Supplementary Material (ESI) for Chemical Communications

Supporting Information

Construction of Protected Hydroxylated Pyrrolidines Using Nitrogen-Centered Radical Cyclizations

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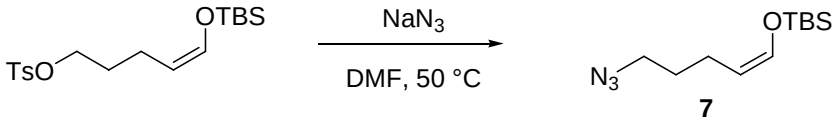
General Methods

All reactions were performed under a nitrogen atmosphere in flame-dried glassware. Tetrahydrofuran, diethyl ether, dichloromethane and benzene were purified by MBRAUN MB-SPS solvent purification system. Thin layer chromatography (TLC) was performed on Whatman Partisil K6F UV_{254} pre-coated TLC plates. Chromatographic separations were effected over Fluka 60 silica gel. Triethylamine washed silica gel has been stirred with triethylamine prior to packing. All chemicals were purchased from commercial sources and used as received. Azide-containing silyl enol ethers, such as azides **7**, **13**, **16**, **19**, **20** and **25,** are bench-stable for at least 2 weeks.

Instrumentation

A KD-Scientific KDS100 syringe pump was used for all slow additions. Melting points were performed using a Mel-Temp II apparatus (Lab devices USA) and are uncorrected. Optical rotations were recorded using a Perkin-Elmer 241 ML Polarimeter. Infrared (IR) spectra were obtained using a Thermo Nicolet 4700 FT-IR spectrometer. Proton nuclear magnetic resonance (^{1}H NMR) spectra were recorded in deuterochloroform using a Bruker AV-300 or AV-400 spectrometer. Carbon nuclear magnetic resonance (^{13}C NMR) spectra were recorded in deuterochloroform using a Bruker AV-300 or AV-400 spectrometer. Chemical shifts are reported in parts per million (ppm) and are referenced to the centerline of deuterochloroform (7.27 ppm ^{1}H NMR; 77.0 ppm ^{13}C NMR). Low resolution mass spectra (LRMS) and high resolution mass spectra (HRMS) were recorded on either a Bruker Esquire-LC spectrometer (for LRMS) or a Waters/Micromass LCT spectrometer (for HRMS).

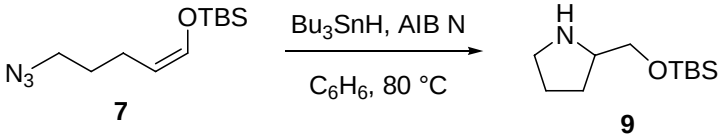
Syntheses of silyl enol ether 7



7

(*Z*)-*tert*-butyl-dimethyl-silanoxy-5-azido-pent-1-ene (7): To a solution of tosylate[1] (1.381 g, 3.73 mmol) in DMF (20 mL) was added sodium azide (533 mg, 7.5 mmol). The mixture was heated at 50 °C for 10 h, then taken up in EtOAc (40 mL). The mixture was then washed with water (2x15 mL), brine (15 mL), dried over Na_2SO_4, filtrated and concentrated by rotary evaporation to provide a yellow oil. Purification by flash chromatography (hexanes) gave 749 mg (83%) of azide **7** (*Z*/*E* = 88:12)[2] as a clear oil. IR (neat) 2931, 2859, 2097, 1656, 1259 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 6.27 (d, *J* = 12.0 Hz, *trans* 1 H), 6.23 (d, *J* = 5.2 Hz, *cis* 1 H), 4.98-4.89 (m, *trans* 1 H), 4.43 (q, *J* = 6.4 Hz, *cis* 1 H), 3.27 (t, *J* = 6.8 Hz, 1 H), 2.17 (q, *J* = 7.2 Hz, 2 H), 1.70-1.58 (m, 2 H), 0.94 (s, 9 H), 0.14 (s, 6 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 139.6, 108.4, 51.0, 28.8, 25.6, 20.8, 18.2, –5.4; HRMS-ESI (*m/z*) $[M+Na]^+$ calcd for $C_{11}H_{23}N_3ONaSi$: 264.1508. Found: 264.1514.

Cyclization to form pyrrolidine 9



7 **9**

2-(*tert*-Butyl-dimethyl-silanyloxymethyl)-pyrrolidine (9): A solution of silyl enol ether **7** (301 mg, 1.27 mmol) Bu_3SnH (438 mg, 1.5 mmol), AIBN (27 mg, 0.15 mmol) in degassed benzene[3] (40 mL) was heated to 80 °C and stirred for 10 h, and the solution was allowed to cool to room temperature and the solvent was removed by rotary evaporation. Purification by flash chromatography (1% methanol in EtOAc) afforded 206 mg (75%) of pyrrolidine **9** as a yellow oil. IR (neat) 3354, 2954, 2857, 1652, 1418 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 3.56 (dd, *J* = 10.0, 4.8 Hz, 1 H), 3.49 (dd, *J* = 10.0, 5.6 Hz, 1 H), 3.19-3.08 (m, 1 H), 2.96 (dt, *J* = 10.0, 6.4 Hz, 1 H), 2.81 (dt, *J* = 10.0, 7.2 Hz, 1 H), 2.57 (s, br, 1 H), 1.79-1.49 (m, 3 H), 1.56-1.46 (m, 1 H), 0.86 (s, 9 H), 0.02 (s, 6 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 65.6, 59.9, 46.4, 27.4, 25.8, 25.3, 18.2, –5.5; HRMS-ESI (*m/z*): $[M+Na]^+$ calcd for $C_{11}H_{26}NOSiNa$: 216.1784. Found: 216.1785.

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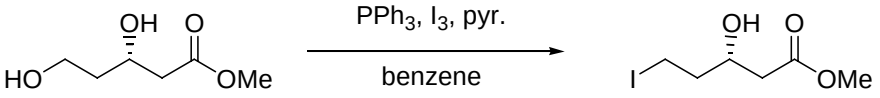
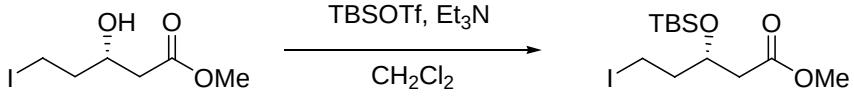
[1] Zlotorzynska, M.; Zhai, H.; Sammis, G.M. *Org. Lett.*, **2008**, *10*, 5083–5086.
[2] The geometry of the silyl enol ethers was assigned based on the magnitude of the *J* coupling in the ^1H NMR.
[3] Benzene is a listed carcinogen within the EEC. Appropriate ventilation and safety precautions should be taken when working with this solvent.



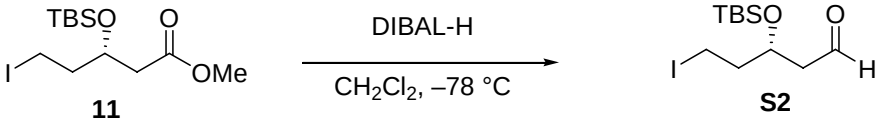
10 **S1**

(3*R*)-Methyl-3-hydroxy-5-iodopentanoate (S1): A solution of (3*S*)-3,5-dihydroxy-pentanoic acid methyl ester (**10**)[4] (6.31 g, 42.6 mmol), triphenylphosphine (17.37 g, 64.5 mmol), pyridine (10.20 g, 129.0 mmol), and iodine (10.91 g, 43.0 mmol) in benzene (500 mL) was stirred for 18 h at room temperature. The reaction mixture was then filtered through a pad of Celite. The filtrate was concentrated by rotary evaporation to provide a light yellow oil. Purification by flash chromatography (20% EtOAc in hexanes) afforded 8.42 g (76%) of iodide **S1** as a colorless oil. $[\alpha]^{D}_{24} = -14.9°$ (*c* = 0.7, CH_2Cl_2); IR (neat) 3434, 2950, 1730, 1436 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 4.11-4.01 (m, 1 H), 3.65 (s, 3 H), 3.32 (d, *J* = 4.4 Hz, 1 H), 3.24 (t, *J* = 6.4 Hz, 2 H), 2.50-2.38 (m, 2 H), 1.98-1.82 (m, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 172.5, 67.5, 51.7, 40.6, 39.7, 2.0. HRMS-ESI (*m/z*): $[M+Na]^+$ calcd for $C_6H_{11}O_3INa$: 280.9651. Found: 280.9657.



S1 **11**

(3*R*)-Methyl-(*tert*-Butyl-dimethyl-silanyloxy)-5-iodo-pentanoate (11): A solution of alcohol **S1** (1.49 g, 5.8 mmol) and triethylamine (1.17 g, 11.6 mmol) in CH_2Cl_2 (50 mL) was cooled to 0 °C and *tert*-butyldimethylsilyl trifluoromethanesulfonate (2.30 g, 8.7 mmol) was added dropwise over 3 min. The resulting solution was stirred for 45 min and then washed with saturated $NaHCO_3$ solution (40 mL). The layers were separated the aqueous layer was extracted with CH_2Cl_2 (30 mL). The combined organic layers were dried over anhydrous Na_2SO_4, filtered and concentrated by rotary evaporation to provide a yellow oil. Purification by flash chromatography (10% EtOAc in petroleum ether) afforded 2.04 g of silyl ether **11** (94 %) as a colorless oil. $[\alpha]^{D}_{24} = -18.9°$ (*c* = 2.6, CH_2Cl_2); (neat) 2952, 2929, 2856, 1738, 1436 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 4.18 (quint, *J* = 5.8 Hz, 1H), 3.69 (s, 3H), 3.11-3.28 (m, 2H), 2.31-2.58 (m, 2H), 1.90-2.13 (m, 2H), 0.88 (s, 9H), 0.12 (s, 3H), 0.08 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 171.3, 69.3, 51.6, 42.0, 41.3, 25.7, 17.9, 1.4, -4.5, -4.7; MS-CI (*m/z*): $[M+H]^+$ calcd for $C_{12}H_{26}IO_3Si$: 373.3. Found: 373.2.

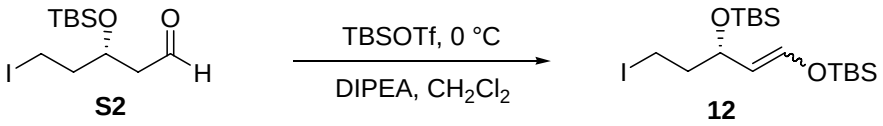


11 **S2**

(3*R*)-(*tert*-Butyl-dimethyl-silanyloxy)-5-iodo-pentanal (S2): Ester **11** (1.98 g, 5.3 mmol) was dissolved in CH_2Cl_2 (27 mL), cooled to –78 °C, and DIBAL-H (1.0 M in hexanes, 10.7 mL) was added in one portion. The solution was stirred for 30 min, then quenched with 20 mL 1:1 MeOH:H_2O. The resulting solution was warmed to ambient temperature and stirred for 15 min. The mixture was then filtered through anhydrous $MgSO_4$ and the solids were rinsed with EtOAc (70 mL). The filtrate was concentrated by rotary evaporation to provide the crude aldehyde as a colorless oil. Purification by flash chromatography (15% EtOAc in petroleum ether) afforded

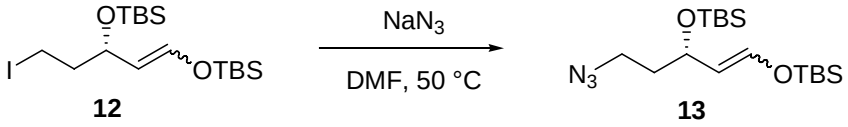
[4] Loubinoux, B.; Sinnes, J. L.; O'Sullivan, A. C.; Winkler, T. *Tetrahedron* **1995**, *51*, 3549-58.

1.55 g of aldehyde **S2** (86 %) as a colorless oil. $[\alpha]^{D}_{24} = -20.6°$ (*c* = 10.8, CH_2Cl_2); IR (neat) 2953, 2928, 2887, 2856, 1724, 1471 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 9.80 (t, *J* = 2.4 Hz, 1H), 4.28 (quint, *J* = 5.5 Hz, 1H), 3.18 (t, *J* = 7.1 Hz, 2H), 2.49 - 2.64 (m, 2H), 1.92 - 2.16 (m, 2H), 0.88 (s, 9H), 0.13 (s, 3H), 0.10 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 201.0, 68.0, 50.4, 41.3, 25.7, 17.9, 1.4, 1.3, -4.4, -4.6, -4.6; MS-CI (*m/z*): $[M+H]^+$ calcd for $C_{11}H_{24}IO_2Si$: 343.1. Found: 343.2.



S2 **12**

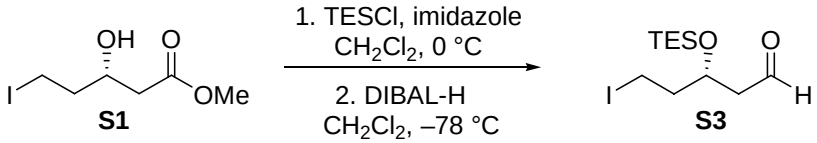
(3*R*)-Bis-(*tert*-butyl-dimethyl-silanyloxy)-5-iodo-pent-1-ene (12): A solution of alcohol **S2** (500 mg, 1.56 mmol) and DIPEA (377 mg, 2.92 mmol) in CH_2Cl_2 (8.0 mL) was cooled to 0 °C and *tert*-butyldimethylsilyl trifluoromethanesulfonate (579 mg, 2.19 mmol) was added dropwise over 2 min. The resulting solution was stirred for 2 h and then washed with saturated $NaHCO_3$ solution (15 mL). The layers were separated the aqueous layer was extracted with CH_2Cl_2 (15 mL). The combined organic layers were dried over anhydrous Na_2SO_4, filtered and concentrated by rotary evaporation to provide a yellow oil. Purification by flash chromatography (hexanes) afforded 610 mg (91 %) of silyl enol ether **12** (*E/Z* 40:60) as a colorless oil. IR (neat) 2929, 2857, 1471, 1252, 1048 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 6.45 (d, *J* = 12.0 Hz, *E*, 1 H), 6.19 (d, *J* = 5.6 Hz, *Z*, 1 H), 4.99 (dd, *J* = 12.0, 8.8 Hz, *E*, 1 H), 4.84-4.77 (m, *Z*, 1 H), 4.52 (dd, *J* = 8.8, 5.6 Hz, *E*, 1 H), 4.20-4.12 (m, *E*, 1 H), 3.28-3.19 (m, 2 H), 2.10-1.91 (m, 2 H), 0.98 (s, 9 H), 0.96 (s, 9 H), 0.92 (s, 9 H), 0.91 (s, 9 H), 0.18 (s, 3 H), 0.14 (s, 3 H), 0.10 (s, 3 H), 0.06 (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 142.5, 138.7, 113.6, 113.4, 70.8, 66.1, 42.5, 42.3, 25.916, 25.877, 25.63, 25.61, 18.1, 3.4, 3.2, -4.0, -4.3, -4.6, -4.9, -5.2, -5.4.[5]



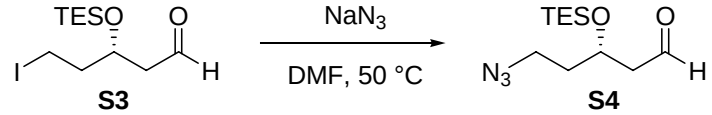
12 **13**

(3*R*)-Bis-(*tert*-butyl-dimethyl-silanyloxy)-5-azido-pent-1-ene (13): A solution of iodide **12** (457 mg, 1.0 mmol) and NaN_3 (130 mg, 2.0 mmol) in DMF (8 mL) was heated to 50 °C for 1 h. The resulting yellow mixture was taken up in Et_2O (10 mL) and washed with brine (5x10 mL). The organic layer was dried over anhydrous Na_2SO_4, filtered and concentrated by rotary evaporation to provide crude azide (**13**) as a yellow oil. Purification by flash chromatography (5% EtOAc in hexanes) afforded 237 mg (64 %) of azide **13** (*E/Z* 40:60) as a yellow oil. IR (neat) 2954, 2928, 2857, 2095, 1655, 1472, 1463 cm^{-1};^1H NMR (400 MHz, $CDCl_3$) δ 6.40 (d, *J* = 12.3 Hz, *E*, 1 H), 6.15 (d, *J* = 6.2 Hz, *Z*, 1 H), 4.81 (dd, *J* = 12.0, 8.1 Hz, *E*, 1H), 4.49 (dd, *J* = 8.5, 6.2 Hz, *Z*, 1H), 3.41-3.21 (m, 2H), 1.88-1.71 (m, 2H), 0.94 (s, 9 H), 0.93 (s, 9 H), 0.89 (s, 9 H), 0.88 (s, 9 H), 0.14 (s, 3 H), 0.08 (s, 3 H), 0.06 (s, 3 H), 0.03 (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 142.3, 138.4, 114.0, 113.6, 68.0, 63.5, 48.0, 38.1, 37.3, 25.9, 25.7, 25.7, 25.6, 25.5, -2.9, -4.4, -4.8, -5.1, -5.3, -5.5; MS-ESI (*m/z*): $[M+H]^+$ calcd for $C_{17}H_{37}N_3NaO_2Si_2$: 394.2. Found: 394.3.

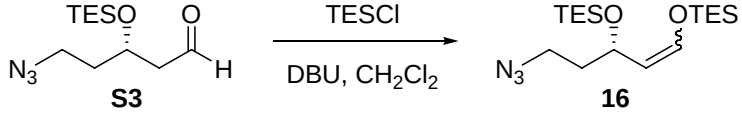
[5] Mass spectroscopy was attempted, but was not successful. The material was further derivatized for structural proof.



(3*R*)-5-iodo-3-(triethylsilanyloxy)pentanal (S3): To a solution of alcohol **S1** (2.51 g, 9.7 mmol) and imidazole (990 mg, 14.6 mmol) in CH_2Cl_2 (35 mL) at 0 °C was added chlorotriethylsilane (1.77 g, 11.6 mmol) dropwise over 3 min. The solution was stirred for 40 min and a white precipitate appeared during this time. The reaction was quenched with saturated $NaHCO_3$ solution (30 mL) and the layers were separated. The aqueous layer was extracted with CH_2Cl_2 (20 mL). The combined organic layers were dried over anhydrous $MgSO_4$, filtered, and concentrated by rotary evaporation to provide 4.14 g of silyl ether as a yellow oil. The crude product was dissolved in CH_2Cl_2 (27 mL), cooled to –78 °C, and DIBAL-H (1.0 M in hexanes, 29 mL) was added in one portion. The solution was stirred for 2 h, then quenched with 20 mL 1:1 MeOH:H_2O. The resulting solution was warmed to ambient temperature and stirred for 15 min. The mixture was then filtered through anhydrous $MgSO_4$ and the solids were rinsed with EtOAc (100 mL). The filtrate was concentrated by rotary evaporation to provide the crude aldehyde (**S3)** as a colorless oil. Purification by flash chromatography (10% EtOAc in hexanes) afforded 2.01 g of aldehyde **S3** (61 %) as a colorless oil. IR (neat) 2954, 2909, 2875, 1723, 1457 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 9.81 (t, J = 2.4 Hz, 1 H), 4.30 (dt, J = 6.2, 5.5 Hz, 1 H), 3.21 (t, J = 7.3 Hz, 2 H), 2.60-S2.57 (m, 2 H), 2.12-2.00 (m, 2 H), 0.97 (t, J = 7.9 Hz, 9 H), 0.65 (q, J = 7.9 Hz, 6 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 201.0, 68.0, 50.6, 41.4, 6.8, 5.0, 1.3.

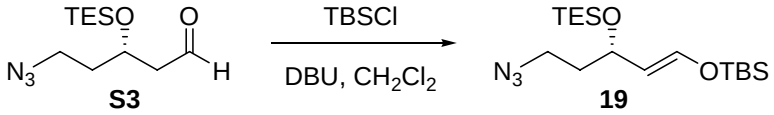


(3*S*)-5-azido-3-(triethylsilanyloxy)pentanal (S4): A solution of iodide **S3** (1.87g, 5.5 mmol) and NaN_3 (710 mg, 10.9 mmol) in DMF (20 mL) was heated to 50 °C for 18 h. The resulting yellow mixture was taken up in Et_2O (30 mL) and washed with brine (5x20 mL). The organic layer was dried over anhydrous Na_2SO_4, filtered and concentrated by rotary evaporation to provide the crude azide (**S4**) as a yellow oil. Purification by flash chromatography (5% EtOAc in hexanes) afforded 447 mg of azide **S4** (31 %) as a yellow oil. $[\alpha]^D_{24} = -34.0°$ (c = 0.2, CH_2Cl_2); IR (neat) 2955, 2912, 2877, 1094, 1724, 1458 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 9.82 (t, J = 2.4 Hz, 1 H), 4.35 (quint, J = 5.8 Hz, 1 H), 3.43-3.39 (m, 2 H), 2.61 (dd, J = 5.8, 2.1 Hz, 2 H), 1.83-1.78 (m, 2 H), 0.97 (t, J = 7.9 Hz, 9 H), 0.63 (q, J = 7.9 Hz, 6 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 201.0, 65.0, 51.0, 47.5, 36.4, 6.7, 4.8.



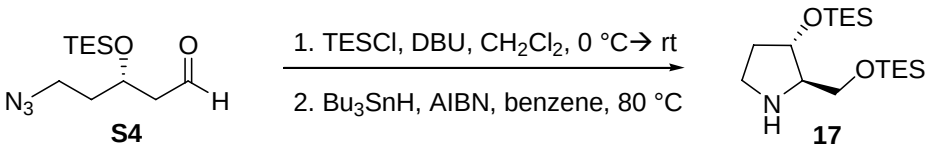
(3*R*)-Bis-(triethylsilanyloxy)-5-azido-pent-1-ene (16): To a solution of **S4** (45 mg, 0.17 mmol) and 1,8-diazabicyclo[5.4.0]undec-7-ene (52 mg, 0.34 mmol) in CH_2Cl_2 (0.9 mL) was added chlorotriethylsilane (38 mg, 0.26 mmol). The solution was stirred for 20 h. The resulting yellow

solution was then concentrated by rotary evaporation and purified by flash chromatography (hexanes) to afford 21 mg of the silyl enol ether **16** (*Z*/*E* = 40:60), along with 82 mg of triethylsilanol as a colorless oil. ^{1}H NMR (300 MHz, $CDCl_3$) δ 6.41 (d, *J*=11.9 Hz, 1H, *trans*), 6.19 (dd, *J*=5.9, 1.1 Hz, 1H, *cis*) 4.98 (dd, *J*=12.1, 8.5 Hz, 1H, *trans*), 4.87-4.79 (m, 1H, *cis*), 4.48 (dd, *J*=8.7, 5.9 Hz, 1H, *cis*), 4.23-4.00 (m, 1H, *trans*), 3.45-3.17 (m, 2H), 1.94-1.62 (m, 2H), 0.93 (t, *J*=9 Hz, 9 H, triethylsilanol), 0.53 (q, *J*=9 Hz, 6 H, triethylsilanol).



S3 **19**

***(E)*-(3*R*)-5-azido-3-triethylsilanyloxy-1-(*tert*-butyl-dimethyl-silanyloxy)-pent-1-ene (19)**: To a solution of **S4** (50 mg, 0.19 mmol) and 1,8-diazabicyclo[5.4.0]undec-7-ene (86 mg, 0.57 mmol) in CH_2Cl_2 (2 mL) was added *tert*-butyldimethylsilyl chloride (57 mg, 0.38 mmol). The solution was heated to 35 °C in a sealed tube for 14 h. The resulting yellow solution was then concentrated by rotary evaporation and purified by flash chromatography (1% EtOAc in hexanes) to afford 54 mg (76%) of silyl enol ether **19** (*Z*/*E* < 5:95). ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.40 (d, *J*=12.0 Hz, 1H), 4.98 (dd, *J*=8.5, 12.0 Hz, 1H), 4.25-3.95 (m, 1H), 3.44-3.17 (m, 2H), 1.90-1.75 (m, 1H), 1.75-1.63 (m, 1 H), 0.95 (t, *J*=8.0 Hz, 9H), 0.93 (s, 9H), 0.60 (q, *J*=8.0 Hz, 6H), 0.16 (s, 6H).



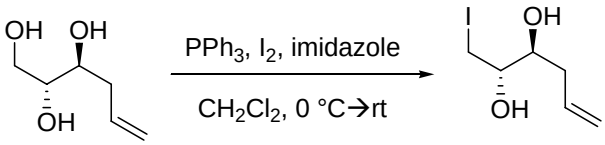
S4 **17**

(2*R*,3*S*)-2,3-bis(triethylsilanyloxy)-pyrrolidine (17): To a solution of aldehyde **S4** (80 mg, 0.31 mmol) and 1,8-diazabicyclo[5.4.0]undec-7-ene (142 mg, 0.93 mmol) in CH_2Cl_2 (2 mL) at 0 °C was added chlorotriethylsilane (93 mg, 0.62 mmol) in one portion. The solution was stirred for 15 min, then the solution was allowed to warm to room temperature and stirred for 18 h. The resulting yellow solution was then concentrated by rotary evaporation and purified by flash chromatography (hexanes) to afford 17 mg of the silyl enol ether **20** (*Z*/*E* > 95:5), along with 74 mg of triethylsilanol as a colorless oil. ^{1}H NMR (300 MHz, $CDCl_3$) δ 6.19 (dd, *J*=5.9, 1.1 Hz, 1H), 4.87-4.79 (m, 1H), 4.48 (dd, *J*=8.7, 5.7 Hz, 1H), 3.33 (t, *J*=7.4 Hz, 2H), 1.76-1.69 (m, 2H), 0.93 (t, *J*=9 Hz, 9 H, triethylsilanol), 0.53 (q, *J*=9 Hz, 6 H, triethylsilanol).[6]

This oil was taken up in benzene (10 mL) and the solution was degassed by bubbling with N_2 for 30 min. The solution was then brought to reflux and a solution of tributyltin hydride (73 mg, 0.25 mmol) and AIBN (9 mg, 0.05 mmol) in benzene (2 mL) was added dropwise over 2 hours. After refluxing for an additional 11 h, the solution was allowed to cool to room temperature and the solvent was removed by rotary evaporation. Purification by flash chromatography (2% MeOH in CH_2Cl_2) afforded 12 mg of amine **17** (77% from silyl enol ether **20**). $[\alpha]^D_{24} = -17.2°$ (*c* = 0.8, CH_2Cl_2); IR (neat) 2955, 2876, 1652, 1458 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.18-4.05 (m, 1H), 3.65-3.45 (m, 2H), 3.14-3.01 (m, 1H), 3.01-2.98 (m, 2H), 1.99-1.77 (m, 3H), 0.96 (t, *J*=7.9

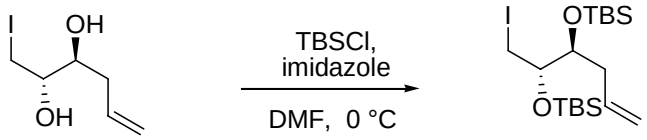
[6] For NMR data for a mixture of the *E* and *Z* silyl enol ether, see data for compound **16**.

