补充材料

铑催化芳香羧酸和丙烯酸酯的交叉脱氢偶联反应

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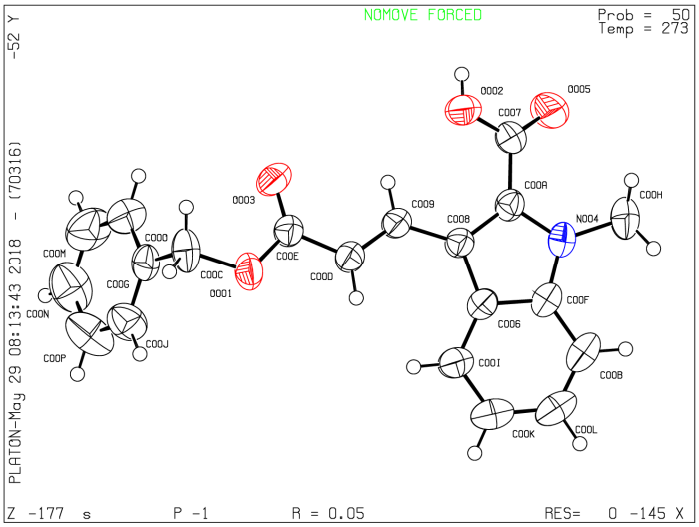
1. 化合物 **3q** 的 X-射线单晶衍射数据



图式 1 化合物 **3q** 的单晶结构热椭球图

Figure S1. Thermal ellipsoid plot for the X-ray crystal structure of **3q**

表 S1 化合物 3q(CCDC 1825538)的晶体数据及结构精化

Table S1 Crystal data and structure refinement for 3q (CCDC 1825538)

Compound Number	**3q**
Identification code	1825538
Empirical formula	$C_{20}H_{17}NO_4$
Formula weight	335.35
Temperature/K	273.15
Crystal system	triclinic
Space group	P-1
a/Å	7.940(2)
b/Å	9.117(2)
c/Å	12.026(3)
α/°	96.061(7)
β/°	100.727(7)
γ/°	90.406(7)
Volume/Å^3	850.3(4)
Z	2
ρ_{calc}g/cm^3	1.310
μ/mm^{-1}	0.752

F(000)	352.0
Crystal size/mm^3	0.5 × 0.4 × 0.3
Radiation	CuKα (λ = 1.54178)
2Θ range for data collection/°	14.782 to 136.724
Index ranges	-9 ≤ h ≤ 9, -10 ≤ k ≤ 10, -14 ≤ l ≤ 14
Reflections collected	16925
Independent reflections	2947 [R_{int} = 0.0792, R_{sigma} = 0.1661]
Data/restraints/parameters	2947/0/228
Goodness-of-fit on F^2	1.042
Final R indexes [I>=2σ (I)]	R_1 = 0.0461, wR_2 = 0.1570
Final R indexes [all data]	R_1 = 0.1696, wR_2 = 0.2037
Largest diff. peak/hole / e $Å^{-3}$	0.32/-0.35

2. 羧酸转化率及目标产物的选择性

表 S2 文章表 2 中羧酸的转化率和目标产物的选择性 [a)]

Table S2. The conversion of acids and the chemoselectivities of the desired products in Table 2[a)]

Entry	羧酸转化率 (%)	产物选择性 (%)	Entry	羧酸转化率 (%)	产物选择性 (%)
1	**1a**: 92	**3a**: 74	13	**1m**: 95	**3m**: 74
2	**1b**: 93	**3b**: 84	14	**1n**: 97	**3n**: 78
3	**1c**: 85	**3c**: 86	15	**1o**: 94	**3o**: 84
4	**1d**: 89	**3d**: 94	16	**1p**: 87	**3p**: 82
5	**1e**: 77	**3e**: 84	17	**1q**: 95	**3q**: 79
6	**1f**: 76	**3f**: 88	18	**1r**: 93	**3r**: 88
7	**1g**: 90	**3g**: 82	19	**1s**: 95	**3s**: 86
8	**1h**: 95	**3h**: 65	20	**1t**: 95	**3t**: 88
9	**1i**: 98	**3i**: 74	21	**1u**: 95	**3u**: 94
10	**1j**: 95	**3j**: 76	22	**1v**: 96	**3v**: 81
11	**1k**: 82	**3k**: 89	23	**1w**: 96	**3w**: 90
12	**1l**: 86	**3l**: 70	24	**1x**: 86	**3x**: 81

[a)]1,3,5-三甲氧基苯为内标, 根据粗产物的 ^{1}H NMR 表征结果计算产率.

表 S3 文章表 3 中羧酸的转化率和目标产物的选择性 [a)]

Table S3. The conversion of acids and the chemoselectivities of the desired products in Table3[a)]

Entry	对位取代羧酸的转化率(%)	单烯基化产物选择性(%)	双烯基化产物选择性(%)
1	**1y**: 67	**3y**: 51	**3y'**: 40
2	**1z**: 65	**3z**: 52	**3z'**: 42
3	**1aa**: 68	**3aa**: 44	**3aa'**: 38
4	**1ab**: 63	**3ab**: 51	**3ab'**: 38
5	**1ac**: 60	**3ac**: 45	**3ac'**: 42
6	**1ad**: 67	**3ad**: 46	**3ad'**: 34

[a)]1,3,5-三甲氧基苯为内标, 根据粗产物的 ^{1}H NMR 表征结果计算产率.

表 S4 不同摩尔比下单烯基化产物和双烯基化产物的产率 [a)]

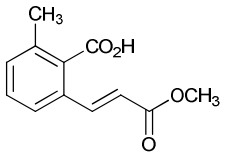
Table S4 The yields of mono- and di-olefinated products under different molar ratios [a)]

Entry	酸	酸和酯的摩尔比	单烯基化产率(%)	双烯基化产率(%)	Entry	酸	酸和酯的摩尔比	单烯基化产率(%)	双烯基化产率(%)
1	**1y**	1.0:0.6	25	7	4	**1ab**	1.0:0.6	20	5
		1.0:0.8	29	15			1.0:0.8	23	19
		1.0:1.0	26	16			1.0:1.0	11	2
		1.0:1.5	30	30			1.0:1.5	25	23
		1.0:2.0	34	27			1.0:2.0	32	24
		1.0:2.5	36	31			1.0:2.5	29	20
		1.0:3.0	34	31			1.0:3.0	29	25
2	**1z**	1.0:0.6	25	4	5	**1ac**	1.0:0.6	23	13
		1.0:0.8	26	6			1.0:0.8	19	13
		1.0:1.0	24	13			1.0:1.0	23	15
		1.0:1.5	28	25			1.0:1.5	27	24
		1.0:2.0	34	27			1.0:2.0	27	25
		1.0:2.5	30	27			1.0:2.5	28	23
		1.0:3.0	29	27			1.0:3.0	29	25
3	**1aa**	1.0:0.6	28	12	6	**1ad**	1.0:0.6	17	13
		1.0:0.8	26	13			1.0:0.8	16	14
		1.0:1.0	23	10			1.0:1.0	18	14
		1.0:1.5	28	25			1.0:1.5	22	15
		1.0:2.0	30	26			1.0:2.0	31	23
		1.0:2.5	24	24			1.0:2.5	25	22
		1.0:3.0	26	27			1.0:3.0	26	22

[a)]1,3,5-三甲氧基苯为内标, 根据粗产物的 ^{1}H NMR 表征结果计算产率.

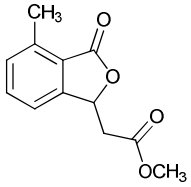
3. 化合物的表征数据

(*E*)-2-(3-methoxy-3-oxoprop-1-enyl)-6-methylbenzoic acid (3a)



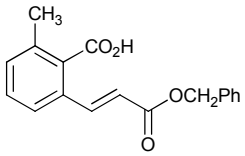
White solid, 13.6 mg, 62% (isolated yield), low temperature storage in inert atmosphere. ^{1}H NMR (400 MHz, $CDCl_3$): δ [ppm] = 7.95 (d, J = 15.8 Hz, 1H), 7.49 (d, J = 7.7 Hz, 1H), 7.36 (t, J = 7.8 Hz, 1H), 7.28 (d, J = 7.8 Hz, 1H), 6.42 (d, J = 15.8 Hz, 1H), 3.81 (s, 3H), 2.48 (s, 3H). ^{13}C NMR (150 MHz, $CDCl_3$): δ [ppm] = 172.8, 167.3, 142.5, 136.3, 133.3, 132.5, 132.0, 130.1, 124.2, 120.3, 51.9, 20.0. HRMS (ESI) m/z: calculated for $C_{12}H_{12}O_4$, $[M+Na]^+$ 243.0628; found: 243.0640.

methyl 2-(4-methyl-3-oxo-1,3-dihydroisobenzofuran-1-yl) acetate (3a')



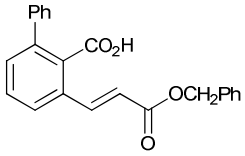
White solid, 18.3 mg, 83% (isolated yield). ^{1}H NMR (600 MHz, $CDCl_3$): δ [ppm] = 7.54 (t, J = 7.6 Hz, 1H), 7.29 (t, J = 7.5 Hz, 2H), 5.82 (t, J = 6.6 Hz, 1H), 3.77 (s, 3H), 2.88 (dd, J = 6.6, 3.8 Hz, 2H), 2.69 (s, 3H). ^{13}C NMR (150 MHz, $CDCl_3$): δ [ppm] = 169.9, 169.7, 149.1, 139.8, 133.9, 131.1, 123.2, 119.2, 75.9, 52.1, 39.5, 17.2. HRMS (ESI) m/z: calculated for $C_{12}H_{12}O_4$, $[M+Na]^+$ 243.0628; found: 243.0640.

(*E*)-2-(3-(benzyloxy)-3-oxoprop-1-enyl)-6-methylbenzoic acid (3b)



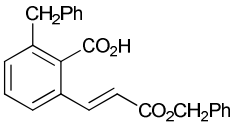
Yellow oil, 21.3 mg, 72% (isolated yield), low temperature storage in inert atmosphere. ^{1}H NMR (400 MHz, $CDCl_3$): δ [ppm] = 8.01 (d, J = 15.8 Hz, 1H), 7.47 (d, J = 7.6 Hz, 1H), 7.34 (m, 7H), 6.45 (d, J = 15.7 Hz, 1H), 5.23 (s, 2H), 2.44 (s, 3H). ^{13}C NMR (150 MHz, $CDCl_3$): δ [ppm] = 172.4, 166.5, 142.8, 136.6, 135.9, 132.80,132.77, 132.1, 130.2, 128.6, 128.2, 124.3, 120.6, 66.5, 20.2. HRMS (ESI) m/z: calculated for $C_{18}H_{16}O_4$, $[M+Na]^+$ 319.0941; found: 319.0948.

(*E*)-3-(3-(benzyloxy)-3-oxoprop-1-enyl)biphenyl-2-carboxylic acid (3c)



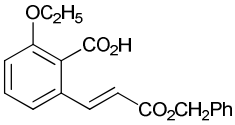
Yellow oil, 24.0 mg, 67% (isolated yield), low temperature storage in inert atmosphere. ^{1}H NMR (600 MHz, $CDCl_3$): δ [ppm] = 8.01 (d, J = 15.8 Hz, 1H), 7.64 (d, J = 7.8 Hz, 1H), 7.48 (t, J = 7.8 Hz, 1H), 7.42 – 7.31 (m, 11H), 6.51 (d, J = 15.8 Hz, 1H), 5.23 (s, 2H). ^{13}C NMR (150 MHz, $CDCl_3$): δ [ppm] = 172.3, 166.4, 142.3, 140.9, 139.9, 135.8, 133.2, 132.4, 131.6, 129.9, 128.6, 128.4, 128.3, 128.2, 127.8, 125.3, 121.0, 66.5. HRMS (ESI) m/z: calculated for $C_{23}H_{18}O_4$, $[M+Na]^+$ 381.1097; found: 381.1101.

(*E*)-2-benzyl-6-(3-(benzyloxy)-3-oxoprop-1-enyl)benzoic acid (3d)



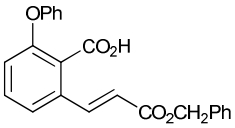
Yellow oil, 29.8 mg, 80% (isolated yield), low temperature storage in inert atmosphere. ^{1}H NMR (400 MHz, $CDCl_3$): δ [ppm] = 8.01 (d, J = 15.7 Hz, 1H), 7.49 (d, J = 7.6 Hz, 1H), 7.37 – 7.30 (m, 5H), 7.28 (d, J = 6.7 Hz, 1H), 7.23 (t, J = 7.0 Hz, 2H), 7.20 – 7.12 (m, 4H), 5.19 (s, 2H), 4.11 (s, 2H). ^{13}C NMR (100 MHz, $CDCl_3$): δ [ppm] = 172.8, 166.5, 142.7, 139.7, 139.5, 135.8, 133.4, 132.5, 131.9, 130.1, 129.2, 128.6, 128.5, 128.5, 128.2, 126.3, 124.6, 120.6, 66.5, 39.2. HRMS (ESI) m/z: calculated for $C_{24}H_{20}O_4$, $[M+Na]^+$ 395.1254; found: 395.1261.

(*E*)-2-(3-(benzyloxy)-3-oxoprop-1-enyl)-6-ethoxybenzoic acid (3e)



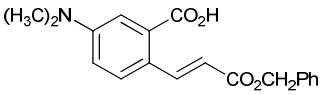
Yellow oil, 19.2 mg, 59% (isolated yield), low temperature storage in inert atmosphere. ^{1}H NMR (400 MHz, $CDCl_3$): δ [ppm] = 8.18 (d, J = 15.8 Hz, 1H), 7.51 – 7.28 (m, 6H), 7.21 (d, J = 7.8 Hz, 1H), 7.03 (d, J = 8.3 Hz, 1H), 6.34 (d, J = 15.8 Hz, 1H), 5.25 (s, 2H), 4.22 (q, J = 7.0 Hz, 2H), 1.49 (t, J = 7.0 Hz, 3H). ^{13}C NMR (150 MHz, $CDCl_3$): δ [ppm] = 169.3, 166.3, 156.4, 142.8, 135.8, 135.0, 131.6, 128.5, 128.1, 122.2, 120.7, 119.5, 113.7, 66.4, 65.2, 14.5. HRMS (ESI) m/z: calculated for $C_{19}H_{18}O_5$, $[M+Na]^+$ 349.1046; found: 349.1047.

(*E*)-2-(3-(benzyloxy)-3-oxoprop-1-enyl)-6-phenoxybenzoic acid (3f)



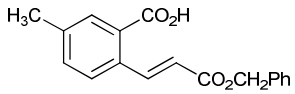
Yellow oil, 22.8 mg, 61% (isolated yield), low temperature storage in inert atmosphere. ^{1}H NMR (600 MHz, $CDCl_3$): δ [ppm] = 8.02 (d, J = 15.8 Hz, 1H), 7.40 – 7.30 (m, 9H), 7.14 (t, J = 7.4 Hz, 1H), 7.04 (d, J = 8.0 Hz, 2H), 6.92 (dd, J = 6.8, 2.1 Hz, 1H), 6.49 (d, J = 15.8 Hz, 1H), 5.24 (s, 2H). ^{13}C NMR (150 MHz, $CDCl_3$): δ [ppm] = 169.0, 166.2, 156.4, 155.4, 141.9, 135.9, 135.0, 131.4, 129.9, 128.6, 128.2, 124.7, 124.2, 121.6, 121.5, 119.8, 119.4, 66.6. HRMS (ESI) m/z: calculated for $C_{23}H_{18}O_5$, $[M+Na]^+$ 397.1046; found: 397.1051.

(*E*)-2-(3-(benzyloxy)-3-oxoprop-1-enyl)-5-(dimethylamino)benzoic acid (3g)



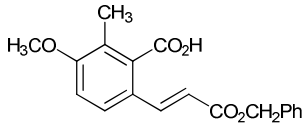
Yellow solid, 21.5 mg, 66% (isolated yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ [ppm] = 8.62 (d, J = 15.8 Hz, 1H), 7.60 (d, J = 8.8 Hz, 1H), 7.44 – 7.30 (m, 6H), 6.84 (dd, J = 8.8, 2.6 Hz, 1H), 6.31 (d, J = 15.8 Hz, 1H), 5.25 (s, 2H), 3.05 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$): δ [ppm] = 172.6, 167.3, 150.9, 143.9, 136.4, 130.3, 128.9, 128.5, 128.02, 127.96, 123.2, 115.9, 115.7, 114.1, 66.0, 40.1. HRMS (ESI) m/z: calculated for $C_{19}H_{19}NO_4$, $[M+Na]^+$ 348.1206; found: 348.1208.

(*E*)-2-(3-(benzyloxy)-3-oxoprop-1-enyl)-5-methylbenzoic acid (3h)



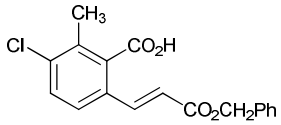
White solid, 16.6 mg, 56% (isolated yield). ^{1}H NMR (600 MHz, $CDCl_3$): δ [ppm] = 8.62 (d, J = 15.9 Hz, 1H), 7.93 (s, 1H), 7.54 (d, J = 7.9 Hz, 1H), 7.43 (d, J = 7.5 Hz, 2H), 7.39 (m, 3H), 7.32 (t, J = 7.2 Hz, 1H), 6.37 (d, J = 15.9 Hz, 1H), 5.27 (s, 2H), 2.43 (s, 3H). ^{13}C NMR (150 MHz, $CDCl_3$): δ [ppm] = 172.0, 166.5, 144.1, 140.0, 136.1, 134.2, 134.0, 132.2, 128.54, 128.49, 128.1, 128.0, 120.1, 66.3, 21.1. HRMS (ESI) m/z: calculated for $C_{18}H_{16}O_4$, $[M+Na]^+$ 319.0941; found: 319.0939.

(*E*)-6-(3-(benzyloxy)-3-oxoprop-1-enyl)-3-methoxy-2-methylbenzoic acid (3i)



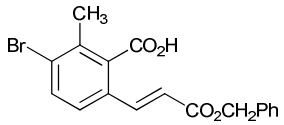
White solid, 21.8 mg, 67% (isolated yield), low temperature storage in inert atmosphere. ^{1}H NMR (600 MHz, $CDCl_3$): δ [ppm] = 7.89 (d, J = 15.7 Hz, 1H), 7.53 (d, J = 8.7 Hz, 1H), 7.40 (d, J = 7.4 Hz, 2H), 7.36 (t, J = 7.5 Hz, 2H), 7.31 (t, J = 7.2 Hz, 1H), 6.91 (d, J = 8.7 Hz, 1H), 6.38 (d, J = 15.7 Hz, 1H), 5.23 (s, 2H), 3.88 (s, 3H), 2.27 (s, 3H). ^{13}C NMR (150 MHz, $CDCl_3$): δ [ppm] = 171.8, 166.9, 159.2, 142.3, 136.1, 135.0, 128.6, 128.21, 128.17, 125.7, 124.7, 124.0, 117.9, 111.5, 66.4, 55.8, 13.1. HRMS (ESI) m/z: calculated for $C_{19}H_{18}O_5$, $[M+Na]^+$ 349.1046; found: 349.1054.

(*E*)-6-(3-(benzyloxy)-3-oxoprop-1-enyl)-3-chloro-2-methylbenzoic acid (3j)



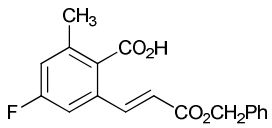
White solid, 21.8 mg, 66% (isolated yield), low temperature storage in inert atmosphere. ^{1}H NMR (600 MHz, $CDCl_3$): δ [ppm] = 8.35 (s, 1H), 7.86 (d, J = 15.8 Hz, 1H), 7.42 – 7.31 (m, 7H), 6.44 (d, J = 15.8 Hz, 1H), 5.21 (s, 2H), 2.40 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ [ppm] = 172.1, 166.7, 141.8, 136.9, 136.7, 135.6, 133.5, 130.3, 130.0, 128.5, 128.3, 128.2, 124.8, 120.3, 66.7, 17.4. HRMS (ESI) m/z: calculated for $C_{18}H_{15}ClO_4$, $[M+Na]^+$ 353.0551; found: 353.0547.

(*E*)-6-(3-(benzyloxy)-3-oxoprop-1-enyl)-3-bromo-2-methylbenzoic acid (3k)



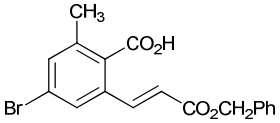
White solid, 25.1 mg, 67% (isolated yield), low temperature storage in inert atmosphere. ^{1}H NMR (600 MHz, $CDCl_3$): δ [ppm] = 7.84 (d, J = 15.8 Hz, 1H), 7.62 (d, J = 8.4 Hz, 1H), 7.41 – 7.30 (m, 6H), 6.47 (d, J = 15.8 Hz, 1H), 5.24 (s, 2H), 2.47 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ [ppm] = 171.0, 166.5, 141.5, 135.7, 135.4, 134.1, 131.0, 128.6, 128.33, 128.26, 127.8, 125.1, 120.9, 66.8, 20.6. HRMS (ESI) m/z: calculated for $C_{18}H_{15}BrO_4$, $[M+Na]^+$ 397.0046, $[M+Na+2]^+$ 399.0031; found: 397.0042, 399.0023.

(*E*)-2-(3-(benzyloxy)-3-oxoprop-1-enyl)-4-fluoro-6-methylbenzoic acid (3l)



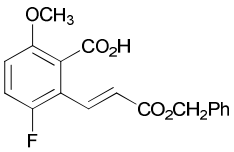
White solid, 17.0 mg, 54% (isolated yield), low temperature storage in inert atmosphere. ^{1}H NMR (400 MHz, $CDCl_3$): δ [ppm] = 8.00 (d, J = 15.8 Hz, 1H), 7.43 – 7.30 (m, 5H), 7.16 (dd, J = 9.3, 2.2 Hz, 1H), 6.98 (dd, J = 9.0, 2.1 Hz, 1H), 6.43 (d, J = 15.8 Hz, 1H), 5.25 (s, 2H), 2.47 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ [ppm] = 171.8, 166.3, 163.1 (d, $J_{C\text{-}F}$ = 249.1 Hz), 141.9, 140.3 (d, $J_{C\text{-}F}$ = 8.6 Hz), 135.8, 135.7, 128.6, 128.3, 128.2, 121.6, 119.1 (d, $J_{C\text{-}F}$ = 21.4 Hz), 111.0 (d, $J_{C\text{-}F}$ = 22.6 Hz), 66.7, 20.5. HRMS (ESI) m/z: calculated for $C_{18}H_{15}FO_4$, $[M+Na]^+$ 337.0847; found: 337.0856.

(*E*)-2-(3-(benzyloxy)-3-oxoprop-1-enyl)-4-bromo-6-methylbenzoic acid (3m)



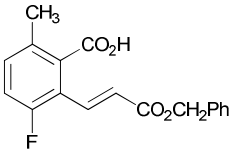
White solid, 23.9 mg, 64% (isolated yield), low temperature storage in inert atmosphere. ^{1}H NMR (600 MHz, $CDCl_3$): δ [ppm] = 7.89 (d, J = 15.8 Hz, 1H), 7.61 (s, 1H), 7.42 (s, 1H), 7.39 – 7.32 (m, 5H), 6.43 (d, J = 15.7 Hz, 1H), 5.24 (s, 2H), 2.42 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ [ppm] = 172.2, 166.3, 141.6, 138.9, 135.7, 134.7, 131.8, 128.6, 128.3, 128.2, 127.3, 124.6, 121.6, 66.8, 20.1. HRMS (ESI) m/z: calculated for $C_{18}H_{15}BrO_4$, $[M+Na]^+$ 397.0046, $[M+Na+2]^+$ 399.0031; found: 397.0053, 399.0034.

(*E*)-2-(3-(benzyloxy)-3-oxoprop-1-enyl)-3-fluoro-6-methoxybenzoic acid (3n)



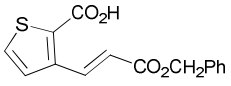
White solid, 23.1 mg, 70% (isolated yield), low temperature storage in inert atmosphere. ^{1}H NMR (600 MHz, D_6-DMSO): δ [ppm] = 7.51 (d, J = 16.2 Hz, 1H), 7.42 – 7.35 (m, 6H), 7.19 (d, J = 7.5 Hz, 1H), 6.59 (d, J = 16.2 Hz, 1H), 5.23 (s, 2H), 3.79 (s, 3H). ^{13}C NMR (100 MHz, D_6-DMSO): δ [ppm] = 167.0, 165.5, 155.9, 153.5, 151.6, 135.9, 135.5, 128.5, 128.2, 123.7 (d, $J_{C\text{-}F}$ = 12.3 Hz), 118.4 (d, $J_{C\text{-}F}$ = 14.6 Hz), 116.9, 116.7, 114.7 (d, $J_{C\text{-}F}$ = 8.8 Hz), 66.0, 56.4. HRMS (ESI) m/z: calculated for $C_{18}H_{15}FO_5$, $[M+Na]^+$ 353.0796; found: 353.0791.

(*E*)-2-(3-(benzyloxy)-3-oxoprop-1-enyl)-3-fluoro-6-methylbenzoic acid (3o)



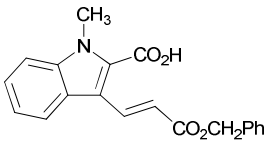
White solid, 22.9 mg, 73% (isolated yield). ^{1}H NMR (600 MHz, $CDCl_3$): δ [ppm] = 7.76 (d, J = 16.2 Hz, 1H), 7.40 (d, J = 7.2 Hz, 2H), 7.37 (t, J = 7.4 Hz, 2H), 7.32 (t, J = 7.1 Hz, 1H), 7.21 (dd, J = 8.4, 4.8 Hz, 1H), 7.10 (t, J = 8.7 Hz, 1H), 6.68 (d, J = 16.2 Hz, 1H), 5.25 (s, 2H), 2.39 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ [ppm] = 171.5, 167.0, 159.4 (d, $J_{C\text{-}F}$ = 251.2 Hz), 136.6 (d, $J_{C\text{-}F}$ = 251.2 Hz), 135.0, 132.8 (d, $J_{C\text{-}F}$ = 9.0 Hz), 131.5 (d, $J_{C\text{-}F}$ = 3.8 Hz), 128.5, 128.20, 128.16, 124.3 (d, $J_{C\text{-}F}$ = 13.2 Hz), 119.9 (d, $J_{C\text{-}F}$ = 12.8 Hz), 117.3 (d, $J_{C\text{-}F}$ = 22.7 Hz), 66.7, 19.2. HRMS (ESI) m/z: calculated for $C_{18}H_{15}FO_4$, $[M+Na]^+$ 337.0847; found: 337.0850.

(*E*)-3-(3-(benzyloxy)-3-oxoprop-1-enyl)thiophene-2-carboxylic acid (3p)



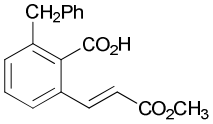
White solid, 19.0 mg, 66% (isolated yield). ^{1}H NMR (600 MHz, $CDCl_3$): δ [ppm] = 8.60 (d, J = 16.1 Hz, 1H), 7.53 (d, J = 5.2 Hz, 1H), 7.43 – 7.32 (m, 6H), 6.45 (d, J = 16.1 Hz, 1H), 5.27 (s, 2H). ^{13}C NMR (150 MHz, $CDCl_3$): δ [ppm] = 166.9, 166.6, 142.7, 137.0, 135.9, 132.1, 131.0, 128.6, 128.21, 128.16, 126.9, 121.9, 66.5. HRMS (ESI) m/z: calculated for $C_{15}H_{12}O_4S$, $[M+Na]^+$ 311.0349; found: 311.0354.

(*E*)-3-(3-(benzyloxy)-3-oxoprop-1-enyl)-1-methyl-1H-indole-2-carboxylic acid (3q)



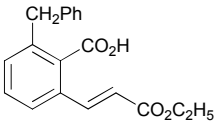
Yellow solid, 23.1 mg, 69% (isolated yield). ^{1}H NMR (600 MHz, $CDCl_3$): δ [ppm] = 8.71 (d, J = 16.2 Hz, 1H), 8.00 (d, J = 8.2 Hz, 1H), 7.49 – 7.37 (m, 6H), 7.34 (t, J = 7.2 Hz, 1H), 7.29 – 7.27 (m, 1H), 6.69 (d, J = 16.2 Hz, 1H), 5.32 (s, 2H), 4.09 (s, 3H). ^{13}C NMR (150 MHz, $CDCl_3$): δ [ppm] = 167.9, 166.1, 139.6, 138.9, 136.2, 128.6, 128.3, 128.2, 127.3, 126.3, 124.5, 122.4, 122.3, 119.1, 118.5, 110.9, 66.4, 32.6. HRMS (ESI) m/z: calculated for $C_{20}H_{17}NO_4$, $[M+Na]^+$ 358.1050; found: 358.1055.

(*E*)-2-benzyl-6-(3-methoxy-3-oxoprop-1-enyl)benzoic acid (3r)



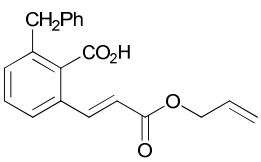
White solid, 22.5 mg, 76% (isolated yield), low temperature storage in inert atmosphere. ^{1}H NMR (600 MHz, $CDCl_3$): δ [ppm] = 7.93 (d, J = 15.8 Hz, 1H), 7.52 (d, J = 7.8 Hz, 1H), 7.37 (t, J = 7.8 Hz, 1H), 7.30 – 7.26 (m, 2H), 7.20 (d, J = 8.0 Hz, 2H), 7.17 (d, J = 7.7 Hz, 2H), 6.43 (d, J = 15.8 Hz, 1H), 4.14 (s, 2H), 3.79 (s, 3H). ^{13}C NMR (150 MHz, $CDCl_3$): δ [ppm] = 173.0, 167.2, 142.3, 139.7, 139.3, 133.7, 132.4, 131.8, 130.0, 129.2, 128.4, 126.3, 124.6, 120.4, 51.9, 39.2. HRMS (ESI) m/z: calculated for $C_{18}H_{16}O_4$, $[M+Na]^+$ 319.0941; found: 319.0940.

