Supporting Information for:

Asymmetric Lithiation–Substitution of Amines Involving Rearrangement of Borates

Iain Coldham,*[†] Jignesh J. Patel,[†] Sophie Raimbault,[†] David T.E. Whittaker,[‡] Harry Adams,[†] Guang Y Fang[¶] and Varinder K. Aggarwal*[¶]

[†]*Department of Chemistry, University of Sheffield, Sheffield S3 7HF, UK*

[‡]*AstraZeneca, Mereside, Alderley Park, Macclesfield, Cheshire SK10 4TG*

[¶]*School of Chemistry, University of Bristol, Bristol BS8 1TS, UK*

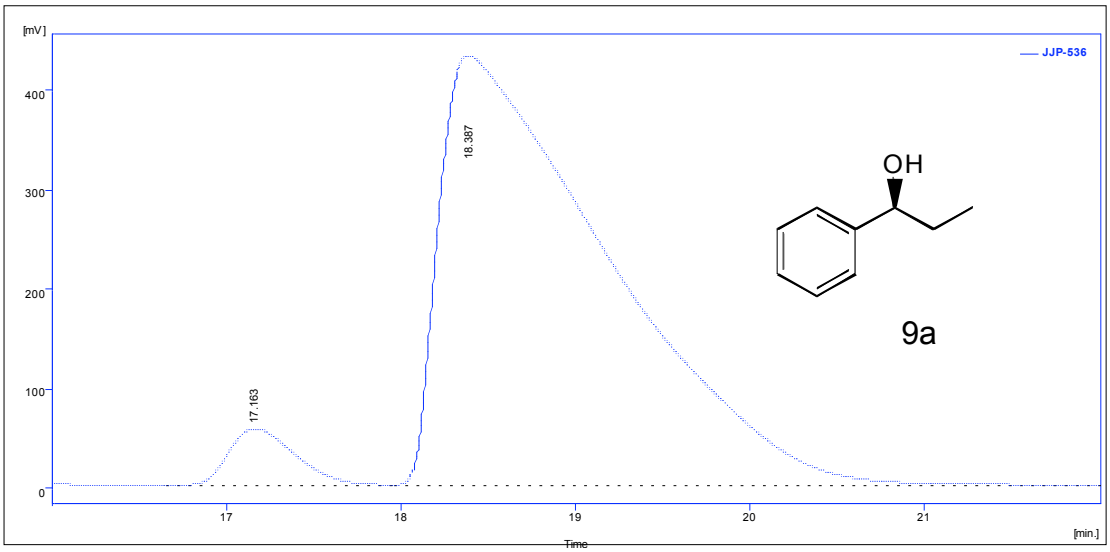
i.coldham@sheffield.ac.uk

Experimental procedure for the lithiation–substitution–rearrangement of **5**:

To a solution of (–)-sparteine (1.2 equivalents) in toluene (concentration 0.2 M) at –78 °C was added *n*-BuLi (1.2 equivalents). After 30 min, a solution of the starting material **5** (1.0 equivalent) in toluene (concentration 0.33 M) was added at –78 °C. The mixture was stirred at –78 °C for 6 h, and the borane R_3B (1.5 equivalents) was added. After 30 min, TMSOTf (1.0 equivalent) was added and the mixture was allowed to warm to room temperature over 3 h. A solution of aqueous NaOH (2 mL, 2 M) followed by H_2O_2 (1 mL, 30% in water) was added at 0 °C and the mixture was allowed to warm to room temperature over 16 h. The mixture was extracted with CH_2Cl_2 (2 × 10 mL), dried (Na_2SO_4), filtered and evaporated. Purification by column chromatography on silica gel, eluting with petrol–EtOAc, gave the alcohols **9** (yields 62–83%) as oils.

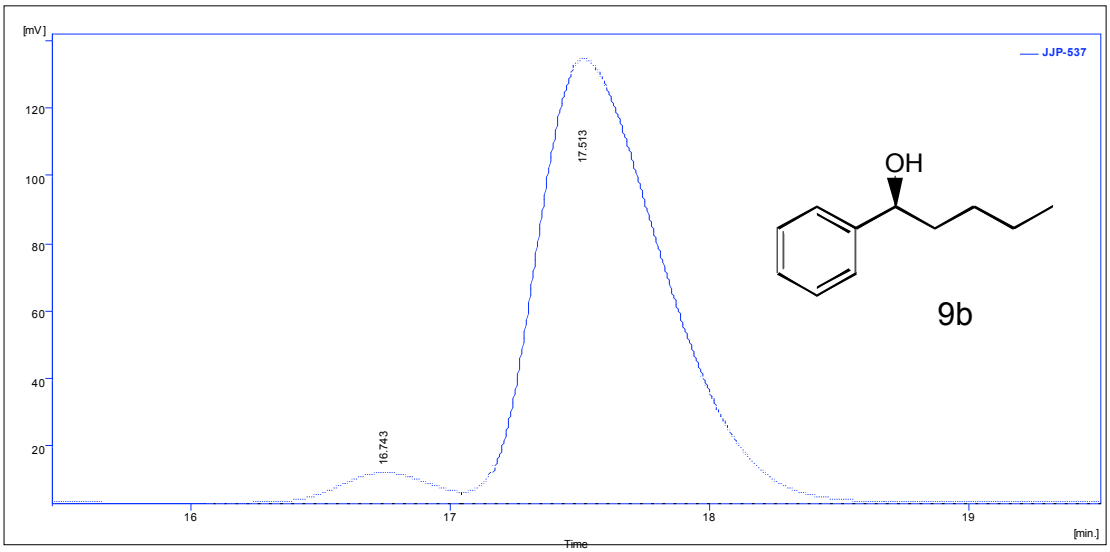
Chiral chromatography traces for the alcohols **9**:

Alcohol **9a**: 83% yield; er 95:5 (*S*:*R*); $[\alpha]_D^{22}$ –47.9 (c 0.96, $CHCl_3$) [lit. (*S*)-enantiomer er >99:1 $[\alpha]_D^{24}$ –50.8 (c 1.03, $CHCl_3$) – see Yang, W.; Xu, J.-H.; Xie, Y.; Xu, Y.; Zhao, G.; Lin, G.-Q. *Tetrahedron: Asymmetry* **2006**, *17*, 1769]. Resolution between the enantiomers was achieved using a Beckman system fitted with a Chiralcel OD column (250 mm × 4.6 mm i.d.) as the stationary phase with a mixture of *n*-hexane: isopropanol (98:2 v/v) as the mobile phase at a flow rate of 1 $mL.min^{-1}$; ambient temperature, detection by UV absorbance at 254 nm. Injection volume 20 μL of the sample prepared in a 2 $mg.L^{-1}$ solution of isopropanol. Under these conditions, the components were eluted at 17.2 min (minor enantiomer (*R*)) and 18.4 min (major enantiomer (*S*)).



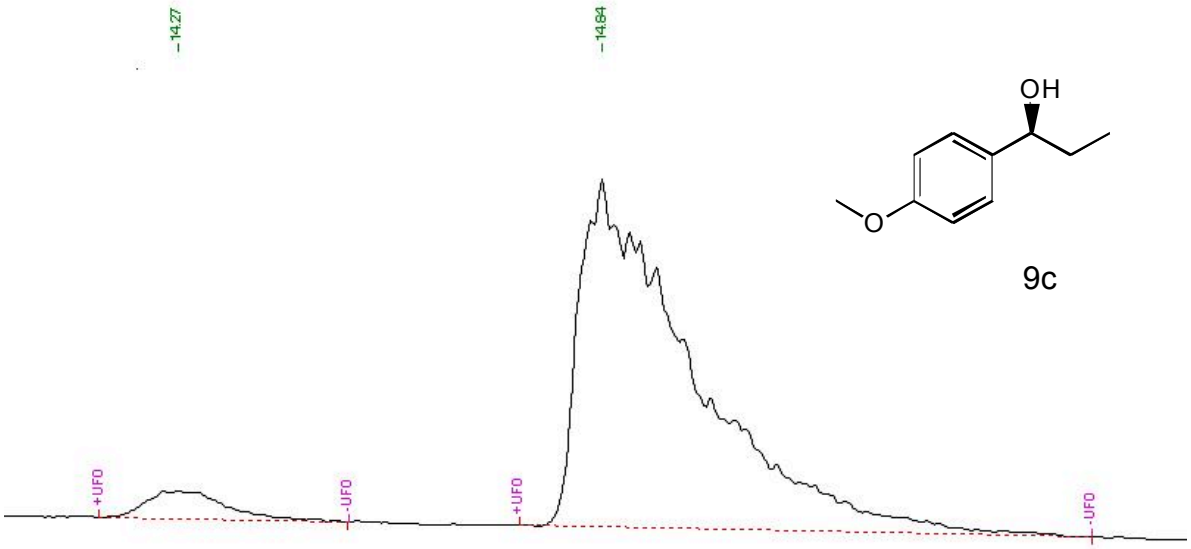
	Reten. Time [min]	Area [mV.s]	Height [mV]	Area [%]	Height [%]
1	17.163	1489.797	56.570	4.9	11.6
2	18.387	29161.501	431.881	95.1	88.4
	Total	30651.298	488.451	100.0	100.0

Alcohol **9b**: 82% yield; er 95:5 (*S*:*R*); $[\alpha]_D^{22}$ –31.8 (c 1.0, C_6H_6) [lit. (*S*)-enantiomer er 89:11 $[\alpha]_D^{22}$ –31.6 (c 1.03, $CHCl_3$) – see Yong, K.H.; Taylor, N.J.; Chong, J.M. *Org. Lett.* **2002**, *4*, 3553]. Resolution between the enantiomers was achieved using a Beckman system fitted with a Chiralcel OD column (250 mm × 4.6 mm i.d.) as the stationary phase with a mixture of *n*-hexane: isopropanol (98:2 v/v) as the mobile phase at a flow rate of 1 $mL.min^{-1}$; ambient temperature, detection by UV absorbance at 254 nm. Injection volume 20 µL of the sample prepared in a 2 $mg.L^{-1}$ solution of isopropanol. Under these conditions, the components were eluted at 16.7 min (minor enantiomer (*R*)) and 17.5 min (major enantiomer (*S*)).

