Electronic Supplementary Material (ESI) for ChemComm.

Supporting Information

Visible-Light-Driven Site-selective Alkylation of Benzo Core of Coumarins

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Table of Content

1. General Information.

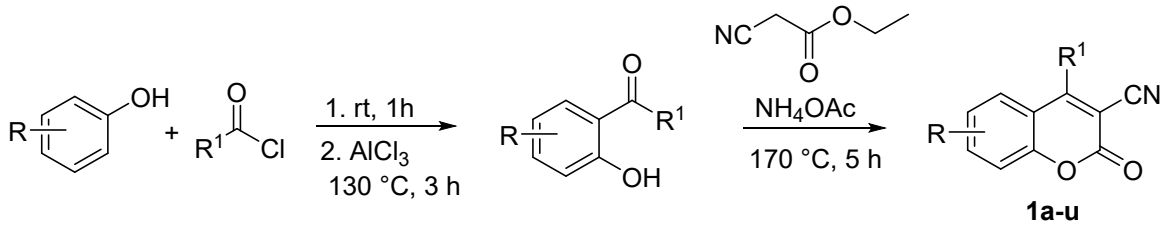
Nuclear magnetic resonance (NMR) spectra were recorded in deuterated solvents with residual protonated solvent signal as internal reference on a Bruker-Ava-400 and Bruker-Ava-500. Chemical shifts are reported in parts per million using the solvent resonance internal standard (chloroform, 7.26 and 77.0 ppm). Data is reported as follows: chemical shift, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet), coupling constant, and integration. Electrospray and electron impact high resolution mass spectrometry was performed by Bruker mass spectrometer. The data is recorded as the ionization method followed by the calculated and measured masses. The Fluorescence emission intensities were measured on Horiba-Jobin-Yvon. Solvents for starting material preparation and coupling reactions were dried before use. Blue LEDs (2.50 W, λ = 465 nm) Rebel LED, mounted on a 25 mm cool base was purchased from commercial supplier Luxeon Star LEDs Quadica Developments Inc.10-3447 30 Ave N. Lethbridge, Alberta T1H 7B5 Canada.

2. Preparation of Starting Materials

2.1. Preparation of Coumarins

3, 4-disubstituted cyanocoumarins **1a-1b**[1a], **1f-1h**[2], **1i**[3], **1t**[4] are known starting materials and synthesized accordingly. **1c-1e, 1j-1n, 1o, 1p-1s, 1u** were synthesized by using known literature procedure.[1a]

2.1.1. Preparation of 3, 4-disubstituted cyanocoumarins (1c-1e, 1g, 1k-1n, 1p-1s, 1u):

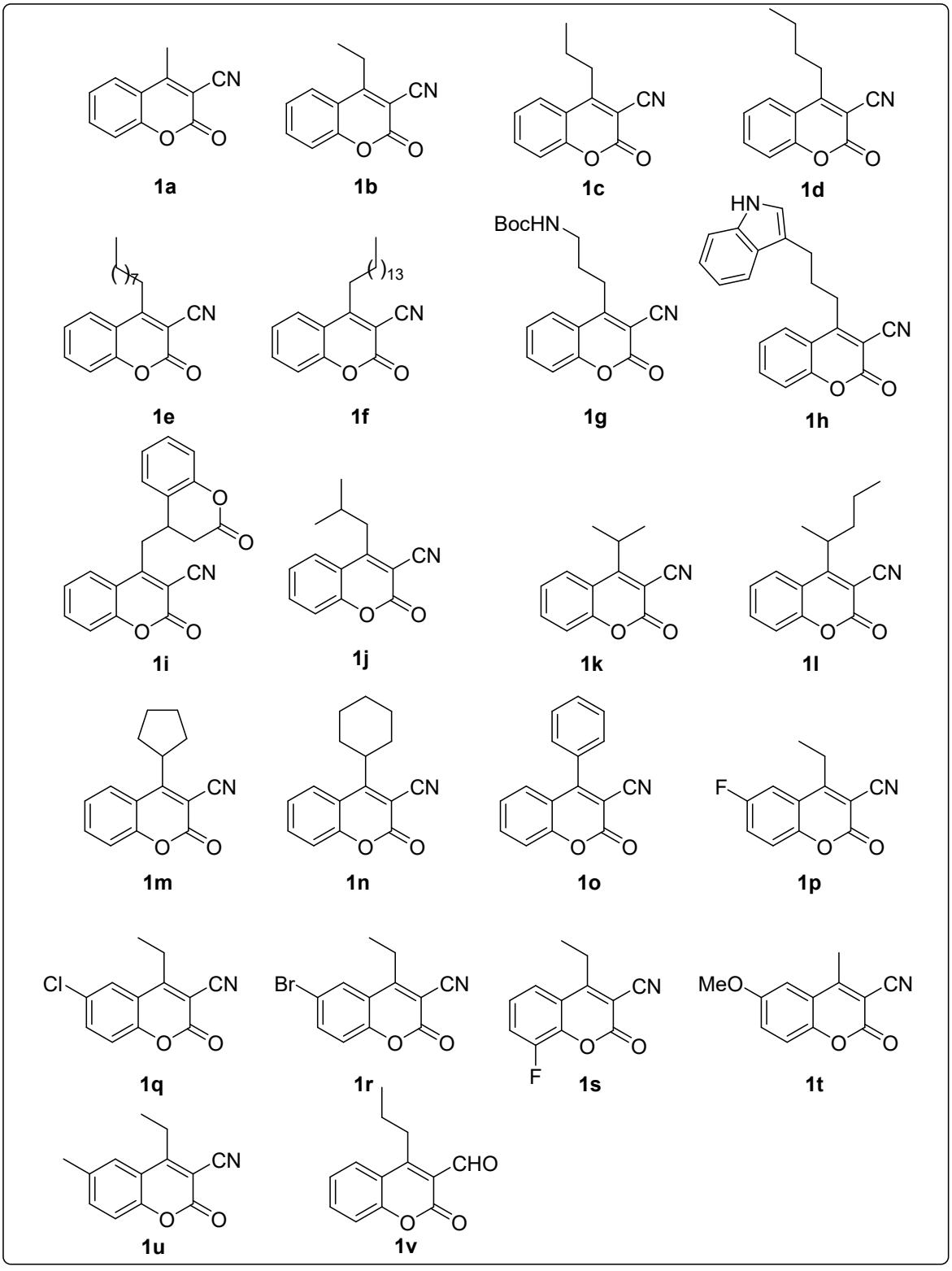


1a-u

Substituted phenol (4 mmol, 1 equiv) was added in corresponding acyl chloride (6 mmol and 1.5 equiv) and reaction mixture stir for 1 h at rt. After that, $AlCl_3$ (4 mmol, 1 equiv) was added and reaction mixture heated at 130 ˚C for 3 h. Brown sticky mixture diluted with EtOAc and extracted with EtOAc (3X50 mL) and washed with brine solution. Resulted oily compound used for further reaction. To a solution of *o*-hydroxy phenone (2 mmol, 1 equiv.) ethyl cyanoacetate (1.5 equiv.) and ammonium acetate (2.5 equiv.) were mixed in 250 mL flask and reflux at 170 ˚C in oil bath for 5 h. the mixture was then cooled to rt, EtOH (100 mL) was added in the reaction mixture, and stirred for 12 h at rt. The precipitate solid is then filtered and dried. If it is not precipitated, solution was concentrated by evaporation of the solvent.

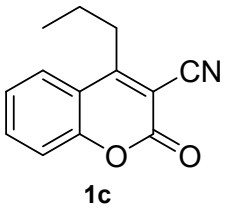
Purification by column chromatography on silica gel (EtOAc: hexane = 5:5) gave a yellow powder solid **1.**

Table S1: Substrate Scope of Substituted Coumarins



2.1.1.1 Characterization of 3, 4-disubstituted cyanocoumarins.

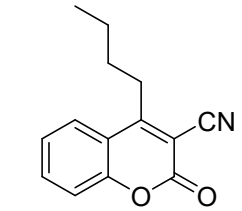
2-Oxo-4-propyl-2*H*-chromene-3-carbonitrile (1c)



1c

Physical state: White solid; **Yield**: 250 mg (59%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.76-7.68 (m, 2H), 7.43 – 7.40 (m, 2 H), 3.10 (t, *J* = 8.0 Hz, 2H), 1.85-1.79 (m, 2H), 1.16-1.12 (t, *J* = 8.0 Hz, 3H). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 166.6, 157.0, 153.9, 135.2, 126.1, 125.5, 118.1, 117.5, 113.6, 102.0, 33.8, 23.5, 14.3. **HRMS (ESI/QTOF), m/z:** $[M+Na]^+$ Calcd. For $C_{13}H_{11}NO_2Na$, 236.0682; Found: 236.0678.

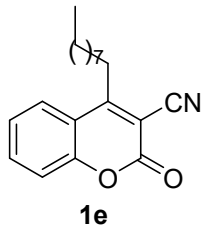
4-butyl-2-oxo-2*H*-chromene-3-carbonitrile (1d)



1d

Physical state: White solid; **Yield**: 200 mg (44%). **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.78 – 7.73 (m, 1H), 7.72 – 7.66 (m, 1H), 7.48 – 7.35 (m, 2H), 3.14 – 3.05 (m, 2H), 1.73 (dt, *J* = 15.6, 7.6 Hz, 2H), 1.61 – 1.49 (m, 2H), 1.00 (t, *J* = 7.3 Hz, 3H). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 166.9, 156.9, 153.9, 135.2, 126.1, 125.6, 118.0, 117.5, 113.5, 101.7, 31.9, 31.8, 23.0, 13.8. **HRMS (ESI/QTOF), m/z:** $[M+Na]^+$ Calcd. For $C_{14}H_{13}NO_2Na$, 250.0838; Found: 250.0832.

4-nonyl-2-oxo-2*H*-chromene-3-carbonitrile (1e):

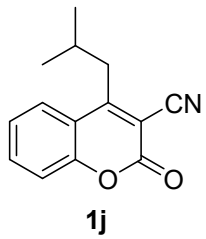


1e

Physical state: white solid; **Yield**: 200 mg (34%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.79 – 7.65 (m, 2H), 7.51 – 7.30 (m, 2H), 3.16 – 3.02 (m, 2H), 1.80 – 1.67 (m, 2H), 1.57 – 1.45 (m, 2H), 1.42 – 1.18 (m, 10H), 0.85 (dd, *J* = 6.7, 5.2 Hz, 3H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 166.9, 156.9, 153.8, 135.2, 126.0, 125.6, 117.9, 117.4,

113.5, 101.7, 32.0, 31.8, 29.9, 29.8, 29.4, 29.3, 29.2, 22.7, 14.1. **HRMS (ESI/QTOF), m/z:** $[M+Na]^+$ Calcd. For $C_{19}H_{23}NNaO_2$ 320.1621; Found: 320.1626.

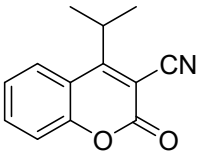
4-isobutyl-2-oxo-2*H*-chromene-3-carbonitrile (1j):



1j

Physical state: white solid; **Yield**: 213 mg (47 %). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.77 – 7.65 (m, 2H), 7.44 – 7.35 (m, 2H), 3.00 (dd, J = 7.4, 1.4 Hz, 2H), 2.14 (dt, J = 13.6, 6.8 Hz, 1H), 1.09 (dd, J = 6.7, 2.1 Hz, 6H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 165.8, 156.9, 153.7, 135.2, 126.3, 125.5, 117.9, 117.8, 113.9, 102.4, 40.6, 30.4, 22.7. **HRMS (ESI/QTOF), m/z:** $[M+H]^+$ Calcd. For $C_{14}H_{14}NO_2$, 228.1019; Found: 218.1025.

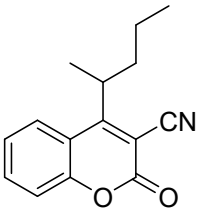
4-isopropyl-2-oxo-2*H*-chromene-3-carbonitrile (1k):



1k

Physical state: yellow solid; **Yield**: 170 mg (40 %). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.96 (d, *J* = 7.8 Hz, 1H), 7.77 – 7.60 (m, 1H), 7.40 (t, *J* = 7.3 Hz, 2H), 3.75 (dt, *J* = 14.3, 7.1 Hz, 1H), 1.59 (d, *J* = 7.2 Hz, 6H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 171.4, 157.6, 153.8, 135.0, 126.1, 125.3, 118.4, 117.1, 113.9, 100.8, 29.8, 20.8. **HRMS (ESI/QTOF), m/z:** $[M+H]^+$ Calcd. For $C_{13}H_{12}NO_2$, 214.0862; Found: 214.0874.

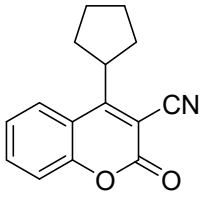
2-oxo-4-(pentan-2-yl)-2*H*-chromene-3-carbonitrile (1l)



1l

Physical state: white solid; **Yield:**193 mg (40 %). **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.97 (s, 1H), 7.69 (t, *J* = 7.8 Hz, 1H), 7.40 (dd, *J* = 12.5, 7.9 Hz, 2H), 3.60 (s, 1H), 1.93 (ddd, J = 13.5, 9.6, 6.5 Hz, 1H), 1.57 (d, J = 7.2 Hz, 3H), 1.31 – 1.21 (m, 2H), 0.93 (t, J = 7.3 Hz, 3H). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 170.9, 157.5, 153.8, 134.9, 125.2, 118.4, 113.9, 37.2, 29.8, 22.8, 21.6, 14.0. **HRMS (ESI/QTOF), m/z:** $[M+Na]^+$ Calcd. For $C_{15}H_{15}NNaO_2$, 264.0994; Found 264.1003.

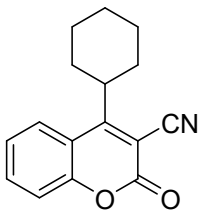
4-cyclopentyl-2-oxo-2*H*-chromene-3-carbonitrile (1m)



1m

Physical state: yellow solid; **Yield**: 277 mg (58%). **^{1}H NMR** (300 MHz, $CDCl_3$) δ 7.87 (d, *J* = 8.1 Hz, 1H), 7.68 (t, *J* = 7.8 Hz, 1H), 7.39 (dd, *J* = 15.6, 7.9 Hz, 2H), 3.88 – 3.64 (m, 1H), 2.26 – 2.04 (m, 6H), 1.90 (s, 2H); **^{13}C NMR** (75 MHz, $CDCl_3$) δ 170.5, 157.5, 153.8, 134.9, 126.1, 125.1, 118.5, 117.3, 113.9, 101.3, 43.1, 33.4, 27.7; **HRMS (ESI/QTOF), m/z:** $[M+Na]^+$ Calcd. For $C_{15}H_{13}NO_2Na$, 262.0838; Found: 262.0836.

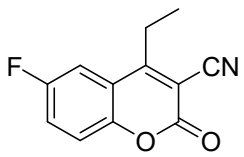
4-cyclohexyl-2-oxo-2*H*-chromene-3-carbonitrile (1n):



1n

Physical state: white solid; **Yield**: 329 mg (65%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.97 (s, 1H), 7.67 (t, *J* = 7.8 Hz, 1H), 7.38 (t, *J* = 7.5 Hz, 2H), 3.32 (s, 1H), 2.19 (m, 2H), 1.97 (d, *J* = 7.1 Hz, 2H), 1.86 (d, *J* = 10.6 Hz, 3H), 1.45 (t, *J* = 8.9 Hz, 3H). **^{13}C NMR** (75 MHz, $CDCl_3$) δ 169.9, 157.7, 153.6, 135.0, 125.2, 118.2, 117.3, 114.2, 100.7, 29.9, 26.5, 25.3. **HRMS (ESI/QTOF), m/z:** $[M+Na]^+$ Calcd. For $C_{16}H_{15}NO_2Na$, 276.0994; Found: 276.0991.

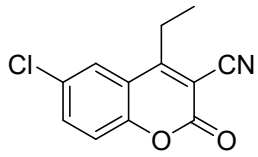
4-ethyl-6-fluoro-2-oxo-2*H*-chromene-3-carbonitrile (1p):



1p

Physical state: Yellow powder; **Yield**: 252 mg (58%). **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.47 – 7.40 (m, 3H), 3.10 (q, *J* = 7.7 Hz, 2H), 1.43 (t, *J* = 7.7 Hz, 3H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 167.0, 160.4, 158.4, 156.6, 150.2, 122.7, 119.8, 118.1, 112.9, 111.4, 102.7, 25.8, 13.9; **^{19}F NMR** (471 MHz, $CDCl_3$) -114.6**. HRMS (ESI/QTOF), m/z:** $[M+H]^+$ Calcd. For $C_{12}H_9NO_2$, 218.0611; Found: 218.0610.

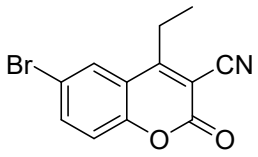
6-chloro-4-ethyl-2-oxo-2*H*-chromene-3-carbonitrile (1q):



1q

Physical state: Yellow powder; **Yield**: 265 mg (52%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.71 (s, 1H), 7.64 (d, *J* = 8.4 Hz, 1H), 7.37 (d, *J* = 8.8 Hz, 1H), 3.10 (q, *J* = 7.6 Hz, 2H), 1.42 (t, *J* = 7.6 Hz, 3H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 166.9, 156.4, 152.3, 135.1, 131.3, 125.3, 119.6, 118.3, 112.9, 102.6, 25.4, 13.9; **HRMS (ESI/QTOF), m/z:** $[M+Na]^+$ Calcd. For $C_{12}H_8ClNO_2Na$, 256.0135; Found: 256.0127.

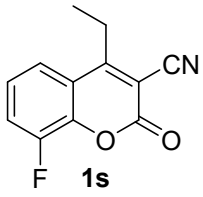
6-bromo-4-ethyl-2-oxo-2*H*-chromene-3-carbonitrile (1r):



1r

Physical state: Yellow powder; **Yield**: 358 mg (65%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.85 (d, *J* = 2.2 Hz, 1H), 7.78 (dd, *J* = 8.8, 2.2 Hz, 1H), 7.30 (d, *J* = 8.8 Hz, 1H), 3.10 (q, *J* = 7.7 Hz, 2H), 1.42 (t, *J* = 7.7 Hz, 3H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 166.9, 156.3, 152.8, 137.9, 128.3, 119.8, 118.7, 118.5, 112.9, 102.6, 25.4, 14.0; **HRMS (ESI/QTOF), m/z:** $[M+H]^+$ Calcd. For $C_{12}H_8BrNO_2$, 277.9811; Found: 277.9805.

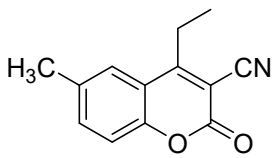
4-ethyl-8-fluoro-2-oxo-2*H*-chromene-3-carbonitrile (1s):



1s

Physical state: pale yellow solid; **Yield**: 230 mg (53%). **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.55 (d, *J* = 8.1 Hz, 1H), 7.52 – 7.46 (m, 1H), 7.38 (td, *J* = 8.2, 4.7 Hz, 1H), 3.14 (q, *J* = 7.7 Hz, 2H), 1.42 (t, *J* = 7.7 Hz, 3H). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 167.9, 155.6, 151.0, 149.0, 142.4, 125.4, 121.2, 119.0, 112.9, 102.3, 25.8, 14.1. **^{19}F NMR** (471 MHz, $CDCl_3$) -130.8**. HRMS (ESI/QTOF), m/z:** $[M+Na]^+$ Calcd. For $C_{12}H_8FN\ O_2Na$, 240.0431; Found: 240.0427.

4-ethyl-6-methyl-2-oxo-2*H*-chromene-3-carbonitrile (1u):

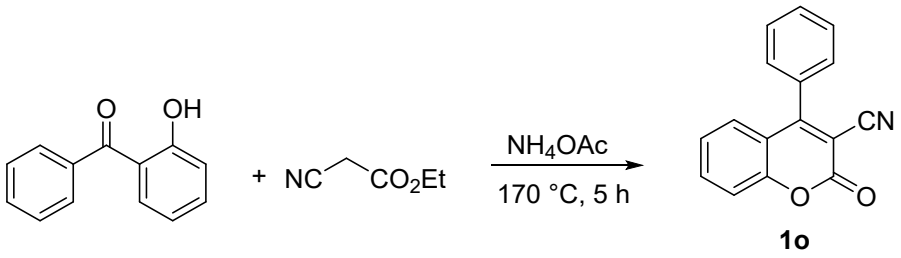


1u

Physical state: Yellow powder; **Yield**: 221 mg (52%). **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.50 (d, *J* = 8.2 Hz, 2H), 7.29 (d, *J* = 8.3 Hz, 1H), 3.11 (q, *J* = 7.7 Hz, 2H), 2.47 (s, 3H), 1.41 (t, *J* = 7.7 Hz, 3H); **^{13}C NMR** (126 MHz, $CDCl_3$) δ 168.1,

157.2, 152.1, 136.4, 135.6, 125.5, 117.8, 116.9, 113.4, 101.2, 25.3, 21.1, 14.1; **HRMS (ESI/QTOF), m/z:** $[M+H]^+$ Calcd. For $C_{13}H_{12}NO_2$, 214.0862; Found: 214.0870.

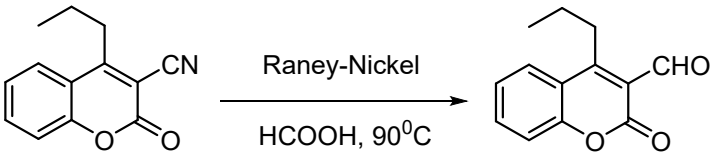
2.1.2. Synthesis of 2-oxo-4-phenyl-2*H*-chromene-3-carbonitrile (1o):



1o

To a solution of 2-hydroxy benzophenone (2 mmol, 1 equiv.) ethyl cyanoacetate (1.5 equiv.) and ammonium acetate (2.5 equiv.) were mixed in 250 mL flask and reflux at 170 ˚C in oil bath for 5 h. the mixture was then cooled to rt, EtOH (100 mL) was added in the reaction mixture, and stirred for overnight at rt. The precipitate solid is then filtered and dried gave pale yellow solid compound **1o. Yield**: 148 mg (30 %). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.71 (ddd, *J* = 8.7, 7.2, 1.7 Hz, 1H), 7.61 (ddd, *J* = 9.5, 5.3, 1.4 Hz, 3H), 7.53 – 7.43 (m, 3H), 7.40 (dd, *J* = 8.1, 1.5 Hz, 1H), 7.34 – 7.28 (m, 1H). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 164.3, 157.1, 154.2, 135.4, 131.8, 131.3, 129.3, 129.2, 128.6, 125.5, 118.2, 117.8, 113.6, 101.8. **HRMS (ESI/QTOF), m/z:** $[M+Na]^+$ Calcd. For $C_{16}H_9NNaO_2$, 270.0525; Found 270.0522**.**

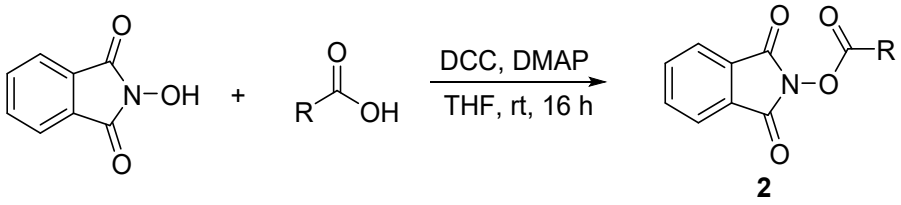
2.1.3. Synthesis of 2-oxo-4-propyl-2H-chromene-3-carbaldehyde (1v):[1b]



A solution of 3-cyanocoumarin (2 mmol) in hot (80–90°C) formic acid (6 mL) was stirred and treated with Raney nickel (400 mg, wet) as suspension in formic acid (1 mL). The mixture was vigorously stirred at 80–90°C until completion of reaction (1.5–2 h) as monitored by TLC. Then the mixture was filtered through a Celite pad, which was washed with hot ethyl acetate (30 mL). The resulting clear yellow solution was concentrated in vacuo to give crude aldehyde as yellow oil. A solution of this oil was dissolved in dichloromethane and filtered through a silica gel pad (3–4 cm), which was further washed with dichloromethane until the eluting solution contained no product. Product **1v** was purified by crystallization from ethanol. **Yield**: 216 mg (50 %). **^{1}H NMR (500 MHz, $CDCl_3$)** δ 10.43 (s, 1H), 7.85 (dd, *J* = 8.1, 1.5 Hz, 1H), 7.64 (ddd, *J* = 8.5, 7.3, 1.5 Hz, 1H), 7.43 – 7.30 (m, 2H), 3.26 (ddd, *J* = 9.7, 5.7, 1.4 Hz, 2H), 1.73 – 1.61 (m, 2H), 1.13 (td, *J* = 7.3, 1.4 Hz, 3H). **^{13}C NMR (126 MHz, $CDCl_3$)** δ 191.2, 163.2, 161.4, 154.5, 134.4, 127.0, 125.2, 119.4, 118.3, 117.7, 29.7, 24.0, 14.7.

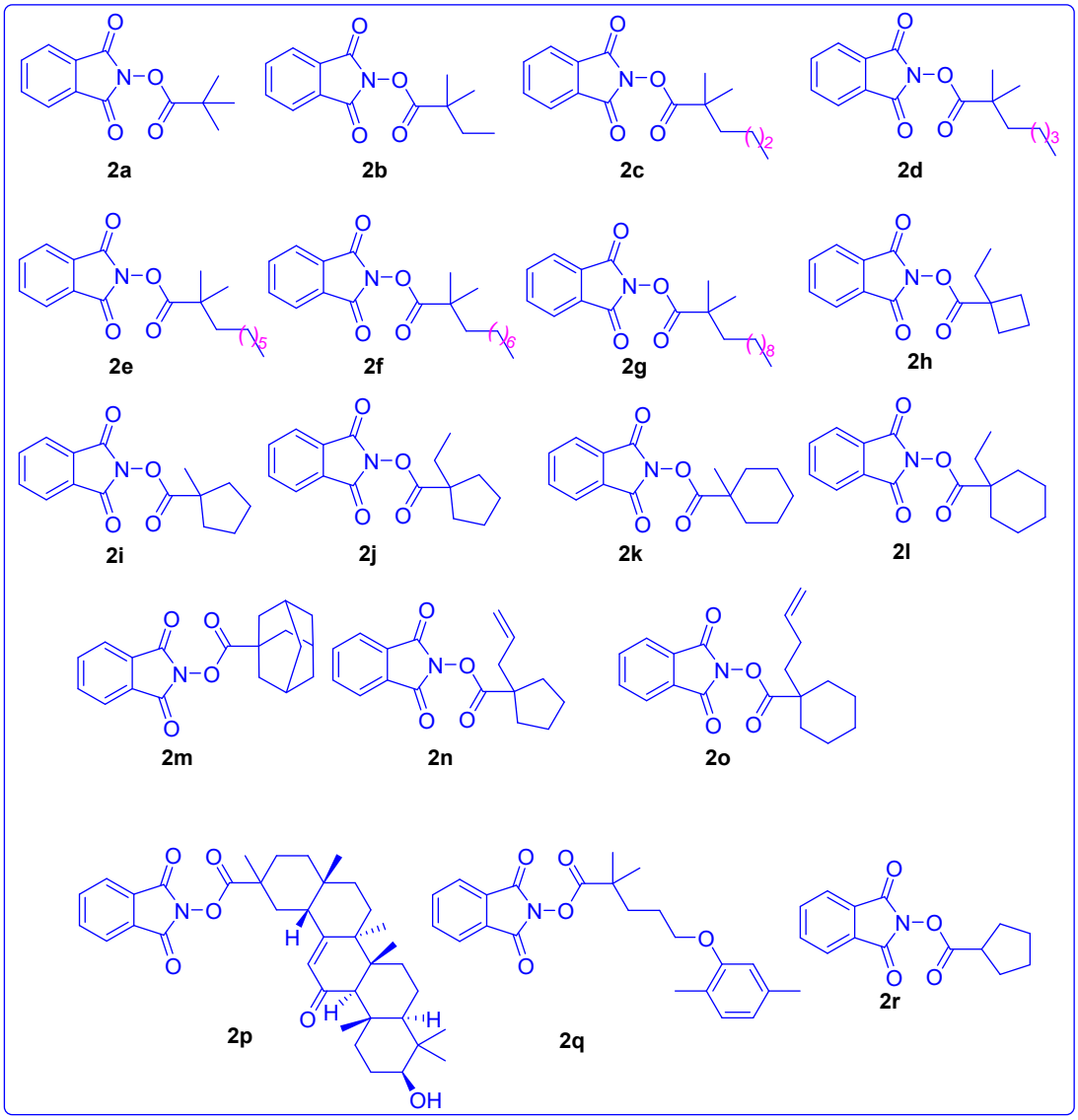
2.2 Preparation of *N*-(acyloxy)phthalimides (2):

All *N*-(Acyloxy)phthalimides) (**2**) were synthesized by following known literature procedure.[2] The respective carboxylic acid (4.00 mmol, 1.0 equiv.), *N*-hydroxyphthalimide (721 mg, 4.40 mmol, 1.1 equiv.), *N*,*N*'-dicyclohexylcarbodiimide (988 mg, 4.8 mmol, 1.2 equiv.) and 4-dimethylaminopyridine (48 mg, 0.80 mmol, 0.1 equiv.) were mixed in a flask with a magnetic stirring bar. Dry THF (20 mL) was added and the orange reaction mixture was stirred for 15 h at rt. After completion of reaction the white precipitate was filtered off and the solution was concentrated by evaporation of the solvent. Purification by column chromatography on silica gel (EtOAc: hexane = 3:7) gave a white solid **2a-r.**



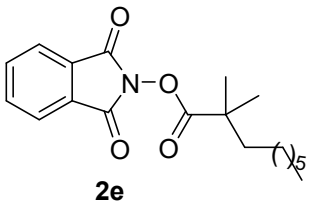
2

Table S2: Substrate Scope of N-(acyloxy) phthalimide esters



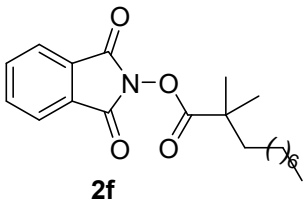
2.2.1 Characterization of NHPI esters

1,3-dioxoisoindolin-2-yl 2,2-dimethylnonanoate (2e):



Physical state: white solid; **Yield**: 700 mg (52%). **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.87 – 7.81 (m, 2H), 7.78 – 7.73 (m, 2H), 1.72 – 1.67 (m, 2H), 1.43 – 1.39 (m, 2H), 1.37 (s, 6H), 1.32-1.28 (m, 8H), 0.87 (t, J = 6.7 Hz, 3H). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 174.1, 162.2, 134.7, 129.1, 123.9, 42.2, 40.8, 31.9, 30.1, 29.2, 25.2, 24.8, 22.7, 14.2. **HRMS (ESI/QTOF), m/z:** $[M+Na]^+$ Calcd. For $C_{19}H_{25}NNaO_4$, 354.1676; Found 354.1680.

1,3-dioxoisoindolin-2-yl 2,2-dimethyldecanoate (2f)



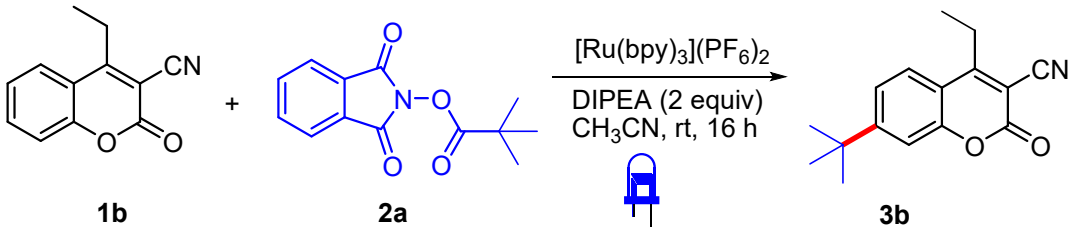
2f

Physical state: white solid; **Yield**: 740 mg (54 %). **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.83 (dt, *J* = 7.1, 3.6 Hz, 2H), 7.78 – 7.71 (m, 2H), 1.72 – 1.66 (m, 2H), 1.42 (d, *J* = 8.7 Hz, 2H), 1.37 (d, *J* = 10.5 Hz, 6H), 1.33 – 1.23 (m, 10H), 0.86 (t, *J* = 6.8 Hz, 3H). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 174.0, 162.2, 134.7, 129.1, 123.9, 42.2, 40.8, 31.9, 30.1, 29.5, 29.4, 25.2, 24.8, 22.8, 14.2. **HRMS (ESI/QTOF), m/z:** $[M+Na]^+$ Calcd. For $C_{20}H_{27}NNaO_4$, 368.1832; Found 368.1835.

3: General procedure of the C-7alkylation of coumarins

3.1. Optimization of reaction condition

Table S3: Catalyst loading

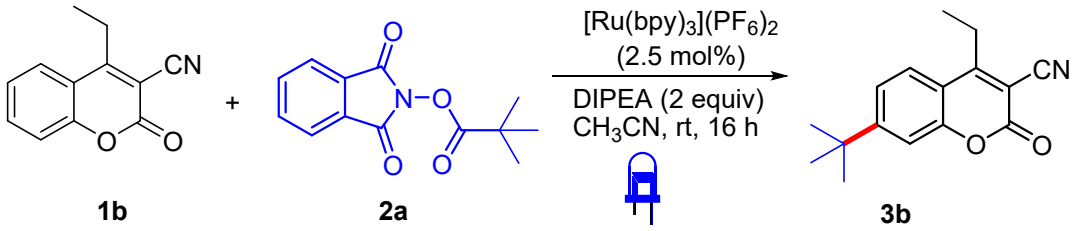


1b **2a** **3b**

Entry	mol% of $[Ru(bpy)_3](PF_6)_2$	Yield (%)
1	2.5	65
2	5	62
3	10	60

[a]Reaction conditions: reactions were carried out with 0.2 mmol of **1b** and 0.4 mmol of **2a** in the presence of $[Ru(bpy)_3](PF_6)_2$, 0.4 mmol of DIPEA in 2 mL of CH_3CN at rt under blue light irradiation.

Table S4: Solvent Concentration

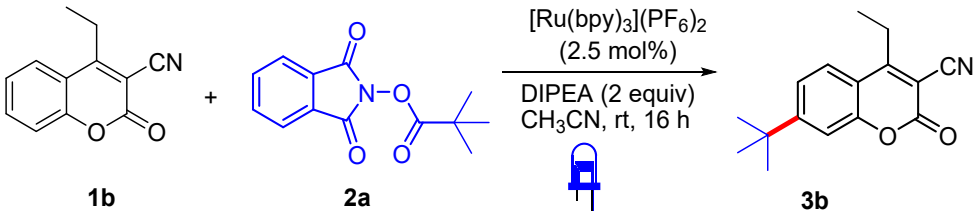


1b **2a** **3b**

Entry	Concentration (M)	Yield (%)
1	0.4	56
2	0.2	58
3	0.1	65
4	0.06	48
5	0.05	32

[a]Reaction conditions: reactions were carried out with 0.2 mmol of **1b** and 0.4 mmol of **2a** in the presence of 2.5 mol% of $[Ru(bpy)_3](PF_6)_2$, 0.4 mmol of DIPEA in CH_3CN at rt under blue light irradiation.

Table S5: Tert-Butyl NHPI ester loading screening



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

Entry	Equiv of **2a**	Yield (%)
1	1	35
2	1.5	58
3	2	65
4	3	62

[a]Reaction conditions: reactions were carried out with 0.2 mmol of **1b** and **2a** in the presence of 2.5 mol% of $[Ru(bpy)_3](PF_6)_2$, 0.4 mmol of DIPEA in 2 mL of CH_3CN at rt under blue light irradiation.

4. Mechanistic Investigations

4.1 Fluorescence titration of photocatalyst

The Fluorescence emission intensities were measured on Horiba-Jobin-Yvon. The excitation wavelength was fixed at 450 nm and the emission wavelength was measured at 613 nm. The samples were prepared in DCM by mixing $[Ru(bpy)_3(PF_6)_2$ of concentration $[1*10^6]$ M and different amount of **1a** of concentration $[1*10^3]$ M in quartz cuvette. For successive quenching, respective amount of quencher was added as described in Figure S1 followed by recording the emission intensity.

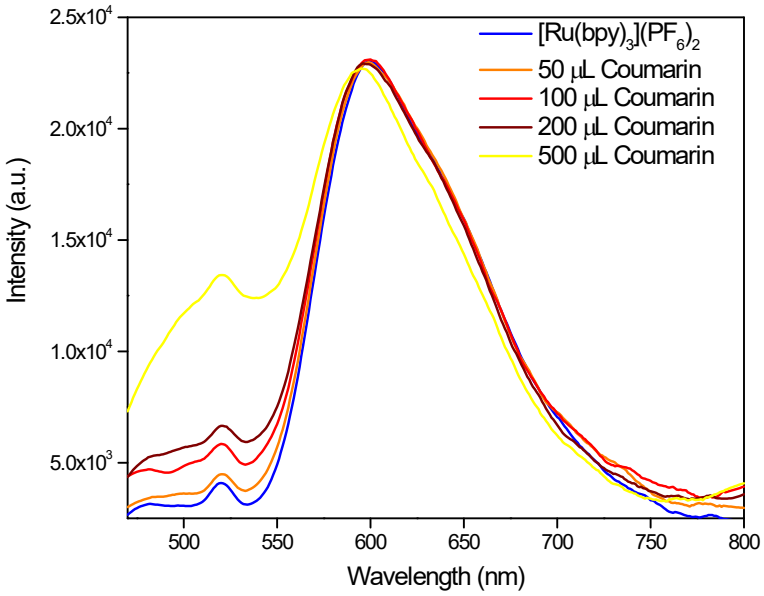


Figure S1: Fluorescence response of $[Ru(bpy)_3(PF_6)_2]$ upon successive addition of **1a** (100 mM in CH_2Cl_2)

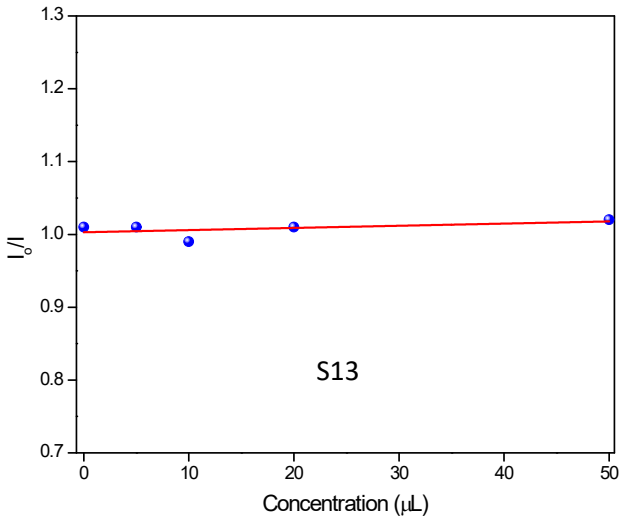


Figure S2: Stern Volmer Plot for Coumarin

The Fluorescence emission intensities were measured on Horiba-Jobin-Yvon. The excitation wavelength was fixed at 450 nm and the emission wavelength was measured at 613 nm. The samples were prepared in DCM by mixing $[Ru(bpy)_3](PF_6)_2$ of concentration $[1*10^6]$ M and different amount of **2a** of concentration $[1*10^3]$ M in quartz cuvette. For successive quenching, respective amount of quencher was added as described in Figure S3 followed by recording the emission intensity.

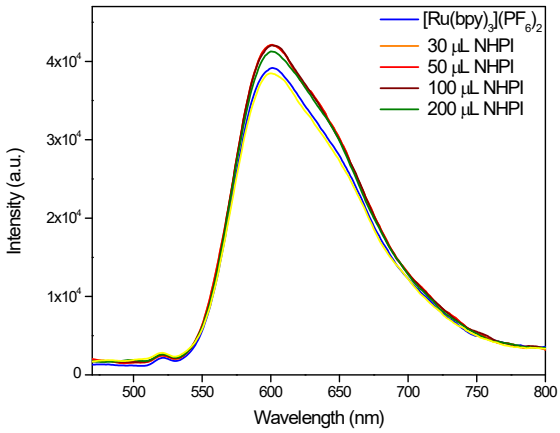


Figure S3: Fluorescence response of $[Ru(bpy)_3](PF_6)_2$ upon successive addition of active ester **2a** (100 mM in CH_2Cl_2).

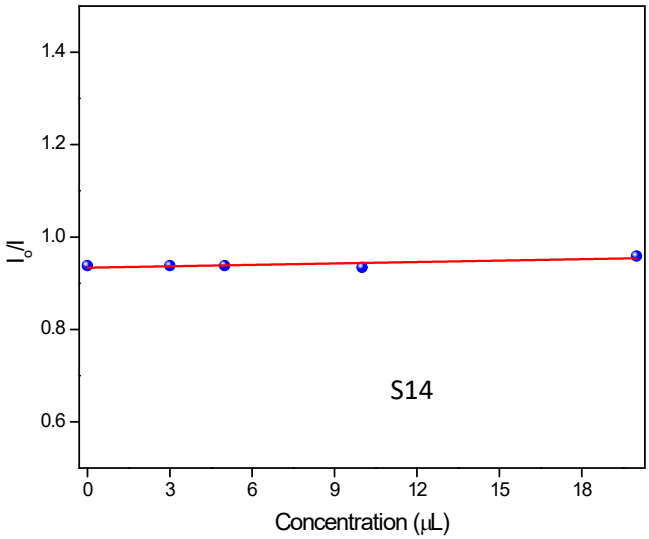


Figure S4: Stern Volmer Plot for NHPI ester.

The Fluorescence emission intensities were measured on Horiba-Jobin-Yvon. The excitation wavelength was fixed at 450 nm and the emission wavelength was measured at 613 nm. The samples were prepared in DCM by mixing $[Ru(bpy)_3](PF_6)_2$ of concentration $[1*10^6]$ M and different amount of **DIPEA** of concentration $[1*10^3]$ M in quartz cuvette. For successive quenching, respective amount of quencher was added as described in Figure S5 followed by recording the emission intensity.

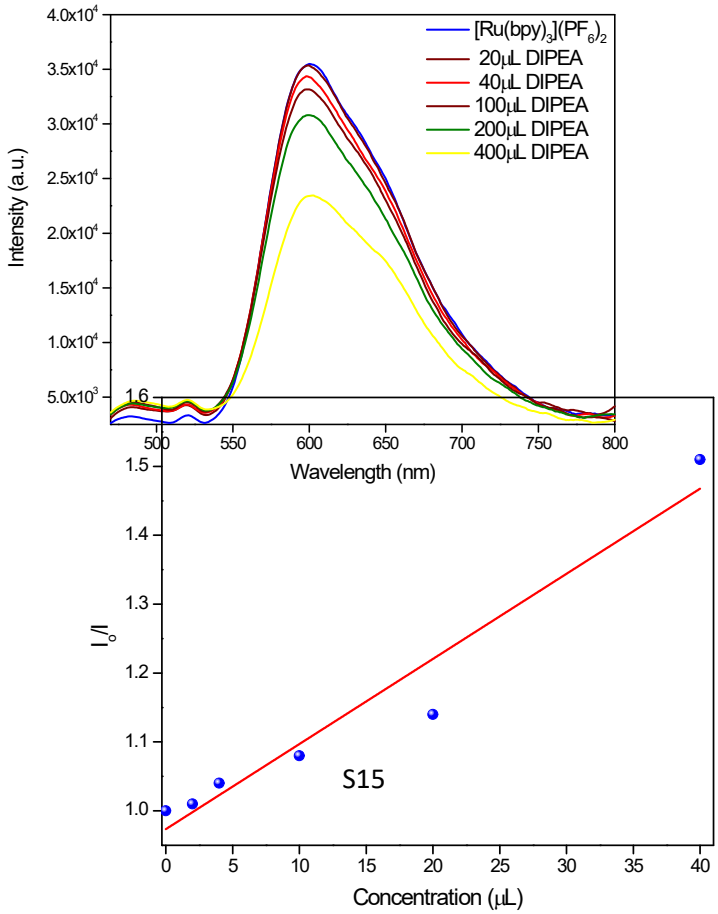


Figure S5: Fluorescence response of $[Ru(bpy)_3](PF_6)_2$

upon successive addition of DIPEA (100 mM in CH_2Cl_2).

Figure S6: Stern Volmer Plot for DIPEA

4.2 DFT calculations:

All quantum chemical calculations were conducted using DFT as implemented in the Gaussian 09 software suite of *ab initio* quantum chemistry programs with B3LYP level of theory.[5-11] Electronic structure complexes were optimized at the unrestricted level using 6-311G (d,p) basis set. All energy calculations were performed in solvated state. We used the Polarizable Continuum Model (PCM) using the integral equation formalism variant (IEFPCM) as the default self-consistent reaction field (SCRF)[10-12] approach based on accurate numerical solutions of the Poisson-Boltzmann equation by using Acetonitrile (ACN) as a solvent in this DFT calculation. The Gibbs free energies in solution phase G(sol) at room temperature were computed with the following equation (A).

$\Delta G(sol) = \Sigma G(sol)$ for products - $\Sigma G(sol)$ for reactants …….. (A)

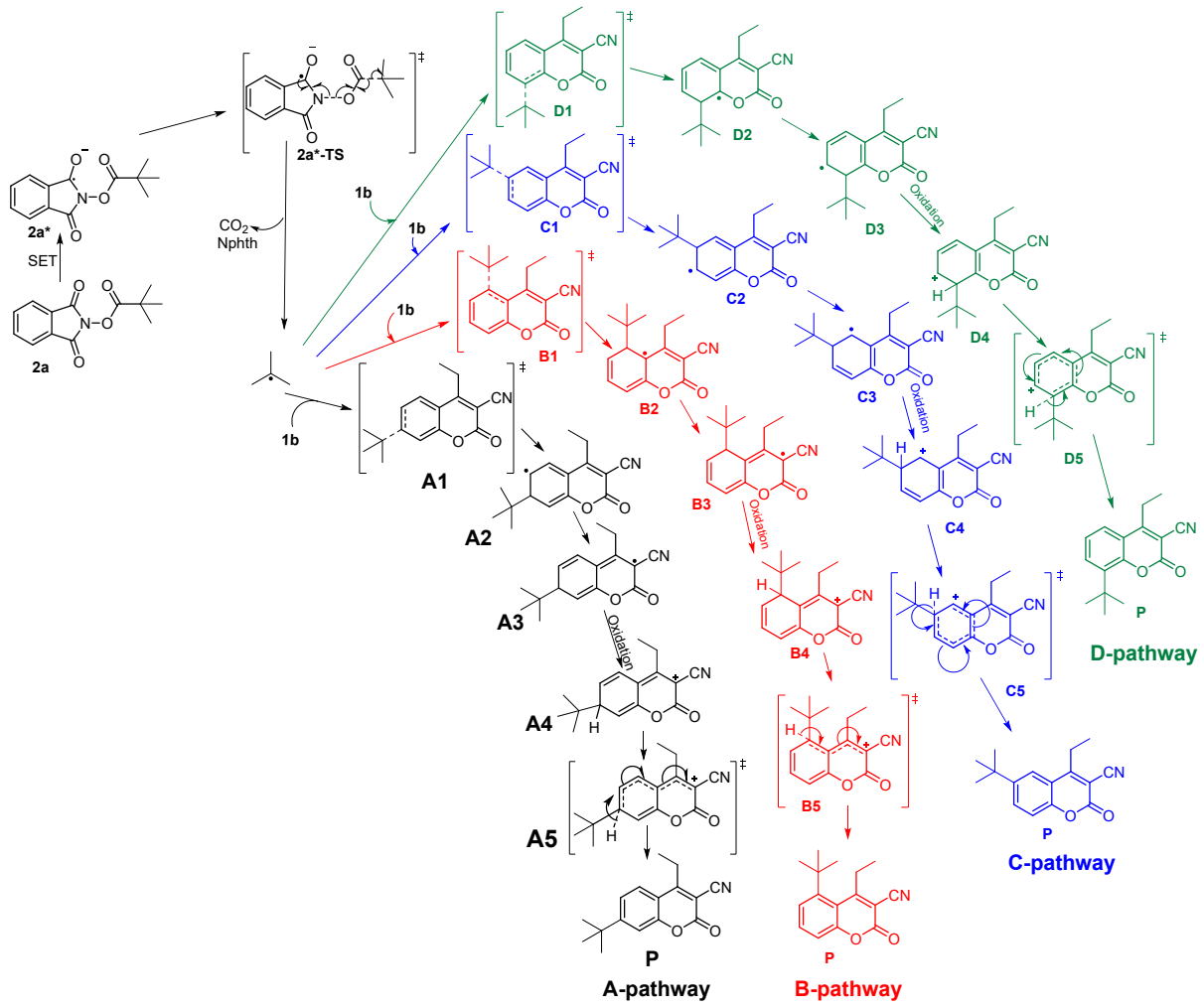
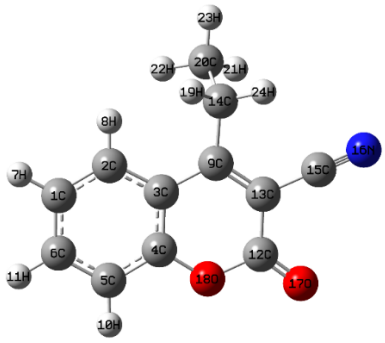


Figure S7. The proposed different pathways (A-D) leading to the production of different regioisomers.



S

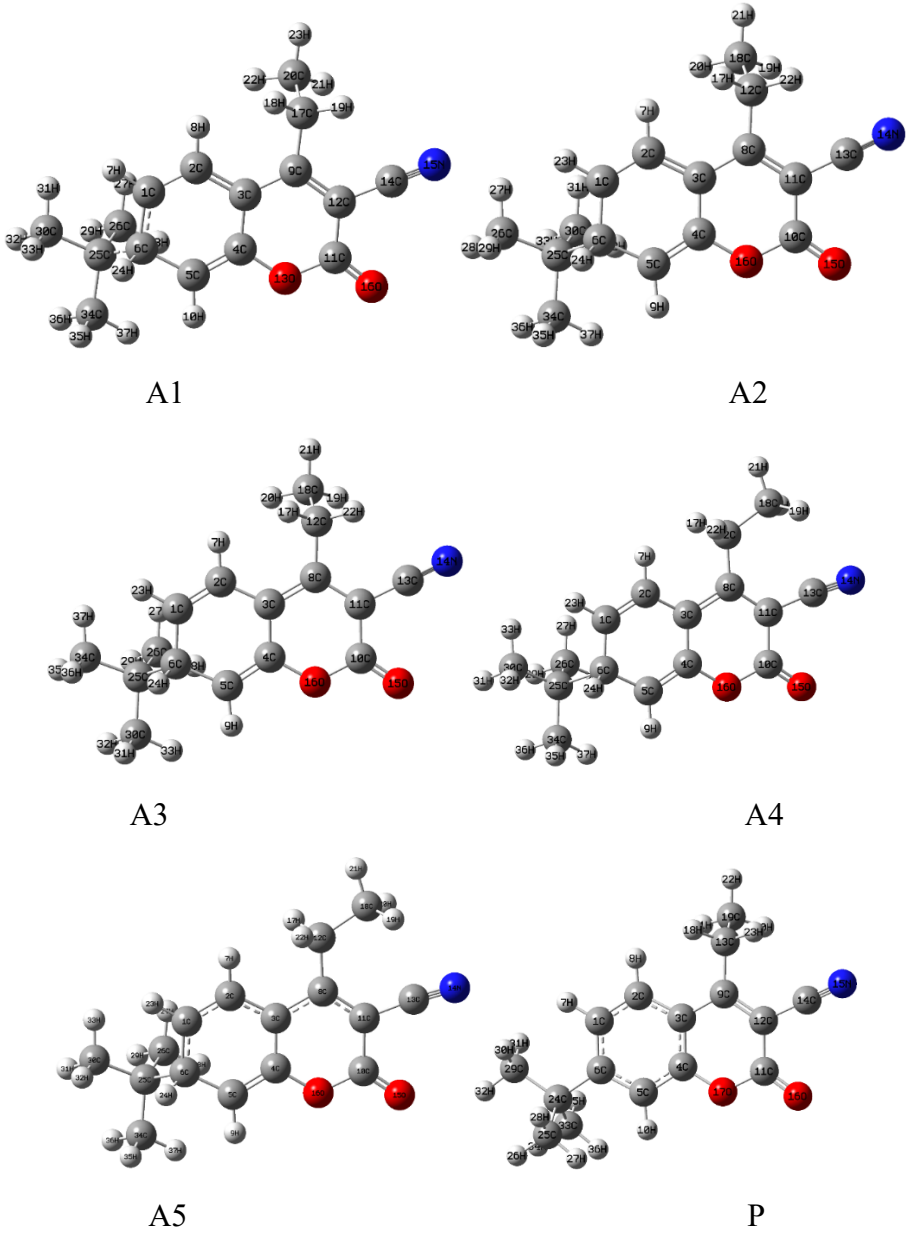
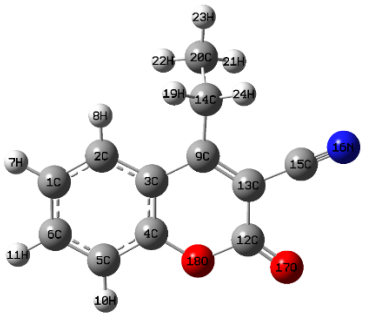


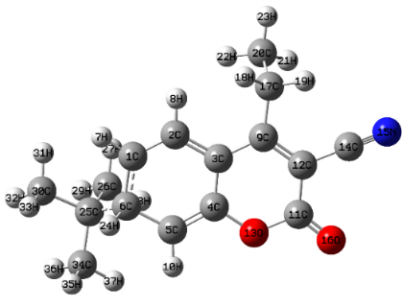
Figure S8. DFT-optimized structures of substrates, product, intermediates and transition states in the A-pathway.



S

Cartesian Coordinate of Starting Compound (S)

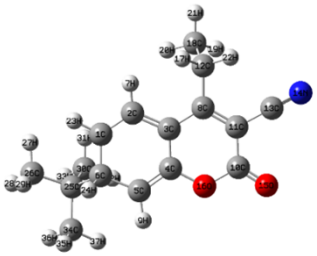
S.No.	Atoms	Coordinates (Angstroms) X	Y	Z
1	C	-4.604459	0.899397	-0.015853
2	C	-3.231658	0.899397	-0.015853
3	C	-2.509720	2.124518	-0.015853
4	C	-3.227590	3.348384	-0.015483
5	C	-4.649006	3.319011	-0.015329
6	C	-5.320511	2.121036	-0.015619
7	H	-5.165190	-0.046949	-0.015933
8	H	-2.666869	-0.044925	-0.016081
9	C	-1.087993	2.154061	-0.016116
10	H	-5.196247	4.273467	-0.015247
11	H	-6.420148	2.094669	-0.015517
12	C	-1.131979	4.573178	-0.015641
13	C	-0.415967	3.351286	-0.016100
14	C	-0.321922	0.818122	-0.016088
15	C	1.123587	3.388339	-0.016354
16	N	2.593162	3.423708	-0.016591
17	O	-0.403055	5.803450	-0.015872
18	O	-2.504840	4.573110	-0.015368
19	H	-0.902385	0.074130	0.488331
20	C	1.024226	0.998318	0.709872
21	H	1.768343	1.313320	0.008471
22	H	0.920147	1.738170	1.475827
23	H	1.319496	0.068667	1.149717
24	H	-0.144498	0.508695	-1.024887



A1

Cartesian Coordinate of A1

S.No.	Atoms	Coordinates (Angstroms) X	Y	Z
1	C	-4.507597	0.030059	0.012291
2	C	-3.134796	0.030059	0.012291
3	C	-2.412858	1.255180	0.012291
4	C	-3.130728	2.479046	0.012661
5	C	-4.552144	2.449673	0.012815
6	C	-5.223649	1.251698	0.012525
7	H	-5.068328	-0.916287	0.012211
8	H	-2.570007	-0.914263	0.012063
9	C	-0.991131	1.284723	0.012028
10	H	-5.099385	3.404129	0.012897
11	C	-1.035117	3.703840	0.012503
12	C	-0.319105	2.481948	0.012044
13	O	-2.407978	3.703772	0.012776
14	C	1.220449	2.519001	0.011789
15	N	2.366717	2.546589	0.011600
16	O	-0.393664	4.786480	0.012299
17	C	-0.225060	-0.051216	0.012056
18	H	-0.194271	-0.444686	1.006608
19	H	-0.721491	-0.747046	-0.631587
20	C	1.211188	0.180621	-0.492962
21	H	1.198699	0.897970	-1.286785
22	H	1.816620	0.547189	0.309522
23	H	1.616157	-0.742214	-0.852511
24	H	-5.856389	1.245788	-0.850322
25	C	-6.134432	1.242652	1.254295
26	C	-5.268607	1.163316	2.525379
27	H	-4.623698	0.311640	2.465052
28	H	-4.678803	2.051947	2.611211
29	H	-5.901741	1.071239	3.383029
30	C	-7.071670	0.022153	1.194599
31	H	-7.942930	0.212249	1.785928
32	H	-7.361118	-0.155986	0.180012
33	H	-6.562161	-0.837814	1.576381
34	C	-6.973799	2.533442	1.284678
35	H	-7.269943	2.789832	0.288955
36	H	-7.844482	2.378608	1.887038
37	H	-6.390169	3.328734	1.699150



A2

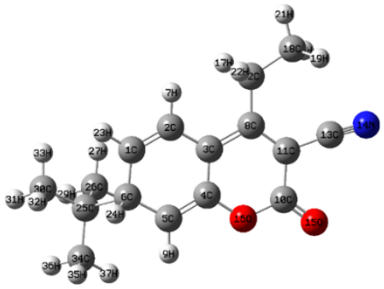
Cartesian Coordinate of A2

S.No.	Atoms	Coordinates (Angstroms) X	Y	Z
1	C	-4.604459	0.899397	-0.015853
2	C	-3.231658	0.899397	-0.015853
3	C	-2.509720	2.124518	-0.015853
4	C	-3.227590	3.348384	-0.015483
5	C	-4.649006	3.319011	-0.015329
6	C	-5.320511	2.121036	-0.015619
7	H	-2.666869	-0.044925	-0.016081
8	C	-1.087993	2.154061	-0.016116
9	H	-5.196247	4.273467	-0.015247
10	C	-1.131979	4.573178	-0.015641
11	C	-0.415967	3.351286	-0.016100
12	C	-0.321922	0.818122	-0.016088
13	C	1.123587	3.388339	-0.016354
14	N	2.593162	3.423708	-0.016591
15	O	-0.403055	5.803450	-0.015872
16	O	-2.504840	4.573110	-0.015368
17	H	-0.902385	0.074130	0.488331
18	C	1.024226	0.998318	0.709872
19	H	1.768343	1.313320	0.008471
20	H	0.920147	1.738170	1.475827
21	H	1.319496	0.068667	1.149717
22	H	-0.144498	0.508695	-1.024887
23	H	-5.136413	-0.029002	-0.016030
24	H	-5.953251	2.115126	-0.878466
25	C	-6.231294	2.111990	1.226152
26	C	-7.162094	0.886355	1.171140
27	H	-6.670920	0.045303	1.614176
28	H	-8.062421	1.097799	1.709289
29	H	-7.399667	0.664384	0.151734
30	C	-5.365125	2.042117	2.497556
31	H	-4.719511	1.190590	2.442937
32	H	-4.776052	2.931813	2.577150
33	H	-5.997994	1.955401	3.355960
34	C	-7.077443	3.398453	1.251528
35	H	-7.376861	3.648130	0.255079
36	H	-7.946130	3.242116	1.856377
37	H	-6.497247	4.198954	1.660760

Cartesian Coordinate of A3

S.No.	Atoms	Coordinates (Angstroms) X	Y	Z
1	C	-4.604459	0.899397	-0.015853
2	C	-3.231658	0.899397	-0.015853
3	C	-2.509720	2.124518	-0.015853
4	C	-3.227590	3.348384	-0.015483
5	C	-4.649006	3.319011	-0.015329
6	C	-5.320511	2.121036	-0.015619
7	H	-2.666869	-0.044925	-0.016081
8	C	-1.087993	2.154061	-0.016116
9	H	-5.196247	4.273467	-0.015247
10	C	-1.131979	4.573178	-0.015641
11	C	-0.415967	3.351286	-0.016100
12	C	-0.321922	0.818122	-0.016088
13	C	1.123587	3.388339	-0.016354
14	N	2.593162	3.423708	-0.016591
15	O	-0.403055	5.803450	-0.015872
16	O	-2.504840	4.573110	-0.015368
17	H	-0.902385	0.074130	0.488331
18	C	1.024226	0.998318	0.709872
19	H	1.768343	1.313320	0.008471
20	H	0.920147	1.738170	1.475827
21	H	1.319496	0.068667	1.149717
22	H	-0.144498	0.508695	-1.024887
23	H	-5.136413	-0.029002	-0.016030
24	H	-5.953251	2.115126	-0.878466
25	C	-6.231294	2.111990	1.226152
26	C	-5.365125	2.042117	2.497556
27	H	-4.718492	1.191406	2.442288
28	H	-4.777119	2.932450	2.577912
29	H	-5.997946	1.953949	3.355848
30	C	-7.077443	3.398453	1.251528
31	H	-7.325179	3.682223	0.250029
32	H	-7.976112	3.223404	1.805290
33	H	-6.518948	4.183574	1.716898
34	C	-7.162094	0.886355	1.171140
35	H	-7.997672	1.043624	1.820737
36	H	-7.510531	0.747805	0.168995
37	H	-6.624804	0.016057	1.485467

A3



A4

Cartesian Coordinate of A4

S.No.	Atoms	Coordinates (Angstroms) X	Y	Z
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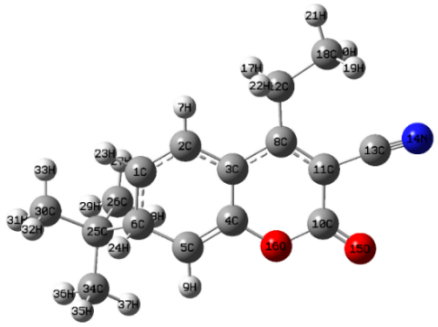
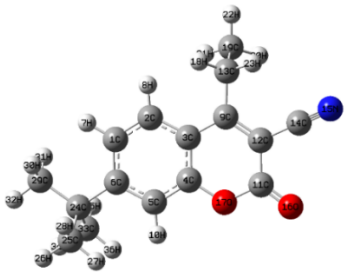
2	C	-3.231658	0.899397	-0.015853
3	C	-2.509720	2.124518	-0.015853
4	C	-3.227590	3.348384	-0.015483
5	C	-4.649006	3.319011	-0.015329
6	C	-5.320511	2.121036	-0.015619
7	H	-2.666869	-0.044925	-0.016081
8	C	-1.087993	2.154061	-0.016116
9	H	-5.196247	4.273467	-0.015247
10	C	-1.131979	4.573178	-0.015641
11	C	-0.415967	3.351286	-0.016100
12	C	-0.321922	0.818122	-0.016088
13	C	1.123587	3.388339	-0.016354
14	N	2.593162	3.423708	-0.016591
15	O	-0.403055	5.803450	-0.015872
16	O	-2.504840	4.573110	-0.015368
17	H	-0.902385	0.074130	0.488331
18	C	1.024226	0.998318	0.709872
19	H	1.768343	1.313320	0.008471
20	H	0.920147	1.738170	1.475827
21	H	1.319496	0.068667	1.149717
22	H	-0.144498	0.508695	-1.024887
23	H	-5.136413	-0.029002	-0.016030
24	H	-5.953251	2.115126	-0.878466
25	C	-6.231294	2.111990	1.226152
26	C	-5.365125	2.042117	2.497556
27	H	-4.718492	1.191406	2.442288
28	H	-4.777119	2.932450	2.577912
29	H	-5.997946	1.953949	3.355848
30	C	-7.162094	0.886355	1.171140
31	H	-8.034113	1.073928	1.762156
32	H	-7.450997	0.703117	0.157306
33	H	-6.647898	0.030441	1.555736
34	C	-7.077443	3.398453	1.251528
35	H	-7.374602	3.649622	0.254778
36	H	-7.947499	3.241259	1.854183
37	H	-6.498137	4.198320	1.663255

Cartesian Coordinate of A5

S.No.	Atoms	Coordinates (Angstroms) X	Y	Z
-				
1	C	-4.604459	0.899397	-0.015853
2	C	-3.231658	0.899397	-0.015853
3	C	-2.509720	2.124518	-0.015853
4	C	-3.227590	3.348384	-0.015483
5	C	-4.649006	3.319011	-0.015329
6	C	-5.320511	2.121036	-0.015619
7	H	-2.666869	-0.044925	-0.016081
8	C	-1.087993	2.154061	-0.016116
9	H	-5.196247	4.273467	-0.015247
10	C	-1.131979	4.573178	-0.015641
11	C	-0.415967	3.351286	-0.016100
12	C	-0.321922	0.818122	-0.016088
13	C	1.123587	3.388339	-0.016354
14	N	2.593162	3.423708	-0.016591
15	O	-0.403055	5.803450	-0.015872
16	O	-2.504840	4.573110	-0.015368
17	H	-0.902385	0.074130	0.488331
18	C	1.024226	0.998318	0.709872
19	H	1.768343	1.313320	0.008471
20	H	0.920147	1.738170	1.475827
21	H	1.319496	0.068667	1.149717
22	H	-0.144498	0.508695	-1.024887
23	H	-5.136413	-0.029002	-0.016030
24	H	-5.953251	2.115126	-0.878466
25	C	-6.231294	2.111990	1.226152
26	C	-5.365125	2.042117	2.497556
27	H	-4.718492	1.191406	2.442288
28	H	-4.777119	2.932450	2.577912
29	H	-5.997946	1.953949	3.355848
30	C	-7.162094	0.886355	1.171140
31	H	-8.034113	1.073928	1.762156
32	H	-7.450997	0.703117	0.157306
33	H	-6.647898	0.030441	1.555736
34	C	-7.077443	3.398453	1.251528
35	H	-7.374602	3.649622	0.254778
36	H	-7.947499	3.241259	1.854183
37	H	-6.498137	4.198320	1.663255



A5



P

Cartesian Coordinate of Product (P)

Coordinates (Angstroms)				
S.No.	Atoms	X	Y	Z
1	C	-4.604459	0.899397	-0.015853
2	C	-3.231658	0.899397	-0.015853
3	C	-2.509720	2.124518	-0.015853
4	C	-3.227590	3.348384	-0.015483
5	C	-4.649006	3.319011	-0.015329
6	C	-5.320511	2.121036	-0.015619
7	H	-5.165190	-0.046949	-0.015933
8	H	-2.666869	-0.044925	-0.016081
9	C	-1.087993	2.154061	-0.016116
10	H	-5.196247	4.273467	-0.015247
11	C	-1.131979	4.573178	-0.015641
12	C	-0.415967	3.351286	-0.016100
13	C	-0.321922	0.818122	-0.016088
14	C	1.123587	3.388339	-0.016354
15	N	2.593162	3.423708	-0.01659
16	O	-0.403055	5.803450	-0.015872
17	O	-2.504840	4.573110	-0.015368
18	H	-0.902385	0.074130	0.488331
19	C	1.024226	0.998318	0.709872
20	H	1.768343	1.313320	0.008471
21	H	0.920147	1.738170	1.475827
22	H	1.319496	0.068667	1.149717
23	H	-0.144498	0.508695	-1.024887
24	C	-6.860440	2.106197	-0.015690
25	C	-7.380775	2.836367	-1.267769
26	H	-8.411928	2.594108	-1.419206
27	H	-7.278723	3.892895	-1.132732
28	H	-6.813204	2.529424	-2.121321
29	C	-7.359759	0.649431	-0.026344
30	H	-6.999842	0.155445	-0.904603
31	H	-6.996656	0.141574	0.842643
32	H	-8.429707	0.639106	-0.024475
33	C	-7.380713	2.817954	1.246973
34	H	-8.434361	2.655987	1.339129
35	H	-6.882740	2.425009	2.108668
36	H	-7.186527	3.867398	1.170427

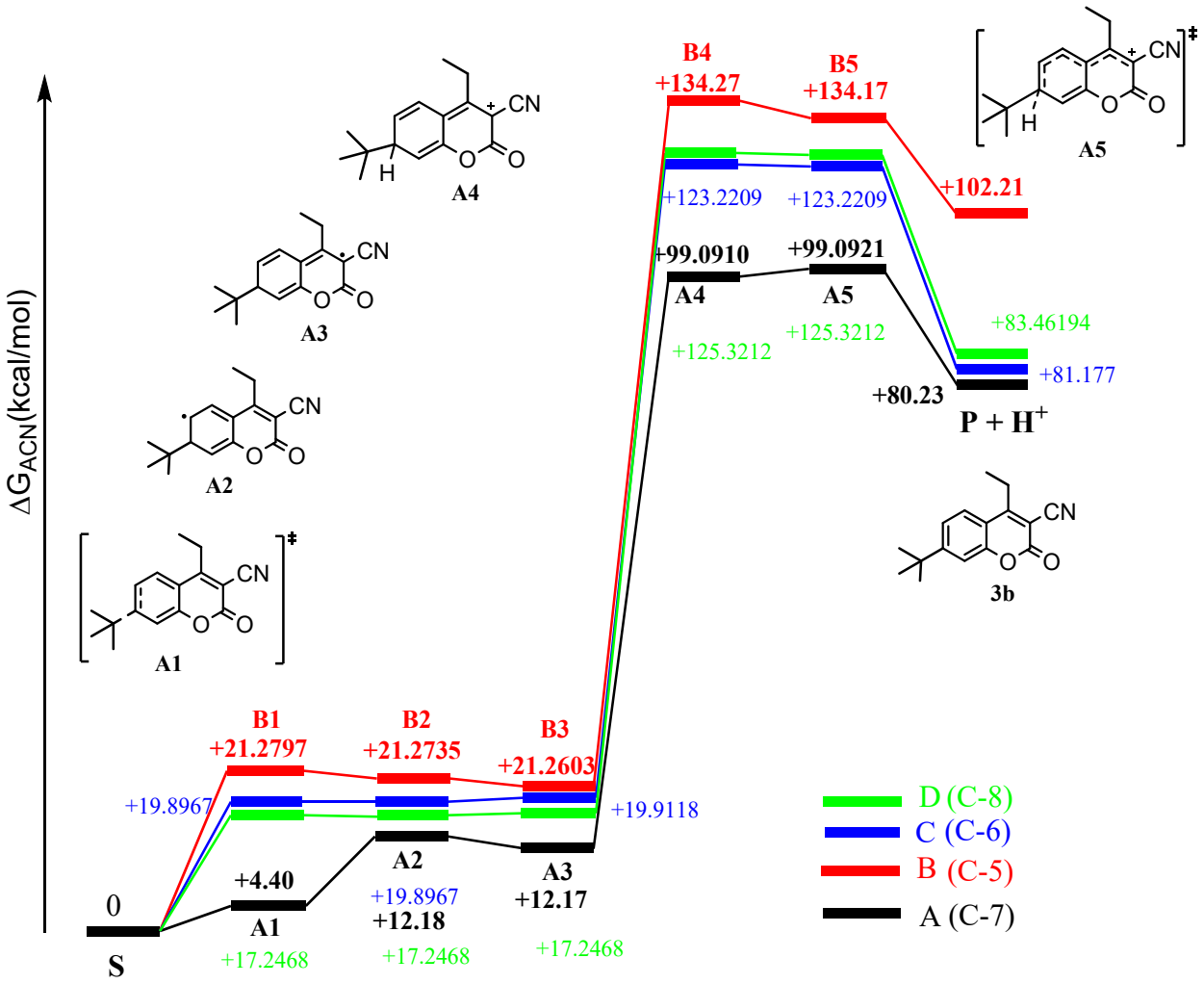
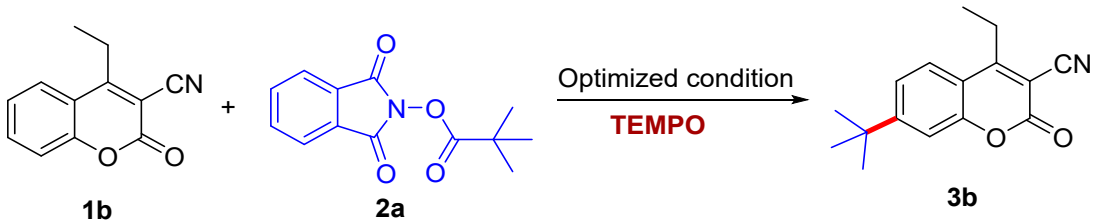


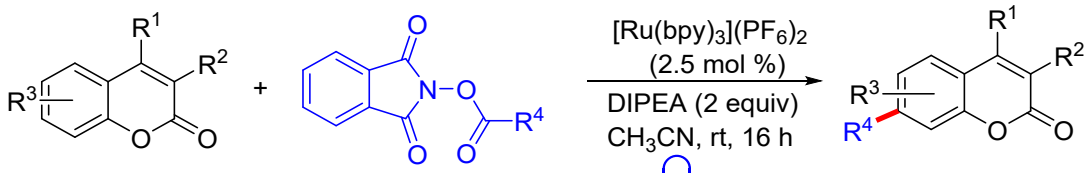
Figure S9. DFT-calculated reaction energy profile of regioselective alkylation.

