Electronic Supplementary Information

Fe-catalyzed radical-type difunctionalization of styrenes with aliphatic aldehydes and trimethylsilyl azide via decarbonylative alkylation-azidation cascade

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I. General information

Unless otherwise noted, all commercially available compounds were used as provided without further purification. Dry solvents (toluene, ethyl acetate, dichloromethane, acetonitrile, chlorobenzene, fluorobenzene) were used as commercially available.

Thin-layer chromatography (TLC) was performed using E. Merck silica gel 60 F254 precoated plates (0.25 mm) or Sorbent Silica Gel 60 F254 plates. The developed chromatography was analyzed by UV lamp (254 nm). High-resolution mass spectra (HRMS) were obtained from a JEOL JMS-700 instrument (ESI). Melting points are uncorrected. Nuclear magnetic resonance (NMR) spectra were recorded on a Bruker Avance 400 spectrometer at ambient temperature. Chemical shifts for ^{1}H NMR spectra are reported in parts per million (ppm) from tetramethylsilane with the solvent resonance as the internal standard (chloroform: δ 7.26 ppm). Chemical shifts for ^{13}C NMR spectra are reported in parts per million (ppm) from tetramethylsilane with the solvent as the internal standard ($CDCl_3$: δ 77.16 ppm). Data are reported as following: chemical shift, multiplicity (s = singlet, d = doublet, dd = doublet of doublets, t = triplet, q = quartet, m = multiplet, br = broad signal), coupling constant (Hz), and integration.

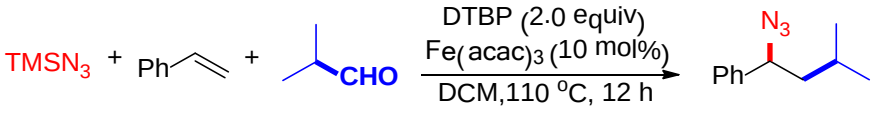
II. General experimental procedures

A general experimental procedure is described as following:

An oven-dried microwave reaction vessel was charged with $Fe(acac)_3$ (0.0005 mmol, 0.25 mol%) in fluorobenzene (1.0 mL, pre-prepared solution), alkene (**1a**, 0.2 mmol, 1.0 equiv), $TMSN_3$ (0.4 mmol, 2.0 equiv), isobutyraldehyde (**2a**, 0.6 mmol, 3.0 equiv) and DTBP (0.6 mmol, 3.0 equiv) under argon atmosphere. The vessel was sealed and heated was stirred at 110 °C (oil bath temperature) for 12 h. Afterwards the resulting mixture was cooled to room temperature, The solvent was removed in vacuo, The residue was purified by column chromatography on silica gel with a mixture of dichloromethane/petroleum ether as eluent to give products **3a**.

III. Condition optimization

Table S1. Optimization of the reactants ratio [a]

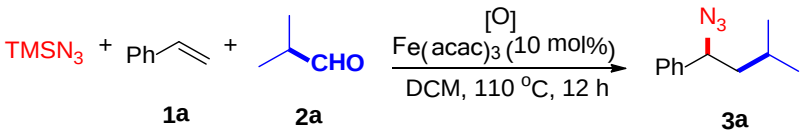


1a **2a** **3a**

entry	ratio $TMSN_3$:1a:2a	yield [%] [b]
1	2:1:2	32
2	2:1:3	59
3	3:1:2	38
4	3:1:3	61

[a] Reaction conditions: **1a** (0.2 mmol, 1.0 equiv), **2a** (equiv), $TMSN_3$ (equiv), DTBP (0.4 mmol 2.0 equiv), $Fe(acac)_3$ (0.02 mmol, 10 mol %), DCM (1.0 mL), stirred at 110 °C for 12 h under air. [b] Isolated yields.

Table S2. Optimization of the oxidants [a]

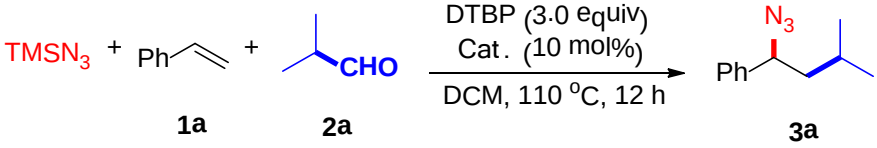


1a 2a 3a

entry	[O] (equiv)	yield [%][b]
1	DTBP	59
2	TBHP in decane	31
3	$PhI(AcO)_2$	<2
4	$K_2S_2O_8$	<2
5	DTBP (2.5)	66
6	DTBP (3.0)	74

[a] Reaction conditions: **1a** (0.2 mmol, 1.0 equiv), **2a** (0.6 mmol, 3.0 equiv), $TMSN_3$ (0.4 mmol, 2.0 equiv), [O] (2.0 equiv), $Fe(acac)_3$ (0.02 mmol, 10 mol %), DCM (1.0 mL), stirred at 110 °C for 12 h under air. [b] Isolated yields.

Table S3. Optimization of the catalyst [a]

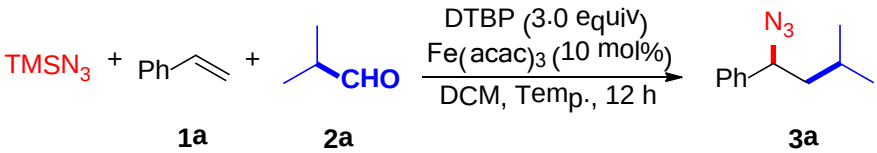


1a 2a 3a

entry	Cat. (mol%)	yield [%][b]
1	$FeCl_2$	57
2	$FeCl_3$	55
3	$Fe(acac)_3$	74
4	$Fe(AcO)_2{\cdot}4H_2O$	38
5	$Co(acac)_3$	<2
6	$Mn(AcO)_2$	<2
7	$Cu(AcO)_2$	51
8	CuCl	49
9	$AgNO_3$	17

[a] Reaction conditions: **1a** (0.2 mmol, 1.0 equiv), **2a** (0.6 mmol, 3.0 equiv), $TMSN_3$ (0.4 mmol, 2.0 equiv), DTBP (0.6 mmol, 3.0 equiv), Cat. (0.02 mmol, 10 mol %), DCM (1.0 mL), stirred at 110 °C for 12 h under air. [b] Isolated yields.

Table S4. Optimization of the temperature [a]



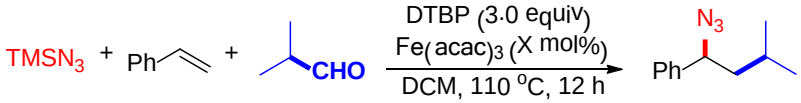
1a 2a 3a

entry	Temp. (°C)	yield [%][b]

1	**100**	**67**
2	**110**	**74**
3	**120**	**68**

[a] Reaction conditions: **1a** (0.2 mmol, 1.0 equiv), **2a** (0.6 mmol, 3.0 equiv), $TMSN_3$ (0.4 mmol, 2.0 equiv), DTBP (0.6 mmol, 3.0 equiv), $Fe(acac)_3$ (0.02 mmol, 10 mol %), DCM (1.0 mL) for 12 h under air. [b] Isolated yields.

Table S5. Optimization of the amounts of catalyst [a]

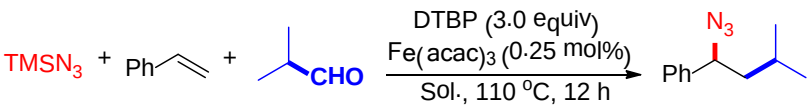


1a **2a** **3a**

entry	$Fe(acac)_3$ (X mol%)	yield [%][b]
1	**10**	**74**
2	**5**	**75**
3	**1**	**77**
4	**0.5**	**79**
5	**0.25**	**80**
6	**0.1**	**65**
7		**11**
8 [c]	**0.25**	**81**

[a] Reaction conditions: **1a** (0.2 mmol, 1.0 equiv), **2a** (0.6 mmol, 3.0 equiv), $TMSN_3$ (0.4 mmol, 2.0 equiv), DTBP (0.6 mmol, 3.0 equiv), $Fe(acac)_3$ (X mol %), DCM (1.0 mL), stirred at 110 °C for 12 h under air. For precise weighting, a solution of $Fe(acac)_3$ in organic solvent was prepared and used. [b] Isolated yields. [c] Argon atmosphere.

Table S6. Optimization of the solvent [a]



1a **2a** **3a**

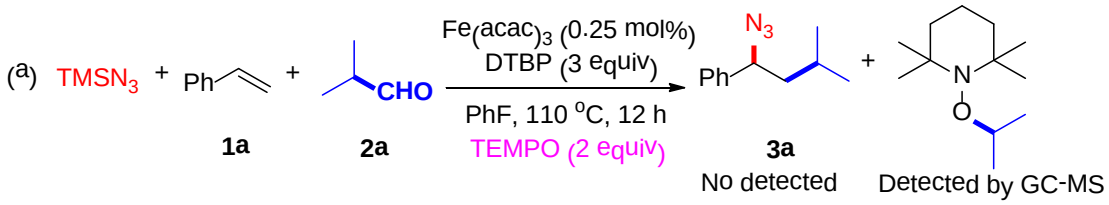
entry	Sol.	yield [%][b]
1	**DCM**	**81**
2	**PhCl**	**71**
3	***o*-$PhCl_2$**	**67**
4	**DCE**	**<2**
5	**EA**	**33**
6	**PhMe**	**75**
7	**CH_3CN**	**68**
8	**PhF**	**84**

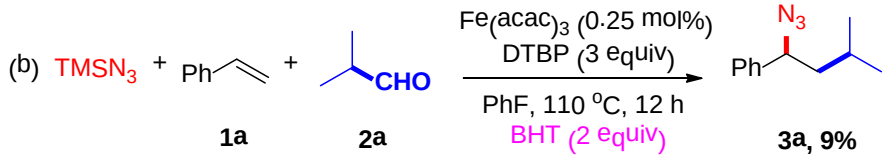
[a] Reaction conditions: **1a** (0.2 mmol, 1.0 equiv), **2a** (0.6 mmol, 3.0 equiv), $TMSN_3$ (0.4 mmol, 2.0 equiv), DTBP (0.6 mmol, 3.0 equiv), $Fe(acac)_3$ (0.0005 mmol, 0.25 mol %), Sol. (1.0 mL), stirred at 110 °C for 12 h under Ar. For precise weighting, a solution of $Fe(acac)_3$ in organic solvent was prepared and used. [b] Isolated yields.

IV. Mechanistic experiments

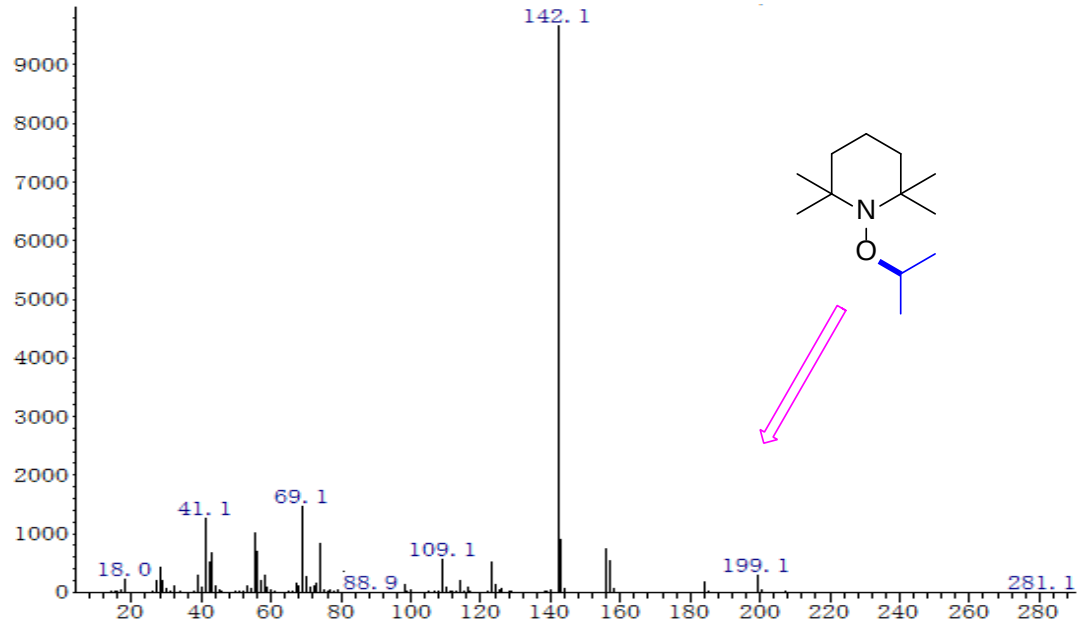
To further understand this Fe-catalyzed alkylative azidation of styrenes with aliphatic aldehydes and trimethylsilyl azide, several mechanistic experiments were carried out in the presence of various radical scavengers.

We found that: (a) in the presence of TEMPO (2,2,6,6-tetramethylpiperidine-1-oxyl, 2.0 equiv), this reaction was completely inhibited and the 1-isopropoxy-2,2,6,6-tetramethylpiperidine was detected by GC-MS, which supported our speculation that the reaction proceeded via a radical pathway and confirmed the generation of alkyl radical; (b) in the presence of BHT (2,6-di-tert-butyl-4-methylphenol, 2.0 equiv), the product **3a** was detected in an 9% yield, which further confirmed that this cascade reaction was realized via radical pathway.

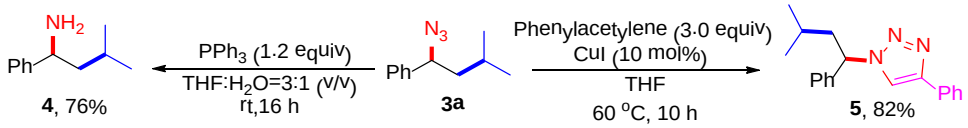




The detected GC-MS spectrum of 1-isopropoxy-2,2,6,6-tetramethylpiperidine:



V. Synthetic transformations of alkylation-azidation product

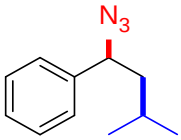


An oven-dried sealed tube containing **3a** (0.2 mmol, 1.0 equiv), PPh_3 (0.24 mmol, 1.2 equiv), was evacuated and purged with argon gas three times. Then, THF/H_2O (3:1, 2.0 mL) was added via syringe. The reaction mixture was stirred at room temperature for 16 h. The reaction was quenched with NH_4Cl (aq.), extracted with CH_2Cl_2 (10×3.0 mL), dried over anhydrous sodium sulfate. The solvent was removed in vacuo and the residue was purified by flash chromatography on silica gel (CH_2Cl_2/MeOH = 40:1) to give the colorless oil **4** (24.8 mg, 76%).

To an oven-dried glass tube, **3a** (0.2 mmol, 1.0 equiv) was dissolved in THF (l.0 mL), then phenylacetylene (0.6 mmol, 3.0 equiv) and CuI (0.02 mmol, 0.1 equiv) were added. The reaction was performed at 60 ºC for 10 h, and the resulting solution was concentrated under vacuum. The residue was purified by column chromatography on silica gel with an eluent of petroleum ether and ethyl acetate (5:1) to afford the white solid **5** (47.7 mg, 82%).

VI. Spectra data of products

(3a) (1-azido-3-methylbutyl)benzene [1]



The title compound was prepared according to the general procedure described above by the reaction between styrene (**1a**) with $TMSN_3$ and isobutyraldehyde (**2a**), and purified by flash column chromatography as colorless oil (31.7 mg, 84%).

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.41 – 7.29 (m, 5H), 4.47 (dd, *J* = 8.4, 6.4 Hz, 1H), 1.76 (ddd, *J* = 14.4, 8.4, 6.0 Hz, 1H), 1.70 – 1.53 (m, 2H), 0.94 (s, 3H), 0.93 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 140.15, 128.93, 128.34, 127.05, 64.65, 45.19, 25.13, 22.76, 22.34. IR (cm^{-1}): 2959, 2870, 2097, 1245, 699.

(3b) 1-(1-azido-3-methylbutyl)-4-methoxybenzene [2]

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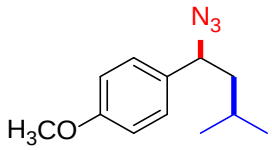
[1] M. Asada, M. Iwahashi, T. Obitsu, A. Kinoshita, Y. Naka, T. Onoda, T. Nagase, M. Tanaka, Y. Yamaura, H. Takizawa, K. Yoshikawa, K. Sato, M. Narita, S. Ohuchida, H. Naka and M. Toda, *Bioorganic and Medicinal Chemistry*., **2010**, *18*, 1641.

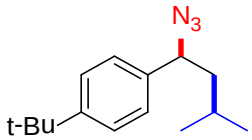
[2] G. V. M. Sharma, K. S. Kumar, B. S. Kumar, S. V. Reddy, R. S. Prakasham and H. Hugel, *Synthetic Communications.*, **2014**, *44*, 3156.



The title compound was prepared according to the general procedure described above by the reaction between 4-methoxystyrene (**1b**) with $TMSN_3$ and isobutyraldehyde (**2a**), and purified by flash column chromatography as colorless oil (29.8 mg, 68%).

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.25 – 7.22 (m, 2H), 6.93 – 6.88 (m, 2H), 4.42 (dd, *J* = 8.4, 6.8 Hz, 1H), 3.82 (s, 3H), 1.74 (ddd, *J* = 14.0, 8.0, 6.0 Hz, 1H), 1.67 – 1.52 (m, 2H), 0.93 (s, 3H), 0.92 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.54, 132.04, 128.32, 114.21, 64.16, 55.42, 44.96, 25.11, 22.66, 22.41. IR(cm^{-1}): 2958, 2870, 2096, 1250, 833.

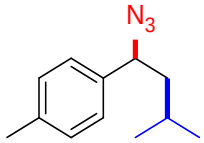
(3c) 1-(1-azido-3-methylbutyl)-4-(tert-butyl)benzene



The title compound was prepared according to the general procedure described above by the reaction between 4-tert-butylstyrene (**1c**) with $TMSN_3$ and isobutyraldehyde (**2a**), and purified by flash column chromatography as colorless oil (37.3 mg, 75%).

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.41 – 7.37 (m, 2H), 7.25 – 7.21 (m, 2H), 4.43 (dd, *J* = 8.4, 6.4 Hz, 1H), 1.76 (ddd, *J* = 14.8, 8.4, 6.0 Hz, 1H), 1.71 – 1.52 (m, 2H), 1.32 (s, 9H), 0.95 (d, *J* = 1.2 Hz, 3H), 0.93 (d, *J* = 1.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 151.24, 137.13, 126.69, 125.80, 64.36, 45.09, 34.72, 31.46, 25.15, 22.81, 22.32, 0.15. IR (cm^{-1}): 2960, 2870, 2097, 1248, 699. HRMS: calcd. for $C_{15}H_{24}N$ ($M + H^+ - N_2$): 218.1909, Found: 218.1899.

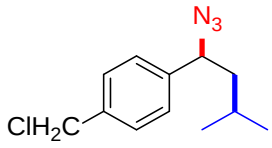
(3d) 1-(1-azido-3-methylbutyl)-4-methylbenzene



The title compound was prepared according to the general procedure described above by the reaction between 4-methylphenylene (**1d**) with $TMSN_3$ and isobutyraldehyde (**2a**), and purified by flash column chromatography as colorless oil (32.3 mg, 78%).

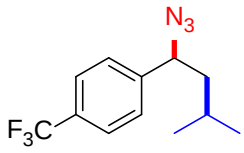
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.41 – 7.29 (m, 4H), 4.47 (dd, *J* = 8.4, 6.4 Hz, 1H), 1.76 (ddd, *J* = 14.4, 8.4, 6.0 Hz, 1H), 1.70 – 1.53 (m, 2H), 0.94 (s, 3H), 0.93 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 140.15, 128.93, 128.34, 127.05, 64.65, 45.19, 25.13, 22.76, 22.34. IR (cm^{-1}): 2958, 2927, 2069, 1248, 699. HRMS: calcd. for $C_{12}H_{18}N$ ($M + H^+ - N_2$): 176.1439, Found: 176.1433.

(3e) 1-(1-azido-3-methylbutyl)-4-(chloromethyl)benzene



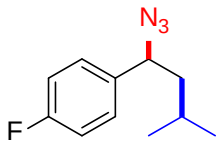
The title compound was prepared according to the general procedure described above by the reaction between 1-(chloromethyl)-4-ethenyl-benzene (**1e**) with $TMSN_3$ and isobutyraldehyde (**2a**), and purified by flash column chromatography as colorless oil (33.5 mg, 71%).
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.41 (d, *J* = 8.4 Hz, 2H), 7.31 (d, *J* = 8.0 Hz, 2H), 4.60 (s, 2H), 4.48 (dd, *J* = 8.8, 6.4 Hz, 1H), 1.76 (ddd, *J* = 14.4, 8.4, 6.0 Hz, 1H), 1.70 – 1.69 (m, 1H), 1.59 – 1.51 (m, 1H), 0.95 (d, *J* = 1.2 Hz, 3H), 0.93 (d, *J* = 1.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 140.50, 137.52, 129.17, 127.42, 64.25, 45.93, 45.21, 25.10, 22.74, 22.32. IR (cm^{-1}): 2958, 2870, 2097, 1267, 669. HRMS: calcd. for $C_{12}H_{17}NCl$ ($M + H^+ - N_2$): 210.1050, Found: 210.1043.

(3f) 1-(1-azido-3-methylbutyl)-4-(trifluoromethyl)benzene



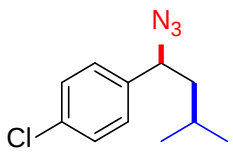
The title compound was prepared according to the general procedure described above by the reaction between 4-vinylbenzotrifluoride (**1f**) with $TMSN_3$ and isobutyraldehyde (**2a**), and purified by flash column chromatography as colorless oil (31.3 mg, 61%).
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.64 (d, *J* = 8.1 Hz, 2H), 7.43 (d, *J* = 8.1 Hz, 2H), 4.54 (dd, *J* = 8.5, 6.3 Hz, 1H), 1.80 – 1.71 (m, 1H), 1.70 – 1.61 (m, 1H), 1.59 – 1.50 (m, 1H), 0.96 (d, *J* = 2.2 Hz, 2H), 0.94 (d, *J* = 2.2 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 144.36, 130.50 (q, *J* = 32.5 Hz), 127.34, 125.95 (q, *J* = 3.8 Hz), 124.11 (q, *J* = 272.0 Hz), 64.08, 45.39, 25.09, 22.74, 22.22. IR (cm^{-1}): 2959, 2873, 2099, 1270, 669. HRMS: calcd. for $C_{12}H_{15}NF_3$ ($M + H^+ - N_2$): 230.1157, Found: 230.1151.

(3g) 1-(1-azido-3-methylbutyl)-4-fluorobenzene



The title compound was prepared according to the general procedure described above by the reaction between 4-fluorostyrene (**1g**) with $TMSN_3$ and isobutyraldehyde (**2a**), and purified by flash column chromatography as colorless oil (34.4 mg, 83%).
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.31 – 7.26 (m, 2H), 7.11 – 7.04 (m, 2H), 4.46 (dd, *J* = 8.4, 6.6 Hz, 1H), 1.74 (ddd, *J* = 14.8, 8.4, 6.4 Hz, 1H), 1.68 – 1.59 (m, 1H), 1.58 – 1.50 (m, 1H), 0.94 (s, 3H), 0.93 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.61 (d, *J* = 245.5 Hz), 135.97 (d, *J* = 3.0 Hz), 128.73 (d, *J* = 8.1 Hz), 115.95 (d, *J* = 21.3 Hz), 63.93, 45.25, 25.10, 22.70, 22.33. IR (cm^{-1}): 2960, 2872, 2098, 1280, 836. HRMS: calcd. for $C_{11}H_{15}NF$ ($M + H^+ - N_2$): 180.1189, Found: 180.1182.

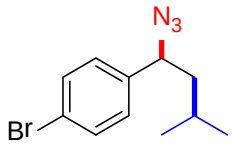
(3h) 1-(1-azido-3-methylbutyl)-4-chlorobenzene [1]



The title compound was prepared according to the general procedure described above by the reaction between 4-chlorostyrene (**1h**) with $TMSN_3$ and isobutyraldehyde (**2a**), and purified by flash column chromatography as colorless oil (32.2 mg, 71%).

^1H NMR (400 MHz, $CDCl_3$) δ 7.43 – 7.39 (m, 2H), 7.32 – 7.29 (m, 2H), 4.60 (s, 2H), 4.48 (dd, *J* = 8.8, 6.4 Hz, 1H), 1.76 (ddd, *J* = 14.4, 8.4, 6.0 Hz, 1H), 1.70 – 1.69 (m, 1H), 1.59 – 1.51 (m, 1H), 0.95 (d, *J* = 1.2 Hz, 3H), 0.93 (d, *J* = 1.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 138.72, 134.10, 129.14, 128.40, 63.96, 45.21, 25.09, 22.71, 22.32. IR (cm^{-1}): 2959, 2871, 2098, 1246, 699.

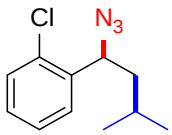
(3i) 1-(1-azido-3-methylbutyl)-4-bromobenzene



The title compound was prepared according to the general procedure described above by the reaction between 4-bromostyrene (**1i**) with $TMSN_3$ and isobutyraldehyde (**2a**), and purified by flash column chromatography as colorless oil (34.7 mg, 67%).

^1H NMR (400 MHz, $CDCl_3$) δ 7.49 – 7.42 (m, 2H), 7.26 – 7.23 (m, 2H), 4.43 (dd, *J* = 8.4, 6.4 Hz, 1H), 1.77 – 1.61 (m, 2H), 1.57 – 1.48 (m, 1H), 0.95 (d, *J* = 1.2 Hz, 3H), 0.93 (d, *J* = 1.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 139.26, 132.09, 128.72, 122.21, 64.02, 45.20, 25.09, 22.71, 22.31. IR (cm^{-1}): 2958, 2869, 2097, 1246, 783. HRMS: calcd. for $C_{11}H_{15}NBr$ ($M + H^+ - N_2$): 240.0388, Found: 240.0381.

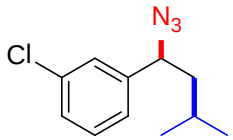
(3j) 1-(1-azido-3-methylbutyl)-2-chlorobenzene



The title compound was prepared according to the general procedure described above by the reaction between 2-chlorostyrene (**1j**) with $TMSN_3$ and isobutyraldehyde (**2a**), and purified by flash column chromatography as colorless oil (34.8 mg, 78%).

^1H NMR (400 MHz, $CDCl_3$) δ 7.45 (dd, *J* = 7.6, 0.8 Hz, 1H), 7.38 (d, *J* = 8.0 Hz, 1H), 7.32 (t, *J* = 7.4 Hz, 1H), 7.23 (dd, *J* = 7.6, 1.2 Hz, 1H), 5.07 (dd, *J* = 9.2, 5.4 Hz, 1H), 1.77 (tt, *J* = 13.6, 6.8 Hz, 1H), 1.67 (ddd, *J* = 14.0, 9.2, 5.2 Hz, 1H), 1.60 – 1.50 (m, 2H), 1.01 (d, *J* = 6.8 Hz, 3H), 0.95 (d, *J* = 6.8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 138.29, 132.90, 129.89, 129.16, 127.72, 127.54, 60.67, 44.76, 25.37, 23.22, 21.81. IR (cm^{-1}): 2959, 2870, 2106, 1248, 784. HRMS: calcd. for $C_{11}H_{15}NCl$ ($M + H^+ - N_2$): 196.0893, Found: 196.0887.

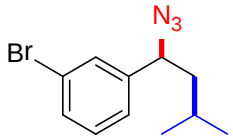
(3k) 1-(1-azido-3-methylbutyl)-3-chlorobenzene [1]



The title compound was prepared according to the general procedure described above by the reaction between 3-chlorostyrene (**1k**) with $TMSN_3$ and isobutyraldehyde (**2a**), and purified by

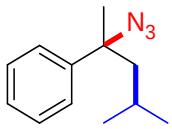
flash column chromatography as colorless oil (33.9 mg, 76%).
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.32 – 7.29 (m, 3H), 7.20 – 7.17 (m, 1H), 4.44 (dd, *J* = 8.5, 6.3 Hz, 1H), 1.77 – 1.62 (m, 2H), 1.56 – 1.48 (m, 1H), 0.95 (d, *J* = 0.8 Hz, 1H), 0.93 (d, *J* = 0.8 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 142.66, 131.41, 130.50, 130.08, 125.61, 122.98, 64.01, 45.30, 25.08, 22.78, 22.22. IR (cm^{-1}): 2958, 2870, 2102, 1247, 754.

(3l) 1-(1-azido-3-methylbutyl)-3-bromobenzene



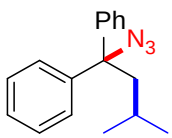
The title compound was prepared according to the general procedure described above by the reaction between 3-bromostyrene (**1l**) with $TMSN_3$ and isobutyraldehyde (**2a**), and purified by flash column chromatography as colorless oil (40.0 mg, 75%).
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.48 – 7.44 (m, 2H), 7.26 – 7.22 (m, 2H), 4.44 (dd, *J* = 8.4, 6.4 Hz, 1H), 1.79 – 1.61 (m, 2H), 1.59 – 1.51 (m, 1H), 0.95 (s, 3H), 0.94 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 142.65, 131.42, 130.51, 130.07, 125.61, 122.98, 64.00, 45.30, 25.07, 22.79, 22.23. IR (cm^{-1}): 2958, 2869, 2102, 1244, 818. HRMS: calcd. for $C_{11}H_{15}NBr$ ($M + H^+ - N_2$): 240.0388, Found: 240.0382.

(3m) (2-azido-4-methylpentan-2-yl)benzene



The title compound was prepared according to the general procedure described above by the reaction between alpha-methylstyrene (**1m**) with $TMSN_3$ and isobutyraldehyde (**2a**), and purified by flash column chromatography as colorless oil (31.0 mg, 71%).
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.42 – 7.33 (m, 4H), 7.29 – 7.24 (m, 1H), 1.79 (d, *J* = 2.0 Hz, 1H), 1.78 (d, *J* = 2.0 Hz, 1H), 1.68 (d, *J* = 2.0 Hz, 3H), 1.57 – 1.50 (m, 1H), 0.85 (dd, *J* = 6.8, 2.0 Hz, 3H), 0.75 (dd, *J* = 6.8, 2.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 143.92, 128.52, 127.22, 125.67, 67.09, 50.46, 26.95, 24.74, 24.35, 23.85. IR (cm^{-1}): 2957, 2870, 2107, 1260, 699. HRMS: calcd. for $C_{12}H_{18}N$ ($M+H^+ - N_2$): 176.1439. Found: 176.1434.

