Complex α–Pyrones Synthesized by a Gold-Catalyzed Coupling Reaction

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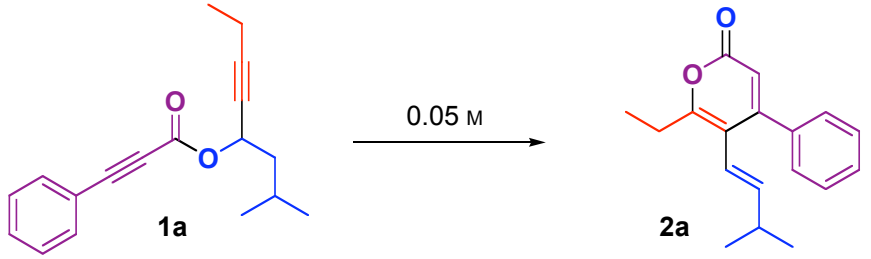
Supporting Information

Contents:

I. Material and Methods:

Dry solvents were dispensed from a solvent purification system that passes solvents through packed columns (THF and CH_2Cl_2: dry neutral alumina; toluene: dry neutral alumina and Q5 reactant). Unless otherwise stated, all reagents were obtained from commercial sources and used without further purification. Infrared spectra were recorded on a Nicolet Avatar 370 DTGS FTIR. ^{1}H NMR spectra were recorded on Varian Unity/Inova 500 (500MHz), or Bruker Ultrashield 300(300MHz) spectrometers. ^{1}H data are reported as follows: chemical shift in parts per million relative to $CHCl_3$ (7.27 ppm) multiplicity (s, singlet; d, doublet; t, triplet; q, quartet; m, multiplet; br, broadened), coupling constant (Hz), and integration. ^{13}C magnetic resonance spectra were recorded on Varian Unity/Inova 500(125MHz) or Bruker Ultrashield 300(75MHz) spectrometers. ^{13}C chemical shifts are reported in parts per million relative to solvent. All ^{13}C spectra were determined with broadband decoupling. High-resolution mass spectra were obtained through the Harvard University mass spectrometry facility. All reactions were magnetically stirred and monitored by thin-layer chromatography (TLC) using E. Merck silica gel 60 F254 precoated plates (0.25 mm). Flash chromatography was performed either on EM Science silica gel 60 (230–400 mesh) or using a CombiFlash companion system(Teledyne ISCO, Inc.) with pre-packed FLASH silica gel columns (Biotage, Inc.). SFC/MS chromatography was performed with a Berger analytic SFC using CO_2 and MeOH as the mobile phase and using a Chiralcel OJ column, a Chiralcel OD column, or a Chiralpak® IC column purchased from Chiral Technology Inc.

II. Table S1. Optimization of reaction conditions for the rearrangement of **1a** into **2a**



(1)

Entry	Catalyst	Conditions	*t* (h)	Yield [%][a] **1a**	**2a**
1	5% $AgSbF_6$, 2%PPh_3[b]	CH_2Cl_2, RT	24	95	trace
2	10% $AgSbF_6$, 4%PPh_3	CH_2Cl_2, RT	24	31	11
3	5% [$(Ph_3P)AuCl$] / $AgSbF_6$	CH_2Cl_2, RT	24	0	61
4	**5% [$(Ph_3P)AuCl$] / $AgSbF_6$**	**CH_2Cl_2, reflux**	**12**	**0**	**81**
5	5% $AgSbF_6$	CH_2Cl_2, reflux	12	25	11
6	2.5% [$(Ph_3P)AuCl$] / $AgSbF_6$	CH_2Cl_2, reflux	12	0	65
7	5% [$(Ph_3P)AuCl$] / $AgSbF_6$	1,2-DCE, 60°C	12	0	67
8	5% [$(Ph_3P)AuCl$] / $AgSbF_6$[c]	CH_2Cl_2, RT	12	96	0
9	5% [$(Ph_3P)AuCl$] / $AgSbF_6$	$MeNO_2$, 40°C	12	0	34
10	5% [$(Ph_3P)AuCl$] / $AgSbF_6$	MeCN, 40°C	12	99	0
11	5% [$(Ph_3P)AuCl$] / $AgSbF_6$	toluene, 40°C	12	0	82
12	5% [$(Ph_3P)AuCl$] / $AgSbF_6$	THF, 40°C	12	--	--[d]
13	5% [$(Ph_3P)AuCl$] / $AgSbF_6$	Et_2O, reflux	12	0	53
14	2% [$(Ph_3PAu)_3O$]BF_4	CH_2Cl_2, reflux	12	95	0
15	5% [$(Ph_3P)AuNTf_2$]	CH_2Cl_2, reflux	12	0	45
16	5% [$(Ph_3P)AuCl$] / AgOTf	CH_2Cl_2, reflux	12	0	48

[a] Isolated yields after column chromatography. [b] 1.5 equiv. MgO as additive. [c] 10 mol % pyridine as additive. [d] The reaction mixture became vigorous and solidified. [f] 2 mol % catalyst.

III. General experimental procedure

General procedure of synthesizing propargyl propiolates:

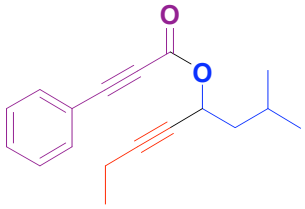
To a solution of propiolic acid (1.5 equiv.), propargyl alcohol (1 equiv.) and *N*,*N*-dimethylaminopyridine (DMAP, 0.1 equiv.) in dry CH_2Cl_2 was added *N*-(3-Dimethylaminopropyl)-*N*'-ethylcarbodiimide hydrochloride (EDCI, 1.2 equiv.) at 0 ^oC with stirring. The reaction mixture was stirred at room temperature overnight. The mixture was quenched with water, and extracted with EtOAc. The organic layers were then washed with saturated aqueous $NaHCO_3$, brine, dried over sodium sulfate, filtered, and evaporated under reduced pressure. The resulting residue was further purified by silica gel chromatography.

General procedure of gold-catalyzed rearrangement of propargyl propiolate to vinyl α-pyrones:

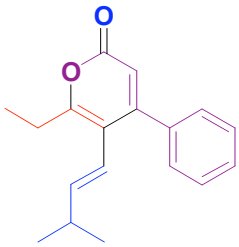
In a 4 mL vial with a threaded cap, the propargyl propiolate was dissolved in dry CH_2Cl_2 (0.05 M). 5 mol % $(Ph_3P)AuCl$ and 5 mol % $AgSbF_6$ were added to the solution at room temperature respectively. The reaction mixture was stirred in the sealed vial under 40^oC for 12h. The solvent was evaporated to dryness and the residue was purified by flash chromatography on silica gel.

General procedure of the gold-catalyzed syntheses of trisubstituted α-pyrones via Friedel-Crafts-type addition of electronic rich arenes or heteroarenes:

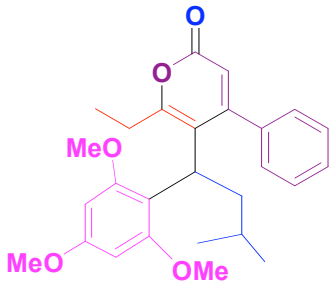
The propargyl propiolate and the nucleophile were dissolved in dry CH_2Cl_2 (0.05 M propargyl propiolate). 5 mol % $(Ph_3P)AuCl$ and 5 mol % $AgSbF_6$ were added respectively. The resulting reaction mixture was stirred at room temperature for 24h. The solvent was evaporated to dryness and the residue was purified by flash chromatography on silica gel to furnish the trisubstituted α-pyrone.



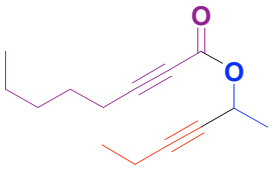
2-methyloct-5-yn-4-yl 3-phenylpropiolate (**1a**). Yield: 61%. IR (neat, cm^{-1}): 2958, 2872, 2359, 2215, 1709, 1282, 1185, 1161, 925, 758, 689; ^1H NMR (500 MHz, $CDCl_3$) δ = 0.96 (d, *J*=6.4 Hz, 3 H), 0.95 (d, *J*=6.4 Hz, 3 H), 1.13 (t, *J*=7.6 Hz, 3 H), 1.64-1.70 (m, 1 H), 1.73-1.86 (m, 2 H), 2.19 - 2.25 (m, 2 H), 5.50-5.53 (m, 1 H), 7.36 (m, 2 H), 7.42-7.45 (m, 1 H), 7.57 ppm (d, *J*=6.83 Hz, 2 H); ^{13}C NMR (75 MHz, $CDCl_3$) δ = 12.30, 13.47, 22.20, 22.34, 24.64, 43.78, 65.06, 76.29, 80.49, 86.49, 88.24, 119.53, 128.45, 130.53, 132.85, 153.02 ppm; HRMS (EI) calcd. for $[C_{18}H_{21}O_2]$ 269.1541, found 269.1529.



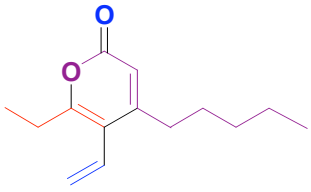
(E)-6-ethyl-5-(3-methylbut-1-enyl)-4-phenyl-2H-pyran-2-one (2a). Yield: 81%. IR (neat, cm^{-1}): 2961, 2872, 1721, 1462, 1384, 1131, 972, 766, 734, 699; ^1H NMR (300 MHz, $CDCl_3$) δ = 0.91 (d, *J*=6.8 Hz, 6 H), 1.29 (t, *J*=7.5 Hz, 3 H), 2.15-2.38 (m, 1 H), 2.68 (q, *J*=7.54 Hz, 2 H), 5.42 (dd, *J*=16.0, 7.0 Hz, 1 H), 5.71 (d, *J*=16.0 Hz, 1 H), 6.13 (s, 1 H), 7.20-7.32 (m, 2 H), 7.34-7.44 ppm (m, 3 H); ^{13}C NMR (75 MHz, $CDCl_3$) δ = 12.20, 21.87, 25.35, 31.66, 112.03, 114.32, 119.50, 128.09, 128.56, 128.87, 137.23, 144.73, 158.67, 162.39, 163.32 ppm; HRMS (EI) calcd. for $[C_{18}H_{21}O_2]$ 269.1541, found 269.1535.



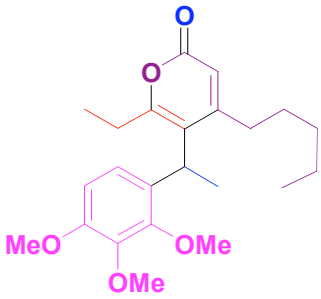
6-ethyl-5-(3-methyl-1-(2,4,6-trimethoxyphenyl)butyl)-4-phenyl-2H-pyran-2-one (3a). Yield: 82%. IR (neat, cm^{-1}): 2954, 2838, 1723, 1604, 1454, 1130, 731, 700; ^1H NMR (500 MHz, $CDCl_3$) δ = 0.32 (d, *J*=6.4 Hz, 3H), 0.76-0.85 (m, 6 H), 1.10-1.19 (m, 1 H), 1.29-1.40 (m, 1 H), 2.33-2.43 (m, 1 H), 2.47-2.57 (m, 1 H), 2.62-2.73 (m, 1 H), 3.67 (s, 6 H), 3.78 (s, 3 H), 4.16 (dd, *J*=12.7, 4.39 Hz, 1 H), 5.29 (s, 1 H), 5.96 (s, 1 H), 6.05 (s, 2 H), 7.28 (d, *J*=13.2 Hz, 2 H), 7.34-7.40 ppm (m, 3 H); ^{13}C NMR (126 MHz, $CDCl_3$) δ = 11.59, 20.43, 23.83, 24.65, 26.04, 33.94, 42.50, 55.16, 90.67, 109.76, 112.88, 120.38, 127.69, 127.98, 128.06, 138.42, 159.58, 159.69, 162.30, 162.84, 163.91 ppm; HRMS (EI) calcd. for $[C_{27}H_{33}O_5]$ 437.2328, found 437.2325.



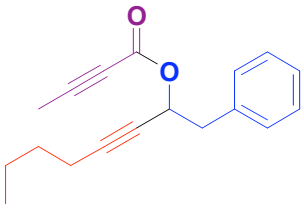
hex-3-yn-2-yl oct-2-ynoate (1b). Yield: 38%. IR (neat, cm^{-1}): 2937, 2873, 2232, 1710, 1456, 1241, 1050, 854, 752; ^1H NMR (500 MHz, $CDCl_3$) δ = 0.91 (t, *J*=7.3 Hz, 3 H), 1.13 (t, *J*=7.6 Hz, 3 H), 1.29 - 1.42 (m, 4 H), 1.50 (d, *J*=6.4 Hz, 3 H), 1.55-1.63 (m, 2 H), 2.21 (dq, *J*=7.3, 2.0 Hz, 2 H), 2.33 (t, *J*=7.3 Hz, 2 H), 5.46-5.50 ppm (m, 1 H); ^{13}C NMR (126 MHz, $CDCl_3$) δ = 12.32, 13.49, 13.80, 18.65, 21.61, 22.04, 27.13, 30.93, 62.31, 72.88, 77.09, 87.55, 90.14, 152.77 ppm.



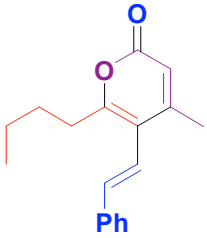
6-ethyl-4-pentyl-5-vinyl-2H-pyran-2-one (2b). Yield: 74%. IR (neat, cm^{-1}): 2956, 2930, 2871, 1717, 1542, 1062, 991, 922, 885, 856, 732; ^1H NMR (500 MHz, $CDCl_3$) δ = 0.90 (t, *J*=6.8 Hz, 3 H), 1.23 (t, *J*=7.3 Hz, 3 H), 1.29 - 1.37 (m, 4 H), 1.48-1.55 (m, 2 H), 2.36 (d, *J*=7.81 Hz, 2 H), 2.62 (q, *J*=7.7 Hz, 2 H), 5.29 (dd, *J*=17.6, 1.5 Hz, 1 H), 5.53 (dd, *J*=10.5, 1.5 Hz, 1 H), 6.00 (s, 1 H), 6.38 ppm (dd, *J*=17.6, 11.2 Hz, 1 H); ^{13}C NMR (126 MHz, $CDCl_3$) δ = 12.35, 13.85, 22.31, 25.05, 27.60, 31.34, 33.34, 110.09, 115.75, 121.80, 129.49, 160.31, 162.63 ppm; HRMS (EI) calcd. for $[C_{14}H_{21}O_2]$ 221.1541, found 221.1530.



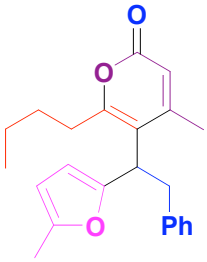
6-ethyl-4-pentyl-5-(1-(2,3,4-trimethoxyphenyl)ethyl)-2H-pyran-2-one (3b). Yield: 73%. IR (neat, cm^{-1}): 2934, 2873, 2360, 1713, 1493, 1461, 1414, 1288, 1270, 1106, 1084, 1024, 733; ^1H NMR (500 MHz, $CDCl_3$) δ = 0.81 (br. s., 3 H), 0.90 (t, *J*=7.1 Hz, 3 H), 1.30 - 1.40 (m, 4 H), 1.57 (br. s., 2 H), 1.52 (d, *J*=7.3 Hz, 3 H), 2.28-2.41 (m, 2 H), 2.53-2.62 (m, 2 H), 3.55 (s, 3 H) 3.80 (s, 3 H) 3.86 (s, 3 H), 4.23 (t, *J*=7.3 Hz, 3 H), 6.05 (s, 1H), 6.66 (d, *J*=8.3 Hz, 1 H), 7.00 ppm (d, *J*=8.8 Hz, 1 H); ^{13}C NMR (75 MHz, $CDCl_3$) δ = 11.19, 13.88, 18.53, 22.42, 24.98, 27.86, 30.52, 31.63, 33.26, 55.99, 59.97, 60.48, 106.40, 110.88, 120.96, 121.02, 129.61, 142.33, 151.88, 152.73, 161.63, 162.08, 163.11 ppm; HRMS (EI) calcd. for $[C_{23}H_{33}O_5]$ 389.2328, found 389.2326.



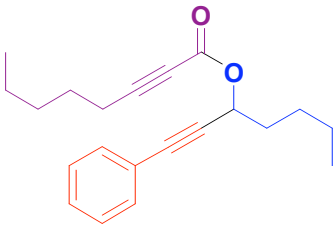
(2-(2-methylenepent-3-ynyl)oct-3-ynyl)benzene (1c). Yield: 38%. IR (neat, cm^{-1}): 2957, 2932, 2871, 2239, 1709, 1240, 1059, 972, 943, 747, 698, 531; ^1H NMR (500 MHz, $CDCl_3$) δ = 0.89 (t, *J*=7.3 Hz, 3 H), 1.31 - 1.39 (m, 2 H), 1.41 - 1.48 (m, 2 H), 1.96 (s, 3 H), 2.15 - 2.21 (m, 2 H), 3.02 - 3.13 (m, 2 H), 5.57 – 5.60 (m, 1 H), 7.22 - 7.33 ppm (m, 5 H); ^{13}C NMR (126 MHz, $CDCl_3$) δ = 3.61, 13.39, 18.17, 21.65, 30.19, 41.19, 66.39, 72.04, 76.21, 86.06, 87.85, 126.75, 128.11, 129.51, 135.67, 152.39 ppm; HRMS (EI) calcd. for $[C_{18}H_{25}NO_2]$ $(M+NH_4)^+$ 286.1807, found 286.1803.



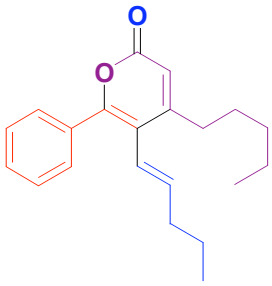
(E)-6-butyl-4-methyl-5-styryl-2H-pyran-2-one (2c). Yield: 84%. IR (neat, cm^{-1}): 2958, 2930, 2871, 2360, 1712, 1542, 1028, 843, 732, 692; ^1H NMR (500 MHz, $CDCl_3$) δ = 0.91 (t, *J*=7.3 Hz, 3 H), 1.32 - 1.40 (m, 2 H), 1.67 – 1.73 (m, 2 H), 2.15 (s, 3 H), 2.64 (t, *J*=7.6 Hz, 2 H), 6.05 (s, 1 H), 6.57 (d, *J*=16.1 Hz, 1 H), 6.70 (d, *J*=16.1 Hz, 1 H), 7.30 – 7.33 (m, 1H), 7.37 – 7.40 (m, 2 H), 7.45 ppm (d, *J*=7.3 Hz, 2 H); ^{13}C NMR (126 MHz, $CDCl_3$) δ = 13.74, 21.09, 22.34, 29.88, 31.42, 111.41, 115.88, 120.62, 126.40, 128.29, 128.78, 135.87, 136.33, 156.55, 162.08, 162.19 ppm; HRMS (EI) calcd. for $[C_{18}H_{21}O_2]$ 269.1541, found 269.1552.



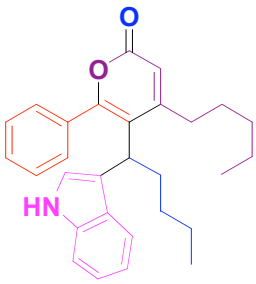
6-butyl-4-methyl-5-(1-(5-methylfuran-2-yl)-2-phenylethyl)-2H-pyran-2-one (3c). Yield: 85%. IR (neat, cm^{-1}): 2957, 2929, 2871, 2360, 1716, 1539, 1453, 1359, 1217, 1076, 734, 699; ^1H NMR (500 MHz, $CDCl_3$) δ = 0.81 (t, *J*=7.3 Hz, 3 H), 1.11 - 1.23 (m, 3 H), 1.43 - 1.52 (m, 1 H), 1.84 (br. s., 1 H), 2.17 - 2.30 (m, 5 H), 3.02 (dd, *J*=13.2, 10.7 Hz, 1 H), 3.47 (dd, *J*=13.7, 4.9 Hz, 1 H), 4.21 (dd, *J*=10.3, 4.9 Hz, 1 H), 5.92 (m, 2 H), 6.02 (s, 1H), 7.05 (d, *J*=6.8 Hz, 2 H) 7.18 - 7.26 (m, 3 H) ppm; ^{13}C NMR (126 MHz, $CDCl_3$) δ = 13.47, 13.67, 20.84, 22.49, 29.23, 31.20, 37.74, 37.81, 105.37, 105.58, 106.15, 106.39, 126.68, 128.50, 129.06, 138.70, 151.02, 153.60, 157.43, 162.42, 163.40 ppm; HRMS (EI) calcd. for $[C_{23}H_{26}O_3]$ 351.1960, found 351.1945.



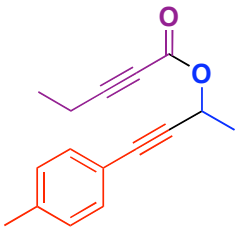
1-phenylhept-1-yn-3-yl oct-2-ynoate (1d). Yield: 39%. IR (neat, cm^{-1}): 2956, 2931, 2862, 2231, 1710, 1232, 957, 753, 690; ^1H NMR (500 MHz, $CDCl_3$) δ = 0.90 (t, *J*=7.3 Hz, 3 H), 0.94 (t, *J*=7.3 Hz, 3 H), 1.29 - 1.43 (m, 6 H), 1.47 - 1.53 (m, 2 H), 1.56 - 1.62 (m, 2 H), 1.87 – 1.92 (m, 2 H), 2.33 (t, *J*=7.1 Hz, 2 H), 5.64 (t, *J*=6.8 Hz, 2 H), 7.26 - 7.33 (m, 3 H), 7.43 – 7.44 ppm (m, 2 H); ^{13}C NMR (126 MHz, $CDCl_3$) δ = 13.80, 13.88, 18.68, 22.04, 22.19, 27.12, 30.95, 34.46, 65.99, 72.81, 85.82, 90.51, 122.17, 128.18, 128.58, 131.84, 152.86 ppm; HRMS (EI) calcd. for $[C_{21}H_{30}NO_2]$ $(M+NH_4)^+$ 328.2277, found 328.2272.



(E)-5-(pent-1-enyl)-4-pentyl-6-phenyl-2H-pyran-2-one (2d). Yield: 78%. IR (neat, cm^{-1}): 2955, 2928, 2870, 2360, 1720, 1099, 855, 736, 694; ^1H NMR (500 MHz, $CDCl_3$) δ = 0.82 (t, *J*=7.3 Hz, 3 H), 0.92 (t, *J*=7.1 Hz, 3 H), 1.26 - 1.38 (m, 7 H), 1.53 – 1.58 (m, 3 H), 2.03 (q, *J*=6.8 Hz, 2 H), 2.46 (t, *J*=7.8 Hz, 2 H), 5.52 (dt, *J*=16.1, 6.8 Hz, 1 H), 6.04 (d, *J*=16.1 Hz, 1 H), 6.13 (s, 1H), 7.35 – 7.37 (m, 3 H), 7.60 – 7.62 ppm (m, 2 H); ^{13}C NMR (126 MHz, $CDCl_3$) δ = 13.61, 13.89, 21.83, 22.35, 27.84, 31.41, 33.54, 35.14, 111.18, 116.34, 121.51, 127.89, 129.37, 129.59, 133.14, 139.46, 157.16, 161.11, 162.21 ppm; HRMS (EI) calcd. for $[C_{21}H_{27}O_2]$ 311.2011, found 311.2015.

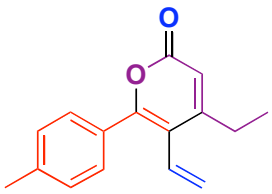


5-(1-(1H-indol-3-yl)pentyl)-4-pentyl-6-phenyl-2H-pyran-2-one (3d). Yield: 52%. IR (neat, cm^{-1}): 3308, 2955, 2929, 2859, 2359, 1670, 1489, 1078, 908, 732, 698; ^1H NMR (500 MHz, $CDCl_3$) δ = 0.76 (t, *J*=6.8 Hz, 3 H), 0.86 (t, *J*=6.8 Hz, 3 H), 1.01 - 1.16 (m, 4 H), 1.21 - 1.29 (m, 4 H), 1.40 - 1.43 (m, 1 H), 1.86 - 1.91 (m, 1 H), 2.24 – 2.37 (m, 2 H), 2.40 – 2.47 (m, 1 H), 4.38 (t, *J*=7.3 Hz, 1 H), 6.18 (s, 1H), 6.88 (br. s., 1H), 7.01 – 7.04 (m, 1H), 7.15 – 7.18 (m, 1H), 7.32 - 7.41 (m, 5 H), 7.45 (br. s., 2 H), 8.17 ppm (br. s., 1 H); ^{13}C NMR (126 MHz, $CDCl_3$) δ = 13.82, 13.99, 22.22, 22.78, 28.60, 29.97, 31.45, 32.14, 33.65, 36.65, 111.28, 113.38, 117.79, 119.21, 119.57, 119.72, 121.15, 122.13, 126.65, 128.17, 129.16, 129.50, 133.74, 136.68, 158.75, 162.55, 162.78 ppm; HRMS (EI) calcd. for $[C_{29}H_{34}NO_2]$ 428.2589, found 428.2601.

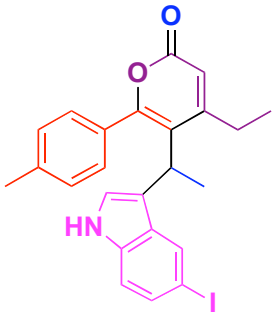


4-p-tolylbut-3-yn-2-yl pent-2-ynoate (1e). Yield: 52%. Chiral SFC chromatography: Chiralcel OJ column, 5% MeOH, 95% $sfCO_2$, t_R = 2.38 min (area 49.99%), 2.77 min (area 50.01%) (0% ee); IR (neat, cm^{-1}): 2986, 2938, 2234, 1709, 1233, 1077, 1048, 1025, 815, 749; ^1H NMR (500 MHz, $CDCl_3$) δ = 1.21 (t, *J*=7.6 Hz, 3 H), 1.61 (d, *J*=6.8 Hz, 3 H), 2.32 - 2.38 (m, 5 H), 5.72 (q, *J*=6.7 Hz, 1 H), 7.10 (d, *J*=8.3 Hz, 2 H), 7.32 ppm (d, *J*=8.3 Hz, 2 H); ^{13}C NMR (75 MHz, $CDCl_3$) δ = 12.39, 21.38, 62.37, 72.26, 85.40, 85.86, 91.28, 119.01, 128.94, 131.72, 138.78, 152.67 ppm; HRMS (EI)

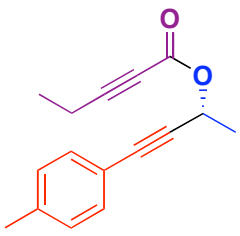
calcd. for [$C_{16}H_{17}O_2$] 241.1228, found 241.1229.



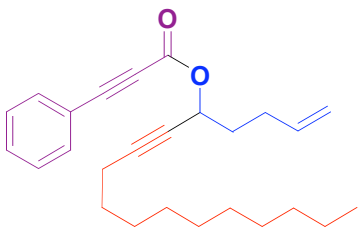
4-ethyl-6-p-tolyl-5-vinyl-2H-pyran-2-one (**2e**). Yield: 65%. IR (neat, cm^{-1}): 2972, 1716, 1501, 1087, 1087, 819, 733, 481; ^1H NMR (500 MHz, $CDCl_3$) δ = 1.20 (t, *J*=7.3 Hz, 3 H), 2.38 (s, 3 H), 2.54 (q, *J*=7.3 Hz, 2 H), 5.20 (d, *J*=17.6 Hz, 1 H), 5.41 (d, *J*=11.2 Hz, 1 H), 6.16 (s, 1 H), 6.43 (dd, *J*=18.1, 11.2 Hz, 1 H), 7.19 (d, *J*=8.3 Hz, 2 H), 7.53 ppm (d, *J*=8.3 Hz, 2 H); ^{13}C NMR (75 MHz, $CDCl_3$) δ = 12.34, 21.38, 26.67, 110.38, 115.89, 122.57, 128.75, 129.55, 129.85, 129.95, 140.04, 157.68, 161.64, 162.19 ppm; HRMS (EI) calcd. for [$C_{16}H_{17}O_2$] 241.1228, found 241.1216.



