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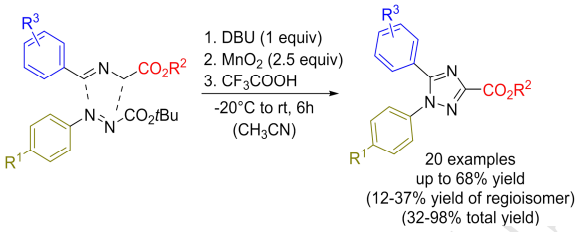

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Cycloaddition reactions of glycine imine anions to phenylazocarboxylic esters – a new access to 1,3,5-trisubstituted 1,2,4-triazoles

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ABSTRACT

Phenylazocarboxylic *tert*-butyl esters have recently been shown to be highly versatile building blocks due to their ability to undergo nucleophilic aromatic substitutions under mild conditions, particularly well with [^{18}F]fluoride, and to act as precursors for aryl radicals. In this article, we now report first examples for cycloaddition reactions to phenylazocarboxylates. In a one-pot reaction with readily accessible glycine imines, a variety of highly substituted 1,2,4-triazoles could be obtained with an unexpected preference for one regioisomer.

1. Introduction

1,2,4-Triazoles represent a common structural motif in a broad variety of commercial products,[1] including pharmaceuticals and agrochemicals such as rilmazafone[2] and flupoxam.[3] Which synthetic strategy is chosen for the preparation of a particular triazole – from the numerous options and variants being available today - mainly depends on the required substitution pattern.[4] Syntheses of 3,4,5-trisubstituted 1,2,4-triazoles,[5] for example, most often proceed via acylated amidrazones, which finally undergo condensation reactions.[6] Alternatively, the 3,4,5-substitution pattern can be established by reactions of 1,3,4-oxadiazoles with amines, in which the oxygen atom in the heterocyclic system is exchanged for a substituted nitrogen atom.[7] Regarding the second major subgroup of 1,3,5-trisubstituted 1,2,4-triazoles,[8] condensation reactions are applicable as well,[9] but cycloaddition strategies now play a more important role.[10]

Our interest in cycloaddition reactions was due to recent studies on phenylazocarboxylic esters **1** (Scheme 1), which were shown to be versatile bifunctional reagents as they are able to undergo mild nucleophilic aromatic substitutions and a large variety of reactions proceeding via aryl radicals.[11,12] Up to date, however, only single nucleophilic attacks[13] on the N-N double bond of phenylazo-carboxylates **1** or related phenylazosulfones[14] have been reported with organobismut compounds,[13a] organolithium and Grignard reagents[13b-d,14] as well as arylboronic acids[13e] and enamines.[13f,g]

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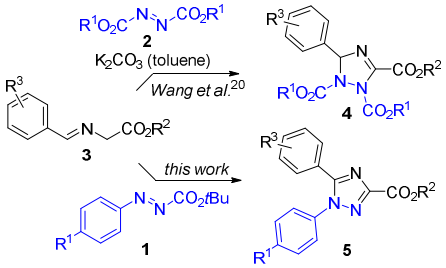


Scheme 1. Cycloaddition reactions of glycine imines **3** to azodicarboxylates **2**[20] and phenylazocarboxylates **1**.

Cycloadditions to azo compounds, on the other hand, so far appear to be limited to activated *N*-benzoylphenyldiazenes,[15] diazirines,[16] azobenzenes[17] and most importantly, to the group of dialkyl azodicarboxylates **2**. Azodiesters **2** have thereby successfully been allowed to react with such diverse reagents as α-isocyano-esters,[18] azidoacrylates[19] or glycine imines[20] to give 1,2,4-triazolines.[21] A generalized example illustrating the base-mediated preparation of triazolines **4** from glycine imines **3** and azodiesters **2** is depicted in Scheme 1.[20] Whereas the fact that no regioisomeric products can be formed from glycinates **3** and azodiesters **2** is certainly advantageous, reaction conditions for the further conversion of the highly functionalized triazolines **4** into triazoles have yet to be developed.

Against this background, it was an interesting question whether the reactivity of phenylazocarboxylates **1** would at all be sufficient to allow cycloadditions. In this article, we now report first examples for [3+2]-cycloadditions of glycine imines **3** to phenyl-azocarboxylates **1** leading to triazoles **5**, as well as insights into the effects governing the regioselectivity of these reactions.

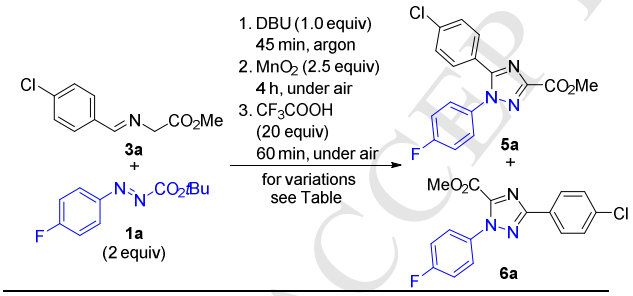
2. Results and discussion

The first experiments on the feasibility of cycloaddition reactions were carried out with 4-fluorophenylazocarboxylate **1a** and *N*-4-chlorobenzylidene glycinate **3a** (Table 1) or methyl 2-isocyano-3-phenylpropanoate,[22] as the latter starting materials had successfully been applied as dipoles in reactions with azo-diesters.[18,20]

These early attempts readily confirmed DBU as preferred additive compared to potassium carbonate[20] with regard to conversion of the starting materials, but complex mixtures of products were yet obtained from **1a** and **3a**, which could not be well analyzed or separated due to the low stability of the compounds they contained. As several analyses of those product mixtures by ^{1}H-NMR had suggested the presence of at least one triazoline,[23] we reasoned that an oxidant such as manganese dioxide might be helpful to convert this intermediate to a more stable triazole. Furthermore, trifluoroacetic acid was added to facilitate the cleavage of the *tert*-butyloxycarbonyl (Boc) group on the heterocyclic core and thus to allow final aromatization.[24]

Results from the improved one-pot procedure leading to triazoles **5a** and **6a**, as well as subsequently performed variations, are summarized in Table 1. The first attempt, in which all sub-steps were carried out in acetonitrile at room temperature, gave triazoles **5a** and **6a** in a ratio of 2.5:1 and in a combined yield of 80% (entry 1). As the initial attack of deprotonated glycine imine **3a** onto **1a** appeared to determine the regioselectivity of the reaction, we varied the temperature at that particular stage. Unexpectedly, these changes had almost no effect on the overall yield and regioselectivity (entries 2-4).

Table 1. Optimization of reaction conditions.

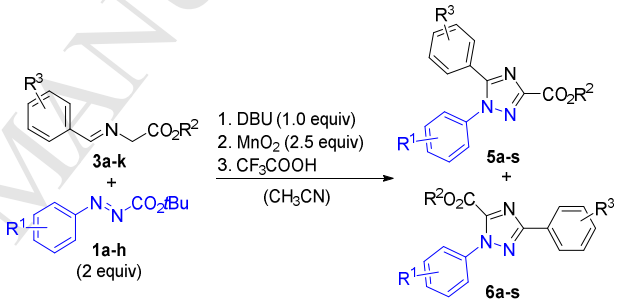


entry	solvent	variations[a]	yield **5a**:**6a** (%:%)
1	CH_3CN	1st step at rt	57:23
2	CH_3CN	1st step at 40°C	51:23
3	CH_3CN	1st step at 0°C	56:30
4	CH_3CN	1st step at -20°C	54:28
5	CH_3CN	1st step at -20°C, MS, DBU (1 eq.)	**58:36**
6	Toluene	1st step at rt	9:16
7	MTBE	1st step at rt	1:4
8	CH_3CN	1st step at 0°C, then O_2 atmosphere[c]	47:16
9	CH_3CN	1st step at rt, then O_2 atmosphere	48:17

[a] The second and third step of the procedure were conducted at rt. [b]Yields determined by ^{1}H-NMR using 1,3,5-trimethoxybenzene as internal standard. [c]Reaction carried out in the absence of MnO_2.

An improvement in yield could however be observed by the addition of a larger amount of DBU and molecular sieves (4Å) to reduce moisture (entry 5). Experiments in the less polar solvents toluene[20] and methyl *tert*-butyl ether (MTBE) gave far lower yields and a reversed regioselectivity, which points to the fact that the stabilization of charged intermediates might play a critical role in the mechanism (entries 6 and 7). Attempts to influence the regioselectivity by accelerating the oxidation step by an oxygen-atmosphere produced **5a** and **6a** in a slightly better ratio of 3:1, but with a remarkably decreased overall yield. In further experiments, Lewis acids such as $TiCl_4$ or BF_3 were added to tune the reactivity of the deprotonated glycine imine **3a** towards an azomethine ylide bearing a positively charged nitrogen atom.[25] All these reactions however gave far lower yields as well as they did not lead to improvements in regioselectivity. Azomethine ylides were not yet investigated as alternative starting materials for **3a**, since they could only lead to triazolium salts as final products. With the best conditions available (Table 1, entry 5), we explored the scope and the limitations of the access to triazoles.

Table 2. Scope and limitations of the cycloaddition to phenylazocarboxylic esters **1**.



entry	azocarboxylate **1**: R^1 =	glycine imine **3**: R^2 =	R^3 =	triazoles[a] **5**:**6** (%:%)[b]
1	**1a**: 4-F	**3a**: Me	4-Cl	**5a**:**6a** (58:36)
2	**1a**: 4-F	**3b**: Et	4-Cl	**5b**:**6b** (41:30)
3	**1a**: 4-F	**3c**: *t*Bu	4-Cl	**5c**:**6c** (48:16)[c]
4	**1a**: 4-F	**3d**: Me	H	**5d**:**6d** (42:12)[c]
5	**1a**: 4-F	**3e**: Et	2,4-Cl_2	**5e**:**6e** (12:20)
6	**1a**: 4-F	**3f**: Me	4-Br	**5f**:**6f** (68:25)
7	**1a**: 4-F	**3g**: Me	3,4-$(OMe)_2$	**5g**:**6g** (41:18)
8	**1b**: 4-Br	**3h**: Me	4-F	**5h**:**6h** (51:29)
9	**1b**: 4-Br	**3c**: *t*Bu	4-Cl	**5i**:**6i** (62:27)
10	**1b**: 4-Br	**3i**: Me	3-Br	**5j**:**6j** (52:23)
11	**1b**: 4-Br	**3j**: Me	Ph	**5k**:**6k** (41:25)
12	**1c**: 4-I	**3k**: Me	4-CN	**5l**:**6l** (61:37)
13	**1c**: 4-I	**3f**: Me	4-Br	**5m**:**6m** (58:22)
14	**1c**: 4-I	**3i**: Me	3-Br	**5n**:**6n** (58:26)
15	**1d**: 4-F, 2-Me	**3a**: Me	4-Cl	**5o**:**6o** (22:33)
16	**1e**: 2,4-Cl_2	**3a**: Me	4-Cl	**5p**:**7**[e] (40:32)
17	**1f**: 4-(4-FPhO)	**3a**: Me	4-Cl	**5q**:**6q** (55:19)[d]
18	**1g**: 4-NO_2	**3a**: Me	4-Cl	**5r**:**8**[e] (32:17)[c]
19	**1h**: 4-NO_2, 3-OMe	**3c**: *t*Bu	4-Cl	**5s**:**6s** (47:24)

[a]Standard conditions: glycine imine **3** (1 mmol), azocarboxylate **1** (2 equiv), DBU (1 equiv), CH_3CN (5 mL), -15°C, 45 min, then MnO_2 (2.5 equiv), rt, 4 h, then CF_3COOH, rt, 60 min. [b]Yields after purification by column chromatography. [c]First step at rt. [d]First step at 0°C. [e]Decarboxylated products **7** and **8** obtained instead of **6p** and **6r** (Scheme 3).

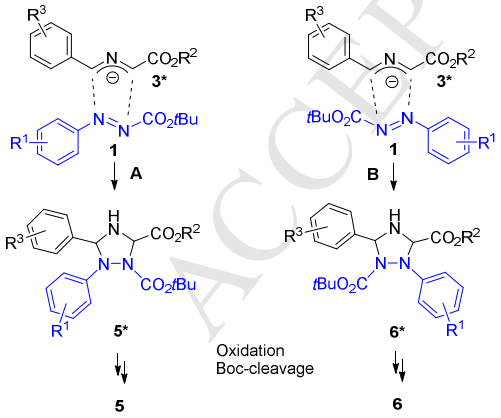
In the first series of experiments, 4-fluorophenylazocarboxylic ester **1a** reacted with a variety of glycine imines **3a-g** (entries 1-7). Methyl ester **3a** hereby gave a better yield than its corresponding ethyl or *tert*-butyl esters (entries 1-3), and the only low yield, which was combined with a reversed regioselectivity, resulted from the 2,4-dichlorophenyl-substituted glycine imine **3e** (entry 5). Triazole **5d** (entry 4) was further helpful to unambiguously assign the regioisomers **5** and **6** through its comparison with literature data.[10]

In the next series, 4-bromo- and 4-iodophenylazocarboxylates **1b**,**c** could be shown to be well suited precursors for triazoles **5h-n** (entries 8-14), with the biphenyl-4-carboxaldehyde-derived glycine imine **3j** leading to the only yield lower than 50%. Within the structural variations on the phenylazocarboxylate (entries 15-19), it was interesting to see that neither the weakly donating phenoxy substituent (entry 17) nor the strongly electron-withdrawing nitro group (entry 18) had been able to significantly change the ratio of regioisomers through directing the attack of anion **3*** to the phenylazocarboxylate **1** (pathways **A** and **B**, Scheme 2). Only steric hindrance, with *ortho*-substituents being placed on either the aryl group of **1** (entry 5) or **3** (entries 15, 16) showed an impact, as it complicates the formation of triazole **5** (Scheme 2, left) while the formation of triazole **6** remains more or less unaffected (Scheme 2, right).

A nearly quantitative combined yield of **5** and **6** could only be reached with the acceptor-substituted glycine imine **3k** (entry 12). Whereas the glycine imine anions **3*** can reliably, although not regioselectively, be trapped even with unactivated phenylazocarboxylates such as **1c**, only an electrophilic imine, as it is present in **3k**, allows both pathways **A** and **B** to proceed efficiently.

In the second part of the sequence the intermediate 1,2,4-triazolidines **5*** and **6*** are oxidized along with cleavage of the *tert*-butyloxycarbonyl group to give the final products **5** and **6**.

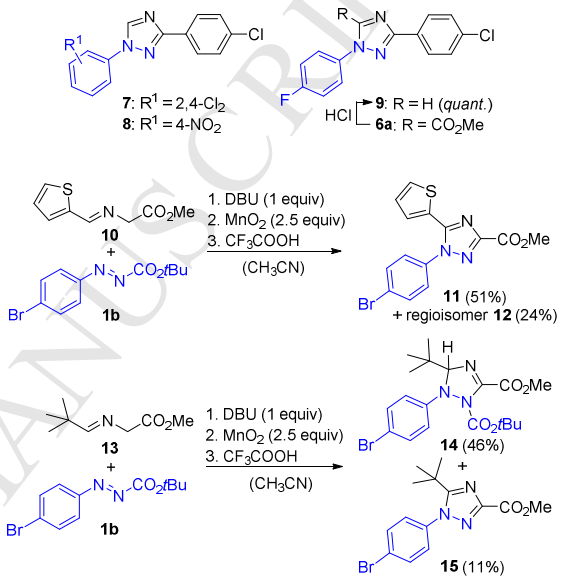
Scheme 2. Pathways leading to regioisomeric triazoles **5** and **6**.



In two reactions (entries 16 and 18), ester hydrolysis and decarboxylation were found to occur spontaneously for the minor regioisomer **6**, so that triazoles **7** and **8** were isolated instead of **6p** and **6r** (Scheme 3). This effect could be attributed to particular steric or electronic effects.[26] The same conversion can otherwise be cleanly achieved in concentrated hydrochloric acid, as exemplified by the formation of 1,3-disubstituted triazole **9** from 1,3,5-trisubstituted triazole **6a**.

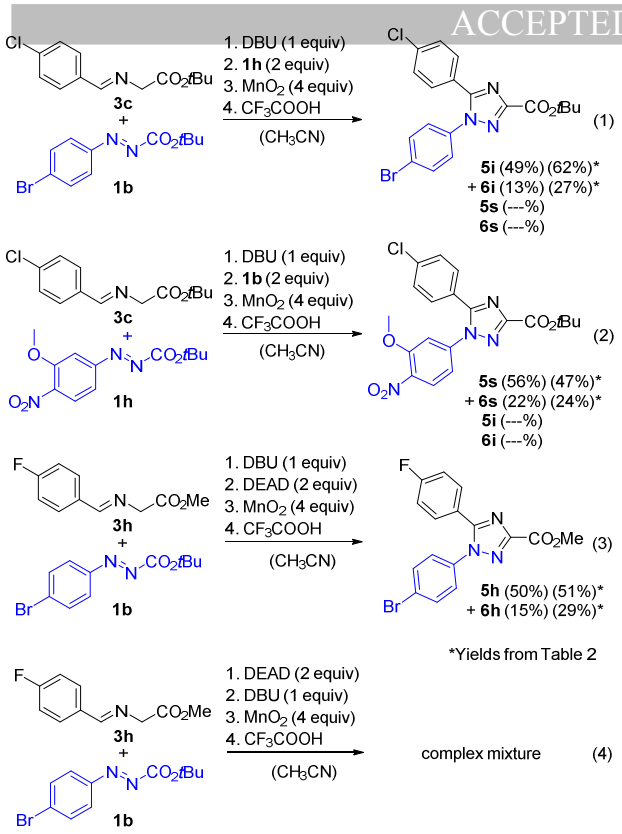
An attempt to extend the reaction principle to heterocyclic glycine imines such as **10** provided the thiophene-substituted triazoles **11** and **12** in a ratio comparable to those observed before (Scheme 3). Submission of the aliphatic glycine imine **13** to the same reaction conditions however furnished triazoline **14**[27] along with triazole **15** as single regioisomers hereby indicating that the replacement of the aromatic unit by an aliphatic side chain significantly complicates aromatization and cleavage of the *tert*-butyloxycarbonyl (Boc) group.[28]

Scheme 3. Decarboxylation and extension to heterocyclic and aliphatic glycine imines.



Finally, we ran a number of experiments to get further insights into the reaction course (Scheme 4). In experiment (1) a second azocarboxylate **1h** was added to the reaction mixture containing glycine imine **3c**, azocarboxylate **1b**, and DBU, which had been added first. As only triazoles derived from **1b** were found as products, the overall reaction is not able to reversibly form the anion of glycine imine **3c** after DBU has been added. To further verify this hypothesis we have conducted the same experiment (2) with a modified order of addition of **1h** and **1b**, and again, only the triazoles **5s** and **6s** derived from the initially added azocarboxylate **1h** were obtained. The assumed irreversibility was also supported by experiment (3), in which the even more reactive electrophile diethyl azodicarboxylate (DEAD) was added to the reaction mixture containing **3h**, **1b** and DBU, but the desired products were still obtained.

In experiment (4), in which DBU was added to a mixture containing the two azocarboxylates **1b** and DEAD as well as glycine imine **3h**, no formation of triazoles **5h** and **6h** could be observed any more. This indicates that the addition of the anion of glycine imine **3h** to DEAD proceeds significantly faster than to phenyl-azocarboxylic ester **1b**.



Scheme 4. Competition experiments

3. Conclusions

In summary, this study presents first examples for [3+2]cycloadditions to phenylazocarboxylates. Since all known nucleophilic attacks on phenylazocarboxylic esters so far occurred at the nitrogen atom located in β-position to the ester,[13] hereby following the orientation of the underlying diaza-Michael system,[29,30] it was surprising to find that the major isomers obtained in our experiments resulted from an attack of the nucleophilic glycine imine onto the α-nitrogen atom. Whereas electronic modifications on the glycine imine or the azocarboxylate had no or small impacts on the regioselectivity, only increased steric demand was able to reverse it, but at the cost of lower yields. Studies on the reaction course revealed that the initial addition of the deprotonated glycine imine to the azocarboxylate is irreversible for both regioisomers. Differences between both pathways were, on the other hand, observed in the subsequently occuring cyclization step, which turned out to be in one case sensitive to the presence of additional azo compounds. Further experiments are now directed towards shorter reactions times which would allow the extension of the methodology to radiosyntheses with readily available *tert*-butyl 4-[^{18}F]fluorophenylazocarboxylate.[12]

4. Experimental section

4.1 General information

Solvents and reagents were used as received. ^{1}H NMR spectra were recorded on 360 and 600 MHz spectrometers using $CDCl_3$ as solvent referenced to TMS (0.00 ppm) or $CDCl_3$ (7.26 ppm).^{13}C NMR spectra were recorded at 91 or 151 MHz in $CDCl_3$ (77.0 ppm) as standard. Chemical shifts are reported in parts per million (ppm). Coupling constants are in Hertz (*J* Hz). The following abbreviations are used for the description of signals: s (singlet), d (doublet), t (triplet), q (quartet), m (multiplet), mc (centered multiplet) and bs (broad singlet). Mass spectra were recorded using electron impact (EI) or electron spray ionization (ESI). A sector field mass analyzer or TOF were used for HRMS measurements.

Analytical TLC was carried out on *Merck* silica gel plates using short wave (254 nm) UV light, $KMnO_4$ [3.0 g $KMnO_4$, 20 g potassium carbonate, 5.0 mL aqueous sodium hydroxide (5% *w*/*w*) in 300 mL H_2O] and ninhydrin [200 mg ninhydrin in 100 mL ethanol] to visualize components. For flash column chromatography silica gel (Kieselgel 60, grain size 40 - 63 µm, *Merck*) was used.

General procedure for the synthesis of imine esters (GP 1)

A suspension of the glycine ester hydrochloride (5.00 mmol), aldehyde (4.00 mmol) and sodium sulfate (5.00 mmol) in dry dichloromethane (10 mL) is stirred at 0 °C. Triethylamine (5.00 mmol) is added dropwise. The reaction is allowed to warm to ambient temperature and stirred for 15 hours. Diethyl ether (10 mL) is added and the solution is filtered. The filtrate is washed with water (3 × 30 mL), a saturated aqueous solution of sodium chloride (3 × 20 mL) and dried over sodium sulfate. The solvent is removed under reduced pressure and the product is dried in vacuum. The product is used without further purification.

General procedure for the synthesis of isomeric 1,2,4-triazoles (GP 2)

A mixture of the imine (1.00 mmol, from GP 1), tert-butyl phenylazocarboxylate (2.00 mmol) and molecular sieve (4 Å, 1.00 g) in dry acetonitrile (10 mL) under nitrogen is cooled to -15 C and treated with 1,8-diazabicyclo[5.4.0]undec-7-ene (1.00 mmol) and stirred for 45 minutes. Manganese dioxide (2.50 mmol) is added, the cooling is removed and the reaction is stirred for four hours at ambient air. Trifluoroacetic acid (20.0 mmol) is added and the reaction is stirred for one hour. After addition of a saturated aqueous solution of potassium carbonate (40 mL), the mixture is filtered and then extracted with dichloromethane (4 × 30 mL). The combined organic phases are washed with a saturated aqueous solution of sodium chloride (20 mL) and dried over sodium sulfate. The solvent is removed under reduced pressure and the residue is subjected to column chromatography.

4.1.1 (4-Chlorobenzylidene-amino)-acetic acid methyl ester (3a)[30a] is prepared from glycine methyl ester hydrochloride (8.89 mmol, 1.12 g) and 4-chlorobenzaldehyde (7.11 mmol, 1.00 g) according to general procedure GP 1. The title compound **3a** is identified as a white solid (6.24 mmol, 1.32 g, 87%): R_f = 0.5 (hexane / ethyl acetate = 9:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ 3.79 (s, 3 H), 4.42 (mc, 2 H), 7.41 (d, *J* = 8.5 Hz, 2 H), 7.73 (d, *J* = 8.5 Hz, 2 H), 8.27 (mc, 1 H).

4.1.2 (4-Chlorobenzylidene-amino)-acetic acid ethyl ester (3b)[30b] is prepared from glycine ethyl ester hydrochloride (8.89 mmol, 1.35 g) and 4-chlorobenzaldehyde (7.11 mmol, 1.00 g) according to general procedure GP 1. The title compound **3b** is identified as a white solid (6.04 mmol, 1.38 g, 85%): R_f = 0.5 (hexane / ethyl acetate = 9:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ 1.30 (t, *J* = 7.1 Hz, 3 H), 4.42 (q, *J* = 7.1 Hz, 2 H), 4.39 (mc, 2 H), 7.39 (d, *J* = 8.4 Hz, 2 H), 7.72 (d, *J* = 8.4 Hz, 2 H), 8.26 (mc, 1 H).

4.1.3 (4-Chlorobenzylidene-amino)-acetic acid tert-butyl ester (3c)[30c] is prepared from glycine *tert*-butyl ester hydrochloride (2.98 mmol, 500 mg) and 4-chlorobenzaldehyde (2.38 mmol, 335 mg) according to general procedure GP 1. Compound **3c** is identified as a pale yellow solid (2.36 mmol, 637 mg, 99%): R_f = 0.8 (hexane / ethyl acetate = 3:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ 1.49 (s, 9 H), 4.30 (mc, 2 H), 7.39 (d, *J* = 8.4 Hz, 2 H), 7.71 (d, *J* = 8.4 Hz, 2 H), 8.22 (mc, 1 H); ^{13}C NMR (91 MHz, $CDCl_3$) δ 28.1 (3 × CH_3), 62.5 (CH_2), 81.5 (C_q), 128.8 (2 × CH), 129.6 (2 × CH), 134.2 (C_q), 137.1 (C_q), 163.7 (CH), 169.2 (C_q).

4.1.4 (Benzylidene-amino)-acetic acid methyl ester (3d)[30a] is prepared from glycine methyl ester hydrochloride (3.98 mmol, 500 mg) and benzaldehyde (3.31 mmol, 335 µL) according to general procedure GP 1. Compound **3d** is identified as a colorless oil (3.63 mmol, 644 mg, 91%): R_f = 0.8 (hexane / ethyl acetate = 3:1) (UV); ^{1}H NMR (360 MHz, $CDCl_3$) δ 1.49 (s, 9 H), 4.30 (mc, 2 H), 7.39 (d, *J* = 8.4 Hz, 2 H), 7.71 (d, *J* = 8.4 Hz, 2 H), 8.22 (mc, 1 H).

4.1.5 (2,4-Dichlorobenzylidene-amino)-acetic acid ethyl ester (3e) is prepared from glycine ethyl ester hydrochloride (5.00 mmol, 698 mg) and 2,4-dichlorobenzaldehyde (4.00 mmol, 700 mg) according to general procedure GP 1. The title compound **3e** is identified as a white oil (4.00 mmol, 1.05 g, *quant*.): R_f = 0.5 (hexane / ethyl acetate = 9:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ 1.32 (t, *J* = 7.2 Hz, 3 H), 4.26 (q, *J* = 7.2 Hz, 2 H), 4.45 (mc, 2 H), 7.30 (ddd, *J* = 0.7 Hz, *J* = 2.0 Hz, *J* = 8.5 Hz, 1 H), 7.41 (d, *J* = 2.0 Hz, 1 H), 8.07 (d, *J* = 8.5 Hz, 1 H), 8.67 (mc, 1 H); ^{13}C NMR (151 MHz, $CDCl_3$) δ 14.2 (CH_3), 61.2 (CH_2), 62.0 (CH_2), 127.6 (CH), 131.3 (C_q), 135.9 (C_q), 137.6 (C_q), 160.9 (CH), 169.7 (C_q); HRMS (ESI) calcd for $C_{11}H_{11}Cl_2NO_2$ [M^++Na^+]: 282.0059, found: 282.0056.

4.1.6 (4-Bromobenzylidene-amino)-acetic acid methyl ester (3f)[30a] is prepared from glycine methyl ester hydrochloride (8.11 mmol, 1.02 g) and 4-bromobenzaldehyde (6.49 mmol, 1.20 g) according to general procedure GP 1. The title compound **3f** is identified as a white solid (6.00 mmol, 1.59 g, 93%): R_f = 0.5 (hexane / ethyl acetate = 9:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ 3.78 (s, 3 H), 4.41 (mc, 2 H), 7.56 (d, *J* = 8.4 Hz, 2 H), 7.64 (d, *J* = 8.4 Hz, 2 H), 8.24 (mc, 1 H).

4.1.7 2-(3,4-Dimethoxybenzylidene-amino)-acetic acid methyl ester (3g) is prepared from glycine methyl ester hydrochloride (7.53 mmol, 945 mg) and 3,4-dimethoxybenzaldehyde (6.02 mmol, 1.00 g) according to general procedure GP 1. Compound **3g** is identified as a pale yellow solid (5.21 mmol, 1.36 g, 86%): R_f = 0.8 (hexane / ethyl acetate = 3:1) (UV); ^{1}H NMR (360 MHz, $CDCl_3$) δ 3.77 (s, 3 H), 3.91 (s, 3 H), 3.93 (s, 3 H), 4.38 (mc, 2 H), 6.88 (d, *J* = 8.2 Hz, 1 H), 7.18 (dd, *J* = 1.9 Hz, *J* = 8.2 Hz, 1 H), 7.46 (d, *J* = 1.9 Hz, 1 H), 8.19 (mc, 1 H); ^{13}C NMR (91 MHz, $CDCl_3$) δ 52.0 (CH_3), 55.9 (CH_3), 56.0 (CH_3), 61.8 (CH_2), 108.9 (CH), 110.3 (CH), 123.8 (CH), 128.8 (C_q), 149.3 (C_q), 151.8 (C_q), 164.9 (CH), 170.7 (C_q); HRMS (ESI) calcd for $C_{12}H_{15}NO_4$ [M^++Na^+]: 260.0893, found: 260.0900.

4.1.8 (4-Fluorobenzylidene-amino)-acetic acid methyl ester (3h)[30c] is prepared from glycine methyl ester hydrochloride (10.1 mmol, 1.27 g) and 4-fluorobenzaldehyde (8.06 mmol, 1.00 g) according to general procedure GP 1. The title compound **3h** is identified as a white solid (7.44 mmol, 1.60 g, 96%): R_f = 0.5 (hexane / ethyl acetate = 9:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ 3.79 (s, 3 H), 4.41 (mc, 2 H), 7.16 (t, *J* = 8.7 Hz, 2 H), 7.79 (dd, J_{HF} = 5.5 Hz, *J* = 8.7 Hz, 2 H), 8.27 (mc, 1 H).

4.1.9 (3-Bromobenzylidene-amino)-acetic acid methyl ester (3i)[30d] is prepared from glycine methyl ester hydrochloride (8.11 mmol, 1.02 g) and 3-bromobenzaldehyde (6.49 mmol, 1.20 g) according to general procedure GP 1. The title compound **3i** is identified as a white solid (6.48 mmol, 1.77 g, 100%): R_f = 0.5 (hexane / ethyl acetate = 9:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ 3.79 (s, 3 H), 4.42 (mc, 2 H), 7.30 (t, *J* = 7.8 Hz, 1 H), 7.57 (ddd, *J* = 1.1 Hz, *J* = 2.0 Hz, *J* = 8.0 Hz, 1 H), 7.67 (td, *J* = 1.3 Hz, *J* = 7.8 Hz, 1 H), 7.98 (t, *J* = 1.8 Hz, 1 H), 8.24 (mc, 1 H).

4.1.10 (4-Phenylbenzylidene-amino)-acetic acid methyl ester (3j) is prepared from glycine methyl ester hydrochloride (6.86 mmol, 861 mg) and biphenyl-4-carboxaldehyde (5.49 mmol, 1.00 mg) according to general procedure GP 1. The title compound **3j** is identified as a white solid (4.39 mmol, 1.35 g, 80%): R_f = 0.5 (hexane / ethyl acetate = 9:1) (UV); ^{1}H NMR (360 MHz, $CDCl_3$) δ 3.80 (s, 3 H), 4.45 (mc, 2 H), 7.35-7.51 (m, 3 H), 7.61-7.64 (m, 2 H), 7.66 (d, *J* = 8.3 Hz, 2 H), 7.86 (d, *J* = 8.3 Hz, 2 H), 8.34 (mc, 1 H); ^{13}C NMR (91 MHz, $CDCl_3$) δ 52.1 (CH_3), 62.1 (CH_2), 127.2 (2 × CH), 127.3 (2 × CH), 127.8 (CH), 128.8 (2 × CH), 128.9 (2 × CH), 134.5 (C_q), 140.3 (C_q), 144.0 (C_q), 165.0 (CH), 170.5 (C_q); HRMS (ESI) calcd for $C_{16}H_{15}NO_2$ [M^++Na^+]: 276.0995, found: 276.1000.

4.1.11 (4-Cyanobenzylidene-amino)-acetic acid methyl ester (3k)[30c] is prepared from glycine methyl ester hydrochloride (9.54 mmol, 1.20 g) and 4-cyanobenzaldehyde (7.63 mmol, 1.00 g) according to general procedure GP 1. The crude product is purified by recrystallization in diethyl ether to afford the pure compound **3k** as a pale yellow solid (5.80 mmol, 1.17 g, 76%): R_f = 0.5 (hexane / ethyl acetate = 9:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ 3.80 (s, 3 H), 4.47 (mc, 2 H), 7.73 (d, *J* = 8.4 Hz, 2 H), 7.90 (d, *J* = 8.4 Hz, 2 H), 8.34 (mc, 1 H).

4.1.122-((Thiophen-2-ylmethylene)amino)-acetic acid methyl ester (10)[30a] is prepared from glycine methyl ester hydrochloride (7.80 mmol, 979 mg) and 2-thiophenecarboxaldehyde (6.24 mmol, 583 µg) according to general procedure GP 1. The title compound **10** is identified as a pale yellow solid (3.56 mmol, 652 mg, 57%): R_f = 0.5 (hexane / ethyl acetate = 9:1) (UV); ^{1}H NMR (360 MHz, $CDCl_3$) δ 3.77 (s, 3 H), 4.37 (mc, 2 H), 7.08 (dd, *J* = 3.7 Hz, *J* = 5.0 Hz, 1 H), 7.37 (dd, *J* = 1.0 Hz, *J* = 3.7 Hz, 1 H), 7.45 (td, *J* = 1.0 Hz, *J* = 5.0 Hz, 1 H), 8.34 (mc, 1 H).

4.1.13 Tert-butyl 2-(4-fluorophenyl)azocarboxylate (1a)[11b]. A solution of 4-fluoroaniline (20.0 mmol, 1.92 mL) in glacial acetic acid (10 mL) is treated with concentrated hydrochloric acid (50 mL) and cooled to 0 °C. A solution of sodium nitrite (20.0 mmol, 1.38 g) in water (4.0 mL) is added over a period of 20 minutes and the reaction is stirred for one hour at 0° C. A prechilled solution of tin chloride dihydrate (44.0 mmol, 9.93 g) in concentrated hydrochloric acid (10 mL) is added drop wise over a period of 45 minutes. After stirring for one hour at 0 °C the precipitate is collected by filtration and dissolved in a 3 M solution of potassium hydroxide (200 mL). The composite is extracted with diethyl ether (4 × 50 mL). The combined organic phases are washed with a saturated aqueous solution of sodium chloride and dried over sodium sulfate. The crude product is used without further purification. The crude product is dissolved in dry acetonitrile (20 mL) and treated with di-*tert*-butyl dicarbonate

(18.0 mmol, 3.93 g) under argon atmosphere. After complete consumption of the reactants, as monitored by TLC, the solvent is removed under reduced pressure. The residue is subjected to column chromatography (silica gel, hexane / ethyl acetate = 4:1) to give *tert*-butyl 2-(4-fluorophenyl)hydrazine carboxylate as an orange solid (9.75 mmol, 2.21 g, 49%): R_f = 0.6 (hexane / ethyl acetate = 3:1) ($KMnO_4$); ^{1}H NMR (360 MHz, $CDCl_3$) δ 1.45 (s, 9 H), 6.36 (bs, 1 H), 6.77 (dd, J_{HF} = 4.5 Hz, J = 9.0 Hz, 2 H), 6.94 (dd, J_{HF} = 8.5 Hz, J = 9.0 Hz, 2 H). To a stirred solution of *tert*-butyl 2-(4-fluorophenyl)hydrazine carboxylate (10.0 mmol, 2.26 g) in dry dichloromethane (15 mL), manganese dioxide (50.0 mmol, 4.35 g) is subsequently added under nitrogen atmosphere. After complete consumption of the reactants, as monitored by TLC, the mixture is filtered over Celite. Removal of the solvent under reduced pressure and column chromatography (silica gel, hexane / ethyl acetate = 19:1) give the title compound **1a** as an orange oil (7.86 mmol, 1.76 g, 79%): R_f = 0.6 (hexane / ethyl acetate = 19:1) (UV); ^{1}H NMR (360 MHz, $CDCl_3$) δ 1.66 (s, 9 H), 7.19 (dd, J_{HF} = 8.2 Hz, J = 9.0 Hz, 2 H), 7.94 (dd, J_{HF} = 5.0 Hz, J = 9.0 Hz, 2 H).

4.1.14 Tert-butyl 2-(4-bromophenyl)azocarboxylate (1b). A solution of 4-bromoaniline (28.0 mmol, 4.82 g) in glacial acetic acid (15 mL) is treated with concentrated hydrochloric acid (60 mL) and cooled to 0 °C. A solution of sodium nitrite (28.0 mmol, 1.93 g) in water (6.5 mL) is added over a period of 20 minutes and the reaction is stirred for one hour at 0° C. A prechilled solution of tin chloride dihydrate (62.0 mmol, 14.0 g) in concentrated hydrochloric acid (15 mL) is added drop wise over a period of 45 minutes. After stirring for one hour at 0 °C the precipitate is collected by filtration and dissolved in a saturated aqueous solution of potassium carbonate (200 mL). The composite is extracted with diethyl ether (4 × 50 mL). The combined organic phases are washed with a saturated aqueous solution of sodium chloride and dried over sodium sulfate. The crude product is used without further purification. The crude product is dissolved in dry acetonitrile (30 mL) and treated with di-*tert*-butyl dicarbonate (27.1 mmol, 5.92 g) under argon atmosphere. After complete consumption of the reactants, as monitored by TLC, the solvent is removed under reduced pressure. The residue is subjected to column chromatography (silica gel, hexane / ethyl acetate = 6:1) to give *tert*-butyl 2-(4-bromophenyl)hydrazine carboxylate as a white solid (16.4 mmol, 4.70 g, 59%): R_f = 0.6 (hexane / ethyl acetate = 3:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ 1.46 (s, 9 H), 6.35 (bs, 1 H), 6.71 (d, J = 8.8 Hz, 2 H), 7.32 (d, J = 8.8 Hz, 2 H). To a stirred solution of *tert*-butyl 2-(4-bromophenyl)hydrazine carboxylate (16.5 mmol, 4.70 g) in dry dichloromethane (30 mL), manganese dioxide (82.5 mmol, 7.17 g) is subsequently added under nitrogen atmosphere. After complete consumption of the reactants, as monitored by TLC, the mixture is filtered over Celite. Removal of the solvent under reduced pressure and column chromatography (silica gel, hexane / ethyl acetate = 20:1) give the title compound **1b** as an orange solid (14.7 mmol, 4.18 g, 89%): R_f = 0.7 (hexane / ethyl acetate = 15:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ 1.65 (s, 9 H), 7.65 (d, J = 8.9 Hz, 2 H), 7.77 (d, J = 8.9 Hz, 2 H).

4.1.15 Tert-butyl 2-(4-iodophenyl)azocarboxylate (1c)[13c]. A solution of 4-iodoaniline (28.0 mmol, 6.13 g) in glacial acetic acid (15 mL) is treated with concentrated hydrochloric acid (65 mL) and cooled to 0 °C. A solution of sodium nitrite (28.0 mmol, 1.93 g) in water (6.5 mL) is added over a period of 20 minutes and the reaction is stirred for one hour at 0° C. A prechilled solution of tin chloride dihydrate (62.0 mmol, 14.0 g) in concentrated hydrochloric acid (15 mL) is added drop wise over a period of 45 minutes. After stirring for one hour at 0 °C the precipitate is collected by filtration and dissolved in a saturated aqueous solution of potassium carbonate (200 mL). The composite is extracted with diethyl ether (4 × 50 mL). The combined organic phases are washed with a saturated aqueous solution of sodium chloride and dried over sodium sulfate. The crude product is used without further purification. The crude product is dissolved in dry acetonitrile (40 mL) and treated with di-*tert*-butyl dicarbonate (18.6 mmol, 4.06 g) under argon atmosphere. After complete consumption of the reactants, as monitored by TLC, the solvent is removed under reduced pressure. The crude product is purified by recrystallization in hexane / ethyl acetate to afford *tert*-butyl 2-(4-iodophenyl)hydrazine carboxylate as a white solid (9.90 mmol, 3.29 g, 35%): R_f = 0.3 (hexane / ethyl acetate = 6:1) (UV); ^{1}H NMR (360 MHz, $CDCl_3$) δ 1.45 (9 H), 6.36 (bs, 1 H), 6.60 (d, J = 8.8 Hz, 2 H), 7.49 (d, J = 8.8 Hz, 2 H). To a stirred solution of *tert*-butyl 2-(4-iodophenyl)hydrazine carboxylate (9.90 mmol, 3.29 g) in dry dichloromethane (40 mL), manganese dioxide (50.0 mmol, 4.35 g) is subsequently added under nitrogen atmosphere. After complete consumption of the reactants, as monitored by TLC, the mixture is filtered over Celite. Removal of the solvent under reduced pressure and column chromatography (silica gel, hexane / ethyl acetate = 10:1) give the title compound **1c** as an orange solid (8.21 mmol, 2.73 g, 83%): R_f = 0.9 (hexane / ethyl acetate = 6:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ 1.66 (s, 9 H), 7.62 (d, J = 8.8 Hz, 2 H), 7.88 (d, J = 8.8 Hz, 2 H).

4.1.16 Tert-butyl 2-(4-fluoro-2-methylphenyl)azocarboxylate (1d). A solution of 4-fluoro-2-methylaniline (32.0 mmol, 3.55 mL) in glacial acetic acid (16 mL) is treated with concentrated hydrochloric acid (70 mL) and cooled to 0 °C. A solution of sodium nitrite (32.0 mmol, 2.21 g) in water (7 mL) is added over a period of 20 minutes and the reaction is stirred for one hour at 0° C. A prechilled solution of tin chloride dihydrate (70.4 mmol, 15.9 g) in concentrated hydrochloric acid (15 mL) is added drop wise over a period of 45 minutes. After stirring for one hour at 0 °C the precipitate is collected by filtration and dissolved in a saturated aqueous solution of potassium carbonate (200 mL). The composite is extracted with diethyl ether (4 × 50 mL). The combined organic phases are washed with a saturated aqueous solution of sodium chloride and dried over sodium sulfate. The crude product is used without further purification. The crude product is dissolved in dry acetonitrile (40 mL) and treated with di-*tert*-butyl dicarbonate (25.6 mmol, 5.58 g) under argon atmosphere. After complete consumption of the reactants, as monitored by TLC, the solvent is removed under reduced pressure. The residue is subjected to column chromatography (silica gel, hexane / ethyl acetate = 10:1) to give *tert*-butyl 2-(4-fluoro-2-methylphenyl)hydrazine carboxylate as a pale yellow solid (18.0 mmol, 4.33 g, 65%): R_f = 0.5 (hexane / ethyl acetate = 3:1) (UV); ^{1}H NMR (360 MHz, $CDCl_3$) δ 1.45 (9 H), 2.19 (3 H), 6.32 (bs, 1 H), 6.74-6.83 (m, 3 H). To a stirred solution of *tert*-butyl 2-(4-fluoro-2-methylphenyl)hydrazine carboxylate (18.0 mmol, 4.33 g) in dry dichloromethane (40 mL), manganese dioxide (90.0 mmol, 7.82 g) is subsequently added under nitrogen atmosphere. After complete consumption of the reactants, as monitored by TLC, the mixture is filtered over Celite. Removal of the solvent under reduced pressure give the title compound **1d** as an orange solid (16.6 mmol, 3.96 g, 92%): R_f = 0.8 (hexane / ethyl acetate = 9:1) (UV); ^{1}H NMR (360 MHz, $CDCl_3$) δ 1.66 (s, 9 H), 2.69 (3 H), 6.90-6.93 (m, 1 H), 7.04 (dd, J_{HF} = 2.6 Hz, J = 9.0 Hz, 1 H), 7.62 (dd, J_{HF} = 5.7 Hz, J = 9.0 Hz, 1 H); ^{13}C NMR (91 MHz, $CDCl_3$) δ 17.5 (CH_3), 27.9 (3 × CH_3), 84.7 (C_q), 113.8 (d, J_{CF} = 23.2 Hz,

CH), 117.7 (d, J_{CF} = 1.8 Hz, C_q), 117.8 (d, J_{CF} = 10.5 Hz, CH), 143.5 (d, J_{CF} = 9.2 Hz, CH), 146.4 (d, J_{CF} = 2.9 Hz, C_q), 161.3 (C_q), 165.8 (d, J_{CF} = 254.8 Hz, C_q).

4.1.17 Tert-butyl 2-(2,4-dichlorophenyl)azocarboxylate (1e). A solution of 2,4-dichloroaniline (31.0 mmol, 5.00 g) in glacial acetic acid (15 mL) is treated with concentrated hydrochloric acid (70 mL) and cooled to 0 °C. A solution of sodium nitrite (31.0 mmol, 2.14 g) in water (7 mL) is added over a period of 20 minutes and the reaction is stirred for one hour at 0° C. A prechilled solution of tin chloride dihydrate (68.2 mmol, 15.4 g) in concentrated hydrochloric acid (15 mL) is added drop wise over a period of 45 minutes. After stirring for one hour at 0 °C the precipitate is collected by filtration and dissolved in a saturated aqueous solution of potassium carbonate (200 mL). The composite is extracted with diethyl ether (4 × 50 mL). The combined organic phases are washed with a saturated aqueous solution of sodium chloride and dried over sodium sulfate. The crude product is used without further purification. The crude product is dissolved in dry acetonitrile (35 mL) and treated with di-*tert*-butyl dicarbonate (23.9 mmol, 5.22 g) under argon atmosphere. After complete consumption of the reactants, as monitored by TLC, the solvent is removed under reduced pressure. The residue is subjected to column chromatography (silica gel, hexane / ethyl acetate = 9:1) to give *tert*-butyl 2-(2,4-dichlorophenyl)hydrazine carboxylate as a pale yellow solid (21.9 mmol, 6.07 g, 71%): R_f = 0.3 (hexane / ethyl acetate = 9:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ 1.45 (9 H), 6.16 (bs, 1 H), 6.37 (bs, 1 H), 6.88 (d, *J* = 8.8 Hz, 1 H), 7.14 (dd, *J* = 2.3 Hz, *J* = 8.8 Hz, 1 H), 7.27 (d, *J* = 2.3 Hz, 1 H). To a stirred solution of *tert*-butyl 2-(2,4-dichlorophenyl)hydrazine carboxylate (21.9 mmol, 6.07 g) in dry dichloromethane (35 mL), manganese dioxide (99.5 mmol, 8.65 g) is subsequently added under nitrogen atmosphere. After complete consumption of the reactants, as monitored by TLC, the mixture is filtered over Celite. Removal of the solvent under reduced pressure and column chromatography (silica gel, hexane / ethyl acetate = 15:1) give the title compound **1e** as an orange solid (17.6 mmol, 4.85 g, 80%): R_f = 0.3 (hexane / ethyl acetate = 9:1) (UV); ^{1}H NMR (360 MHz, $CDCl_3$) δ 1.66 (s, 9 H), 7.30 (dd, *J* = 2.2 Hz, *J* = 8.7 Hz, 1 H), 7.56 (d, *J* = 8.7 Hz, 1 H), 7.59 (d, *J* = 2.2 Hz, 1 H); ^{13}C NMR (151 MHz, $CDCl_3$) δ 28.2 (3 × CH_3), 81.8 (C_q), 114.1 (CH), 129.2 (C_q), 125.1 (C_q), 127.4 (CH), 128.9 (CH), 143.1 (C_q), 155.6 (C_q); HRMS (ESI) calcd for $C_{11}H_{12}Cl_2N_2O_2$ [M^++Na^+]: 297.0168, found: 297.0167.

4.1.18 Tert-butyl 2-(4-(4-fluorophenoxy)phenyl)azocarboxylate (1f)[11b]. A solution of 4-fluorophenol (2.38 mmol, 268 mg) in dry *N*,*N*-dimethylformamide (15 mL) is treated with cesium carbonate (9.52 mmol, 3.10 g) under argon at room temperature. After stirring for 45 minutes *tert*-butyl-2-(4-nitrophenyl)azocarboxylate (**1g**) (1.99 mmol, 500 mg) is added and the reaction is stirred for five hours. Water (15 mL) is added at 0 °C and the mixture is extracted with ethyl acetate (3 × 50 mL). The combined organic phases are washed with a saturated aqueous solution of sodium chloride and dried over sodium sulfate. The solvent is removed under reduced pressure. The obtained residue is subjected to column chromatography (silica gel, hexane / ethyl acetate = 19:1) to afford **1f** as an orange solid (1.42 mmol, 414 mg, 71%): R_f = 0.8 (hexane / ethyl acetate = 19:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ 1.56 (s, 9 H), 7.01 (d, *J* = 9.1 Hz, 2 H), 7.05-7.12 (m, 4 H), 7.91 (d, *J* = 9.1 Hz, 2 H).

4.1.19 Tert-butyl 2-(3-methoxy-4-nitrophenyl)azocarboxylate (1h). A solution 4-fluoro-2-methoxy-1-nitrobenzene (13.8 mmol, 2.36 g) in ethanol (20 mL) is treated with hydrazine monohydrate (69.0 mmol, 5.58 g) and heated to reflux for six hours at 65° C. The yellow precipitate is filtered and washed with cold ethanol. Drying in vacuum gives the pure 3-methoxy-4-nitrophenylhydrazine as fluffy yellow powder (9.80 mmol, 1.80 g, 71%): R_f = 0.5 (hexane / ethyl acetate = 4:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ 3.89 (3 H), 6.36 (dd, *J* = 2.3 Hz, *J* = 9.2 Hz, 1 H), 6.55 (d, *J* = 2.3 Hz, 1 H), 6.61 (bs, 1 H), 7.88 (d, *J* = 9.2 Hz, 1 H). A suspension of 3-methoxy-4-nitrophenylhydrazine (6.55 mmol, 1.20 g) in dry acetonitrile (12 mL) and treated with di-*tert*-butyl dicarbonate (9.83 mmol, 2.15 g) under argon atmosphere and stirred overnight. After complete consumption of the reactants, as monitored by TLC, the solvent is removed under reduced pressure. The obtained residue is subjected to column chromatography (silica gel, hexane / ethyl acetate = 1:1) to afford *tert*-butyl 2-(3-methoxy-4-nitrophenyl)hydrazine carboxylate as an orange solid (6.55 mmol, 1.86 g, *quant.*): R_f = 0.5 (hexane / ethyl acetate = 1:1) (UV); ^{1}H NMR (360 MHz, $CDCl_3$) δ 1.50 (9 H), 3.89 (3 H), 6.21 (bs, 1 H), 6.34-6.38 (m, 2 H), 6.46 (bs, 1 H), 7.93 (d, *J* = 9.2 Hz, 1 H). To a stirred solution of *tert*-butyl 2-(3-methoxy-4-nitrophenyl)hydrazine carboxylate (6.55 mmol, 1.86 g) in dry dichloromethane (20 mL), manganese dioxide (35.3 mmol, 3.07 g) is subsequently added under nitrogen atmosphere. After complete consumption of the reactants, as monitored by TLC, the mixture is filtered over Celite. Removal of the solvent under reduced pressure and column chromatography (silica gel, hexane / ethyl acetate = 5:1) give the title compound **1h** as an orange solid (5.54 mmol, 1.56 g, 84%): R_f = 0.5 (hexane / ethyl acetate = 5:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ 1.68 (s, 9 H), 4.03 (3 H), 7.57 (d, *J* = 1.9 Hz, 1 H), 7.59 (d, *J* = 1.9 Hz, *J* = 8.5 Hz, 1 H), 7.96 (d, *J* = 8.5 Hz, 1 H); ^{13}C NMR (151 MHz, $CDCl_3$) δ 27.8 (3 × CH_3), 56.8 (CH_3), 86.1 (C_q), 106.9 (CH), 116.5 (CH), 126.3 (CH), 142.0 (C_q), 153.4 (C_q), 154.0 (C_q), 160.5 (C_q); HRMS (ESI) calcd for $C_{12}H_{15}N_3O_5$ [M^++K^+]: 304.0899, found: 304.0694.

4.1.20 Methyl 3-(4-chlorophenyl)-1-(4-fluorophenyl)-1H-1,2,4-triazole-5-carboxylate (6a) and methyl 5-(4-chlorophenyl)-1-(4-fluorophenyl)-1H-1,2,4-triazole-3-carboxylate (5a) are prepared from (4-chlorobenzylidene-amino) acetic acid methyl ester (**3a**) (236 µmol, 50.0 mg) and *tert*-butyl 2-(4-fluorophenyl)azocarboxylate (**1a**) (472 µmol, 106 mg) according to general procedure GP 2. The crude product is subjected to column chromatography (silica gel, dichloromethane / ethyl acetate = 100:1) to give the title compounds **6a** (85.0 µmol, 28.2 mg, 36%) and **5a** (137 µmol, 45.4 mg, 58%) as pale yellow solids. Methyl 3-(4-chlorophenyl)-1-(4-fluorophenyl)-1*H*-1,2,4-triazole-5-carboxylate (**6a**): R_f = 0.8 (dichloromethane / ethyl acetate = 100:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ 3.95 (s, 3 H), 7.22 (dd, J_{HF} = 8.1 Hz, *J* = 9.0 Hz, 2 H), 7.43 (d, *J* = 8.8 Hz, 2 H), 7.50 (dd, J_{HF} = 5.0 Hz, *J* = 9.0 Hz, 2 H), 8.13 (d, *J* = 8.8 Hz, 2 H); ^{13}C NMR (91 MHz, $CDCl_3$) δ 53.3 (CH_3), 116.1 (d, J_{CF} = 23.3 Hz, 2 × CH), 127.8 (d, J_{CF} = 9.0 Hz, 2 × CH), 128.1 (2 × CH), 128.1 (C_q), 129.0 (2 × CH), 133.9 (d, J_{CF} = 3.4 Hz, C_q), 136.1 (C_q), 145.3 (C_q), 157.7 (C_q), 161.3 (C_q), 163.1 (d, J_{CF} = 250.7 Hz, C_q); MS (EI) *m/z* 331 (15) [^{35}Cl-M^+], 276 (10), 274 (33), 109 (52), 57 (100), 41 (13); HRMS (EI) calcd for $C_{16}H_{11}ClFN_3O_2$ [M^+]: 331.0524, found: 331.0525. Methyl 5-(4-chlorophenyl)-1-(4-fluorophenyl)-1*H*-1,2,4-triazole-3-carboxylate (**5a**): R_f = 0.4 (dichloromethane / ethyl acetate = 100:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ 4.06 (s, 3 H), 7.18 (dd, J_{HF} = 8.0 Hz, *J* = 9.0 Hz, 2 H), 7.36 (d, *J* = 8.6 Hz), 7.40 (dd, J_{HF} = 4.6 Hz, *J* = 9.0 Hz, 2 H), 7.49 (d, *J* = 8.6 Hz); ^{13}C NMR (91 MHz, $CDCl_3$) δ 60.3 (CH_3), 116.7 (d, J_{CF} = 23.3 Hz, 2 × CH), 127.5 (d, J_{CF} = 8.9 Hz, 2 × CH), 128.3

(C_q), 129.0 (2 × CH), 130.2 (2 × CH), 133.4 (d, J_{CF} = 3.5 Hz, C_q), 137.1 (C_q), 154.7 (C_q), 160.0 (C_q), 162.9 (d, J_{CF} = 251.6 Hz, C_q), 171.0 (C_q); MS (EI) *m/z* 333 (15) [^{37}Cl-M$^+$], 331 (43) [^{35}Cl-M$^+$], 194 (34), 109 (100), 75 (10); HRMS (EI) calcd for $C_{16}H_{11}ClFN_3O_2$ [M$^+$]: 331.0524, found: 331.0523.

4.1.21 Ethyl 3-(4-chlorophenyl)-1-(4-fluorophenyl)-1H-1,2,4-triazole-5-carboxylate (6b) and ethyl 5-(4-chlorophenyl)-1-(4-fluorophenyl)-1H-1,2,4-triazole-3-carboxylate (5b) are prepared from (4-chlorobenzylidene-amino) acetic acid ethyl ester (**3b**) (709 µmol, 160 mg) and *tert*-butyl 2-(4-fluorophenyl)azocarboxylate (**1a**) (1.42 mmol, 318 mg) according to general procedure GP 2. The crude product is subjected to column chromatography (silica gel, dichloromethane / ethyl acetate = 150:1) to give the title compounds **6b** (212µmol, 73.5 mg, 30%) and **5b** (289 µmol, 100 mg, 41%) as white solids. Ethyl 3-(4-chlorophenyl)-1-(4-fluorophenyl)-1*H*-1,2,4-triazole-5-carboxylate (**6b**): R_f = 0.8 (dichloromethane / ethyl acetate = 100:1) (UV); ^{1}H NMR (360 MHz, $CDCl_3$) δ 1.35 (t, *J* = 7.1 Hz, 3 H), 4.41 (q, *J* = 7.1 Hz, 2 H), 7.21 (dd, J_{HF} = 8.1 Hz, *J* = 9.1 Hz, 2 H), 7.44 (d, *J* = 8.8 Hz, 2 H), 7.50 (dd, J_{HF} = 4.7 Hz, *J* = 9.1 Hz, 2 H), 8.12 (d, *J* = 8.8 Hz, 2 H); ^{13}C NMR (151 MHz, $CDCl_3$) δ 14.0 (CH_3), 62.9 (CH_2), 116.0 (d, J_{CF} = 23.3 Hz, 2 × CH), 127.8 (d, J_{CF} = 8.9 Hz, 2 × CH), 128.1 (2 × CH), 128.1 (C_q), 128.9 (2 × CH), 134.0 (d, J_{CF} = 3.3 Hz, C_q), 136.1 (C_q), 145.8 (C_q), 157.3 (C_q), 161.3 (C_q), 163.1 (d, J_{CF} = 250.5 Hz, C_q); MS (ESI) *m/z* 348 [^{37}Cl-MH$^+$], 346 [^{35}Cl-MH$^+$]; HRMS (ESI) calcd for $C_{17}H_{13}ClFN_3O_2$ [M$^+$+Na$^+$]: 368.0573, found: 368.0561. Ethyl 5-(4-chlorophenyl)-1-(4-fluorophenyl)-1*H*-1,2,4-triazole-3-carboxylate (**5b**): R_f = 0.4 (dichloromethane / ethyl acetate = 100:1) (UV); ^{1}H NMR (360 MHz, $CDCl_3$) δ 1.46 (t, *J* = 7.1 Hz, 3 H), 4.45 (q, *J* = 7.1 Hz, 2 H), 7.17 (dd, J_{HF} = 8.0 Hz, *J* = 9.1 Hz, 2 H), 7.35 (d, *J* = 8.8 Hz, 2 H), 7.38 (dd, J_{HF} = 4.6 Hz, *J* = 9.1 Hz, 2 H), 7.48 (d, *J* = 8.8 Hz, 2 H); ^{13}C NMR (91 MHz, $CDCl_3$) δ 14.3 (CH_3), 62.2 (CH_2), 116.8 (d, J_{CF} = 23.3 Hz, 2 × CH), 125.0 (C_q), 127.6 (d, J_{CF} = 8.9 Hz, 2 × CH), 129.1 (2 × CH), 130.3 (2 × CH), 133.5 (d, J_{CF} = 3.4 Hz, C_q), 137.1 (C_q), 154.7 (C_q), 154.7 (C_q), 159.7 (C_q), 162.9 (d, J_{CF} = 251.4 Hz, C_q); MS (ESI) *m/z* 348 [^{37}Cl-MH$^+$], 346 [^{35}Cl-MH$^+$]; HRMS (ESI) calcd for $C_{17}H_{13}ClFN_3O_2$ [M$^+$+Na$^+$]: 368.0573, found: 368.0564.

