Direct Conjugate Additions Using Aryl and Alkyl Organic Halides in Air and Water

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Supplmentary Information

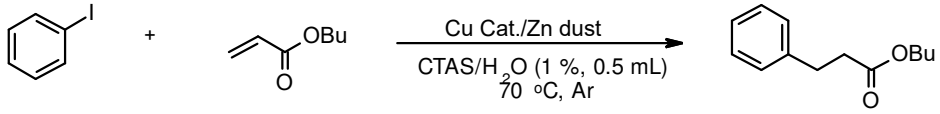
Contents

I. General Comments and Materials

All commercially available compounds were purchased from Sigma-Aldrich, Strem and Acros used as received. Unless otherwise noted, all reagents were weighed and handled in air and deionized water was used. For the optimization of reaction condition, the degassed water was used; for the reactions in substrate scope and scale-up reactions, there is no need to use degassed water. NMR spectra were recorded on Varian Mercury plus-300 spectrometer, Varian MERCURY plus-400 spectrometer, Varian VNMRS 500 spectrometer with proton resonances at 300/400/500 MHz and carbon resonances at 75/100/125 MHz, respectively. Chemical shifts are reported in parts per million (ppm). The solvent residual peaks, e.g., of chloroform ($CDCl_3$: δ 7.26 ppm and δ 77.26 ppm), were used as references. Data are reported as following: chemical shift, multiplicity (s = singlet, d = doublet, dd = doublet of doublets, t = triplet, q = quartet, m = multiplet, br = broad signal) and integration. Flash column chromatography was performed with Biotage Isolera with cartridge. Analytical thin layer chromatography (TLC) was performed using Merck silica gel 60 F254 pre-coated plates (0.25 mm). HRMS were conducted through atmospheric pressure chemical ionization (APCI) or electro-spraying ionization (ESI), and was performed by McGill University on a Thermo-Scientific Exactive Orbitrap. GC-MS were recorded on an Agilent 5975 GC-MS instrument (EI). Zinc dust was treated by the standard procedure (Armarego, W. L. F.; Chai, C. L. L. *Purification of Laboratory Chemicals; Elsevier Science*, **2003**) and other chemicals used as received. The complex I^iPrS-CuCl was prepared according to this reference[1].

II. Supplementary Results of Condition Optimization

Table S1. Survey of copper catalysts

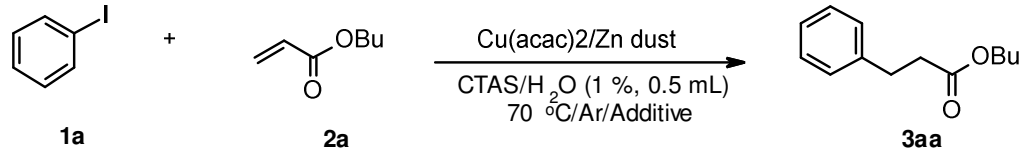


1a **2a** **3aa**

Entry	Cu Cat. (mol%)	Yield (%) [1]	Entry	Cu Cat. (mol%)	Yield (%) [1]
1	$Cu(acac)_2$ (5)	41	12	$Cu(BF_4)_2$ (10)	30
2 .	$Cu(acac)_2$ (20)	50	13	Cu $(acac)_2$ (10), hv(S)	25
3.	$Cu(OAc)_2$ (10)	34	14	Cu $(acac)_2$ (10), rt, hv(W)	23
4	$CuCl_2$ (10)	29	15	CuCl (10)	33
5	$Cu(OTf)_2$. toluene(10)	32	16	$Cu_2(CN)_2.H_2O$ (10)	28
6	$Cu(C_6H_5CO_2)_2$ (10)	38	17	CuI (10)	37
7	CuO (10)	41	18	CuBr (10)	21
8	$CuSO_4$ (10)	29	19	$[Cu(MeCN)_4]PF_6$ (10)	33
9	$Cu(OTf)_2$ (10)	50	20	Cu_2Se (10)	31
10	$Cu(CF_3CO_2)_2.H_2O$ (10)	36	21	Cu_2O (10)	28
11	$CuBr_2$ (10)	35	22	$Cu(ClO_4)_2.6H_2O$ (10)	23

Conditions: Iodobenzene (**1a**) (0.6 mmol), butyl acrylate (**2a**) (0.2 mmol), Cu Cat. Zn dust (0.78 mmol), CTAS (1%,W/V) /H_2O (0.5 mL), 70 °C , 24 h under argon. [1]The yields were determined by crude ^1H NMR by using the trimethoxybenzene as an internal standard. CTAS = Cetyltrimethylammonium hydrogensulfate

Table S2. Influence of halide salts as additive

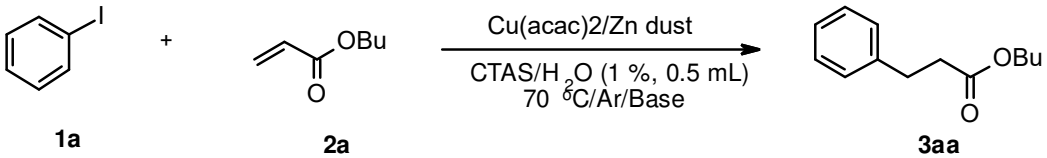


1a **2a** **3aa**

Entry	Additive (mol%)	Yield (%) [1]
1	LiF (20)	49
2	LiCl (20)	47
3	LiI (20)	49
4	acac (20)	45
5	I_2 (5)	41
6	$BrCH_2CH_2Br$ (10)	42
7	LiBr (20)	50
8	LiBr(100)	43
9	LiBr (500)	42

Conditions: Iodobenzene (**1a**) (0.6 mmol), butyl acrylate (**2a**) (0.2 mmol), $Cu(acac)_2$ (10 mol%). Zn dust (0.78 mmol), CTAS (1%,W/V) /H_2O (0.5 mL), 70 °C , 24 h under argon. [1]The yields were determined by crude ^1H NMR by using the trimethoxybenzene as an internal standard.

Table S3. Bases screening

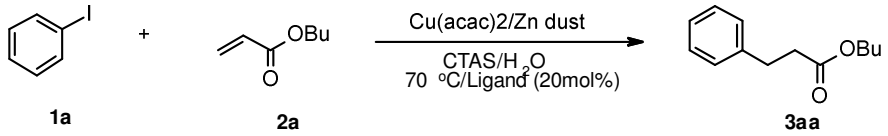


1a **2a** **3aa**

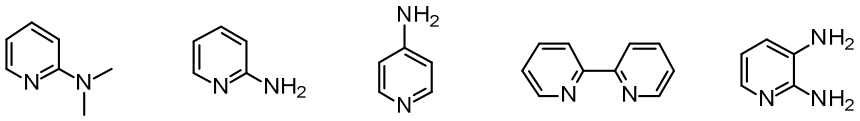
Entry	Base (mol%)	Yield (%) [1]
1	$KHCO_3$ (20)	40
2	KOH (20)	15
3	Cs_2CO_3 (20)	39
4	TMEDA 20)	23
5	DABCO (20)	39
6	DMAP (20)	56
7	DMAP (10)	57
8	DMAP (20)*	57
9	DMAP (50)	36
10	DMAP (100)	17

Conditions: Iodobenzene (**1a**) (0.6 mmol), butyl acrylate (**2a**) (0.2 mmol), $Cu(acac)_2$ (10 mol%). Zn dust (0.78 mmol), CTAS (1%,W/V) /H_2O (0.5 mL), 70 °C , 24 h under argon. [1]The yields were determined by crude ^1H NMR by using the trimethoxybenzene as an internal standard. *Pre-mix $Cu(acac)_2$ and DMAP.

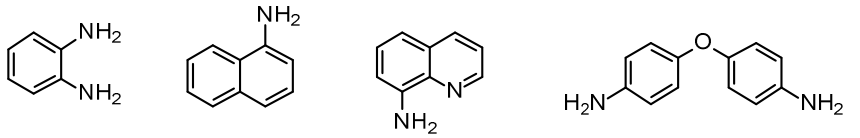
Table S4. Survey of ligands



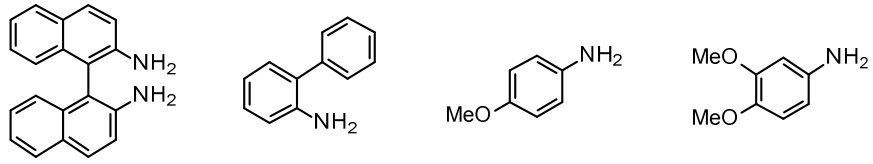
1a 2a 3aa



50% 55% 60% 50% 63%



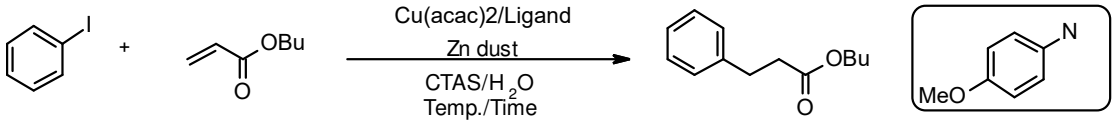
66% 64% 61% 58%



54% 52% 70% 82%

Conditions: Iodobenzene (**1a**) (0.6 mmol), butyl acrylate (**2a**) (0.2 mmol), $Cu(acac)_2$ (10 mol%), Zn dust (0.78 mmol), CTAS (1%,W/V) /H_2O (0.5 mL), 70 °C , 24 h under argon. [1]The yields were determined by crude ^1H NMR by using the trimethoxybenzene as an internal standard.

Table S5. Test of reaction temperature and time

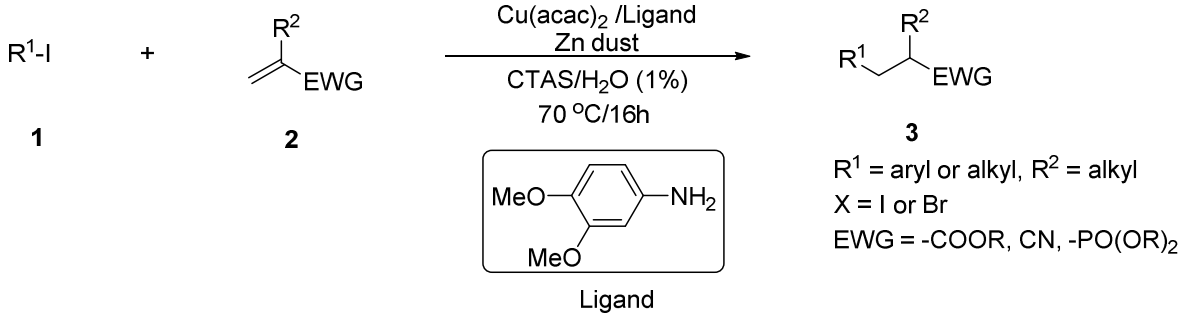


1a 2a 3aa Ligand

Entry	Temp. (°C)	Time (h)	Yield (%) [1]
1	70	24	70
2	70	5	62
3 [2]	70	5	50
4	50	46	64
5	rt	46	60

Conditions: Iodobenzene (**1a**) (0.6 mmol), butyl acrylate (**2a**) (0.2 mmol), $Cu(acac)_2$ (10 mol%), *p*-anisidine (20 mol%), Zn dust (0.78 mmol), CTAS (1%,W/V) /H_2O (0.5 mL), temperature and time, under argon. [1]The yields were determined by crude ^1H NMR by using the trimethoxybenzene as an internal standard. [2] Iodobenzene (0.3 mmol, 1.5 equiv.) was used.

III. Typical Procedure for the Copper-Catalyzed, Zinc-Mediated Intermolecular Arylation and Alkylation of Electron-Deficient Alkenes Using Organohalides in Air and Water



To a microwave tube was charged with $Cu(acac)_2$ (0.02 mmol, 5.2 mg), 3,4-dimethoxyaniline (0.04 mmol, 6.1 mg), Zinc dust (0.78 mmol, 50.7 mg). [Organoiodide (0.40 mmol) or electron-deficient alkene (0.20 mmol) was added at this point if the compound is solid]. Then the solvent CTAS in H_2O (1% w/v) was injected via syringe, followed by the addition of iodobenzene (**1a,** 0.40 mmol, 81.6 mg, 45.0 µL) and butyl acrylate (**2a**, 0.20 mmol, 25.6 mg, 29.0 µL). The tube was then sealed. The reaction mixture was heated to 70 °C and stirred vigorously (1400 rpm) for 16 h. After cooling to room temperature, the mixture was diluted with EtOAc (8 mL) and filtered through a short silica gel pad. The filter cake was further flushed with EtOAc (6 x 4 mL). The combined solution was concentrated under vacuum, and the residue was purified by flash chromatography on silica gel to afford the analytically pure product **3aa** (32.2 mg, 78%)

Preparation of 1% of CTAS/H_2O solution: A 20 mL vial was charged with CTAS (Cetyltrimethylammonium hydrogensulfate) (100 mg). Then degassed water (10 mL) was added via syringe. The mixture was placed in a sonicator and oscillated for 10 min. Occasional vigorous shaking was essential for the formation of well-distributed emulsion. The emulsion was stored under argon. Before injecting it (1% w/v, 0.5 mL) into the reaction tube, shake it vigorously.

IV. Typical Procedure for Copper-Catalyzed, Zinc-Mediated Intermolecular Conjugate Addition of Iodobenzene to Butyl Acrylate in Air and Water Using L-2 as Ligand

Preparation of ligand **L-1** and **L-2** according to the reference[2]: a mixture of acetylacetone (5.0 mmol, 0.5 mL), aniline (5.0 mmol, 0.62 g) and formic acid (1.0 mol%) in methanol (20 mL) was heated at 85 °C for 4 h. After cooling to room temperature, the product was precipitated out and collected as a solid. Then it was further recrystallized from a mixture of

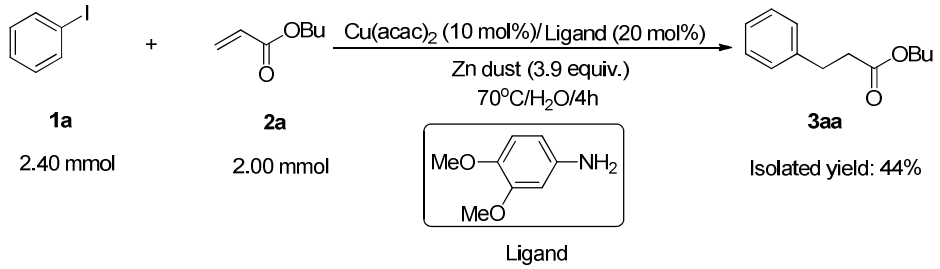
methanol/ether (6/4) to afford β-enaminone **L-2** (0.856 g, 78%).

L-1: ^{1}H NMR (500 MHz, $CDCl_3$) δ 12.3 (s, 1H), 6.82 (d, *J* = 8.5 Hz, 1H), 6.69−6.64 (m, 2H), 5.16 (s, 1H), 3.88 (s, 3H), 3.85 (s, 3H), 2.09 (s, 3H), 1.93 (s, 3H).

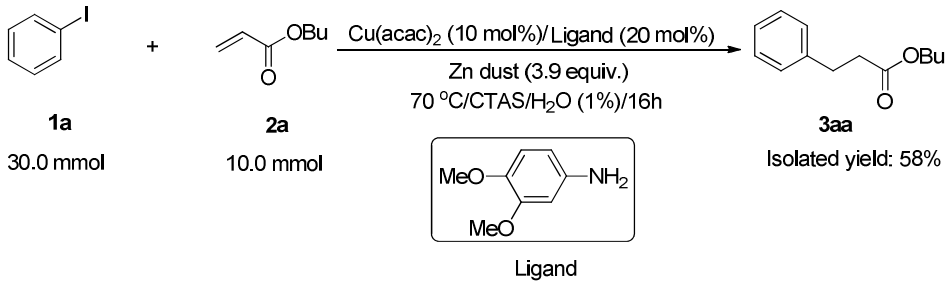
L-2: ^{1}H NMR (500 MHz, $CDCl_3$) δ 12.29 (s, 1H), 7.04 (d, *J* = 8.9 Hz, 2H), 6.86 (d, *J* = 8.9 Hz, 2H), 5.15 (s, 1H), 3.80 (s, 3H), 2.08 (s, 3H), 1.90 (s, 3H).

To a Biotage microwave tube was charged with $Cu(acac)_2$ (0.02 mmol, 5.2 mg), **L-2** (0.02 mmol, 4.1 mg), Zinc dust (0.78 mmol, 50.7 mg), followed by the addition of solvent CTAS in H_2O (1% w/v, 1.0 mL). The mixture was stirred at room temperature for 15 minutes. Then iodobenzene (**1a,** 0.40 mmol, 81.6 mg, 45 µL) and butyl acrylate (**2a**, 0.20 mmol, 25.6 mg, 30.0 µL) were injected. The reaction mixture was heated to 70 °C and stirred vigorously (1200 rpm) for 4 h. After cooling to room temperature, the mixture was diluted with EtOAc (6 mL) and filtered through a short silica gel pad. The filter cake was further flushed with EtOAc (6 x 4 mL). The combined solution was concentrated under vacuum, and the residue was purified by flash chromatography on silica gel to afford the analytically pure product **3aa** (20.3 mg, yield 49%).

V. The Gram-Scale Synthesis



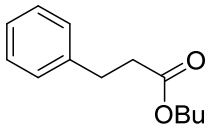
To a round-bottom flask was charged with $Cu(acac)_2$ (0.20 mmol, 52.0 mg), 3,4-dimethoxyaniline (0.40 mmol, 61.0 mg), Zinc dust (7.8 mmol, 507 mg). The flask was plugged with a rubber stopper. The deionized water (5.0 mL) was injected via syringe, followed by the addition of iodobenzene (**1a,** 2.40 mmol, 490 mg, 0.274 mL) and butyl acrylate (**2a**, 2.00 mmol, 256 mg, 0.290 mL). The reaction mixture was heated to 70 °C and stirred vigorously (1200 rpm) for 4 h. After cooling to room temperature, water (15 mL) and EtOAc (15 mL) were added. The organic layer was separated and the aqueous phase was extracted with EtOAc (3 x 25 mL). The combined organic layers were dried over $MgSO_4$, filtered and concentrated under reduced pressure. The residue was purified by flash chromatography on silica gel to afford the product **3aa** (182 mg, 44%).



To a round-bottom flask was charged with $Cu(acac)_2$ (1.00 mmol, 262 mg), 3,4-dimethoxyaniline (2.00mmol, 306 mg), Zinc dust (39.0 mmol, 2.54 g). The flask was plugged with a rubber stopper. Under an air atmosphere, 1% of CTAS/H_2O (15.0 mL) was injected via syringe, followed by the addition of iodobenzene (**1a,** 30.0 mmol, 6.13 g, 3.50 mL) and butyl acrylate (**2a**, 10.0 mmol, 1.28 g, 1.50 mL). The reaction mixture was heated to 70 °C and stirred vigorously (1200 rpm) for 16 h. After cooling to room temperature, EtOAc (15 mL) were added. The organic layer was separated and the aqueous phase was extracted with EtOAc (3 x 15 mL). The combined organic layers were dried over $MgSO_4$, filtered and concentrated under reduced pressure. The residue was purified by flash chromatography on silica gel to afford the product **3aa** (1.191 g, 58%).

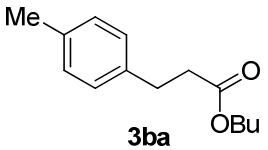
VI. The Spectroscopic Data of Products

For the known compounds, ^{1}H-NMR and ^{13}C-NMR data and spectra, as well as MS data are provided. Full characterization data are provided for compounds **3ka**, **3ja**, **3ha**, **3cc**, **3ib**, **3la**, **3ae, 3kd**, **3cf, 3ee**, **3ad**, **3cd**, **3ce**, **3ec**, **3ed**, **3ic and 3ke**.



3aa

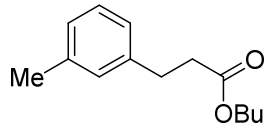
Butyl 3-phenylpropanoate (3aa)[3]: 32.2 mg, 78% yield, colorless oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.31-7.27 (m, 2H), 7.21−7.19 (m, 3H), 4.08 (t, *J* = 6.7 Hz, 2H), 2.96 (t, *J* = 6.7 Hz, 2H), 2.63 (t, *J* = 6.7 Hz, 2H), 1.60-1.57 (m, 2H), 1.38-1.31 (m, 2H), 0.92 (t, *J* = 7.4 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.2, 140.8, 128.7, 128.5, 126.5, 64.6, 36.2, 31.3, 30.9, 19.3, 13.9. MS (EI) m/z: 206.1



3ba

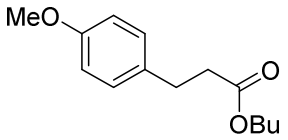
Butyl 3-(*p*-tolyl)propanoate (3ba)[4]: 38.3 mg, 78% yield, colorless oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.10 (s, 4H), 4.08 (t, *J* = 6.7 Hz, 2H), 2.92 (t, *J* = 6.7 Hz, 2H), 2.61 (t, *J* = 6.7 Hz, 2H), 2.32 (s, 3H), 1.62-1.56 (m, 2H), 1.37-1.33 (m, 2H), 0.93 (t, *J* = 7.4 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.3, 137.7, 135.9, 129.4, 128.4, 64.5, 36.3, 30.9, 30.8, 21.2, 19.3, 13.9. MS (EI)

m/z: 220.1



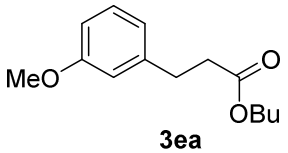
3ca

Butyl 3-(*m*-tolyl)propanoate (3ca)[5]: 25.5 mg, 58% yield, colorless oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.20-7.17 (m, 1H), 7.03−7.00 (m, 3H), 4.08 (t, *J* = 6.7 Hz, 2H), 2.92 (t, *J* = 6.7 Hz, 2H), 2.62 (t, *J* = 6.7 Hz, 2H), 2.33 (s, 3H), 1.62-1.57 (m, 2H),1.38-1.33 (m, 2H), 0.93 (t, *J* = 7.4 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.3, 140.7, 138.2, 129.3, 128.6, 127.2, 125.5, 64.5, 36.2, 31.2, 30.9, 21.6, 19.3, 13.9. MS (EI) m/z: 220.1



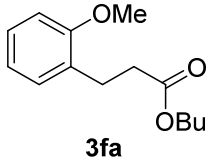
3da

Butyl 3-(4-methoxyphenyl)propanoate (3da)[5]: 22.7 mg, 48% yield, colorless oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.13-7.10 (m, 2H), 6.84−6.81 (m, 2H), 4.06 (t, *J* = 6.7 Hz, 2H), 3.78 (s, 3H), 2.89 (t, *J* = 7.8 Hz, 2H), 2.59 (t, *J* = 7.8 Hz, 2H), 1.59-1.56 (m, 2H), 1.36-1.32 (m, 2H), 0.92 (t, *J* = 7.4 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.3, 158.3, 132.9, 129.5, 114.1, 64.6, 55.5, 36.5, 30.9, 30.4, 19.4, 14.0. MS (EI) m/z: 236.1



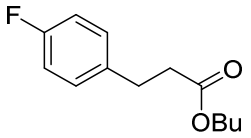
3ea

Butyl 3-(3-methoxyphenyl)propanoate (3ea)[6]: 19.8 mg, 42% yield, colorless oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.22-7.18 (m, 1H), 6.80−6.74 (m, 3H), 4.08 (t, *J* = 6.7 Hz, 2H), 3.79 (s, 3H), 2.93 (t, *J* = 6.7 Hz, 2H), 2.62 (t, *J* = 6.7 Hz, 2H), 1.60-1.57 (m, 2H), 1.37-1.33 (m, 2H), 0.92 (t, *J* = 7.4 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.2, 159.9, 142.4, 129.7, 120.9, 114.3, 111.8, 64.6, 55.4, 36.1, 31.3, 30.9, 19.4, 13.9. MS (EI) m/z: 236.1



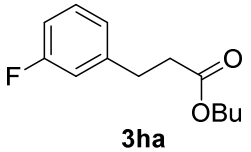
3fa

Butyl 3-(2-methoxyphenyl)propanoate (3fa)[6]: 12.3 mg, 26% yield, colorless oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.21-7.14 (m, 2H), 6.89−6.83 (m, 2H), 4.07 (t, *J* = 6.7 Hz, 2H), 3.82 (s, 3H), 2.94 (t, *J* = 7.8 Hz, 2H), 2.60 (t, *J* = 7.8 Hz, 2H), 1.62-1.57 (m, 2H), 1.39-1.32 (m, 2H), 0.92 (t, *J* = 7.4 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.9, 157.7, 130.2, 129.1, 127.8, 120.6, 110.4, 64.5, 55.4, 34.5, 30.9, 26.4, 19.4, 14.0. MS (EI) m/z: 236.1



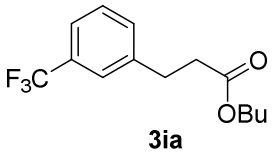
3ga

Butyl 3-(4-fluorophenyl)propanoate (3ga)[5]: 16.6 mg, 37% yield, colorless oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.17-7.14 (m, 2H), 6.98−6.95 (m, 2H), 4.06 (t, *J* = 6.7 Hz, 2H), 2.92 (t, *J* = 7.7 Hz, 2H), 2.60 (t, *J* = 7.7 Hz, 2H), 1.59-1.54 (m, 2H),1.36-1.31 (m, 2H), 0.91 (t, *J* = 7.4 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.1, 162.7, 160.7, 136.4 (d, *J* = 3.2 Hz), 129.9 (d, *J* = 7.8 Hz), 115.5 (d, *J* = 21.2 Hz), 64.6, 36.3, 30.9, 30.4, 19.3, 13.9. MS (EI) m/z: 224.1



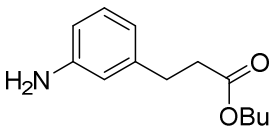
3ha

Butyl 3-(3-fluorophenyl)propanoate (3ha): 17.0 mg, 38% yield, colorless oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.24-7.22 (m, 1H), 6.97 (d, *J* = 7.6 Hz, 1H), 6.91-6.87 (m, 2H), 4.07 (t, *J* = 6.7 Hz, 2H), 2.95 (t, *J* = 7.7 Hz, 2H), 2.62 (t, *J* = 7.7 Hz, 2H), 1.60-1.55 (m, 2H),1.36-1.32 (m, 2H), 0.92 (t, *J* = 7.4 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 172.9, 164.1, 162.2, 143.3 (d, *J* = 7.3 Hz), 130.1 (d, *J* = 8.3 Hz), 124.2 (d, *J* = 2.8 Hz), 115.4 (d, *J* = 21.1 Hz), 113.4 (d, *J* = 21.0 Hz), 64.7, 35.8, 30.92 (d, *J* = 1.7 Hz), 30.88, 19.3, 13.9. HRMS calcd $C_{13}H_{17}FO_2Na$ $[M+Na]^+$: 247.1105. Found: 247.1105



3ia

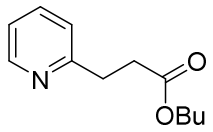
B**utyl 3-(3-(trifluoromethyl)phenyl)propanoate (3ia)**[7]: 14.2 mg, 26% yield, colorless oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.47-7.39 (m, 4H), 4.07 (t, *J* = 6.7 Hz, 2H), 3.01 (t, *J* = 7.7 Hz, 2H), 2.65 (t, *J* = 7.7 Hz, 2H), 1.59-1.56 (m, 2H), 1.35-1.29 (m, 2H), 0.91 (t, *J* = 7.4 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 172.5, 141.4, 131.8, 130.8 (q, *J* = 32.0 Hz), 128.9, 125.1 (q, *J* = 3.8 Hz), 124.1 (q, *J* = 270 Hz), 123.2 (q, *J* = 3.8 Hz), 64.5, 35.6, 30.7, 30.6, 19.1, 13.7. MS (EI) m/z: 274.1



3ja

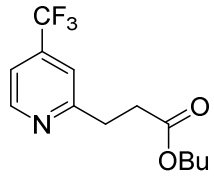
Butyl 3-(3-aminophenyl)propanoate (3ja): 5.3 mg, 12% yield, yellow oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.08-7.05 (m, 1H), 6.61-6.52 (m, 3H), 4.07 (t, J = 6.7 Hz, 2H), 3.69 (brs, 2H),

2.87-2.84 (m, 2H), 2.61-2.58 (m, 2H), 1.62-1.58 (m, 2H), 1.38-1.33 (m, 2H), 0.92 (t, J = 7.4 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.4, 146.7, 142.1, 129.6, 118.8, 115.3, 113.3, 64.6, 36.1, 31.2, 30.9, 19.4, 14.0. HRMS calcd $C_{13}H_{20}NO_2$ $[M+H]^+$: 222.1488. Found: 222.1488