4.3 Radical quenching experiments:



TEMPO (Equiv)	Yield
1	45%
2	22%
3	0%

5. General procedure of the C7-alkylation of coumarins



1

R^1 = Alkyl, heteroaromatics, phenyl

R^2 = CN, CHO

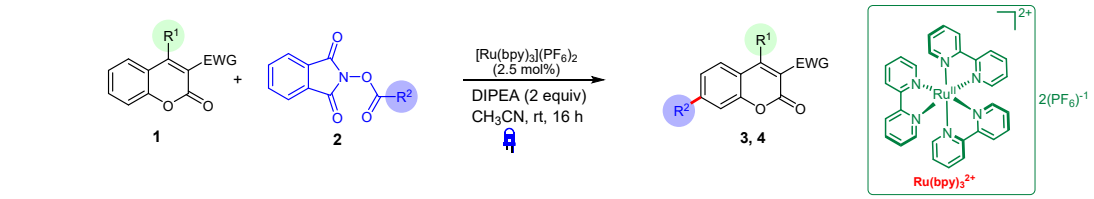
R^3 = Me, OMe, Halogen

2

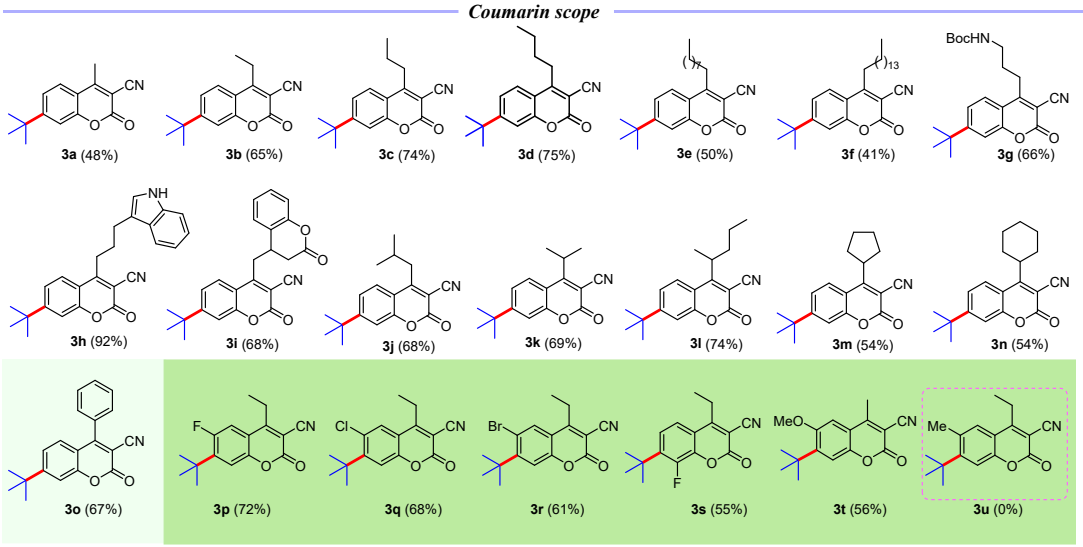
R^4 = 2°, 3° Alkyl group

3, 4

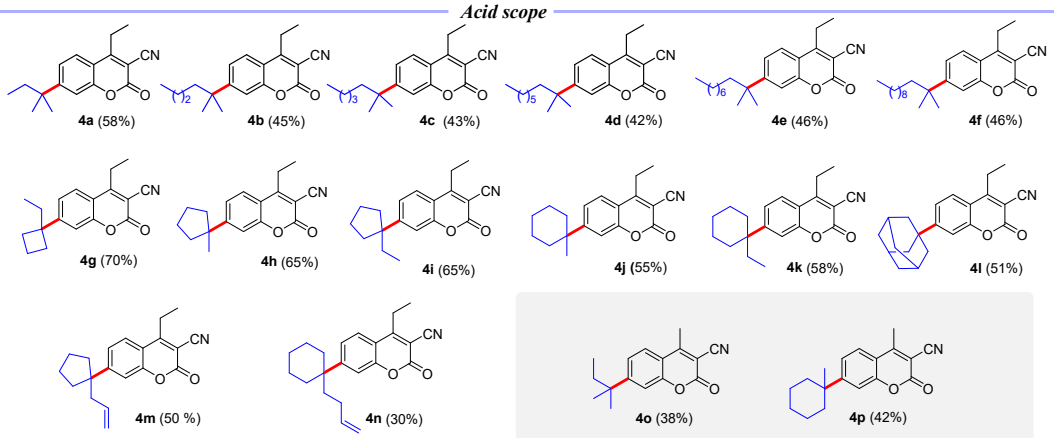
0.2 mmol of coumarin (1.0 equiv.), *N*-(acyloxy) phthalimides (0.4 mmol, 2 equiv.) were taken in a long neck round bottom flask and 2.5 mol % of $[Ru(bpy)_3](PF_6)_2$ was added into it, the RB was capped with septum. After that 2.0 equiv. of DIPEA and 2 ml of dry CH_3CN were added into the reaction mixture via syringe. The mixture was degassed and filled with N_2 (three times). The reaction mixture was irradiated with blue LED for 16 h. After completion (monitored through TLC), reaction was quenched with saturated $NaHCO_3$ solution and extracted with DCM (3 x 10 mL), washed with brine solution. After removal of solvent in vacuo, the product was purified by silica gel chromatography using EtOAc-hexane (3:7 to 5:5) as eluent to provide the desired product.



Coumarin scope



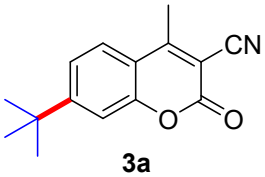
Acid scope



[a]Reaction Conditions: All of the reactions were carried out with 0.2 mmol of **1** and 0.4 mmol of **2** in presence of 2.5 mol % of $[Ru(bpy)_3](PF_6)_2$, 0.4 mmol of DIPEA in 2 mL of CH_3CN at rt under blue light irradiation.

5.1. Characterization of products

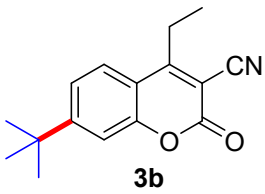
7-(*tert*-butyl)-4-methyl-2-oxo-2*H*-chromene-3-carbonitrile (3a):



3a

Physical state: white solid; **Yield**: 23 mg (48%). **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.65 (d, *J* = 8.5 Hz, 1H), 7.44 (dd, *J* = 8.4, 1.9 Hz, 1H), 7.38 (d, *J* = 1.8 Hz, 1H), 2.75 (s, 3H), 1.36 (s, 9H). **^{13}C-NMR** (126 MHz, $CDCl_3$) δ 162.3, 160.6, 157.3, 153.6, 125.7, 123.2, 115.9, 114.5, 113.8, 101.5, 35.8, 31.0, 18.3. **HRMS (ESI/QTOF), m/z:** $[M+H]^+$ Calcd. For $C_{15}H_{16}NO_2$, 242.1176; Found: 242.1151.

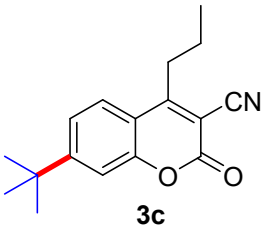
7-(*tert*-butyl)-4-ethyl-2-oxo-2*H*-chromene-3-carbonitrile (3b):



3b

Physical state: white solid; **Yield**: 33 mg (65%). **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.67 (d, *J* = 8.5 Hz, 1H), 7.44 (dd, *J* = 8.5, 1.9 Hz, 1H), 7.39 (d, *J* = 1.9 Hz, 1H), 3.11 (q, *J* = 7.7 Hz, 2H), 1.41 (t, *J* = 7.7 Hz, 3H), 1.37 (s, 9H); **^{13}C-NMR** (126 MHz, $CDCl_3$) δ 167.9, 160.5, 157.5, 154.2, 125.5, 123.2, 114.9, 114.8, 113.6, 100.4, 35.8, 31.0, 25.3, 14.1. **HRMS (ESI/QTOF), m/z:** $[M+H]^+$ Calcd. For $C_{16}H_{18}NO_2$, 256.0135; Found: 256.0127

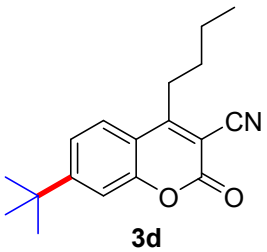
7-(*tert*-butyl)-2-oxo-4-propyl-2*H*-chromene-3-carbonitrile (3c):



3c

Physical state: white solid; **Yield**: 40 mg (74%). **^{1}H NMR** (300 MHz, $CDCl_3$) δ 7.66 (d, *J* = 8.5 Hz, 1H), 7.50 – 7.32 (m, 2H), 3.16 – 2.91 (m, 2H), 1.79 (dt, *J* = 14.9, 7.5 Hz, 2H), 1.36 (s, 9H), 1.12 (t, *J* = 7.4 Hz, 3H); **^{13}C NMR** (75 MHz, $CDCl_3$) δ 166.5, 160.4, 157.5, 154.0, 125.7, 123.2, 115.1, 114.8, 113.8, 100.8, 35.7, 33.8, 30.9, 23.5, 14.3; **HRMS (ESI/QTOF), m/z:** $[M+H]^+$ Calcd. For $C_{17}H_{20}NO_2$, 270.1488; Found: 270.1479

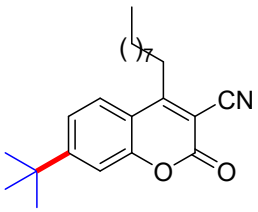
7-(*tert*-butyl)-4-butyl-2-oxo-2*H*-chromene-3-carbonitrile (3d):



3d

Physical state: white solid; **Yield**: 42 mg (75%). **^{1}H NMR** (300 MHz, $CDCl_3$) δ 7.65 (d, *J* = 8.5 Hz, 1H), 7.53 – 7.31 (m, 2H), 3.19 – 2.94 (m, 2H), 1.73 (s, 2H), 1.58 (d, *J* = 9.5 Hz, 2H), 1.37 (d, *J* = 2.6 Hz, 9H), 1.03 – 0.96 (m, 3H). **13C NMR** (75 MHz, $CDCl_3$) δ 166.8, 160.4, 157.5, 154.1, 125.6, 123.2, 115.1, 114.8, 113.8, 100.7, 35.8, 32.1, 31.8, 30.9, 23.1, 13.9; **HRMS (ESI/QTOF), m/z:** $[M+Na]^+$ Calcd. For $C_{18}H_{21}NO_2Na$, 306.1464; Found: 303.1465

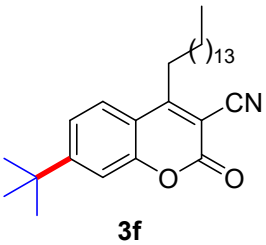
7-(tert-butyl)-4-nonyl-2-oxo-2*H*-chromene-3-carbonitrile (3e)



3e

Physical state: yellow oil; **Yield**: 35 mg (50%) **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.65 (d, J = 8.5 Hz, 1H), 7.44 (dd, J = 8.5, 1.9 Hz, 1H), 7.38 (d, J = 1.9 Hz, 1H), 3.12 – 3.02 (m, 2H), 1.78 – 1.69 (m, 2H), 1.50 (q, J = 7.6 Hz, 2H), 1.36 (s, 9H), 1.29 – 1.22 (m, 10H), 0.89 – 0.85 (m, 3H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 166.8, 160.4, 157.5, 154.1, 125.6, 123.2, 115.1, 114.8, 113.8, 100.7, 35.8, 32.0, 31.9, 30.9, 30.1, 29.9, 29.8, 29.4, 29.4, 22.7, 14.2. **HRMS (ESI/QTOF), m/z:** $[M+Na]^+$ Calcd. For $C_{23}H_{31}NO_2Na$, 376.2247; Found 376.2254.

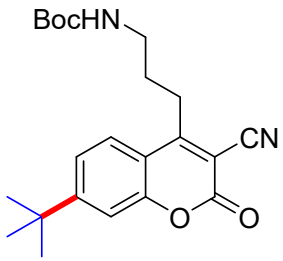
7-(tert-butyl)-2-oxo-4-pentadecyl-2*H*-chromene-3-carbonitrile (3f)



3f

Physical state: yellow oil; **Yield**: 36 mg (41 %) **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.65 (d, *J* = 8.5 Hz, 1H), 7.46 – 7.42 (m, 1H), 7.38 (d, *J* = 1.8 Hz, 1H), 3.12 – 3.03 (m, 2H), 1.73 (dd, *J* = 15.6, 7.9 Hz, 2H), 1.50 (dd, *J* = 15.2, 7.7 Hz, 2H), 1.36 (s, 9H), 1.27 (d, *J* = 19.9 Hz, 22H), 0.87 (t, *J* = 6.9 Hz, 3H). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 166.8, 160.4, 157.5, 154.1, 125.6, 123.2, 115.1, 114.8, 113.8, 100.7, 35.7, 32.0, 31.0, 30.1, 29.9, 29.8, 29.8, 29.8, 29.7, 29.7, 29.5, 29.5, 29.4, 22.8, 14.2. **HRMS (ESI/QTOF), m/z:** $[M+Na]^+$ Calcd. For $C_{29}H_{43}NO_2Na$, 460.3186; Found 460.3182.

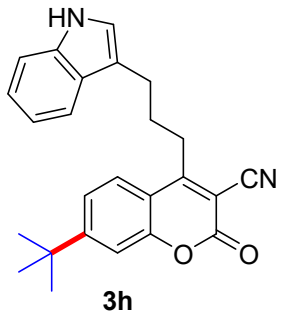
tert-butyl (3-(7-(tert-butyl)-3-cyano-2-oxo-2*H*-chromen-4-yl)propyl)carbamate (3g)



3g

Physical state: brown solid; **Yield**: 51 mg (66%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.66 (d, *J* = 8.5 Hz, 1H), 7.43 (dd, *J* = 8.5, 1.9 Hz, 1H), 7.38 (d, *J* = 1.8 Hz, 1H), 4.82 (s, 1H), 3.31 (dd, *J* = 12.6, 6.3 Hz, 2H), 3.17 – 3.05 (m, 2H), 2.02 – 1.88 (m, 2H), 1.45 (s, 9H), 1.36 (s, 9H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 166.1, 160.7, 157.3, 156.2, 154.2, 125.6, 123.4, 114.9, 114.9, 113.8, 100.9, 79.8, 40.4, 35.8, 30.9, 30.1, 29.2, 28.5. **HRMS (ESI/QTOF), m/z:** $[M+Na]^+$ Calcd. For $C_{22}H_{28}N_2O_4Na$, 407.1941; Found 407.1944.

4-(3-(1*H*-indol-3-yl)propyl)-7-(tert-butyl)-2-oxo-2*H*-chromene-3-carbonitrile (3h)

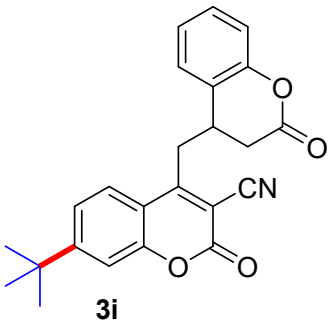


3h

Physical state: brown solid; **Yield**: 71 mg (92%). **^{1}H NMR** (500 MHz, $CDCl_3$) δ 8.07 (s, 1H), 7.55 (d, *J* = 7.9 Hz, 1H), 7.40 (d, *J* = 8.1 Hz, 1H), 7.33 – 7.27 (m, 2H), 7.24 – 7.17 (m, 2H), 7.12 – 7.07 (m, 2H), 3.13 – 3.08 (m, 2H), 3.02 (t, *J* = 7.1 Hz, 2H), 2.23 – 2.14 (m, 2H),

1.32 (s, 9H). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 166.8, 160.3, 157.5, 153.9, 136.6, 127.3, 125.6, 123.1, 122.3, 122.1, 119.6, 118.9, 115.0, 114.7, 114.6, 113.9, 111.4, 100.6, 35.7, 31.6, 30.9, 30.1, 25.5. **HRMS (ESI/QTOF), m/z:** $[M+Na]^+$ Calcd. For $C_{25}H_{24}N_2O_2Na$, 407.1729; Found 407.1730.

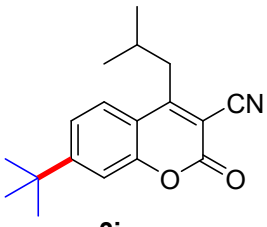
7-(tert-butyl)-2-oxo-4-((2-oxochroman-4-yl)methyl)-2*H*-chromene-3-carbonitrile (3i)



3i

Physical state: Brown solid **Yield**: 53 mg (68%) **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.44 – 7.27 (m, 4H), 7.12 (d, J = 8.1 Hz, 1H), 7.00 (d, J = 4.0 Hz, 2H), 3.57 (dd, J = 5.2, 2.9 Hz, 1H), 3.36 – 3.25 (m, 2H), 2.93 (qd, J = 16.2, 4.4 Hz, 2H), 1.34 (s, 9H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 166.9, 162.6, 161.2, 156.9, 153.9, 151.5, 129.8, 127.8, 125.4, 125.0, 123.5, 123.4, 117.7, 115.2, 114.8, 113.5, 102.0, 36.1, 35.8, 35.8, 34.9, 30.9. **HRMS (ESI/QTOF), m/z:** $[M+Na]^+$ Calcd. For $C_{24}H_{21}NNaO_4$ 410.1362; Found 410.1361.

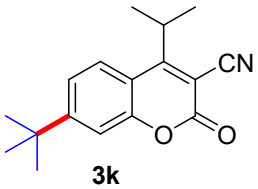
7-(tert-butyl)-4-isobutyl-2-oxo-2*H*-chromene-3-carbonitrile (3j)



3j

Physical state: white solid; **Yield**: 39 mg (68%). **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.64 (d, J = 8.5 Hz, 1H), 7.42 (dd, J = 8.5, 1.9 Hz, 1H), 7.38 (d, J = 1.8 Hz, 1H), 2.98 (d, J = 7.3 Hz, 2H), 2.15 (dp, J = 13.6, 6.8 Hz, 1H), 1.36 (s, 9H), 1.09 (d, J = 6.7 Hz, 6H). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 165.6, 160.4, 157.4, 153.9, 125.9, 123.1, 115.5, 114.7, 114.1, 101.4, 40.6, 35.7, 30.9, 30.5, 22.8. **HRMS (ESI/QTOF), m/z:** $[M+Na]^+$ Calcd. For $C_{18}H_{21}NO_2Na$, 306.1464; Found 306.1474.

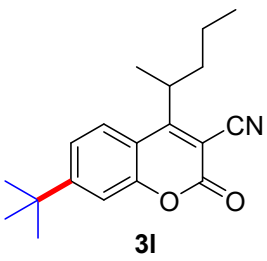
7-(tert-butyl)-4-isopropyl-2-oxo-2*H*-chromene-3-carbonitrile (3k)



3k

Physical state: white solid; **Yield**: 37 mg (69%) **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.87 (d, J = 8.6 Hz, 1H), 7.46 – 7.35 (m, 2H), 3.72 (dt, J = 14.3, 7.1 Hz, 1H), 1.59 (d, J = 7.2 Hz, 6H), 1.36 (s, 9H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 171.2, 160.2, 158.0, 154.0, 125.7, 122.9, 115.1, 114.6, 114.1, 99.7, 35.7, 30.9, 20.8. **HRMS (ESI/QTOF), m/z:** $[M+Na]^+$ Calcd. For $C_{17}H_{19}NO_2Na$, 292.130800; Found 292.131330.

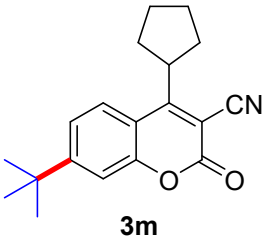
7-(tert-butyl)-2-oxo-4-(pentan-2-yl)-2*H*-chromene-3-carbonitrile (3l)



3l

Physical state: sticky oil; **Yield**: 44 mg (74%) **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.94 – 7.80 (m, 1H), 7.39 (dd, *J* = 11.4, 5.3 Hz, 2H), 3.56 (d, *J* = 6.5 Hz, 1H), 2.06 – 1.85 (m, 2H), 1.55 (d, *J* = 7.2 Hz, 3H), 1.35 (s, 9H), 1.27 – 1.12 (m, 2H), 0.92 (t, *J* = 7.3 Hz, 3H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 170.9, 160.1, 157.9, 153.9, 134.9,122.9, 114.9, 114.2, 92.2, 36.7, 35.6, 30.8, 28.5, 24.8, 21.5, 14.0. **HRMS (ESI/QTOF), m/z:** $[M+Na]^+$ Calcd. For $C_{19}H_{23}NO_2Na$, 320.162100; Found 320.163010.

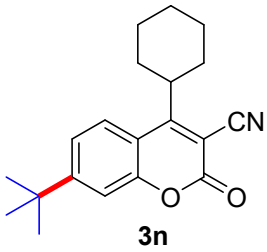
7-(tert-butyl)-4-cyclopentyl-2-oxo-2*H*-chromene-3-carbonitrile (3m)



3m

Physical state: white solid; **Yield**: 32 mg (54%) **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.81 – 7.76 (m, 1H), 7.42 – 7.35 (m, 2H), 3.79-3.71 (m, 1H), 2.22 – 2.06 (m, 6H), 1.93 – 1.85 (m, 2H), 1.36 (s, 9H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 170.4, 160.0, 157.9, 153.9, 125.8, 122.8, 115.1, 114.8, 114.2, 100.1, 43.2, 35.7, 33.4, 30.9, 27.7. **HRMS (ESI/QTOF), m/z:** $[M+Na]^+$ Calcd. For $C_{19}H_{21}NO_2Na$, 318.1464; Found 318.1478.

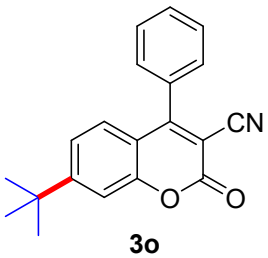
7-(tert-butyl)-4-cyclohexyl-2-oxo-2*H*-chromene-3-carbonitrile (3n)



3n

Physical state: white solid; **Yield**: 33 mg (54%) **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.91 (s, 1H), 7.42 (dd, *J* = 8.6, 1.6 Hz, 1H), 7.38 (d, *J* = 1.8 Hz, 1H), 3.31 (s, 1H), 2.19 (d, *J* = 20.9 Hz, 2H), 1.97 (d, *J* = 7.5 Hz, 2H), 1.84 (s, 3H), 1.45 (t, *J* = 9.5 Hz, 3H), 1.36 (s, 9H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 169.7, 160.1, 153.9, 122.9, 115.0, 76.8, 35.6, 30.9, 29.9, 26.6, 25.5. **HRMS (ESI/QTOF), m/z:** $[M+Na]^+$ Calcd. For $C_{20}H_{23}NO_2Na$, 332.1621; Found 332.1625.

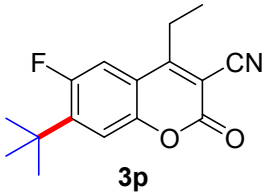
7-(tert-butyl)-2-oxo-4-phenyl-2*H*-chromene-3-carbonitrile (3o)



3o

Physical state: white solid; **Yield**: 41 mg (67%) **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.63 – 7.58 (m, 3H), 7.48 (dd, *J* = 7.2, 1.9 Hz, 2H), 7.44 (d, *J* = 1.2 Hz, 1H), 7.36 – 7.30 (m, 2H), 1.36 (s, 9H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 164.1, 160.7, 157.6, 154.4, 132.1, 131.2, 129.2, 128.7, 128.6, 123.2, 115.8, 114.5, 113.9, 100.6, 35.8, 30.9. **HRMS (ESI/QTOF), m/z:** $[M+Na]^+$ Calcd. For $C_{20}H_{17}NO_2Na$, 326.1151; Found 326.1150.

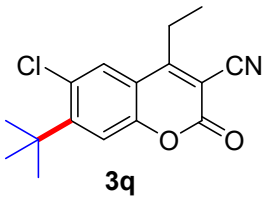
7-(*tert*-butyl)-4-ethyl-6-fluoro-2-oxo-2*H*-chromene-3-carbonitrile (3p):



3p

Physical state: white solid; **Yield**: 39 mg (72%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.42 – 7.27 (m, 2H), 3.06 (q, *J* = 7.7 Hz, 2H), 1.46 – 1.36 (m, 12H); **^{13}C NMR** (75 MHz, $CDCl_3$) δ 167.1, 160.4, 157.1, 150.0, 146.8, 117.0, 115.8, 113.2, 111.9, 101.4, 77.5, 76.9, 35.5, 29.5, 25.5, 13.9; **^{19}F NMR** (471 MHz, $CDCl_3$) -111.6. **HRMS (ESI/QTOF), m/z:** $[M+H]^+$ Calcd. For $C_{16}H_{17}FNO_2$, 274.1237; Found: 274.1243.

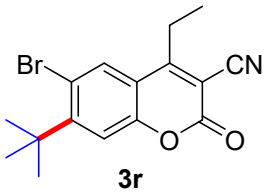
7-(*tert*-butyl)-6-chloro-4-ethyl-2-oxo-2*H*-chromene-3-carbonitrile (3q):



3q

Physical state: white solid; **Yield**: 40 mg (68%). **^{1}H-NMR** (400 MHz, $CDCl_3$) δ 7.68 (s, 1H), 7.47 (s, 1H), 3.08 (q, *J* = 7.7 Hz, 2H), 1.52 (s, 9H), 1.41 (t, *J* = 7.7 Hz, 3H); **^{13}C-NMR** (101 MHz, $CDCl_3$) δ 166.8, 156.8, 155.3, 152.3, 130.8, 128.2, 117.6, 115.9, 113.1, 101.7, 37.2, 29.3, 25.2, 14.0; **HRMS (ESI/QTOF), m/z:** $[M+Na]^+$ Calcd. For $C_{16}H_{16}ClNO_2Na$, 312.0761; Found: 312.0773

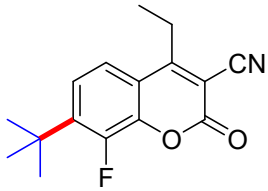
6-bromo-7-(*tert*-butyl)-4-ethyl-2-oxo-2*H*-chromene-3-carbonitrile (3r):



3r

Physical state: white solid; **Yield**: 41 mg (61%). **^{1}H NMR** (300 MHz, $CDCl_3$) δ 7.90 (s, 1H), 7.48 (s, 1H), 3.08 (q, *J* = 7.7 Hz, 2H), 1.54 (s, 9H), 1.41 (t, *J* = 7.7 Hz, 3H); **^{13}C NMR** (75 MHz, $CDCl_3$) δ 166.6, 156.6, 156.5, 152.7, 132.0, 118.6, 117.7, 116.3, 113.0, 101.7, 37.7, 29.3, 25.2, 14.0; **HRMS (ESI/QTOF), m/z:** $[M+Na]^+$ Calcd. For $C_{16}H_{16}BrNO_2Na$, 356.0256; Found: 356.0273

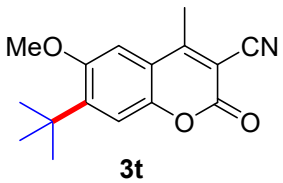
7-(tert-butyl)-4-ethyl-8-fluoro-2-oxo-2H-chromene-3-carbonitrile (3s)



3s

Physical state: white solid; **Yield**: 30 mg (55%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.44 (dd, J = 8.7, 1.6 Hz, 1H), 7.35 (dd, J = 8.6, 6.8 Hz, 1H), 3.11 (q, J = 7.7 Hz, 2H), 1.45 – 1.38 (m, 12H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 167.8, 156.1, 147.9, 144.8, 123.2, 120.0, 119.9, 116.9, 113.2, 101.3, 35.6, 29.7, 25.5, 14.5. **^{19}F NMR** (471 MHz, $CDCl_3$) -128.8. **HRMS (ESI/QTOF), m/z:** $[M+Na]^+$ Calcd. For $C_{16}H_{16}FNO_2Na$, 296.1057; Found 296.1056.

7-(tert-butyl)-6-methoxy-4-methyl-2-oxo-2*H*-chromene-3-carbonitrile (3t)



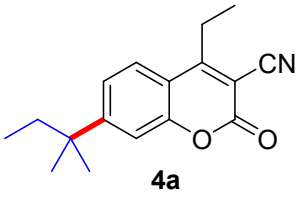
3t

Physical state: yellow solid; **Yield**: 30 mg (56%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.31 (s, 1H), 6.98 (s, 1H), 3.94 (s, 3H), 2.74 (s, 3H),

1.39 (s, 9H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 161.8, 157.5, 156.1, 148.8, 148.0, 116.3, 114.0, 105.6, 101.5, 55.8, 36.1, 29.3, 18.4

. **HRMS (ESI/QTOF), m/z:** $[M+Na]^+$ Calcd. For $C_{16}H_{17}NO_3Na$, 294.1101; Found 294.1093.

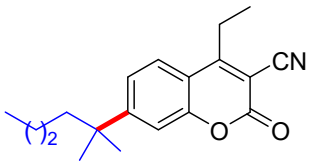
4-ethyl-2-oxo-7-(tert-pentyl)-2*H*-chromene-3-carbonitrile (4a):



4a

Physical state: white solid; **Yield**: 31 mg (58%). **^{1}H NMR** (300 MHz, $CDCl_3$) δ 7.67 (d, *J* = 8.5 Hz, 1H), 7.46 – 7.30 (m, 2H), 3.11 (q, *J* = 7.7 Hz, 2H), 1.70 (dd, *J* = 14.9, 7.4 Hz, 3H), 1.41 (t, *J* = 7.7 Hz, 4H), 1.32 (s, 4H), 0.69 (t, *J* = 7.4 Hz, 3H); **^{13}C NMR** (75 MHz, $CDCl_3$) δ 168.0, 159.2, 157.5, 154.1, 125.4, 123.8, 115.6, 114.8, 113.6, 100.3, 39.1, 36.7, 28.2, 25.3, 14.1, 9.2; **HRMS (ESI/QTOF), m/z:** $[M+Na]^+$ Calcd. For $C_{17}H_{19}NO_2Na$, 292.1307; Found: 292.1316

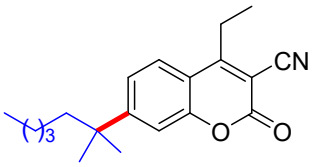
4-ethyl-7-(2-methylhexan-2-yl)-2-oxo-2*H*-chromene-3-carbonitrile (4b):



4b

Physical state: white solid; **Yield**: 27 mg (45%). **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.67 (d, *J* = 8.5 Hz, 1H), 7.38 (dd, *J* = 8.5, 1.7 Hz, 1H), 7.33 (d, *J* = 1.7 Hz, 1H), 3.11 (q, *J* = 7.7 Hz, 2H), 1.63 (dd, *J* = 8.4, 4.4 Hz, 2H), 1.41 (t, *J* = 7.7 Hz, 3H), 1.33 (s, 6H), 1.22 (dd, *J* = 14.9, 7.5 Hz, 2H), 1.00 (ddd, *J* = 12.1, 10.3, 7.8 Hz, 2H), 0.82 (t, *J* = 7.3 Hz, 3H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 168.0, 159.5, 157.5, 154.2, 125.4, 123.7, 115.5, 114.7, 113.6, 100.3, 44.0, 38.9, 28.7, 27.0, 25.3, 23.4, 14.1, 14.1. **HRMS (ESI/QTOF), m/z:** $[M+Na]^+$ Calcd. For $C_{19}H_{23}NO_2Na$, 320.1621, Found 320.1629.

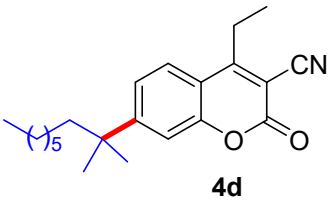
4-ethyl-7-(2-methylheptan-2-yl)-2-oxo-2*H*-chromene-3-carbonitrile (4c)



4c

Physical state: white solid; **Yield**: 27 mg (43%) **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.66 (d, *J* = 8.5 Hz, 1H), 7.38 (dd, *J* = 8.5, 1.5 Hz, 1H), 7.33 (s, 1H), 3.11 (q, *J* = 7.7 Hz, 2H), 1.67 – 1.59 (m, 4H), 1.41 (t, *J* = 7.7 Hz, 3H), 1.33 (s, 6H), 1.23 – 1.17 (m, 4H), 0.82 (t, *J* = 6.9 Hz, 3H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 167.9, 159.5, 157.5, 154.2, 125.4, 123.7, 115.5, 114.7, 113.6, 100.3, 44.2, 38.9, 32.5, 28.7, 25.3, 24.5, 22.6, 14.2, 14.1. **HRMS (ESI/QTOF), m/z:** $[M+Na]^+$ Calcd. For $C_{20}H_{25}NNaO_2$, 334.1777; Found 334.1781.

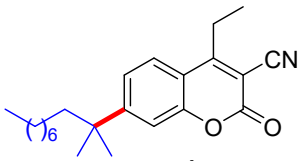
4-ethyl-7-(2-methylnonan-2-yl)-2-oxo-2*H*-chromene-3-carbonitrile (4d):



4d

Physical state: white solid; **Yield**: 29 mg (42%) **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.67 (d, *J* = 8.5 Hz, 1H), 7.38 (dd, *J* = 8.5, 1.3 Hz, 1H), 7.33 (d, *J* = 1.5 Hz, 1H), 3.11 (q, *J* = 7.7 Hz, 2H), 1.64 – 1.61 (m, 2H), 1.41 (t, *J* = 7.7 Hz, 3H), 1.32 (s, 6H), 1.26 – 1.21 (m, 3H), 1.18 (s, 5H), 1.01 (s, 2H), 0.83 (t, *J* = 7.1 Hz, 3H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 168.0, 159.5, 157.5, 154.1, 125.4, 123.7, 115.5, 114.7, 113.6, 100.3, 44.3, 38.9, 31.9, 30.3, 29.3, 28.7, 25.3, 24.8, 22.7, 14.2, 14.1. **HRMS (ESI/QTOF), m/z:** $[M+Na]^+$ Calcd. For $C_{22}H_{29}NO_2Na$, 362.2090; Found 362.2095.

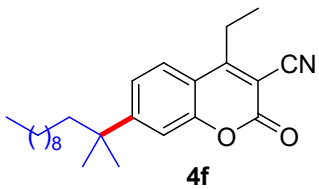
4-ethyl-7-(2-methyldecan-2-yl)-2-oxo-2*H*-chromene-3-carbonitrile (4e)



4e

Physical state: white solid; **Yield**: 33 mg (46%) **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.66 (d, *J* = 8.5 Hz, 1H), 7.38 (dd, *J* = 8.5, 1.8 Hz, 1H), 7.33 (d, *J* = 1.7 Hz, 1H), 3.11 (q, *J* = 7.7 Hz, 2H), 1.65 – 1.59 (m, 3H), 1.41 (t, *J* = 7.7 Hz, 3H), 1.34 (d, *J* = 9.0 Hz, 6H), 1.24 (d, *J* = 1.4 Hz, 3H), 1.19 (s, 6H), 1.05 – 0.98 (m, 2H), 0.84 (t, *J* = 6.9 Hz, 3H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 168.0, 159.5, 157.5, 154.2, 125.4, 123.7, 115.5, 114.7, 113.6, 100.3, 44.3, 38.9, 31.9, 30.3, 29.6, 29.4, 28.7, 25.3, 24.8, 22.8, 14.2, 14.1. **HRMS (ESI/QTOF), m/z:** $[M+Na]^+$ Calcd. For $C_{23}H_{31}NO_2Na$, 376.2247; Found: 376.2252.

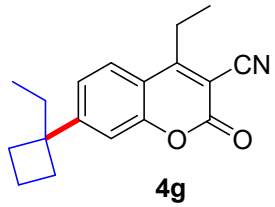
4-ethyl-7-(2-methyldodecan-2-yl)-2-oxo-2*H*-chromene-3-carbonitrile (4f)



4f

Physical state: sticky; **Yield**: 35 mg (46%) **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.66 (d, *J* = 8.5 Hz, 1H), 7.38 (dd, *J* = 8.5, 1.8 Hz, 1H), 7.33 (d, *J* = 1.7 Hz, 1H), 3.11 (q, *J* = 7.7 Hz, 2H), 1.66 – 1.59 (m, 3H), 1.41 (t, *J* = 7.7 Hz, 3H), 1.32 (s, 6H), 1.25 (s, 3H), 1.20 (d, *J* = 11.8 Hz, 10H), 1.06 – 0.98 (m, 2H), 0.86 (t, *J* = 6.9 Hz, 3H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 168.0, 159.5, 157.5, 154.2, 125.4, 123.7, 115.5, 114.7, 113.6, 100.3, 44.3, 38.9, 32.0, 29.7, 29.7, 29.6, 29.4, 28.7, 24.8, 22.7, 14.2, 14.1. **HRMS (ESI/QTOF), m/z:** $[M+Na]^+$ Calcd. For $C_{25}H_{35}NO_2Na$, 404.2560; Found: 404.2566.

4-ethyl-7-(1-ethylcyclobutyl)-2-oxo-2*H*-chromene-3-carbonitrile (4g)

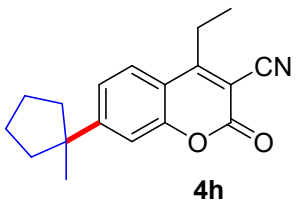


4g

Physical state: white solid **Yield**: 39 mg (70%). **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.65 (d, *J* = 8.3 Hz, 1H), 7.16 – 7.09 (m, 2H), 3.11 (q, *J* = 7.7 Hz, 2H), 2.33 (dd, *J* = 20.1, 9.4 Hz, 2H), 2.22 – 2.15 (m, 2H), 2.14

– 2.05 (m, 1H), 1.89 – 1.82 (m, 3H), 1.41 (t, *J* = 7.7 Hz, 3H), 0.66 (t, *J* = 7.3 Hz, 3H). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 168.0, 159.9, 157.5, 154.1, 125.4, 123.6, 115.3, 114.7, 113.6, 100.2, 47.7, 34.8, 32.5, 25.4, 15.9, 14.2, 8.9. **HRMS (ESI/QTOF), m/z:** $[M+Na]^+$ Calcd. For $C_{18}H_{19}NO_2Na$, 304.1308; Found 304.1308.

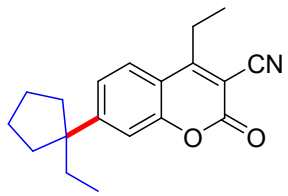
4-ethyl-7-(1-methylcyclopentyl)-2-oxo-2H-chromene-3-carbonitrile (4h)



4h

Physical state: white solid; **Yield**: 36 mg (65%). **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.66 (d, *J* = 8.5 Hz, 1H), 7.38 (dd, *J* = 8.4, 1.8 Hz, 1H), 7.34 (d, *J* = 1.8 Hz, 1H), 3.11 (q, *J* = 7.7 Hz, 2H), 1.93 – 1.81 (m, 6H), 1.79 – 1.71 (m, 2H), 1.41 (t, *J* = 7.7 Hz, 3H), 1.29 (s, 3H). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 168.1, 160.8, 157.6, 154.1, 125.5, 124.1, 115.4, 114.7, 113.6, 100.2, 77.4, 77.2, 76.9, 48.0, 39.6, 29.1, 25.3, 23.8, 14.2. **HRMS (ESI/QTOF), m/z:** $[M+Na]^+$ Calcd. For $C_{18}H_{19}NO_2Na$, 304.1308; Found 304.1314.

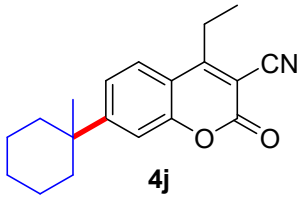
4-ethyl-7-(1-ethylcyclopentyl)-2-oxo-2*H*-chromene-3-carbonitrile (4i)



4i

Physical state: sticky white solid; **Yield**: 38 mg (65%). **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.65 (d, *J* = 8.4 Hz, 1H), 7.32 (d, *J* = 8.6 Hz, 1H), 7.29 (s, 1H), 3.11 (q, *J* = 7.7 Hz, 2H), 1.94 – 1.86 (m, 4H), 1.77-1.75 (s, 2H), 1.67 (t, *J* = 7.3 Hz, 4H), 1.42 (t, *J* = 7.6 Hz, 4H), 0.62 (t, *J* = 7.4 Hz, 3H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 168.0, 158.7, 157.5, 153.9, 125.2, 124.8, 116.5, 114.8, 113.6, 100.3, 52.5, 37.2, 34.2, 25.4, 23.3, 14.2, 9.6. **HRMS (ESI/QTOF), m/z:** $[M+Na]^+$ Calcd. For $C_{19}H_{21}NO_2Na$, 318.1464; Found: 318.1466.

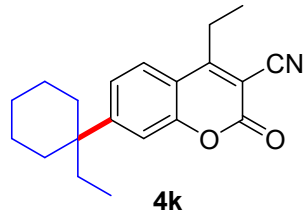
4-ethyl-7-(1-methylcyclohexyl)-2-oxo-2*H*-chromene-3-carbonitrile (4j):



4j

Physical state: white solid; **Yield**: 32 mg (55%). **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.68 (d, *J* = 8.5 Hz, 1H), 7.43 (d, *J* = 8.5 Hz, 1H), 7.39 (s, 1H), 3.11 (q, *J* = 7.5 Hz, 2H), 2.00 (s, 2H), 1.66 – 1.57 (m, 6H), 1.42 (t, *J* = 7.6 Hz, 5H), 1.22 (s, 3H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 168.0, 159.7, 157.6, 154.4, 125.6, 123.7, 115.6, 114.7, 113.6, 100.3, 77.4, 39.3, 37.7, 26.2, 25.3, 22.7, 14.2; **HRMS (ESI/QTOF), m/z:** $[M+Na]^+$ Calcd. For $C_{19}H_{21}NO_2Na$, 318.1464; Found: 318.1472.

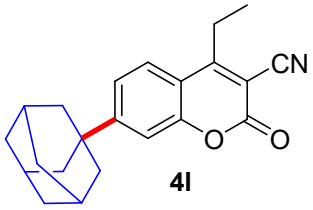
4-ethyl-7-(1-ethylcyclohexyl)-2-oxo-2*H*-chromene-3-carbonitrile (4k)



4k

Physical state: white solid; **Yield**: 36 mg (58%) **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.68 (d, *J* = 8.5 Hz, 1H), 7.37 (dd, *J* = 8.6, 1.9 Hz, 1H), 7.34 (d, *J* = 1.9 Hz, 1H), 3.12 (q, *J* = 7.7 Hz, 2H), 2.07 (d, *J* = 10.0 Hz, 2H), 1.60 (dq, *J* = 14.9, 8.3, 7.4 Hz, 8H), 1.42 (t, *J* = 7.7 Hz, 4H), 1.33 – 1.30 (m, 1H), 0.56 (t, *J* = 7.5 Hz, 3H). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 168.0, 157.3, 154.2, 125.3, 124.6, 116.8, 114.7, 113.6, 100.3, 42.8, 35.7, 26.5, 25.3, 22.5, 14.2, 8.0. **HRMS (ESI/QTOF), m/z:** $[M+Na]^+$ Calcd. For $C_{20}H_{23}NNaO_2$, 332.1621; Found 332.1626.

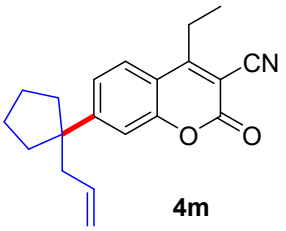
7-(adamantan-1-yl)-4-ethyl-2-oxo-2*H*-chromene-3-carbonitrile (4l):



4l

Physical state: white solid; **Yield**: 34 mg (51%). **^{1}H NMR** (300 MHz, $CDCl_3$) δ 7.68 (d, *J* = 8.5 Hz, 1H), 7.43 (d, *J* = 8.5 Hz, 1H), 7.34 (s, 1H), 3.10 (dd, *J* = 14.5, 7.5 Hz, 2H), 2.13 (s, 3H), 1.91 (s, 6H), 1.76 (t, *J* = 10.4 Hz, 6H), 1.40 (dd, *J* = 7.6, 6.7 Hz, 3H); **^{13}C NMR** (75 MHz, $CDCl_3$) δ 168.1, 160.5, 157.6, 154.3, 125.5, 122.8, 114.8,114.7, 113.6, 100.1, 42.8, 37.3, 36.6, 28.7, 25.3, 14.2; **HRMS (ESI/QTOF), m/z:** $[M+Na]^+$ Calcd. For $C_{22}H_{23}NO_2Na$, 356.1621; Found: 356.1617.

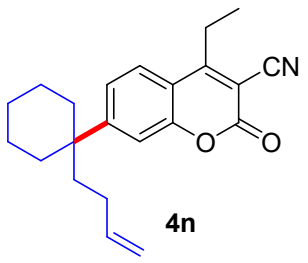
7-(1-allylcyclopentyl)-4-ethyl-2-oxo-2*H*-chromene-3-carbonitrile (4m)



4m

Physical state: white sticky solid; **Yield**: 31 mg (50%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.65 (d, *J* = 8.5 Hz, 1H), 7.31 (dd, *J* = 8.4, 1.8 Hz, 1H), 7.27 (d, *J* = 1.8 Hz, 1H), 5.40 (ddt, *J* = 17.4, 10.1, 7.3 Hz, 1H), 4.96 – 4.84 (m, 2H), 3.11 (q, *J* = 7.7 Hz, 2H), 2.36 (dt, *J* = 7.2, 1.2 Hz, 2H), 1.96 (ddd, *J* = 12.7, 8.8, 4.1 Hz, 2H), 1.89 – 1.84 (m, 2H), 1.83 – 1.76 (m, 2H), 1.74 – 1.68 (m, 2H), 1.41 (t, *J* = 7.7 Hz, 3H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 167.9, 158.3, 157.5, 153.9, 134.3, 125.2, 124.7, 117.9, 116.4, 114.8, 113.6, 100.4, 51.8, 45.6, 37.2, 37.1, 25.3, 23.2, 14.2. **HRMS (ESI/QTOF), m/z:** $[M+Na]^+$ Calcd. For $C_{20}H_{21}NNaO_2$, 330.146450; Found 330.146096.

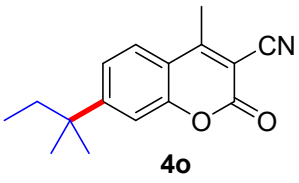
7-(1-(but-3-en-1-yl)cyclohexyl)-4-ethyl-2-oxo-2*H*-chromene-3-carbonitrile (4n)



4n

Physical state: pale white solid; **Yield**: 20 mg (30%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.69 (d, *J* = 8.5 Hz, 1H), 7.40 – 7.34 (m, 2H), 5.63 (dq, *J* = 16.9, 5.2 Hz, 1H), 4.92 – 4.81 (m, 2H), 3.12 (q, *J* = 7.7 Hz,

2H), 2.14 – 2.06 (m, 2H), 1.67-1.62 (m, 8H), 1.43 (t, *J* = 7.7 Hz, 3H), 1.34 – 1.28 (m, 3H), 1.25-1.22 (m, 1H), 0.89 – 0.85 (m, 1H). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 167.9, 157.4, 157.0, 154.3, 138.6, 125.5, 124.5, 116.8, 114.8, 114.6, 113.6, 100.5, 42.5, 36.2, 29.8, 28.0, 26.4, 25.3, 22.5, 14.2. **HRMS (ESI/QTOF), m/z:** $[M+Na]^+$ Calcd. For $C_{22}H_{25}NO_2Na$, 358.1777; Found 358.1762.

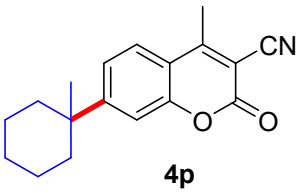


4o

4-methyl-2-oxo-7-(tert-pentyl)-2*H*-chromene-3-carbonitrile (4o):

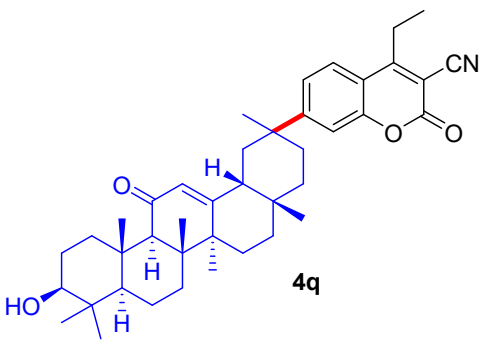
Physical state: white solid; **Yield**: 19 mg (38%). **^{1}H-NMR** (300 MHz, $CDCl_3$) δ 7.65 (d, *J* = 8.5 Hz, 1H), 7.37 (dd, *J* = 14.6, 6.2 Hz, 2H), 2.75 (s, 3H), 1.69 (dd, *J* = 14.9, 7.4 Hz, 2H), 1.32 (s, 6H), 0.68 (t, *J* = 7.4 Hz, 3H); **^{13}C-NMR** (75 MHz, $CDCl_3$) δ 162.3, 159.3, 157.3, 153.6, 125.6, 123.7, 115.9, 115.3, 113.8, 101.5, 39.2, 36.7, 28.2, 18.2, 9.2; **HRMS (ESI/QTOF), m/z:** $[M+H]^+$ Calcd. For $C_{16}H_{18}NO_2$, 256.1332; Found: 256.1343

4-methyl-7-(1-methylcyclohexyl)-2-oxo-2*H*-chromene-3-carbonitrile (4p)



4p

Physical state: white solid; **Yield**: 23 mg (42%) **^{1}H-NMR** (300 MHz, $CDCl_3$) δ 7.66 (d, *J* = 8.5 Hz, 1H), 7.45-7.39 (m, 1H), 7.39 (s, 1H) 2.76 (s, 3H), 2.04-2.01 (m, 2H), 1.64-1.60 (m, 4H), 1.46-1.44 (m, 4H) 1.22 (s, 3H); **^{13}C-NMR** (75 MHz, $CDCl_3$) δ 162.3, 159.8, 153.8, 125.8, 123.7, 115.8, 115.4, 101.4, 39.3, 37.7, 26.2, 22.7 18.3. **HRMS (ESI/QTOF), m/z:** $[M+Na]^+$ Calcd. For $C_{18}H_{19}NNaO_2$, 304.1307; Found: 304.1312



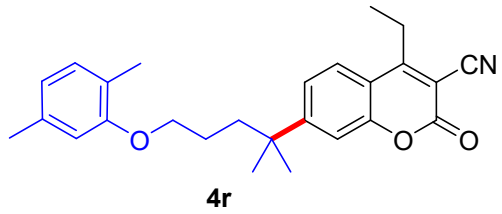
4q

4-ethyl-7-((4a*R*,6a*S*,6b*R*,8a*R*,10*S*,12a*S*,12b*R*,14b*R*)-10-hydroxy-2,4a,6a,6b,9,9,12aheptamethyl-13-oxo-1,2,3,4,4a,5,6,6a,6b,7,8,8a,9,10,11,12,12a,12b,13,14*b*-icosahydropicen-2-yl)-2-oxo-2*H*-chromene-3-carbonitrile (4q):

Physical state: white solid; **Yield**: 77 mg (62%).**^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.68 (d, *J* = 8.6 Hz, 1H), 7.40 (dd, *J* = 8.6, 1.7 Hz, 1H), 7.35 (s, 1H), 5.66 (s, 1H), 3.22 (dd, *J* = 10.7, 5.4 Hz, 1H), 3.10 (q, *J* = 7.6 Hz, 2H), 2.77 (d, *J* = 13.5 Hz, 1H), 2.34 (d, *J* = 15.2 Hz, 2H), 2.07 – 1.99 (m, 2H), 1.88 – 1.81 (m, 2H), 1.72 – 1.52 (m, 9H), 1.40 (dt, *J* = 15.1, 5.1 Hz, 6H), 1.32 (s, 3H), 1.30 (s, 3H), 1.13 (d, *J* = 7.2 Hz, 6H), 0.99 (s, 3H), 0.94 (s, 3H), 0.79 (s, 3H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 200.3, 169.2, 167.9, 160.7, 157.4, 154.2, 128.8, 125.7, 123.0, 114.9, 114.5, 113.5, 100.5, 78.8,

61.9, 54.9, 47.4, 45.6, 43.4, 42.9, 39.2, 38.7, 37.2, 32.8, 32.3, 32.0, 28.7, 28.2, 27.3, 26.4, 25.3, 23.7, 23.5, 18.9, 17.6, 16.5, 15.7, 14.1; **HRMS (ESI/QTOF), m/z:** $[M+K]^+$ Calcd. For $C_{41}H_{53}NO_4K$, 662.3606; Found: 662.3614

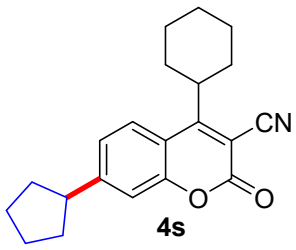
7-(5-(2,5-dimethylphenoxy)-2-methylpentan-2-yl)-4-ethyl-2-oxo-2*H*-chromene-3-carbonitrile (4r):



4r

Physical state: white solid; **Yield**: 48 mg (55%).**^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.64 – 8.49 (m, 1H), 8.38 (t, *J* = 15.9 Hz, 1H), 8.19 – 8.11 (m, 1H), 8.01 (s, 1H), 7.74 (d, *J* = 7.5 Hz, 1H), 7.39 (d, *J* = 7.4 Hz, 1H), 4.58 (t, *J* = 6.1 Hz, 2H), 3.85 (q, *J* = 7.6 Hz, 1H), 3.02 (s, 3H), 2.91 (s, 3H), 2.64 (dd, *J* = 8.3, 4.9 Hz, 2H), 2.38 – 2.26 (m, 4H), 2.18 – 2.11 (m, 8H); **^{13}C NMR** (101 MHz, $CDCl_3$) δ 168.3, 167.9, 158.8, 157.5, 156.9, 154.2, 136.6, 132.9, 132.0, 130.5, 125.5, 123.6, 121.4, 120.9, 115.6, 114.9, 113.6, 111.9, 100.4, 67.6, 40.4, 38.7, 29.1, 28.8, 25.3, 25.0, 21.5, 15.9, 14.2; **HRMS (ESI/QTOF), m/z:** $[M+Na]^+$ Calcd. For $C_{26}H_{29}NO_3Na$, 426.2039; Found: 426.2032.

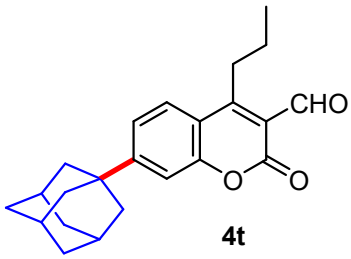
4-cyclohexyl-7-cyclopentyl-2-oxo-2*H*-chromene-3-carbonitrile (4s)



4s

Physical state: white solid **Yield**: 29 mg (46%). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.89 (d, *J* = 6.8 Hz, 1H), 7.28 (d, *J* = 2.2 Hz, 1H), 7.26 (s, 1H), 3.31 (s, 1H), 3.19 – 3.05 (m, 1H), 2.13 (ddd, *J* = 10.7, 6.6, 3.3 Hz, 2H), 1.99 (d, *J* = 7.4 Hz, 2H), 1.85 (dt, *J* = 12.2, 6.6 Hz, 5H), 1.75 (ddd, *J* = 7.1, 6.1, 3.3 Hz, 2H), 1.67 – 1.56 (m, 4H), 1.46 (s, 3H). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 169.8, 158.5, 155.9, 154.1, 124.6, 116.4, 46.1, 34.5, 29.8, 26.7, 25.7, 25.5. **HRMS (ESI/QTOF), m/z:** $[M+Na]^+$ Calcd. For $C_{21}H_{23}NO_2Na$, 344.1621; Found: 344.1607.