4.1.22 Tert-butyl 3-(4-chlorophenyl)-1-(4-fluorophenyl)-1H-1,2,4-triazole-5-carboxylate (6c) and tert-butyl 5-(4-chlorophenyl)-1-(4-fluorophenyl)-1H-1,2,4-triazole-3-carboxylate (5c) are prepared from (4-chlorobenzylidene-amino) acetic acid *tert*-butyl ester (**3c**) (79.0 µmol, 20.0 mg) and *tert*-butyl 2-(4-fluorophenyl)azocarboxylate (**1a**) (158 µmol, 35.4 mg) according to general procedure GP 2. After addition of trifluoroacetic acid, the reaction is stirred for three hours. The crude product is subjected to column chromatography (silica gel, dichloromethane / ethyl acetate = 100:1) to give the title compounds **6c** (12.6 µmol, 4.70 mg, 16%) and **5c** (37.7 µmol, 14.1 mg, 48%) as pale yellow solids. Tert-butyl 3-(4-chlorophenyl)-1-(4-fluorophenyl)-1*H*-1,2,4-triazole-5-carboxylate (**6c**): R_f = 0.7 (dichloromethane / ethyl acetate = 100:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ 1.45 (s, 9 H), 7.21 (dd, J_{HF} = 8.1 Hz, *J* = 9.0 Hz, 2 H), 7.42 (d, *J* = 8.7 Hz, 2 H), 7.46 (dd, J_{HF} = 4.7 Hz, *J* = 9.0 Hz, 2 H), 8.13 (d, *J* = 8.7 Hz, 2 H); ^{13}C NMR (91 MHz, $CDCl_3$) δ 27.8 (3 × CH_3), 84.9 (C_q), 116.0 (d, J_{CF} = 23.2 Hz, 2 × CH), 127.7 (d, J_{CF} = 8.9 Hz, 2 × CH), 128.1 (2 × CH), 128.4 (C_q), 128.9 (2 × CH), 134.5 (d, J_{CF} = 3.4 Hz, C_q), 135.9 (C_q), 147.2 (C_q), 156.2 (C_q), 161.1 (C_q), 163.0 (d, J_{CF} = 250.4 Hz, C_q); MS (EI) *m/z* 373 (12) [^{35}Cl-M$^+$], 317 (18), 275 (16), 273 (41), 136 (41), 109 (100), 95 (11), 82 (12), 56 (10), 44 (10), 41 (19); HRMS (EI) calcd for $C_{19}H_{17}ClFN_3O_2$ [M$^+$]: 373.0993, found: 373.0994. *Tert*-butyl 5-(4-chlorophenyl)-1-(4-fluorophenyl)-1*H*-1,2,4-triazole-3-carboxylate (**5c**): R_f = 0.3 (dichloromethane / ethyl acetate = 100:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ 1.67 (s, 9 H), 7.16 (dd, J_{HF} = 8.0 Hz, *J* = 9.1 Hz, 2 H), 7.34 (d, *J* = 8.8 Hz, 2 H), 7.38 (dd, J_{HF} = 4.7 Hz, *J* = 9.1 Hz, 2 H), 7.47 (d, *J* = 8.8 Hz, 2 H); ^{13}C NMR (91 MHz, $CDCl_3$) δ 28.1 (3 × CH_3), 83.4 (C_q), 116.7 (d, J_{CF} = 23.3 Hz, 2 × CH), 125.3 (C_q), 127.6 (d, J_{CF} = 8.9 Hz, 2 × CH), 129.0 (2 × CH), 130.3 (2 × CH), 133.7 (d, J_{CF} = 3.5 Hz, C_q), 136.9 (C_q), 154.4 (C_q), 155.7 (C_q), 159.0 (C_q), 162.9 (d, J_{CF} = 251.3 Hz, C_q); MS (EI) *m/z* 375 (10) [^{37}Cl-M$^+$], 373 (31) [^{35}Cl-M$^+$], 319 (25), 318 (25), 317 (70), 302 (10), 300 (31), 232 (16), 180 (25), 139 (16), 138 (25), 136 (24), 135 (21), 109 (100), 95 (31), 83 (11), 75 (17), 57 (58), 56 (22), 55 (10), 41 (55), 39 (17), 29 (15); HRMS (EI) calcd for $C_{19}H_{17}ClFN_3O_2$ [M$^+$]: 373.0993, found: 373.0992.

4.1.23 Methyl 1-(4-fluorophenyl)-3-phenyl-1H-1,2,4-triazole-5-carboxylate (6d) and methyl 1-(4-fluorophenyl)-5-phenyl-1H-1,2,4-triazole-3-carboxylate (5d) are prepared from (benzylidene-amino) acetic acid methyl ester (**3d**) (339 µmol, 60.0 mg) and *tert*-butyl 2-(4-fluorophenyl)azocarboxylate (**1a**) (678 µmol, 152 mg) according to general procedure GP 2. The crude product is subjected to column chromatography (silica gel, dichloromethane / ethyl acetate = 50:1) to give the title compounds **6d** (41.7 µmol, 12.4 mg, 12%) and **5d** (141 µmol, 41.9 mg, 42%) as pale yellow solids. Methyl 1-(4-fluorophenyl)-3-phenyl-1*H*-1,2,4-triazole-5-carboxylate (**6d**): R_f = 0.7 (dichloromethane / ethyl acetate = 50:1) (UV); ^{1}H NMR (360 MHz, $CDCl_3$) δ 3.96 (s, 3 H), 7.21 (dd, J_{HF} = 8.1 Hz, *J* = 9.1 Hz, 2 H), 7.44-7.49 (m, 2 H), 7.51 (dd, J_{HF} = 4.7 Hz, *J* = 9.1 Hz, 2 H), 8.17-8.22 (m, 2 H); ^{13}C NMR (151 MHz, $CDCl_3$) δ 52.3 (CH_3), 116.0 (d, J_{CF} = 23.3 Hz, 2 × CH), 126.8 (2 × CH), 127.8 (d, J_{CF} = 8.9 Hz, 2 × CH), 128.7 (2 × CH), 129.5 (C_q), 130.1 (CH), 134.0 (d, J_{CF} = 3.4 Hz, C_q), 145.2 (C_q), 157.9 (C_q), 162.2 (C_q), 163.0 (d, J_{CF} = 248.4 Hz, C_q); MS (EI) *m/z* 297 (81) [M$^+$], 109 (100); HRMS (EI) calcd for $C_{16}H_{12}FN_3O_2$ [M$^+$]: 297.0914, found: 297.0914. Methyl 1-(4-fluorophenyl)-5-phenyl-1*H*-1,2,4-triazole-3-carboxylate (**5d**): R_f = 0.3 (dichloromethane / ethyl acetate = 50:1) (UV); ^{1}H NMR (360 MHz, $CDCl_3$) δ 4.05 (s, 3 H), 7.13 (dd, J_{HF} = 8.0 Hz, *J* = 9.2 Hz, 2 H), 7.32-7.47 (m, 5 H), 7.50-7.55 (m, 2 H); ^{13}C NMR (91 MHz, $CDCl_3$) δ 52.9 (CH_3), 116.6 (d, J_{CF} = 23.3 Hz, 2 × CH), 126.5 (C_q), 127.5 (d, J_{CF} = 8.9 Hz, 2 × CH), 128.7 (2 × CH), 129.1 (2 × CH), 130.7 (CH), 133.7 (d, J_{CF} = 3.4 Hz, C_q), 154.3 (C_q), 155.7 (C_q), 160.2 (C_q), 162.8 (d, J_{CF} = 251.0 Hz, C_q); MS (EI) *m/z* 297 (81) [M$^+$], 109 (100); HRMS (EI) calcd for $C_{16}H_{12}FN_3O_2$ [M$^+$]: 297.0914, found: 297.0914.

4.1.24 Ethyl 3-(2,4-dichlorophenyl)-1-(4-fluorophenyl)-1H-1,2,4-triazole-5-carboxylate (6e) and ethyl 5-(2,4-dichlorophenyl)-1-(4-fluorophenyl)-1H-1,2,4-triazole-3-carboxylate (5e) are prepared from 2-((2,4-dichlorobenzylidene)-amino) acetic acid ethyl ester (**3e**) (577 µmol, 150 mg) and *tert*-butyl 2-(4-fluorophenyl)azocarboxylate (**1a**) (1.15 mmol, 258 mg) according to general procedure GP 2. The crude product is subjected to column chromatography (silica gel, dichloromethane / ethyl acetate = 100:1) to give the title compounds **6e** (115 µmol, 43.7 mg, 20%) and **5e** (69.4 µmol, 26.4 mg, 12%) as white solids. Ethyl 3-(2,4-dichlorophenyl)-1-(4-fluorophenyl)-1*H*-1,2,4-triazole-5-carboxylate (**6e**): R_f = 0.8 (dichloromethane / ethyl acetate = 100:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ 1.35 (t, *J* = 7.1 Hz, 3 H), 4.40 (q, *J* = 7.1 Hz, 2 H), 7.21 (dd, J_{HF} = 8.1 Hz, *J* = 9.0 Hz, 2 H), 7.35 (dd, *J* = 2.1 Hz, *J* = 8.4 Hz, 1 H), 7.50-7.54 (m, 3 H), 7.93

(d, J = 8.4 Hz, 1 H); ^{13}C NMR (91 MHz, $CDCl_3$) δ 14.0 (CH_3), 62.9 (CH_2), 116.0 (d, J_{CF} = 23.3 Hz, 2 × CH), 127.1 (CH), 127.4 (C_q), 127.8 (d, J_{CF} = 9.0 Hz, 2 × CH), 130.6 (CH), 132.4 (CH), 133.8 (C_q), 133.9 (d, J_{CF} = 3.3 Hz, C_q), 136.1 (C_q), 145.2 (C_q), 157.3 (C_q), 159.8 (C_q),163.1 (d, J_{CF} = 250.6 Hz, C_q); MS (ESI) *m/z* 384 [$^{37}Cl_2$-MH^+], 382 [$^{37}Cl^{35}Cl$-MH^+], 380 [$^{35}Cl_2$-MH^+]; HRMS (ESI) calcd for $C_{17}H_{12}Cl_2FN_3O_2$ [M^++Na^+]: 402.0183, found: 402.0171. Ethyl 5-(2,4-dichlorophenyl)-1-(4-fluorophenyl)-1*H*-1,2,4-triazole-3-carboxylate (**5e**): R_f = 0.6 (dichloromethane / ethyl acetate = 100:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ 1.48 (t, J = 7.1 Hz, 3 H), 4.55 (q, J = 7.1 Hz, 2 H), 7.08 (dd, J_{HF} = 8.0 Hz, J = 9.1 Hz, 2 H), 7.32 (dd, J_{HF} = 4.6 Hz, J = 9.1 Hz, 2 H), 7.39 (dd, J = 2.0 Hz, J = 8.3 Hz, 1 H), 7.43 (d, J = 2.0 Hz, 1 H), 7.50 (d, J = 8.3 Hz, 1 H); ^{13}C NMR (91 MHz, $CDCl_3$) δ 14.2 (CH_3), 62.2 (CH_2), 116.3 (d, J_{CF} = 23.3 Hz, 2 × CH), 125.6 (C_q), 125.8 (J_{CF} = 8.9 Hz, 2 × CH), 127.6 (CH), 130.0 (CH), 132.7 (CH), 133.0 (d, J_{CF} = 3.3 Hz, C_q), 134.5 (C_q), 137.7 (C_q), 152.3 (C_q), 154.7 (C_q), 159.5 (C_q), 162.5 (d, J_{CF} = 251.0 Hz, C_q); MS (ESI) *m/z* 384 [$^{37}Cl_2$-M^+], 380 [^{35}Cl-M^+]; HRMS (ESI) calcd for $C_{17}H_{12}Cl_2FN_3O_2$ [M^++Na^+]: 402.0183, found: 402.0178.

4.1.25 Methyl 3-(4-bromophenyl)-1-(4-fluorophenyl)-1H-1,2,4-triazole-5-carboxylate (6f) and methyl 5-(4-bromophenyl)-1-(4-fluorophenyl)-1H-1,2,4-triazole-3-carboxylate (5f) are prepared from (4-bromobenzylidene-amino) acetic acid methyl ester (**3f**) (377 µmol, 100 mg) and *tert*-butyl 2-(4-fluorophenyl)azocarboxylate (**1a**) (754 µmol, 169 mg) according to general procedure GP 2. The crude product is subjected to column chromatography (silica gel, dichloromethane / ethyl acetate = 100:1) to give the title compounds **6f** (94.0 µmol, 35.4 mg, 25%) and **5f** (255 µmol, 95.8 mg, 68%) as white solids. Methyl 3-(4-bromophenyl)-1-(4-fluorophenyl)-1*H*-1,2,4-triazole-5-carboxylate (**6f**): R_f = 0.7 (dichloromethane / ethyl acetate = 100:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ 3.95 (3 H), 7.21 (dd, J_{HF} = 8.2 Hz, J = 8.8 Hz, 2 H), 7.49 (dd, J_{HF} = 4.7 Hz, J = 8.8 Hz, 2 H), 7.59 (d, J = 8.6 Hz, 2 H), 8.06 (d, J = 8.6 Hz, 2 H); ^{13}C NMR (151 MHz, $CDCl_3$) δ 53.5 (CH_3), 116.1 (d, J_{CF} = 23.4 Hz, 2 × CH), 124.5 (C_q), 127.9 (d, J_{CF} = 8.9 Hz, 2 × CH), 128.4 (2 × CH), 128.5 (C_q), 131.9 (2 × CH), 133.8 (d, J_{CF} = 3.3 Hz, C_q), 145.3 (C_q), 157.7 (C_q), 161.3 (C_q), 163.1 (d, J_{CF} = 250.8 Hz, C_q); MS (ESI) *m/z* 379 [^{81}Cl-MH^+], 376 [^{79}Cl-MH^+]; HRMS (ESI) calcd for $C_{16}H_{11}BrFN_3O_2$ [M^++Na^+]: 397.9911, found: 397.9903. Methyl 5-(4-bromophenyl)-1-(4-fluorophenyl)-1*H*-1,2,4-triazole-3-carboxylate (**5f**): R_f = 0.3 (dichloromethane / ethyl acetate = 100:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ 4.04 (3 H), 7.16 (dd, J_{HF} = 8.0 Hz, J = 9.0 Hz, 2 H), 7.38 (dd, J_{HF} = 4.7 Hz, J = 9.0 Hz, 2 H), 7.40 (d, J = 8.6 Hz, 2 H), 7.50 (d, J = 8.6 Hz, 2 H); ^{13}C NMR (91 MHz, $CDCl_3$) δ 53.0 (CH_3), 116.8 (d, J_{CF} = 23.4 Hz, 2 × CH), 125.4 (C_q), 126.0 (C_q), 127.6 (d, J_{CF} = 8.9 Hz, 2 × CH), 130.5 (2 × CH), 132.1 (2 × CH), 133.5 (d, J_{CF} = 3.3 Hz, C_q), 154.4 (C_q), 154.8 (C_q), 160.1 (C_q), 163.0 (d, J_{CF} = 251.7 Hz, C_q); MS (ESI) *m/z* 379 [^{81}Cl-MH^+], 376 [^{79}Cl-MH^+]; HRMS (ESI) calcd for $C_{16}H_{11}BrFN_3O_2$ [M^++Na^+]: 397.9911, found: 397.9904.

4.1.26 Methyl 3-(3,4-dimethoxyphenyl)-1-(4-fluorophenyl)-1H-1,2,4-triazole-5-carboxylate (6g) and methyl 5-(3,4-dimethoxyphenyl)-1-(4-fluorophenyl)-1H-1,2,4-triazole-3-carboxylate (5g) are prepared from 2-((3,4-dimethoxybenzylidene)amino)-acetic acid methyl ester (**3g**) (422 µmol, 100 mg) and *tert*-butyl 2-(4-fluorophenyl)azocarboxylate (**1a**) (844 µmol, 190 mg) according to general procedure GP 2. The crude product is subjected to column chromatography (silica gel, dichloromethane / ethyl acetate = 20:1 → 10:1) to give the title compounds **6g** (78.4 µmol, 28.0 mg, 18%) and **5g** (173 µmol, 61.9 mg, 41%) as pale yellow solids. Methyl 3-(3,4-dimethoxyphenyl)-1-(4-fluorophenyl)-1*H*-1,2,4-triazole-5-carboxylate (**6g**): R_f = 0.4 (dichloromethane / ethyl acetate = 20:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ 3.94 (s, 3 H), 3.95 (s, 3 H), 3.97 (s, 3 H), 6.94 (d, J = 8.4 Hz, 1 H), 7.21 (dd, J_{HF} = 8.1 Hz, J = 9.0 Hz, 2 H), 7.51 (dd, J_{HF} = 4.7 Hz, J = 9.0 Hz, 2 H), 7.68 (d, J = 1.9 Hz, 1 H), 7.80 (dd, J = 1.9 Hz, J = 8.4 Hz, 1 H); ^{13}C NMR (91 MHz, $CDCl_3$) δ 53.2 (CH_3), 56.0 (CH_3), 56.1 (CH_3), 109.6 (CH), 111.1 (CH), 116.0 (d, J_{CF} = 23.3 Hz, 2 × CH), 119.9 (CH), 122.4 (C_q), 127.9 (d, J_{CF} = 9.0 Hz, 2 × CH), 134.0 (d, J_{CF} = 3.4 Hz, C_q), 145.1 (C_q), 149.1 (C_q), 150.7 (C_q), 157.8 (C_q), 162.2 (C_q), 163.0 (d, J_{CF} = 250.0 Hz, C_q); MS (EI) *m/z* 358 (18) [MH^+], 357 (100) [M^+], 314 (12), 109 (22); HRMS (EI) calcd for $C_{18}H_{16}FN_3O_4$ [M^+]: 357.1125, found: 357.1125. Methyl 5-(3,4-dimethoxyphenyl)-1-(4-fluorophenyl)-1*H*-1,2,4-triazole-3-carboxylate (**5g**): R_f = 0.2 (dichloromethane / ethyl acetate = 20:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ 3.80 (s, 3 H), 3.90 (s, 3 H), 4.07 (s, 3 H), 6.80 (d, J = 8.5 Hz, 1 H), 7.00 (dd, J = 2.0 Hz, J = 8.4 Hz, 1 H), 7.15-7.21 (m, 3 H), 7.43 (dd, J_{HF} = 4.7 Hz, J = 9.0 Hz, 2 H); ^{13}C NMR (151 MHz, $CDCl_3$) δ 52.9 (CH_3), 55.9 (CH_3), 110.8 (CH), 112.0 (CH), 116.6 (d, J_{CF} = 23.1 Hz, 2 × CH), 118.8 (C_q), 122.3 (CH), 127.8 (d, J_{CF} = 8.9 Hz, 2 × CH), 134.0 (d, J_{CF} = 3.3 Hz, C_q), 149.0 (C_q), 151.1 (C_q), 154.2 (C_q), 155.7 (C_q), 160.4 (C_q). (One CH_3 and one C_q signal are missing due to overlap); MS (EI) *m/z* 358 (15) [MH^+], 357 (75) [M^+], 194 (10), 109 (100); HRMS (EI) calcd for $C_{18}H_{16}FN_3O_4$ [M^+]: 357.1125, found: 357.1125.

4.1.27 Methyl 1-(4-bromophenyl)-3-(4-fluorophenyl)-1H-1,2,4-triazole-5-carboxylate (6h) and methyl 1-(4-bromophenyl)-5-(4-fluorophenyl)-1H-1,2,4-triazole-3-carboxylate (5h) are prepared from (4-fluorobenzylidene-amino) acetic acid methyl ester (**3h**) (768 µmol, 150 mg) and *tert*-butyl 2-(4-bromophenyl)azocarboxylate (**1b**) (1.54 mmol, 439 mg) according to general procedure GP 2. The crude product is subjected to column chromatography (silica gel, dichloromethane / ethyl acetate = 100:1) to give the title compounds **6h** (223 µmol, 83.9 mg, 29%) and **5h** (389 µmol, 146 mg, 51%) as white solids. Methyl 1-(4-bromophenyl)-3-(4-fluorophenyl)-1*H*-1,2,4-triazole-5-carboxylate (**6h**): R_f = 0.9 (dichloromethane / ethyl acetate = 100:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ 3.96 (s, 3 H), 7.14 (t, J_{HF} = 8.8 Hz, J = 8.8 Hz, 2 H), 7.40 (d, J = 8.8 Hz, 2 H), 7.66 (d, J = 8.8 Hz, 2 H), 8.17 (dd, J_{HF} = 5.4 Hz, J = 8.8 Hz, 2 H); ^{13}C NMR (151 MHz, $CDCl_3$) δ 53.4 (CH_3), 115.8 (d, J_{CF} = 21.9 Hz, 2 × CH), 123.9 (C_q), 125.7 (d, J_{CF} = 3.2 Hz, C_q), 127.3 (2 × CH), 128.8 (d, J_{CF} = 8.6 Hz, 2 × CH), 132.2 (2 × CH), 136.8 (C_q), 145.2 (C_q), 157.8 (C_q), 161.6 (C_q), 164.0 (d, J_{CF} = 248.9 Hz, C_q); MS (ESI) *m/z* 376 [^{79}Br-MH^+]; HRMS (ESI) calcd for $C_{16}H_{11}BrFN_3O_2$ [M^++Na^+]: 397.9911, found: 397.9909. Methyl 1-(4-bromophenyl)-5-(4-fluorophenyl)-1*H*-1,2,4-triazole-3-carboxylate (**5h**): R_f = 0.9 (dichloromethane / ethyl acetate = 100:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ 4.06 (s, 3 H), 7.12 (t, J_{HF} = 8.6 Hz, J = 8.6 Hz, 2 H), 7.29 (d, J = 8.8 Hz, 2 H), 7.54 (dd, J_{HF} = 5.2 Hz, J = 8.9 Hz, 2 H), 7.61 (d, J = 8.8 Hz, 2 H); ^{13}C NMR (91 MHz, $CDCl_3$) δ 53.0 (CH_3), 116.1 (d, J_{CF} = 22.1 Hz, 2 × CH), 122.7 (d, J_{CF} = 3.5 Hz, C_q), 123.8 (C_q), 126.9 (2 × CH), 131.3 (d, J_{CF} = 8.8 Hz, 2 × CH), 132.9 (2 × CH), 136.4 (C_q), 154.5 (C_q), 154.8 (C_q), 160.1 (C_q), 164.1 (d, J_{CF} = 253.0 Hz, C_q); MS (ESI) *m/z* 376 [^{79}Br-MH^+]; HRMS (ESI) calcd for $C_{16}H_{11}BrFN_3O_2$ [M^++Na^+]: 397.9911, found: 397.9904.

4.1.28 Tert-butyl 1-(4-bromophenyl)-3-(4-chlorophenyl)-1H-1,2,4-triazole-5-carboxylate (6i) and tert-butyl 1-(4-chlorophenyl)-5-(4-bromophenyl)-1H-1,2,4-triazole-3-

carboxylate (5i) are prepared from (4-chlorobenzylidene-amino) acetic acid *tert*-butyl ester (**3c**) (591 µmol, 150 mg) and *tert*-butyl 2-(4-bromophenyl)azocarboxylate (**1b)** (1.18 mmol, 336 mg) according to general procedure GP 2. The crude product is subjected to column chromatography (silica gel, dichloromethane / ethyl acetate = 150:1) to give the title compounds **6i** (160 µmol, 69.6 mg, 27%) and **5i** (365 µmol, 159 mg, 62%) as white solids. *Tert*-butyl 1-(4-bromophenyl)-3-(4-chlorophenyl)-1*H*-1,2,4-triazole-5-carboxylate (**6i**): R_f = 0.7 (dichloromethane / ethyl acetate = 100:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ 1.47 (9 H), 7.38 (d, *J* = 8.8 Hz, 2 H), 7.42 (d, *J* = 8.8 Hz, 2 H), 7.65 (d, *J* = 8.8 Hz, 2 H), 8.12 (d, *J* = 8.8 Hz, 2 H); ^{13}C NMR (91 MHz, $CDCl_3$) δ 27.7 (3 × CH_3), 85.0 (C_q), 123.5 (C_q), 127.2 (2 × CH), 128.0 (2 × CH), 128.2 (C_q), 128.8 (2 × CH), 132.1 (2 × CH), 135.9 (C_q), 137.2 (C_q), 150.0 (C_q), 156.2 (C_q), 161.2 (C_q); MS (ESI) *m/z* 438 [^{37}Cl^{81}Br-MH$^+$], 436 [^{37}Cl^{79}Br-MH$^+$], 436 [^{35}Cl^{81}Br-MH$^+$], 434 [^{35}Cl^{79}Br-MH$^+$]; HRMS (ESI) calcd for $(C_{19}H_{17}BrClN_3O_2)_2$ [M^++Na^+]: 891.0258, found: 891.0254. *Tert*-butyl 1-(4-chlorophenyl)-5-(4-bromophenyl)-1*H*-1,2,4-triazole-3-carboxylate (**5i**): R_f = 0.5 (dichloromethane / ethyl acetate = 100:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ 1.67 (9 H), 7.27 (d, *J* = 8.8 Hz, 2 H), 7.36 (d, *J* = 8.8 Hz, 2 H), 7.47 (d, *J* = 8.8 Hz, 2 H), 7.59 (d, *J* = 8.8 Hz, 2 H); ^{13}C NMR (91 MHz, $CDCl_3$) δ 28.0 (3 × CH_3), 83.4 (C_q), 123.6 (C_q), 125.1 (C_q), 127.0 (2 × CH), 129.0 (2 × CH), 130.3 (2 × CH), 132.8 (2 × CH), 136.4 (C_q), 137.0 (C_q), 154.3 (C_q), 155.8 (C_q), 158.9 (C_q); MS (ESI) *m/z* 438 [^{37}Cl^{81}Br-MH$^+$], 436 [^{37}Cl^{79}Br-MH$^+$], 436 [^{35}Cl^{81}Br-MH$^+$], 434 [^{35}Cl^{79}Br-MH$^+$]; HRMS (ESI) calcd for $(C_{19}H_{17}BrClN_3O_2)_2$ [M^++Na^+]: 891.0258, found: 891.0243.

4.1.29 Methyl 3-(3-bromophenyl)-1-(4-bromophenyl)-1H-1,2,4-triazole-5-carboxylate (6j) and methyl 5-(3-bromophenyl)-1-(4-bromophenyl)-1H-1,2,4-triazole-3-carboxylate (5j) are prepared from (3-bromobenzylidene-amino) acetic acid methyl ester (**3i**) (566 µmol, 150 mg) and *tert*-butyl 2-(4-bromophenyl)azocarboxylate (**1b)** (1.11 mmol, 317 mg) according to general procedure GP 2. The crude product is subjected to column chromatography (silica gel, dichloromethane / ethyl acetate = 100:1) to give the title compounds **6j** (128 µmol, 55.9 mg, 23%) and **5j** (286 µmol, 125 mg, 52%) as white solids. Methyl 3-(3-bromophenyl)-1-(4-bromophenyl)-1*H*-1,2,4-triazole-5-carboxylate (**6j**): R_f = 0.9 (dichloromethane / ethyl acetate = 100:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ 3.97 (s, 3 H), 7.33 (t, *J* = 8.0 Hz, 1 H), 7.40 (d, *J* = 8.8 Hz, 2 H), 7.57 (ddd, *J* = 1.1 Hz, *J* = 1.8 Hz, *J* = 8.0 Hz, 1 H), 7.66 (d, *J* = 8.8 Hz, 2 H), 8.11 (ddd, *J* = 1.1 Hz, *J* = 1.8 Hz, *J* = 8.8 Hz, 1 H), 8.36 (t, *J* = 1.8 Hz, 1 H); ^{13}C NMR (91 MHz, $CDCl_3$) δ 53.4 (CH_3), 122.9 (CH), 124.0 (CH), 125.3 (CH), 127.3 (2 × CH), 129.7 (C_q), 130.2 (CH), 131.4 (C_q), 132.2 (2 × CH), 133.1 (C_q), 136.7 (C_q), 145.3 (C_q), 157.7 (C_q), 161.0 (C_q); MS (ESI) *m/z* 438 [^{81}Br^{79}Br-MH$^+$]; HRMS (ESI) calcd for $C_{16}H_{11}Br_2N_3O_2$ [M^++Na^+]: 459.9091, found: 459.9082. Methyl 5-(3-bromophenyl)-1-(4-bromophenyl)-1*H*-1,2,4-triazole-3-carboxylate (**5j**): R_f = 0.6 (dichloromethane / ethyl acetate = 100:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ 4.07 (s, 3 H), 7.22 (t, *J* = 8.0 Hz, 1 H), 7.28-7.32 (m, 3 H), 7.59-7.64 (m, 3H), 7.88 (t, *J* = 1.8 Hz, 1 H); ^{13}C NMR (151 MHz, $CDCl_3$) δ 53.0 (CH_3), 122.9 (CH), 124.0 (CH), 126.9 (CH), 127.3 (2 × CH), 128.3 (C_q), 130.1 (CH), 132.2 (C_q), 132.9 (2 × CH), 133.9 (C_q), 136.1 (C_q), 154.1 (C_q), 154.5 (C_q), 160.0 (C_q); MS (ESI) *m/z* 440 [^{81}Br$_2$-MH$^+$], 438 [^{81}Br^{79}Br-MH$^+$]; HRMS (ESI) calcd for $C_{16}H_{11}Br_2N_3O_2$ [M^++Na^+]: 459.9091, found: 459.9079.

4.1.30 Methyl 3-([1,1'-biphenyl]-4-yl)-1-(4-bromophenyl)-1H-1,2,4-triazole-5-carboxylate (6k) and methyl 5-([1,1'-biphenyl]-4-yl)-1-(4-bromophenyl)-1H-1,2,4-triazole-3-carboxylate (5k) are prepared from methyl 2-(([1,1'-biphenyl]-4-ylmethylene)-amino)acetate (**3j**) (592 µmol, 150 mg) and *tert*-butyl 2-(4-bromophenyl)azocarboxylate (**1b)** (1.18 mmol, 336 mg) according to general procedure GP 2. The crude product is subjected to column chromatography (silica gel, dichloromethane / ethyl acetate = 100:1) to give the title compounds **6k** (148 µmol, 64.3 mg, 25%) and **5k** (141 µmol, 105 mg, 41%) as white solids. Methyl 3-([1,1'-biphenyl]-4-yl)-1-(4-bromophenyl)-1*H*-1,2,4-triazole-5-carboxylate (**6k**): R_f = 0.9 (dichloromethane / ethyl acetate = 100:1) (UV); ^{1}H NMR (360 MHz, $CDCl_3$) δ 3.98 (s, 3 H), 7.35-7.40 (m, 1 H), 7.42-7.49 (m, 4 H), 7.64-7.72 (m, 6 H), 8.27 (d, *J* = 8.6 Hz, 2 H); ^{13}C NMR (91 MHz, $CDCl_3$) δ 53.2 (CH_3), 123.7 (C_q), 127.0 (2 × CH), 127.1 (2 × CH), 127.2 (2 × CH), 127.2 (2 × CH), 127.6 (CH), 128.2 (C_q), 128.7 (2 × CH), 132.1 (2 × CH), 136.7 (C_q), 140.3 (C_q), 142.7 (C_q), 145.0 (C_q), 157.7 (C_q), 162.0 (C_q); MS (ESI) *m/z* 436 [^{81}Br-MH$^+$]; HRMS (ESI) calcd for $C_{22}H_{16}BrN_3O_2$ [M^++Na^+]: 456.0318, found: 456.0317. Methyl 5-([1,1'-biphenyl]-4-yl)-1-(4-bromophenyl)-1*H*-1,2,4-triazole-3-carboxylate (**5k**): R_f = 0.5 (dichloromethane / ethyl acetate = 100:1) (UV); ^{1}H NMR (360 MHz, $CDCl_3$) δ 4.06 (s, 3 H), 7.33 (d, *J* = 8.8 Hz, 2 H), 7.36-7.40 (m, 1 H), 7.43-7.47 (m, 2 H), 7.59-7.61 (m, 8 H); ^{13}C NMR (91 MHz, $CDCl_3$) δ 52.9 (CH_3), 123.7 (C_q), 125.1 (C_q), 127.0 (2 × CH), 127.0 (2 × CH), 127.3 (2 × CH), 128.1 (CH), 128.9 (2 × CH), 129.5 (2 × CH), 132.8 (2 × CH), 136.6 (C_q), 139.5 (C_q), 143.5 (C_q), 154.5 (C_q), 155.4 (C_q), 160.2 (C_q); MS (ESI) *m/z* 436 [^{81}Br-MH$^+$]; HRMS (ESI) calcd for $C_{22}H_{16}BrN_3O_2$ [M^++Na^+]: 456.0318, found: 456.0309.

4.1.31 Methyl 1-(4-iodophenyl)-3-(4-cyanophenyl)-1H-1,2,4-triazole-5-carboxylate (6l) and methyl 1-(4-iodophenyl)-5-(4-cyanophenyl)-1H-1,2,4-triazole-3-carboxylate (5l) are prepared from (4-cyanobenzylidene-amino) acetic acid methyl ester (**3k**) (742 µmol, 150 mg) and *tert*-butyl 2-(4-iodophenyl)azocarboxylate (**1c)** (1.19 mmol, 395 mg) according to general procedure GP 2. The crude product is subjected to column chromatography (silica gel, dichloromethane / ethyl acetate = 100:1) to give the title compounds **6l** (274 µmol, 118 mg, 37%) and **5l** (453 µmol, 195 mg, 61%) as pale yellow solids. Methyl 1-(4-iodophenyl)-3-(4-cyanophenyl)-1*H*-1,2,4-triazole-5-carboxylate (**6l**): R_f = 0.8 (dichloromethane / ethyl acetate = 100:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ 3.98 (s, 3 H), 7.26 (d, *J* = 8.7 Hz, 2 H), 7.76 (d, *J* = 8.7 Hz, 2 H), 7.88 (d, *J* = 8.7 Hz, 2 H), 8.30 (d, *J* = 8.7 Hz, 2 H); ^{13}C NMR (91 MHz, $CDCl_3$) δ 53.5 (CH_3), 95.8 (C_q), 113.6 (C_q), 118.5 (C_q), 127.2 (2 × CH), 127.3 (2 × CH), 132.6 (2 × CH), 133.7 (C_q), 137.3 (C_q), 138.3 (2 × CH), 145.6 (C_q), 157.6 (C_q), 160.7 (C_q); MS (ESI) *m/z* 431 [MH^+]; HRMS (ESI) calcd for $C_{17}H_{11}IN_4O_2$ [M^++Na^+]: 452.9819, found: 452.9809. Methyl 1-(4-iodophenyl)-5-(4-cyanophenyl)-1*H*-1,2,4-triazole-3-carboxylate (**5l**): R_f = 0.5 (dichloromethane / ethyl acetate = 100:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ 4.05 (s, 3 H), 7.12 (d, *J* = 8.7 Hz, 2 H), 7.67 (d, *J* = 8.8 Hz, 2 H), 7.68 (d, *J* = 8.8 Hz, 2 H), 7.82 (d, *J* = 8.7 Hz, 2 H); ^{13}C NMR (151 MHz, $CDCl_3$) δ 53.1 (CH_3), 95.9 (C_q), 114.7 (C_q), 117.7 (C_q), 127.0 (2 × CH), 129.6 (2 × CH), 130.6 (C_q), 132.5 (2 × CH), 136.7 (C_q), 139.1 (2 × CH), 153.7 (C_q), 154.8 (C_q), 159.8 (C_q); MS (ESI) *m/z* 431 [MH^+]; HRMS (ESI) calcd for $C_{17}H_{11}IN_4O_2$ [MH^+]: 430.9999, found: 430.9996.

4.1.32 Methyl 3-(4-bromophenyl)-1-(4-iodophenyl)-1H-1,2,4-triazole-5-carboxylate (6m) and methyl 5-(4-bromophenyl)-1-(4-iodophenyl)-1H-1,2,4-triazole-3-carboxylate (5m) are prepared from (4-bromobenzylidene-amino) acetic acid methyl ester (**3f**) (566 µmol, 150 mg) and *tert*-butyl 2-(4-

iodophenyl)azocarboxylate (**1c)** (1.13 mmol, 375 mg) according to general procedure GP 2. The crude product is subjected to column chromatography (silica gel, dichloromethane / ethyl acetate = 100:1) to give the title compounds **6m** (122 µmol, 59.1 mg, 22%) and **5m** (329 µmol, 159 mg, 58%) as white solids. Methyl 3-(4-bromophenyl)-1-(4-iodophenyl)-1*H*-1,2,4-triazole-5-carboxylate (**6m**): R_f = 0.8 (dichloromethane / ethyl acetate = 100:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ 3.96 (s, 3 H), 7.26 (d, *J* = 8.7 Hz, 2 H), 7.59 (d, *J* = 8.7 Hz, 2 H), 7.86 (d, *J* = 8.7 Hz, 2 H), 8.06 (d, *J* = 8.7 Hz, 2 H); ^{13}C NMR (91 MHz, $CDCl_3$) δ 53.4 (CH_3), 95.5 (C_q), 124.5 (C_q), 127.4 (2 × CH), 128.3 (2 × CH), 128.5 (C_q), 131.9 (2 × CH), 137.4 (C_q), 138.2 (2 × CH), 145.2 (C_q), 157.7 (C_q), 161.5 (C_q); MS (ESI) *m/z* 486 [^{81}Br-MH$^+$], 484 [^{79}Br-MH$^+$]; HRMS (ESI) calcd for $C_{16}H_{11}BrIN_3O_2$ [M^++Na^+]: 505.8972, found: 505.8961. Methyl 5-(4-bromophenyl)-1-(4-iodophenyl)-1*H*-1,2,4-triazole-3-carboxylate (**5m**): R_f = 0.5 (dichloromethane / ethyl acetate = 100:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ 4.06 (s, 3 H), 7.16 (d, *J* = 8.8 Hz, 2 H), 7.42 (d, *J* = 8.8 Hz, 2 H), 7.54 (d, *J* = 8.8 Hz, 2 H), 7.81 (d, *J* = 8.8 Hz, 2 H); ^{13}C NMR (151 MHz, $CDCl_3$) δ 53.0 (CH_3), 95.4 (C_q), 125.3 (C_q), 125.7 (C_q), 127.0 (2 × CH), 130.5 (2 × CH), 132.1 (2 × CH), 136.9 (C_q), 138.6 (2 × CH), 154.5 (C_q), 154.7 (C_q), 160.0 (C_q); MS (ESI) *m/z* 486 [^{81}Br-MH$^+$], 484 [^{79}Br-MH$^+$]; HRMS (ESI) calcd for $C_{16}H_{11}BrIN_3O_2$ [M^++Na^+]: 505.8972, found: 505.8951.

4.1.33 Methyl 3-(3-bromophenyl)-1-(4-iodophenyl)-1H-1,2,4-triazole-5-carboxylate (6n) and methyl 5-(3-bromophenyl)-1-(4-iodophenyl)-1H-1,2,4-triazole-3-carboxylate (5n) are prepared from (3-bromobenzylidene-amino) acetic acid methyl ester (**3i**) (566 µmol, 150 mg) and *tert*-butyl 2-(4-iodophenyl)azocarboxylate (**1c)** (1.13 mmol, 375 mg) according to general procedure GP 2. The crude product is subjected to column chromatography (silica gel, dichloromethane / ethyl acetate = 100:1) to give the title compounds **6n** (147 µmol, 71.2 mg, 26%) and **5n** (326 µmol, 158 mg, 58%) as white solids. Methyl 3-(3-bromophenyl)-1-(4-iodophenyl)-1*H*-1,2,4-triazole-5-carboxylate (**6n**): R_f = 0.8 (dichloromethane / ethyl acetate = 100:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ 3.97 (s, 3 H), 7.26 (d, *J* = 8.8 Hz, 2 H), 7.33 (t, *J* = 7.9 Hz, 1 H), 7.57 (ddd, *J* = 1.4 Hz, *J* = 2.0 Hz, *J* = 7.9 Hz, 1 H), 7.87 (d, *J* = 8.8 Hz, 2 H), 8.10-8.12 (m, 1 H), 8.36 (t, *J* = 1.7 Hz, 1 H); ^{13}C NMR (91 MHz, $CDCl_3$) δ 53.4 (CH_3), 95.6 (C_q), 122.9 (C_q), 125.3 (CH), 127.4 (2 × CH), 129.7 (CH), 130.2 (CH), 131.4 (C_q), 133.1 (CH), 137.4 (C_q), 138.3 (2 × CH), 145.2 (C_q), 157.7 (C_q), 161.1 (C_q); MS (ESI) *m/z* 486 [^{81}Br-M$^+$], 484 [^{79}Br-M$^+$]; HRMS (ESI) calcd for $C_{16}H_{11}BrIN_3O_2$ [M^++Na^+]: 505.8972, found: 505.8962. Methyl 5-(3-bromophenyl)-1-(4-iodophenyl)-1*H*-1,2,4-triazole-3-carboxylate (**5n**): R_f = 0.5 (dichloromethane / ethyl acetate = 100:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ 4.05 (s, 3 H), 7.14 (d, *J* = 8.8 Hz, 2 H), 7.21 (t, *J* = 7.9 Hz, 1 H), 7.30 (ddd, *J* = 1.1 Hz, *J* = 1.7 Hz, *J* = 7.9 Hz, 1 H), 7.59 (ddd, *J* = 1.1 Hz, *J* = 2.0 Hz, *J* = 7.9 Hz, 1 H), 7.80 (d, *J* = 8.8 Hz, 2 H), 7.86 (d, *J* = 1.7 Hz, 1 H); ^{13}C NMR (91 MHz, $CDCl_3$) δ 53.1 (CH_3), 95.5 (C_q), 123.0 (C_q), 126.9 (2 × CH), 127.3 (CH), 128.3 (C_q), 130.0 (CH), 132.2 (CH), 133.9 (CH), 136.9 (C_q), 138.9 (2 × CH), 154.1 (C_q), 154.6 (C_q), 160.1 (C_q); MS (ESI) *m/z* 486 [^{81}Br-MH$^+$], 484 [^{79}Br-MH$^+$]; HRMS (ESI) calcd for $C_{16}H_{11}BrIN_3O_2$ [M^++Na^+]: 505.8972, found: 505.8959.

4.1.34 Methyl 3-(4-chlorophenyl)-1-(4-fluoro-2-methylphenyl)-1H-1,2,4-triazole-5-carboxylate (6o) and methyl 5-(4-chlorophenyl)-1-(4-fluoro-2-methylphenyl)-1H-1,2,4-triazole-3-carboxylate (5o) are prepared from (4-chlorobenzylidene-amino) acetic acid methyl ester (**3a**) (709 µmol, 150 mg) and *tert*-butyl 2-(4-fluoro-2-methylphenyl)azocarboxylate (**1d**) (1.42 mmol, 338 mg) according to general procedure GP 2. The crude product is subjected to column chromatography (silica gel, dichloromethane / ethyl acetate = 100:1 → 50:1) to give the title compounds **6o** (234 µmol, 80.9 mg, 33%) and **5o** (156 µmol, 53.9 mg, 22%) as pale yellow solids. Methyl 3-(4-chlorophenyl)-1-(4-fluoro-2-methylphenyl)-1*H*-1,2,4-triazole-5-carboxylate (**6o**): R_f = 0.8 (dichloromethane / ethyl acetate = 100:1) (UV); ^{1}H NMR (360 MHz, $CDCl_3$) δ 2.10 (s, 3 H), 3.93 (s, 3 H), 7.02-7.06 (m, 1 H), 7.08-7.10 (m, 1 H), 7.27 (dd, J_{HF} = 5.2 Hz, *J* = 8.7 Hz, 1 H), 7.44 (d, *J* = 8.8 Hz, 2 H), 8.14 (d, *J* = 8.8 Hz, 2 H); ^{13}C NMR (91 MHz, $CDCl_3$) δ 17.5 (d, J_{CF} = 1.5 Hz, CH_3), 53.3 (CH_3), 113.7 (d, J_{CF} = 23.1 Hz, CH), 117.7 (d, J_{CF} = 22.8 Hz, CH), 128.1 (2 × CH), 128.1 (C_q), 128.7 (d, J_{CF} = 9.4 Hz, CH), 129.0 (2 × CH), 133.3 (d, J_{CF} = 3.2 Hz, C_q), 136.1 (C_q), 137.7 (d, J_{CF} = 8.9 Hz, C_q), 146.1 (C_q), 157.4 (C_q), 161.6 (C_q), 163.2 (d, J_{CF} = 250.3 Hz, C_q); MS (ESI) *m/z* 348 [^{37}Cl-MH$^+$], 346 [^{35}Cl-MH$^+$]; HRMS (ESI) calcd for $C_{17}H_{13}ClFN_3O_2$ [M^++Na^+]: 368.0573, found: 368.0556. Methyl 5-(4-chlorophenyl)-1-(4-fluoro-2-methylphenyl)-1*H*-1,2,4-triazole-3-carboxylate (**5o**): R_f = 0.5 (dichloromethane / ethyl acetate = 100:1) (UV); ^{1}H NMR (360 MHz, $CDCl_3$) δ 1.96 (s, 3 H), 4.06 (s, 3 H), 7.06 (d, *J* = 8.8 Hz, 2 H), 7.28-7.33 (m, 3 H),7.48 (d, *J* = 8.8 Hz, 2 H); ^{13}C NMR (91 MHz, $CDCl_3$) δ 17.5 (d, J_{CF} = 1.5 Hz, CH_3), 53.0 (CH_3), 114.5 (d, J_{CF} = 23.1 Hz, CH), 118.3 (d, J_{CF} = 22.8 Hz, CH), 129.2 (2 × CH), 129.3 (d, J_{CF} = 9.4 Hz, CH), 129.5 (C_q), 129.5 (2 × CH), 132.9 (d, J_{CF} = 3.5 Hz, C_q), 137.3 (C_q), 137.9 (d, J_{CF} = 8.9 Hz, C_q), 154.5 (C_q), 155.5 (C_q), 160.2 (C_q), 163.3 (d, J_{CF} = 251.7 Hz, C_q); MS (ESI) *m/z* 348 [^{37}Cl-MH$^+$], 346 [^{35}Cl-MH$^+$]; HRMS (ESI) calcd for $C_{17}H_{13}ClFN_3O_2$ [M^++Na^+]: 368.0573, found: 368.0557.

4.1.35 3-(4-Chlorophenyl)-1-(2,4-dichlorophenyl)-1H-1,2,4-triazole (7) and methyl 5-(4-chlorophenyl)-1-(2,4-dichlorophenyl)-1H-1,2,4-triazole-3-carboxylate (5p) are prepared from (4-chlorobenzylidene-amino) acetic acid methyl ester (**3a**) (236 µmol, 50 mg) and *tert*-butyl 2-(2,4-dichlorophenyl)azocarboxylate (**1e**) (472 µmol, 130 mg) according to general procedure GP 2. The crude product is subjected to column chromatography (silica gel, dichloromethane / ethyl acetate = 100:1 → 50:1) to give the title compounds **7** (234 µmol, 80.9 mg, 32%) and **5p** (156 µmol, 53.9 mg, 40%) as white solids. 3-(4-Chlorophenyl)-1-(2,4-dichlorophenyl)-1*H*-1,2,4-triazole (**7**): R_f = 0.9 (dichloromethane / ethyl acetate = 100:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.42-7.45 (m, 3 H), 7.60 (d, *J* = 2.2 Hz, 1 H), 7.63 (d, *J* = 8.6 Hz, 1 H), 8.12 (d, *J* = 8.8 Hz, 2 H), 8.55 (s, 1 H); ^{13}C NMR (91 MHz, $CDCl_3$) δ 127.9 (2 × CH), 128.3 (CH), 128.4 (CH), 128.7 (C_q), 128.9 (2 × CH), 129.0 (C_q), 130.6 (CH), 133.5 (C_q), 135.6 (C_q), 135.7 (C_q), 145.3 (C_q), 162.1 (C_q); MS (ESI) *m/z* 328 [^{37}Cl$_2$-^{35}Cl-MH$^+$], 326 [^{37}Cl-^{35}Cl$_2$-MH$^+$]; HRMS (ESI) calcd for $C_{14}H_8Cl_3N_3$ [MH$^+$]: 323.9857, found: 323.9839. Methyl 5-(4-chlorophenyl)-1-(2,4-dichlorophenyl)-1*H*-1,2,4-triazole-3-carboxylate (**5p**): R_f = 0.5 (dichloromethane / ethyl acetate = 100:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ 4.20 (s, 3 H), 7.49 (d, *J* = 8.8 Hz, 2 H), 7.60 (dd, *J* = 2.1 Hz, *J* = 8.5 Hz, 1 H), 7.61-7.63 (m, 3 H), 7.71 (d, *J* = 2.1 Hz, 1 H); ^{13}C NMR (91 MHz, $CDCl_3$) δ 53.0 (CH_3), 124.7 (C_q), 128.6 (CH), 129.2 (2 × CH), 129.5 (2 × CH), 130.0 (CH), 130.8 (CH), 132.7 (C_q), 134.1 (C_q), 137.4 (C_q), 137.6 (C_q), 154.9 (C_q), 156.2 (C_q), 160.0 (C_q); MS (ESI) *m/z* 383 [^{35}Cl-MH$^+$]; HRMS (ESI) calcd for $C_{16}H_{10}Cl_3N_3O_2$ [M^++Na^+]: 403.9731, found: 403.9718.

4.1.36 Methyl 3-(4-chlorophenyl)-1-(4-(4-fluorophenoxy)phenyl)-1H-1,2,4-triazole-5-carboxylate (6q) and methyl 5-(4-chlorophenyl)-1-(4-(4-fluorophenoxy)phenyl)-1H-1,2,4-triazole-3-carboxylate (5q) are prepared from (4-

chlorobenzylidene-amino) acetic acid methyl ester (**3a**) (472 µmol, 100 mg) and *tert*-Butyl 2-(4-(4-fluorophenoxy)-phenyl)azocarboxylate (**1f**) (945 µmol, 300 mg) according to general procedure GP 2. The crude product is subjected to column chromatography (silica gel, dichloromethane / ethyl acetate = 50:1 → 20:1) to give the title compounds **6q** (89.0 µmol, 37.7 mg, 19%) and **5q** (260 µmol, 110 mg, 55%) as pale orange solids. Methyl 3-(4-chlorophenyl)-1-(4-(4-fluorophenoxy)phenyl)-1*H*-1,2,4-triazole-5-carboxylate (**6q**): R_f = 0.6 (dichloromethane / ethyl acetate = 50:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ 3.97 (s, 3 H), 7.05-7.11 (m, 6 H), 7.42-7.47 (m, 4 H), 8.14 (d, J = 8.8 Hz, 2 H); ^{13}C NMR (91 MHz, $CDCl_3$) δ 53.3 (CH_3), 116.7 (d, J_{CF} = 23.4 Hz, 2 × CH), 117.7 (2 × CH), 121.5 (d, J_{CF} = 8.3 Hz, 2 × CH), 127.3 (2 × CH), 128.1 (2 × CH), 128.2 (C_q), 128.9 (2 × CH), 132.5 (C_q), 136.1 (C_q), 145.2 (C_q), 151.7 (d, J_{CF} = 2.7 Hz, C_q), 157.8 (C_q), 159.1 (C_q), 159.4 (d, J_{CF} = 243.2 Hz, C_q), 161.2 (C_q); MS (EI) *m/z* 423 (100) [^{35}Cl-M$^+$], 202 (13), 201 (93), 200 (22), 149 (11), 95 (17), 90 (27), 75 (10), 63 (10); HRMS (EI) calcd for $C_{22}H_{15}ClFN_3O_3$ [M$^+$]: 423.0786, found: 423.0785. Methyl 5-(4-chlorophenyl)-1-(4-(4-fluorophenoxy)phenyl)-1*H*-1,2,4-triazole-3-carboxylate (**5q**): R_f = 0.3 (dichloromethane / ethyl acetate = 50:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ 4.04 (s, 3 H), 7.00 (d, J = 9.0 Hz, 2 H), 7.03 (dd, J_{HF} = 4.5 Hz, J = 9.2 Hz, 2 H), 7.09 (dd, J_{HF} = 8.0 Hz, J = 9.2 Hz, 2 H), 7.32 (d, J = 9.0 Hz, 2 H), 7.35 (d, J = 8.8 Hz, 2 H), 7.51 (d, J = 8.8 Hz, 2 H); ^{13}C NMR (91 MHz, $CDCl_3$) δ 52.9 (CH_3), 116.8 (d, J_{CF} = 23.5 Hz, 2 × CH), 118.2 (2 × CH), 121.5 (d, J_{CF} = 8.4 Hz, 2 × CH), 125.1 (C_q), 127.1 (2 × CH), 129.0 (2 × CH), 130.3 (2 × CH), 132.0 (C_q), 137.0 (C_q), 151.4 (d, J_{CF} = 2.7 Hz, C_q), 154.2 (C_q), 154.6 (C_q), 159.1 (C_q), 159.5 (d, J_{CF} = 243.6 Hz, C_q), 160.2 (C_q); MS (EI) *m/z* 425 (24) [^{37}Cl-M$^+$], 424 (15) [^{35}Cl-MH$^+$], 423 (62) [^{35}Cl-M$^+$], 202 (14), 201 (100), 200 (14), 95 (17), 90 (18); HRMS (EI) calcd for $C_{22}H_{15}ClFN_3O_3$ [M$^+$]: 423.0786, found: 423.0786.

4.1.37 3-(4-chlorophenyl)-1-(4-nitrophenyl)-1H-1,2,4-triazole (8) and methyl 5-(4-chlorophenyl)-1-(4-nitrophenyl)-1H-1,2,4-triazole-3-carboxylate (5r) are prepared from (4-chlorobenzylidene-amino) acetic acid methyl ester (**3a**) (238 µmol, 60.0 mg) and *tert*-butyl 2-(4-nitrophenyl)azocarboxylate (**1g**) (566 µmol, 142 mg) according to general procedure GP 2. The crude product is subjected to column chromatography (silica gel, dichloromethane / ethyl acetate = 50:1) to give the title compounds **8** (48.1 µmol, 14.5 mg, 17%) and **5r** (90.6 µmol, 32.5 mg, 32%) as an orange solid. 3-(4-chlorophenyl)-1-(4-nitrophenyl)-1*H*-1,2,4-triazole (**8**): R_f = 0.5 (dichloromethane / ethyl acetate = 50:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) = 7.47 (d, J = 8.7 Hz, 2 H), 7.97 (d, J = 9.2 Hz, 2 H), 8.15 (d, J = 8.7 Hz, 2 H), 8.42 (d, J = 9.2 Hz, 2 H), 8.71 (s, 1 H). Methyl 5-(4-chlorophenyl)-1-(4-nitrophenyl)-1*H*-1,2,4-triazole-3-carboxylate (**5r**): R_f = 0.3 (dichloromethane / ethyl acetate = 50:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ 4.06 (s, 3 H), 7.39 (d, J = 8.8 Hz, 2 H), 7.46 (d, J = 8.8 Hz, 2 H), 7.61 (d, J = 9.1 Hz, 2 H), 8.32 (d, J = 9.2 Hz, 2 H); ^{13}C NMR (91 MHz, $CDCl_3$) δ 53.2 (CH_3), 124.6 (C_q), 125.1 (2 × CH), 125.9 (2 × CH), 129.5 (2 × CH), 130.4 (2 × CH), 137.9 (C_q), 141.9 (C_q), 147.9 (C_q), 155.1 (C_q), 155.1 (C_q), 159.8 (C_q); MS (EI) *m/z* 360 (35) [^{37}Cl-M$^+$], 359 (19) [MH$^+$], 358 (100) [^{35}Cl-M$^+$], 221 (72), 137 (10), 136 (29), 111 (10), 90 (52), 89 (18), 80 (14), 76 (18), 75 (16), 64 (11), 63 (29), 59 (50), 50 (12), 39 (15), 30 (52), 28 (11); HRMS (EI) calcd for $C_{16}H_{11}ClN_4O_4$ [M$^+$]: 358.0469, found: 358.0470.

