Electronic Supplementary Information:

Efficient Bromination of Olefins, Alkynes, and Ketones with Dimethyl Sulfoxide and Hydrobromic Acid

Song Song, Xinwei Li, Xiang Sun, Yizhi Yuan and Ning Jiao*

Tables of Contents:

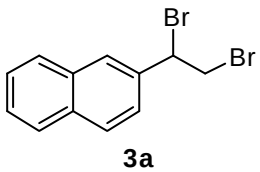
(A) General Remarks

All commercially available compounds were purchased from Sigma-Aldrich, Alfa-Aesar, Acros, Beijing Ouhe and Beijing Chemical Works, Ltd. Unless otherwise noted, materials obtained from commercial suppliers were used without further purification. Analysis of crude reaction mixture was done on an Agilent 7890 GC System with an Agilent 5975 Mass Selective Detector. Products were purified by flash chromatography on silica gel. ^{1}H-NMR spectra were recorded on Bruker AVANCE III-400 spectrometers. Chemical shifts (in ppm) were referenced TMS in $CDCl_3$ (0 ppm). ^{13}C-NMR spectra were obtained by using the same NMR spectrometers and were calibrated with $CDCl_3$ (δ = 77.00 ppm). Mass spectra were recorded using a PE SCLEX QSTAR spectrometer. High resolution mass spectra were obtained with a Bruker APEX IV Fourier transform ion cyclotron resonance mass spectrometer.

(B) Experimental Procedure and Characterization Data of Products

Typical procedure for dibromination of olefins and alkynes: Olefin **1** or alkyne **6** (0.5 mmol) and DMSO (43 μL, 0.6 mmol) were dissolved in EA (2 mL). Aqueous hydrobromic acid (48%, 202 mg, 1.2 mmol) was added to the solution at 60 ^{o}C and the mixture were stirred for 0.5 h under air at that temperature. After cooling down to room temperature and concentrating in vacuum, the residue was purified by chromatography on silica gel (petroleum ether/ethyl acetate) to afford the dibrominated product **3** or **7**.

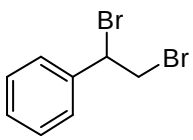
2-(1,2-Dibromoethyl)naphthalene (3a)[1]



3a

The reaction of 2-vinylnaphthalene **1a** (77.1 mg, 0.5 mmol), DMSO (43 μL, 0.6 mmol), and aqueous hydrobromic acid (48%, 202 mg, 1.2 mmol) in EA (2 mL) at 60 ^{o}C for 0.5 h, affords 125.4 mg (80%) of **3a** as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.89–7.83 (m, 4H), 7.53–7.50 (m, 3H), 5.33 (dd, *J* = 8.8, 7.2 Hz, 1H), 4.16–4.13 (m, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 135.7, 133.5, 132.9, 129.1, 128.2, 127.8, 127.4, 126.9, 126.7, 124.4, 51.3, 34.8.

(1,2-Dibromoethyl)benzene (3b)[2]

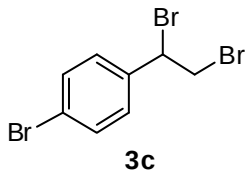


3b

The reaction of styrene **1b** (52.1 mg, 0.5 mmol), DMSO (43 μL, 0.6 mmol), and aqueous hydrobromic acid (48%, 202 mg, 1.2 mmol) in

EA (2 mL) at 60 °C for 0.5 h, affords 93.6 mg (71%) of **3b** as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.38–7.31 (m, 5H), 5.13 (dd, *J* = 10.4, 5.6 Hz, 1H), 4.08–3.98 (m, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 138.6, 129.1, 128.8, 127.6, 50.9, 35.0.

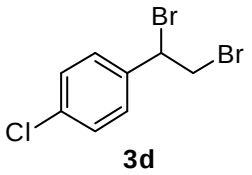
1-Bromo-4-(1,2-dibromoethyl)benzene (3c)[3]



3c

The reaction of 1-bromo-4-vinylbenzene **1c** (91.5 mg, 0.5 mmol), DMSO (43 μL, 0.6 mmol), and aqueous hydrobromic acid (48%, 202 mg, 1.2 mmol) in EA (2 mL) at 60 °C for 0.5 h, affords 130.1 mg (76%) of **3c** as a white solid. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.52 (d, *J* = 8.8 Hz, 2H), 7.28 (d, *J* = 8.0 Hz, 2H), 5.09 (dd, *J* = 11.2, 5.2 Hz, 1H), 4.06 (dd, *J* = 10.2, 5.0 Hz, 1H), 3.99–3.94 (m, 1H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 137.7, 132.1, 129.3, 123.2, 49.5, 34.6.

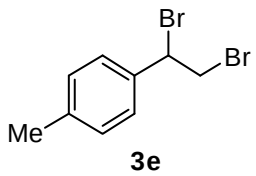
1-Chloro-4-(1,2-dibromoethyl)benzene (3d)[4]



3d

The reaction of 1-chloro-4-vinylbenzene **1d** (69.3 mg, 0.5 mmol), DMSO (43 μL, 0.6 mmol), and aqueous hydrobromic acid (48%, 202 mg, 1.2 mmol) in EA (2 mL) at 60 °C for 0.5 h, affords 110.5 mg (74%) of **3d** as a white solid. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.38–7.33 (m, 4H), 5.10 (dd, *J* = 11.0, 5.0 Hz, 1H), 4.06 (dd, *J* = 10.4, 5.2 Hz, 1H), 3.99–3.94 (m, 1H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 137.1, 135.0, 129.1, 129.0, 49.5, 34.6.

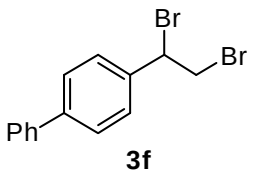
1-(1,2-Dibromoethyl)-4-methylbenzene (3e)[4]



3e

The reaction of 1-methyl-4-vinylbenzene **1e** (59.1 mg, 0.5 mmol), DMSO (43 μL, 0.6 mmol), and aqueous hydrobromic acid (48%, 202 mg, 1.2 mmol) in EA (2 mL) at 60 °C for 0.5 h, affords 109.7 mg (79%) of **3e** as a white solid. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.29 (d, *J* = 8.0 Hz, 2H), 7.19 (d, *J* = 8.0 Hz, 2H), 5.14 (dd, *J* = 10.6, 5.2 Hz, 1H), 4.07 (dd, *J* = 10.4, 5.6 Hz, 1H), 4.05–3.99 (m, 1H), 2.36 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 139.2, 135.6, 129.6, 127.5, 51.0, 35.0, 21.3.

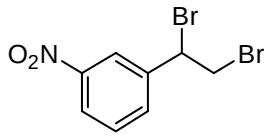
4-(1,2-Dibromoethyl)-1,1'-biphenyl (3f)[5]



3f

The reaction of 4-vinyl-1,1'-biphenyl **1f** (90.1 mg, 0.5 mmol), DMSO (43 μL, 0.6 mmol), and aqueous hydrobromic acid (48%, 202 mg, 1.2 mmol) in EA (2 mL) at 60 °C for 0.5 h, affords 137.7 mg (81%) of **3f** as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.65–7.63 (m, 4H), 7.52–7.41 (m, 5H), 5.25 (dd, *J* = 8.7, 5.9 Hz, 1H), 4.16–4.07 (m, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 142.0, 140.1, 137.4, 128.8, 128.0, 127.6, 127.5, 127.1, 50.7, 34.8.

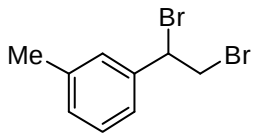
1-(1,2-Dibromoethyl)-3-nitrobenzene (3g)[6]



3g

The reaction of 1-nitro-3-vinylbenzene **1g** (74.6 mg, 0.5 mmol), DMSO (43 μL, 0.6 mmol), and aqueous hydrobromic acid (48%, 202 mg, 1.2 mmol) in EA (2 mL) at 60 °C for 0.5 h, affords 117.4 mg (76%) of **3g** as a yellow solid. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.29 (t, *J* = 1.8 Hz, 1H), 8.23–8.21 (m, 1H), 7.75 (d, *J* = 7.6 Hz, 1H), 7.59 (t, *J* = 8.0 Hz, 1H), 5.19 (dd, *J* = 11.2, 4.8 Hz, 1H), 4.11 (dd, *J* = 10.6, 5.0 Hz, 1H), 4.04–3.98 (m, 1H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 148.4, 140.8, 133.7, 129.9, 124.0, 122.8, 48.0, 34.1.

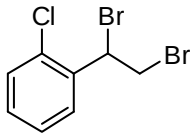
1-(1,2-Dibromoethyl)-3-methylbenzene (3h)[7]



3h

The reaction of 1-methyl-3-vinylbenzene **1h** (59.1 mg, 0.5 mmol), DMSO (43 μL, 0.6 mmol), and aqueous hydrobromic acid (48%, 202 mg, 1.2 mmol) in EA (2 mL) at 60 °C for 0.5 h, affords 104.0 mg (75%) of **3h** as a white solid. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.29–7.25 (m, 1H), 7.20–7.19 (m, 2H), 7.15 (d, *J* = 7.2 Hz, 1H), 5.11 (dd, *J* = 10.4, 5.6 Hz, 1H), 4.08–3.99 (m, 2H), 2.37 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 138.6, 138.5, 130.0, 128.7, 128.3, 124.7, 51.1, 35.0, 21.4.

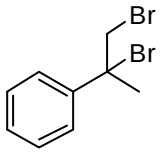
1-Chloro-2-(1,2-dibromoethyl)benzene (3i)



3i

The reaction of 1-chloro-2-vinylbenzene **1i** (69.3 mg, 0.5 mmol), DMSO (43 μL, 0.6 mmol), and aqueous hydrobromic acid (48%, 202 mg, 1.2 mmol) in EA (2 mL) at 60 °C for 0.5 h, affords 110.3 mg (74%) of **3i** as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.52 (d, *J* = 7.6 Hz, 1H), 7.39 (d, *J* = 7.8 Hz, 1H), 7.33 (t, *J* = 7.4 Hz, 1H), 7.27 (t, *J* = 8.2 Hz, 1H), 5.70 (t, *J* = 7.7 Hz, 1H), 4.12–4.07 (m, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 136.0, 133.9, 130.1, 130.0, 128.3, 127.5, 45.5, 33.6.

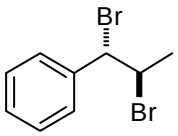
(1,2-Dibromopropan-2-yl)benzene (3j)[8]



3j

The reaction of α-methylstryene **1j** (59.1 mg, 0.5 mmol), DMSO (43 μL, 0.6 mmol), and aqueous hydrobromic acid (48%, 202 mg, 1.2 mmol) in EA (2 mL) at 60 °C for 0.5 h, affords 101.0 mg (73%) of **3j** as colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.56–7.54 (m, 2H), 7.38–7.30 (m, 3H), 4.35 (d, *J* = 10.2 Hz, 1H), 4.13 (d, *J* = 10.2 Hz, 1H), 2.31 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 141.9, 128.5, 128.4, 126.5, 63.7, 43.5, 29.9.

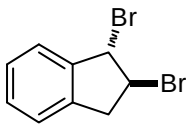
(1,2-Dibromopropyl)benzene (3k)[8]



3k

The reaction of (*E*)-β-methylstryene **1k** (59.1 mg, 0.5 mmol), DMSO (43 μL, 0.6 mmol), and aqueous hydrobromic acid (48%, 202 mg, 1.2 mmol) in EA (2 mL) at 60 °C for 0.5 h, affords 108.4 mg (78%) of **3k** as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.41–7.32 (m, 5H), 5.05 (d, *J* = 10.4 Hz, 1H), 4.63–4.59 (m, 1H), 2.05(d, *J* = 6.4 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 140.6, 128.8, 126.6, 127.7, 59.1, 51.1, 25.8.

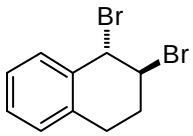
1,2-Dibromo-2,3-dihydro-1*H*-indene (3l)[9]



3l

The reaction of indene **1l** (58.1 mg, 0.5 mmol), DMSO (43 μL, 0.6 mmol), and aqueous hydrobromic acid (48%, 202 mg, 1.2 mmol) in EA (2 mL) at 60 °C for 0.5 h, affords 101.2 mg (73%) of **3l** as colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.46–7.44 (m, 1H), 7.34–7.27 (m, 3H), 5.62 (s, 1H), 4.86 (dt, *J* = 5.2, 1.2 Hz, 1H), 3.79 (dd, *J* = 17.5, 5.2 Hz, 1H), 3.25 (d, *J* = 17.5 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 140.5, 140.5, 129.7, 127.9, 125.7, 125.4, 57.7, 54.4, 41.4.

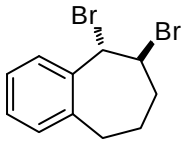
1,2-Dibromo-1,2,3,4-tetrahydronaphthalene (3m)[10]



3m

The reaction of 1,2-dihydronaphthalene **1m** (65.1 mg, 0.5 mmol), DMSO (43 μL, 0.6 mmol), and aqueous hydrobromic acid (48%, 202 mg, 1.2 mmol) in EA (2 mL) at 60 °C for 0.5 h, affords 112.4 mg (78%) of **3m** as colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.29 (dd, *J* = 7.5, 1.4 Hz, 1H), 7.25–7.16 (m, 2H), 7.11 (d, *J* = 7.5 Hz, 1H), 5.64–5.63 (m, 1H), 4.93–4.90 (m, 1H), 3.25 (ddd, *J* = 17.7, 11.9, 6.2 Hz, 1H), 2.91 (dd, *J* = 17.4, 6.0 Hz, 1H), 2.84–2.76 (m, 1H), 2.20–2.13 (m, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 134.4, 132.8, 131.2, 129.2, 128.9, 126.6, 51.52, 51.49, 25.1, 24.4.

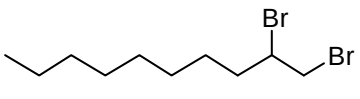
5,6-Dibromo-6,7,8,9-tetrahydro-5*H*-benzo[7]annulene (3n)[11]



3n

The reaction of 6,7-dihydro-5*H*-benzo[7]annulene **1n** (72.1 mg, 0.5 mmol), DMSO (43 μL, 0.6 mmol), and aqueous hydrobromic acid (48%, 202 mg, 1.2 mmol) in EA (2 mL) at 60 °C for 0.5 h, affords 129.2 mg (85%) of **3n** as colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.25–7.12 (m, 4H), 5.49 (d, *J* = 5.3 Hz, 1H), 4.88–4.85 (m, 1H), 3.31–3.23 (m, 1H), 3.00–2.92 (m, 1H), 2.80–2.74 (m, 1H), 2.27–2.21 (m, 1H), 1.98–1.91 (m, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 142.9, 136.3, 131.3, 130.9, 129.3, 126.1, 58.4, 54.7, 35.3, 34.6, 22.8.

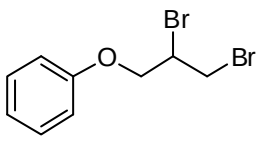
1,2-Dibromodecane (3o)[8]



3o

The reaction of 1-decene **1o** (70.1 mg, 0.5 mmol), DMSO (43 μL, 0.6 mmol), and aqueous hydrobromic acid (48%, 202 mg, 1.2 mmol) in EA (2 mL) at 60 °C for 0.5 h, affords 141.0 mg (94%) of **3o** as colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.20–4.13 (m, 1H), 3.85 (dd, *J* = 10.2, 4.4 Hz, 1H), 3.63 (t, *J* = 10.0 Hz, 1H), 2.18–2.09 (m, 1H), 1.83–1.73 (m, 1H), 1.60–1.53 (m, 1H), 1.45–1.28 (m, 11H), 0.89 (t, *J* = 6.5 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 53.1, 36.3, 36.0, 31.8, 29.3, 29.1, 28.8, 26.7, 22.6, 14.1.

(2,3-Dibromopropoxy)benzene (3p)[12]

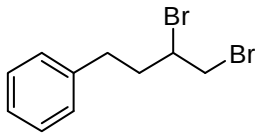


3p

The reaction of (allyloxy)benzene **1p** (67.1 mg, 0.5 mmol), DMSO (43 μL, 0.6 mmol), and aqueous hydrobromic acid (48%, 202 mg, 1.2 mmol) in EA (2 mL) at 60 °C for 0.5 h, affords 119.1 mg (81%) of **3p** as colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.32–7.28 (m, 2H), 7.00 (t, *J* = 7.4 Hz, 1H),

6.95–6.92 (m, 2H), 4.44–4.33 (m, 3H), 3.95–3.86 (m, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 157.9, 129.6, 121.6, 114.8, 69.0, 47.7, 32.7.

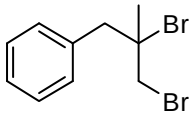
(3,4-Dibromobutyl)benzene (3q)[13]



3q

The reaction of (allyloxy)benzene **1q** (66.1 mg, 0.5 mmol), DMSO (43 μL, 0.6 mmol), and aqueous hydrobromic acid (48%, 202 mg, 1.2 mmol) in EA (2 mL) at 60 °C for 0.5 h, affords 131.5 mg (90%) of **3q** as colorless oil. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.29–7.21 (m, 5H) ,4.09 (m, 1H), 3.83–3.81 (m, 1H), 3.64–3.59 (m, 1H), 2.92–2.90 (m, 1H), 2.75–2.73 (m, 1H), 2.46–2.45 (m, 1H), 2.07–2.06 (m, 1H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 140.2, 128.51, 128.47, 126.2, 52.0, 37.6, 36.2, 32.9.

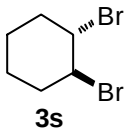
(2,3-Dibromo-2-methylpropyl)benzene (3r)[14]



3r

The reaction of (2-methylallyl)benzene **1r** (66.1 mg, 0.5 mmol), DMSO (43 μL, 0.6 mmol), and aqueous hydrobromic acid (48%, 202 mg, 1.2 mmol) in EA (2 mL) at 60 °C for 0.5 h, affords 121.7 mg (83%) of **3r** as colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.40–7.31 (m, 5H), 3.81 (d, J = 10.2 Hz, 1H), 3.74 (d, J = 10.2 Hz, 1H), 3.33–3.21 (m, 2H), 1.91 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 136.0, 130.9, 128.0, 127.3, 66.6, 47.1, 42.2, 30.7.

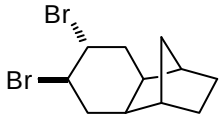
1,2-Dibromocyclohexane (3s)[15]



3s

The reaction of cyclohexene **1s** (41.1 mg, 0.5 mmol), DMSO (43 μL, 0.6 mmol), and aqueous hydrobromic acid (48%, 202 mg, 1.2 mmol) in EA (2 mL) at 60 °C for 0.5 h, affords 100.5 mg (83%) of **3s** as colorless oil. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 4.46 (s, 2H), 2.49–2.43 (m, 2H), 1.91–1.79 (m, 4H), 1.55–1.50 (m, 2H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 55.2, 31.9, 22.4.

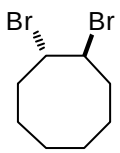
6,7-Dibromodecahydro-1,4-methanonaphthalene (3t)[16]



3t

The reaction of octahydro-1,4-methanonaphthalene **1t** (74.1 mg, 0.5 mmol), DMSO (43 μL, 0.6 mmol), and aqueous hydrobromic acid (48%, 202 mg, 1.2 mmol) in EA (2 mL) at 60 °C for 0.5 h, affords 135.5 mg (88%) of **3t** as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.70 (dt, J = 6.3, 3.1 Hz, 1H), 4.34–4.27 (m, 1H), 2.02 (dt, J = 12.9, 5.0 Hz, 1H), 1.96–1.87 (m, 5H), 1.72–1.66 (m, 1H), 1.60–1.50 (m, 4H), 1.29–1.19 (m, 2H), 1.12 (d, J = 10.4 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 56.8, 54.8, 42.8, 41.9, 41.3, 36.4, 36.1, 33.5, 33.2, 29.3, 29.2.

1,2-Dibromocyclooctane (3u)[17]

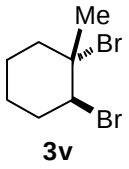


3u

The reaction of (*Z*)-cyclooctene **1u** (55.1 mg, 0.5 mmol), DMSO (43 μL, 0.6 mmol), and aqueous hydrobromic acid (48%, 202 mg, 1.2 mmol) in EA (2 mL) at 60 °C for 0.5 h, affords 109.3 mg (81%) of **3u** as colorless oil. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 4.61–4.56 (m, 2H), 2.45–2.38 (m, 2H),

2.14–2.05 (m, 2H) ,1.89–1.82 (m, 2H), 1.71–1.55 (m, 4H), 1.52–1.45 (m, 2H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 61.5, 33.2, 25.9, 25.4.

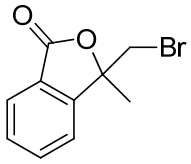
1,2-Dibromo-1-methylcyclohexane (3v)[18]



3v

The reaction of 1-methylcyclohexene **1v** (48.1 mg, 0.5 mmol), DMSO (43 μL, 0.6 mmol), and aqueous hydrobromic acid (48%, 202 mg, 1.2 mmol) in EA (2 mL) at 60 °C for 0.5 h, affords 107.7 mg (84%) of **3v** as colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.65 (s, 1H), 2.58–2.50 (m, 1H), 2.12–2.05 (m, 1H), 2.02–1.93 (m, 5H), 1.86–1.75 (m, 2H), 1.68–1.53 (m, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 70.7, 61.9, 37.6, 34.0, 32.5, 22.7, 20.7.

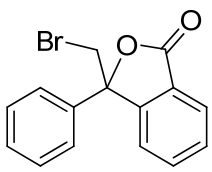
3-(Bromomethyl)-3-methylisobenzofuran-1(3*H*)-one (5a)



5a

The reaction of 2-(prop-1-en-2-yl)benzoic acid **4a** (81.1 mg, 0.5 mmol), DMSO (43 μL, 0.6 mmol), and aqueous hydrobromic acid (48%, 202 mg, 1.2 mmol) in EA (2 mL) at 60 °C for 1 h, affords 105.4 mg (87%) of **5a** as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.82 (d, *J* = 7.6 Hz, 1H), 7.64 (t, *J* = 7.3 Hz, 1H), 7.50 (t, *J* = 7.4 Hz, 1H), 7.45 (d, *J* = 7.6 Hz, 1H), 3.68 (d, *J* = 11.1 Hz, 1H), 3.65 (d, *J* = 11.1 Hz, 1H), 1.75 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.9, 151.1, 134.3, 129.8, 126.2, 125.8, 121.4, 84.5, 37.8, 24.2. HRMS (ESI) Calcd for $[C_{10}H_{10}BrO_2, M + H]^+$: 240.9859, Found: 240.9863.

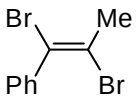
3-(Bromomethyl)-3-phenylisobenzofuran-1(3*H*)-one (5b)



5b

The reaction of 2-(1-phenylvinyl)benzoic acid **4b** (112.1 mg, 0.5 mmol), DMSO (43 μL, 0.6 mmol), and aqueous hydrobromic acid (48%, 202 mg, 1.2 mmol) in EA (2 mL) at 60 °C for 1 h, affords 148.2 mg (98%) of **5b** as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.93 (d, *J* = 7.6 Hz, 1H), 7.76–7.72 (m, 1H), 7.67 (d, *J* = 7.7 Hz, 1H), 7.61–7.56 (m, 3H), 7.42–7.36 (m, 3H), 4.15 (d, *J* = 11.4 Hz, 1H), 4.09 (d, *J* = 11.4 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.8, 149.8, 137.5, 134.3, 129.9, 129.1, 129.0, 126.5, 126.0, 125.4, 122.5, 87.2, 37.9. HRMS (ESI) Calcd for $[C_{15}H_{12}BrO_2, M + H]^+$: 303.0015, Found: 303.0018.

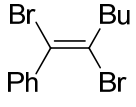
(*E*)-(1,2-Dibromoprop-1-en-1-yl)benzene (7a)[14]



7a

The reaction of 1-phenyl-1-propyne **6a** (58.1 mg, 0.5 mmol), DMSO (43 μL, 0.6 mmol), and aqueous hydrobromic acid (48%, 202 mg, 1.2 mmol) in EA (2 mL) at 60 °C for 8 h, affords 118.7 mg (86%) of **7a** as colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.38–7.32 (m, 5H), 2.62 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 140.8, 129.1, 128.6, 128.2, 117.2, 116.8, 29.3.

(*E*)-(1,2-Dibromohex-1-en-1-yl)benzene (7b)[19]

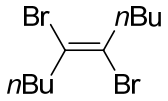


7b

The reaction of hex-1-yn-1-ylbenzene **6b** (79.1 mg, 0.5 mmol), DMSO (43 μL, 0.6 mmol), and aqueous hydrobromic acid (48%, 202 mg, 1.2 mmol) in EA (2 mL) at 60 °C for 8 h, affords 108.3 mg (68%) of **7b** as colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.38–7.23 (m, 5H), 2.85 (t, *J*

= 7.6 Hz, 2H), 1.72–1.64 (m, 2H), 1.50–1.42 (m, 2H), 0.99 (t, *J* = 7.6 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 141.0, 129.1, 128.5, 128.2, 123.7, 116.2, 40.8, 29.6, 21.8, 14.0.

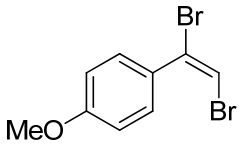
(*E*)-5,6-Dibromodec-5-ene (7c)[20]



7c

The reaction of dec-5-yne **6c** (69.1 mg, 0.5 mmol), DMSO (43 μL, 0.6 mmol), and aqueous hydrobromic acid (48%, 202 mg, 1.2 mmol) in EA (2 mL) at 60 °C for 8 h, affords 123.2 mg (83%) of **7c** as colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 2.67 (t, *J* = 7.4 Hz, 4H), 1.59–1.52 (m, 4H), 1.40–1.31 (m, 4H), 0.94 (t, *J* = 7.4 Hz, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 121.6, 40.5, 29.6, 21.7, 13.9.

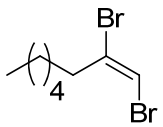
(*E*)-1-(1,2-Dibromovinyl)-4-methoxybenzene (7d)[20]



7d

The reaction of 1-ethynyl-4-methoxybenzene **6d** (66.1 mg, 0.5 mmol), DMSO (43 μL, 0.6 mmol), and aqueous hydrobromic acid (48%, 202 mg, 1.2 mmol) in EA (2 mL) at 60 °C for 5 h, affords 118.2 mg (81%) of **7d** as colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.48 (d, *J* = 8.4 Hz, 2H), 6.90 (d, *J* = 8.4 Hz, 2H), 6.73 (s, 1H), 3.83 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 160.2, 130.8, 129.1, 121.5, 113.5, 101.9, 55.3.

(*E*)-1,2-dibromooct-1-ene (7e)[21]

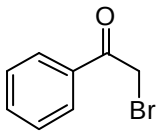


7e

The reaction of 1-phenyl-1-propyne **6e** (55.1 mg, 0.5 mmol), DMSO (43 μL, 0.6 mmol), and aqueous hydrobromic acid (48%, 202 mg, 1.2 mmol) in EA (2 mL) at 60 °C for 8 h, affords 86.6 mg (64%) of **7e** as colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.40 (s, 1H), 2.59 (t, *J* = 7.4 Hz, 2H), 1.59–1.55 (m. 2H), 1.36–1.31 (m. 6H), 0.90 (t, *J* = 6.8 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 127.0, 102.1, 36.9, 31.5, 28.0, 27.0, 22.5, 14.0.

Typical procedure for bromination of ketones: Ketone **8** (0.5 mmol) and DMSO (43 μL, 0.6 mmol) in EA (2 mL) were added hydrobromic acid (48%, 0.6 mmol) at 60 °C under air. The mixture were stirred at that temperature. After cooling down to room temperature and concentrating in vacuum, the residue was purified by chromatography on silica gel (petroleum ether/ethyl acetate) to afford the brominated product **9**.

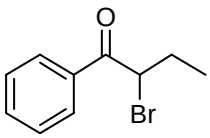
2-Bromoacetophenone (9a)[22]



9a

The reaction of acetophenone **8a** (60.1 mg, 0.5 mmol), DMSO (43 μL, 0.55 mmol), and aqueous hydrobromic acid (48%, 101 mg, 0.6 mmol) in EA (2 mL) at 60 °C for 2 h, affords 72.3 mg (73%) of **9a** as a pale yellow solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.99–7.97 (m, 2H), 7.62–7.59 (m, 1H), 7.50–7.47 (m, 2H), 4.45 (s, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 191.2, 133.9, 133.9, 128.9, 128.8, 30.9.

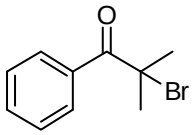
2-Bromo-1-phenylbutan-1-one (9b)[23]



9b

The reaction of butyrophenone **8b** (74.1 mg, 0.5 mmol), DMSO (43 μL, 0.6 mmol), and aqueous hydrobromic acid (48%, 101 mg, 0.6 mmol) in EA (2 mL) at 60 °C for 6 h, affords 108.0 mg (94%) of **9b** as pale yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.02–8.01 (m, 2H), 7.61 (t, *J* = 7.6 Hz, 1H), 7.50 (t, *J* = 7.8 Hz, 1H), 5.08 (dd, *J* = 7.6, 6.4 Hz, 1H), 2.28–2.10 (m, 2H), 1.08 (t, *J* = 7.4 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 193.2, 134.5, 133.6, 128.8, 128.7, 49.0, 26.9, 12.1.

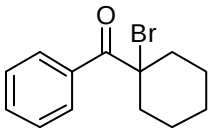
2-Bromo-1-phenylbutan-1-one (9c)[24]



9c

The reaction of isobutyrophenone **8c** (74.1 mg, 0.5 mmol), DMSO (43 μL, 0.6 mmol), and aqueous hydrobromic acid (48%, 101 mg, 0.6 mmol) in EA (2 mL) at 60 °C for 6 h, affords 102.6 mg (90%) of **9c** as colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.15–8.12 (m, 2H), 7.54–7.50 (m, 1H), 7.45–7.42 (m, 1H), 2.04 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 196.9, 134.9, 132.3, 130.0, 128.1, 60.3, 31.5.

(1-Bromocyclohexyl)(phenyl)methanone (9d)[25]



9d

The reaction of cyclohexyl(phenyl)methanone **8d** (94.1 mg, 0.5 mmol), DMSO (43 μL, 0.6 mmol), and aqueous hydrobromic acid (48%, 101 mg, 0.6 mmol) in EA (2 mL) at 60 °C for 6 h, affords 122.9 mg (92%) of **9d** as colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.09–8.07 (m, 2H), 7.53 (t, *J* = 7.6 Hz, 1H), 7.43 (t, *J* = 7.6 Hz, 2H), 2.38–2.32 (m, 2H), 2.22–2.17 (m, 2H), 1.83–1.77 (m, 2H), 1.59–1.52 (m, 3H), 1.41–1.38 (m, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 197.4, 135.8, 132.0, 129.7, 128.1, 67.9, 38.2, 24.9, 23.5.

(F) References

[1] Nair, V.; Panicker, S. B.; Augustine, A.; George, T. G.; Thomas, S.; Vairamani, M. *Tetrahedron* **2001**, *57*, 7417.

[2] Yu, T.-Y.; Wang, Y.; Hu, X.-Q.; Xu, P.-F. Chem. Commun. **2014**, *50*, 7817.

[3] Das, B.; Srinivas, Y.; Sudhakar, C.; Ravikanth, B. *J. Chem. Res.* **2008** , *4*, 188.

[4] MacHarla, A. K.; Chozhiyath N. R.; Nama, N. *Tetrahedron Lett.* **2012**, *53*, 1401.

[5] Piou, T.; Rovis, T. *J. Am. Chem. Soc.* **2014**, *136*, 11292.

[6] Wang, Y.-F.; Ton, K. K.; Chiba, S.; Narasaka, K. *Org. Lett.* **2008**, *10*, 5019.

[7] Qaseer *Polish J. Chemistry,* **2007**, *81*, 31.

[8] Kikushima, K.; Moriuchi, T.; Hirao, T. *Chem. Asian J.* **2009**, *4*, 1213.

[9] Austin, R. A.; Lillya, C. P. *J. Org. Chem.* **1969**, *34*, 1327.

[10] Cagle, Mike D.; Firsan, Sharbil J.; Eisenbraun, E. J. *Org. Prep. Proced. Int.* **1994**, *26*, 370.

[11] Yildiz, Y. K.; Ozturk, T.; Balci, M. *Tetrahedron* **1999**, *55*, 9317.

[12] Braddock, D. C.; Cansell, G.; Hermitage, S. A. *Synlett* **2004**, *3*, 461.

[13] Hernandez-Torres, G.; Tan, B.; Barbas, C. F. *Org. Lett.* **2012**, *14*, 1858.

[11] Braddock, D. C.; Cansell, G.; Hermitage, S. A. *Synlett* **2004**, *3*, 461.

[14] Stodulski, M.; Gotzinger, A.; Kohlhepp, S. V.; Gulder, T. *Chem. Commun.* **2014**, *50*, 3435.

[15] Van Zee, N. J.; Dragojlovic, V. *Org. Lett.* **2009**, *11*, 3190.

[16] Rye, A. R.; Wege, D. *Australia J. Chem.* **1974**, *27*, 1943.

[17] Wu, L.; Yin, Z. *Eur. J. Inorg. Chem.* **2013**, 6156.

[18] Altona, C.; Buys, H. R.; Hageman, H. J.; Havinga, E. *Tetrahedron* **1967**, *23*, 2265.

[19] Bianchini, R.; Chiappe, C.; Moro, G. L.; Lenoir, D.; Lemmen, P.; Goldberg, N. *Chem.– Eur. J.* **1999**, *5*, 1570.

[20] Xiang, J.; Yuan, R.; Wang, R.; Yi, N.; Lu, L.; Zou, H.; He, W. *J. Org. Chem.* **2014**, 79, 11378

[21] Yonehara, K.; Kamata, K.; Yamaguchi, K.; Mizuno, N. *Chem. Commun.* **2011**, 47, 1692.

[19] Zhang, J.; Wang, J.; Qiu, Z.; Wang, Y. *Tetrahedron* **2011**, *67*, 6859.

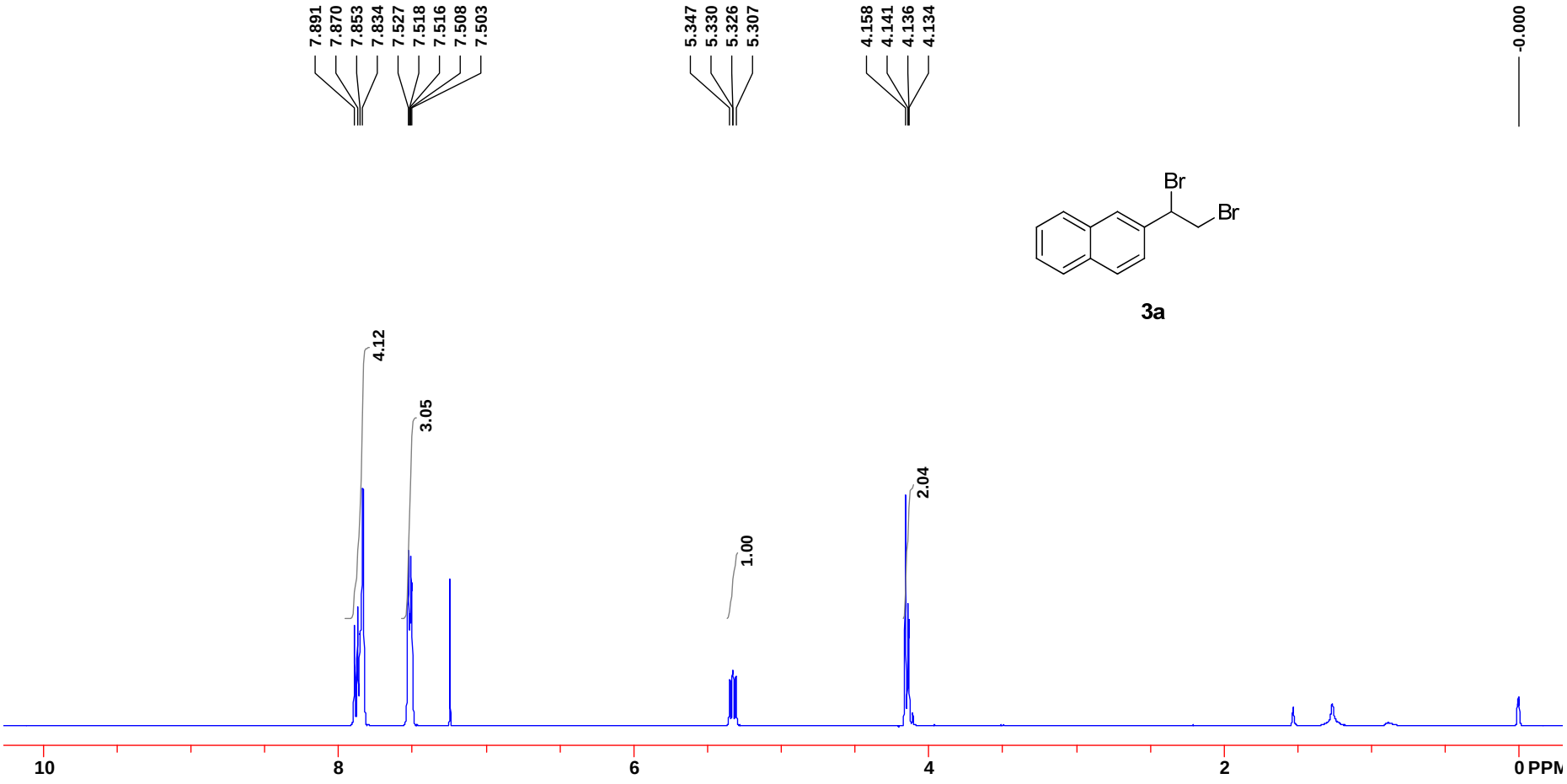
[20] Lundin, P. M.; Esquivias, J.; Fu, G. C. *Angew. Chem. Int. Ed.* **2009**, *48*, 154.

