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Graphical Abstract

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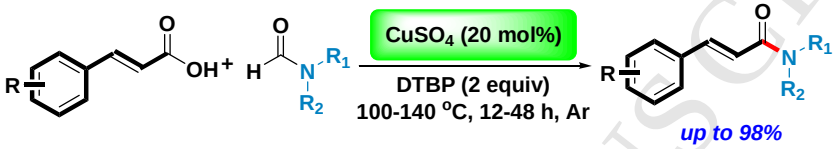

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ABSTRACT

A highly effective synthesis of *α*, *β*-unsaturated acylamides is reported for the first time *via* copper-catalyzed direct amidation between readily available cinnamic acids and *N*-substituted formamides. The protocol was easily accessible and practical.

1. Introduction

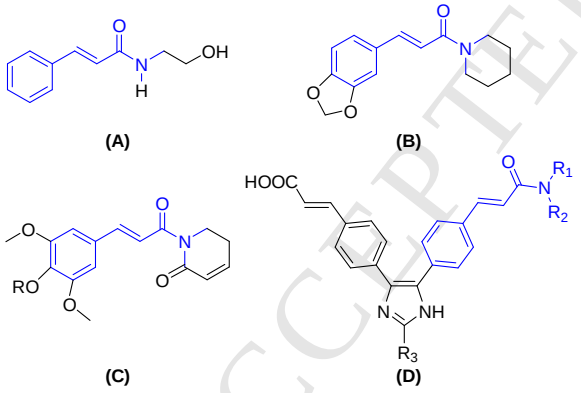
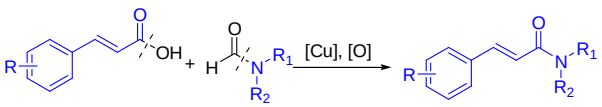


Figure 1. Examples of molecules containing cinnamamide moiety

α, *β*-Unsaturated acylamides, such as cinnamamides and their derivatives, possess many biological activities such as anticonvulsant, antidepressant, analgesic, antiestrogenic and antifungal properties which have been widely applied in agricultural, pharmaceutical and synthetic chemistry since the 19th century.[1-7] For example, as shown in Figure 1, *N*-(2-hydroxyethyl)cinnamamide (**A**) was found to show good anticonvulsant activity and also low toxicity;[2] The natural piperidine derivative (**B**) showed good insecticidal activity against the fall armyworm, *S. frugiperda*.[3] The genus piperaceae molecules (**C**) have been widely studied, due to the biological properties of secondary metabolites from these plants.[4] Compounds (**D**) represent a novel series of potent small molecule inhibitors that not only have excellent in vitro profiles but also have activity *in vivo*.[5] In addition, in the course of screening compounds for pharmacological action, it was observed that *α*-phenyl-*N*,*N*-diethyl cinnamamide potentiated nembutal hypnosis in rats.[6] Furthermore, *N*,*N*-dimethylcinnamamide compounds are potentially antidepressant. It is noteworthy that the *trans*-isomers possess much more pronounced biological activity than do the *cis*-isomers.[7] Therefore, the essentially pure *trans*-isomers are preferred.



Scheme 1. Our protocol to prepare cinnamamides *via* coupling between cinnamic acids with *N*-substituted formamides.

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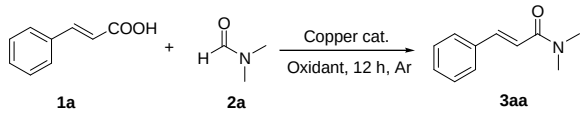
In view of the preparation of cinnamamides, the routine approach is cascade chlorination of cinnamic acid and amination with secondary amines. These chlorination reagents, such as phosphoryl chloride or thionyl chloride, are usually toxic, volatile, irritative and corrosive. Therefore, a more practical and accessible way to synthesize cinnamamides is highly desirable. Recently, our group reported a copper-catalyzed decarboxylative C–H functionalization between cinnamic acids and benzylic molecules.[8] As a further extension of our work, we have developed an example of copper-catalyzed direct amidation from cinnamic acids and *N*-substituted formamides to afford various cinnamamides as shown in Scheme 1. It is noteworthy that in this study, *N*-substituted formamides were used not only as the solvent, but also as an amine source.[9] Actually, *N*,*N*-dimethylformamide (DMF) has been extensively applied to the preparation of amides in different reactions: a) aminocarbonylation of aryl halides using DMF as an amide source;[10] b) direct aminocarbonylation of azoles with DMF *via* C–H activation;[11] c) tandem chlorination and amidation of carboxylic acids in DMF;[12] d) direct amidation of alcohols or aldehydes with DMF.[13]

2. Results and discussion

Table 1. Optimization of reaction conditions for the synthesis of cinnamamide (**3aa**) [a]



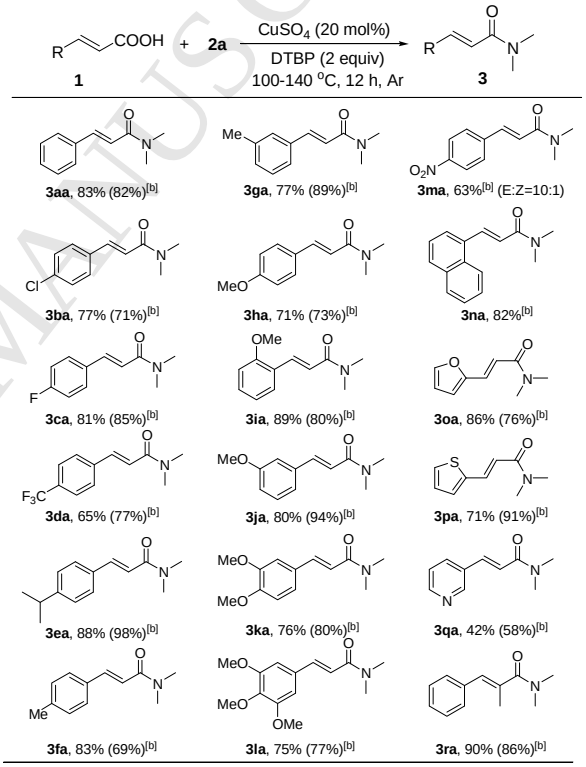
1a **2a** **3aa**

entry	Copper cat. (mol%)	Oxidant	T (°C)	Yield (%)[b]
1	CuI (20)	DTBP	140	48
2	CuBr (20)	DTBP	140	62
3	CuCl (20)	DTBP	140	64
4	Cu_2O (20)	DTBP	140	30
5	Cu powder (20)	DTBP	140	47
6	CuO (20)	DTBP	140	9
7	$CuBr_2$ (20)	DTBP	140	41
8	$CuCl_2•2H_2O$ (20)	DTBP	140	45
9	$Cu(OAc)_2•H_2O$ (20)	DTBP	140	62
10	$Cu(acac)_2•H_2O$ (20)	DTBP	140	56
11	$CuSO_4$ (20)	DTBP	140	82
12	$Cu(OTf)_2$ (20)	DTBP	140	82
13	$CuSO_4$ (20)	$(NH_4)_2S_2O_8$	140	40
14	$CuSO_4$ (20)	TBHP	140	75
15	$CuSO_4$ (20)	BQ	140	ND
16	$CuSO_4$ (20)	DCP	140	58
17	$CuSO_4$ (20)	DTBP	150	80
18	$CuSO_4$ (20)	DTBP	130	75
19	$CuSO_4$ (20)	DTBP	120	78
20	$CuSO_4$ (20)	DTBP	100	83
21	$CuSO_4$ (20)	DTBP	80	NR
22	$CuSO_4$ (10)	DTBP	100	50
23	$CuSO_4$ (5)	DTBP	100	40
24[c]	$CuSO_4$ (20)	DTBP	100	71
25	–	DTBP	100	NR
26	$CuSO_4$ (20)	–	100	NR

[a] Catalytic conditions: cinnamic acid (**1a**) (0.3 mmol), Copper cat., DMF (2 mL), oxidant (2 equiv), 80-140 °C, 12 h, Ar. [b] Isolated yield based on cinnamic acid. [c] In air.

Initially, the model reaction of cinnamic acid (0.3 mmol) with 2 mL of DMF was performed in the presence of CuI (20 mol %) and di-*tert*-butyl peroxide (DTBP) (2 equiv) as the oxidant at 140 °C under argon atmosphere and *N*,*N*-dimethylcinnamamide was acquired in the yield of 48% (Table 1, entry 1). Among the copper sources screened, most of the copper salts gave moderate yields (entries 1–12). Notably, $CuSO_4$ and $Cu(OTf)_2$ showed their best catalytic properties for the amidation (entries 11–12). In view of the cost of these two salts, we chose readily available $CuSO_4$ as the ideal catalyst. Furthermore, various oxidants were studied, including $(NH_4)_2S_2O_8$, *tert*-butyl hydroperoxide (TBHP) and dicumyl peroxide (DCP) (entries 13–16), and DTBP proved the best. We found that temperatures in the range from 100 to 150 °C did not influence the model reaction greatly (entries 17–20). However, when the reaction was carried out at 80 °C, no reaction was observed (entry 21). Less copper catalyst led to lower yields of the desired product (entries 22–23). The reaction performed in air afforded a reduced yield of **3aa** (entry 24). The control experiments showed that $CuSO_4$ or DTBP alone could not catalyze the reaction (entries 25–26).

Table 2. Copper-catalyzed amidation between different cinnamic acids (**1**) with DMF (**2a**) [a]



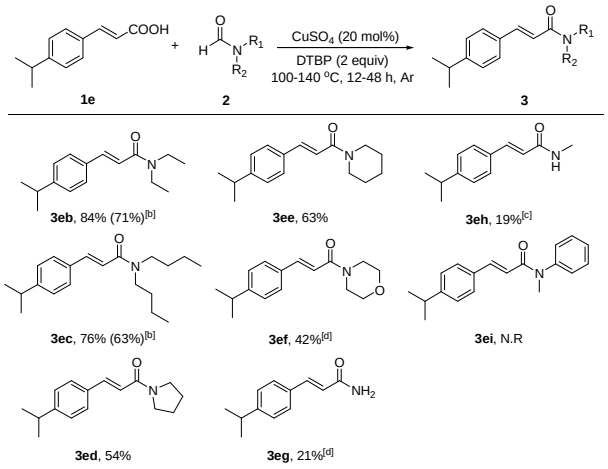
1 **3**

[a] Catalytic conditions: cinnamic acid (**1a**) (0.3 mmol), DMF (**2a**) (2 mL), $CuSO_4$ (20 mol%), DTBP (2 equiv.), 100 °C, 24 h, Ar. Isolated yield based on cinnamic acid; All of the products were pure *trans*-isomers. [b] 140 °C, 12h.

With the optimized conditions in hand, various cinnamic acids were explored for the amidation reactions at 100–140 °C as shown in Table 2. We were pleased to observe that amidation of the cinnamic acids with electron-withdrawing groups such as 4-Cl, 4-F and 4-CF_3 groups as well as electron-donating groups such as methyl, methoxyl and isopropyl could offer good to excellent yields of corresponding products (**3ba-3la**), and all of the products were the pure *trans*-isomers. However, it is strange to observe that the reaction of (*E*)-4-nitrocinnamic acid afforded the desired product with mixed isomers (*E*/*Z*=10:1) (**3ma**). 1-Naphthylcrylic acid was also a suitable substrate and the desired product was obtained in 82% yield (**3na**). Subsequently, various heterocyclic acrylic acids were investigated in the reaction. 2-

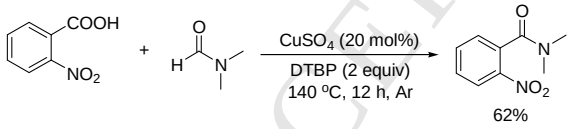
Furylcrylic acid, 2-thienylcrylic acid and 3-pyridylcrylic acid afforded the corresponding products in moderate to good yields (**3oa, 3pa** and **3qa**). When the *α*-hydrogen of cinnamic acid was substituted by methyl group, the reaction still occurred smoothly (**3ra**).

Table 3. Copper-catalyzed amidation between **1e** with different *N*-substituted formamides (**2**) [a]

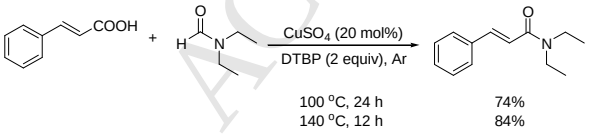


[a] Reaction conditions: 4-isopropylcinnamic acid (**1e**) (0.3 mmol), *N*-substituted formamide (**2**) (2 mL), $CuSO_4$ (20 mol%), DTBP (2 equiv.), 140 °C, 12 h, Ar. Isolated yield based on cinnamic acid. [b] 100 °C, 24 h [c] 48 h. [d] 24 h

Then, we examined a series of *N*-substituted formamide derivatives and the results were listed in Table 3. It was showed that the longer carbon chain on the N atom resulted in the lower yields of cinnamamides (**3ea** *vs* **3eb** and **3ec**). On the other hand, *N*-formylpyrrolidine, *N*-formylpiperidine and *N*-formylmorpholine afforded the desired products in moderate yields (**3ed**, **3ee** and **3ef**). *N*-Methylformanilide was not suitable for our methodology which probably attributed to the difficulty to destroy the strong conjugation between the amide group and phenyl ring (**3ei**).[13] For formamide and *N*-methylformamide, neither of them exhibited good reactivities in the reactions with 4-propylcinnamic acid (**3eg** and **3eh**).

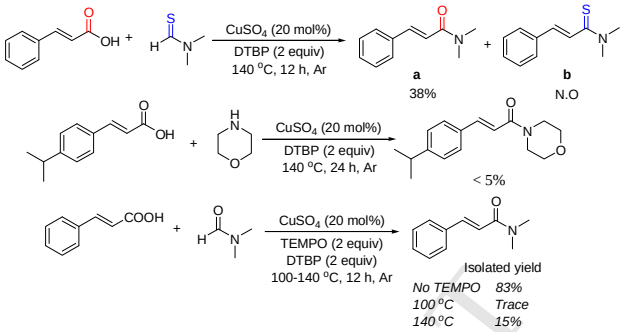


Scheme 2. Copper-catalyzed amidation of 2-nitrobenzoic acid with DMF



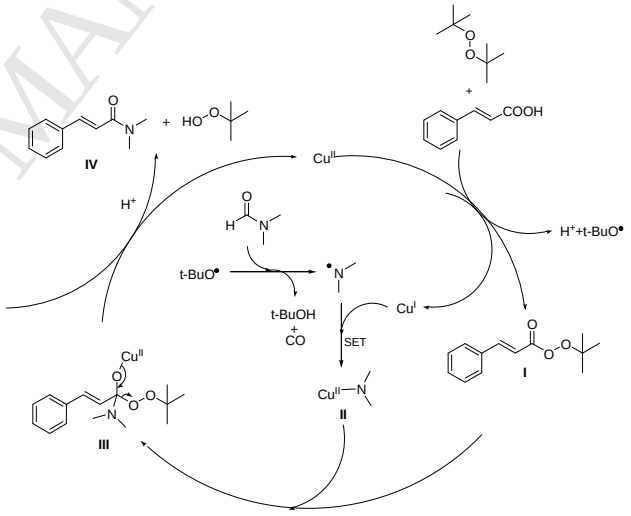
Scheme 3. Copper-catalyzed amidation between **1a** and *N*,*N*-diethylformamide.

To broaden the scope of amidation, 2-nitrobenzoic acid afforded the desired product with a moderate yield using our catalytic system (Scheme 2).[14] Furthermore, *N*,*N*-diethylcinnamamide which showed good activity against Aspergillus niger[15] was obtained in good yield by direct copper-catalyzed amidation between cinnamic acid and *N*,*N*-dimethylformamide (Scheme 3).

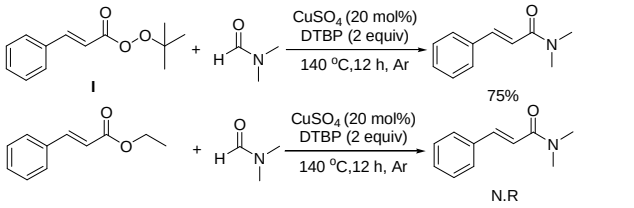


Scheme 4. Control experiments and effect of radical inhibitor.

To gain more understanding of this reaction, several experiments were performed (Scheme 4). First, *N*,*N*-dimethylthioformamide was employed instead of DMF as the reactant, affording only product **a** in 38% yield whereas decarbonylated product **b** was not observed. This indicated that the carbonyl group of cinnamamide came from cinnamic acid possibly.[9] When morpholine was used to replace DMF, only a trace of cinnamamide was detected by LC-MS. Radical scavenger TEMPO completely inhibited the reaction at 100 °C whereas the reaction was seriously suppressed at 140 °C. We believe that it might involve a participation of radicals in the catalytic cycle of the reaction.



Scheme 5. The possible mechanism.



Scheme 6. Control experiments to prove the mechanism

Based on previous observations, a plausible mechanism is proposed in Scheme 5. Cu(II) firstly oxidized DTBP and cinnamic acid to create the peroxyester **I**.[16-18] At the same time, amino radical was generated in situ from DMF.[13] Secondly, Cu(I) reduced amino radical to the intermediate **II** through a single-electron transfer process.[19] Finally, peroxyester **I** and

intermediate **II** produced the cinnamamide *via* addition-elimination. To prove the hypothesis, we exclusively prepared peroxyester **I**[20] and treated it with DMF under the foregoing optimized conditions. The expected product was obtained in 75% yield as shown in Scheme 6. However, compared with peroxyester **I,** ethyl cinnamate was not reacted at all in the same condition.

3. Conclusions

In conclusion, we have developed an efficient and direct method for the synthesis of *α*, *β*-unsaturated acylamides from cinnamic acids and *N*-substituted formamides. Both electron-withdrawing and electron-donating groups of the substrates used are well tolerated. In addition, 2-nitrobenzoic acid is also suitable for our catalyst system. It is noteworthy that our protocol is easily accessible and practical: 1) the readily available cinnamic acids could be directly used as the starting materials; 2) our catalyst system is low-cost and ligand-free; 3) the catalytic reaction is highly selective and the desired cinnamic acids were obtained exclusively. Further studies on the mechanism and the application of the reactions are currently in progress.

4. Experiment

4.1 General information

All reactions were carried out under an argon atmosphere condition. Cupric sulfate was purchased from Alfa. Various cinnamic acids and *N*-substituted formamides were purchased from Aldrich, Acros or Alfa. Column chromatography was generally performed on silica gel (100-200 mesh) and reactions were monitored by thin layer chromatography (TLC) using UV light (254 nm) to visualize the course of the reactions. The ^{1}H (300 MHz or 400 MHz) and ^{13}C NMR (75 MHz or 100 MHz) data were recorded on Varian 300 M or 400 M spectrometers using $CDCl_3$ as solvent. The chemical shifts (δ) are reported in ppm and coupling constants (J) in Hz. ^{1}H NMR spectra was recorded with tetramethylsilane (δ = 0.00 ppm) as internal reference; ^{13}C NMR spectra was recorded with $CDCl_3$ (δ = 77.000 ppm) or DMSO-d_6 (δ = 39.500 ppm) as internal reference. ESI-MS and HRMS were performed by the State-authorized Analytical Center in Soochow university.

4.2 General procedure for copper-catalyzed direct amidation between cinnamic acid and *N*-substituted formamide:

$CuSO_4$ (0.06 mmol) and cinnamic acid (0.3 mmol) were added to a Schlenk tube equipped with a magnetic stir bar under argon atmosphere. Then *N*-substituted formamide (2.0 mL) and DTBP (di-tert-butyl peroxide, 0.6 mmol) were added under Ar. The resulting reaction mixture was kept stirring until TLC monitoring indicated the complete disappearance of the starting material. At the end of the reaction, the reaction mixture was cooled to room temperature and was diluted with ethyl acetate and water was added. The combined organic phase was dried over anhydrous Na_2SO_4. After removal of the solvent, the residue was subjected to column chromatography on silica gel using ethyl acetate and petroleum ether mixtures to afford the corresponding product.

(*E*)-*N*,*N*-Dimethylcinnamamide (3aa)
White solid, m.p. 96-98 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ: 7.68 (d, J = 15.0 Hz, 1H), 7.52 (s, 2H), 7.35 (s, 2H), 6.90 (d, J = 15.0 Hz, 1H), 3.17 (s,3H), 3.07 (s,3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ: 166.7, 142.3, 135.3, 129.5, 128.8, 127.8, 117.4, 37.4, 35.9. MS ESI (m/z): $[M+H]^+$ calcd for $C_{11}H_{14}NO$, 176.1; found, 176.1.

(*E*)-3-(4-Chlorophenyl)-*N*,*N*-dimethylacrylamide (3ba)
White solid, m.p. 118-120 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.61 (d, J = 16.0 Hz, 1H), 7.45 (d, J = 8.0 Hz, 2H), 7.33 (d, J = 8.0 Hz, 2H), 6.86 (d, J = 16.0 Hz, 1H), 3.16 (s, 3H), 3.06 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ: 166.3, 140.9, 135.2, 133.7, 128.9, 128.9, 117.9, 37.3, 35.9. HRMS ESI (m/z): $[M+Na]^+$ calcd for $C_{11}H_{12}ClNNaO$, 232.0500; found, 232.0500.

(*E*)-3-(4-Fluorophenyl)-*N*,*N*-dimethylacrylamide (3ca)
White solid, m.p. 94-96 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ: 7.64 (d, J = 15.0 Hz, 1H), 7.54-7.49 (m, 2H), 7.09-7.02 (m, 2H), 6.83 (d, J = 15.0 Hz, 1H), 3.17 (s, 3H), 3.07 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ: 166.4, 163.3 (d, J = 201.8 Hz), 140.9, 131.4 (d, J = 2.3 Hz), 129.4 (d, J = 8.3 Hz), 117.0, 115.7 (d, J = 21.8 Hz), 37.3, 35.8. HRMS ESI (m/z): $[M+H]^+$ calcd for $C_{11}H_{13}FNO$, 194.0976; found, 194.0987.

(*E*)-*N*,*N*-Dimethyl-3-(4-(trifluoromethyl)phenyl)acrylamide (3da)
White solid, m.p. 104-106 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.67 (d, J = 16.0 Hz, 1H), 7.62 (s, 4H), 6.97 (d, J = 16.0 Hz, 1H), 3.19 (s, 3H), 3.08 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ: 166.0, 139.6 (d, J = 136.5 Hz), 131.0 (d, J = 32.3 Hz), 127.9, 125.7 (q, J = 3.5 Hz), 122.1, 119.9, 37.4, 35.9. HRMS ESI (m/z): $[M+Na]^+$ calcd for $C_{12}H_{12}F_3NNaO$, 266.0763; found, 266.0766.

(*E*)-3-(4-Isopropylphenyl)-N,N-dimethylacrylamide (3ea)
White solid, m.p. 42-44 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.65 (d, J = 16.0 Hz, 1H), 7.46 (d, J = 8.0 Hz, 2H), 7.23 (d, J = 8.0 Hz, 2H), 6.85 (d, J = 16.0 Hz, 1H), 3.16 (s, 3H), 3.06 (s, 3H), 2.95-2.86 (m, 1H), 1.25 (d, J = 8.0 Hz, 6H); ^{13}C NMR (75 MHz, $CDCl_3$) δ: 166.8, 150.6, 142.2, 132.9, 127.7, 126.8, 116.3, 37.3, 35.8, 33.9, 23.7. HRMS ESI (m/z): $[M+Na]^+$ calcd for $C_{14}H_{19}NNaO$, 240.1359; found, 240.1364.

(*E*)-*N*,*N*-Dimethyl-3-(p-tolyl)acrylamide (3fa)
White solid, m.p. 98-100 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.64 (d, J = 16.0 Hz, 1H), 7.42 (d, J = 8.0 Hz, 2H), 7.17 (d, J = 8.0 Hz, 2H), 6.84 (d, J = 16.0 Hz, 1H), 3.15 (s, 3H), 3.05 (s, 3H), 2.36 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ: 166.9, 142.3, 139.8, 132.6, 129.5, 127.7, 116.3, 37.4, 35.9, 21.4. HRMS ESI (m/z): $[M+Na]^+$ calcd for $C_{12}H_{15}NNaO$, 212.1046; found, 212.1053.

(*E*)-*N*,*N*-Dimethyl-3-(*m*-tolyl)acrylamide (3ga)
Colorless oil; ^{1}H NMR (300 MHz, $CDCl_3$) δ: 7.65 (d, J = 15.0 Hz, 1H), 7.33-7.23 (m, 3H), 7.17 (s, 1H), 6.88 (d, J = 15.0 Hz, 1H), 3.17 (s, 3H), 3.06 (s, 3H), 2.36 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ: 166.6, 142.3, 138.2, 135.1, 130.2, 128.5, 128.2, 124.8, 117.0, 37.2, 35.7, 21.2. HRMS ESI (m/z): $[M+Na]^+$ calcd for $C_{12}H_{15}NNaO$, 212.1046; found, 212.1054.

(*E*)-3-(4-Methoxyphenyl)-*N*,*N*-dimethylacrylamide (3ha)
White solid, m.p. 87-89 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ: 7.64 (d, J = 15.0 Hz, 1H), 7.48 (d, J = 9.0 Hz, 2H), 6.89 (d, J = 9.0 Hz, 2H), 6.76 (d, J = 15.0 Hz, 1H), 3.81 (s, 3H), 3.15 (s, 3H), 3.05 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 166.9, 160.7, 141.9, 129.2, 127.9, 114.8, 114.1, 55.2, 37.3, 35.8. HRMS ESI (m/z): $[M+H]^+$ calcd for $C_{12}H_{16}NO_2$, 206.1176; found, 206.1175.

(*E*)-3-(2-Methoxyphenyl)-*N*,*N*-dimethylacrylamide (3ia)
White solid, m.p. 70-72°C; ^{1}H NMR (300 MHz, $CDCl_3$) δ: 7.92 (d, J = 15.0 Hz, 1H), 7.49 (d, J = 6.0 Hz, 1H), 7.30-7.27 (m, 1H), 7.02-6.89 (m, 3H), 3.86 (s, 3H), 3.15 (s, 3H), 3.05 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ: 167.1, 157.9, 137.6, 130.4, 128.7,

124.1, 120.4, 118.2, 110.9, 55.2, 37.2, 35.6. HRMS ESI (m/z): $[M+Na]^+$ calcd for $C_{12}H_{15}NNaO_2$, 228.0995; found, 228.1003.

(*E*)-3-(3-Methoxyphenyl)-*N*,*N*-dimethylacrylamide (3ja)
Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.63 (d, J = 16.0 Hz, 1H), 7.28 (d, J = 8.0 Hz, 1H), 7.13 (d, J = 4.0 Hz, 1H), 7.04 (s, 1H), 6.91-6.85 (m, 2H), 3.83 (s, 3H), 3.16 (s, 3H), 3.06 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ: 166.6, 159.8, 142.2, 136.7, 129.7, 120.3, 117.7, 115.0, 113.1, 55.3, 37.4, 35.9. HRMS ESI (m/z): $[M+H]^+$ calcd for $C_{12}H_{16}NO_2$, 206.1176; found, 206.1179.

