Synthesis of 4*H*-chromenes by an unexpected, K_3PO_4-mediated intramolecular Rauhut-Currier type reaction

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Supporting Information

1. General Information

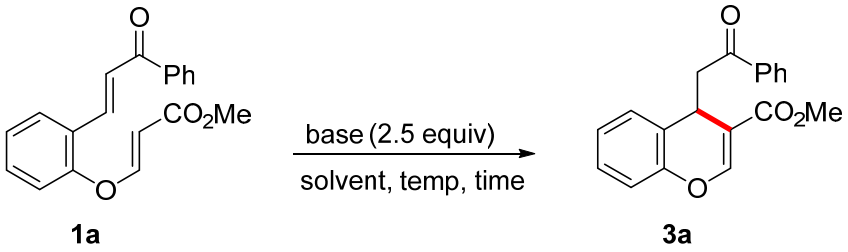
Unless otherwise specified, all reactions were carried out under an atmosphere of argon in flame-dried reaction vessels with Teflon screw caps. Reaction temperatures are reported as the temperature of the bath surrounding the reaction vessel. 25 °C corresponds to the room temperature of the lab when the experiments were carried out. THF was freshly purified by distillation over Na-benzophenone and was transferred under argon. The enone-enoate **1a** and the other enone-enoate derivatives were synthesized following literature procedure.[1] Salicylaldehyde and acetophenone derivatives were purchased from commercial source and used directly without any further purification. K_3PO_4 was purchased from Sigma Aldrich and was stored in glovebox.

Analytical thin layer chromatography was performed on TLC Silica gel 60 F_{254}. Visualization was accomplished with short wave UV light or KMnO4 staining solutions followed by heating. Flash chromatography was performed on silica gel (230-400 mesh) by standard techniques eluting with solvents as indicated.

All compounds were fully characterized. ^{1}H and ^{13}C NMR spectra were recorded on Bruker AV 400, AV 500 in solvents as indicated. Chemical shifts (δ) are given in ppm. The residual solvent signals were used as references and the chemical shifts converted to the TMS scale ($CDCl_3$: δH = 7.26 ppm, δC = 77.16 ppm). Infrared spectra were recorded on a Bruker Alpha-E Infrared Spectrophotometer. The wave numbers (n) of recorded IR-signals are quoted in cm^{-1}. HRMS mass spectra were recorded on a Thermo Scientific Q-Exactive, Accela 1250 pump.

[1] Z.-X. Jia, Y.-C. Luo, X.-N. Cheng, P.-F. Xu and Y.-C. Gu, *J. Org. Chem*., 2013, **78**, 6488.

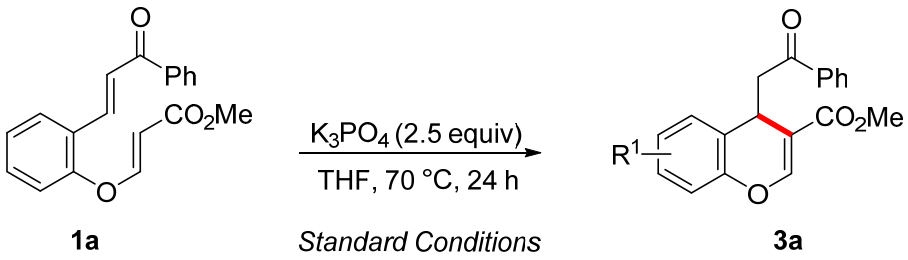
2. General Procedure for the Optimization of Reaction Conditions



1a **3a**

To a flame-dried screw-capped test tube equipped with a magnetic stir bar was charged with base (0.625 mmol). To this was added the methyl (*E*)-3-(2-((*E*)-3-oxo-3-phenylprop-1-en-1-yl)phenoxy)acrylate **1a** (0.25 mmol) outside the glovebox followed by addition of solvent (2.0 mL) under a positive pressure of argon, and the reaction mixture was placed in a preheated oil bath at the indicated temperature for the indicated time. Then the reaction mixture was diluted with CH_2Cl_2 (2.0 mL) and filtered through a short pad of silica gel and eluted with CH_2Cl_2 (10 mL). The solvent was evaporated to obtain the crude product, which was analyzed using ^1H NMR using CH_2Br_2 (18.0 µL, 0.25 mmol) as the internal standard.

3. Optimization Studies



1a *Standard Conditions* **3a**

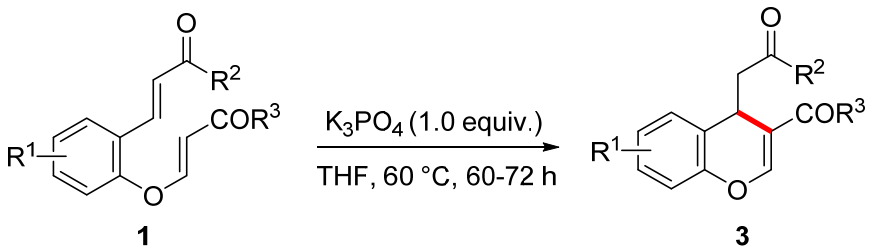
We started off with the treatment of methyl (*E*)-3-(2-((*E*)-3-oxo-3-phenylprop-1-en-1-yl)phenoxy)acrylate **1a** (0.077 g, 0.25 mmol) with K_3PO_4 at 70 °C in THF resulting in the formation of methyl 4-(2-oxo-2-phenylethyl)-4H-chromene-3-carboxylate **3a** in 50% yield (entry 1). The reaction did not work at all in the absence of K_3PO_4 (entry 2). The conversion of **1a** to **3a** did not take place when the reaction was performed using nucleophilic bases such as DBU and DABCO (entries 3,4). Moreover, **1a** to **3a**

transformation was not effective in the presence of phosphines such as PPh_3 and P*n*-Bu_3 (entries 5,6). These studies indicate that the present cyclization reaction takes place in the absence of nucleophilic catalysts. Other Inorganic bases were not efficient in this intramolecular cyclization to 4*H*-chromemes (entries 7-12). The use of Brønsted acid and Lewis acid was not beneficial in this reaction (entries 13-18). A quick solvent screening indicated that reaction tried in DME returned the 4*H*-chromene in same yield as in THF (entry 19), but the reaction carried out in MeOH did not work at all (entry 20). The reaction was found to be equally efficient at 60 °C (entry 21), but when the temperature was further lowered to 50 °C, the yield of **3a** dropped to 23% (entry 22). Interestingly, reducing the amount of K_3PO_4 at 60 °C improved the yield of **3a** (entry 23), and increasing the reaction time further enhanced the amount of **3a** (entry 24). Finally, performing the reaction at 60 °C using 1.0 equiv K_3PO_4 for 72 h afforded the 4*H*-chromeme **3a** in 88% isolated yield (entry 25).

entry	variation from the standard conditions	yield of **3a** (%)[b]
1	None	50 (48)
2[c]	No K_3PO_4	<5
3[c]	DBU instead of K_3PO_4	<5
4[c]	DABCO instead of K_3PO_4	<5
5[c]	PPh_3 instead of K_3PO_4	<5
6[c]	P*n*-Bu_3 instead of K_3PO_4	<5
7[d]	KO*t*-Bu instead of K_3PO_4	<5
8[d]	NaO*t*-Bu instead of K_3PO_4	<5
9[d]	LiO*t*-Bu instead of K_3PO_4	<5
10[c]	K_2CO_3 instead of K_3PO_4	<5
11	Cs_2CO_3 instead of K_3PO_4	28
12	CsF instead of K_3PO_4	20
13[c]	HCl in dioxane instead of K_3PO_4	<5
14[c]	H_3PO_4 instead of K_3PO_4	<5
15[c]	$Sc(OTf)_3$ instead of K_3PO_4	<5
16[c]	$Sc(OTf)_2$ instead of K_3PO_4	<5
17[c]	$Zn(OTf)_2$ instead of K_3PO_4	<5
18[c]	I_2 instead of K_3PO_4	<5
19	DME instead of THF	50
20[c]	MeOH instead of THF	<5
21	Run at 60 °C	49
22	Run at 50 °C	23
23	60 °C, 1.0 equiv of K_3PO_4	52
24	60 °C, 1.0 equiv of K_3PO_4, 48 h	78
25	60 °C, 1.0 equiv of K_3PO_4, 72 h	92 (88)

[a]Standard conditions: **1a** (0.25 mmol), K_3PO_4 (2.5 equiv), THF (2.0 mL), 70 °C and 24 h. [b]The yields were determined by ^{1}H-NMR analysis (in $CDCl_3$) of crude products using CH_2Br_2 as the internal standard; Isolated yield in parentheses. [c]No reaction was observed and **1a** was recovered. [d]Decomposition of **1a** was observed.

4. General Procedure for the Intramolecular Rauhut-Currier Reaction

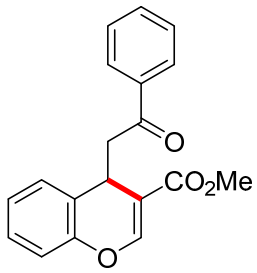


1 **3**

To a flame-dried screw-capped test tube equipped with a magnetic stir bar was charged with K_3PO_4 (0.50 mmol), inside the glovebox. To this was added the enone-enoate **1** (0.50 mmol) outside the glovebox followed by addition of THF (4.0 mL) under a positive pressure of argon, and the reaction mixture was placed in a preheated oil bath at 60 °C for the 60/72 h. When TLC control showed the completion of the reaction (typically after 72 h), the solvent was evaporated and the crude residue purified by flash column chromatography on silica gel to afford the corresponding 4*H*-chromenes **3** in moderate to good yields.

5. Synthesis and Characterization of 4*H*-Chromenes

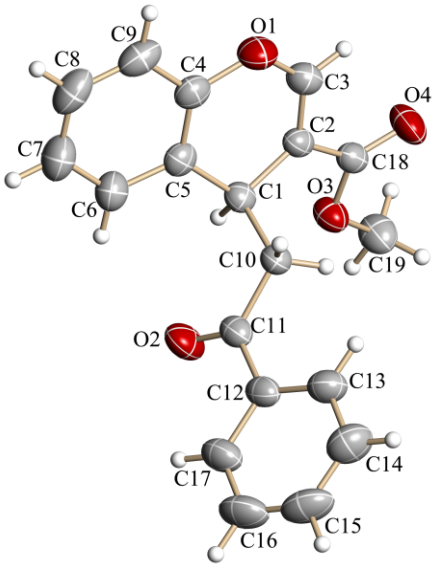
Methyl-4-(2-oxo-2-phenylethyl)-4*H*-chromene-3-carboxylate (3a)



3a

Following the general procedure, treatment of methyl (*E*)-3-(2-((*E*)-3-oxo-3-phenylprop-1-en-1-yl)phenoxy)acrylate **1a** (0.154 g, 0.5 mmol) with anhydrous tribasic potassium phosphate (0.106 g, 0.5 mmol) in THF (4.0 mL) at 60 °C for 72 h followed by flash column chromatography using (Pet. ether/EtOAc = 90/10) of the crude reaction mixture using silica gel afforded methyl-4-(2-oxo-2-phenylethyl)-4*H*-chromene-3-carboxylate as white solid **3a** (0.135 g, 88% yield).

***R*f** (Pet. ether /EtOAc = 80/20): 0.56; Melting point: 97-99 °C; **^{1}H NMR (400 MHz, CDCl$_3$)** δ 7.93– 7.91 (m, 2H), 7.74 (s, 1H), 7.54– 7.50 (m, 1H), 7.44 – 7.40 (m, 2H), 7.21 (dd, J_1 = 1.5 Hz, J_2 = 7.6 Hz, 1H), 7.15 (td, J_1 = 1.6 Hz, J_2 = 7.8 Hz, 1H), 7.04 – 6.98 (m, 2H), 4.53 (dd, J_1 = 4.1 Hz, J_2 = 7.0 Hz, 1H), 3.74 (s, 3H), 3.40 – 3.29 (m, 2H). **^{13}C NMR (100 MHz, CDCl$_3$)** δ 197.98, 166.94, 152.04, 150.14, 137.03, 133.14, 129.30, 128.65, 128.27, 128.05, 125.00, 123.96, 116.60, 109.24, 51.65, 47.49, 29.82. **HRMS (ESI)** calculated $[M+Na]^+$ for $C_{19}H_{16}O_4Na$: 331.0941, found: 331.0953. **FTIR (cm^{-1})** 2922, 2855, 1705, 1650, 1586, 1487, 1446, 1389, 1294, 1230, 1195, 1088, 1035, 914, 828, 759, 691. **CCDC 1451380** This data can be obtained free of charge from the Cambridge Crystallographic Data Centre via www.ccdc.cam.ac.uk/data_request/cif.

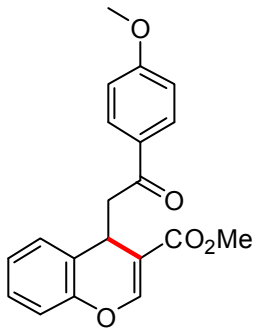


X-ray intensity data measurements of compound **3a** was carried out on a Bruker SMART APEX II CCD diffractometer with graphite-monochromatized (MoK_α= 0.71073Å) radiation. The X-ray generator was operated at 50 kV and 30 mA. A preliminary set of cell constants and an orientation matrix were calculated from three sets of 36 frames. Data were collected with ω scan width of 0.5° at different settings of φ and 2θ with a frame time of 10 sec for **3a** keeping the sample-to-detector distance fixed at 5.00 cm. The X-ray data collection was monitored by

APEX2 program (Bruker, 2006).[2] All the data were corrected for Lorentzian, polarization and absorption effects using SAINT and SADABS programs (Bruker, 2006). SHELX-97 was used for structure solution and full matrix least-squares refinement on F^2.[3] All the hydrogen atoms were placed in geometrically idealized position and constrained to ride on their parent atoms except metyl H-taoms of **3a** which were located in difference Fourier and refined isotropically. An *ORTEP* III[4] view of both compounds were drawn with 50% probability displacement ellipsoids and H atoms are shown as small spheres of arbitrary radii.

Crystal data of **3a** $C_{19}H_{16}O_4$, M = 308.32, colorless block, 0.42 x 0.31 x 0.21 mm^3, monoclinic, space group $P2_1/n$, a = 14.6923(14) Å, b = 5.7956(6) Å, c = 18.3537(17) Å, β = 103.638(7)°, V = 1518.8(3) $Å^3$, Z = 4, T = 296(2) K, $2\theta_{max}$ = 50.00°, D_{calc} (g cm^{-3}) = 1.348, $F(000)$ = 648, μ (mm^{-1}) = 0.094, 8929 reflections collected, 2627 unique reflections (R_{int}=0.0503), 1888 observed ($I > 2\sigma(I)$) reflections, multi-scan absorption correction, T_{min} = 0.961, T_{max} = 0.980, 209 refined parameters, S = 1.056, $R1$ = 0.0462, $wR2$ = 0.1054 (all data R = 0.0697, $wR2$ = 0.1180), maximum and minimum residual electron densities; $\Delta\rho_{max}$ = 0.126, $\Delta\rho_{min}$= -0.192 ($eÅ^{-3}$).

Methyl 4-(2-(4-methoxyphenyl)-2-oxoethyl)-4*H*-chromene-3-carboxylate (3b)



3b

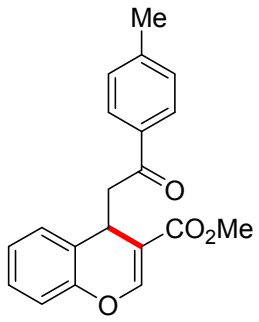
Following the general procedure, treatment of methyl (*E*)-3-(2-((*E*)-3-(4-methoxyphenyl)-3-oxoprop-1-en-1-yl)phenoxy)acrylate **1b** (0.169 g, 0.5 mmol) with anhydrous tribasic potassium phosphate (0.106 g, 0.5 mmol) in THF (4.0 mL) at 60 °C for 72 h followed by flash column chromatography using (Pet. ether/EtOAc = 90/10) of the crude reaction mixture using silica gel afforded methyl 4-(2-(4-methoxyphenyl)-2-oxoethyl)-4*H*-chromene-3-carboxylate as white solid **3b** (0.124 g, 73% yield).

***R*f** (Pet. ether /EtOAc = 80/20): 0.41; Melting point: 96-98 °C; **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.973– 7.9 (m, 2H), 7.74 (s, 1H), 7.169-7.13(m, 2H), 7.03 – 6.97 (m, 2H), 6.91 – 6.89 (m, 2H), 4.50 (dd, J_1 = 3.6 Hz, J_2 = 7.7 Hz, 1H), 3.85 (s, 3H), 3.75 (s, 3H), 3.28 (dd, J_1 = 5.7 Hz, J_2 = 18.1

[2] Bruker (2006). *APEX2*, *SAINT* and *SADABS*. Bruker AXS Inc., Madison, Wisconsin, USA.
[3] G. M. Sheldrick, *Acta Crystallogr*., 2008, **A64**, 112.
[4] L. J. Farrugia, *J. Appl. Cryst.,* 1997, **30**, 565.

Hz, 2H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 196.61, 167.05, 163.57, 152.04, 150.15, 130.64, 130.19, 129.38, 128.04, 124.99, 124.04, 116.60, 113.82, 109.40, 55.58, 51.71, 47.29, 30.08. **HRMS (ESI)** calculated $[M+Na]^+$ for $C_{20}H_{18}O_5Na$: 361.1046, found: 361.1043. **FTIR (cm^{-1})** 3017, 2952, 2844, 1708, 1662, 1593, 1449, 1299, 1227, 1180, 1091, 1032, 982, 833, 758.

Methyl-4-(2-oxo-2-(*p*-tolyl)ethyl)-4*H*-chromene-3-carboxylate (3c)

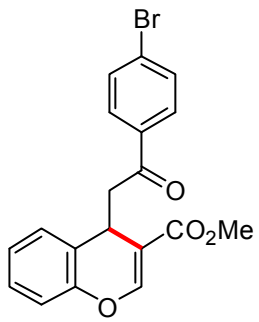


3c

Following the general procedure, treatment of methyl (*E*)-3-(2-((*E*)-3-oxo-3-(*p*-tolyl)prop-1-en-1-yl)phenoxy)acrylate **1c** (0.161 g, 0.5 mmol) with anhydrous tribasic potassium phosphate (0.106 g, 0.5 mmol) in THF (4.0 mL) at 60 °C for 72 h followed by flash column chromatography using (Pet. ether/EtOAc = 90/10) of the crude reaction mixture using silica gel afforded methyl-4-(2-oxo-2-(*p*-tolyl)ethyl)-4*H*-chromene-3-carboxylate as white solid **3c** (0.110 g, 68% yield).

***R*$_f$** (Pet. ether /EtOAc = 80/20): 0.45; Melting point: 104-106 °C; **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.84 (d, J = 8.0 Hz, 2H), 7.76 (s, 1H), 7.24 – 7.15 (m, 4H), 7.02 (dd, J_1 = 14.5 Hz, J_2 = 7.7 Hz, 2H), 4.54 (dd, J_1 = 7.1 Hz, J_2 = 3.8 Hz, 1H), 3.76 (s, 3H), 3.38 – 3.27 (m, 2H), 2.40 (s, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 197.60, 166.93, 151.97, 150.12, 143.90, 134.59, 129.31, 128.39, 127.99, 124.95, 124.03, 116.56, 109.34, 51.62, 47.45, 29.87, 21.68. **HRMS (ESI)** calculated $[M+Na]^+$ for $C_{20}H_{18}O_4Na$: 345.1097, found: 345.1090. **FTIR (cm^{-1})** 3349, 3022, 2954, 2402, 1918, 1708, 1610, 1487, 1447, 1397, 1294, 1230, 1194, 1092, 1045, 983, 917, 758, 667, 624.

Methyl 4-(2-(4-bromophenyl)-2-oxoethyl)-4*H*-chromene-3-carboxylate (3d)

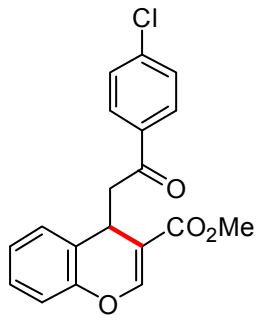


3d

Following the general procedure, treatment of methyl (*E*)-3-(2-((*E*)-3-(4-bromophenyl)-3-oxoprop-1-en-1-yl)phenoxy)acrylate **1d** (0.193 g, 0.5 mmol) with anhydrous tribasic potassium phosphate (0.106 g, 0.5 mmol) in THF (4.0 mL) at 60 °C for 72 h followed by flash column chromatography using (Pet. ether/EtOAc = 90/10) of the crude reaction mixture using silica gel afforded methyl 4-(2-(4-bromophenyl)-2-oxoethyl)-4*H*-chromene-3-carboxylate as white solid **3d** (0.130 g, 67% yield).

***R*f** (Pet. ether /EtOAc = 80/20): 0.52; Melting point: 80-82 °C; **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.78 – 7.75 (m, 2H), 7.73 (s, 1H), 7.54 (d, J = 8.6 Hz, 2H), 7.15 (t, J = 7.1 Hz, 2H), 7.03– 6.97 (m, 2H), 4.47 (dd, J_1 = 3.9 Hz, J_2 = 7.2, 1H), 3.74 (s, 3H), 3.29 (qd, J_1 = 5.6 Hz, J_2 = 16.3, 2H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 197.08, 166.92, 152.11, 150.07, 135.65, 131.93, 129.81, 129.16, 128.34, 128.16, 125.04, 123.65, 116.65, 108.96, 51.71, 47.31, 29.89. **HRMS (ESI)** calculated $[M+Na]^+$ for $C_{19}H_{15}O_4BrNa$: 409.0046, found: 409.0041. **FTIR (cm^{-1})** 2998, 2952, 1704, 1649, 1580, 1485, 1446, 1394, 1295, 1232, 1083, 999, 825, 752.

Methyl 4-(2-(4-chlorophenyl)-2-oxoethyl)-4*H*-chromene-3-carboxylate (3e)

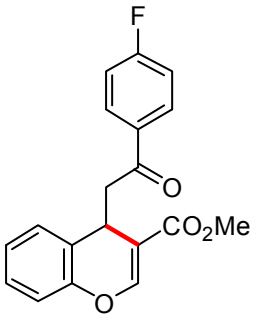


3e

Following the general procedure, treatment of methyl (*E*)-3-(2-((*E*)-3-(4-chlorophenyl)-3-oxoprop-1-en-1-yl)phenoxy)acrylate **1e** (0.171 g, 0.5 mmol) with anhydrous tribasic potassium phosphate (0.106 g, 0.5 mmol) in THF (4.0 mL) at 60 °C for 72 h followed by flash column chromatography using (Pet. ether/EtOAc = 90/10) of the crude reaction mixture using silica gel afforded methyl 4-(2-(4-chlorophenyl)-2-oxoethyl)-4*H*-chromene-3-carboxylate as white solid **3e** (0.103 g, 60% yield).

***R*f** (Pet. ether /EtOAc = 80/20): 0.56; Melting point: 100-102 °C; **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.85 (d, J = 8.2 Hz, 2H), 7.73 (s, 1H), 7.38 (d, J = 8.2 Hz, 2H), 7.16 (t, J = 7.8 Hz, 2H), 7.00 (dd, J_1 = 8.0 Hz, J_2 = 17.2 Hz, 2H), 4.48 (dd, J_1 = 3.8 Hz, J_2 = 7.2 Hz, 1H), 3.74 (s, 3H), 3.30 (qd, J_1 = 5.6 Hz, J_2 = 16.2 Hz, 2H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 196.85, 166.90, 152.09, 150.09, 139.58, 135.28, 129.71, 129.18, 128.94, 128.15, 125.03, 123.68, 116.65, 109.00, 51.70, 47.35, 29.91. **HRMS (ESI)** calculated $[M+Na]^+$ for $C_{19}H_{15}O_4ClNa$: 365.0551, found: 365.0547. **FTIR (cm^{-1})** 3059, 2952, 1644, 1592, 1488, 1446, 1396, 1265, 1232, 1093, 1022, 833, 740, 666.

Methyl 4-(2-(4-fluorophenyl)-2-oxoethyl)-4*H*-chromene-3-carboxylate (3f)



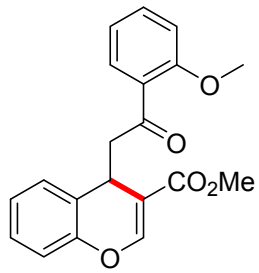
3f

Following the general procedure, treatment of methyl (*E*)-3-(2-((*E*)-3-(4-fluorophenyl)-3-oxoprop-1-en-1-yl)phenoxy)acrylate **1f** (0.163 g, 0.5 mmol) with anhydrous tribasic potassium phosphate (0.106 g, 0.5 mmol) in THF (4.0 mL) at 60 °C for 72 h followed by flash column chromatography using (Pet. ether/EtOAc = 90/10) of the crude reaction mixture using silica

gel afforded methyl 4-(2-(4-fluorophenyl)-2-oxoethyl)-4*H*-chromene-3-carboxylate as white solid **3f** (0.133 g, 81% yield).

***R*f** (Pet. ether /EtOAc = 80/20): 0.61; Melting point: 79-81 °C; **^{1}H NMR (400 MHz, CDCl$_3$)** δ 7.96 – 7.93 (m, 2H), 7.73 (s, 1H), 7.219– 7.13 (m, 2H), 7.10-7.06 (m, 2H), 7.04 – 6.97 (m, 2H), 4.49 (dd, J_1 = 3.7 Hz, J_2 = 7.3 Hz, 1H), 3.74 (s, 3H), 3.31 (qd, J_1 = 5.6 Hz, J_2 = 16.2, Hz, 2H). **^{13}C NMR (100 MHz, CDCl$_3$)** δ 196.46, 166.94, 165.79 (d, J = 255.1 Hz), 152.09, 150.11, 133.46, 130.96 (d, J = 9.3 Hz), 129.22, 128.13, 125.02, 123.76, 116.64, 115.73 (d, J = 21.79 Hz), 109.08, 51.69, 47.33, 29.95. **^{19}F NMR (376 MHz, CDCl$_3$)** δ -105.18. **HRMS (ESI)** calculated $[M+Na]^+$ for $C_{19}H_{15}O_4FNa$: 349.0847, found: 349.0841. **FTIR (cm^{-1})** 3022, 2953, 1704, 1646, 1595, 1496, 1447, 1401, 1294, 1225, 1092, 1042, 838, 759, 668.

Methyl-4-(2-(2-methoxyphenyl)-2-oxoethyl)-4*H*-chromene-3-carboxylate (3g)

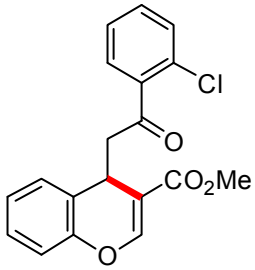


3g

Following the general procedure, treatment of methyl (*E*)-3-(2-((*E*)-3-(2-methoxyphenyl)-3-oxoprop-1-en-1-yl)phenoxy)acrylate **1g** (0.169 g, 0.5 mmol) with anhydrous tribasic potassium phosphate (0.106 g, 0.5 mmol) in THF (4.0 mL) at 60 °C for 72 h followed by flash column chromatography using (Pet. ether/EtOAc = 90/10) of the crude reaction mixture using silica gel afforded methyl-4-(2-(2-methoxyphenyl)-2-oxoethyl)-4*H*-chromene-3-carboxylate as white solid **3g** (0.135 g, 80% yield).

***R*f** (Pet. ether /EtOAc = 80/20): 0.32; Melting point: 89-91 °C; **^{1}H NMR (400 MHz, CDCl$_3$)** δ 7.68 (s, 1H), 7.59 (dd, J_1 = 7.7 Hz, J_2 = 1.7 Hz, 1H), 7.39 – 7.35 (m, 1H), 7.28 – 7.26 (m, 1H), 7.14 – 7.10 (m, 1H), 7.01 (t, J = 10.8 Hz, 1H), 6.94-6.90 (m, 2H), 6.84 (d, J = 8.4 Hz, 1H), 4.51 (dd, J_1 = 7.0 Hz, J_2 = 3.9 Hz, 1H), 3.76 (s, 3H), 3.72 (s, 3H), 3.42 (dd, J_1 = 16.9 Hz, J_2 = 7.1 Hz, 1H), 3.31 (dd, J_1 = 16.9 Hz, J_2 = 3.9 Hz, 1H). **^{13}C NMR (100 MHz, CDCl3)** δ 200.07, 166.86, 158.43, 151.58, 150.05, 133.46, 130.32, 129.30, 128.37, 127.67, 124.74, 124.48, 120.50, 116.30, 111.36, 109.57, 55.32, 52.26, 51.45, 29.57. **HRMS (ESI)** calculated $[M+Na]^+$ for $C_{20}H_{18}O_5Na$: 361.1046, found: 361.1041. **FTIR (cm^{-1})** 3402, 3015, 2951, 2844, 1709, 1661, 1592, 1476, 1449, 1390, 1295, 1240, 1194, 1088, 1026, 955, 821, 758, 663, 624.