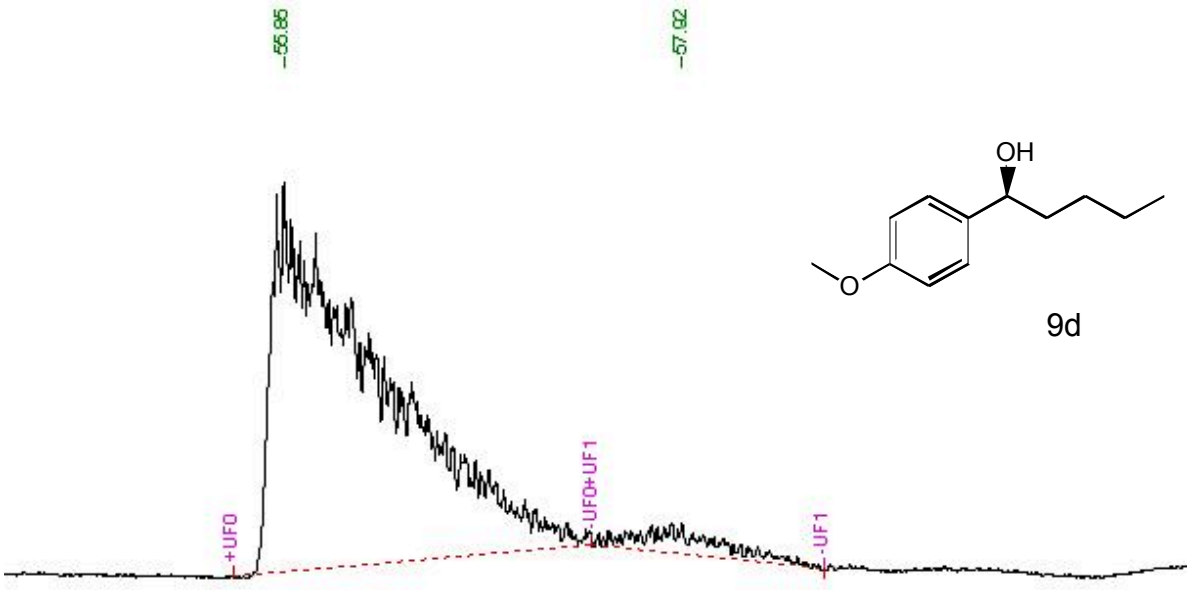


	Reten. Time [min]	Area [mV.s]	Height [mV]	Area [%]	Height [%]
1	16.743	220.021	8.940	4.7	6.4
2	17.513	4486.314	131.138	95.3	93.6
	Total	4706.336	140.078	100.0	100.0

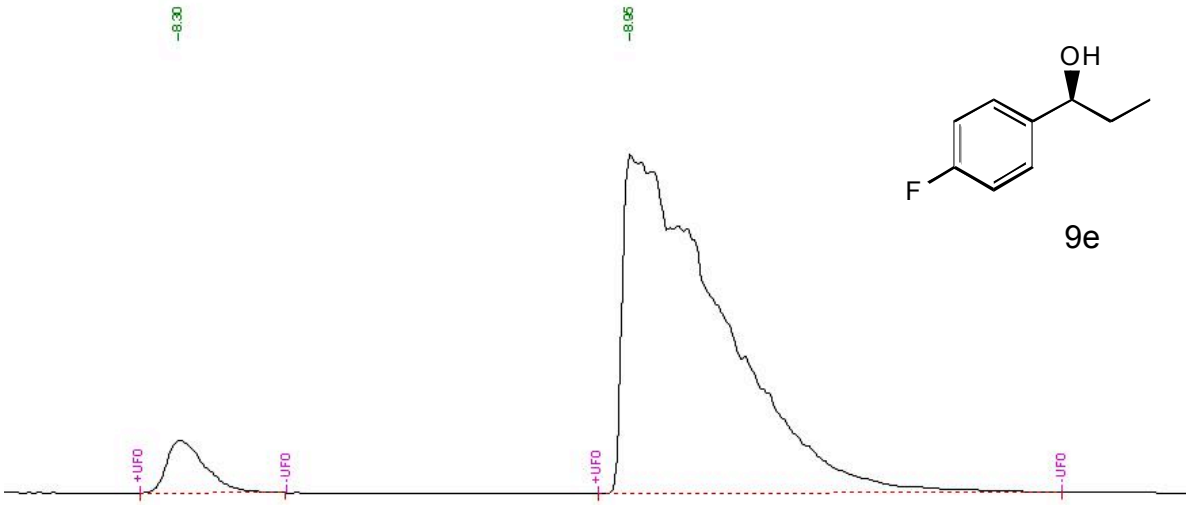
Alcohol **9c**: 82% yield; er 95:5 (*S*:*R*); $[\alpha]_D^{22}$ –21.8 (c 2.75, EtOH) [lit. (*S*)-enantiomer er >99:1 $[\alpha]_D^{24}$ –24.8 (c 1.0–2.6, EtOH) – see Homann, M.J.; Vail, R.B.; Previte, E.; Tamarez, M.; Morgan, B.; Dodds, D.R.; Zaks, A. *Tetrahedron*, **2004**, *60*, 789]. Resolution between the enantiomers was achieved using chiral gas chromatography with a Chiracel-bonded column (30 m × 0.25 m, β-cyclodextrin, permethyl) T = 130 °C isothermal, H_2 carrier gas at 14 psi. Under these conditions, the faster running component (*R*) and slower running component (*S*) were eluted at 14.3 min and 14.8 min respectively.



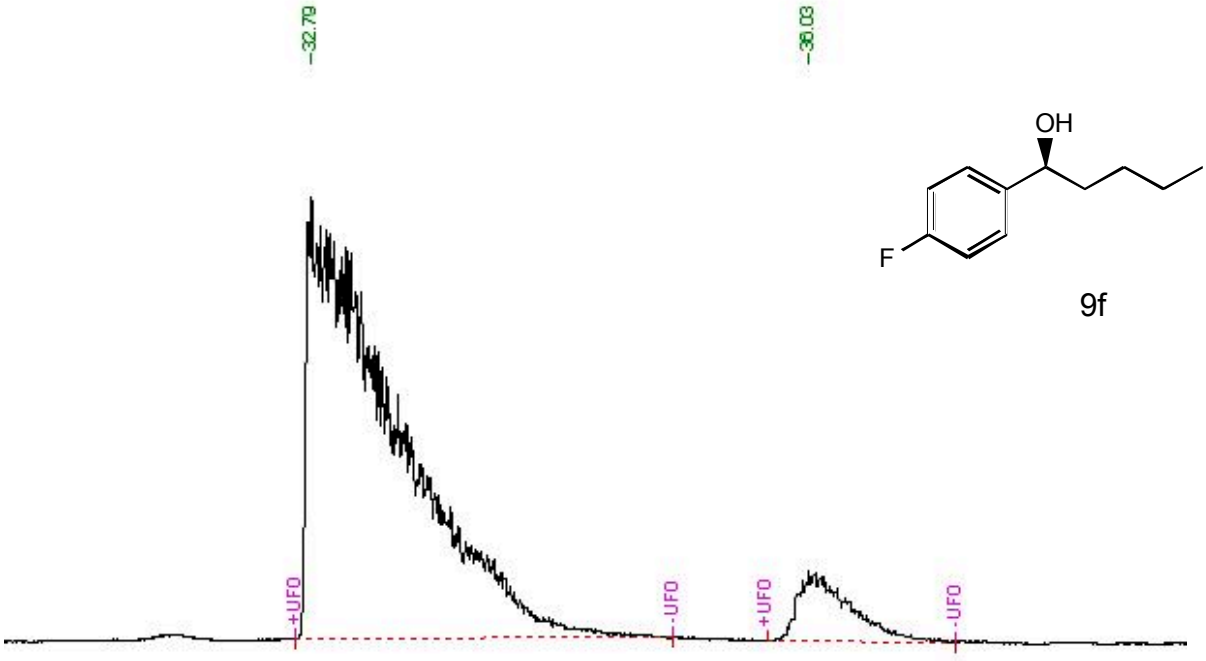
Alcohol **9d**: 72% yield; er 95:5 (*S*:*R*). Resolution between the enantiomers was achieved using chiral gas chromatography with a Chiracel-bonded column (30 m × 0.25 m, β-cyclodextrin, permethyl) T = 112 °C isothermal, H_2 carrier gas at 14 psi. Under these conditions, the faster running component (*S*) and slower running component (*R*) were eluted at 55.8 min and 57.9 min respectively.



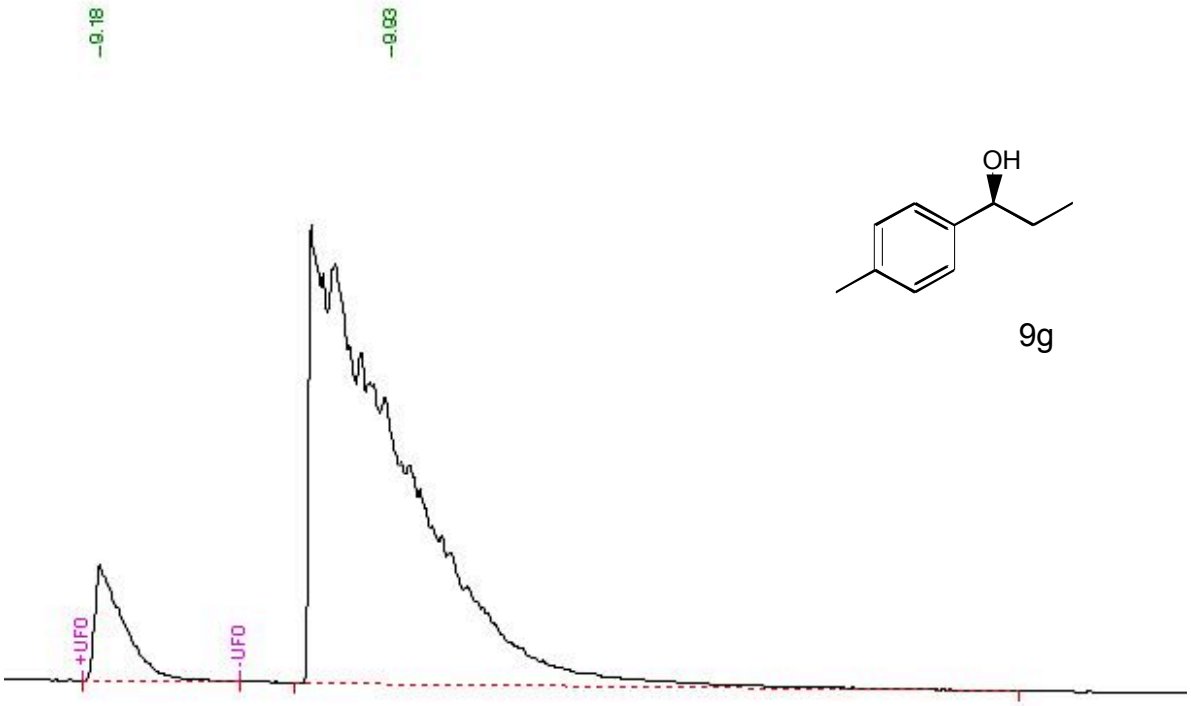
Alcohol **9e**: 79% yield; er 95:5 (*S*:*R*). Resolution between the enantiomers was achieved using chiral gas chromatography with a Chiracel-bonded column (30 m × 0.25 m, β-cyclodextrin, permethyl) T = 110 °C isothermal, H_2 carrier gas at 14 psi. Under these conditions, the faster running component (*R*) and slower running component (*S*) were eluted at 8.3 min and 8.9 min respectively.