4-ethyl-5-(1-(5-iodo-1H-indol-3-yl)ethyl)-6-p-tolyl-2H-pyran-2-one (**3e**). Yield: 74%. SFC: Chiralcel OJ column, 20% MeOH, 80% $sfCO_2$, t_R = 4.25 min (area 50.75%), 5.52 min (area 49.25%) (1.5 % ee); IR (neat, cm^{-1}): 3412, 2967, 2360, 2342, 1692, 1502, 1086, 857, 599; ^1H NMR (500 MHz, $CDCl_3$) δ = 0.93 (t, *J*=7.6 Hz, 3 H), 1.73 (d, *J*=7.3 Hz, 3 H), 2.38 (s, 3 H), 2.51 (m, 1 H), 4.46 (q, *J*=7.3 Hz, 1 H), 6.16 (s, 1 H), 6.86 (s, 1 H), 7.09 (d, *J*=8.3 Hz, 1 H), 7.23 (d, *J*=7.8 Hz, 1 H), 7.37 (dd, *J*=8.8, 1.5 Hz, 1 H), 7.42 (d, *J*=7.8 Hz, 1 H), 7.60(d, *J*=1.5 Hz, 1 H), 8.24 ppm (br. s.,1 H); ^{13}C NMR (126 MHz, $CDCl_3$) δ = 12.75, 19.88, 21.39, 25.07, 30.96, 82.99, 112.82, 113.17, 118.30, 119.59, 121.82, 128.54, 128.78, 129.14, 130.45, 130.62, 135.59, 140.03, 158.50, 162.52, 163.44 ppm; HRMS (EI) calcd. for [$C_{24}H_{23}INO_2$] 484.0773, found 484.0794.

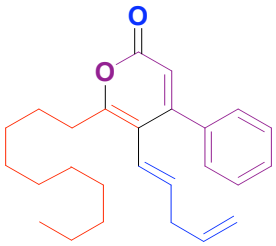


(*R*)-4-p-tolylbut-3-yn-2-yl pent-2-ynoate ((*R*)-1e). Yield: 50%. SFC: Chiralcel OJ column, 5% MeOH, 95% $sfCO_2$, $t_R^{(minor)}$ = 2.21 min (area 1.13%), $t_R^{(major)}$ = 2.53 min (area 98.87%) (98% ee); IR (neat, cm^{-1}): 2986, 2940, 2235, 1709, 1235, 1077, 1048, 1025, 816, 750; ^1H NMR (500 MHz, $CDCl_3$) δ = 1.21 (t, *J*=7.3 Hz, 3 H), 1.61 (d, *J*=6.8 Hz, 3 H), 2.32 - 2.38 (m, 5 H), 5.72 (q, *J*=6.8 Hz, 1 H), 7.10 (d, *J*=8.3 Hz, 2 H), 7.32 ppm (d, *J*=8.3 Hz, 2 H); ^{13}C NMR (75 MHz, $CDCl_3$) δ = 12.41, 21.39, 62.39, 72.27, 85.41, 85.87, 91.31, 119.02, 128.96, 131.74, 138.80, 152.69 ppm.

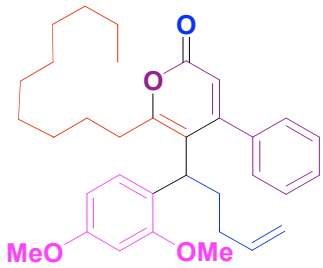


heptadec-1-en-6-yn-5-yl 3-phenylpropiolate (**1f**). Yield: 64%. IR (neat, cm^{-1}): 2924, 2853, 2212, 1711, 1277, 1168, 914, 756, 688; ^1H NMR (500 MHz, $CDCl_3$) δ = 0.87 (t, *J*=7.1 Hz, 3 H), 1.26 – 1,30 (m, 13 H), 1.34 - 1.38 (m, 2 H), 1.48 - 1.54 (m, 2 H), 1.88 - 1.99 (m, 2 H), 2.20 - 2.28 (m, 4 H), 5.02 (dd, *J*=10.3, 1.5 Hz, 1 H), 5.08 (dd, *J*=17.1, 1.5 Hz, 1 H), 5.48 – 5.50 (m, 1H), 5.79 – 5.87 (m, 1H), 7.37 (t, *J*=7.6 Hz, 2 H), 7.45 (t, *J*=7.3 Hz, 1 H), 7.59 ppm (d, *J*=6.8 Hz, 2 H); ^{13}C NMR (126 MHz, $CDCl_3$) δ = 14.08,

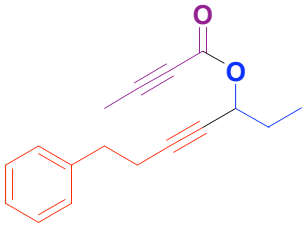
18.70, 22.65, 28.38, 28.80, 29.06, 29.20, 29.29, 29.49, 29.54, 31.87, 34.13, 65.89, 76.51, 80.47, 86.71, 87.62, 115.56, 119.58, 128.52, 130.64, 132.99, 136.88, 153.07 ppm; HRMS (EI) calcd. for $[C_{26}H_{38}NO_2]$ $(M+NH_4)^+$ 396.2903, found 396.2889.



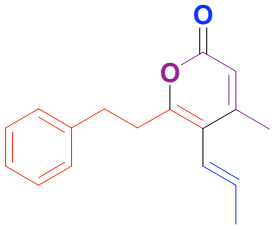
(E)-6-decyl-5-(penta-1,4-dienyl)-4-phenyl-2H-pyran-2-one (2f). Yield: 79%. IR (neat, cm^{-1}): 2924, 2854, 1720, 1265, 734, 700; ^1H NMR (500 MHz, $CDCl_3$) δ = 0.88 (t, *J*=7.1 Hz, 3 H), 1.27 - 1.38 (m, 15 H), 1.69 - 1.75 (m, 2 H), 2.63 – 2.66 (m, 2 H), 2.76 – 2.79 (m, 2 H), 4.91 - 4.99 (m, 2 H), 5.46 – 5.52 (m, 1 H), 5.65 – 5.73 (m, 1 H), 5.81 (d, *J*=16.1 Hz, 1 H), 6.11 (s, 1H), 7.27 - 7.29 (m, 2 H), 7.38 - 7.39 ppm (m, 3 H); ^{13}C NMR (126 MHz, $CDCl_3$) δ = 14.07, 22.64, 27.89, 29.24, 29.26, 29.29, 29.45, 29.53, 31.85, 31.92, 36.98, 111.99, 114.43, 115.89, 123.57, 128.15, 128.45, 128.91, 134.98, 135.42, 137.12, 158.41, 162.23, 162.86 ppm; HRMS (EI) calcd. for $[C_{26}H_{35}O_2]$ $(M+H)^+$ 379.2637, found 379.2630.



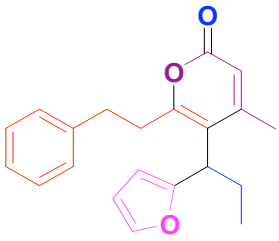
6-decyl-5-(1-(2,4-dimethoxyphenyl)pent-4-enyl)-4-phenyl-2H-pyran-2-one (3f). Yield: 59%. IR (neat, cm^{-1}): 2924, 2853, 1716, 1612, 1504, 1463, 1208, 1034, 735, 701; ^1H NMR (500 MHz, $CDCl_3$) δ = 0.89 (t, *J*=6.8 Hz, 3 H), 1.03 - 1.32 (m, 15 H), 1.40 - 1.48 (m, 1H), 1.72 – 1.83 (m, 2H), 1.95 – 2.03 (m, 1H), 2.18 – 2.42 (m, 3H), 3.64 (s, 3 H), 3.78 (s, 3 H), 3.89 (dd, *J*=9.8, 4.3 Hz, 1 H), 4.86 – 4.91 (m, 2H), 5.59 – 5.67 (m, 1H), 6.01 (s, 1H), 6.37 – 6.40 (m, 2H), 6.98 (d, *J*=8.3 Hz, 1 H), 7.24 (br. s., 2H), 7.37 - 7.38 ppm (m, 3 H); ^{13}C NMR (75 MHz, $CDCl_3$) δ = 14.06, 22.64, 27.29, 29.26, 29.37, 29.48, 29.55, 29.62, 31.86, 31.91, 32.32, 36.31, 55.05, 55.28, 98.88, 103.60, 112.89, 114.81, 119.52, 122.00, 127.63, 127.82, 128.03, 128.27, 137.69, 138.51, 158.57, 159.51, 161.75, 162.51, 162.65 ppm; HRMS (EI) calcd. for $[C_{34}H_{45}O_4]$ $(M+H)^+$ 517.3318, found 517.3308.



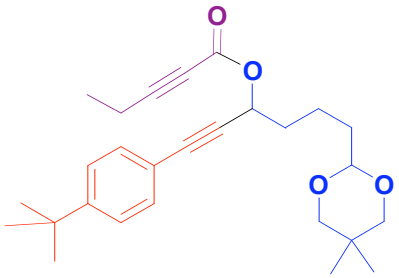
7-phenylhept-4-yn-3-yl but-2-ynoate (1g). Yield: 34%. IR (neat, cm^{-1}): 2973, 2937, 2239, 1708, 1454, 1241, 1057, 914, 749, 698; ^1H NMR (500 MHz, $CDCl_3$) δ = 0.96 (t, *J*=7.6 Hz, 3 H), 1.73 - 1.79 (m, 2 H),1.98 (s, 3 H), 2.47 - 2.51 (m, 2 H), 2.81 (t, *J*=7.6 Hz, 2 H), 5.32 (t, *J*=6.4 Hz, 1 H), 7.19 - 7.21 (m, 3 H), 7.27 - 7.30 ppm (m, 2 H); ^{13}C NMR (126 MHz, $CDCl_3$) δ = 3.73, 9.23, 20.87, 28.10, 34.77, 67.09, 72.27, 85.92, 86.11, 126.24, 128.30, 128.40, 140.39, 152.73 ppm; HRMS (EI) calcd. for $[C_{17}H_{22}NO_2]$ $(M+NH_4)^+$ 272.1651, found 272.1660.



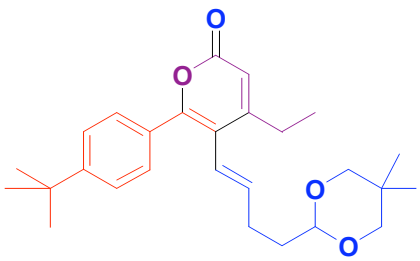
(E)-4-methyl-6-phenethyl-5-(prop-1-enyl)-2H-pyran-2-one (2g). Yield: 71%. IR (neat, cm^{-1}): 3028, 2360, 1717, 1265, 732, 699; ^1H NMR (500 MHz, $CDCl_3$) δ = 1.79 (dd, *J*=6.4, 1.5 Hz, 3 H), 2.03 (s, 3 H), 2.83 -2.86 (m, 2 H), 2.95 - 2.98 (m, 2 H), 5.42 (dq, *J*=15.6, 6.4 Hz, 1 H), 5.82 (dd, *J*=17.57, 1.5 Hz, 1 H), 6.01 (s, 1 H), 7.14 (d, *J*=7.3 Hz, 2 H), 7.19 - 7.22 (m, 1 H), 7.26 – 7.29 ppm (m, 2 H); ^{13}C NMR (75 MHz, $CDCl_3$) δ = 18.41, 20.90, 33.53, 33.68, 111.34, 116.81, 122.40, 126.25, 128.35, 128.43, 133.22, 140.45, 156.82, 159.92, 162.31 ppm; HRMS (EI) calcd. for $[C_{17}H_{19}O_2]$ $(M+H)^+$ 255.1385, found 255.1386.



5-(1-(furan-2-yl)propyl)-4-methyl-6-phenethyl-2H-pyran-2-one (3g). Yield: 72%. IR (neat, cm^{-1}): 2966, 2934, 2874, 1714, 1540, 1394, 733, 699; ppm; ^1H NMR (500 MHz, $CDCl_3$) δ = 0.93 (t, *J*=7.3 Hz, 3 H), 1.70 – 1.80 (m, 1 H), 2.04 (br. s., 3 H), 2.15 – 2.24 (m, 1 H), 2.77 (br. s., 3 H), 2.93 – 2.98 (m, 1H), 3.93 – 3.96 (m, 1H), 6.03 (s, 1H), 6.04 (d, *J*=4.9 Hz, 1 H), 6.33 - 6.34 (m, 1H), 7.13 (d, *J*=7.3 Hz, 2 H), 7.17 – 7.20 (m, 1H), 7.25 - 7.28 (m, 2 H), 7.31 ppm (br. s., 1 H); ^{13}C NMR (75 MHz, $CDCl_3$) δ = 12.28, 21.01, 24.85, 33.51, 33.79, 38.66, 105.48, 110.35, 113.21, 116.38, 126.27, 128.30, 128.49, 140.39, 141.29, 155.90, 157.20, 161.48, 162.10 ppm; HRMS (EI) calcd. for $[C_{21}H_{23}O_3]$ $(M+H)^+$ 323.1647, found 323.1660.

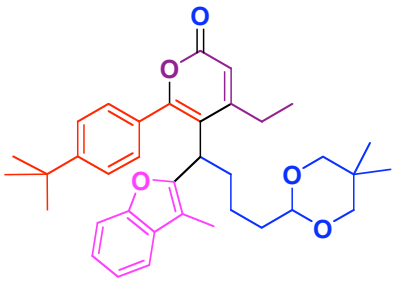


1-(4-tert-butylphenyl)-6-(5,5-dimethyl-1,3-dioxan-2-yl)hex-1-yn-3-yl pent-2-ynoate (1h). Yield: 73%. IR (neat, cm^{-1}): 2954, 2868, 2235, 1712, 1237, 1078, 1048, 836, 749; ^1H NMR (300 MHz, $CDCl_3$) δ = 0.71 (s, 3 H), 1.18 (s, 3 H), 1.21 (t, *J*=.7.5 Hz, 3 H), 1.30 (s, 9 H), 1.60 - 1.75 (m, 4 H), 1.88 - 1.95 (m, 2 H), 2.35 (q, 3.41 (d, *J*=10.9 Hz, 1 H), 3.59 (d, *J*=11.1 Hz, 1 H), 4.42 – 4.45 (m, 1H), 5.63 (t, *J*=6.5 Hz, 1 H), 7.32 (d, *J*=8.7 Hz, 2 H), 7.38 ppm (d, *J*=8.7 Hz, 2 H); ^{13}C NMR (75 MHz, $CDCl_3$) δ = 12.39, 19.62, 21.76, 22.93, 30.03, 31.06, 34.19, 34.68, 53.33, 65.95, 72.27, 77.12, 84.98, 86.06, 91.26, 101.76, 119.12, 125.13, 131.60, 151.88, 152.75 ppm; HRMS (EI) calcd. for $[C_{27}H_{40}NO_4]$ $(M+NH_4)^+$ 442.2957, found 442.2938.

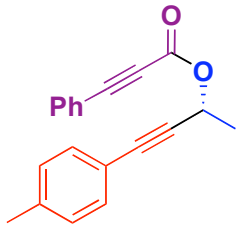


(E)-6-(4-tert-butylphenyl)-5-(4-(5,5-dimethyl-1,3-dioxan-2-yl)but-1-enyl)-4-ethyl-2H-pyran-2-one (2h). Yield: 40%. IR (neat, cm^{-1}): 2956, 2868, 2362, 1721, 1085, 1132, 1110, 1085, 1016, 734; ^1H NMR (500 MHz, $CDCl_3$) δ = 0.72 (s, 3 H) 1.17 – 1.20 (m, 6 H), 1.32 (s., 9 H), 1.63 - 1.68 (m, 2 H), 2.19 - 2.24 (m, 2 H), 2.47 - 2.52 (m, 2 H), 3.39 (d, *J*=11.2 Hz, 2 H), 3.59 (d, *J*=11.2 Hz, 2 H), 4.38 (t, *J*=4.9 Hz, 1 H), 5.58 (dt, *J*=16.1, 6.8 Hz, 1 H),

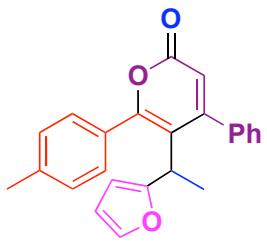
6.09 (d, *J*=16.1 Hz, 1 H), 6.13 (s, 1H), 7.38 (d, *J*=8.3 Hz, 2 H), 7.56 ppm (d, *J*=8.8 Hz, 2 H); ^{13}C NMR (75 MHz, $CDCl_3$) δ = 12.32, 21.81, 22.93, 26.73, 27.43, 30.13, 31.17, 33.78, 34.80, 77.23, 101.32, 110.22, 115.72, 122.03, 124.94, 129.29, 130.18, 138.28, 152.88, 157.20, 162.19, 162.38 ppm; HRMS (EI) calcd. for $[C_{27}H_{37}O_4]$ $(M+H)^+$ 425.2692, found 425.2677.



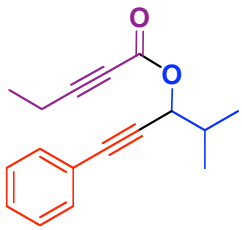
6-(4-tert-butylphenyl)-5-(4-(5,5-dimethyl-1,3-dioxan-2-yl)-1-(3-methylbenzofuran-2-yl)butyl)-4-ethyl-2H-pyran-2-one (3h). Yield: 59%. IR (neat, cm^{-1}): 2955, 2867, 1721, 1173, 1129, 857, 734; ^{1}H NMR (500 MHz, $CDCl_3$) δ = 0.71 (s, 3 H), 1.09 (t, *J*=7.3 Hz, 3 H), 1.17 (s, 3 H), 1.33 (s, 10 H) 1.36 – 1.42 (m, 2 H), 1.59 – 1.63 (m, 2H), 1.91 (s, 3H), 2.37 – 2.45 (m, 1H), 2.47 – 2.55 (m, 1H), 2.57 – 2.65 (m, 1H), 3.39 (dd, *J*=11.2, 2.4 Hz, 2 H), 3.56 – 3.60 (m, 2H), 4.35 – 4.38 (m, 2H), 6.20 (s, 1H), 7.19 – 7.25 (m, 2H), 7.36 - 7.42 ppm (m, 6 H); ^{13}C NMR (126 MHz, $CDCl_3$) δ = 8.00, 12.84, 21.80, 22.47, 22.90, 22.95, 25.31, 30.10, 31.16, 32.49, 34.47, 34.80, 38.32, 77.16, 101.74, 110.74, 111.13, 112.47, 117.11, 118.70, 122.22, 123.60, 124.91, 125.33, 128.81, 129.26, 130.32, 130.40, 152.30, 153.11, 153.27, 159.36, 162.18, 162.78 ppm; HRMS (EI) calcd. for $[C_{36}H_{45}O_5]$ $(M+H)^+$ 557.3267, found 557.3273.



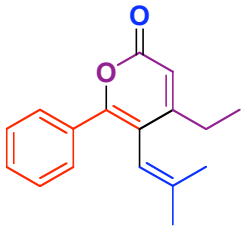
(*R*)-4-p-tolylbut-3-yn-2-yl 3-phenylpropiolate ((*R*)-1i). Yield: 63%. SFC: Chiralcel OD column, 5% MeOH, 95% $sfCO_2$, $t_R^{(major)}$ = 7.24 min, area = 100% (100% ee) (racemic compound t_R = 5.19 min, 6.92 min); IR (neat, cm^{-1}): 2991, 2214, 1708, 1510, 1490, 1279, 1184, 1169, 1083, 1025, 907, 817, 729, 688; ^{1}H NMR (500 MHz, $CDCl_3$) δ = 1.70 (d, *J*=6.8 Hz, 3 H), 2.35 (s., 3 H), 5.84 (q, *J*=6.8 Hz, 3 H), 7.15 (d, *J*=7.8 Hz, 2 H), 7.38 – 7.42 (m, 4 H), 7.47 – 7.50 (m, 1 H), 7.63 ppm (d, *J*=7.8 Hz, 2 H); ^{13}C NMR (126 MHz, $CDCl_3$) δ = 21.44, 62.76, 80.43, 85.63, 85.78, 86.88, 118.94, 119.50, 128.53, 128.99, 130.67, 131.77, 132.99, 138.87, 152.95 ppm; HRMS (EI) calcd. for $[C_{20}H_{17}O_2]$ $(M+H)^+$ 289.1228 found 289.1232.



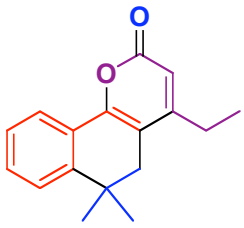
5-(1-(furan-2-yl)ethyl)-4-phenyl-6-p-tolyl-2H-pyran-2-one (3i). Yield: 53%. SFC: Chiralpak® IC column, 5% MeOH, 95% $sfCO_2$, $t_R^{(major)}$ = 7.56 min (area 50.57%), $t_R^{(minor)}$ = 9.31 min (area 49.43%) (1% ee); IR (neat, cm^{-1}): 2936, 2360, 2251, 1720, 1500, 1376, 1006, 908, 727, 701, 516; ^{1}H NMR (500 MHz, $CDCl_3$) δ = 1.12 (d, *J*=6.8 Hz, 3 H), 2.39 (s, 3 H), 4.12 (q, *J*=6.8 Hz, 1 H), 5.48 – 5.49 (m, 1H), 6.11 (s, 1H), 6.17 – 6.18 (m, 1H), 6.87 (br. s., 2 H), 7.20 - 7.22 (m, 4 H), 7.27 – 7.30 (m, 1 H), 7.35 (br. s., 1 H), 7.43 - 7.44 pm (d, *J*=7.8 Hz, 2 H); ^{13}C NMR (126 MHz, $CDCl_3$) δ = 17.67, 21.38, 32.80, 105.47, 110.75, 115.65, 117.81, 127.34, 127.62, 128.25, 128.96, 129.10, 130.21, 137.53, 140.13, 140.69, 156.91, 160.29, 160.36, 161.58 ppm; HRMS (EI) calcd. for $[C_{24}H_{21}O_3]$ $(M+H)^+$ 357.1485, found 357.1488.



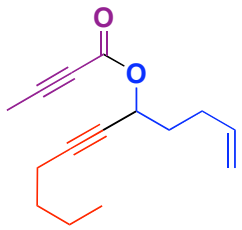
4-methyl-1-phenylpent-1-yn-3-yl pent-2-ynoate (1j). Yield: 29%. IR (neat, cm^{-1}): 2967, 2876, 2234, 1709, 1232, 1077, 1048, 754, 690; ^1H NMR (500 MHz, $CDCl_3$) δ = 1.08 (d, *J*=6.8 Hz, 3 H), 1.12 (d, *J*=6.8 Hz, 3 H), 1.22 (t, *J*=7.6 Hz, 3 H), 2.11 – 2.17 (m, 1 H), 2.37 (q, *J*=7.3 Hz, 2 H), 5.50 (d, *J*=5.9 Hz, 1 H), 7.28 - 7.33 (m, 3 H), 7.44 - 7.46 ppm (m, 2 H); ^{13}C NMR (75 MHz, $CDCl_3$) δ = 12.42, 17.57, 18.24, 32.56, 70.83, 72.24, 84.48, 86.44, 91.36, 122.25, 128.18, 128.56, 131.85, 152.94 ppm; HRMS (EI) calcd. for $[C_{17}H_{22}NO_2]$ $(M+NH_4)^+$ 272.1651, found 272.1638.



4-ethyl-5-(2-methylprop-1-enyl)-6-phenyl-2H-pyran-2-one (2j). Yield: 16%. IR (neat, cm^{-1}): 2971, 2934, 1717, 1533, 1444, 1088, 897, 733, 693; ^1H NMR (500 MHz, $CDCl_3$) δ = 1.16 (t, *J*=7.3 Hz, 3 H), 1.22 (s, 3 H), 1.74 (s, 3 H), 2.42 (d, *J*=6.4 Hz, 2 H), 5.86 (s, 1 H), 6.16 (s, 1 H), 7.34 - 7.36 (m, 3 H), 7.64 ppm (dd, *J*=6.59, 3.17 Hz, 2 H); ^{13}C NMR (75 MHz, $CDCl_3$) δ = 12.18, 19.15, 25.09, 26.65, 110.28, 115.06, 116.67, 127.93, 128.68, 129.39, 133.49, 139.45, 156.81, 162.62, 163.14 ppm; HRMS (EI) calcd. for $[C_{17}H_{19}O_2]$ $(M+H)^+$ 255.1385, found 255.1390.

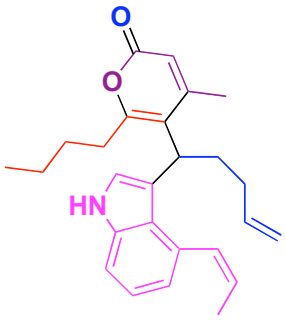


4-ethyl-6,6-dimethyl-5,6-dihydrobenzo[h]chromen-2-one (4). Yield: 69%. IR (neat, cm^{-1}): 2964, 2359, 1712, 1531, 1448, 1073, 891, 796, 729; ^1H NMR (500 MHz, $CDCl_3$) δ = 1.43 (t, *J*=7.3 Hz, 3 H), 1.53 (s, 6 H), 2.71 (q, *J*=7.3 Hz, 2 H), 2.77 (s, 2 H), 6.33 (s, 1H), 7.50 – 7.53 (m, 1 H), 7.55 – 7.60 (m, 2 H), 8.10 – 8.12 ppm (m, 1 H); ^{13}C NMR (75 MHz, $CDCl_3$) δ = 12.23, 25.68, 28.42, 33.91, 36.23, 110.64, 111.00, 123.98, 124.09, 126.69, 126.75, 130.64, 145.46, 153.29, 161.23, 162.33 ppm; HRMS (EI) calcd. for $[C_{17}H_{19}O_2]$ $(M+H)^+$ 255.1385, found 255.1381.

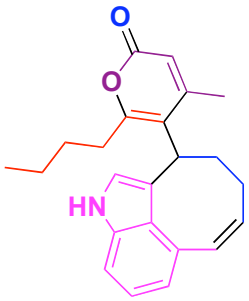


undec-1-en-6-yn-5-yl but-2-ynoate (1k). To a solution of 2-butynoic acid (504 mg, 1.8 equiv.), undec-1-en-6-yn-5-ol (550 mg, 3.3 mmol, 1 equiv.) and *N*,*N*-dimethylaminopyridine (DMAP, 0.1 equiv.) in 10mL dry CH_2Cl_2 was added *N*,*N'*-Dicyclohexylcarbodiimide (DCC, 825 mg, 4.0 mmol, 1.2 equiv.) at 0 °C with stirring. The reaction mixture was stirred at room temperature overnight and then filtered through a short column of silica gel. The organic solvent was evaporated under reduced pressure and the resulting residue was further purified by silica gel chromatography (5% EtOAc in hexane). Yield: 679mg, 89%. IR (neat, cm^{-1}): 2957, 2933, 2863, 2240, 1710, 1243, 1060, 913, 749; ^1H NMR (500 MHz, $CDCl_3$) δ = 0.90 (t, *J*=7.1 Hz, 3 H), 1.35 - 1.43 (m, 2 H), 1.44 - 1.51 (m, 2 H), 1.83 - 1.89 (m, 2 H), 1.99 (s, 3 H), 2.17 - 2.24 (m, 4 H), 4.96 - 5.07 (m, 2 H), 5.38 – 5.40 (m, 1 H), 5.76 – 5.84 ppm (m, 1 H); ^{13}C NMR (126 MHz, $CDCl_3$) δ = 3.81, 13.51, 18.33, 21.84, 29.14,

30.42, 34.07, 65.53, 72.22, 76.49, 86.04, 87.30, 115.50, 136.88, 152.68 ppm; HRMS (EI) calcd. for $[C_{15}H_{24}NO_2]$ $(M+NH_4)^+$ 250.1802, found 250.1804.