(*E*)-2-benzyl-6-(3-ethoxy-3-oxoprop-1-enyl)benzoic acid (3s)



Yellow oil, 23.6 mg, 76% (isolated yield), low temperature storage in inert atmosphere. ^{1}H NMR (600 MHz, $CDCl_3$): δ [ppm] = 7.97 (d, J = 15.8 Hz, 1H), 7.53 (d, J = 7.9 Hz, 1H), 7.36 (t, J = 7.8 Hz, 1H), 7.27 (t, J = 7.5 Hz, 2H), 7.19 (t, J = 7.5 Hz, 4H), 6.44 (d, J = 15.8 Hz, 1H), 4.25 (q, J = 7.1 Hz, 2H), 4.15 (s, 2H), 1.31 (t, J = 7.1 Hz, 3H). ^{13}C NMR (150 MHz, $CDCl_3$): δ [ppm] = 172.4, 166.8, 142.1, 139.6, 139.4, 133.2, 132.7, 131.8, 130.2, 129.2, 128.5, 126.3, 124.7, 121.0, 60.8, 39.2, 14.2. HRMS (ESI) m/z: calculated for $C_{19}H_{18}O_4$, $[M+Na]^+$ 333.1097; found: 333.1102.

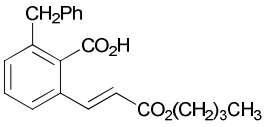
(*E*)-2-(3-(allyloxy)-3-oxoprop-1-enyl)-6-benzylbenzoic acid (3t)



Yellow oil, 25.1 mg, 78% (isolated yield), low temperature storage in inert atmosphere. ^{1}H NMR (600 MHz, $CDCl_3$): δ [ppm] = 7.94 (d, J = 15.8 Hz, 1H), 7.53 (d, J = 7.8 Hz, 1H), 7.37 (t, J = 7.8 Hz, 1H), 7.28 (d, J = 7.6 Hz, 2H), 7.20 (d, J = 7.4 Hz, 2H), 7.17 (d, J = 7.6 Hz, 2H), 6.45 (d, J = 15.8 Hz, 1H), 6.02 –

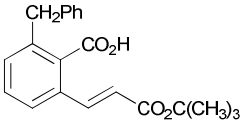
5.91 (m, 1H), 5.36 (d, J = 17.2 Hz, 1H), 5.25 (d, J = 10.4 Hz, 1H), 4.70 (d, J = 5.6 Hz, 2H), 4.14 (s, 2H). ^{13}C NMR (150 MHz, $CDCl_3$): δ [ppm] = 173.1, 166.4, 142.5, 139.7, 139.3, 133.7, 132.4, 132.0, 131.9, 130.1, 129.2, 128.5, 126.3, 124.6, 120.5, 118.3, 65.4, 39.2. HRMS (ESI) m/z: calculated for $C_{20}H_{18}O_4$, $[M+Na]^+$ 345.1097; found: 345.1102.

(*E*)-2-benzyl-6-(3-butoxy-3-oxoprop-1-enyl)benzoic acid (3u)



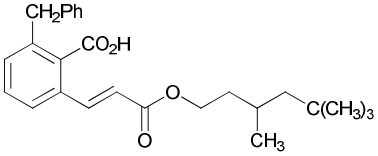
Yellow oil, 28.1 mg, 83% (isolated yield), low temperature storage in inert atmosphere. ^{1}H NMR (600 MHz, $CDCl_3$): δ [ppm] = 7.94 (d, J = 15.8 Hz, 1H), 7.50 (d, J = 7.8 Hz, 1H), 7.32 (t, J = 7.8 Hz, 1H), 7.24 (t, J = 6.4 Hz, 2H), 7.18 – 7.15 (m, 4H), 6.41 (d, J = 15.8 Hz, 1H), 4.17 (t, J = 6.7 Hz, 2H), 4.11 (s, 2H), 1.69 – 1.60 (m, 2H), 1.42 – 1.36 (m, 2H), 0.92 (t, J = 7.4 Hz, 3H). ^{13}C NMR (150 MHz, $CDCl_3$): δ [ppm] = 172.5, 167.0, 142.2, 139.8, 139.3, 133.8, 132.5, 131.8, 130.0, 129.2, 128.5, 126.3, 124.6, 120.9, 64.7, 39.2, 30.7, 19.1, 13.7. HRMS (ESI) m/z: calculated for $C_{21}H_{22}O_4$, $[M+Na]^+$ 361.1410; found: 361.1406.

(*E*)-2-benzyl-6-(3-tert-butoxy-3-oxoprop-1-enyl)benzoic acid (3v)



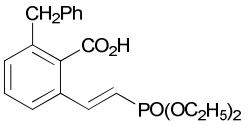
Yellow oil, 24.3 mg, 72% (isolated yield), low temperature storage in inert atmosphere. ^{1}H NMR (600 MHz, $CDCl_3$): δ [ppm] = 7.87 (d, J = 15.8 Hz, 1H), 7.50 (d, J = 7.8 Hz, 1H), 7.31 (t, J = 7.8 Hz, 1H), 7.25 (t, J = 7.4 Hz, 2H), 7.20 – 7.12 (m, 4H), 6.35 (d, J = 15.8 Hz, 1H), 4.11 (s, 2H), 1.49 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$): δ [ppm] = 172.7, 166.2, 141.0, 139.7, 139.2, 133.2, 132.7, 131.6, 130.1, 129.2, 128.4, 126.3, 124.5, 122.8, 81.0, 39.2, 28.1. HRMS (ESI) m/z: calculated for $C_{21}H_{22}O_4$, $[M+Na]^+$ 361.1410; found: 361.1406.

(*E*)-2-benzyl-6-(3-oxo-3-(3,5,5-trimethylhexyloxy)prop-1-enyl)benzoic acid (3w)



Yellow oil, 32.7 mg, 80% (isolated yield), low temperature storage in inert atmosphere. ^{1}H NMR (600 MHz, $CDCl_3$): δ [ppm] = 7.95 (d, J = 15.8 Hz, 1H), 7.50 (d, J = 7.8 Hz, 1H), 7.31 (t, J = 7.8 Hz, 1H), 7.25 (d, J = 8.4 Hz, 2H), 7.19 – 7.14 (m, 4H), 6.41 (d, J = 15.8 Hz, 1H), 4.17 (t, J = 6.8 Hz, 2H), 4.11 (s, 2H), 1.69 – 1.59 (m, 2H), 1.52 – 1.45 (m, 1H), 1.22 (dd, J = 14.0, 3.5 Hz, 1H), 1.07 (dd, J = 14.0, 6.0 Hz, 1H), 0.94 (d, J = 6.5 Hz, 3H), 0.88 (s, 9H). ^{13}C NMR (150 MHz, $CDCl_3$): δ [ppm] = 172.7, 167.0, 142.2, 139.8, 139.2, 134.0, 132.3, 131.8, 129.9, 129.2, 128.4, 126.3, 124.5, 120.7, 63.4, 50.9, 39.2, 37.7, 31.1, 29.9, 26.2, 22.6. HRMS (ESI) m/z: calculated for $C_{26}H_{32}O_4$, $[M+Na]^+$ 431.2193; found: 431.2191.

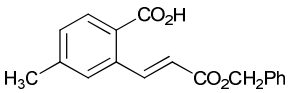
(*E*)-2-benzyl-6-(2-(diethoxyphosphoryl)vinyl)benzoic acid (3x)



White solid, 22.7 mg, 61% (isolated yield), ^{1}H NMR (400 MHz, $CDCl_3$): δ [ppm] = 7.91 (dd, J = 23.1, 17.4 Hz, 1H), 7.46 (d, J = 7.8 Hz, 1H), 7.26 (t, J = 7.7 Hz, 4H), 7.21 – 7.16 (m, 2H), 7.10 (d, J = 7.7 Hz, 1H), 6.21 (t, J = 17.9 Hz, 1H), 4.13 – 4.09 (m, 6H), 1.31 (t, J = 7.1 Hz, 6H). ^{13}C NMR (100 MHz, $CDCl_3$): δ

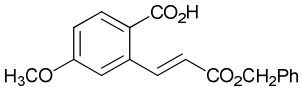
[ppm] = 170.0, 148.3 (d, $J_{C\text{-}P}$ = 8.3 Hz), 140.0, 138.7, 135.4, 132.3 (d, $J_{C\text{-}P}$ = 23.9 Hz), 131.6, 129.24, 129.16, 128.4, 126.2, 123.9, 115.0 (d, $J_{C\text{-}P}$ = 190.1 Hz), 62.4 (d, $J_{C\text{-}P}$ = 5.2 Hz), 38.8, 16.3(d, $J_{C\text{-}P}$ = 6.5 Hz). HRMS (ESI) m/z: calculated for $C_{20}H_{23}O_5P$, $[M+Na]^+$ 397.1181; found: 397.1170.

(*E*)-2-(3-(benzyloxy)-3-oxoprop-1-enyl)-4-methylbenzoic acid (3y)



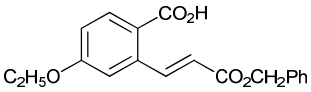
Yellow oil, 8.3 mg, 28% (isolated yield), low temperature storage in inert atmosphere. ^{1}H NMR (600 MHz, CDCl3): δ [ppm] = 8.56 (d, J = 15.9 Hz, 1H), 7.93 (d, J = 7.9 Hz, 1H), 7.38 – 7.31 (m, 3H), 7.29 (t, J = 7.4 Hz, 2H), 7.24 – 7.17 (m, 2H), 6.27 (d, J = 15.9 Hz, 1H), 5.17 (s, 2H), 2.33 (s, 3H). ^{13}C NMR (150 MHz, $CDCl_3$): δ [ppm] = 172.1, 166.4, 144.7, 144.0, 137.2, 136.0, 131.9, 130.3, 128.8, 128.5, 128.1, 125.8, 120.6, 66.3, 21.5. HRMS (ESI) m/z: calculated for $C_{18}H_{16}O_4$, $[M+Na]^+$ 319.0941; found: 319.0935.

(*E*)-2-(3-(benzyloxy)-3-oxoprop-1-enyl)-4-methoxybenzoic acid (3z)



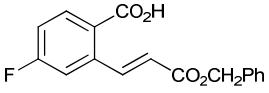
White solid, 8.7 mg, 28% (isolated yield), low temperature storage in inert atmosphere. ^{1}H NMR (600 MHz, CDCl3): δ [ppm] = 8.64 (d, J = 15.8 Hz, 1H), 8.09 (d, J = 8.7 Hz, 1H), 7.43 (d, J = 7.3 Hz, 2H), 7.38 (t, J = 7.5 Hz, 2H), 7.33 (t, J = 7.2 Hz, 1H), 7.06 (d, J = 2.3 Hz, 1H), 6.96 (dd, J = 8.8, 2.4 Hz, 1H), 6.34 (d, J = 15.8 Hz, 1H), 5.27 (s, 2H), 3.89 (s, 3H). ^{13}C NMR (150 MHz, $CDCl_3$): δ [ppm] = 171.6, 166.5, 163.0, 145.1, 139.4, 136.1, 134.0, 128.6, 128.2, 121.6, 120.7, 114.7, 113.2, 66.4, 55.6. HRMS (ESI) m/z: calculated for $C_{18}H_{16}O_5$, $[M+Na]^+$ 335.0890; found: 335.0884.

(*E*)-2-(3-(benzyloxy)-3-oxoprop-1-enyl)-4-ethoxybenzoic acid (3aa)



White solid, 7.8 mg, 24% (isolated yield), low temperature storage in inert atmosphere. ^{1}H NMR (600 MHz, $CDCl^3$): δ [ppm] = 8.65 (d, J = 15.9 Hz, 1H), 8.09 (d, J = 8.7 Hz, 1H), 7.43 (d, J = 7.4 Hz, 2H), 7.39 (t, J = 7.5 Hz, 2H), 7.33 (t, J = 7.2 Hz, 1H), 7.05 (d, J = 2.2 Hz, 1H), 6.95 (dd, J = 8.8, 2.3 Hz, 1H), 6.33 (d, J = 15.8 Hz, 1H), 5.27 (s, 2H), 4.12 (q, J = 6.9 Hz, 2H), 1.45 (t, J = 7.0 Hz, 3H).
. ^{13}C NMR (150 MHz, $CDCl_3$): δ [ppm] = 171.6, 166.5, 162.4, 145.1, 139.4, 136.1, 134.0, 128.5, 128.1, 121.2, 120.6, 115.1, 113.7, 66.3, 63.9, 14.6. HRMS (ESI) m/z: calculated for $C_{19}H_{18}O_5$, $[M+Na]^+$ 349.1046; found: 349.1031.

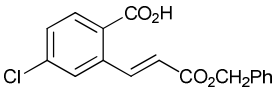
(*E*)-2-(3-(benzyloxy)-3-oxoprop-1-enyl)-4-fluorobenzoic acid (3ab)



White solid, 7.8 mg, 26% (isolated yield). ^{1}H NMR (600 MHz, D_6-DMSO): δ [ppm] = 8.47 (d, J = 16.0 Hz, 1H), 7.96 (dd, J = 8.2, 6.4 Hz, 1H), 7.74 (d, J = 9.8 Hz, 1H), 7.43 (d, J = 7.5 Hz, 2H), 7.39 (t, J = 7.4 Hz, 2H), 7.35 (d, J = 7.5 Hz, 2H), 6.68 (d, J = 16.0 Hz, 1H), 5.24 (s, 2H). ^{13}C NMR (150 MHz, D_6-DMSO): δ [ppm] = 167.3, 165.7, 164.5, 162.9, 142.4, 137.6 (d, $J_{C\text{-}F}$ = 8.5 Hz), 136.1, 133.3 (d, $J_{C\text{-}F}$ = 9.3 Hz), 128.5,

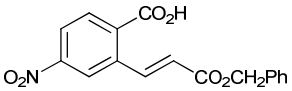
128.1, 121.2, 116.8, 116.7, 114.4 (d, J_{C-F} = 23.1 Hz), 65.7. HRMS (ESI) m/z: calculated for $C_{17}H_{13}FO_4$, $[M+Na]^+$ 323.0690; found: 323.0690.

(*E*)-2-(3-(benzyloxy)-3-oxoprop-1-enyl)-4-chlorobenzoic acid (3ac)



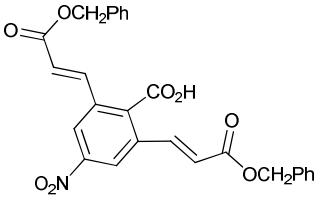
White solid, 6.6 mg, 21% (isolated yield), low temperature storage in inert atmosphere. ^{1}H NMR (400 MHz, CDCl3): δ [ppm] = 10.30 (s, 1H), 8.55 (d, J = 15.9 Hz, 1H), 8.01 (d, J = 8.4 Hz, 1H), 7.55 (s, 1H), 7.40 – 7.30 (m, 6H), 6.34 (d, J = 15.9 Hz, 1H), 5.24 (s, 2H). ^{13}C NMR (100 MHz, $CDCl_3$): δ [ppm] = 170.9, 166.2, 143.2, 139.3, 138.6, 135.8, 133.0, 129.5, 128.5, 128.2, 128.1, 128.0, 127.5, 121.7, 66.6. HRMS (ESI) m/z: calculated for $C_{17}H_{13}ClO_4$, $[M+Na]^+$ 339.0395; found: 339.0396.

(*E*)-2-(3-(benzyloxy)-3-oxoprop-1-enyl)-4-nitrobenzoic acid (3ad)



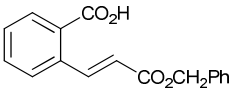
White solid, 8.2 mg, 25% (isolated yield), low temperature storage in inert atmosphere. ^{1}H NMR (600 MHz, $CDCl_3$): δ [ppm] = 8.50 (d, J = 15.9 Hz, 1H), 8.38 (s, 1H), 8.18 (d, J = 8.5 Hz, 1H), 8.12 (d, J = 8.5 Hz, 1H), 7.37 – 7.30 (m, 5H), 6.48 (d, J = 15.9 Hz, 1H), 5.21 (s, 2H). ^{13}C NMR (100 MHz, $CDCl_3$): δ [ppm] = 169.1, 166.2, 149.9, 142.1, 137.9, 135.4, 132.6, 128.7, 128.4, 128.2, 123.8, 122.9, 122.6, 66.9. HRMS (ESI) m/z: calculated for $C_{17}H_{13}NO_6$, $[M+Na]^+$ 350.0635; found: 350.0631.

2,6-bis((*E*)-3-(benzyloxy)-3-oxoprop-1-enyl)-4-nitrobenzoic acid (3ad')



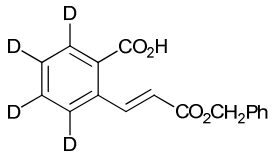
White solid, 8.3 mg, 17% (isolated yield), low temperature storage in inert atmosphere. ^{1}H NMR (400 MHz, CDCl3): δ [ppm] = 8.70 (s, 2H), 7.66 (d, J = 15.8 Hz, 2H), 7.46 – 7.35 (m, 10H), 7.01 (d, J = 15.8 Hz, 2H), 5.25 (s, 4H). ^{13}C NMR (100 MHz, $CDCl_3$): δ [ppm] = 168.7, 165.8, 148.9, 141.6, 139.1, 136.4, 133.1, 129.0, 128.7, 128.6, 124.3, 123.3, 66.6. HRMS (ESI) m/z: calculated for $C_{27}H_{21}NO_8$, $[M+Na]^+$ 510.1159; found: 510.1153.

(*E*)-2-(3-(benzyloxy)-3-oxoprop-1-enyl)benzoic acid (3ae)



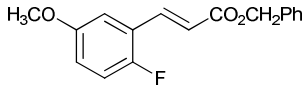
White solid, 6.8 mg, 24% (isolated yield). ^{1}H NMR (600 MHz, $CDCl_3$): δ [ppm] = 8.62 (d, J = 15.9 Hz, 1H), 8.11 (d, J = 7.8 Hz, 1H), 7.63 (d, J = 7.7 Hz, 1H), 7.59 (t, J = 7.5 Hz, 1H), 7.49 (t, J = 7.5 Hz, 1H), 7.43 (d, J = 7.5 Hz, 2H), 7.38 (t, J = 7.5 Hz, 2H), 7.32 (t, J = 7.2 Hz, 1H), 6.38 (d, J = 15.9 Hz, 1H), 5.27 (s, 2H). ^{13}C NMR (150 MHz, $CDCl_3$): δ [ppm] = 171.9, 166.4, 144.4, 137.1, 136.0, 133.2, 131.7, 129.5, 128.6, 128.5, 128.1, 120.9, 66.4. HRMS (ESI) m/z: calculated for $C_{17}H_{14}O_4$, $[M+Na]^+$ 305.0784; found: 305.0782.

***D*$_4$-3ae**



12.6 mg, 22% (isolated yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ [ppm] = 8.64 (d, J = 15.9 Hz, 1H), 7.44 (d, J = 7.3 Hz, 2H), 7.39 (t, J = 7.2 Hz, 2H), 7.36 – 7.30 (m, 1H), 6.39 (d, J = 15.9 Hz, 1H), 5.28 (s, 2H). ^{13}C NMR (101 MHz, $CDCl_3$): δ [ppm] = 171.9, 166.4, 144.3, 137.1, 136.0, 133.0 – 132.9 (m), 131.6 – 131.1 (m), 129.3 – 128.8 (m), 128.54, 128.47, 128.14, 128.11, 121.0, 66.4. HRMS (ESI) m/z: calculated for $C_{17}H_{10}D_4O_4$, $[M+Na]^+$ 309.1035; found: 309.1021.

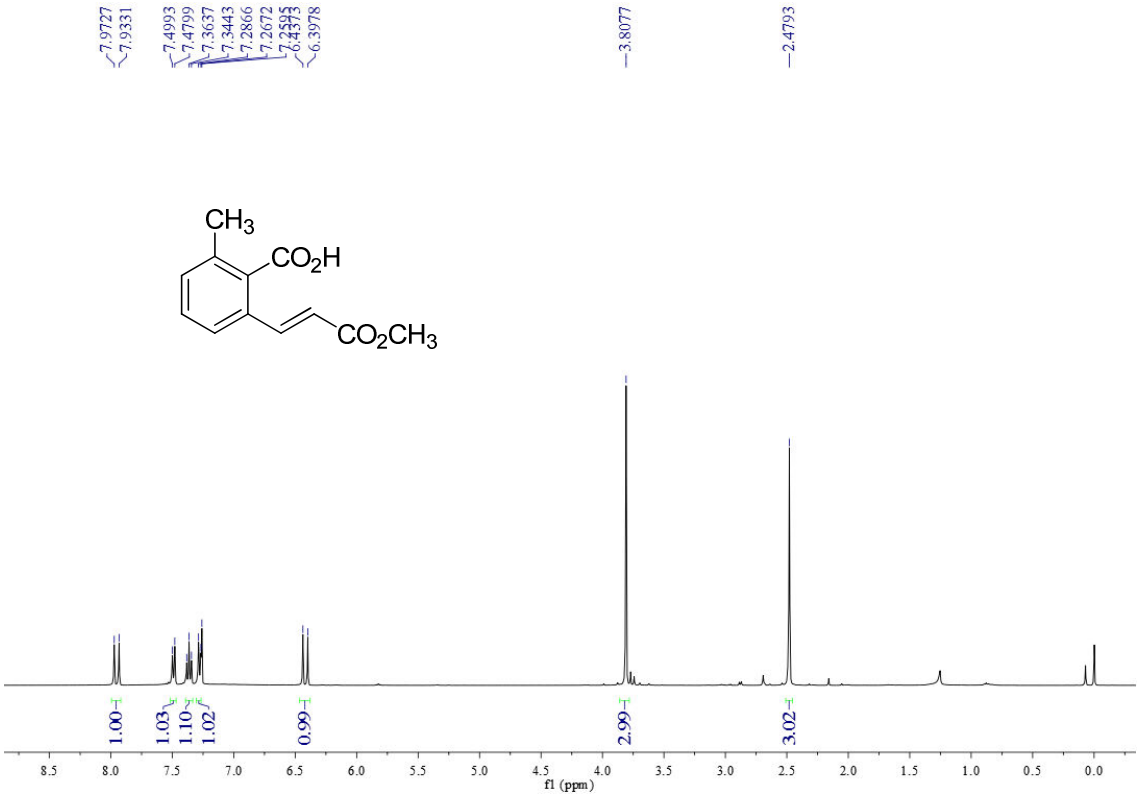
(*E*)-benzyl 3-(2-fluoro-5-methoxyphenyl)acrylate (3af)



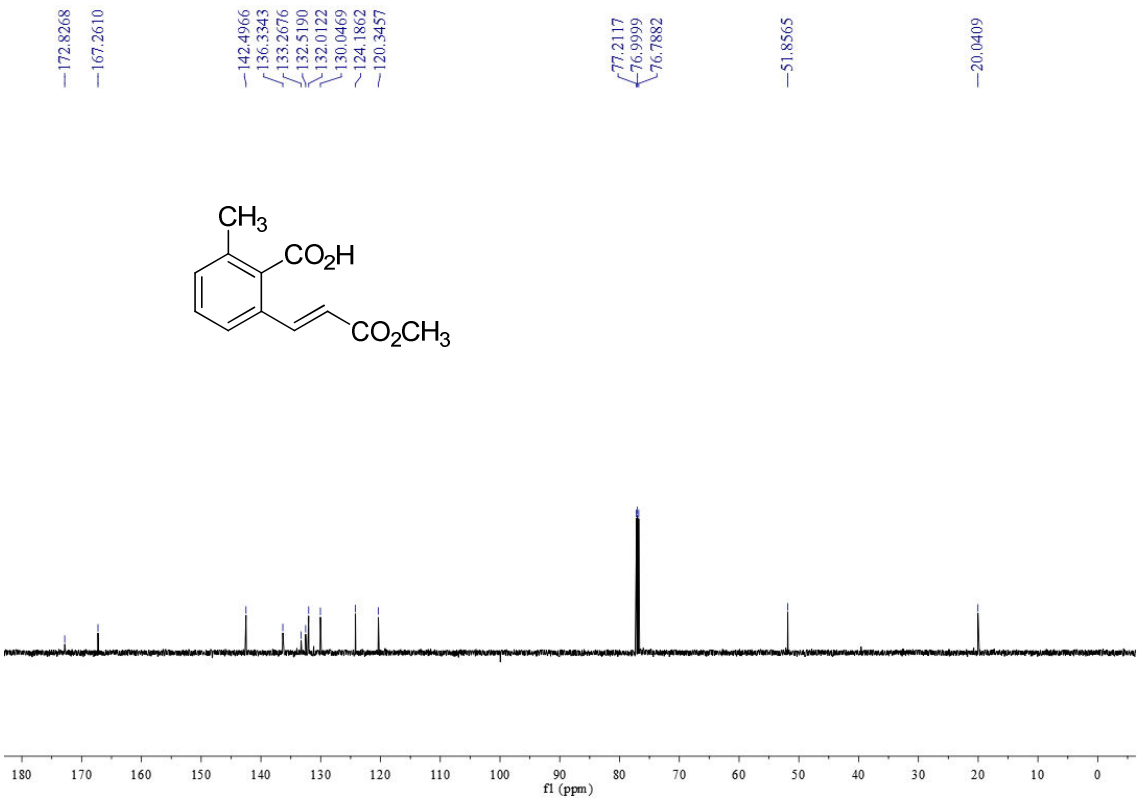
Colorless oil, 20.0 mg, 70% (isolated yield). ^{1}H NMR (600 MHz, $CDCl_3$): δ [ppm] = 7.83 (d, J = 16.2 Hz, 1H), 7.46 – 7.33 (m, 5H), 7.05 – 6.97 (m, 2H), 6.91 – 6.85 (m, 1H), 6.57 (d, J = 16.2 Hz, 1H), 5.26 (s, 2H), 3.79 (s, 3H). ^{13}C NMR (150 MHz, $CDCl_3$): δ [ppm] = 166.5, 156.7, 155.7, 155.1, 137.8, 135.9, 128.6, 128.3, 122.6 (d, $J_{C\text{-}F}$ = 13.5 Hz), 120.5 (d, $J_{C\text{-}F}$ = 6.4 Hz), 117.5 (d, $J_{C\text{-}F}$ = 8.4 Hz), 116.8 (d, $J_{C\text{-}F}$ = 24.0 Hz), 112.6, 66.5, 55.8. HRMS (ESI) m/z: calculated for $C_{17}H_{15}FO_3$, $[M+Na]^+$ 309.0897; found: 309.0893.