7-((3r,5r,7r)-adamantan-1-yl)-2-oxo-4-propyl-2H-chromene-3-carbaldehyde (4t)



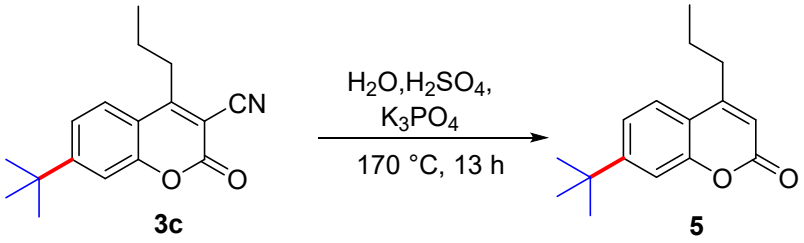
4t

Physical state: Light yellow liquid. **Yield:** 21 mg (30%). **^{1}H NMR** (500 MHz, $CDCl_3$) δ 10.45 (s, 1H), 7.78 (d, *J* = 8.6 Hz, 1H), 7.40 (d, *J* = 1.9 Hz, 1H), 7.33 (d, *J* = 1.9 Hz, 1H), 3.30 – 3.21 (m, 2H), 2.16 – 2.12 (m, 4H), 1.93 (d, *J* = 2.9 Hz, 6H), 1.83 – 1.75 (m, 6H), 1.67 (d, *J* = 7.9 Hz, 1H), 1.13 (t, *J* = 7.3 Hz, 3H). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 191.4,

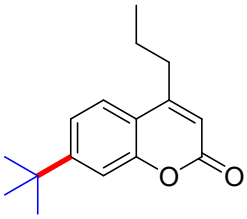
163.4, 161.9, 159.6, 154.9, 126.6, 122.4, 117.5, 117.1, 114.2, 42.8, 36.9, 36.7, 29.8, 28.8, 24.0, 14.7. **HRMS (ESI/QTOF), m/z:** $[M+Na]^+$ Calcd. For $C_{23}H_{26}O_3Na$ 373.1780; Found 373.1781.

5.2. Transformations of 3c

7-(tert-butyl)-4-propyl-2*H*-chromen-2-one (5):

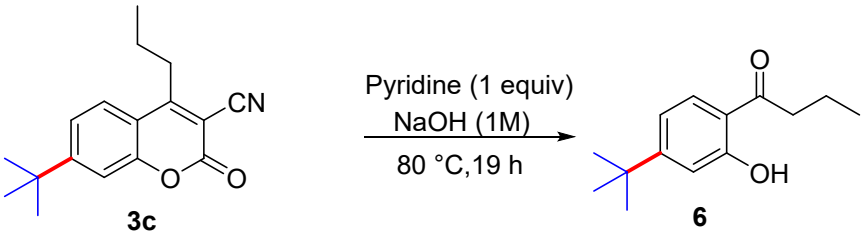


Compound **5** was synthesized using known literature procedure,[1] **3c** 40 mg (0.14 mmol)**,** distilled H_2O (1mL), conc. H_2SO_4 (0.12 mL), and conc. H_3PO_4 (0.5 mL) were charged in 5mL round bottom flask and fitted with reflux condenser. The reaction mixture was then heated to 170^o C for 13 hr. Upon completion of reaction, the reaction mixture was cooled to rt and distilled H_20 (5mL) was added slowly. The precipitated solid was filtered, washed with distilled H_2O, hexane and dried over vacuum pump.



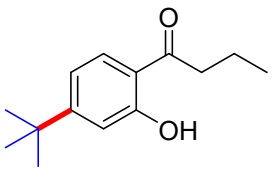
Physical state: white solid; **Yield**: 9 mg (26 %). **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.56 (d, J = 8.3 Hz, 1H), 7.35 (d, J = 1.7 Hz, 1H), 7.32 (dd, J = 8.3, 1.9 Hz, 1H), 6.23 (s, 1H), 2.73 (t, J = 8.0 Hz, 2H), 1.80 – 1.70 (m, 2H), 1.35 (s, 9H), 1.05 (t, J = 7.4 Hz, 3H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ 161.6, 156.1, 153.9, 124.0, 121.8, 117.0, 114.3, 113.3, 35.3, 33.8, 31.2, 29.9, 21.6, 14.0. **HRMS (ESI/QTOF), m/z:** $[M+Na]^+$ Calcd. For $C_{16}H_{20}NaO_2$, 267.1356; Found 267.1359.

1-(4-(tert-butyl)-2-hydroxyphenyl)butan-1-one (6):



Compound **6** was synthesized using known literature procedure[1], **3c** (40 mg, 1.0 eq, 0.14 mmol) was suspended in 1M aqueous NaOH (1.5 mL, 10.0 eq, 1.48 mmol) in a 5mL vial. Pyridine (approx. 11µL, 1.0 eq) was added whereupon the mixture turned slightly yellowish. The vial was purged with argon, capped and heated under magnetic stirring in an oil bath at 80 ˚C for

19 h. The clear yellow reaction mixture was cooled down to rt and treated with 1M HCl till a pH of 2-3 was reached. The formed solid was extracted with EtOAc (3x1 mL). The combined organic phases were washed with concentrated $NaHCO_3$ solution (1 mL), brine (1 mL) and concentrated under reduced pressure. The crude mixture was purified by flash chromatography (9:1 Hexane:Ethyl acetate) to afford the title compound **6** (19 mg, 0.086 mmol) as oily liquid in 62 % yield.

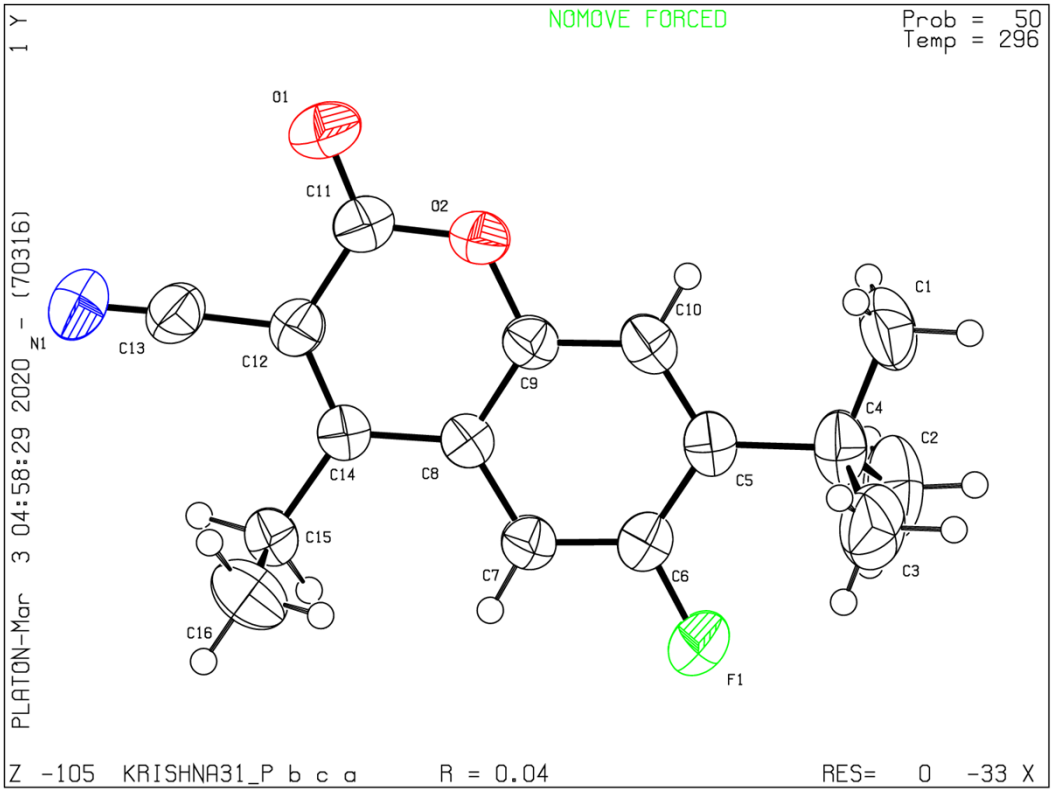


Physical state: oil; **Yield**: 19 mg (62 %). **^{1}H NMR** (500 MHz, $CDCl_3$) δ 12.39 (s, 1H), 7.69 (d, *J* = 8.5 Hz, 1H), 6.99 (d, *J* = 1.9 Hz, 1H), 6.93 (dd, *J* = 8.5, 1.9 Hz, 1H), 2.93 (t, *J* = 7.4 Hz, 2H), 1.78 (q, *J* = 7.4 Hz, 2H), 1.31 (s, 9H), 1.02 (t, *J* = 7.4 Hz, 3H). **^{13}C NMR** (126 MHz, $CDCl_3$) δ 206.3, 162.6, 160.9, 129.8, 117.2, 116.7, 115.3, 40.2, 35.4, 30.9, 18.3, 14.0, 1.2. **HRMS (ESI/QTOF), m/z:** $[M+H]^+$ Calcd. For $C_{14}H_{21}O_2$, 221.153606; Found 221.154024.

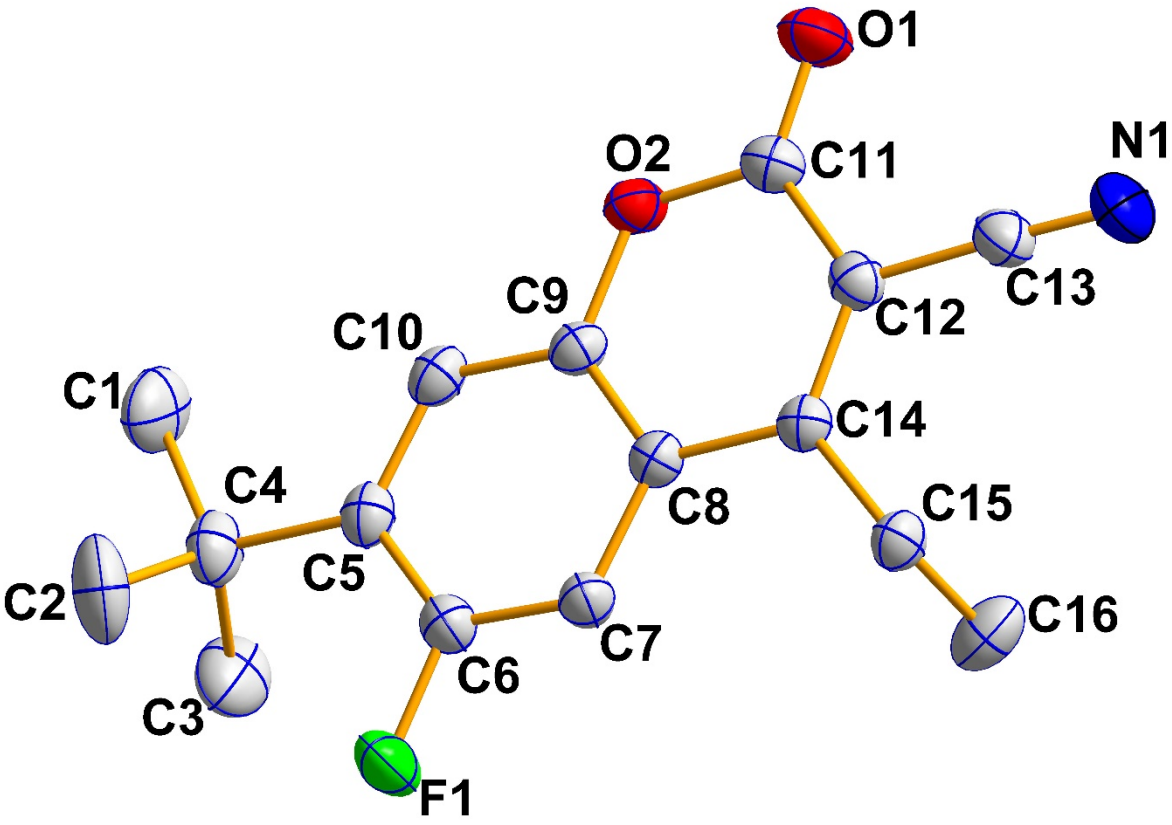
6. Crystallographic data

Sample preparation: Single crystal of compound **3p** suitable for the X-ray diffraction studies were grown from its EtOH/Heptane solution at room temperature.

Molecular structure determination of compounds **3p**: Single crystal X-ray diffraction data for compound **3p** was collected using a Bruker SMART APEX diffractometer equipped with a 3-axis goniometer. The crystals were covered with Paratone–*N* and mounted a glass capillary. The data were collected at room temperature using Mo Kα radiation (λ = 0.71073). Integration of data was performed using SAINT. Empirical absorption correction was applied using SADABS. Structure solutions were accomplished by directs methods and refine by full matrix least-square on F2 using OLEX2. All non-hydrogen atoms were refined anisotropically. The position of hydrogen atoms was fixed according to a riding model and were refined isotropically.



Single Crystal X-ray Structure of Compound **3p.**



Single Crystal X-ray Structure of Compound **3p.**

Table S15. Crystal data and structure refinement for 3p

Bond precision:	C-C = 0.0020 A	Wavelength=0.71073	
Cell:	a=13.0253(3)	b=10.4167(3)	c=21.3841(5)
	alpha=90	beta=90	gamma=90
Temperature:	296 K		
	Calculated	Reported	
Volume	2901.41(13)	2901.41(13)	
Space group	P b c a	P b c a	
Hall group	-P 2ac 2ab	-P 2ac 2ab	
Moiety formula	C_{16} H_{16} F N O_2	C_{16} H_{16} F N O_2	
Sum formula	C_{16} H_{16} F N O_2	C_{16} H_{16} F N O_2	
Mr	273.30	273.30	

Dx,g cm^{-3}	1.251	1.251	
Z	8	8	
Mu (mm^{-1})	0.091	0.091	
F000	1152.0	1152.0	
F000’	1152.61		
h,k,l max	17,13,28	17,13,28	
Nref	3610	3610	
Tmin,Tmax	0.981,0.986	0.981,0.986	
Tmin’	0.978		
Correction method=	# Reported T Limits:	Tmin=0.981	Tmax=0.986
AbsCorr =	NONE		
Data completeness=	1.000	Theta(max)=	28.301
R(reflections)=	0.0422(2805)	wR2(reflections)=	0.1683(3591)
S =	1.101	Npar=	185

7. References

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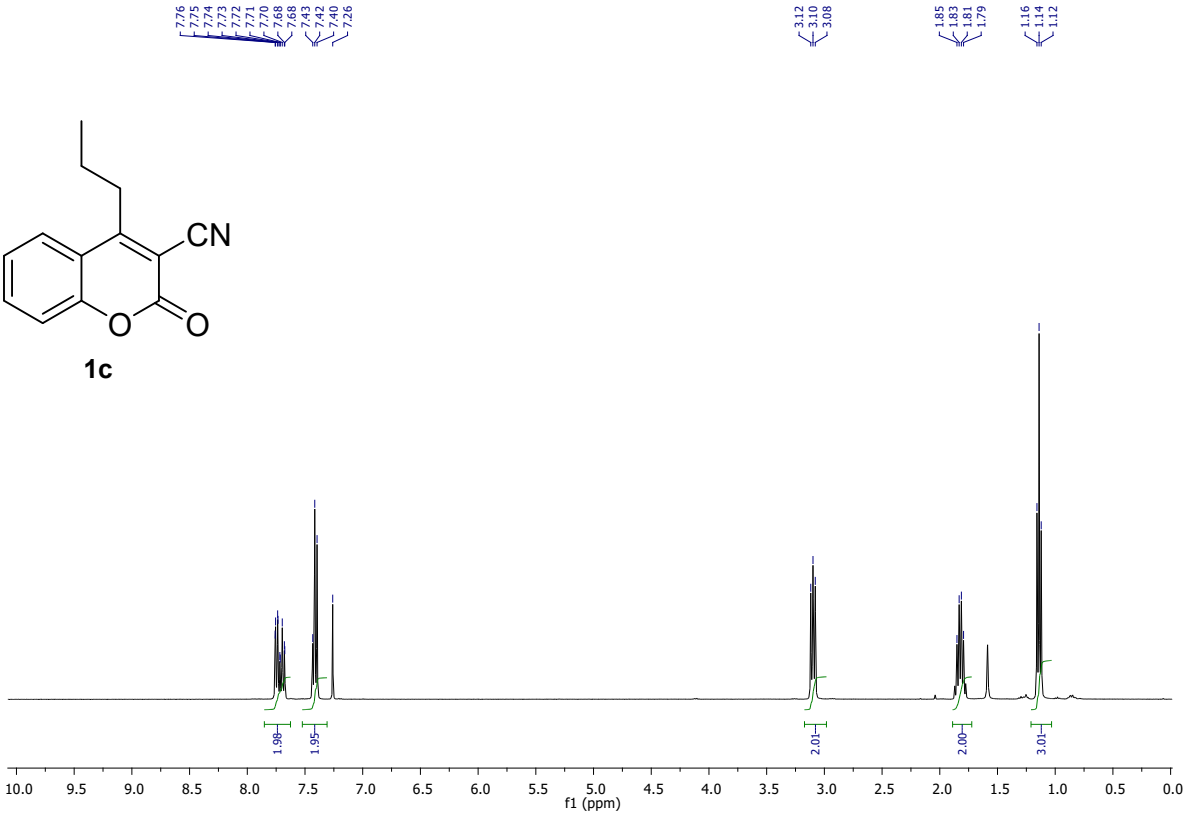
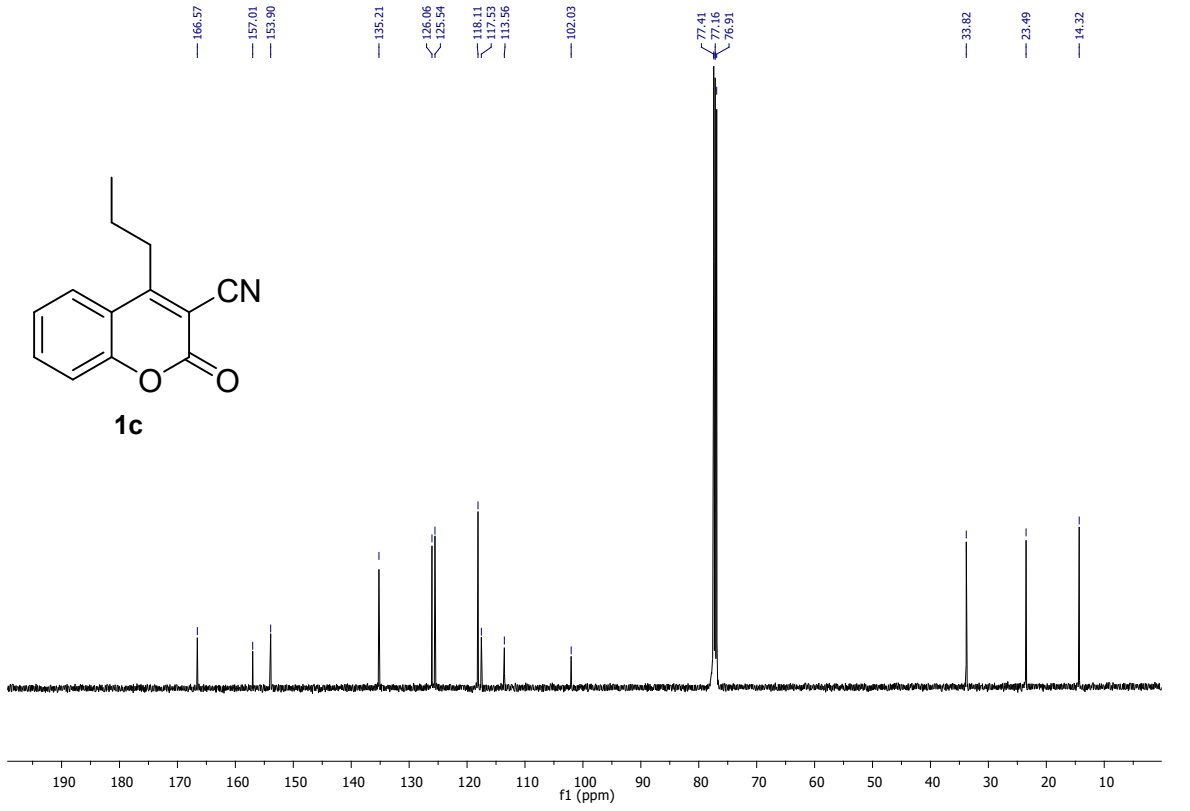
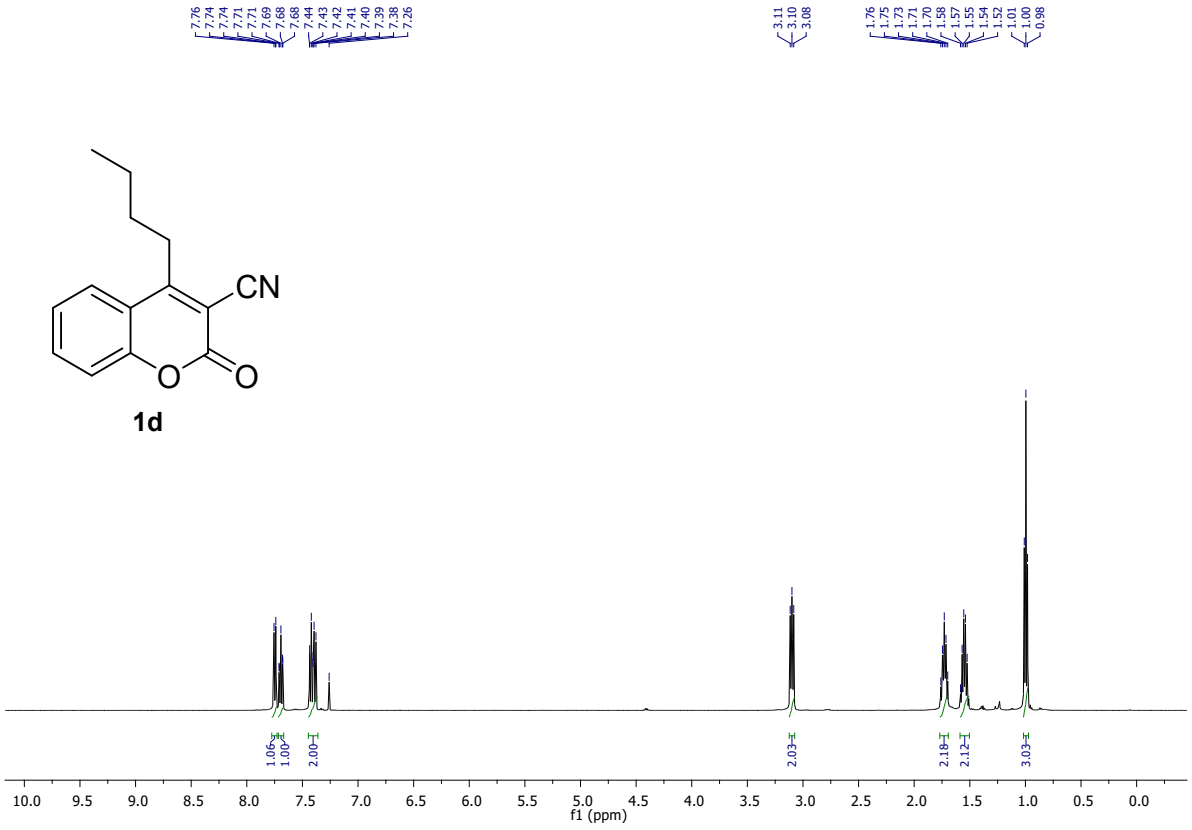
8. ^{1}H and ^{13}C spectra of compounds



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7.38
7.26
3.11
3.10
3.08
1.76
1.75
1.73
1.71
1.70
1.58
1.57
1.55
1.54
1.52
1.01
1.00
0.98
CN
O
O
1d
1.06
1.00
2.00
2.03
2.18
2.12
3.03
10.0
9.5
9.0
8.5
8.0
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7.0
6.5
6.0
5.5
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2.5
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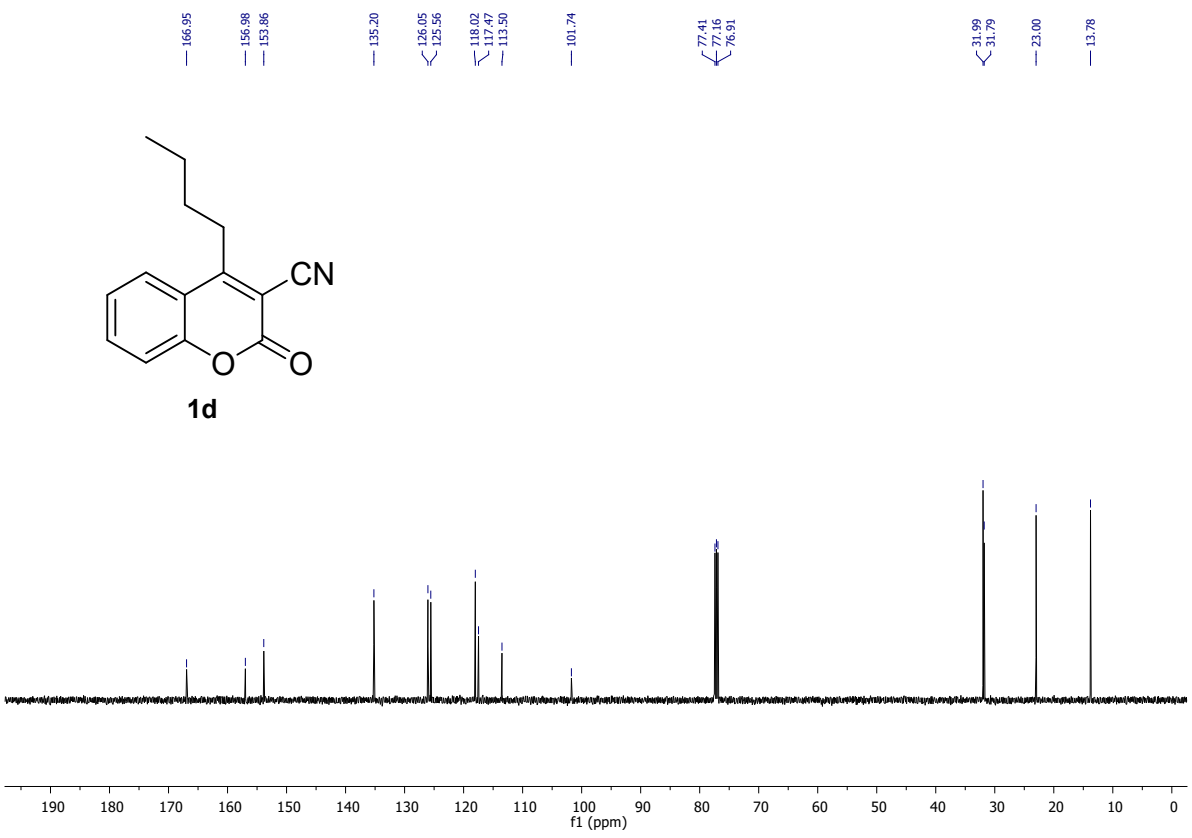
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76.91
31.99
31.79
23.00
13.78
CN
O
O
1d
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180
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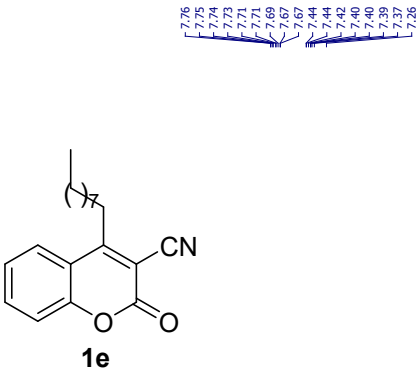
f1 (ppm)



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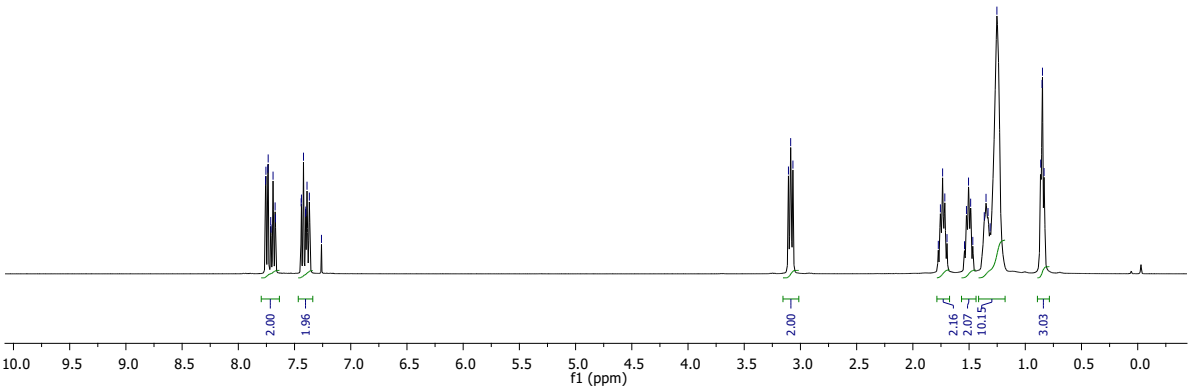

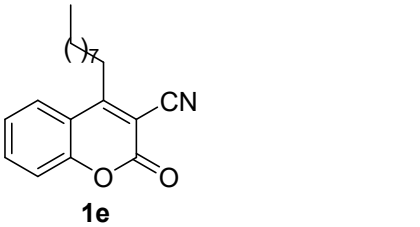

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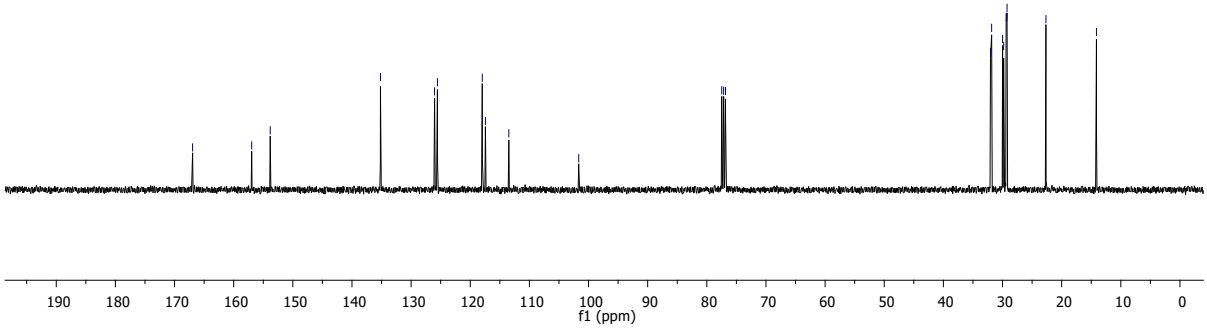

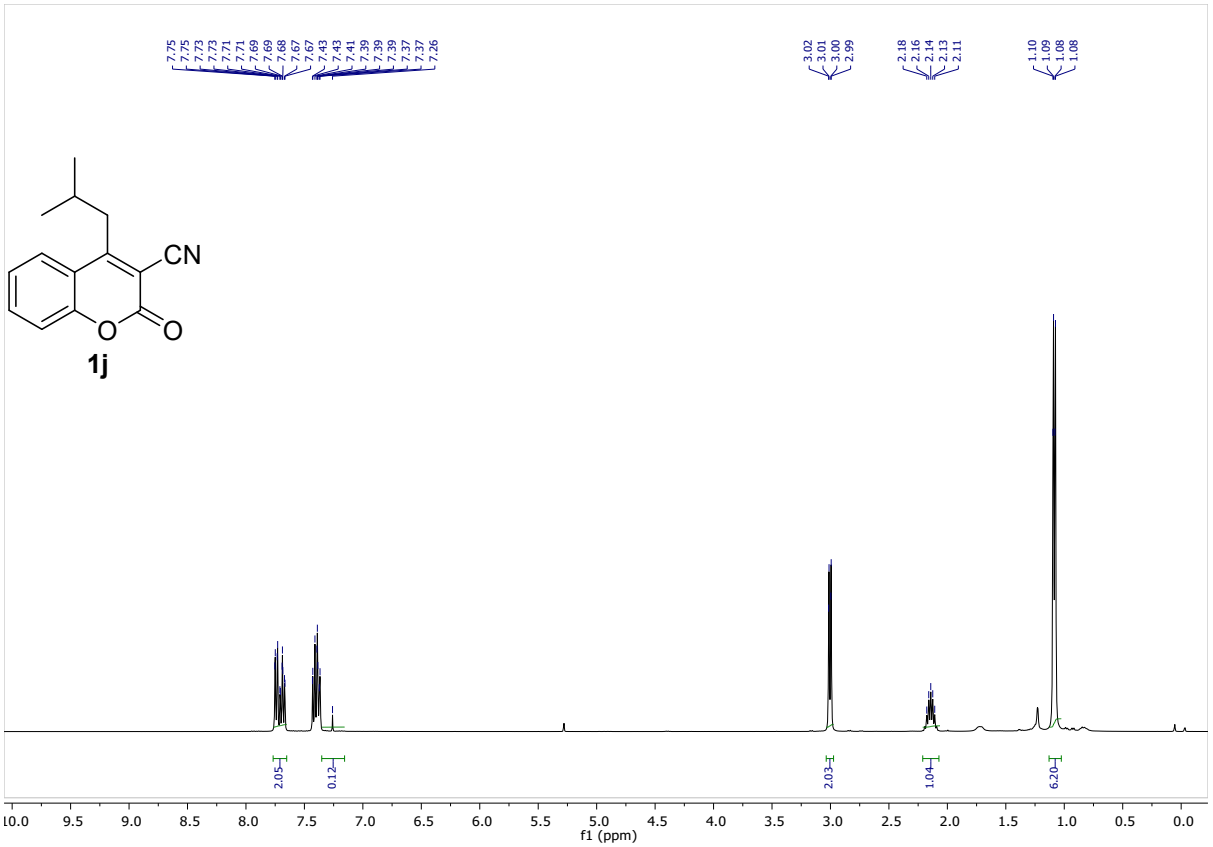
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7.37
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3.00
2.99
2.18
2.16
2.14
2.13
2.11
1.10
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1.08
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O
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1.04
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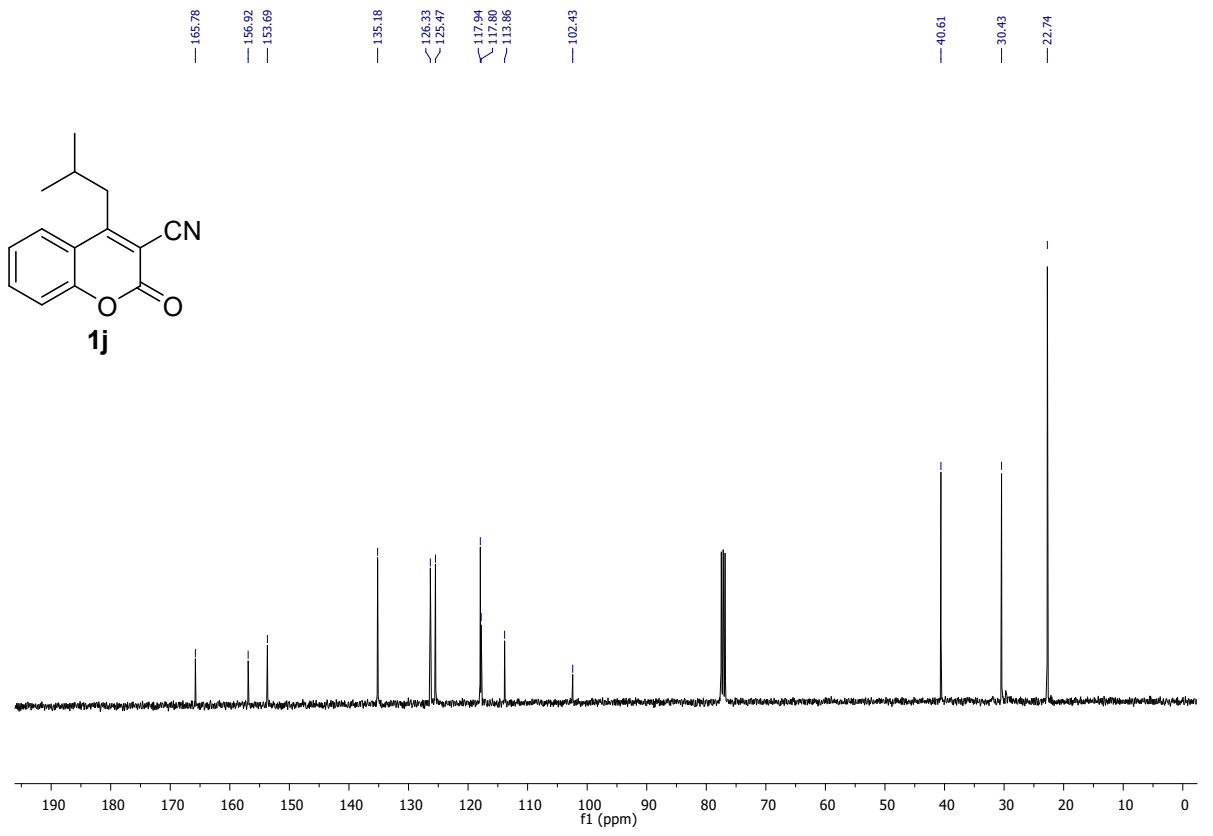
f1 (ppm)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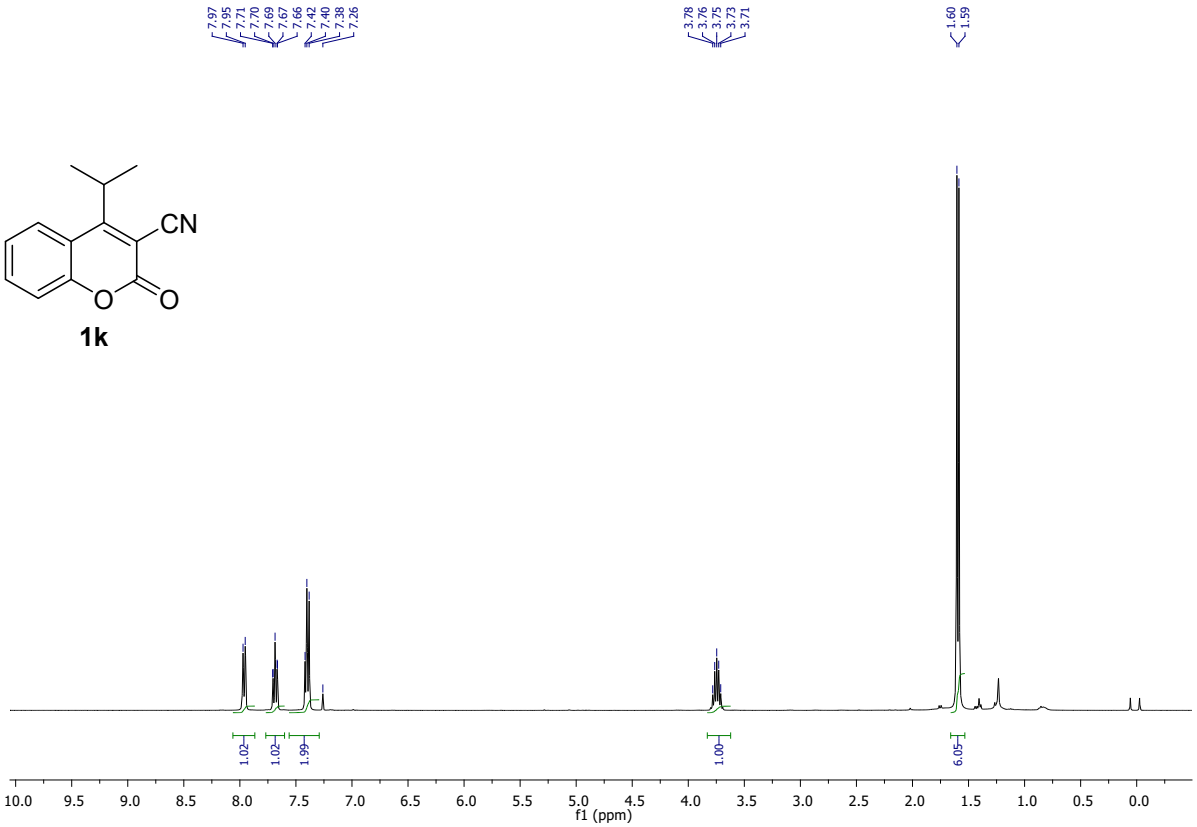
O
1j
f1 (ppm)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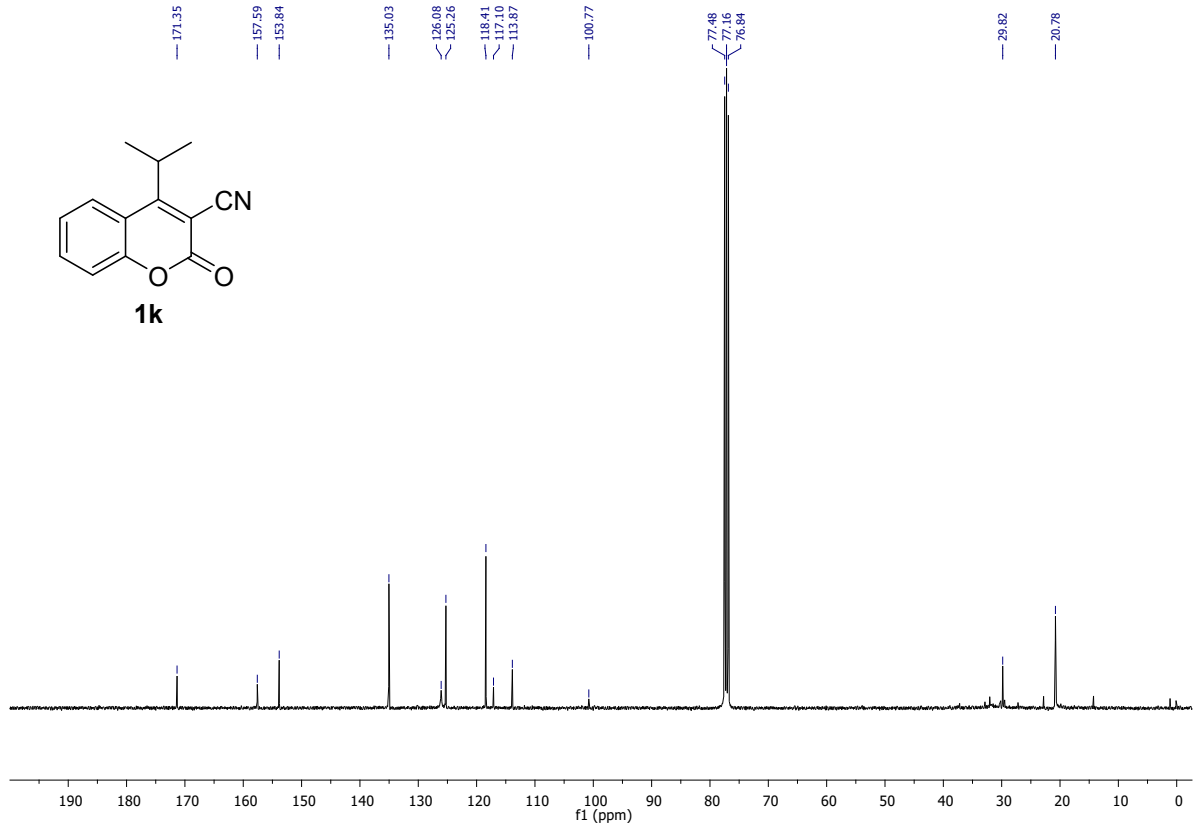
f1 (ppm)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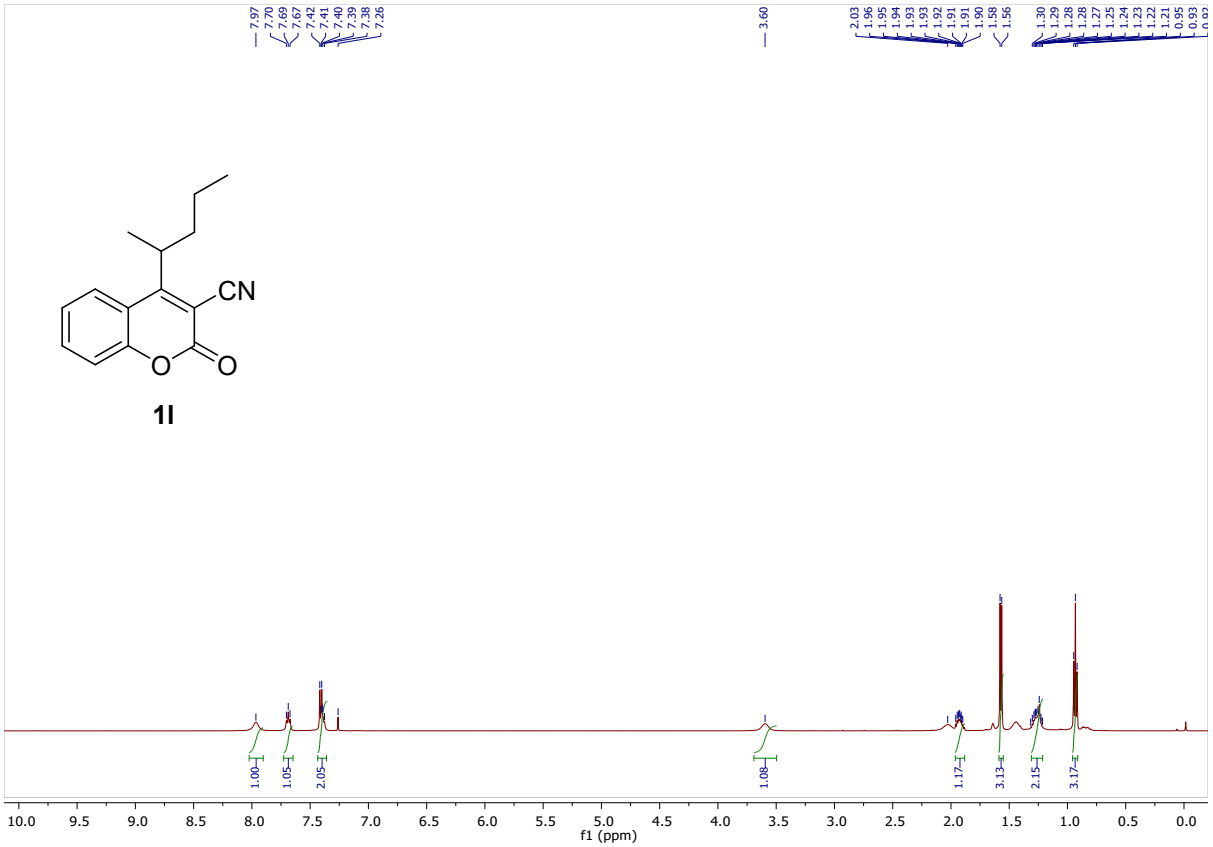
O
1k
f1 (ppm)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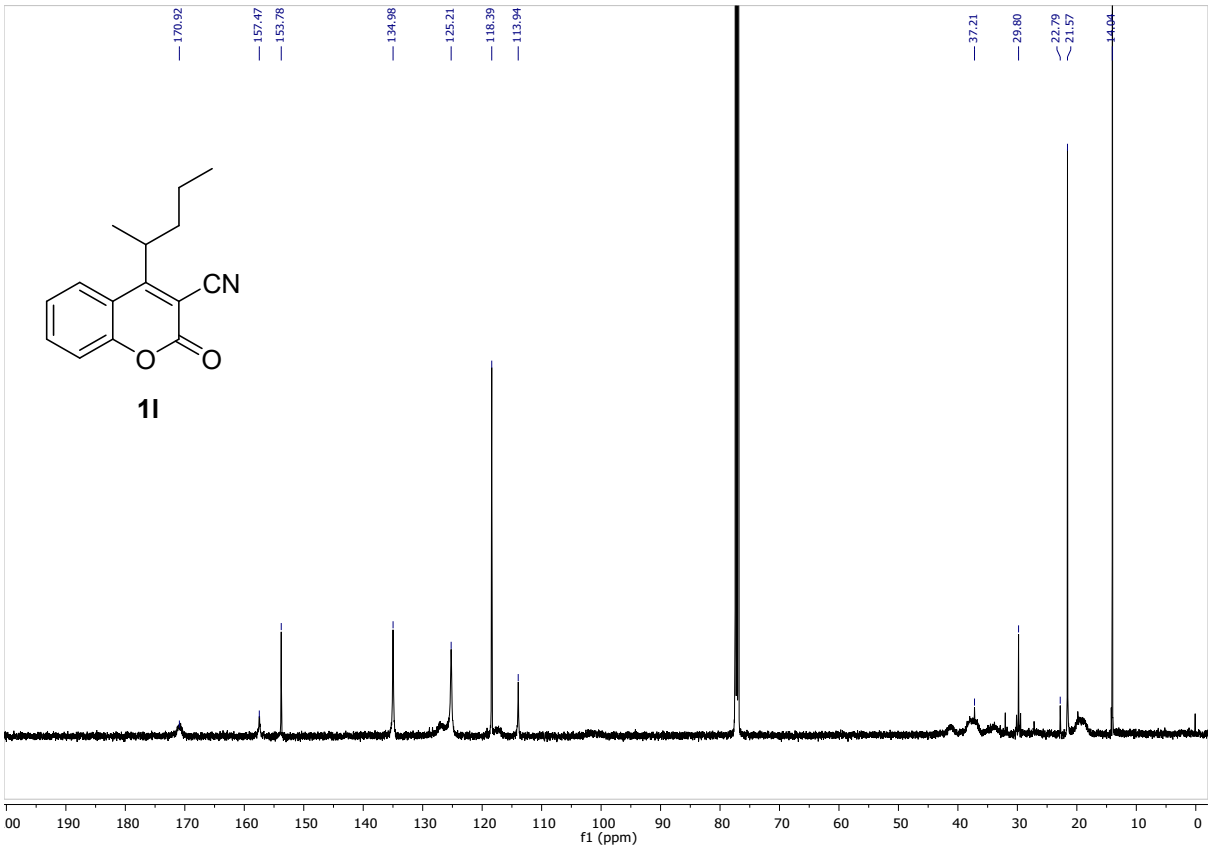
f1 (ppm)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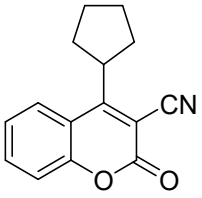
O
1l
f1 (ppm)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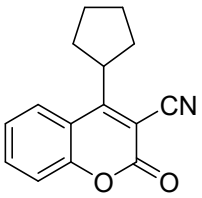
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1m

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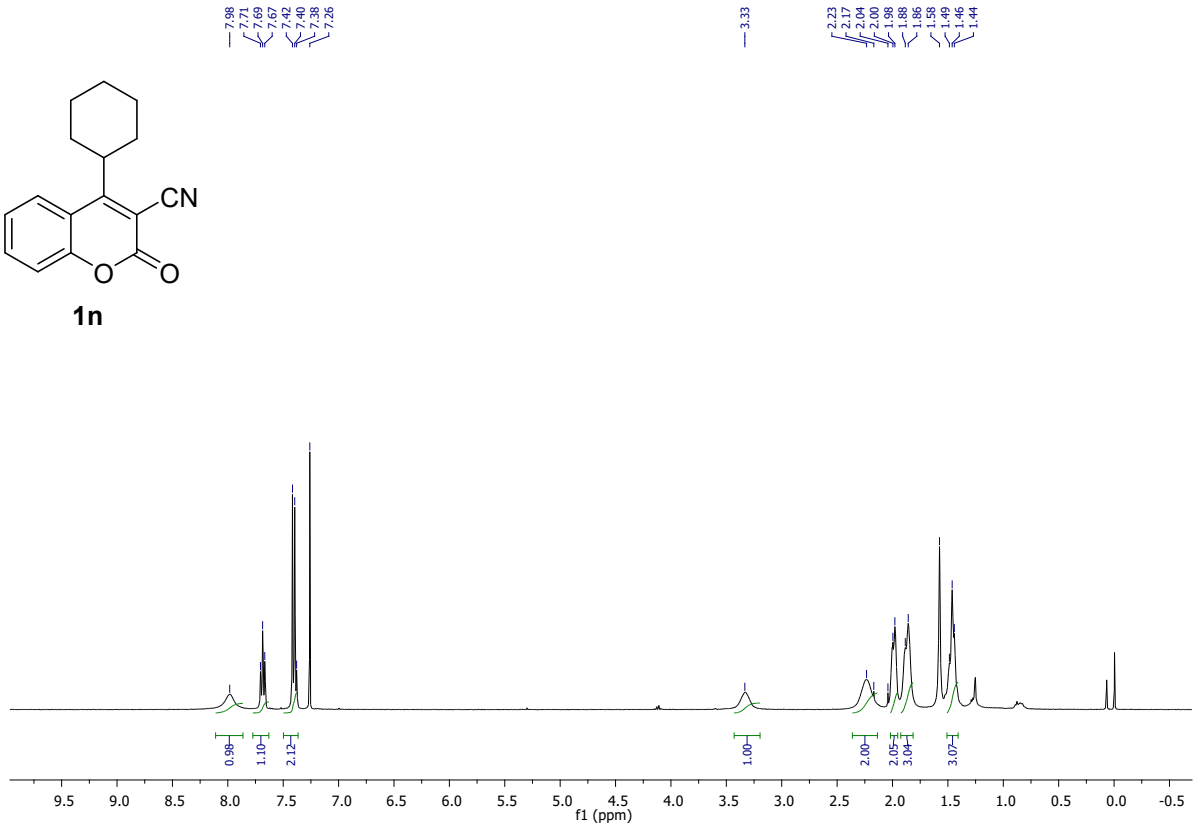
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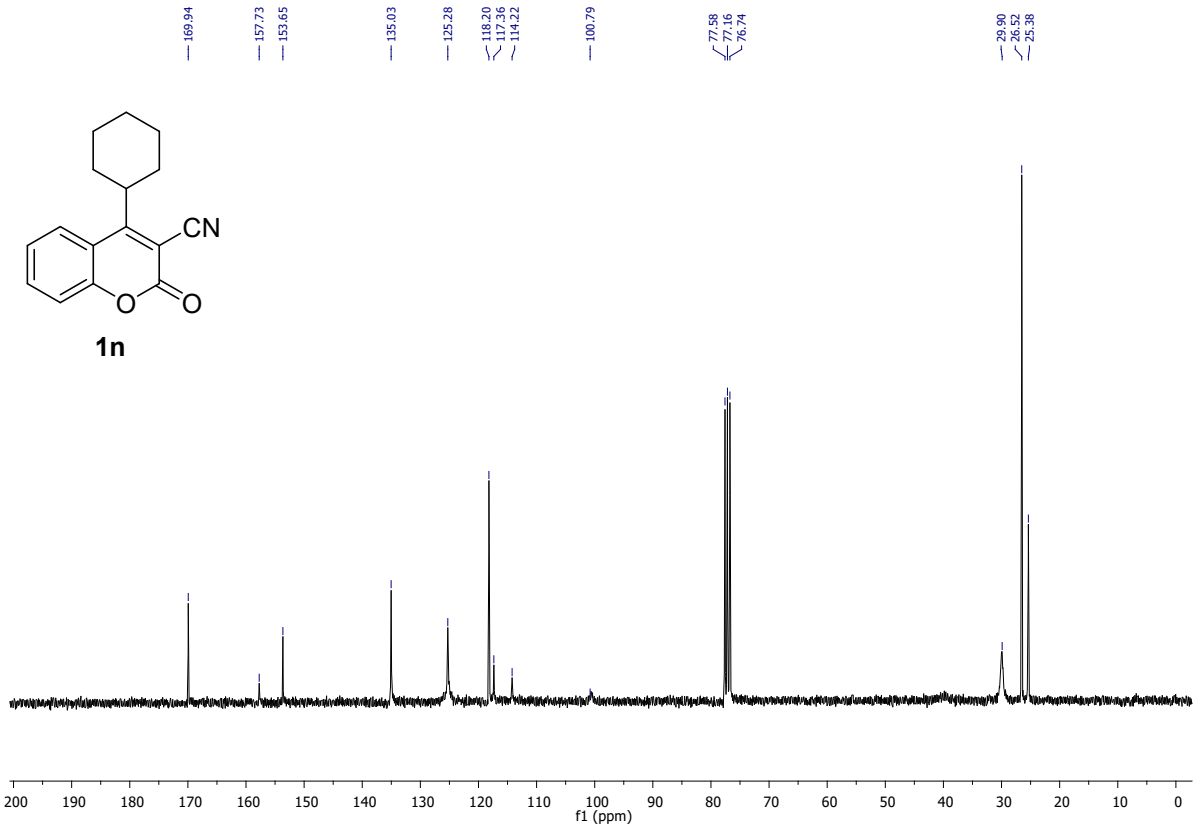
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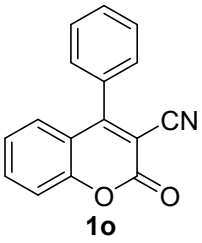
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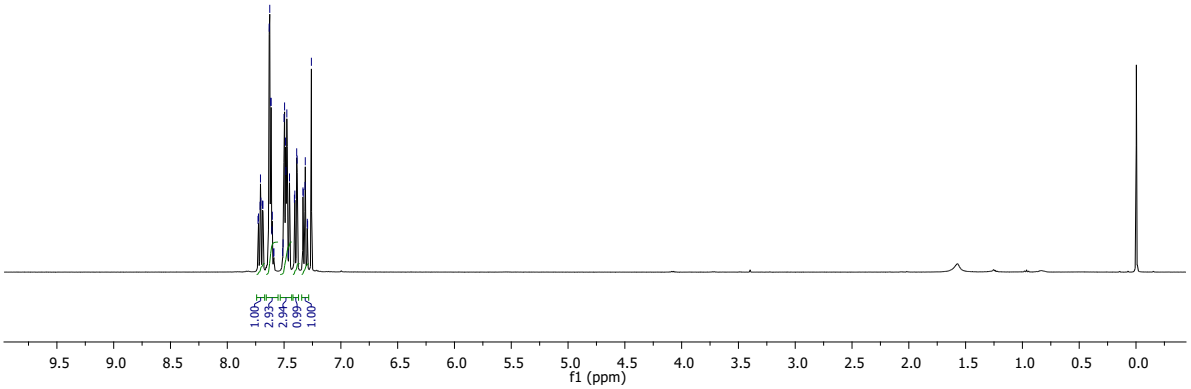
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1.00
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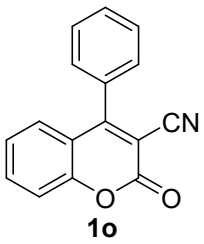
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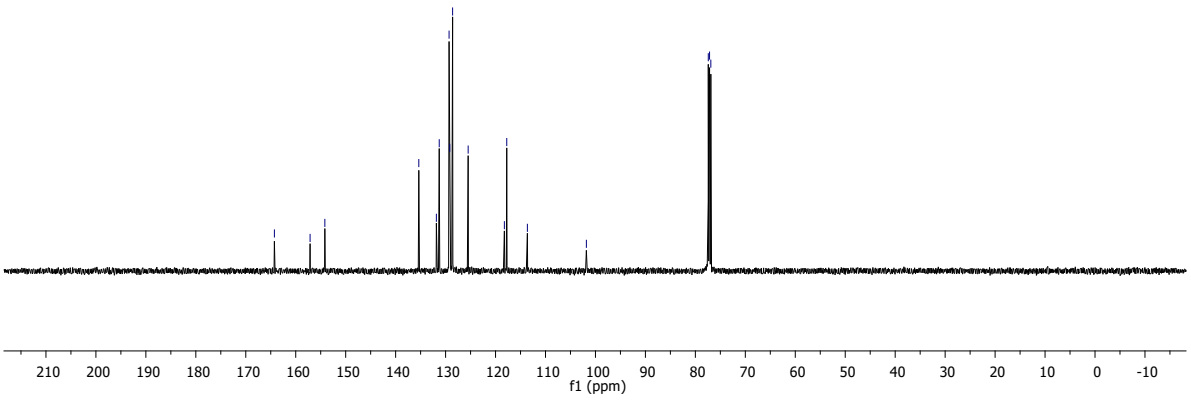
O
O

1o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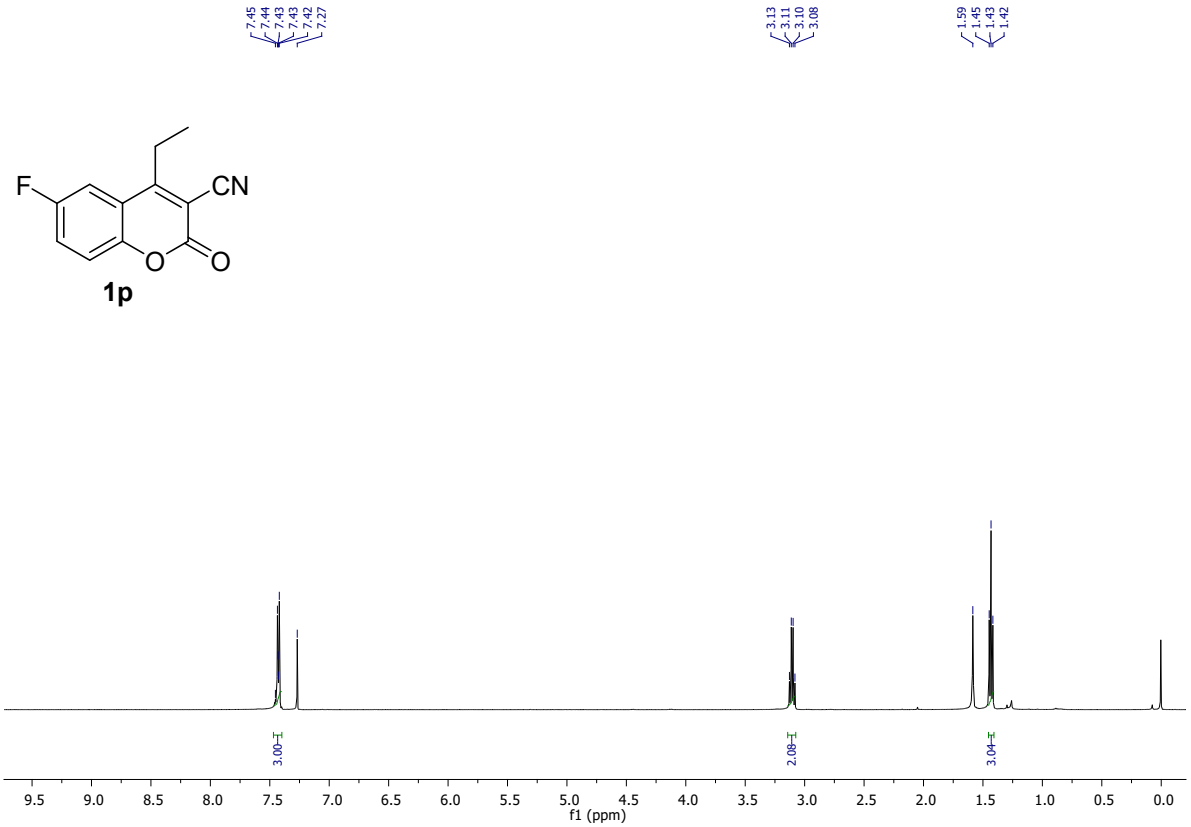
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F
CN
O
O
1p
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6.0
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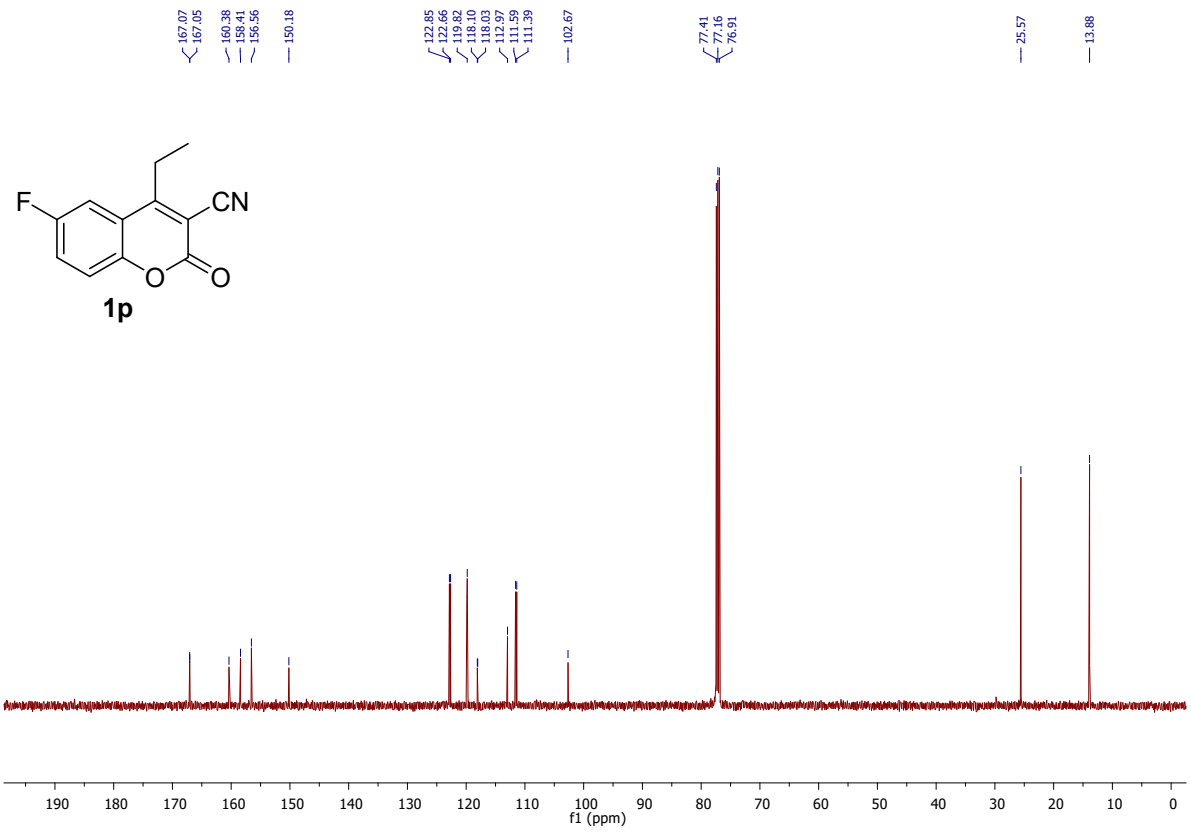
f1 (ppm)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111.39
102.67
77.41
77.16
76.91
25.57
13.88
F
CN
O
O
1p
190
180
170
160
150
140
130
120
110
100
90
80
70
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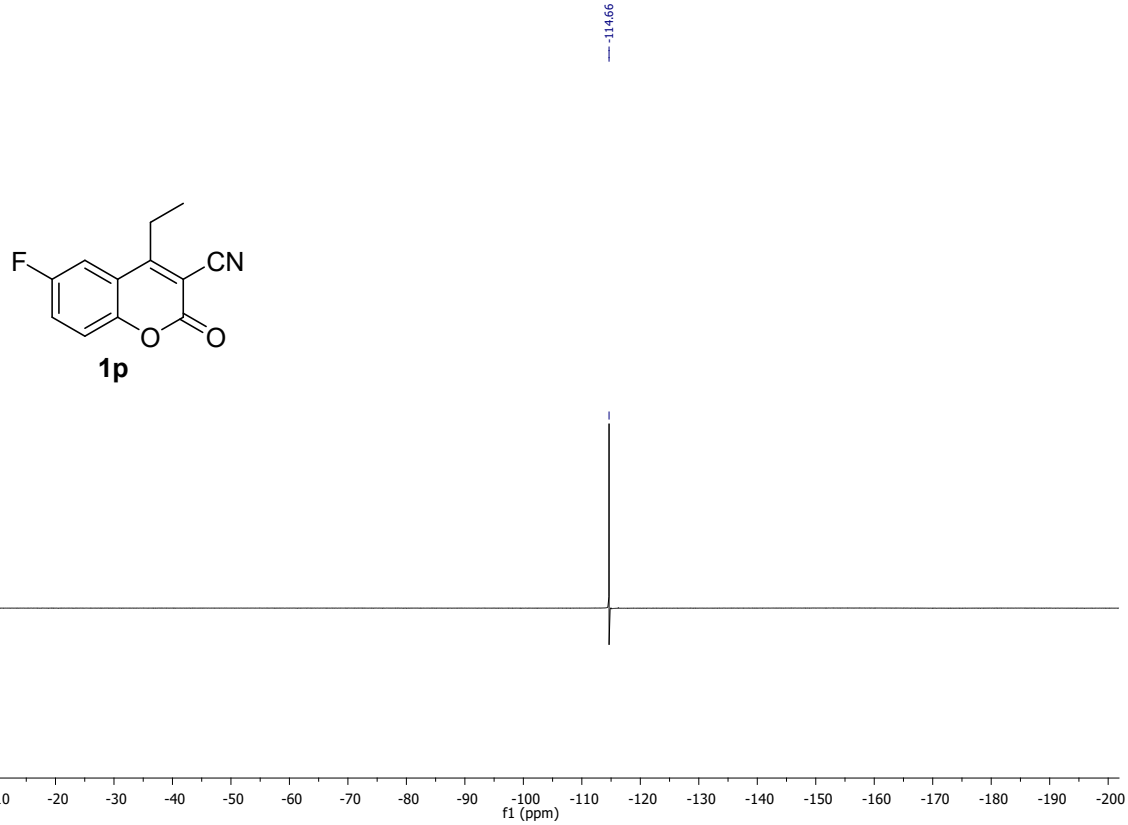
50
40
30
20
10
0
f1 (ppm)