4.1.38 Tert-butyl 3-(4-chlorophenyl)-1-(3-methoxy-4-nitrophenyl)-1H-1,2,4-triazole-5-carboxylate (6s) and tert-butyl 5-(4-chlorophenyl)-1-(3-methoxy-4-nitrophenyl)-1H-1,2,4-triazole-3-carboxylate (5s) are prepared from (4-chlorobenzylidene-amino) acetic acid *tert*-butyl ester (**3a**) (591 µmol, 150 mg) and *tert*-butyl 2-(3-methoxy-4-nitrophenyl)azocarboxylate (**1h**) (1.18 mmol, 332 mg) according to general procedure GP 2. The crude product is subjected to column chromatography (silica gel, dichloromethane / ethyl acetate = 100:1) to give the title compounds **6s** (142 µmol, 61.1 mg, 24%) and **5s** (263 µmol, 113 mg, 47%) as pale orange solids. *Tert*-butyl 3-(4-chlorophenyl)-1-(3-methoxy-4-nitrophenyl)-1*H*-1,2,4-triazole-5-carboxylate (**6s**): R_f = 0.8 (dichloromethane / ethyl acetate = 100:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ 1.52 (s, 9 H), 4.02 (s, 3 H), 7.18 (dd, J = 2.1 Hz, J = 8.6 Hz, 1 H), 7.29 (d, J = 2.1 Hz, 1 H), 7.44 (d, J = 8.8 Hz, 2 H), 8.00 (d, J = 8.6 Hz, 1 H), 8.13 (d, J = 8.8 Hz, 2 H); ^{13}C NMR (91 MHz, $CDCl_3$) δ 27.8 (3 × CH_3), 57.0 (CH_3), 85.5 (C_q), 111.3 (CH), 117.3 (CH), 126.2 (CH), 127.9 (C_q), 128.1 (2 × CH), 129.0 (2 × CH), 136.4 (C_q), 139.6 (C_q), 142.3 (C_q), 147.1 (C_q), 153.4 (C_q), 156.3 (C_q), 161.6 (C_q); MS (ESI) *m/z* 433 [^{37}Cl-MH$^+$], 431 [^{35}Cl-MH$^+$], 333 [^{37}Cl-MH$^+$-Boc], 331 [^{35}Cl-MH$^+$-Boc]; HRMS (ESI) calcd for $(C_{20}H_{19}ClN_4O_5)_2$ [M$^+$+Na$^+$]: 883.1980, found: 883.1985. *Tert*-butyl 5-(4-chlorophenyl)-1-(3-methoxy-4-nitrophenyl)-1*H*-1,2,4-triazole-3-carboxylate (**5s**): R_f = 0.5 (dichloromethane / ethyl acetate = 100:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ 1.67 (s, 9 H), 3.92 (s, 3 H), 6.92 (dd, J = 2.1 Hz, J = 8.7 Hz, 1 H), 7.25 (d, J = 2.1 Hz, 1 H), 7.40 (d, J = 8.7 Hz, 2 H), 7.49 (d, J = 8.7 Hz, 2 H), 7.87 (d, J = 8.7 Hz, 1 H); ^{13}C NMR (91 MHz, $CDCl_3$) δ 28.1 (3 × CH_3), 57.0 (CH_3), 83.8 (C_q), 110.6 (CH), 116.6 (CH), 125.1 (C_q), 126.7 (CH), 129.3 (2 × CH), 130.5 (2 × CH), 137.6 (C_q), 139.4 (C_q), 141.6 (C_q), 153.8 (C_q), 154.7 (C_q), 156.2 (C_q), 158.7 (C_q); MS (ESI) *m/z* 433 [^{37}Cl-MH$^+$], 431 [^{35}Cl-MH$^+$]; HRMS (ESI) calcd for $(C_{20}H_{19}ClN_4O_5)_2$ [M$^+$+Na$^+$]: 883.1980, found: 883.1972.

4.1.39 Methyl 1-(4-bromophenyl)-3-(thiophen-2-yl)-1H-1,2,4-triazole-5-carboxylate (12) and methyl 1-(4-bromophenyl)-5-(thiophen-2-yl)-1H-1,2,4-triazole-3-carboxylate (11) are prepared from methyl-2-((thiophen-2-ylmethylene)amino)acetate (**10**) (546 µmol, 100 mg) and *tert*-butyl 2-(4-bromophenyl)azocarboxylate (**1b**) (1.09 mmol, 310 mg) according to general procedure GP 2. The crude product is subjected to column chromatography (silica gel, dichloromethane / ethyl acetate = 100:1) to give the title compounds **12** (131 µmol, 47.7 mg, 24%) and **11** (278 µmol, 101 mg, 51%) as white solids. Methyl 1-(4-bromophenyl)-3-(thiophen-2-yl)-1*H*-1,2,4-triazole-5-carboxylate (**12**): R_f = 0.8 (dichloromethane / ethyl acetate = 100:1) (UV); ^{1}H NMR (360 MHz, $CDCl_3$) δ 3.96 (s, 3 H), 7.13 (dd, J = 3.7 Hz, J = 5.0 Hz, 1 H), 7.40 (d, J = 8.9 Hz, 2 H), 7.41 (dd, J = 1.2 Hz, J = 5.0 Hz, 1 H), 7.65 (d, J = 8.9 Hz, 2 H), 7.83 (dd, J = 1.2 Hz, J = 3.7 Hz, 1 H); ^{13}C NMR (91 MHz, $CDCl_3$) δ 53.4 (CH_3), 123.9 (C_q), 127.4 (2 × CH), 127.6 (CH), 127.7 (CH), 127.8 (CH), 132.0 (C_q), 132.2 (2 × CH), 136.6 (C_q), 144.9 (C_q), 157.6 (C_q), 158.6 (C_q); MS (ESI) *m/z* 366 [^{81}Br-MH$^+$], 364 [^{79}Br-MH$^+$]; HRMS (ESI) calcd for $C_{14}H_{10}BrN_3O_2S$ [MH$^+$]: 363.9749, found: 363.9741. Methyl 1-(4-bromophenyl)-5-(thiophen-2-yl)-1*H*-1,2,4-triazole-3-carboxylate (**11**): R_f = 0.5 (dichloromethane / ethyl acetate = 100:1) (UV); ^{1}H NMR (360 MHz, $CDCl_3$) δ 4.04 (s, 3 H), 7.01 (dd, J = 3.8 Hz, J = 5.1 Hz, 1 H), 7.23 (dd, J = 1.2 Hz, J = 3.8 Hz, 1 H), 7.37 (d, J = 8.8 Hz, 2 H), 7.45 (dd, J = 1.2 Hz, J = 5.1 Hz, 1 H), 7.68 (d, J = 8.8 Hz, 2 H); ^{13}C NMR (91 MHz, $CDCl_3$) δ 52.9 (CH_3), 124.7 (C_q), 127.6 (C_q), 127.7 (CH), 128.1 (2 × CH), 130.0 (CH), 130.2 (CH), 132.9 (2 × CH), 136.0 (C_q), 151.3 (C_q), 154.3 (C_q), 160.0 (C_q); MS (ESI) *m/z* 366 [^{81}Br-MH$^+$], 364 [^{79}Br-MH$^+$]; HRMS (ESI) calcd for $C_{14}H_{10}BrN_3O_2S$ [MH$^+$]: 363.9749, found: 363.9754.

4.1.40 3-(4-Chlorophenyl)-1-(4-fluorophenyl)-1H-1,2,4-triazole (9). A solution of methyl 3-(4-chlorophenyl)-1-(4-fluorophenyl)-1*H*-1,2,4-triazole-5-carboxylate (**6a**) (19.6 µmol, 6.50 mg) in acetonitrile (1.0 mL) and is treated with concentrated hydrochloric acid (2.0 mL) and heated to reflux for four hours at 80° C. After cooling to room temperature water (2.0 mL) is added. The composite is extracted with diethyl ether (3 × 15 mL). The combined organic phases are washed with a saturated aqueous solution of sodium chloride and dried over sodium sulfate. The title compound **9** is identified as a white solid (19.6 µmol, 5.40 mg, *quant.*): R_f = 0.5 (dichloromethane / ethyl acetate = 50:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.22 (dd, J_{HF} = 8.0 Hz, J = 9.0 Hz, 2 H), 7.44 (d, J = 8.5 Hz, 2 H), 7.71 (dd, J_{HF} = 4.6 Hz, J = 9.0 Hz, 2 H), 8.12 (d, J = 8.5 Hz, 2 H), 8.51 (s, 1 H); ^{13}C NMR (91 MHz, $CDCl_3$) δ 116.7 (d, J_{CF} = 23.2 Hz, 2 × CH), 121.9 (d, J_{CF} = 8.5 Hz, 2 × CH), 125.5 (C_q), 127.8 (2 × CH), 128.9 (2 × CH), 129.0 (C_q), 133.3 (d, J_{CF} = 3.1 Hz, C_q), 135.6 (C_q), 141.6 (d, J_{CF} = 1.6 Hz, CH), 162.0 (d, J_{CF} = 248.6 Hz, C_q).

4.1.41 Methyl (E)-N-[(tert-butyl)methylene]glycinate (13) is prepared from glycine ethyl ester hydrochloride (5.74 mmol, 721 mg) and pivaldehyde (4.59 mmol, 500 µL) according to general procedure GP 1. The title compound **13** is identified as a colorless oil 4.22 mmol, 664 mg, 92%): R_f = 0.2 (chloroform / methanol = 20:1) ($KMnO_4$); ^{1}H NMR (360 MHz, $CDCl_3$) δ 1.11 (s, 9 H), 3.74 (s, 3 H), 4.16 (d, J = 1.1 Hz, 2 H), 7.56 (t, J = 1.2 Hz, 1 H).

4.1.42 1-(tert-Butyl) 5-methyl 2-(4-bromophenyl)-3-(tert-butyl)-2,3-dihydro-1H-1,2,4-triazole-1,5-dicarboxylate (14) and methyl 1-(4-bromophenyl)-5-(tert-butyl)-1H-1,2,4-triazole-3-carboxylate (15) are prepared from methyl (*E*)-*N*-[(*tert*-butyl)methylene]glycinate (**13**) (636 µmol, 100 mg) and *tert*-butyl 2-(4-bromophenyl)azocarboxylate (**1b)** (1.27 mmol, 362 mg) according to general procedure GP 2. The crude product is subjected to column chromatography (silica gel, dichloromethane / ethyl acetate = 100:1 → 20:1) to give the title compounds **14** (290 µmol, 128 mg, 46%) and **15** (69.9 µmol, 23.7 mg, 11%) as pale brown solids. 1-(*tert*-Butyl) 5-methyl 2-(4-bromophenyl)-3-(*tert*-butyl)-2,3-dihydro-1*H*-1,2,4-triazole-1,5-dicarboxylate (**14**): R_f = 0.3 (dichloromethane / ethyl acetate = 100:1) (UV); ^{1}H NMR (360 MHz, $CDCl_3$) δ 0.94 (s, 9 H), 1.46 (s, 9 H), 3.89 (s, 3 H), 5.57 (s, 1 H), 7.17 (d, J = 9.0 Hz, 2 H), 7.44 (d, J = 9.0 Hz, 2 H); ^{13}C NMR (91 MHz, $CDCl_3$) δ 25.4 (3 × CH_3), 28.1 (3 × CH_3), 35.8 (CH), 53.5 (CH_3), 83.3 (C_q), 94.0 (C_q), 118.9 (C_q), 123.1 (2 × CH), 131.9 (2 × CH), 141.9 (C_q), 150.5 (C_q), 158.5 (C_q), 159.5 (C_q); MS (ESI) *m/z* 442 [^{81}Br-MH^+], 384 [^{81}Br-M^+-$C(CH_3)_3$]; HRMS (ESI) calcd for $C_{19}H_{26}BrN_3O_4$ [MH^+]: 440.1180, found: 440.1173. Methyl 1-(4-bromophenyl)-5-(*tert*-butyl)-1*H*-1,2,4-triazole-3-carboxylate (**15**): R_f = 0.4 (dichloromethane / ethyl acetate = 100:1) (UV); ^{1}H NMR (600 MHz, $CDCl_3$) δ 1.45 (s, 9 H), 3.92 (s, 3 H), 7.35 (d, J = 8.8 Hz, 2 H), 7.63 (d, J = 8.8 Hz, 2 H); ^{13}C NMR (91 MHz, $CDCl_3$) δ 29.5 (3 × CH_3), 53.2 (CH_3), 85.3 (C_q), 123.5 (C_q), 127.3 (2 × CH), 132.1 (2 × CH), 137.0 (C_q), 144.4 (C_q), 158.1 (C_q), 172.4 (C_q); MS (ESI) *m/z* 340 [^{81}Br-MH^+], 338 [^{79}Br-MH^+]; HRMS (ESI) calcd for $C_{14}H_{16}BrN_3O_2$ [MH^+]: 338.0492, found: 338.0499.

Description of competition experiments (Scheme 4)

Experiment (1): A mixture of (4-chlorobenzylideneamino)acetic acid *tert*-butyl ester (**3c**) (200 µmol, 50.0 mg, from GP 1), *tert*-butyl 2-(4-bromophenyl)azocarboxylate (**1b)** (400 µmol, 114 mg) and molecular sieve (4 Å, 200 mg) in dry acetonitrile (2.5 mL) under nitrogen is cooled to -15 °C and treated with 1,8-diazabicyclo[5.4.0]undec-7-ene (200 µmol, 30.0 µL) and stirred for 45 minutes. *Tert*-butyl 2-(3-methoxy-4-nitrophenyl)-azocarboxylate (**1h**) (400 µmol, 113 mg) is added and the reaction is stirred for 30 minutes. Manganese dioxide (800 µmol, 70 mg) is added, the cooling is removed and the reaction is stirred for four hours at ambient air. Trifluoroacetic acid (4.00 mmol, 300 µL) is added and the reaction is stirred for one hour. After addition of a saturated aqueous solution of potassium carbonate (40 mL), the mixture is filtered and then extracted with dichloromethane (4 × 30 mL). The combined organic phases are washed with a saturated aqueous solution of sodium chloride (20 mL) and dried over sodium sulfate. The triazoles **5i** (98.0 µmol, 42.3 mg, 49%) and **6i** (26.0 µmol, 11.2 mg, 13%) are determined with an internal standard 1,3,5-trimethoxybenzene. The 1,2,4-triazoles **5s** and **6s** cannot be identified.

Experiment (2): A mixture of (4-chlorobenzylideneamino)acetic acid *tert*-butyl ester (**3c**) (200 µmol, 50.0 mg, from GP 1), *tert*-butyl 2-(3-methoxy-4-nitrophenyl)-azocarboxylate (**1h**) (400 µmol, 113 mg) and molecular sieve (4 Å, 200 mg) in dry acetonitrile (2.5 mL) under nitrogen is cooled to -15 °C and treated with 1,8-diazabicyclo[5.4.0]undec-7-ene (200 µmol, 30.0 µL) and stirred for 45 minutes. *Tert*-butyl 2-(4-bromophenyl)azocarboxylate (**1b)** (400 µmol, 114 mg) is added and the reaction is stirred for 30 minutes. Manganese dioxide (800 µmol, 70 mg) is added, the cooling is removed and the reaction is stirred for four hours at ambient air. Trifluoroacetic acid (4.00 mmol, 300 µL) is added and the reaction is stirred for one hour. After addition of a saturated aqueous solution of potassium carbonate (40 mL), the mixture is filtered and then extracted with dichloromethane (4 × 30 mL). The combined organic phases are washed with a saturated aqueous solution of sodium chloride (20 mL) and dried over sodium sulfate. The triazoles **5s** (112 µmol, 48.3 mg, 56%) and **6s** (43.2 µmol, 18.6 mg, 22%) are determined with an internal standard 1,3,5-trimethoxybenzene. The 1,2,4-triazoles **5i** and **6i** cannot be identified.

Experiment (3): A mixture of (4-fluorobenzylideneamino)acetic acid methyl ester (**3h**) (256 µmol, 50.0 mg, from GP 1), *tert*-butyl 2-(4-bromophenyl)azocarboxylate (**1b)** (512 µmol, 146 mg) and molecular sieve (4 Å, 200 mg) in dry acetonitrile (2 mL) under nitrogen is cooled to -15 °C and treated with 1,8-diazabicyclo[5.4.0]undec-7-ene (256 µmol, 40.0 µL) and stirred for 45 minutes. Diethyl azodicarboxylate (512 µmol, 223 µL, 40% in toluene) is added and the reaction is stirred for 30 minutes. Manganese dioxide (1.02 mmol, 88.7 mg) is added, the cooling is removed and the reaction is stirred for four hours at ambient air. Trifluoroacetic acid (5.12 mmol, 400 µL) is added and the reaction is stirred for one hour. After addition of a saturated aqueous solution of potassium carbonate (40 mL), the mixture is filtered and then extracted with dichloromethane (4 × 30 mL). The combined organic phases are washed with a saturated aqueous solution of sodium chloride (20 mL) and dried over sodium sulfate. The triazoles **5h** (128 µmol, 48.2 mg, 50%) and **6h** (38.4 µmol, 14.4 mg, 15%) are determined with an internal standard 1,3,5-trimethoxybenzene. 1,2,4-Triazolines cannot be identified in the crude ^{1}H-NMR.

Experiment (4): A mixture of (4-fluorobenzylideneamino)acetic acid methyl ester (**3h**) (256 µmol, 50 mg, from GP 1), *tert*-butyl 2-(4-bromophenyl)azocarboxylate (**1b)** (512 µmol, 146 mg), diethyl azodicarboxylate (512 µmol, 223 µL, 40% in toluene) and molecular sieve (4 Å, 200 mg) in dry acetonitrile (2 mL) under nitrogen is cooled to -15 °C and treated with 1,8-

diazabicyclo[5.4.0]undec-7-ene (265 µmol, 40.0 µL) and stirred for 45 minutes. Manganese dioxide (1.02 mmol, 70.0 mg) is added, the cooling is removed and the reaction is stirred for four hours at ambient air. Trifluoroacetic acid (5.12 mmol, 400 µL) is added and the reaction is stirred for one hour. After addition of a saturated aqueous solution of potassium carbonate (40 mL), the mixture is filtered and then extracted with dichloromethane (4 × 30 mL). The combined organic phases are washed with a saturated aqueous solution of sodium chloride (20 mL) and dried over sodium sulfate. The reaction gives a complex mixture, no 1,2,4-triazoles or 1,2,4-triazolines could be identified.

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23. The presence of a triazoline was assumed due to a 1H-NMR singlett signal around 5.70 ppm.
24. Related experiments indicated that the presence of the oxidant MnO_2 alone is not sufficient to achieve Boc-cleavage and aromatization.
25. (a) Coldham, I.; Hufton, R. *Chem. Rev*. **2005**, *105*, 2765. (b) Kudryavtsev, K. V.; Ivantcova, P. M.; Churakov, A. V.; Wiedmann, S.; Luy, B.; Muhle-Goll, C.; Zefirov, N. S.; Bräse, S. *Angew. Chem. Int. Ed*. **2013**, *52*, 12736.
26. The formation of triazole **8** can be explained by an increased reactivity of the *tert*-butyl ester on the triazoline stage of the reaction while the decarboxylation of **6p** forming product **7** might be favored due to steric reasons.
27. The position of the double bond in triazoline **14** was determined by HSQC and HMBC experiments.
28. The reaction of azocarboxylate **1b** and glycine imine **13** further gave 11% of 1-(*tert*-butyl) 2-(4-bromophenyl)-3-(*tert*-butyl)-2,3-dihydro-1*H*-1,2,4-triazole-1-carboxylate, resulting from methyl ester cleavage and decarboxylation of **14**.
29. For the addition (and cycloaddition) of deprotonated glycine imines to enones, see: Zhang, Y.; Pan, L.; Xu, X.; Liu, Q. *RSC Adv*. **2012**, *2*, 5138.
30. For the regioselectivity in cycloadditions of nitrile oxides to Michael systems, see: Mayo, P.; Hecnar, T.; Tam, W. *Tetrahedron* **2001**, *57*, 5931.
31. References for known compounds **1a, f, g**: (a) Jasch, H.; Höfling, S. B.; Heinrich, M. R. *J. Org. Chem.* **2012**, *77*, 1520. Compound **1c**: (b) Zhu, M.; Zheng, N. *Synthesis* **2011**, *14*, 2223. Compounds **3a, d, f**, **10** and **13**: (c) Robles-Machín, R.; López-Pérez, A.; González-Esguevillas, M.; Adrio, J.; Carretero, J. C. *Chem. Eur. J.* **2010**, *16*, 9864. Compound **3b**: (d) Patrick, T. B.; Shadmehr, M.; Khan, A. H.; Singh, R. K.; Asmelash, B. *J. Fluorine Chem.* **2012**, *143*, 109. Compounds **3c**,**h**,**k**: (e) Mazaleyrat, J.-P.; Goubard, Y.; Azzini, M.-V.; Wakselman, M.; Peggion, C.; Formaggio, F.; Toniolo, C. *Eur. J. Org. Chem.* **2002**, 1232. Compound **3i**: (f) Gu, X.; Xu, Z.-J.; Lo, V. K.-Y.; Che, C.-M. *Synthesis* **2012**, 3307.

Supplementary Material

Copies of ^{1}H and ^{13}C-NMR spectra of the new triazoles or triazolines **5-7**, **11**, **12**, **14** and **15**.

Supporting Information

Cycloaddition reactions of glycine imine anions to phenylazocarboxylic esters – an access to 1,3,5-trisubstituted 1,2,4-triazoles

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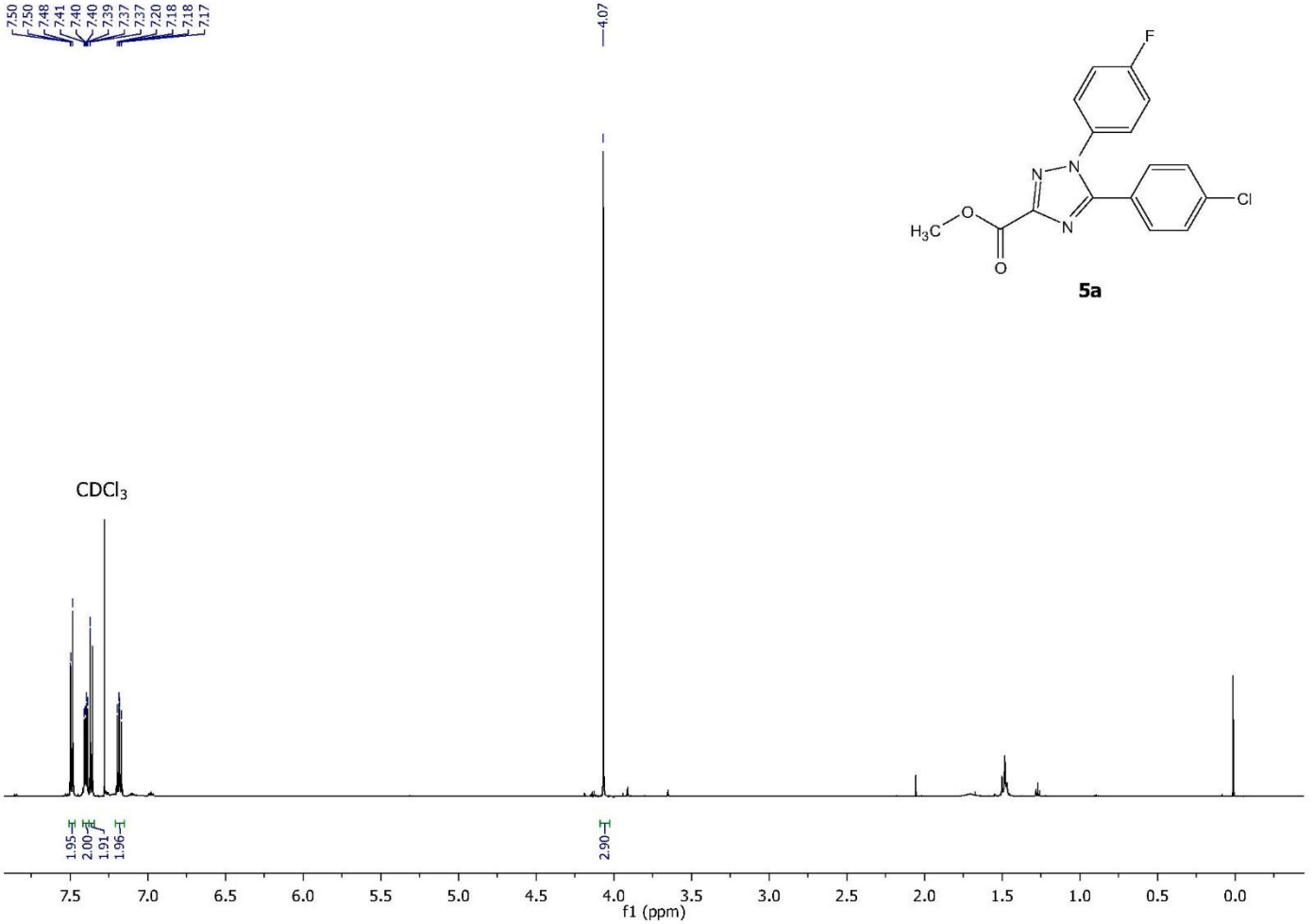
markus.heinrich@fau.de

NMR spectra images of 1,2,4-triazoles



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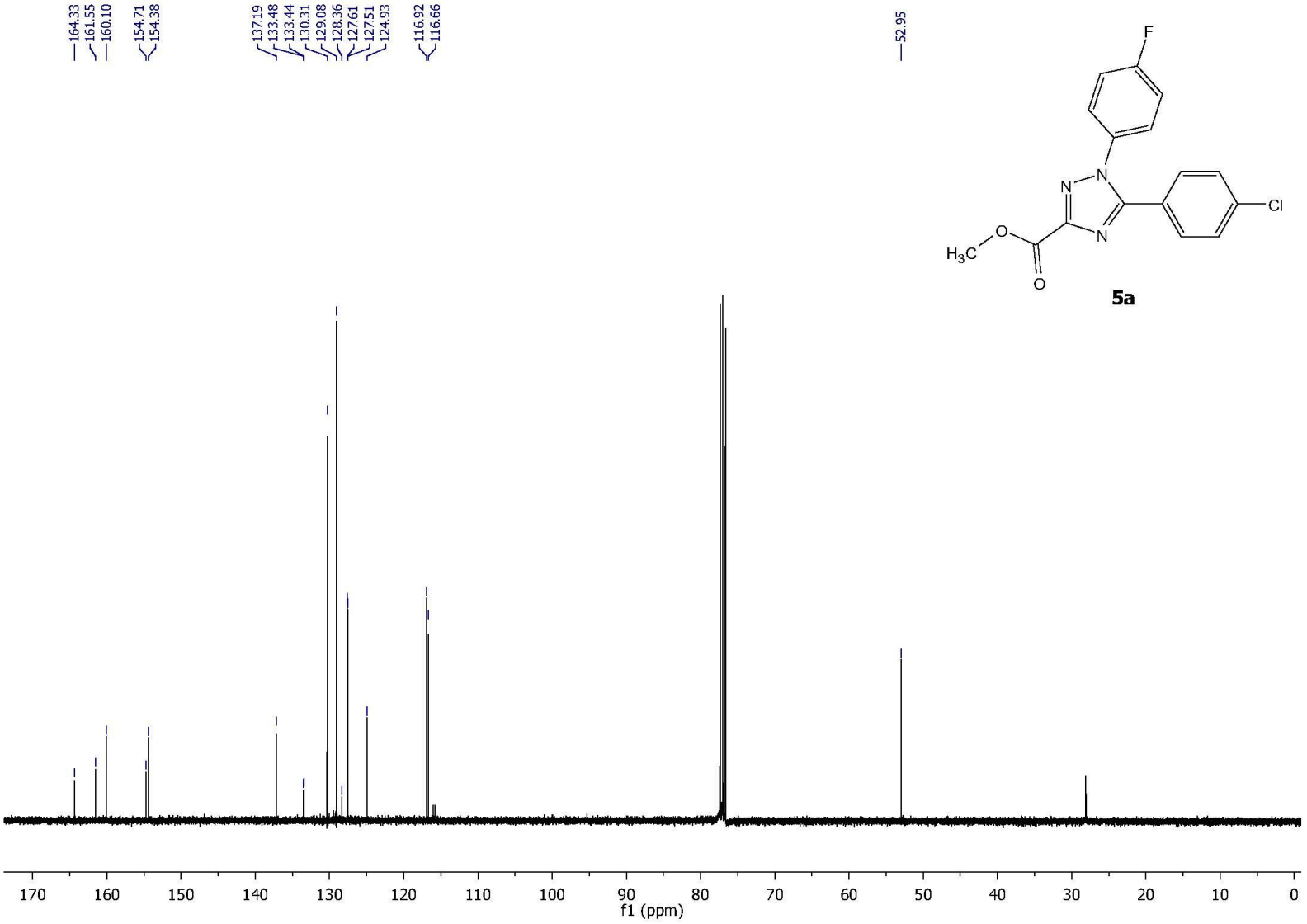
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H_3C
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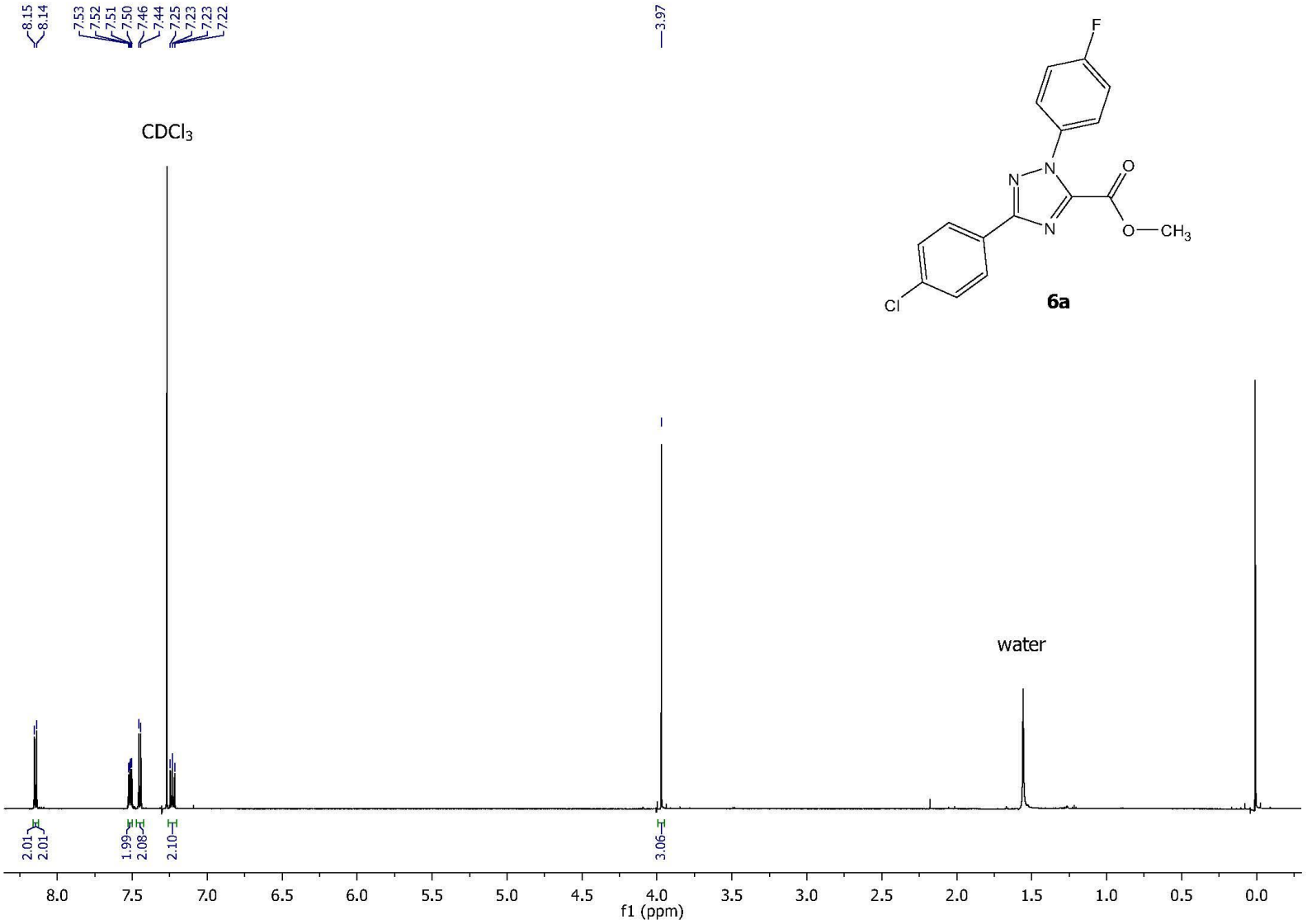
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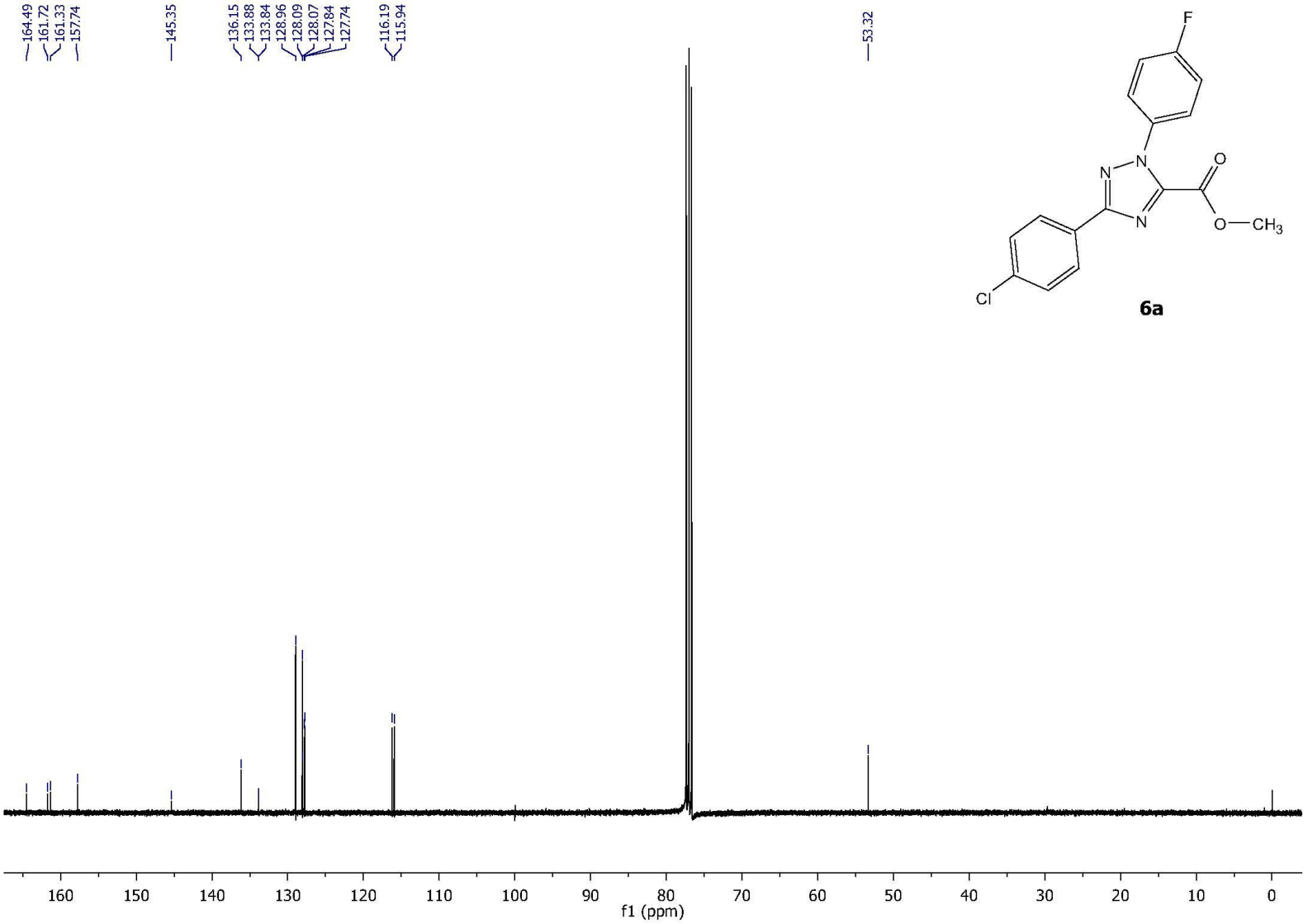
O—CH3
Cl