Methyl 4-(2-(2-chlorophenyl)-2-oxoethyl)-4*H*-chromene-3-carboxylate (3h)

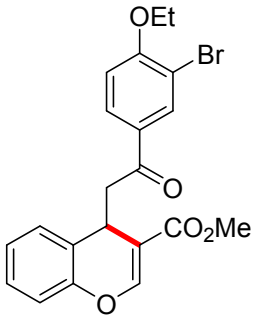


3h

Following the general procedure, treatment of methyl (*E*)-3-(2-((*E*)-3-(2-chlorophenyl)-3-oxoprop-1-en-1-yl)phenoxy)acrylate **1h** (0.171 g, 0.5 mmol) with anhydrous tribasic potassium phosphate (0.106 g, 0.5 mmol) in THF (4.0 mL) at 60 °C for 72 h followed by flash column chromatography using (Pet. ether/EtOAc = 90/10) of the crude reaction mixture using silica gel afforded methyl 4-(2-(2-chlorophenyl)-2-oxoethyl)-4*H*-chromene-3-carboxylate as white solid **3h** (0.141 g, 82% yield).

***R*f** (Pet. ether /EtOAc = 80/20): 0.41; Melting point: 90-92 °C; **^{1}H NMR (400 MHz, CDCl$_3$)** δ 7.72 (s, 1H), 7.36 – 7.30 (m, 4H), 7.26 – 7.22 (m, 1H), 7.18 (t, J = 7.2 Hz, 1H), 7.07 (t, J = 7.5 Hz, 1H), 6.98 (d, J = 8.1 Hz, 1H), 4.53 (dd, J_1 = 4.0 Hz, J_2 = 6.9 Hz, 1H), 3.78 (s, 3H), 3.44 – 3.31 (m, 2H). **^{13}C NMR (100 MHz, CDCl$_3$)** δ 201.04, 166.86, 151.96, 150.03, 139.30, 131.77, 131.02, 130.55, 129.34, 129.16, 128.14, 126.87, 125.10, 123.71, 116.62, 108.94, 51.70, 51.28, 29.64. **HRMS (ESI)** calculated $[M+Na]^+$ for $C_{19}H_{15}O_4ClNa$: 365.0551, found: 365.0550. **FTIR (cm^{-1})** 3019, 1708, 1708, 1650, 1624, 1607, 1581, 1488, 1457, 1435, 1389, 1349, 1330, 1286, 1257, 1230, 1191, 1088, 1035.

Methyl-4-(2-(3-bromo-4-ethoxyphenyl)-2-oxoethyl)-4*H*-chromene-3-carboxylate (3i)



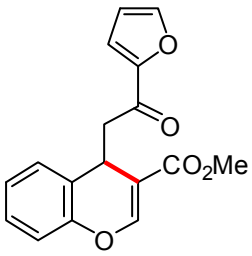
3i

Following the general procedure, treatment of methyl (*E*)-3-(2-((*E*)-3-(3-bromo-4-ethoxyphenyl)-3-oxoprop-1-en-1-yl)phenoxy)acrylate **1i** (0.216 g, 0.5 mmol) with anhydrous tribasic potassium phosphate (0.106 g, 0.5 mmol) in THF (4.0 mL) at 60 °C for 72 h followed by flash column chromatography using (Pet. ether/EtOAc = 90/10) of the crude reaction mixture using silica gel afforded methyl-4-(2-(3-bromo-4-ethoxyphenyl)-2-oxoethyl)-4*H*-chromene-3-carboxylate as white semisolid **3i** (0.174 g, 80% yield).

***R*f** (Pet. ether /EtOAc = 80/20): 0.44; **^{1}H NMR (400 MHz, CDCl$_3$)** δ 8.11 (d, J = 2.1 Hz, 1H), 7.86 (dd, J_1 = 8.6 Hz, J_2 = 2.2 Hz, 1H), 7.72 (s, 1H), 7.18 – 7.0 (m, 2H), 7.05 – 6.94 (m, 2H), 6.85 (d, J = 8.7 Hz, 1H), 4.47 (dd, J = 6.9, 4.2 Hz, 1H), 4.13 (q, J_1 = 7.0 Hz, J_2 = 14.0 Hz, 2H), 3.75 (s, 3H), 3.38 – 3.15 (m, 2H), 1.47 (t, J = 7.0 Hz, 3H). **^{13}C NMR (100 MHz, CDCl$_3$)** δ

195.54, 166.96, 159.16, 152.08, 150.14, 133.88, 130.83, 129.46, 129.28, 128.13, 125.03, 123.80, 116.63, 112.27, 111.97, 109.17, 65.15, 51.73, 47.13, 30.06, 14.61. **HRMS (ESI)** calculated $[M+H]^+$ for $C_{21}H_{19}O_5BrNa$: 453.0308, found: 453.0302. **FTIR (cm^{-1})** 3347, 2989, 2945, 2587, 1914, 1707, 1589, 1488, 1445, 1396, 1262, 1232, 1092, 1044, 918, 806, 758, 677, 624.

Methyl 4-(2-(furan-2-yl)-2-oxoethyl)-4*H*-chromene-3-carboxylate (3j)

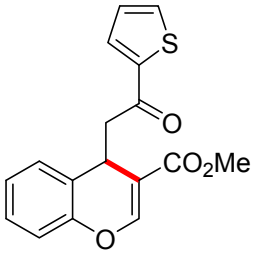


3j

Following the general procedure, treatment of methyl (*E*)-3-(2-((*E*)-3-(furan-2-yl)-3-oxoprop-1-en-1-yl)phenoxy)acrylate **1j** (0.149 g, 0.5 mmol) with anhydrous tribasic potassium phosphate (0.106 g, 0.5 mmol) in THF (4.0 mL) at 60 °C for 72 h followed by flash column chromatography using (Pet. ether/EtOAc = 90/10) of the crude reaction mixture using silica gel afforded methyl 4-(2-(furan-2-yl)-2-oxoethyl)-4*H*-chromene-3-carboxylate as brown solid **3j** (0.121 g, 81% yield).

***R*f** (Pet. ether /EtOAc = 80/20): 0.38; Melting point: 101-103 °C; **^{1}H NMR (500 MHz, $CDCl_3$)** δ 7.72 (s, 1H), 7.52 (s, 1H), 7.21 (d, *J* = 7.6 Hz, 1H), 7.15 (m, 2H), 7.03 (t, *J* = 7.5 Hz, 1H), 6.98 (d, *J* = 8.1 Hz, 1H), 6.50 – 6.47 (m, 1H), 4.47 (t, *J* = 5.8 Hz, 1H), 3.74 (s, 3H), 3.17 (d, *J* = 5.9 Hz, 2H). **^{13}C NMR (125 MHz, $CDCl_3$)** δ 187.02, 166.92, 152.80, 152.06, 150.11, 146.58, 129.37, 128.14, 125.07, 123.62, 117.60, 116.64, 112.34, 109.09, 51.71, 47.46, 30.07. **HRMS (ESI)** calculated $[M+Na]^+$ for $C_{17}H_{14}O_5Na$: 321.0733, found: 321.0732. **FTIR (cm^{-1})** 3137, 3021, 2956, 1711, 1653, 1575, 1454, 1392, 1297, 1228, 1092, 1024, 915, 758.

Methyl-4-(2-oxo-2-(thiophen-2-yl)ethyl)-4*H*-chromene-3-carboxylate (3k)



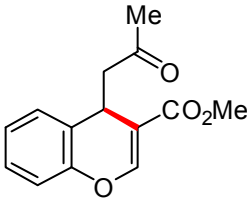
3k

Following the general procedure, treatment of methyl (*E*)-3-(2-((*E*)-3-oxo-3-(thiophen-2-yl)prop-1-en-1-yl)phenoxy)acrylate **1k** (0.157 g, 0.5 mmol) with anhydrous tribasic potassium phosphate (0.106 g, 0.5 mmol) in THF (4.0 mL) at 60 °C for 72 h followed by flash column chromatography using (Pet. ether/EtOAc = 90/10) of the crude reaction mixture using silica gel afforded methyl-4-(2-oxo-2-(thiophen-2-yl)ethyl)-4*H*-chromene-3-carboxylate as white solid **3k** (0.121 g, 77% yield).

***R*f** (Pet. ether /EtOAc = 80/20): 0.34; Melting point: 99-101 °C; **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.73 (s, 1H), 7.67 (d, *J* = 3.4 Hz, 1H), 7.58 (d, *J* = 4.8 Hz, 1H), 7.21 – 7.13 (m, 2H), 7.07 – 6.96

(m, 3H), 4.48 (dd, J_1 = 7.6 Hz, J_2 = 3.6 Hz, 1H), 3.74 (s, 3H), 3.30 (dd, J_1 = 15.5 Hz, J_2 = 3.6 Hz, 1H), 3.20 (dd, J_1 = 15.5 Hz, J_2 = 7.7 Hz, 1H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 190.85, 166.85, 152.04, 150.07, 144.51, 133.86, 132.35, 129.29, 128.20, 128.12, 125.02, 123.54, 116.60, 109.03, 51.65, 48.15, 30.44. **HRMS (ESI)** calculated $[M+Na]^+$ for $C_{17}H_{14}O_4SNa$: 337.0505, found: 337.0500. **FTIR (cm^{-1})** 3348, 3095, 2948, 1707, 1654, 1588, 1477, 1447, 1297, 1227, 1090, 858, 757, 624.

Methyl 4-(2-oxopropyl)-4*H*-chromene-3-carboxylate (3l)

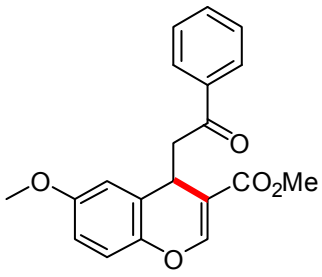


3l

Following the general procedure, treatment of methyl (*E*)-3-(2-((*E*)-3-oxobut-1-en-1-yl)phenoxy)acrylate **1l** (0.123 g, 0.5 mmol) with anhydrous tribasic potassium phosphate (0.106 g, 0.5 mmol) in THF (4.0 mL) at 60 °C for 72 h followed by flash column chromatography using (Pet. ether/EtOAc = 90/10) of the crude reaction mixture using silica gel afforded methyl 4-(2-oxopropyl)-4*H*-chromene-3-carboxylate as white semisolid **3l** (0.085 g, 69% yield).

***R*$_f$** (Pet. ether /EtOAc = 80/20): 0.32; Melting point: 97-99 °C; **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.69 (s, 1H), 7.23 (d, *J* = 7.6 Hz, 1H), 7.17 (t, *J* = 7.7 Hz, 1H), 7.06 (t, *J* = 7.4 Hz, 1H), 6.97 (d, *J* = 8.1 Hz, 1H), 4.32 (t, *J* = 5.4 Hz, 1H), 3.76 (s, 3H), 2.79 (d, *J* = 5.5 Hz, 2H), 2.04 (s, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 206.60, 166.89, 151.83, 149.99, 129.17, 128.08, 125.12, 124.07, 116.66, 109.05, 52.32, 51.68, 30.72, 29.14. **HRMS (ESI)** calculated $[M+Na]^+$ for $C_{14}H_{14}O_4Na$: 269.0784, found: 269.0783. **FTIR (cm^{-1})** 2951, 1712, 1646, 1486, 1444, 1358, 1299, 1233, 1190, 1087, 1036, 950, 759, 624.

Methyl 6-methoxy-4-(2-oxo-2-phenylethyl)-4*H*-chromene-3-carboxylate (3m)



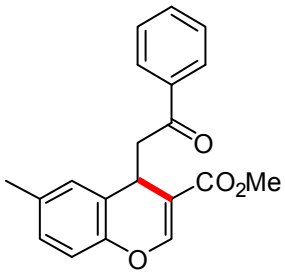
3m

Following the general procedure, treatment of methyl (*E*)-3-(4-methoxy-2-((*E*)-3-oxo-3-phenylprop-1-en-1-yl)phenoxy)acrylate **1m** (0.169 g, 0.5 mmol) with anhydrous tribasic potassium phosphate (0.106 g, 0.5 mmol) in THF (4.0 mL) at 60 °C for 72 h followed by flash column chromatography using (Pet. ether/EtOAc = 90/10) of the crude reaction mixture using silica gel afforded methyl 6-

methoxy-4-(2-oxo-2-phenylethyl)-4*H*-chromene-3-carboxylate as yellow solid **3m** (0.142 g, 84% yield).

***R*f** (Pet. ether /EtOAc = 80/20): 0.32; Melting point: 104-106 °C; **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.92 (d, *J* = 7.5 Hz, 2H), 7.72 (s, 1H), 7.52 (t, *J* = 7.3 Hz, 1H), 7.42 (t, *J* = 7.6 Hz, 2H), 6.91 (d, *J* = 8.8 Hz, 1H), 6.73 – 6.67 (m, 2H), 4.50 (dd, J_1 = 3.7 Hz, J_2 = 3.7 Hz, 1H), 3.73 (s, 3H), 3.68 (s, 3H), 3.34 (qd, J_1 = 5.6 Hz, J_2 = 16.4 Hz, 2H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 198.12, 167.05, 156.49, 152.22, 144.08, 137.01, 133.15, 128.64, 128.24, 124.73, 117.41, 114.09, 113.18, 108.17, 55.62, 51.60, 47.54, 30.14. **HRMS (ESI)** calculated $[M+Na]^+$ for $C_{20}H_{18}O_5Na$: 361.1046, found: 361.1043. **FTIR (cm^{-1})** 3016, 2951, 2841, 1703, 1648, 1595, 1493, 1440, 1286, 1214, 1091, 1037, 988, 756, 698.

Methyl 6-methyl-4-(2-oxo-2-phenylethyl)-4*H*-chromene-3-carboxylate (3n)

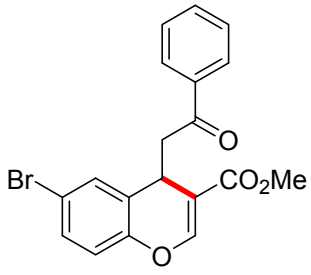


3n

Following the general procedure, treatment of methyl (*E*)-3-(4-methyl-2-((*E*)-3-oxo-3-phenylprop-1-en-1-yl)phenoxy)acrylate **1n** (0.161 g, 0.5 mmol) with anhydrous tribasic potassium phosphate (0.106 g, 0.5 mmol) in THF (4.0 mL) at 60 °C for 72 h followed by flash column chromatography using (Pet. ether/EtOAc = 90/10) of the crude reaction mixture using silica gel afforded methyl 6-methyl-4-(2-oxo-2-phenylethyl)-4*H*-chromene-3-carboxylate as yellow solid **3n** (0.083 g, 52% yield).

***R*f** (Pet. ether /EtOAc = 80/20): 0.32; Melting point: 109-111 °C; **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.95 – 7.91 (m, 2H), 7.74 (s, 1H), 7.54 – 7.39 (m, 3H), 7.00 – 6.86 (m, 3H), 4.48 (t, *J* = 5.5 Hz, 1H), 3.74 (s, 3H), 3.45 – 3.24 (m, 2H), 2.23 (s, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 198.08, 167.10, 152.20, 148.07, 137.16, 134.57, 133.12, 129.49, 128.65, 128.29, 123.65, 116.32, 108.96, 51.63, 47.56, 29.83, 20.88. **HRMS (ESI)** calculated $[M+Na]^+$ for $C_{20}H_{18}O_4Na$: 345.1097, found: 345.1094. **FTIR (cm^{-1})** 3021, 2949, 1719, 1638, 1638, 1587, 1493, 1443, 1372, 1252, 1216, 1089, 1040, 815, 756, 701.

Methyl-6-bromo-4-(2-oxo-2-phenylethyl)-4*H*-chromene-3-carboxylate (3o)



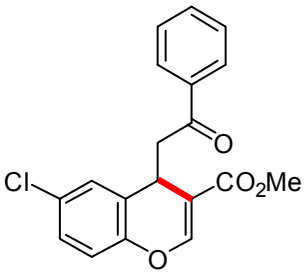
3o

Following the general procedure, treatment of methyl (*E*)-3-(4-bromo-2-((*E*)-3-oxo-3-phenylprop-1-en-1-yl)phenoxy)acrylate **1o** (0.194 g, 0.5 mmol) with anhydrous tribasic potassium phosphate (0.106 g, 0.5 mmol) in THF (4.0 mL) at 60 °C for 72 h followed by

flash column chromatography using (Pet. ether/EtOAc = 90/10) of the crude reaction mixture using silica gel afforded methyl-6-bromo-4-(2-oxo-2-phenylethyl)-4*H*-chromene-3-carboxylate as white solid **3o** (0.145 g, 75% yield).

***R*f** (Pet. ether /EtOAc = 80/20): 0.52; Melting point: 139-141°C; **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.92 (d, *J* = 7.7 Hz, 2H), 7.73 (s, 1H), 7.55 (t, *J* = 7.3 Hz, 1H), 7.45 (t, *J* = 7.6 Hz, 2H), 7.40 (d, *J* = 1.6 Hz, 1H), 7.28 – 7.26 (m, 1H), 6.89 (d, *J* = 8.7 Hz, 1H), 4.48 (dd, J_1 = 6.5 Hz, J_2 = 3.9 Hz, 1H), 3.76 (s, 3H), 3.40 (dd, *J* = 9.3, 5.3 Hz, 2H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 197.53, 166.65, 151.80, 149.38, 136.88, 133.32, 131.91, 131.06, 128.71, 128.21, 126.25, 118.36, 117.28, 108.99, 51.77, 46.90, 29.49. **HRMS (ESI)** calculated $[M+Na]^+$ for $C_{19}H_{15}O_4BrNa$: 409.0046, found: 409.0043. **FTIR (cm^{-1})** 3348, 3066, 2921, 2855, 1705, 1649, 1588, 1476, 1442, 1364, 1314, 1285, 1234, 1191, 1084, 1040, 814, 757, 691, 624.

Methyl 6-chloro-4-(2-oxo-2-phenylethyl)-4*H*-chromene-3-carboxylate (3p)

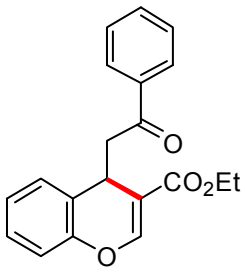


3p

Following the general procedure, treatment of methyl (*E*)-3-(4-chloro-2-((*E*)-3-oxo-3-phenylprop-1-en-1-yl)phenoxy)acrylate **1p** (0.171 g, 0.5 mmol) with anhydrous tribasic potassium phosphate (0.106 g, 0.5 mmol) in THF (4.0 mL) at 60 °C for 72 h followed by flash column chromatography using (Pet. ether/EtOAc = 90/10) of the crude reaction mixture using silica gel afforded methyl 6-chloro-4-(2-oxo-2-phenylethyl)-4*H*-chromene-3-carboxylate as yellow solid **3p** (0.114 g, 66% yield).

***R*f** (Pet. ether /EtOAc = 80/20): 0.45; Melting point: 131-133 °C; **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.91 (d, *J* = 7.4 Hz, 2H), 7.71 (s, 1H), 7.54 (t, *J* = 7.4 Hz, 1H), 7.43 (t, *J* = 7.7 Hz, 2H), 7.23 (d, *J* = 2.4 Hz, 1H), 7.11 (dd, J_1 = 2.4 Hz, J_2 = 8.7 Hz, 1H), 6.93 (d, *J* = 8.7 Hz, 1H), 4.46 (dd, J_1 = 3.9 Hz, J_2 = 6.7 Hz, 1H), 3.73 (s, 3H), 3.44 – 3.32 (m, 2H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 197.55, 166.69, 151.86, 148.84, 136.86, 133.33, 129.77, 128.97, 128.72, 128.22, 128.13, 125.78, 117.97, 108.87, 51.78, 46.92, 29.53. **HRMS (ESI)** calculated $[M+Na]^+$ for $C_{19}H_{15}O_4ClNa$: 365.0551, found: 365.0551. **FTIR (cm^{-1})** 3022, 2951, 1706, 1648, 1586, 1478, 1440, 1366, 1284, 1236, 1192, 1086, 1039, 756, 694.

Ethyl 4-(2-oxo-2-phenylethyl)-4*H*-chromene-3-carboxylate (3q)

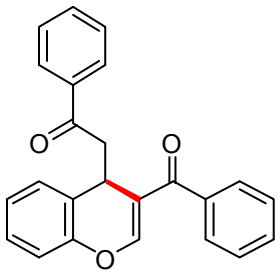


3q

Following the general procedure, treatment of ethyl (*E*)-3-(2-((*E*)-3-oxo-3-phenylprop-1-en-1-yl)phenoxy)acrylate **1q** (0.161 g, 0.5 mmol) with anhydrous tribasic potassium phosphate (0.106 g, 0.5 mmol) in THF (4.0 mL) at 60 °C for 72 h followed by flash column chromatography using (Pet. ether/EtOAc = 90/10) of the crude reaction mixture using silica gel afforded ethyl 4-(2-oxo-2-phenylethyl)-4*H*-chromene-3-carboxylate as white solid **3q** (0.128 g, 79% yield).

***R*f** (Pet. ether /EtOAc = 80/20): 0.50; Melting point: 94-96 °C; **^{1}H NMR (400 MHz, CDCl$_3$)** δ 7.94 -7.92 (m, 2H), 7.74 (s, 1H), 7.53 (t, J = 7.4 Hz, 1H), 7.42 (t, J = 7.6 Hz, 2H), 7.21 – 7.13 (m, 2H), 7.01 (dt, J_1 = 4.5 Hz, J_2 = 14.2 Hz, 2H), 4.53 (dd, J_1 = 3.7 Hz, J_2 = 7.5 Hz, 1H), 4.21 (q, J = 7.1 Hz, 2H), 3.34 (qd, J_1 = 5.6 Hz, J_2 = 16.3 Hz, 2H), 1.28 (t, J = 7.1 Hz, 3H). **^{13}C NMR (100 MHz, CDCl$_3$)** δ 198.07, 166.54, 151.90, 150.20, 137.05, 133.17, 129.32, 128.68, 128.32, 128.05, 124.98, 124.02, 116.62, 109.49, 60.56, 47.64, 29.87, 14.39. **HRMS (ESI)** calculated $[M+Na]^+$ for $C_{20}H_{18}O_4Na$: 345.1097, found: 345.1093. **FTIR (cm^{-1})** 2981, 1700, 1652, 1587, 1484, 1454, 1392, 1291, 1230, 1087, 1033, 757, 689.

2-(3-Benzoyl-4*H*-chromen-4-yl)-1-phenylethan-1-one (3r)



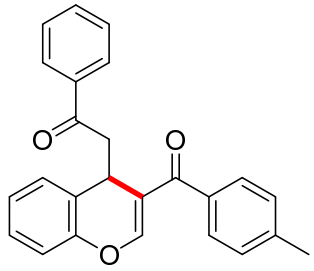
3r

Following the general procedure, treatment of (*E*)-3-(2-(((*E*)-3-oxo-3-phenylprop-1-en-1-yl)oxy)phenyl)-1-phenylprop-2-en-1-one **1r** (0.177 g, 0.5 mmol) with anhydrous tribasic potassium phosphate (0.106 g, 0.5 mmol) in THF (4.0 mL) at 60 °C for 60 h followed by flash column chromatography using (Pet. ether/EtOAc = 90/10) of the crude reaction mixture using silica gel afforded 2-(3-benzoyl-4*H*-chromen-4-yl)-1-phenylethan-1-one as white solid **3r** (0.152 g, 86% yield).

***R*f** (Pet. ether /EtOAc = 80/20): 0.44; Melting point: 87-89 °C; **^{1}H NMR (400 MHz, CDCl$_3$)** δ 8.01 – 7.99 (m, 2H), 7.68 – 7.66 (m, 2H), 7.57 – 7.54 (m, 2H), 7.51 – 7.44 (m, 5H), 7.32 (dd, J_1 = 1.5 Hz, J_2 = 7.6 Hz, 1H), 7.22 (t, J = 7.5 Hz, 1H), 7.12 (t, J = 7.4 Hz, 1H), 7.06 (d, J = 8.1 Hz, 1H), 4.80 (dd, J_1 = 3.8 Hz, J_2 = 6.9 Hz, 1H), 3.56 (dd, J_1 = 3.9 Hz, J_2 = 16.1 Hz, 1H), 3.47 (dd, J_1 = 7.0 Hz, J_2 = 16.2 Hz, 1H). **^{13}C NMR (100 MHz, CDCl$_3$)** δ 198.13, 195.03, 156.59, 150.16, 138.72, 136.98, 133.03, 131.48, 129.17, 128.77, 128.57, 128.36, 128.22, 127.98, 125.10, 124.01,

118.24, 116.44, 46.10, 29.79. **HRMS (ESI)** calculated $[M+Na]^+$ for $C_{24}H_{18}O_3Na$: 377.1148, found: 377.1146. **FTIR (cm^{-1})** 3006, 3020, 1966, 1681, 1632, 1584, 1487, 1452, 1392, 1225, 1109, 1034, 983, 890, 810, 760, 695.

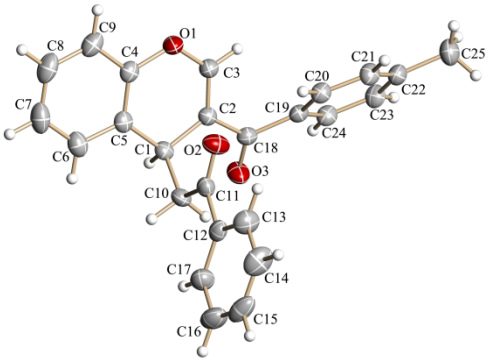
2-(3-(4-Methylbenzoyl)-4*H*-chromen-4-yl)-1-phenylethan-1-one (3s)



3s

Following the general procedure, treatment of (*E*)-3-(2-(((*E*)-3-oxo-3-(p-tolyl)prop-1-en-1-yl)oxy)phenyl)-1-phenylprop-2-en-1-one **1s** (0.184 g, 0.5 mmol) with anhydrous tribasic potassium phosphate (0.106 g, 0.5 mmol) in THF (4.0 mL) at 60 °C for 60 h followed by flash column chromatography using (Pet. ether/EtOAc = 90/10) of the crude reaction mixture using silica gel afforded 2-(3-(4-methylbenzoyl)-4*H*-chromen-4-yl)-1-phenylethan-1-one as white solid **3s** (0.136 g, 74% yield).

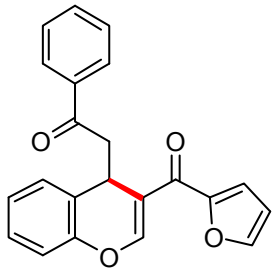
***R*f** (Pet. ether /EtOAc = 80/20): 0.40; Melting point: 129-131 °C; **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.97 – 7.95 (m, 2H), 7.55– 7.51 (m, 3H), 7.47 (s, 1H), 7.43 (t, J = 7.6 Hz, 2H), 7.27 – 7.23 (m, 3H), 7.19 (td, J_1 = 1.5 Hz, J_2 = 7.9 Hz, 1H), 7.07 (td, J_1 = 1.2 Hz, J_2 = 7.5 Hz, 1H), 7.02 (d, J = 8.1 Hz, 1H), 4.73 (dd, J_1 = 3.8 Hz, J_2 = 7.1 Hz, 1H), 3.52 (dd, J_1 = 3.8 Hz, J_2 = 16.1 Hz, 1H), 3.41 (dd, J_1 = 7.2 Hz, J_2 = 16.1 Hz, 1H), 2.42 (s, 3H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 198.32, 194.98, 156.24, 150.37, 142.25, 137.14, 136.10, 133.13, 129.29, 129.14, 128.69, 128.38, 128.07, 125.14, 124.18, 118.34, 116.54, 46.28, 30.08, 21.65. **HRMS (ESI)** calculated $[M+Na]^+$ for $C_{25}H_{20}O_3Na$: 391.1305, found: 391.1303. **FTIR (cm^{-1})** 3022, 2923, 1681, 1630, 1487, 1452, 1395, 1301, 1226, 1189, 1112, 1035, 982, 755, 693. **CCDC 1451381** This data can be obtained free of charge from the Cambridge Crystallographic Data Centre via www.ccdc.cam.ac.uk/data_request/cif.



