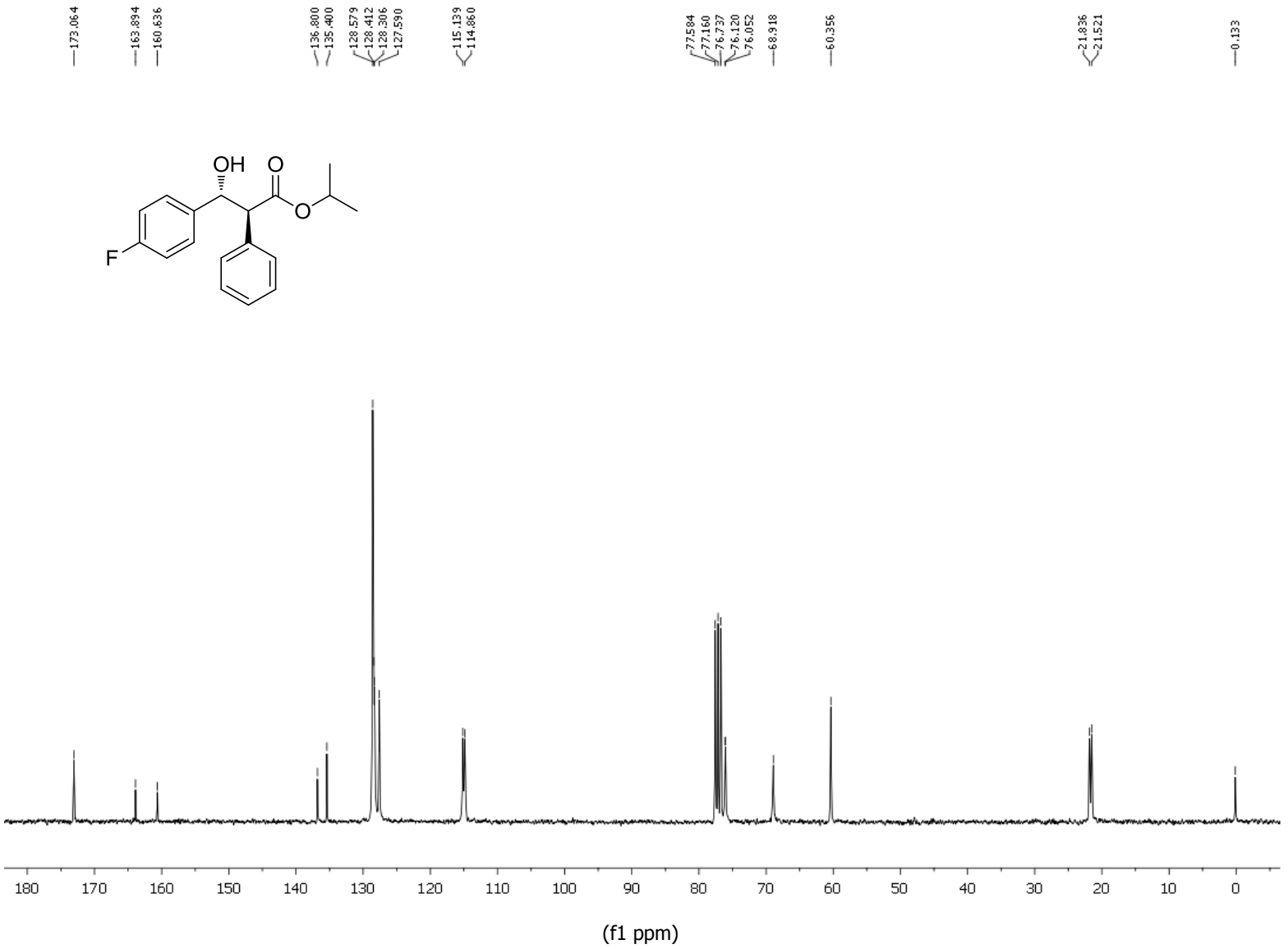
^{1}H NMR spectrum of isopropyl (2*S*,3*R*)-3-hydroxy -3-(4-methoxyphenyl)-2-phenylpropanoate (**9c**)



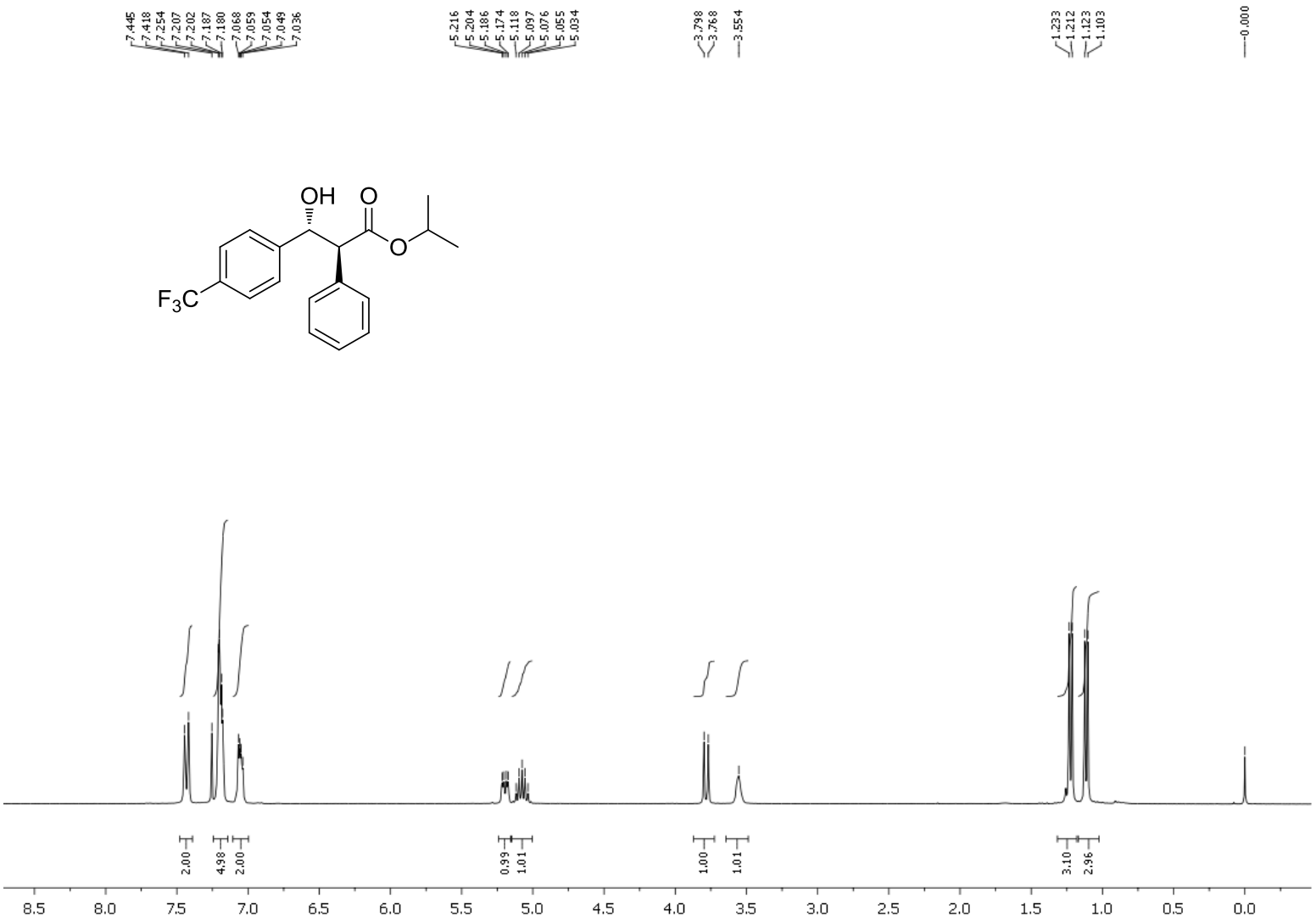
^{13}C NMR spectrum of isopropyl (2*S*,3*R*)-3-hydroxy -3-(4-methoxyphenyl)-2-phenylpropanoate (**9c**)



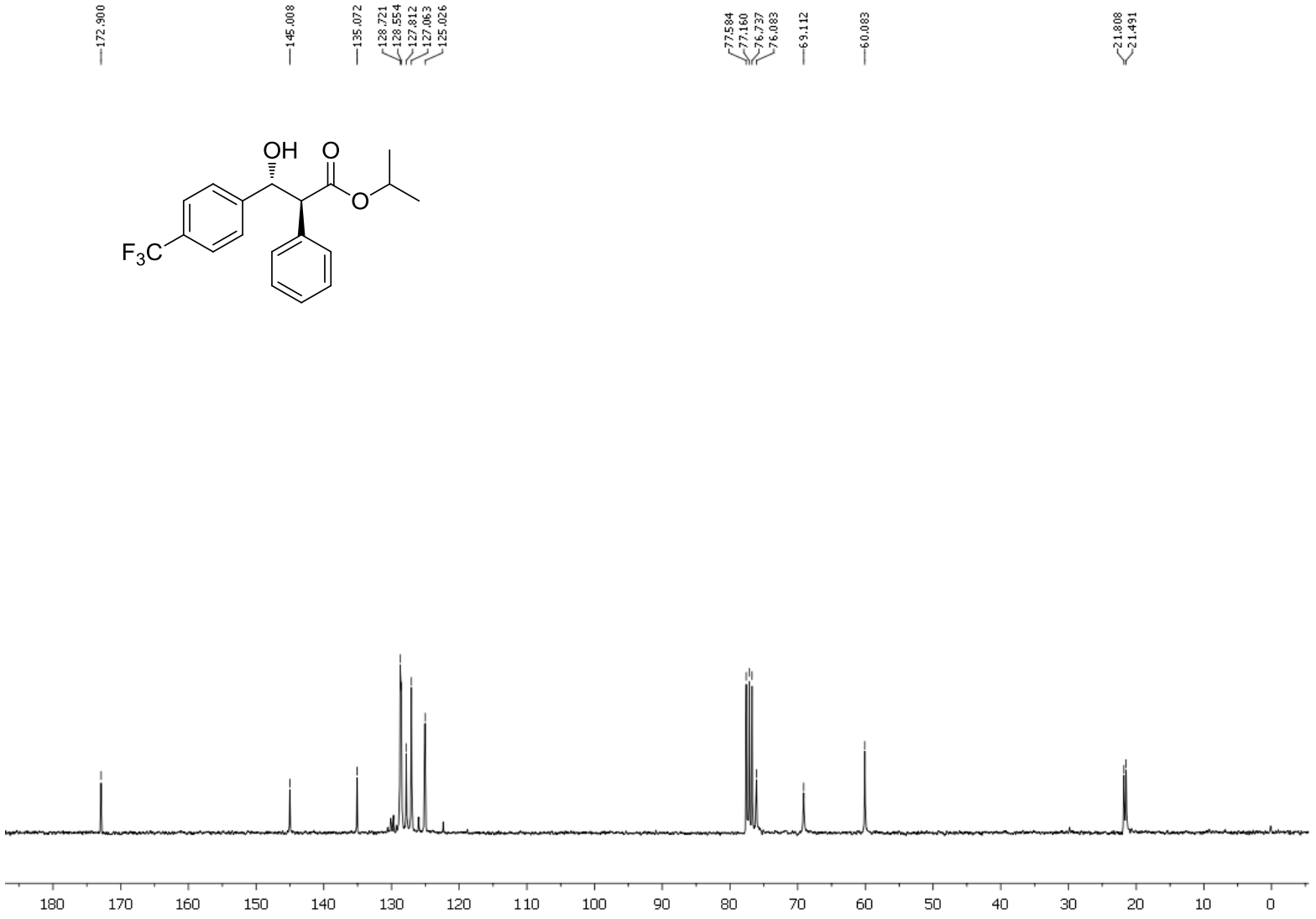
^{1}H NMR spectrum of isopropyl (2*S*,3*R*)-3-(4-fluorophenyl)-3-hydroxy-2-phenylpropanoate (**9d**)



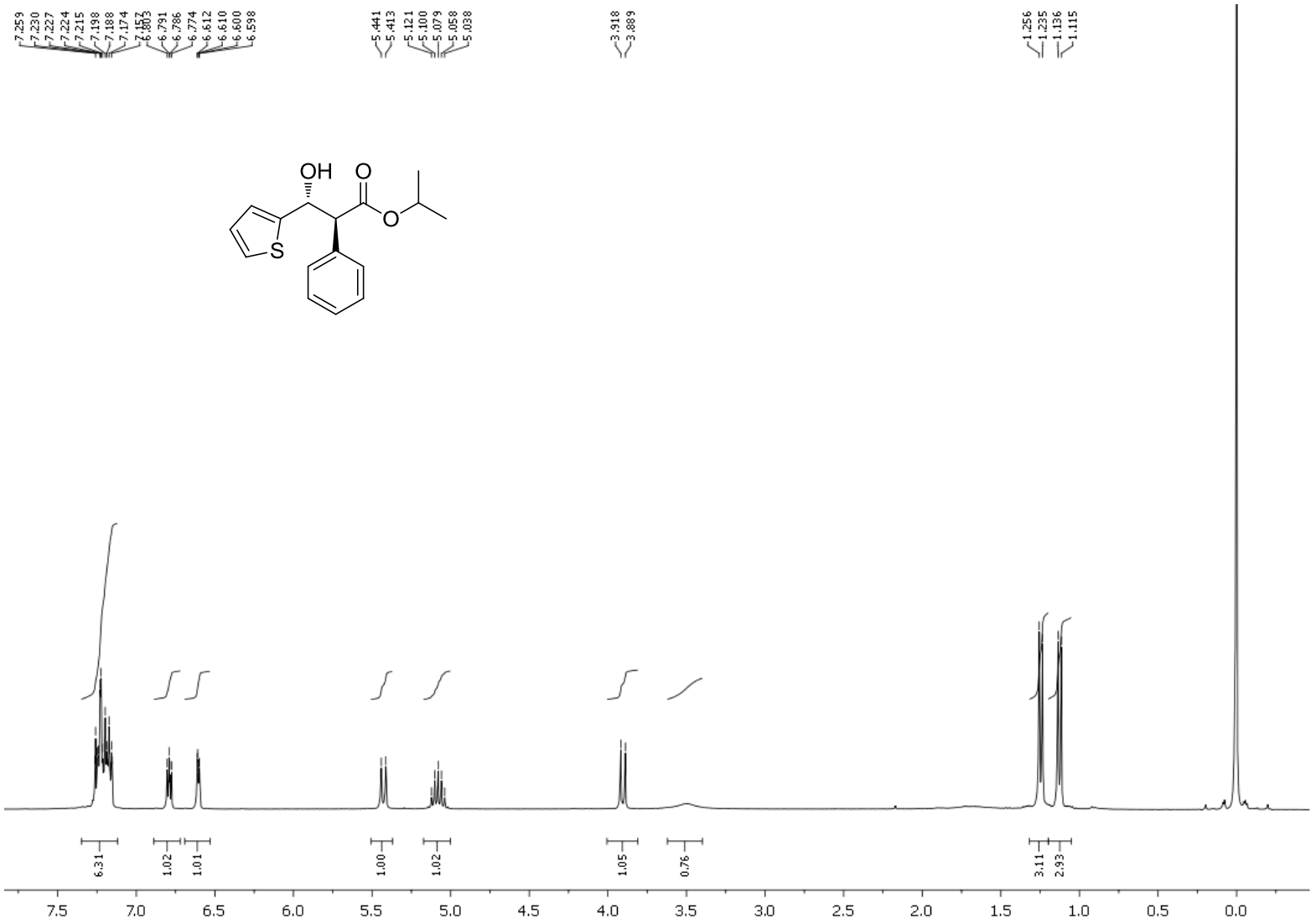
^{13}C NMR spectrum of isopropyl (2*S*,3*R*)-3-(4-fluorophenyl)-3-hydroxy-2-phenylpropanoate (**9d**)



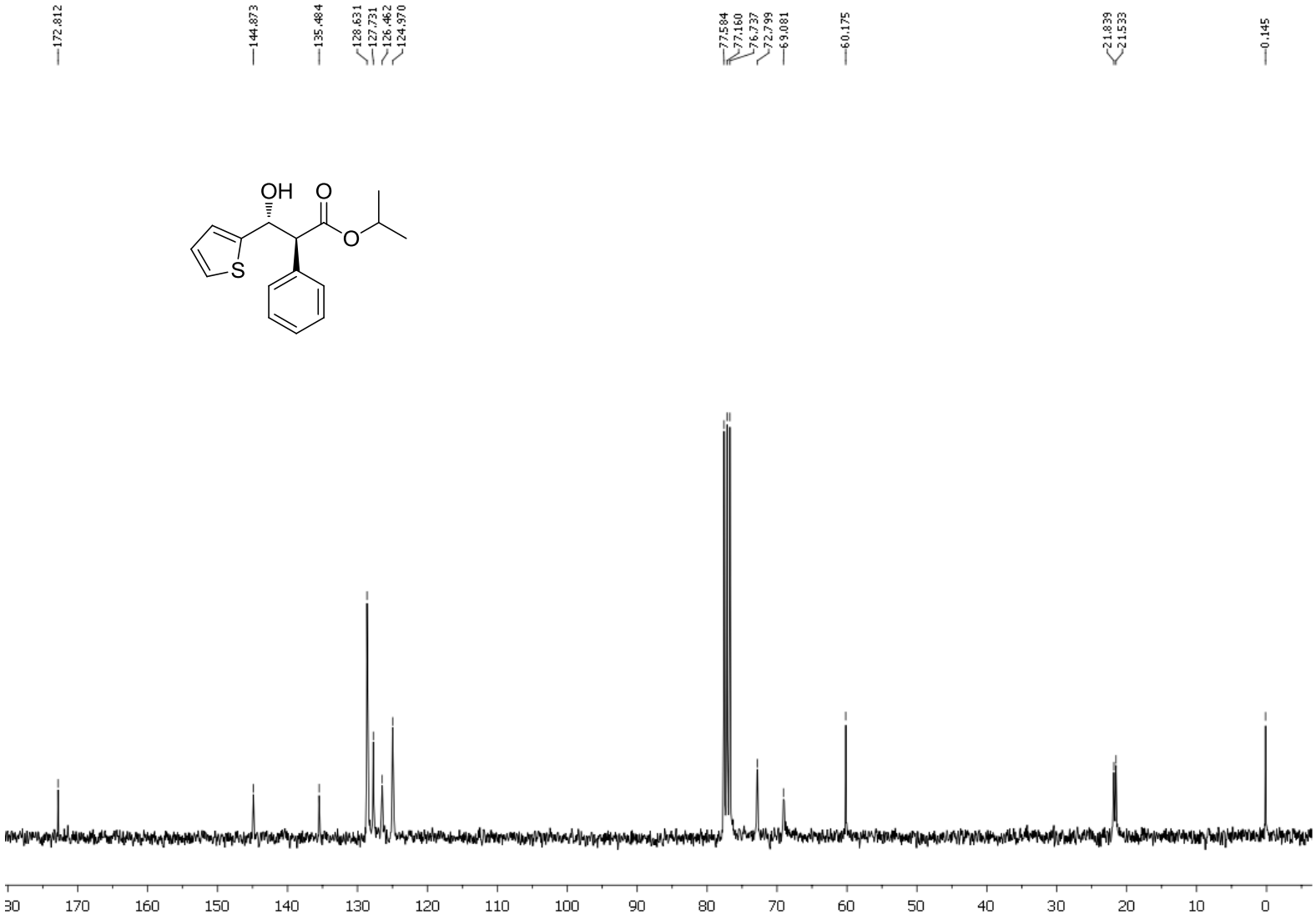
^{1}H NMR spectrum of isopropyl (2*S*,3*R*)-3-hydroxy-2-phenyl-3-(4-(trifluoromethyl)phenyl)propanoate (**9e**)