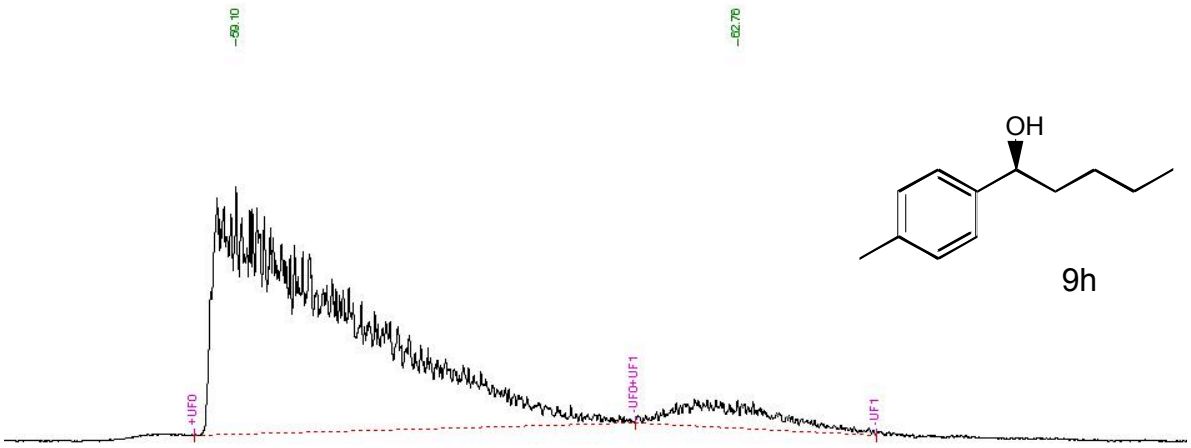
Alcohol **9f**: 68% yield; er 92:8 (*S*:*R*); $[\alpha]_D^{22}$ –36.7 (c 0.6, $CHCl_3$). Resolution between the enantiomers was achieved using chiral gas chromatography with a Chiracel-bonded column (30 m × 0.25 m, β-cyclodextrin, permethyl) T = 100 °C isothermal, H_2 carrier gas at 14 psi. Under these conditions, the faster running component (*S*) and slower running component (*R*) were eluted at 32.8 min and 36.0 min respectively.



Alcohol **9g**: 62% yield; er 92:8 (*S*:*R*); $[\alpha]_D^{22}$ –25.0 (c 0.5, EtOH) [lit. (*S*)-enantiomer er >99:1 $[\alpha]_D^{24}$ –34.8 (c 1.0–2.6, EtOH) – see Homann, M.J.; Vail, R.B.; Previte, E.; Tamarez, M.; Morgan, B.; Dodds, D.R.; Zaks, A. *Tetrahedron*, **2004**, *60*, 789]. Resolution between the enantiomers was achieved using chiral gas chromatography with a Chiracel-bonded column (30 m × 0.25 m, β-cyclodextrin, permethyl) T = 110 °C isothermal, H_2 carrier gas at 14 psi. Under these conditions, the faster running component (*R*) and slower running component (*S*) were eluted at 9.2 min and 9.9 min respectively.



Alcohol **9h**: 64% yield; er 92:8 (*S*:*R*); $[\alpha]_D^{22}$ –30.0 (c 0.95, C_6H_6) [lit. (*S*)-enantiomer er 95.5:4.5 $[\alpha]_D^{24}$ –34.8 (c 2.3, C_6H_6) – see Soai, K.; Konishi, T.; Shibata, T. *Heterocycles* **1999**, *51*, 1421]. Resolution between the enantiomers was achieved using chiral gas chromatography with a Chiracel-bonded column (30 m × 0.25 m, β-cyclodextrin, permethyl) T = 95 °C isothermal, H_2 carrier gas at 14 psi. Under these conditions, the faster running component (*S*) and slower running component (*R*) were eluted at 59.1 min and 62.8 min respectively.



Experimental procedure for the lithiation–substitution–rearrangement of **10**:

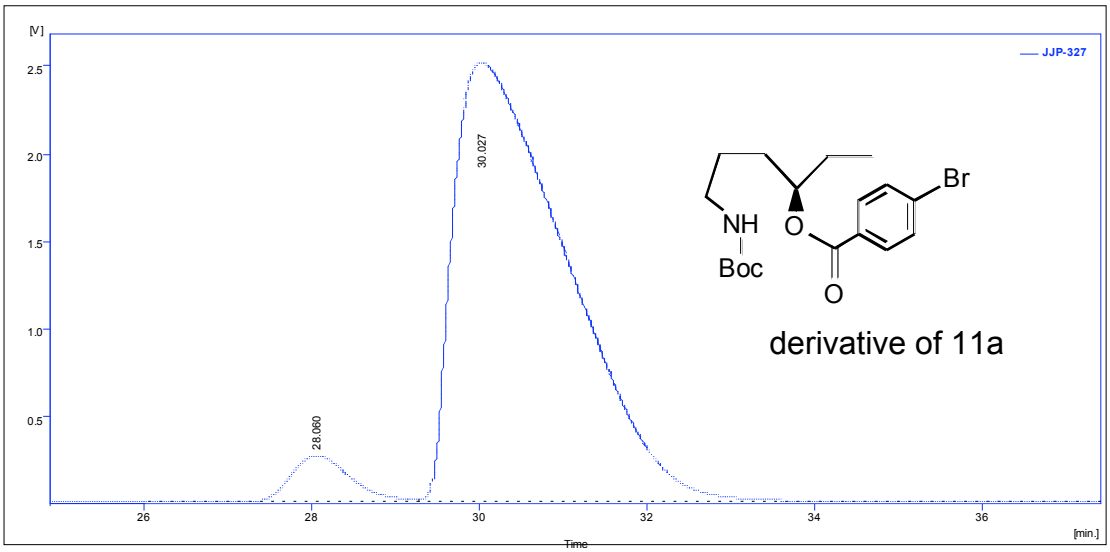
To a solution of *N*-Boc-pyrrolidine **10** (1.0 equivalent) and (–)-sparteine (1.2 equivalents) in Et_2O (concentration 0.4 M) at –78 ° C was added *sec*-BuLi (1.2 equivalents). After 4 h, BEt_3 (1.4 equivalents) was added. After 30 min, freshly distilled TMSOTf (1.0 equivalent) was added and the mixture was warmed to room temperature over a period of 3 h. The mixture was cooled to 0 °C followed by addition of NaOH (2 mL, 2 M) and H_2O_2 (1 mL, 30 % in water) and the mixture was allowed to warm to room temperature over 16 h. The mixture was diluted with H_2O (2 mL), extracted with CH_2Cl_2 (2 × 20 ml), dried ($MgSO_4$), filtered and evaporated. The crude product was dissolved in a small amount of CH_2Cl_2 and stirred for 30 min with a small amount of silica DAVISIL 40–63 (to cleave any trimethylsilyl ether product). Purification was carried out on silica with petrol–EtOAc (2:1) to give the alcohols **11**.

Data for the product **11a**:

58% yield; er 95:5 (*S*:*R*); $[\alpha]_D^{24}$ +10.0 (c 1.0, $CHCl_3$); R_f 0.50 [petrol–EtOAc (1:1)]; ν_{max} (film)/cm^{-1} 3385, 2945, 2915, 2860, 1690; δ_H(250 MHz, $CDCl_3$) 4.70–4.50 (1H, br), 3.58–3.47 (1H, m), 3.19–3.06 (2H, m), 1.75–1.30 (6H, m), 1.43 (9H, s), 0.92 (3H, t, *J* 7); δ_C(63 MHz, $CDCl_3$) 156.1, 78.8, 72.3, 40.3, 33.5, 30.1, 28.2, 26.1, 9.8; Found (ES): MNa^+, 240.1577. $C_{11}H_{23}NO_3Na$ requires 240.1576; GCMS *m*/*z* (ES) 240 (100%, MNa^+).

Chiral chromatography:

The alcohol **11a** was converted to its *p*-bromobenzoate ester derivative using *p*-bromobenzoyl chloride, Et_3N and 4-dimethylaminopyridine in CH_2Cl_2. The enantiomer ratio of the *p*-bromobenzoate ester derivative of the alcohol **11a** was determined by chiral HPLC. Resolution between the enantiomers was achieved using a Gilson 300 series system fitted with a Chiralcel OD column (250 mm × 4.6 mm i.d.) as the stationary phase with a mixture of *n*-hexane : *iso*-propanol (97.5:2.5 v/v) as the mobile phase at a flow rate of 0.5 $mL.min^{-1}$; ambient temperature, detection by UV absorbance at 254 nm. Injection volume 25 μL of the sample prepared in a 2–4 $mg.mL^{-1}$ solution of eluent. Under these conditions, the faster running component and slower running component were eluted at 20.2 min (minor) and 22.2 min (major) respectively.