^{19}F NMR of 1p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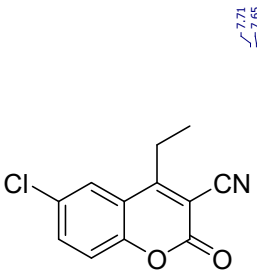
-200
f1 (ppm)


Cl
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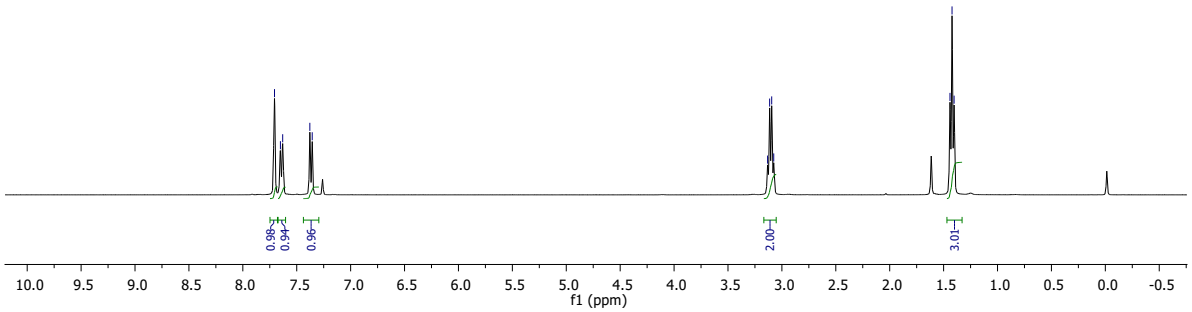
O
O

1q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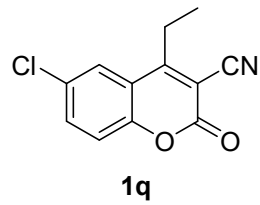
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1q

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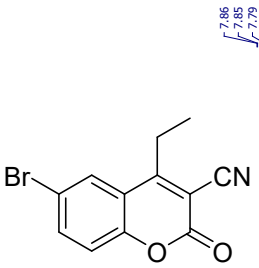
76.91
25.43
13.99
f1 (ppm)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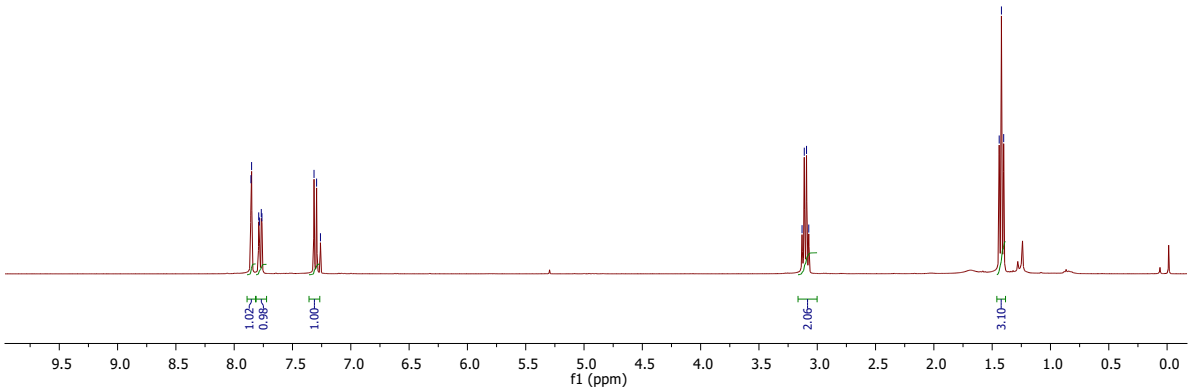
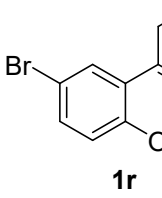
CN
O
O

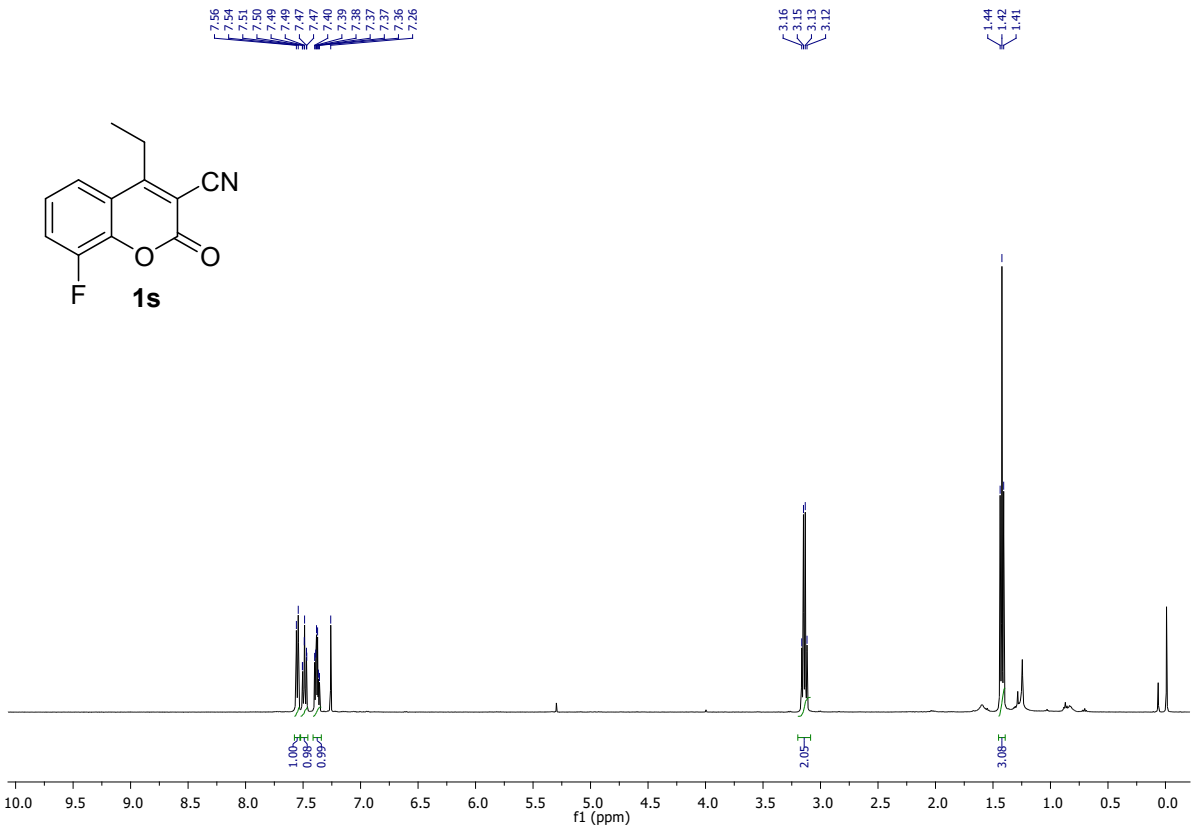
1r

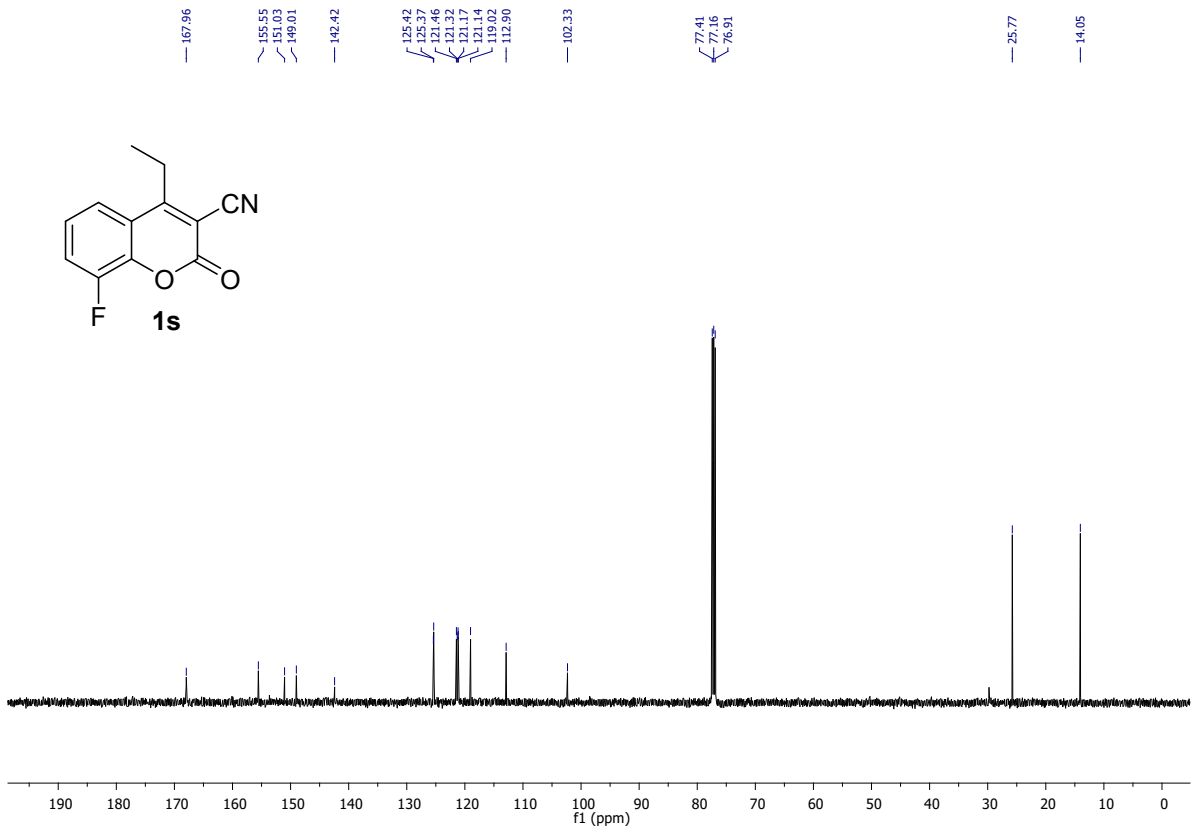

7.86
7.85
7.79
7.78
7.77
7.76
7.32
7.29
7.26
3.13
3.11
3.09
3.07
1.44
1.42
1.40
1.02
0.98
1.00
2.06
3.10
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


Br
CN
O
O

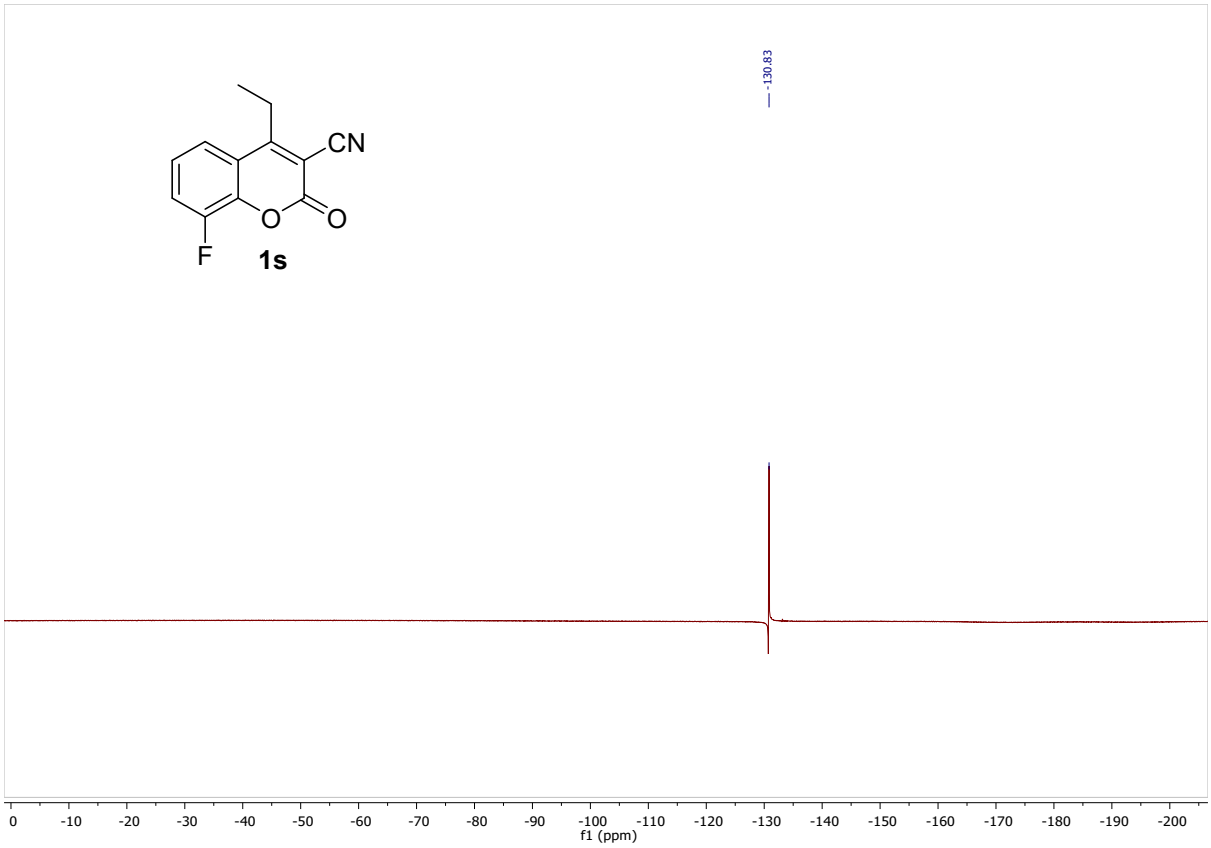
1r

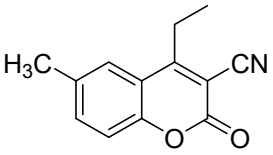
166.86
156.28
152.80
137.89
128.32
119.82
118.72
118.53
112.87
102.57
77.41
77.16
76.91
25.40
14.02
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


7.56
7.54
7.51
7.50
7.49
7.49
7.47
7.47
7.40
7.39
7.38
7.37
7.37
7.36
7.26
3.16
3.15
3.13
3.12
1.44
1.42
1.41
CN
O
O
F
1s
1.00
0.98
0.99
2.05
3.08
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
f1 (ppm)


167.96
155.55
151.03
149.01
142.42
125.42
125.37
121.46
121.32
121.17
121.14
119.02
112.90
102.33
77.41
77.16
76.91
25.77
14.05
CN
O
O
F
1s
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

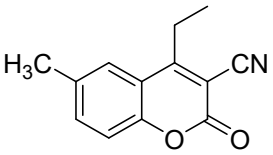
^{19}F NMR of 1s


CN
O
O
F
1s
-130.83
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
-200
f1 (ppm)


H3C
CN
O
O

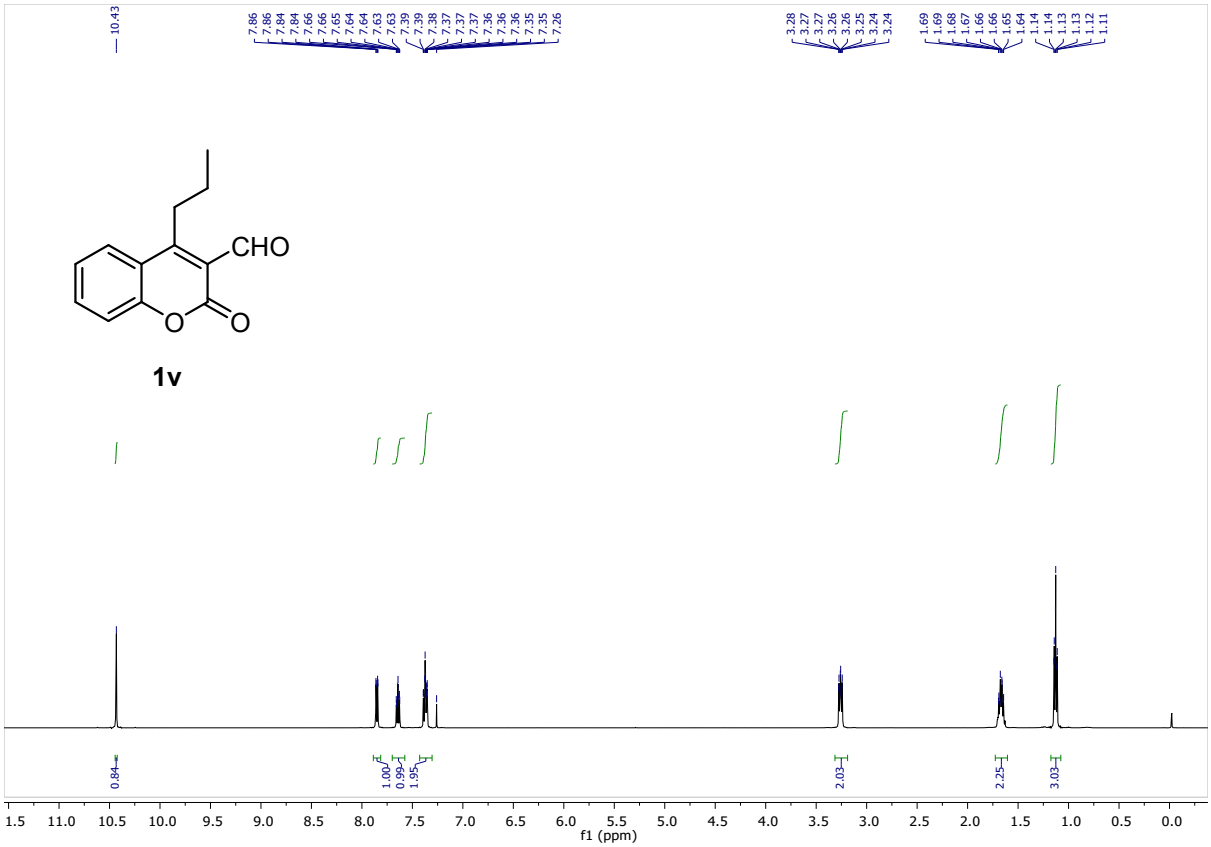
1u

7.51
7.49
7.30
7.29
7.26
3.14
3.12
3.11
3.09
2.47
1.43
1.41
1.40
1.25
2.00
0.96
2.04
3.00
3.10
f1 (ppm)

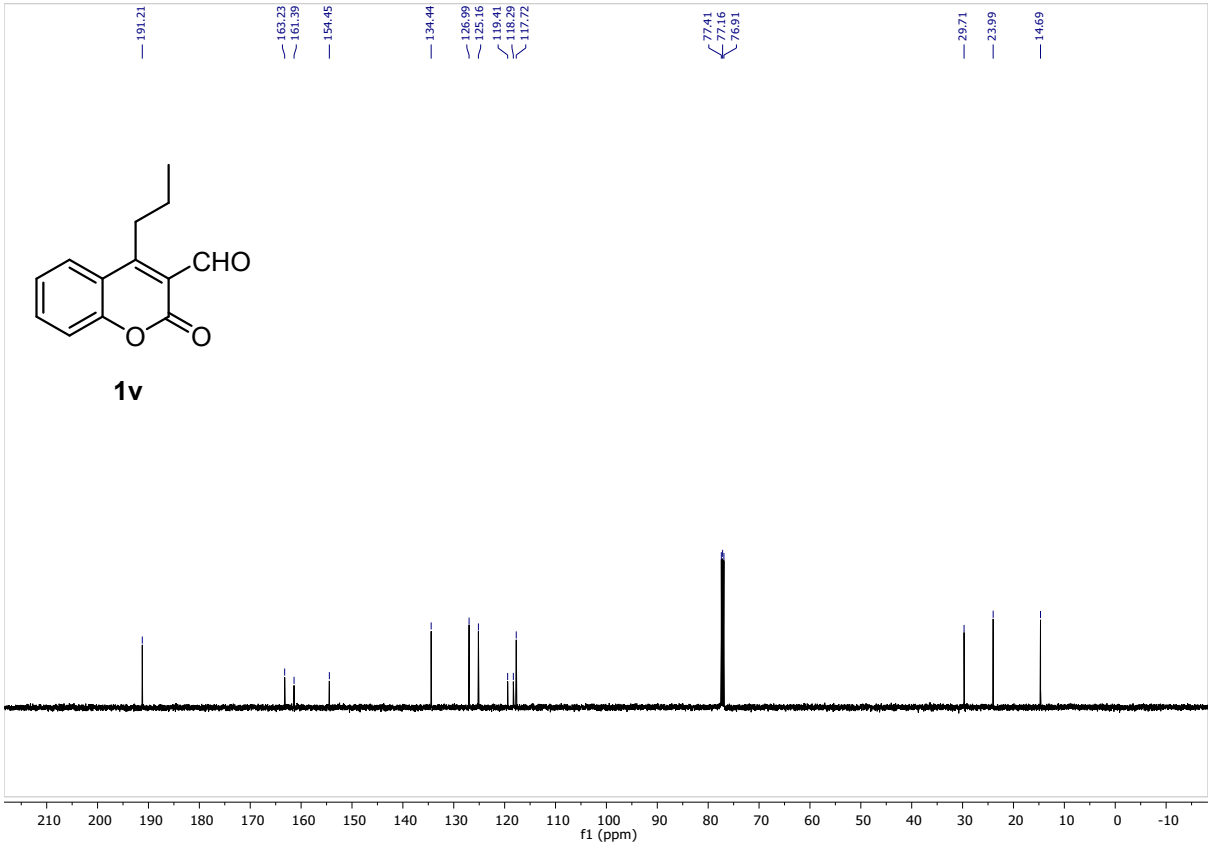

H3C
CN
O
O

1u

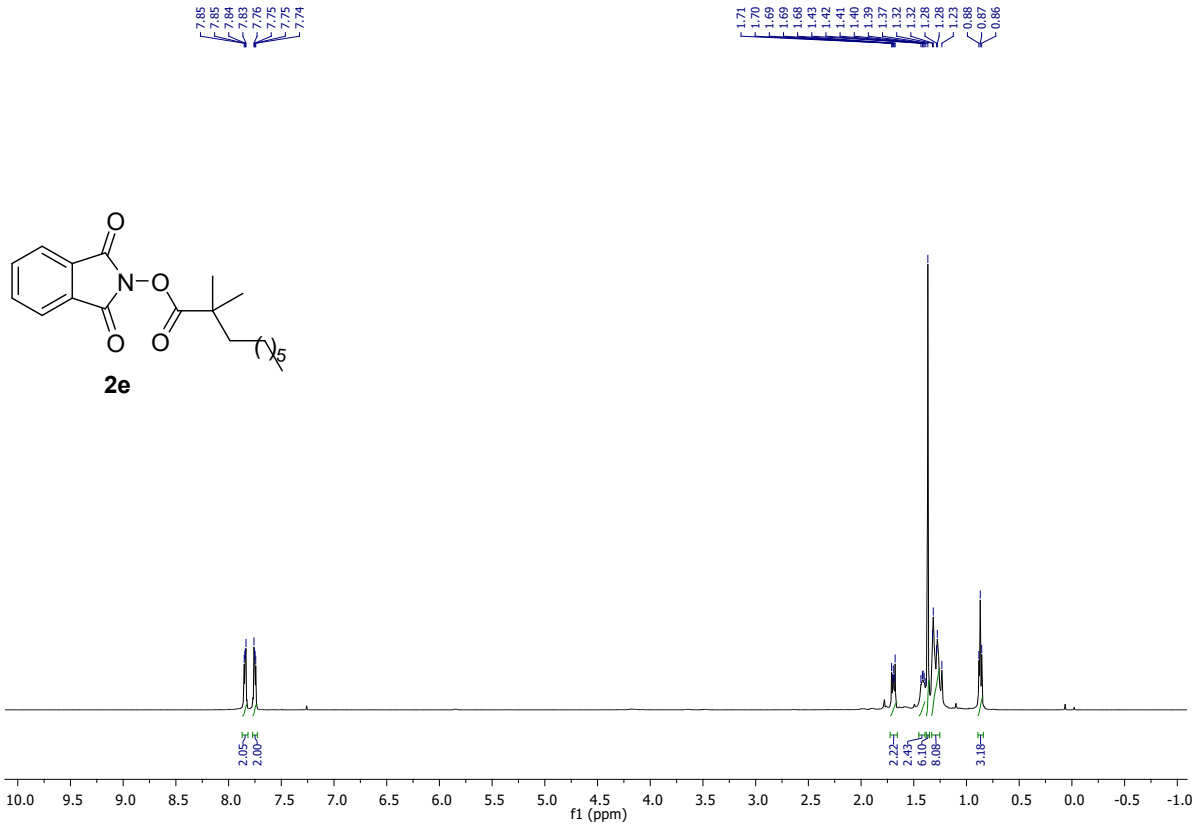
168.11
157.24
152.12
136.37
135.56
125.53
117.76
116.85
113.43
101.21
77.41
77.16
76.91
25.29
21.12
14.08
f1 (ppm)

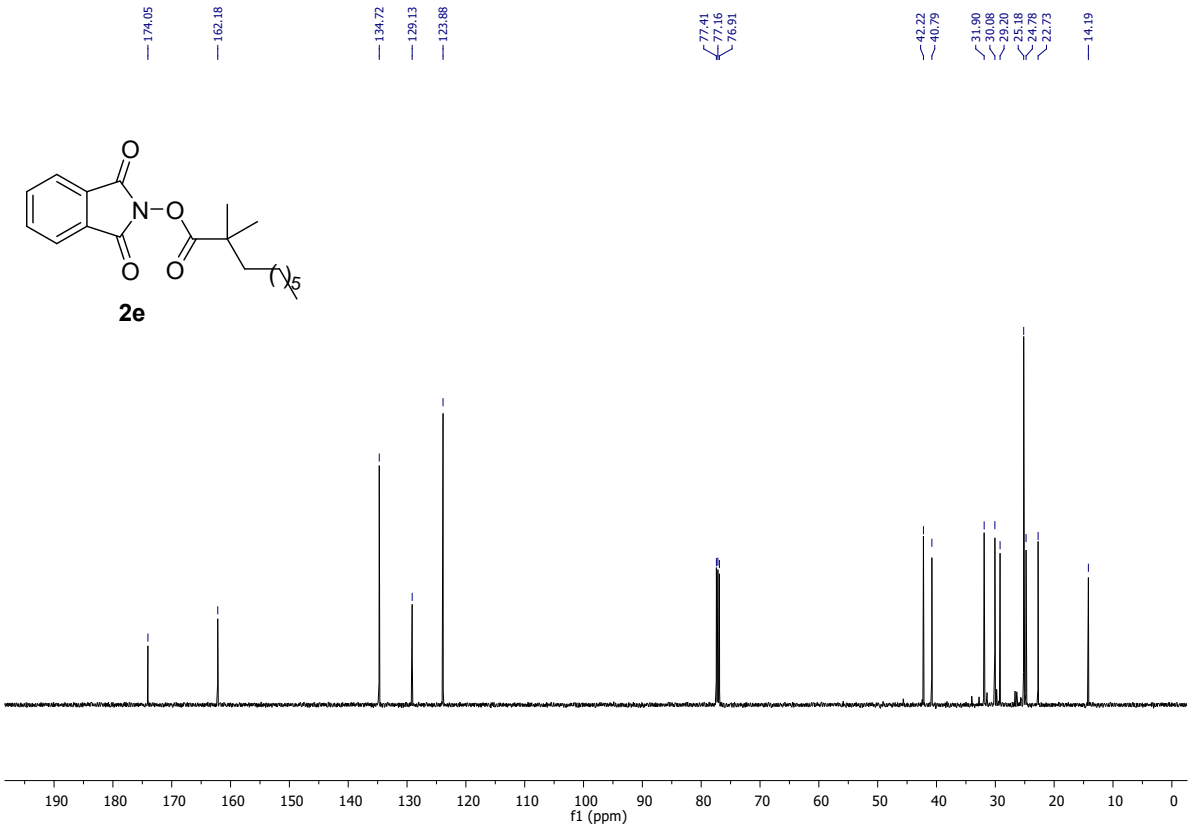

10.43
7.86
7.86
7.84
7.84
7.66
7.66
7.65
7.64
7.64
7.63
7.63
7.39
7.39
7.38
7.37
7.37
7.37
7.36
7.36
7.36
7.35
7.35
7.26
3.28
3.27
3.27
3.26
3.26
3.25
3.24
3.24
1.69
1.69
1.68
1.67
1.66
1.66
1.65
1.64
1.14
1.14
1.13
1.13
1.12
1.11
CHO
O
O
0.84
1.00
0.99
1.95
2.03
2.25
3.03
f1 (ppm)

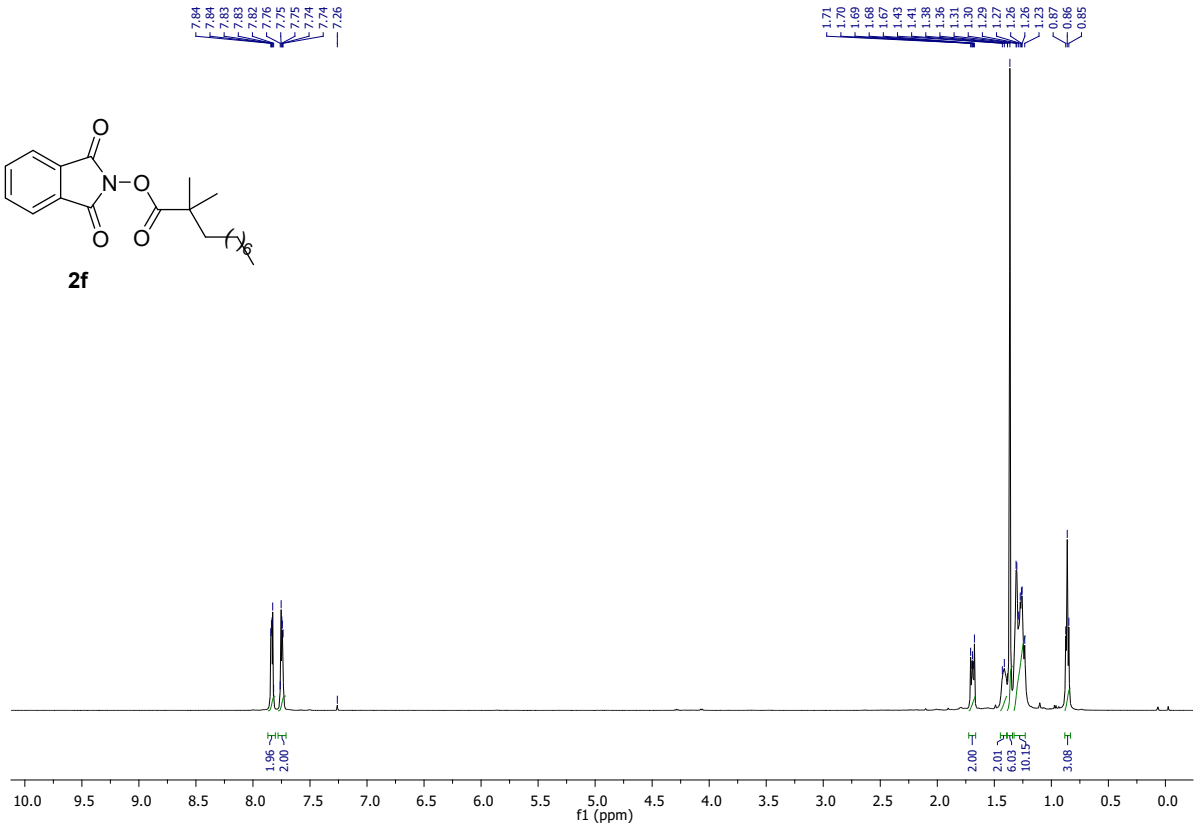
1v

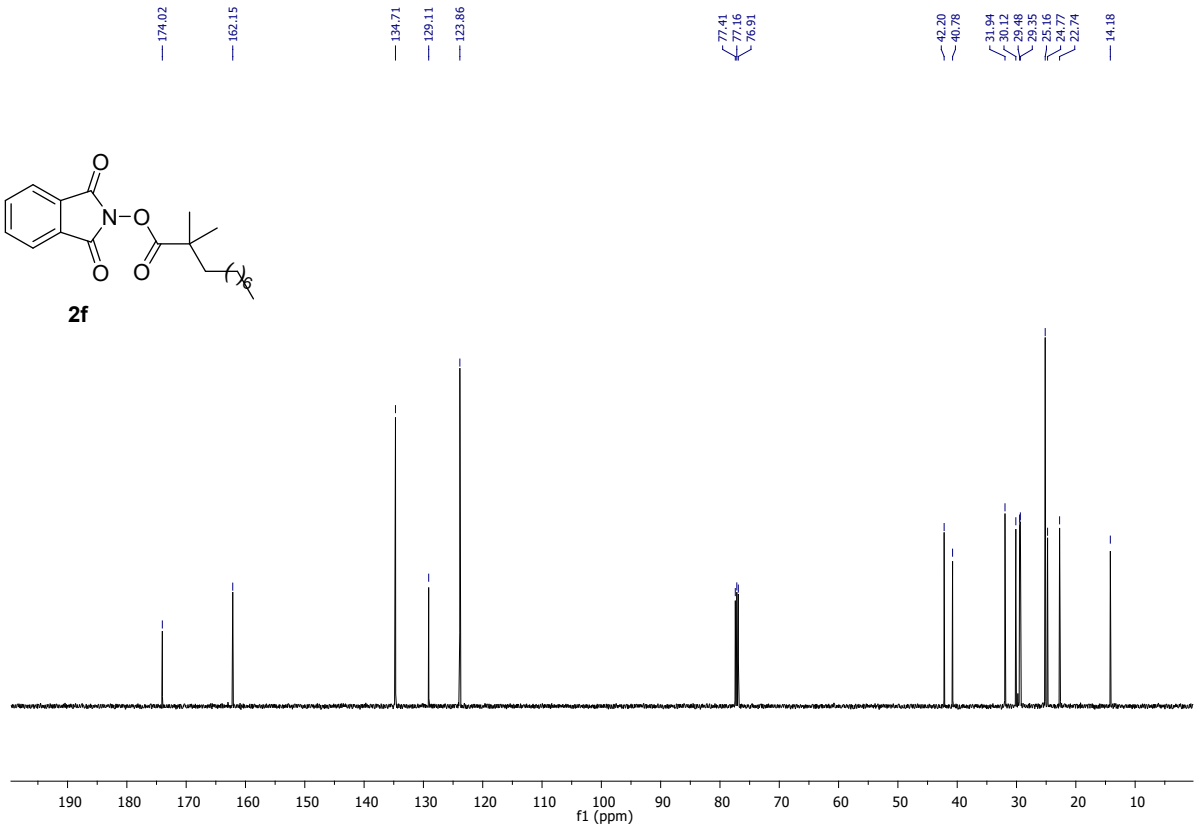

191.21
163.23
161.39
154.45
134.44
126.99
125.16
119.41
118.29
117.72
77.41
77.16
76.91
29.71
23.99
14.69
CHO
O
O
f1 (ppm)

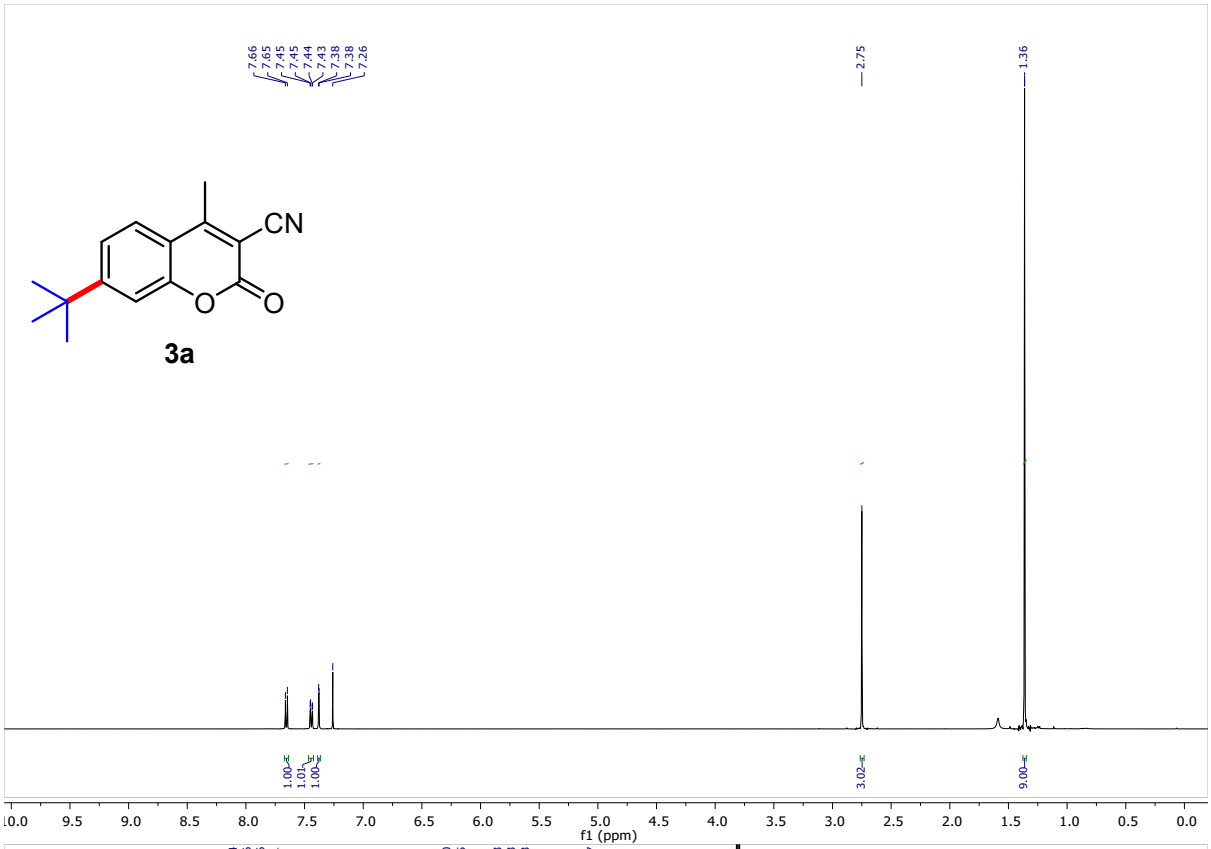
1v

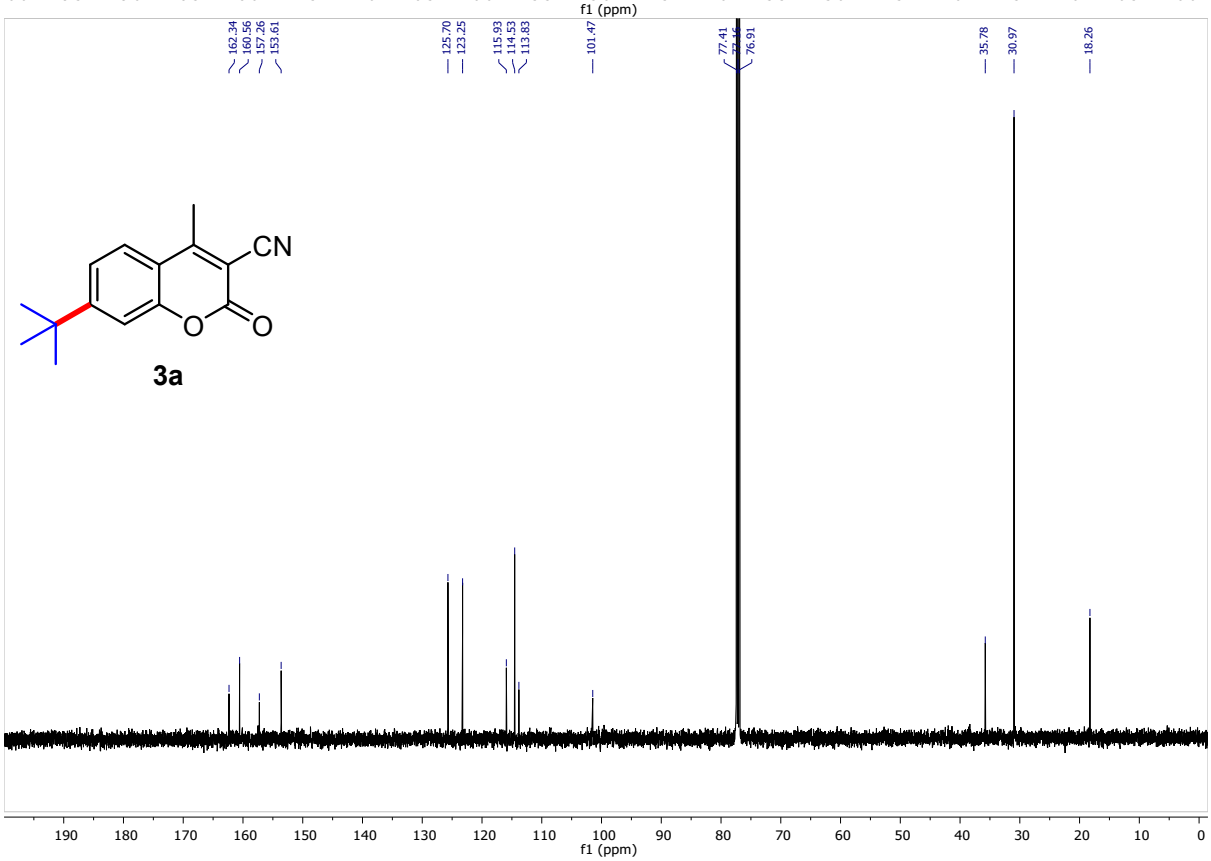

7.85
7.85
7.84
7.83
7.76
7.75
7.75
7.74
1.71
1.70
1.69
1.69
1.68
1.43
1.42
1.41
1.40
1.39
1.37
1.32
1.32
1.28
1.28
1.23
0.88
0.87
0.86
O
N
O
O
O
5
2e
2.05
2.00
2.22
2.43
6.10
8.08
3.18
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
f1 (ppm)


174.05
162.18
134.72
129.13
123.88
77.41
77.16
76.91
42.22
40.79
31.90
30.08
29.20
25.18
24.78
22.73
14.19
O
N
O
O
O
5
2e
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


7.84
7.84
7.83
7.83
7.82
7.76
7.75
7.75
7.74
7.74
7.26
1.71
1.70
1.69
1.68
1.67
1.43
1.41
1.38
1.36
1.31
1.30
1.29
1.27
1.26
1.26
1.23
0.87
0.86
0.85
O
N–O
O
O
2f
1.96
2.00
2.00
2.01
6.03
10.15
3.08
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
f1 (ppm)


174.02
162.15
134.71
129.11
123.86
77.41
77.16
76.91
42.20
40.78
31.94
30.12
29.48
29.35
25.16
24.77
22.74
14.18
O
N–O
O
O
2f
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
f1 (ppm)


7.66
7.65
7.45
7.45
7.44
7.43
7.38
7.26
2.75
1.36
CN
O
O
3a
1.00
1.01
1.00
3.02
9.00
f1 (ppm)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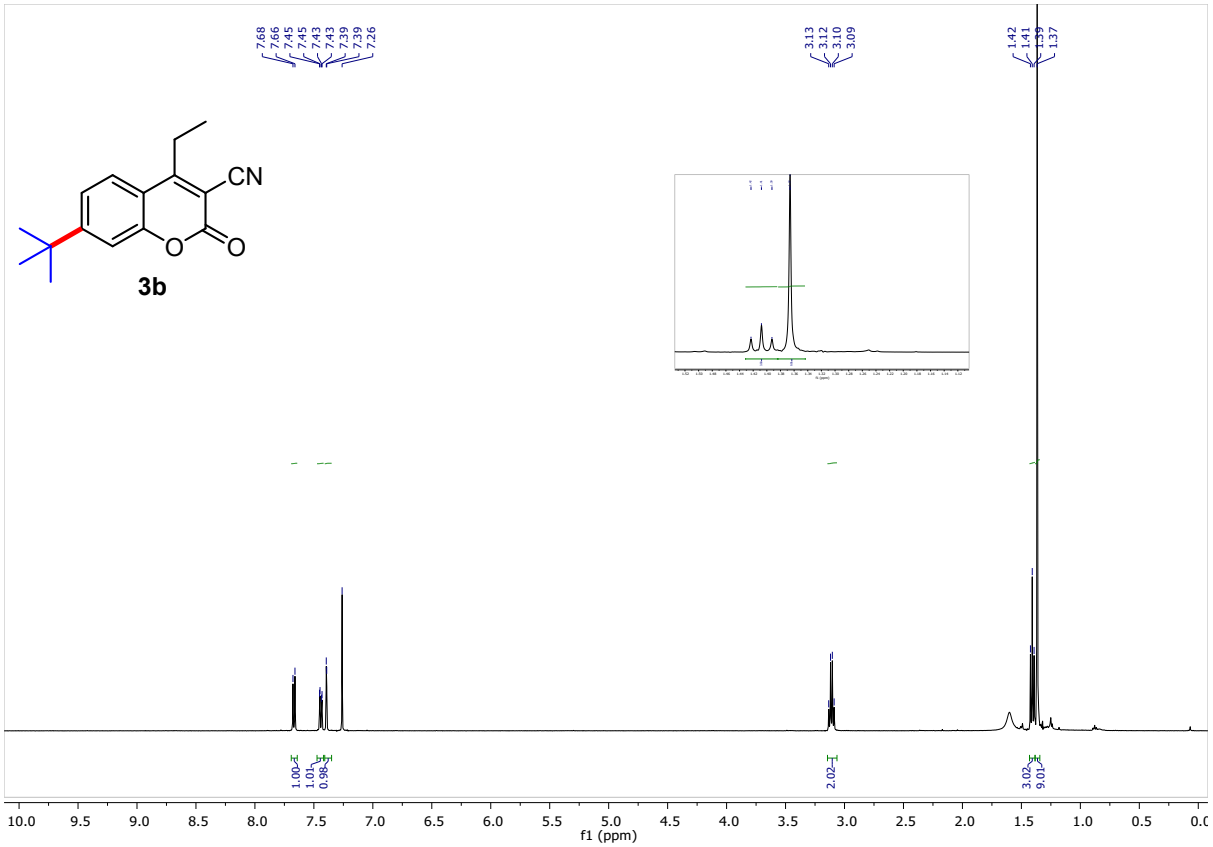
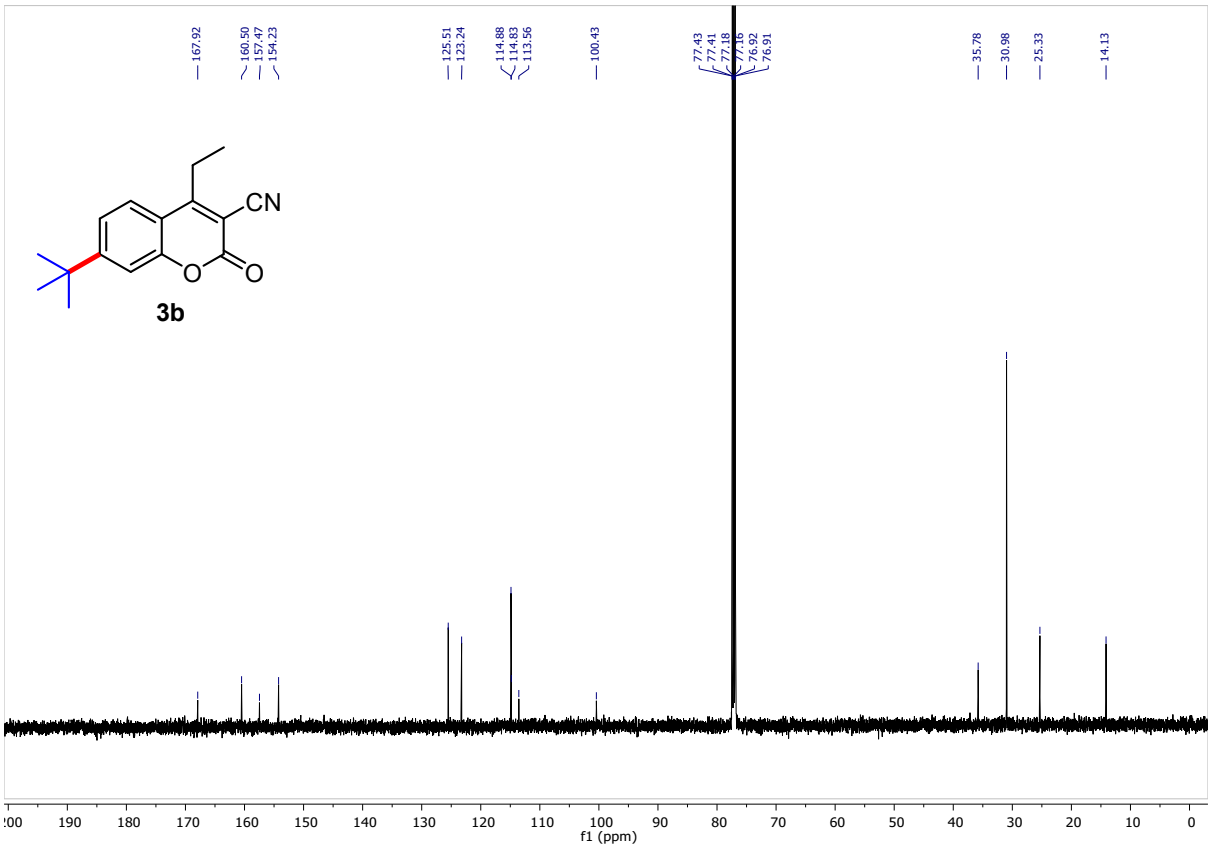
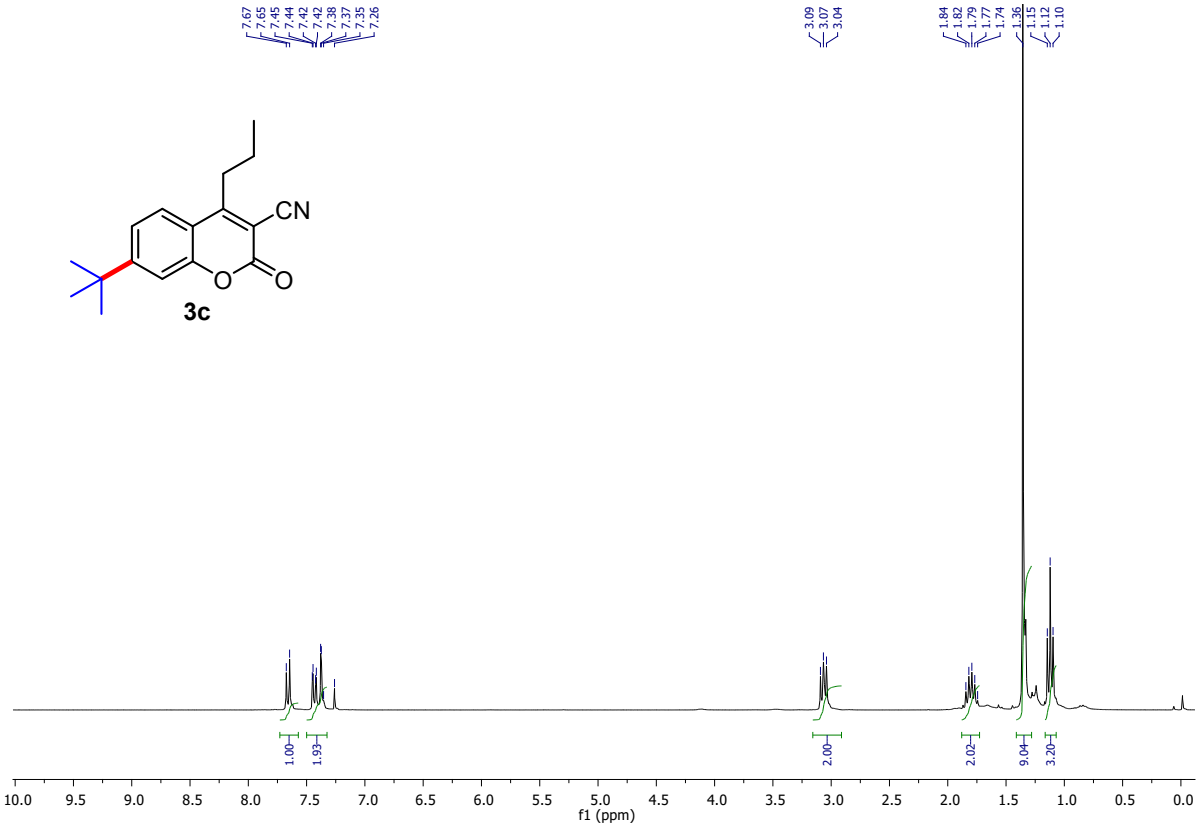
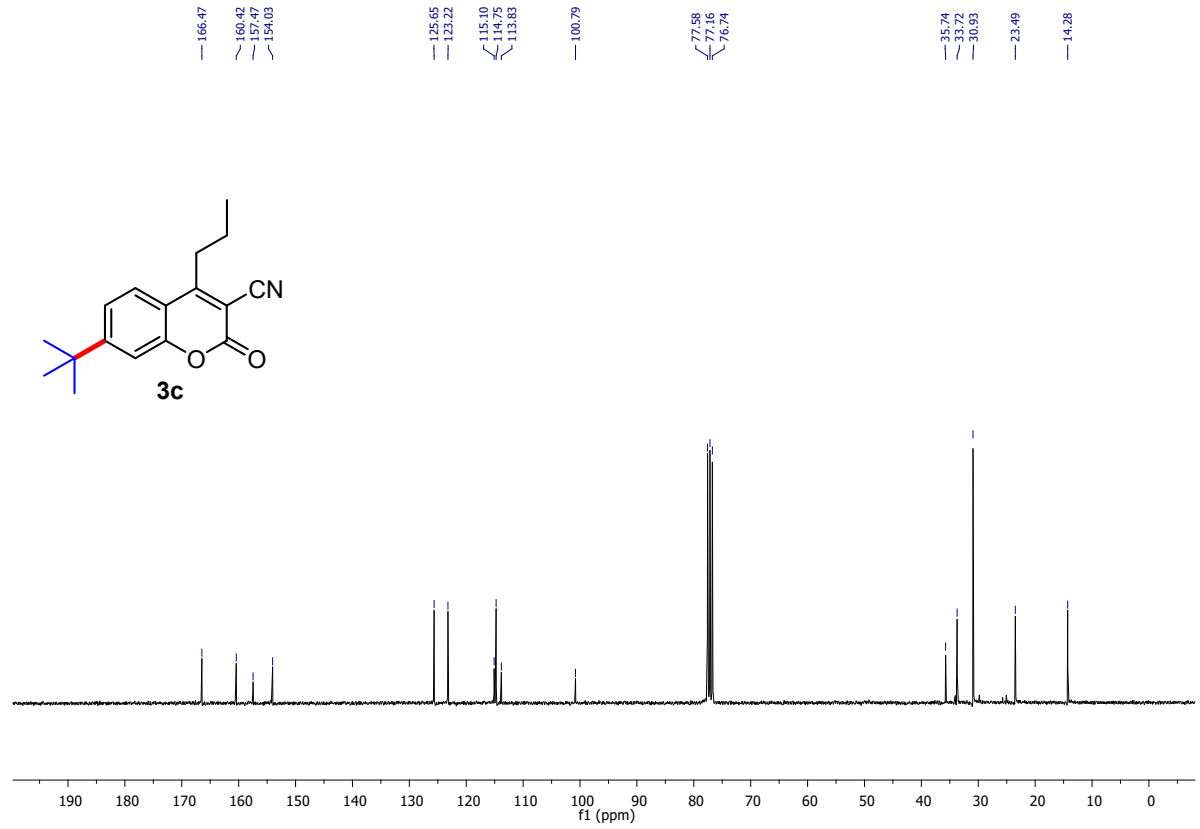
157.26
153.61
125.70
123.25
115.93
114.53
113.83
101.47
77.41
77.16
76.91
35.78
30.97
18.26
CN
O
O
3a
f1 (ppm)


7.68
7.66
7.45
7.45
7.43
7.43
7.39
7.39
7.26
3.13
3.12
3.10
3.09
1.42
1.41
1.39
1.37
CN
O
O
3b
1.00
1.01
0.98
2.02
3.02
9.01
f1 (ppm)


167.92
160.50
157.47
154.23
125.51
123.24
114.88
114.83
113.56
100.43
77.43
77.41
77.18
77.16
76.92
76.91
35.78
30.98
25.33
14.13
CN
O
O
3b
f1 (ppm)


7.67
7.65
7.45
7.44
7.42
7.42
7.38
7.37
7.35
7.26
3.09
3.07
3.04
1.84
1.82
1.79
1.77
1.74
1.36
1.15
1.12
1.10
CN
O
O
3c
1.00
1.93
2.00
2.02
9.04
3.20
f1 (ppm)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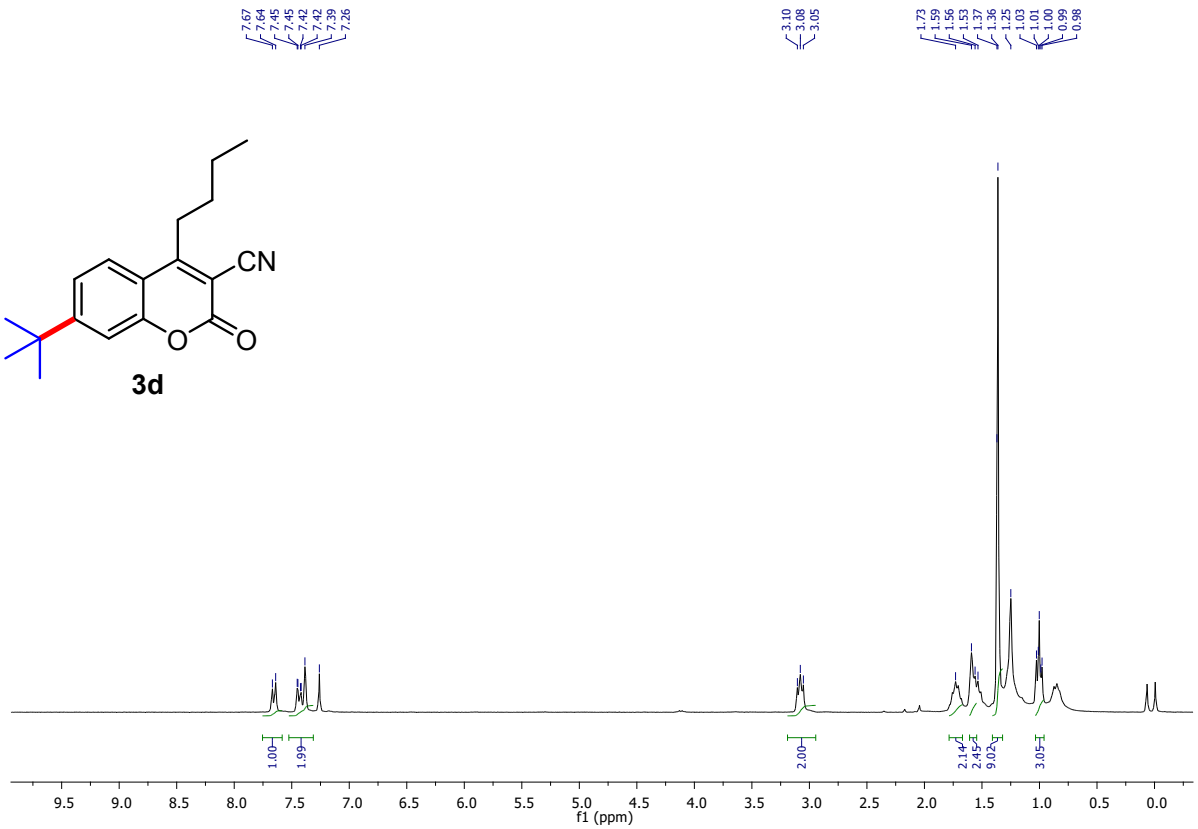
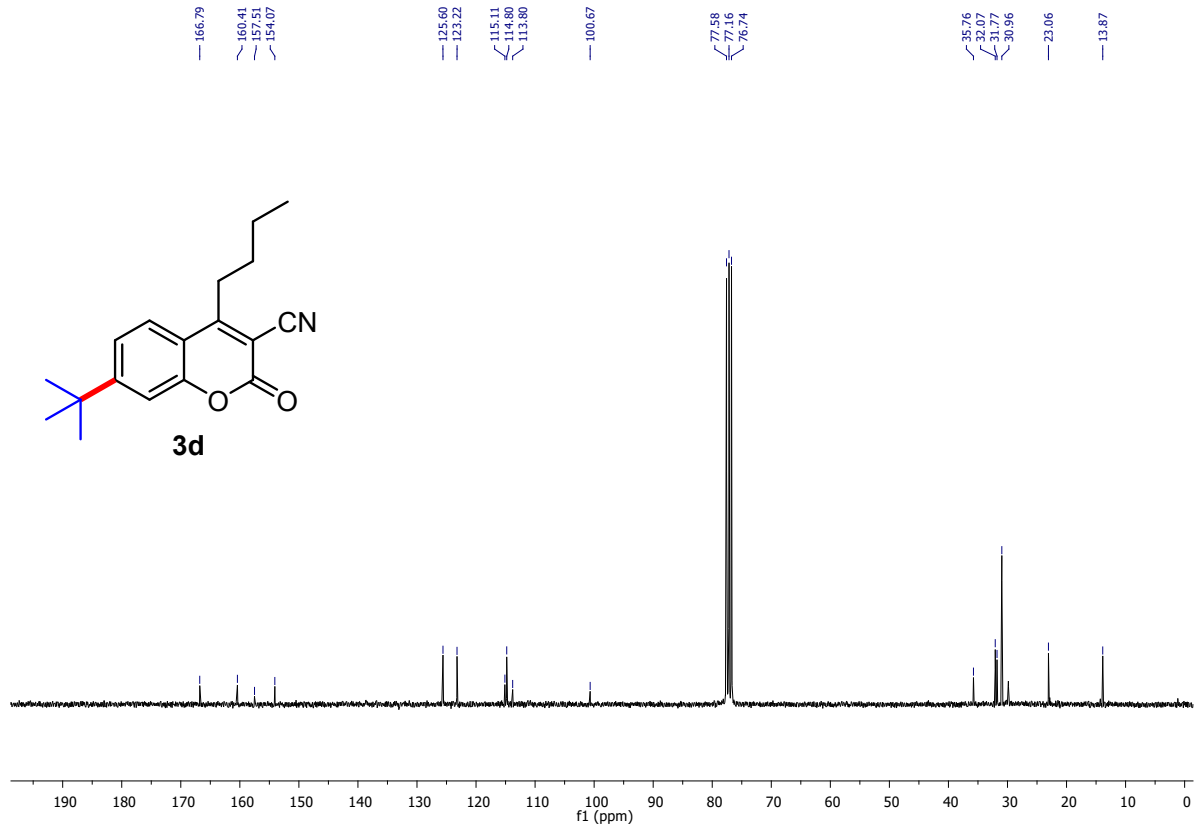
154.03
125.65
123.22
115.10
114.75
113.83
100.79
77.58
77.16
76.74
35.74
33.72
30.93
23.49
14.28
CN
O
O
3c
f1 (ppm)