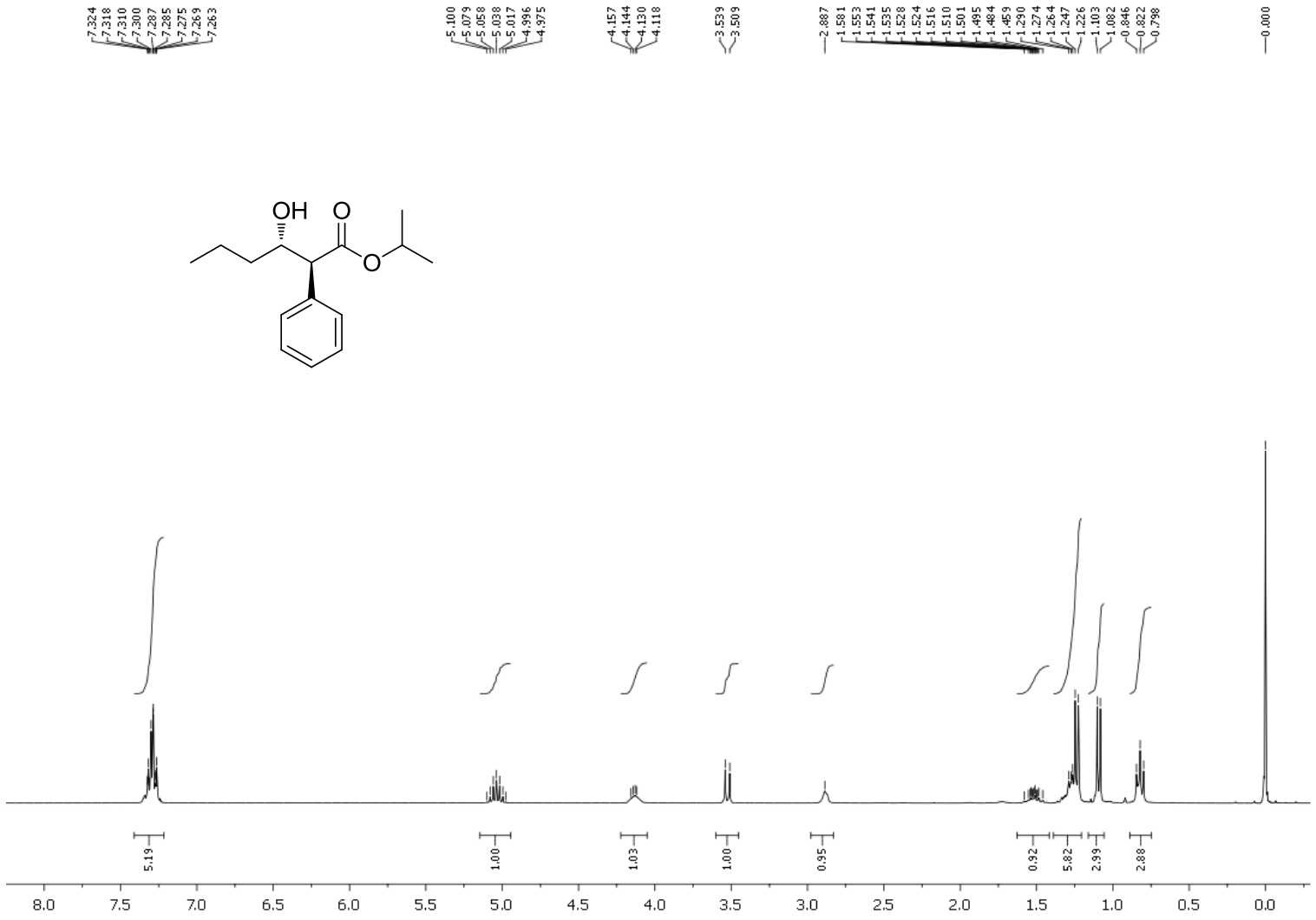
^{13}C NMR spectrum of isopropyl (2*S*,3*R*)-3-hydroxy-2-phenyl-3-(4-(trifluoromethyl)phenyl)propanoate (**9e**)



^{1}H NMR spectrum of isopropyl (2*S*,3*R*)-3-hydroxy-2-phenyl-3-(thiophen-2-yl)propanoate (**9f**)

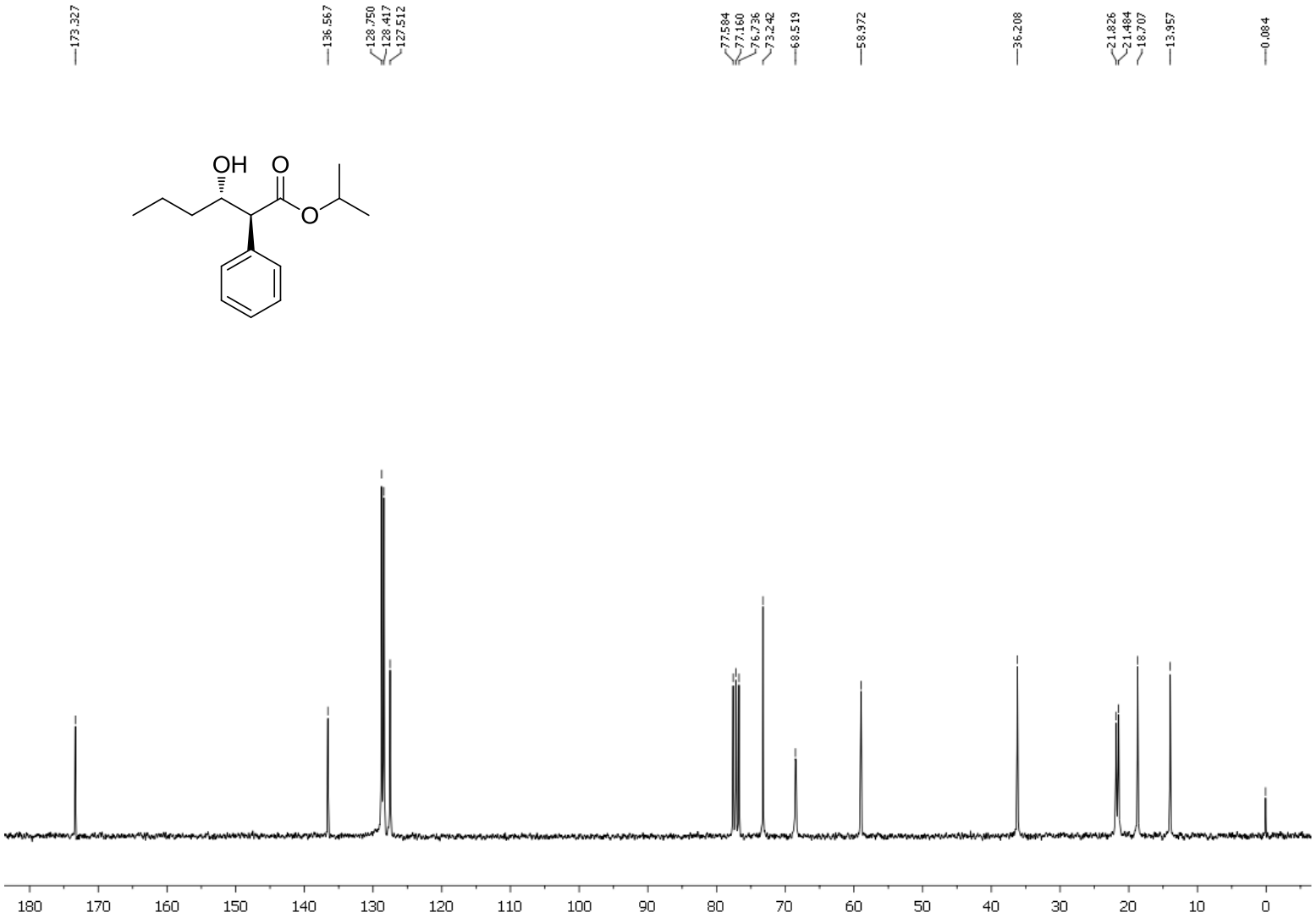


^{13}C NMR spectrum of isopropyl (2*S*,3*R*)-3-hydroxy-2-phenyl-3-(thiophen-2-yl)propanoate (**9f**)

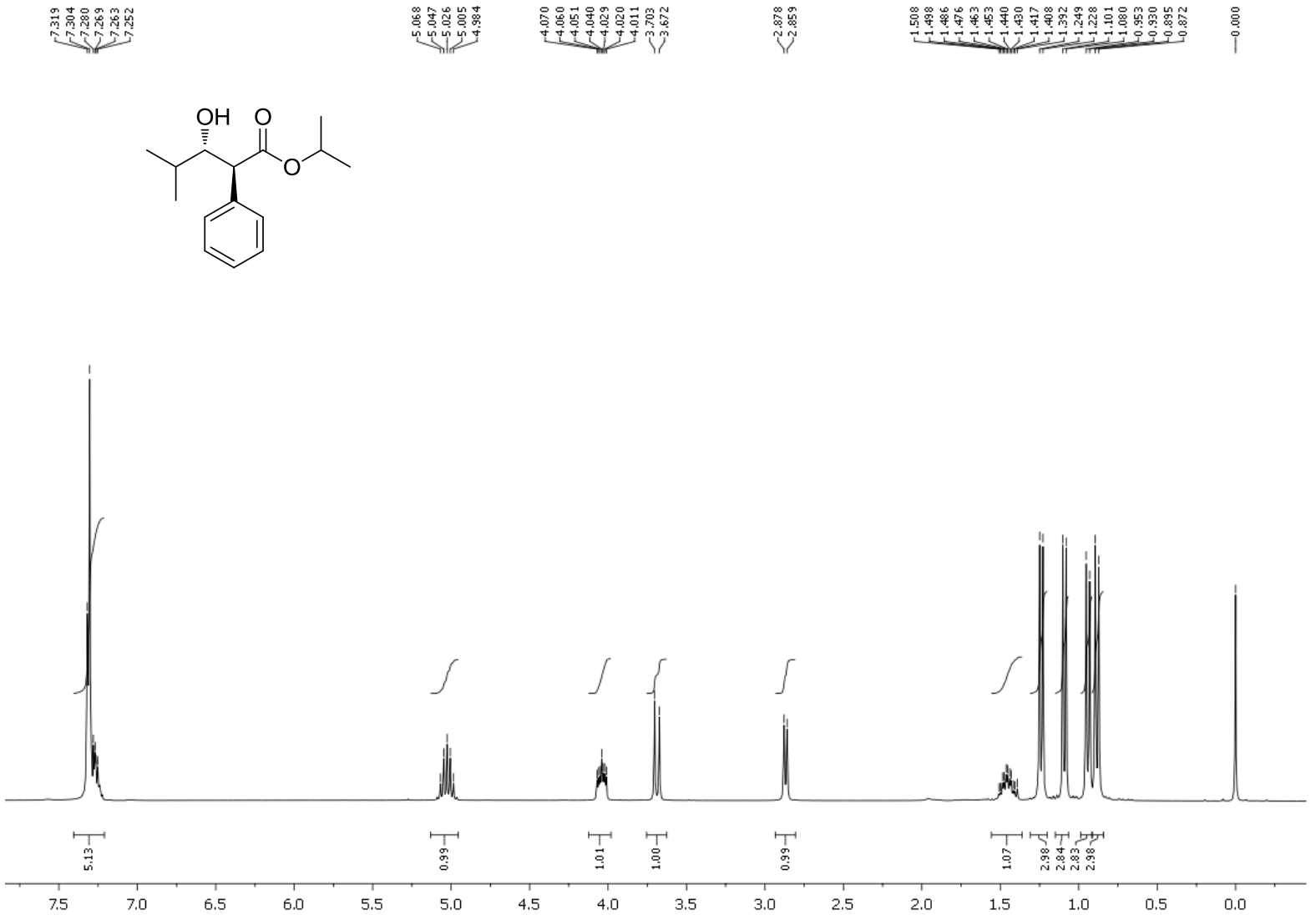


(f1 ppm)

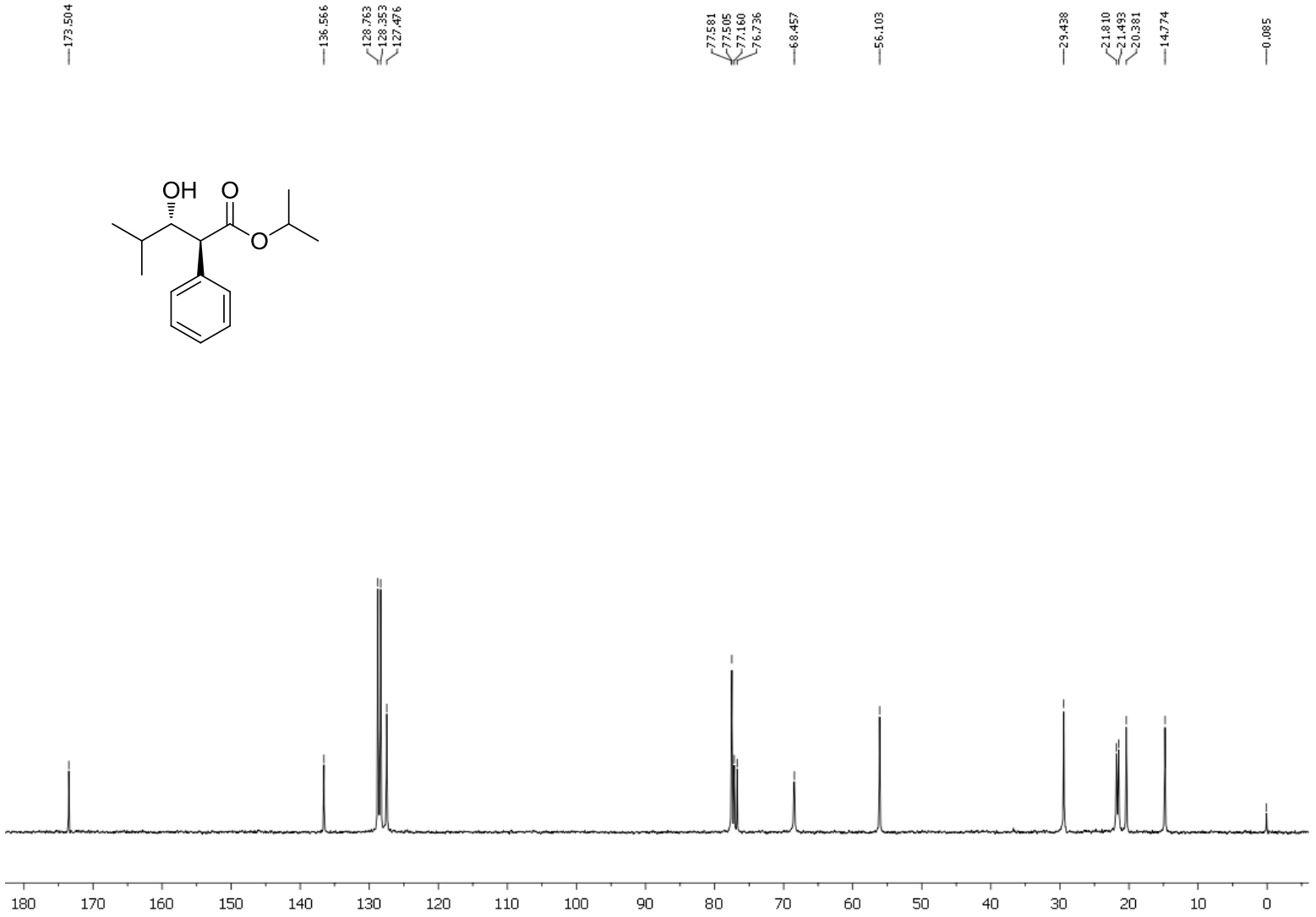
^{1}H NMR spectrum of isopropyl (2*S*,3*S*)-3-hydroxy-2-phenylhexanoate (**9g**)



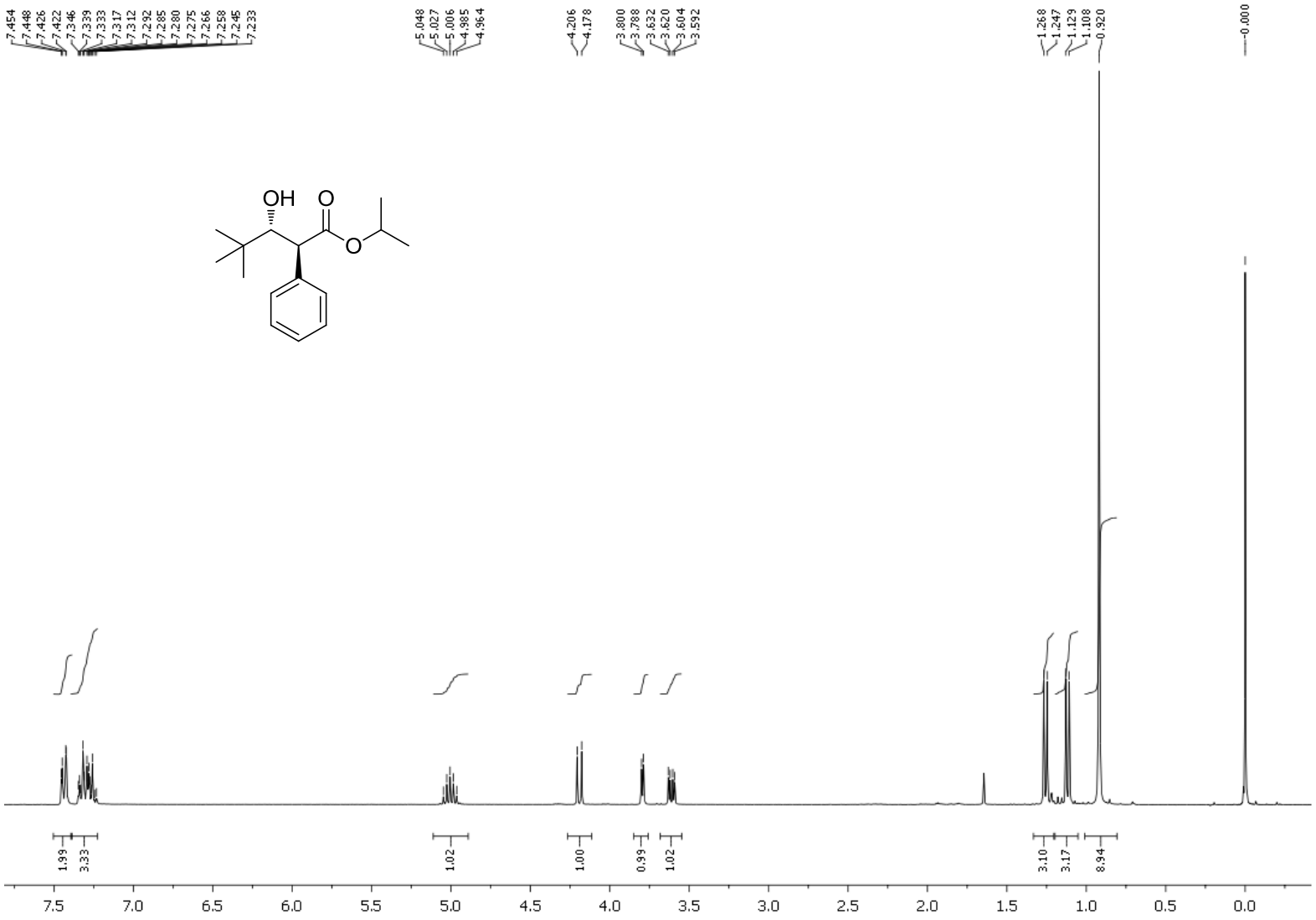
^{13}C NMR spectrum of isopropyl (2*S*,3*S*)-3-hydroxy-2-phenylhexanoate (**9g**)



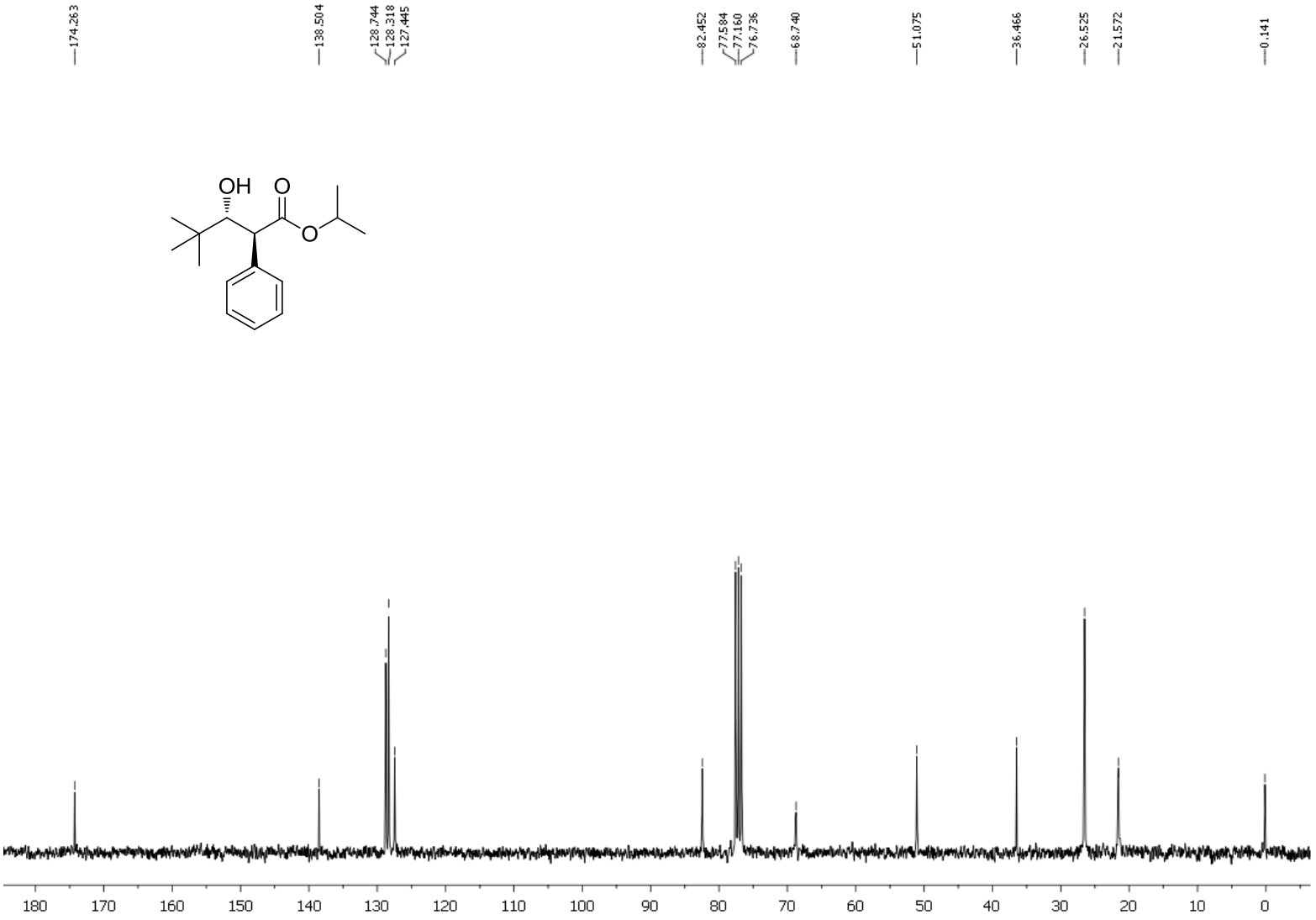
^{1}H NMR spectrum of isopropyl (2*S*,3*S*)-3-hydroxy-4-methyl-2-phenylpentanoate (**9h**)