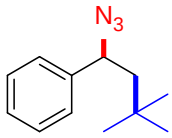
(3n) (1-azido-3-methylbutane-1, 1-diyl)dibenzene



The title compound was prepared according to the general procedure described above by the reaction between 1,1-diphenylethylene (**1n**) with $TMSN_3$ and isobutyraldehyde (**2a**), and purified by flash column chromatography as colorless oil (41.1 mg, 81%).
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.33 – 7.29 (m, 8H), 7.28 – 7.23 (m, 2H), 2.34 (s, 1H), 2.33 (s, 1H), 1.56 – 1.48 (m, 1H), 0.85 (s, 3H), 0.83 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 143.70, 128.36,

127.44, 127.15, 72.52, 46.56, 24.46, 24.16. IR (cm^{-1}): 2956, 2869, 2106, 1259, 298. HRMS: calcd. for $C_{17}H_{20}N$ ($M + H^+ - N_2$): 238.1596, Found: 238.1590.

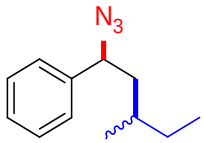
(3o) (1-azido-3, 3-dimethylbutyl)benzene



The title compound was prepared according to the general procedure described above by the reaction between styrene (**1a**) with $TMSN_3$ and pivaldehyde (**2b**), and purified by flash column chromatography as colorless oil (34.1 mg, 84%).

^1H NMR (400 MHz, $CDCl_3$) δ 7.40 – 7.29 (m, 5H), 4.45 (dd, *J* = 8.0, 4.8 Hz, 1H), 1.82 (dd, *J* = 14.4, 8.4 Hz, 1H), 1.66 (dd, *J* = 14.4, 4.8 Hz, 1H), 0.97 (d, *J* = 6.7 Hz, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 141.40, 128.95, 128.23, 127.00, 63.72, 49.24, 30.65, 29.99. IR (cm^{-1}): 2959, 2868, 2104, 1243, 700. HRMS: calcd. for $C_{12}H_{18}N$ ($M + H^+ - N_2$): 176.1439, Found: 176.1434.

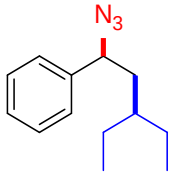
(3p) (1-azido-3-methylpentyl)benzene



The title compound was prepared according to the general procedure described above by the reaction between styrene (**1a**) with $TMSN_3$ and 2-methylbutanal (**2c**), and purified by flash column chromatography as colorless oil (31.7 mg, 78%).

^1H NMR (400 MHz, $CDCl_3$) δ 7.42 – 7.36 (m, 2H), 7.35 – 7.29 (m, 3H), 4.52 – 4.45 (m, 1H), 1.87 (ddd, *J* = 14.0, 9.6, 4.8 Hz, 0.63×1H), 1.80 – 1.61 (m, 0.86×1H), 1.56 – 1.49 (m, 0.75×1H), 1.48 – 1.30 (m, 2H), 1.26 – 1.30 (m, 1H), 0.95 – 0.82 (m, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 140.56, 139.92, 128.93, 128.38, 128.28, 127.15, 126.95, 64.63, 64.49, 43.40, 42.81, 31.43, 31.28, 29.75, 29.22, 19.22, 18.90, 11.28, 11.11. IR (cm^{-1}): 2962, 2929, 2095, 1242, 699. HRMS: calcd. for $C_{12}H_{18}N$ ($M + H^+ - N_2$): 176.1439, Found: 176.1434.

(3q) (1-azido-3-ethylpentyl)benzene

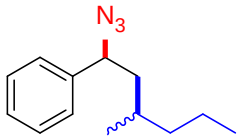


The title compound was prepared according to the general procedure described above by the reaction between styrene (**1a**) with $TMSN_3$ and 2-ethylbutanal (**2e**), and purified by flash column chromatography as colorless oil (29.5 mg, 68%).

^1H NMR (400 MHz, $CDCl_3$) δ 7.42 – 7.29 (m, 5H), 4.47 (dd, *J* = 8.4, 6.8 Hz, 1H), 1.78 (ddd, *J* = 13.6, 8.4, 4.8 Hz, 1H), 1.66 – 1.59 (m, 1H), 1.43 – 1.25 (m, 5H), 0.89 – 0.79 (m, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 140.32, 128.92, 128.31, 127.03, 64.58, 39.76, 36.97, 25.35, 24.92, 10.67,

10.48. IR (cm^{-1}): 2962, 2932, 2093, 1245, 699. HRMS: calcd. for $C_{13}H_{20}N$ ($M + H^+ - N_2$): 190.1596, Found: 190.1590.

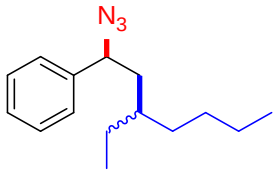
(3r) (1-azido-3- methylhexyl)benzene



The title compound was prepared according to the general procedure described above by the reaction between styrene (**1a**) with $TMSN_3$ and 2-methylpentanal (**2d**), and purified by flash column chromatography as colorless oil (31.7 mg, 73%).

^1H NMR (400 MHz, $CDCl_3$) δ 7.41 – 7.28 (m, 5H), 4.48 (t, *J* = 7.6 Hz, 1H), 1.86 (ddd, *J* = 14.0, 9.6, 4.8 Hz, 0.32×1H), 1.80 – 1.60 (m, 2H), 1.47 – 1.37 (m, 0.78×1H), 1.36 – 1.22 (m, 3H), 1.16 – 1.07 (m, 1H), 0.93 – 0.83 (m, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 139.87, 128.92, 128.37, 127.15, 126.94, 64.56, 64.43, 43.80, 43.19, 39.51, 39.04, 29.54, 20.00, 19.92, 19.76, 19.35, 14.41. IR (cm^{-1}): 2959, 2928, 2094, 1243, 699. HRMS: calcd. for $C_{13}H_{20}N$ ($M + H^+ - N_2$): 190.1596, Found: 190.1590.

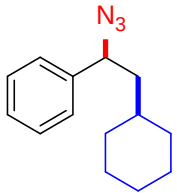
(4s) (1-azido-3-ethylheptyl)benzene



The title compound was prepared according to the general procedure described above by the reaction between styrene (**1a**) with $TMSN_3$ and 2-ethylhexanal (**2f**), and purified by flash column chromatography as colorless oil (32.8 mg, 67%).

^1H NMR (400 MHz, $CDCl_3$) δ 7.41 – 7.29 (m, 5H), 4.47 (t, *J* = 7.4 Hz, 1H), 1.82 – 1.73 (m, 1H), 1.66 – 1.58 (m, 1H), 1.38 – 1.20 (m, 9H), 0.91 – 0.81 (m, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 140.39, 140.33, 128.91, 128.31, 127.06, 127.04, 64.63, 40.23, 35.69, 35.60, 32.77, 32.44, 28.69, 28.58, 25.95, 25.46, 23.17, 14.25, 10.63, 10.45. IR (cm^{-1}): 2930, 2928, 2094, 1244, 699. HRMS: calcd. for $C_{15}H_{24}N$ ($M + H^+ - N_2$): 218.1909, Found: 218.1903.

(3t) (1-azido-2-cyclohexylethyl)benzene

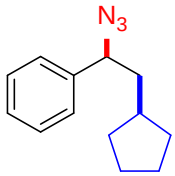


The title compound was prepared according to the general procedure described above by the reaction between styrene (**1a**) with $TMSN_3$ and cyclohexanecarboxaldehyde (**2g**), and purified by flash column chromatography as colorless oil (29.3 mg, 64%).

^1H NMR (400 MHz, $CDCl_3$) δ 7.41 – 7.28 (m, 5H), 4.51 (dd, *J* = 8.4, 6.4 Hz, 1H), 1.80 – 1.53 (m, 7H), 1.39 – 1.31 (m, 1H), 1.26 – 1.12 (m, 3H), 0.99 – 0.87 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$)

δ 140.29, 128.92, 128.30, 127.02, 63.94, 43.85, 34.47, 33.57, 32.97, 26.60, 26.26, 26.17. IR (cm^{-1}): 2957, 2929, 2106, 1261, 699. HRMS: calcd. for $C_{14}H_{20}N$ ($M+H^+ - N_2$): 202.1596, Found: 202.1590

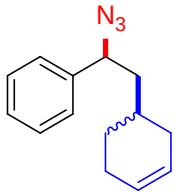
(3u) (1-azido-2-cyclopentylethyl)benzene



The title compound was prepared according to the general procedure described above by the reaction between styrene (**1a**) with $TMSN_3$ and cyclopentanecarbaldehyde (**2h**), and purified by flash column chromatography as colorless oil (28.0 mg, 65%).

^1H NMR (400 MHz, $CDCl_3$) δ 7.42 – 7.30 (m, 5H), 4.43 (t, *J* = 7.0 Hz, 1H), 1.93 – 1.85 (m, 1H), 1.84 – 1.71 (m, 4H), 1.67 – 1.57 (m, 2H), 1.56 – 1.46 (m, 2H), 1.19 – 1.07 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 140.13, 128.88, 128.31, 127.06, 65.89, 42.55, 36.99, 32.66, 25.20, 25.11. IR (cm^{-1}): 2949, 2867, 2560, 2094, 1246, 700. HRMS: calcd. for $C_{13}H_{18}N$ ($M+H^+ - N_2$): 188.1439, Found: 188.1434.

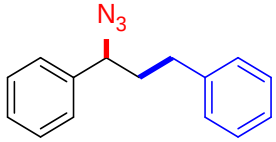
(3v) (1-azido-2-(cyclohex-3-en-1-yl)ethyl)benzene



The title compound was prepared according to the general procedure described above by the reaction between styrene (**1a**) with $TMSN_3$ and 1-cyclohexene-3-carboxaldehyde (**2i**), and purified by flash column chromatography as colorless oil (34.0 mg, 75%).

^1H NMR (400 MHz, $CDCl_3$) δ 7.42 – 7.30 (m, 5H), 5.65 (d, *J* = 3.2 Hz, 2H), 4.53 (t, *J* = 7.4 Hz, 1H), 2.13 (d, *J* = 13.6 Hz, 1H), 2.03 (d, *J* = 3.2 Hz, 1H), 1.87 – 1.61 (m, 5H), 1.34 – 1.23 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 140.16, 139.93, 128.95, 128.39, 128.37, 127.25, 127.14, 127.07, 126.98, 126.10, 125.98, 64.08, 64.04, 43.03, 42.81, 31.84, 31.45, 30.44, 30.37, 28.98, 28.47, 25.02, 24.91. IR (cm^{-1}): 3025, 2915, 2837, 2094, 1244, 700. HRMS: calcd. for $C_{14}H_{18}N$ ($M + H^+ - N_2$): 200.1439, Found: 200.1434.

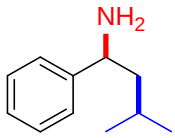
(3w) (1-azidopropane-1, 3-diyl)dibenzene



The title compound was prepared according to the general procedure described above by the reaction between styrene (**1a**) with $TMSN_3$ and phenylacetaldehyde (**2j**), and purified by flash column chromatography as colorless oil (26.1 mg, 55%).

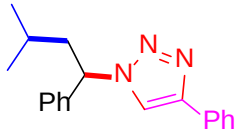
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.41 – 7.15 (m, 10H), 4.40 (t, *J* = 7.2 Hz, 1H), 2.75 – 2.60 (m, 2H), 2.21 – 2.11 (m, 1H), 2.10 – 2.00 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 141.01, 139.60, 128.97, 128.64, 128.58, 128.46, 127.09, 126.25, 65.56, 37.80, 32.47. IR (cm^{-1}): 2926, 2861, 2095, 1244, 697. HRMS: calcd. for $C_{15}H_{16}N$ ($M + H^+ - N_2$): 210.1283, Found: 210.1278.

(4) 3-methyl-1-phenylbutan-1-amine [3]



^{1}H NMR (400 MHz, $CDCl_3$) δ 7.32 – 7.20 (m, 5H), 3.95 (s, 1H), 1.62 – 1.47 (m, 5H), 0.94 – 0.83 (m, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 147.18, 128.62, 127.00, 126.42, 54.21, 49.08, 25.24, 22.97, 22.67. IR (cm^{-1}): 2440, 2955, 1463, 699.

(5) 1-(3-methyl-1-phenylbutyl)-4-phenyl-1H-1,2,3-triazole

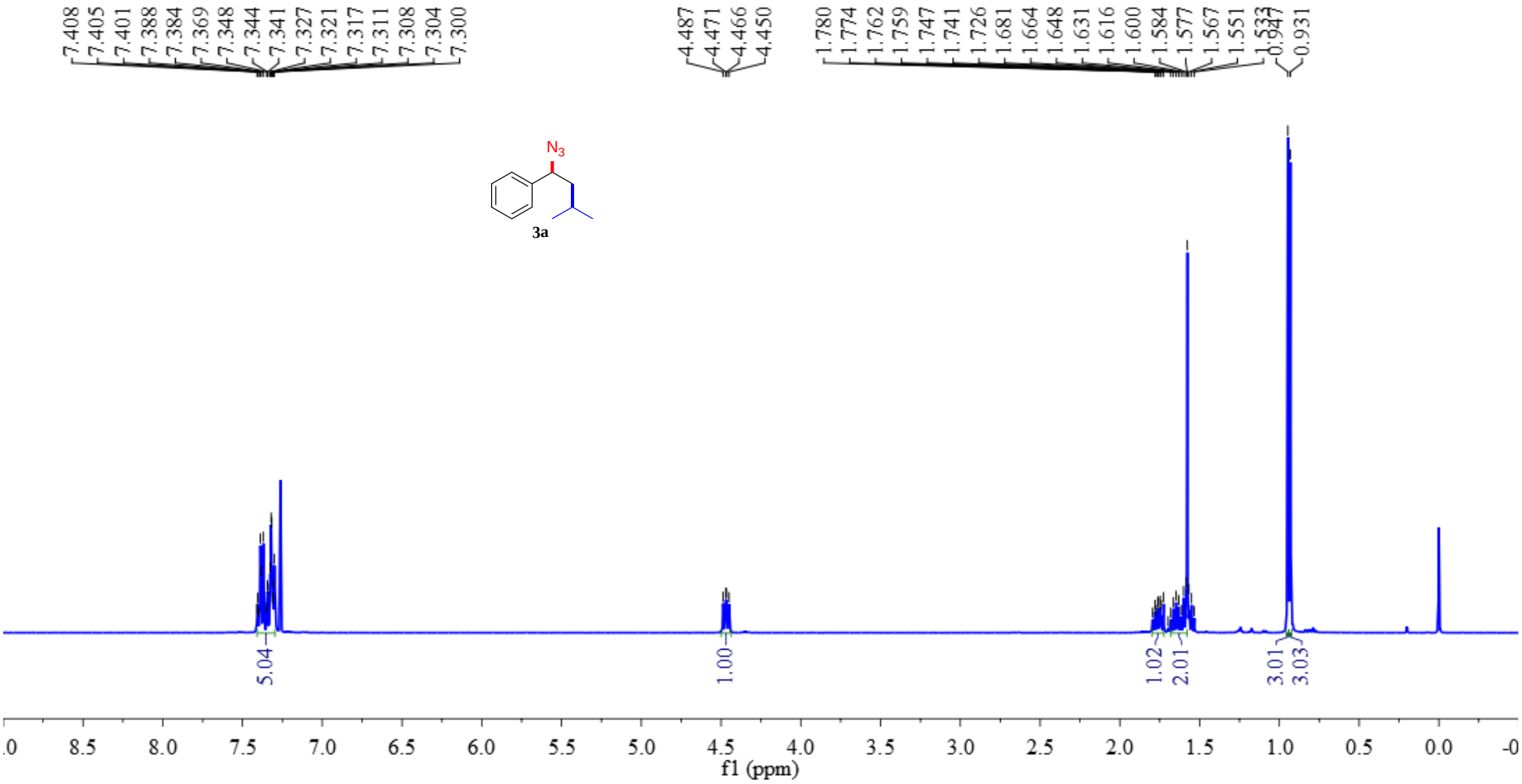


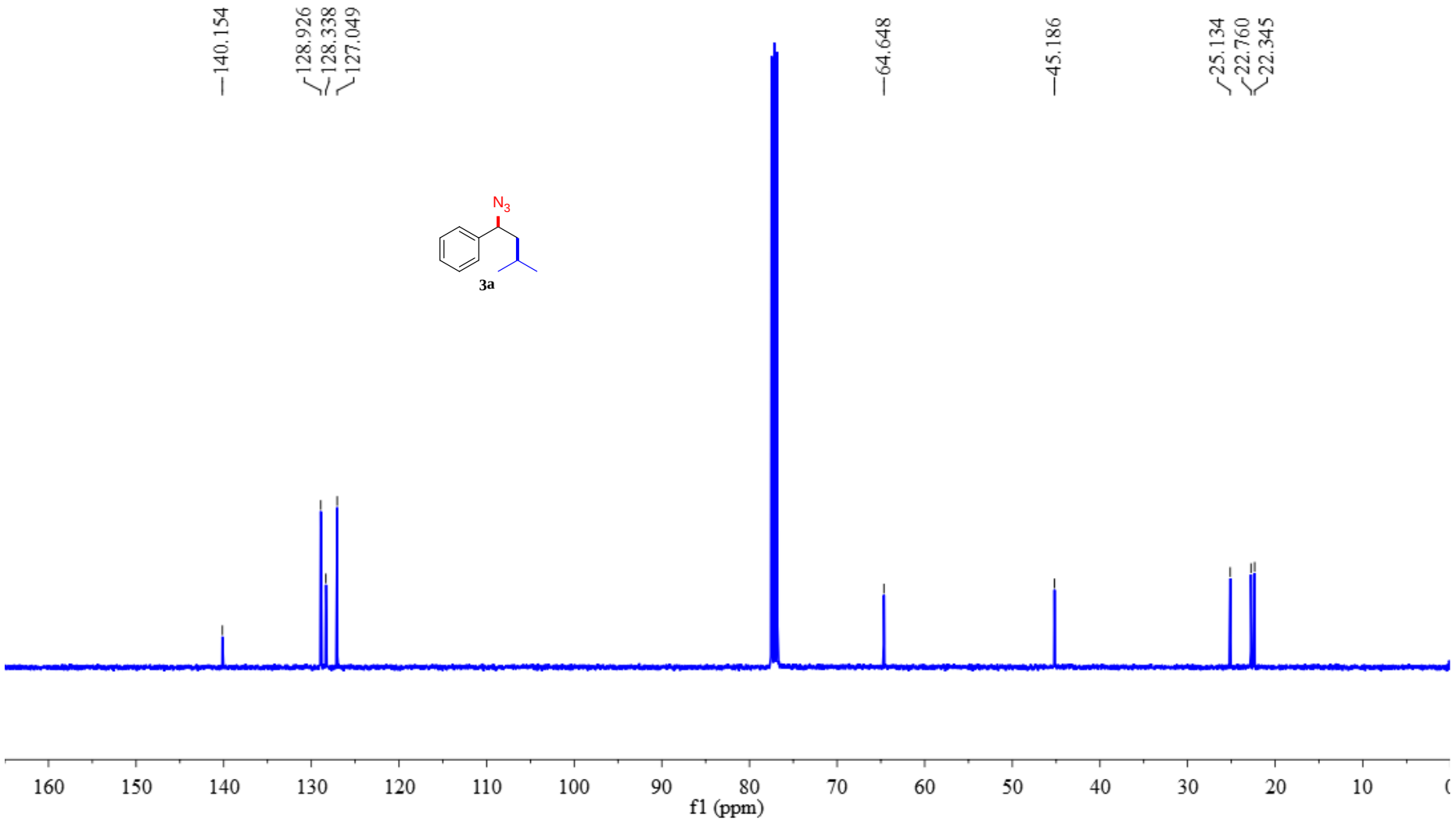
Melting point: 128.5 - 130 °C.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.82 (s, 1H), 7.80 (s,1H), 7.70 (s, 1H), 7.42 – 7.20 (m, 8H), 5.76 (dd, *J* = 8.8, 6.8 Hz, 1H), 2.47 – 2.38 (m, 1H), 2.13 (dt, *J* = 14.4, 7.2 Hz, 1H), 1.48 (dp, *J* = 13.4, 6.6 Hz, 1H), 1.01 (d, *J* = 6.6 Hz, 3H), 0.97 (d, *J* = 6.6 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 147.82, 139.27, 130.78, 129.14, 128.89, 128.65, 128.19, 127.09, 125.77, 118.53, 63.46, 44.11, 24.95, 22.64, 22.27. IR (cm^{-1}): 2958, 2870, 1459, 1074, 694. HRMS: calcd. for $C_{19}H_{21}N_3$ ($M + H^+$): 292.1814, Found: 292.1803.

[3] Y. Mori , Y. Ogawa, A. Mochizuki, Y. Nakamura, T. Fujimoto, C. Sugita, S. Miyazaki, K. Tamaki, T. Nagayama, Y. Nagai, S. Inoue, K. Chiba and T. Nishi, *Bioorganic and Medicinal Chemistry*., **2013**, *18*. 5907.