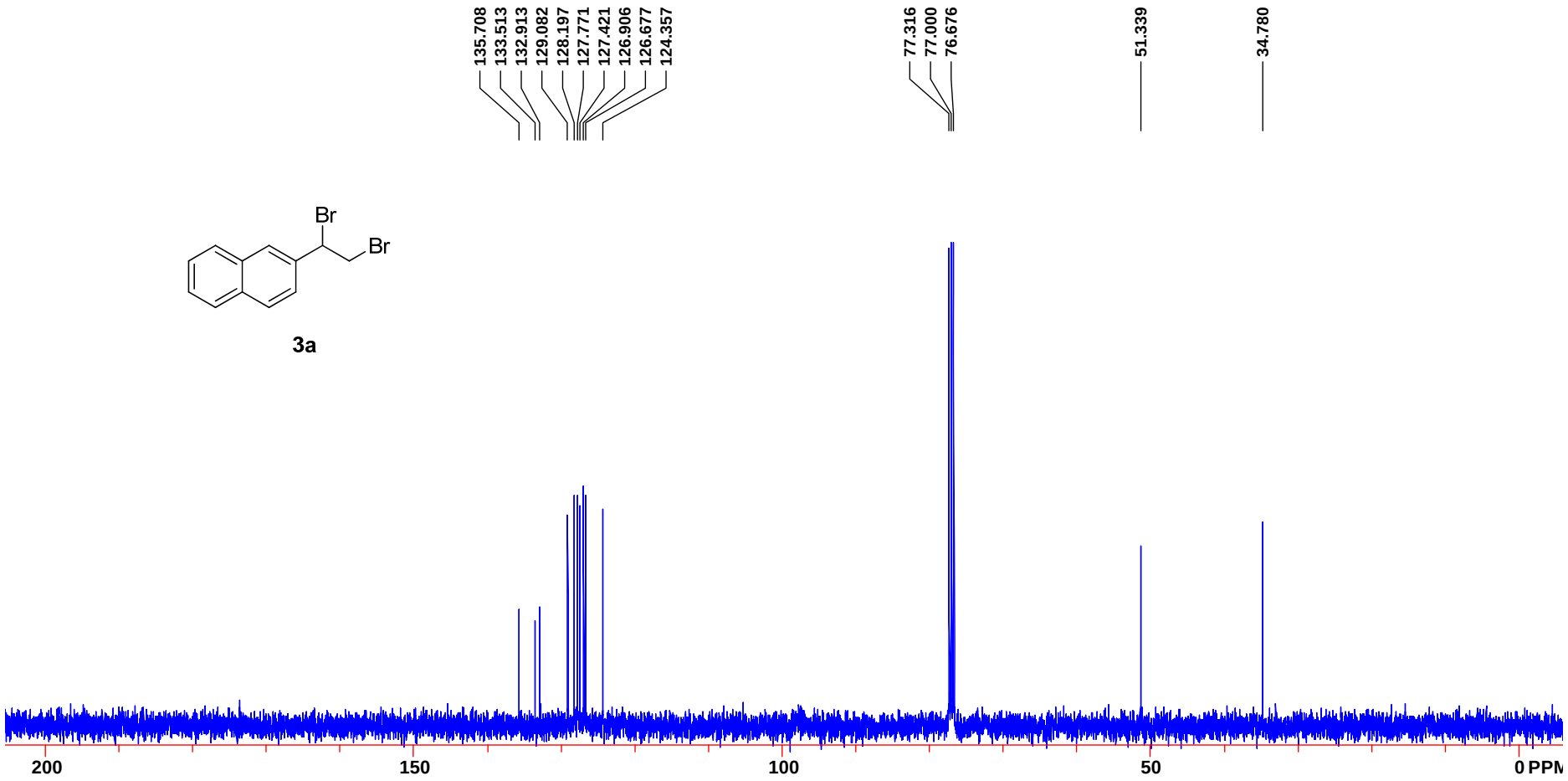
[21] Tada, N.; Ban, K.; Hirashima, S.; Miura, T.; Itoh, A. *Org. Biomol. Chem.* **2010**, *8*, 4701.

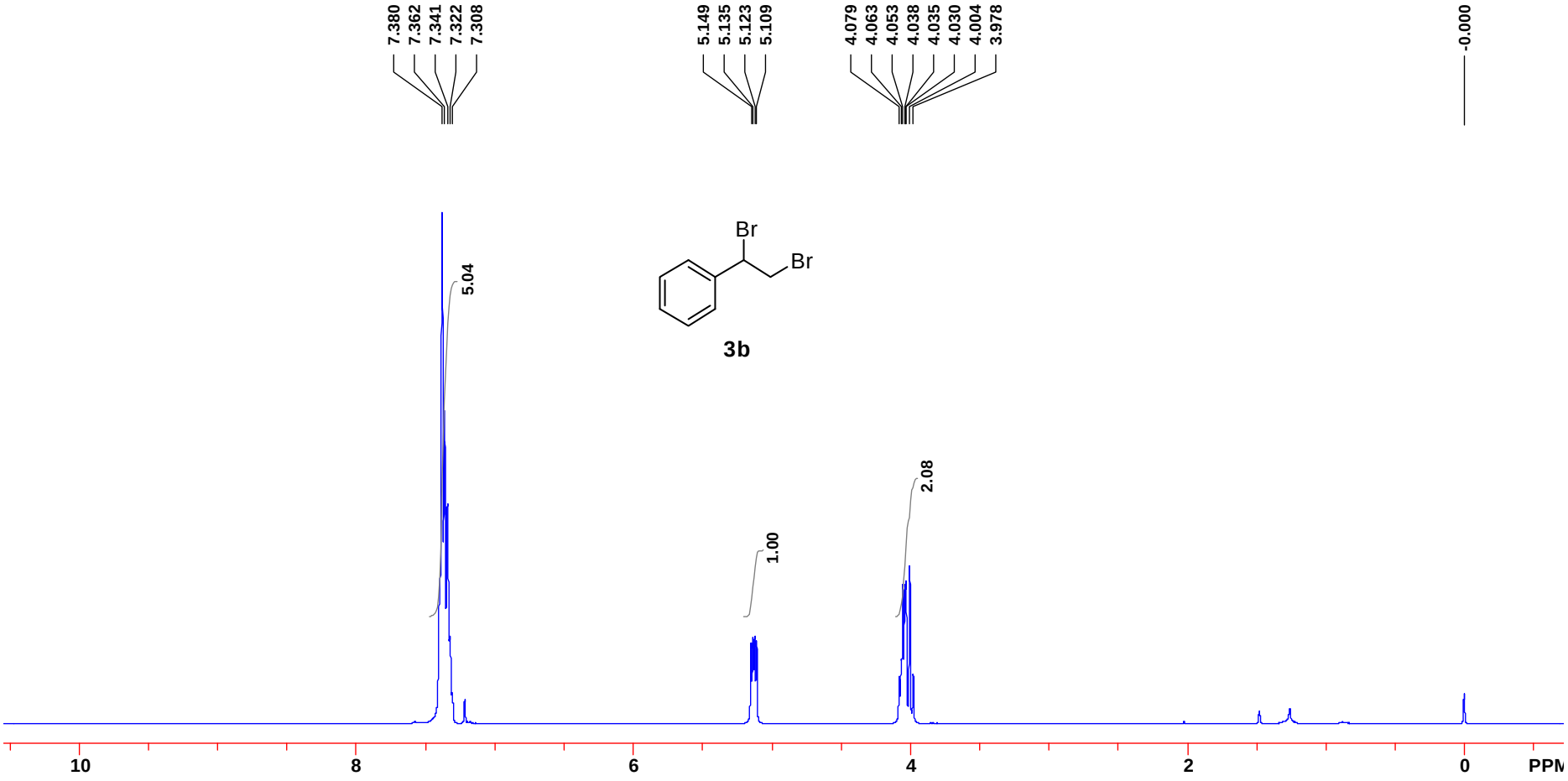
[22] Meneguzzo, E.; Norcini, G.; Li, B. G. Patent: US2011/65962 A1,2011.

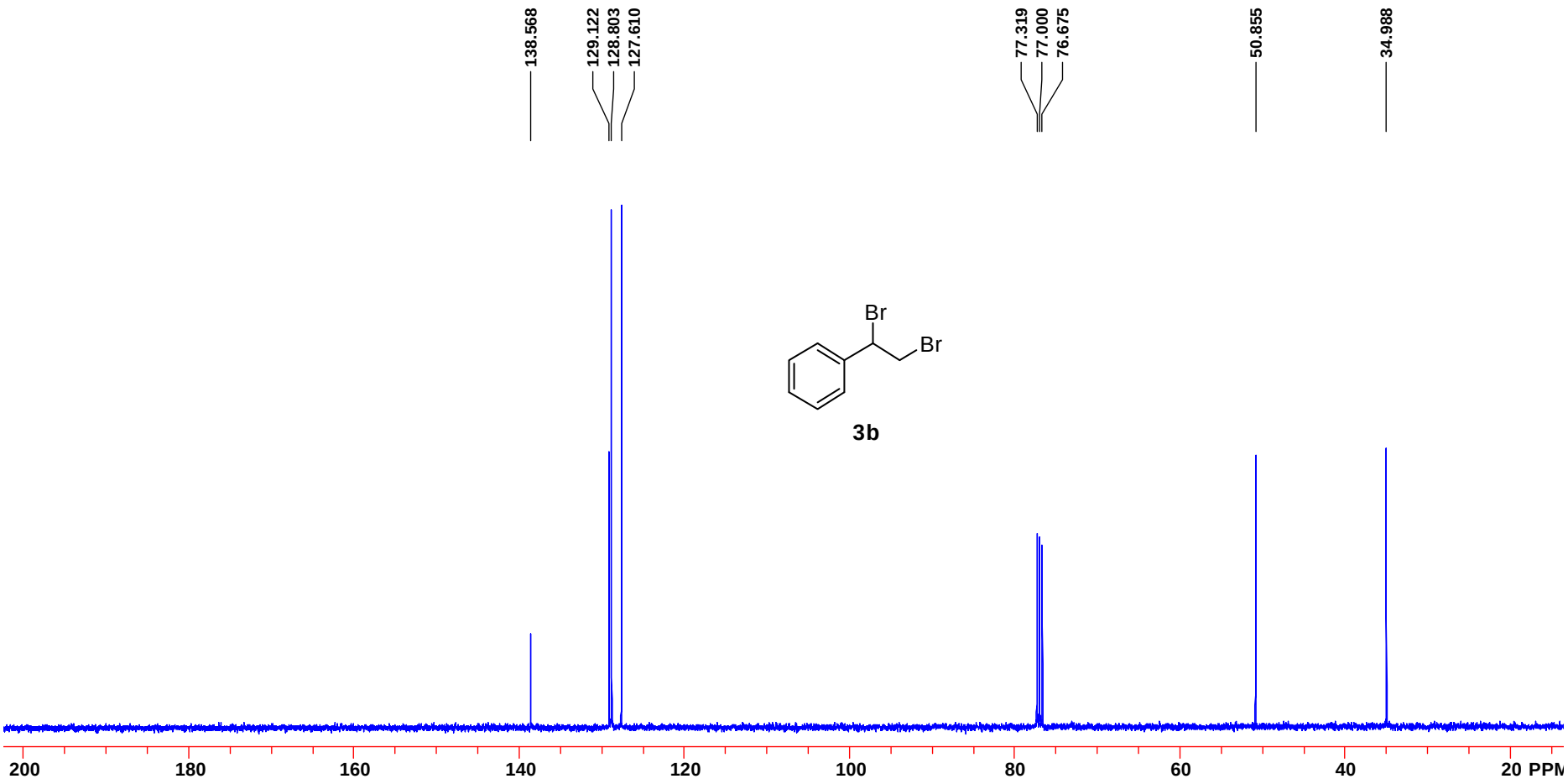
[23] Patel, A.; Böhmdorfer, S.; Hofinger, A.; Netscher, T.; Rosenau, T. *Eur. J. Org. Chem.* **2009**, 4873.

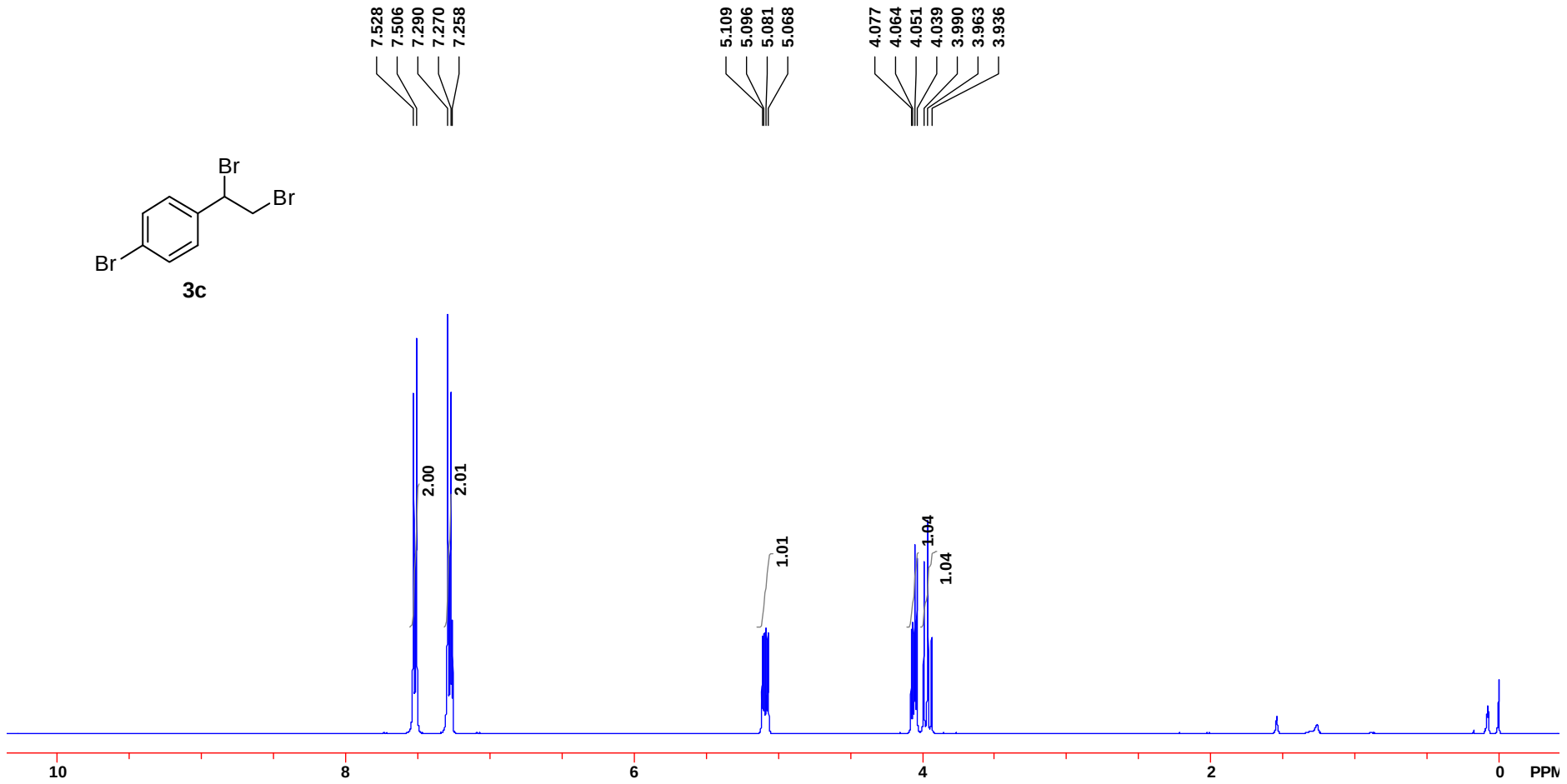
(G) ^{1}H NMR and ^{13}C NMR Spectra of Products

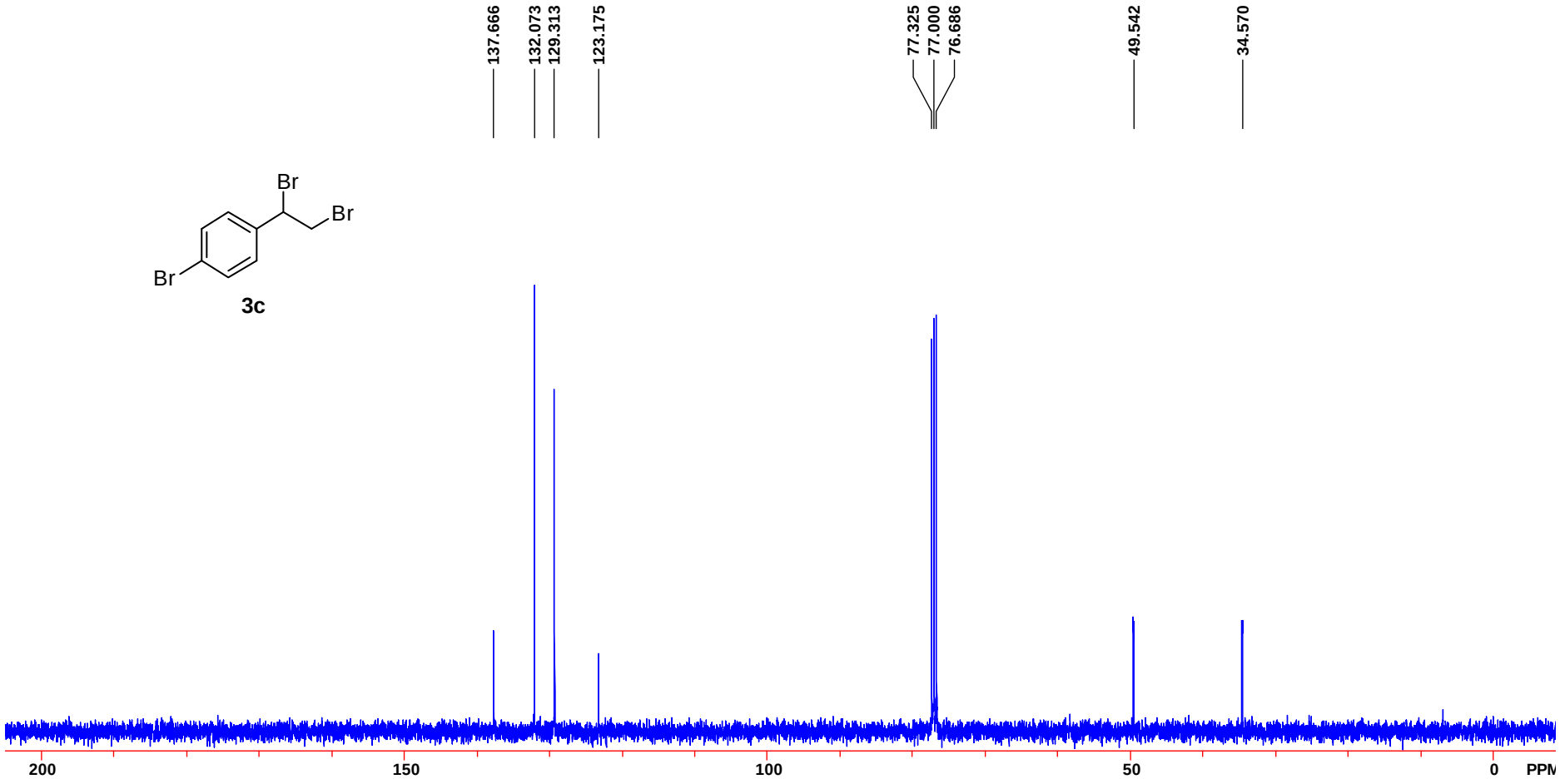


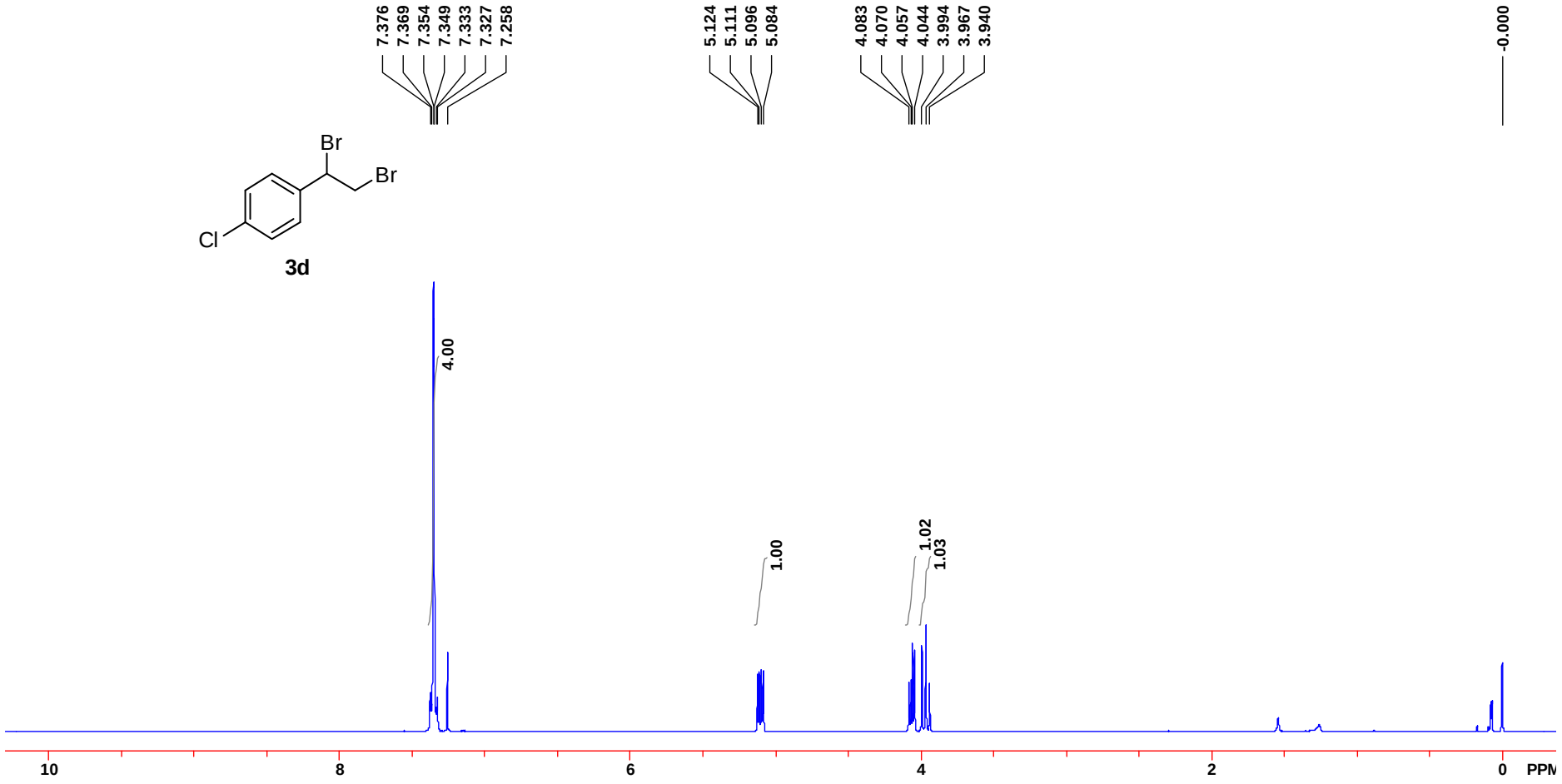

135.708
133.513
132.913
129.082
128.197
127.771
127.421
126.906
126.677
124.357
77.316
77.000
76.676
51.339
34.780
Br
Br
3a
200
150
100
50
0 PPM

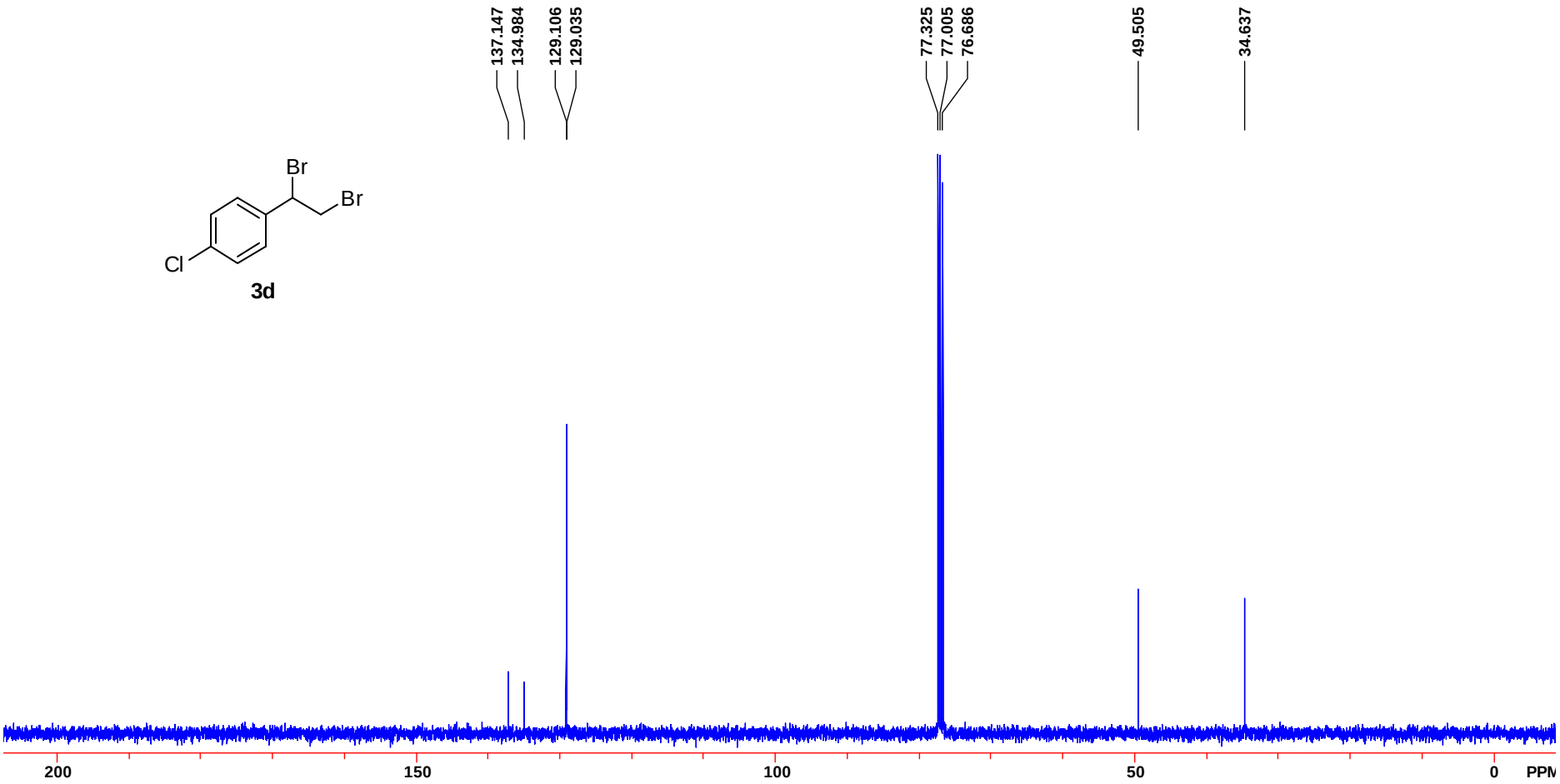

7.380
7.362
7.341
7.322
7.308
5.149
5.135
5.123
5.109
4.079
4.063
4.053
4.038
4.035
4.030
4.004
3.978
-0.000
Br
Br
3b
5.04
1.00
2.08
10
8
6
4
2
0
PPM

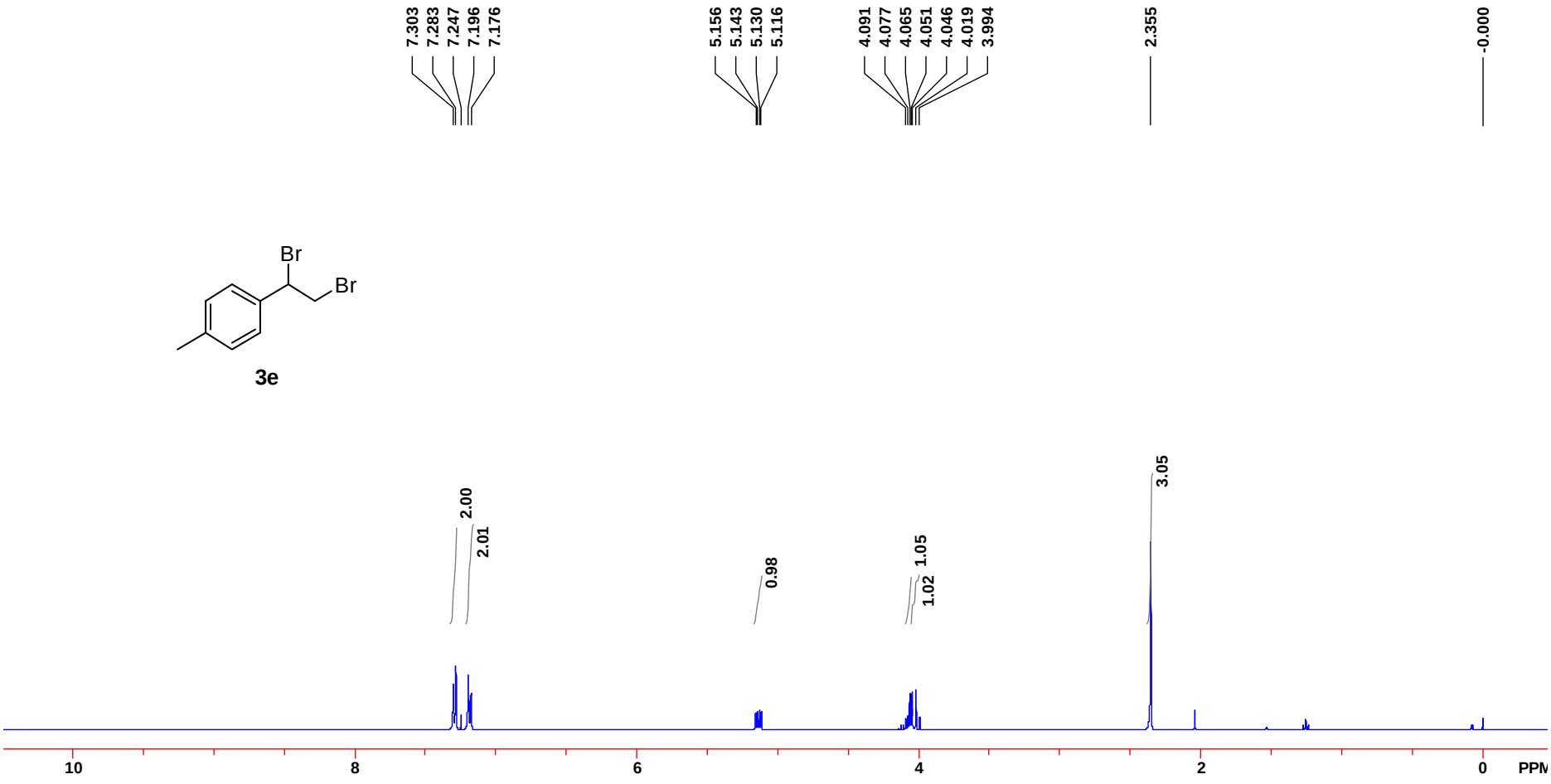

138.568
129.122
128.803
127.610
77.319
77.000
76.675
50.855
34.988
Br
Br
3b
200
180
160
140
120
100
80
60
40
20 PPM

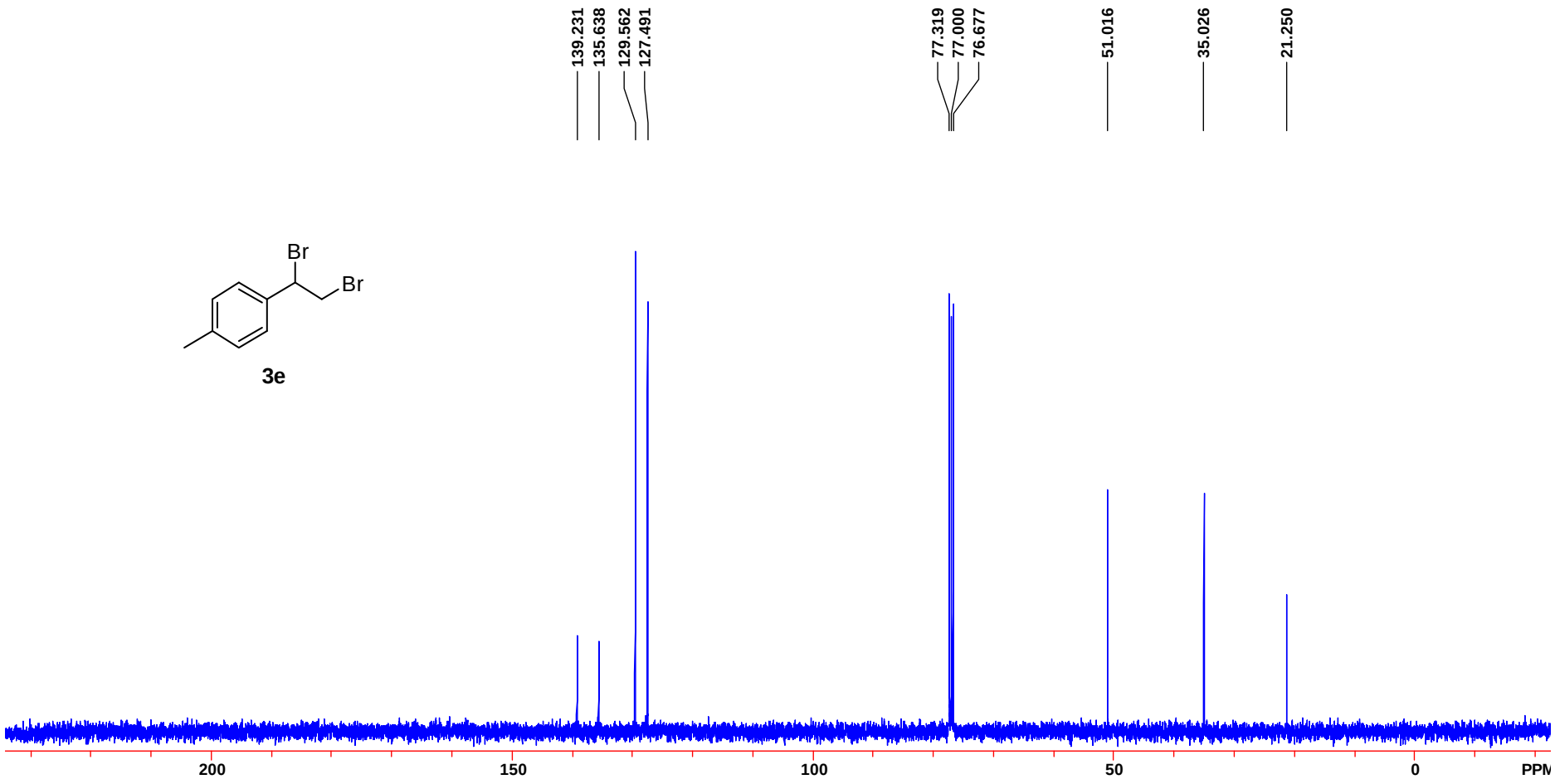

7.528
7.506
7.290
7.270
7.258
5.109
5.096
5.081
5.068
4.077
4.064
4.051
4.039
3.990
3.963
3.936
Br
Br
Br
3c
2.00
2.01
1.01
1.04
1.04
10
8
6
4
2
0
PPM