Hz, 18 H), 0.60 (q, *J*=7.9 Hz, 12 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 73.9, 68.5, 63.4, 45.1, 35.6, 6.9, 5.0, 4.5; HRMS-ESI (*m/z*): $[M+H]^+$ calcd for $C_{17}H_{40}NO_2Si_2$: 346.2598. Found: 346.2605.



22 **S5**

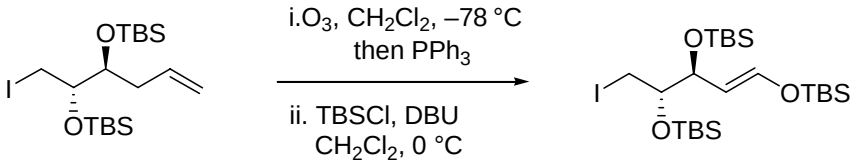
(4*S*,5*S*)-6-Iodo-hex-1-ene-diol (S5): To a solution of known triol **22**[7] (3.72 g, 28.0 mmol) in THF (150 mL) at 0 °C was added triphenylphosphine (9.61 g, 36.4 mmol), imidazole (2.86 g, 42.0 mmol), and iodine (8.53 g, 33.6 mmol) and the solution was stirred for 5 h at room temperature. A white precipitate of imidazole hydroiodide was formed, which was removed by filtering the mixture through a pad of Celite. The filtrate was washed with saturated $Na_2S_2O_3$ solution (2x25 mL), brine (25 mL), dried over Na_2SO_4, filtered and concentrated by rotary evaporation to provide a yellow oil. Purification by flash chromatography (4:1 hexanes/EtOAc) afforded 4.61 g (68%) of iodide **S5** as a white solid. $[\alpha]^D_{24}$ = 342.7° (*c* = 0.2, CH_2Cl_2); Mp: 83 °C; IR (neat) 3275, 2893, 1500, 1413, 1105 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.92-5.75 (m, 1 H), 5.19 (m, 2 H), 3.68 (s, br 1 H), 3.59-3.33 (m, 3 H), 2.47 (d, *J* = 4.0 Hz, 2 H), 2.32-2.12 (m, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 133.9, 119.0, 73.5, 72.4, 37.2, 12.2; MS-ESI (*m/z*): $[M+H]^+$ calcd for $C_6H_{12}IO_2$: 243.1. Found: 243.2.



S5 **23**

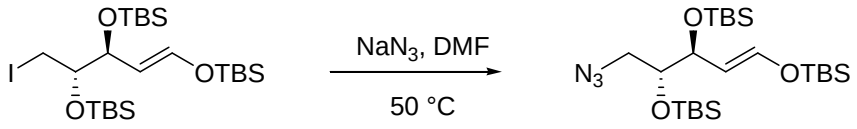
(4*S*,5*S*)-Bis-(*tert*-butyl-dimethyl-silanyloxy)-6-iodo-hex-1-ene (23): To a solution of iodide **S5** (4.48 g, 18.5 mmol) in DMF (60 mL) at 0 °C was added imidazole (7.55 g, 111 mmol) in one portion. *tert*-Butyldimethylsilyl chloride (6.70 g, 44.4 mmol) was added in small portions to the cold solution. The reaction mixture then allowed to warm to ambient temperature and stirred for 2 days. The reaction was diluted with EtOAc (90 mL) an then the mixture was washed with water (3x40 mL) and brine (40 mL). The organic layer was dried over Na_2SO_4, and the solvent was removed by rotary evaporation to provide a light yellow oil. Purification by flash chromatography (1% EtOAC in hexanes) afforded 7.04 g (81%) of iodide **23** as a white solid. $[\alpha]^D_{24}$ = 95.3° (*c* = 0.5, CH_2Cl_2); Mp: 42 °C; IR (neat) 2956, 2858, 1666, 1472, 1255 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.91-5.78 (m, 1 H), 5.10 (d, *J* = 6.8 Hz, 1 H), 5.07 (s, 1 H), 3.76 (q, *J* = 4.8 Hz, 1 H), 3.49-3.39 (m, 1 H), 3.33-3.24 (m, 2 H), 2.41-2.29 (m, 2 H), 0.94 (s, 9 H), 0.90 (s, 9 H), 0.16 (s,0 3 H), 0.14 (s, 3 H), 0.11 (s, 3 H), 0.09 (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 134.5, 117.4, 74.6, 73.1, 37.0, 26.0, 25.9, 18.1, 13.3, –4.1, –4.2, –4.4. [5]

[7] Morita, M.; Haketa, T.; Koshino, H.; Nakata, T. *Org. Lett.* **2008**, *10*, 1679-1682.



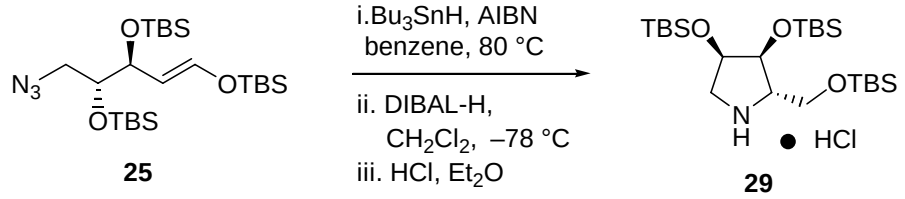
23 **24**

(*E*)-(1,3*S*,4*S*)-Tris-(*tert*-butyl-dimethyl-silanyloxy)-5-iodo-pent-1-ene (24): A solution of iodide **23** (2.71 g, 5.77 mmol) in CH_2Cl_2 (60 mL) at –78 °C was sparged with ozone for 50 min. Triphenylphosphine (1.58 g, 6.0 mmol) was then added in one portion, and the mixture was stirred for an additional 30 min at –78 °C. The reaction was then warmed to 0 °C. To this solution was added 1,8-diazabicyclo[5.4.0]undec-7-ene (2.90 g, 19.0 mmol) and *tert*-butyldimethylsilyl chloride (1.30 g, 8.7 mmol). The resulting solution was allowed to warm to ambient temperature and stirred for 24 h. The reaction mixture was then quenched with saturated $NaHCO_3$ solution (15 mL) and extracted with CH_2Cl_2 (2x10 mL). Excess triphenylphosphine was quenched by adding a solution of I_2 in CH_2Cl_2 (1 M). The organic extracts were dried over Na_2SO_4, filtered, and the solvent was removed by rotary evaporation to provide a yellow oil. Purification by flash chromatography (1% EtOAc in hexanes) gave 1.90 g (55% over 2 steps) of silyl enol ether **24** (*E*/*Z* > 95:5) as a colorless oil. IR (neat) 2958, 2858, 1655, 1463, 1363, 1256 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 6.36 (d, *J* = 12.0 Hz, 1 H), 4.91 (dd, *J* = 12.0, 9.2 Hz, 1 H), 4.00 (dd, *J* = 9.2, 6.4 Hz, 1 H), 3.43 (dd, *J* = 10.0, 3.2 Hz, 1 H), 3.28-3.22 (m, 1 H), 3.17 (dd, *J* = 10.0, 5.2 Hz, 1 H), 0.93 (s, 9 H), 0.91 (s, 9 H), 0.90 (s, 9 H), 0.16 (s, 3 H), 0.15 (s, 3 H), 0.11 (s, 3 H), 0.09 (s, 3 H), 0.08 (s, 3 H), 0.07 (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 143.6, 110.7, 74.5, 73.9, 26.0, 25.9, 25.6, 18.13, 18.10, –3.8, –4.3, –4.4, –4.5, –5.1, –5.2.[5]



24 **25**

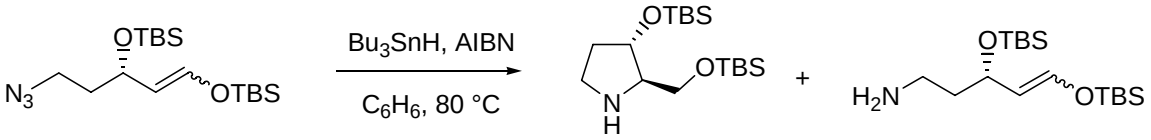
(*E*)-5-Azido-(1,3*S*,4*S*)-(*tert*-butyl-dimethyl-silanyloxy)-pent-1-ene (25): To a solution of iodide **24** (1.708 g, 2.91 mmol) in DMF (20 mL) was added sodium azide (426 mg, 6.0 mmol). The mixture was heated at 50 °C for 10 h and then diluted with EtOAc (60 mL). The reaction solution was washed with water (2x20 mL), brine (20 mL). The organics layer was then dried over Na_2SO_4, filtrated and concentrated by rotary evaporation to provide a yellow oil. Purification by flash chromatography (hexanes) gave 1.23 g (84%) of azide **25** (*E*/*Z* > 95:5) as a clear oil. $[\alpha]^D_{24}$ = 262.7° (*c* = 0.2, CH_2Cl_2); IR (neat) 2956, 2858, 2102, 1667, 1472, 1256 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 6.35 (d, *J* = 12.0 Hz, 1 H), 4.90 (dd, *J* = 12.0, 7.2 Hz, 1 H), 3.99 (dd, *J* = 8.8, 5.6 Hz, 1 H), 3.61 (q, *J* = 4.8 Hz, 1 H), 3.39 (dd, *J* = 12.4, 3.6 Hz, 1 H), 3.31 (dd, *J* = 12.4, 4.8 Hz, 1 H), 0.93 (s, 9 H), 0.91 (s, 9 H), 0.88 (s, 9 H), 0.150 (s, 3 H), 0.147 (s, 3 H), 0.11 (s, 3 H), 0.08 (s, 3 H), 0.07 (s, 3 H), 0.05 (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 143.4, 111.3, 75.7, 72.6, 54.0, 25.90, 25.88, 25.58, 18.15, 18.11, 18.07, –3.9, –4.4, –4.6, –4.7, –5.1, –5.2.[5]



(2*S*,3*S*,4*R*)-3,4-Bis(*tert*-butyldimethylsilyloxy)-2-((*tert*-butyldimethylsilyloxy)methyl)-pyrrolidine Hydrochloride (29): To a solution of silyl enol ether (131 mg, 0.26 mmol), and AIBN (4 mg) in degassed benzene (26 mL) at 80 °C was added a solution of tributyltin hydride (76 mg, 0.26 mmol) and AIBN (4 mg, 0.1 equiv.) in benzene (5 mL) dropwise, via syringe pump, over 2 hours. The reaction was stirred at 80 °C for another 3 hours. The solution was allowed to cool to room temperature and the solvent was removed by rotary evaporation. The resulting residue was dissolved in CH_2Cl_2 (5 mL) and cooled to –78 °C. DIBALH (0.4 mL, 1.0 M in toluene) was added dropwise over 3 min and the solution was stirred at –78 °C for 1 hour. The reaction was quenched with saturated $NaHCO_3$ (5 mL), and the aqueous layer was extracted with CH_2Cl_2 (2x10 mL). The combined organic extracts were dried over Na_2SO_4, filtered, and the solvent was removed by rotary evaporation to provide a pale yellow oil. Purification by flash chromatography (15% EtOAc in hexanes) afforded 78 mg colorless oil as the cyclized product **26** (containing 8% of reduced primary amine **28**) and 6 mg (5 %) of pure cylized product **26**: $[\alpha]^{D}_{24} = -88.8°$ (*c* = 0.3, CH_2Cl_2); IR (neat) 2950, 2856, 1252, 1164 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 4.16-4.05 (m, 2 H), 3.79 (d, *J* = 6.8 Hz, 2 H), 3.29 (q, *J* = 6.4 Hz, 1 H), 3.15 (dd, *J* = 10.8, 5.6 Hz, 1 H), 3.27 (dd, *J* = 10.8, 4.2 Hz, 1 H), 2.94-2.72 (br, s, 1 H), 0.92 (s, 9 H), 0.90 (s, 18 H), 0.11 (s, 3 H), 0.10 (s, 3 H), 0.08 (s, 6 H), 0.07 (s, 6 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 73.9, 73.7, 62.6, 61.7, 50.1, 25.98, 25.94, 18.34, 18.30, 18.24, –4.3, –4.6, –4.8, –5.0, –5.27, –5.28; HRMS-ESI (*m/z*): $[M+H]^+$ calcd for $C_{23}H_{54}NO_3Si_3$: 476.3412. Found: 476.3415.

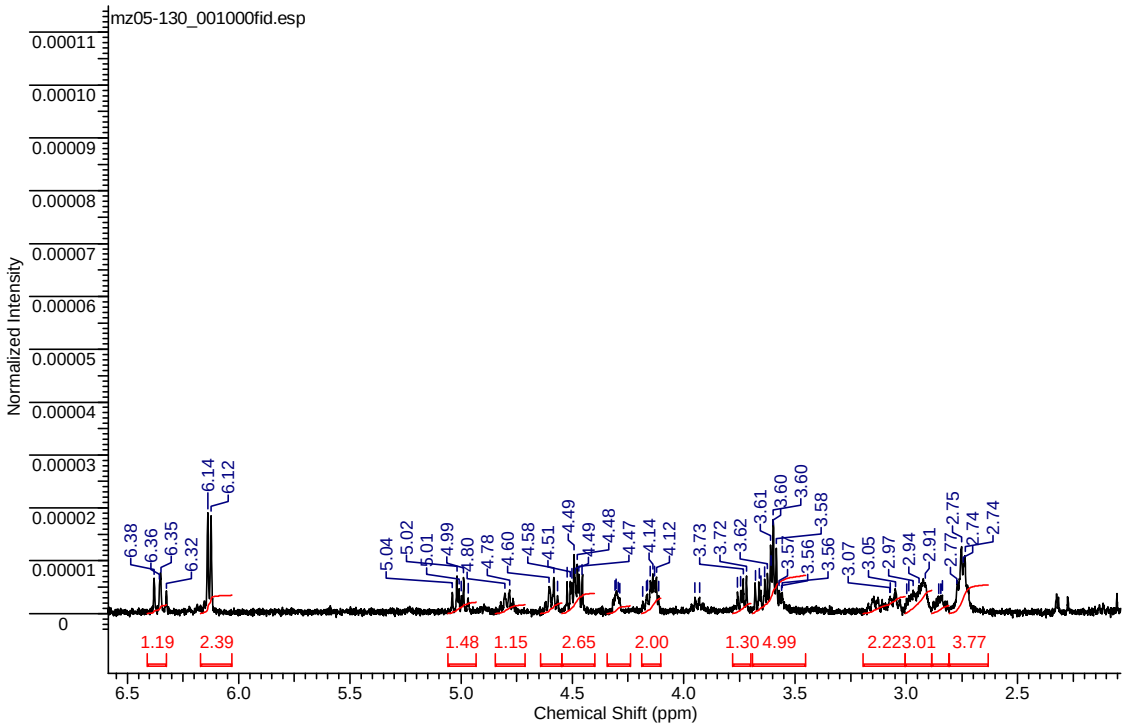
To further purify the cyclized product from the free amine byproduct, the impure product mixture (78 mg) was dissolved in CH_2Cl_2 (1 mL) and HCl in diethyl ether (0.2 mL, 1.0 M) was added and the flask. The resulting solution was stirred for 5 min. Hexanes (10 mL) was added and the solution was cooled to 4 °C and let stand for 6h. Pure white solid as the HCl salt **29** (77 mg, 58%) was isolated by filtration. $[\alpha]^{D}_{24} = -18.5°$ (*c* = 0.6, CH_2Cl_2); Mp: 271-272 °C; IR (neat) 2954, 2857, 1472, 1254 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 10.9-10.2 (b, s, 1 H), 9.3-8.4 (b, s, 1 H), 4.24 (dd, *J* = 10.8, 4.0 Hz, 2 H), 3.98 (d, *J* = 7.6 Hz, 2 H), 3.57 (t, *J* = 4.0 Hz, 1 H), 3.47-3.40 (m, 1 H), 3.27 (dd, *J* = 11.2, 6.4 Hz, 1 H), 0.93 (s, 9 H), 0.90 (s, 18 H), 0.12 (s, 12 H), 0.10 (s, 6 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 72.2, 72.0, 61.5, 58.8, 47.4, 25.92, 25.87, 18.22, 18.17, –4.3, –4.6, –4.9, –5.0, –5.2, –5.4.

Cyclization optimization for Protected CYB-3



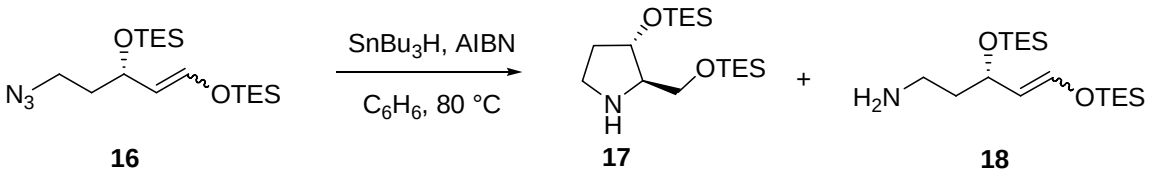
13 **14** **15**

A solution of silyl enol ether **13** (402 mg, 1.08 mmol) Bu_3SnH (409 mg, 1.4 mmol), AIBN (36 mg, 0.22 mmol) in degassed benzene (22 mL) was heated to 80 °C and stirred for 18 h. The solution was allowed to cool to room temperature and the solvent was removed by rotary evaporation. Analysis of the ^1H NMR spectrum showed no remaining starting material, and products **14**[8] and **15** in a 46:54 ratio. Amine **14** was present in a 60:40 ratio of *trans* and *cis* isomers.



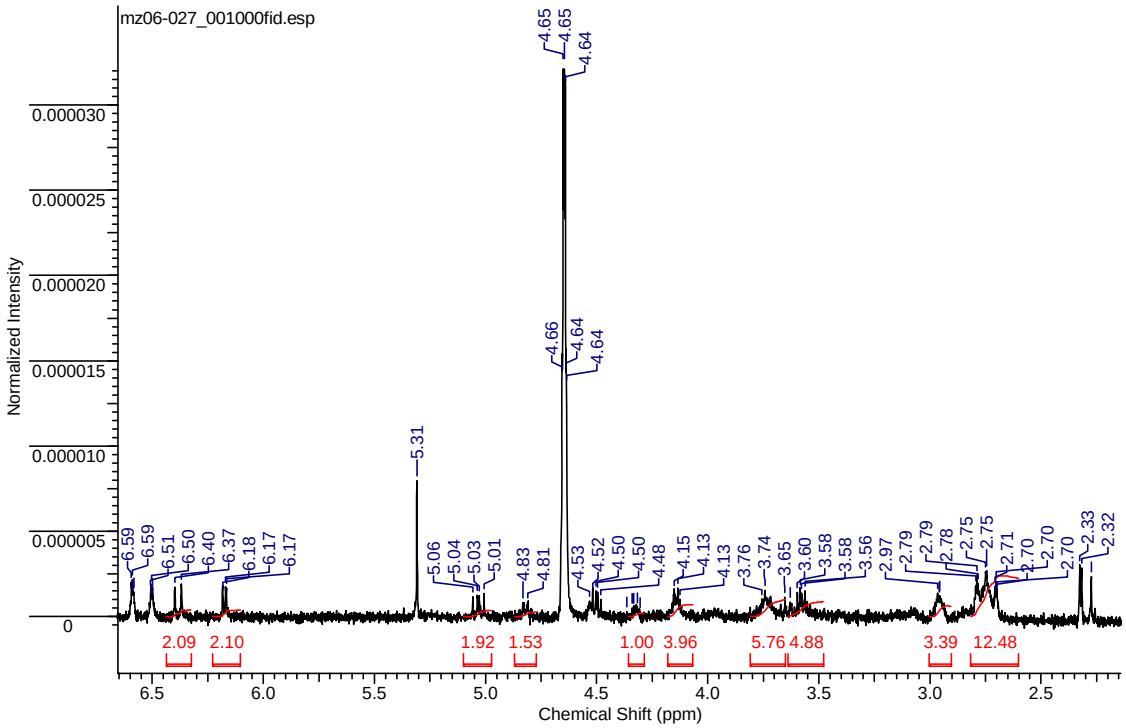
Crude mixture of **14** and **15** after cyclization.

[8] A, Häberli and C. J. Leumann, *Org. Lett.*, 2001, **3**, 489.

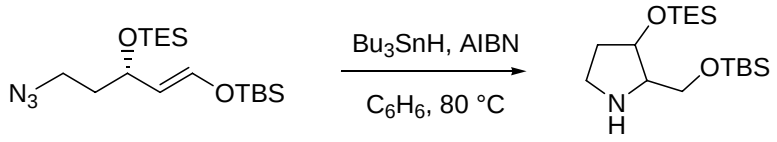


16 **17** **18**

A solution of silyl enol ether **16** (21 mg, 0.06 mmol) Bu_3SnH (106 mg, 0.36 mmol), AIBN (9.2 mg, 0.08 mmol) in degassed benzene (6 mL) was heated to 80 °C and stirred for 18 h. The solution was allowed to cool to room temperature and the solvent was removed by rotary evaporation. Analysis of the ^1H NMR spectrum showed no remaining starting material, and products **17** and **18** in a 54:46 ratio. Amine **14** was present in a 80:20 ratio of *trans* and *cis* isomers.



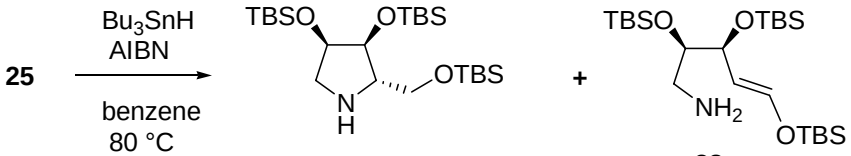
Crude mixture of **17** and **18** after cyclization.



19 **21**

A solution of silyl enol ether **16** (54 mg, 0.14 mmol) Bu_3SnH (55 mg, 0.19 mmol), AIBN (6.1 mg, 0.16 mmol) in degassed benzene (20 mL) was heated to 80 °C and stirred for 4 h, and the solution was allowed to cool to room temperature and the solvent was removed by rotary evaporation. Purification by flash chromatography (2% MeOH in CH_2Cl_2) afforded 28 mg of amine **21** (57%) as a 1:1 mixture of *cis* and *trans* diastereomers. ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.32-4.30 (m, 1H, *cis*), 4.16-4.11 (m, 1H, *trans*), 3.79-3.58 (m, 1H), 3.18-3.08 (m, 1H), 3.00-2.89 (m, 2H), 2.89-2.74 (m, 1H), 2.06 (broad s, 1H), 2.01-1.83 (m, 2H), 0.96 (t, *J*=7.9 Hz, 9H), 0.90 (s, 9H), 0.59 (q, *J*=7.9 Hz, 6H), 0.06 (s, 6 H).

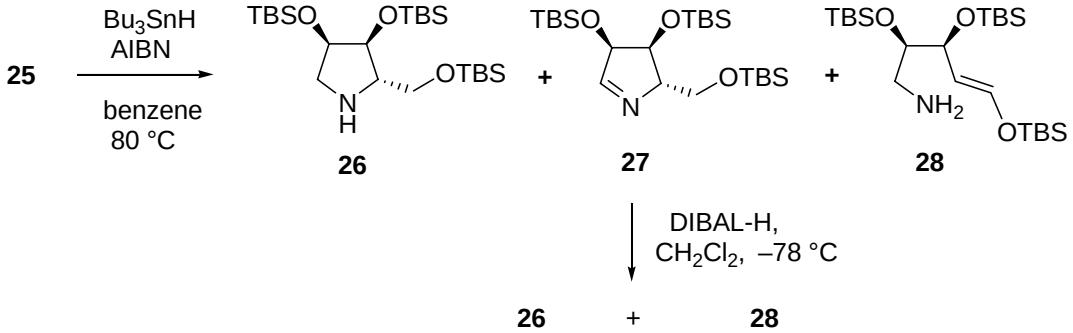
Fast Addition of Tributyltin Hydride to 25



26 **28**

To a solution of silyl enol ether (726 mg, 1.45 mmol), and AIBN (20 mg) in degassed benzene (50 mL) at 80 °C was added a solution of tributyltin hydride (506 mg, 1.74 mmol) and AIBN (20 mg) in benzene (5 mL) dropwise over 5 min. The reaction was stirred at 80 °C for another 5 hours. The solution was allowed to cool to room temperature and the solvent was removed by rotary evaporation. Crude NMR shows there is a miture of **26** and **28** with a ratio about 3:5. Only trace amount of imine **27** was formed.

