

Supporting Information

Facile synthesis of halogenated spiroketals *via* a tandem iodocyclization

Jia Wang,[†] Hai-Tao Zhu,[†] Ying-Xiu Li,[†] Li-Jing Wang,[†] Yi-Feng Qiu,[†]
Zi-Hang Qiu,[†] Mei-jin Zhong,[†] Xue-Yuan Liu[†] and Yong-Min Liang^{*,†,‡}

State Key Laboratory of Applied Organic Chemistry, Lanzhou University

Lanzhou 730000, Fax: 0086-931-8912582 Tel: 0086-931-8912582

E-mail: liangym@lzu.edu.cn

Table of Contents

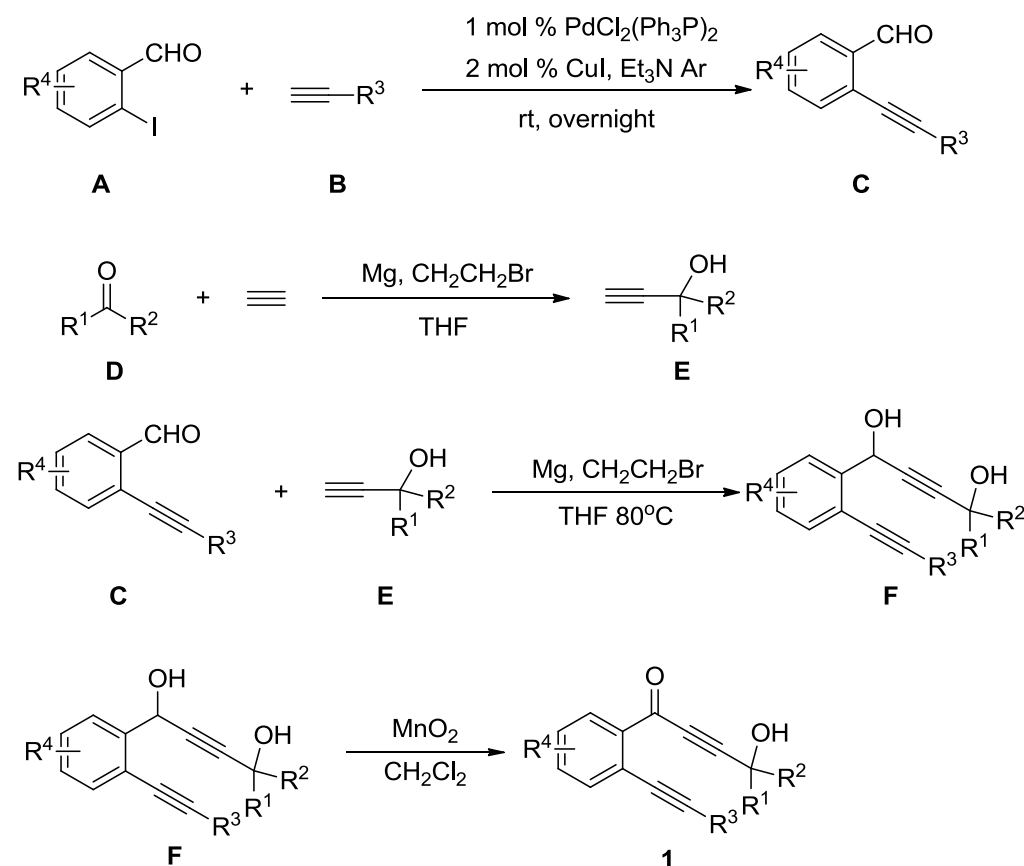
1	General Remarks	S2
2	General Procedure for the Synthesis of Substrates (1a – 1t)	S2 - S4
3	Characterization Data of 1a-1t	S4 - S10
4	General Procedure for the Synthesis of Substrates (1u and 1v)	S11 - S12
5	Characterization Data of 1u and 1v	S12
6	General Procedure for the Synthesis of Products	S12 - S13
7	Characterization Data of Products	S13 - S25
8	Typical Procedure for 3a and 3aa Synthesis and Characterization Data of 3a and 3aa	S25 - S26
9	Crystallographic data of 2a and 2aa	S27 - S28
10	¹ H NMR and ¹³ C NMR Spectra for Substrates	S29 - S72
11	¹ H NMR and ¹³ C NMR Spectra for Products and 2D NMR spectra for 2f and 2'f	S73 – S144

General Remarks

Column chromatography was carried out on silica gel. ^1H NMR spectra were recorded on 400/600 MHz in $\text{CDCl}_3/\text{DMSO}$ and ^{13}C NMR spectra were recorded on 100/150 MHz in $\text{CDCl}_3/\text{DMSO}$. IR spectra were recorded on a FT-IR spectrometer and only major peaks are reported in cm^{-1} . **2f** and **2'f** were divided by reversed phase HPLC ($\text{MeOH}/\text{H}_2\text{O} = 0.95:0.05$). All products were further characterized by high resolution mass spectra (HRMS); Copies of their ^1H NMR and ^{13}C NMR spectra are provided in the Supporting Information. Room temperature is 23–25 °C. THF were distilled over Na/benzophenone, dichloromethane, CH_3CN , CH_3NO_2 and CH_3COCH_3 were distilled over CaH_2 , other solvents were used without further purification.

Synthetic Procedures and Spectral Data

Synthesis of 1-(2-ethynylphenyl)-4-hydroxybut-2-yn-1-one derivatives (**1a-1f** and **1h-1t**)



To a solution of 2-iodobenzaldehyde **A** in Et_3N (5 mL) was added $\text{PdCl}_2(\text{PPh}_3)_2$ (1 mol %) and CuI (2 mol %) and the reaction vial was flushed with Ar and the reaction mixture was stirred for 5 minutes. A solution of aryl and aliphatic alkyne **B** in Et_3N (5 mL) were then added dropwise through a syringe for 5 minutes. The resulting solution was stirred at room temperature overnight. When the reaction was considered complete as determined by TLC analysis, the mixture was quenched by addition of saturated aqueous ammonium chloride (10 mL) and extracted with ethyl ether (3 x 40

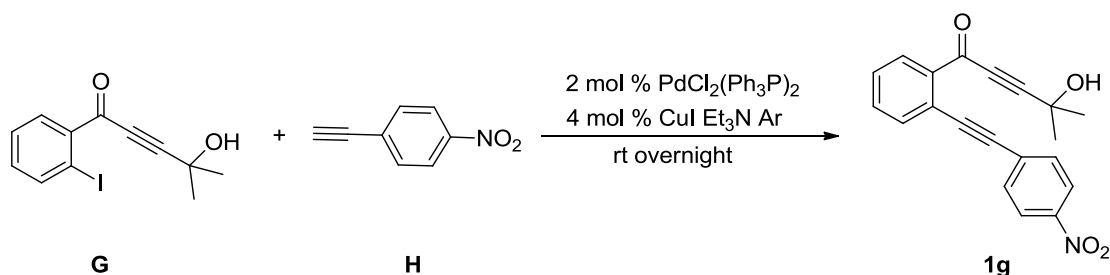
mL). The combined organic layers were washed with water, brine, dried over Na₂SO₄, and concentrated under reduced pressure. The crude material was purified by flash column chromatography to give **C**.

To a 250 mL three-necked round bottom flask containing the solution of ethylmagnesium bromide (45 mmol, 3.0 equiv) in 100 mL of dry THF was tenvilated acetylene gas 40 minutes with stirring at 0 °C. After stirring for 30 minutes at room temperature, the solution of ketone **D** (15 mmol, 1.0 equiv) in 20 mL of dry THF was added to the resulting magnesium salt slowly via syringe. Then, the mixture was stirred at room temperature for 5h. When the reaction was considered complete as determined by TLC analysis, 40 mL of saturated ammonium chloride solution was added, and extracted with ethyl acetate (3 x 50 mL). The combined organic layers were washed with water, brine, dried over Na₂SO₄, and concentrated under reduced pressure. The crude material was purified by flash column chromatography to give **E**.

To a 100 mL three-necked round bottom flask containing the solution of ethylmagnesium bromide (20 mmol, 2.0 equiv) in 40 mL of dry THF was added **E** (10 mmol, 1.0 equiv) in 5mL dry THF dropwise, with stirring over a period of 15 minutes under argon at 20 °C. After stirring for 30 minutes at room temperature, the solution of **C** (11mmol, 1.1 equiv) in 5 mL of dry THF was added to the resulting magnesium salt slowly via syringe. Then, the mixture was heated at reflux for 5h. With cooling, 10 mL of saturated ammonium chloride solution was added, and extracted with ethyl acetate (3 x 20 mL). The combined organic layers were washed with water, brine, dried over Na₂SO₄, and concentrated under reduced pressure. The crude material was purified by flash column chromatography to give **F**.

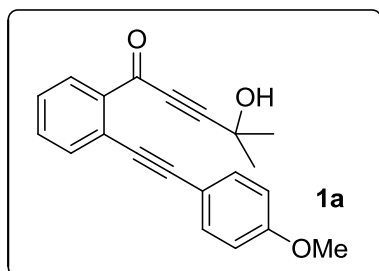
To a stirred solution of **F** in 50 mL of dry CH₂Cl₂, was added activated MnO₂ (15 equiv). The resulting solution was stirred overnight at room temperature then filtered through a sand core funnel and washed with ethyl acetate (2 x 40mL). The combined organic layers were directly concentrated under reduced pressure. Purification of the residue by column chromatography on silica gel gave product compound **1**.

Synthesis of 4-hydroxy-4-methyl-1-(2-((4-nitrophenyl)ethynyl)phenyl)-2-pentyn-1-one(**1g**)

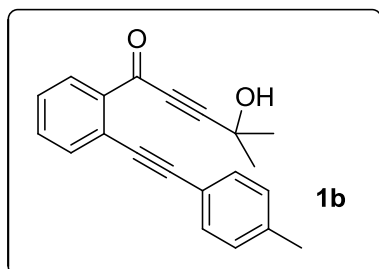


To a solution of 4-hydroxy-1-(2-iodophenyl)-4-methylpent-2-yn-1-one **G** in Et₃N (20 mL) was added PdCl₂(PPh₃)₂ (2 mol %) and CuI (4 mol %) and the reaction vial

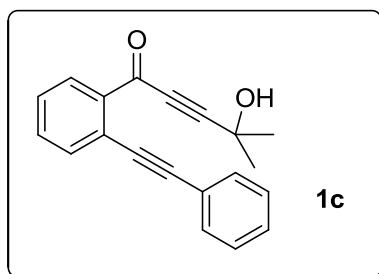
was flushed with Ar and the reaction mixture was stirred for 5 minutes. A solution of 1-ethynyl-4-nitrobenzene **H** in Et₃N (5 mL) were then added dropwise through a syringe for 5 minutes. The resulting solution was stirred at room temperature overnight. When the reaction was considered complete as determined by TLC analysis, the mixture was quenched by addition of saturated aqueous ammonium chloride (10 mL) and extracted with ethyl ether (3 x 40 mL). The combined organic layers were washed with water, brine, dried over Na₂SO₄, and concentrated under reduced pressure. The crude material was purified by flash column chromatography to give the **1g**.



4-hydroxy-1-(2-((4-methoxyphenyl)ethynyl)phenyl)-4-methylpent-2-yn-1-one **1a** Solid, ¹H NMR (400 MHz, CDCl₃) δ ppm 8.07 (d, *J* = 7.6 Hz, 1H), 7.60 (d, *J* = 7.6 Hz, 1H), 7.55 (d, *J* = 8.8 Hz, 2H), 7.50 (t, *J* = 7.6 Hz, 1H), 7.38 (t, *J* = 7.6 Hz, 1H), 6.88 (d, *J* = 8.8 Hz, 2H), 3.81 (s, 3H), 2.68 (s, 1H), 1.59 (s, 6H). ¹³C NMR (100 MHz, CDCl₃) δ ppm 177.4, 160.0, 137.5, 134.0, 133.4, 132.5, 131.9, 127.5, 123.3, 115.1, 114.0, 98.0, 95.6, 87.1, 80.9, 65.2, 55.2, 30.6. IR (neat, cm⁻¹): 3405, 2983, 2210, 1644, 1249, 958, 834, 757.

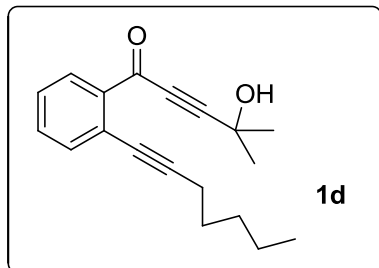


4-hydroxy-4-methyl-1-(2-(p-tolylethynyl)phenyl)pent-2-yn-1-one **1b** Oil, ¹H NMR (400 MHz, CDCl₃) δ ppm 8.07 (d, *J* = 8.0 Hz, 1H), 7.60 (d, *J* = 7.6 Hz, 1H), 7.51-7.46 (m, 3H), 7.37 (t, *J* = 7.6 Hz, 1H), 7.15 (d, *J* = 8.0 Hz, 2H), 3.03 (s, 1H), 2.35 (s, 3H), 1.59 (s, 6H). ¹³C NMR (100 MHz, CDCl₃) δ ppm 177.4, 138.9, 137.5, 134.1, 132.5, 131.9, 131.7, 129.1, 127.7, 123.0, 119.9, 98.2, 95.6, 87.6, 80.8, 65.1, 30.5, 21.5. IR (neat, cm⁻¹): 3387, 2983, 2210, 1646, 1248, 958, 818, 757.

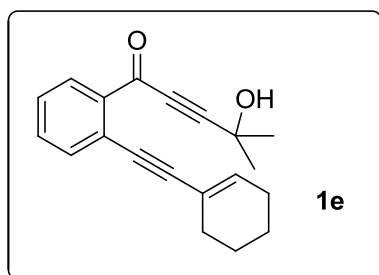


4-hydroxy-4-methyl-1-(2-(phenylethynyl)phenyl)pent-2-yn-1-one **1c** Oil, ¹H NMR

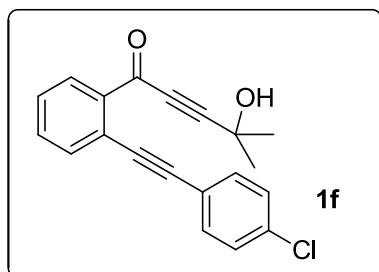
(400 MHz, CDCl₃) δ ppm 8.09-8.07 (m, 1H), 7.62-7.60 (m, 3H), 7.49 (td, J = 7.6, 2.0 Hz, 1H), 7.41-7.33 (m, 4H), 3.13 (s, 1H), 1.59 (s, 6H). ¹³C NMR (100 MHz, CDCl₃) δ ppm 177.4, 137.6, 134.2, 132.6, 131.9, 131.8, 128.6, 128.3, 127.9, 123.0, 122.8, 98.3, 95.2, 88.1, 80.7, 65.1, 30.5. IR (neat, cm⁻¹): 3387, 2984, 2211, 1646, 1248, 959, 756, 692.



1-(2-(hept-1-yn-1-yl)phenyl)-4-hydroxy-4-methylpent-2-yn-1-one **1d** Oil, ¹H NMR (400 MHz, CDCl₃) δ ppm 8.01 (d, J = 8.0 Hz, 1H), 7.51-7.46 (m, 1H), 7.43 (dd, J = 7.6, 0.8 Hz, 1H), 7.33 (td, J = 8.0, 1.2 Hz, 1H), 3.09 (s, 1H), 2.46 (t, J = 7.2 Hz, 2H), 1.68-1.61 (m, 8H), 1.51-1.40 (m, 2H), 1.38-1.31 (m, 2H), 0.92 (t, J = 7.2 Hz, 3H). ¹³C NMR (100 MHz, CDCl₃) δ ppm 177.6, 137.7, 134.6, 132.4, 131.7, 127.1, 123.7, 97.9, 97.2, 80.8, 79.0, 65.1, 31.1, 30.6, 28.2, 22.1, 19.8, 13.9. IR (neat, cm⁻¹): 3373, 2963, 1701, 1461, 1224, 964, 757, 664.

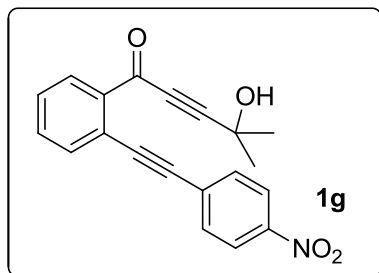


1-(2-(cyclohex-1-en-1-ylethynyl)phenyl)-4-hydroxy-4-methylpent-2-yn-1-one **1e** Oil, ¹H NMR (400 MHz, CDCl₃) δ ppm 8.04-8.03 (m, 1H), 7.52-7.50 (m, 1H), 7.46 (td, J = 7.6, 1.2 Hz, 1H), 7.37-7.32 (m, 1H), 6.62-6.30 (m, 1H), 3.07 (s, 1H), 2.28-2.26 (m, 2H), 2.18-2.14 (m, 2H), 1.69-1.65 (m, 2H), 1.62-1.60 (m, 7H). ¹³C NMR (100 MHz, CDCl₃) δ ppm 177.4, 137.4, 136.6, 134.1, 132.4, 131.8, 127.3, 123.4, 121.0, 98.0, 97.3, 85.7, 80.8, 65.1, 30.5, 28.8, 25.8, 22.1, 21.4. IR (neat, cm⁻¹): 3370, 2933, 2206, 1681, 1245, 960, 756, 664.

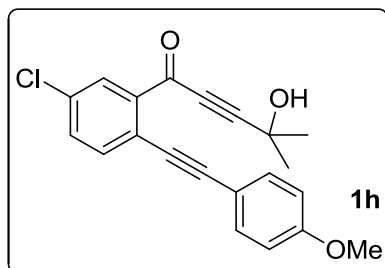


1-(2-((4-chlorophenyl)ethynyl)phenyl)-4-hydroxy-4-methylpent-2-yn-1-one **1f** Solid, ¹H NMR (400 MHz, CDCl₃) δ ppm 8.10 (dd, J = 8.0, 0.8 Hz, 1H), 7.59 (dd, J = 8.0, 0.8 Hz, 1H), 7.53 (d, J = 8.4 Hz, 2H), 7.48 (dd, J = 7.6, 1.2 Hz, 1H), 7.39 (td, J = 7.6, 1.2 Hz, 1H), 7.31 (d, J = 8.8 Hz, 2H), 3.30 (s, 1H), 1.61 (s, 6H). ¹³C NMR (100 MHz,

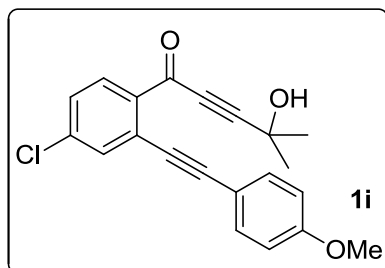
CDCl₃) δ ppm 177.2, 137.4, 134.6, 134.2, 133.0, 132.6, 132.2, 128.6, 128.0, 122.4, 121.5, 98.4, 93.8, 89.1, 80.5, 65.1, 30.5. IR (neat, cm⁻¹): 3389, 2984, 2210, 1644, 1250, 969, 758, 521.



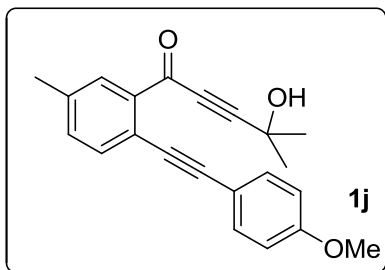
4-hydroxy-4-methyl-1-(2-((4-nitrophenyl)ethynyl)phenyl)pent-2-yn-1-one **1g** Solid, ¹H NMR (400 MHz, CDCl₃) δ ppm 8.21-8.17 (m, 3H), 7.74 (d, *J* = 8.4 Hz, 2H), 7.66 (d, *J* = 7.6 Hz, 1H), 7.58 (t, *J* = 7.6 Hz, 1H), 7.51 (t, *J* = 8.0 Hz, 1H), 2.77 (s, 1H), 1.65 (s, 6H). ¹³C NMR (100 MHz, CDCl₃) δ ppm 176.9, 147.1, 137.7, 134.5, 132.8, 132.6, 132.5, 130.1, 128.9, 123.5, 121.6, 98.4, 93.2, 92.5, 80.4, 65.2, 30.6. IR (neat, cm⁻¹): 3432, 2983, 2211, 1647, 1248, 958, 858, 669.



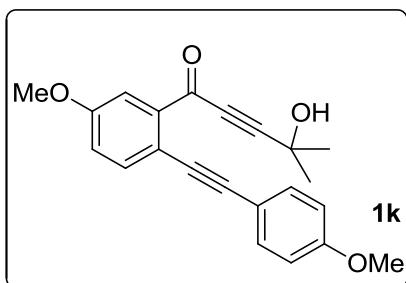
1-(5-chloro-2-((4-methoxyphenyl)ethynyl)phenyl)-4-hydroxy-4-methylpent-2-yn-1-one **1h** Solid, ¹H NMR (400 MHz, CDCl₃) δ ppm 7.98 (d, *J* = 2.0 Hz, 1H), 7.54-7.53 (m, 1H), 7.53-7.51 (m, 2H), 7.46-7.44 (m, 1H), 6.88 (d, *J* = 8.8 Hz, 2H), 3.82 (s, 3H), 2.70 (s, 1H), 1.59 (s, 6H). ¹³C NMR (100 MHz, CDCl₃) δ ppm 176.1, 160.1, 138.5, 135.0, 133.4, 133.3, 132.5, 131.4, 121.7, 114.8, 114.0, 99.0, 96.7, 86.2, 80.4, 65.1, 55.2, 30.5. IR (neat, cm⁻¹): 3405, 2984, 2210, 1652, 1250, 857, 735, 533.



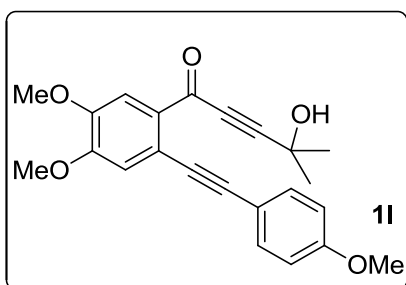
1-(4-chloro-2-((4-methoxyphenyl)ethynyl)phenyl)-4-hydroxy-4-methylpent-2-yn-1-one **1i** Solid, ¹H NMR (400 MHz, CDCl₃) δ ppm 7.99 (d, *J* = 8.0 Hz, 1H), 7.55(s, 2H), 7.53(s, 1H), 7.31 (dd, *J* = 8.4, 0.8 Hz, 1H), 6.88 (d, *J* = 8.8 Hz, 2H), 3.81 (s, 3H), 3.06 (s, 1H), 1.60 (s, 6H). ¹³C NMR (100 MHz, CDCl₃) δ ppm 176.2, 160.2, 139.0, 135.5, 133.6, 133.2, 127.6, 125.0, 114.6, 114.0, 98.5, 97.1, 86.1, 80.5, 65.1, 55.2, 30.5. IR (neat, cm⁻¹): 3397, 2983, 2209, 1651, 1248, 833, 767, 537.



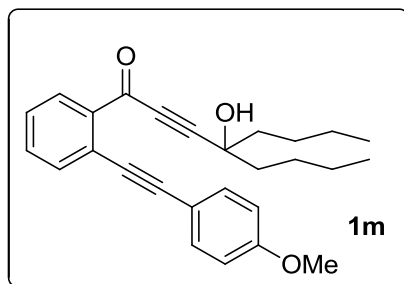
4-hydroxy-1-(2-((4-methoxyphenyl)ethynyl)-5-methylphenyl)-4-methylpent-2-yn-1-one **1j** Solid, ^1H NMR (400 MHz, CDCl_3) δ ppm 7.82 (s, 1H), 7.53 (d, $J = 8.8$ Hz, 2H), 7.47 (d, $J = 7.6$ Hz, 1H), 7.28 (d, $J = 8.8$ Hz, 1H), 6.86 (d, $J = 8.4$ Hz, 2H), 3.80 (s, 3H), 2.99 (s, 1H), 2.38 (s, 3H), 1.58 (s, 6H). ^{13}C NMR (100 MHz, CDCl_3) δ ppm 177.7, 159.8, 137.8, 137.4, 133.8, 133.4, 133.3, 132.2, 120.3, 115.3, 113.9, 98.1, 94.7, 87.1, 80.9, 65.1, 55.2, 30.5, 21.2. IR (neat, cm^{-1}): 3460, 2981, 2208, 1645, 1251, 962, 832, 773.



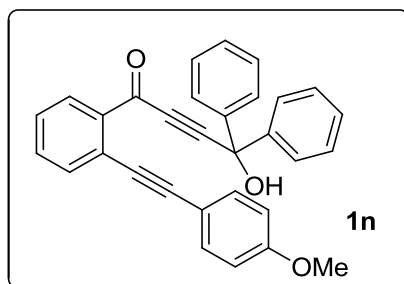
4-hydroxy-1-(5-methoxy-2-((4-methoxyphenyl)ethynyl)phenyl)-4-methylpent-2-yn-1-one **1k** Solid, ^1H NMR (400 MHz, CDCl_3) δ ppm 7.54-7.50 (m, 4H), 7.03 (dd, $J = 8.4$, 2.8 Hz, 1H), 6.87 (d, $J = 8.8$ Hz, 2H), 3.84 (s, 3H), 3.81 (s, 3H), 2.79 (s, 1H), 1.57 (s, 6H). ^{13}C NMR (100 MHz, CDCl_3) δ ppm 177.4, 159.7, 158.7, 138.8, 135.4, 133.1, 118.8, 116.2, 115.5, 115.4, 114.0, 98.4, 93.8, 86.8, 80.9, 65.1, 55.5, 55.2, 30.5. IR (neat, cm^{-1}): 3403, 2982, 2210, 1606, 1513, 1249, 833.



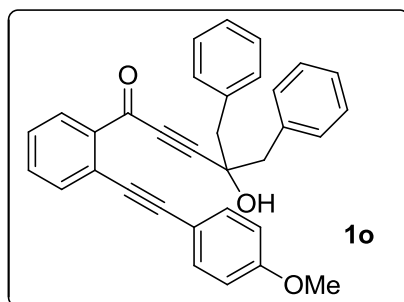
1-(4,5-dimethoxy-2-((4-methoxyphenyl)ethynyl)phenyl)-4-hydroxy-4-methylpent-2-yn-1-one **1l** Solid, ^1H NMR (400 MHz, CDCl_3) δ ppm 7.56-7.54 (m, 3H), 7.00 (d, $J = 1.6$ Hz, 1H), 6.88 (d, $J = 8.0$ Hz, 2H), 3.94 (s, 3H), 3.92 (s, 3H), 3.81 (s, 3H), 3.24 (s, 1H), 1.57 (s, 6H). ^{13}C NMR (100 MHz, CDCl_3) δ ppm 176.0, 159.8, 152.3, 148.1, 133.2, 130.6, 117.5, 115.6, 115.2, 114.0, 113.9, 98.3, 94.4, 87.3, 80.8, 64.9, 56.1, 55.8, 55.2, 30.5. IR (neat, cm^{-1}): 3440, 2925, 2204, 1602, 1250, 1167, 849, 759.



4-butyl-4-hydroxy-1-(2-((4-methoxyphenyl)ethynyl)phenyl)oct-2-yn-1-one **1m** Solid, ^1H NMR (400 MHz, CDCl_3) δ ppm 8.01 (d, $J = 7.6$ Hz, 1H), 7.61 (d, $J = 7.6$ Hz, 1H), 7.56 (d, $J = 8.8$ Hz, 2H), 7.50 (td, $J = 7.6$, 1.2 Hz, 1H), 7.41-7.37 (m, 1H), 6.88 (d, $J = 8.8$ Hz, 2H), 3.81 (s, 3H), 2.43 (s, 1H), 1.79-1.67 (m, 4H), 1.55-1.47 (m, 4H), 1.38-1.29 (m, 4H), 0.91 (t, $J = 7.2$ Hz, 6H). ^{13}C NMR (100 MHz, CDCl_3) δ ppm 177.1, 160.0, 137.5, 134.1, 133.4, 132.5, 131.9, 127.4, 123.3, 115.2, 114.0, 97.1, 95.5, 87.2, 82.9, 71.4, 55.2, 41.1, 26.2, 22.7, 13.9. IR (neat, cm^{-1}): 3411, 2954, 2209, 1648, 1249, 1031, 760, 633.

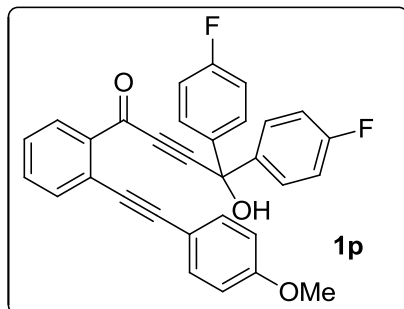


4-hydroxy-1-(2-((4-methoxyphenyl)ethynyl)phenyl)-4,4-diphenylbut-2-yn-1-one **1n** Solid, ^1H NMR (400 MHz, CDCl_3) δ ppm 8.07 (d, $J = 8.0$ Hz, 1H), 7.60 (d, $J = 7.6$ Hz, 5H), 7.51-7.47 (m, 3H), 7.36-7.24 (m, 7H), 6.81 (d, $J = 8.8$ Hz, 2H), 3.79 (s, 3H), 3.22 (s, 1H). ^{13}C NMR (100 MHz, CDCl_3) δ ppm 177.0, 159.9, 143.4, 137.4, 134.1, 133.5, 133.3, 132.8, 132.7, 132.0, 128.5, 128.1, 127.6, 126.0, 123.4, 115.0, 114.2, 114.0, 113.8, 95.8, 95.2, 87.2, 85.3, 74.6, 55.2. IR (neat, cm^{-1}): 3430, 2924, 2212, 1649, 1511, 1248, 790, 700.

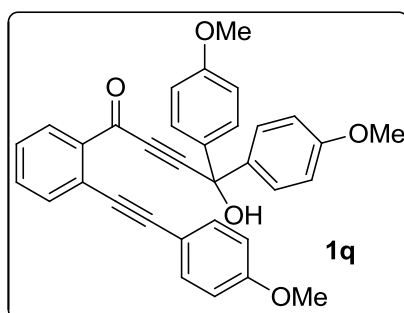


4-benzyl-4-hydroxy-1-(2-((4-methoxyphenyl)ethynyl)phenyl)-5-phenylpent-2-yn-1-one **1o** Solid, ^1H NMR (400 MHz, CDCl_3) δ ppm 7.65 (d, $J = 8.0$ Hz, 1H), 7.57 (d, $J = 7.6$ Hz, 1H), 7.53 (d, $J = 8.8$ Hz, 2H), 7.50 (td, $J = 7.6$, 0.8 Hz, 1H), 7.35 (dd, $J = 8.0$, 1.6 Hz, 4H), 7.32-7.25 (m, 6H), 7.24-7.20 (m, 1H), 6.86 (d, $J = 8.8$ Hz, 2H), 3.79 (s, 3H), 3.13-3.06 (m, 4H), 2.33 (s, 1H). ^{13}C NMR (100 MHz, CDCl_3) δ ppm 176.5,

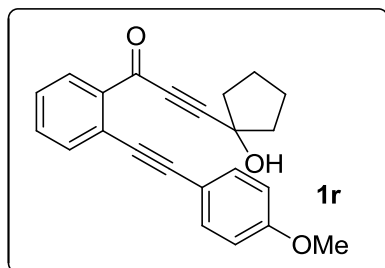
159.9, 137.0, 135.2, 134.1, 133.5, 132.5, 132.5, 130.8, 128.3, 127.3, 127.2, 123.2, 115.2, 114.0, 95.4, 94.7, 87.3, 85.1, 71.4, 55.2, 47.5. IR (neat, cm^{-1}): 3501, 2933, 2212, 1648, 1249, 1039, 835, 699.



4,4-bis(4-fluorophenyl)-4-hydroxy-1-(2-((4-methoxyphenyl)ethynyl)phenyl)but-2-yn-1-one **1p** Solid, ^1H NMR (400 MHz, CDCl_3) δ ppm 8.00 (d, $J = 7.2$ Hz, 1H), 7.60 (d, $J = 7.6$ Hz, 1H), 7.54-7.51 (m, 4H), 7.50-7.48 (m, 1H), 7.45 (d, $J = 8.8$ Hz, 2H), 7.35-7.31 (m, 1H), 6.97 (t, $J = 8.8$ Hz, 4H), 6.81 (d, $J = 8.8$ Hz, 2H), 3.79 (s, 3H), 3.61 (s, 1H). ^{13}C NMR (100 MHz, CDCl_3) δ ppm 177.1, 163.7, 161.2, 160.0, 139.2, 139.2, 137.3, 134.2, 133.4, 132.8, 131.7, 128.0, 127.9, 127.6, 123.5, 115.4, 115.2, 115.0, 114.1, 96.1, 94.8, 87.0, 85.5, 73.7, 55.2. IR (neat, cm^{-1}): 3420, 3281, 2211, 1644, 1249, 1031, 834, 748.

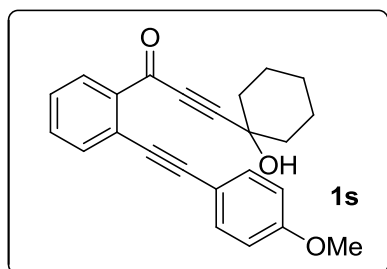


4-hydroxy-4,4-bis(4-methoxyphenyl)-1-(2-((4-methoxyphenyl)ethynyl)phenyl)but-2-yn-1-one **1q** Solid, ^1H NMR (400 MHz, CDCl_3) δ ppm 8.05 (d, $J = 8.0$ Hz, 1H), 7.59 (d, $J = 7.6$ Hz, 1H), 7.49-7.47 (m, 7H), 7.33 (t, $J = 7.6$ Hz, 1H), 6.81 (d, $J = 8.8$ Hz, 6H), 3.78 (s, 3H), 3.75 (s, 6H), 3.34 (s, 1H). ^{13}C NMR (100 MHz, CDCl_3) δ ppm 177.1, 159.9, 159.3, 137.5, 135.9, 134.1, 133.4, 132.6, 131.9, 27.5, 127.4, 123.3, 115.1, 114.0, 113.7, 95.8, 87.2, 85.1, 73.9, 55.2. IR (neat, cm^{-1}): 3448, 3009, 2210, 1646, 1241, 1030, 837, 744.

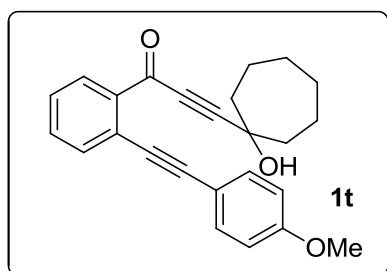


3-(1-hydroxycyclopentyl)-1-(2-((4-methoxyphenyl)ethynyl)phenyl)prop-2-yn-1-one **1r** Oil, ^1H NMR (400 MHz, CDCl_3) δ ppm 8.08-8.06 (m, 1H), 7.59 (d, $J = 7.6$ Hz, 1H), 7.55 (d, $J = 8.8$ Hz, 2H), 7.50-7.46 (m, 1H), 7.38-7.34 (m, 1H), 6.87 (d, $J = 8.4$

Hz, 2H), 3.80 (s, 3H), 2.73 (s, 1H), 2.10-1.99 (m, 4H), 1.90-1.80 (m, 2H), 1.78-1.70 (m, 2H). ^{13}C NMR (100 MHz, CDCl_3) δ ppm 177.5, 160.0, 137.5, 133.9, 133.4, 132.5, 131.8, 127.5, 123.2, 115.2, 114.0, 97.9, 95.6, 87.1, 82.0, 74.2, 55.2, 42.1, 23.6. IR (neat, cm^{-1}): 3386, 2950, 2208, 1643, 1292, 1030, 750, 652.