7.67
7.64
7.45
7.45
7.42
7.42
7.39
7.26
3.10
3.08
3.05
1.73
1.59
1.56
1.53
1.37
1.36
1.25
1.03
1.01
1.00
0.99
0.98
CN
O
O
3d
1.00
1.99
2.00
2.14
2.45
9.02
3.05
f1 (ppm)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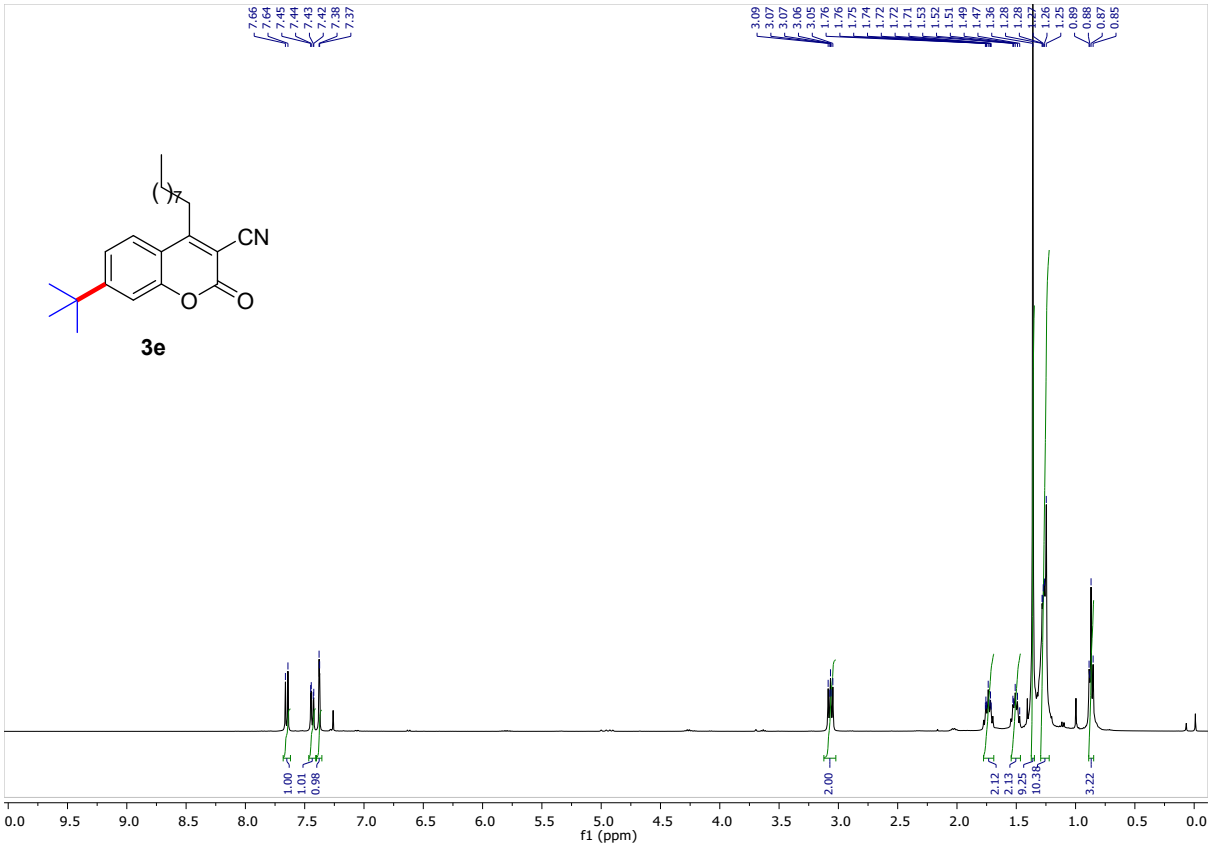
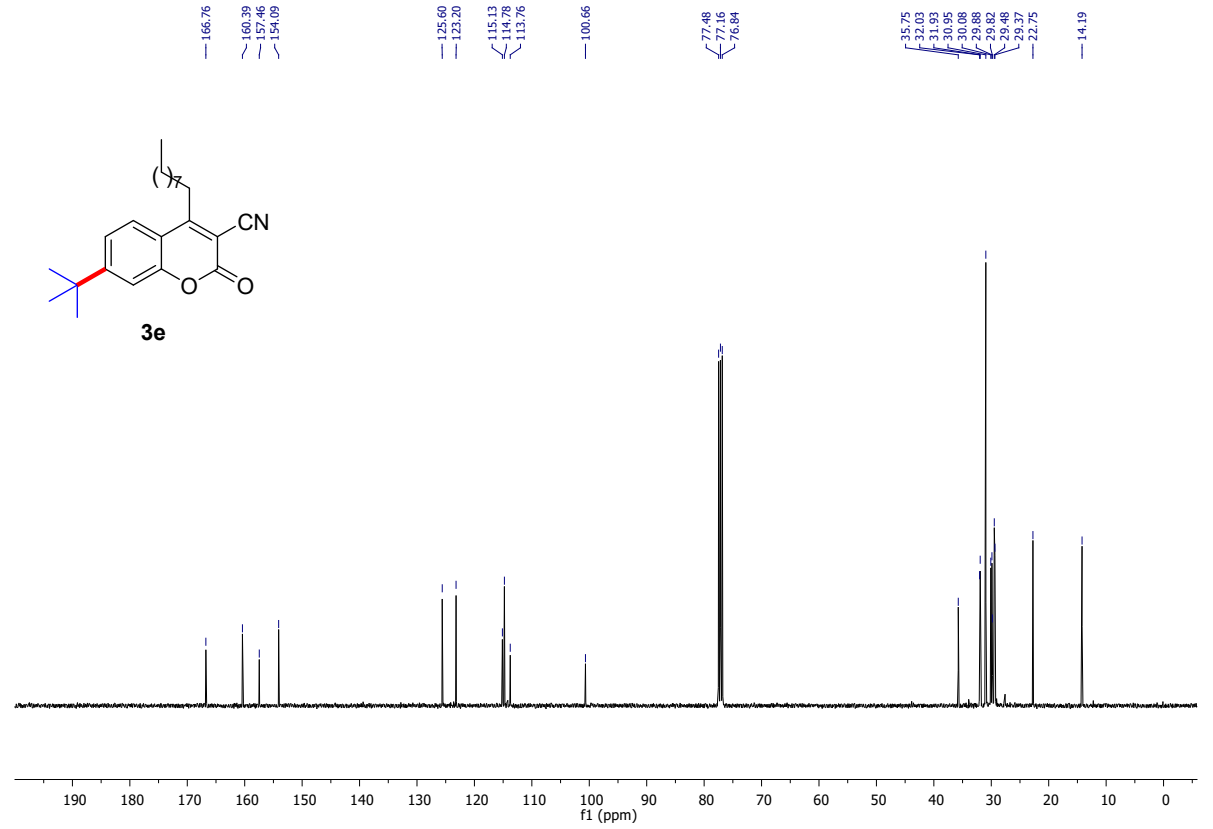
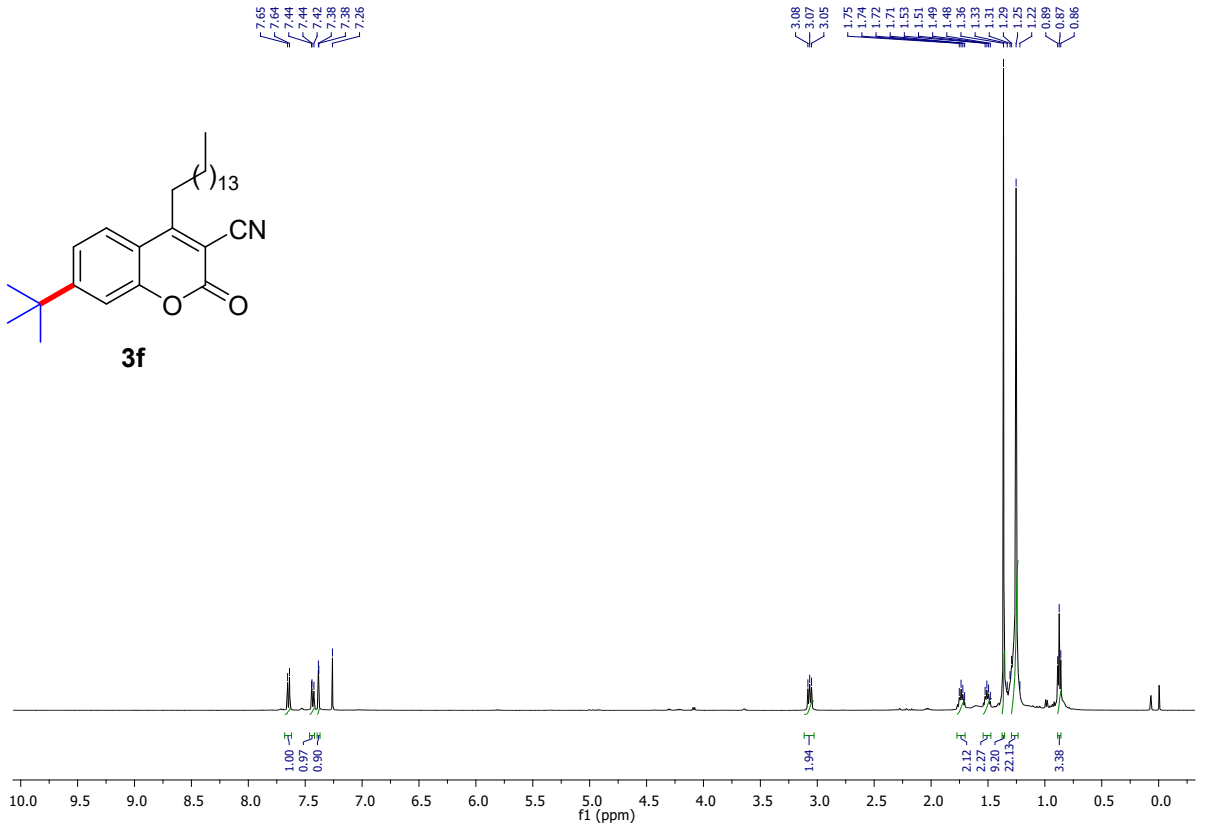
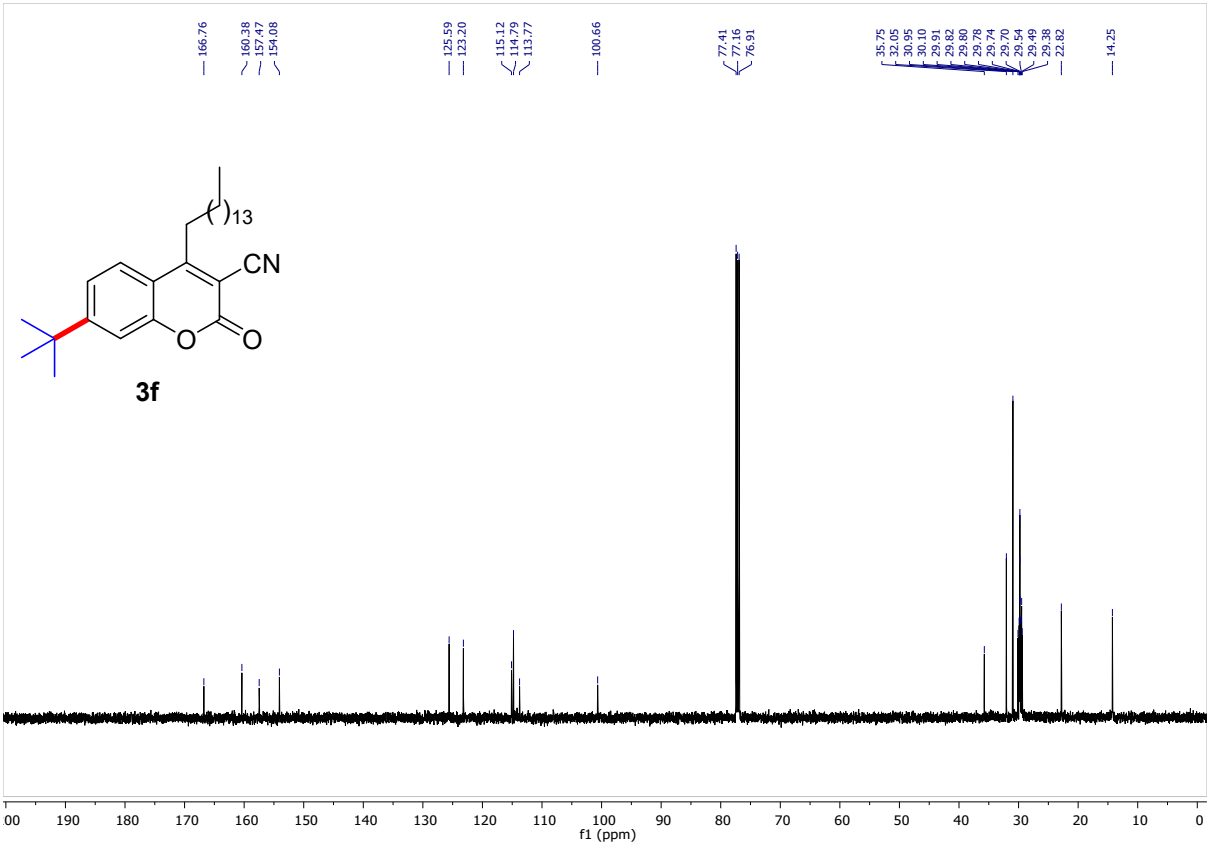
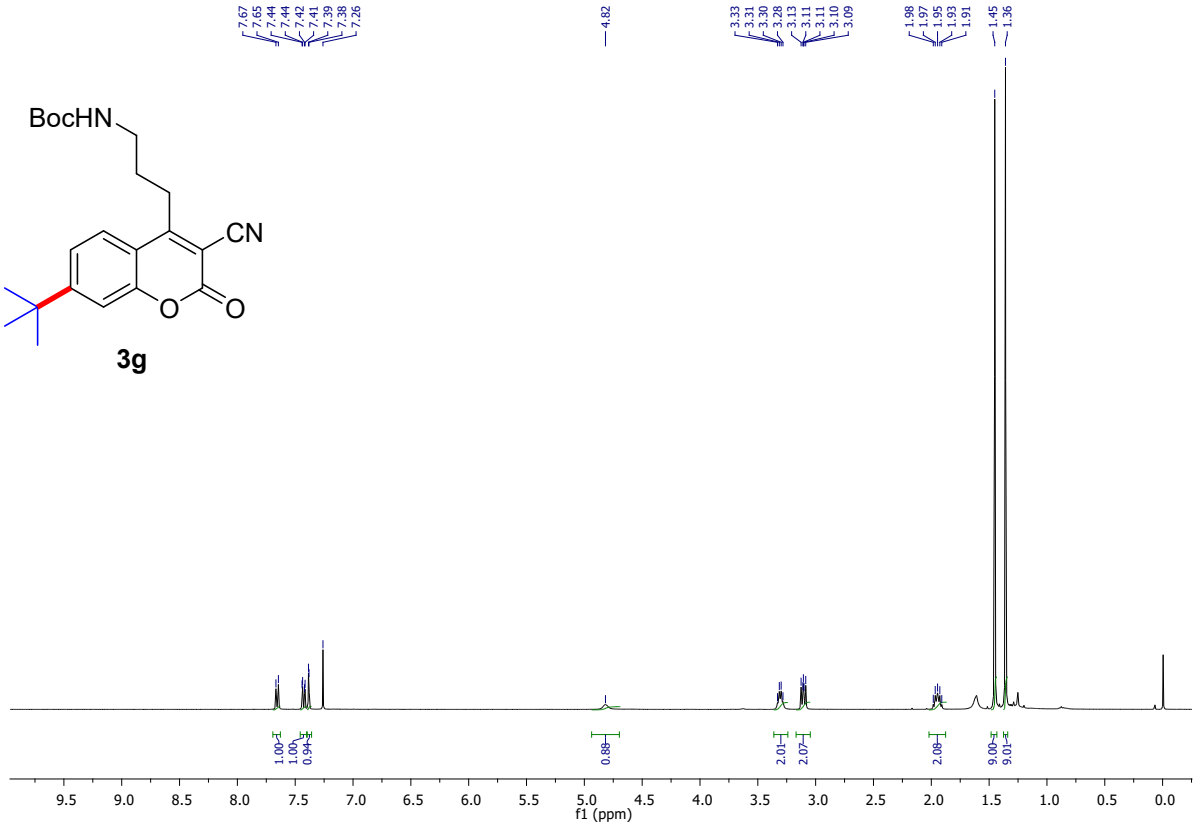
160.41
157.51
154.07
125.60
123.22
115.11
114.80
113.80
100.67
77.58
77.16
76.74
35.76
32.07
31.77
30.96
23.06
13.87
CN
O
O
3d
f1 (ppm)


CN
O
O
3e
f1 (ppm)


CN
O
O
3e
f1 (ppm)


7.65
7.64
7.44
7.44
7.42
7.38
7.38
7.26
3.08
3.07
3.05
1.75
1.74
1.72
1.71
1.53
1.51
1.49
1.48
1.36
1.33
1.31
1.29
1.25
1.22
0.89
0.87
0.86
13
CN
O
O
3f
1.00
0.97
0.90
1.94
2.12
2.27
9.20
22.13
3.38
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
f1 (ppm)


166.76
160.38
157.47
154.08
125.59
123.20
115.12
114.79
113.77
100.66
77.41
77.16
76.91
35.75
32.05
30.95
30.10
29.91
29.82
29.80
29.78
29.74
29.70
29.54
29.49
29.38
22.82
14.25
13
CN
O
O
3f
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


BocHN
CN
O
O
3g
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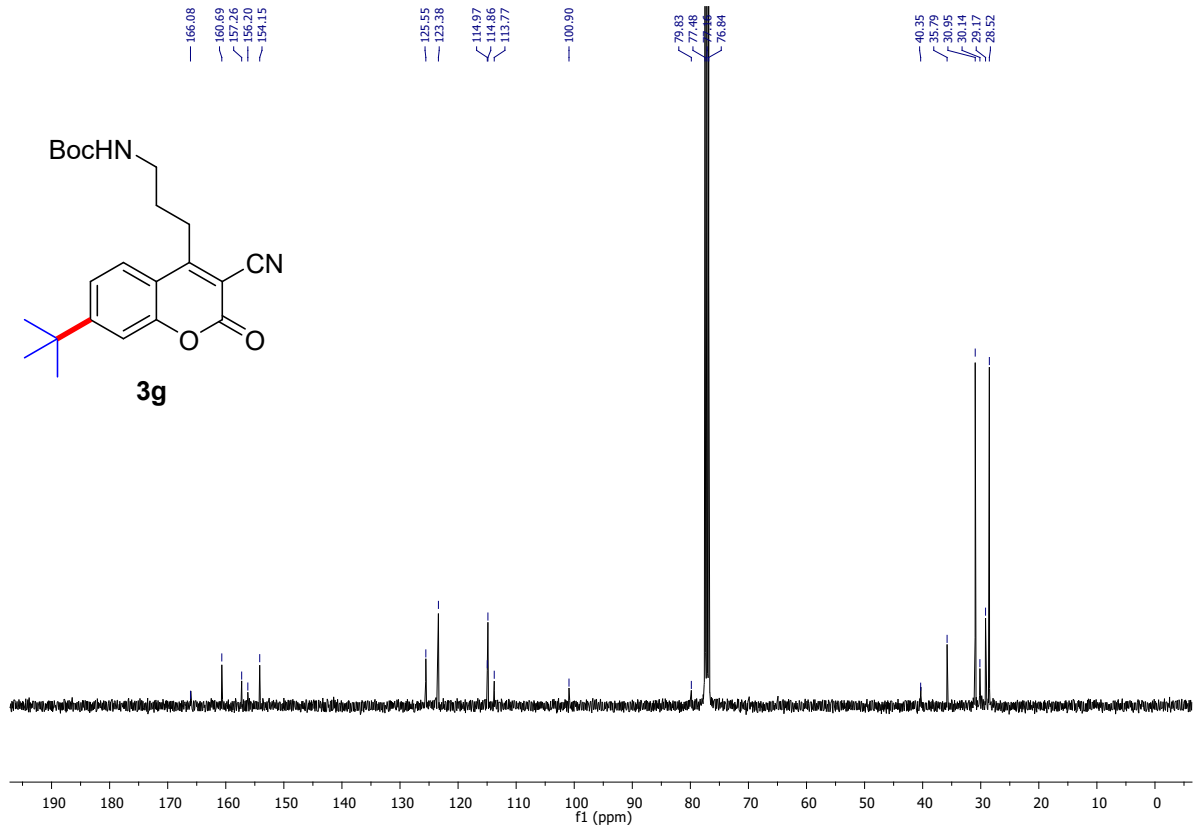
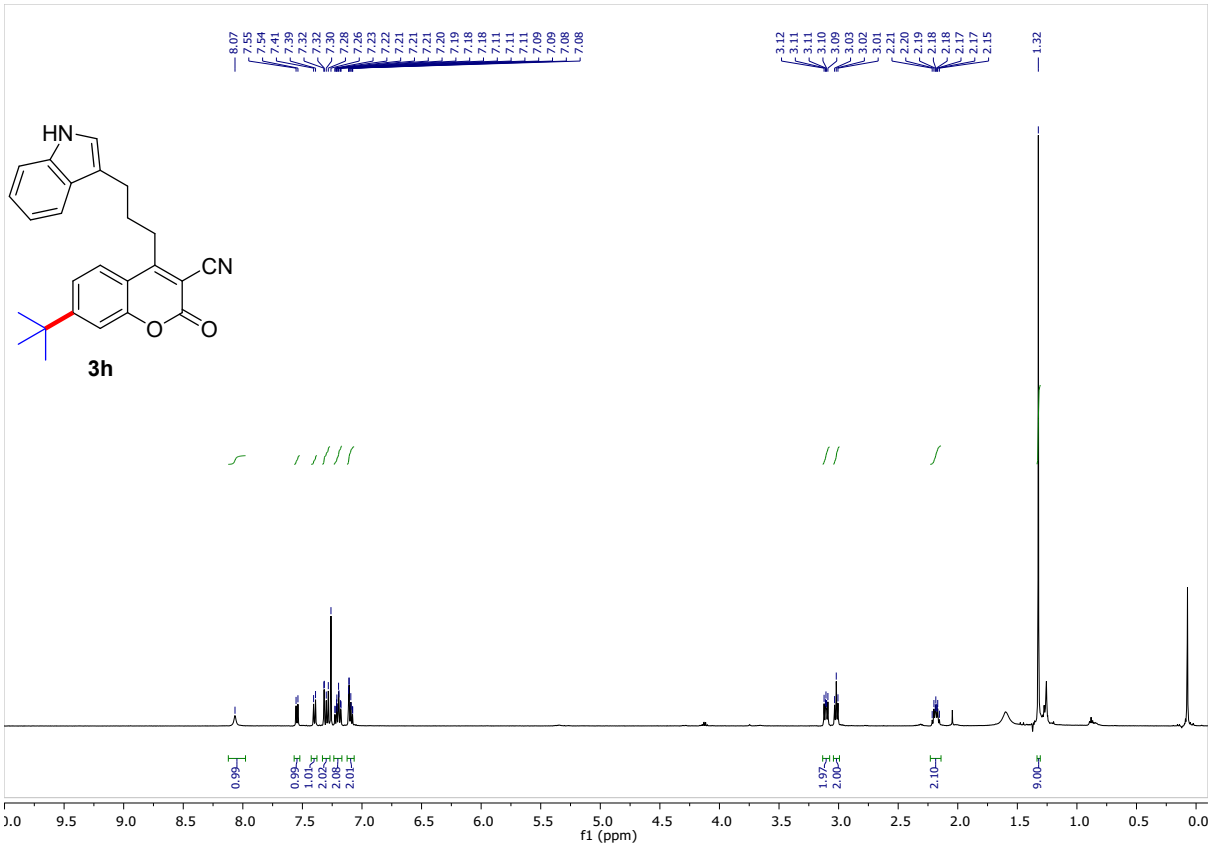
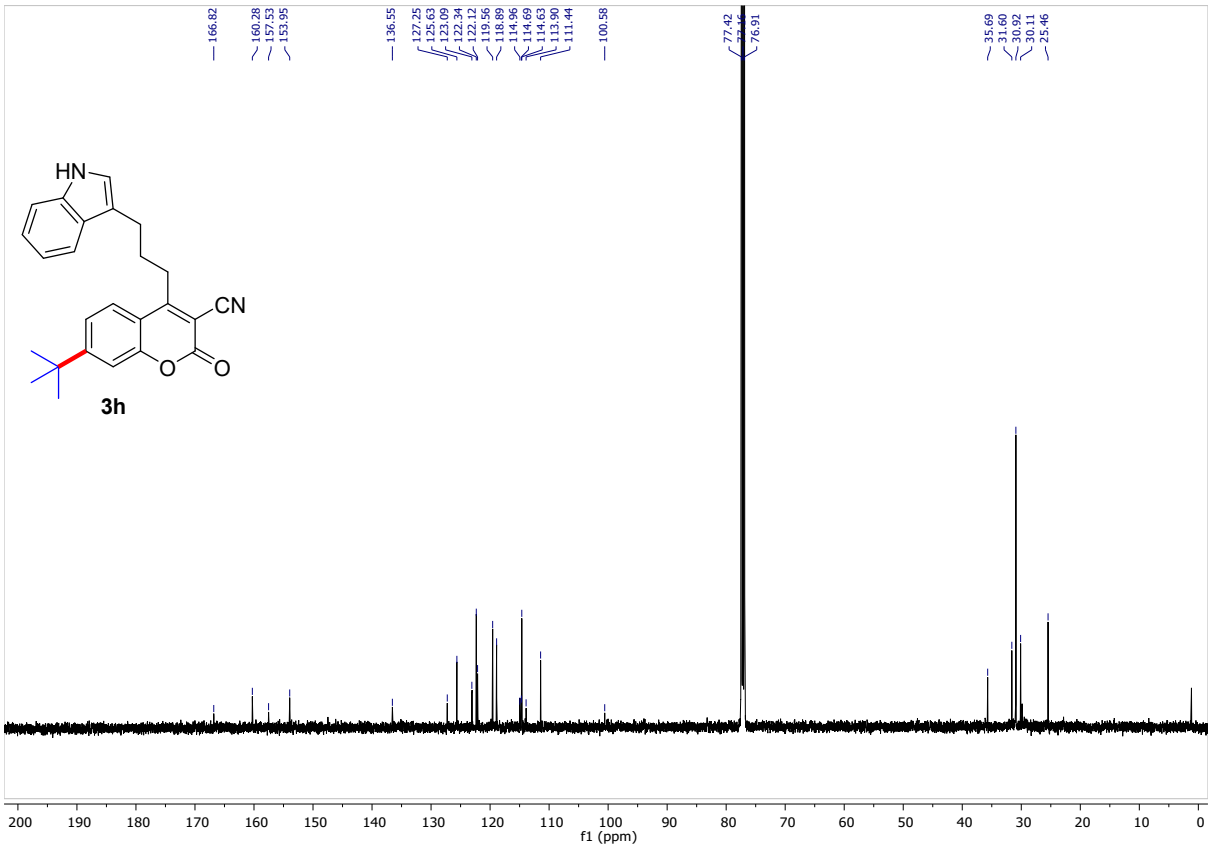
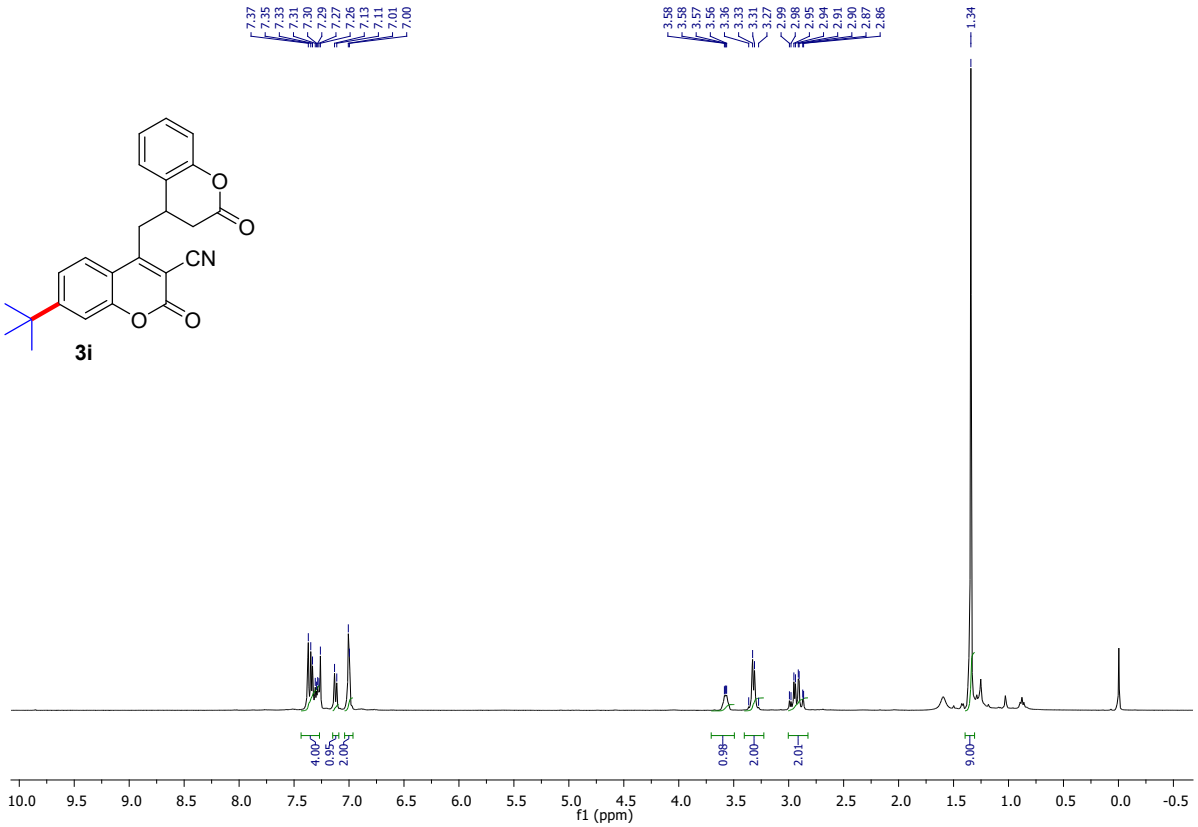
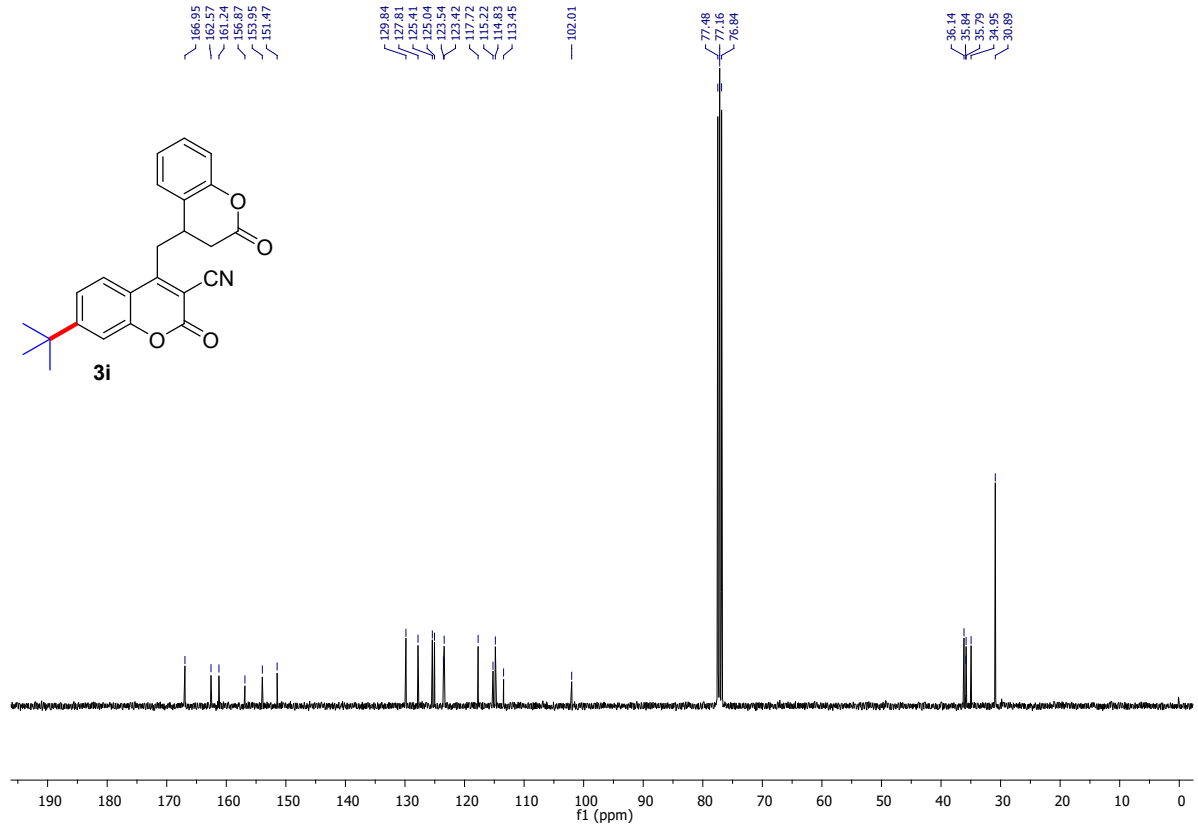
7.65
7.44
7.44
7.42
7.41
7.39
7.38
7.26
4.82
3.33
3.31
3.30
3.28
3.13
3.11
3.11
3.10
3.09
1.98
1.97
1.95
1.93
1.91
1.45
1.36
1.00
1.00
0.94
0.88
2.01
2.07
2.08
9.00
9.01
f1 (ppm)

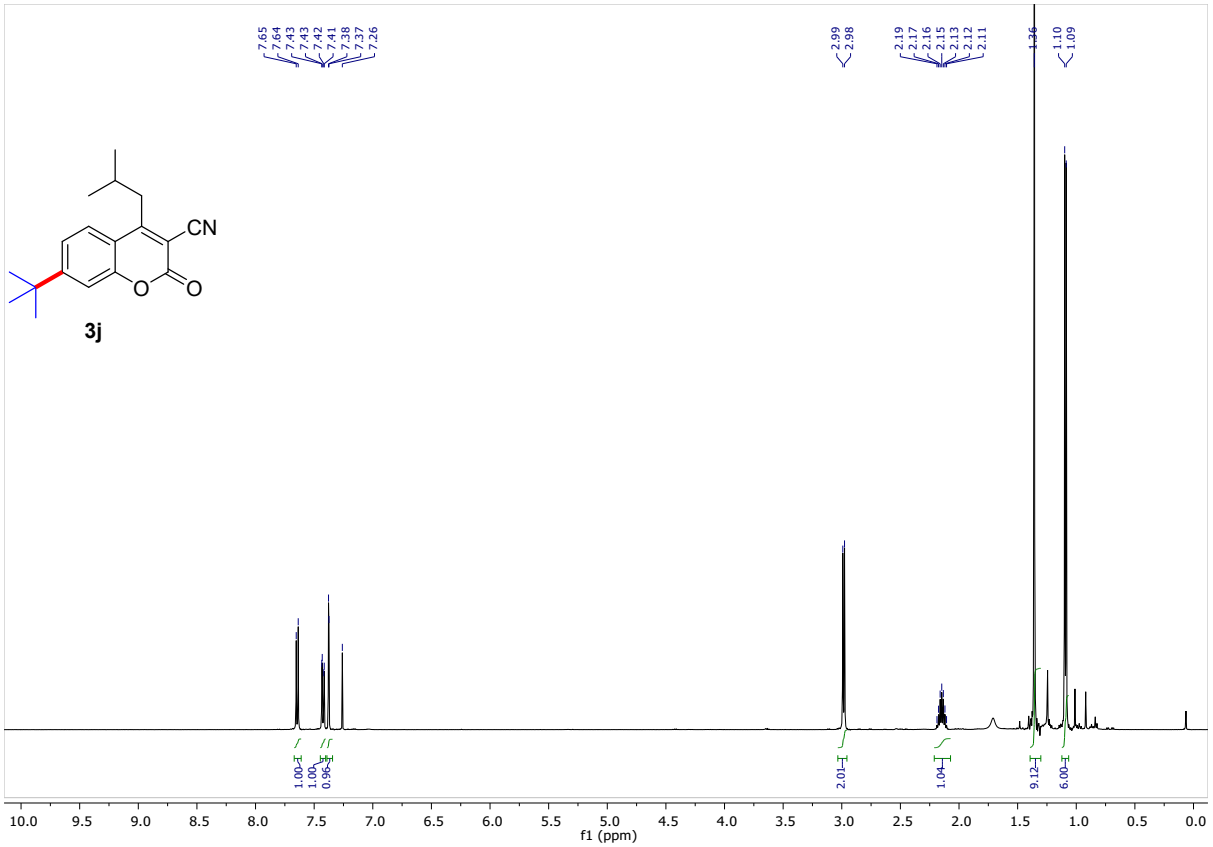

BocHN
CN
O
O
3g
166.08
160.69
157.26
156.20
154.15
125.55
123.38
114.97
114.86
113.77
100.90
79.83
77.48
76.84
40.35
35.79
30.95
30.14
29.17
28.52
f1 (ppm)

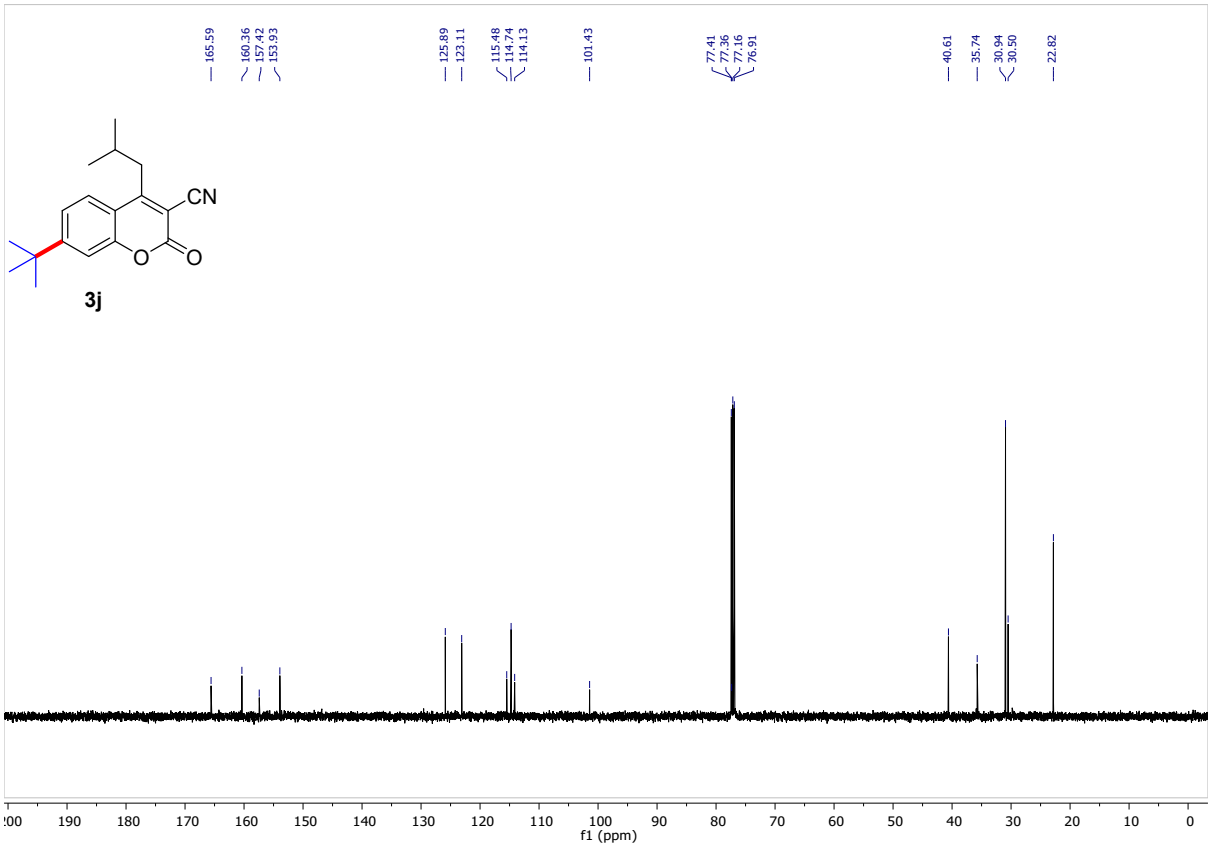

HN
CN
O
O
3h
f1 (ppm)

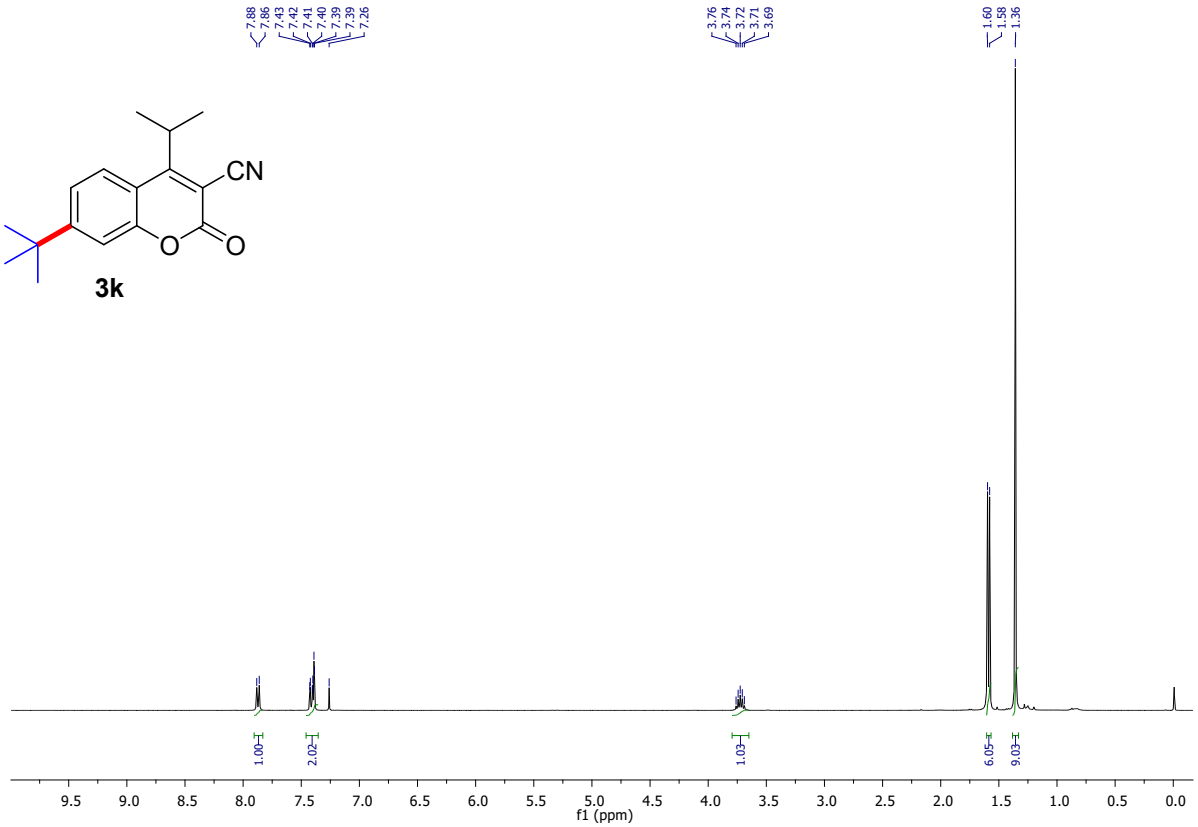

HN
CN
O
O
3h
f1 (ppm)

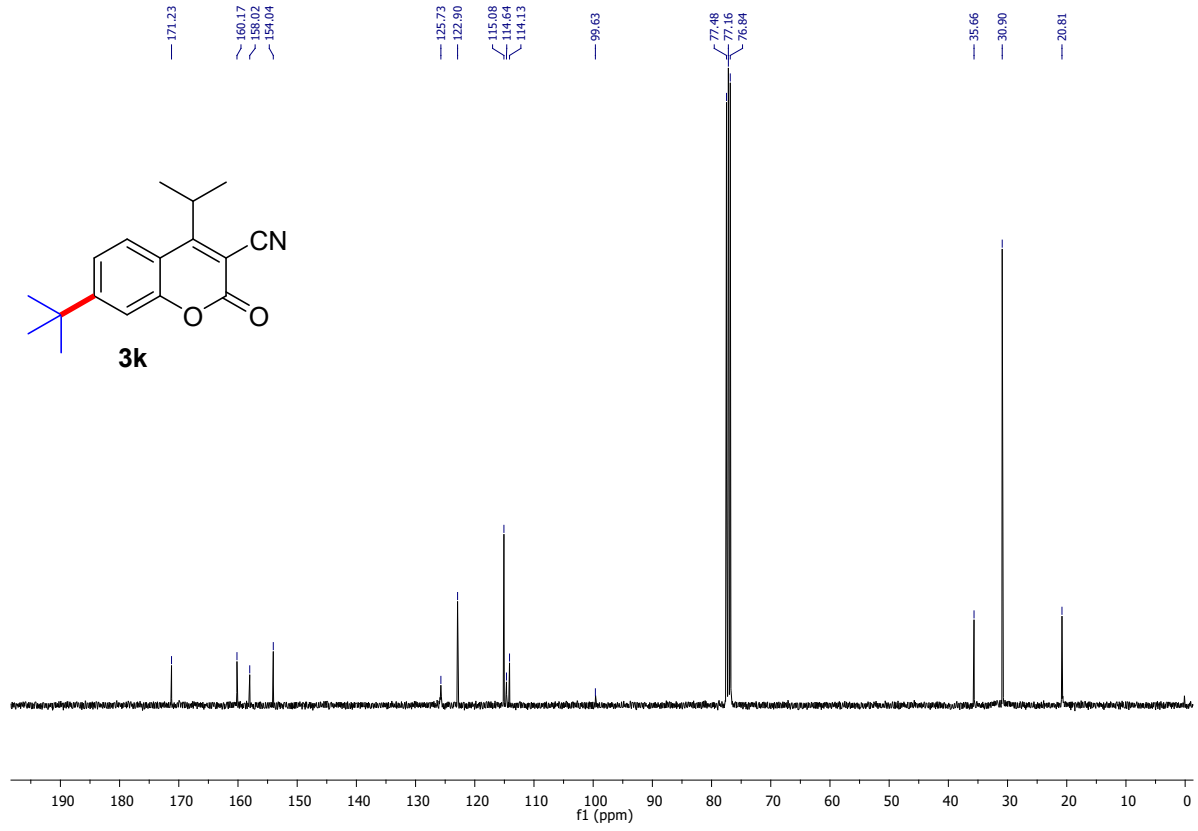

7.37
7.35
7.33
7.31
7.30
7.29
7.27
7.26
7.13
7.11
7.01
7.00
3.58
3.58
3.57
3.56
3.36
3.33
3.31
3.27
2.99
2.98
2.95
2.94
2.91
2.90
2.87
2.86
1.34
O
O
CN
O
O
3i
4.00
0.95
2.00
0.98
2.00
2.01
9.00
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)


166.95
162.57
161.24
156.87
153.95
151.47
129.84
127.81
125.41
125.04
123.54
123.42
117.72
115.22
114.83
113.45
102.01
77.48
77.16
76.84
36.14
35.84
35.79
34.95
30.89
O
O
CN
O
O
3i
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


7.65
7.64
7.43
7.43
7.42
7.41
7.38
7.37
7.26
2.99
2.98
2.19
2.17
2.16
2.15
2.13
2.12
2.11
1.36
1.10
1.09
CN
O
O
3j
1.00
1.00
0.96
2.01
1.04
9.12
6.00
f1 (ppm)


165.59
160.36
157.42
153.93
125.89
123.11
115.48
114.74
114.13
101.43
77.41
77.36
77.16
76.91
40.61
35.74
30.94
30.50
22.82
CN
O
O
3j
f1 (ppm)


7.88
7.86
7.43
7.42
7.41
7.40
7.39
7.39
7.26
3.76
3.74
3.72
3.71
3.69
1.60
1.58
1.36
CN
O
O
3k
1.00
2.02
1.03
6.05
9.03
f1 (ppm)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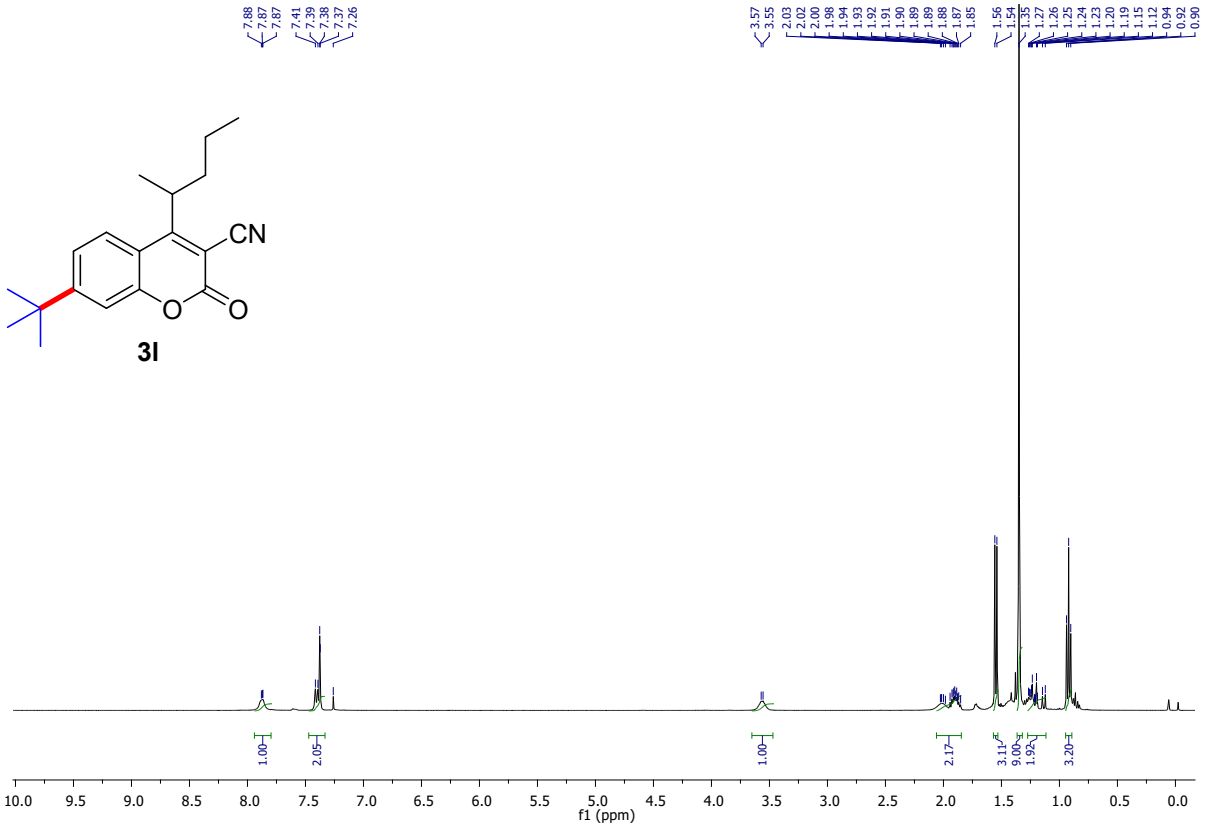
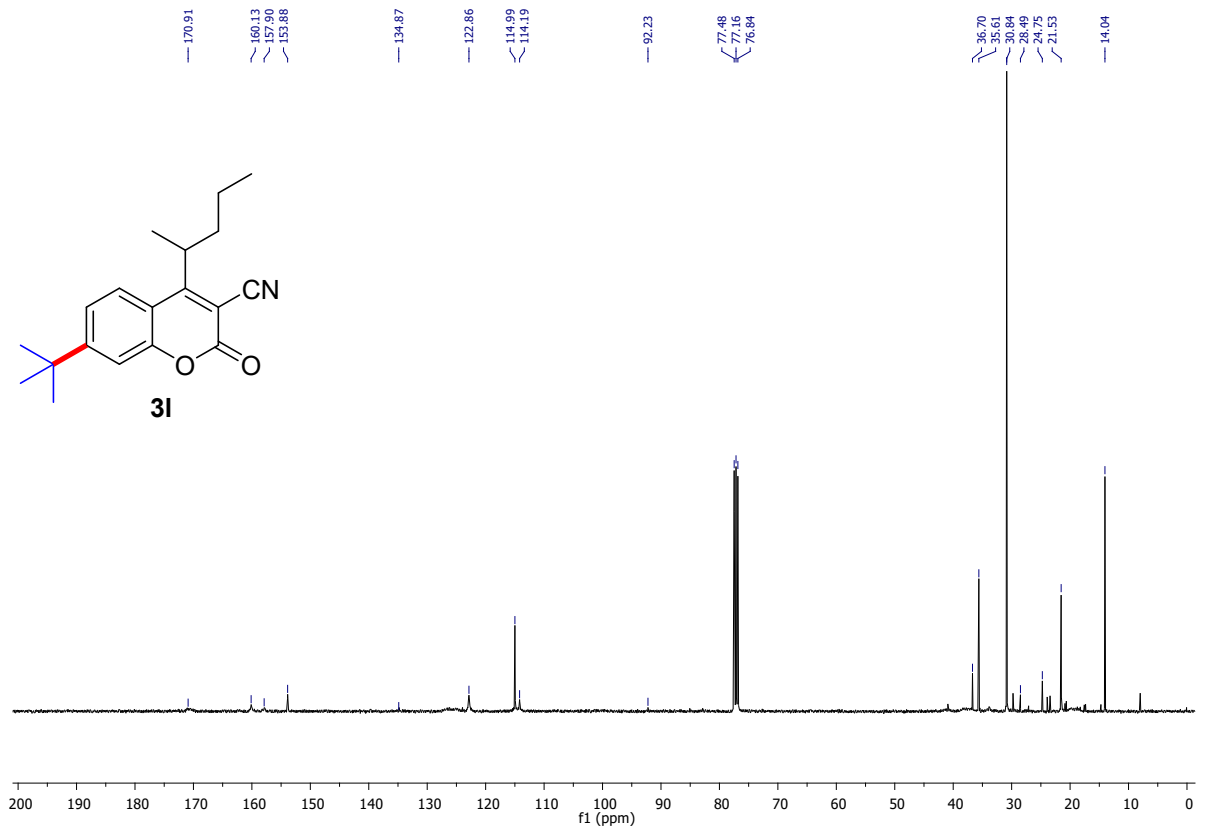
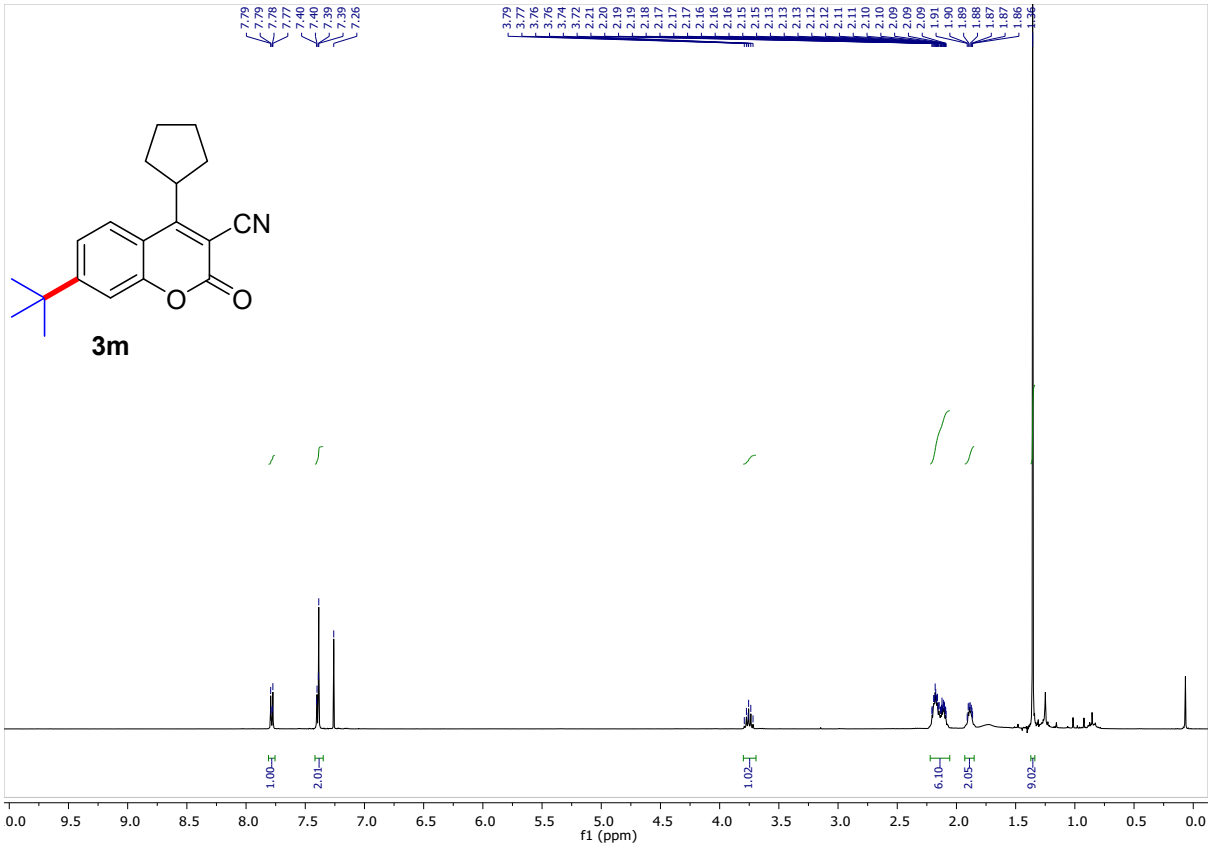
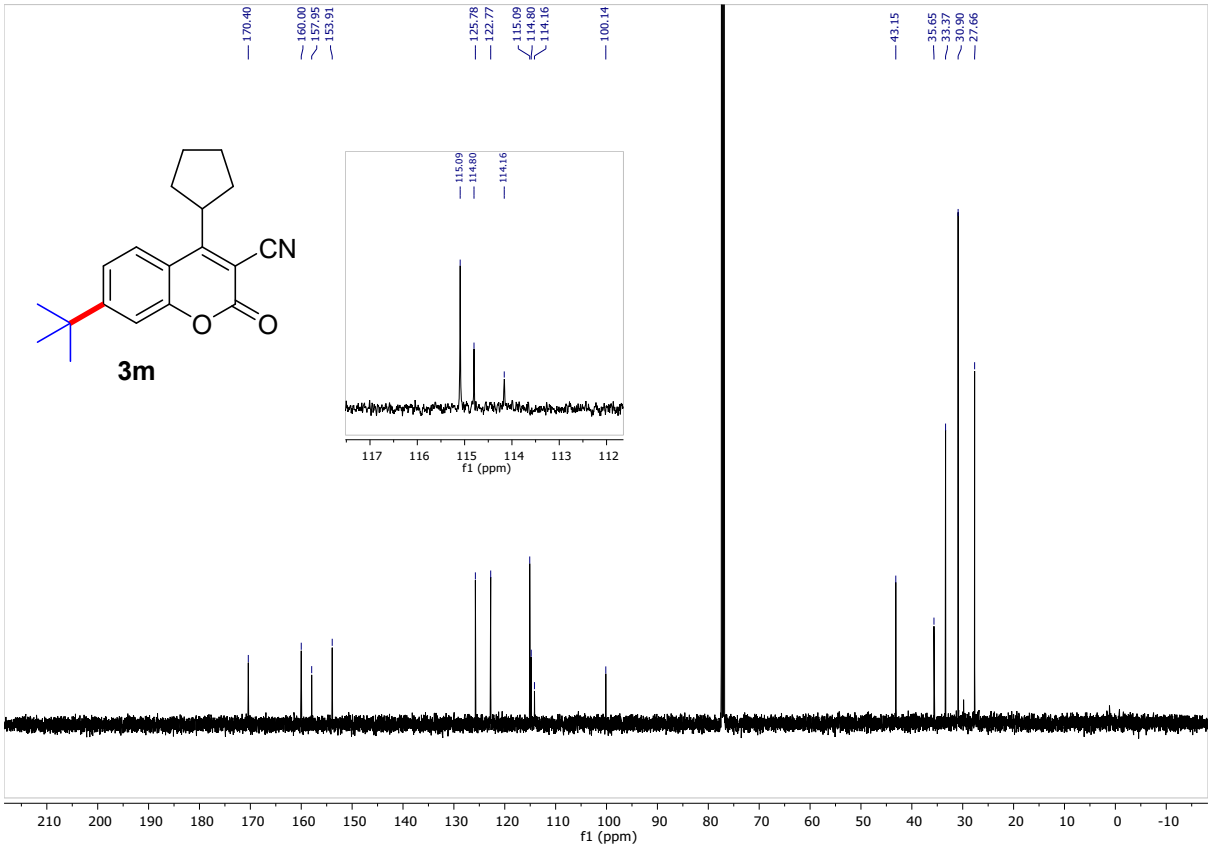
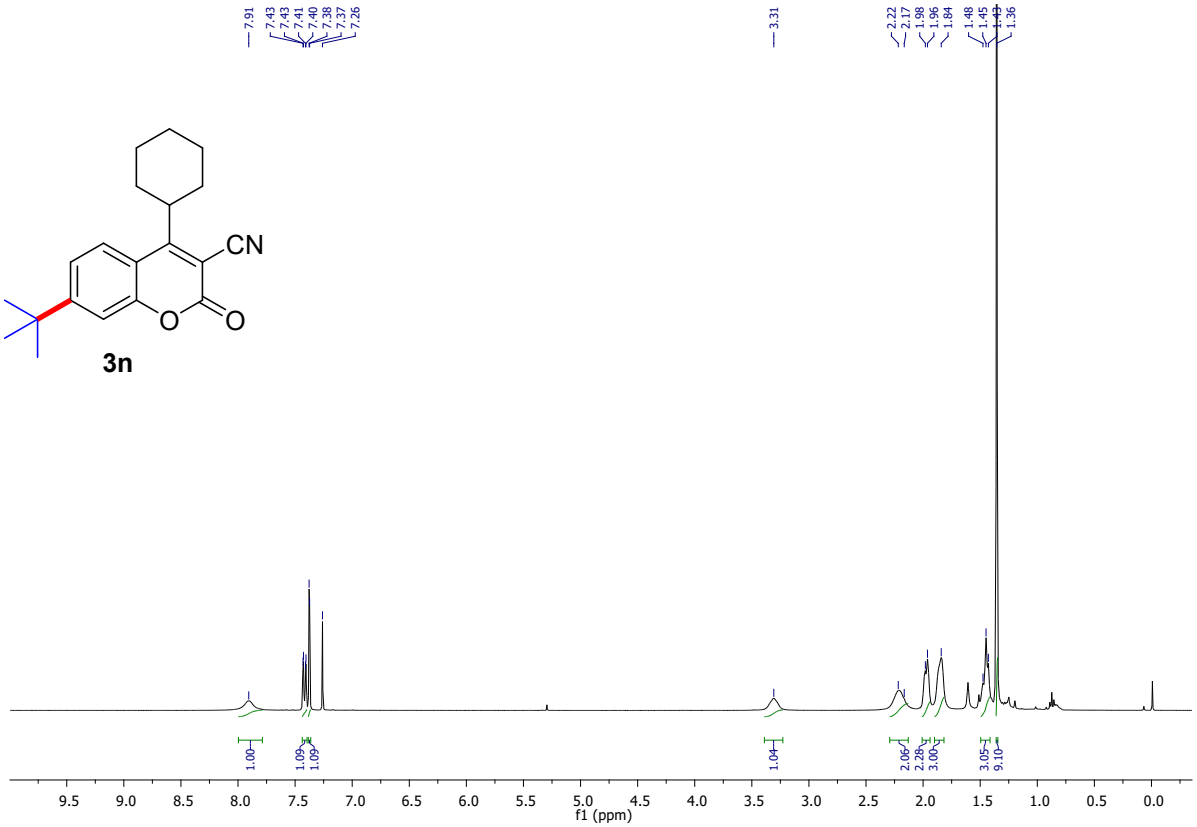
160.17
158.02
154.04
125.73
122.90
115.08
114.64
114.13
99.63
77.48
77.16
76.84
35.66
30.90
20.81
CN
O
O
3k
f1 (ppm)