(*E*)-3-(3,4-Dimethoxyphenyl)-*N*,*N*-dimethylacrylamide (3ka)
White solid, m.p. 93-95 ^{o}C; ^{1}H NMR (300 MHz, $CDCl_3$) δ: 7.61 (d, J = 15.0 Hz, 1H), 7.11 (d, J = 6.0 Hz, 1H), 7.03 (s, 1H), 6.85 (d, J = 6.0 Hz, 1H), 6.75 (d, J = 15.0 Hz, 1H), 3.91 (d, J = 3.0 Hz, 6H), 3.17 (s, 3H), 3.06 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ: 166.9, 150.4, 149.0, 142.3, 128.3, 121.7, 115.1, 111.1, 109.9, 55.9, 37.4, 35.9. HRMS ESI (m/z): $[M+H]^+$ calcd for $C_{13}H_{18}NO_3$, 236.1281; found, 236.1285.

(*E*)-*N*,*N*-Dimethyl-3-(3,4,5-trimethoxyphenyl)acrylamide (3la)
White solid, m.p. 110-112 ^{o}C; ^{1}H NMR (300 MHz, $CDCl_3$) δ: 7.50 (d, J = 15.0 Hz, 1H), 6.70 (d, J = 18.0 Hz, 3H), 3.80 (d, J = 6.0 Hz, 9H), 3.10 (s, 3H), 2.98 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ: 166.4, 153.2, 142.2, 139.3, 130.7, 116.5, 104.8, 60.7, 56.0, 37.3, 35.8. HRMS ESI (m/z): $[M+H]^+$ calcd for $C_{14}H_{20}NO_4$, 266.1387; found, 266.1395.

***N*,*N*-Dimethyl-3-(4-nitrophenyl)acrylamide (3ma)**
Yellow solid, m.p. 174-180 ^{o}C. **(*E*)-*N*,*N*-Dimethyl-3-(4-nitrophenyl)acrylamide:** ^{1}H NMR (400 MHz, $CDCl_3$) δ: 8.23 (d, J = 8.0 Hz, 2H), 7.71-7.66 (m, 3H), 7.04 (d, J = 16.0 Hz, 1H), 3.21 (s, 3H), 3.10 (s, 3H); **(*Z*)-*N*,*N*-Dimethyl-3-(4-nitrophenyl)acrylamide:** ^{1}H NMR (400 MHz, $CDCl_3$) δ: 8.18 (d, J = 8.0 Hz, 2H), 7.55 (d, J = 12.0 Hz, 2H), 6.72 (d, J = 12.0 Hz, 1H), 6.31 (d, J = 12.0 Hz, 1H), 3.01 (s, 3H), 2.91 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 165.6, 148.0, 141.5, 139.5, 128.3, 124.0, 121.7, 37.4, 36.0. HRMS ESI (m/z): $[M+H]^+$ calcd for $C_{11}H_{13}N_2O_3$, 221.0921; found, 221.0920.

(*E*)-*N*,*N*-Dimethyl-3-(naphthalen-1-yl)acrylamide (3na)
Light yellow oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 8.49 (d, J = 16.0 Hz, 1H), 8.22 (d, J = 8.0 Hz, 1H), 7.85 (d, J = 8.0 Hz, 2H), 7.70 (d, J = 8.0 Hz, 1H), 7.57-7.50 (m, 2H), 7.49-7.44 (m, 1H), 6.94 (d, J = 16.0 Hz, 1H), 3.18 (s, 3H), 3.10 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ: 166.6, 139.7, 133.6, 133.1, 131.5, 129.7, 128.5, 126.6, 126.1, 125.4, 124.5, 123.8, 120.5, 37.5, 36.0. HRMS ESI (m/z): $[M+Na]^+$ calcd for $C_{15}H_{15}NNaO$, 248.1046; found, 248.1046.

(*E*)-3-(Furan-2-yl)-*N*,*N*-dimethylacrylamide (3oa)
Brown oil. ^{1}H NMR (300 MHz, $CDCl_3$) δ: 7.47-7.36 (m, 2H), 6.81(d, J = 15.0 Hz, 1H), 6.55 (s, 1H), 6.45 (s, 1H), 3.16 (s, 3H), 3.06(s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ: 166.5, 151.6, 143.7, 129.1, 114.8, 113.7, 112.1, 37.3, 35.9. HRMS ESI (m/z): $[M+Na]^+$ calcd for $C_9H_{11}NNaO_2$, 188.0687; found, 188.0694.

(*E*)-*N*,*N*-Dimethyl-3-(thiophen-2-yl)acrylamide (3pa)
Brown solid, m.p. 92-94 ^{o}C; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.79 (d, J = 16.0 Hz, 1H), 7.31 (d, J = 4.0 Hz, 1H), 7.21 (d, J = 4.0 Hz, 1H), 7.04-7.02 (m, 1H), 6.69 (d, J = 16.0 Hz, 1H), 3.14 (s, 3H), 3.05 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ: 166.2, 140.4, 135.0, 130.0, 127.8, 127.0, 116.0, 37.3, 35.8. HRMS ESI (m/z): $[M+H]^+$ calcd for $C_9H_{12}NOS$, 182.0634; found, 182.0639.

(*E*)-*N*,*N*-Dimethyl-3-(pyridin-3-yl)acrylamide (3qa)
Yellow solid, m.p. 100-102 ^{o}C; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 8.76 (d, J = 1.6.0 Hz, 1H), 8.58-8.56 (m, 1H), 7.84-7.81 (m, 1H), 7.65 (d, J = 16.0 Hz, 1H), 7.33-7.30 (m, 1H), 6.98 (d, J = 16.0 Hz, 1H), 3.19 (s, 3H), 3.08 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ: 165.9, 150.1, 149.1, 138.5, 134.2, 131.0, 123.5, 119.5, 37.3, 35.9. HRMS ESI (m/z): $[M+H]^+$ calcd for $C_{10}H_{13}N_2O$, 177.1022; found, 177.1014.

(*E*)-*N*,*N*,2-Trimethyl-3-phenylacrylamide (3ra)
Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.40-7.33 (m, 4H), 7.30-7.28 (m, 1H), 6.55 (s, 1H), 3.07 (s, 6H), 2.12 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ: 173.6, 136.0, 133.3, 129.6, 129.0, 128.3, 127.3, 38.7, 34.9, 15.9. HRMS ESI (m/z): $[M+H]^+$ calcd for $C_{12}H_{16}NO$, 190.1226; found, 190.1231.

(*E*)-*N*,*N*-Diethyl-3-(4-isopropylphenyl)acrylamide (3eb)
Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.69 (d, J = 16.0 Hz, 1H), 7.45 (d, J = 8.0 Hz, 2H), 7.23 (d, J = 8.0 Hz, 2H), 6.78 (d, J = 16.0 Hz, 1H), 3.52-3.44 (m, 4H), 2.97- 2.86 (m, 1H), 1.25 (d, J = 8.0 Hz, 9H), 1.19 (t, J = 6.0 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ: 165.8, 150.5, 142.2, 133.0, 127.7, 126.8, 116.7, 42.2, 41.0, 33.9, 23.7, 15.0, 13.2. HRMS ESI (m/z): $[M+H]^+$ calcd for $C_{16}H_{24}NO$, 246.1852; found, 246.1854.

(*E*)-*N*,*N*-Dibutyl-3-(4-isopropylphenyl)acrylamide (3ec)
Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.68 (d, J = 16.0 Hz, 1H), 7.44 (d, J = 8.0 Hz, 2H), 7.23 (d, J = 8.0 Hz, 2H), 6.79 (d, J = 16.0 Hz, 1H), 3.44-3.37 (m, 4H), 2.97-2.87 (m, 1H), 1.66-1.54 (m, 4H), 1.42-1.31 (m, 4H), 1.26 (d, J = 8.0 Hz, 6H), 0.99-0.93 (m, 6H); ^{13}C NMR (75 MHz, $CDCl_3$) δ: 166.2, 150.5, 142.1, 133.2, 127.8, 126.8, 116.8, 47.9, 46.7, 34.0, 31.9, 30.1, 23.8, 20.3, 20.1, 13.9, 13.8. HRMS ESI (m/z): $[M+H]^+$ calcd for $C_{20}H_{32}NO$, 302.2478; found, 302.2468.

(*E*)-3-(4-Isopropylphenyl)-1-(pyrrolidin-1-yl)prop-2-en-1-one (3ed)
Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.68 (d, J = 16.0 Hz, 1H), 7.47 (d, J = 8.0 Hz, 2H), 7.23 (d, J = 8.0 Hz, 2H), 6.69 (d, J = 16.0 Hz, 1H), 3.64-3.57 (m, 4H), 2.97-2.86 (m, 1H), 2.03-1.96 (m, 2H), 1.92-1.85 (m, 2H), 1.25 (d, J = 8.0 Hz, 6H); ^{13}C NMR (75 MHz, $CDCl_3$) δ: 164.8, 150.6, 141.6, 132.8, 127.8, 126.7, 117.7, 46.5, 45.9, 33.9, 26.0, 24.2, 23.7. HRMS ESI (m/z): $[M+H]^+$ calcd for $C_{16}H_{22}NO$, 244.1696; found, 244.1695.

(*E*)-3-(4-Isopropylphenyl)-1-(piperidin-1-yl)prop-2-en-1-one (3ee)
White solid, m.p. 53-55 ^{o}C; ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.62 (d, J = 16.0 Hz, 1H), 7.45 (d, J = 8.0 Hz, 2H), 7.22 (d, J = 8.0 Hz, 2H), 6.85 (d, J = 16.0 Hz, 1H), 3.62 (d, J = 28.0 Hz, 4H), 2.96-2.86 (m, 1H), 1.69-1.66 (m, 2H), 1.61-1.57 (m, 4H), 1.25 (d, J = 8.0 Hz, 6H); ^{13}C NMR (75 MHz, $CDCl_3$) δ: 165.51, 150.51, 142.14, 133.06, 127.69, 126.78, 116.63, 46.96, 43.29, 33.95, 26.70, 25.56, 24.60, 23.77. HRMS ESI (m/z): $[M+H]^+$ calcd for $C_{17}H_{24}NO$, 258.1852; found, 258.1841.

(*E*)-3-(4-Isopropylphenyl)-1-morpholinoprop-2-en-1-one (3ef)
Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.69 (d, J = 16.0 Hz, 1H), 7.46 (d, J = 8.0 Hz, 2H), 7.23 (d, J = 8.0 Hz, 2H), 6.80 (d, J = 16.0 Hz, 1H), 3.70 (d, J = 16.0 Hz, 8H), 2.97-2.87 (m, 1H), 1.26 (d, J = 8.0 Hz, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ:

165.7, 150.9, 143.2, 132.7, 127.8, 126.9, 115.4, 66.8, 46.3, 46.1, 42.4, 34.0, 23.7. HRMS ESI (m/z): $[M+H]^+$ calcd for $C_{16}H_{22}NO_2$, 260.1645; found, 260.1646.

(*E*)-3-(4-Isopropylphenyl)acrylamide (3eg)

White solid, m.p. 195-197 °C; ^{1}H NMR (400 MHz, DMSO-d_6) δ: 7.51 (s, 1H), 7.47 (d, J = 8.0 Hz, 2H), 7.38 (d, J = 16.0 Hz, 1H), 7.27 (d, J = 8.0 Hz, 2H), 7.06 (s, 1H), 6.56 (d, J = 16.0 Hz, 1H), 2.94-2.84 (m, 1H), 1.19(d, J = 8.0 Hz, 6H); ^{13}C NMR (100 MHz, DMSO-d_6) δ: 166.9, 150.1, 139.3, 132.6, 127.7, 126.9, 121.3, 33.4, 23.7. HRMS ESI (m/z): $[M+Na]^+$ calcd for $C_{12}H_{15}NNaO$, 212.1046; found, 212.1042.

(*E*)-3-(4-Isopropylphenyl)-N-methylacrylamide (3eh)

Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.61 (d, J = 16.0 Hz, 1H), 7.42 (d, J = 8.0 Hz, 2H), 7.21 (d, J = 8.0 Hz, 2H), 6.38 (d, J = 16.0 Hz, 1H), 5.90 (s, 1H), 2.94-2.87 (m, 4H), 1.24 (d, J = 8.0 Hz, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 167.2, 151.0, 140.9, 132.7, 128.0, 127.1, 119.8, 34.2, 26.7, 24.0. HRMS ESI (m/z): $[M+H]^+$ calcd for $C_{13}H_{18}NO$, 204.1383; found, 204.1384.

***N*,*N*-Dimethyl-2-nitrobenzamide**

Yellow oil. ^{1}H NMR (300 MHz, $CDCl_3$) δ: 8.20 (d, J = 6.0 Hz, 1H), 7.73 (t, J = 7.5 Hz, 1H), 7.58 (t, J = 7.5 Hz, 1H), 7.41 (d, J = 6 Hz, 1H), 3.17 (s, 3H), 2.85 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ: 167.9, 145.1, 134.6, 133.3, 129.7, 128.1, 124.7, 38.2, 34.9. HRMS ESI (m/z): $[M+Na]^+$ calcd for $C_9H_{10}N_2NaO_3$, 217.0584; found, 217.0593.

***N*,*N*-Diethylcinnamamide**

White solid, m.p. 67-69 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.71 (d, J = 16.0 Hz, 1H), 7.54-7.51 (m, 2H), 7.39-7.33 (m, 3H), 6.83 (d, J = 16.0 Hz, 1H), 3.52-3.45 (m, 4H), 1.26 (t, J = 8.0 Hz, 3H), 1.19 (t, J = 8.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 165.9, 142.5, 135.7, 129.6, 128.9, 127.9, 118.0, 42.5, 41.3, 15.3, 13.4. HRMS ESI (m/z): $[M+H]^+$ calcd for $C_{13}H_{18}NO$, 204.1383; found, 204.1379.

(*E*)-*tert*-Butyl 3-phenylprop-2-eneperoxoate (I)

^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.75 (d, J = 16.0 Hz, 1H), 7.53 (t, J = 4.0 Hz, 2H), 7.40 (t, J = 3.0 Hz, 3H), 6.41 (d, J = 16.0 Hz, 1H), 1.38 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 165.5, 146.3, 134.2, 130.9, 129.2, 128.4, 113.4, 83.9, 26.4. MS ESI (m/z): $[M+Na]^+$ calcd for $C_{13}H_{16}NaO_3$, 243.1; found, 243.1.

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Supporting Information

Copper-Catalyzed Synthesis of *α, β*-Unsaturated Acylamides *via* Direct Amidation from Cinnamic Acids and *N*-Substituted Formamides

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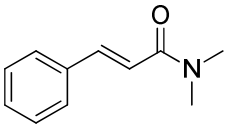
General Information:

All reactions were carried out under an argon atmosphere condition. Cupric sulfate was purchased from Alfa. Various cinnamic acids and *N*-substituted formamides were purchased from Aldrich, Acros or Alfa. Column chromatography was generally performed on silica gel (100-200 mesh) and reactions were monitored by thin layer chromatography (TLC) using UV light (254 nm) to visualize the course of the reactions. The ^{1}H (300 MHz or 400 MHz) and ^{13}C NMR (75 MHz or 100 MHz) data were recorded on Varian 300 M or 400 M spectrometers using $CDCl_3$ as solvent. The chemical shifts (δ) are reported in ppm and coupling constants (J) in Hz. ^{1}H NMR spectra was recorded with tetramethylsilane (δ = 0.00 ppm) as internal reference; ^{13}C NMR spectra was recorded with $CDCl_3$ (δ = 77.000 ppm) or DMSO-d_6 (δ = 39.500 ppm) as internal reference. ESI-MS and HRMS were performed by the State-authorized Analytical Center in Soochow University.

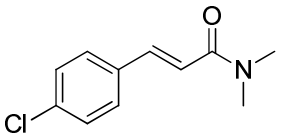
General procedure for copper-catalyzed direct amidation between cinnamic acid and *N*-substituted formamide: $CuSO_4$ (0.06 mmol) and cinnamic acid (0.3 mmol) were added to a Schlenk tube equipped with a magnetic stir bar under argon atmosphere. Then *N*-substituted formamide (2.0 mL) and DTBP (di-tert-butyl peroxide, 0.6 mmol) were added under Ar. The resulting reaction mixture was kept stirring until TLC monitoring indicated the complete disappearance of the starting material. At the end of the reaction, the reaction mixture was cooled to room temperature and was diluted with ethyl acetate and water was added. The combined organic phase was dried over anhydrous Na_2SO_4. After removal of the solvent, the residue was subjected to column chromatography on silica gel using ethyl acetate and petroleum ether mixtures to afford the corresponding product.

Characterization of the corresponding products:



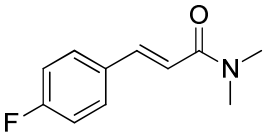
(*E*)-*N*,*N*-Dimethylcinnamamide (3aa)

^{1}H NMR (300 MHz, $CDCl_3$) δ: 7.68 (d, J = 15.0 Hz, 1H), 7.52 (s, 2H), 7.35 (s, 2H), 6.90 (d, J = 15.0 Hz, 1H), 3.17 (s,3H), 3.07 (s,3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ: 166.7, 142.3, 135.3, 129.5, 128.8, 127.8, 117.4, 37.4, 35.9. MS ESI (m/z): $[M+H]^+$ calcd for $C_{11}H_{14}NO$, 176.1; found, 176.1.



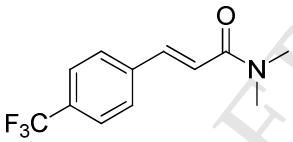
(*E*)-3-(4-Chlorophenyl)-*N*,*N*-dimethylacrylamide (3ba)

^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.61 (d, J = 16.0 Hz, 1H), 7.45 (d, J = 8.0 Hz, 2H), 7.33 (d, J = 8.0 Hz, 2H), 6.86 (d, J = 16.0 Hz, 1H), 3.16 (s, 3H), 3.06 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ: 166.3, 140.9, 135.2, 133.7, 128.9, 128.9, 117.9, 37.3, 35.9. HRMS ESI (m/z): $[M+Na]^+$ calcd for $C_{11}H_{12}ClNNaO$, 232.0500; found, 232.0500.



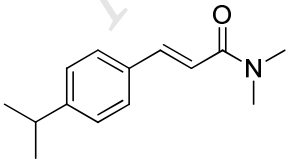
(*E*)-3-(4-Fluorophenyl)-*N*,*N*-dimethylacrylamide (3ca)

^{1}H NMR (300 MHz, $CDCl_3$) δ: 7.64 (d, J = 15.0 Hz, 1H), 7.54-7.49 (m, 2H), 7.09-7.02 (m, 2H), 6.83 (d, J = 15.0 Hz, 1H), 3.17 (s, 3H), 3.07 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ: 166.4, 163.3 (d, J = 201.8 Hz), 140.9, 131.4 (d, J = 2.3 Hz), 129.4 (d, J = 8.3 Hz), 117.0, 115.7 (d, J = 21.8 Hz), 37.3, 35.8. HRMS ESI (m/z): $[M+H]^+$ calcd for $C_{11}H_{13}FNO$, 194.0976; found, 194.0987.



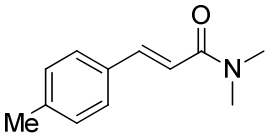
(*E*)-*N*,*N*-Dimethyl-3-(4-(trifluoromethyl)phenyl)acrylamide (3da)

^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.67 (d, J = 16.0 Hz, 1H), 7.62 (s, 4H), 6.97 (d, J = 16.0 Hz, 1H), 3.19 (s, 3H), 3.08 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ: 166.0, 139.6 (d, J = 136.5 Hz), 131.0 (d, J = 32.3 Hz), 127.9, 125.7 (q, J = 3.5 Hz), 122.1, 119.9, 37.4, 35.9. HRMS ESI (m/z): $[M+Na]^+$ calcd for $C_{12}H_{12}F_3NNaO$, 266.0763; found, 266.0766.



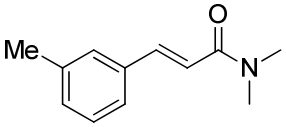
(*E*)-3-(4-Isopropylphenyl)-N,N-dimethylacrylamide (3ea)

^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.65 (d, J = 16.0 Hz, 1H), 7.46 (d, J = 8.0 Hz, 2H), 7.23 (d, J = 8.0 Hz, 2H), 6.85 (d, J = 16.0 Hz, 1H), 3.16 (s, 3H), 3.06 (s, 3H), 2.95-2.86 (m, 1H), 1.25 (d, J = 8.0 Hz, 6H); ^{13}C NMR (75 MHz, $CDCl_3$) δ: 166.8, 150.6, 142.2, 132.9, 127.7, 126.8, 116.3, 37.3, 35.8, 33.9, 23.7. HRMS ESI (m/z): $[M+Na]^+$ calcd for $C_{14}H_{19}NNaO$, 240.1359; found, 240.1364.



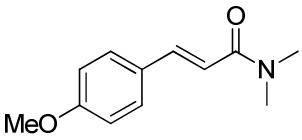
(*E*)-*N*,*N*-Dimethyl-3-(p-tolyl)acrylamide (3fa)

^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.64 (d, J = 16.0 Hz, 1H), 7.42 (d, J = 8.0 Hz, 2H), 7.17 (d, J = 8.0 Hz, 2H), 6.84 (d, J = 16.0 Hz, 1H), 3.15 (s, 3H), 3.05 (s, 3H), 2.36 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ: 166.9, 142.3, 139.8, 132.6, 129.5, 127.7, 116.3, 37.4, 35.9, 21.4. HRMS ESI (m/z): $[M+Na]^+$ calcd for $C_{12}H_{15}NNaO$, 212.1046; found, 212.1053.



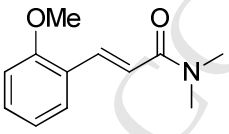
(*E*)-*N*,*N*-Dimethyl-3-(*m*-tolyl)acrylamide (3ga)

^{1}H NMR (300 MHz, $CDCl_3$) δ: 7.65 (d, J = 15.0 Hz, 1H), 7.33-7.23 (m, 3H), 7.17 (s, 1H), 6.88 (d, J = 15.0 Hz, 1H), 3.17 (s, 3H), 3.06 (s, 3H), 2.36 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ: 166.6, 142.3, 138.2, 135.1, 130.2, 128.5, 128.2, 124.8, 117.0, 37.2, 35.7, 21.2. HRMS ESI (m/z): $[M+Na]^+$ calcd for $C_{12}H_{15}NNaO$, 212.1046; found, 212.1054.



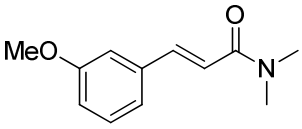
(*E*)-3-(4-Methoxyphenyl)-*N*,*N*-dimethylacrylamide（3ha）

^{1}H NMR (300 MHz, $CDCl_3$) δ: 7.64 (d, J = 15.0 Hz, 1H), 7.48 (d, J = 9.0 Hz, 2H), 6.89 (d, J = 9.0 Hz, 2H), 6.76 (d, J = 15.0 Hz, 1H), 3.81 (s, 3H), 3.15 (s, 3H), 3.05 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 166.9, 160.7, 141.9, 129.2, 127.9, 114.8, 114.1, 55.2, 37.3, 35.8. HRMS ESI (m/z): $[M+H]^+$ calcd for $C_{12}H_{16}NO_2$, 206.1176; found, 206.1175.



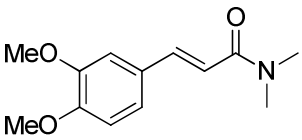
(*E*)-3-(2-Methoxyphenyl)-*N*,*N*-dimethylacrylamide（3ia）

^{1}H NMR (300 MHz, $CDCl_3$) δ: 7.92 (d, J = 15.0 Hz, 1H), 7.49 (d, J = 6.0 Hz, 1H), 7.30-7.27 (m, 1H), 7.02-6.89 (m, 3H), 3.86 (s, 3H), 3.15 (s, 3H), 3.05 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ: 167.1, 157.9, 137.6, 130.4, 128.7, 124.1, 120.4, 118.2, 110.9, 55.2, 37.2, 35.6. HRMS ESI (m/z): $[M+Na]^+$ calcd for $C_{12}H_{15}NNaO_2$, 228.0995; found, 228.1003.



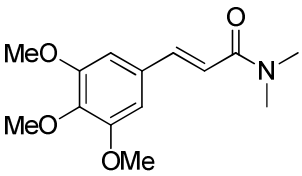
(*E*)-3-(3-Methoxyphenyl)-*N*,*N*-dimethylacrylamide（3ja）

^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.63 (d, J = 16.0 Hz, 1H), 7.28 (d, J = 8.0 Hz, 1H), 7.13 (d, J = 4.0 Hz, 1H), 7.04 (s, 1H), 6.91-6.85 (m, 2H), 3.83 (s, 3H), 3.16 (s, 3H), 3.06 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ: 166.6, 159.8, 142.2, 136.7, 129.7, 120.3, 117.7, 115.0, 113.1, 55.3, 37.4, 35.9. HRMS ESI (m/z): $[M+H]^+$ calcd for $C_{12}H_{16}NO_2$, 206.1176; found, 206.1179.



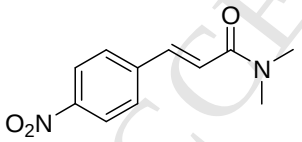
(*E*)-3-(3,4-Dimethoxyphenyl)-*N*,*N*-dimethylacrylamide (3ka)

^{1}H NMR (300 MHz, $CDCl_3$) δ: 7.61 (d, J = 15.0 Hz, 1H), 7.11 (d, J = 6.0 Hz, 1H), 7.03 (s, 1H), 6.85 (d, J = 6.0 Hz, 1H), 6.75 (d, J = 15.0 Hz, 1H), 3.91 (d, J = 3.0 Hz, 6H), 3.17 (s, 3H), 3.06 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ: 166.9, 150.4, 149.0, 142.3, 128.3, 121.7, 115.1, 111.1, 109.9, 55.9, 37.4, 35.9. HRMS ESI (m/z): $[M+H]^+$ calcd for $C_{13}H_{18}NO_3$, 236.1281; found, 236.1285.



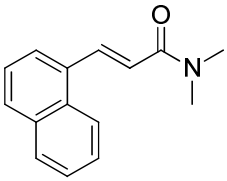
(*E*)-*N*,*N*-Dimethyl-3-(3,4,5-trimethoxyphenyl)acrylamide (3la)

^{1}H NMR (300 MHz, $CDCl_3$) δ: 7.50 (d, J = 15.0 Hz, 1H), 6.70 (d, J = 18.0 Hz, 3H), 3.80 (d, J = 6.0 Hz, 9H), 3.10 (s, 3H), 2.98 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ: 166.4, 153.2, 142.2, 139.3, 130.7, 116.5, 104.8, 60.7, 56.0, 37.3, 35.8. HRMS ESI (m/z): $[M+H]^+$ calcd for $C_{14}H_{20}NO_4$, 266.1387; found, 266.1395.