Crystal data of **3s** $C_{25}H_{20}O_3$, M = 368.41, colorless block, 0.44 x 0.40 x 0.32 mm^3, monoclinic, space group $P2_1/c$, a = 6.0700(10) Å, b = 21.309(3) Å, c = 14.389(2) Å, β = 93.273(2)°, V = 1858.1(5) $Å^3$, Z = 4, T = 200(2) K, $2\theta_{max}$=50.00°, D_{calc} (g cm^{-3}) = 1.317, $F(000)$ = 776, μ (mm^{-1}) = 0.086, 14303 reflections collected, 3271

unique reflections (R_{int}=0.0197), 2945 observed ($I > 2\sigma(I)$) reflections, multi-scan absorption correction, T_{min} = 0.963, T_{max} = 0.973, 265 refined parameters, S = 1.053, $R1$ = 0.0378, $wR2$ = 0.0949 (all data R = 0.0423, $wR2$ = 0.0987), maximum and minimum residual electron densities; $\Delta\rho_{max}$ = 0.183, $\Delta\rho_{min}$= -0.184 (eÅ^{-3}).

2-(3-(Furan-2-carbonyl)-4*H*-chromen-4-yl)-1-phenylethan-1-one (3t)

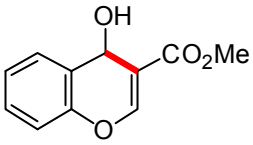


3t

Following the general procedure, treatment of (*E*)-1-(furan-2-yl)-3-(2-((*E*)-3-oxo-3-phenylprop-1-en-1-yl)phenoxy)prop-2-en-1-one **1t** (0.172 g, 0.5 mmol) with anhydrous tribasic potassium phosphate (0.106 g, 0.5 mmol) in THF (4.0 mL) at 60 °C for 60 h followed by flash column chromatography using (Pet. ether/EtOAc = 90/10) of the crude reaction mixture using silica gel afforded 2-(3-(furan-2-carbonyl)-4*H*-chromen-4-yl)-1-phenylethan-1-one as yellow solid **3t** (0.151 g, 88% yield).

***R*$_f$** (Pet. ether /EtOAc = 80/20): 0.35; Melting point: 93-95 °C; **^{1}H NMR (400 MHz, CDCl$_3$)** δ 8.22 (s 1H), 7.96 (d, J = 8.0 Hz, 2H), 7.60 (s, 1H), 7.54 – 7.51 (m, 1H), 7.43 (t, J = 7.6 Hz, 2H), 7.25 – 7.18 (m, 3H), 7.07 (t, J = 7.4 Hz, 2H), 6.55 (s, 1H), 4.72 (dd, J_1 = 3.1 Hz, J_2 = 7.3 Hz, 1H), 3.49 (dd, J_1 = 3.3 Hz, J_2 = 16.2 Hz, 1H), 3.35 (dd, J_1 = 7.7 Hz, J_2 = 16.2 Hz, 1H). **^{13}C NMR (100 MHz, CDCl$_3$)** δ 198.11, 179.80, 155.08, 152.73, 150.20, 145.88, 137.02, 133.10, 129.31, 128.65, 128.35, 128.05, 125.15, 124.21, 118.16, 117.87, 116.47, 112.05, 46.88, 29.76. **HRMS (ESI)** calculated $[M+Na]^+$ for $C_{22}H_{16}O_4Na$: 367.0941, found: 367.0933. **FTIR (cm^{-1})** 3019, 2922, 1681, 1627, 1574, 1467, 1395, 1310, 1269, 1225, 1020, 856, 758, 679.

Methyl 4-hydroxy-4*H*-chromene-3-carboxylate (10a)



10a

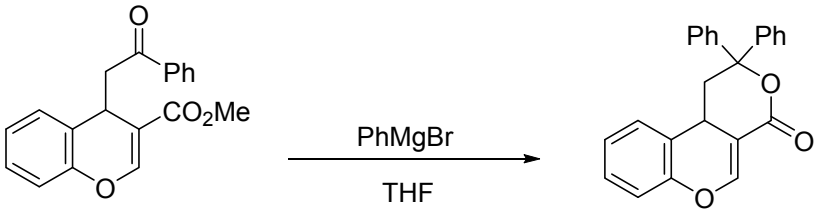
Following the general procedure, treatment of methyl (E)-3-(2-formylphenoxy)acrylate **9a** (0.103 g, 0.5 mmol) with anhydrous tribasic potassium phosphate (0.106 g, 0.5 mmol) in THF (4.0 mL) at 60 °C for 72 h followed by flash column chromatography using (Pet. ether/EtOAc = 80/20) of the crude reaction mixture using silica gel afforded methyl 4-hydroxy-4*H*-chromene-3-carboxylate as white solid **10a** (0.046 g, 45% yield).

***R*$_f$** (Pet. ether /EtOAc = 80/20): 0.30; Melting point: 104-106 °C; **^{1}H NMR (400 MHz, CDCl$_3$)** δ 7.71 (s, 1H), 7.38 – 7.31 (m, 2H), 7.07 – 7.02 (m, 2H), 6.40 (d, J = 6.0 Hz, 1H), 3.85 (s, 3H), 3.73 – 3.54 (bs, 1H, OH). **^{13}C NMR (100 MHz, CDCl$_3$)** δ 165.41, 152.10, 134.39, 132.48,

129.31, 122.38, 122.31, 119.09, 117.46, 88.79, 52.30. **HRMS (ESI)** calculated $[M+Na]^+$ for $C_{11}H_{10}O_4Na$: 229.0471, found: 229.0471. **FTIR (cm^{-1})** 3366, 3021, 2924, 2856, 1719, 1609, 1447, 1298, 1251, 1218, 1128, 1041, 756.

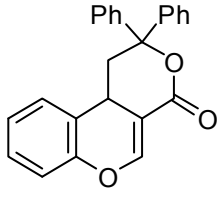
6. Product Functionalizations

2,2-Diphenyl-1,10b-dihydro-2H,4H-pyrano[3,4-c]chromen-4-one (11)



3a **11**

To a flame-dried screw-capped test tube equipped with a magnetic stir bar was added methyl-4-(2-oxo-2-phenylethyl)-4*H*-chromene-3-carboxylate **3a** (0.077 g, 0.25 mmol). Then the screw-capped tube was evacuated and backfilled with argon. The mixture was dissolved in THF (2.0 mL) undera positive pressure of argon atmosphere. The resultant reaction mixture was kept stirring at -78 °C. To this mixture was added the 1 (M) solution of phenyl magnesium bromide (PhMgBr) in THF (0.4 mL, 0.4 mmol, 1.6 equiv) and continued stirring at -78 °C to rt. After 2 h stirring, water (2 mL) was added to quench the reaction. The organic layer was extracted with ethyl acetate, dried over Na_2SO_4 and concentrated under reduced pressure. The crude reaction mixture was purified by flash column chromatography through silica gel (petroleum ether: ethyl acetate 80:20) to afford 2,2-diphenyl-1,10b-dihydro-2*H*,4*H*-pyrano[3,4-c]chromen-4-one **11** as a white solid (0.067 g, 76% yield).

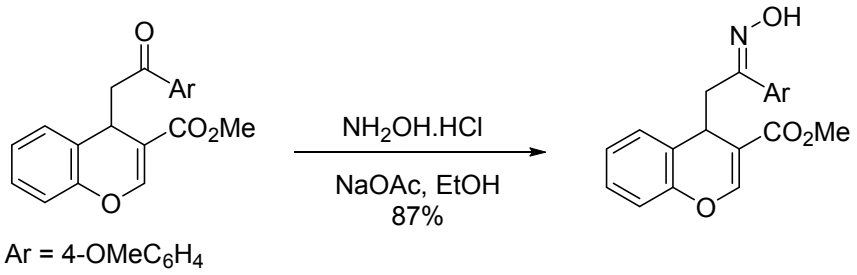


11

***R*$_f$** (Pet. ether /EtOAc = 80/20): 0.17; Melting point: 87-89 °C; **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.65 (d, *J* = 7.7 Hz, 2H), 7.44 (t, *J* = 7.6 Hz, 2H), 7.35 (d, *J* = 6.5 Hz, 2H), 7.21 - 7.17 (m, 3H), 7.12 - 7.10 (m, 1H), 7.02 (s, 1H), 6.98 (t, *J* = 7.7 Hz, 1H), 6.81 (t, *J* = 7.3 Hz, 1H), 6.61 (d, *J* = 7.9 Hz, 1H), 6.50 (s, 1H), 4.12 – 4.07 (m, 1H), 3.16 (dd, J_1 = 7.6 Hz, J_2 = 14.6 Hz, 1H), 2.85 - 2.78 (m, 1H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 169.04, 154.00, 144.32,

142.00, 141.32, 135.05, 130.20, 130.15, 129.27, 128.94, 128.46, 128.33, 128.26, 127.94, 127.59, 126.46, 125.65, 119.87, 116.64, 86.82, 41.83, 39.57. **HRMS (ESI)** calculated $[M+H]^+$ for $C_{24}H_{19}O_3$: 355.1329, found: 355.1320. **FTIR (cm^{-1})** 3062, 2954, 1704, 1599, 1497, 1452, 1375, 1218, 1128, 1101, 1058, 990, 909, 737, 708, 652.

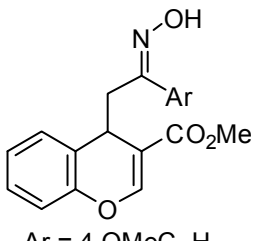
Methyl (Z)-4-(2-(hydroxyimino)-2-(4-methoxyphenyl)ethyl)-4H-chromene-3-carboxylate (12)



Ar = 4-OMeC$_6$H$_4$

3b **12**

To a flame-dried screw-capped test tube equipped with a magnetic stir bar was charged with hydroxylamine hydrochloride (0.045 g, 0.65 mmol, 5.0 equiv.) and sodium acetate (0.043 g, 0.52 mmol, 4.0 equiv.). The resultant mixture was dissolved in ethanol (2.0 mL) followed by addition of methyl 4-(2-(4-methoxyphenyl)-2-oxoethyl)-4*H*-chromene-3-carboxylate **3b** (0.045 g, 0.13 mmol) and the resulting reaction mixture was stirred at rt for 48 h. Water (2.0 mL) was added to quench the reaction. The organic layer was extracted with ethyl acetate, dried over Na_2SO_4 and concentrated under reduced pressure. The crude reaction mixture was purified by flash column chromatography through silica gel (petroleum ether: ethyl acetate 80:20) to afford methyl (*Z*)-4-(2-(hydroxyimino)-2-(4-methoxyphenyl)ethyl)-4*H*-chromene-3-carboxylate **12** as a white semisolid (0.040 g, 87% yield).



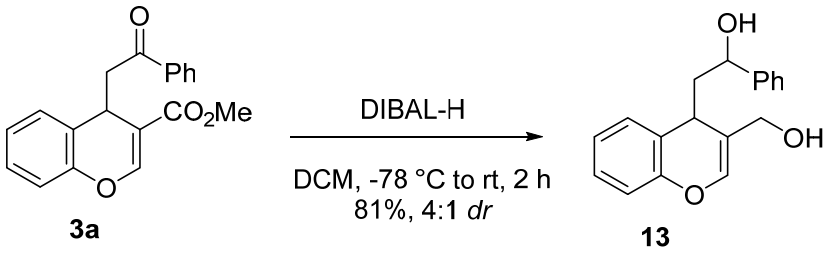
Ar = 4-OMeC $_6$H$_4$

12

***R*$_f$** (Pet. ether /EtOAc = 80/20): 0.30; **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.65 (s, 1H), 7.57 – 7.54 (m, 2H), 7.33 – 7.31 (m, 3H), 6.84 (d, J = 8.9 Hz, 1H), 6.64 (dd, J_1 = 2.8 Hz, J_2 = 8.9 Hz, 1H), 6.52 (d, J = 2.7 Hz, 1H), 4.21 (dd, J_1 = 4.9 Hz, J_2 = 8.3 Hz, 1H), 3.74 (s, 3H), 3.65 (s, 3H), 3.30 (dd, J_1 = 8.5 Hz, J_2 = 13.2 Hz, 1H), 3.11 (dd, J_1 = 4.9 Hz, J_2 = 13.2 Hz, 1H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 167.27, 157.27, 156.42, 152.03, 144.45, 135.56, 129.29, 128.54, 126.57, 124.12, 117.14, 114.27, 113.14, 109.03, 77.48,

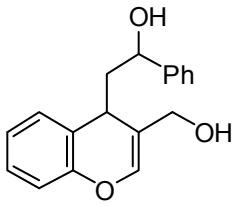
77.16, 76.84, 55.76, 51.64, 34.29, 31.97. **HRMS (ESI)** calculated $[M+Na]^+$ for $C_{20}H_{19}O_5NNa$: 376.1155, found: 376.1150. **FTIR (cm^{-1})** 3358, 2948, 2851, 1706, 1641, 1493, 1439, 1374, 1300, 1215, 1096, 1033, 922, 759.

2-(3-(Hydroxymethyl)-4H-chromen-4-yl)-1-phenylethan-1-ol (13)



3a **13**

To a flame-dried screw-capped test tube equipped with a magnetic stir bar was added methyl 4-(2-oxo-2-phenylethyl)-4*H*-chromene-3-carboxylate **3a** (0.077 g, 0.25 mmol). Then the screw-capped tube was evacuated and backfilled with argon followed by addition of 2.0 mL dry DCM and the resultant reaction mixture was kept stirring at -78 °C. To this mixture 1 (M) solution DIBAL-H in cyclohexane (0.6 mL, 0.60 mmol, 2.4 equiv.) was added under argon atmosphere. After stirring for 2 h at -78 °C to rt, the reaction was quenched with water. The organic layer was extracted with ethyl acetate, dried over Na_2SO_4 and concentrated under reduced pressure. The crude reaction mixture was purified by flash column chromatography through silica gel (petroleum ether: ethyl acetate 60:40) to afford 2-(3-(hydroxymethyl)-4*H*-chromen-4-yl)-1-phenylethan-1-ol **13** inseparable mixture of diastereomers as a sticky colourless liquid (0.057 g, 81% yield, 4:1 dr detected by ^{1}H NMR).

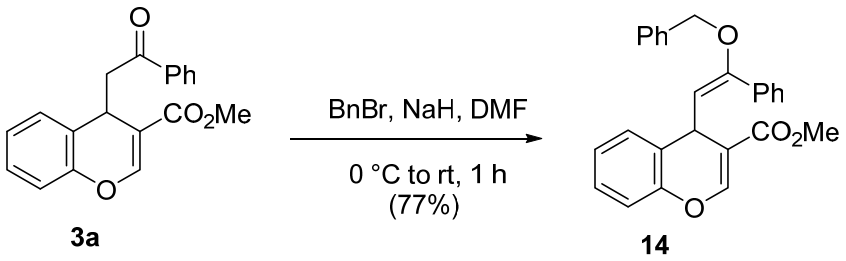


13

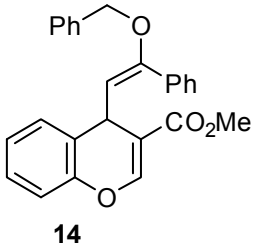
***R*$_f$** (Pet. ether /EtOAc = 60/40): 0.25; **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.42 – 7.16 (m, 7H), 7.11 - 7.02 (m, 1H), 6.98 (d, *J* = 8.2 Hz, 1H), 6.63 (s, 1H), 4.81 – 4.75 (m, 1H), 4.32 – 4.25 (m, 1H), 4.15 – 4.05 (m, 1H), 3.89 – 3.80 (m, 1H), 3.09 – 2.70 (bs, 2H, 2OH), 2.25 – 2.15 (m, 1H), 1.86 – 1.81 (m, 1H). **^{13}C NMR (100 MHz, $CDCl_3$)** δ 151.58, 144.74, 139.28, 129.24, 128.57, 127.69, 127.61, 125.80, 125.62, 124.66, 123.64, 117.36, 116.57, 72.07, 61.99, 46.81, 32.30. Representative peak for minor isomer **^{1}H NMR** δ 6.74 (s), 4.14 (d, *J* = 11.5 Hz), 3.83 – 3.80 (m), 2.44 – 2.37 (m), 2.11 – 2.06 (m). **^{13}C NMR** δ 145.00, 140.17, 128.65, 127.50, 123.96, 116.39, 71.70, 63.66, 47.08, 34.13. **HRMS (ESI)** calculated $[M+Na]^+$ for $C_{18}H_{18}O_3Na$:

305.1148, found: 305.1145. **FTIR (cm^{-1})** 3386, 2925, 2860, 1671, 1583, 1454, 1230, 1190, 1114, 1050, 909, 806, 734.

Methyl (E)-4-(2-(benzyloxy)-2-phenylvinyl)-4H-chromene-3-carboxylate (14)



To a flame-dried screw-capped test tube equipped with a magnetic stir bar was added methyl-4-(2-oxo-2-phenylethyl)-4*H*-chromene-3-carboxylate **3a** (0.077 g, 0.25 mmol). Then the screw-capped tube was evacuated and backfilled with argon. The mixture was dissolved in DMF (2.0 mL) under argon atmosphere. The resultant reaction mixture was kept stirring at 0 °C. To this mixture was added the NaH (55% in mineral oil) (16 mg, 0.375 mmol, 1.5 equiv.) followed by the addition of benzyl bromide (43 mg, 30 µL, 0.25 mmol). After 1 h stirring, water (2.0 mL) was added to quench the reaction. The organic layer was extracted with ethyl acetate, dried over Na_2SO_4 and concentrated under reduced pressure. The crude reaction mixture was purified by flash column chromatography through silica gel (petroleum ether: ethyl acetate 80:20) to afford methyl (*E*)-4-(2-(benzyloxy)-2-phenylvinyl)-4*H*-chromene-3-carboxylate **14** as a white solid (0.077 g, 77% yield).

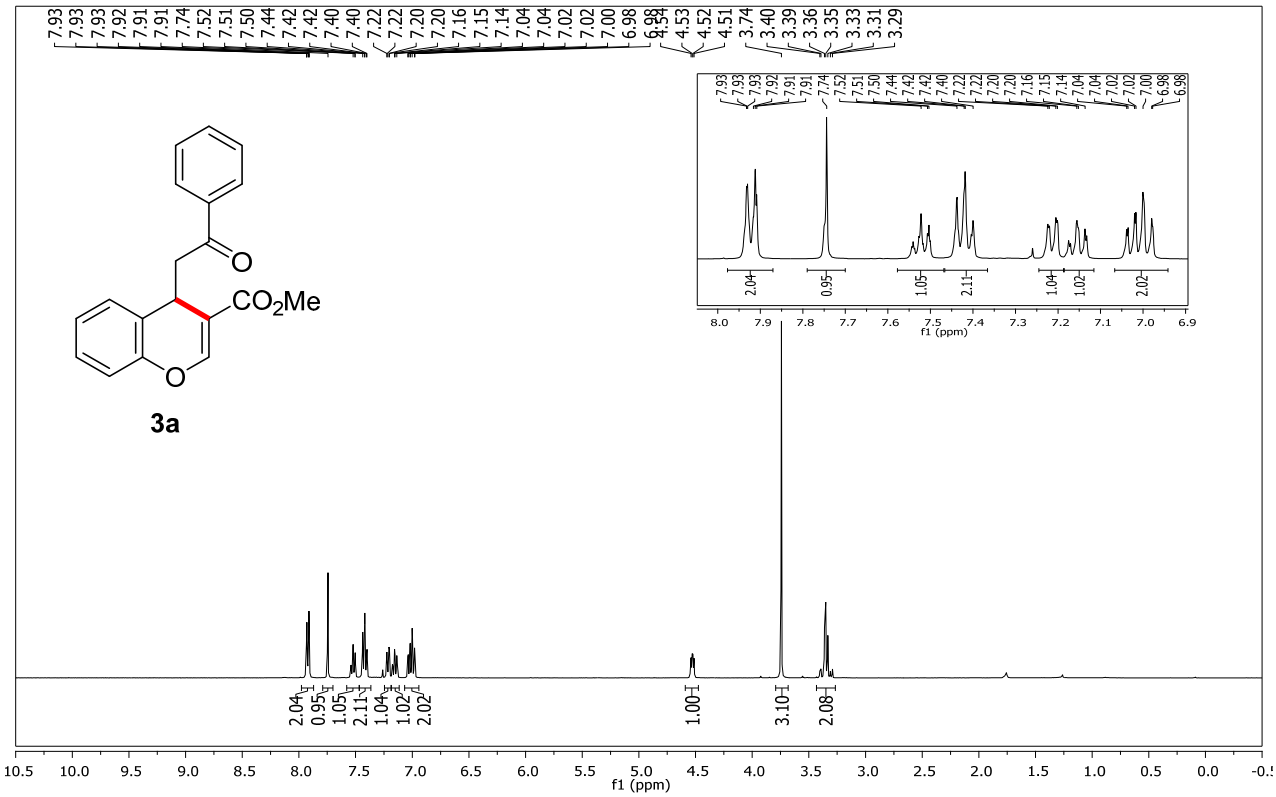


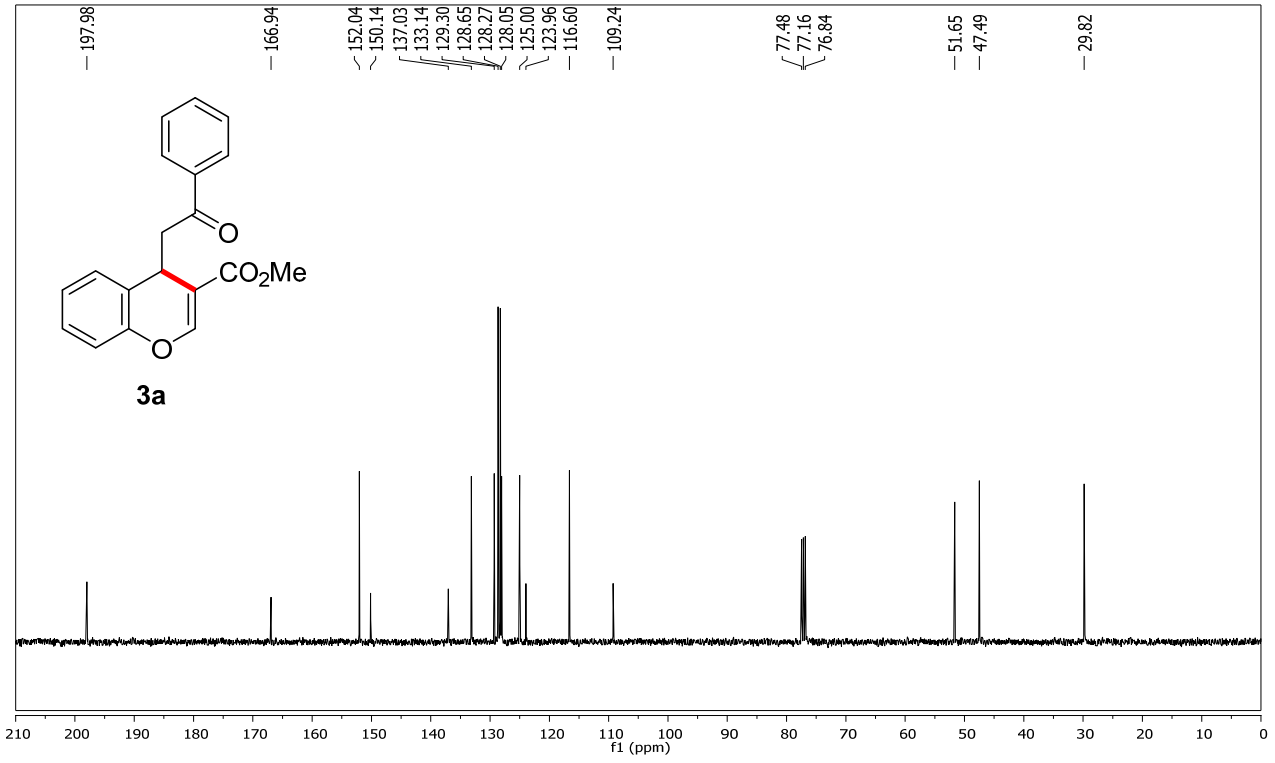
14

***R*$_f$** (Pet. ether /EtOAc = 80/20): 0.27; Melting point: 100-102 °C; **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.91 (s, 1H), 7.52 (bs, 4H), 7.43 (t, *J* = 7.2 Hz, 2H), 7.38 – 7.33 (m, 4H), 7.28 – 7.18 (m, 2H), 6.99 – 6.96 (m, 2H), 5.68 (d, *J* = 3.9 Hz, 1H), 5.20 (s, 2H), 5.07 (d, *J* = 4.1 Hz, 1H), 3.67 (d, *J* = 1.0 Hz, 3H).**^{13}C NMR (100 MHz, $CDCl_3$)** δ 167.23, 155.54, 151.85, 146.63, 137.47, 133.71, 133.28, 129.11, 128.69, 128.62, 128.40, 127.96, 127.83, 127.46, 125.91, 124.53, 121.50, 112.37, 108.39, 103.02, 70.48, 51.54, 30.50. **HRMS (ESI)** calculated $[M+Na]^+$ for $C_{26}H_{22}O_4Na$: 421.1410, found: 421.1405. **FTIR (cm^{-1})** 3023, 2926, 2859, 1712, 1633, 1596, 1489, 1450, 1377, 1298, 1247, 1098, 1201, 756, 698.