6a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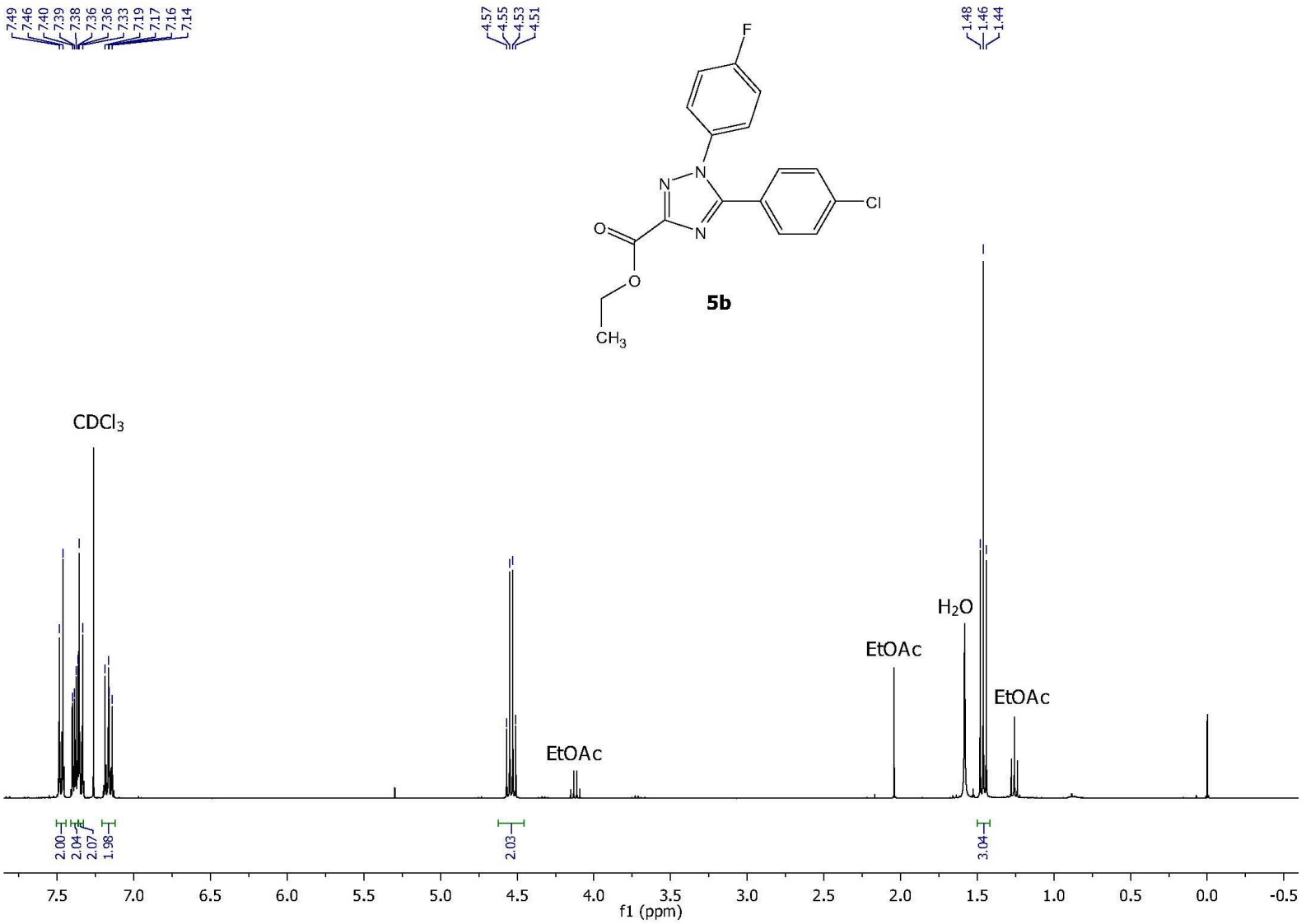
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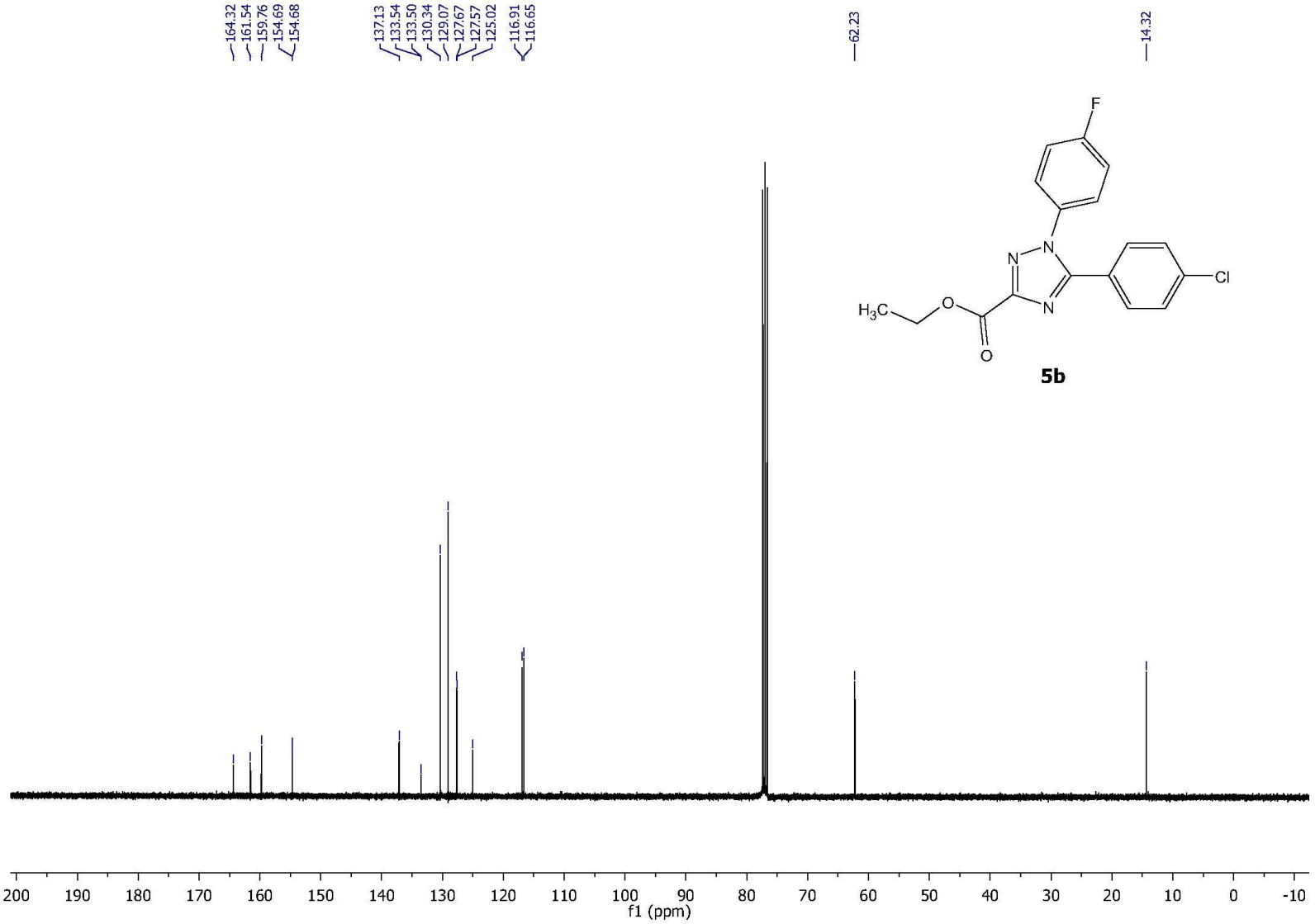
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5b
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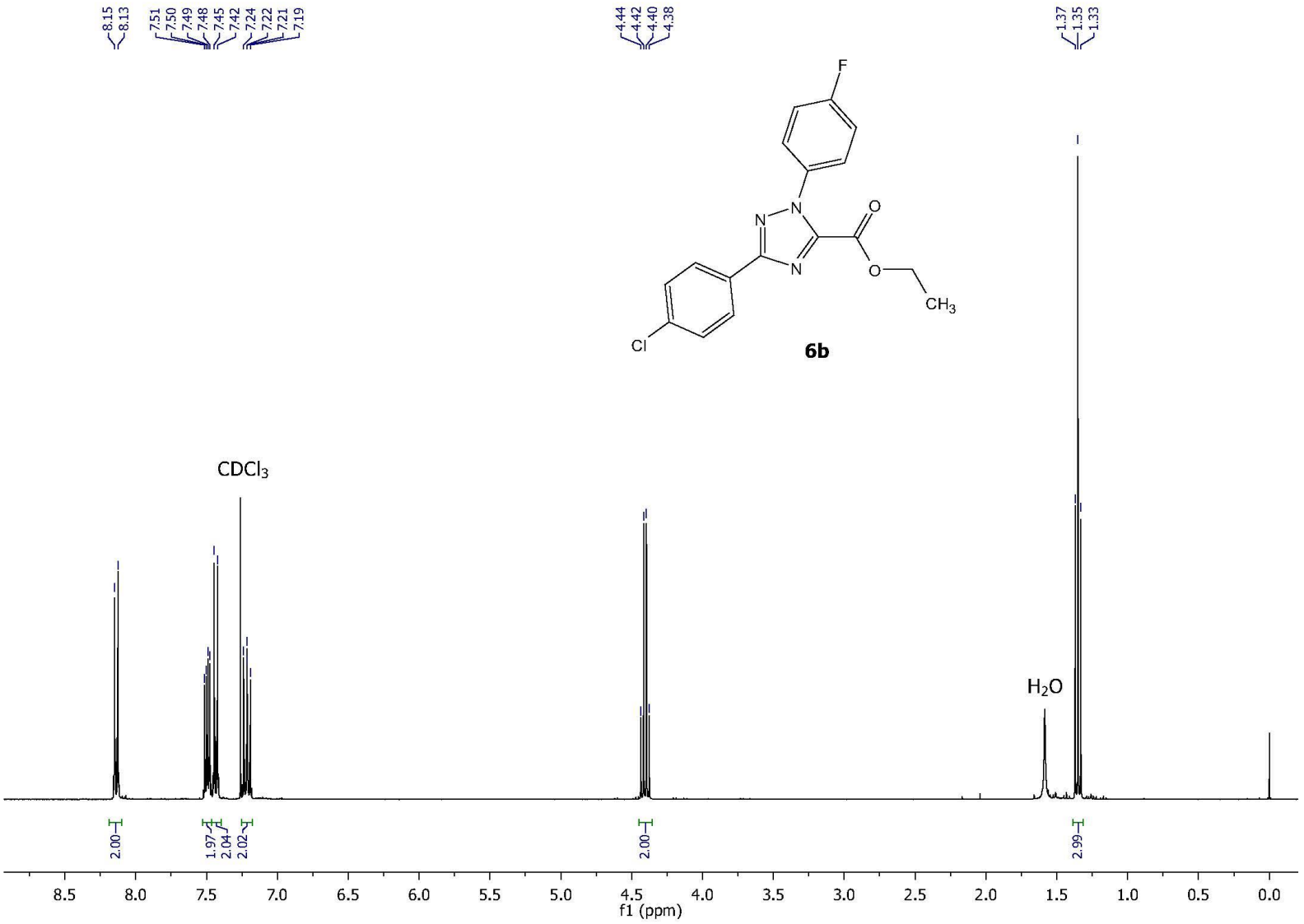
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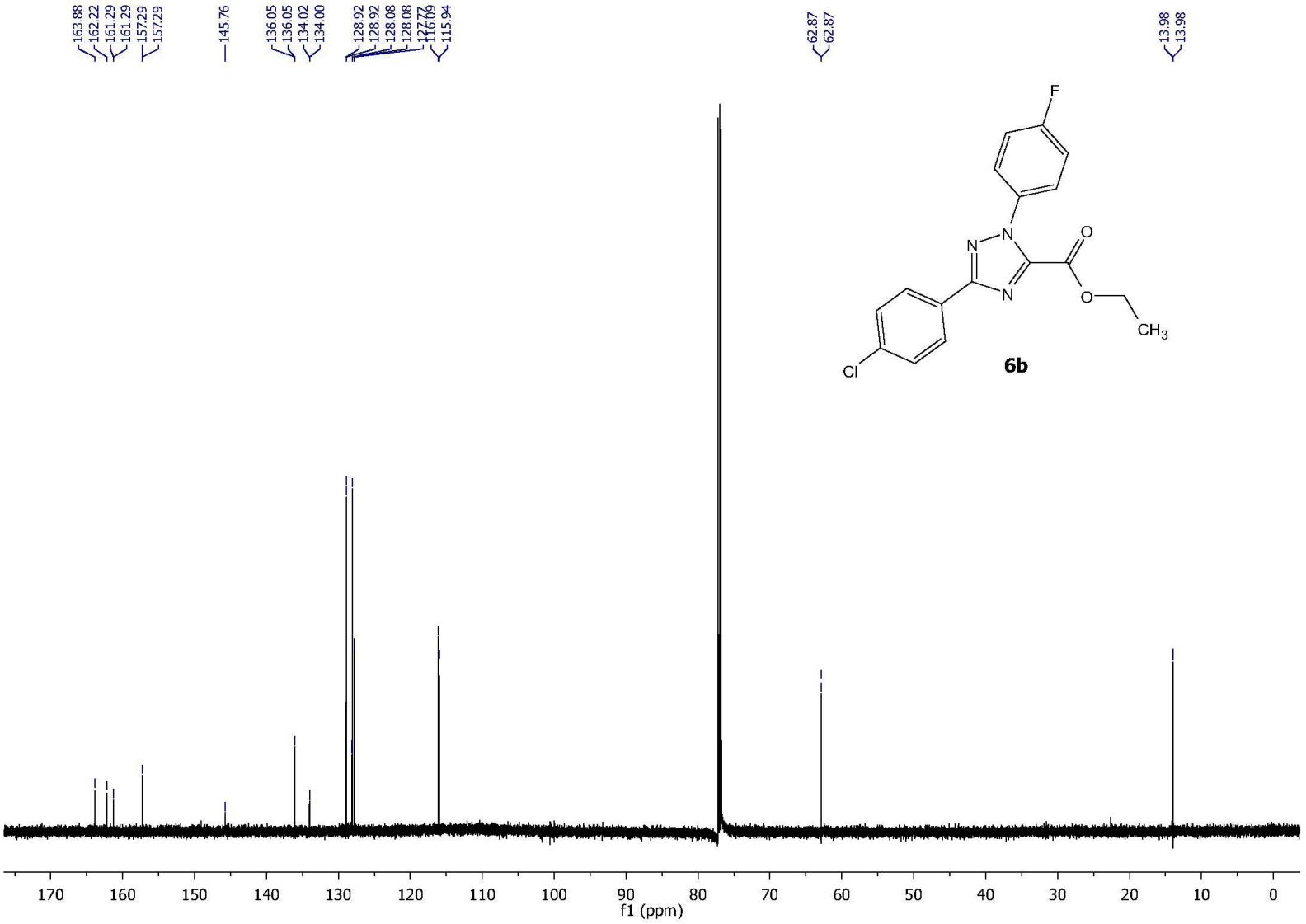
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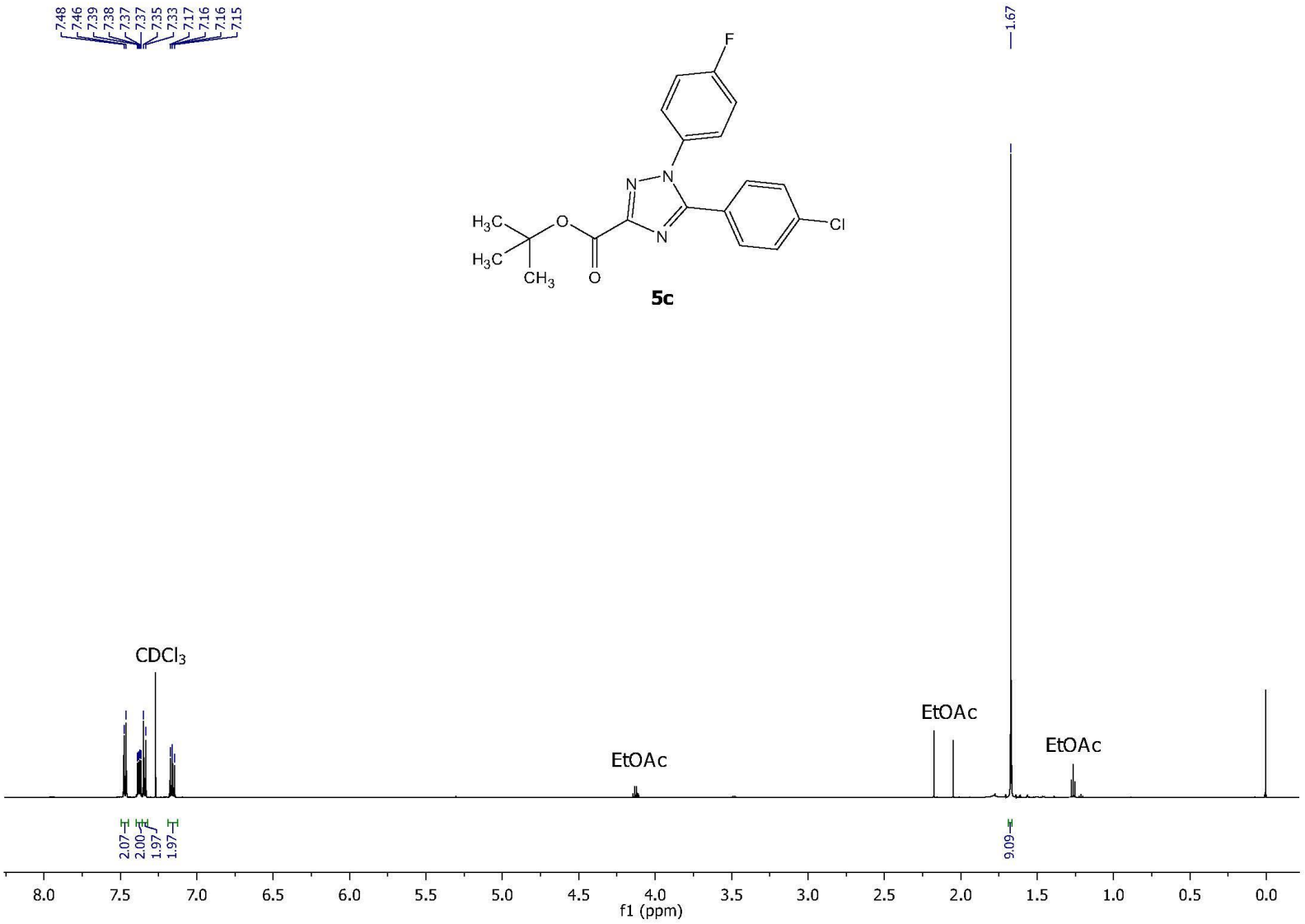
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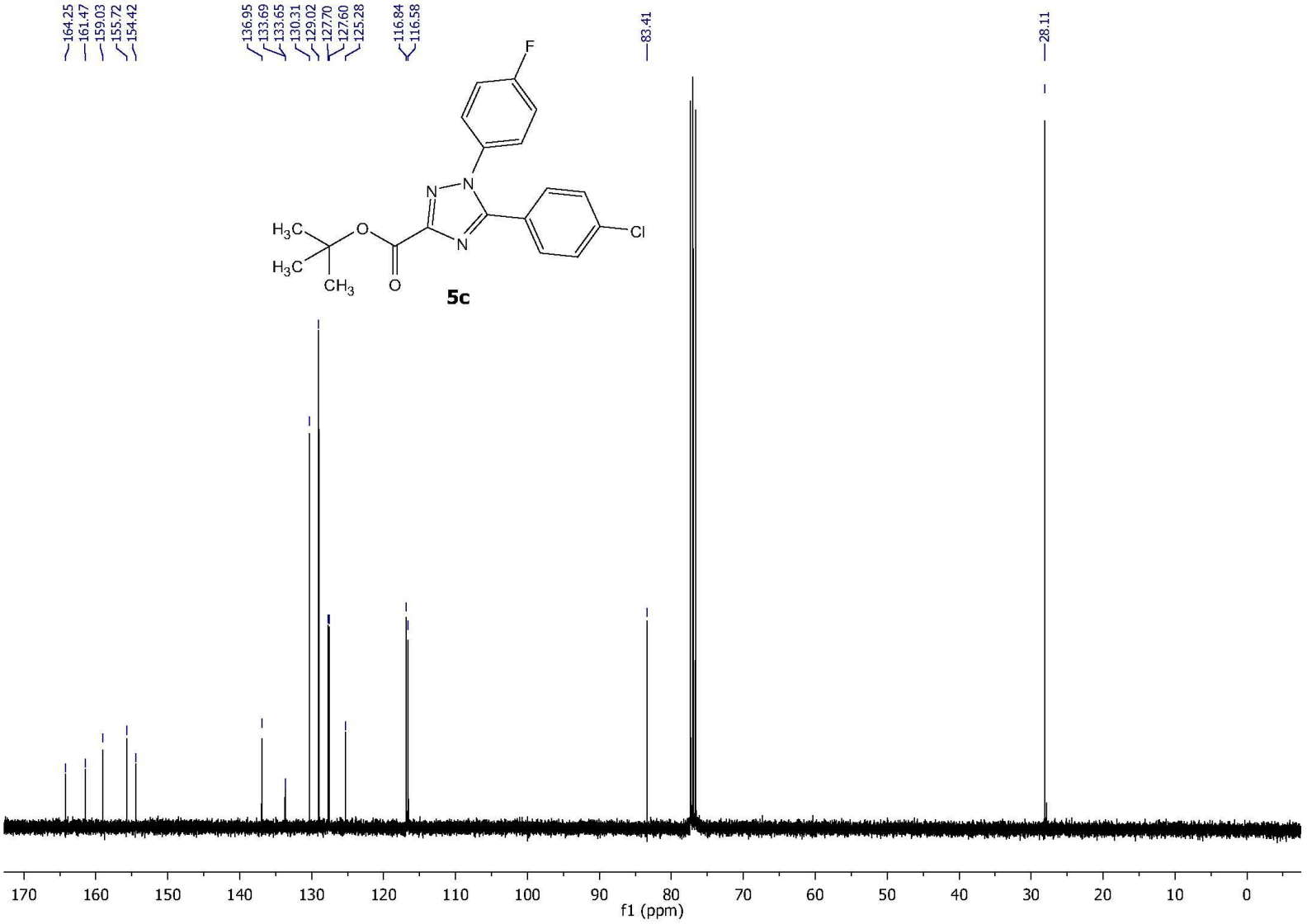
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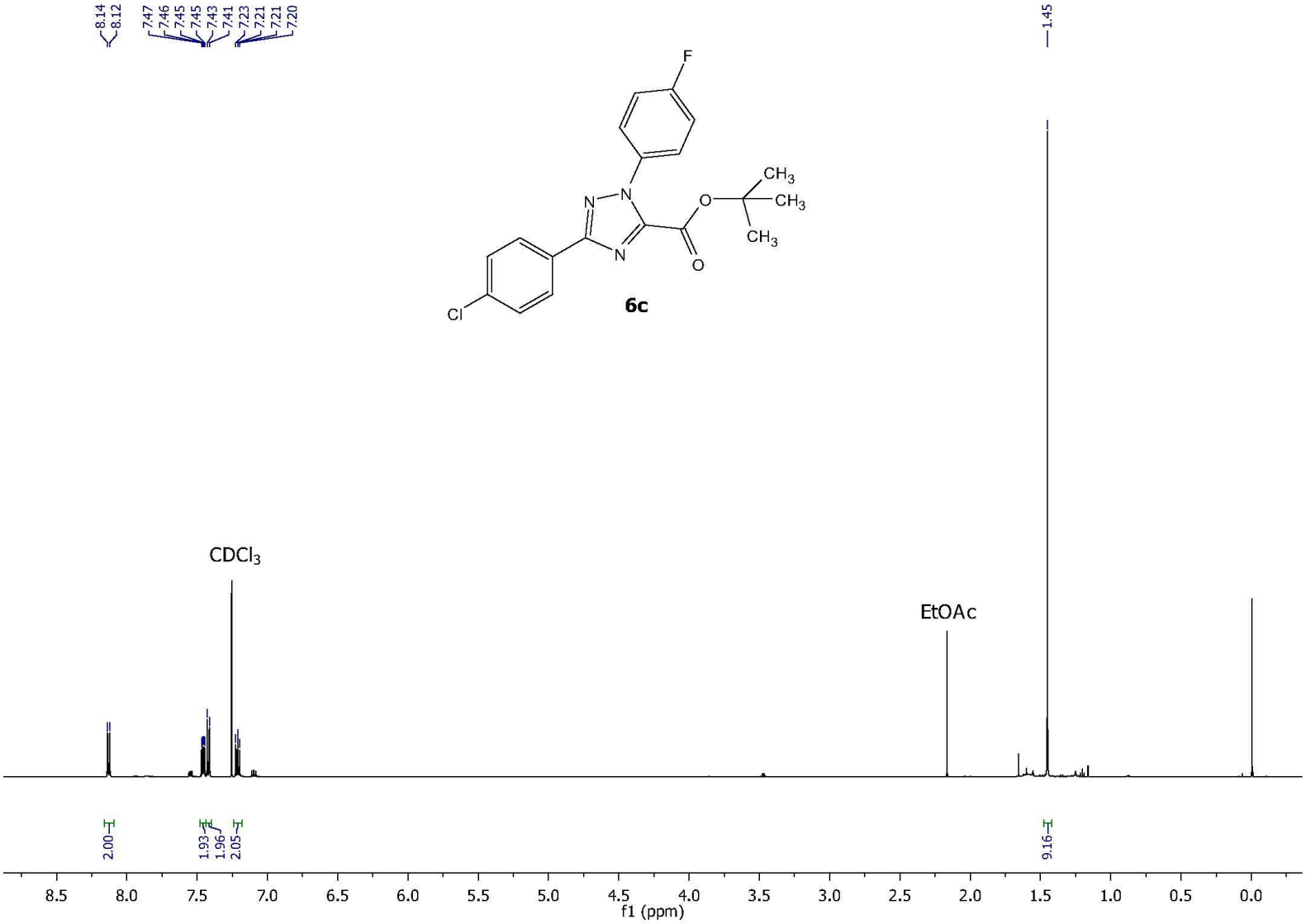
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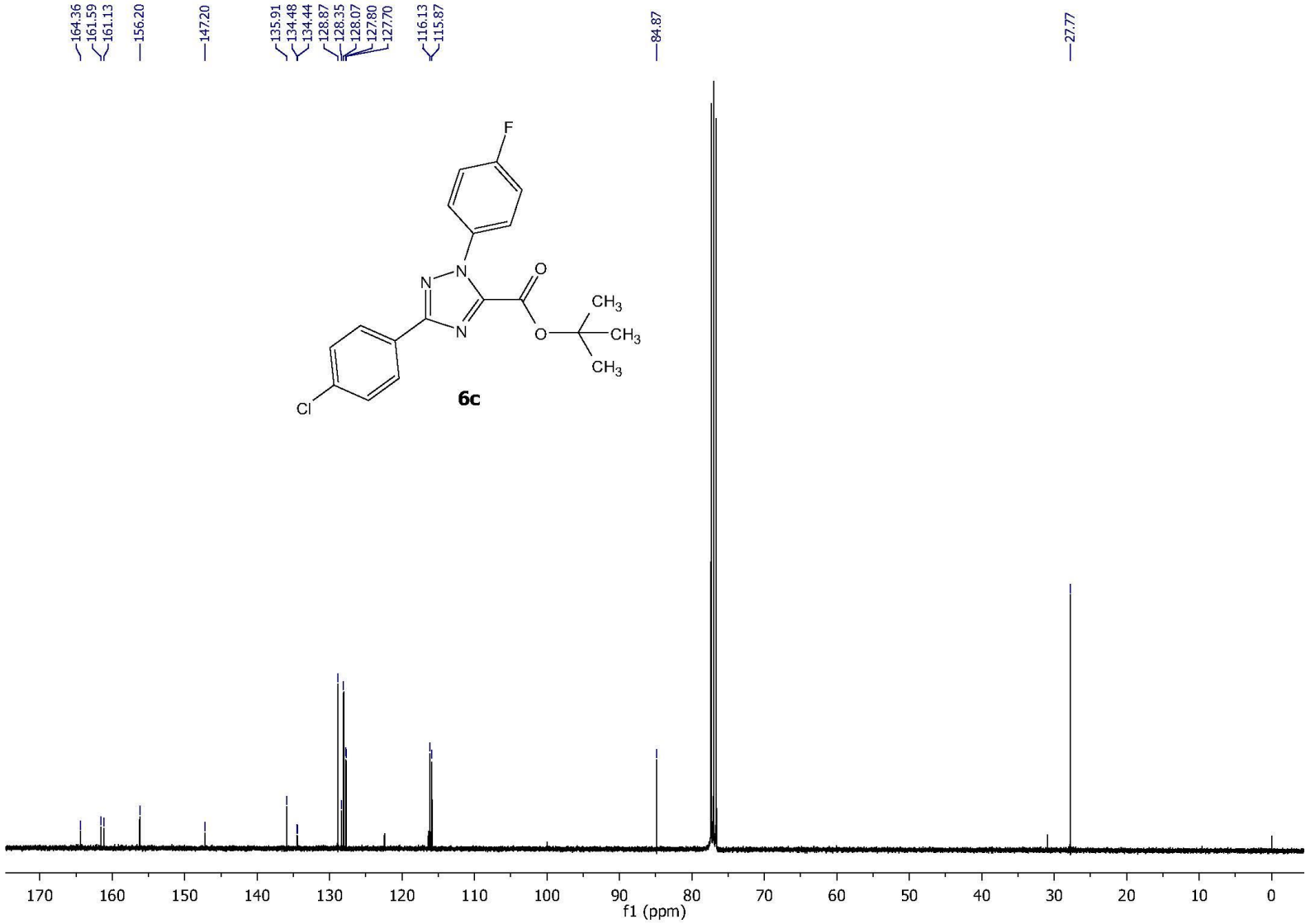
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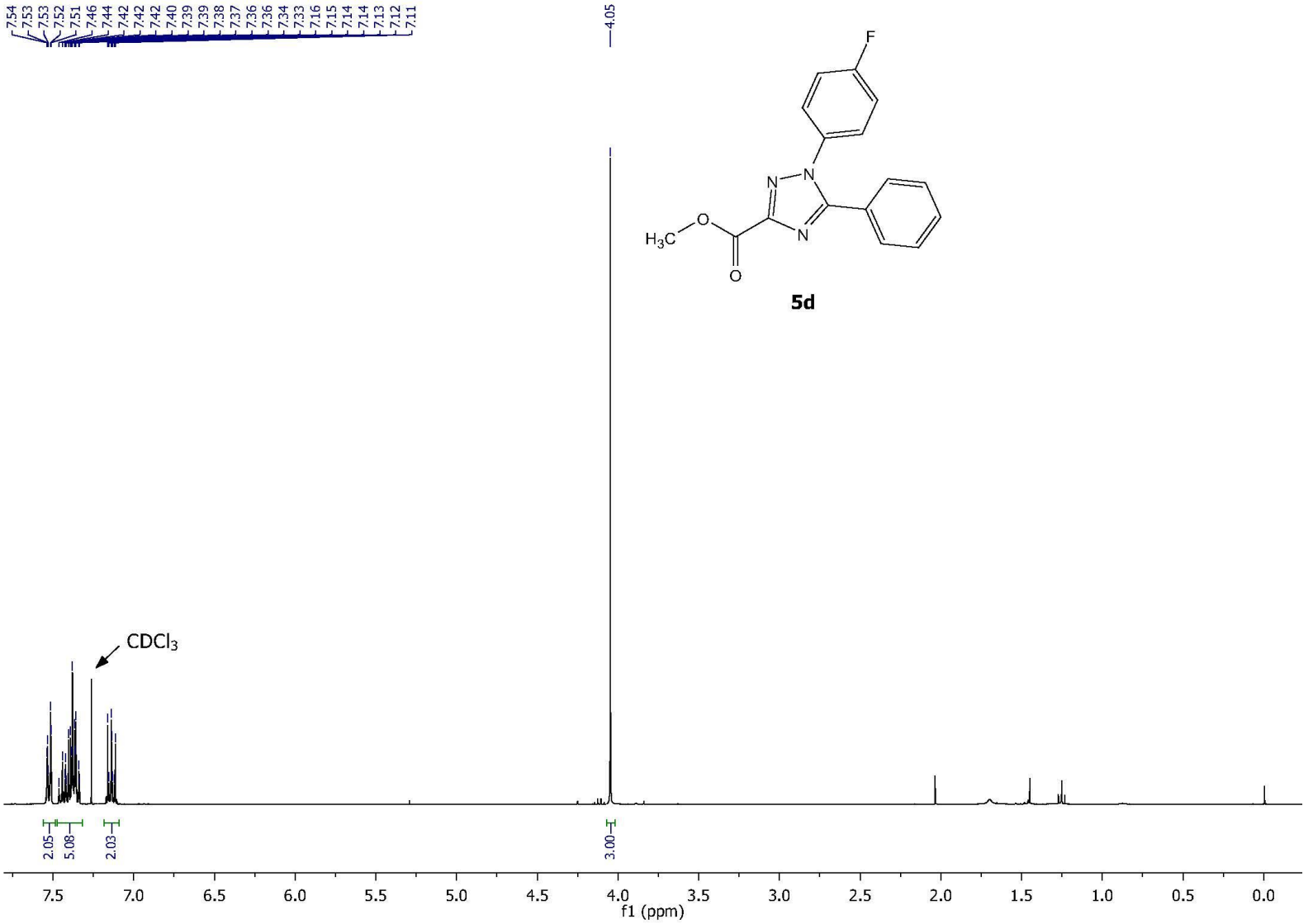
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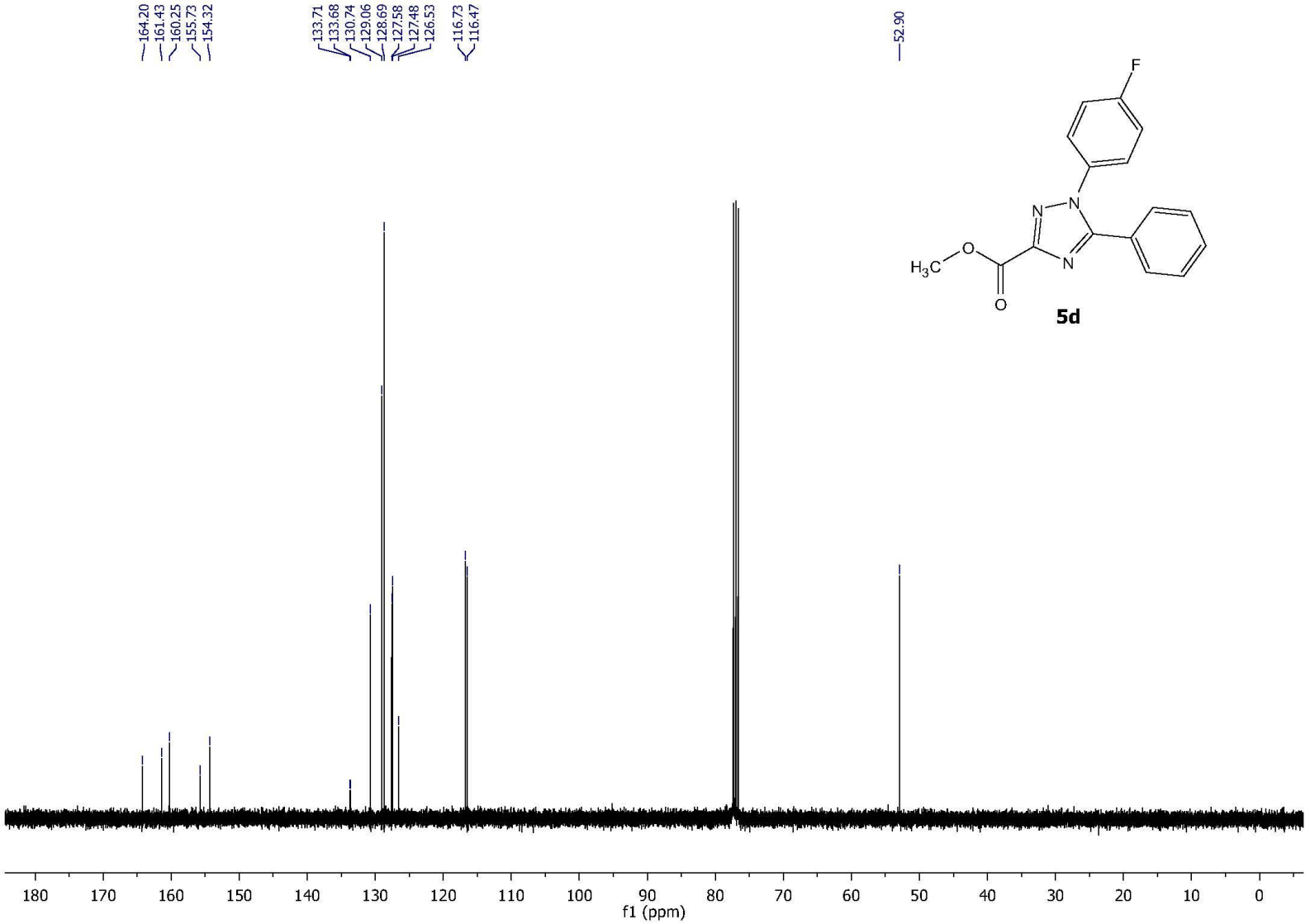
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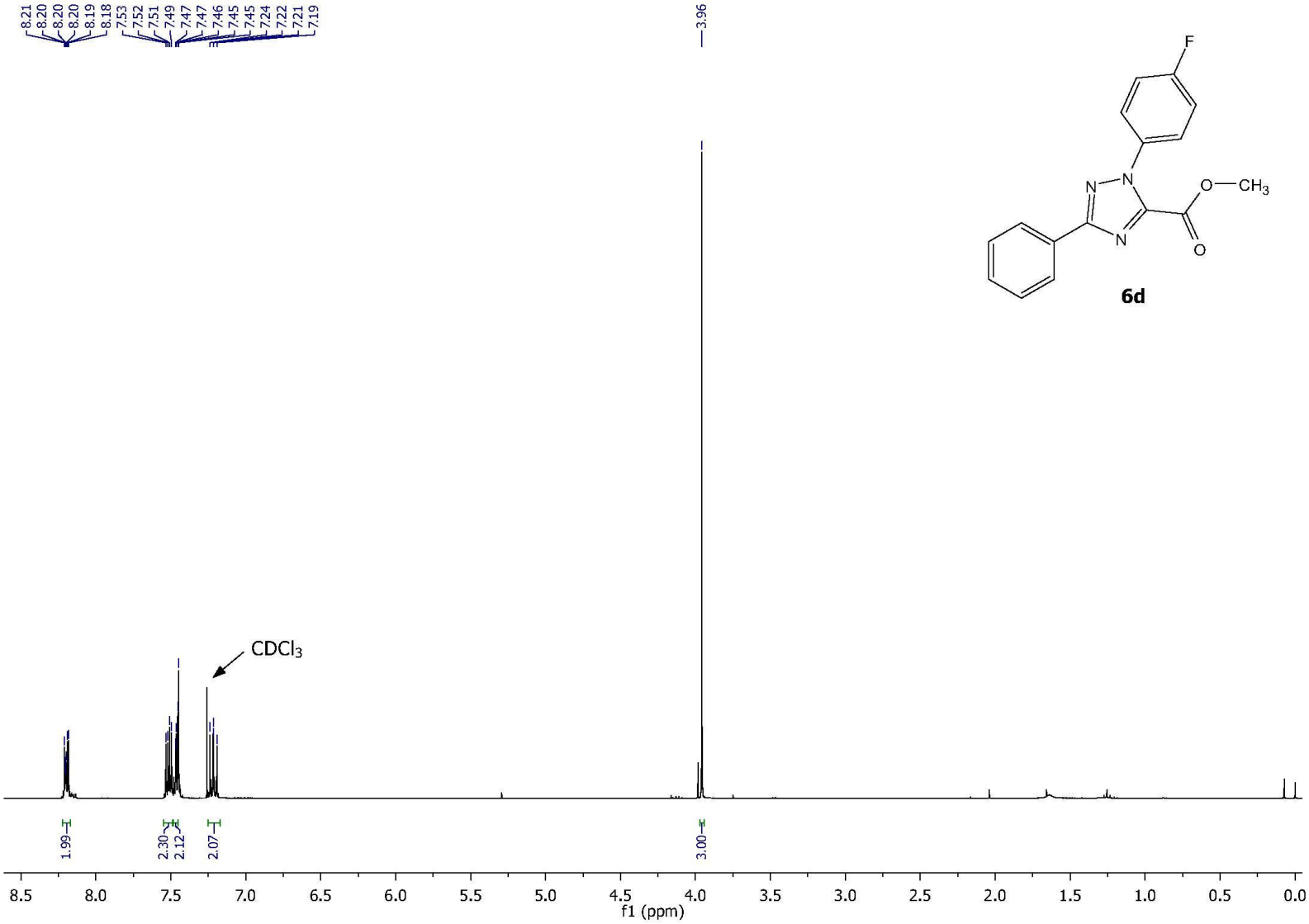
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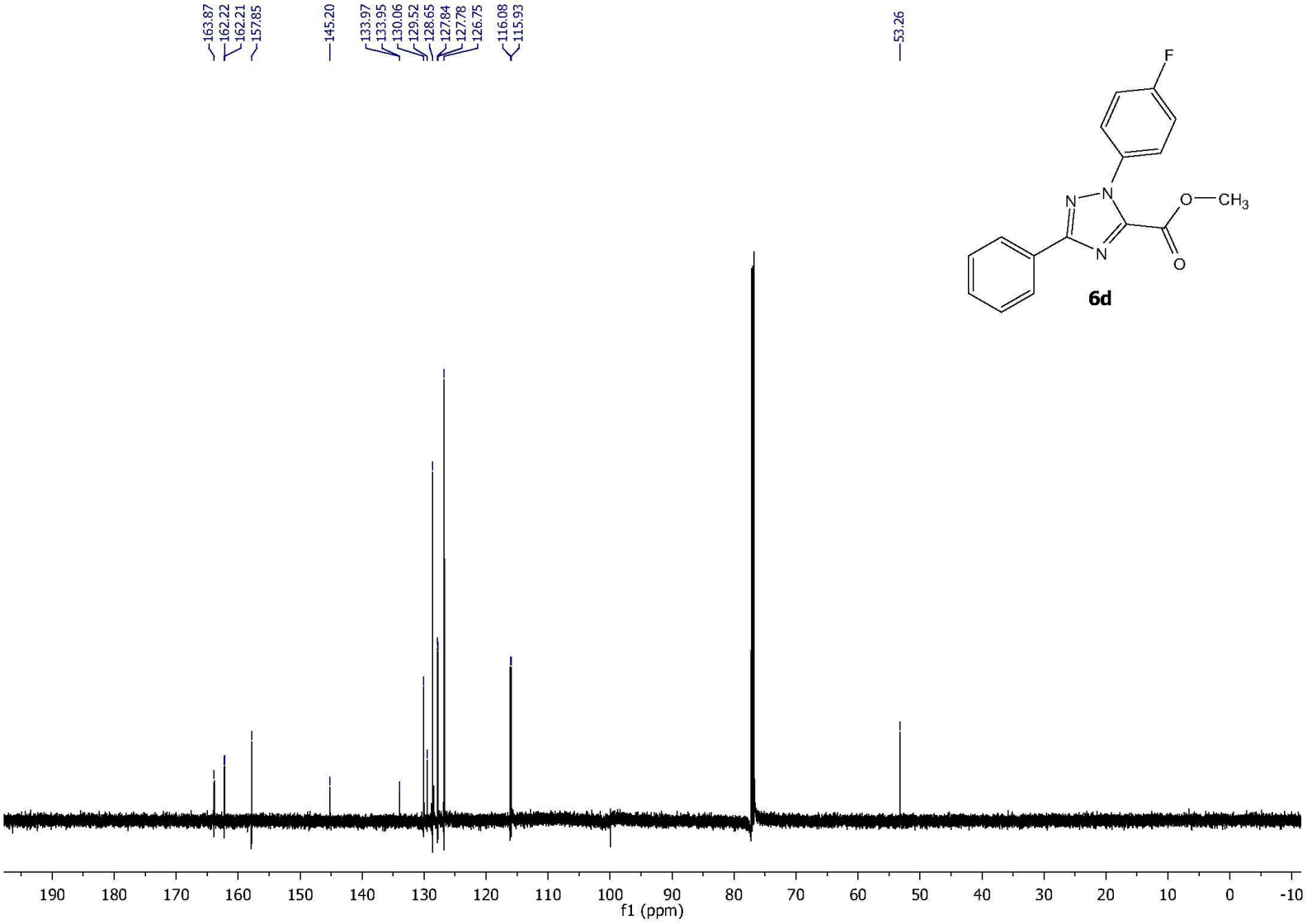
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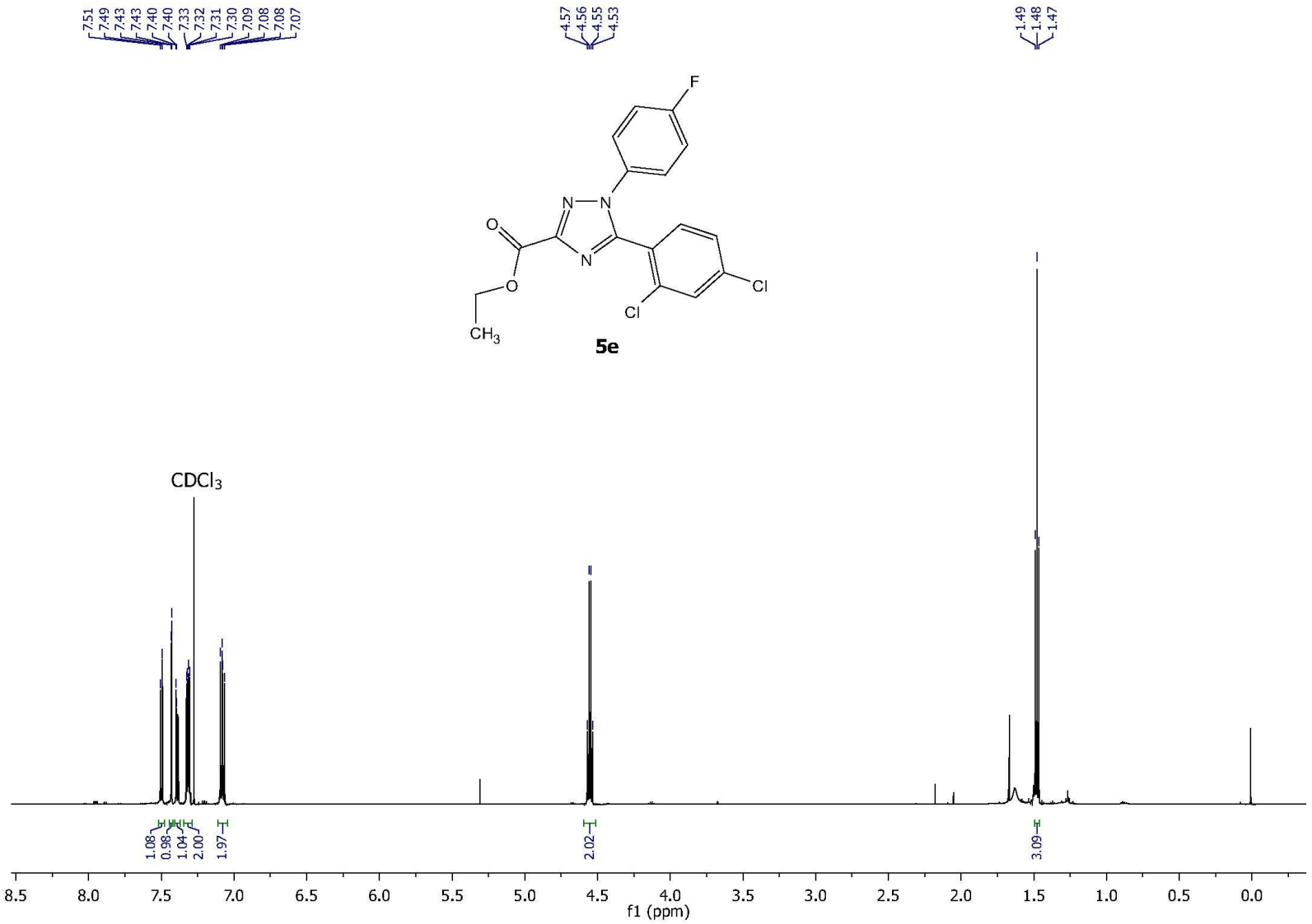
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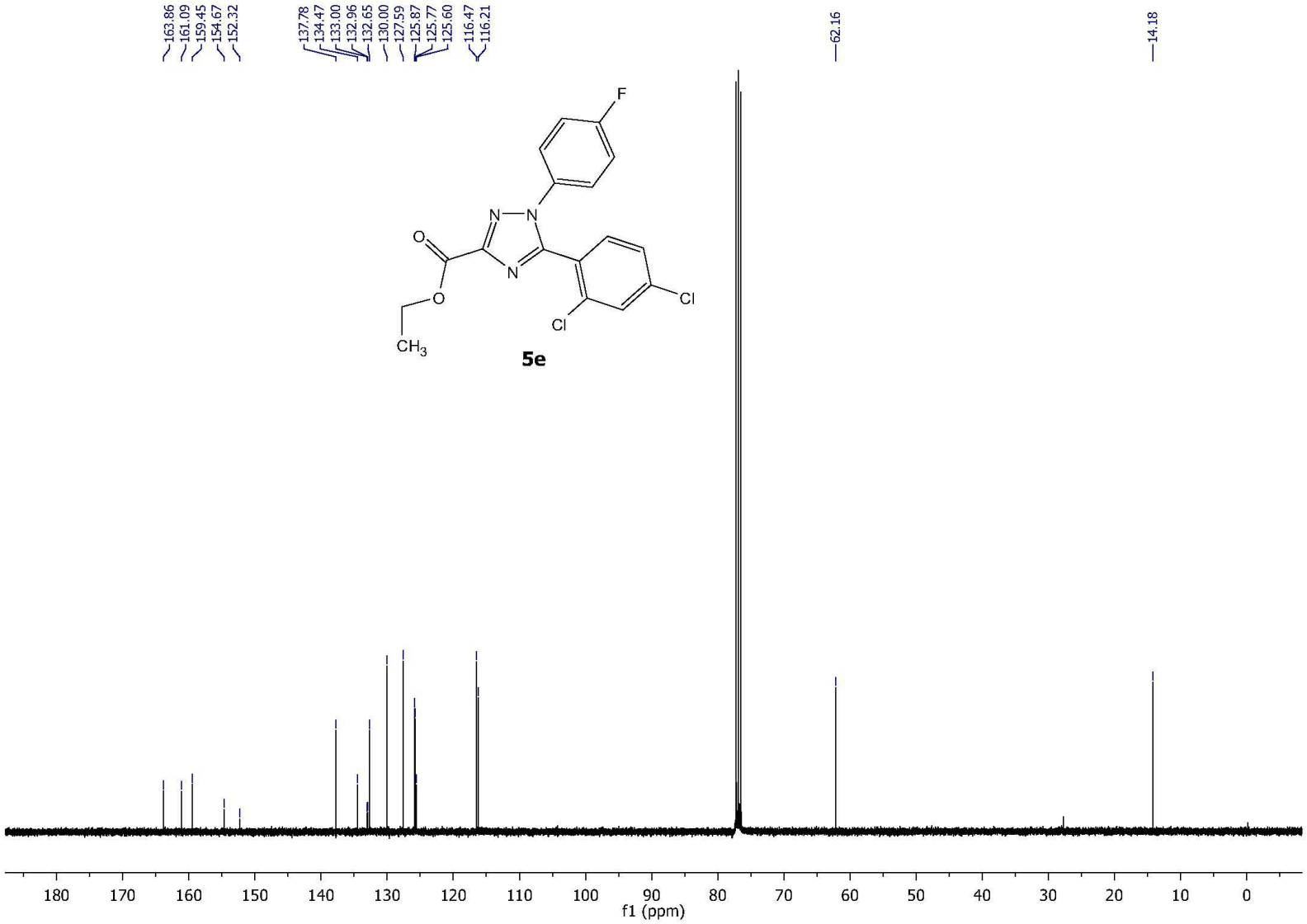
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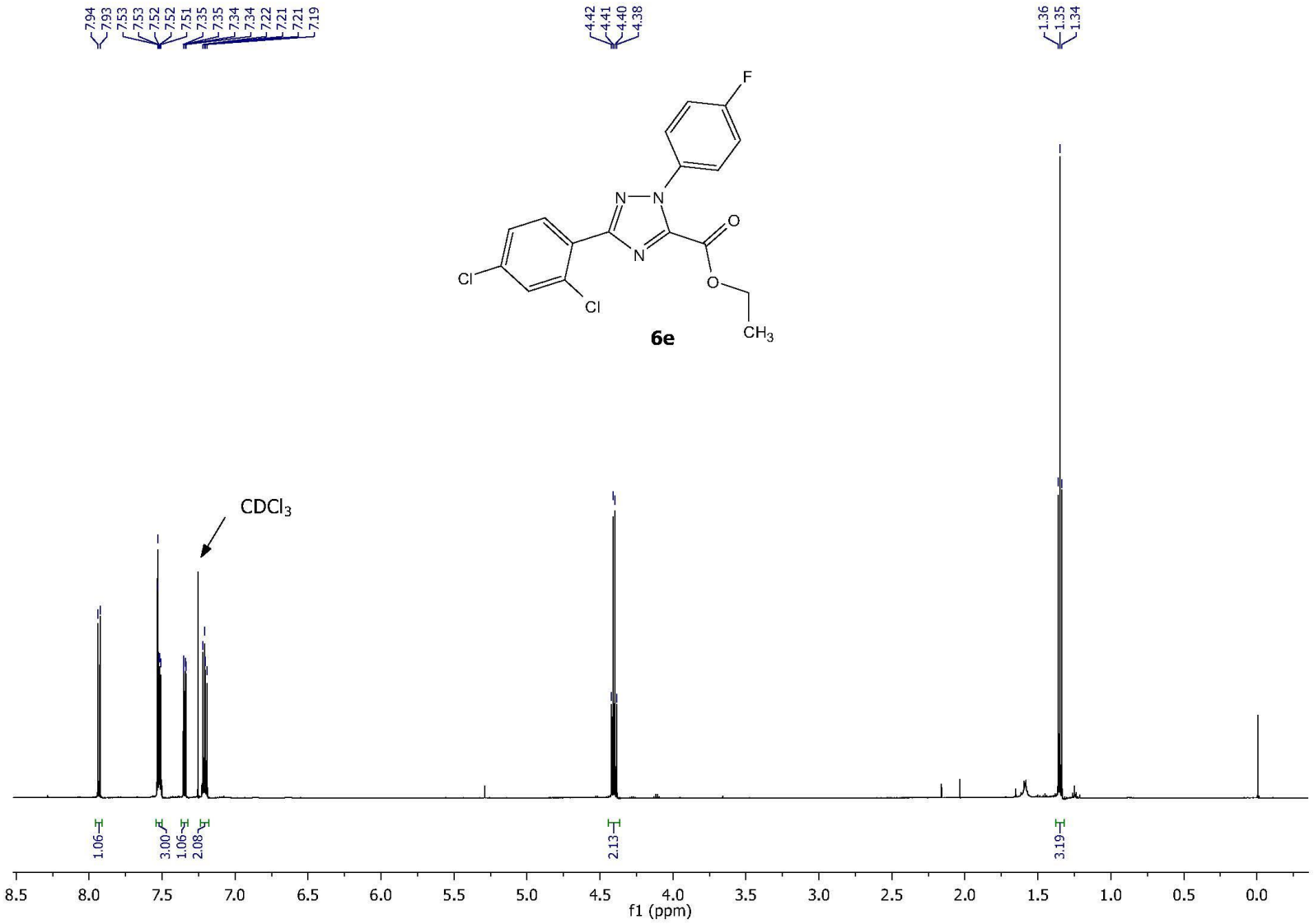
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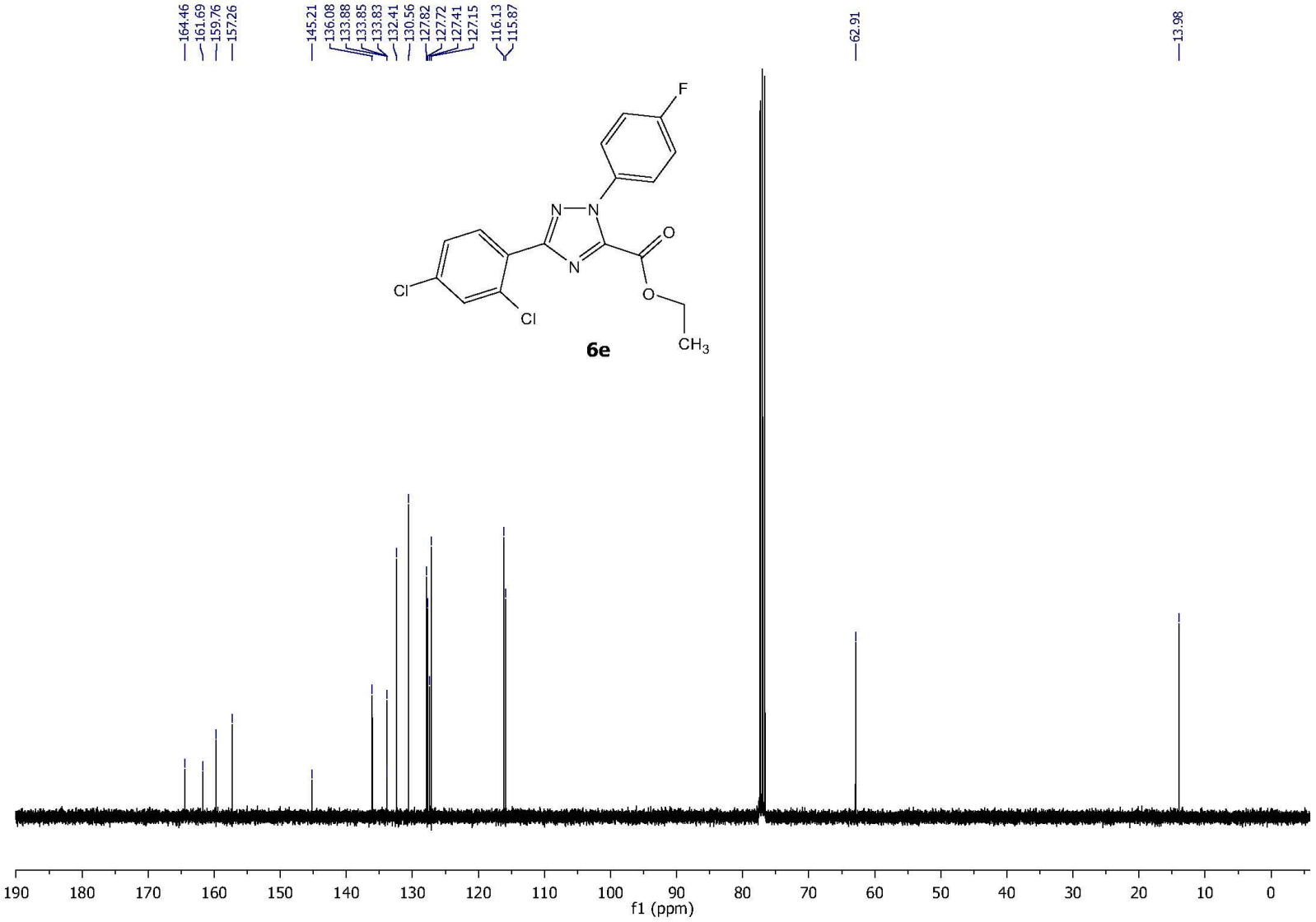
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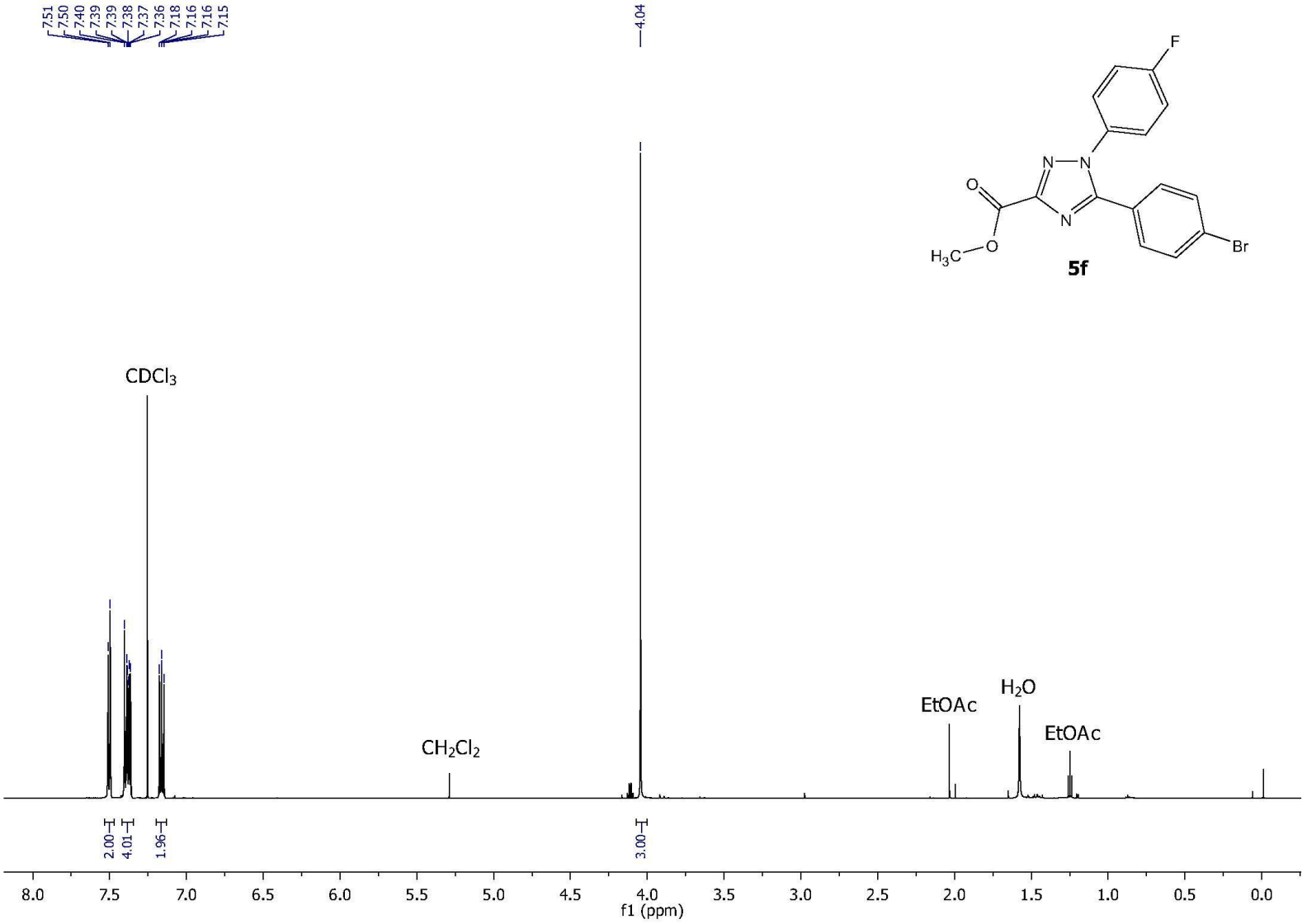
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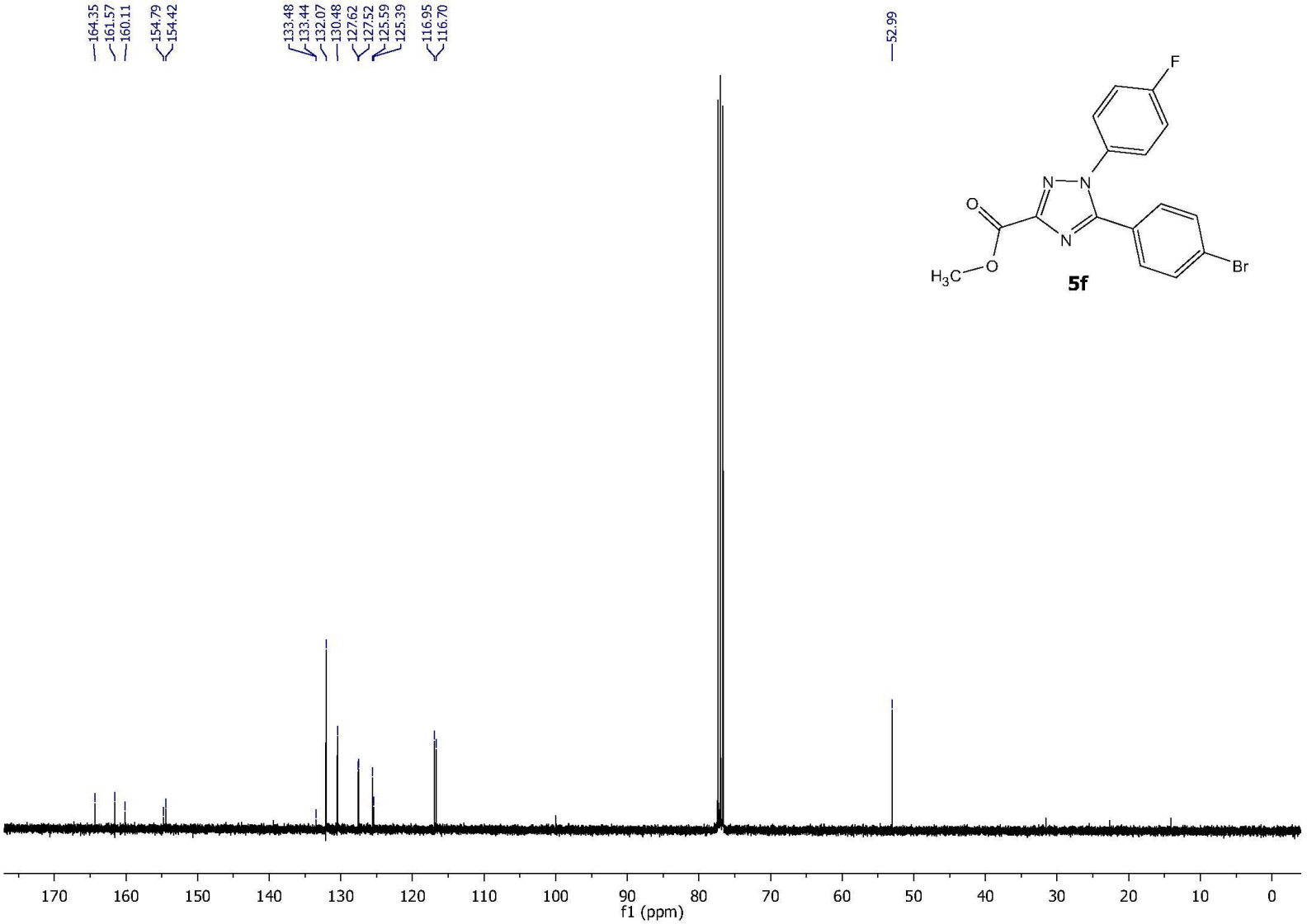
CH2Cl2
EtOAc
H2O
EtOAc
2.00
4.01
1.96
3.00
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)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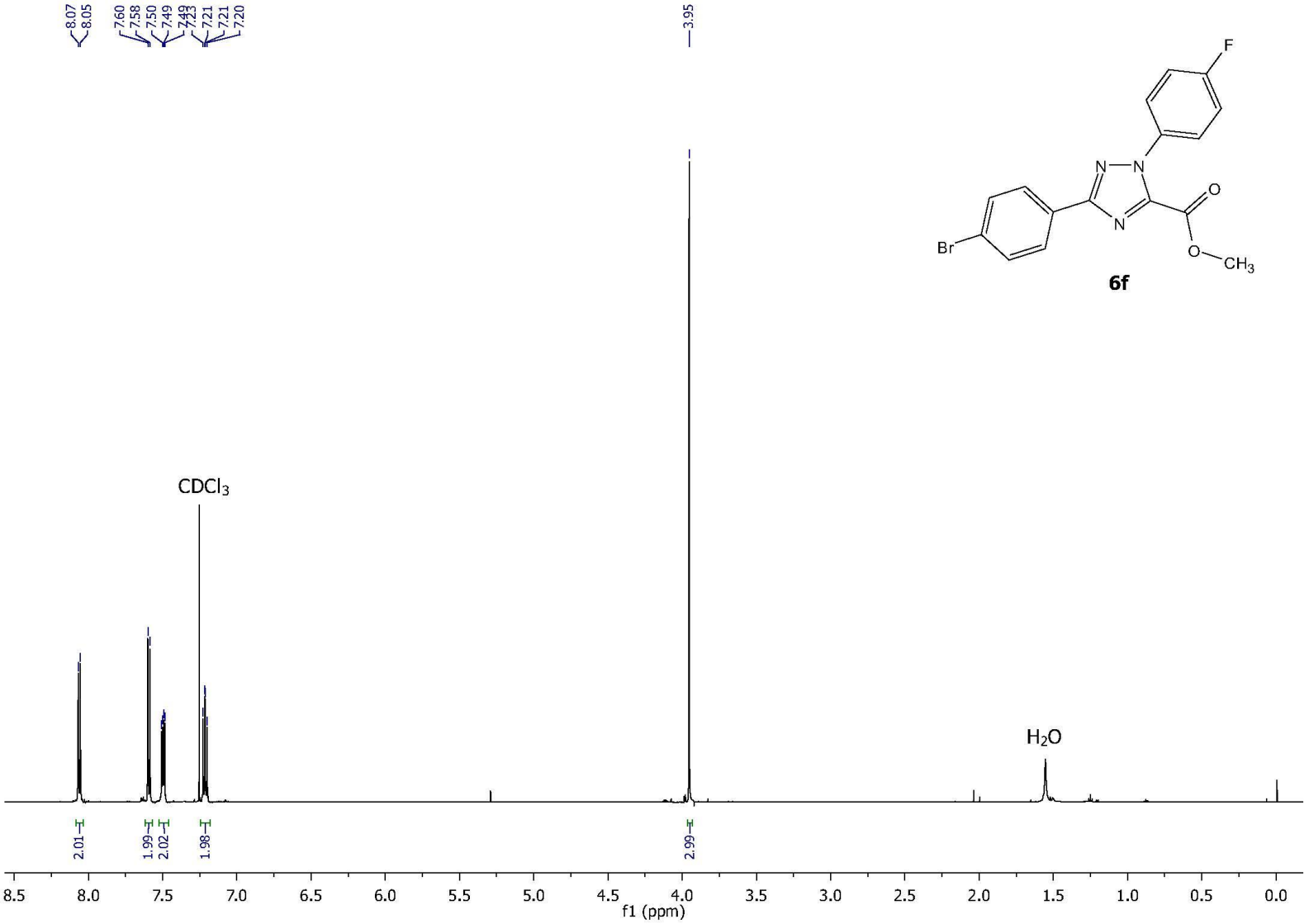
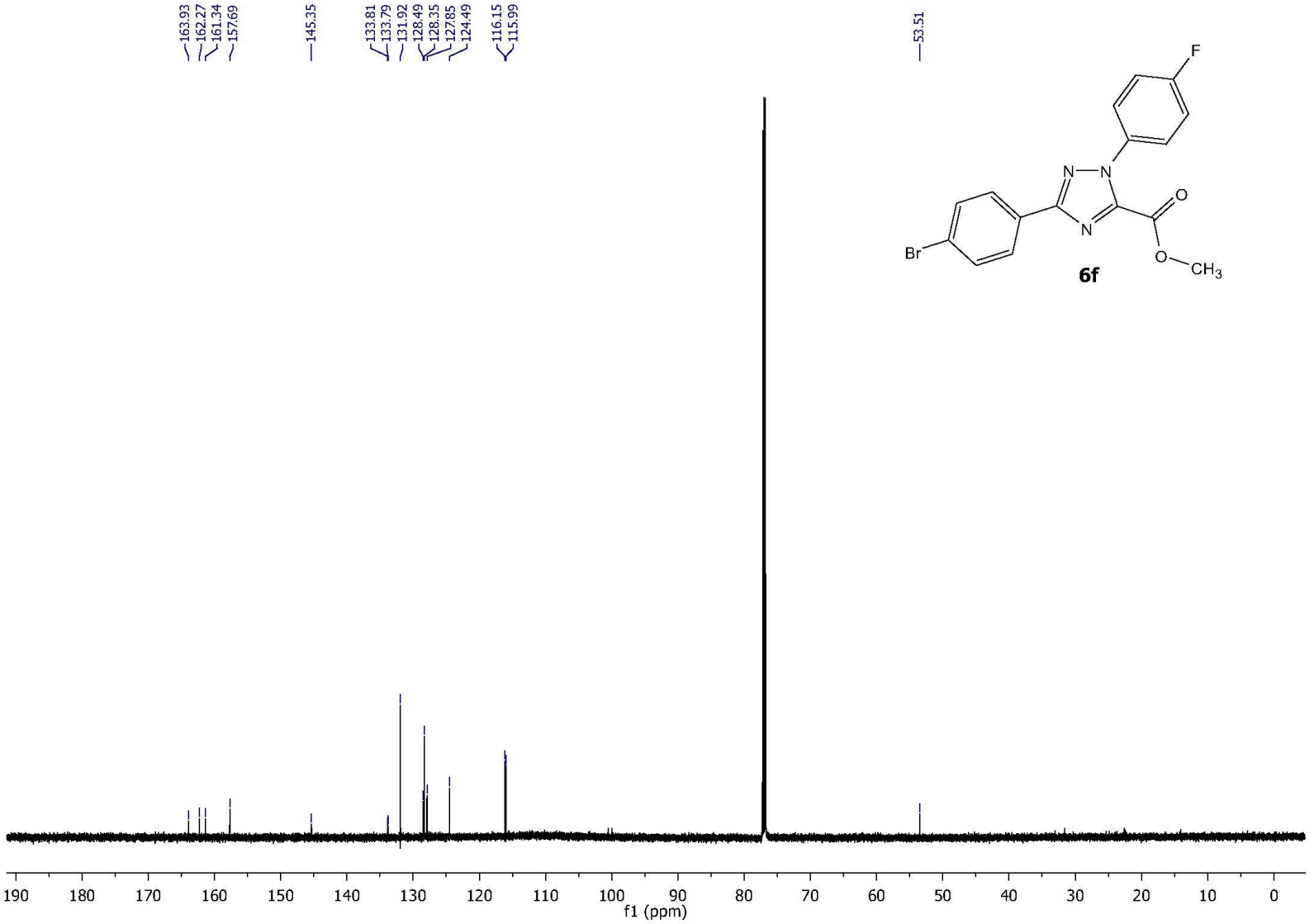
161.57
160.11
154.79
154.42
133.48
133.44
132.07
130.48
127.62
127.52
125.59
125.39
116.95
116.70
52.99
F
N
N
O
O
N
H3C
Br
5f
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


8.07
8.05
7.60
7.58
7.50
7.49
7.21
7.21
7.20
3.95
CDCl3
H2O
2.01
1.99
2.02
1.98
2.99
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

F
N
N
N
O
O
CH3
Br

6f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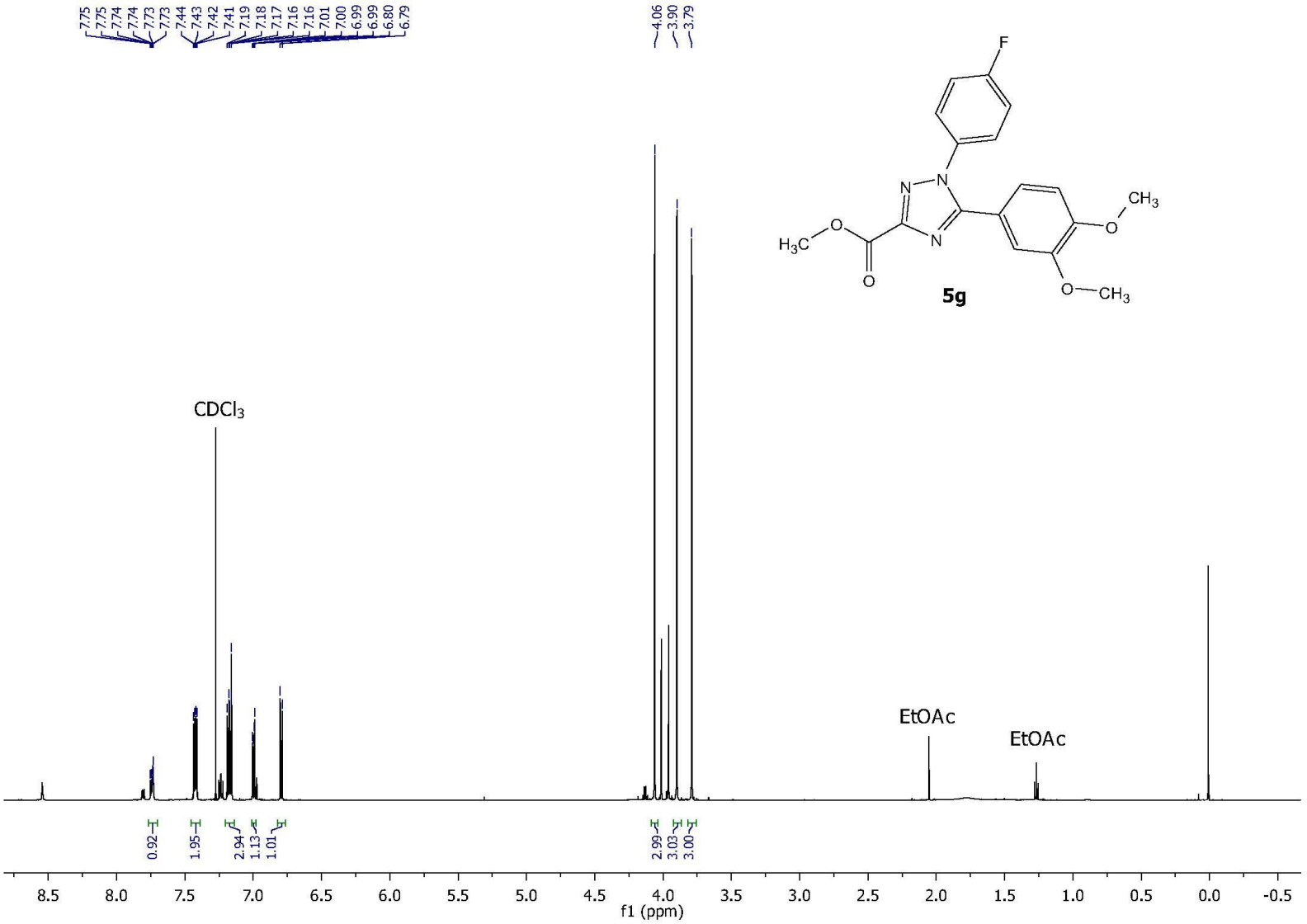
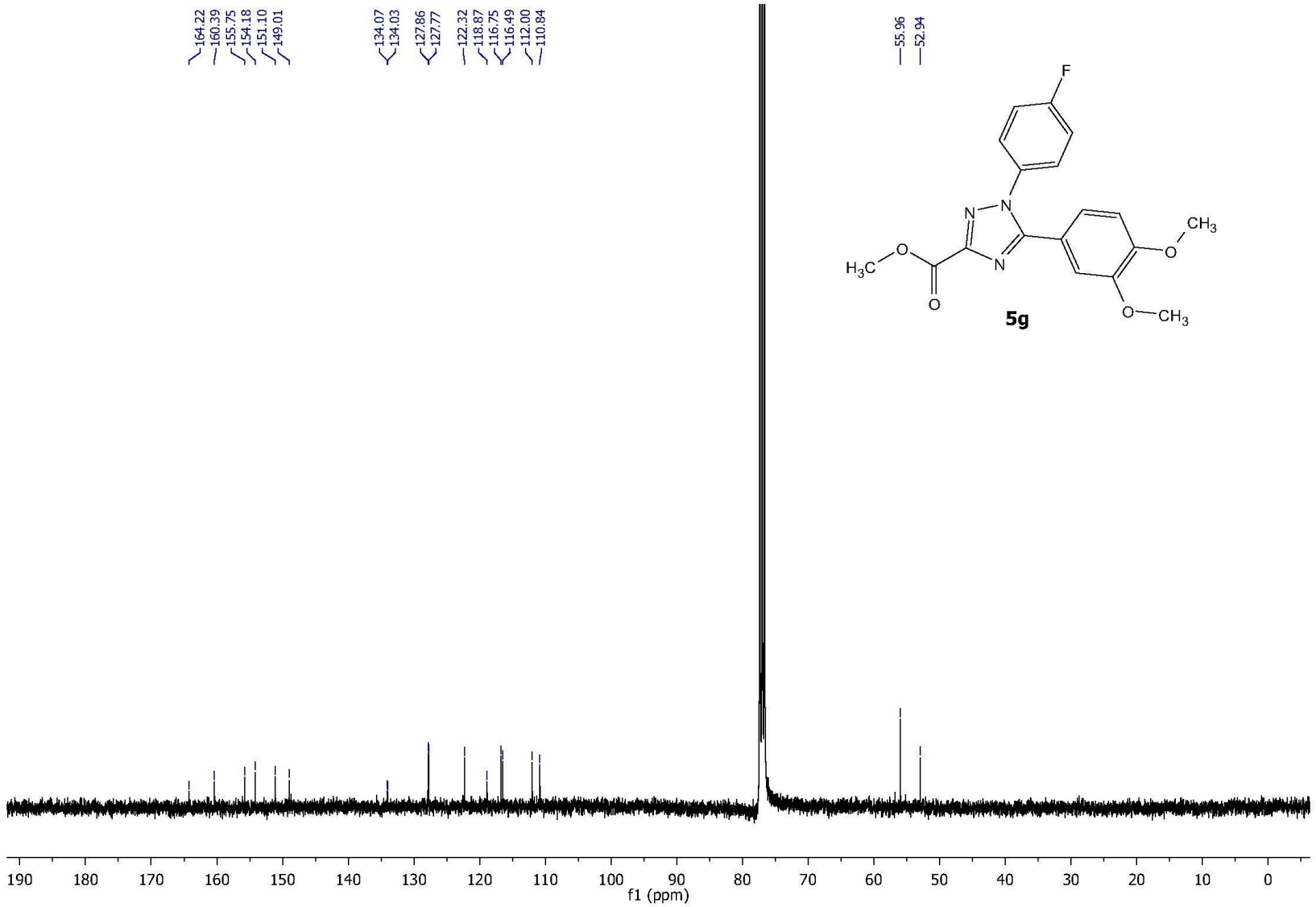
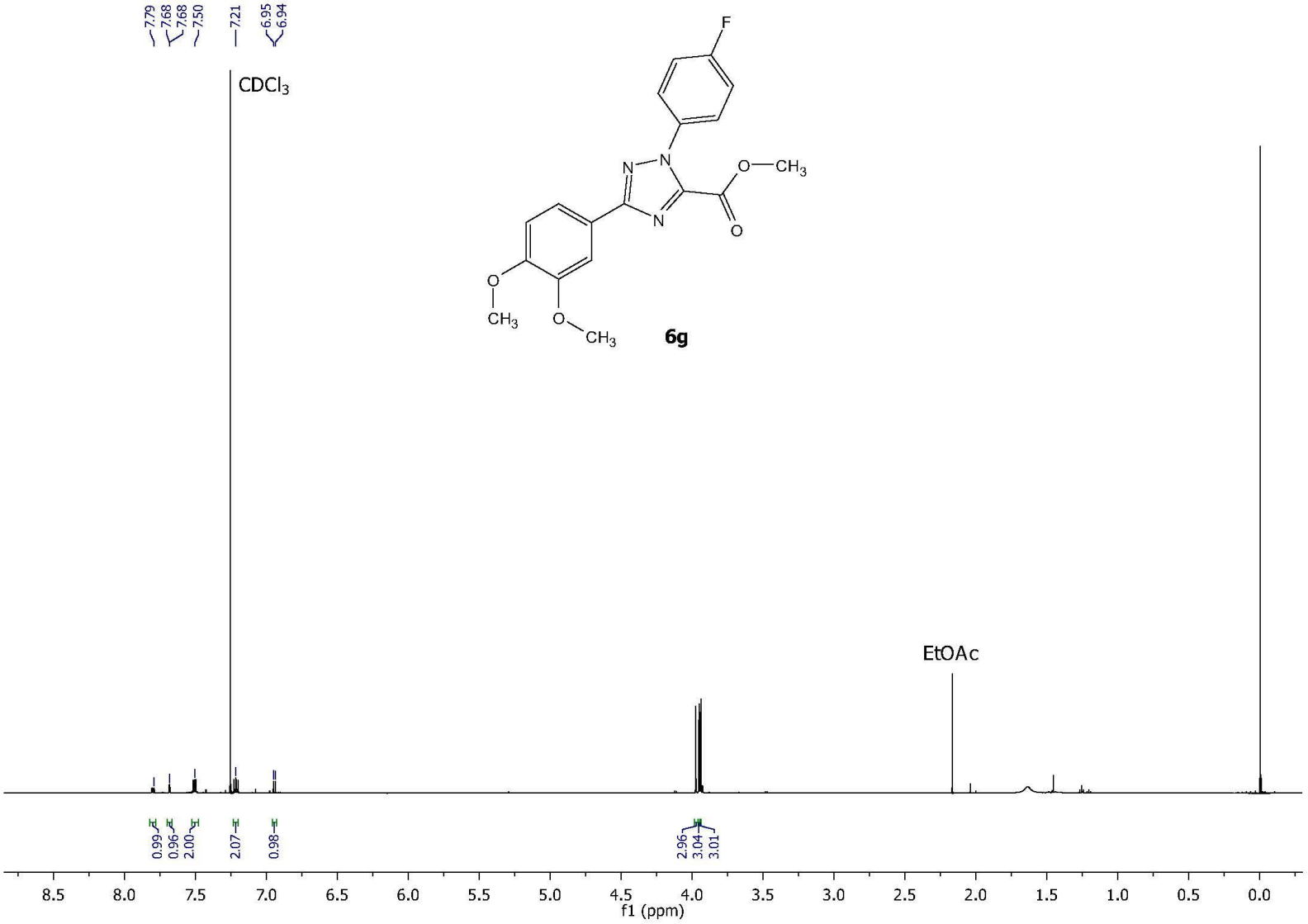
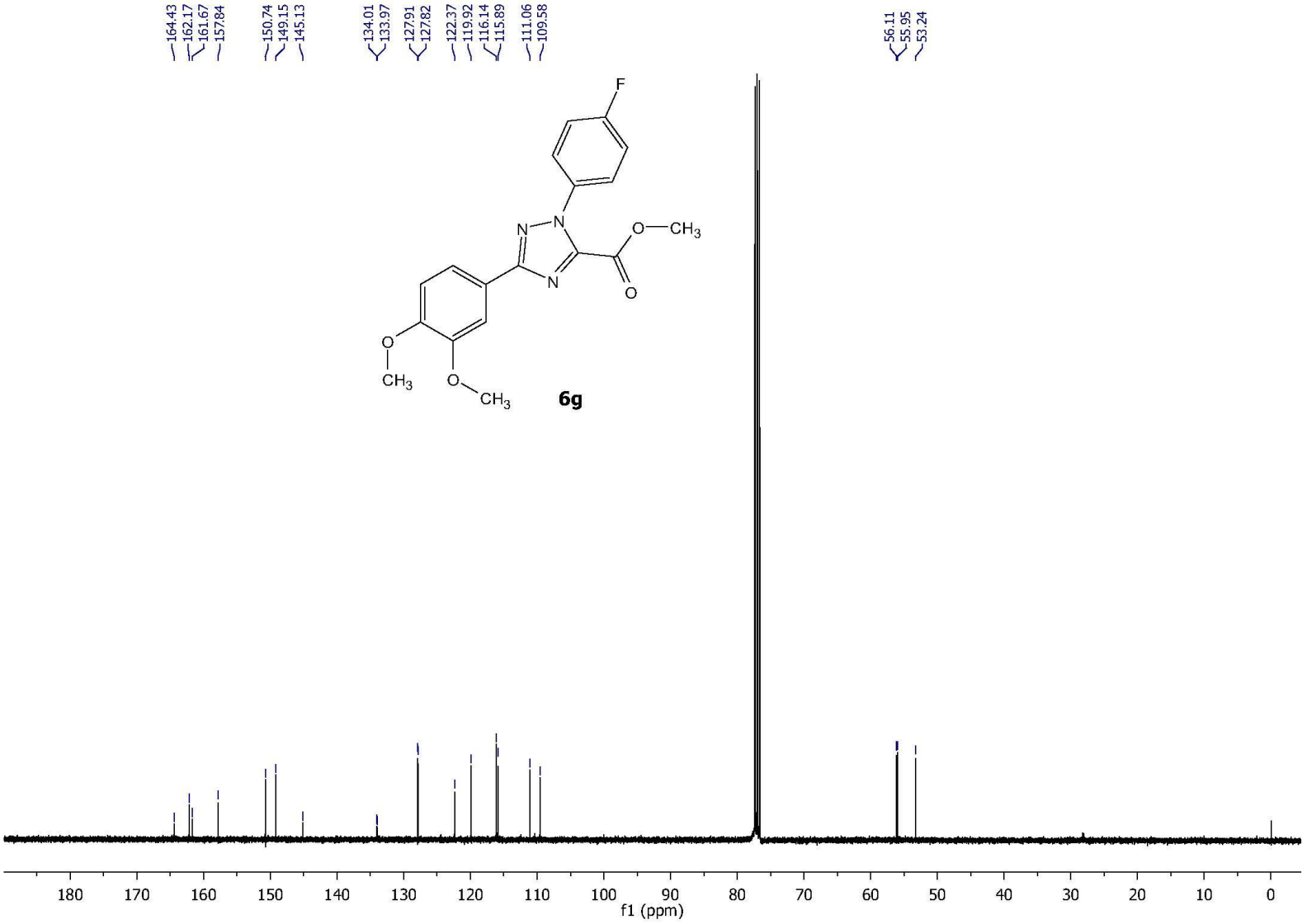
161.34
157.69
145.35
133.81
133.79
131.92
128.49
128.35
127.85
124.49
116.15
115.99
53.51
F
N
N
N
O
O
CH3
Br
6f
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