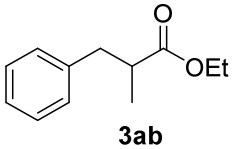
3ka

Butyl 3-(pyridin-2-yl)propanoate (3ka): 27.7 mg, 67% yield, yellow oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.52 (d, *J* = 4.3 Hz, 1H), 7.58 (td, *J* = 7.7, 1.8 Hz, 1H), 7.19-7.09 (m, 2H), 4.06 (t, *J* = 6.7 Hz, 2H), 3.11 (t, *J* = 7.5 Hz, 2H), 2.80 (t, *J* = 7.5 Hz, 2H), 1.60-1.54 (m, 2H), 1.35-1.31 (m, 2H), 0.90 (t, *J* = 7.4 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.4, 160.4, 149.5, 136.6, 123.2, 121.6, 64.6, 33.7, 33.2, 30.9, 19.3, 13.9. HRMS calcd $C_{12}H_{18}NO_2$ $[M+H]^+$: 208.1332. Found: 208.1331



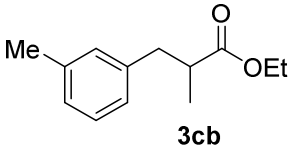
3la

Butyl 3-(4-(trifluoromethyl)pyridin-2-yl)propanoate (3la): 30.8 mg, 56% yield, yellow oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.69 (d, *J* = 5.1 Hz, 1H), 7.41 (s, 1H), 7.34 (d, *J* = 5.0 Hz, 1H), 4.07 (t, *J* = 6.7 Hz, 2H), 3.19 (t, *J* = 7.3 Hz, 2H), 2.84 (t, *J* = 7.3 Hz, 2H), 1.59-1.54 (m, 2H), 1.36-1.30 (m, 2H), 0.90 (t, *J* = 7.4 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.0, 162.0, 150.5, 138.8 (q, *J* = 33.9 Hz), 123.1 (q, *J* = 273.2 Hz), 118.9 (q, *J* = 3.6 Hz), 117.2 (q, *J* = 3.5 Hz), 64.7, 33.2, 33.1, 30.9, 19.3, 13.9. HRMS calcd $C_{13}H_{17}F_3NO_2$ $[M+H]^+$: 276.1206. Found: 276.1205



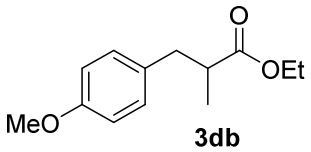
3ab

Ethyl 2-methyl-3-phenylpropanoate (3ab)[8]: 23.0 mg, 60% yield, colorless oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.29-7.27 (m, 2H), 7.21−7.16 (m, 3H), 4.09 (q, *J* = 7.1 Hz, 2H), 3.02 (dd, *J* = 13.0, 6.6 Hz, 1H), 2.74-2.64 (m, 2H), 1.19 (t, *J* = 7.1 Hz, 3H), 1.15 (d, *J* = 6.8 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 176.4, 139.7, 129.2, 128.6, 126.5, 60.5, 41.8, 40.0, 17.0, 14.4. MS (EI) m/z: 192.1



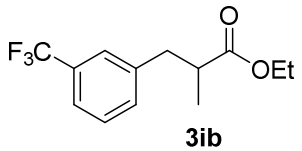
3cb

Ethyl 2-methyl-3-(3-methylphenyl)propanoate (3cb)[9]: 24.7 mg, 60% yield, colorless oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.18-7.15 (m, 1H), 7.02-6.96 (m, 3H), 4.10 (q, *J* = 7.1 Hz, 2H), 2.99 (dd, *J* = 13.3, 6.8 Hz, 1H), 2.72-2.60 (m, 2H), 2.32 (s, 3H), 1.20 (t, *J* = 7.1 Hz, 3H), 1.15 (d, *J* = 6.9 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 176.4, 139.6, 138.1, 130.0, 128.4, 127.2, 126.2, 60.5, 41.7, 39.9, 21.6, 17.0, 14.4. MS (EI) m/z: 206.1



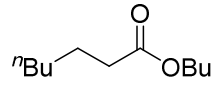
3db

Ethyl 2-methyl-3-(3-methoxylphenyl)propanoate (3db)[10]: 9.32 mg, 21% yield, colorless oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.08 (d, *J* = 8.6 Hz, 2H), 6.82 (d, *J* = 8.6 Hz, 2H), 4.09 (q, *J* = 7.1 Hz, 2H), 3.78 (s, 3H), 2.95 (dd, *J* = 13.2, 6.7 Hz, 1H), 2.68-2.59 (m, 2H), 1.20 (t, *J* = 7.1 Hz, 3H), 1.14 (d, *J* = 6.8 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 176.4, 158.3, 131.7, 130.2, 114.0, 60.5, 55.5, 42.0, 39.1, 17.0, 14.4. MS (EI) m/z: 222.1



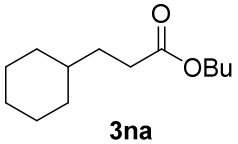
3ib

Ethyl 2-methyl-3-(3-(trifluoromethyl)phenyl)propanoate (3ib): 17.7 mg, 34% yield, colorless oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.47-7.35 (m, 4H), 4.08 (q, *J* = 7.1 Hz, 2H), 3.08-3.03 (m, 1H), 2.77-2.71 (m, 2H), 1.19-1.16 (m, 6H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 175.8, 140.6, 132.7, 130.9 (q, *J* = 32.0 Hz), 129.0, 125.9 (q, *J* = 3.8 Hz), 124.4 (q, *J* = 270 Hz), 123.5 (q, *J* = 3.8 Hz), 60.7, 41.6, 39.7, 17.2, 14.3. MS (EI) m/z: 260.1. HRMS calcd $C_{13}H_{16}F_3O_2$ $[M+H]^+$: 261.1097. Found: 261.1095



3ma

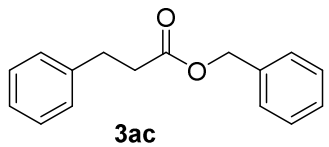
Butyl heptanoate (3ma)[11]: 26.0 mg, 70% yield, colorless oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 4.06 (t, *J* = 6.7 Hz, 2H), 2.29 (t, *J* = 7.5 Hz, 2H), 1.62-1.59 (m, 4H), 1.31-1.25 (m, 8H), 0.93 (t, *J* = 7.4 Hz, 3H), 0.88 (t, *J* = 6.8 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 174.3, 64.3, 34.7, 31.7, 31.0, 29.1, 25.2, 22.7, 19.4, 14.3, 14.0. MS (EI) m/z: 186.1



3na

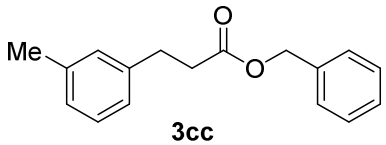
Butyl 3-cyclohexylpropanoate (3na)[12]: 37.3 mg, 88% yield, colorless oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 4.06 (t, *J* = 6.7 Hz, 2H), 2.31-2.28 (m, 2H), 1.71-1.57 (m, 7H), 1.52 (dd, *J* = 15.4, 7.1

Hz, 2H), 1.40-1.35 (m, 2H), 1.22-1.20 (m, 4H), 0.95-0.84 (m, 5H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 174.3, 64.1, 37.3, 33.0, 32.4, 30.0, 30.7, 26.6, 26.2, 19.2, 13.7. MS (EI) m/z: 212.1



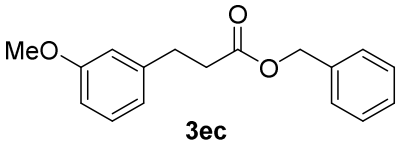
3ac

Benzyl 3-phenylpropanoate (3ac)[13]: 34.6 mg, 72% yield, colorless oil, ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.38-7.28 (m, 7H), 7.23-7.19 (m, 3H), 5.13 (s, 2H), 2.99 (t, *J* = 7.8 Hz, 2H), 2.70 (t, *J* = 7.8 Hz, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 172.9, 140.6, 136.2, 128.8, 128.7, 128.5, 128.4, 126.5, 66.5, 36.1, 31.2. MS (EI) m/z: 240.1



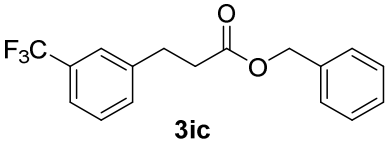
3cc

Benzyl 3-(m-tolyl)propanoate (3cc)[14]: 31.0 mg, 61% yield, colorless oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.38-7.31 (m, 5H), 7.18 (t, *J* = 7.4 Hz, 1H), 7.04-6.99 (m, 3H), 5.13 (s, 2H), 2.95 (t, *J* = 7.8 Hz, 2H), 2.69 (t, *J* = 7.8 Hz, 2H), 2.32 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.0, 140.6, 138.3, 136.2, 129.3, 128.8, 128.6, 128.4, 127.2, 125.5, 66.5, 36.2, 31.1, 21.6. HRMS calcd $C_{17}H_{18}O_2Na$ $[M+Na]^+$: 277.1199. Found: 277.1201



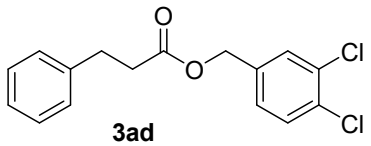
3ec

Benzyl 3-(3-methoxyphenyl)propanoate (3ec): 23.2 mg, 43% yield, colorless oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.36-7.31 (m, 5H), 7.22-7.18 (m, 1H), 6.80-6.75 (m, 3H), 5.13 (s, 2H), 3.78 (s, 3H), 2.96 (t, *J* = 7.8 Hz, 2H), 2.69 (t, *J* = 7.8 Hz, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 172.9, 159.9, 142.3, 136.2, 129.7, 128.8, 128.4, 120.9, 114.2, 111.9, 66.5, 55.4, 36.0, 31.2. HRMS calcd $C_{17}H_{18}O_3Na$ $[M+Na]^+$: 277.1148. Found: 277.1144



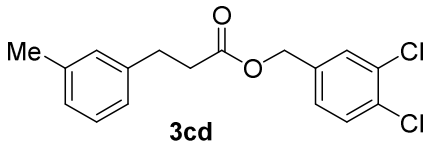
3ic

Benzyl 3-(3-(trifluoromethyl)phenyl)propanoate (3ic): 17.2 mg, 28% yield, colorless oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.47-7.46 (m, 2H), 7.40-7.29 (m, 7H), 5.11 (s, 2H), 3.03 (t, *J* = 7.7 Hz, 2H), 2.71 (t, *J* = 7.7 Hz, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 172.5, 141.5, 136.0, 132.0, 131.1 (q, *J* = 32.0 Hz), 128.8, 128.6, 128.5, 125.3 (q, *J* = 3.8 Hz), 124.4 (q, *J* = 270.0 Hz), 123.5 (q, *J* = 3.8 Hz), 66.7, 35.8, 30.9. HRMS calcd $C_{17}H_{15}F_3O_2Na$ $[M+Na]^+$: 331.0916. Found: 331.0908



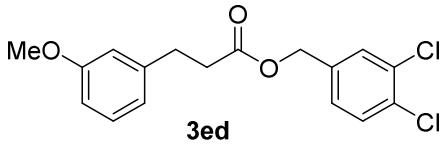
3ad

3,4-Dichlorobenzyl 3-phenylpropanoate (3ad): 43.3 mg, 70% yield, colorless oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ7.41-7.38 (m, 2H), 7.29-7.27 (m, 2H), 7.23-7.17 (m, 3H), 7.11-7.09 (m, 1H), 5.04 (s, 2H), 2.97 (t, *J* = 7.7 Hz, 2H), 2.70 (t, *J* = 7.8 Hz, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 172.7, 140.4, 136.4, 132.9, 132.5, 130.8, 130.3, 128.8, 128.5, 127.6, 126.6, 64.9, 36.0, 31.1. HRMS calcd $C_{16}H_{14}Cl_2O_2Na$ $[M+Na]^+$: 331.0263. Found: 331. 0254



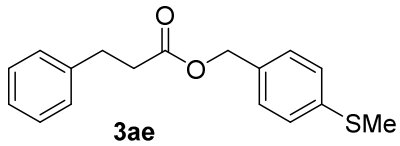
3cd

3,4-Dichlorobenzyl 3-(m-tolyl)propanoate (3cd): 32.9 mg, 51% yield, colorless oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ7.41-7.38 (m, 2H), 7.17 (t, *J* = 7.5 Hz, 1H), 7.11 (dd, *J* = 8.2, 2.0 Hz, 1H), 7.03-6.97 (m, 3H), 5.04 (s, 2H), 2.93 (t, *J* = 7.7 Hz, 2H), 2.69 (t, *J* = 7.8 Hz, 2H), 2.31 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 172.8, 140.3, 138.4, 136.4, 132.9, 132.5, 130.8, 130.3, 129.3, 128.7, 127.6, 127.4, 125.5, 64.9, 36.0, 31.1, 21.6. HRMS calcd $C_{17}H_{16}Cl_2O_2Na$ $[M+Na]^+$: 345.0420. Found: 345. 0412



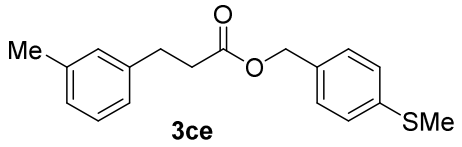
3ed

3,4-dichlorobenzyl 3-(3-methoxyphenyl)propanoate (3ed): 30.5 mg, 45% yield, colorless oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.41-7.39 (m, 2H), 7.20 (t, *J* = 7.8 Hz, 1H), 7.11 (dd, *J* = 8.2, 2.0 Hz, 1H), 6.78-6.73 (m, 3H), 5.04 (s, 2H), 3.78 (s, 3H), 2.95 (t, *J* = 7.7 Hz, 2H), 2.70 (t, *J* = 7.7 Hz, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 172.7, 159.9, 142.0, 136.3, 132.9, 132.5, 130.7, 130.3, 129.7, 127.6, 120.8, 114.3, 111.9, 64.9, 55.4, 35.9, 31.1. HRMS calcd $C_{17}H_{16}O_3Na$ $[M+Na]^+$: 361.0369. Found: 361.0361



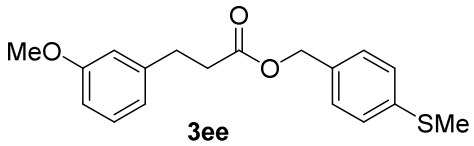
3ae

4-(Methylthio)benzyl 3-phenylpropanoate (3ae): 37.8 mg, 66% yield, colorless oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.28 (t, *J* = 7.4 Hz, 2H), 7.23 (s, 4H), 7.20 (dd, *J* = 14.6, 7.4 Hz, 3H), 5.07 (s, 2H), 2.97 (t, *J* = 7.8 Hz, 2H), 2.68 (t, *J* = 7.8 Hz, 2H), 2.49 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 172.9, 140.6, 139.0, 132.9, 129.1, 128.7, 128.5, 126.8, 126.5, 66.1, 36.1, 31.2, 16.0. HRMS calcd $C_{17}H_{18}NaSO_2$ $[M+Na]^+$: 309.0920. Found: 309.0918



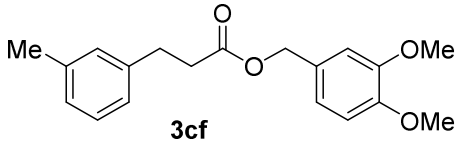
3ce

4-(Methylthio)benzyl 3-(*m*-tolyl)propanoate (3ce): 34.2 mg, 57% yield, colorless oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.29 (dd, *J* = 13.6, 8.4 Hz, 1H), 7.23 (s, 3H), 7.16 (t, *J* = 7.5 Hz, 1H), 7.02-6.97 (m, 3H), 5.06 (s, 2H), 2.92 (t, *J* = 7.8 Hz, 2H), 2.66 (t, *J* = 7.8 Hz, 2H), 2.48 (s, 3H), 2.31 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.0, 140.6, 139.0, 138.3, 132.9, 129.3, 129.14, 128.6, 127.2, 126.8, 125.5, 66.1, 36.2, 31.1, 21.6, 16.0. HRMS calcd $C_{18}H_{20}NaSO_2$ $[M+Na]^+$: 323.1076. Found: 323.1076



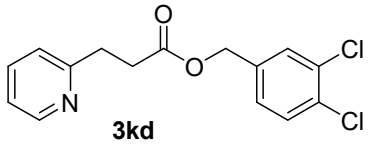
3ee

4-(Methylthio)benzyl 3-(3-methoxyphenyl)propanoate (3ee): 36.0 mg, 57% yield, colorless oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ7.23 (s, 4H), 7.19 (t, *J* = 7.8 Hz, 1H), 6.78-6.74 (m, 3H), 5.07 (s, 2H), 3.78 (s, 3H), 2.94 (t, *J* = 7.8 Hz, 2H), 2.67 (t, *J* = 7.8 Hz, 2H), 2.49 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 172.9, 159.9, 142.2, 139.0, 132.9, 129.7, 129.1, 126.7, 120.8, 114.2, 111.9, 66.2, 55.4, 36.0, 31.2, 16.0. HRMS calcd $C_{18}H_{20}O_3NaS$ $[M+Na]^+$: 339.1025. Found: 339.1025



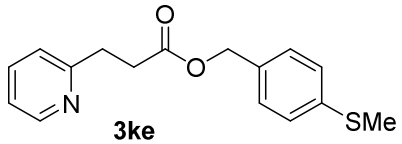
3cf

3,4-Dimethoxybenzyl 3-(*m*-tolyl)propanoate (3cf): 38.9 mg, 62% yield, colorless oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.18-7.14 (m, 1H), 7.02-6.97 (m, 3H), 6.91-6.89 (m, 1H), 6.86-6.83 (m, 2H), 5.05 (s, 2H), 3.89 (s, 3H), 3.87 (s, 3H), 2.93 (t, *J* = 7.8 Hz, 2H), 2.66 (t, *J* = 7.8 Hz, 2H), 2.31 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.1, 149.3, 149.2, 140.6, 138.3, 129.3, 128.7, 128.6, 127.2, 125.5, 121.5, 112.0, 111.2, 66.6, 56.2, 56.1, 36.2, 31.1, 21.6. HRMS calcd $C_{19}H_{22}O_4Na$ $[M+Na]^+$: 337.1410. Found: 337.1412



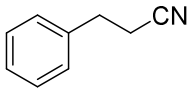
3kd

3-Chloro-4-(methylthio)benzyl 3-(pyridin-2-yl)propanoate (3kd): 39.1 mg, 63% yield, light yellow oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.50 (d, *J* = 4.3 Hz, 1H), 7.57 (td, *J* = 7.7, 1.8 Hz, 1H), 7.39 (d, *J* = 8.4 Hz, 2H), 7.16-7.10 (m, 3H), 5.04 (s, 2H), 3.13 (t, *J* = 7.3 Hz, 2H), 2.87 (t, *J* = 7.3 Hz, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 172.9, 159.8, 149.5, 136.6, 136.5, 132.8, 132.4, 130.7, 130.2, 127.5, 123.2, 121.7, 64.8, 33.4, 32.9. HRMS calcd $C_{15}H_{14}Cl_2NO_2$ $[M+H]^+$: 310.0396. Found: 310.0398



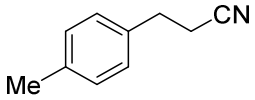
3ke

4-(Methylthio)benzyl 3-(pyridin-2-yl)propanoate (3ke): 37.3 mg, 65% yield, light yellow oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.50 (d, *J* = 4.3 Hz, 1H), 7.56 (td, *J* = 7.7, 1.8 Hz, 1H), 7.24-7.20 (m, 4H), 7.15-7.09 (m, 2H), 5.06 (s, 2H), 3.12 (t, *J* = 7.4 Hz, 2H), 2.85 (t, *J* = 7.4 Hz, 2H), 2.47 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.1, 160.1, 149.5, 138.9, 136.6, 133.0, 129.1, 126.8, 123.2, 121.6, 66.1, 33.6, 33.1, 16.0. HRMS calcd $C_{16}H_{17}NSO_2Na$ $[M+Na]^+$: 310.0872. Found: 310.0868



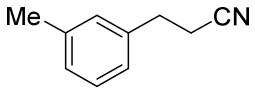
3ag

3-Phenylpropanenitrile (3ag)[15]: 15.7 mg, 60% yield, colorless oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.33-7.36 (m, 2H), 7.23−7.29 (m, 3H), 2.96 (t, *J* = 7.4 Hz, 2H), 2.62 (t, *J* = 7.4 Hz, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 138.3, 129.1, 128.5, 127.5, 119.4, 31.8, 19.6. MS (EI) m/z: 131.1



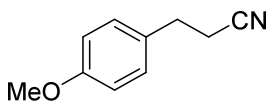
3bg

3-(*P*-tolyl)propanenitrile (3bg)[16]: 13.1 mg, 45% yield, colorless oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.14 (q, *J* = 8.1 Hz, 4H), 2.92 (t, *J* = 7.4 Hz, 2H), 2.60 (t, *J* = 7.4 Hz, 2H), 2.34 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 137.1, 135.3, 129.8, 128.4, 119.5, 31.4, 21.3, 19.7. MS (EI) m/z: 145.1



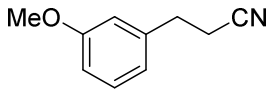
3cg

3-(*M*-tolyl)propanenitrile (3cg)[17]: 18.0 mg, 62% yield, colorless oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.23 (t, *J* = 7.5 Hz, 1H), 7.10 – 7.02 (m, 3H), 2.93 (t, *J* = 7.5 Hz, 2H), 2.61 (t, *J* = 7.5 Hz, 2H), 2.35 (s, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 138.8, 138.2, 129.3, 129.0, 128.2, 125.5, 119.4, 31.8, 21.6, 19.6. MS (EI) m/z: 145.1



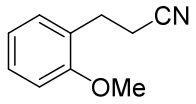
3dg

3-(4-Methoxyphenyl)propanenitrile (3dg)[16]: 6.76 mg, 21% yield, colorless oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.16-7.14 (m, 2H), 6.88-6.86 (m, 2H), 3.80 (s, 3H), 2.90 (t, *J* = 7.4 Hz, 2H), 2.58 (t, *J* = 7.4 Hz, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 159.0, 130.4, 129.6, 119.5, 114.5, 55.5, 31.0, 20.0. MS (EI) m/z: 161.1



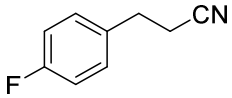
3eg

3-(3-Methoxyphenyl)propanenitrile (3eg)[16]: 19.3 mg, 60% yield, colorless oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.27-7.24 (m, 1H), 6.83-6.77 (m, 3H), 3.81 (s, 3H), 2.94 (t, *J* = 7.5 Hz, 2H), 2.62 (t, *J* = 7.5 Hz, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 160.2, 139.8, 130.2, 120.7, 119.3, 114.3, 112.7, 55.5, 31.9, 19.5. MS (EI) m/z: 161.1



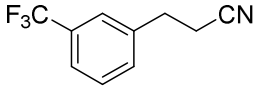
3fg

3-(2-Methoxyphenyl)propanenitrile (3fg)[18]: 17.1 mg, 53% yield, yellow oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.26 (dd, *J* = 15.7, 1.7 Hz, 1H), 7.18 (dd, *J* = 7.4, 1.6 Hz, 1H), 6.94-6.86 (m, 2H), 3.84 (s, 3H), 2.96 (t, *J* = 7.4 Hz, 2H), 2.62 (t, *J* = 7.5 Hz, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 157.5, 130.5, 128.90, 126.6, 120.9, 119.9, 110.6, 55.5, 27.3, 17.7. MS (EI) m/z: 161.1



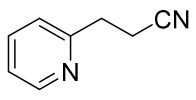
3gg

3-(4-Fluorophenyl)propanenitrile (3gg)[16]: 12.5 mg, 42% yield, yellow oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.21-7.19 (m, 2H), 7.05-7.01 (m, 2H), 2.94 (t, *J* = 7.3 Hz, 2H), 2.61 (t, *J* = 7.3 Hz, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 163.3, 161.3, 133.9 (d, *J* = 3.3 Hz), 130.1 (d, *J* = 8.1 Hz), 119.1, 116.1, 115.9, 31.0, 19.8. MS (EI) m/z: 149.1



3ig

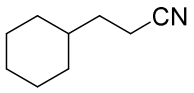
3-(3-(Trifluoromethyl)phenyl)propanenitrile (3ig)[19]: 14.3 mg, 36% yield, colorless oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.56 (d, *J* = 7.1 Hz, 1H), 7.50-7.44 (m, 3H), 3.03 (t, *J* = 7.4 Hz, 2H), 2.66 (t, *J* = 7.4 Hz, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 139.0, 132.0, 131.7, 131.4, 129.7, 129.2, 129.0, 127.8, 127.5, 125.3 (q, *J* = 3.8 Hz), 124.51 (q, *J* = 3.8 Hz), 118.8, 31.6, 19.4. MS (EI) m/z: 199.1



3kg

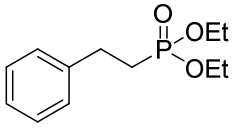
3-(Pyridin-2-yl)propanenitrile (3kg)[20]: 12.9 mg, 49% yield, yellow oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.56 (d, *J* = 4.3 Hz, 1H), 7.65 (td, *J* = 7.7, 1.8 Hz, 1H), 7.23 – 7.18 (m, 2H), 3.12 (t, *J* = 7.3 Hz, 2H), 2.85 (t, *J* = 7.4 Hz, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 157.4, 149.9, 137.0, 123.4,

122.4, 119.7, 33.6, 16.9. MS (EI) m/z: 132.1



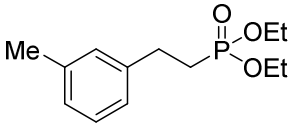
3ng

3-Cyclohexylpropanenitrile (3ng)[21]: 26.3 mg, 96% yield, colorless oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 2.34 (t, *J* = 7.4 Hz, 2H), 1.73-1.65 (m, 5H), 1.58-1.53 (m, 2H), 1.42-1.36 (m, 1H), 1.28-1.12 (m, 3H), 0.94-0.86 (m, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 120.3, 36.8, 32.80, 32.75, 26.6, 26.2, 14.9. MS (EI) m/z: 137.1



3ah

Diethyl phenethylphosphonate (3ah)[22]: 16.9 mg, 35% yield, yellow oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.31-7.28 (m, 2H), 7.22-7.19 (m, 3H), 4.13-4.06 (m, 4H), 2.92 (dd, J = 17.2, 9.8 Hz, 2H), 2.05 (ddd, *J* = 11.7, 10.3, 7.0 Hz, 2H), 1.32 (t, *J* = 7.1 Hz, 6H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 141.3, 141.2, 128.8, 128.3, 126.6, 61.8 (d, *J* = 6.5 Hz), 28.8 (d, *J* = 4.4 Hz), 27.8 (d, *J* = 139.4 Hz), 16.7 (d, *J* = 6.0 Hz). MS (EI) m/z: 242.1



3ch

Diethyl (3-methylphenethyl)phosphonate (3ch)[23]: 24.1 mg, 47% yield, yellow oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.19-7.16 (m, 1H), 7.03-7.00 (m, 3H), 4.15-4.13 (m, 4H), 2.92-2.86 (m, 2H), 2.32 (s, 3H), 2.11 (brs, 2H), 1.33 (t, *J* = 7.1 Hz, 6H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 138.4, 129.1, 128.7, 127.4, 125.3, 61.9 (d, *J* = 6.5 Hz), 28.6 (d, *J* = 4.2 Hz), 27.8 (d, *J* = 139.2 Hz), 21.6, 16.7 (d, *J* = 6.1 Hz). MS (EI) m/z: 256.1

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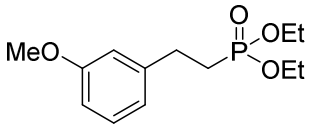

3eh

Diethyl (3-methoxyphenethyl)phosphonate (3eh)[23]: 19.6 mg, 36% yield, yellow oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.23-7.20 (m, 1H), 6.80-6.75 (m, 3H), 4.14-4.07 (m, 4H), 3.80 (s, 3H), 2.92-2.86 (m, 2H), 2.09-2.02 (m, 2H), 1.33 (t, *J* = 7.1 Hz, 6H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 160.0, 129.8, 120.6, 114.1, 111.9, 61.9 (d, *J* = 6.5 Hz), 55.4, 28.9, 27.8 (d, *J* = 139.2 Hz), 16.7 (d, *J* = 6.2 Hz). MS (EI) m/z: 272.1