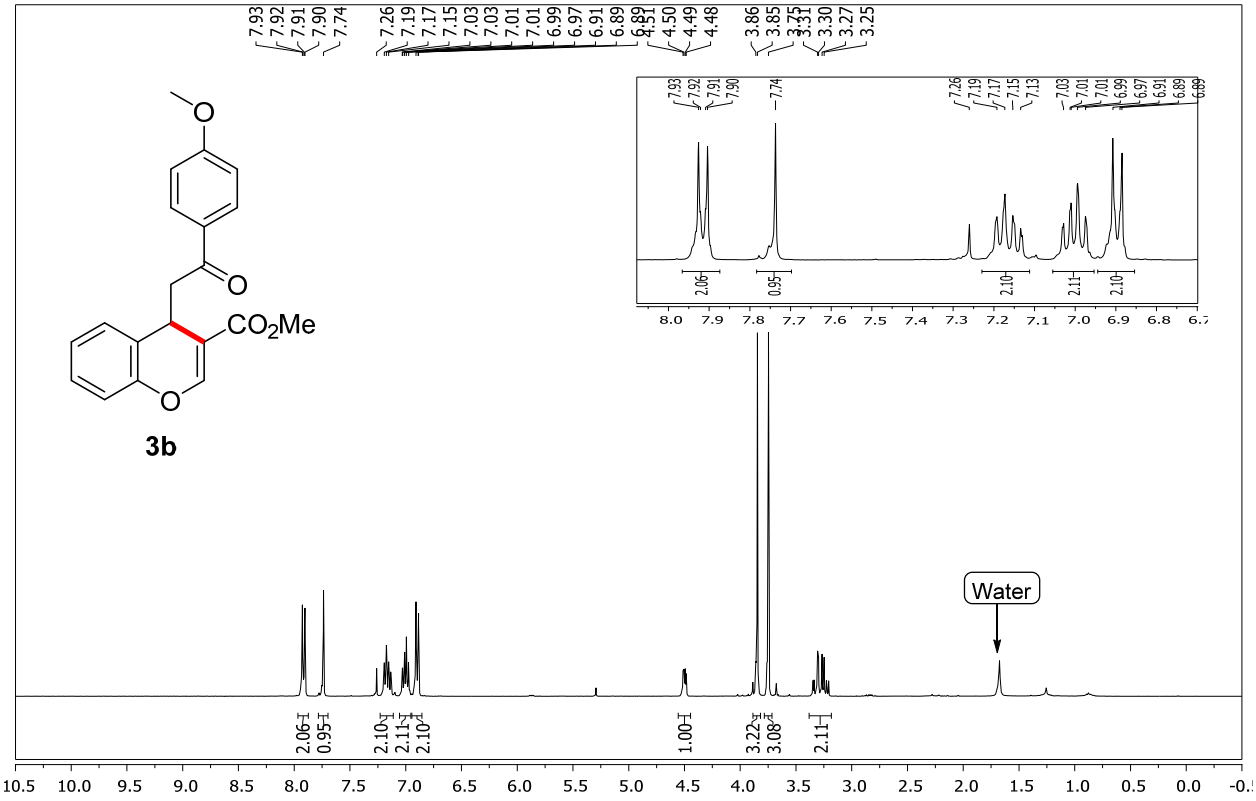
^{1}H and ^{13}C NMR Spectra of 4*H*-Chromenes

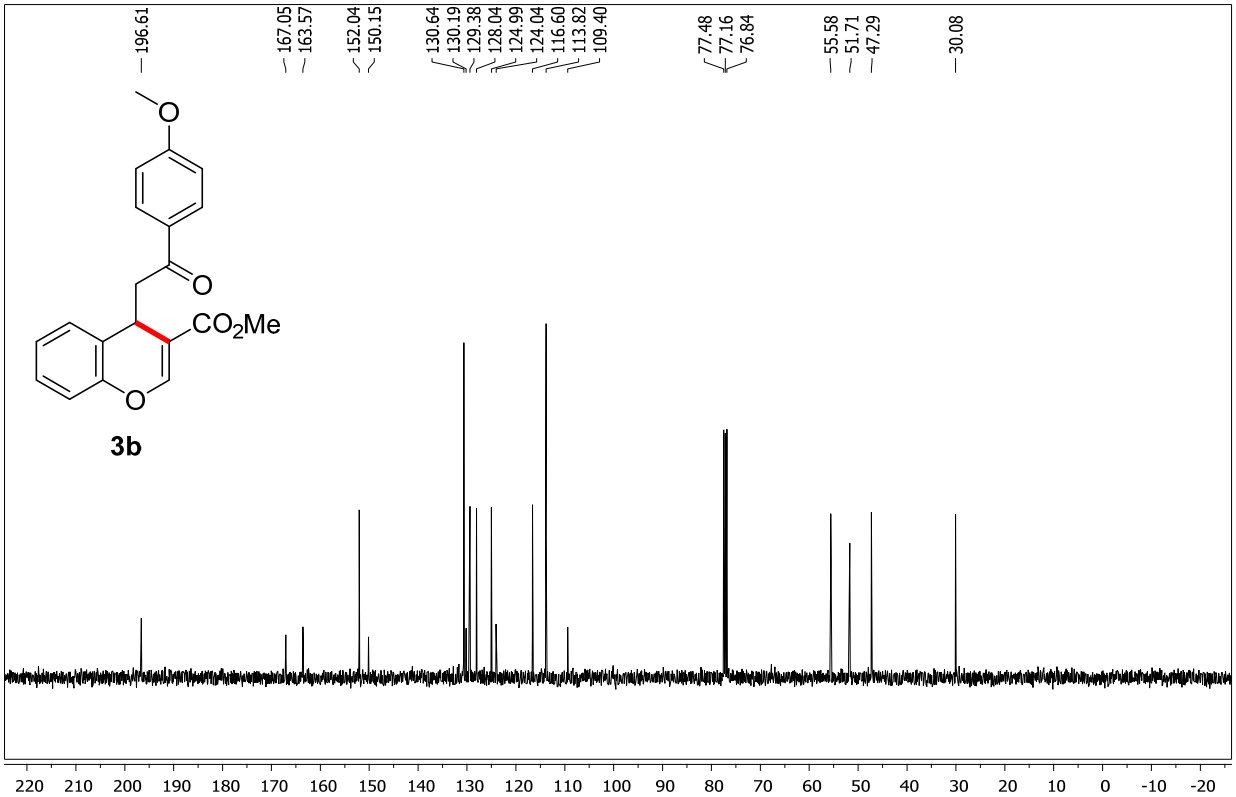
Methyl-4-(2-oxo-2-phenylethyl)-4*H*-chromene-3-carboxylate (3a)



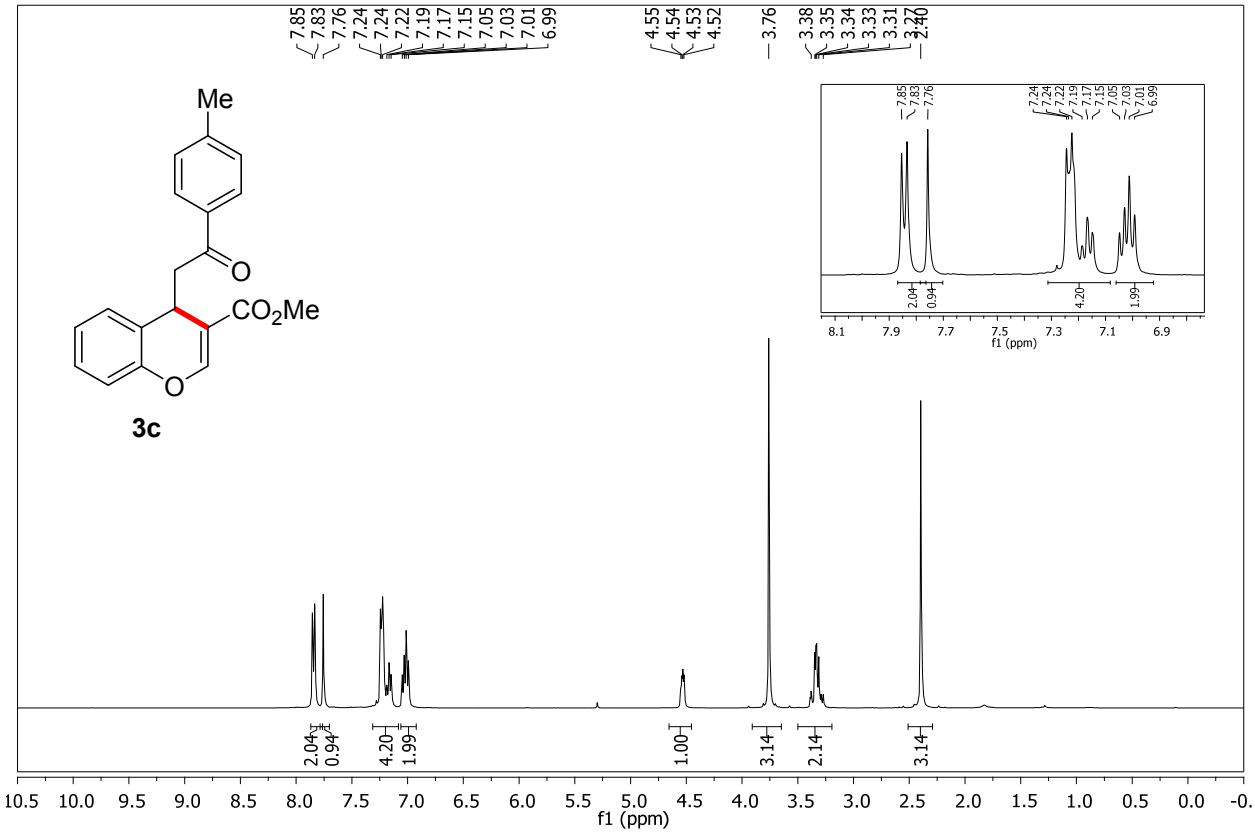


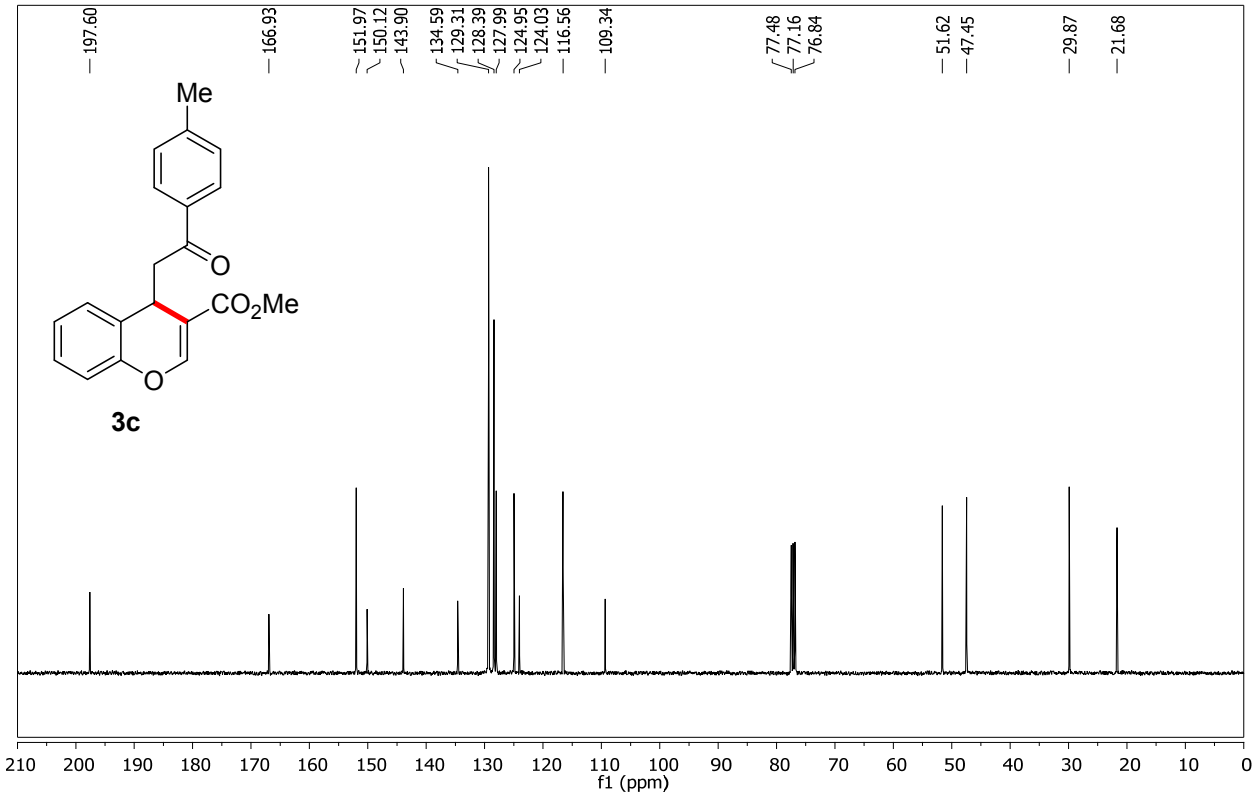
Methyl 4-(2-(4-methoxyphenyl)-2-oxoethyl)-4*H*-chromene-3-carboxylate (3b)



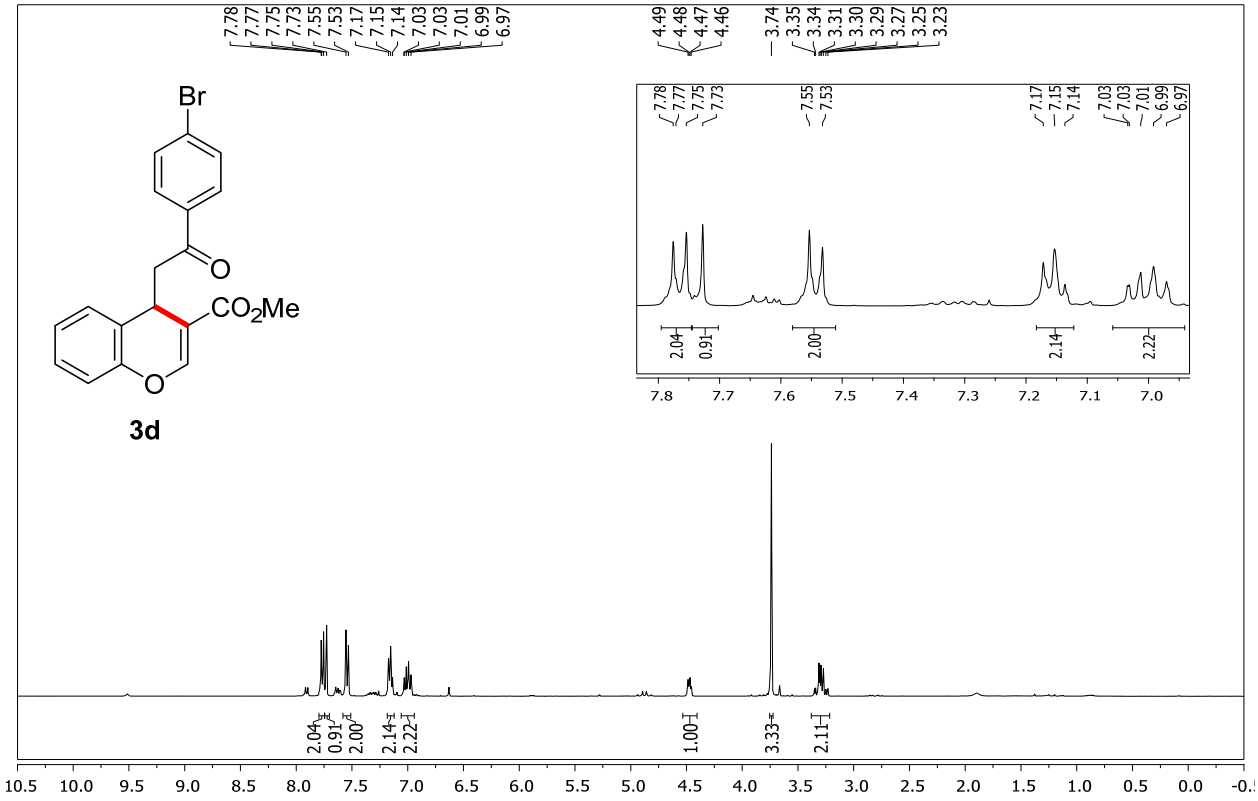


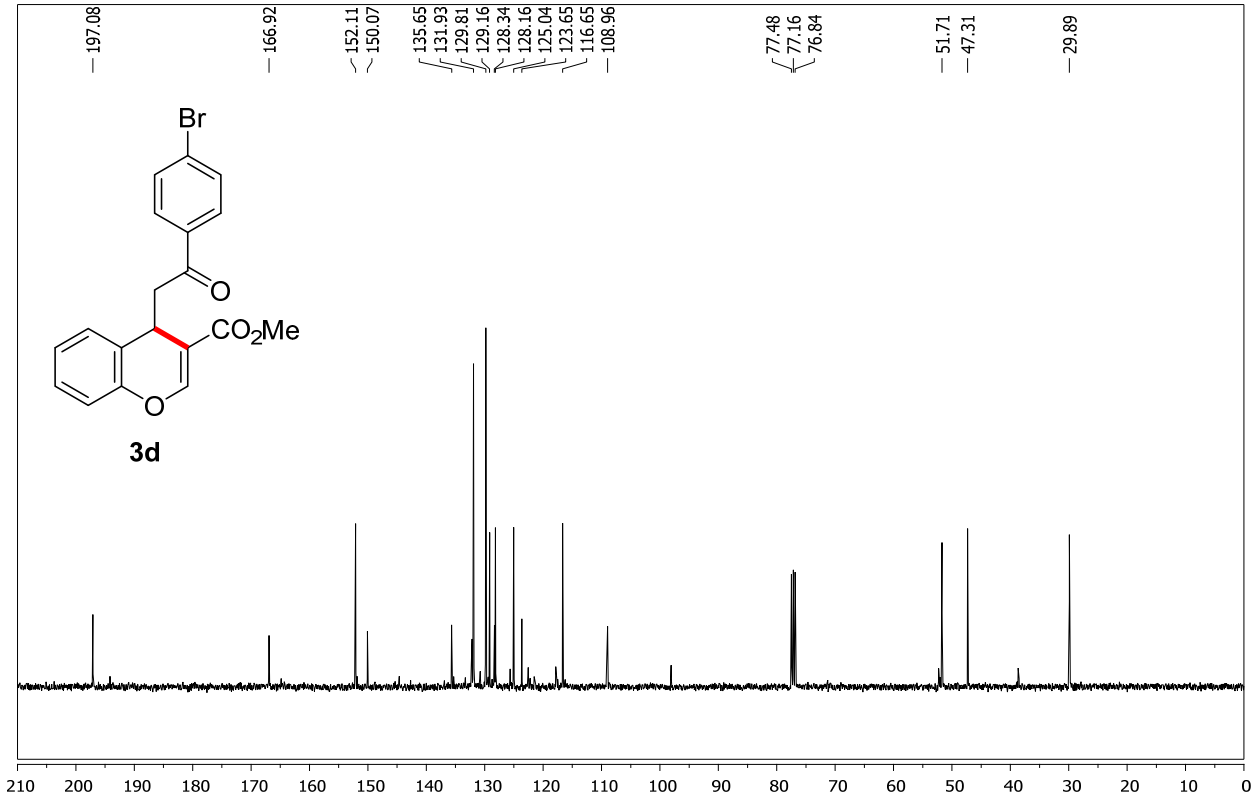
Methyl-4-(2-oxo-2-(*p*-tolyl)ethyl)-4*H*-chromene-3-carboxylate (3c)



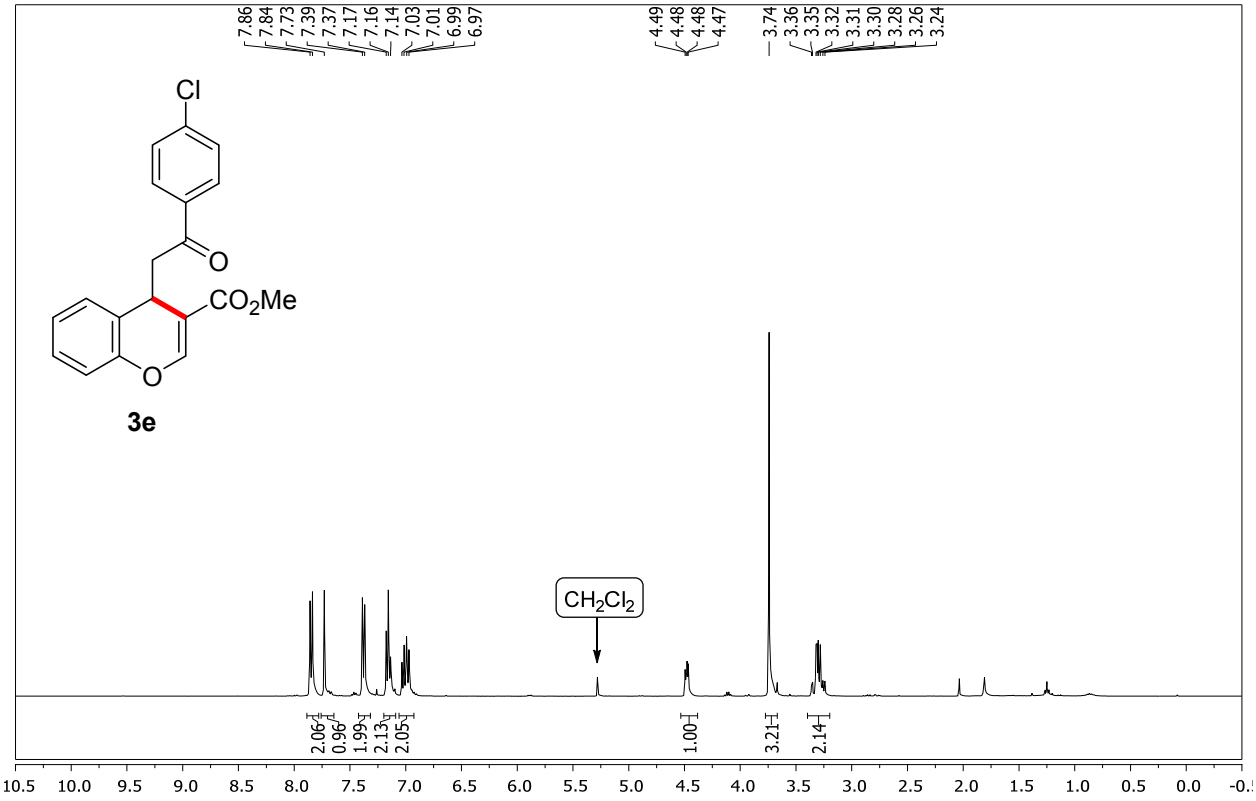


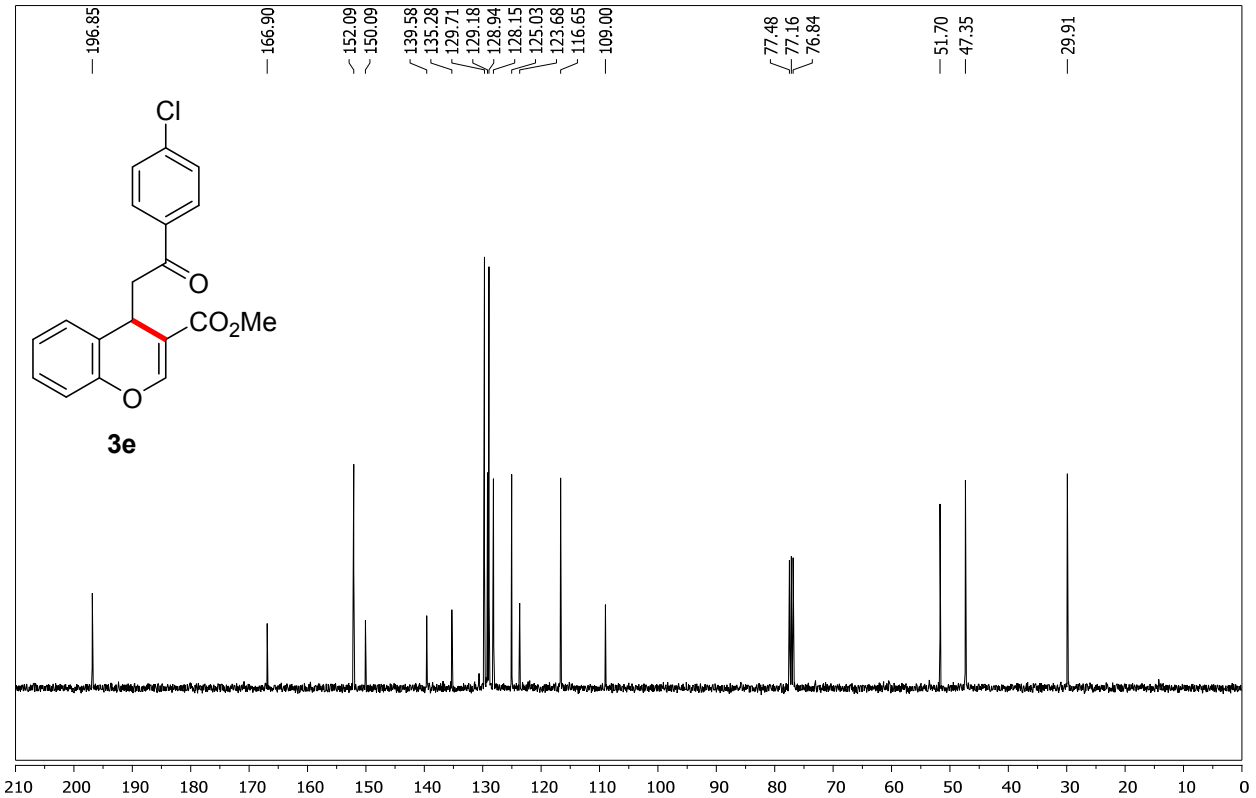
Methyl 4-(2-(4-bromophenyl)-2-oxoethyl)-4*H*-chromene-3-carboxylate (3d)



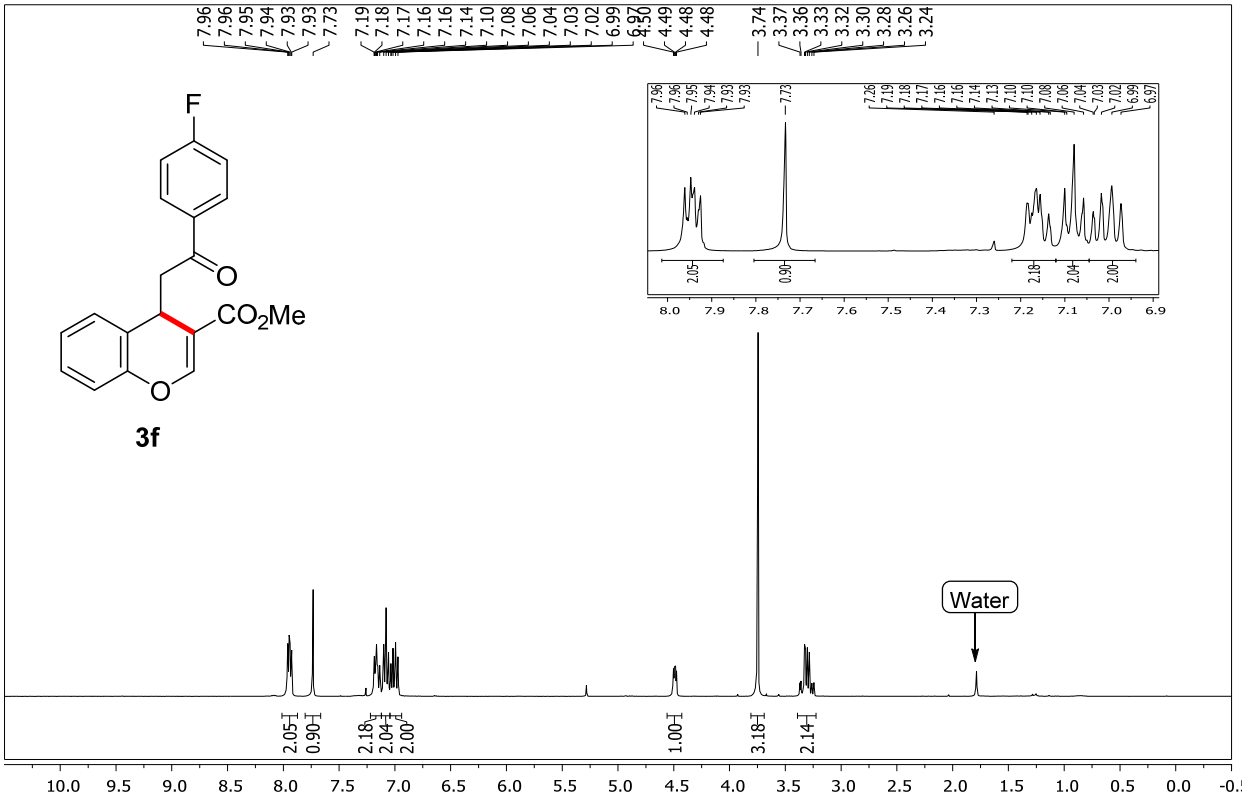


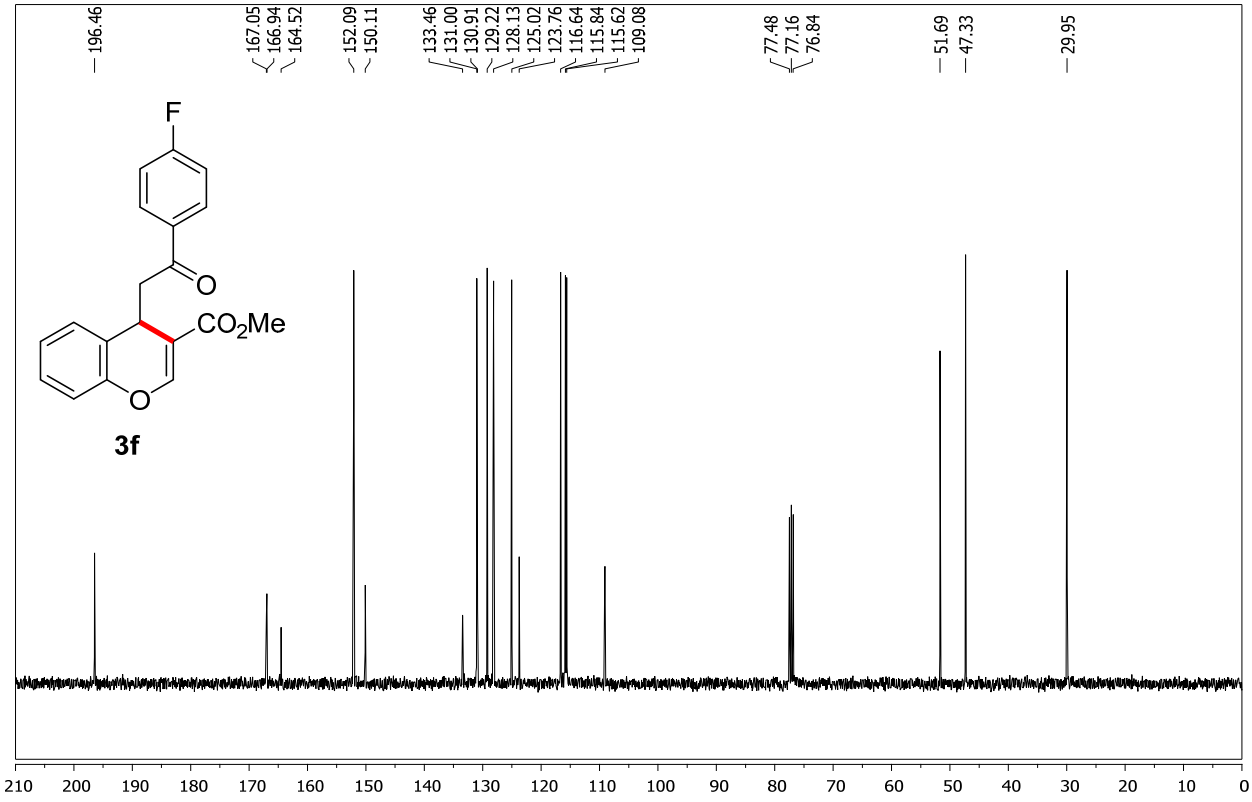
Methyl 4-(2-(4-chlorophenyl)-2-oxoethyl)-4*H*-chromene-3-carboxylate (3e)