VII. Copies of ^{1}H and ^{13}C NMR spectra of products

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22.760
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3a
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140
130
120
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100
90
80
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30
20
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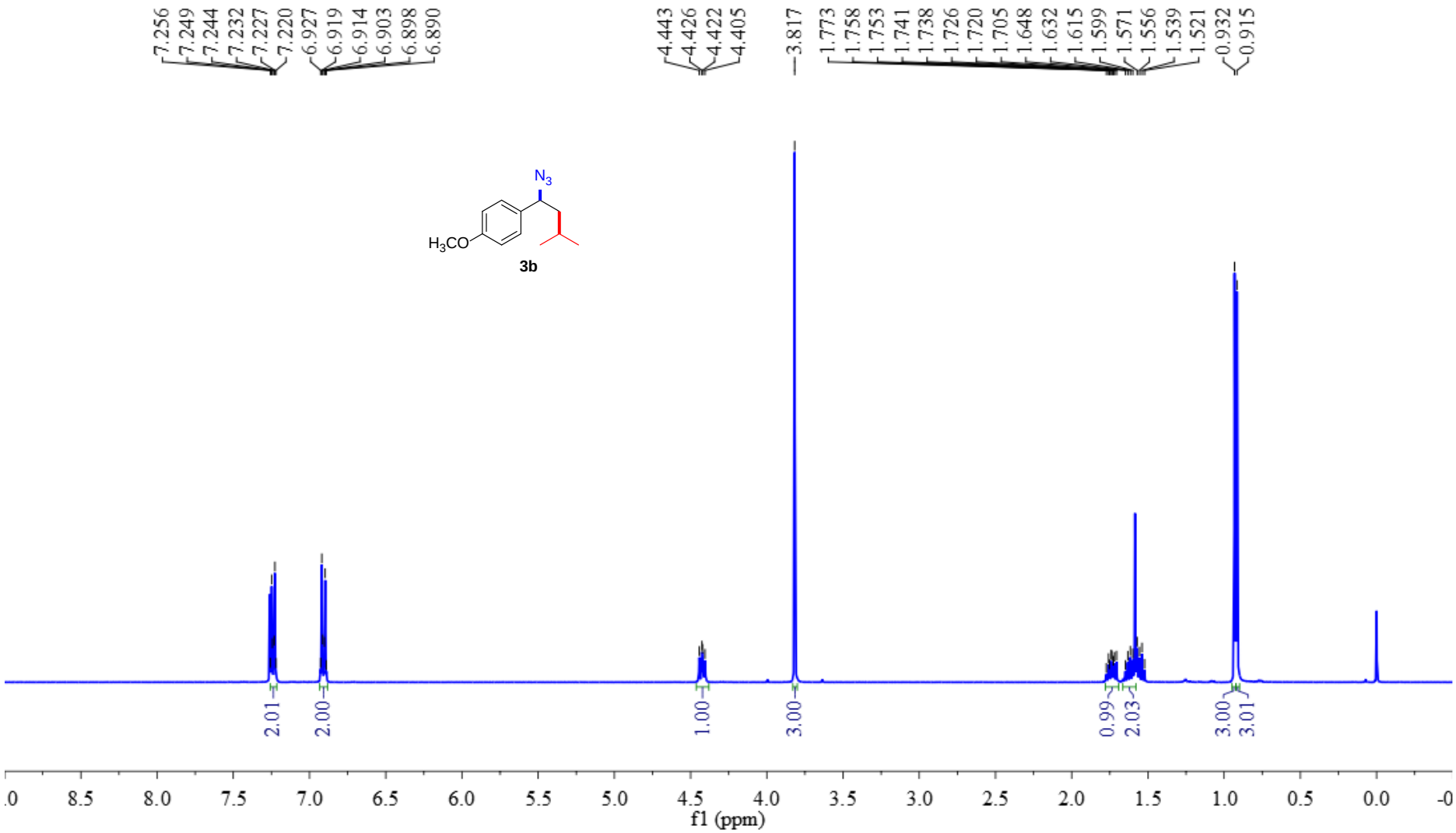
f1 (ppm)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6.919
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6.890
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4.426
4.422
4.405
3.817
1.773
1.758
1.753
1.741
1.738
1.726
1.720
1.705
1.648
1.632
1.615
1.599
1.571
1.556
1.539
1.521
0.932
0.915
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H3CO
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1.00
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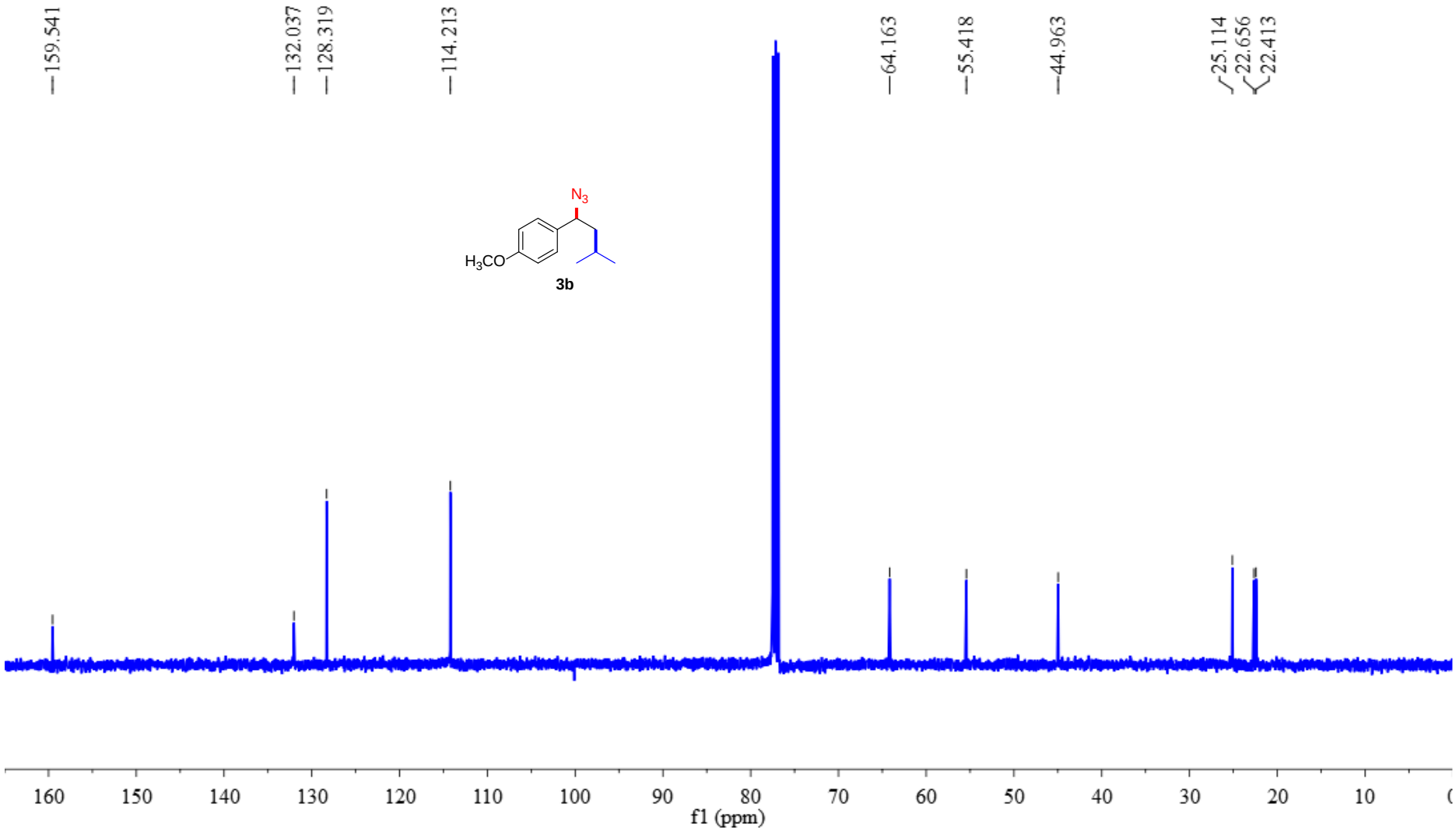
3.00
3.01
f1 (ppm)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22.413
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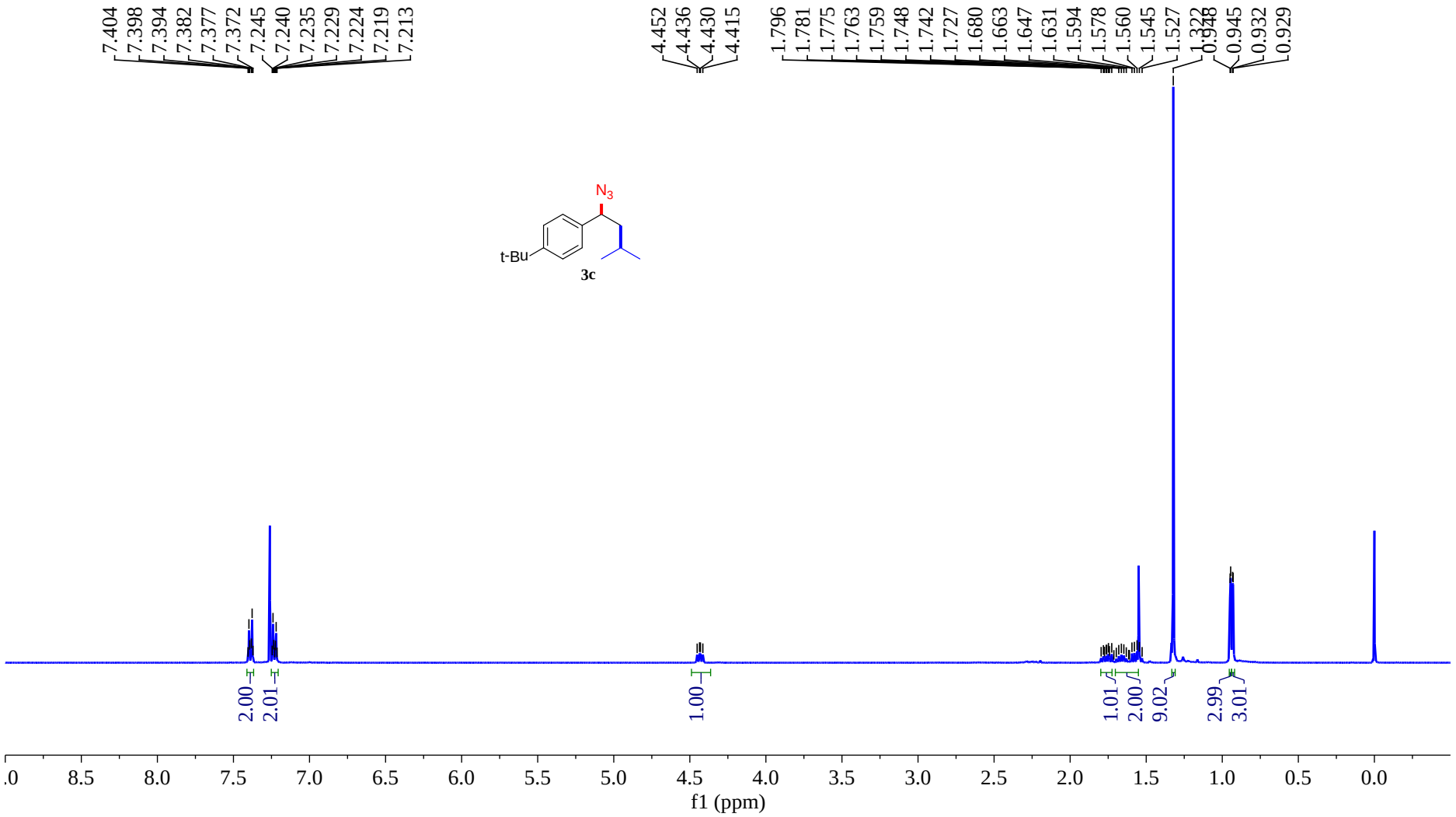
f1 (ppm)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7.213
4.452
4.436
4.430
4.415
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1.781
1.775
1.763
1.759
1.748
1.742
1.727
1.680
1.663
1.647
1.631
1.594
1.578
1.560
1.545
1.527
1.322
0.948
0.945
0.932
0.929
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t-Bu
3c
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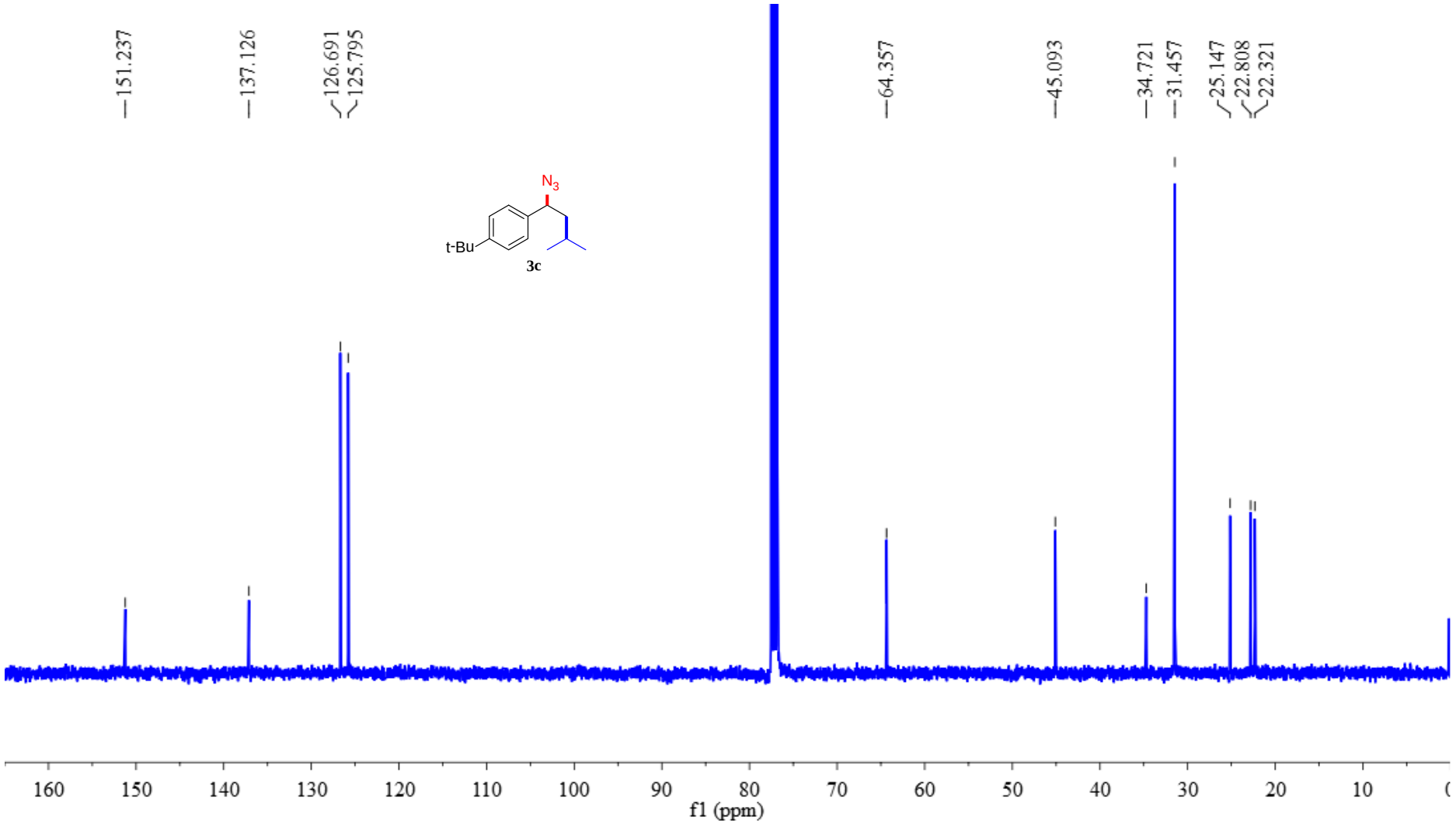
3.01
f1 (ppm)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t-Bu
3c
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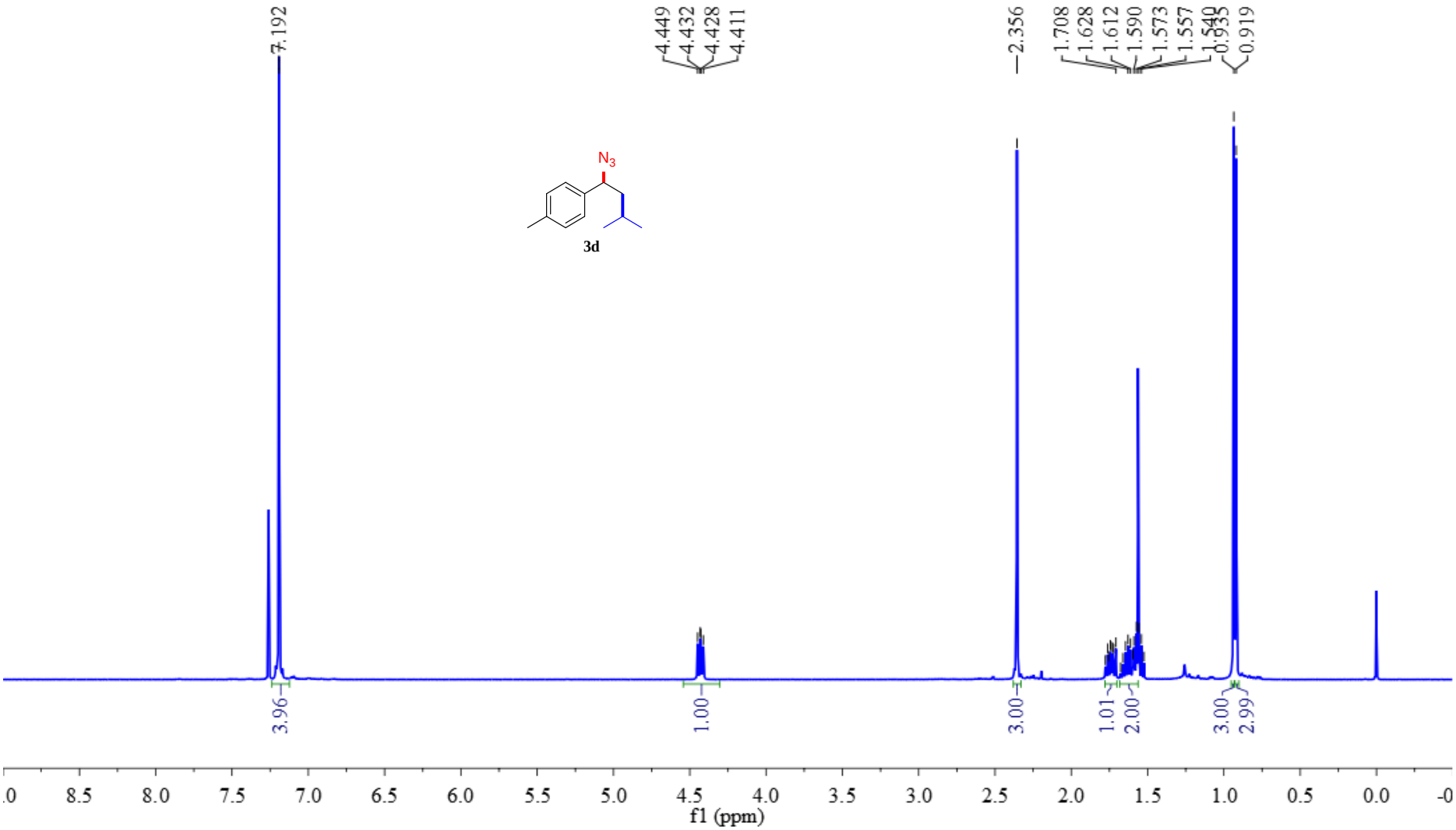
f1 (ppm)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4.428
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1.628
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1.590
1.573
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1.540
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3d
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3.00
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2.00
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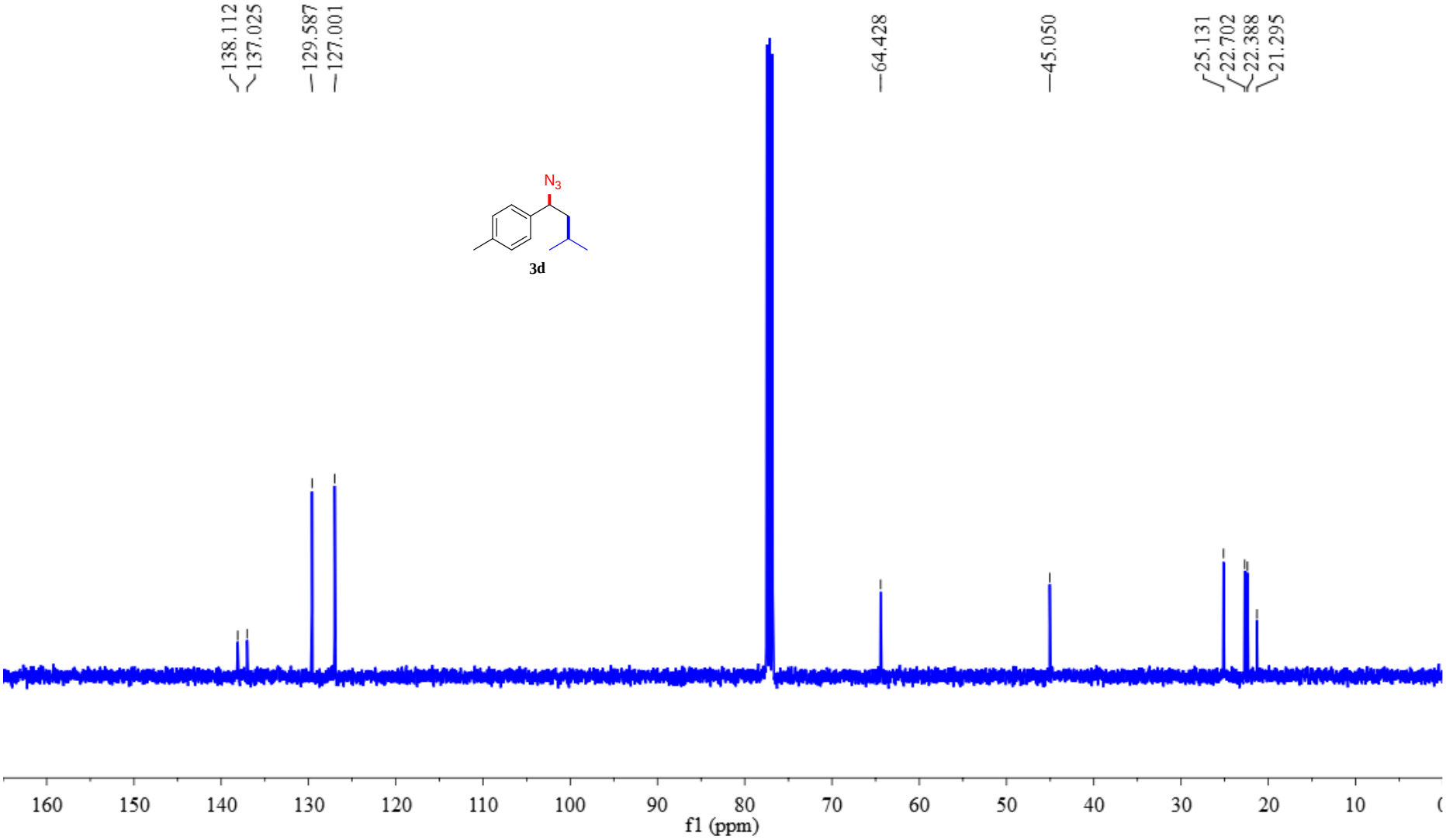
2.99
f1 (ppm)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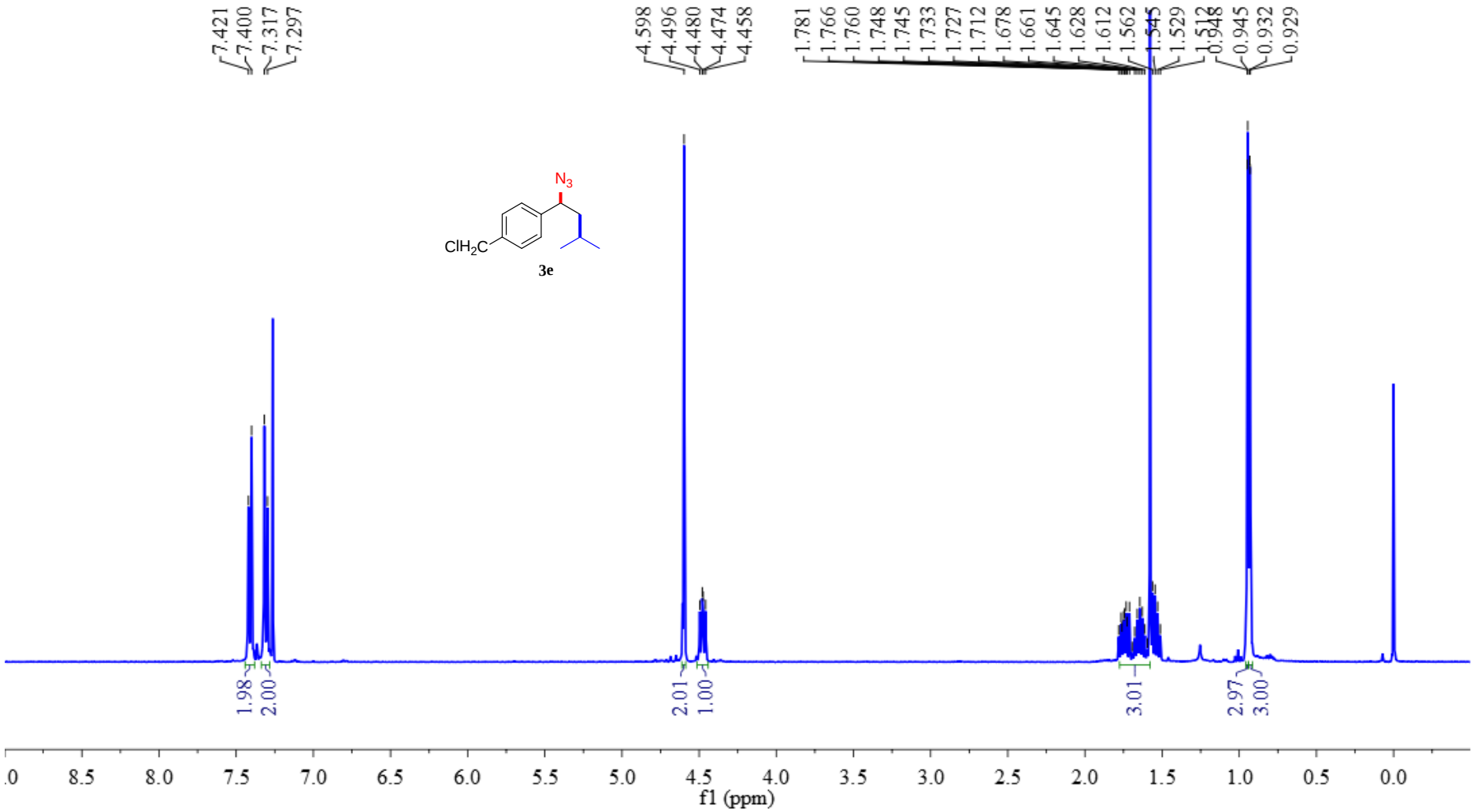
f1 (ppm)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1.745
1.733
1.727
1.712
1.678
1.661
1.645
1.628
1.612
1.562
1.545
1.529
0.948
0.945
0.932
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3e
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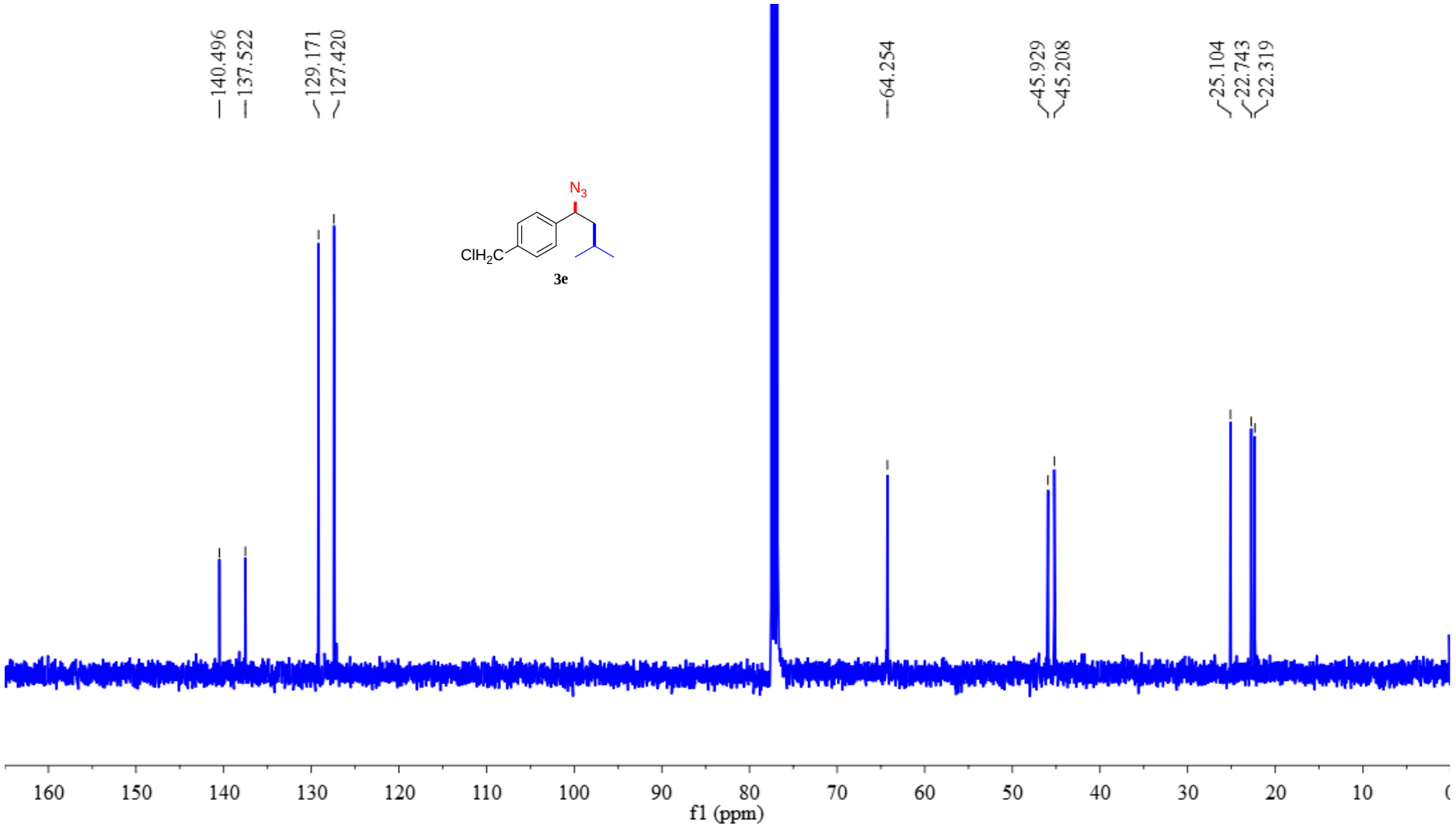
1.00
3.01