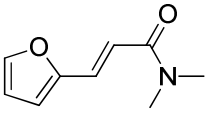
***N*,*N*-Dimethyl-3-(4-nitrophenyl)acrylamide (3ma)**

(*E*)-*N*,*N*-Dimethyl-3-(4-nitrophenyl)acrylamide: ^{1}H NMR (400 MHz, $CDCl_3$) δ: 8.23 (d, J = 8.0 Hz, 2H), 7.71-7.66 (m, 3H), 7.04 (d, J = 16.0 Hz, 1H), 3.21 (s, 3H), 3.10 (s, 3H); **(*Z*)-*N*,*N*-Dimethyl-3-(4-nitrophenyl)acrylamide:** ^{1}H NMR (400 MHz, $CDCl_3$) δ: 8.18 (d, J = 8.0 Hz, 2H), 7.55 (d, J = 12.0 Hz, 2H), 6.72 (d, J = 12.0 Hz, 1H), 6.31 (d, J = 12.0 Hz, 1H), 3.01 (s, 3H), 2.91 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 165.6, 148.0, 141.5, 139.5, 128.3, 124.0, 121.7, 37.4, 36.0. HRMS ESI (m/z): $[M+H]^+$ calcd for $C_{11}H_{13}N_2O_3$, 221.0921; found, 221.092.



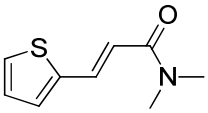
(*E*)-*N*,*N*-Dimethyl-3-(naphthalen-1-yl)acrylamide (3na)

^{1}H NMR (400 MHz, $CDCl_3$) δ: 8.49 (d, J = 16.0 Hz, 1H), 8.22 (d, J = 8.0 Hz, 1H), 7.85 (d, J = 8.0 Hz, 2H), 7.70 (d, J = 8.0 Hz, 1H), 7.57-7.50 (m, 2H), 7.49-7.44 (m, 1H), 6.94 (d, J = 16.0 Hz, 1H), 3.18 (s, 3H), 3.10 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ: 166.6, 139.7, 133.6, 133.1, 131.5, 129.7, 128.5, 126.6, 126.1, 125.4, 124.5, 123.8, 120.5, 37.5, 36.0. HRMS ESI (m/z): $[M+Na]^+$ calcd for $C_{15}H_{15}NNaO$, 248.1046; found, 248.1046.



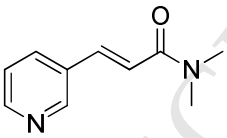
(*E*)-3-(Furan-2-yl)-*N*,*N*-dimethylacrylamide (3oa)

^{1}H NMR (300 MHz, $CDCl_3$) δ: 7.47-7.36 (m, 2H), 6.81(d, J = 15.0 Hz, 1H), 6.55 (s, 1H), 6.45 (s, 1H), 3.16 (s, 3H), 3.06(s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ: 166.5, 151.6, 143.7, 129.1, 114.8, 113.7, 112.1, 37.3, 35.9. HRMS ESI (m/z): $[M+Na]^+$ calcd for $C_9H_{11}NNaO_2$, 188.0687; found, 188.0694.



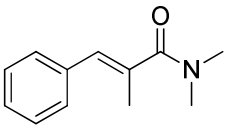
(*E*)-*N*,*N*-Dimethyl-3-(thiophen-2-yl)acrylamide (3pa)

^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.79 (d, J = 16.0 Hz, 1H), 7.31 (d, J = 4.0 Hz, 1H), 7.21 (d, J = 4.0 Hz, 1H), 7.04-7.02 (m, 1H), 6.69 (d, J = 16.0 Hz, 1H), 3.14 (s, 3H), 3.05 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ: 166.2, 140.4, 135.0, 130.0, 127.8, 127.0, 116.0, 37.3, 35.8. HRMS ESI (m/z): $[M+H]^+$ calcd for $C_9H_{12}NOS$, 182.0634; found, 182.0639.



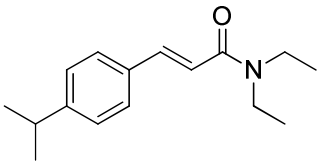
(*E*)-*N*,*N*-Dimethyl-3-(pyridin-3-yl)acrylamide (3qa)

^{1}H NMR (400 MHz, $CDCl_3$) δ: 8.76 (d, J = 1.6.0 Hz, 1H), 8.58-8.56 (m, 1H), 7.84-7.81 (m, 1H), 7.65 (d, J = 16.0 Hz, 1H), 7.33-7.30 (m, 1H), 6.98 (d, J = 16.0 Hz, 1H), 3.19 (s, 3H), 3.08 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ: 165.9, 150.1, 149.1, 138.5, 134.2, 131.0, 123.5, 119.5, 37.3, 35.9. HRMS ESI (m/z): $[M+H]^+$ calcd for $C_{10}H_{13}N_2O$, 177.1022; found, 177.1014.



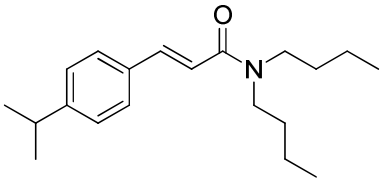
(*E*)-*N*,*N*,2-Trimethyl-3-phenylacrylamide (3ra)

^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.40-7.33 (m, 4H), 7.30-7.28 (m, 1H), 6.55 (s, 1H), 3.07 (s, 6H), 2.12 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ: 173.6, 136.0, 133.3, 129.6, 129.0, 128.3, 127.3, 38.7, 34.9, 15.9. HRMS ESI (m/z): $[M+H]^+$ calcd for $C_{12}H_{16}NO$, 190.1226; found, 190.1231.



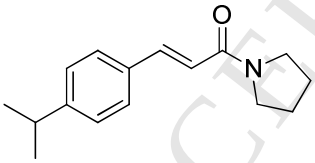
(*E*)-*N*,*N*-Diethyl-3-(4-isopropylphenyl)acrylamide (3eb)

^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.69 (d, J = 16.0 Hz, 1H), 7.45 (d, J = 8.0 Hz, 2H), 7.23 (d, J = 8.0 Hz, 2H), 6.78 (d, J = 16.0 Hz, 1H), 3.52-3.44 (m, 4H), 2.97- 2.86 (m, 1H), 1.25 (d, J = 8.0 Hz, 9H), 1.19 (t, J = 6.0 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ: 165.8, 150.5, 142.2, 133.0, 127.7, 126.8, 116.7, 42.2, 41.0, 33.9, 23.7, 15.0, 13.2. HRMS ESI (m/z): $[M+H]^+$ calcd for $C_{16}H_{24}NO$, 246.1852; found, 246.1854.



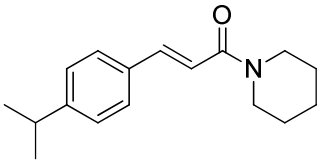
(*E*)-*N*,*N*-Dibutyl-3-(4-isopropylphenyl)acrylamide (3ec)

^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.68 (d, J = 16.0 Hz, 1H), 7.44 (d, J = 8.0 Hz, 2H), 7.23 (d, J = 8.0 Hz, 2H), 6.79 (d, J = 16.0 Hz, 1H), 3.44-3.37 (m, 4H), 2.97-2.87 (m, 1H), 1.66-1.54 (m, 4H), 1.42-1.31 (m, 4H), 1.26 (d, J = 8.0 Hz, 6H), 0.99-0.93 (m, 6H); ^{13}C NMR (75 MHz, $CDCl_3$) δ: 166.2, 150.5, 142.1, 133.2, 127.8, 126.8, 116.8, 47.9, 46.7, 34.0, 31.9, 30.1, 23.8, 20.3, 20.1, 13.9, 13.8. HRMS ESI (m/z): $[M+H]^+$ calcd for $C_{20}H_{32}NO$, 302.2478; found, 302.2468.



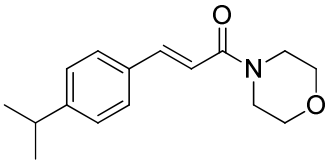
(*E*)-3-(4-Isopropylphenyl)-1-(pyrrolidin-1-yl)prop-2-en-1-one (3ed)

^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.68 (d, J = 16.0 Hz, 1H), 7.47 (d, J = 8.0 Hz, 2H), 7.23 (d, J = 8.0 Hz, 2H), 6.69 (d, J = 16.0 Hz, 1H), 3.64-3.57 (m, 4H), 2.97-2.86 (m, 1H), 2.03-1.96 (m, 2H), 1.92-1.85 (m, 2H), 1.25 (d, J = 8.0 Hz, 6H); ^{13}C NMR (75 MHz, $CDCl_3$) δ: 164.8, 150.6, 141.6, 132.8, 127.8, 126.7, 117.7, 46.5, 45.9, 33.9, 26.0, 24.2, 23.7. HRMS ESI (m/z): $[M+H]^+$ calcd for $C_{16}H_{22}NO$, 244.1696; found, 244.1695.



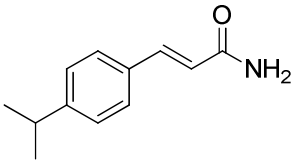
(E)-3-(4-isopropylphenyl)-1-(piperidin-1-yl)prop-2-en-1-one (3ee)

^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.62 (d, *J* = 16.0 Hz, 1H), 7.45 (d, *J* = 8.0 Hz, 2H), 7.22 (d, *J* = 8.0 Hz, 2H), 6.85 (d, *J* = 16.0 Hz, 1H), 3.62 (d, *J* = 28.0 Hz, 4H), 2.96-2.86 (m, 1H), 1.69-1.66 (m, 2H), 1.61-1.57 (m, 4H), 1.25 (d, *J* = 8.0 Hz, 6H); ^{13}C NMR (75 MHz, $CDCl_3$) δ: 165.51, 150.51, 142.14, 133.06, 127.69, 126.78, 116.63, 46.96, 43.29, 33.95, 26.70, 25.56, 24.60, 23.77. HRMS ESI (m/z): $[M+H]^+$ calcd for $C_{17}H_{24}NO$, 258.1852; found, 258.1841.



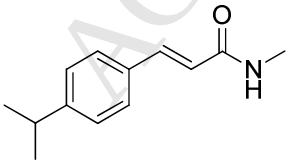
(E)-3-(4-Isopropylphenyl)-1-morpholinoprop-2-en-1-one (3ef)

^{1}H NMR (400 MHz, $CDCl_3$) *δ*: 7.69 (d, *J* = 16.0 Hz, 1H), 7.46 (d, *J* = 8.0 Hz, 2H), 7.23 (d, *J* = 8.0 Hz, 2H), 6.80 (d, *J* = 16.0 Hz, 1H), 3.70 (d, *J* = 16.0 Hz, 8H), 2.97-2.87 (m, 1H), 1.26 (d, *J* = 8.0 Hz, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ*: 165.7, 150.9, 143.2, 132.7, 127.8, 126.9, 115.4, 66.8, 46.3, 46.1, 42.4, 34.0, 23.7. HRMS ESI (m/z): $[M+H]^+$ calcd for $C_{16}H_{22}NO_2$, 260.1645; found, 260.1646.



(*E*)-3-(4-Isopropylphenyl)acrylamide (3eg)

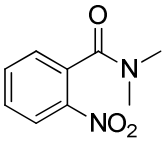
^{1}H NMR (400 MHz, DMSO-d_6) *δ*: 7.51 (s, 1H), 7.47 (d, *J* = 8.0 Hz, 2H), 7.38 (d, *J* = 16.0 Hz, 1H), 7.27 (d, *J* = 8.0 Hz, 2H), 7.06 (s, 1H), 6.56 (d, *J* = 16.0 Hz, 1H), 2.94-2.84 (m, 1H), 1.19(d, *J* = 8.0 Hz, 6H); ^{13}C NMR (100 MHz, DMSO-d_6) *δ*: 166.9, 150.1, 139.3, 132.6, 127.7, 126.9, 121.3, 33.4, 23.7. HRMS ESI (m/z): $[M+Na]^+$ calcd for $C_{12}H_{15}NNaO$, 212.1046; found, 212.1042.



(*E*)-3-(4-Isopropylphenyl)-N-methylacrylamide (3eh)

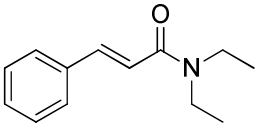
^{1}H NMR (400 MHz, $CDCl_3$) *δ*: 7.61 (d, *J* = 16.0 Hz, 1H), 7.42 (d, *J* = 8.0 Hz, 2H), 7.21 (d, *J* = 8.0 Hz, 2H), 6.38 (d, *J* = 16.0 Hz, 1H), 5.90 (s, 1H), 2.94-2.87 (m, 4H), 1.24 (d, *J* = 8.0 Hz, 6H); ^{13}C

NMR (100 MHz, $CDCl_3$) δ: 167.2, 151.0, 140.9, 132.7, 128.0, 127.1, 119.8, 34.2, 26.7, 24.0. HRMS ESI (m/z): $[M+H]^+$ calcd for $C_{13}H_{18}NO$, 204.1383; found, 204.1384.



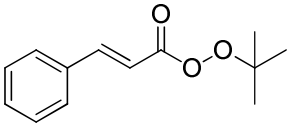
***N,N*-Dimethyl-2-nitrobenzamide**

^{1}H NMR (300 MHz, $CDCl_3$) δ: 8.20 (d, J = 6.0 Hz, 1H), 7.73 (t, J = 7.5 Hz, 1H), 7.58 (t, J = 7.5 Hz, 1H), 7.41 (d, J = 6 Hz, 1H), 3.17 (s, 3H), 2.85 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ: 167.9, 145.1, 134.6, 133.3, 129.7, 128.1, 124.7, 38.2, 34.9. HRMS ESI (m/z): $[M+Na]^+$ calcd for $C_9H_{10}N_2NaO_3$, 217.0584; found, 217.0593.



N,N-diethylcinnamamide

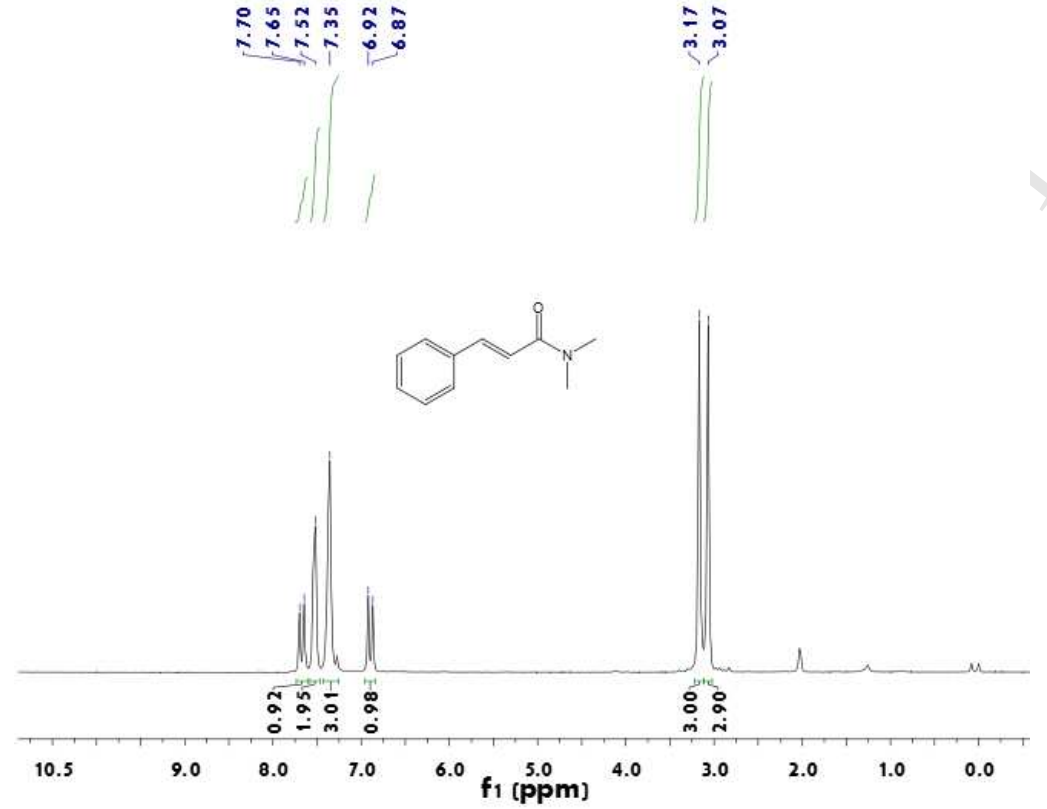
^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.71 (d, J = 16.0 Hz, 1H), 7.54-7.51 (m, 2H), 7.39-7.33 (m, 3H), 6.83 (d, J = 16.0 Hz, 1H), 3.52-3.45 (m, 4H), 1.26 (t, J = 8.0 Hz, 3H), 1.19 (t, J = 8.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 165.9, 142.5, 135.7, 129.6, 128.9, 127.9, 118.0, 42.5, 41.3, 15.3, 13.4. HRMS ESI (m/z): $[M+H]^+$ calcd for $C_{13}H_{18}NO$, 204.1383; found, 204.1379.

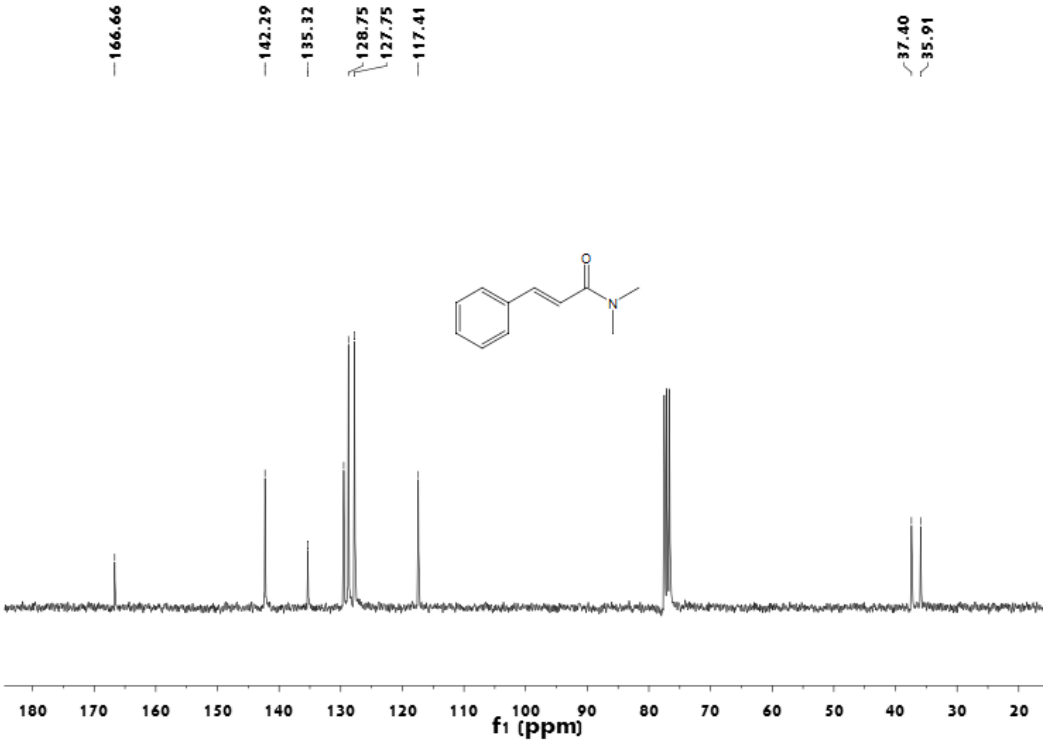


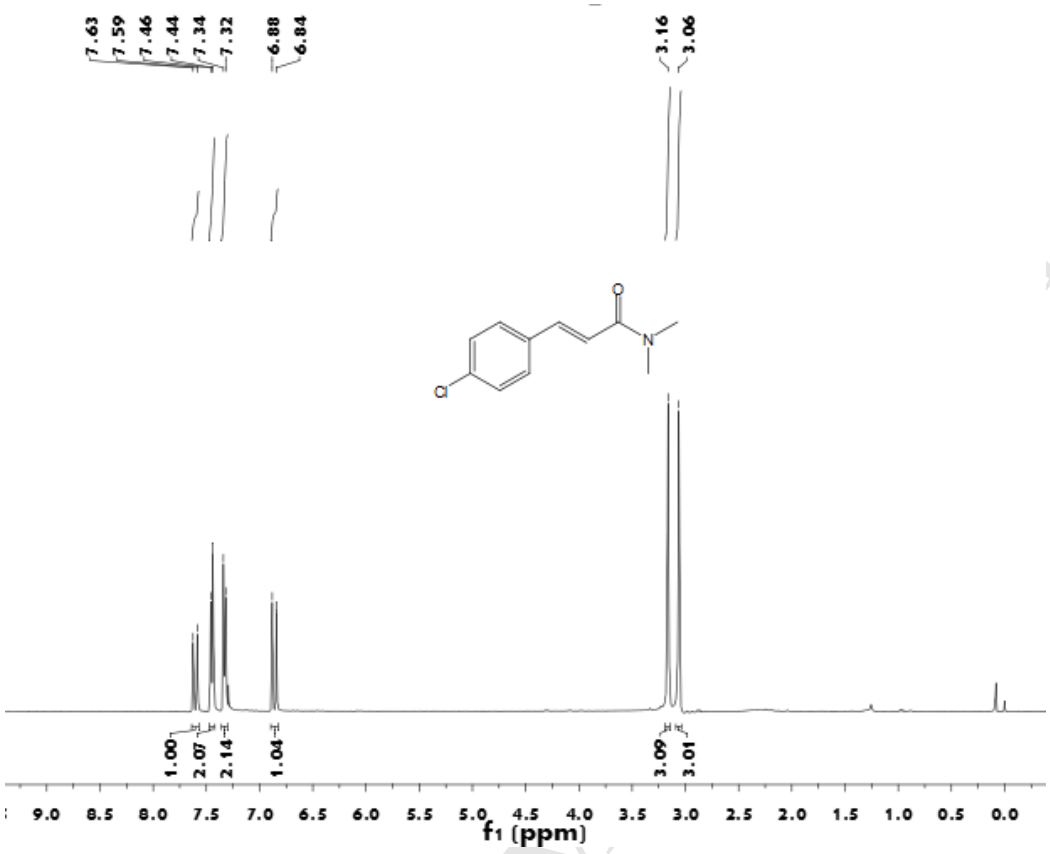
(*E*)-*tert*-Butyl 3-phenylprop-2-eneperoxoate (I)

^{1}H NMR (400 MHz, $CDCl_3$) δ: 7.75 (d, J = 16.0 Hz, 1H), 7.53 (t, J = 4.0 Hz, 2H), 7.40 (t, J = 3.0 Hz, 3H), 6.41 (d, J = 16.0 Hz, 1H), 1.38 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ: 165.5, 146.3, 134.2, 130.9, 129.2, 128.4, 113.4, 83.9, 26.4. MS ESI (m/z): $[M+Na]^+$ calcd for $C_{13}H_{16}NaO_3$, 243.1; found, 243.1.