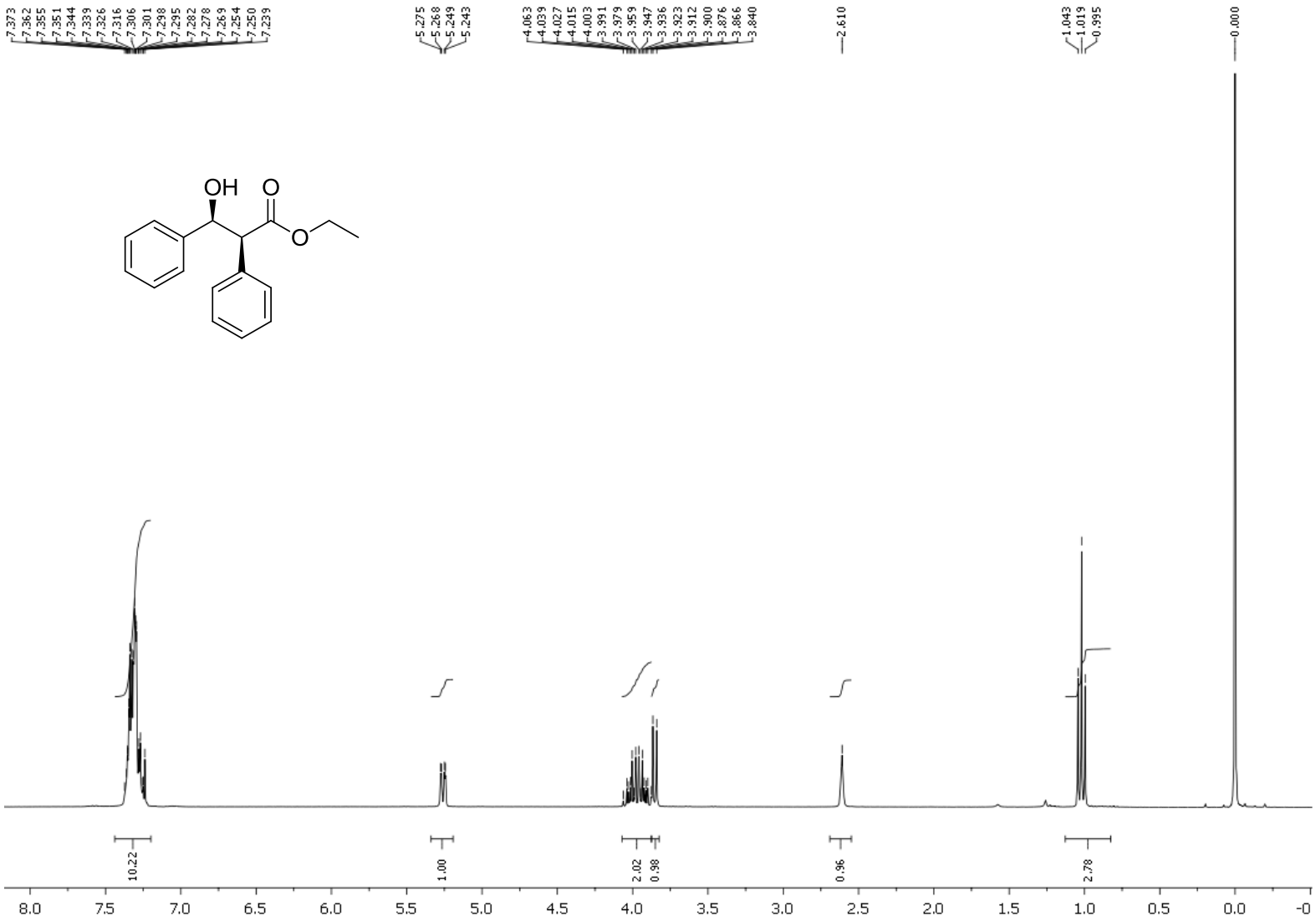
^{13}C NMR spectrum of isopropyl (2*S*,3*S*)-3-hydroxy-4-methyl-2-phenylpentanoate (**9h**)



^{1}H NMR spectrum of isopropyl (2*S*,3*R*)-3-hydroxy-4,4-dimethyl-2-phenylpentanoate (**9i**)

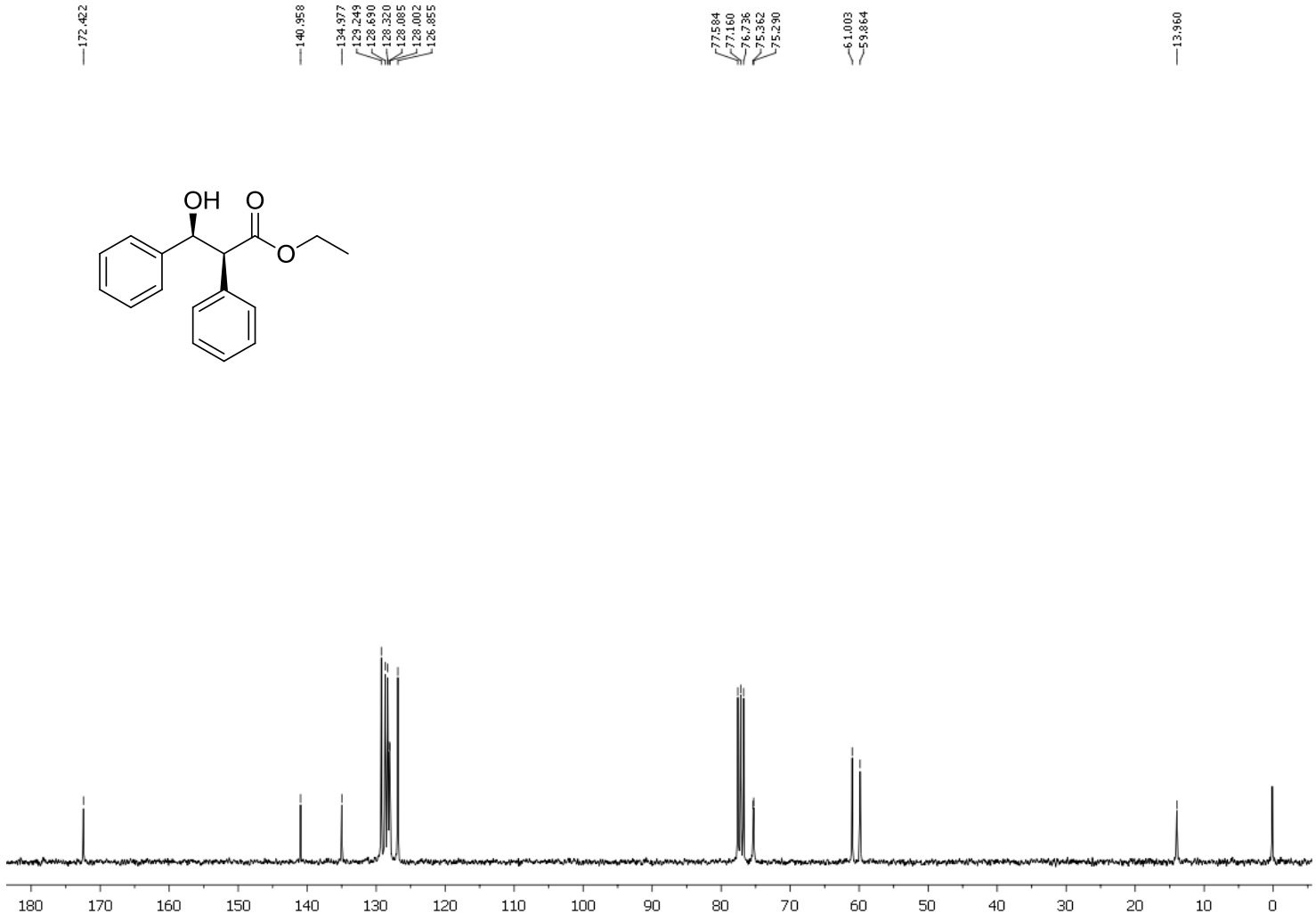


^{13}C NMR spectrum of isopropyl (2*S*,3*R*)-3-hydroxy-4,4-dimethyl-2-phenylpentanoate (**9i**)

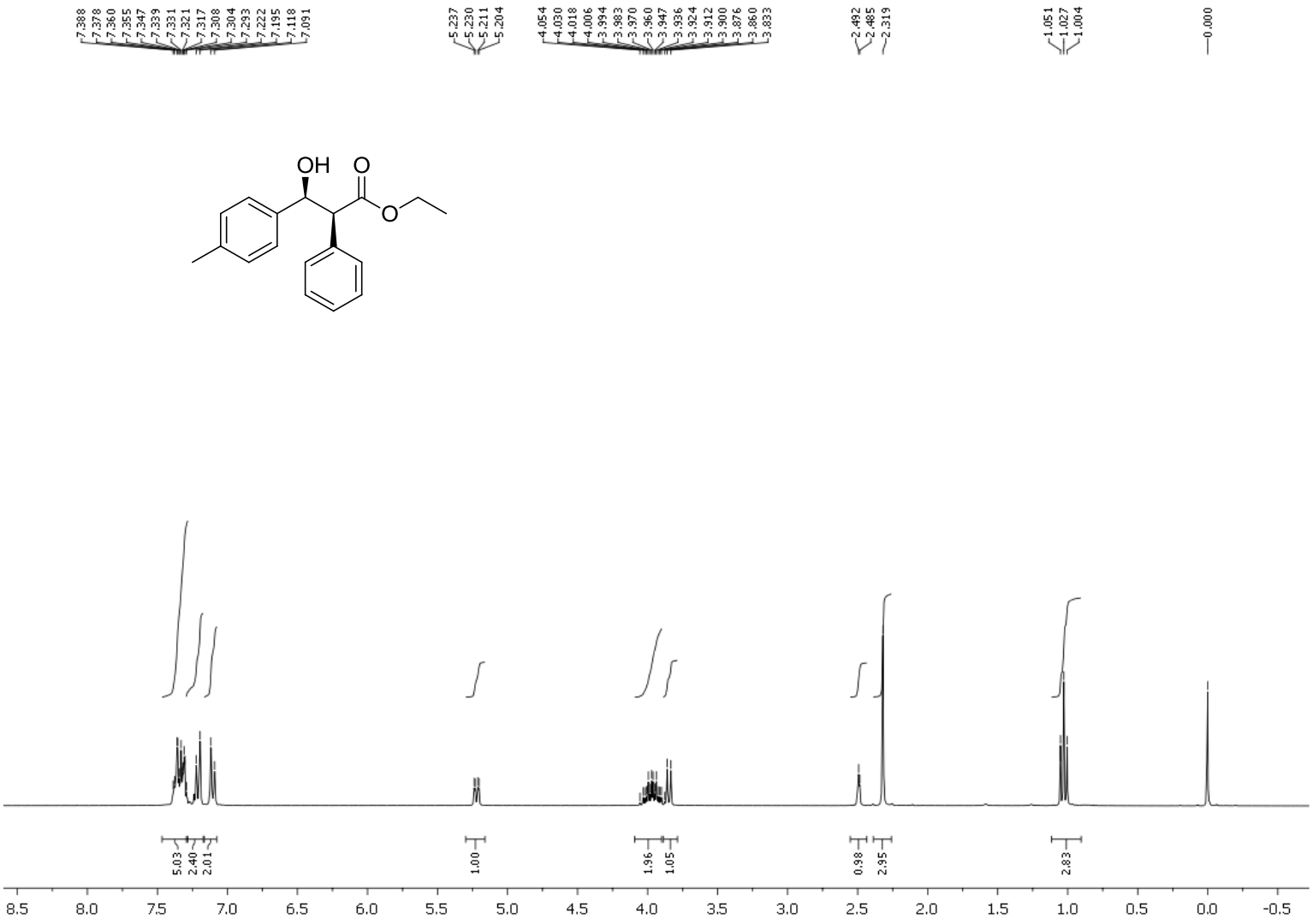


(f1 ppm)

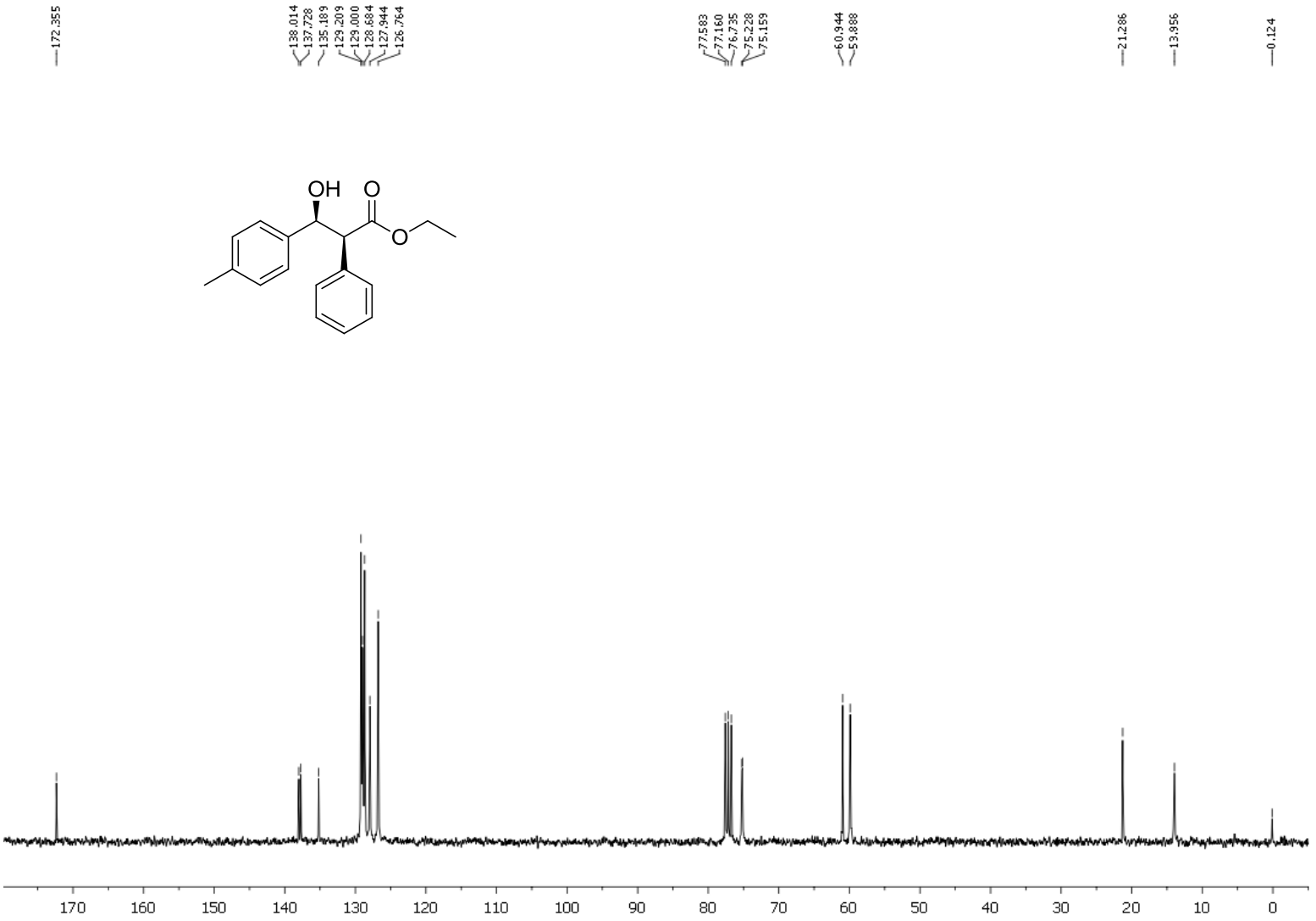
^{1}H NMR spectrum of ethyl (2*S*,3*S*)-3-hydroxy-2,3-diphenylpropanoate (**8a**)



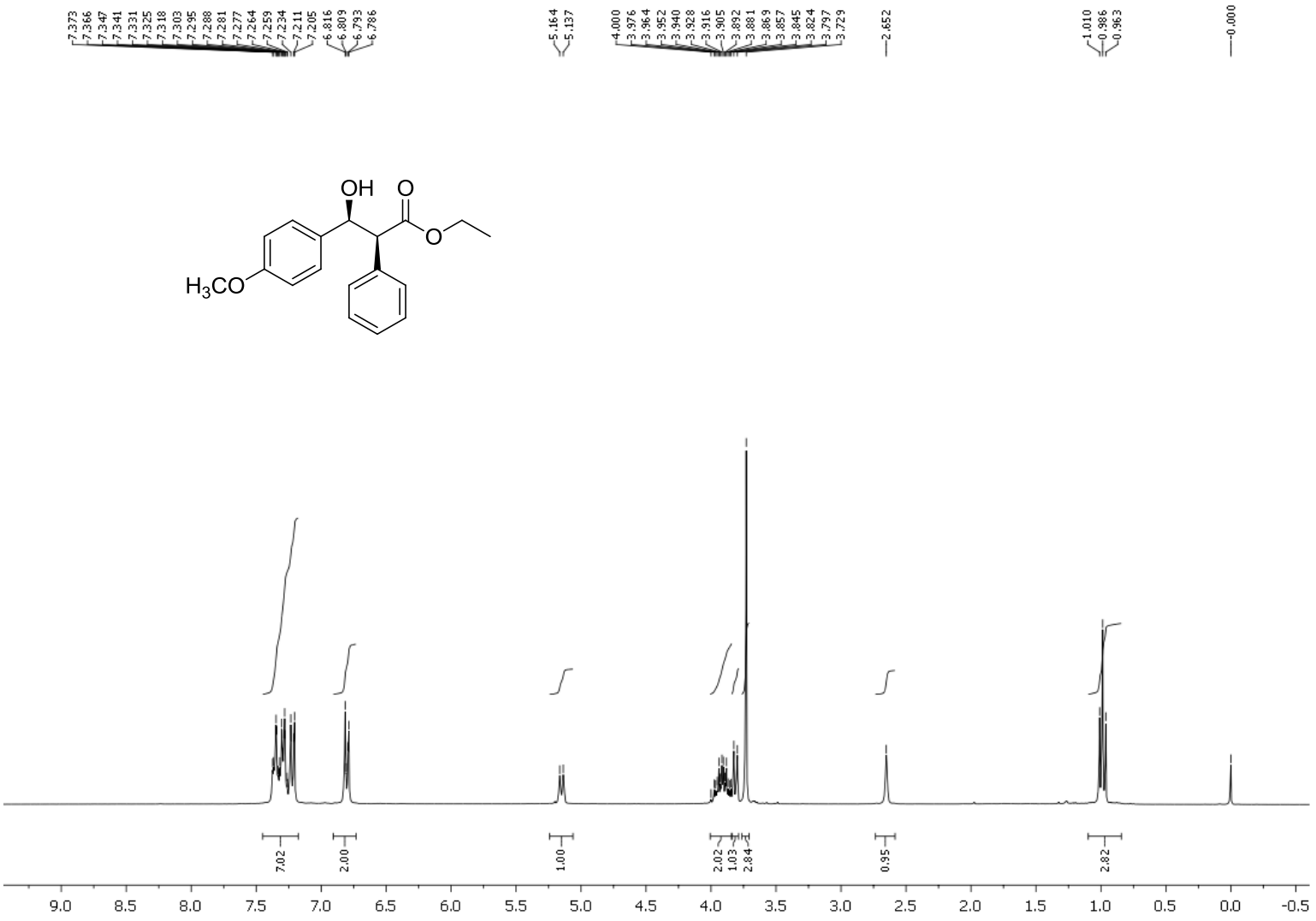
^{13}C NMR spectrum of ethyl (2*S*,3*S*)-3-hydroxy-2,3-diphenylpropanoate (**8a**)