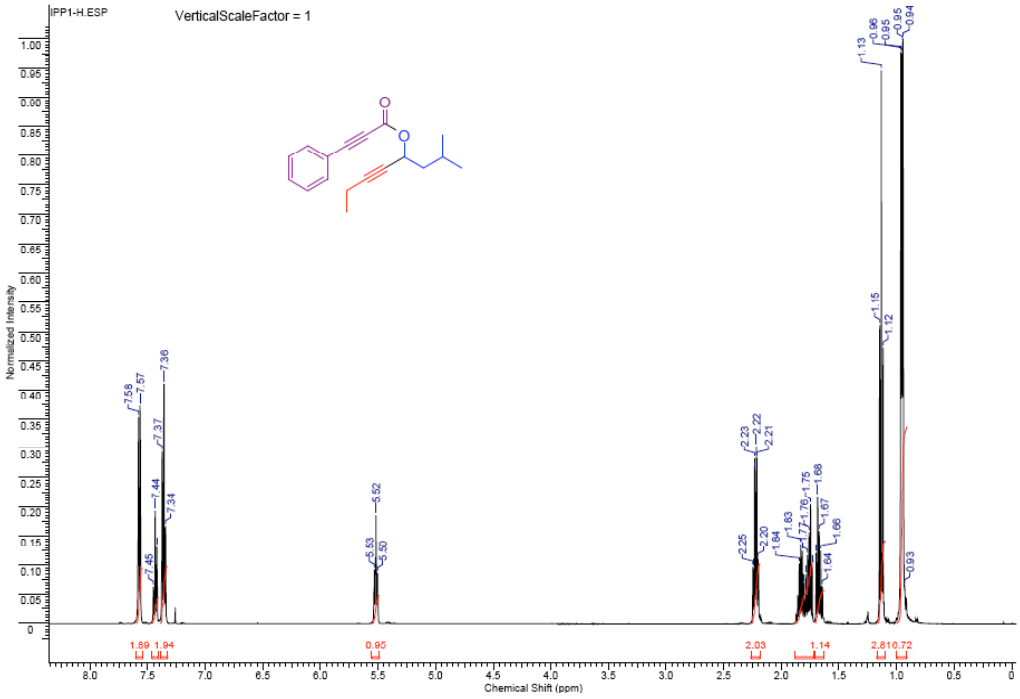


(Z)-6-butyl-4-methyl-5-(1-(4-(prop-1-enyl)-1H-indol-3-yl)pent-4-enyl)-2H-pyran-2-one (3k). Yield: 56%. IR (neat, cm^{-1}): 3292, 2930, 1695, 1616, 1538, 1264, 913, 734; ^{1}H NMR (500 MHz, $CDCl_3$) δ = 0.71 (t, *J*=6.6 Hz, 3 H), 1.02 – 1.14 (m, 3 H), 1.40 (br. s., 1 H), 1.67 (dd, *J*=6.8, 1.4 Hz, 3 H), 1.85 – 1.92 (m, 1 H), 2.19 (s, 3 H), 2.22 - 2.40 (m, 5 H), 4.33 (t, *J*=6.8 Hz, 1 H), 4.99 - 5.04 (m, 2 H), 5.71 – 5.77 (m, 1 H), 5.82 – 5.90 (m, 1 H), 6.04 (s, 1 H), 6.67 (d, *J*=11.2 Hz, 1 H), 6.86 (d, *J*=7.3 Hz, 1 H), 6.96 (s, 1 H), 7.14 (dd, *J*=8.3, 7.3 Hz, 1 H), 7.28 (d, *J*=8.3 Hz, 1 H), 8.29 ppm (br. s., 1 H); ^{13}C NMR (75 MHz, $CDCl_3$) δ = 13.64, 14.20, 21.70, 22.69, 29.46, 31.91, 32.31, 34.23, 35.25, 110.08, 112.74, 115.37, 117.59, 117.63, 119.37, 121.30, 122.01, 122.30, 124.85, 127.18, 129.02, 130.31, 137.22, 137.70, 158.28, 158.31, 162.45, 162.77 ppm; HRMS (EI) calcd. for $[C_{26}H_{32}NO_2]$ $(M+H)^+$ 390.2428, found 390.2421.

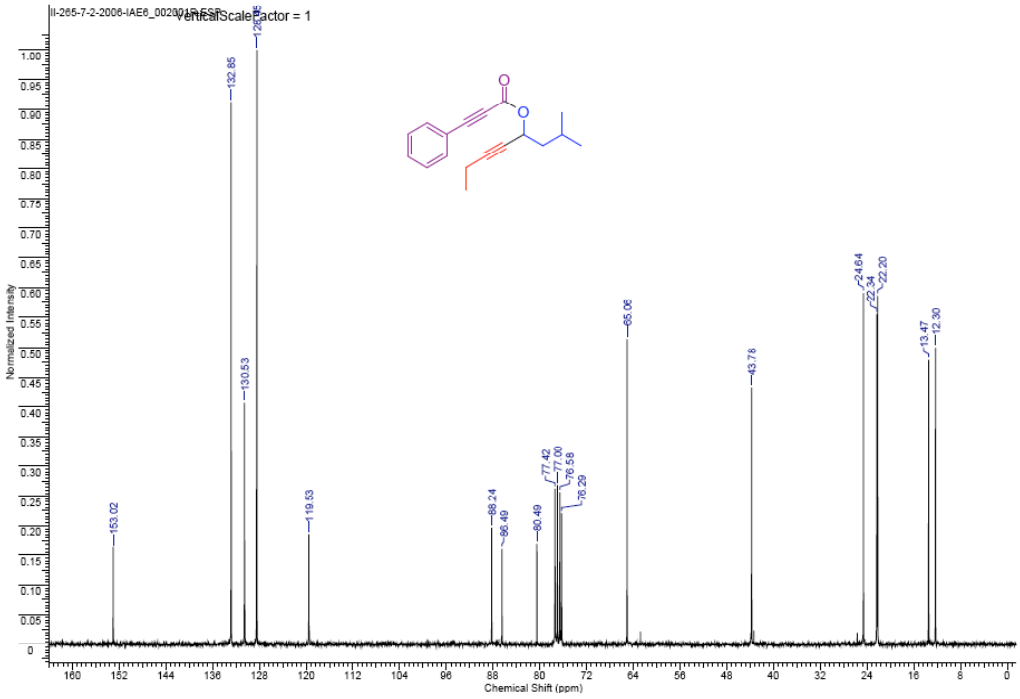


(Z)-6-butyl-4-methyl-5-(2,8,9,10-tetrahydrocycloocta[cd]indol-10-yl)-2H-pyran-2-one (5). 20.0 mg **3k** (0.0513 mmol) was dissolved with 10 mL dry CH_2Cl_2 in a 50 mL round-bottom flask equipped with condenser. The vessel was degassed with argon, and then 10 mol % Hoveyda-Grubbs 2nd generation catalyst (3.2 mg, 0.00513 mmol) was added. The mixture was heated under reflux for 4 hours, cooled to room temperature and solvent was evaporated under reduced pressure. The resulting residue was purified by flash chromatography on silica gel (20% EtOAc in hexane) to provide 14.1 mg **5** as brown oil (80% yield, atropisomer with 2:1 ratio). IR (neat, cm^{-1}): 3252, 2929, 2863, 2360, 1702, 1621, 1541, 1025, 1006, 731, 699; ^{1}H NMR (500 MHz, $CDCl_3$) δ = *0.78 (t, *J*=7.1 Hz, 3 H), 0.94 (t, *J*=7.3 Hz, 3 H), *1.22 (br. s., 2 H), 1.39 – 1. 46 (m, 3 H), $^\#$1.65 – 1.79 (m, 2 H), 1.82 – 1.92 (m, 1 H), 1.99 (s, 3 H), 2.07 – 2.13 (m, 1 H), 2.29 – 2.32 (m, 1 H), *2.36 – 2.42 (m, 1 H), *2.50 (s, 3 H), 2.60 – 2.71 (m, 3 H), 2.82 – 2.88 (m, 1 H), 4.85 (dd, *J*=7.9, 4.8 Hz, 1 H), *4.91 (dd, *J*=7.8, 3.9 Hz, 1 H), $^\#$5.77 – 5.82 (m, 1 H), 6.00 (s, 1 H), *6.13 (s, 1 H), *6.60 (s, 1 H), 6.63 (s, 1 H), $^\#$6.67 (d, *J*=7.3 Hz, 1 H), $^\#$6.91 (d, *J*=10.7 Hz, 1 H), $^\#$7.14 – 7.17 (m, 1 H), $^\#$7.23 – 7.26 (m, 1 H), $^\#$8.13 (br. s., 1 H) (* represents signals of minor isomer, $^\#$ represents overlapping signals of both major and minor isomers); ^{13}C NMR (75 MHz, $CDCl_3$) δ = 13.82, 21.35, 22.85, 26.38, 28.67, 30.30, 32.14, 34.09, 110.29, 112.30, 113.99, 116.07, 118.83, 120.68, 122.25, 122.61, 126.50, 129.70, 130.39, 131.68, 137.12, 158.32, 163.06 ppm (major isomer); HRMS (EI) calcd. for $[C_{23}H_{26}NO_2]$ $(M+H)^+$ 348.1958, found 348.1953.

Spectra. Spectral Data for **2-methyloct-5-yn-4-yl 3-phenylpropiolate 1a**

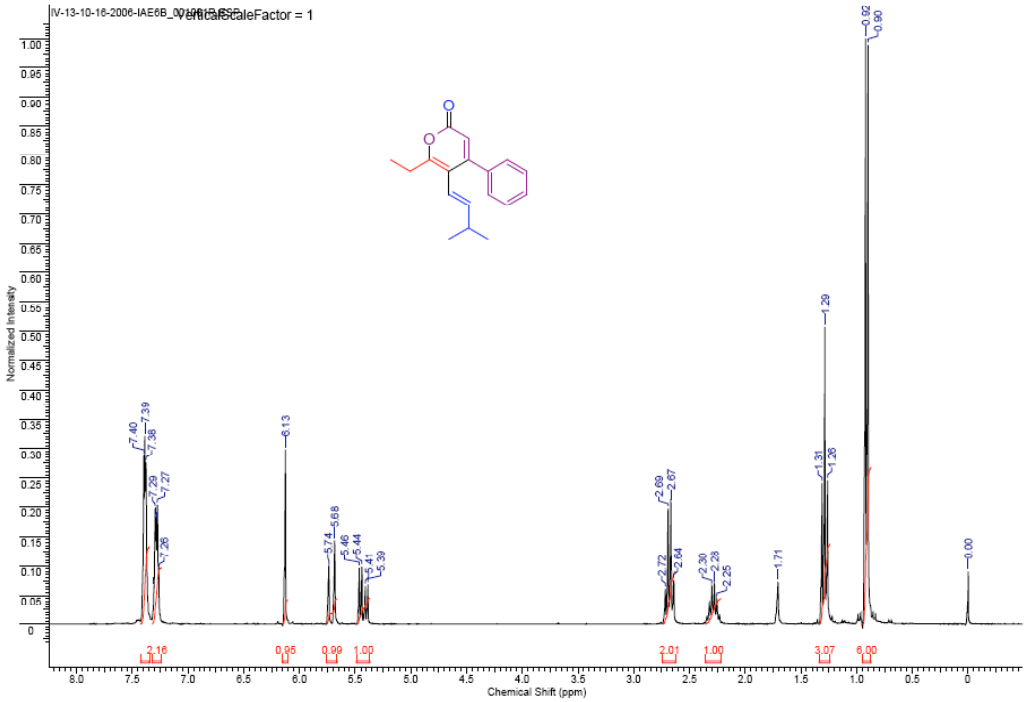


^{1}H NMR (500 MHz, $CDCl_3$) of compound **1a**

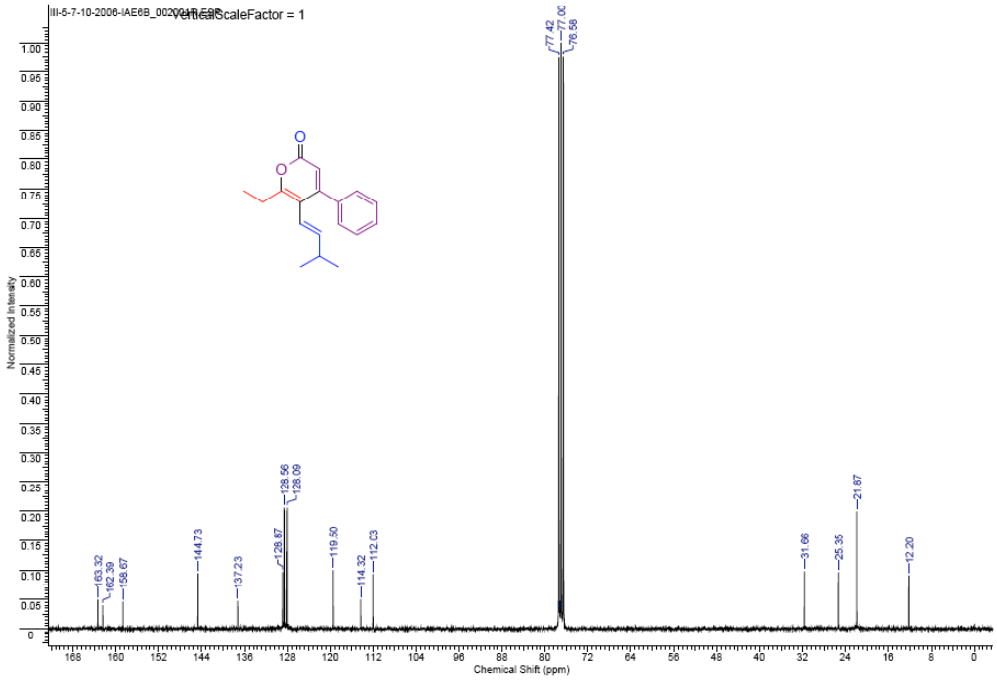


^{13}C NMR (75 MHz, $CDCl_3$) for compound **1a**

Spectra. Spectral Data for **(E)-6-ethyl-5-(3-methylbut-1-enyl)-4-phenyl-2H-pyran-2-one (2a)**



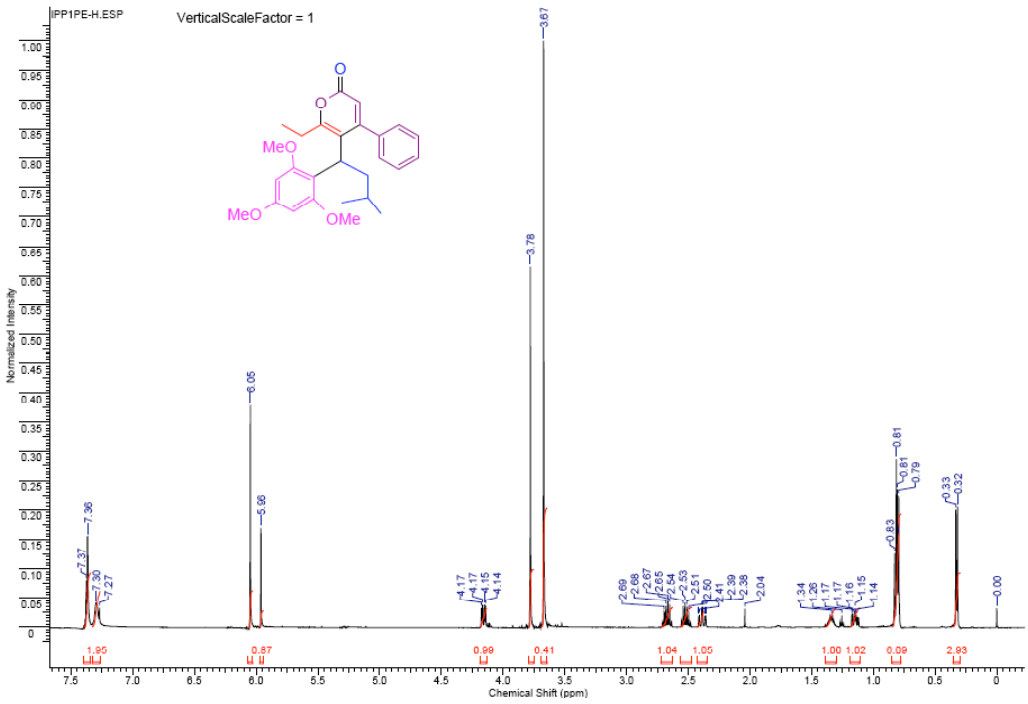
^{1}H NMR (300 MHz, $CDCl_3$) of compound **2a**



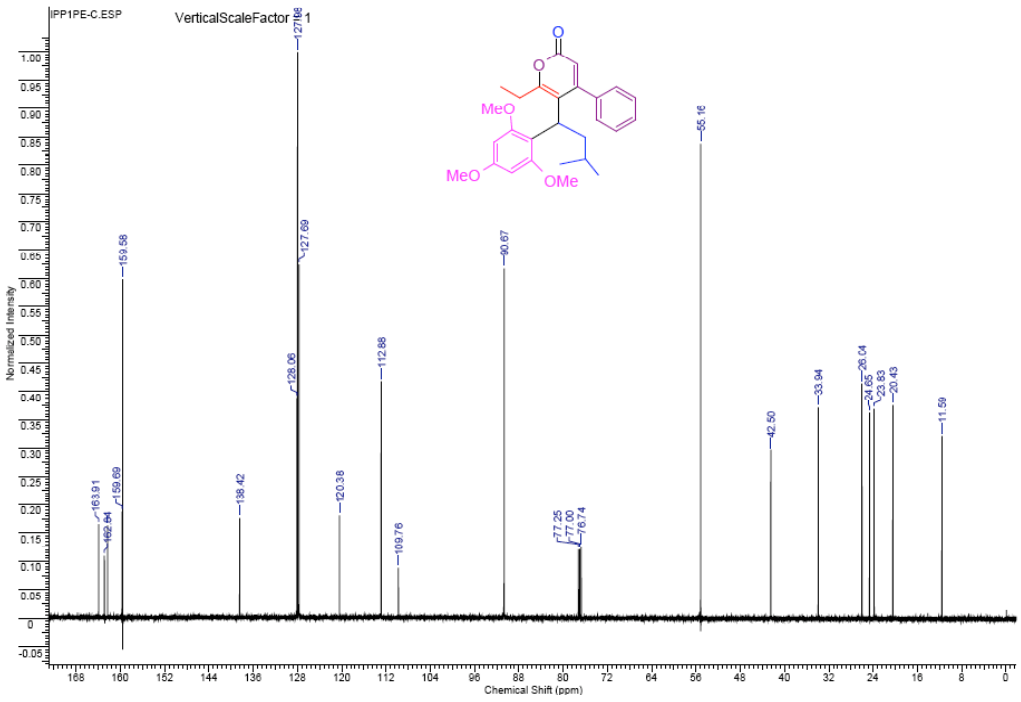
^{13}C NMR (75 MHz, $CDCl_3$) for compound **2a**

Spectra. Spectral Data for

6-ethyl-5-(3-methyl-1-(2,4,6-trimethoxyphenyl)butyl)-4-phenyl-2H-pyran-2-one (3a)