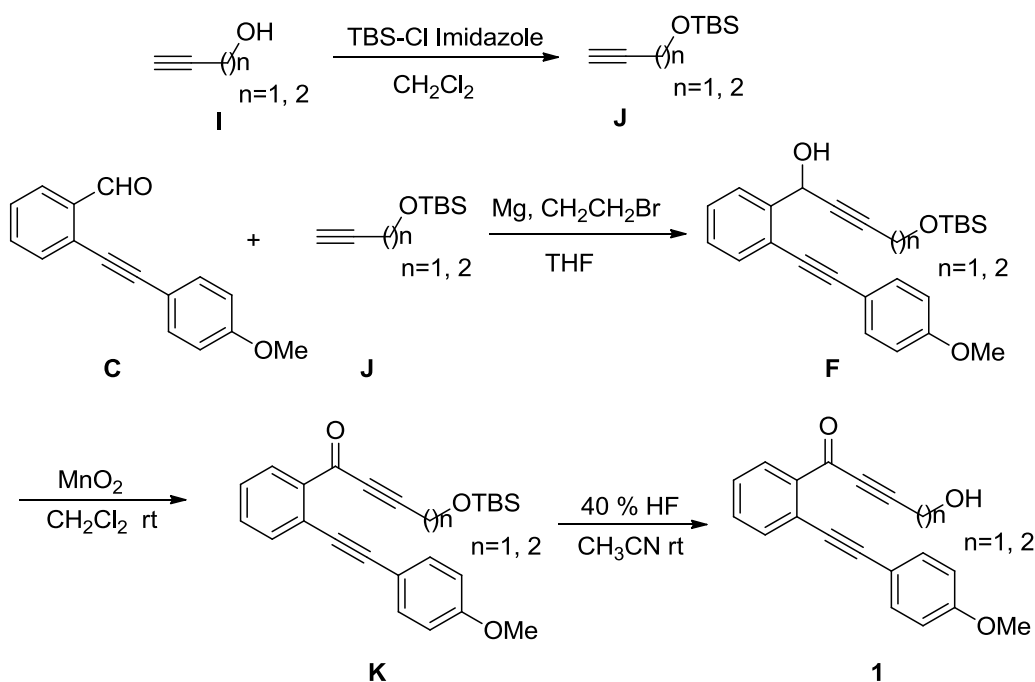


3-(1-hydroxycyclohexyl)-1-(2-((4-methoxyphenyl)ethynyl)phenyl)prop-2-yn-1-one **1s** Oil, ^1H NMR (400 MHz, CDCl_3) δ ppm 8.10 (dd, $J = 8.0, 1.2$ Hz, 1H), 7.60-7.58 (m, 1H), 7.55 (dd, $J = 6.8, 2.0$ Hz, 2H), 7.49-7.46 (m, 1H), 7.37 (dd, $J = 7.6, 1.2$ Hz, 1H), 6.87 (d, $J = 8.8$ Hz, 2H), 3.80 (s, 3H), 3.05 (s, 1H), 2.03-1.99 (m, 2H), 1.73-1.64 (m, 4H), 1.66-1.51 (m, 3H), 1.30-1.21 (m, 1H). ^{13}C NMR (100 MHz, CDCl_3) δ ppm 177.3, 159.9, 137.4, 134.0, 133.4, 132.5, 132.0, 127.4, 123.2, 115.2, 113.9, 97.6, 95.5, 87.2, 82.7, 68.6, 55.2, 39.1, 24.8, 22.9. IR (neat, cm^{-1}): 3397, 2936, 2208, 1645, 1249, 1027, 834, 755.



3-(1-hydroxycycloheptyl)-1-(2-((4-methoxyphenyl)ethynyl)phenyl)prop-2-yn-1-one **1t** Solid, ^1H NMR (400 MHz, CDCl_3) δ ppm 8.09 (dd, $J = 7.6, 0.8$ Hz, 1H), 7.61-7.59 (m, 1H), 7.57-7.54 (m, 2H), 7.48 (dd, $J = 7.6, 1.2$ Hz, 1H), 7.39-7.35 (m, 1H), 6.87 (d, $J = 8.8$ Hz, 2H), 3.80 (s, 3H), 2.67 (s, 1H), 2.11 (dd, $J = 14.0, 8.0$ Hz, 2H), 1.96-1.90 (m, 2H), 1.71-1.66 (m, 2H), 1.63-1.54 (m, 6H). ^{13}C NMR (100 MHz, CDCl_3) δ ppm 177.4, 159.9, 137.5, 134.0, 133.4, 132.4, 131.9, 127.4, 123.2, 115.2, 114.0, 98.7, 95.5, 87.2, 82.0, 71.7, 55.2, 42.3, 28.0, 21.9. IR (neat, cm^{-1}): 3399, 2930, 2209, 1646, 1288, 1030, 758, 670.

Synthesis of 1u and 1v

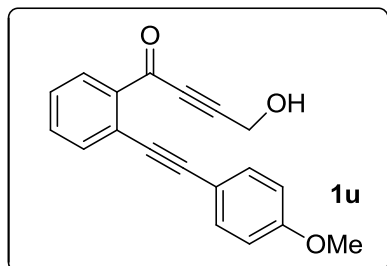


To a solution of alkynol **I** (20 mmol) in dry CH_2Cl_2 , was added TBS-Cl (*tert*-butylchlorodimethylsilane, 30 mmol, 1.5 equiv), imidazole (44 mmol, 2.2 equiv) in sequence at 0 °C. After stirring 30 minutes at 0 °C, the resulting solution was stirred at room temperature overnight. The mixture was quenched by addition of water (30 mL) and extracted with CH_2Cl_2 (3 x 40 mL). The combined organic layers were washed with water, brine, dried over Na_2SO_4 , and concentrated under reduced pressure. The crude material was purified by flash column chromatography to give **J**.

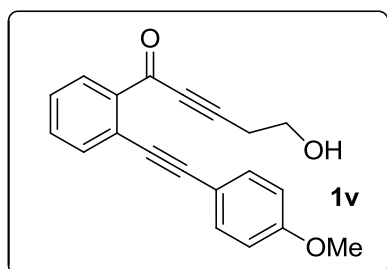
To a 100 mL three-necked round bottom flask containing the solution of ethylmagnesium bromide (20 mmol, 2.0 equiv) in 40 mL of dry THF was added **J** (10 mmol, 1.0 equiv) in 5 mL dry THF dropwise, with stirring over a period of 15 minutes under argon at 20 °C. After stirring for 30 minutes at room temperature, the solution of 2-((4-methoxyphenyl)ethynyl)benzaldehyde **C** (11 mmol, 1.1 equiv) in 5 mL of dry THF was added to the resulting magnesium salt slowly via syringe. Then, the mixture was heated at reflux for 5h. With cooling, 10 mL of saturated ammonium chloride solution was added, and extracted with ethyl acetate (3 x 20 mL). The combined organic layers were washed with water, brine, dried over Na_2SO_4 , and concentrated under reduced pressure. The crude material was purified by flash column chromatography to give **F**.

To a stirred solution of **F** in 50 mL of dry CH_2Cl_2 , was added activated MnO_2 (15 equiv). The resulting solution was stirred overnight at room temperature then filtered through a sand core funnel and washed with ethyl acetate (2 x 40 mL). The combined organic layers were directly concentrated under reduced pressure. Purification of the residue by column chromatography on silica gel gave **K**.

To a stirred solution of **K** (2.0 mmol) in 4 mL CH₃CN, was added 40% HF (20 equiv), the resulting solution was stirred 4h at room temperature. When the reaction was considered complete as determined by TLC analysis, the mixture was quenched by saturated sodium bicarbonate solution (10 mL) and extracted with ethyl acetate (3 x 10 mL). The combined organic layers were washed with saturate water, brine, dried over Na₂SO₄, and concentrated under reduced pressure. Purification of the residue by column chromatography on silica gel gave product compound **1u** and **1v**.

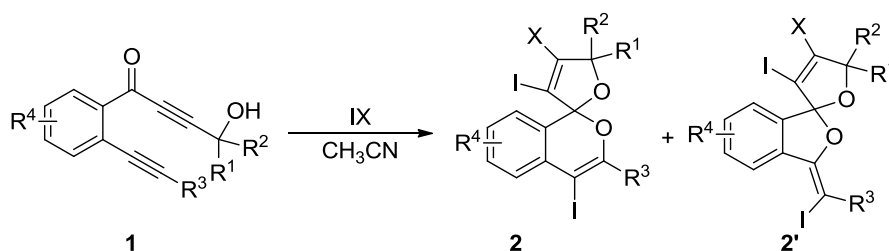


4-hydroxy-1-(2-((4-methoxyphenyl)ethynyl)phenyl)but-2-yn-1-one **1u** Oil, ¹H NMR (400 MHz, CDCl₃) δ ppm 8.10-8.08 (m, 1H), 7.59 (d, *J* = 7.6 Hz, 1H), 7.54 (d, *J* = 8.8 Hz, 2H), 7.48 (t, *J* = 7.6 Hz, 1H), 7.35 (d, *J* = 7.6 Hz, 1H), 6.87 (d, *J* = 8.8 Hz, 2H), 4.48 (s, 2H), 3.80 (s, 3H), 2.95 (s, 1H). ¹³C NMR (100 MHz, CDCl₃) δ ppm 177.2, 160.0, 136.9, 134.0, 133.4, 132.8, 132.0, 127.5, 123.4, 115.1, 114.1, 95.8, 92.8, 87.1, 84.1, 55.2, 50.8. IR (neat, cm⁻¹): 3384, 3015, 2212, 1697, 1250, 1031, 835, 759.

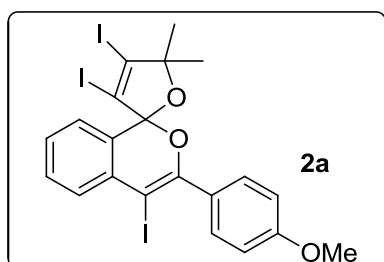


5-hydroxy-1-(2-((4-methoxyphenyl)ethynyl)phenyl)pent-2-yn-1-one **1v** Oil, ¹H NMR (400 MHz, CDCl₃) δ ppm 8.10 (dd, *J* = 8.0, 0.8 Hz, 1H), 7.59 (d, *J* = 7.6 Hz, 1H), 7.55-7.50 (m, 2H), 7.48 (dd, *J* = 7.6, 0.8 Hz, 1H), 7.37 (td, *J* = 7.6, 0.8 Hz, 1H), 6.87 (d, *J* = 8.8 Hz, 2H), 3.83-3.80 (m, 5H), 2.96 (s, 1H), 2.69 (d, *J* = 6.4 Hz, 2H). ¹³C NMR (100 MHz, CDCl₃) δ ppm 177.7, 159.9, 137.5, 133.9, 133.3, 132.5, 131.8, 127.5, 123.2, 115.1, 114.0, 95.6, 93.8, 87.1, 81.6, 60.1, 55.2, 23.6. IR (neat, cm⁻¹): 3396, 2948, 2210, 1642, 1248, 1031, 837, 753.

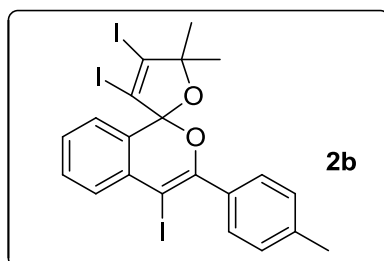
General Procedure for Synthesis of halogenated spiroketal compounds



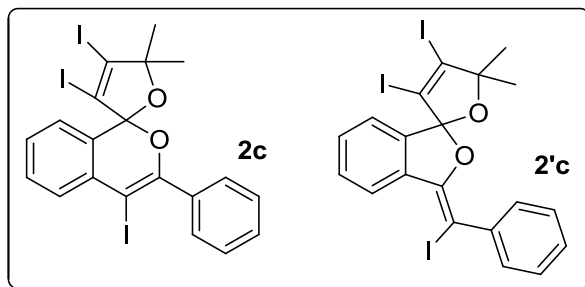
To a solution of 1-(2-ethynylphenyl)-4-hydroxybut-2-yn-1-one derivatives **1** (0.20 mmol) in CH₃CN (4.0 mL) was added IX (0.6 mmol, 3.0 equiv) at room temperature. When the reaction was considered complete as determined by TLC analysis, the reaction mixture was quenched by addition of saturated aqueous sodium thiosulfate and diluted with ethyl acetate (3 x 15 mL), washed with water, saturated brine, dried over Na₂SO₄ and evaporated under reduced pressure. The residue was purified by chromatography on silica gel to afford corresponding halogenated spiroketal derivatives **2** and **2'**.



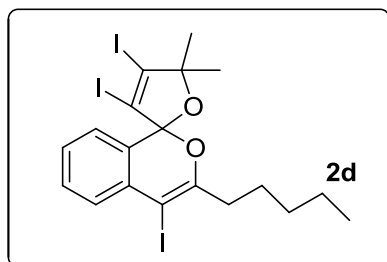
3,4,4'-triiodo-3'-(4-methoxyphenyl)-5,5-dimethyl-5H-spiro[furan-2,1'-isochromene] **2a** Solid, mp: 180-182 °C ¹H NMR (400 MHz, CDCl₃) δ ppm 7.58 (dd, *J* = 15.2, 8.8 Hz, 1H), 7.42 (t, *J* = 8 Hz, 2H), 7.31 (d, *J* = 3.6 Hz, 1H), 7.30 (t, *J* = 7.6 Hz, 1H), 7.03 (d, *J* = 7.6 Hz, 1H), 6.92 (d, *J* = 8.8 Hz, 2H), 3.83 (s, 3H), 1.61 (s, 3H), 1.47 (s, 3H). ¹³C NMR (100 MHz, CDCl₃) δ ppm 160.2, 151.8, 132.2, 131.6, 129.9, 129.8, 129.4, 128.0, 127.7, 125.2, 122.6, 113.1, 113.0, 104.6, 94.14, 72.58, 55.29, 28.19, 27.84. IR (neat, cm⁻¹): 2977, 1611, 1507, 1284, 1251, 1019, 921, 871. HRMS (ESI) *m/z* Calcd for C₂₁H₁₈I₃O₃: [M+H]⁺ = 698.8390. Found: 698.8384.



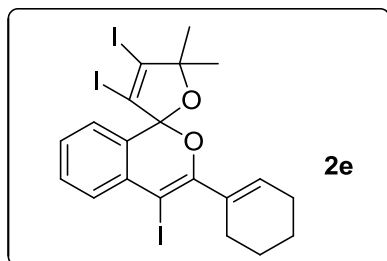
3,4,4'-triiodo-5,5-dimethyl-3'-(p-tolyl)-5H-spiro[furan-2,1'-isochromene] **2b** Solid, mp: 76-78 °C ¹H NMR (400 MHz, CDCl₃) δ ppm 7.61-7.59 (m, 1H), 7.49 (d, *J* = 8.0 Hz, 2H), 7.42 (td, *J* = 8.0, 1.2 Hz, 1H), 7.30 (td, *J* = 7.6, 0.8 Hz, 1H), 7.22-7.20 (m, 2H), 7.03 (dd, *J* = 7.6, 1.2 Hz, 1H), 2.38 (s, 3H), 1.59 (s, 3H), 1.46 (s, 3H). ¹³C NMR (100 MHz, CDCl₃) δ ppm 152.1, 139.3, 134.3, 132.1, 130.5, 129.9, 129.8, 128.5, 128.0, 127.8, 125.3, 122.6, 113.1, 104.7, 94.1, 72.9, 28.1, 27.8, 21.5. IR (neat, cm⁻¹): 2978, 1619, 1479, 1183, 1038, 937, 872, 787. HRMS (ESI) *m/z* Calcd for C₂₁H₁₈I₃O₂: [M+H]⁺ = 682.8441. Found: 682.8433.



3,4,4'-triiodo-5,5-dimethyl-3'-phenyl-5H-spiro[furan-2,1'-isochromene] **2c** and (E)-3,4-diiodo-3'-(iodo(phenyl)methylene)-5,5-dimethyl-3'H,5H-spiro[furan-2,1'-isobenzofuran] **2'c** Oil, **2c:2'c** = 3.5:1.0. ^1H NMR (400 MHz, CDCl_3) δ ppm 7.62-7.53 (m, 3.8H), 7.50-7.36 (m, 4.5H), 7.31 (q, J = 7.6 Hz, 1.6H), 7.23-7.17 (m, 1H), 7.04 (d, J = 7.6 Hz, 1H), 1.60 (s, 3H), 1.53 (s, 0.9H), 1.47 (s, 3H), 1.43 (s, 0.9H). ^{13}C NMR (100 MHz, CDCl_3) δ ppm 152.0, 150.1, 141.5, 140.9, 137.2, 133.9, 131.9, 130.6, 130.2, 130.1, 130.0, 129.9, 129.8, 129.3, 128.0, 127.9, 127.8, 127.5, 127.4, 125.3, 123.0, 122.7, 121.6, 119.8, 113.2, 104.6, 103.7, 94.2, 93.6, 73.2, 68.0, 28.1, 28.0, 27.8, 27.8, 27.2. IR (neat, cm^{-1}): 2977, 1618, 1594, 1253, 1019, 959, 934, 757. HRMS (ESI) m/z Calcd for $\text{C}_{20}\text{H}_{16}\text{I}_3\text{O}_2$: $[\text{M}+\text{H}]^+ = 668.8284$. Found: 668.8279.

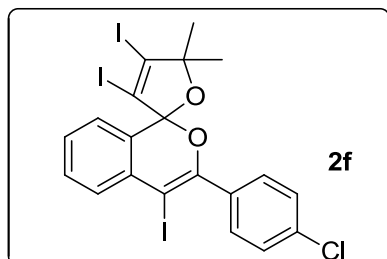


3,4,4'-triiodo-5,5-dimethyl-3'-pentyl-5H-spiro[furan-2,1'-isochromene] **2d** Solid, mp: 96-98 $^{\circ}\text{C}$ ^1H NMR 400 MHz, CDCl_3) δ ppm 7.46 (d, J = 8.0 Hz, 1H), 7.39-7.35 (m, 1H), 7.26-7.22 (m, 1H), 6.96-6.94 (m, 1H), 2.78-2.71 (m, 1H), 2.63-2.56 (m, 1H), 1.66-1.59 (m, 2H), 1.54 (s, 3H), 1.43 (s, 3H), 1.41-1.32 (m, 4H), 0.92-0.89 (m, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ ppm 155.0, 131.5, 129.8, 128.9, 127.4, 127.2, 125.3, 122.4, 112.8, 105.1, 93.9, 72.5, 37.4, 31.1, 28.2, 27.8, 26.5, 22.5, 14.0. IR (neat, cm^{-1}): 2927, 1614, 1480, 1251, 1157, 1052, 949, 756. HRMS (ESI) m/z Calcd for $\text{C}_{19}\text{H}_{22}\text{I}_3\text{O}_2$: $[\text{M}+\text{H}]^+ = 662.8754$. Found: 662.8748.

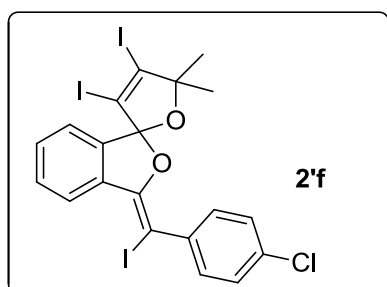


3'-(cyclohex-1-en-1-yl)-3,4,4'-triiodo-5,5-dimethyl-5H-spiro[furan-2,1'-isochromene] **2e** Solid, mp: 152-154 $^{\circ}\text{C}$ ^1H NMR (400 MHz, CDCl_3) δ ppm 7.52 (d, J = 7.6 Hz, 1H), 7.40-7.36 (m, 1H), 7.27-7.23 (m, 1H), 6.98-6.92 (m, 1H), 6.05-6.03 (m, 1H), 2.30-2.25 (m, 1H), 2.19-2.13 (m, 3H), 1.75-1.63 (m, 4H), 1.54 (s, 3H), 1.43 (s, 3H).

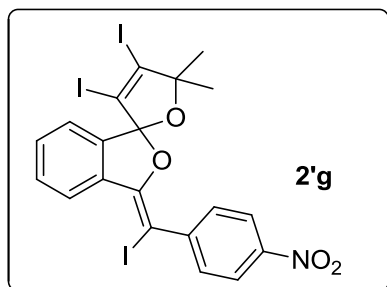
^{13}C NMR (100 MHz, CDCl_3) δ ppm 154.4, 135.0, 133.0, 132.1, 129.8, 129.7, 127.9, 127.4, 125.2, 122.5, 112.9, 104.9, 93.9, 71.4, 28.1, 27.8, 26.2, 25.0, 22.4, 21.7. IR (neat, cm^{-1}): 2928, 1736, 1586, 1188, 1030, 921, 871, 758. HRMS (ESI) m/z Calcd for $\text{C}_{20}\text{H}_{20}\text{I}_3\text{O}_2$: $[\text{M}+\text{H}]^+ = 672.8597$. Found: 672.8592.



3'-(4-chlorophenyl)-3,4,4'-triiodo-5,5-dimethyl-5H-spiro[furan-2,1'-isochromene] **2f**
Solid, mp: 164-166 $^{\circ}\text{C}$ ^1H NMR (600 MHz, CDCl_3) δ ppm 7.61-7.54 (m, 1H), 7.46-7.45 (m, 2H), 7.44-7.43 (m, 1H), 7.39-7.38 (m, 2H), 7.35-7.32 (m, 1H), 7.05-7.04 (m, 1H), 1.58 (s, 3H), 1.47 (s, 3H). ^{13}C NMR (150 MHz, CDCl_3) δ ppm 150.9, 135.5, 135.2, 131.7, 131.5, 130.1, 130.0, 128.2, 128.1, 128.0, 125.4, 122.8, 113.2, 104.4, 94.4, 73.6, 28.2, 27.8. IR (neat, cm^{-1}): 2924, 1595, 1455, 1257, 1110, 1024, 929, 758. HRMS (ESI) m/z Calcd for $\text{C}_{20}\text{H}_{15}\text{ClI}_3\text{O}_2$: $[\text{M}+\text{H}]^+ = 702.7895$. Found: 702.7889.

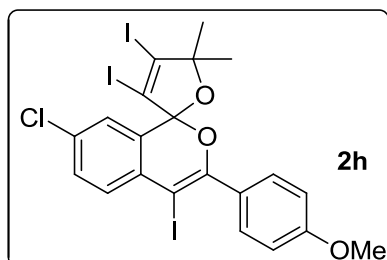


(E)-3'-((4-chlorophenyl)iodomethylene)-3,4-diiodo-5,5-dimethyl-3'H,5H-spiro[furan-2,1'-isobenzofuran] **2'f** Solid, mp: 160-162 $^{\circ}\text{C}$ ^1H NMR (600 MHz, CDCl_3) δ ppm 7.39 (s, 4H), 7.35-7.32 (m, 1H), 7.17-7.13 (m, 2H), 6.52 (d, $J = 6.0$ Hz, 1H), 1.66 (s, 3H), 1.58 (s, 3H). ^{13}C NMR (150 MHz, CDCl_3) δ ppm 153.6, 140.9, 139.1, 134.4, 131.8, 131.3, 130.1, 129.7, 129.2, 123.2, 122.6, 121.7, 120.4, 103.8, 94.2, 65.7, 28.1, 27.4. IR (neat, cm^{-1}): 2924, 1591, 1421, 1253, 1098, 937, 769, 622. HRMS (ESI) m/z Calcd for $\text{C}_{20}\text{H}_{15}\text{ClI}_3\text{O}_2$: $[\text{M}+\text{H}]^+ = 702.7895$. Found: 702.7889.

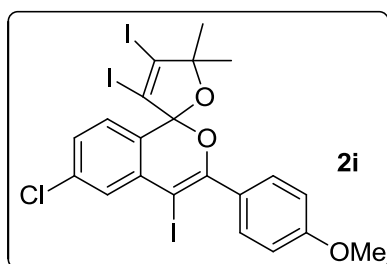


(E)-3,4-diiodo-3'-(iodo(4-nitrophenyl)methylene)-5,5-dimethyl-3'H,5H-spiro[furan-2,1'-isobenzofuran] **2'g** Solid, mp: 192-194 $^{\circ}\text{C}$ ^1H NMR (400 MHz, CDCl_3) δ ppm 8.76

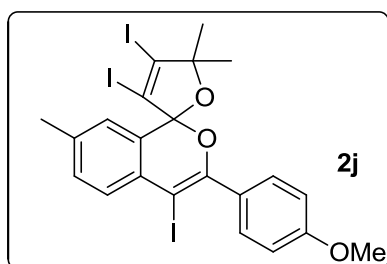
(d, $J = 7.6$ Hz, 1H), 8.16 (d, $J = 9.2$ Hz, 2H), 7.75 (d, $J = 8.8$ Hz, 2H), 7.60 (t, $J = 7.6$ Hz, 1H), 7.56-7.53 (m, 1H), 7.26 (s, 1H), 1.55 (s, 3H), 1.44 (s, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ ppm 152.0, 148.0, 146.4, 141.2, 133.2, 131.6, 131.0, 130.0, 125.5, 123.1, 122.9, 122.1, 120.4, 103.0, 94.1, 63.6, 28.0, 27.3. IR (neat, cm^{-1}): 2978, 1616, 1516, 1364, 1162, 934, 879, 766. HRMS (ESI) m/z Calcd for $\text{C}_{20}\text{H}_{15}\text{I}_3\text{NO}_4$: $[\text{M}+\text{H}]^+ = 713.8135$. Found: 713.8130.



7'-chloro-3,4,4'-triiodo-3'-(4-methoxyphenyl)-5,5-dimethyl-5H-spiro[furan-2,1'-isochromene] **2h** Solid, mp: 182-184 °C ^1H NMR (400 MHz, CDCl_3) δ ppm 7.56-7.54 (m, 3H), 7.37 (d, $J = 8.4$ Hz, 1H), 7.01 (d, $J = 2.4$ Hz, 1H), 6.92 (d, $J = 8.4$ Hz, 2H), 3.83 (s, 3H), 1.60 (s, 3H), 1.48 (s, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ ppm 160.3, 152.2, 133.0, 131.6, 131.5, 131.1, 130.0, 129.2, 129.0, 124.9, 123.2, 113.1, 112.5, 103.7, 94.5, 71.1, 55.3, 28.2, 27.8. IR (neat, cm^{-1}): 2976, 1610, 1507, 1251, 1030, 967, 883, 737. HRMS (ESI) m/z Calcd for $\text{C}_{21}\text{H}_{16}\text{ClI}_3\text{O}_3$: $[\text{M}]^+ = 731.7922$. Found: 731.7917.

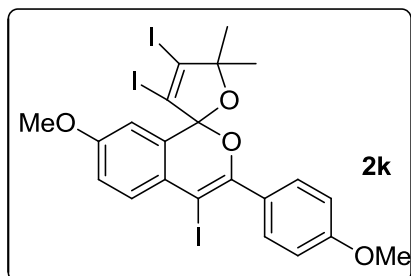


6'-chloro-3,4,4'-triiodo-3'-(4-methoxyphenyl)-5,5-dimethyl-5H-spiro[furan-2,1'-isochromene] **2i** Solid, mp: 184-186 °C ^1H NMR (400 MHz, CDCl_3) δ ppm 7.61 (d, $J = 2$ Hz, 1H), 7.55 (d, $J = 8.8$ Hz, 2H), 7.25 (dd, $J = 8.4$, 2 Hz, 1H), 6.98 (d, $J = 8.4$ Hz, 1H), 6.92 (d, $J = 8.8$ Hz, 2H), 3.83 (s, 3H), 1.60 (s, 3H), 1.46 (s, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ ppm 160.4, 153.0, 135.9, 134.3, 131.6, 129.9, 129.1, 127.6, 126.9, 126.4, 123.0, 113.1, 112.8, 104.1, 94.4, 70.5, 55.3, 28.2, 27.8. IR (neat, cm^{-1}): 2924, 1606, 1507, 1253, 1174, 1024, 869, 735. HRMS (ESI) m/z Calcd for $\text{C}_{21}\text{H}_{17}\text{ClI}_3\text{O}_3$: $[\text{M}+\text{H}]^+ = 732.8000$. Found: 732.7995.

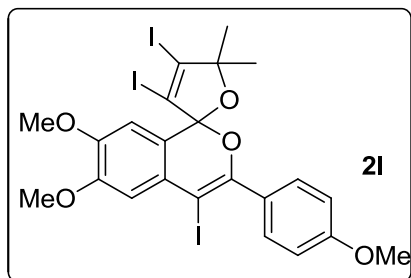


3,4,4'-triiodo-3'-(4-methoxyphenyl)-5,5,7'-trimethyl-5H-spiro[furan-2,1'-isochromene] **2j** Solid, mp: 168-170 °C ^1H NMR (400 MHz, CDCl_3) δ ppm 7.55 (d, $J = 8.8$ Hz, 2H),

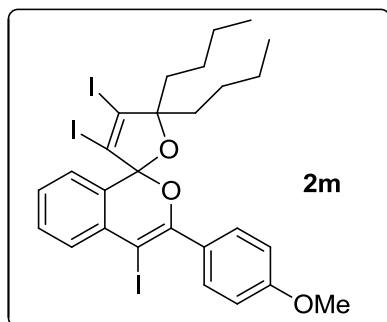
7.47 (d, $J = 8.0$ Hz, 1H), 7.22 (d, $J = 8.8$ Hz, 1H), 6.91 (d, $J = 8.8$ Hz, 2H), 6.81 (s, 1H), 3.82 (s, 3H), 2.38 (s, 3H), 1.60 (s, 3H), 1.47 (s, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ ppm 160.1, 151.0, 137.7, 131.6, 130.7, 129.9, 129.7, 129.5, 127.8, 125.5, 122.4, 113.2, 113.0, 104.9, 94.0, 72.6, 55.3, 28.2, 27.9, 21.3. IR (neat, cm^{-1}): 2928, 1605, 1507, 1254, 1174, 967, 863, 767. HRMS (ESI) m/z Calcd for $\text{C}_{22}\text{H}_{19}\text{I}_3\text{O}_3$: $[\text{M}]^+ = 711.8468$. Found: 711.8463.



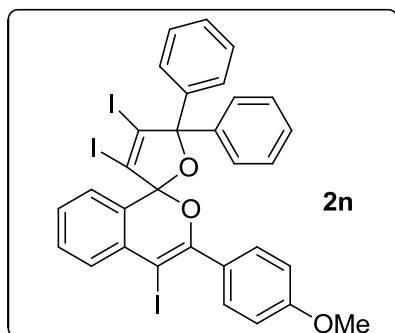
3,4,4'-triiodo-7'-methoxy-3'-(4-methoxyphenyl)-5,5-dimethyl-5H-spiro[furan-2,1'-isochromene] **2k** Solid, mp: 216-218 °C ^1H NMR (400 MHz, CDCl_3) δ ppm 7.56-7.53 (m, 3H), 6.96 (dd, $J = 8.8, 2.4$ Hz, 1H), 6.92 (d, $J = 8.4$ Hz, 2H), 6.58 (d, $J = 2.0$ Hz, 1H), 3.83 (s, 6H), 1.60 (s, 3H), 1.48 (s, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ ppm 160.1, 159.2, 149.9, 131.7, 131.6, 129.5, 129.2, 125.5, 122.7, 114.9, 113.0, 110.8, 104.5, 94.1, 72.2, 55.6, 55.3, 28.2, 27.8. IR (neat, cm^{-1}): 2925, 1598, 1458, 1285, 1111, 1027, 804, 740. HRMS (ESI) m/z Calcd for $\text{C}_{22}\text{H}_{19}\text{I}_3\text{O}_4$: $[\text{M}]^+ = 727.8417$. Found: 727.8412.



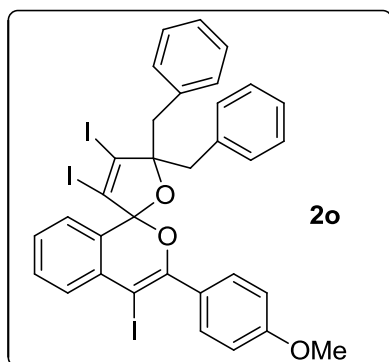
3,4,4'-triiodo-6',7'-dimethoxy-3'-(4-methoxyphenyl)-5,5-dimethyl-5H-spiro[furan-2,1'-isochromene] **2l** Solid, mp: 176-178 °C ^1H NMR (400 MHz, CDCl_3) δ ppm 7.55 (d, $J = 8.8$ Hz, 2H), 7.14 (s, 1H), 6.92 (d, $J = 8.8$ Hz, 2H), 6.52 (s, 1H), 3.97 (s, 3H), 3.89 (s, 3H), 3.83 (s, 3H), 1.60 (s, 3H), 1.48 (s, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ ppm 160.1, 150.4, 150.1, 148.6, 131.5, 129.5, 126.1, 122.6, 119.8, 113.2, 113.0, 108.1, 105.0, 93.7, 72.1, 56.3, 56.0, 55.2, 28.0, 27.9. IR (neat, cm^{-1}): 2925, 1606, 1543, 1200, 1076, 967, 789, 737. HRMS (ESI) m/z Calcd for $\text{C}_{23}\text{H}_{21}\text{I}_3\text{O}_5$: $[\text{M}]^+ = 757.8523$. Found: 757.8547.



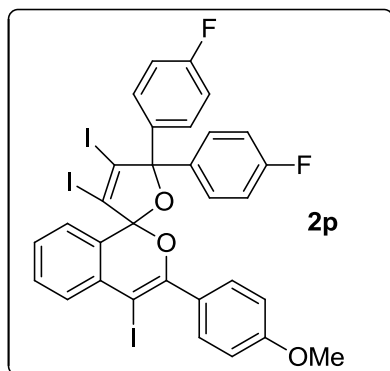
5,5-dibutyl-3,4,4'-triiodo-3'-(4-methoxyphenyl)-5H-spiro[furan-2,1'-isochromene] **2m**
Solid, mp: 118-120 °C ^1H NMR (400 MHz, CDCl_3) δ ppm 7.62 (d, J = 8.0 Hz, 1H), 7.53 (d, J = 8.8 Hz, 2H), 7.42 (t, J = 8.0 Hz, 1H), 7.31-7.27 (m, 1H), 7.07 (d, J = 7.6 Hz, 1H), 6.90 (d, J = 8.8 Hz, 2H), 3.82 (s, 3H), 1.82-1.67 (m, 4H), 1.43-1.33 (m, 2H), 1.25-1.13 (m, 6H), 0.85-0.79 (m, 6H). ^{13}C NMR (100 MHz, CDCl_3) δ ppm 160.1, 151.9, 132.1, 131.2, 129.8, 127.2, 127.1, 126.0, 122.5, 113.0, 112.9, 104.2, 98.6, 73.4, 55.3, 39.6, 36.6, 25.7, 25.5, 23.0, 22.6, 13.9. IR (neat, cm^{-1}): 2954, 1612, 1508, 1284, 1175, 1028, 875, 759. HRMS (ESI) m/z Calcd for $\text{C}_{27}\text{H}_{29}\text{I}_3\text{O}_3$: $[\text{M}]^+ = 781.9251$. Found: 781.9245.



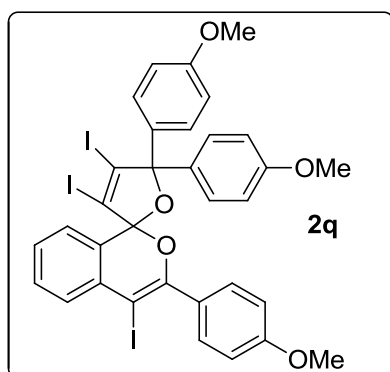
3,4,4'-triiodo-3'-(4-methoxyphenyl)-5,5-diphenyl-5H-spiro[furan-2,1'-isochromene] **2n**
Solid, mp: 202-204 °C ^1H NMR (400 MHz, DMSO) δ ppm 7.59-7.54 (m, 3H), 7.52-7.45 (m, 3H), 7.35-7.32 (m, 5H), 7.17-7.12 (m, 3H), 6.72-6.64 (m, 4H), 3.77 (s, 3H). ^{13}C NMR (100 MHz, DMSO) δ ppm 159.8, 151.1, 141.9, 140.5, 132.0, 131.6, 131.3, 130.3, 129.7, 128.5, 128.4, 128.2, 127.9, 127.8, 127.8, 127.1, 125.8, 123.2, 113.8, 113.2, 112.8, 108.9, 99.3, 72.5, 55.2. IR (neat, cm^{-1}): 2960, 1614, 1507, 1279, 1098, 905, 762, 698. HRMS (ESI) m/z Calcd for $\text{C}_{31}\text{H}_{21}\text{I}_3\text{NaO}_3$: $[\text{M}+\text{Na}]^+ = 844.8522$. Found: 844.8517.