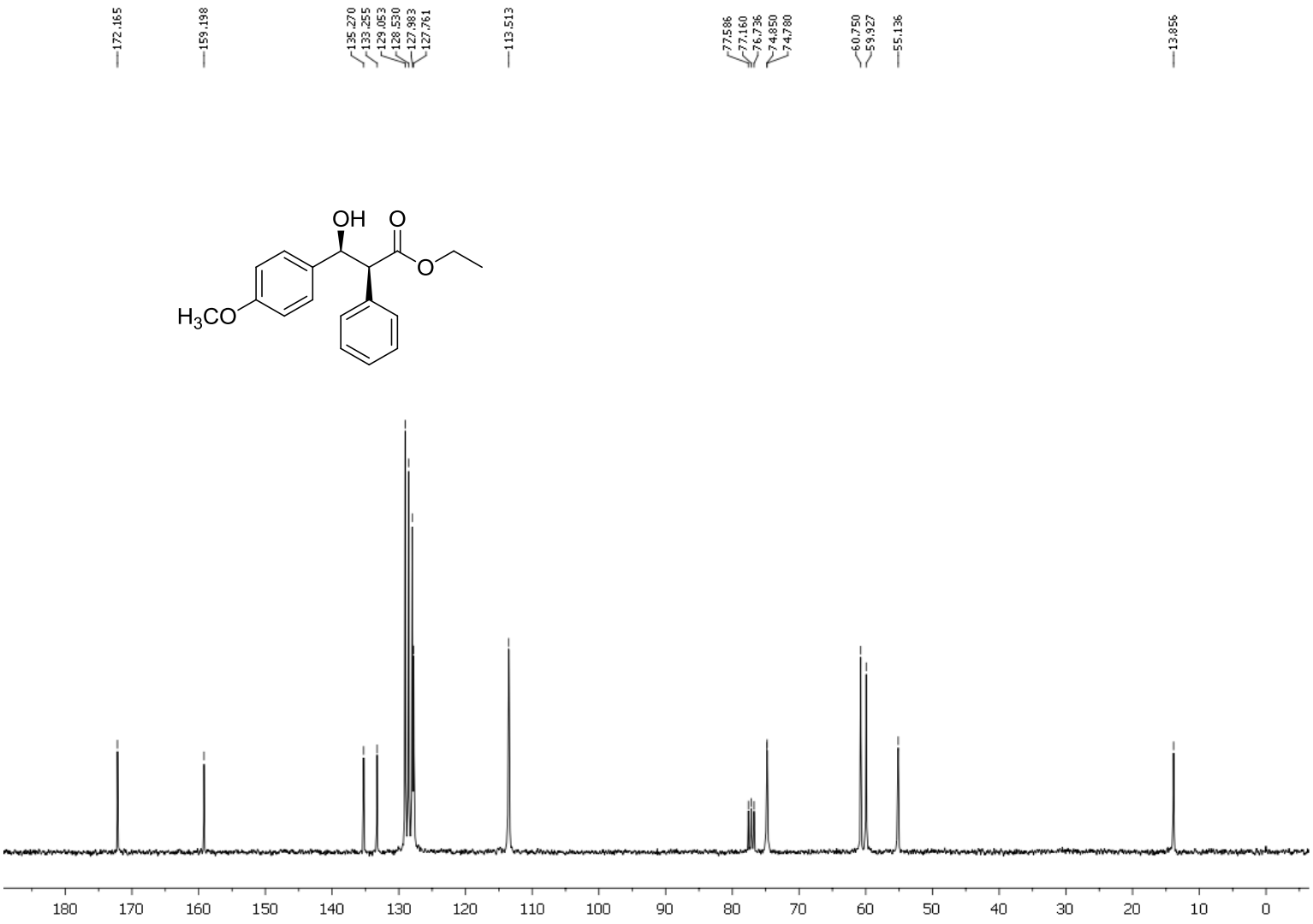
^{1}H NMR spectrum of ethyl (2*S*,3*S*)-3-hydroxy-2-phenyl-3-(*p*-tolyl)propanoate (**8b**)



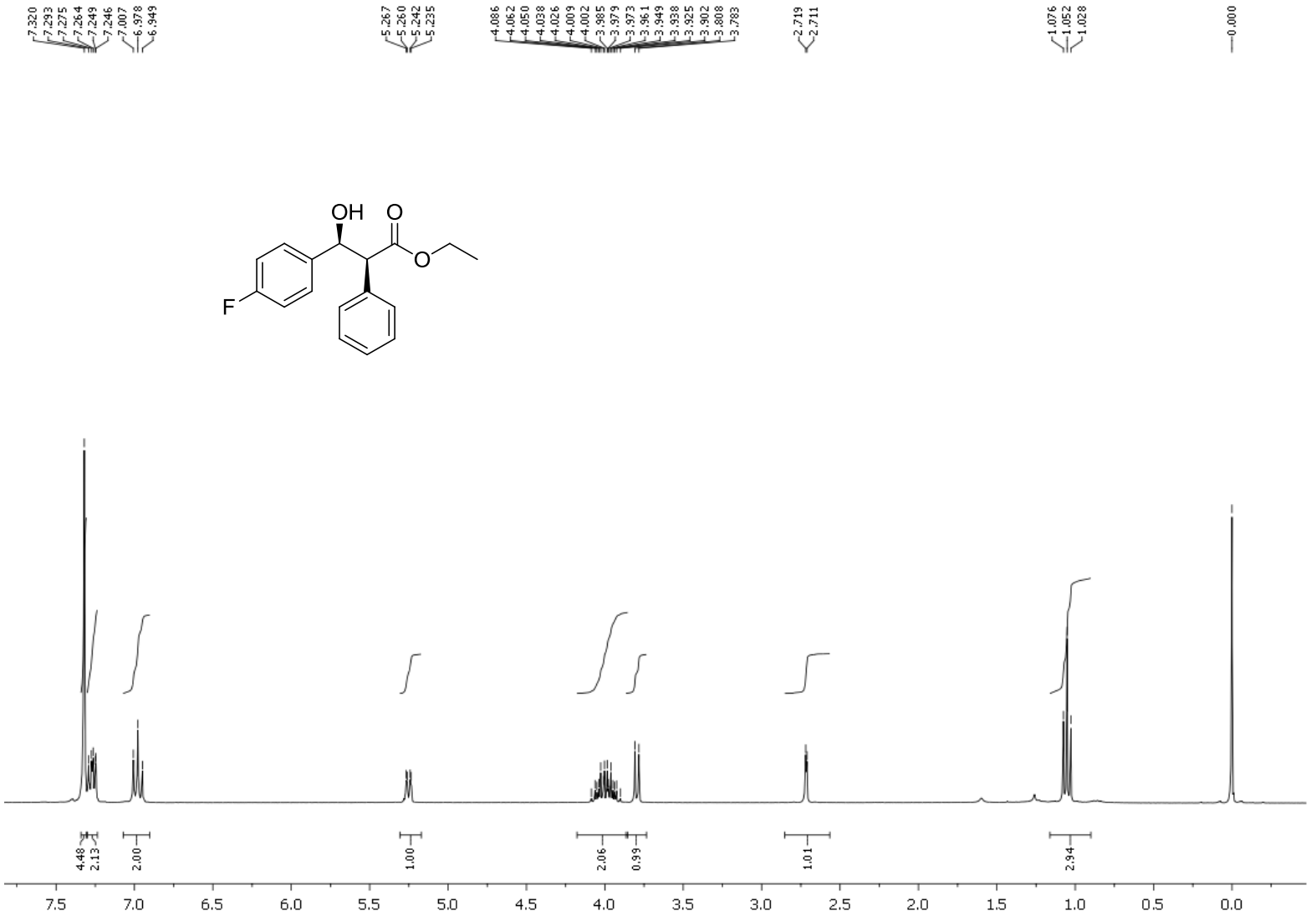
^{13}C NMR spectrum of ethyl (2*S*,3*S*)-3-hydroxy-2-phenyl-3-(*p*-tolyl)propanoate (**8b**)



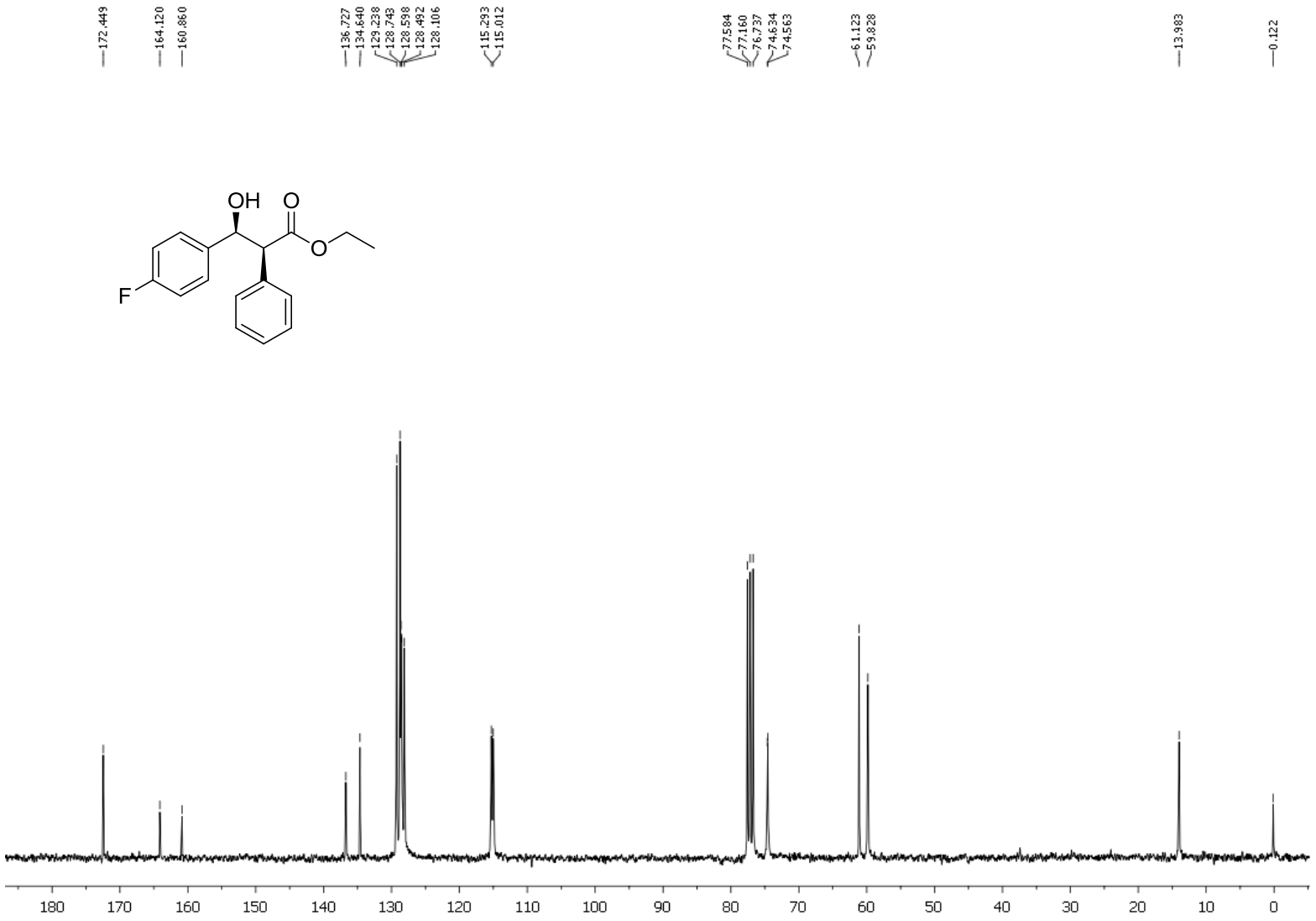
^{1}H NMR spectrum of ethyl (2*S*,3*S*)-3-hydroxy-3-(4-methoxyphenyl)-2-phenylpropanoate (**8c**)



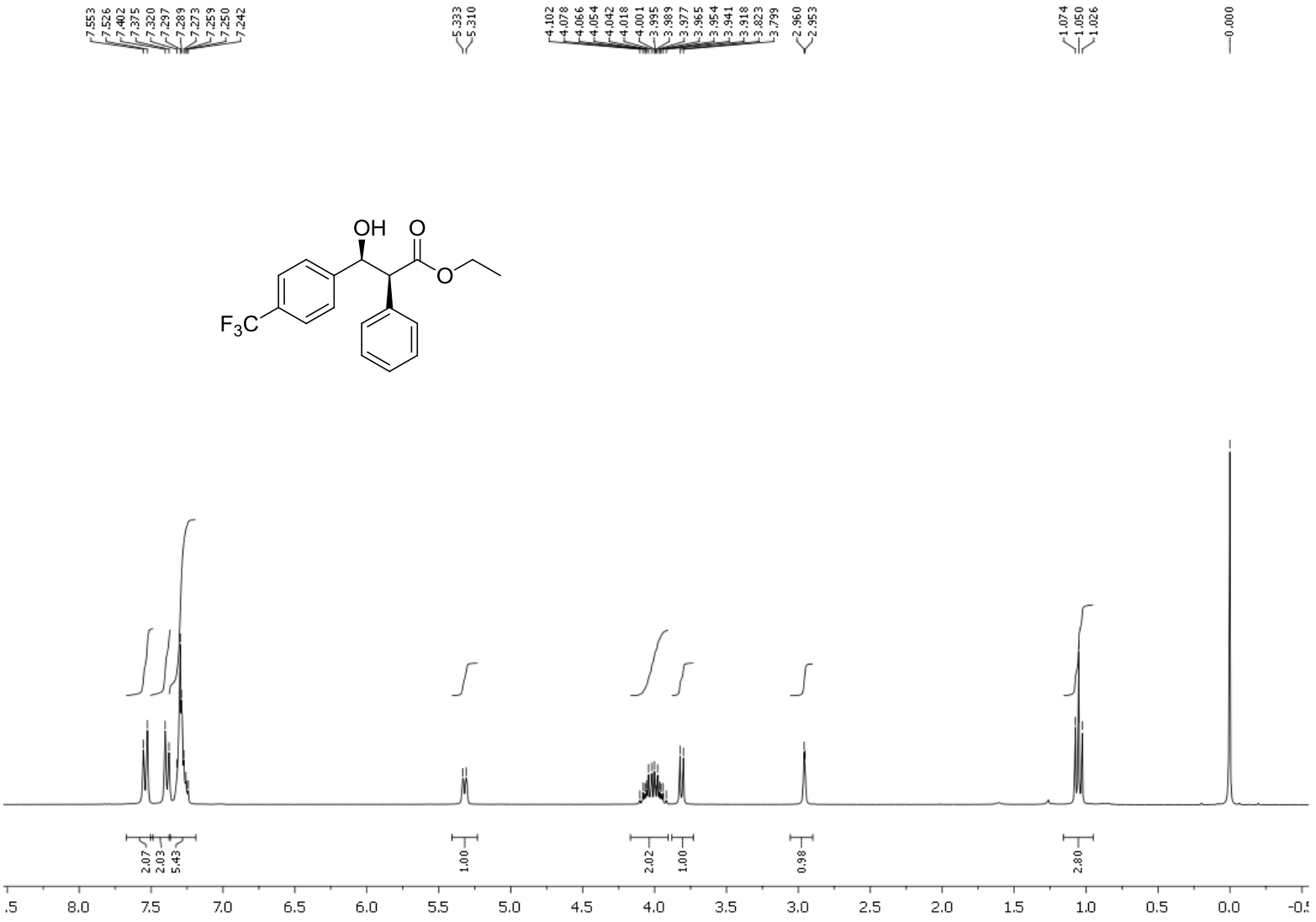
^{13}C NMR spectrum of ethyl (2*S*,3*S*)-3-hydroxy-3-(4-methoxyphenyl)-2-phenylpropanoate (**8c**)



^{1}H NMR spectrum of ethyl (2*S*,3*S*)-3-(4-fluorophenyl)-3-hydroxy-2-phenylpropanoate (**8d**)

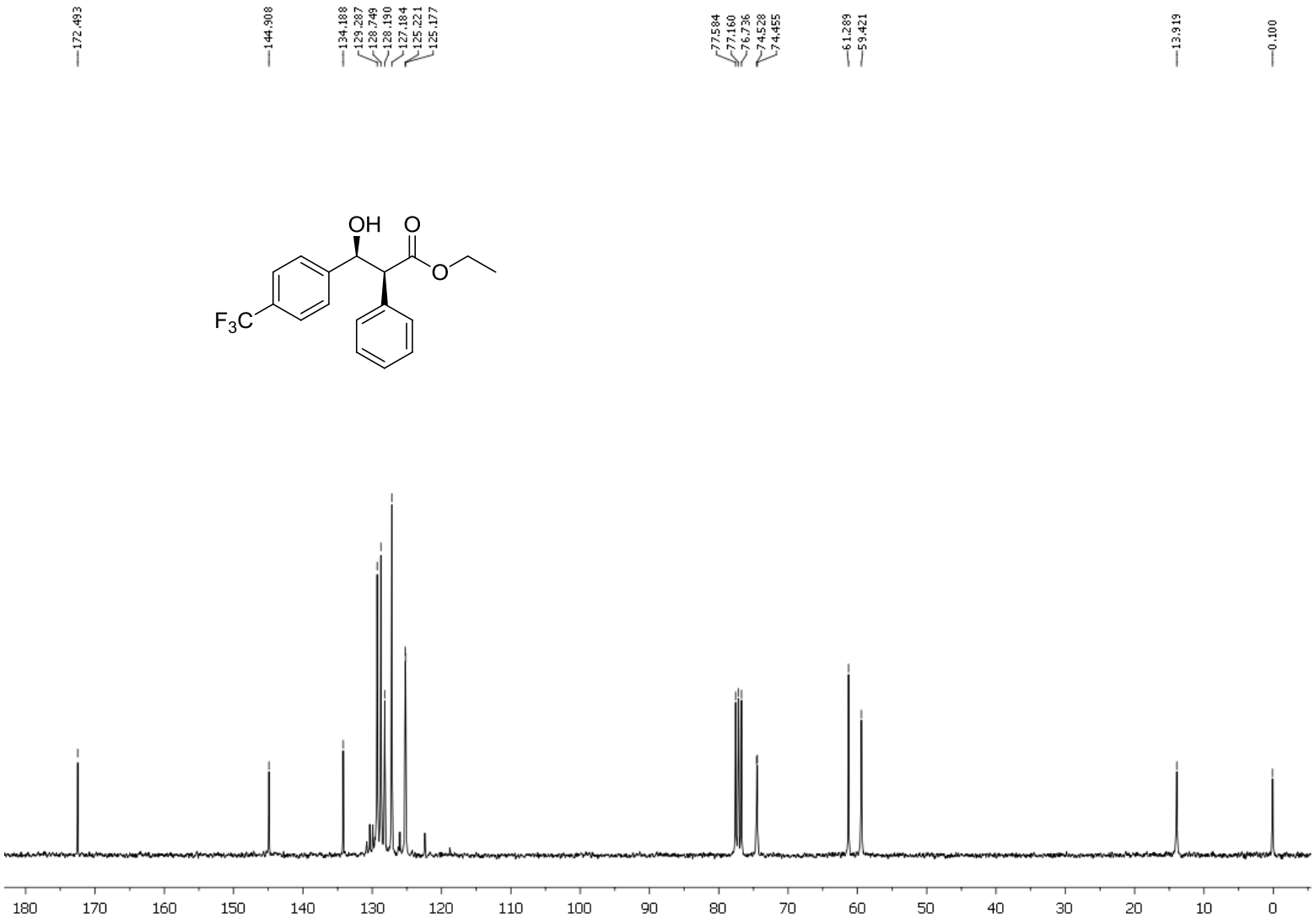


^{13}C NMR spectrum of ethyl (2*S*,3*S*)-3-(4-fluorophenyl)-3-hydroxy-2-phenylpropanoate (**8d**)