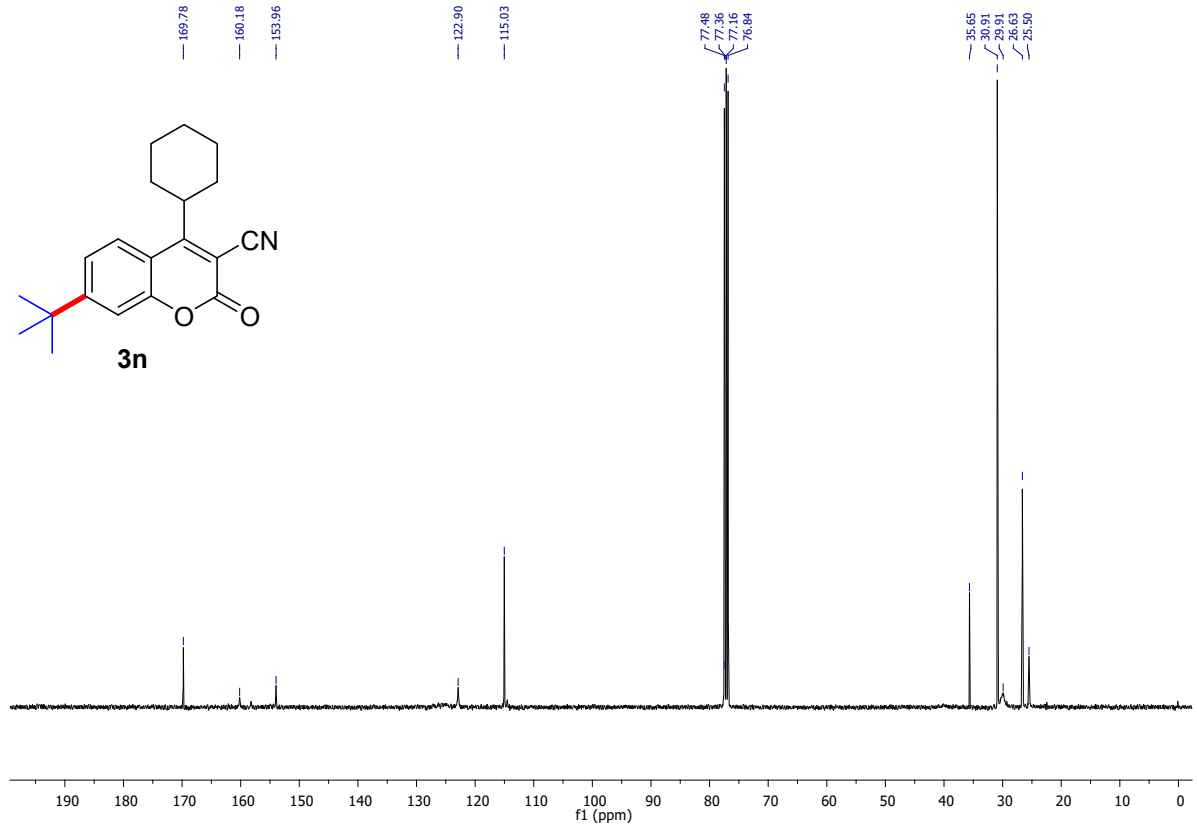

7.88
7.87
7.87
7.41
7.39
7.38
7.37
7.26
3.57
3.55
2.03
2.02
2.00
1.98
1.94
1.93
1.92
1.91
1.90
1.89
1.89
1.88
1.87
1.85
1.56
1.54
1.35
1.27
1.26
1.25
1.24
1.23
1.20
1.19
1.15
1.12
0.94
0.92
0.90
CN
O
O
3l
1.00
2.05
1.00
2.17
3.11
9.00
1.92
3.20
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

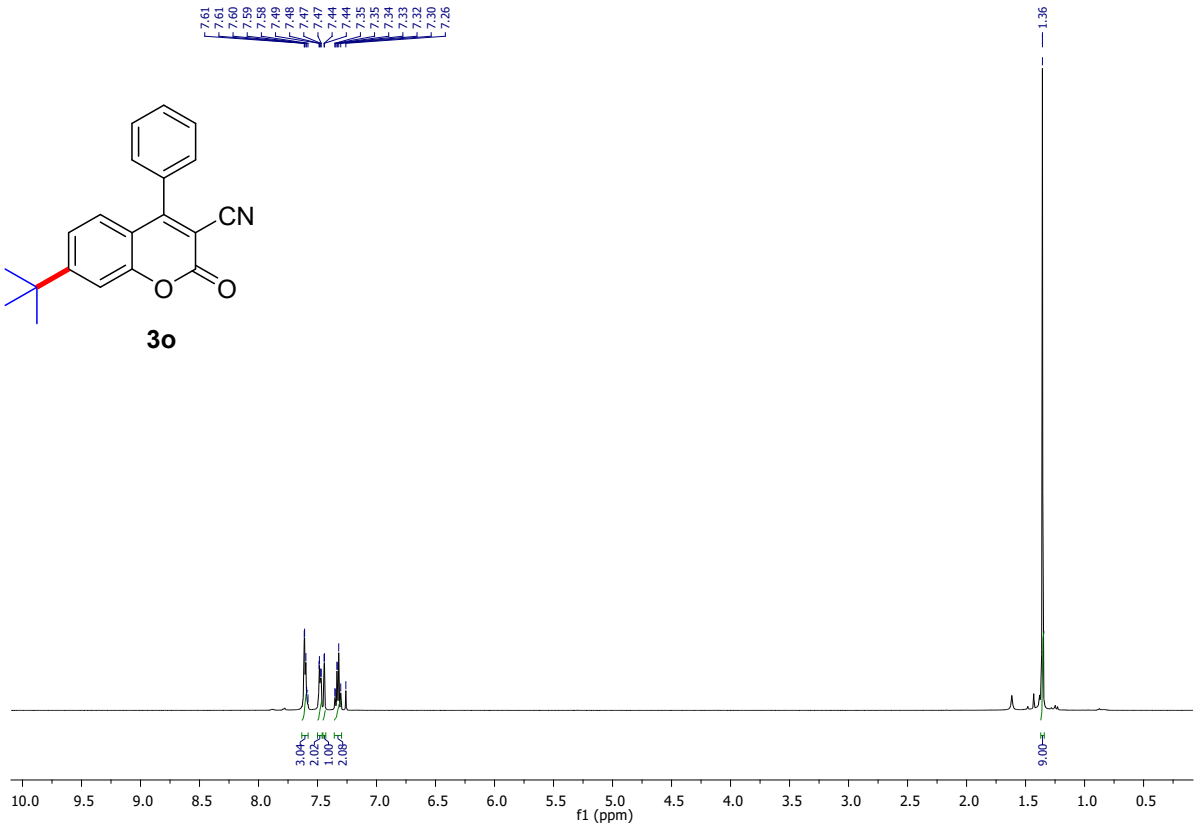

170.91
160.13
157.90
153.88
134.87
122.86
114.99
114.19
92.23
77.48
77.16
76.84
36.70
35.61
30.84
28.49
24.75
21.53
14.04
CN
O
O
3l
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


CN
O
O
3m
f1 (ppm)

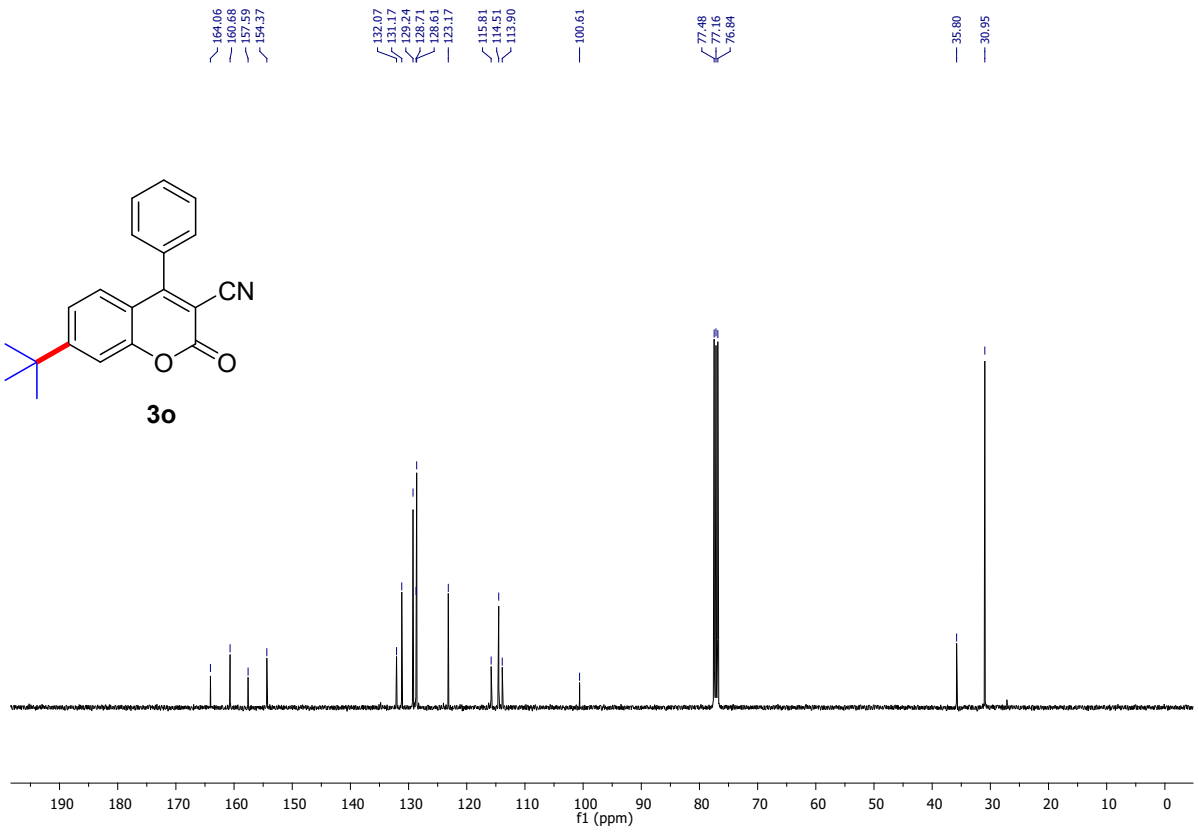

CN
O
O
3m
f1 (ppm)
f1 (ppm)


7.91
7.43
7.43
7.41
7.40
7.38
7.37
7.26
3.31
2.22
2.17
1.98
1.96
1.84
1.48
1.45
1.36
CN
O
O
3n
1.00
1.09
1.09
1.04
2.06
2.28
3.00
3.05
9.10
f1 (ppm)

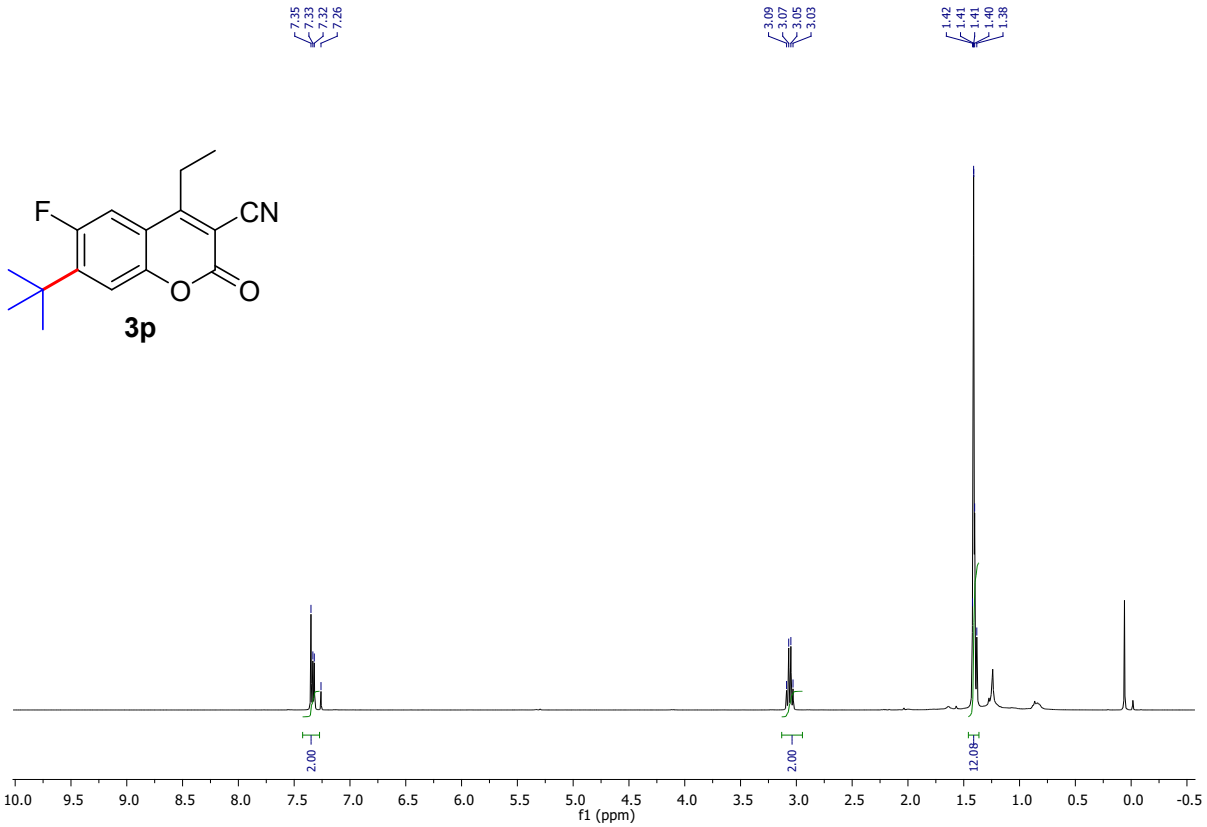

169.78
160.18
153.96
122.90
115.03
77.48
77.36
77.16
76.84
35.65
30.91
29.91
26.63
25.50
CN
O
O
3n
f1 (ppm)

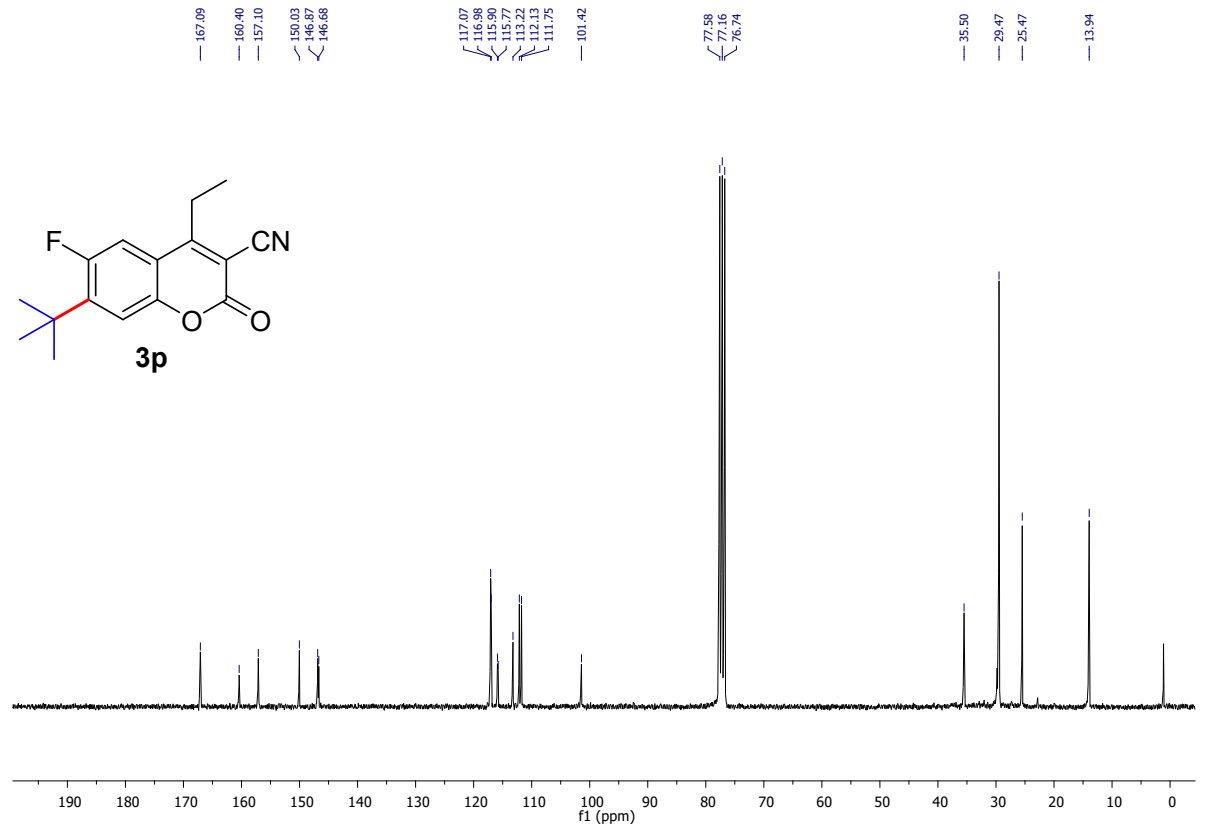

7.61
7.61
7.60
7.59
7.58
7.49
7.48
7.47
7.47
7.44
7.44
7.35
7.35
7.34
7.33
7.32
7.30
7.26
1.36
CN
O
O
3.04
2.02
1.00
2.08
9.00
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)

3o

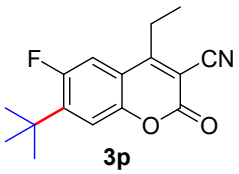

164.06
160.68
157.59
154.37
132.07
131.17
129.24
128.71
128.61
123.17
115.81
114.51
113.90
100.61
77.48
77.16
76.84
35.80
30.95
CN
O
O
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

3o

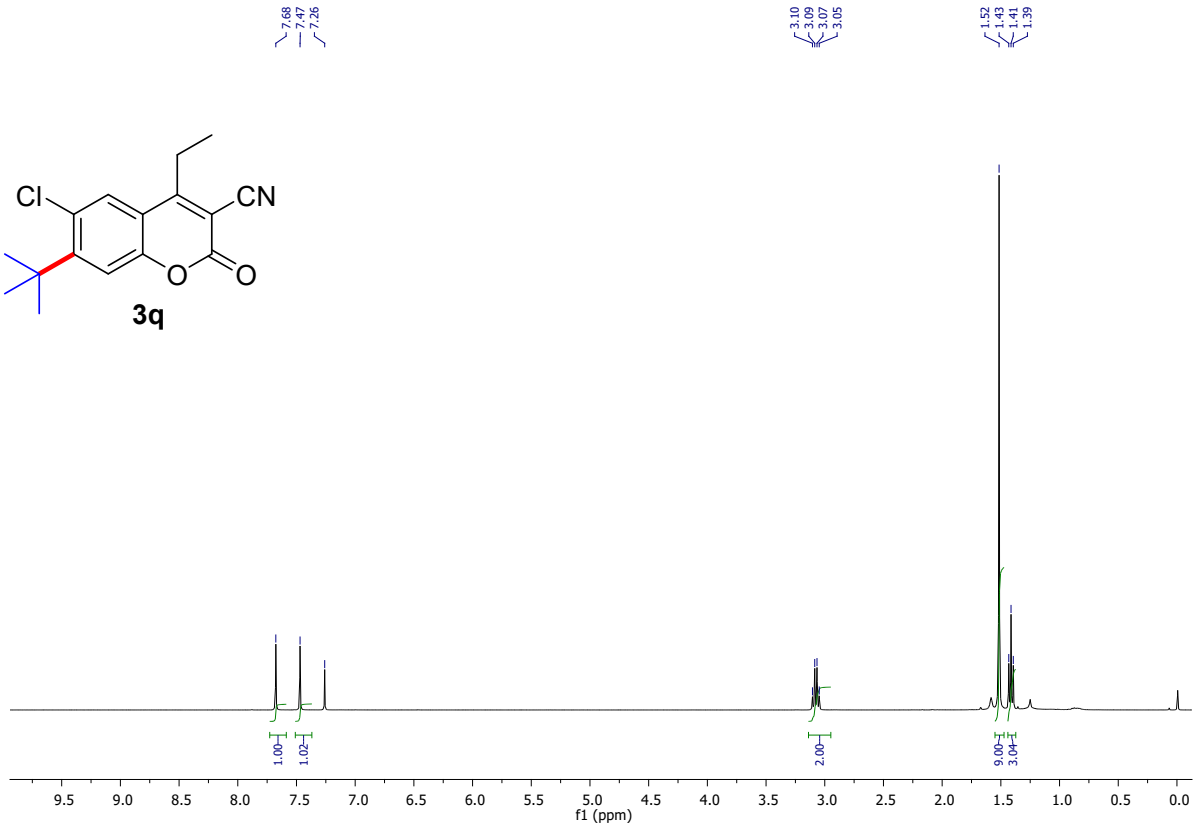

7.35
7.33
7.32
7.26
3.09
3.07
3.05
3.03
1.42
1.41
1.41
1.40
1.38
F
CN
O
O
3p
2.00
2.00
12.08
f1 (ppm)

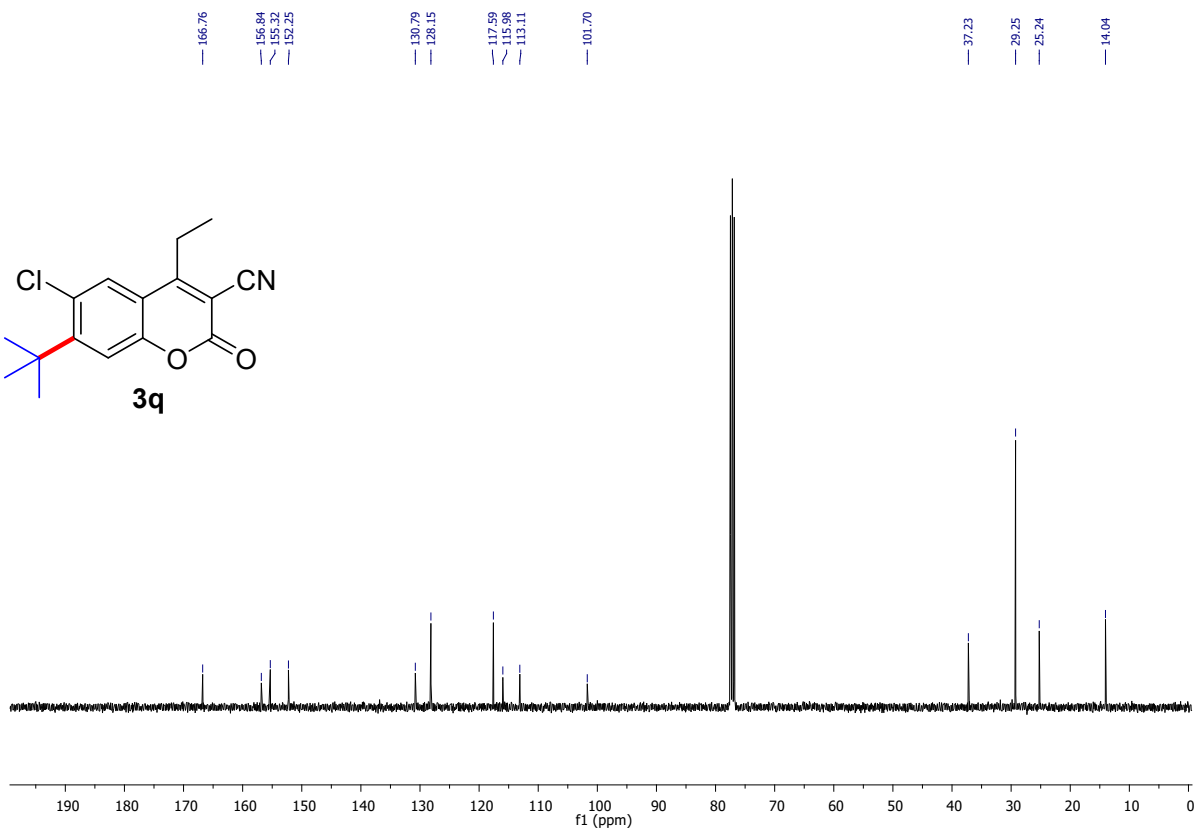

167.09
160.40
157.10
150.03
146.87
146.68
117.07
116.98
115.90
115.77
113.22
112.13
111.75
101.42
77.58
77.16
76.74
35.50
29.47
25.47
13.94
F
CN
O
O
3p
f1 (ppm)

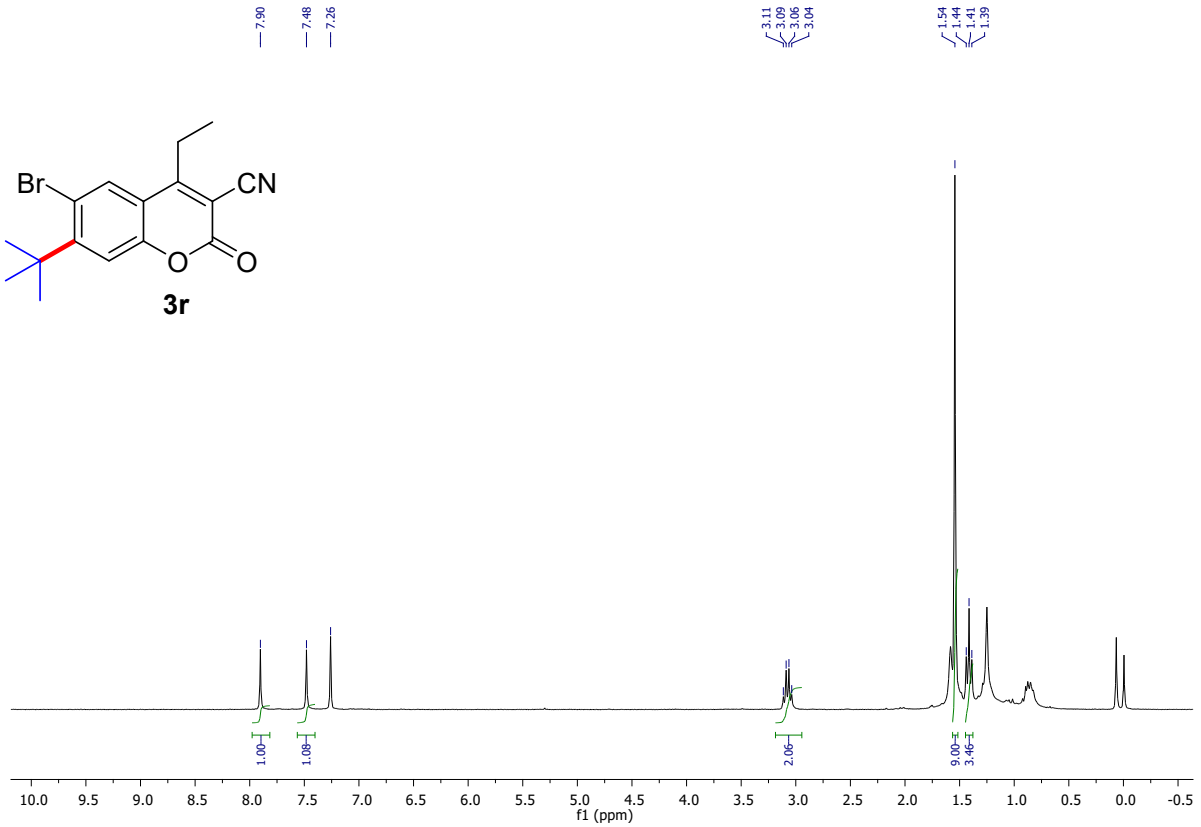
^{19}F NMR of compound 3p

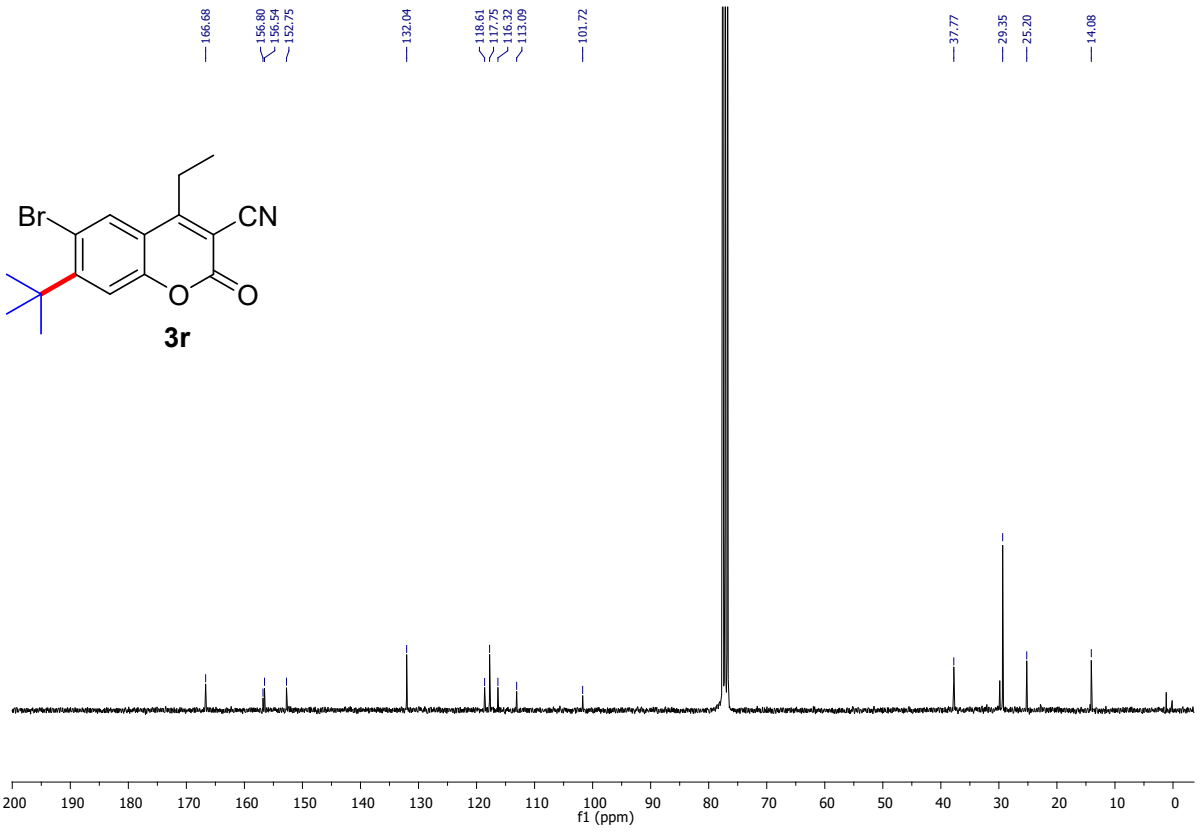


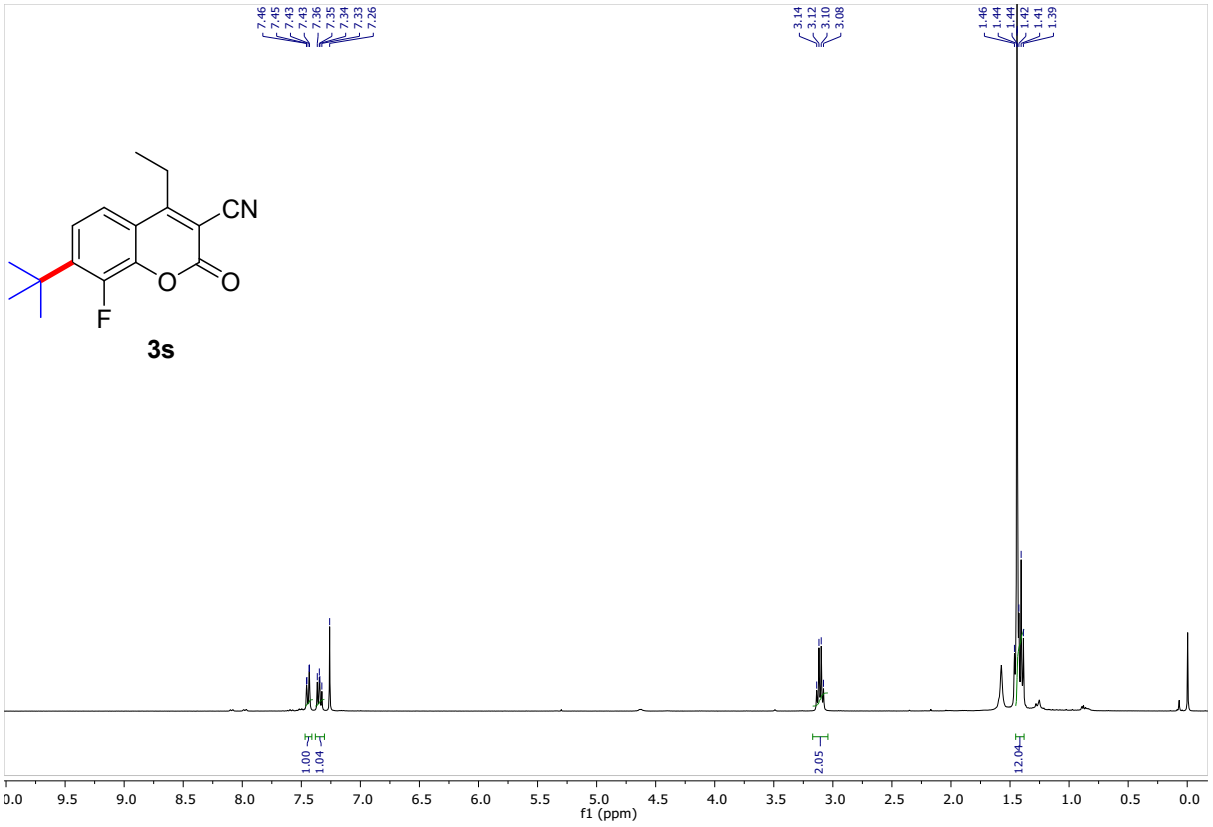
3p

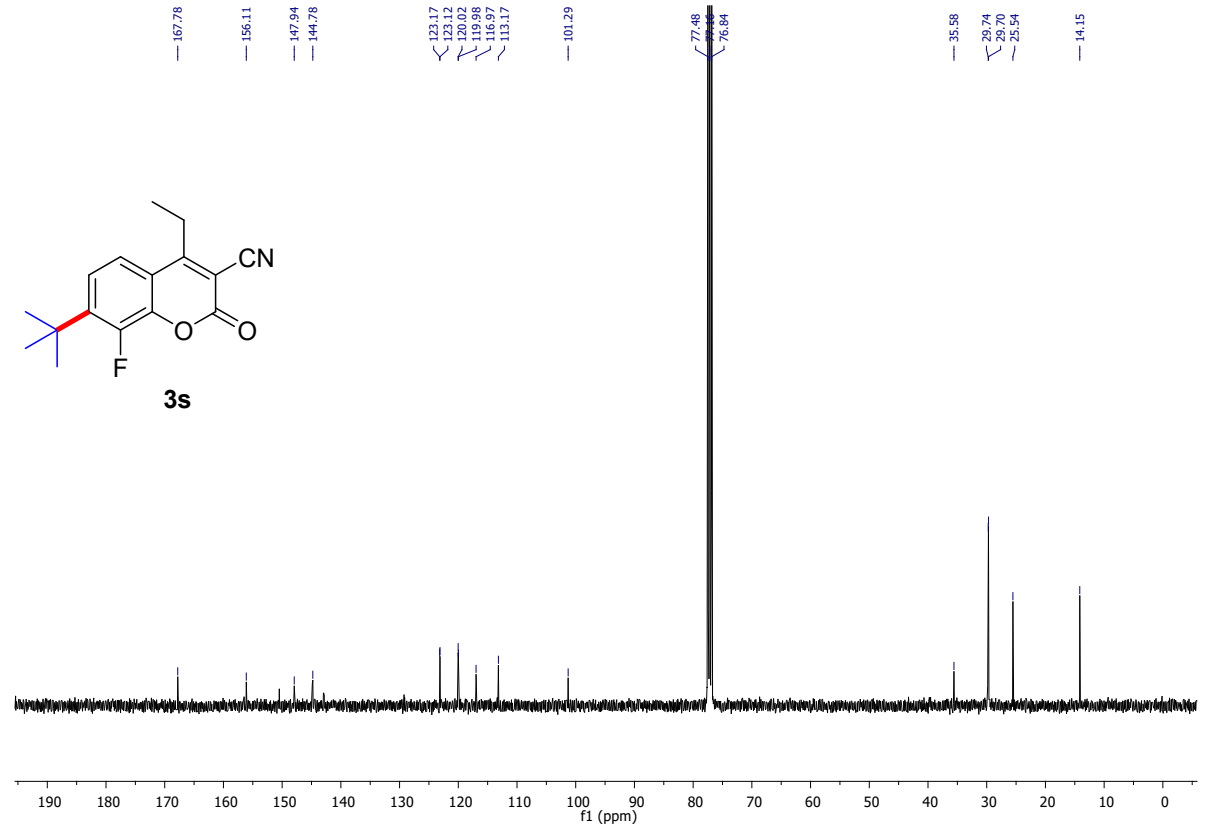

7.68
7.47
7.26
3.10
3.09
3.07
3.05
1.52
1.43
1.41
1.39
Cl
CN
O
O
3q
1.00
1.02
2.00
9.00
3.04
f1 (ppm)


166.76
156.84
155.32
152.25
130.79
128.15
117.59
115.98
113.11
101.70
37.23
29.25
25.24
14.04
Cl
CN
O
O
3q
f1 (ppm)

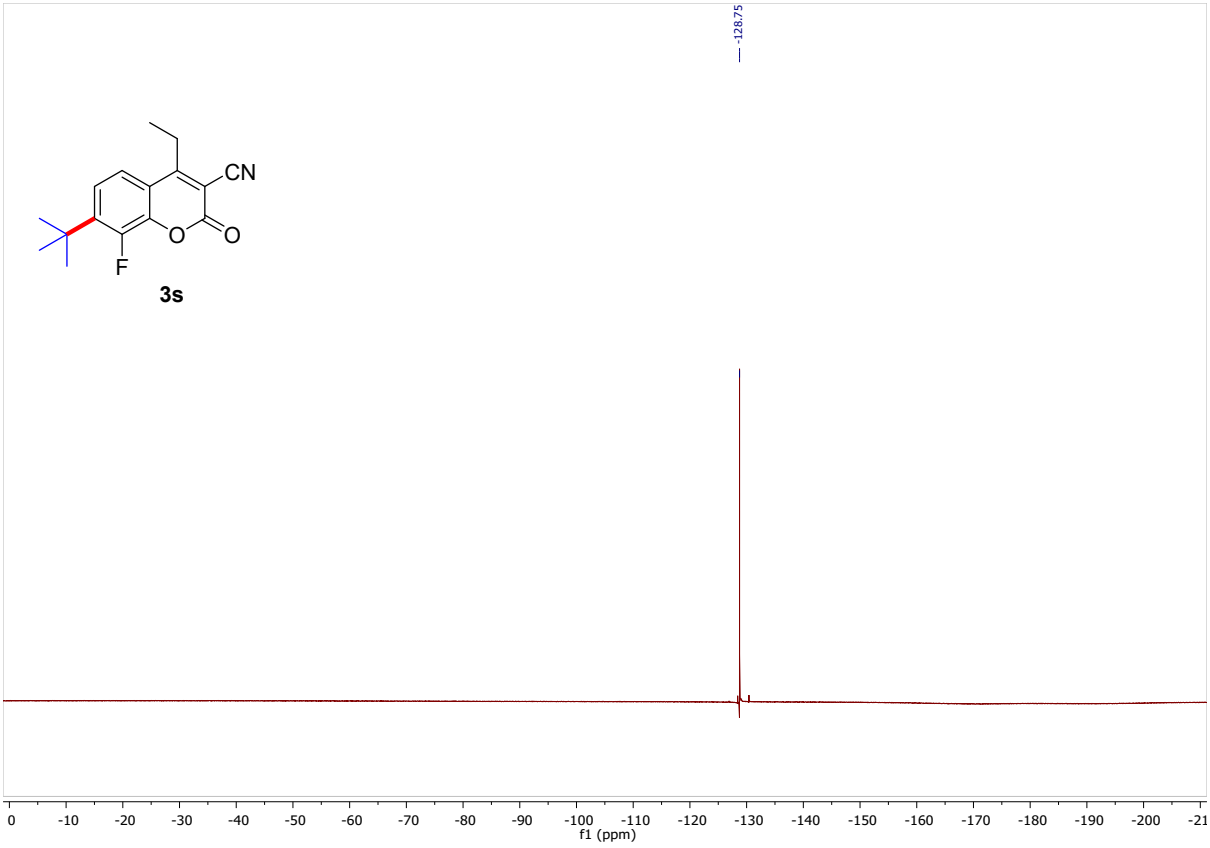

7.90
7.48
7.26
3.11
3.09
3.06
3.04
1.54
1.44
1.41
1.39
Br
CN
O
O
3r
1.00
1.08
2.06
9.00
3.46
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

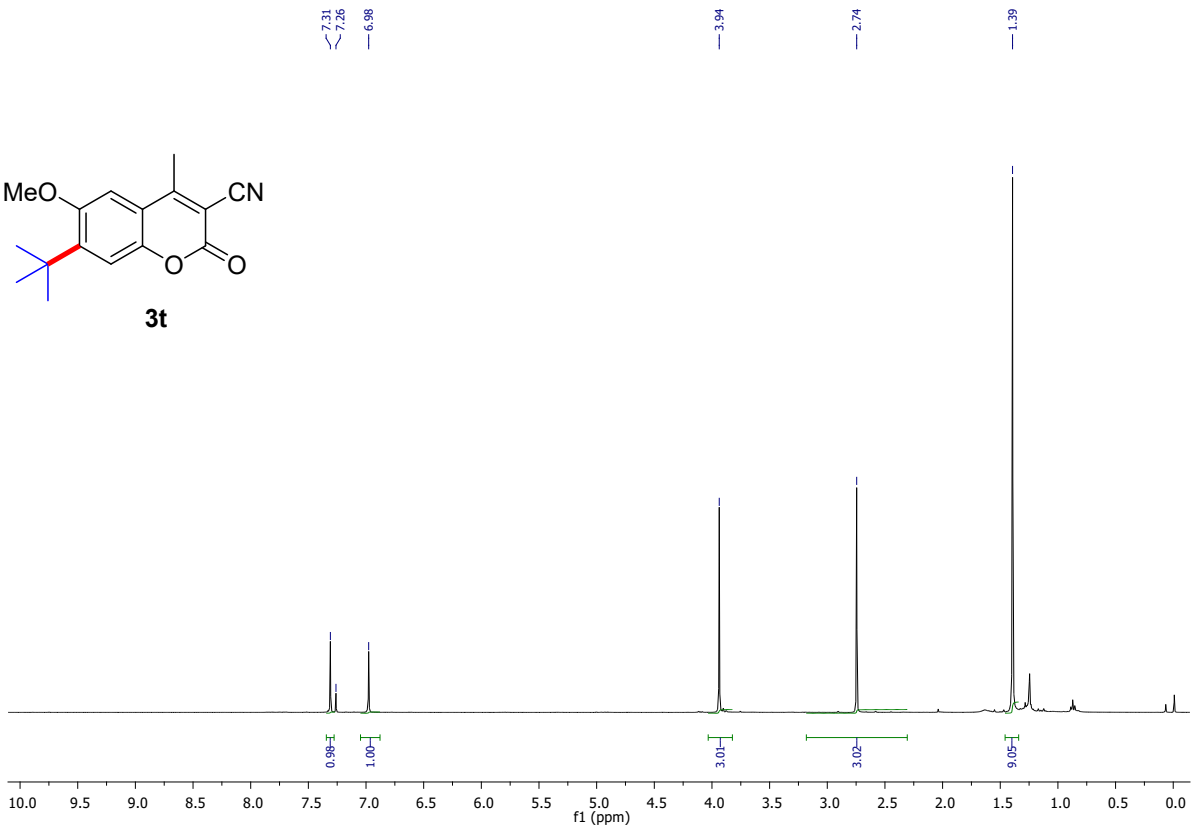

166.68
156.80
156.54
152.75
132.04
118.61
117.75
116.32
113.09
101.72
37.77
29.35
25.20
14.08
Br
CN
O
O
3r
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


7.46
7.45
7.43
7.43
7.36
7.35
7.34
7.33
7.26
3.14
3.12
3.10
3.08
1.46
1.44
1.44
1.42
1.41
1.39
CN
O
O
F
3s
1.00
1.04
2.05
12.04
f1 (ppm)

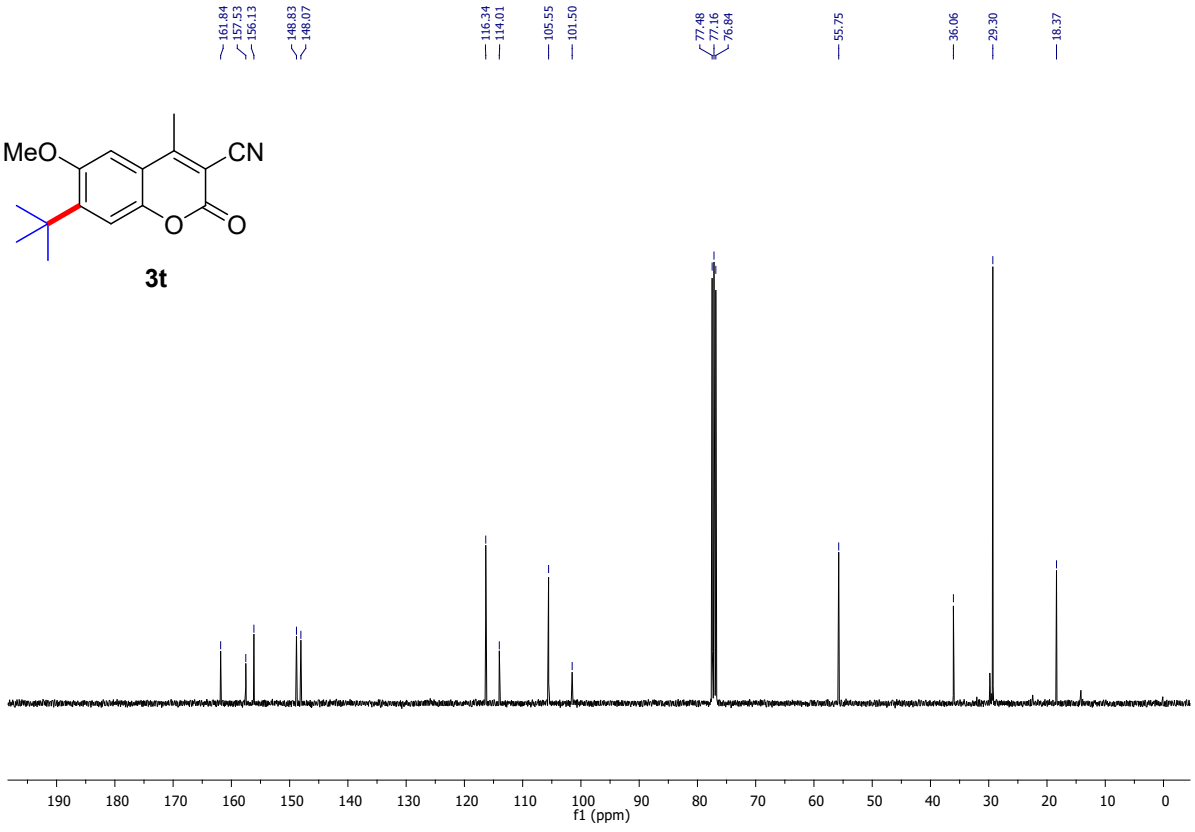

167.78
156.11
147.94
144.78
123.17
123.12
120.02
119.98
116.97
113.17
101.29
77.48
76.84
35.58
29.74
29.70
25.54
14.15
CN
O
O
F
3s
f1 (ppm)

^{19}F NMR of compound 3s

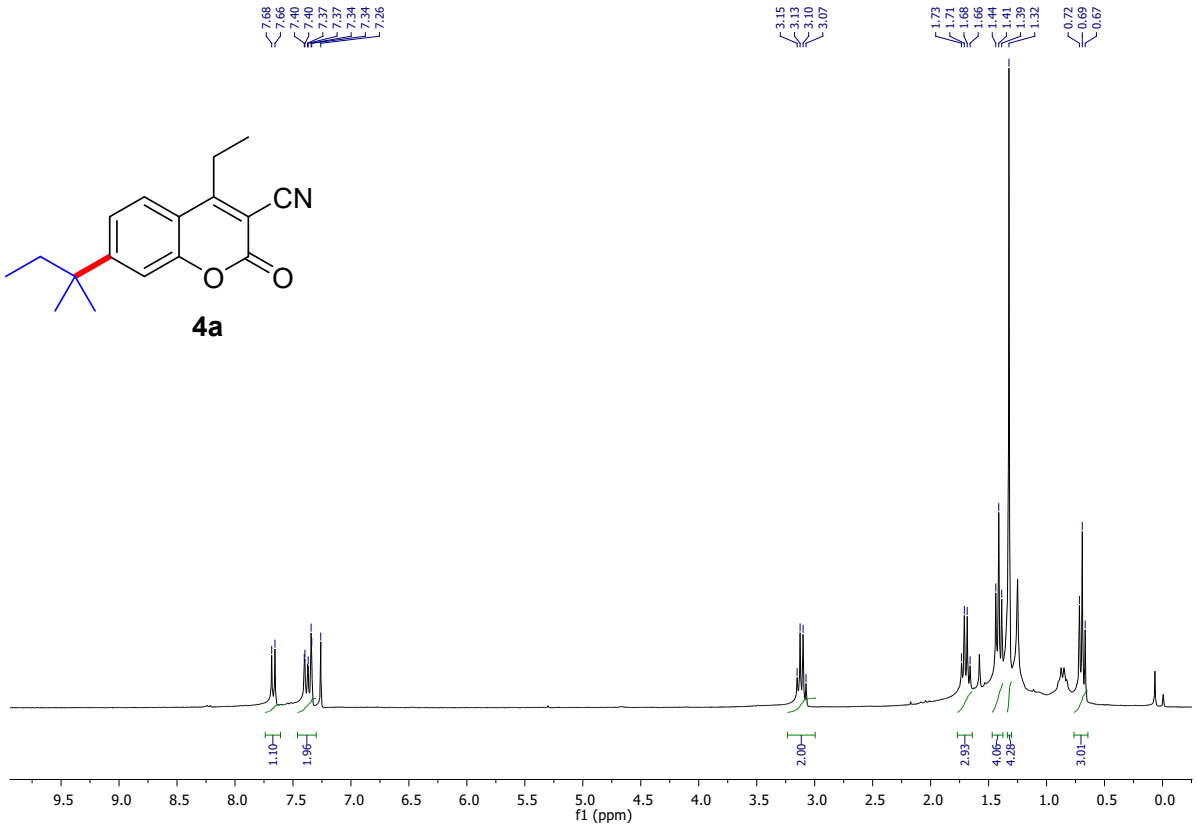



7.31
7.26
6.98
3.94
2.74
1.39
MeO
CN
O
O
0.98
1.00
3.01
3.02
9.05
f1 (ppm)

3t


161.84
157.53
156.13
148.83
148.07
116.34
114.01
105.55
101.50
77.48
77.16
76.84
55.75
36.06
29.30
18.37
MeO
CN
O
O
f1 (ppm)

3t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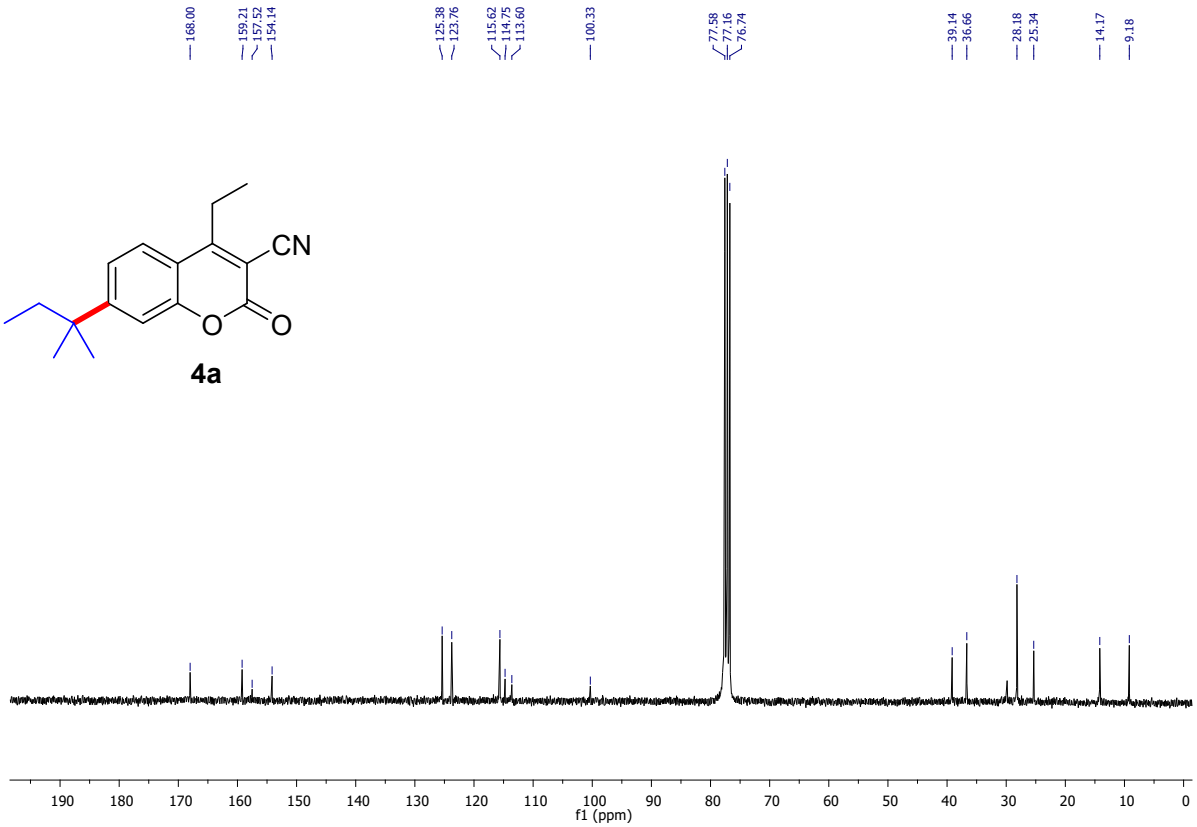
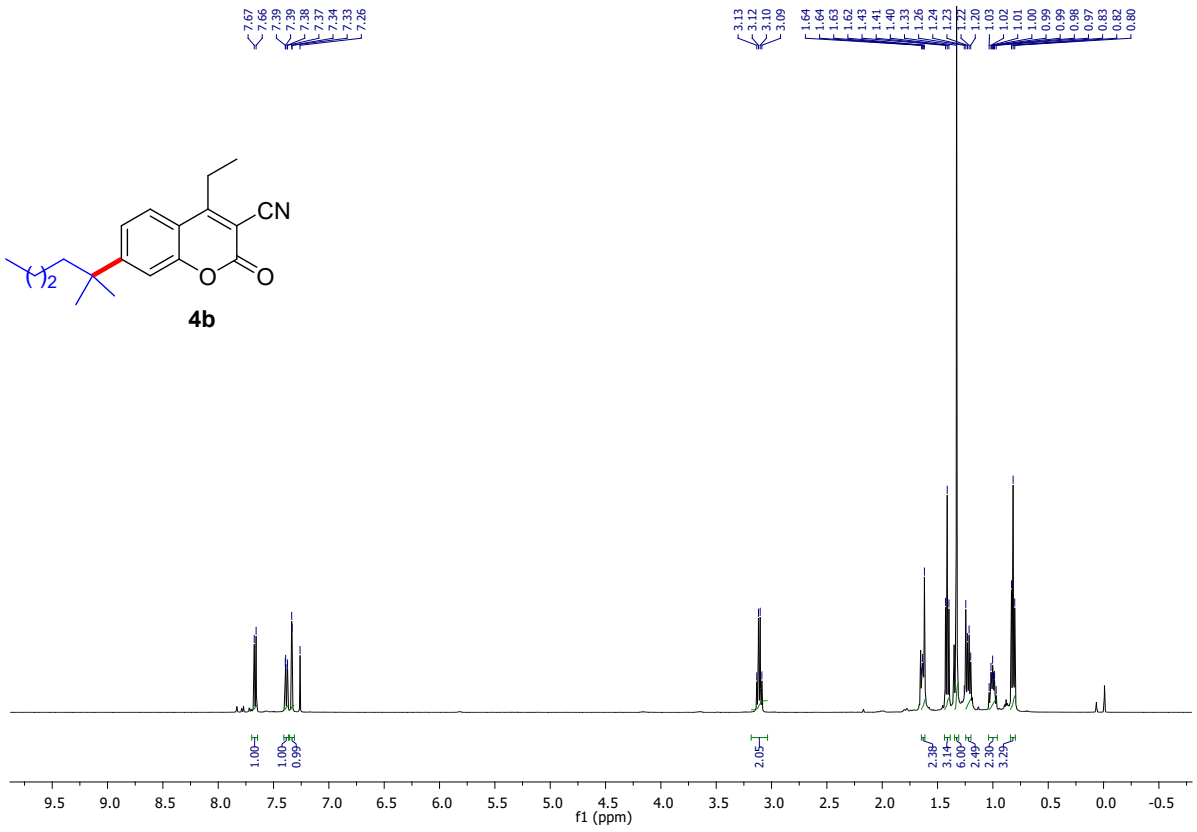
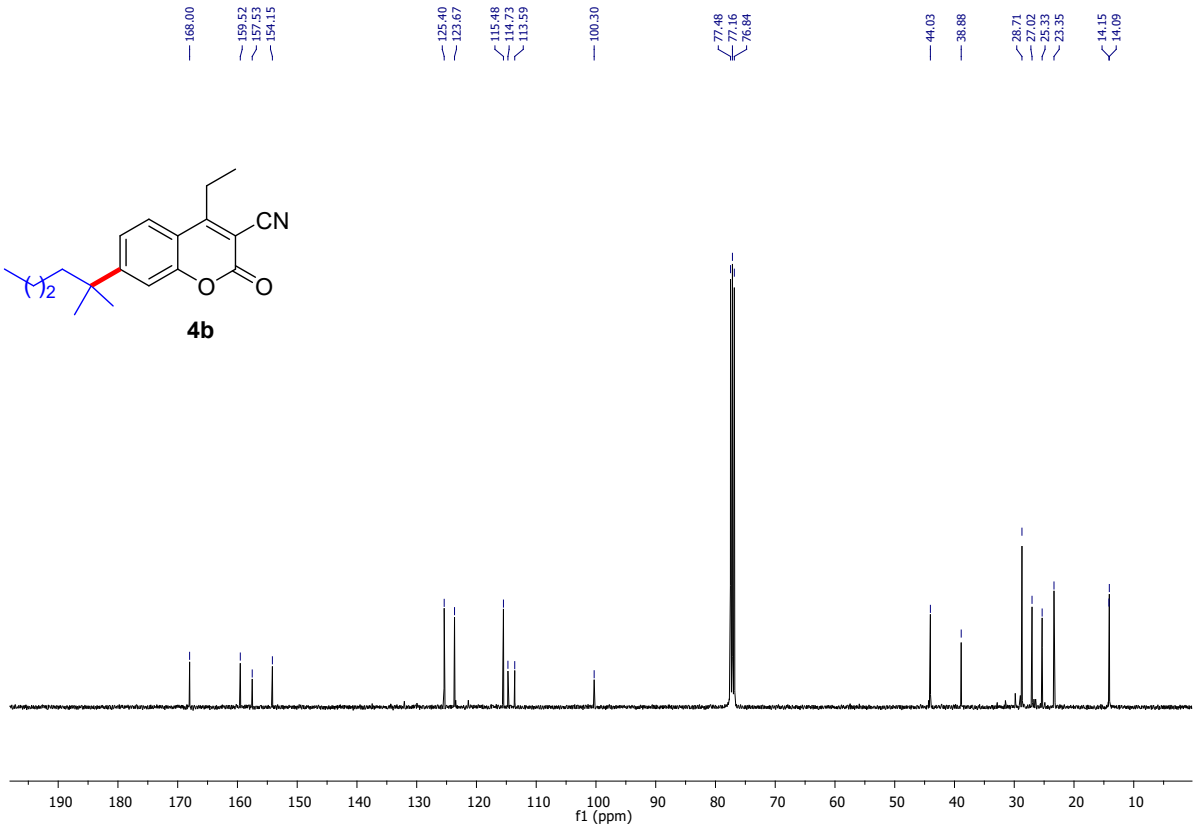
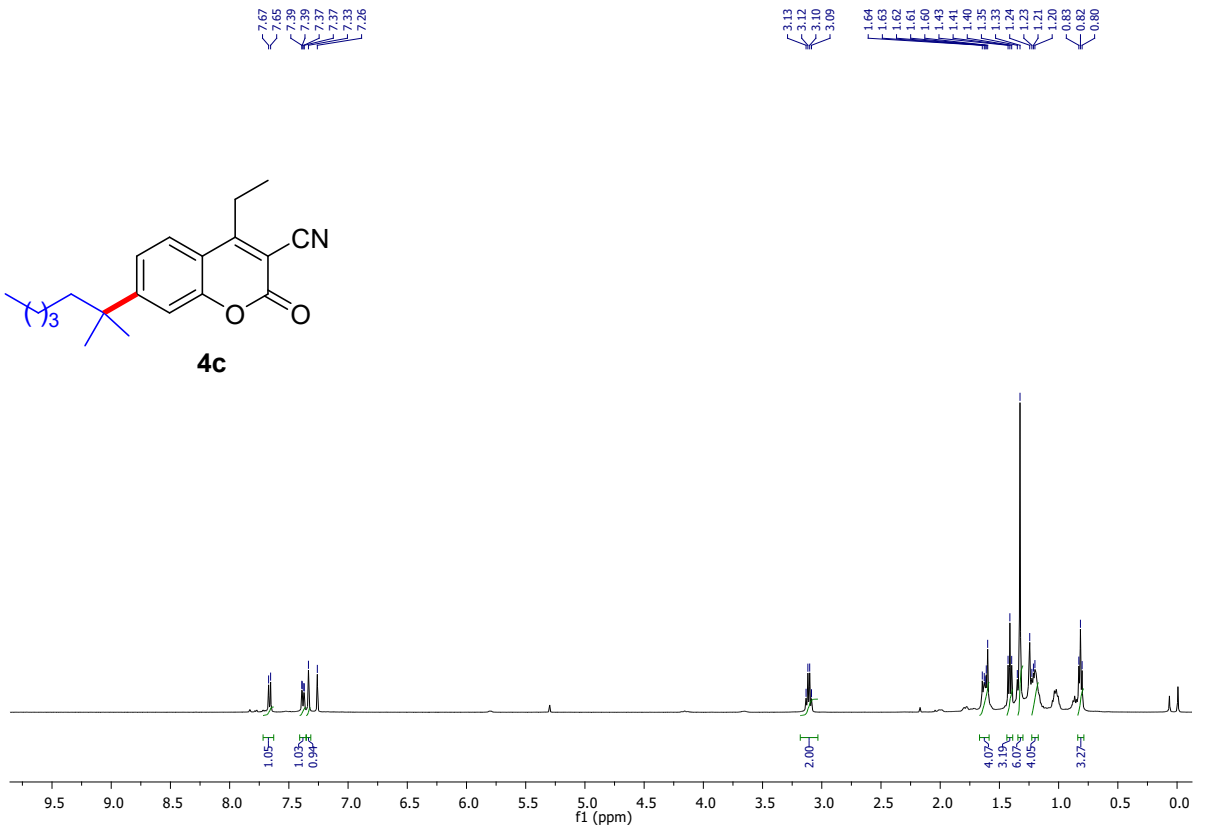
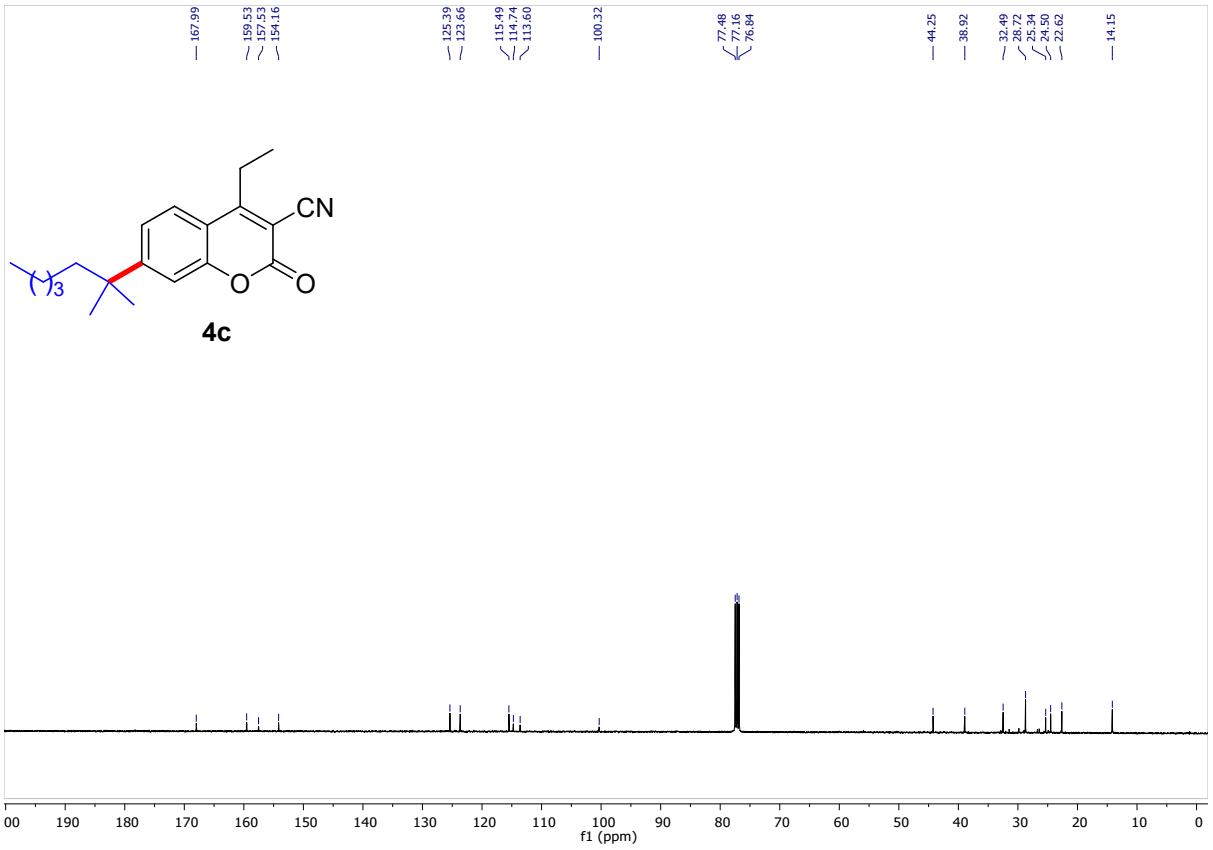
7.40
7.40
7.37
7.37
7.34
7.34
7.26
3.15
3.13
3.10
3.07
1.73
1.71
1.68
1.66
1.44
1.41
1.39
1.32
0.72
0.69
0.67
CN
O
O
4a
1.10
1.96
2.00
2.93
4.06
4.28
3.01
f1 (ppm)