Crude Data for the DIBAL-H Reduction

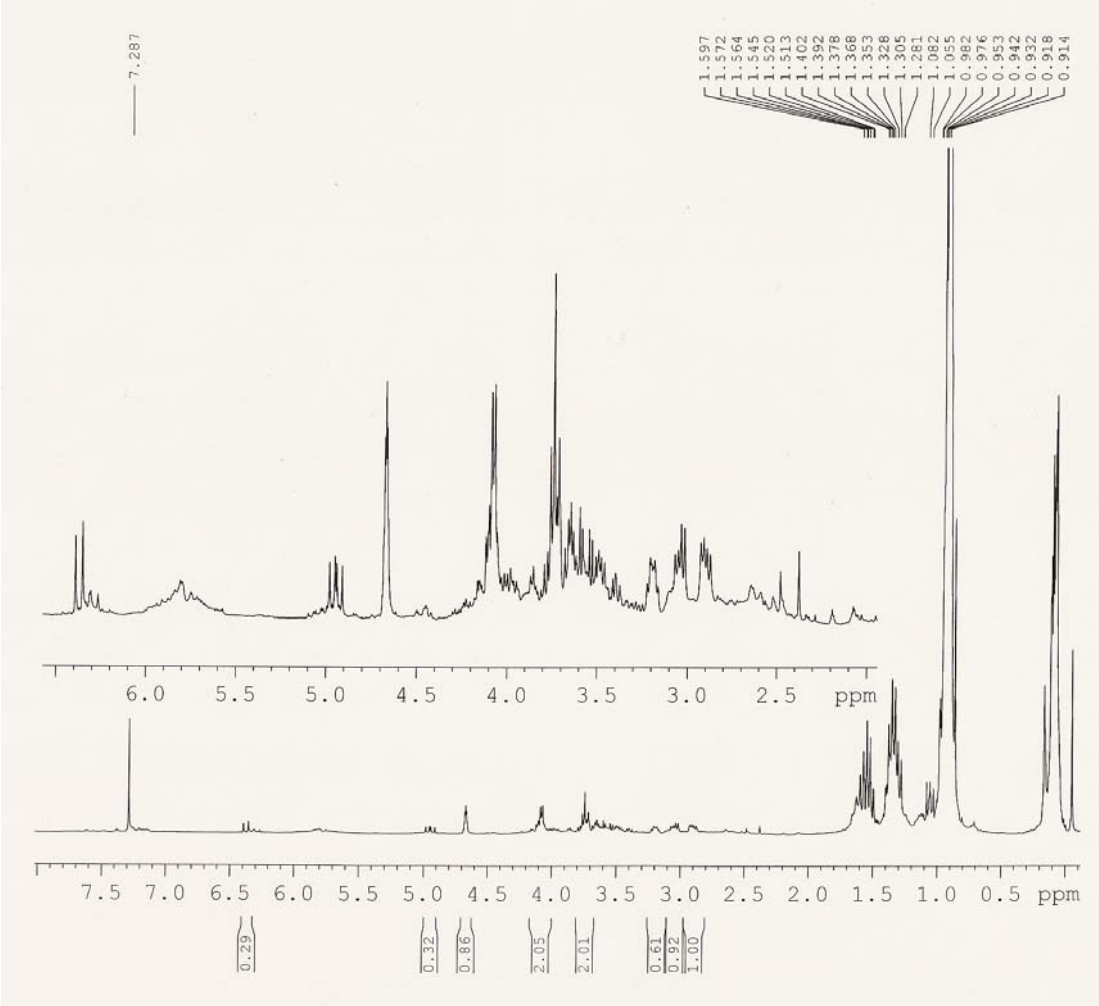


26 **27** **28**

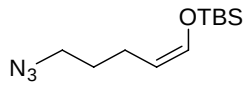
26 + **28**

To a solution of silyl enol ether (65 mg, 0.13 mmol), and AIBN (2 mg) in degassed benzene (13 mL) at 80 °C was added a solution of tributyltin hydride (38 mg, 0.13 mmol) and AIBN (2 mg, 0.1 equiv.) in benzene (5 mL) dropwise, via syringe pump, over 2 hours. The reaction was stirred at 80 °C for another 3 hours. The solution was allowed to cool to room temperature and the solvent was removed by rotary evaporation. Crude NMR shows that there is a miture of **26**, **27** and **28** with a ratio about 2:1:1. The imine proton is a doublet at 7.63 ppm with 4.0 Hz coupling constant. The above crude mixture was dissolved in CH_2Cl_2 (5 mL) and cooled to –78 °C.

DIBAL-H (0.3 mL, 1.0 M in toluene) was added dropwise over 3 min and the solution was stirred at –78 °C for 1 hour. The reaction was quenched with saturated $NaHCO_3$ (5 mL), and the aqueous layer was extracted with CH_2Cl_2 (2x10 mL). The combined organic extracts were dried over Na_2SO_4, filtered, and the solvent was removed by rotary evaporation to provide a pale yellow oil. Crude NMR shows that there is a mixture of **26** and **28** with a ratio about 3:1.



Crude mixture of **26** and **28**, after DIBAL reduction.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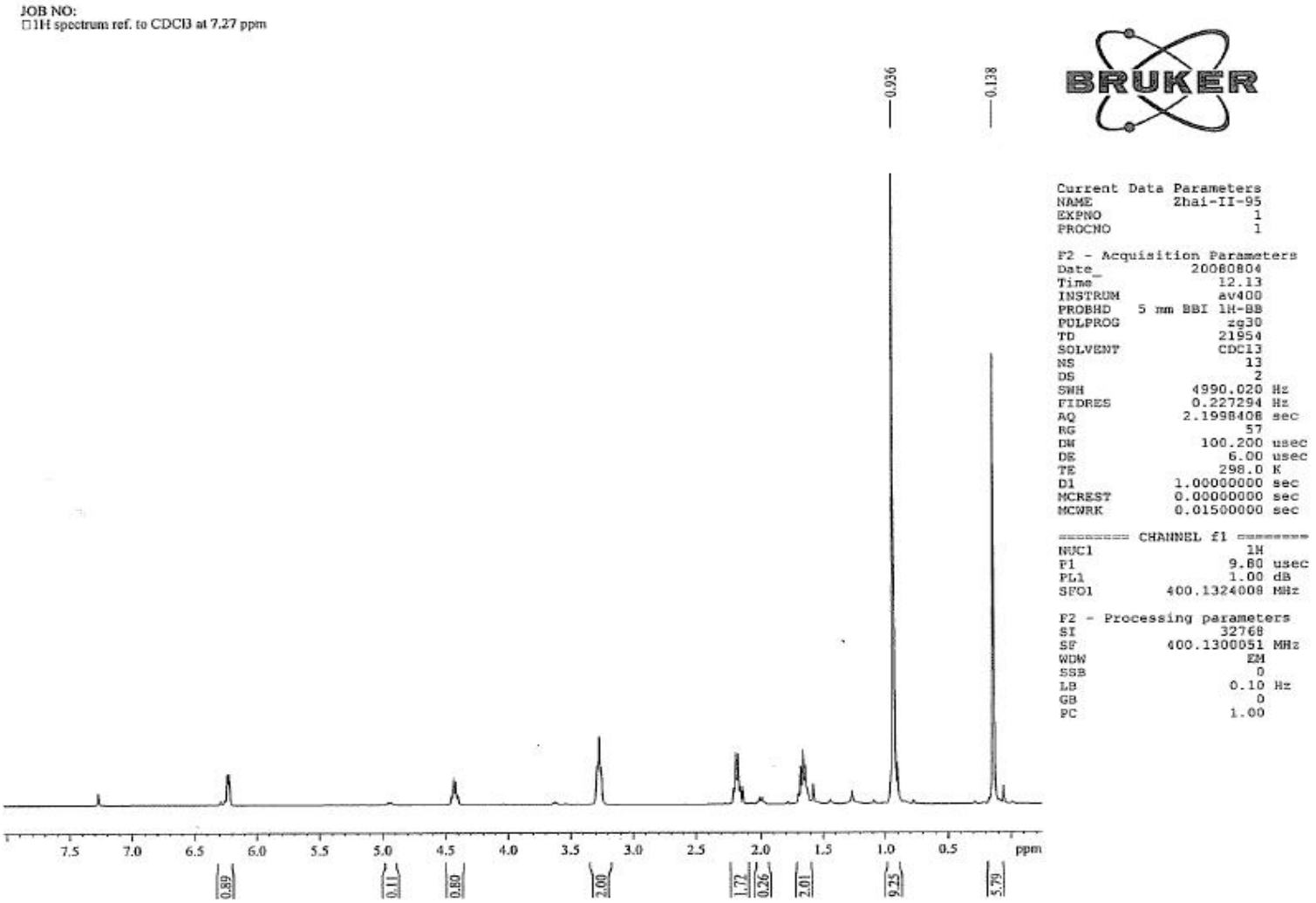
N3

7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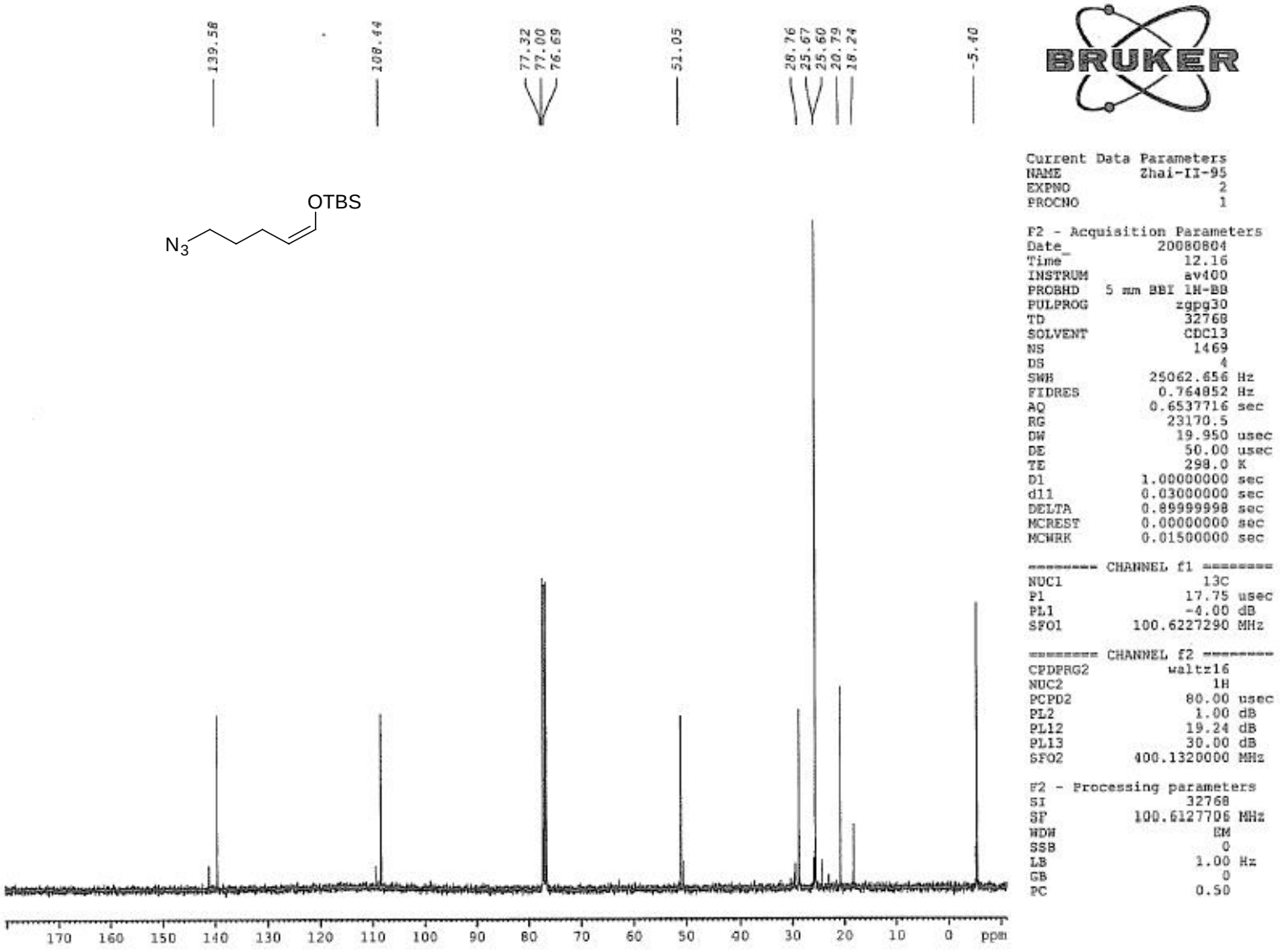

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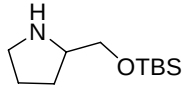
DW 19.950 usec
DE 50.00 usec
TE 298.0 K
D1 1.00000000 sec
d11 0.03000000 sec
DELTA 0.89999998 sec
MCREST 0.00000000 sec
MCWRK 0.01500000 sec

======== CHANNEL f1 ========
NUC1 13C
P1 17.75 usec
PL1 -4.00 dB
SFO1 100.6227290 MHz

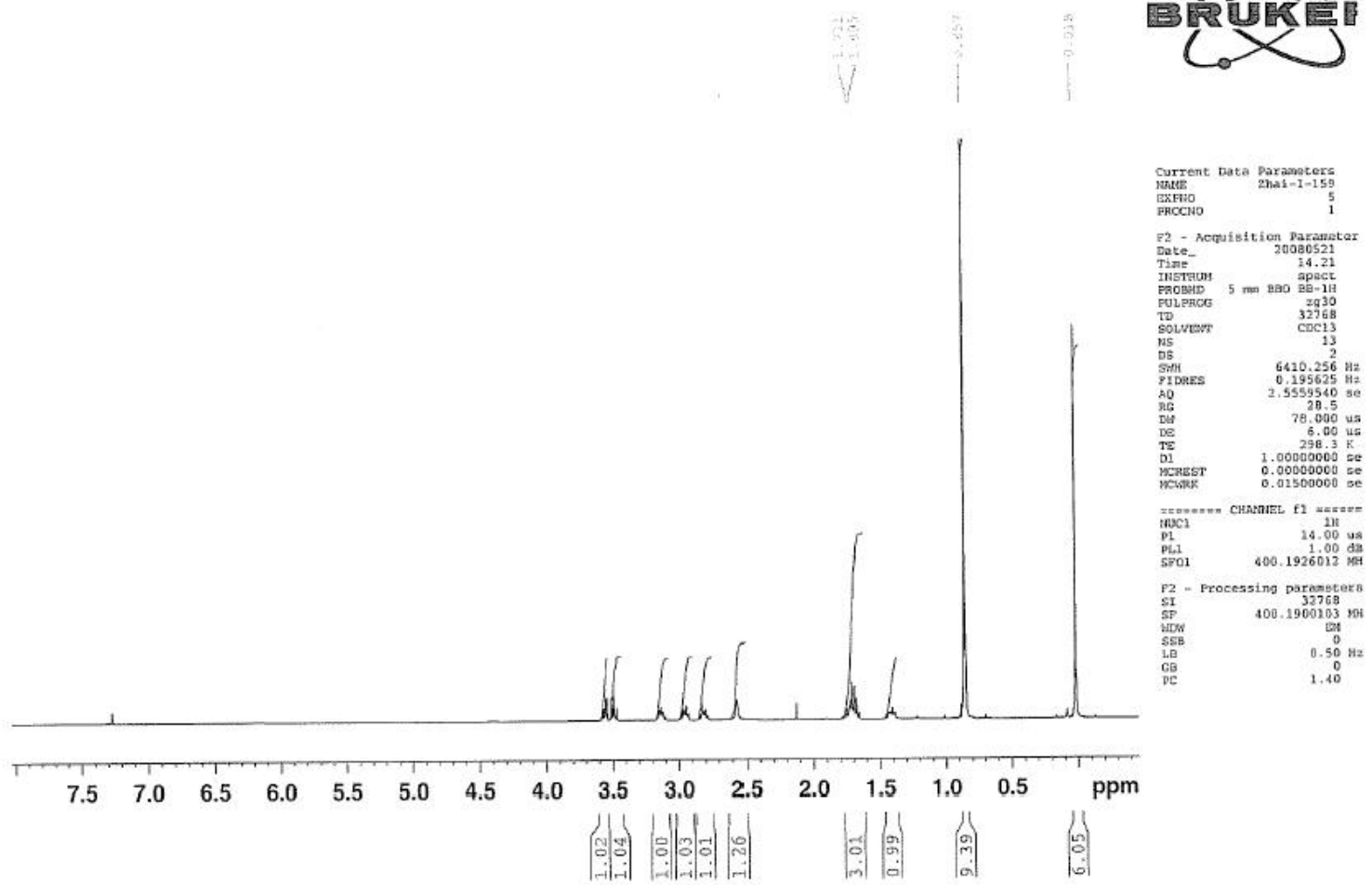
======== CHANNEL f2 ========
CPDPRG2 waltz16
NUC2 1H
PCPD2 80.00 usec
PL2 1.00 dB
PL12 19.24 dB
PL13 30.00 dB
SFO2 400.1320000 MHz

F2 - Processing parameters
SI 32768
SF 100.6127706 MHz
WDW EM
SSB 0
LB 1.00 Hz
GB 0
PC 0.50



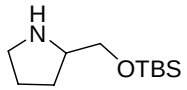
9

1H

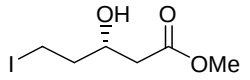



```
Current Data Parameters
NAME                  2hai-1-159
EXPNO                          5
PROCNO                         1

F2 - Acquisition Parameter
Date_              20080521
Time                   14.21
INSTRUM                spect
PROBHD   5 mm BBO BB-1H
PULPROG                 zg30
TD                     32768
SOLVENT                CDCl3
NS                        13
DS                         2
SWH                6410.256 Hz
FIDRES            0.195625 Hz
AQ                2.5559540 se
RG                      28.5
DW                 78.000 us
DE                  6.00 us
TE                  298.3 K
D1                1.00000000 se
MCREST            0.00000000 se
MCWRK             0.01500000 se

======== CHANNEL f1 ======
NUC1                       1H
P1                  14.00 us
PL1                  1.00 dB
SFO1          400.1926012 MH

F2 - Processing parameters
SI                     32768
SF            400.1900103 MH
WDW                       EM
SSB                        0
LB                  0.50 Hz
GB                         0
PC                      1.40
```

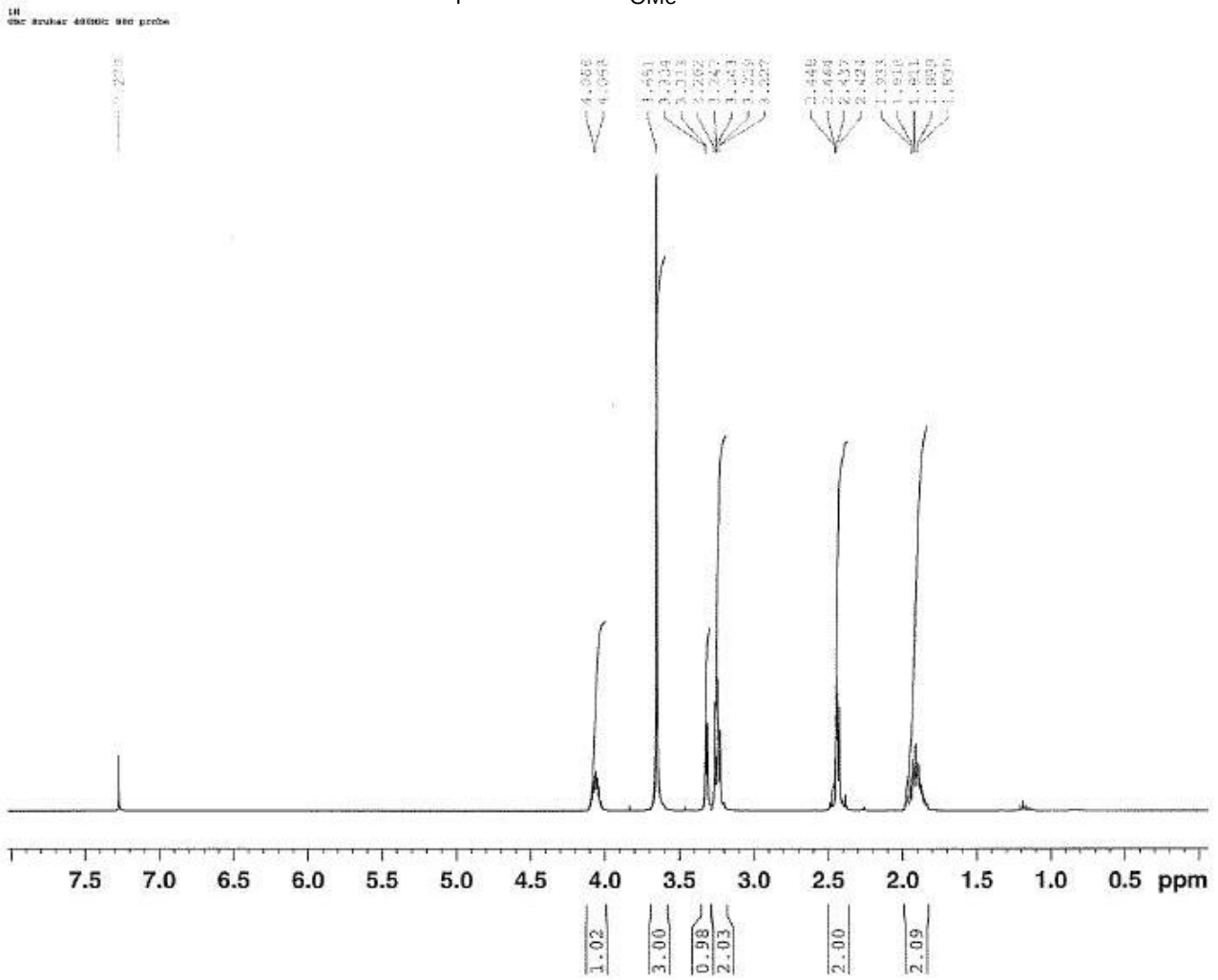
13C




```
Current Data Parameters
NAME            Zhai-I-159
EXPNO                    6
PROCNO                   1

F2 - Acquisition Parameters
Date_             20080521
Time                 14.27
INSTRUM              spect
PROBHD   5 mm BBO BB-1H
PULPROG           zgpg30
TD                  32768
SOLVENT             CDCl3
NS                    170
DS                      4
SWH             25125.629 Hz
FIDRES              0.766773 Hz
AQ                0.6521332 sec
RG                    645.1
DW                 19.900 usec
DE                 10.00 usec
TE                 298.2 K
D1              1.00000000 sec
d11             0.03000000 sec
DELTA           0.89999998 sec
MCREST          0.00000000 sec
MCWRK           0.01500000 sec

======== CHANNEL f1 ========
NUC1                   13C
P1                  7.88 usec
PL1                -3.00 dB
SFO1          100.6379188 MHz

======== CHANNEL f2 ========
CPDPRG2            waltz16
NUC2                    1H
PCPD2              90.00 usec
PL2                 0.00 dB
PL12               16.00 dB
PL13               20.00 dB
SFO2          400.1916008 MHz

F2 - Processing parameters
SI                   32768
SF            100.6278624 MHz
WDW                     EM
SSB                      0
LB                  1.00 Hz
GB                       0
PC                    1.40
```