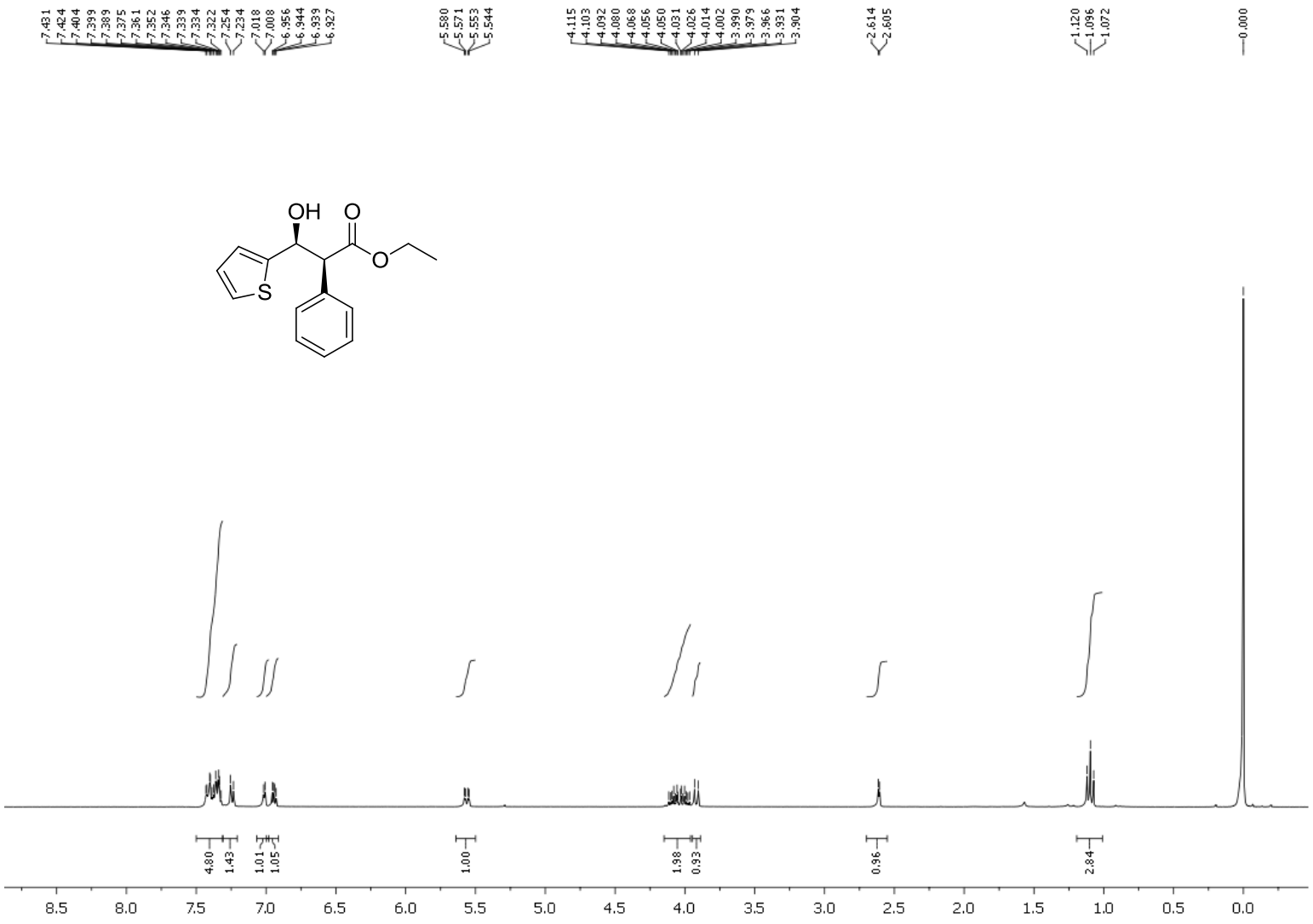


(f1 ppm)

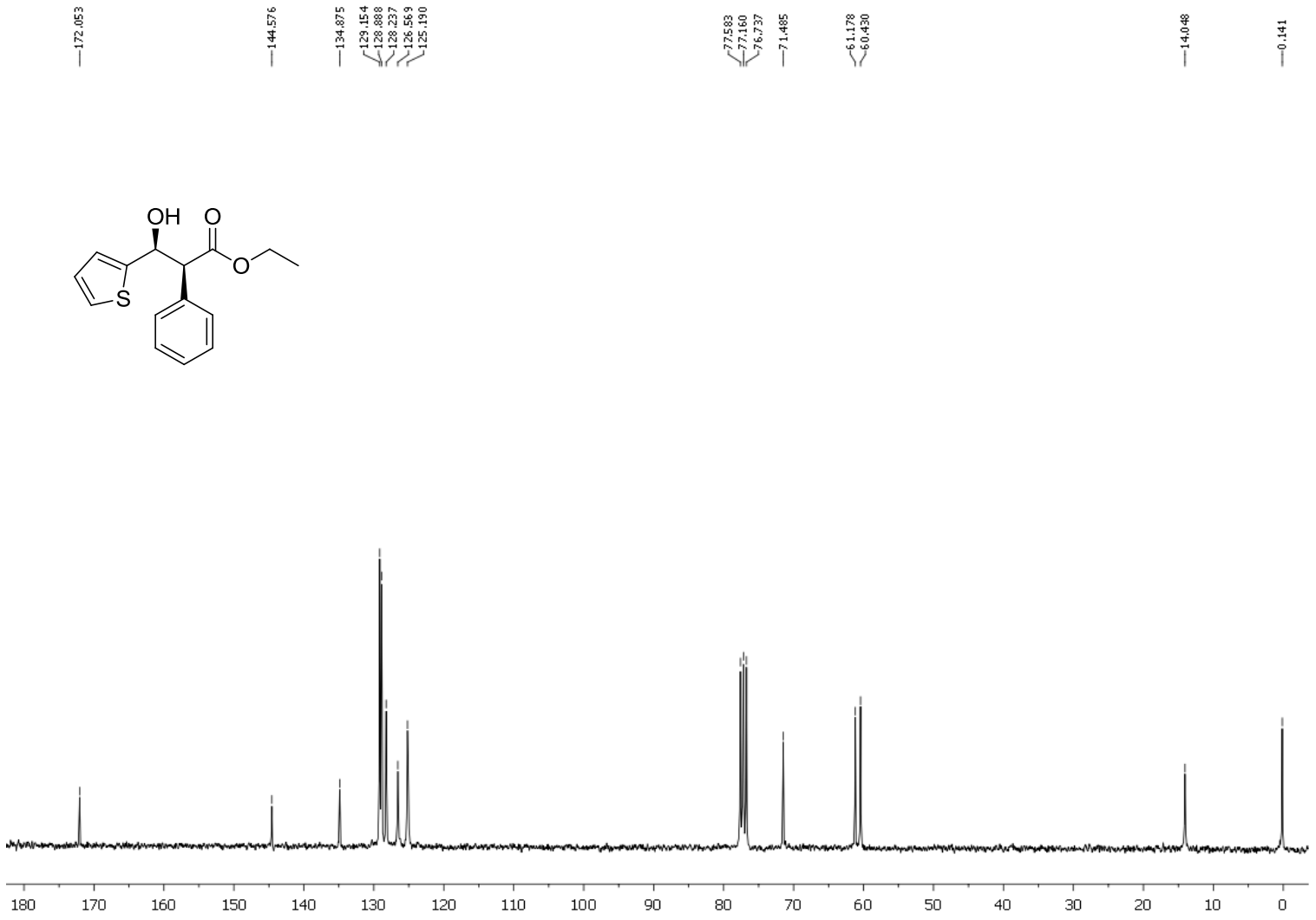
^{1}H NMR spectrum of ethyl (2*S*,3*S*)-3-hydroxy-2-phenyl-3-(4-(trifluoromethyl)phenyl)propanoate (**8e**)



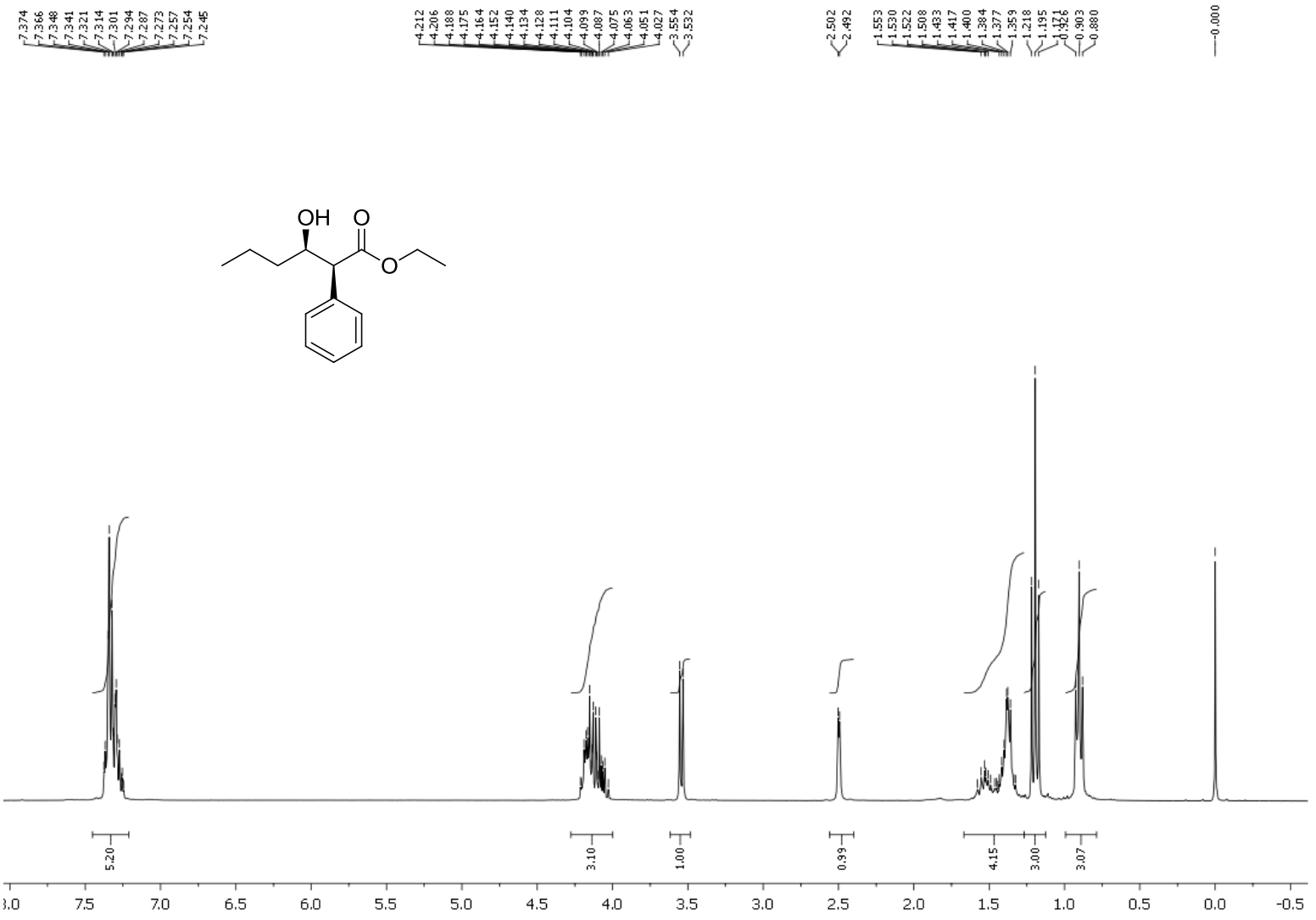
^{13}C NMR spectrum of ethyl (2*S*,3*S*)-3-hydroxy-2-phenyl-3-(4-(trifluoromethyl)phenyl)propanoate (**8e**)



^{1}H NMR spectrum of ethyl (2*S*,3*S*)-3-hydroxy-2-phenyl-3-(thiophen-2-yl)propanoate (**8f**)

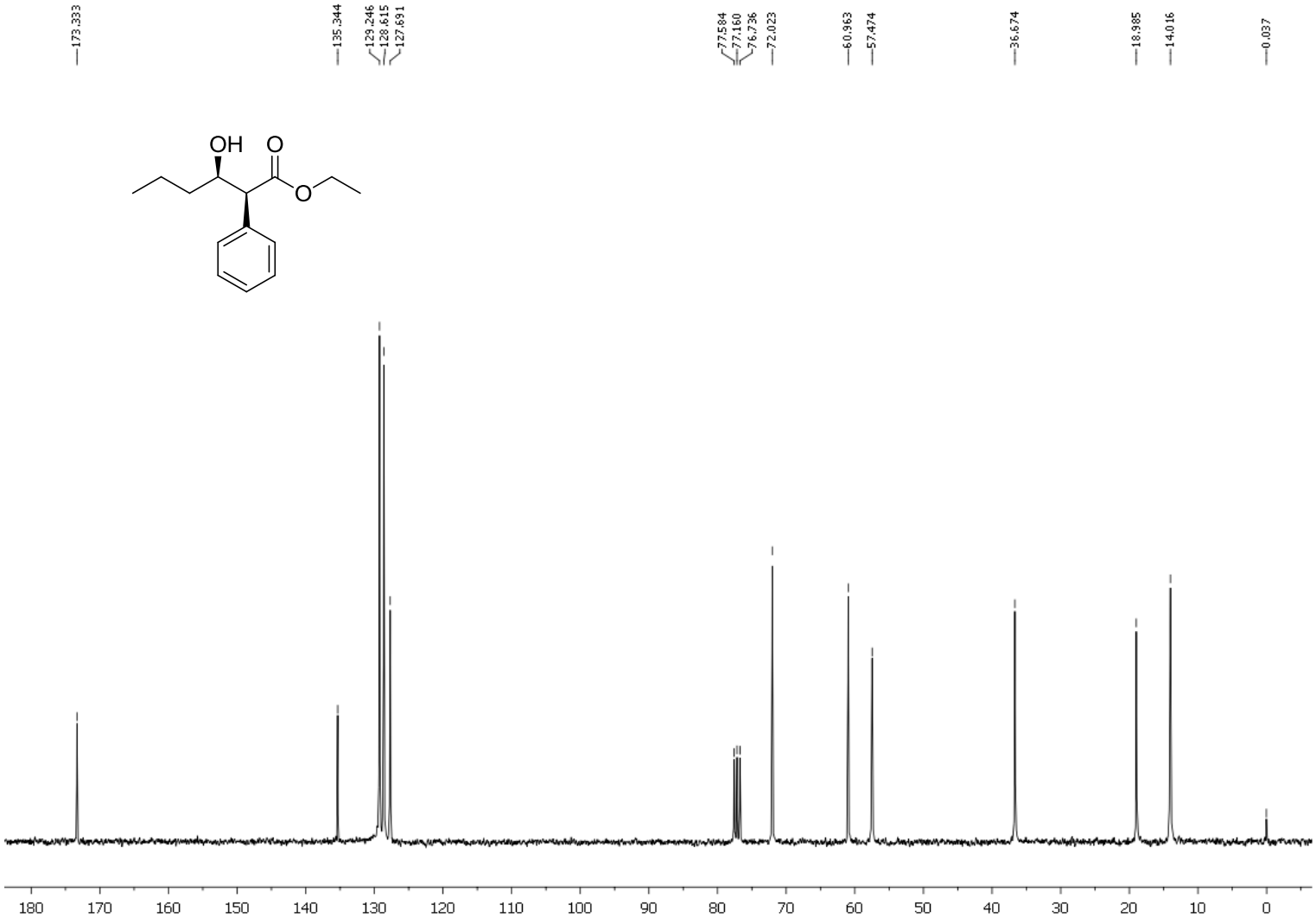


^{13}C NMR spectrum of ethyl (2*S*,3*S*)-3-hydroxy-2-phenyl-3-(thiophen-2-yl)propanoate (**8f**)

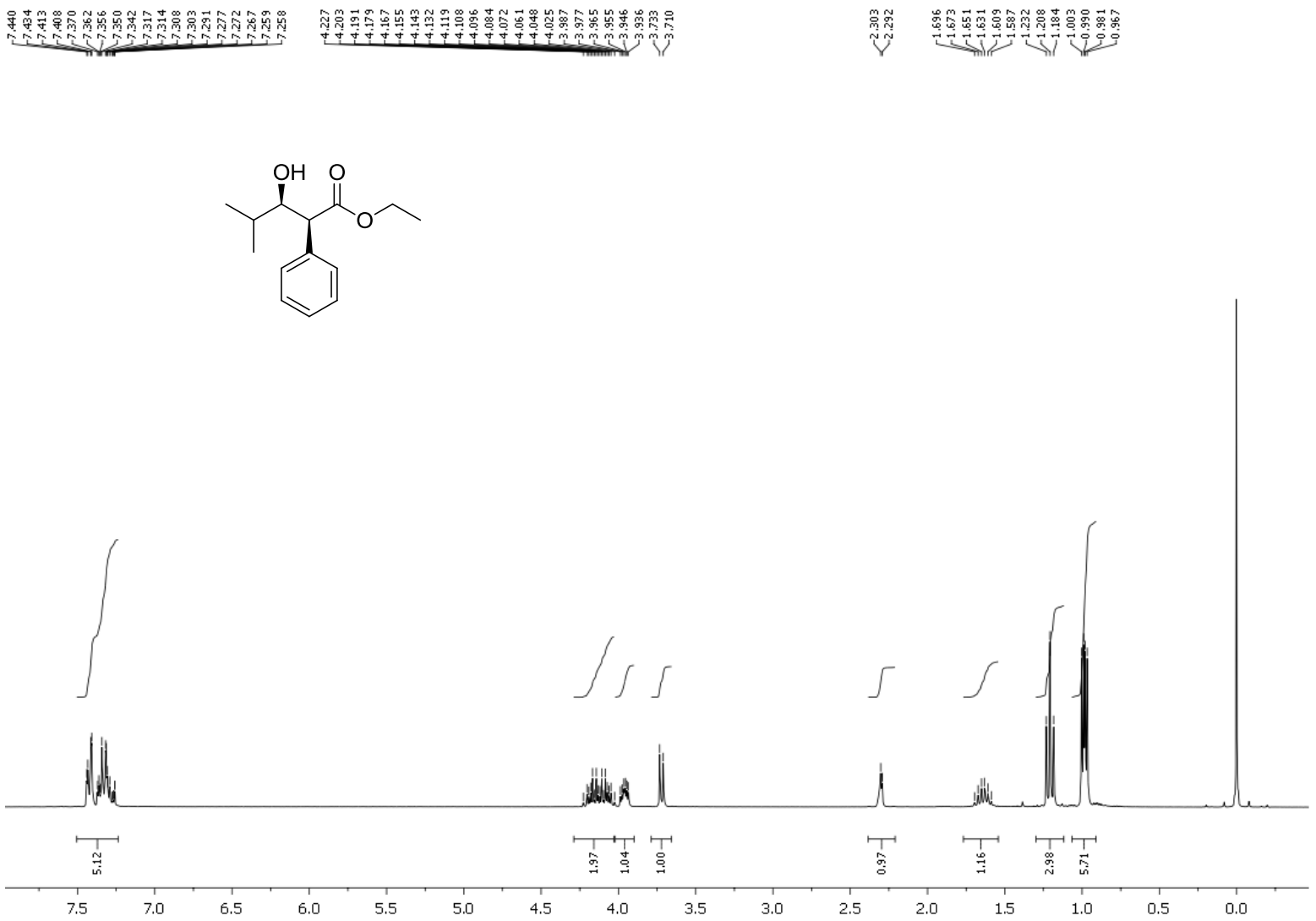


(f1 ppm)