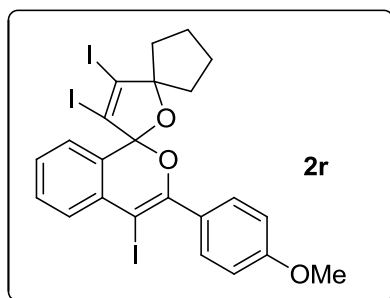
5,5-dibenzyl-3,4,4'-triiodo-3'-(4-methoxyphenyl)-5H-spiro[furan-2,1'-isochromene] **2o**
Solid, mp: 196-198 °C ^1H NMR (300 MHz, CDCl_3) δ ppm 7.65-7.56 (m, 2H), 7.54-7.30 (m, 1H), 7.30--7.25 (m, 6H), 7.22-7.15 (m, 2H), 7.07-7.04 (m, 2H), 6.98 (s, 2H), 6.91-6.88 (m, 2H), 6.81-6.77 (m, 1H), 3.80 (s, 3H), 3.25-3.24 (m, 2H), 3.06-3.01 (m, 1H), 2.74-2.70 (m, 1H). ^{13}C NMR (100 MHz, CDCl_3) δ ppm 160.2, 151.6, 135.6, 135.4, 131.8, 131.4, 131.2, 130.9, 129.5, 129.4, 129.1, 128.7, 128.2, 128.0, 127.4, 126.8, 126.6, 126.4, 126.1, 113.5, 113.2, 107.4, 98.0, 72.9, 55.3, 49.1, 46.4, 40.8. IR (neat, cm^{-1}): 3061, 1600, 1508, 1285, 1031, 902, 738, 701. HRMS (ESI) m/z Calcd for $\text{C}_{33}\text{H}_{25}\text{I}_3\text{O}_3$: $[\text{M}]^+ = 849.8938$. Found: 849.8932.



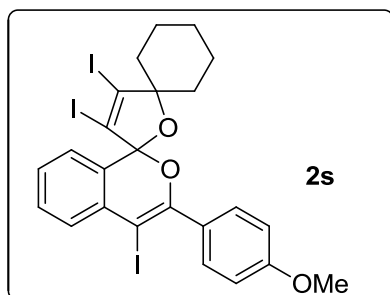
5,5-bis(4-fluorophenyl)-3,4,4'-triiodo-3'-(4-methoxyphenyl)-5H-spiro[furan-2,1'-isochromene] **2p** Solid, mp: 264-266 °C ^1H NMR (400 MHz, DMSO) δ ppm 7.58 (d, J = 3.6 Hz, 2H), 7.51-7.47 (m, 1H), 7.39-7.29 (m, 4H), 7.18 (d, J = 7.2 Hz, 4H), 7.12 (d, J = 7.6 Hz, 1H), 6.72 (dd, J = 13.6, 9.2 Hz, 4H), 3.78 (s, 3H). ^{13}C NMR (100 MHz, DMSO) δ ppm 160.7, 160.6, 159.8, 151.0, 138.2, 136.5, 131.9, 131.4, 130.8, 130.7, 130.4, 130.0, 129.9, 129.7, 128.2, 128.1, 127.0, 125.7, 122.8, 115.4, 115.2, 114.9, 114.7, 113.3, 112.7, 109.4, 98.4, 72.71, 55.2. IR (neat, cm^{-1}): 2926, 1655, 1546, 1196, 1029, 917, 834, 740. HRMS (ESI) m/z Calcd for $\text{C}_{31}\text{H}_{20}\text{F}_2\text{I}_3\text{O}_3$: $[\text{M}+\text{H}]^+ = 858.8515$. Found: 858.8509.



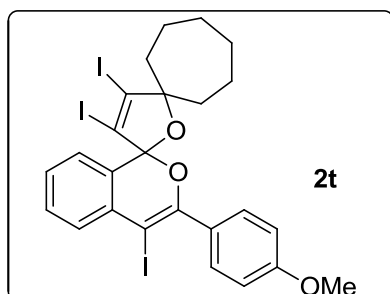
3,4,4'-triiodo-3',5,5-tris(4-methoxyphenyl)-5H-spiro[furan-2,1'-isochromene] **2q** Solid, mp: 248-250 °C ^1H NMR (400 MHz, DMSO) δ ppm 7.57 (d, J = 3.2 Hz, 2H), 7.51-7.47 (m, 1H), 7.26 (d, J = 8.8 Hz, 2H), 7.13 (d, J = 7.6 Hz, 1H), 7.05 (dd, J = 14.8, 8.8 Hz, 4H), 6.88 (d, J = 4.8 Hz, 2H), 6.68 (s, 4H), 3.87 (s, 3H), 3.77 (s, 3H), 3.74 (s, 3H). ^{13}C NMR (100 MHz, DMSO) δ ppm 159.7, 159.2, 158.9, 151.1, 134.2, 132.5, 132.0, 131.7, 130.2, 130.0, 129.6, 129.2, 128.2, 127.9, 127.4, 125.7, 124.2, 113.6, 113.1, 112.9, 112.6, 108.1, 99.1, 72.5, 55.2, 55.1. IR (neat, cm^{-1}): 2926, 1609, 1547, 1255, 1201, 1029, 880, 739. HRMS (ESI) m/z Calcd for $\text{C}_{33}\text{H}_{26}\text{I}_3\text{O}_5$: $[\text{M}+\text{H}]^+ = 882.8914$. Found: 882.8909.



3,4,4'-triiodo-3'-(4-methoxyphenyl)-spiro[furan-5,1''-cyclopentane]-5H-spiro[furan-2,1'-isochromene] **2r** Solid, mp: 198-200 °C ^1H NMR (400 MHz, CDCl_3) δ ppm 7.59 (dd, $J = 8.0, 0.8$ Hz, 1H), 7.55 (d, $J = 8.8$ Hz, 2H), 7.42 (td, $J = 7.6, 1.2$ Hz, 1H), 7.29 (td, $J = 7.6, 1.2$ Hz, 1H), 7.03 (dd, $J = 7.6, 0.8$ Hz, 1H), 6.93 (d, $J = 9.2$ Hz, 2H), 3.84 (s, 3H), 2.15-2.08 (m, 2H), 1.85-1.73 (m, 6H). ^{13}C NMR (100 MHz, CDCl_3) δ ppm 160.2, 152.0, 132.3, 131.6, 129.9, 129.8, 129.6, 128.1, 127.7, 125.4, 121.6, 113.1, 104.7, 103.3, 72.5, 55.3, 39.4, 38.5, 31.9, 24.9, 24.8. IR (neat, cm^{-1}): 2925, 1610, 1508, 1284, 1175, 1031, 894, 738. HRMS (ESI) m/z Calcd for $\text{C}_{23}\text{H}_{19}\text{I}_3\text{O}_3$: $[\text{M}]^+ = 723.8468$. Found: 723.8463.

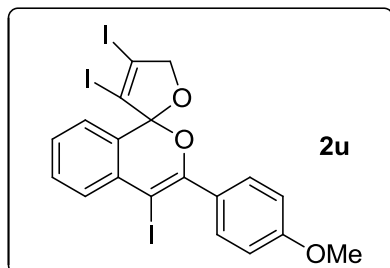


3,4,4'-triiodo-3'-(4-methoxyphenyl)-spiro[furan-5,1''-cyclohexane]-5H-spiro[furan-2,1'-isochromene] **2s** Solid, mp: 200-202 °C ^1H NMR (400 MHz, CDCl_3) δ ppm 7.58 (d, $J = 7.6$ Hz, 1H), 7.52 (d, $J = 8.8$ Hz, 2H), 7.44-7.40 (m, 1H), 7.30 (t, $J = 7.2$ Hz, 1H), 7.03 (d, $J = 7.2$ Hz, 1H), 6.91 (d, $J = 8.8$ Hz, 2H), 3.83 (s, 3H), 1.86 (dd, $J = 12.8, 4$ Hz, 4H), 1.71-1.53 (m, 6H). ^{13}C NMR (100 MHz, CDCl_3) δ ppm 160.1, 152.0, 132.4, 131.5, 129.8, 129.7, 128.4, 127.6, 125.5, 123.2, 113.1, 104.6, 94.8, 72.6, 55.3, 36.0, 35.9, 24.6, 21.9, 21.7. IR (neat, cm^{-1}): 2931, 1612, 1508, 1288, 1031, 905, 880, 758. HRMS (ESI) m/z Calcd for $\text{C}_{22}\text{H}_{22}\text{I}_3\text{O}_3$: $[\text{M}+\text{H}]^+ = 738.8703$. Found: 738.8702.

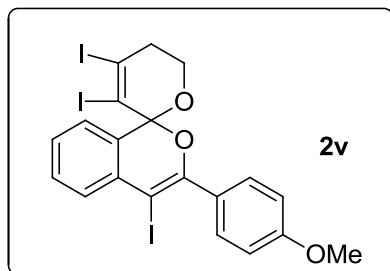


3,4,4'-triiodo-3'-(4-methoxyphenyl)-spiro[furan-5,1''-cycloheptane]-5H-spiro[furan-2,1'-isochromene] **2t** Solid, mp: 174-176 °C ^1H NMR (400 MHz, CDCl_3) δ ppm 7.58 (d, $J = 8.0$ Hz, 1H), 7.53 (d, $J = 8.8$ Hz, 2H), 7.41 (t, $J = 7.6$ Hz, 1H), 7.28 (t, $J = 7.6$ Hz,

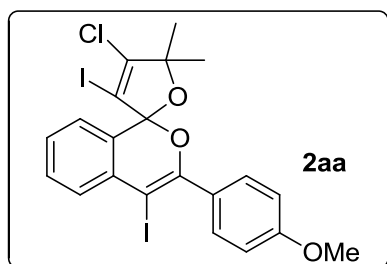
1H), 7.01 (d, $J = 7.6$ Hz, 1H), 6.91 (d, $J = 8.4$ Hz, 2H), 3.82 (s, 3H), 2.09-2.03 (m, 3H), 1.85-1.76 (m, 2H), 1.72-1.66 (m, 3H), 1.60-1.49 (m, 4H). ^{13}C NMR (100 MHz, CDCl_3) δ ppm 160.1, 151.9, 132.3, 131.5, 129.8, 129.7, 129.6, 128.3, 127.6, 125.5, 123.8, 113.0, 112.9, 104.1, 97.6, 72.6, 55.3, 40.1, 39.9, 29.2, 29.0, 22.9, 22.8. IR (neat, cm^{-1}): 2927, 1611, 1508, 1250, 1030, 874, 835, 738. HRMS (ESI) m/z Calcd for $\text{C}_{25}\text{H}_{23}\text{I}_3\text{O}_3$: $[\text{M}]^+ = 751.8781$. Found: 751.8776.



3,4,4'-triiodo-3'-(4-methoxyphenyl)-5H-spiro[furan-2,1'-isochromene] **2u** Solid, mp: 172-174 $^{\circ}\text{C}$ ^1H NMR (400 MHz, CDCl_3) δ ppm 7.62 (td, $J = 7.6, 1.2$ Hz, 1H), 7.57 (d, $J = 8.8$ Hz, 2H), 7.47-7.43 (m, 1H), 7.32 (td, $J = 7.6, 0.8$ Hz, 1H), 7.05 (d, $J = 7.6$ Hz, 1H), 7.94-7.92 (m, 2H), 4.80 (d, $J = 13.6$ Hz, 1H), 4.68 (d, $J = 13.6$ Hz, 1H), 3.84 (s, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ ppm 160.3, 151.5, 132.4, 131.6, 130.1, 130.0, 129.3, 127.7, 127.1, 125.4, 114.0, 113.1, 108.7, 104.4, 82.2, 72.7, 55.3. IR (neat, cm^{-1}): 2861, 1598, 1507, 1253, 1028, 878, 834, 737. HRMS (ESI) m/z Calcd for $\text{C}_{19}\text{H}_{14}\text{I}_3\text{O}_3$: $[\text{M}+\text{H}]^+ = 670.8077$. Found: 670.8071.

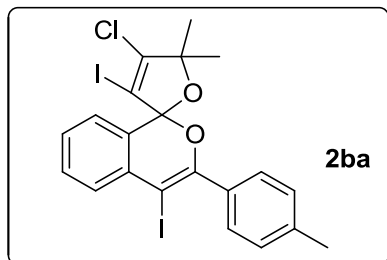


3',4,4'-triiodo-3-(4-methoxyphenyl)-5',6'-dihydrospiro[isochromene-1,2'-pyran] **2v** Solid, mp: 192-194 $^{\circ}\text{C}$ ^1H NMR (400 MHz, CDCl_3) δ ppm 7.58-7.56 (m, 3H), 7.41 (t, $J = 7.6$ Hz, 1H), 7.31 (t, $J = 7.6$ Hz, 1H), 7.11 (d, $J = 3.6$ Hz, 1H), 6.94 (d, $J = 8.8$ Hz, 2H), 4.36 (td, $J = 11.2, 2.8$ Hz, 1H), 3.84 (s, 3H), 3.79 (t, $J = 5.6$ Hz, 1H), 3.19-3.10 (m, 1H), 2.76 (dd, $J = 5.6, 2.0$ Hz, 1H). ^{13}C NMR (100 MHz, CDCl_3) δ ppm 160.3, 151.4, 131.6, 131.1, 130.1, 130.0, 129.9, 129.8, 127.6, 125.9, 114.3, 113.3, 112.3, 101.8, 72.9, 60.7, 55.4, 42.3. IR (neat, cm^{-1}): 2927, 1606, 1508, 1262, 1070, 954, 738, 703. HRMS (ESI) m/z Calcd for $\text{C}_{20}\text{H}_{16}\text{I}_3\text{O}_3$: $[\text{M}+\text{H}]^+ = 684.8233$. Found: 684.8232.

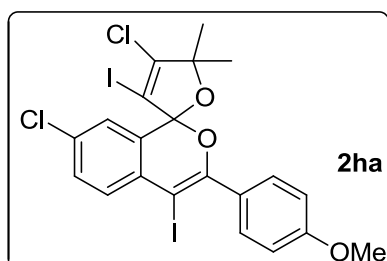


4-chloro-3,4'-diiodo-3'-(4-methoxyphenyl)-5,5-dimethyl-5H-spiro[furan-2,1'-isochro

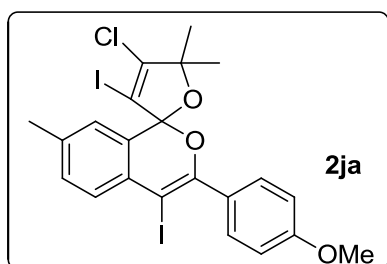
mene] **2aa** Solid, mp: 202-204 °C ^1H NMR (400 MHz, CDCl_3) δ ppm 7.61 (d, J = 7.6 Hz, 1H), 7.57 (d, J = 8.8 Hz, 2H), 7.45 (t, J = 4.0 Hz, 1H), 7.31 (t, J = 3.2 Hz, 1H), 7.06 (d, J = 7.6 Hz, 1H), 6.92 (d, J = 8.8 Hz, 2H), 3.83 (s, 3H), 1.61 (s, 3H), 1.45 (s, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ ppm 160.2, 151.8, 150.3, 132.3, 131.7, 130.0, 129.9, 129.5, 127.8, 127.7, 125.2, 113.1, 111.1, 90.1, 89.5, 72.7, 55.3, 27.4, 26.5. IR (neat, cm^{-1}): 2980, 1612, 1509, 1253, 1172, 1030, 932, 759. HRMS (ESI) m/z Calcd for $\text{C}_{21}\text{H}_{18}\text{ClI}_2\text{O}_3$: $[\text{M}+\text{H}]^+ = 606.9034$. Found: 606.9028.



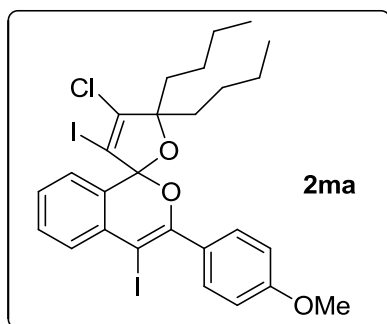
4-chloro-3,4'-diiodo-5,5-dimethyl-3'-(p-tolyl)-5H-spiro[furan-2,1'-isochromene] **2ba** Solid, mp: 178-180 °C ^1H NMR (400 MHz, CDCl_3) δ ppm 7.61 (d, J = 7.6 Hz, 1H), 7.50 (d, J = 8 Hz, 2H), 7.43 (t, J = 7.6 Hz, 1H), 7.31 (t, J = 7.2 Hz, 1H), 7.21 (d, J = 7.2 Hz, 2H), 7.06 (d, J = 7.6 Hz, 1H), 2.39 (s, 3H), 1.60 (s, 3H), 1.44 (s, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ ppm 152.1, 150.3, 139.4, 134.3, 132.1, 130.0, 130.0, 129.9, 128.5, 127.9, 127.8, 125.3, 111.1, 90.1, 89.5, 72.9, 27.3, 26.5, 21.5. IR (neat, cm^{-1}): 2924, 1623, 1263, 1167, 1078, 932, 885, 758. HRMS (ESI) m/z Calcd for $\text{C}_{21}\text{H}_{18}\text{ClI}_2\text{O}_2$: $[\text{M}+\text{H}]^+ = 590.9085$. Found: 590.9079.



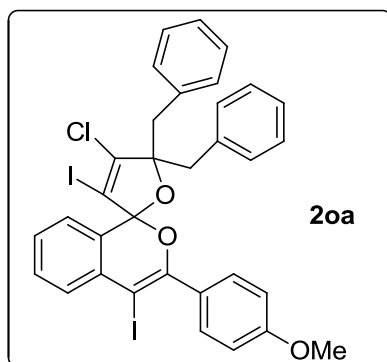
4,7'-dichloro-3,4'-diiodo-3'-(4-methoxyphenyl)-5,5-dimethyl-5H-spiro[furan-2,1'-isochromene] **2ha** Solid, mp: 202-204 °C ^1H NMR (400 MHz, CDCl_3) δ ppm 7.56 (dd, J = 8.8, 2.0 Hz, 3H), 7.38 (dd, J = 8.8, 2.4 Hz, 1H), 7.03 (d, J = 2.4 Hz, 1H), 6.92 (d, J = 8.8 Hz, 2H), 3.84 (s, 3H), 1.61 (s, 3H), 1.46 (s, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ ppm 160.4, 152.2, 150.9, 133.1, 131.6, 131.2, 130.0, 129.1, 129.0, 125.0, 113.1, 110.5, 90.5, 88.7, 71.2, 55.3, 27.4, 26.5. IR (neat, cm^{-1}): 2926, 1612, 1507, 1252, 1170, 1076, 938, 738. HRMS (ESI) m/z Calcd for $\text{C}_{21}\text{H}_{17}\text{Cl}_2\text{I}_2\text{O}_3$: $[\text{M}+\text{H}]^+ = 640.8644$. Found: 640.8639.



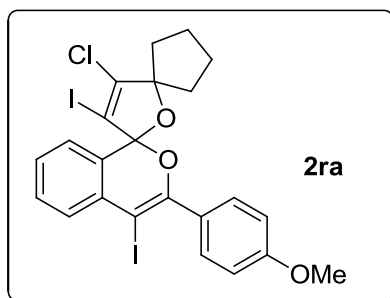
4-chloro-3,4'-diiodo-3'-(4-methoxyphenyl)-5,5,7'-trimethyl-5H-spiro[furan-2,1'-isochromene] **2ja** Solid, mp: 160-162 °C ^1H NMR (400 MHz, CDCl_3) δ ppm 7.56 (dd, J = 8.8, 2.4 Hz, 2H), 7.49 (d, J = 8.0 Hz, 1H), 7.23 (d, J = 8.4 Hz, 1H), 6.92 (d, J = 8.8 Hz, 2H), 6.84 (s, 1H), 3.83 (s, 3H), 2.39 (s, 3H), 1.61 (s, 3H), 1.46 (s, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ ppm 160.1, 151.0, 150.1, 137.8, 131.6, 130.7, 130.0, 129.8, 129.5, 127.6, 113.2, 113.0, 111.1, 90.0, 89.7, 72.7, 55.3, 27.4, 26.5, 21.3. IR (neat, cm^{-1}): 2928, 1619, 1508, 1253, 1175, 1031, 935, 738. HRMS (ESI) m/z Calcd for $\text{C}_{22}\text{H}_{20}\text{ClI}_2\text{O}_3$: $[\text{M}+\text{H}]^+ = 620.9190$. Found: 620.9185.



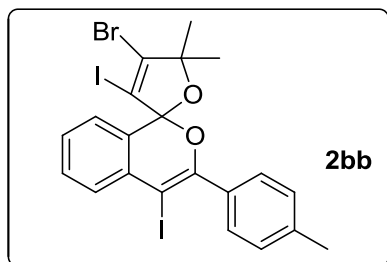
5,5-dibutyl-4-chloro-3,4'-diiodo-3'-(4-methoxyphenyl)-5H-spiro[furan-2,1'-isochromene] **2ma** Solid, mp: 126-128 °C ^1H NMR (400 MHz, CDCl_3) δ ppm 7.63 (d, J = 7.6 Hz, 1H), 7.53 (d, J = 8.4 Hz, 2H), 7.43 (t, J = 7.6 Hz, 1H), 7.31 (t, J = 7.6 Hz, 1H), 7.09 (d, J = 7.6 Hz, 1H), 6.90 (d, J = 8.4 Hz, 2H), 3.83 (s, 3H), 1.78 (dd, J = 11.6, 6 Hz, 3H), 1.67-1.64 (m, 1H), 1.45-1.34 (m, 2H), 1.26-1.21 (m, 6H), 0.85-0.81 (m, 6H). ^{13}C NMR (100 MHz, CDCl_3) δ ppm 160.1, 152.0, 149.7, 132.2, 131.3, 129.9, 129.9, 129.8, 127.2, 127.1, 126.0, 113.1, 110.9, 95.4, 89.6, 73.4, 55.3, 39.1, 35.7, 25.9, 25.5, 22.9, 22.6, 13.9. IR (neat, cm^{-1}): 2956, 1617, 1509, 1250, 1173, 928, 833, 739. HRMS (ESI) m/z Calcd for $\text{C}_{27}\text{H}_{30}\text{ClI}_2\text{O}_3$: $[\text{M}+\text{H}]^+ = 690.9973$. Found: 690.9967.



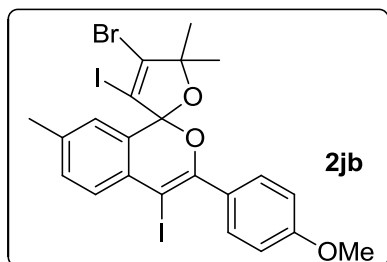
5,5-dibenzyl-4-chloro-3,4'-diiodo-3'-(4-methoxyphenyl)-5H-spiro[furan-2,1'-isochromene] **2oa** Solid, mp: 218-220 °C ^1H NMR (400 MHz, CDCl_3) δ ppm 7.64 (d, J = 8.8 Hz, 2H), 7.53 (d, J = 8.0 Hz, 1H), 7.30-7.18 (m, 8H), 7.07 (t, J = 7.6 Hz, 2H), 6.91-6.87 (m, 4H), 6.81-6.77 (m, 1H), 3.78 (s, 3H), 3.33 (d, J = 14 Hz, 1H), 3.17 (d, J = 13.6 Hz, 1H), 2.94 (d, J = 14.4 Hz, 1H), 2.66 (d, J = 14.4 Hz, 1H). ^{13}C NMR (100 MHz, CDCl_3) δ ppm 160.1, 151.5, 148.0, 135.5, 135.2, 131.8, 131.4, 130.8, 130.8, 129.5, 129.2, 128.3, 128.1, 127.4, 126.9, 126.5, 126.4, 125.8, 113.1, 111.5, 95.2, 92.5, 73.0, 55.2, 45.9, 40.2. IR (neat, cm^{-1}): 2924, 1604, 1509, 1258, 1079, 1032, 925, 739. HRMS (ESI) m/z Calcd for $\text{C}_{33}\text{H}_{25}\text{ClI}_2\text{NaO}_3$: $[\text{M}+\text{Na}]^+ = 780.9479$. Found: 780.9474.



4-chloro-3,4'-diiodo-3'-(4-methoxyphenyl)- spiro[furan-5,1'-cyclopentane]-5H-spiro-[furan-2,1'-isochromene] **2ra** Solid, mp: 162-164 °C ^1H NMR (400 MHz, CDCl_3) δ ppm 7.61-7.55 (m, 3H), 7.43 (t, J = 7.6 Hz, 1H), 7.30 (t, J = 7.6 Hz, 1H), 7.06-7.04 (m, 1H), 6.93 (d, J = 8.4 Hz, 2H), 3.83 (s, 3H), 2.11-2.04 (m, 3H), 1.84-1.69 (m, 5H). ^{13}C NMR (100 MHz, CDCl_3) δ ppm 160.2, 151.9, 148.2, 132.3, 131.6, 129.9, 129.8, 129.5, 127.9, 127.7, 125.3, 113.1, 111.2, 99.3, 89.6, 72.6, 55.3, 38.6, 37.1, 24.9, 24.8. IR (neat, cm^{-1}): 2960, 1614, 1508, 1251, 1173, 1033, 923, 759. HRMS (ESI) m/z Calcd for $\text{C}_{23}\text{H}_{20}\text{ClI}_2\text{O}_3$: $[\text{M}+\text{H}]^+ = 632.9190$. Found: 632.9185.

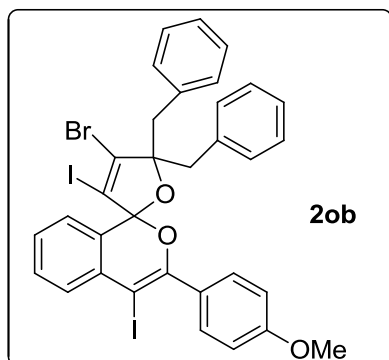


4-bromo-3,4'-diiodo-5,5-dimethyl-3'-(p-tolyl)-5H-spiro[furan-2,1'-isochromene] **2bb** Solid, mp: 176-178 °C ^1H NMR (400 MHz, CDCl_3) δ ppm 7.61 (d, J = 7.6 Hz, 1H), 7.50 (d, J = 8.0 Hz, 2H), 7.43 (t, J = 7.6 Hz, 1H), 7.31 (t, J = 7.6 Hz, 1H), 7.21 (d, J = 8.0 Hz, 2H), 7.06 (d, J = 7.6 Hz, 1H), 2.39 (s, 3H), 1.60 (s, 3H), 1.46 (s, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ ppm 152.1, 142.7, 139.4, 134.3, 132.1, 130.0, 130.0, 129.9, 128.5, 127.9, 127.8, 125.3, 111.9, 94.8, 91.7, 72.9, 27.7, 27.0, 21.5. IR (neat, cm^{-1}): 2980, 1614, 1260, 1164, 1078, 926, 877, 758. HRMS (ESI) m/z Calcd for $\text{C}_{21}\text{H}_{18}\text{BrI}_2\text{O}_2$: $[\text{M}+\text{H}]^+ = 634.8580$. Found: 634.8574.



4-bromo-3,4'-diiodo-3'-(4-methoxyphenyl)-5,5,7'-trimethyl-5H-spiro[furan-2,1'-isochromene] **2jb** Solid, mp: 178-180 °C ^1H NMR (400 MHz, CDCl_3) δ ppm 7.56 (d, J = 8.8 Hz, 2H), 7.48 (d, J = 8.0 Hz, 1H), 7.23 (d, J = 8.8 Hz, 1H), 6.92 (d, J = 8.4 Hz, 2H), 6.83 (s, 1H), 3.83 (s, 3H), 2.39 (s, 3H), 1.61 (s, 3H), 1.47 (s, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ ppm 160.1, 150.9, 142.5, 137.8, 131.6, 130.7, 130.0, 129.7, 129.5, 127.6, 125.5, 113.0, 112.0, 95.0, 91.6, 72.7, 55.3, 27.7, 27.0, 21.3. IR (neat, cm^{-1}):

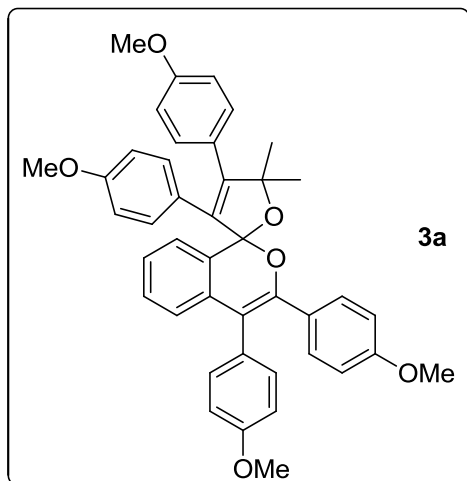
2927, 1612, 1507, 1252, 1175, 928, 833, 738. HRMS (ESI) m/z Calcd for $C_{22}H_{20}BrI_2O_3$: $[M+H]^+ = 664.8685$. Found: 664.8680.



5,5-dibenzyl-4-bromo-3,4'-diiodo-3'-(4-methoxyphenyl)-5H-spiro[furan-2,1'-isochromene] **2ob** Solid, mp: 212-214 °C 1H NMR (400 MHz, $CDCl_3$) δ ppm 7.64 (dd, $J = 8.8, 2.0$ Hz, 2H), 7.53 (d, $J = 8.0$ Hz, 1H), 7.28-7.24 (m, 4H), 7.22-7.18 (m, 4H), 7.07 (t, $J = 7.2$ Hz, 2H), 6.93 (d, $J = 8.0$ Hz, 2H), 6.89 (d, $J = 8.0$ Hz, 2H), 6.79 (t, $J = 7.6$ Hz, 1H), 3.79 (s, 3H), 3.30 (d, $J = 14$ Hz, 1H), 3.20 (d, $J = 14$ Hz, 1H), 2.98 (d, $J = 14.4$ Hz, 1H), 2.68 (d, $J = 14.4$ Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ ppm 160.2, 151.5, 140.6, 135.5, 135.3, 131.8, 131.4, 131.0, 130.8, 129.5, 129.2, 128.3, 128.1, 127.4, 126.9, 126.6, 126.4, 125.8, 113.2, 113.1, 112.4, 97.7, 96.3, 73.0, 55.2, 46.1, 40.4. IR (neat, cm^{-1}): 2922, 1610, 1508, 1252, 1175, 907, 759, 701. HRMS (ESI) m/z Calcd for $C_{33}H_{26}BrI_2O_3$: $[M+H]^+ = 802.9155$. Found: 802.9149.

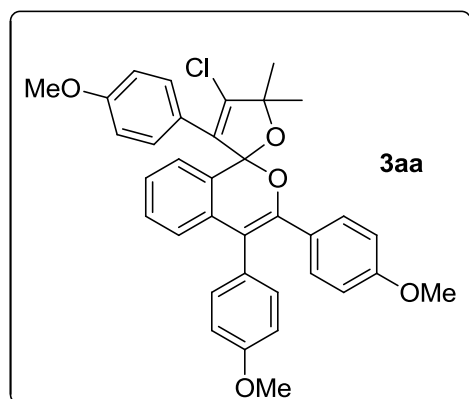
Typical Procedure for 3a and 3aa Synthesis and Characterization

Data of 3a and 3aa



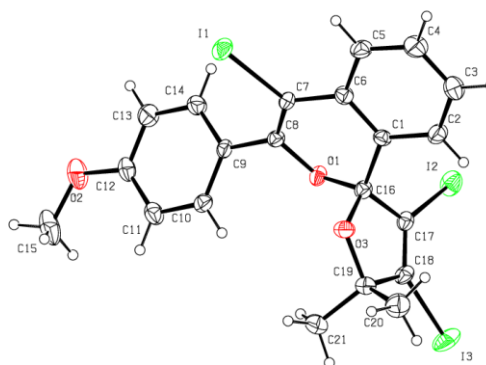
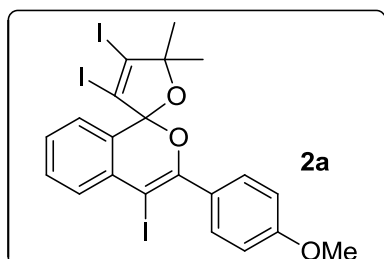
3,3',4,4'-tetrakis(4-methoxyphenyl)-5,5-dimethyl-5H-spiro[furan-2,1'-isochromene] 3a To a solution of 3,4,4'-triiodo-3'-(4-methoxyphenyl)-5,5-dimethyl-5H-spiro[furan-2,1'-isochromene] **2a** (69.8 mg, 0.10 mmol) in dioxane/ H_2O (2:0.5 mL) was added 4-Methoxyphenylboronic acid (91.2 mg, 6.0 equiv), $Pd(PPh_3)_4$ (34.68 mg, 30 mol %), Na_2CO_3 (212mg, 20.0 equiv). The reaction vial was flushed with Ar and the reaction mixture was stirred at 80 °C for 12 h. On completion, the reaction mixture was quenched with H_2O (10 mL) and extracted with ethyl ether (3 x 10 mL). The

combined organic layers were washed with water, brine, dried over Na₂SO₄, and concentrated under reduced pressure. The crude material was purified by flash column chromatography to give **3a** (yield 90%) as a solid. mp: 84-86 °C ¹H NMR (400 MHz, CDCl₃) δ ppm 7.37 (s, 1H), 7.29 (t, *J* = 7.6 Hz, 4H), 7.23-7.16 (m, 3H), 7.13-7.07 (m, 3H), 6.94-6.88 (m, 5H), 6.71-6.68 (m, 2H), 6.56 (d, *J* = 8.4 Hz, 2H), 3.82 (s, 3H), 3.82 (s, 3H), 3.72 (s, 3H), 3.63 (s, 3H), 1.55 (s, 6H). ¹³C NMR (100 MHz, CDCl₃) δ ppm 159.1, 158.8, 158.4, 158.2, 147.2, 135.2, 133.0, 132.9, 130.5, 130.5, 130.4, 129.2, 128.8, 128.7, 128.2, 127.6, 127.1, 126.2, 126.0, 125.7, 123.3, 115.9, 114.1, 113.9, 113.1, 112.8, 112.5, 111.3, 89.4, 55.1, 55.0, 54.9, 28.5, 27.6. IR (neat, cm⁻¹): 2928, 1606, 1510, 1249, 1178, 1033, 834, 731. HRMS (ESI) *m/z* Calcd for C₄₂H₃₈NaO₆: [M+Na]⁺ = 661.2566. Found: 661.2561.



4-chloro-3,3',4'-tris(4-methoxyphenyl)-5,5-dimethyl-5H-spiro[furan-2,1'-isochromene] 3aa To a solution of 4-chloro-3,4'-diiodo-3'-(4-methoxyphenyl)-5,5-dimethyl-5H-spiro[furan-2,1'-isochromene] **2a** (60.6 mg, 0.10 mmol) in dioxane/H₂O (2:0.5 mL) was added 4-Methoxyphenylboronic acid (60.8 mg, 4.0 equiv), Pd(PPh₃)₄ (23.0 mg, 20 mol %), Na₂CO₃ (106mg, 10.0 equiv). The reaction vial was flushed with Ar and the reaction mixture was stirred at 80 °C for 12 h. On completion, the reaction mixture was quenched with H₂O (10 mL) and extracted with ethyl ether (3 x 10 mL). The combined organic layers were washed with water, brine, dried over Na₂SO₄, and concentrated under reduced pressure. The crude material was purified by flash column chromatography to give **3a1** (yield 75%) as a solid. mp: 62-64 °C ¹H NMR (400 MHz, CDCl₃) δ ppm 7.56 (d, *J* = 8.8 Hz, 2H), 7.37-7.36 (m, 1H), 7.24 (t, *J* = 4.8 Hz, 2H), 7.17 (d, *J* = 8.8 Hz, 2H), 7.06 (d, *J* = 8.0 Hz, 2H), 6.92-6.88 (m, 3H), 6.79 (d, *J* = 8.8 Hz, 2H), 6.67 (d, *J* = 8.0 Hz, 2H), 3.82 (s, 3H), 3.73 (s, 3H), 3.72 (s, 3H), 1.65 (s, 3H), 1.52 (s, 3H). ¹³C NMR (100 MHz, CDCl₃) δ ppm 159.1, 158.9, 158.5, 146.7, 137.2, 135.2, 132.9, 132.8, 130.3, 130.0, 128.8, 128.6, 128.2, 128.1, 127.6, 126.4, 125.8, 123.7, 123.5, 114.0, 113.5, 112.8, 112.7, 110.8, 87.5, 55.2, 55.1, 27.4, 26.9. IR (neat, cm⁻¹): 2927, 1607, 1511, 1177, 1033, 934, 834, 739. HRMS (ESI) *m/z* Calcd for C₃₅H₃₁ClNaO₅: [M+Na]⁺ = 589.1758. Found: 589.1752.