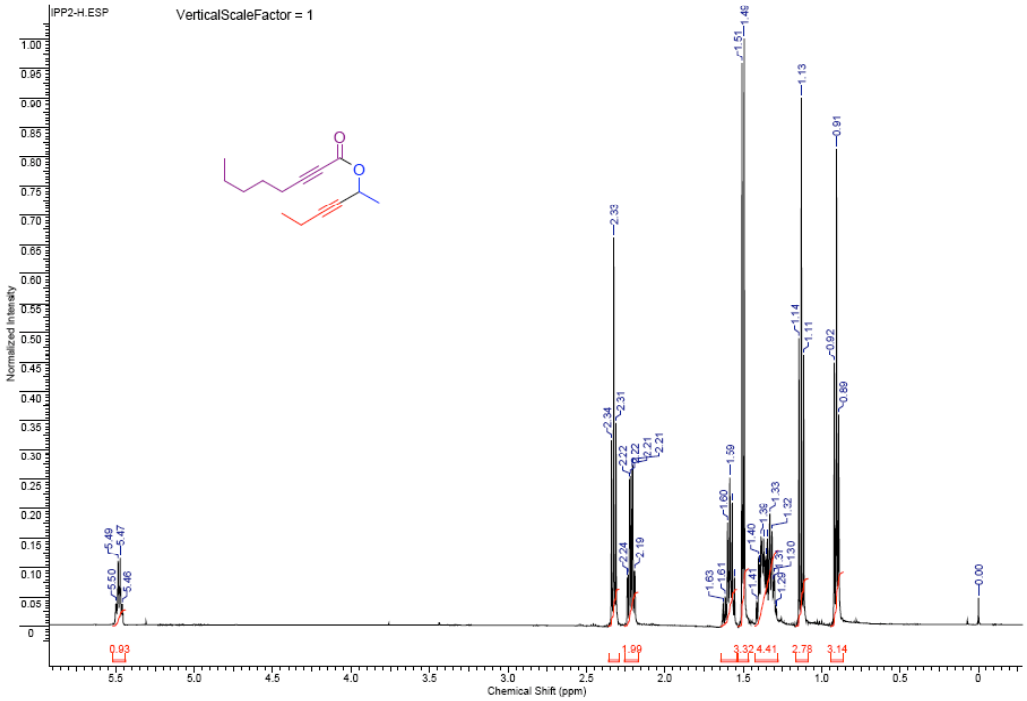


^{1}H NMR (500 MHz, $CDCl_3$) of compound **3a**

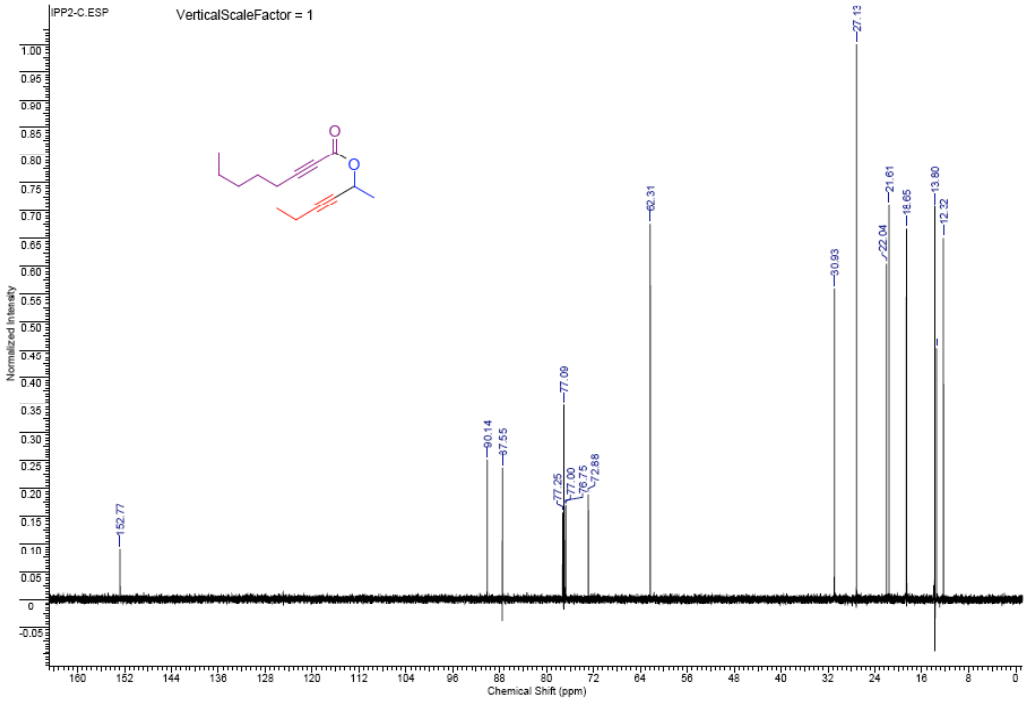


^{13}C NMR (126 MHz, $CDCl_3$) for compound **3a**

Spectra. Spectral Data for **hex-3-yn-2-yl oct-2-ynoate (1b)**

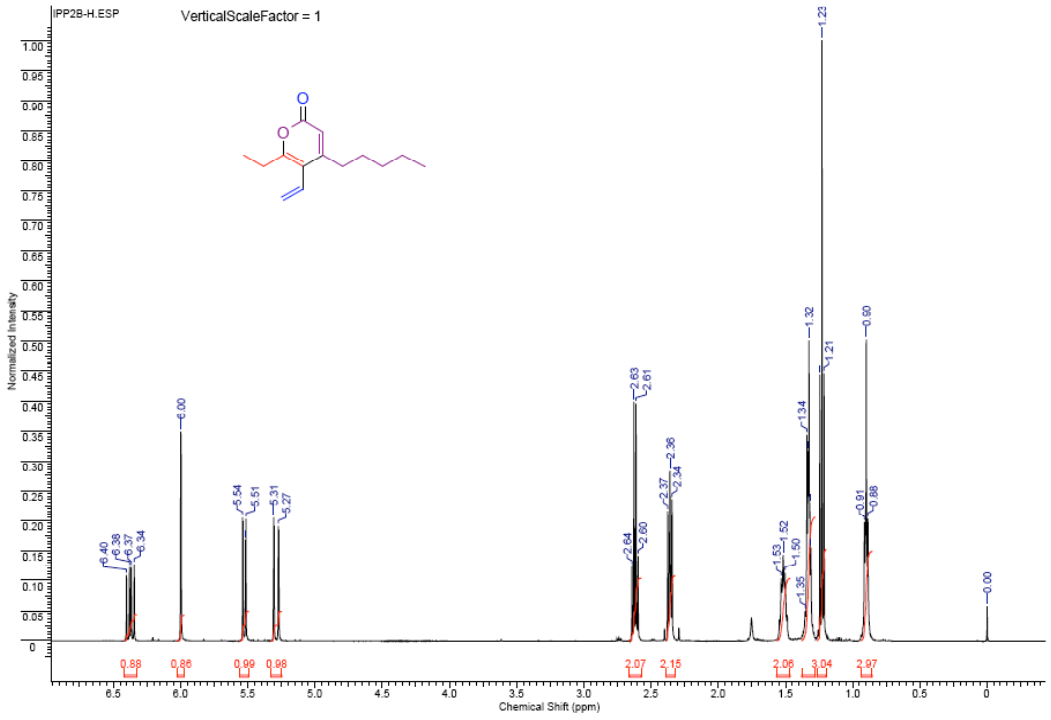


^{1}H NMR (500 MHz, $CDCl_3$) of compound **1b**

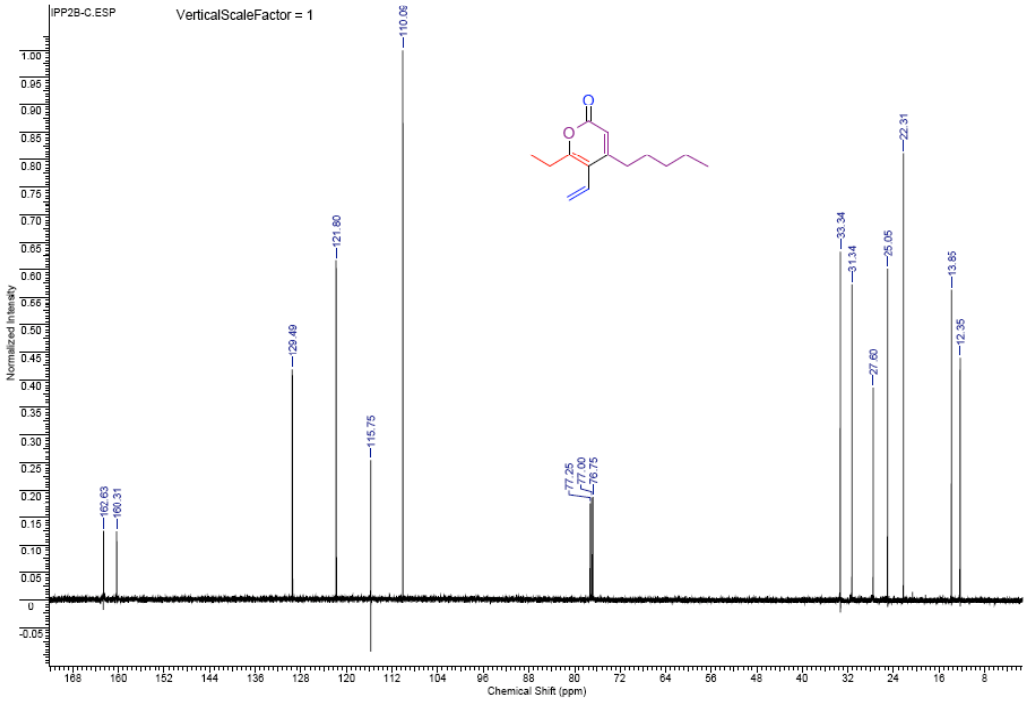


^{13}C NMR (126 MHz, $CDCl_3$) for compound **1b**

Spectra. Spectral Data for **6-ethyl-4-pentyl-5-vinyl-2H-pyran-2-one (2b)**

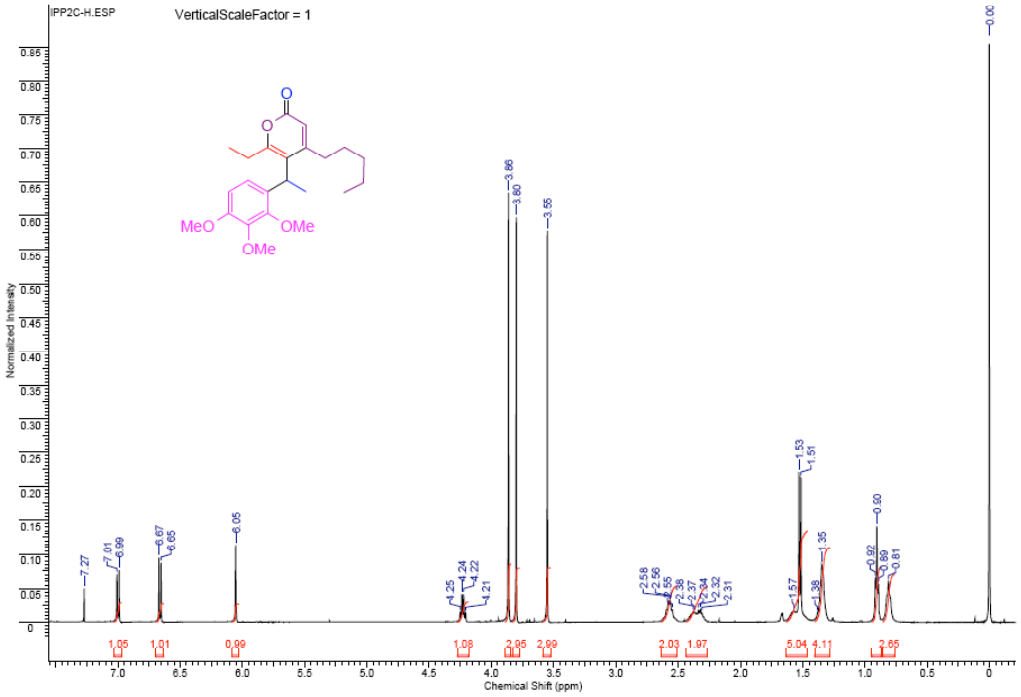


^{1}H NMR (500 MHz, $CDCl_3$) of compound **2b**

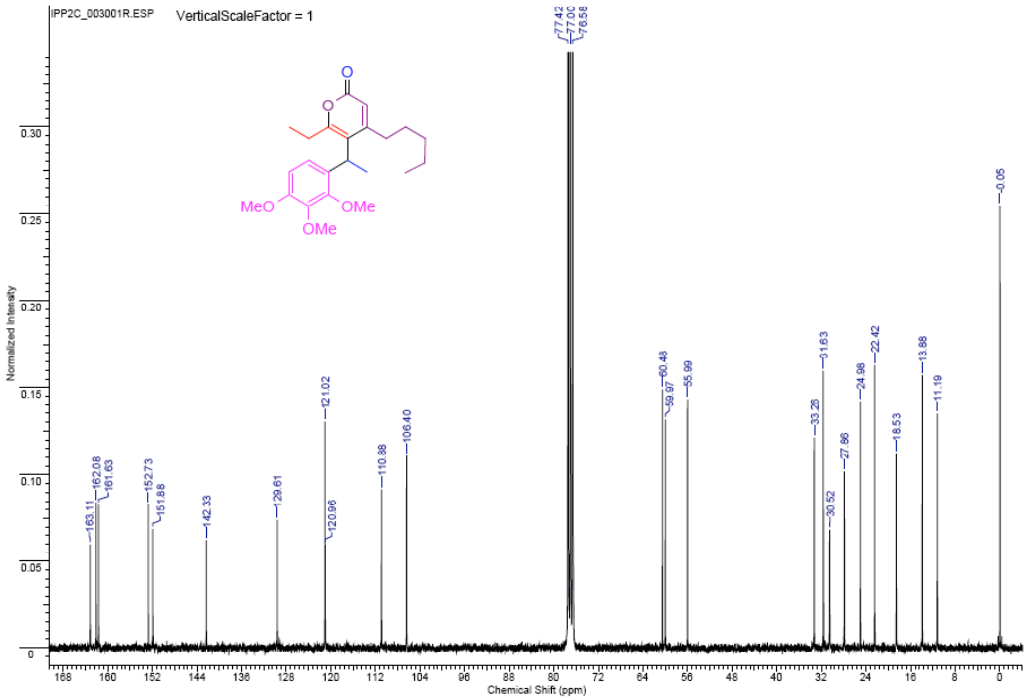


^{13}C NMR (126 MHz, $CDCl_3$) for compound **2b**

Spectra. Spectral Data for
6-ethyl-4-pentyl-5-(1-(2,3,4-trimethoxyphenyl)ethyl)-2H-pyran-2-one (3b)

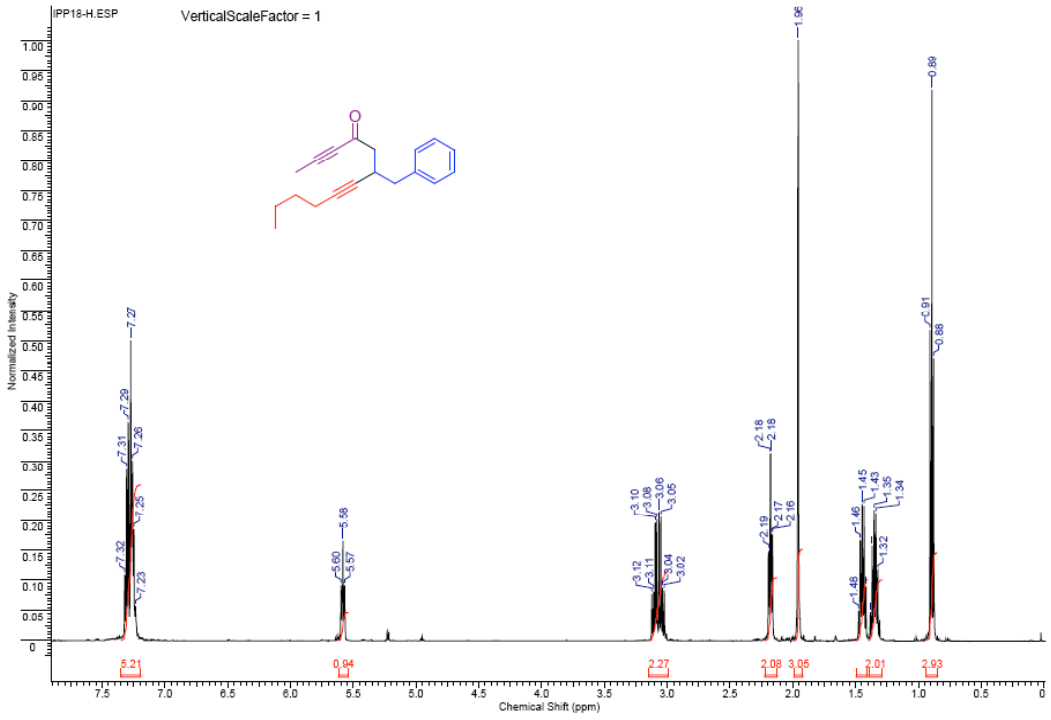


^{1}H NMR (500 MHz, $CDCl_3$) of compound **3b**

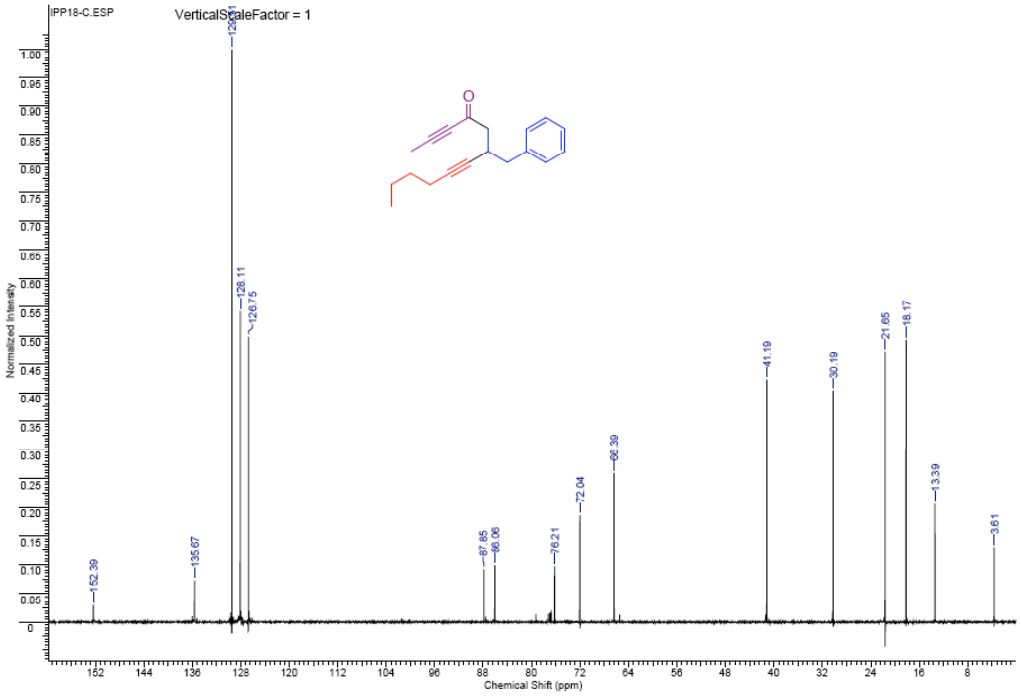


^{13}C NMR (75 MHz, $CDCl_3$) for compound **3b**

Spectra. Spectral Data for **(2-(2-methylenepent-3-ynyl)oct-3-ynyl)benzene (1c)**

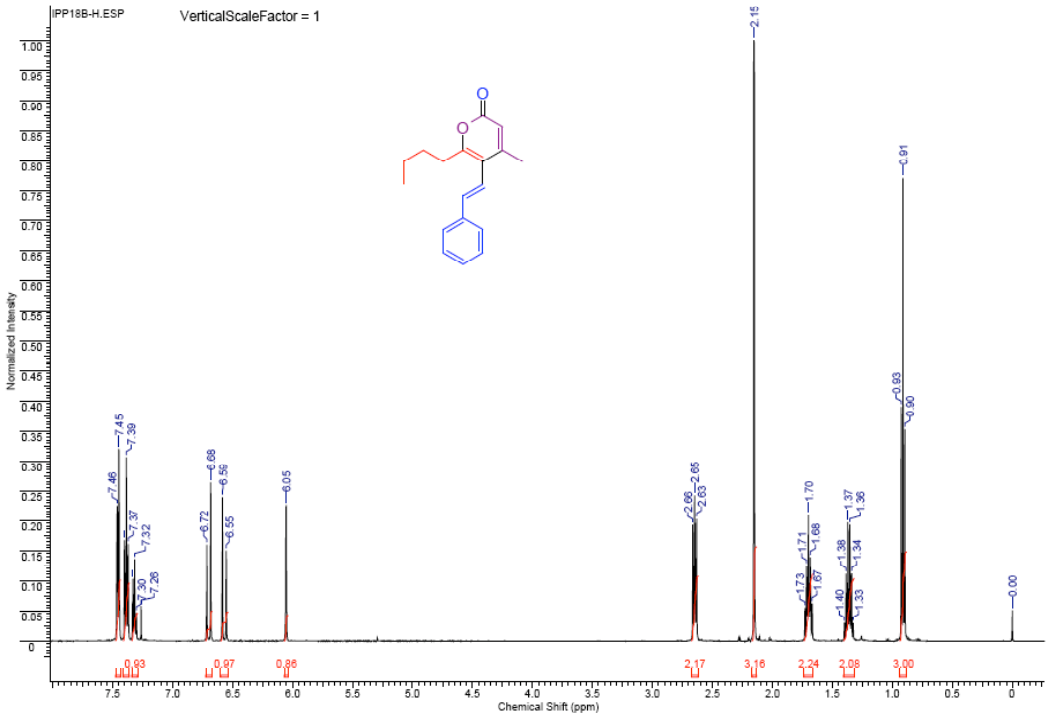


^{1}H NMR (500 MHz, $CDCl_3$) of compound **1c**

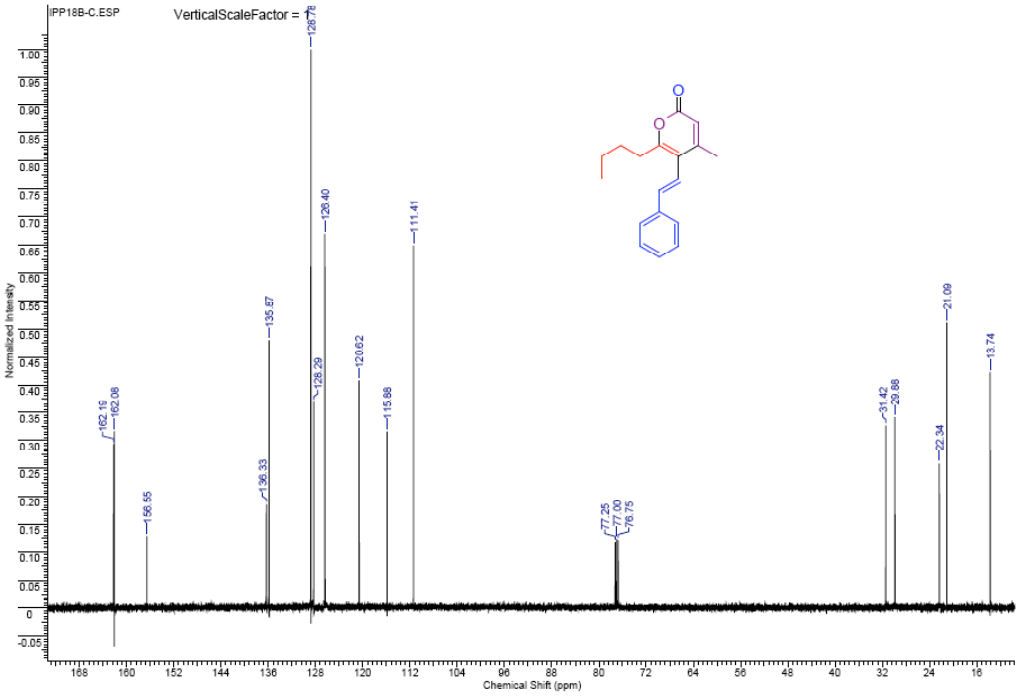


^{13}C NMR (126 MHz, $CDCl_3$) for compound **1c**

Spectra. Spectral Data for **(E)-6-butyl-4-methyl-5-styryl-2H-pyran-2-one (2c)**



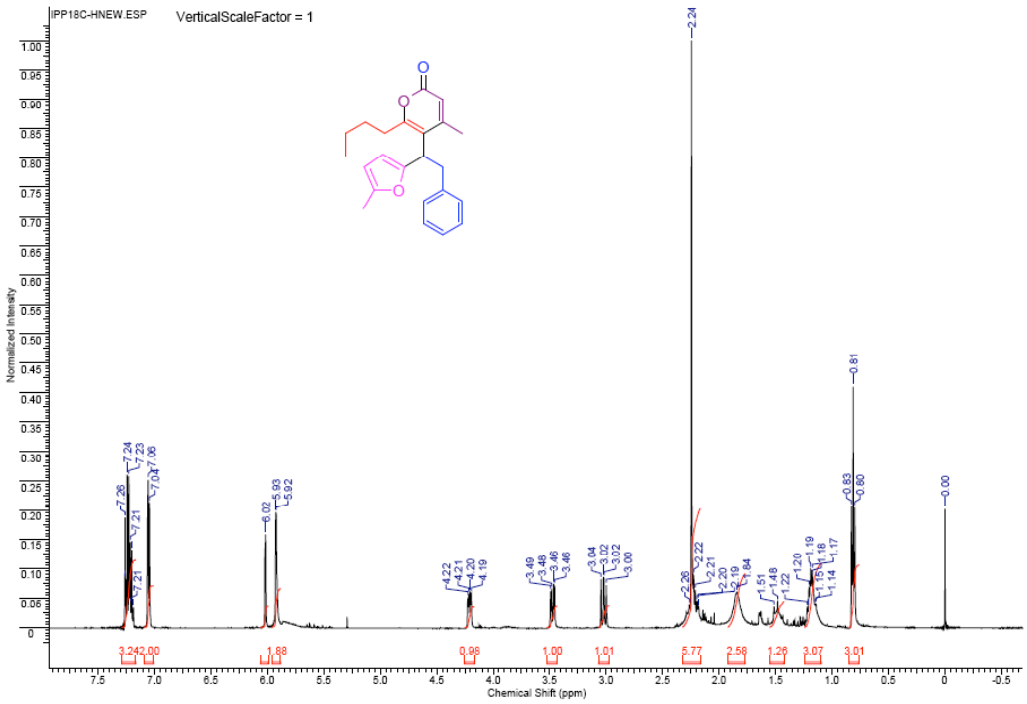
^{1}H NMR (500 MHz, $CDCl_3$) of compound **2c**



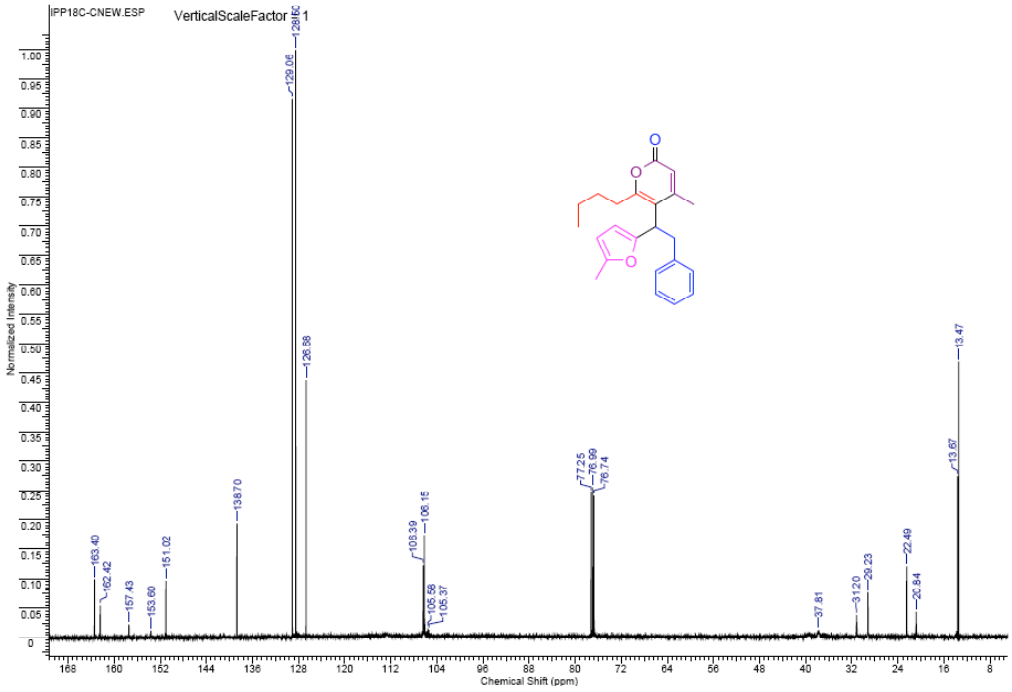
^{13}C NMR (126 MHz, $CDCl_3$) for compound **2c**

Spectra. Spectral Data for

6-butyl-4-methyl-5-(1-(5-methylfuran-2-yl)-2-phenylethyl)-2H-pyran-2-one (3c)

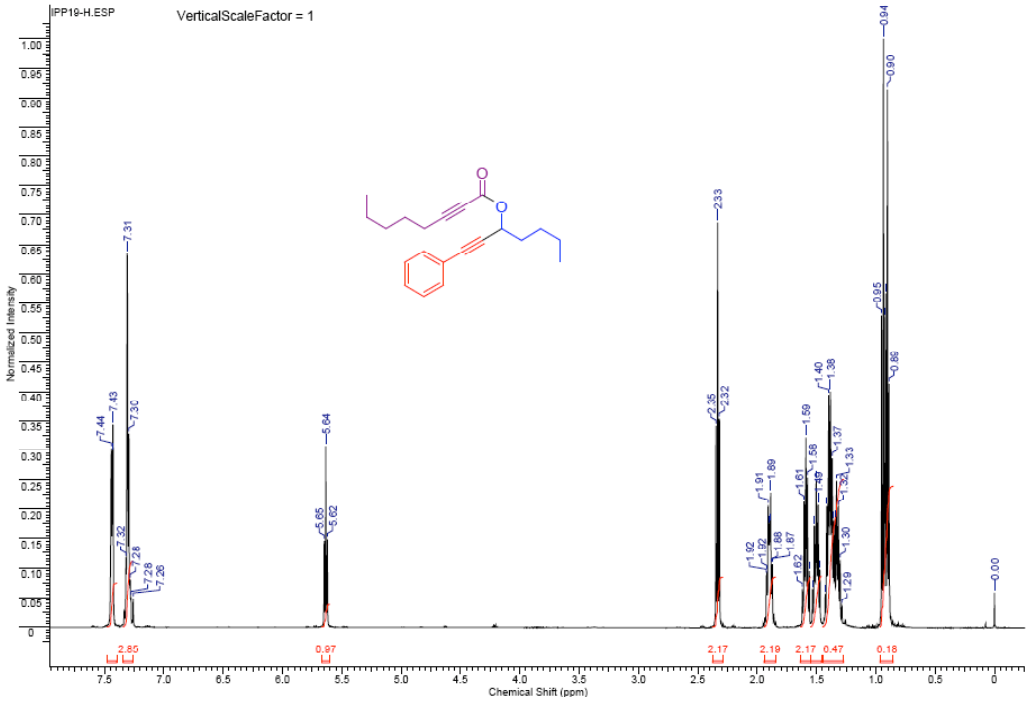


^{1}H NMR (500 MHz, $CDCl_3$) of compound **3c**

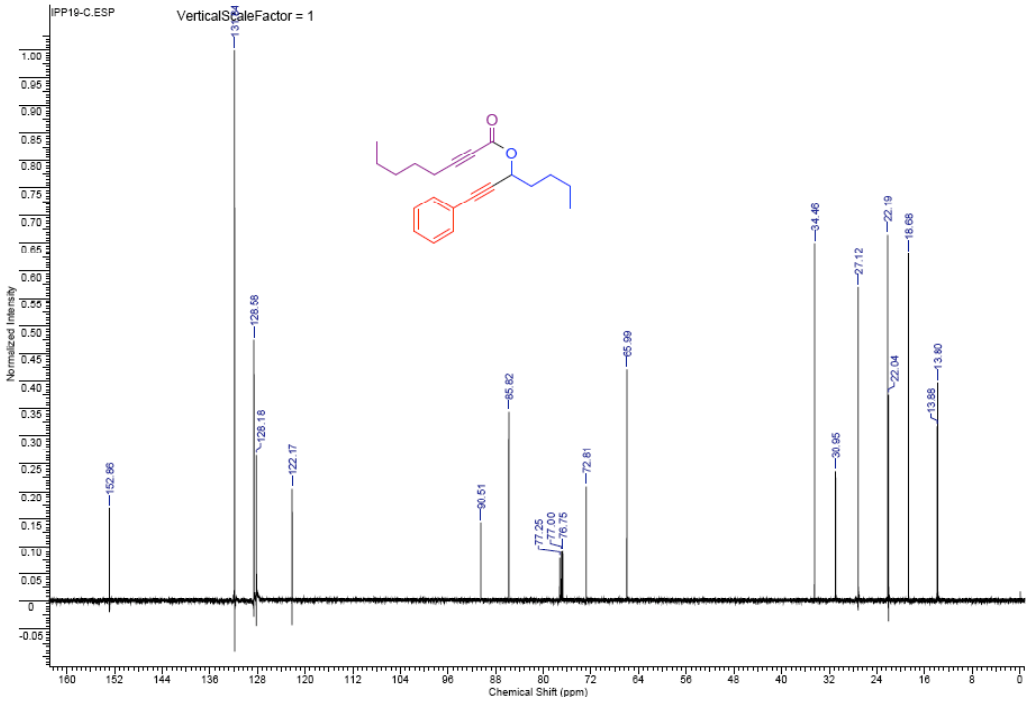


^{13}C NMR (126 MHz, $CDCl_3$) for compound **3c**

Spectra. Spectral Data for **1-phenylhept-1-yn-3-yl oct-2-ynoate (1d)**

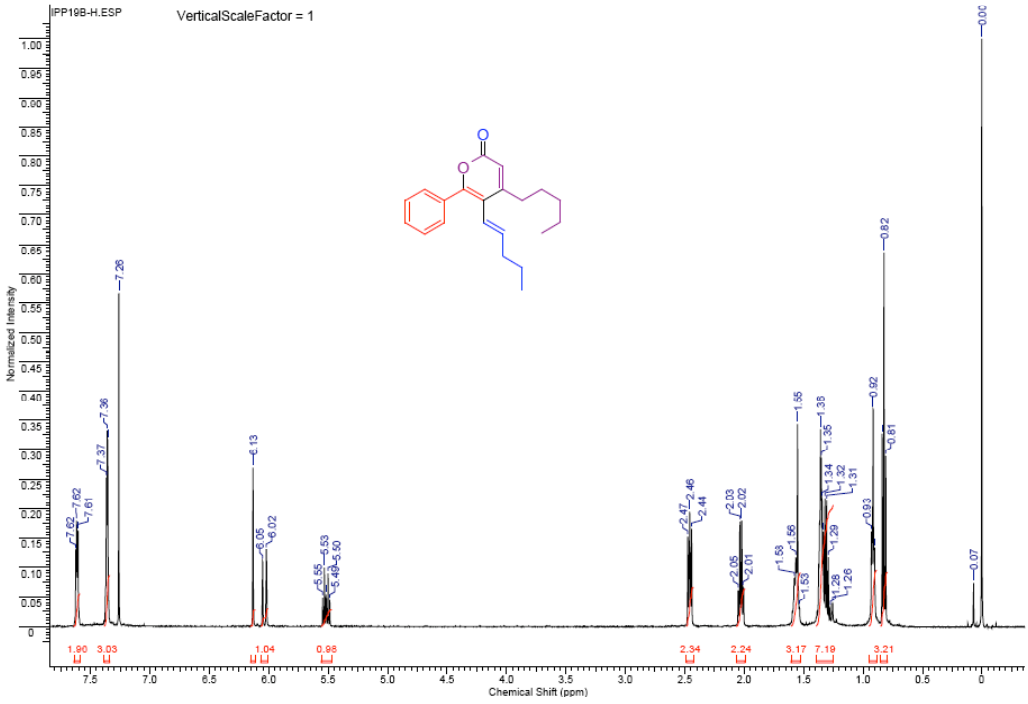


^{1}H NMR (500 MHz, $CDCl_3$) of compound **1d**

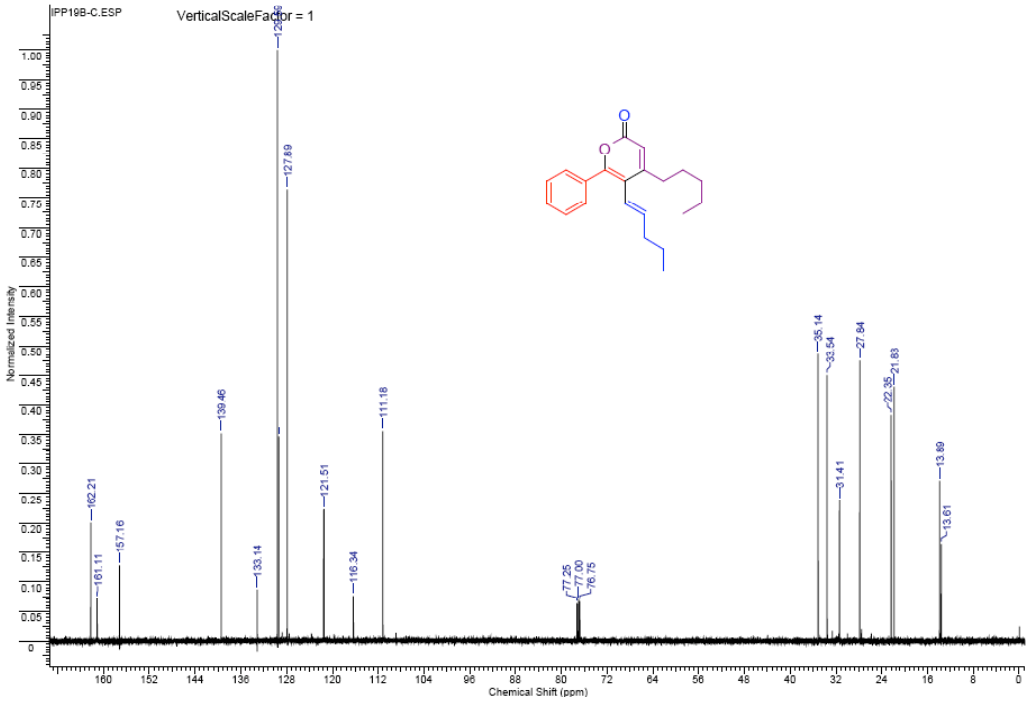


^{13}C NMR (126 MHz, $CDCl_3$) for compound **1d**

Spectra. Spectral Data for **(E)-5-(pent-1-enyl)-4-pentyl-6-phenyl-2H-pyran-2-one (2d)**