2.97
3.00
f1 (ppm)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22.319
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ClH2C
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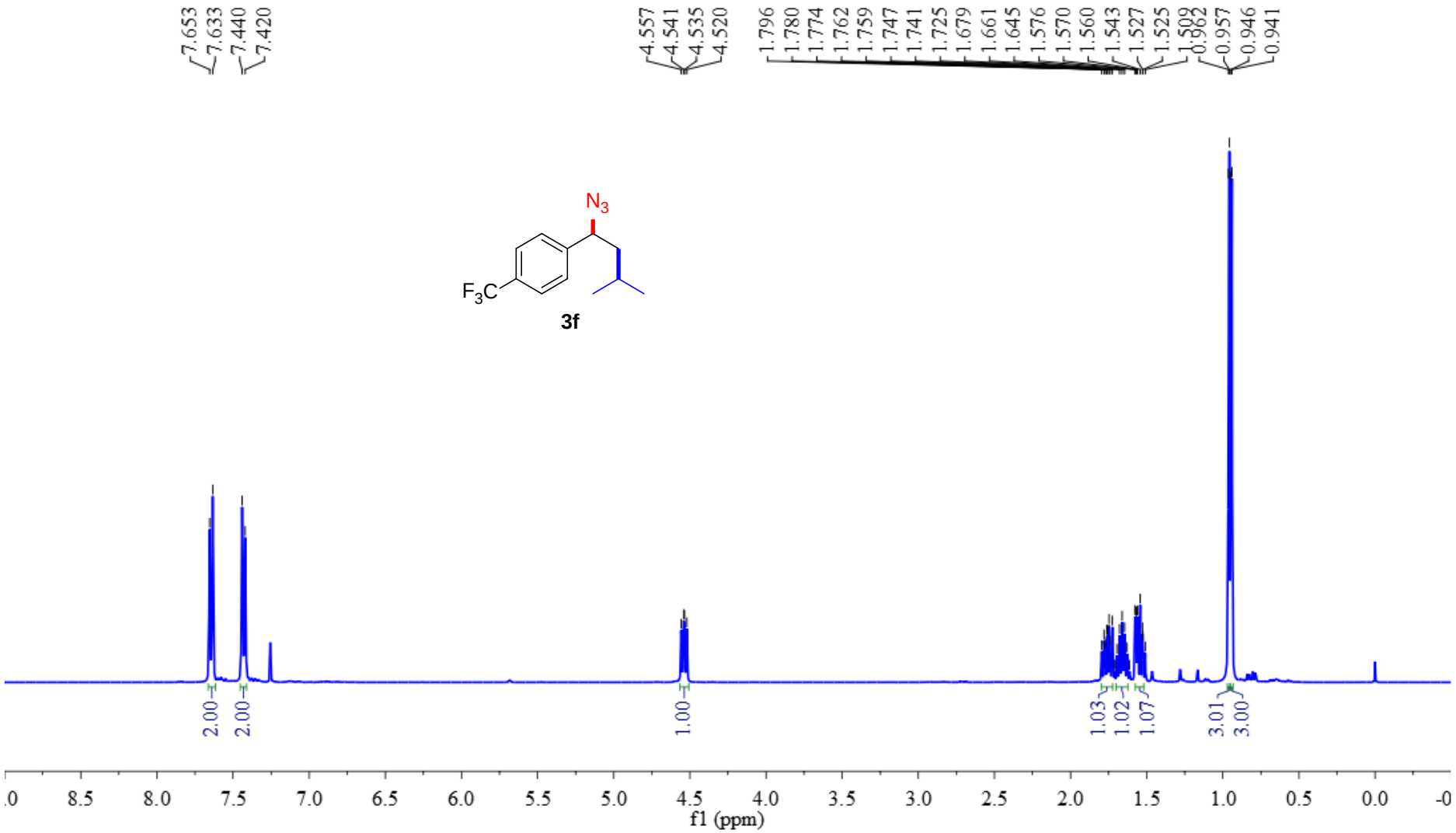
f1 (ppm)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1.774
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1.759
1.747
1.741
1.725
1.679
1.661
1.645
1.576
1.570
1.560
1.543
1.527
1.525
1.509
0.962
0.957
0.946
0.941
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F3C
3f
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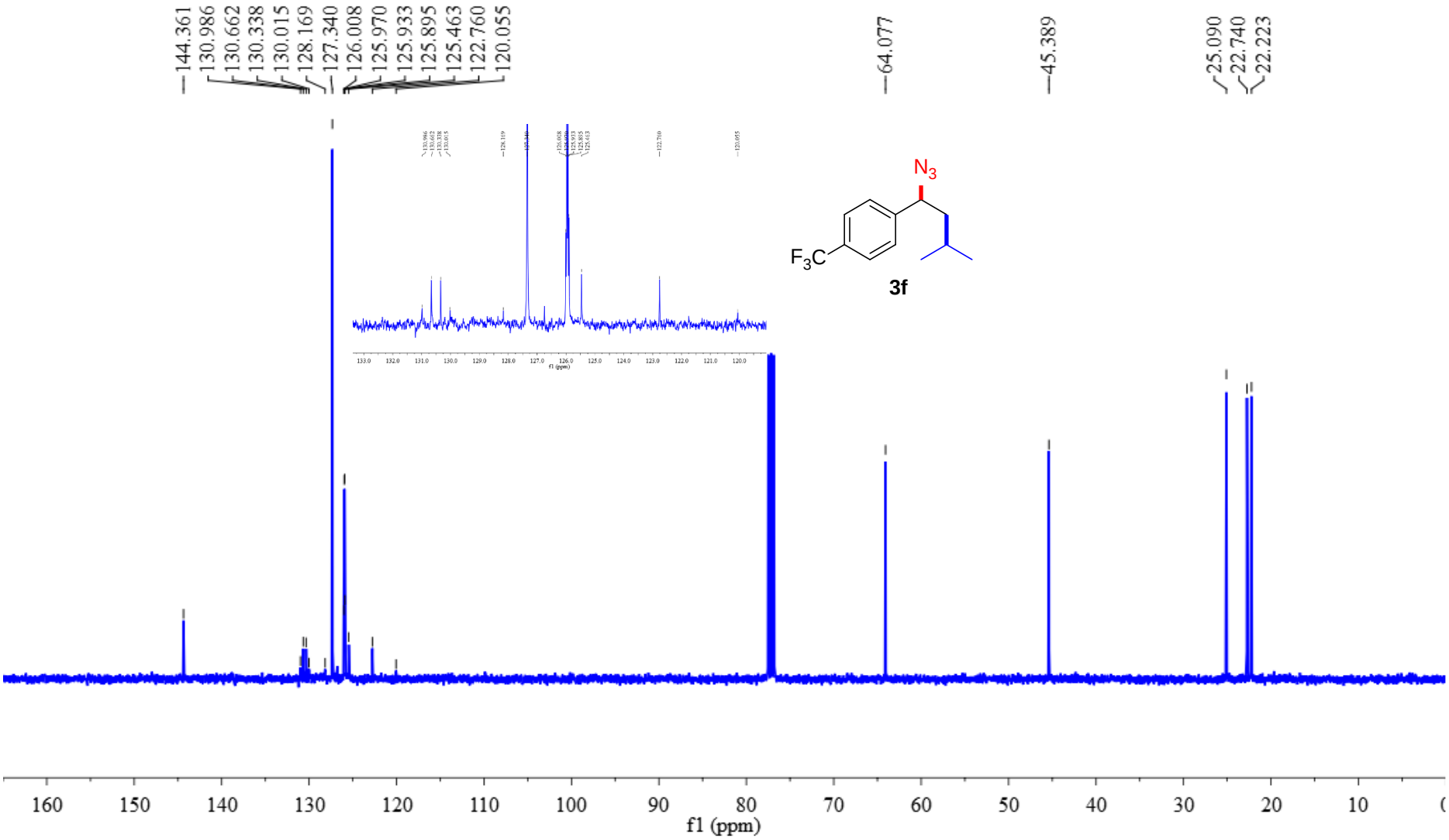
2.00
1.00
1.03
1.02
1.07
3.01
3.00
f1 (ppm)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125.895
125.463
122.760
120.055
64.077
45.389
25.090
22.740
22.223
N3
F3C
3f
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100
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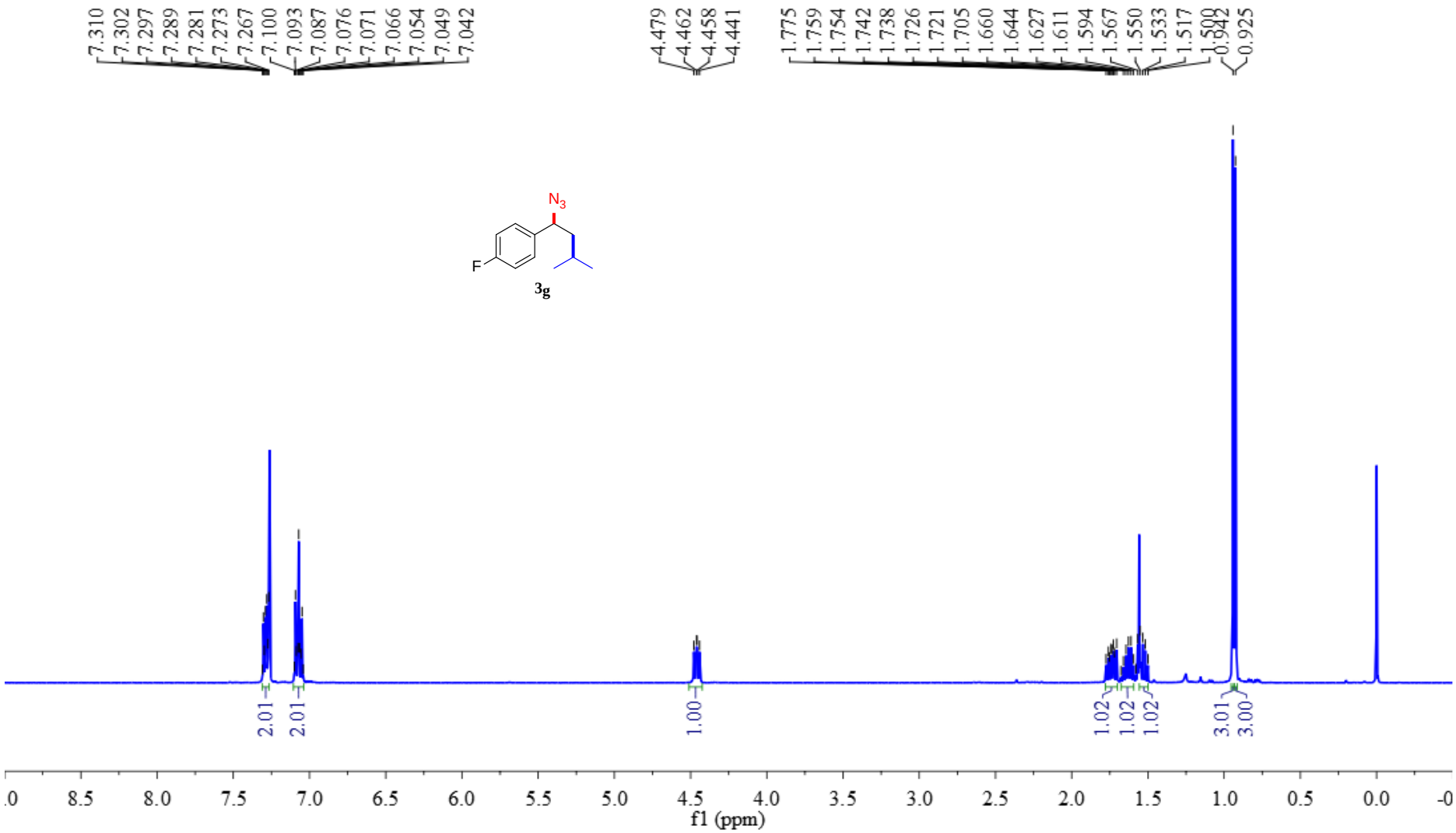
f1 (ppm)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7.076
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7.066
7.054
7.049
7.042
4.479
4.462
4.458
4.441
1.775
1.759
1.754
1.742
1.738
1.726
1.721
1.705
1.660
1.644
1.627
1.611
1.594
1.567
1.550
1.533
1.517
1.500
0.942
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F
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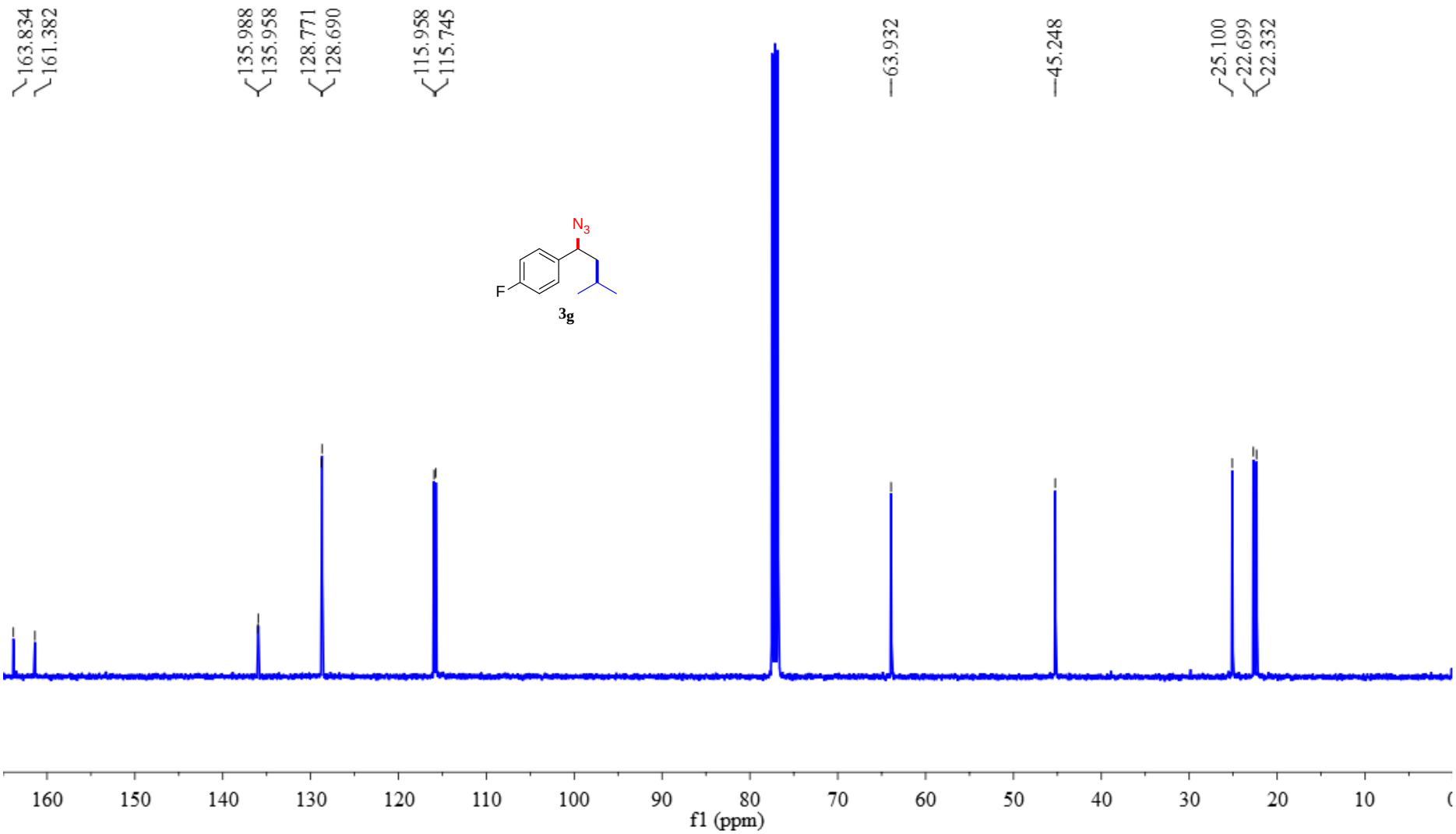
1.02
3.01
3.00
f1 (ppm)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22.332
N3
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3g
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100
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80
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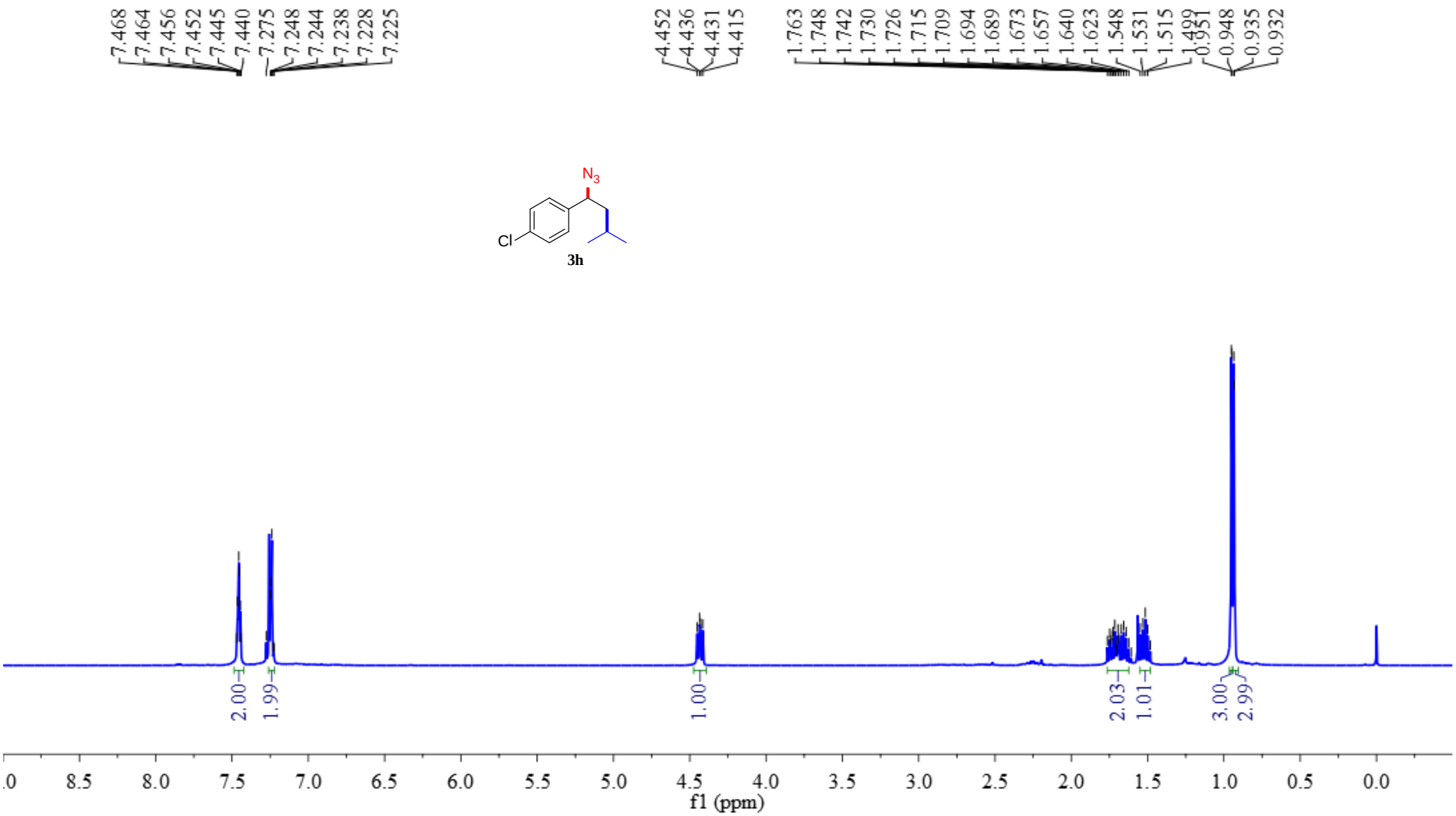
60
50
40
30
20
10
f1 (ppm)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7.445
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7.248
7.244
7.238
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7.225
4.452
4.436
4.431
4.415
1.763
1.748
1.742
1.730
1.726
1.715
1.709
1.694
1.689
1.673
1.657
1.640
1.623
1.548
1.531
1.515
1.499
0.951
0.948
0.935
0.932
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Cl
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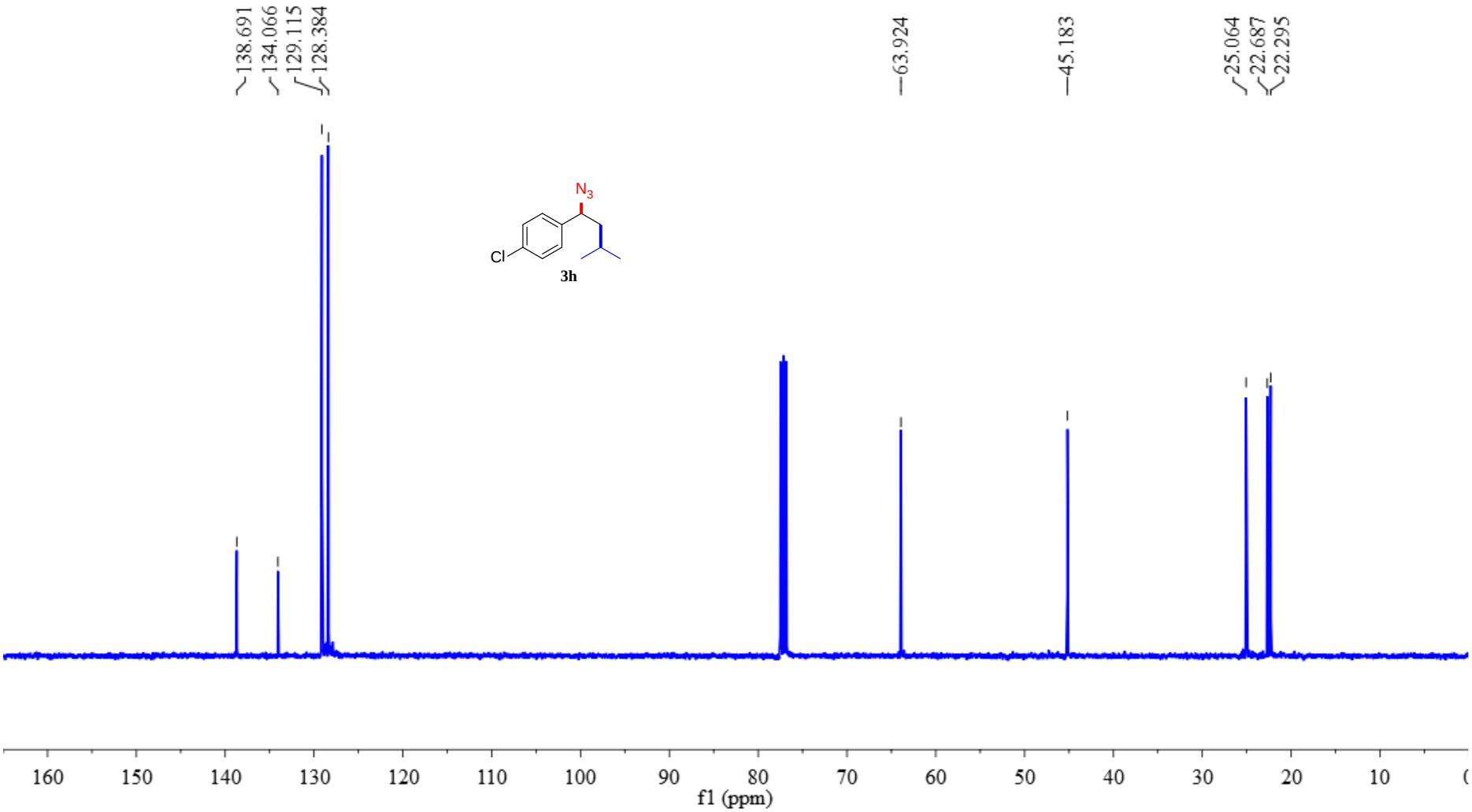
1.00
2.03
1.01
3.00
2.99
f1 (ppm)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80
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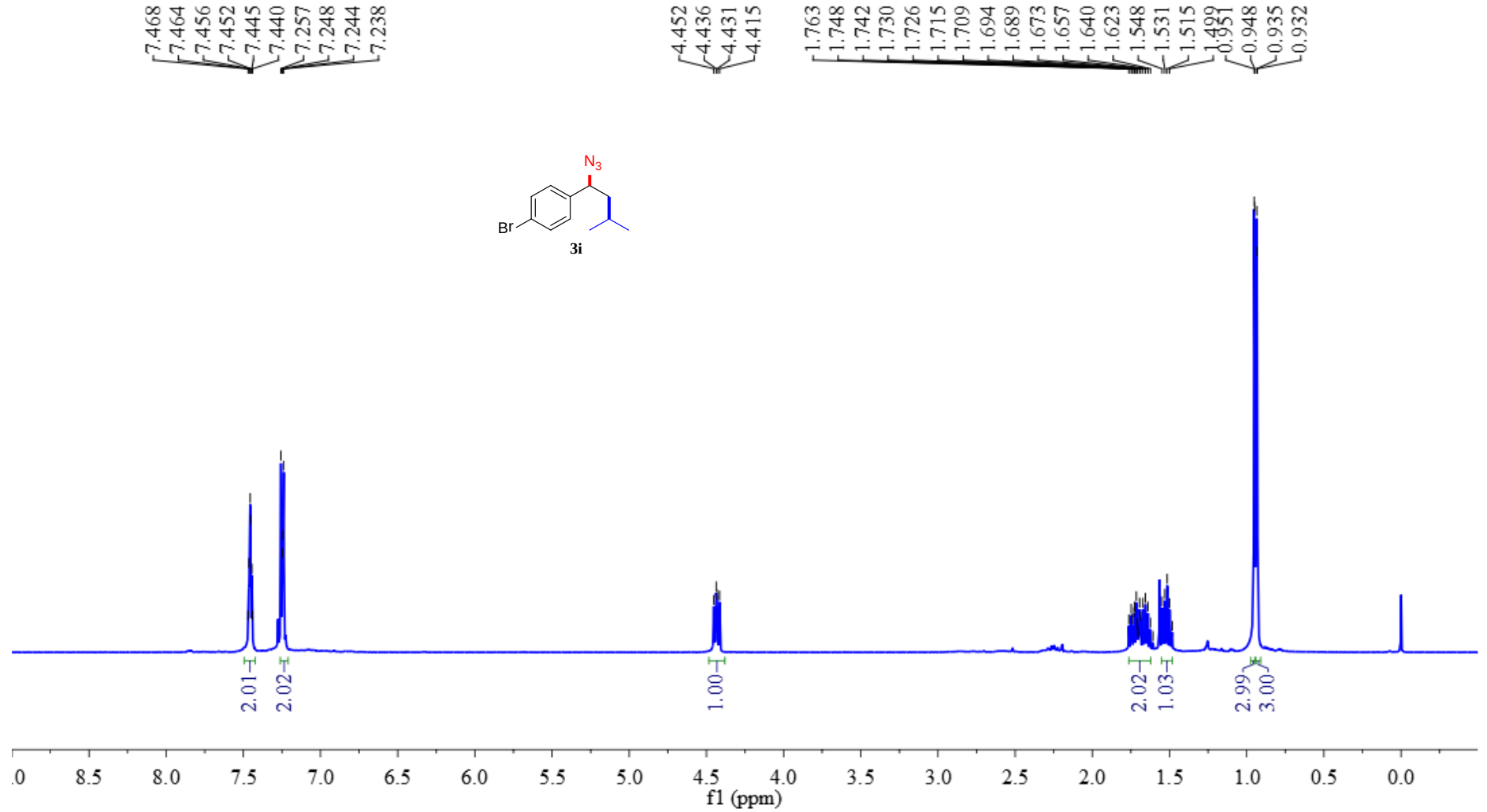
50
40
30
20
10
f1 (ppm)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4.415
1.763
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1.742
1.730
1.726
1.715
1.709
1.694
1.689
1.673
1.657
1.640
1.623
1.548
1.531
1.515
1.499
0.951
0.948
0.935
0.932