Crystallographic data



structure of **2a**

Datablock

Bond precision: C-C = 0.0080 Å Wavelength=0.71073

Cell: a=9.5417(5) b=10.2550(7) c=12.6145(8)

alpha=73.414(6) beta=84.654(5) gamma=68.761(5)

Temperature: 121 K

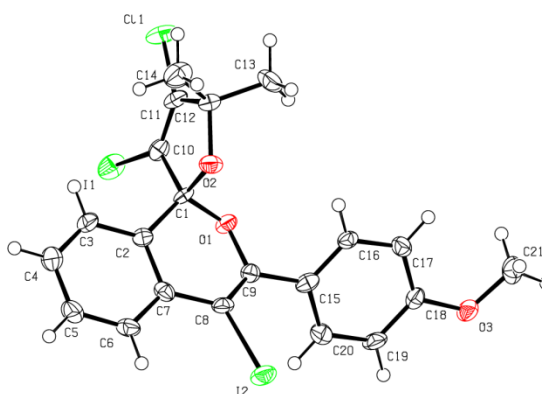
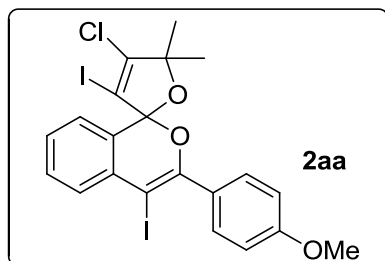
	Calculated	Reported
Volume	1102.55(13)	1102.56(12)
Space group	P -1	P -1
Hall group	-P 1	-P 1
Moiety formula	C21 H17 I3 O3	C21 H17 I3 O3
Sum formula	C21 H17 I3 O3	C21 H17 I3 O3
Mr	698.05	698.05
Dx, g cm ⁻³	2.103	2.103
Z	2	2
Mu (mm ⁻¹)	4.270	4.270
F000	652.0	652.0
F000'	649.41	
h, k, lmax	11, 12, 15	11, 12, 15
Nref	4354	4346
Tmin, Tmax	0.358, 0.408	0.702, 1.000
Tmin'	0.331	

Correction method= MULTI-SCAN

Data completeness= 0.998 Theta(max)= 26.020

R(reflections)= 0.0405(3534) wR2(reflections)= 0.0976(4346)

S = 1.072 Npar= Npar = 248



structure of 2aa

Datablock

Bond precision: C-C = 0.0093 Å Wavelength=0.71070

Cell: a=9.6504(11) b=10.0633(12) c=12.6865(12)
alpha=73.782(10) beta=80.037(9) gamma=62.461(12)

Temperature: 293 K

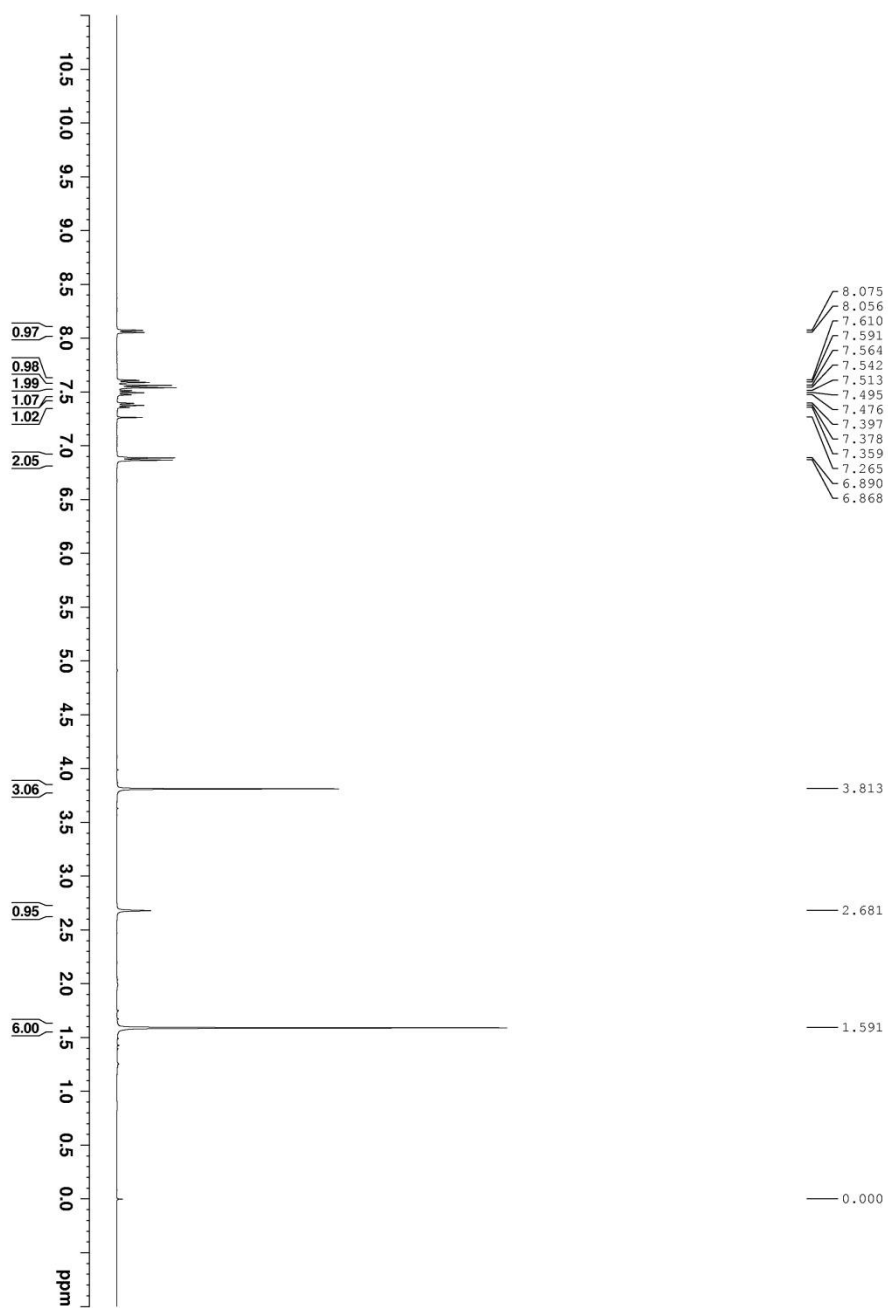
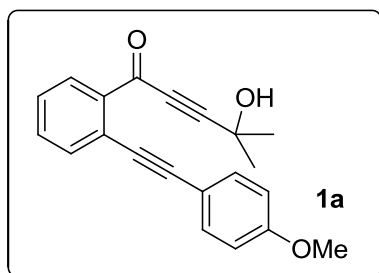
	Calculated	Reported
Volume	1047.6(2)	1047.6(2)
Space group	P -1	P -1
Hall group	-P 1	-P 1
Moiety formula	C21 H17 Cl I2 O3	C21 H17 Cl I2 O3
Sum formula	C21 H17 Cl I2 O3	C21 H17 Cl I2 O3
Mr	606.60	606.60
Dx, g cm ⁻³	1.923	1.923
Z	2	2
Mu (mm ⁻¹)	3.148	3.148
F000	580.0	580.0
F000'	578.62	
h, k, lmax	11, 12, 15	11, 12, 15
Nref	4130	4122
Tmin, Tmax	0.299, 0.365	0.539, 1.000
Tmin'	0.233	

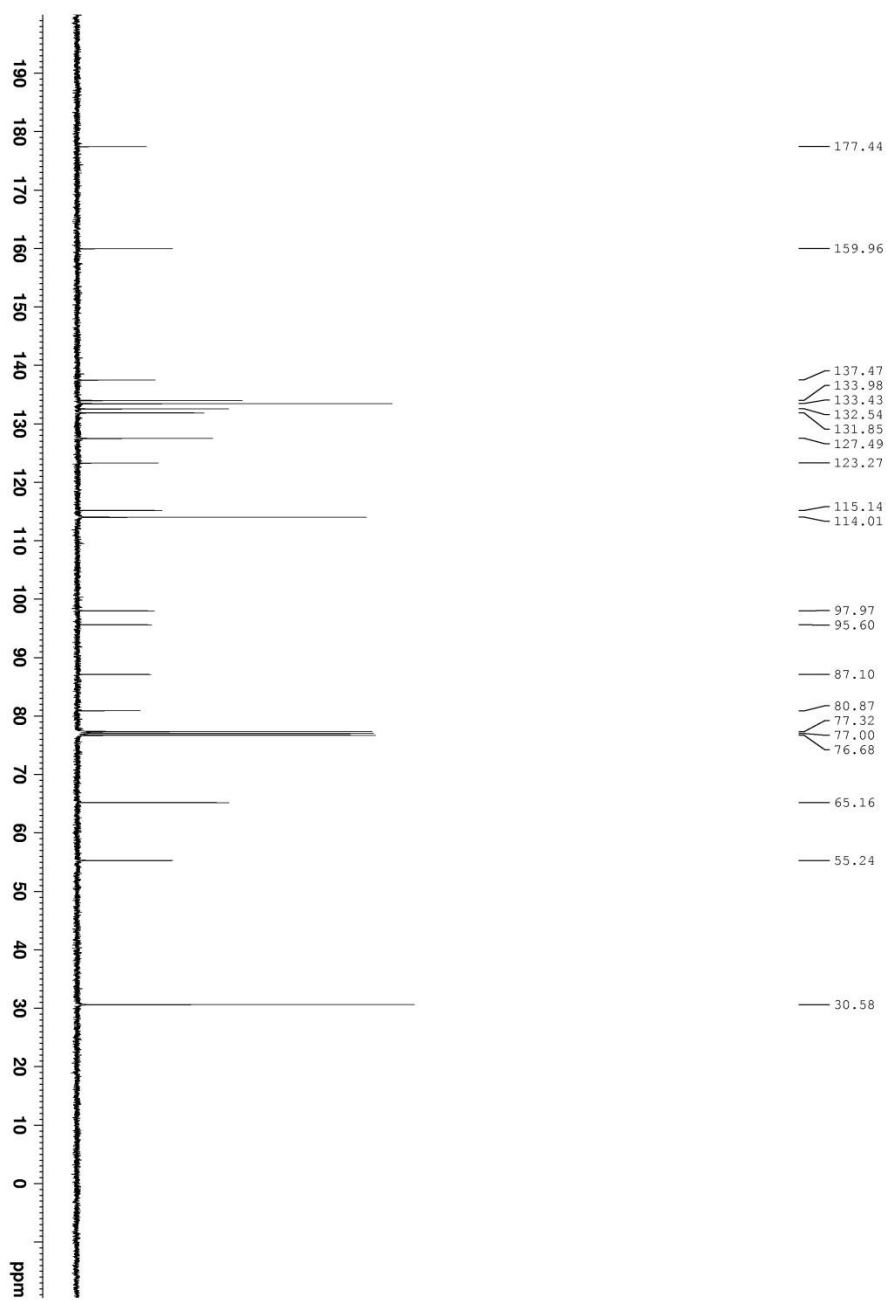
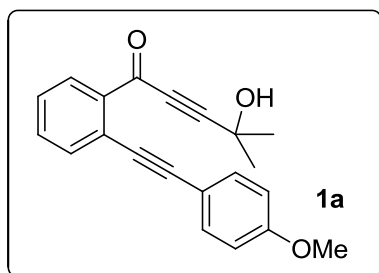
Correction method= MULTI-SCAN

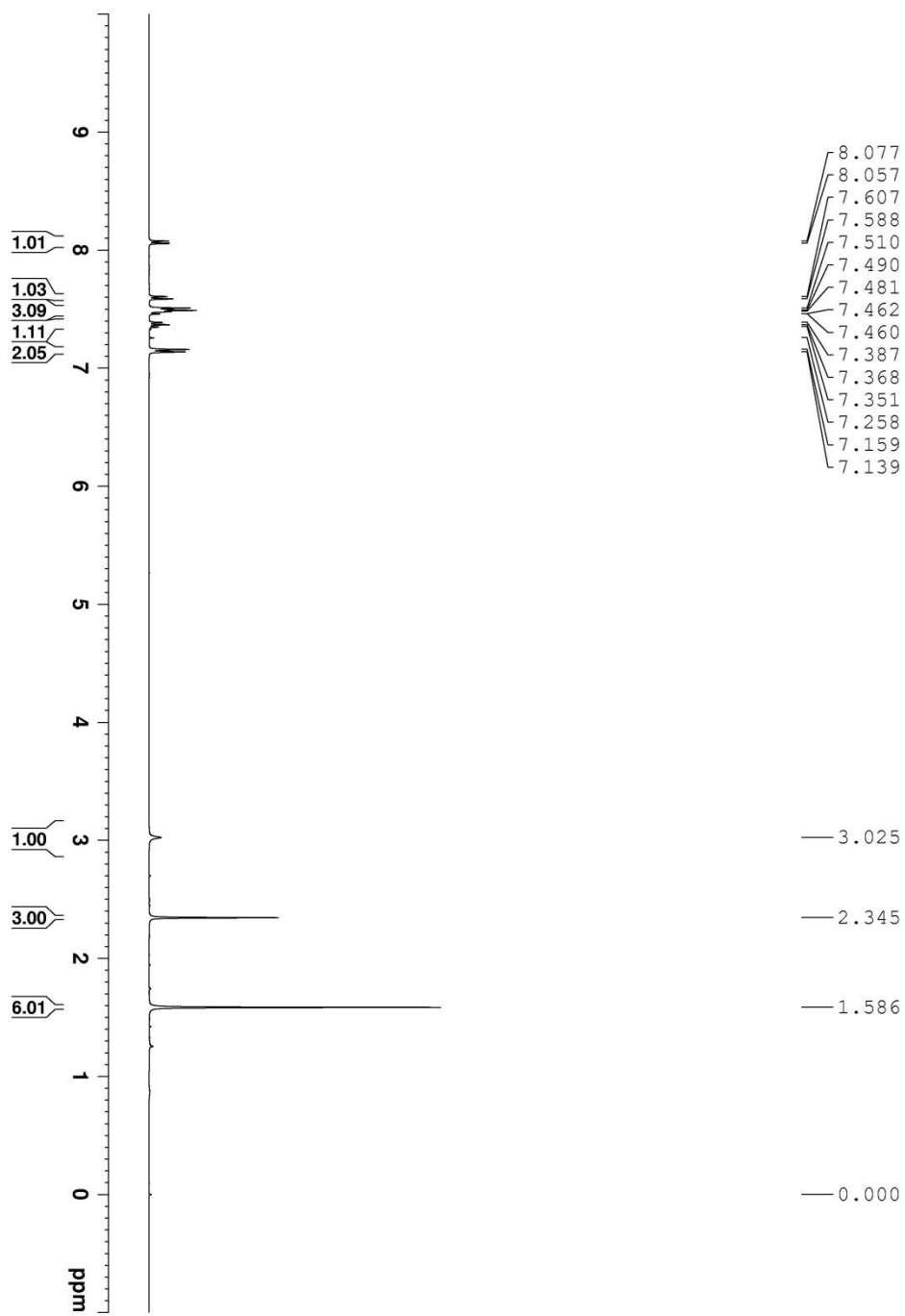
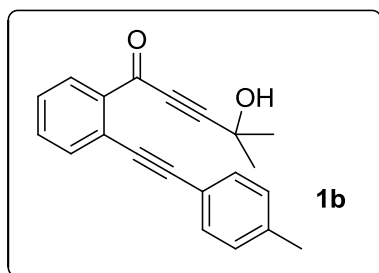
Data completeness= 0.998 Theta(max)= 26.020

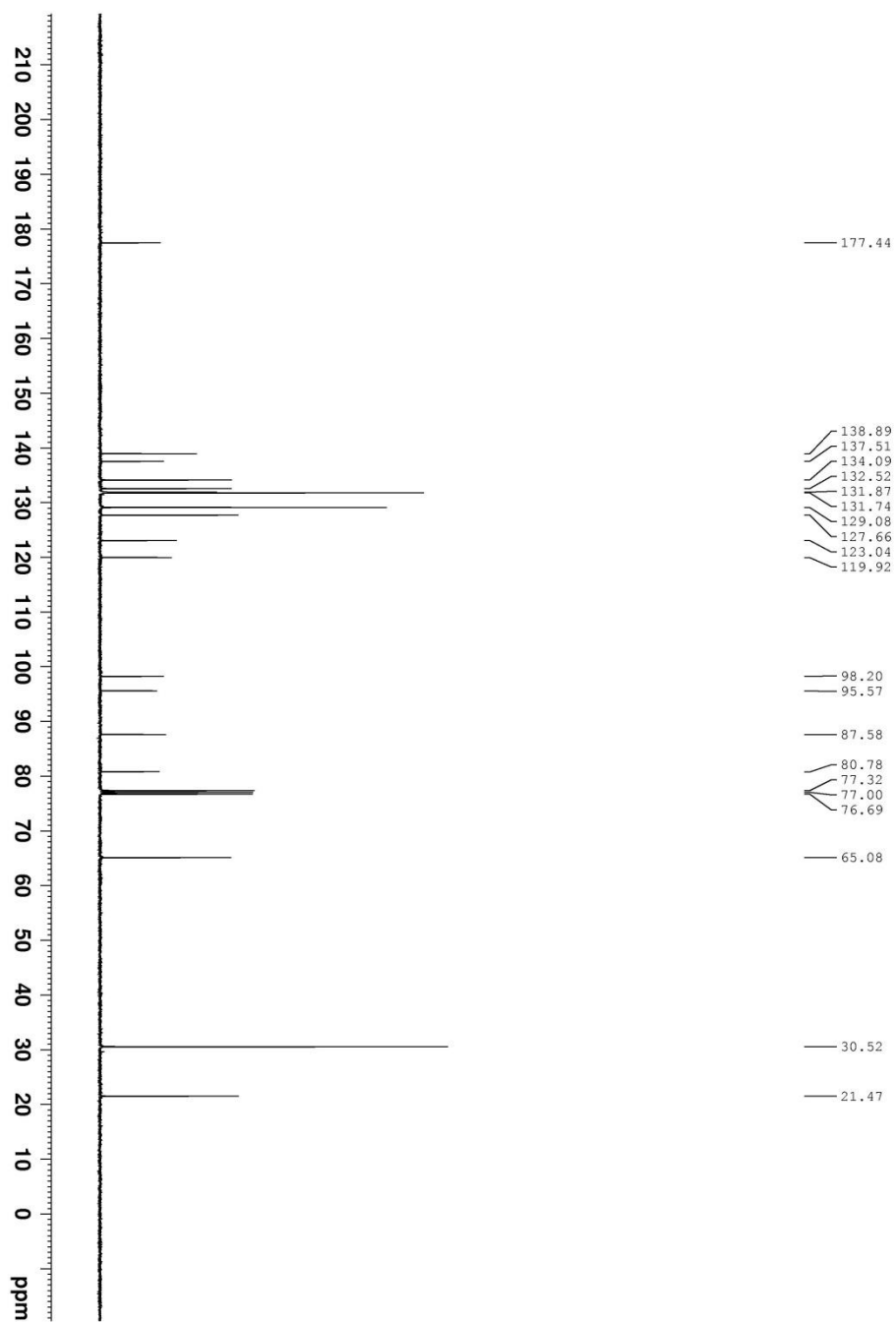
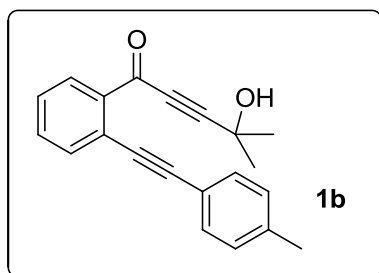
R(reflections)= 0.0447(3023) wR2(reflections)= 0.1048(4122)

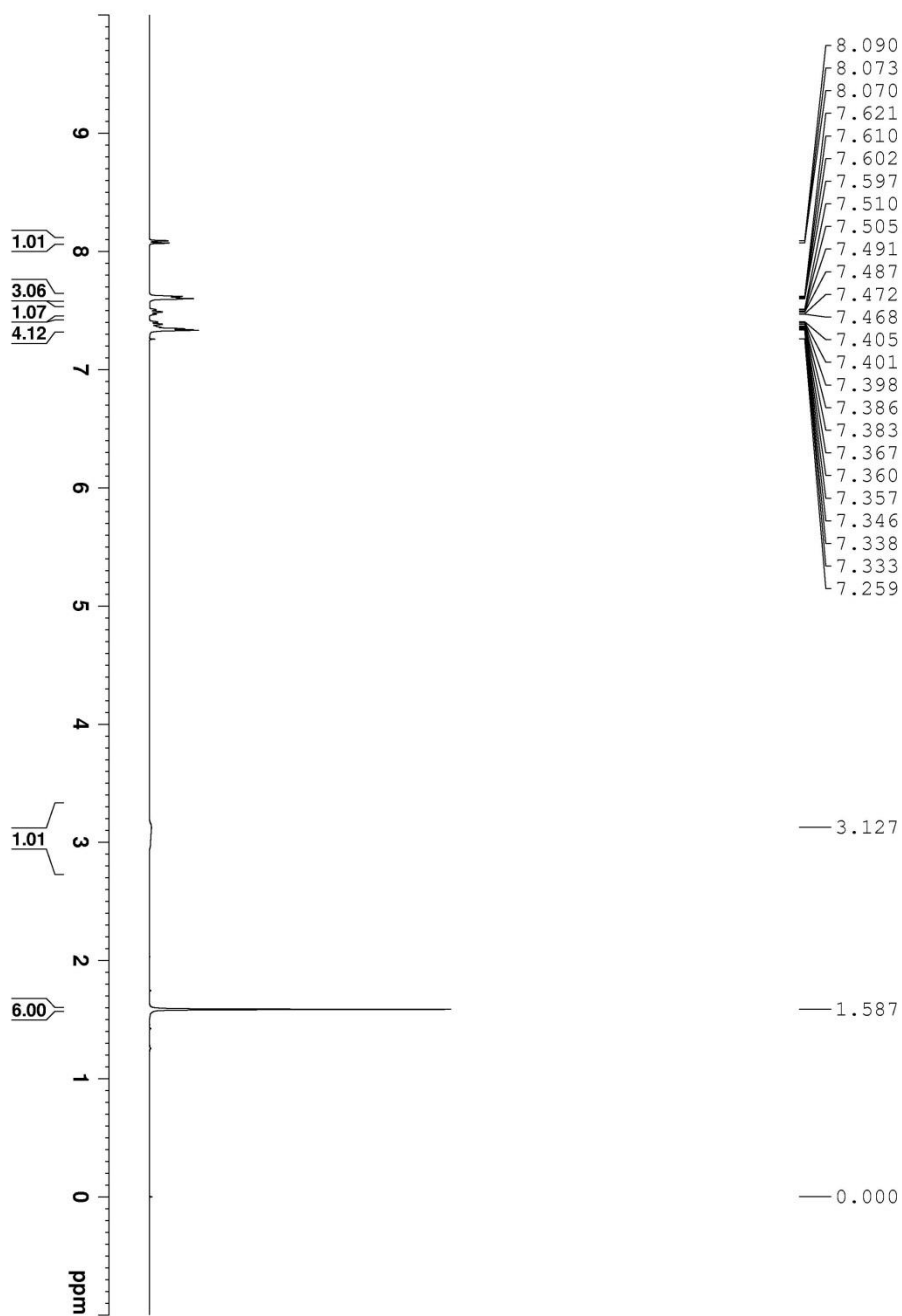
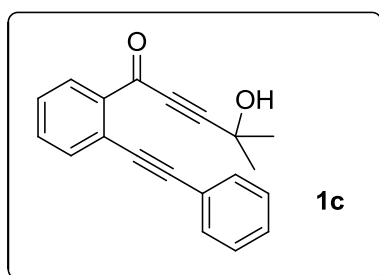
S = 0.942 Npar= Npar = 247

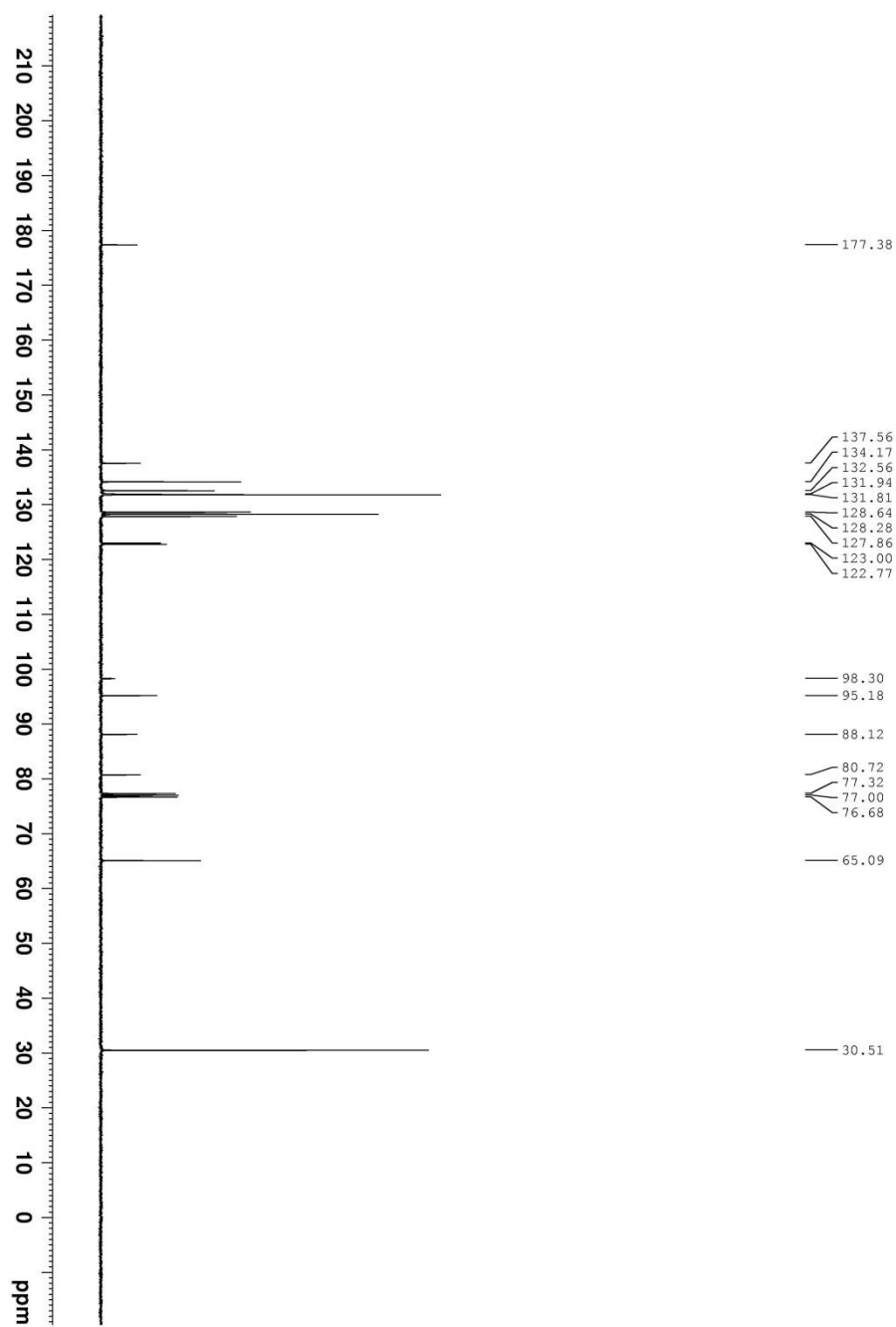
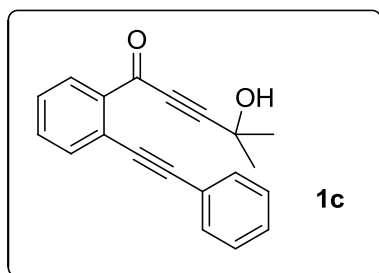


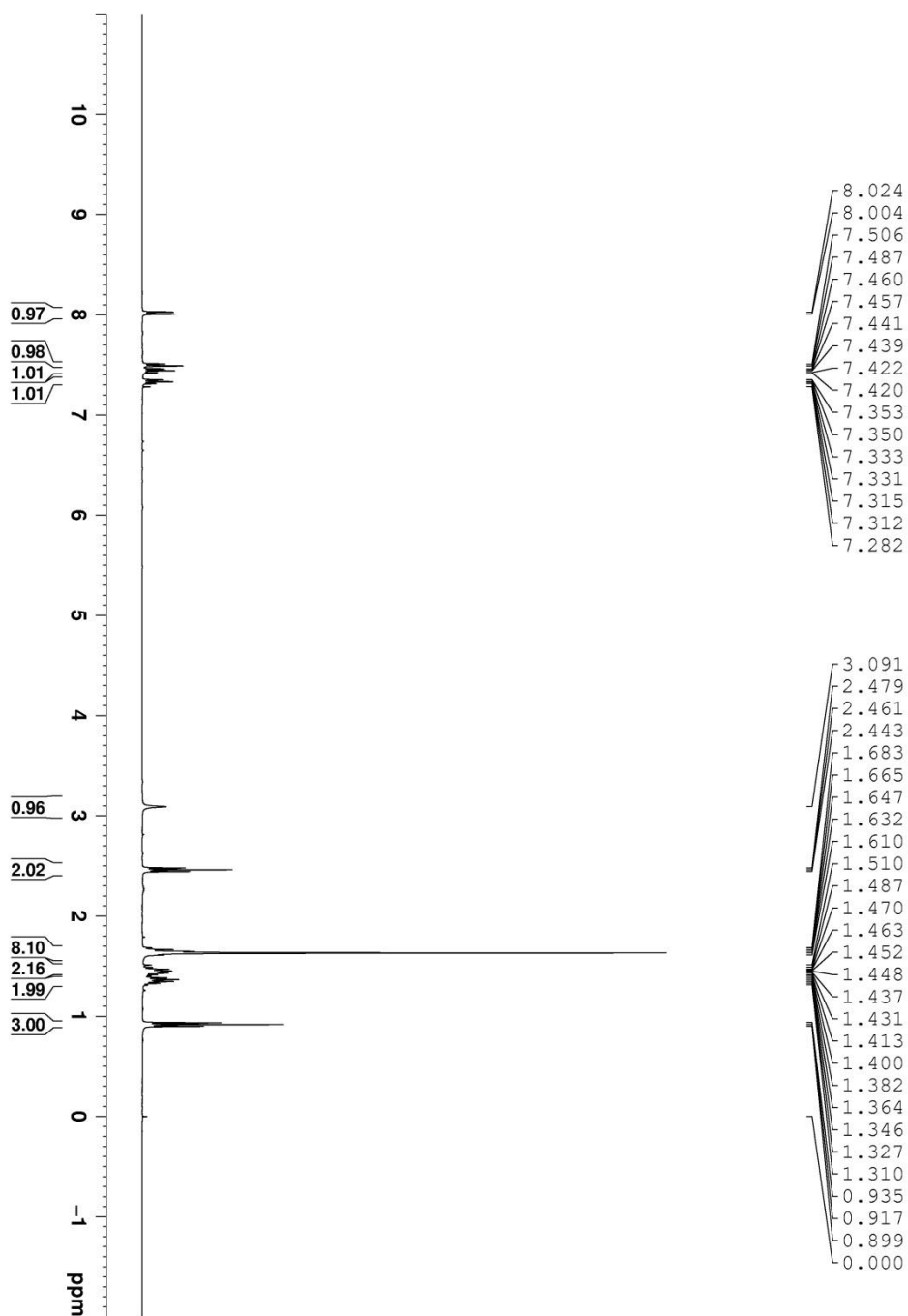
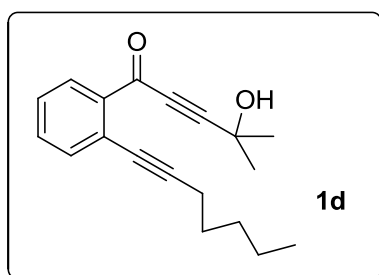


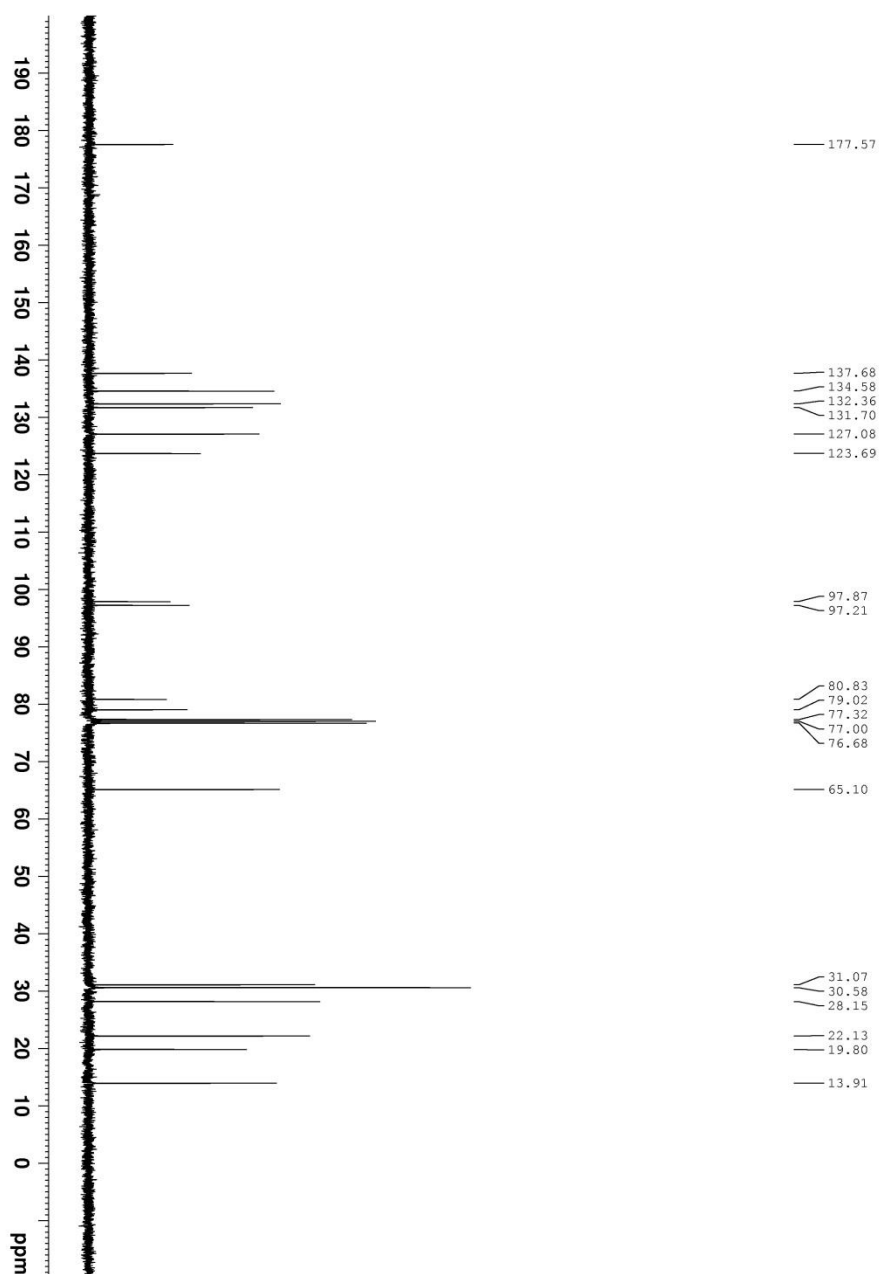
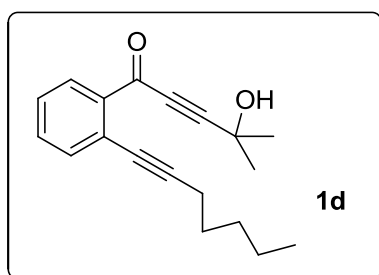