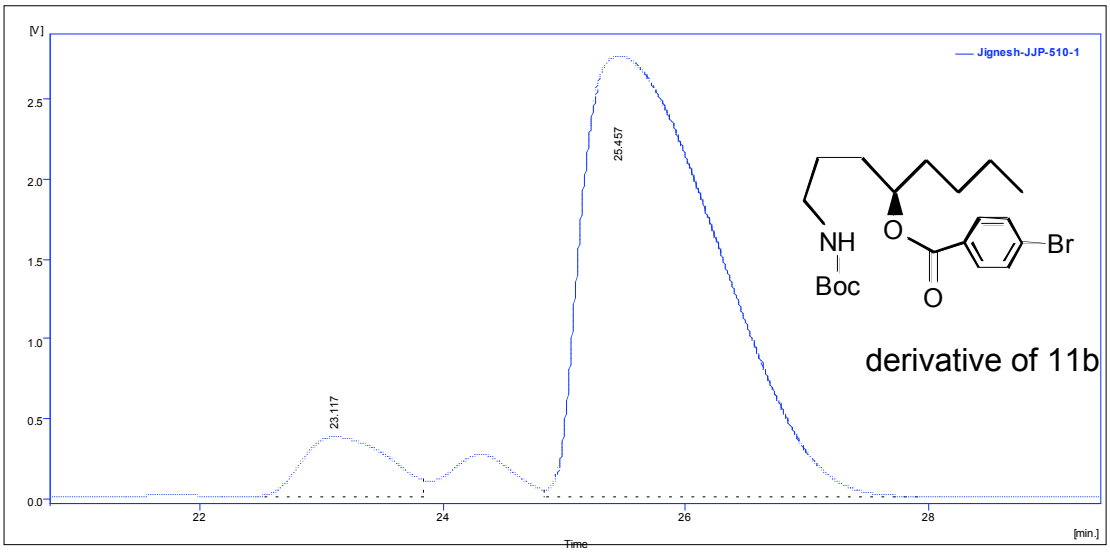
	Reten. Time [min]	Area [mV.s]	Height [mV]	Area [%]	Height [%]
1	28.060	13171.925	263.717	5.3	9.5
2	30.027	237599.579	2507.506	94.7	90.5
	Total	250771.504	2771.223	100.0	100.0

Data for the product **11b**:

59% yield; er 92:8 (*S*:*R*); $[\alpha]_D^{24}$ +3.8 (c 1.0, $CHCl_3$); R_f 0.50 [petrol–EtOAc (1:1)]; ν_{max} (film)/cm^{-1} 3325, 2935, 2930, 2860, 1680; δ_H(250 MHz, $CDCl_3$) 4.70–4.50 (1H, br), 3.75–3.50 (1H, m), 3.30–3.00 (2H, m), 1.75–1.15 (8H, m), 1.43 (9H, s), 1.00–0.82 (5H, m); δ_C(63 MHz, $CDCl_3$) 156.1, 79.0, 71.5, 40.5, 37.3, 34.2, 28.4, 27.8, 26.3, 22.7, 14.0; Found (ES): MNa^+, 268.1885. $C_{13}H_{27}NO_3Na$ requires 268.1889; GCMS *m*/*z* (ES) 268 (100%, MNa^+).

Chiral chromatography:

The alcohol **11b** was converted to its *p*-bromobenzoate ester derivative using *p*-bromobenzoyl chloride, Et_3N and 4-dimethylaminopyridine in CH_2Cl_2. The enantiomer ratio of the *p*-bromobenzoate ester derivative of the alcohol **11b** was determined by chiral HPLC. Resolution between the enantiomers was achieved using a Gilson 300 series system fitted with a Chiralcel OD column (250 mm × 4.6 mm i.d.) as the stationary phase with a mixture of *n*-hexane : *iso*-propanol (97.5:2.5 v/v) as the mobile phase at a flow rate of 0.5 $mL.min^{-1}$; ambient temperature, detection by UV absorbance at 254 nm. Injection volume 25 μL of the sample prepared in a 2–4 $mg.mL^{-1}$ solution of eluent. Under these conditions, the faster running component and slower running component were eluted at 23.0 min (minor) and 25.4 min (major) respectively (together with a small impurity at 24.3 min).



	Reten. Time [min]	Area [mV.s]	Height [mV]	Area [%]	Height [%]
1	23.117	18469.487	373.578	8.0	11.9
2	25.457	212463.858	2758.834	92.0	88.1
	Total	230933.344	3132.412	100.0	100.0

Experimental procedure for the lithiation–substitution–rearrangement of **12**:

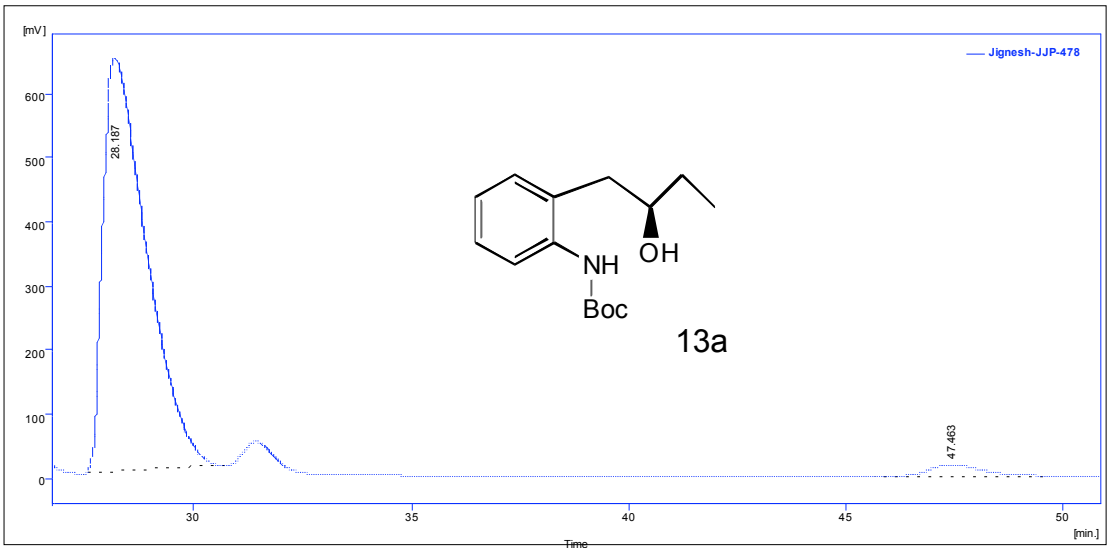
To a solution of *N*-Boc-indoline **12** (1.0 equivalent) and (–)-sparteine (1.3 equivalents) in cumene (concentration 0.4 M) at –78 ° C was added *sec*-BuLi (1.3 equivalents). After 5 h, BEt_3 (1.4 equivalents) was added. After 30 min, freshly distilled TMSOTf (1.0 equivalent) was added and the mixture was warmed to room temperature over a period of 3 h. The mixture was cooled to 0 °C followed by addition of NaOH (2 mL, 2 M) and H_2O_2 (1 mL, 30 % in water) and the mixture was allowed to warm to room temperature over 16 h. The mixture was diluted with H_2O (2 mL), extracted with CH_2Cl_2 (2 × 20 ml), dried ($MgSO_4$), filtered and evaporated. The crude product was dissolved in a small amount of CH_2Cl_2 and stirred for 30 min with a small amount of silica DAVISIL 40–63 (to cleave any trimethylsilyl ether product). Purification was carried out on silica with petrol–EtOAc (2:1) to give the alcohols **13**.

Data for the product **13a**:

67% yield; er 97:3 (*S*:*R*); $[\alpha]_D^{24}$ –8.4 (c 1.8, $CHCl_3$); m.p. 76–78 °C; R_f 0.50 [petrol–EtOAc (4:1)]; ν_{max} (film)/cm^{-1} 3445, 3280, 2960, 2925, 2875, 1690; δ_H(250 MHz, $CDCl_3$) 7.99 (1H, br), 7.72–7.69 (1H, br), 7.30–6.90 (3H, m), 3.90–3.60 (1H, m), 2.80–2.62 (2H, m), 2.37 (1H, br), 1.70–1.40 (2H, m), 1.50 (9H, s), 0.97 (3H, t, *J* 7.5); δ_C(63 MHz, $CDCl_3$) 153.8, 137.3, 130.8, 130.1, 127.0, 123.7, 122.9, 79.8, 75.3, 38.7, 30.1, 28.3, 10.0; Found (ES): MNa^+, 288.1582. $C_{15}H_{23}NO_3Na$ requires 288.1576; GCMS *m*/*z* (ES) 288 (100%, MNa^+); Found: C, 67.84; H, 9.02; N, 5.20; $C_{15}H_{23}NO_3$ requires C, 67.90; H, 8.74; N, 5.28.

Chiral chromatography:

The enantiomer ratio of the product **13a** was determined by chiral HPLC. Resolution between the enantiomers was achieved using a Gilson 300 series system fitted with a Chiralcel OD column (250 mm × 4.6 mm i.d.) as the stationary phase with a mixture of *n*-hexane : *iso*-propanol (97.5:2.5 v/v) as the mobile phase at a flow rate of 0.5 $mL.min^{-1}$; ambient temperature, detection by UV absorbance at 254 nm. Injection volume 25 μL of the sample prepared in a 2–4 $mg.mL^{-1}$ solution of eluent. Under these conditions, the faster running component and slower running component were eluted at 28.2 min (major) and 47.5 min (minor) respectively (together with a small impurity at 31.5 min).