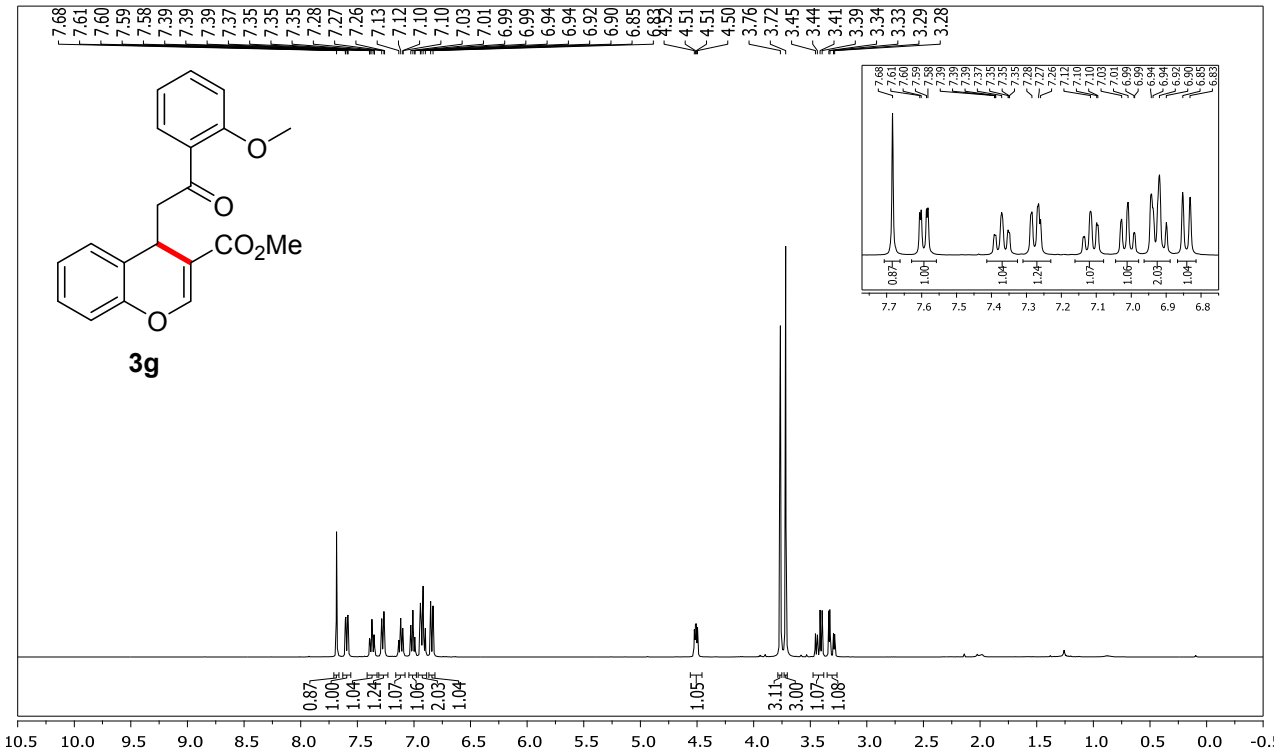


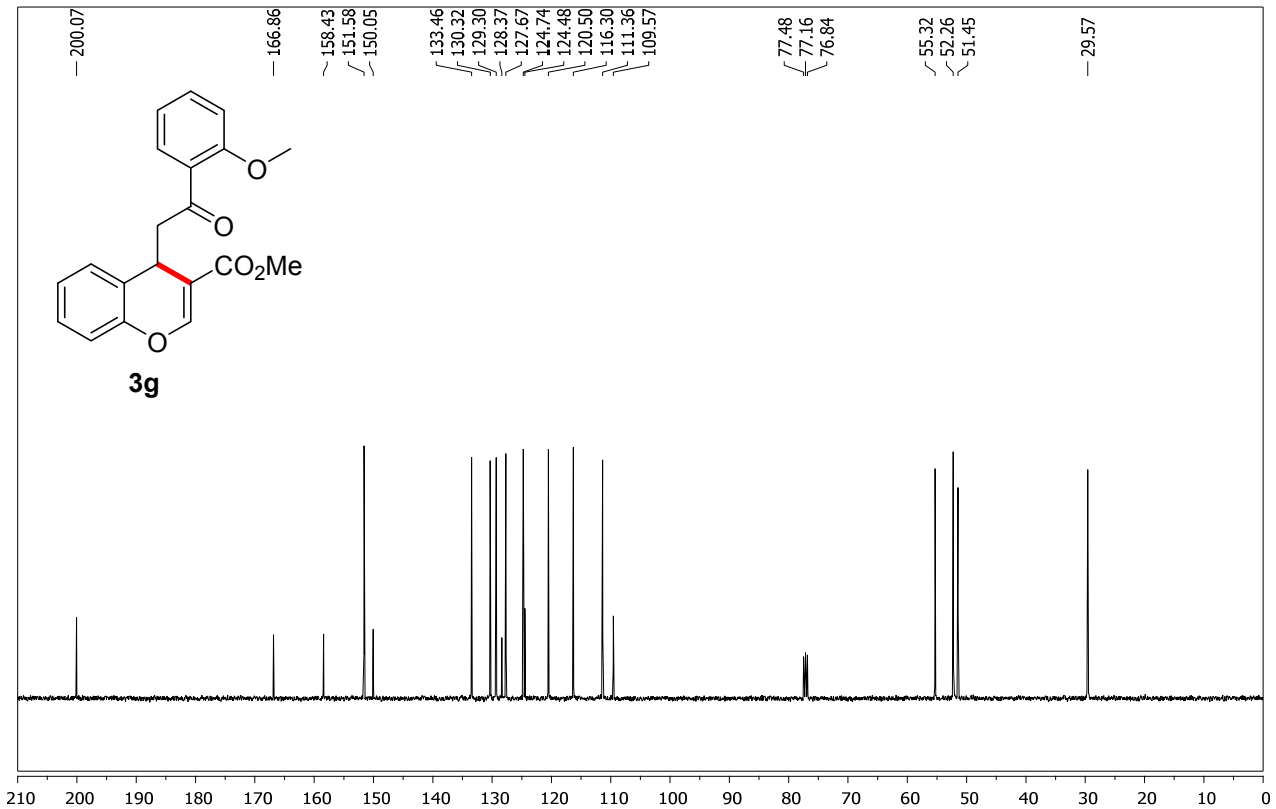
Methyl 4-(2-(4-fluorophenyl)-2-oxoethyl)-4*H*-chromene-3-carboxylate (3f)



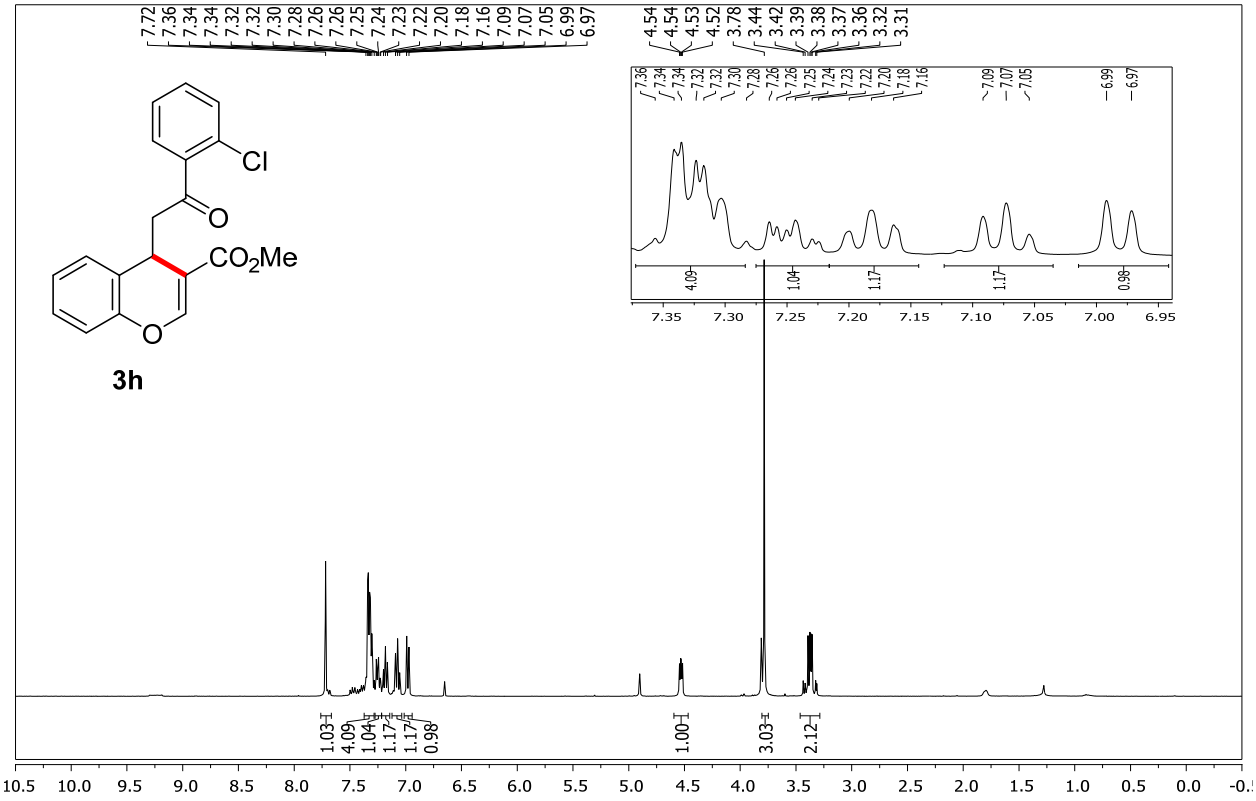


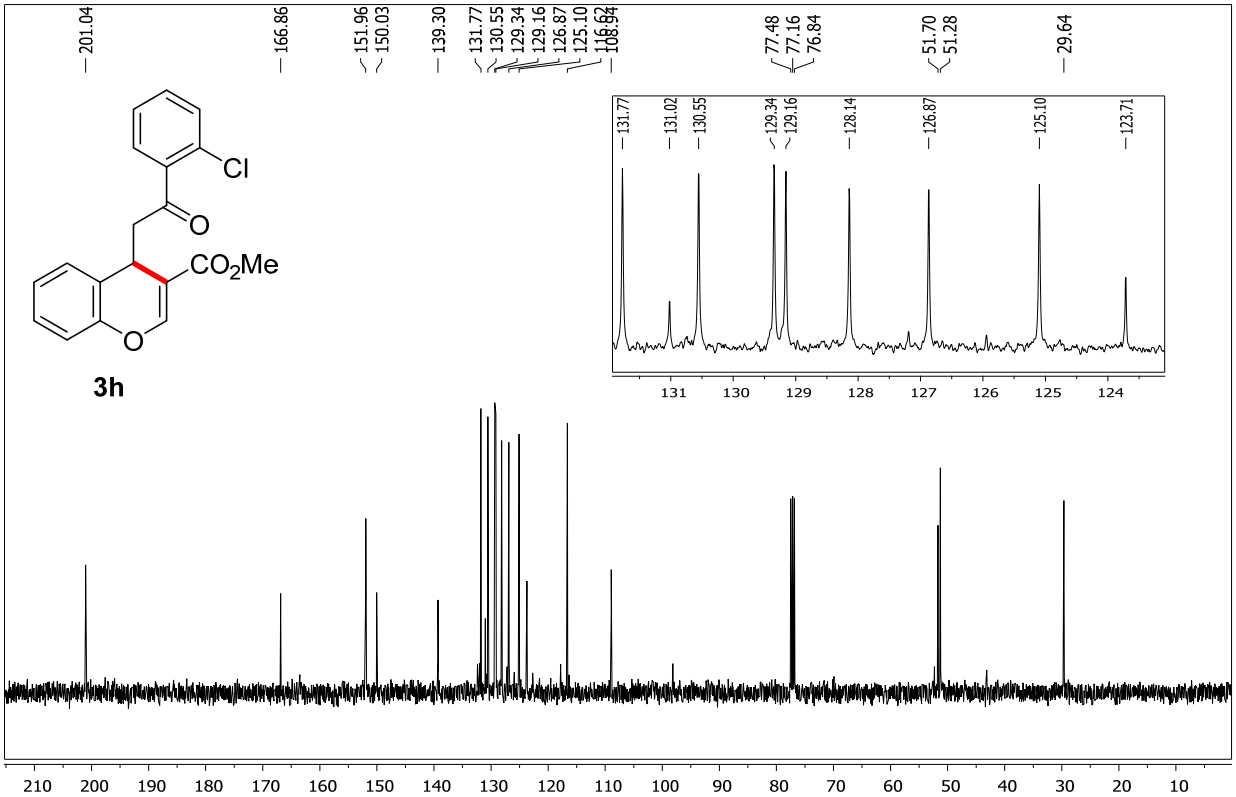
Methyl-4-(2-(2-methoxyphenyl)-2-oxoethyl)-4*H*-chromene-3-carboxylate (3g)



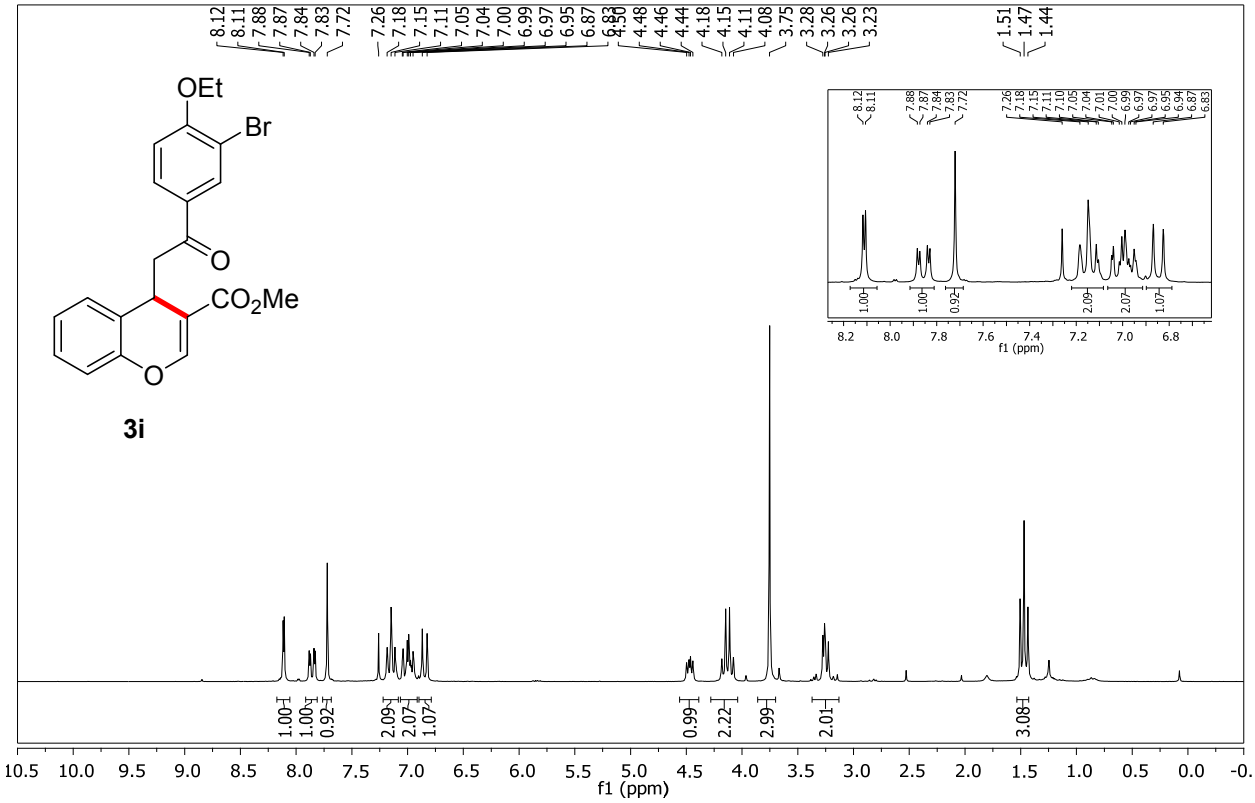


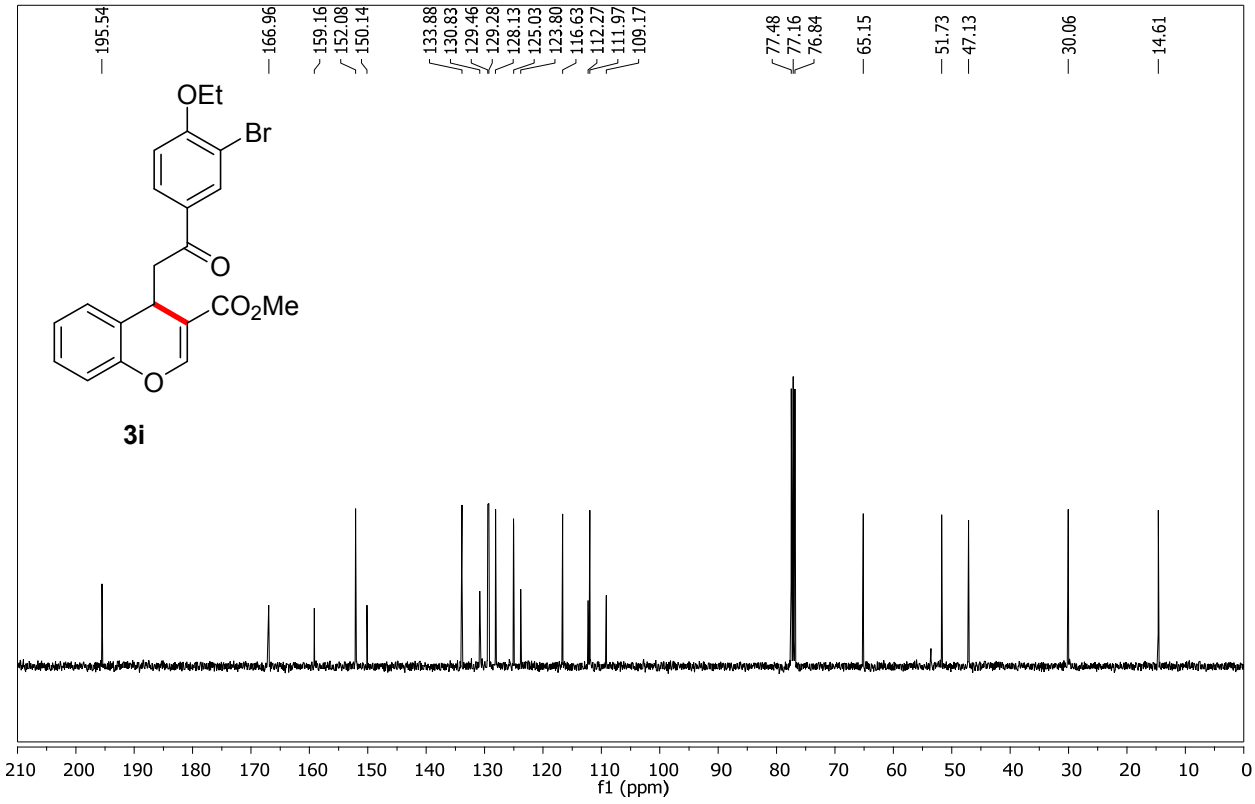
Methyl 4-(2-(2-chlorophenyl)-2-oxoethyl)-4*H*-chromene-3-carboxylate (3h)



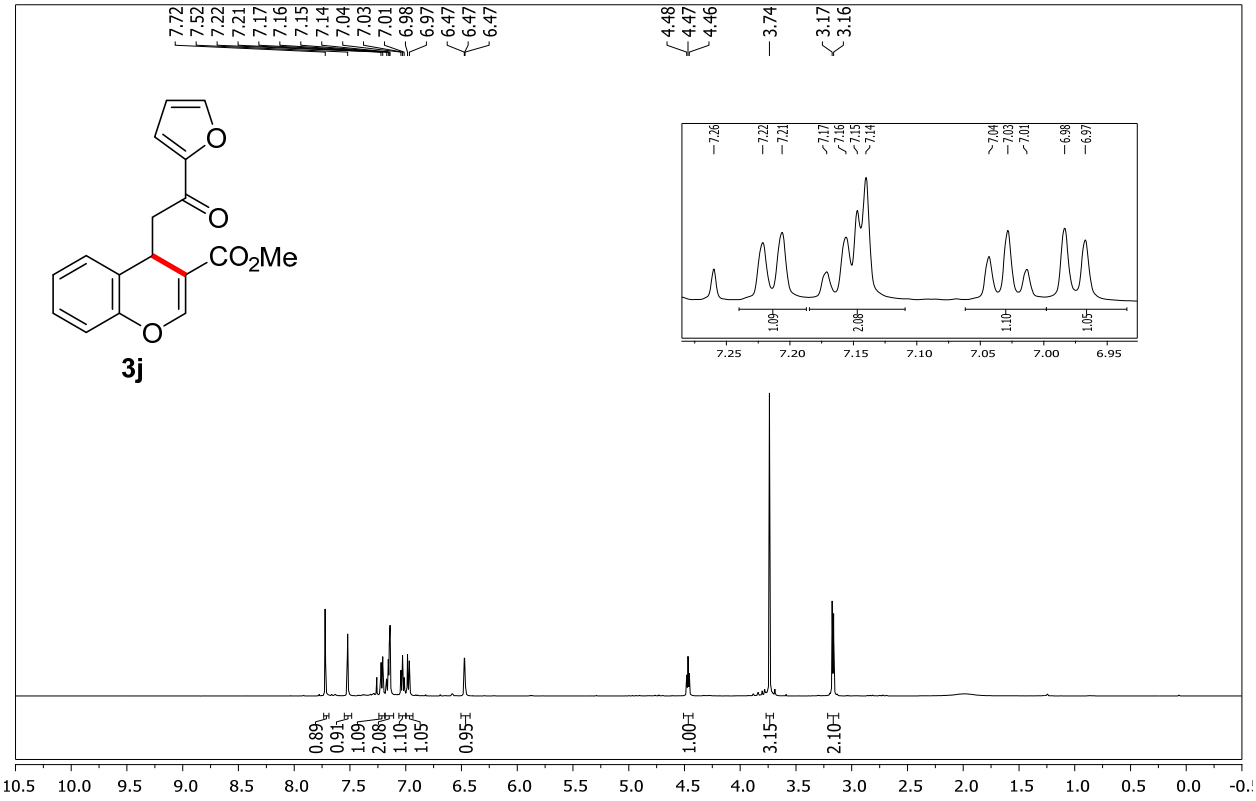


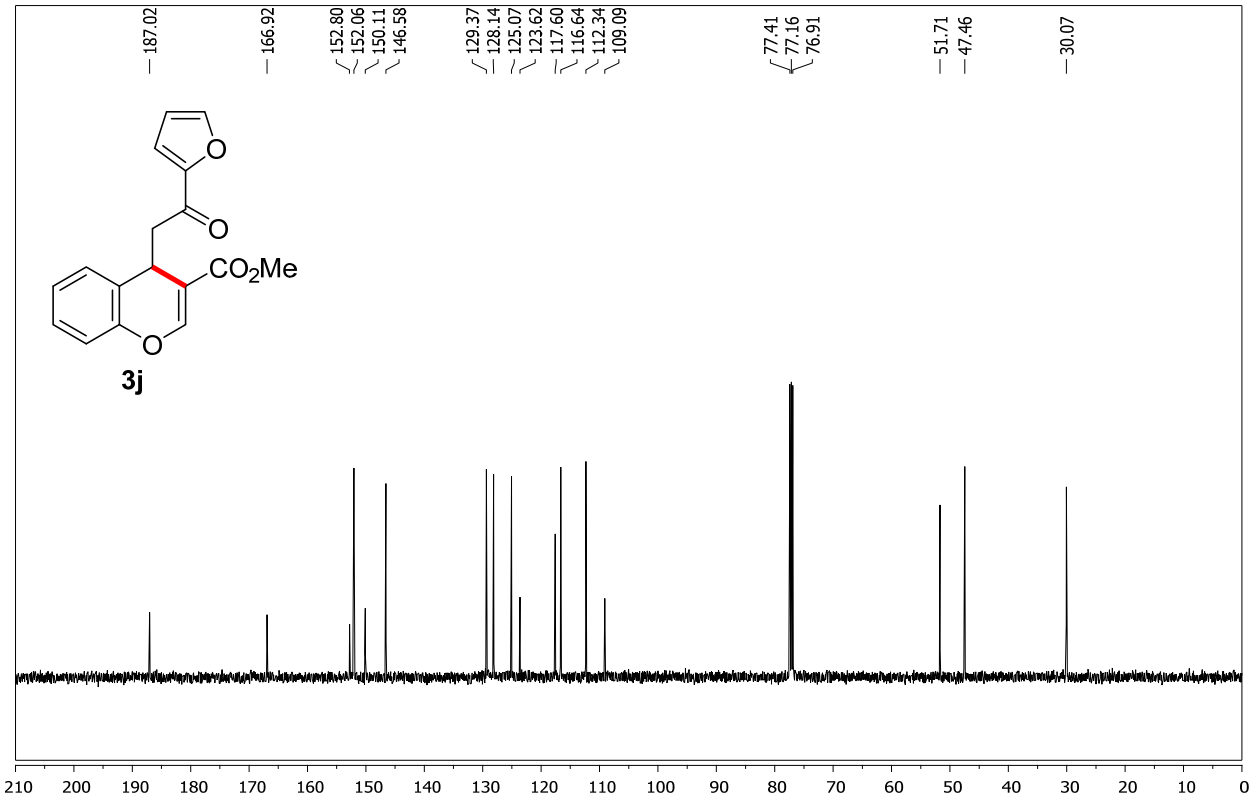
Methyl-4-(2-(3-bromo-4-ethoxyphenyl)-2-oxoethyl)-4*H*-chromene-3-carboxylate (3i)