VII. References

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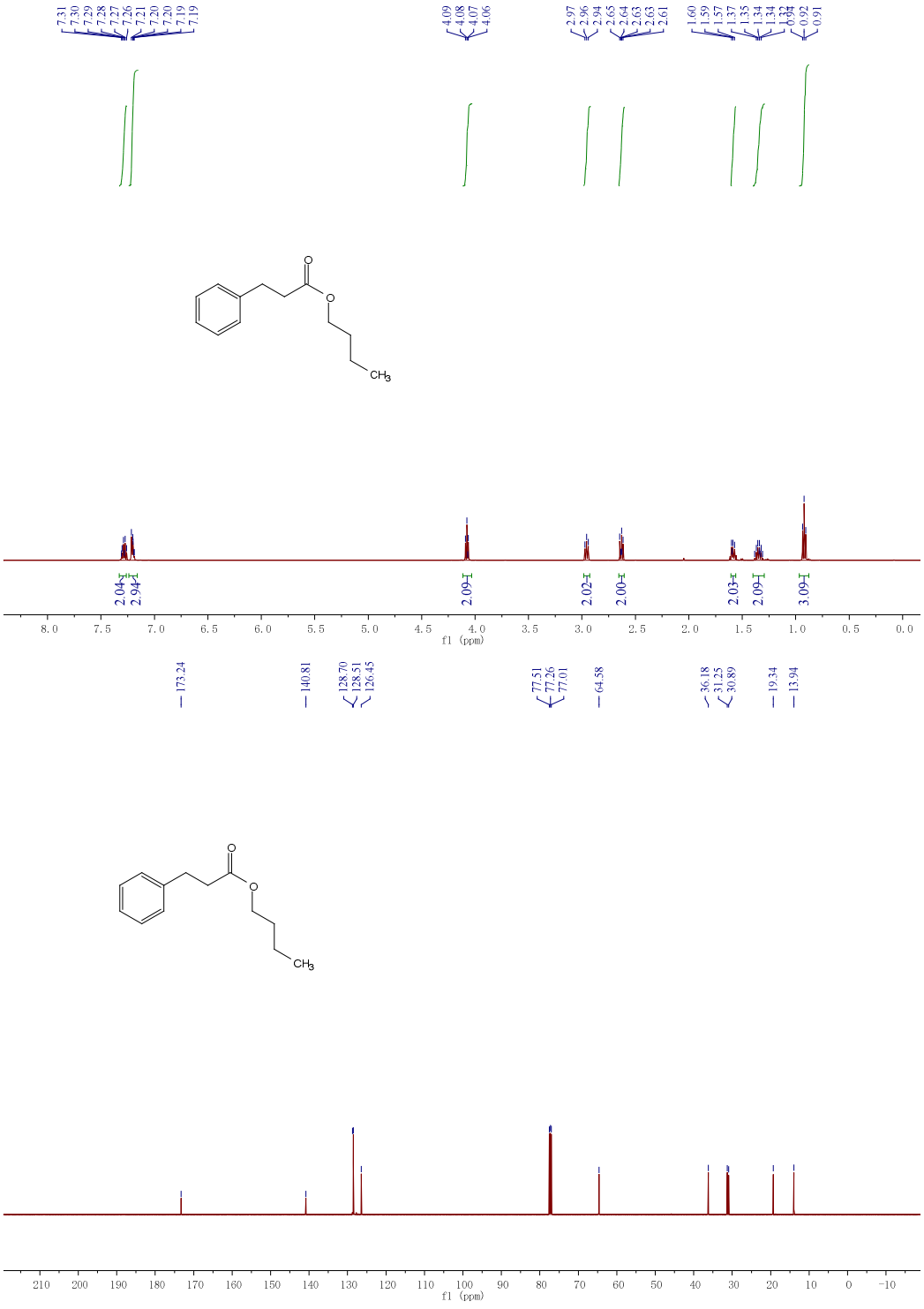
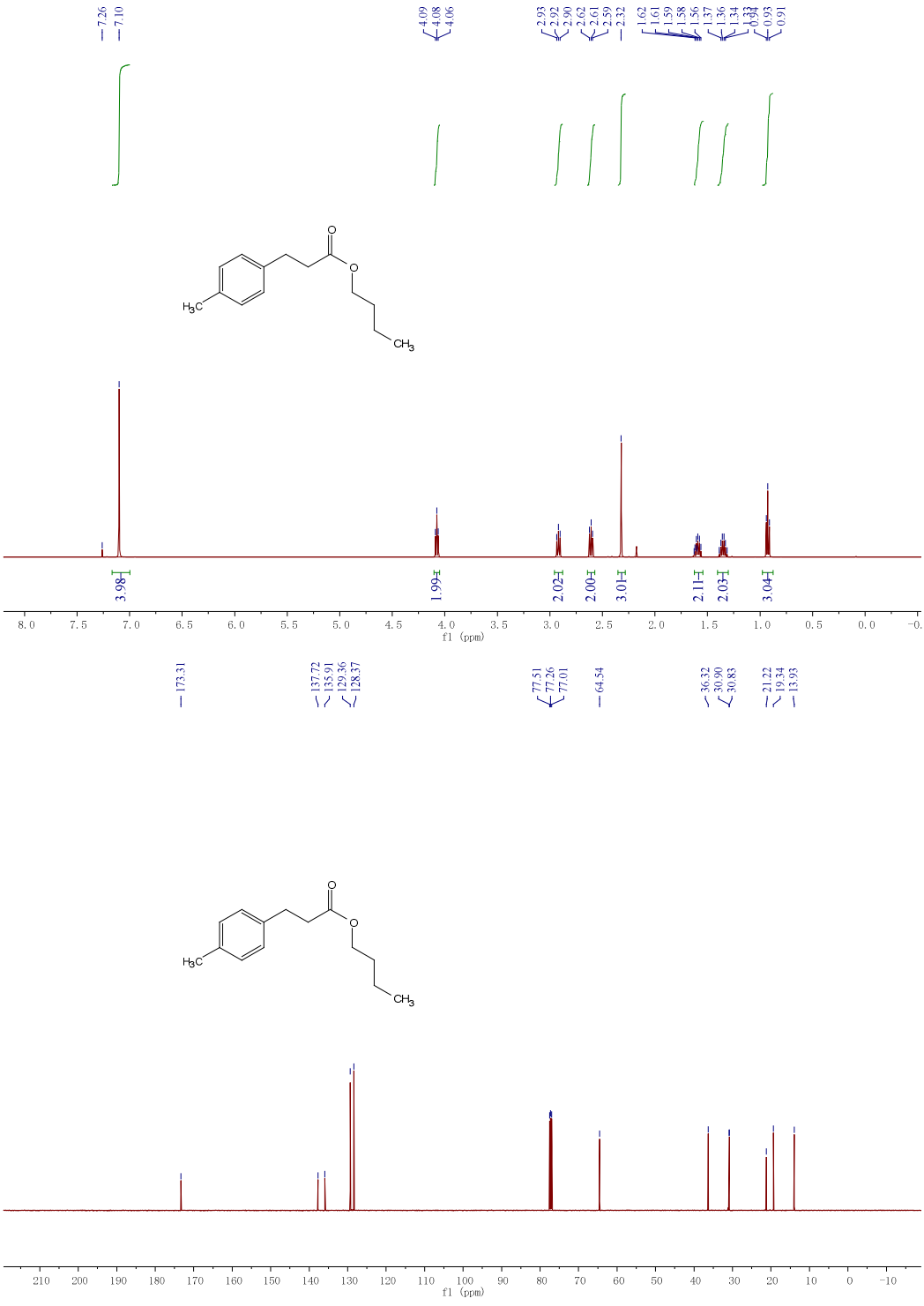
VIII. Copies of ^{1}H, ^{13}C NMR Spectra of products