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Br
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2.02
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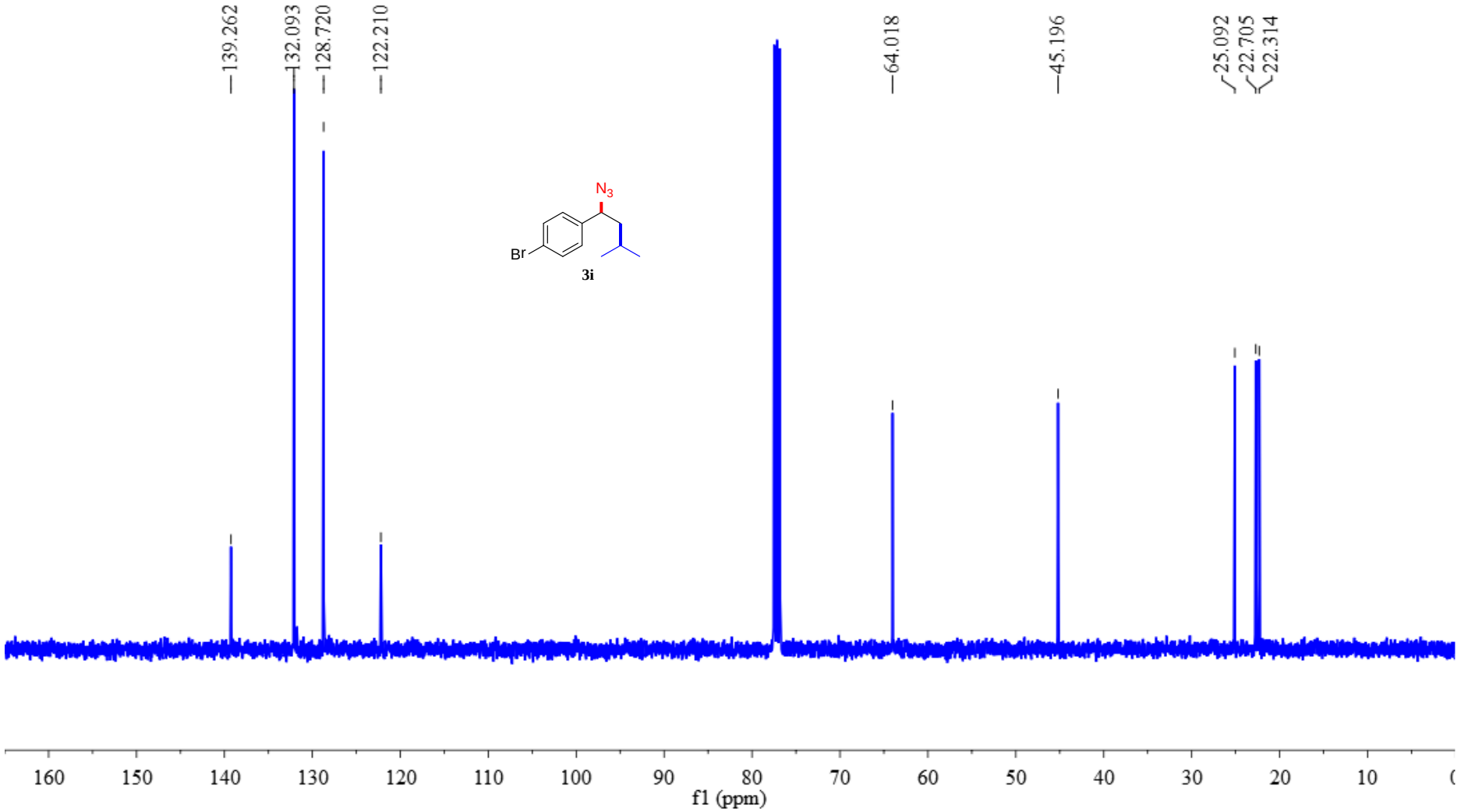
2.02
1.03
2.99
3.00
f1 (ppm)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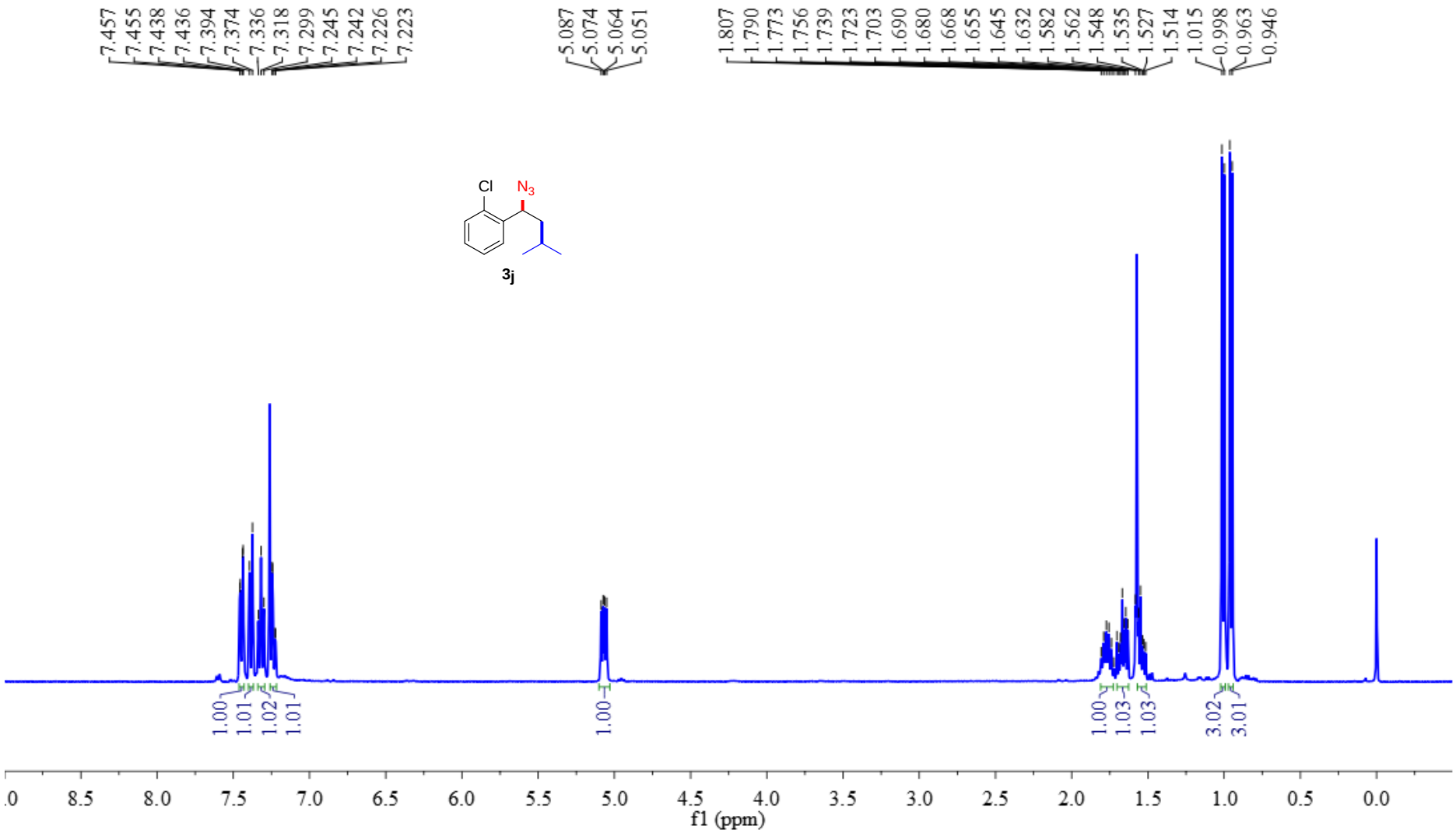
f1 (ppm)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1.548
1.535
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Cl
N3
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1.03
3.02
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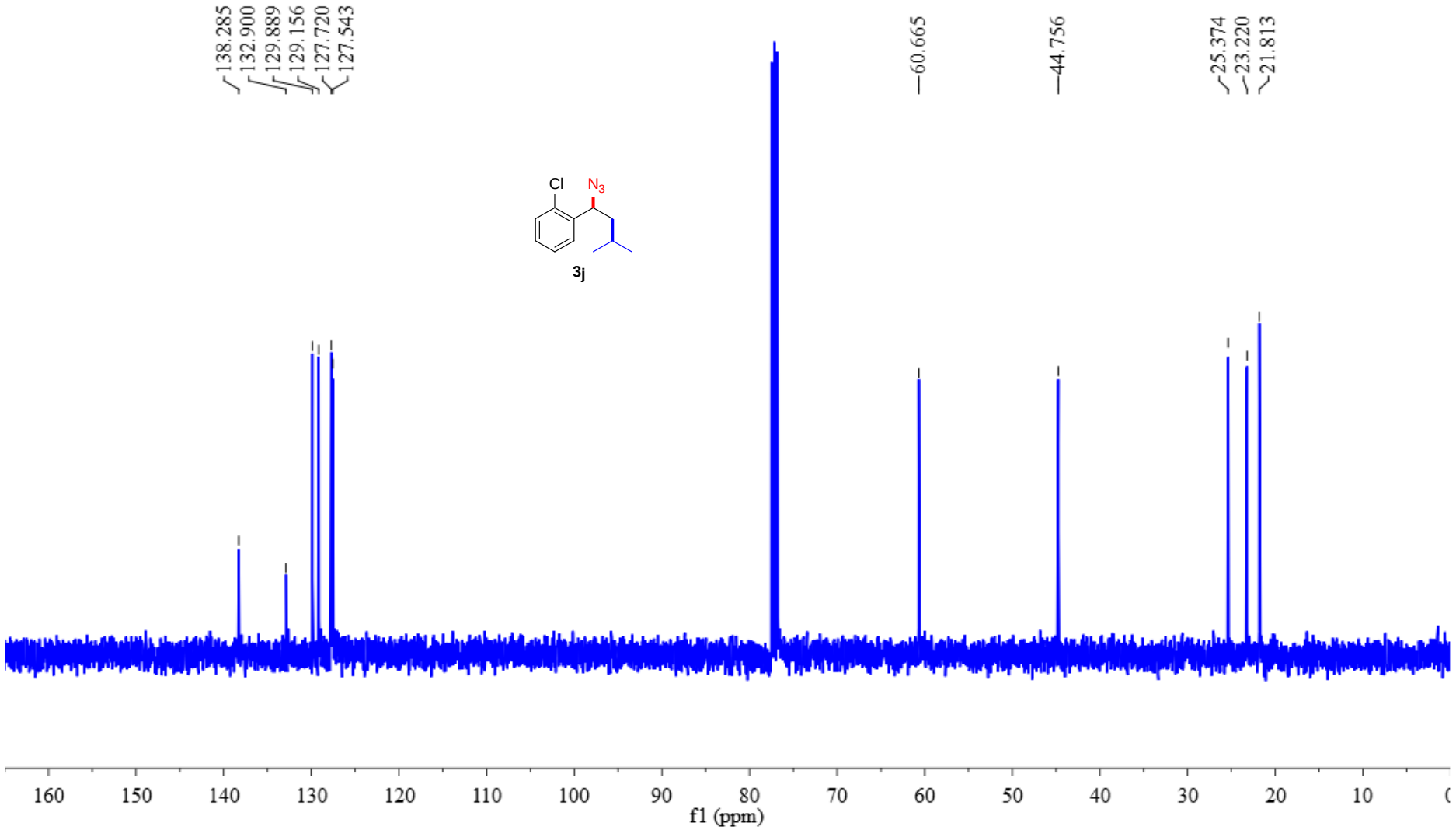
f1 (ppm)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23.220
21.813
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100
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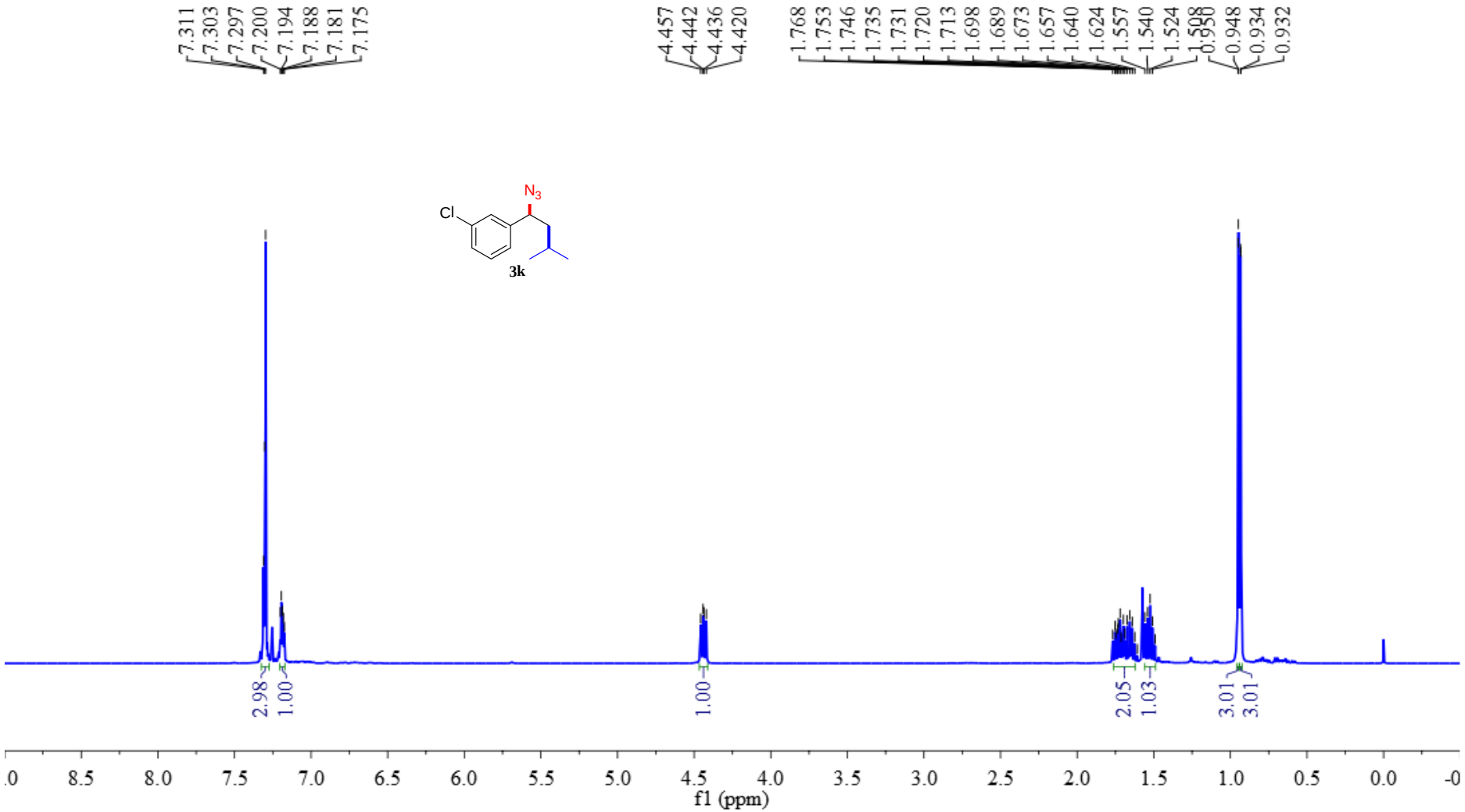
f1 (ppm)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1.753
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1.735
1.731
1.720
1.713
1.698
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1.673
1.657
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1.624
1.557
1.540
1.524
1.508
0.950
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0.934
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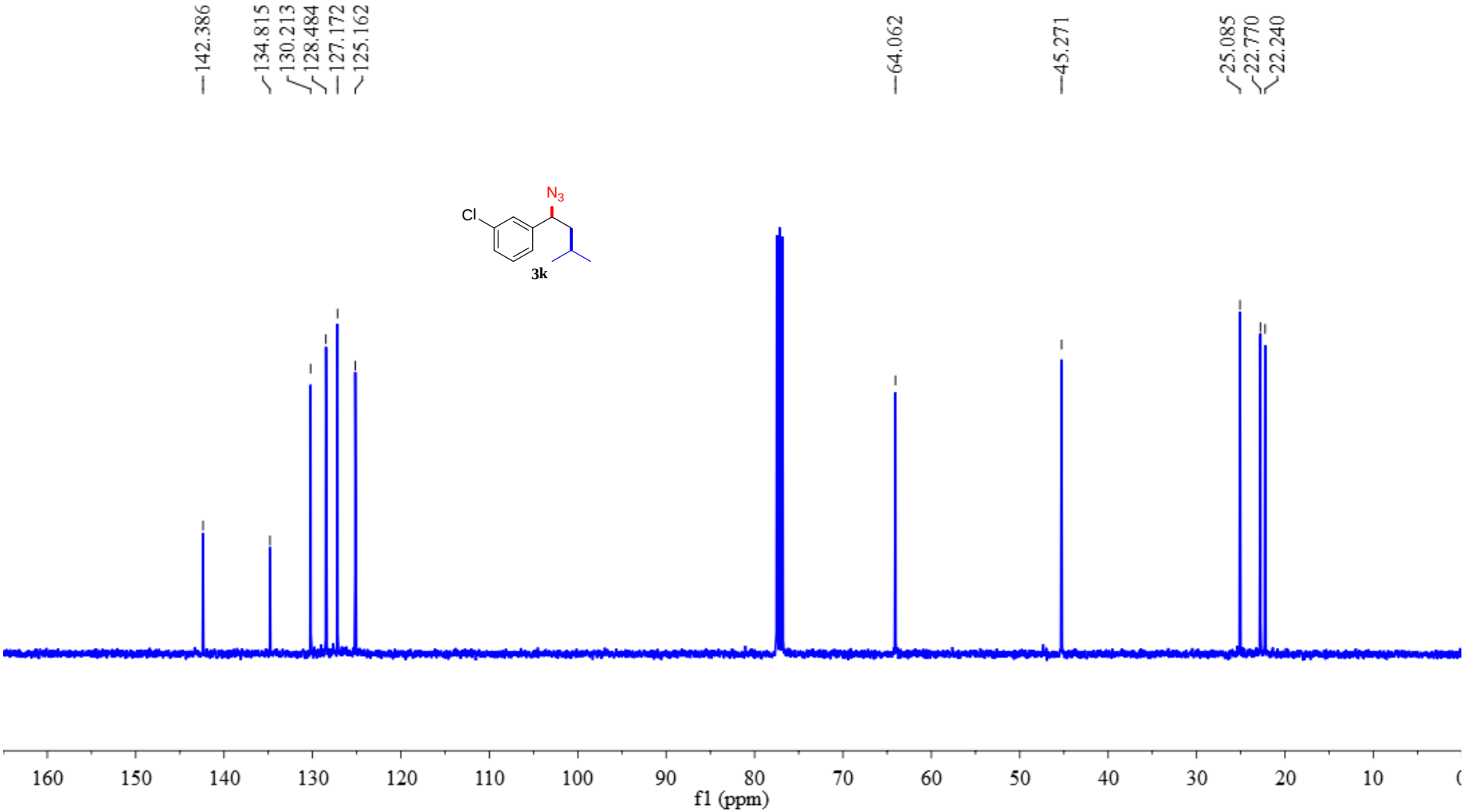
3.01
f1 (ppm)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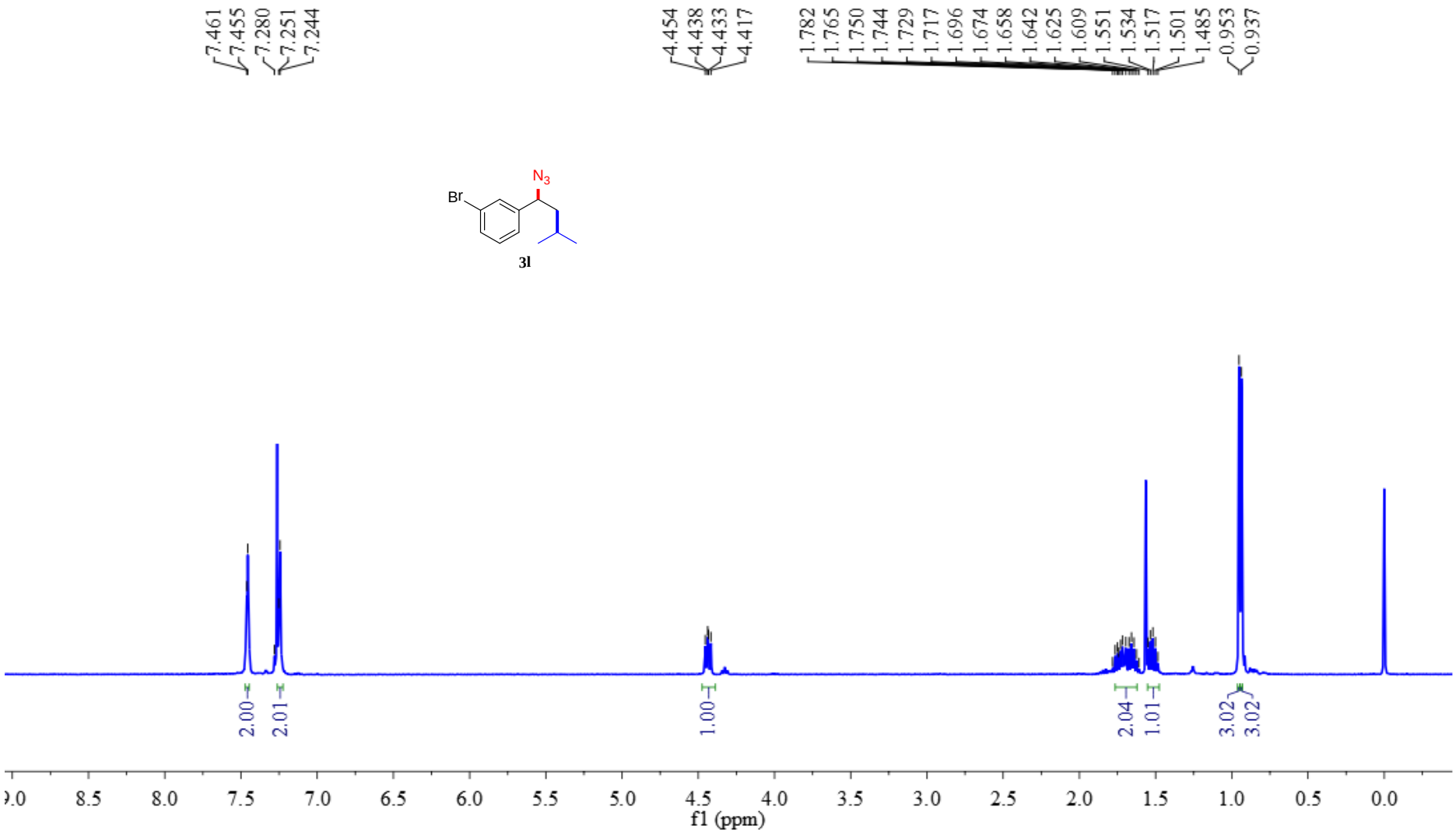
f1 (ppm)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1.717
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1.674
1.658
1.642
1.625
1.609
1.551
1.534
1.517
1.501
1.485
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1.00
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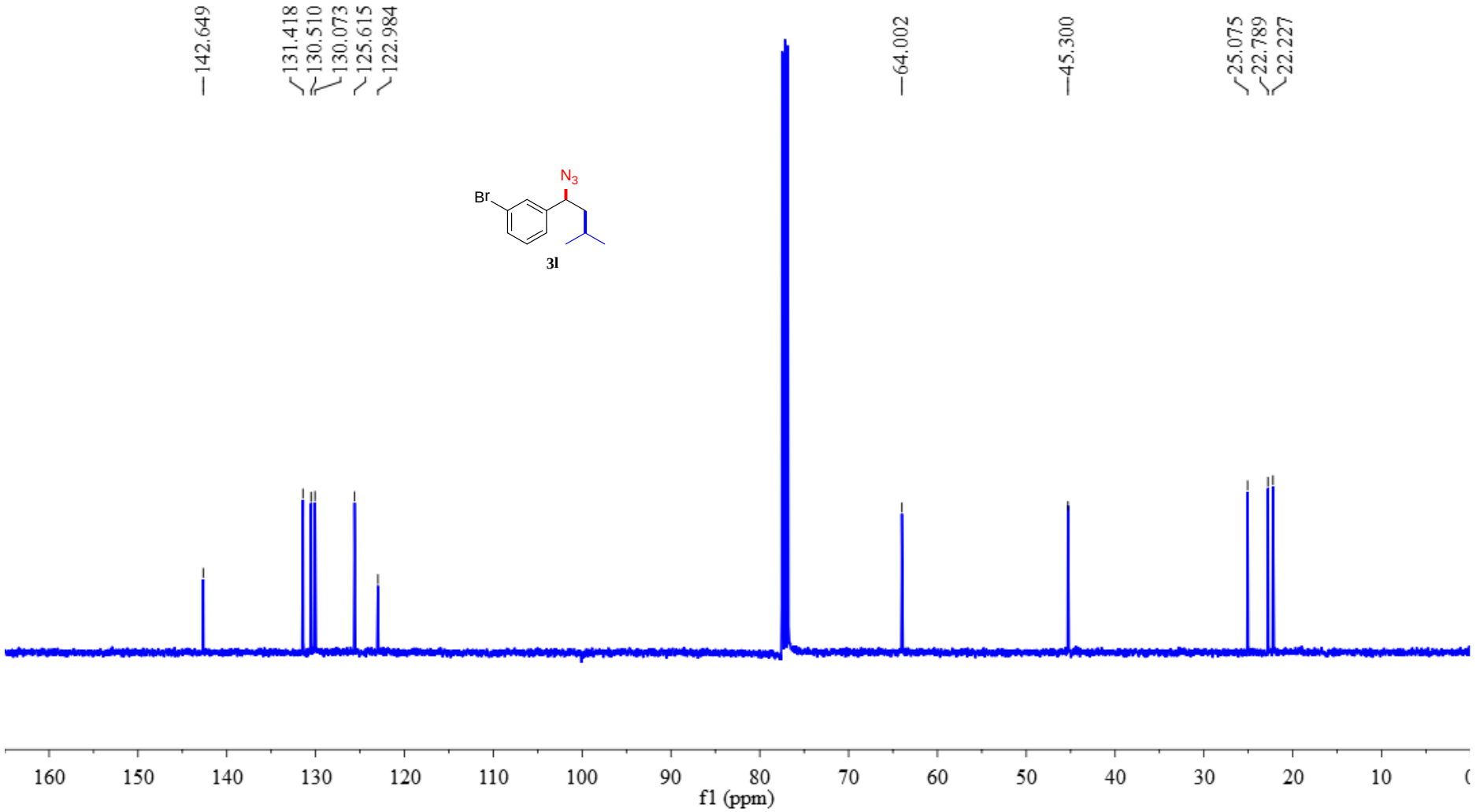
3.02
3.02
f1 (ppm)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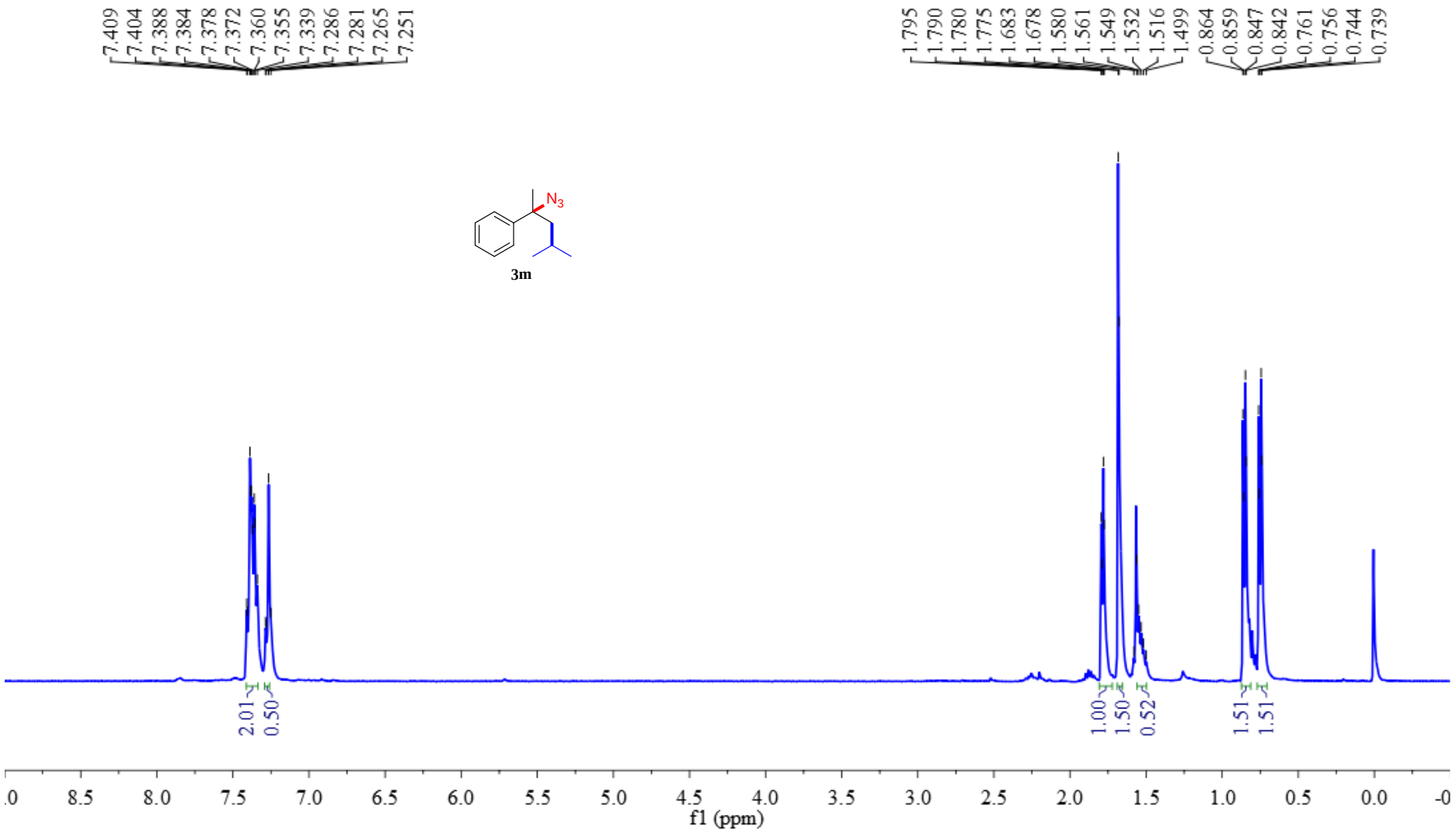
10
f1 (ppm)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1.561
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1.516
1.499
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0.859
0.847
0.842
0.761
0.756
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3m
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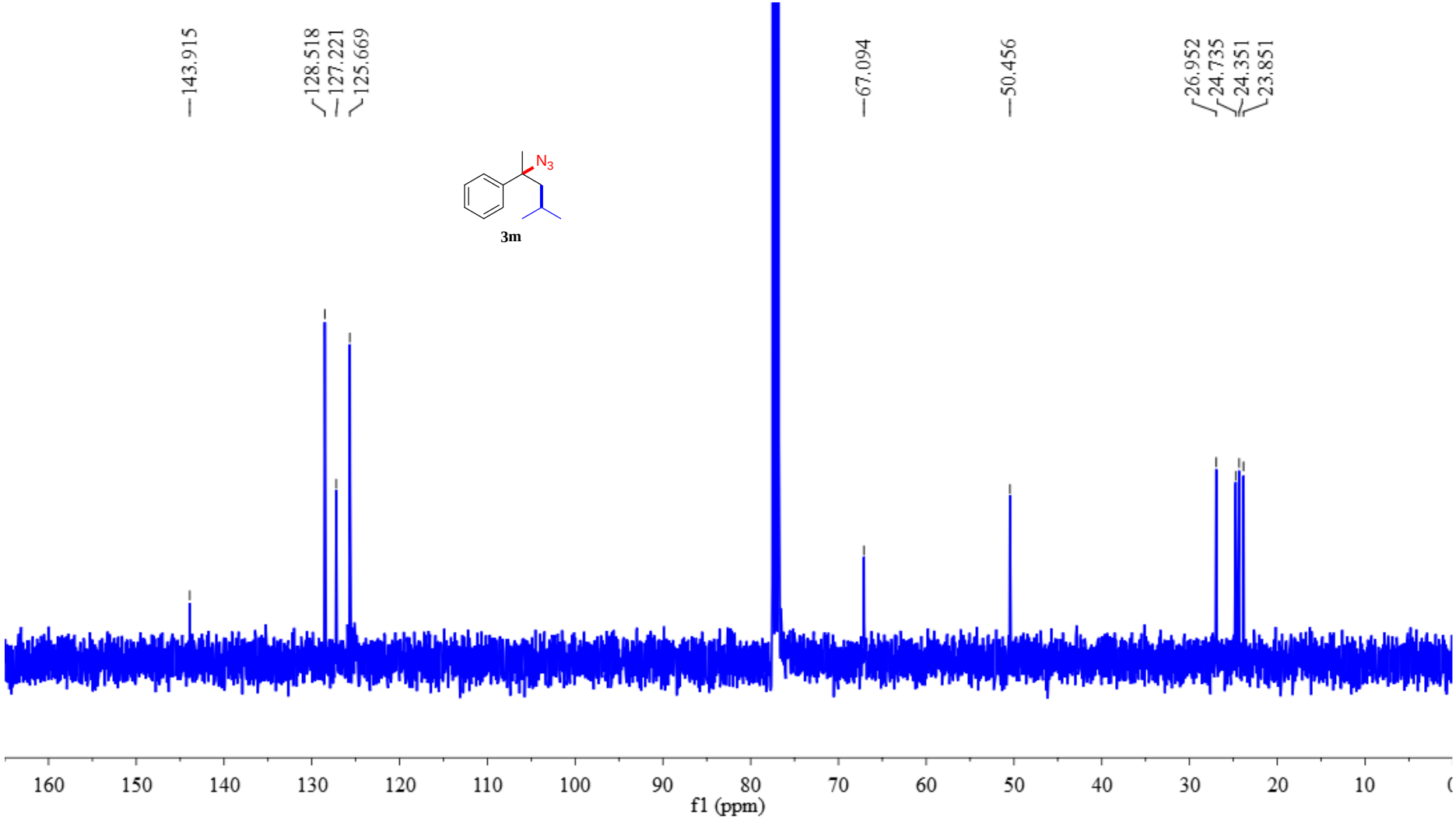
1.51
f1 (ppm)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80
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60
50
40
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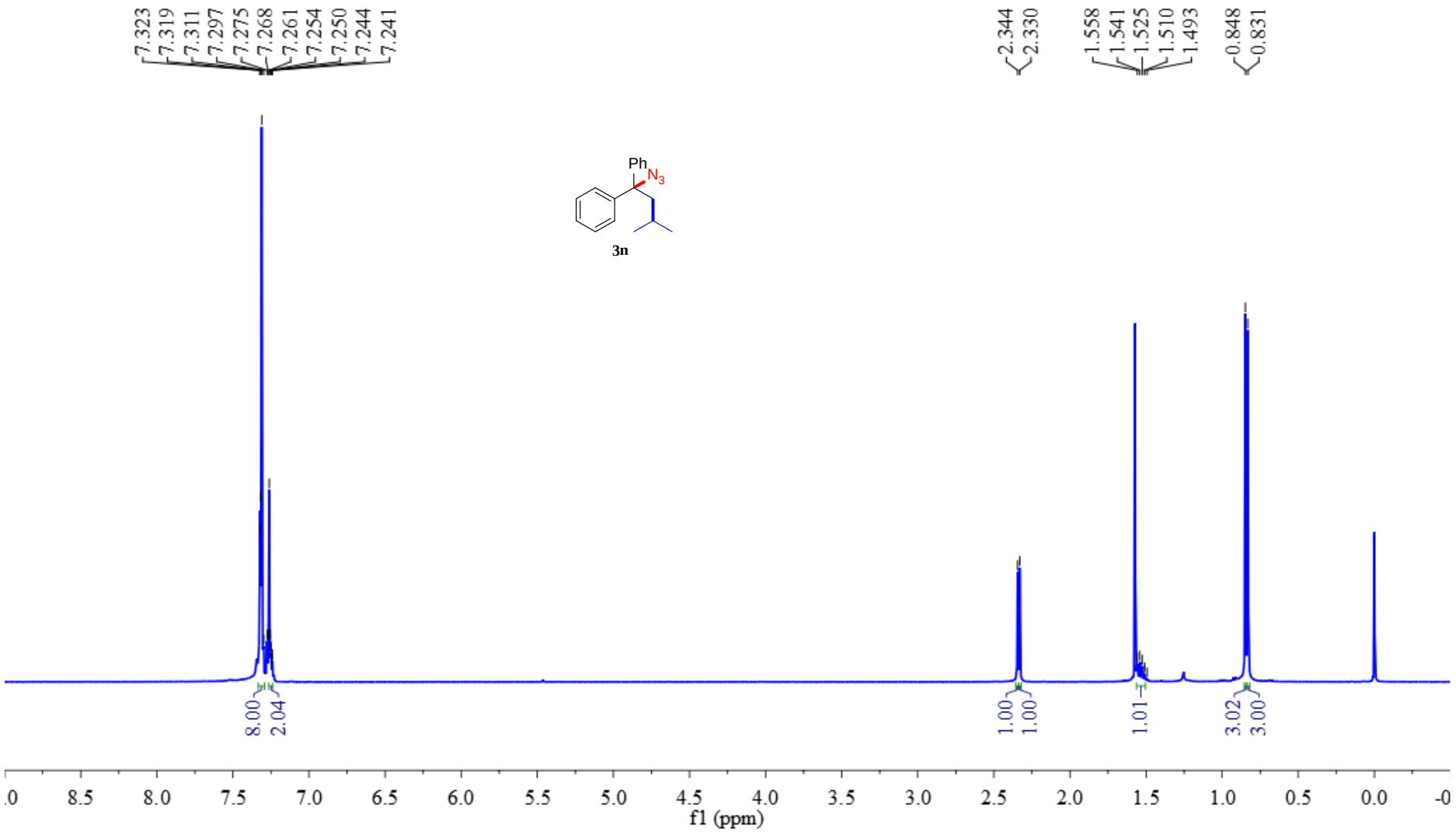
20
10
f1 (ppm)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1.541
1.525
1.510
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Ph
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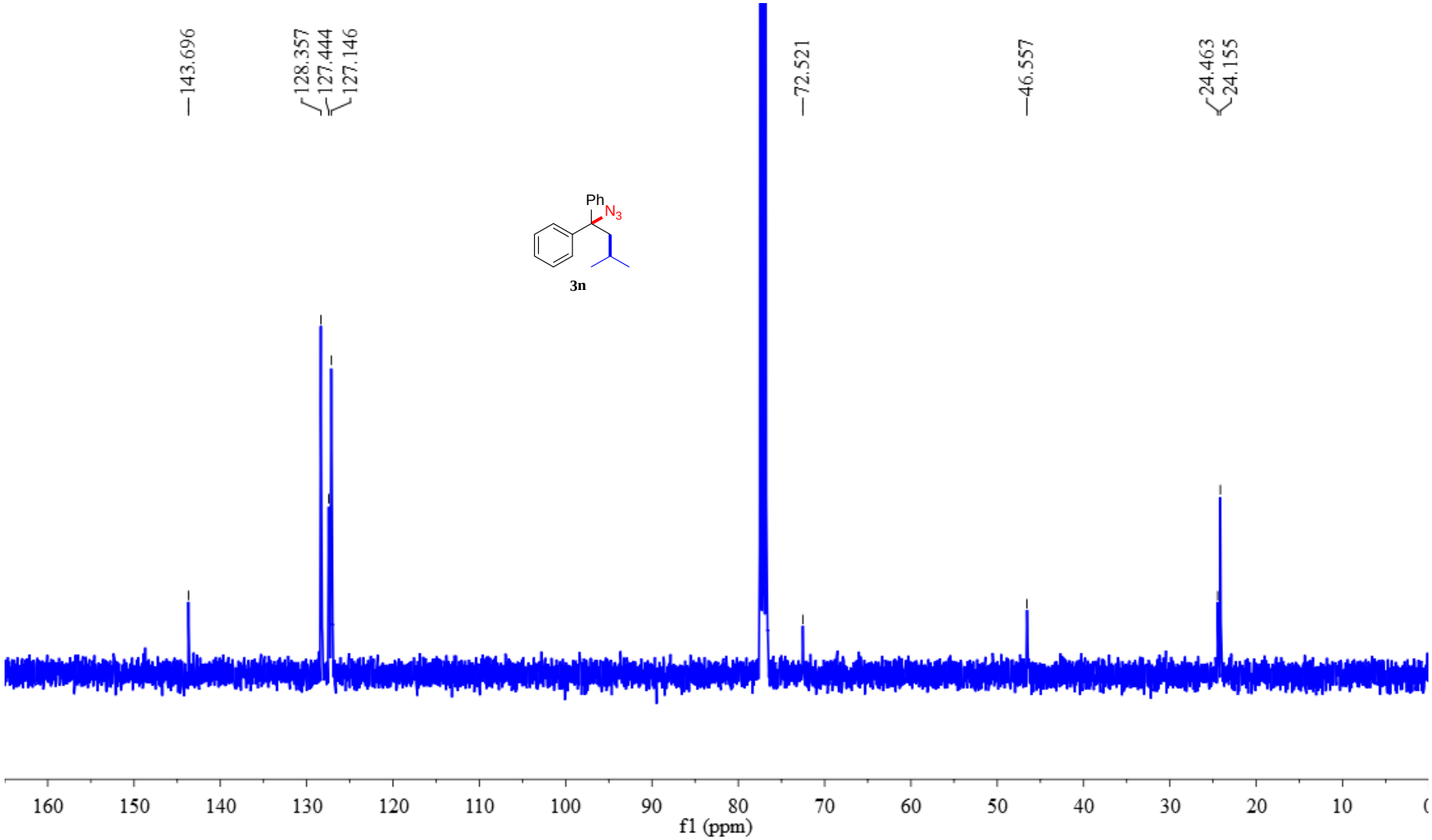
1.00