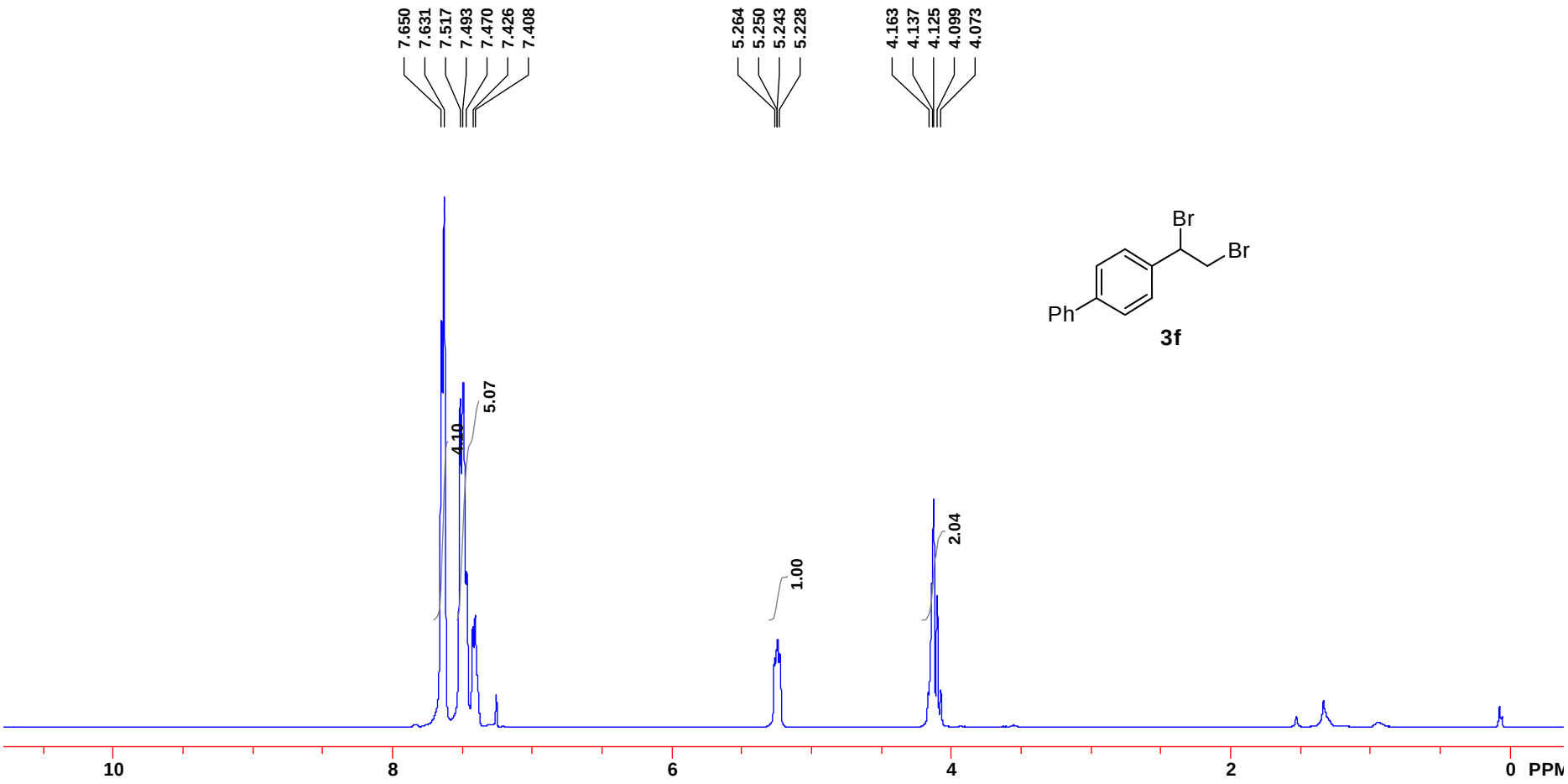

137.666
132.073
129.313
123.175
77.325
77.000
76.686
49.542
34.570
Br
Br
Br
3c
200
150
100
50
0
PPM

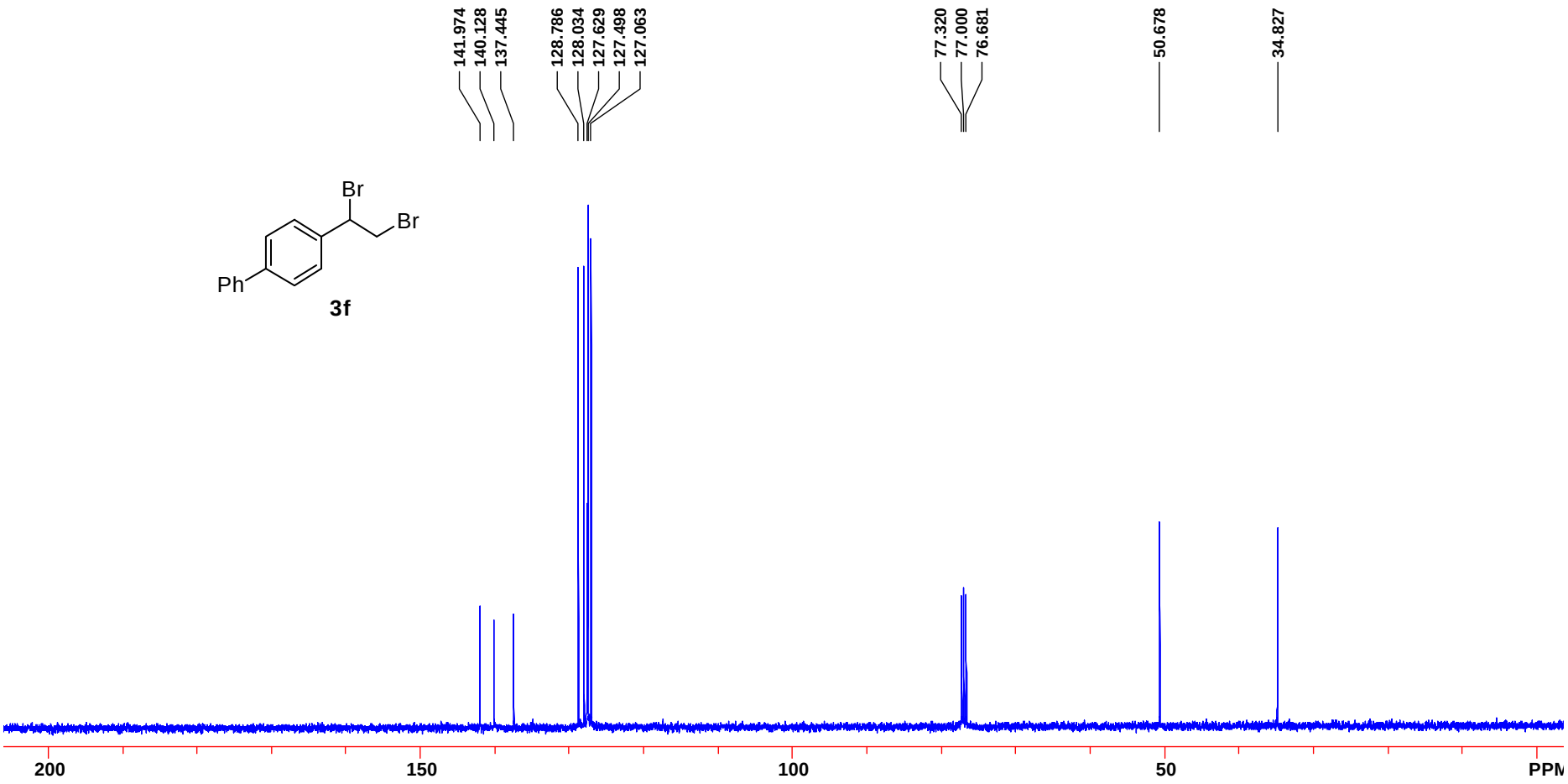

7.376
7.369
7.354
7.349
7.333
7.327
7.258
5.124
5.111
5.096
5.084
4.083
4.070
4.057
4.044
3.994
3.967
3.940
-0.000
Br
Br
Cl
3d
4.00
1.00
1.02
1.03
10
8
6
4
2
0
PPM

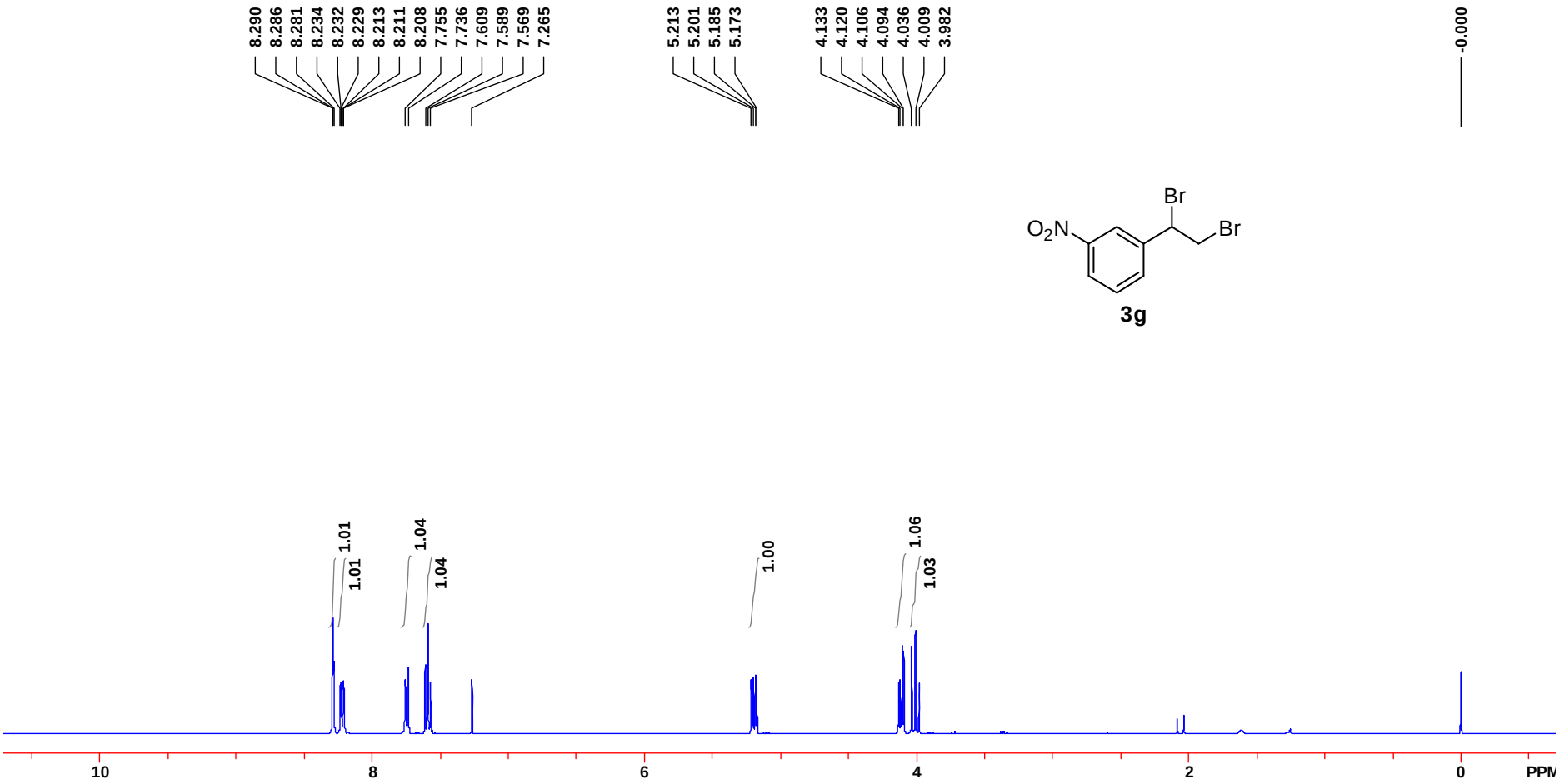

137.147
134.984
129.106
129.035
77.325
77.005
76.686
49.505
34.637
Br
Br
Cl
3d
200
150
100
50
0
PPM

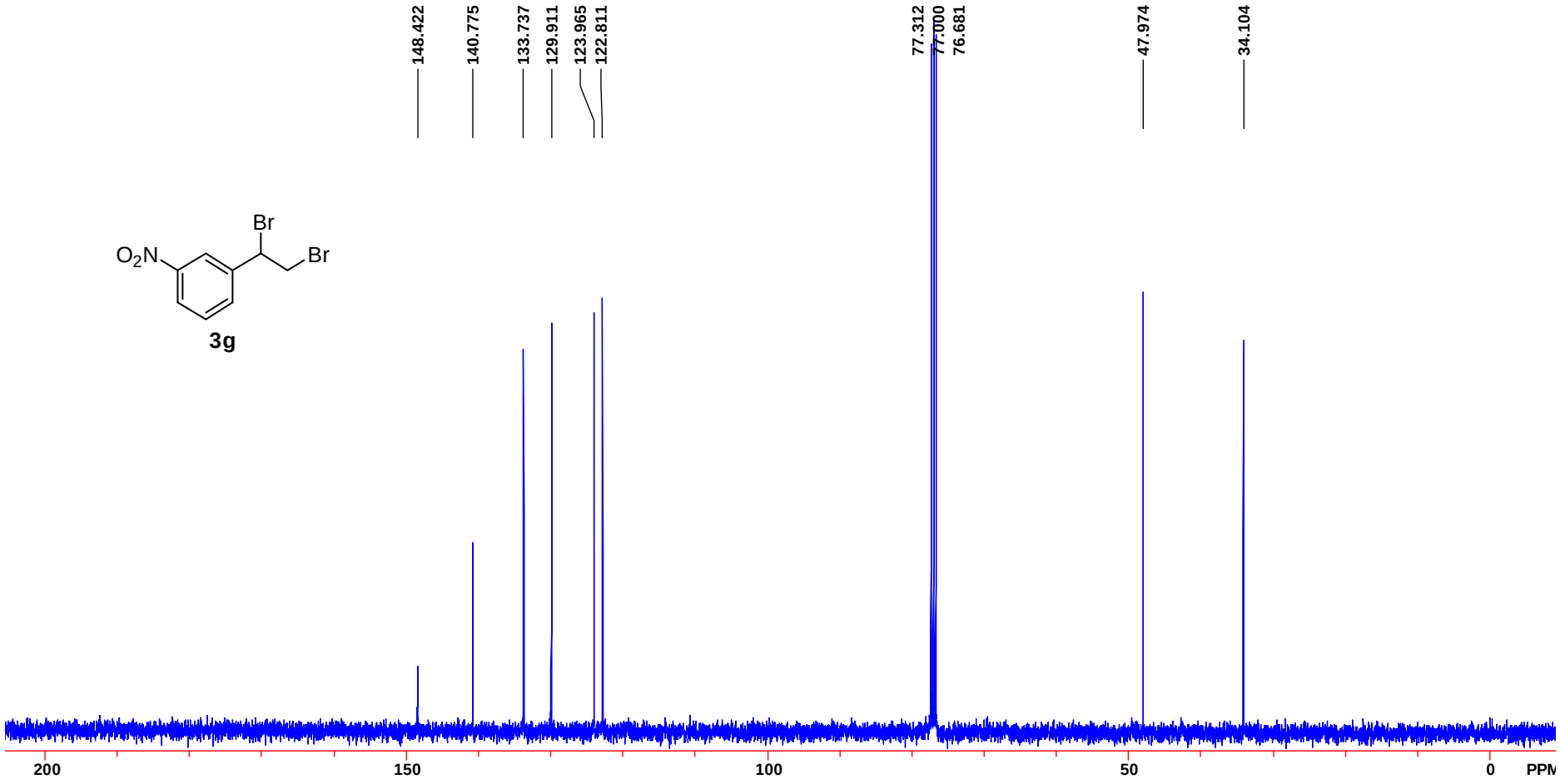

7.303
7.283
7.247
7.196
7.176
5.156
5.143
5.130
5.116
4.091
4.077
4.065
4.051
4.046
4.019
3.994
2.355
-0.000
Br
Br
3e
2.00
2.01
0.98
1.05
1.02
3.05
10
8
6
4
2
0
PPM

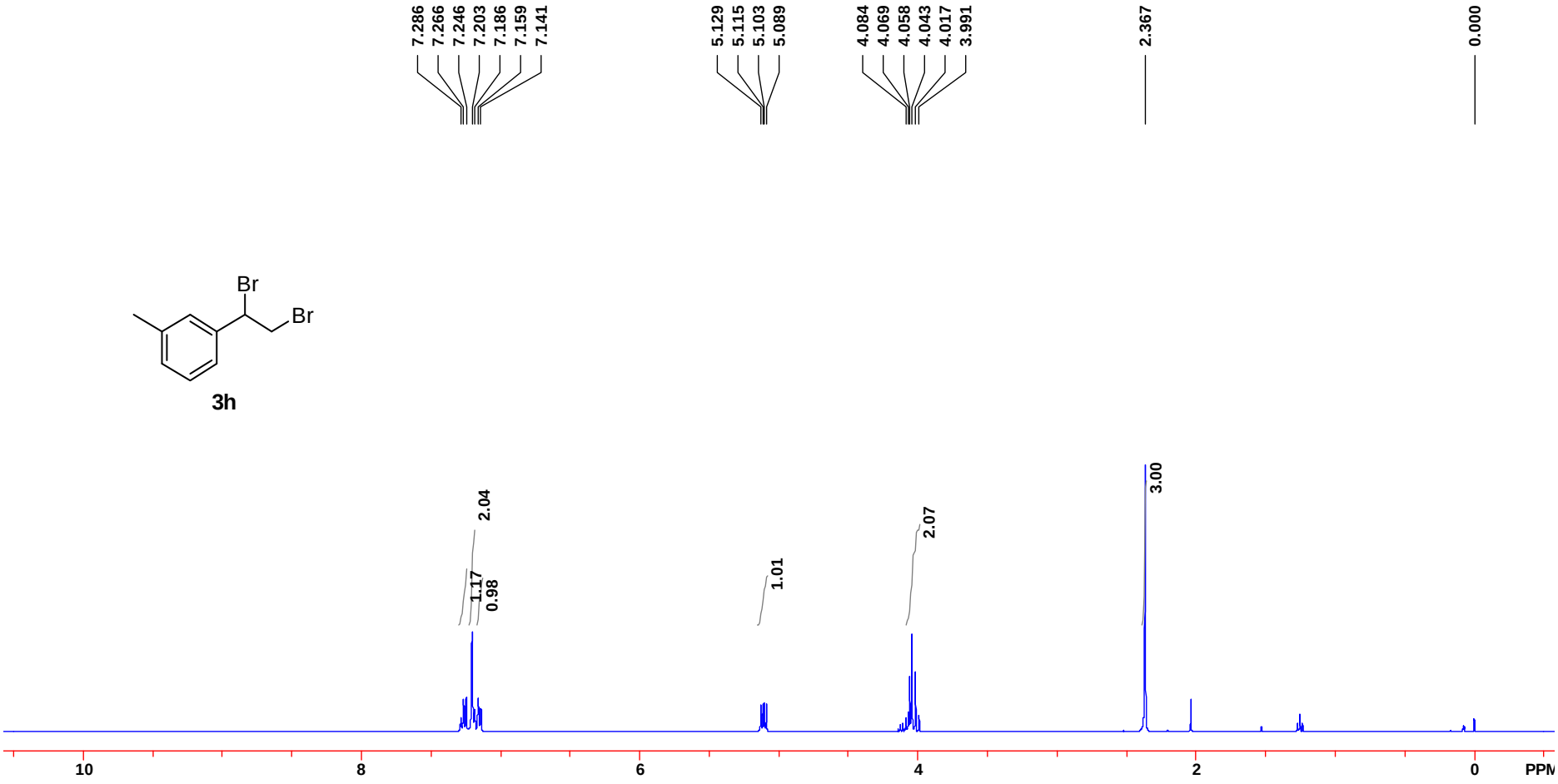

139.231
135.638
129.562
127.491
77.319
77.000
76.677
51.016
35.026
21.250
Br
Br
3e
200
150
100
50
0
PPM

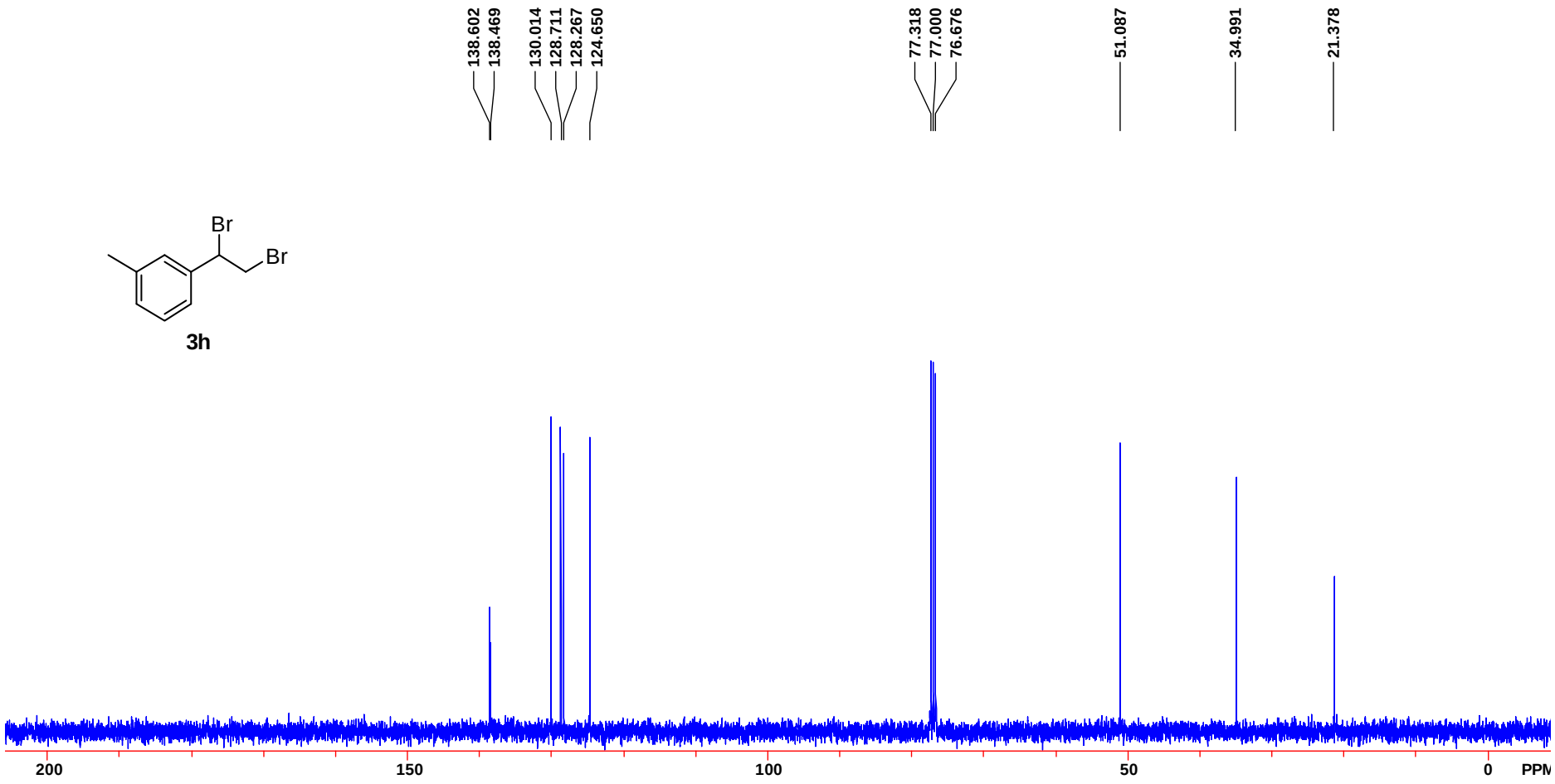

7.650
7.631
7.517
7.493
7.470
7.426
7.408
5.264
5.250
5.243
5.228
4.163
4.137
4.125
4.099
4.073
Br
Br
Ph
3f
5.07
4.10
1.00
2.04
10
8
6
4
2
0 PPM

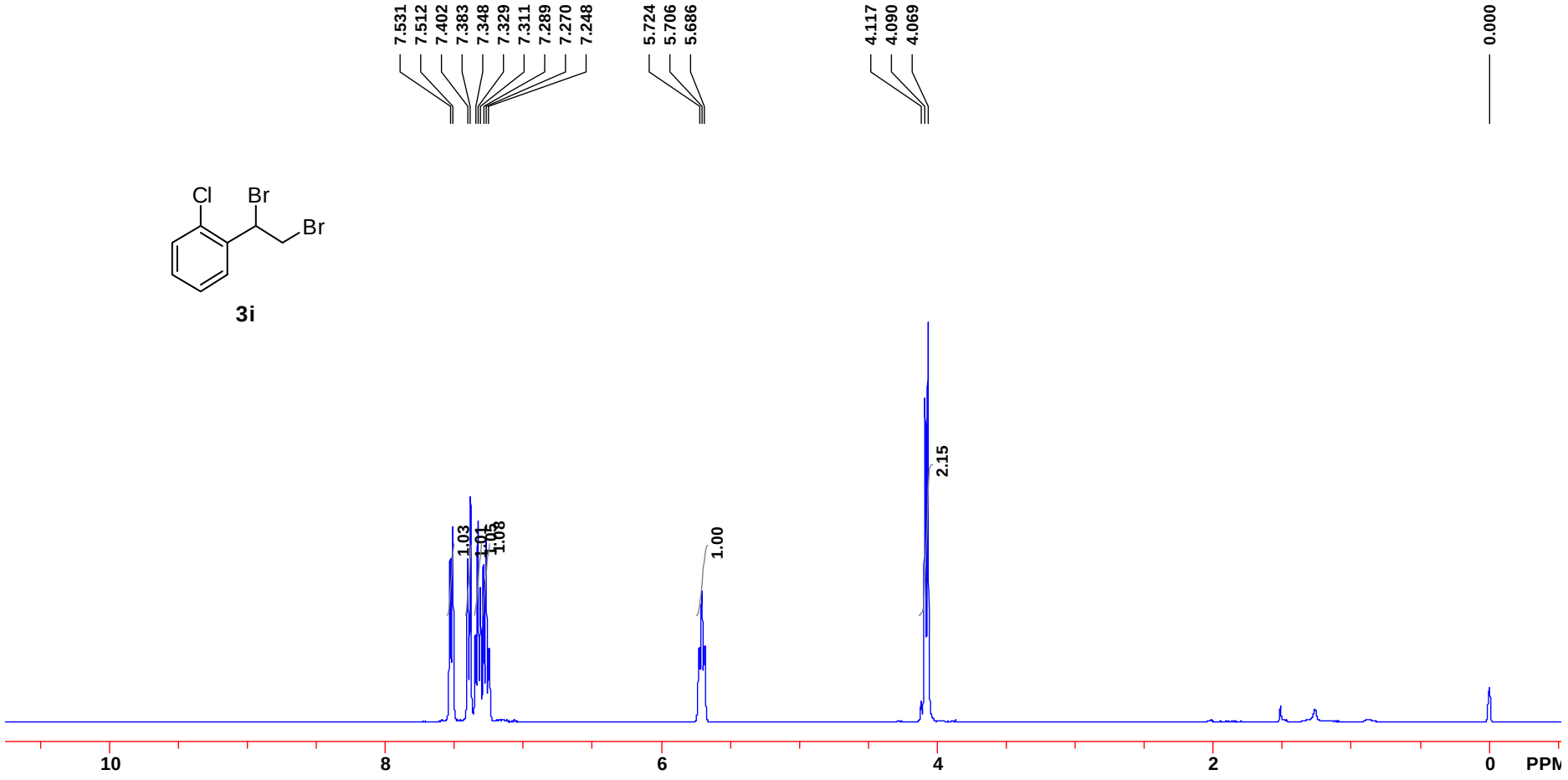

141.974
140.128
137.445
128.786
128.034
127.629
127.498
127.063
77.320
77.000
76.681
50.678
34.827
Br
Br
Ph
3f
200
150
100
50
PPM

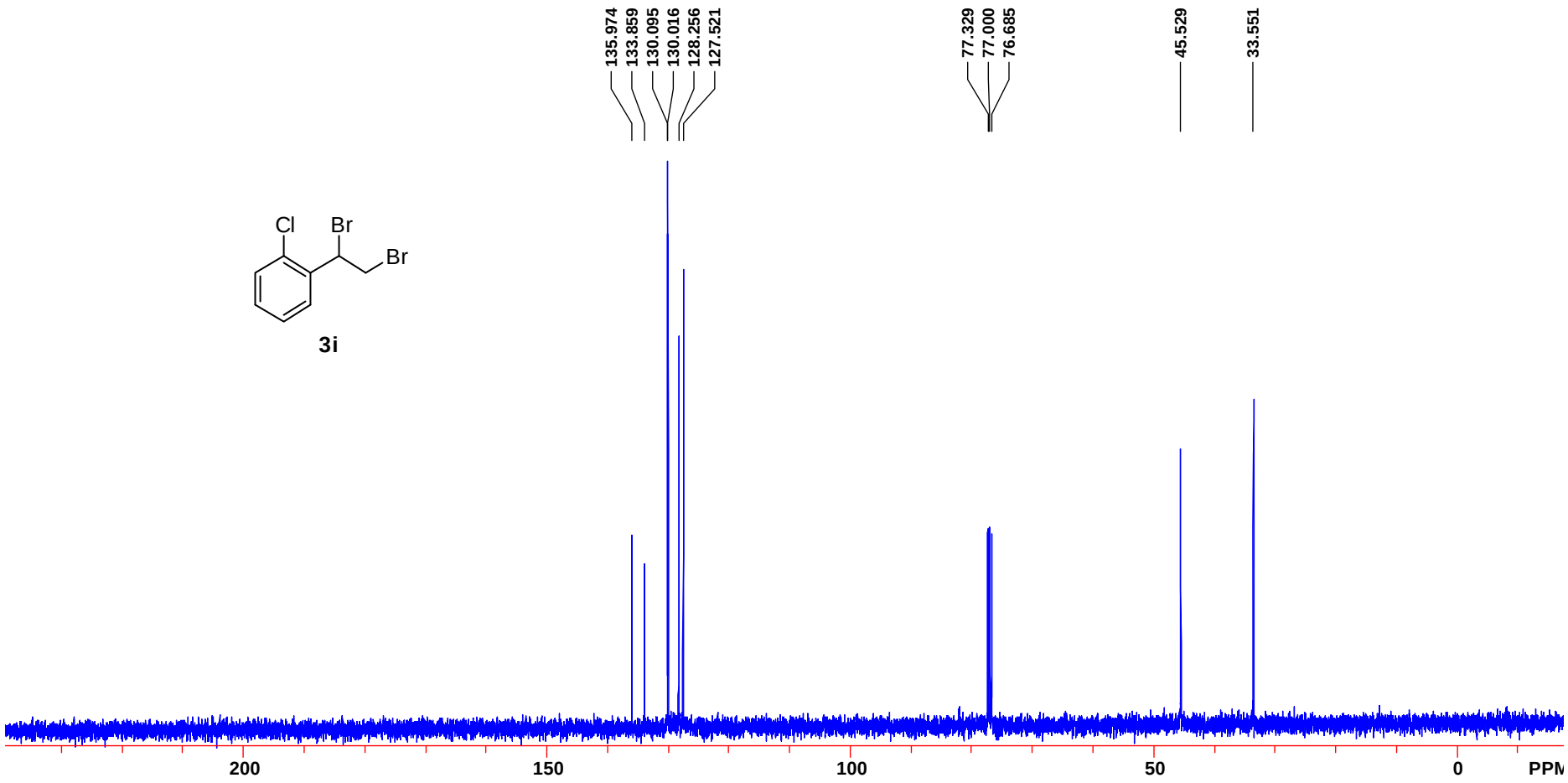

8.290
8.286
8.281
8.234
8.232
8.229
8.213
8.211
8.208
7.755
7.736
7.609
7.589
7.569
7.265
5.213
5.201
5.185
5.173
4.133
4.120
4.106
4.094
4.036
4.009
3.982
-0.000
Br
O2N
Br
3g
1.01
1.01
1.04
1.04
1.00
1.06
1.03
10
8
6
4
2
0
PPM

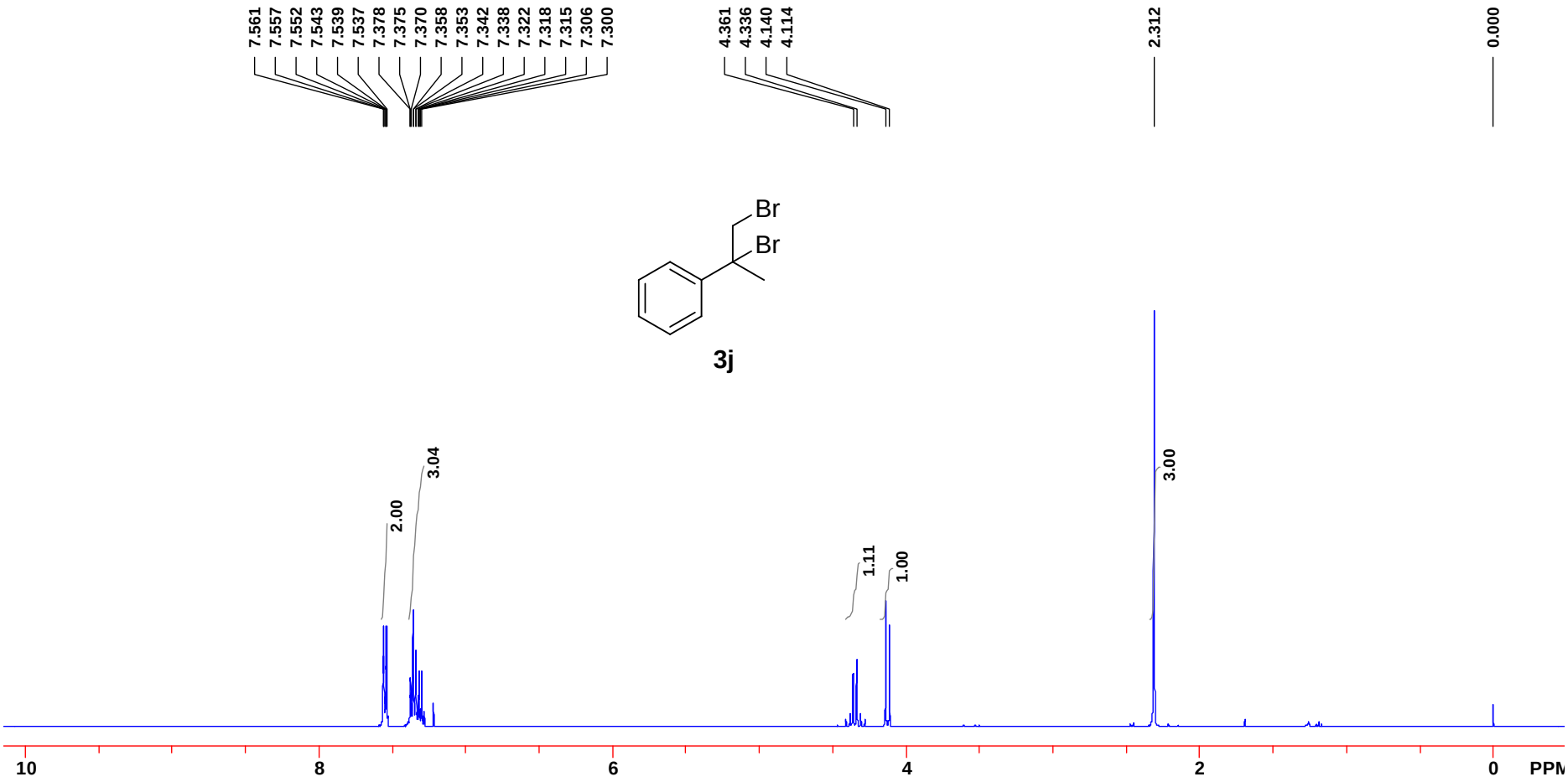

148.422
140.775
133.737
129.911
123.965
122.811
77.312
77.000
76.681
47.974
34.104
Br
O2N
Br
3g
200
150
100
50
0
PPM

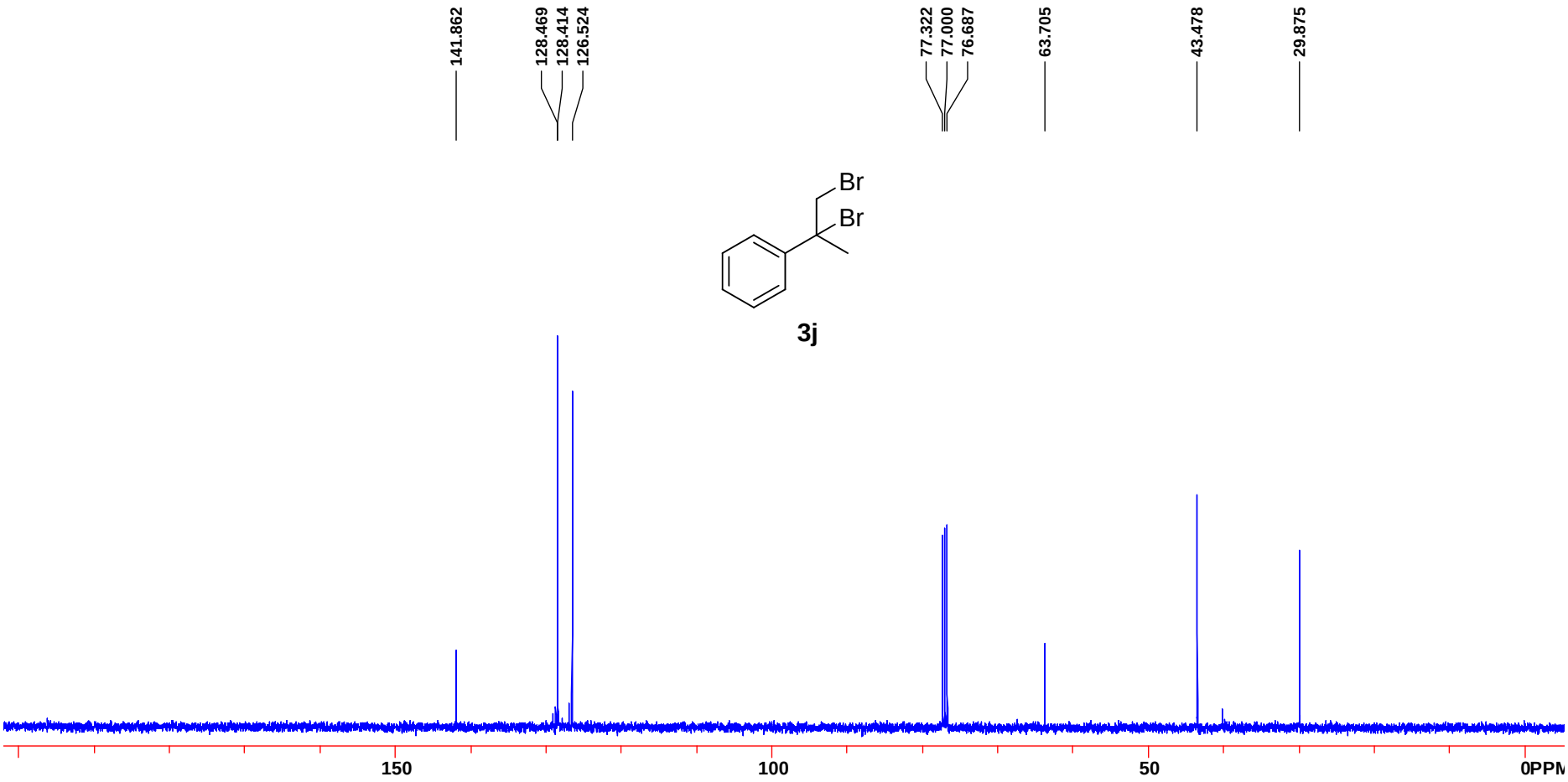

7.286
7.266
7.246
7.203
7.186
7.159
7.141
5.129
5.115
5.103
5.089
4.084
4.069
4.058
4.043
4.017
3.991
2.367
0.000
Br
Br
3h
2.04
1.17
0.98
1.01
2.07
3.00
10
8
6
4
2
0
PPM