7.75
7.75
7.74
7.74
7.73
7.73
7.44
7.43
7.42
7.41
7.19
7.18
7.17
7.16
7.16
7.01
7.00
6.99
6.99
6.80
6.79
4.06
3.90
3.79
F
N
N
N
O
H_3C
O
CH_3
O
O
CH_3
5g
$CDCl_3$
EtOAc
EtOAc
0.92
1.95
2.94
1.13
1.01
2.99
3.03
3.00
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)


164.22
160.39
155.75
154.18
151.10
149.01
134.07
134.03
127.86
127.77
122.32
118.87
116.75
116.49
112.00
110.84
55.96
52.94
F
N
N
N
O
H_3C
O
O
CH_3
O
CH_3
5g
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


7.79
7.68
7.68
7.50
7.21
6.95
6.94
CDCl3
F
N
N
N
O
CH3
O
O
CH3
O
CH3
6g
EtOAc
0.99
0.96
2.00
2.07
0.98
2.96
3.04
3.01
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)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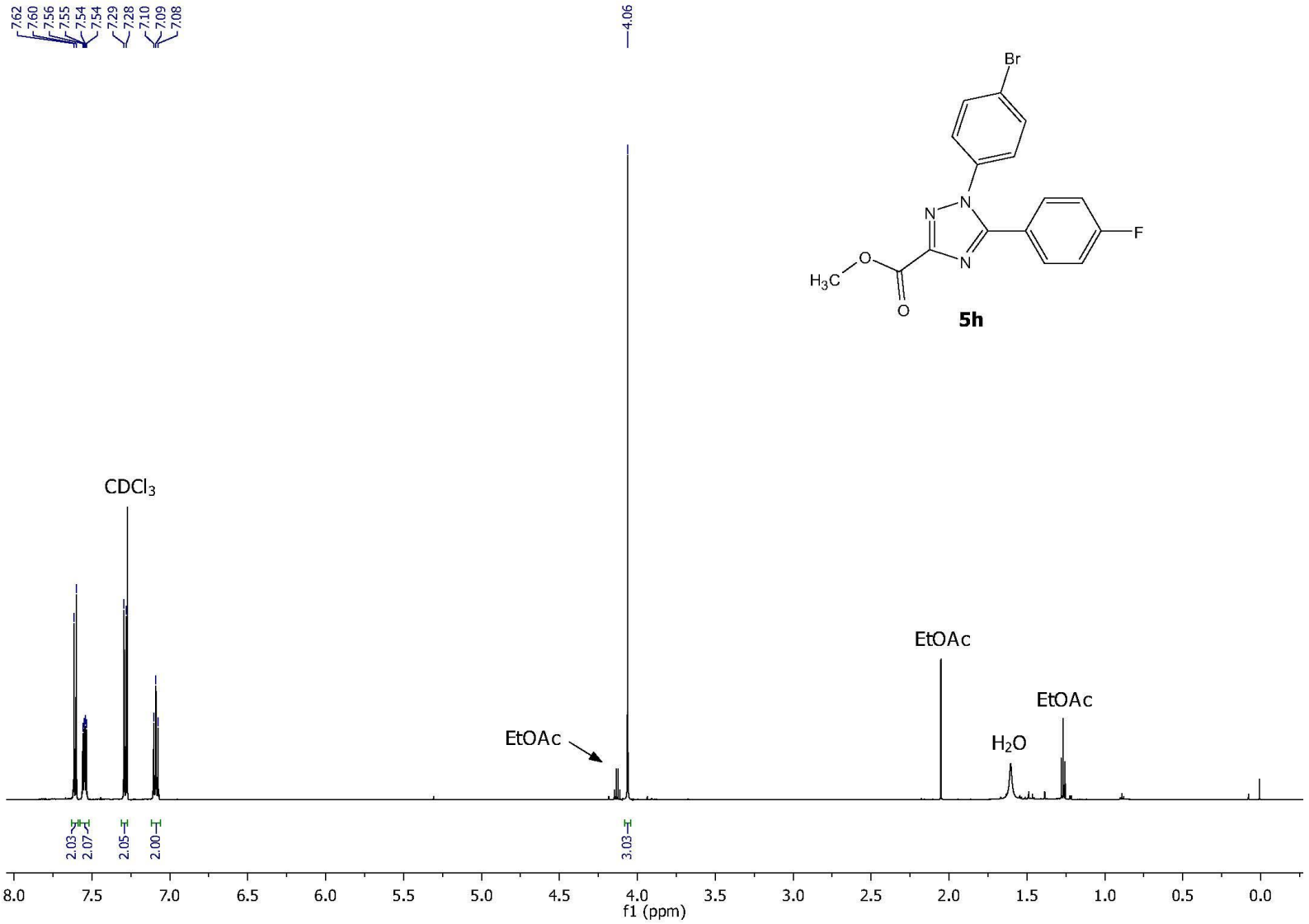
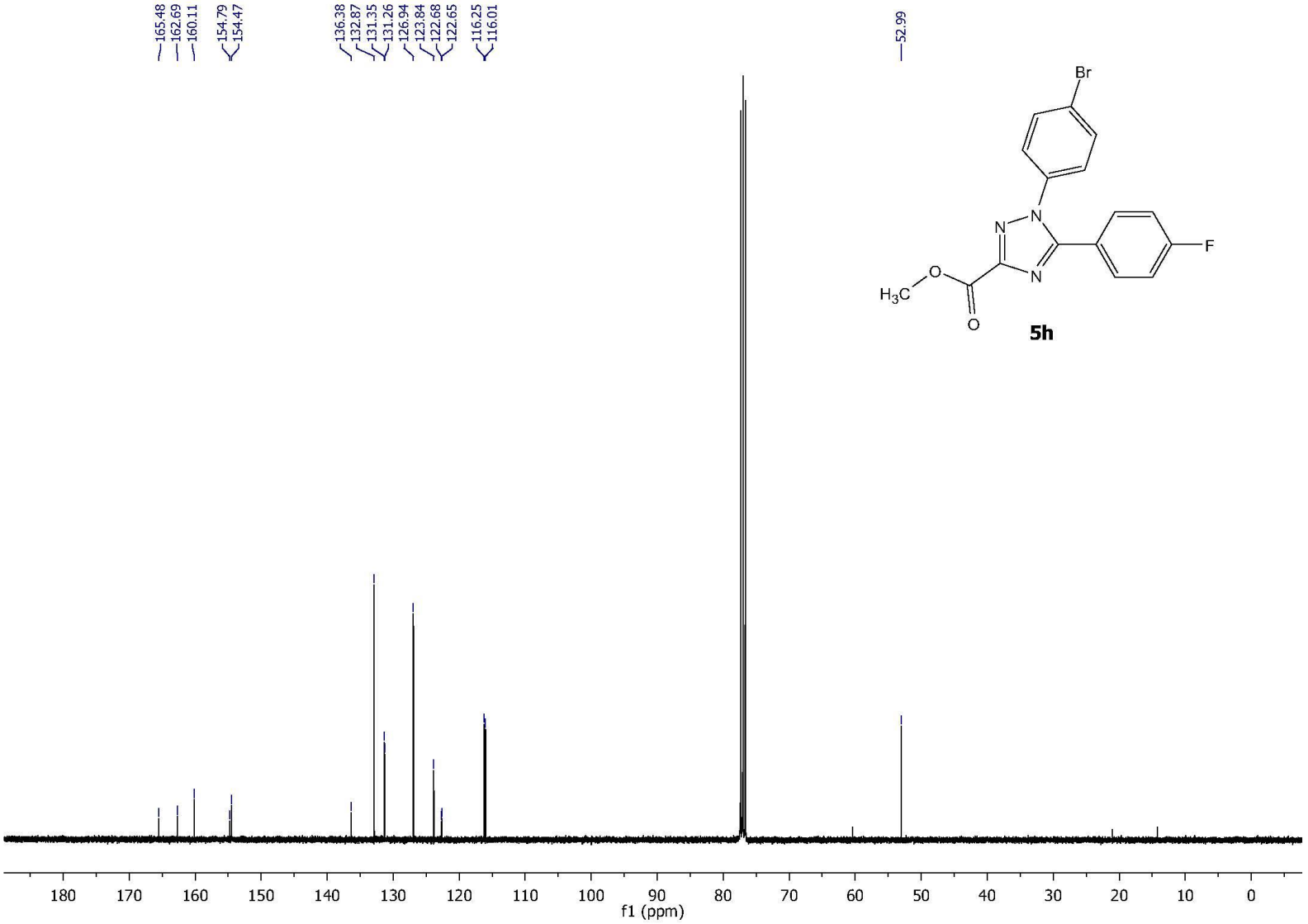
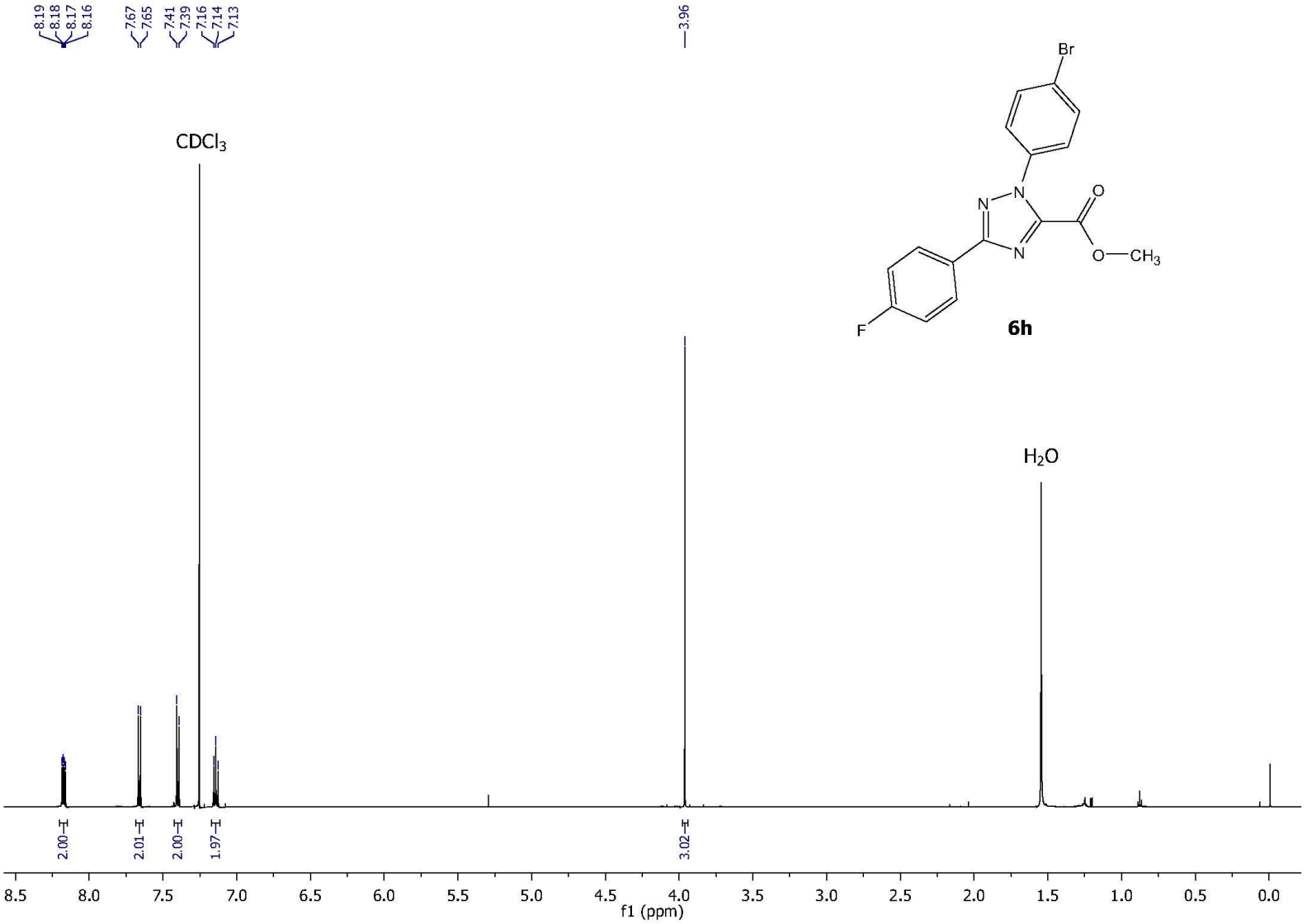
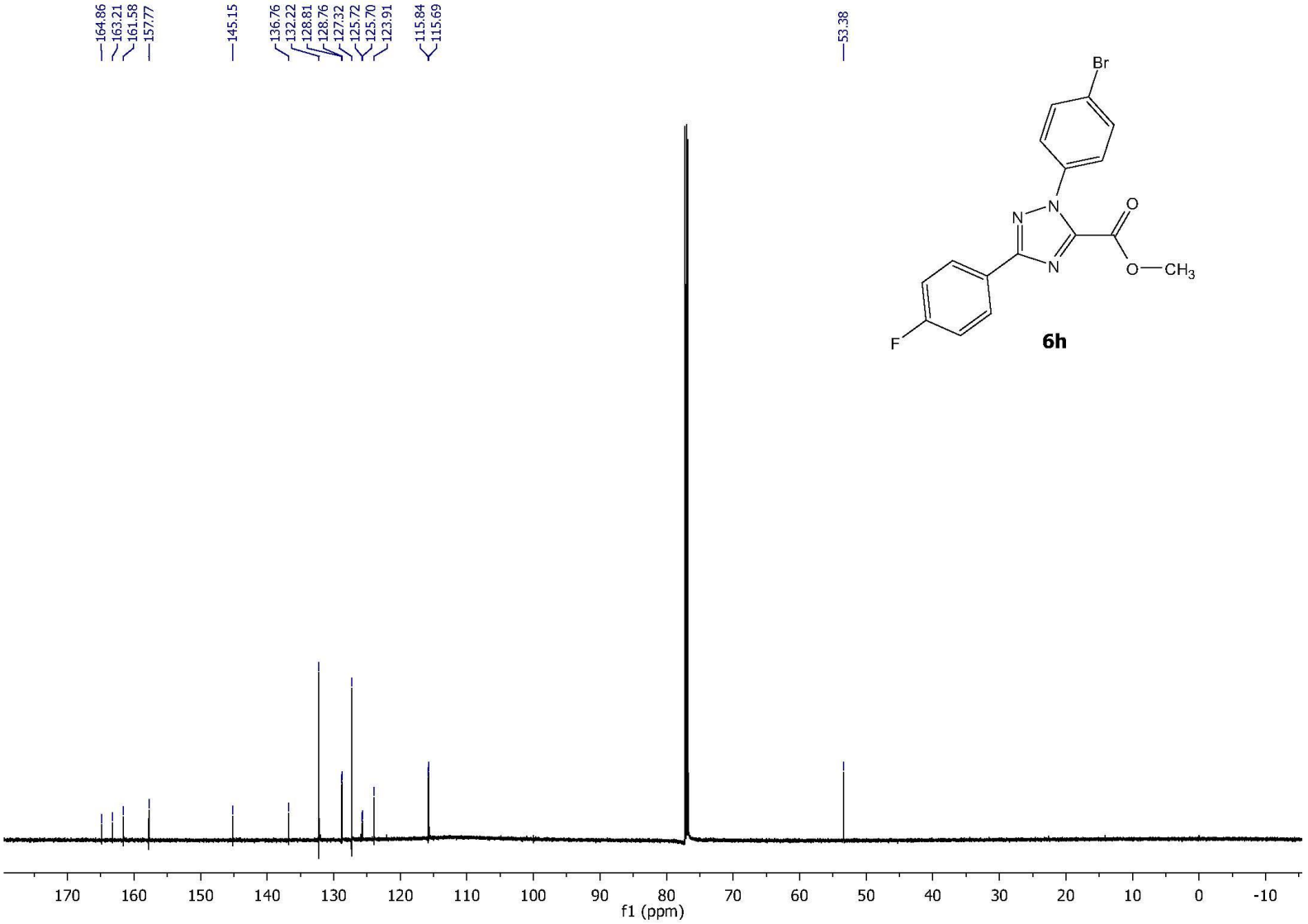
162.17
161.67
157.84
150.74
149.15
145.13
134.01
133.97
127.91
127.82
122.37
119.92
116.14
115.89
111.06
109.58
56.11
55.95
53.24
F
N
N
N
O
CH3
O
O
CH3
O
CH3
6g
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


7.62
7.60
7.56
7.55
7.54
7.54
7.29
7.28
7.10
7.09
7.08
4.06
Br
N
N
N
F
O
H_3C
O
5h
$CDCl_3$
EtOAc
EtOAc
H_2O
EtOAc
2.03
2.07
2.05
2.00
3.03
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


165.48
162.69
160.11
154.79
154.47
136.38
132.87
131.35
131.26
126.94
123.84
122.68
122.65
116.25
116.01
52.99
Br
F
N
N
N
O
O
H3C
5h
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


8.19
8.18
8.17
8.16
7.67
7.65
7.41
7.39
7.16
7.14
7.13
3.96
CDCl3
H2O
Br
N
N
N
O
O—CH3
F
6h
2.00
2.01
2.00
1.97
3.02
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)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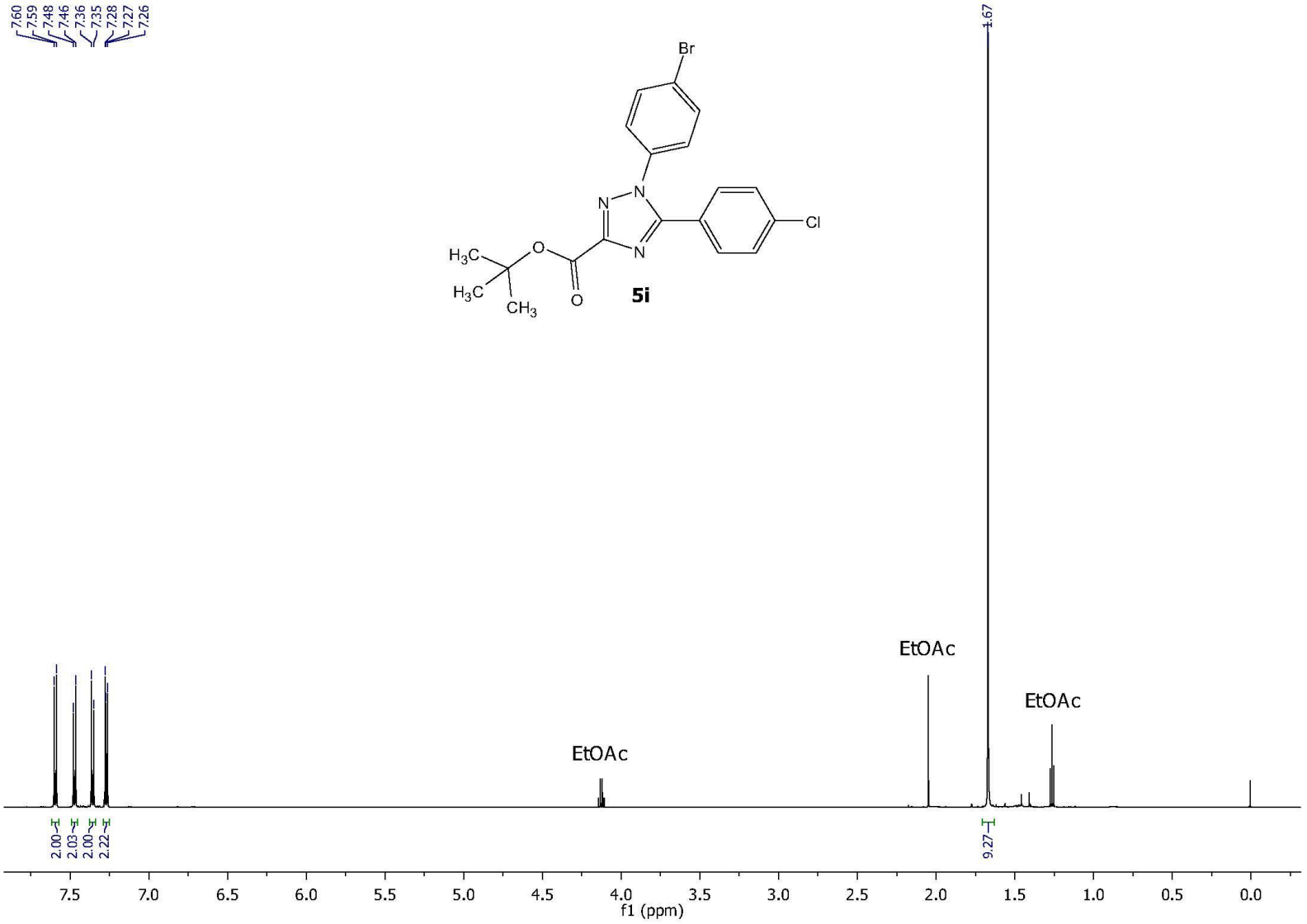
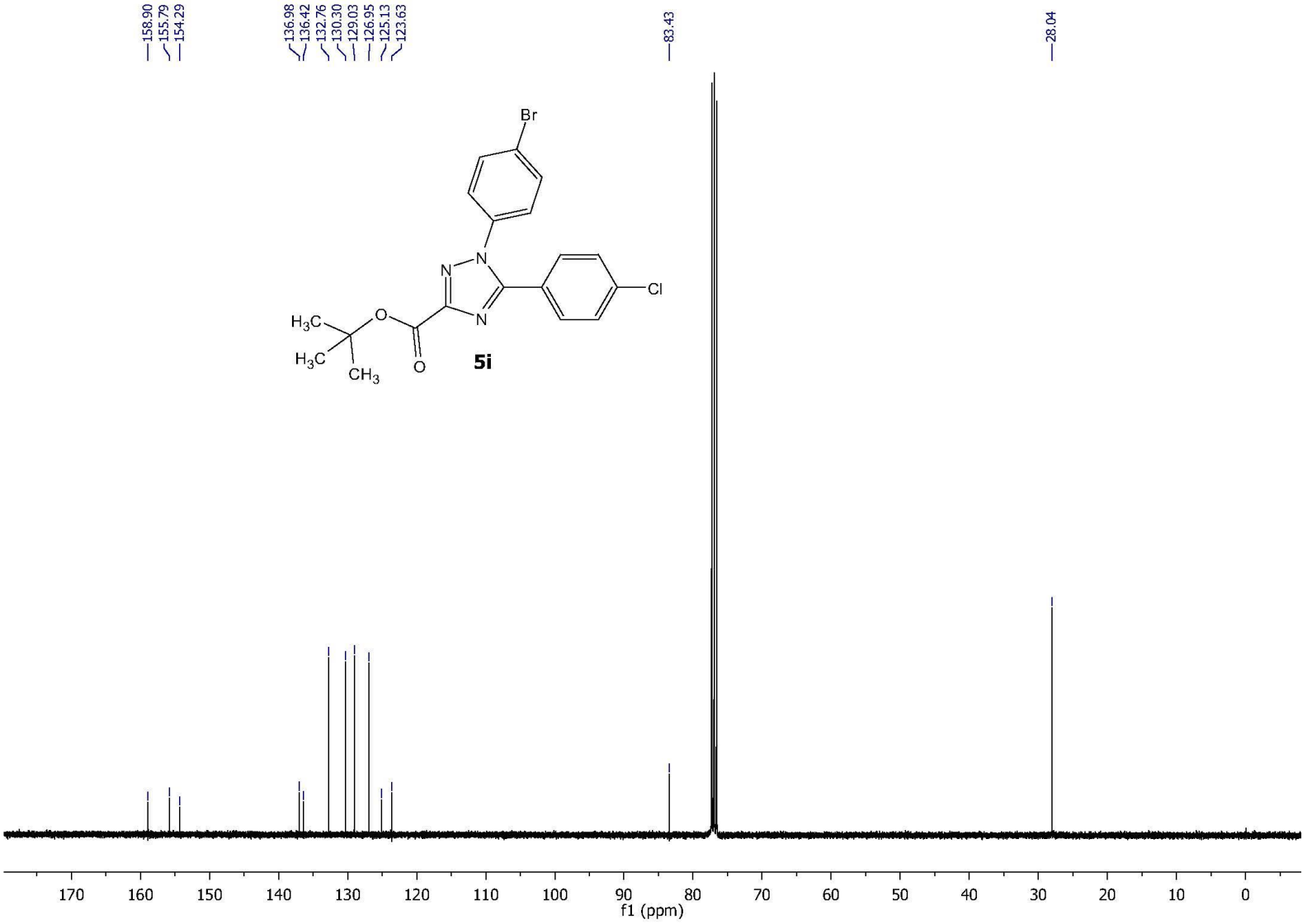
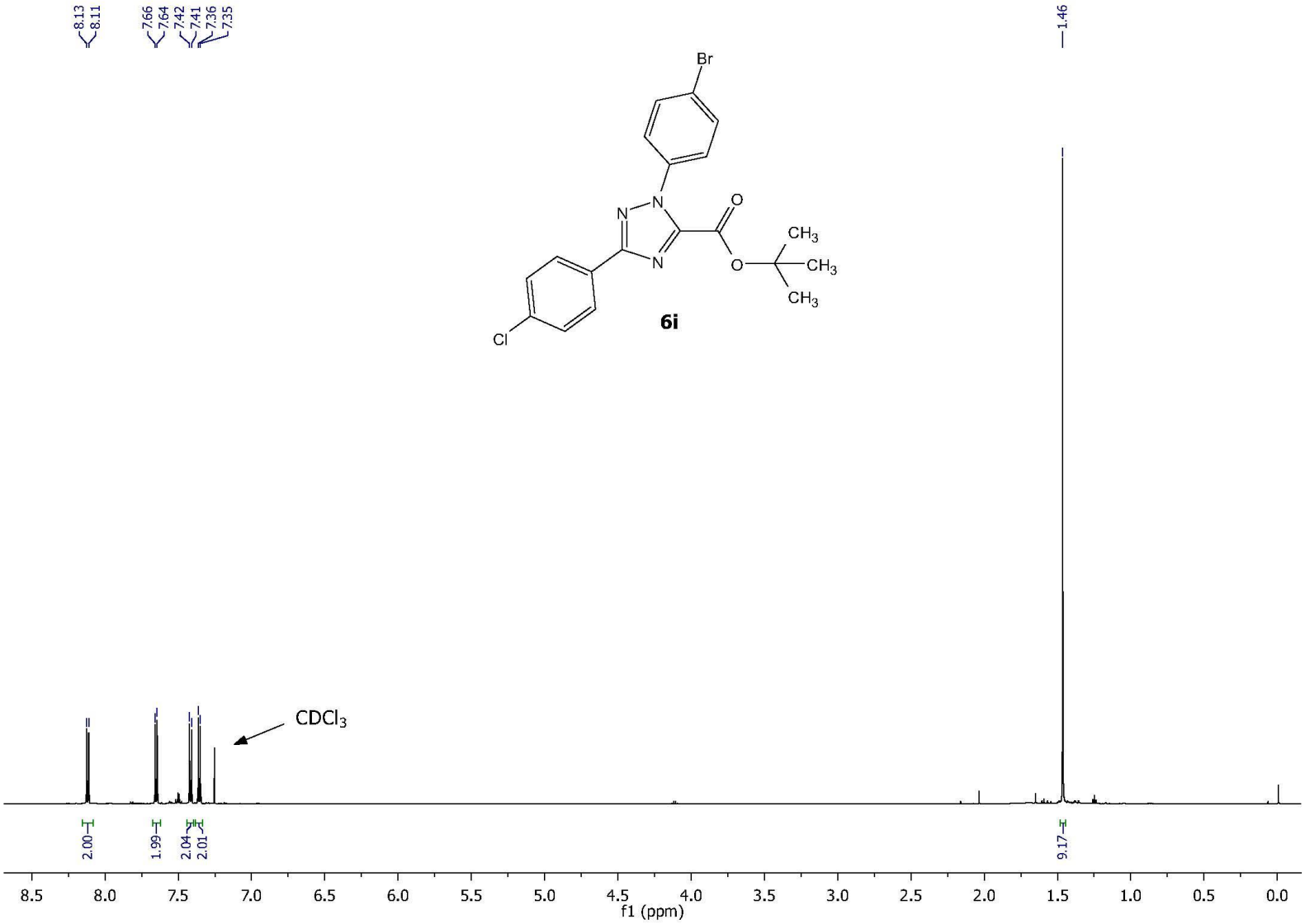
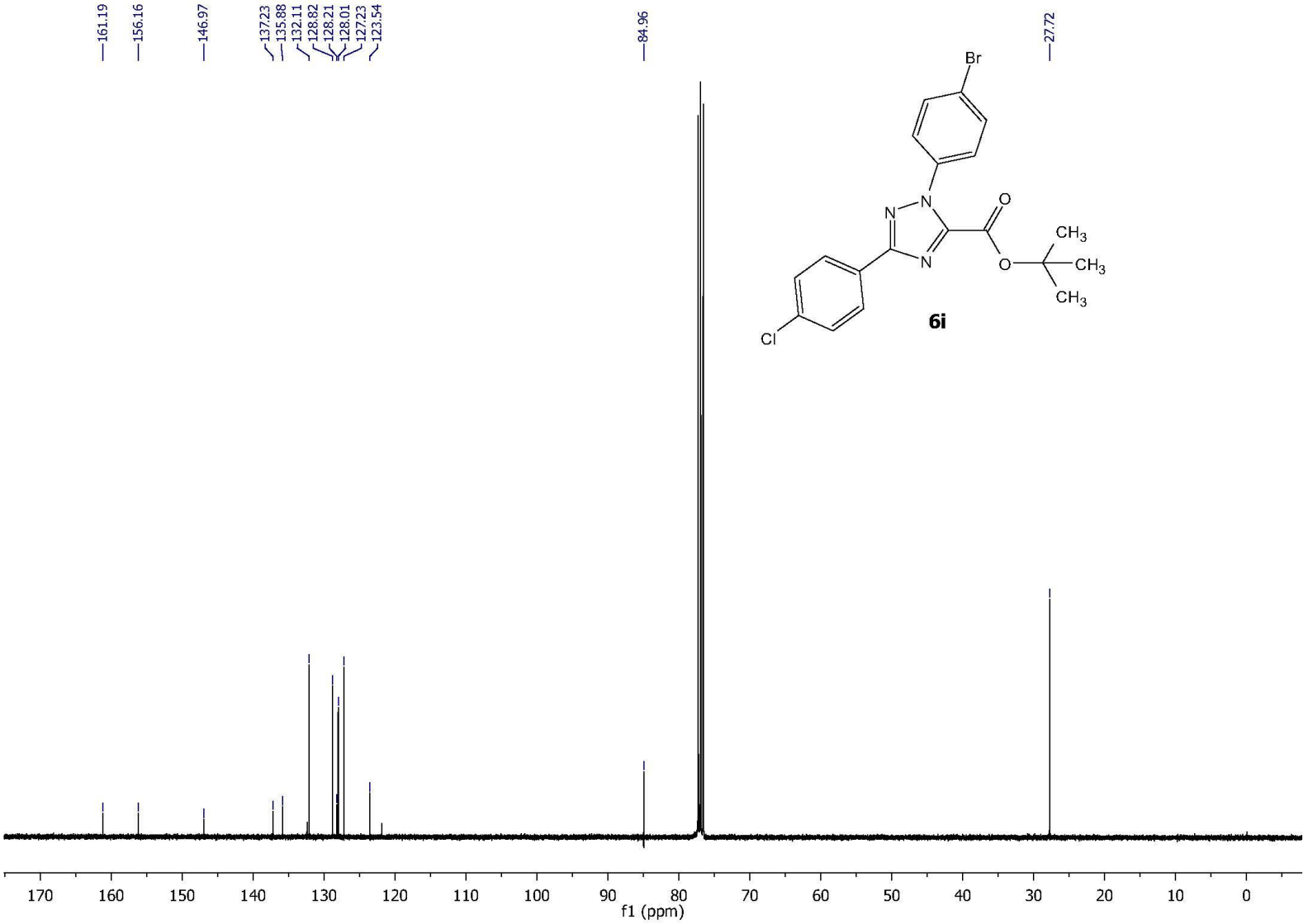
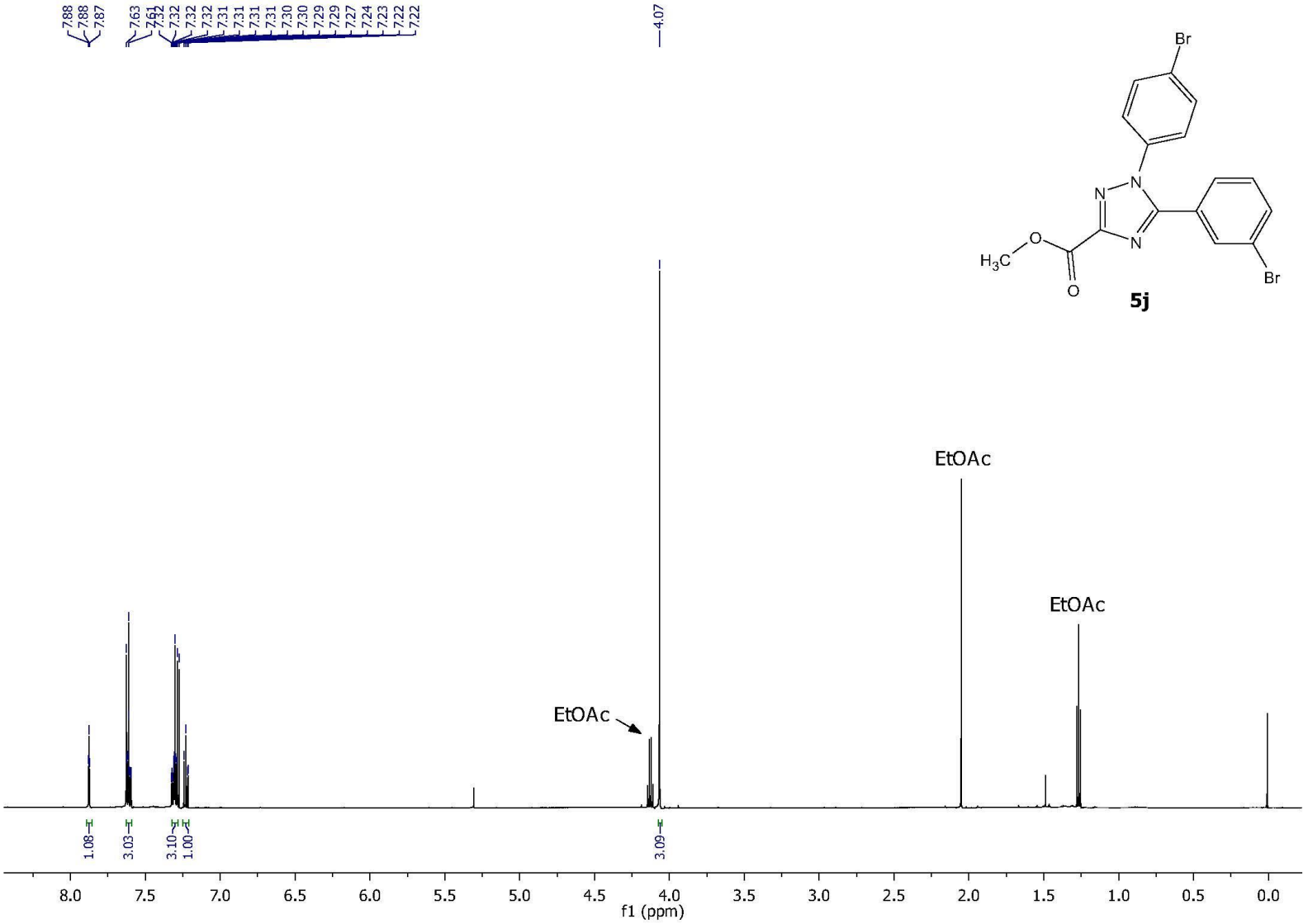
163.21
161.58
157.77
145.15
136.76
132.22
128.81
128.76
127.32
125.72
125.70
123.91
115.84
115.69
53.38
Br
N
N
N
O
O
CH3
F
6h
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)


7.60
7.59
7.48
7.46
7.36
7.35
7.28
7.27
7.26
1.67
Br
N
N
N
Cl
O
O
H3C
H3C
CH3
5i
EtOAc
EtOAc
EtOAc
2.00
2.03
2.00
2.22
9.27
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


158.90
155.79
154.29
136.98
136.42
132.76
130.30
129.03
126.95
125.13
123.63
83.43
28.04
Br
Cl
N
N
N
O
O
H3C
H3C
CH3
5i
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


8.13
8.11
7.66
7.64
7.42
7.41
7.36
7.35
1.46
Br
N
N
N
O
O
CH3
CH3
CH3
Cl
6i
CDCl3
2.00
1.99
2.04
2.01
9.17
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


161.19
156.16
146.97
137.23
135.88
132.11
128.82
128.21
128.01
127.23
123.54
84.96
27.72
Br
Cl
N
N
N
O
O
CH3
CH3
CH3
6i
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)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7.88
7.87
7.63
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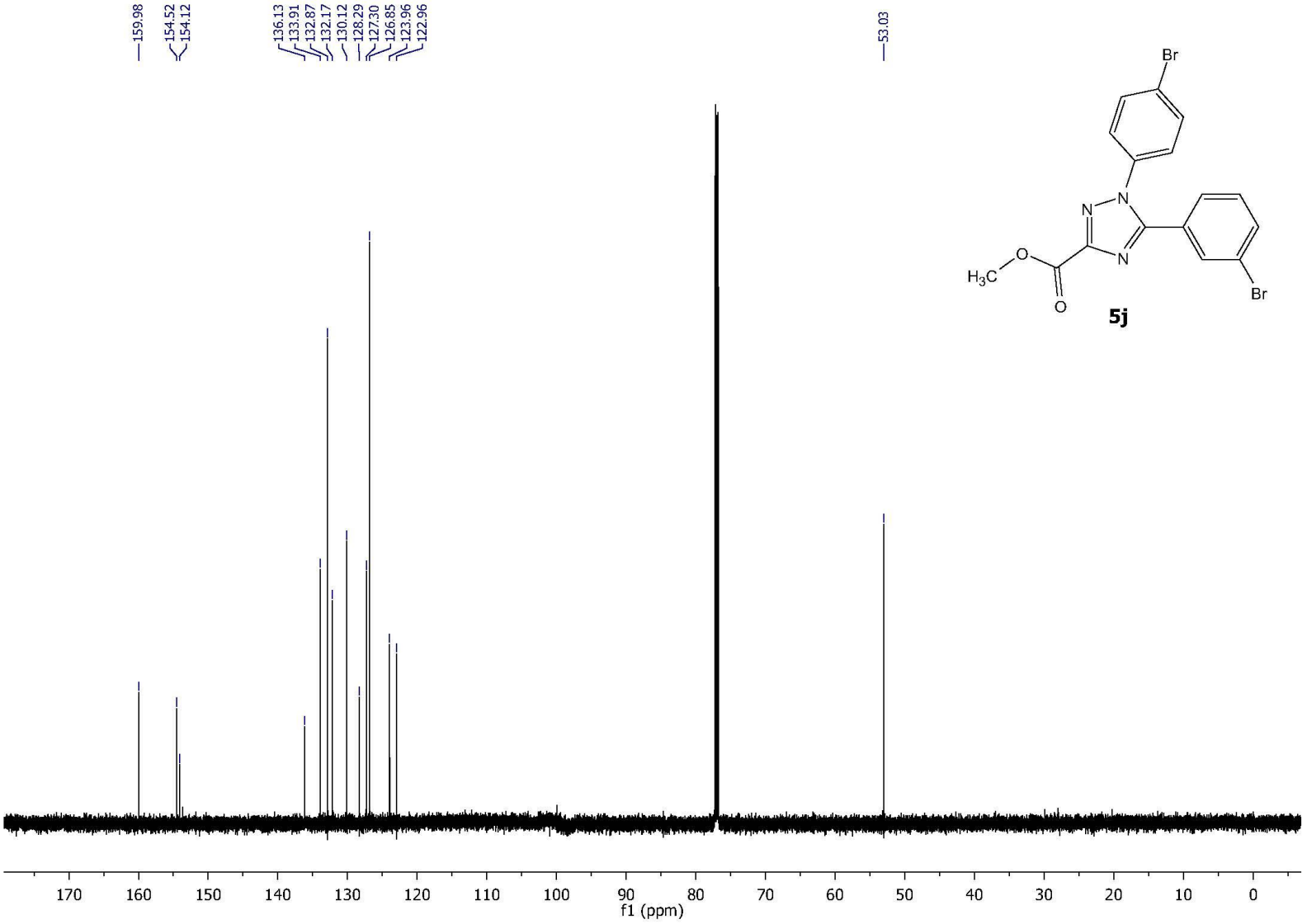
7.32
7.32
7.31
7.31
7.31
7.31
7.30
7.30
7.29
7.29
7.27
7.24
7.23
7.22
7.22
4.07
Br
N
N
N
O
H3C
O
Br
5j
EtOAc
EtOAc
EtOAc
1.08
3.03
3.10
1.00
3.09
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)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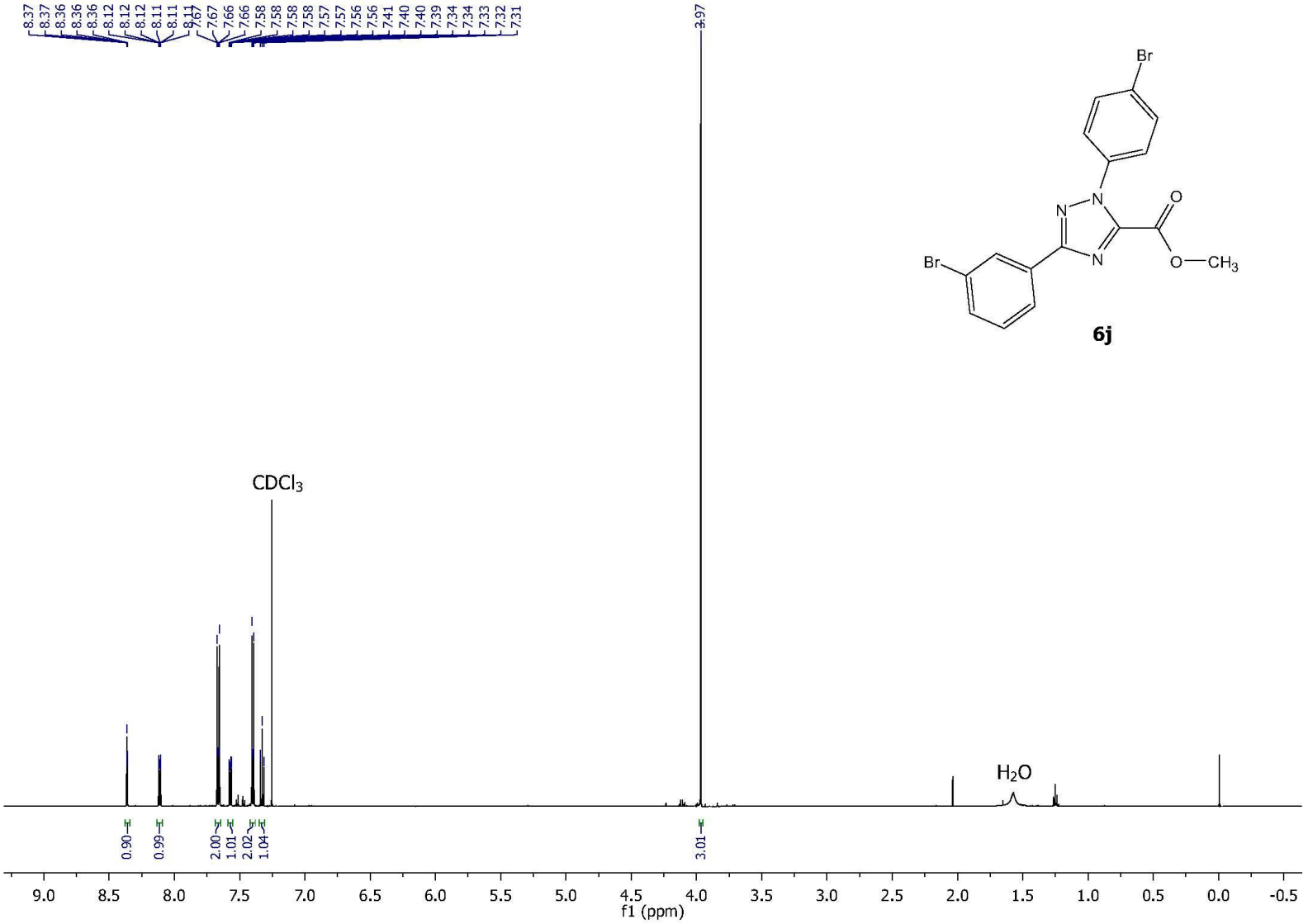
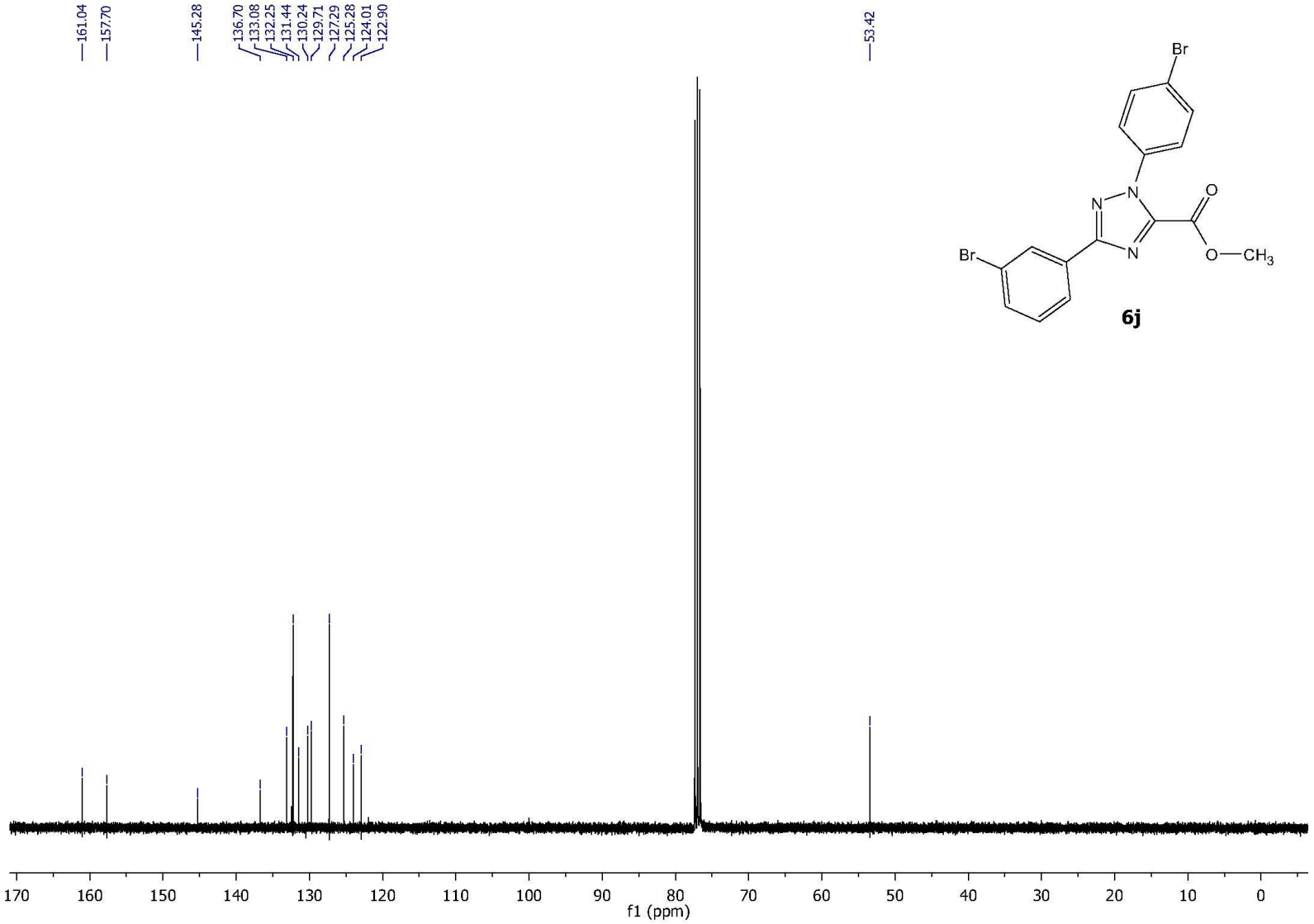
154.52
154.12
136.13
133.91
132.87
132.17
130.12
128.29
127.30
126.85
123.96
122.96
53.03
Br
N
N
N
O
H3C
O
Br
5j
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


8.37
8.37
8.36
8.36
8.36
8.12
8.12
8.11
8.11
8.11
7.67
7.66
7.66
7.58
7.58
7.58
7.58
7.57
7.57
7.56
7.56
7.41
7.40
7.40
7.39
7.34
7.34
7.33
7.32
7.31
3.97
CDCl3
H2O
0.90
0.99
2.00
1.01
2.02
1.04
3.01
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)