4. 化合物核磁共振谱图

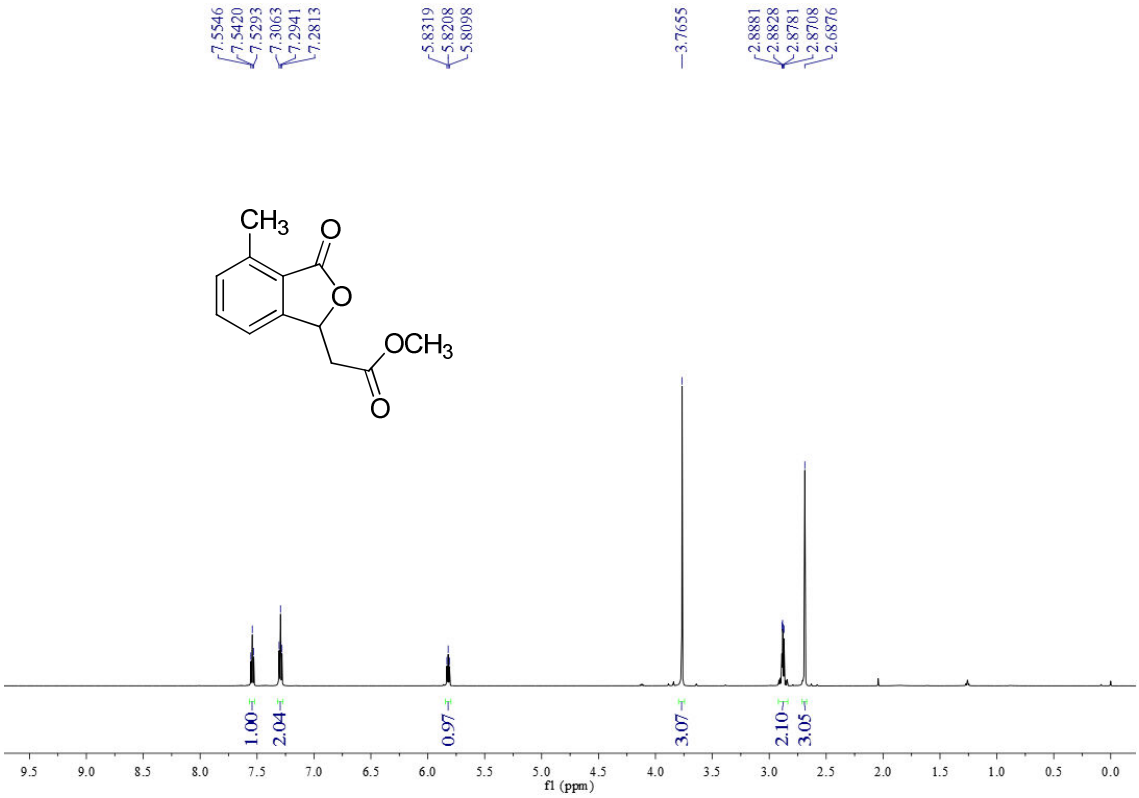
^{1}H NMR spectra of compound of 3a



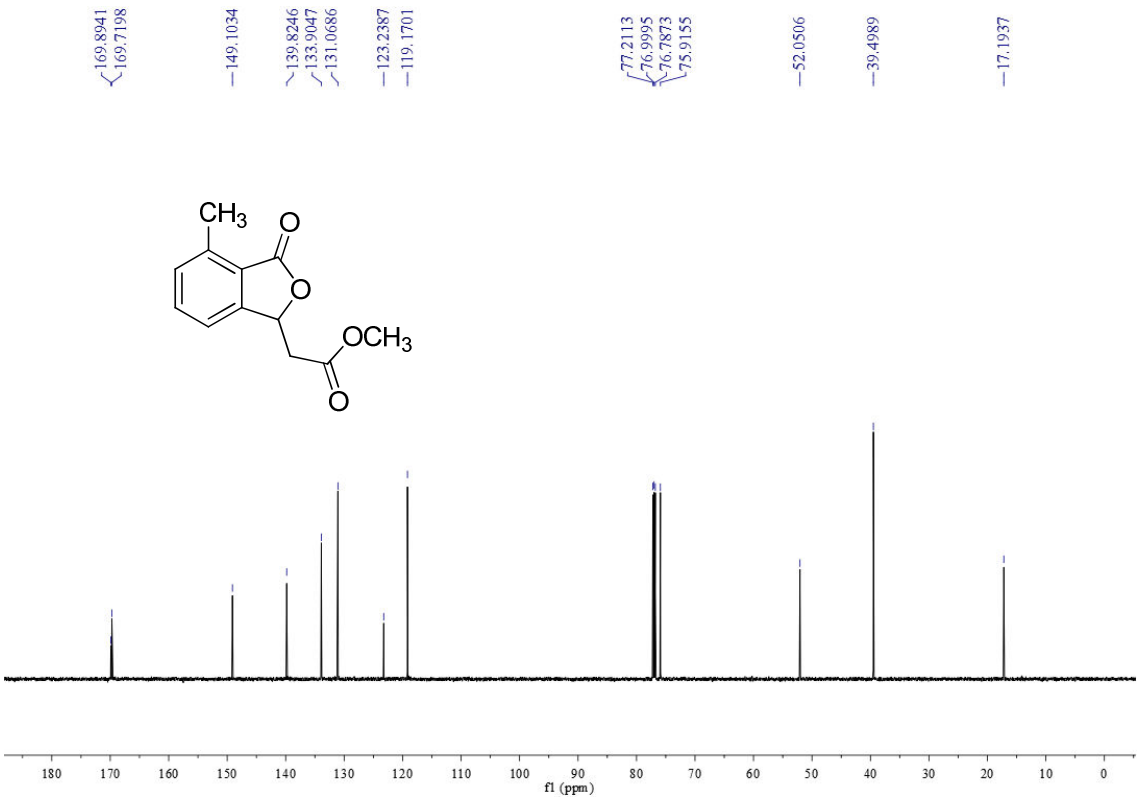
^{13}C NMR spectra of compound of 3a



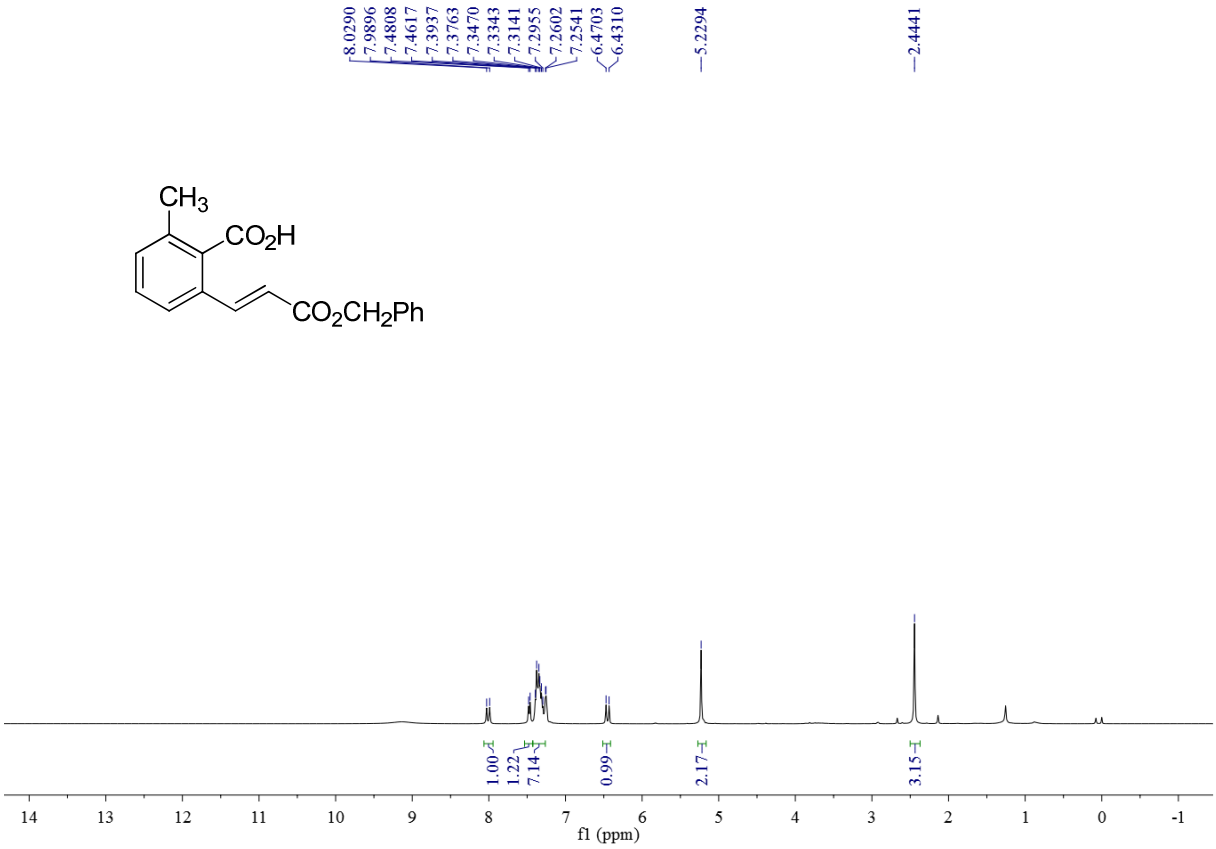
^{1}H NMR spectra of compound 3a'



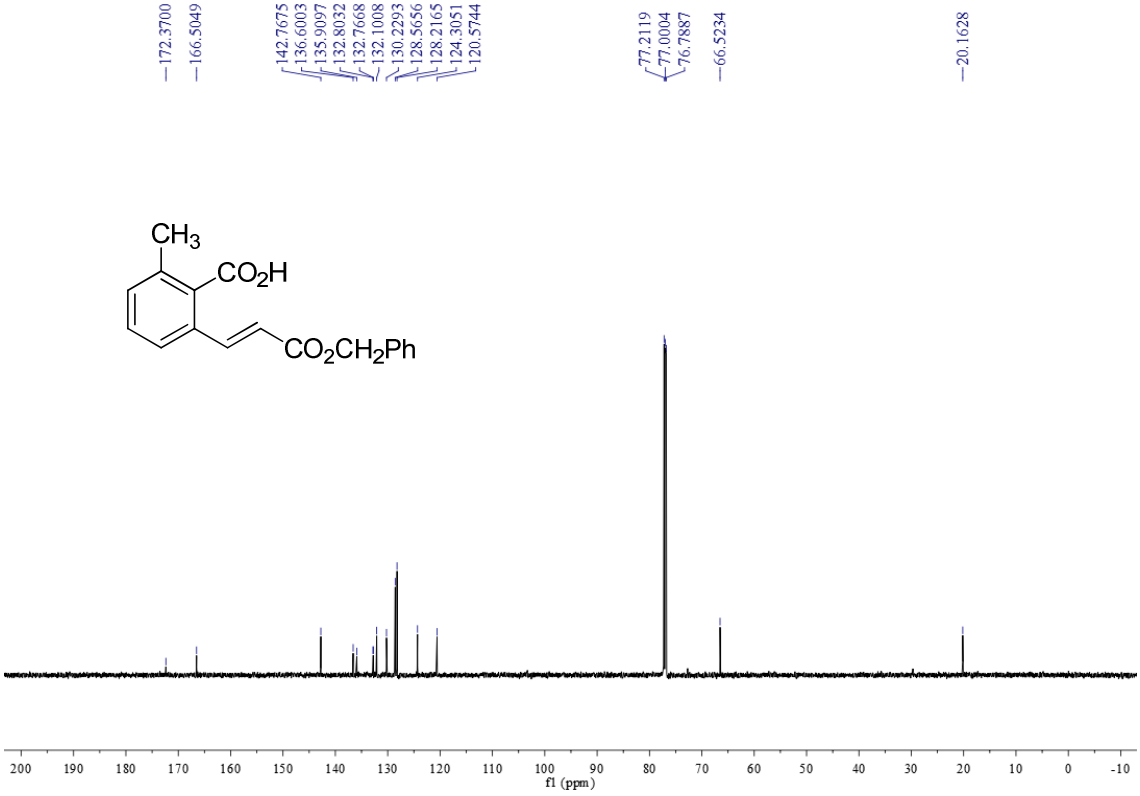
^{13}C NMR spectra of compound 3a'