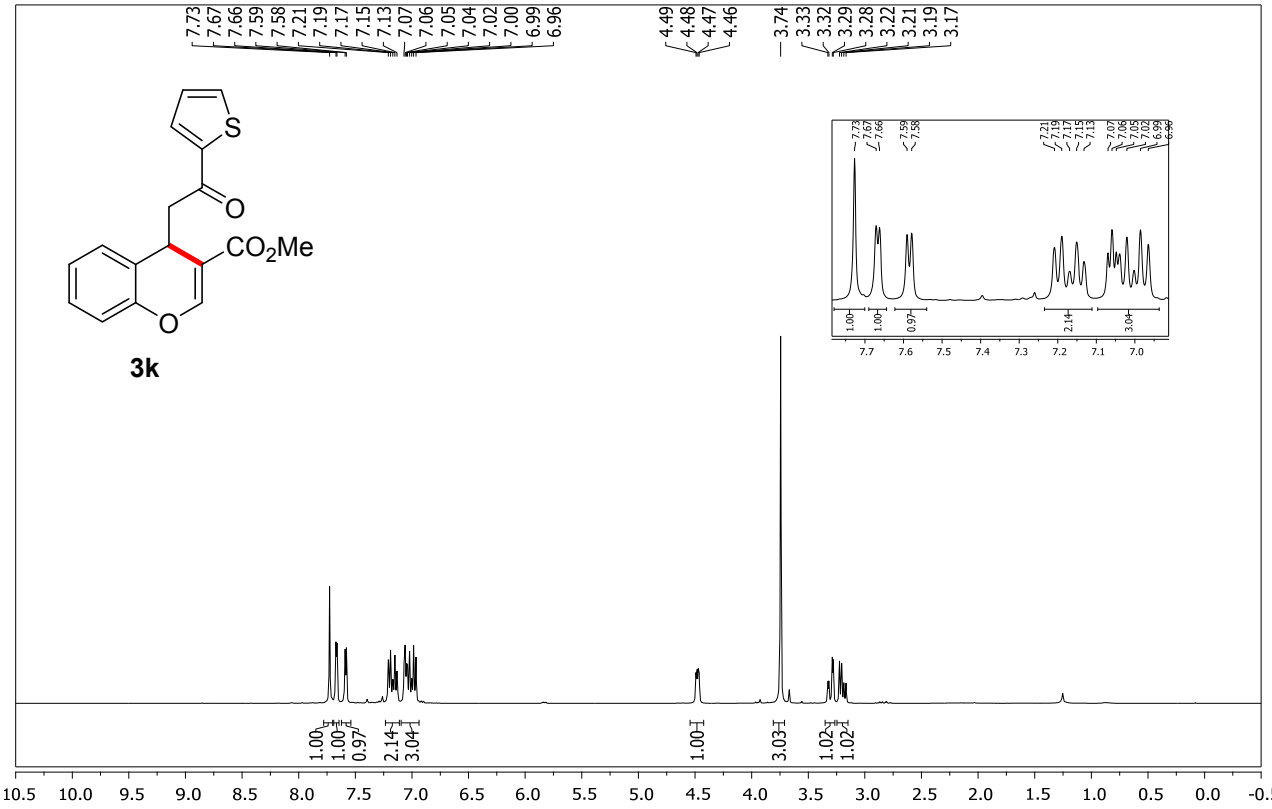


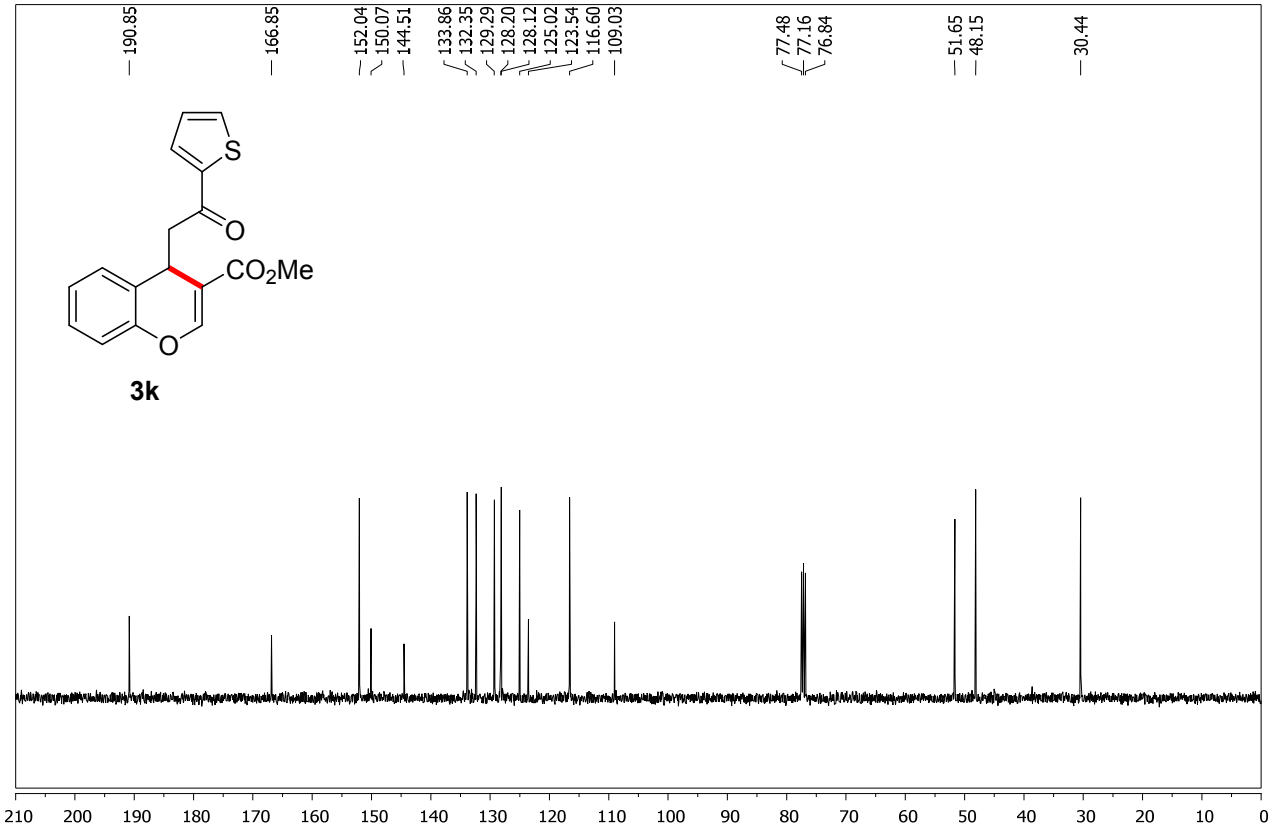
Methyl 4-(2-(furan-2-yl)-2-oxoethyl)-4*H*-chromene-3-carboxylate (3j)



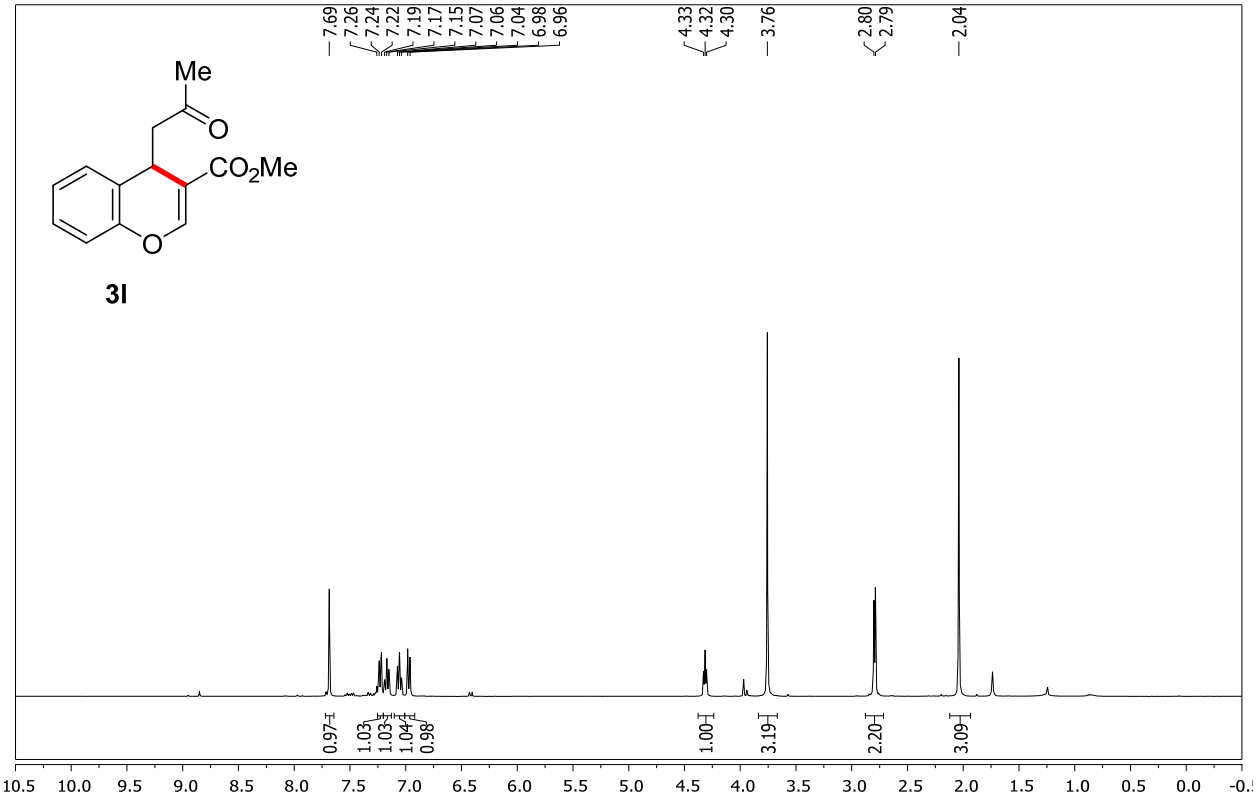


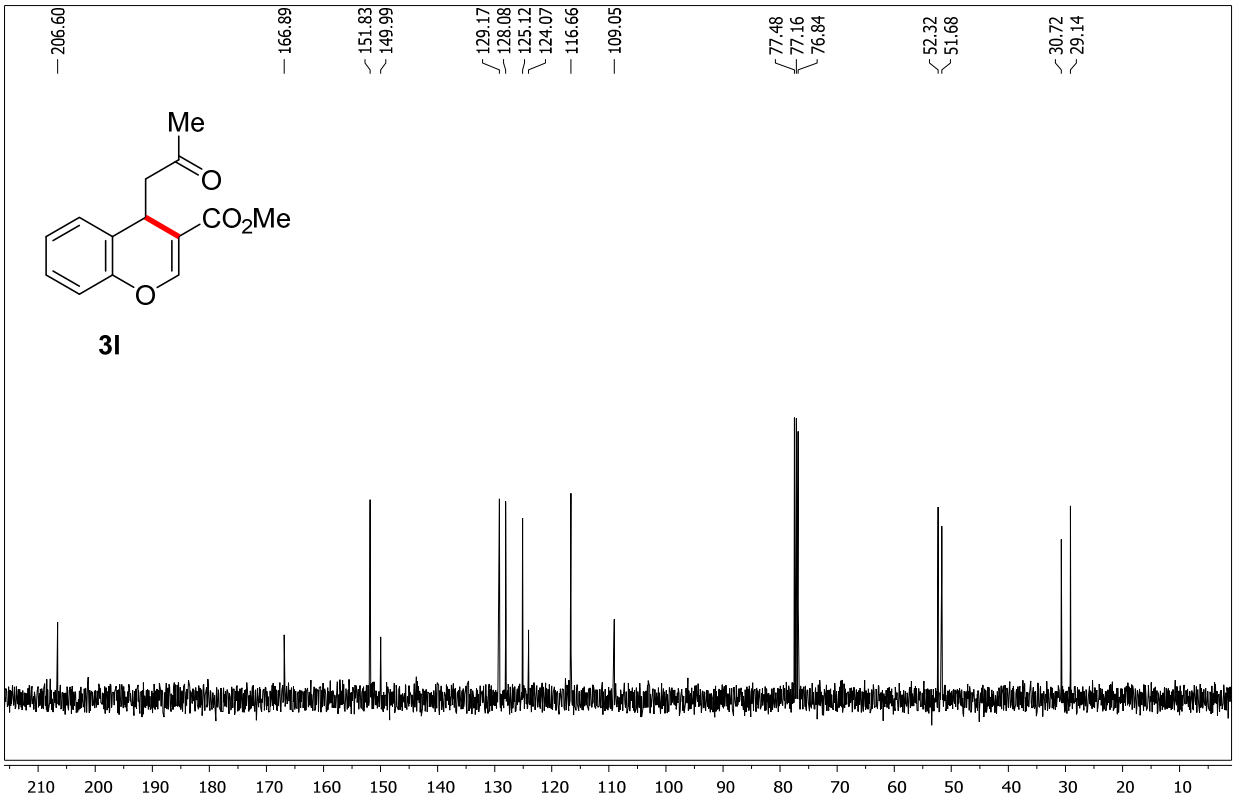
Methyl-4-(2-oxo-2-(thiophen-2-yl)ethyl)-4*H*-chromene-3-carboxylate (3k)



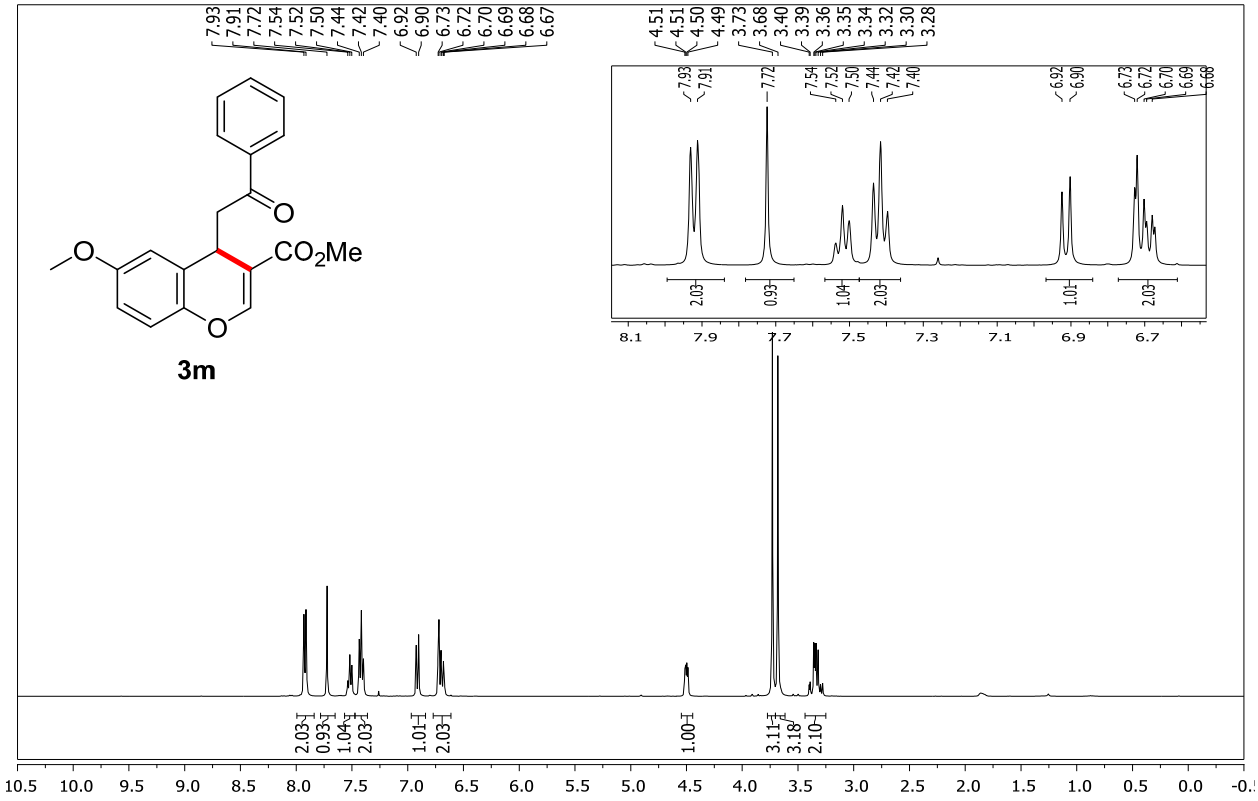


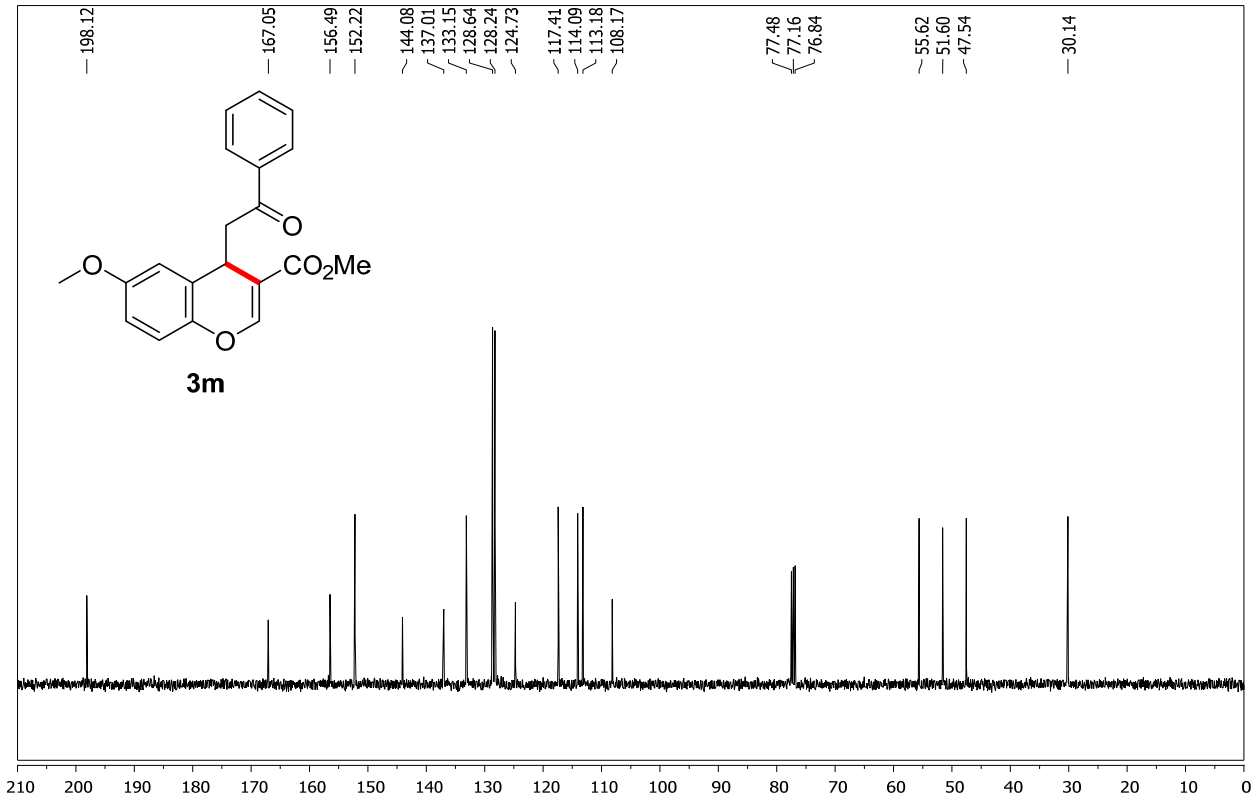
Methyl 4-(2-oxopropyl)-4*H*-chromene-3-carboxylate (3l)



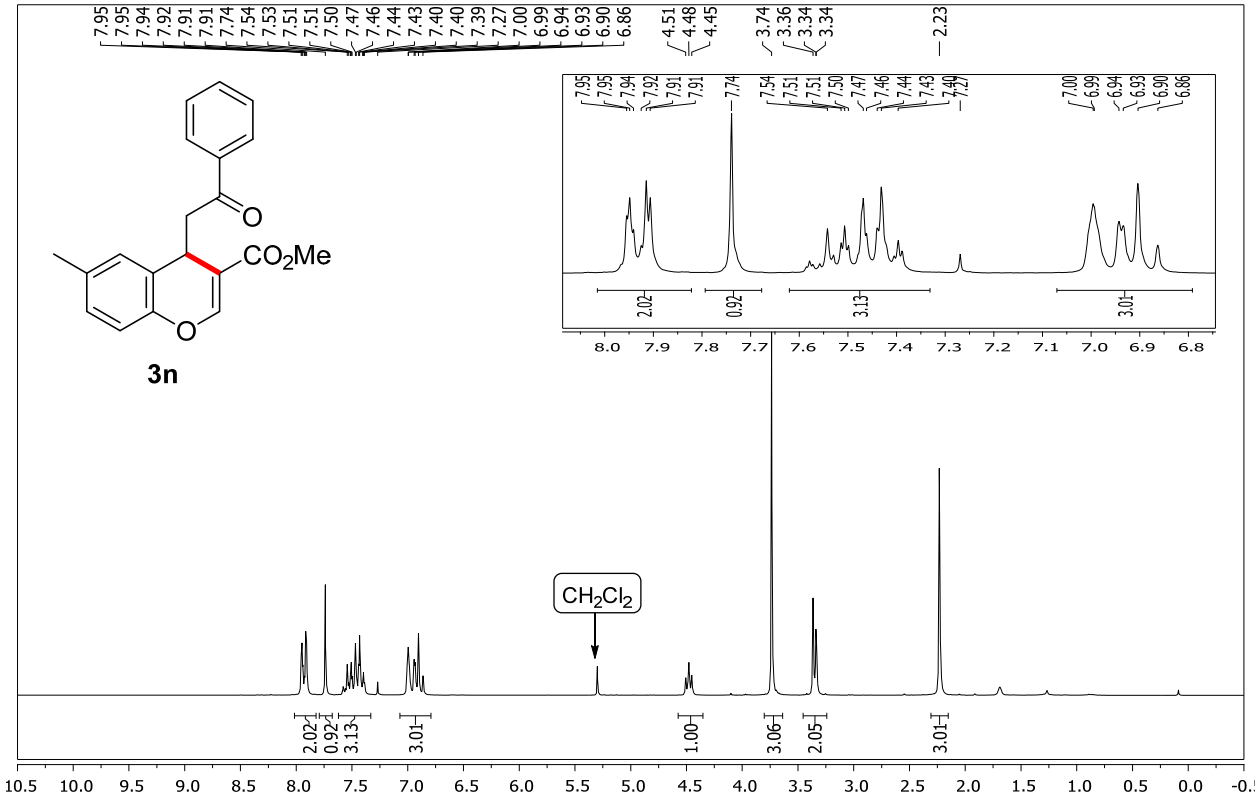


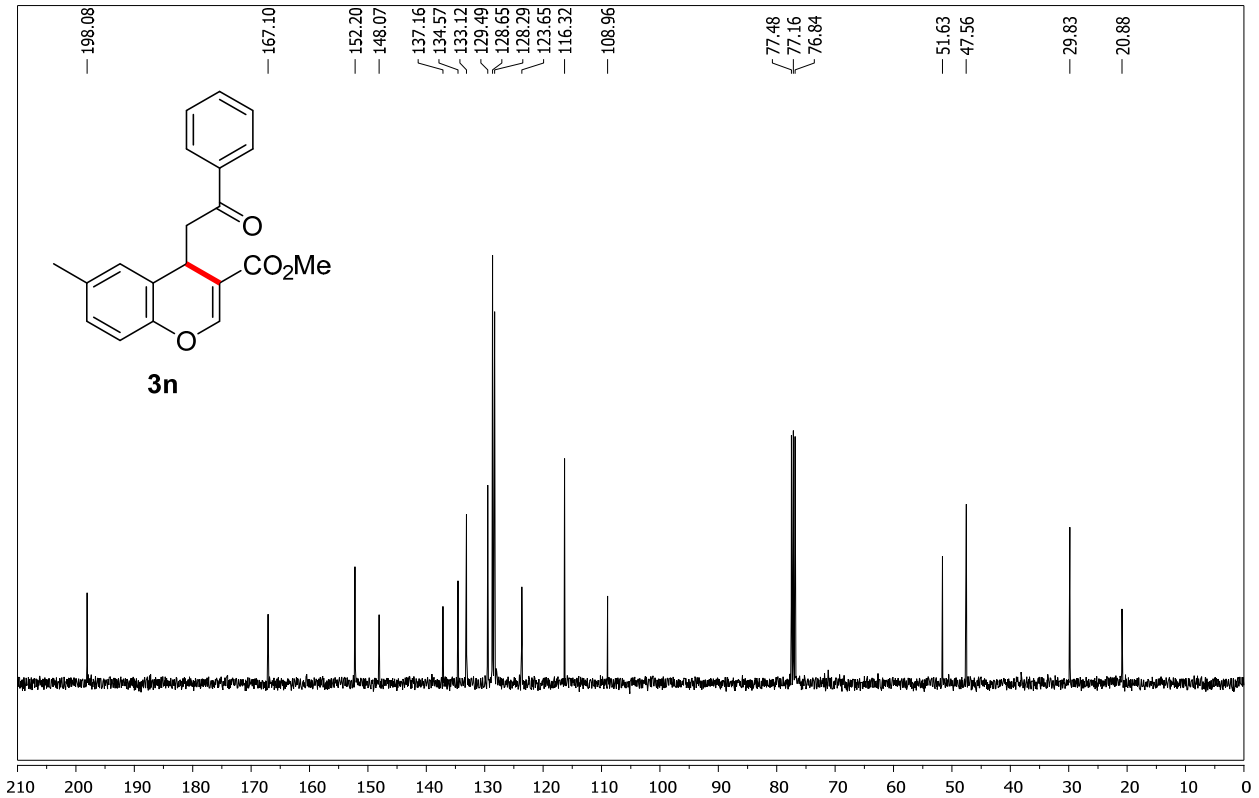
Methyl 6-methoxy-4-(2-oxo-2-phenylethyl)-4*H*-chromene-3-carboxylate (3m)



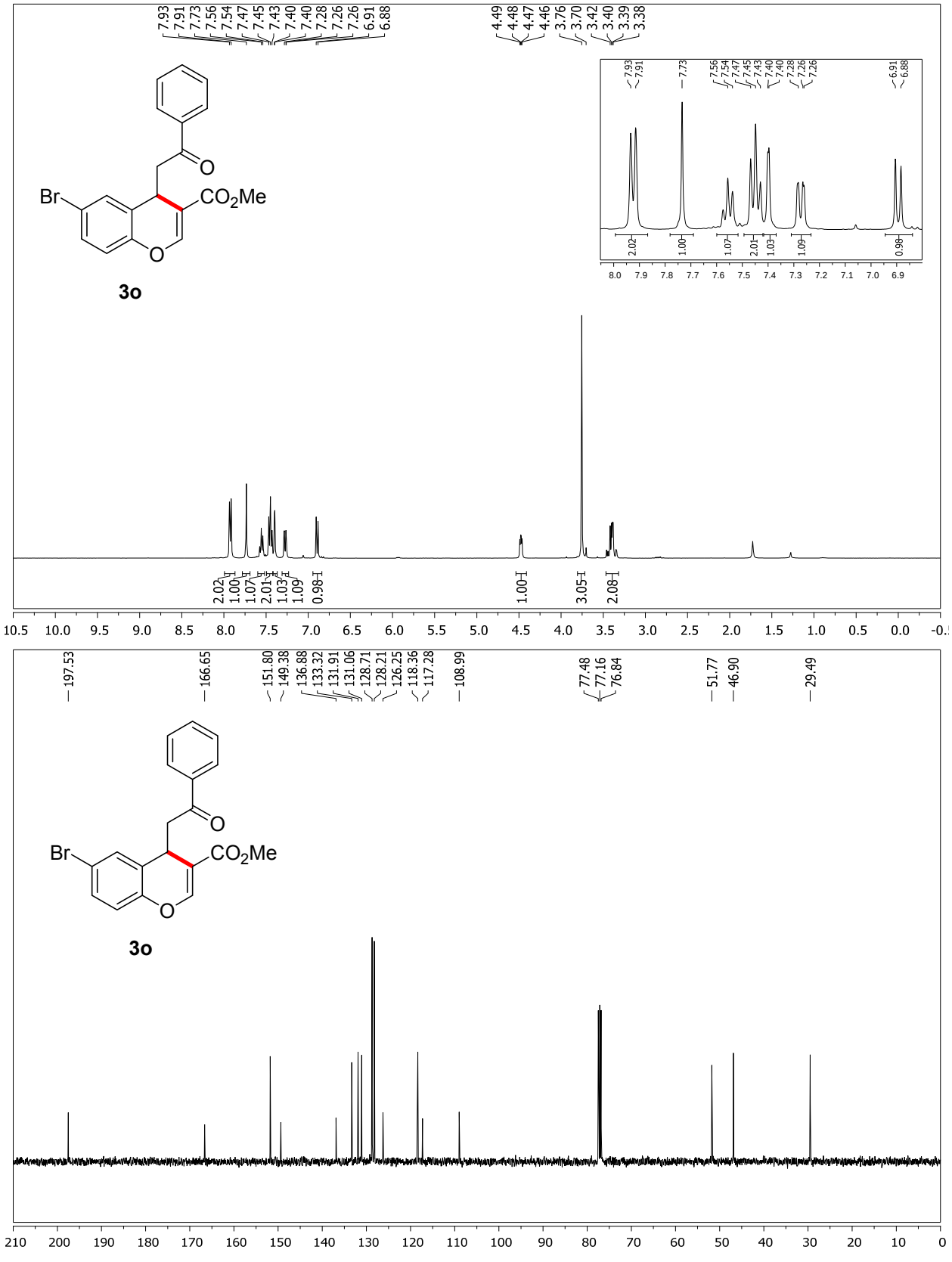


Methyl 6-methyl-4-(2-oxo-2-phenylethyl)-4*H*-chromene-3-carboxylate (3n)