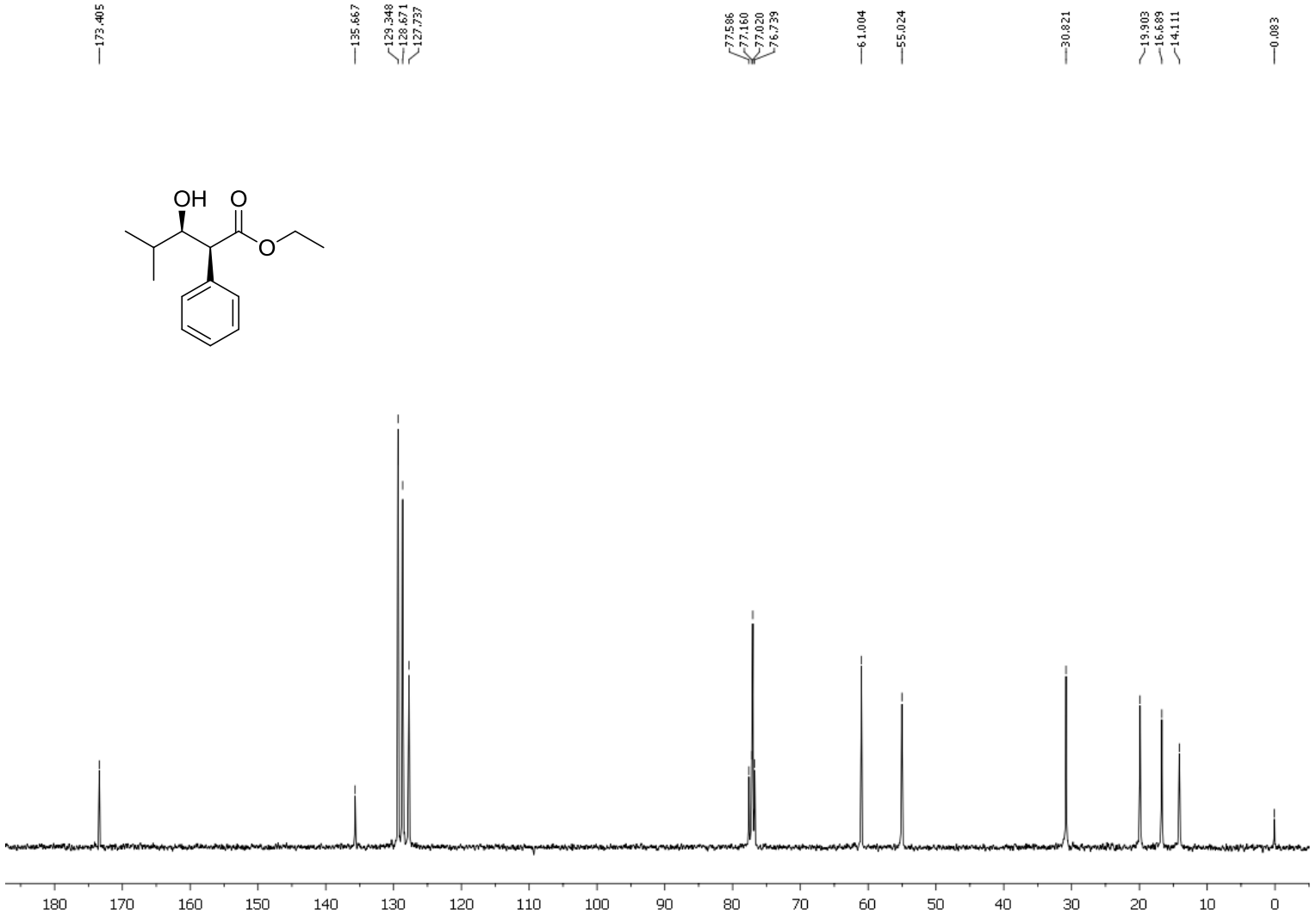
^{1}H NMR spectrum of ethyl (2*S*,3*R*)-3-hydroxy-2-phenylhexanoate (**8g**)



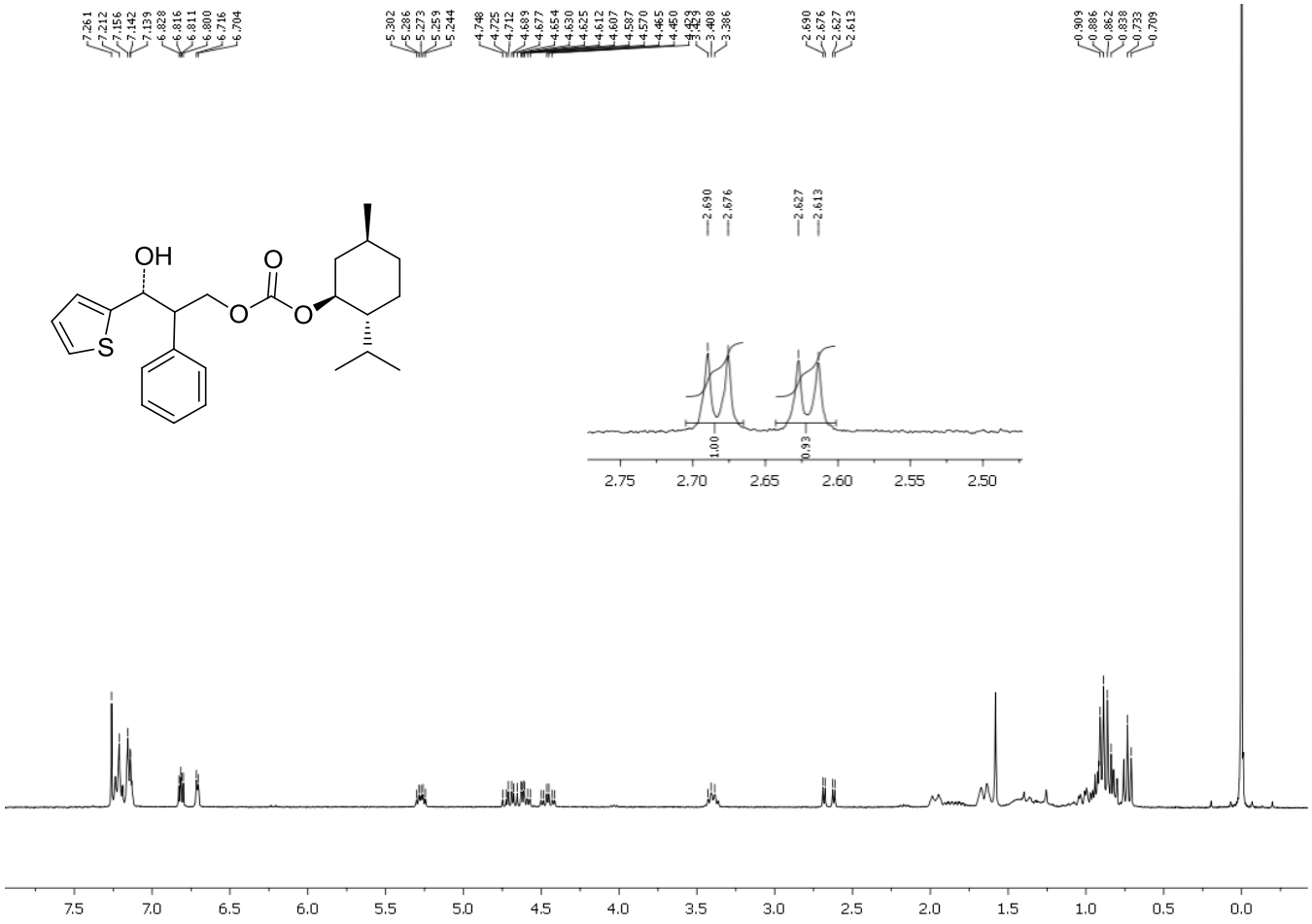
^{13}C NMR spectrum of ethyl (2*S*,3*R*)-3-hydroxy-2-phenylhexanoate (**8g**)



^{1}H NMR spectrum of ethyl (2*S*,3*R*)-3-hydroxy-4-methyl-2-phenylpentanoate (**8h**)

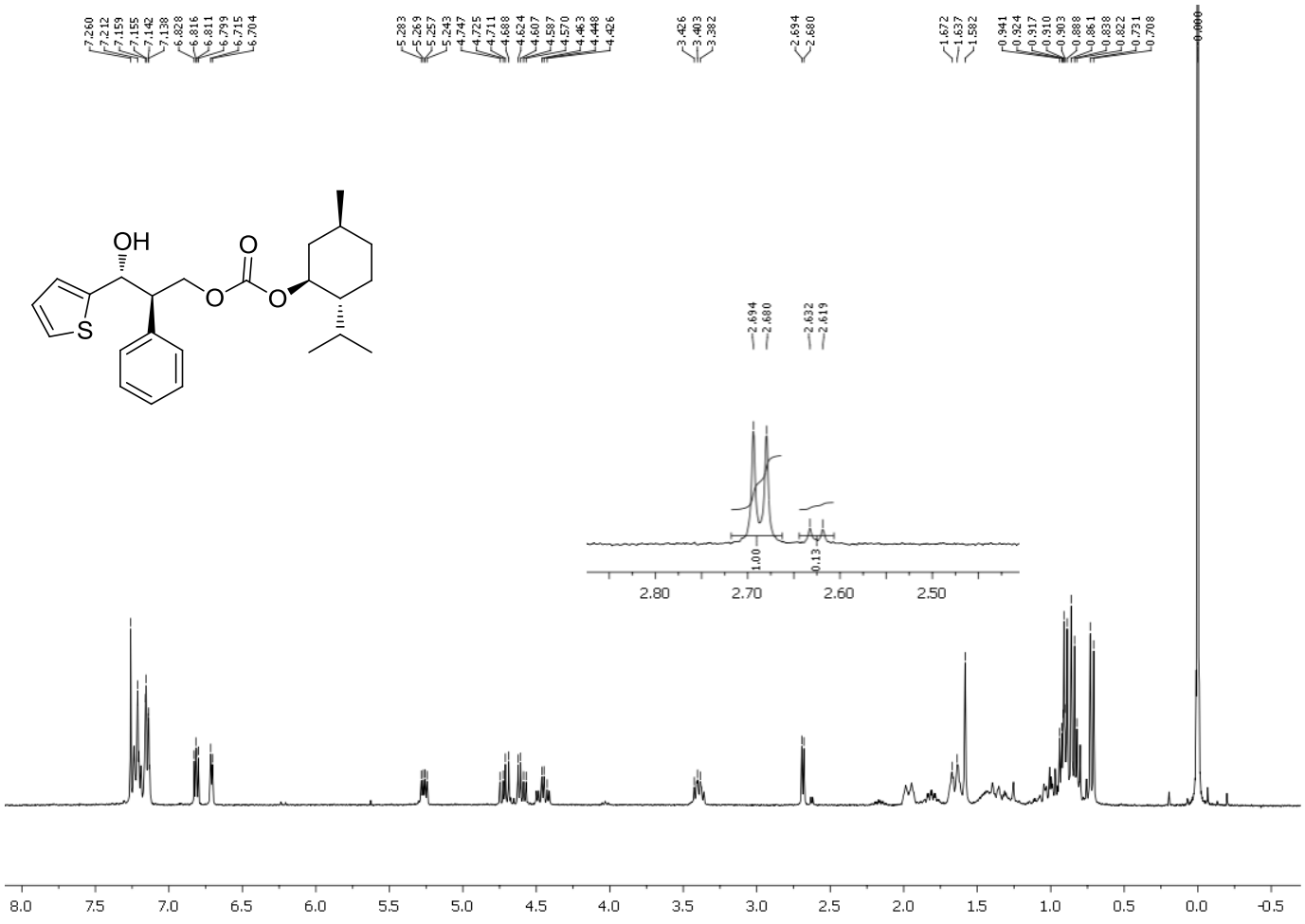


^{13}C NMR spectrum of ethyl (2*S*,3*R*)-3-hydroxy-4-methyl-2-phenylpentanoate (**8h**)



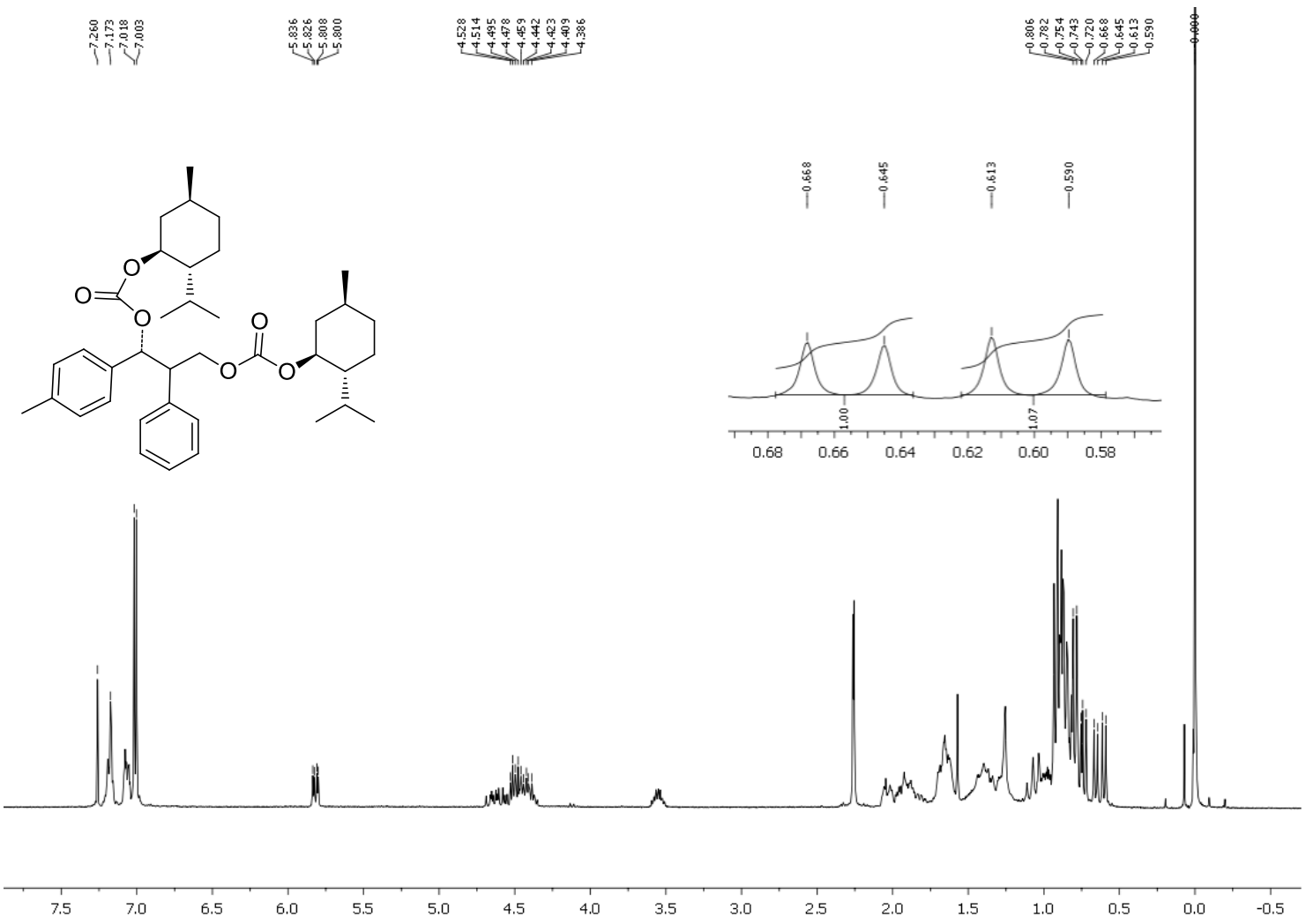
(f1 ppm)

^{1}H NMR spectrum of a crude mixture of menthyl carbonate derivative of diol obtained from racemic methyl *anti*-3-hydroxy-2-phenyl-3-(thiophen-2-yl)propanoate

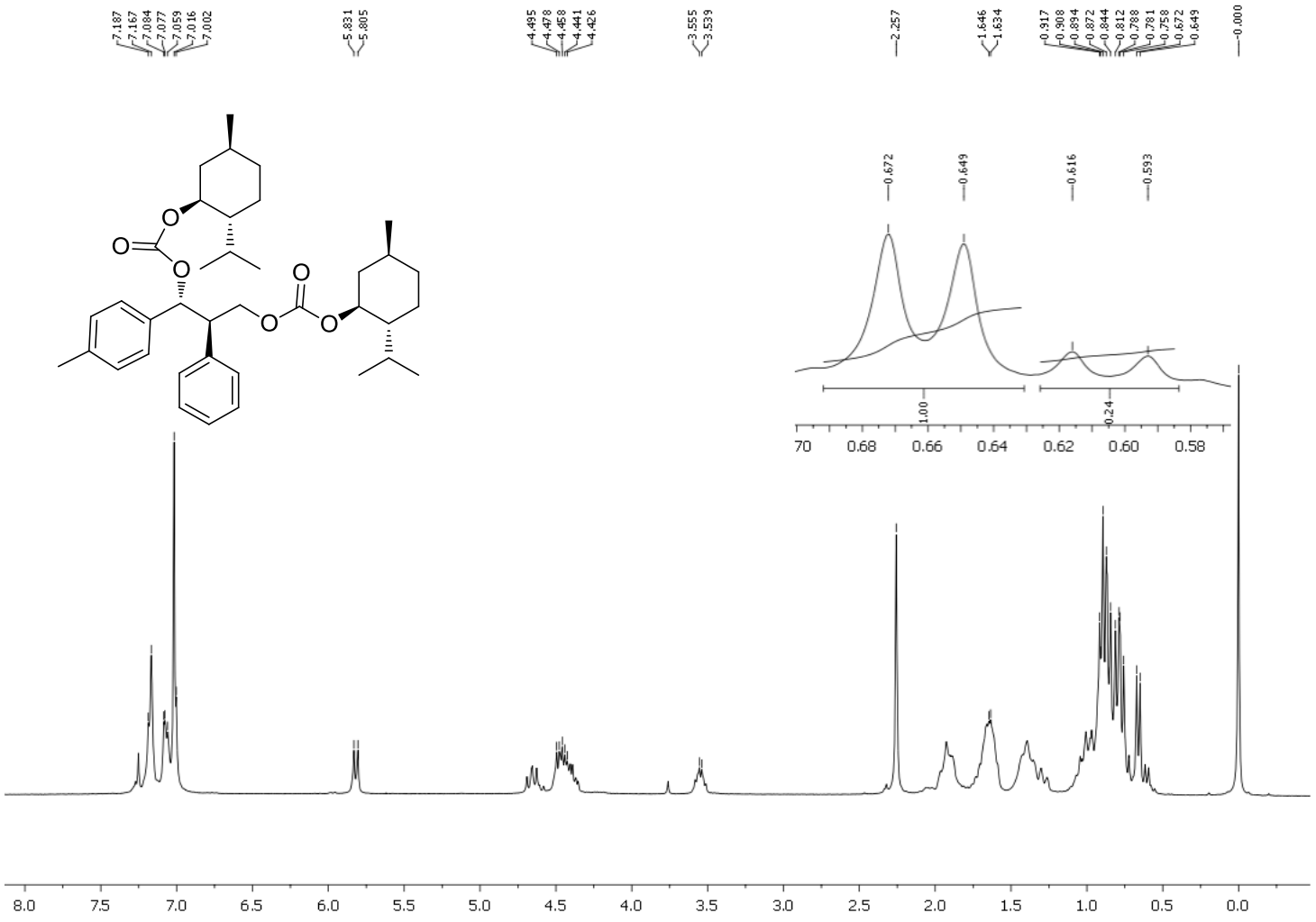


(f1 ppm)

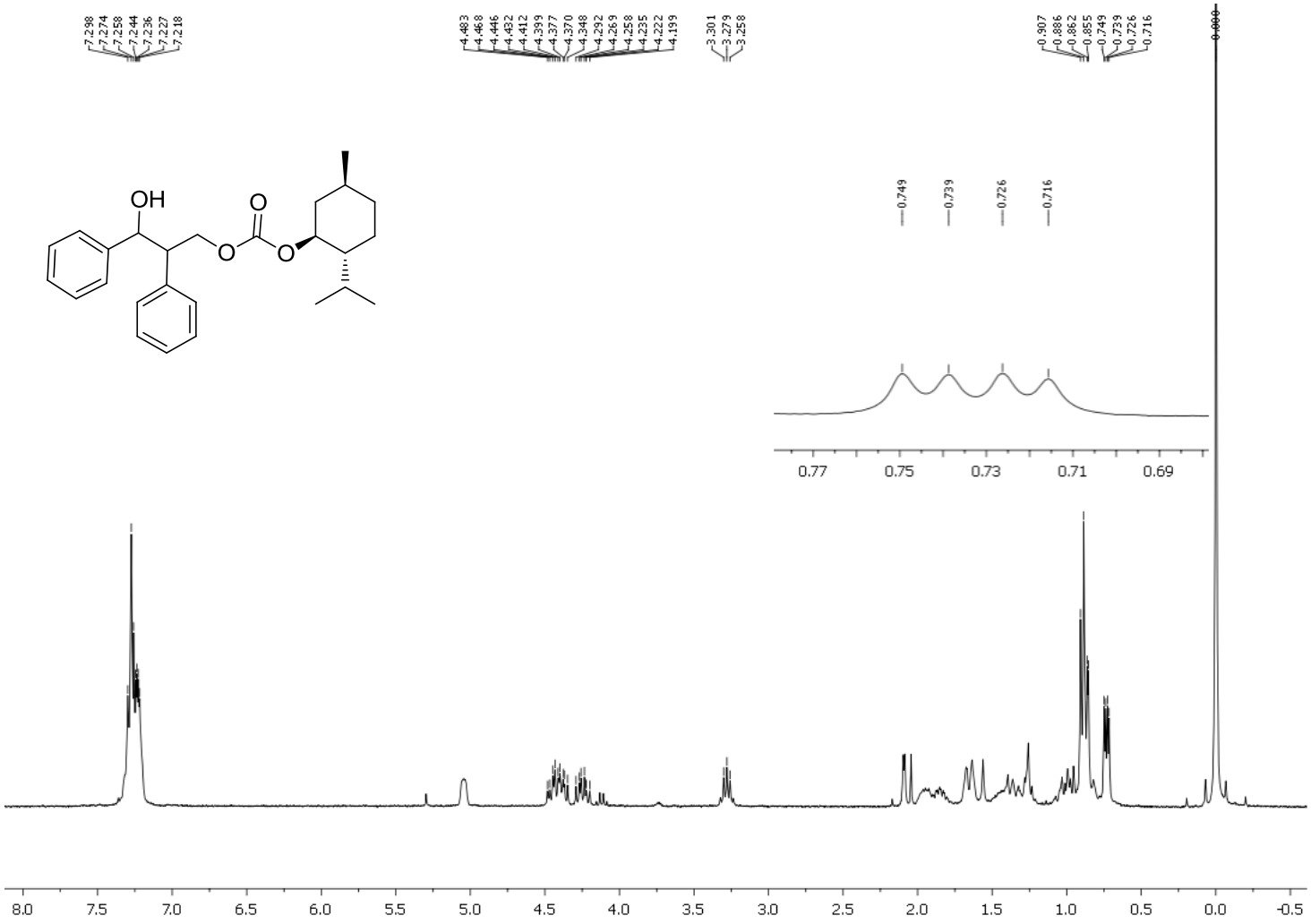
^{1}H NMR spectrum of a crude mixture of menthyl carbonate derivative of diol obtained from isopropyl (2*S*,3*R*)-3-hydroxy-2-phenyl-3-(thiophen-2-yl)propanoate (**9f**)