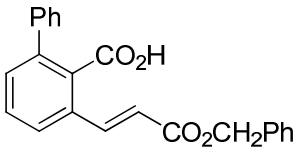
[1]H NMR spectra of compound of 3b

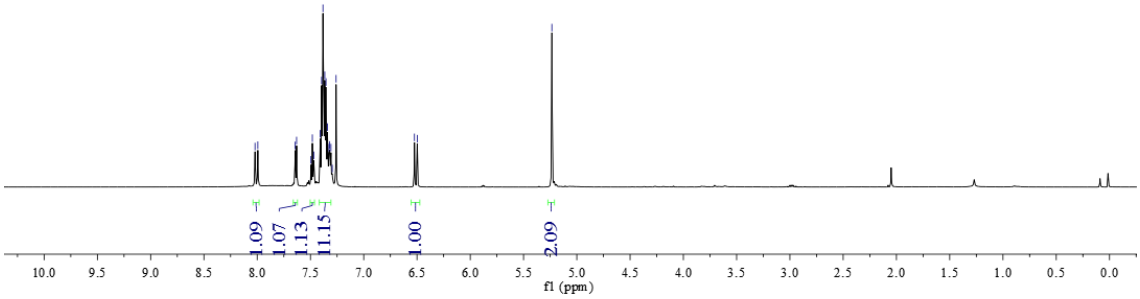


[13]C NMR spectra of compound of 3b

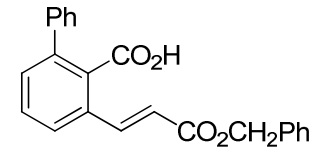


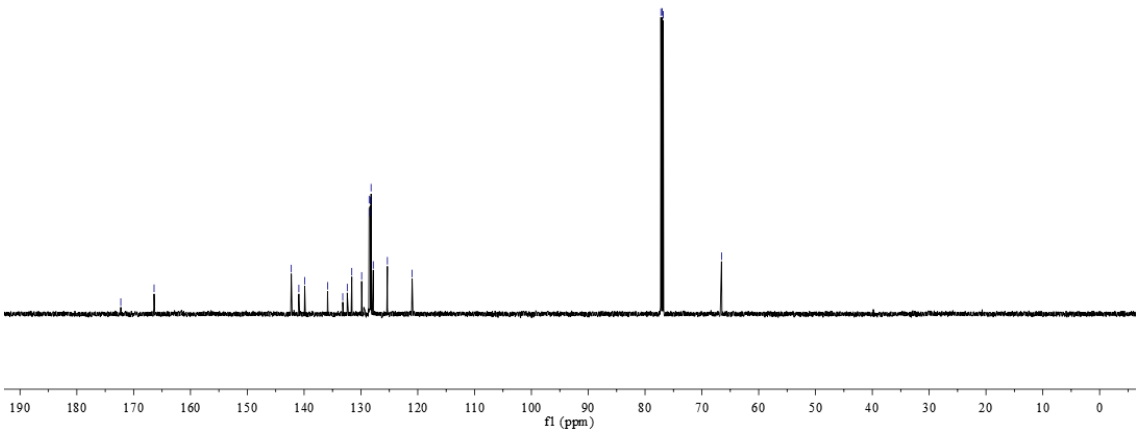
^{1}H NMR spectra of compound of 3c



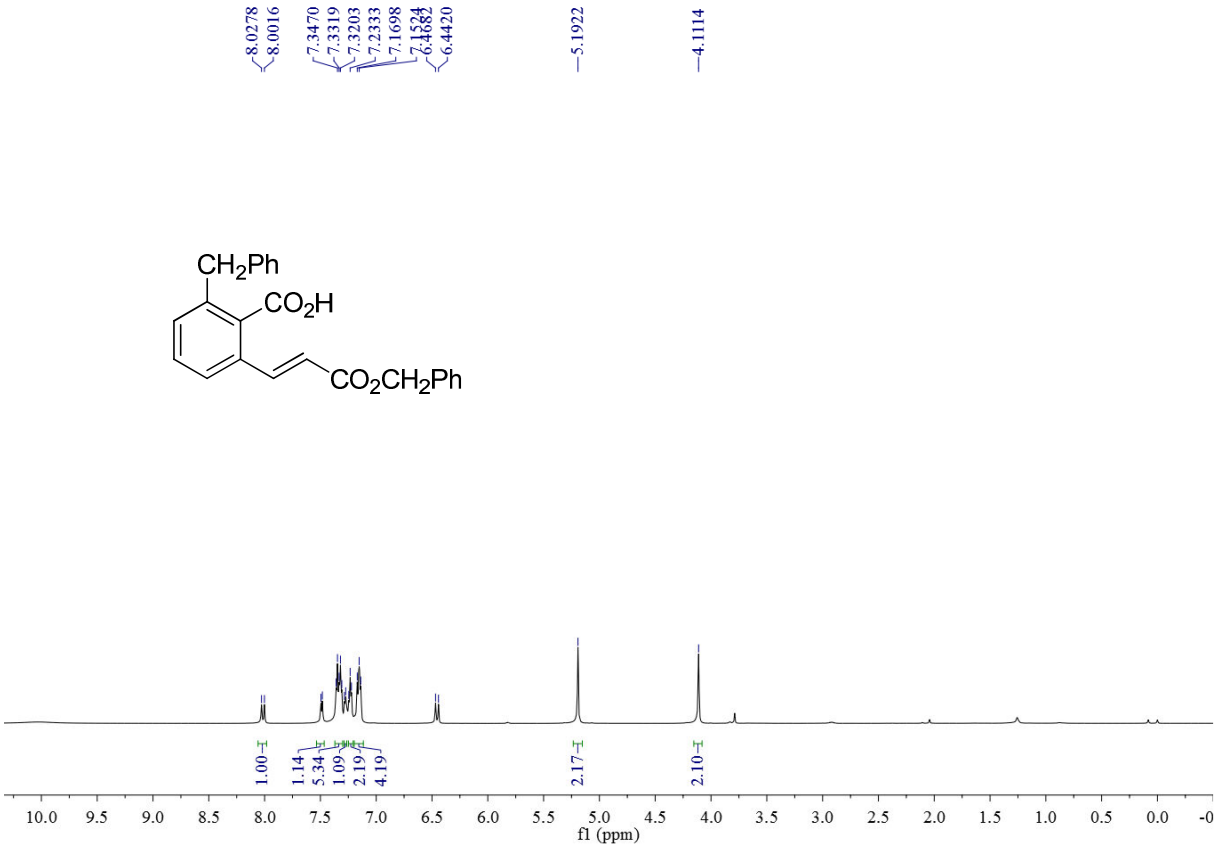


^{13}C NMR spectra of compound of 3c

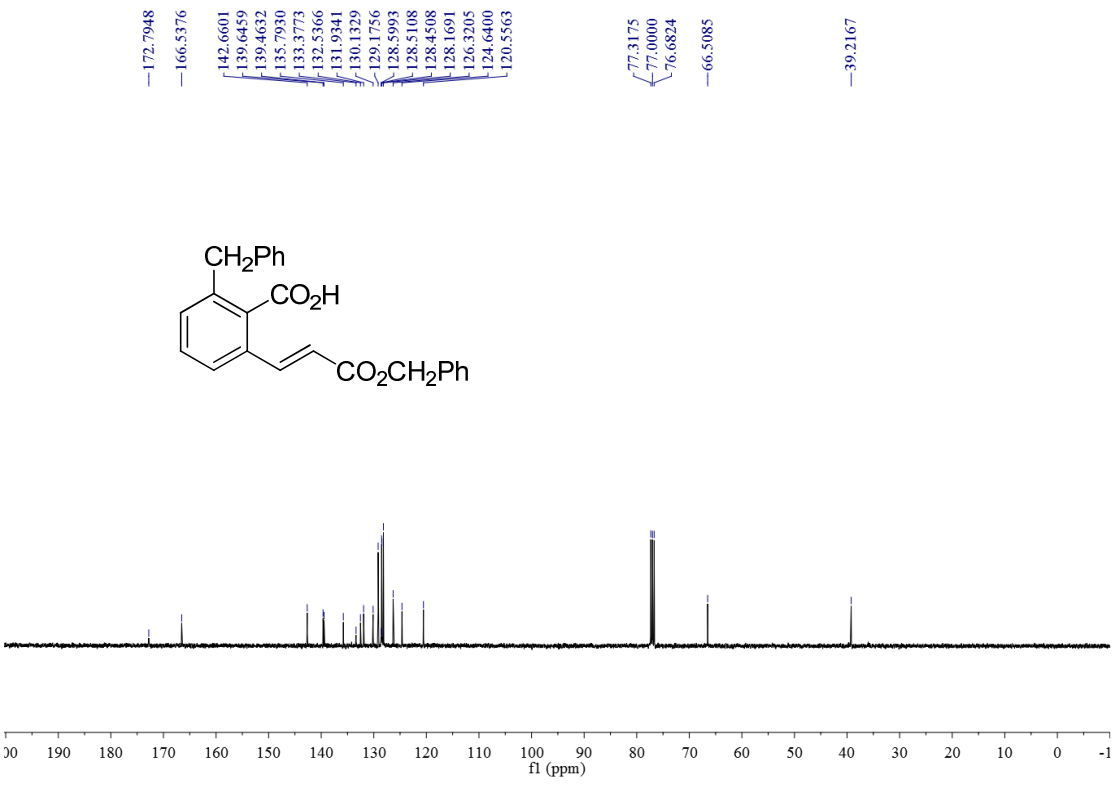




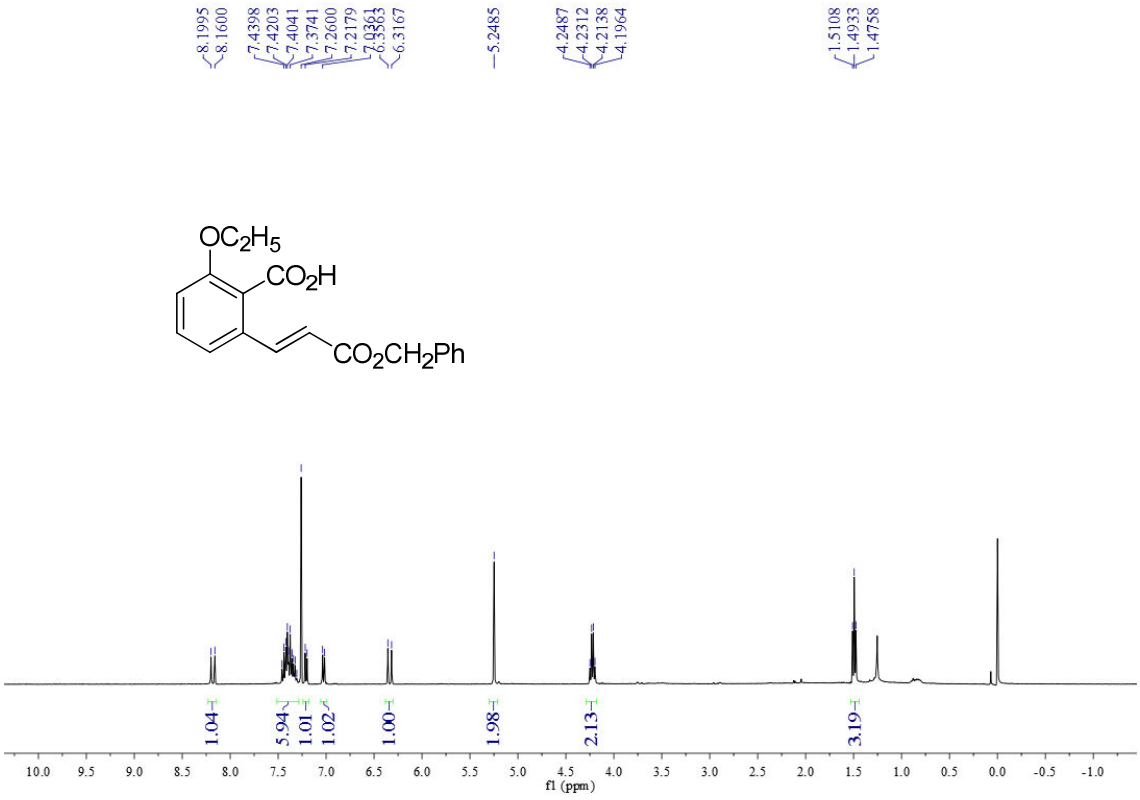
^{1}H NMR spectra of compound of 3d



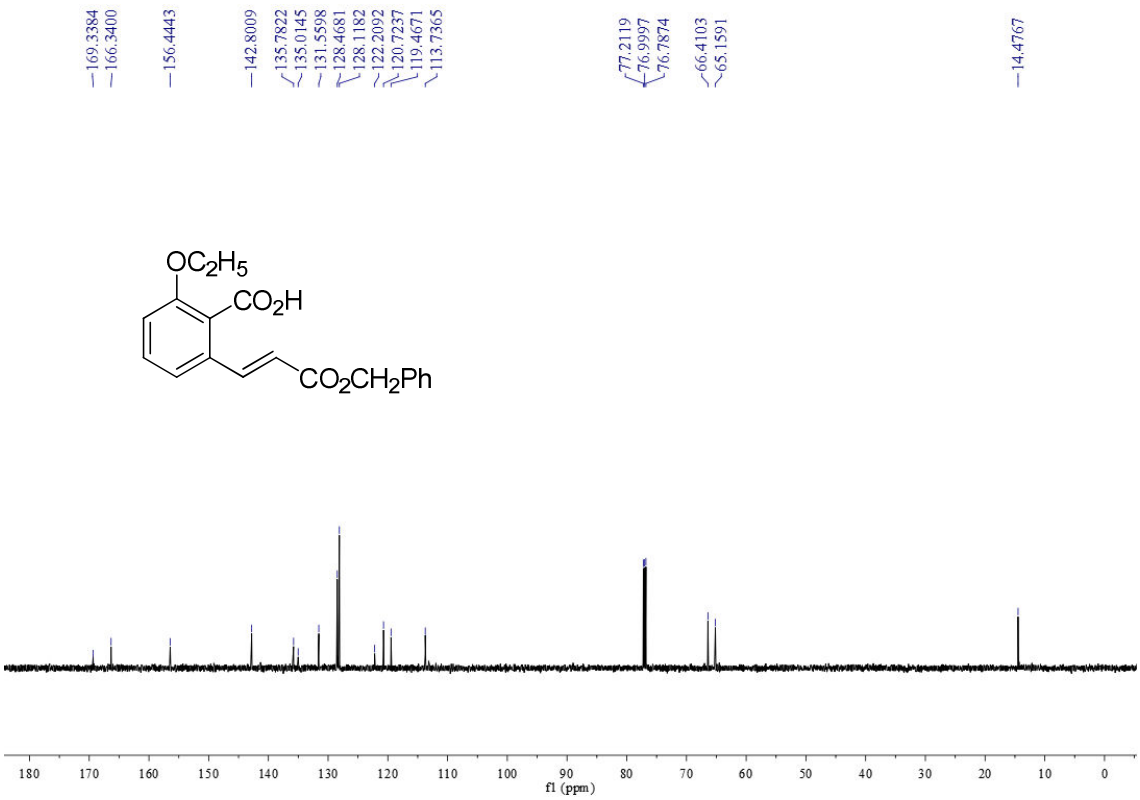
^{13}C NMR spectra of compound of 3d



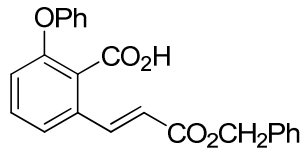
^{1}H NMR spectra of compound of 3e

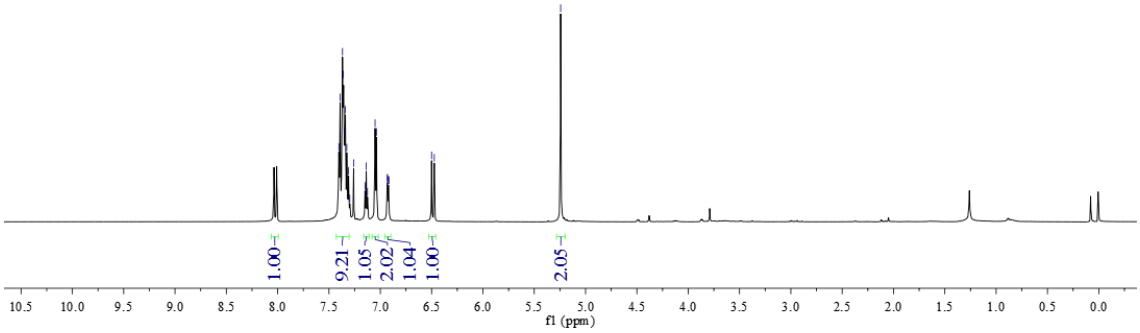


^{13}C NMR spectra of compound of 3e

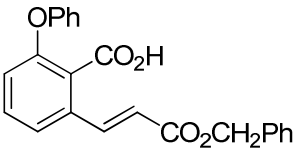


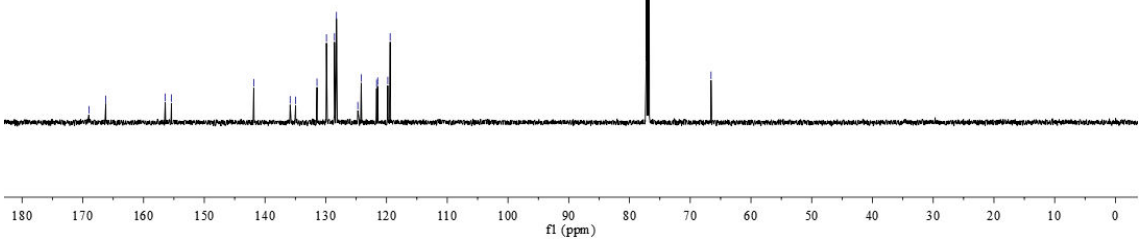
^{1}H NMR spectra of compound of 3f



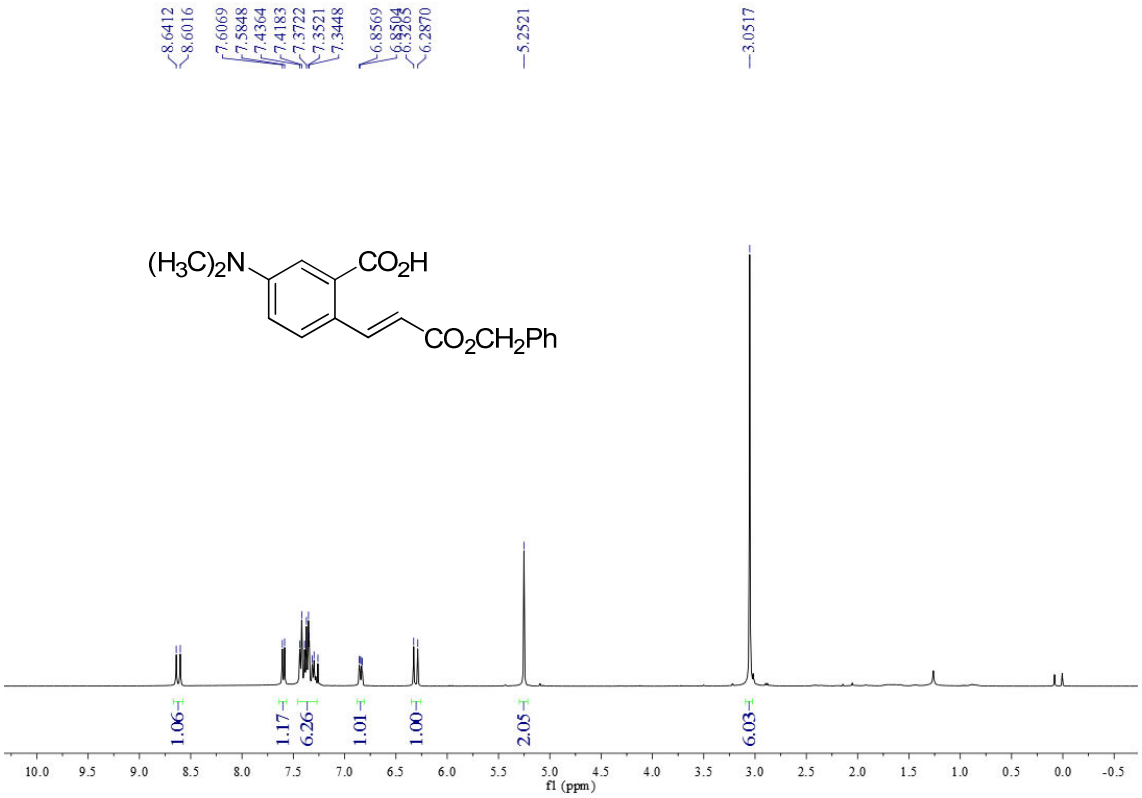


^{13}C NMR spectra of compound of 3f

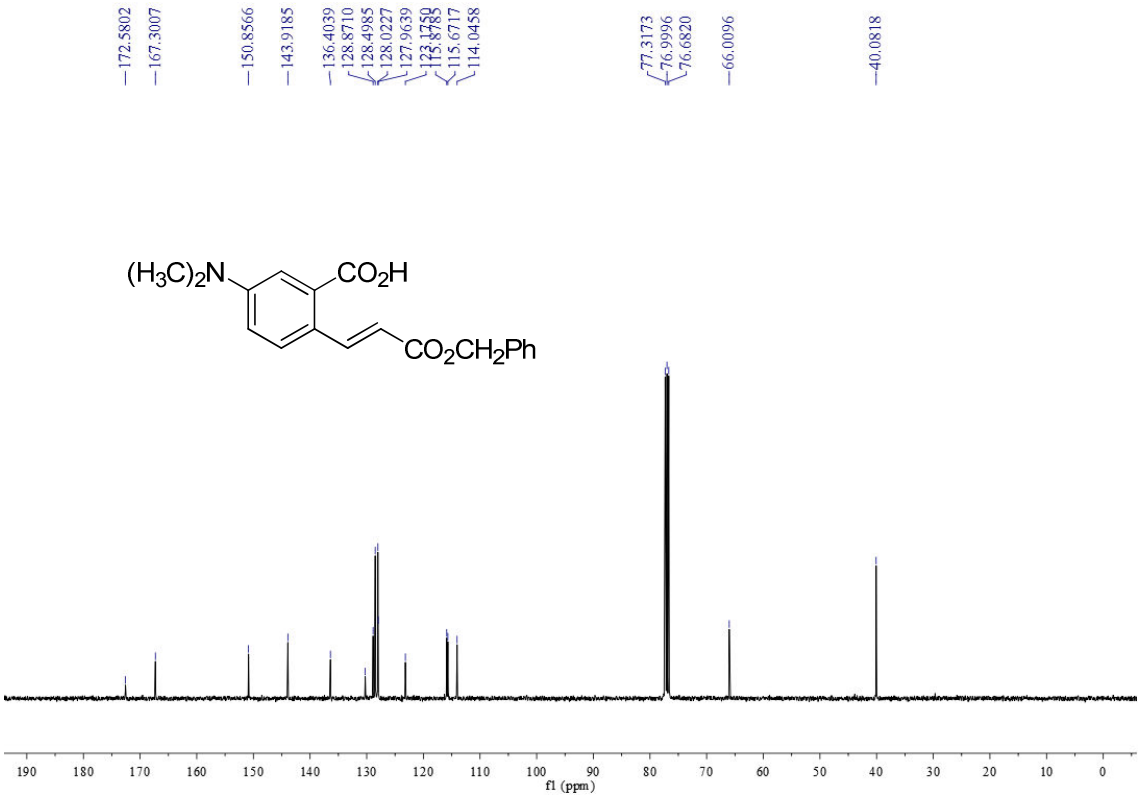




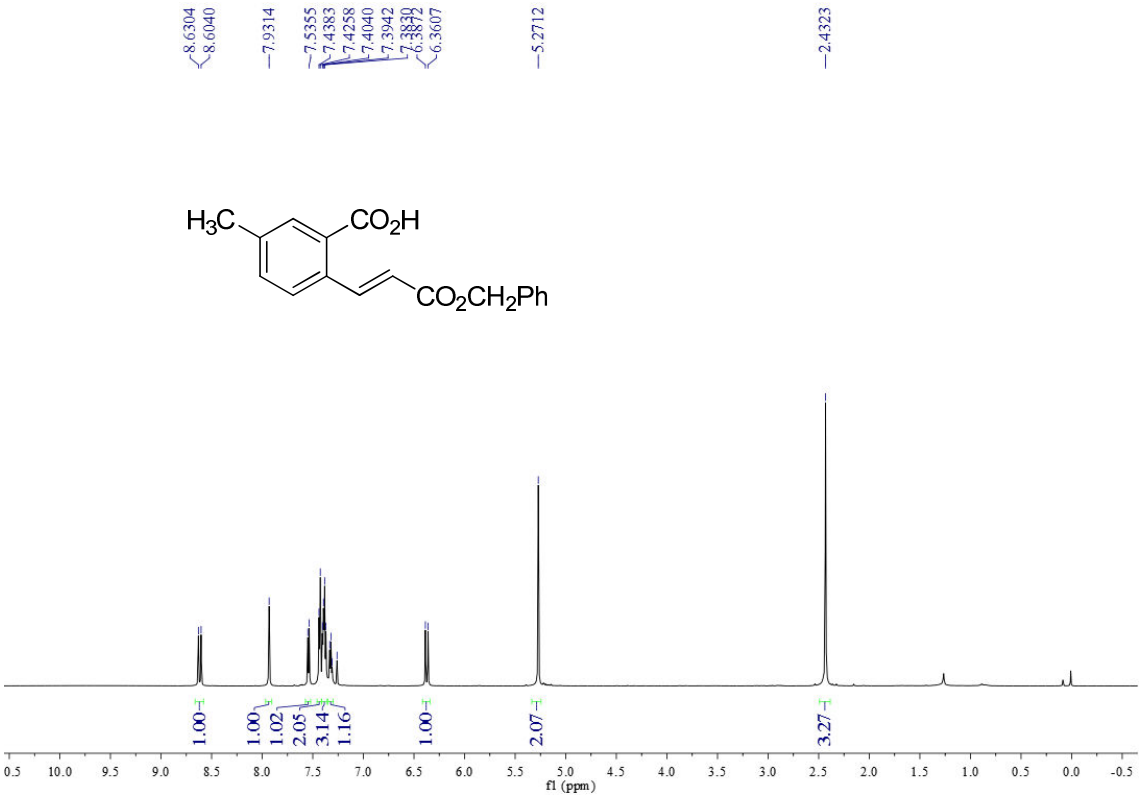
^{1}H NMR spectra of compound of 3g



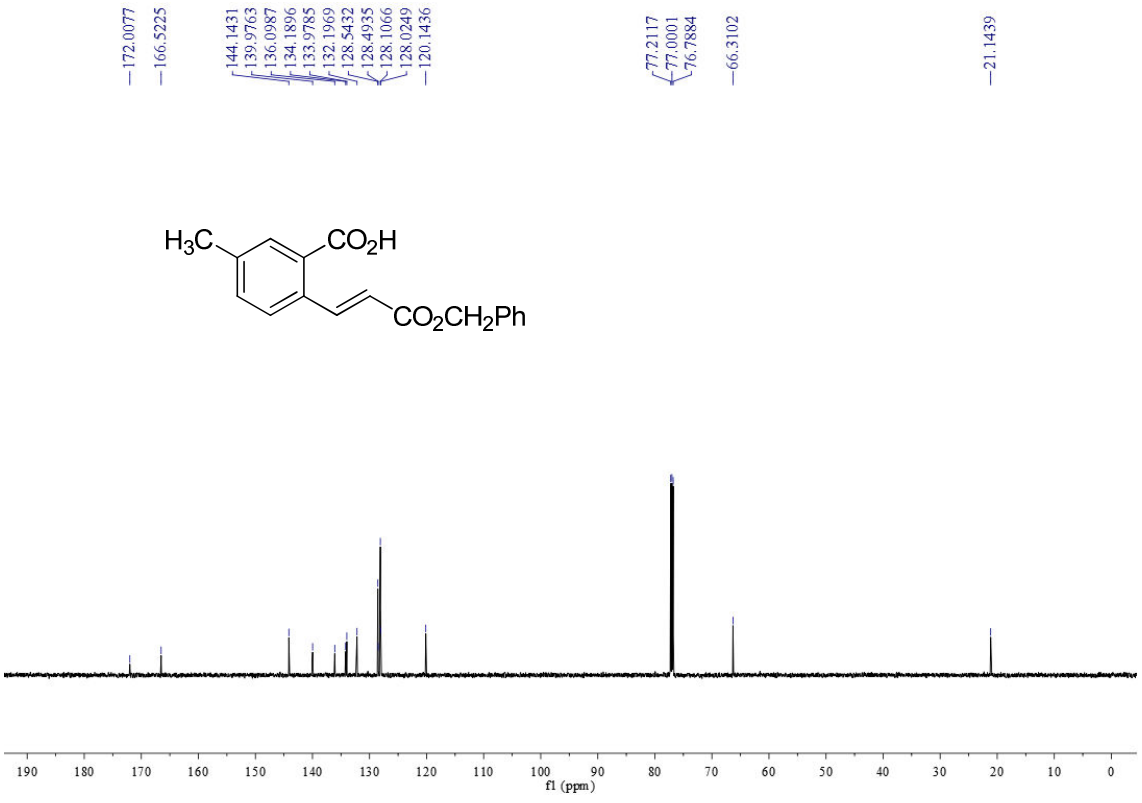
^{13}C NMR spectra of compound of 3g