Br
N
N
N
O
O
CH3
Br

6j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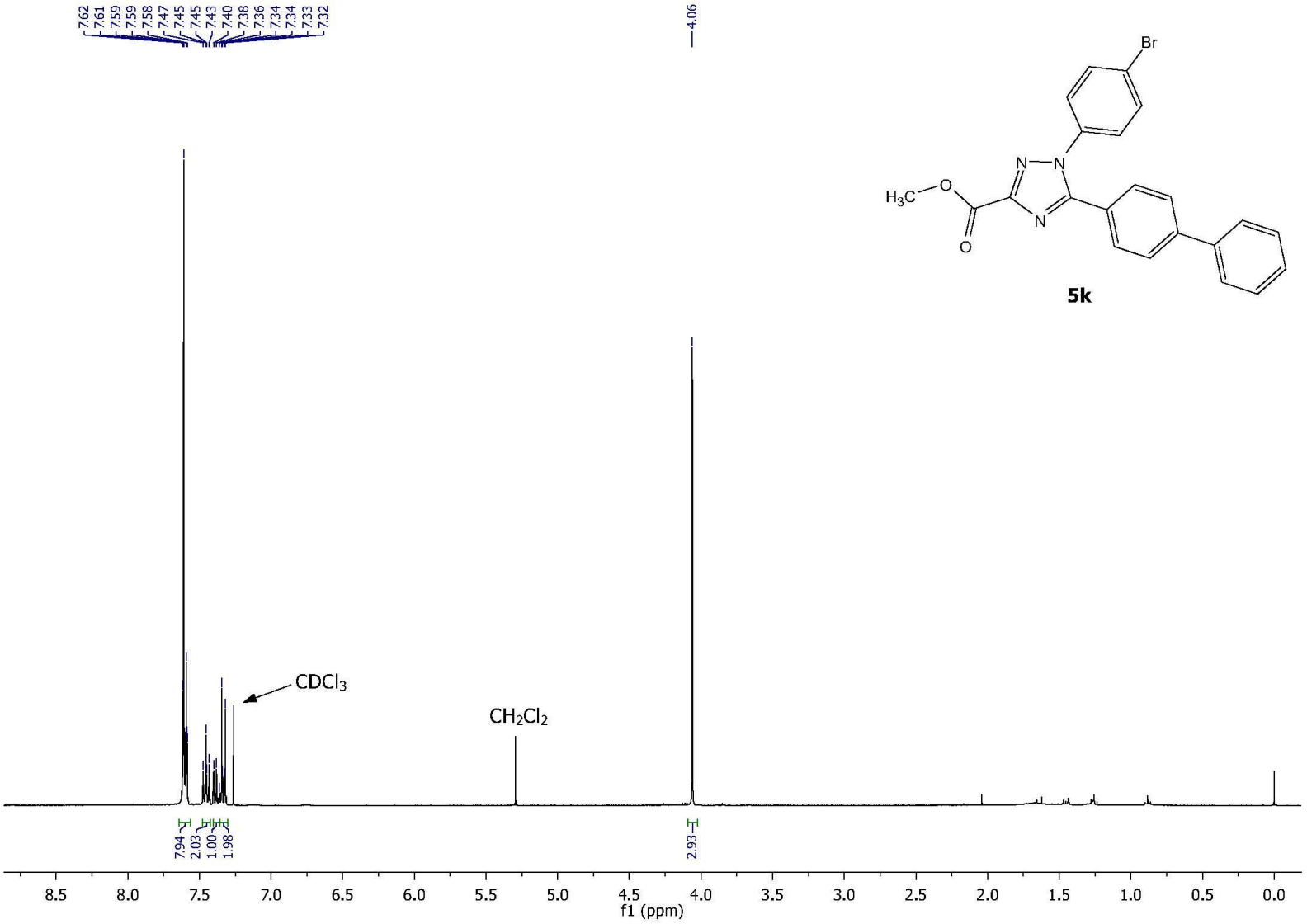
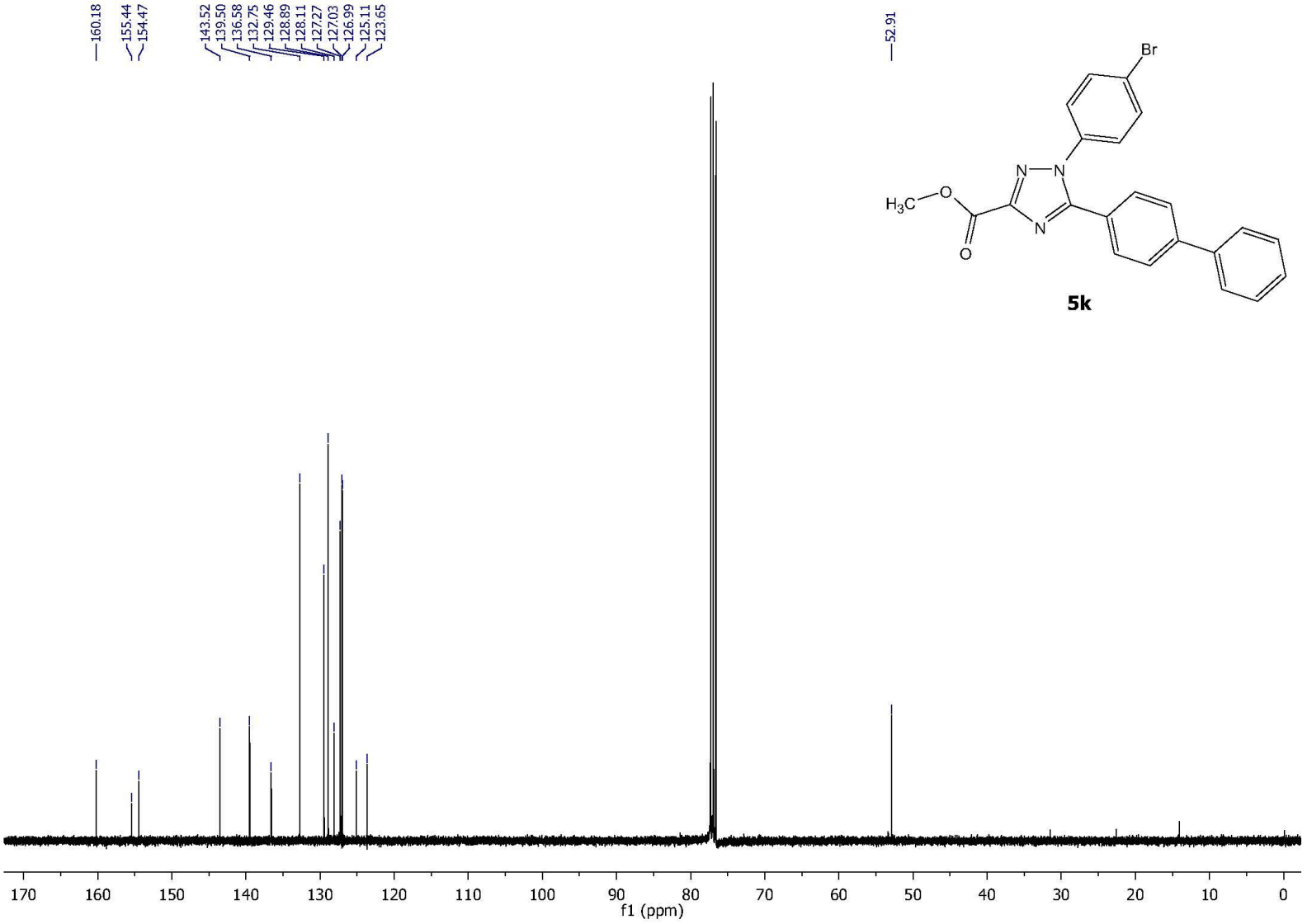
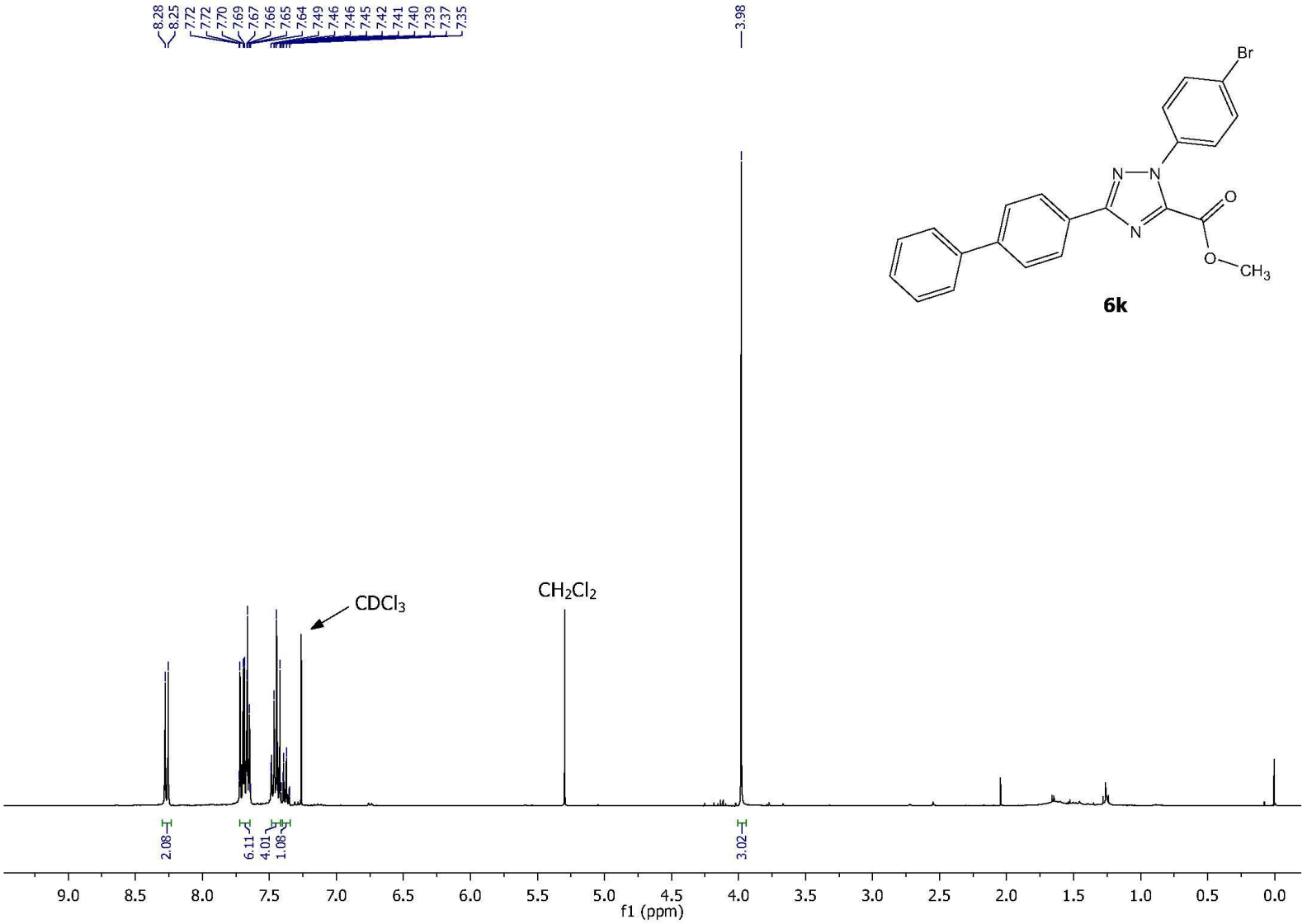
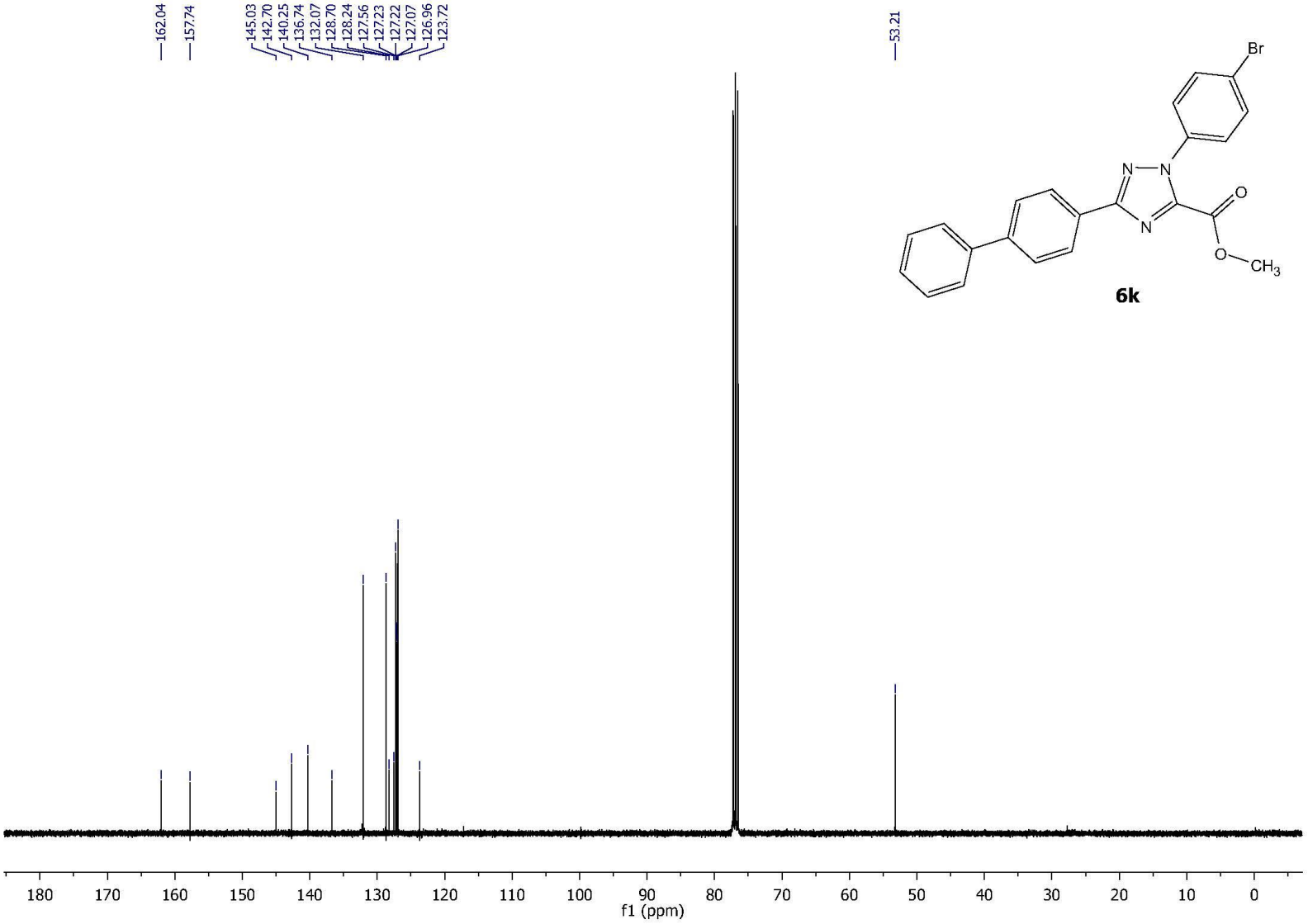
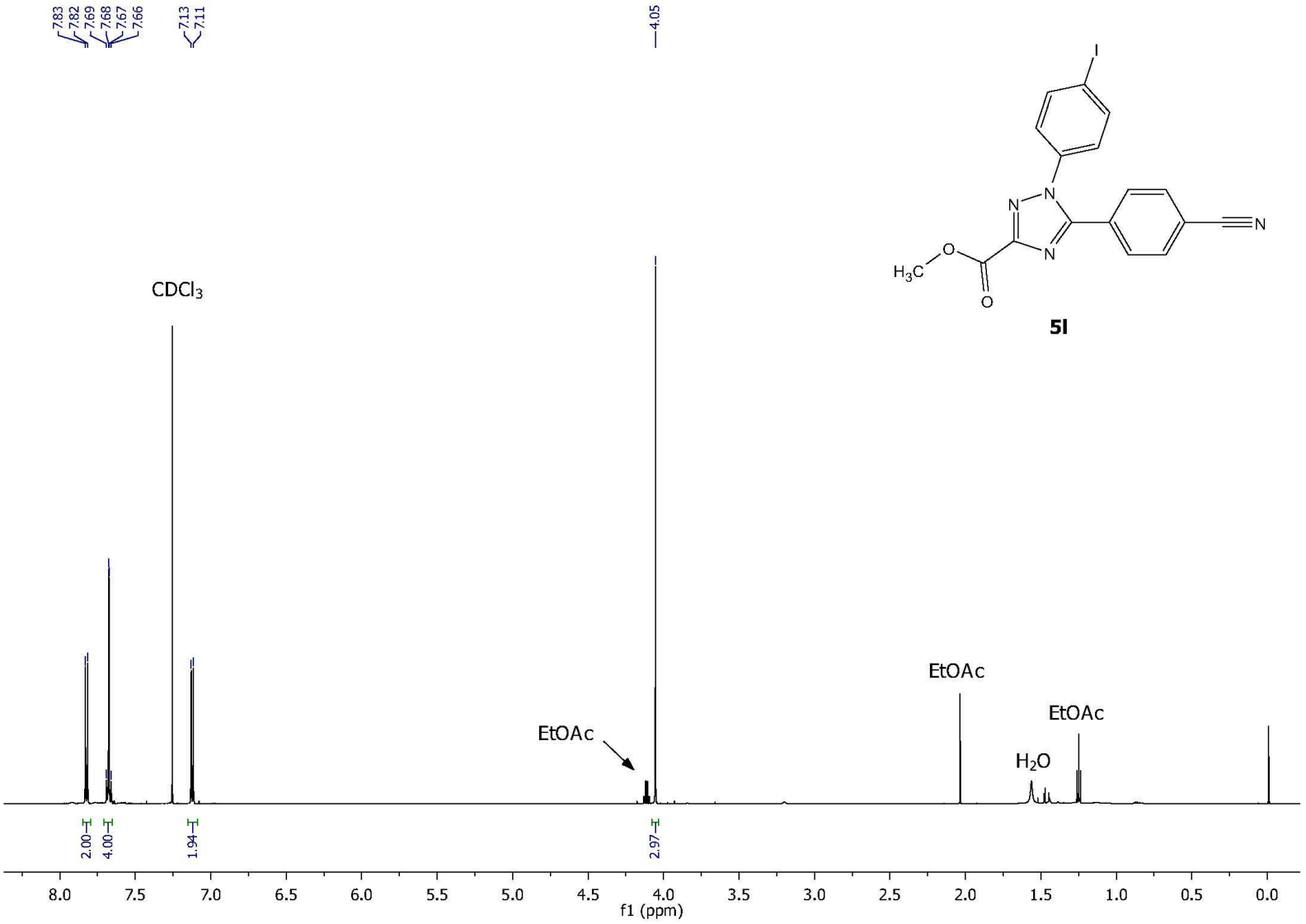
157.70
145.28
136.70
133.08
132.25
131.44
130.24
129.71
127.29
125.28
124.01
122.90
53.42
Br
N
N
N
O
O
CH3
Br
6j
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


7.62
7.61
7.59
7.59
7.58
7.47
7.45
7.45
7.43
7.40
7.38
7.36
7.34
7.34
7.33
7.32
4.06
Br
N
N
N
O
H3C
O
5k
CDCl3
CH2Cl2
7.94
2.03
1.00
1.98
2.93
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

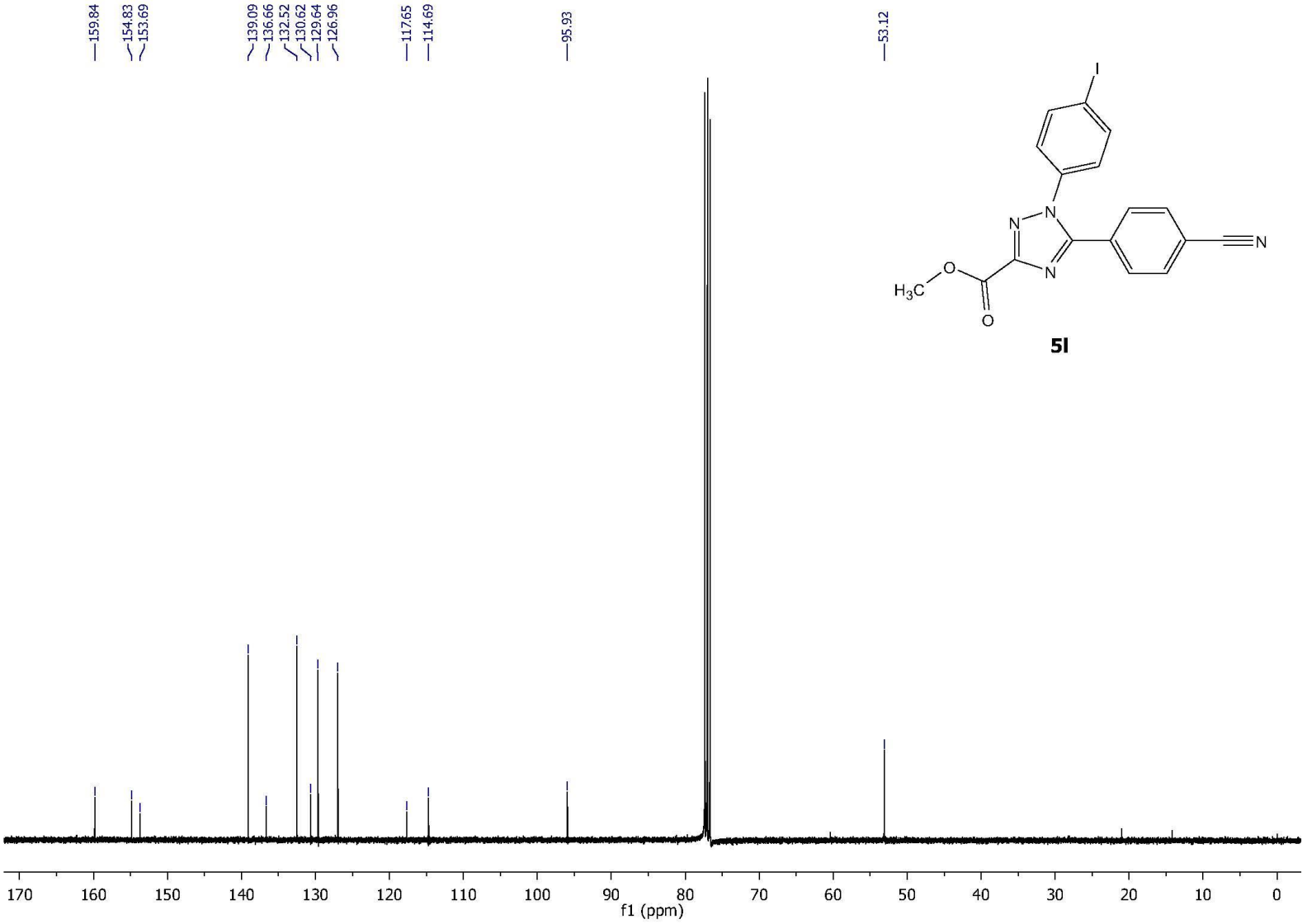

160.18
155.44
154.47
143.52
139.50
136.58
132.75
129.46
128.89
128.11
127.27
127.03
126.99
125.11
123.65
52.91
Br
N
N
N
O
H3C
O
5k
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

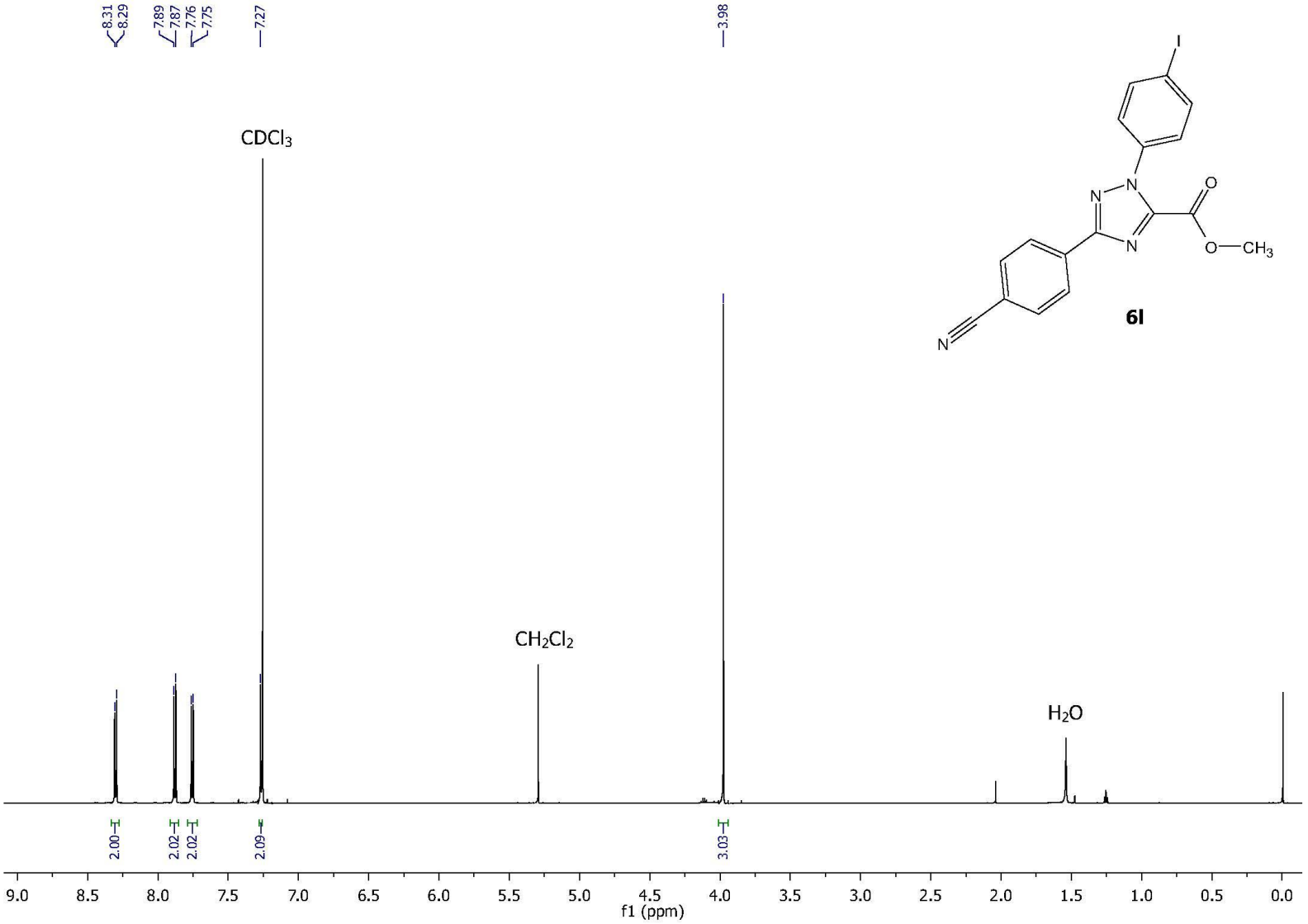

8.28
8.25
7.72
7.72
7.70
7.69
7.67
7.66
7.65
7.64
7.49
7.46
7.46
7.45
7.42
7.41
7.40
7.39
7.37
7.35
3.98
Br
N
N
N
O
O
CH3
6k
CDCl3
CH2Cl2
2.08
6.11
4.01
1.08
3.02
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

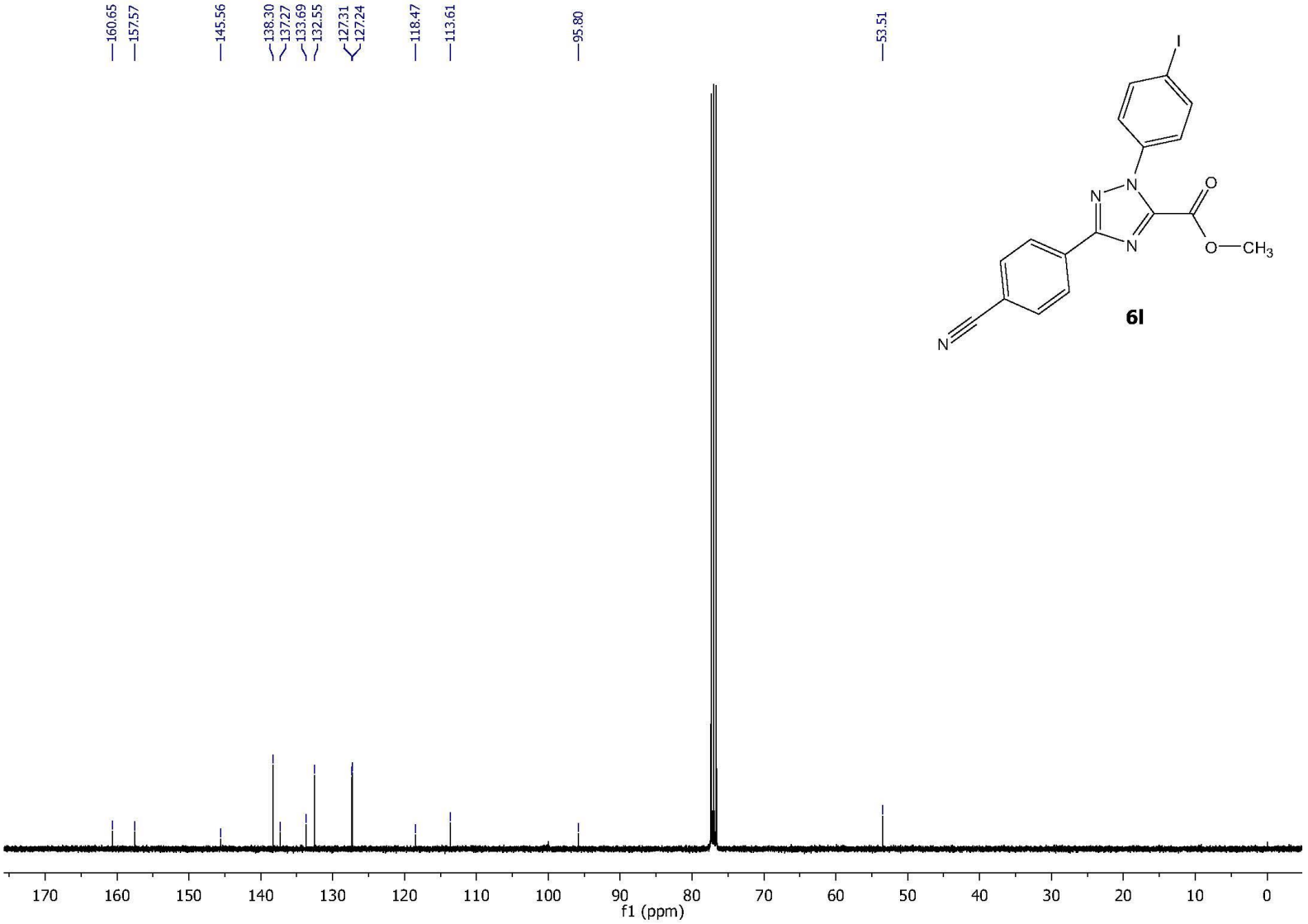

162.04
157.74
145.03
142.70
140.25
136.74
132.07
128.70
128.24
127.56
127.23
127.22
127.07
126.96
123.72
53.21
Br
N
N
N
O
O
CH3
6k
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

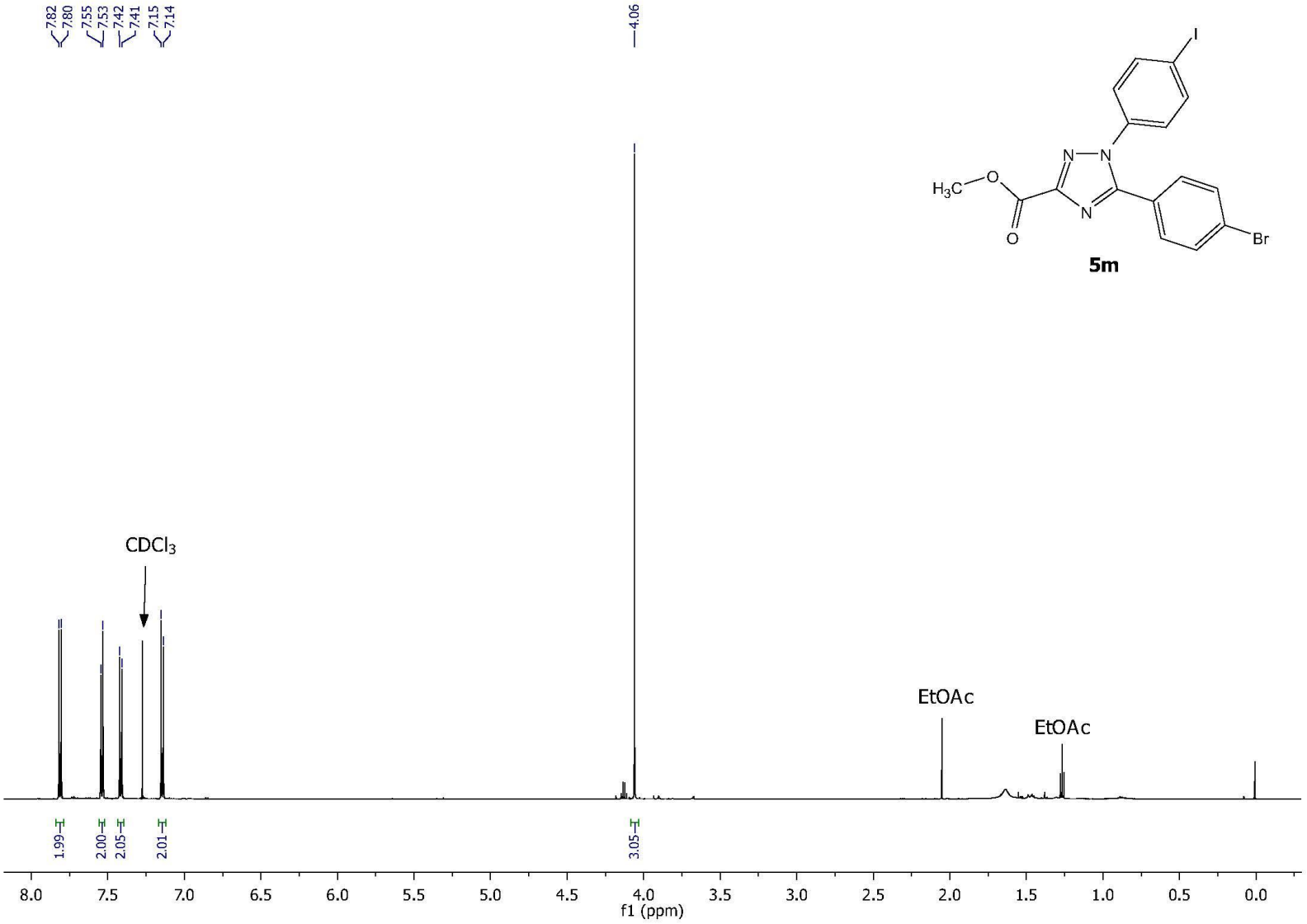

7.83
7.82
7.69
7.68
7.67
7.66
7.13
7.11
4.05
CDCl3
EtOAc
EtOAc
EtOAc
H2O
2.00
4.00
1.94
2.97
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)
I
N
N
N
N
O
O
H3C

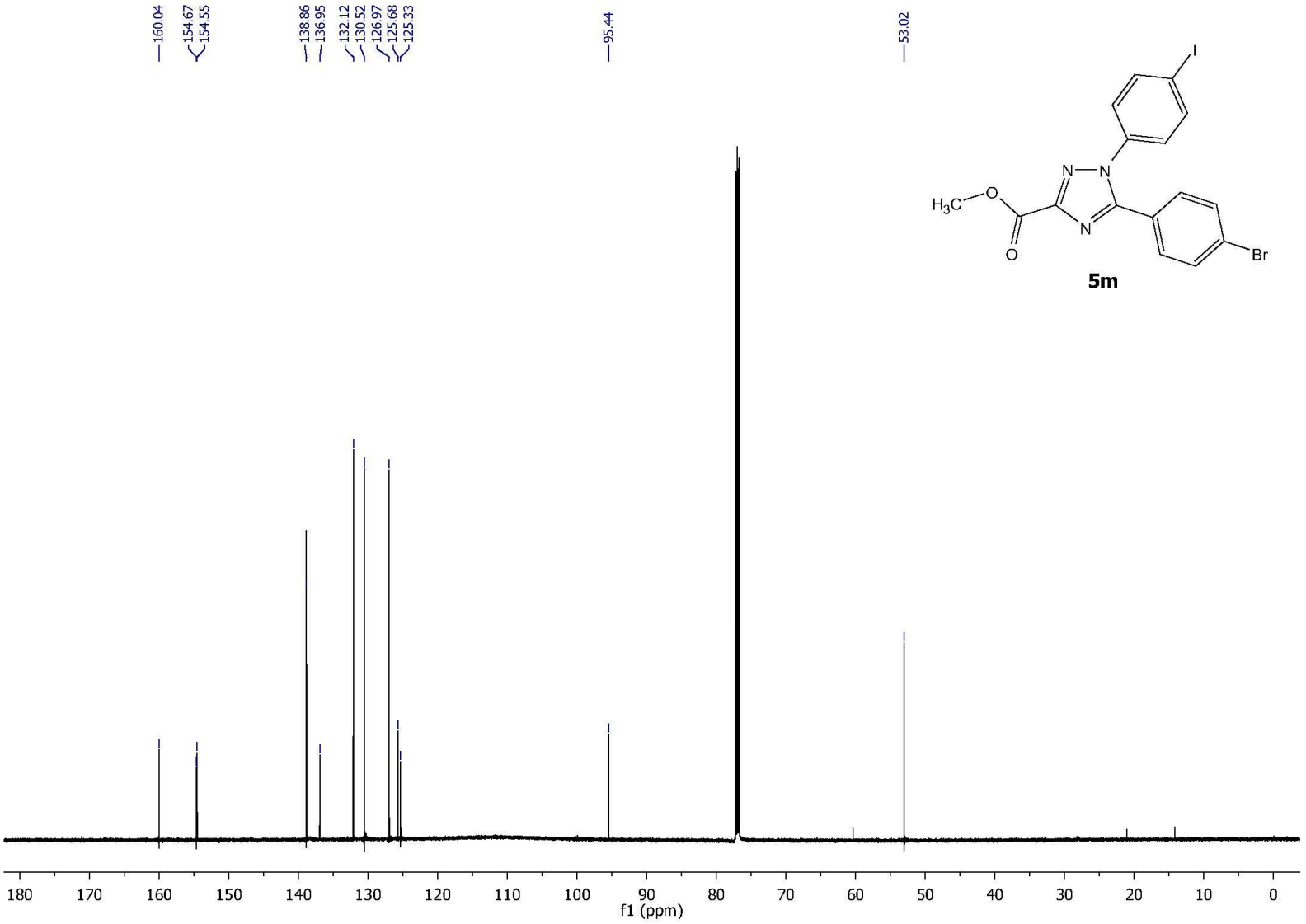
5l

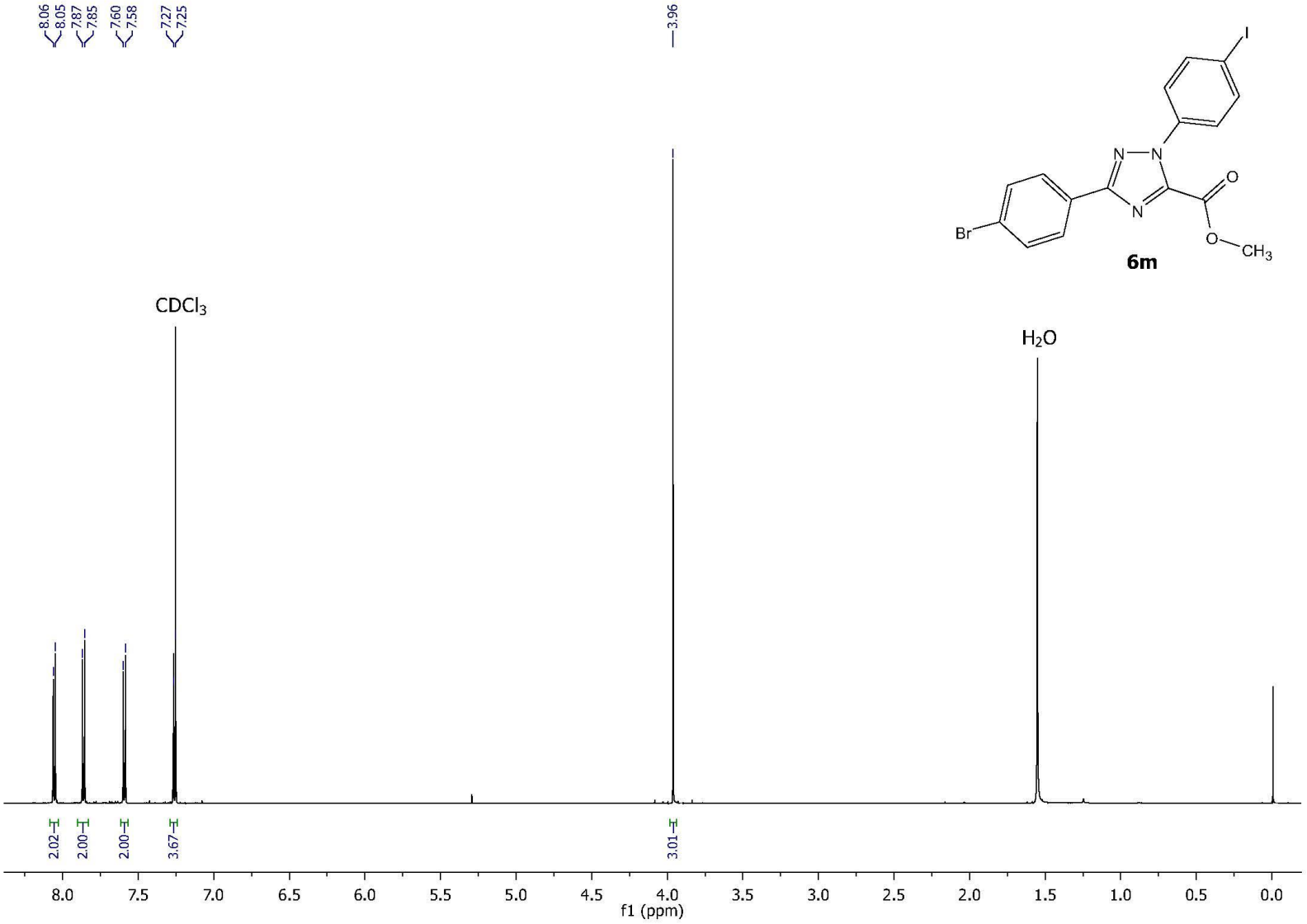

159.84
154.83
153.69
139.09
136.66
132.52
130.62
129.64
126.96
117.65
114.69
95.93
53.12
I
N
N
N
N
O
O
H3C
5l
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

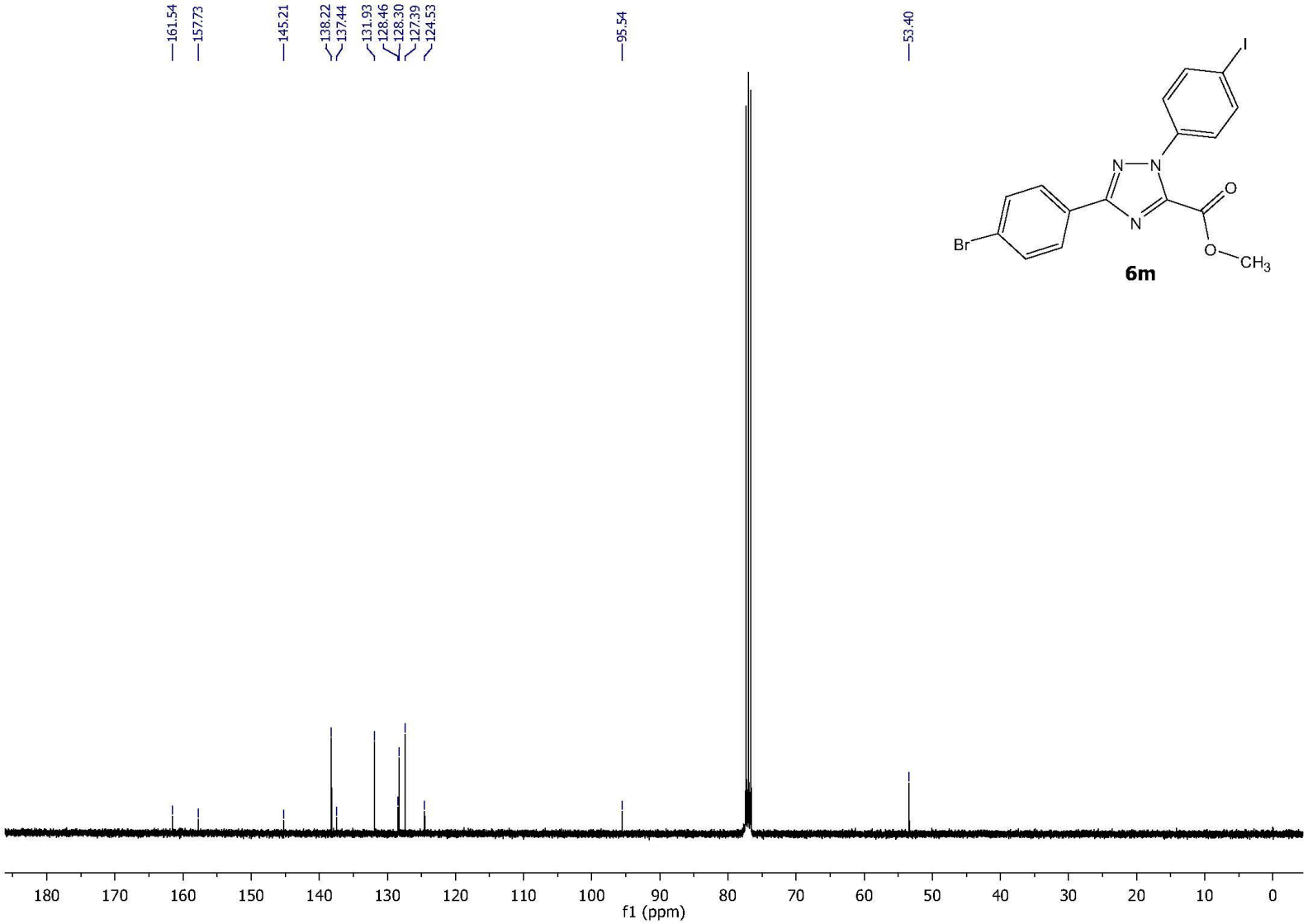

8.31
8.29
7.89
7.87
7.76
7.75
7.27
3.98
CDCl3
CH2Cl2
H2O
2.00
2.02
2.02
2.09
3.03
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)
I
N
N
N
O
O
CH3
N
6l

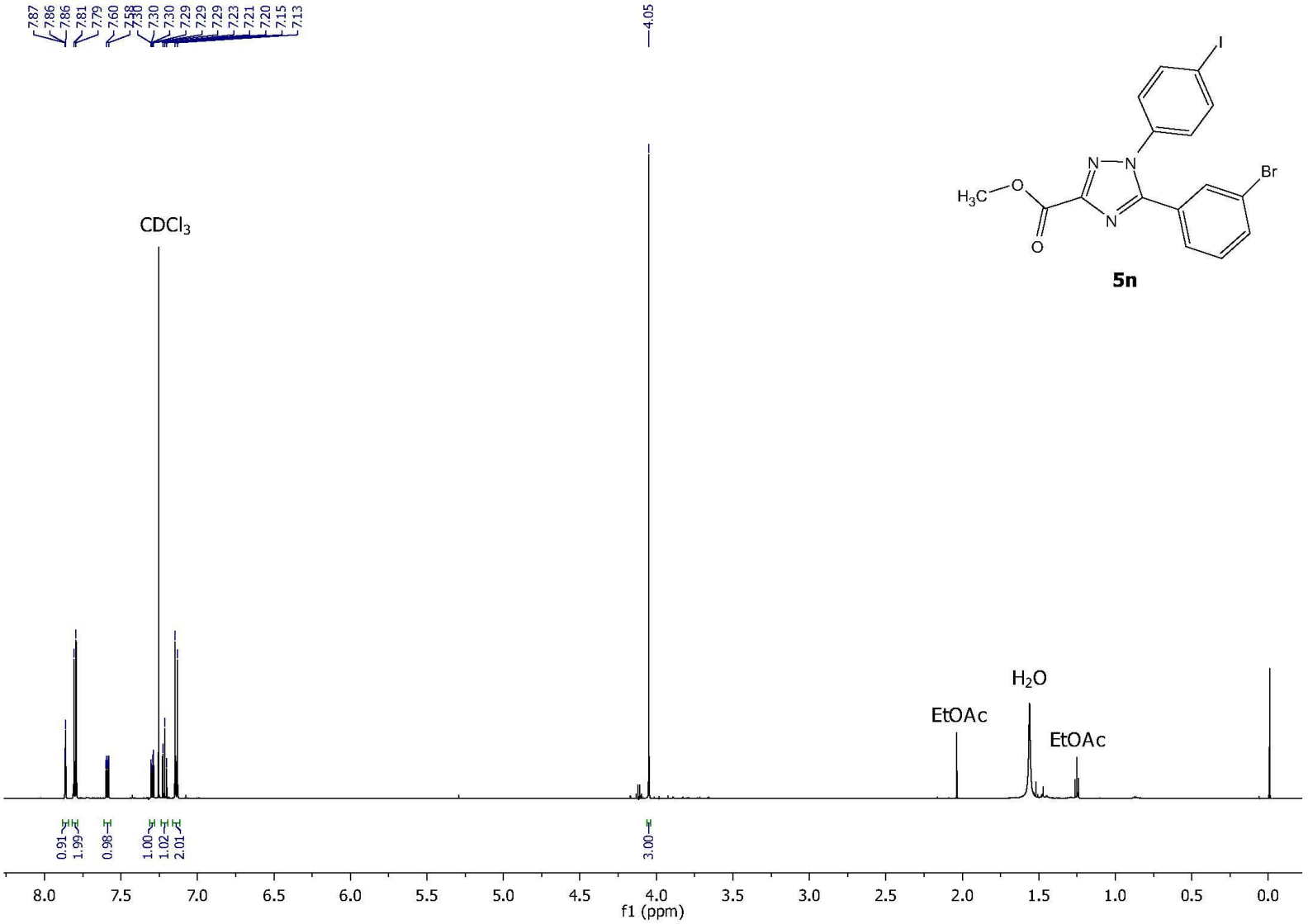

160.65
157.57
145.56
138.30
137.27
133.69
132.55
127.31
127.24
118.47
113.61
95.80
53.51
I
N
N
N
O
O
CH3
N
6l
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

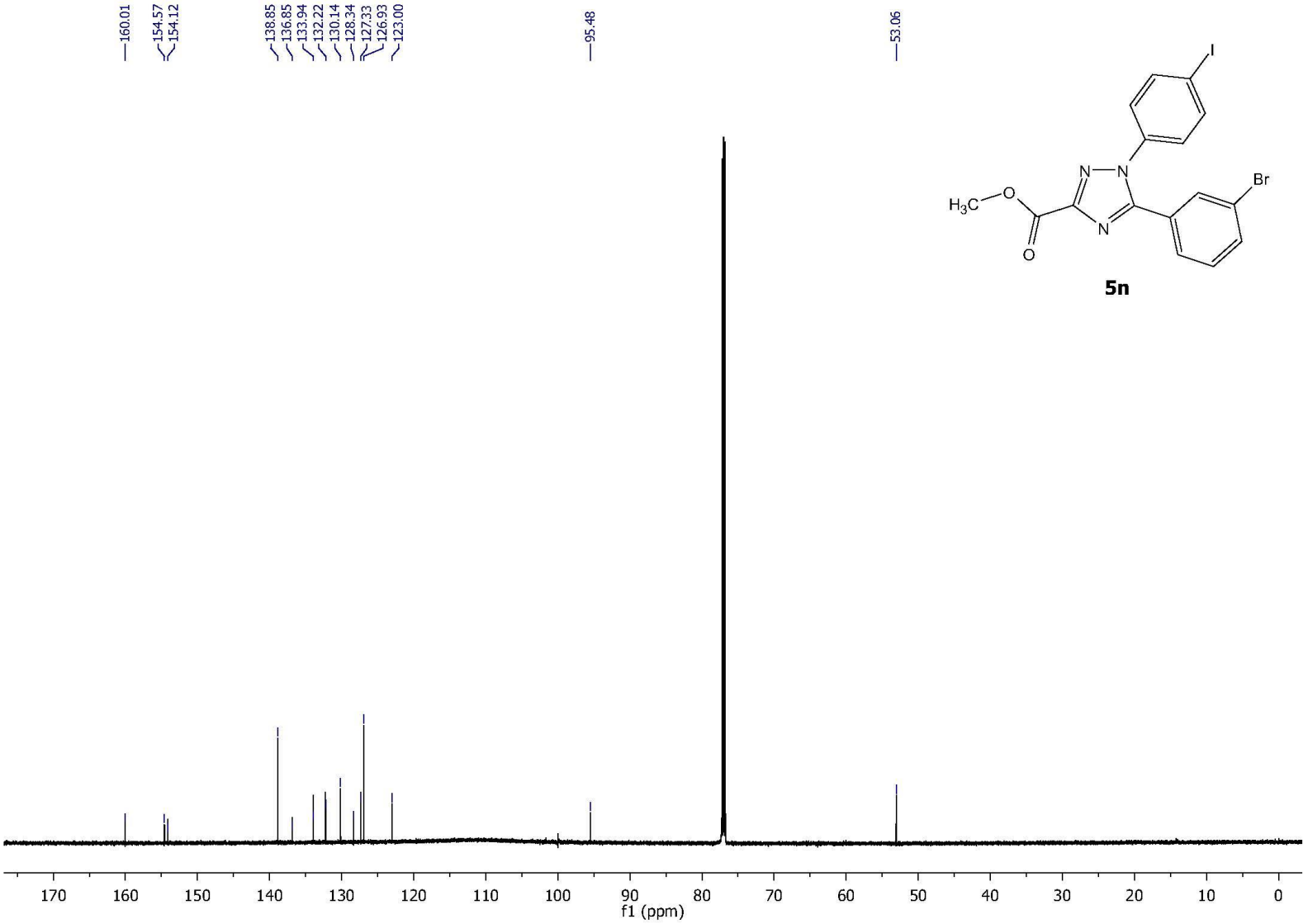

7.82
7.80
7.55
7.53
7.42
7.41
7.15
7.14
4.06
CDCl3
EtOAc
EtOAc
1.99
2.00
2.05
2.01
3.05
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)
I
N
N
N
H3C
O
O
Br
5m

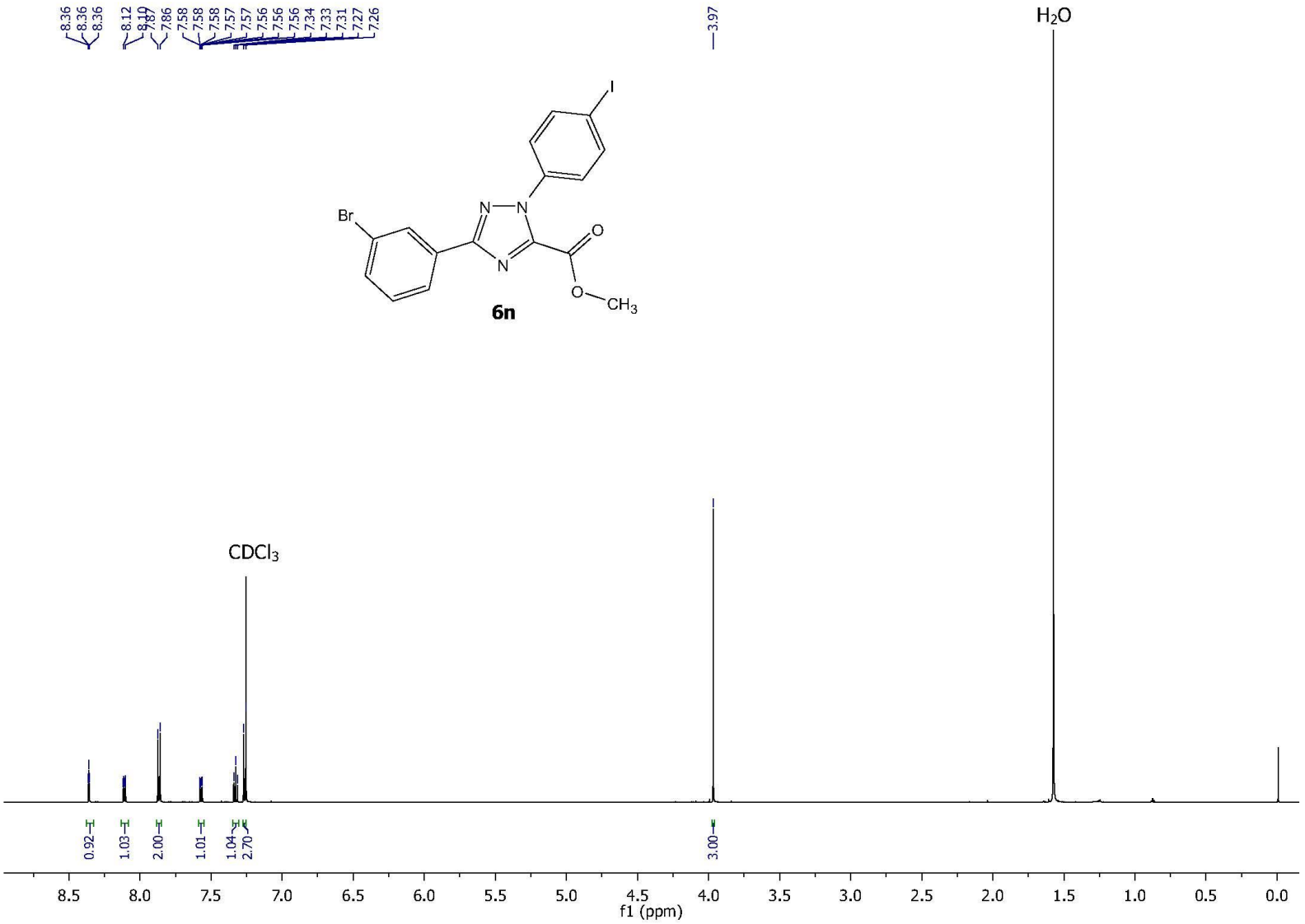

160.04
154.67
154.55
138.86
136.95
132.12
130.52
126.97
125.68
125.33
95.44
53.02
I
N
N
N
O
H3C
O
Br
5m
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

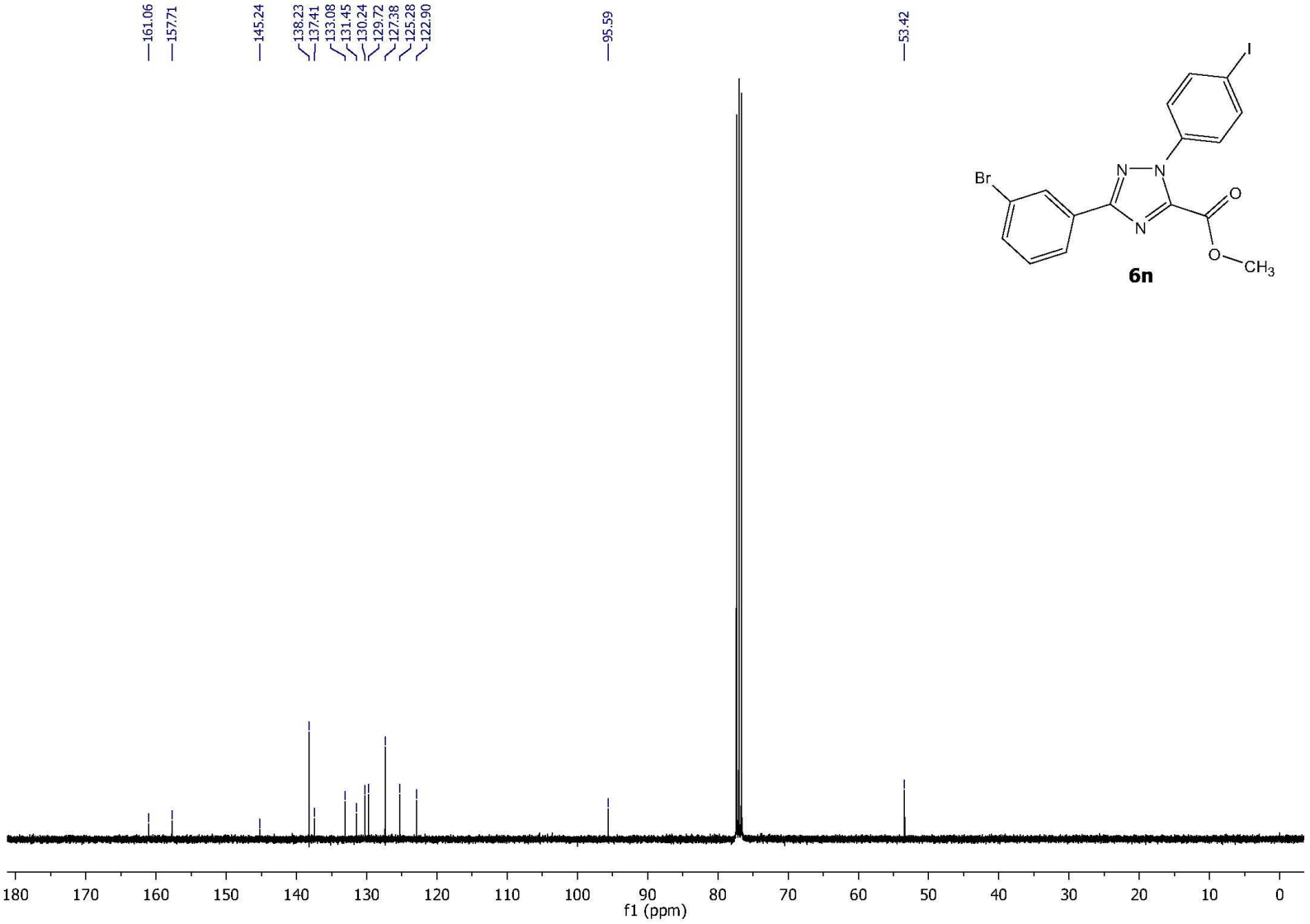

8.06
8.05
7.87
7.85
7.60
7.58
7.27
7.25
3.96
CDCl3
H2O
2.02
2.00
2.00
3.67
3.01
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)
I
N
N
N
O
O
CH3
Br
6m