Copy of HRMS and NMR Spectra for desired products:



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6.84
3.16
3.06
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N
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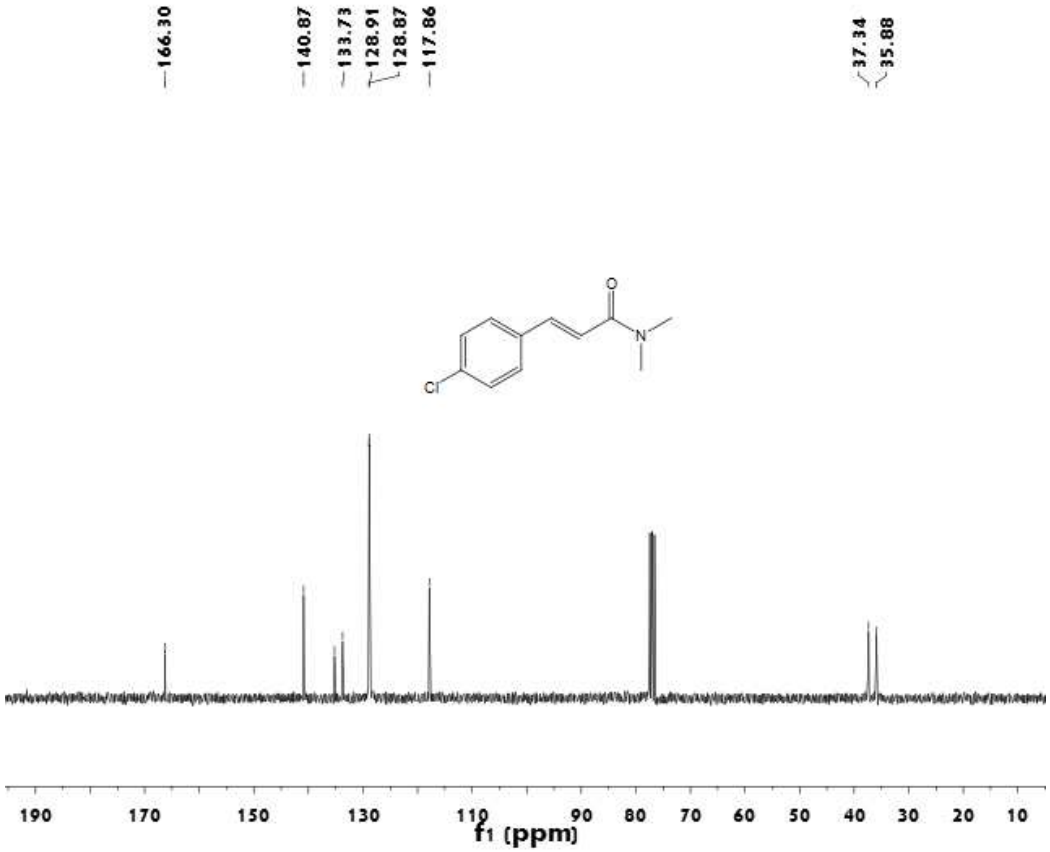
1.04
3.09
3.01
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)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35.88
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N
Cl
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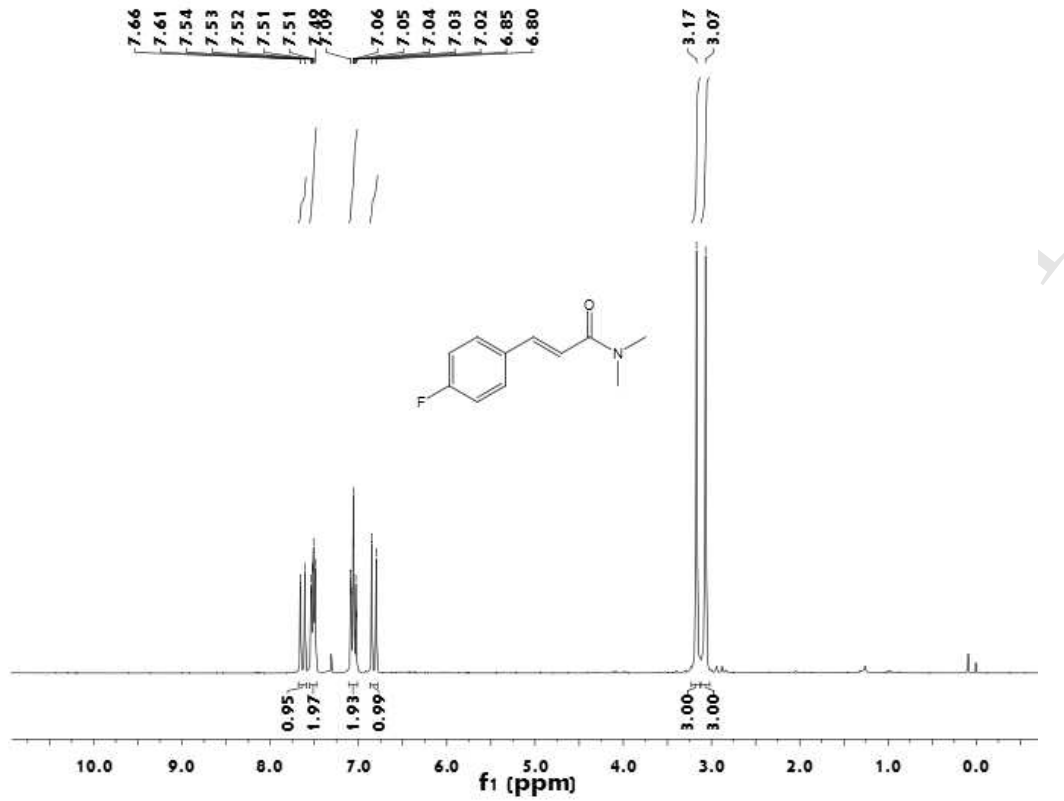
f1 (ppm)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7.03
7.02
6.85
6.80
3.17
3.07
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N
F
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1.93
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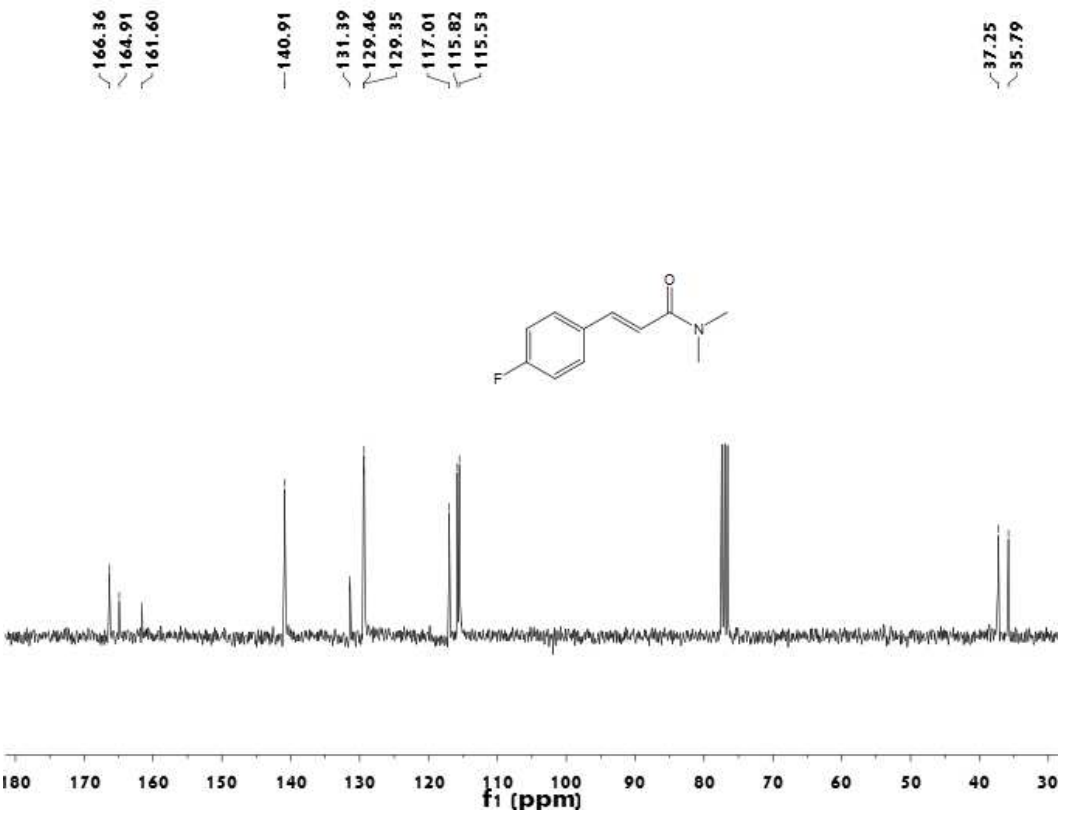
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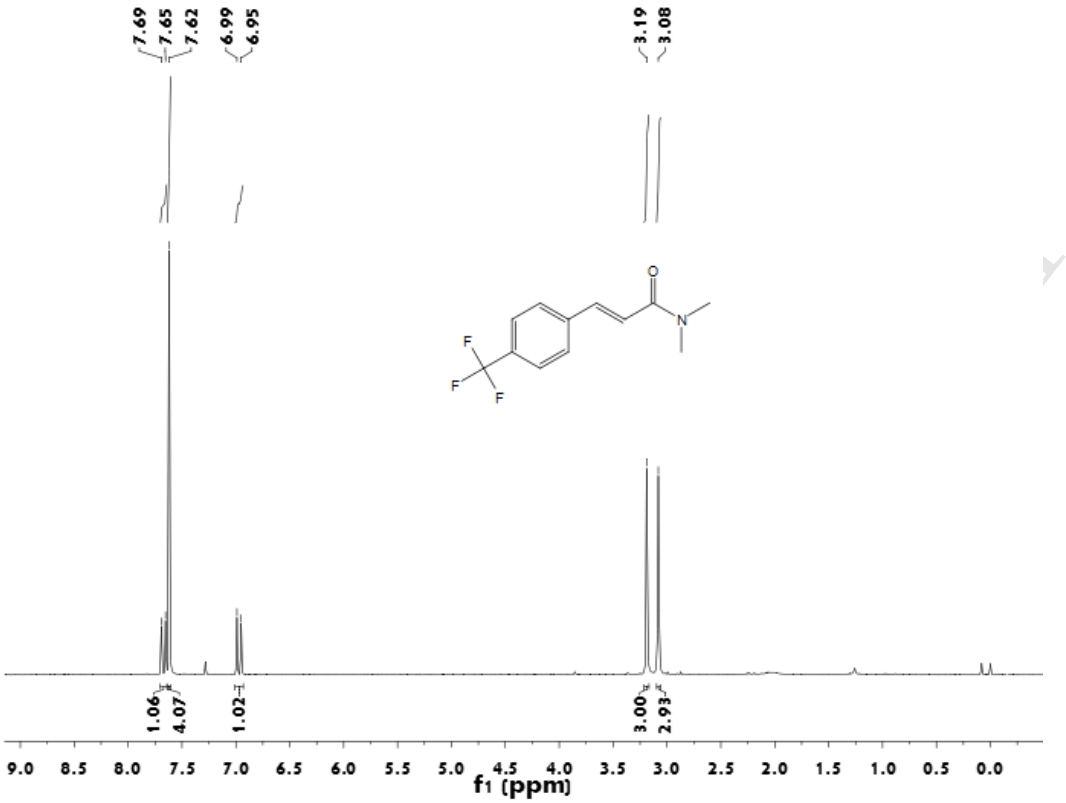
f1 (ppm)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F
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F
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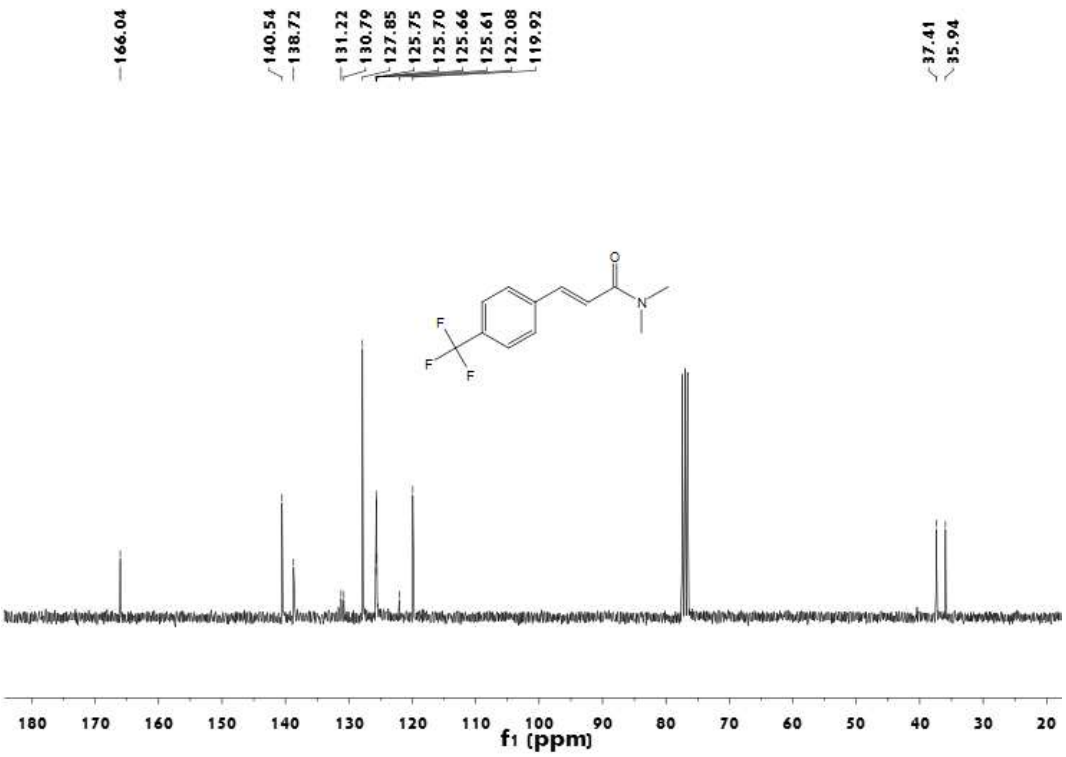
3.00
2.93
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)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F
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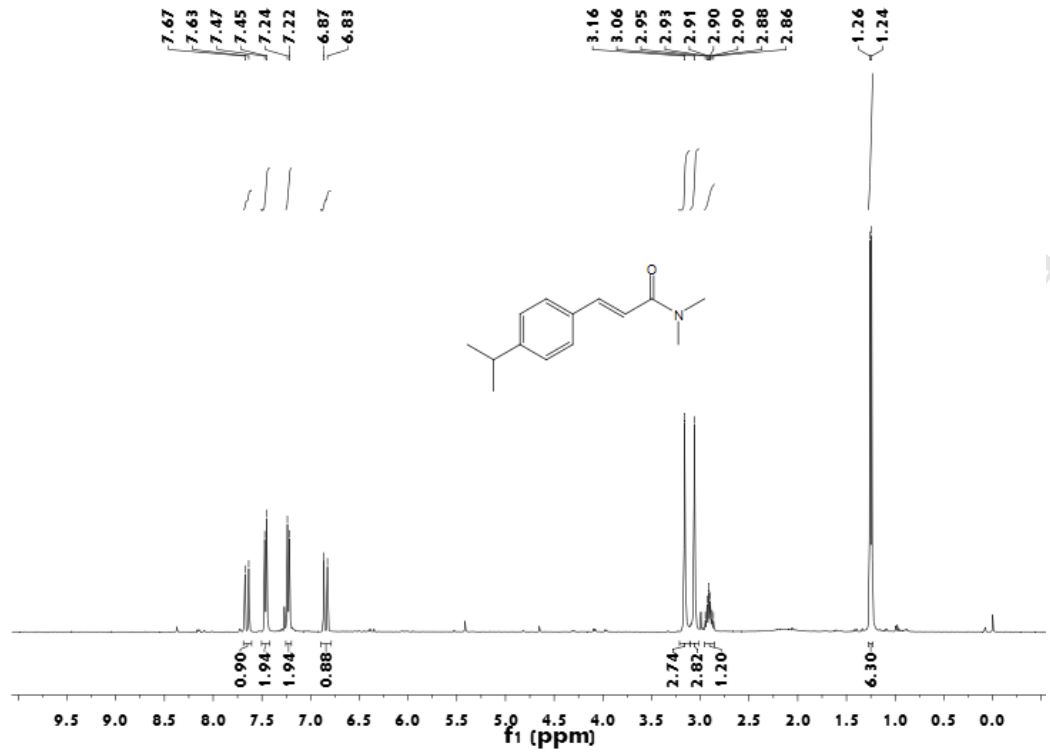
f1 (ppm)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1.24
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2.82
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6.30
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
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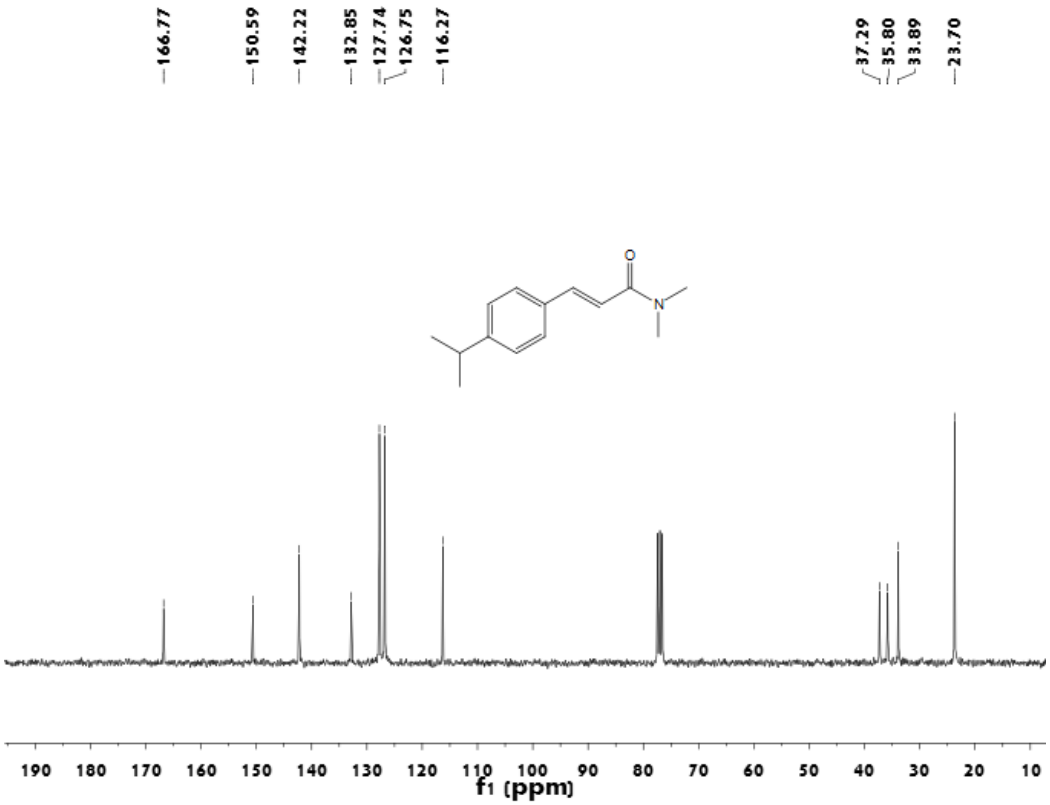
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N
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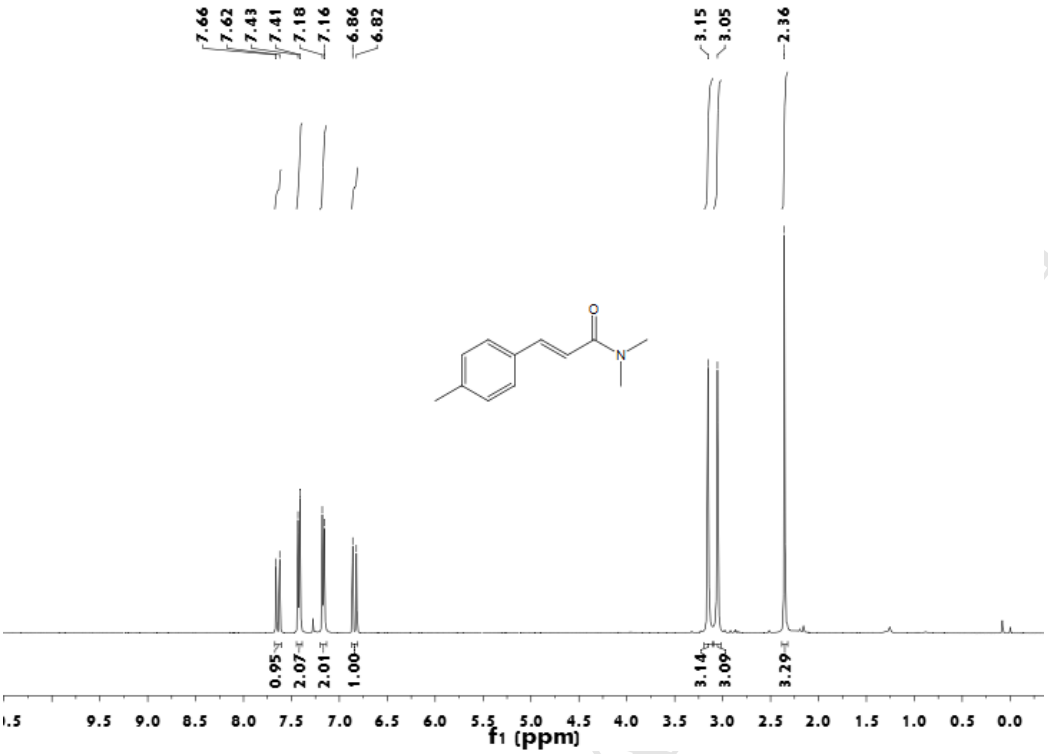
f1 (ppm)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3.14
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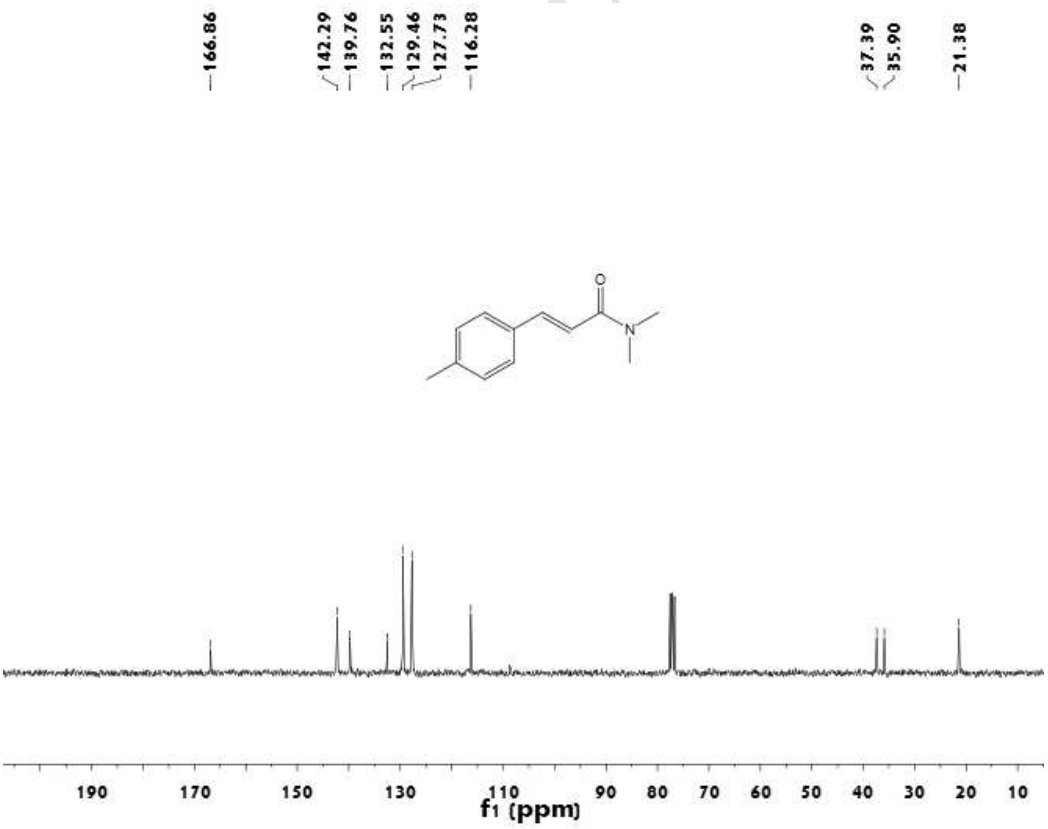
3.29
f1 (ppm)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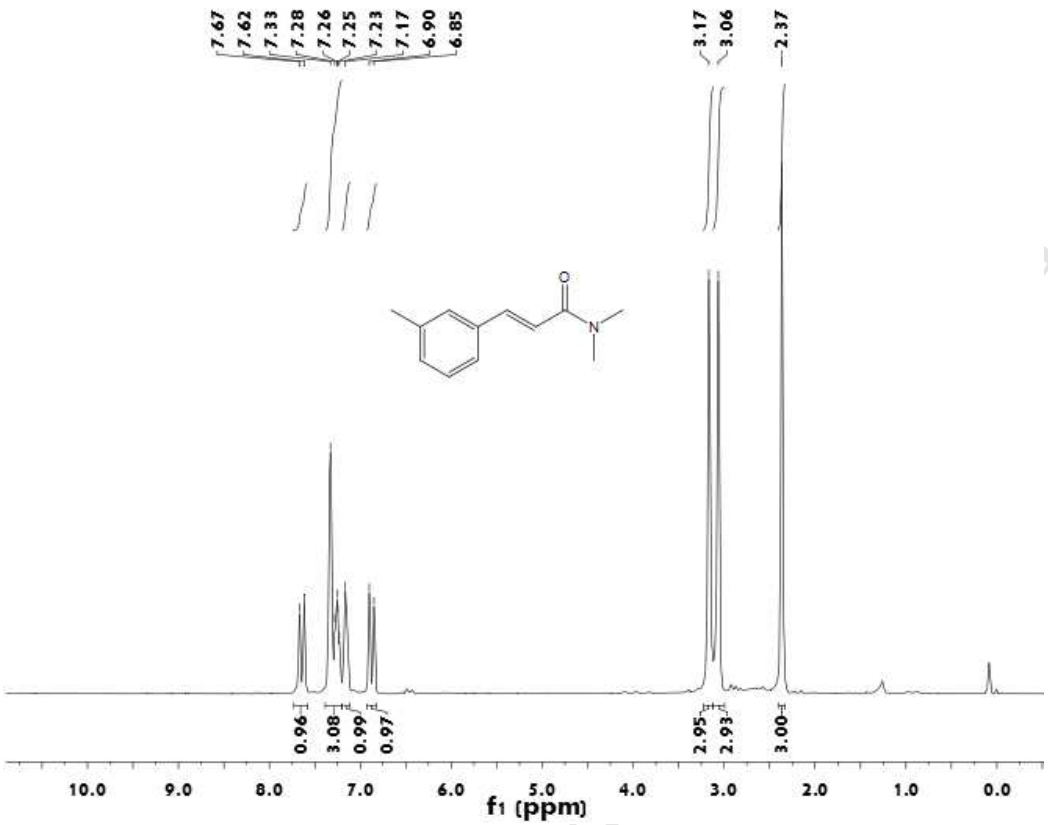
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0.97
2.95
2.93
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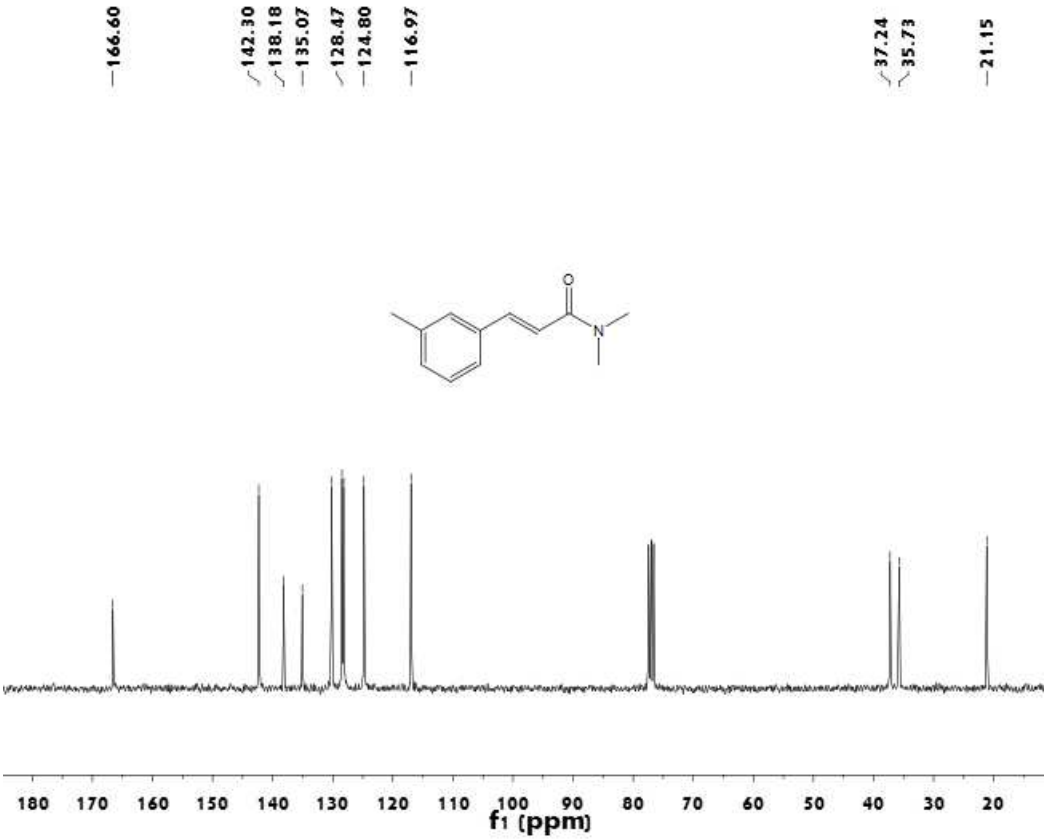
f1 (ppm)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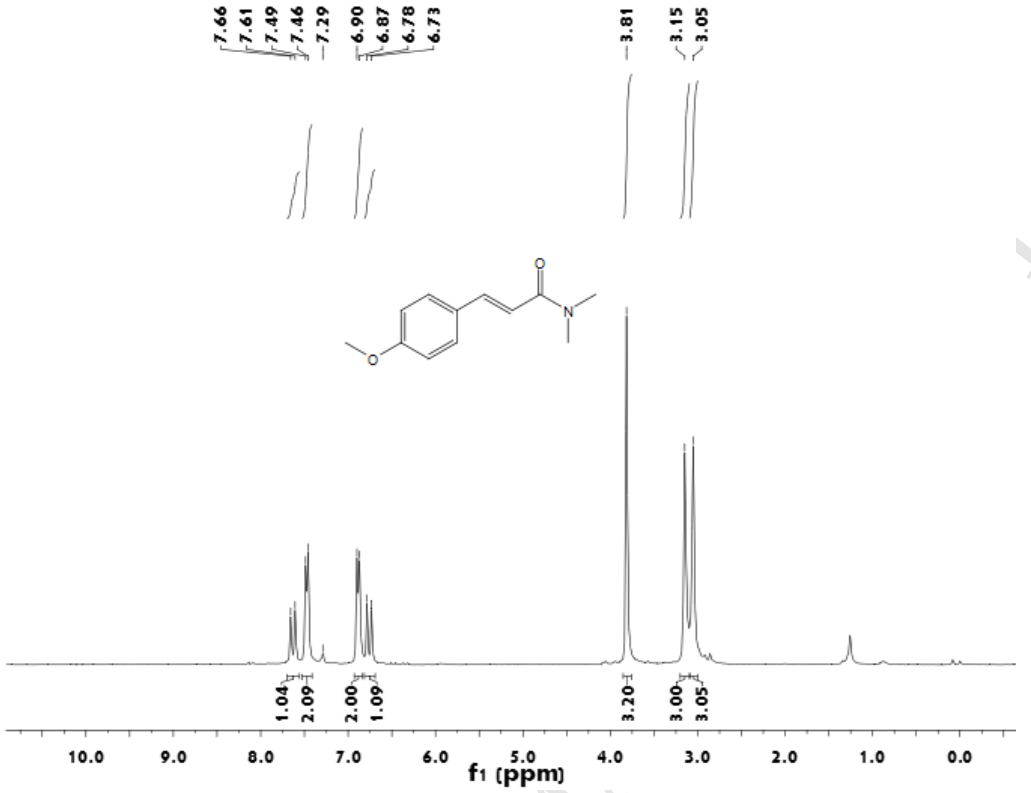