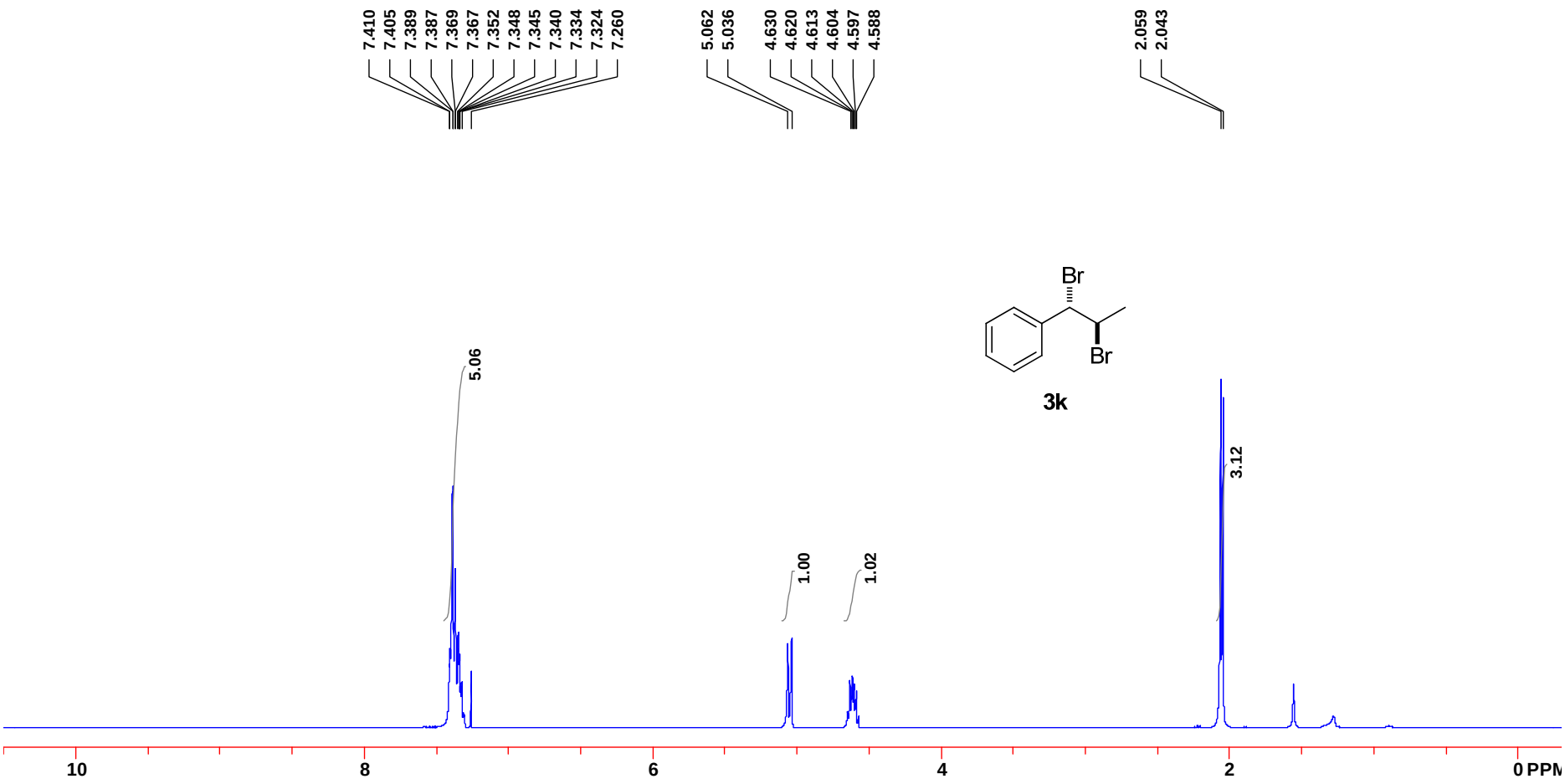

138.602
138.469
130.014
128.711
128.267
124.650
77.318
77.000
76.676
51.087
34.991
21.378
Br
Br
3h
200
150
100
50
0
PPM

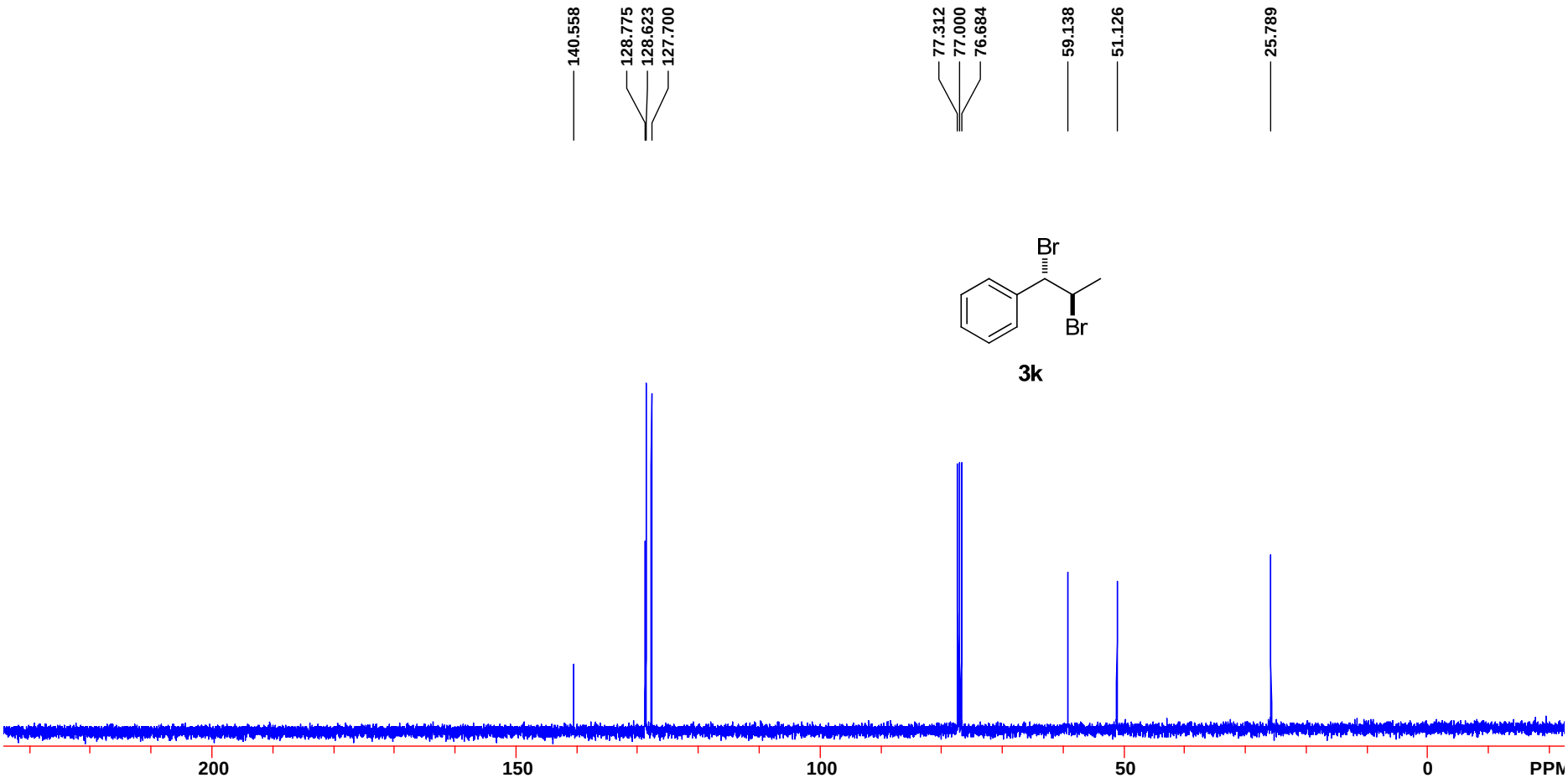

7.531
7.512
7.402
7.383
7.348
7.329
7.311
7.289
7.270
7.248
5.724
5.706
5.686
4.117
4.090
4.069
0.000
Cl
Br
Br
3i
1.03
1.01
1.03
1.08
1.00
2.15
10
8
6
4
2
0
PPM

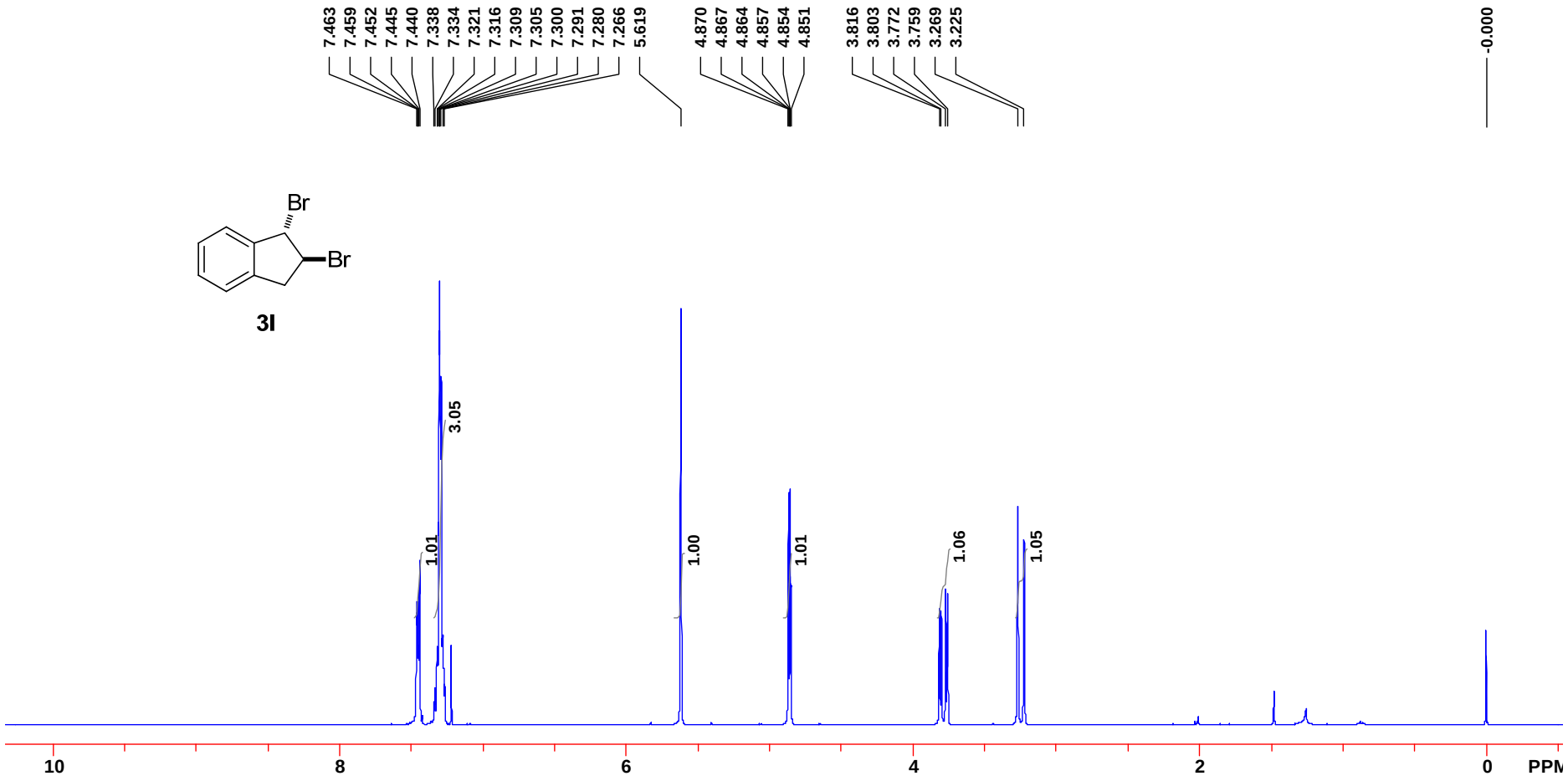

135.974
133.859
130.095
130.016
128.256
127.521
77.329
77.000
76.685
45.529
33.551
Cl
Br
Br
3i
200
150
100
50
0
PPM

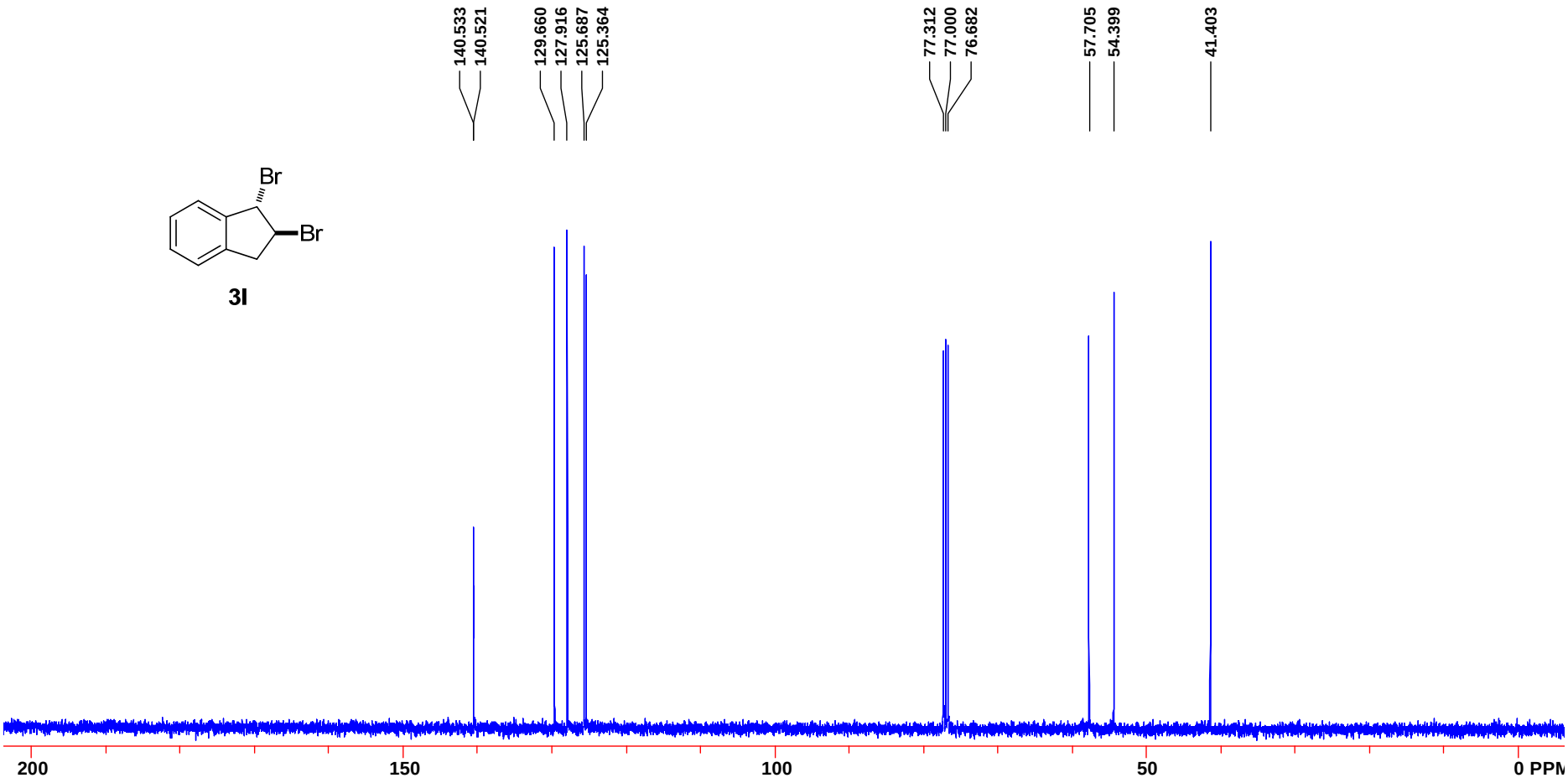

7.561
7.557
7.552
7.543
7.539
7.537
7.378
7.375
7.370
7.358
7.353
7.342
7.338
7.322
7.318
7.315
7.306
7.300
4.361
4.336
4.140
4.114
2.312
0.000
Br
Br
3j
2.00
3.04
1.11
1.00
3.00
10
8
6
4
2
0
PPM

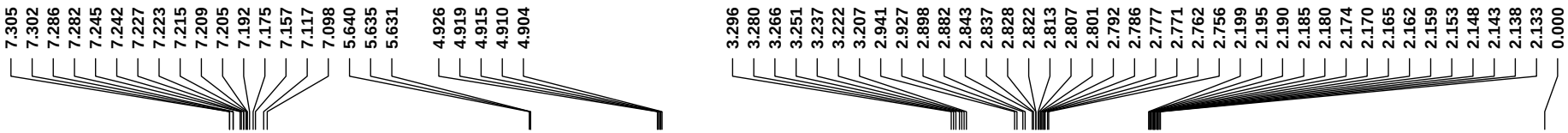

141.862
128.469
128.414
126.524
77.322
77.000
76.687
63.705
43.478
29.875
Br
Br
3j
150
100
50
0PPM

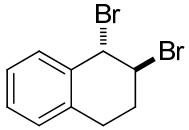

7.410
7.405
7.389
7.387
7.369
7.367
7.352
7.348
7.345
7.340
7.334
7.324
7.260
5.062
5.036
4.630
4.620
4.613
4.604
4.597
4.588
2.059
2.043
Br
Br
3k
5.06
1.00
1.02
3.12
10
8
6
4
2
0 PPM


140.558
128.775
128.623
127.700
77.312
77.000
76.684
59.138
51.126
25.789
Br
Br
3k
200
150
100
50
0
PPM

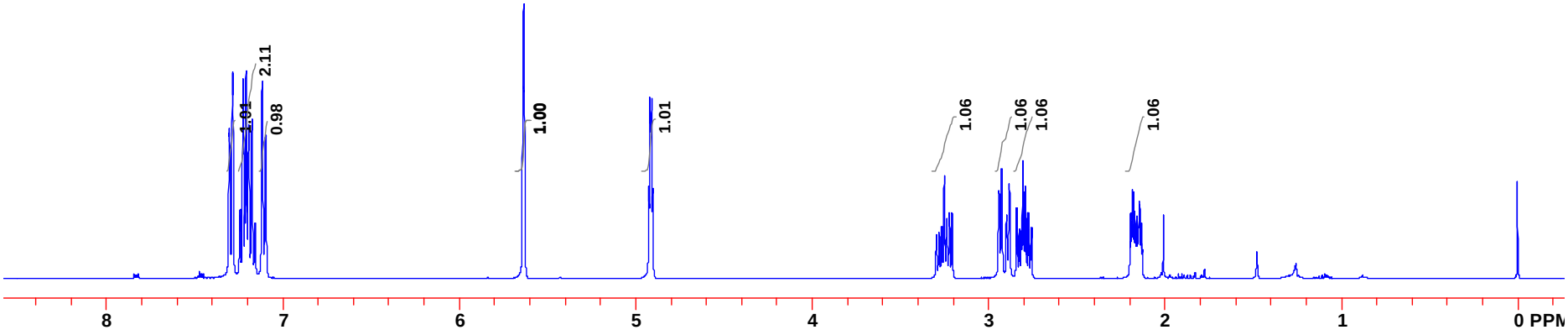

7.463
7.459
7.452
7.445
7.440
7.338
7.334
7.321
7.316
7.309
7.305
7.300
7.291
7.280
7.266
5.619
4.870
4.867
4.864
4.857
4.854
4.851
3.816
3.803
3.772
3.759
3.269
3.225
-0.000
Br
Br
3l
3.05
1.01
1.00
1.01
1.06
1.05
10
8
6
4
2
0
PPM

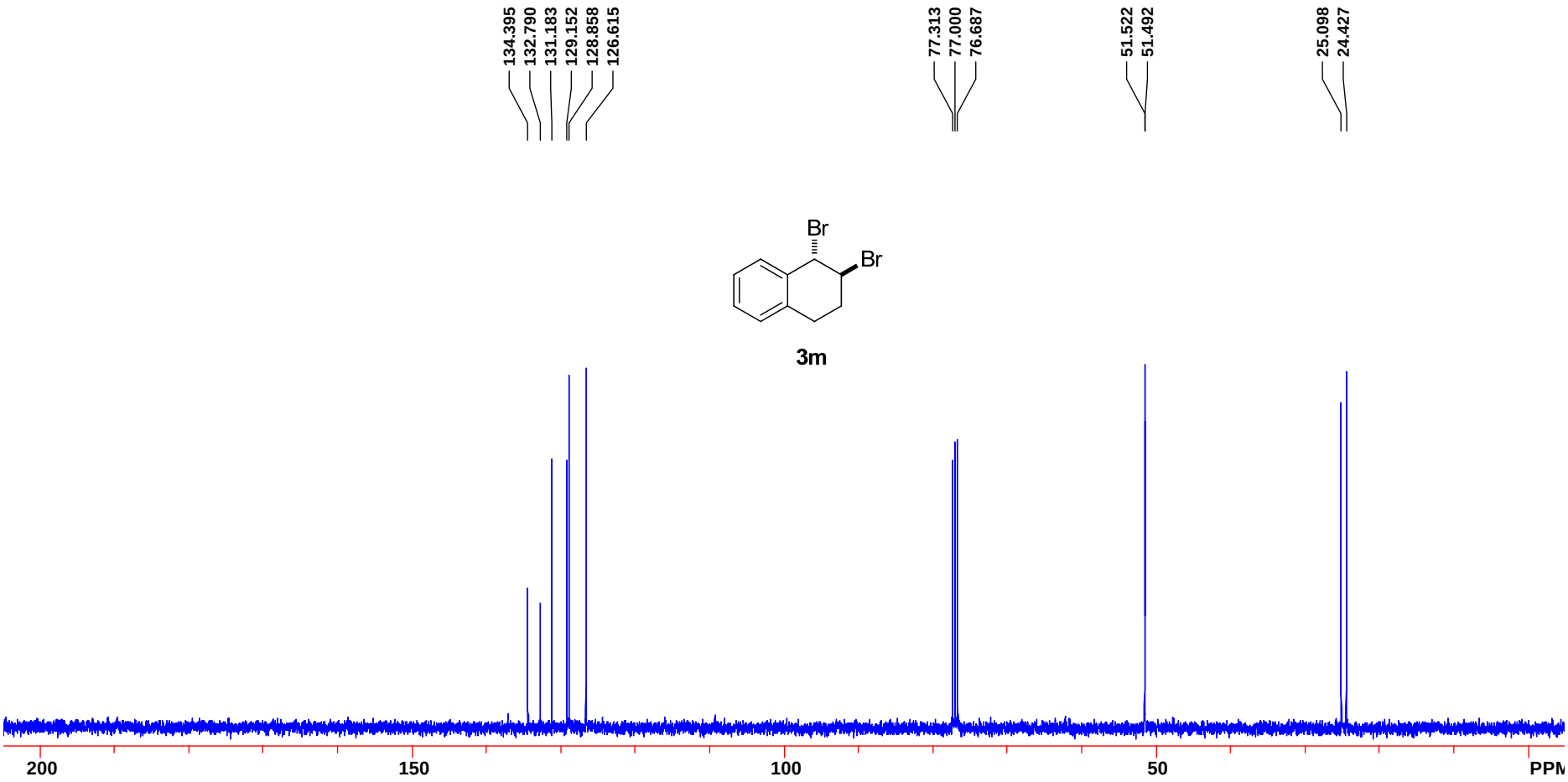

140.533
140.521
129.660
127.916
125.687
125.364
77.312
77.000
76.682
57.705
54.399
41.403
Br
Br
3l
200
150
100
50
0 PPM

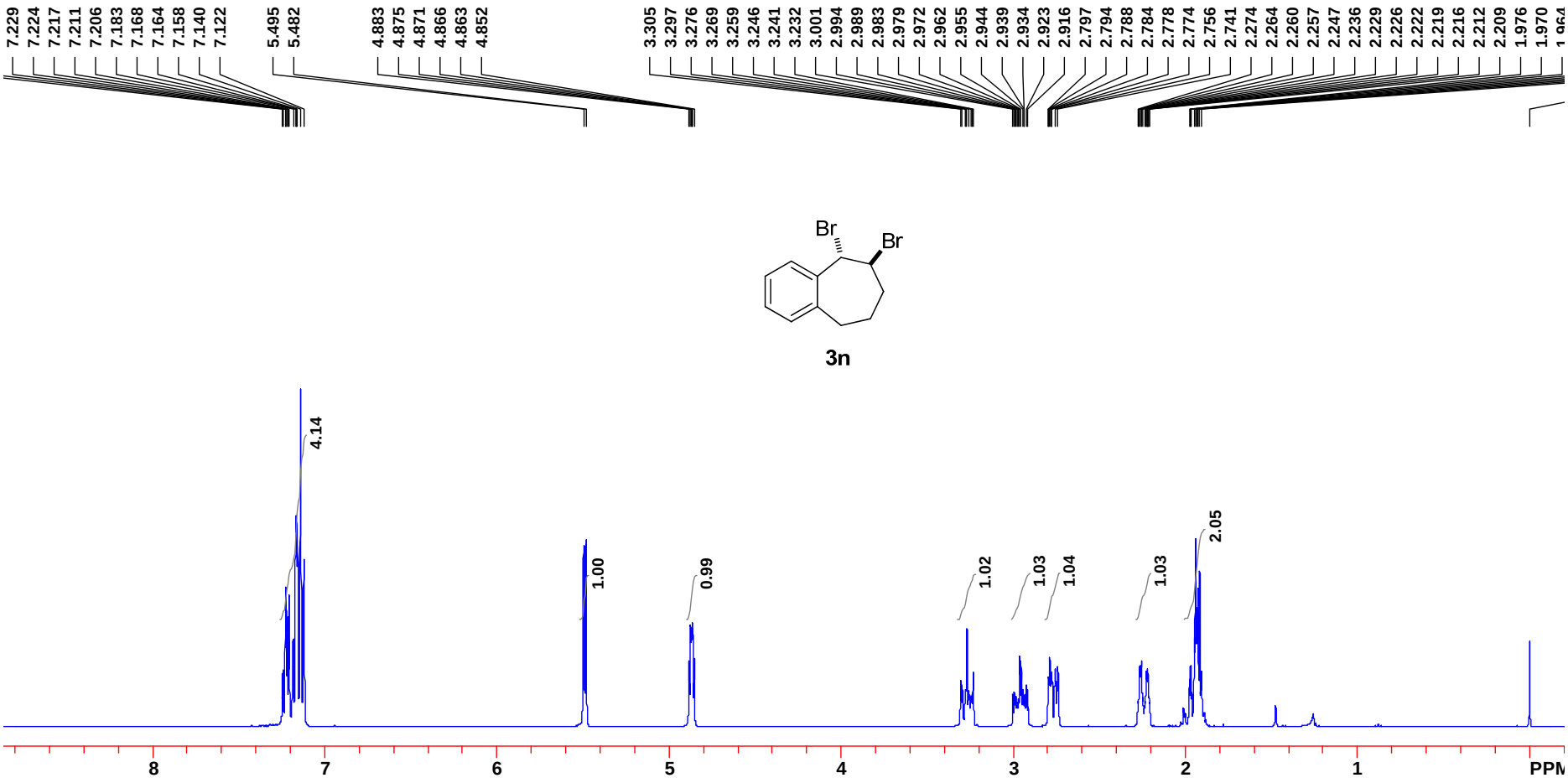

7.305
7.302
7.286
7.282
7.245
7.242
7.227
7.223
7.215
7.209
7.205
7.192
7.175
7.157
7.117
7.098
5.640
5.635
5.631
4.926
4.919
4.915
4.910
4.904
3.296
3.280
3.266
3.251
3.237
3.222
3.207
2.941
2.927
2.898
2.882
2.843
2.837
2.828
2.822
2.813
2.807
2.801
2.792
2.786
2.777
2.771
2.762
2.756
2.199
2.195
2.190
2.185
2.180
2.174
2.170
2.165
2.162
2.159
2.153
2.148
2.143
2.138
2.133
0.000