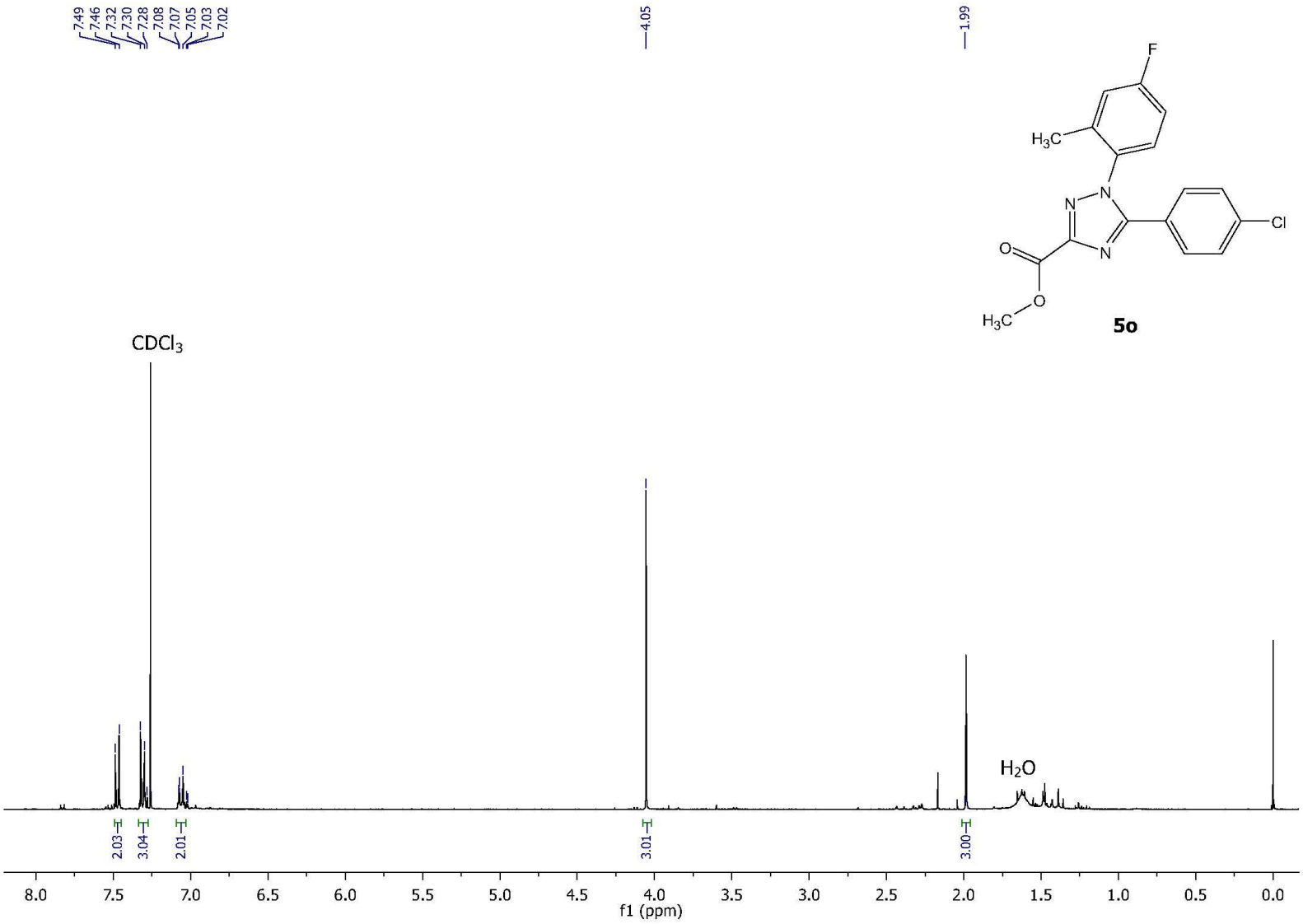

161.54
157.73
145.21
138.22
137.44
131.93
128.46
128.30
127.39
124.53
95.54
53.40
I
N
N
N
O
O
CH3
Br
6m
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

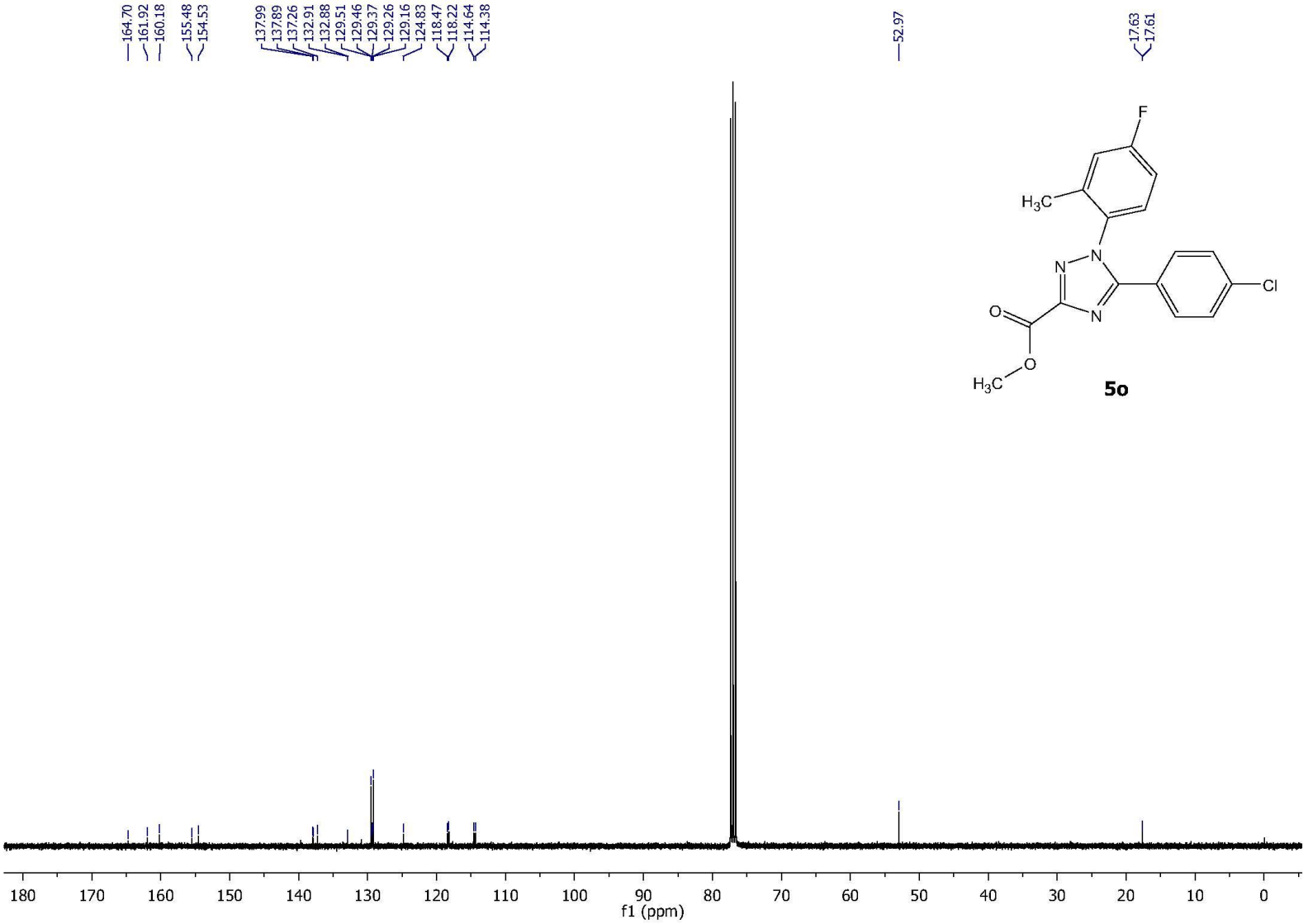

7.87
7.86
7.86
7.81
7.79
7.60
7.58
7.30
7.30
7.30
7.29
7.29
7.29
7.23
7.21
7.20
7.15
7.13
4.05
CDCl3
I
Br
N
N
N
H3C
O
O
5n
H2O
EtOAc
EtOAc
0.91
1.99
0.98
1.00
1.02
2.01
3.00
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

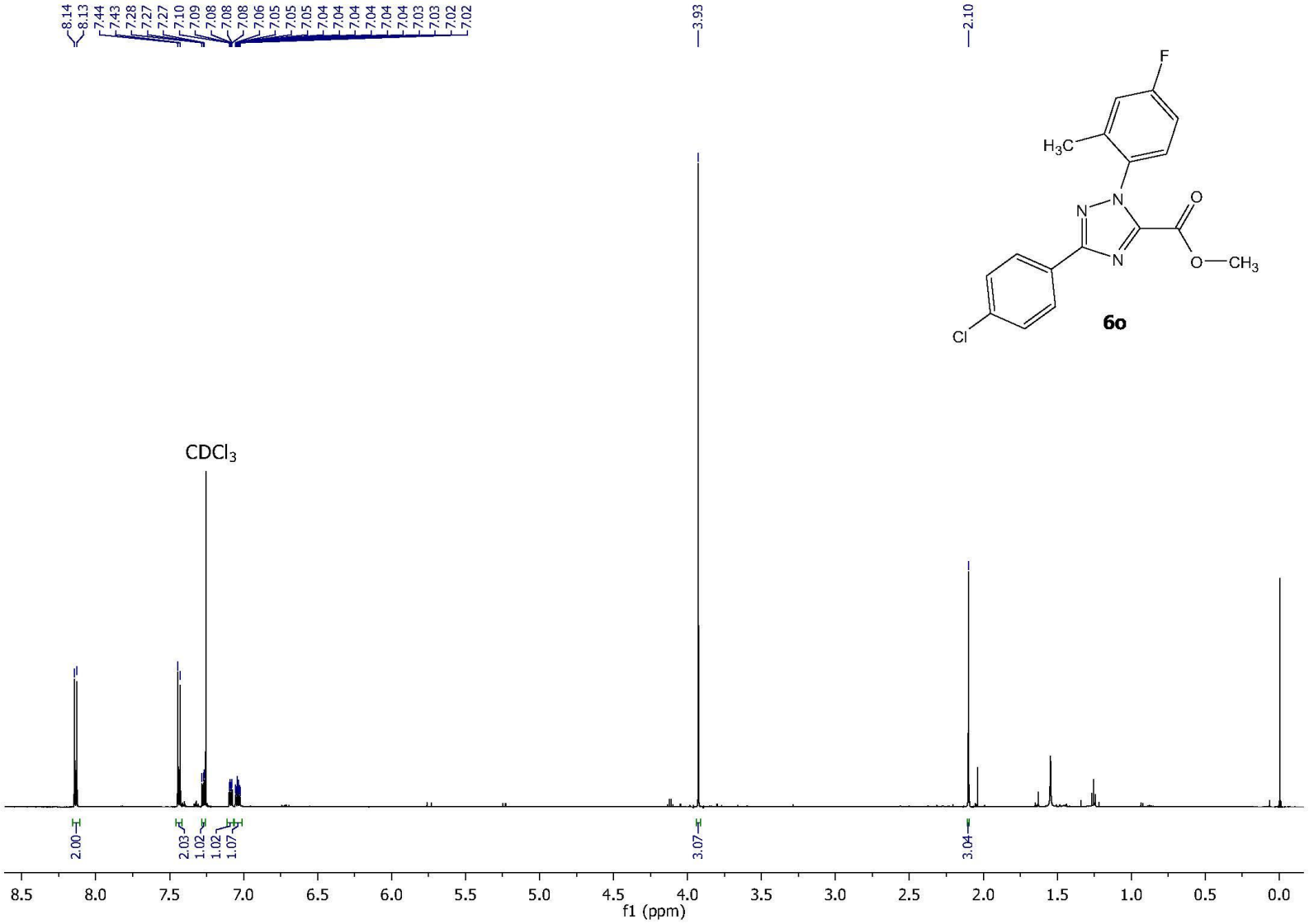

160.01
154.57
154.12
138.85
136.85
133.94
132.22
130.14
128.34
127.33
126.93
123.00
95.48
53.06
I
Br
N
N
N
O
O
H3C
5n
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

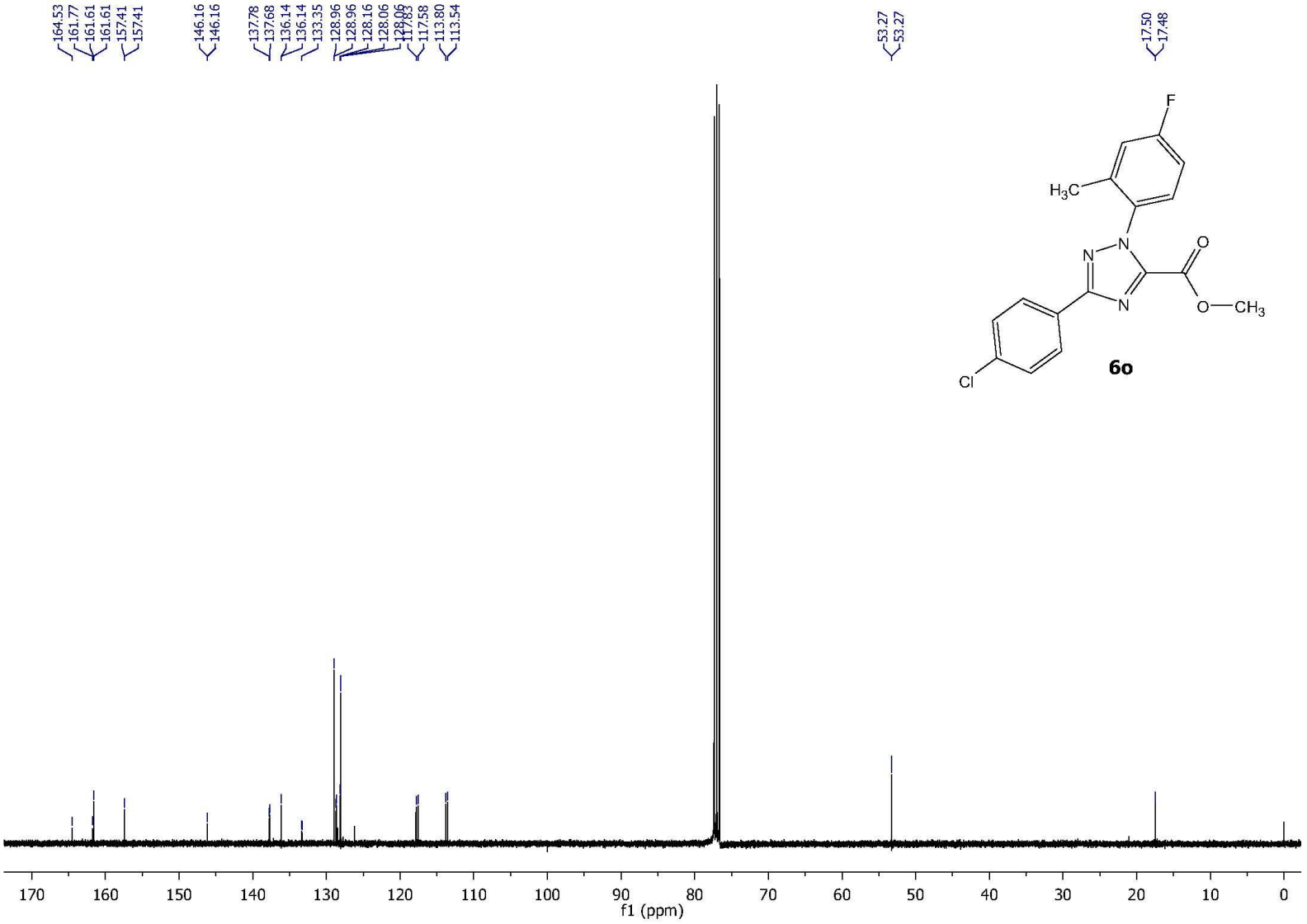

8.36
8.36
8.36
8.12
8.10
7.87
7.86
7.58
7.58
7.58
7.57
7.57
7.56
7.56
7.56
7.34
7.33
7.31
7.27
7.26
3.97
H2O
I
Br
N
N
N
O
O
CH3
6n
CDCl3
0.92
1.03
2.00
1.01
1.04
2.70
3.00
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

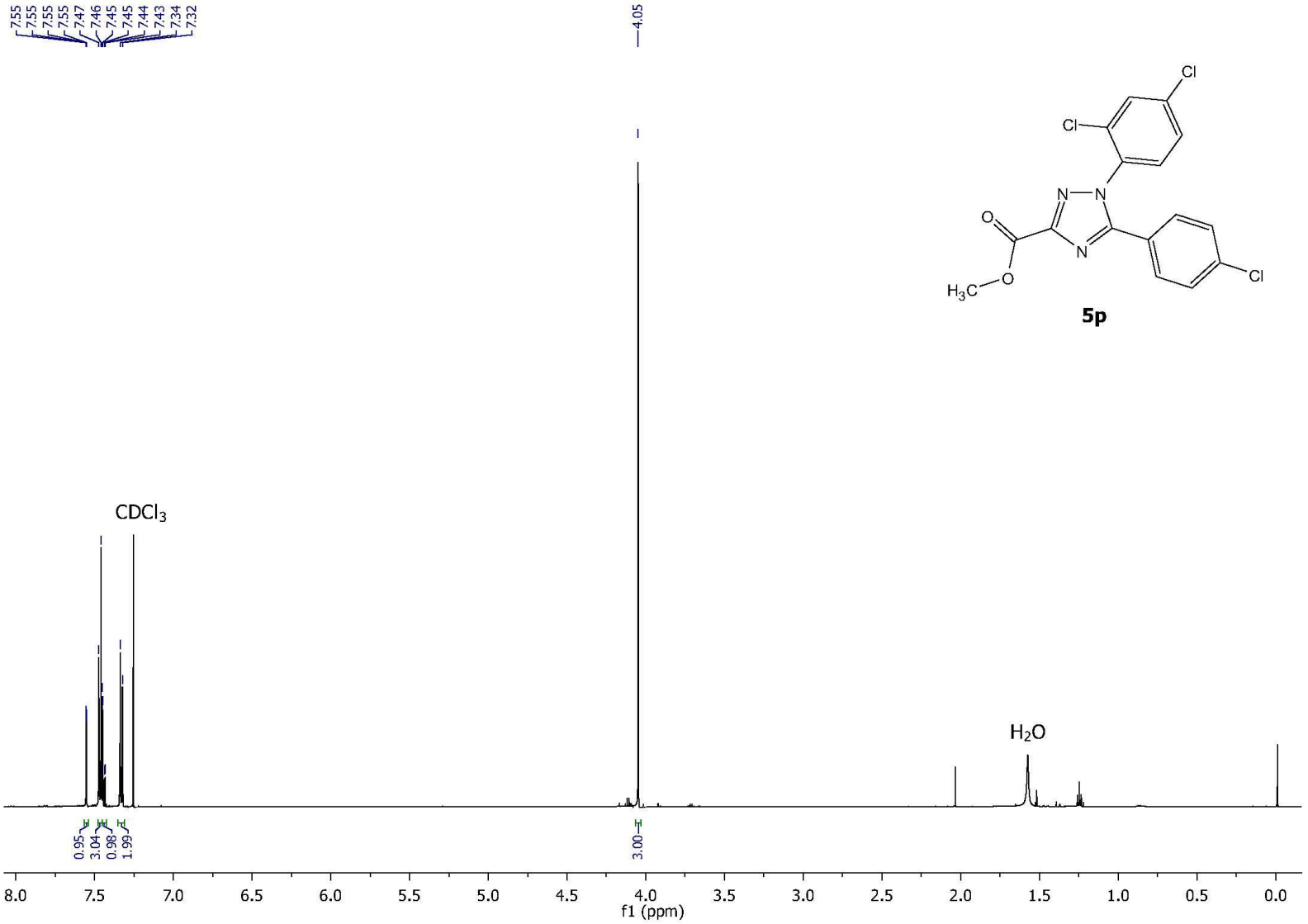

161.06
157.71
145.24
138.23
137.41
133.08
131.45
130.24
129.72
127.38
125.28
122.90
95.59
53.42
Br
N
N
N
O
O
CH3
I
6n
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

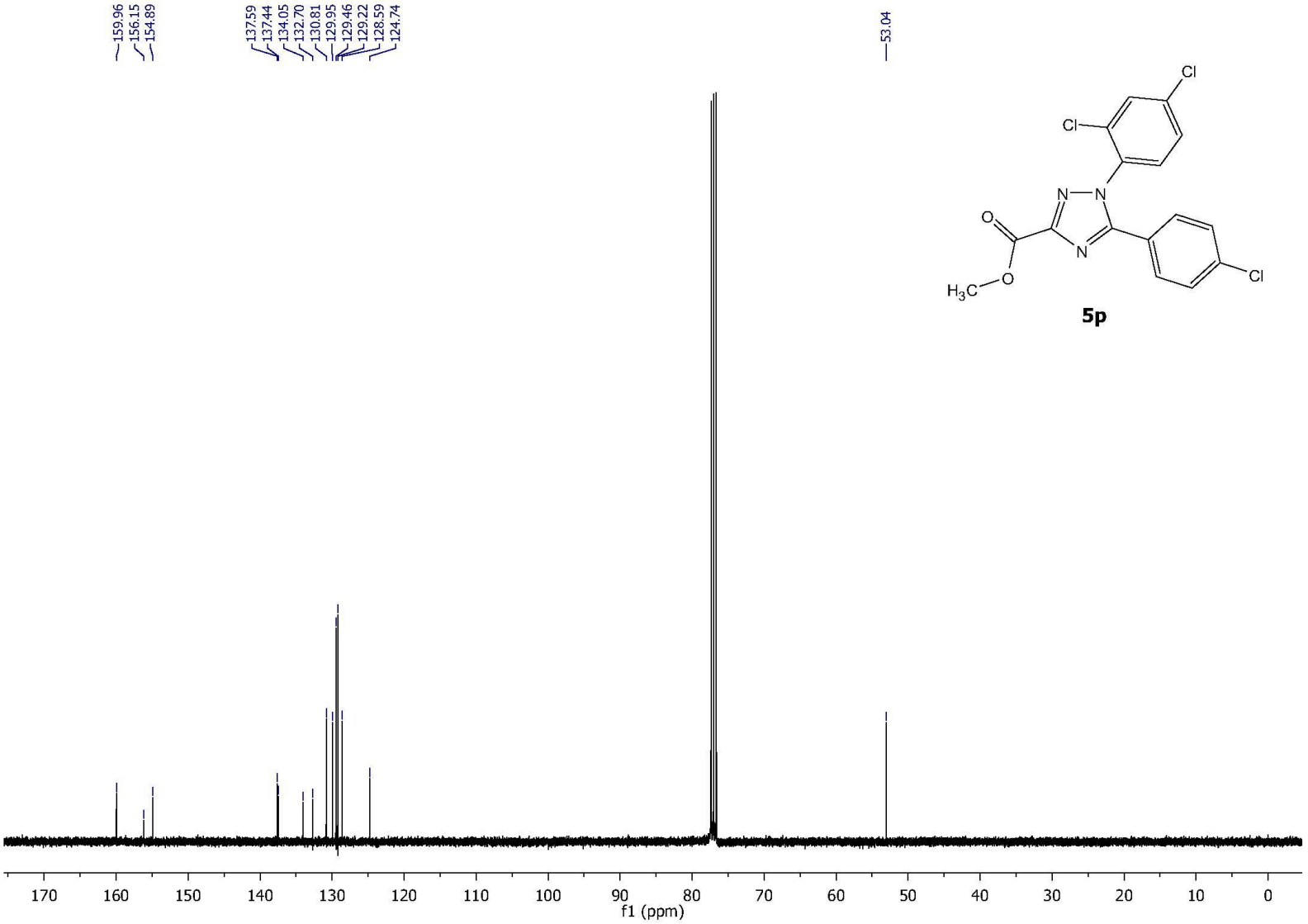

7.49
7.46
7.32
7.30
7.28
7.08
7.07
7.05
7.03
7.02
4.05
1.99
F
H3C
N
N
N
Cl
O
O
H3C
5o
CDCl3
H2O
2.03
3.04
2.01
3.01
3.00
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

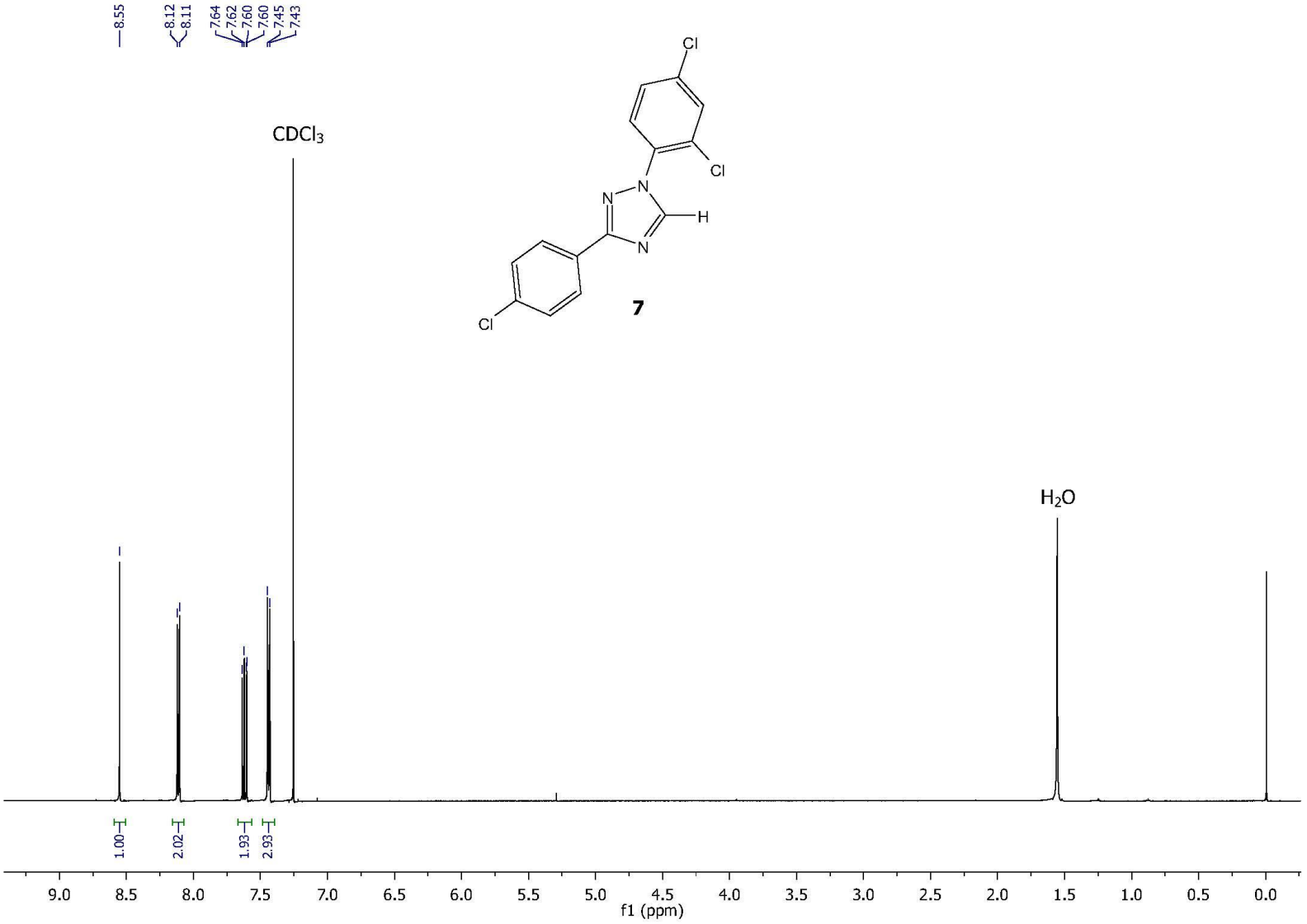

164.70
161.92
160.18
155.48
154.53
137.99
137.89
137.26
132.91
132.88
129.51
129.46
129.37
129.26
129.16
124.83
118.47
118.22
114.64
114.38
52.97
17.63
17.61
F
H3C
N
N
N
Cl
O
O
H3C
5o
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


8.14
8.13
7.44
7.43
7.28
7.27
7.27
7.10
7.09
7.08
7.08
7.08
7.06
7.05
7.05
7.05
7.04
7.04
7.04
7.04
7.04
7.04
7.03
7.03
7.02
7.02
3.93
2.10
F
H3C
N
N
N
O
O
O—CH3
Cl
6o
CDCl3
2.00
2.03
1.02
1.02
1.07
3.07
3.04
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


164.53
161.77
161.61
161.61
157.41
157.41
146.16
146.16
137.78
137.68
136.14
136.14
133.35
128.96
128.96
128.16
128.06
128.06
117.83
117.58
113.80
113.54
53.27
53.27
17.50
17.48
F
H3C
N
N
N
N
O
O
O—CH3
Cl
6o
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

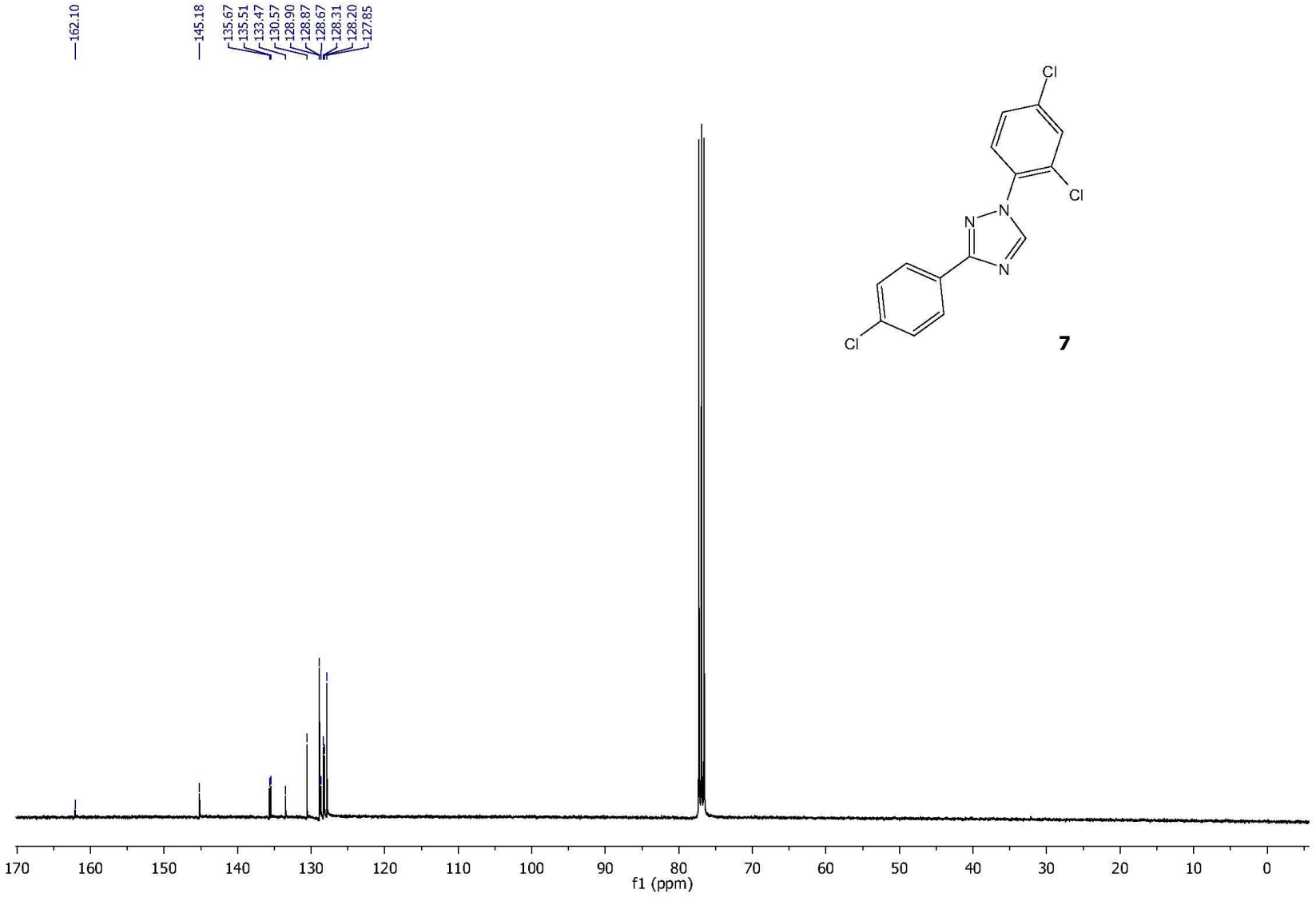

7.55
7.55
7.55
7.55
7.47
7.46
7.45
7.45
7.44
7.43
7.34
7.32
4.05
Cl
Cl
N
N
O
N
O
H3C
Cl
5p
CDCl3
H2O
0.95
3.04
0.98
1.99
3.00
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

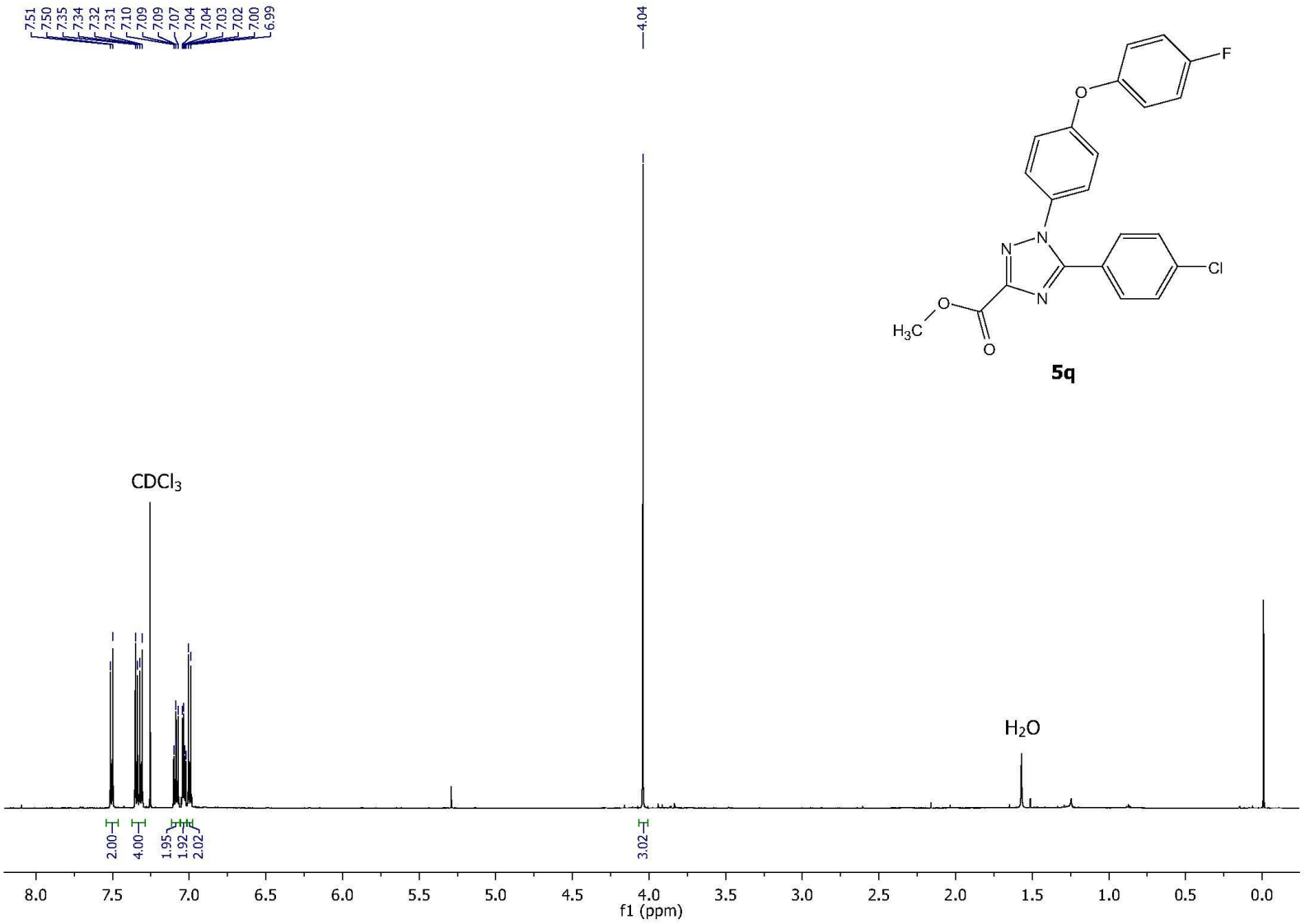

159.96
156.15
154.89
137.59
137.44
134.05
132.70
130.81
129.95
129.46
129.22
128.59
124.74
53.04
Cl
Cl
N
N
O
N
O
H3C
Cl
5p
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


8.55
8.12
8.11
7.64
7.62
7.60
7.60
7.45
7.43
CDCl3
H2O
1.00
2.02
1.93
2.93
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

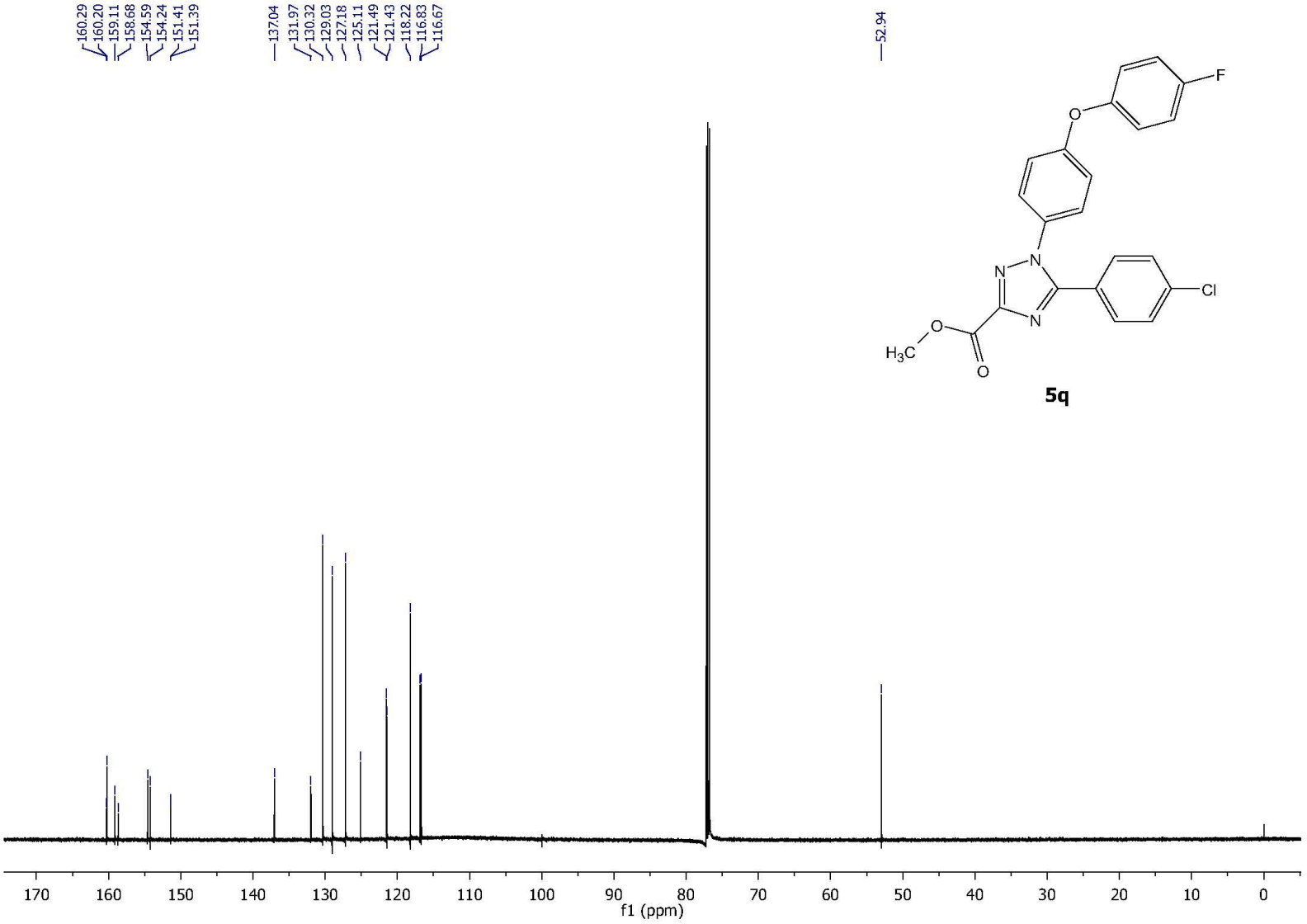
Cl
Cl
N
N
N
H
Cl

7

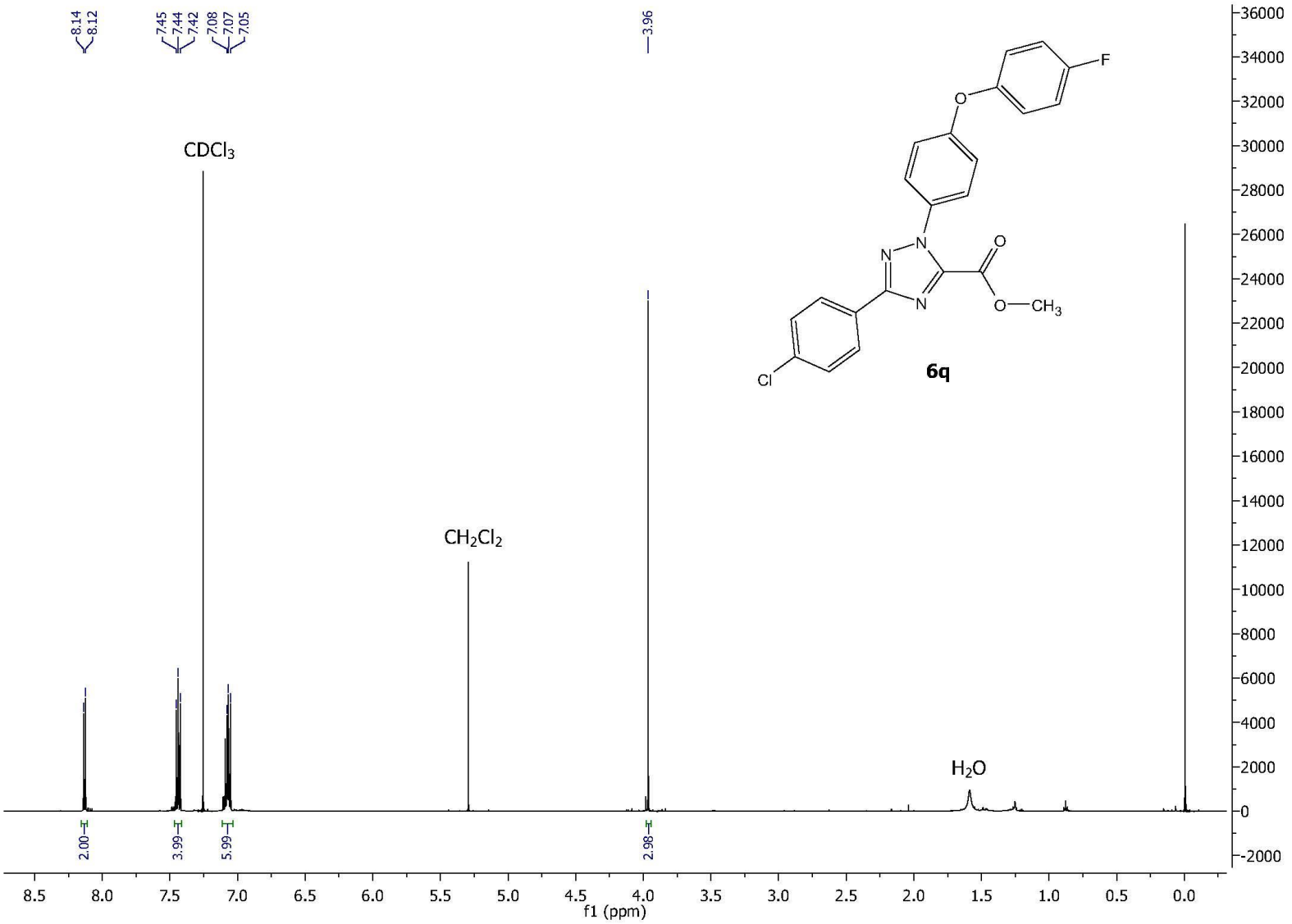

162.10
145.18
135.67
135.51
133.47
130.57
128.90
128.87
128.67
128.31
128.20
127.85
Cl
Cl
N
N
N
Cl
7
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

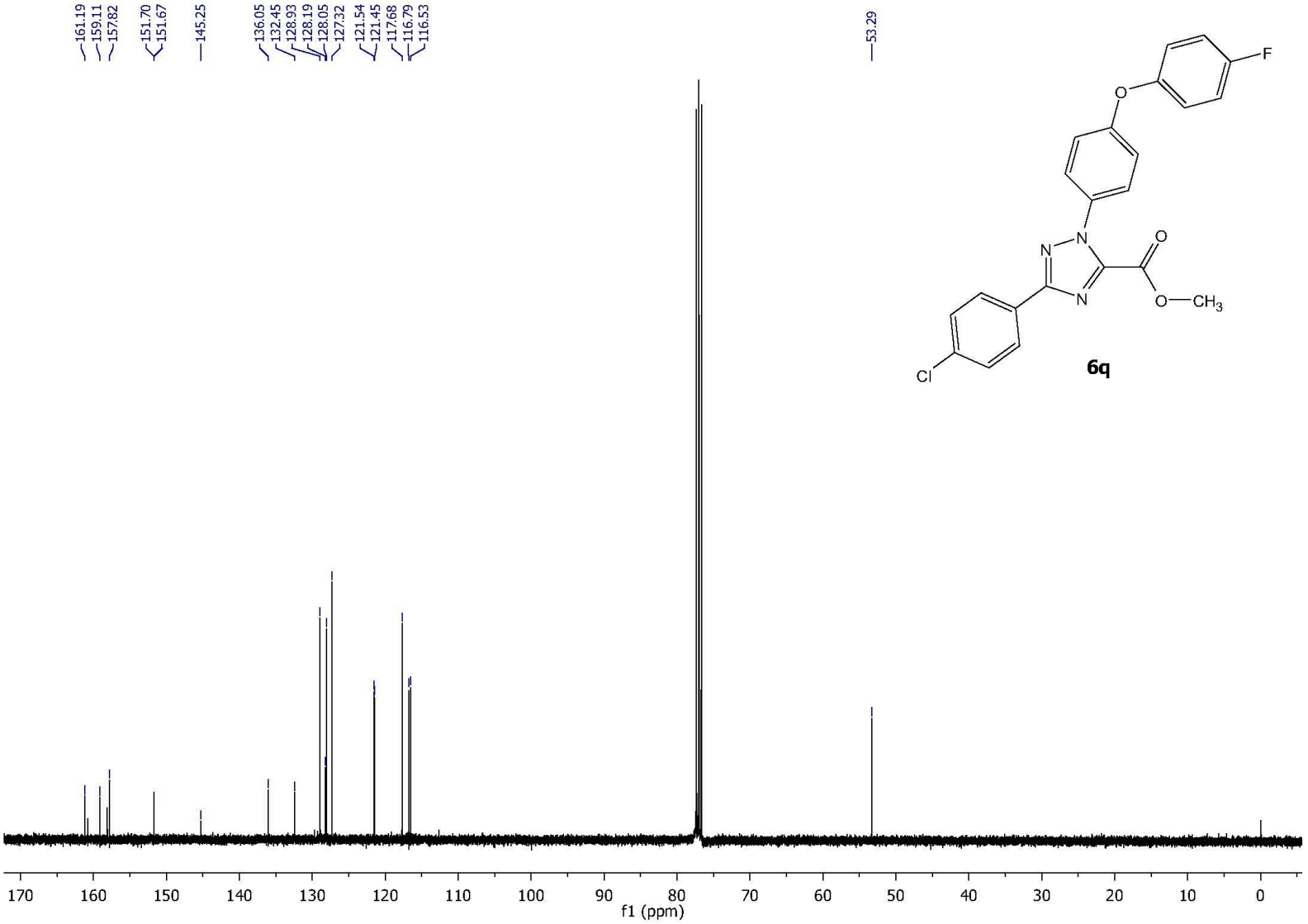

7.51
7.50
7.35
7.34
7.32
7.31
7.10
7.09
7.09
7.07
7.04
7.04
7.03
7.02
7.00
6.99
4.04
CDCl3
H2O
2.00
4.00
1.95
1.92
2.02
3.02
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)
F
O
N
N
N
Cl
O
H3C
O

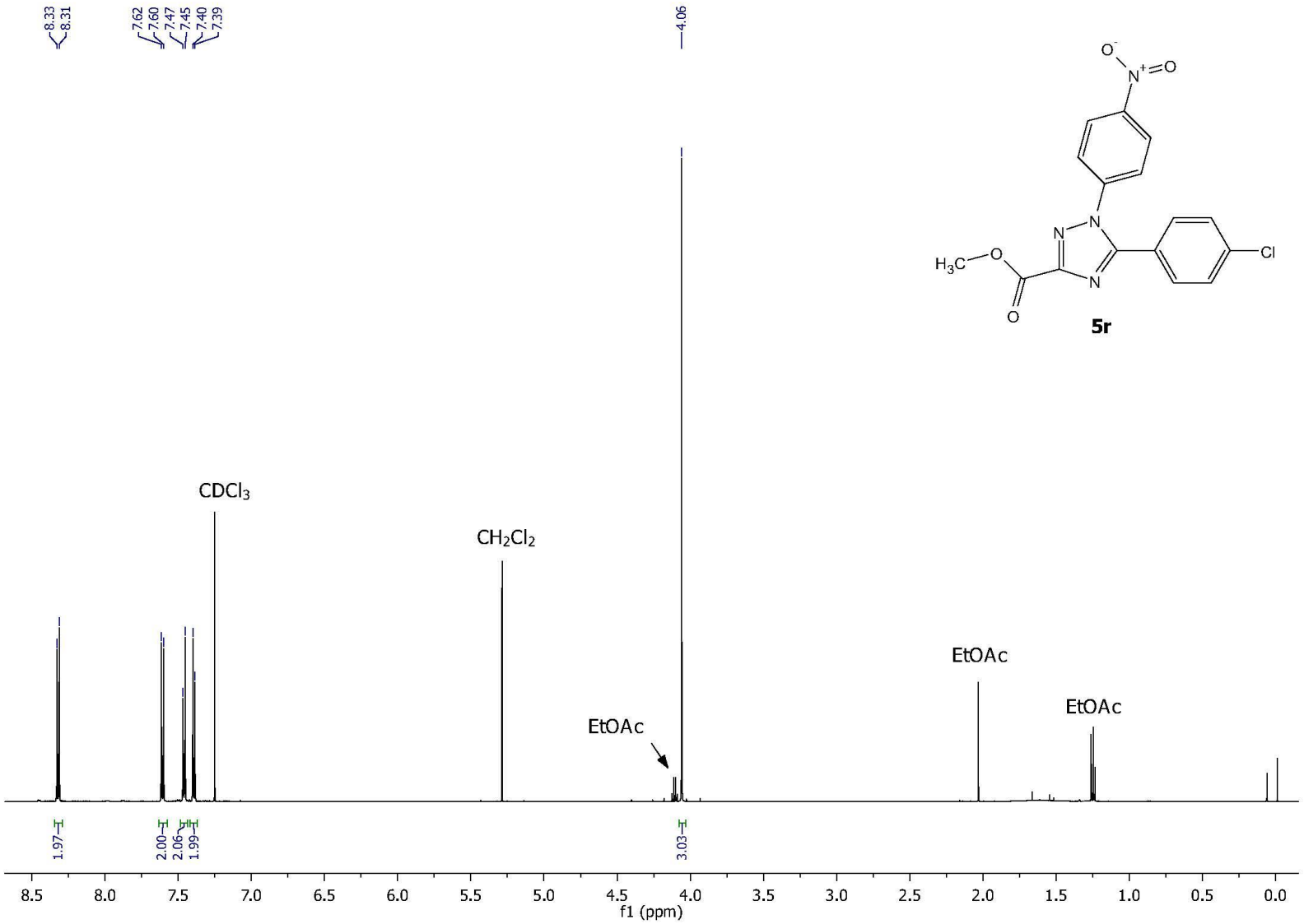
5q

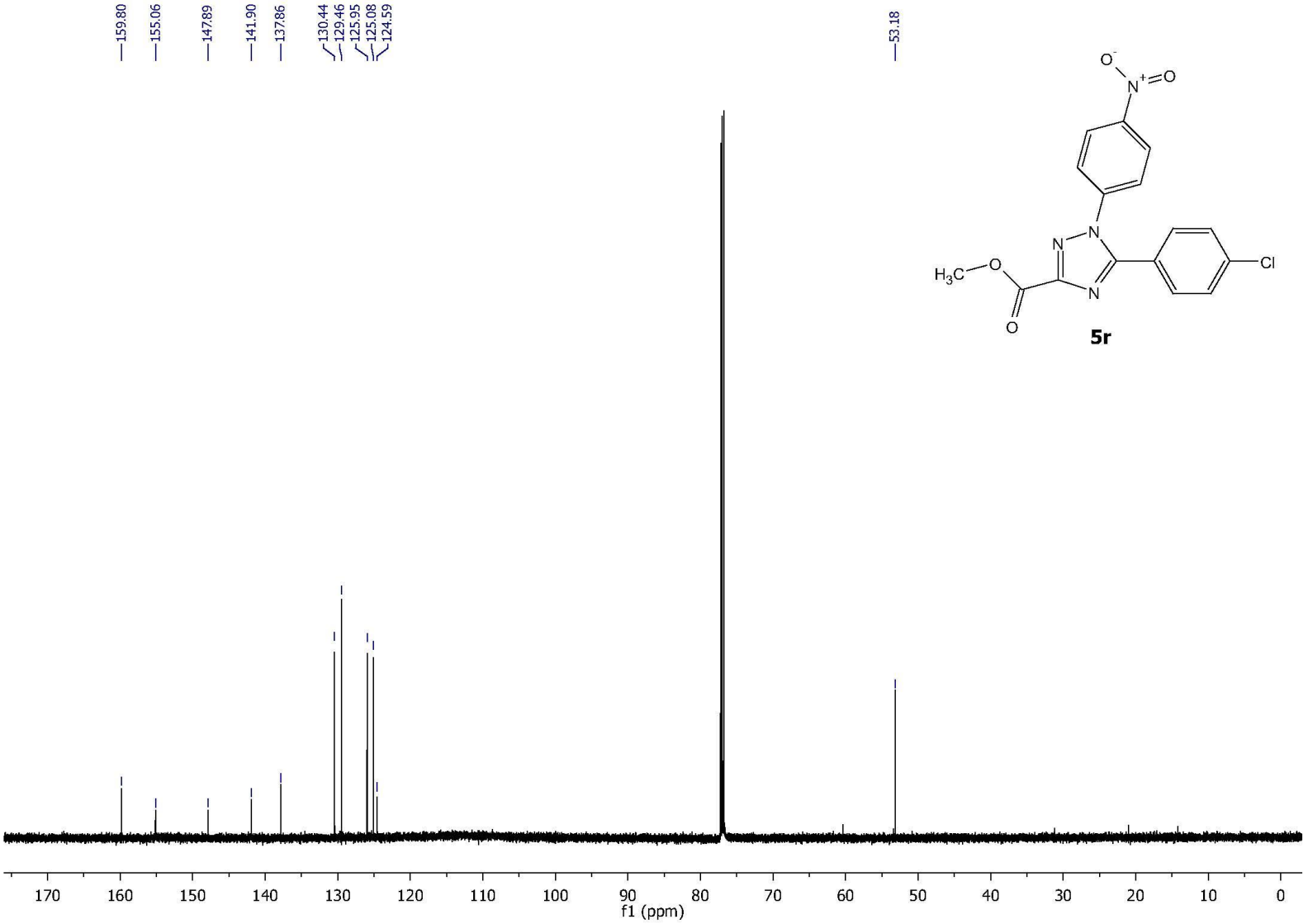

160.29
160.20
159.11
158.68
154.59
154.24
151.41
151.39
137.04
131.97
130.32
129.03
127.18
125.11
121.49
121.43
118.22
116.83
116.67
52.94
F
O
N
N
N
Cl
O
H_3C
O
f1 (ppm)

5q


8.14
8.12
7.45
7.44
7.42
7.08
7.07
7.05
3.96
CDCl3
CH2Cl2
H2O
F
O
N
N
N
O
O
CH3
Cl
6q
2.00
3.99
5.99
2.98
f1 (ppm)