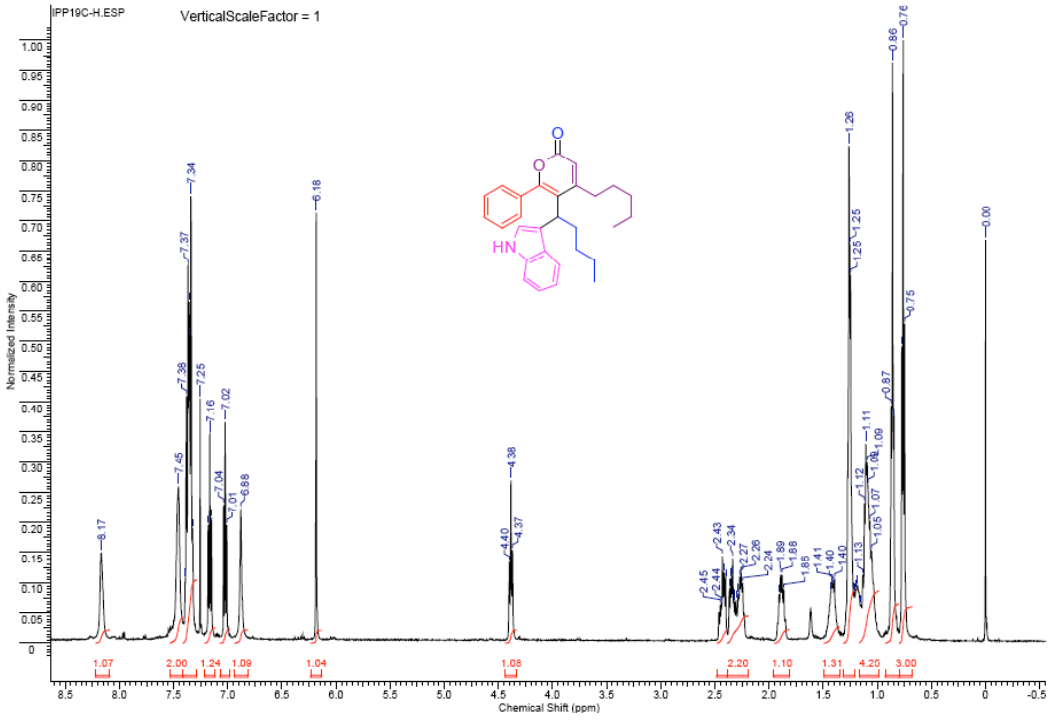


^{1}H NMR (500 MHz, $CDCl_3$) of compound **2d**

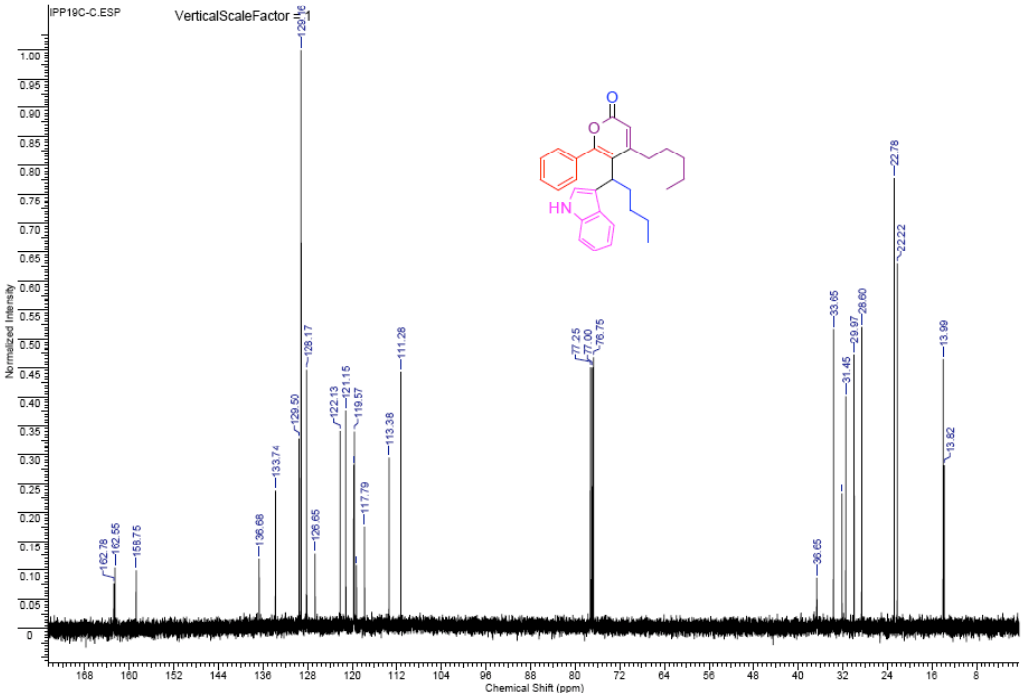


^{13}C NMR (126 MHz, $CDCl_3$) for compound **2d**

Spectra. Spectral Data for **5-(1-(1H-indol-3-yl)pentyl)-4-pentyl-6-phenyl-2H-pyran-2-one (3d)**

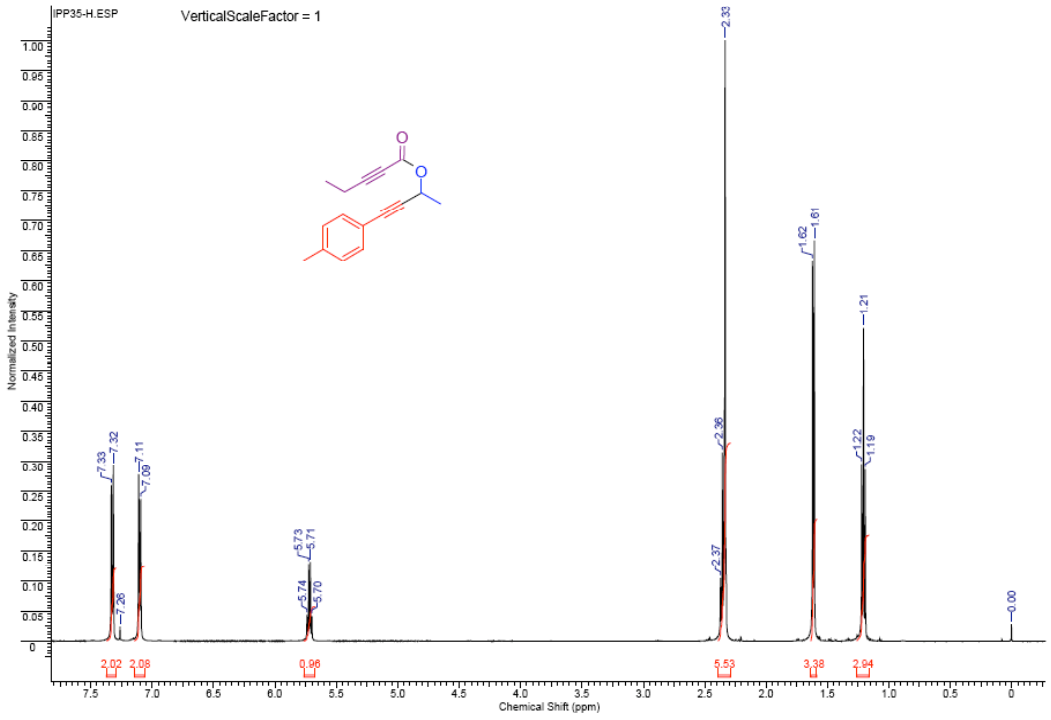


^{1}H NMR (500 MHz, $CDCl_3$) of compound **3d**

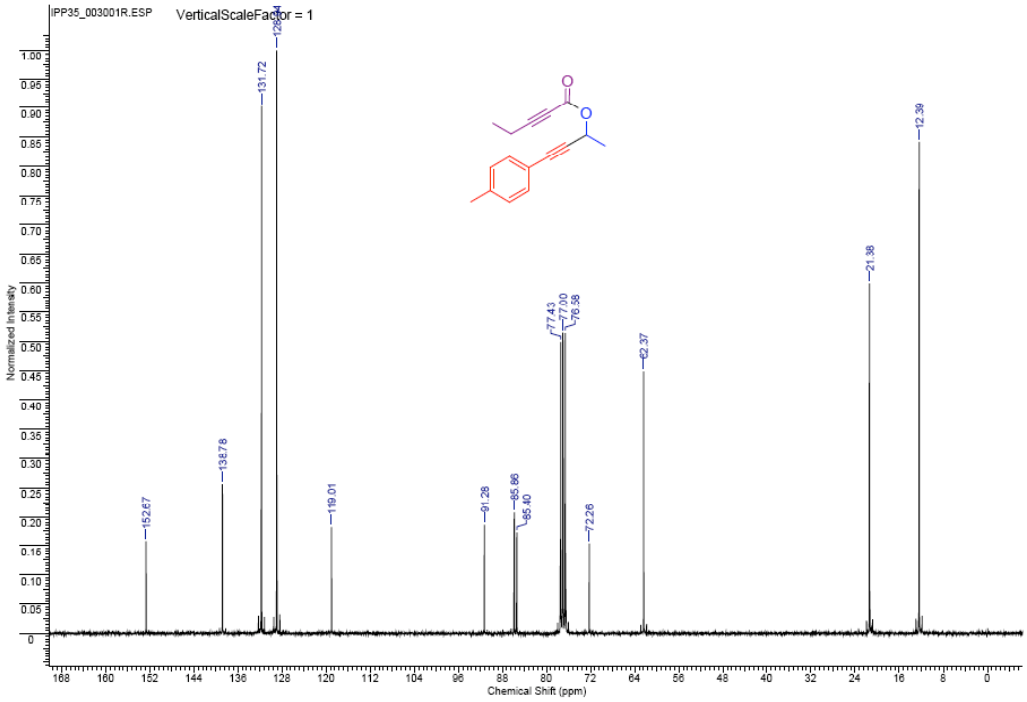


^{13}C NMR (126 MHz, $CDCl_3$) for compound **3d**

Spectra. Spectral Data for **4-p-tolylbut-3-yn-2-yl pent-2-ynoate** (**1e**)

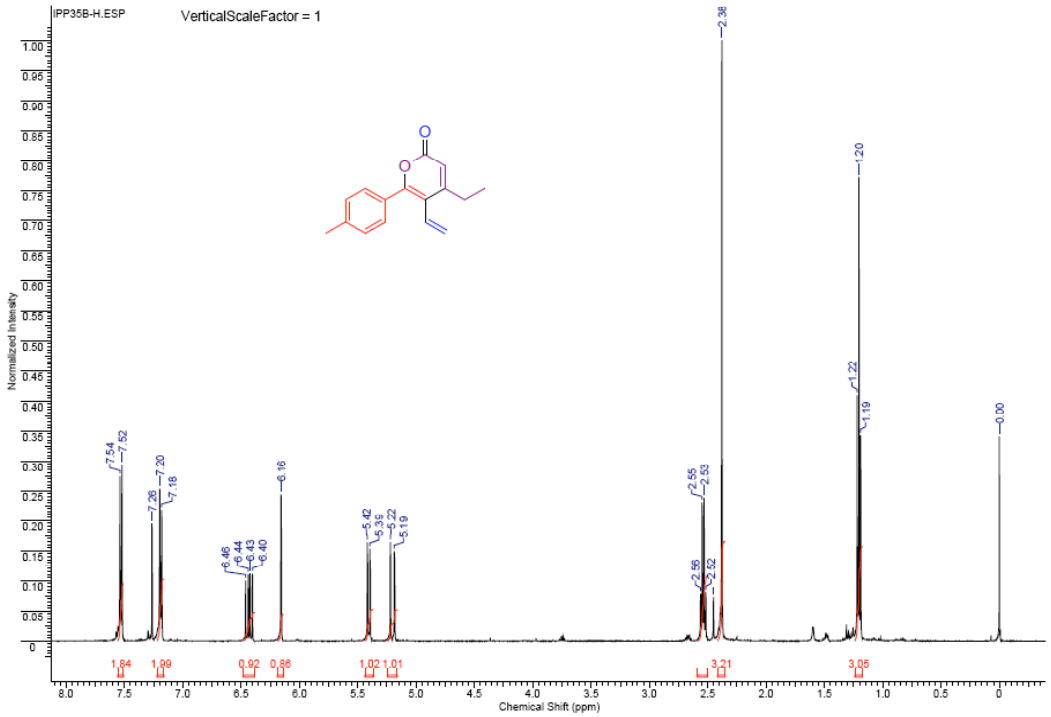


^{1}H NMR (500 MHz, $CDCl_3$) of compound **1e**

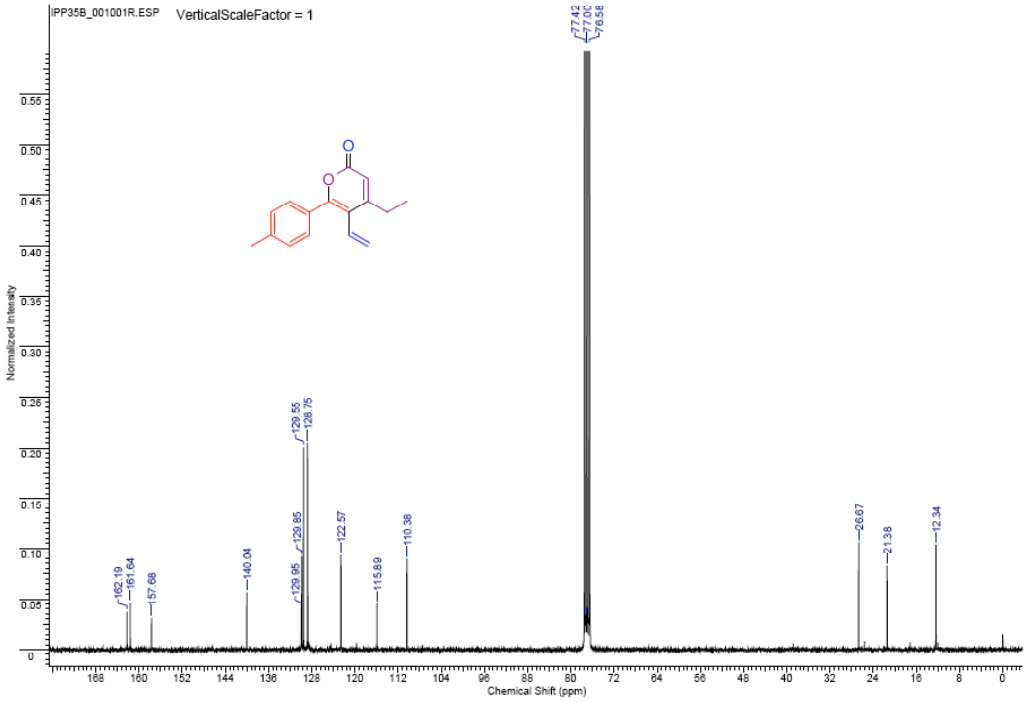


^{13}C NMR (75 MHz, $CDCl_3$) for compound **1e**

Spectra. Spectral Data for **4-ethyl-6-p-tolyl-5-vinyl-2H-pyran-2-one** (**2e**).

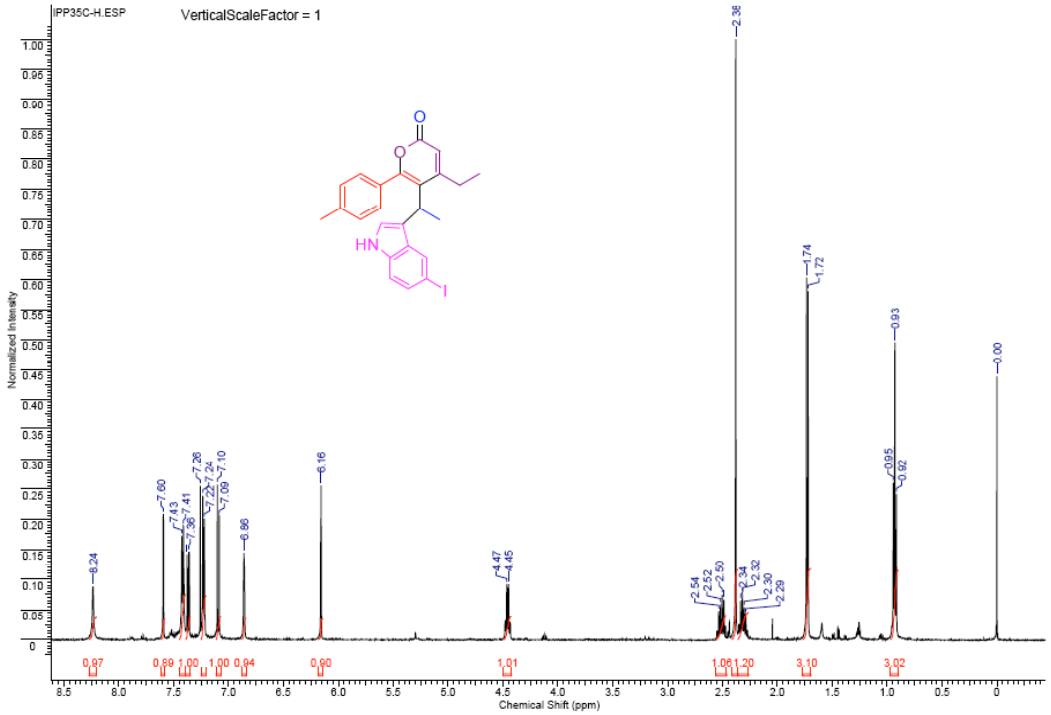


^{1}H NMR (500 MHz, $CDCl_3$) of compound **2e**

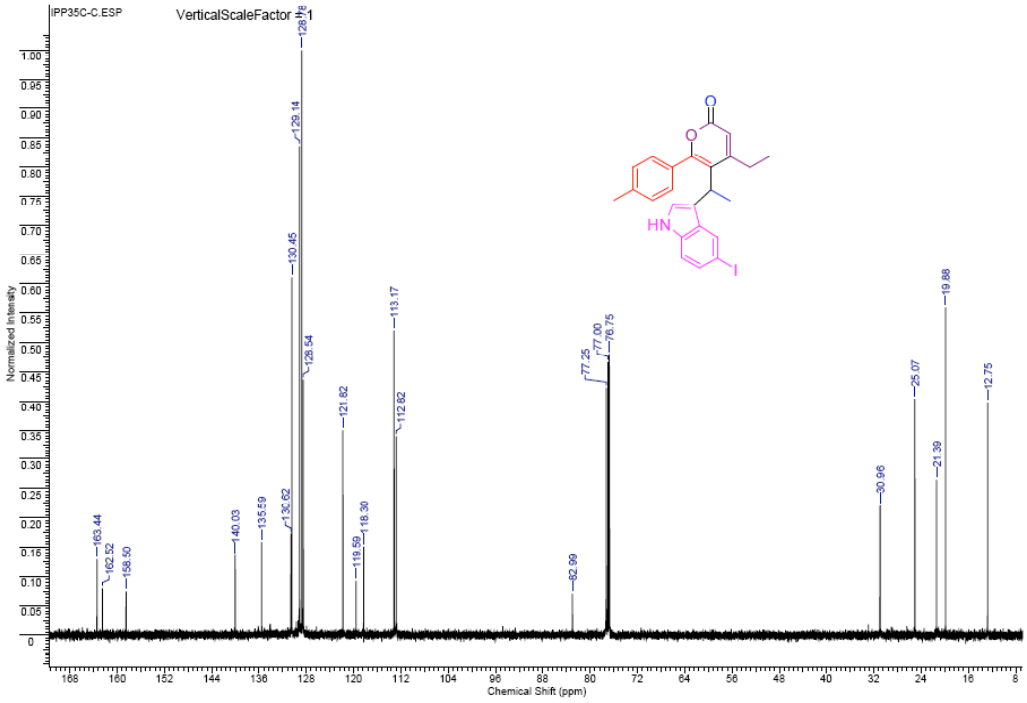


^{13}C NMR (75 MHz, $CDCl_3$) for compound **2e**

Spectra. Spectral Data for **4-ethyl-5-(1-(5-iodo-1H-indol-3-yl)ethyl)-6-p-tolyl-2H-pyran-2-one (3e)**

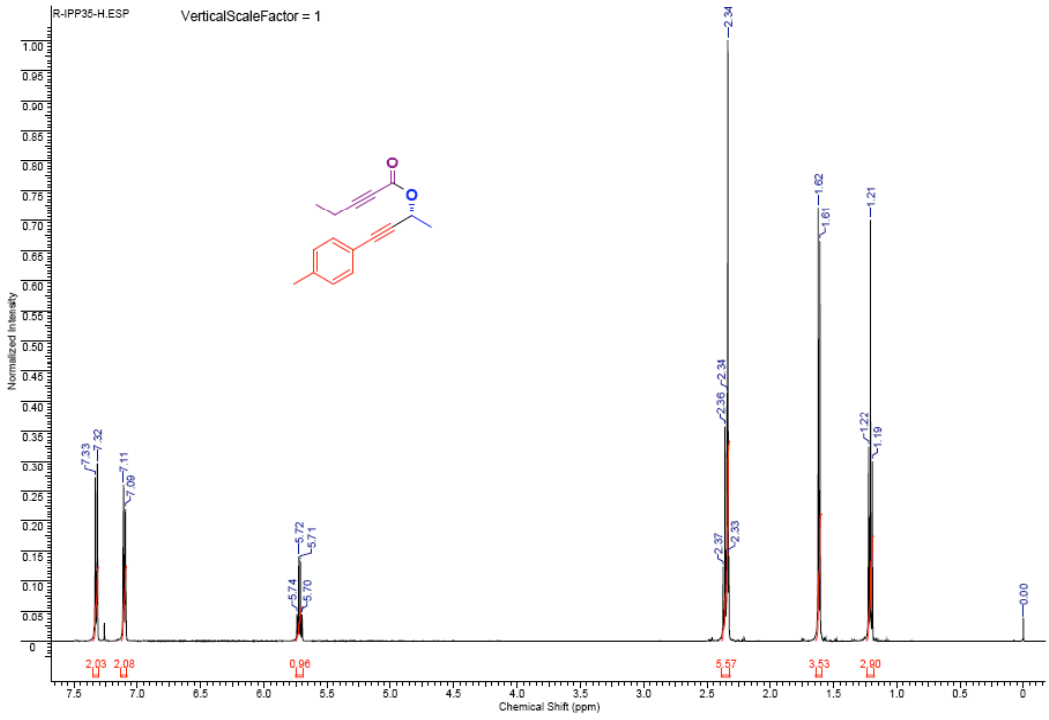


^{1}H NMR (500 MHz, $CDCl_3$) of compound **3e**

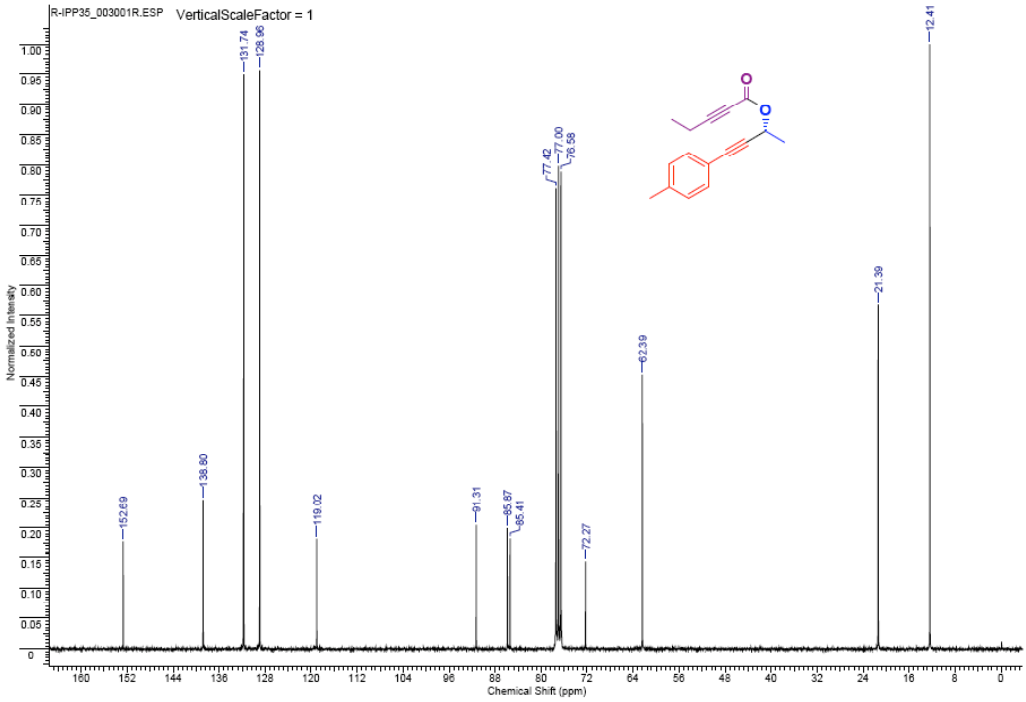


^{13}C NMR (126 MHz, $CDCl_3$) for compound **3e**

Spectra. Spectral Data for **(*R*)-4-p-tolylbut-3-yn-2-yl pent-2-ynoate ((*R*)-1e).**