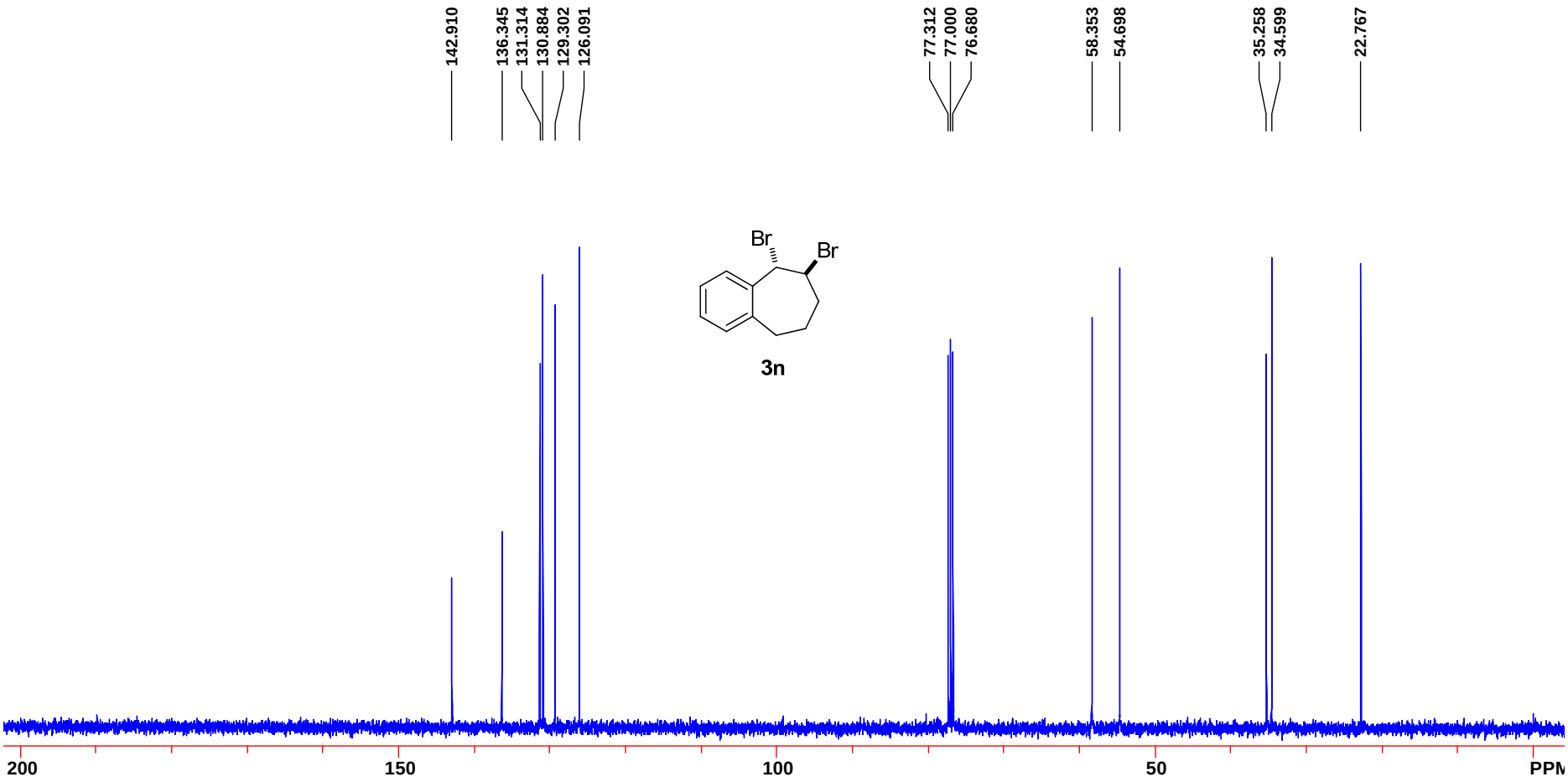

Br
Br

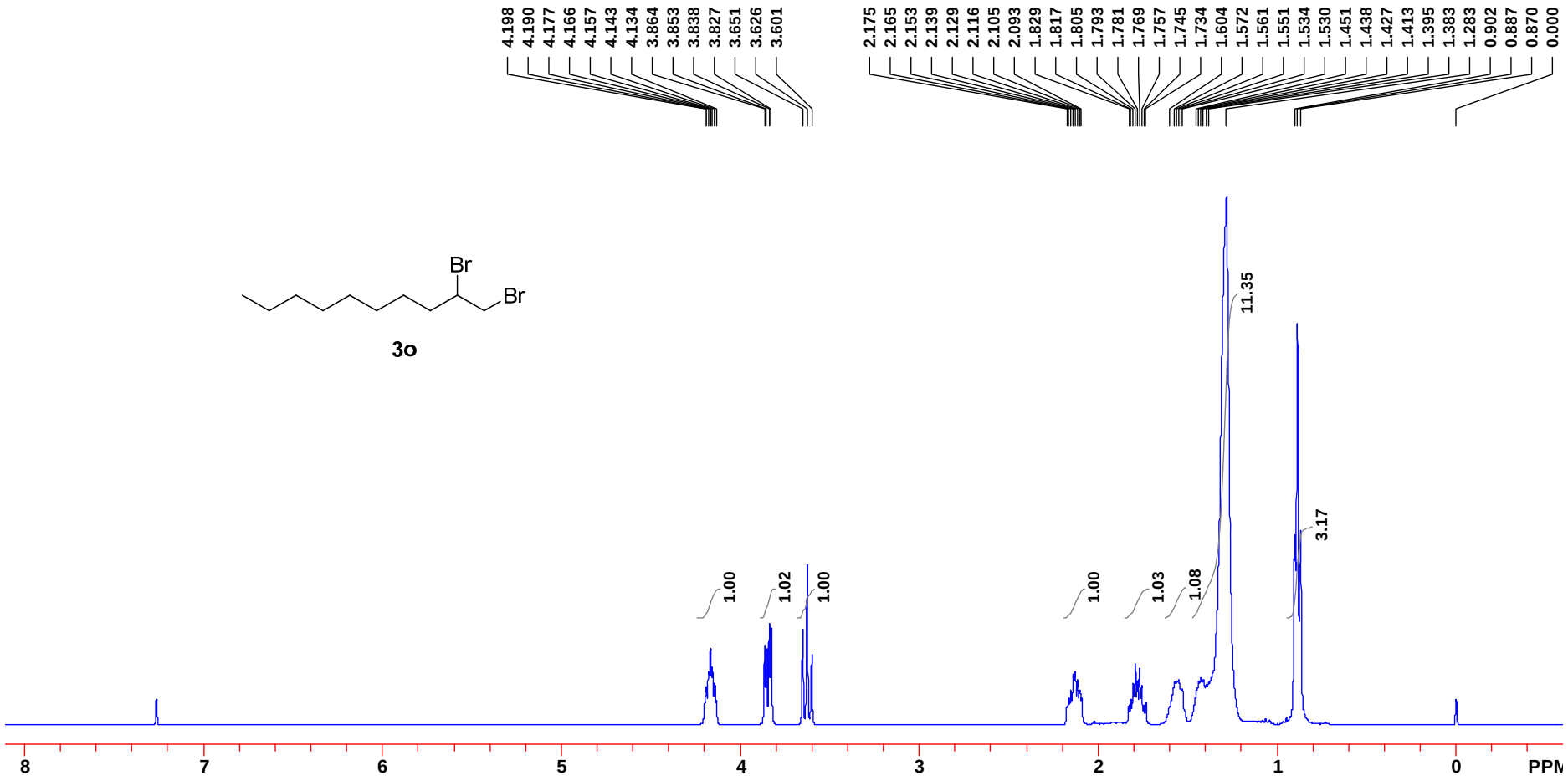
3m

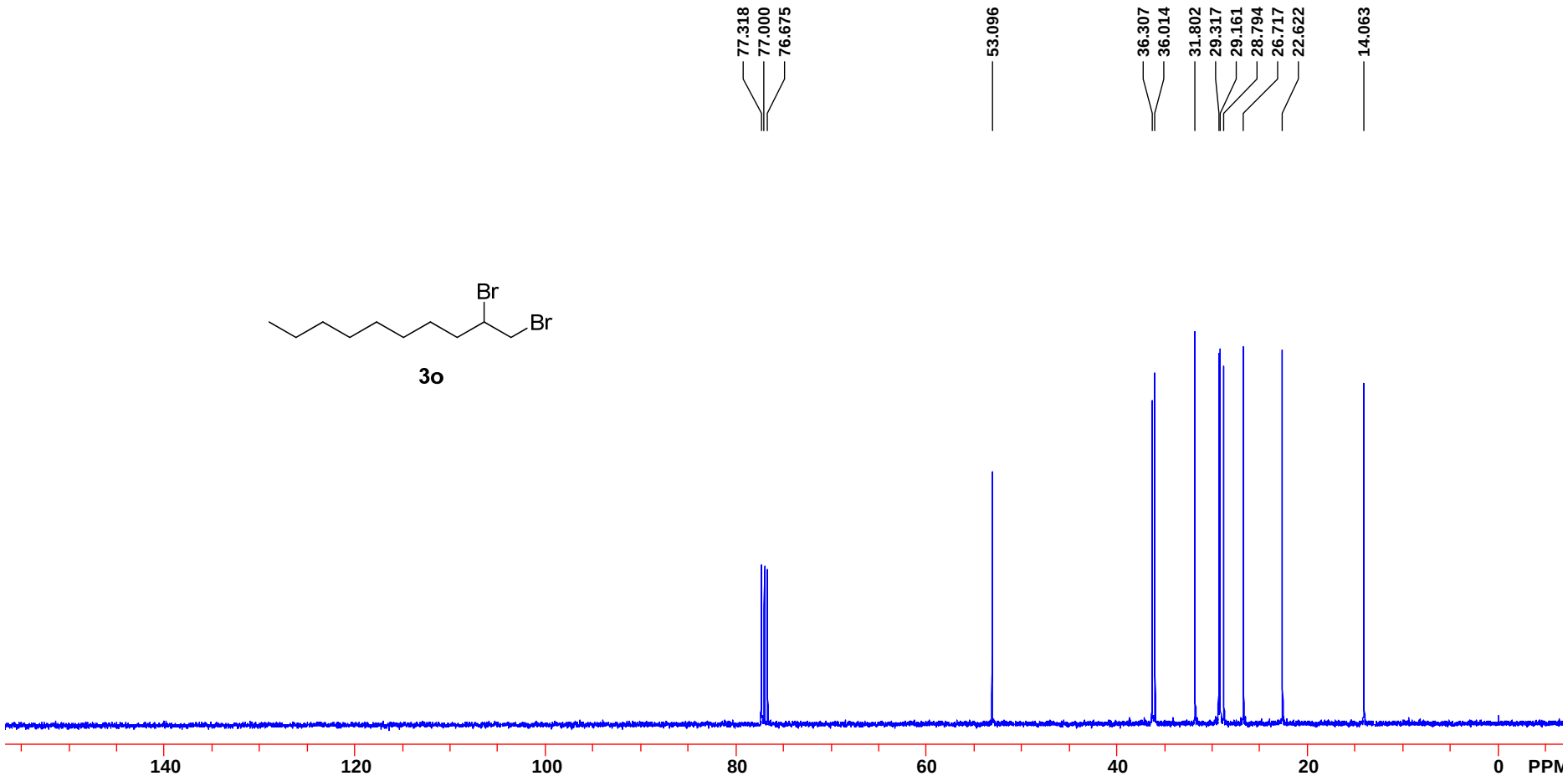

2.11
1.01
0.98
1.00
1.01
1.06
1.06
1.06
1.06
8
7
6
5
4
3
2
1
0 PPM

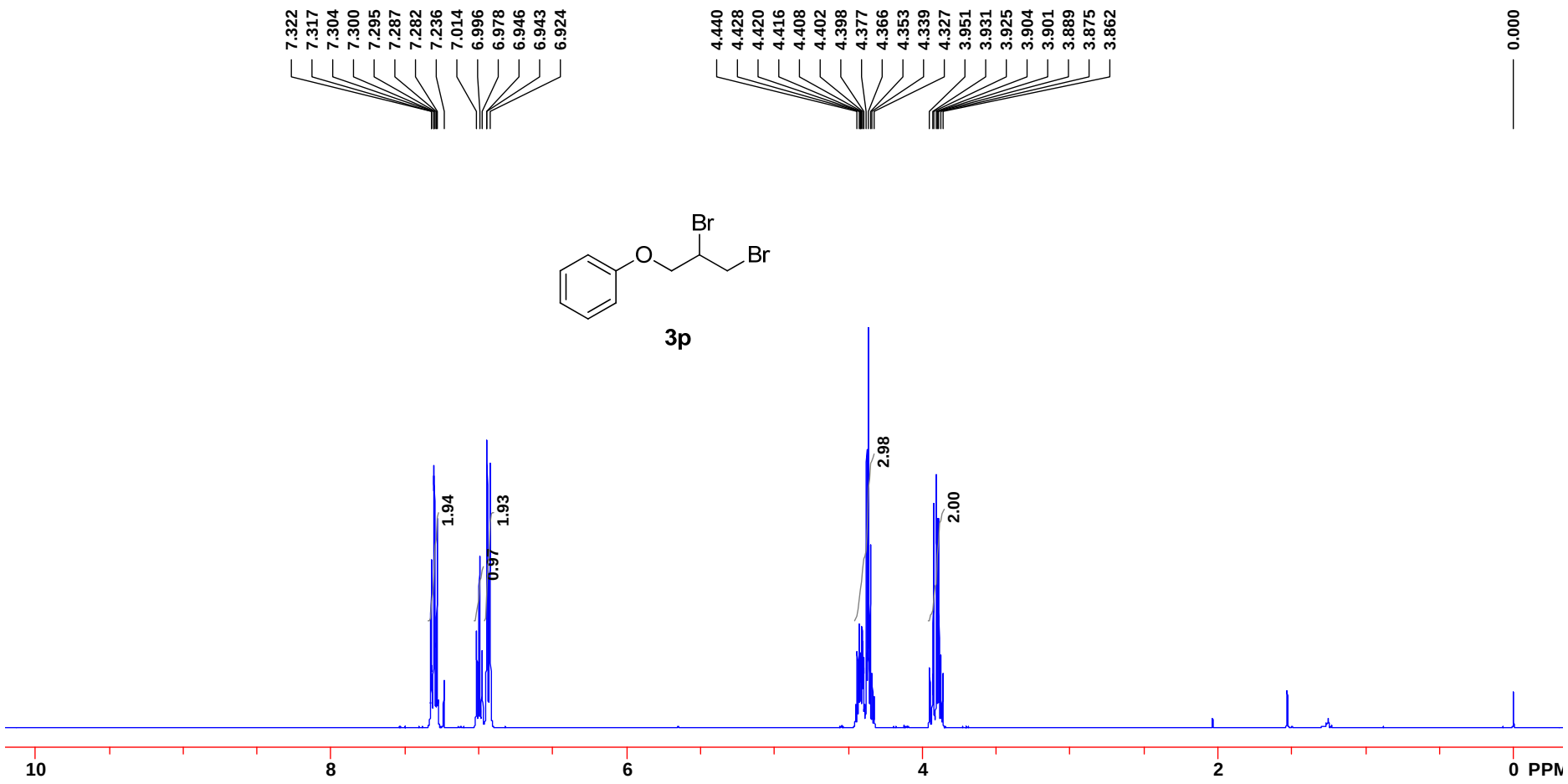

134.395
132.790
131.183
129.152
128.858
126.615
77.313
77.000
76.687
51.522
51.492
25.098
24.427
Br
Br
3m
200
150
100
50
PPM

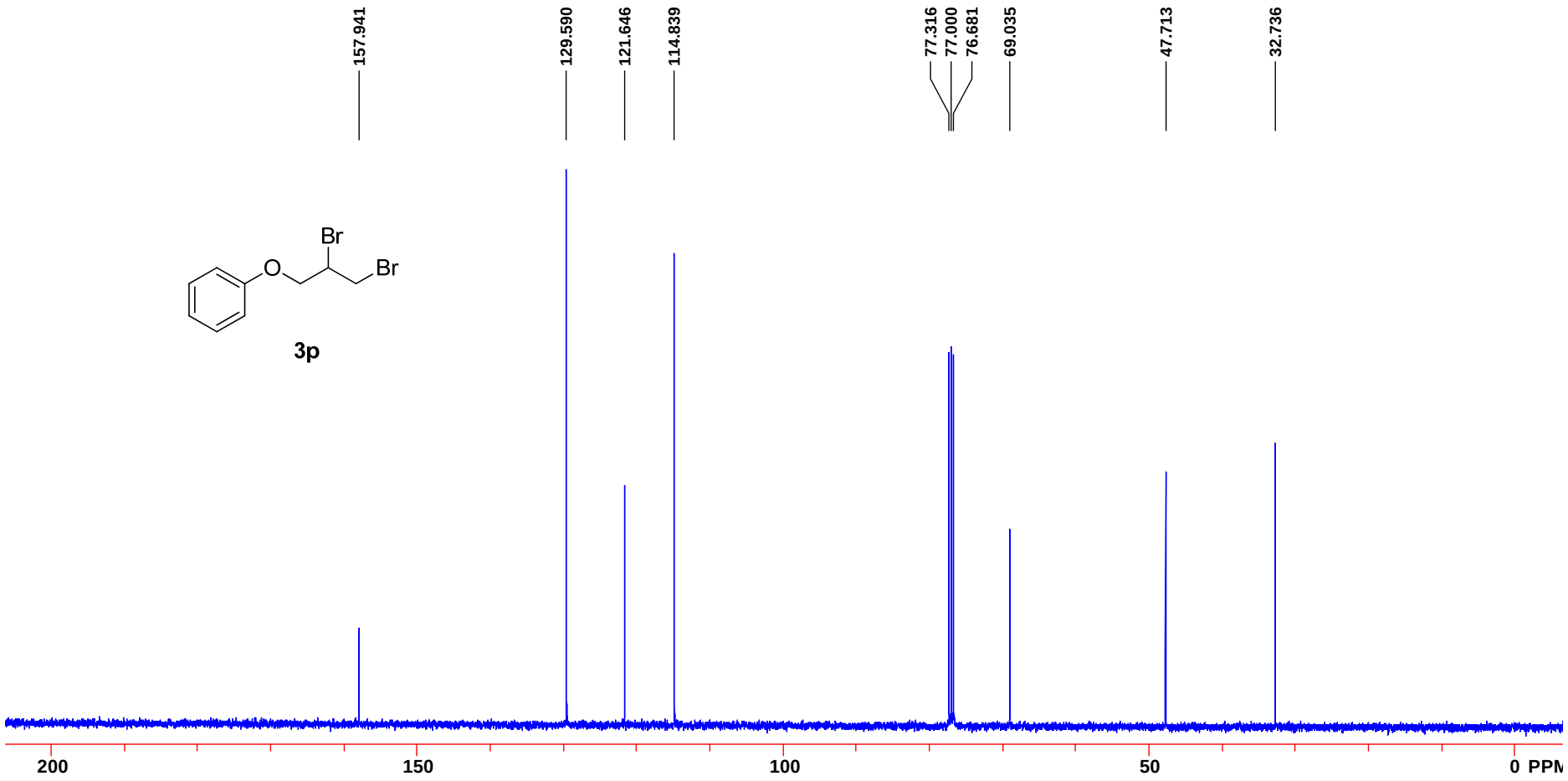

7.229
7.224
7.217
7.211
7.206
7.183
7.168
7.164
7.158
7.140
7.122
5.495
5.482
4.883
4.875
4.871
4.866
4.863
4.852
3.305
3.297
3.276
3.269
3.259
3.246
3.241
3.232
3.001
2.994
2.989
2.983
2.979
2.972
2.962
2.955
2.944
2.939
2.934
2.923
2.916
2.797
2.794
2.788
2.784
2.778
2.774
2.756
2.741
2.274
2.264
2.260
2.257
2.247
2.236
2.229
2.226
2.222
2.219
2.216
2.212
2.209
1.976
1.970
Br
Br
3n
4.14
1.00
0.99
1.02
1.03
1.04
1.03
2.05
8
7
6
5
4
3
2
1
PPM

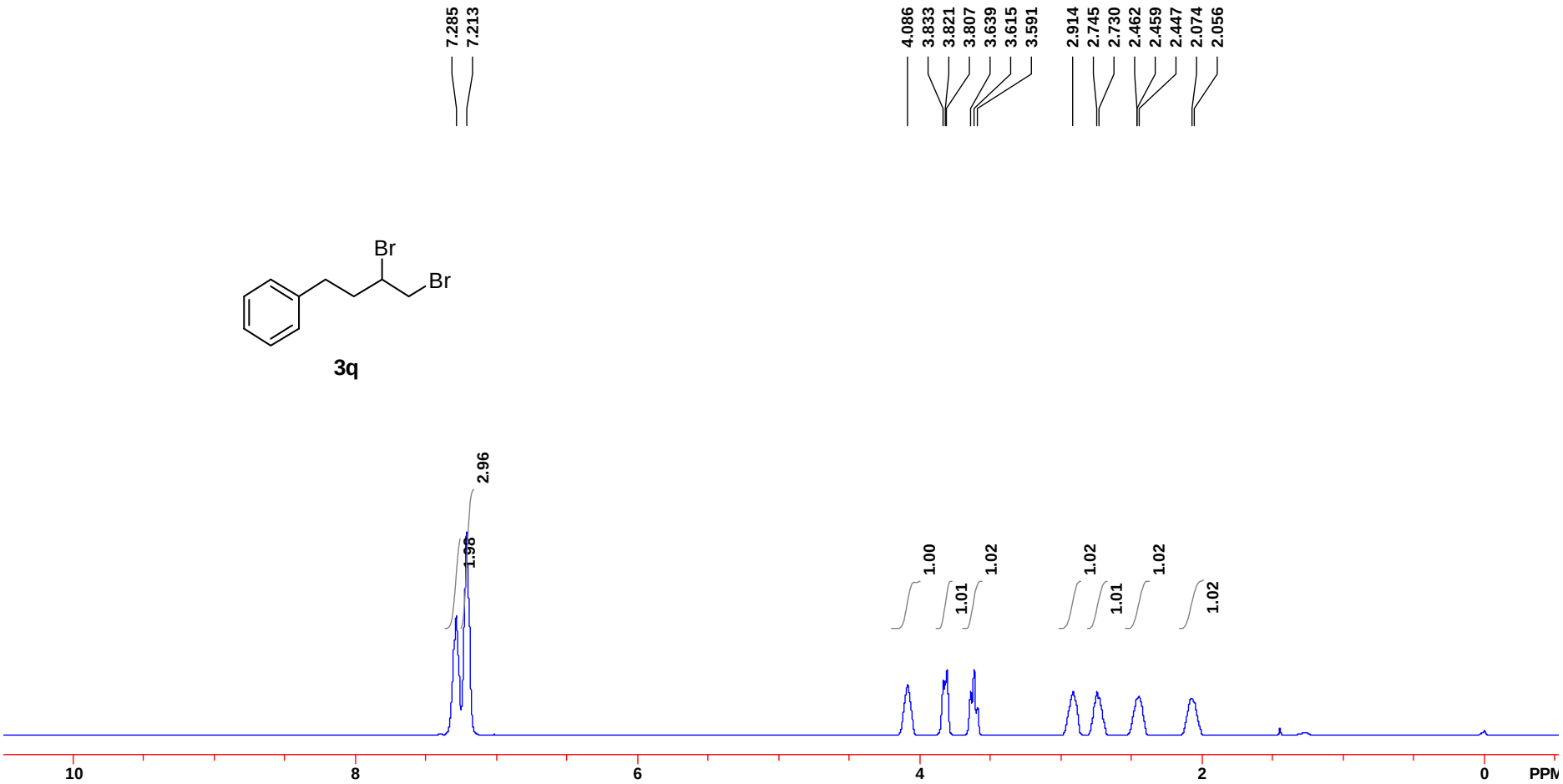

142.910
136.345
131.314
130.884
129.302
126.091
77.312
77.000
76.680
58.353
54.698
35.258
34.599
22.767
Br
Br
3n
200
150
100
50
PPM

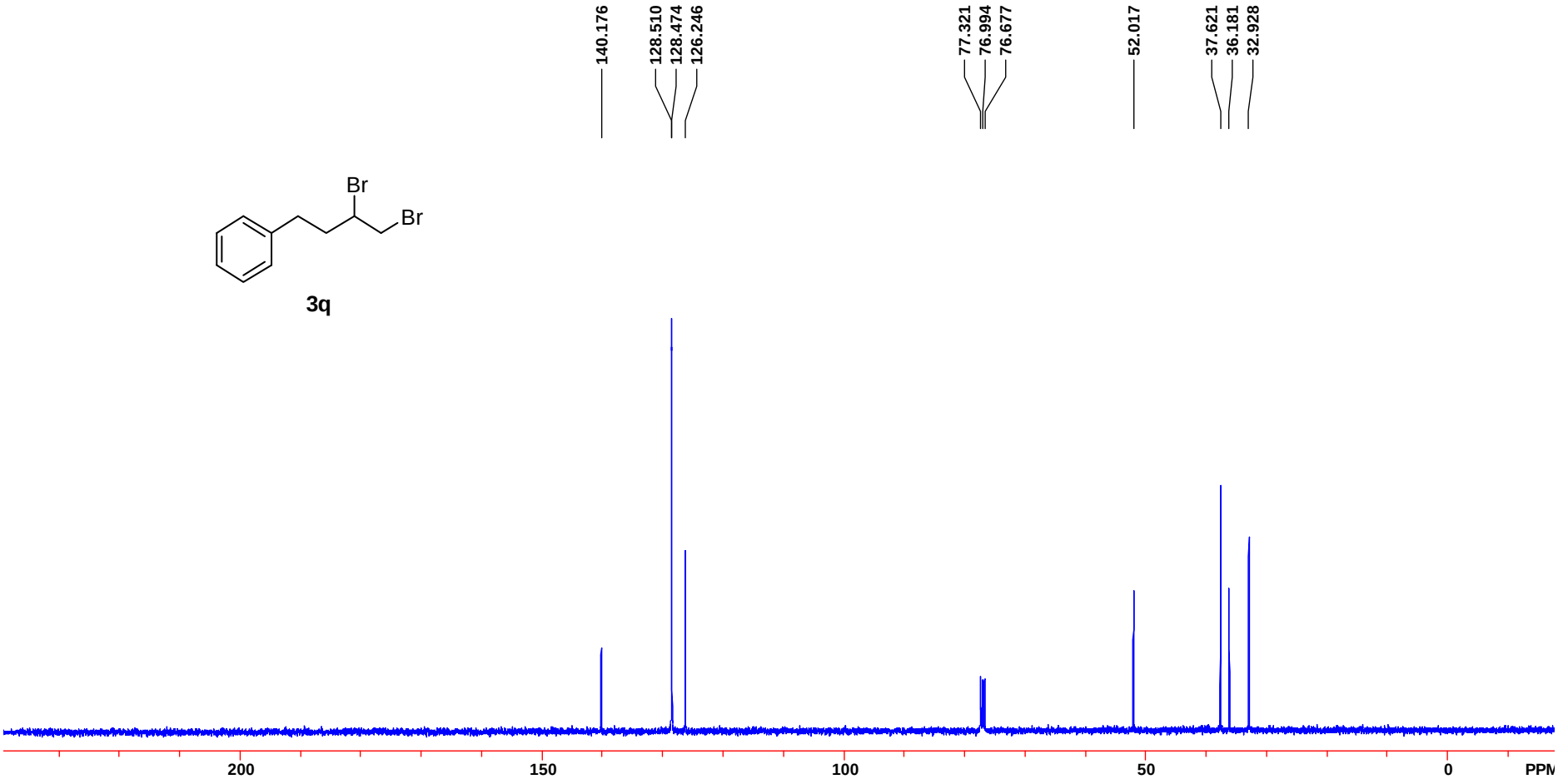

4.198
4.190
4.177
4.166
4.157
4.143
4.134
3.864
3.853
3.838
3.827
3.651
3.626
3.601
2.175
2.165
2.153
2.139
2.129
2.116
2.105
2.093
1.829
1.817
1.805
1.793
1.781
1.769
1.757
1.745
1.734
1.604
1.572
1.561
1.551
1.534
1.530
1.451
1.438
1.427
1.413
1.395
1.383
1.283
0.902
0.887
0.870
0.000
Br
Br
3o
1.00
1.02
1.00
1.00
1.03
1.08
11.35
3.17
8
7
6
5
4
3
2
1
0
PPM

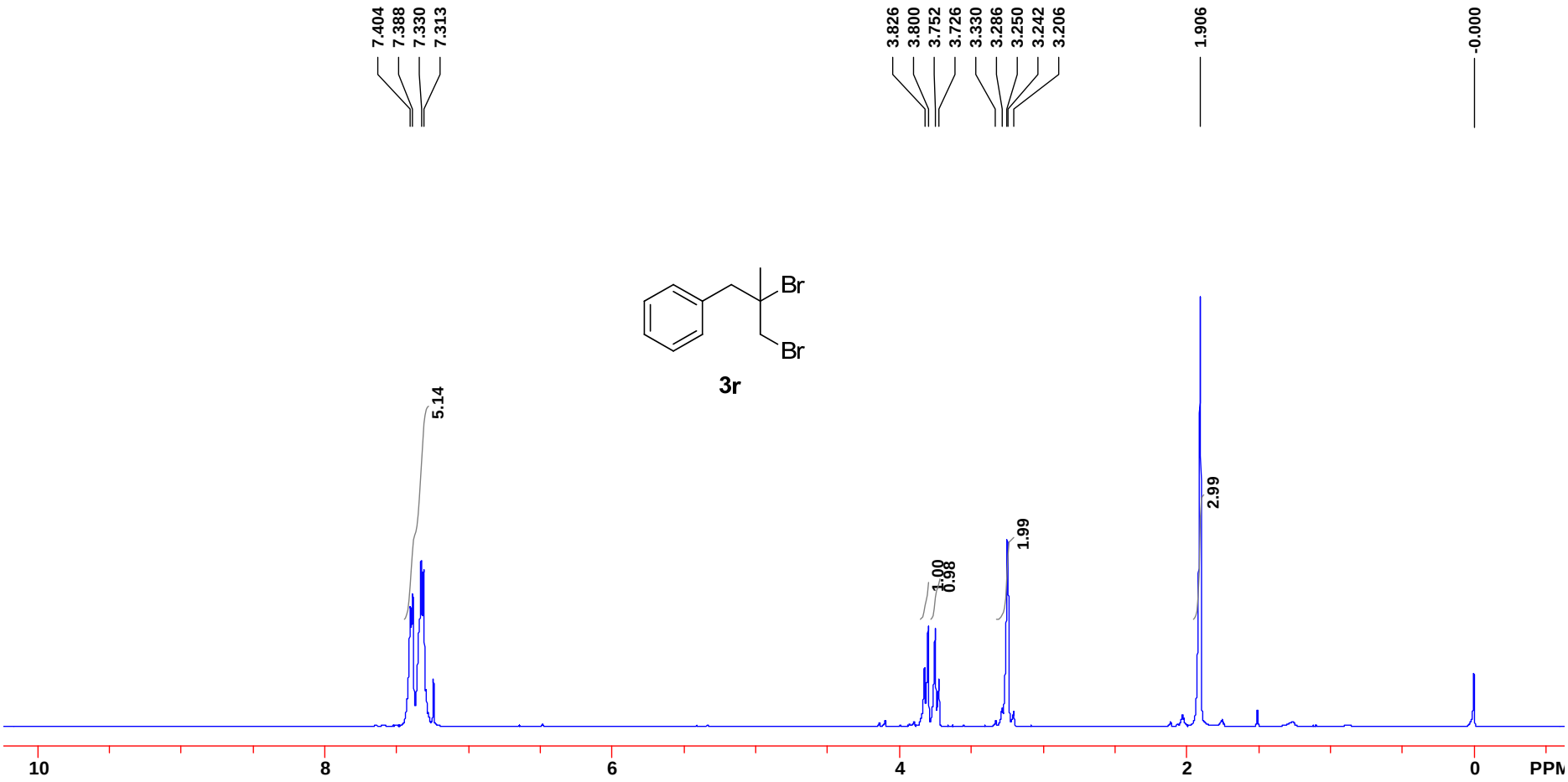

77.318
77.000
76.675
53.096
36.307
36.014
31.802
29.317
29.161
28.794
26.717
22.622
14.063
Br
Br
3o
140
120
100
80
60
40
20
0
PPM

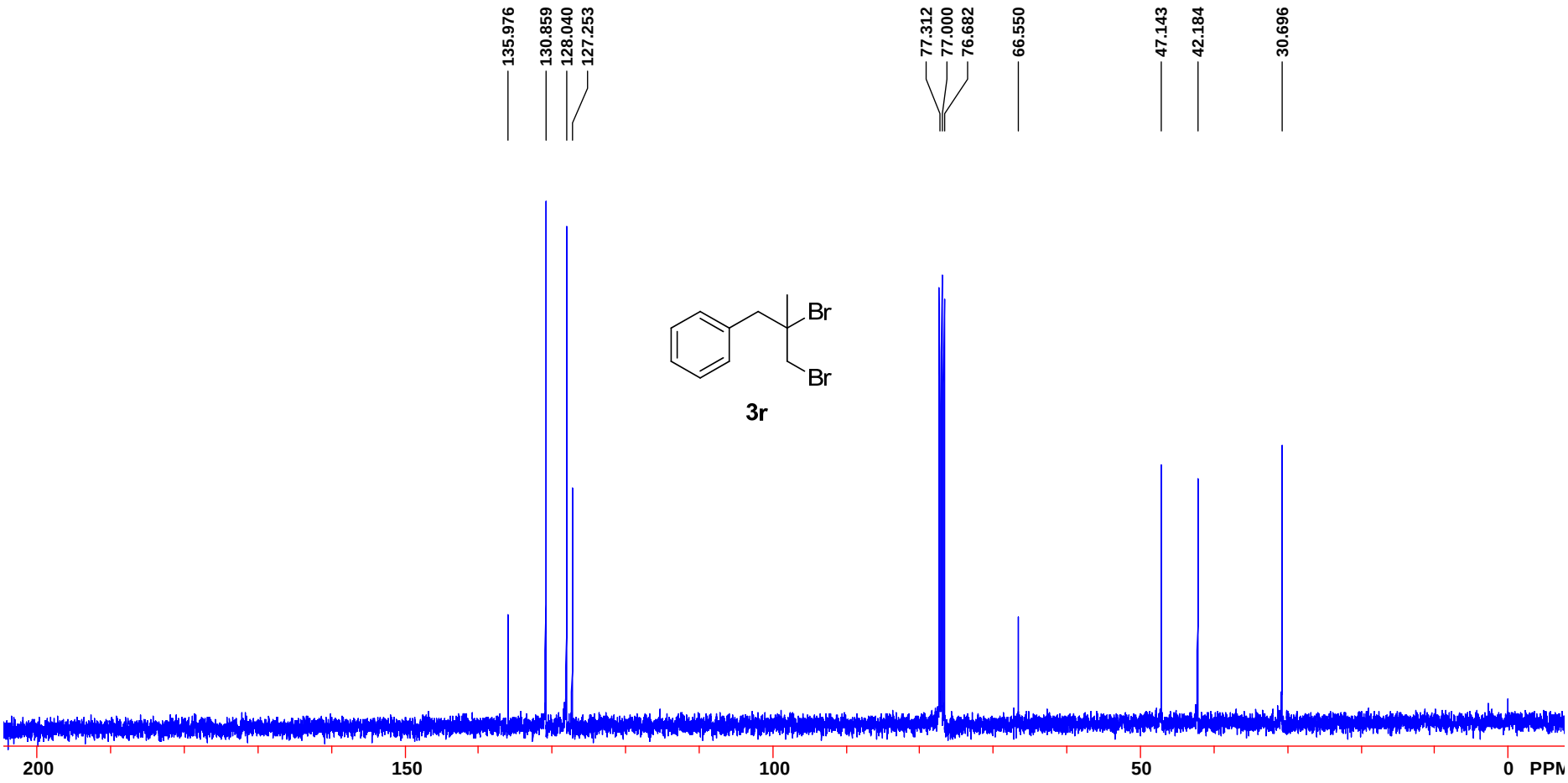

7.322
7.317
7.304
7.300
7.295
7.287
7.282
7.236
7.014
6.996
6.978
6.946
6.943
6.924
4.440
4.428
4.420
4.416
4.408
4.402
4.398
4.377
4.366
4.353
4.339
4.327
3.951
3.931
3.925
3.904
3.901
3.889
3.875
3.862
0.000
Br
O
Br
3p
1.94
1.93
0.97
2.98
2.00
10
8
6
4
2
0 PPM

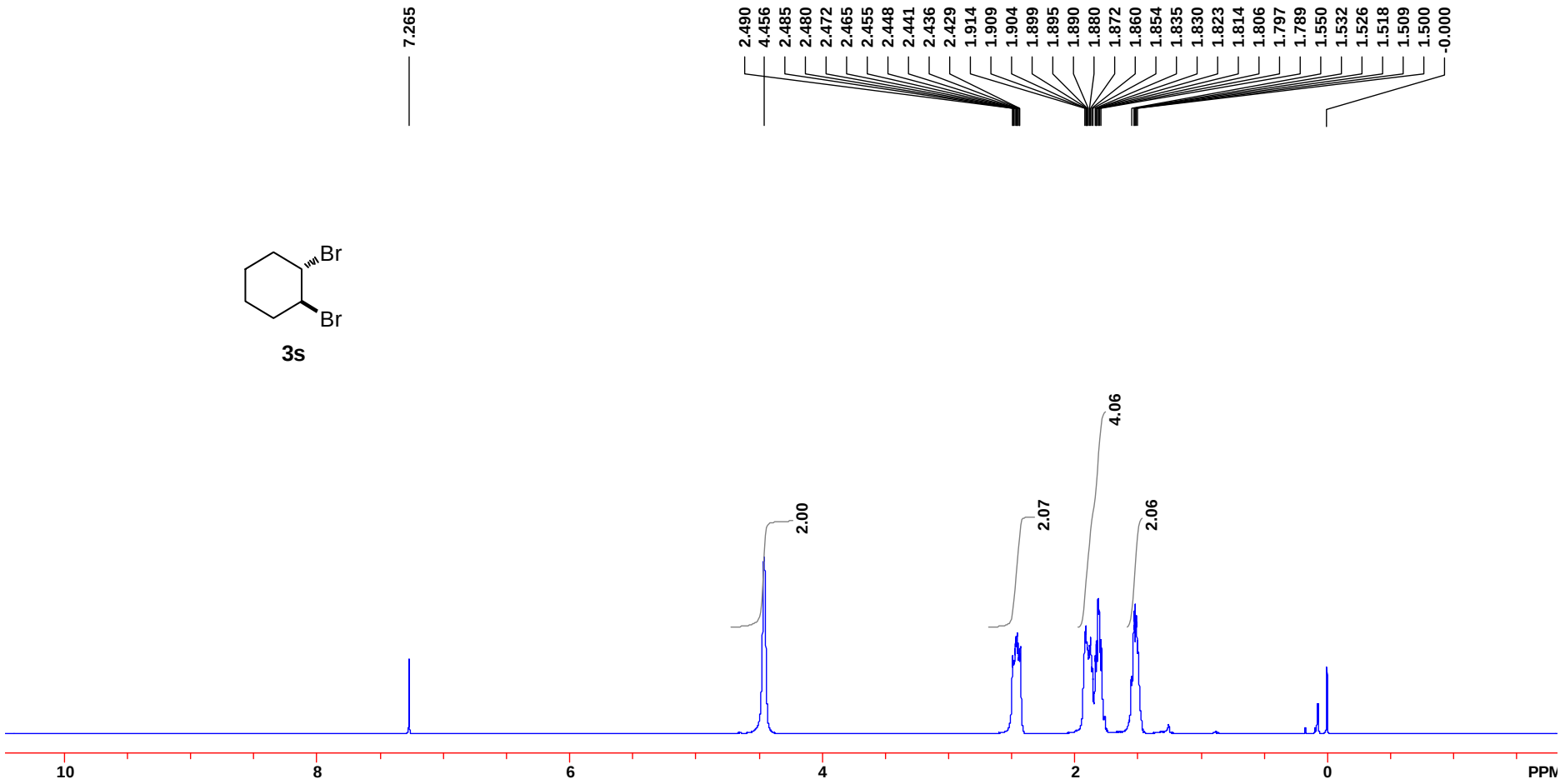

157.941
129.590
121.646
114.839
77.316
77.000
76.681
69.035
47.713
32.736
Br
O
Br
3p
200
150
100
50
0 PPM

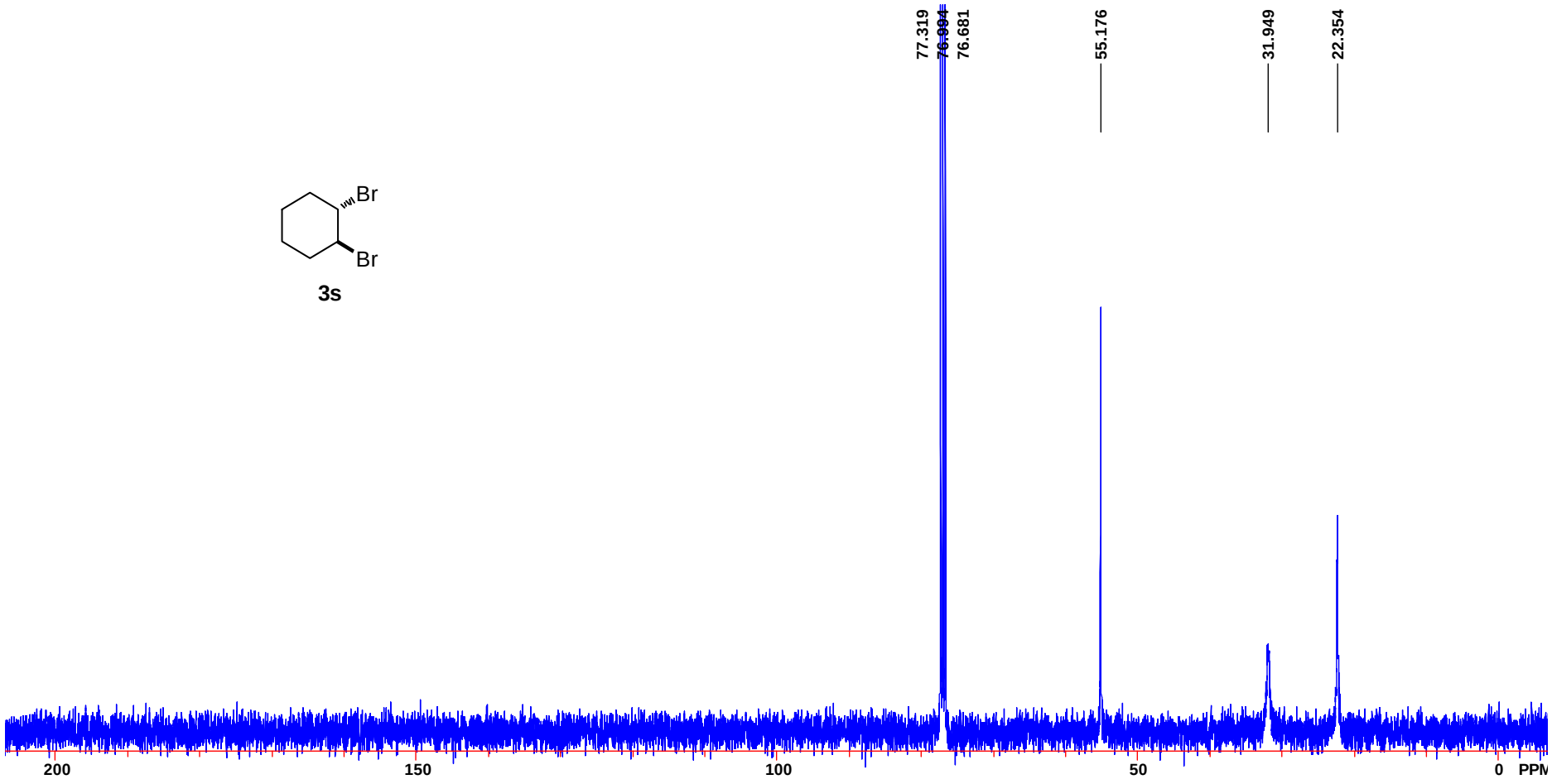

7.285
7.213
4.086
3.833
3.821
3.807
3.639
3.615
3.591
2.914
2.745
2.730
2.462
2.459
2.447
2.074
2.056
Br
Br
3q
2.96
1.98
1.00
1.02
1.01
1.02
1.02
1.01
1.02
10
8
6
4
2
0
PPM