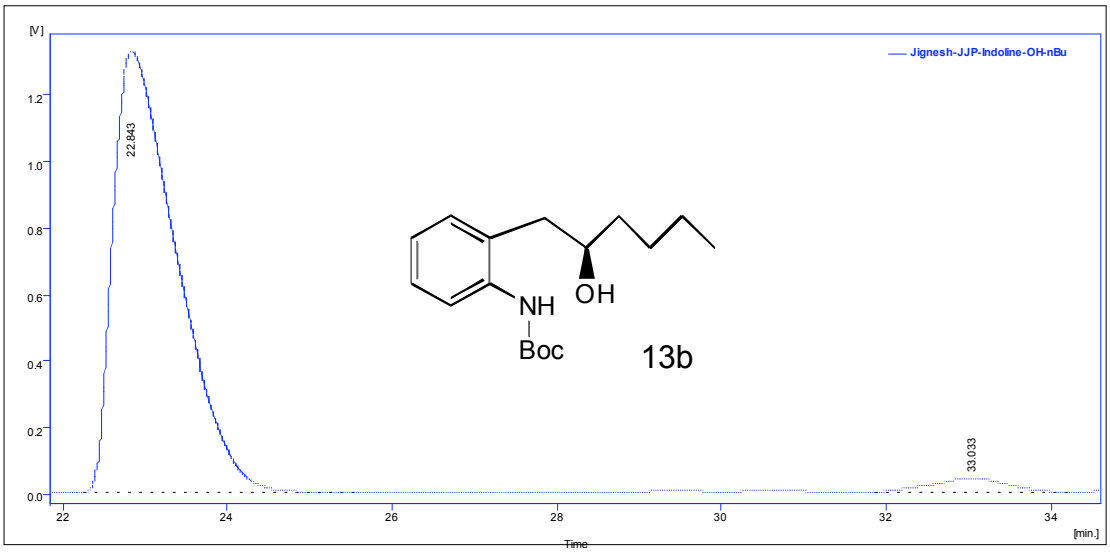
	Reten. Time [min]	Area [mV.s]	Height [mV]	Area [%]	Height [%]
1	28.187	45565.659	646.119	96.9	97.3
2	47.463	1456.652	17.704	3.1	2.7
	Total	47022.312	663.823	100.0	100.0

Data for the product **13b**:

64% yield; er 96:4 (*S*:*R*); $[\alpha]_D^{24}$ –10.4 (c 2.0, $CHCl_3$); m.p. 86–88 °C; R_f 0.50 [petrol–EtOAc (4:1)]; ν_{max} (film)/cm^{-1} 3420, 3255, 2985, 2925, 2860, 1685, 1590; δ_H(250 MHz, $CDCl_3$) 8.10–7.90 (1H, br), 7.80–7.60 (1H, br), 7.30–6.96 (3H, m), 4.00–3.70 (1H, m), 2.90–2.60 (2H, m), 2.45–2.20 (1H, br), 1.70–1.20 (6H, m), 1.50 (9H, s), 1.00–0.80 (3H, m); δ_C(63 MHz, $CDCl_3$) 153.8, 137.4, 130.8, 130.1, 127.0, 123.7, 122.8, 79.8, 73.9, 39.2, 37.0, 28.3, 27.9, 22.6, 14.0; Found (ES): MNa^+, 316.1894. $C_{17}H_{27}NO_3Na$ requires 316.1889; GCMS *m/z* (ES) 316 (100 %, MNa^+); Found: C, 69.65; H, 9.30; N, 4.65; $C_{17}H_{27}NO_3$ requires C, 69.59; H, 9.28; N, 4.77.

Chiral chromatography:

The enantiomer ratio of the product **13b** was determined by chiral HPLC. Resolution between the enantiomers was achieved using a Gilson 300 series system fitted with a Chiralcel OD column (250 mm × 4.6 mm i.d.) as the stationary phase with a mixture of *n*-hexane : *iso*-propanol (97.5:2.5 v/v) as the mobile phase at a flow rate of 0.5 $mL.min^{-1}$; ambient temperature, detection by UV absorbance at 254 nm. Injection volume 25 μL of the sample prepared in a 2–4 $mg.mL^{-1}$ solution of eluent. Under these conditions, the faster running component and slower running component were eluted at 22.8 min (major) and 33.0 min (minor) respectively.



	Reten. Time [min]	Area [mV.s]	Height [mV]	Area [%]	Height [%]
1	22.843	71542.666	1327.726	96.5	96.9
2	33.033	2619.154	42.129	3.5	3.1
	Total	74161.821	1369.855	100.0	100.0

Crystallographic data for compound **13b**:

Crystal data for $C_{16}H_{14}N_2O$; M = 250.29. Crystallises from dichloromethane as colourless blocks; crystal dimensions 0.30 x 0.21 x 0.16 mm. Monoclinic, a = 7.0720(10), b = 10.2888(13), c = 11.8871(17) Å, β =90.800°(7), U = 864.8(2) Å^3, Z = 2, D_c = 1.127 Mg/m^3, space group P2$_1$ (C_2^2 No.4), Mo-K$_\alpha$ radiation ($\bar{\lambda}$ = 0.71073 Å), μ(Mo-K$_\alpha$) = 0.076 mm^{-1}, F(000) = 320.

Data collected were measured on a Bruker Smart CCD area detector with Oxford Cryosystems low temperature system. Cell parameters were refined from the setting angles of 9281 reflections (θ range 1.71 < 27.49°).

Reflections were measured from a hemisphere of data collected of frames each covering 0.3 degrees in omega. Of the 24577 reflections measured, all of which were corrected for Lorentz and polarisation effects and for absorption by semi empirical methods based on symmetry-equivalent and repeated reflections (minimum and maximum transmission coefficients 0.9775 and 0.9879) 2072 independent reflections exceeded the significance level |Fl/σ(|Fl) > 4.0. The structure was solved by direct methods and refined by full matrix least squares methods on F^2. Hydrogen atoms were placed geometrically and refined with a riding model (including torsional freedom for methyl groups) and with U$_{iso}$ constrained to be 1.2 (1.5 for methyl groups) times U$_{eq}$ of the carrier atom. Refinement converged at a final R= 0.0270 (wR$_2$ = 0.0733, for all 2100 data, 196 parameters, mean and maximum δ/σ 0.000, 0.000) with allowance for the thermal anisotropy of all non-hydrogen atoms. Minimum and maximum final electron density -0.232 and 0.223 e.Å^{-3}. A weighting scheme w = 1/[σ^2 (Fo^2) +(0.0488∗P)^2+ 0.1184∗P] where P=(Fo^2+ 2 ∗ Fc^2)/3 was used in the latter stages of refinement. Complex scattering factors were taken from the program package SHELXTL.

Detailed results are deposited at the Cambridge Crystallographic Data Centre. Structure Number CCDC-646310.

Crystallographic data for compound **14**:

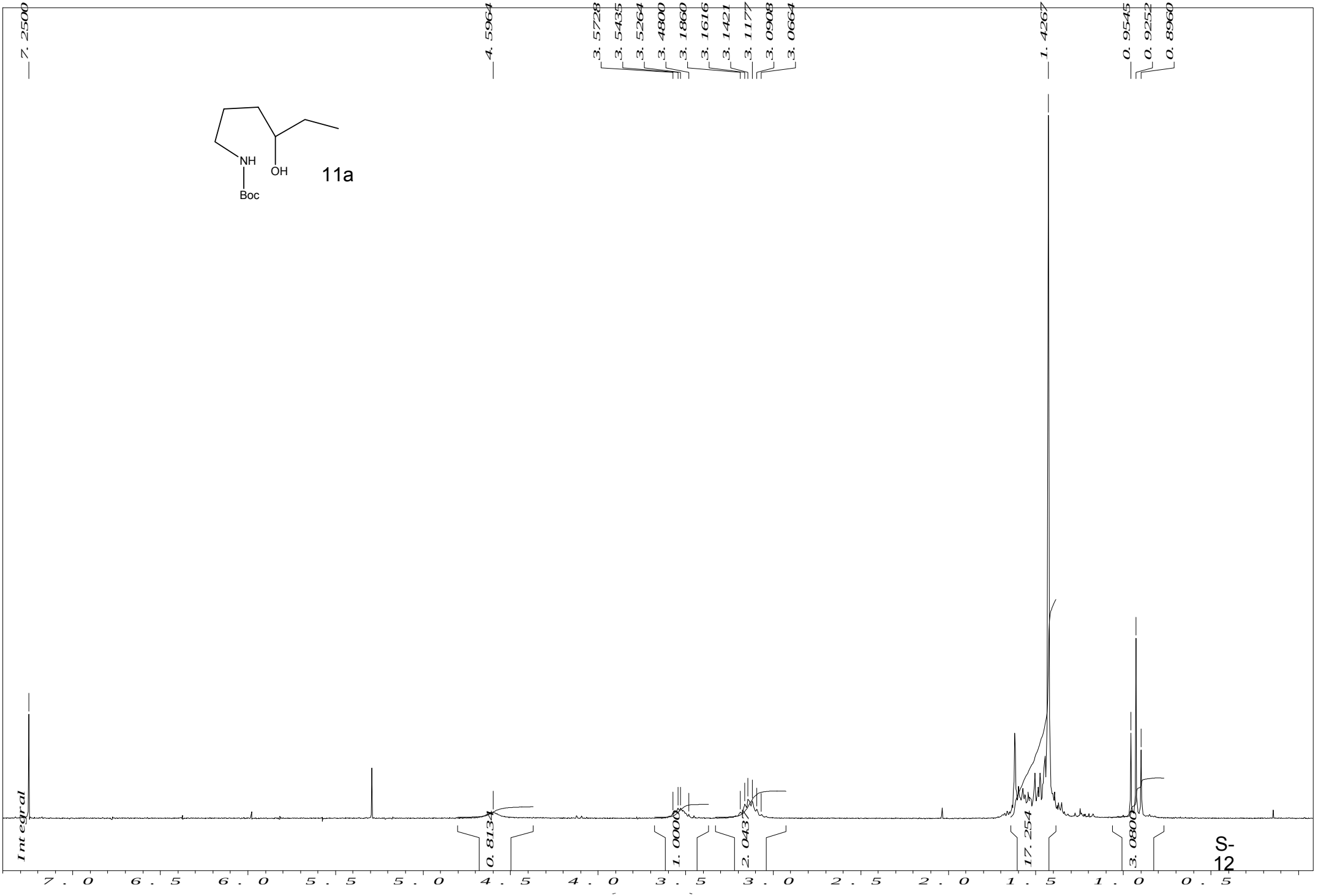
Crystal data for $C_{24}H_{21}Br_2NO_3$; M = 531.24. Crystallises from dichloromethane–petrol as colourless blocks; crystal dimensions 0.2 x 0.03 x 0.02 mm. Monoclinic, a = 12.9163(5), b = 4.9093(2), c = 16.8768(6) Å, b =96.978°(2), U = 1062.23(7) Å^3, Z = 2, D_c = 1.661 Mg/m^3, space group $P2_1$ (C_2^2 No.4), Mo-K_α radiation ($\bar{\lambda}$ = 0.71073 Å), μ(Mo-K_α) = 1.661 mm^{-1}, F(000) = 532.