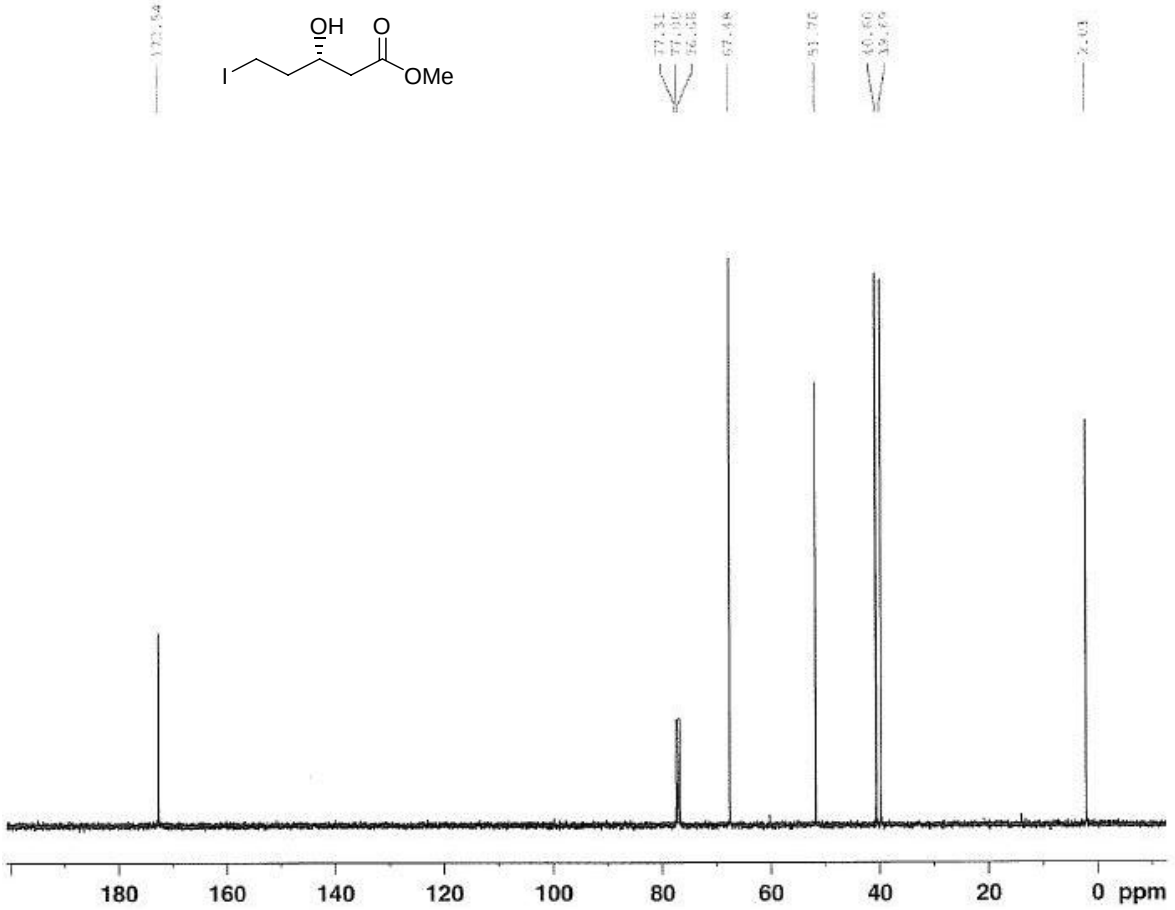


S1

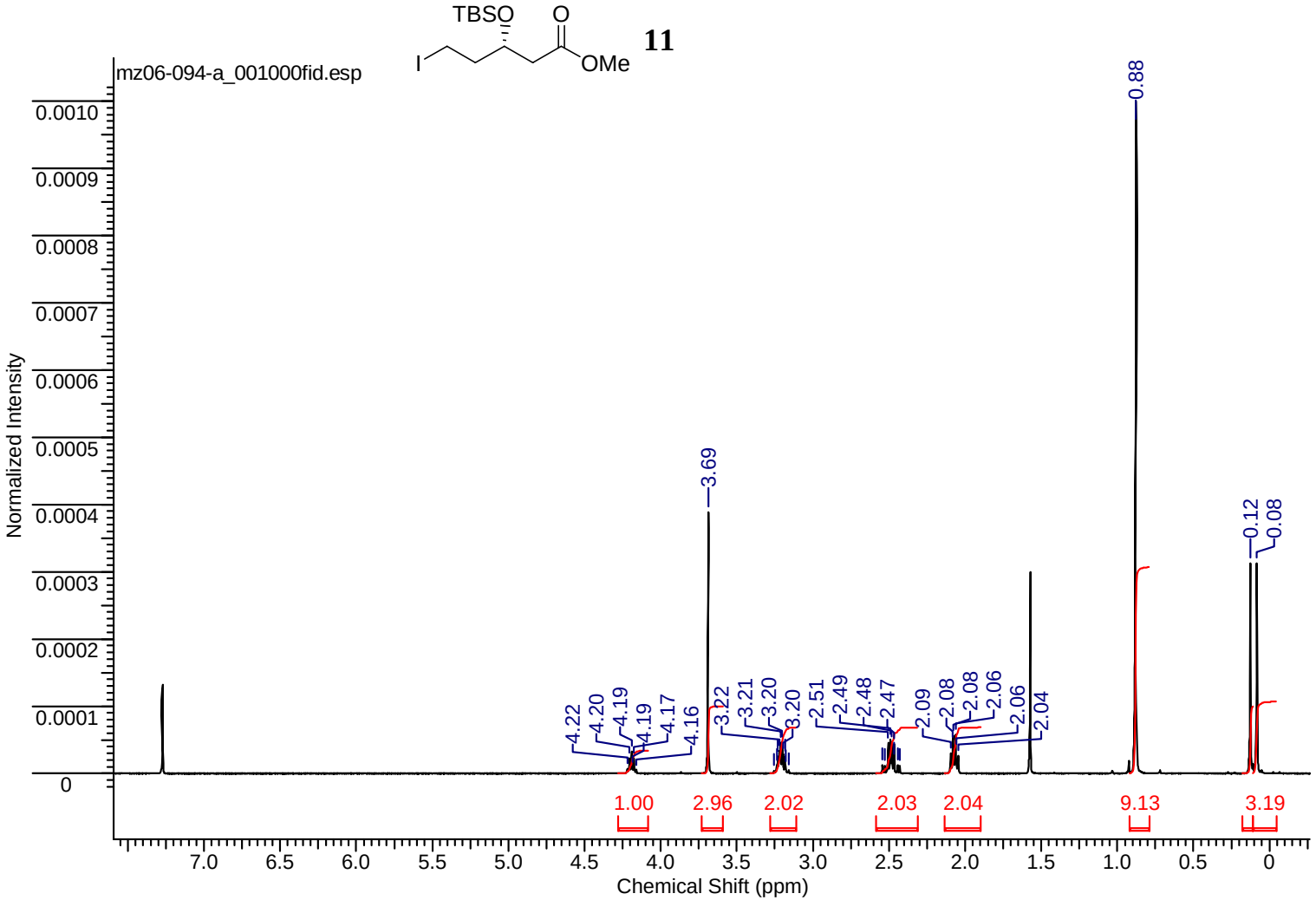


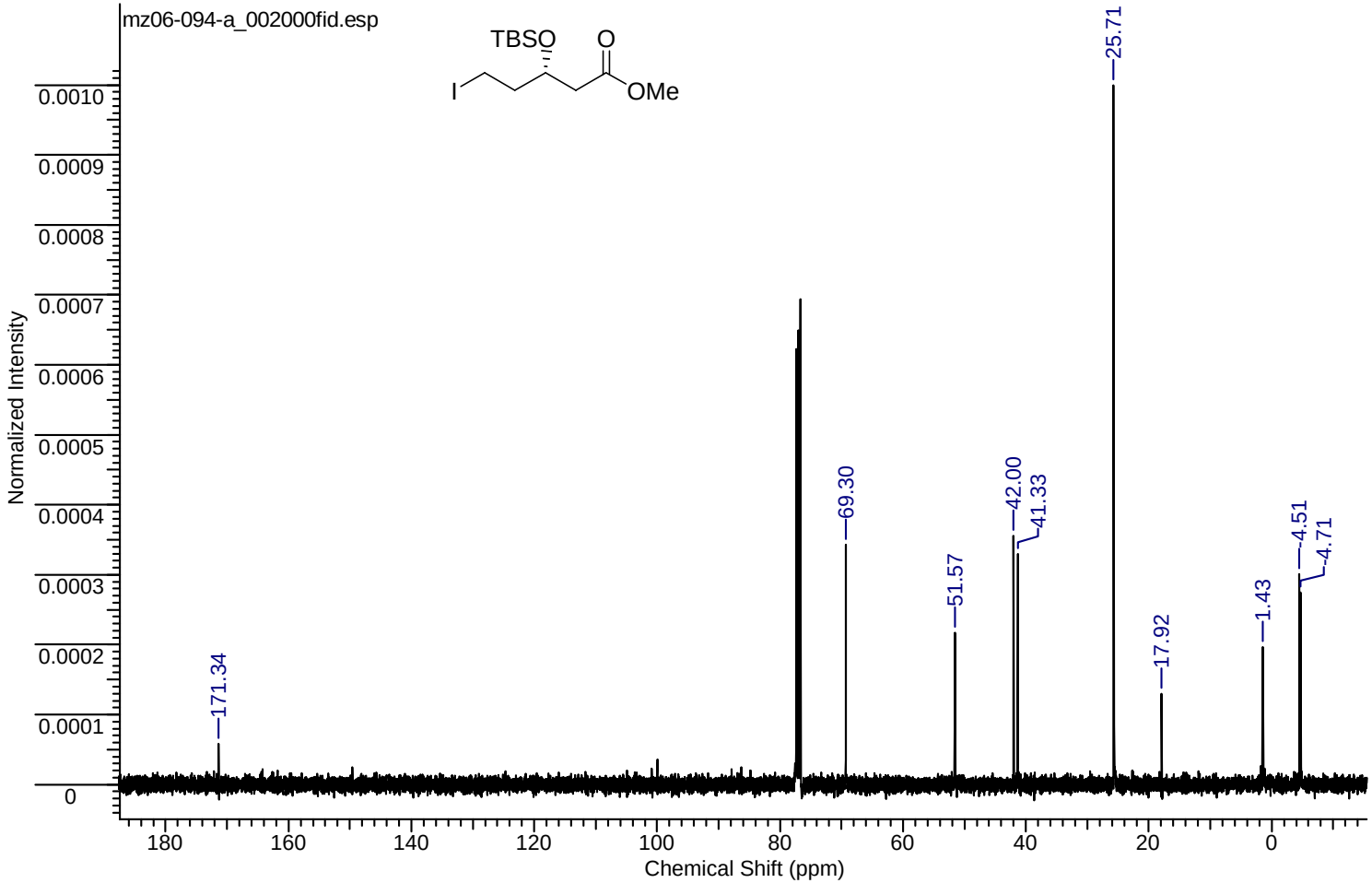

```
Current Data Parameters
NAME          Shai-III-93
EXPNO                   1
PROCNO                  1

F2 - Acquisition Parameter
Date_            20090210
Time                13.35
INSTRUN             spect
PROBHD   5 mm BBO BB-1H
PULPROG             zg30
TD                 32768
SOLVENT            CDCl3
NS                     9
DS                     2
SWH             5592.841 Hz
FIDRES          0.170680 Hz
AQ              2.9295092 se
RG                  20.2
DW                89.400 us
DE                 6.00 us
TE                298.2 K
D1             1.00000000 se
HCREST         0.00000000 se
HCWRX          0.01500000 se

======== CHANNEL f1 ======
NUC1                   1H
P1                 17.00 us
PL1                 1.00 dB
SFO1          400.1926012 MH

F2 - Processing parameters
SI                 32768
SF            400.1900093 MH
WDW                   EM
SSB                    0
LB                  0.50 Hz
GB                     0
PC                  1.40
```

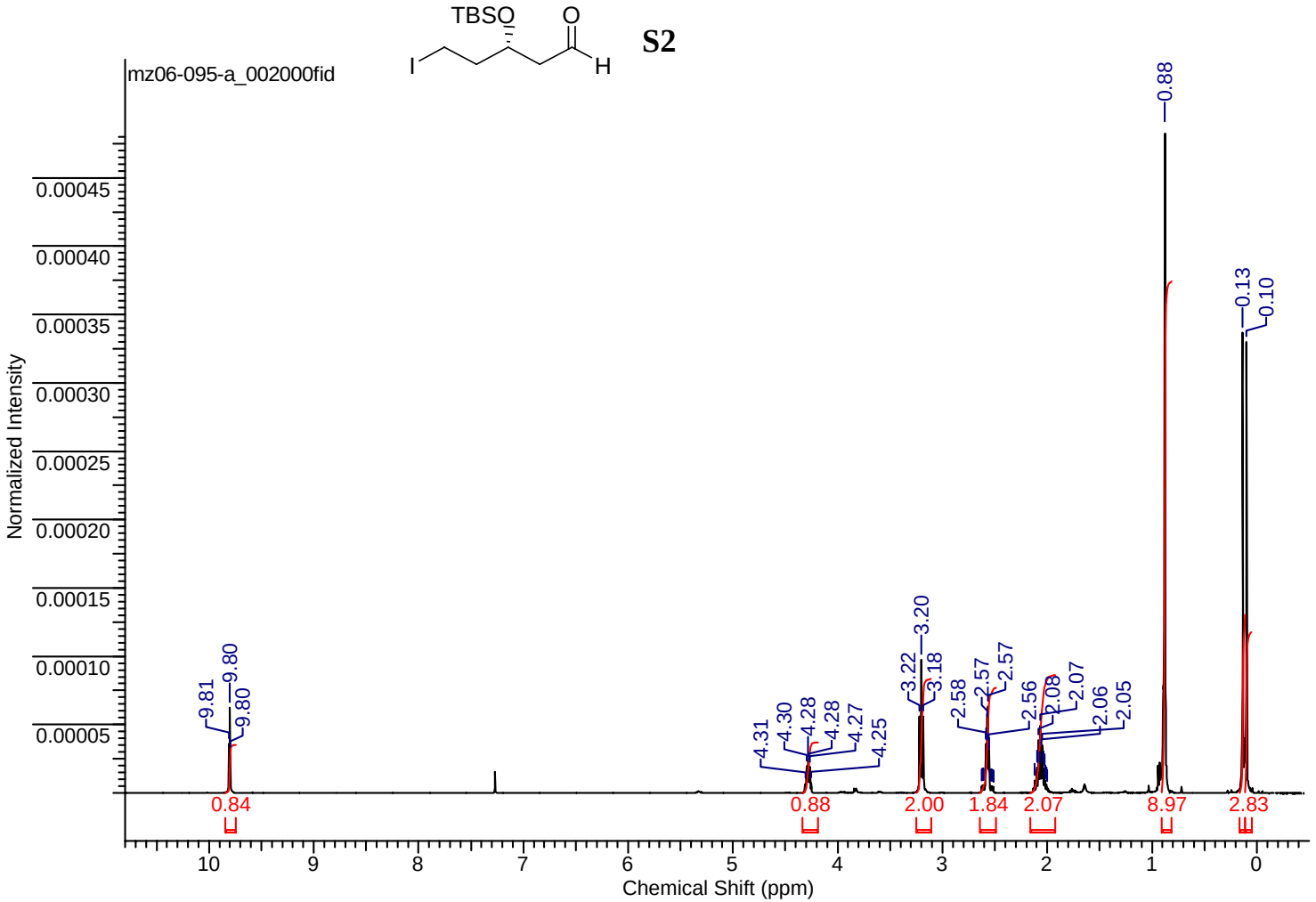
13C
UBC Bruker 400MHz BBO probe

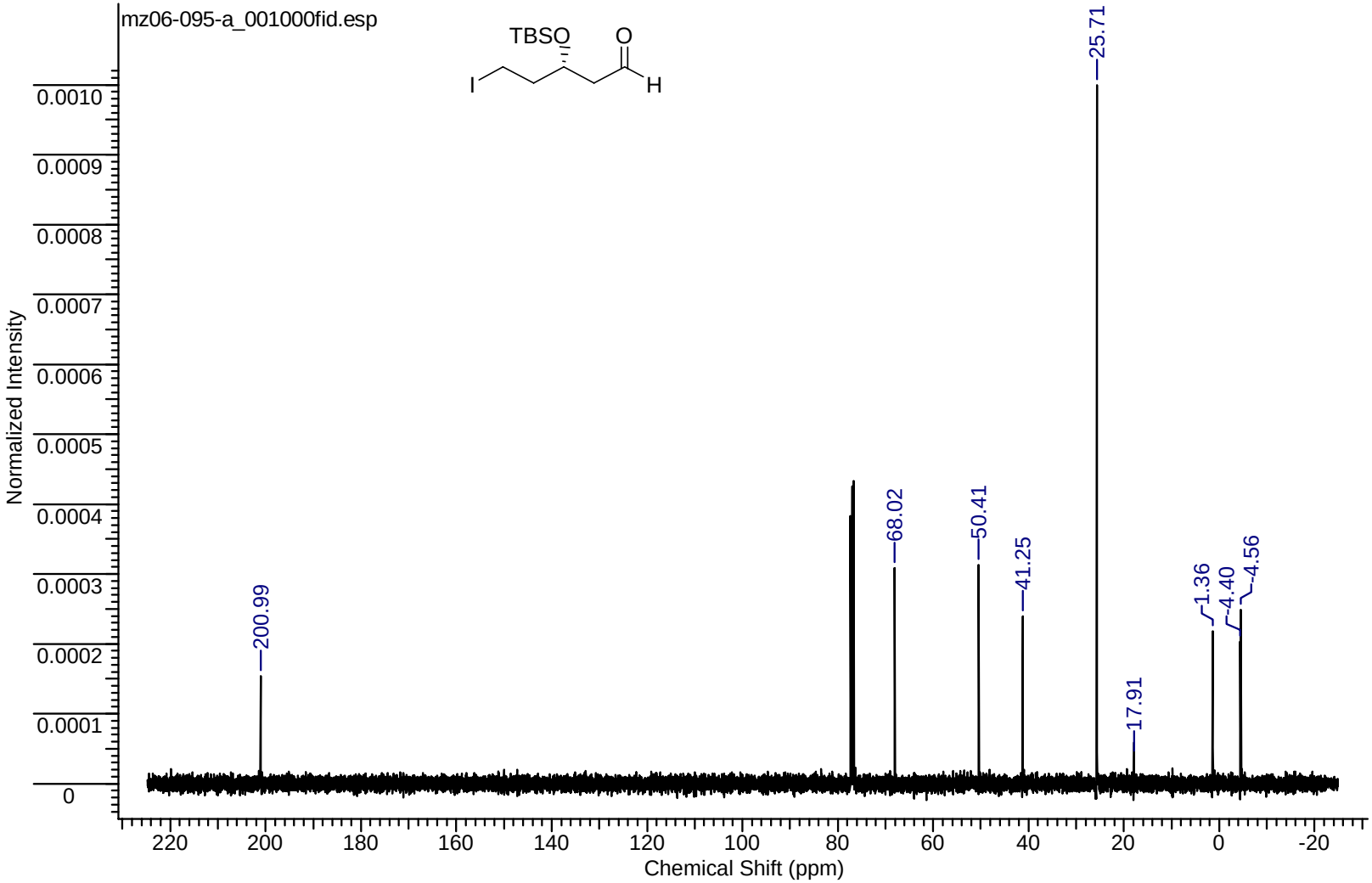


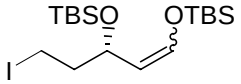

```
Current Data Parameters
NAME          Zhai-III-93
EXPNO                   2
PROCNO                  1

F1 - Acquisition Parameter
Date_            20090210
Time                13.40
INSTRUM             spect
PROBHD   5 mm BBO BB-1H
PULPROG           zgpg30
TD                 32768
SOLVENT            CDCl3
NS                    67
DS                     2
SWH            25125.629 Hz
FIDRES         0.766773 Hz
AQ             0.6521332 se
RG                 812.7
DW                19.900 us
DE                10.00 us
TE                298.9 K
D1             1.00000000 se
d11            0.03000000 se
DELTA          0.89999998 se
MCREST         0.00000000 se
MCWRK          0.01500000 se

======== CHANNEL f1 ======
NUC1                13C
P1                 8.80 us
PL1               -3.00 dB
SFO1        100.6279188 MH

======== CHANNEL f2 ======
CPDPRG2          waltz16
NUC2                1H
PCPD2              90.00 us
PL2                0.00 dB
PL12              14.48 dB
PL13              20.00 dB
SFO2        400.1916008 MH

F2 - Processing parameters
SI                 32768
SF          100.6278786 MH
WDW                   EM
SSB                    0
LB                1.00 Hz
GB                     0
PC                 1.00
```


TBSO
O
I
OMe
11
mz06-094-a_001000fid.esp
Normalized Intensity
0.0010
0.0009
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
4.22
4.20
4.19
4.19
4.17
4.16
3.69
3.22
3.21
3.20
3.20
2.51
2.49
2.48
2.47
2.09
2.08
2.08
2.06
2.06
2.04
0.88
0.12
0.08
1.00
2.96
2.02
2.03
2.04
9.13
3.19
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
Chemical Shift (ppm)

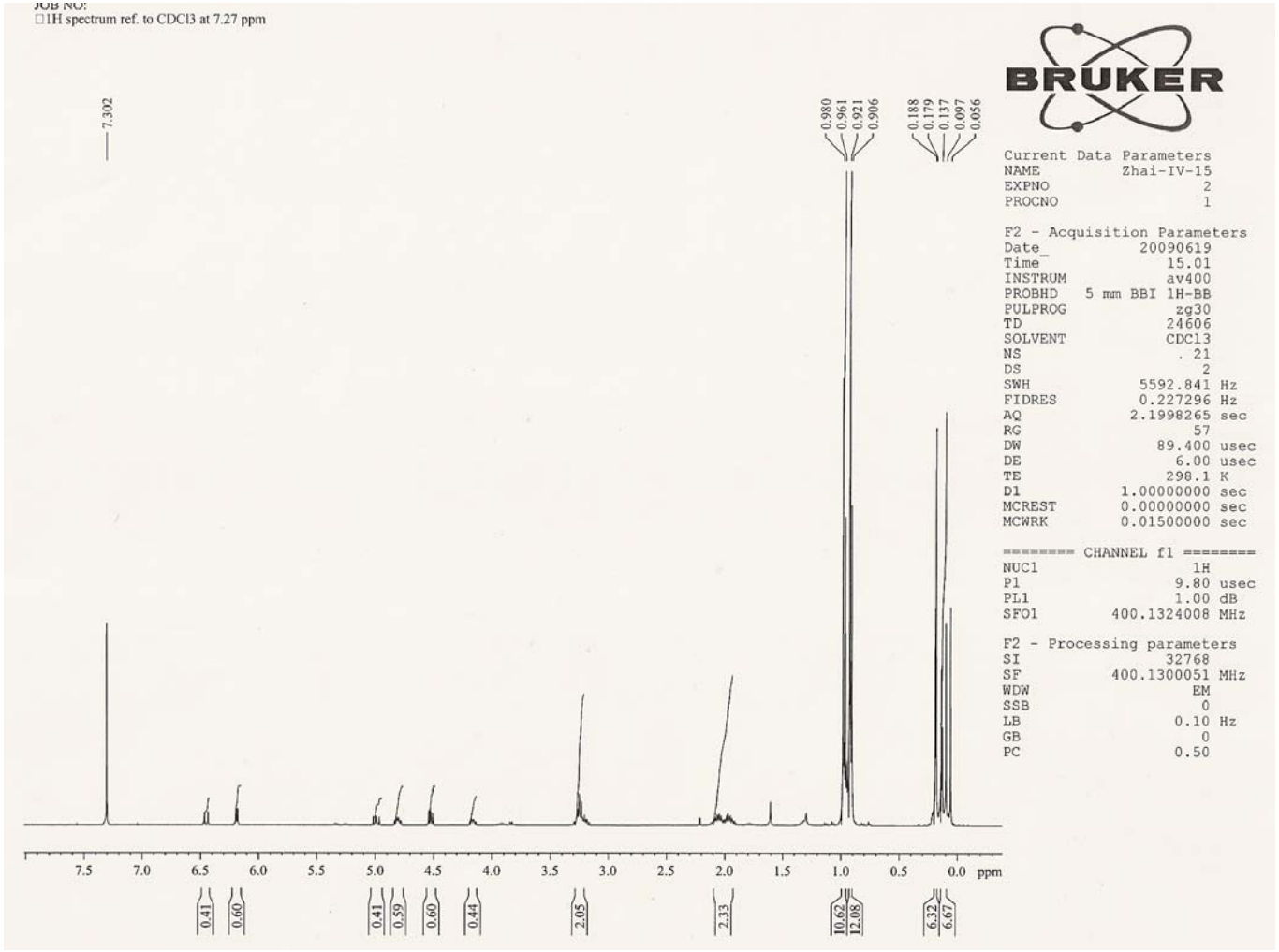

mz06-094-a_002000fid.esp
TBSO
O
I
OMe
Normalized Intensity
0.0010
0.0009
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
171.34
69.30
51.57
42.00
41.33
25.71
17.92
1.43
4.51
4.71
180
160
140
120
100
80
60
40
20
0
Chemical Shift (ppm)

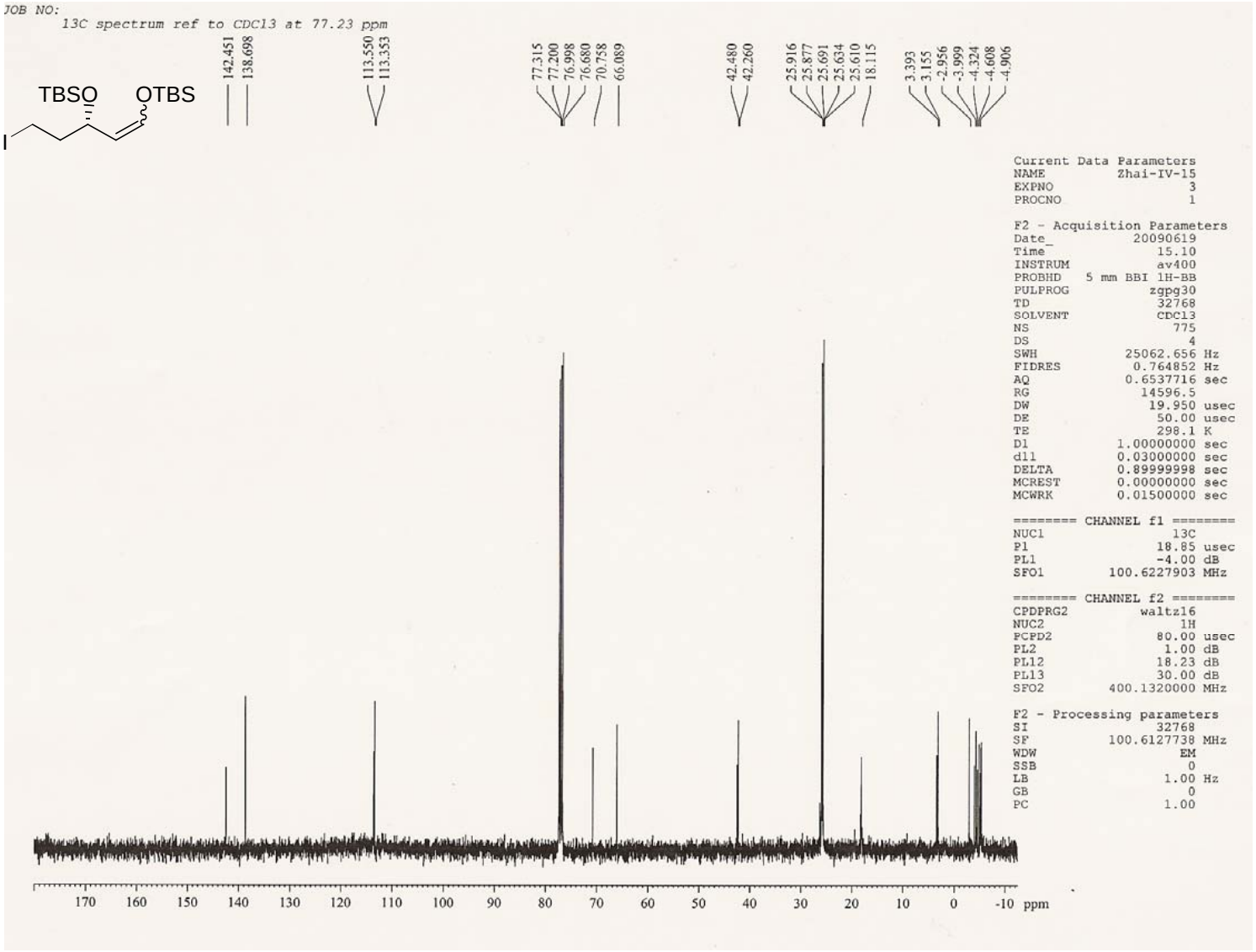

TBSO
O
I
H
S2
mz06-095-a_002000fid
Normalized Intensity
0.00045
0.00040
0.00035
0.00030
0.00025
0.00020
0.00015
0.00010
0.00005
9.81
9.80
9.80
4.31
4.30
4.28
4.28
4.27
4.25
3.22
3.20
3.18
2.58
2.57
2.57
2.56
2.08
2.07
2.06
2.05
0.88
0.13
0.10
0.84
0.88
2.00
1.84
2.07
8.97
2.83
10
9
8
7
6
5
4
3
2
1
0
Chemical Shift (ppm)


mz06-095-a_001000fid.esp
TBSO
O
I
H
Normalized Intensity
0.0010
0.0009
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
200.99
68.02
50.41
41.25
25.71
17.91
1.36
4.40
4.56
220
200
180
160
140
120
100
80
60
40
20
0
-20
Chemical Shift (ppm)