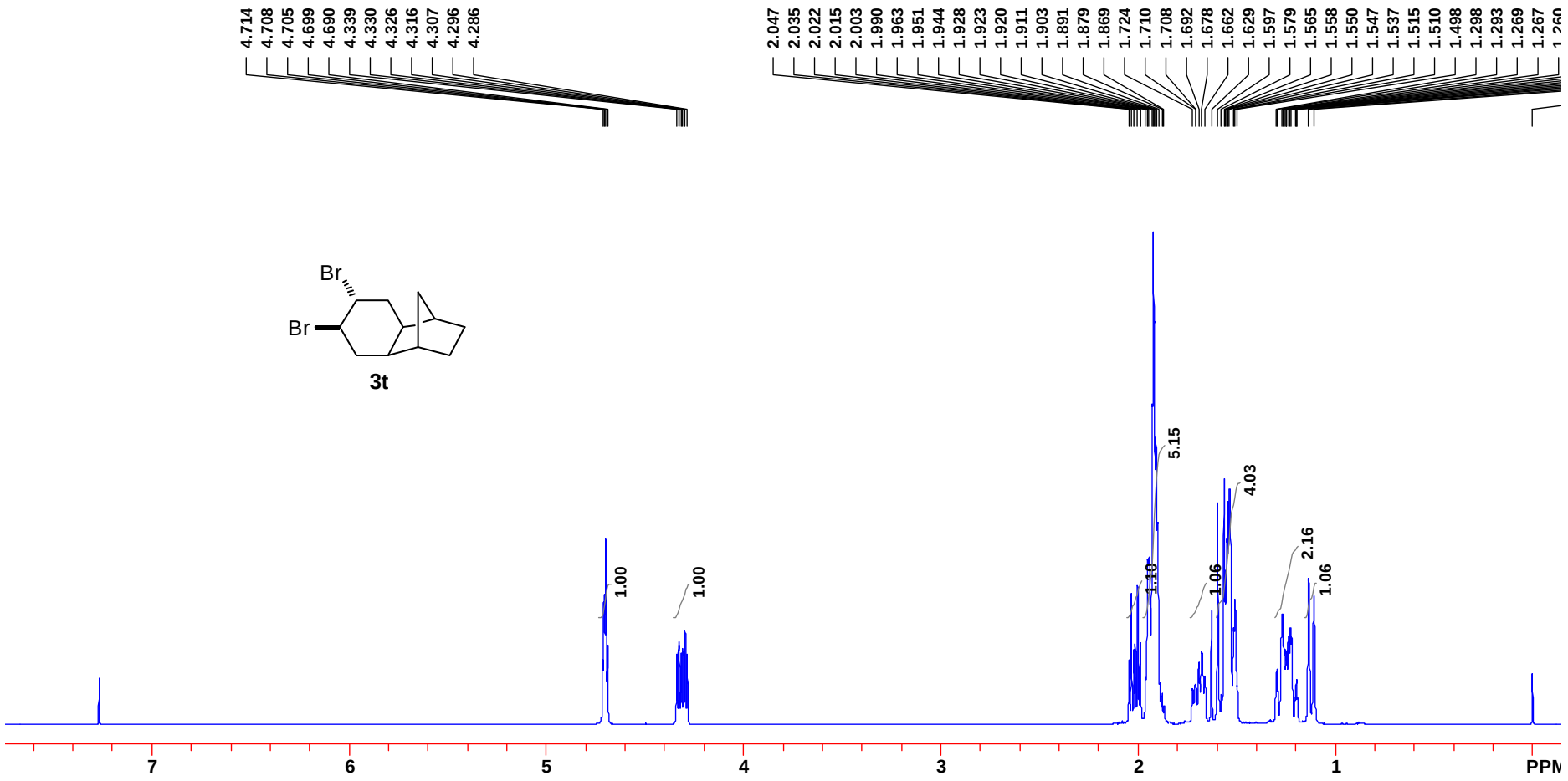

140.176
128.510
128.474
126.246
77.321
76.994
76.677
52.017
37.621
36.181
32.928
Br
Br
3q
200
150
100
50
0
PPM

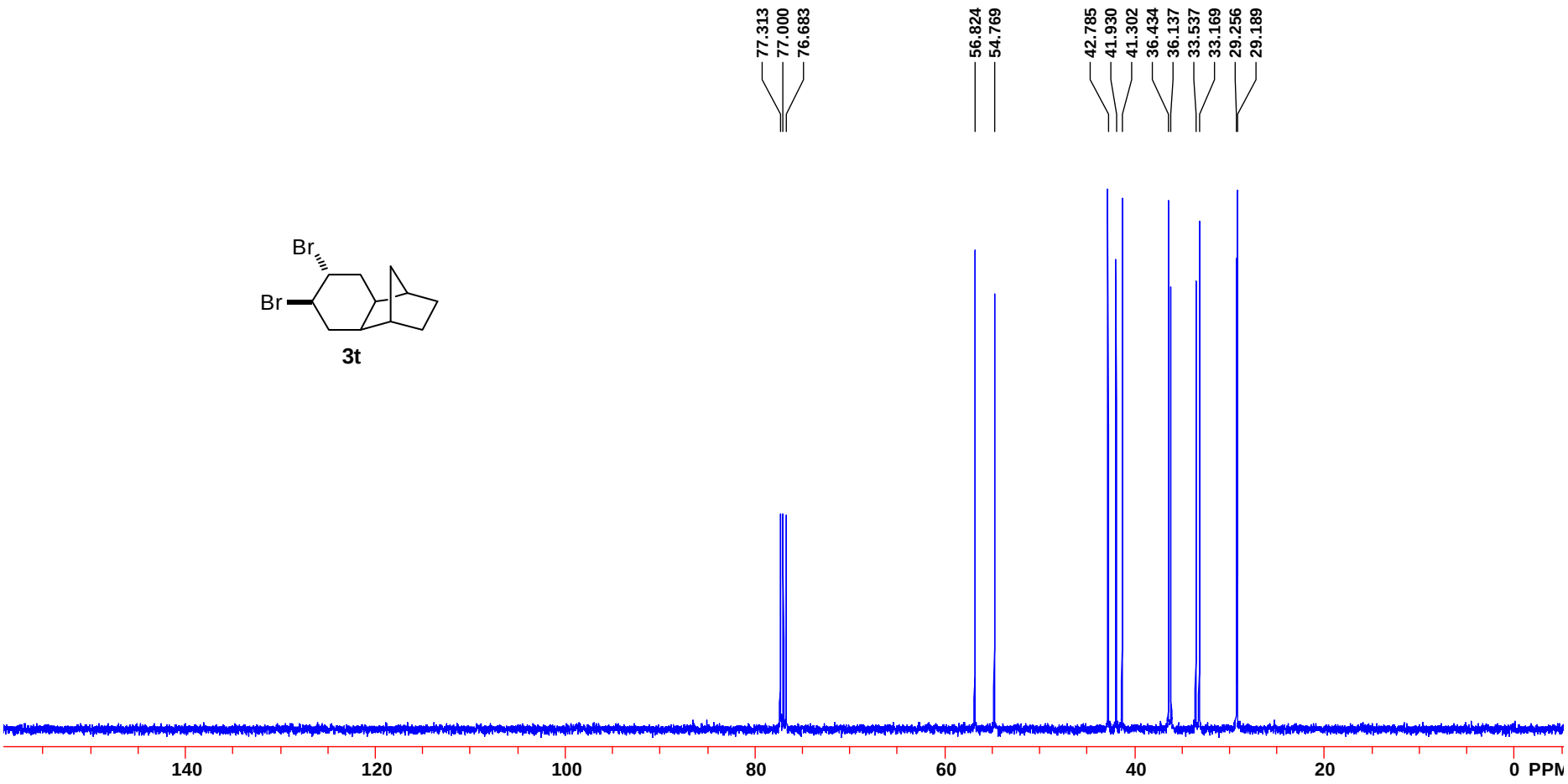

7.404
7.388
7.330
7.313
3.826
3.800
3.752
3.726
3.330
3.286
3.250
3.242
3.206
1.906
-0.000
Br
Br
3r
5.14
1.00
0.98
1.99
2.99
10
8
6
4
2
0
PPM

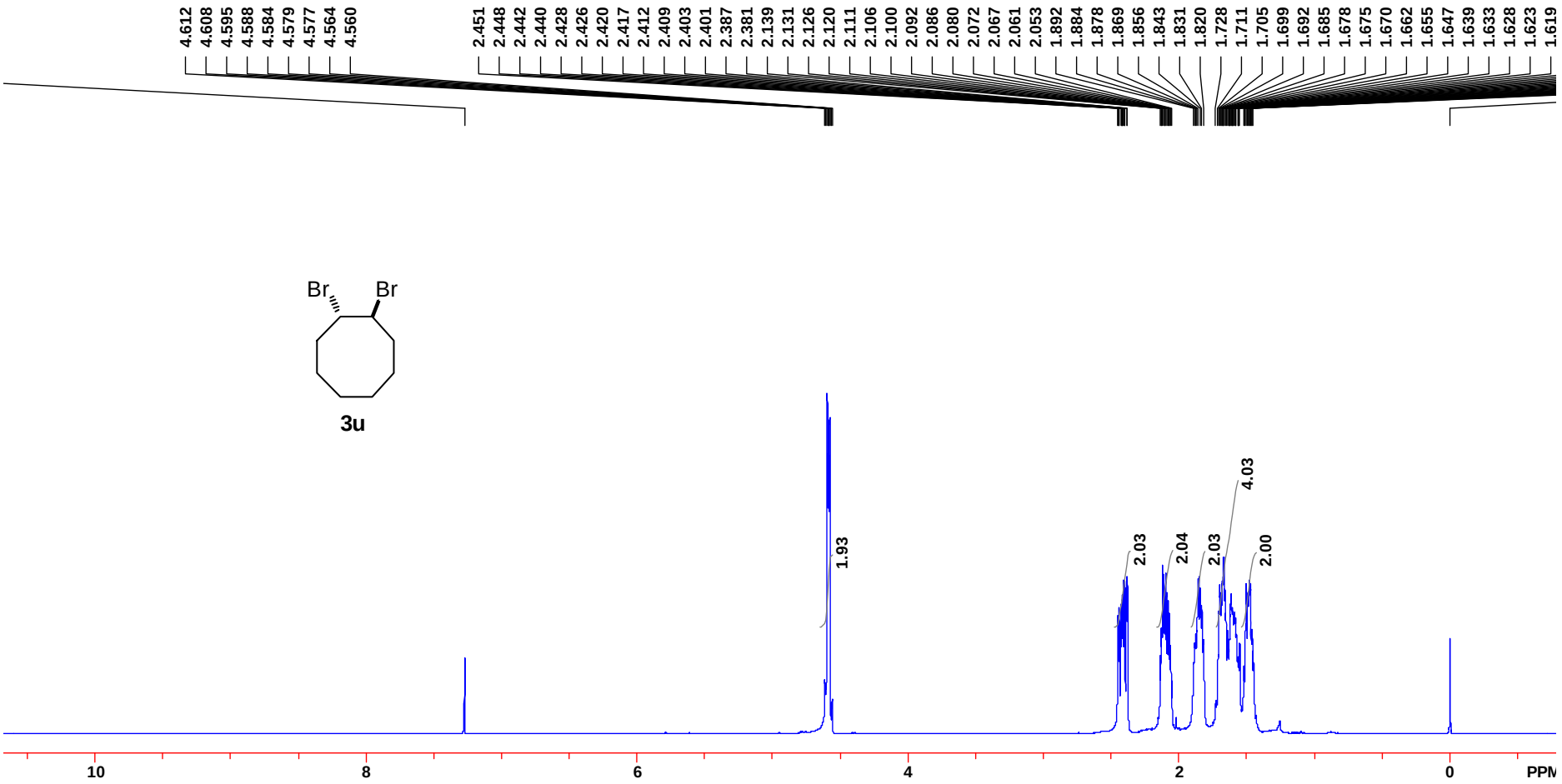

135.976
130.859
128.040
127.253
77.312
77.000
76.682
66.550
47.143
42.184
30.696
Br
Br
3r
200
150
100
50
0
PPM

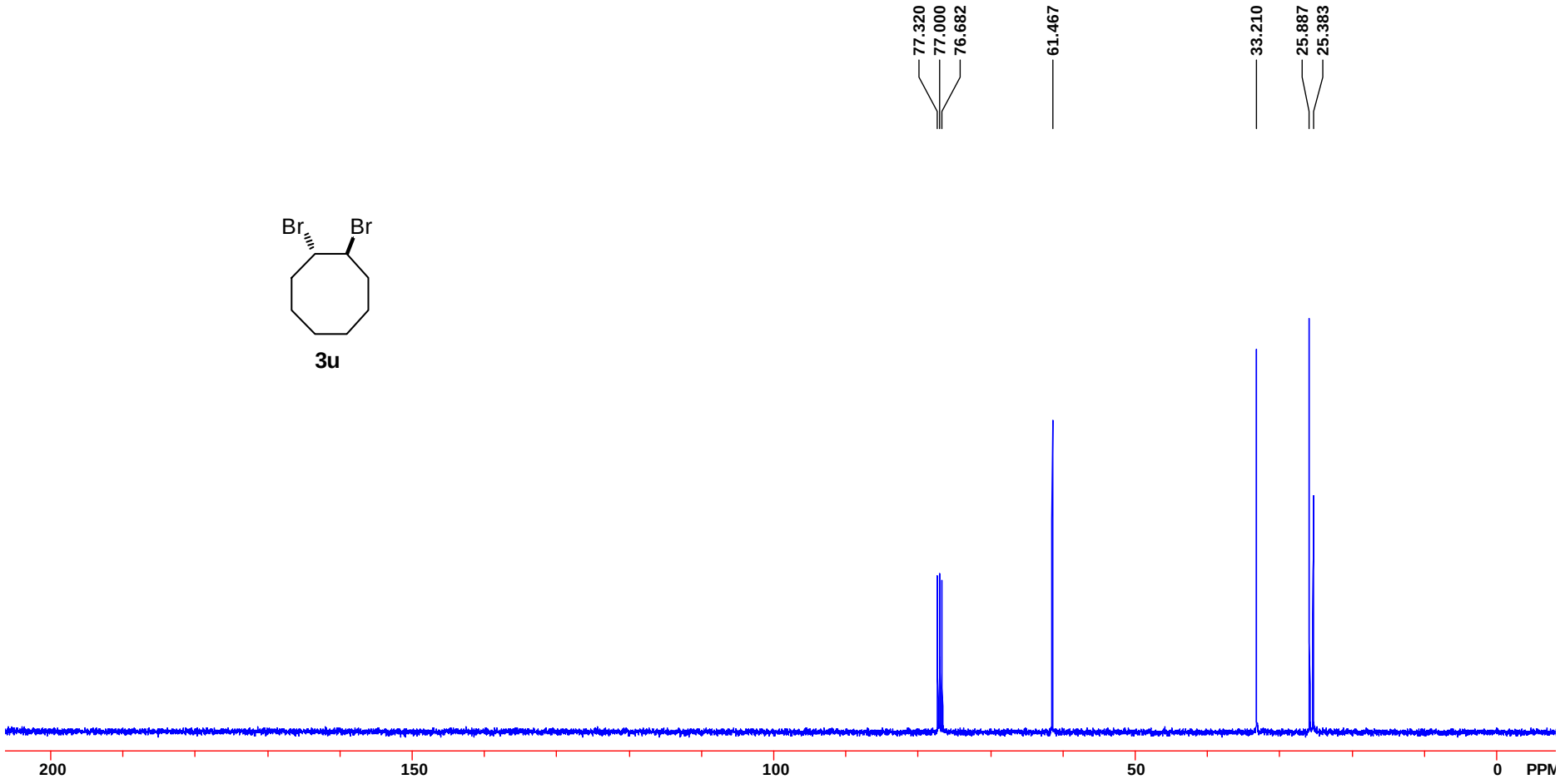

7.265
2.490
4.456
2.485
2.480
2.472
2.465
2.455
2.448
2.441
2.436
2.429
1.914
1.909
1.904
1.899
1.895
1.890
1.880
1.872
1.860
1.854
1.835
1.830
1.823
1.814
1.806
1.797
1.789
1.550
1.532
1.526
1.518
1.509
1.500
-0.000
Br
Br
3s
2.00
2.07
4.06
2.06
10
8
6
4
2
0
PPM

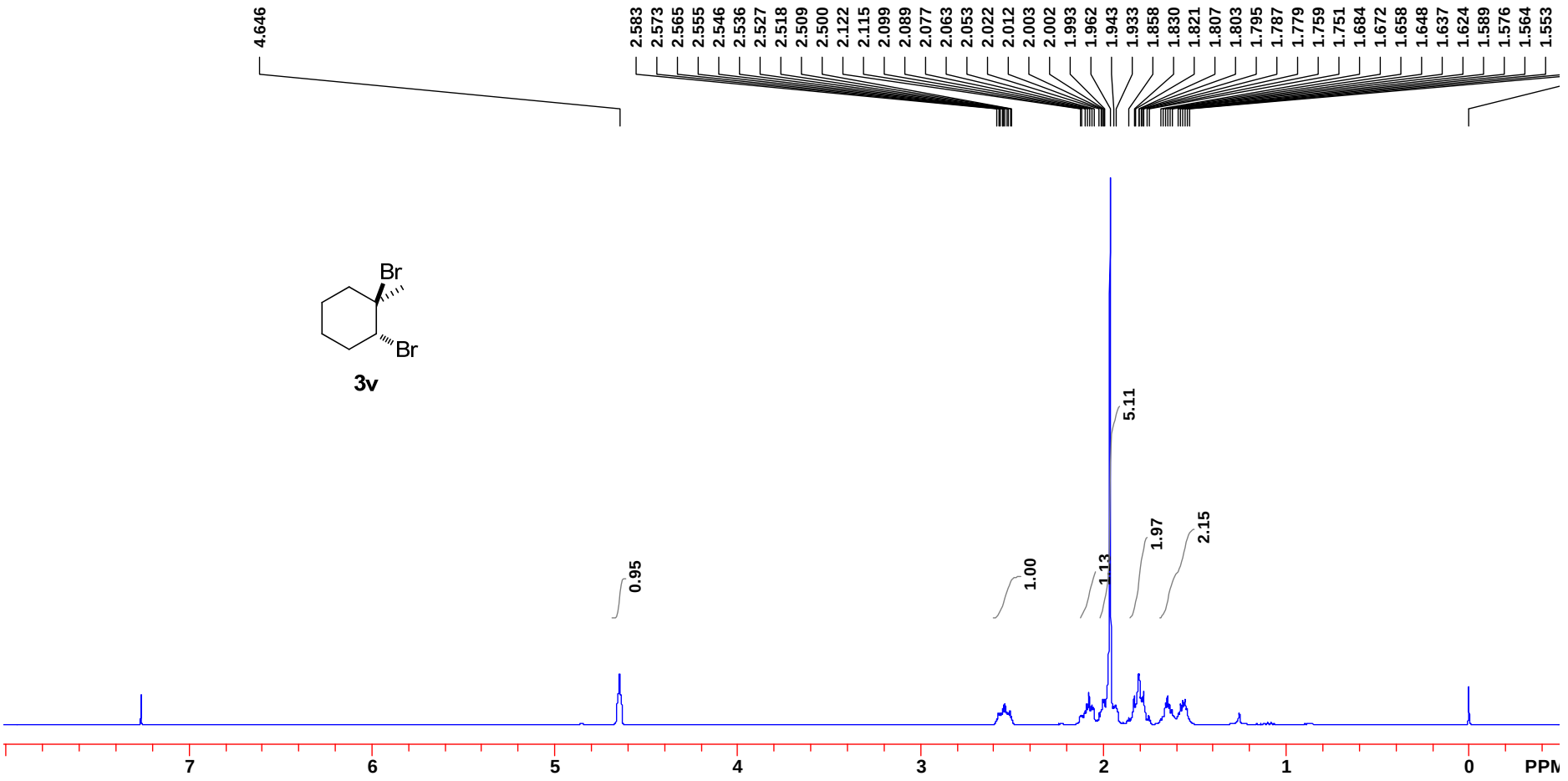

77.319
76.994
76.681
55.176
31.949
22.354
Br
Br
3s
200
150
100
50
0
PPM

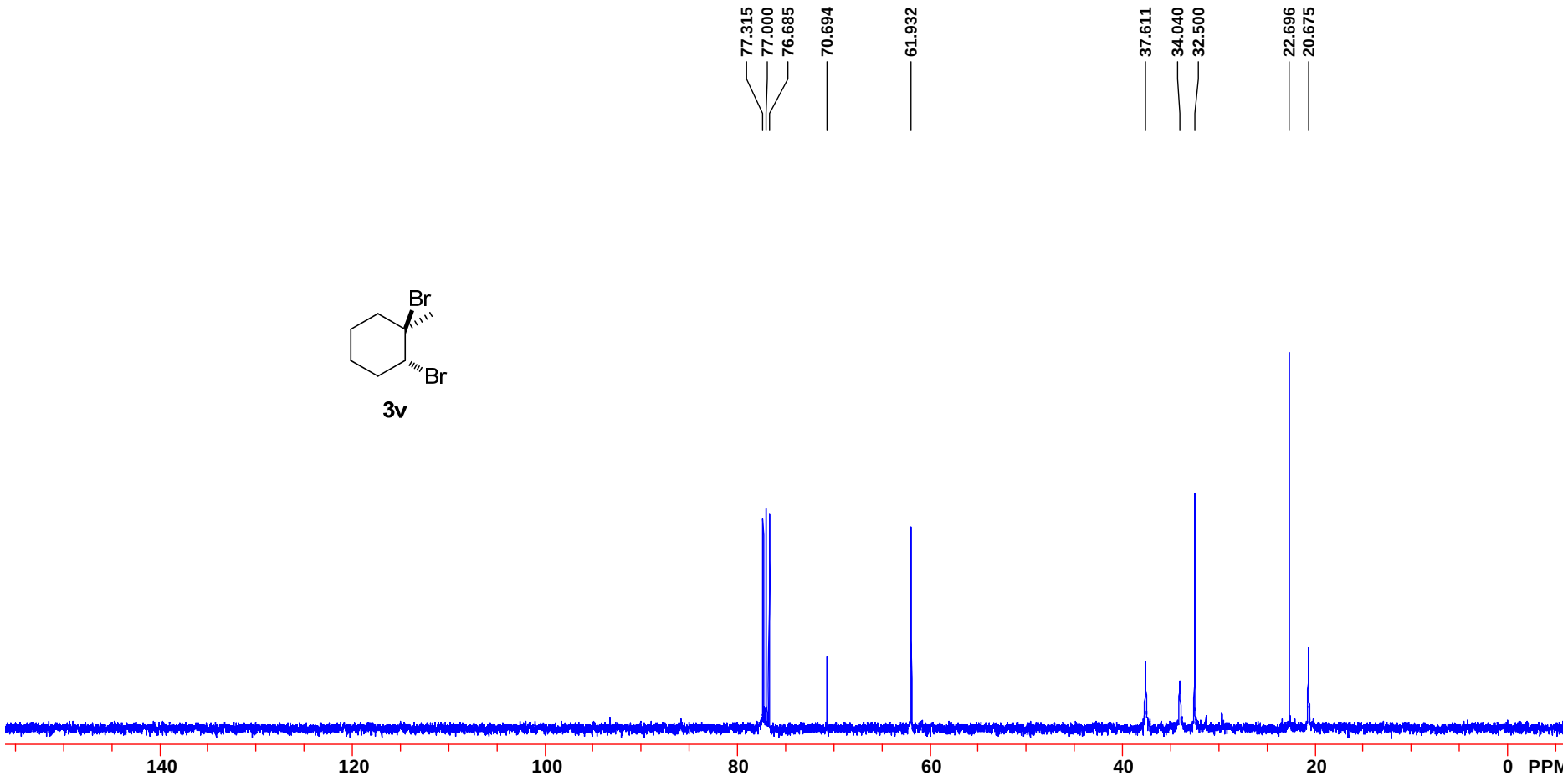

4.714
4.708
4.705
4.699
4.690
4.339
4.330
4.326
4.316
4.307
4.296
4.286
2.047
2.035
2.022
2.015
2.003
1.990
1.963
1.951
1.944
1.928
1.923
1.920
1.911
1.903
1.891
1.879
1.869
1.724
1.710
1.708
1.692
1.678
1.662
1.629
1.597
1.579
1.565
1.558
1.550
1.547
1.537
1.515
1.510
1.498
1.298
1.293
1.269
1.267
Br
Br
3t
1.00
1.00
1.10
5.15
1.06
4.03
2.16
1.06
7
6
5
4
3
2
1
PPM

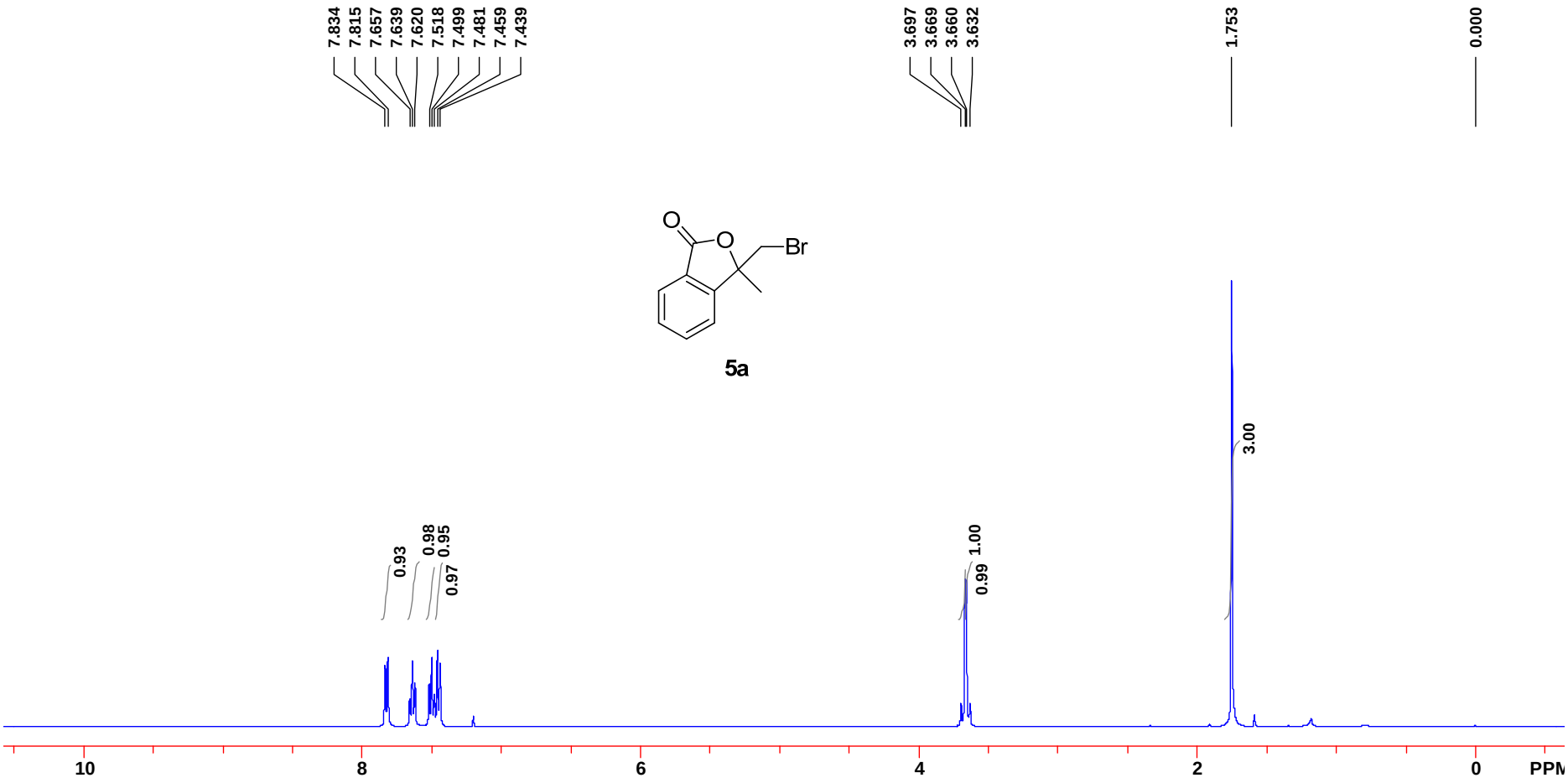

77.313
77.000
76.683
56.824
54.769
42.785
41.930
41.302
36.434
36.137
33.537
33.169
29.256
29.189
Br
Br
3t
140
120
100
80
60
40
20
0 PPM

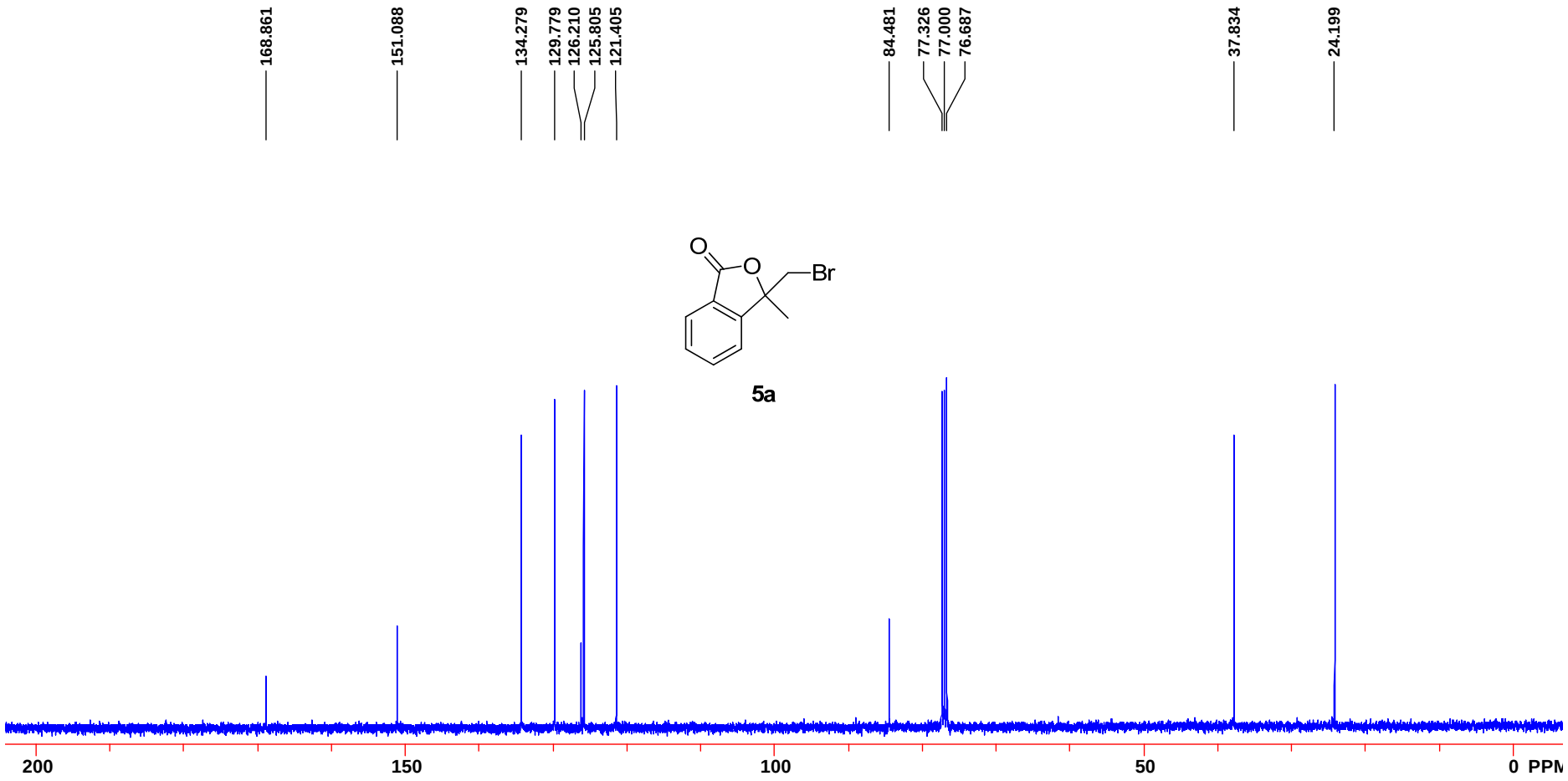

4.612
4.608
4.595
4.588
4.584
4.579
4.577
4.564
4.560
2.451
2.448
2.442
2.440
2.428
2.426
2.420
2.417
2.412
2.409
2.403
2.401
2.387
2.381
2.139
2.131
2.126
2.120
2.111
2.106
2.100
2.092
2.086
2.080
2.072
2.067
2.061
2.053
1.892
1.884
1.878
1.869
1.856
1.843
1.831
1.820
1.728
1.711
1.705
1.699
1.692
1.685
1.678
1.675
1.670
1.662
1.655
1.647
1.639
1.633
1.628
1.623
1.619
Br
Br
3u
1.93
2.03
2.04
2.03
4.03
2.00
10
8
6
4
2
0
PPM

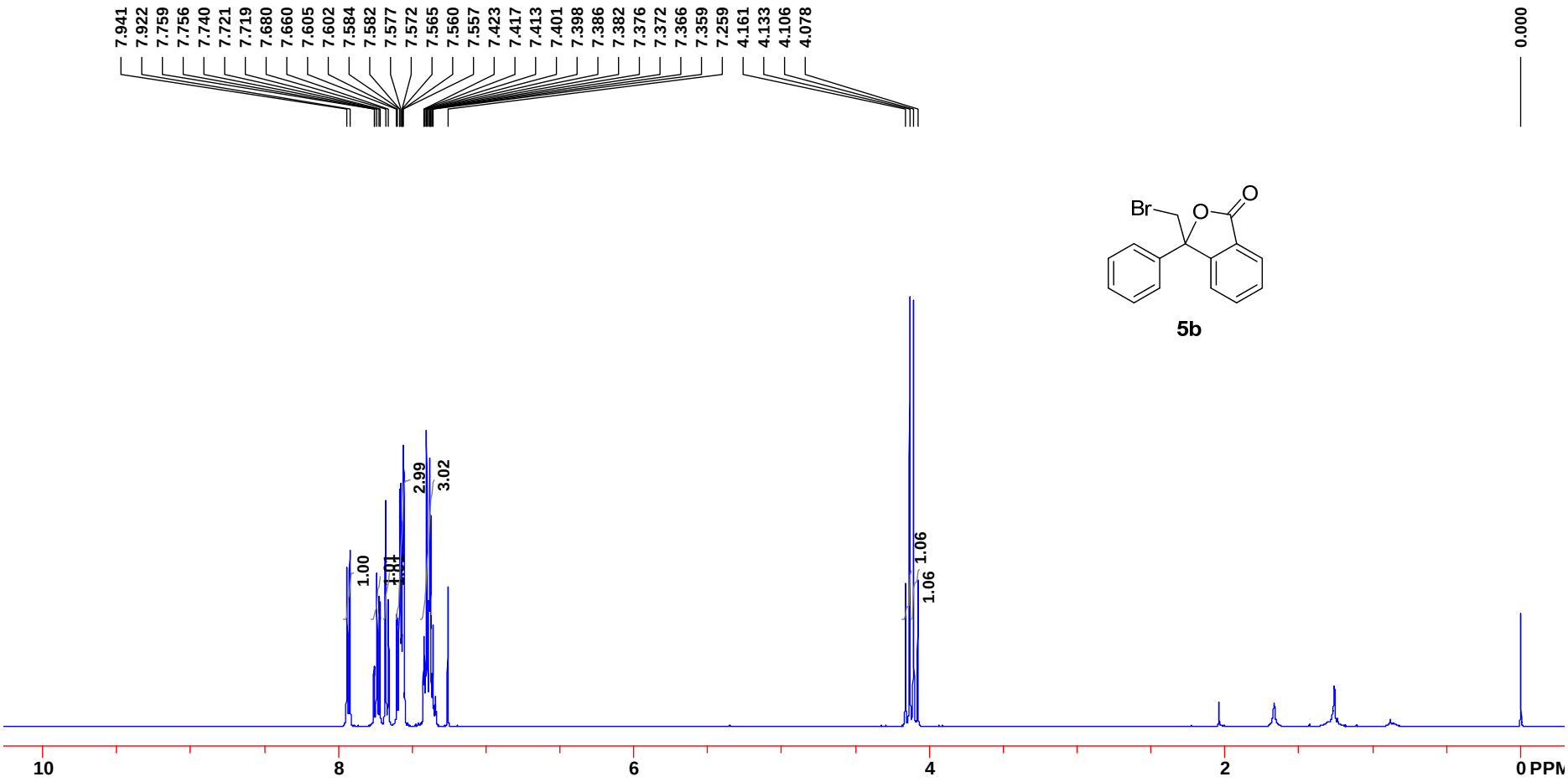

77.320
77.000
76.682
61.467
33.210
25.887
25.383
Br
Br
3u
200
150
100
50
0
PPM

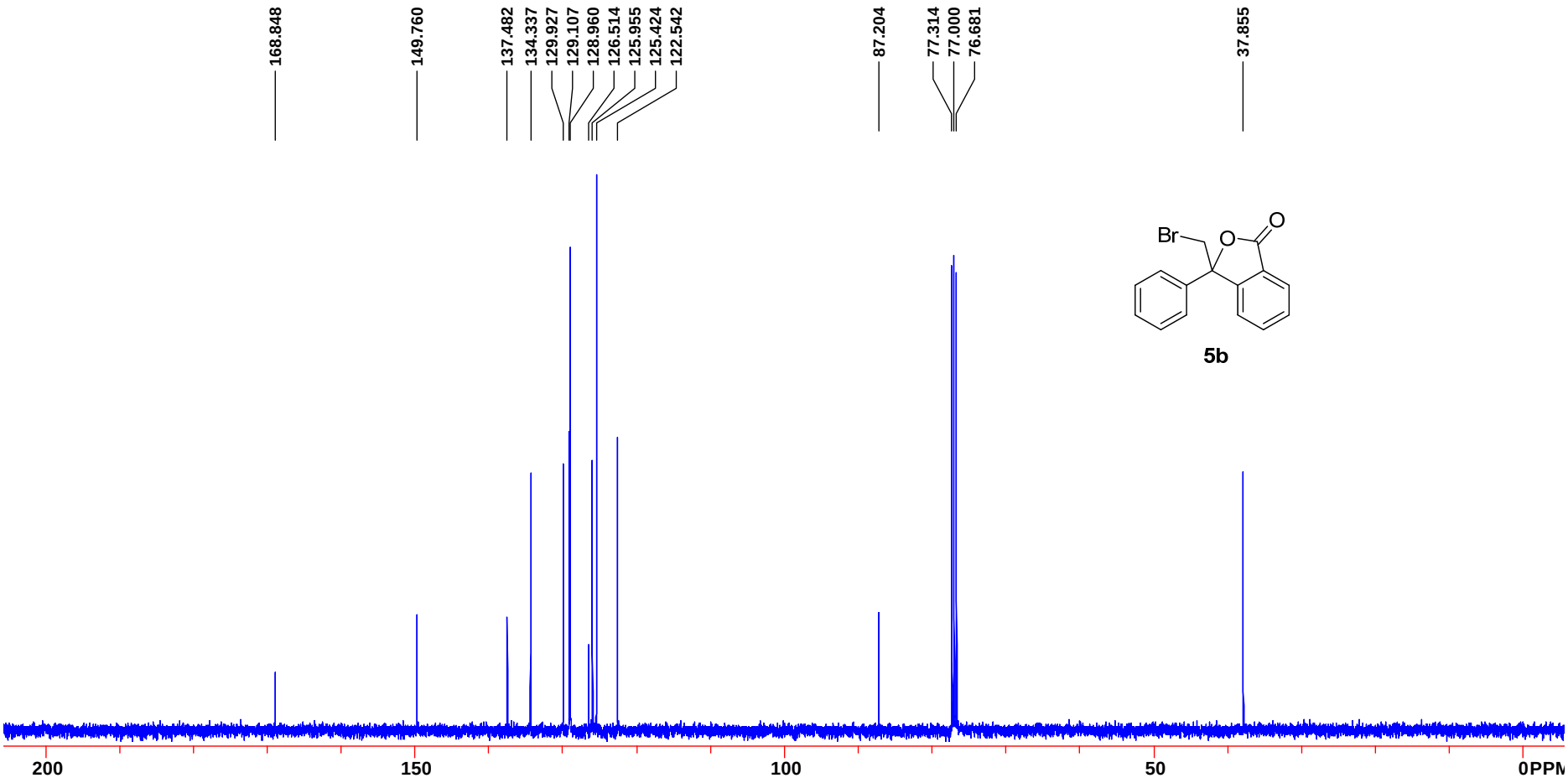

4.646
2.583
2.573
2.565
2.555
2.546
2.536
2.527
2.518
2.509
2.500
2.122
2.115
2.099
2.089
2.077
2.063
2.053
2.022
2.012
2.003
2.002
1.993
1.962
1.943
1.933
1.858
1.830
1.821
1.807
1.803
1.795
1.787
1.779
1.759
1.751
1.684
1.672
1.658
1.648
1.637
1.624
1.589
1.576
1.564
1.553
Br
Br
3v
5.11
0.95
1.00
1.13
1.97
2.15
7
6
5
4
3
2
1
0
PPM