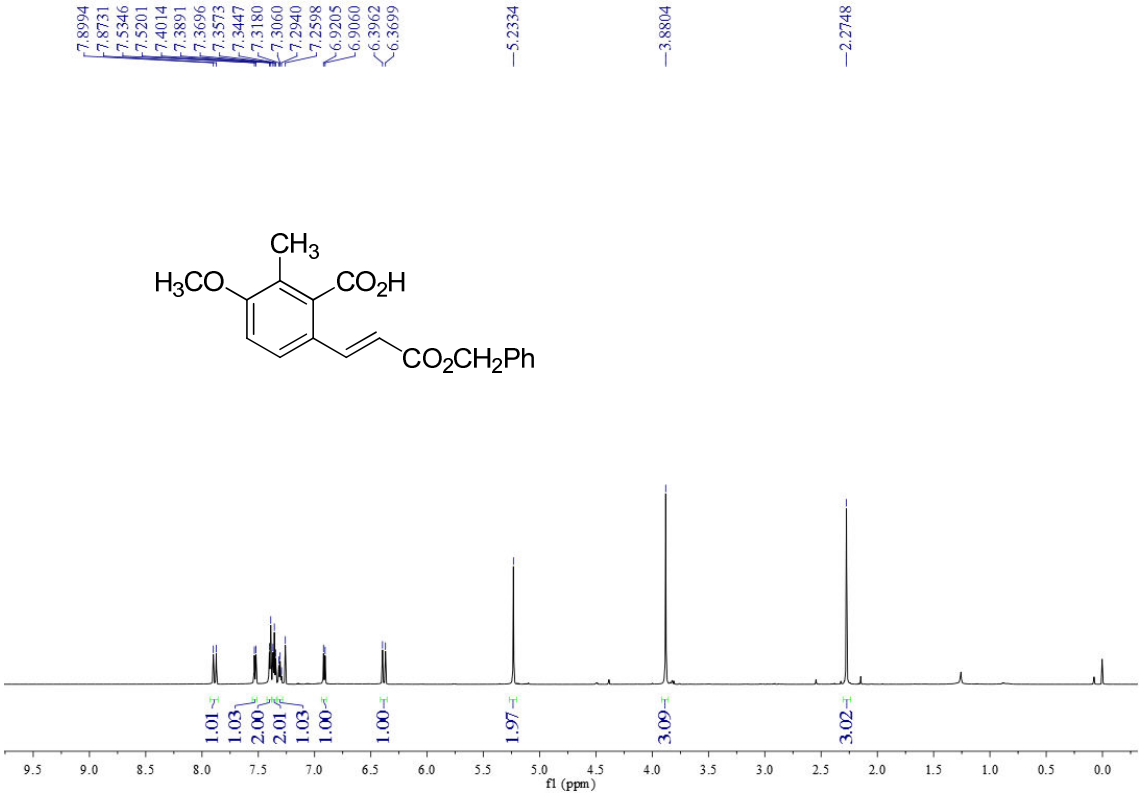
^{1}H NMR spectra of compound of 3h



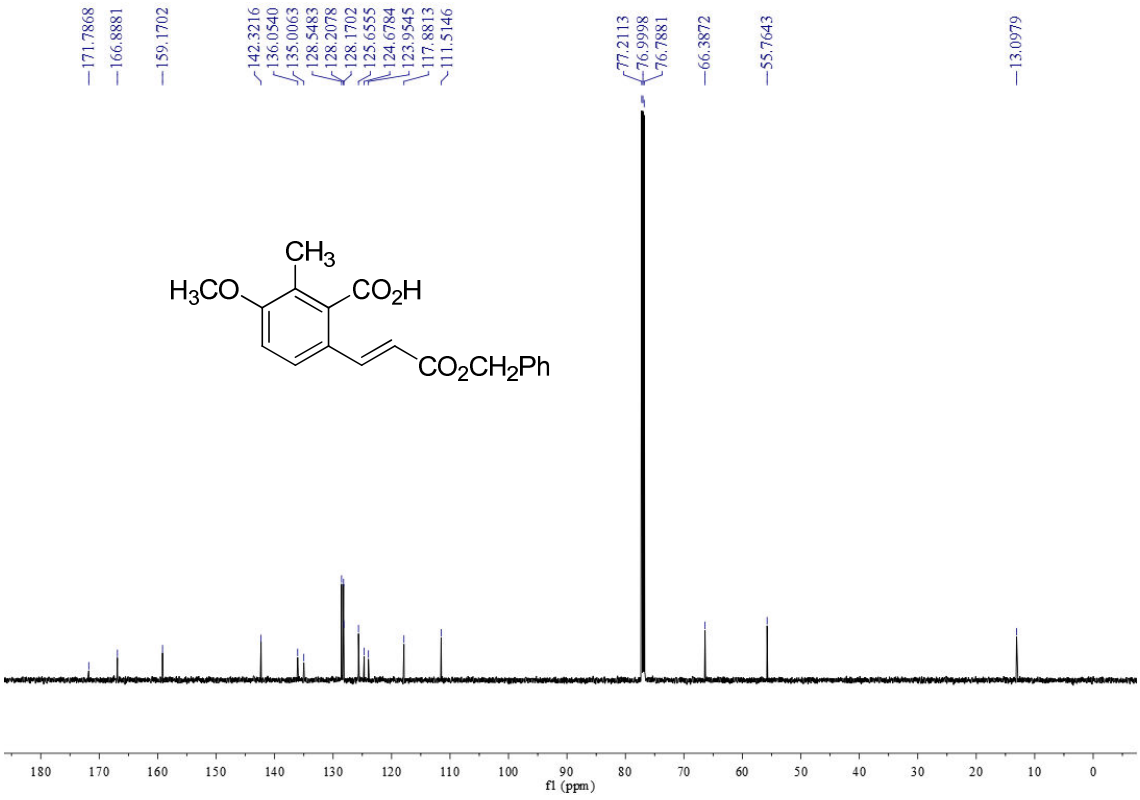
^{13}C NMR spectra of compound of 3h



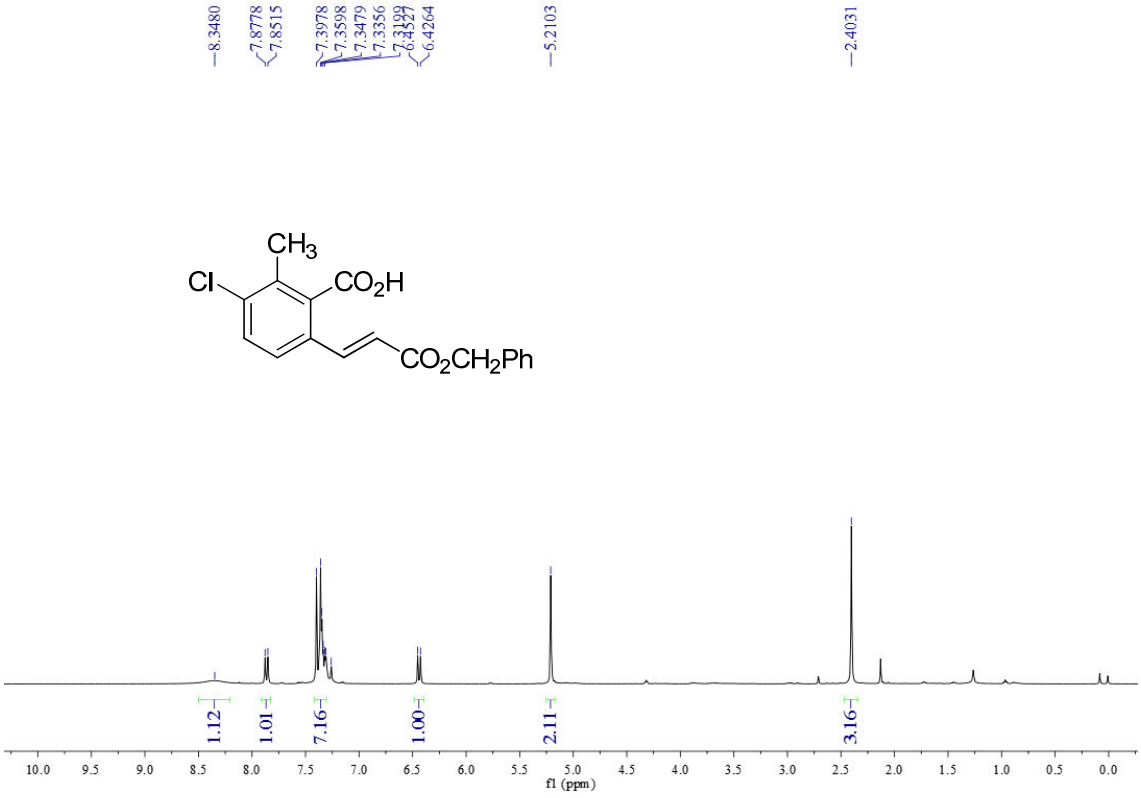
^{1}H NMR spectra of compound of 3i



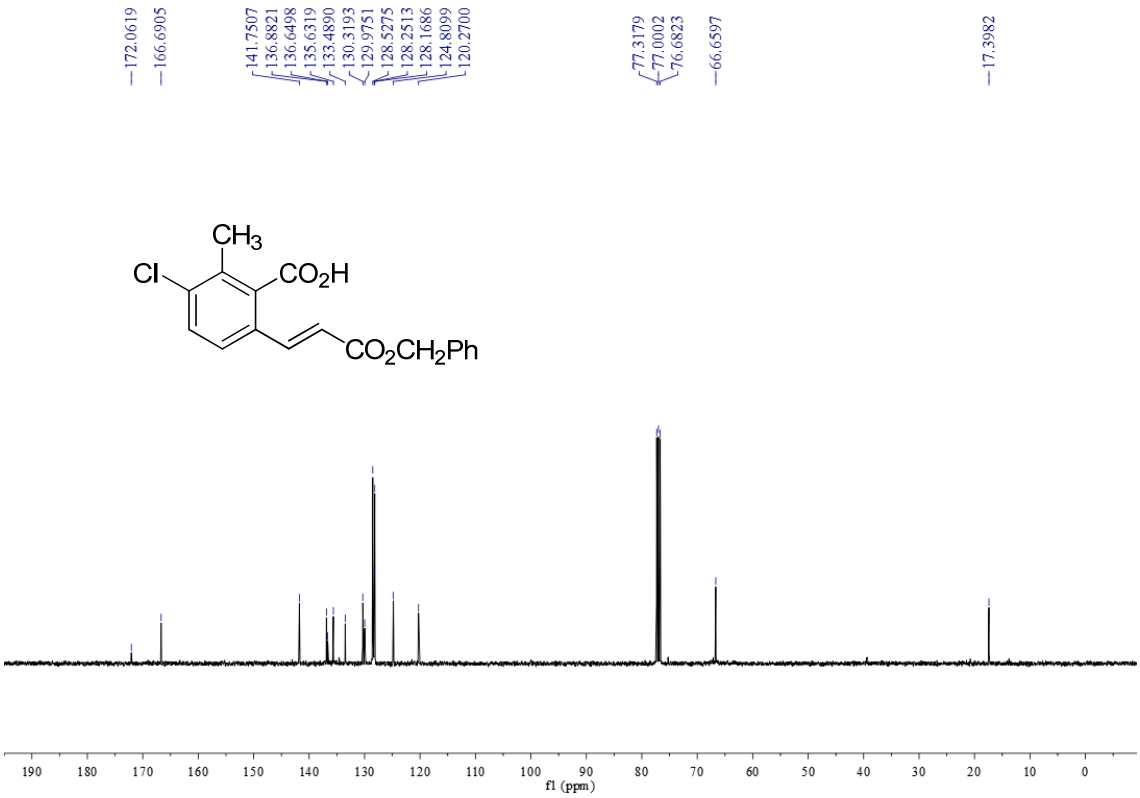
^{13}C NMR spectra of compound of 3i



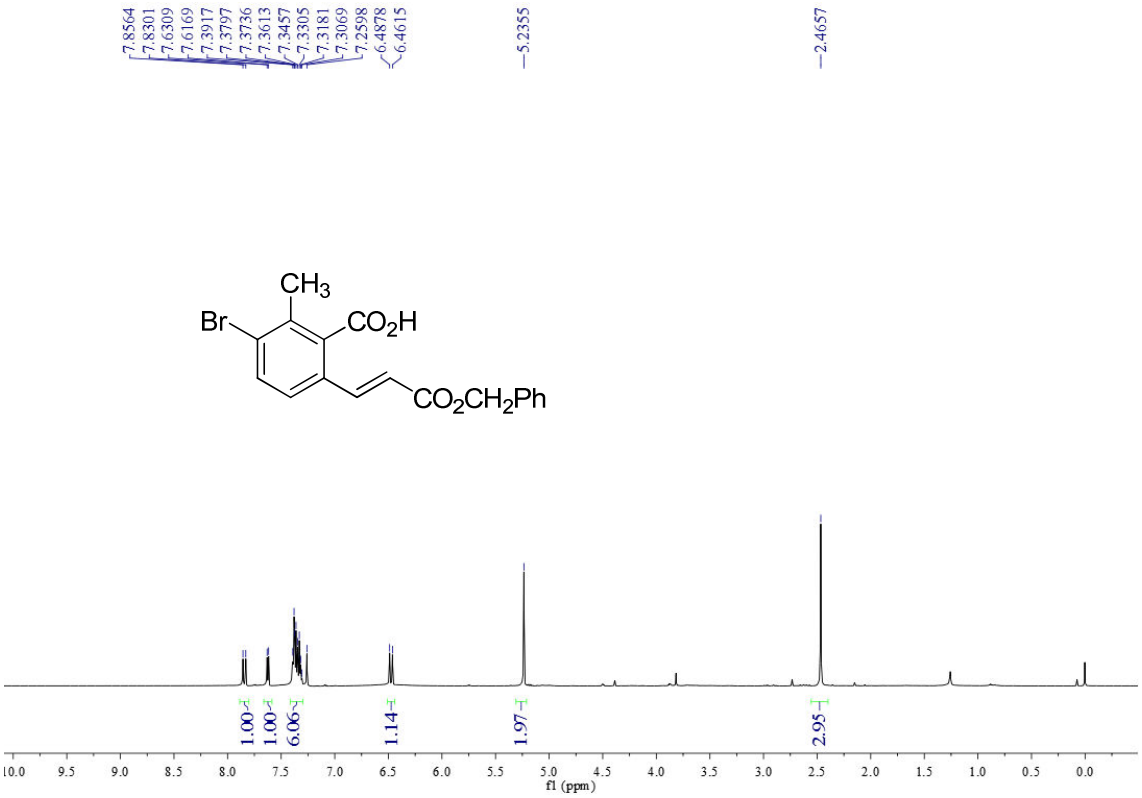
^{1}H NMR spectra of compound of 3j



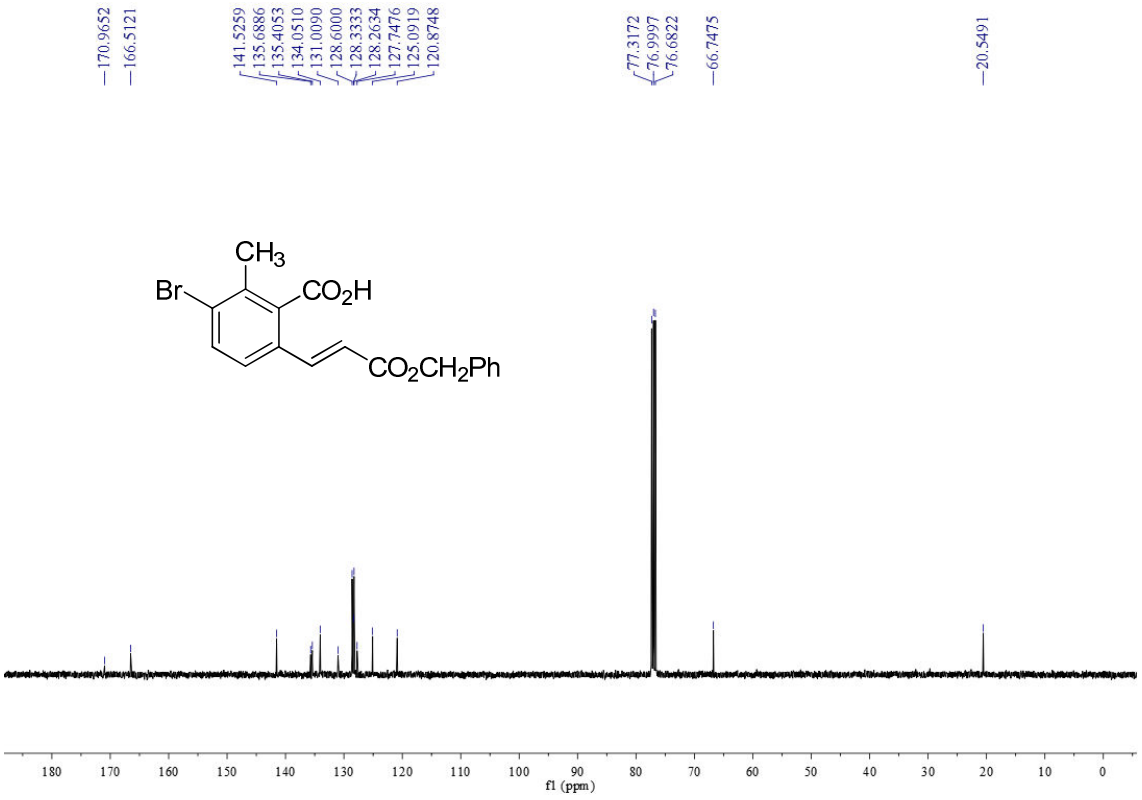
^{13}C NMR spectra of compound of 3j



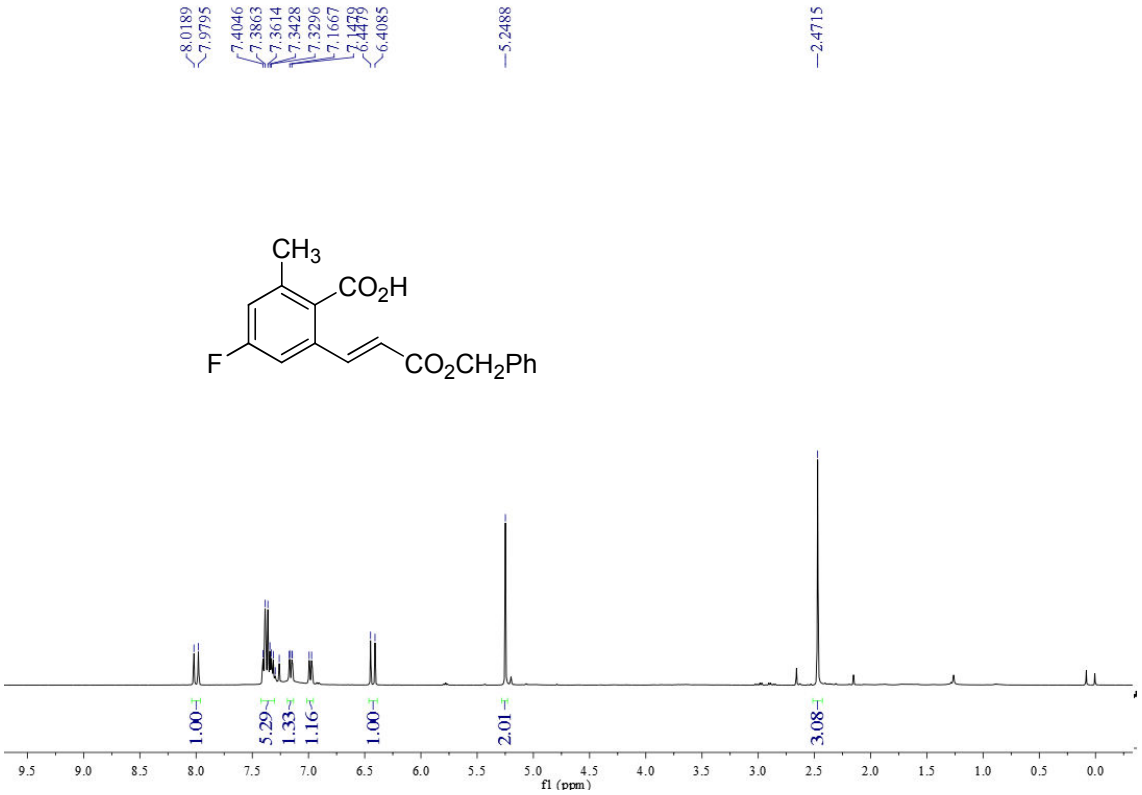
^{1}H NMR spectra of compound of 3k



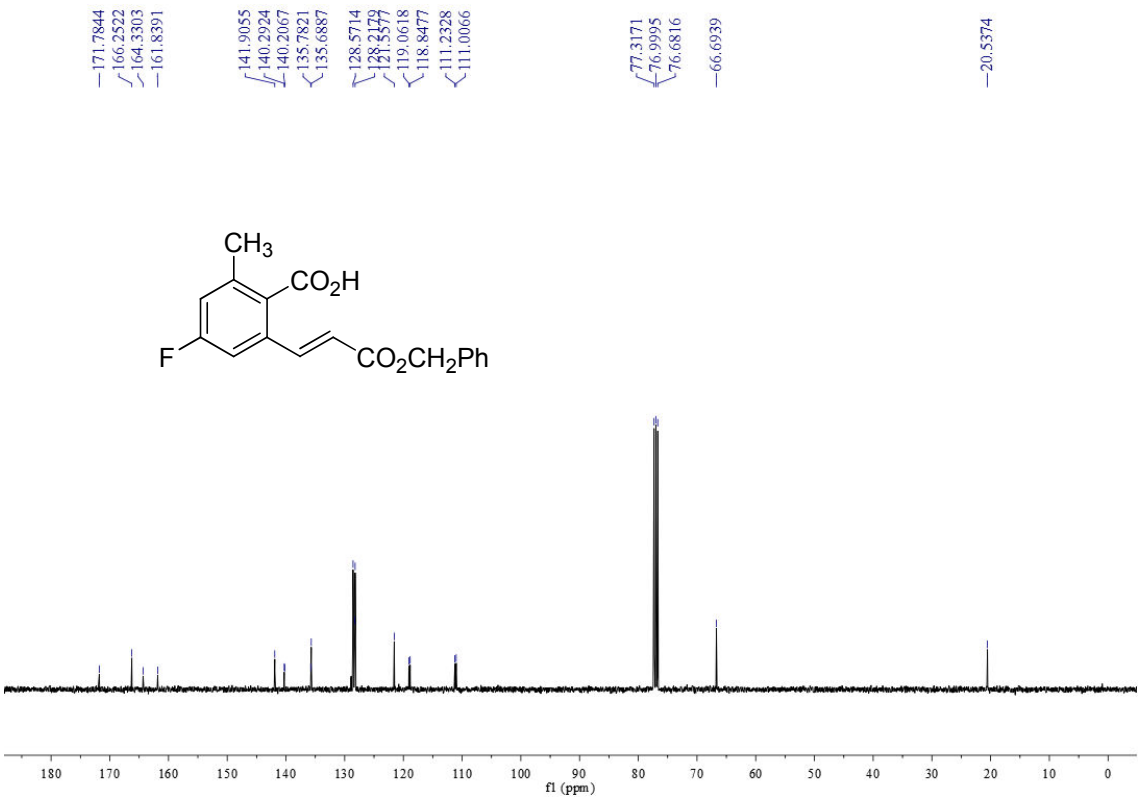
^{13}C NMR spectra of compound of 3k



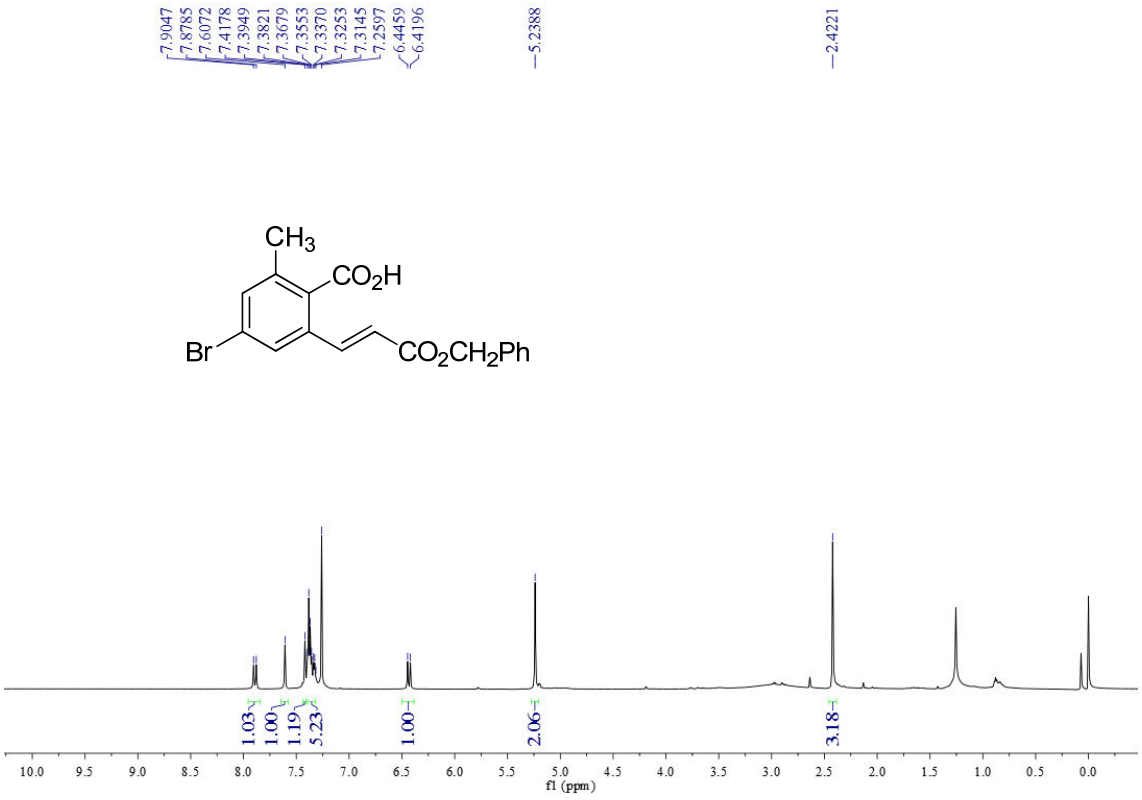
^{1}H NMR spectra of compound of 3l



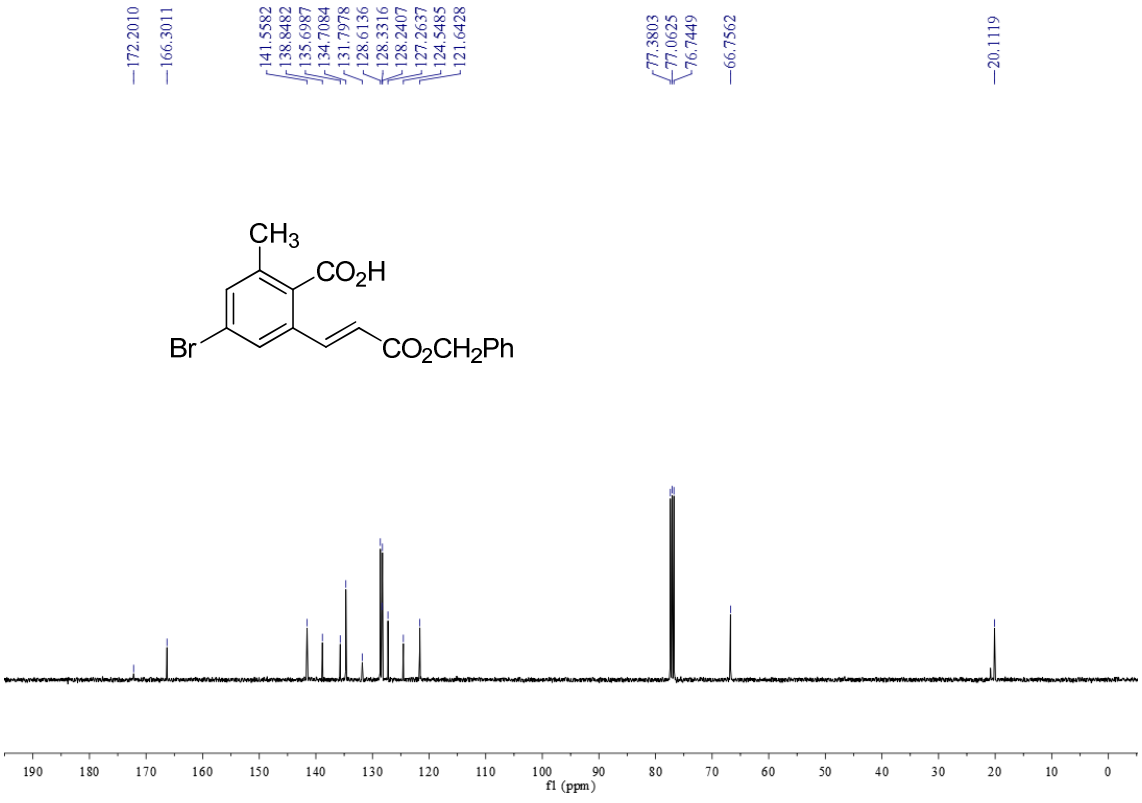
^{13}C NMR spectra of compound of 3l



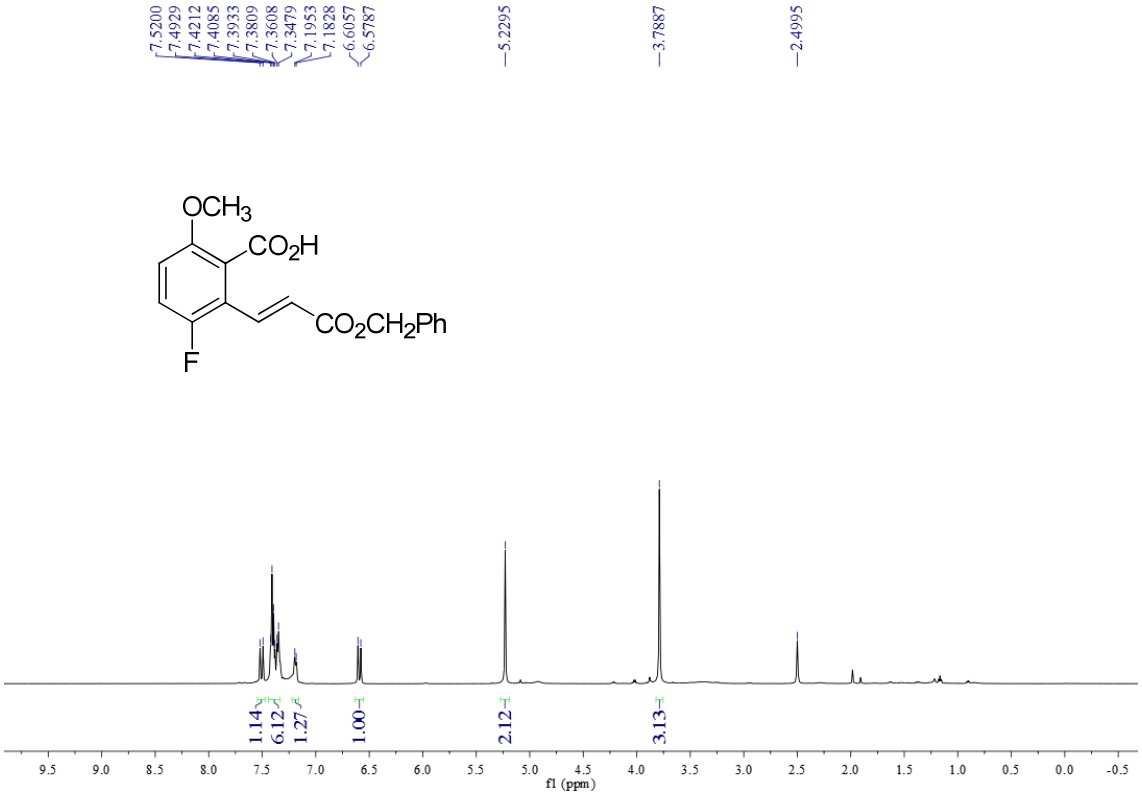
^{1}H NMR spectra of compound of 3m



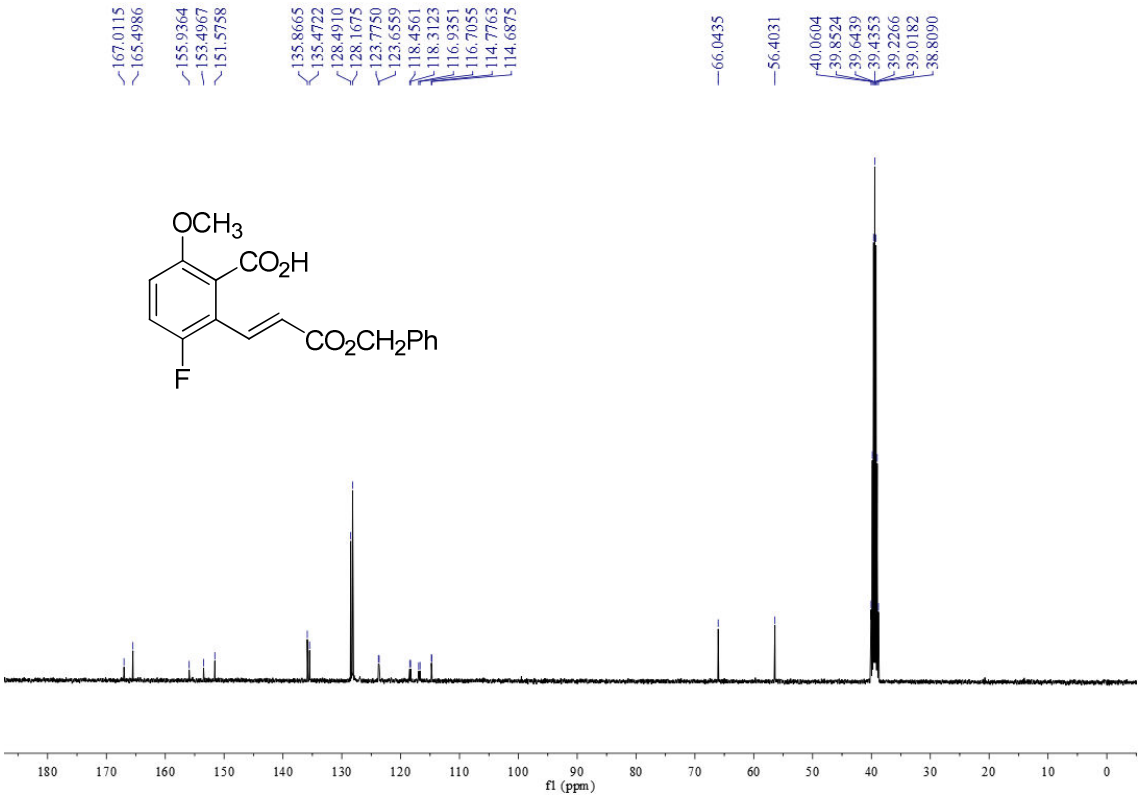
^{13}C NMR spectra of compound of 3m



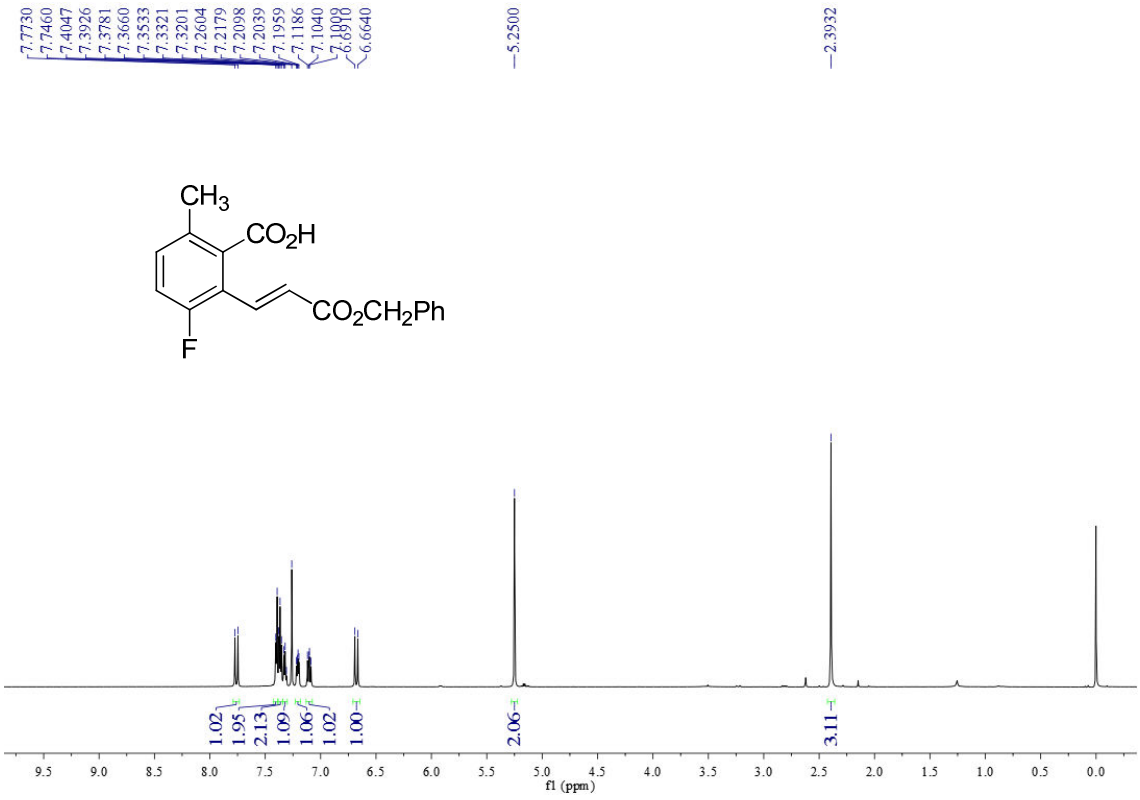
^{1}H NMR spectra of compound of 3n



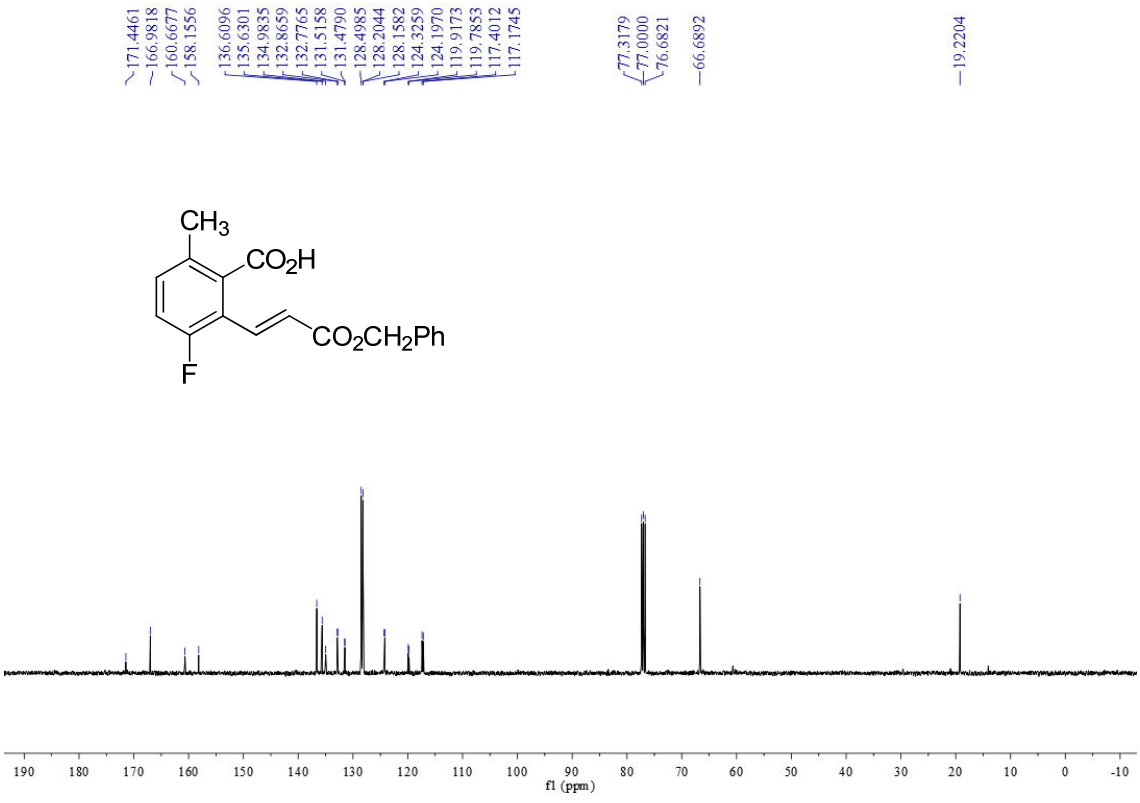