1.01
3.02
3.00
f1 (ppm)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24.463
24.155
Ph
N3
3n
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120
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80
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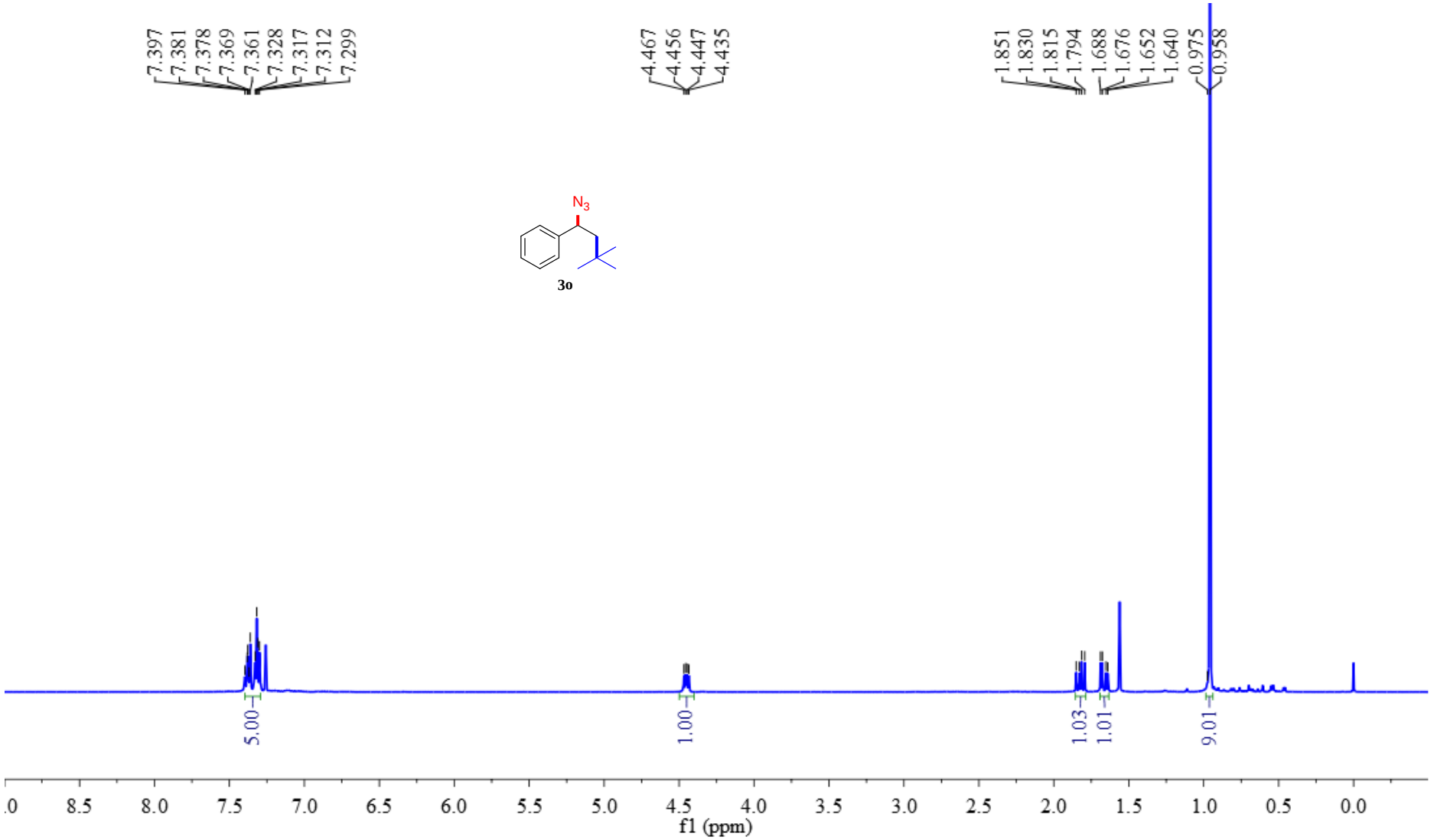
20
10
f1 (ppm)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7.378
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7.317
7.312
7.299
4.467
4.456
4.447
4.435
1.851
1.830
1.815
1.794
1.688
1.676
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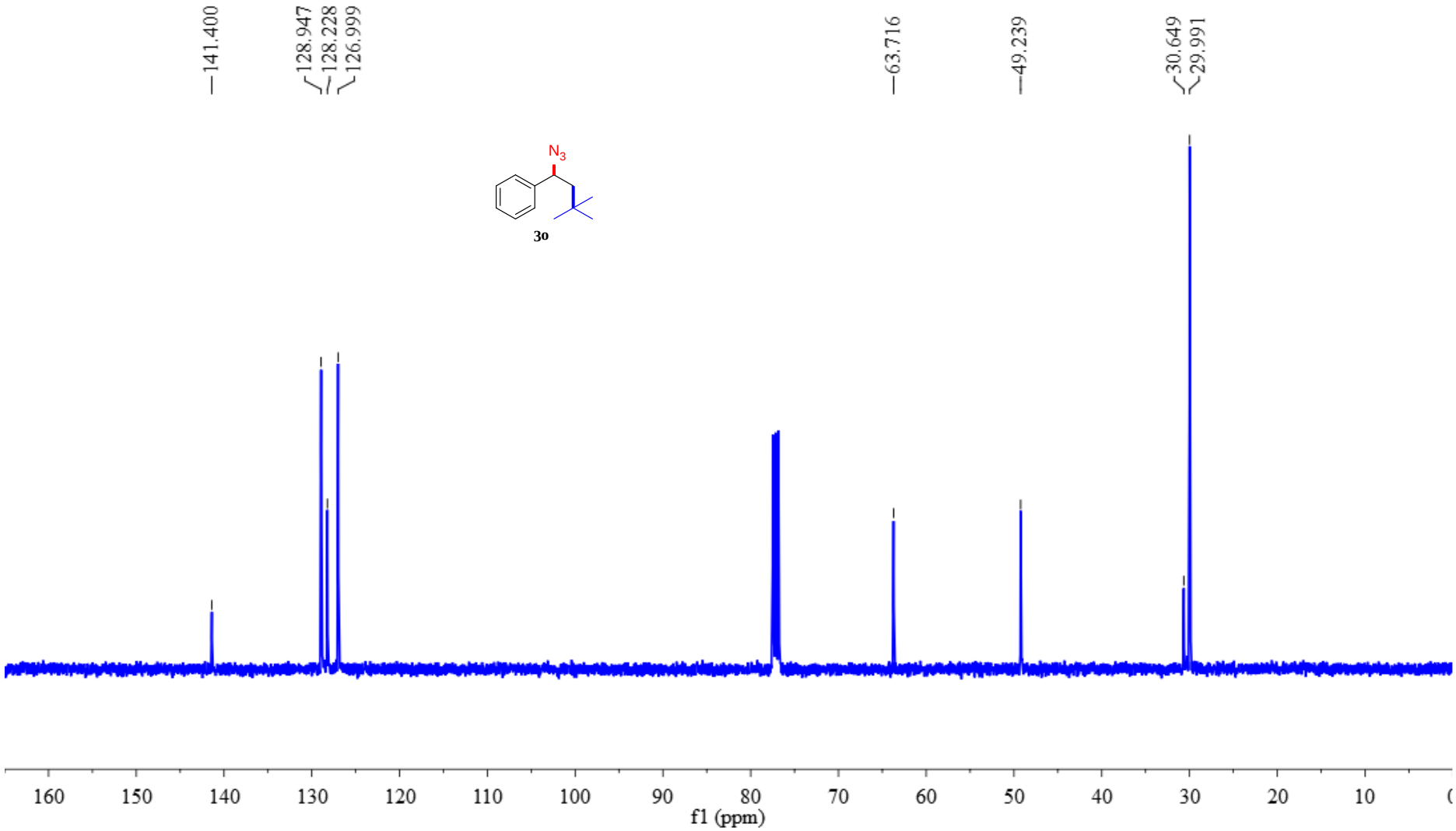
0.958
N3
3o
5.00
1.00
1.03
1.01
9.01
f1 (ppm)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30.649
29.991
N3
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150
140
130
120
110
100
90
80
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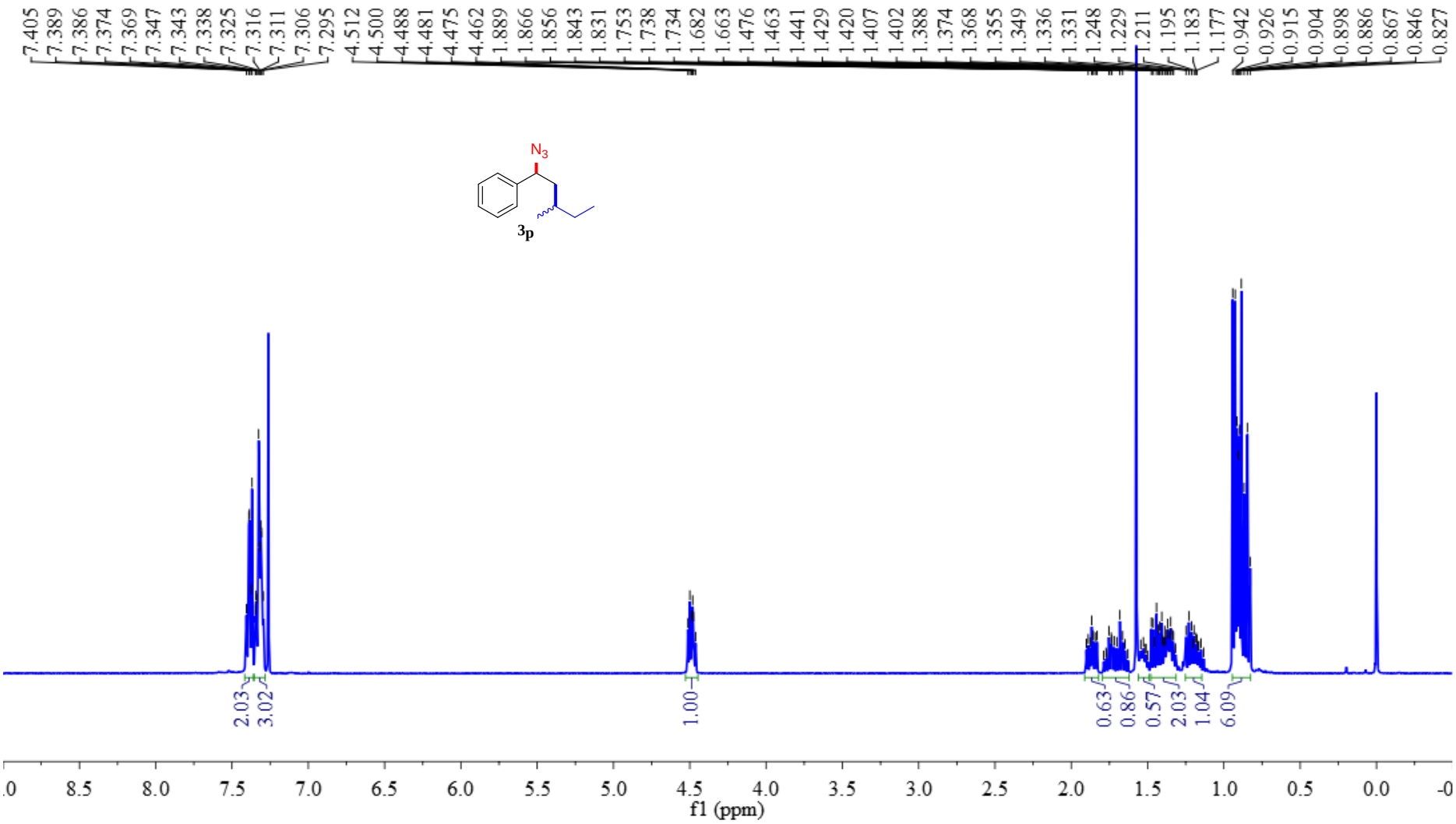
60
50
40
30
20
10
f1 (ppm)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7.386
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7.369
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7.343
7.338
7.325
7.316
7.311
7.306
7.295
4.512
4.500
4.488
4.481
4.475
4.462
1.889
1.866
1.856
1.843
1.831
1.753
1.738
1.734
1.682
1.663
1.476
1.463
1.441
1.429
1.420
1.407
1.402
1.388
1.374
1.368
1.355
1.349
1.336
1.331
1.248
1.229
1.211
1.195
1.183
1.177
0.942
0.926
0.915
0.904
0.898
0.886
0.867
0.846
0.827
N3
3p
2.03
3.02
1.00
0.63
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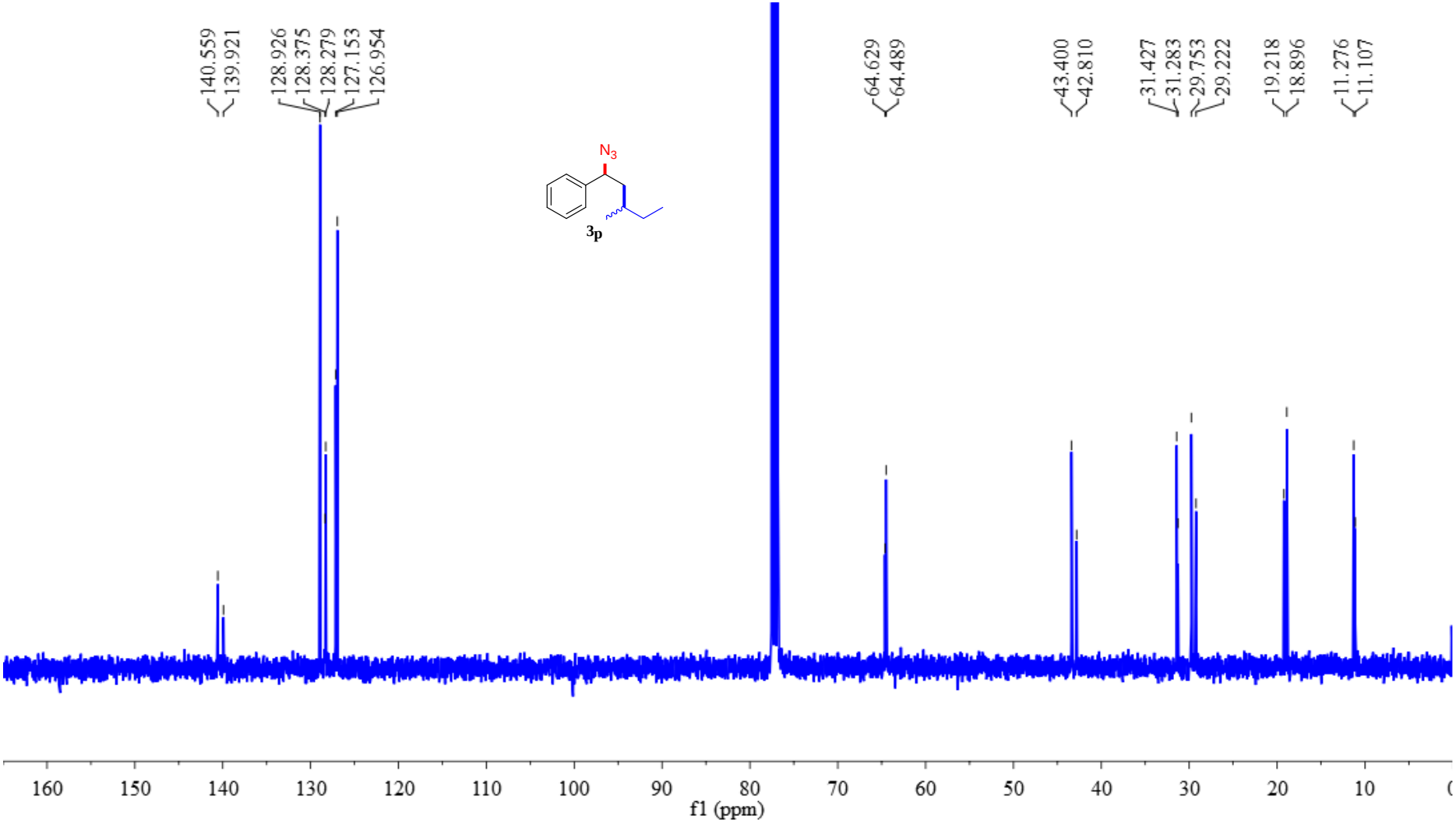
0.57
2.03
1.04
6.09
f1 (ppm)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128.375
128.279
127.153
126.954
64.629
64.489
43.400
42.810
31.427
31.283
29.753
29.222
19.218
18.896
11.276
11.107
N3
3p
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130
120
110
100
90
80
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60
50
40
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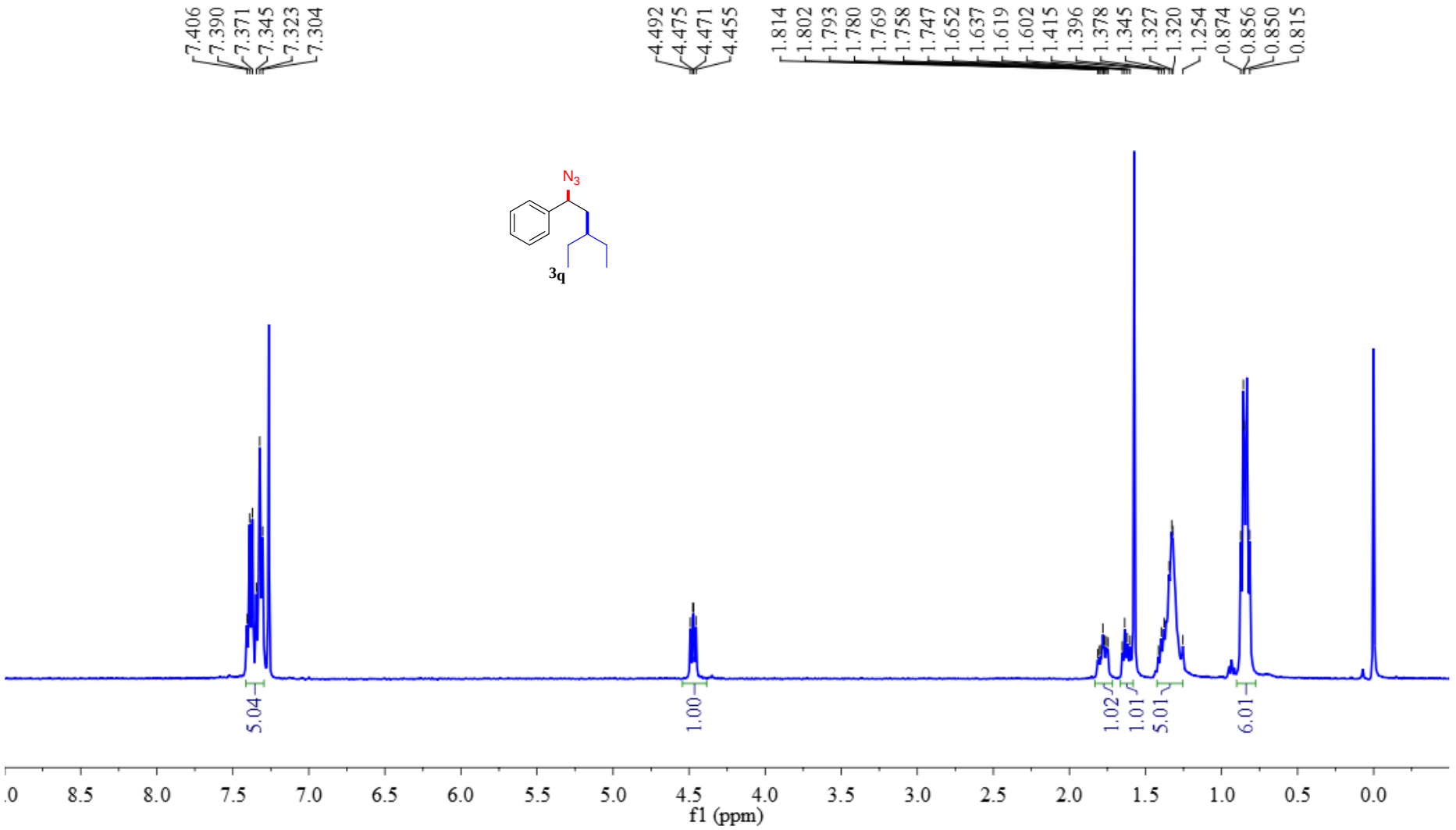
20
10
f1 (ppm)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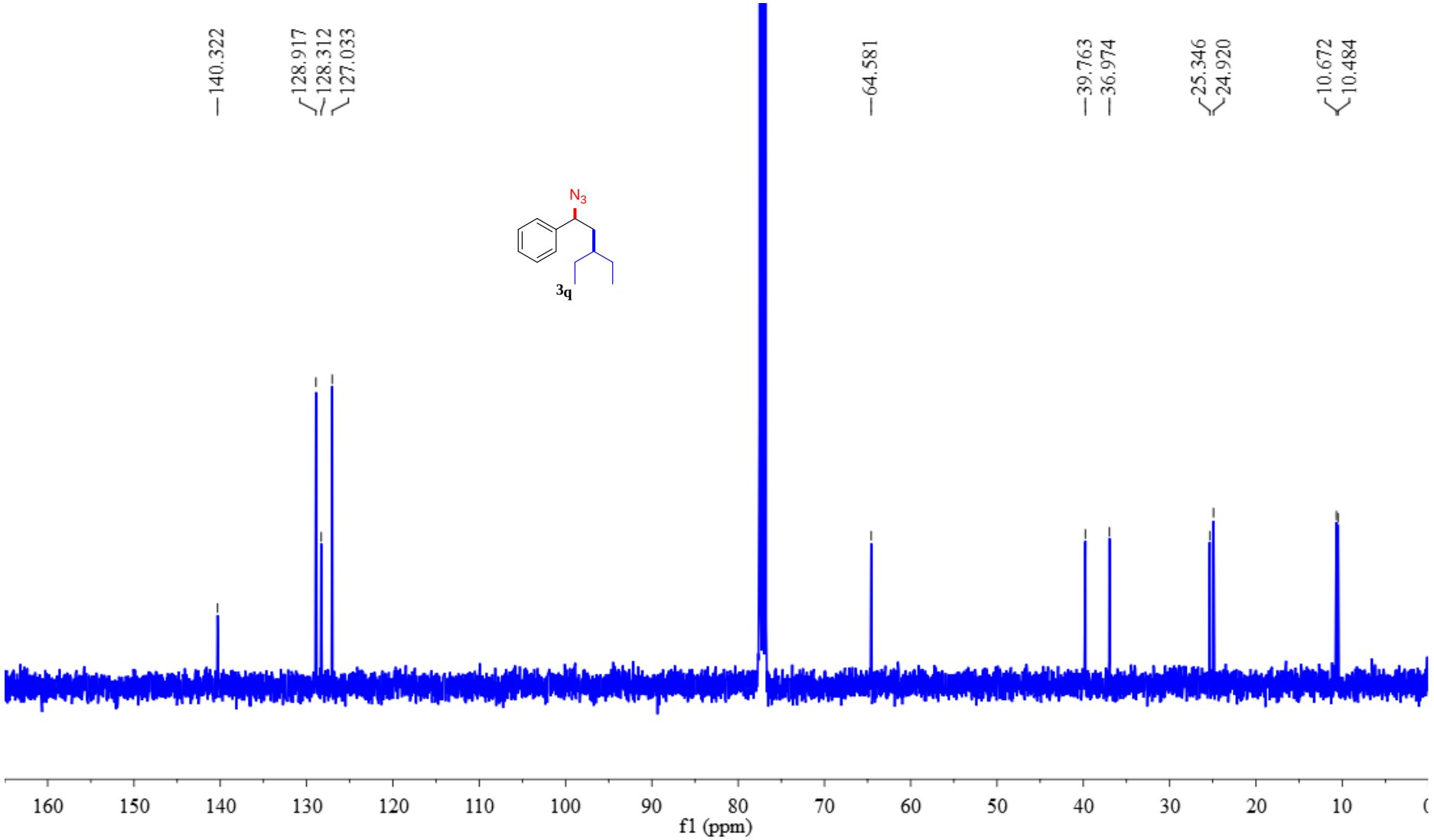
7.390
7.371
7.345
7.323
7.304
4.492
4.475
4.471
4.455
1.814
1.802
1.793
1.780
1.769
1.758
1.747
1.652
1.637
1.619
1.602
1.415
1.396
1.378
1.345
1.327
1.320
1.254
0.874
0.856
0.850
0.815
N3
3q
5.04
1.00
1.02
1.01
5.01
6.01
f1 (ppm)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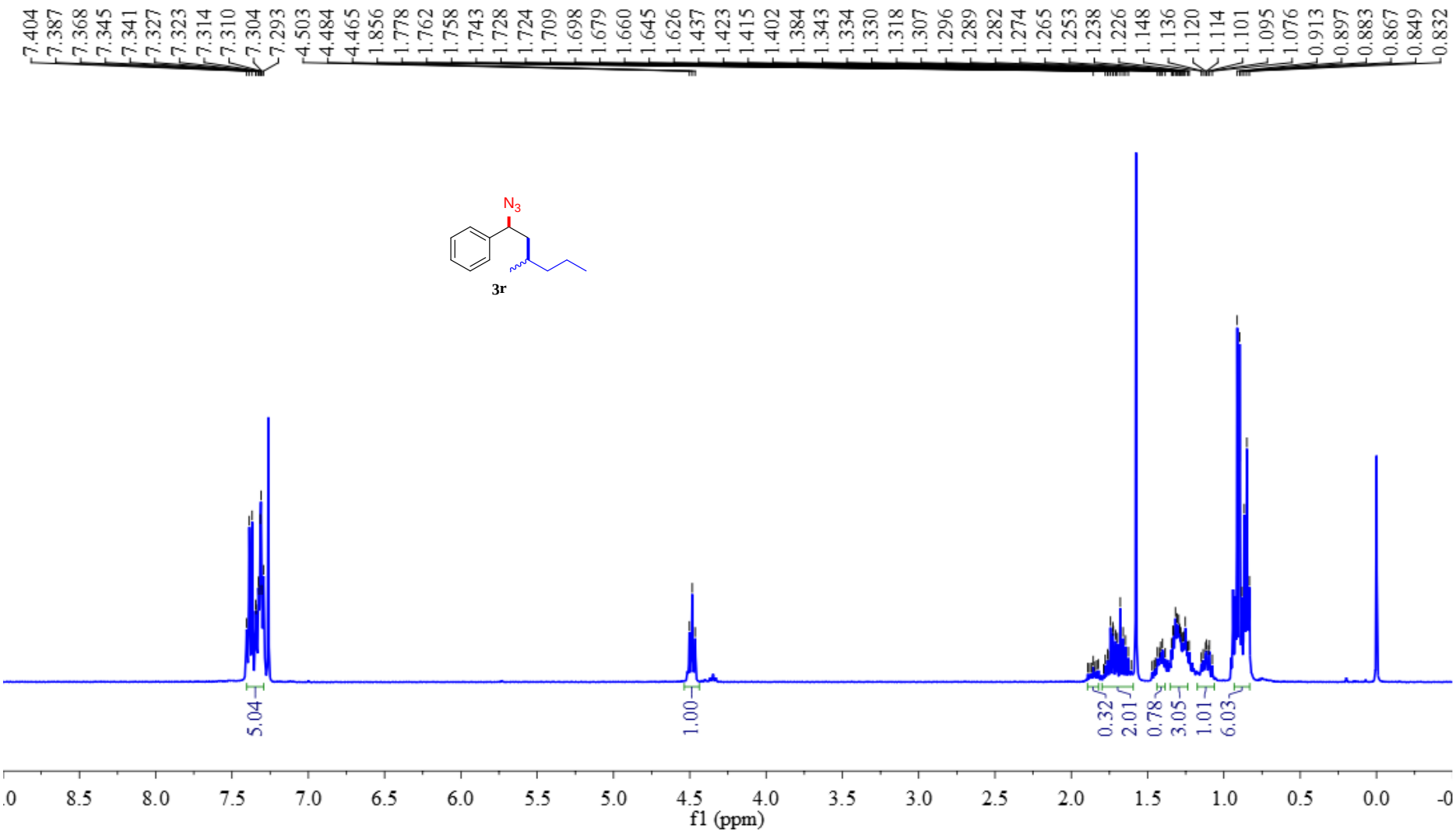
64.581
39.763
36.974
25.346
24.920
10.672
10.484
N3
3q
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)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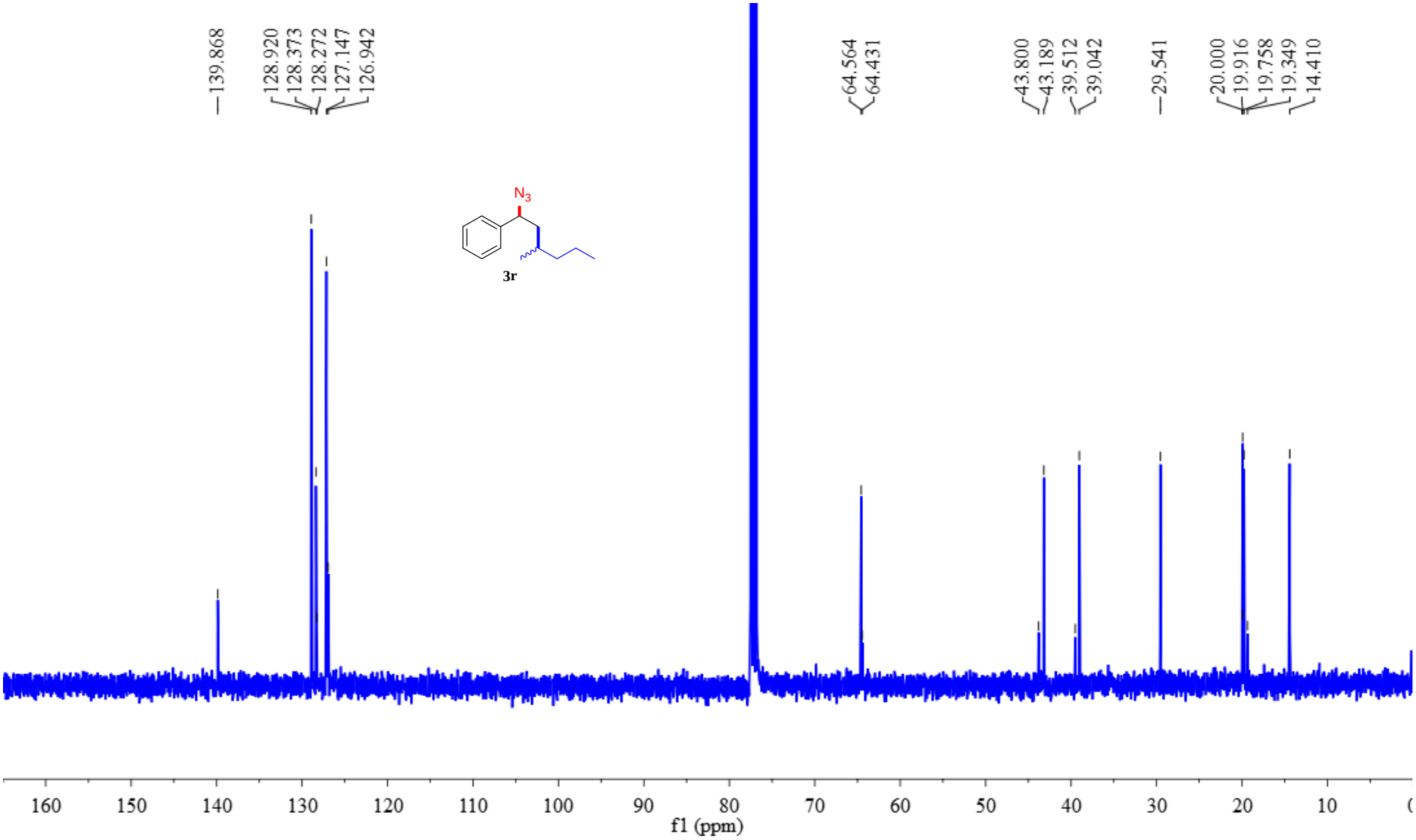
7.327
7.323
7.314
7.310
7.304
7.293
4.503
4.484
4.465
1.856
1.778
1.762
1.758
1.743