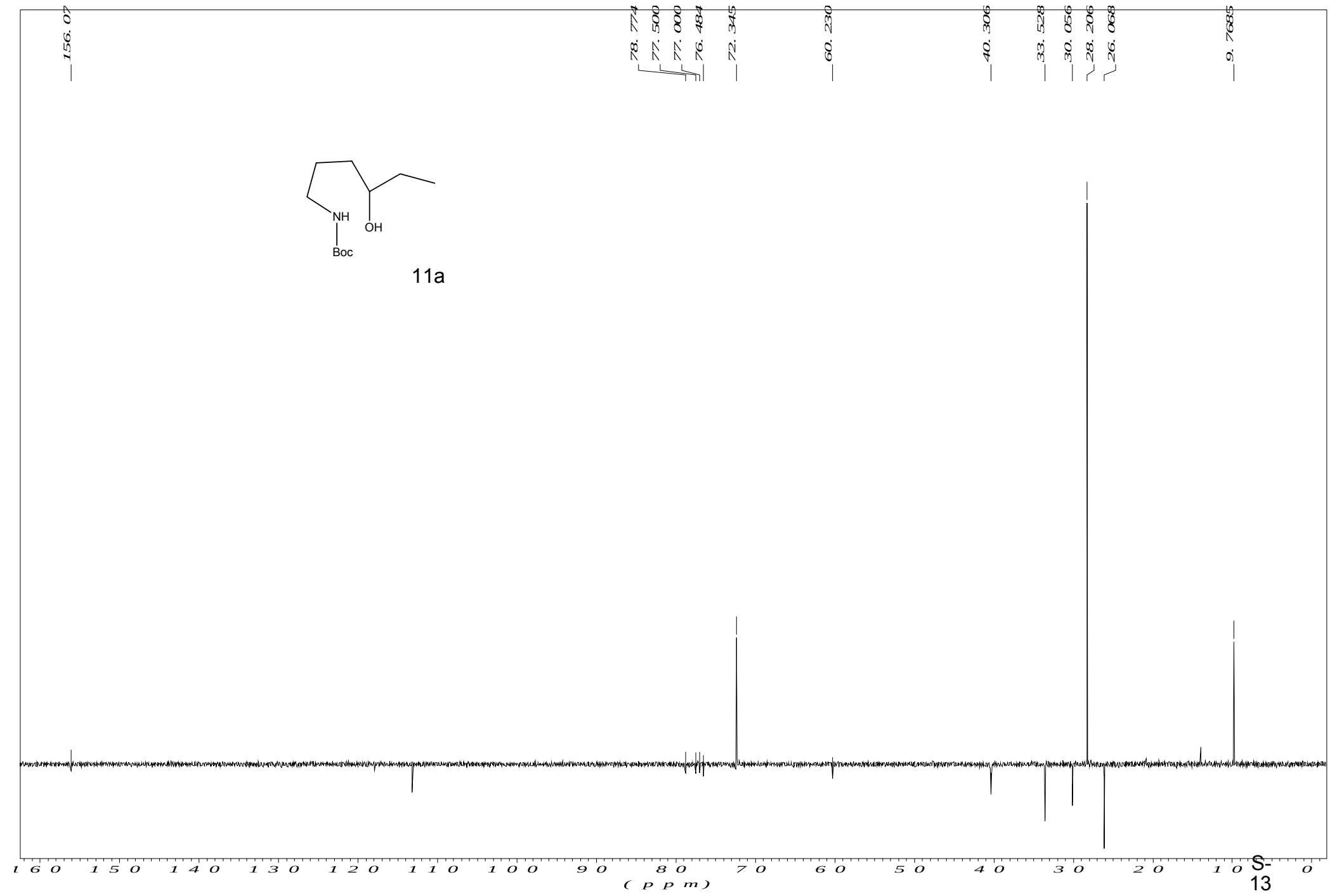
Data collected were measured on a Bruker-Nonius APEX II CCD camera on k-goniostat with Oxford Cryosystems low temperature system. Cell parameters were refined from the setting angles of 11701 reflections (θ range 3.06 < 27.50°).

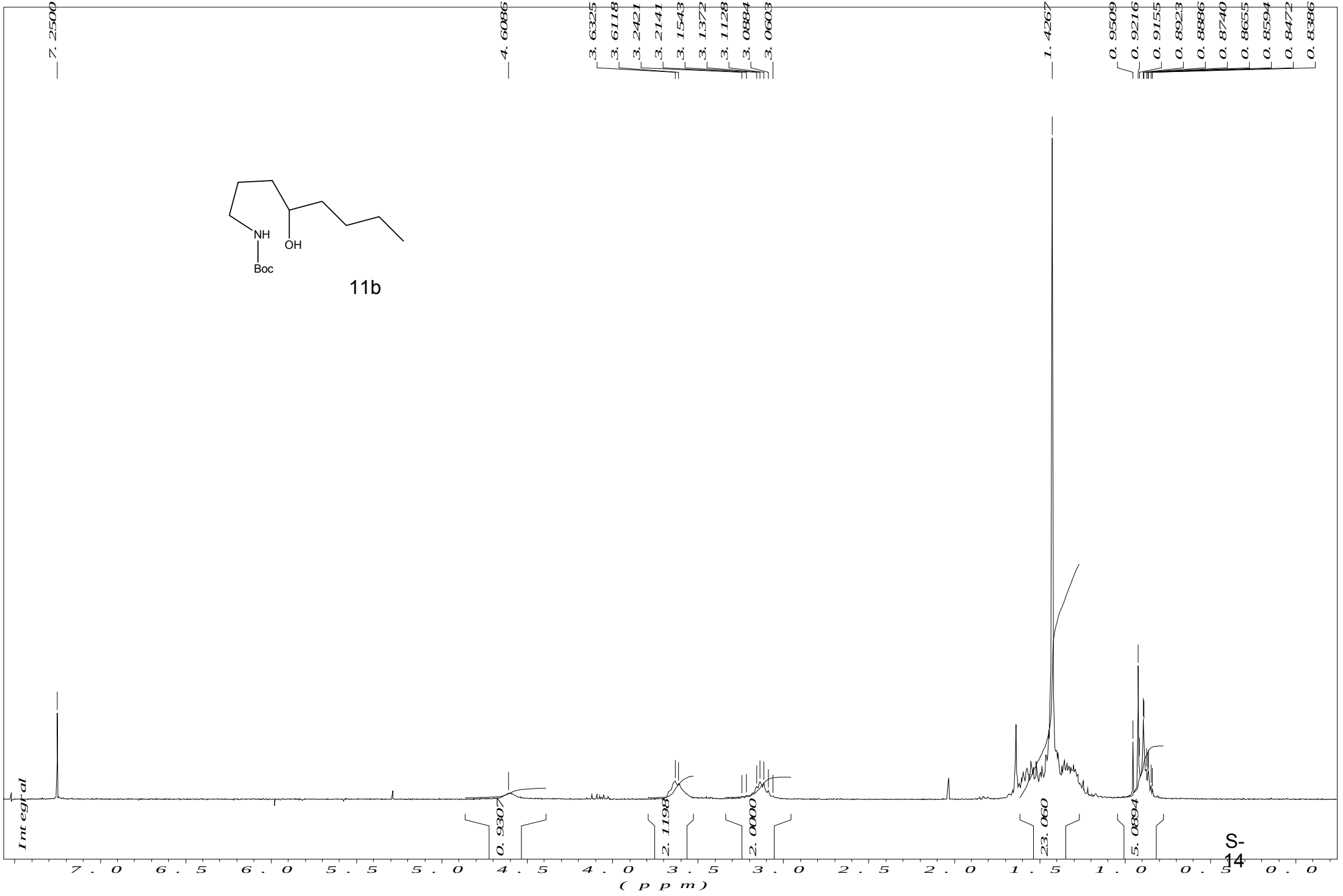
Reflections were measured from a hemisphere of data collected of frames each covering 2.0 degrees in omega. Of the 11793 reflections measured, all of which were corrected for Lorentz and polarisation effects and for absorption by semi empirical methods based on symmetry-equivalent and repeated reflections (minimum and maximum transmission coefficients 0.5137 and 0.9271) 2388 independent reflections exceeded the significance level |Fl/σ(|Fl) > 4.0. The structure was solved by direct methods and refined by full matrix least squares methods on F^2. Hydrogen atoms were placed geometrically and refined with a riding model (including torsional freedom for methyl groups) and with U_{iso} constrained to be 1.2 (1.5 for methyl groups) times U_{eq} of the carrier atom. Refinement converged at a final R= 0.0440 (wR_2 = 0.0900, for all 2714 data, 273 parameters, mean and maximum δ/σ 0.000, 0.000) with allowance for the thermal anisotropy of all non-hydrogen atoms. Minimum and maximum final electron density -0.603 and 0.571 e.Å^{-3}. A weighting scheme w = 1/[σ^2 (Fo^2) +(0.0000∗P)^2+ 2.0845∗P] where P=(Fo^2+ 2 ∗ Fc^2)/3 was used in the latter stages of refinement. Complex scattering factors were taken from the program package SHELXTL.