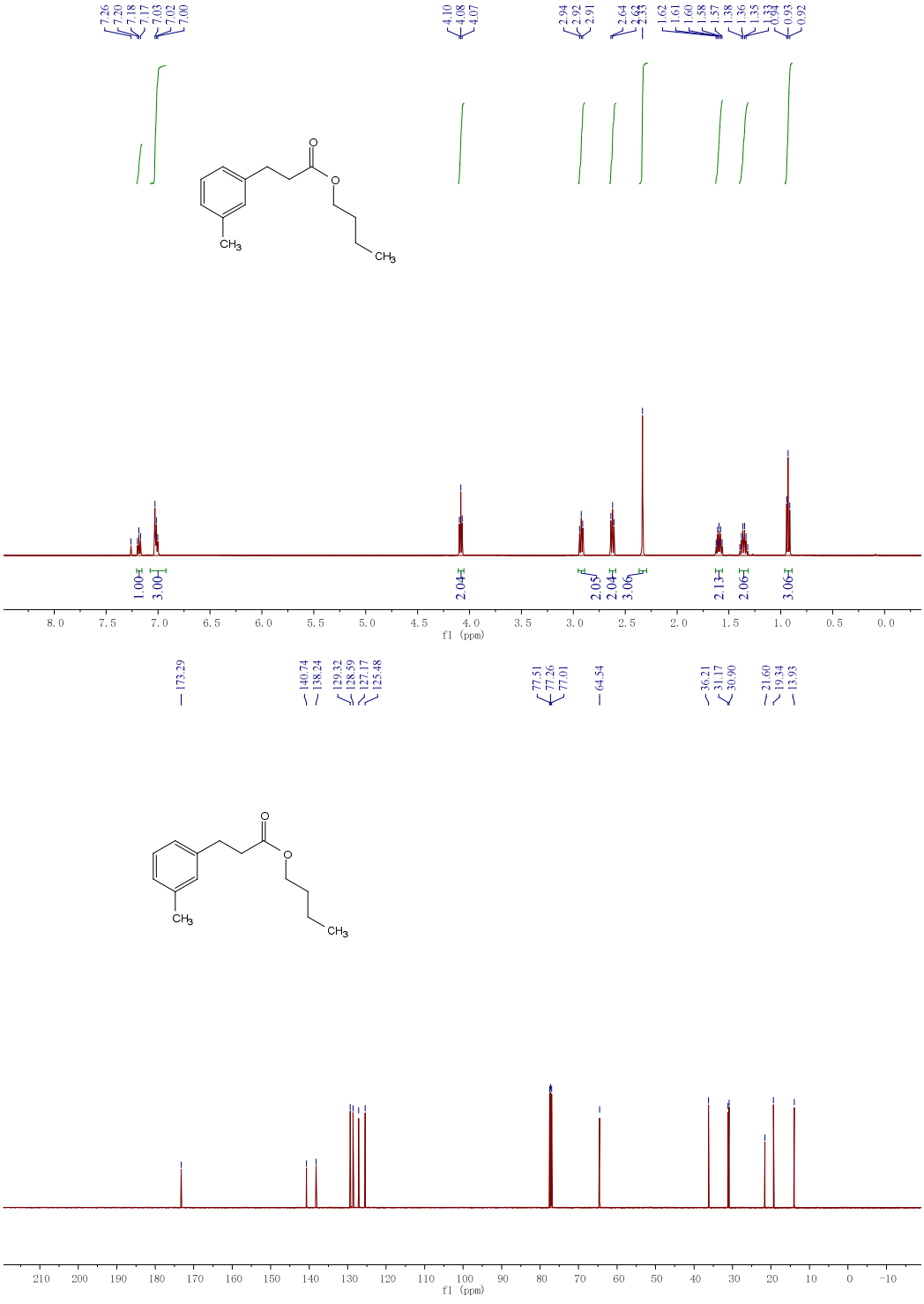
^{1}H NMR and ^{13}C NMR of 3aa



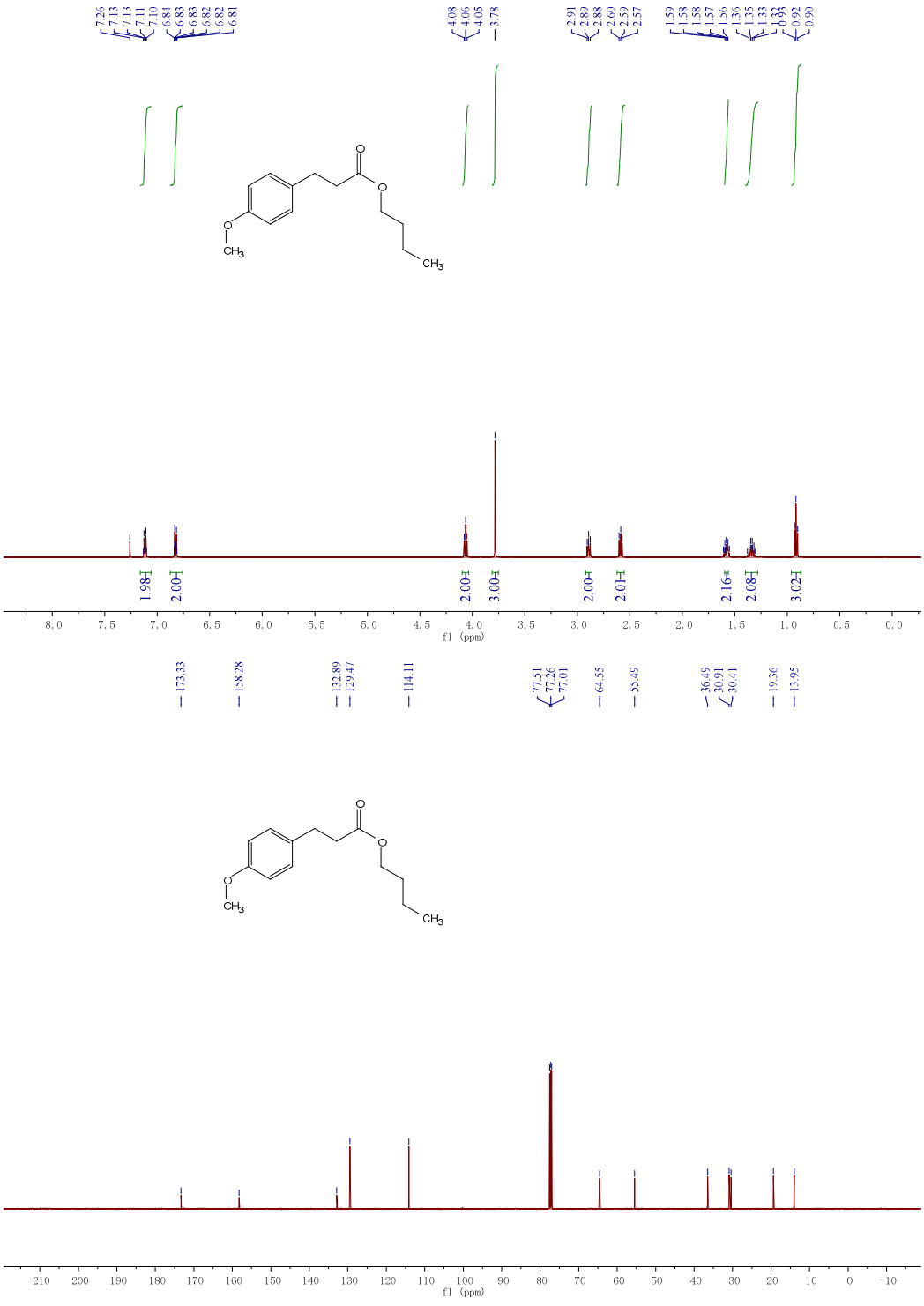
^{1}H NMR and ^{13}C NMR of 3ba



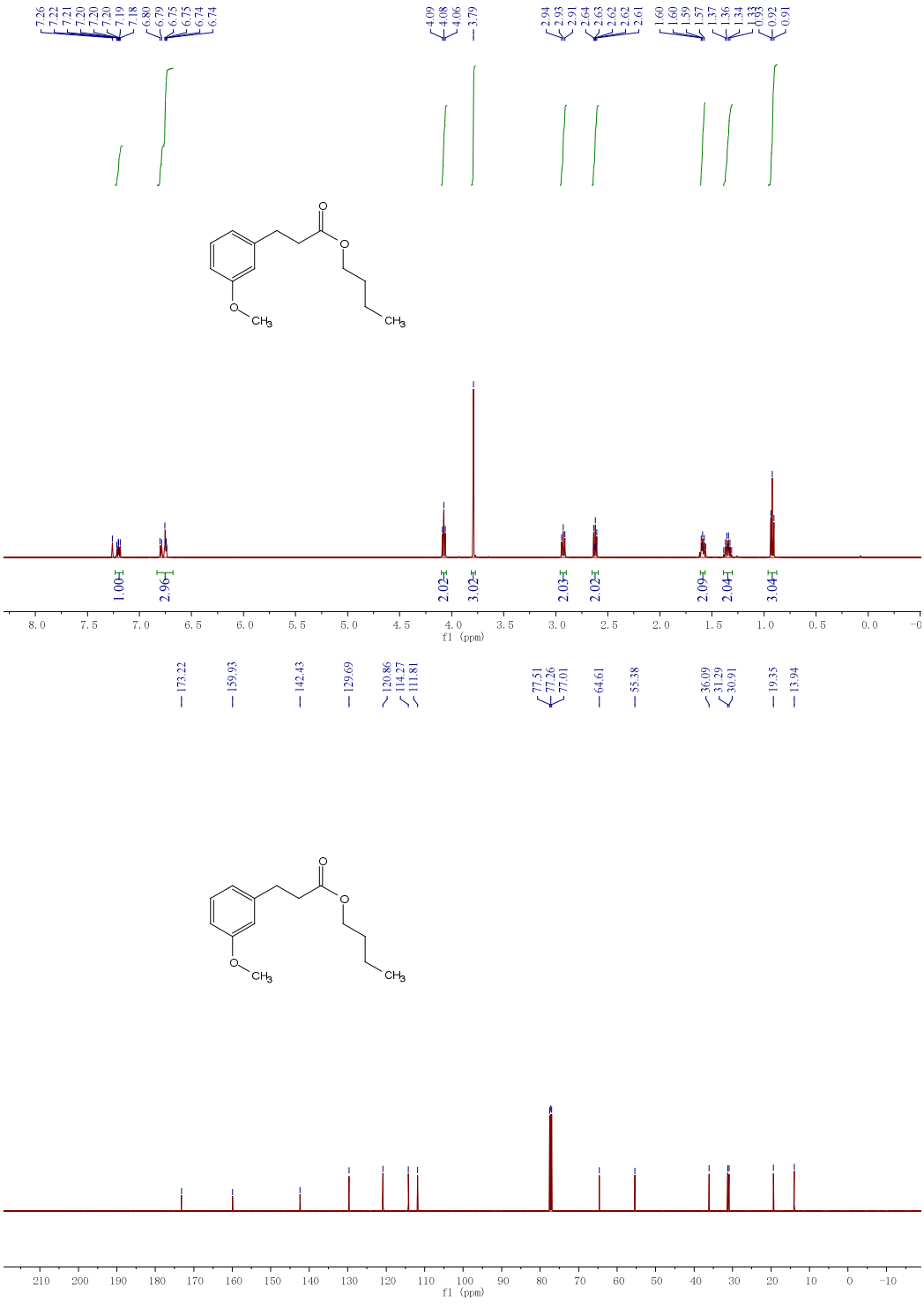
^{1}H NMR and ^{13}C NMR of 3ca



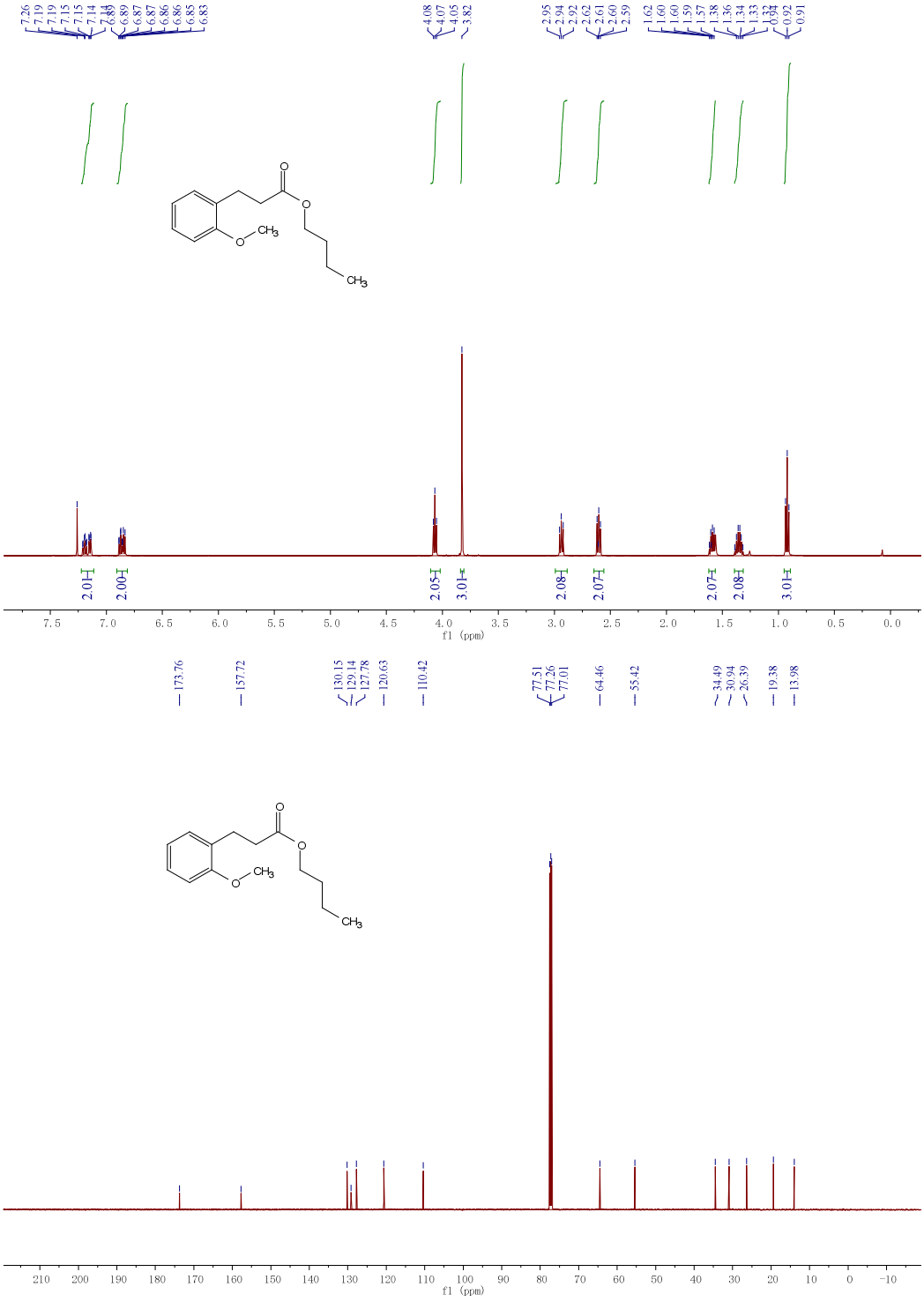
^{1}H NMR and ^{13}C NMR of 3da



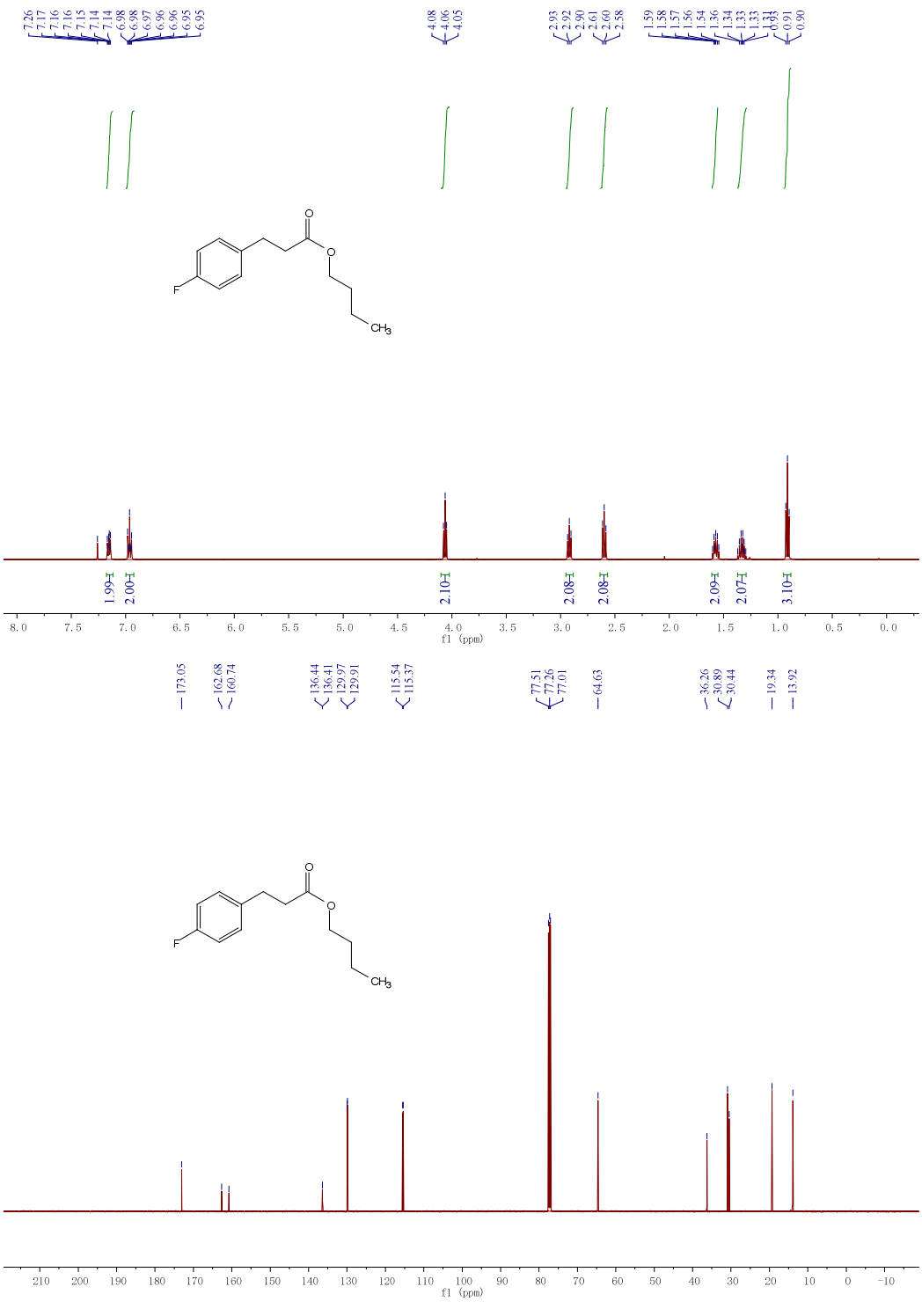
^{1}H NMR and ^{13}C NMR of 3ea



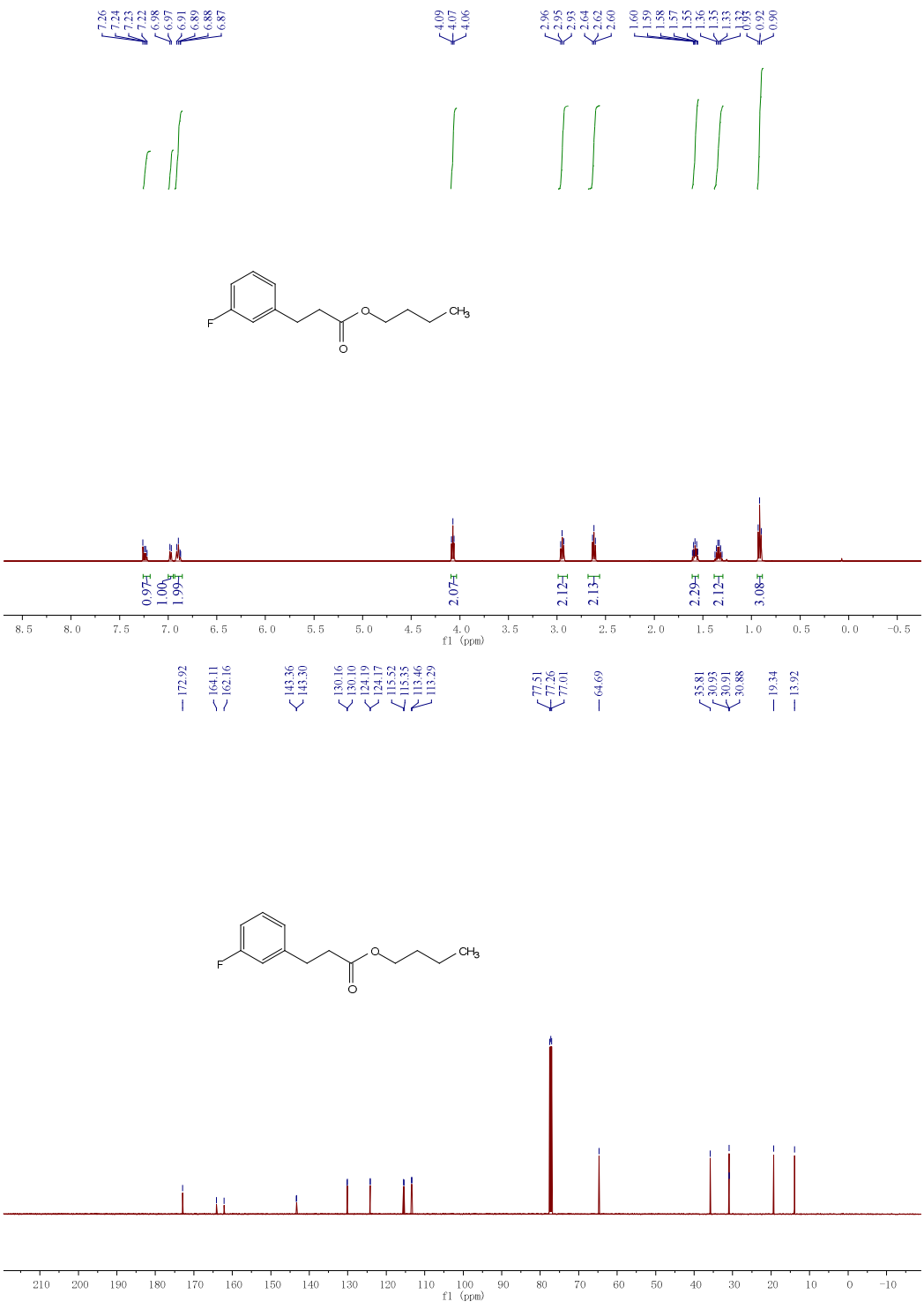
^{1}H NMR and ^{13}C NMR of 3fa



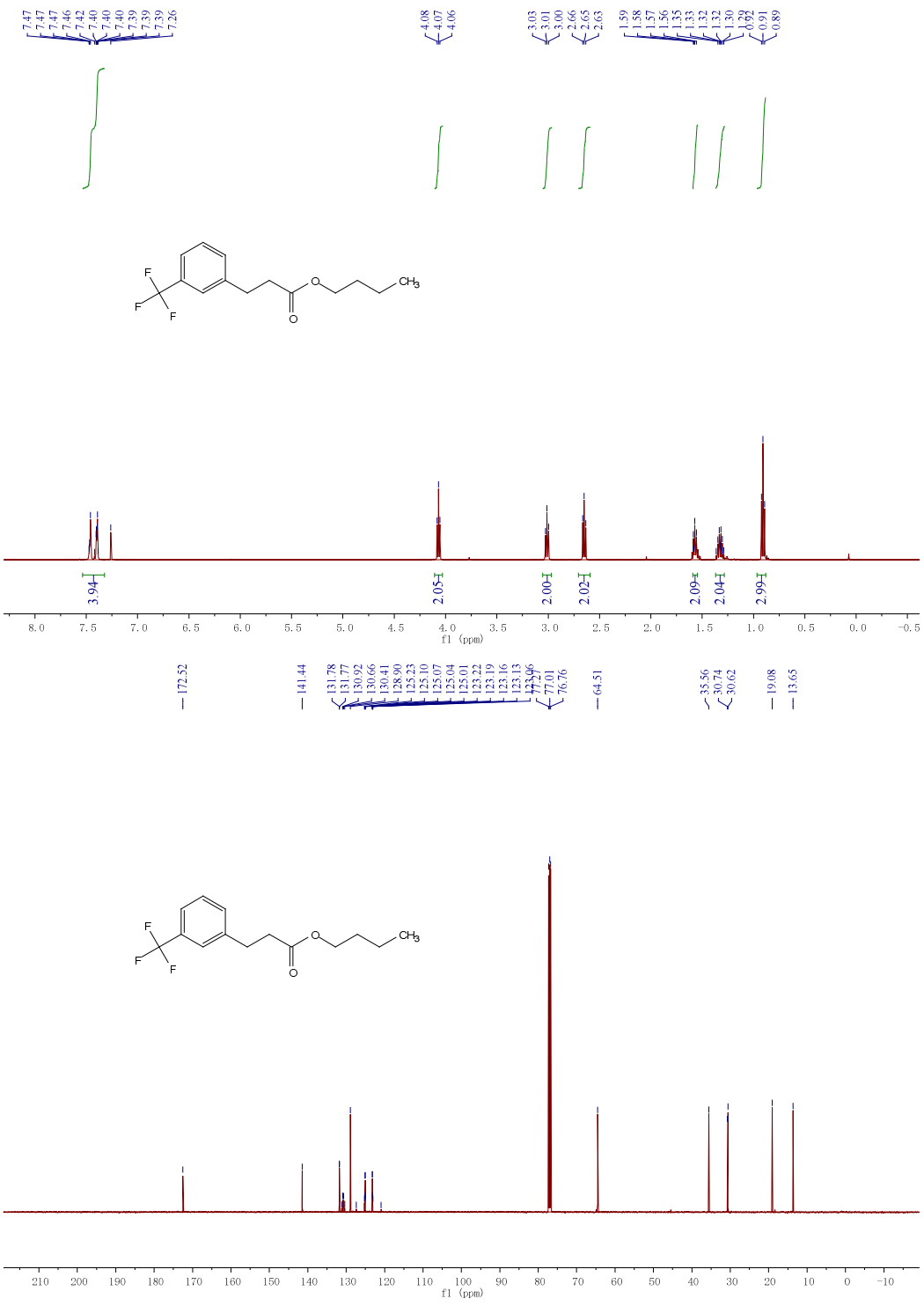
^{1}H NMR and ^{13}C NMR of 3ga



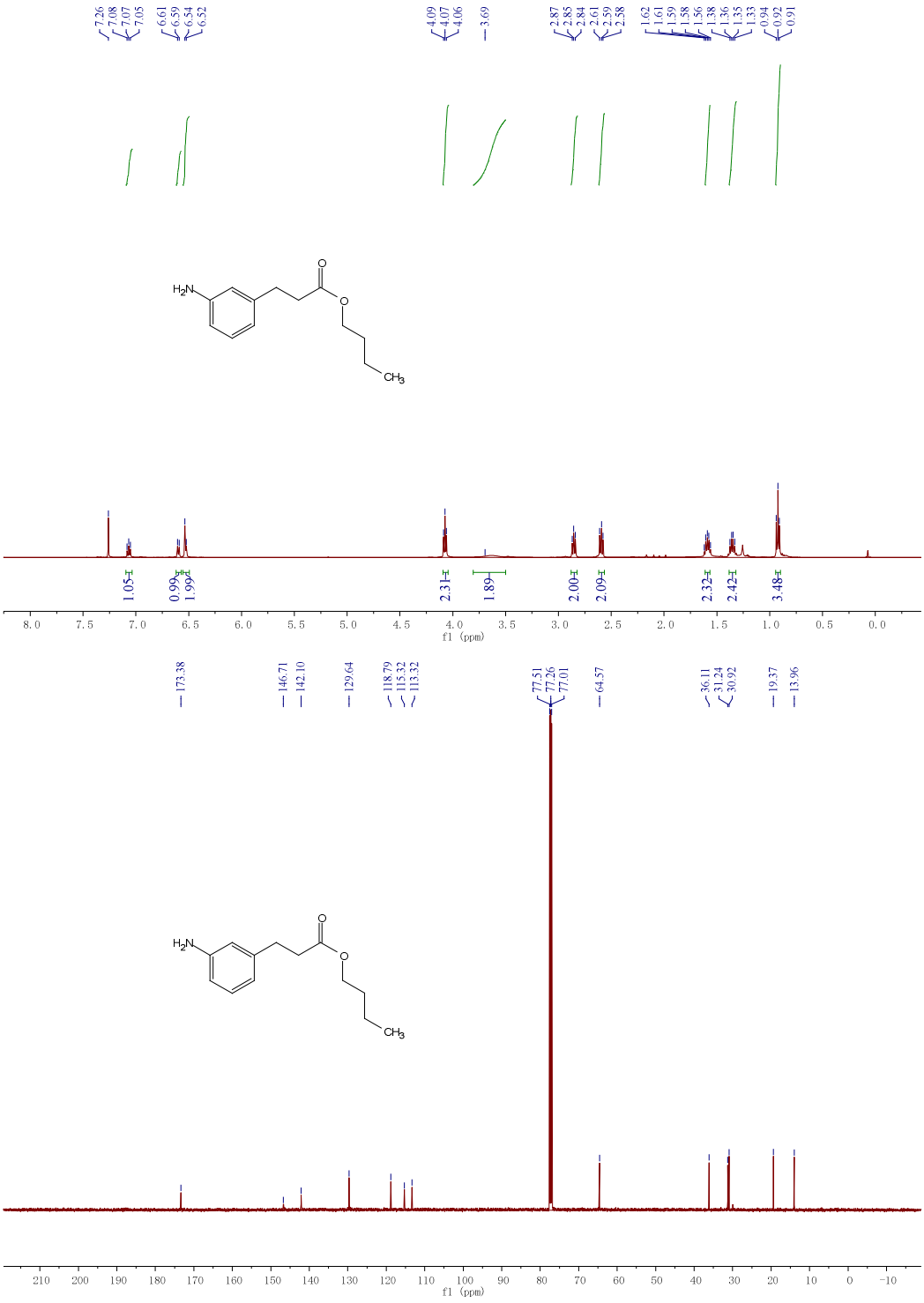
^{1}H NMR and ^{13}C NMR of 3ha



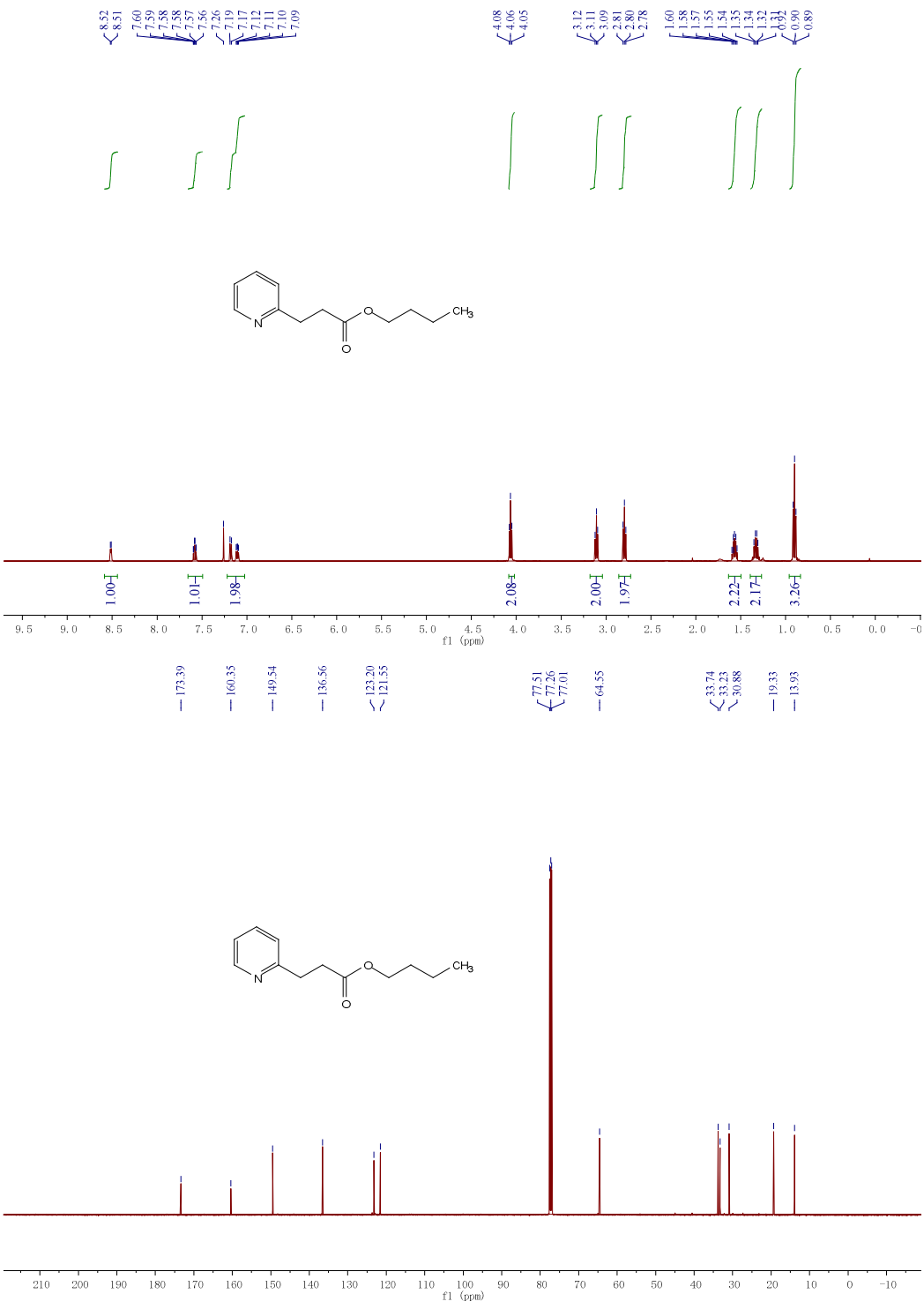
^{1}H NMR and ^{13}C NMR of 3ia



^{1}H NMR and ^{13}C NMR of 3ja

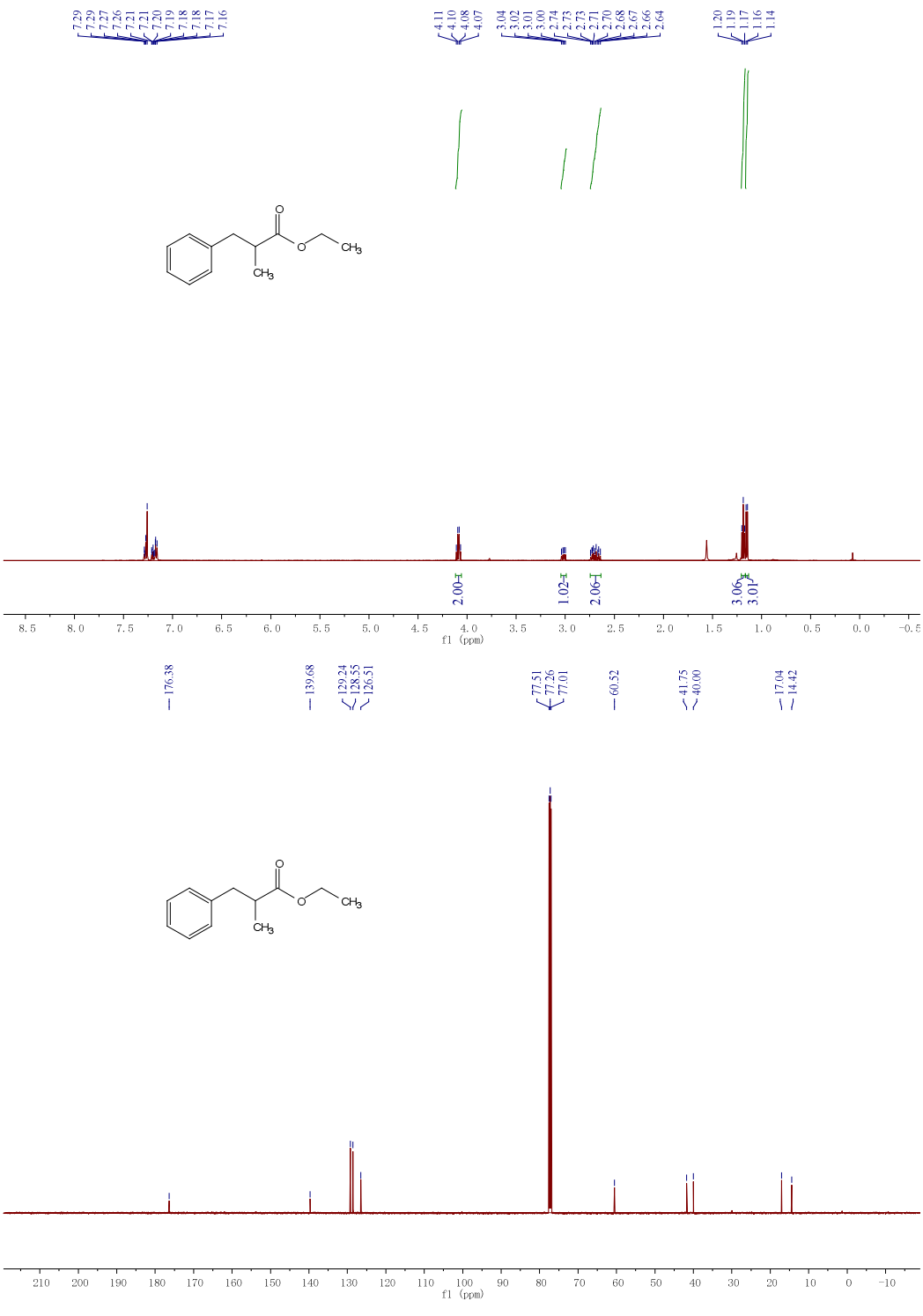