^{13}C NMR spectra of compound of 3n



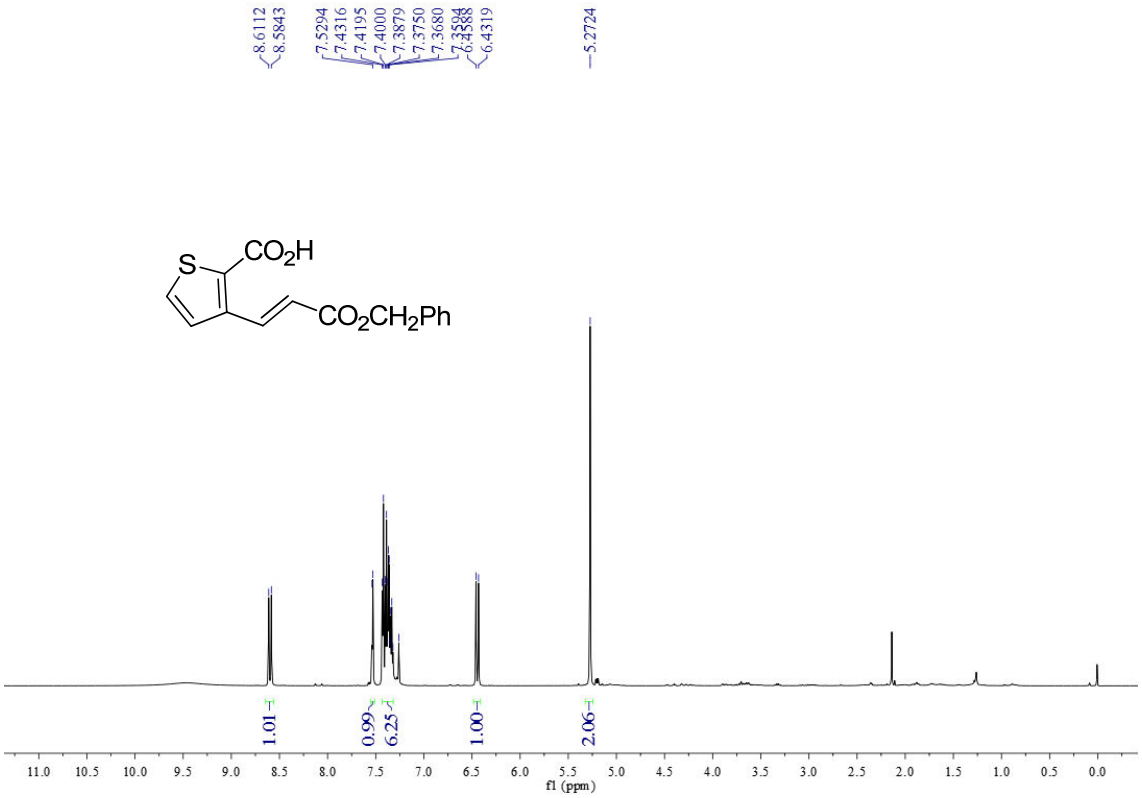
^{1}H NMR spectra of compound of 3o



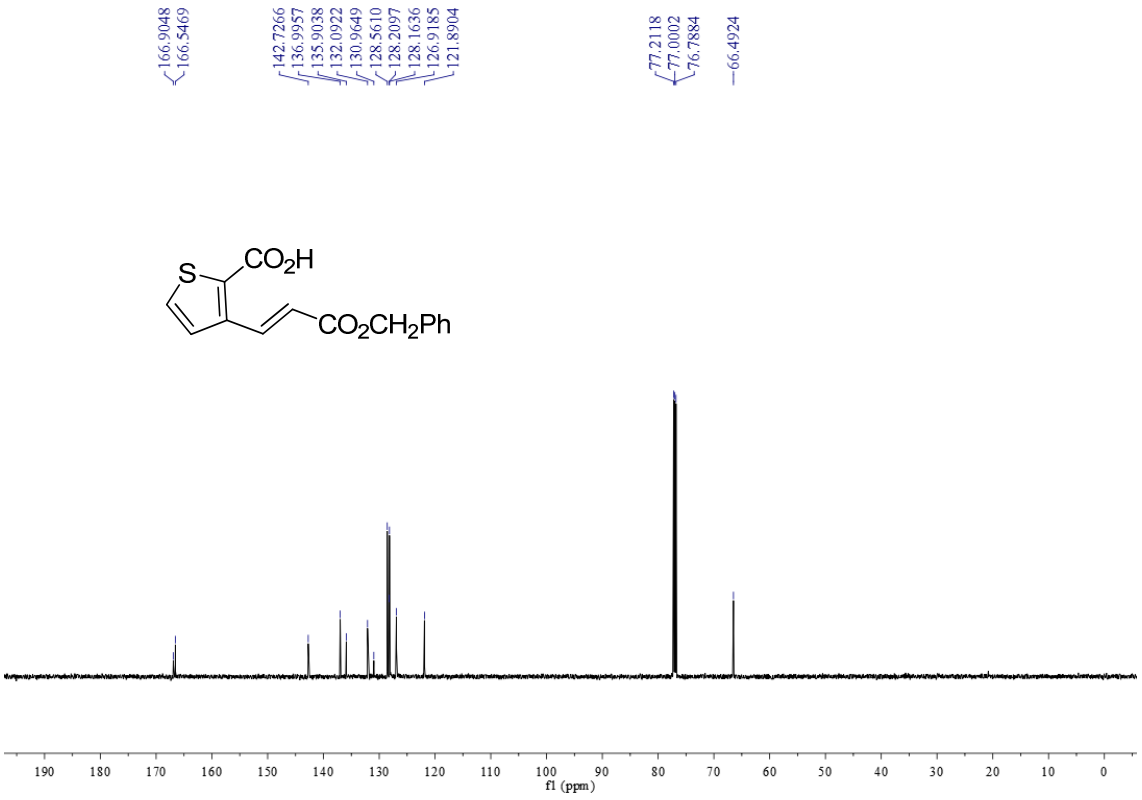
^{13}C NMR spectra of compound of 3o



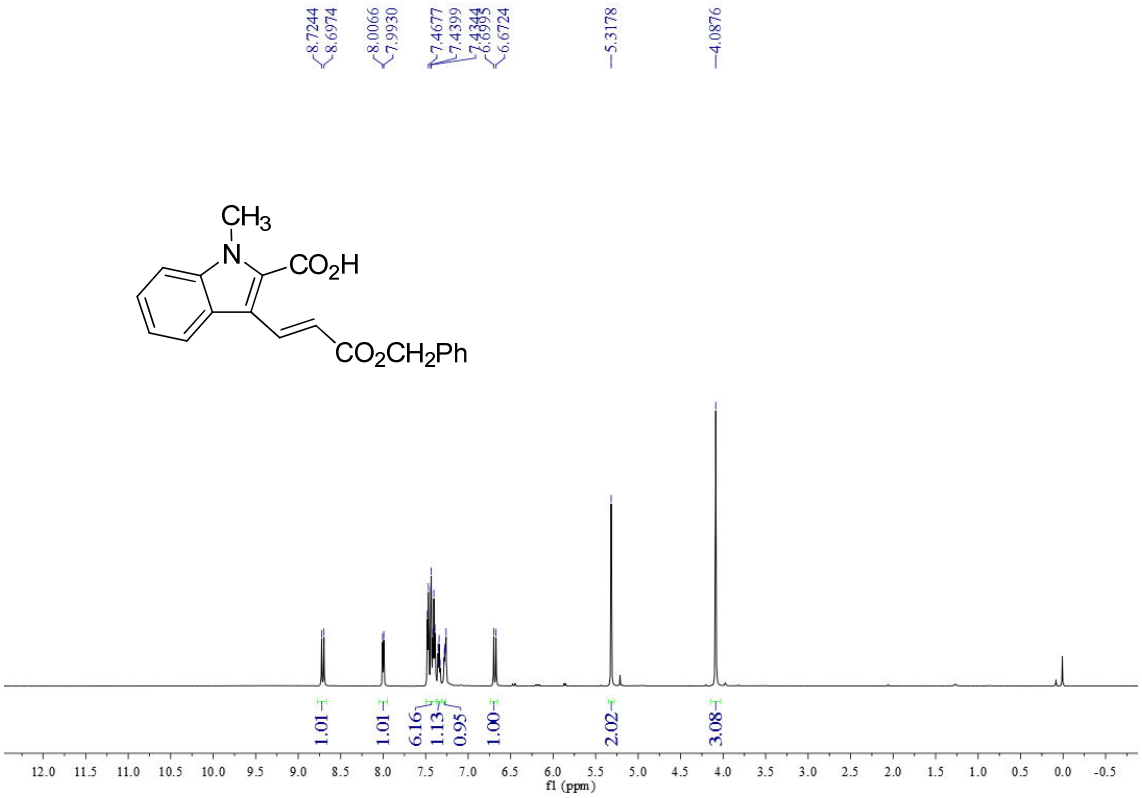
^{1}H NMR spectra of compound of 3p



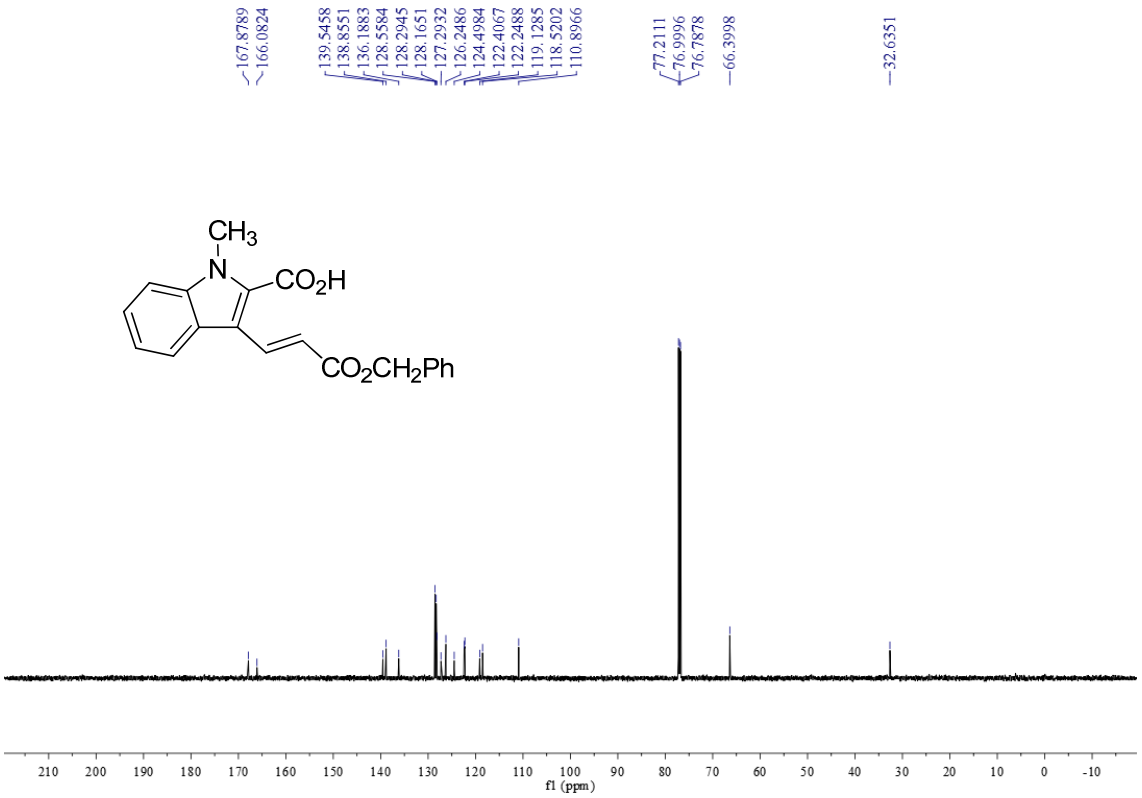
^{13}C NMR spectra of compound of 3p



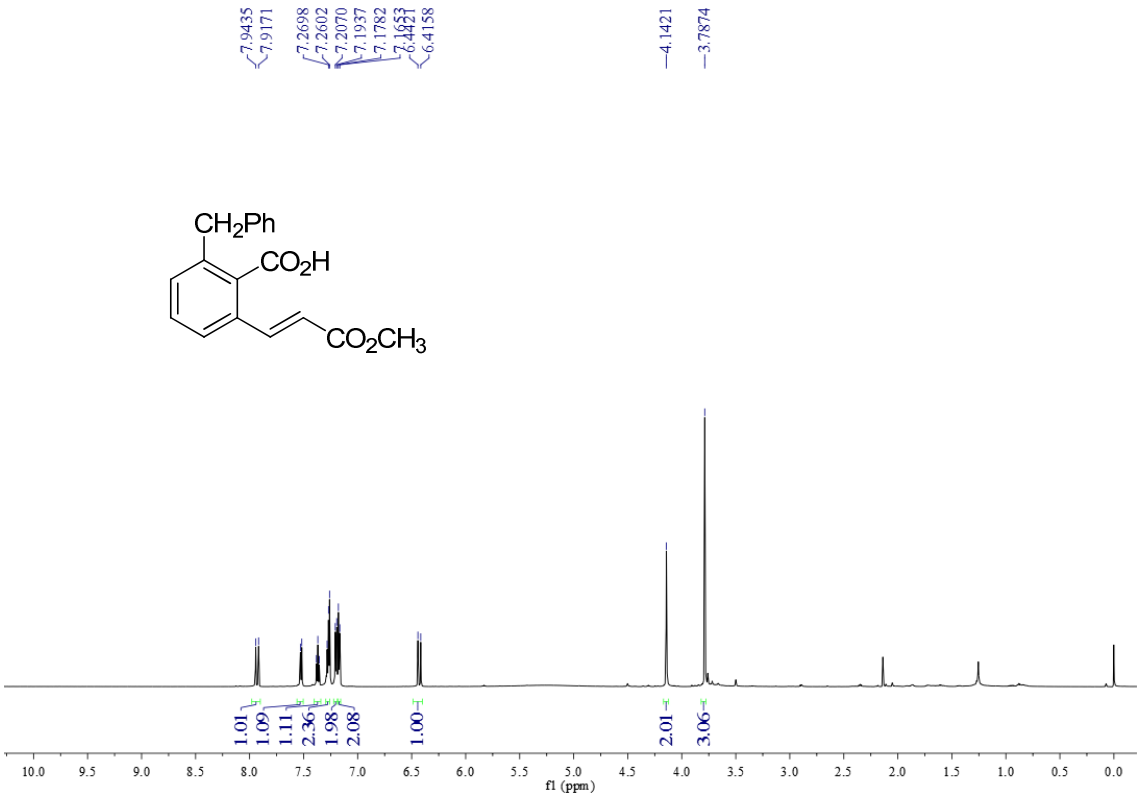
^{1}H NMR spectra of compound of 3q



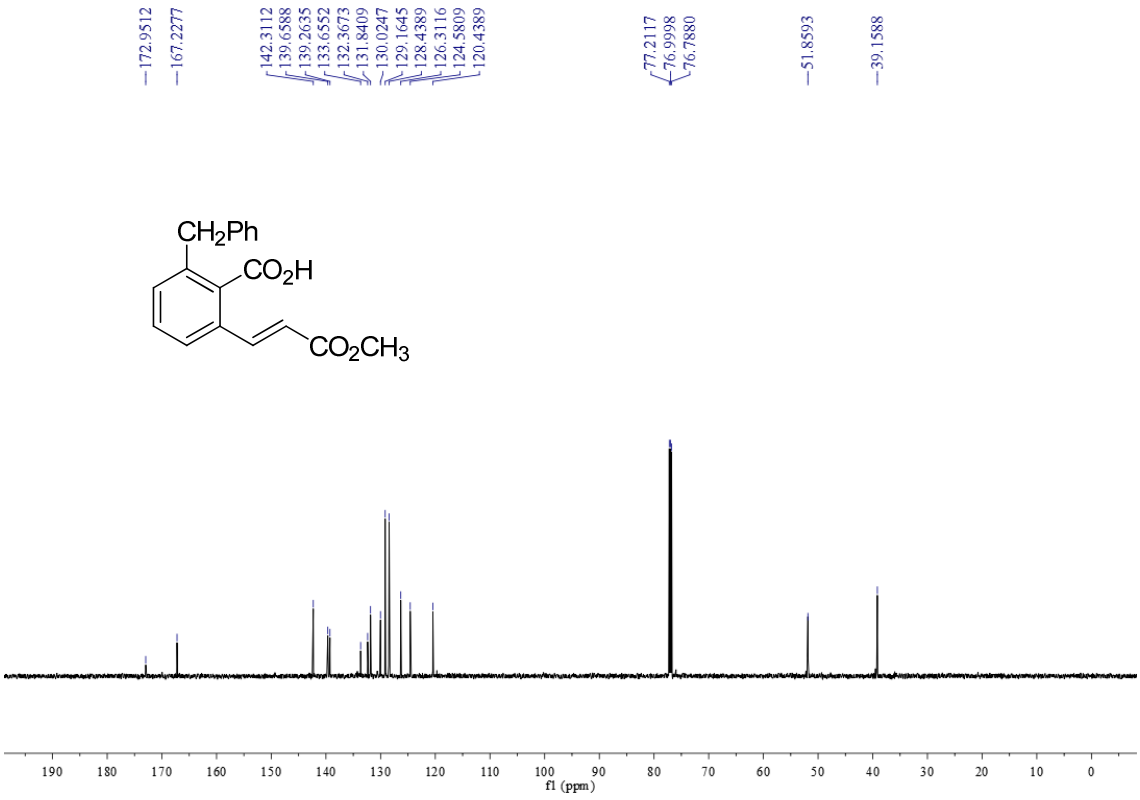
^{13}C NMR spectra of compound of 3q



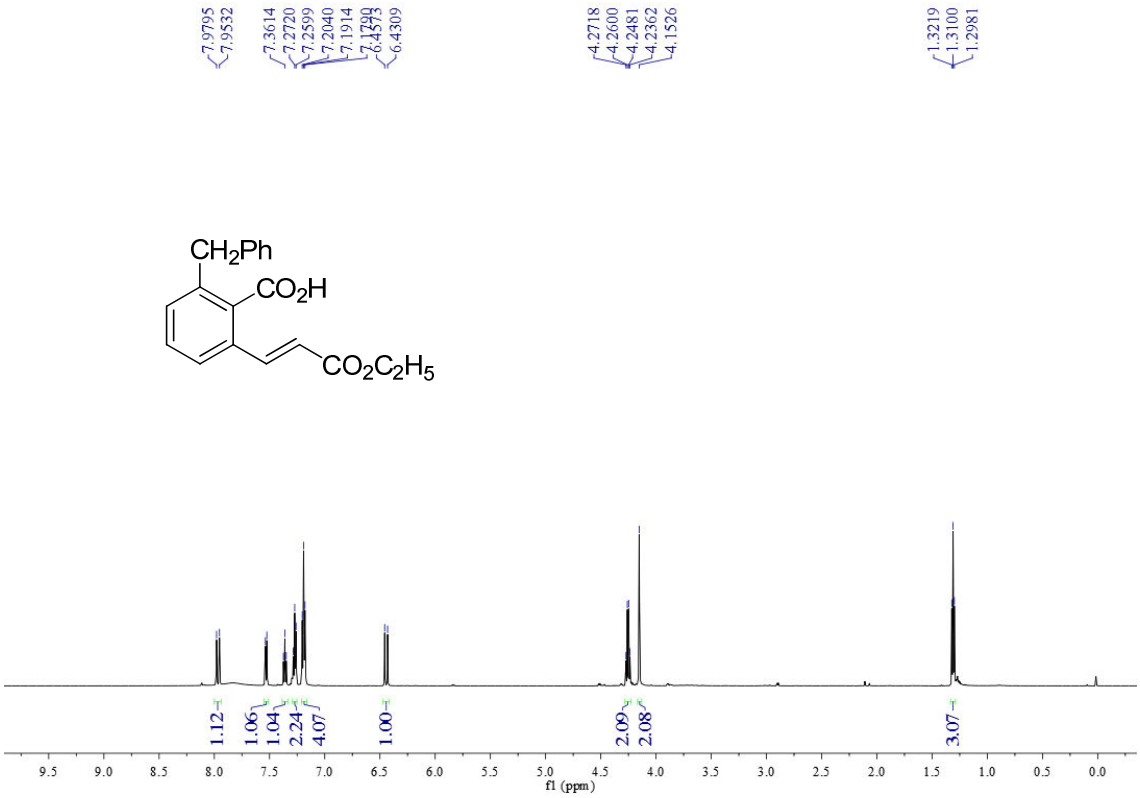
^{1}H NMR spectra of compound of 3r



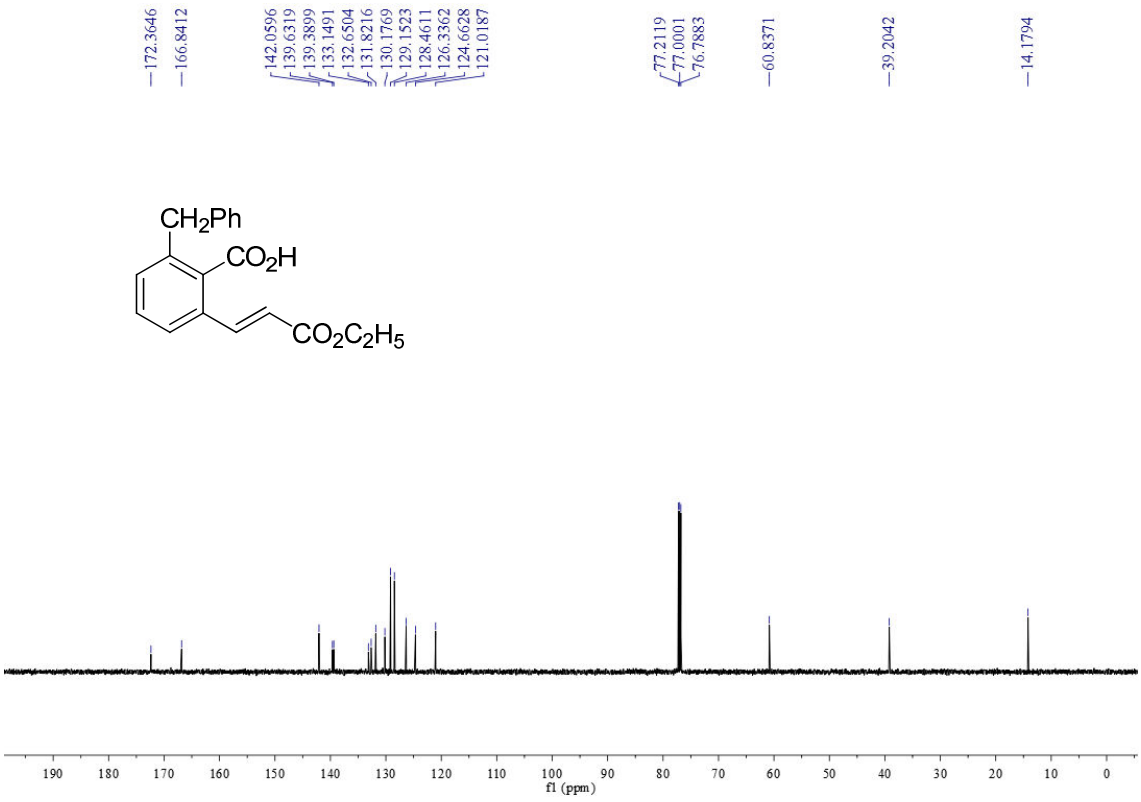
^{13}C NMR spectra of compound of 3r



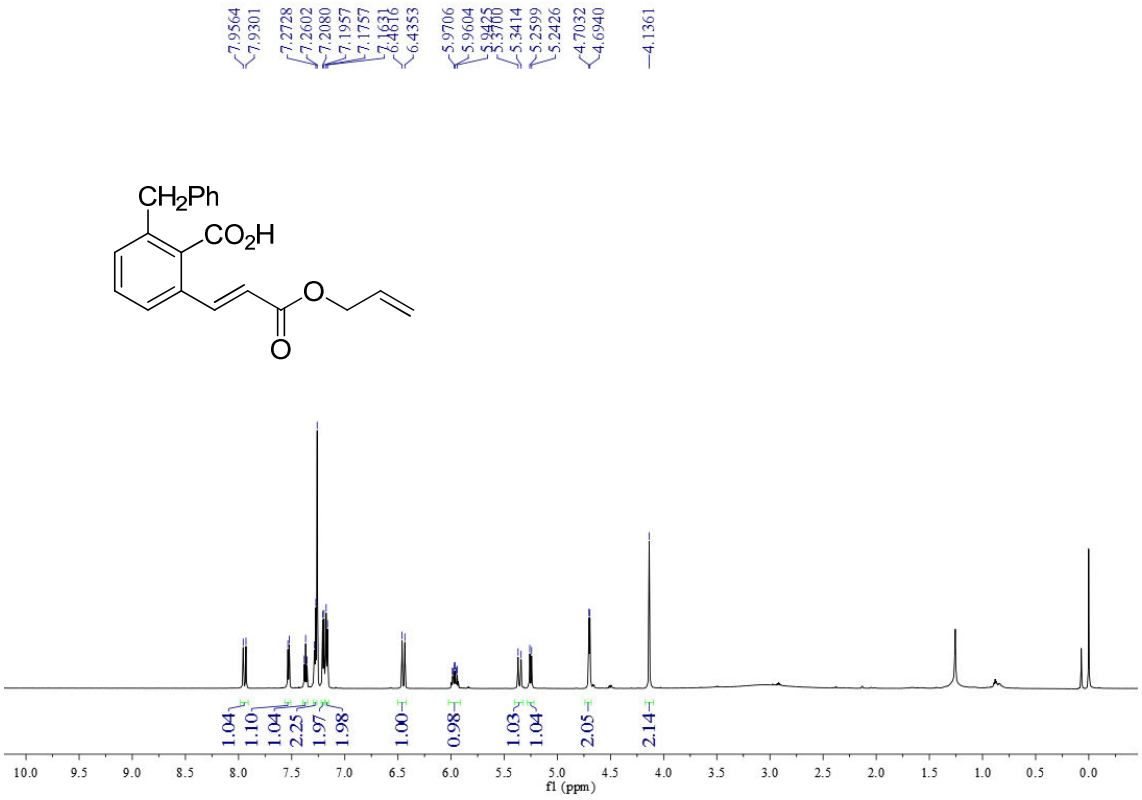
^{1}H NMR spectra of compound of 3s



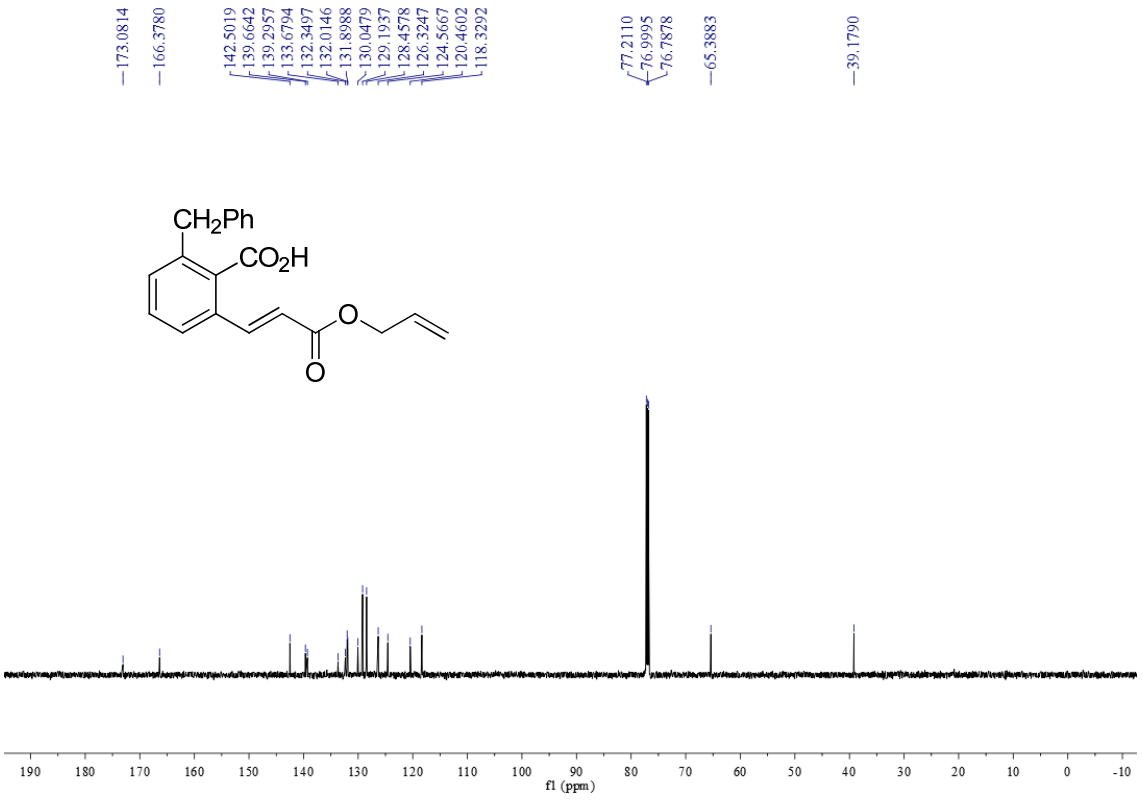
^{13}C NMR spectra of compound of 3s



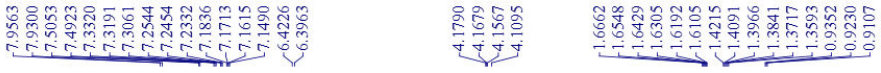
^{1}H NMR spectra of compound of 3t

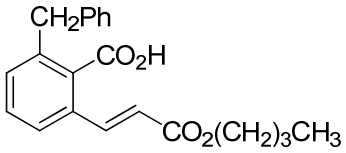


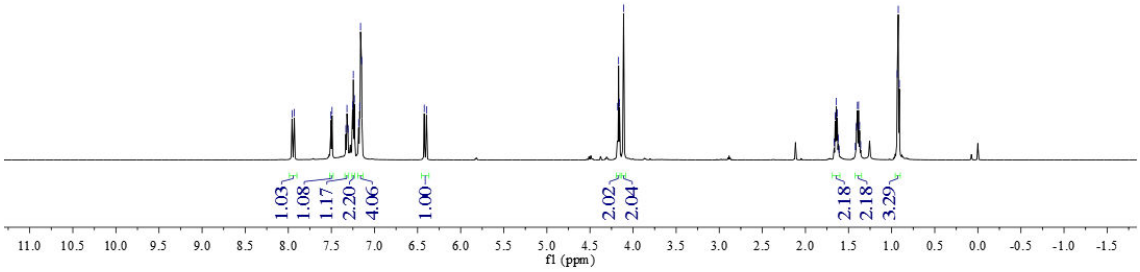
^{13}C NMR spectra of compound of 3t



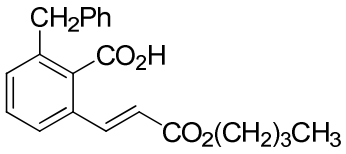
^{1}H NMR spectra of compound of 3u