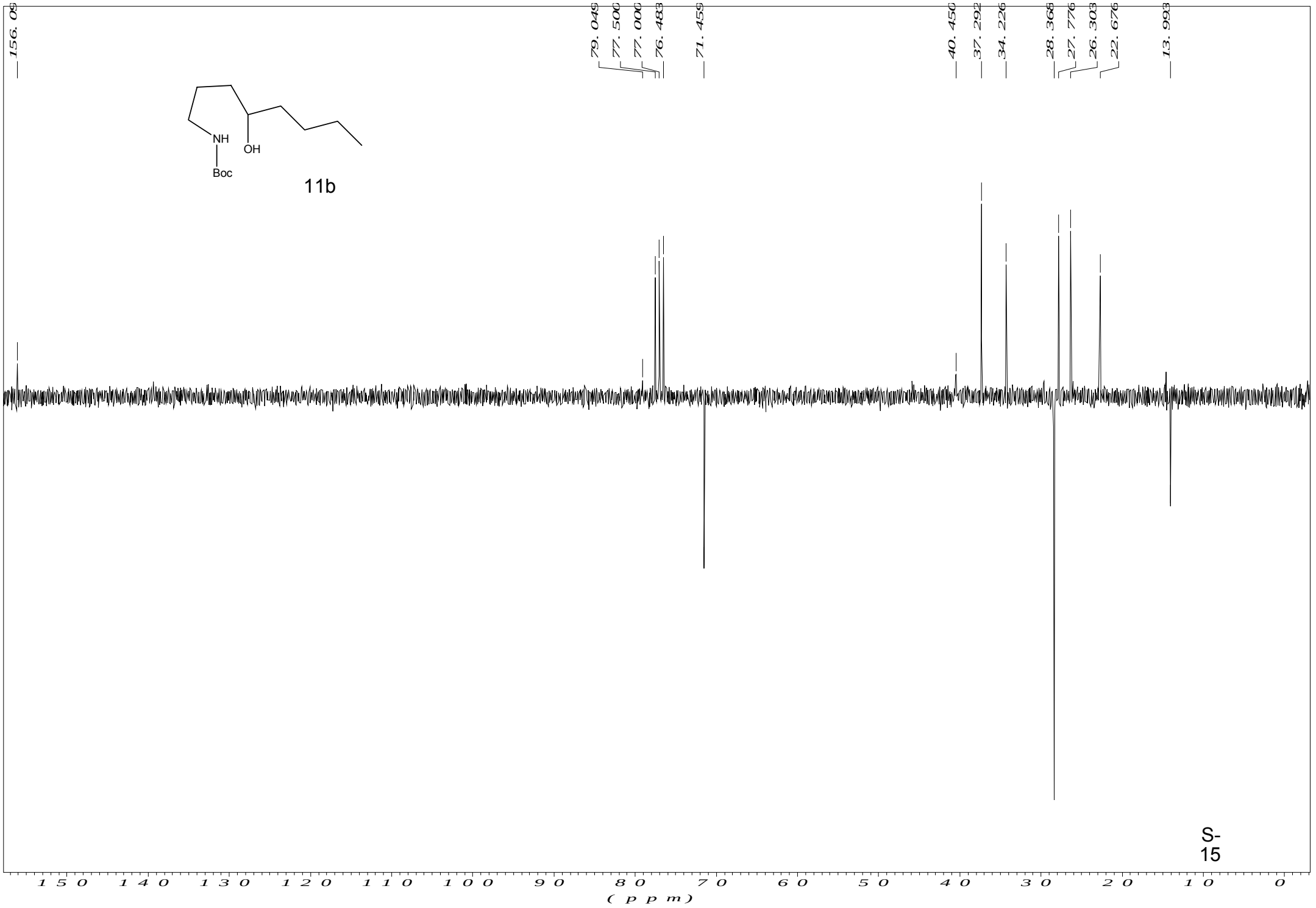
Detailed results are deposited at the Cambridge Crystallographic Data Centre. Structure Number CCDC-664981.

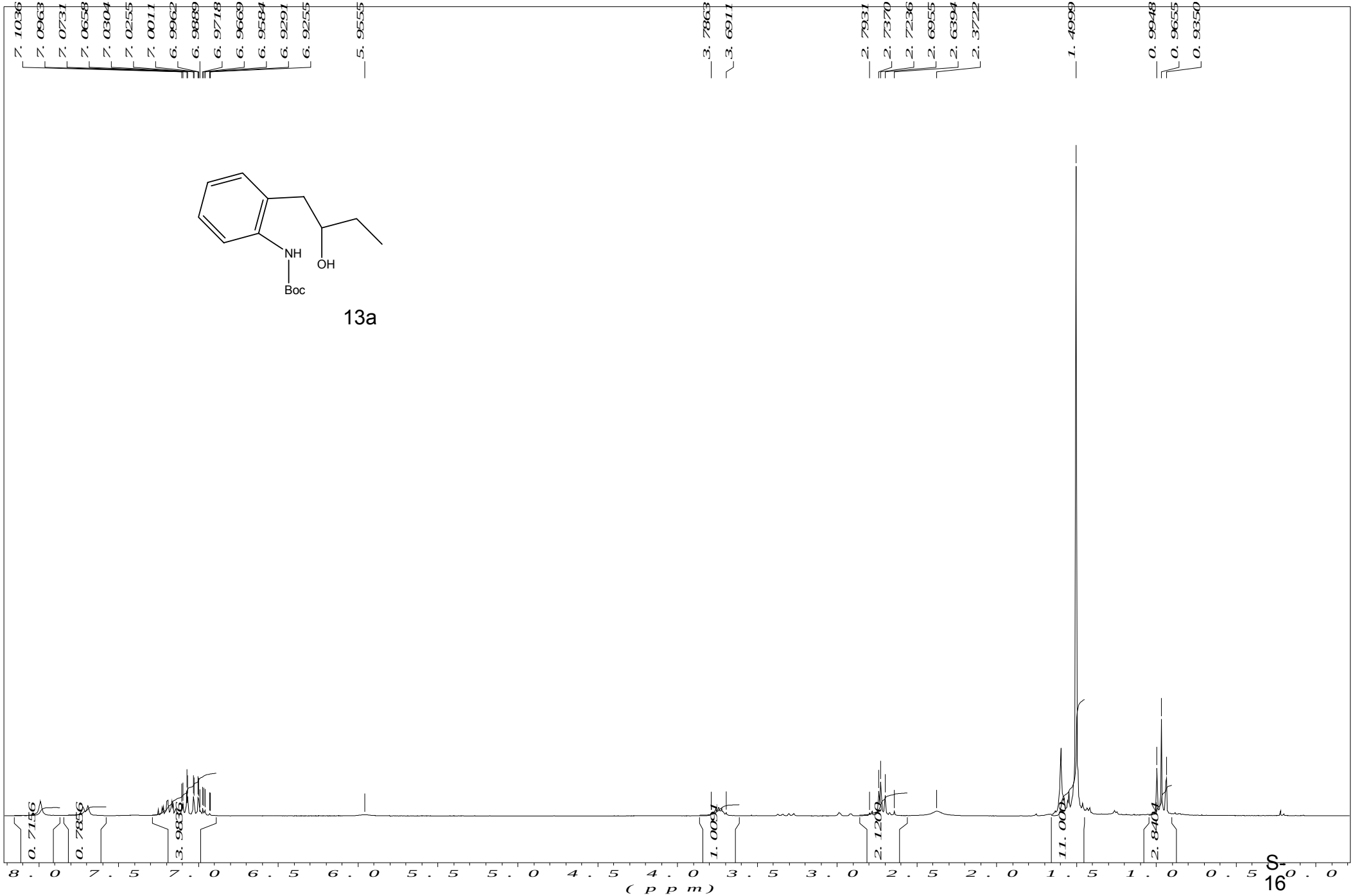
^{1}H and ^{13}C NMR Spectra for products **11a**, **11b**, **13a** and **13b**:


7.2500
4.5964
3.5728
3.5435
3.5264
3.4800
3.1860
3.1616
3.1421
3.1177
3.0908
3.0664
1.4267
0.9545
0.9252
0.8960
NH
OH
Boc
11a
Integral
0.8134
1.0000
2.0437
17.254
3.0800
7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5

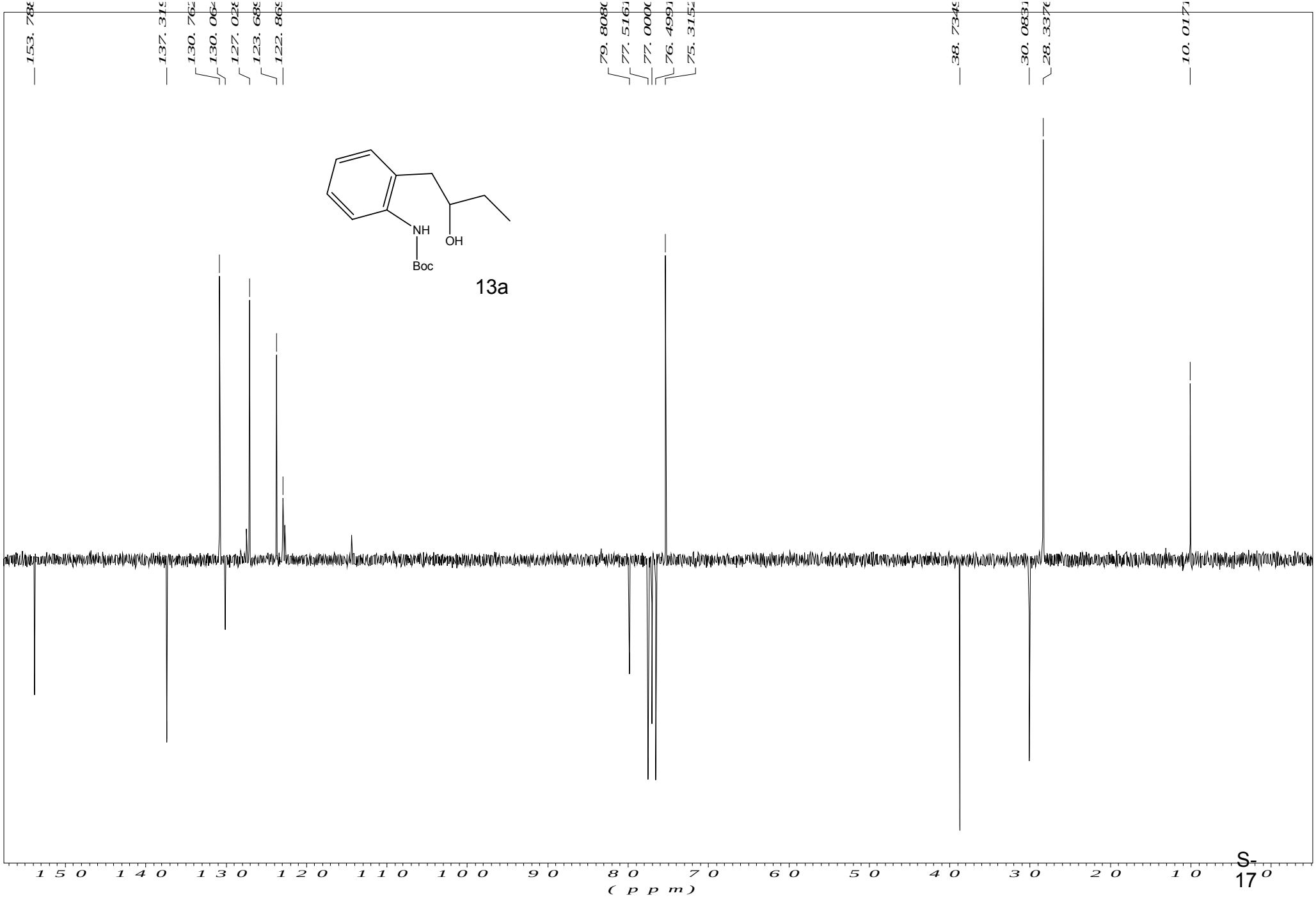

156.07
78.774
77.500
77.000
76.484
72.345
60.230
40.306
33.528
30.056
28.206
26.068
9.7685
NH
OH
Boc
11a
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
(ppm)