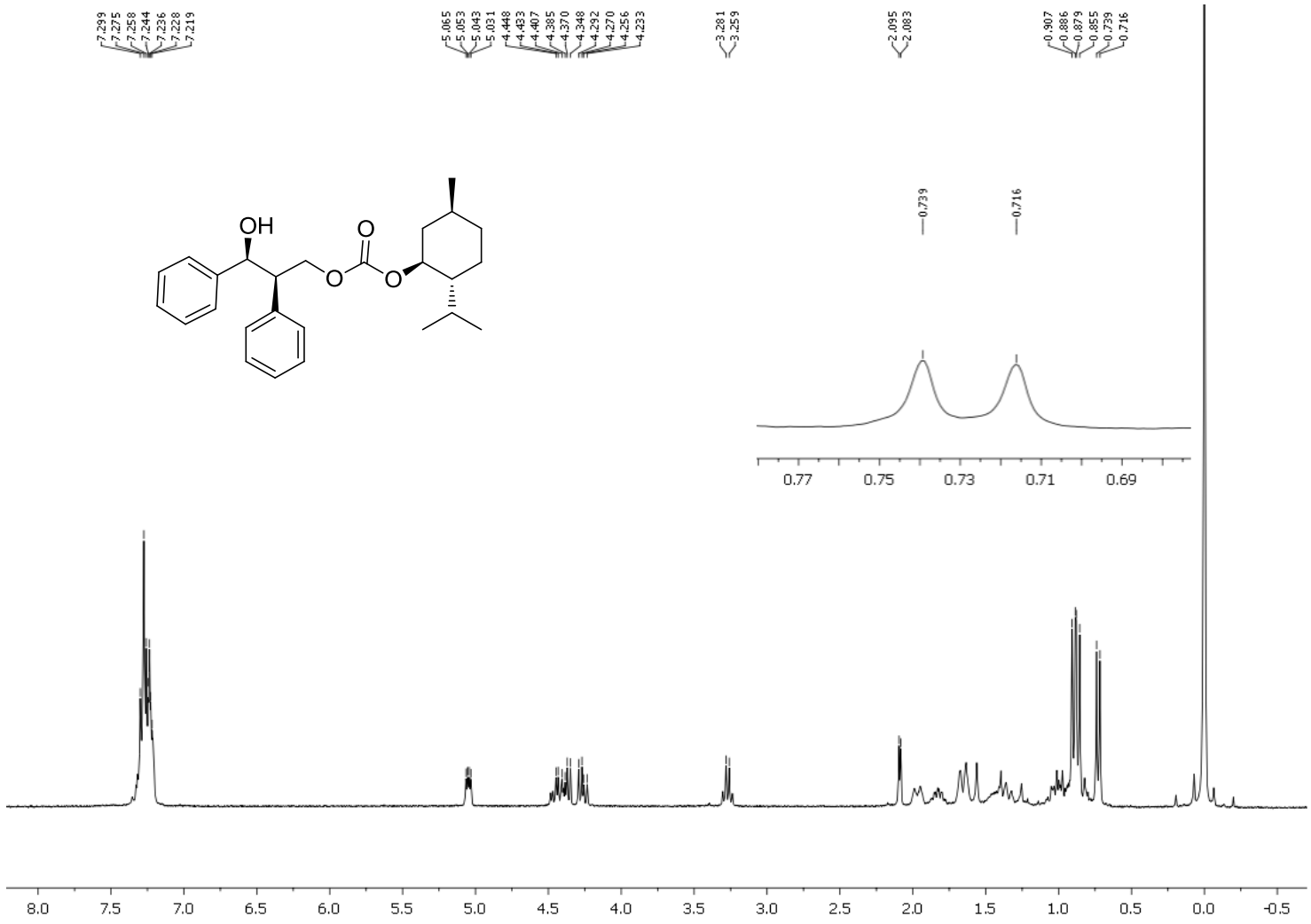
^{1}H NMR spectrum of a crude mixture of dimenthyl carbonate derivative of diol obtained from racemic methyl *anti*-3-hydroxy-2-phenyl-3-(*p*-tolyl)propanoate



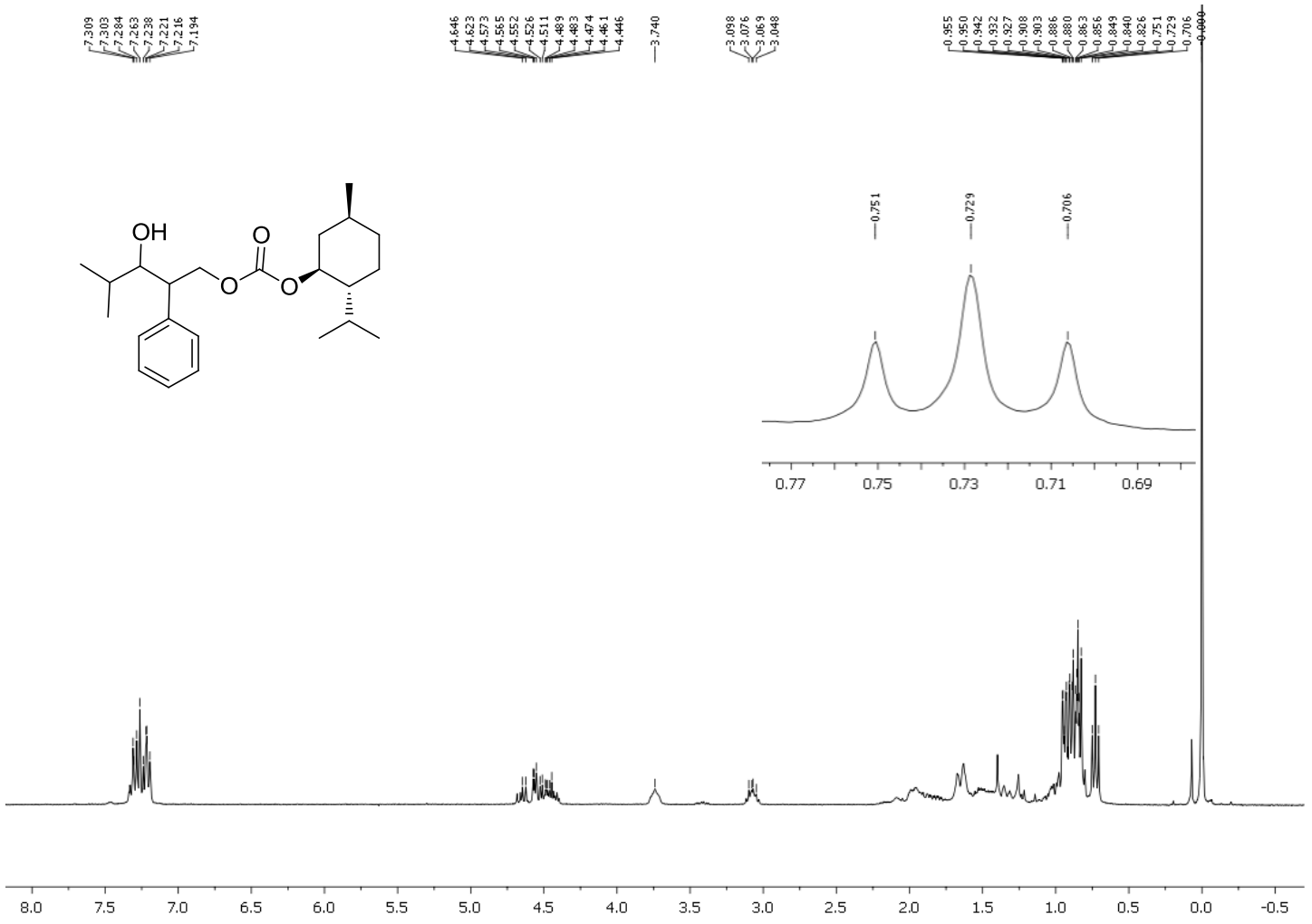
^{1}H NMR spectrum of a crude mixture of dimenthyl carbonate derivative of diol obtained from isopropyl (2*S*,3*R*)-3-hydroxy-2-phenyl-3-(*p*-tolyl)propanoate (**9b**)



^{1}H NMR spectrum of a crude mixture of menthyl carbonate derivative of diol obtained from racemic methyl *syn*-3-hydroxy-2,3-diphenylpropanoate

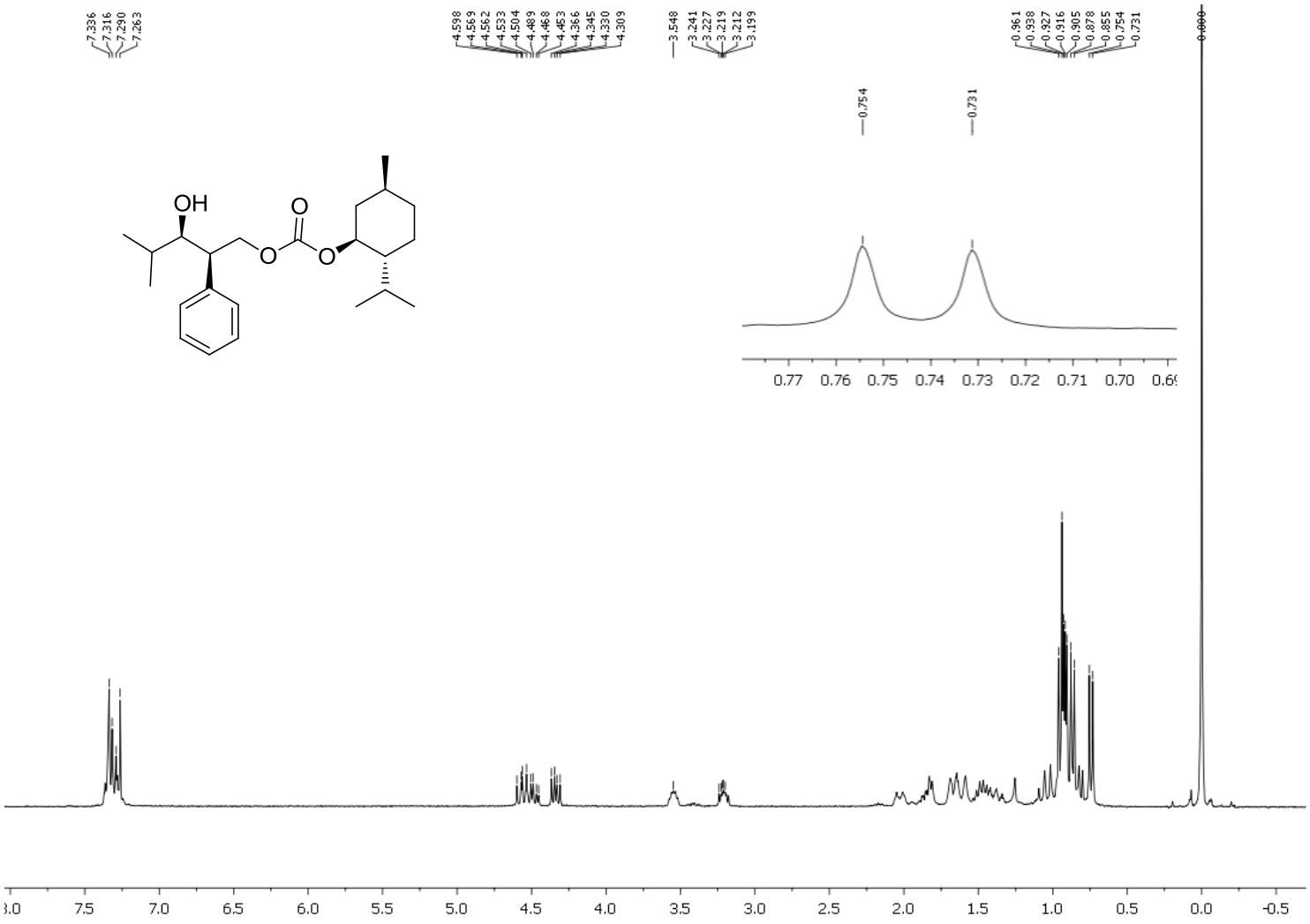


^{1}H NMR spectrum of a crude mixture of menthyl carbonate derivative of diol obtained from ethyl (2*S*,3*S*)-3-hydroxy-2,3-diphenylpropanoate (**8a**)



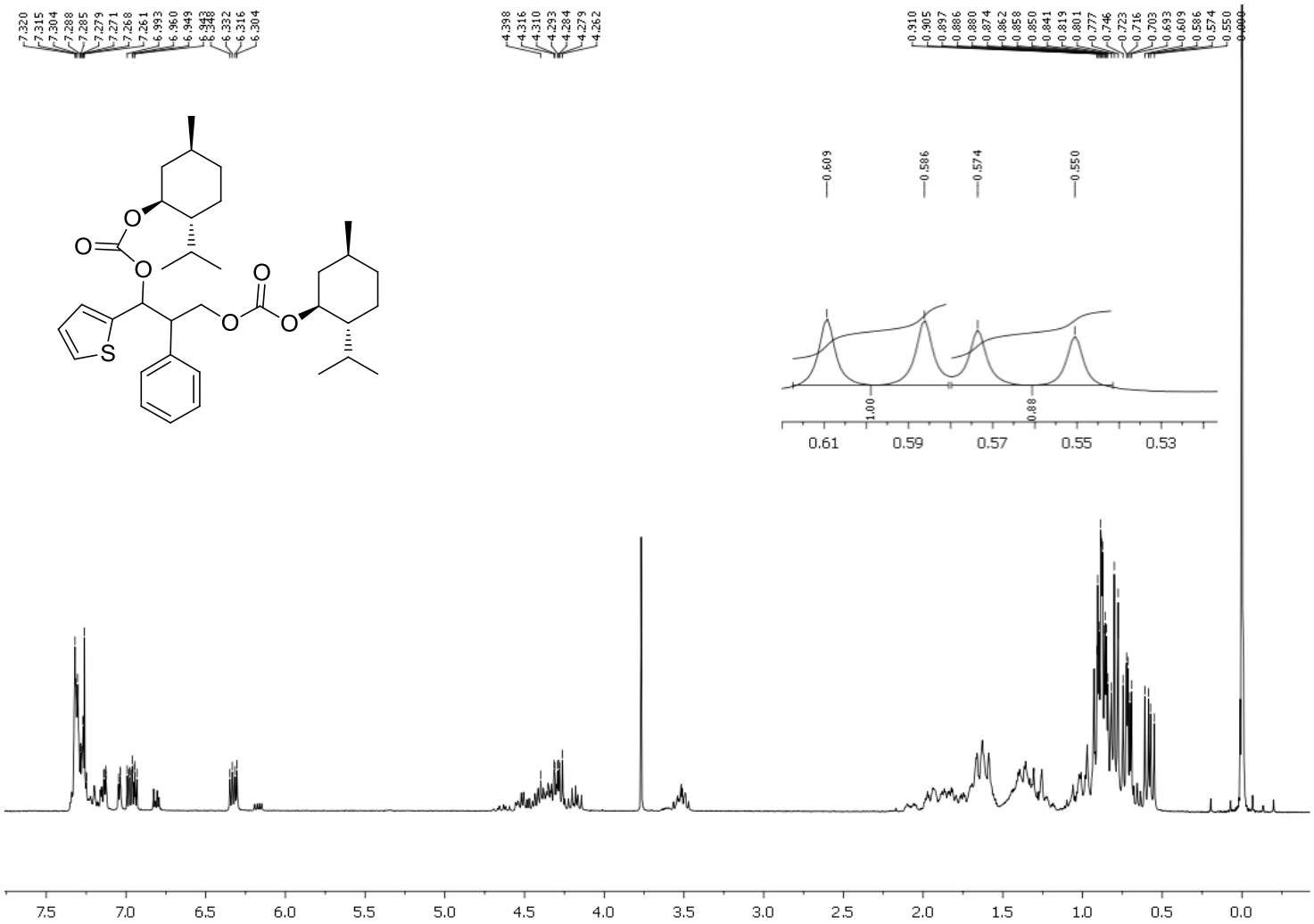
(f1 ppm)

^{1}H NMR spectrum of a crude mixture of menthyl carbonate derivative of diol obtained from racemic methyl *syn*-3-hydroxy-4-methyl-2-phenylpentanoate



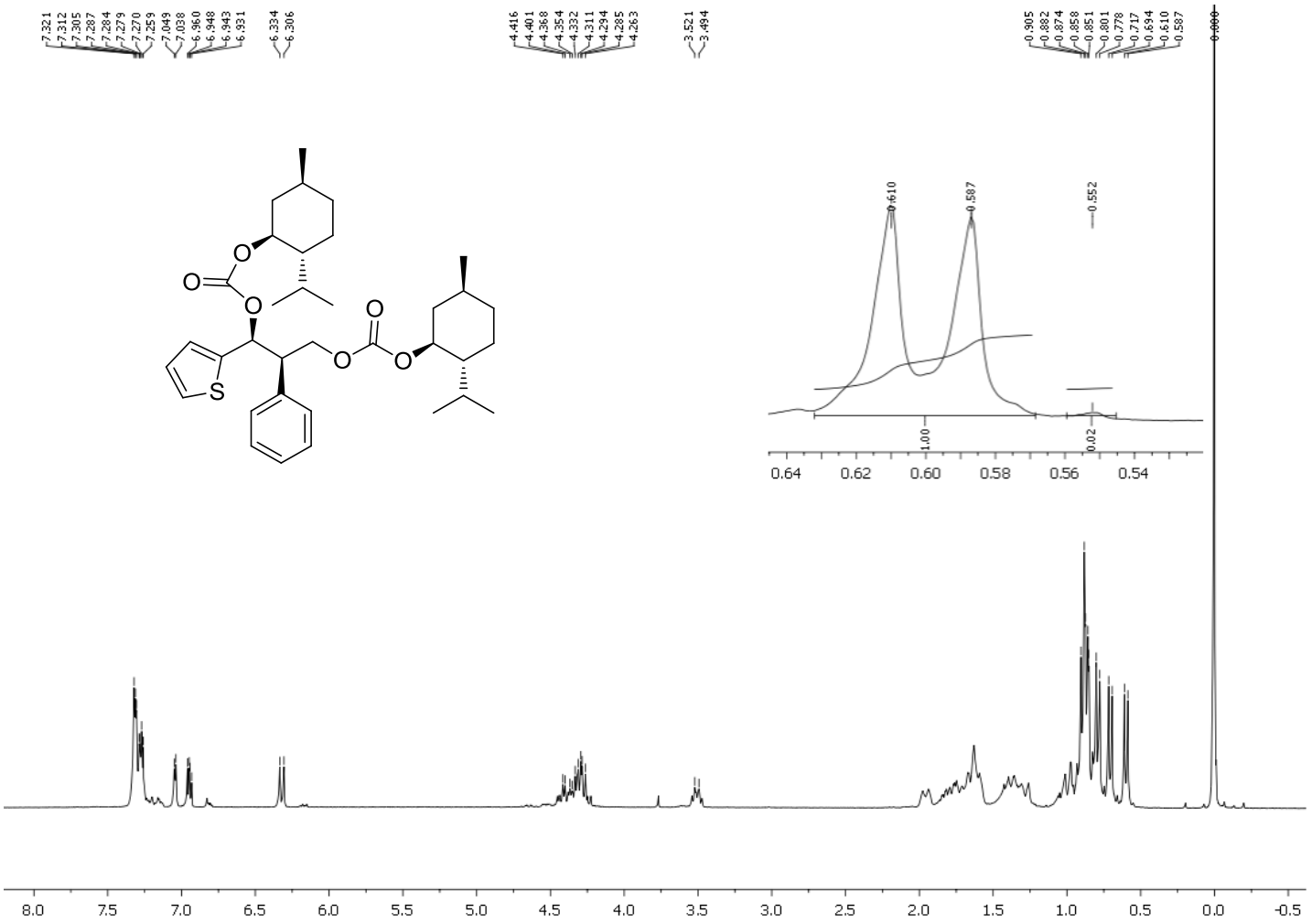
(f1 ppm)