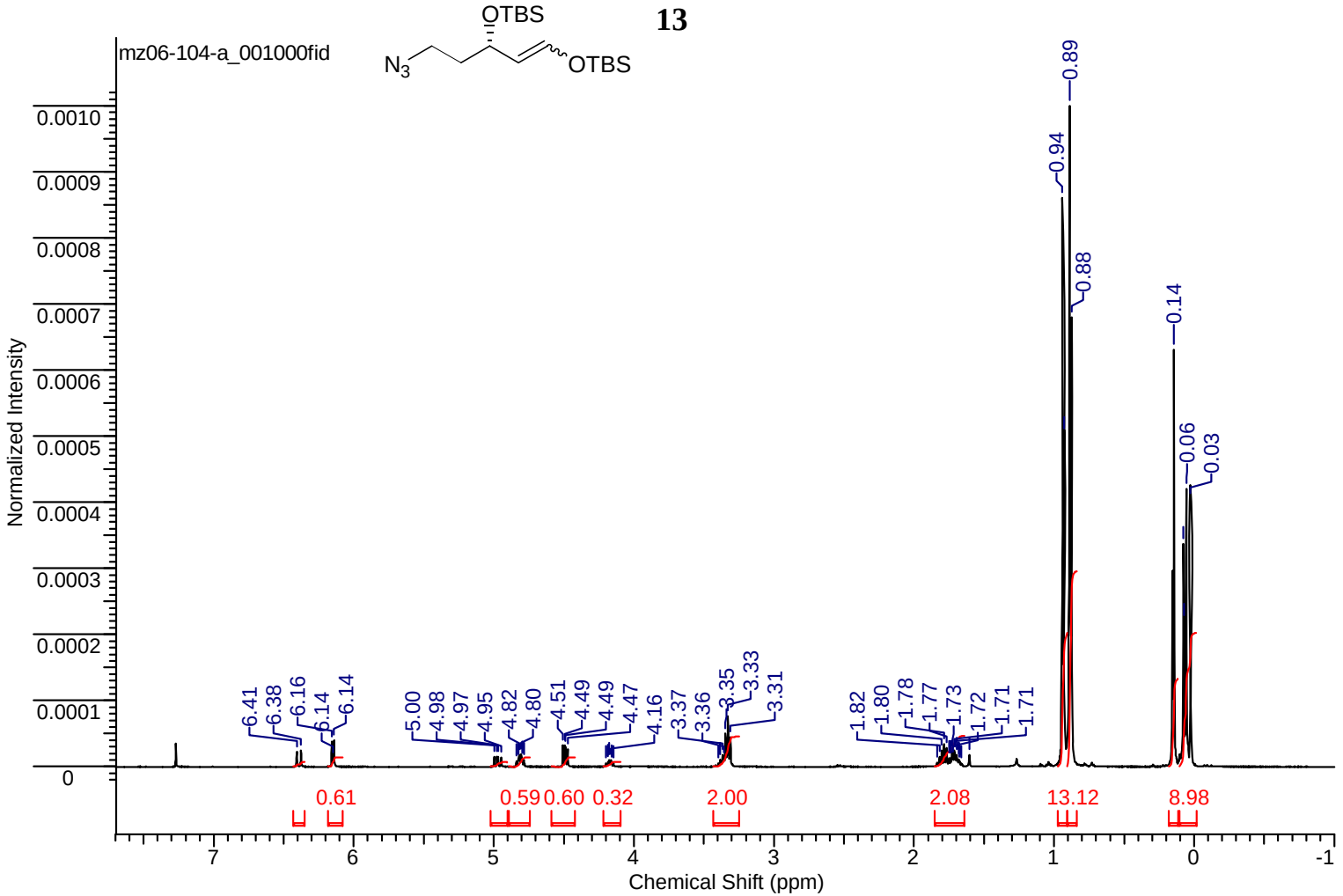

TBSO
OTBS
I

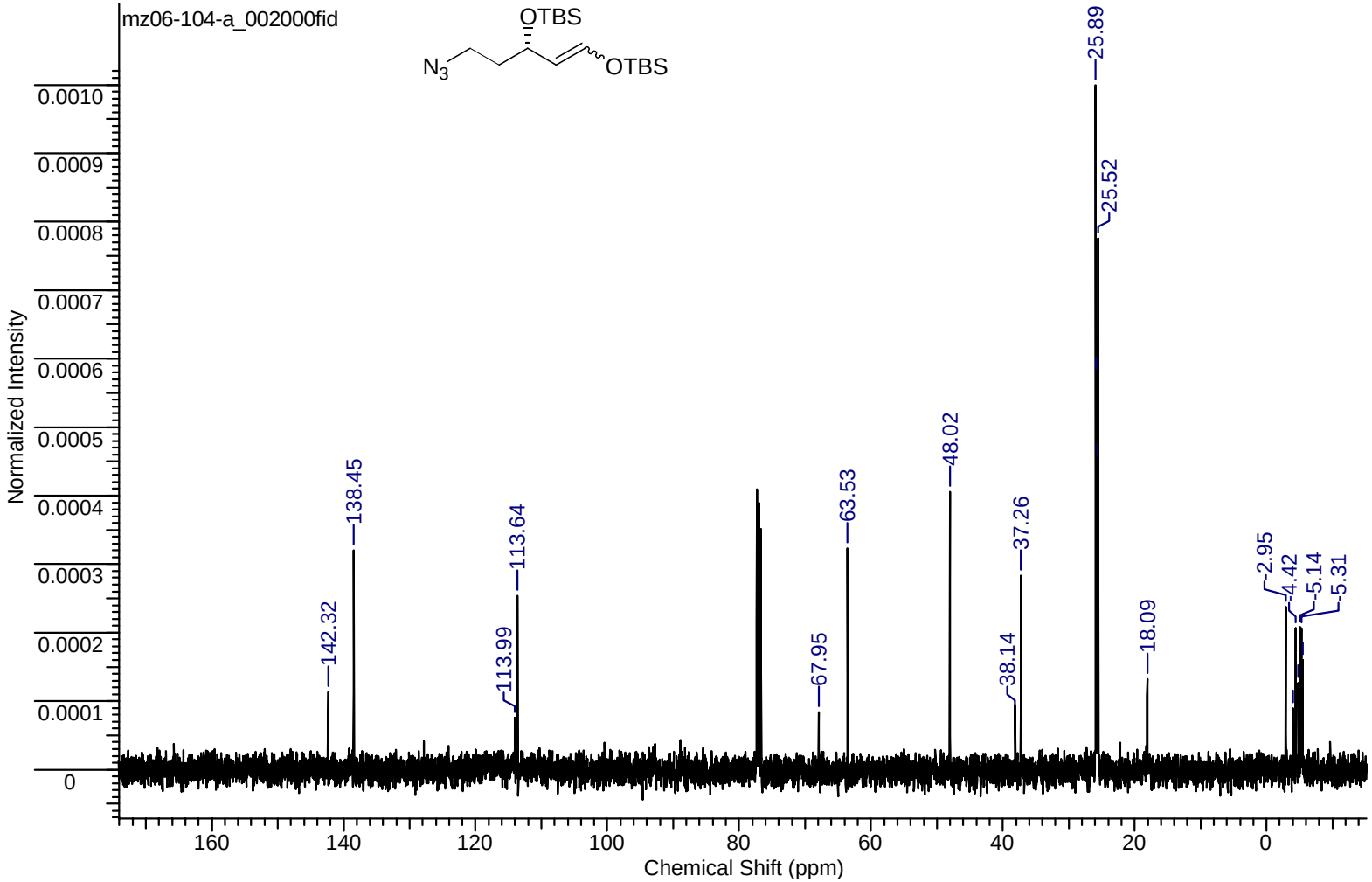
12


JOB NO:
1H spectrum ref. to CDCl3 at 7.27 ppm
7.302
0.980
0.961
0.921
0.906
0.188
0.179
0.137
0.097
0.056
BRUKER
Current Data Parameters
NAME Zhai-IV-15
EXPNO 2
PROCNO 1
F2 - Acquisition Parameters
Date_ 20090619
Time 15.01
INSTRUM av400
PROBHD 5 mm BBI 1H-BB
PULPROG zg30
TD 24606
SOLVENT CDCl3
NS 21
DS 2
SWH 5592.841 Hz
FIDRES 0.227296 Hz
AQ 2.1998265 sec
RG 57
DW 89.400 usec
DE 6.00 usec
TE 298.1 K
D1 1.00000000 sec
MCREST 0.00000000 sec
MCWRK 0.01500000 sec
======== CHANNEL f1 ========
NUC1 1H
P1 9.80 usec
PL1 1.00 dB
SFO1 400.1324008 MHz
F2 - Processing parameters
SI 32768
SF 400.1300051 MHz
WDW EM
SSB 0
LB 0.10 Hz
GB 0
PC 0.50
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
0.41
0.60
0.41
0.59
0.60
0.44
2.05
2.33
10.62
12.08
6.32
6.67

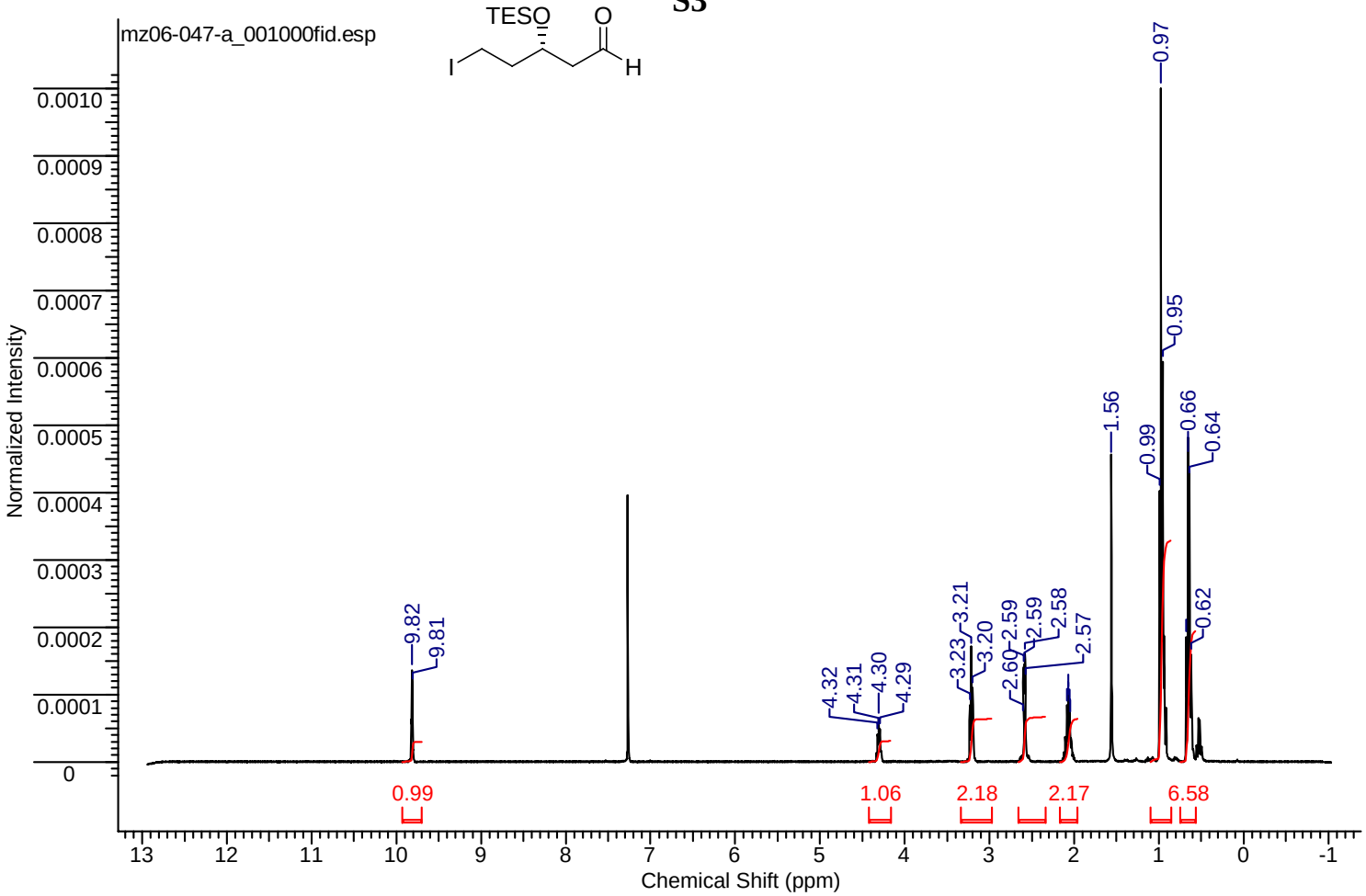

JOB NO:
13C spectrum ref to CDCl3 at 77.23 ppm
TBSO
OTBS
142.451
138.698
113.550
113.353
77.315
77.200
76.998
76.680
70.758
66.089
42.480
42.260
25.916
25.877
25.691
25.634
25.610
18.115
3.393
3.155
-2.956
-3.999
-4.324
-4.608
-4.906
Current Data Parameters
NAME Zhai-IV-15
EXPNO 3
PROCNO 1
F2 - Acquisition Parameters
Date_ 20090619
Time 15.10
INSTRUM av400
PROBHD 5 mm BBI 1H-BB
PULPROG zgpg30
TD 32768
SOLVENT CDCl3
NS 775
DS 4
SWH 25062.656 Hz
FIDRES 0.764852 Hz
AQ 0.6537716 sec
RG 14596.5
DW 19.950 usec
DE 50.00 usec
TE 298.1 K
D1 1.00000000 sec
d11 0.03000000 sec
DELTA 0.89999998 sec
MCREST 0.00000000 sec
MCWRK 0.01500000 sec
======== CHANNEL f1 ========
NUC1 13C
P1 18.85 usec
PL1 -4.00 dB
SFO1 100.6227903 MHz
======== CHANNEL f2 ========
CPDPRG2 waltz16
NUC2 1H
PCPD2 80.00 usec
PL2 1.00 dB
PL12 18.23 dB
PL13 30.00 dB
SFO2 400.1320000 MHz
F2 - Processing parameters
SI 32768
SF 100.6127738 MHz
WDW EM
SSB 0
LB 1.00 Hz
GB 0
PC 1.00
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 ppm

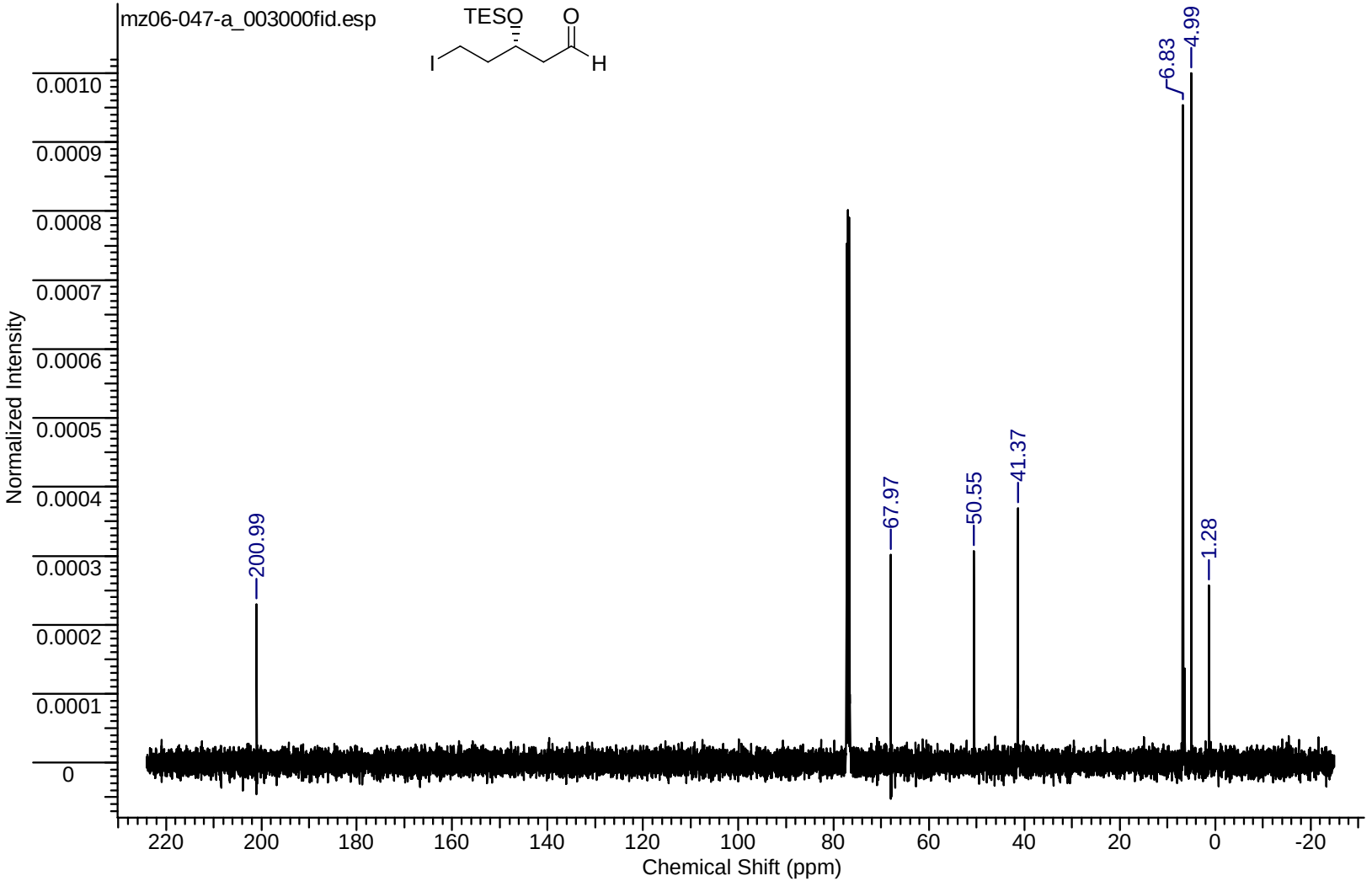
13


OTBS
N3
OTBS
mz06-104-a_001000fid
Normalized Intensity
Chemical Shift (ppm)
6.41
6.38
6.16
6.14
6.14
5.00
4.98
4.97
4.95
4.82
4.80
4.51
4.49
4.49
4.47
4.16
3.37
3.36
3.35
3.33
3.31
1.82
1.80
1.78
1.77
1.73
1.72
1.71
1.71
0.89
0.94
0.88
0.14
0.06
0.03
0.61
0.59
0.60
0.32
2.00
2.08
13.12
8.98

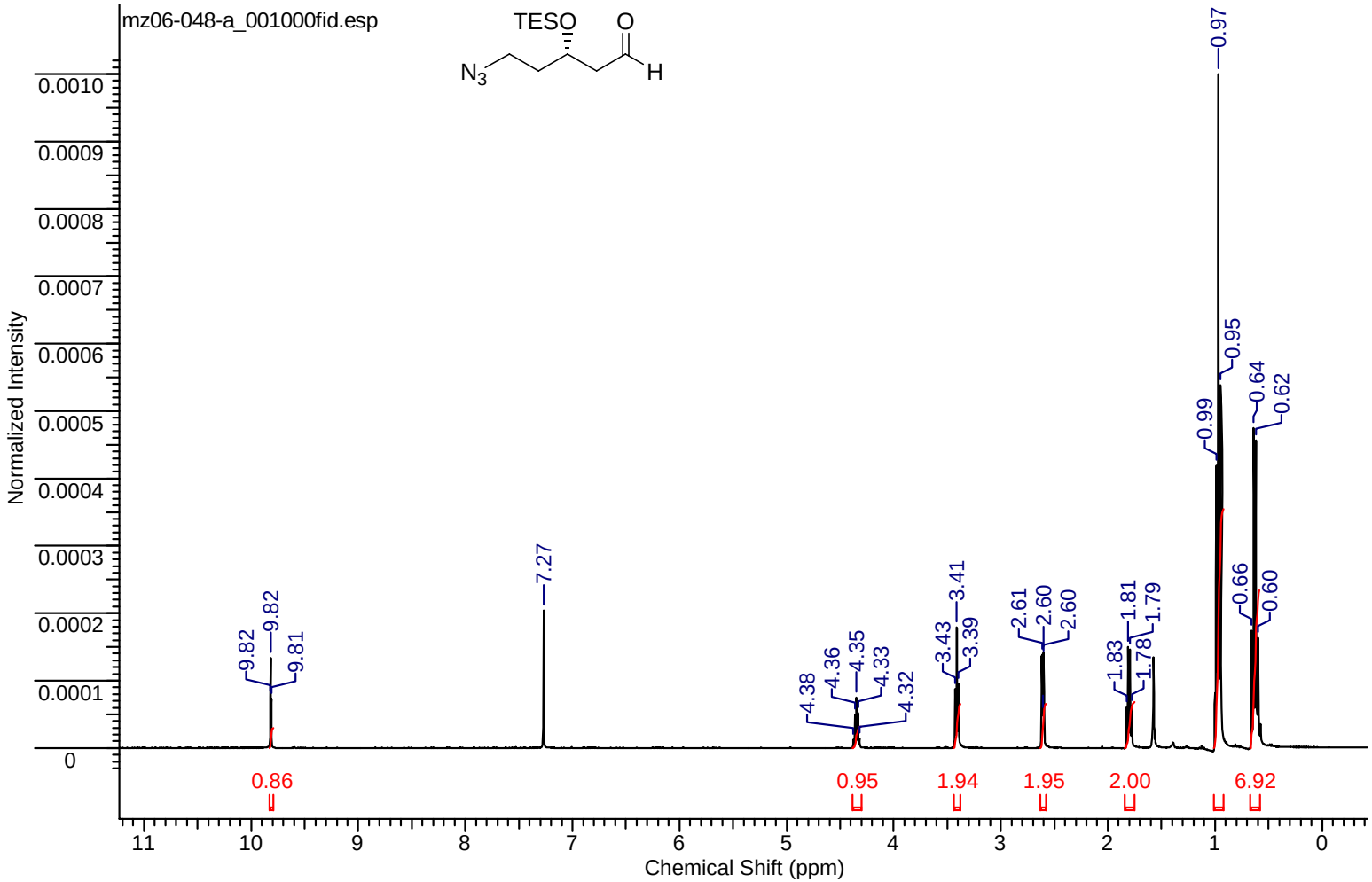

mz06-104-a_002000fid
OTBS
N3
OTBS
Normalized Intensity
0.0010
0.0009
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
142.32
138.45
113.99
113.64
67.95
63.53
48.02
38.14
37.26
25.89
25.52
18.09
2.95
4.42
5.14
5.31
160
140
120
100
80
60
40
20
0
Chemical Shift (ppm)