f1 (ppm)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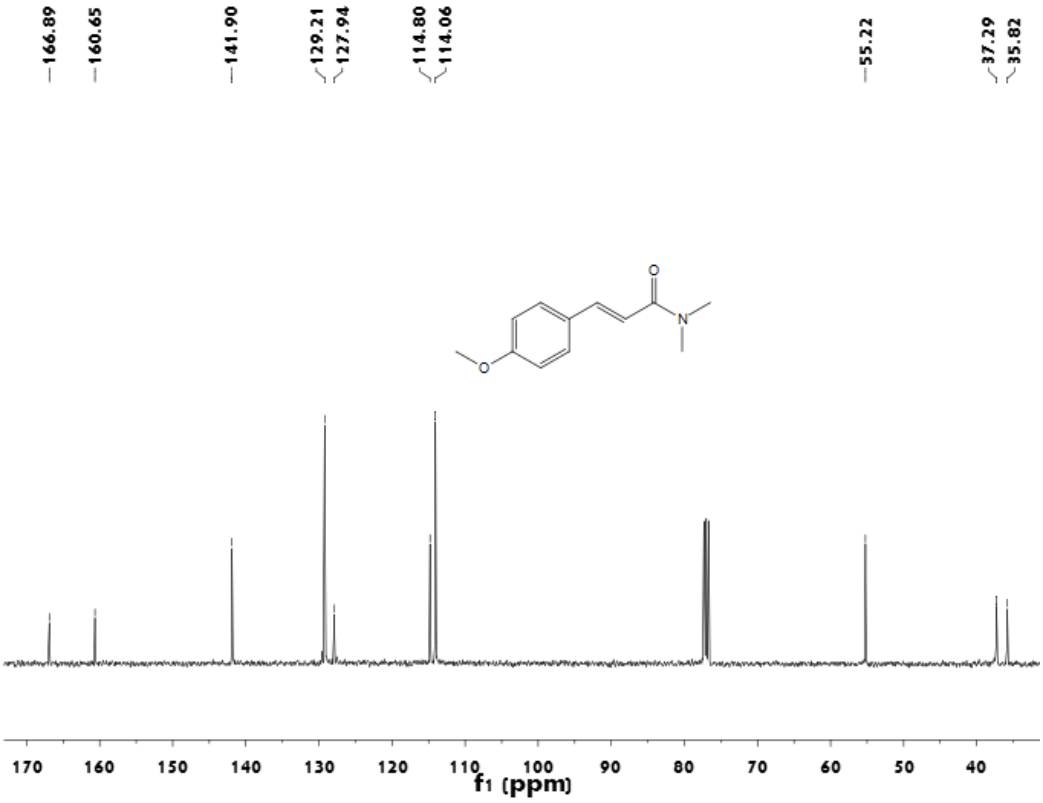
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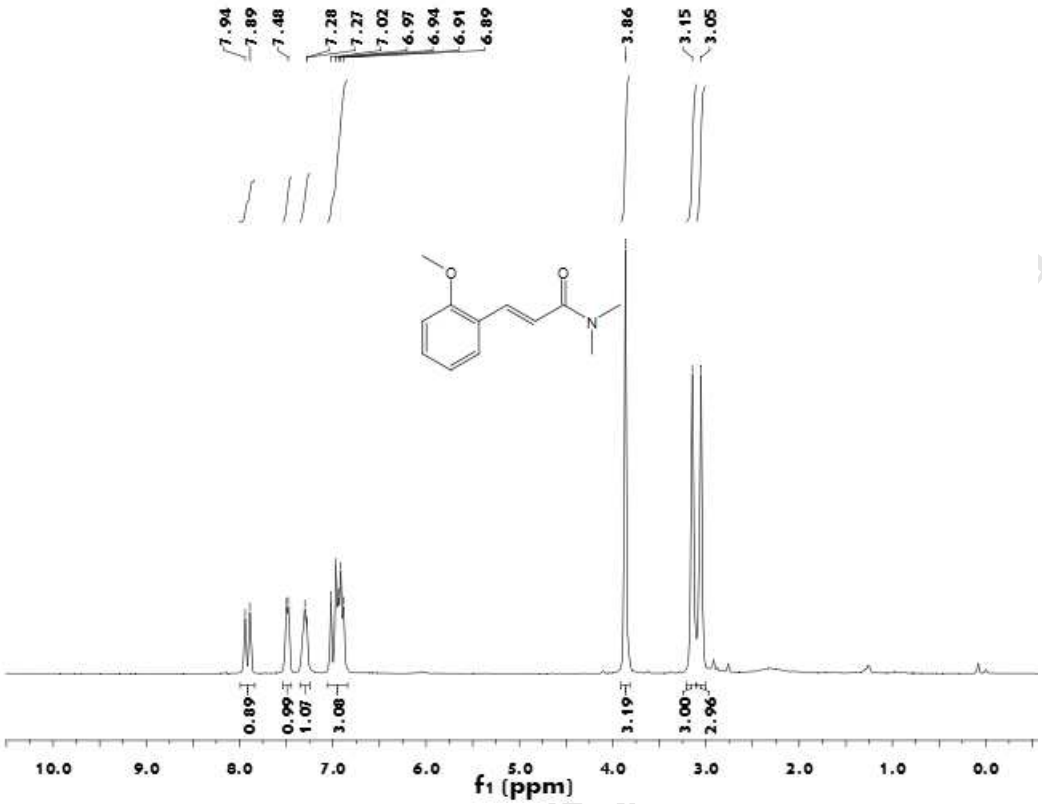
f1 (ppm)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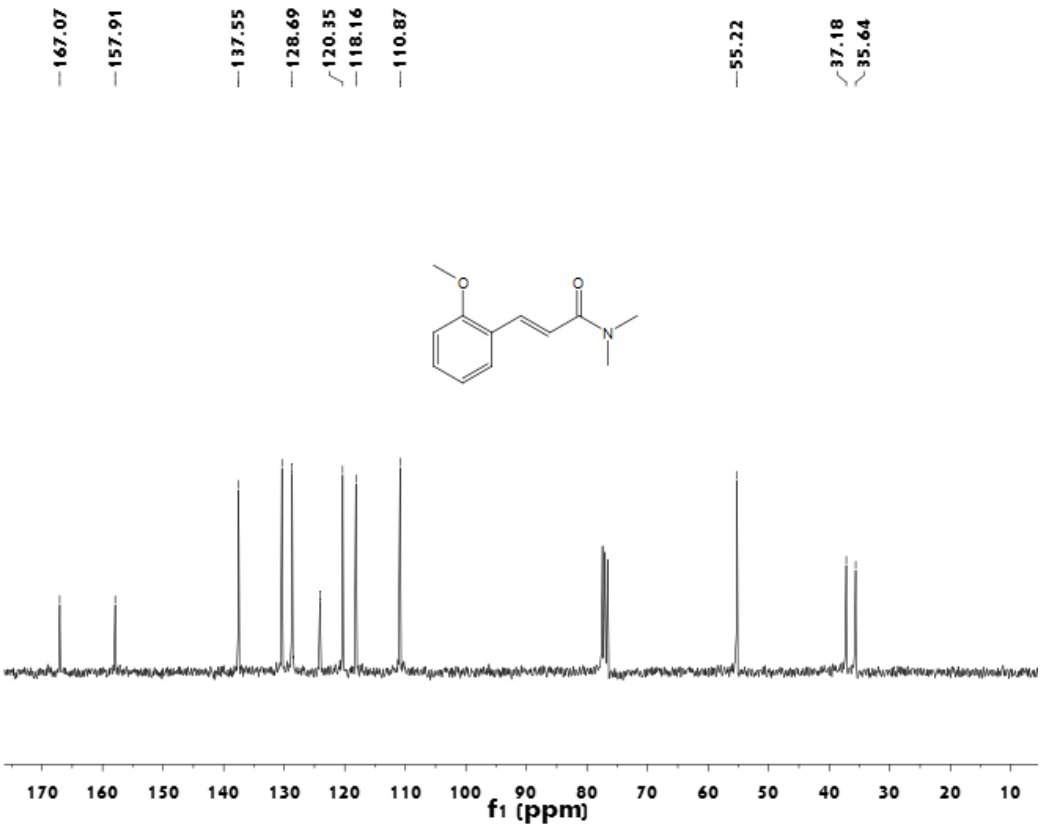
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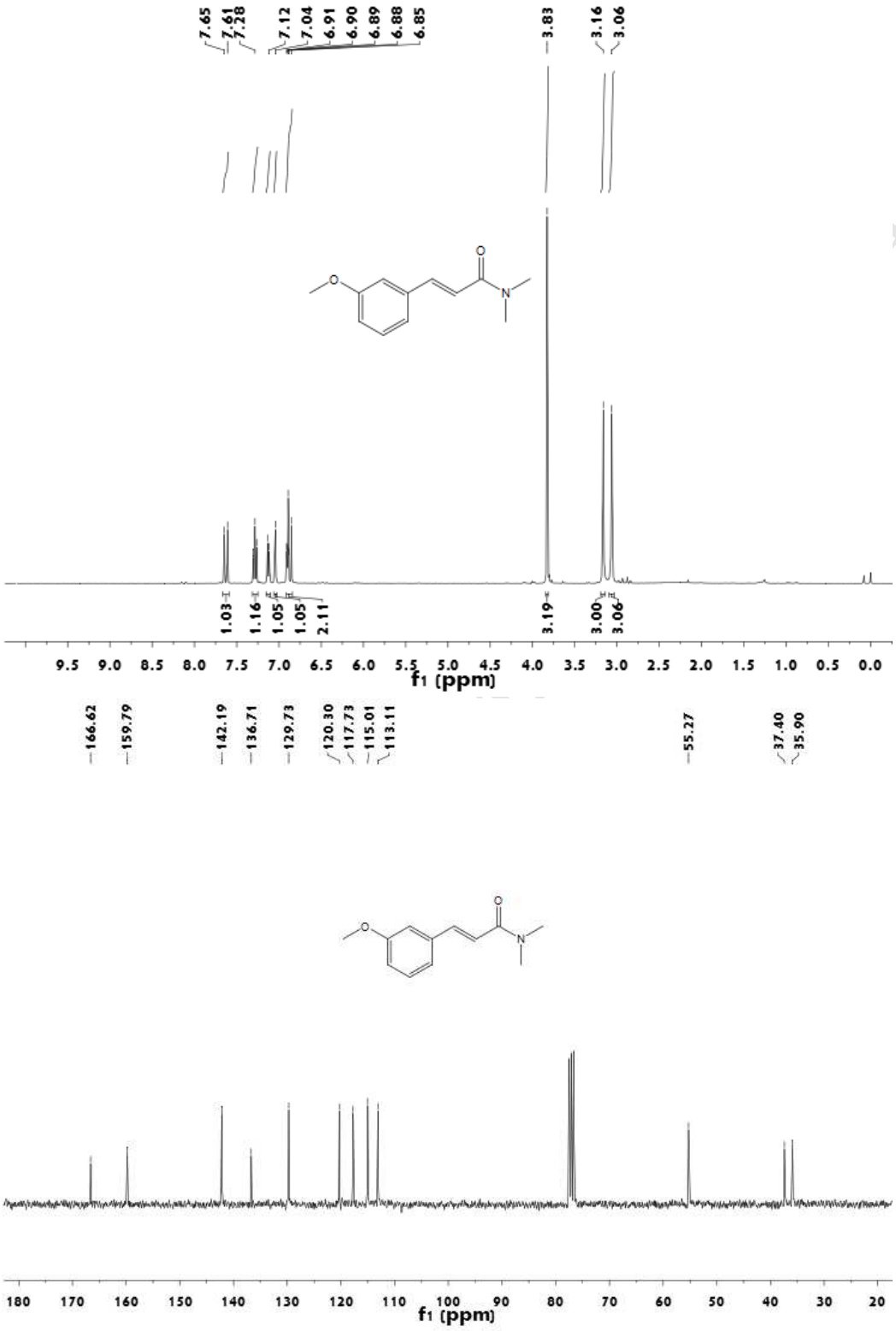
f1 (ppm)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1.16
1.05
1.05
2.11
3.19
3.00
3.06
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N
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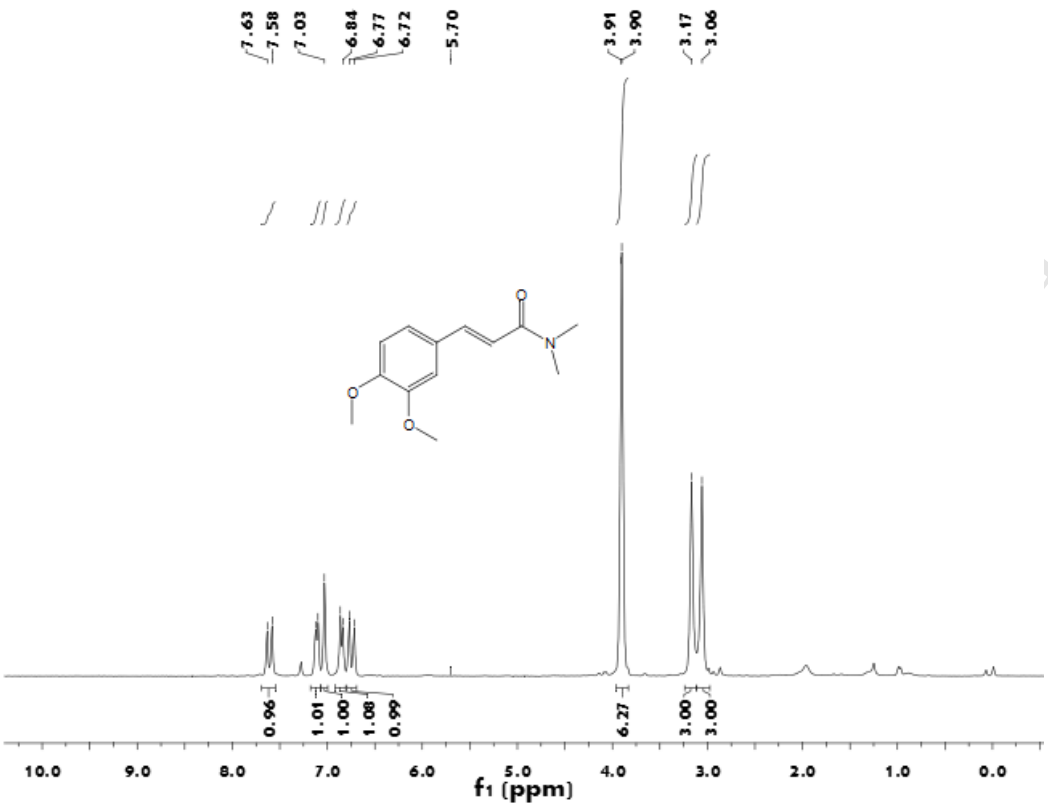
f1 (ppm)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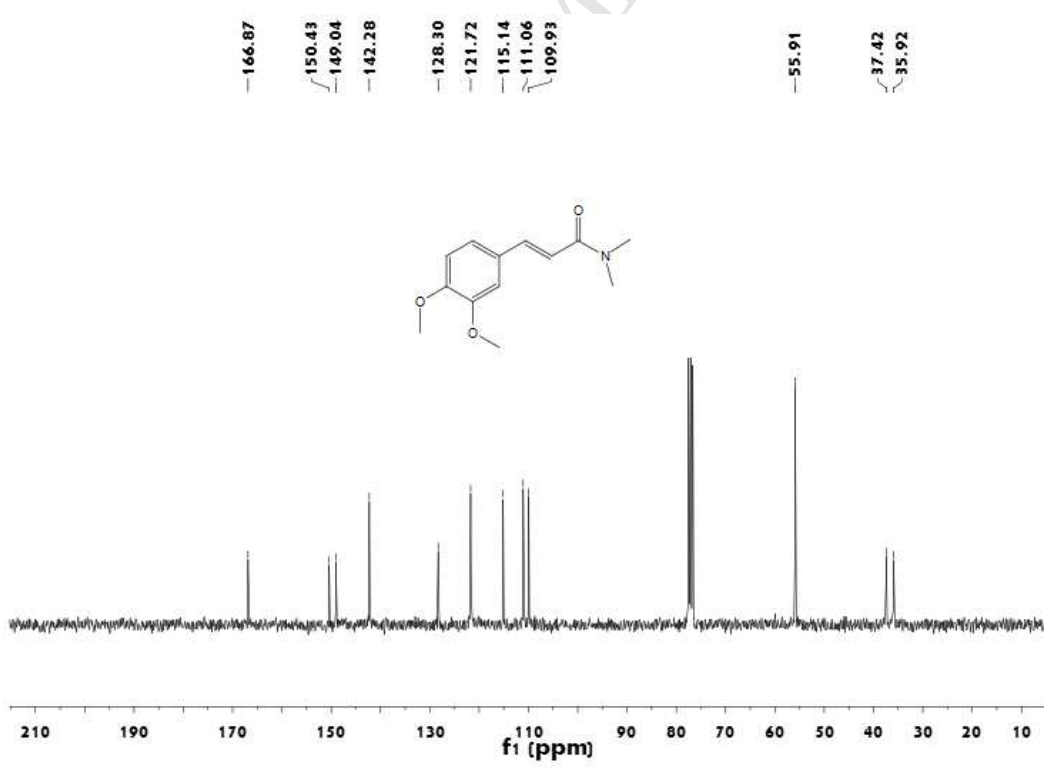
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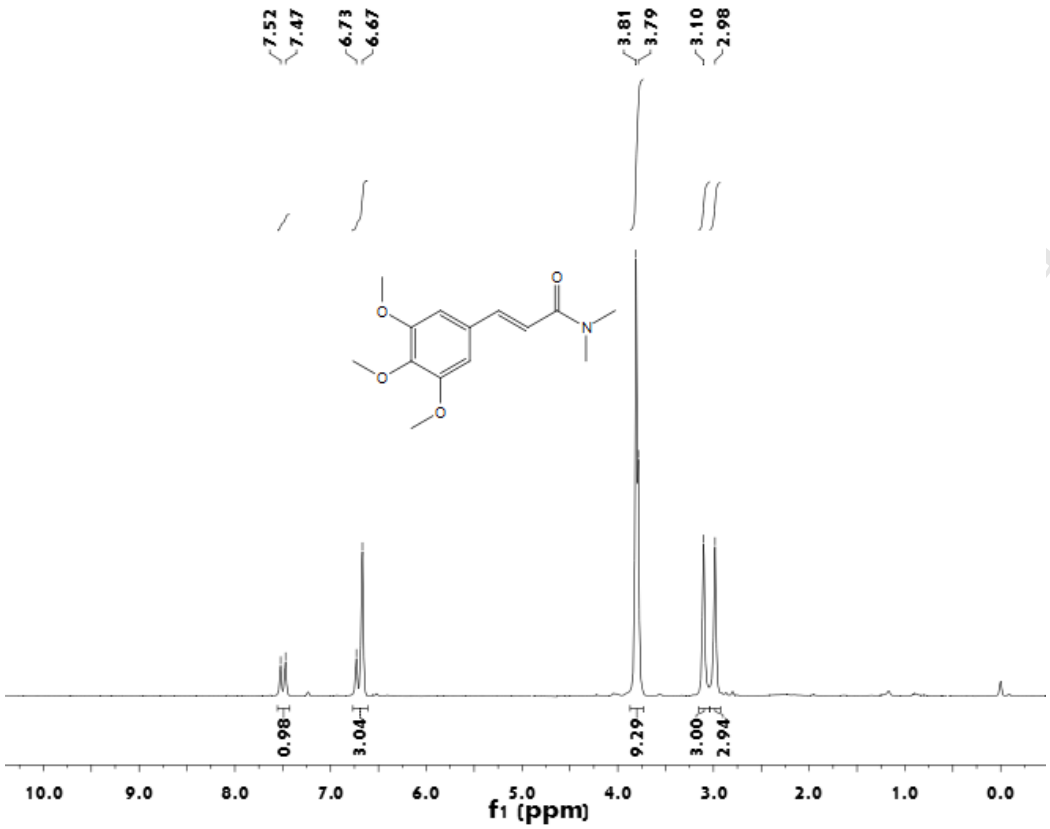
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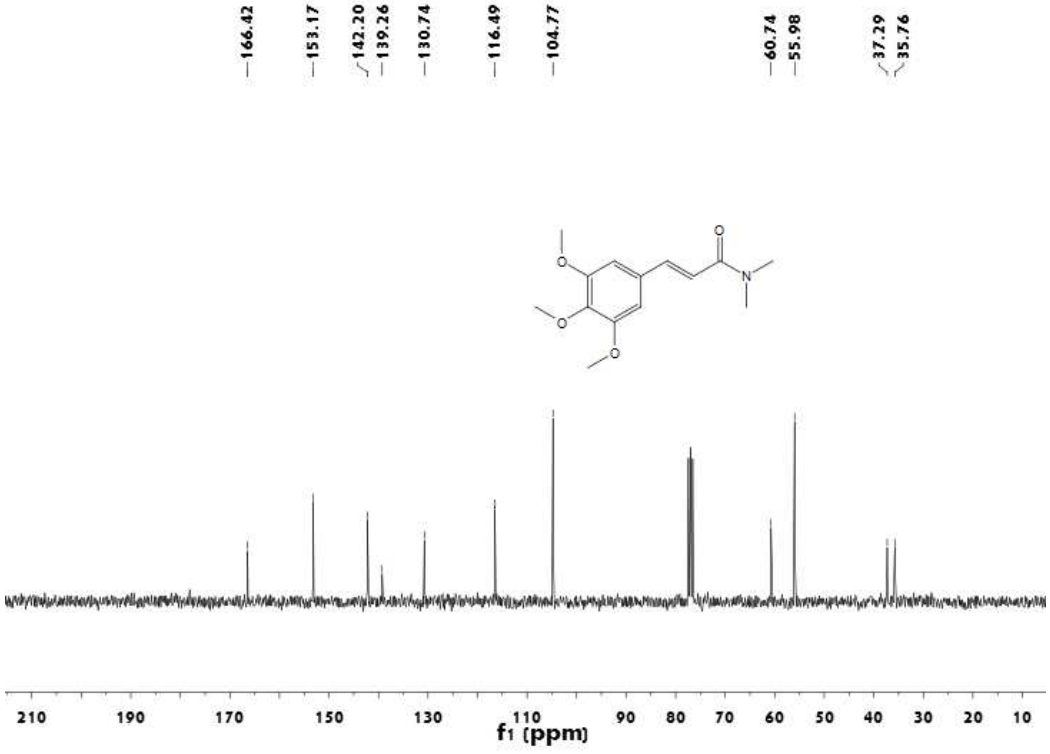
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40
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20
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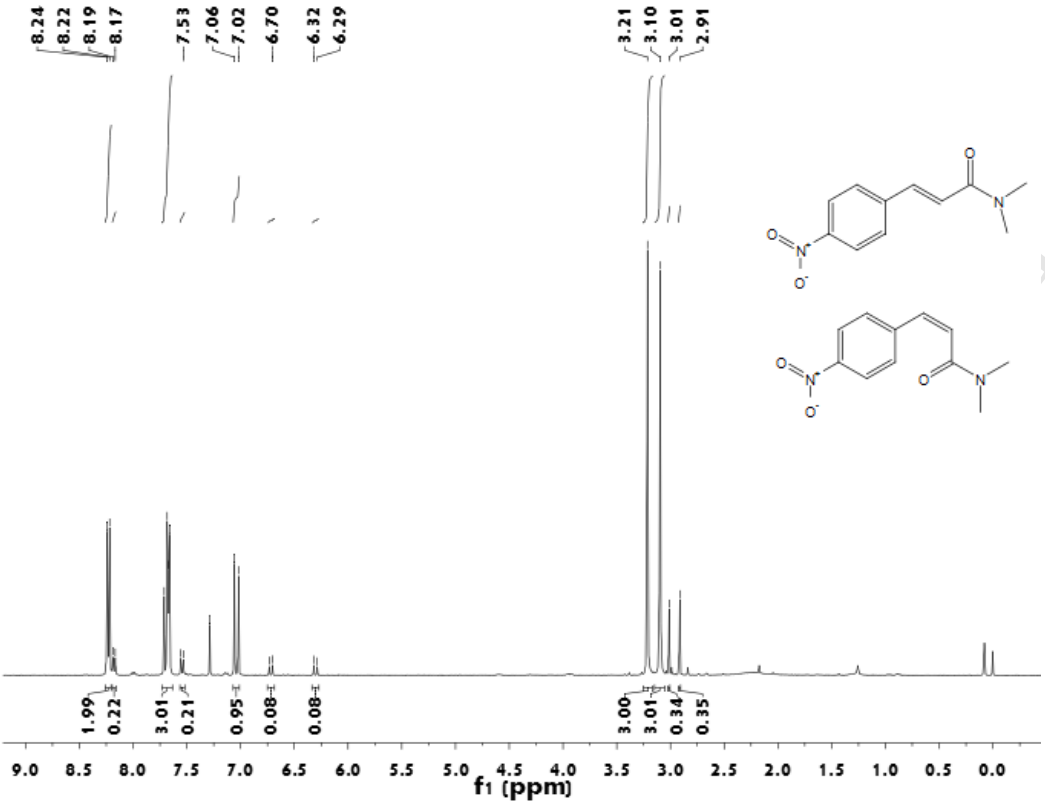
f1 (ppm)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8.22
8.19
8.17
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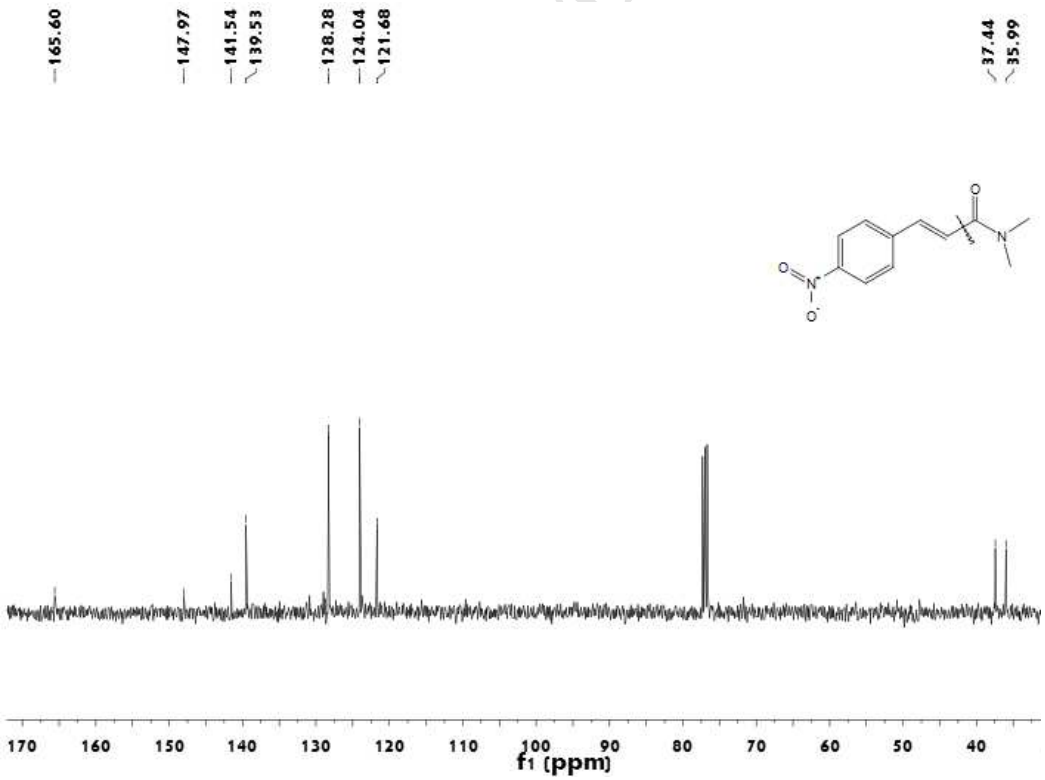
7.06
7.02
6.70
6.32
6.29
3.21
3.10
3.01
2.91
1.99
0.22
3.01
0.21
0.95
0.08
0.08
3.00
3.01
0.34
0.35
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)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147.97
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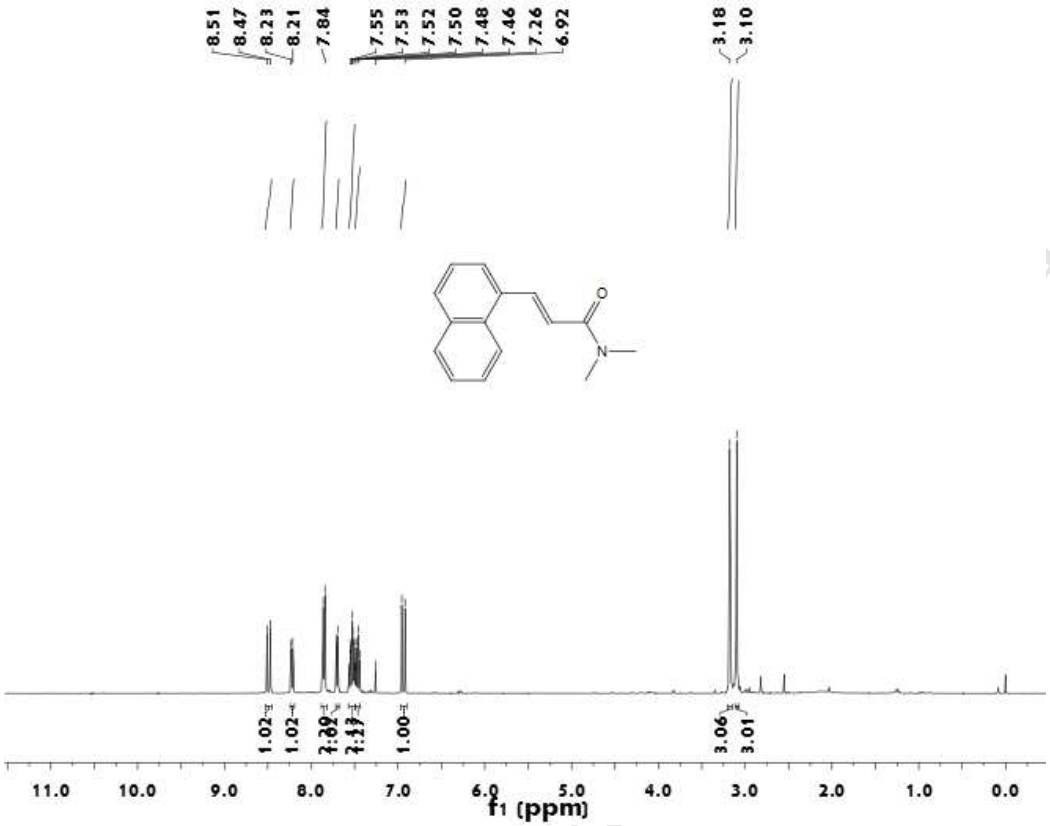
139.53
128.28
124.04
121.68
37.44
35.99
170 160 150 140 130 120 110 100 90 80 70 60 50 40
f1 (ppm)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8.23
8.21
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7.55
7.53
7.52
7.50
7.48
7.46
7.26
6.92
3.18
3.10
O
N
1.02
1.02
2.39
2.17
1.00
3.06
3.01
11.0
10.0
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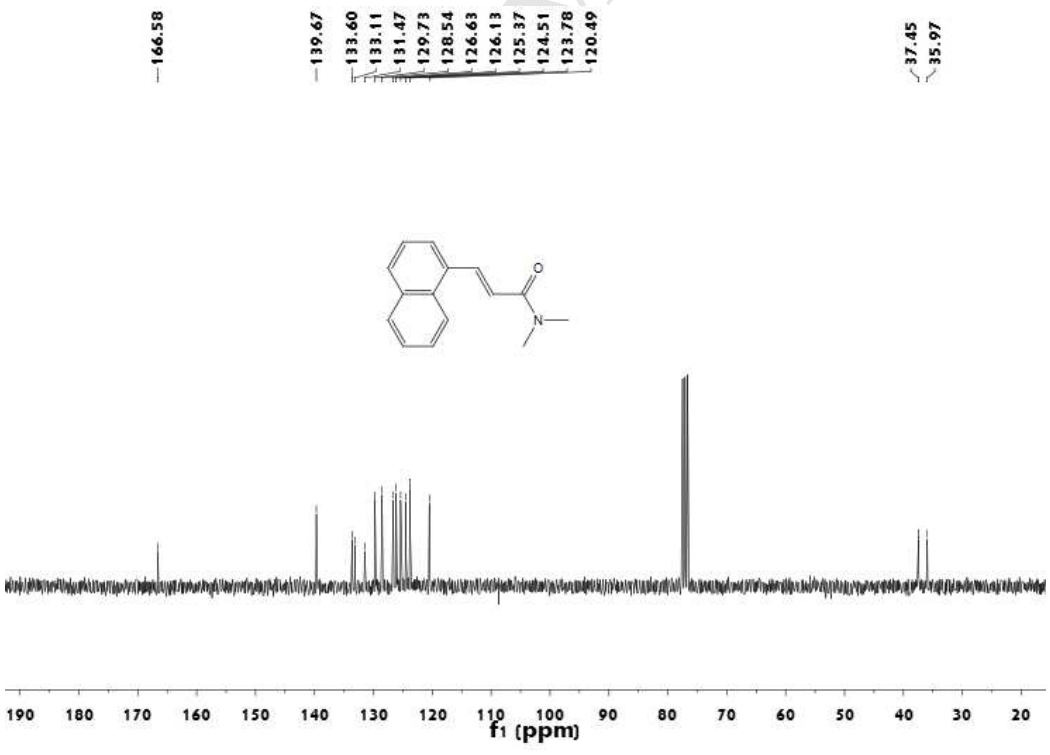
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
f1 (ppm)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133.11
131.47
129.73
128.54
126.63
126.13
125.37
124.51
123.78
120.49
37.45
35.97
O
N
190
180
170
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150
140
130
120
110
100
90
80
70
60
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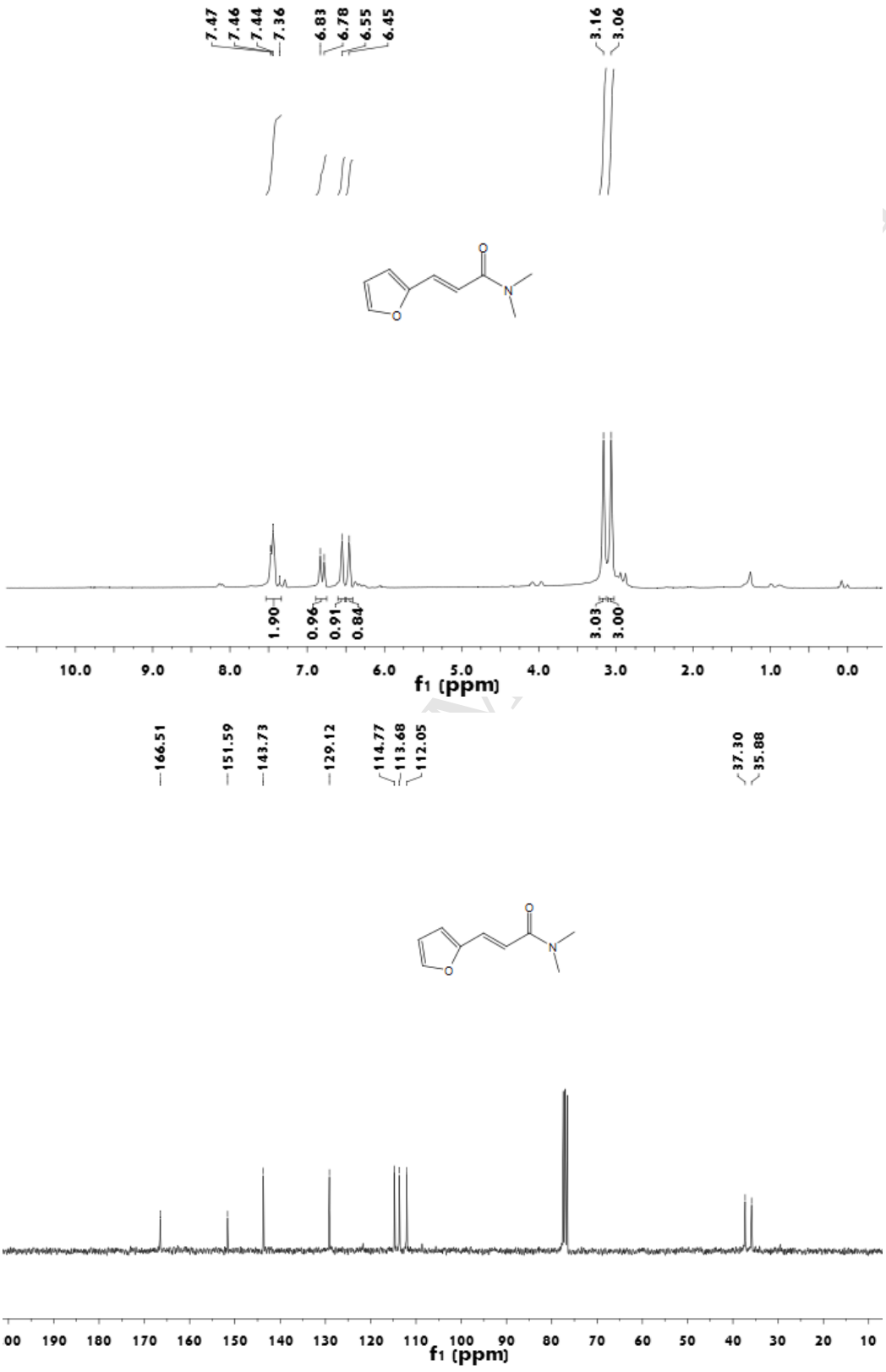
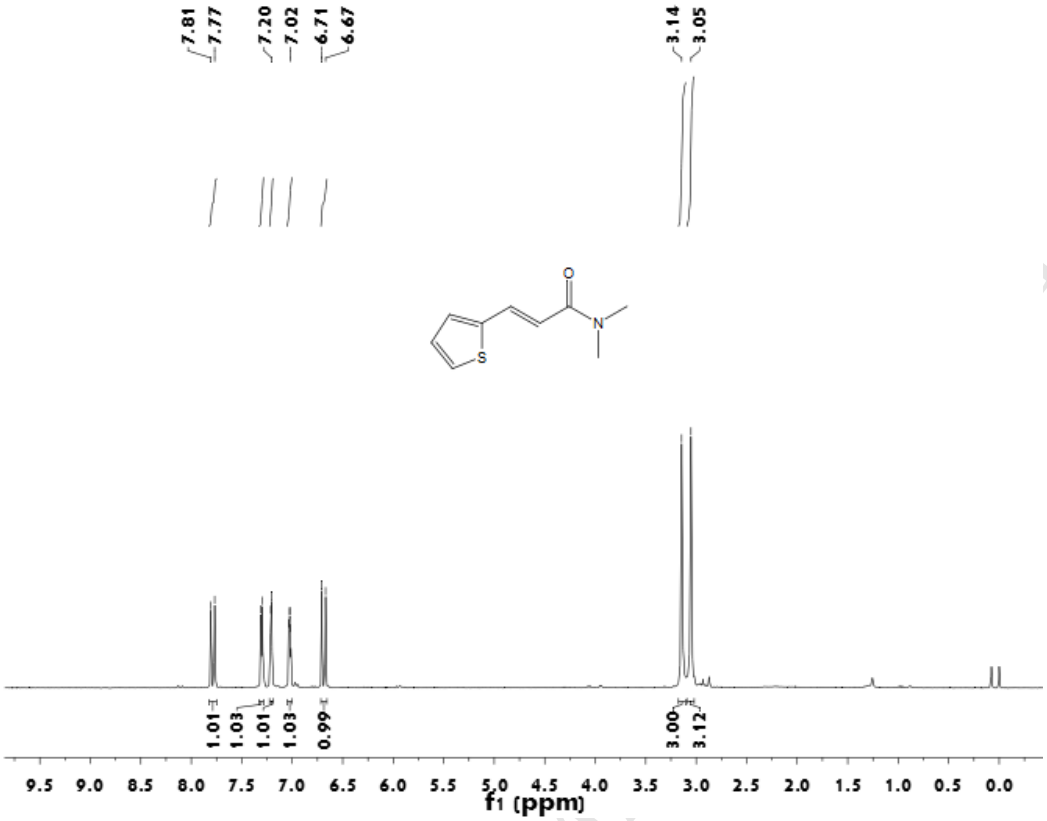
30
20
f1 (ppm)