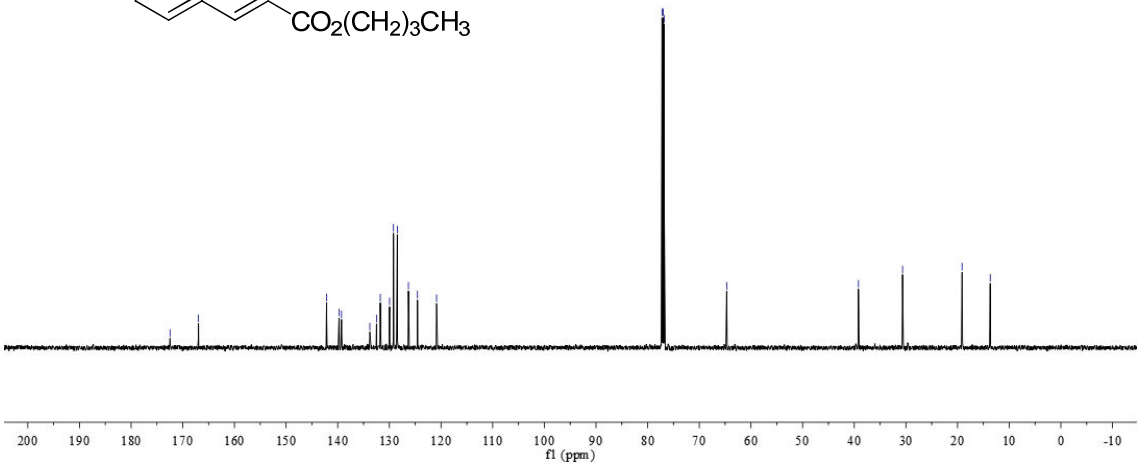




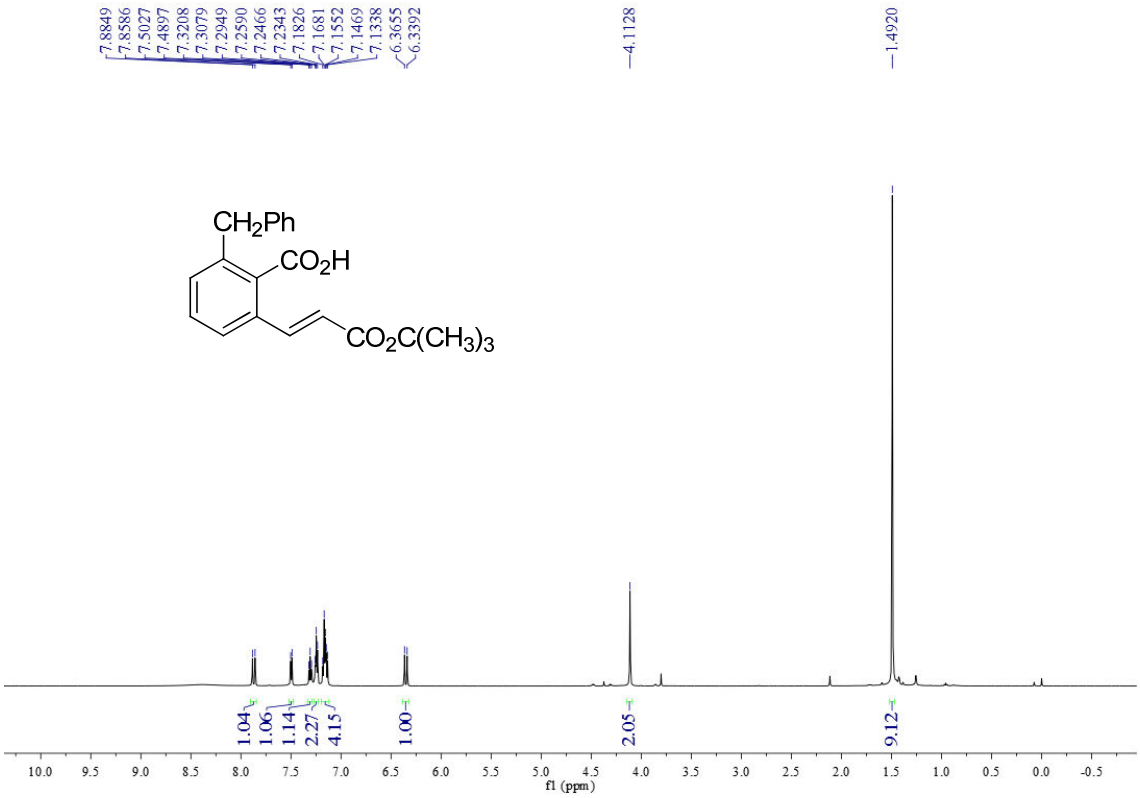


^{13}C NMR spectra of compound of 3u

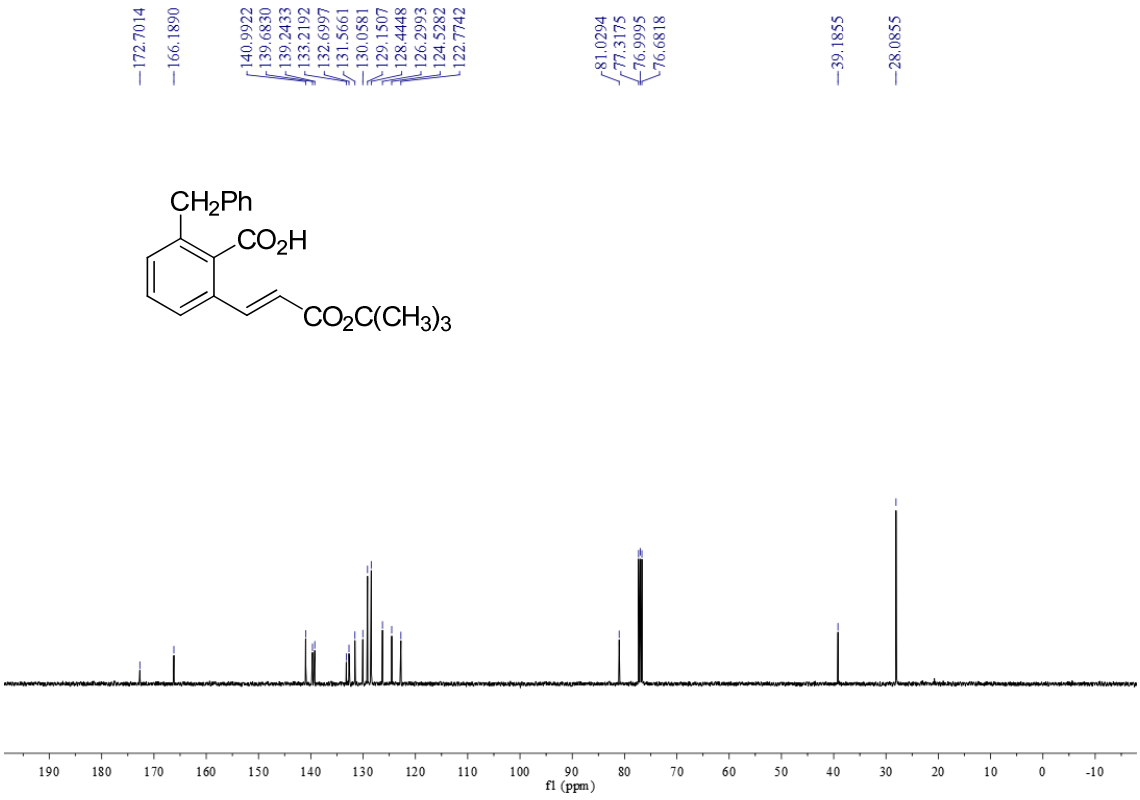




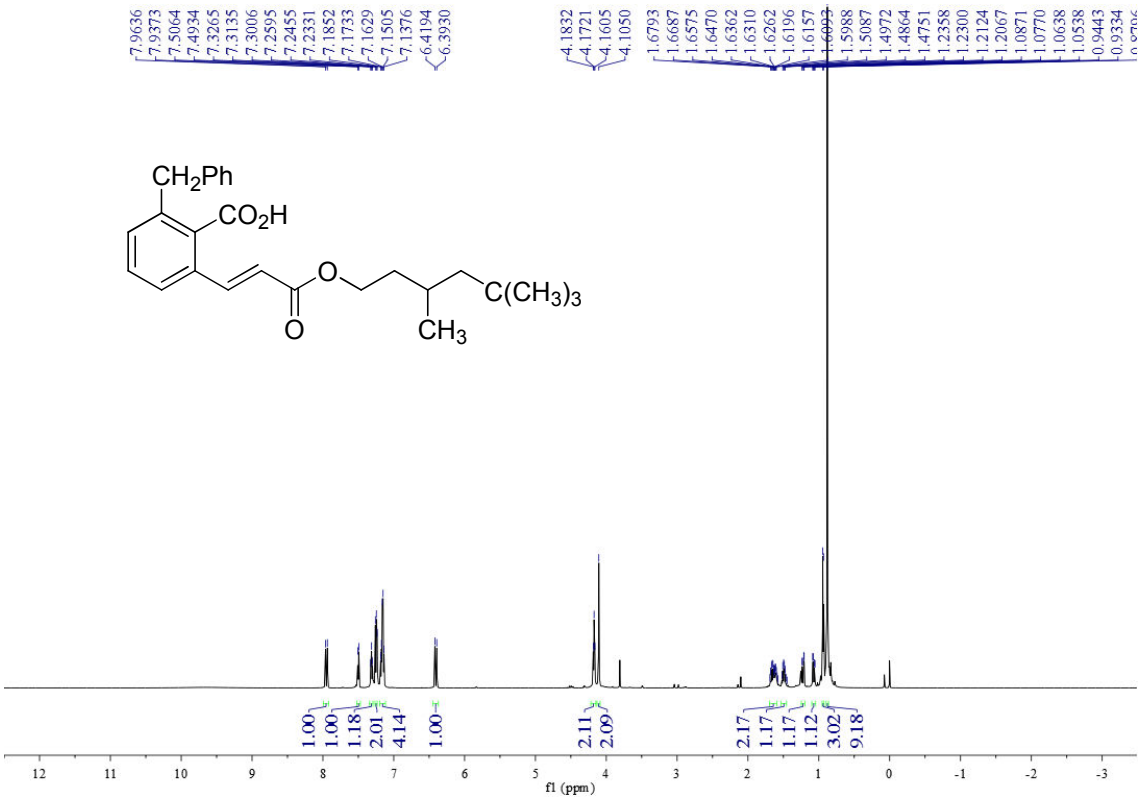
^{1}H NMR spectra of compound of 3v



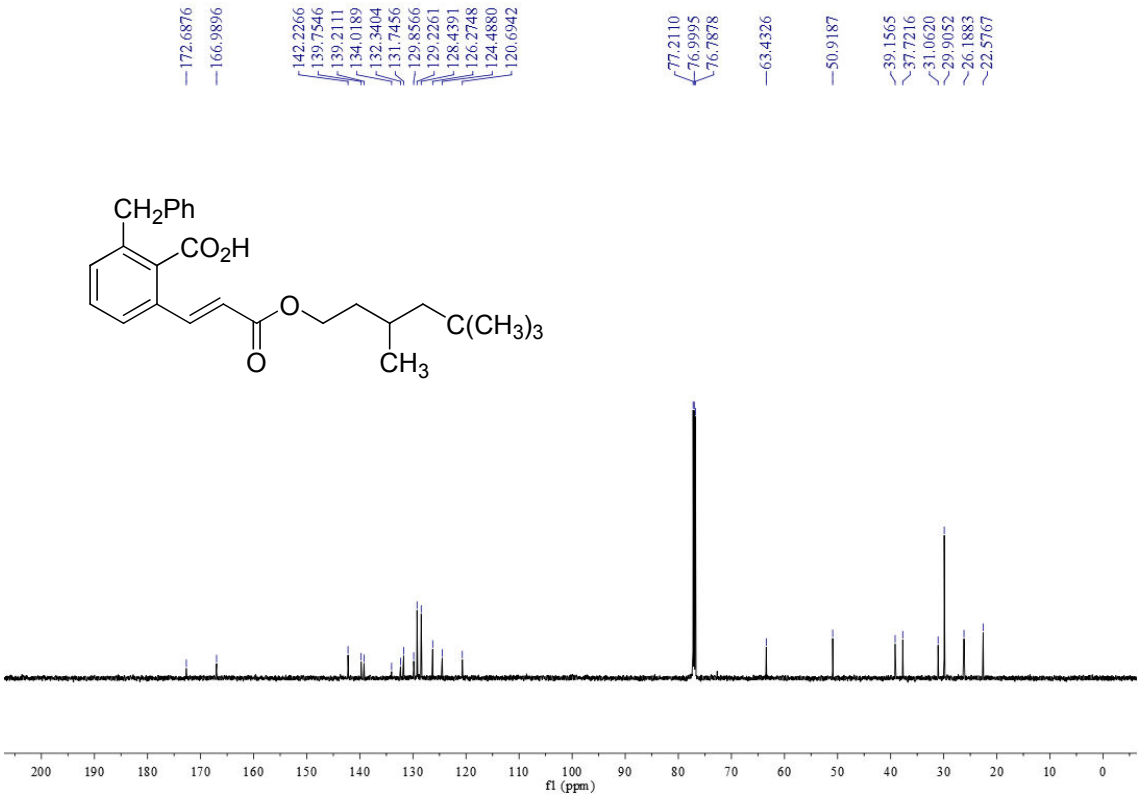
^{13}C NMR spectra of compound of 3v



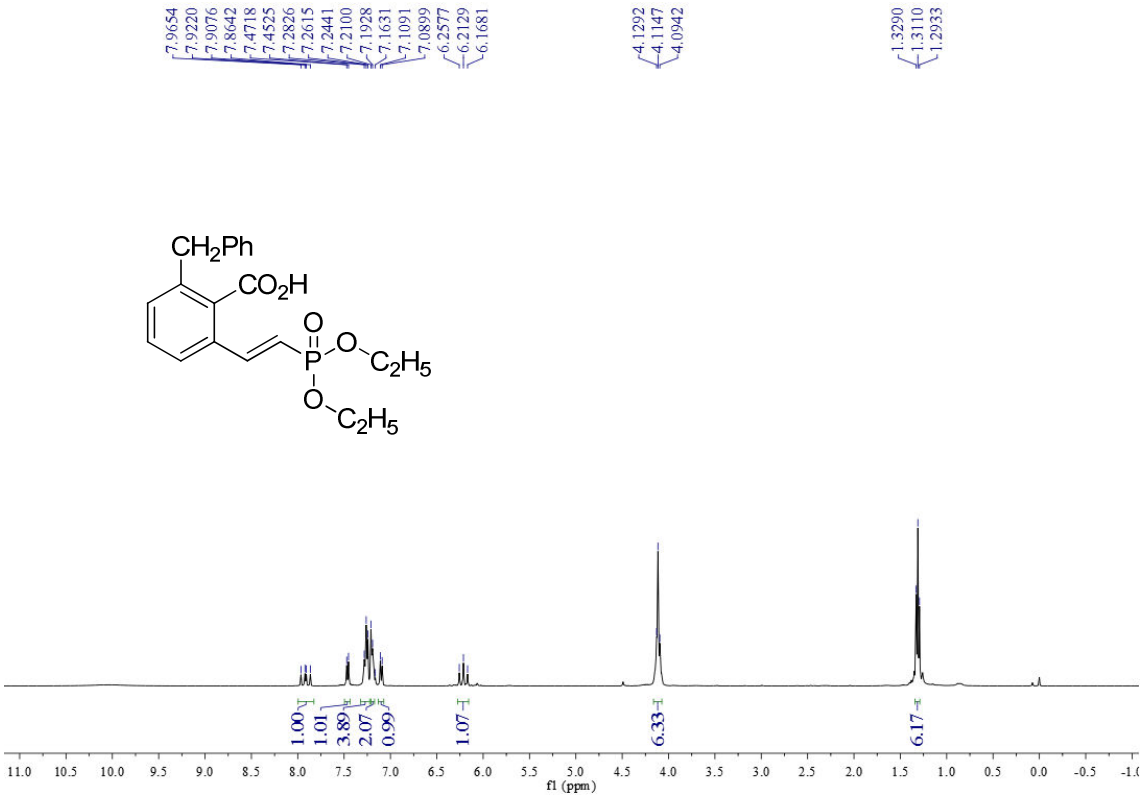
^{1}H NMR spectra of compound of 3w



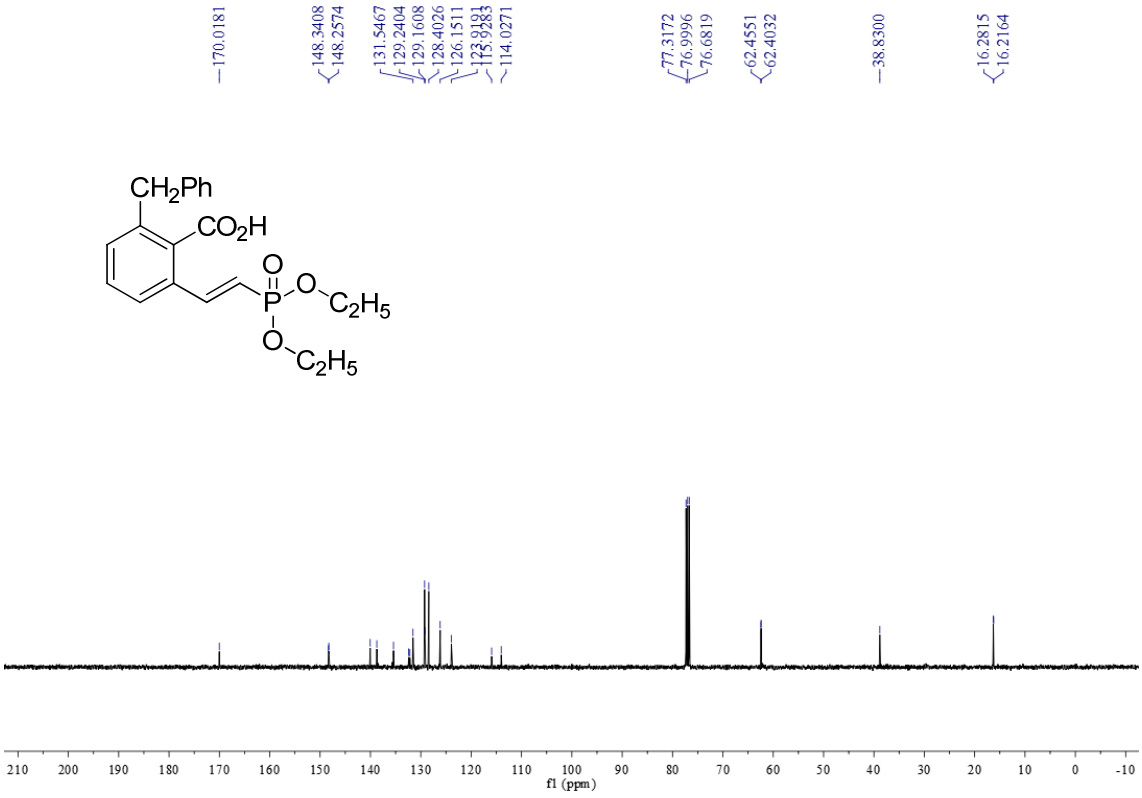
^{13}C NMR spectra of compound of 3w



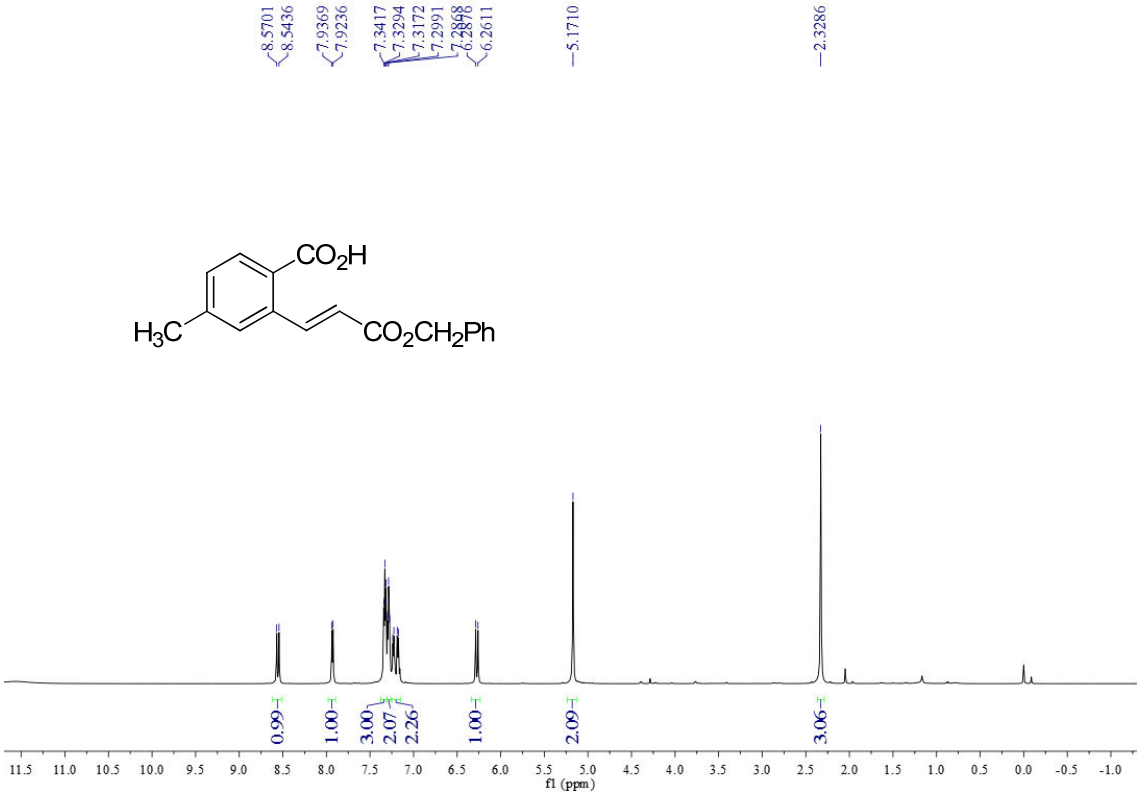
^{1}H NMR spectra of compound of 3x



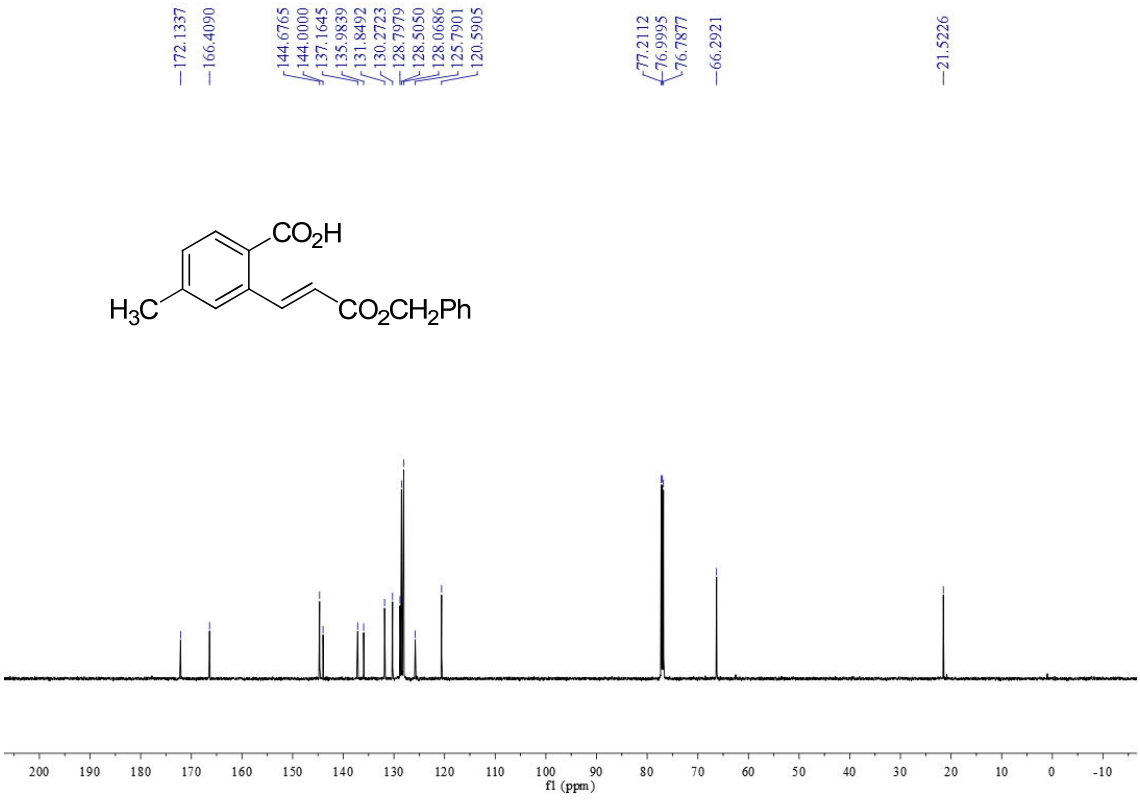
^{13}C NMR spectra of compound of 3x



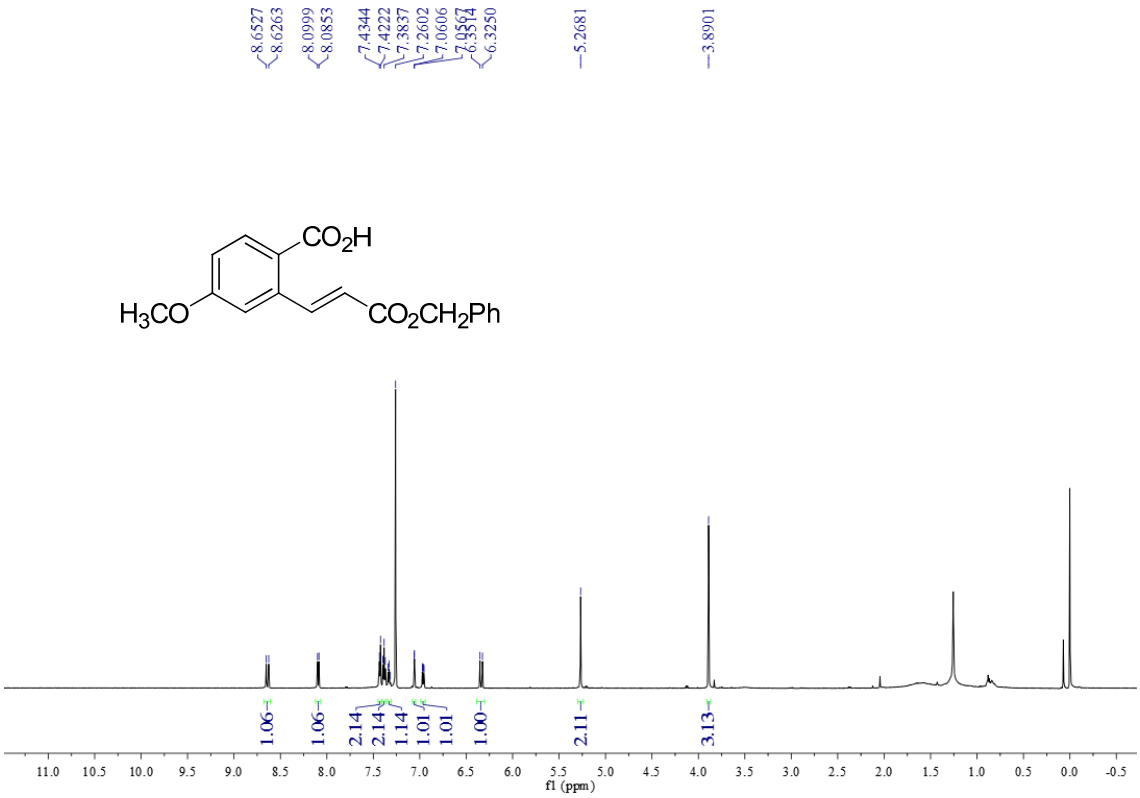
^{1}H NMR spectra of compound of 3y



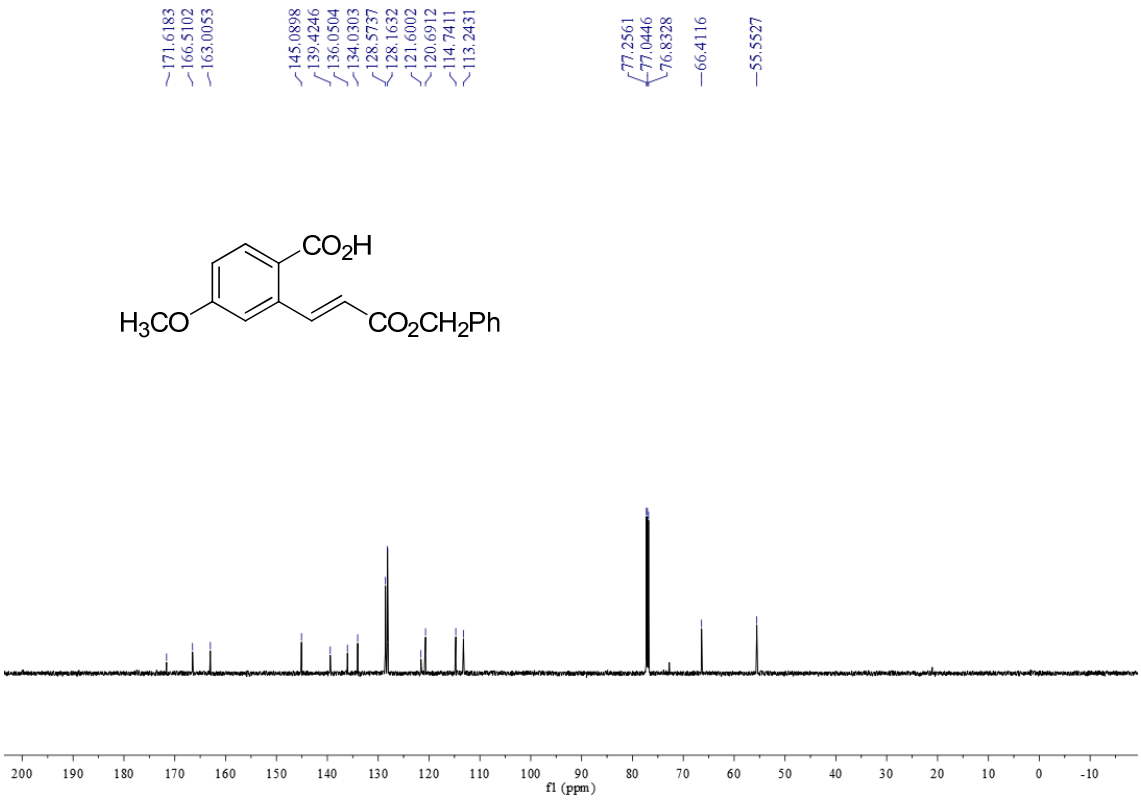
^{13}C NMR spectra of compound of 3y



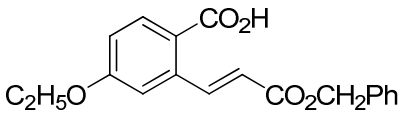
^{1}H NMR spectra of compound of 3z

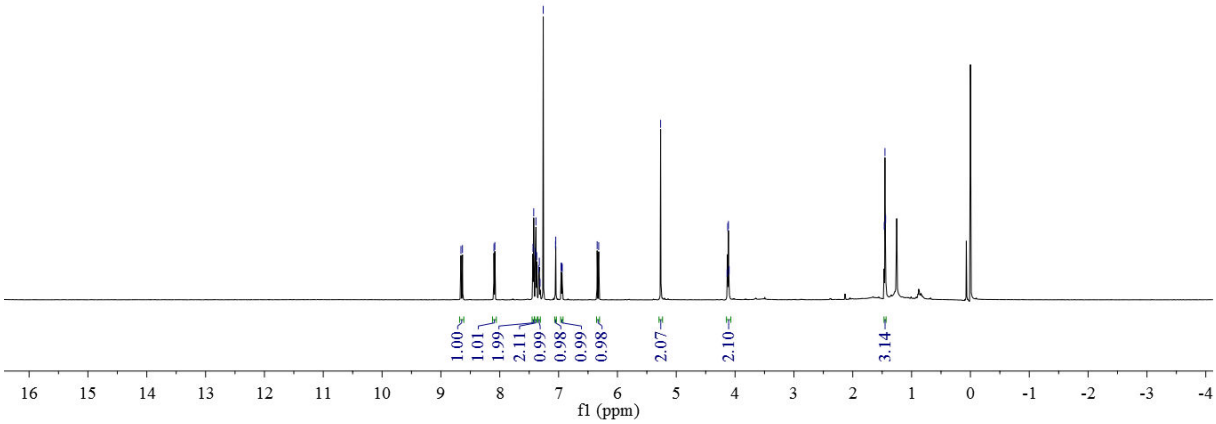


^{13}C NMR spectra of compound of 3z

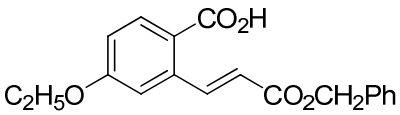


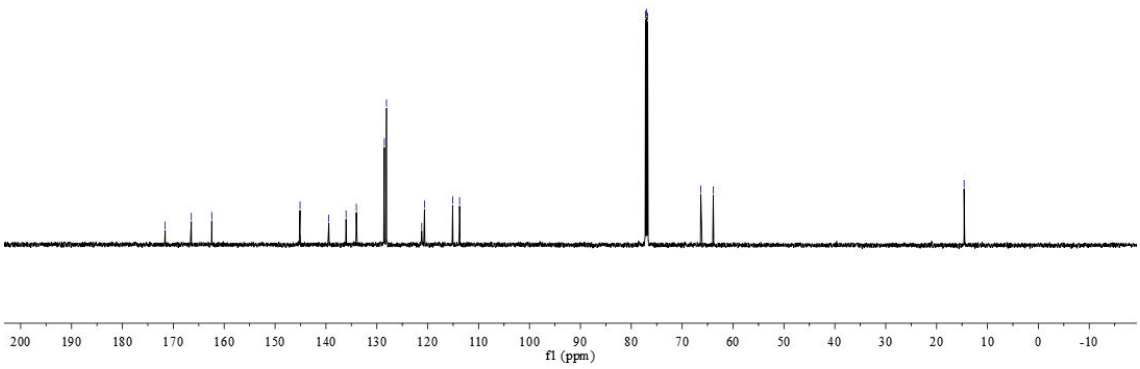
^{1}H NMR spectra of compound of 3aa



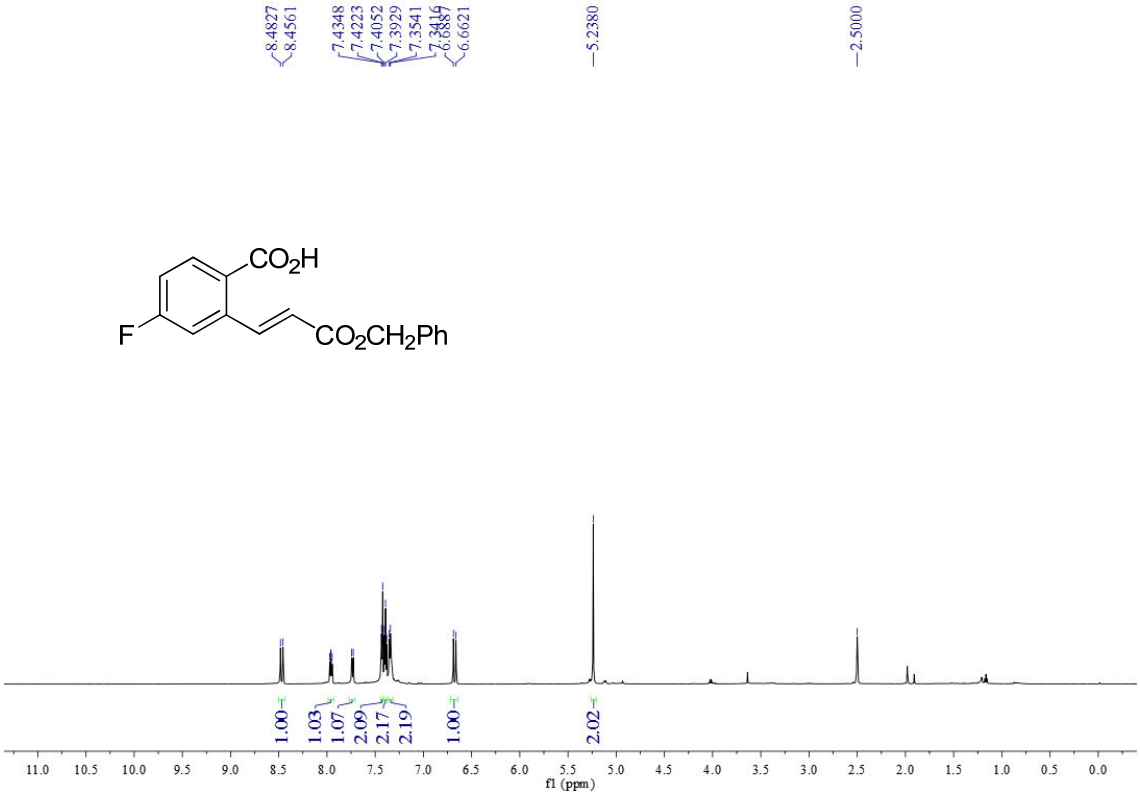