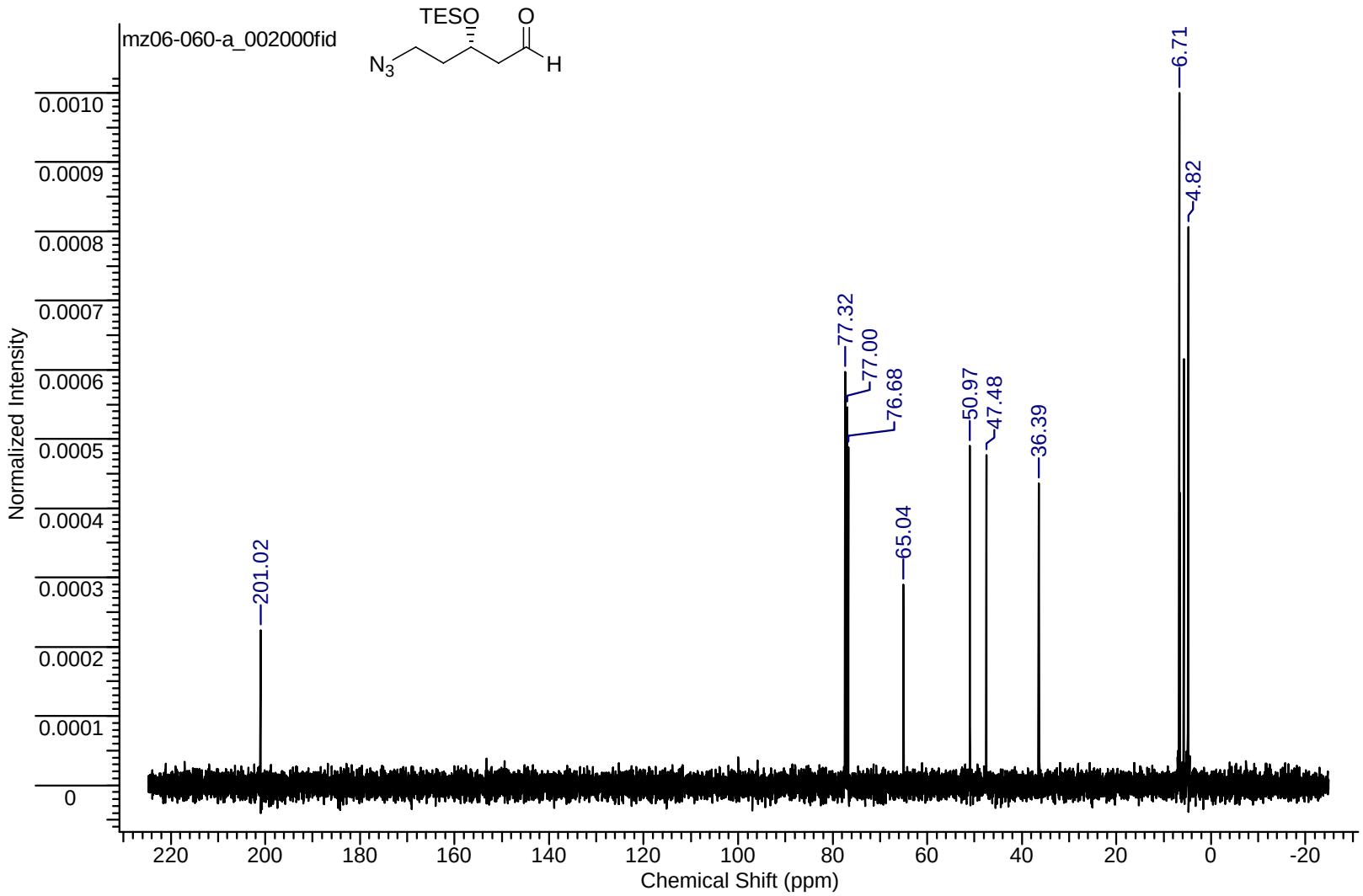
S3

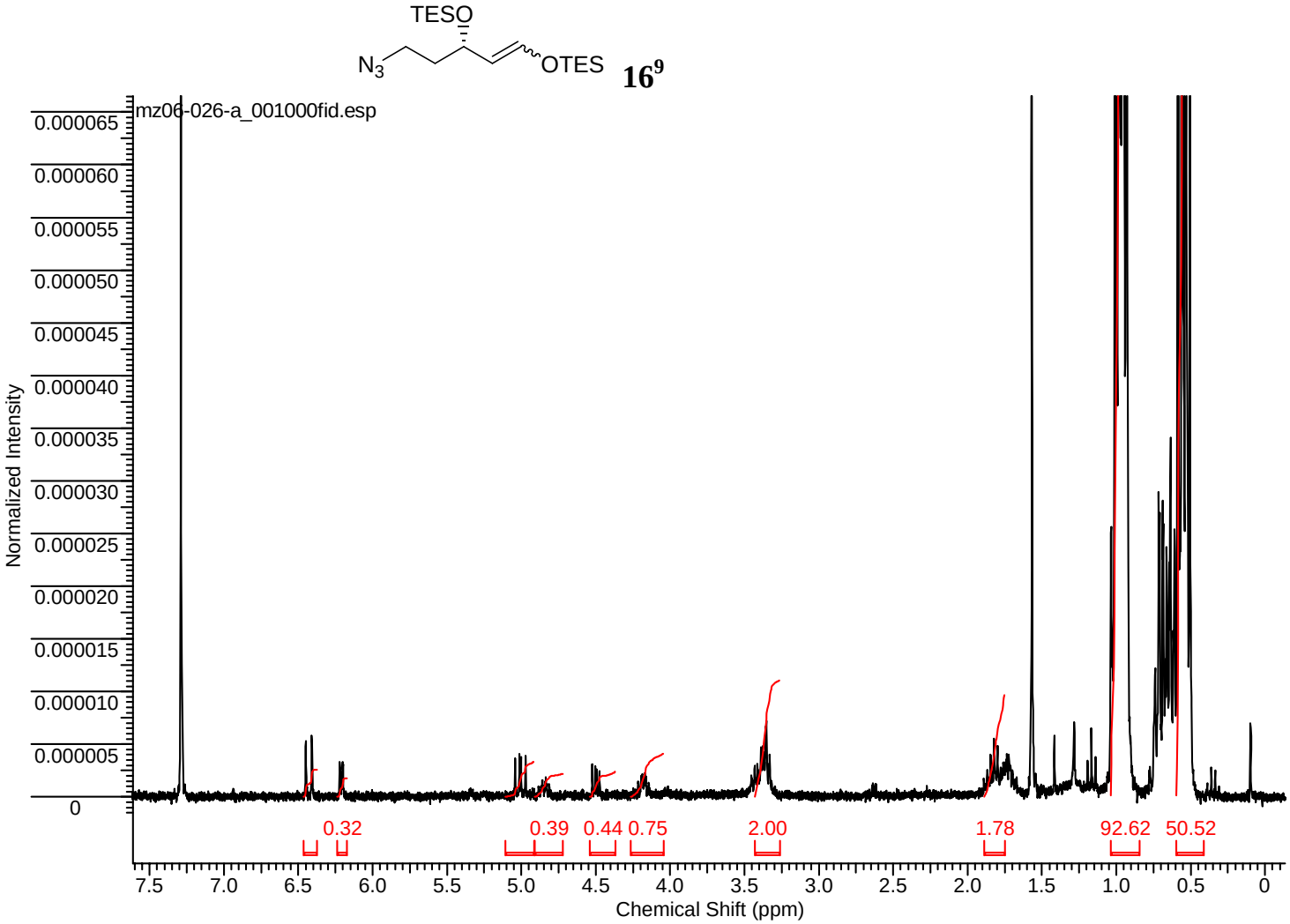

mz06-047-a_001000fid.esp
TESO
O
I
H
Normalized Intensity
0.0010
0.0009
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
9.82
9.81
4.32
4.31
4.30
4.29
3.23
3.21
3.20
2.60
2.59
2.59
2.58
2.57
1.56
0.99
0.97
0.95
0.66
0.64
0.62
0.99
1.06
2.18
2.17
6.58
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
Chemical Shift (ppm)


mz06-047-a_003000fid.esp
TESO
O
I
H
Normalized Intensity
0.0010
0.0009
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
200.99
67.97
50.55
41.37
6.83
4.99
1.28
220
200
180
160
140
120
100
80
60
40
20
0
-20
Chemical Shift (ppm)

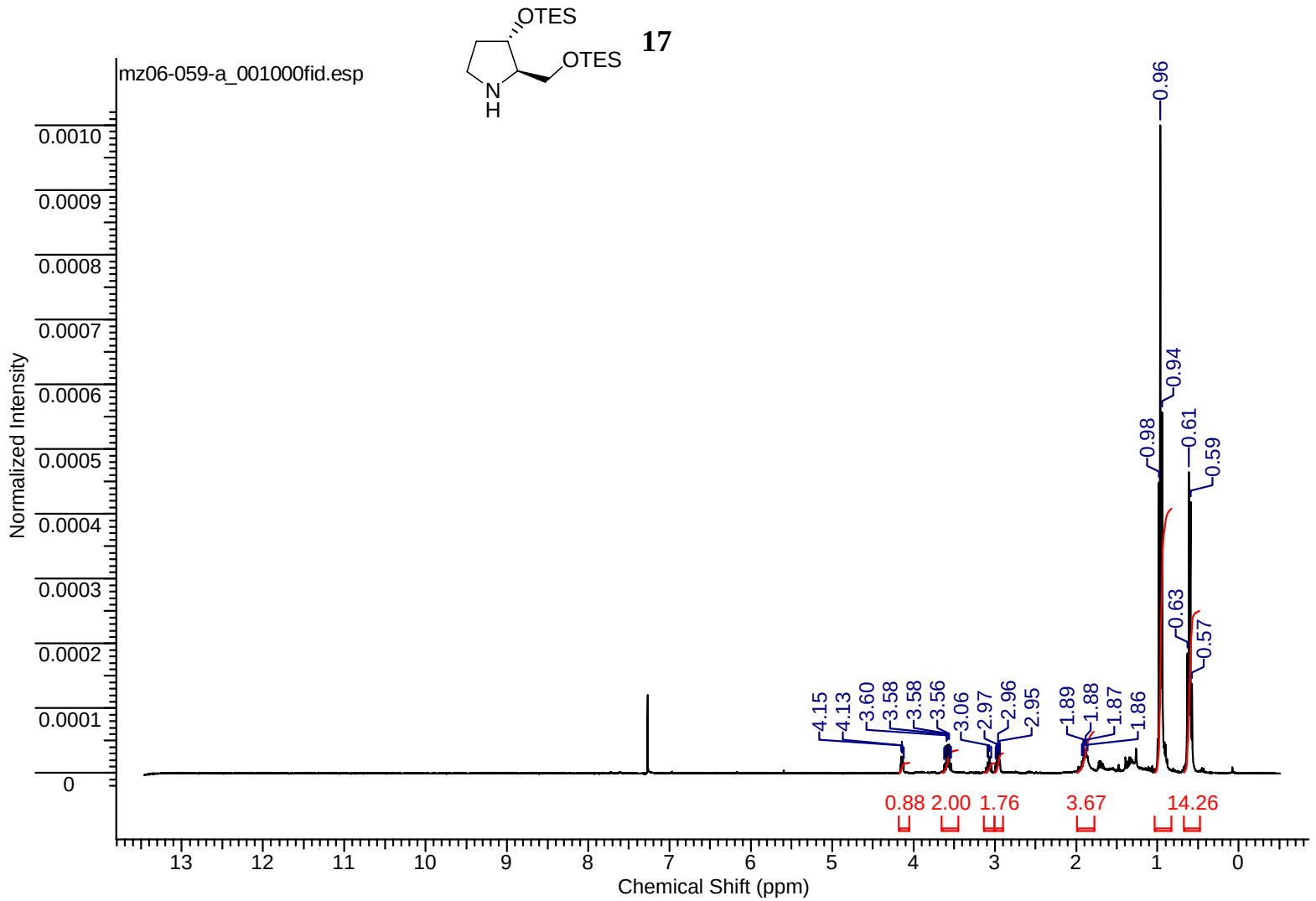
S4

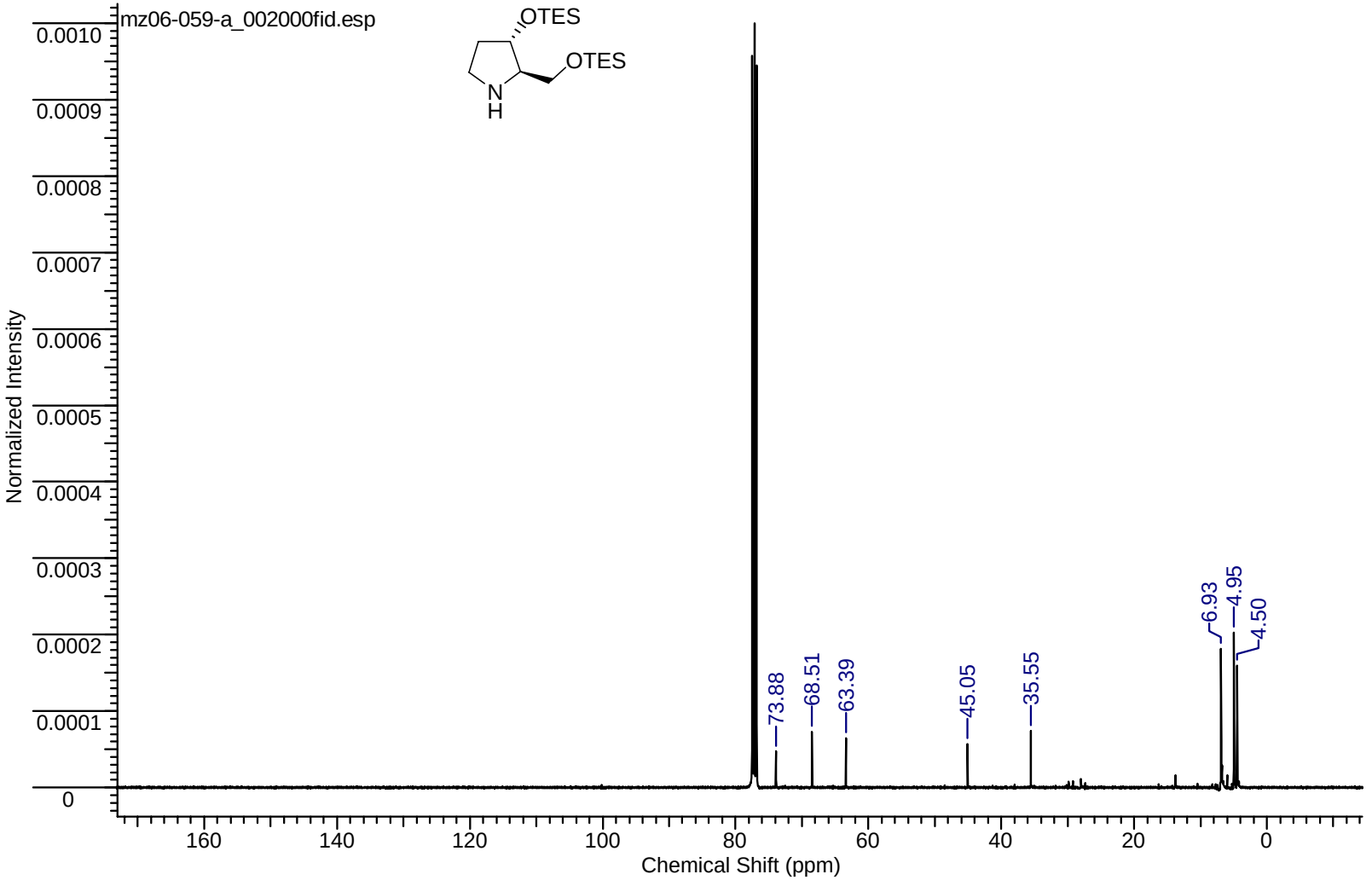

mz06-048-a_001000fid.esp
TESO
O
N3
H
Normalized Intensity
0.0010
0.0009
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
9.82
9.82
9.81
7.27
4.38
4.36
4.35
4.33
4.32
3.43
3.41
3.39
2.61
2.60
2.60
1.83
1.81
1.78
1.79
0.99
0.97
0.95
0.66
0.64
0.62
0.60
0.86
0.95
1.94
1.95
2.00
6.92
11
10
9
8
7
6
5
4
3
2
1
0
Chemical Shift (ppm)

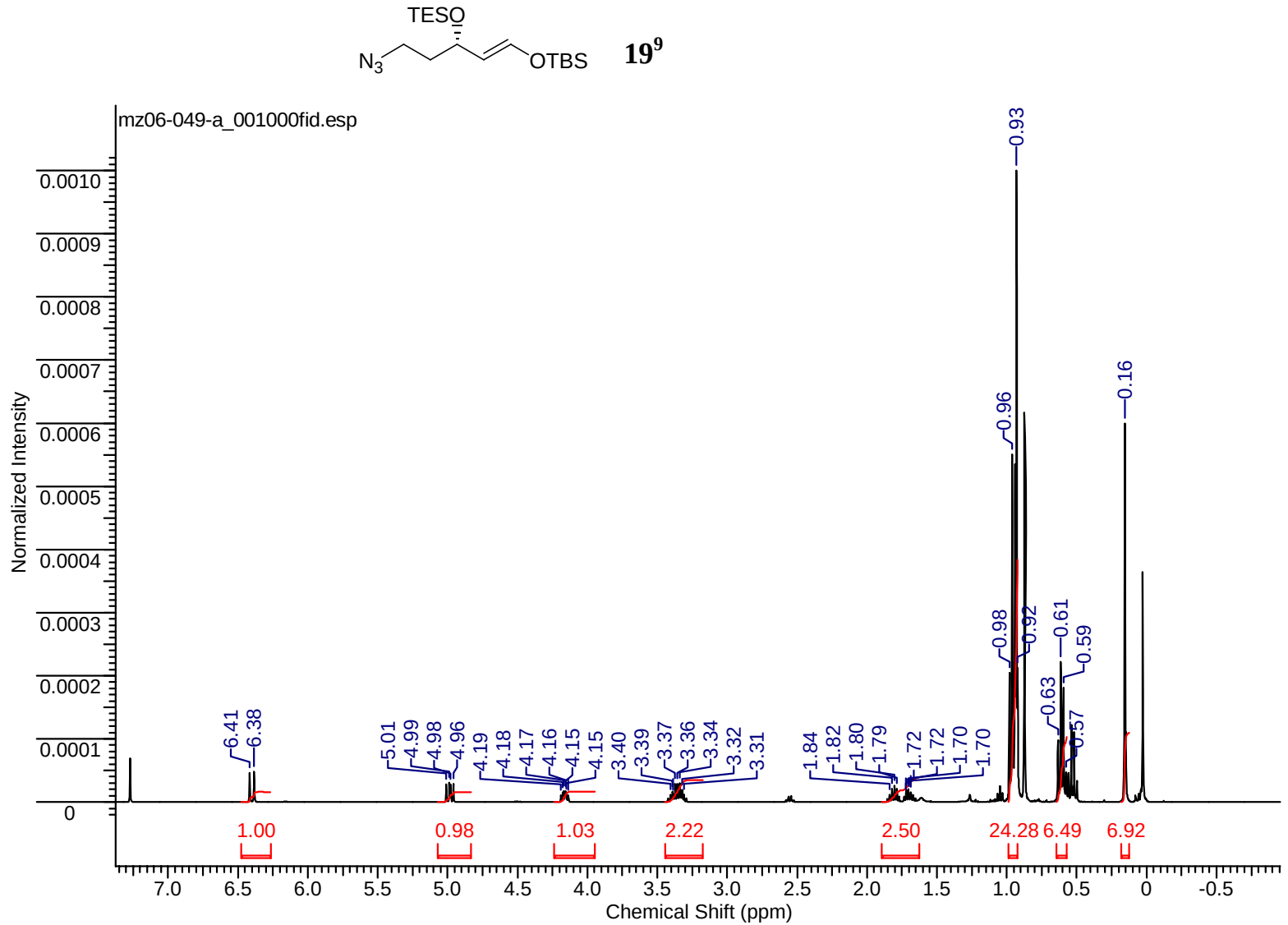

mz06-060-a_002000fid
TESO
O
N3
H
Normalized Intensity
0.0010
0.0009
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
201.02
77.32
77.00
76.68
65.04
50.97
47.48
36.39
6.71
4.82
220
200
180
160
140
120
100
80
60
40
20
0
-20
Chemical Shift (ppm)

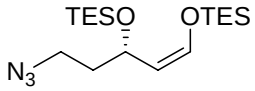


[9] This spectrum has been included for proof of olefin geometry.

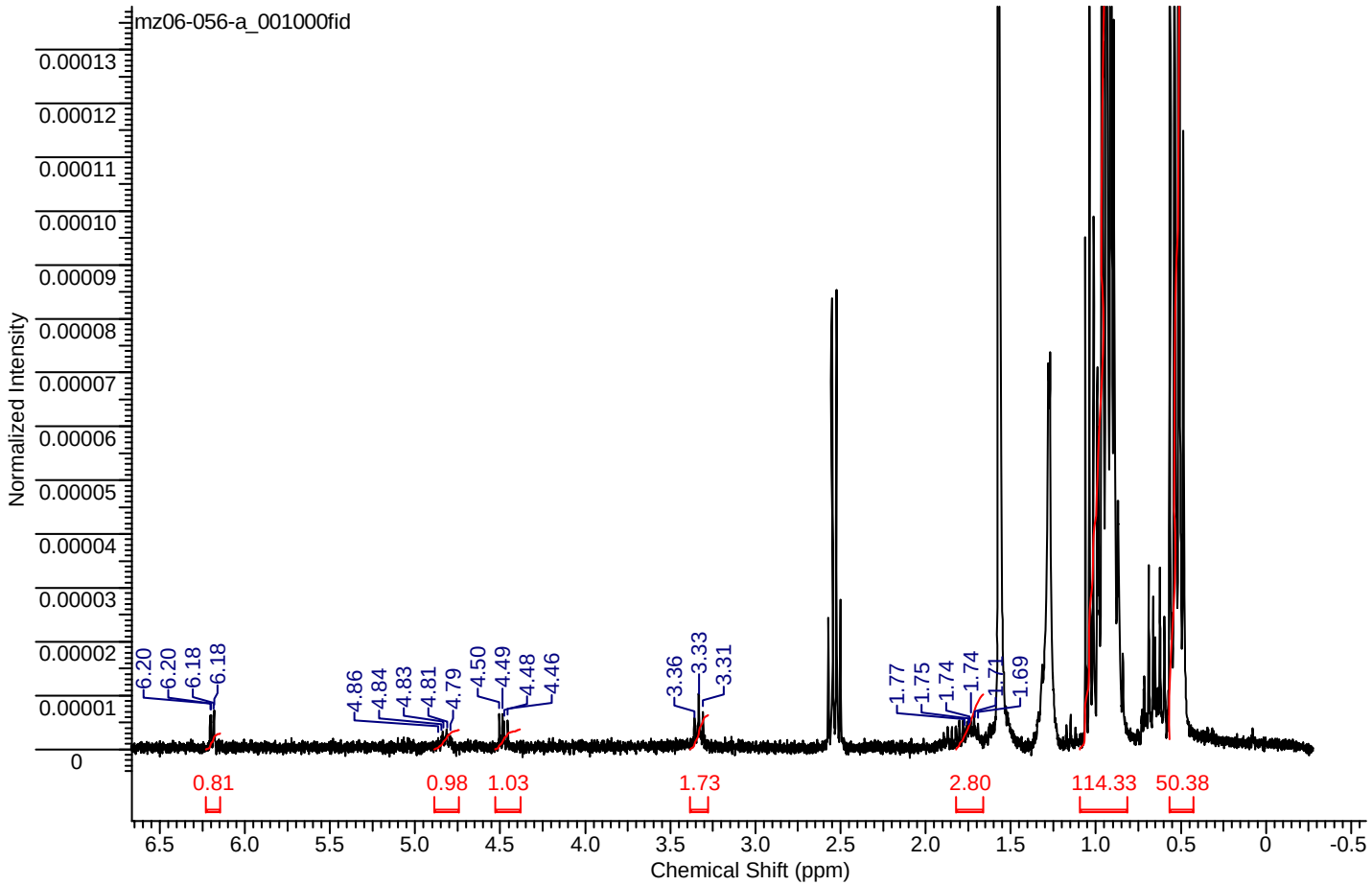

OTES
OTES
N
H
17
mz06-059-a_001000fid.esp
Normalized Intensity
0.0010
0.0009
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
4.15
4.13
3.60
3.58
3.58
3.56
3.06
2.97
2.96
2.95
1.89
1.88
1.87
1.86
0.96
0.94
0.98
0.61
0.59
0.63
0.57
0.88
2.00
1.76
3.67
14.26
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Chemical Shift (ppm)

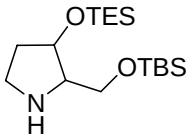

mz06-059-a_002000fid.esp
OTES
OTES
N
H
Normalized Intensity
0.0010
0.0009
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
73.88
68.51
63.39
45.05
35.55
6.93
4.95
4.50
160
140
120
100
80
60
40
20
0
Chemical Shift (ppm)


TESO
N3
OTBS
19[9]
mz06-049-a_001000fid.esp
Normalized Intensity
0.0010
0.0009
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
6.41
6.38
5.01
4.99
4.98
4.96
4.19
4.18
4.17
4.16
4.15
4.15
3.40
3.39
3.37
3.36
3.34
3.32
3.31
1.84
1.82
1.80
1.79
1.72
1.72
1.70
1.70
0.98
0.93
0.92
0.96
0.63
0.61
0.59
0.57
0.16
1.00
0.98
1.03
2.22
2.50
24.28
6.49
6.92
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
-0.5
Chemical Shift (ppm)

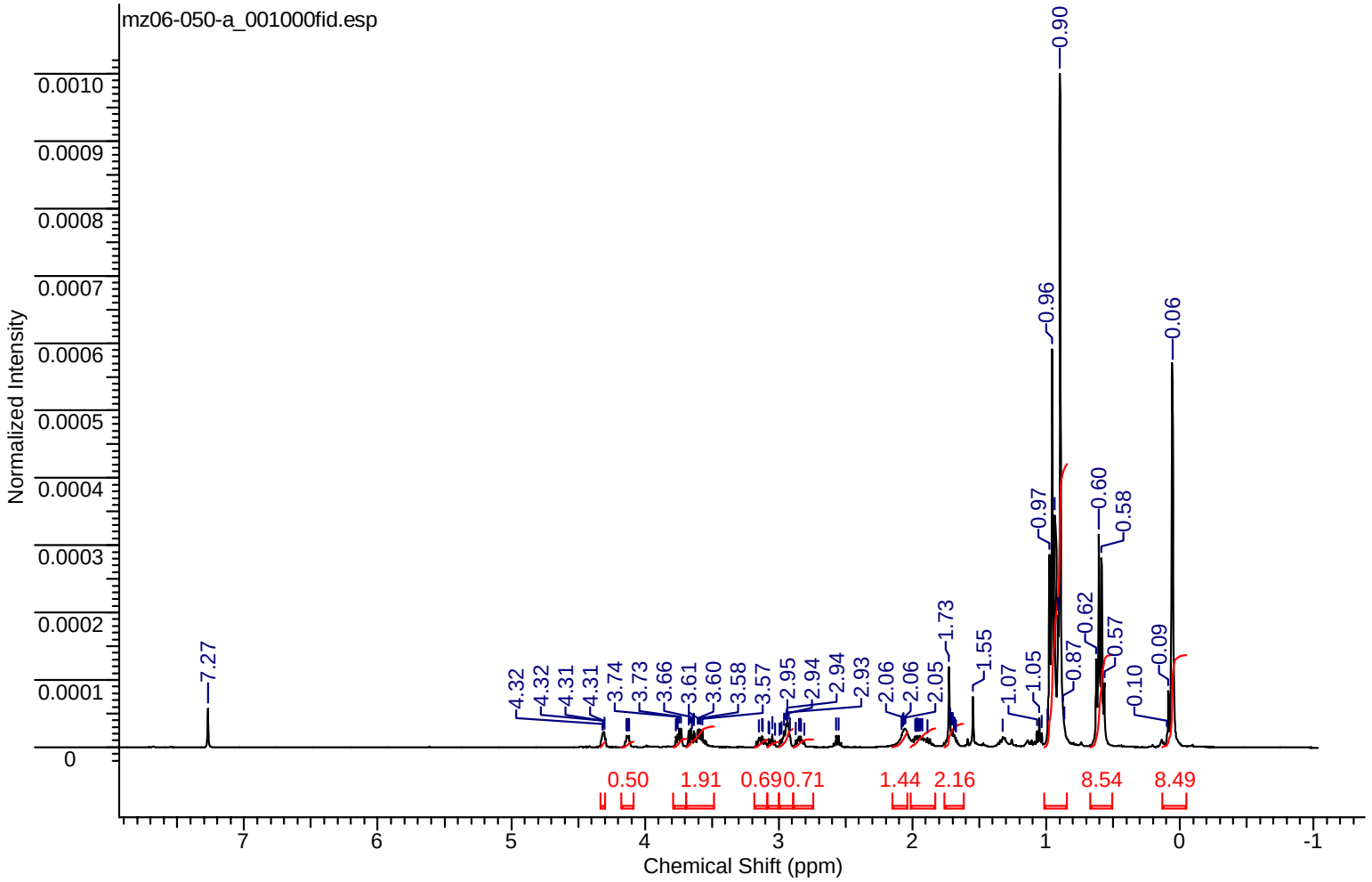

TESO
OTES
N3

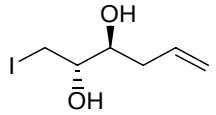
20[9]


mz06-056-a_001000fid
Normalized Intensity
0.00013
0.00012
0.00011
0.00010
0.00009
0.00008
0.00007
0.00006
0.00005
0.00004
0.00003
0.00002
0.00001
0
6.20
6.20
6.18
6.18
4.86
4.84
4.83
4.81
4.79
4.50
4.49
4.48
4.46
3.36
3.33
3.31
1.77
1.75
1.74
1.74
1.71
1.69
0.81
0.98
1.03
1.73
2.80
114.33
50.38
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
-0.5
Chemical Shift (ppm)