168.00
159.21
157.52
154.14
125.38
123.76
115.62
114.75
113.60
100.33
77.58
77.16
76.74
39.14
36.66
28.18
25.34
14.17
9.18
CN
O
O
4a
f1 (ppm)


CN
O
O
4b
f1 (ppm)


CN
O
O
4b
f1 (ppm)


7.67
7.65
7.39
7.39
7.37
7.37
7.33
7.26
3.13
3.12
3.10
3.09
1.64
1.63
1.62
1.61
1.60
1.43
1.41
1.40
1.35
1.33
1.24
1.23
1.21
1.20
0.83
0.82
0.80
CN
O
O
3
4c
1.05
1.03
0.94
2.00
4.07
3.19
6.07
4.05
3.27
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)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114.74
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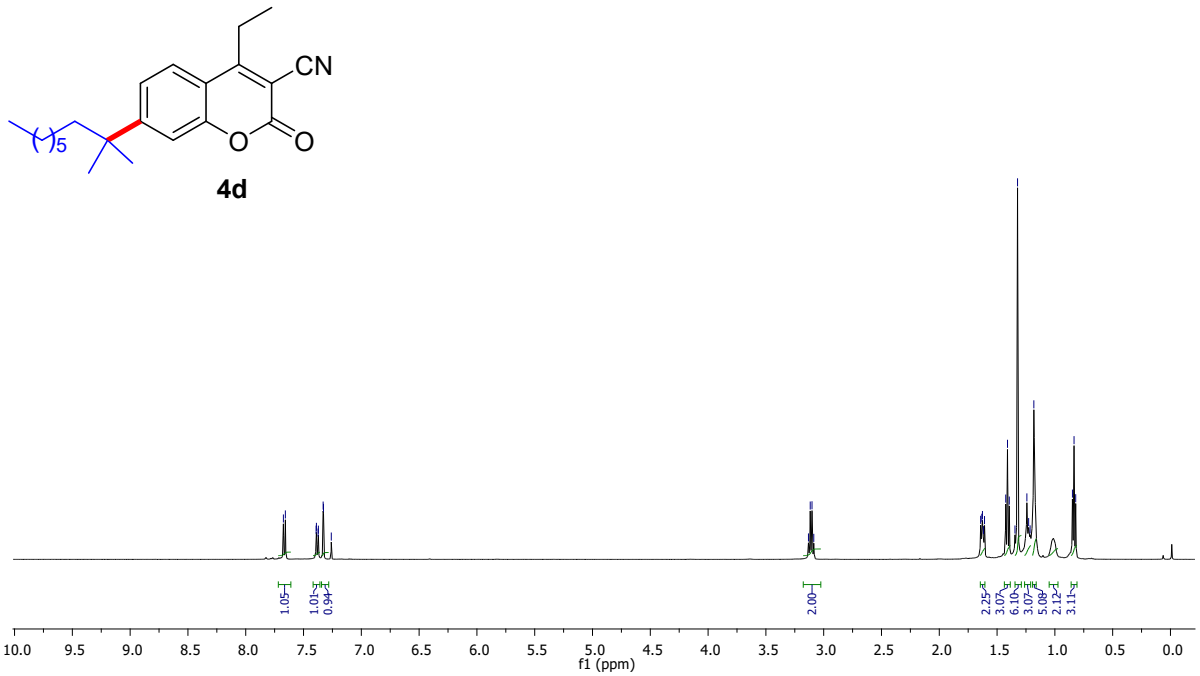
100.32
77.48
77.16
76.84
44.25
38.92
32.49
28.72
25.34
24.50
22.62
14.15
CN
O
O
3
4c
00 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)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7.39
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7.33
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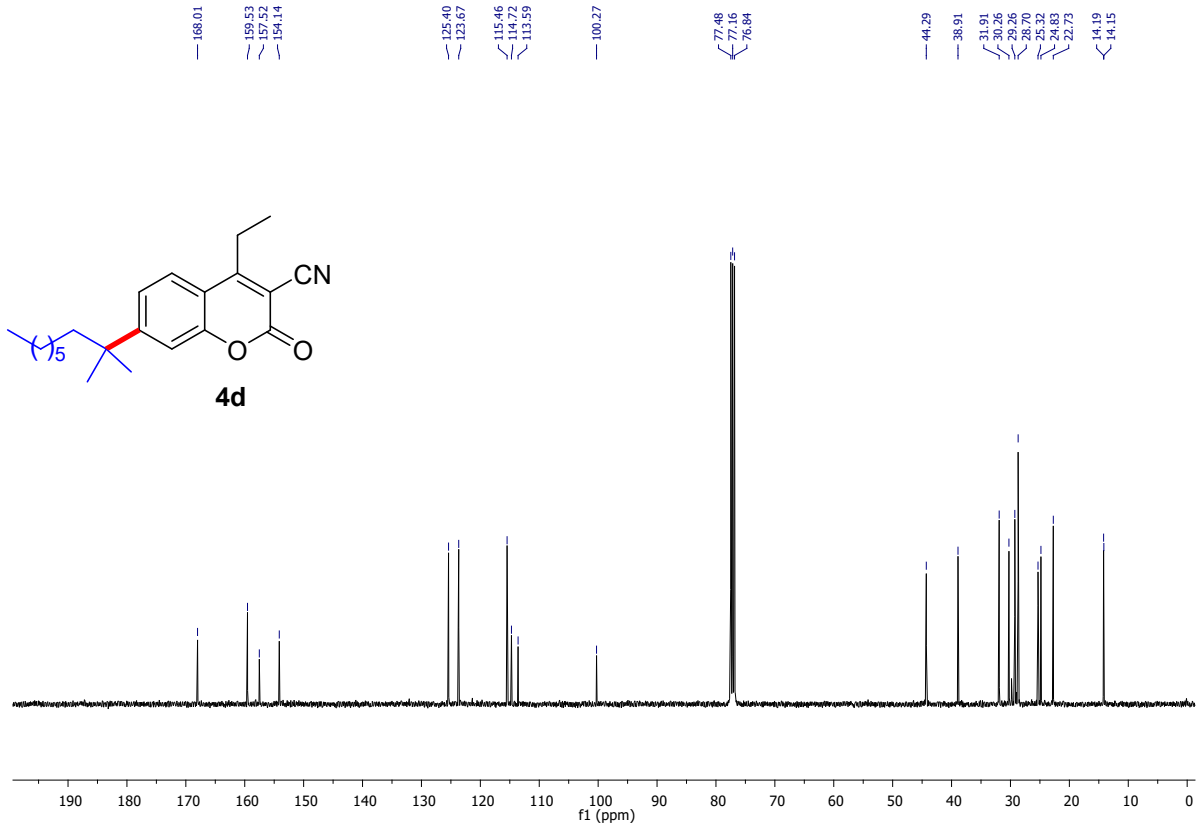
3.12
3.10
3.09
1.64
1.63
1.63
1.62
1.61
1.43
1.41
1.39
1.35
1.32
1.24
1.23
1.21
1.18
0.85
0.83
0.82
CN
O
O
5
4d
1.05
1.01
0.94
2.00
2.25
3.07
6.10
3.07
5.08
2.12
3.11
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)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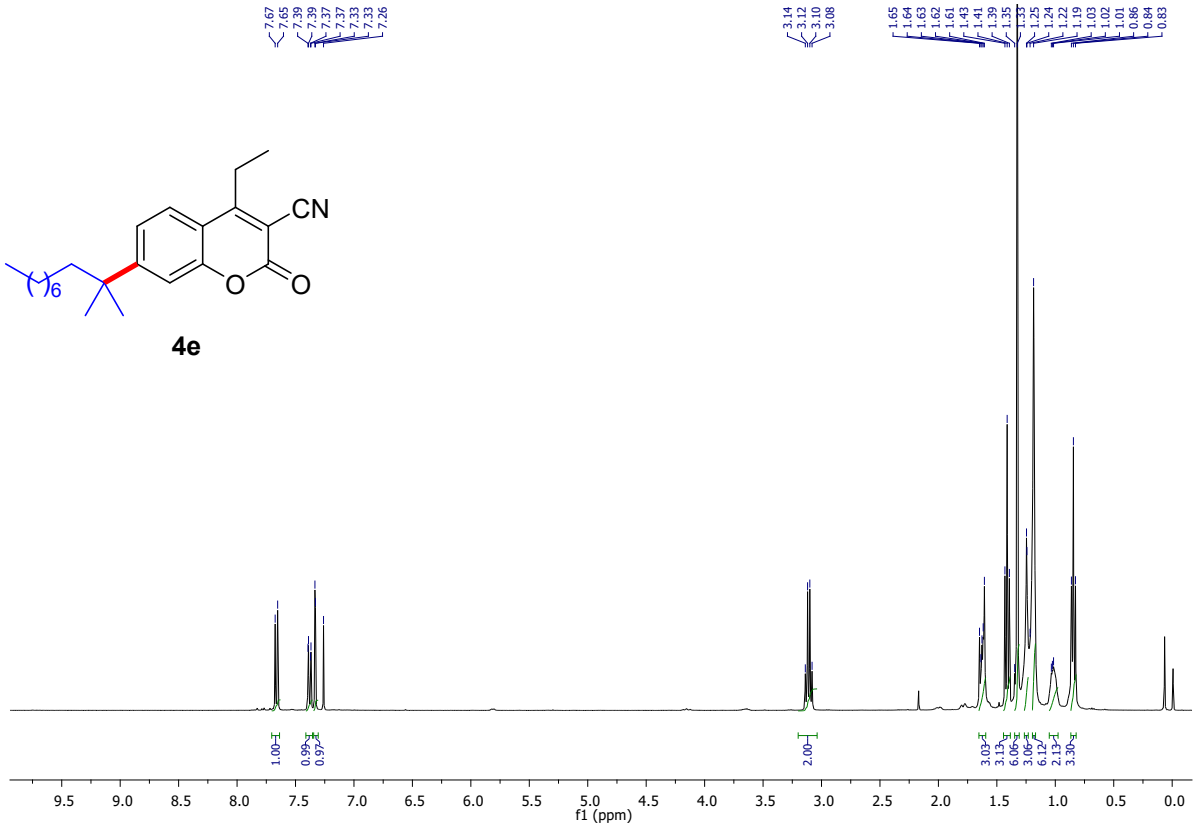
38.91
31.91
30.26
29.26
28.70
25.32
24.83
22.73
14.19
14.15
CN
O
O
5
4d
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)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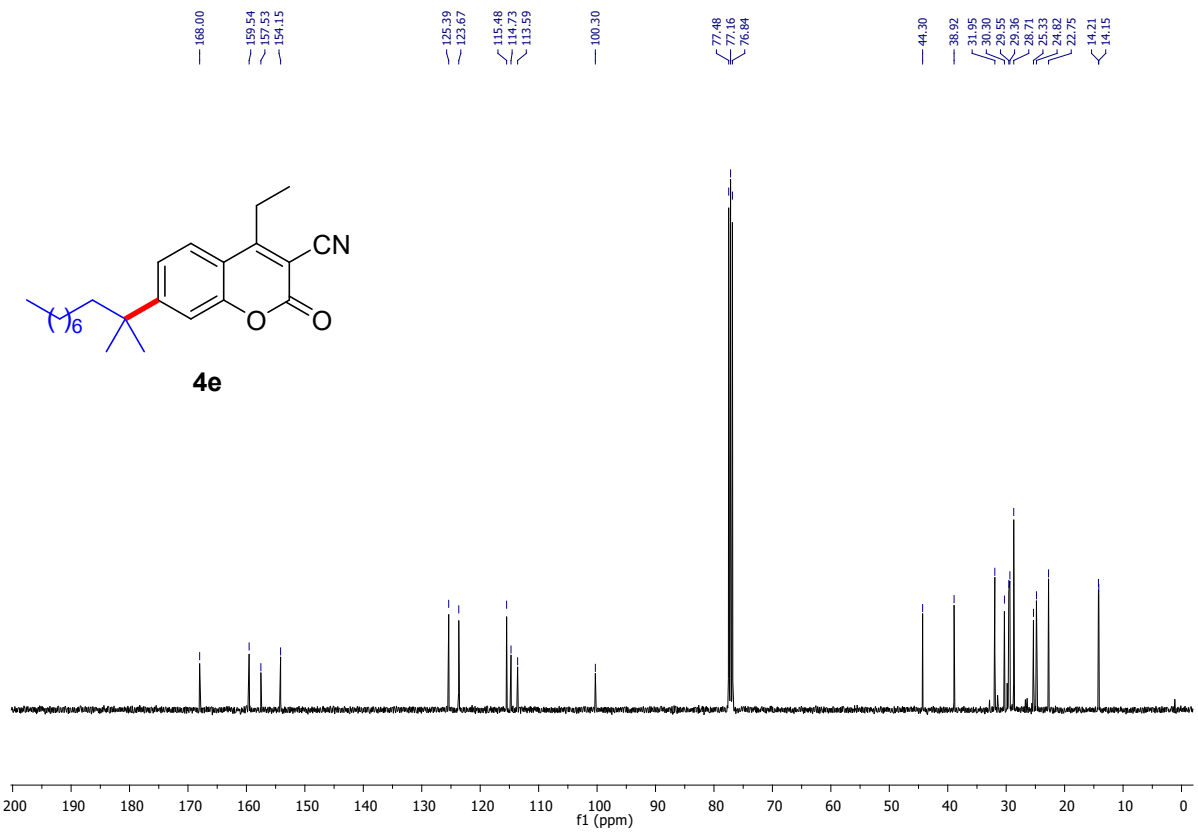
7.33
7.26
3.14
3.12
3.10
3.08
1.65
1.64
1.63
1.62
1.61
1.43
1.41
1.39
1.35
1.25
1.24
1.22
1.19
1.03
1.02
1.01
0.86
0.84
0.83
CN
O
O
6
1.00
0.99
0.97
2.00
3.03
3.13
6.06
3.06
6.12
2.13
3.30
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

4e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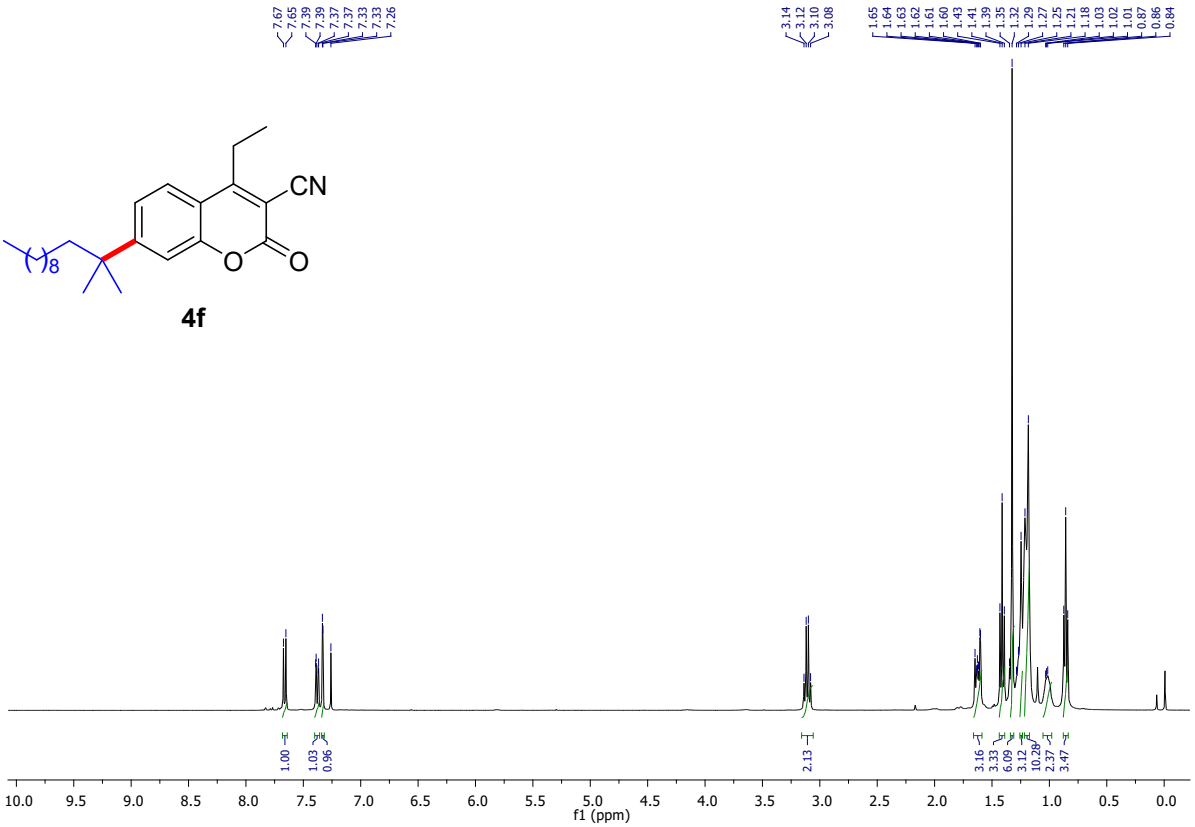
123.67
115.48
114.73
113.59
100.30
77.48
77.16
76.84
44.30
38.92
31.95
30.30
29.55
29.36
28.71
25.33
24.82
22.75
14.21
14.15
CN
O
O
6
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

4e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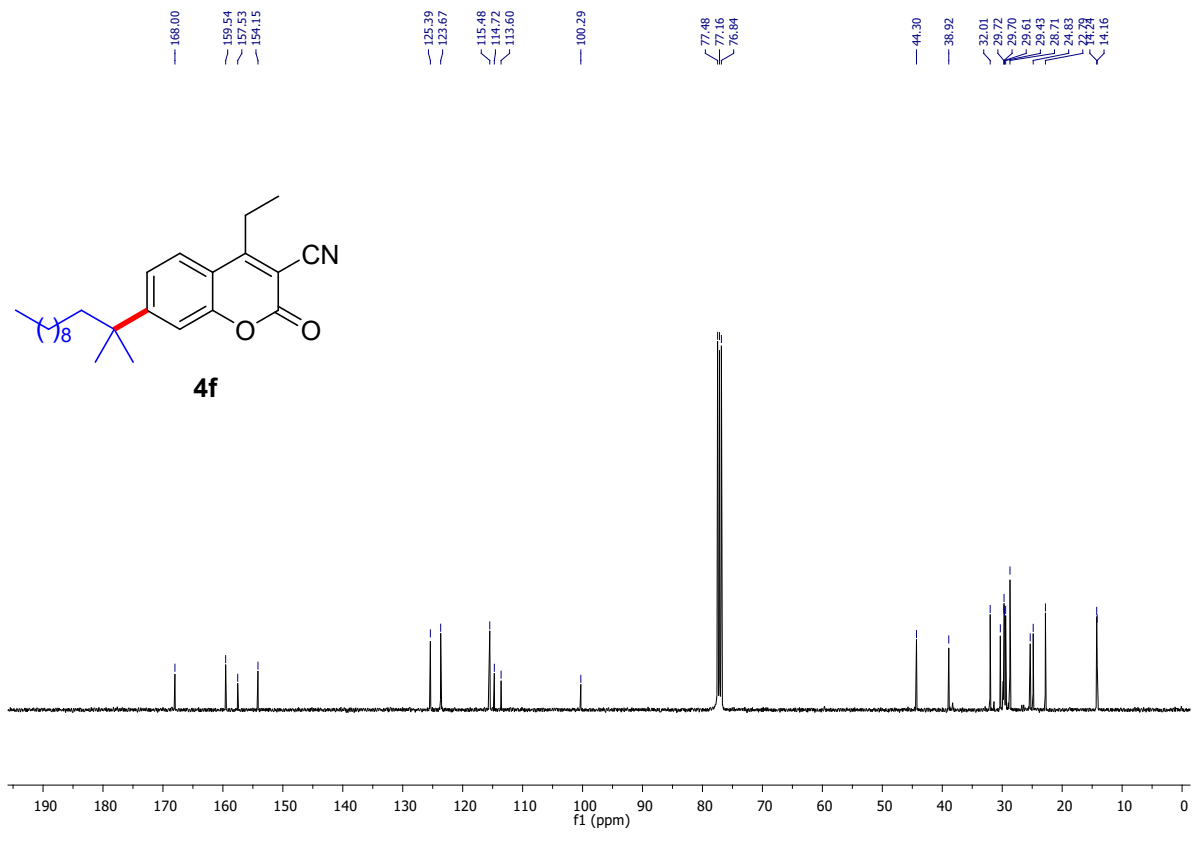
7.39
7.37
7.37
7.33
7.33
7.26
3.14
3.12
3.10
3.08
1.65
1.64
1.63
1.62
1.61
1.60
1.43
1.41
1.39
1.35
1.32
1.29
1.27
1.25
1.21
1.18
1.03
1.02
1.01
0.87
0.86
0.84
CN
O
O
8
4f
1.00
1.03
0.96
2.13
3.16
3.33
6.09
3.12
10.29
2.37
3.47
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)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114.72
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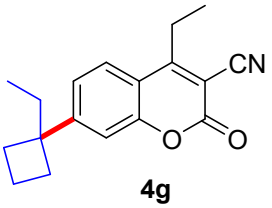
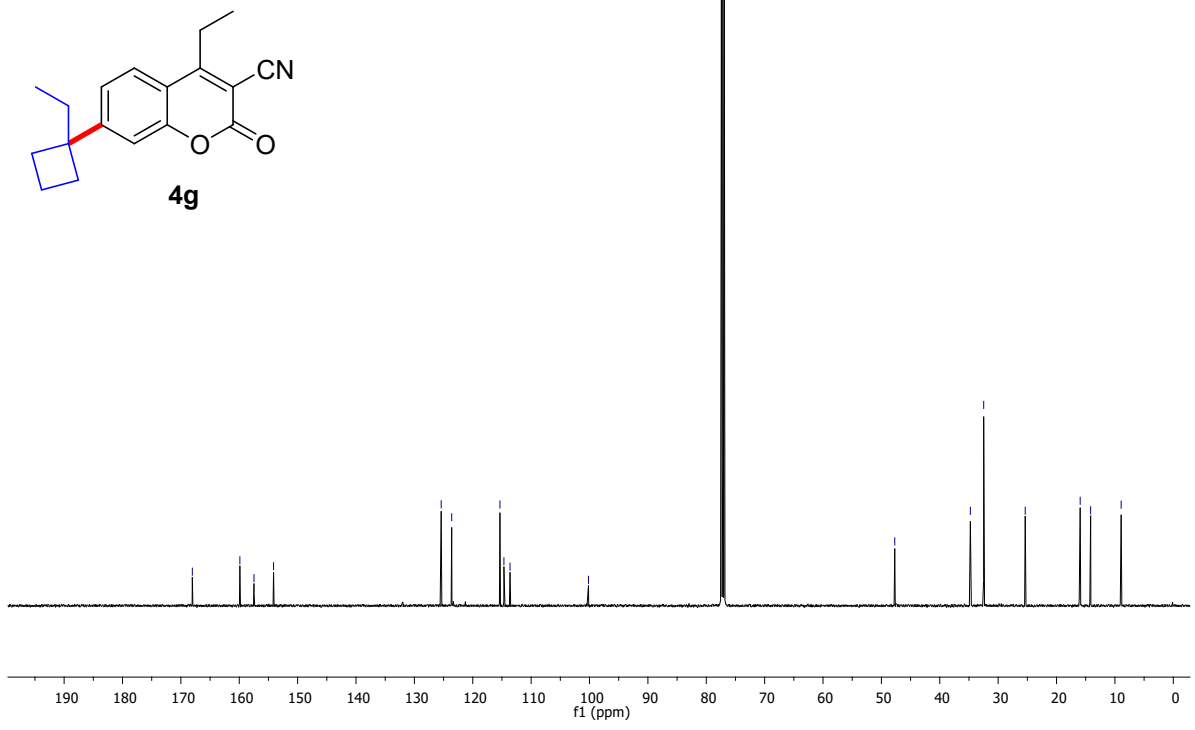
100.29
77.48
77.16
76.84
44.30
38.92
32.01
29.72
29.70
29.61
29.43
28.71
24.83
14.16
CN
O
O
8
4f
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


CN
O
O

4g

7.66
7.64
7.26
7.14
7.14
7.13
7.12
7.11
3.13
3.12
3.10
3.09
2.34
2.31
2.20
2.19
2.18
2.16
1.87
1.86
1.85
1.41
1.39
0.67
0.66
0.64
1.00
1.99
2.08
2.21
2.12
1.09
3.11
3.10
3.20
f1 (ppm)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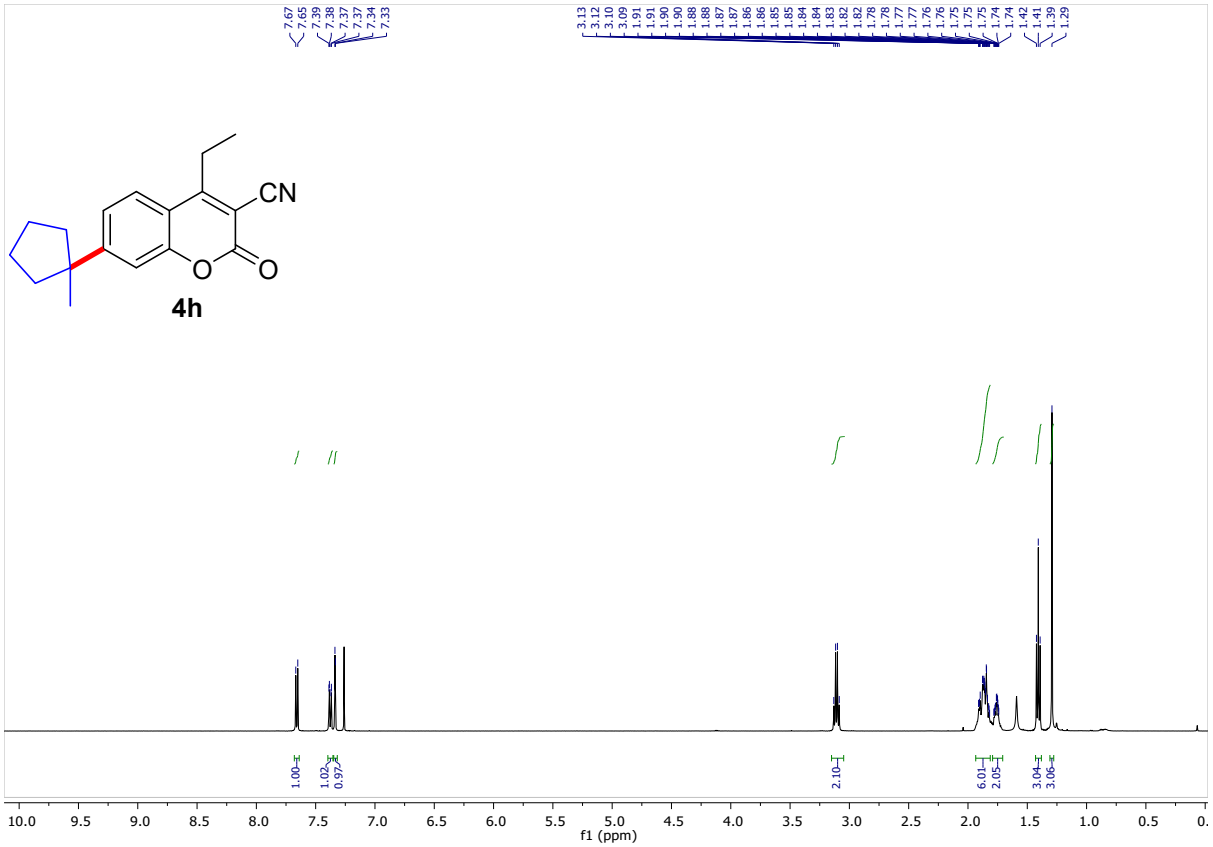
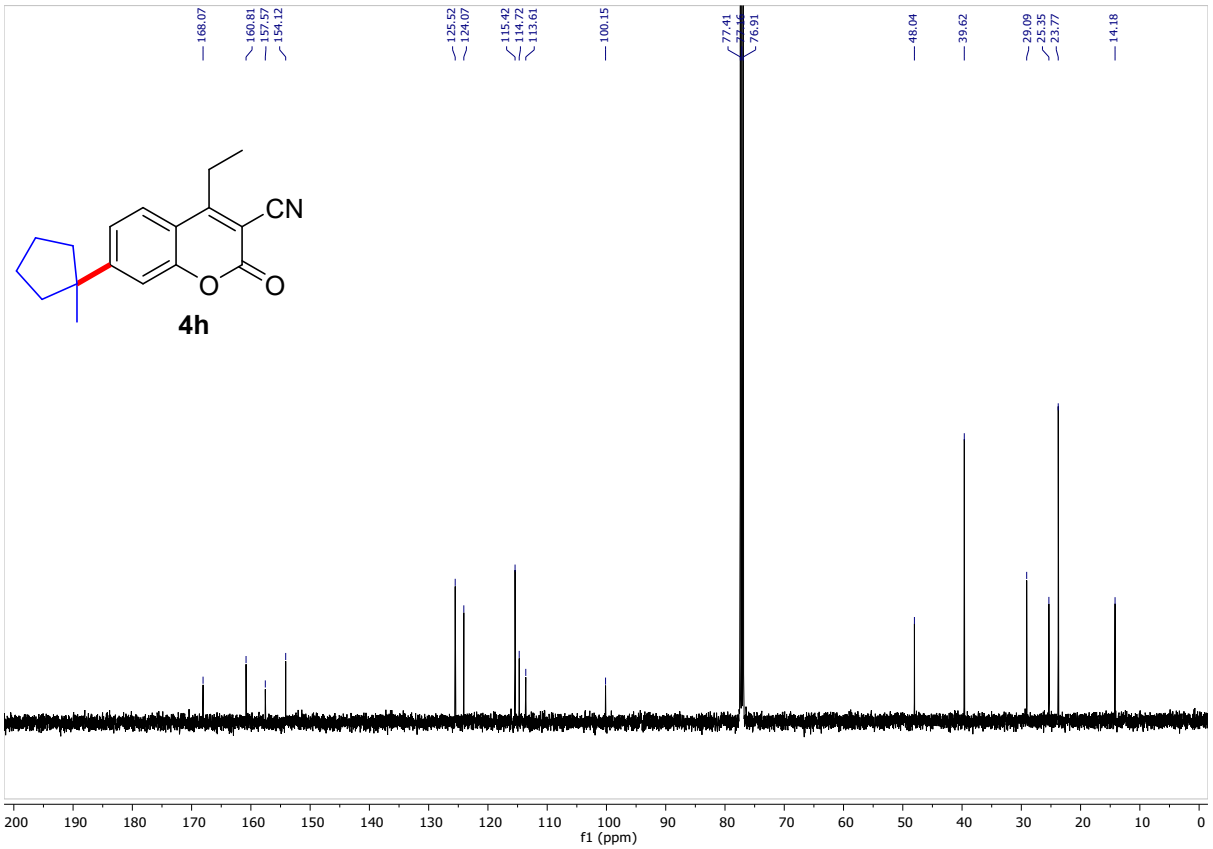
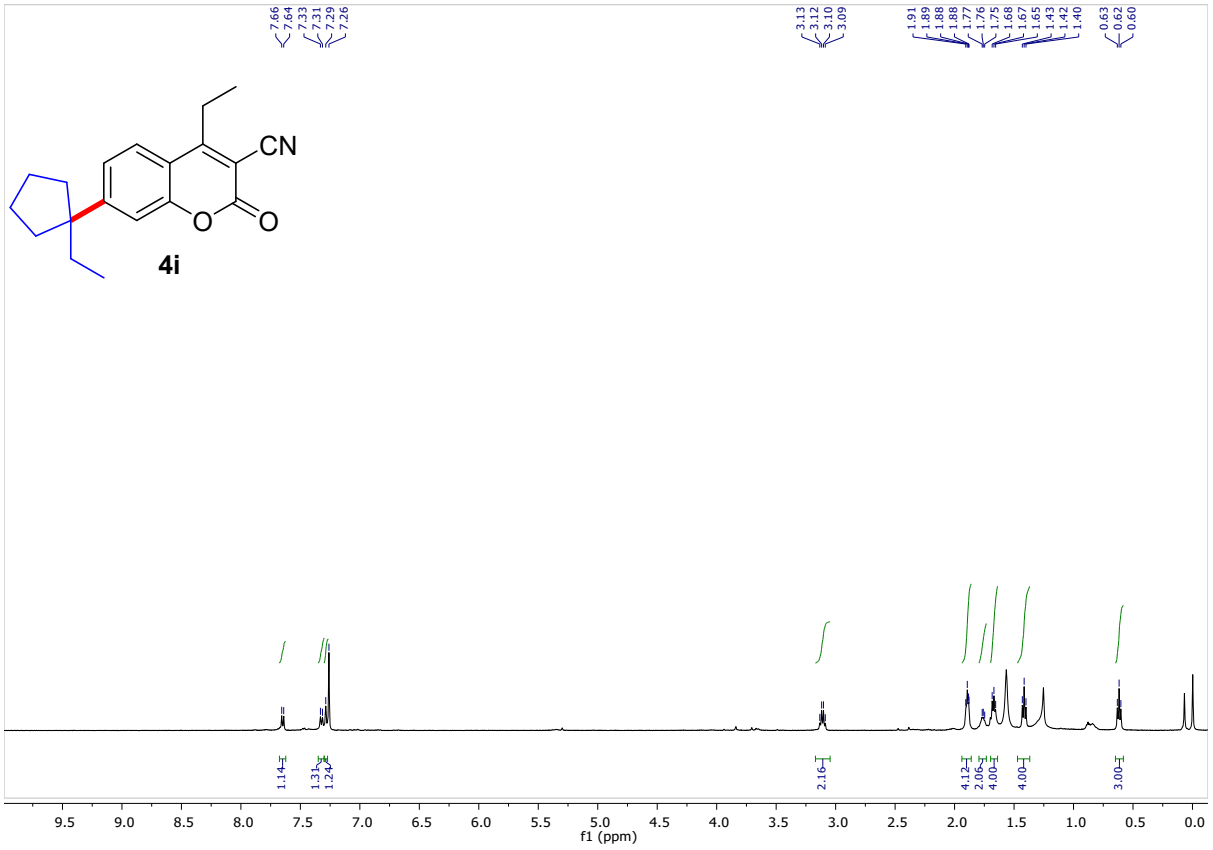
123.61
115.34
114.66
113.62
100.18
77.41
77.16
76.91
47.71
34.76
32.48
25.37
15.95
14.16
8.93
f1 (ppm)

CN
O
O

4g


CN
O
O
4h
f1 (ppm)


CN
O
O
4h
f1 (ppm)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7.31
7.29
7.26
3.13
3.12
3.10
3.09
1.91
1.89
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1.88
1.77
1.76
1.75
1.68
1.67
1.65
1.43
1.42
1.40
0.63
0.62
0.60
CN
O
O
4i
1.14
1.31
1.24
2.16
4.12
2.06
4.00
4.00
3.00
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
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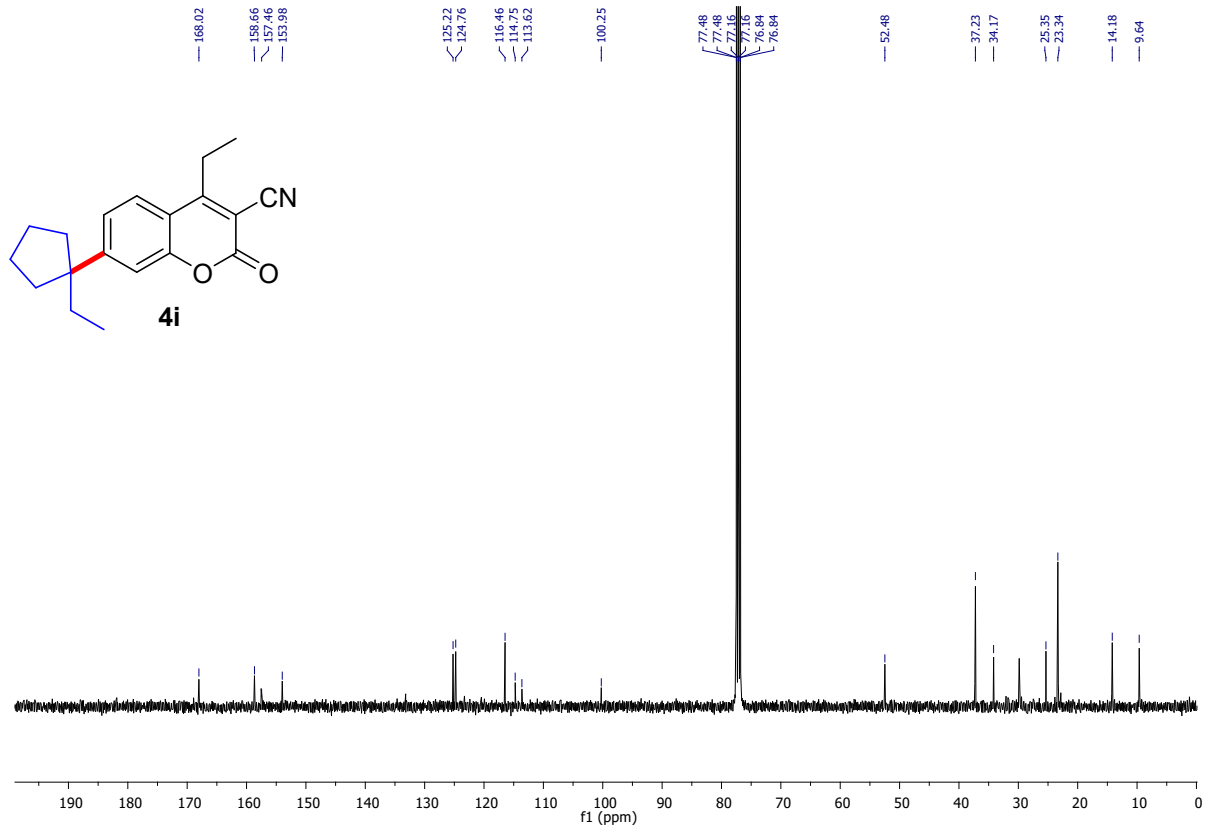
0.0
f1 (ppm)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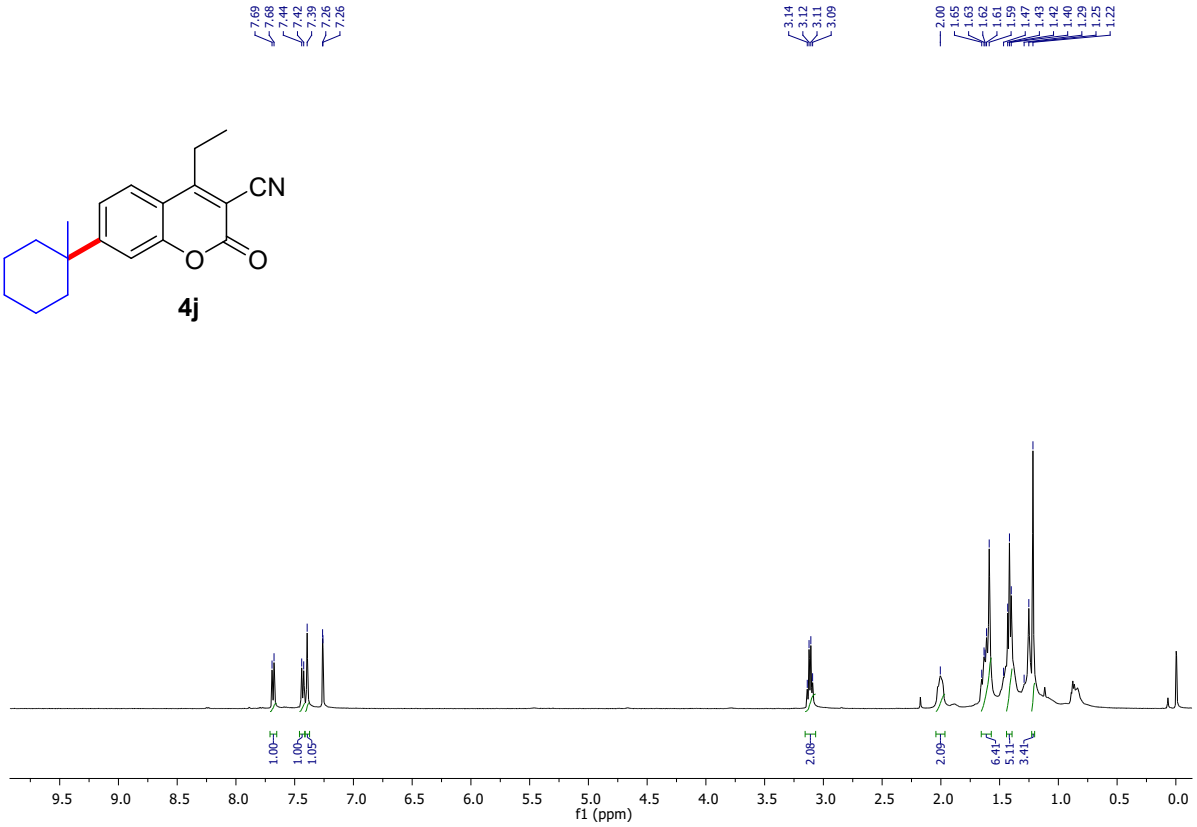
77.48
77.48
77.16
77.16
76.84
76.84
52.48
37.23
34.17
25.35
23.34
14.18
9.64
CN
O
O
4i
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)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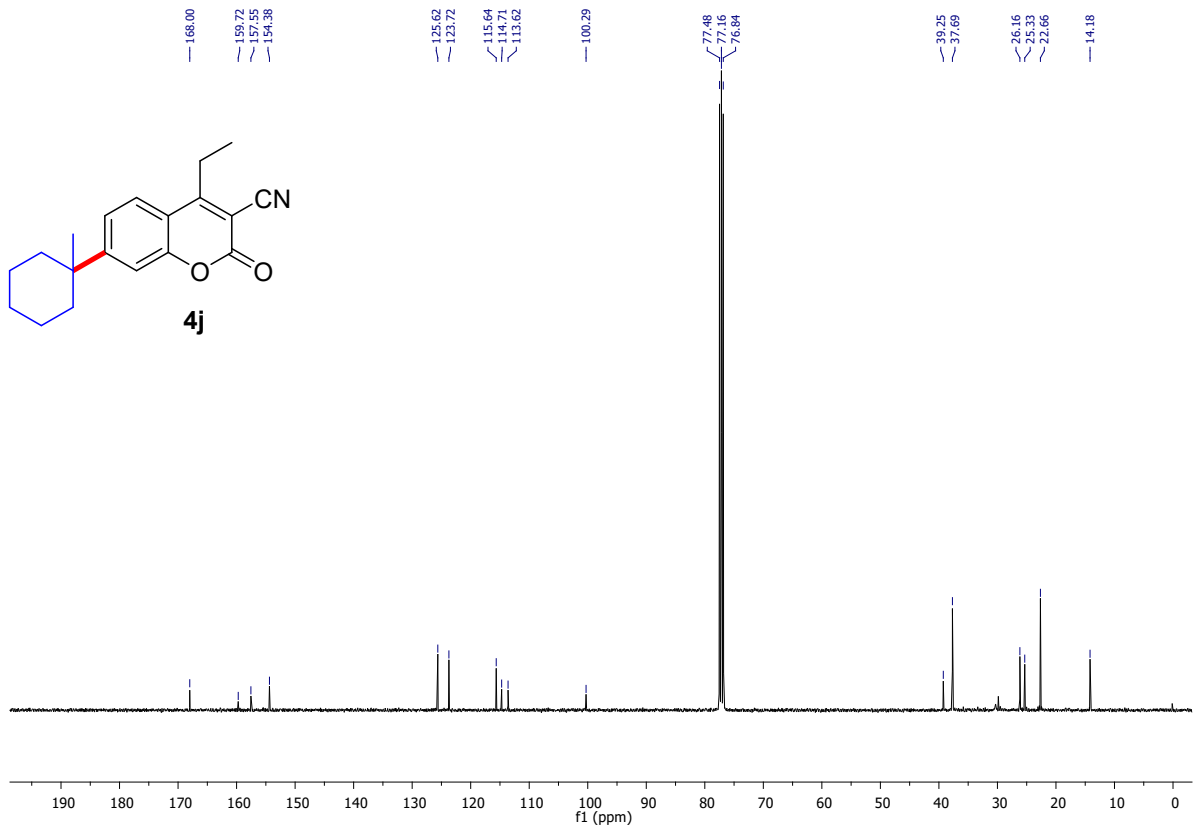
7.26
7.26
3.14
3.12
3.11
3.09
2.00
1.65
1.63
1.62
1.61
1.59
1.47
1.43
1.42
1.40
1.29
1.25
1.22
CN
O
O
4j
1.00
1.00
1.05
2.08
2.09
6.41
5.11
3.41
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)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154.38
125.62
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114.71
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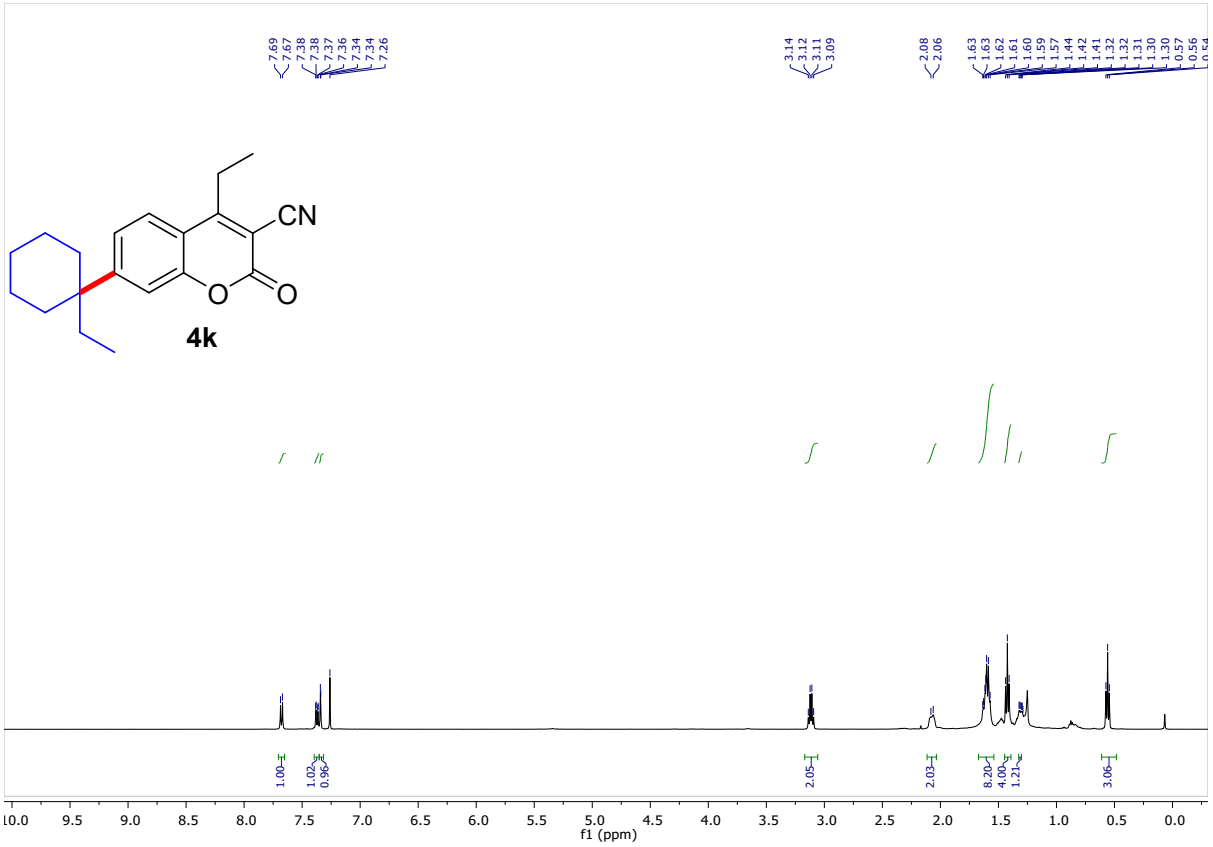
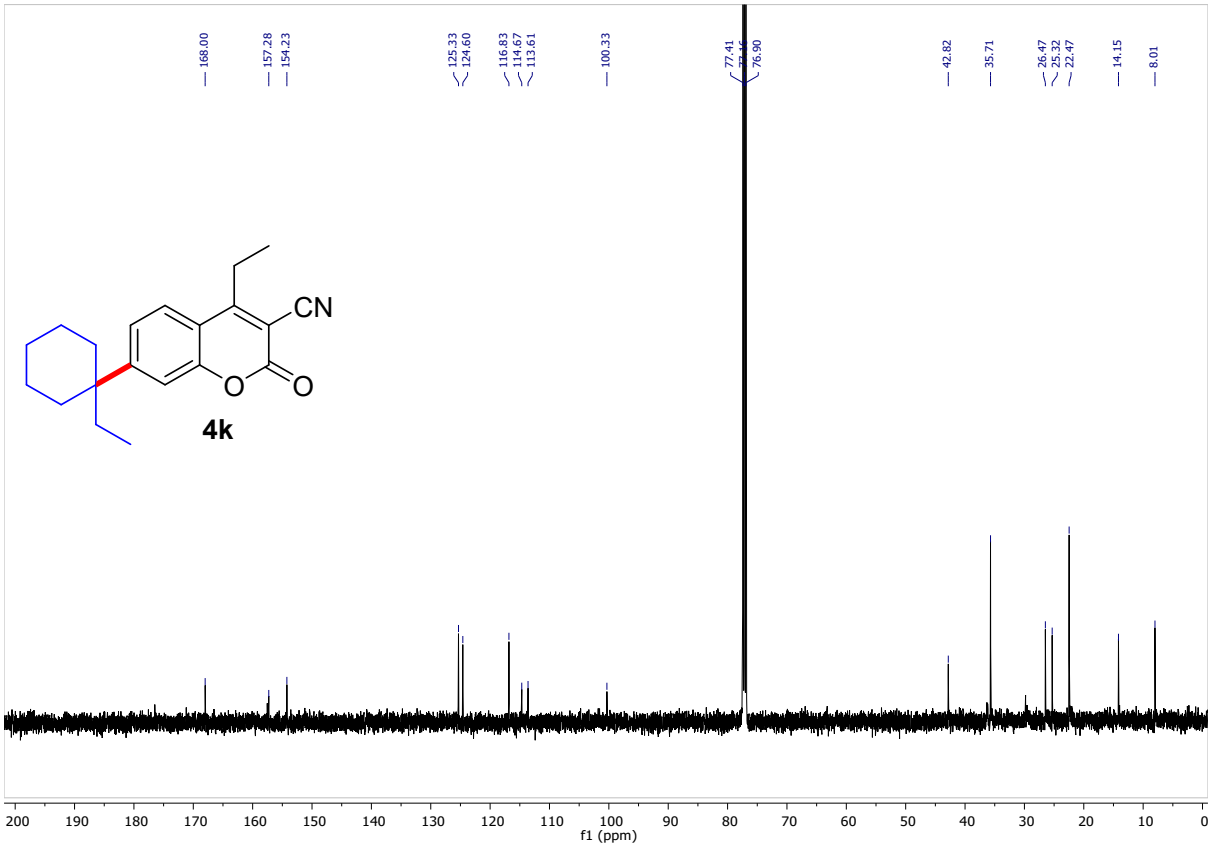
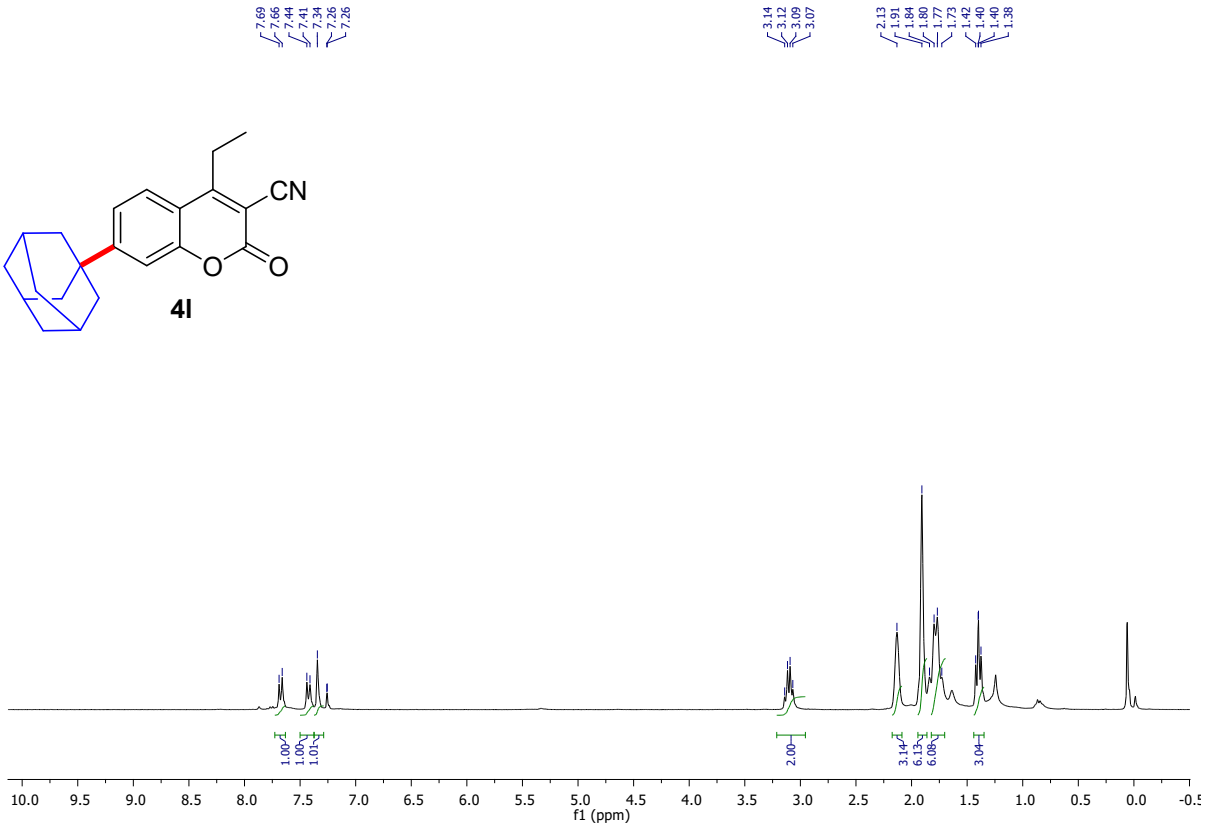
100.29
77.48
77.16
76.84
39.25
37.69
26.16
25.33
22.66
14.18
CN
O
O
4j
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


CN
O
O
4k
f1 (ppm)