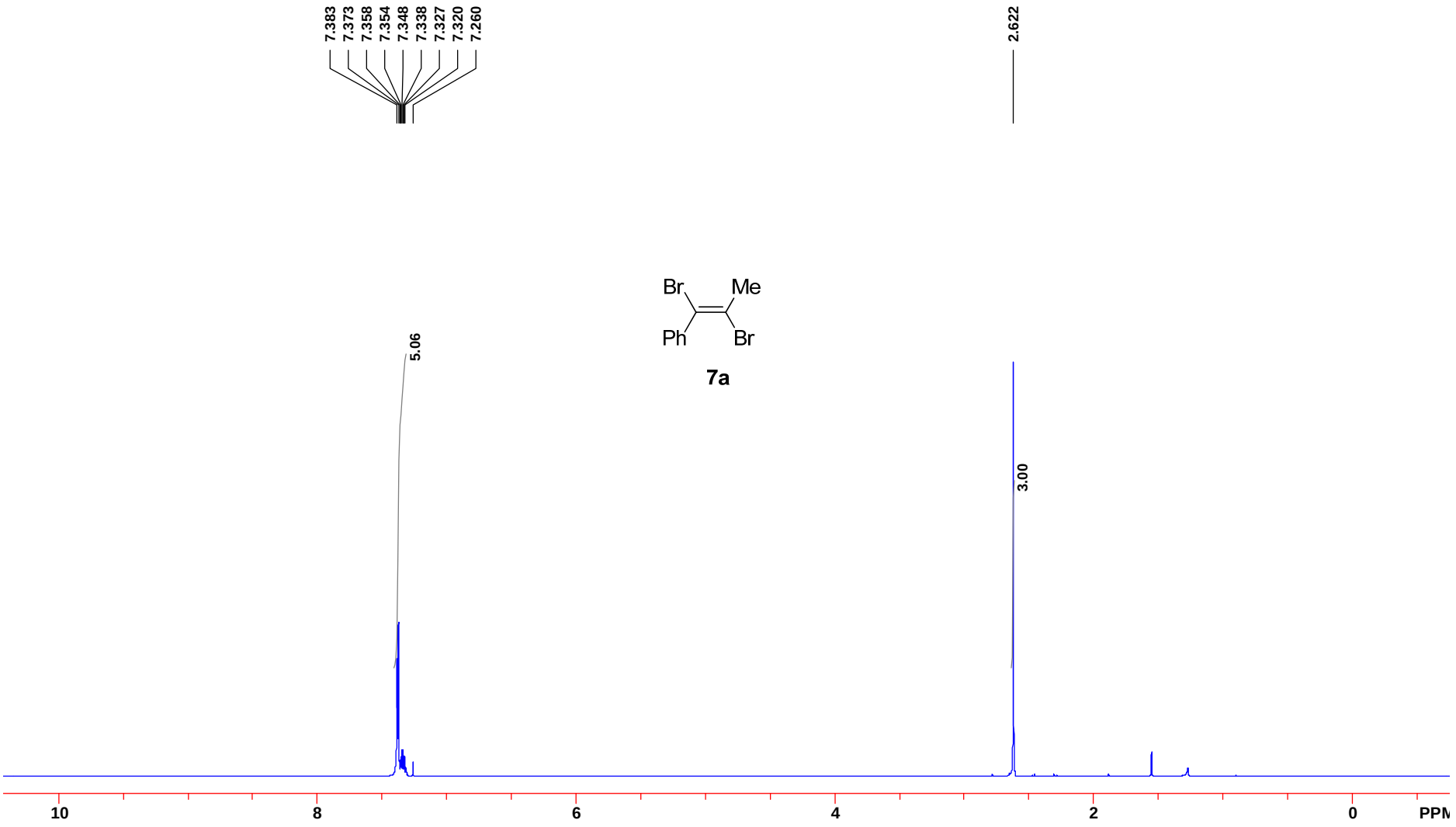

77.315
77.000
76.685
70.694
61.932
37.611
34.040
32.500
22.696
20.675
Br
Br
3v
140
120
100
80
60
40
20
0
PPM

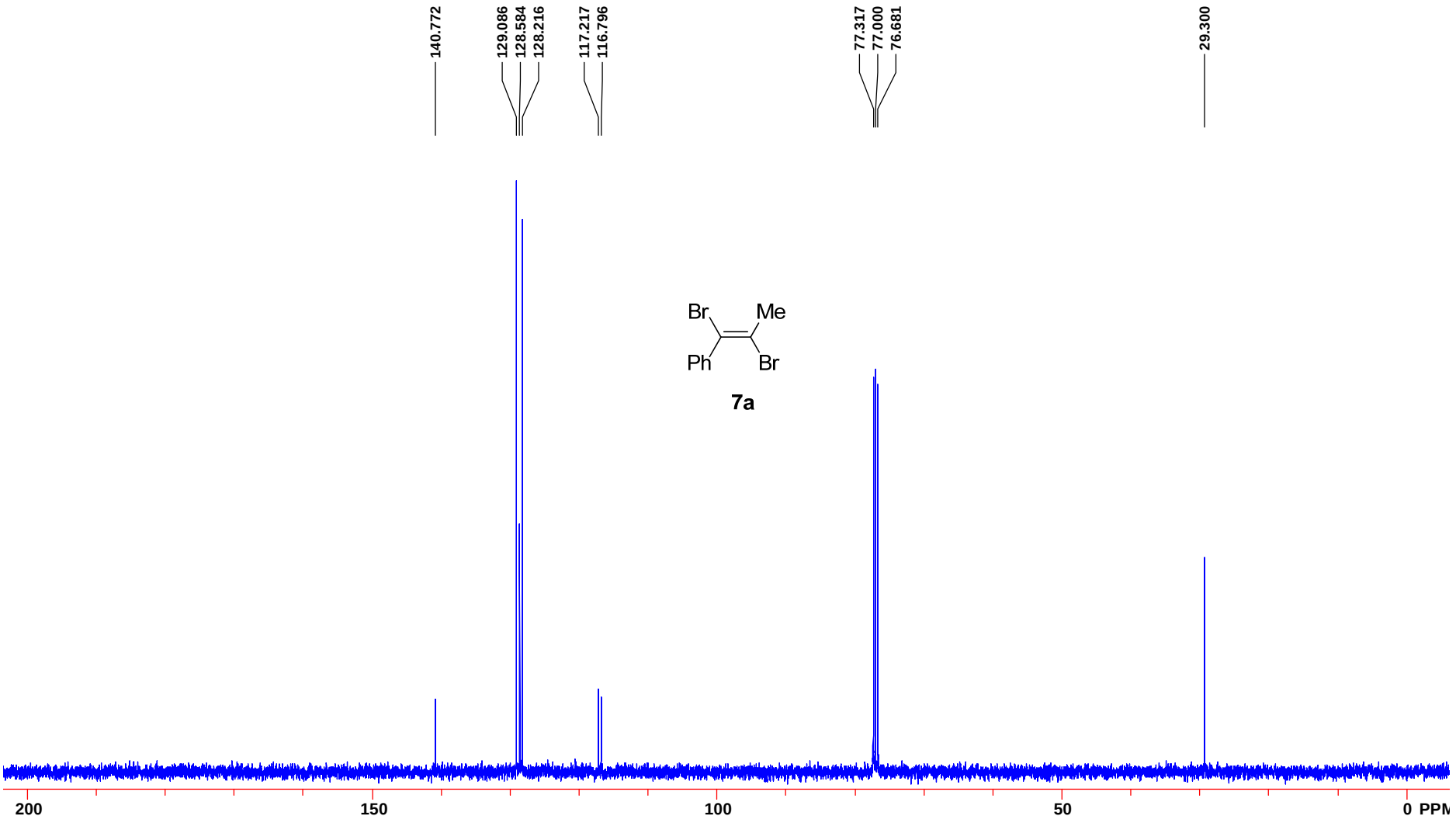

7.834
7.815
7.657
7.639
7.620
7.518
7.499
7.481
7.459
7.439
3.697
3.669
3.660
3.632
1.753
0.000
O
O
Br
5a
0.93
0.98
0.95
0.97
1.00
0.99
3.00
10
8
6
4
2
0
PPM

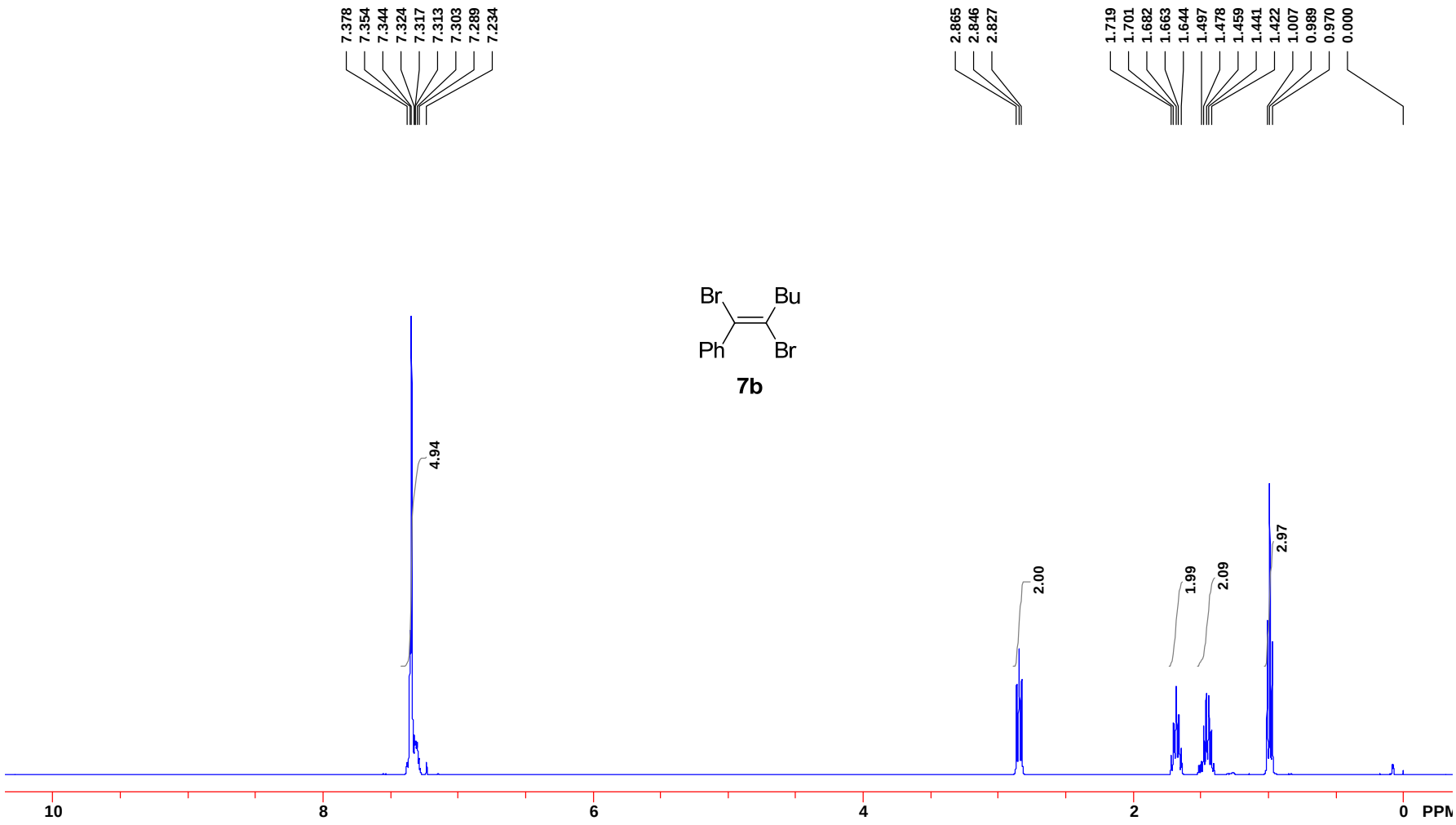

168.861
151.088
134.279
129.779
126.210
125.805
121.405
84.481
77.326
77.000
76.687
37.834
24.199
O
O
Br
5a
200
150
100
50
0 PPM

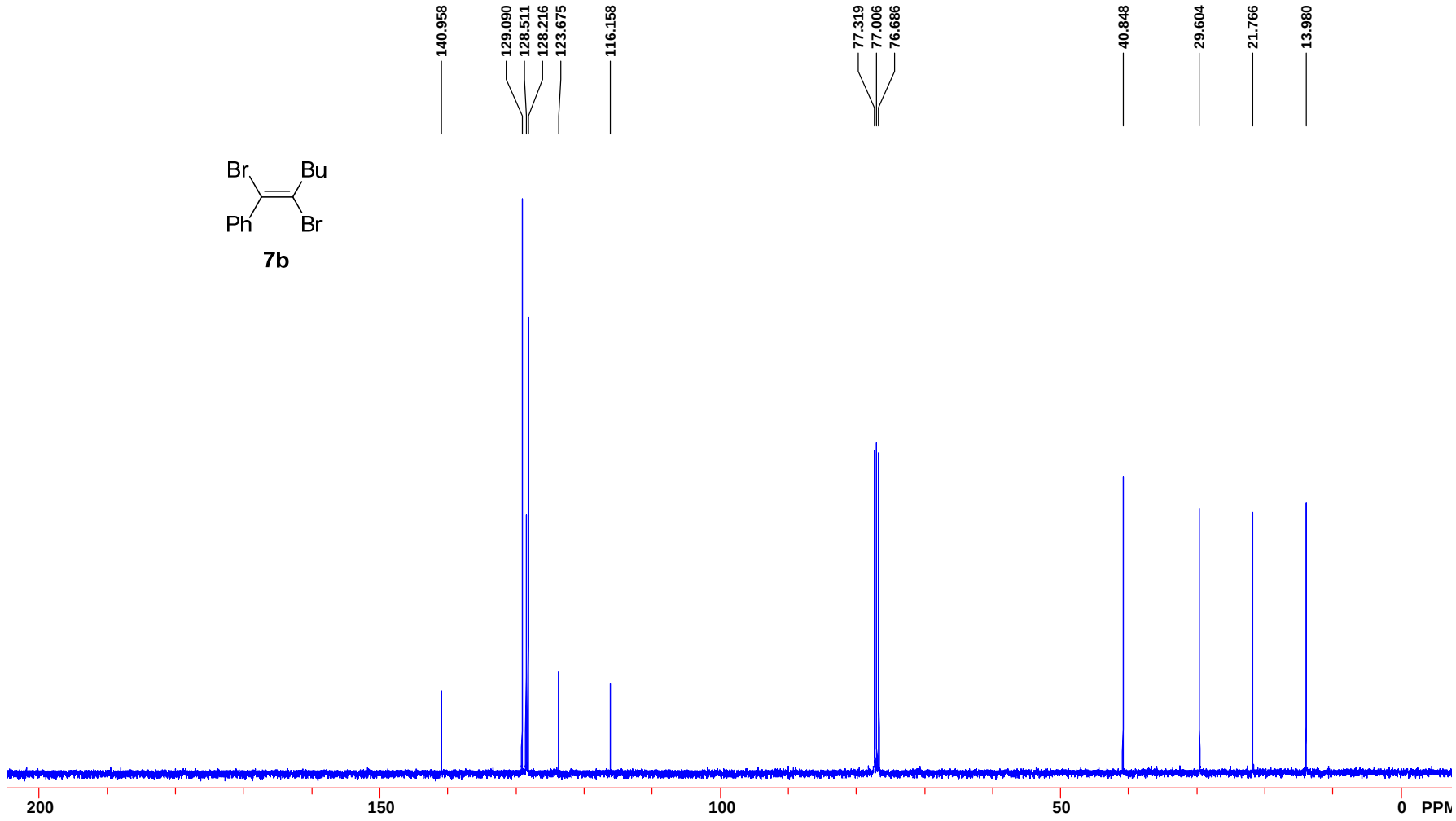

7.941
7.922
7.759
7.756
7.740
7.721
7.719
7.680
7.660
7.605
7.602
7.584
7.582
7.577
7.572
7.565
7.560
7.557
7.423
7.417
7.413
7.401
7.398
7.386
7.382
7.376
7.372
7.366
7.359
7.259
4.161
4.133
4.106
4.078
0.000
Br
O
O
5b
1.00
1.01
1.01
2.99
3.02
1.06
1.06
10
8
6
4
2
0 PPM

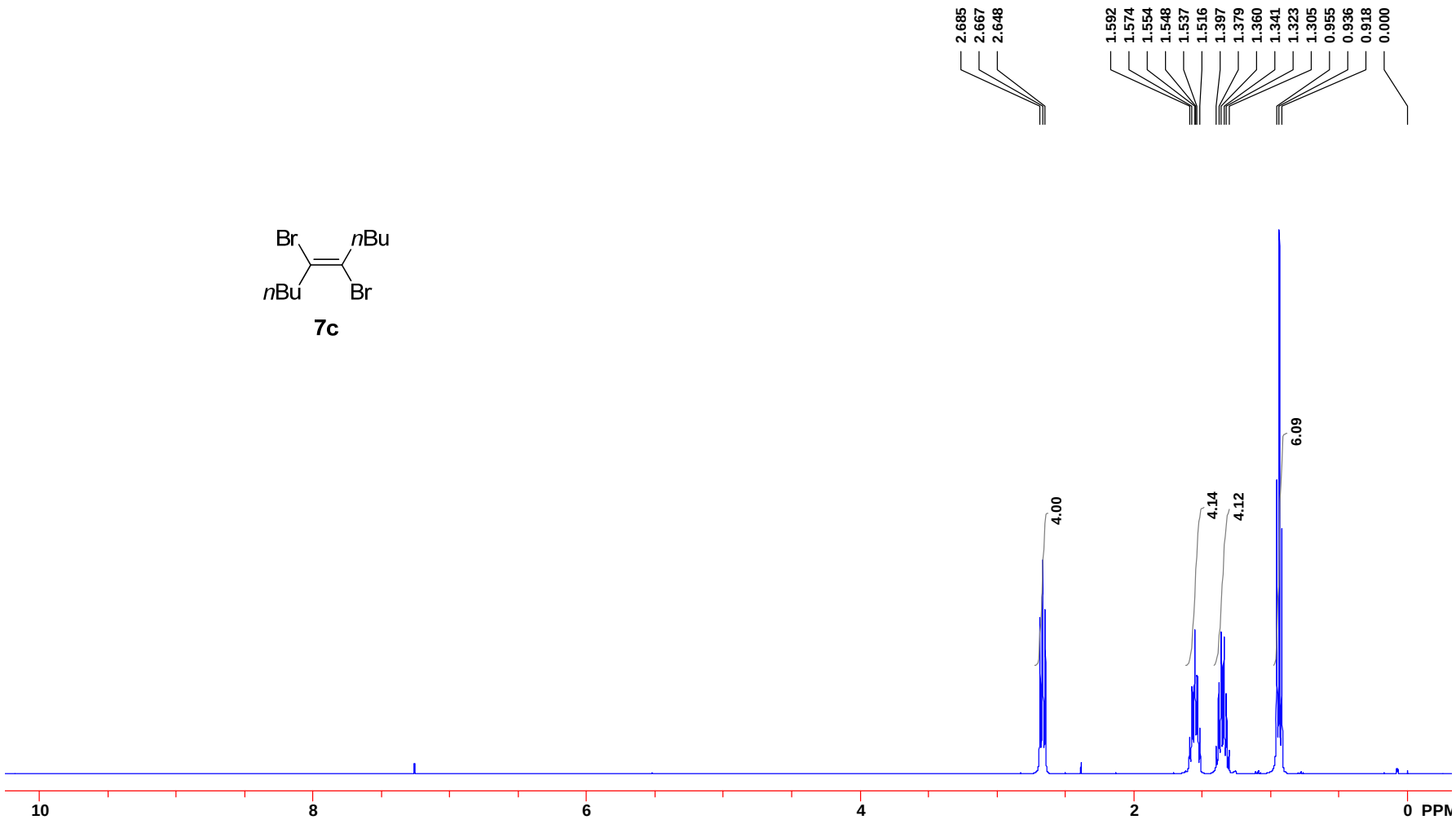

168.848
149.760
137.482
134.337
129.927
129.107
128.960
126.514
125.955
125.424
122.542
87.204
77.314
77.000
76.681
37.855
Br
O
O
5b
200
150
100
50
0PPM

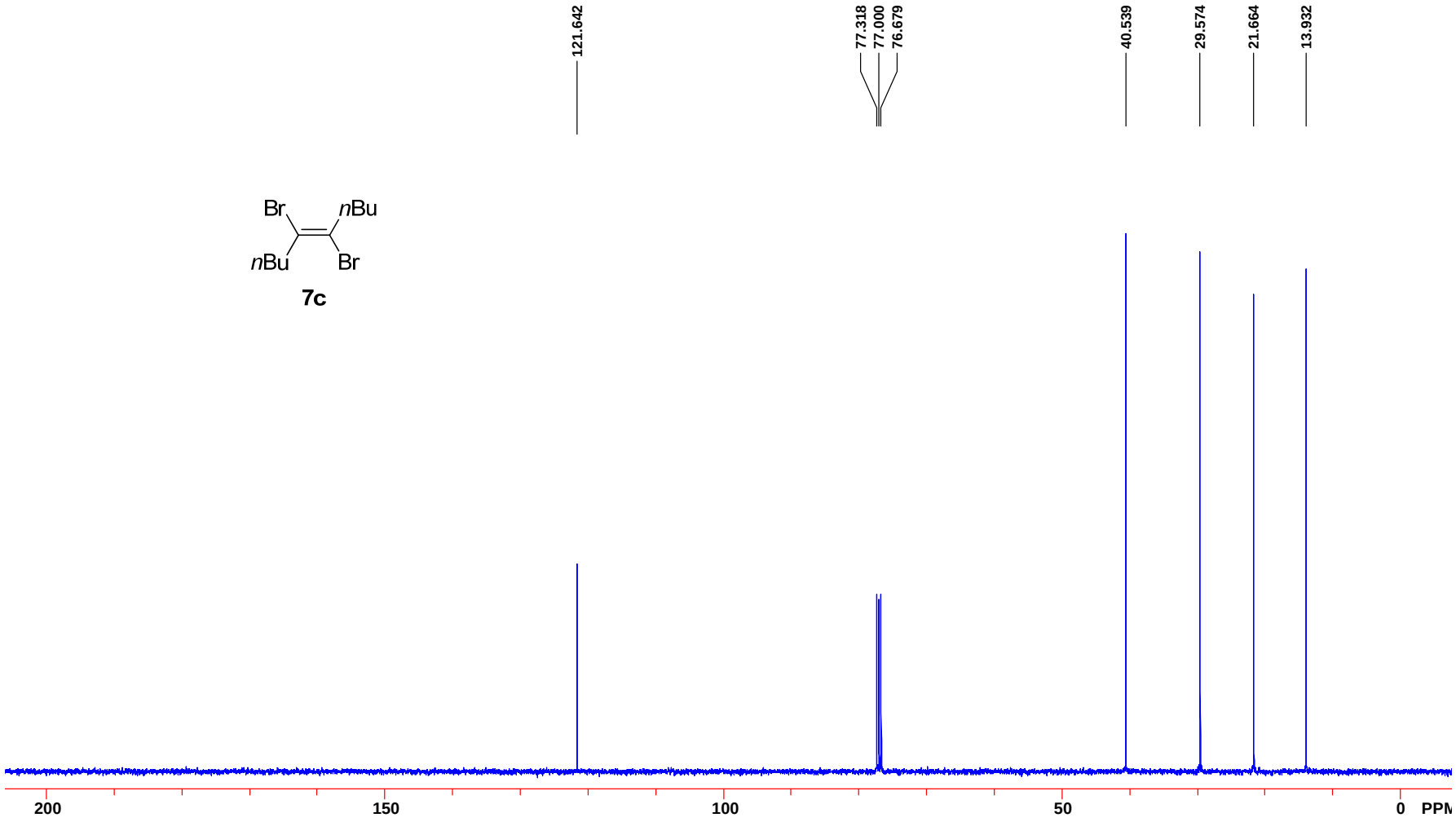

7.383
7.373
7.358
7.354
7.348
7.338
7.327
7.320
7.260
2.622
Br
Me
Ph
Br
7a
5.06
3.00
10
8
6
4
2
0
PPM

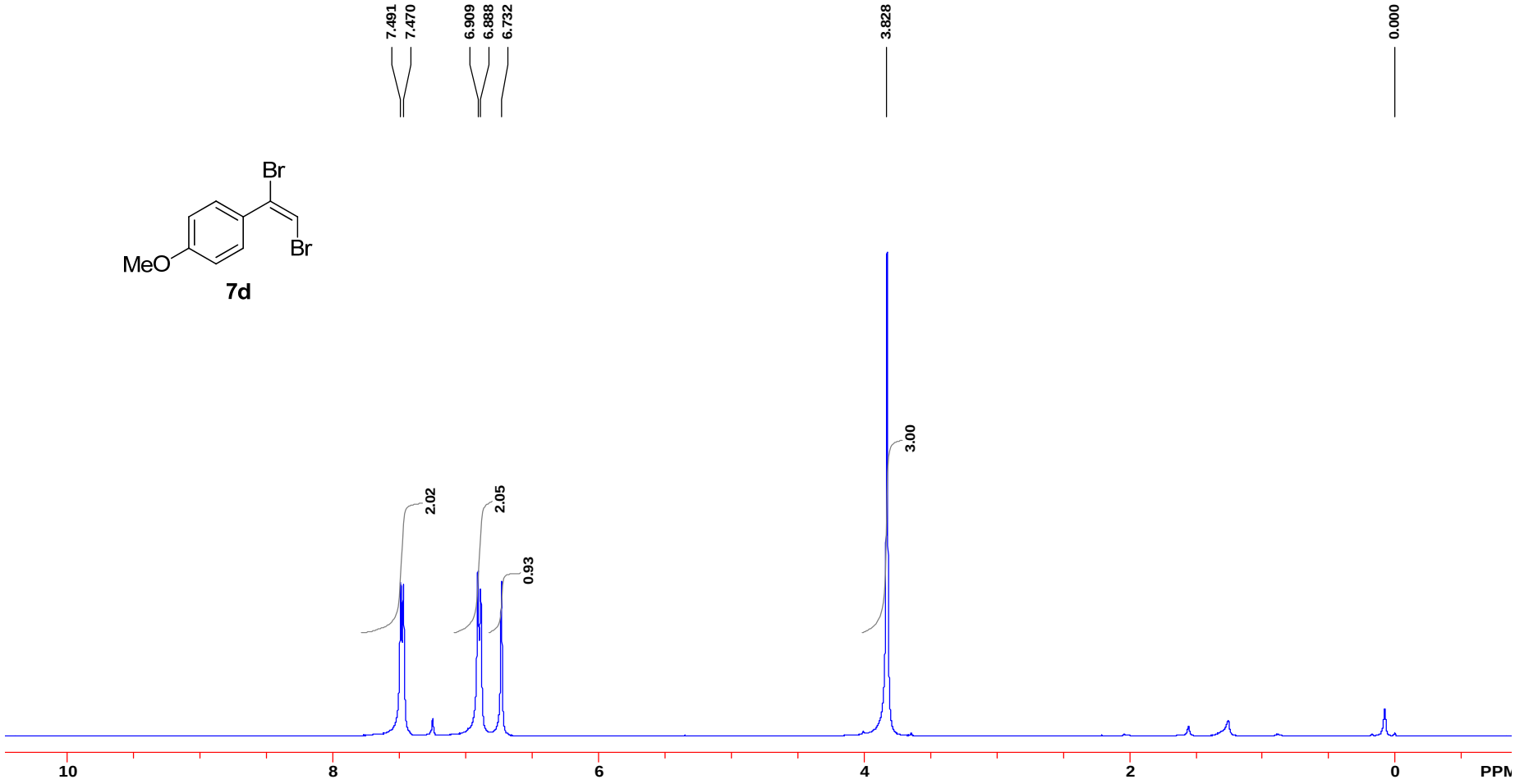

140.772
129.086
128.584
128.216
117.217
116.796
77.317
77.000
76.681
29.300
Br
Me
Ph
Br
7a
200
150
100
50
0 PPM

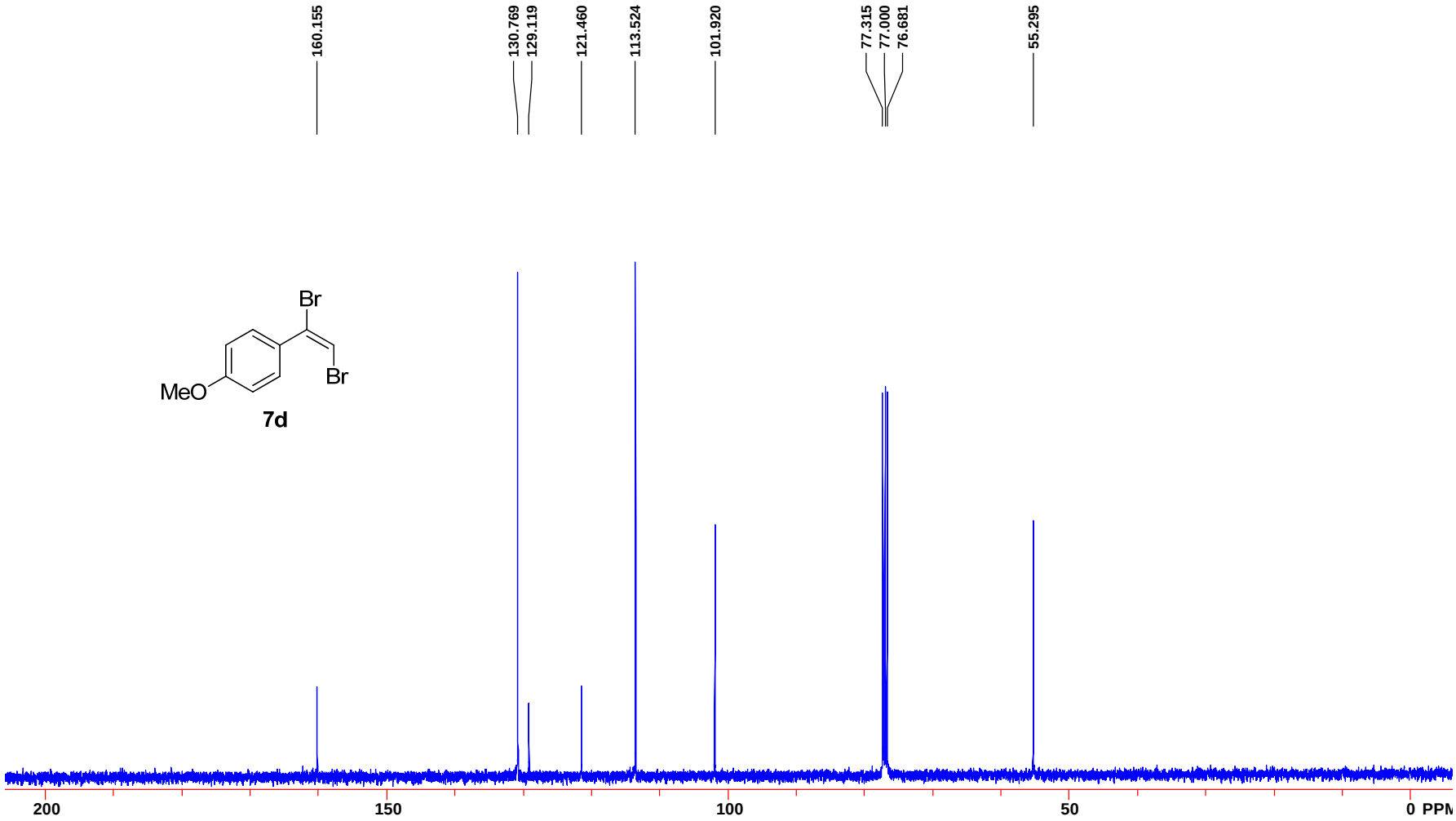

7.378
7.354
7.344
7.324
7.317
7.313
7.303
7.289
7.234
2.865
2.846
2.827
1.719
1.701
1.682
1.663
1.644
1.497
1.478
1.459
1.441
1.422
1.007
0.989
0.970
0.000
Br
Bu
Ph
Br
7b
4.94
2.00
1.99
2.09
2.97
10
8
6
4
2
0
PPM

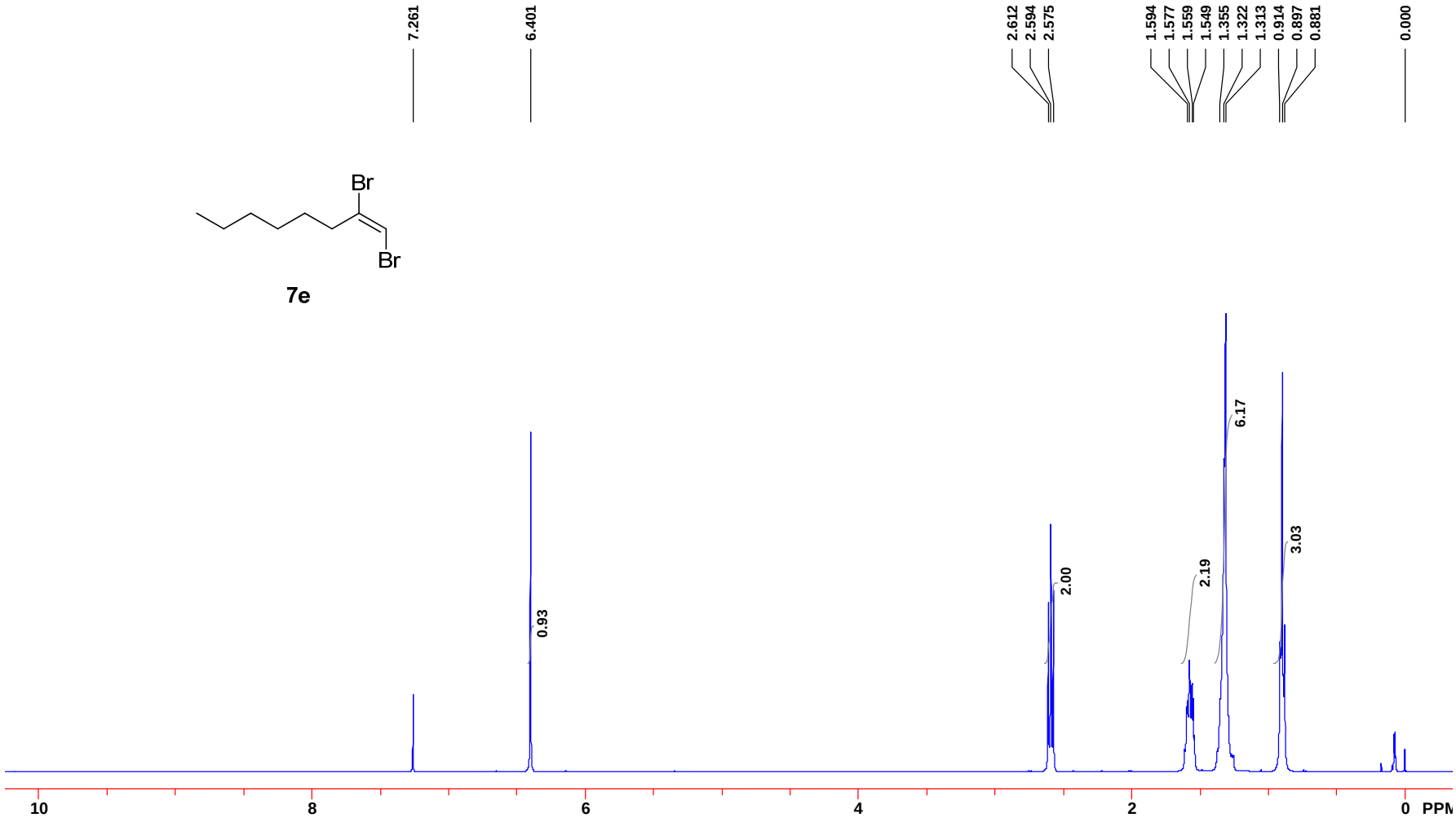

140.958
129.090
128.511
128.216
123.675
116.158
77.319
77.006
76.686
40.848
29.604
21.766
13.980
Br
Bu
Ph
Br
7b
200
150
100
50
0
PPM