1.728
1.724
1.709
1.698
1.679
1.660
1.645
1.626
1.437
1.423
1.415
1.402
1.384
1.343
1.334
1.330
1.318
1.307
1.296
1.289
1.282
1.274
1.265
1.253
1.238
1.226
1.148
1.136
1.120
1.114
1.101
1.095
1.076
0.913
0.897
0.883
0.867
0.849
0.832
N3
3r
5.04
1.00
0.32
2.01
0.78
3.05
1.01
6.03
f1 (ppm)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126.942
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64.431
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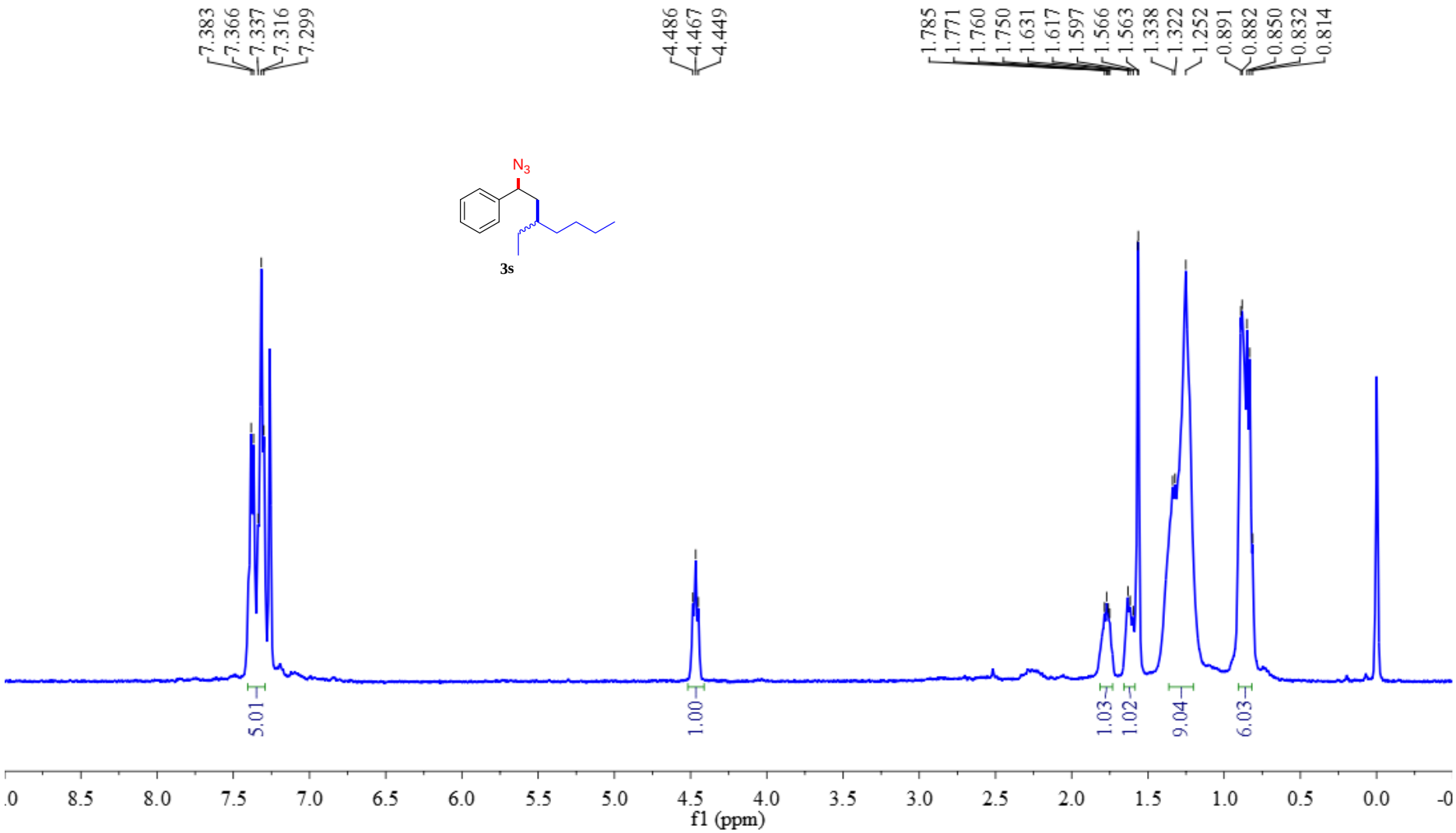
43.189
39.512
39.042
29.541
20.000
19.916
19.758
19.349
14.410
N3
3r
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)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4.467
4.449
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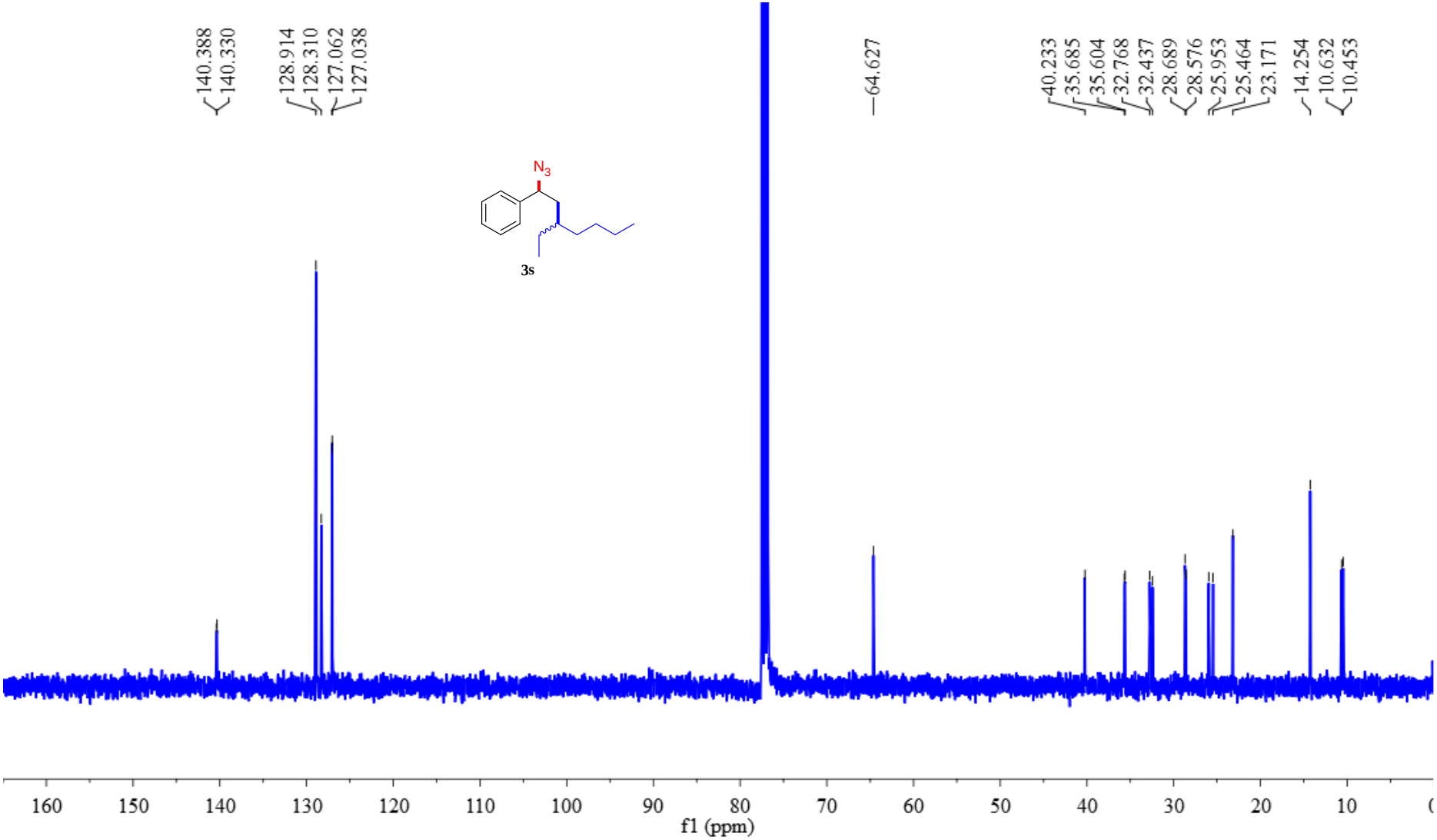
1.771
1.760
1.750
1.631
1.617
1.597
1.566
1.563
1.338
1.322
1.252
0.891
0.882
0.850
0.832
0.814
N3
3s
5.01
1.00
1.03
1.02
9.04
6.03
f1 (ppm)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128.914
128.310
127.062
127.038
64.627
40.233
35.685
35.604
32.768
32.437
28.689
28.576
25.953
25.464
23.171
14.254
10.632
10.453
N3
3s
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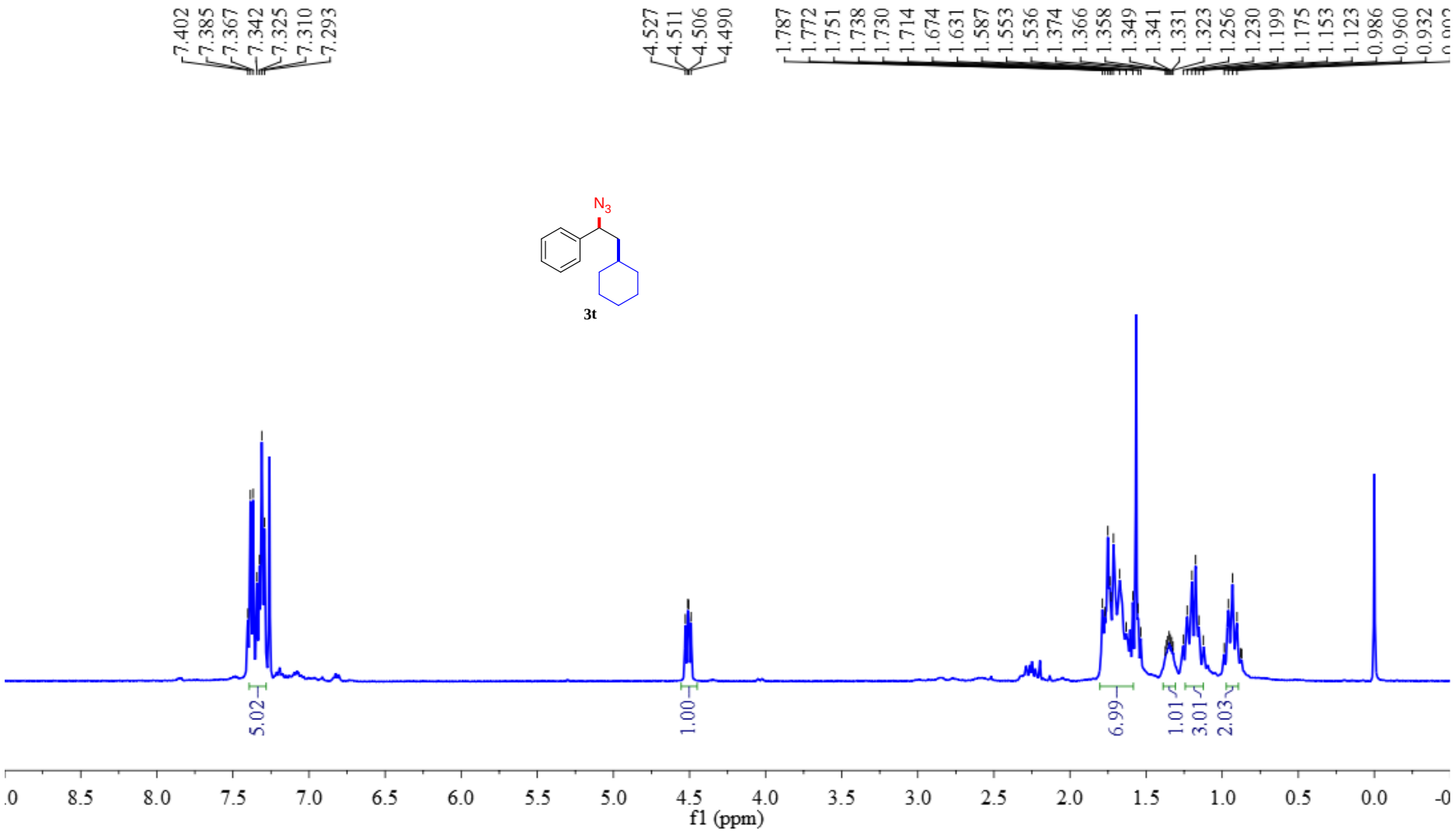
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)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4.490
1.787
1.772
1.751
1.738
1.730
1.714
1.674
1.631
1.587
1.553
1.536
1.374
1.366
1.358
1.349
1.341
1.331
1.323
1.256
1.230
1.199
1.175
1.153
1.123
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3t
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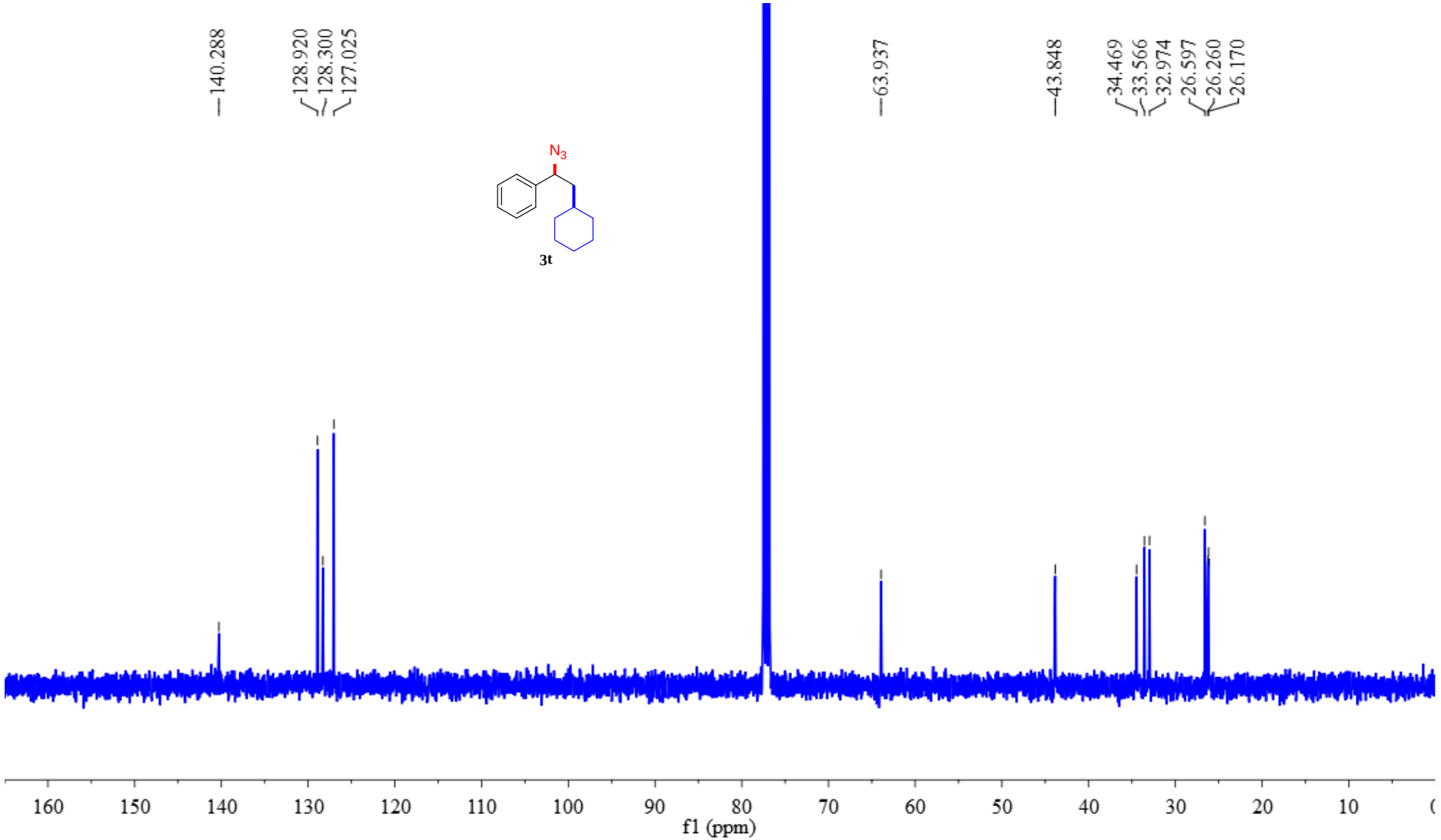
2.03
f1 (ppm)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33.566
32.974
26.597
26.260
26.170
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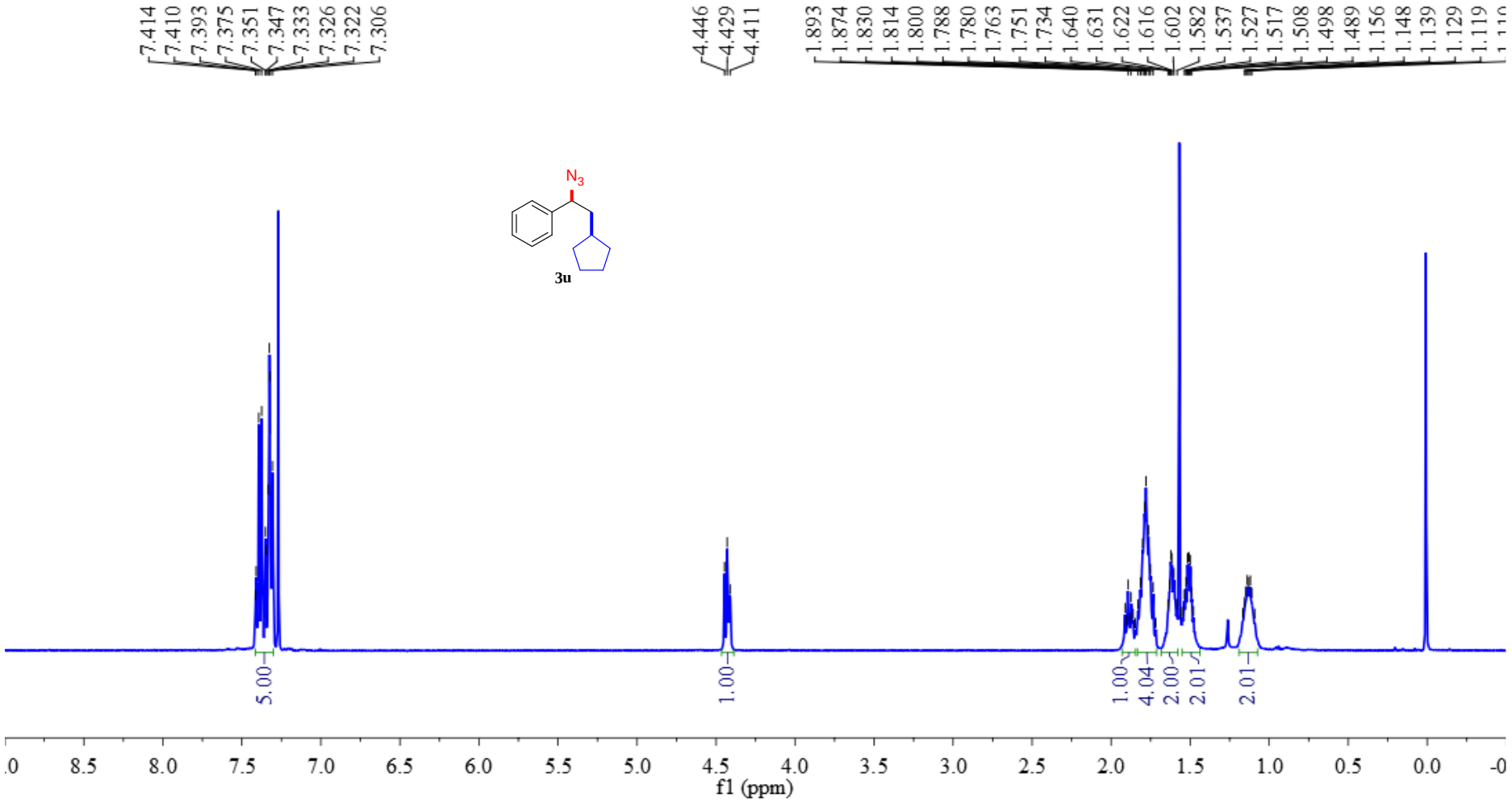
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)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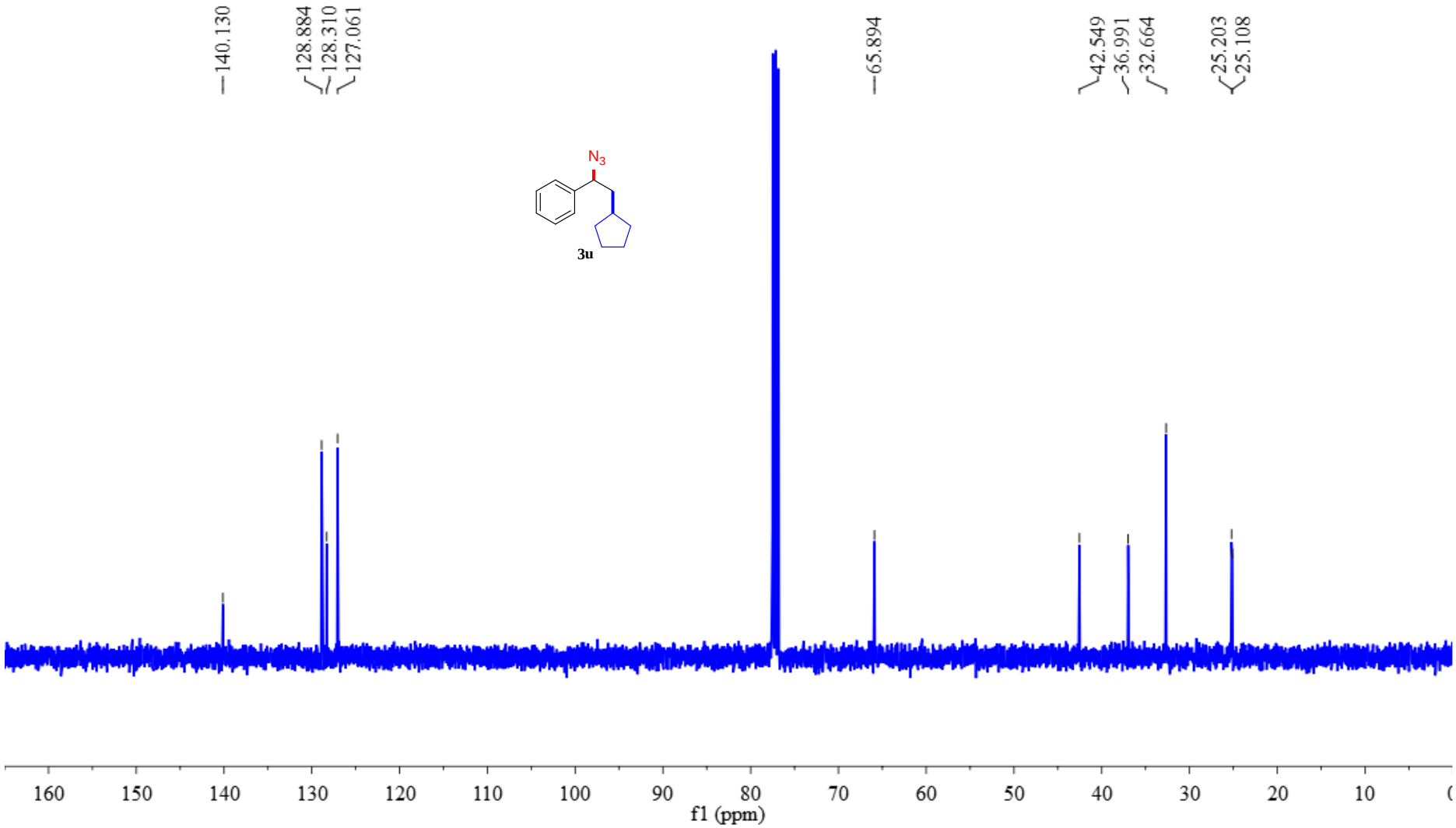
7.351
7.347
7.333
7.326
7.322
7.306
4.446
4.429
4.411
1.893
1.874
1.830
1.814
1.800
1.788
1.780
1.763
1.751
1.734
1.640
1.631
1.622
1.616
1.602
1.582
1.537
1.527
1.517
1.508
1.498
1.489
1.156
1.148
1.139
1.129
1.119
N3
3u
5.00
1.00
1.00
4.04
2.00
2.01
2.01
f1 (ppm)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25.108
N3
3u
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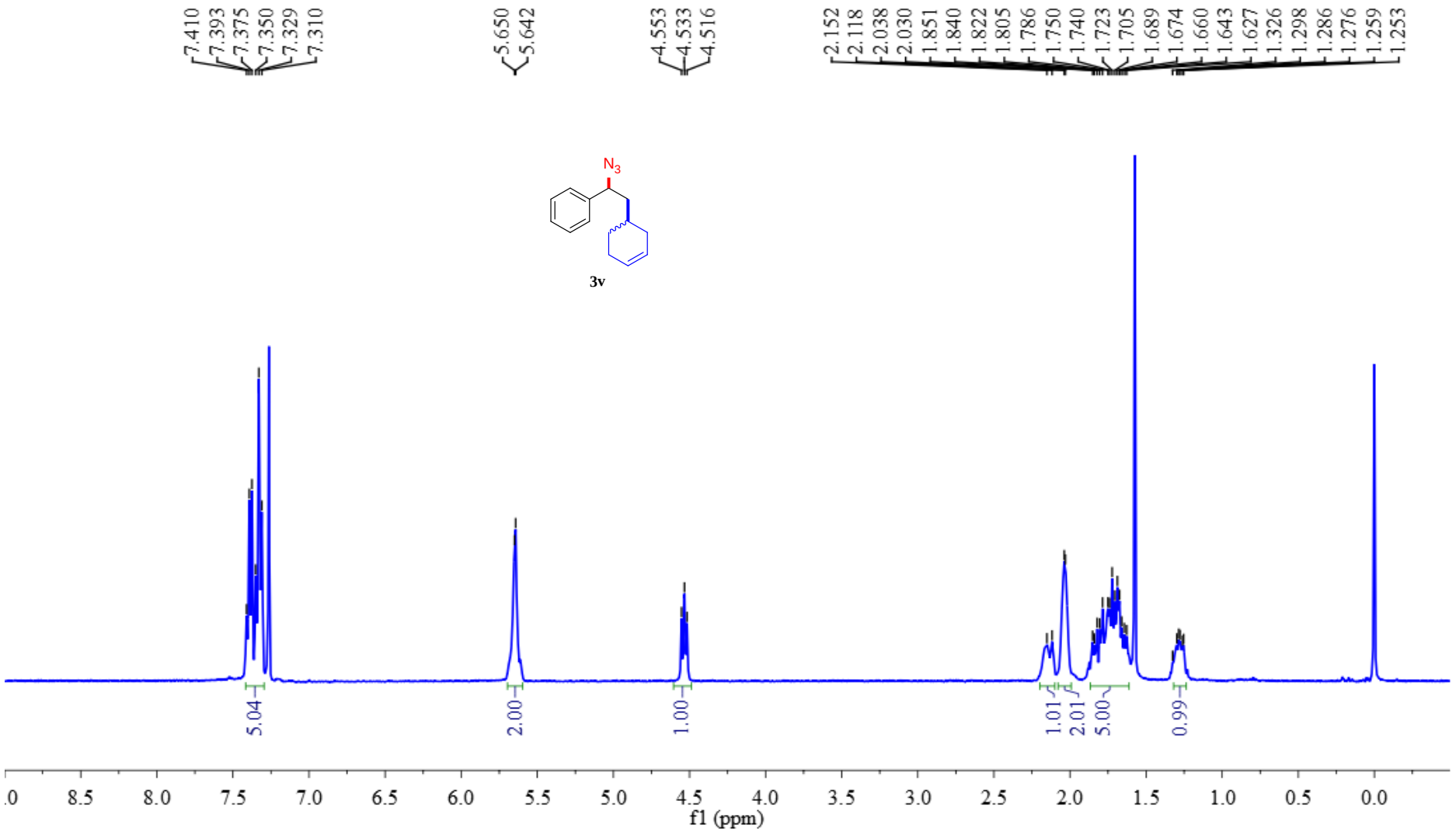
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)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5.642
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4.533
4.516
2.152
2.118
2.038
2.030
1.851
1.840
1.822
1.805
1.786
1.750
1.740
1.723
1.705
1.689
1.674
1.660
1.643
1.627
1.326