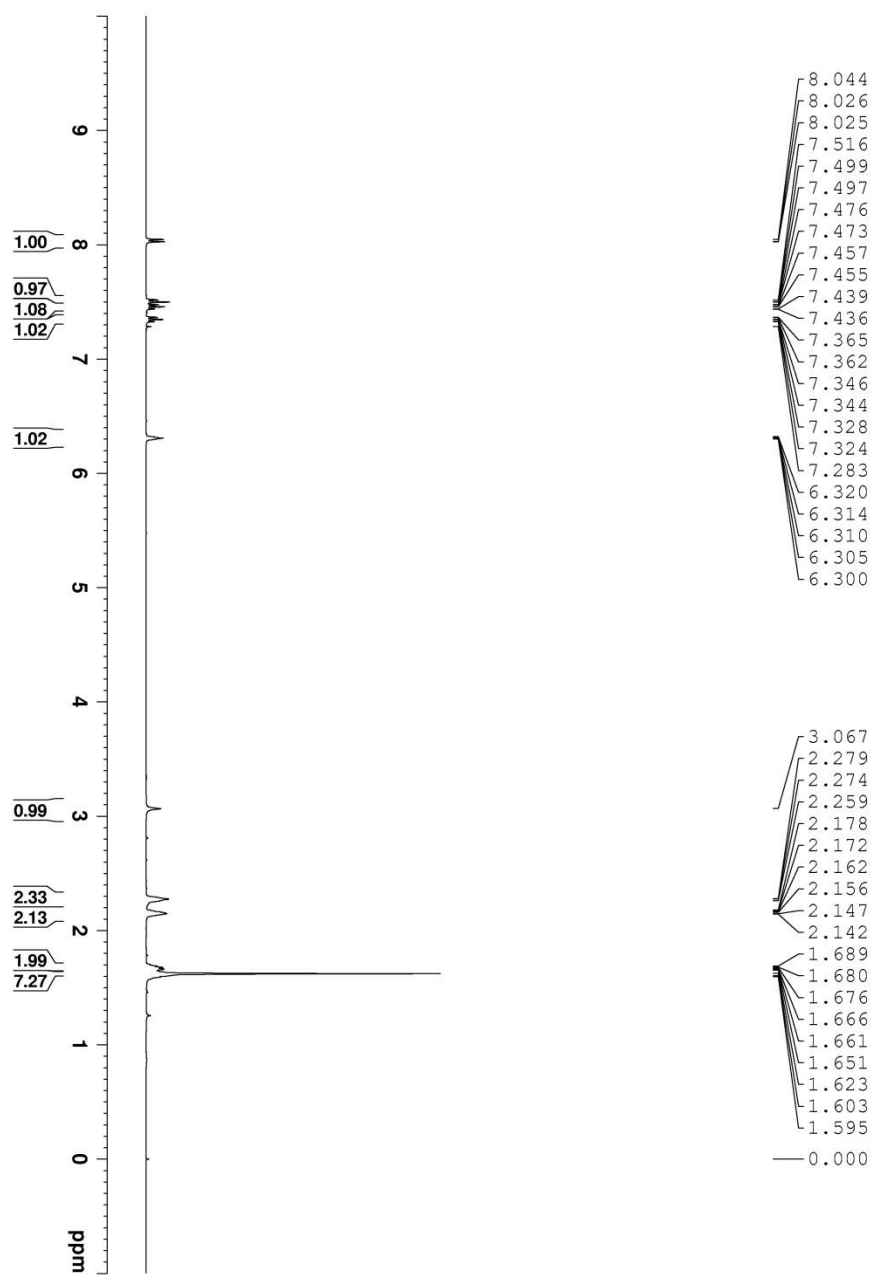
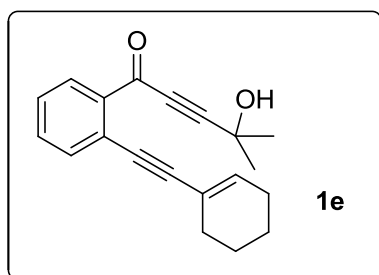


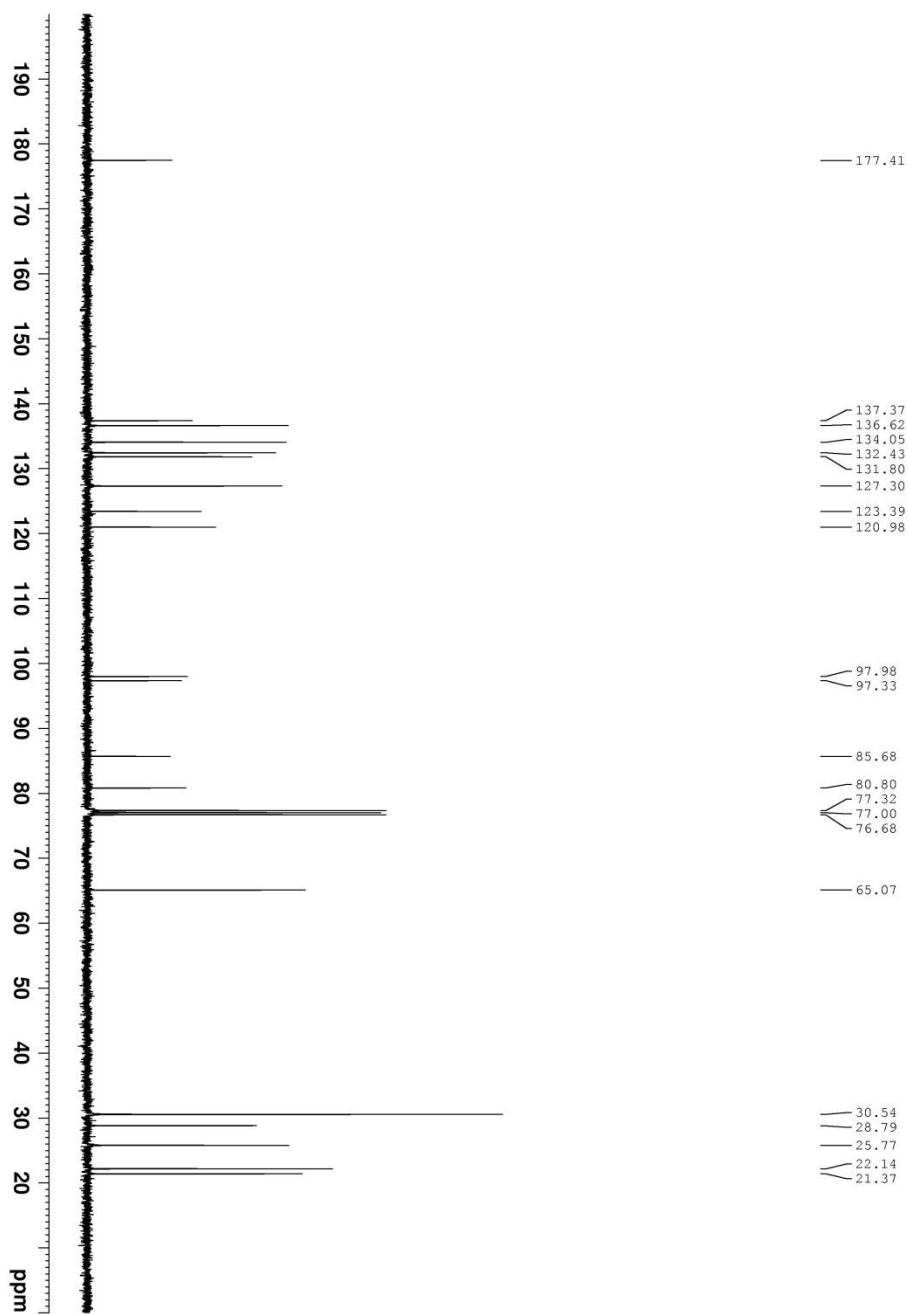
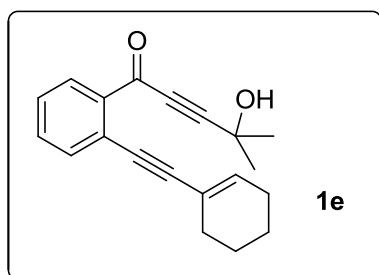


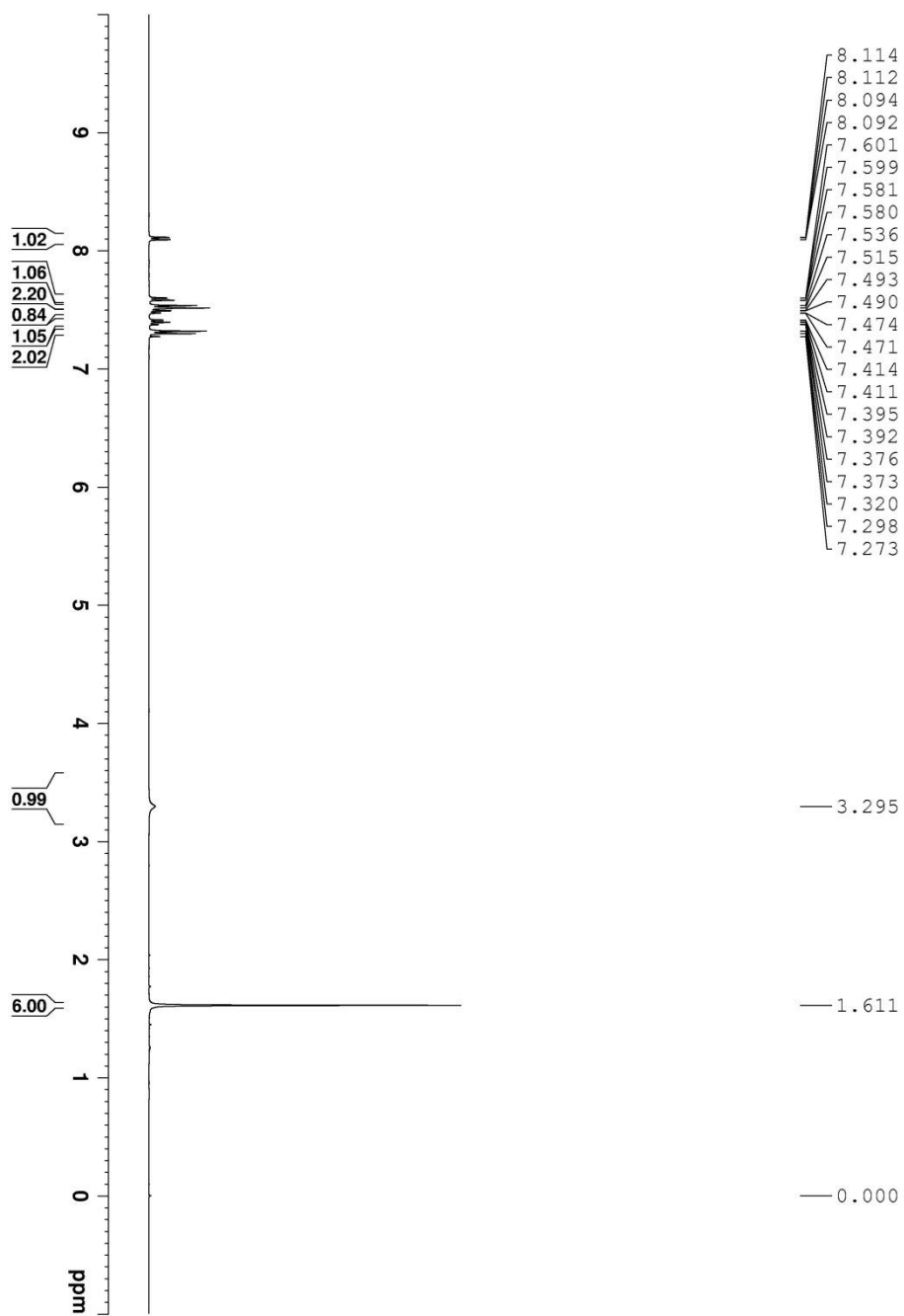
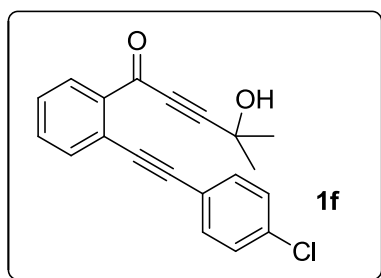


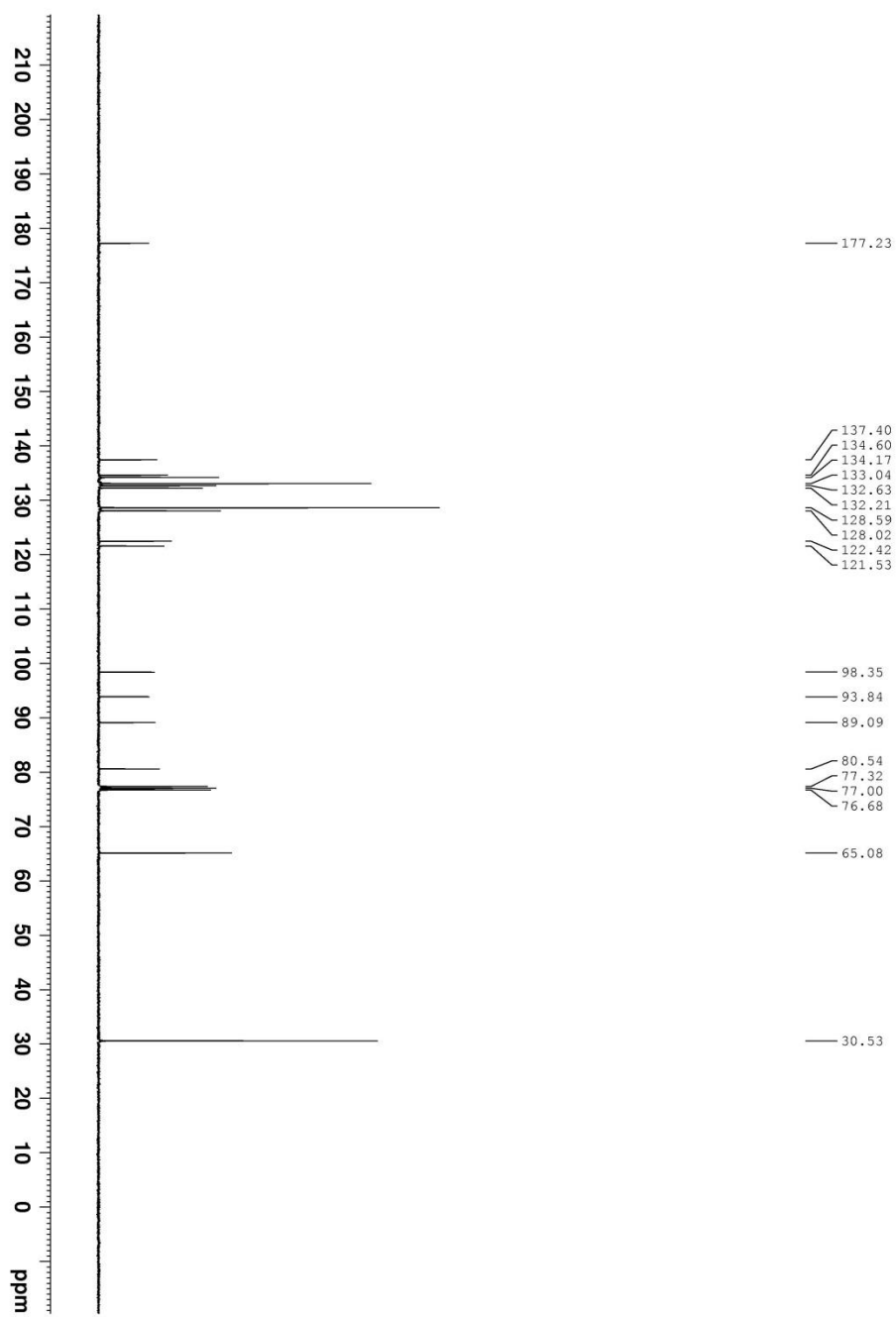
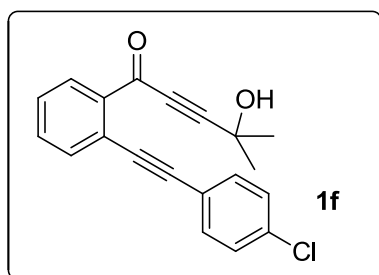


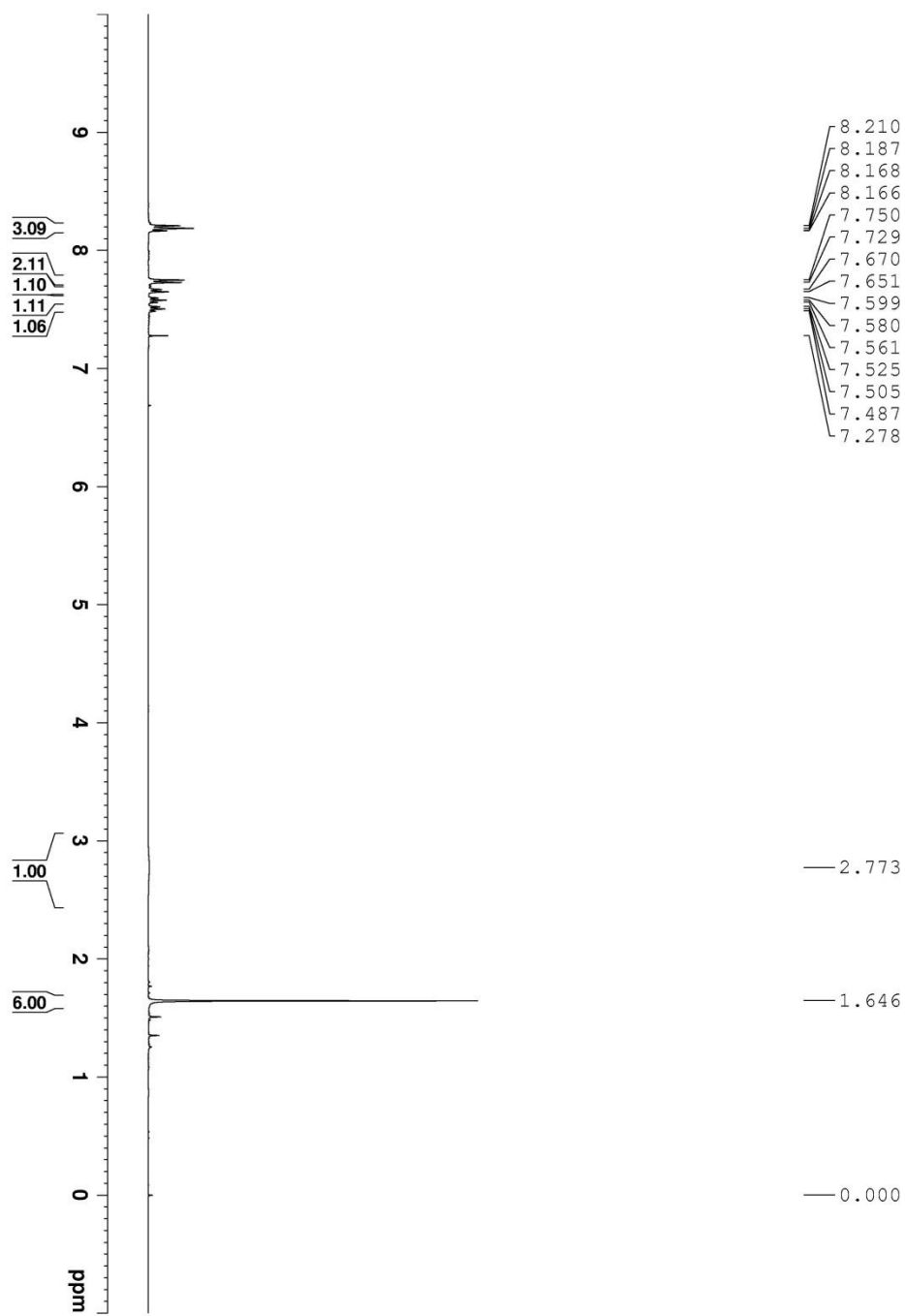
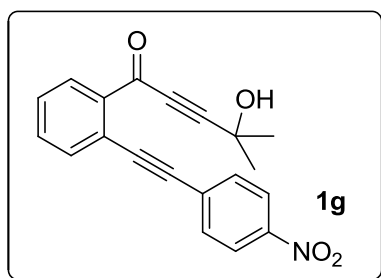


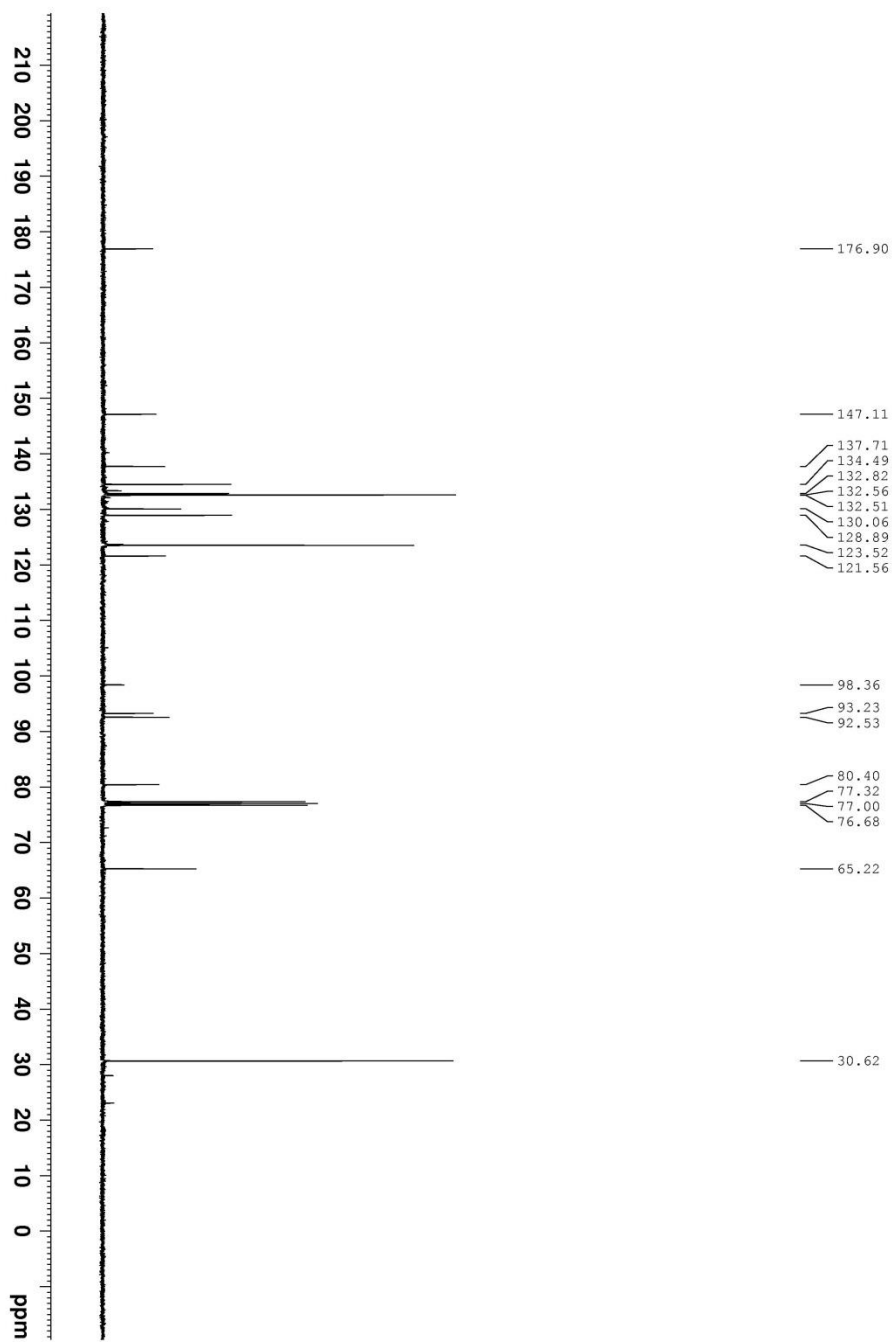
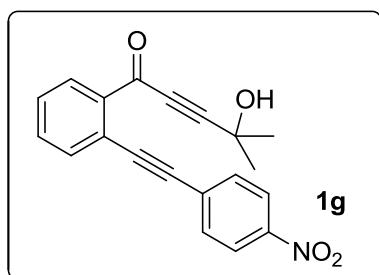


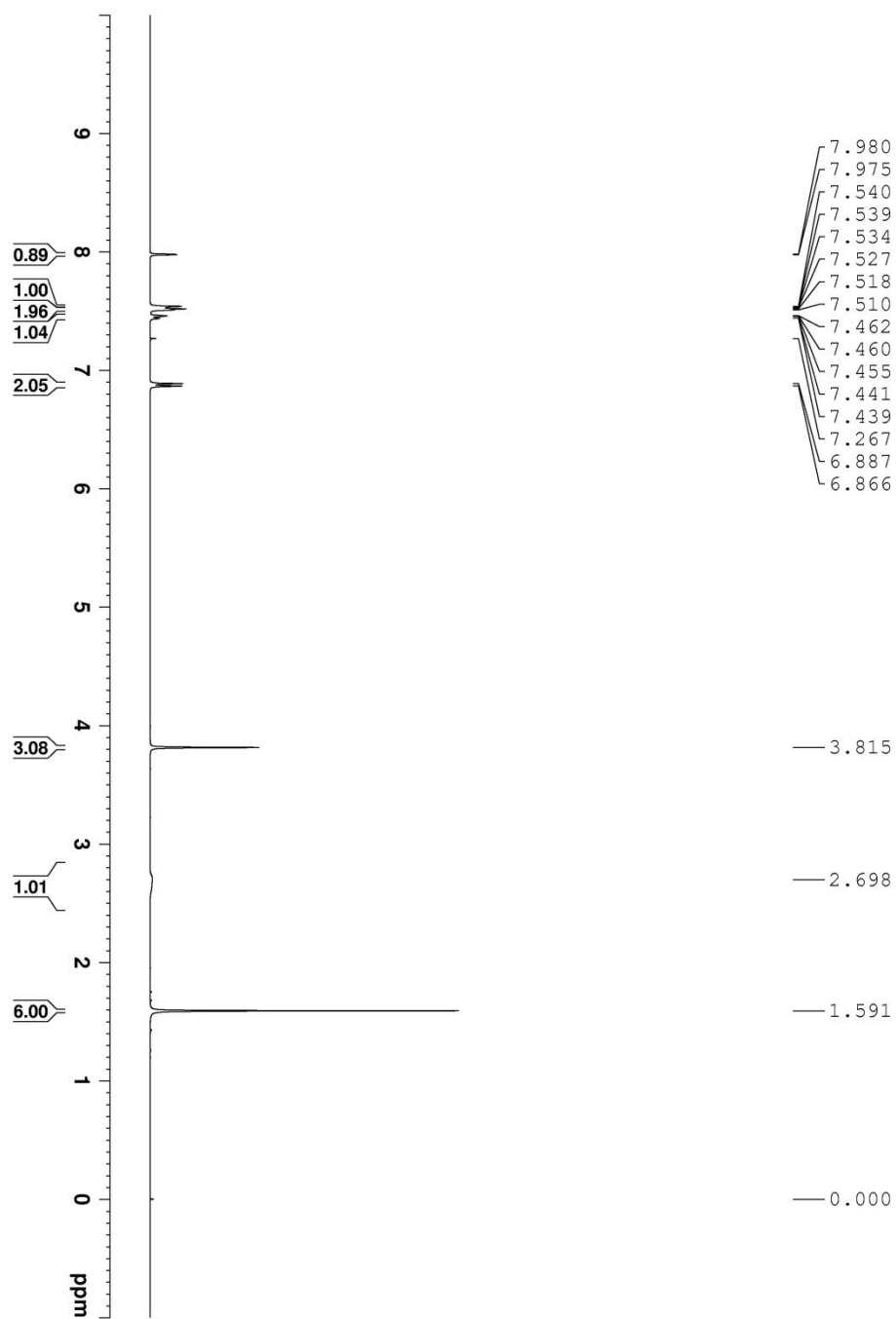
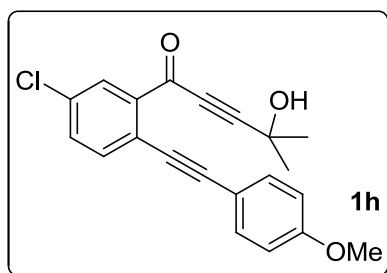


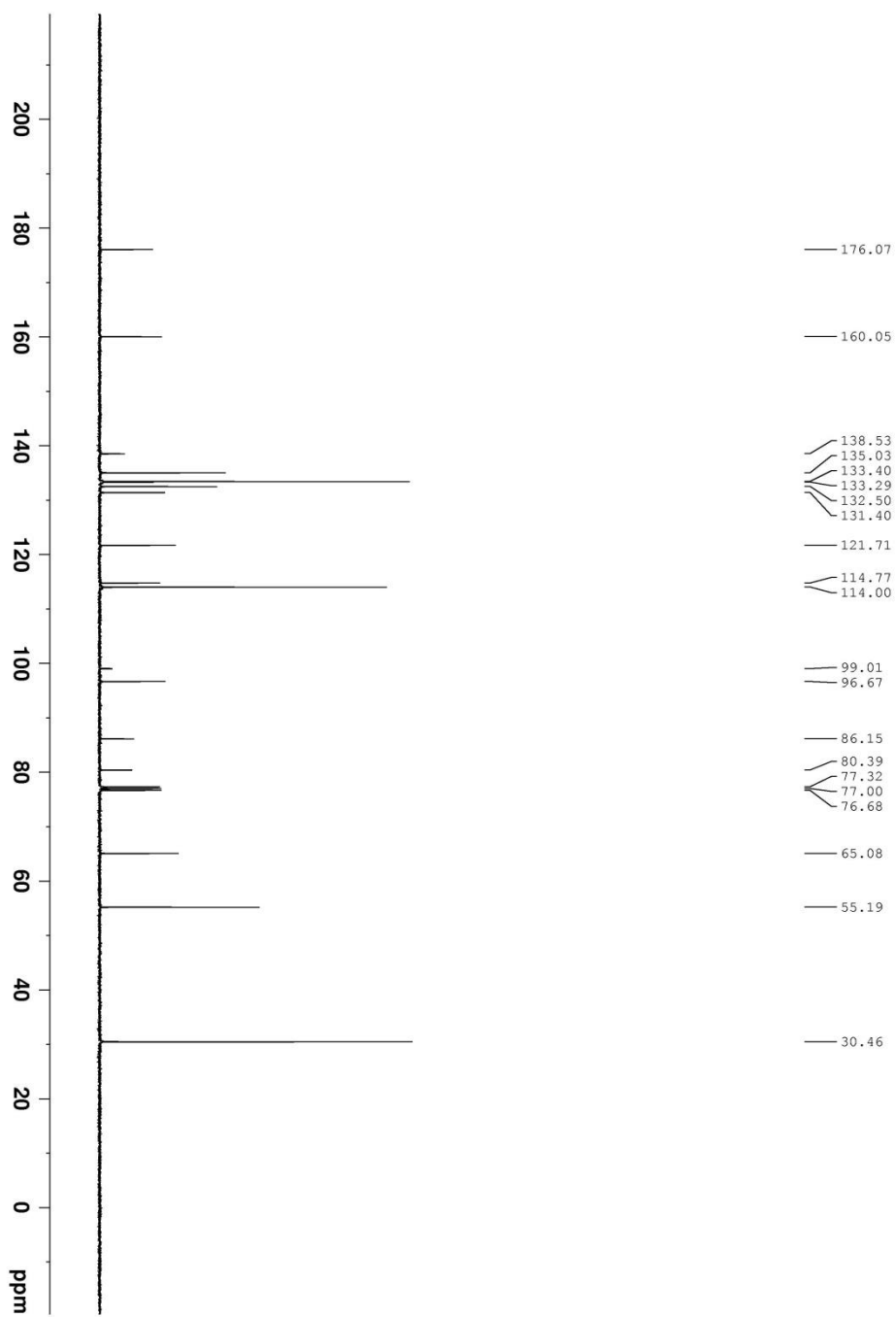
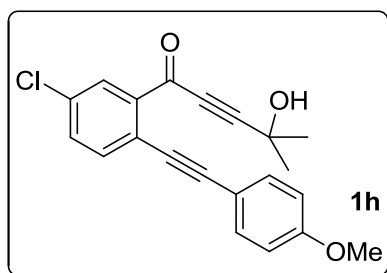


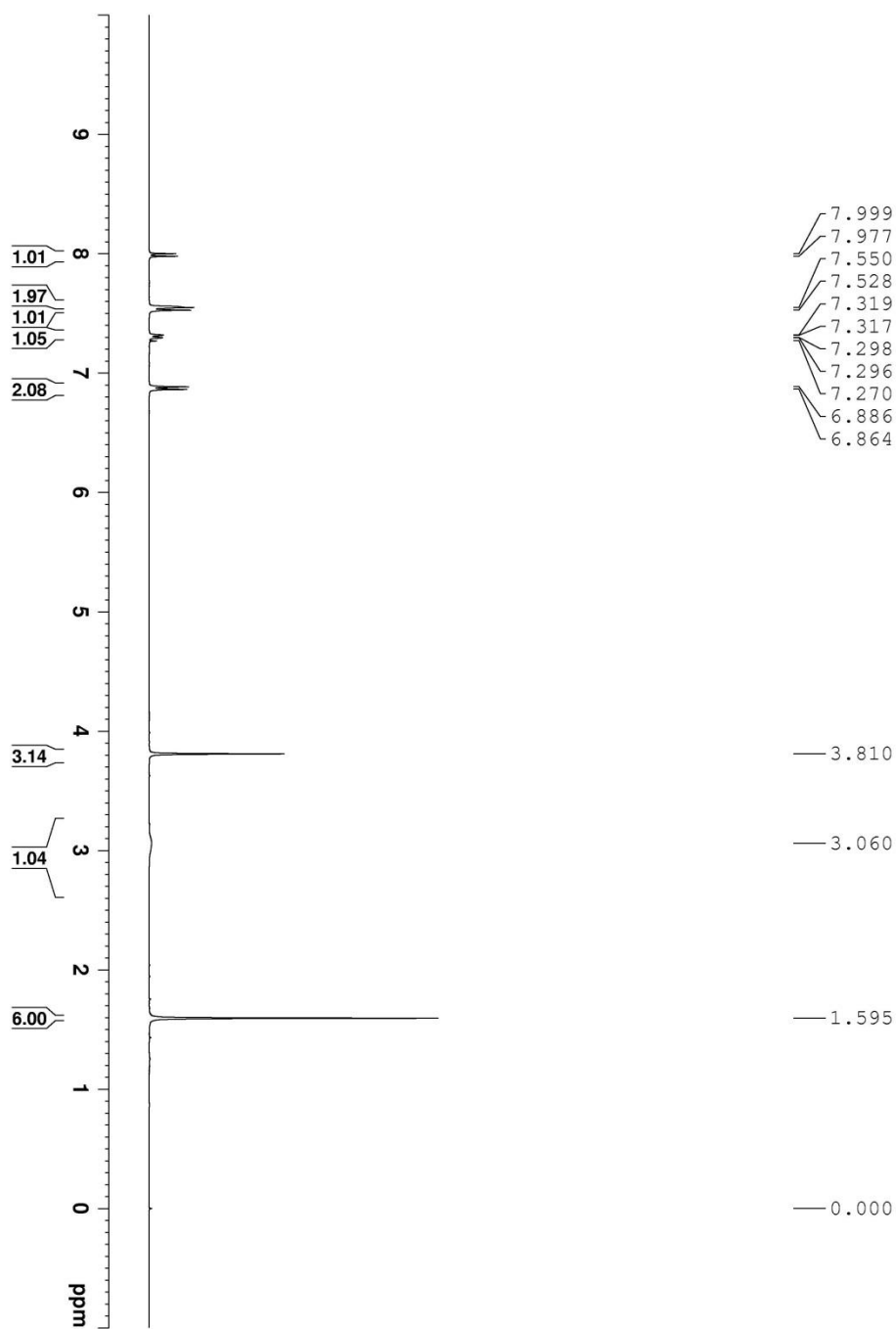
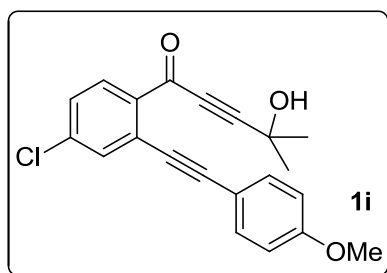