7.47
7.46
7.44
7.36
6.83
6.78
6.55
6.45
3.16
3.06
O
N
O
1.90
0.96
0.91
0.84
3.03
3.00
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
f1 (ppm)
166.51
151.59
143.73
129.12
114.77
113.68
112.05
37.30
35.88
O
N
O
00
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)


7.81
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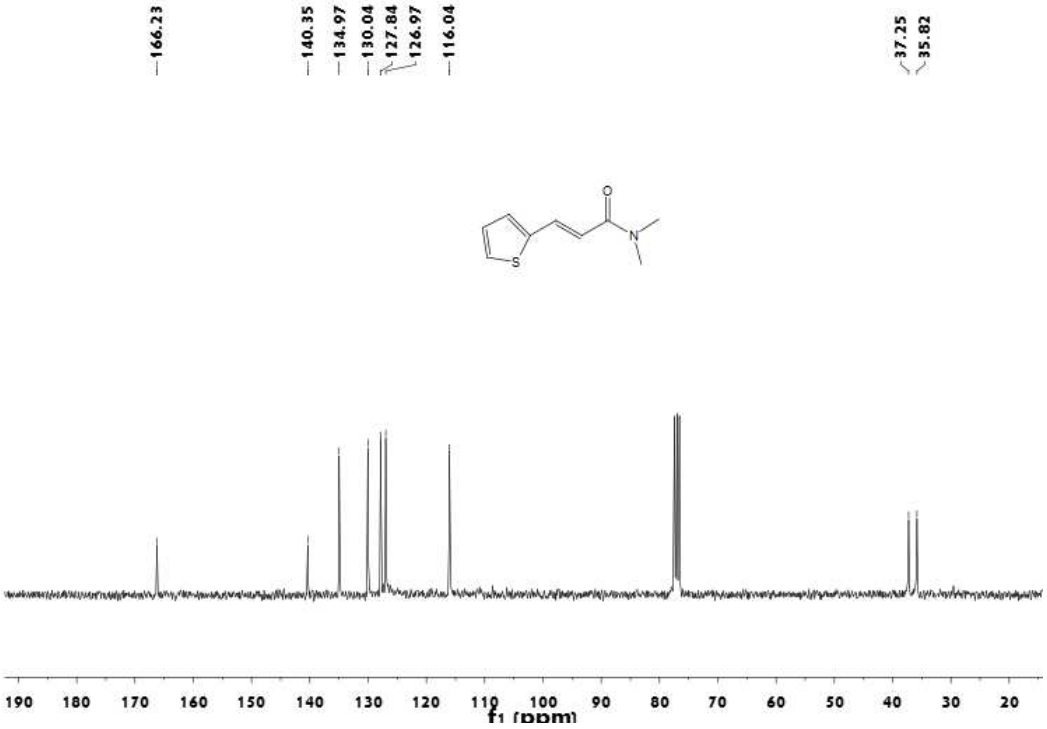
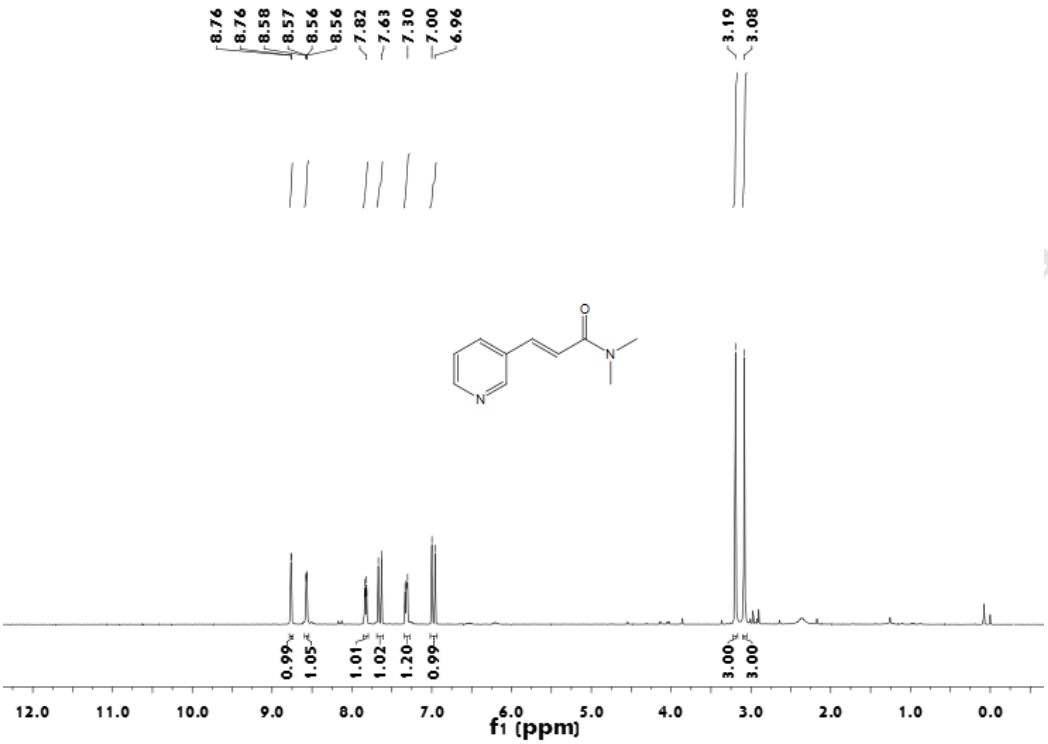
7.02
6.71
6.67
3.14
3.05
O
N
S
1.01
1.03
1.01
1.03
0.99
3.00
3.12
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


166.23
140.35
134.97
130.04
127.84
126.97
116.04
37.25
35.82
O
N
S
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20
f1 (ppm)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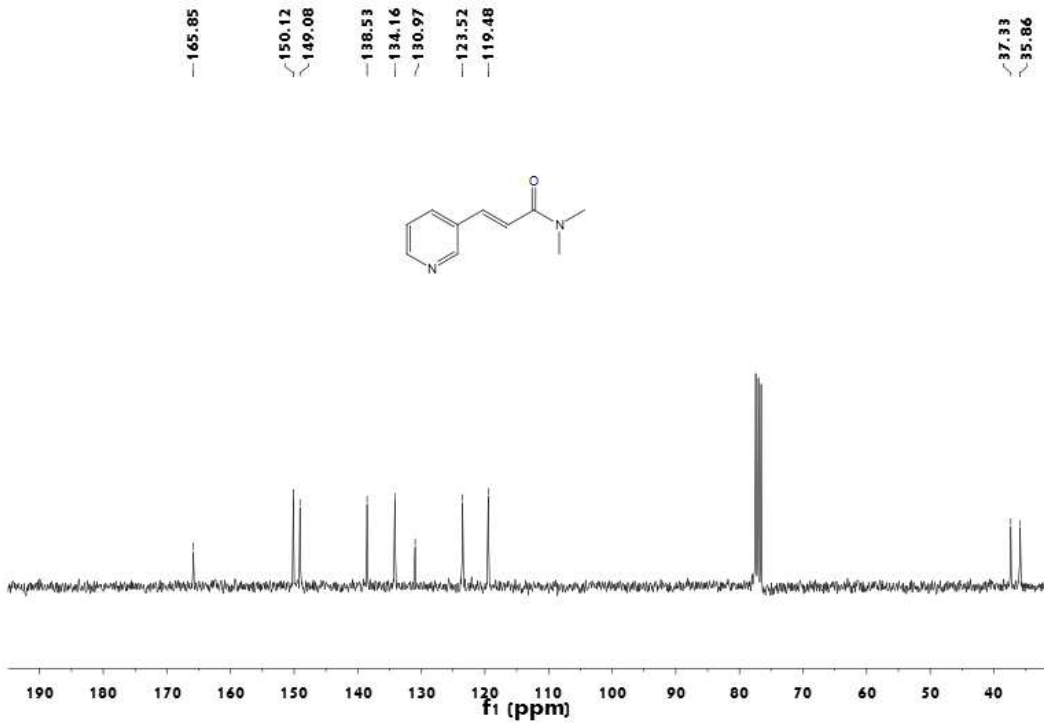
8.76
8.58
8.57
8.56
8.56
7.82
7.63
7.30
7.00
6.96
3.19
3.08
O
N
N
0.99
1.05
1.01
1.02
1.20
0.99
3.00
3.00
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
f1 (ppm)