CN
O
O
4k
f1 (ppm)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7.26
3.14
3.12
3.09
3.07
2.13
1.91
1.84
1.80
1.77
1.73
1.42
1.40
1.40
1.38
CN
O
O
4l
1.00
1.00
1.01
2.00
3.14
6.13
6.08
3.04
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
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4.5
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3.5
3.0
2.5
2.0
1.5
1.0
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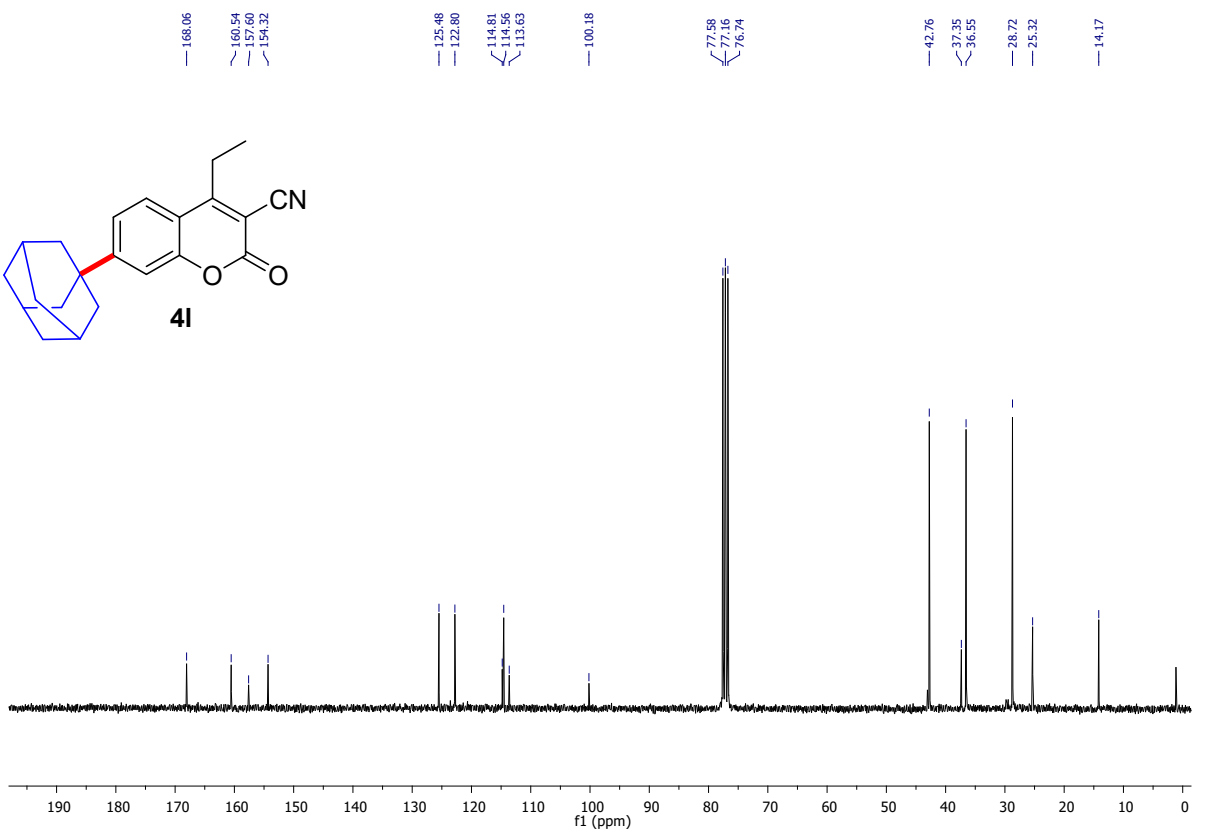
0.0
f1 (ppm)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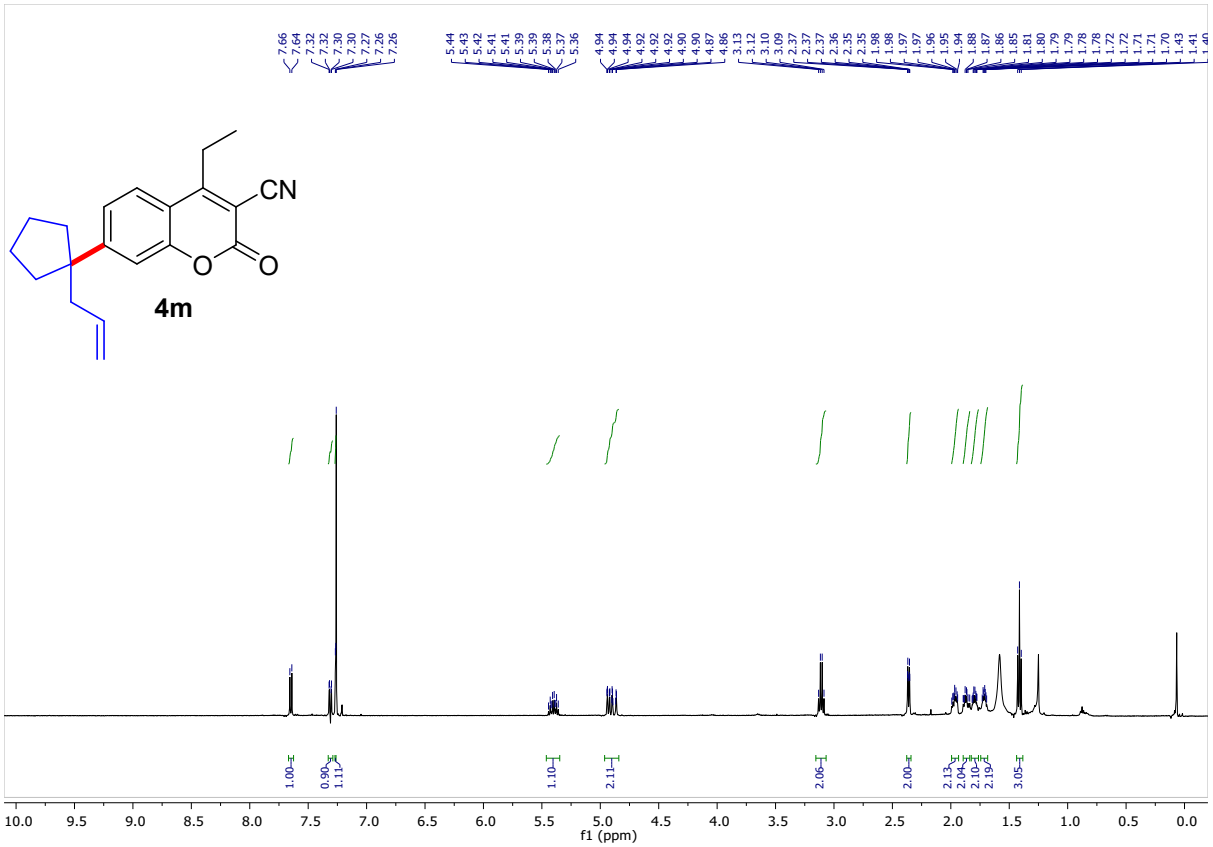
100.18
77.58
77.16
76.74
42.76
37.35
36.55
28.72
25.32
14.17
CN
O
O
4l
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)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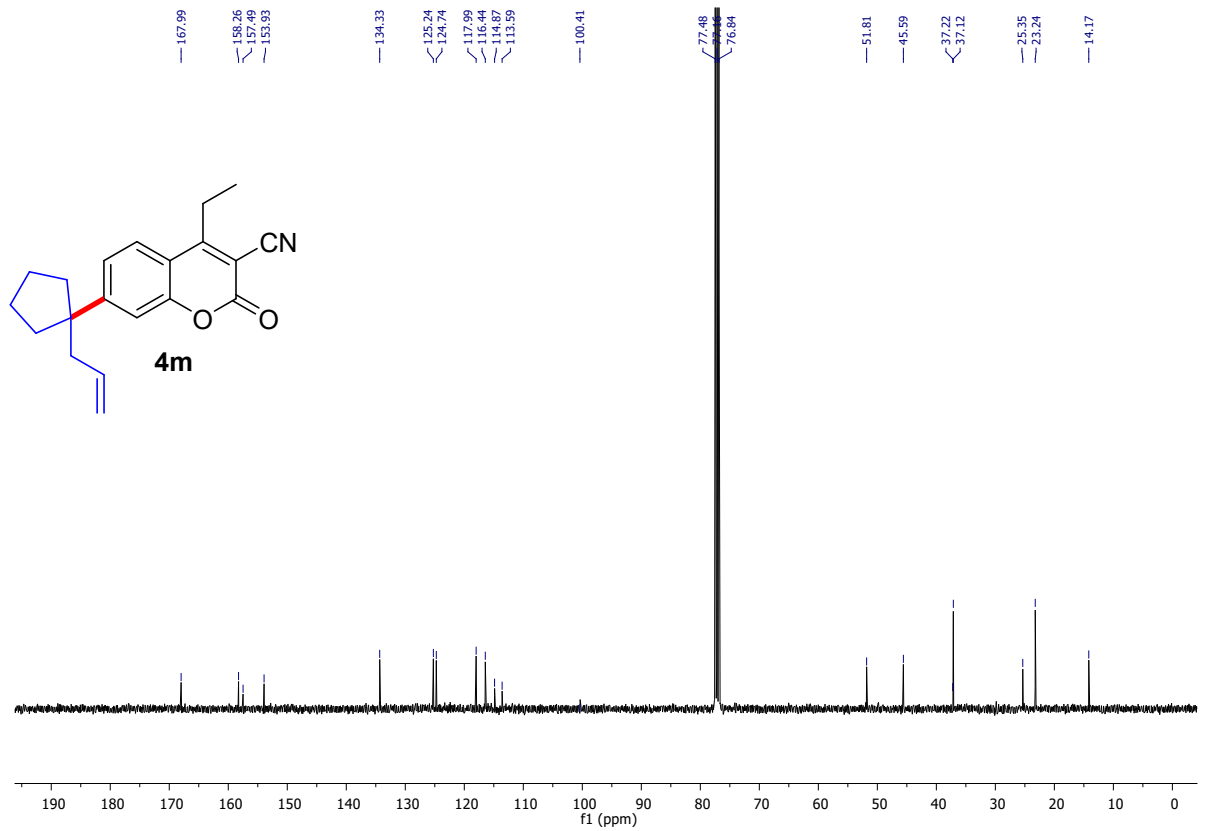
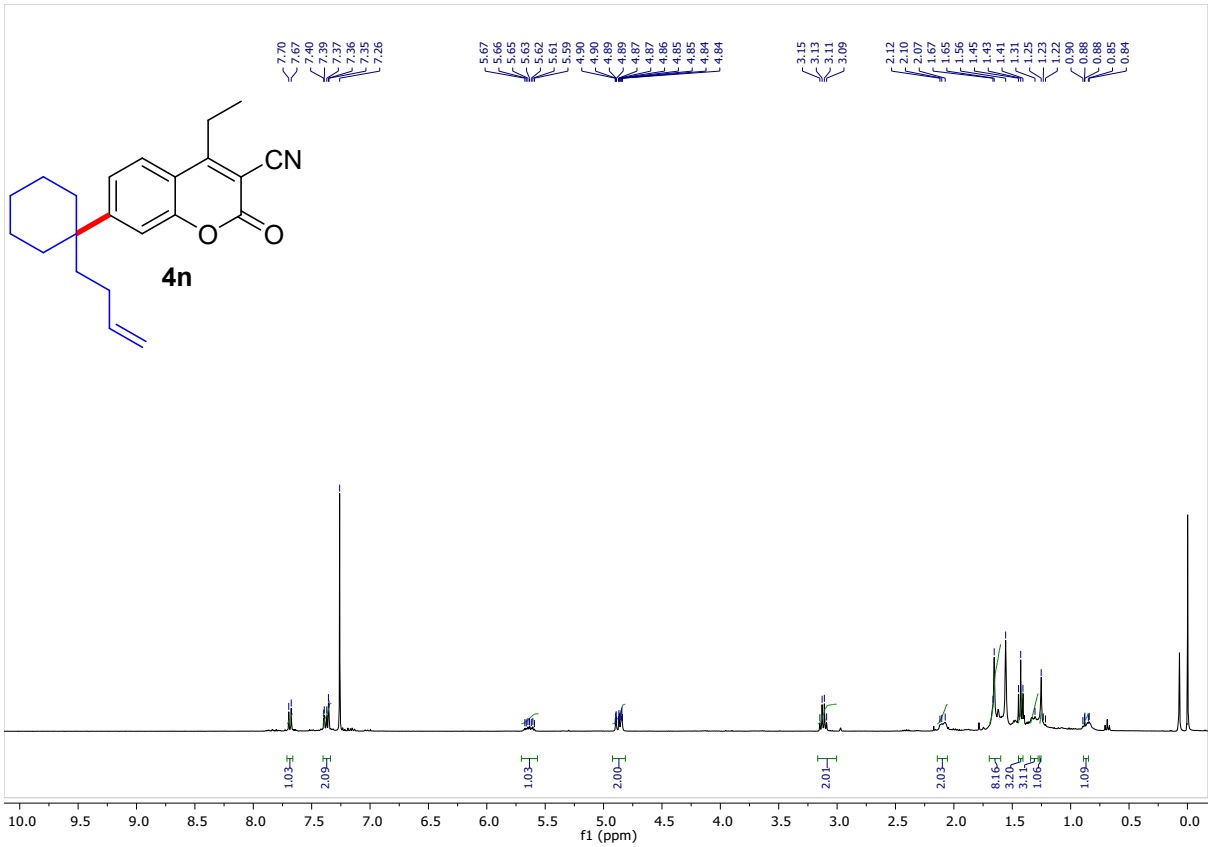
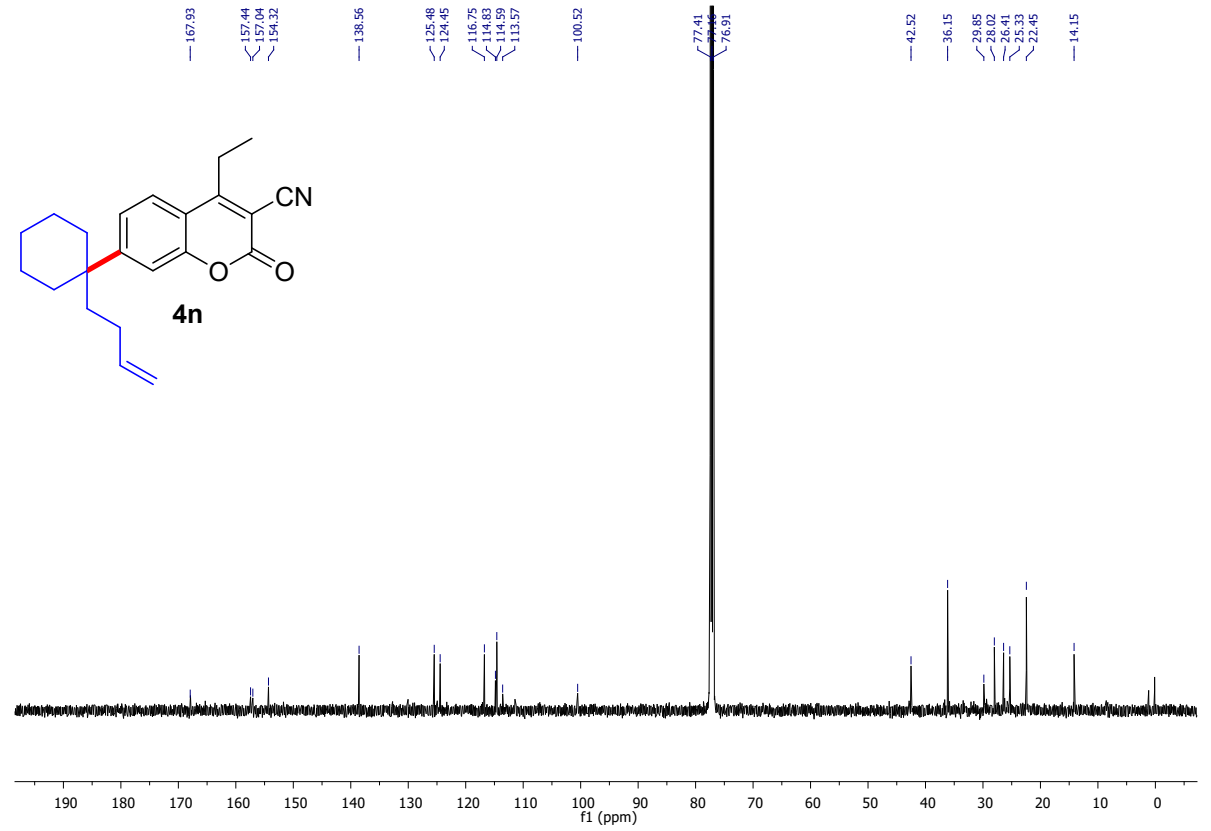
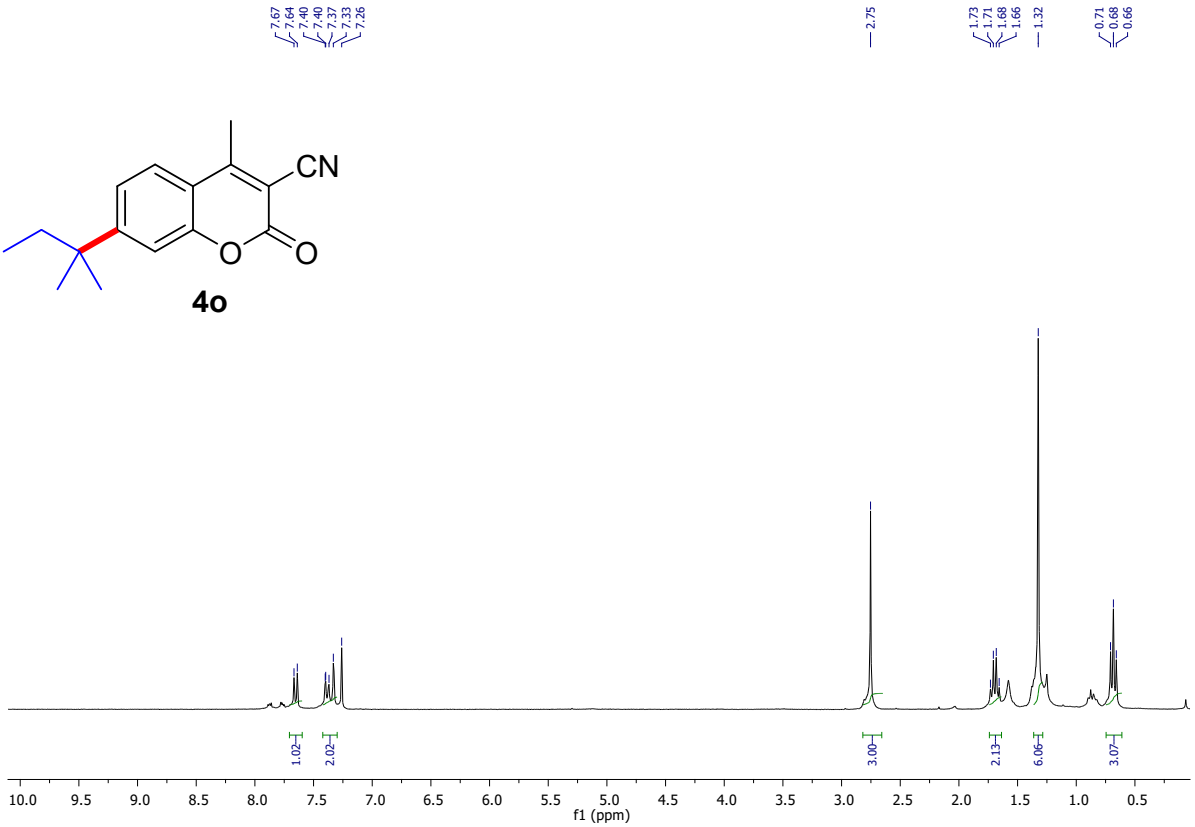
O
O
4m
f1 (ppm)


CN
O
O
4m
f1 (ppm)


CN
O
O
4n
f1 (ppm)


CN
O
O
4n
f1 (ppm)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7.26
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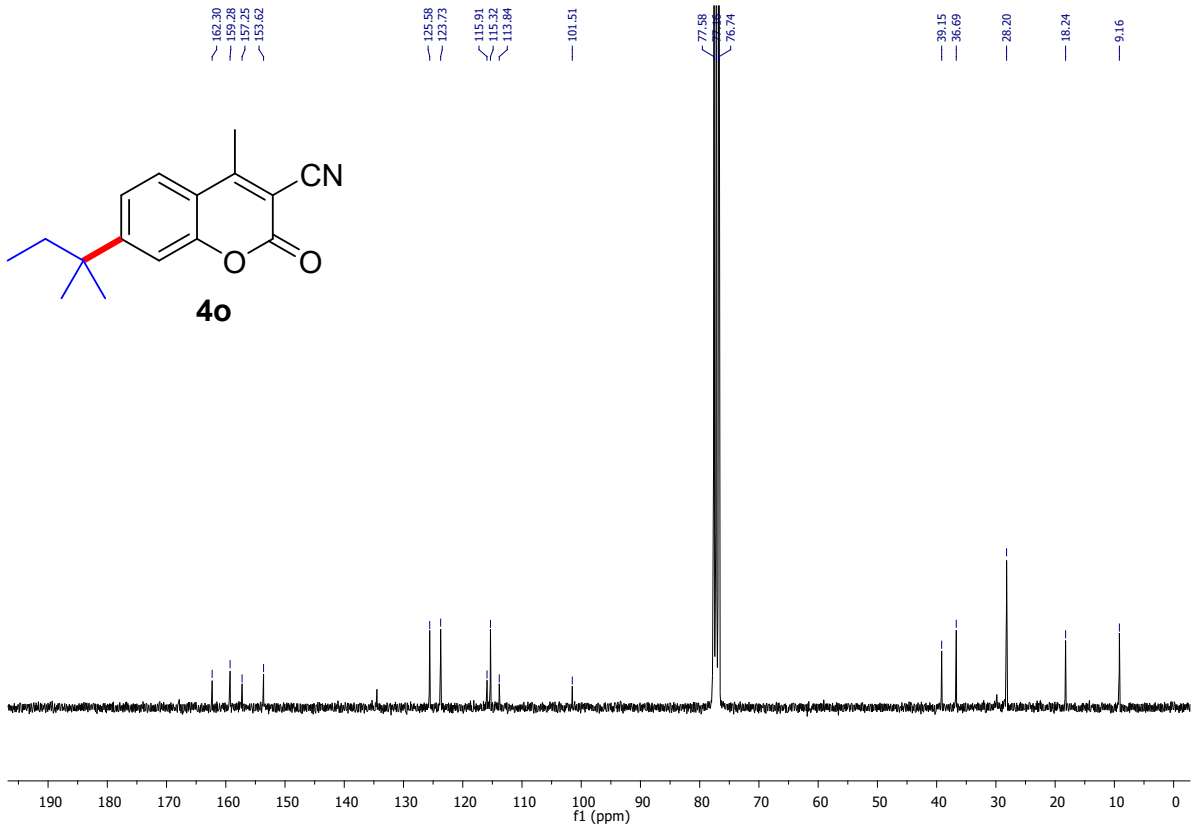
1.68
1.66
1.32
0.71
0.68
0.66
CN
O
O
4o
1.02
2.02
3.00
2.13
6.06
3.07
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)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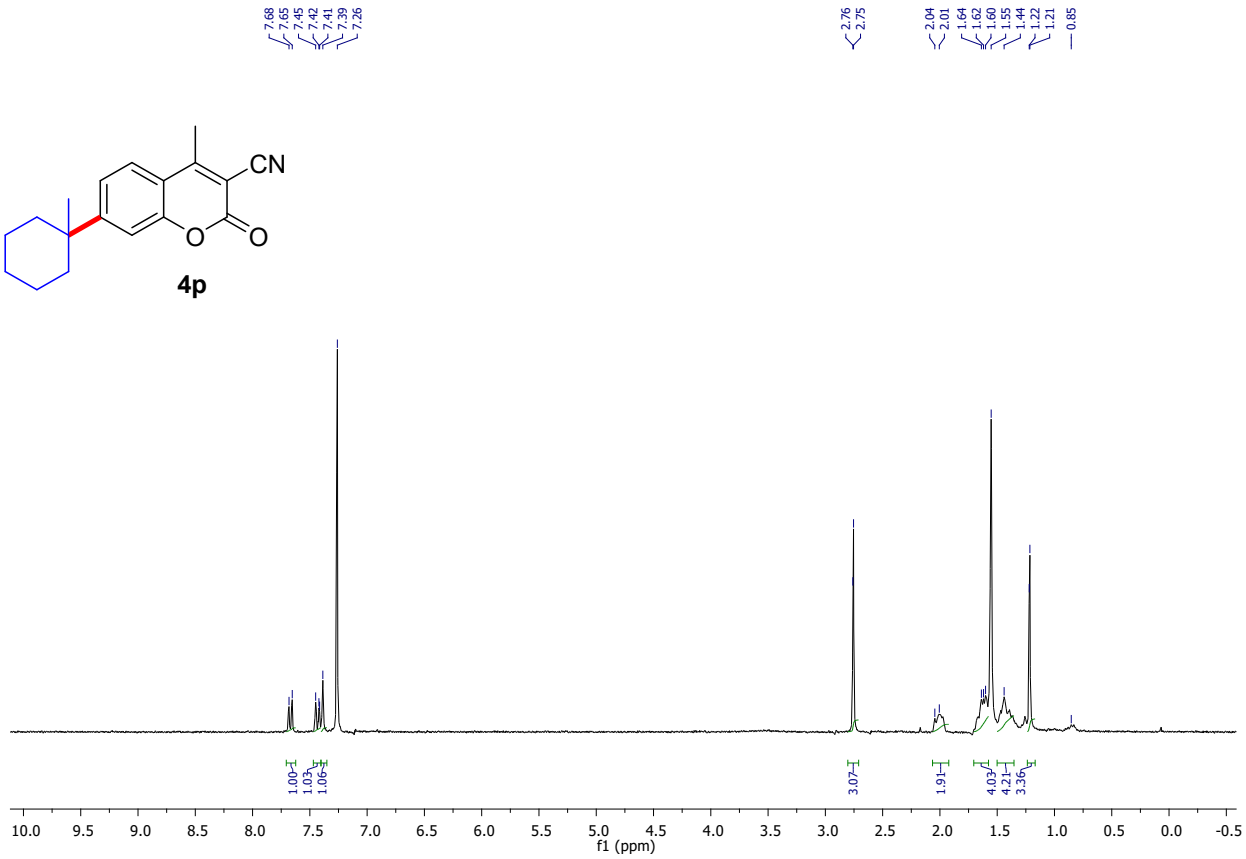
113.84
101.51
77.58
77.32
76.74
39.15
36.69
28.20
18.24
9.16
CN
O
O
4o
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)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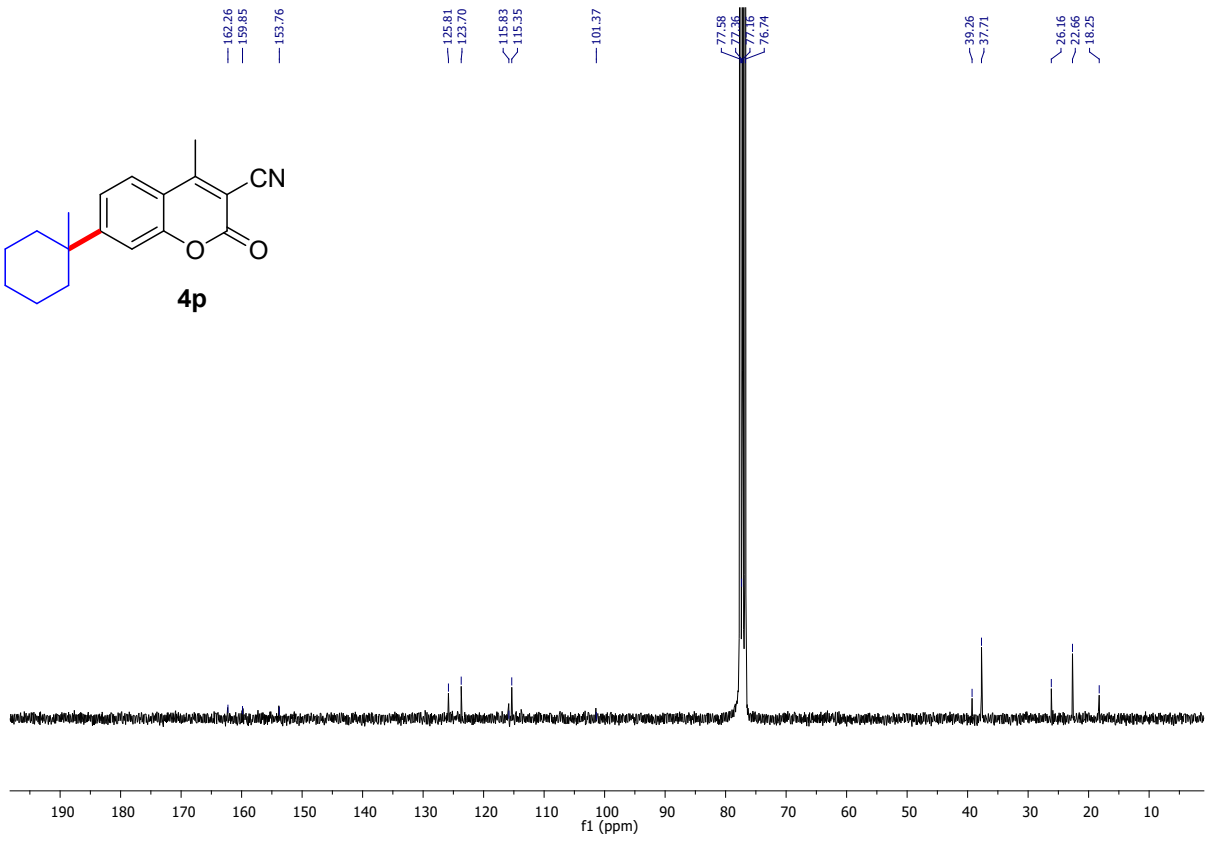
7.39
7.26
2.76
2.75
2.04
2.01
1.64
1.62
1.60
1.55
1.44
1.22
1.21
0.85
CN
O
O
4p
1.00
1.03
1.06
3.07
1.91
4.03
4.21
3.36
f1 (ppm)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101.37
77.58
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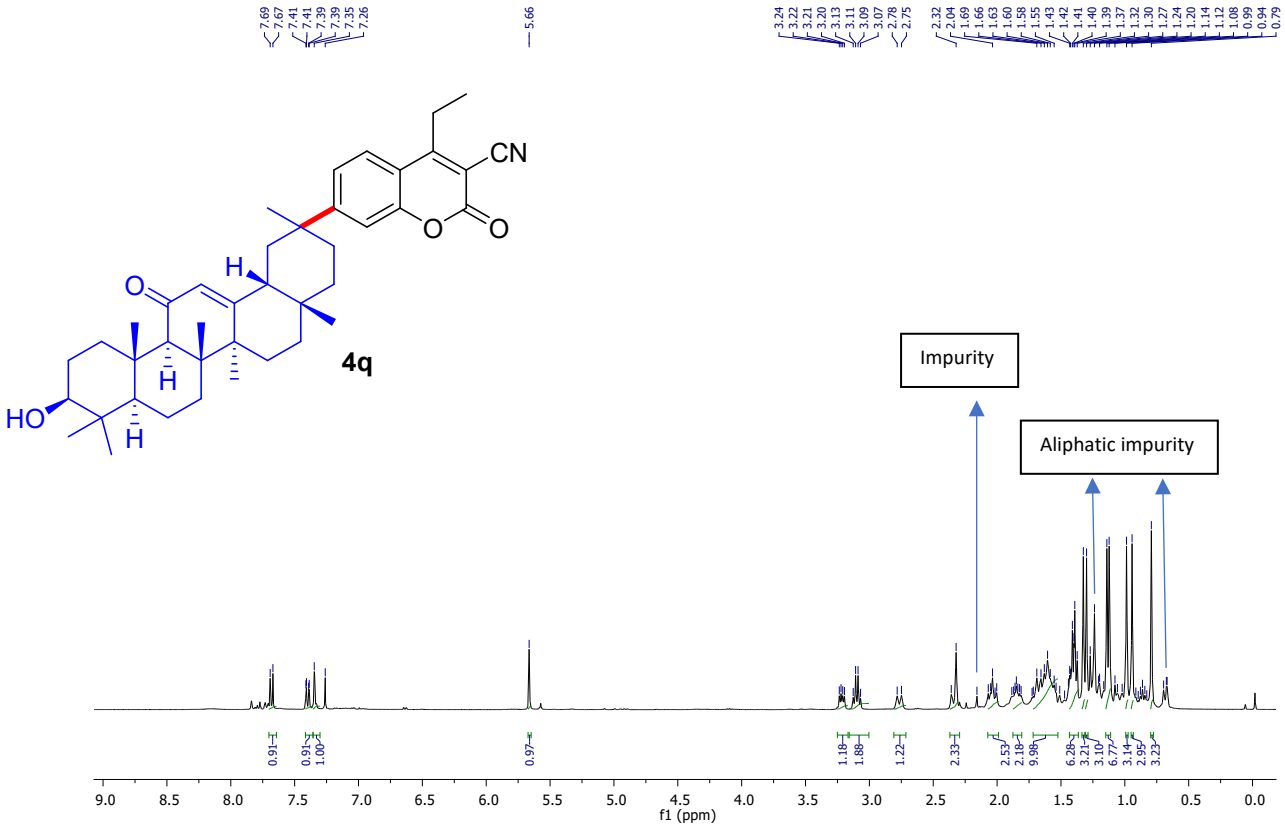
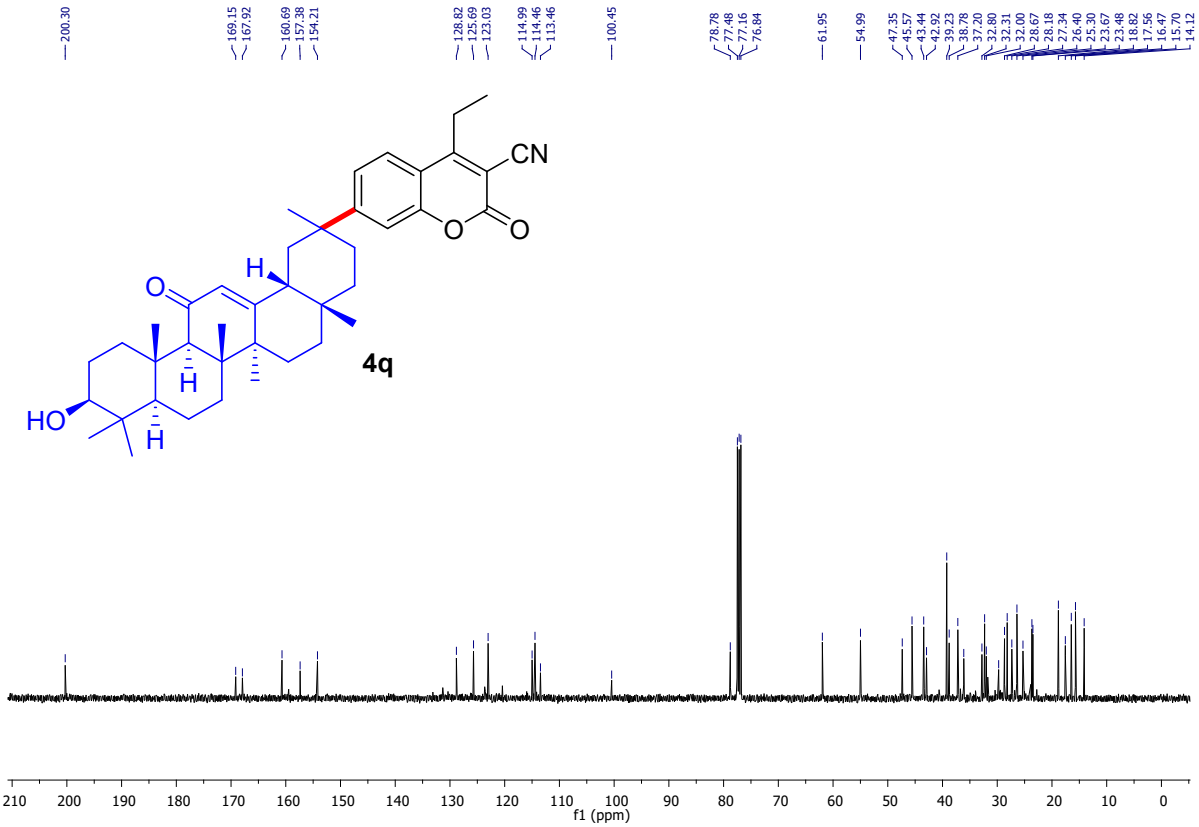
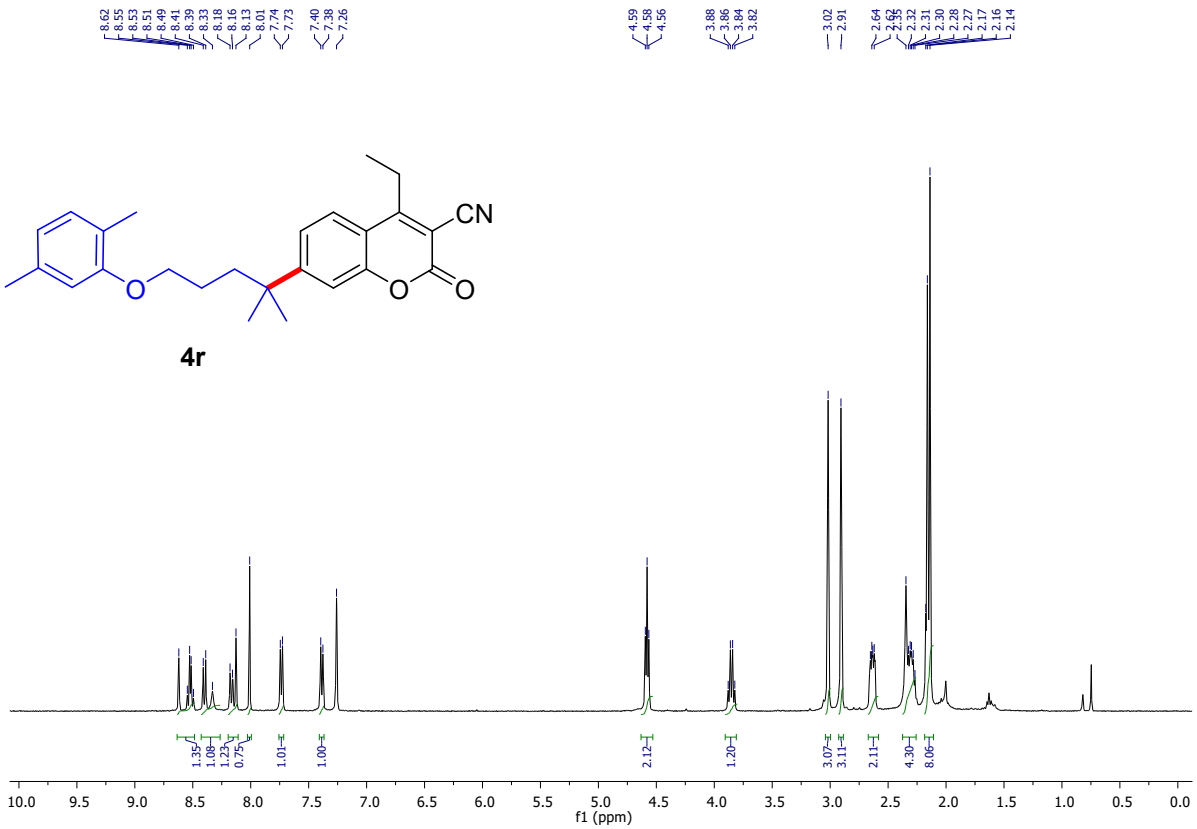
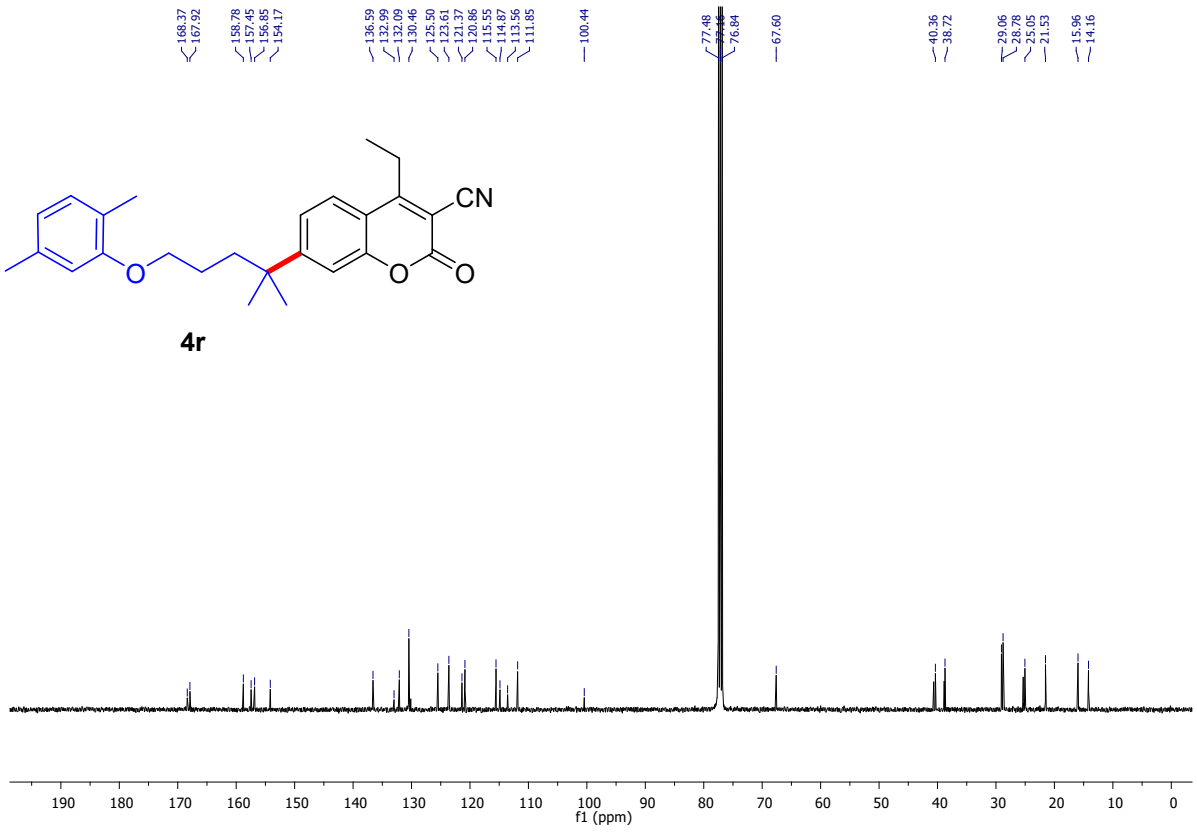
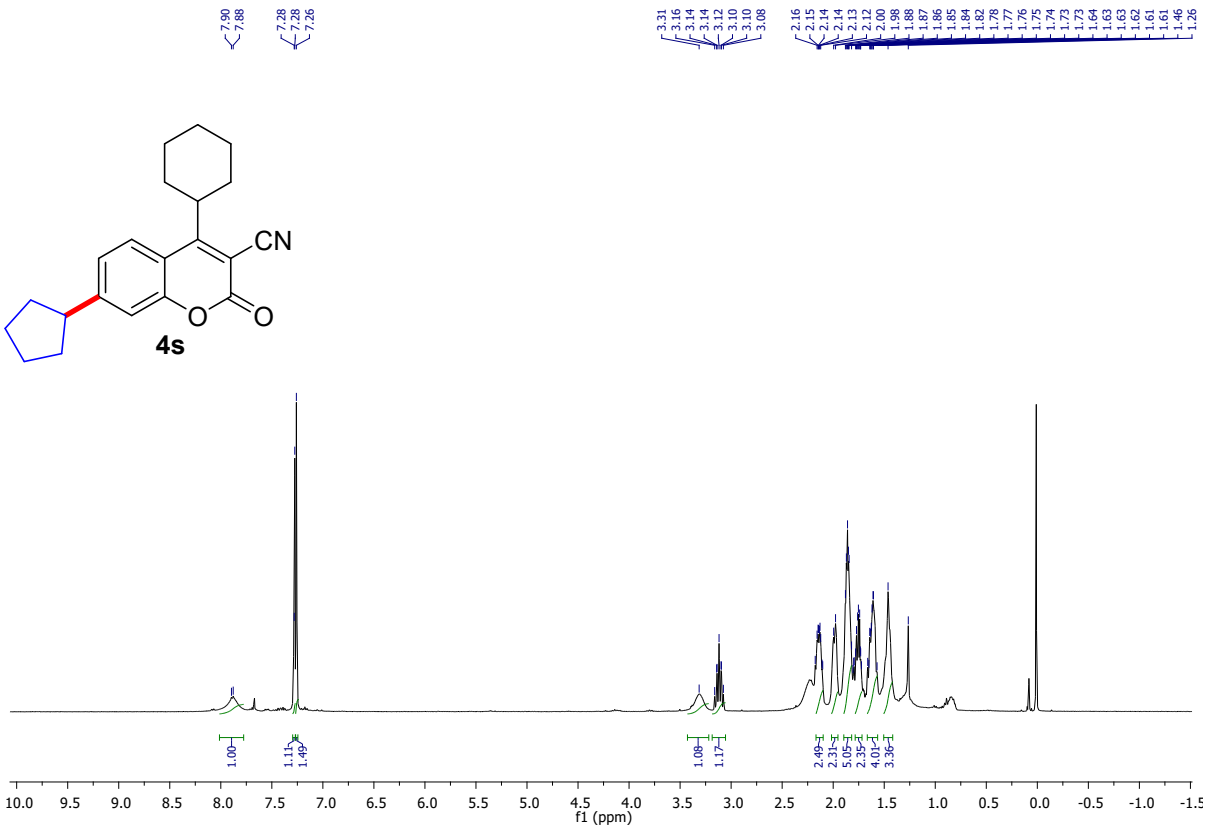
77.16
76.74
39.26
37.71
26.16
22.66
18.25
CN
O
O
4p
f1 (ppm)

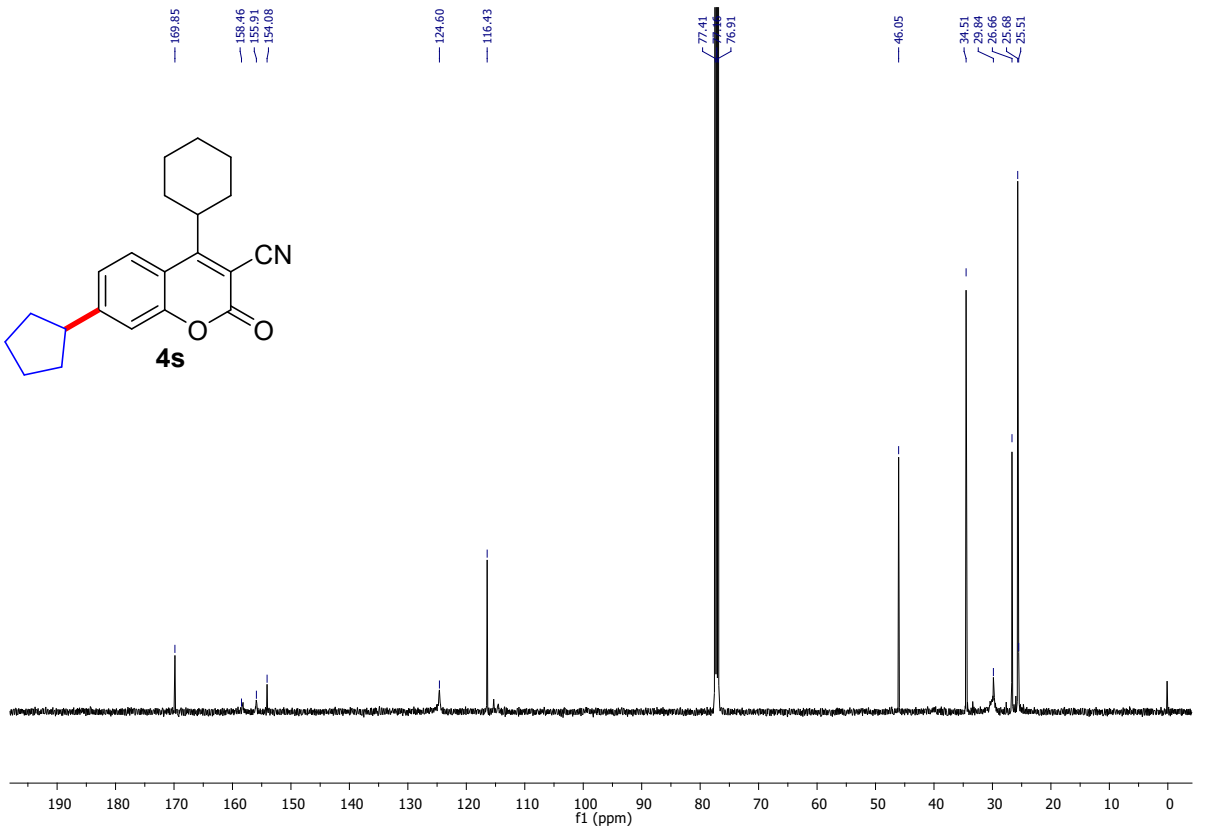

CN
O
O
H
O
H
HO
H
4q
Impurity
Aliphatic impurity
f1 (ppm)

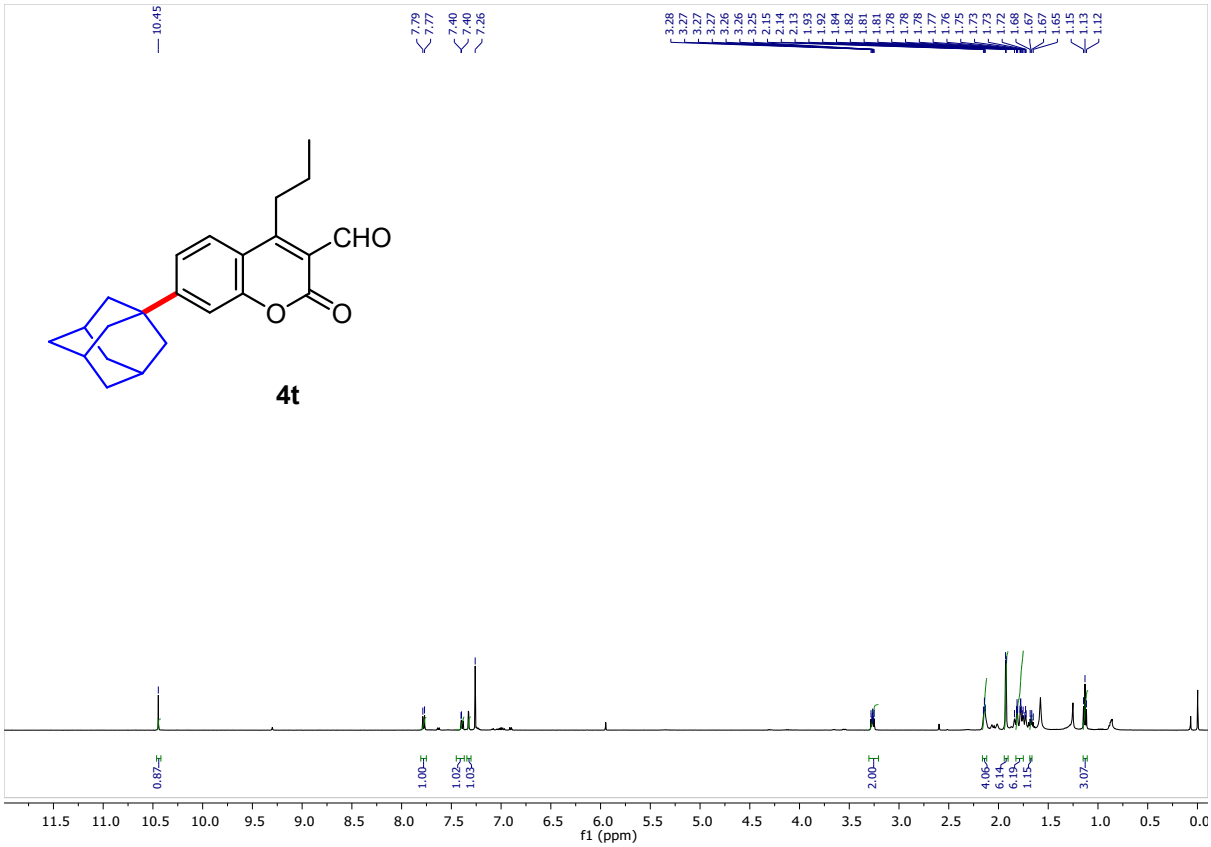

CN
O
O
H
O
H
HO
H
4q
f1 (ppm)

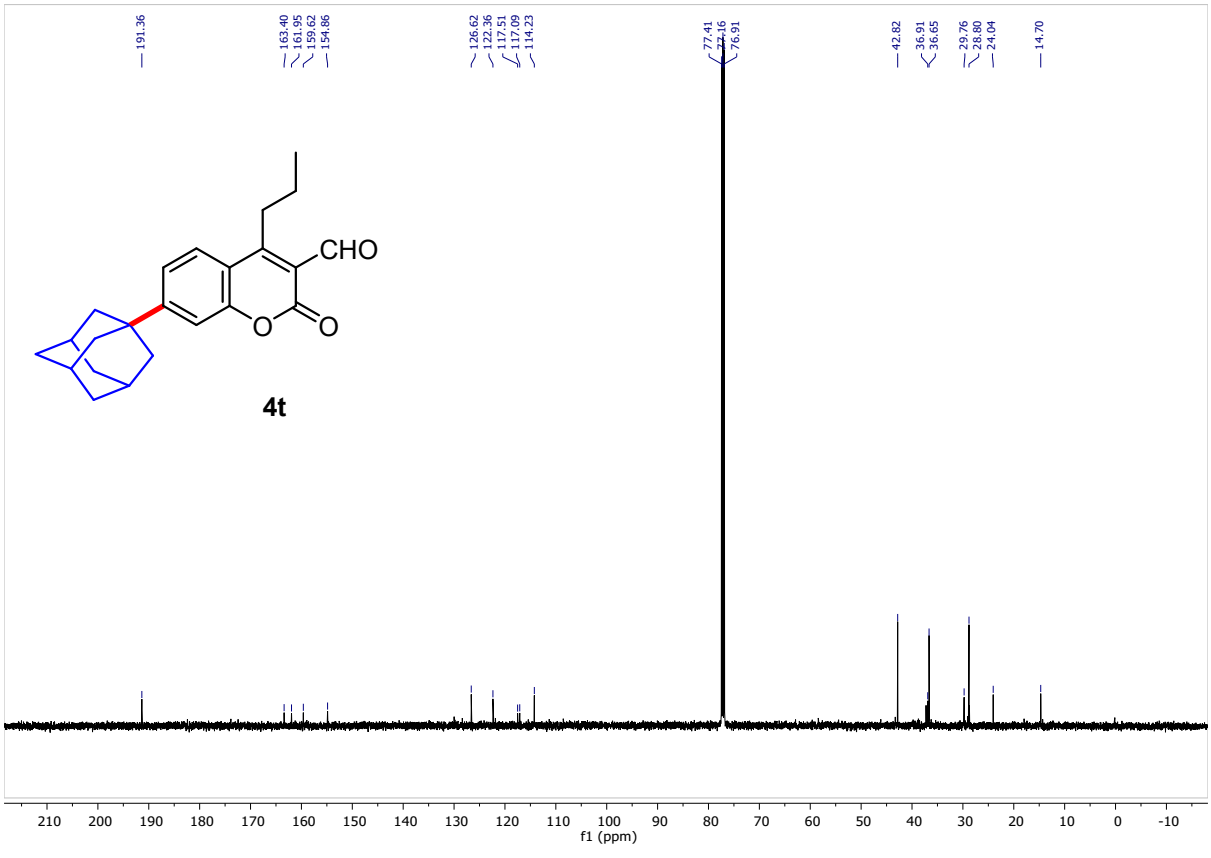

CN
O
O
O
4r
f1 (ppm)

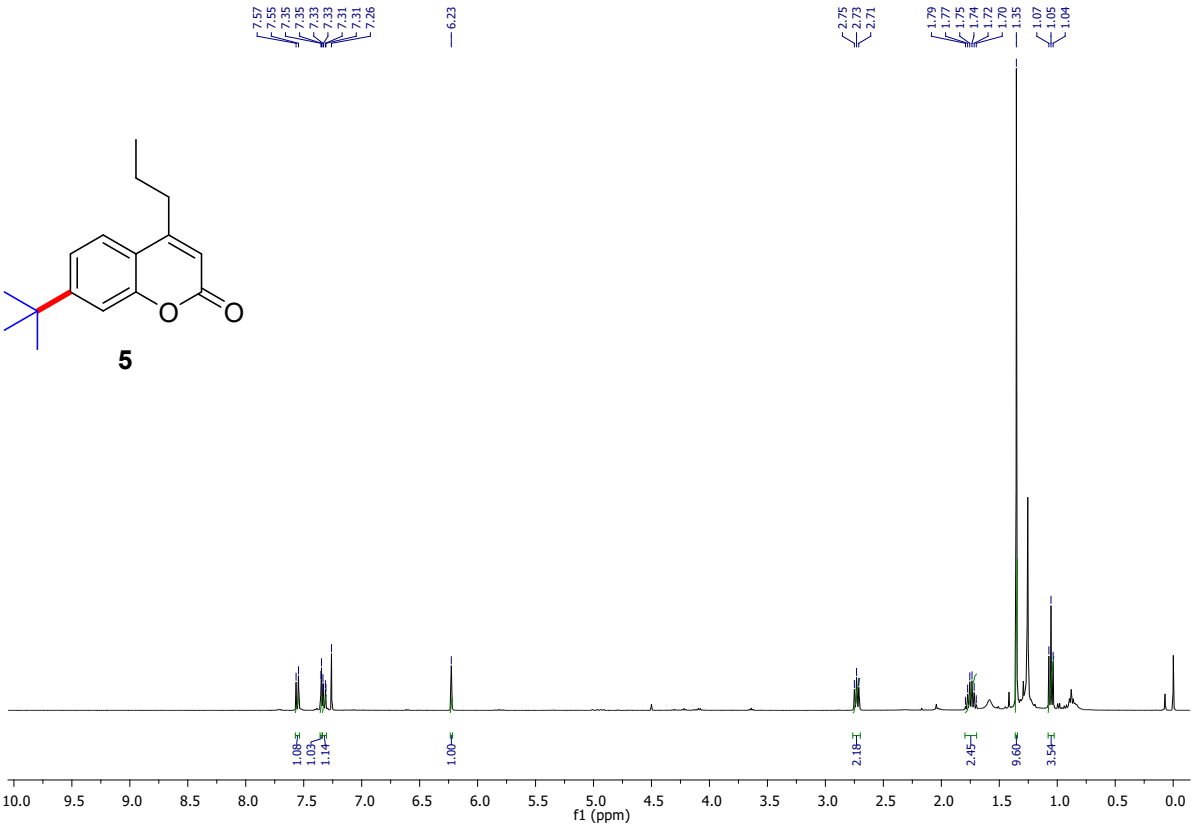

CN
O
O
O
4r
f1 (ppm)


7.90
7.88
7.28
7.28
7.26
3.31
3.16
3.14
3.14
3.12
3.10
3.10
3.08
2.16
2.15
2.14
2.14
2.13
2.12
2.00
1.98
1.88
1.87
1.86
1.85
1.84
1.82
1.78
1.77
1.76
1.75
1.74
1.73
1.73
1.64
1.63
1.63
1.62
1.61
1.61
1.46
1.26
CN
O
O
4s
1.00
1.11
1.49
1.08
1.17
2.49
2.31
5.05
2.35
4.01
3.36
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
-1.0
f1 (ppm)

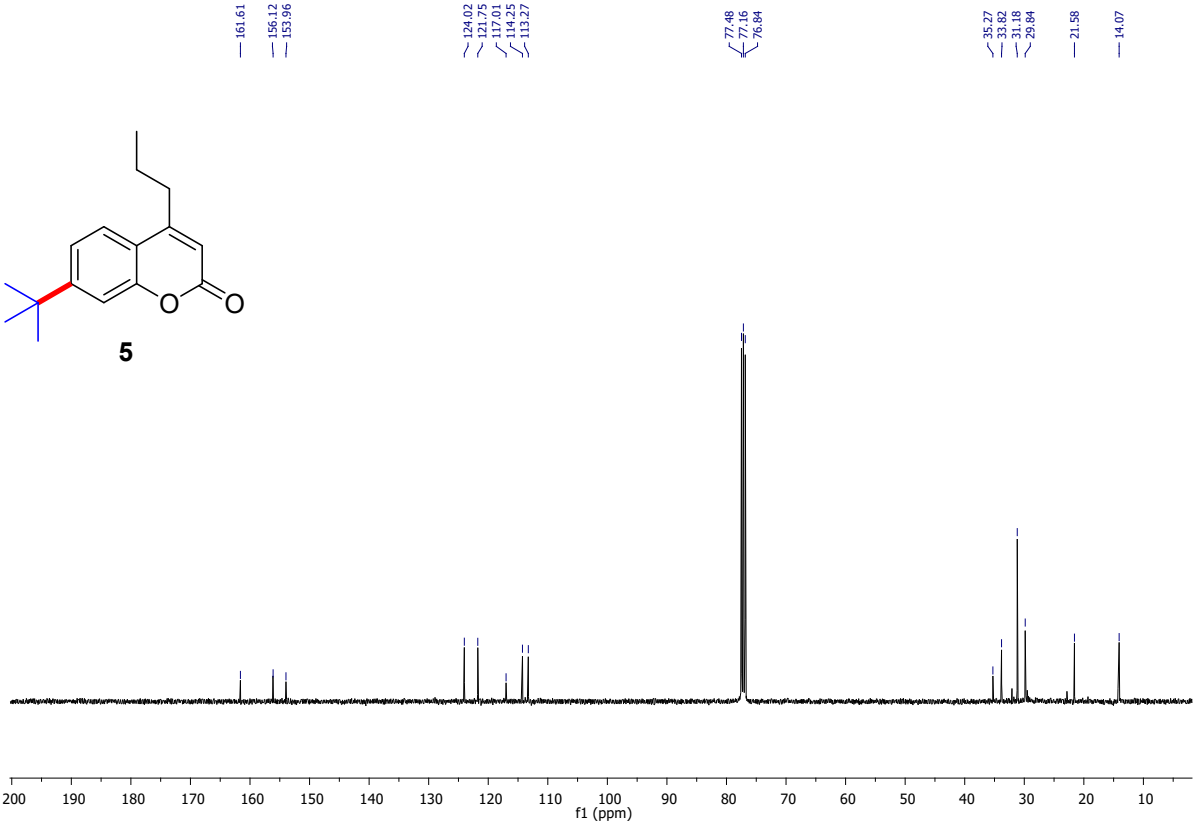

169.85
158.46
155.91
154.08
124.60
116.43
77.41
77.16
76.91
46.05
34.51
29.84
26.66
25.68
25.51
CN
O
O
4s
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


10.45
7.79
7.77
7.40
7.40
7.26
3.28
3.27
3.27
3.27
3.27
3.26
3.26
3.25
2.15
2.14
2.13
1.93
1.92
1.84
1.82
1.81
1.81
1.78
1.78
1.78
1.77
1.76
1.75
1.73
1.72
1.68
1.67
1.67
1.65
1.15
1.13
1.12
CHO
O
O
4t
0.87
1.00
1.02
1.03
2.00
4.06
6.14
6.19
1.15
3.07
f1 (ppm)

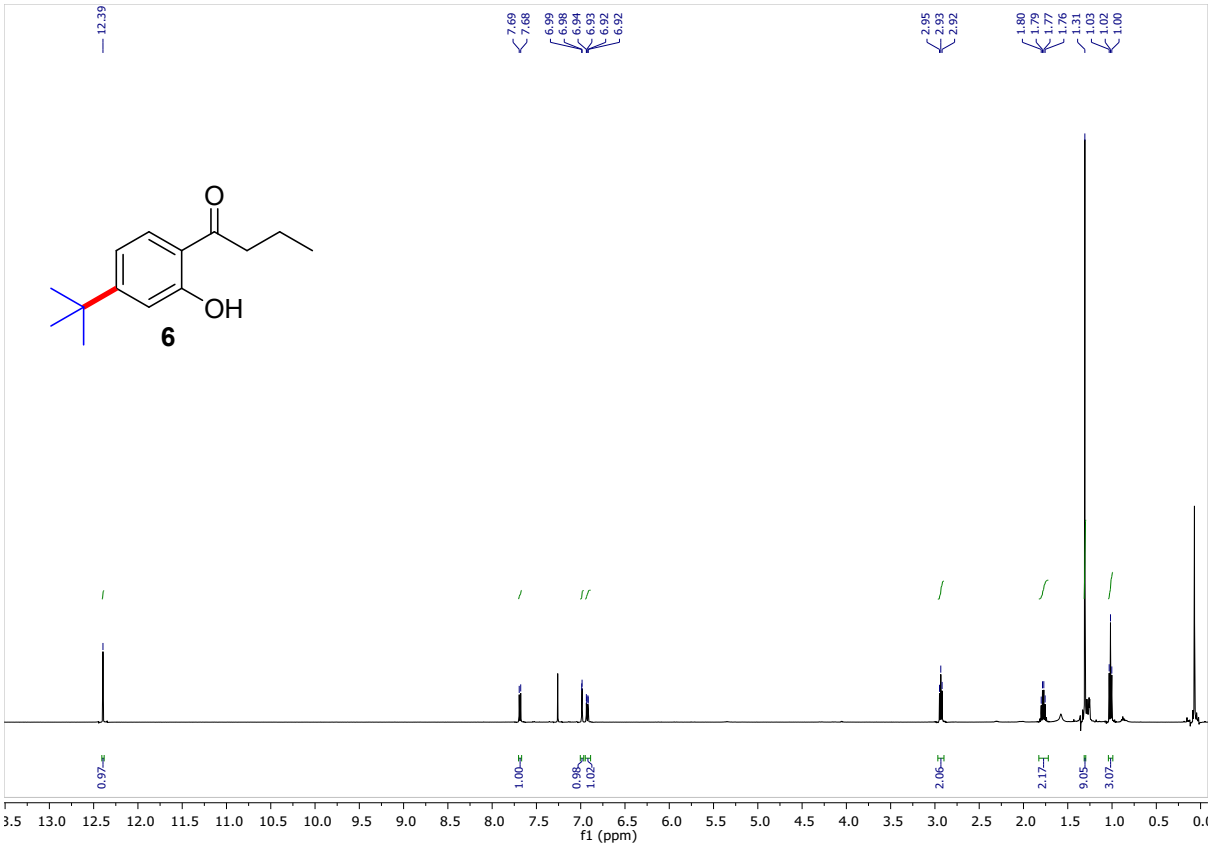

191.36
163.40
161.95
159.62
154.86
126.62
122.36
117.51
117.09
114.23
77.41
77.16
76.91
42.82
36.91
36.65
29.76
28.80
24.04
14.70
CHO
O
O
4t
f1 (ppm)

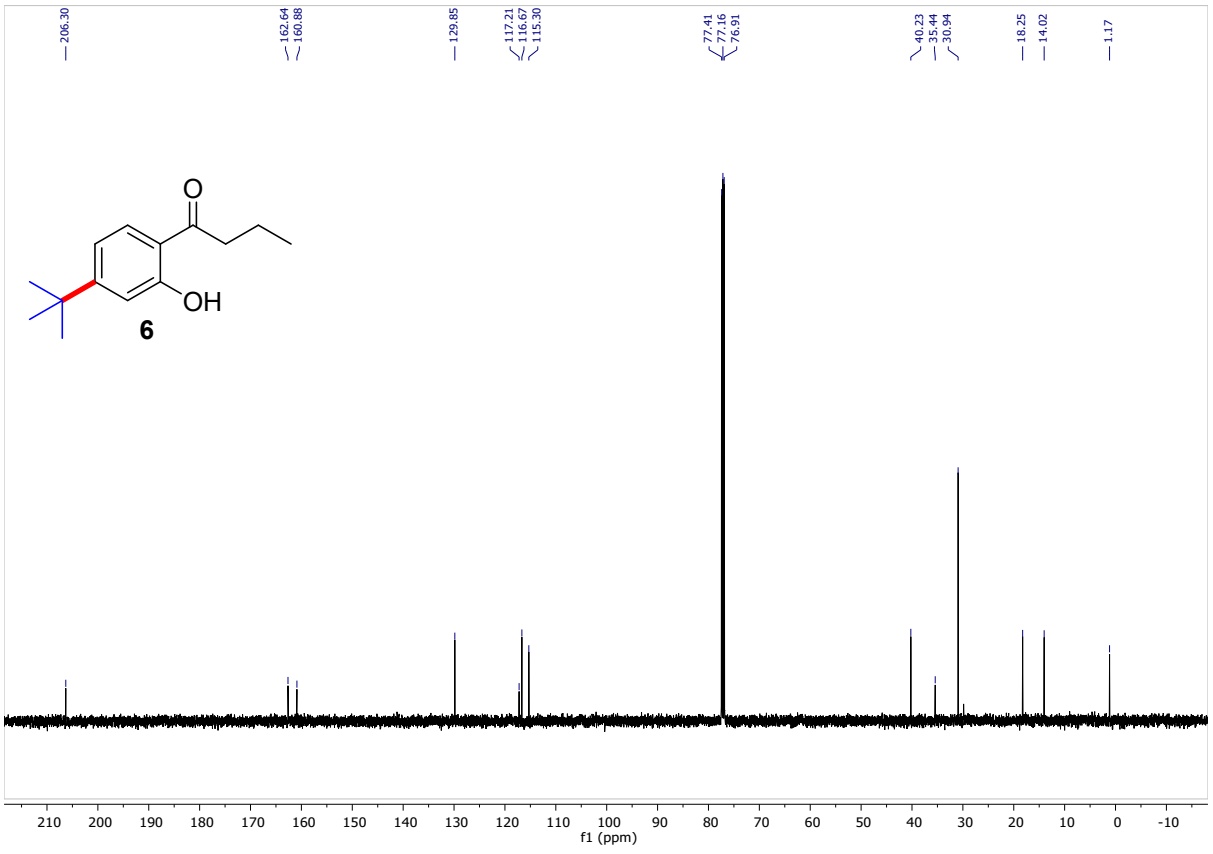

7.57
7.55
7.35
7.35
7.33
7.33
7.31
7.31
7.26
6.23
2.75
2.73
2.71
1.79
1.77
1.75
1.74
1.72
1.70
1.35
1.07
1.05
1.04
1.08
1.03
1.14
1.00
2.18
2.45
9.60
3.54
f1 (ppm)

5


161.61
156.12
153.96
124.02
121.75
117.01
114.25
113.27
77.48
77.16
76.84
35.27
33.82
31.18
29.84
21.58
14.07
f1 (ppm)

5


12.39
7.69
7.68
6.99
6.98
6.94
6.93
6.92
6.92
2.95
2.93
2.92
1.80
1.79
1.77
1.76
1.31
1.03
1.02
1.00
O
OH
6
0.97
1.00
0.98
1.02
2.06
2.17
9.05
3.07
f1 (ppm)


206.30
162.64
160.88
129.85
117.21
116.67
115.30
77.41
77.16
76.91
40.23
35.44
30.94
18.25
14.02
1.17
O
OH
6
f1 (ppm)