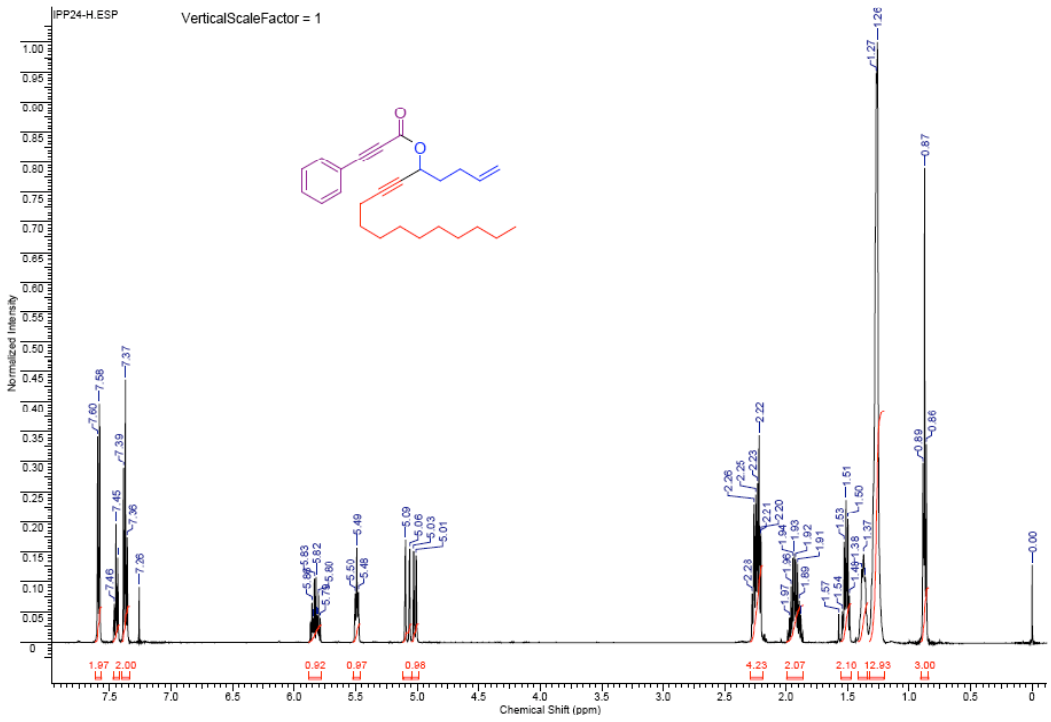


^{1}H NMR (500 MHz, $CDCl_3$) of compound **(*R*)-1e**

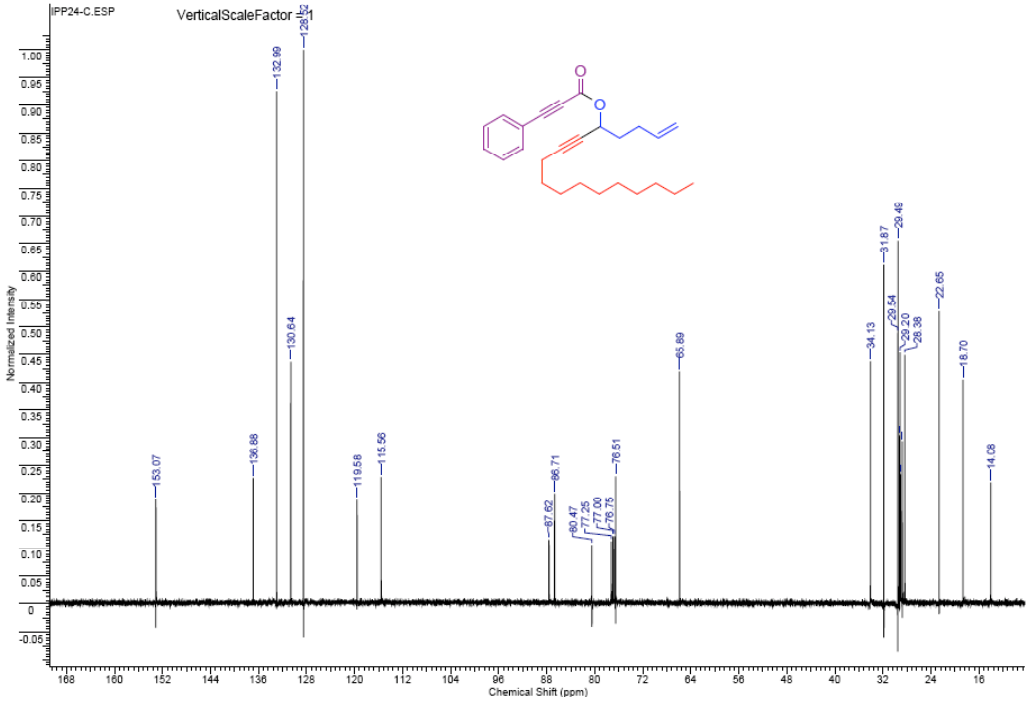


^{13}C NMR (75 MHz, $CDCl_3$) for compound **(*R*)-1e**

Spectra. Spectral Data for **heptadec-1-en-6-yn-5-yl 3-phenylpropiolate (1f)**

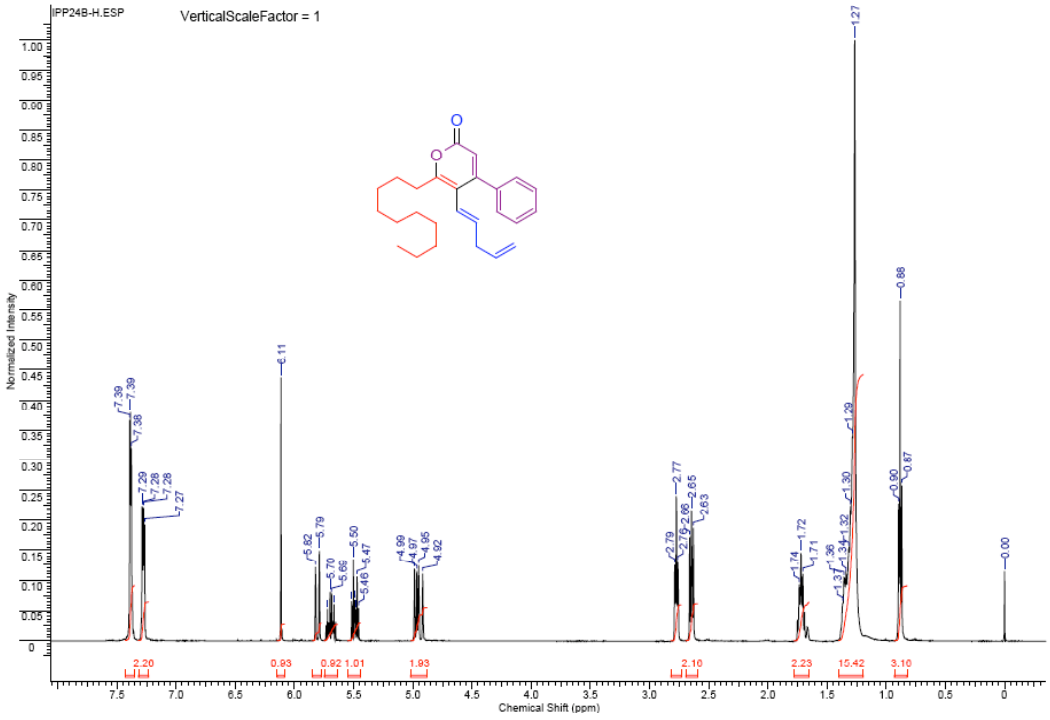


^{1}H NMR (500 MHz, $CDCl_3$) of compound **1f**

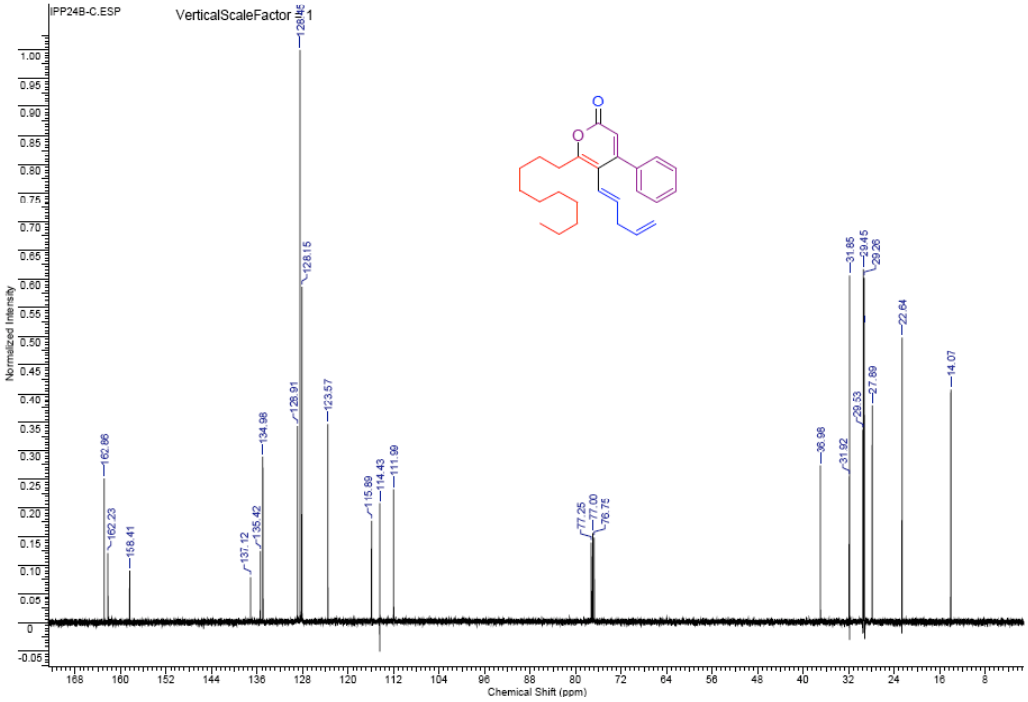


^{13}C NMR (126 MHz, $CDCl_3$) for compound **1f**

Spectra. Spectral Data for **(E)-6-decyl-5-(penta-1,4-dienyl)-4-phenyl-2H-pyran-2-one (2f)**



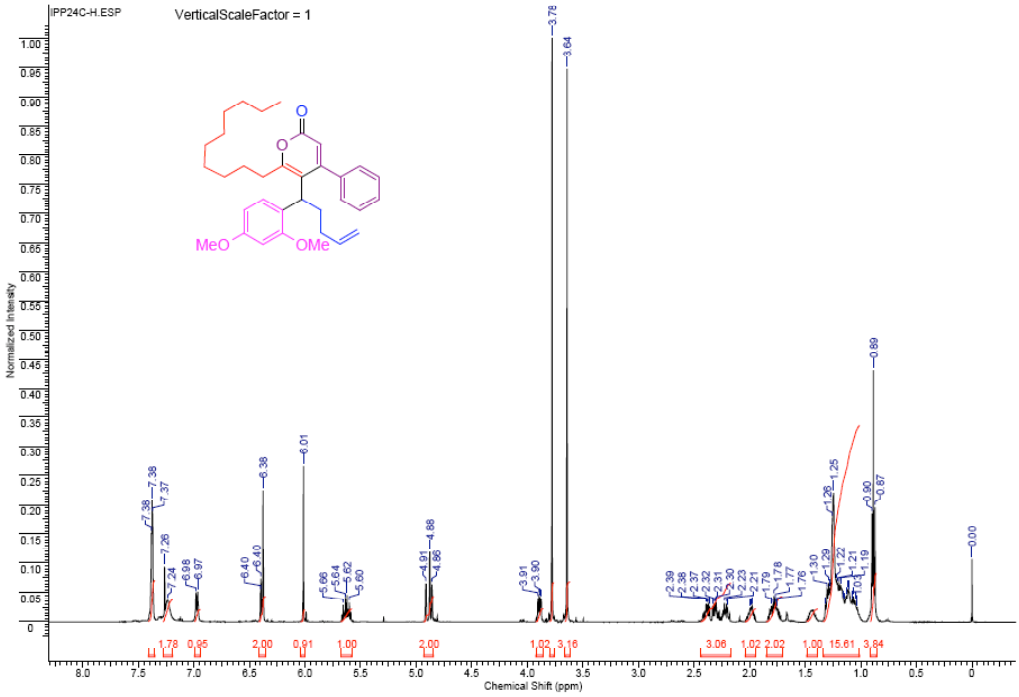
^{1}H NMR (500 MHz, $CDCl_3$) of compound **2f**



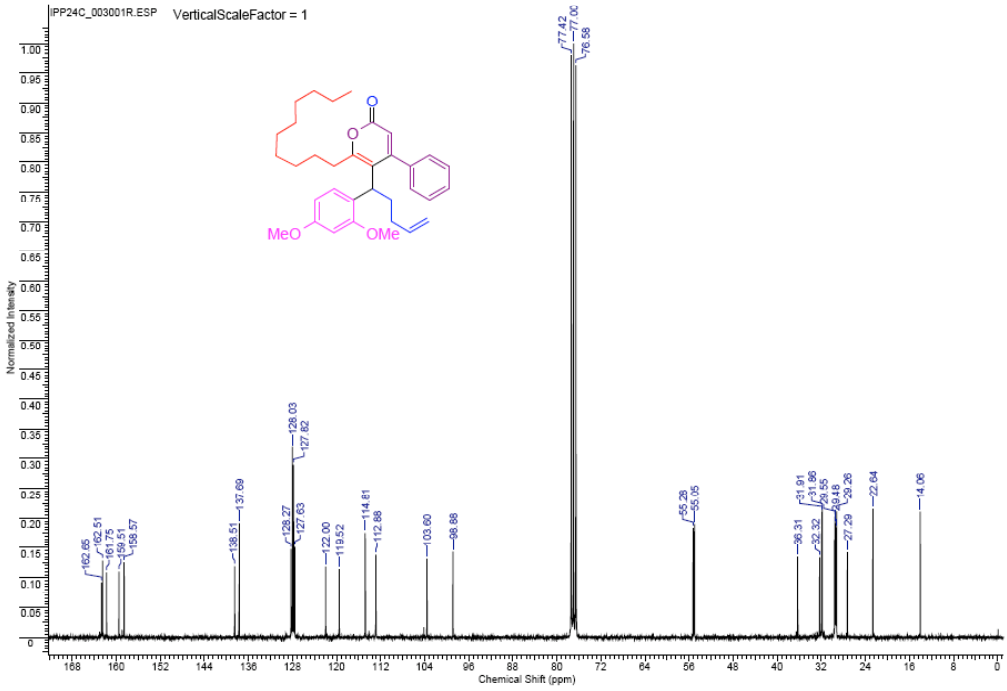
^{13}C NMR (126 MHz, $CDCl_3$) for compound **2f**

Spectra. Spectral Data for

6-decyl-5-(1-(2,4-dimethoxyphenyl)pent-4-enyl)-4-phenyl-2H-pyran-2-one (3f)

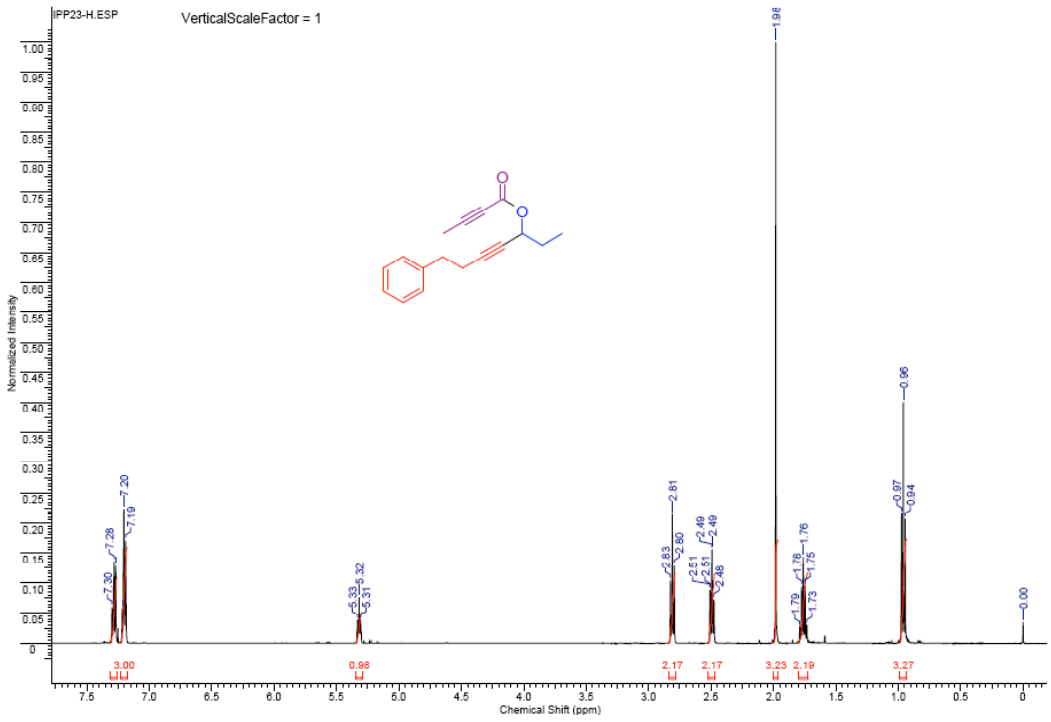


^{1}H NMR (500 MHz, $CDCl_3$) of compound **3f**

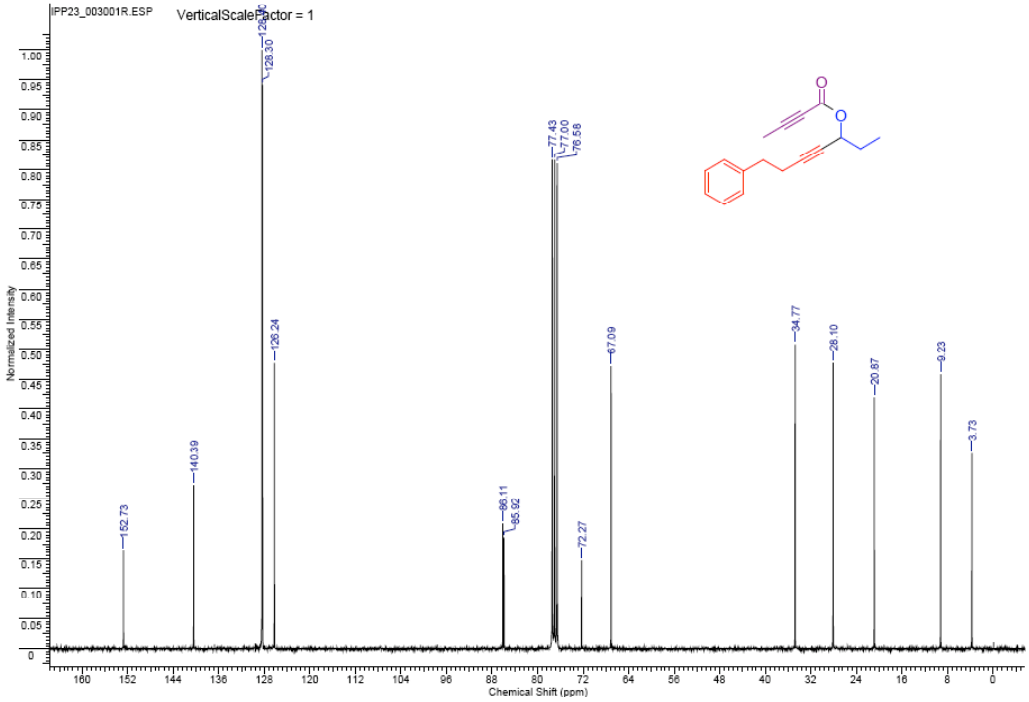


^{13}C NMR (75 MHz, $CDCl_3$) for compound **3f**

Spectra. Spectral Data for **7-phenylhept-4-yn-3-yl but-2-ynoate (1g)**

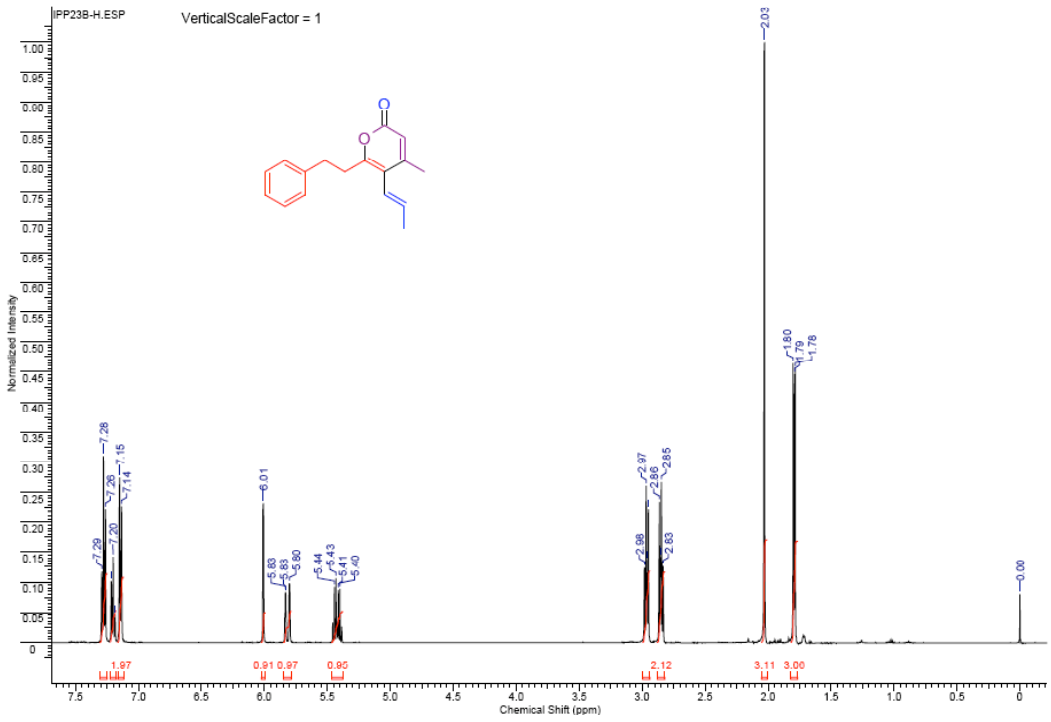


^{1}H NMR (500 MHz, $CDCl_3$) of compound **1g**

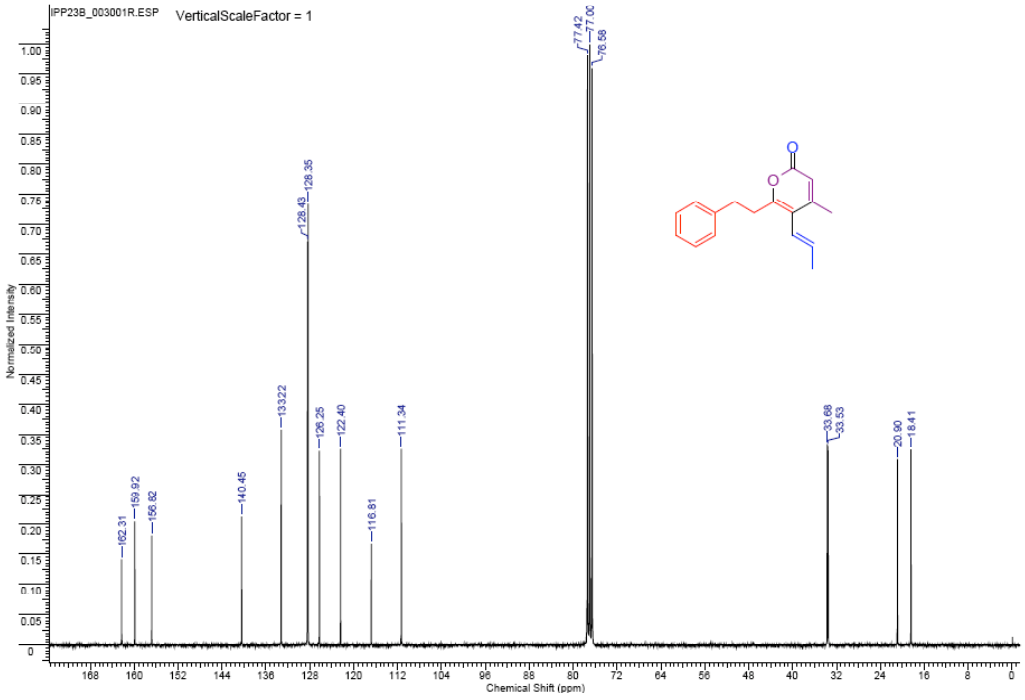


^{13}C NMR (126 MHz, $CDCl_3$) for compound **1g**

Spectra. Spectral Data for **(E)-4-methyl-6-phenethyl-5-(prop-1-enyl)-2H-pyran-2-one (2g)**

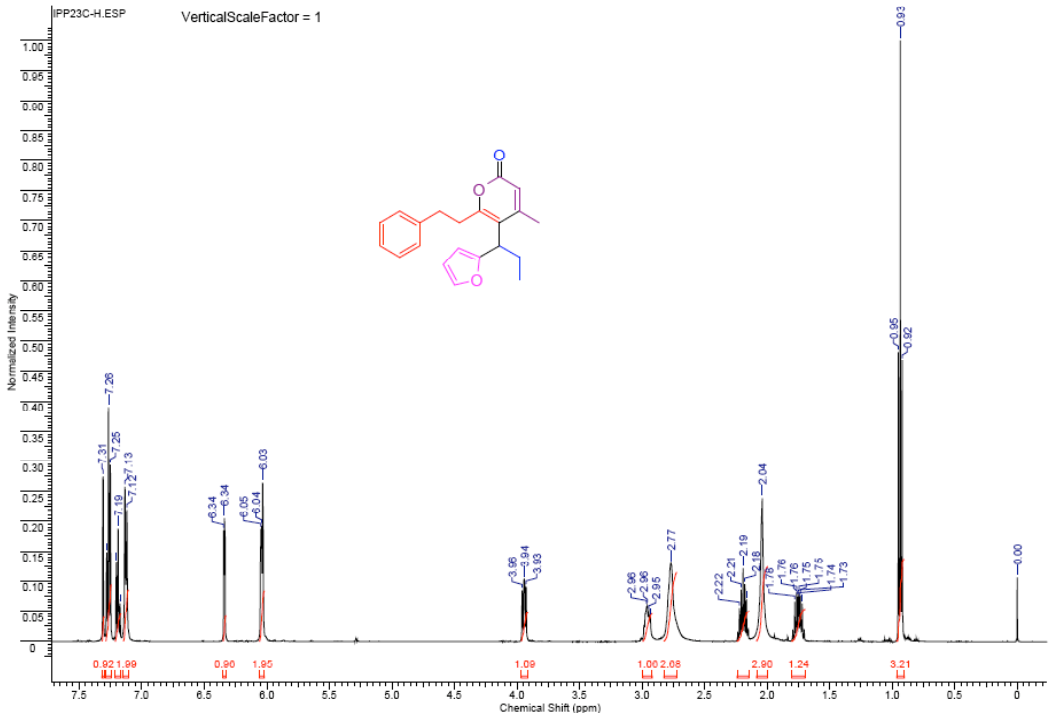


^{1}H NMR (500 MHz, $CDCl_3$) of compound **2g**

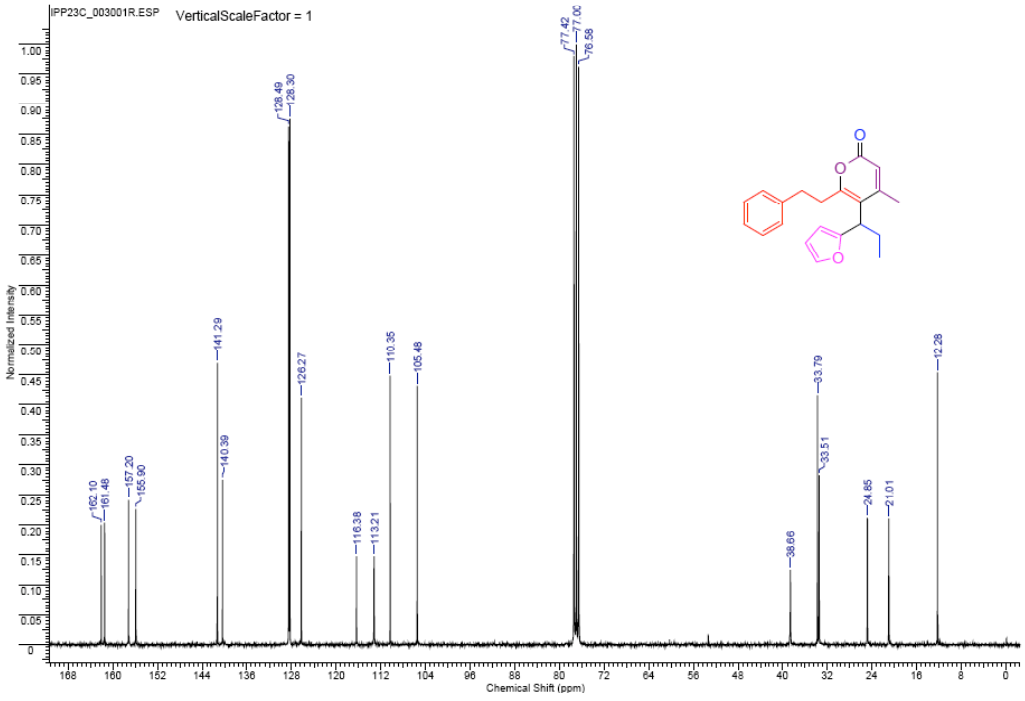


^{13}C NMR (75 MHz, $CDCl_3$) for compound **2g**

Spectra. Spectral Data for **5-(1-(furan-2-yl)propyl)-4-methyl-6-phenethyl-2H-pyran-2-one (3g)**