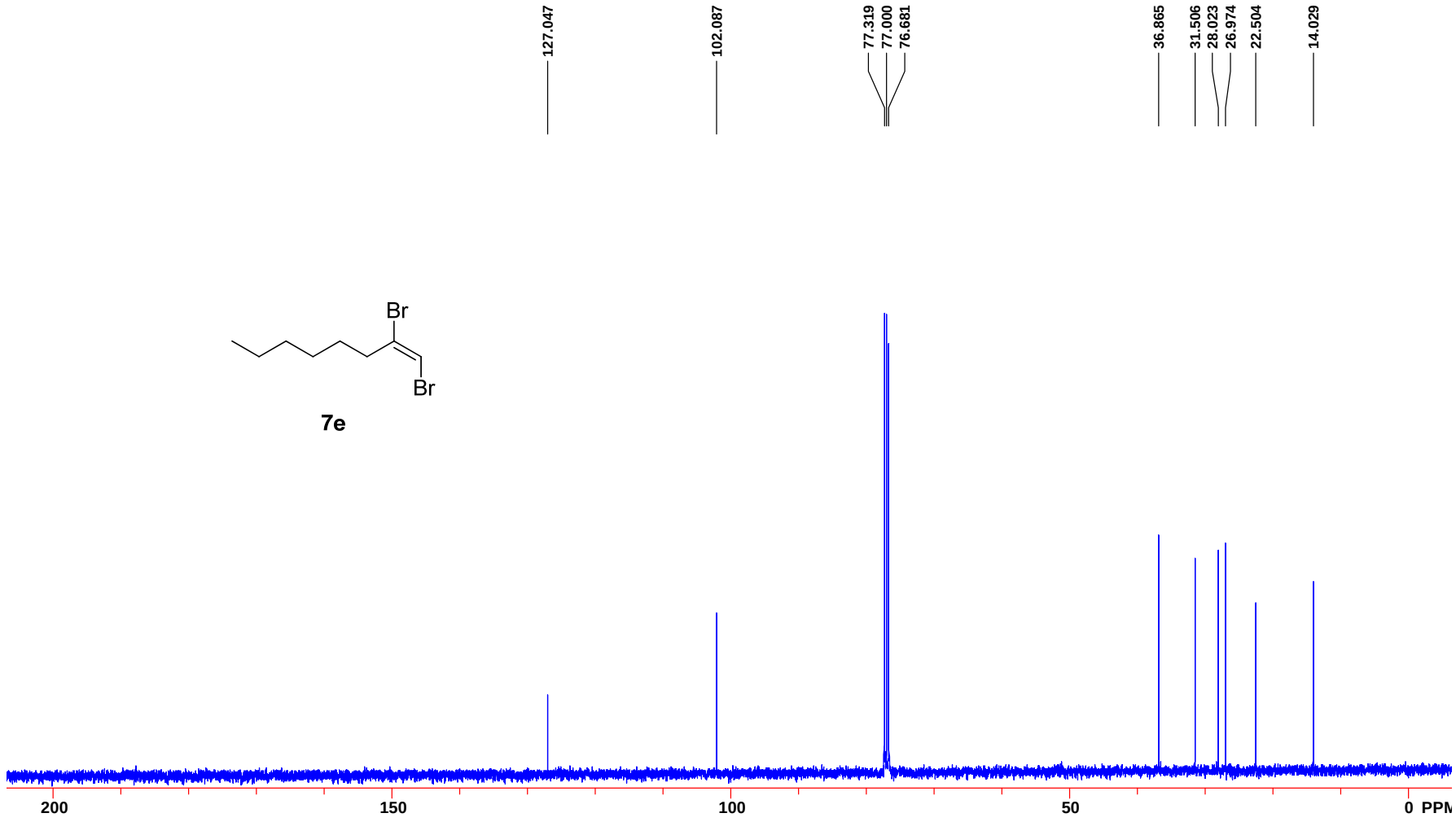

2.685
2.667
2.648
1.592
1.574
1.554
1.548
1.537
1.516
1.397
1.379
1.360
1.341
1.323
1.305
0.955
0.936
0.918
0.000
Br
nBu
nBu
Br
7c
4.00
4.14
4.12
6.09
10
8
6
4
2
0 PPM

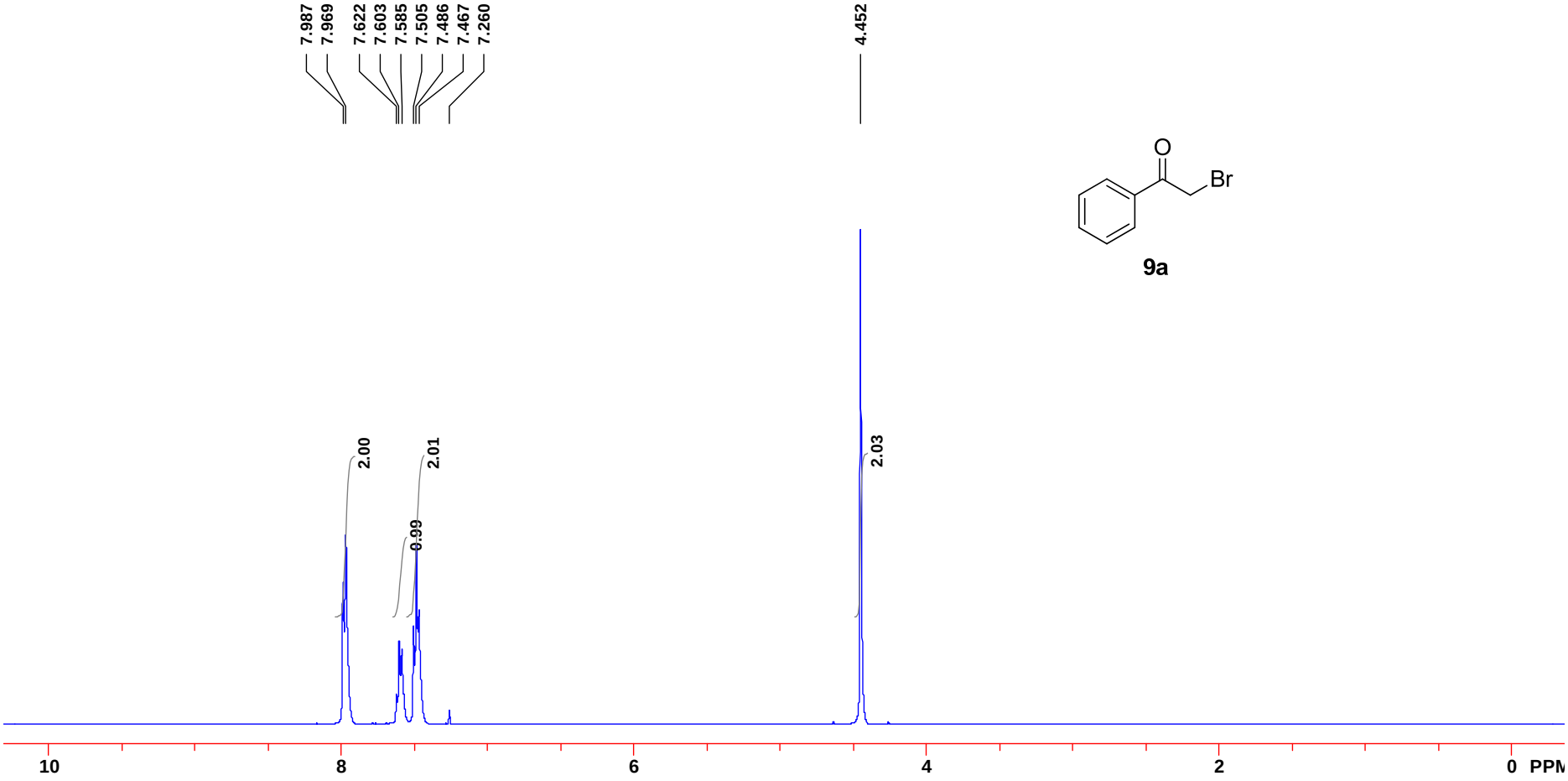

121.642
77.318
77.000
76.679
40.539
29.574
21.664
13.932
Br
nBu
nBu
Br
7c
200
150
100
50
0
PPM

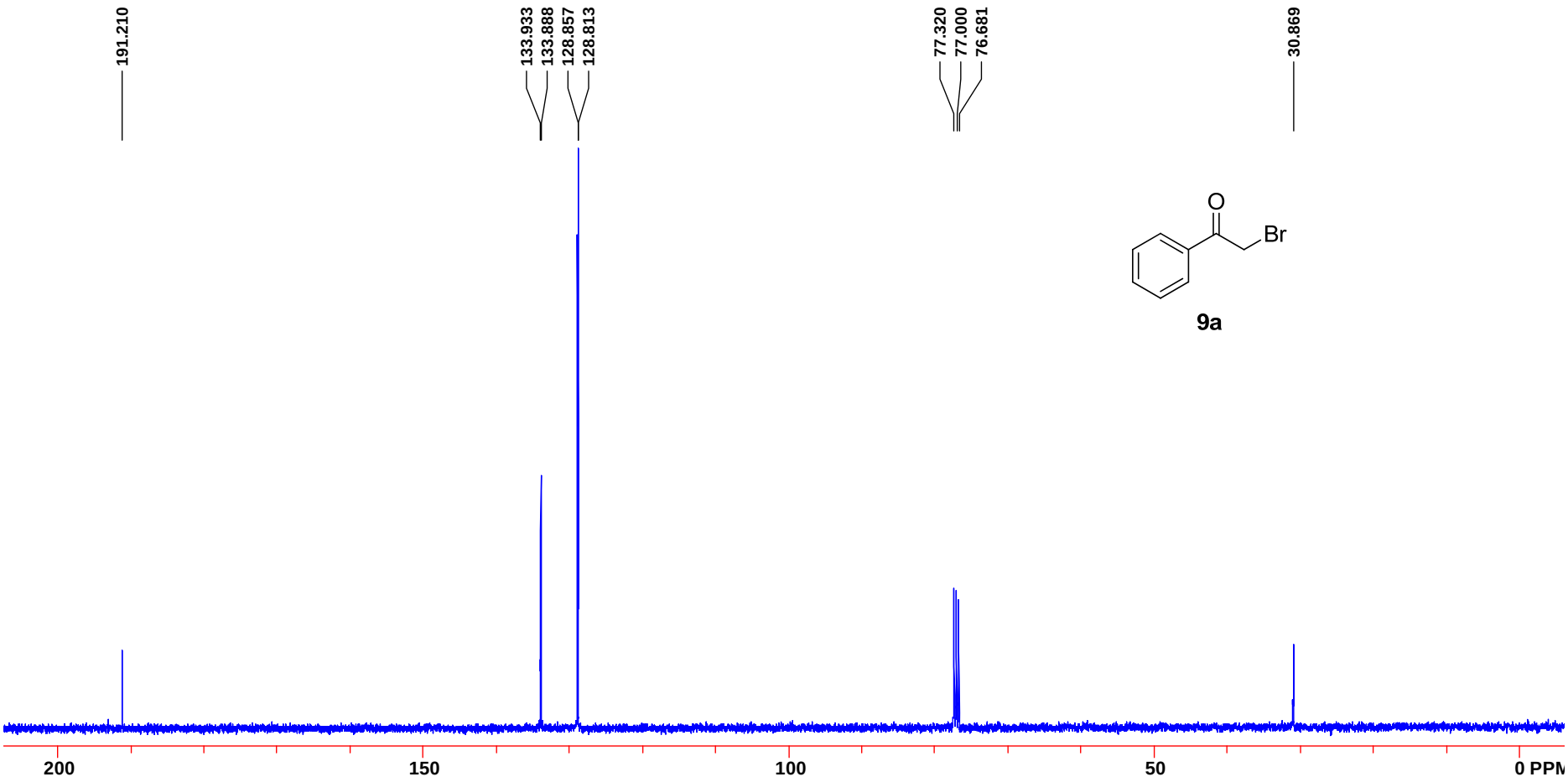

7.491
7.470
6.909
6.888
6.732
3.828
0.000
Br
Br
MeO
7d
2.02
2.05
0.93
3.00
10
8
6
4
2
0
PPM

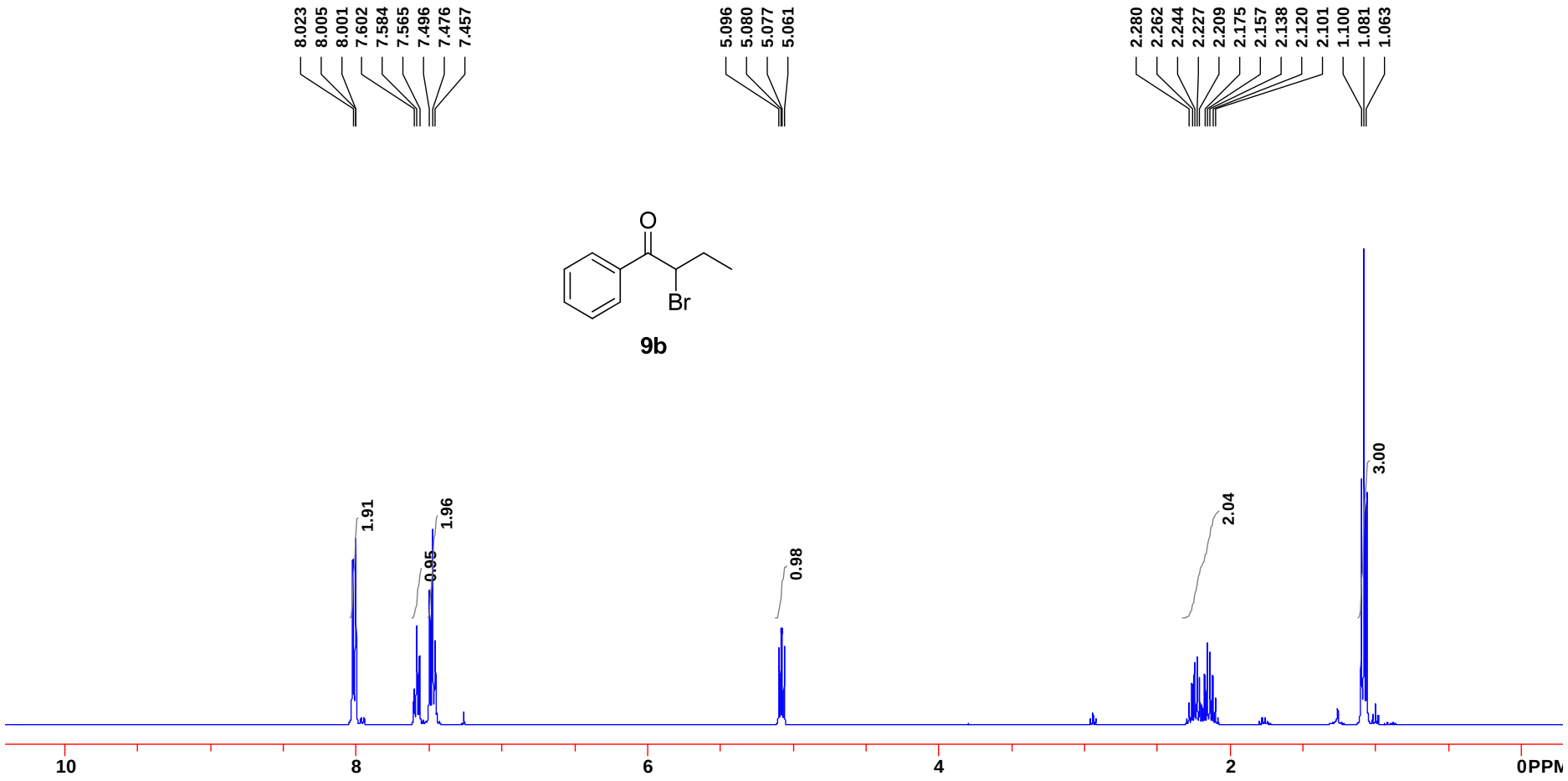

160.155
130.769
129.119
121.460
113.524
101.920
77.315
77.000
76.681
55.295
Br
Br
MeO
7d
200
150
100
50
0 PPM

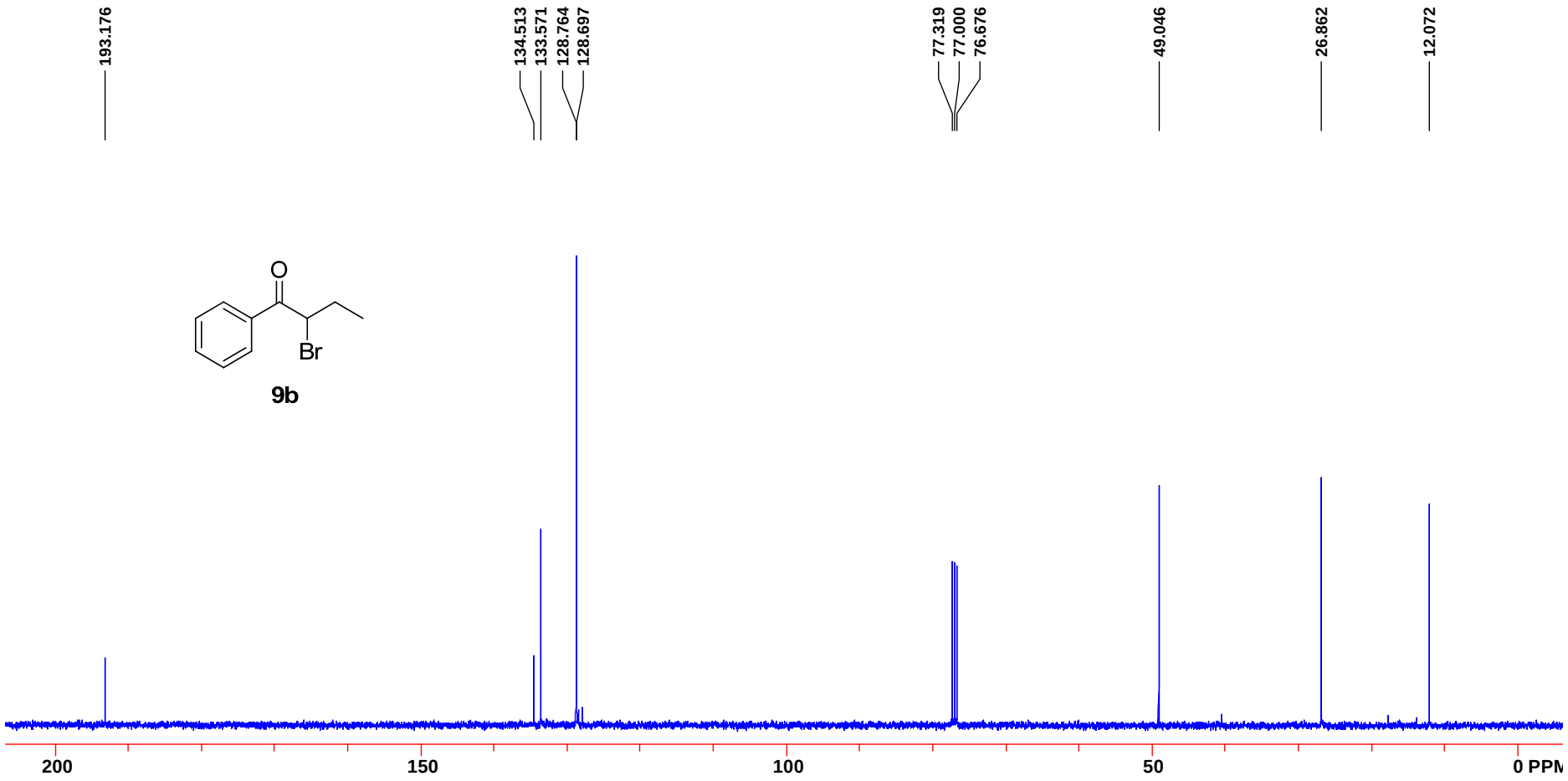

7.261
6.401
2.612
2.594
2.575
1.594
1.577
1.559
1.549
1.355
1.322
1.313
0.914
0.897
0.881
0.000
Br
Br
7e
0.93
2.00
2.19
6.17
3.03
10
8
6
4
2
0
PPM

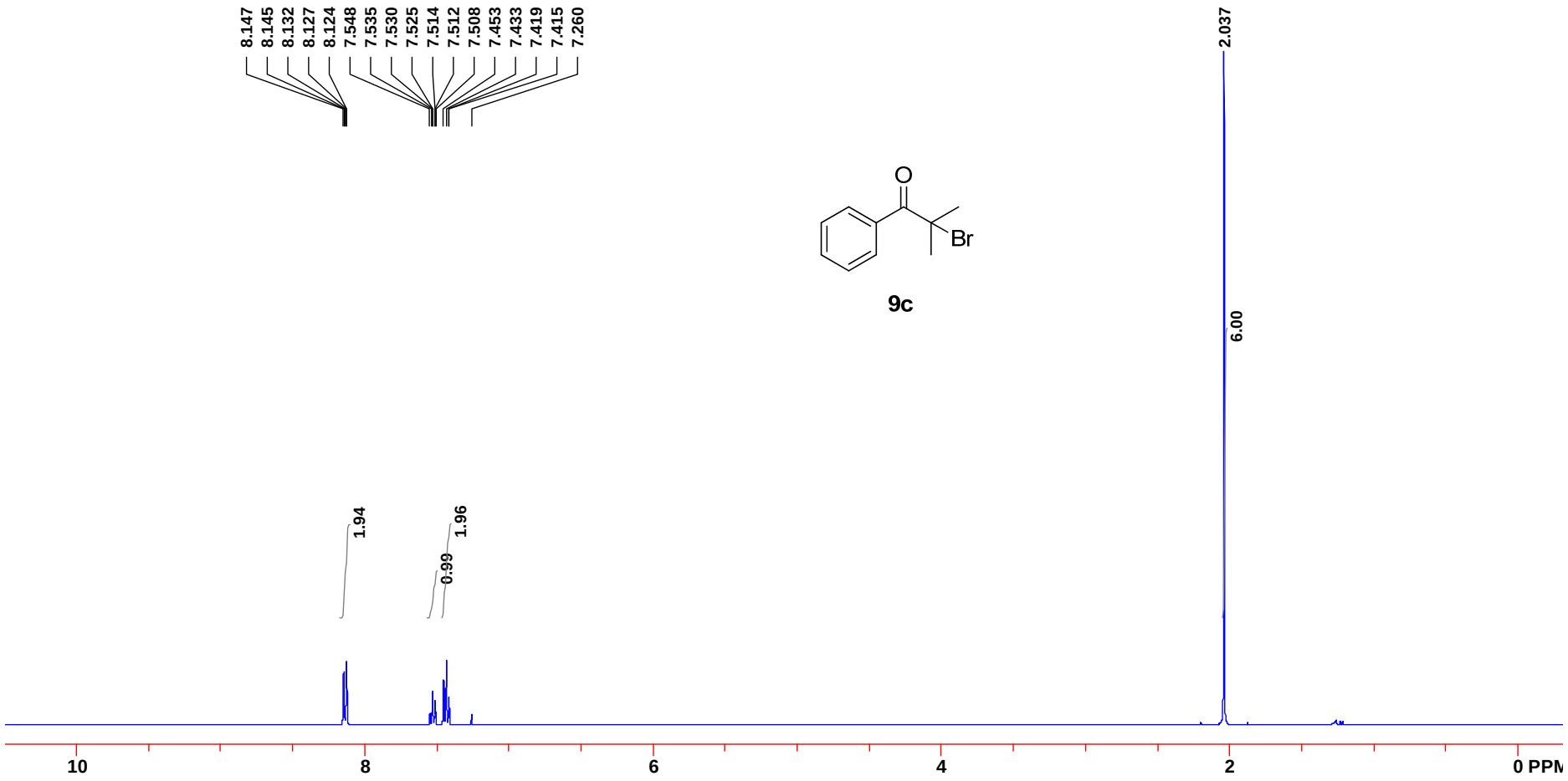

127.047
102.087
77.319
77.000
76.681
36.865
31.506
28.023
26.974
22.504
14.029
Br
Br
7e
200
150
100
50
0 PPM

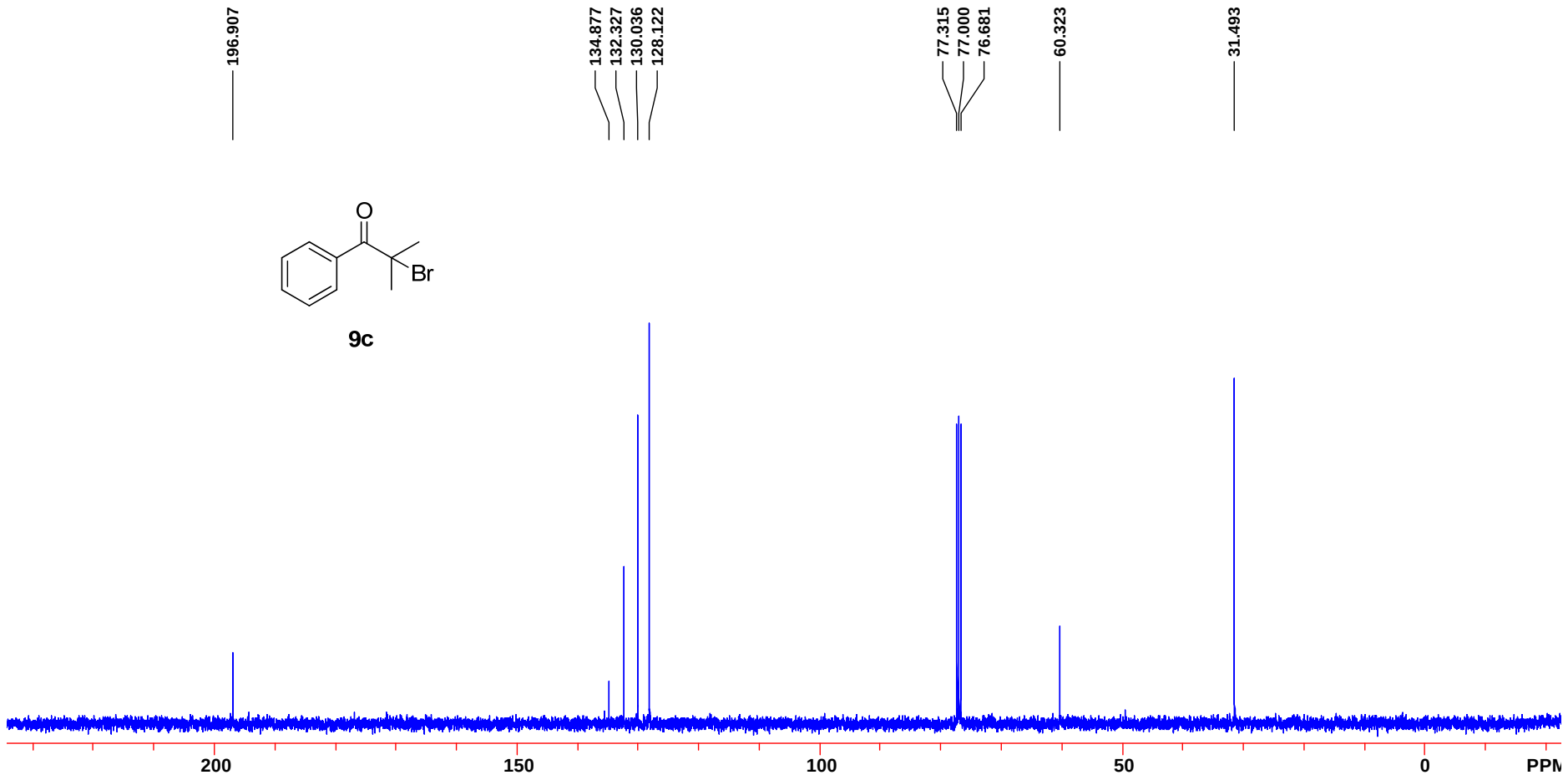

7.987
7.969
7.622
7.603
7.585
7.505
7.486
7.467
7.260
4.452
O
Br
9a
2.00
0.99
2.01
2.03
10
8
6
4
2
0 PPM

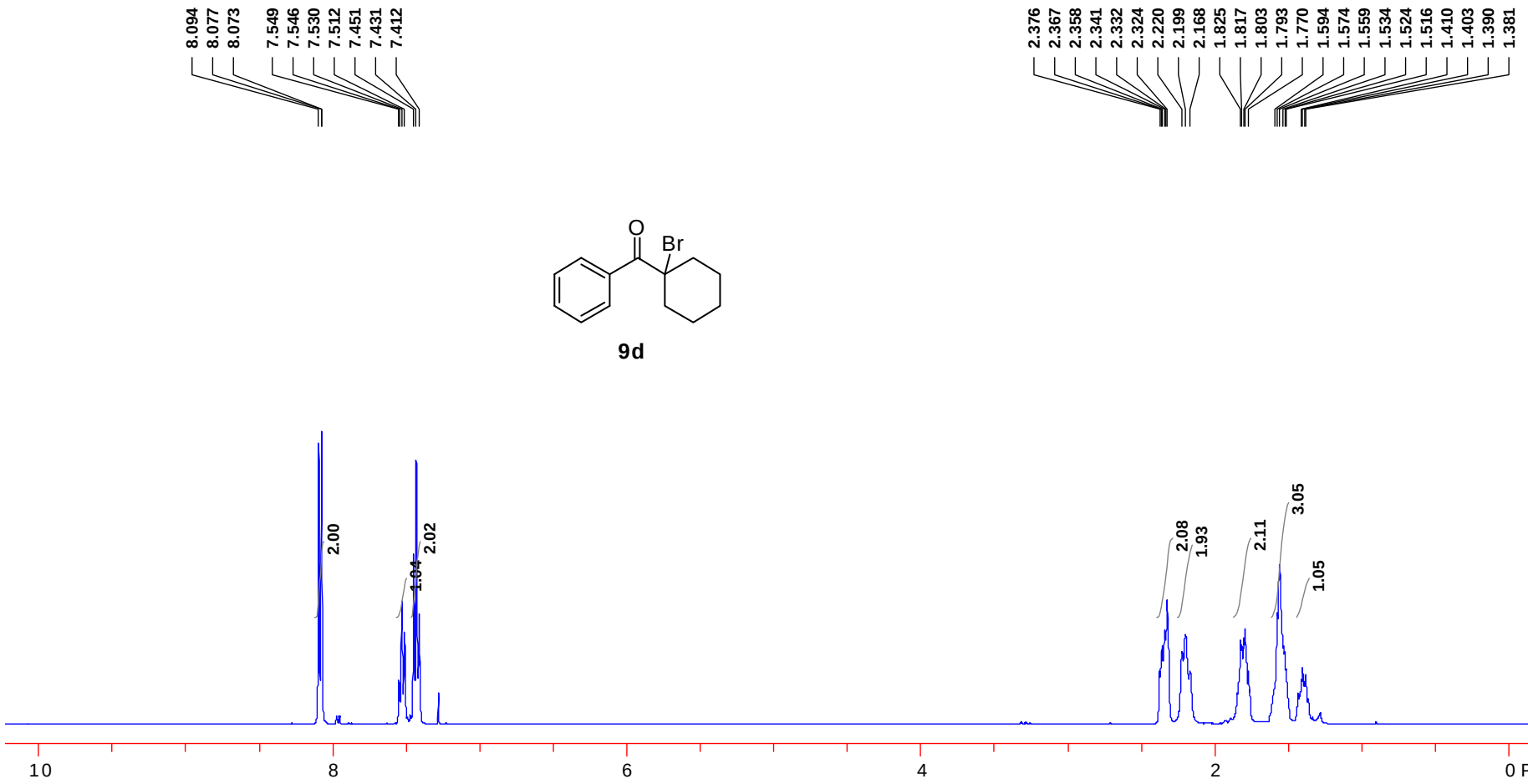

191.210
133.933
133.888
128.857
128.813
77.320
77.000
76.681
30.869
O
Br
9a
200
150
100
50
0 PPM

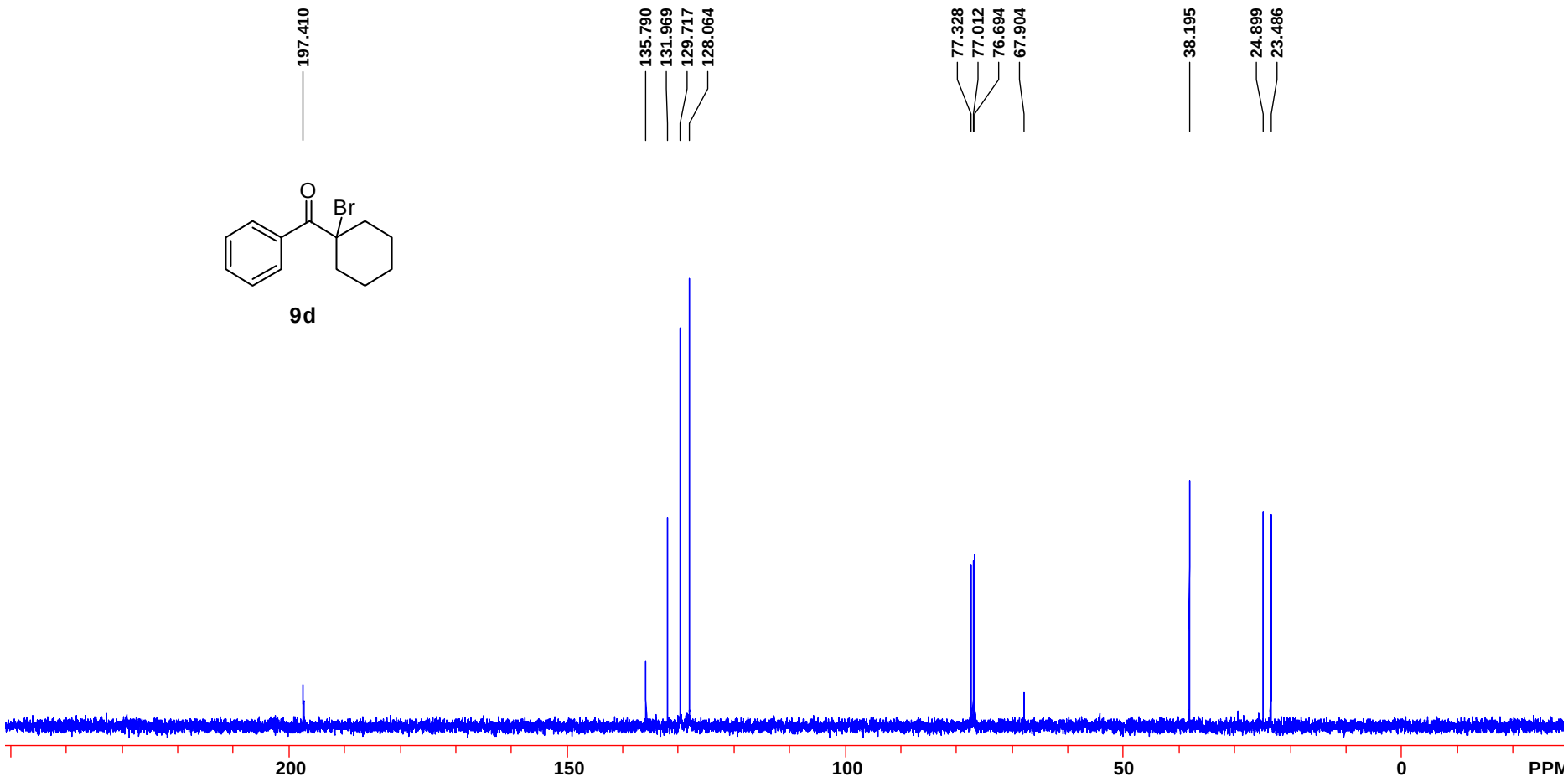

8.023
8.005
8.001
7.602
7.584
7.565
7.496
7.476
7.457
5.096
5.080
5.077
5.061
2.280
2.262
2.244
2.227
2.209
2.175
2.157
2.138
2.120
2.101
1.100
1.081
1.063
O
Br
9b
1.91
0.95
1.96
0.98
2.04
3.00
10
8
6
4
2
0PPM


193.176
134.513
133.571
128.764
128.697
77.319
77.000
76.676
49.046
26.862
12.072
O
Br
9b
200
150
100
50
0 PPM


8.147
8.145
8.132
8.127
8.124
7.548
7.535
7.530
7.525
7.514
7.512
7.508
7.453
7.433
7.419
7.415
7.260
2.037
6.00
1.94
1.96
0.99
O
Br
9c
10
8
6
4
2
0 PPM


196.907
134.877
132.327
130.036
128.122
77.315
77.000
76.681
60.323
31.493
O
Br
9c
200
150
100
50
0
PPM


8.094
8.077
8.073
7.549
7.546
7.530
7.512
7.451
7.431
7.412
2.376
2.367
2.358
2.341
2.332
2.324
2.220
2.199
2.168
1.825
1.817
1.803
1.793
1.770
1.594
1.574
1.559
1.534
1.524
1.516
1.410
1.403
1.390
1.381
O
Br
9d
2.00
1.04
2.02
2.08
1.93
2.11
3.05
1.05
10
8
6
4
2
0 PPM


197.410
135.790
131.969
129.717
128.064
77.328
77.012
76.694
67.904
38.195
24.899
23.486
O
Br
9d
200
150
100
50
0
PPM