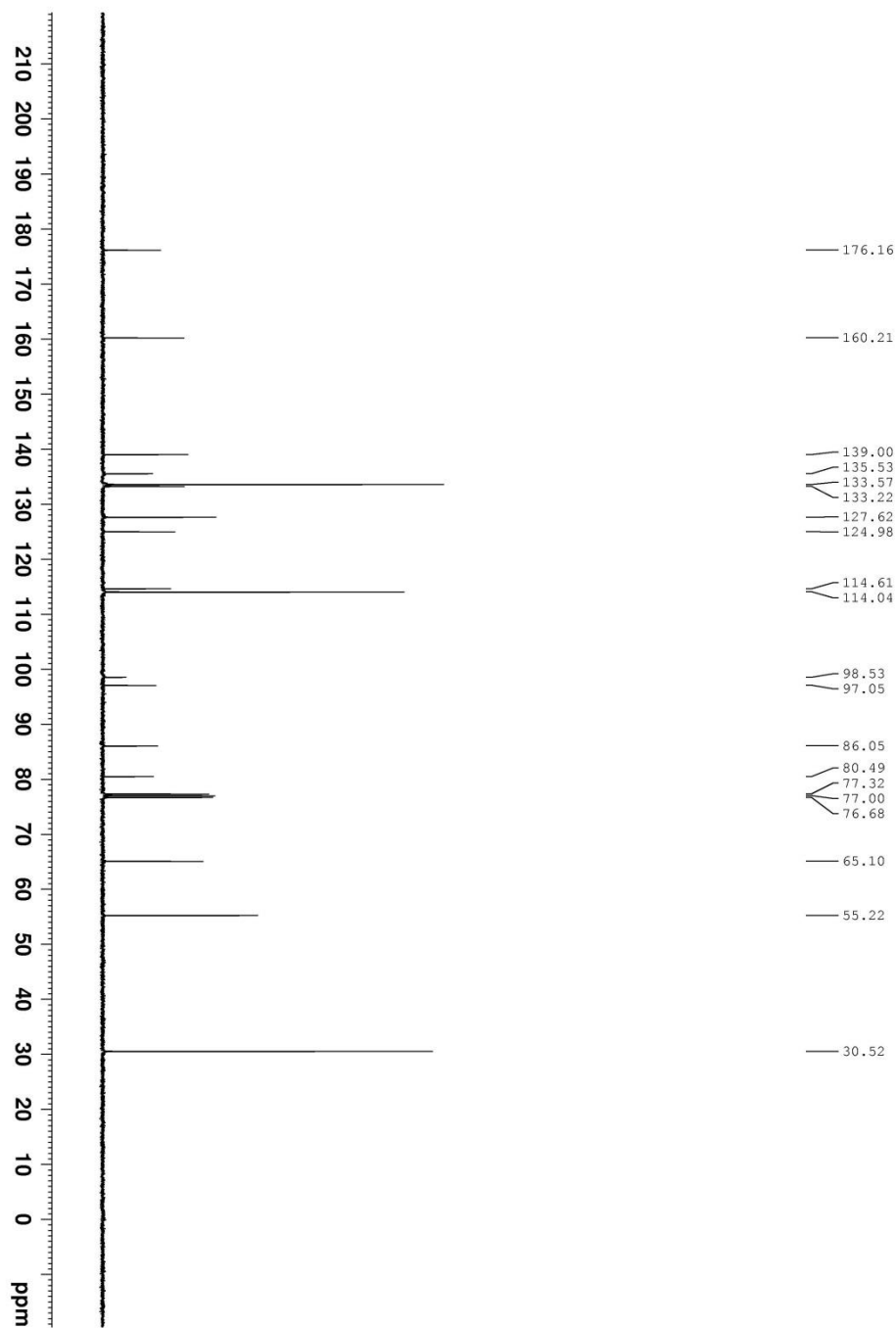
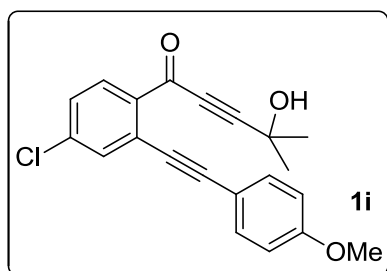


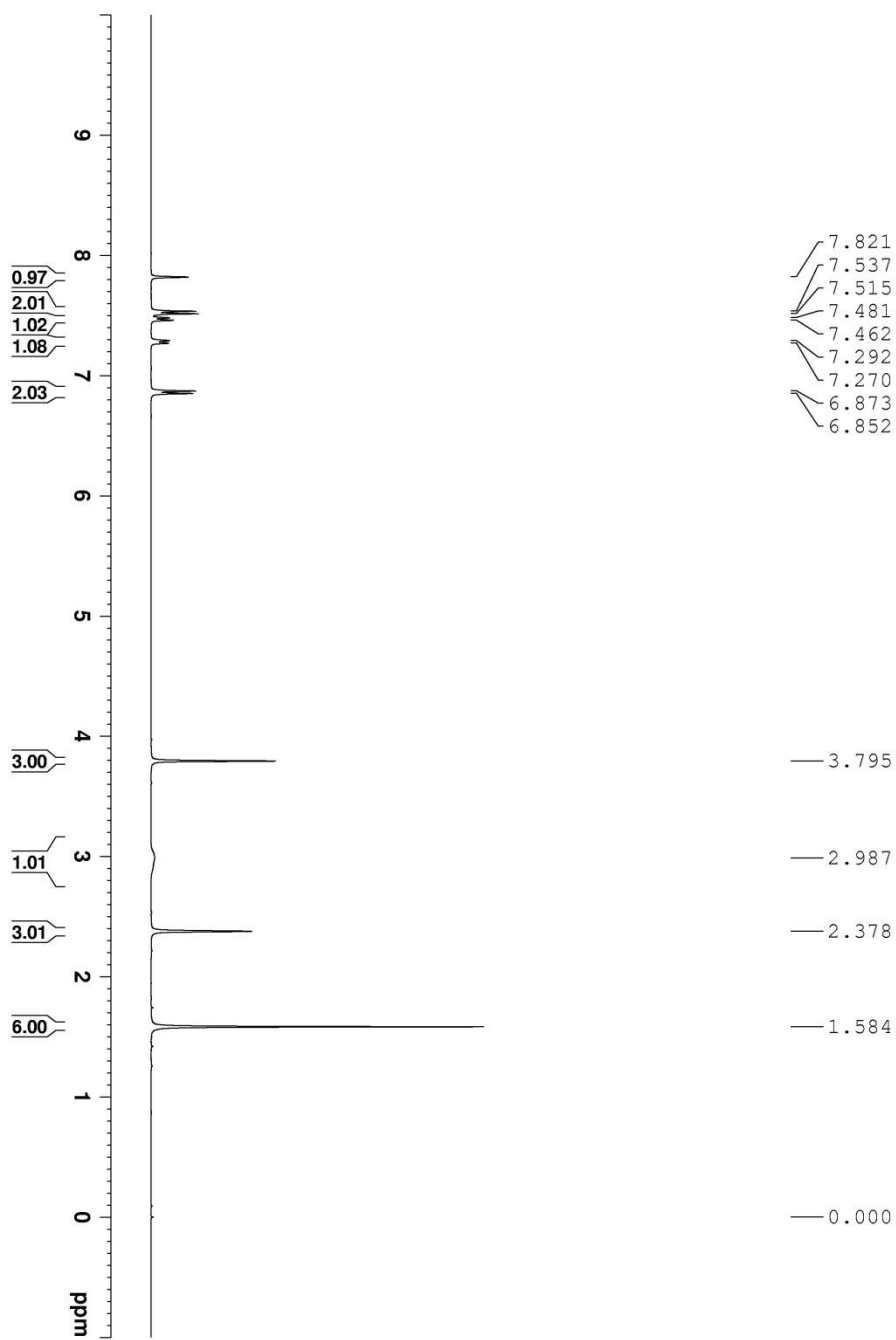
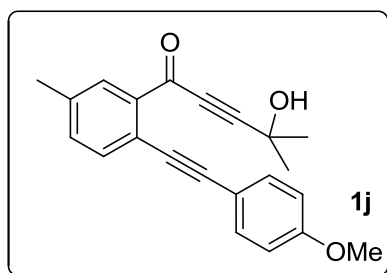


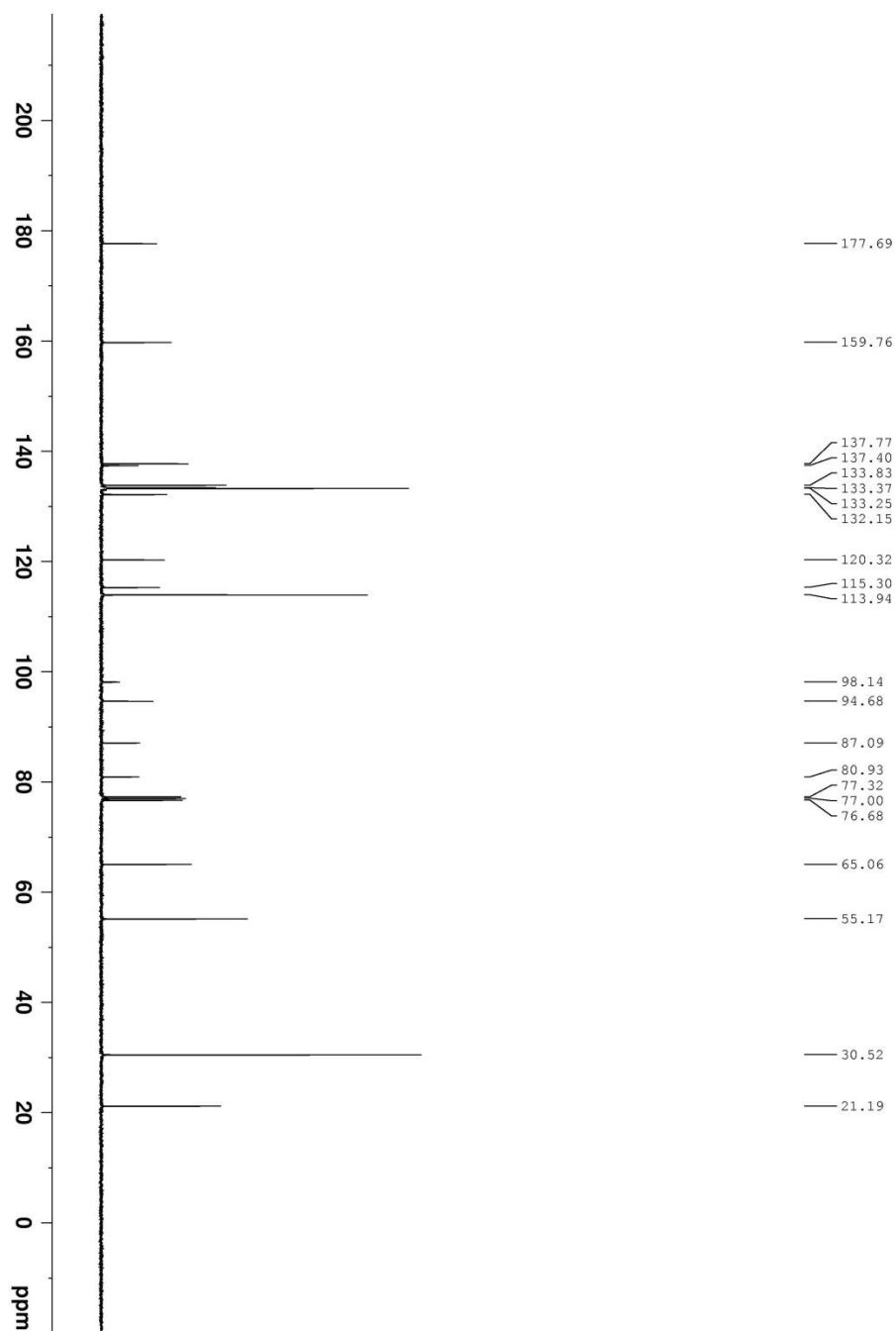
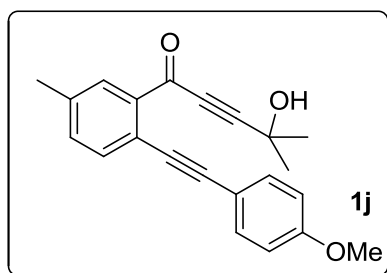


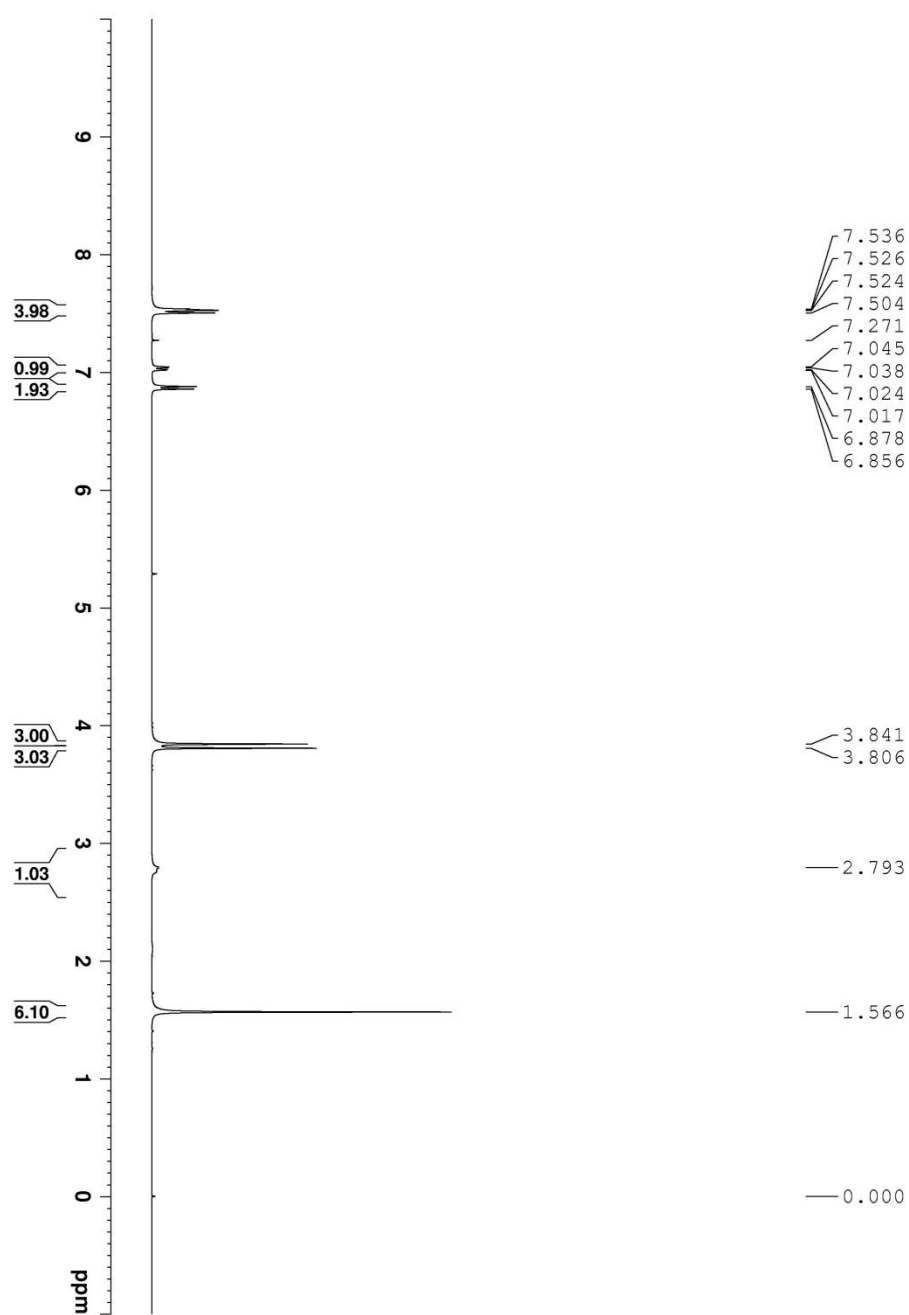
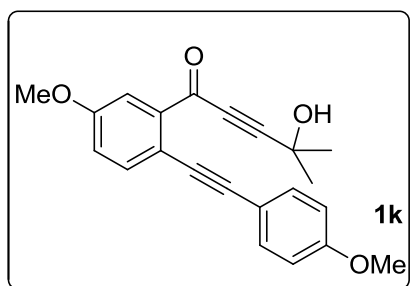


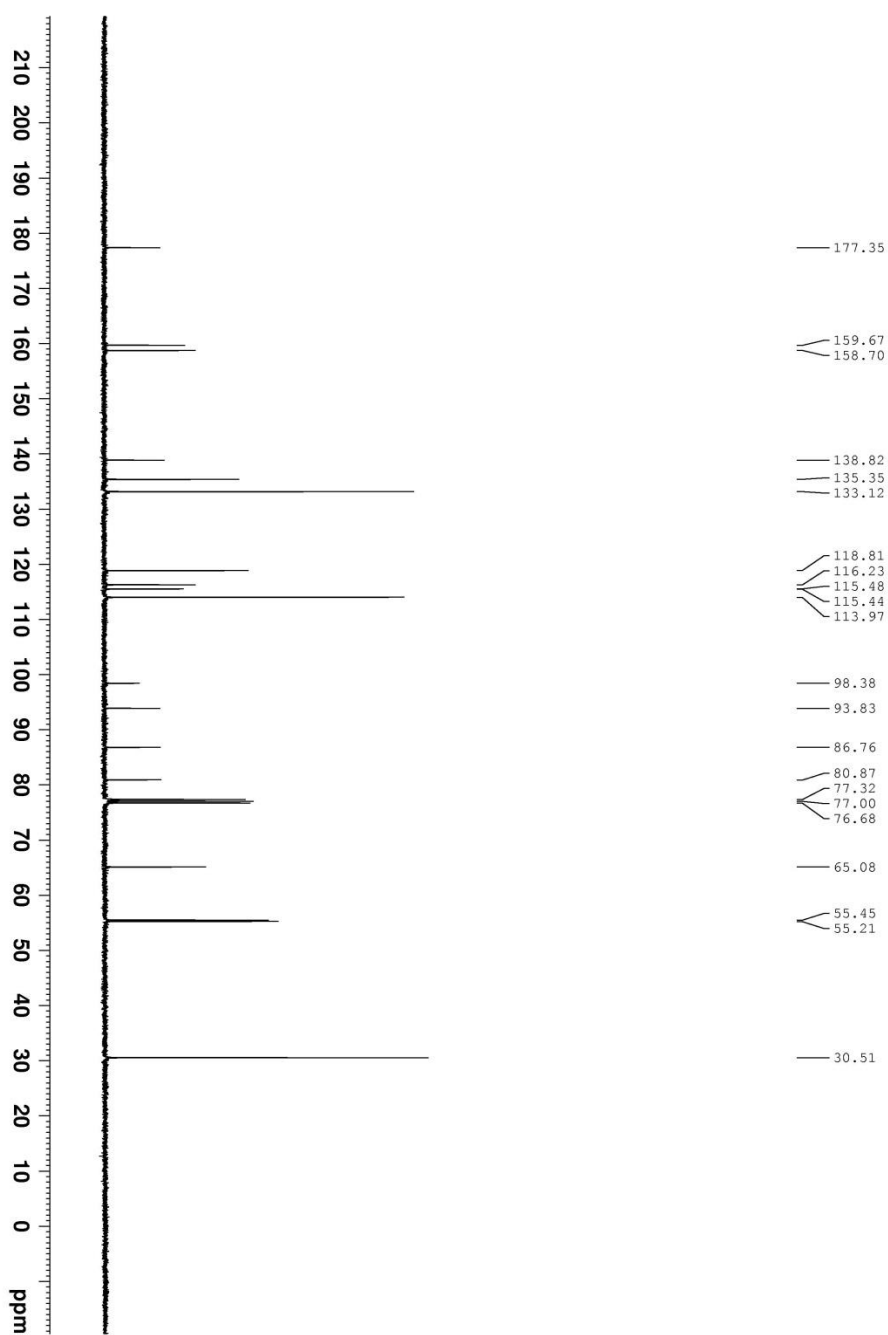
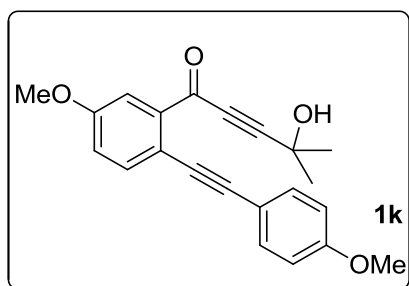


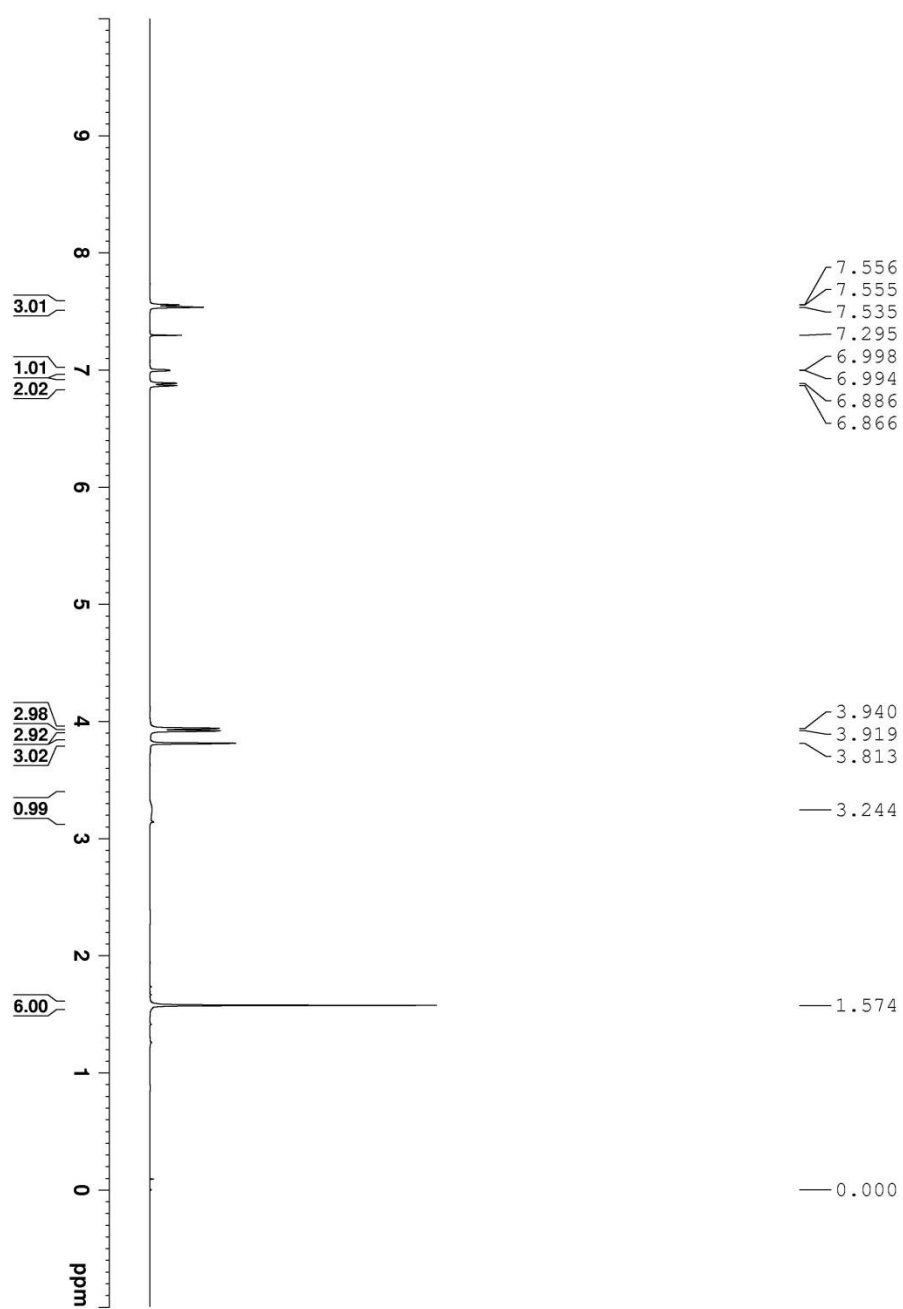
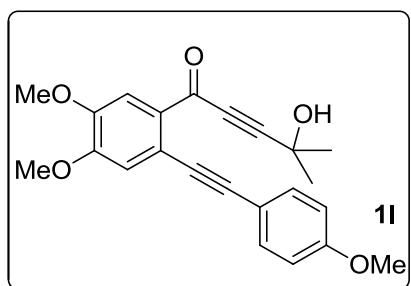


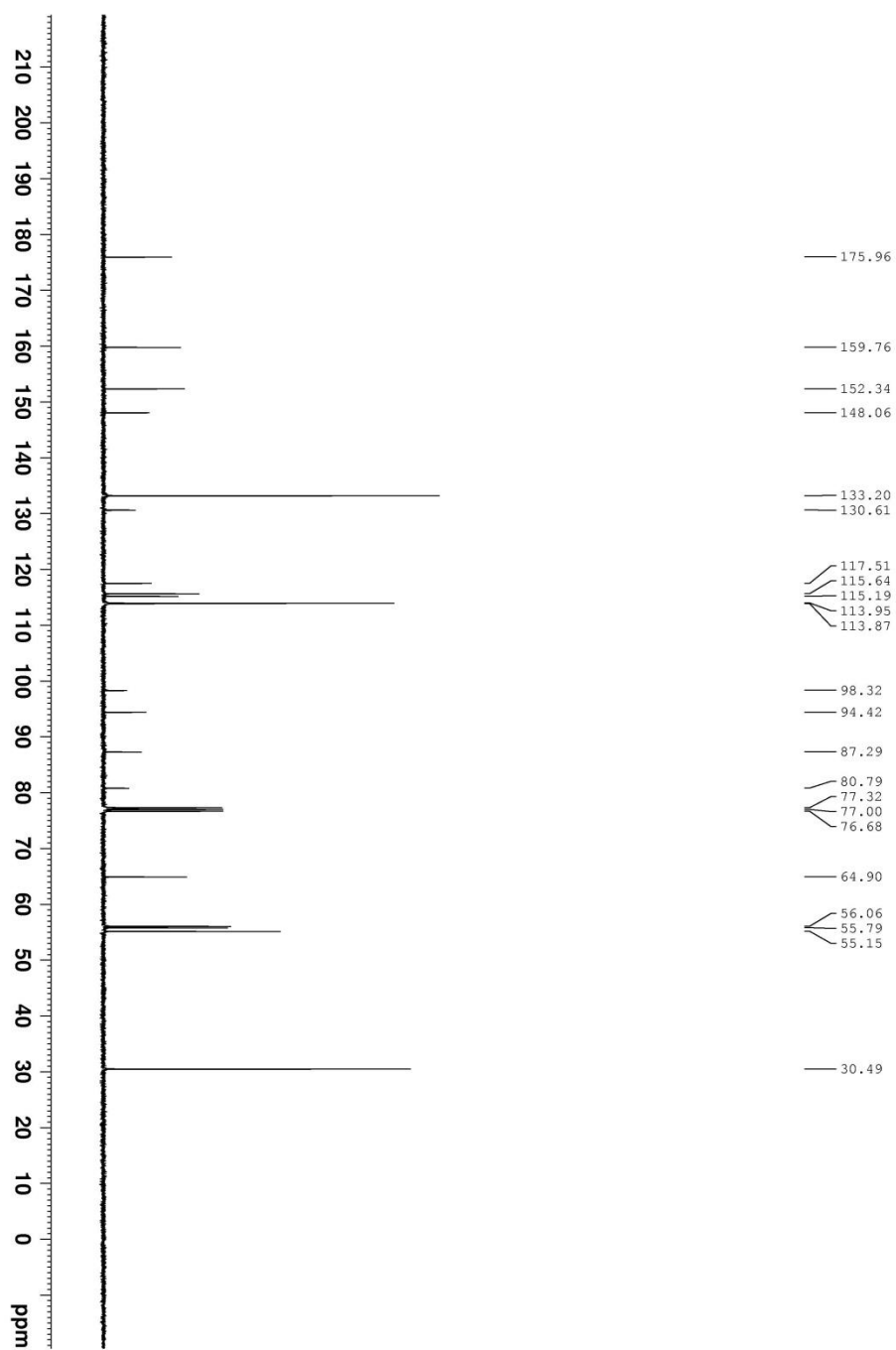
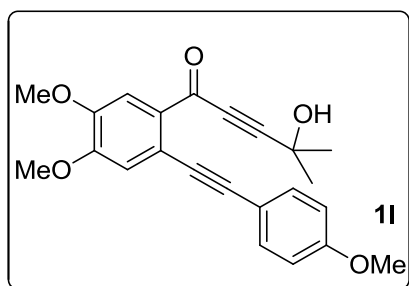


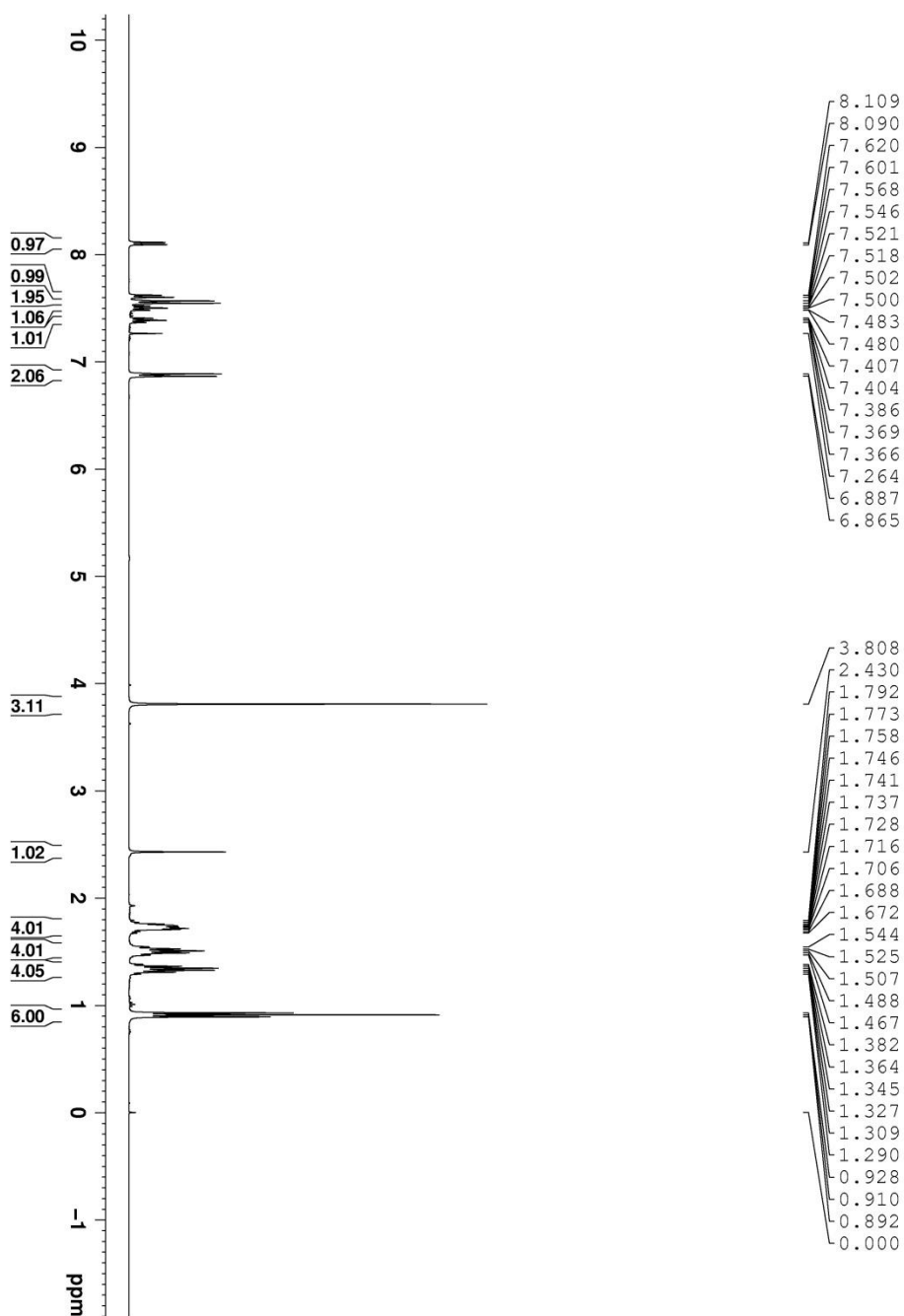
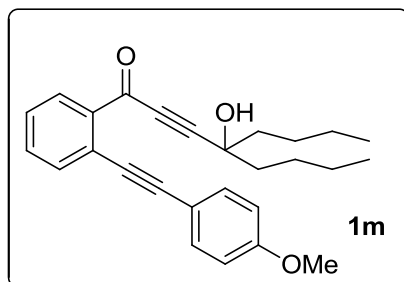


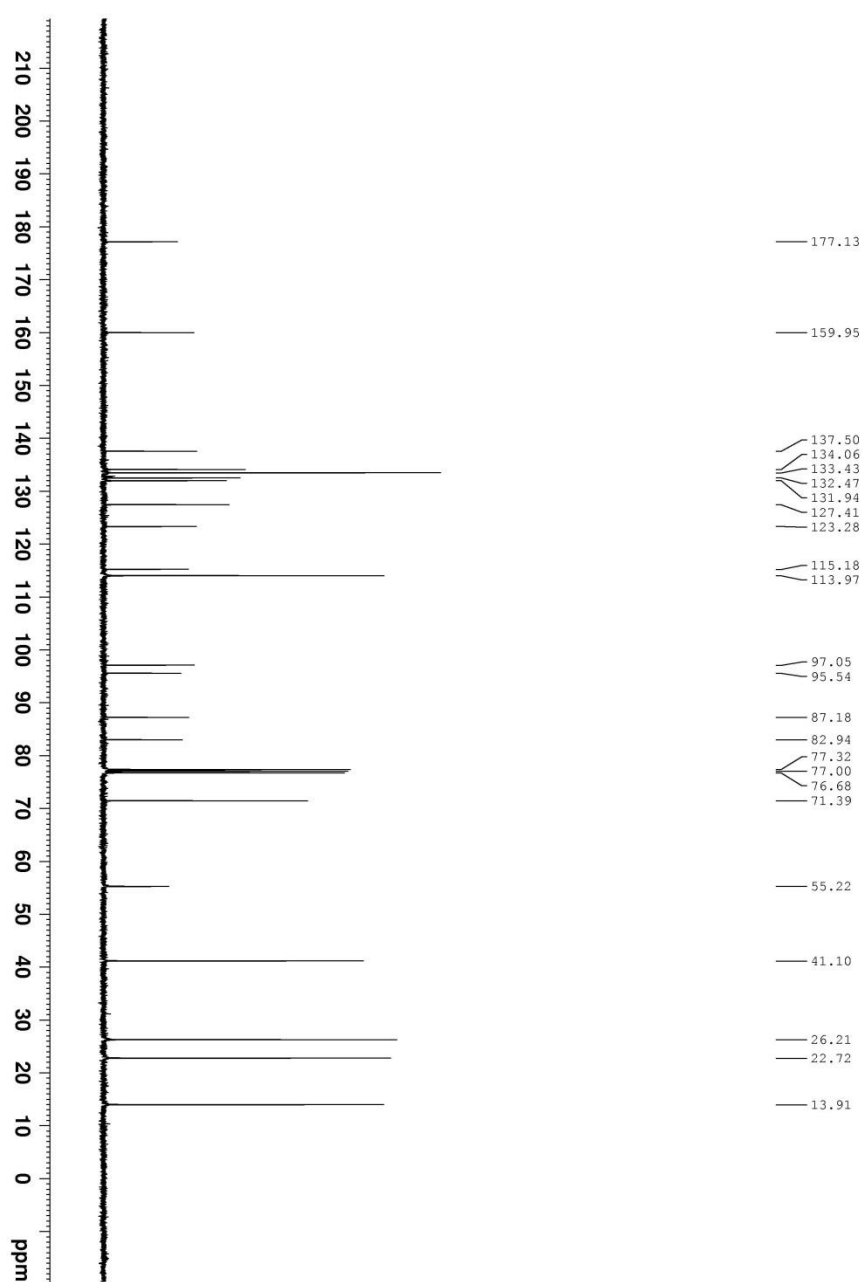
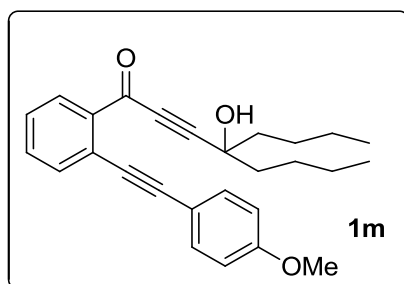