165.85
150.12
149.08
138.53
134.16
130.97
123.52
119.48
37.33
35.86
O
N
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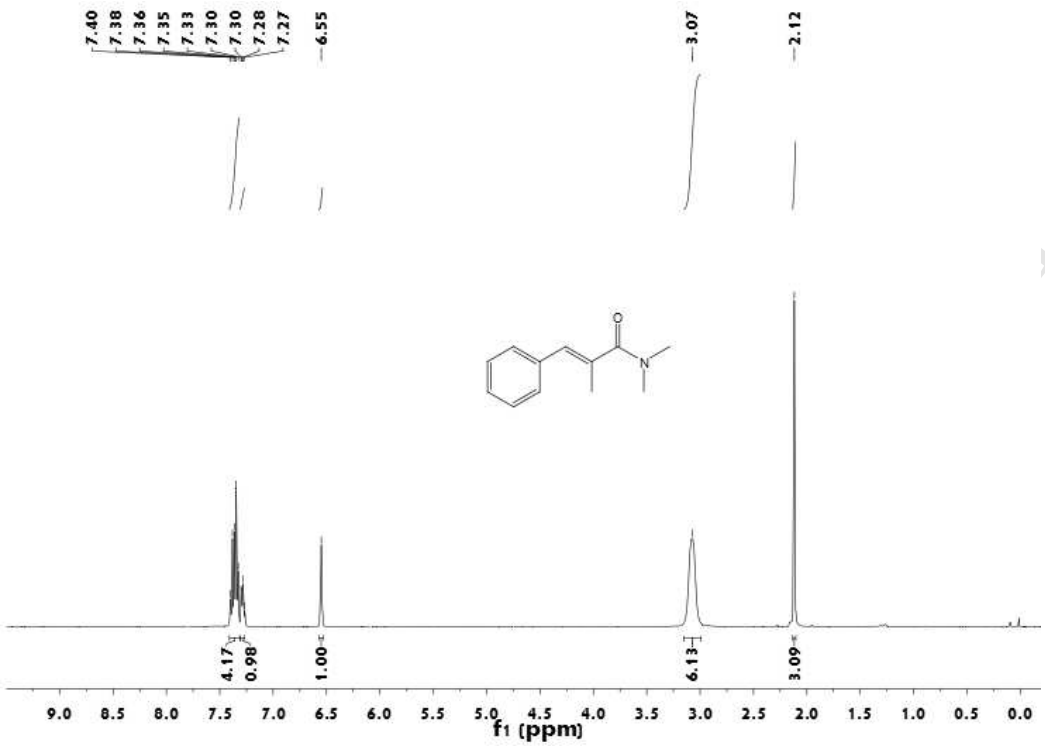
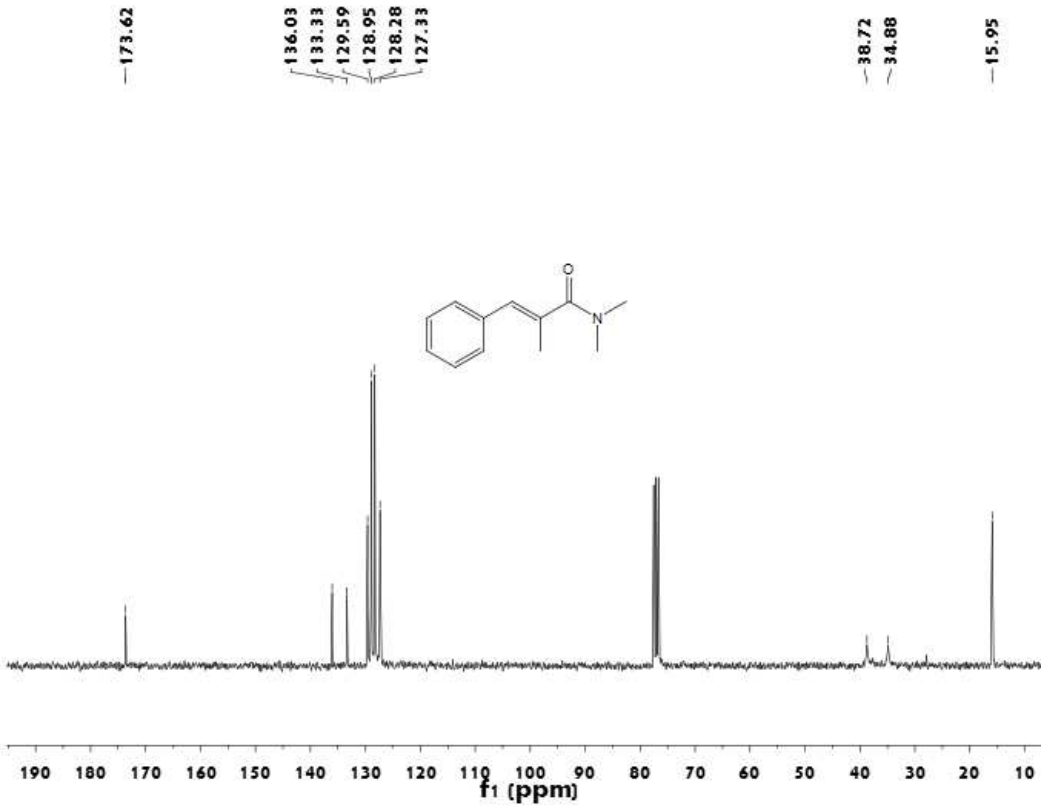
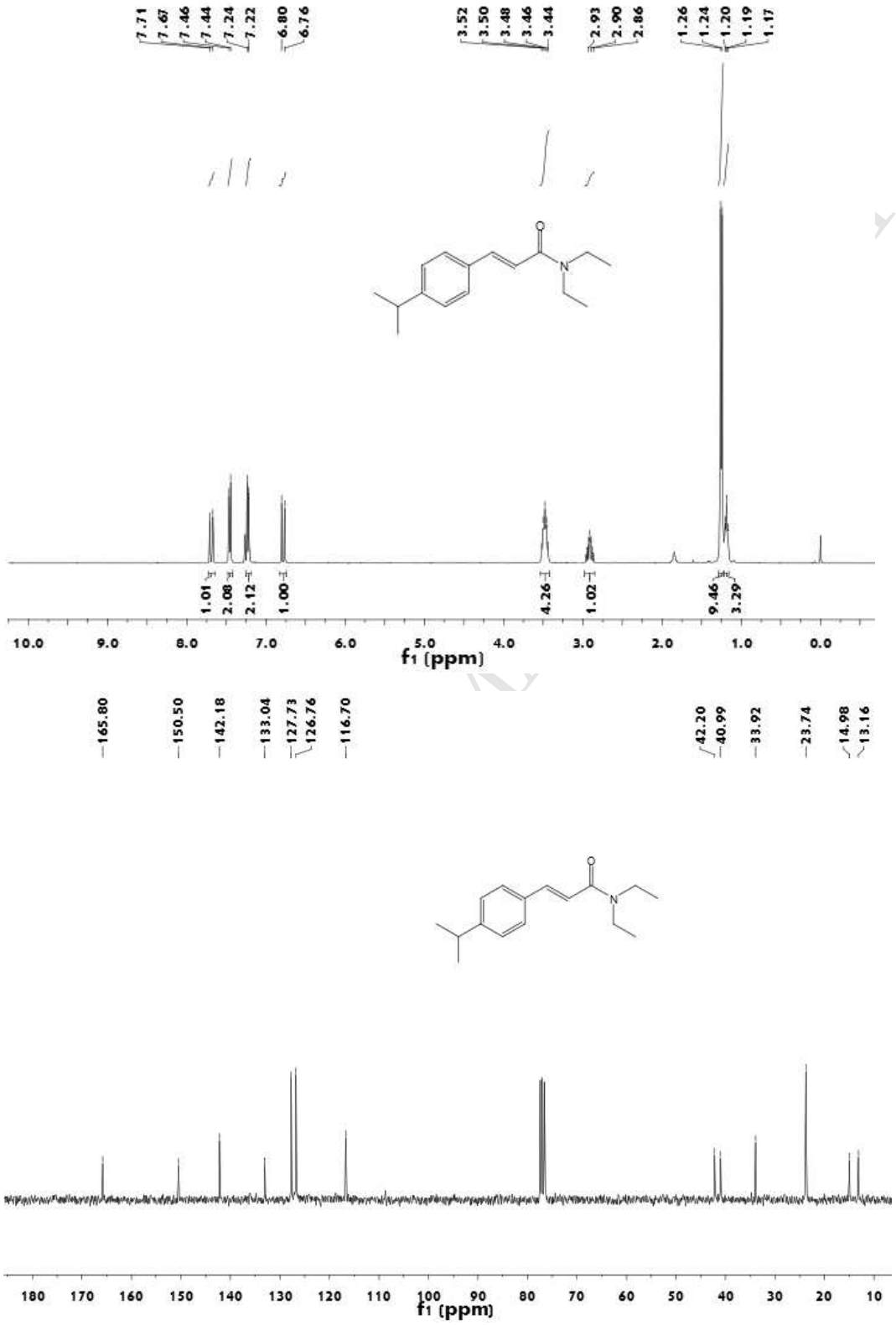
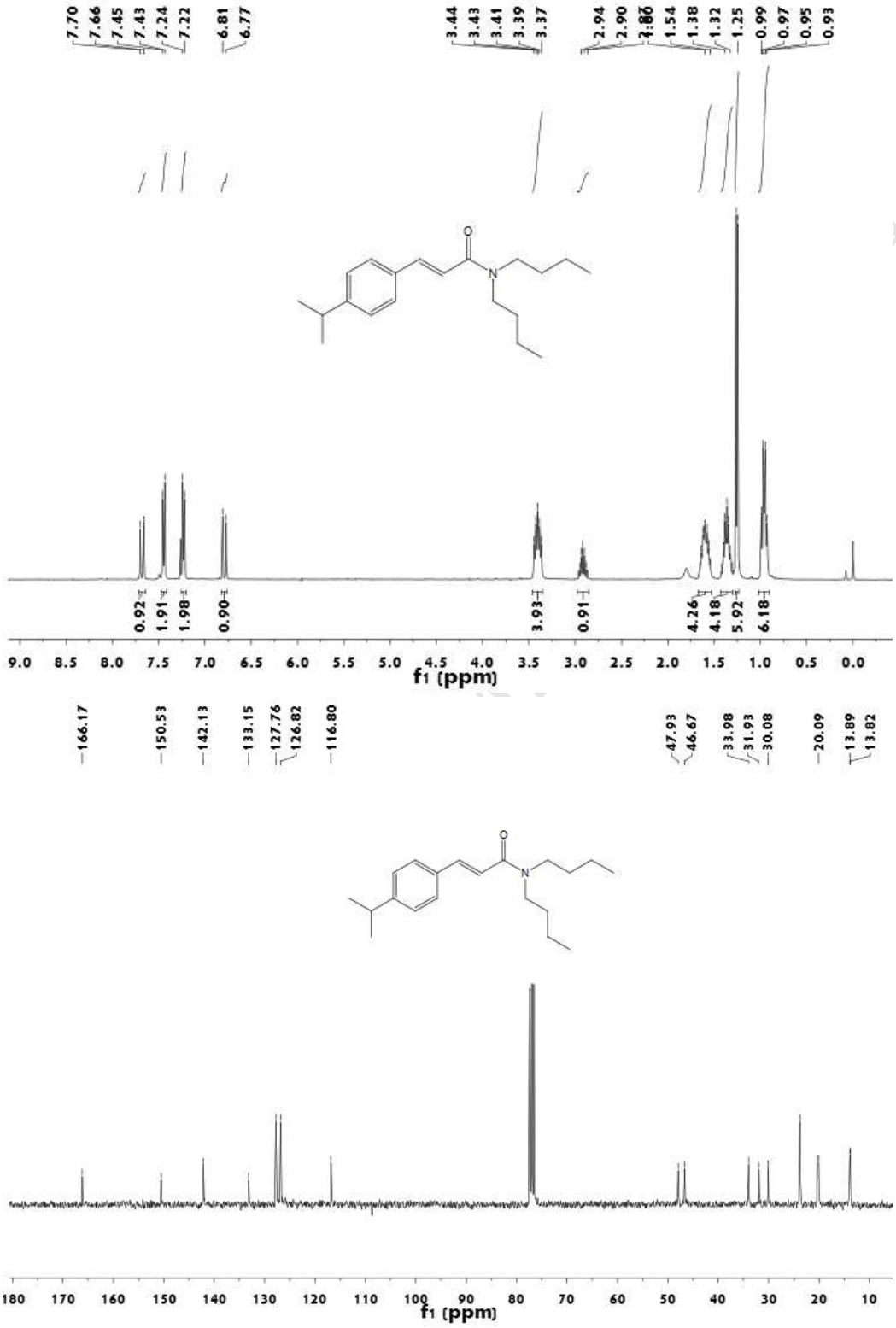
100
90
80
70
60
50
40
f1 (ppm)


7.40
7.38
7.36
7.35
7.33
7.30
7.30
7.28
7.27
6.55
3.07
2.12
4.17
0.98
1.00
6.13
3.09
f1 (ppm)


173.62
136.03
133.33
129.59
128.95
128.28
127.33
38.72
34.88
15.95
f1 (ppm)


7.71
7.67
7.46
7.44
7.24
7.22
6.80
6.76
3.52
3.50
3.48
3.46
3.44
2.93
2.90
2.86
1.26
1.24
1.20
1.19
1.17
1.01
2.08
2.12
1.00
4.26
1.02
9.46
3.29
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
f1 (ppm)
165.80
150.50
142.18
133.04
127.73
126.76
116.70
42.20
40.99
33.92
23.74
14.98
13.16
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)


7.70
7.66
7.45
7.43
7.24
7.22
6.81
6.77
3.44
3.43
3.41
3.39
3.37
2.94
2.90
1.54
1.38
1.32
1.25
0.99
0.97
0.95
0.93
0.92
1.91
1.98
0.90
3.93
0.91
4.26
4.18
5.92
6.18
f1 (ppm)
166.17
150.53
142.13
133.15
127.76
126.82
116.80
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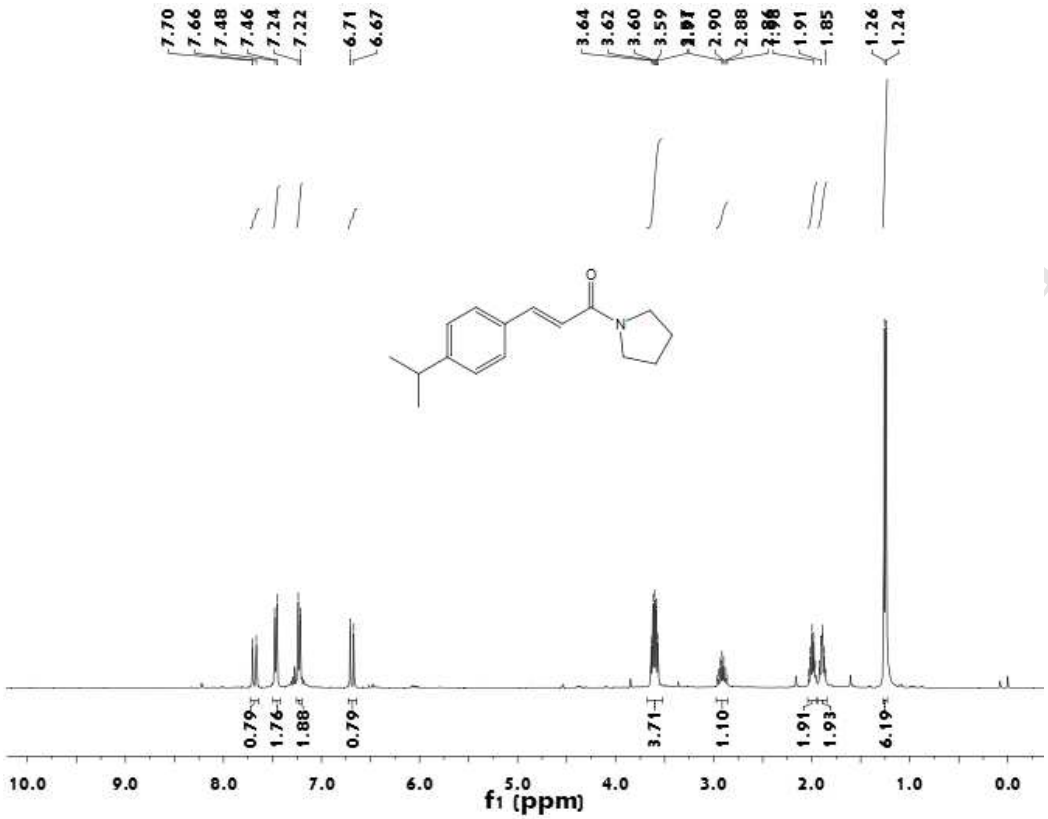
30.08
20.09
13.89
13.82
f1 (ppm)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7.66
7.48
7.46
7.24
7.22
6.71
6.67
3.64
3.62
3.60
3.59
2.90
2.88
1.91
1.85
1.26
1.24
O
N
0.79
1.76
1.88
0.79
3.71
1.10
1.91
1.93
6.19
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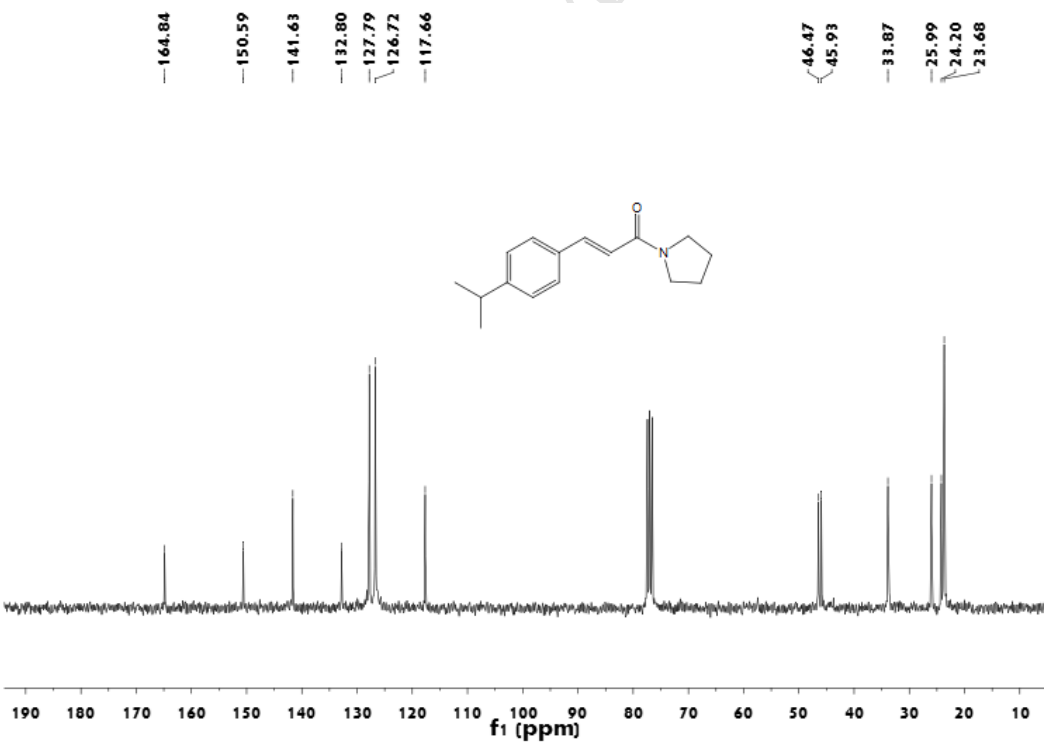
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
f1 (ppm)