^{1}H NMR spectrum of a crude mixture of menthyl carbonate derivative of diol obtained from ethyl (2*S*,3*R*)-3-hydroxy-4-methyl-2-phenylpentanoate (**8h**)



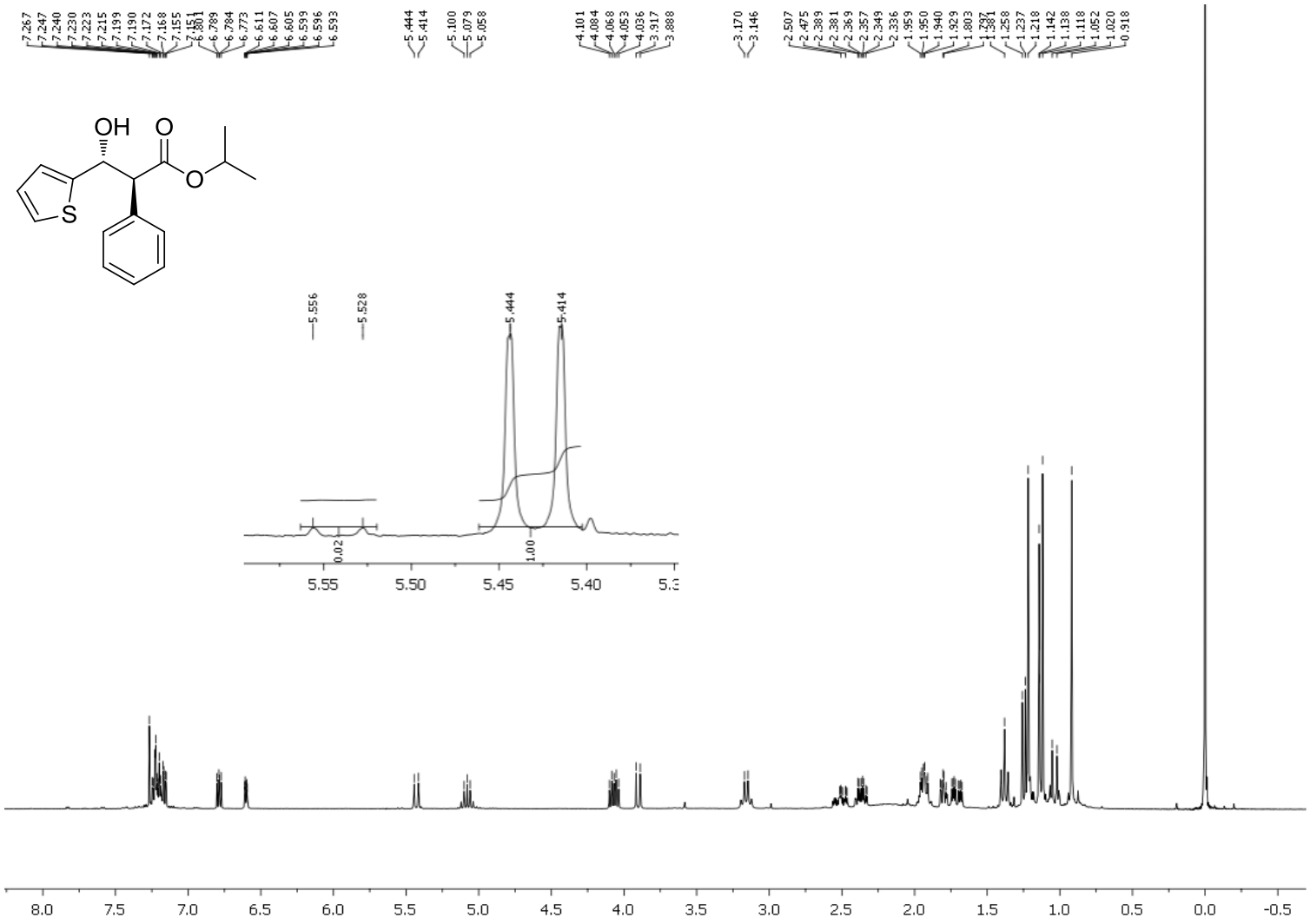
(f1 ppm)

^{1}H NMR spectrum of a crude mixture of dimenthyl carbonate derivative of diol obtained from racemic methyl *syn*-3-hydroxy-2-phenyl-3-(thiophen-2-yl)propanoate

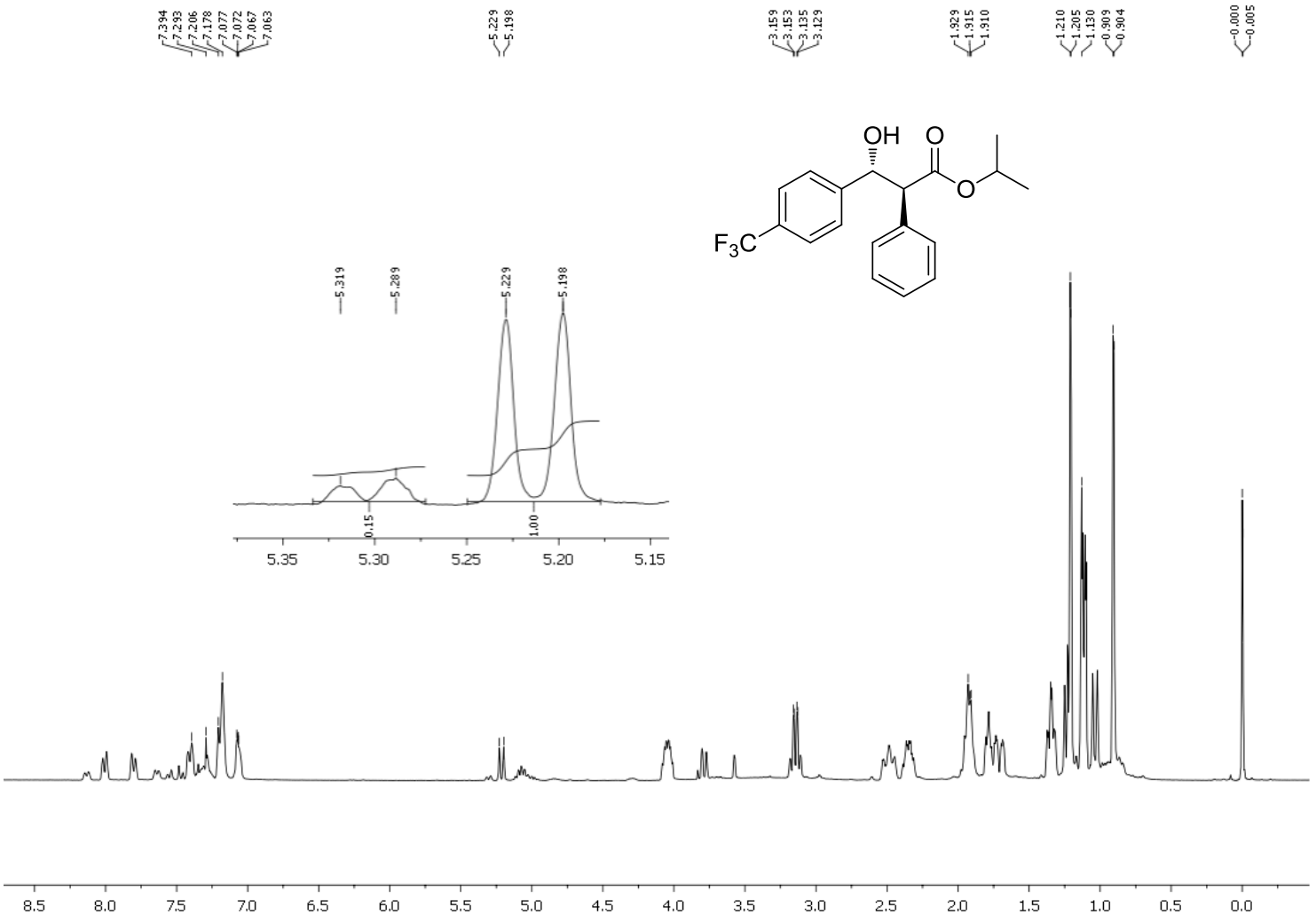


(f1 ppm)

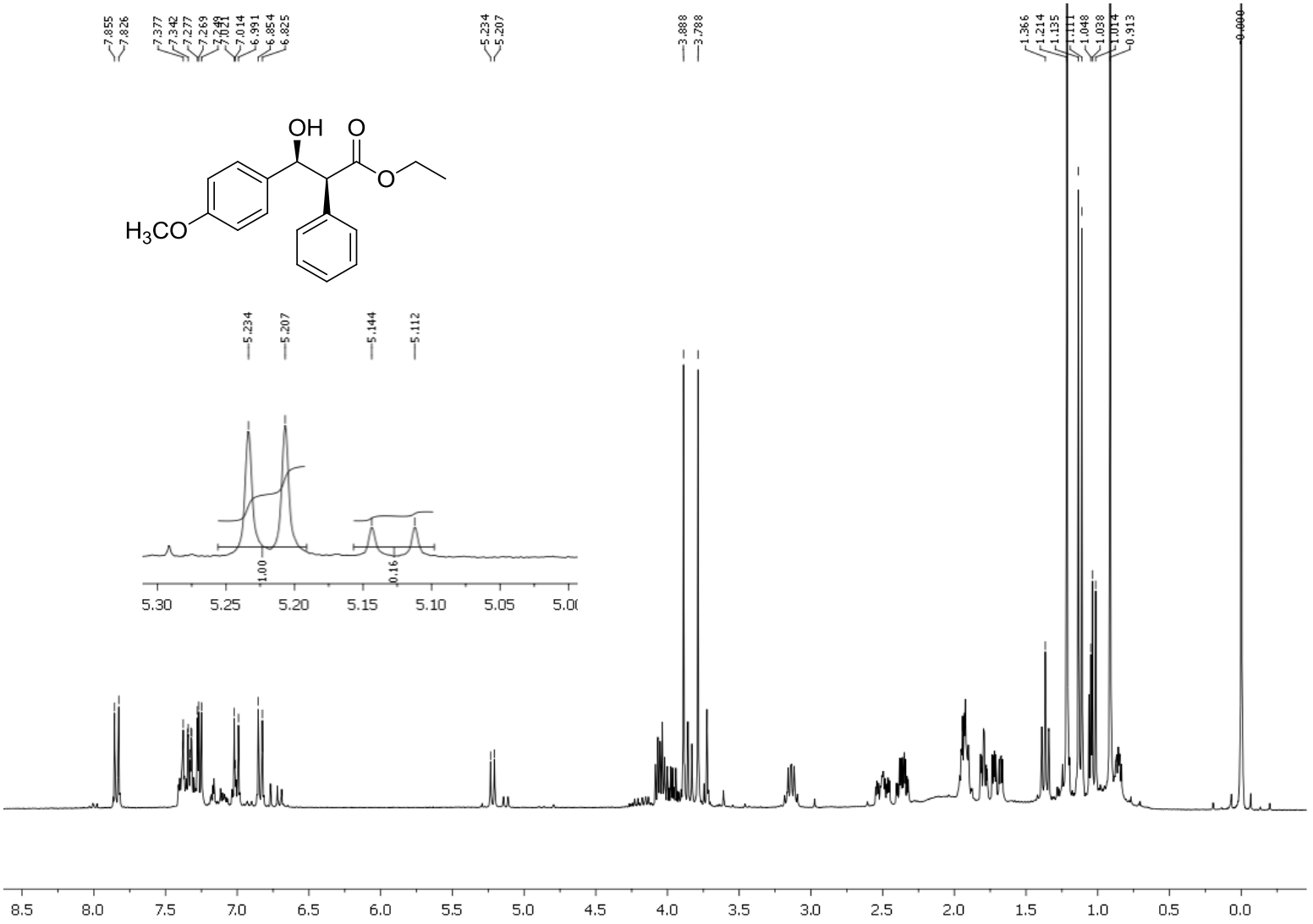
^{1}H NMR spectrum of a crude mixture of dimenthyl carbonate derivative of diol obtained from ethyl (2*S*,3*S*)-3-hydroxy-2-phenyl-3-(thiophen-2-yl)propanoate (**8f**)



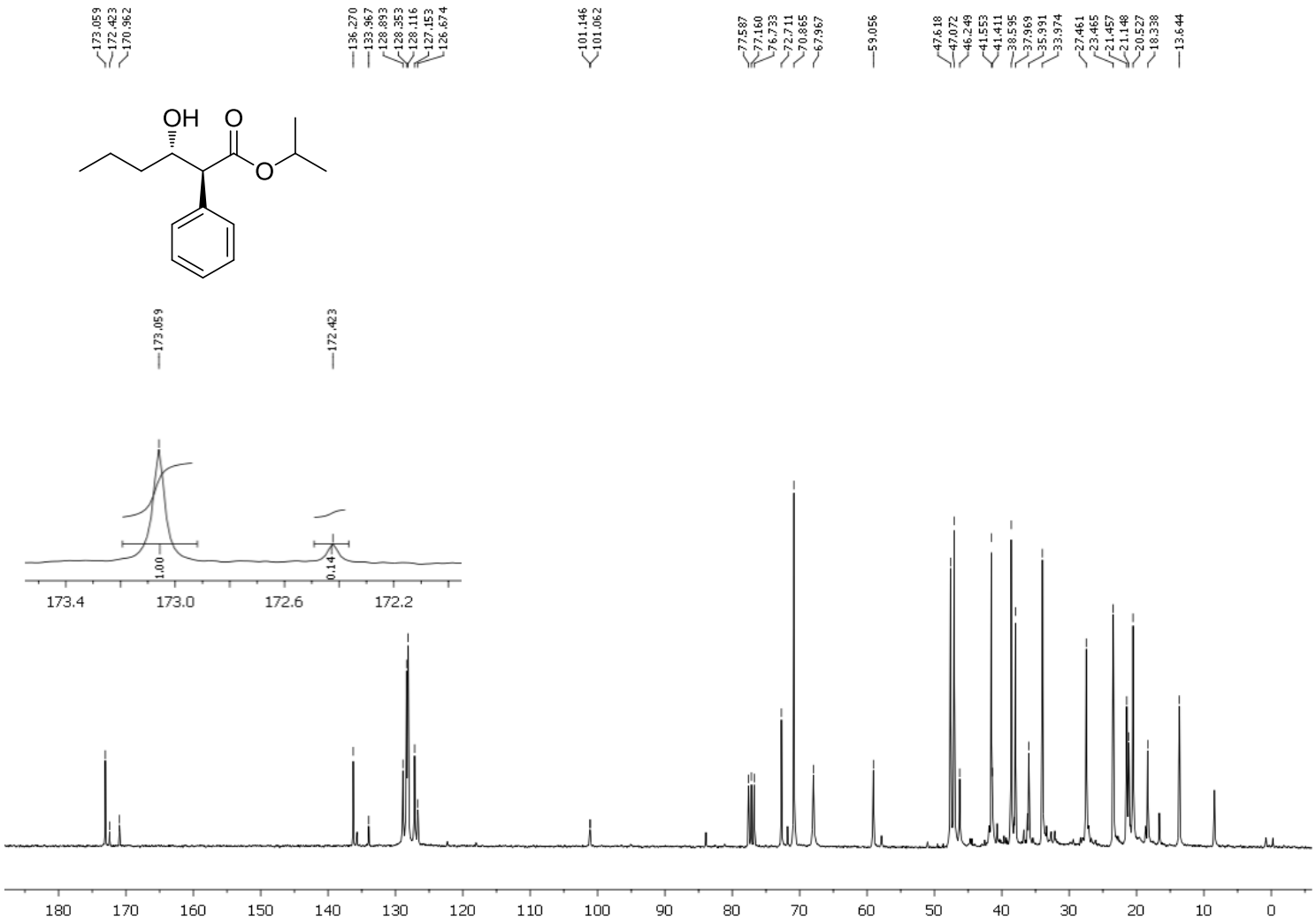
^{1}H NMR spectrum of a crude mixture of isopropyl (2*S*,3*R*)-3-hydroxy-2-phenyl-3-(thiophen-2-yl)propanoate (**9f**)



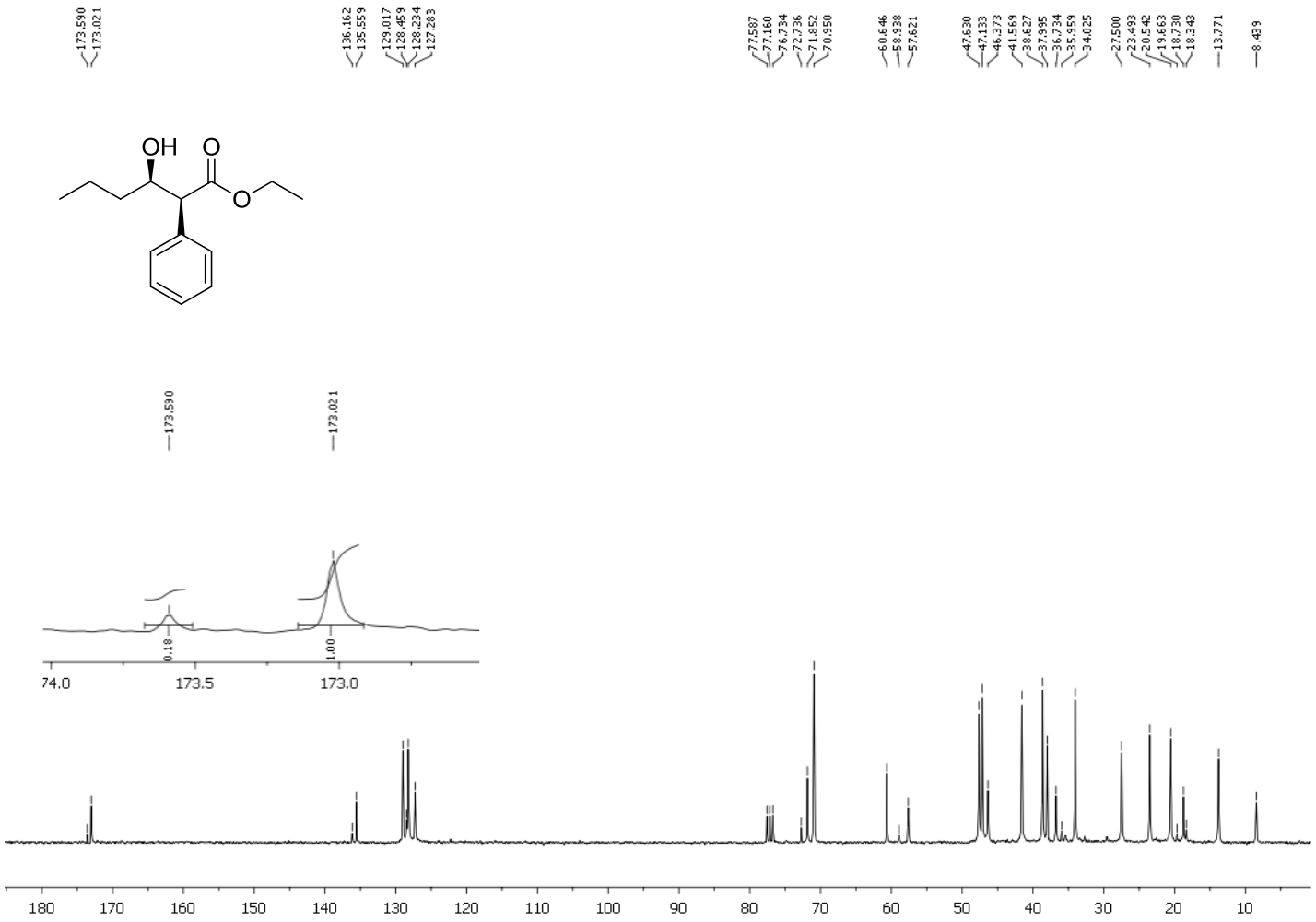
^{1}H NMR spectrum of a crude mixture of isopropyl (2*S*,3*R*)-3-hydroxy-2-phenyl-3-(4-(trifluoromethyl)phenyl)propanoate (**9e**)



^{1}H NMR spectrum of ethyl (2*S*,3*S*)-3-hydroxy-3-(4-methoxyphenyl)-2-phenylpropanoate (**8c**)



^{13}C NMR spectrum of a crude mixture isopropyl (2*S*,3*S*)-3-hydroxy-2-phenylhexanoate (**9g**)



(f1 ppm)

^{13}C NMR spectrum of a crude mixture of ethyl (2*S*,3*R*)-3-hydroxy-2-phenylhexanoate (**8g**)