^{1}H NMR and ^{13}C NMR of 3ka

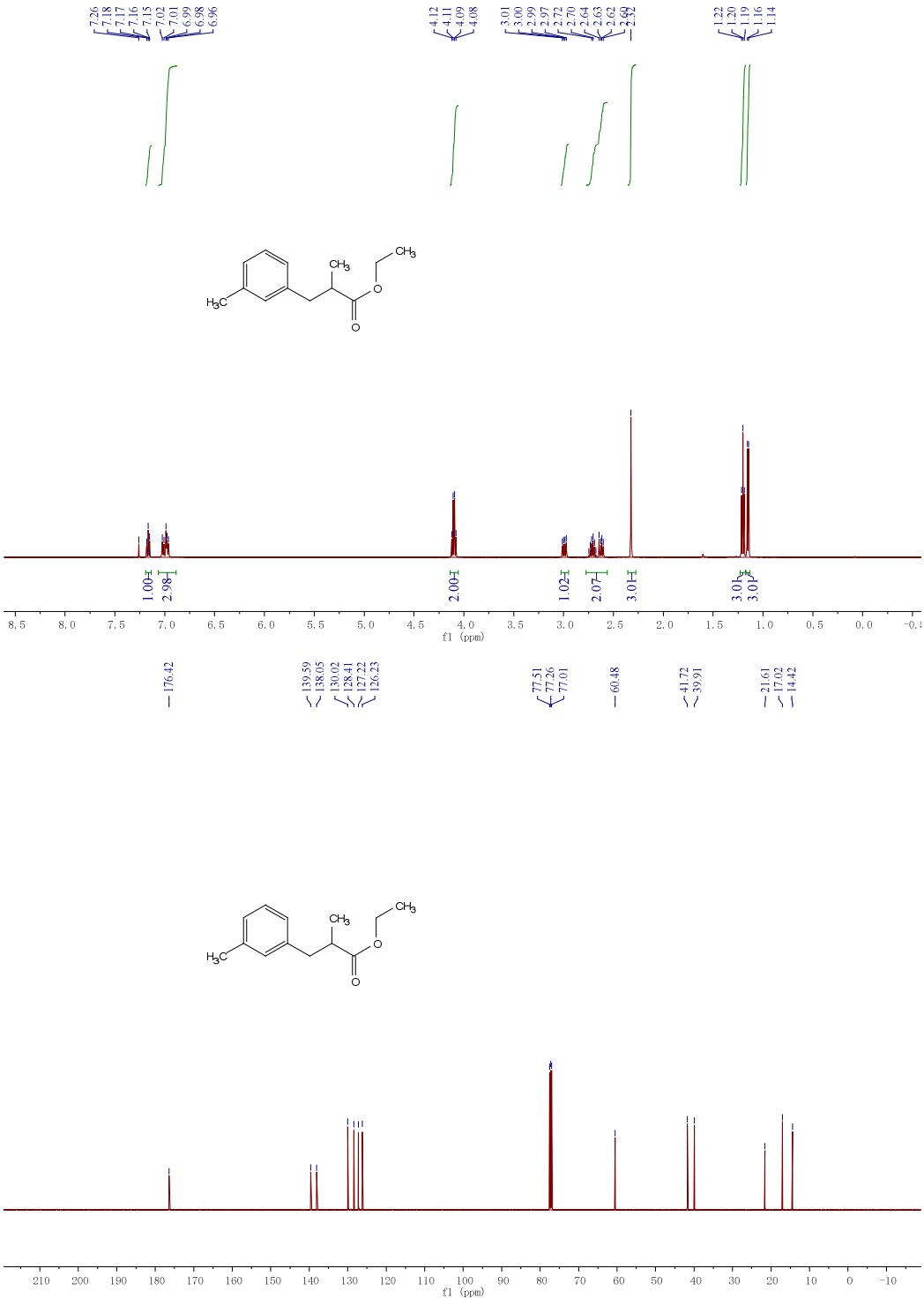


^{1}H NMR and ^{13}C NMR of 3la

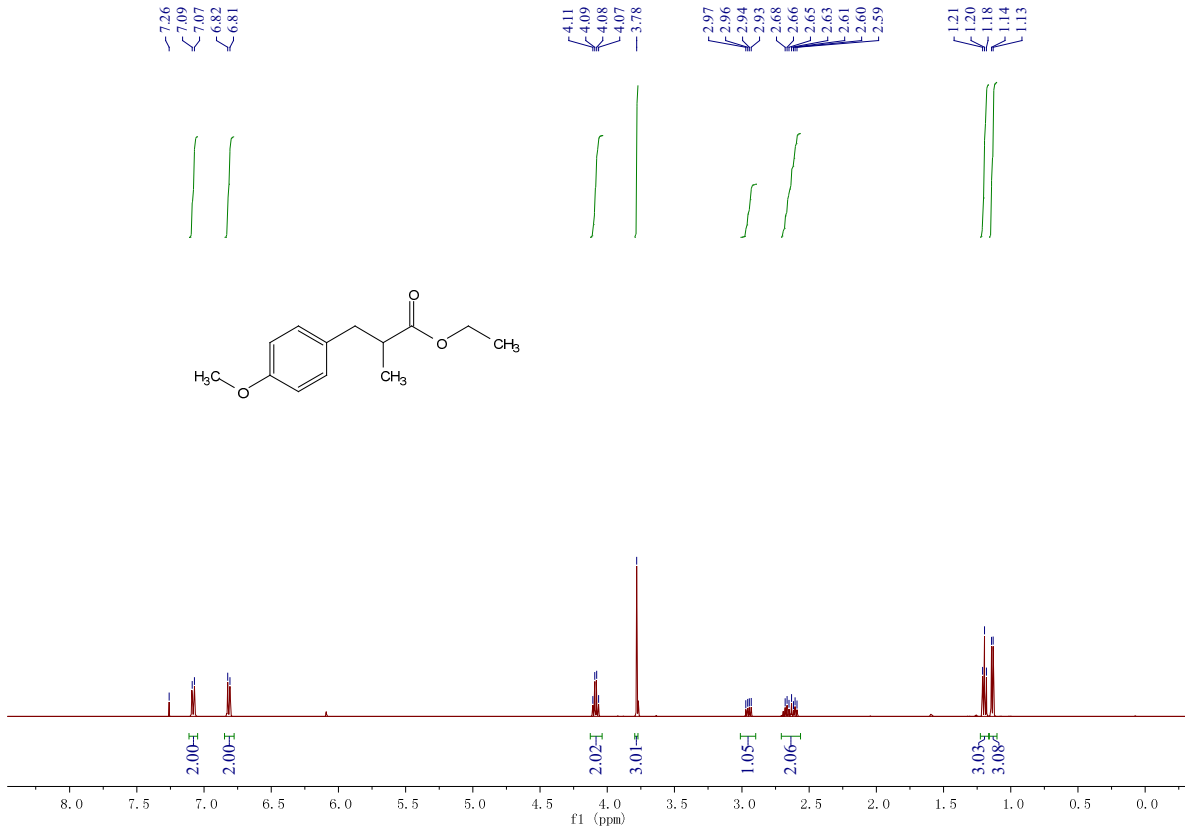
^{1}H NMR and ^{13}C NMR of 3ab

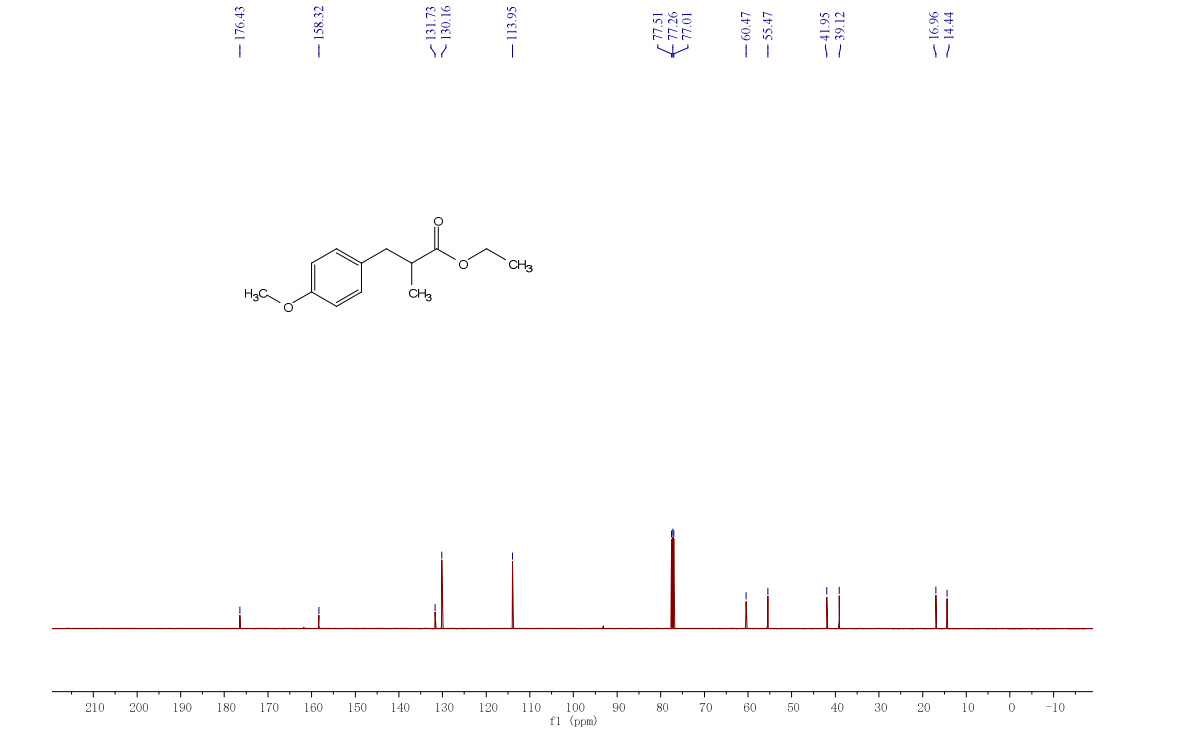


^{1}H NMR and ^{13}C NMR of 3cb

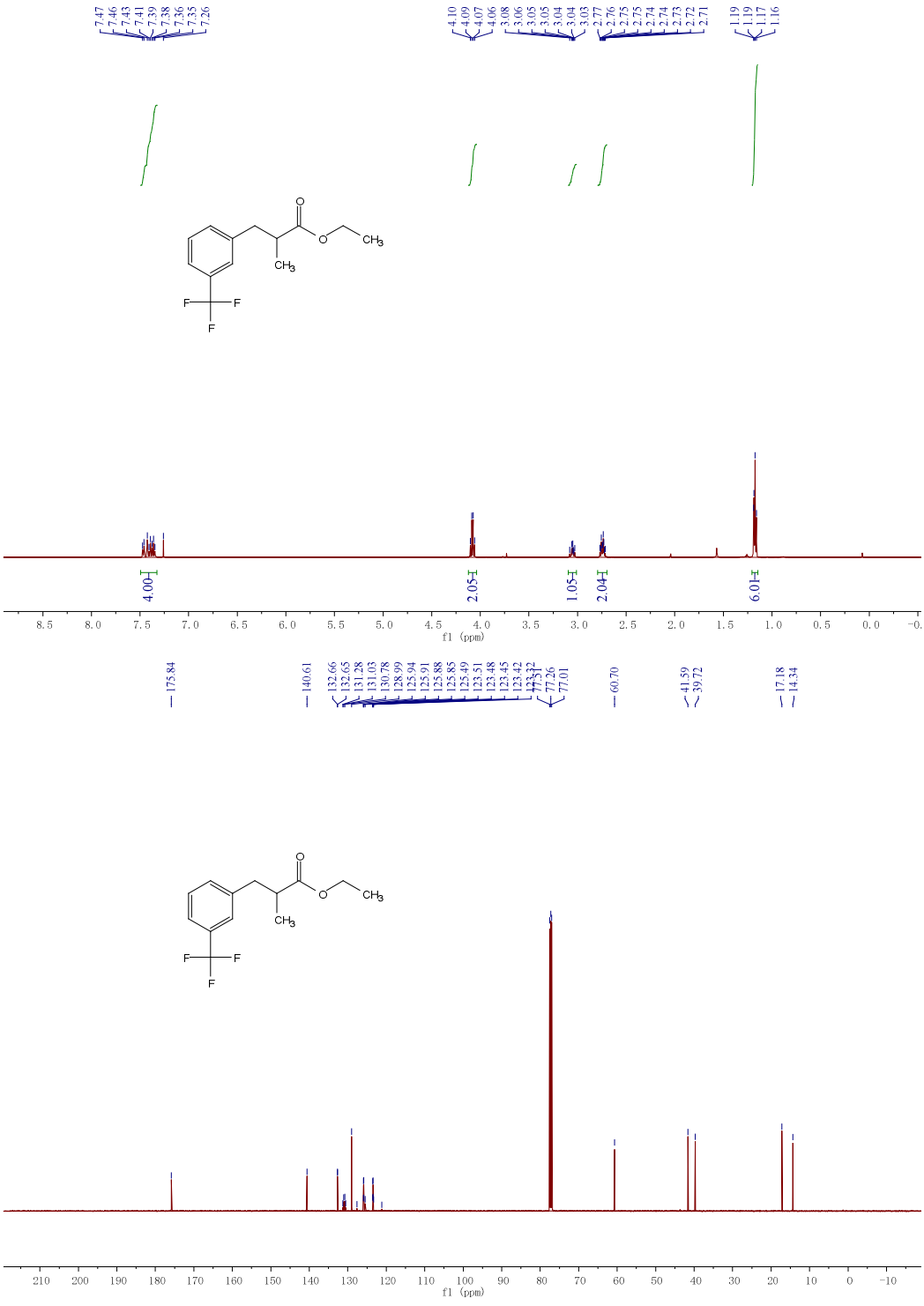


^{1}H NMR and ^{13}C NMR of 3db

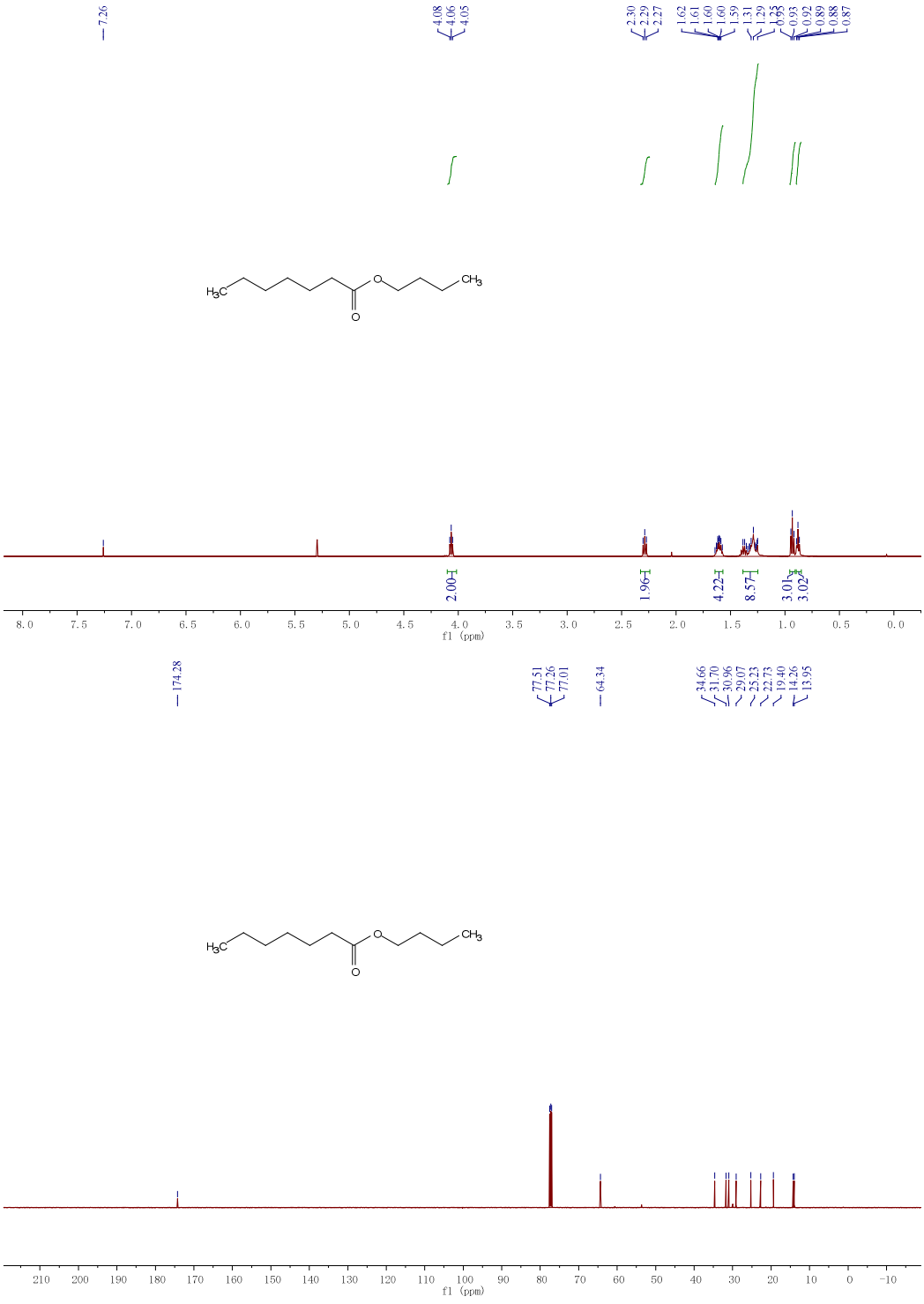




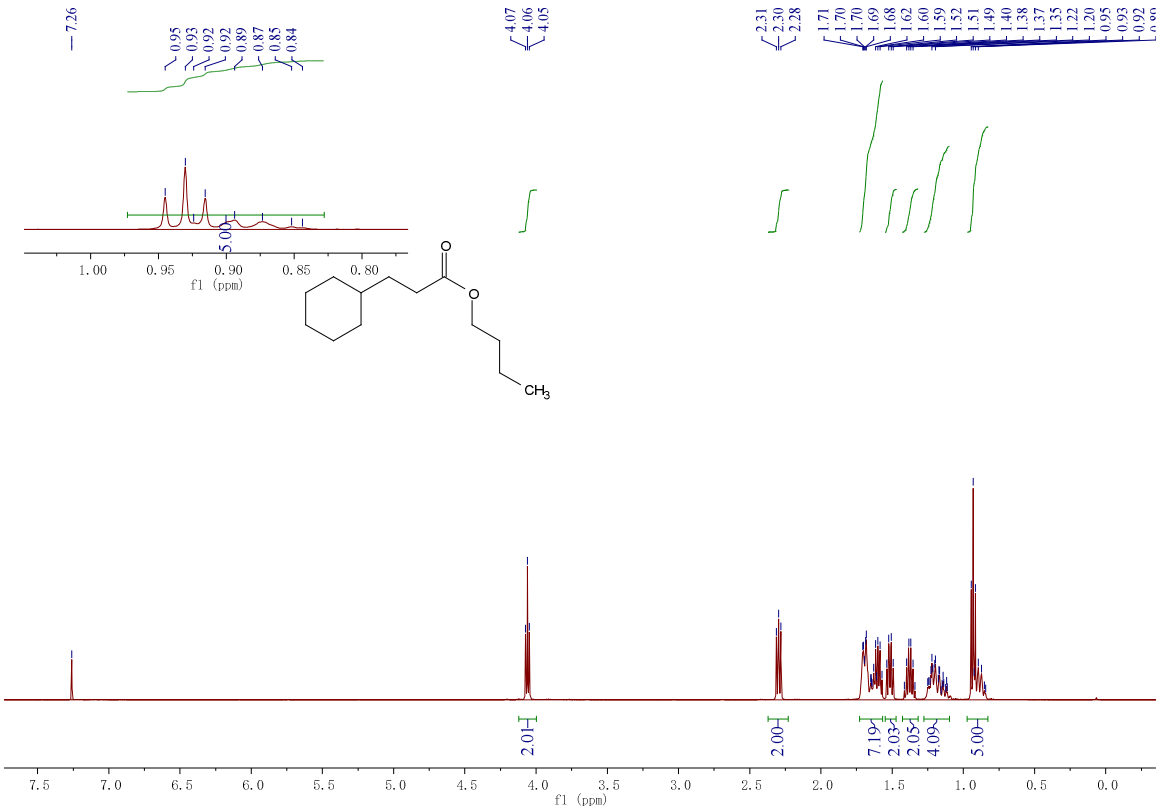
^{1}H NMR and ^{13}C NMR of 3ib

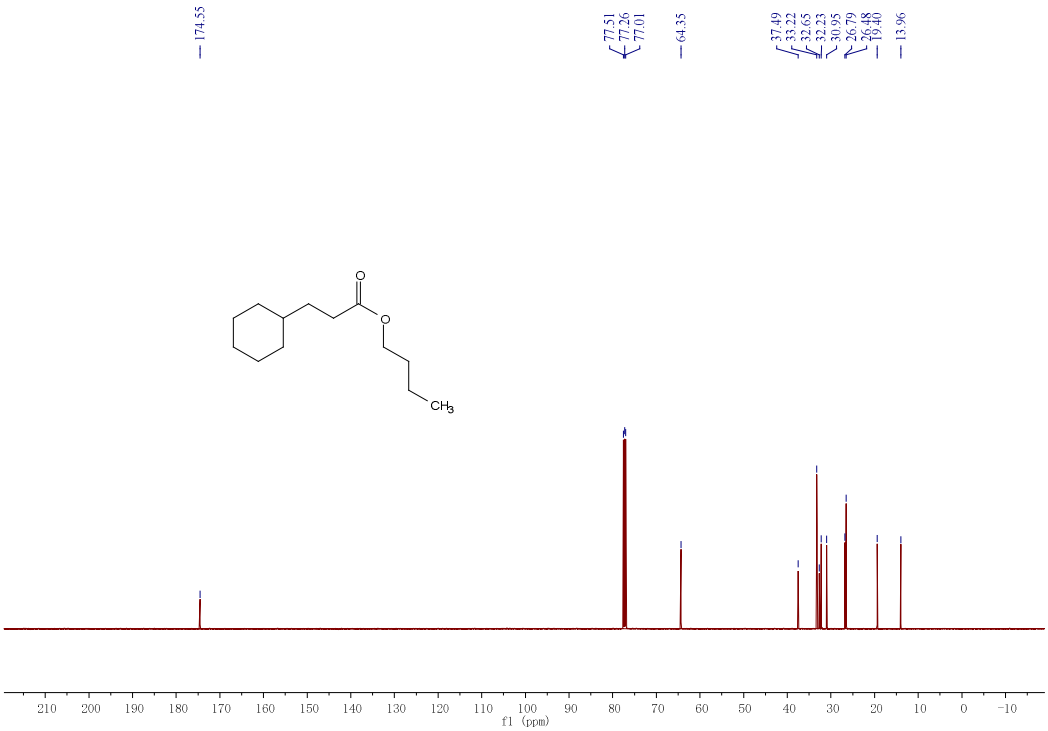


^{1}H NMR and ^{13}C NMR of 3ma

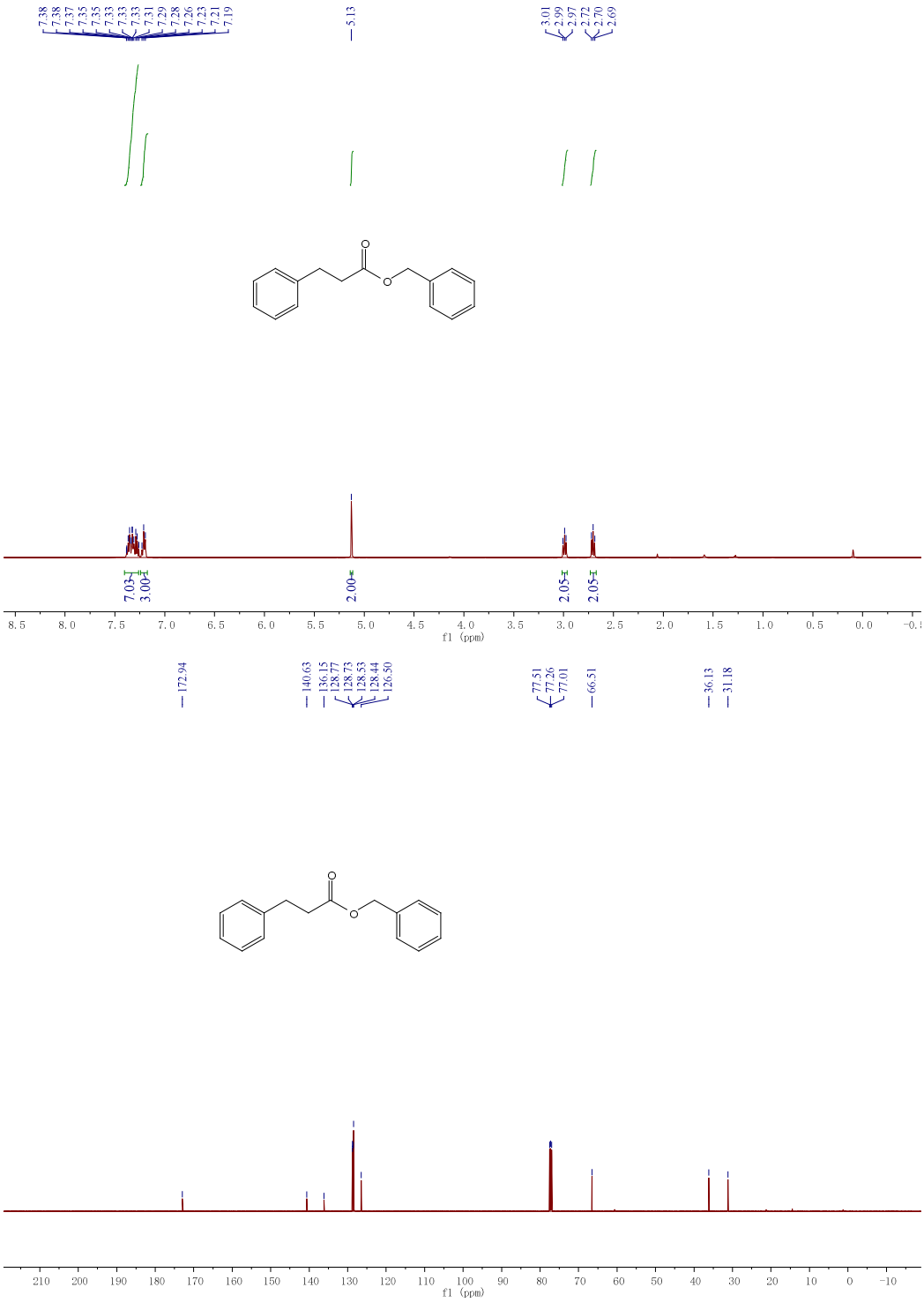


^{1}H NMR and ^{13}C NMR of 3na

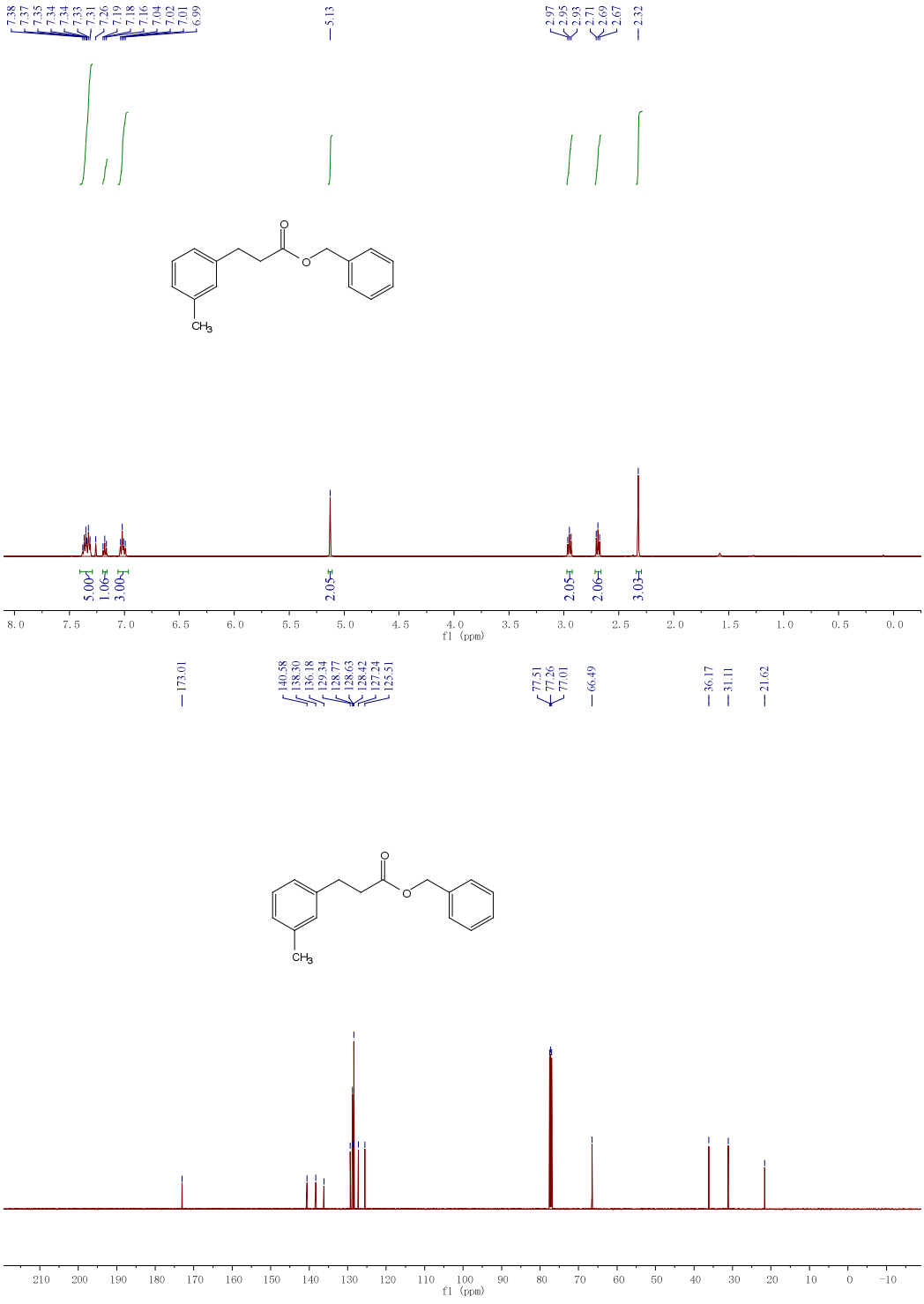




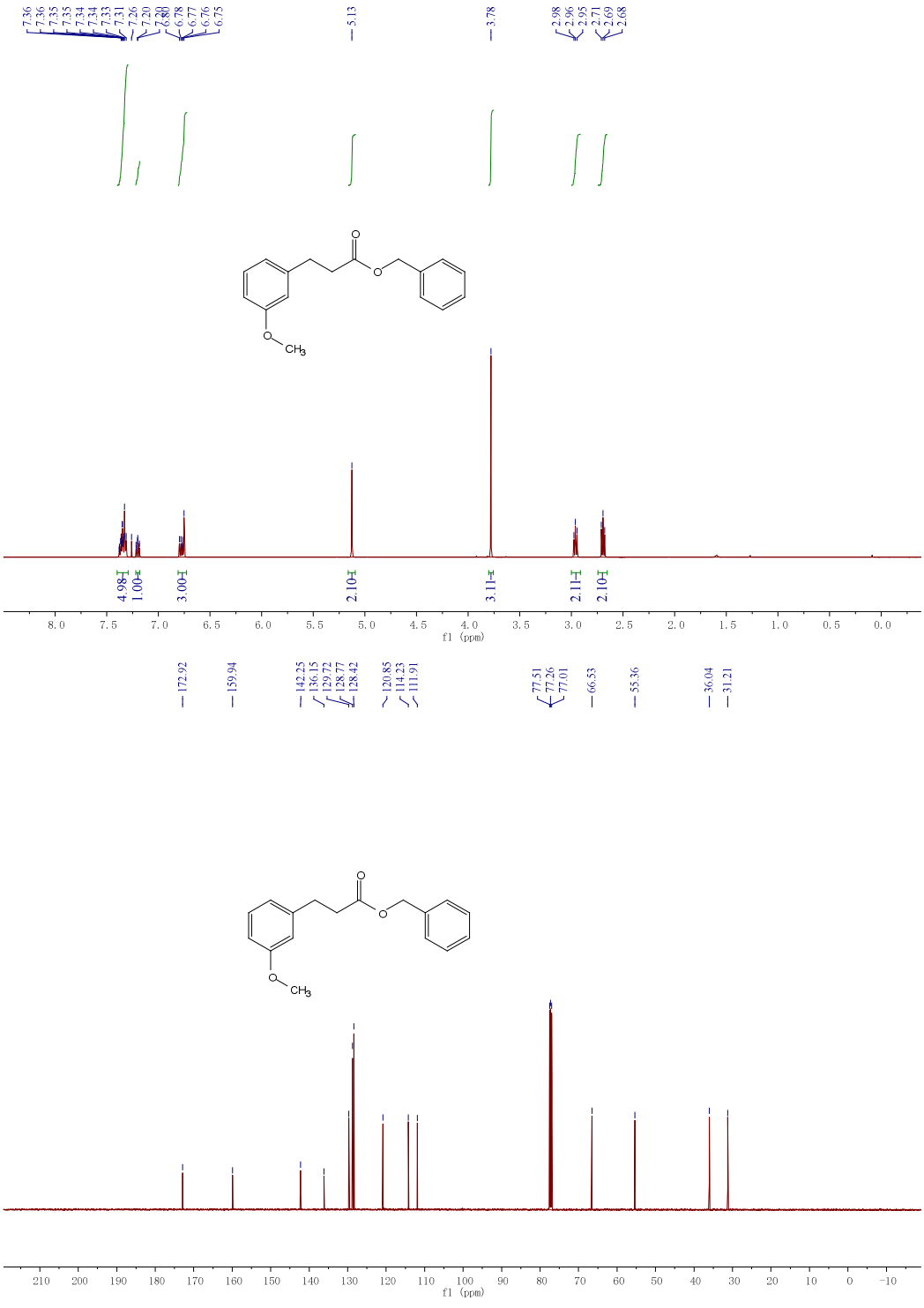
^{1}H NMR and ^{13}C NMR of 3ac



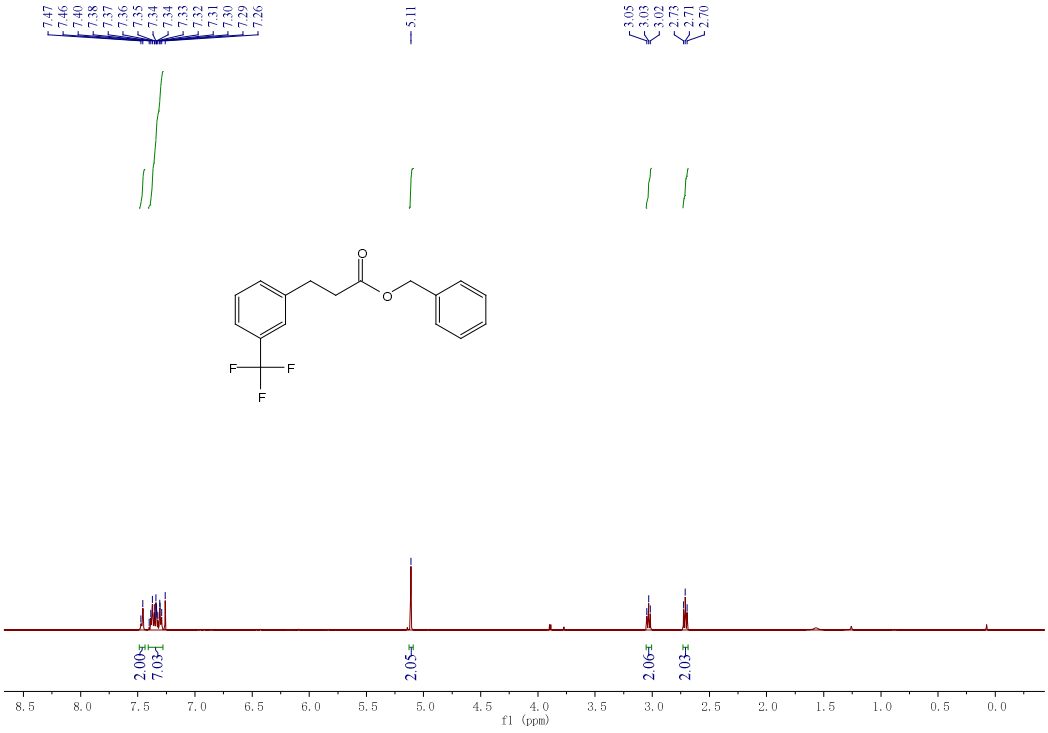