164.84
150.59
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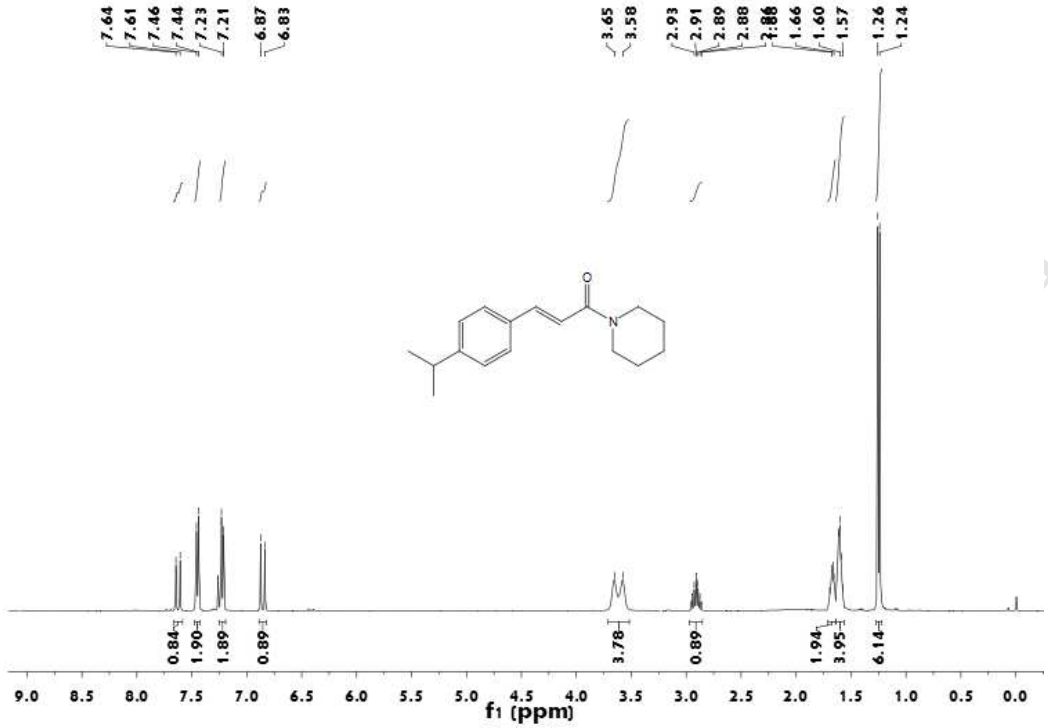
132.80
127.79
126.72
117.66
46.47
45.93
33.87
25.99
24.20
23.68
O
N
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)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7.23
7.21
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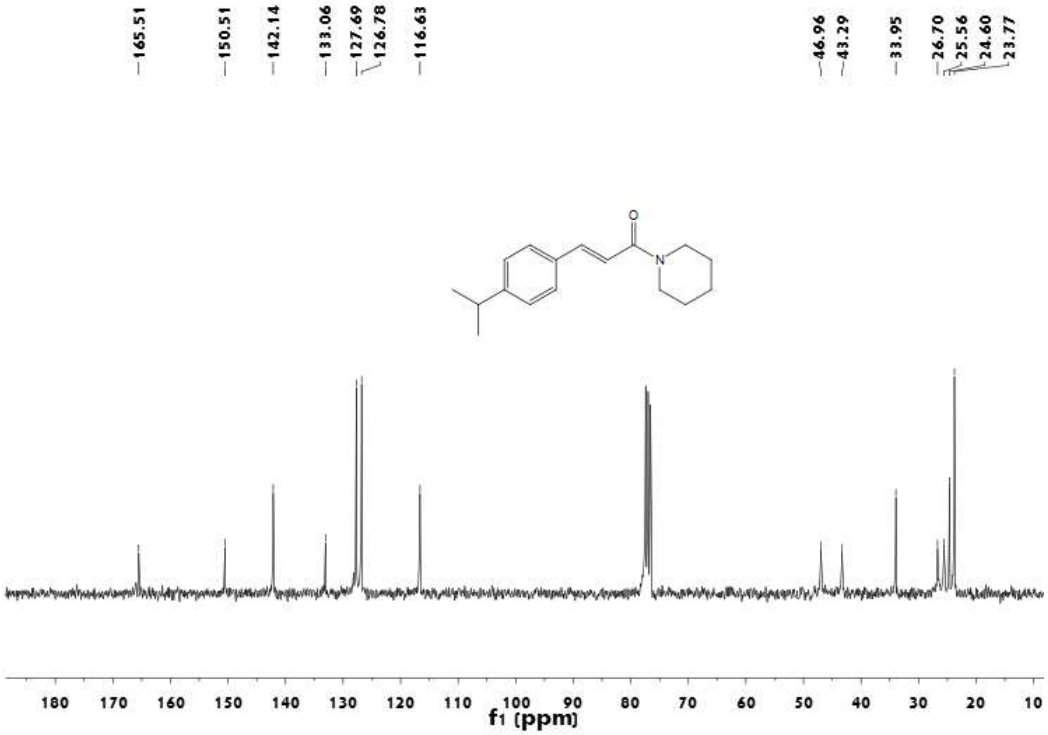
6.83
3.65
3.58
2.93
2.91
2.89
2.88
1.66
1.60
1.57
1.26
1.24
O
N
0.84
1.90
1.89
0.89
3.78
0.89
1.94
3.95
6.14
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)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127.69
126.78
116.63
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43.29
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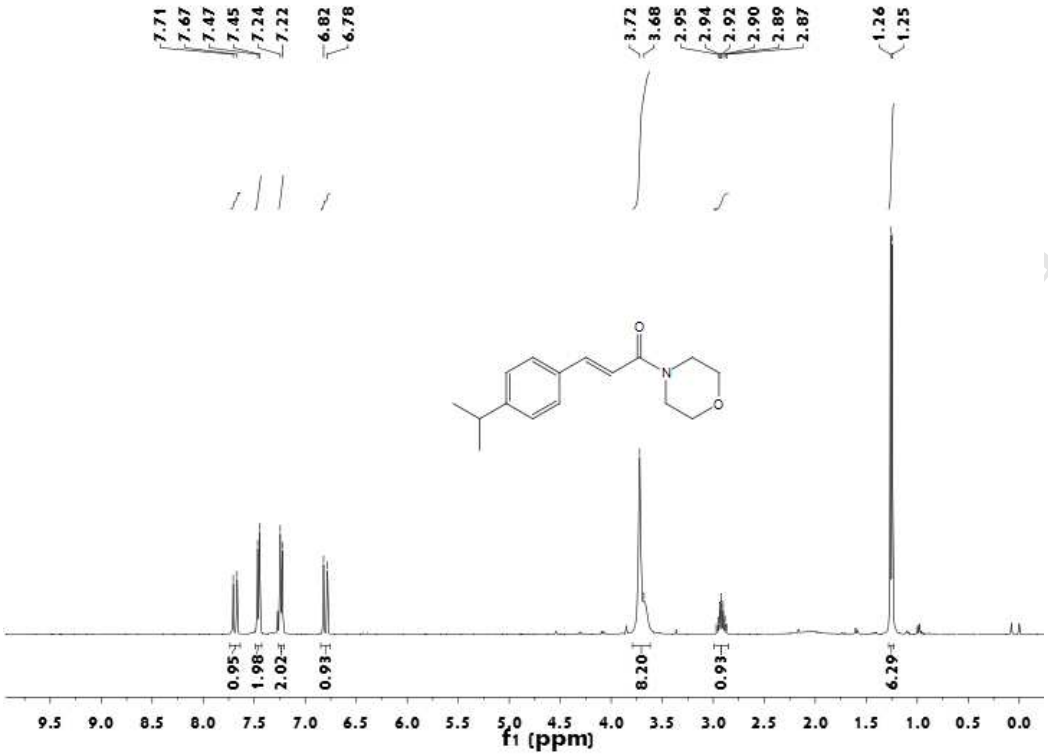
25.56
24.60
23.77
O
N
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
f1 (ppm)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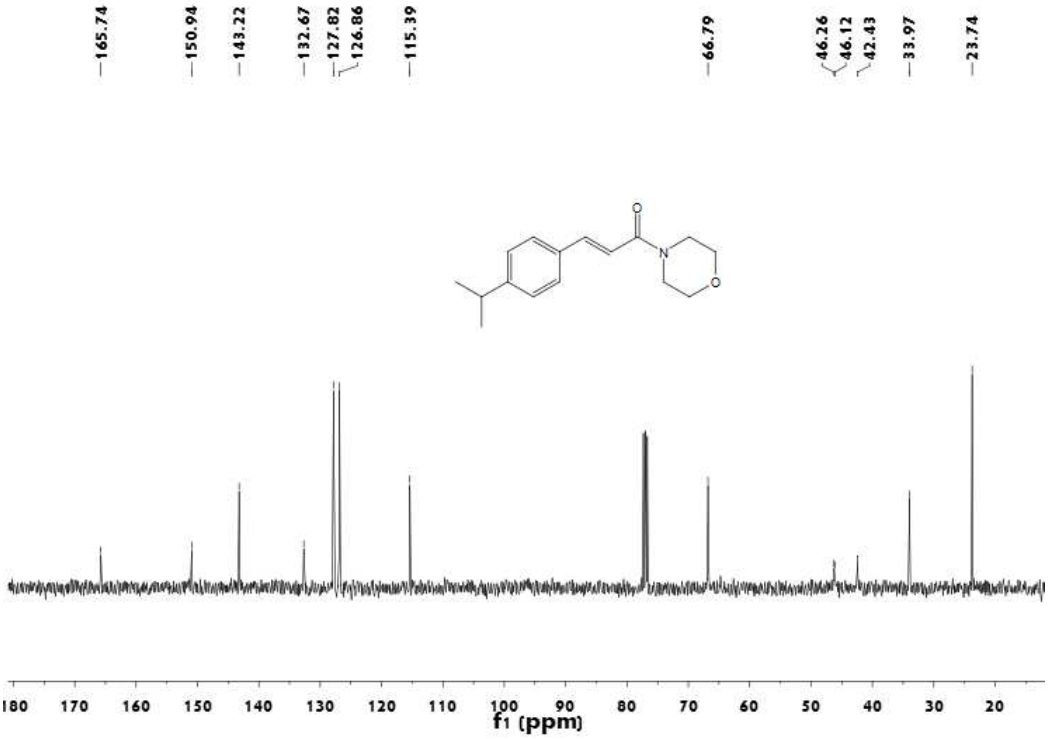
6.82
6.78
3.72
3.68
2.95
2.94
2.92
2.90
2.89
2.87
1.26
1.25
0.95
1.98
2.02
0.93
8.20
0.93
6.29
f1 (ppm)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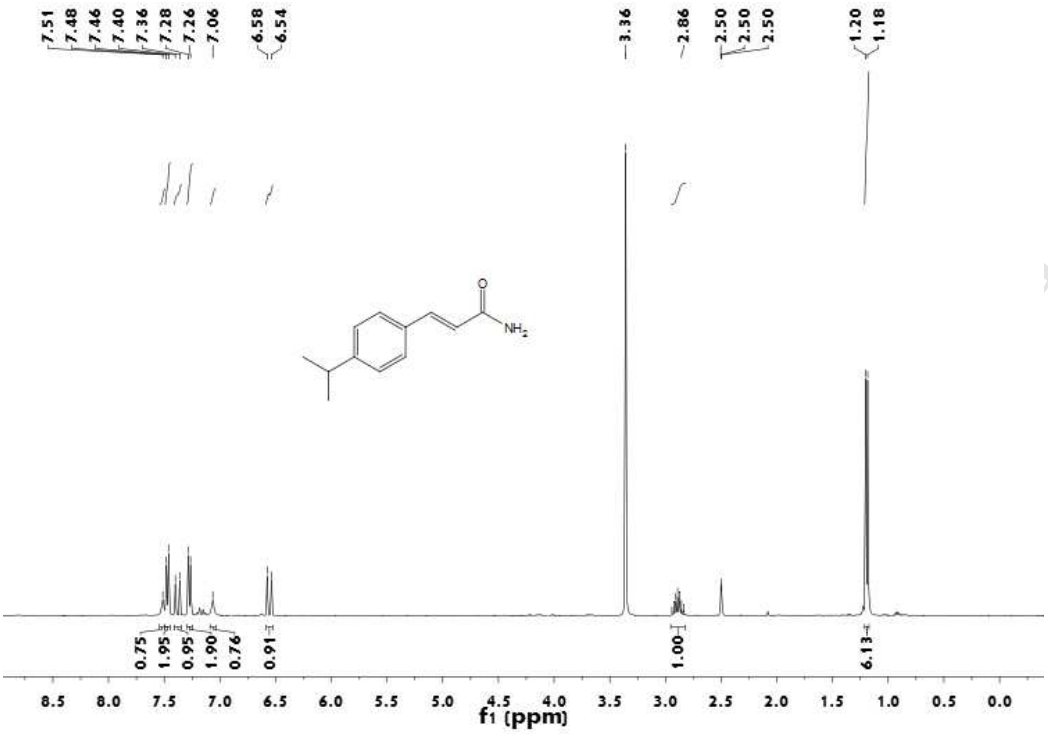
66.79
46.26
46.12
42.43
33.97
23.74
f1 (ppm)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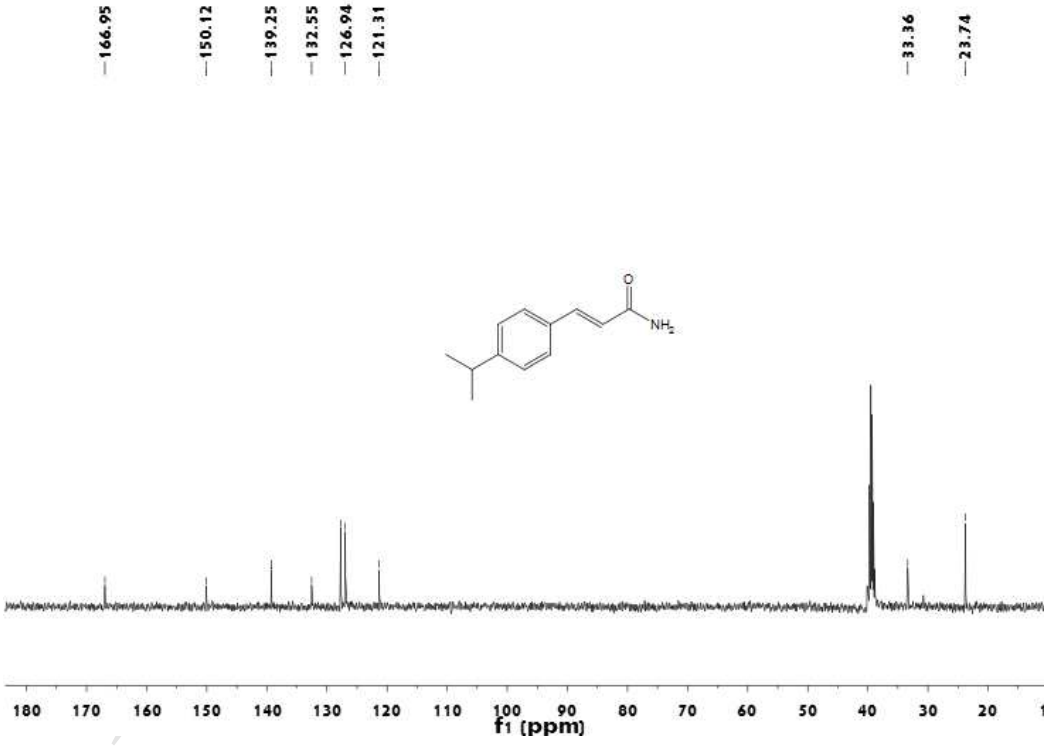
7.48
7.46
7.40
7.36
7.28
7.26
7.06
6.58
6.54
3.36
2.86
2.50
2.50
2.50
1.20
1.18
O
NH2
0.75
1.95
0.95
1.90
0.76
0.91
1.00
6.13
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)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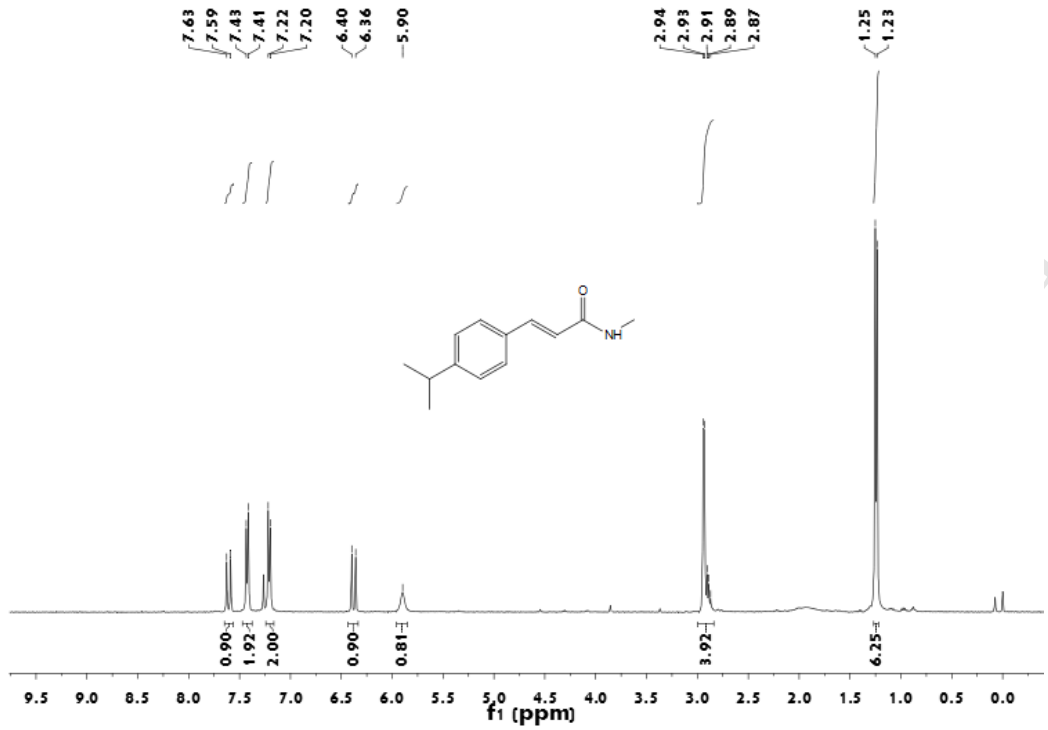
121.31
33.36
23.74
O
NH2
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20
f1 (ppm)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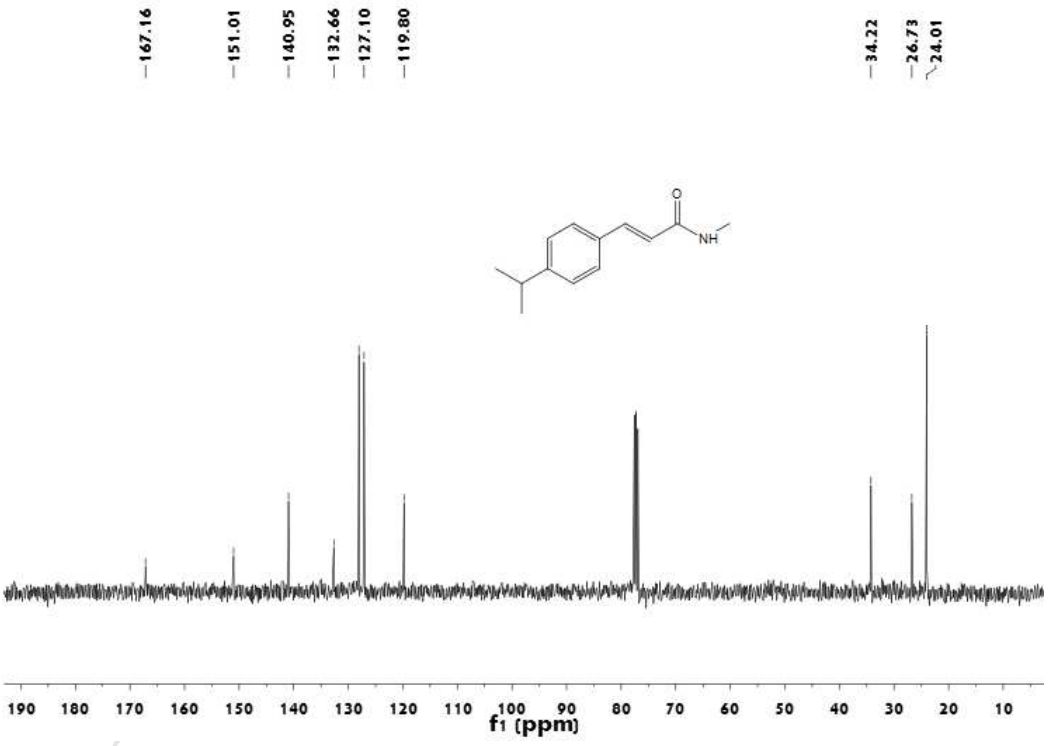
7.20
6.40
6.36
5.90
2.94
2.93
2.91
2.89
2.87
1.25
1.23
O
NH
0.90
1.92
2.00
0.90
0.81
3.92
6.25
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)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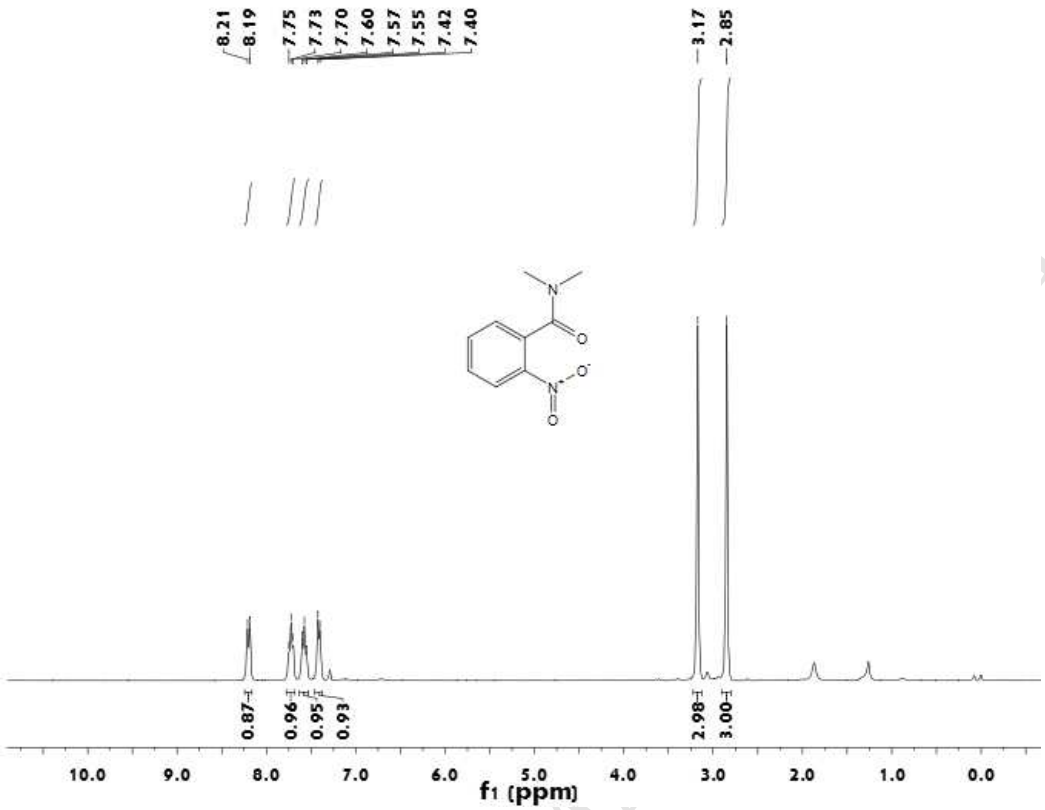
34.22
26.73
24.01
O
NH
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
f1 (ppm)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7.55
7.42
7.40
3.17
2.85
0.87
0.96
0.95
0.93
2.98
3.00
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9.0
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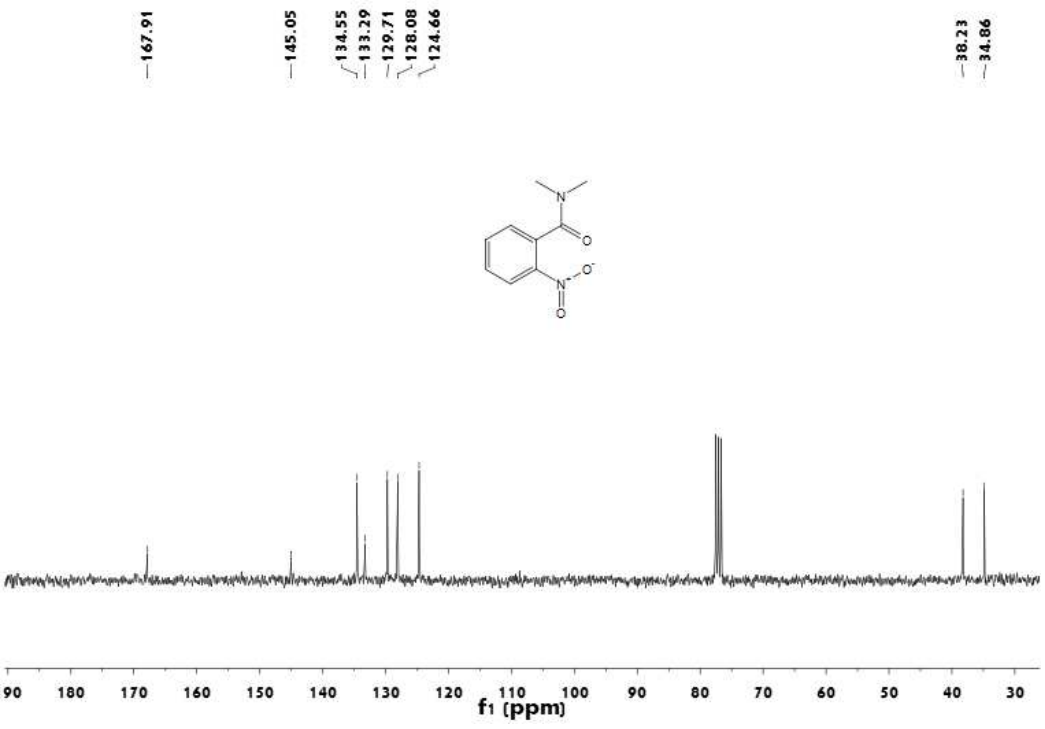
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
f1 (ppm)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124.66
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150
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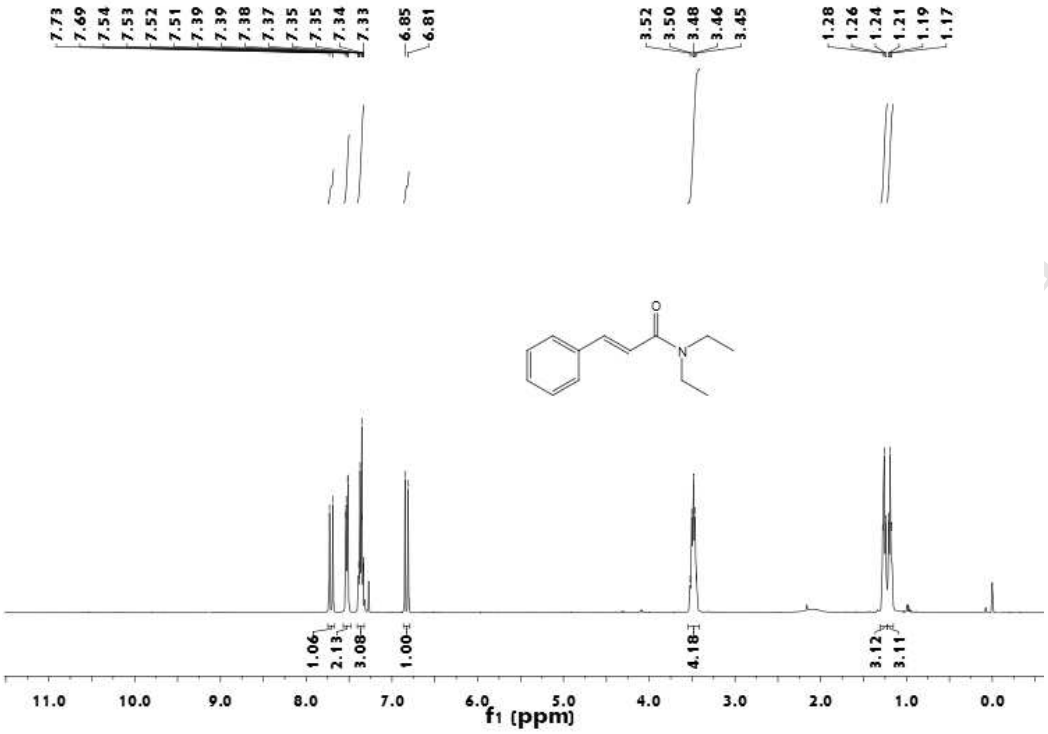
120
110
100
90
80
70
60
50
40
30
f1 (ppm)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7.35
7.35
7.34
7.33
6.85
6.81
3.52
3.50
3.48
3.46
3.45
1.28
1.26
1.24
1.21
1.19
1.17
O
N
1.06
2.13
3.08
1.00
4.18
3.12
3.11
11.0
10.0
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7.0
6.0
5.0
4.0
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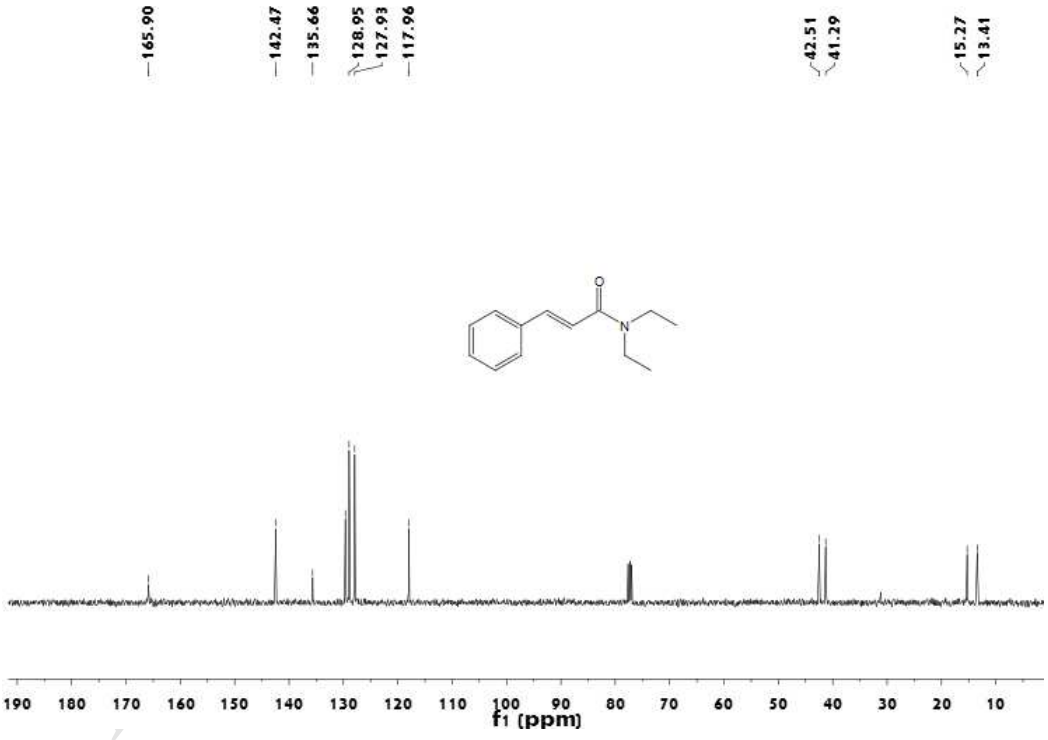
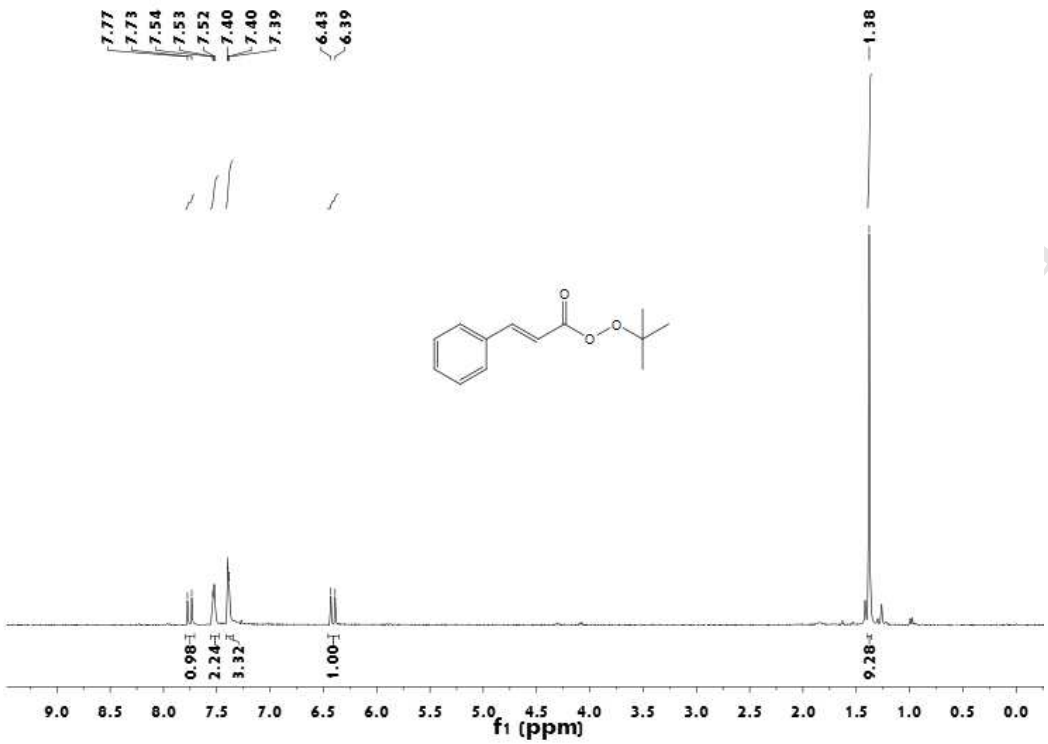
2.0
1.0
0.0
f1 (ppm)


165.90
142.47
135.66
128.95
127.93
117.96
42.51
41.29
15.27
13.41
O
N
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)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7.53
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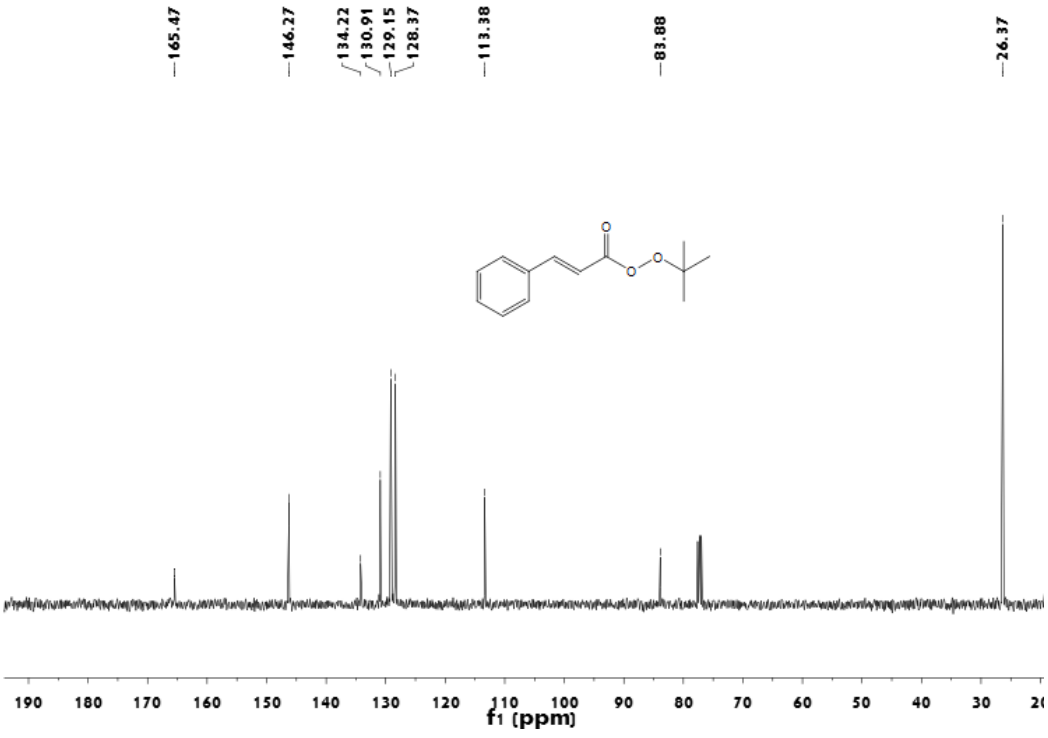
6.43
6.39
1.38
0.98
2.24
3.32
1.00
9.28
f1 (ppm)


165.47
146.27
134.22
130.91
129.15
128.37
113.38
83.88
26.37
f1 (ppm)