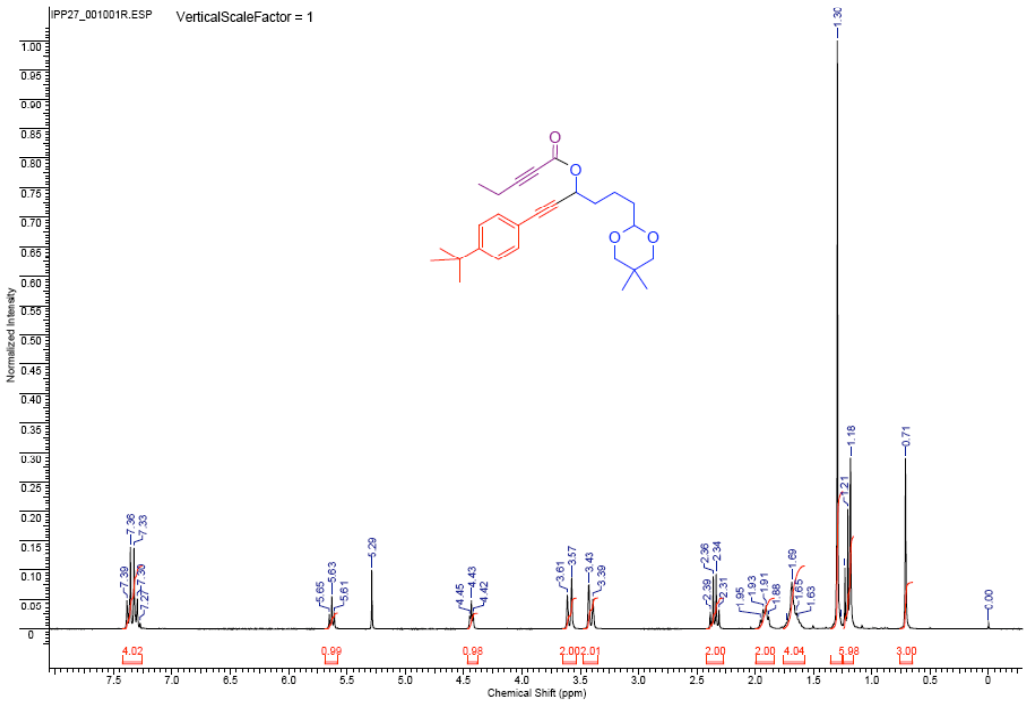
^{1}H NMR (500 MHz, $CDCl_3$) of compound **3g**



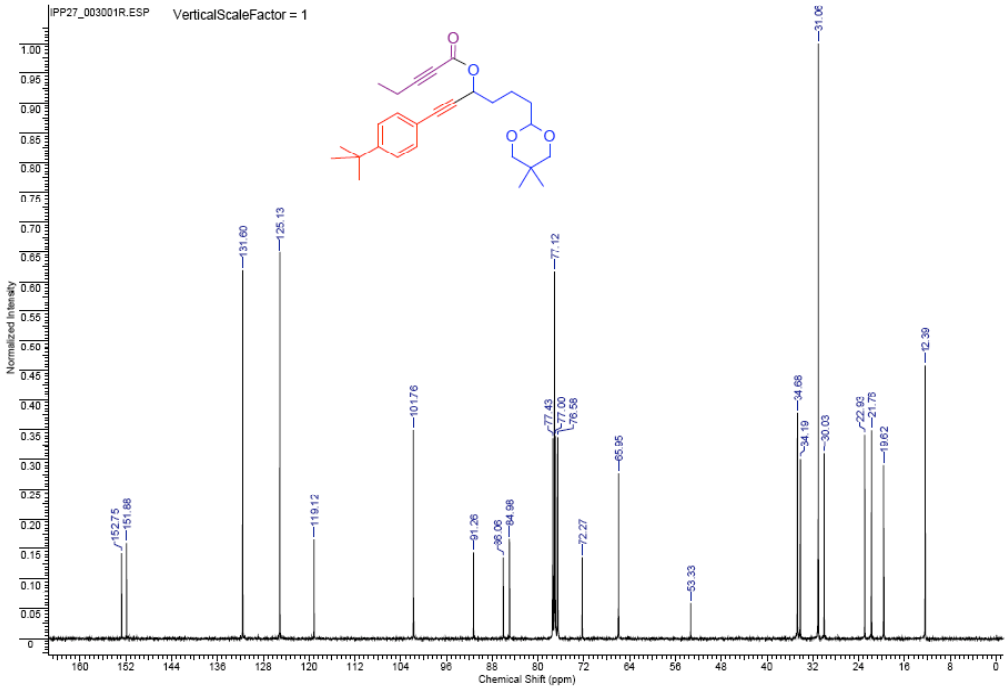
^{13}C NMR (75 MHz, $CDCl_3$) for compound **3g**

Spectra. Spectral Data for

1-(4-tert-butylphenyl)-6-(5,5-dimethyl-1,3-dioxan-2-yl)hex-1-yn-3-yl pent-2-ynoate (1h)

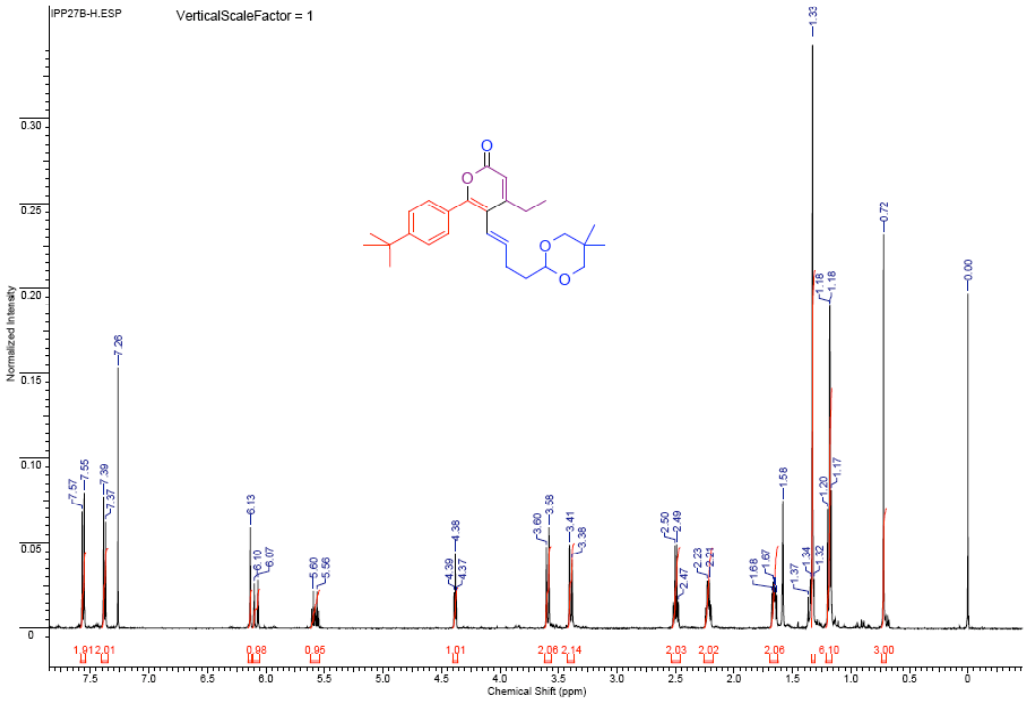


^{1}H NMR (300 MHz, $CDCl_3$) of compound **1h**

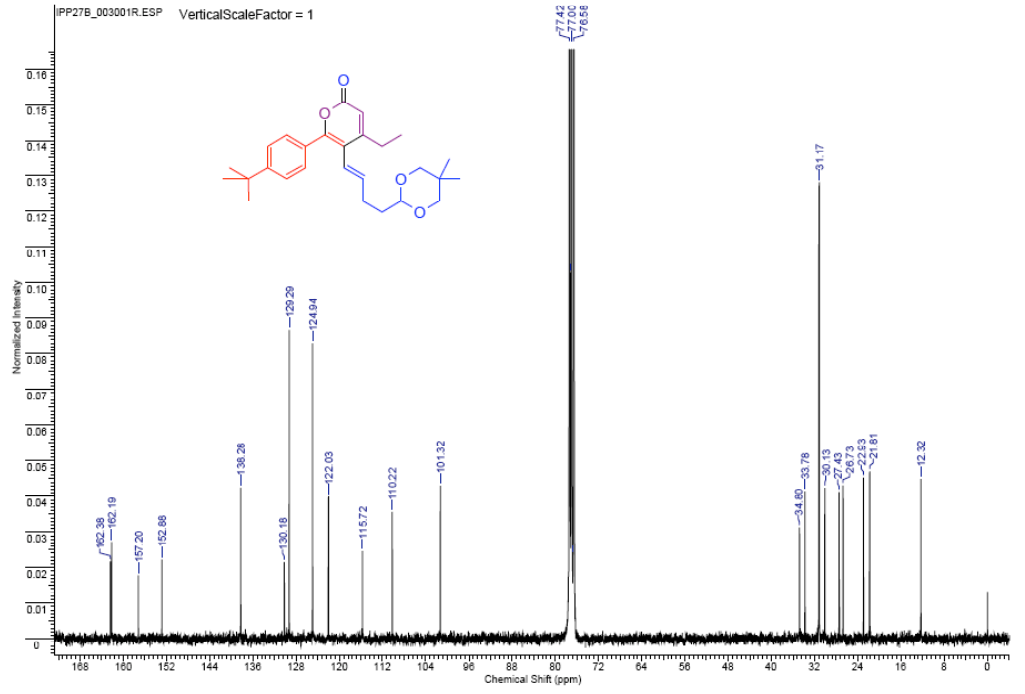


^{13}C NMR (75 MHz, $CDCl_3$) for compound **1h**

Spectra. Spectral Data for
(E)-6-(4-tert-butylphenyl)-5-(4-(5,5-dimethyl-1,3-dioxan-2-yl)but-1-enyl)-4-ethyl-2H-pyran-2-one (2h)



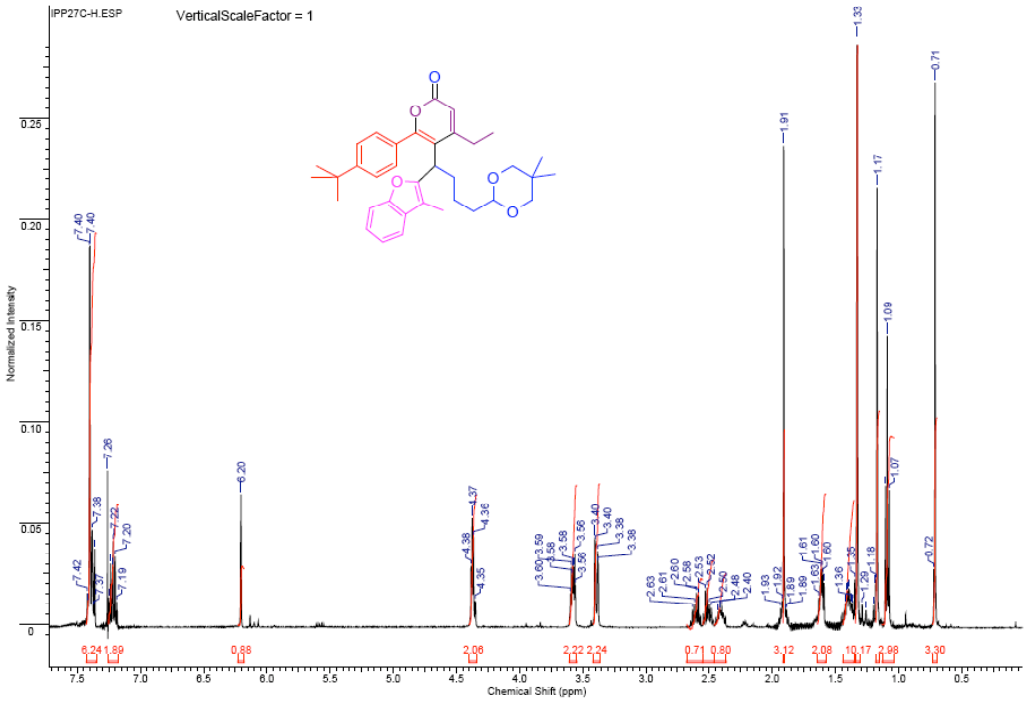
^{1}H NMR (500 MHz, $CDCl_3$) of compound **2h**



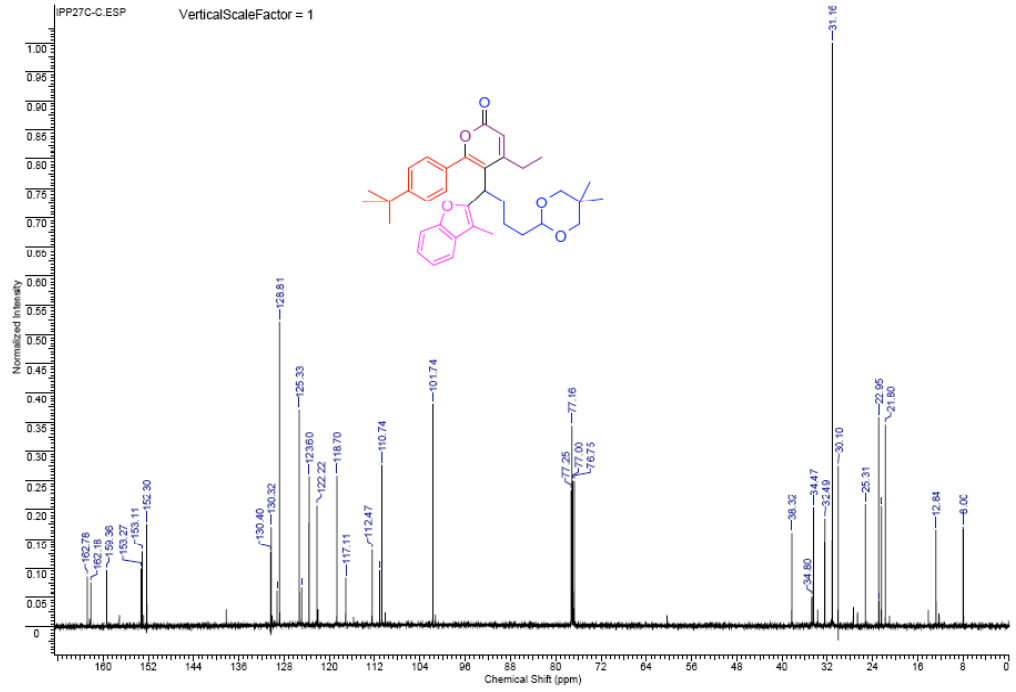
^{13}C NMR (75 MHz, $CDCl_3$) for compound **2h**

Spectra. Spectral Data for

6-(4-tert-butylphenyl)-5-(4-(5,5-dimethyl-1,3-dioxan-2-yl)-1-(3-methylbenzofuran-2-yl)butyl)-4-ethyl-2H-pyran-2-one (3h)

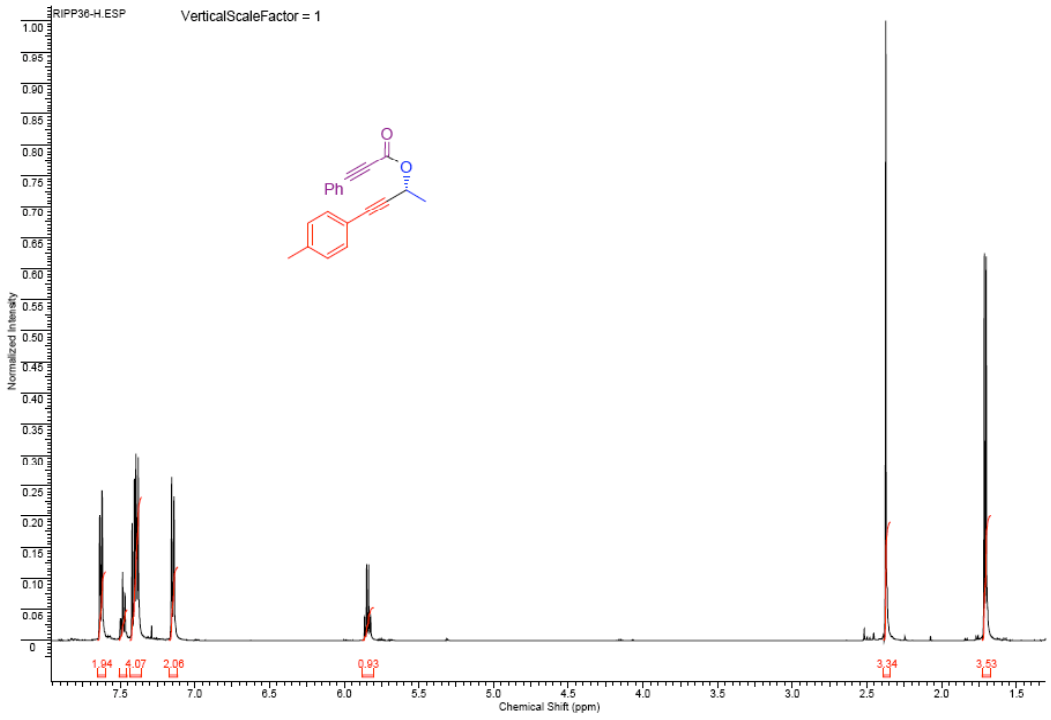


^{1}H NMR (500 MHz, $CDCl_3$) of compound **3h**

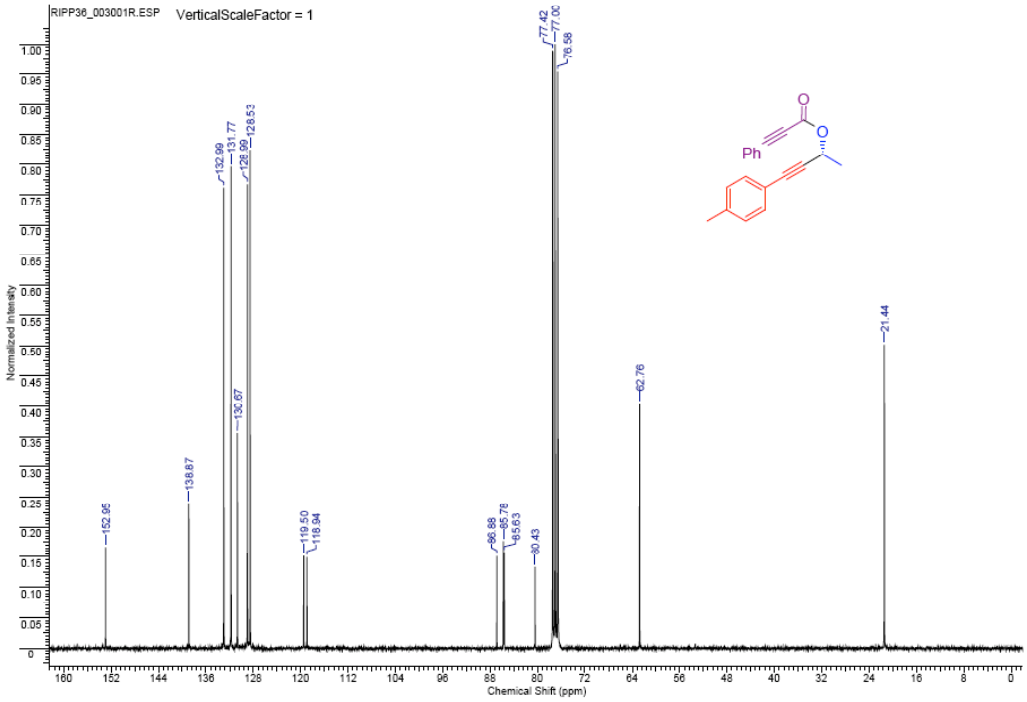


^{13}C NMR (126 MHz, $CDCl_3$) for compound **3h**

Spectra. Spectral Data for **(*R*)-4-p-tolylbut-3-yn-2-yl 3-phenylpropiolate ((*R*)-1i)**

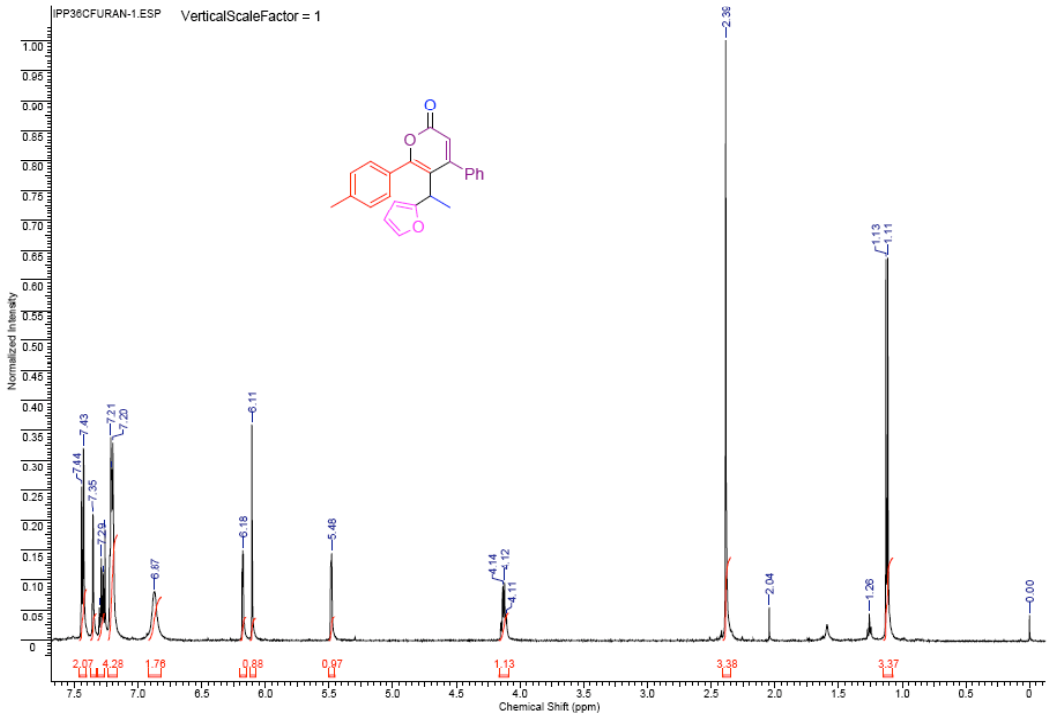


^{1}H NMR (500 MHz, $CDCl_3$) of compound **(*R*)-1i**

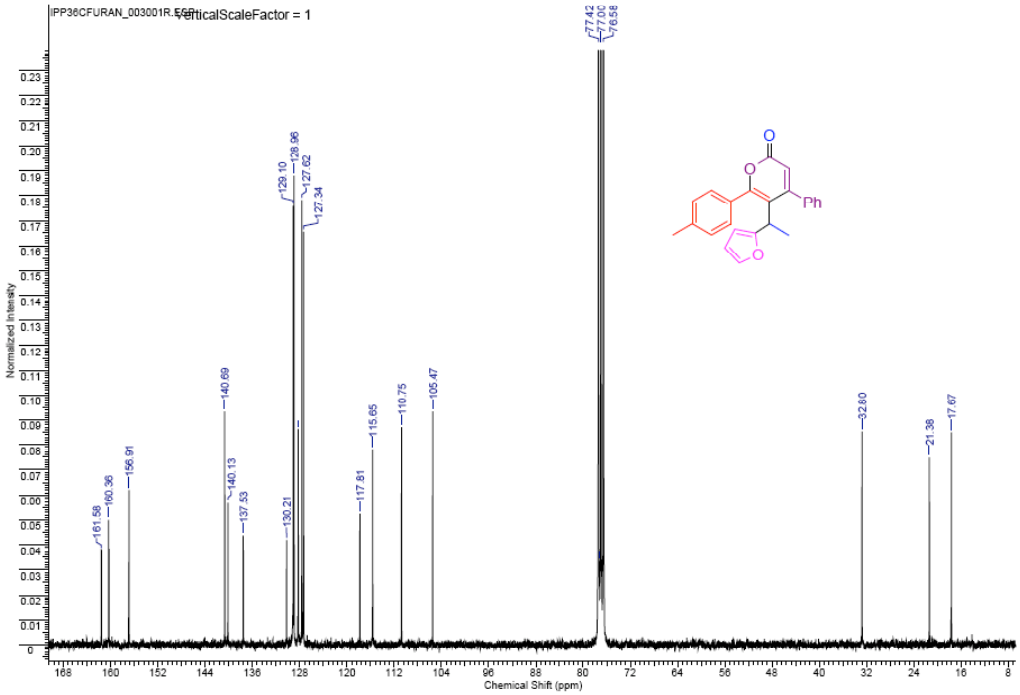


^{13}C NMR (126 MHz, $CDCl_3$) for compound **(*R*)-1i**

Spectra. Spectral Data for **5-(1-(furan-2-yl)ethyl)-4-phenyl-6-p-tolyl-2H-pyran-2-one (3i)**