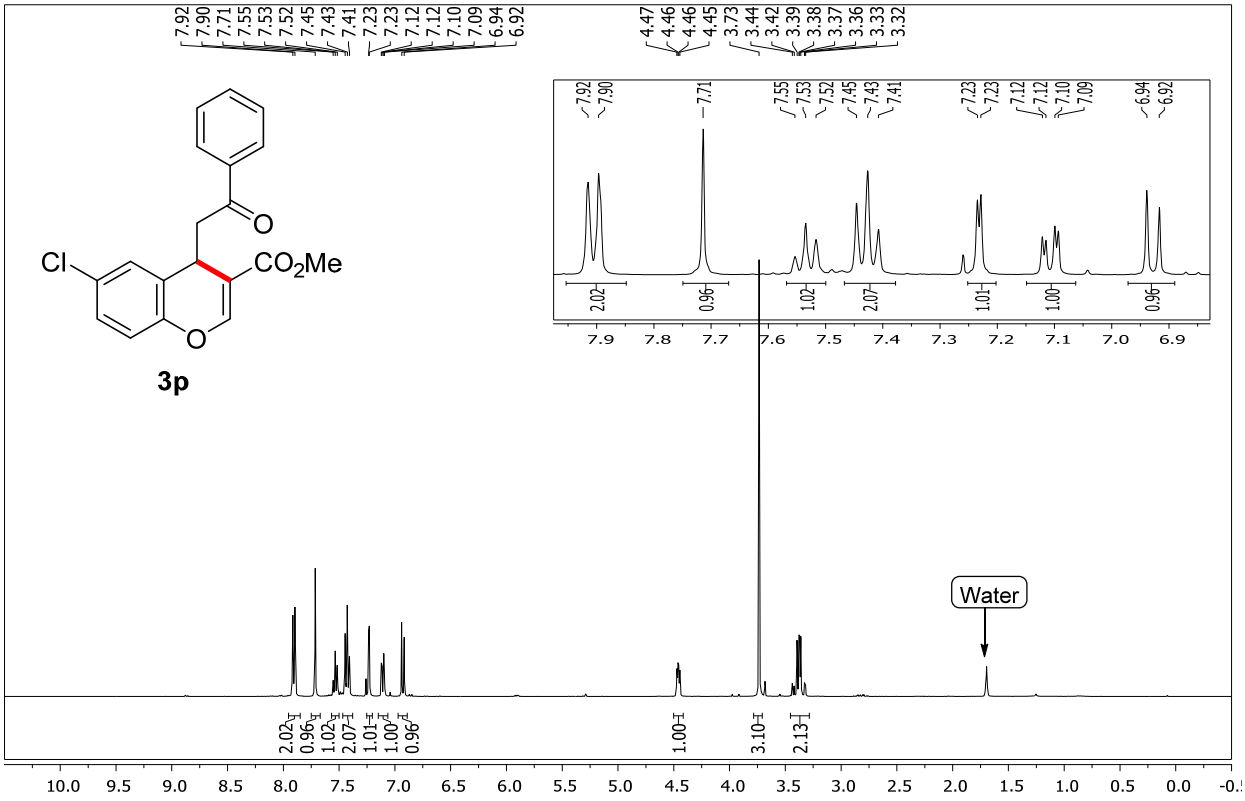


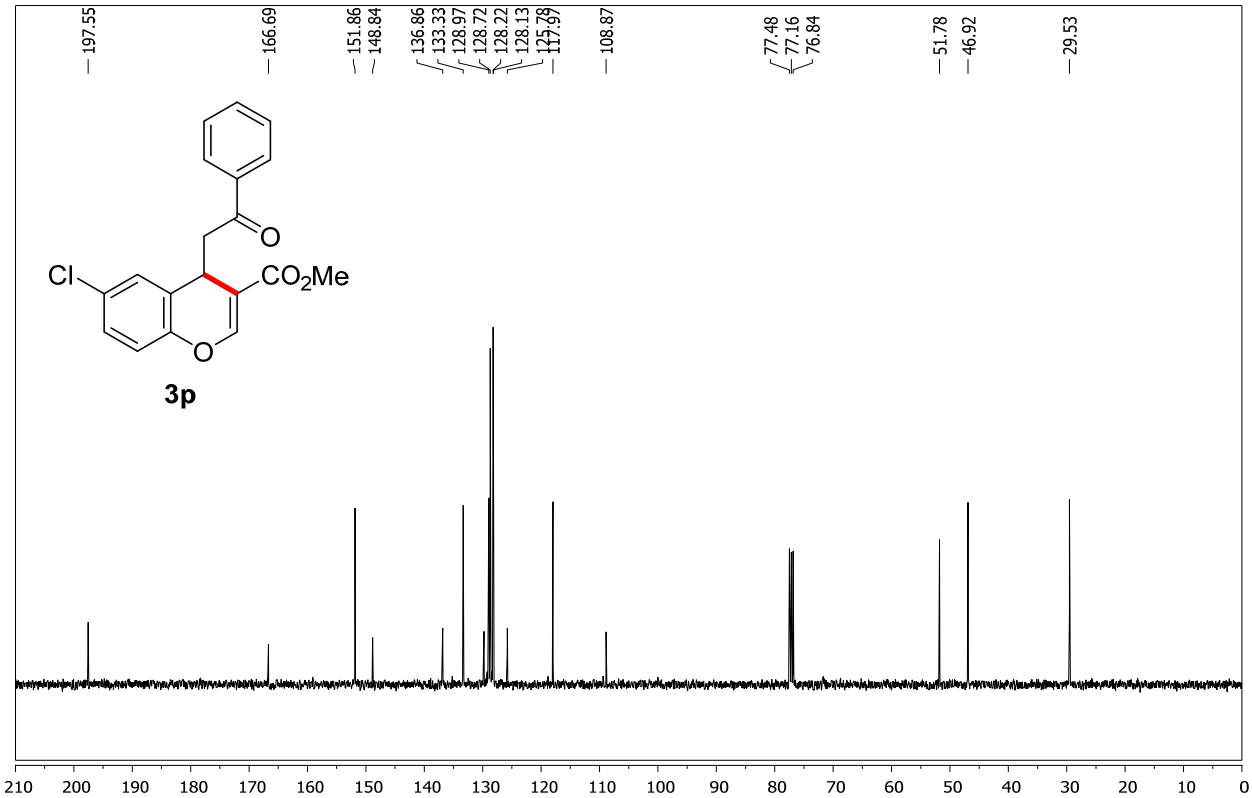


Methyl-6-bromo-4-(2-oxo-2-phenylethyl)-4*H*-chromene-3-carboxylate (3o)

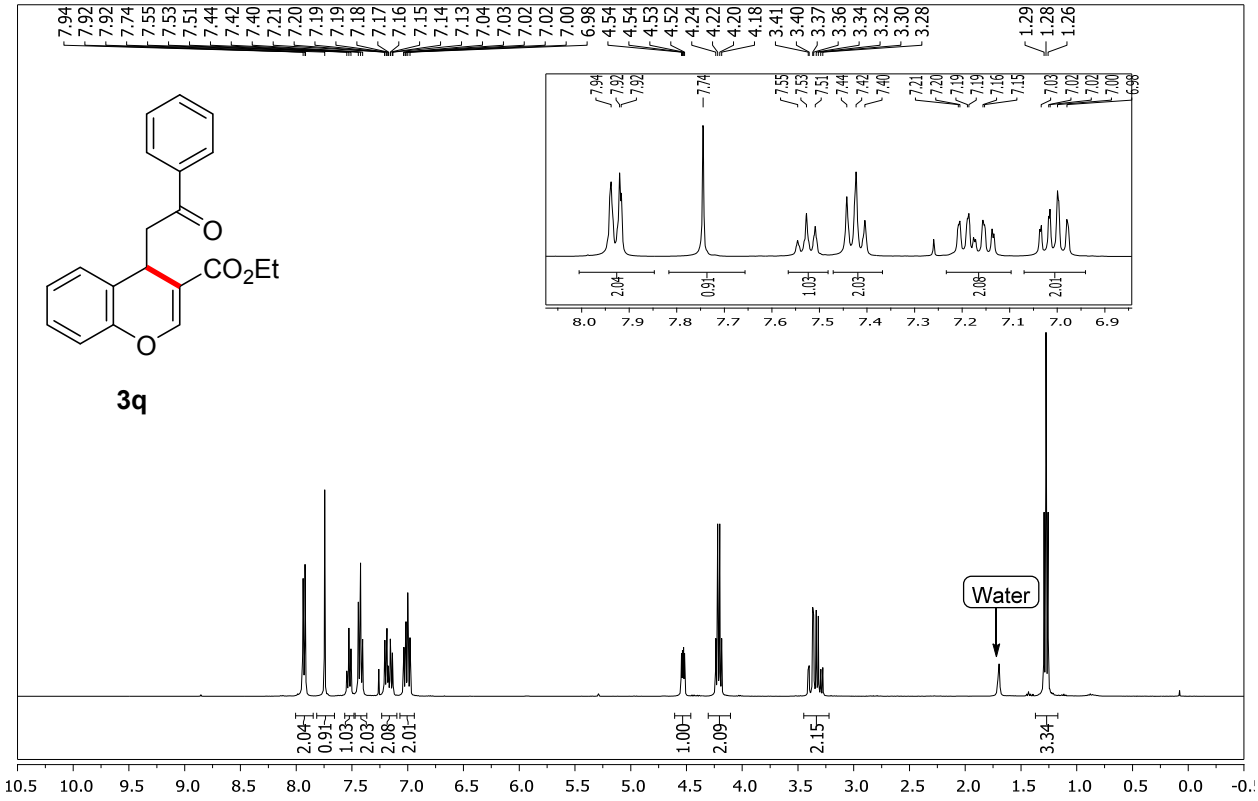


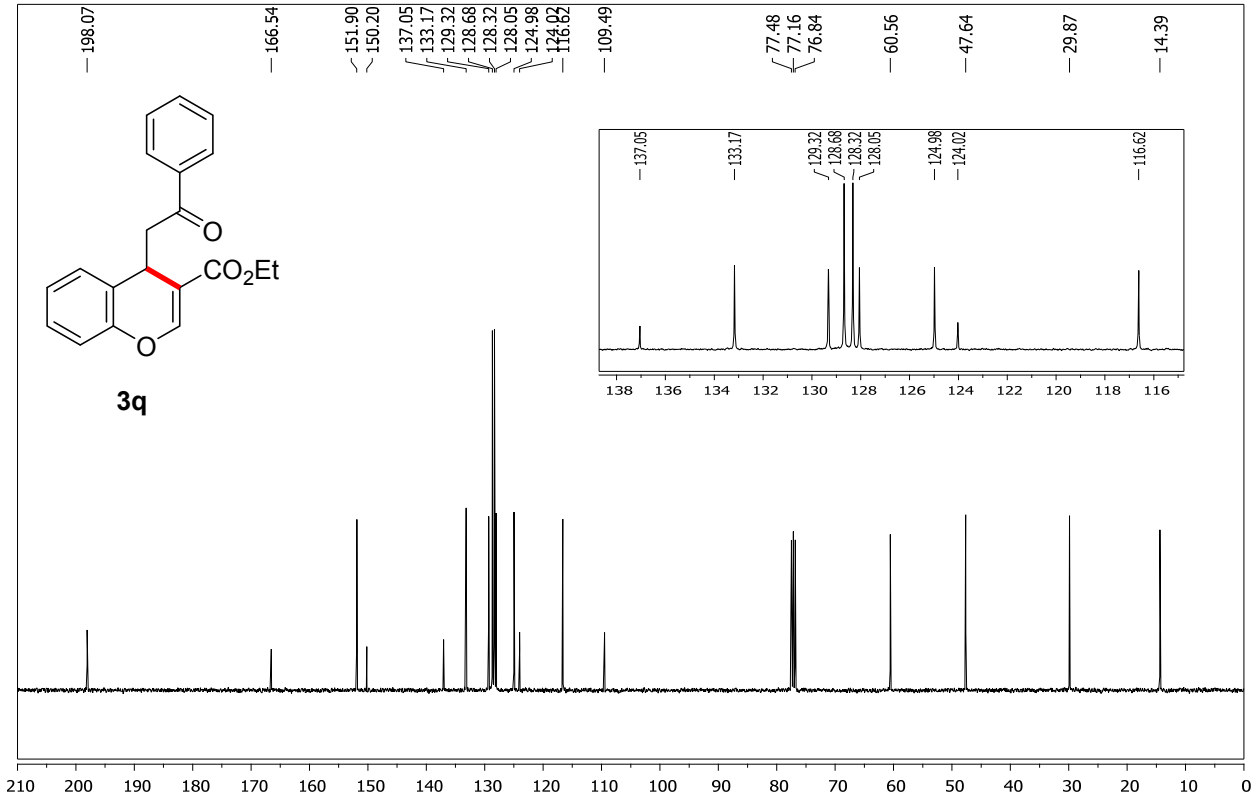
Methyl 6-chloro-4-(2-oxo-2-phenylethyl)-4*H*-chromene-3-carboxylate (3p)



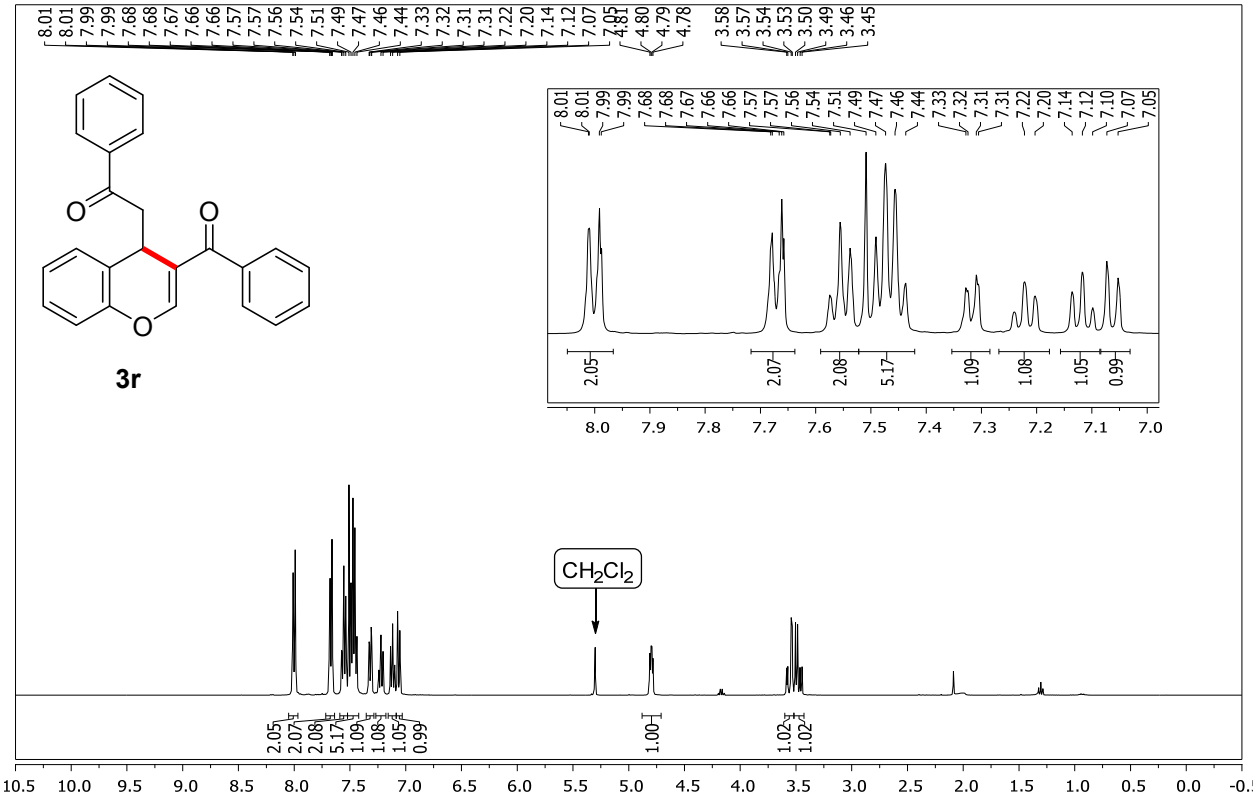


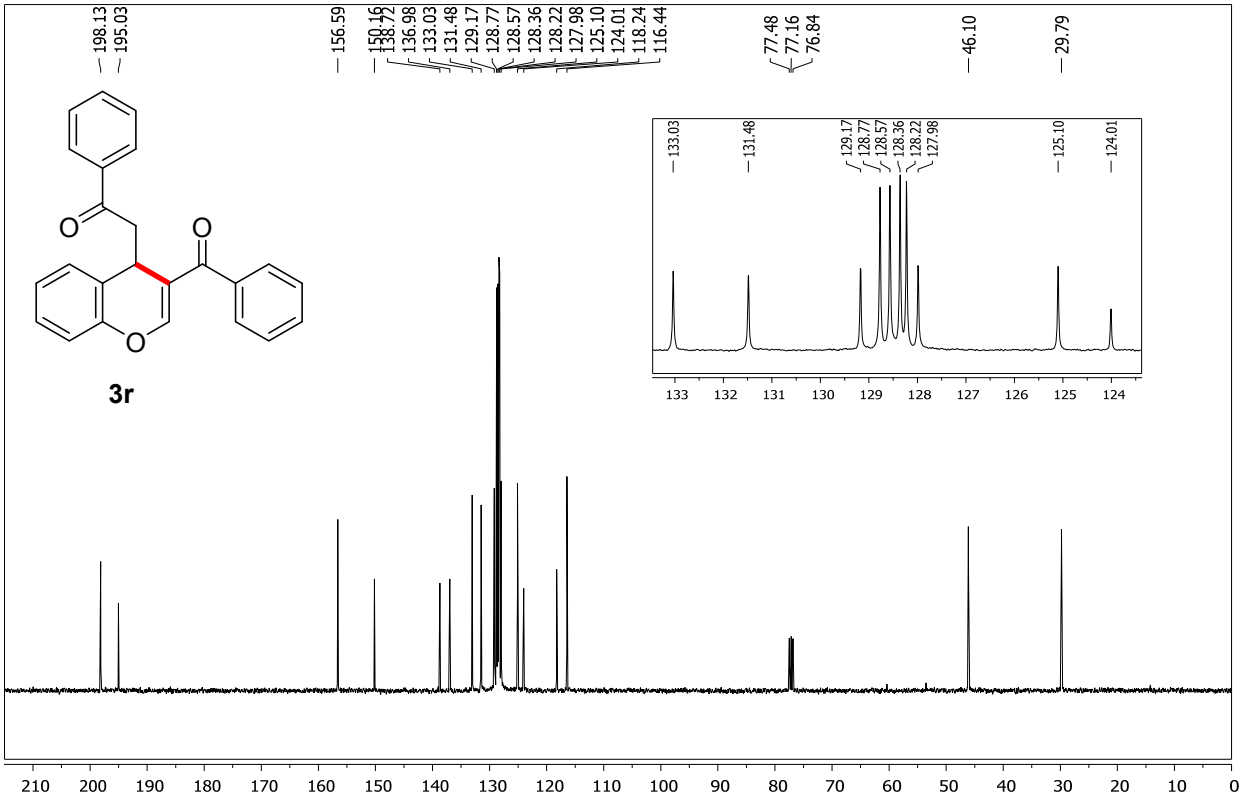
Ethyl 4-(2-oxo-2-phenylethyl)-4*H*-chromene-3-carboxylate (3q)



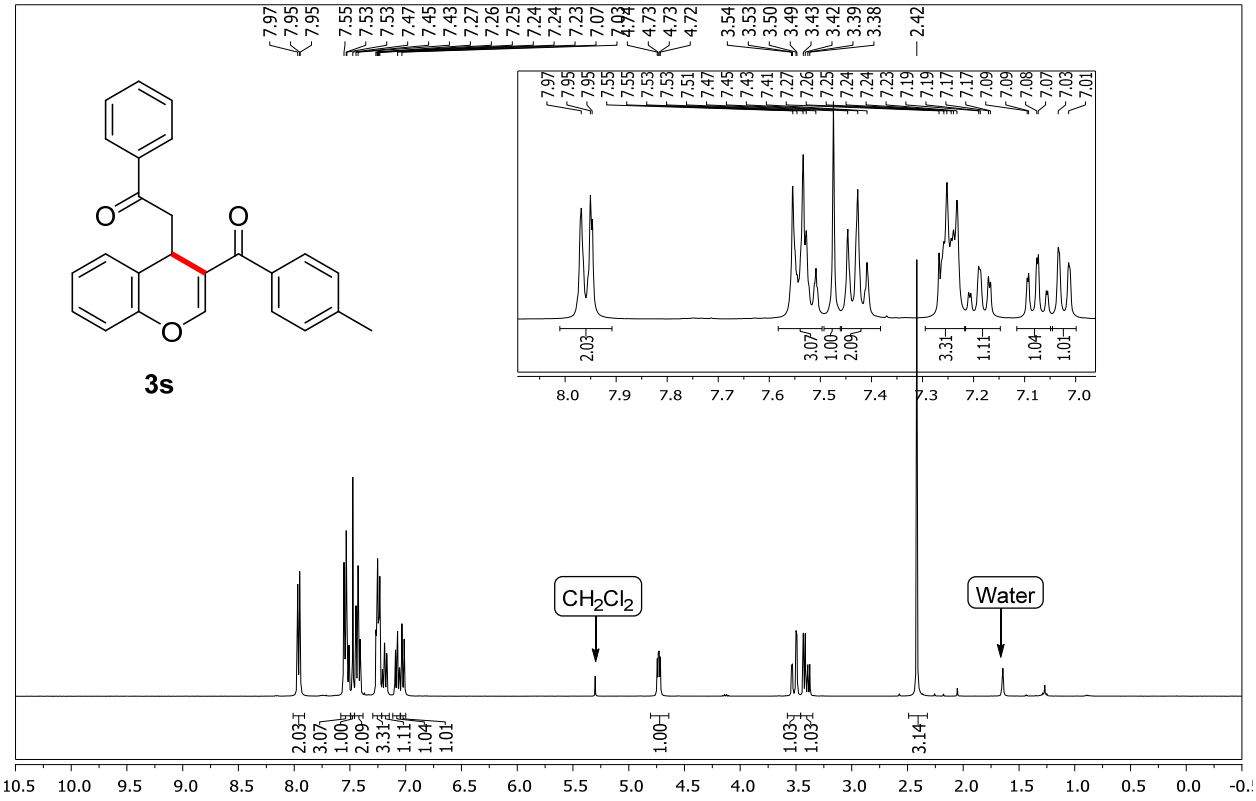


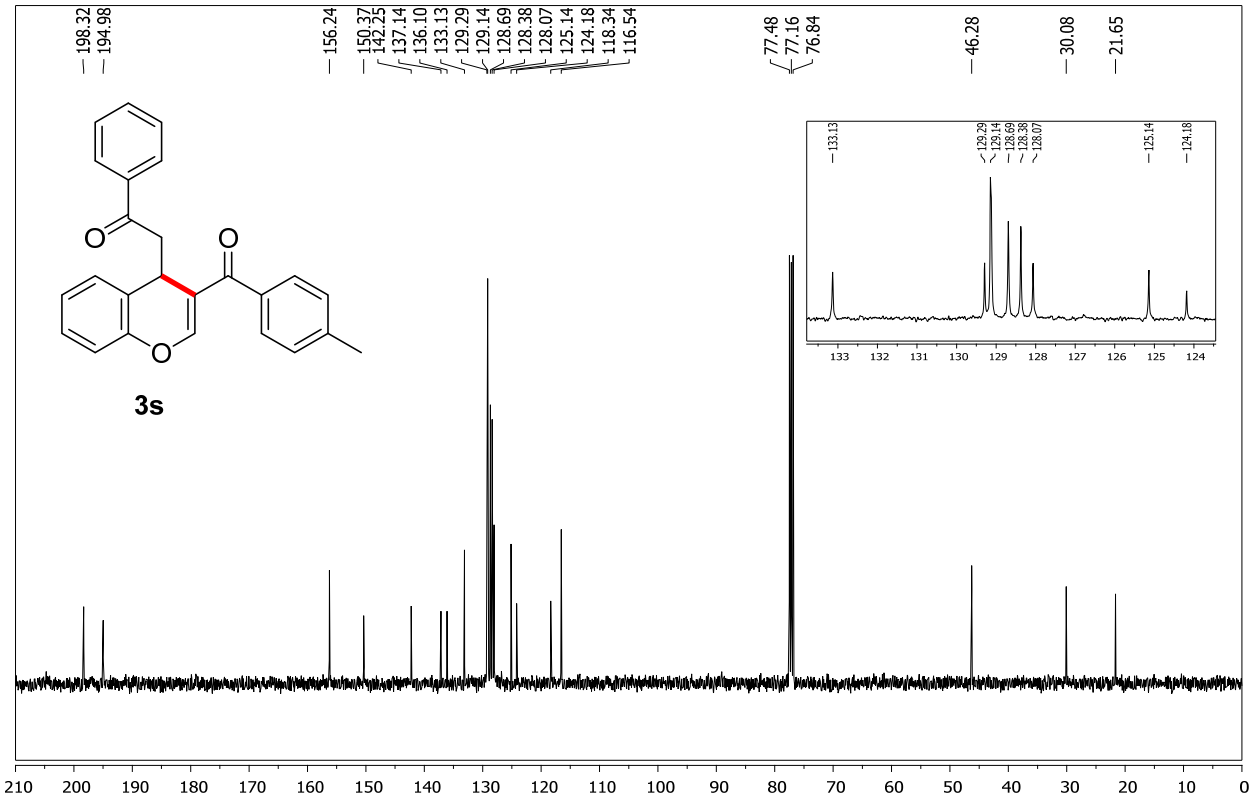
2-(3-Benzoyl-4*H*-chromen-4-yl)-1-phenylethan-1-one (3r)



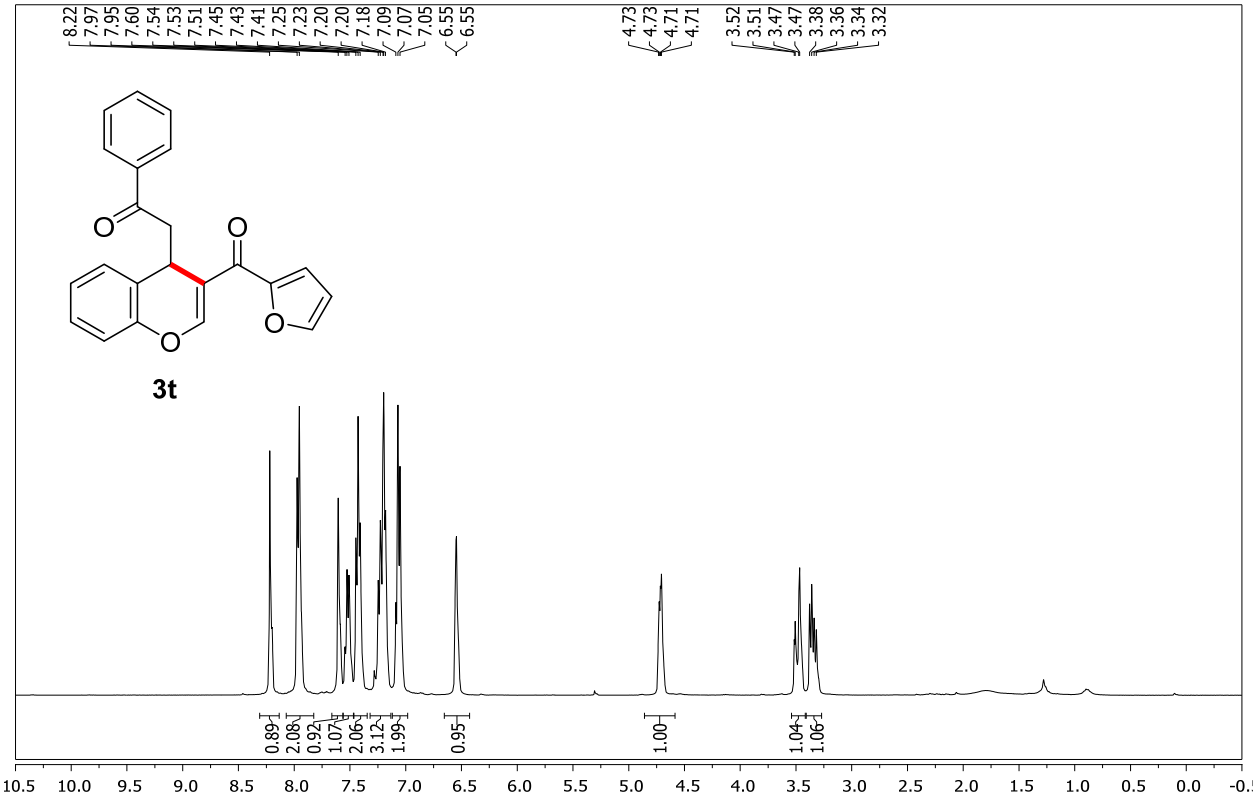


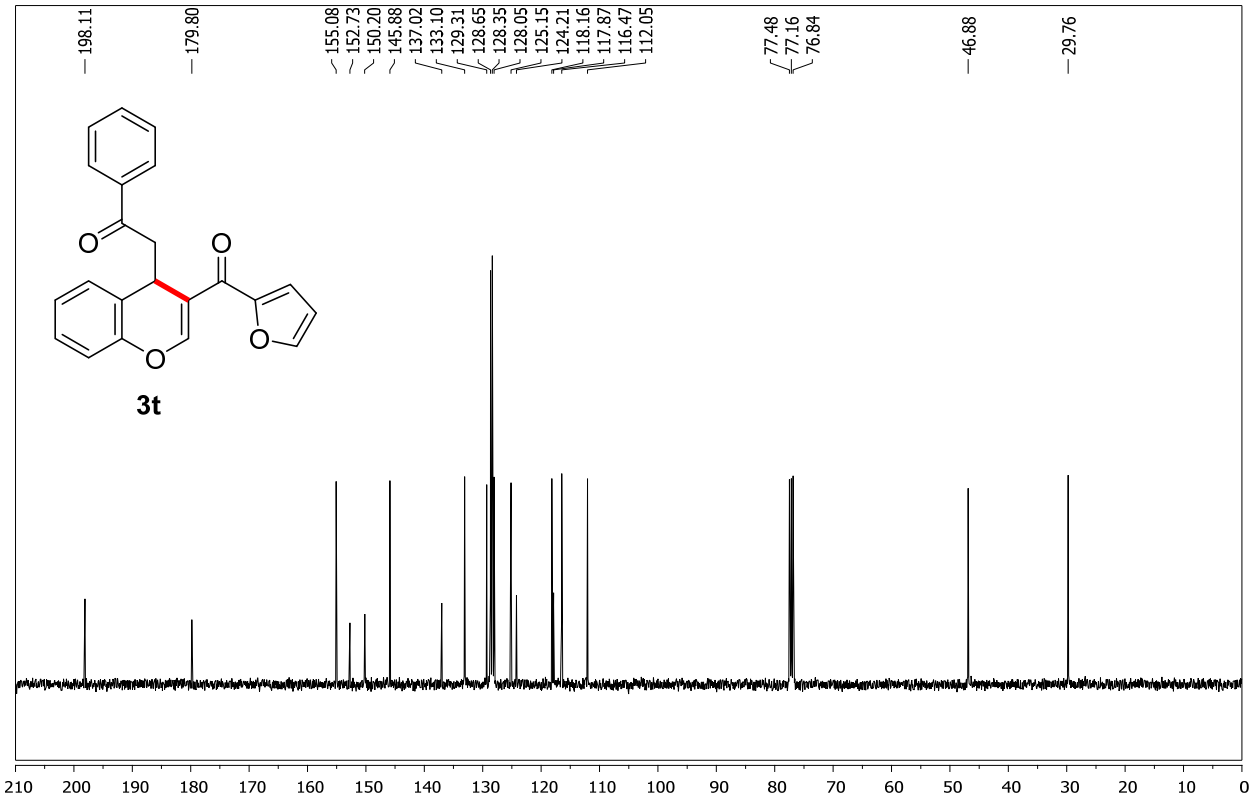
2-(3-(4-Methylbenzoyl)-4*H*-chromen-4-yl)-1-phenylethan-1-one (3s)