^{1}H NMR and ^{13}C NMR of 3cc

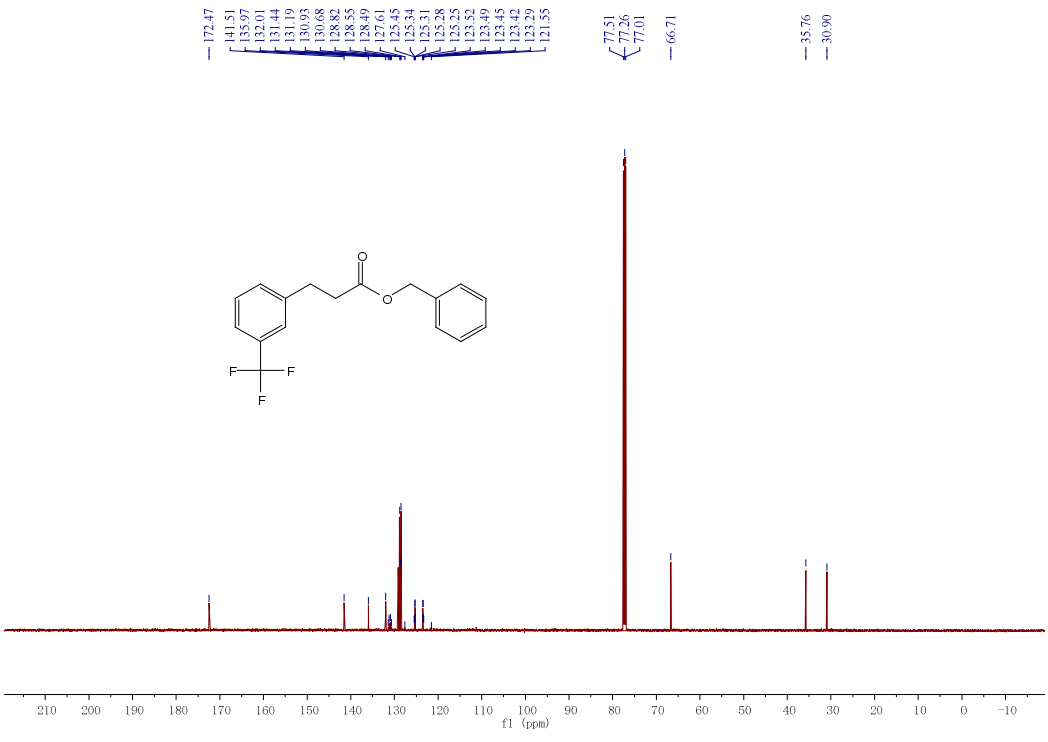


^{1}H NMR and ^{13}C NMR of 3ec

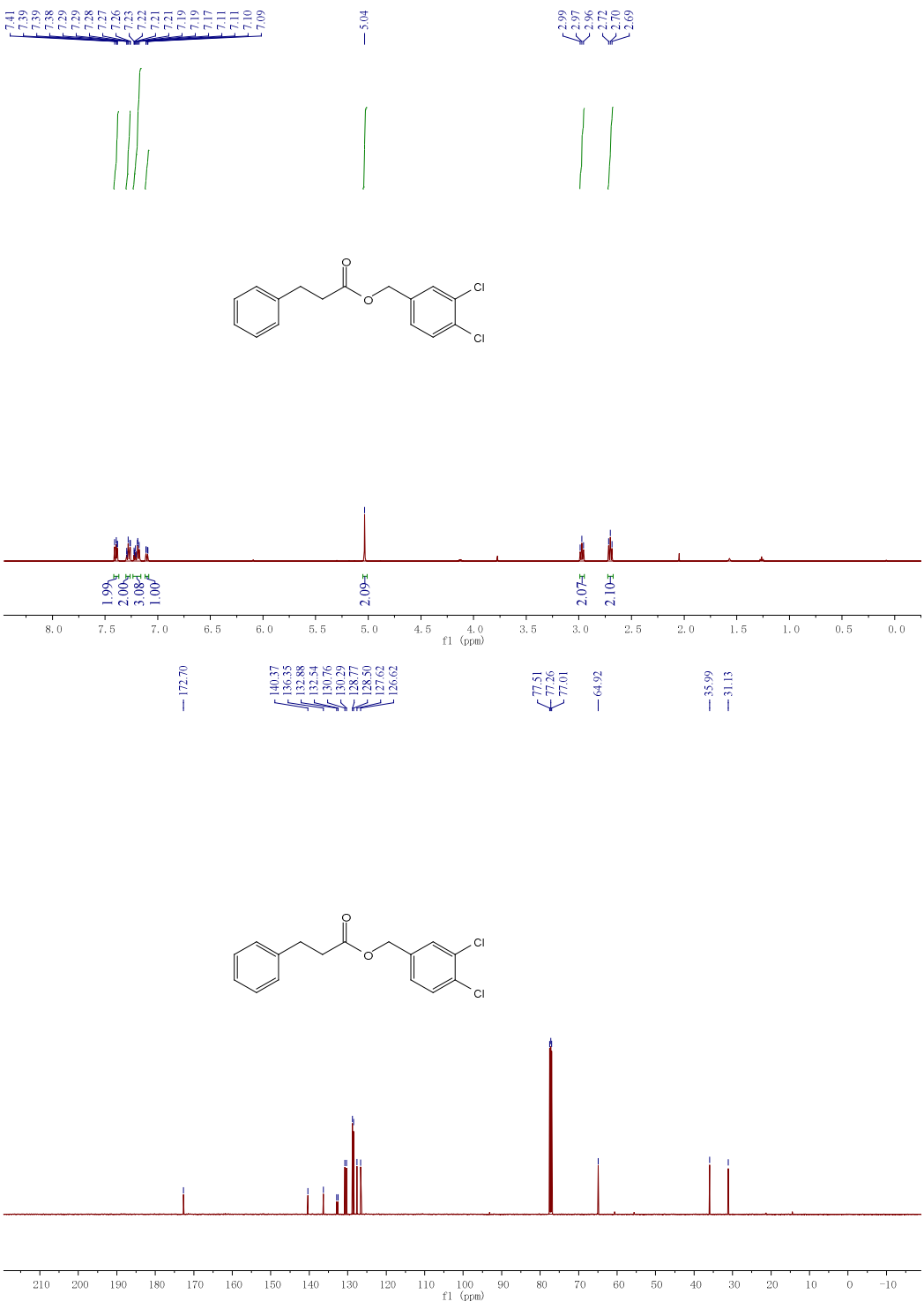


^{1}H NMR and ^{13}C NMR of 3ic

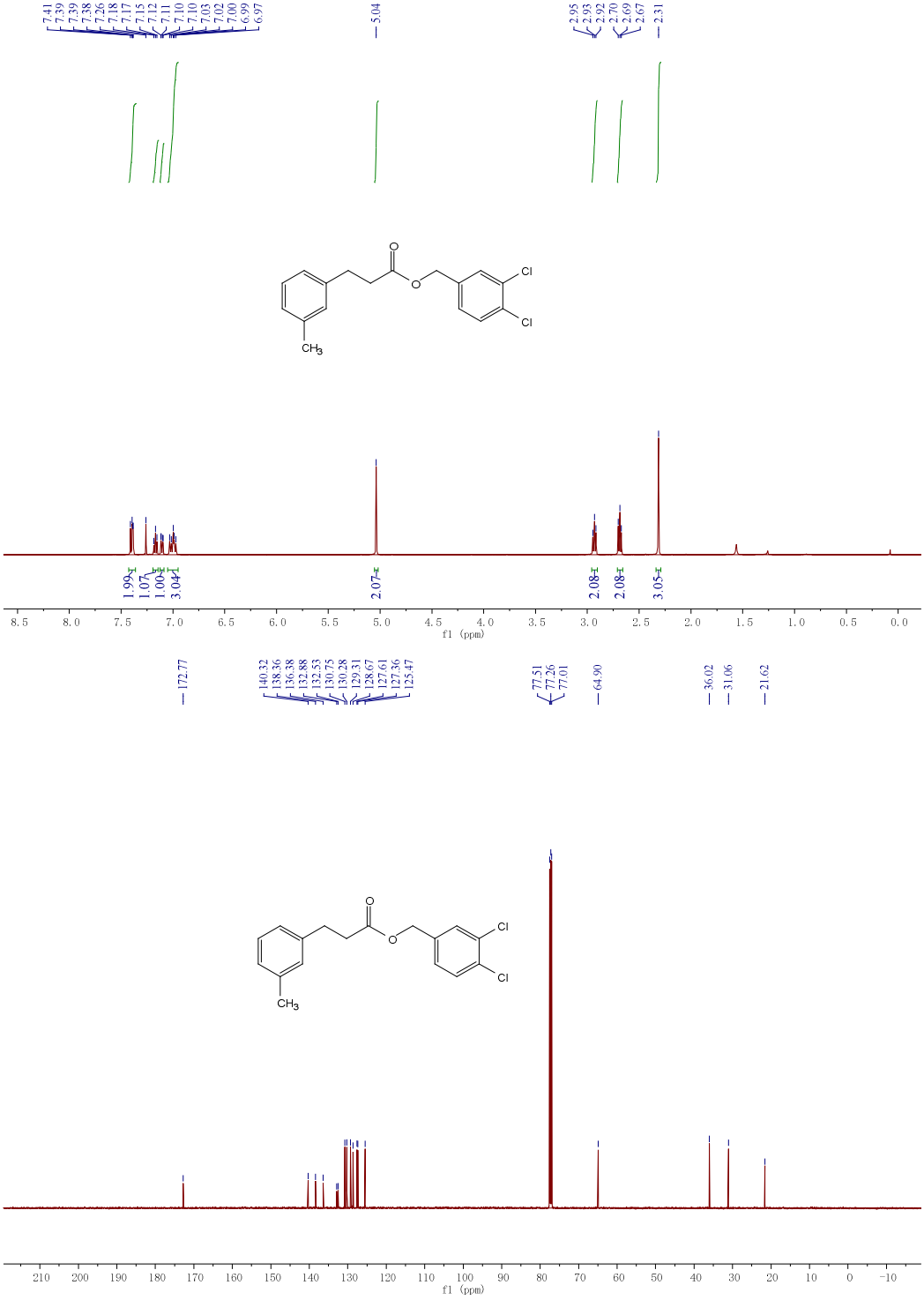




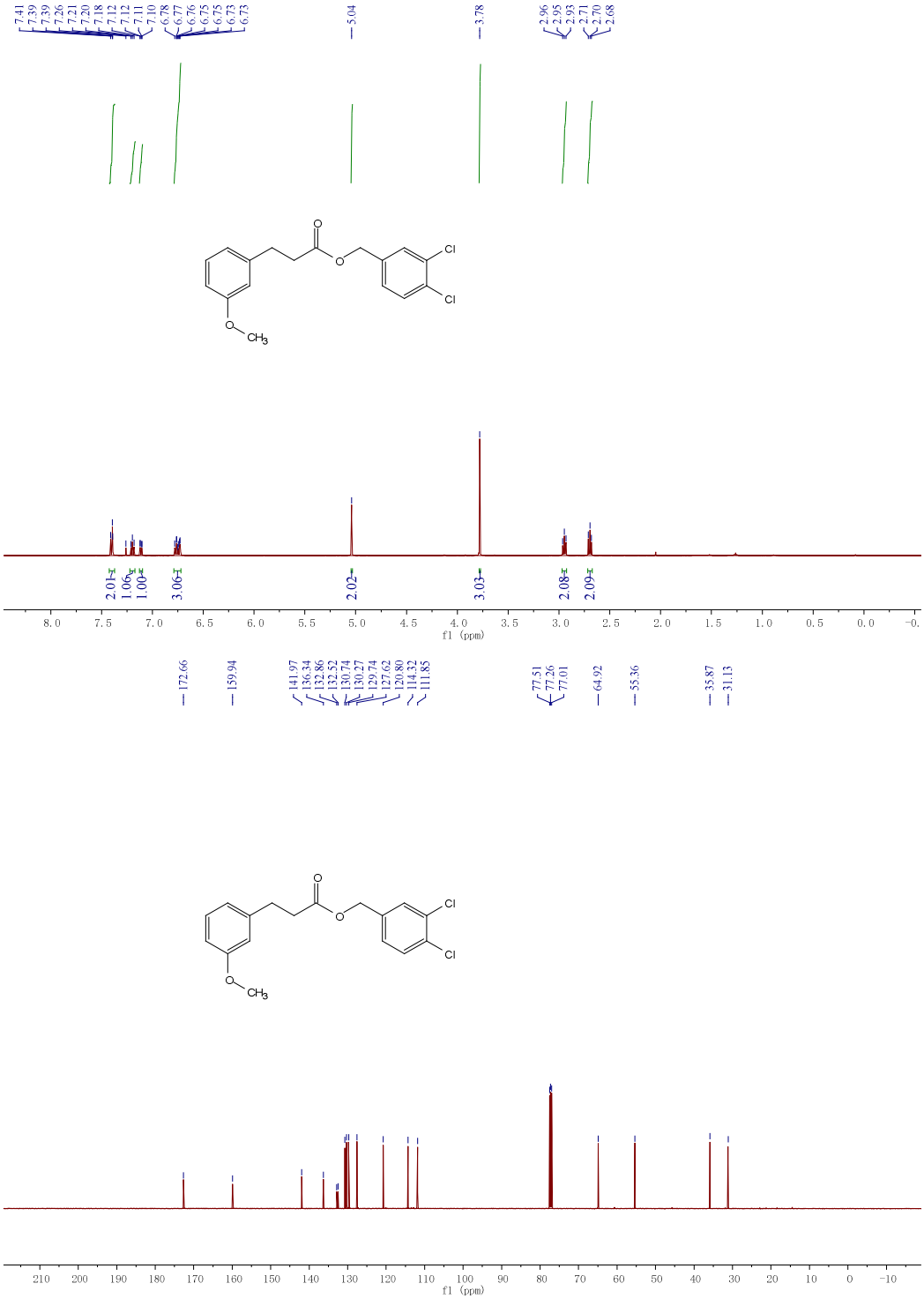
^{1}H NMR and ^{13}C NMR of 3ad



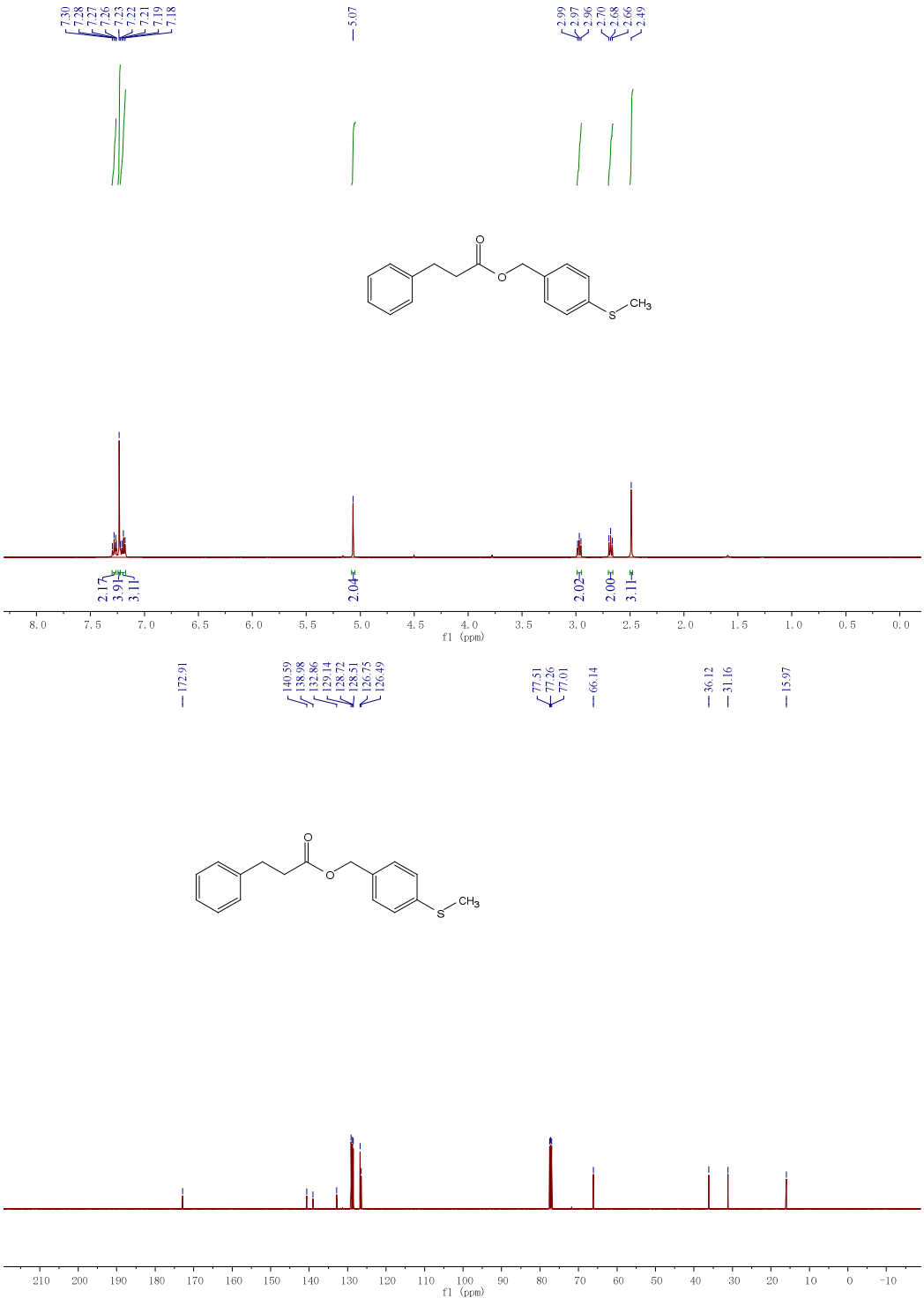
^{1}H NMR and ^{13}C NMR of 3cd



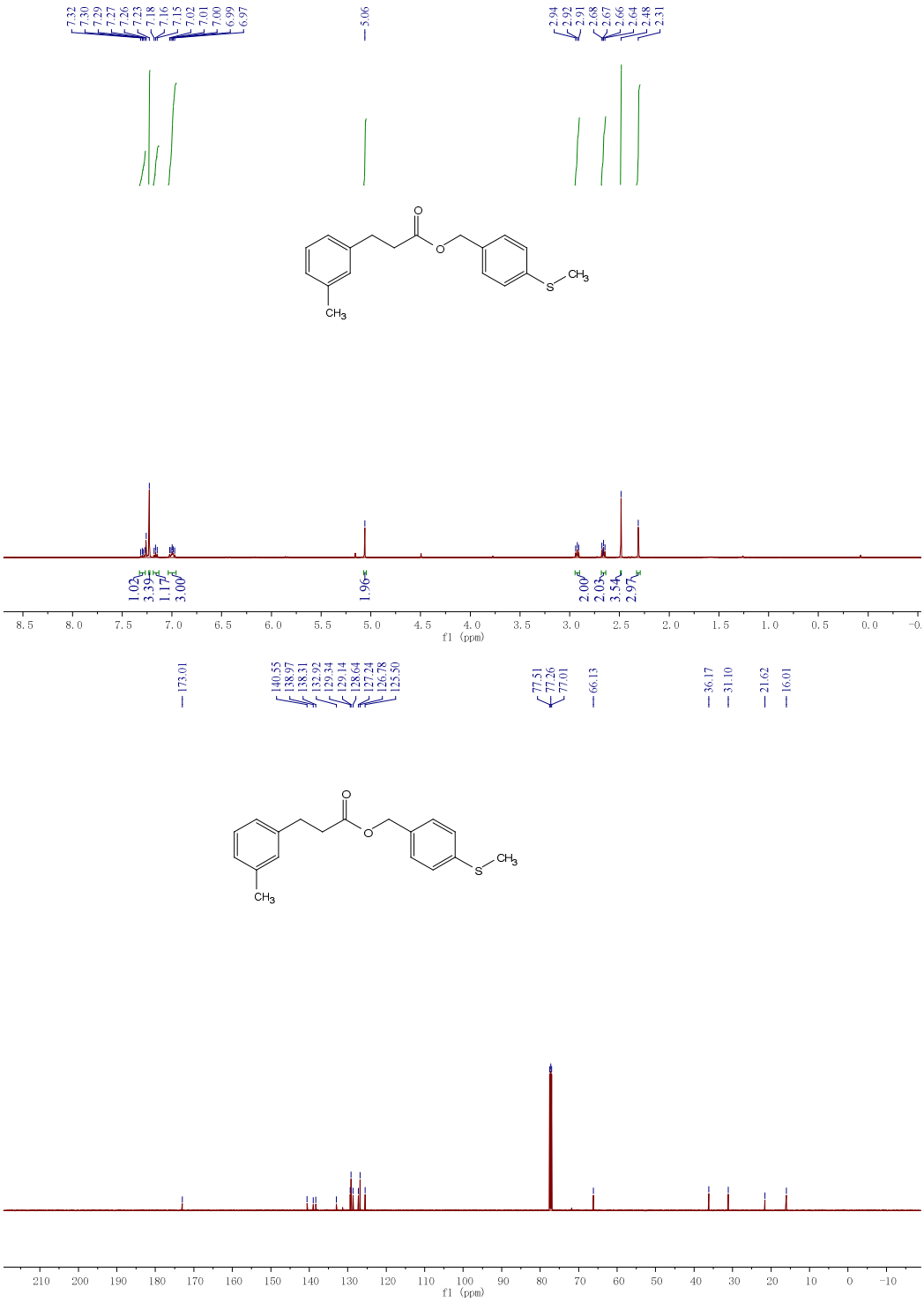
^{1}H NMR and ^{13}C NMR of 3ed



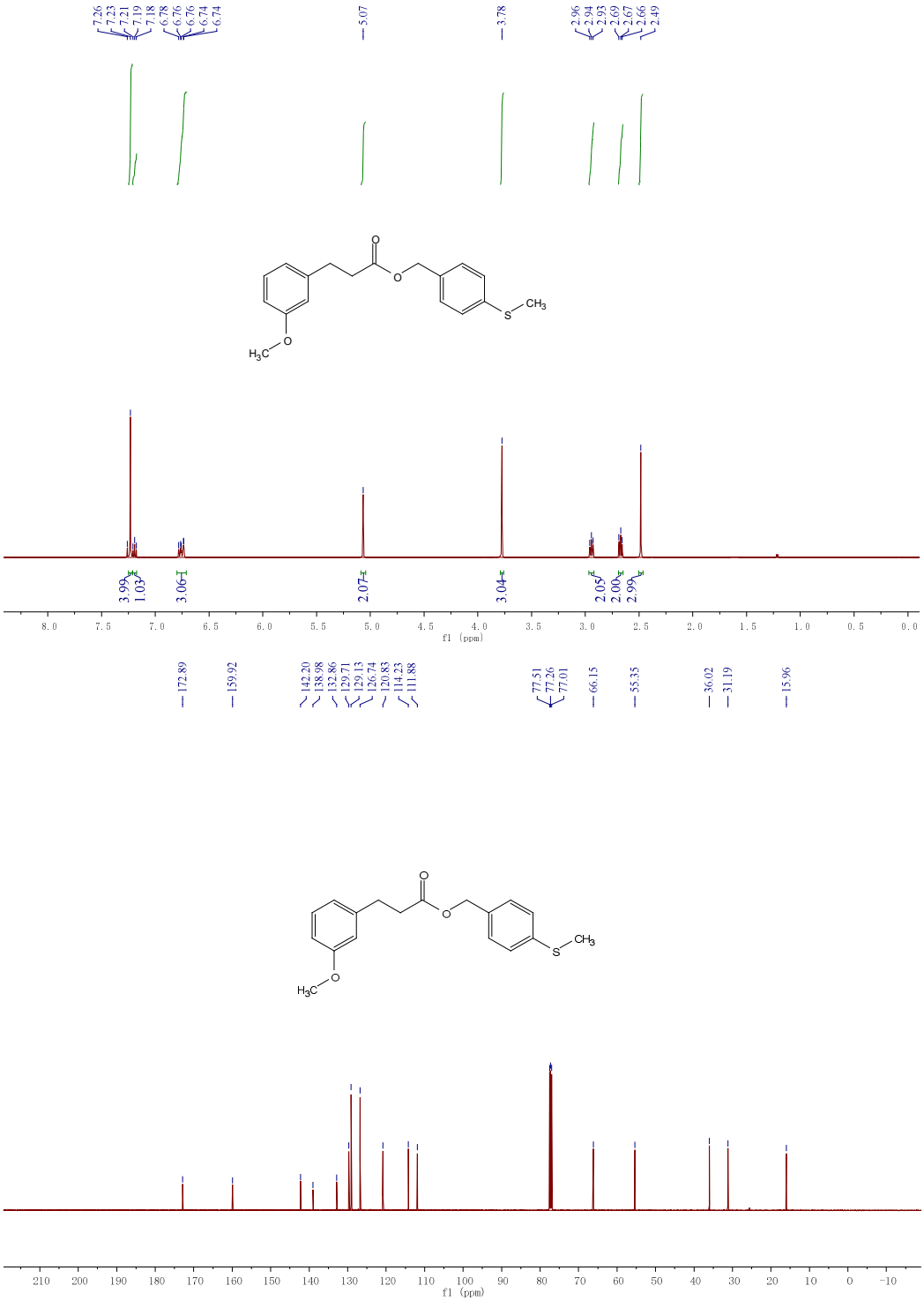
^{1}H NMR and ^{13}C NMR of 3ae



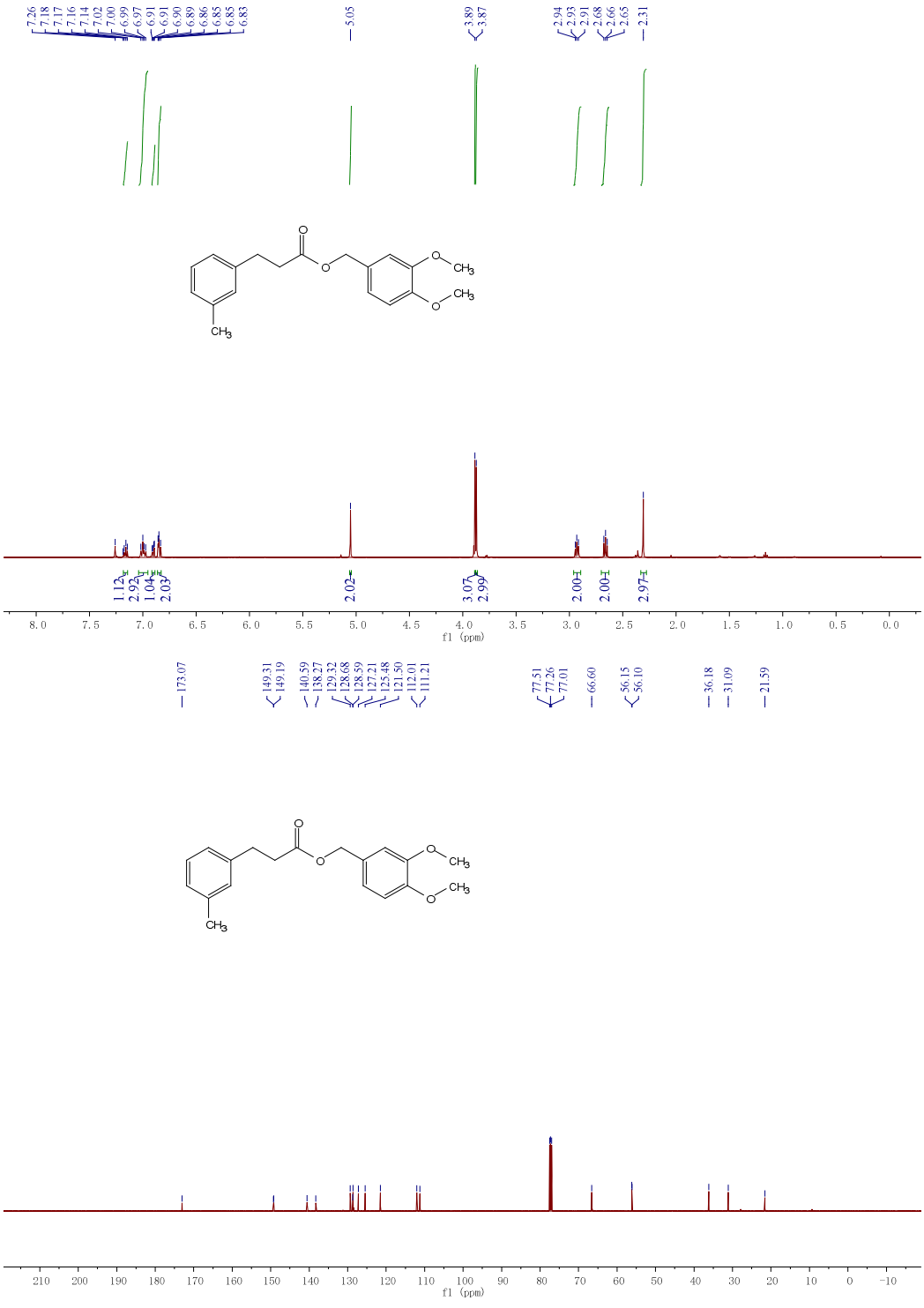
^{1}H NMR and ^{13}C NMR of 3ce



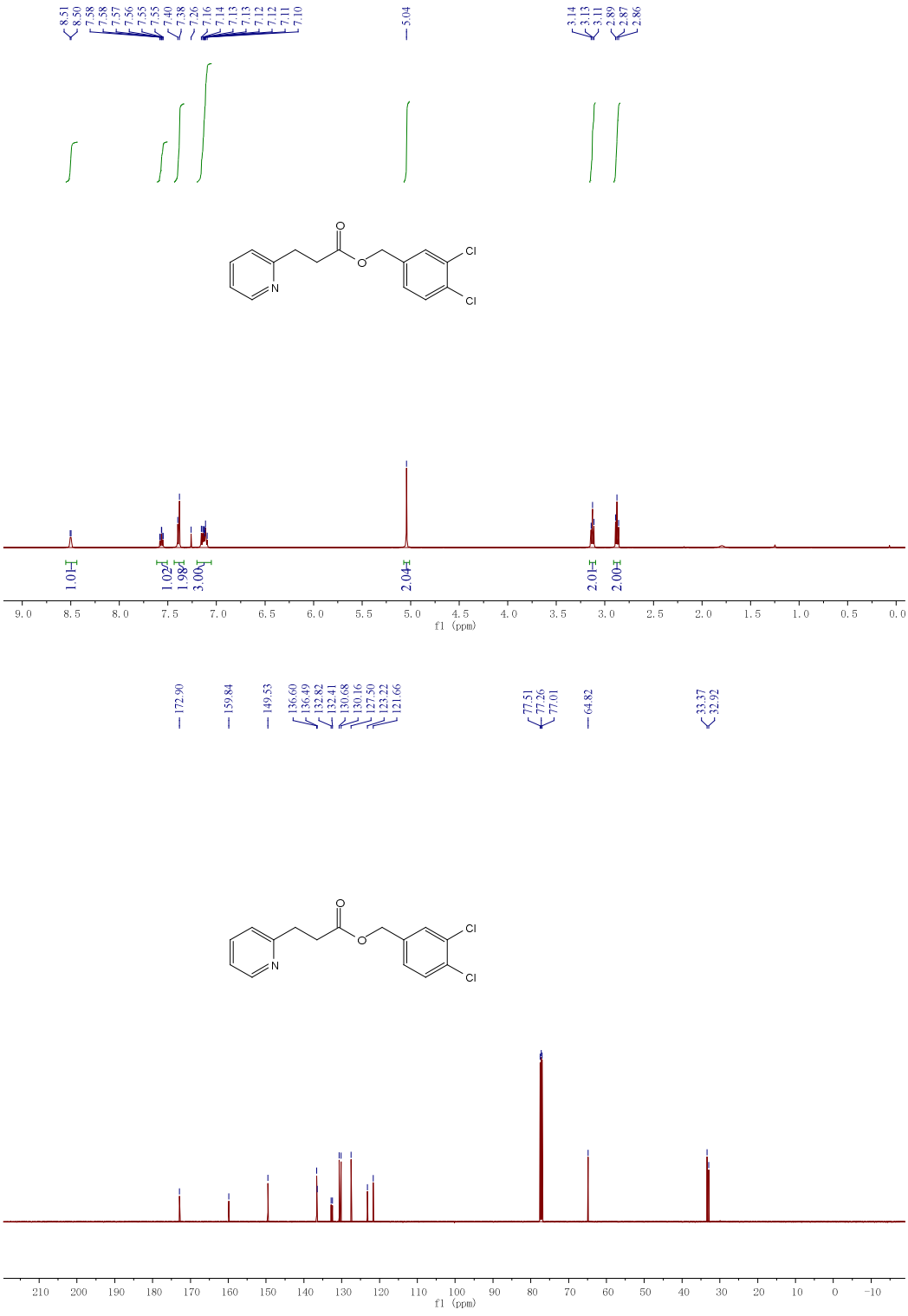
^{1}H NMR and ^{13}C NMR of 3ee



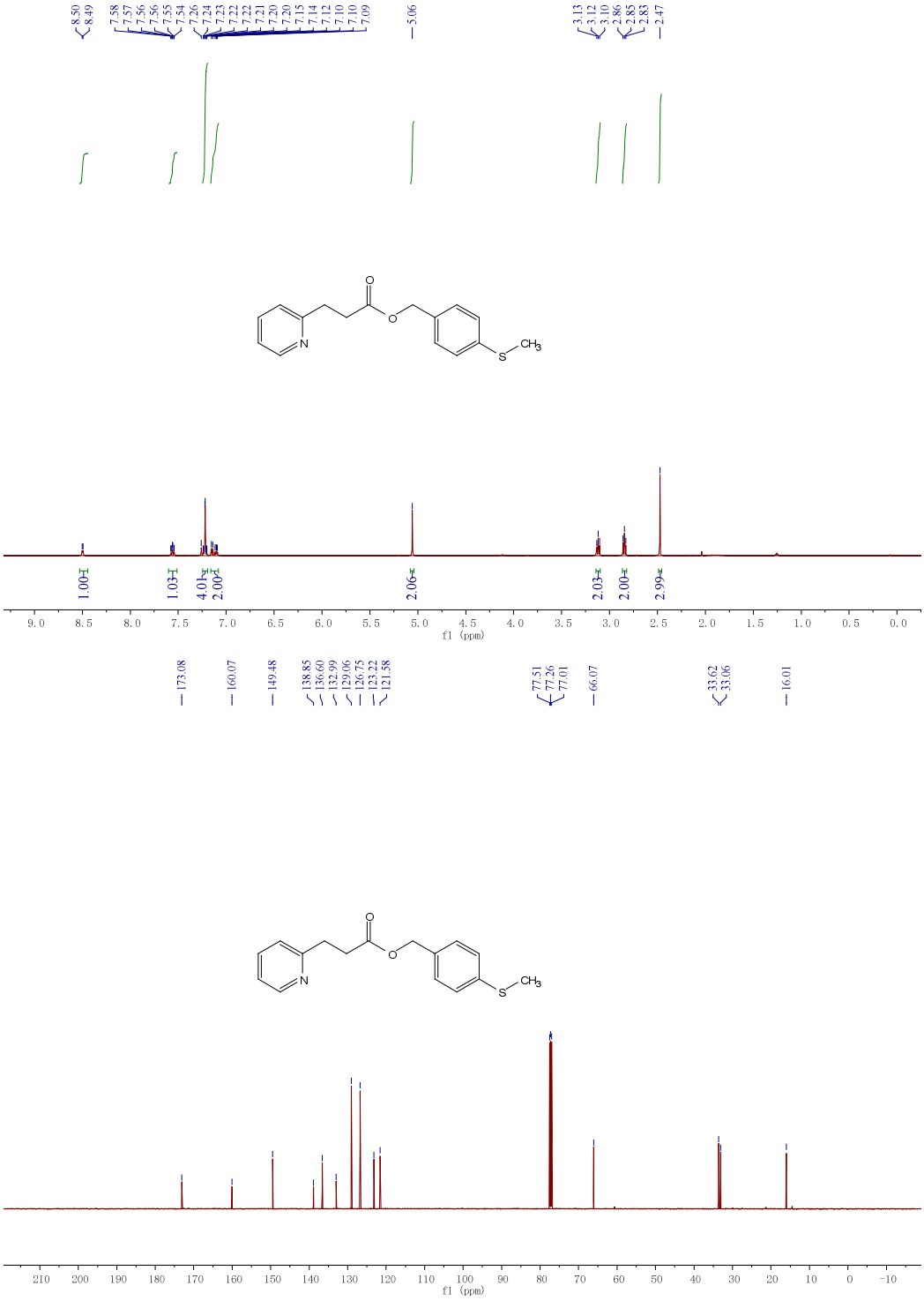
^{1}H NMR and ^{13}C NMR of 3cf