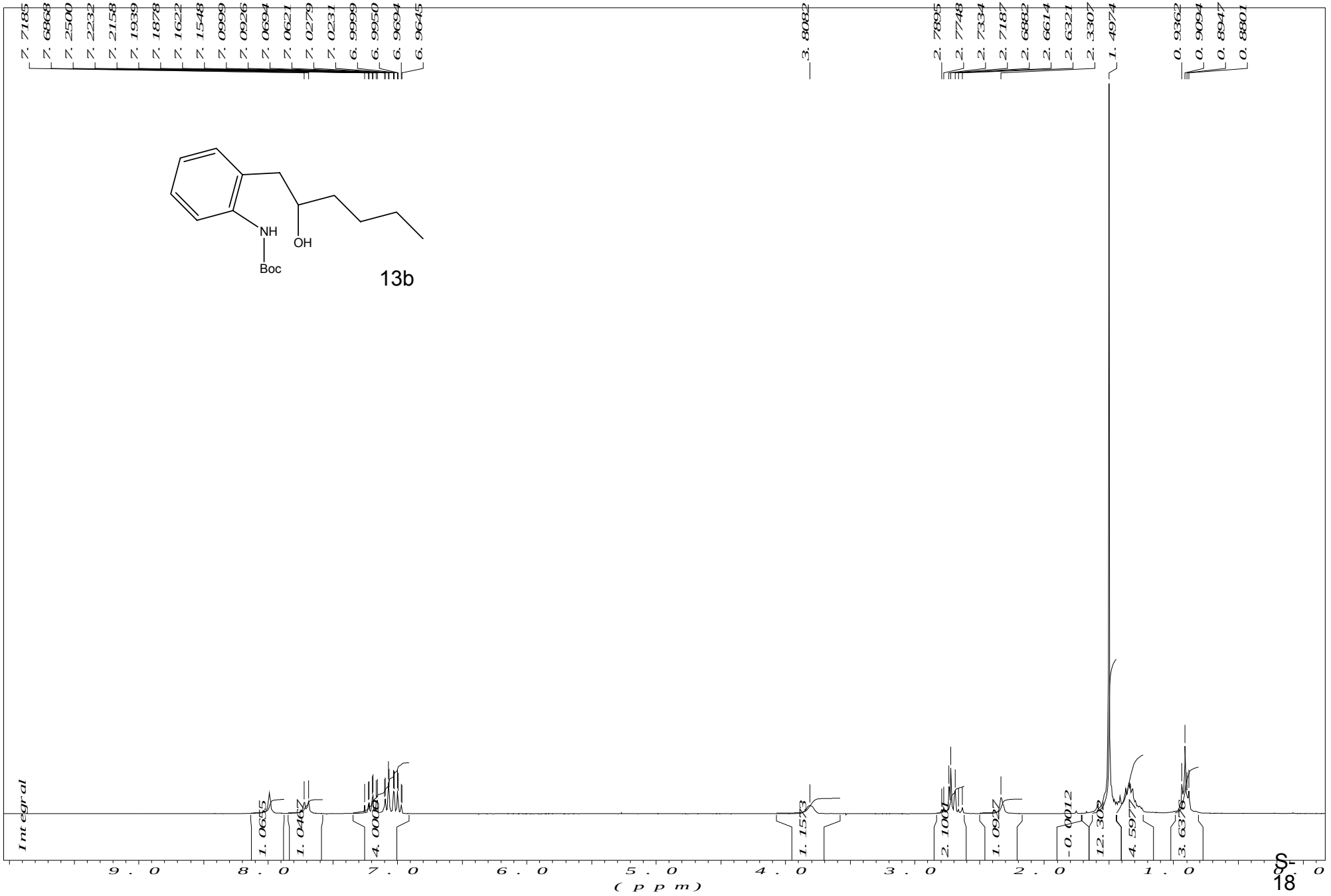

7.2500
4.6086
3.6325
3.6118
3.2421
3.2141
3.1543
3.1372
3.1128
3.0884
3.0603
1.4267
0.9509
0.9216
0.9155
0.8923
0.8886
0.8740
0.8655
0.8594
0.8472
0.8386
NH
OH
Boc
11b
Integral
0.9307
2.1198
2.0000
23.060
5.0894
7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
(ppm)

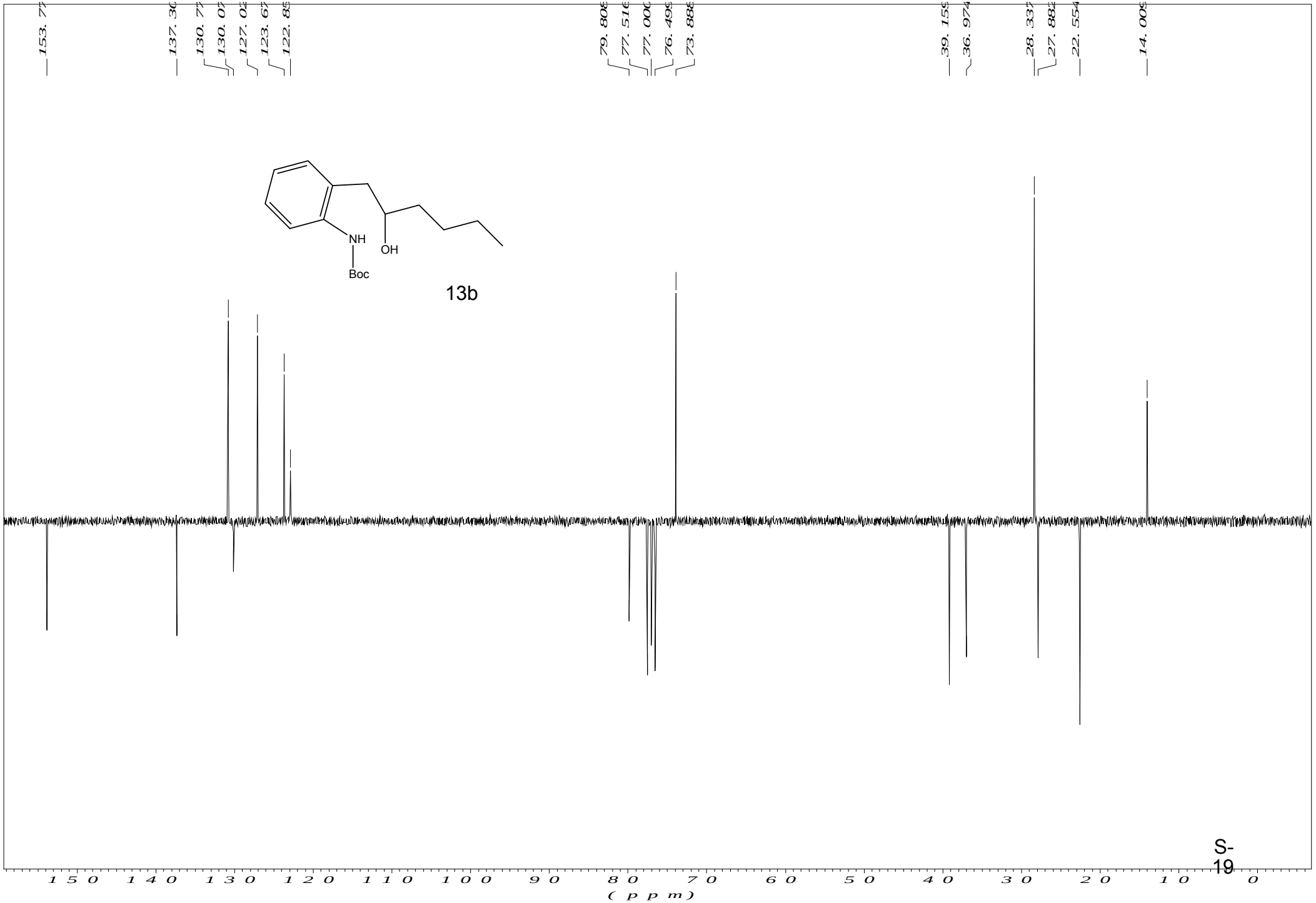

156.09
79.049
77.506
77.000
76.483
71.459
40.450
37.292
34.226
28.368
27.776
26.303
22.676
13.993
NH
OH
Boc
11b
S-15
150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
(ppm)


7.1036
7.0963
7.0731
7.0658
7.0304
7.0255
7.0011
6.9962
6.9889
6.9718
6.9669
6.9584
6.9291
6.9255
5.9555
3.7863
3.6911
2.7931
2.7370
2.7236
2.6955
2.6394
2.3722
1.4999
0.9948
0.9655
0.9350
NH
OH
Boc
0.7156
0.7856
3.9836
1.0091
2.1203
11.0000
2.8404
8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
(ppm)

13a


NH
OH
Boc
13a
(p p m)


7.7185
7.6868
7.2500
7.2232
7.2158
7.1939
7.1878
7.1622
7.1548
7.0999
7.0926
7.0694
7.0621
7.0279
7.0231
6.9999
6.9950
6.9694
6.9645
3.8082
2.7895
2.7748
2.7334
2.7187
2.6882
2.6614
2.6321
2.3307
1.4974
0.9362
0.9094
0.8947
0.8801
NH
OH
Boc
13b
Integral
1.0655
1.0467
4.0003
1.1543
2.1001
1.0927
-0.0012
12.3022
4.5977
3.6378
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
(ppm)


153. 77
137. 30
130. 77
130. 07
127. 04
123. 67
122. 85
79. 80
77. 51
77. 00
76. 49
73. 88
39. 15
36. 97
28. 33
27. 88
22. 55
14. 00
NH
OH
Boc
13b
150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
(ppm)