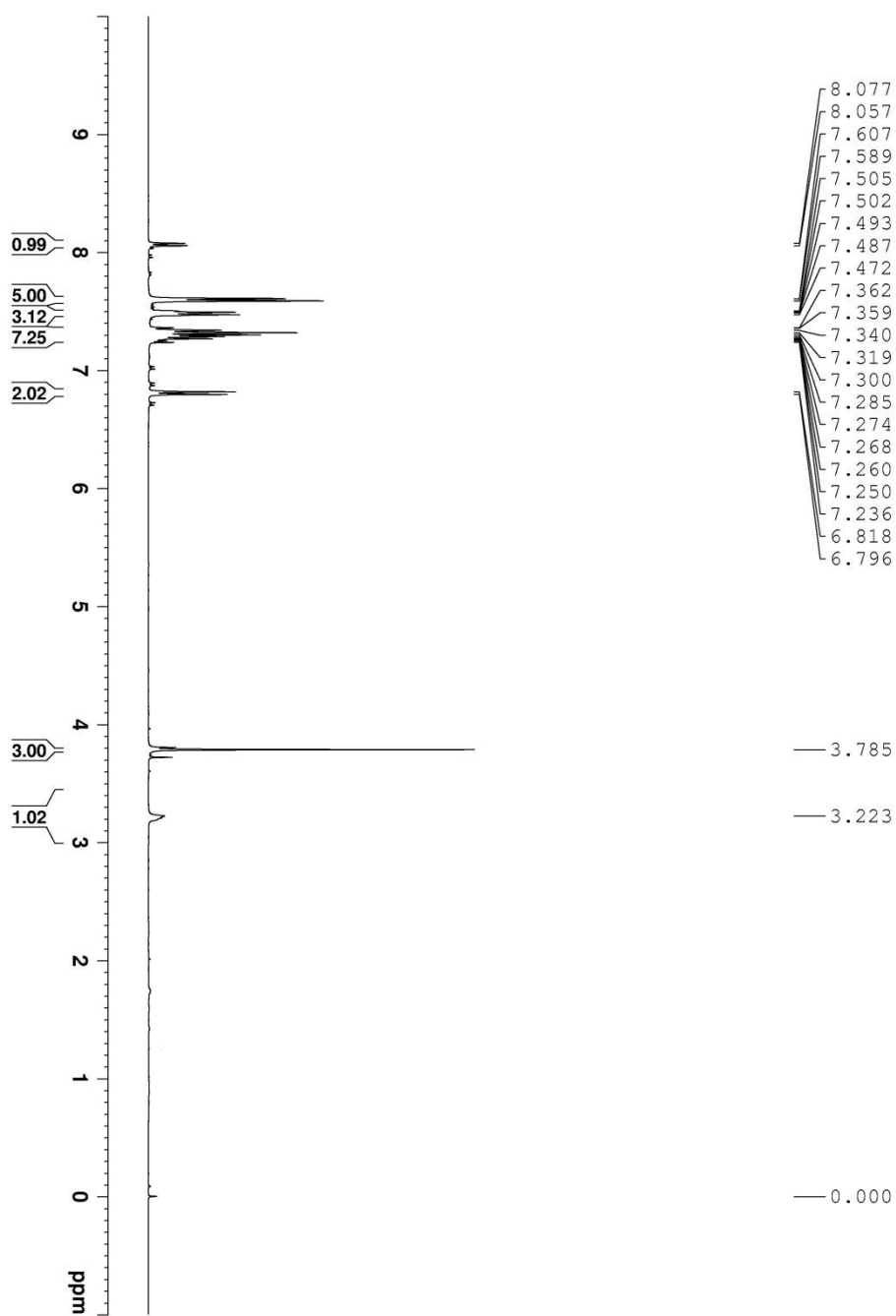
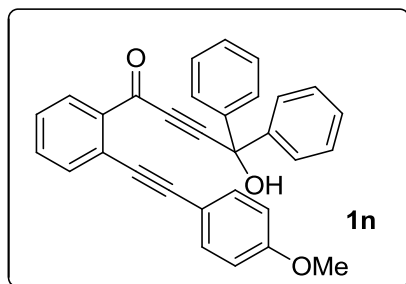


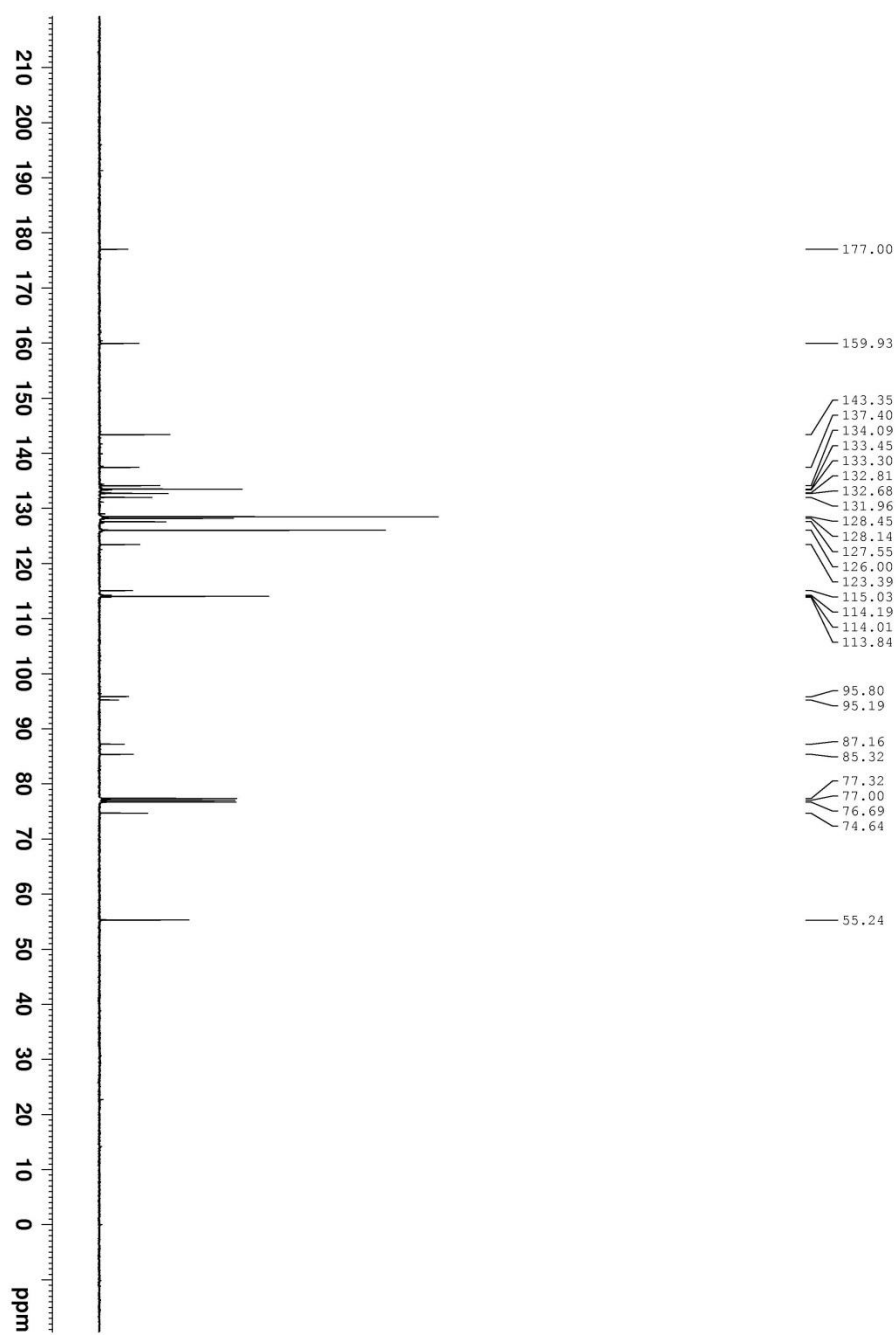
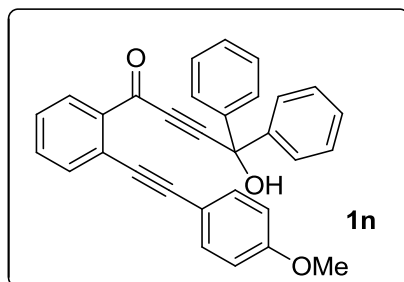


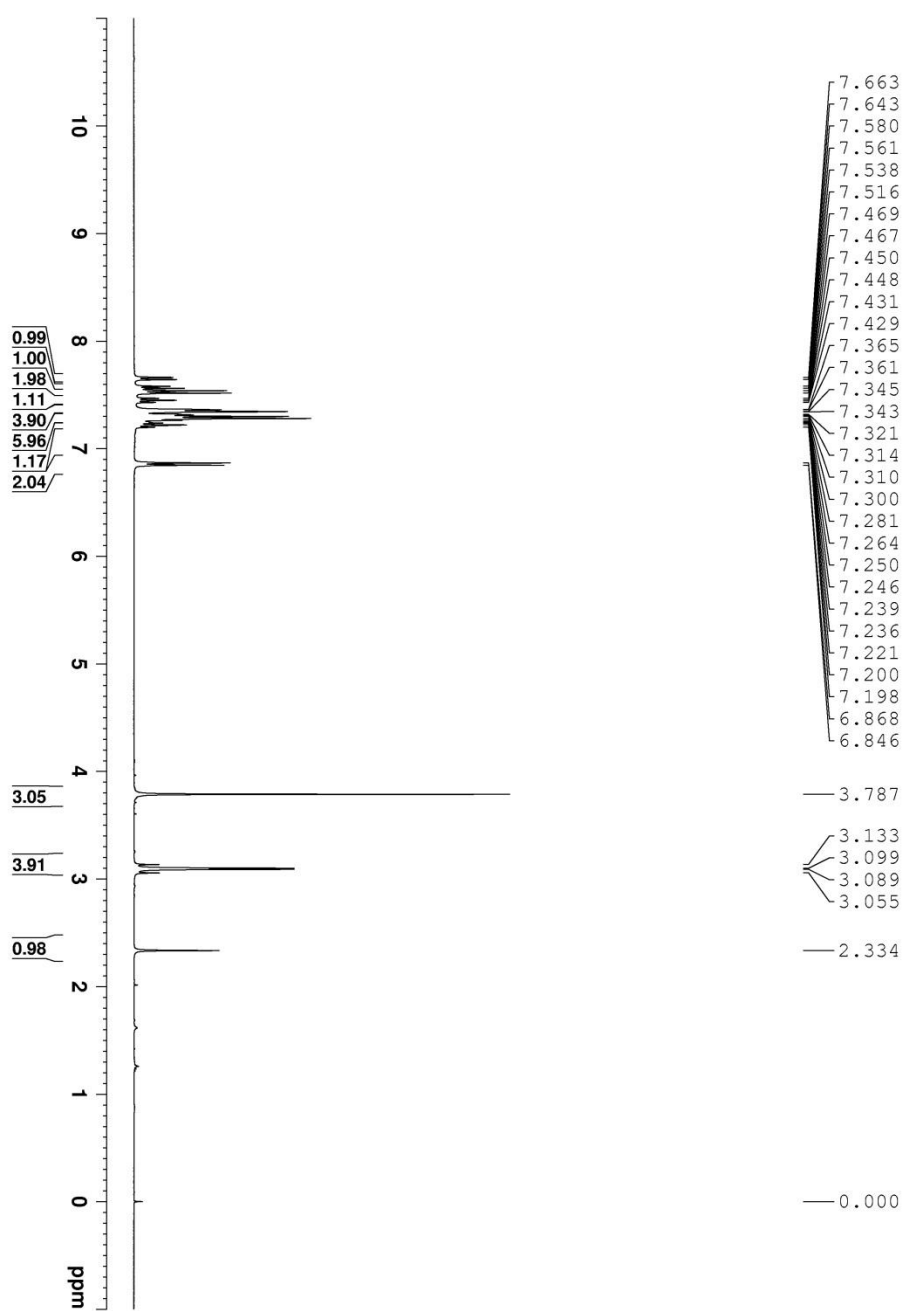
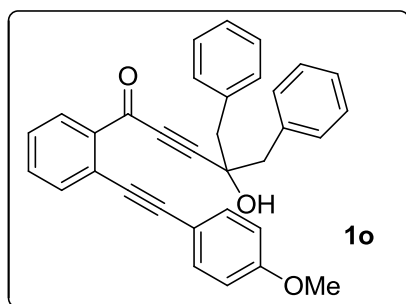


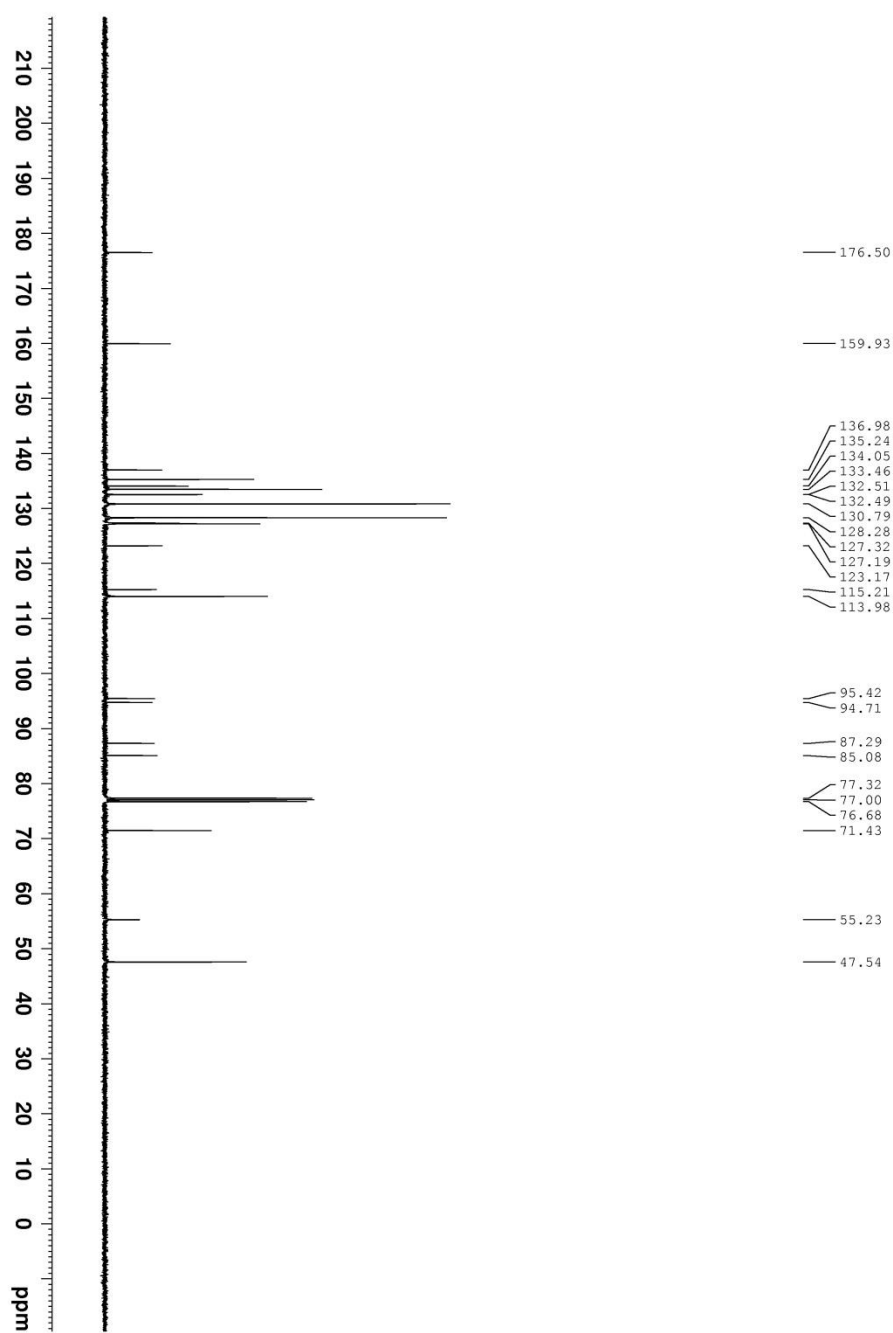
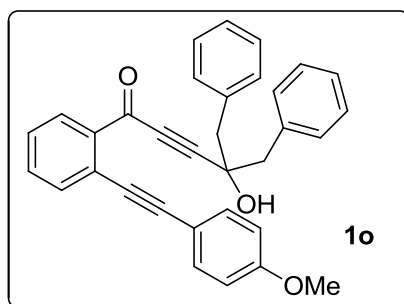


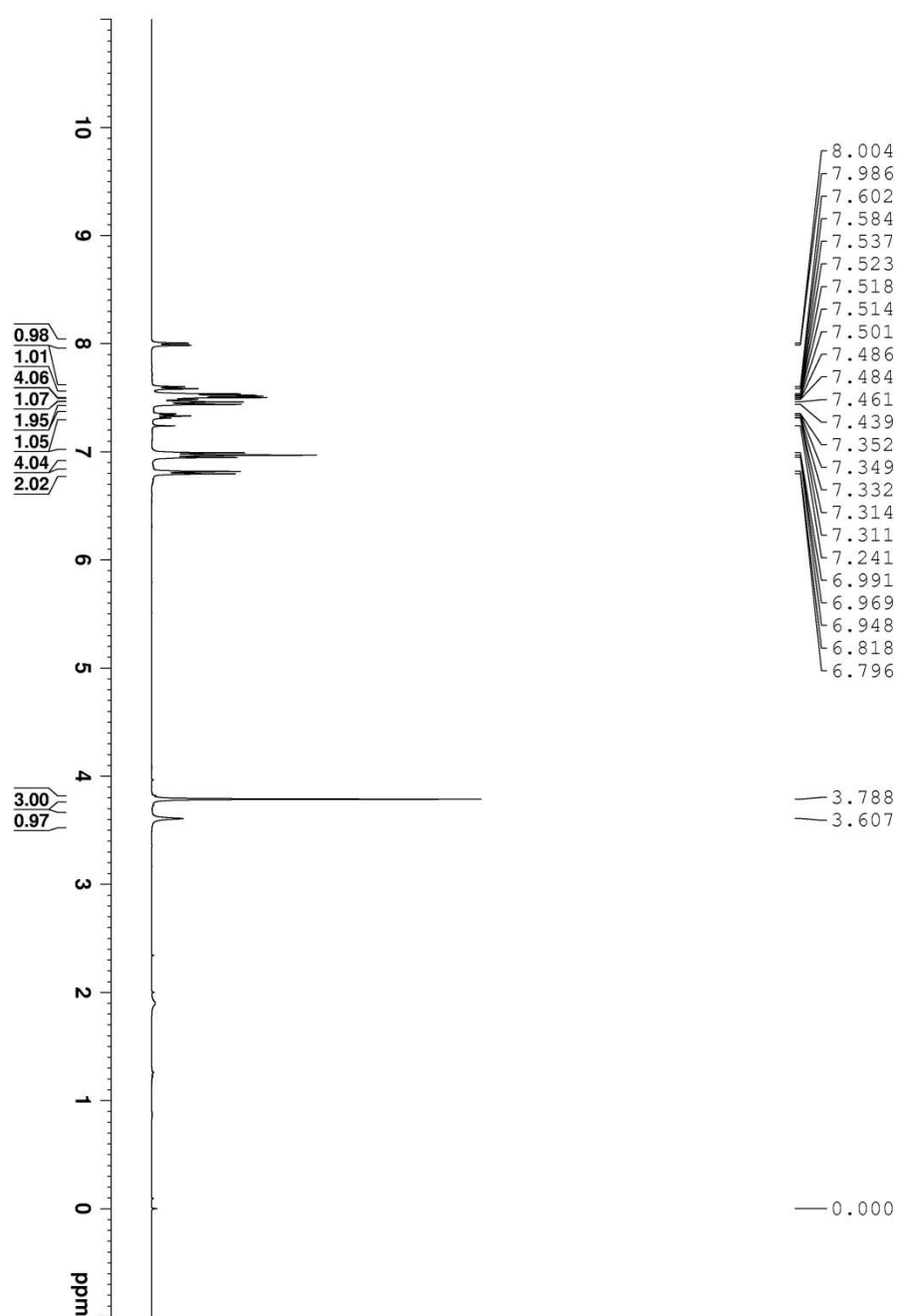
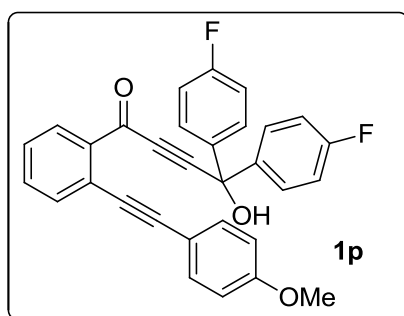


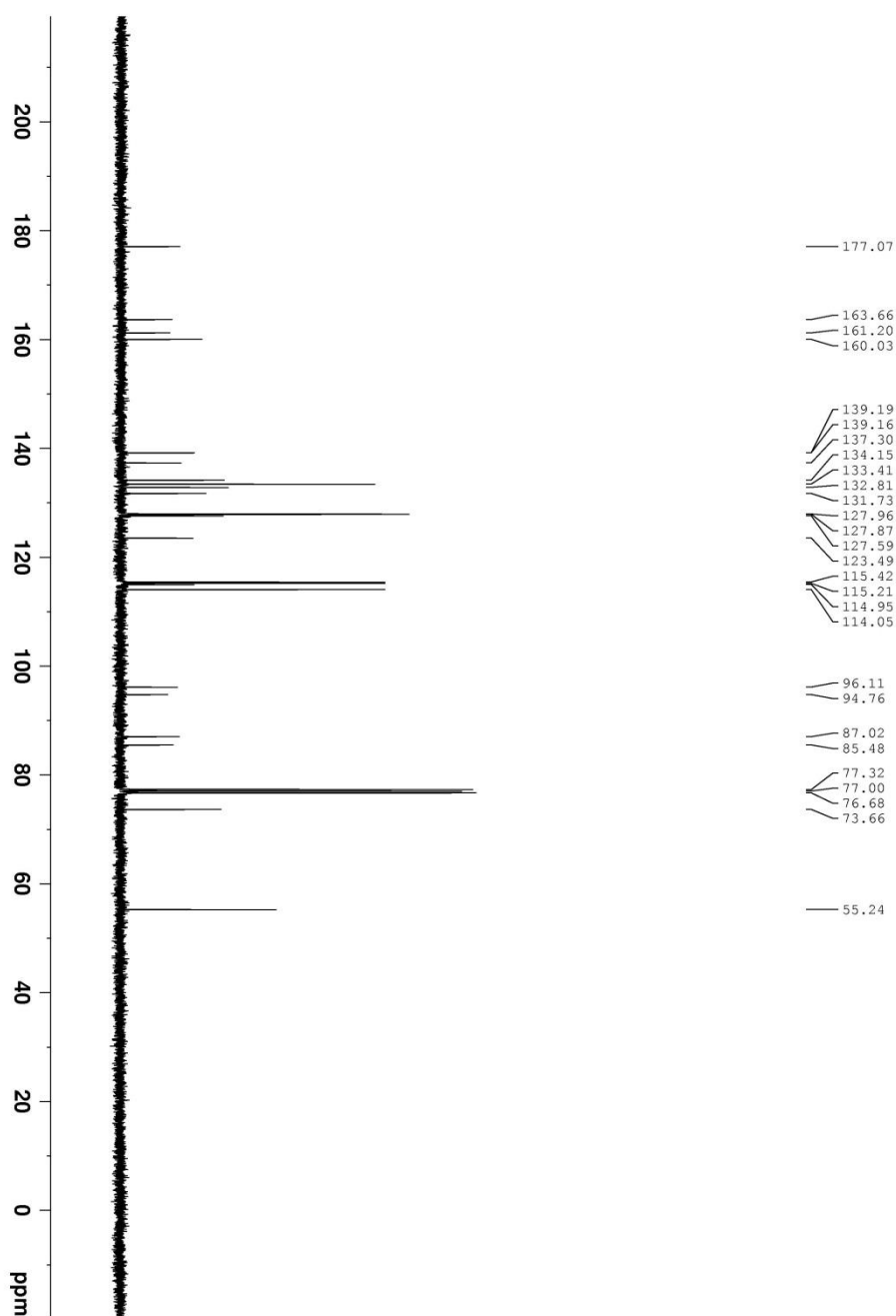
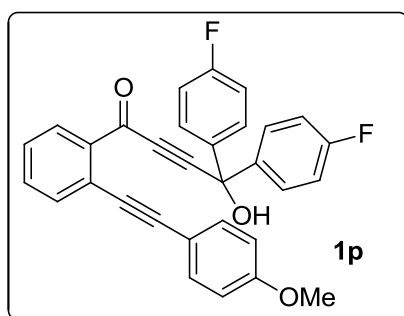


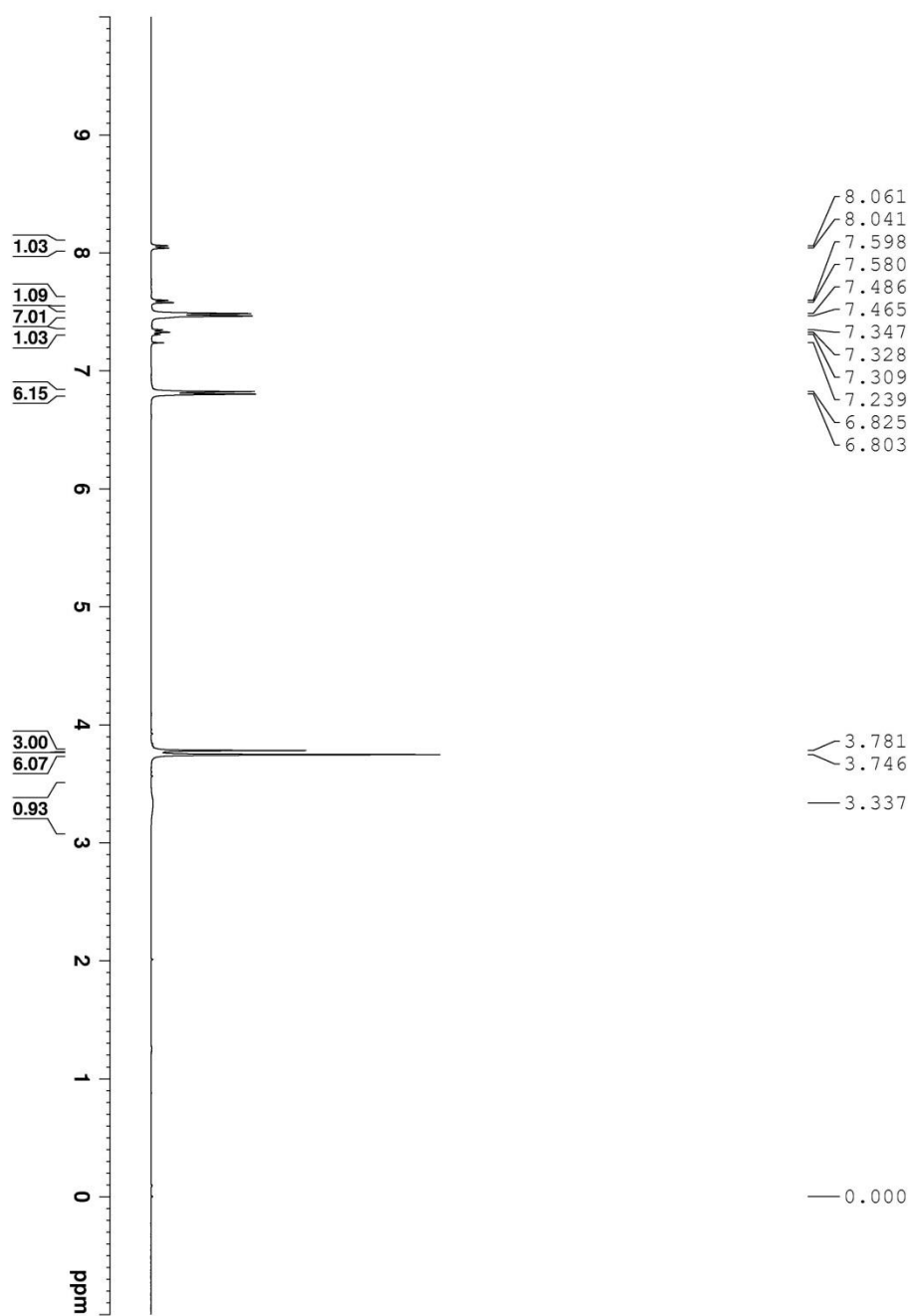
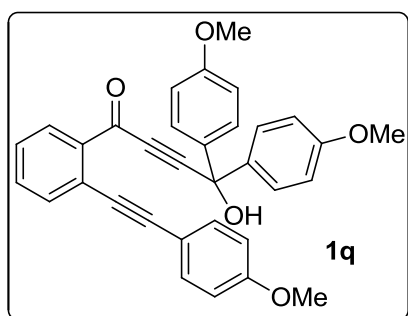


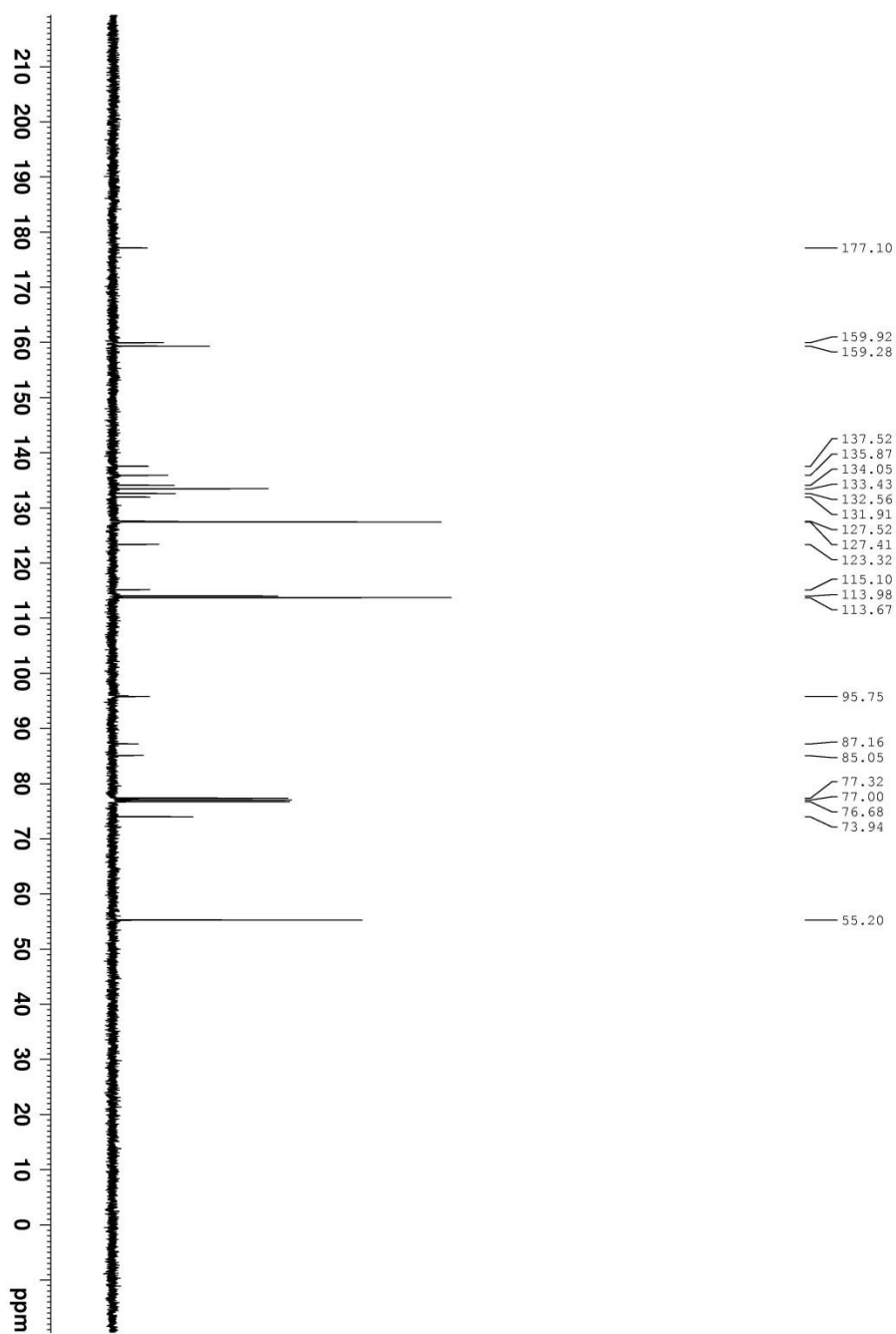
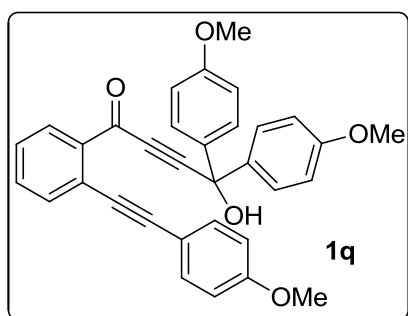


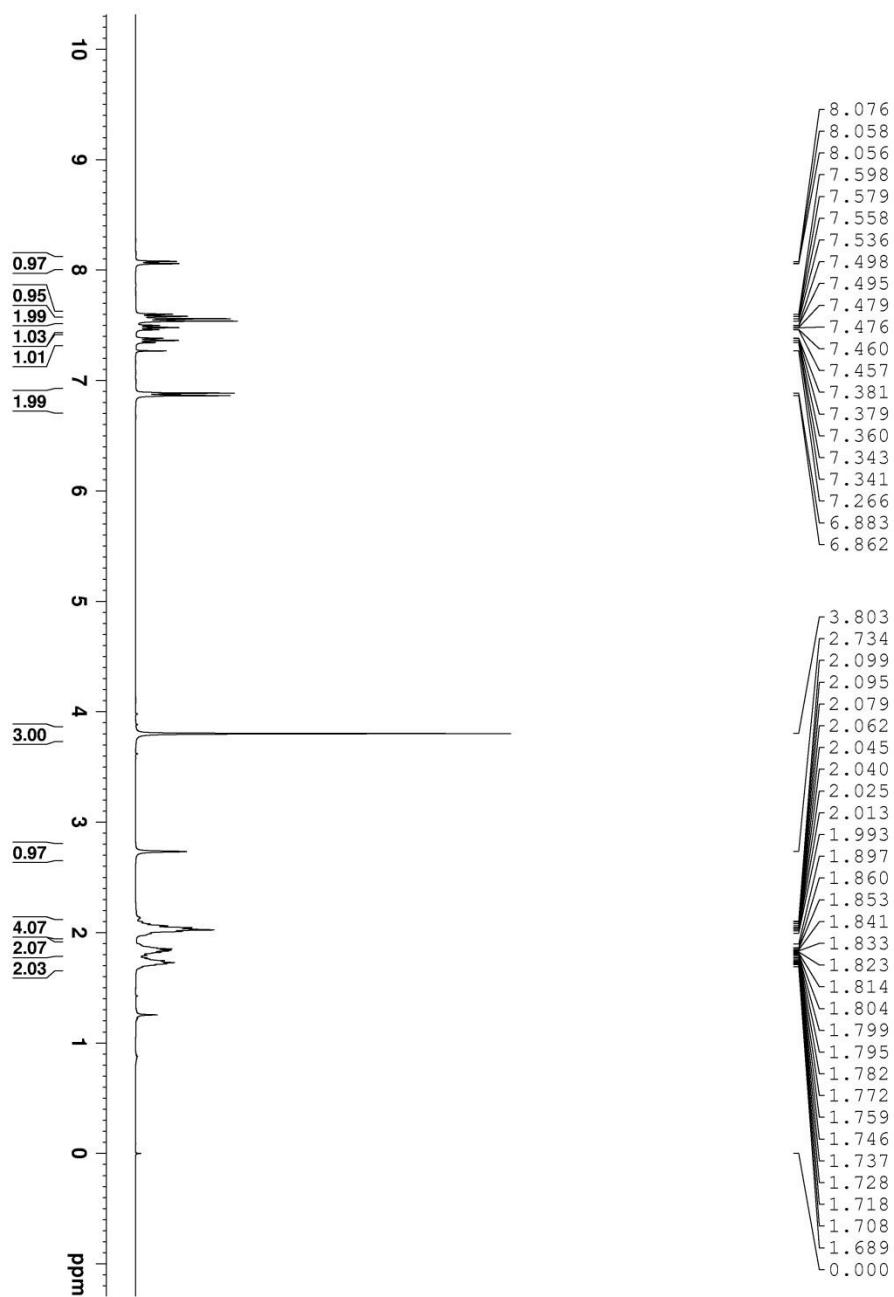
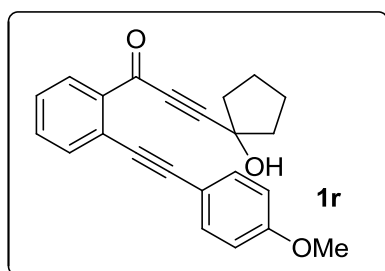