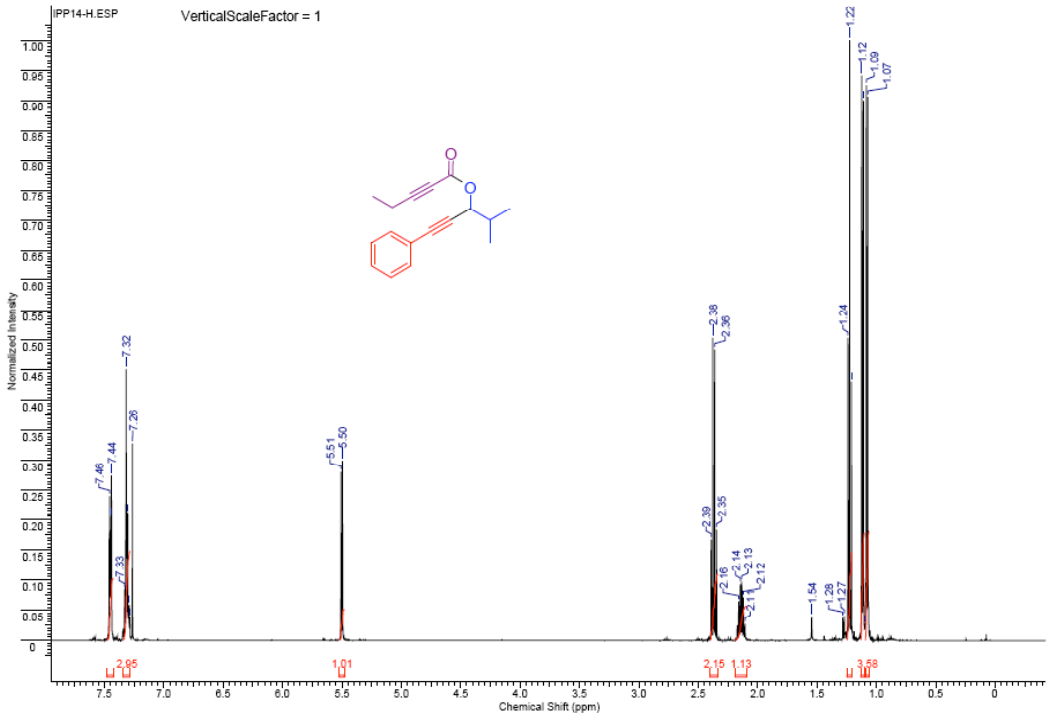


^{1}H NMR (500 MHz, $CDCl_3$) of compound **3i**

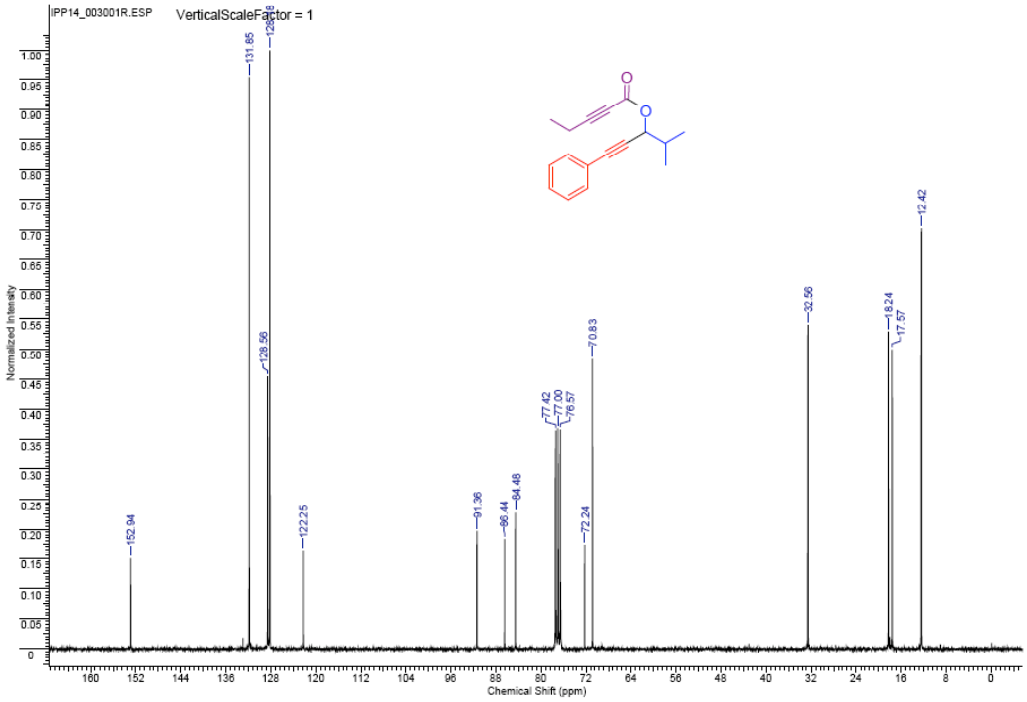


^{13}C NMR (126 MHz, $CDCl_3$) for compound **3i**

Spectra. Spectral Data for **4-methyl-1-phenylpent-1-yn-3-yl pent-2-ynoate (1j)**

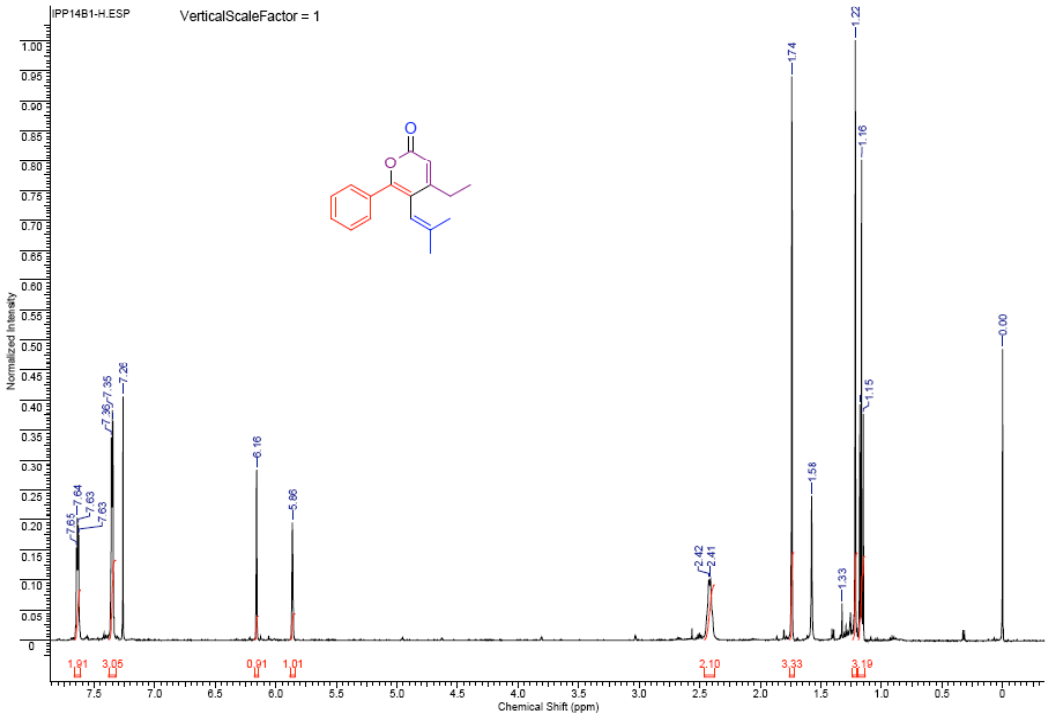


^{1}H NMR (500 MHz, $CDCl_3$) of compound **1j**

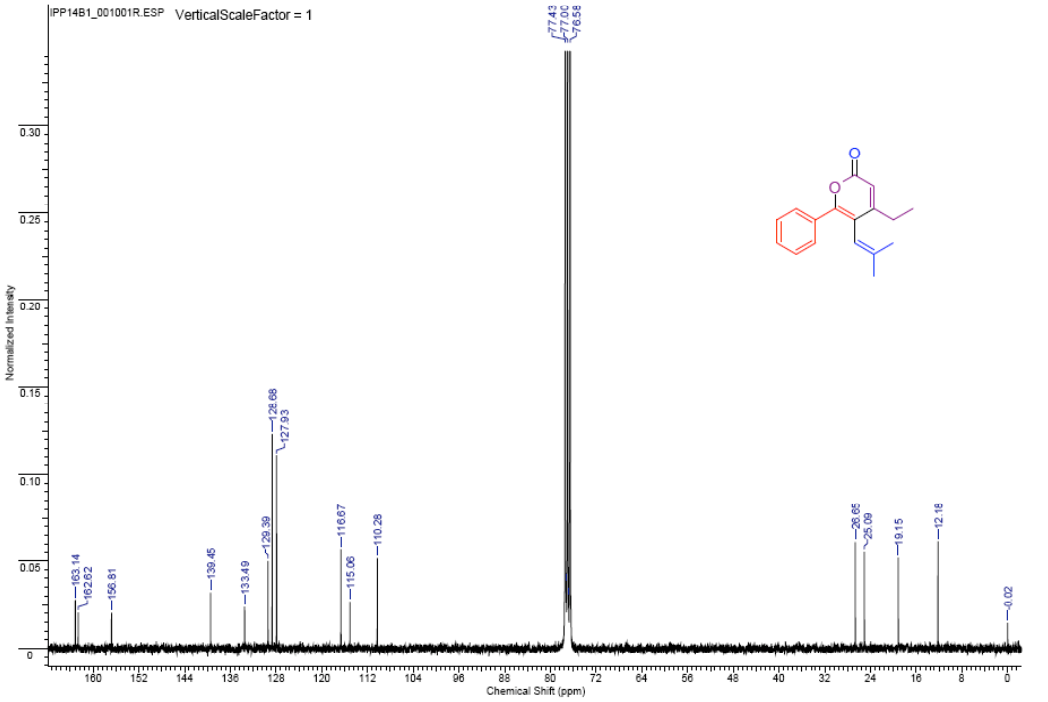


^{13}C NMR (75 MHz, $CDCl_3$) for compound **1j**

Spectra. Spectral Data for **4-ethyl-5-(2-methylprop-1-enyl)-6-phenyl-2H-pyran-2-one (2j)**

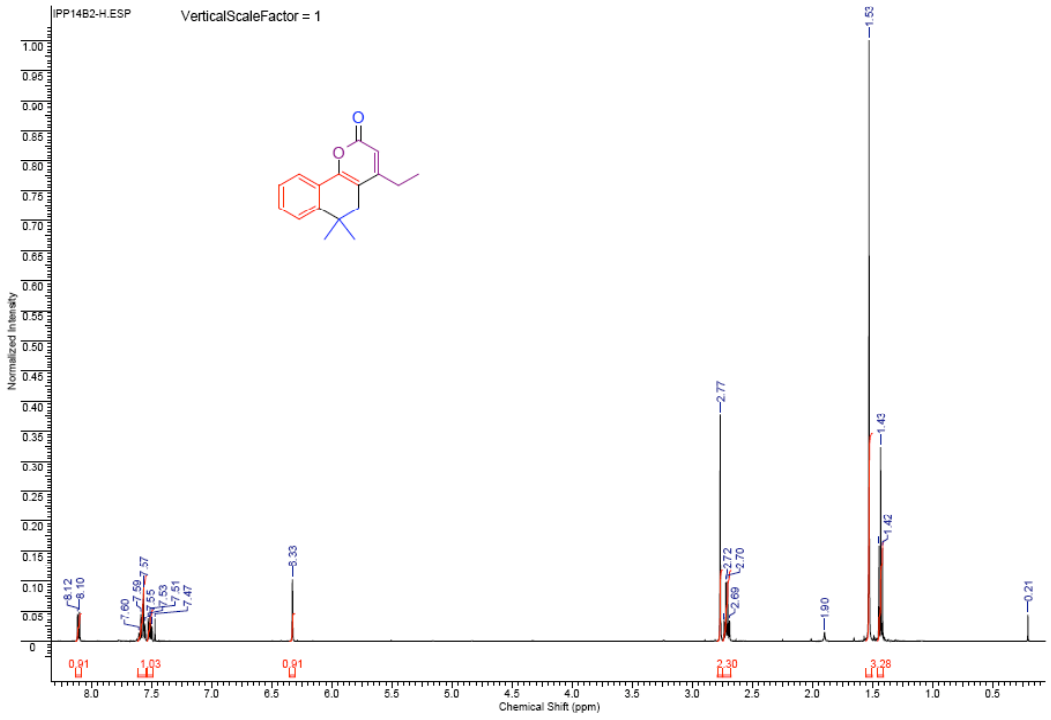


^{1}H NMR (500 MHz, $CDCl_3$) of compound **2j**

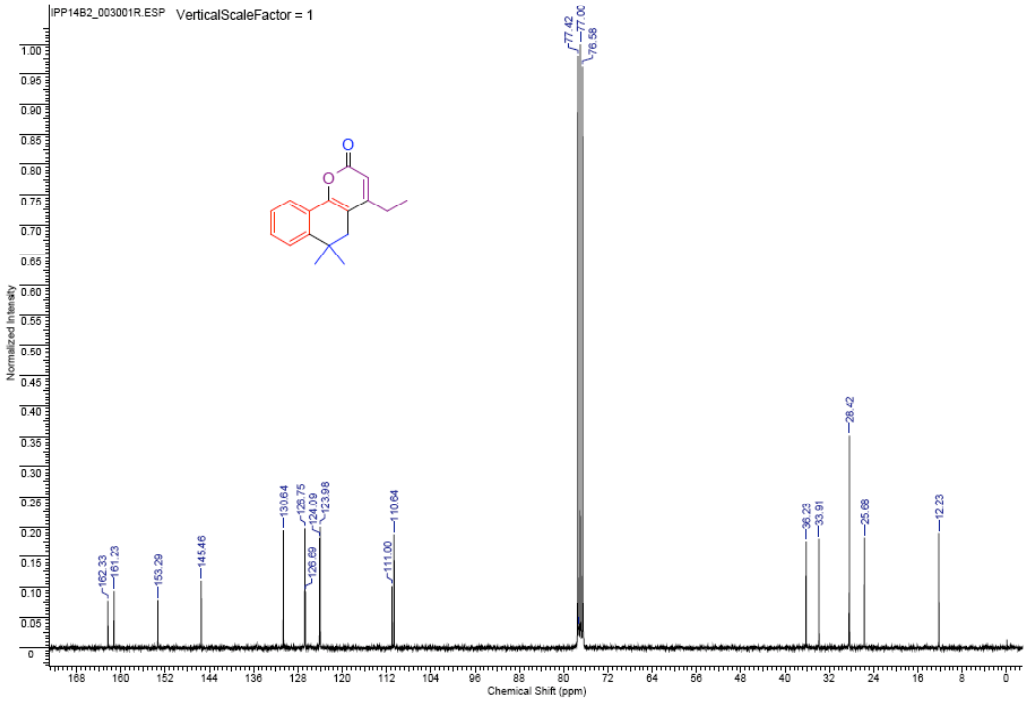


^{13}C NMR (75 MHz, $CDCl_3$) for compound **2j**

Spectra. Spectral Data for **4-ethyl-6,6-dimethyl-5,6-dihydrobenzo[h]chromen-2-one (4)**

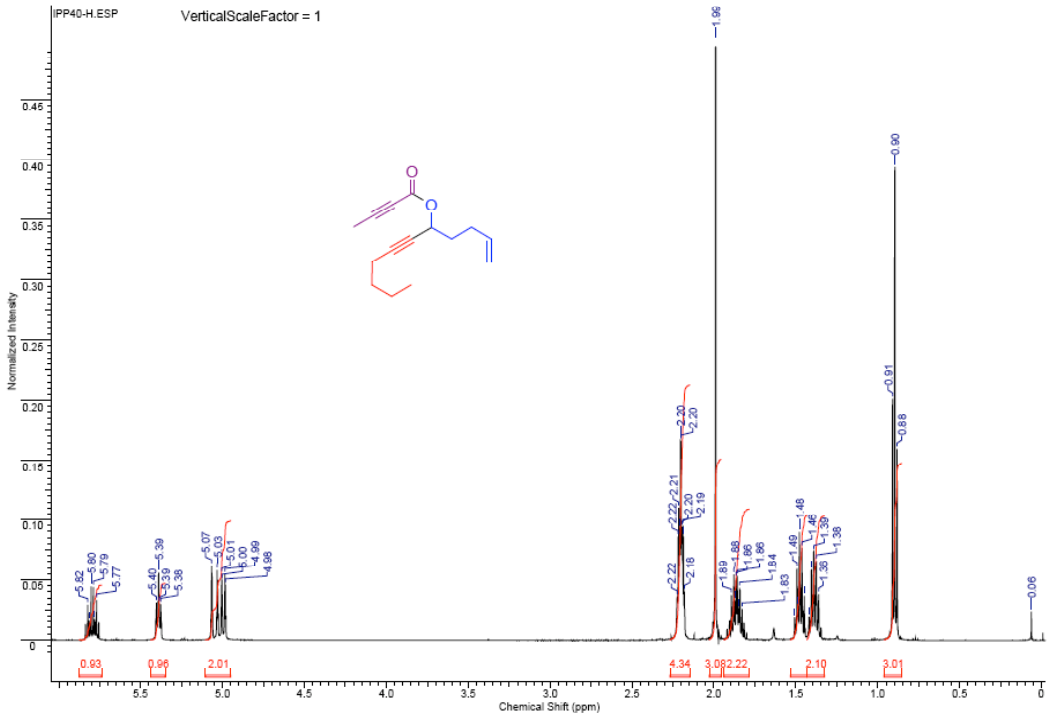


^{1}H NMR (500 MHz, $CDCl_3$) of compound **4**

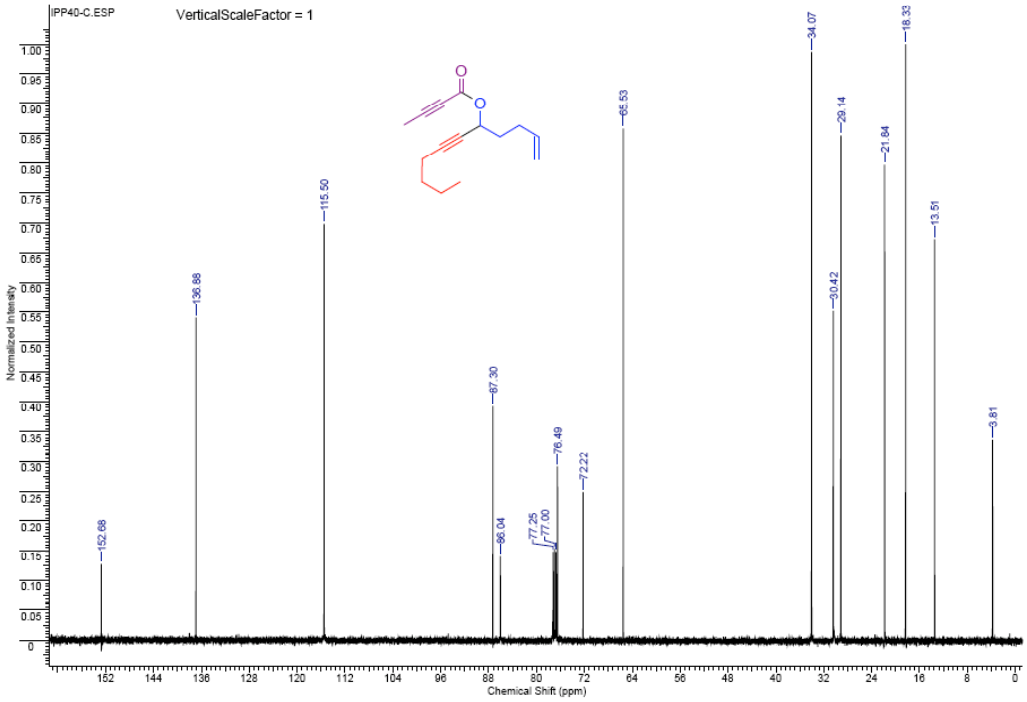


^{13}C NMR (75 MHz, $CDCl_3$) for compound **4**

Spectra. Spectral Data for **undec-1-en-6-yn-5-yl but-2-ynoate (1k)**

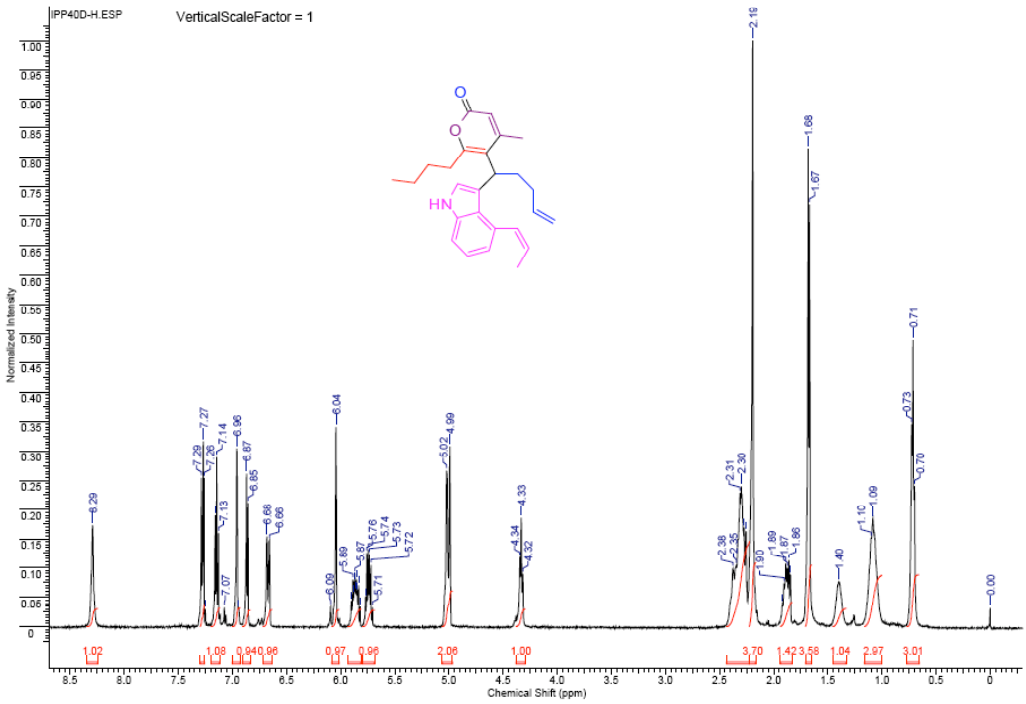


^{1}H NMR (500 MHz, $CDCl_3$) of compound **1k**

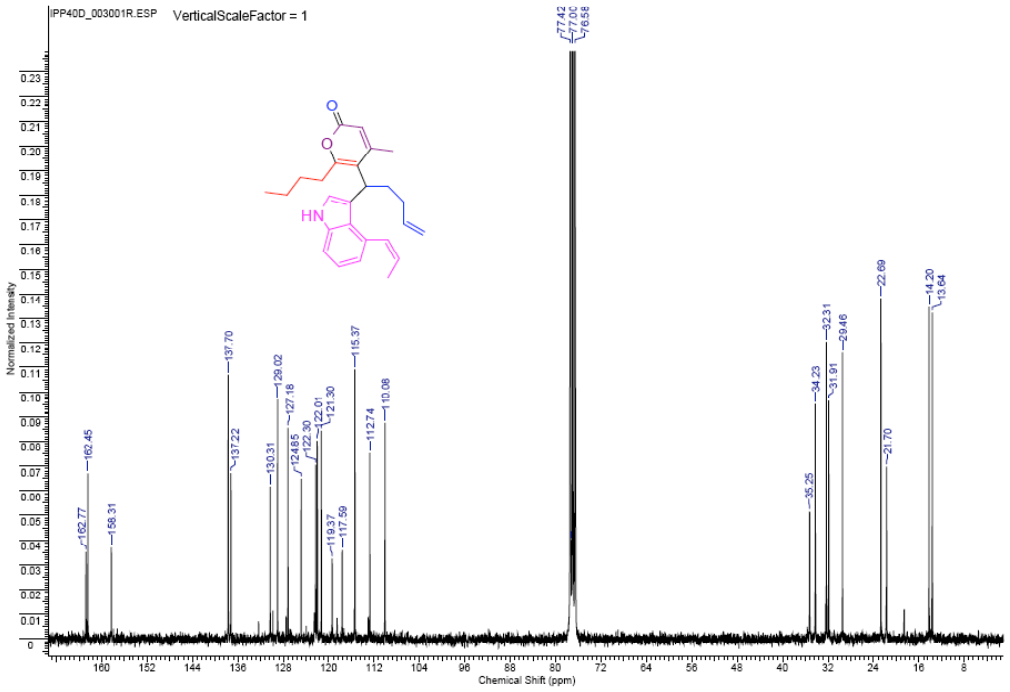


^{13}C NMR (126 MHz, $CDCl_3$) for compound **1k**

Spectra. Spectral Data for
(Z)-6-butyl-4-methyl-5-(1-(4-(prop-1-enyl)-1H-indol-3-yl)pent-4-enyl)-2H-pyran-2-one (3k)



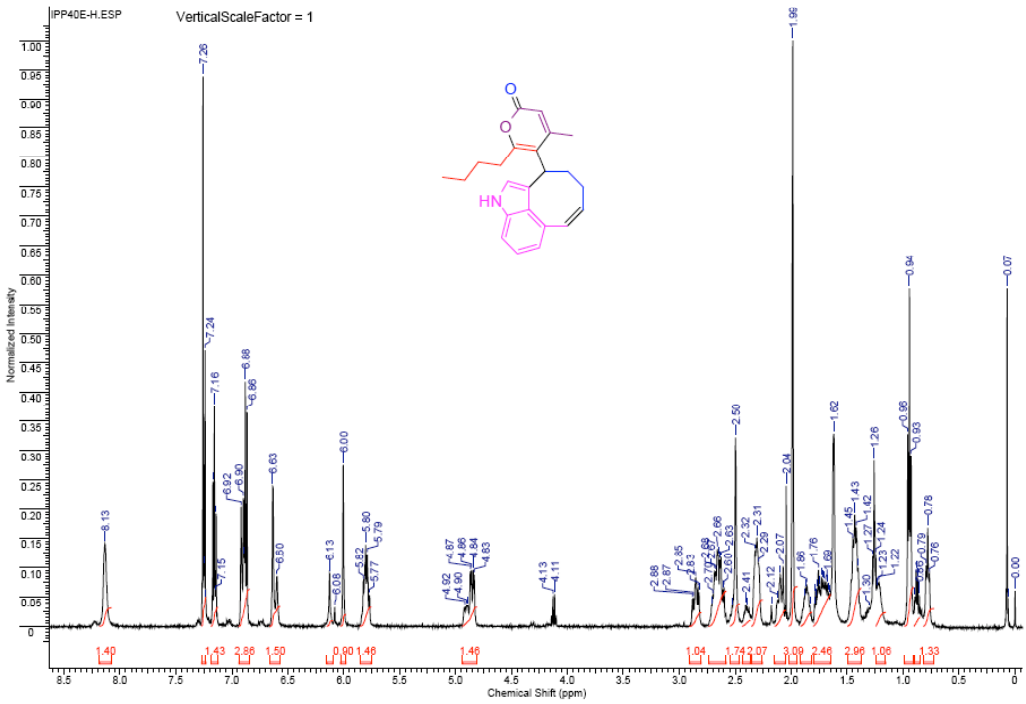
^{1}H NMR (500 MHz, $CDCl_3$) of compound **3k**



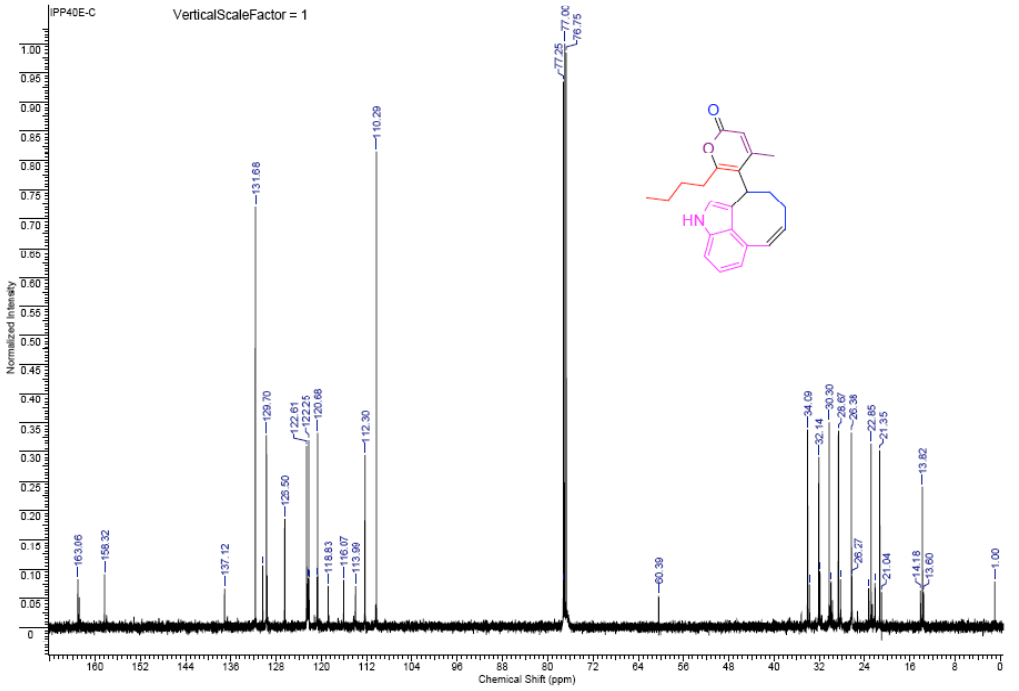
^{13}C NMR (75 MHz, $CDCl_3$) for compound **3k**

Spectra. Spectral Data for

(Z)-6-butyl-4-methyl-5-(2,8,9,10-tetrahydrocycloocta[cd]indol-10-yl)-2H-pyran-2-one (5)



^{1}H NMR (500 MHz, $CDCl_3$) of compound **5**



^{13}C NMR (75 MHz, $CDCl_3$) for compound **5**