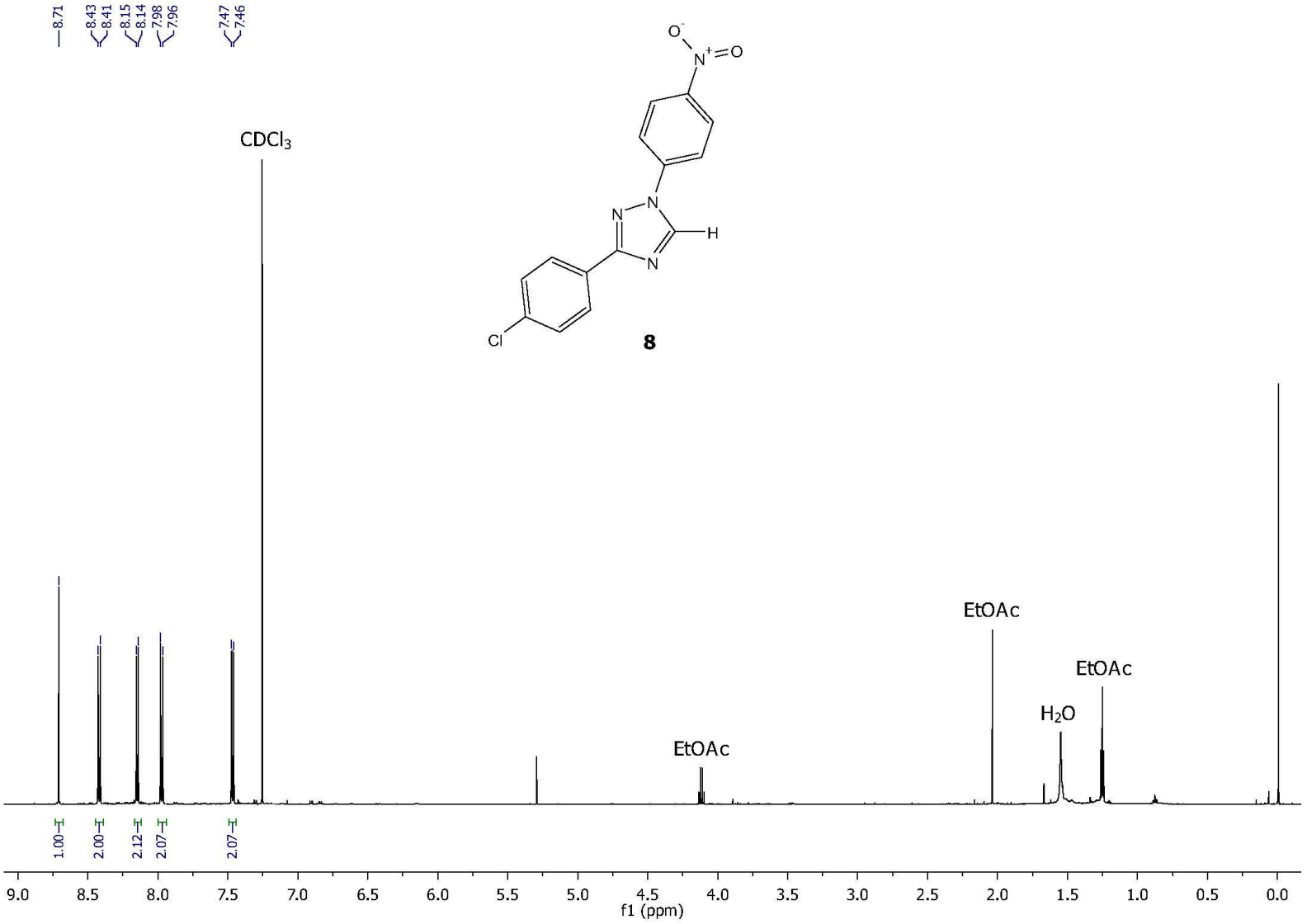

161.19
159.11
157.82
151.70
151.67
145.25
136.05
132.45
128.93
128.19
128.05
127.32
121.54
121.45
117.68
116.79
116.53
53.29
F
O
N
N
N
O
O
CH3
Cl
6q
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


8.33
8.31
7.62
7.60
7.47
7.45
7.40
7.39
4.06
CDCl3
CH2Cl2
EtOAc
EtOAc
EtOAc
1.97
2.00
2.06
1.99
3.03
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)
O
N+=O
N
N
N
H3C
O
O
Cl
5r

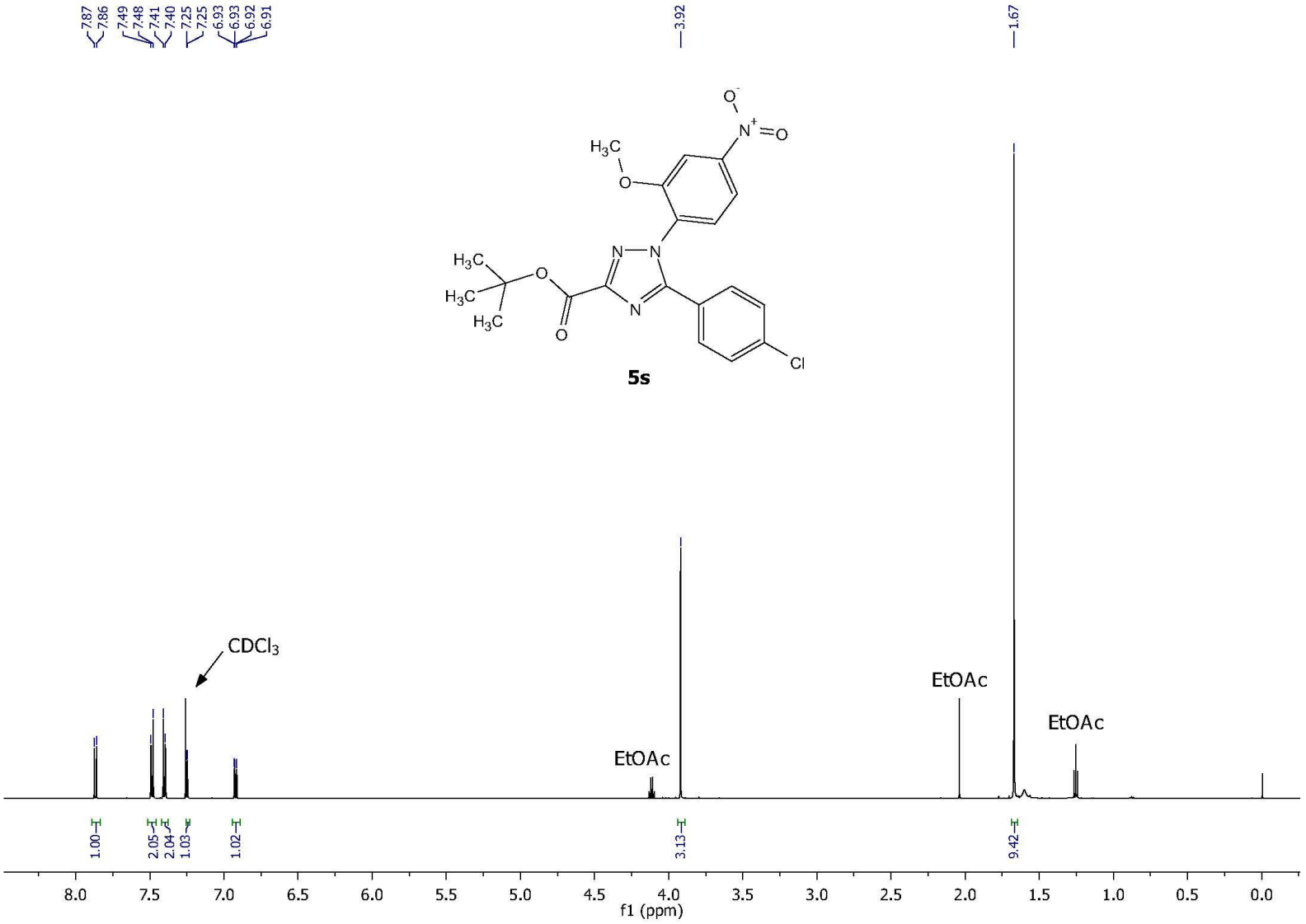

159.80
155.06
147.89
141.90
137.86
130.44
129.46
125.95
125.08
124.59
53.18
f1 (ppm)

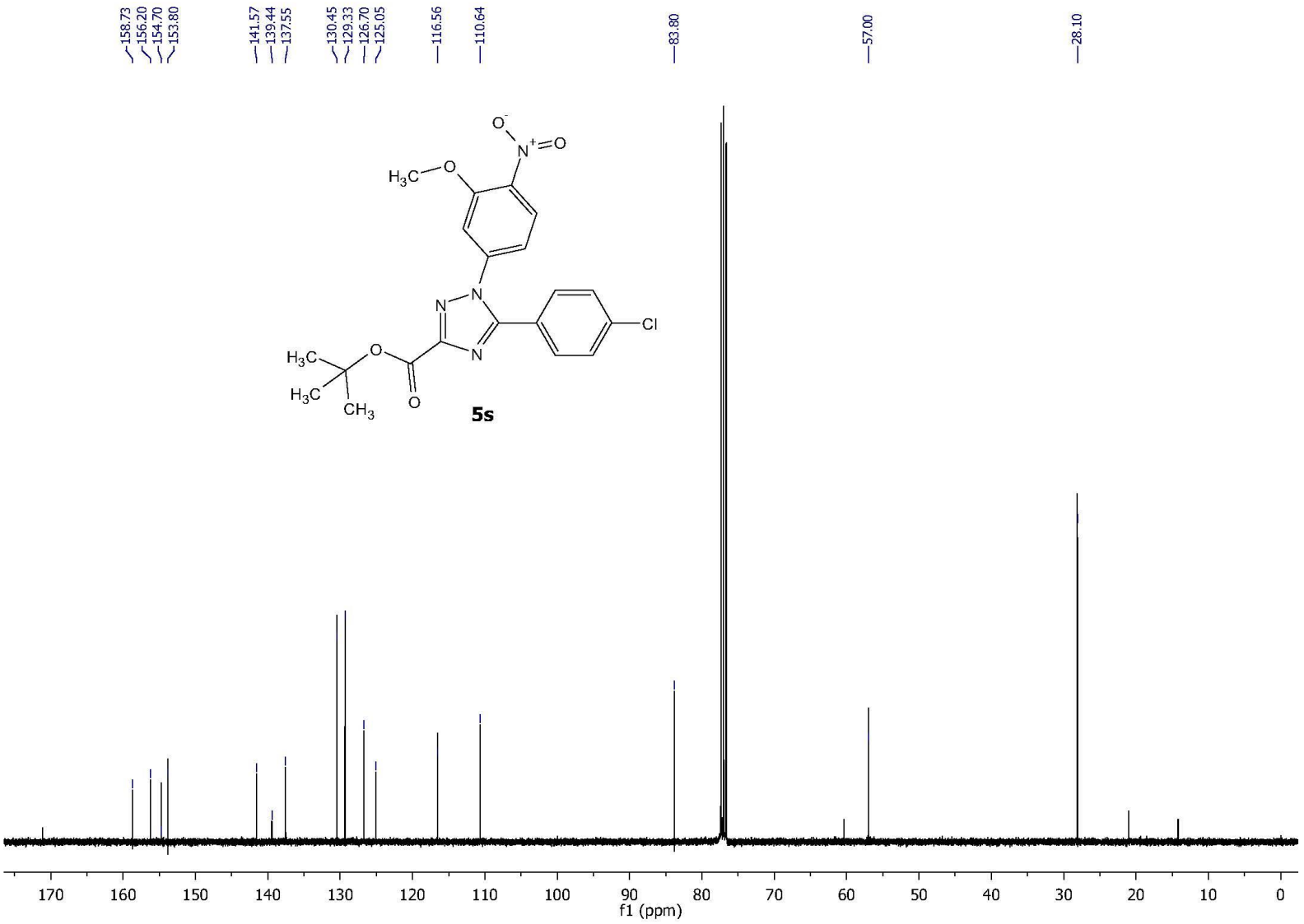
O
N
O
N
N
N
H3C
O
O
Cl

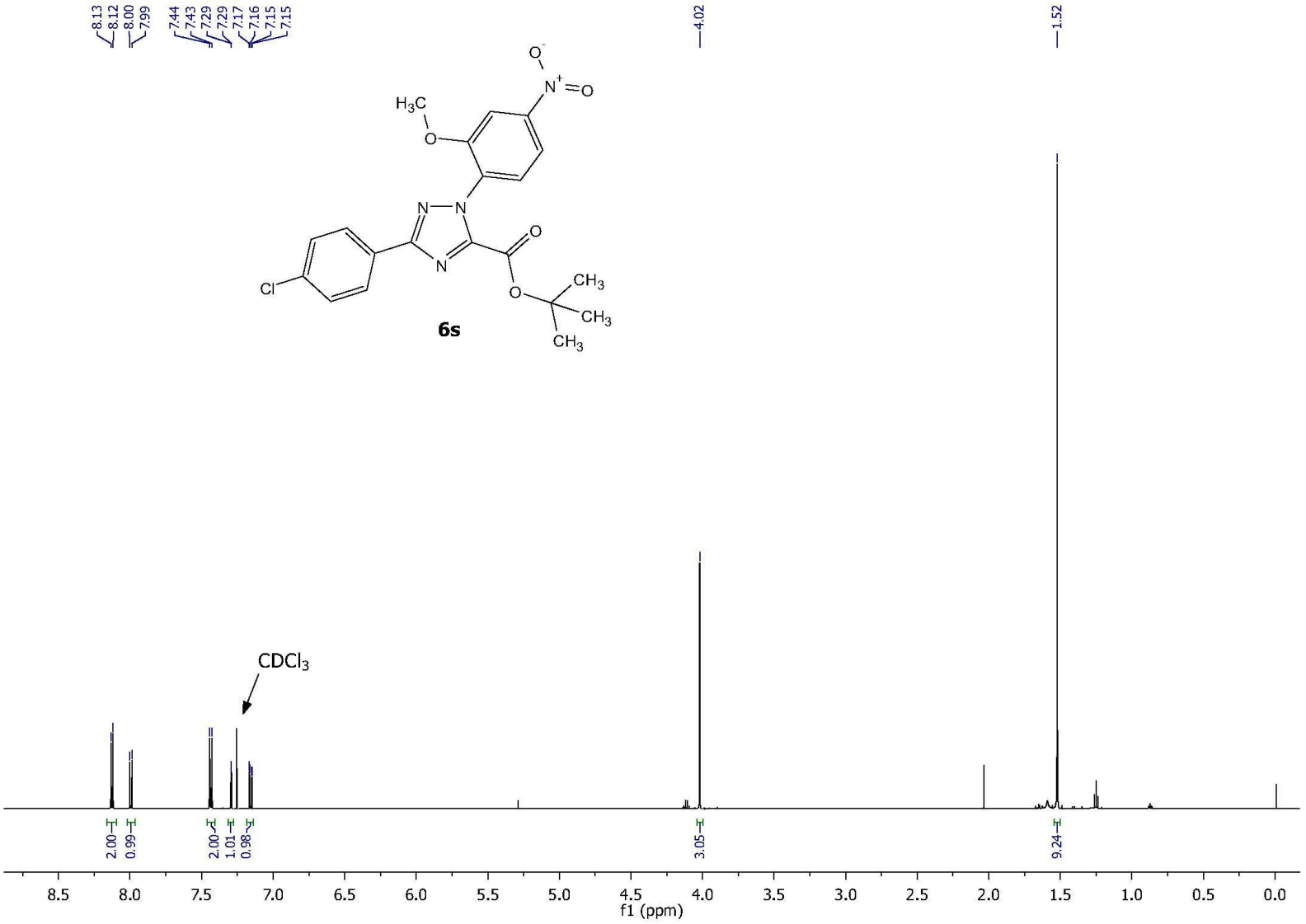
5r

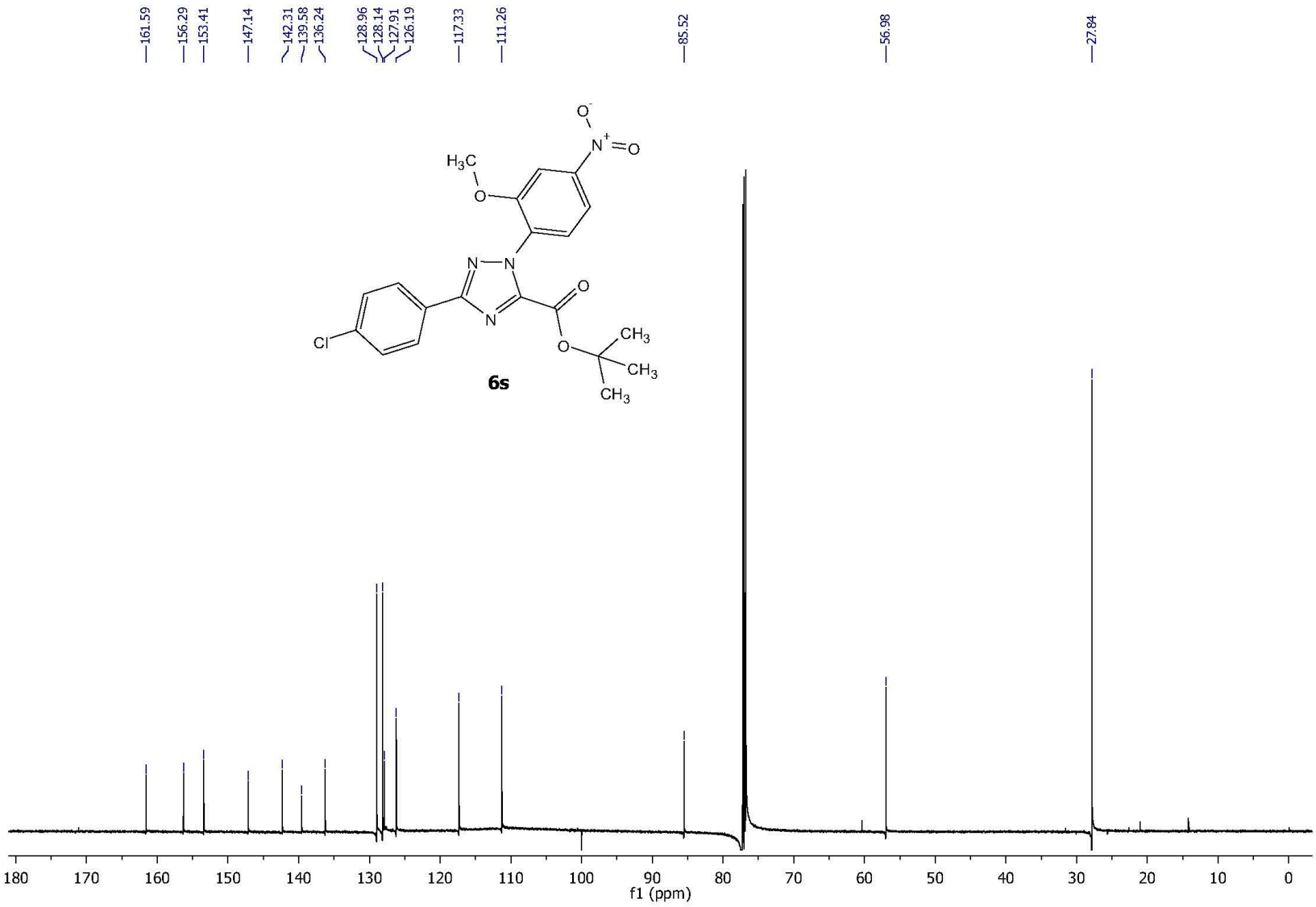

8.71
8.43
8.41
8.15
8.14
7.98
7.96
7.47
7.46
CDCl3
EtOAc
EtOAc
H2O
EtOAc
1.00
2.00
2.12
2.07
2.07
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

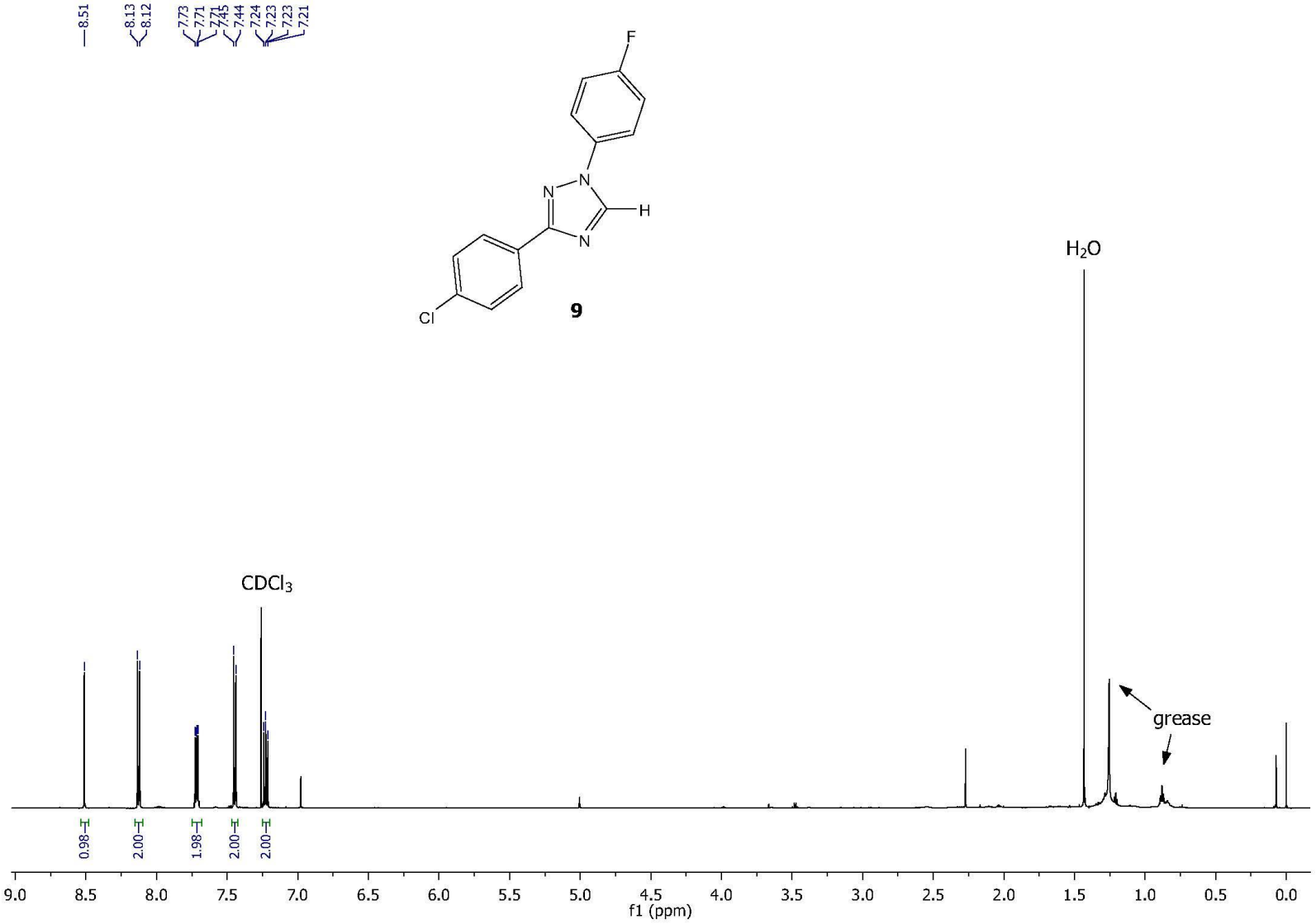
8

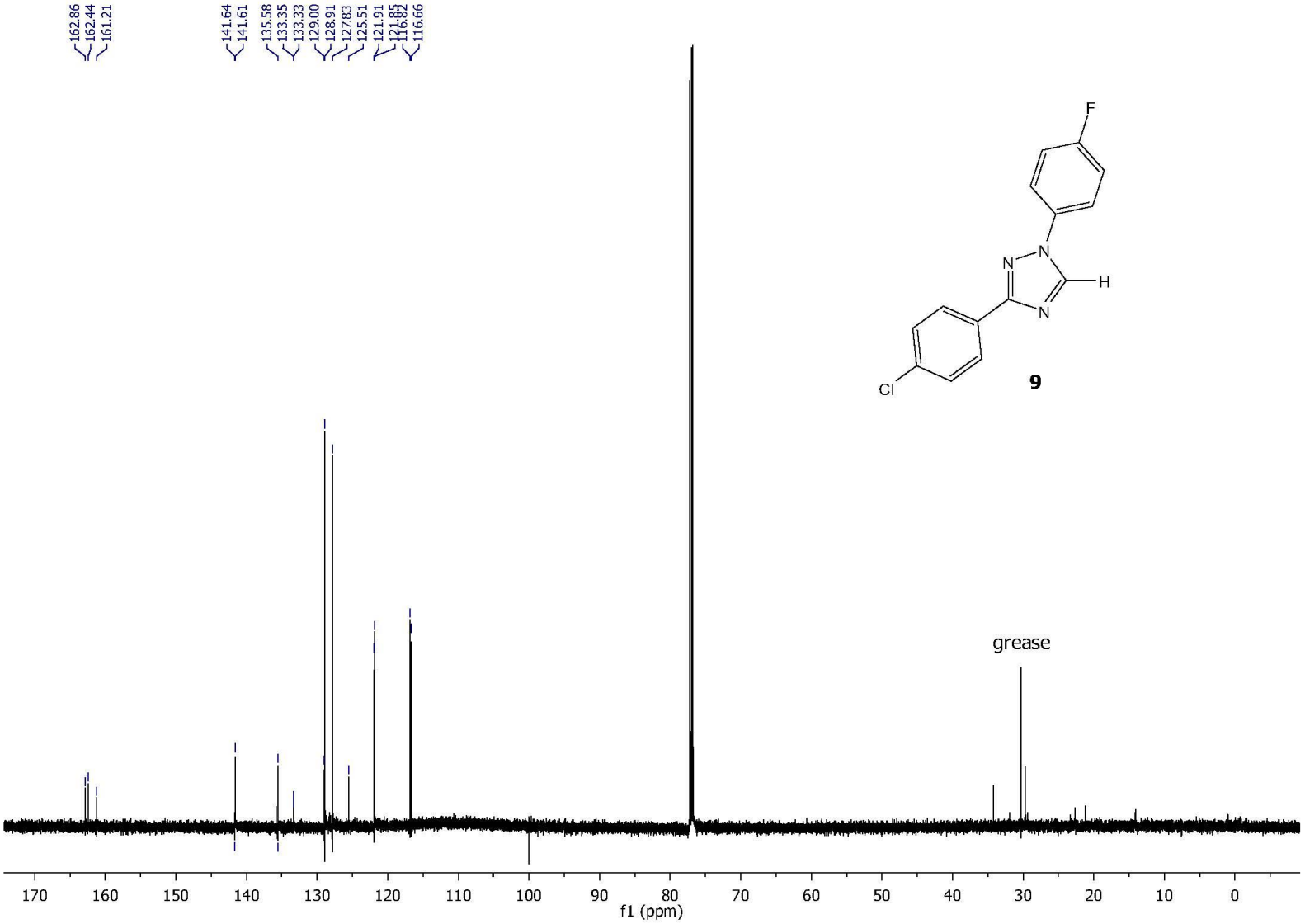

7.87
7.86
7.49
7.48
7.41
7.40
7.25
7.25
6.93
6.93
6.92
6.91
3.92
1.67
5s
CDCl3
EtOAc
EtOAc
EtOAc
1.00
2.05
2.04
1.03
1.02
3.13
9.42
f1 (ppm)

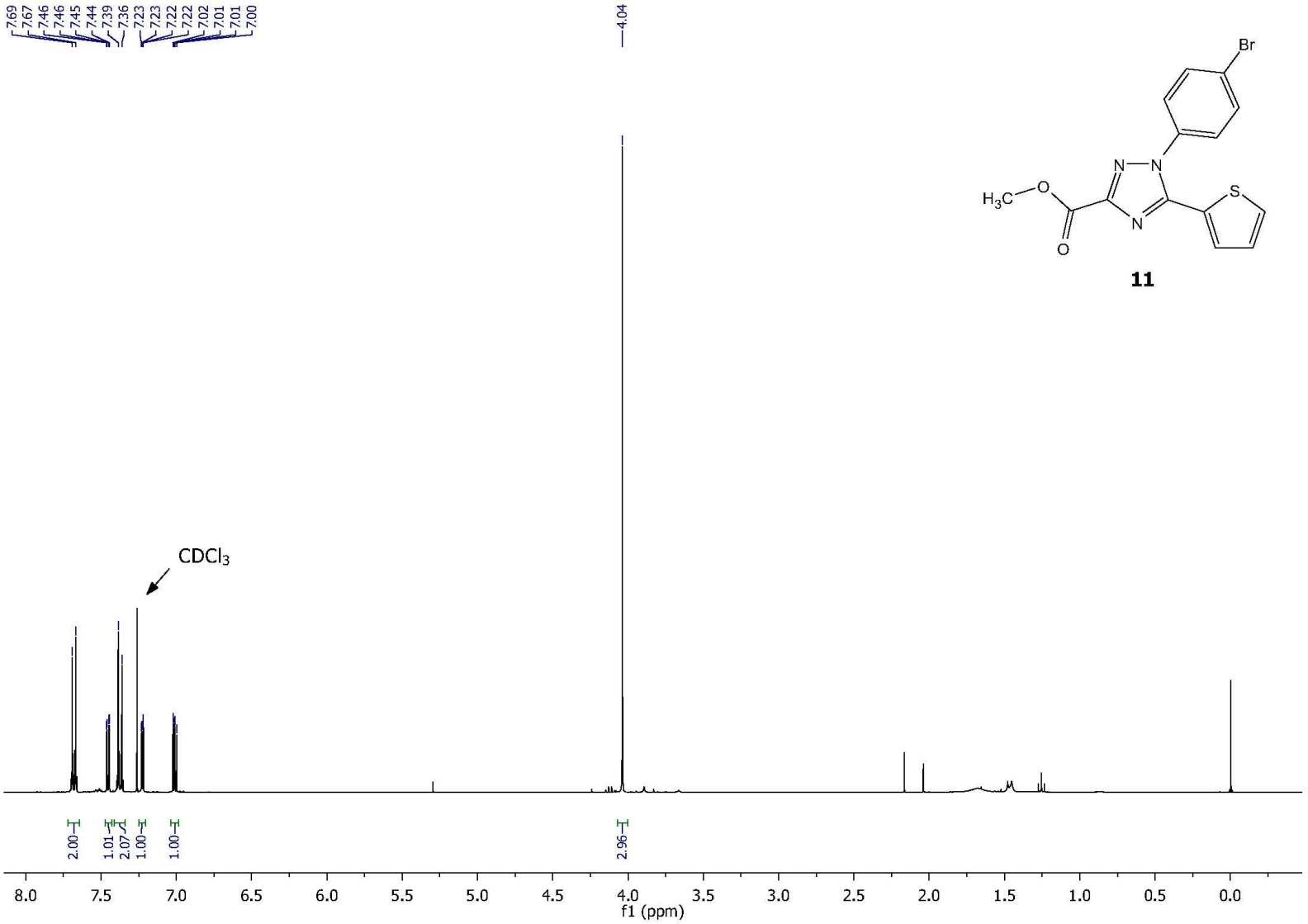

158.73
156.20
154.70
153.80
141.57
139.44
137.55
130.45
129.33
126.70
125.05
116.56
110.64
83.80
57.00
28.10
O
N+=O
H3C
O
N
N
N
Cl
O
H3C
H3C
CH3
O
5s
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


8.13
8.12
8.00
7.99
7.44
7.43
7.29
7.29
7.17
7.16
7.15
7.15
4.02
1.52
6s
CDCl3
2.00
0.99
2.00
1.01
0.98
3.05
9.24
f1 (ppm)

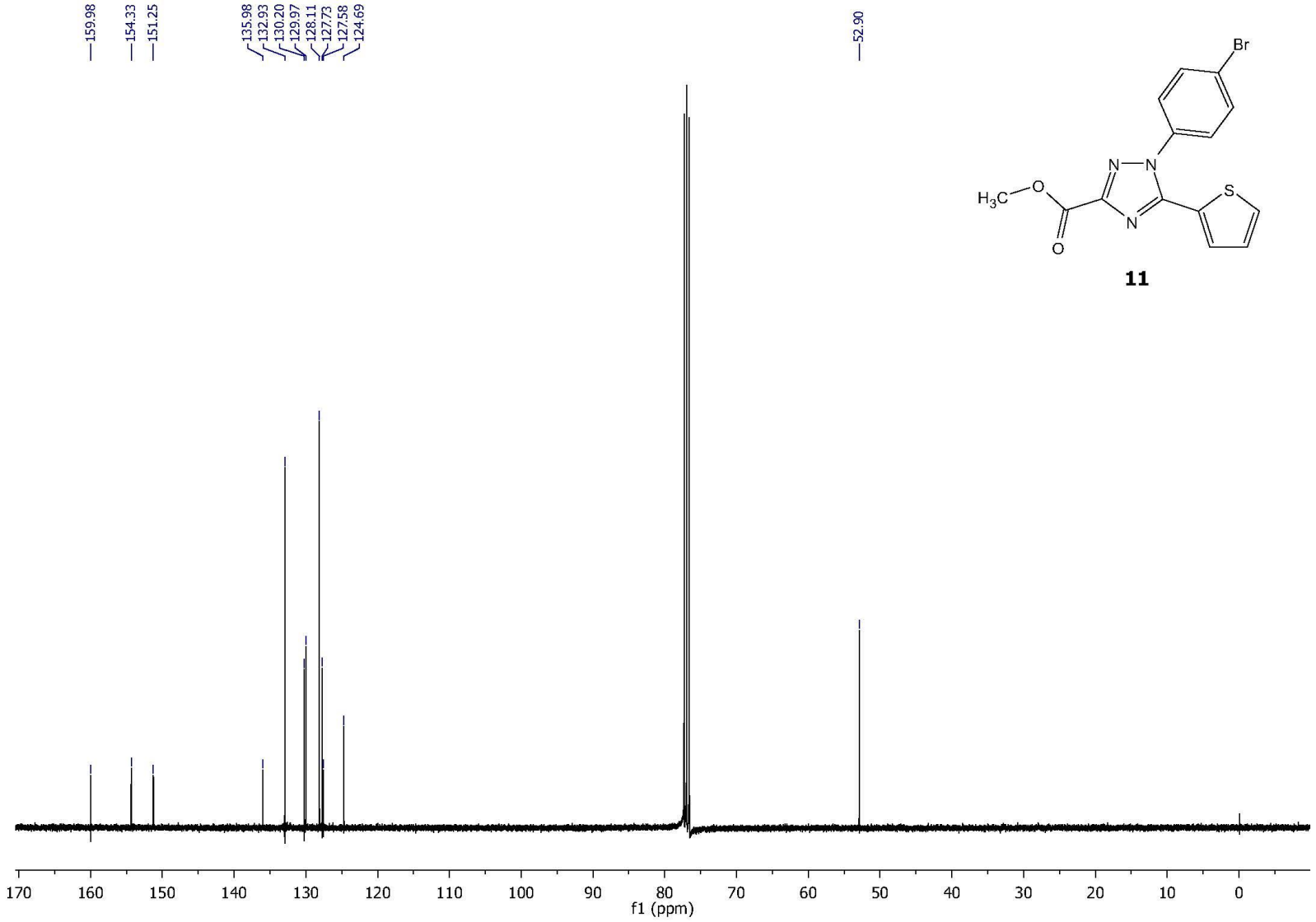

161.59
156.29
153.41
147.14
142.31
139.58
136.24
128.96
128.14
127.91
126.19
117.33
111.26
85.52
56.98
27.84
6s
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

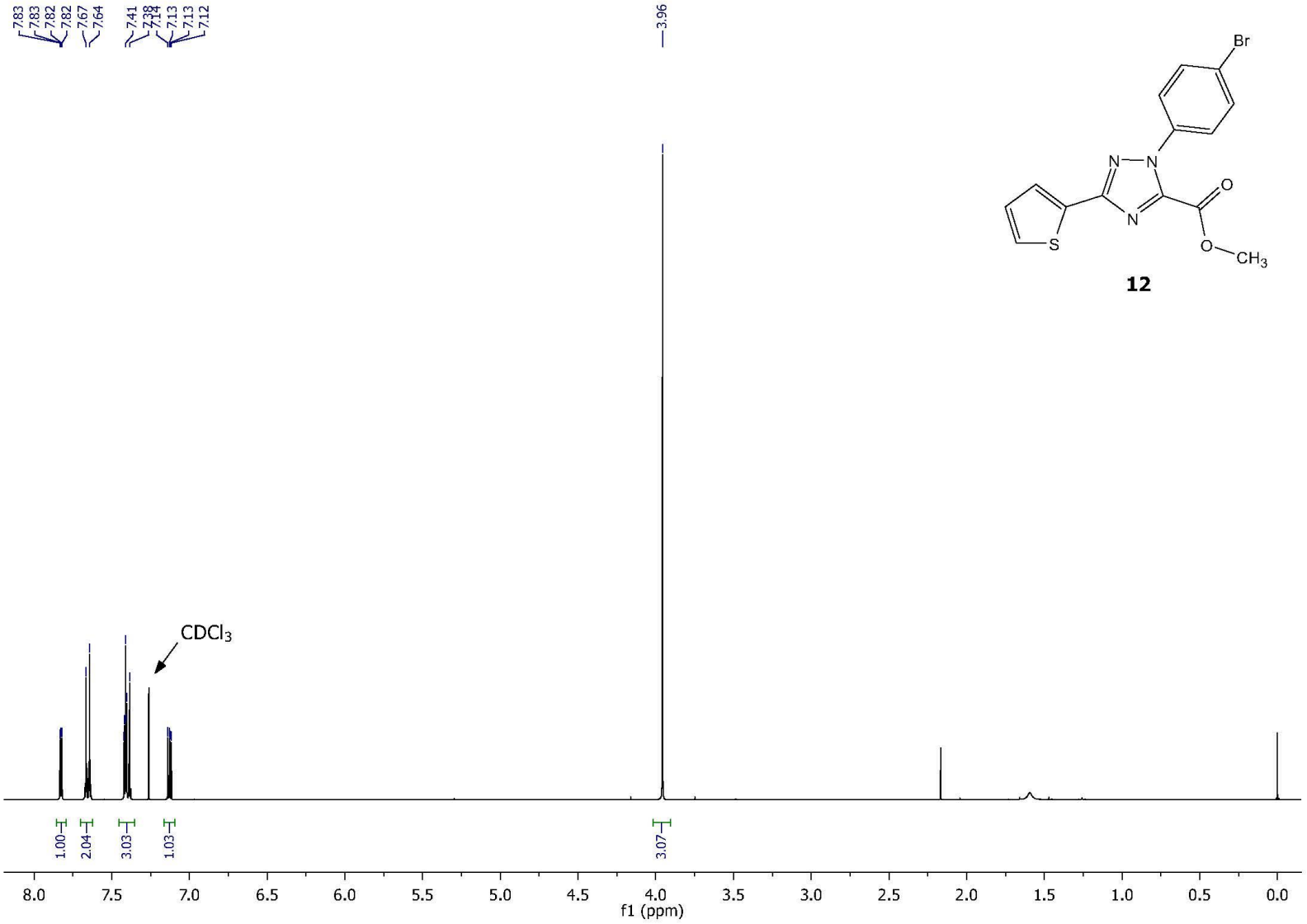

8.51
8.13
8.12
7.73
7.71
7.71
7.45
7.44
7.24
7.23
7.23
7.21
F
N
N
N
H
Cl
9
H2O
CDCl3
grease
0.98
2.00
1.98
2.00
2.00
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


162.86
162.44
161.21
141.64
141.61
135.58
133.35
133.33
129.00
128.91
127.83
125.51
121.91
116.82
116.66
F
N
N
H
N
Cl
9
grease
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


7.69
7.67
7.46
7.46
7.45
7.44
7.39
7.36
7.23
7.23
7.22
7.22
7.02
7.01
7.01
7.00
4.04
CDCl3
2.00
1.01
2.07
1.00
1.00
2.96
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)
Br
N
N
N
O
H3C
O
S

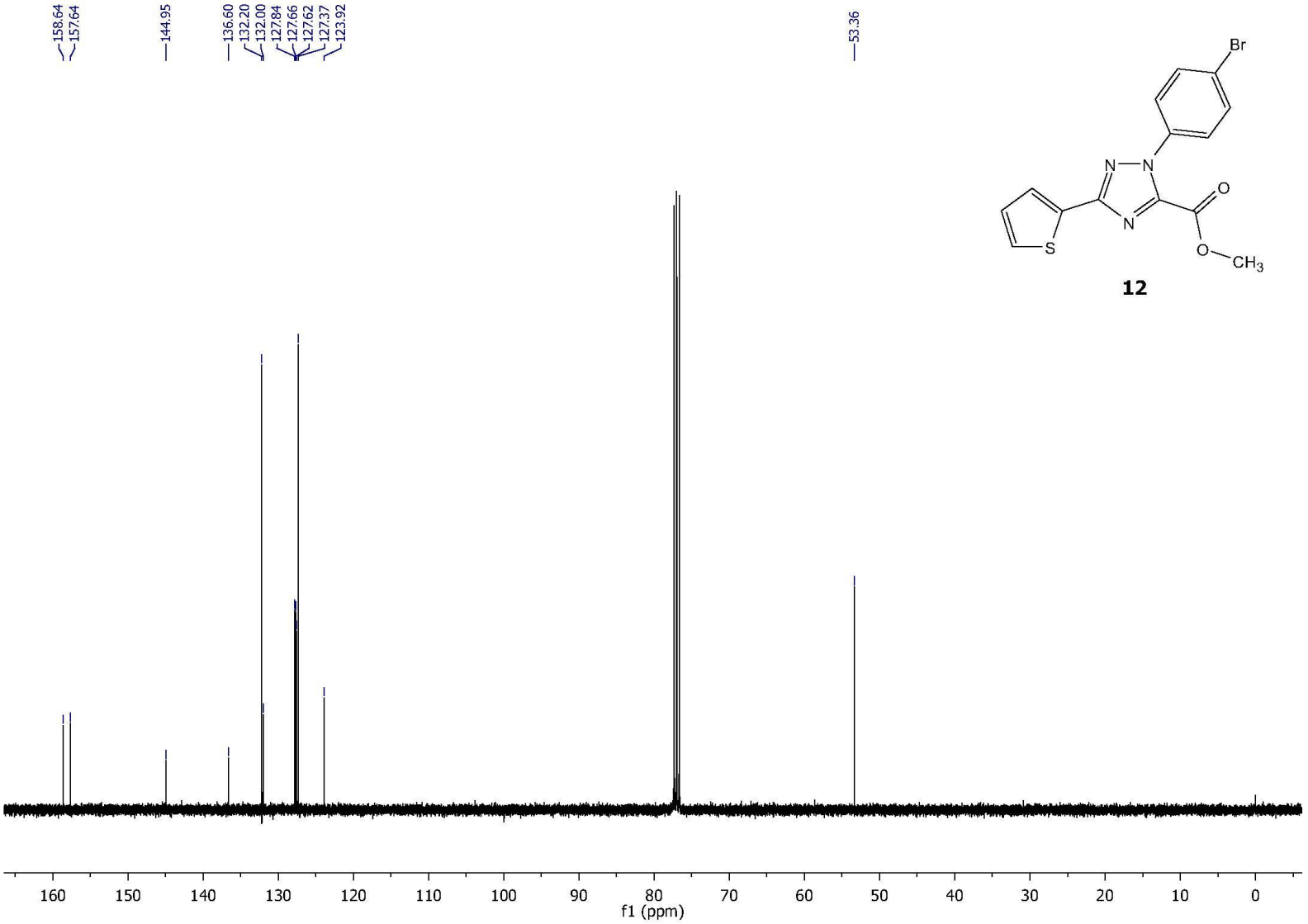
11


159.98
154.33
151.25
135.98
132.93
130.20
129.97
128.11
127.73
127.58
124.69
52.90
Br
N
N
S
H_3C
O
N
O
11
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

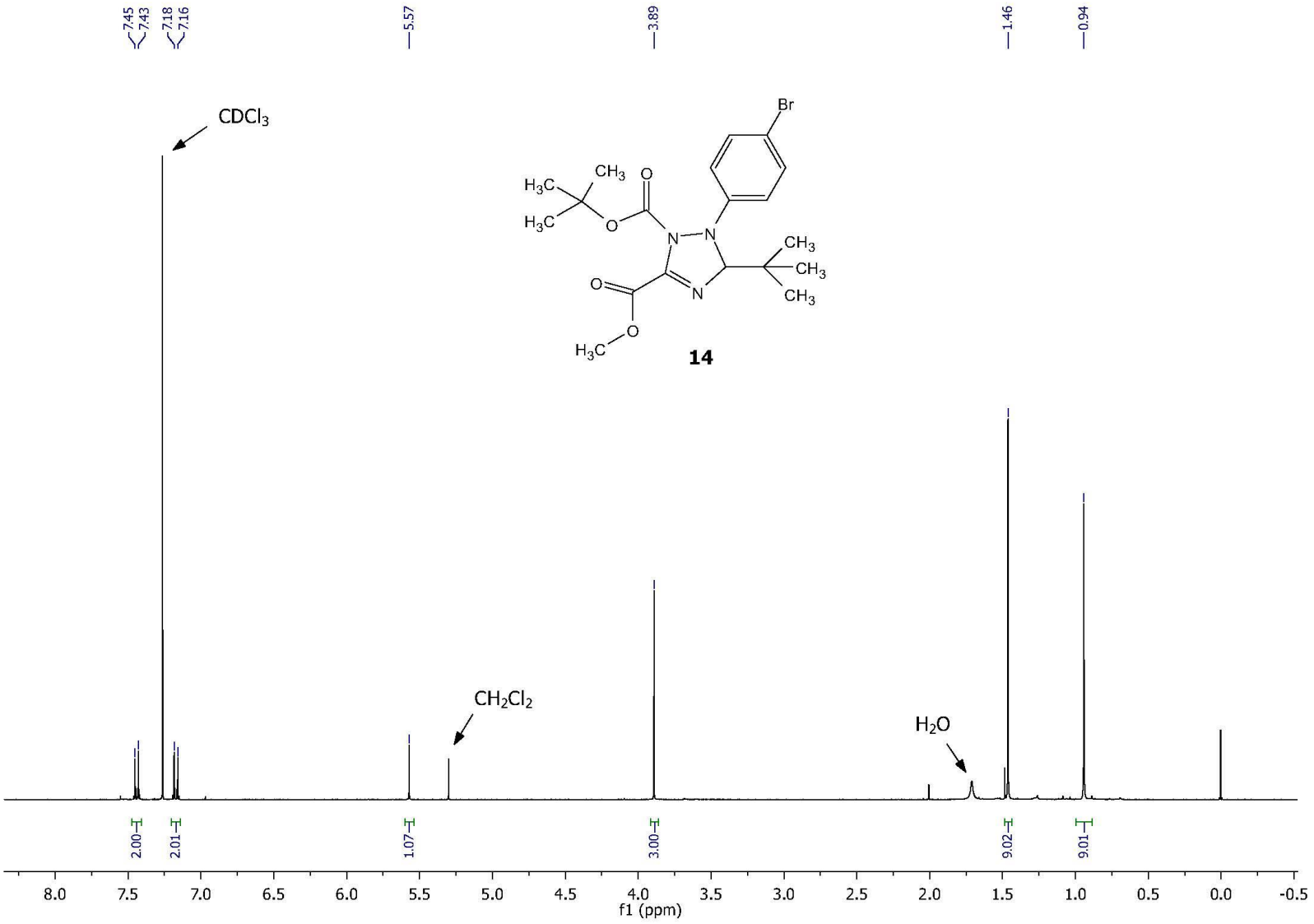

7.83
7.83
7.82
7.82
7.67
7.64
7.41
7.38
7.14
7.13
7.13
7.12
3.96
CDCl3
1.00
2.04
3.03
1.03
3.07
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

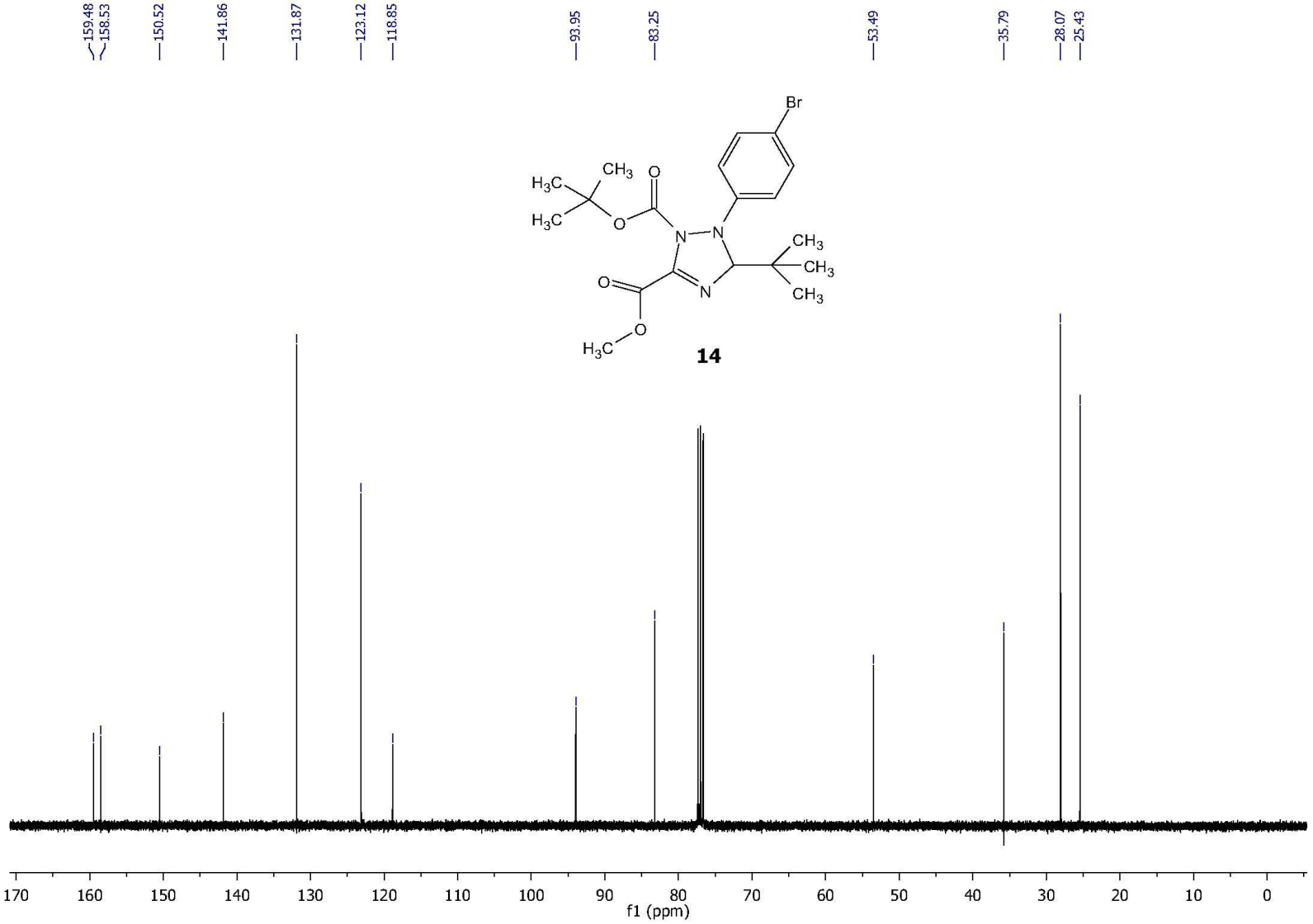
Br
N
N
N
S
O
O
CH3

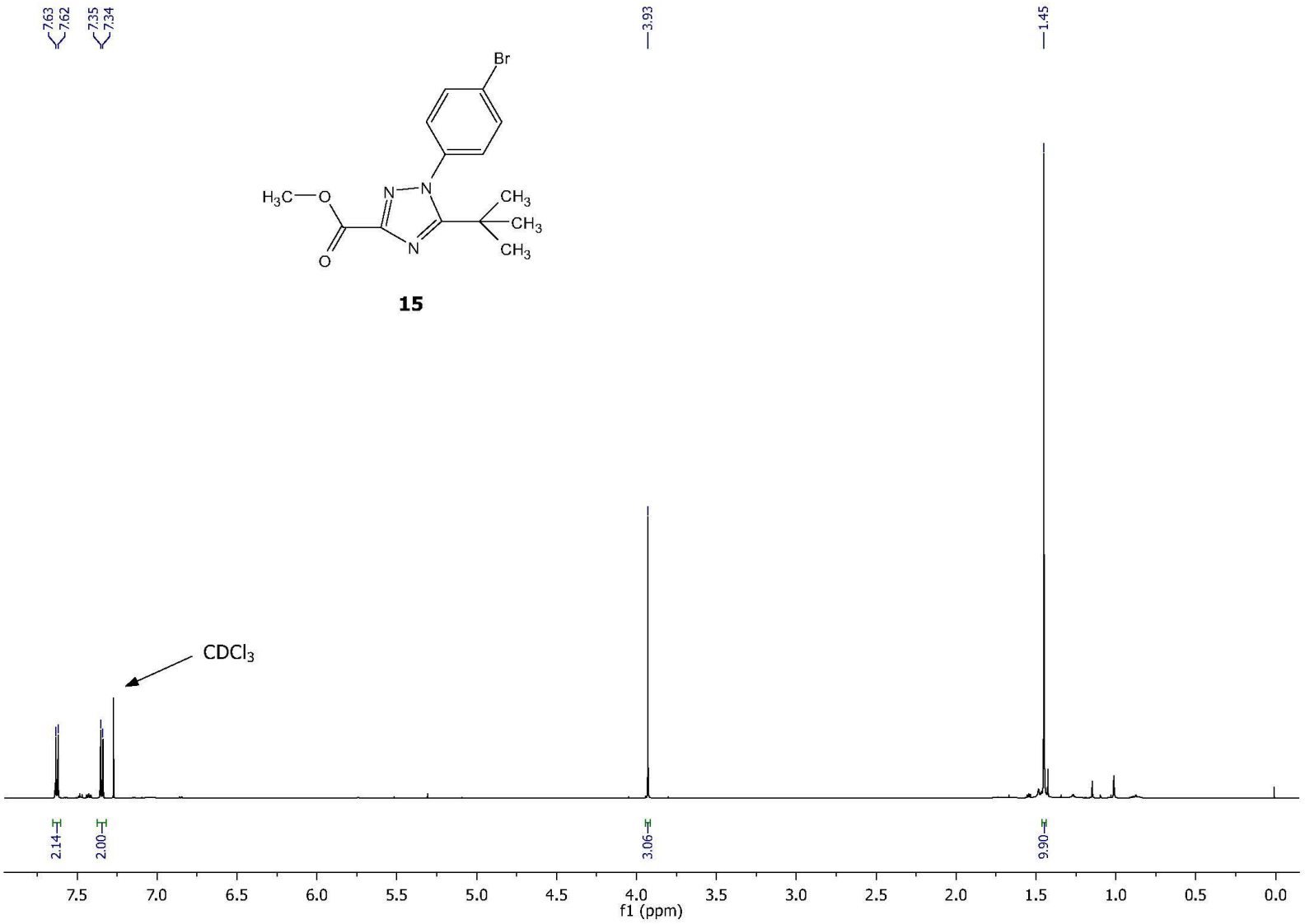
12


158.64
157.64
144.95
136.60
132.20
132.00
127.84
127.66
127.62
127.37
123.92
53.36
Br
N
N
N
S
O
O
CH3
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

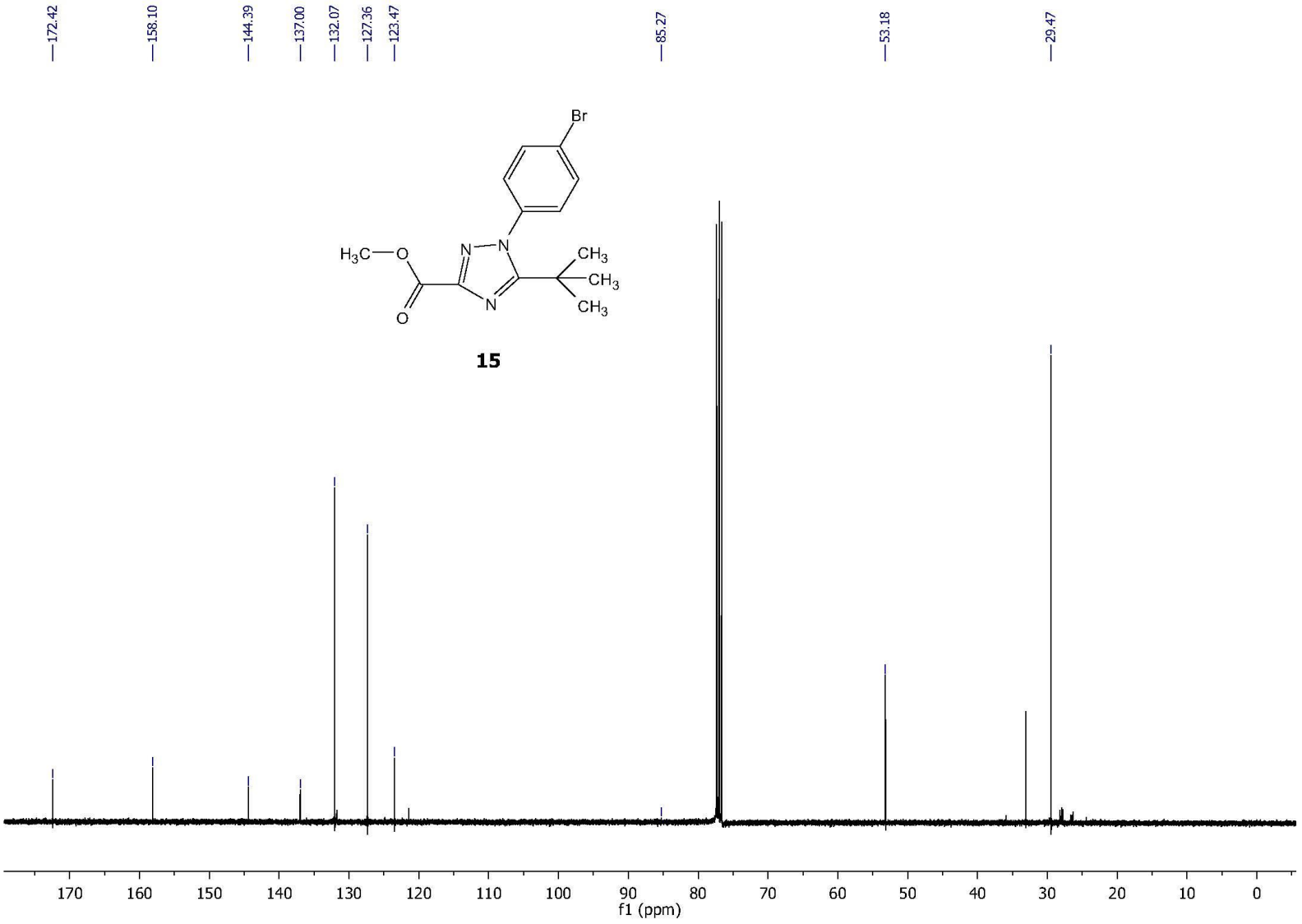
12


7.45
7.43
7.18
7.16
5.57
3.89
1.46
0.94
CDCl3
Br
CH3
H3C
H3C
O
O
N
N
CH3
CH3
CH3
O
N
O
H3C
14
CH2Cl2
H2O
2.00
2.01
1.07
3.00
9.02
9.01
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)


159.48
158.53
150.52
141.86
131.87
123.12
118.85
93.95
83.25
53.49
35.79
28.07
25.43
Br
CH3
H3C
H3C
O
O
N
N
CH3
CH3
CH3
O
N
O
H3C
14
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


7.63
7.62
7.35
7.34
3.93
1.45
Br
H3C—O
N
N
CH3
CH3
CH3
O
O
CDCl3
2.14
2.00
3.06
9.90
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

15


172.42
158.10
144.39
137.00
132.07
127.36
123.47
85.27
53.18
29.47
Br
H3C
O
N
N
N
O
CH3
CH3
CH3
15
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)