^{13}C NMR spectra of compound of 3aa

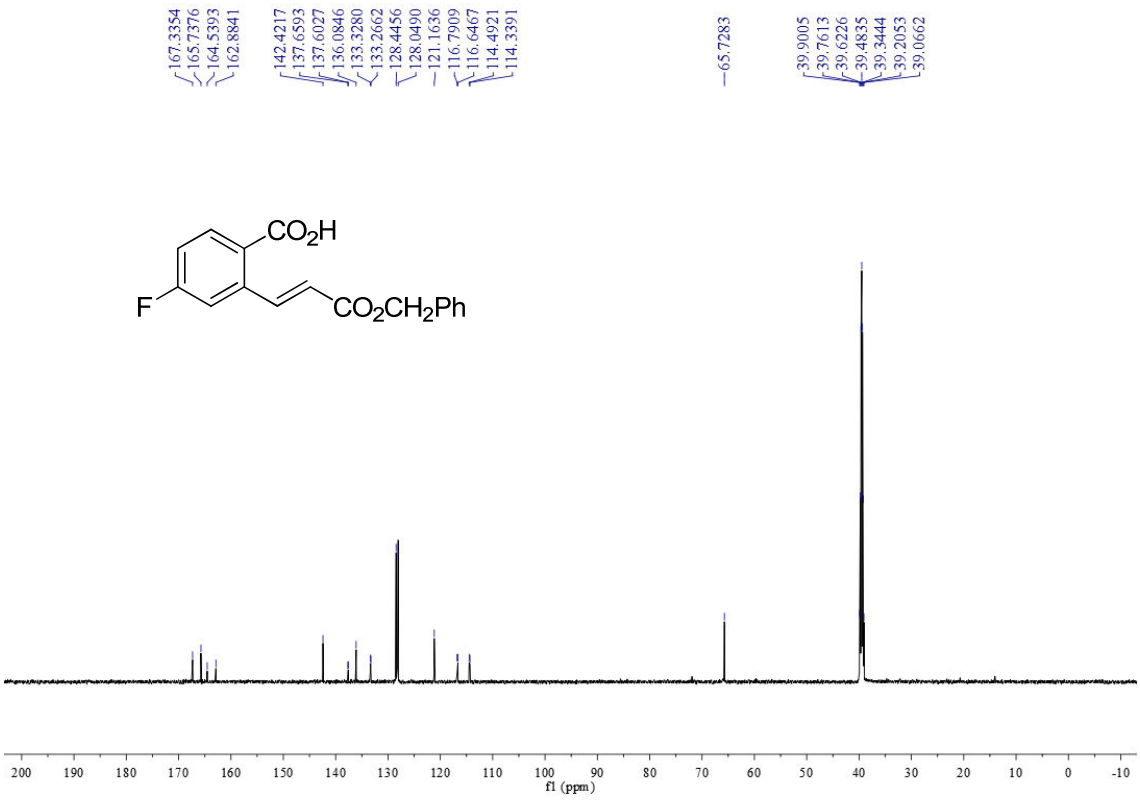




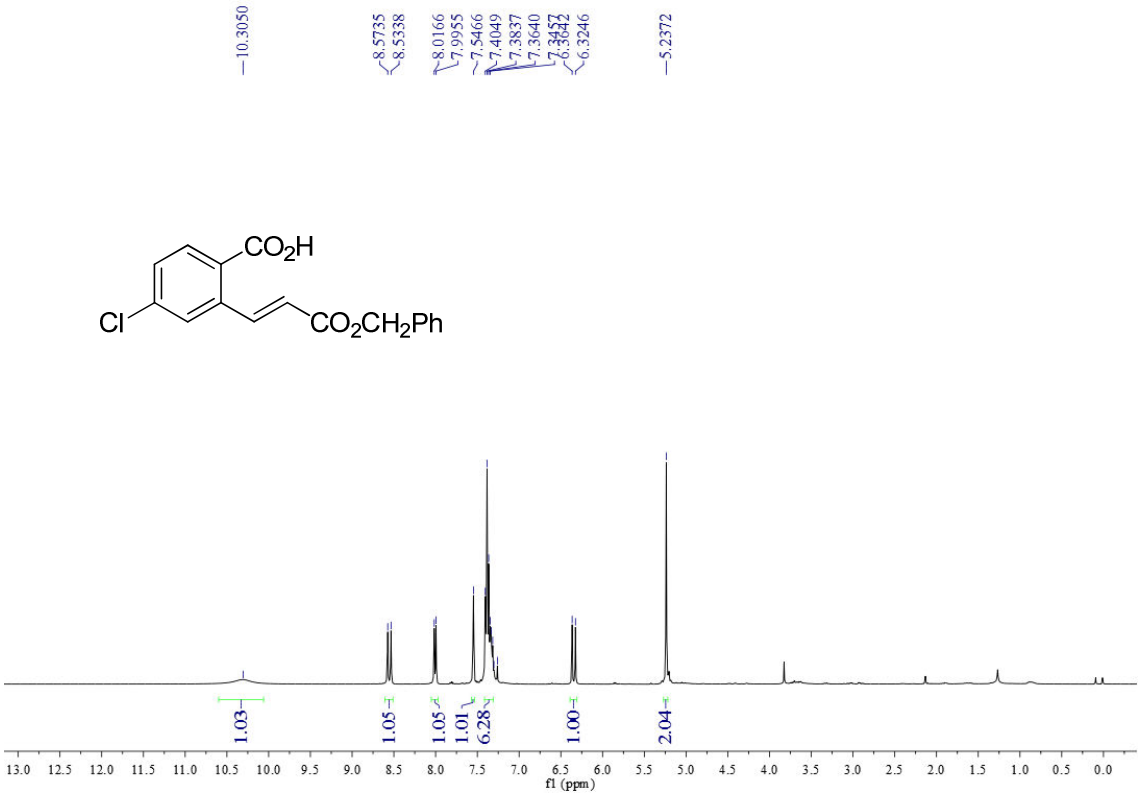
[1]H NMR spectra of compound of 3ab



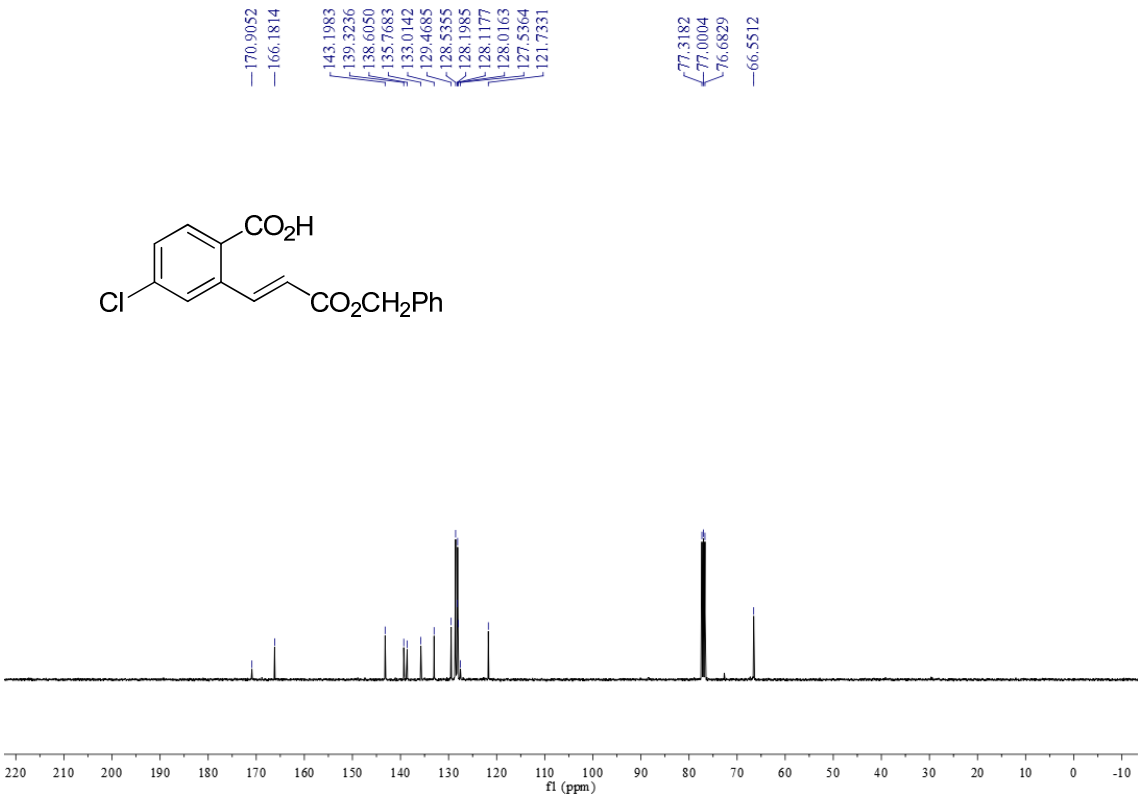
[13]C NMR spectra of compound of 3ab



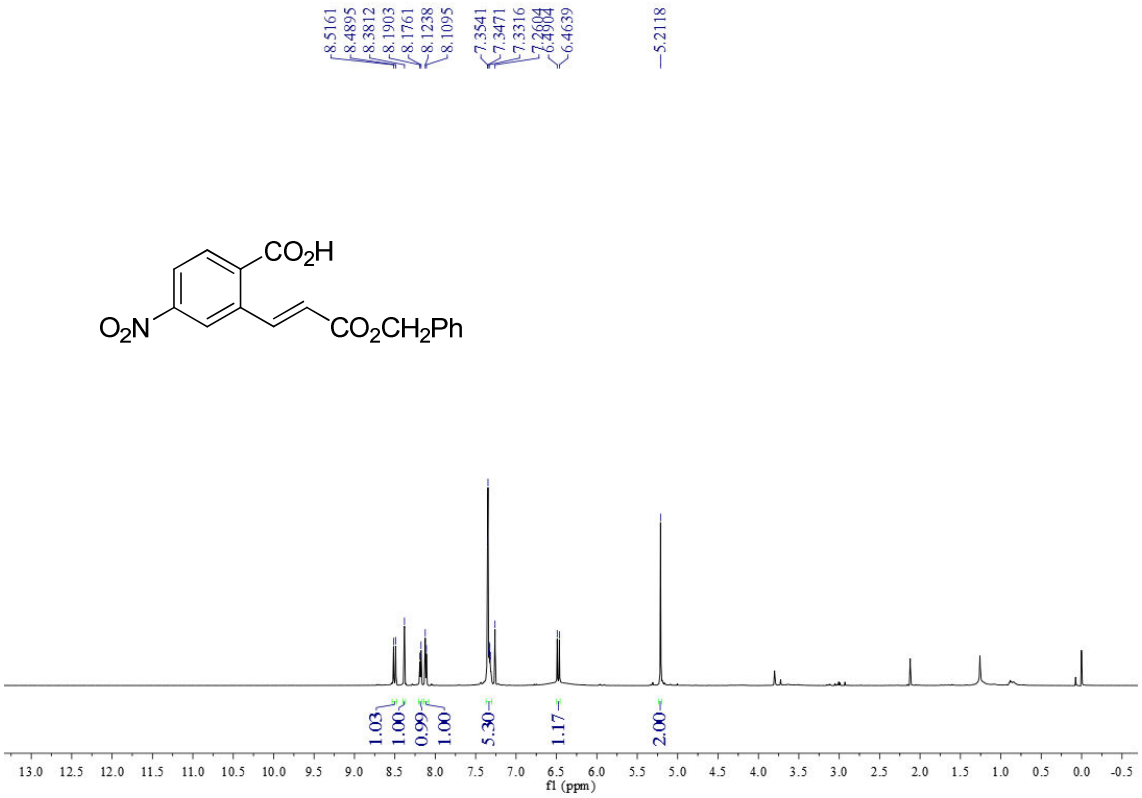
^{1}H NMR spectra of compound of 3ac



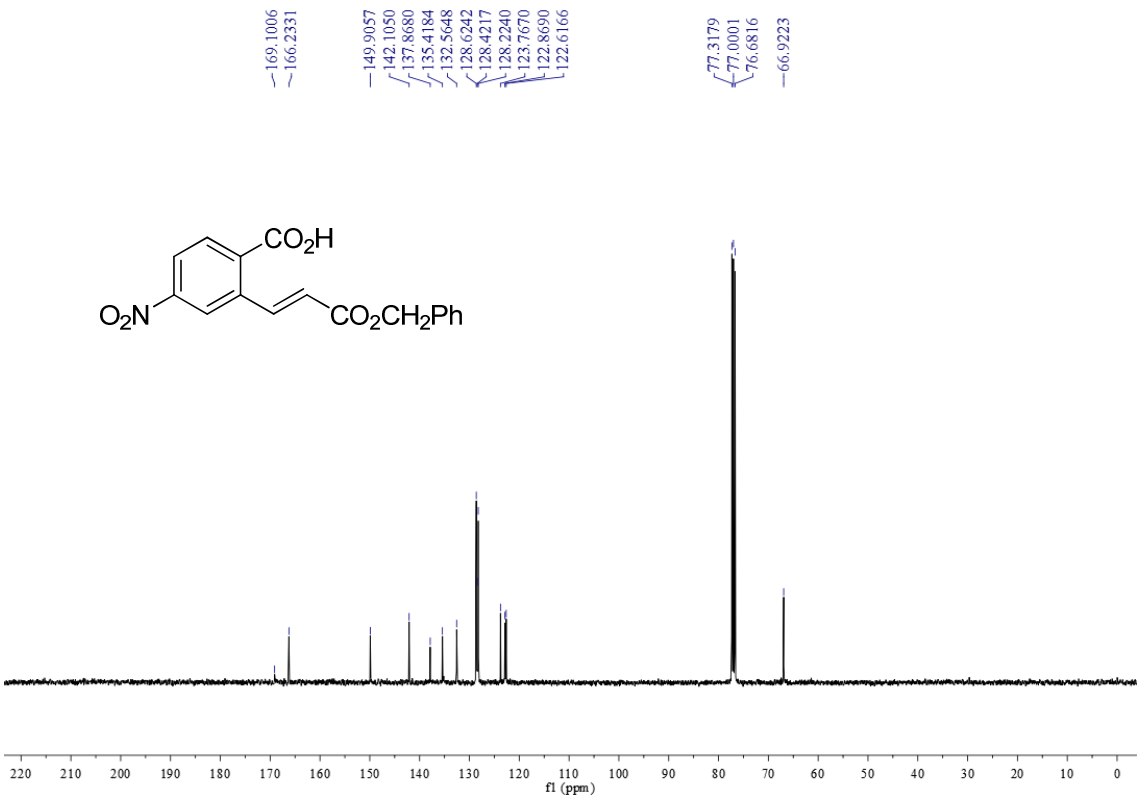
^{13}C NMR spectra of compound of 3ac



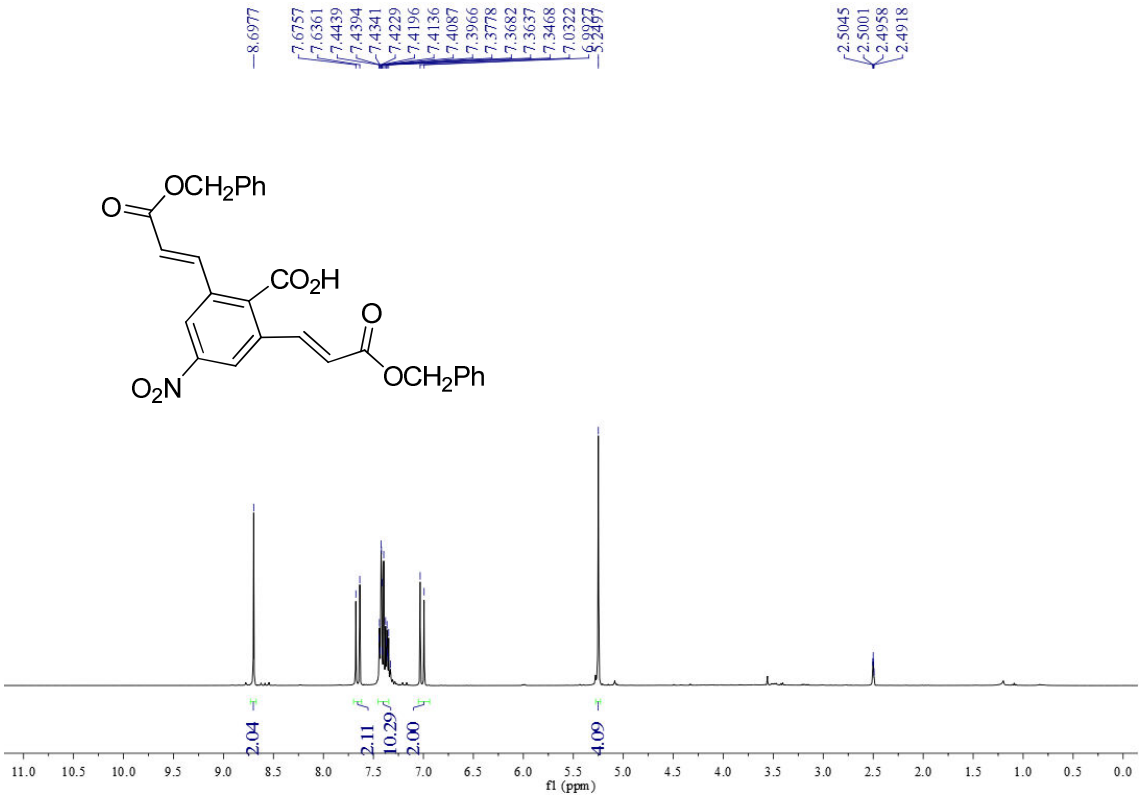
^{1}H NMR spectra of compound of 3ad



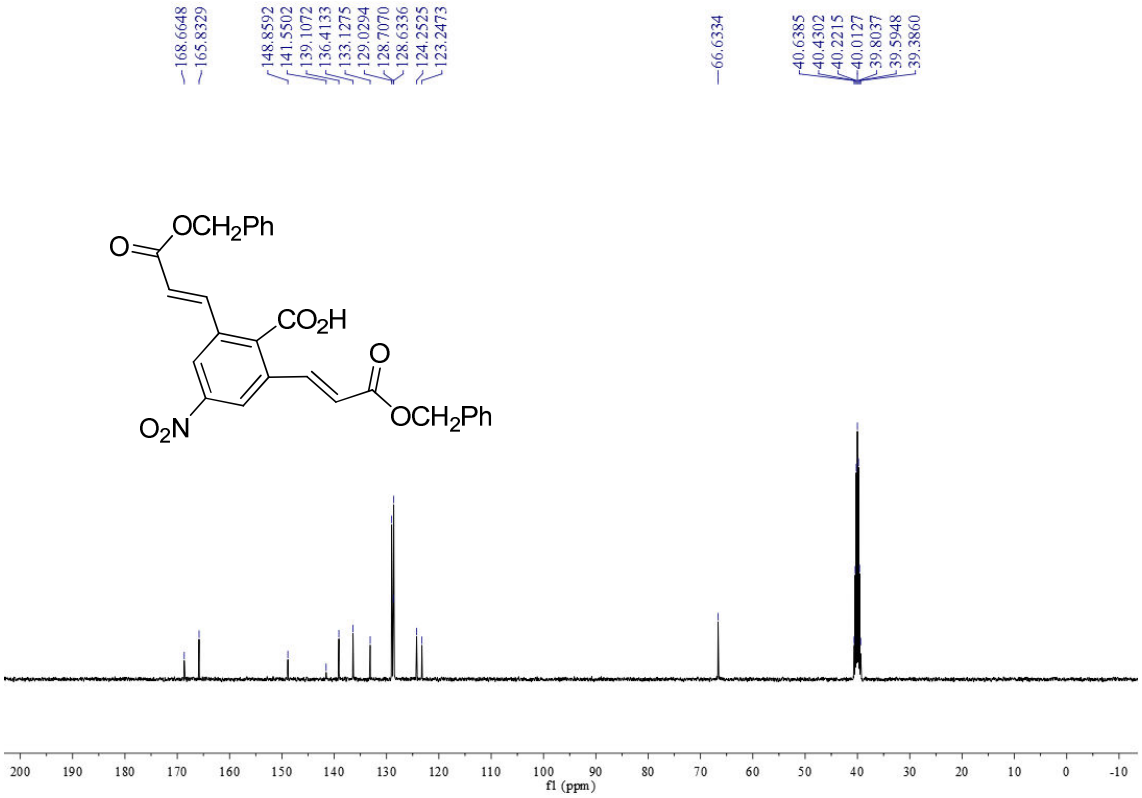
^{13}C NMR spectra of compound of 3ad



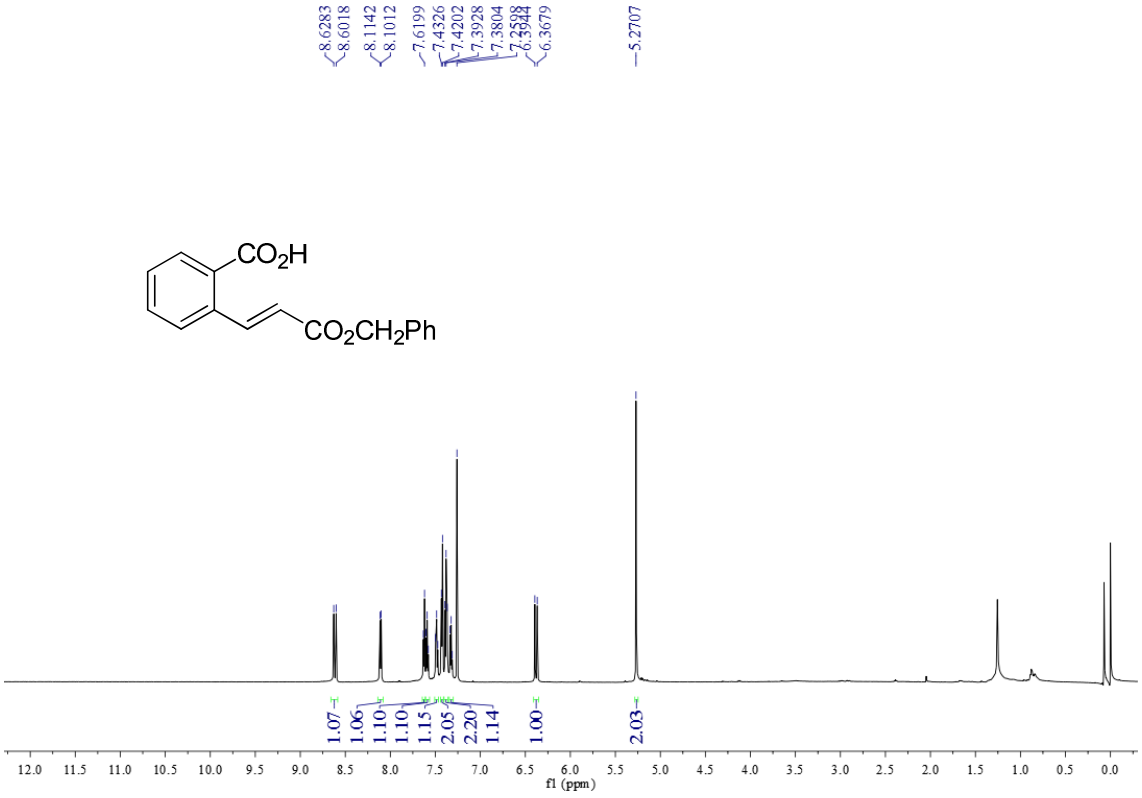
^{1}H NMR spectra of compound of 3ad'



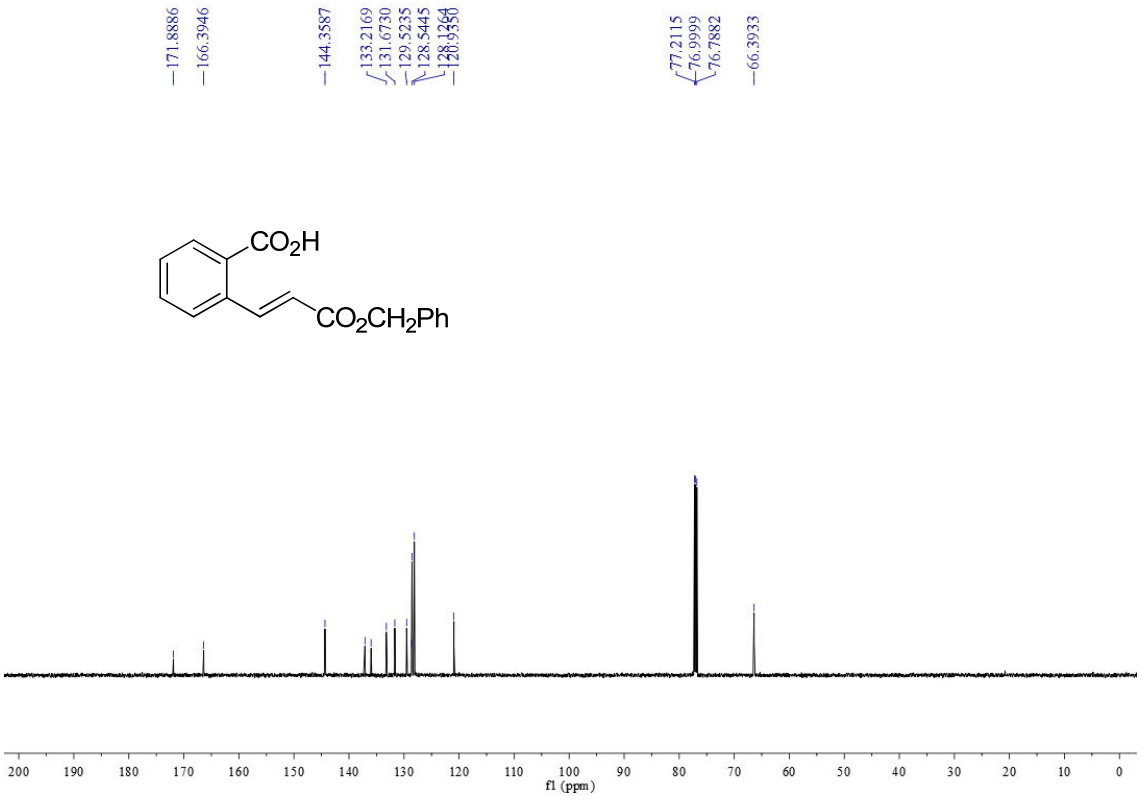
^{13}C NMR spectra of compound of 3ad'



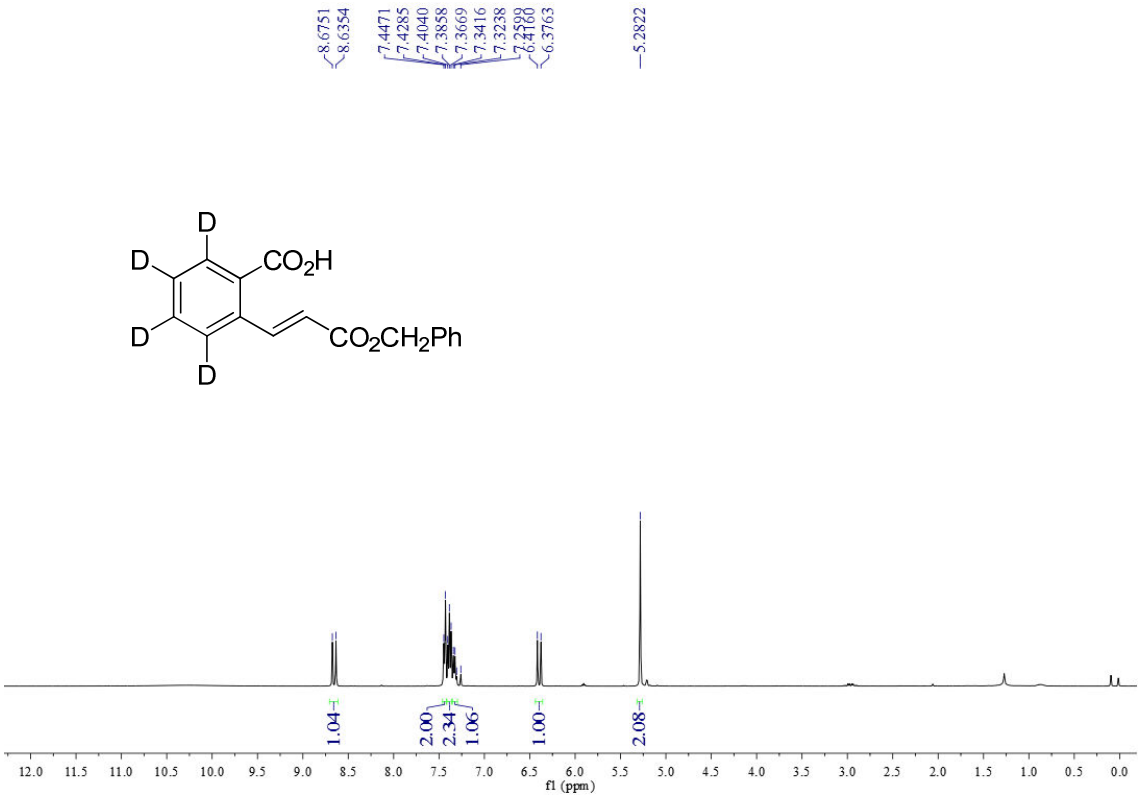
^{1}H NMR spectra of compound of 3ae



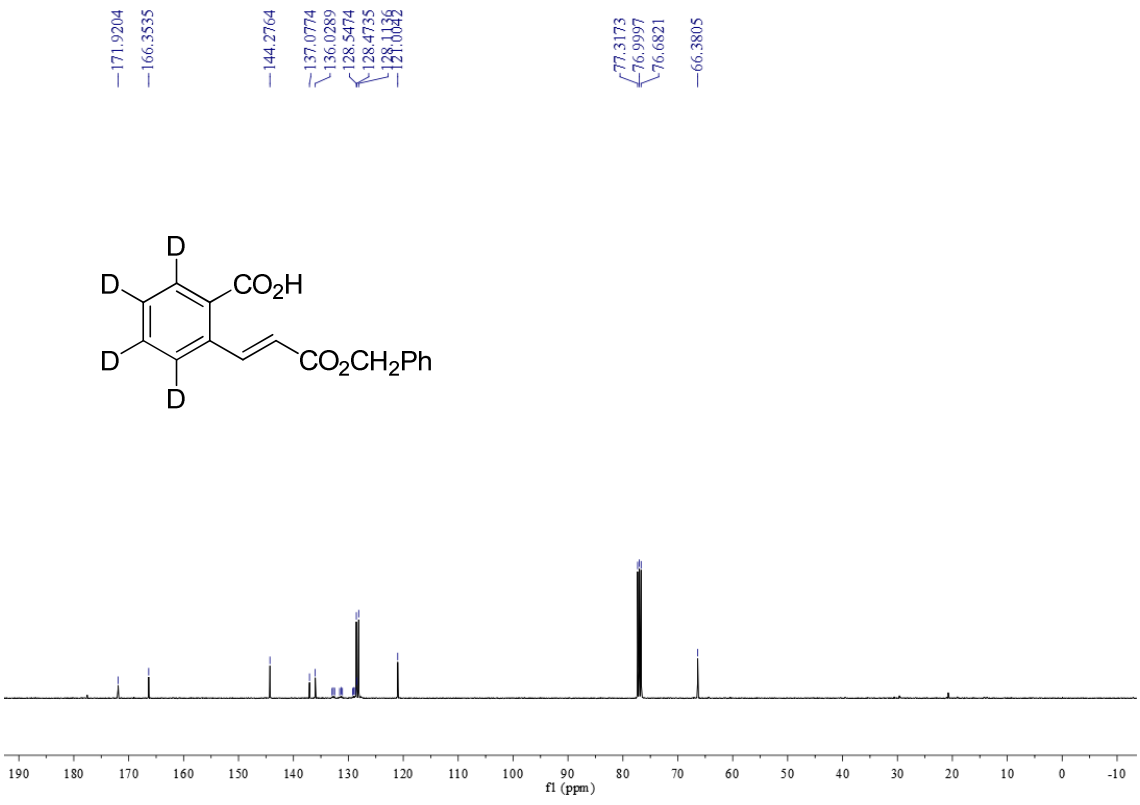
^{13}C NMR spectra of compound of 3ae



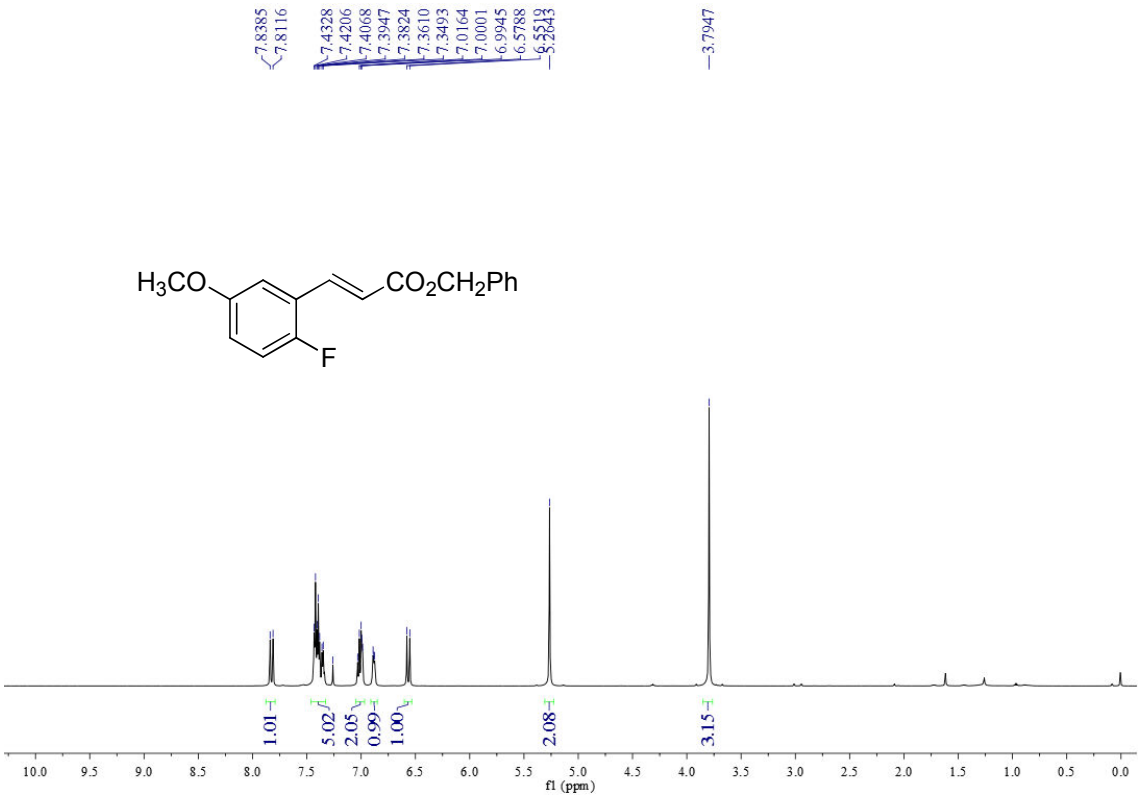
^{1}H NMR spectra of compound of *D*$_4$-3ae



^{13}C NMR spectra of compound of *D*$_4$-3ae



^{1}H NMR spectra of compound of 3af



^{13}C NMR spectra of compound of 3af