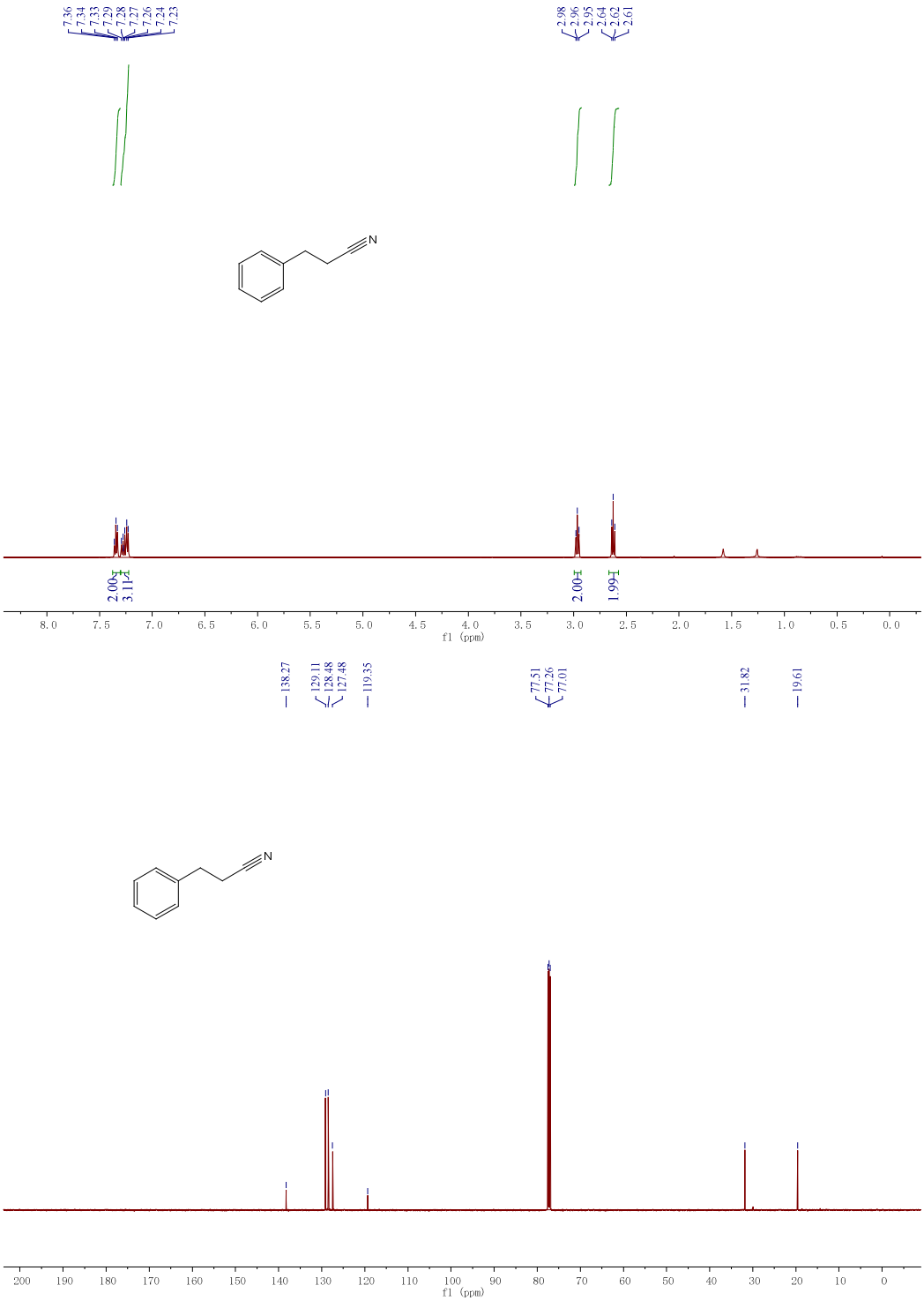
^{1}H NMR and ^{13}C NMR of 3kd



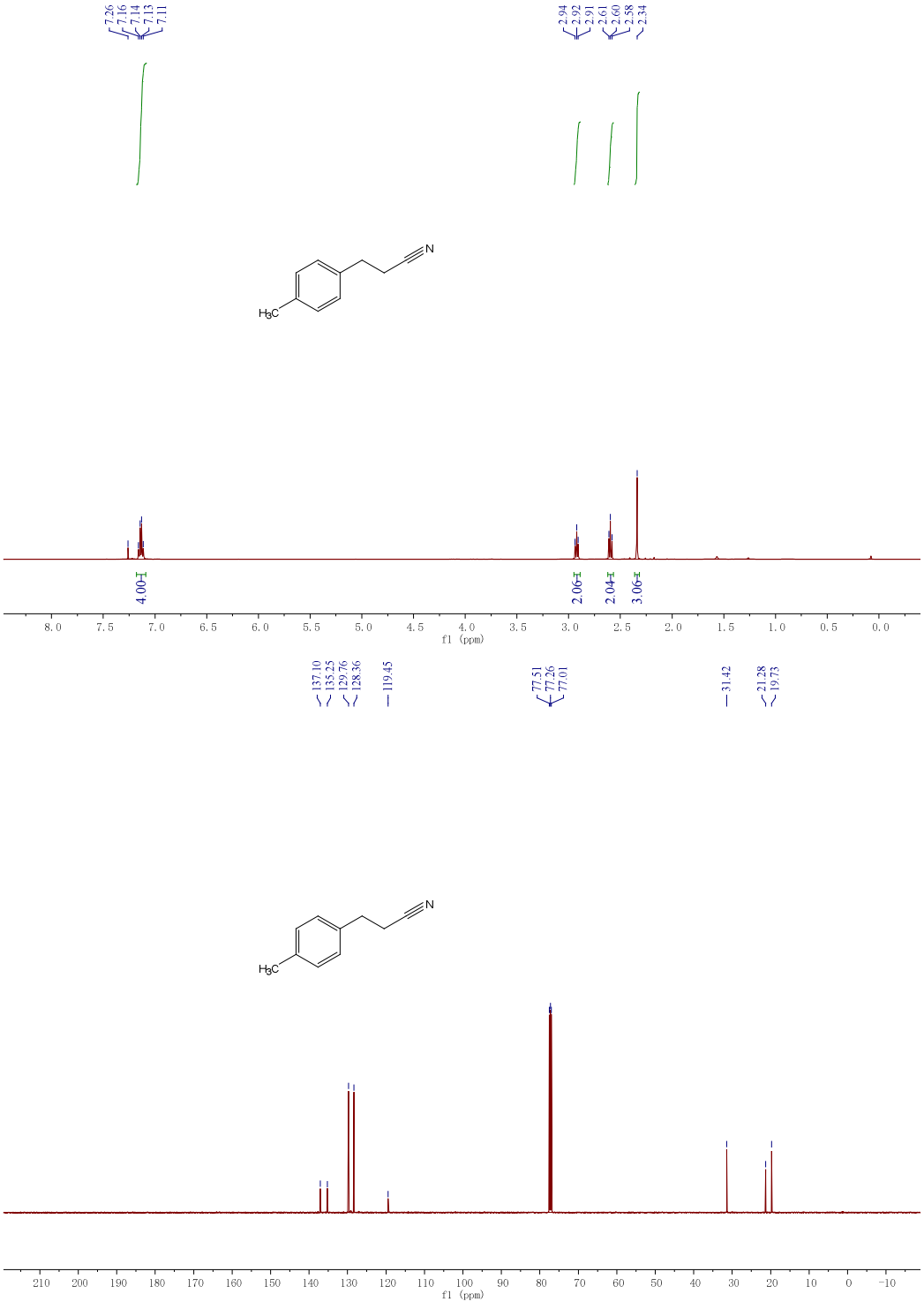
^{1}H NMR and ^{13}C NMR of 3ke



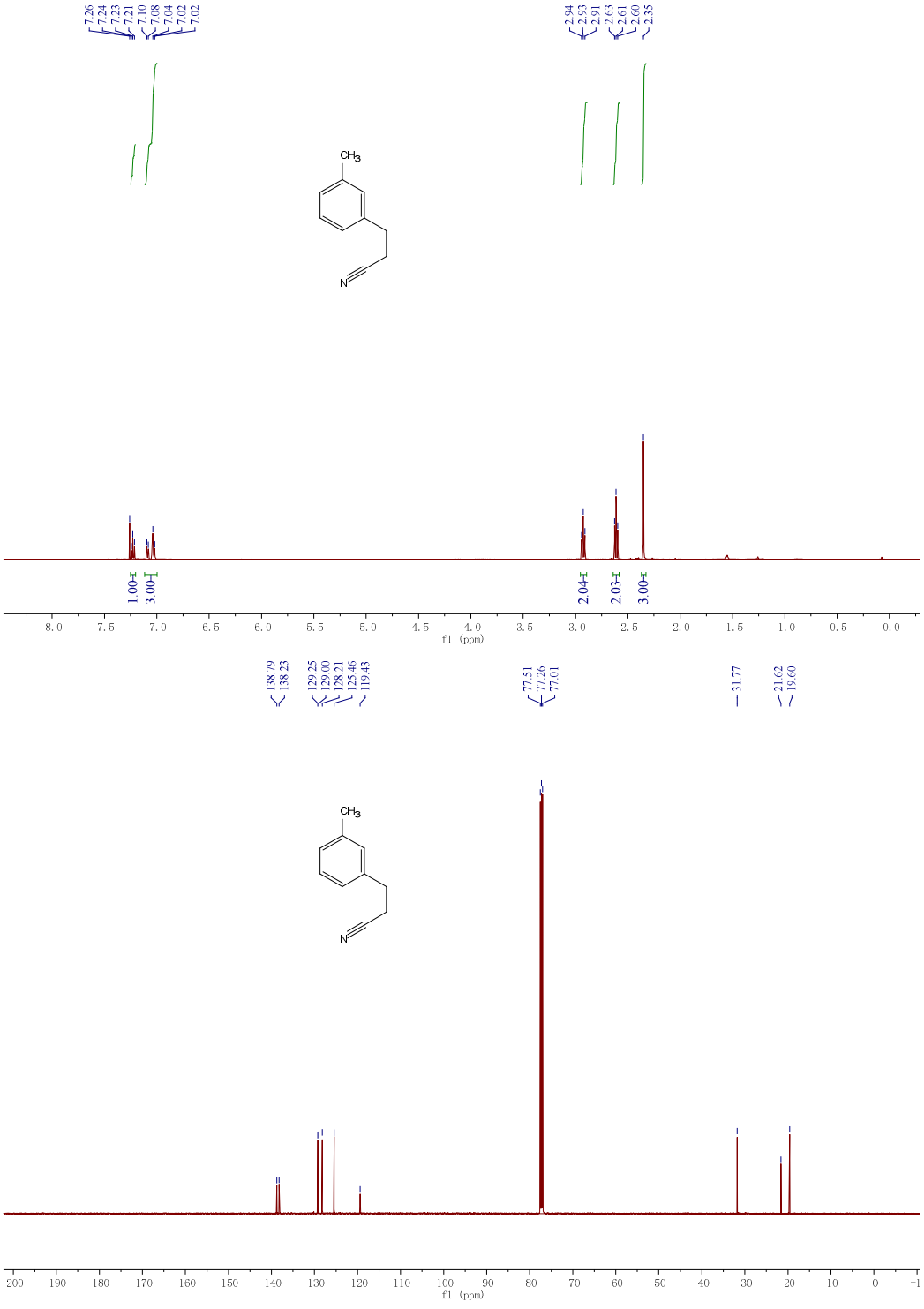
^{1}H NMR and ^{13}C NMR of 3ag



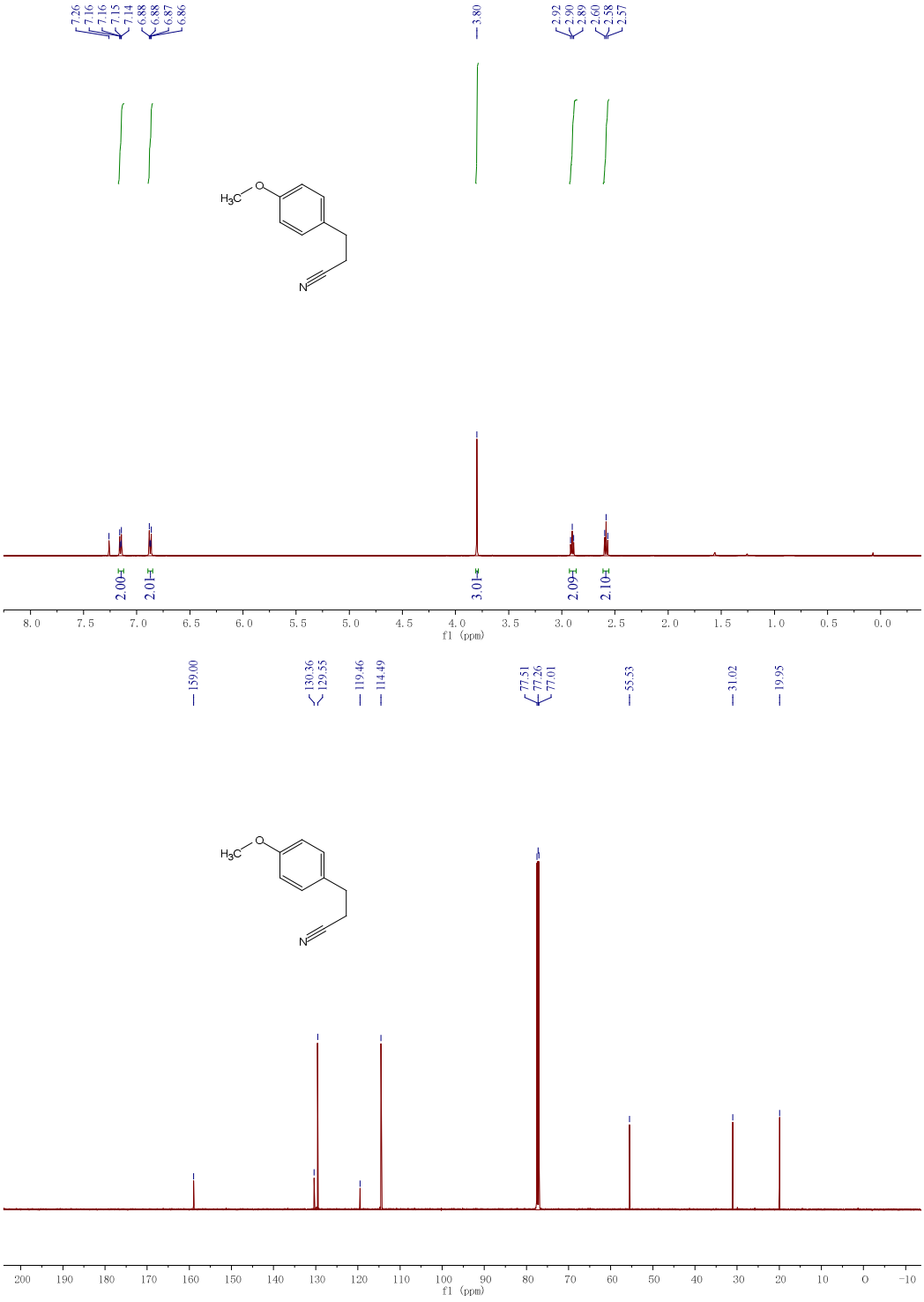
^{1}H NMR and ^{13}C NMR of 3bg



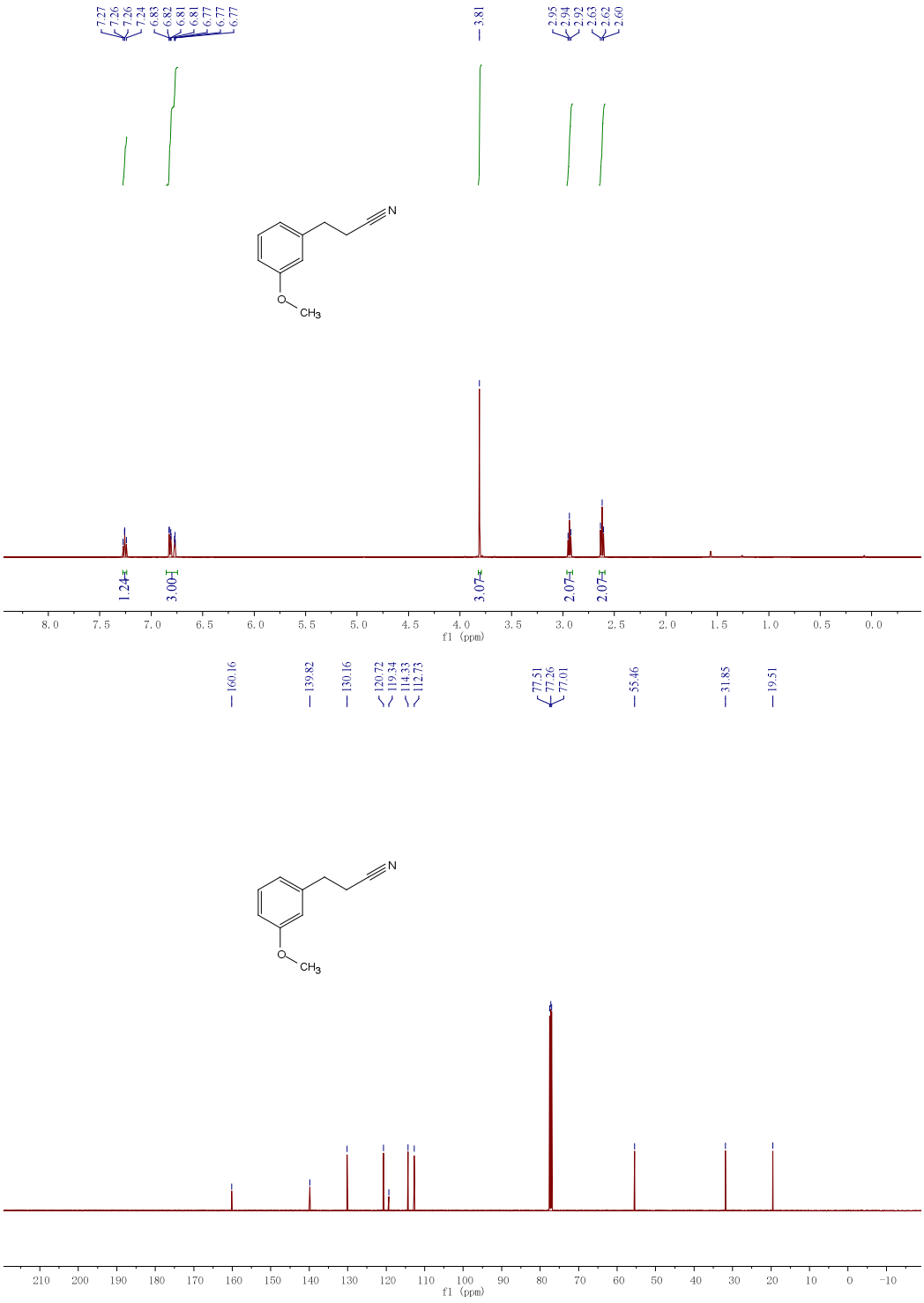
^{1}H NMR and ^{13}C NMR of 3cg



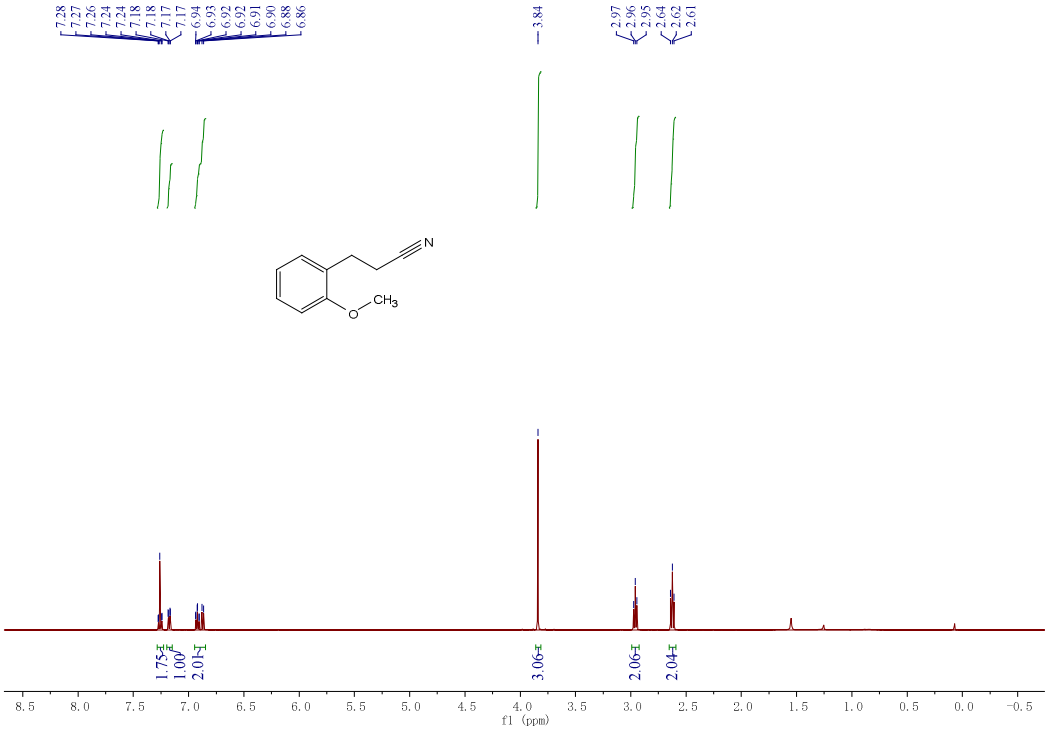
^{1}H NMR and ^{13}C NMR of 3dg

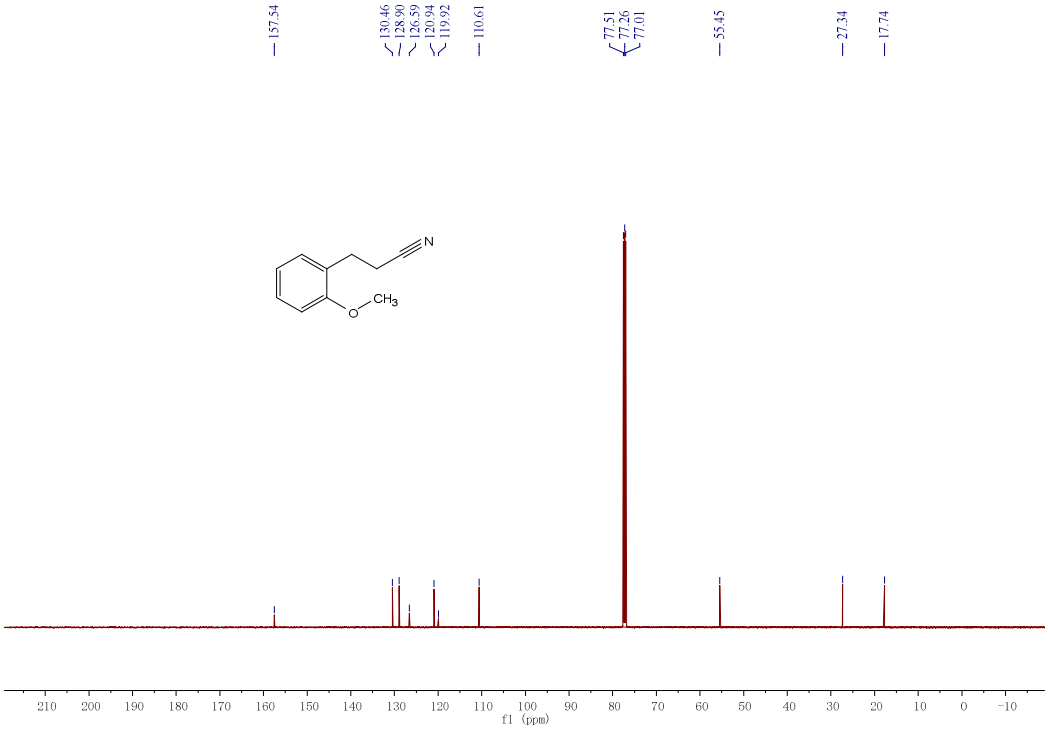


^{1}H NMR and ^{13}C NMR of 3eg



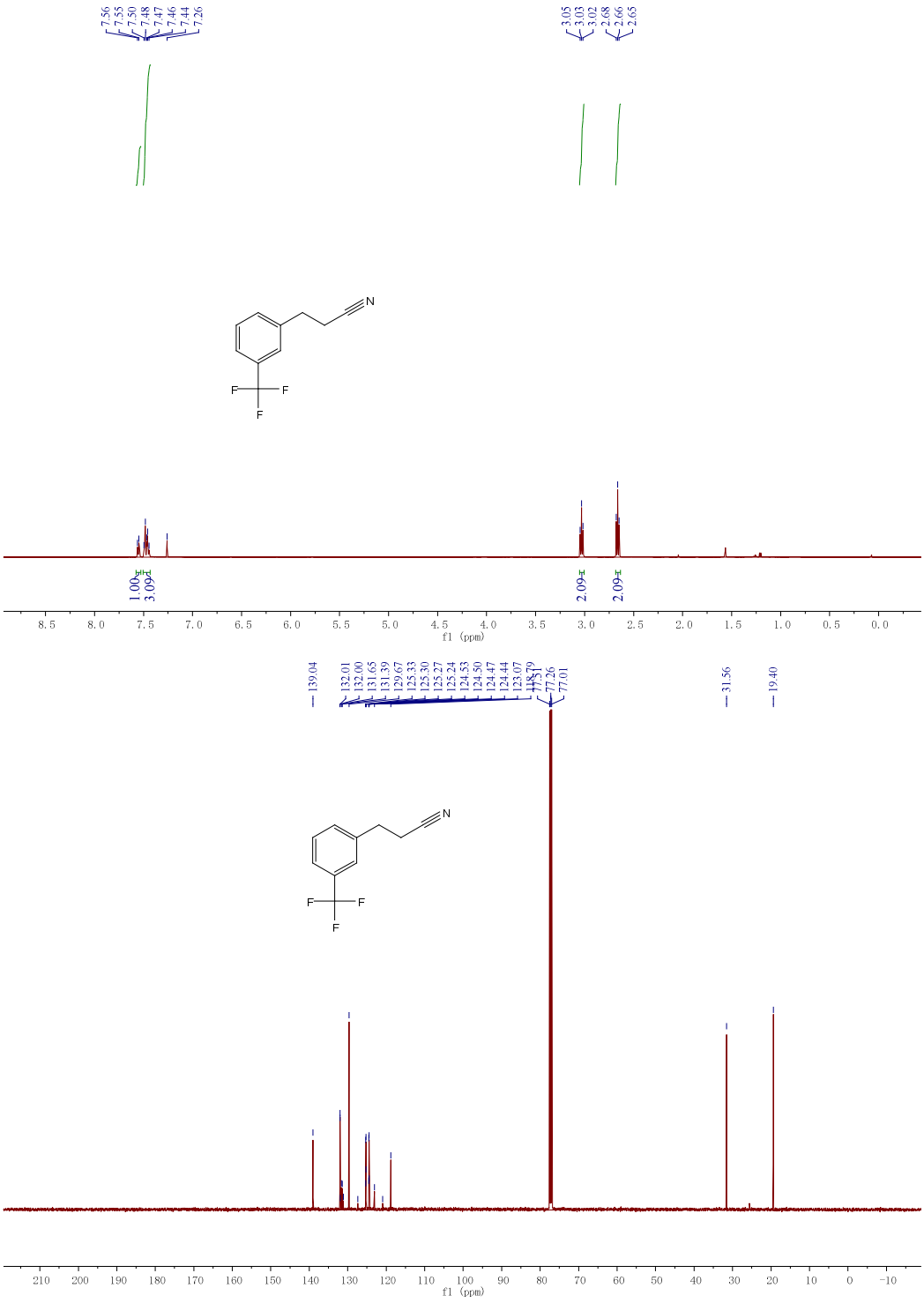
^{1}H NMR and ^{13}C NMR of 3fg



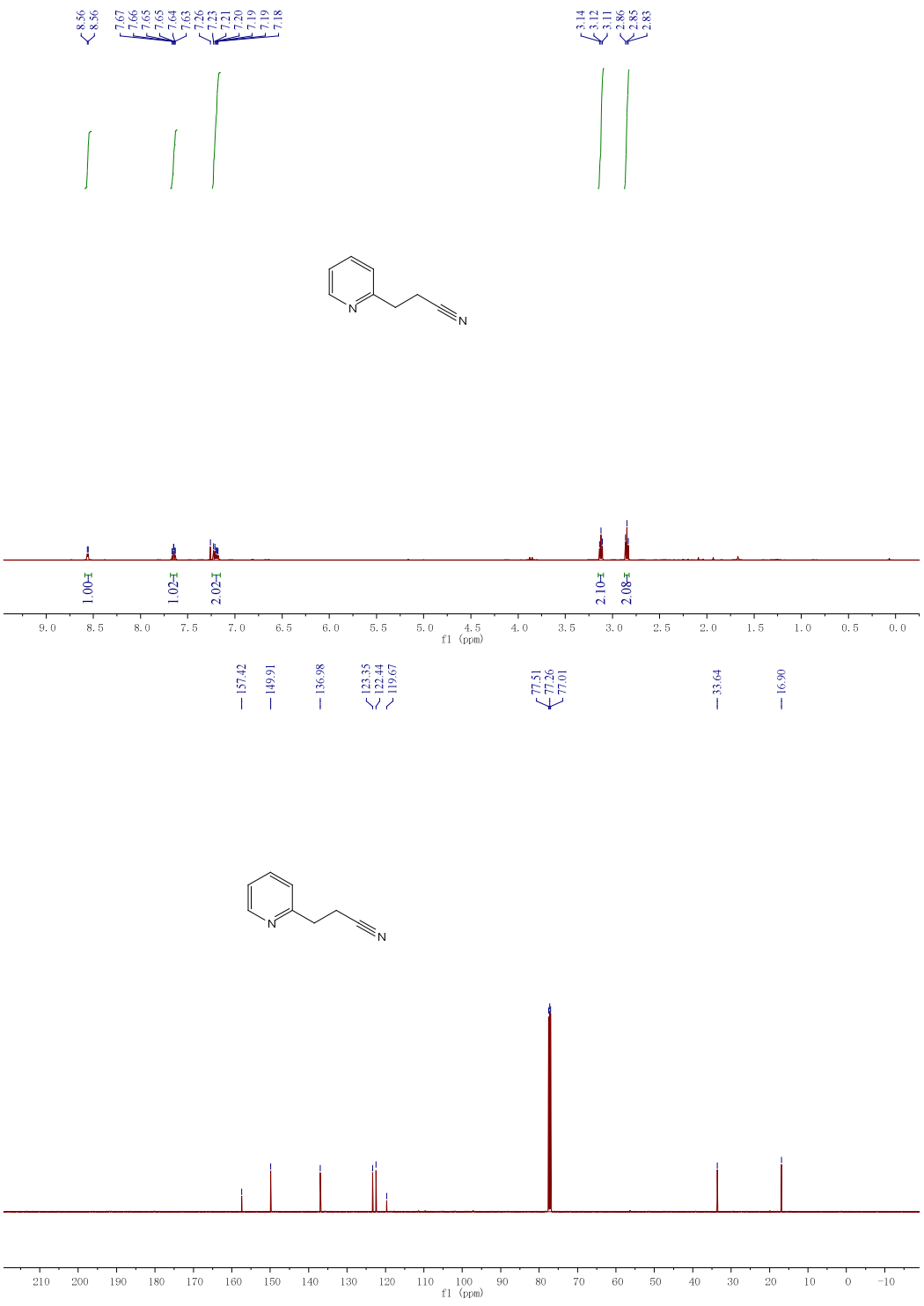


^{1}H NMR and ^{13}C NMR of 3gg

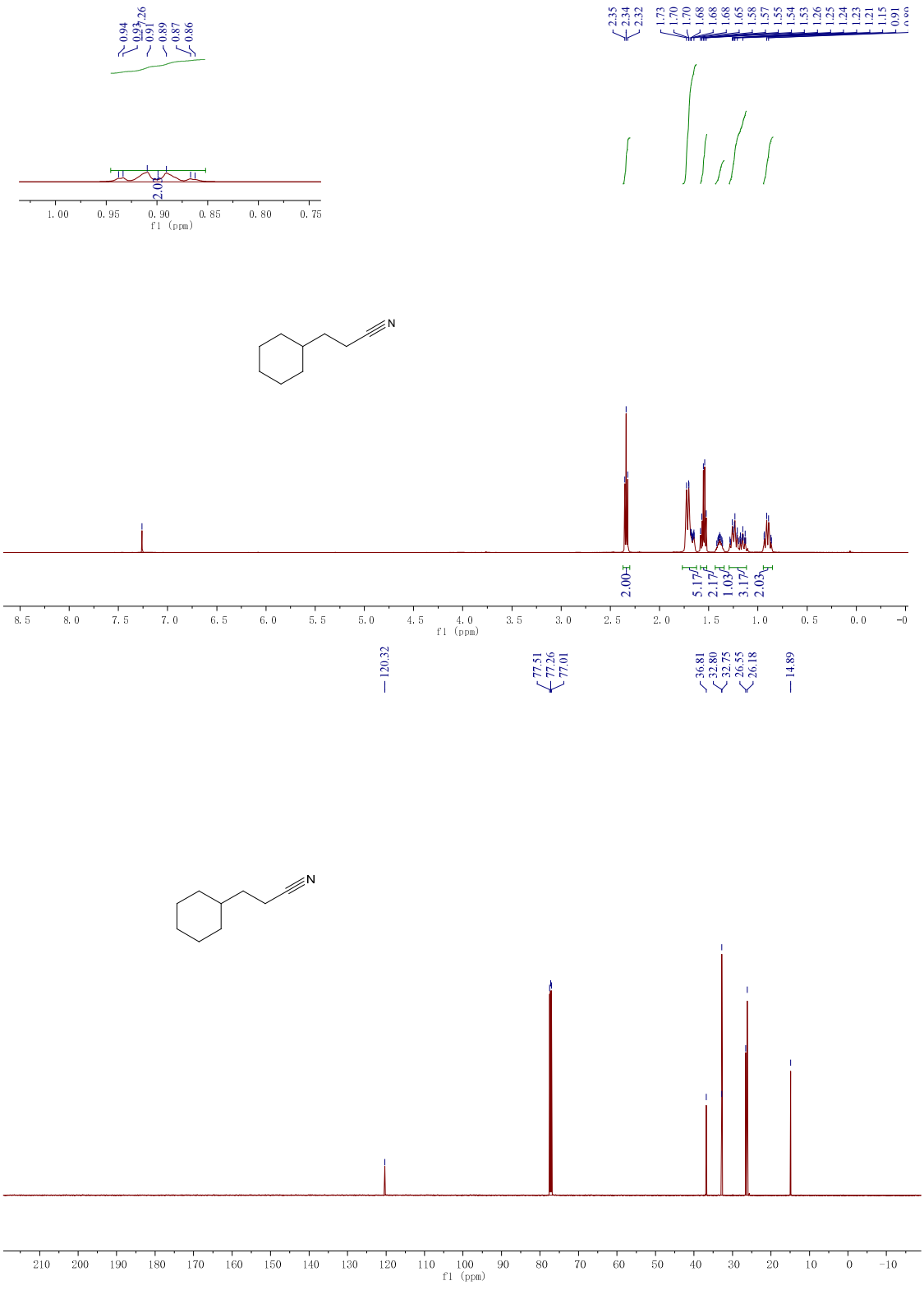
^{1}H NMR and ^{13}C NMR of 3ig