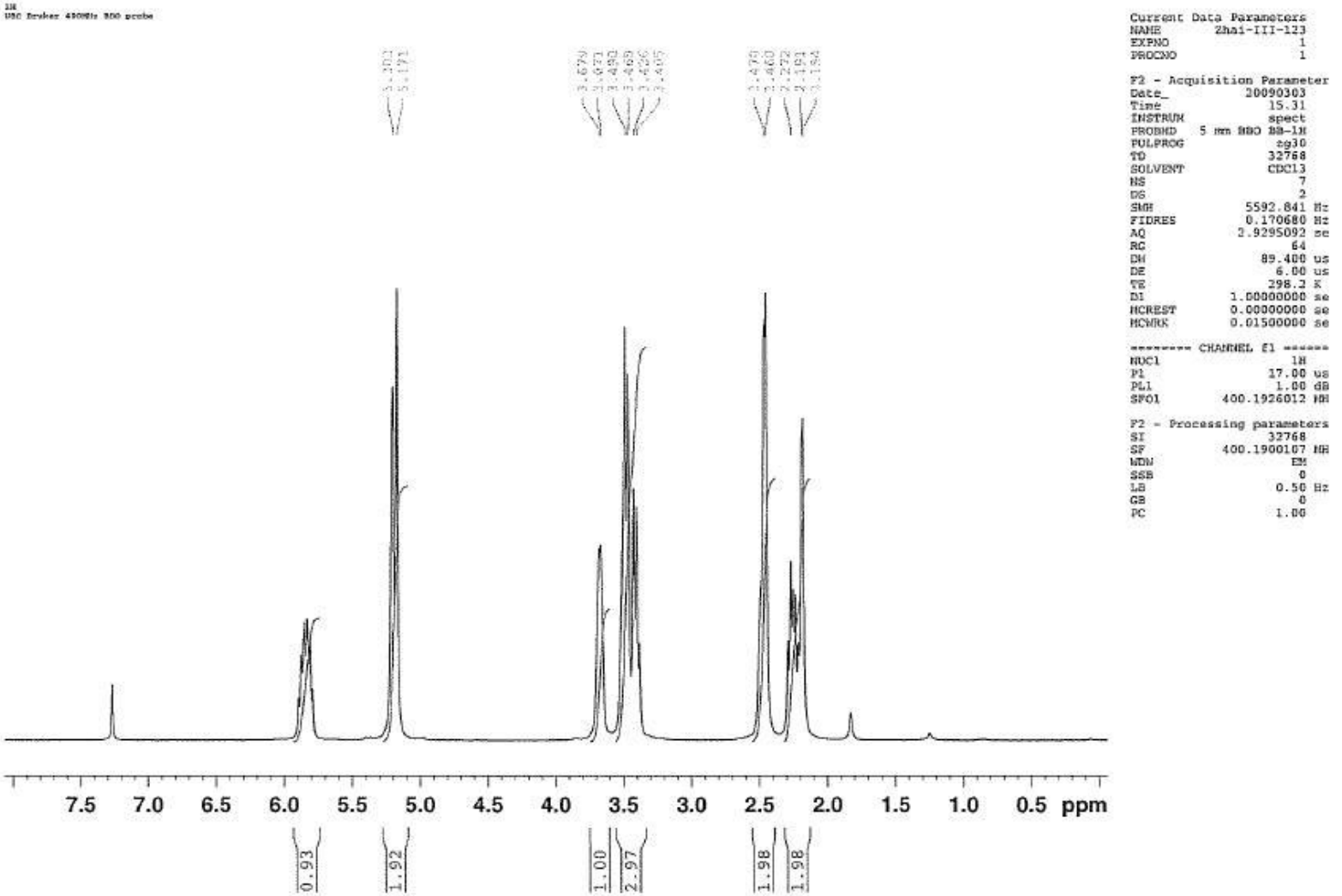

OTES
OTBS
N
H

21

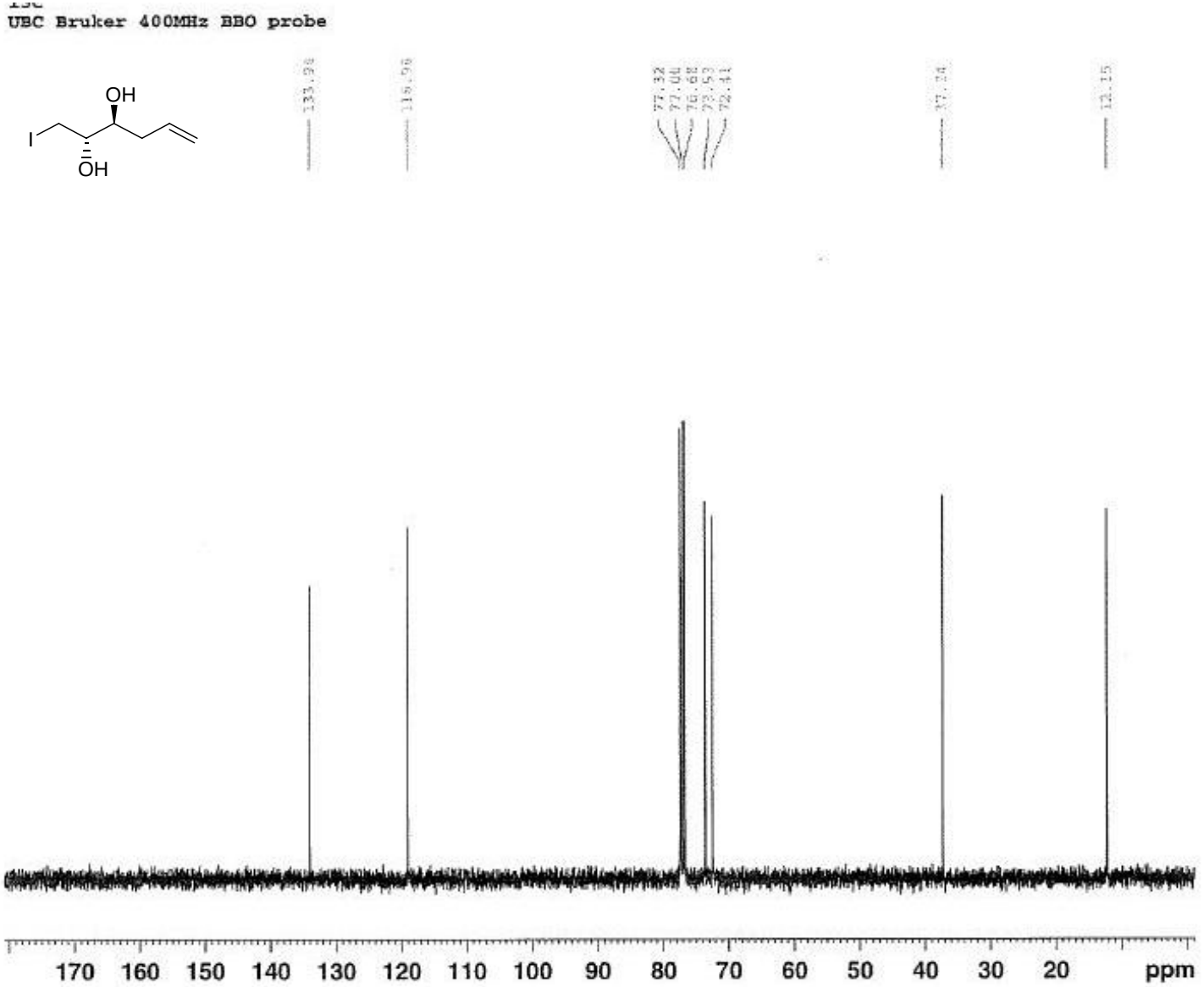

mz06-050-a_001000fid.esp
Normalized Intensity
0.0010
0.0009
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
7.27
4.32
4.32
4.31
4.31
3.74
3.73
3.66
3.61
3.60
3.58
3.57
2.95
2.94
2.94
2.93
2.06
2.06
2.05
1.73
1.55
1.07
1.05
0.97
0.96
0.90
0.87
0.62
0.60
0.58
0.57
0.10
0.09
0.06
0.50
1.91
0.69
0.71
1.44
2.16
8.54
8.49
7
6
5
4
3
2
1
0
-1
Chemical Shift (ppm)

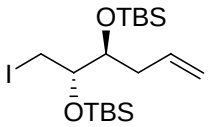


S5

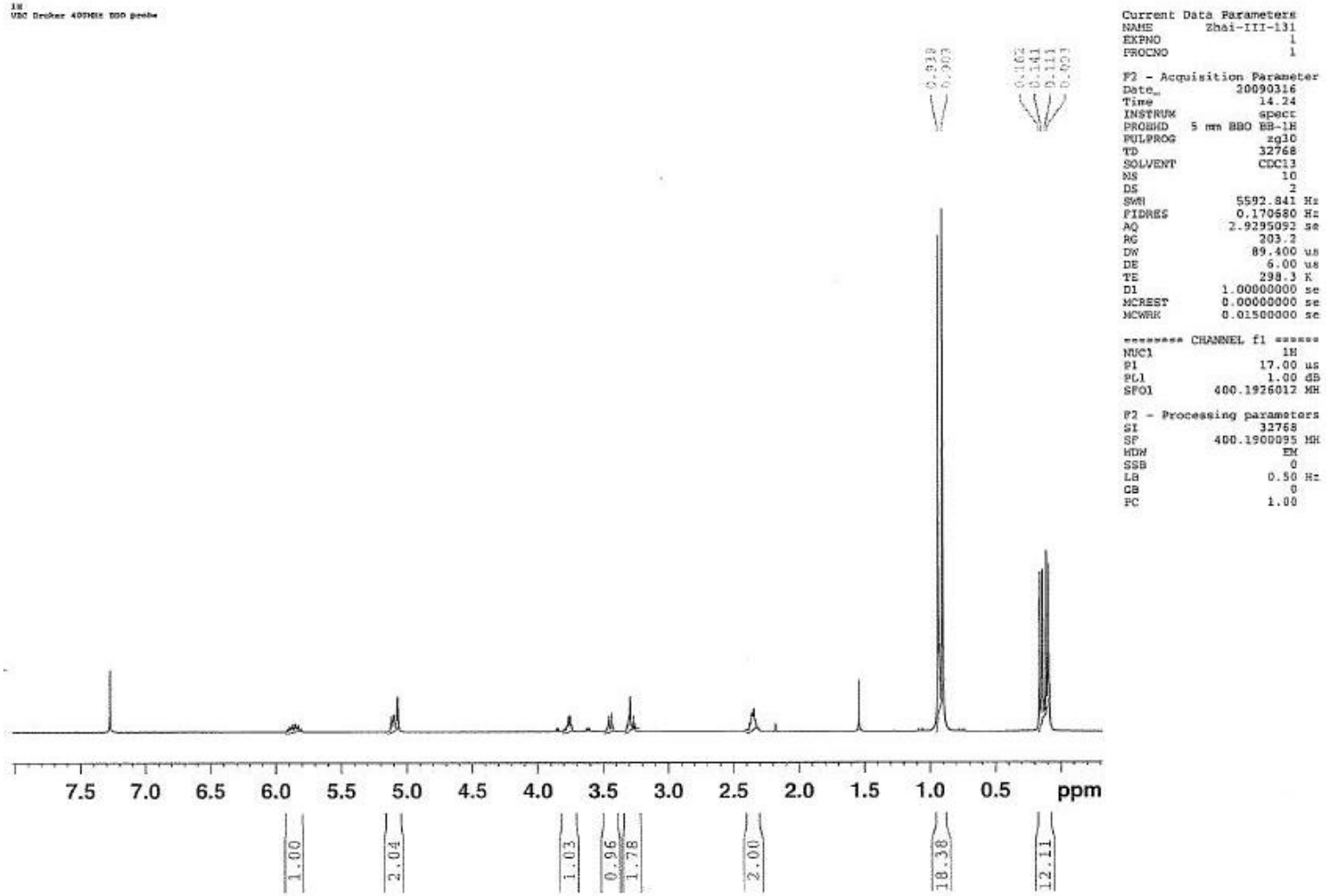


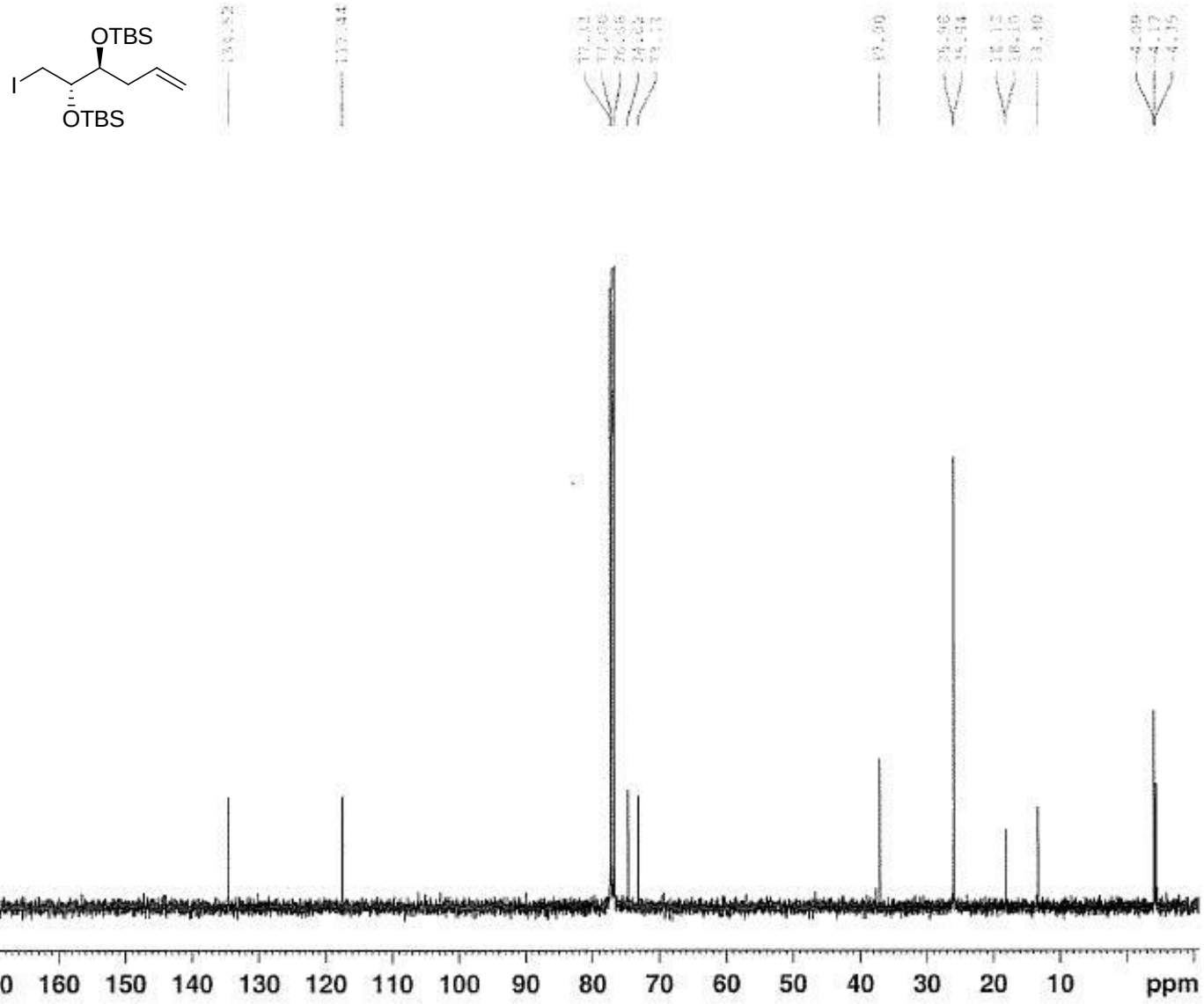

```
Current Data Parameters
NAME         2hai-III-123
EXPNO                   1
PROCNO                  1

F2 - Acquisition Parameter
Date_             20090303
Time                15.31
INSTRUM             spect
PROBHD   5 mm BBO BB-1H
PULPROG             zg30
TD                 32768
SOLVENT            CDCl3
NS                     7
DS                     2
SWH              5592.841 Hz
FIDRES           0.170680 Hz
AQ               2.9295092 se
RG                    64
DW                89.400 us
DE                 6.00 us
TE                298.2 K
D1             1.00000000 se
HCREST         0.00000000 se
HCWRK          0.01500000 se

======== CHANNEL f1 ======
NUC1                  1H
P1                 17.00 us
PL1                 1.00 dB
SFO1         400.1926012 MH

F2 - Processing parameters
SI                 32768
SF           400.1900107 MH
WDW                   EM
SSB                    0
LB                  0.50 Hz
GB                     0
PC                  1.00
```

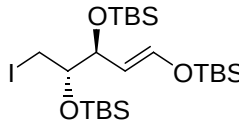

UBC Bruker 400MHz BBO probe
OH
I
OH
133.98
119.96
77.32
77.04
76.68
73.53
72.41
37.24
13.15
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
ppm


OTBS
I
OTBS

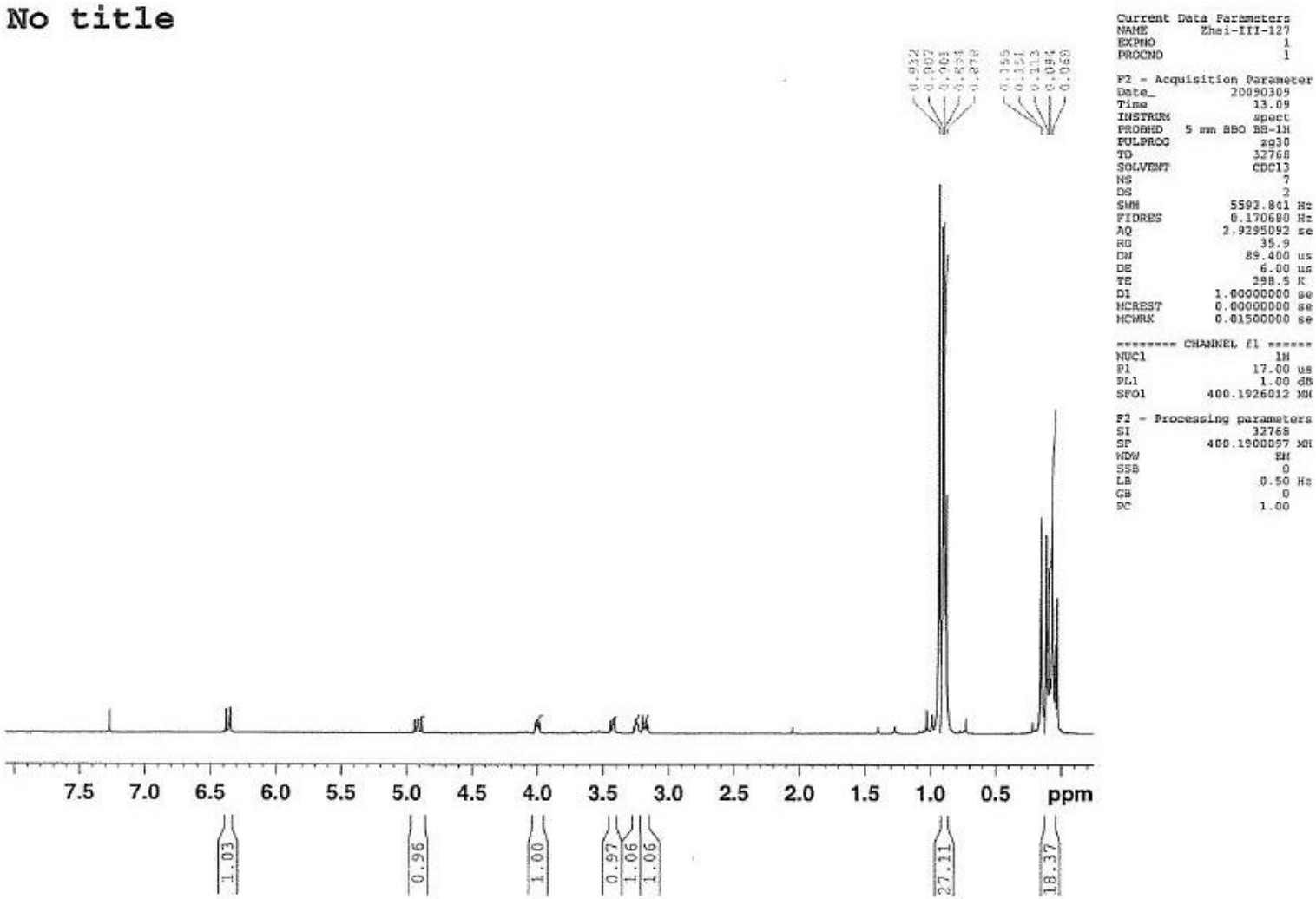
23

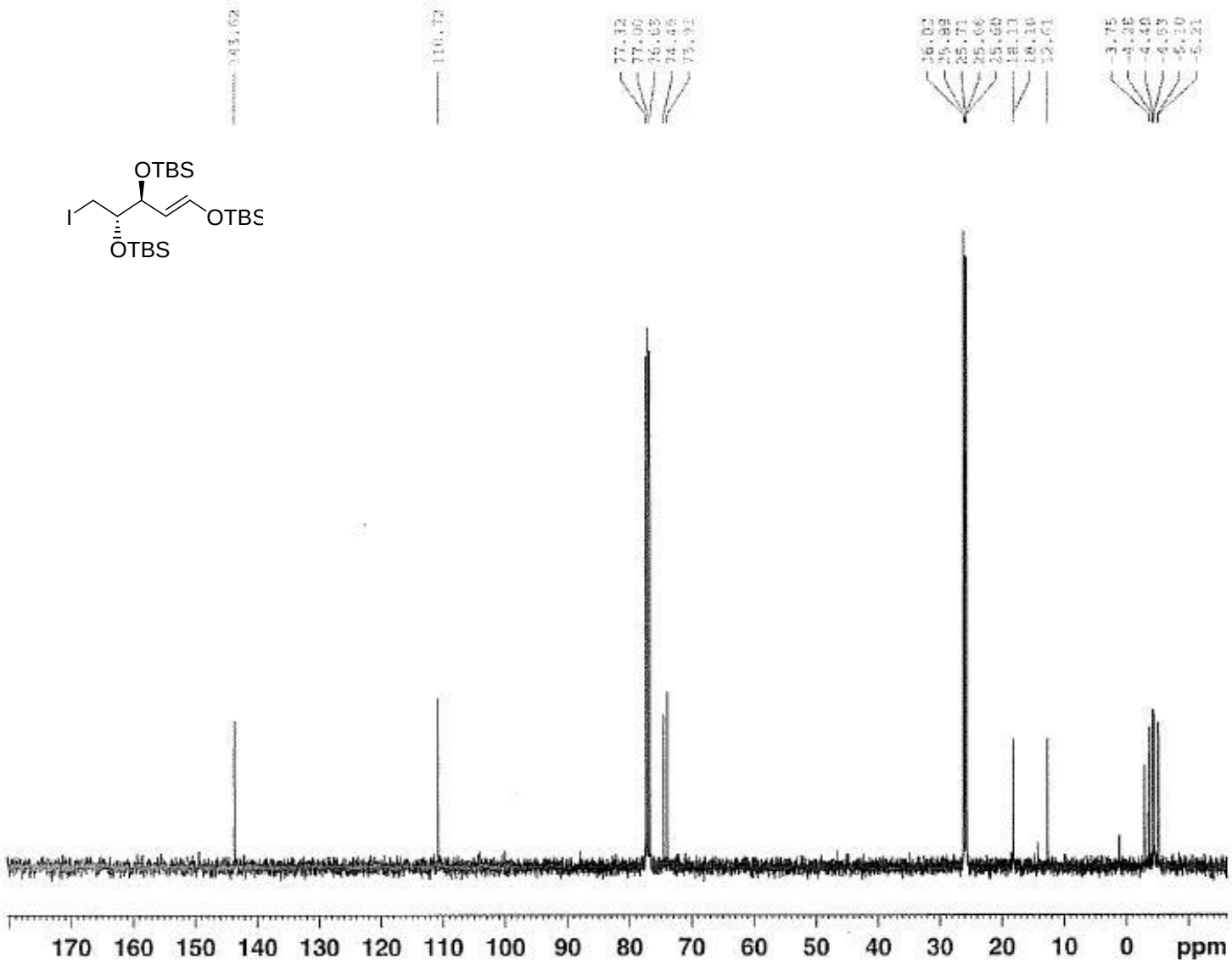

1H
VBC Bruker 400MHz BBO probe
0.939
0.903
0.162
0.141
0.111
0.093
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
ppm
1.00
2.04
1.03
0.96
1.78
2.00
18.38
12.11
Current Data Parameters
NAME Zhai-III-131
EXPNO 1
PROCNO 1
F2 - Acquisition Parameter
Date_ 20090316
Time 14.24
INSTRUM spect
PROBHD 5 mm BBO BB-1H
PULPROG zg30
TD 32768
SOLVENT CDCl3
NS 10
DS 2
SWH 5592.841 Hz
FIDRES 0.170680 Hz
AQ 2.9295092 se
RG 203.2
DW 89.400 us
DE 6.00 us
TE 298.3 K
D1 1.00000000 se
MCREST 0.00000000 se
MCWRK 0.01500000 se
======== CHANNEL f1 ======
NUC1 1H
P1 17.00 us
PL1 1.00 dB
SFO1 400.1926012 MH
F2 - Processing parameters
SI 32768
SF 400.1900095 MH
WDW EM
SSB 0
LB 0.50 Hz
GB 0
PC 1.00