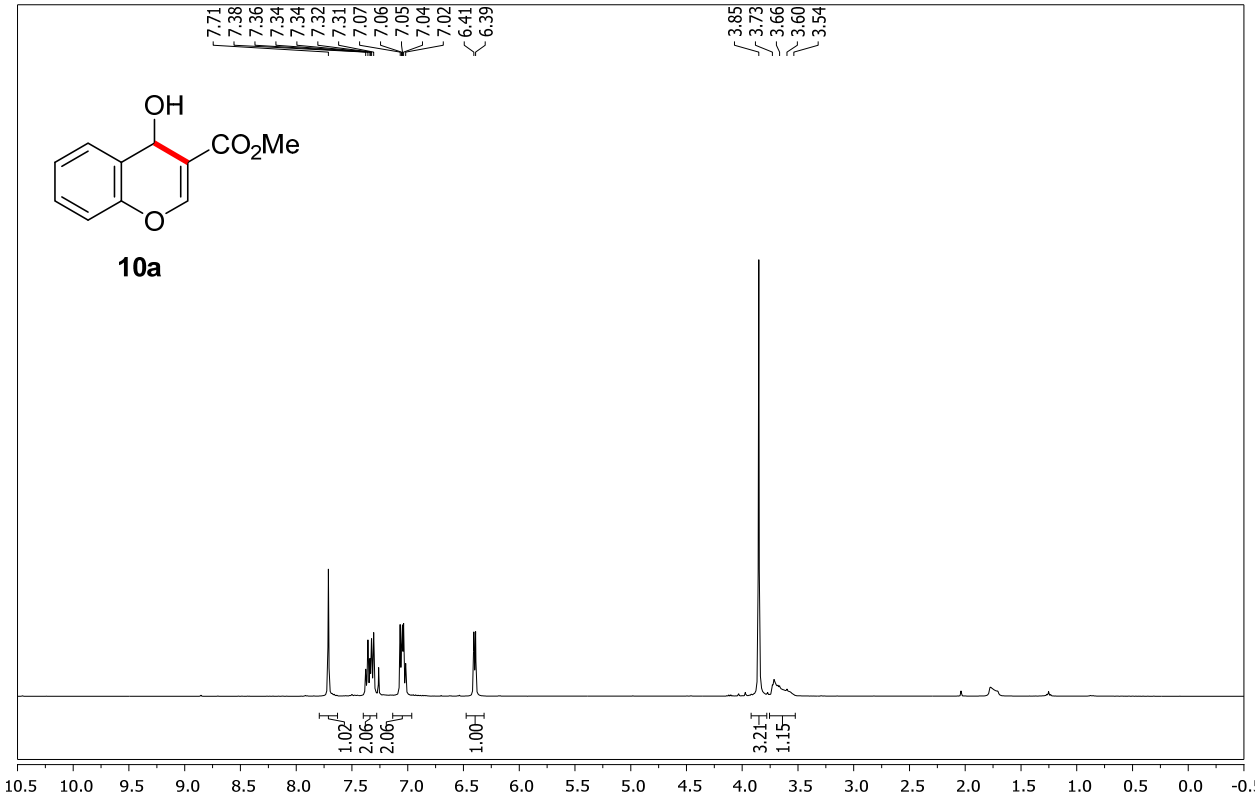


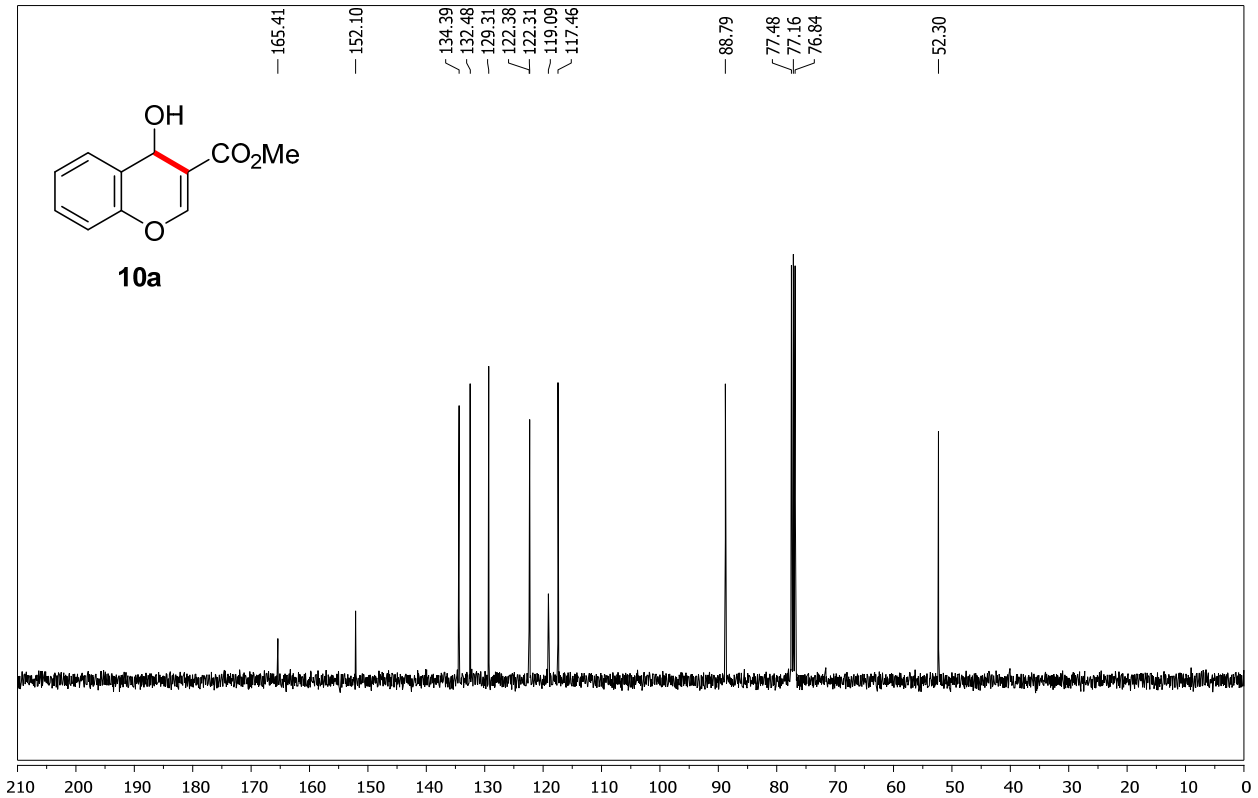
2-(3-(Furan-2-carbonyl)-4*H*-chromen-4-yl)-1-phenylethan-1-one (3t)



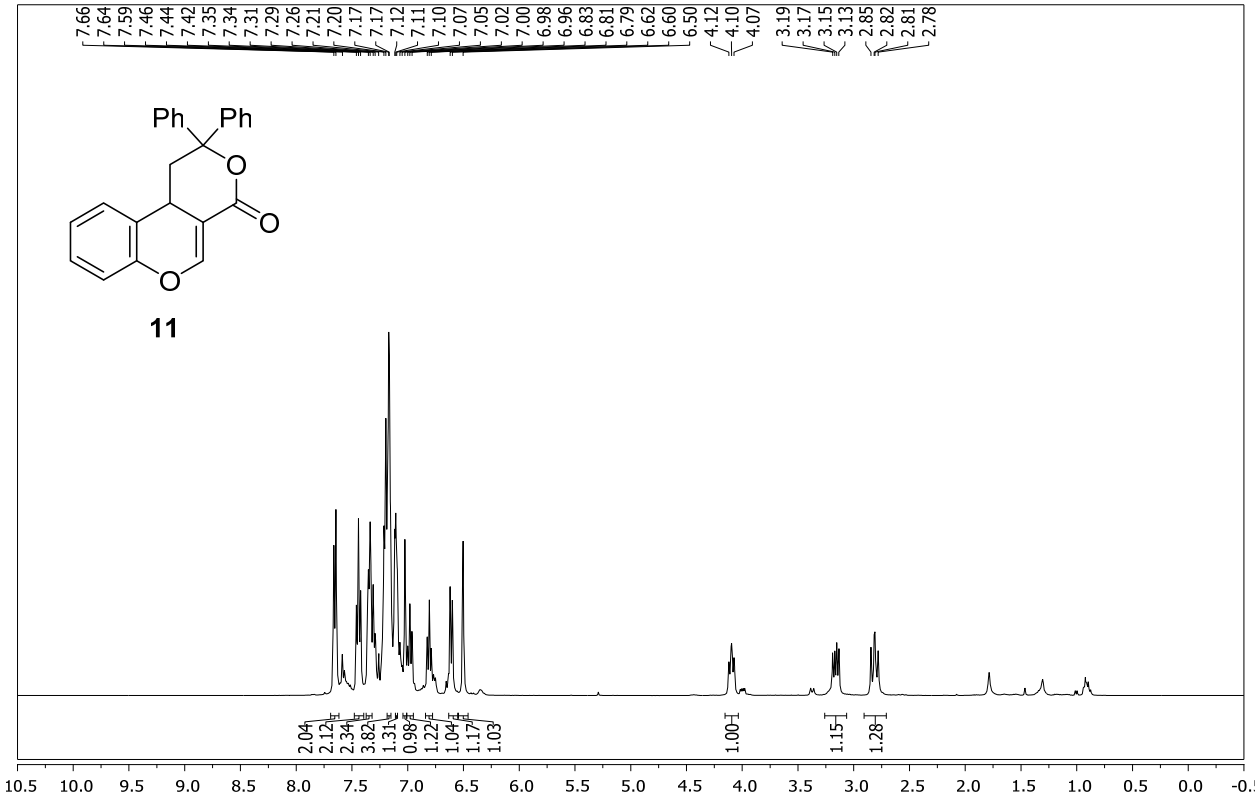


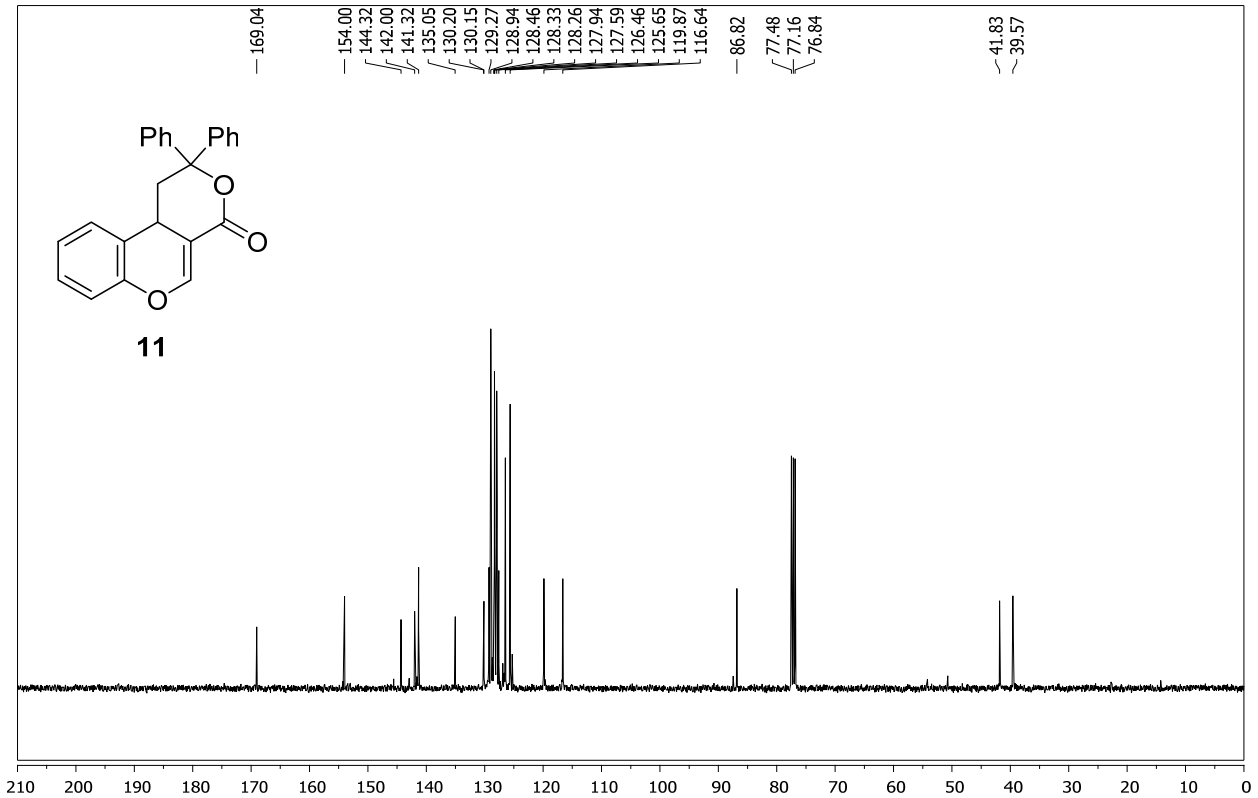
Methyl 4-hydroxy-4*H*-chromene-3-carboxylate (10a)



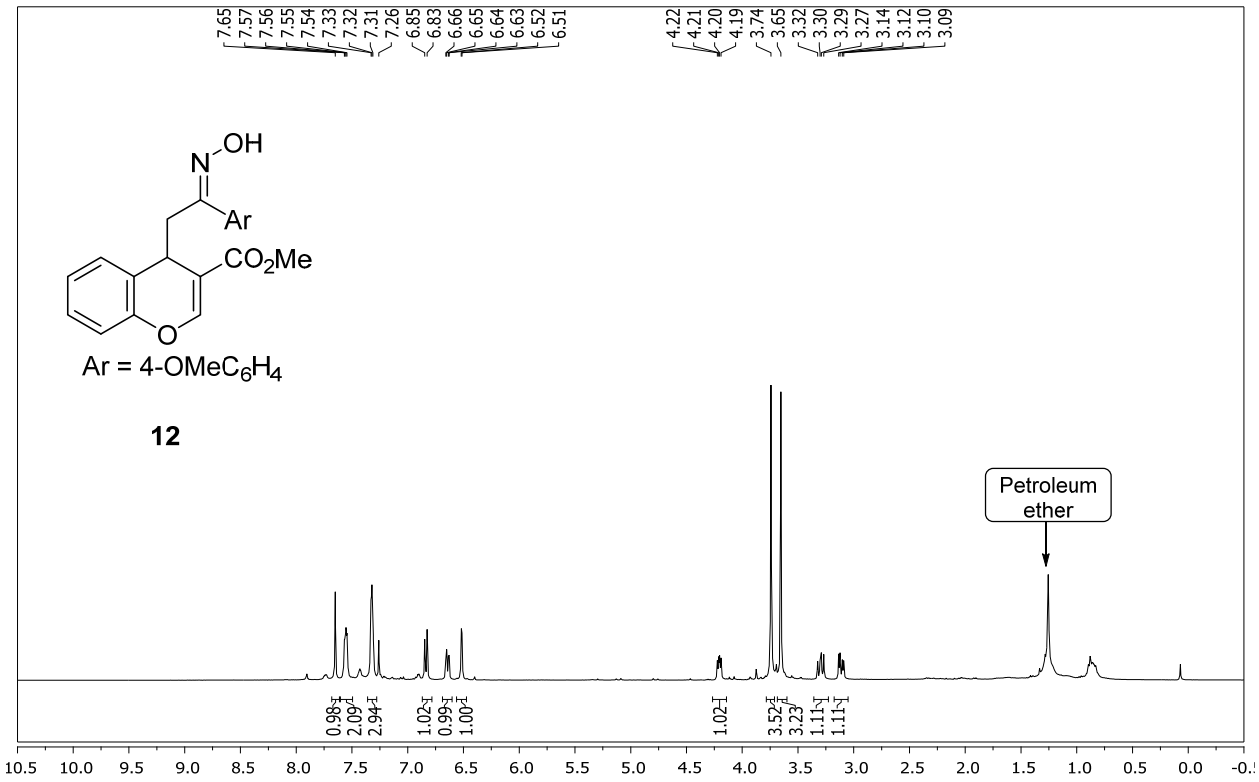


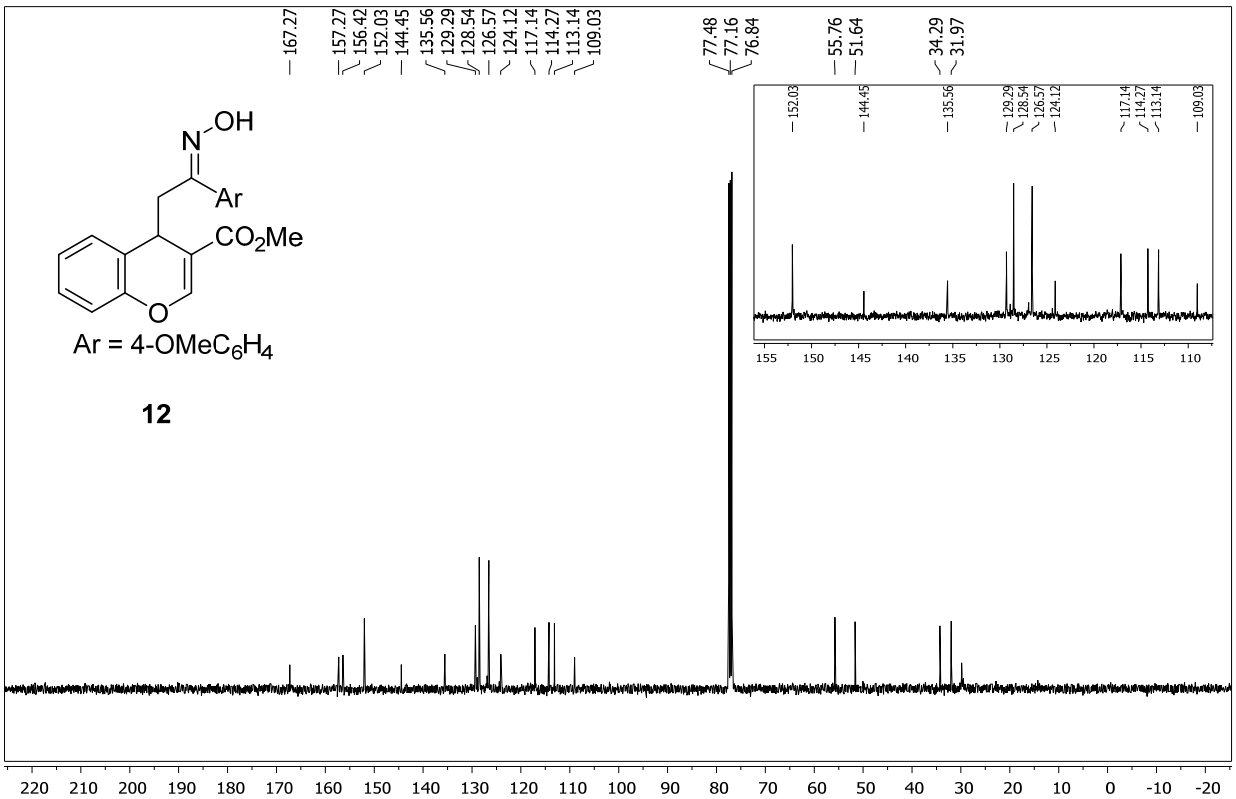
2,2-Diphenyl-1,10b-dihydro-2*H*,4*H*-pyrano[3,4-c]chromen-4-one (11)



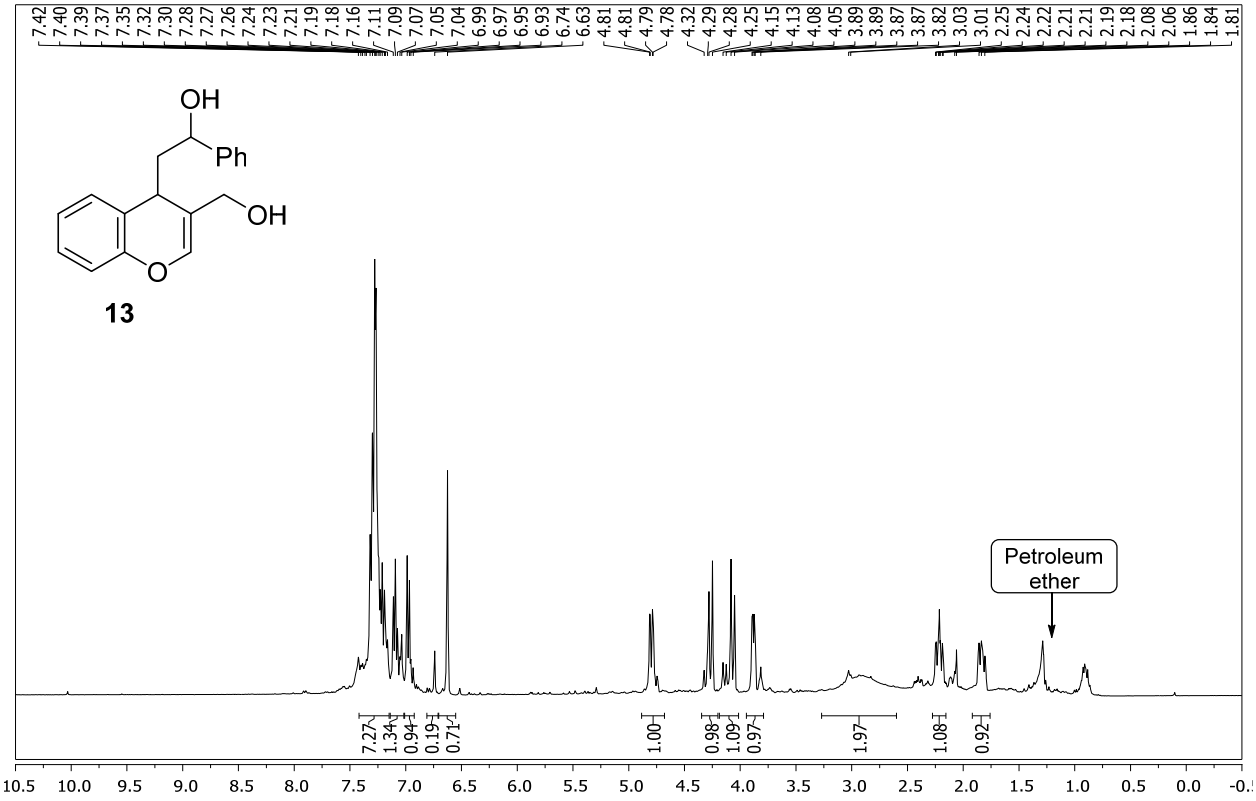


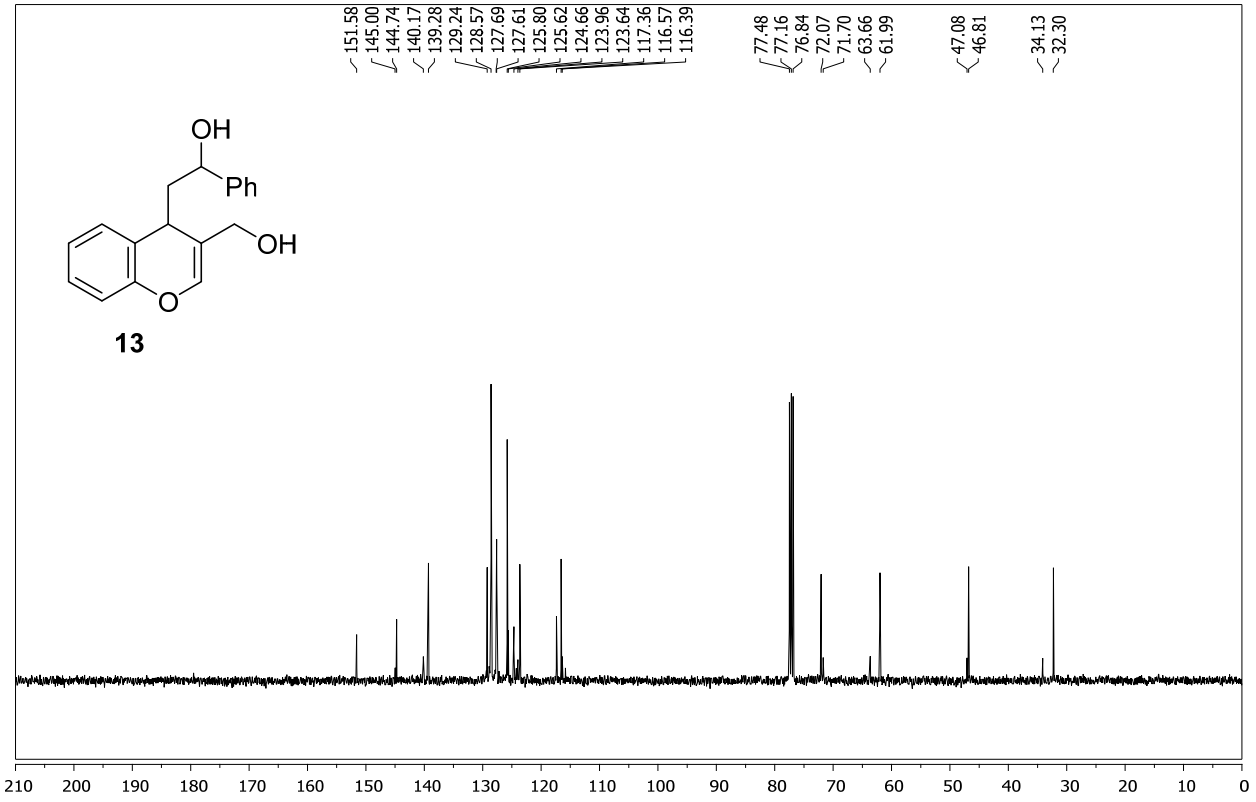
Methyl (Z)-4-(2-(hydroxyimino)-2-(4-methoxyphenyl)ethyl)-4*H*-chromene-3-carboxylate (12)





2-(3-(Hydroxymethyl)-4*H*-chromen-4-yl)-1-phenylethan-1-ol (13)





Methyl (*E*)-4-(2-(benzyloxy)-2-phenylvinyl)-4H-chromene-3-carboxylate (14)