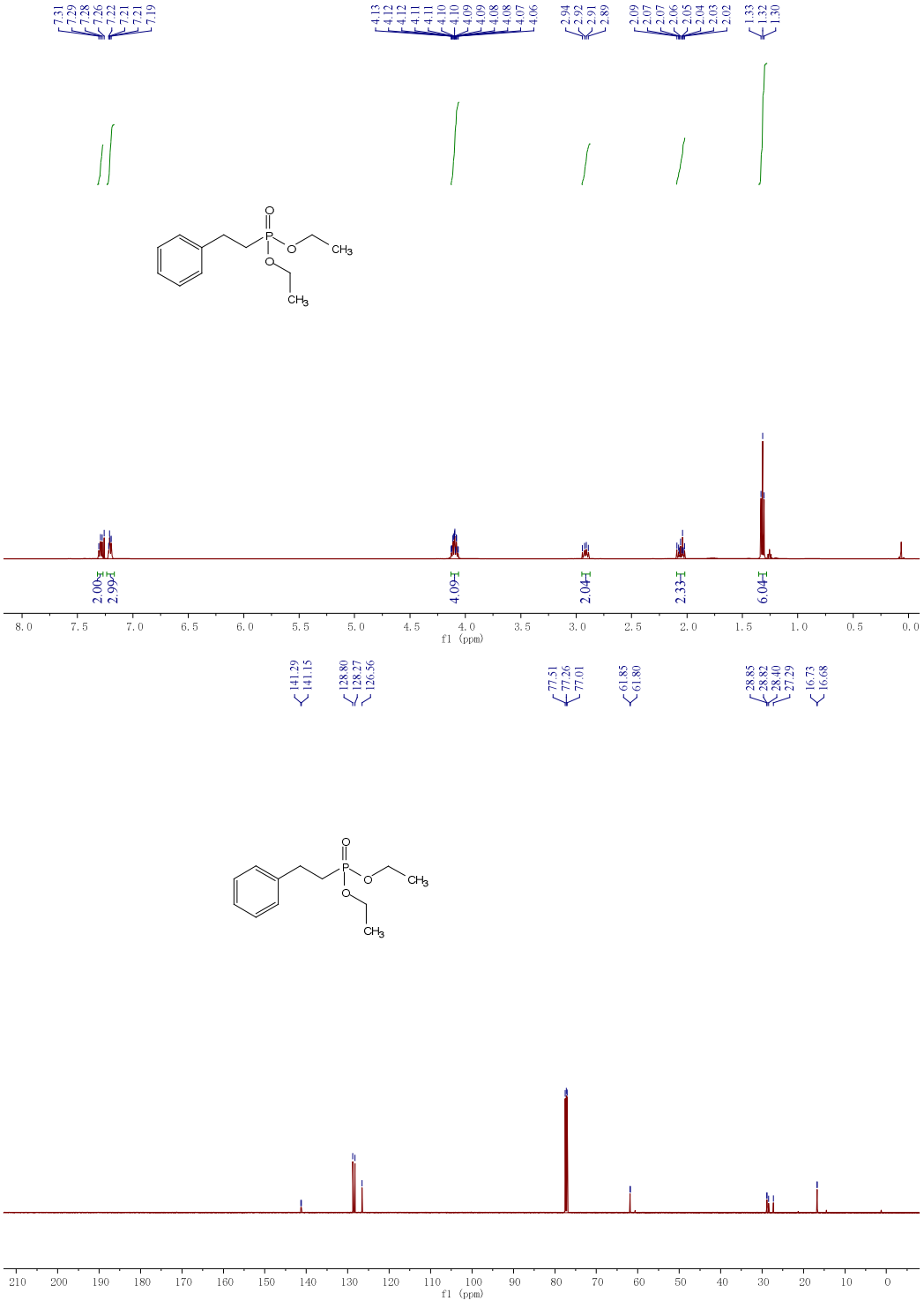
^{1}H NMR and ^{13}C NMR of 3kg



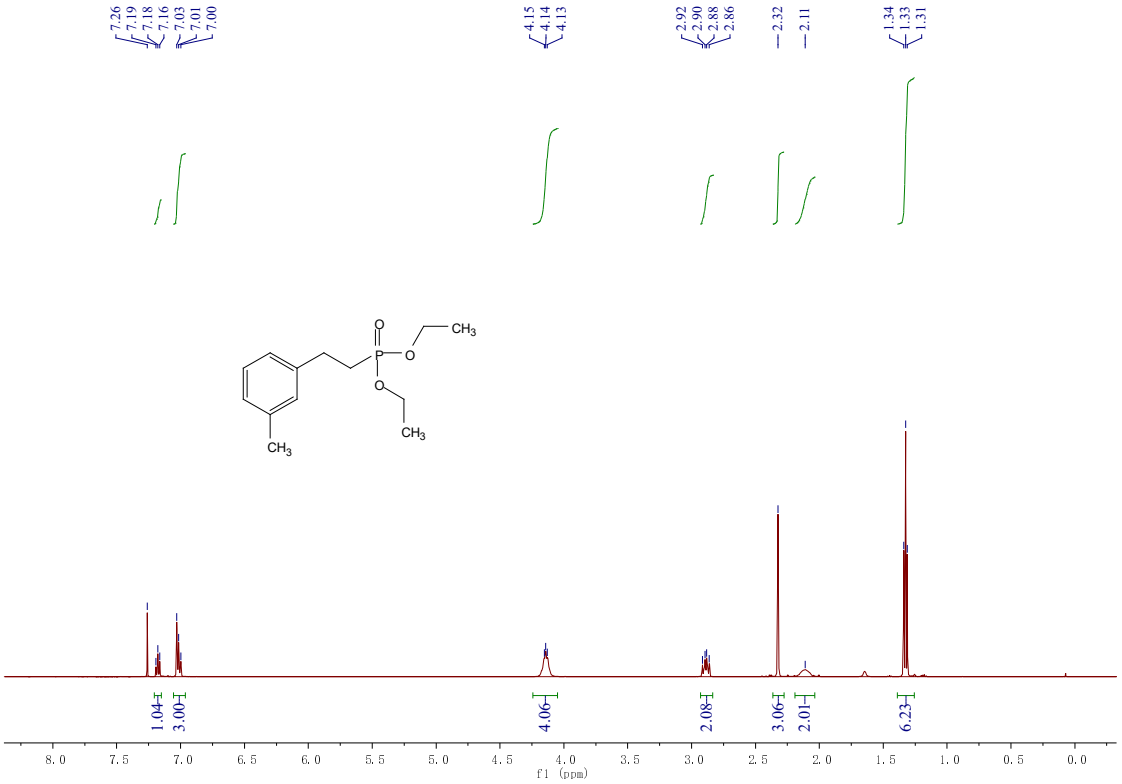
^{1}H NMR and ^{13}C NMR of 3ng

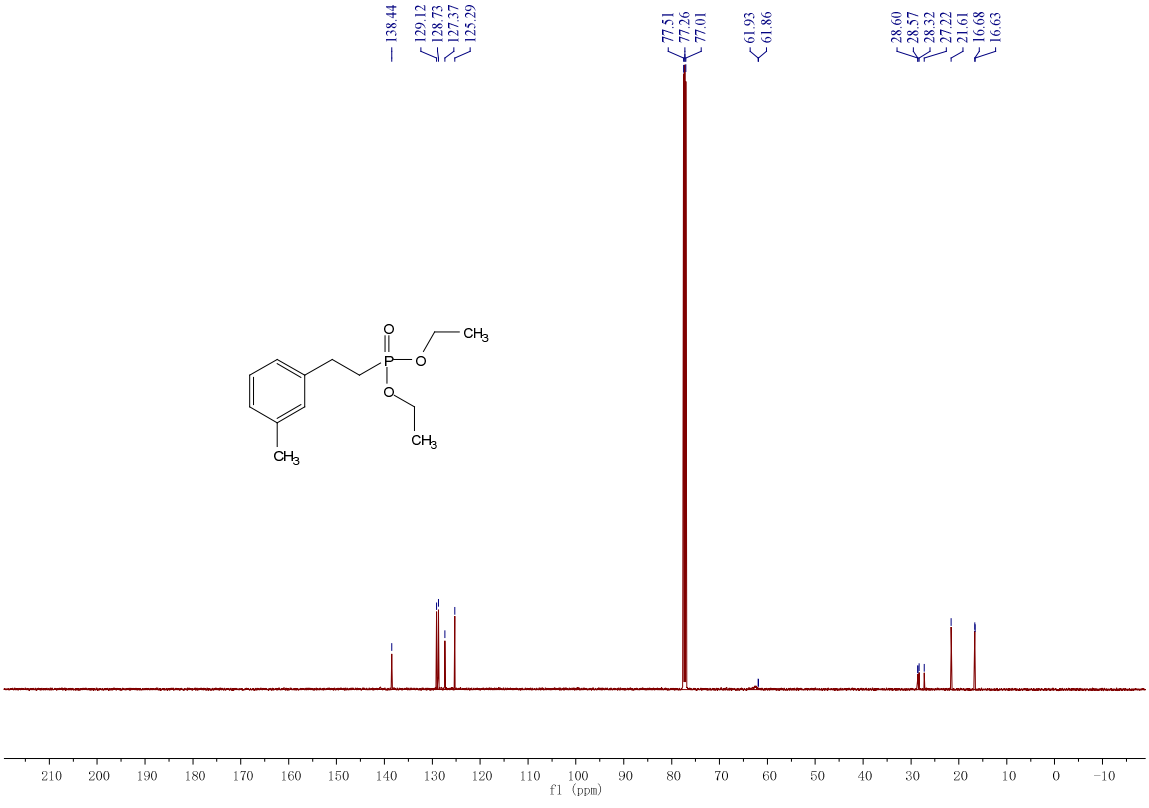


^{1}H NMR and ^{13}C NMR of 3ah

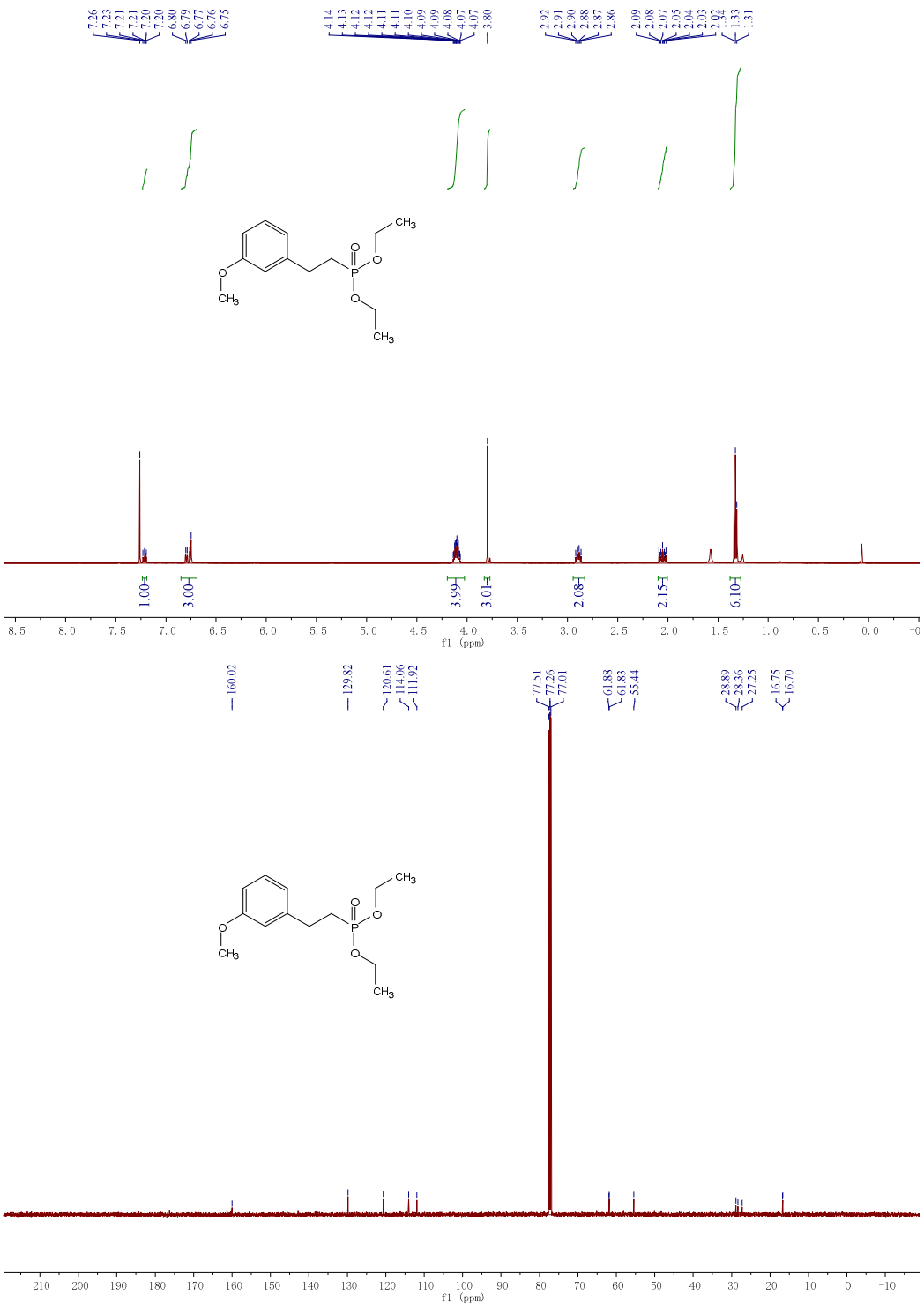


^{1}H NMR and ^{13}C NMR of 3ch





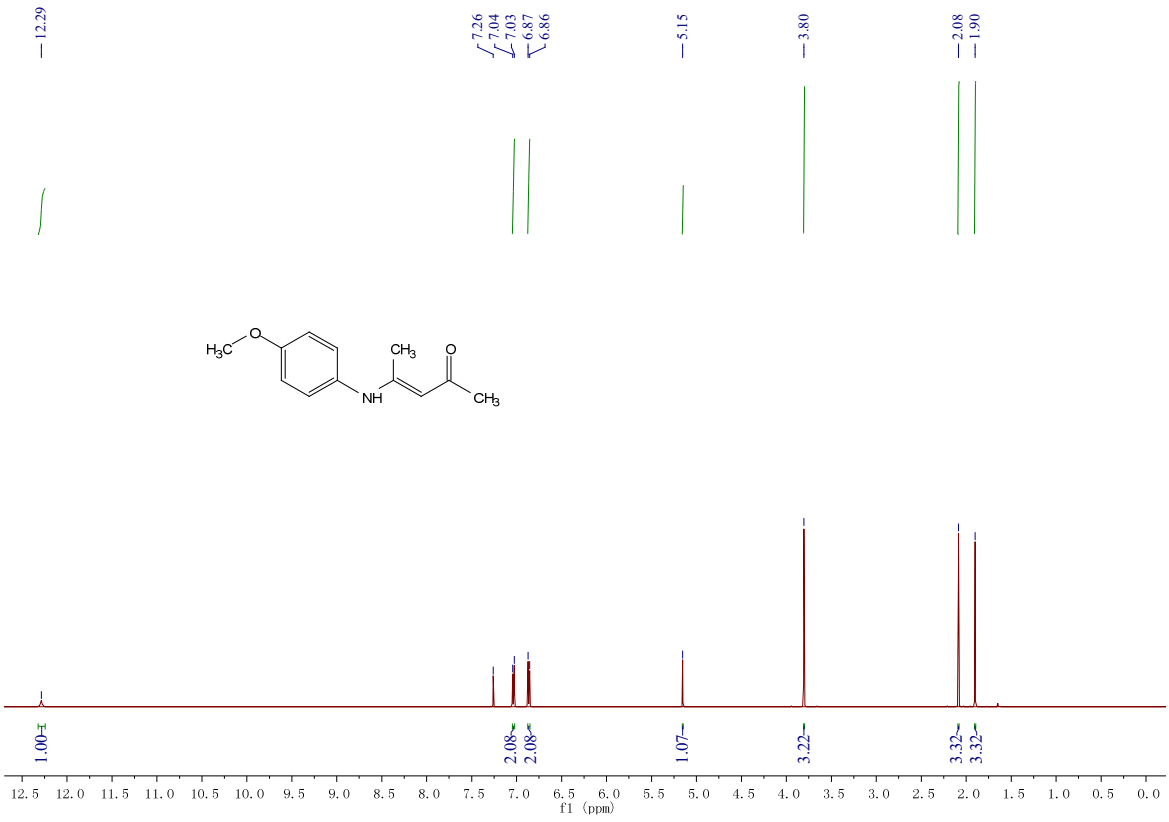
^{1}H NMR and ^{13}C NMR of 3eh



^{1}H NMR of L-2


12.32
7.26
6.83
6.81
6.69
6.68
6.67
6.66
6.64
6.64
5.16
3.88
3.85
2.09
1.93
H3C
O
O
CH3
NH
CH3
O
CH3
0.98
1.14
2.33
0.98
3.06
3.19
2.95
3.00
12.5 12.0 11.5 11.0 10.5 10.0 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 -0.5
f1 (ppm)

^{1}H NMR of L-2


12.29
7.26
7.04
7.03
6.87
6.86
5.15
3.80
2.08
1.90
H3C
O
CH3
O
NH
CH3
1.00
2.08
2.08
1.07
3.22
3.32
3.32
f1 (ppm)