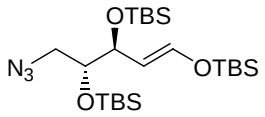

OTBS
I
OTBS
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm


OTBS
I
OTBS
OTBS

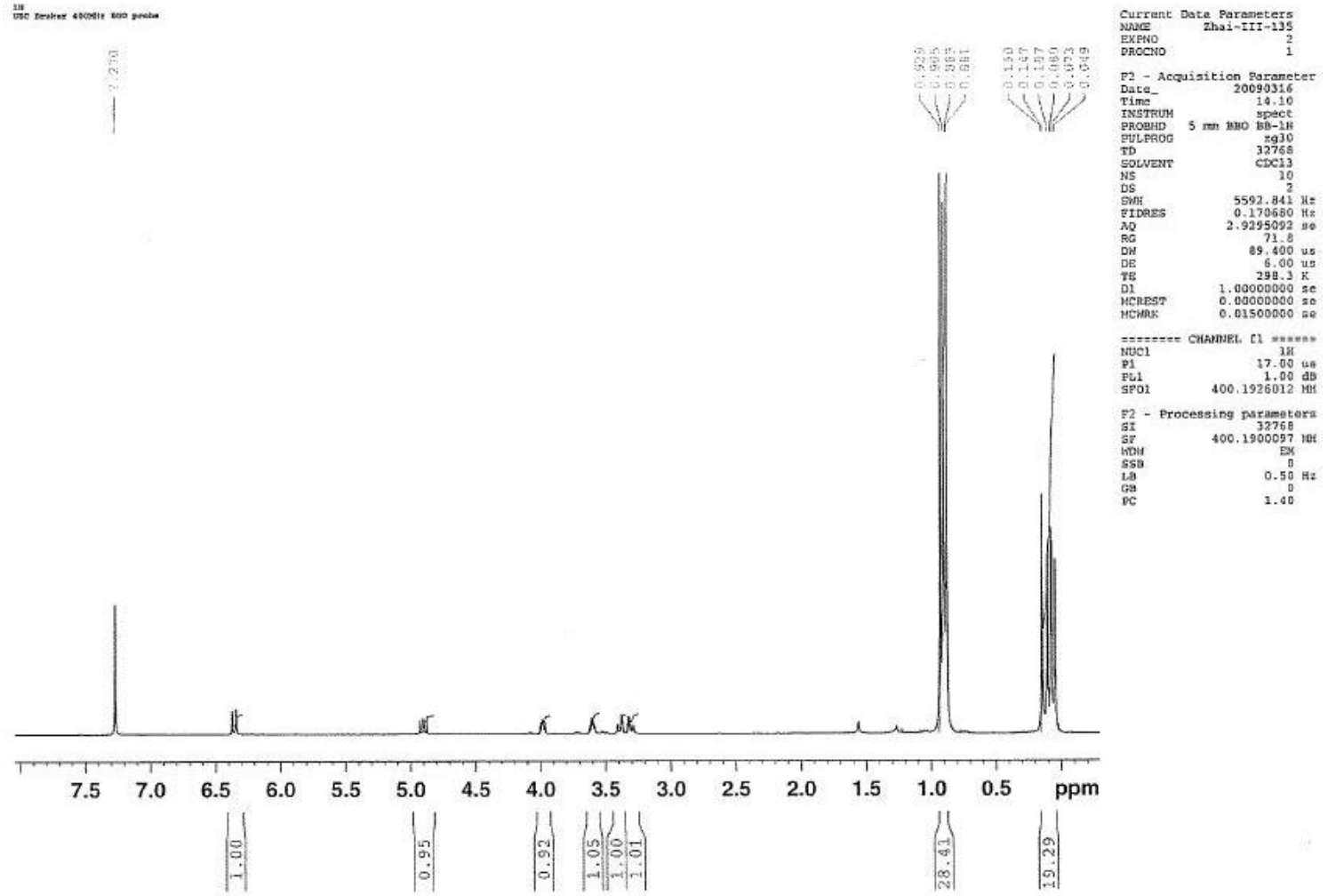
24

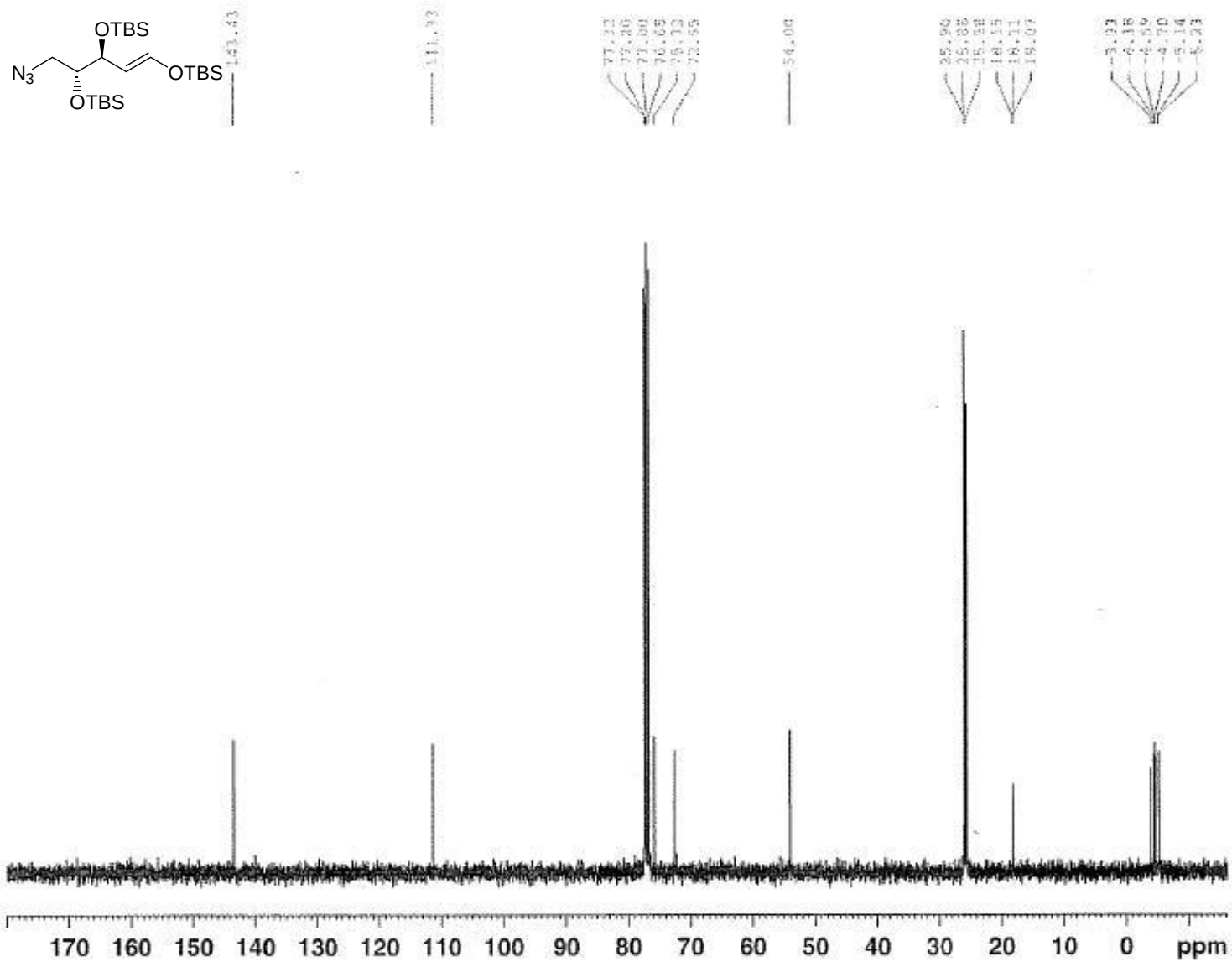

No title
Current Data Parameters
NAME Zhai-III-127
EXPNO 1
PROCNO 1
F2 - Acquisition Parameter
Date_ 20090309
Time 13.09
INSTRUM spect
PROBHD 5 mm BBO BB-1H
PULPROG zg30
TD 32768
SOLVENT CDCl3
NS 7
DS 2
SWH 5592.861 Hz
FIDRES 0.170680 Hz
AQ 2.9295092 se
RG 35.9
DW 89.400 us
DE 6.00 us
TE 298.5 K
D1 1.00000000 se
HCREST 0.00000000 se
HCWRX 0.01500000 se
======== CHANNEL f1 ======
NUC1 1H
P1 17.00 us
PL1 1.00 dB
SFO1 400.1926012 MH
F2 - Processing parameters
SI 32768
SF 400.1900097 MH
WDW EM
SSB 0
LB 0.50 Hz
GB 0
PC 1.00
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 ppm
1.03
0.96
1.00
0.97
1.06
1.06
27.11
18.37

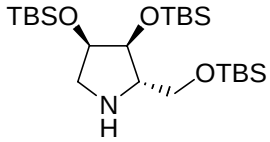

143.62
110.72
77.32
77.06
76.69
74.46
73.92
18.01
25.89
25.71
25.66
25.60
18.13
18.16
12.61
3.75
4.28
4.46
4.53
5.10
5.21
OTBS
I
OTBS
OTBS
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm


OTBS
N3
OTBS
OTBS

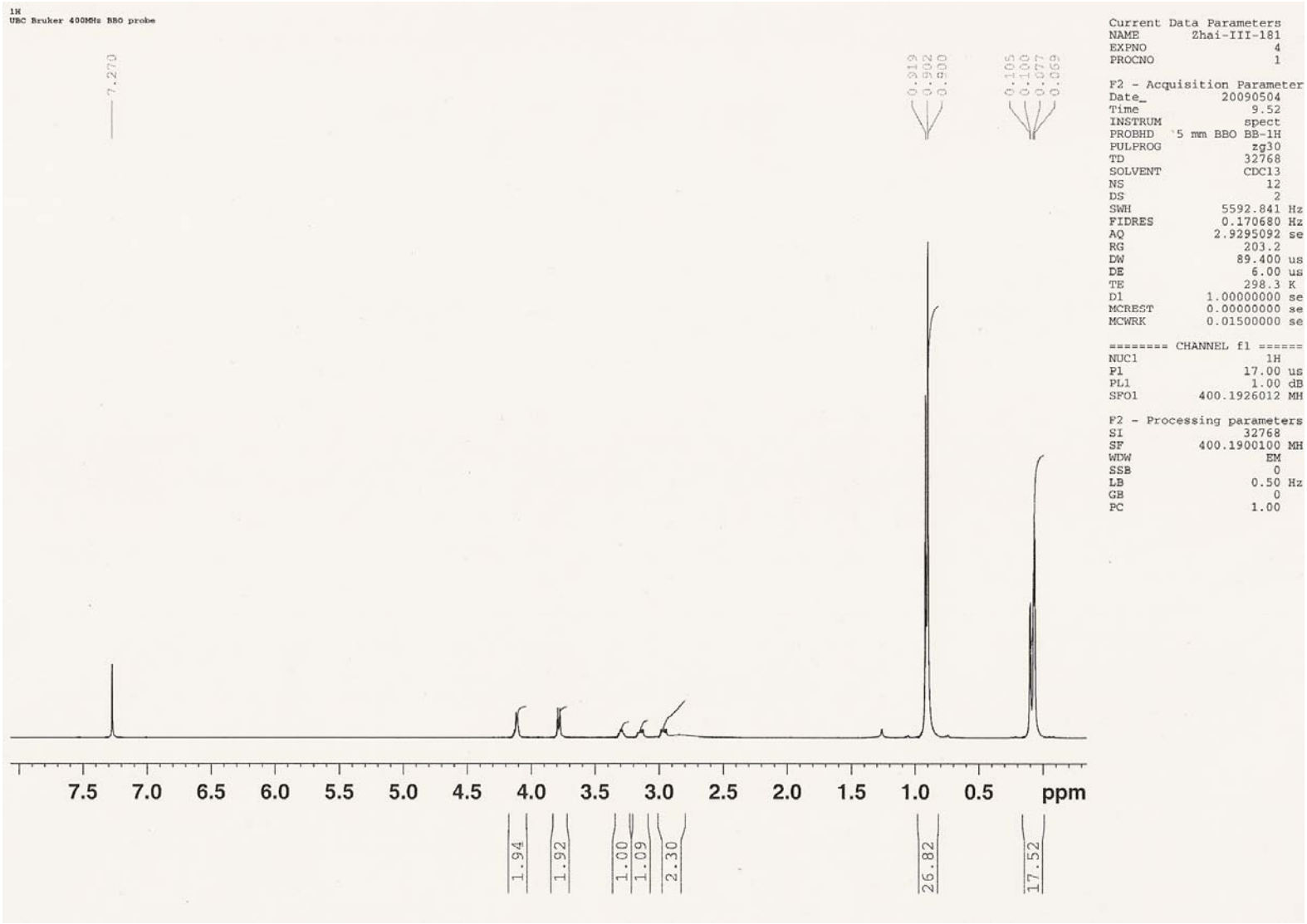
25

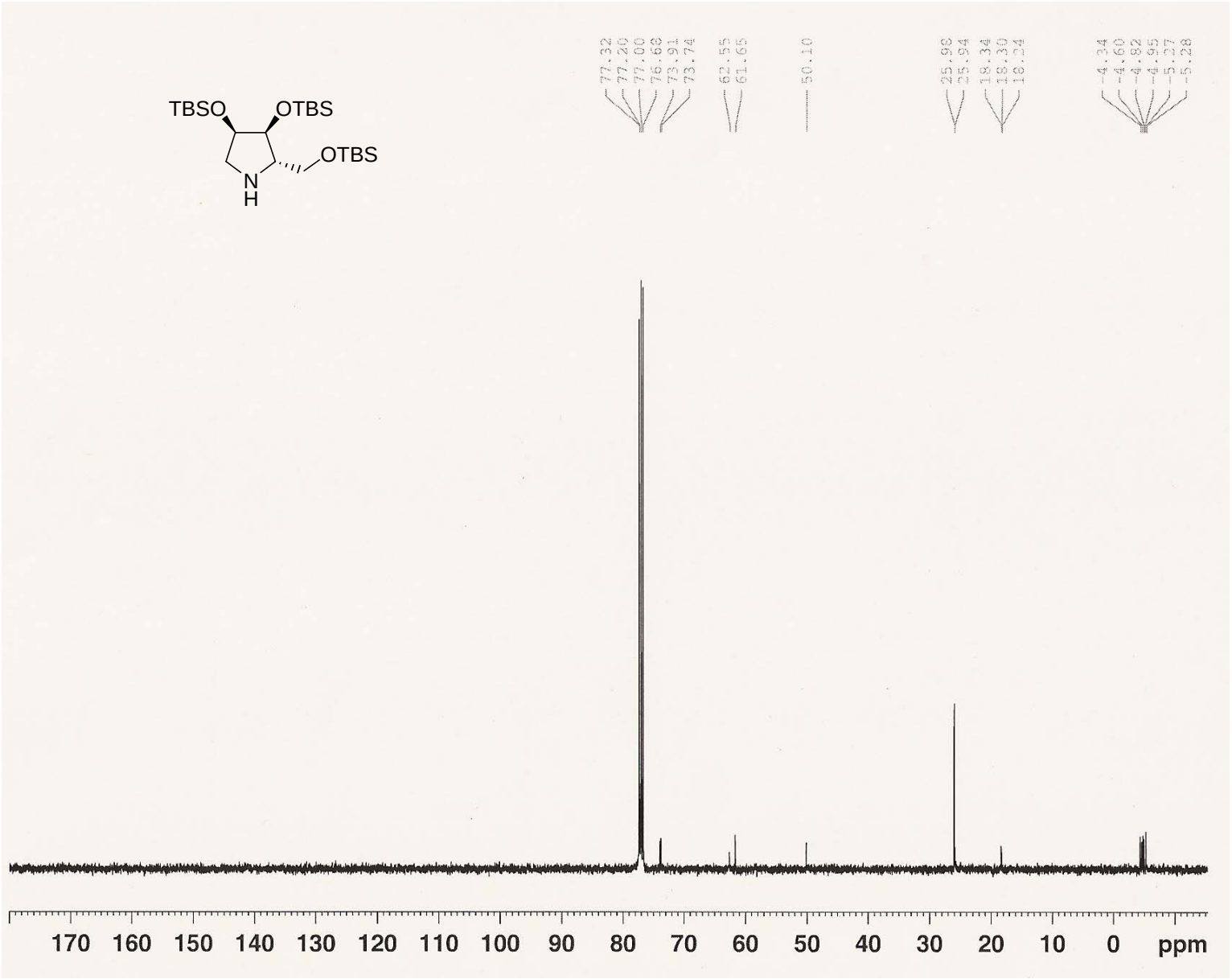

7.279
0.929
0.905
0.565
0.561
0.150
0.147
0.137
0.069
0.073
0.049
Current Data Parameters
NAME Zhai-III-135
EXPNO 2
PROCNO 1
F2 - Acquisition Parameter
Date_ 20090316
Time 14.10
INSTRUM spect
PROBHD 5 mm BBO BB-1H
PULPROG zg30
TD 32768
SOLVENT CDCl3
NS 10
DS 2
SWH 5592.841 Hz
FIDRES 0.170680 Hz
AQ 2.9295092 se
RG 71.8
DW 89.400 us
DE 6.00 us
TE 298.1 K
D1 1.00000000 se
MCREST 0.00000000 se
MCWRK 0.01500000 se
======== CHANNEL f1 ======
NUC1 1H
P1 17.00 us
PL1 1.00 dB
SFO1 400.1926012 MH
F2 - Processing parameters
SI 32768
SF 400.1900097 MH
WDW EM
SSB 0
LB 0.50 Hz
GB 0
PC 1.40
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
ppm
1.00
0.95
0.92
1.05
1.00
1.01
28.41
19.29

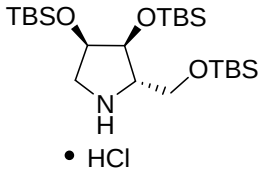

OTBS
N3
OTBS
OTBS
143.43
111.32
77.33
77.00
76.68
75.13
72.56
54.00
25.96
25.89
25.58
18.15
18.11
18.07
-3.33
-4.18
-4.59
-4.70
-5.14
-5.23
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm



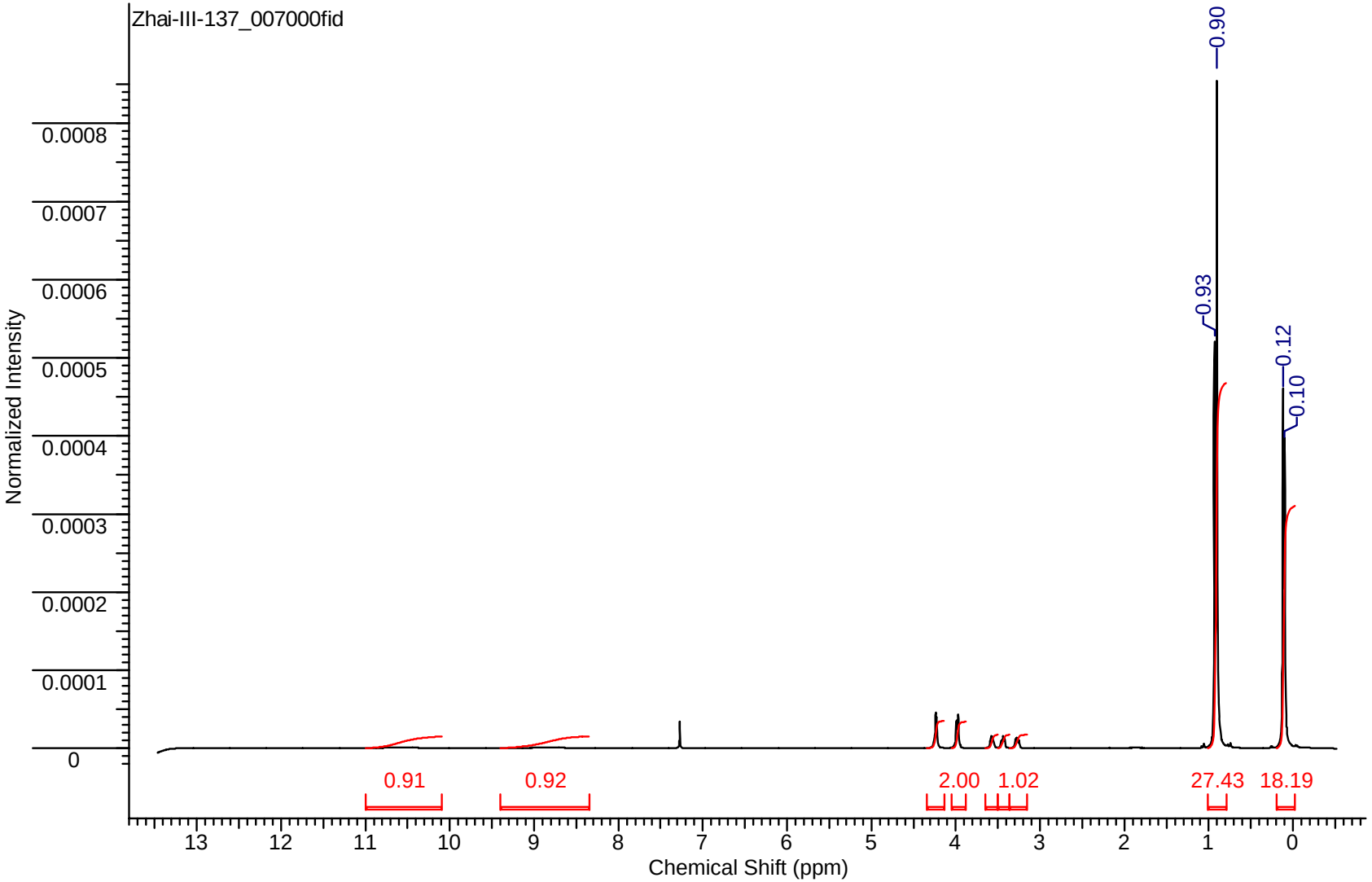
26 (free amine)

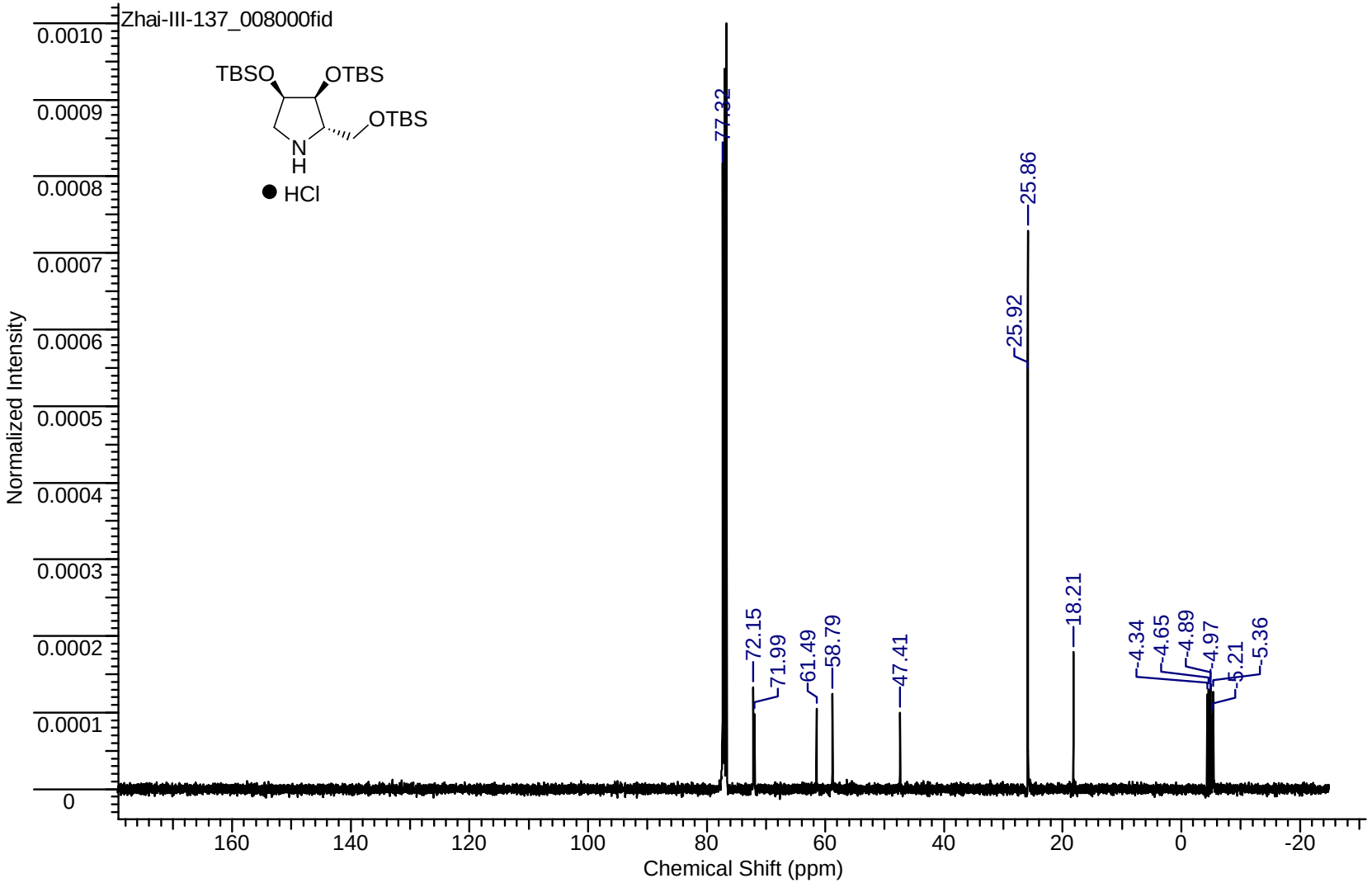



TBSO
OTBS
OTBS
N
H
77.32
77.20
77.00
76.68
73.91
73.74
62.55
61.65
50.10
25.98
25.94
18.34
18.30
18.24
-4.34
-4.60
-4.82
-4.95
-5.27
-5.28
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm


TBSO
OTBS
OTBS
N
H
• HCl

29


Zhai-III-137_007000fid
Normalized Intensity
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
0.90
0.93
0.12
0.10
0.91
0.92
2.00
1.02
27.43
18.19
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Chemical Shift (ppm)


Zhai-III-137_008000fid
TBSO
OTBS
OTBS
N
H
HCl
Normalized Intensity
0.0010
0.0009
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
77.32
25.86
25.92
72.15
71.99
61.49
58.79
47.41
18.21
4.34
4.65
4.89
4.97
5.21
5.36
160
140
120
100
80
60
40
20
0
-20
Chemical Shift (ppm)