1.298
1.286
1.276
1.259
1.253
N3
3v
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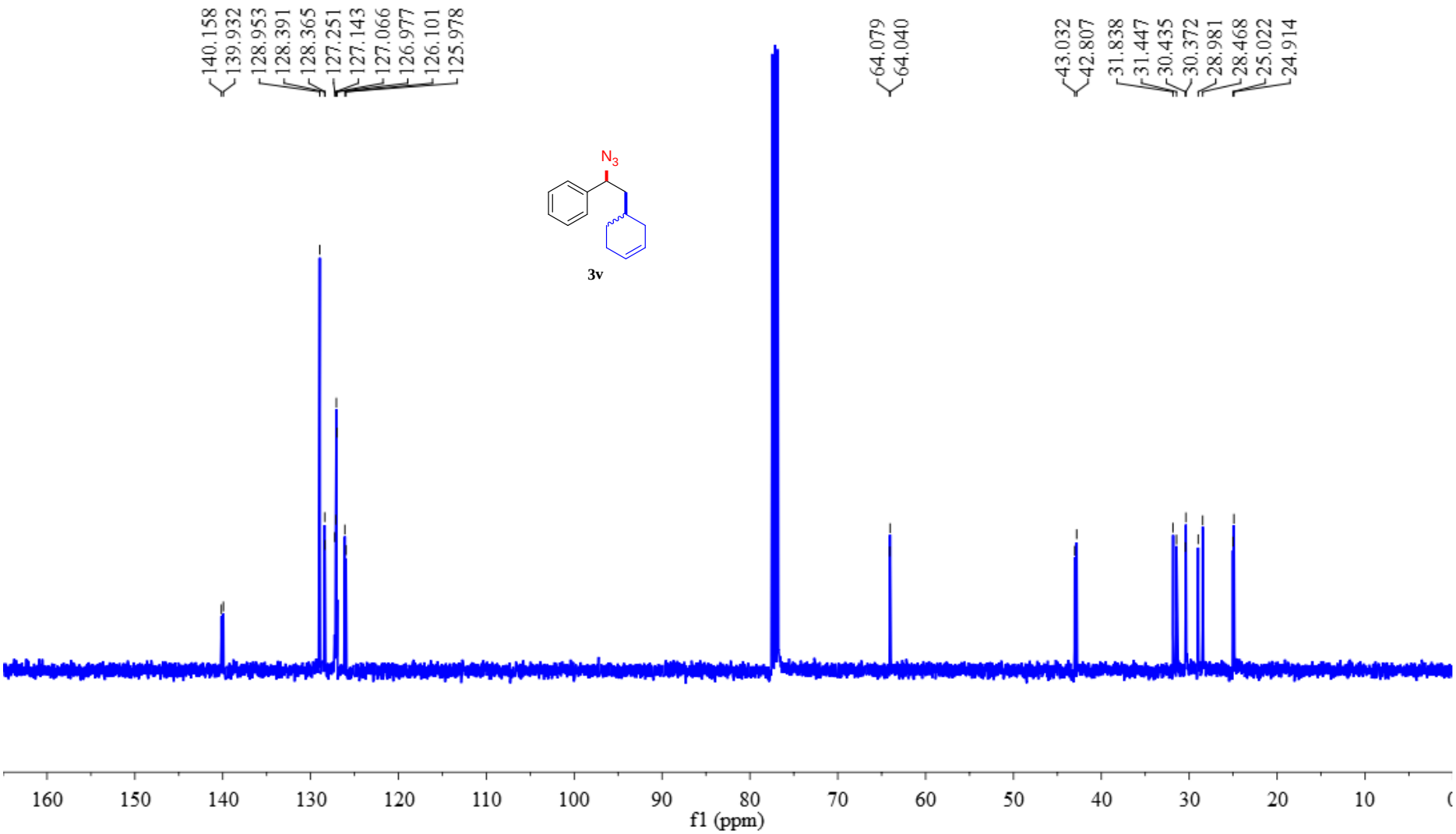
2.00
1.00
1.01
2.01
5.00
0.99
f1 (ppm)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64.040
43.032
42.807
31.838
31.447
30.435
30.372
28.981
28.468
25.022
24.914
N3
3v
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130
120
110
100
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80
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60
50
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20
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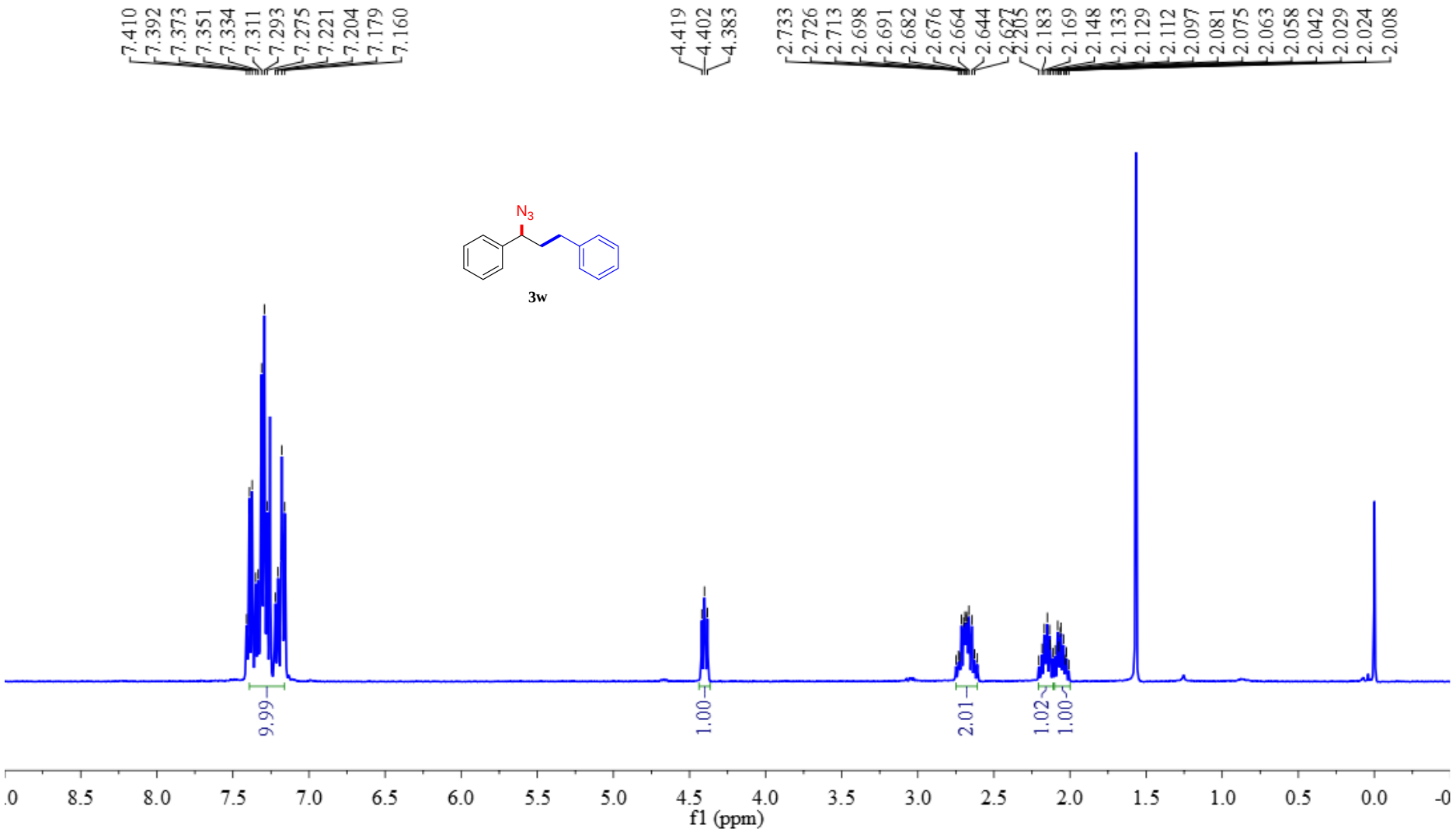
f1 (ppm)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7.275
7.221
7.204
7.179
7.160
4.419
4.402
4.383
2.733
2.726
2.713
2.698
2.691
2.682
2.676
2.664
2.644
2.627
2.265
2.183
2.169
2.148
2.133
2.129
2.112
2.097
2.081
2.075
2.063
2.058
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2.024
2.008
N3
3w
9.99
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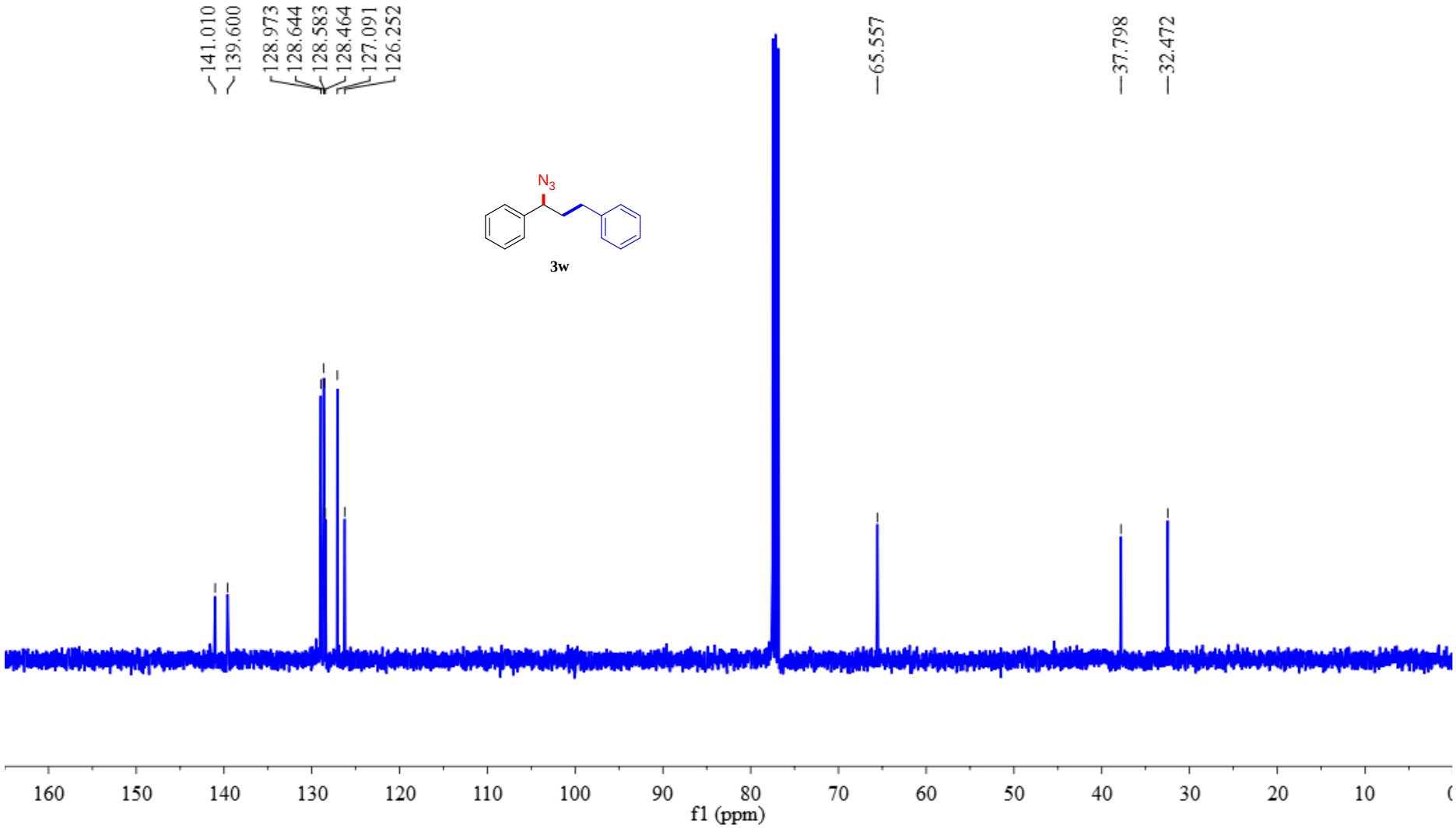
2.01
1.02
1.00
f1 (ppm)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126.252
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37.798
32.472
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3w
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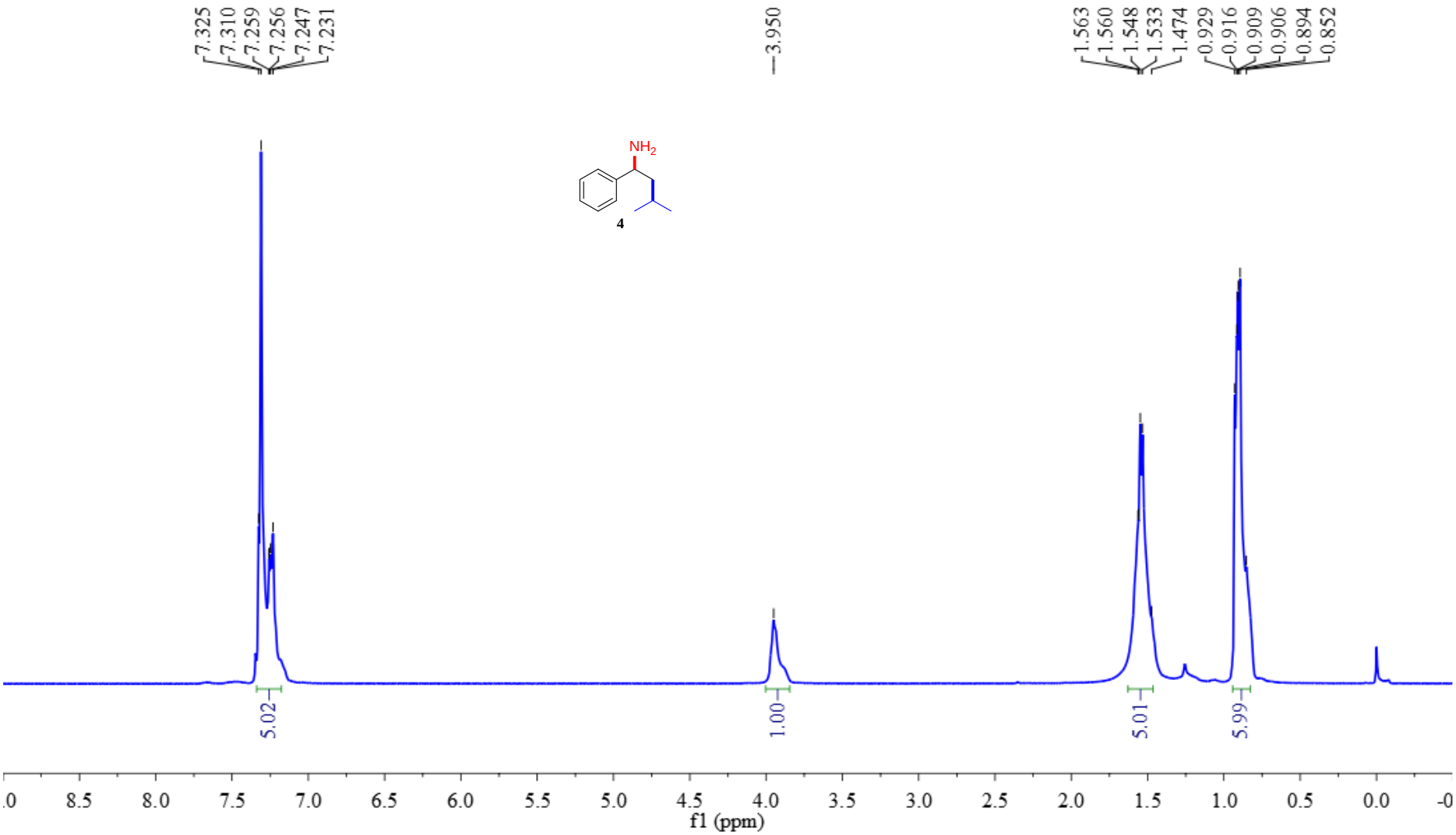
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)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7.231
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1.548
1.533
1.474
0.929
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0.894
0.852
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4
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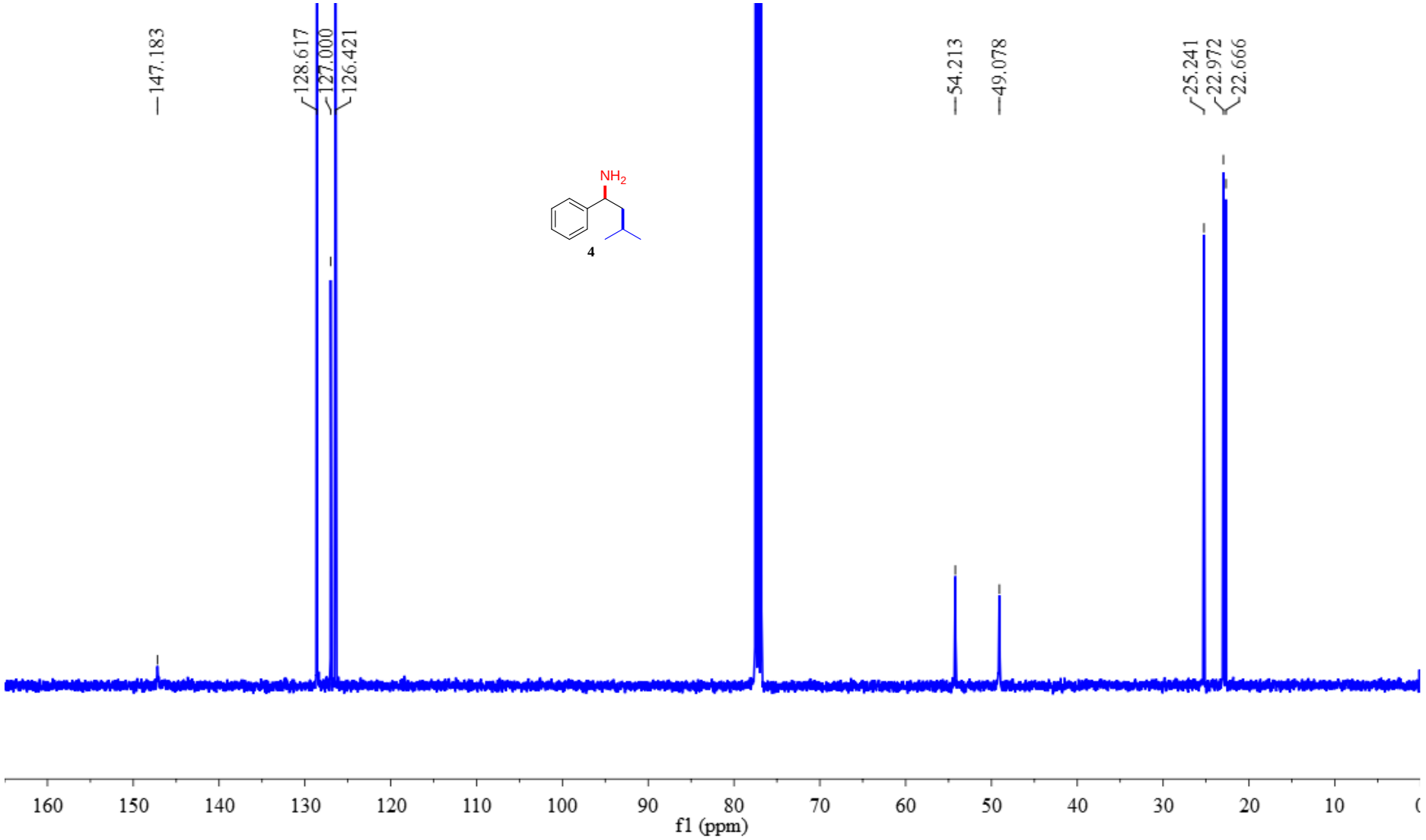
5.99
f1 (ppm)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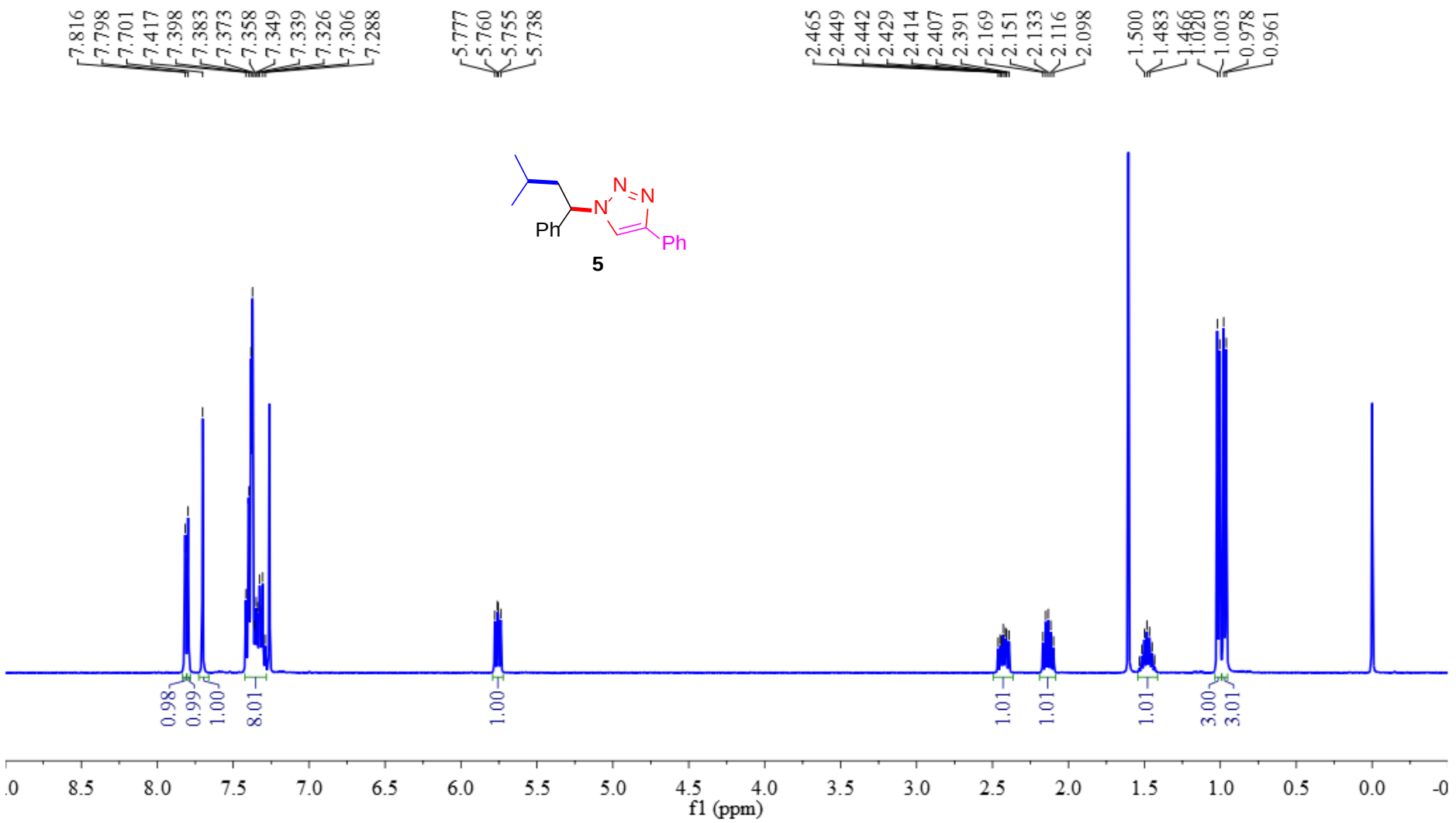
f1 (ppm)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7.306
7.288
5.777
5.760
5.755
5.738
2.465
2.449
2.442
2.429
2.414
2.407
2.391
2.169
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2.133
2.116
2.098
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1.483
1.466
1.020
1.003
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0.961
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N
N
Ph
Ph
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1.01
3.00
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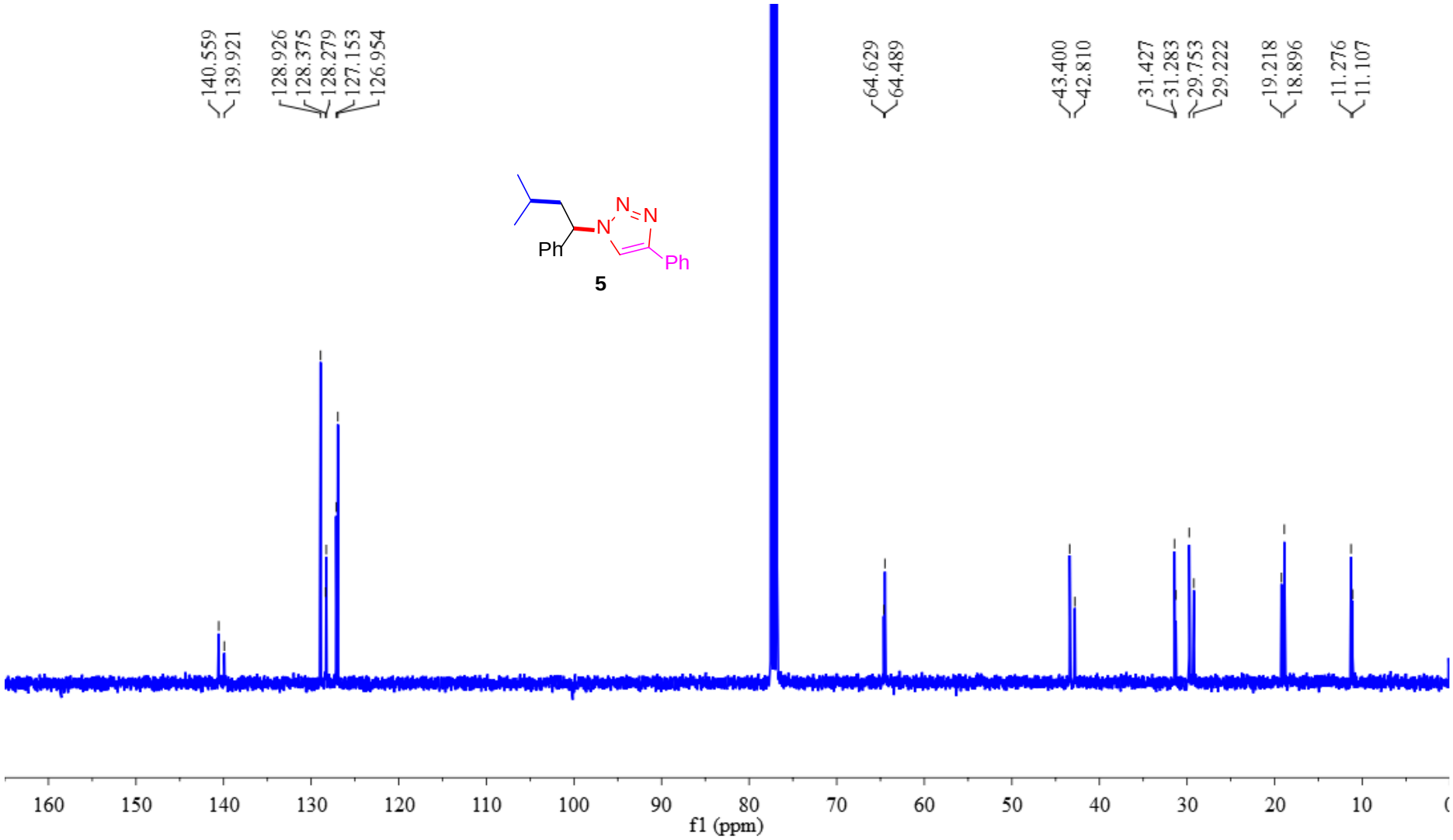
f1 (ppm)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43.400
42.810
31.427
31.283
29.753
29.222
19.218
18.896
11.276
11.107
Ph
N
N
N
Ph
5
160
150
140
130
120
110
100
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30
20
10
f1 (ppm)