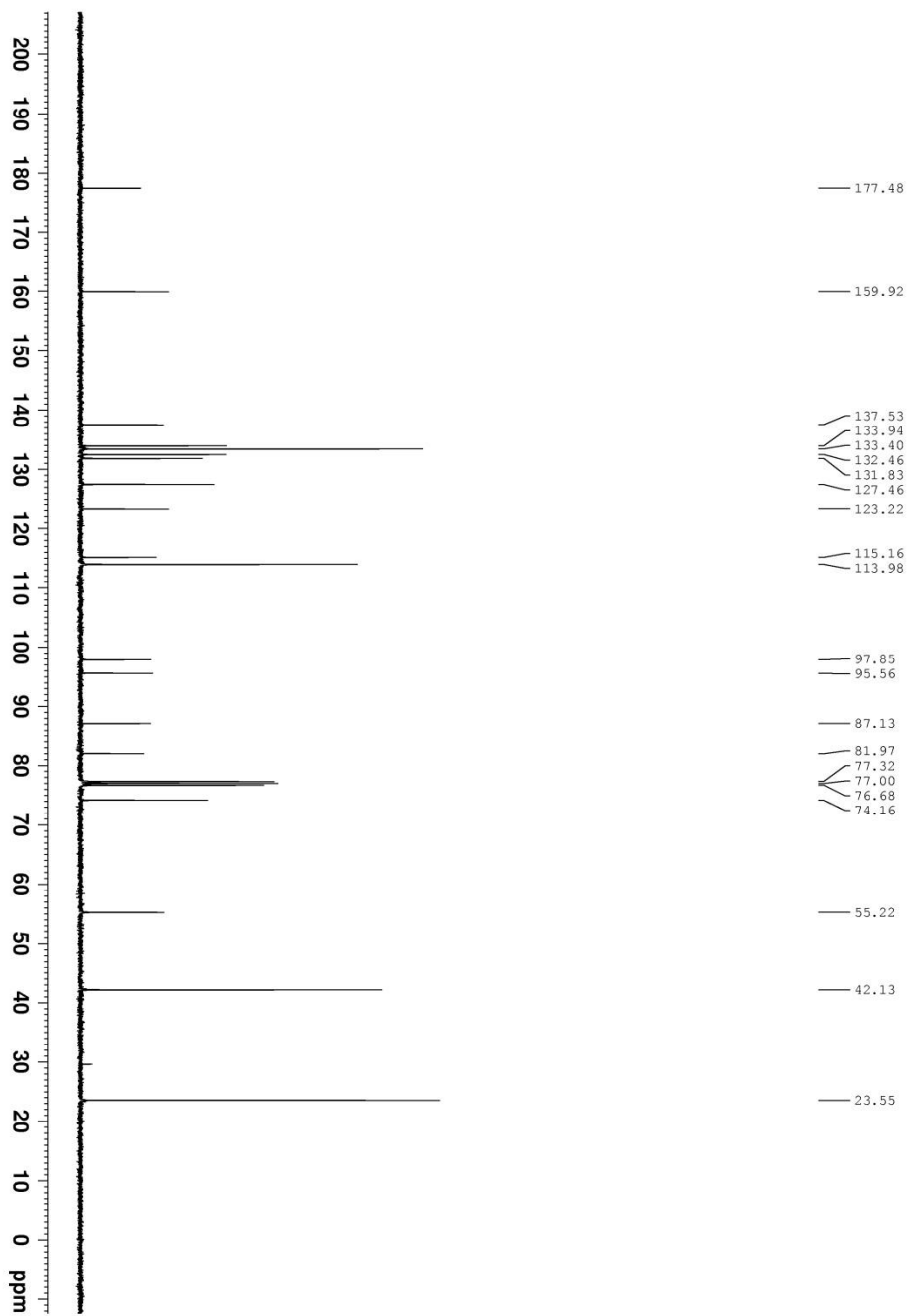
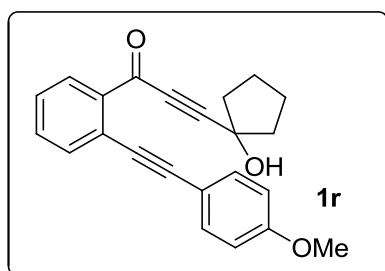


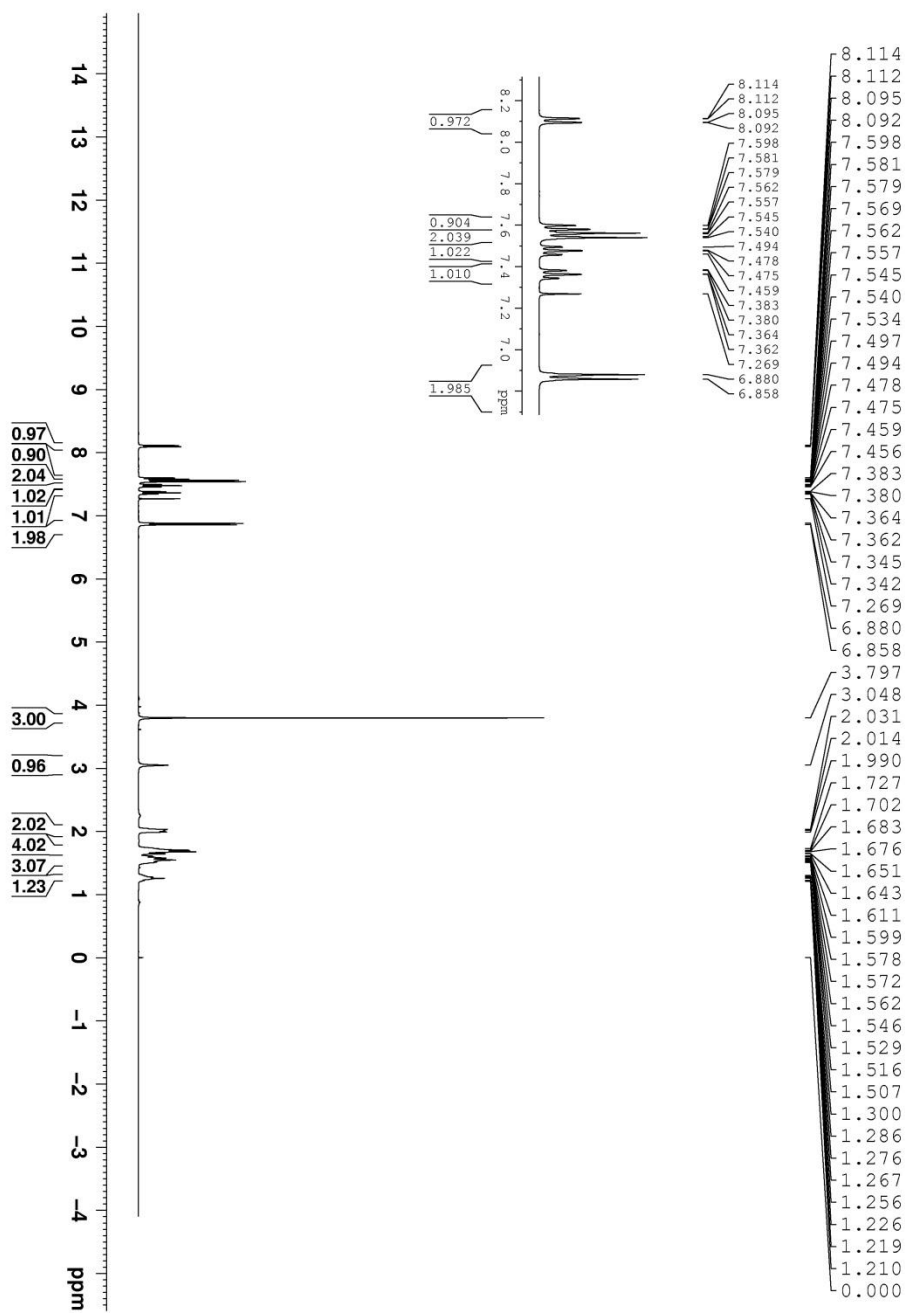
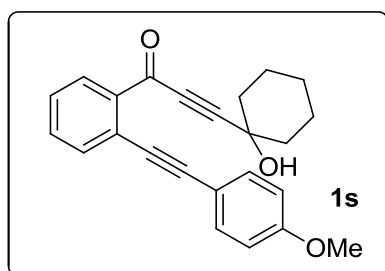


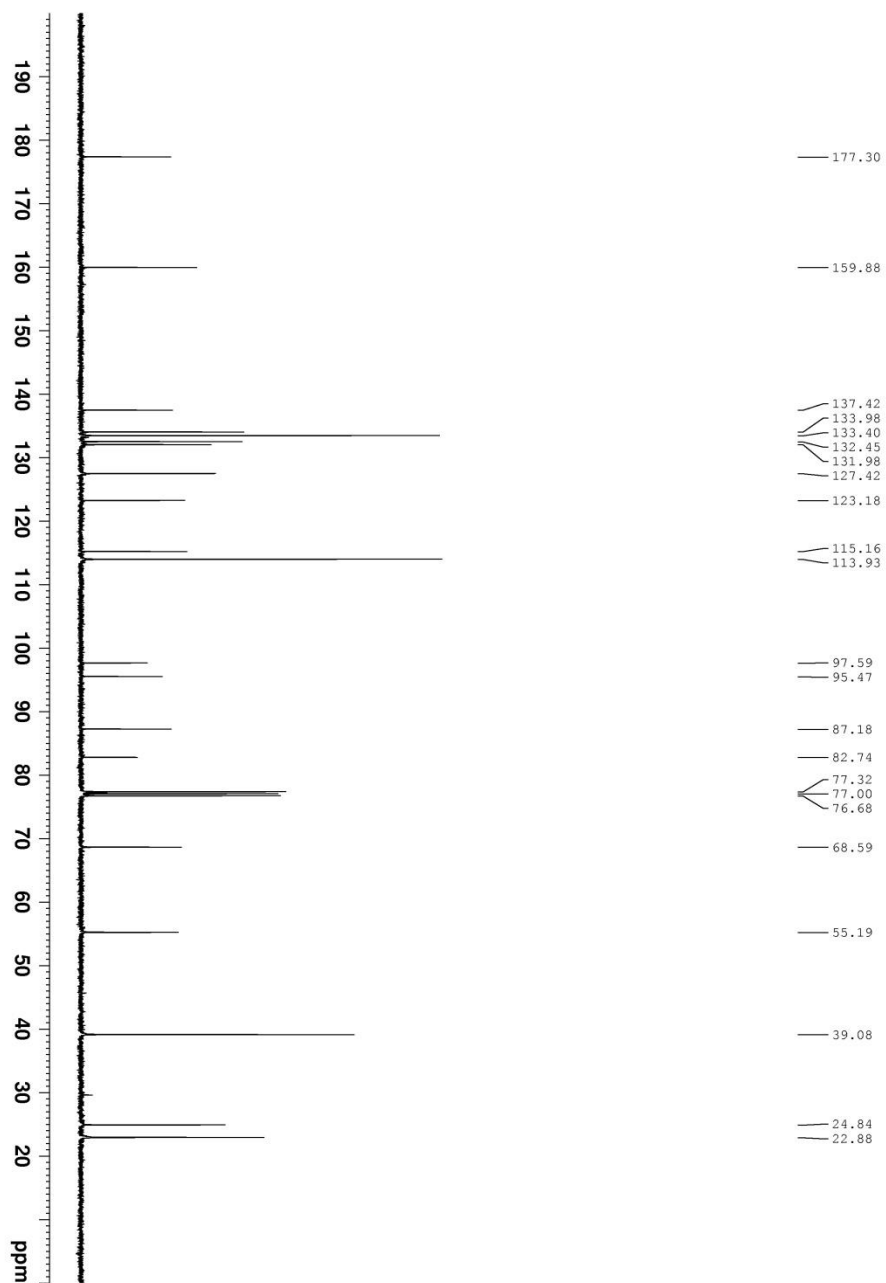
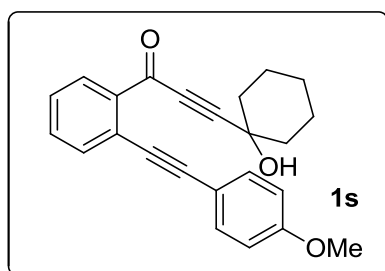


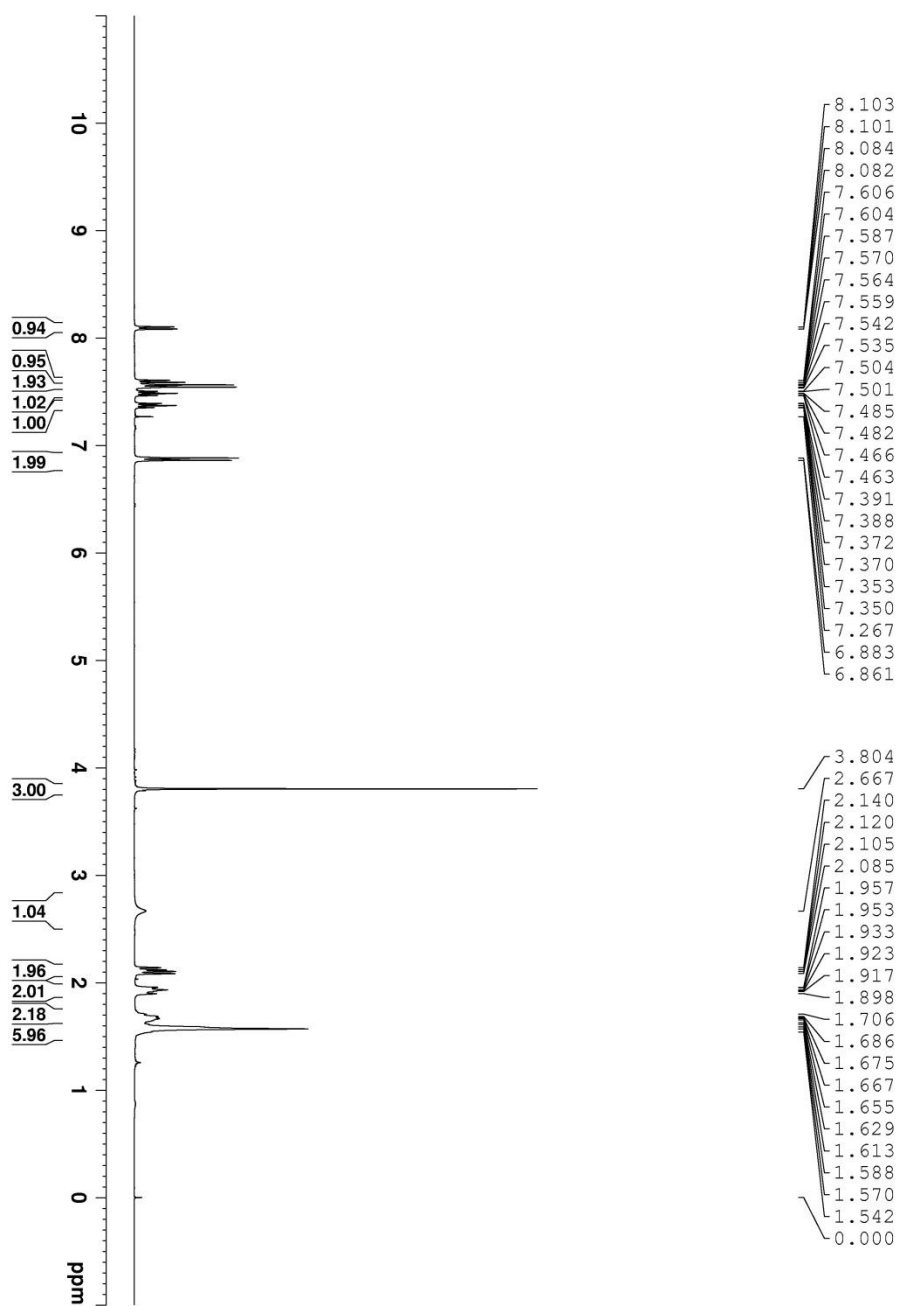
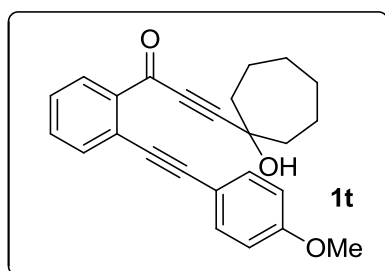


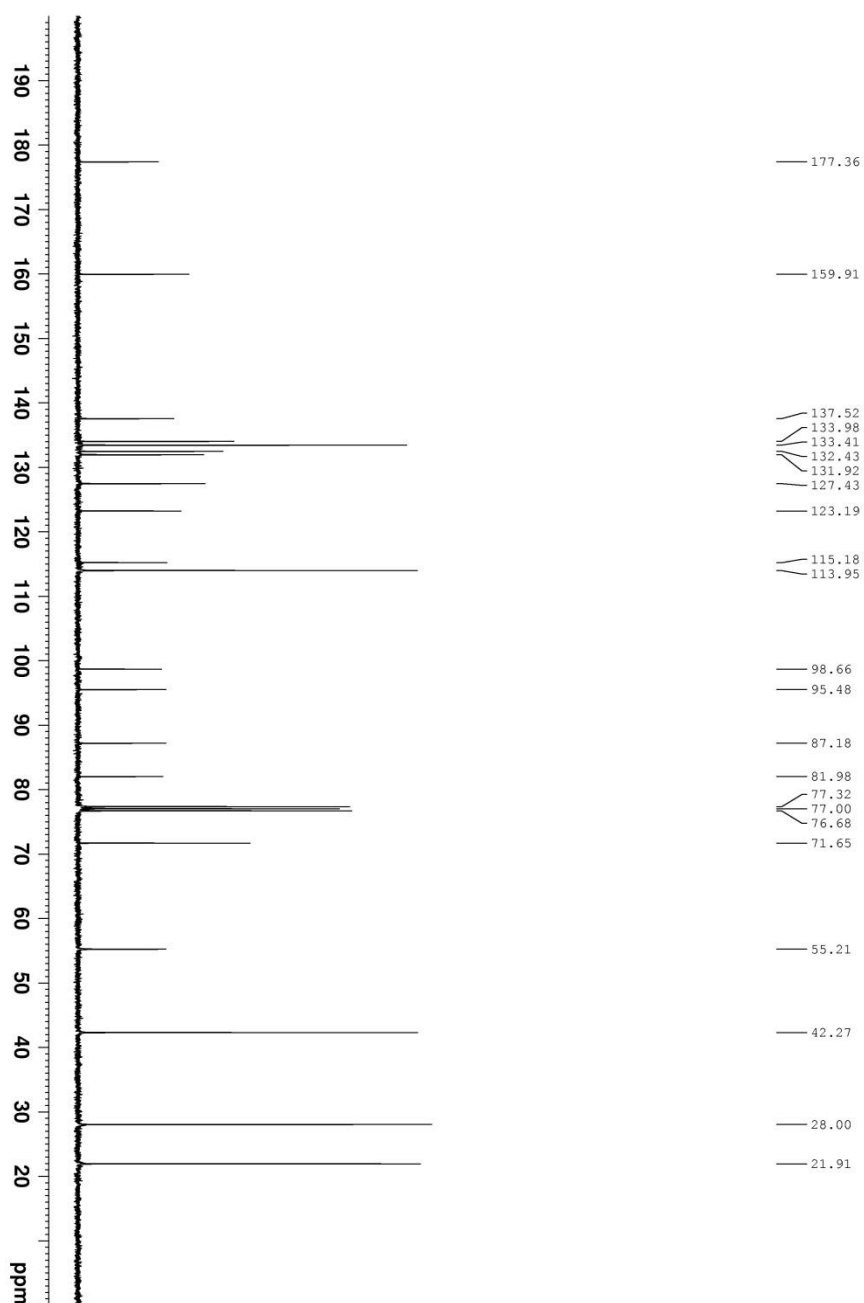
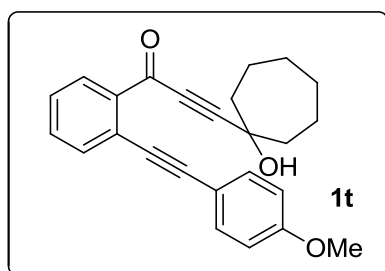


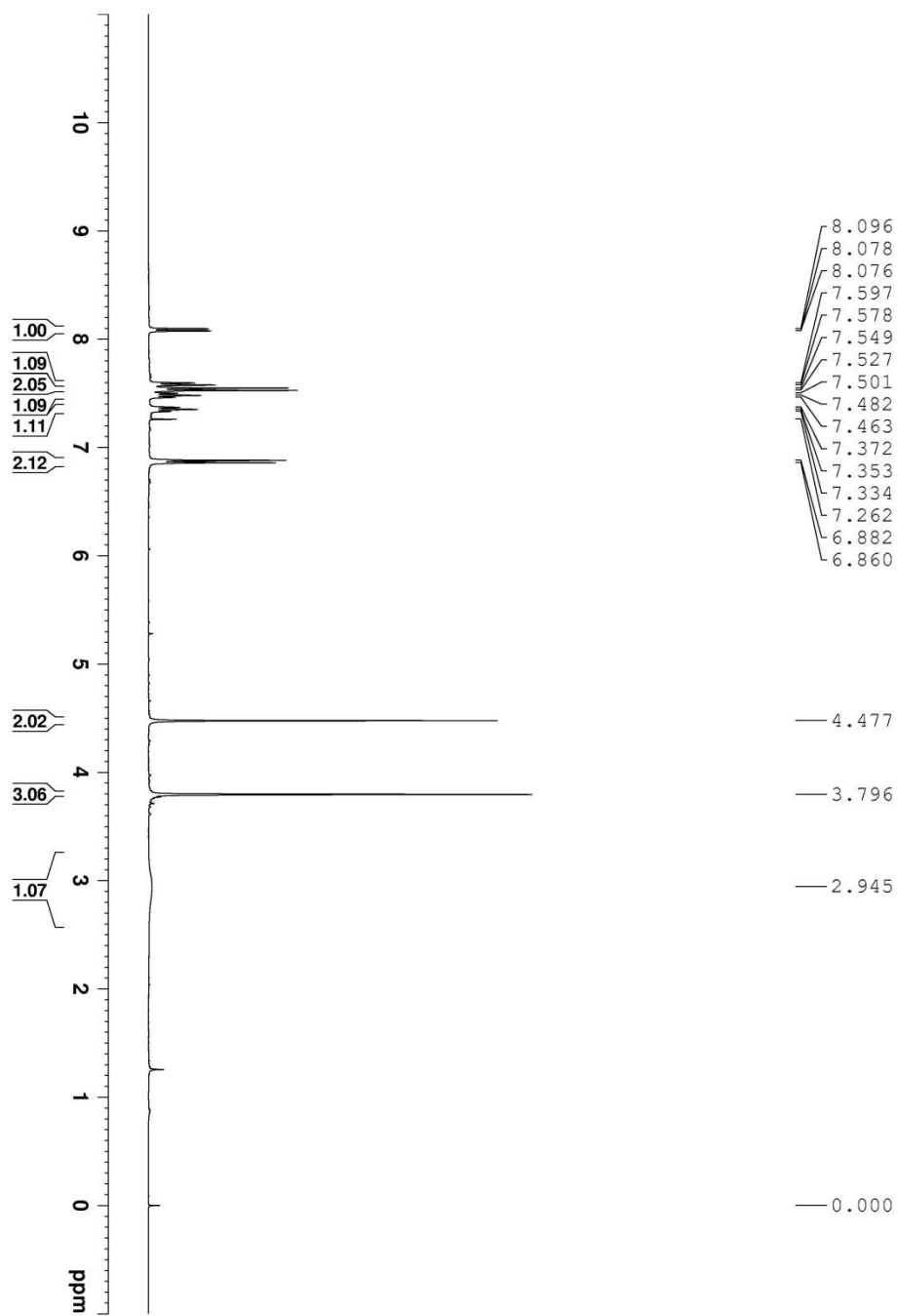
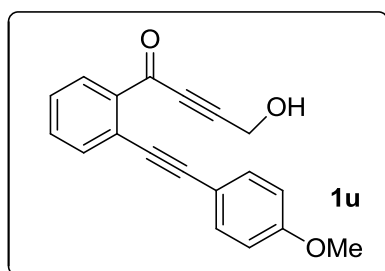


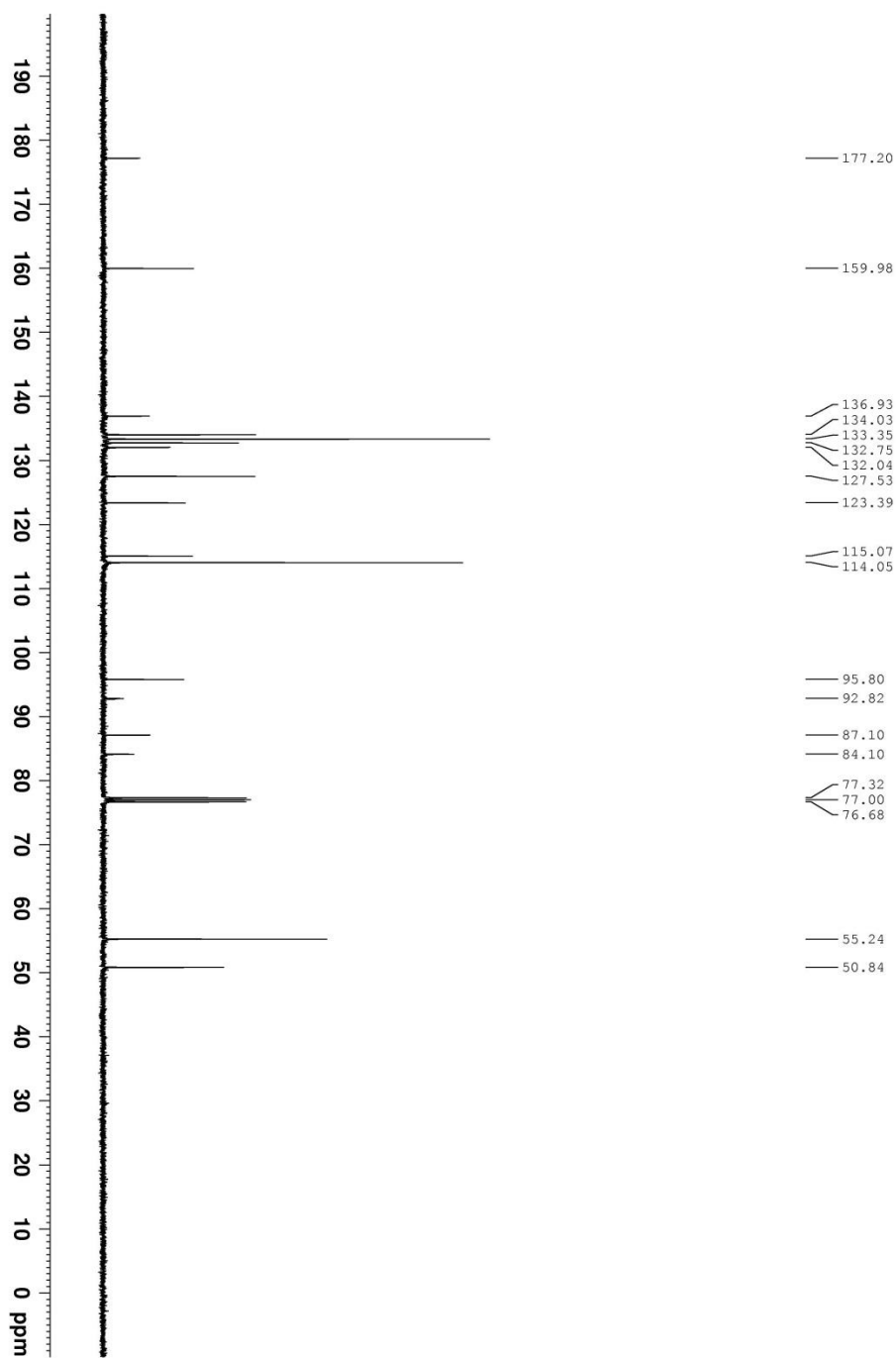
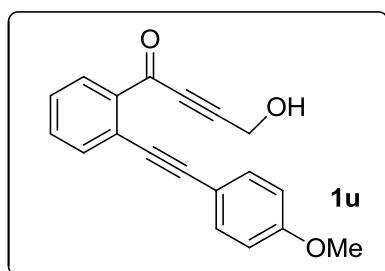


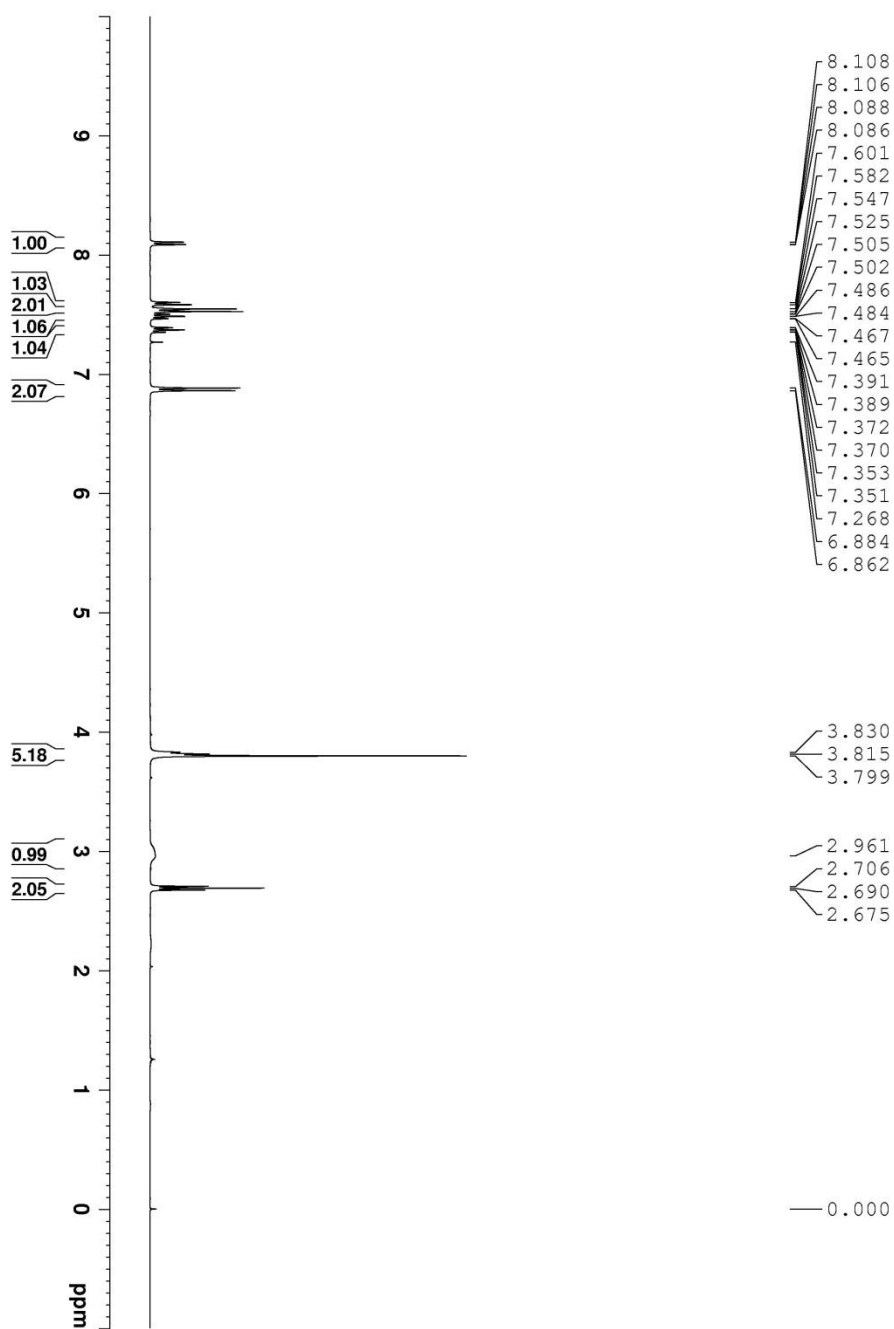
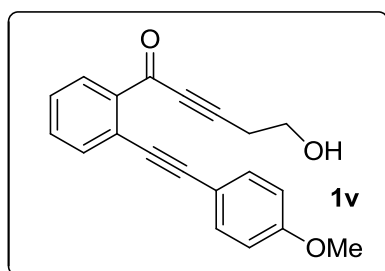


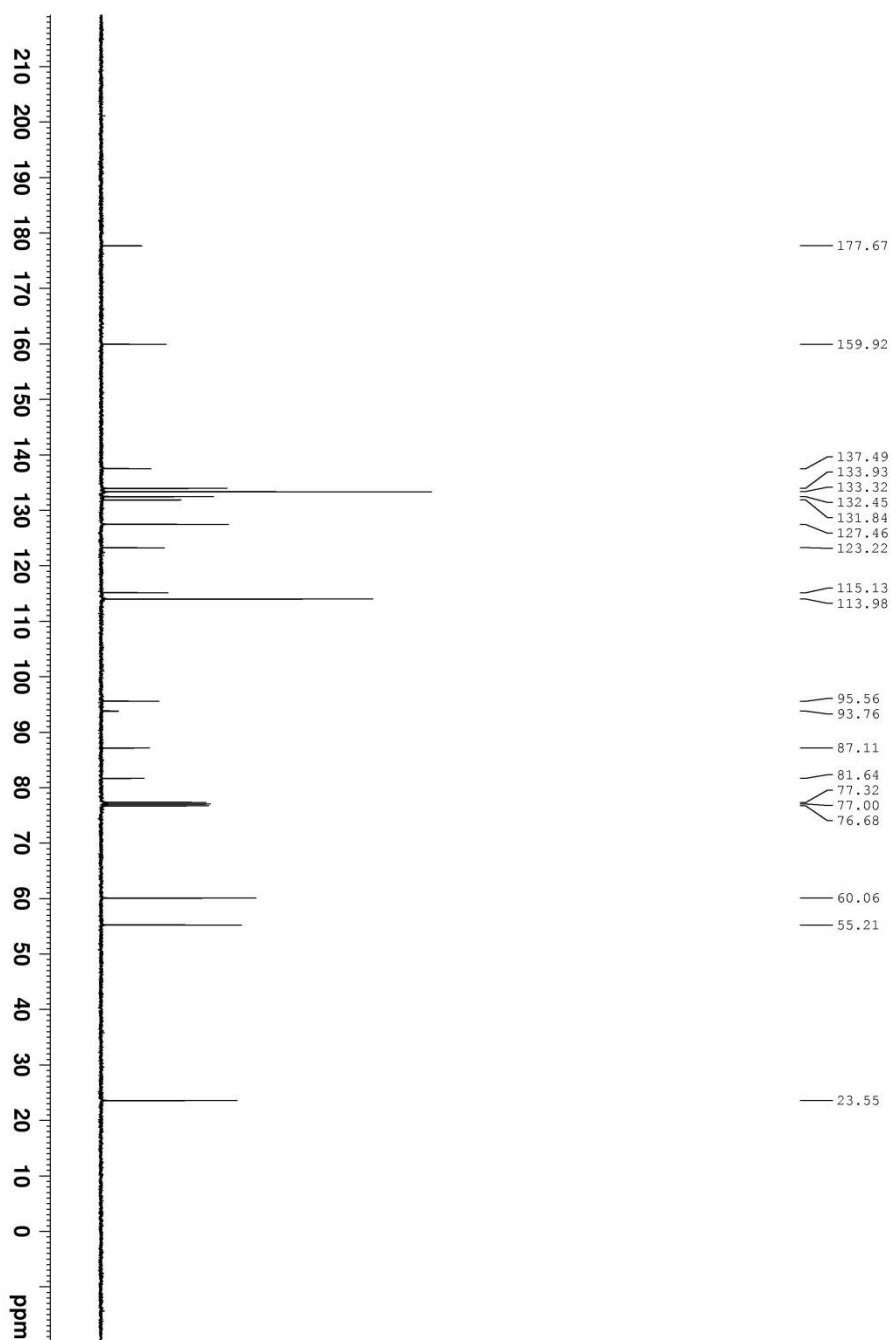
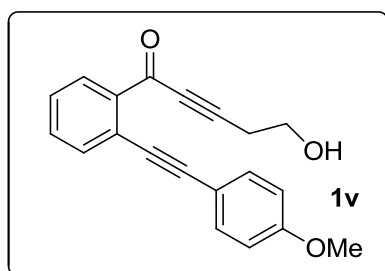


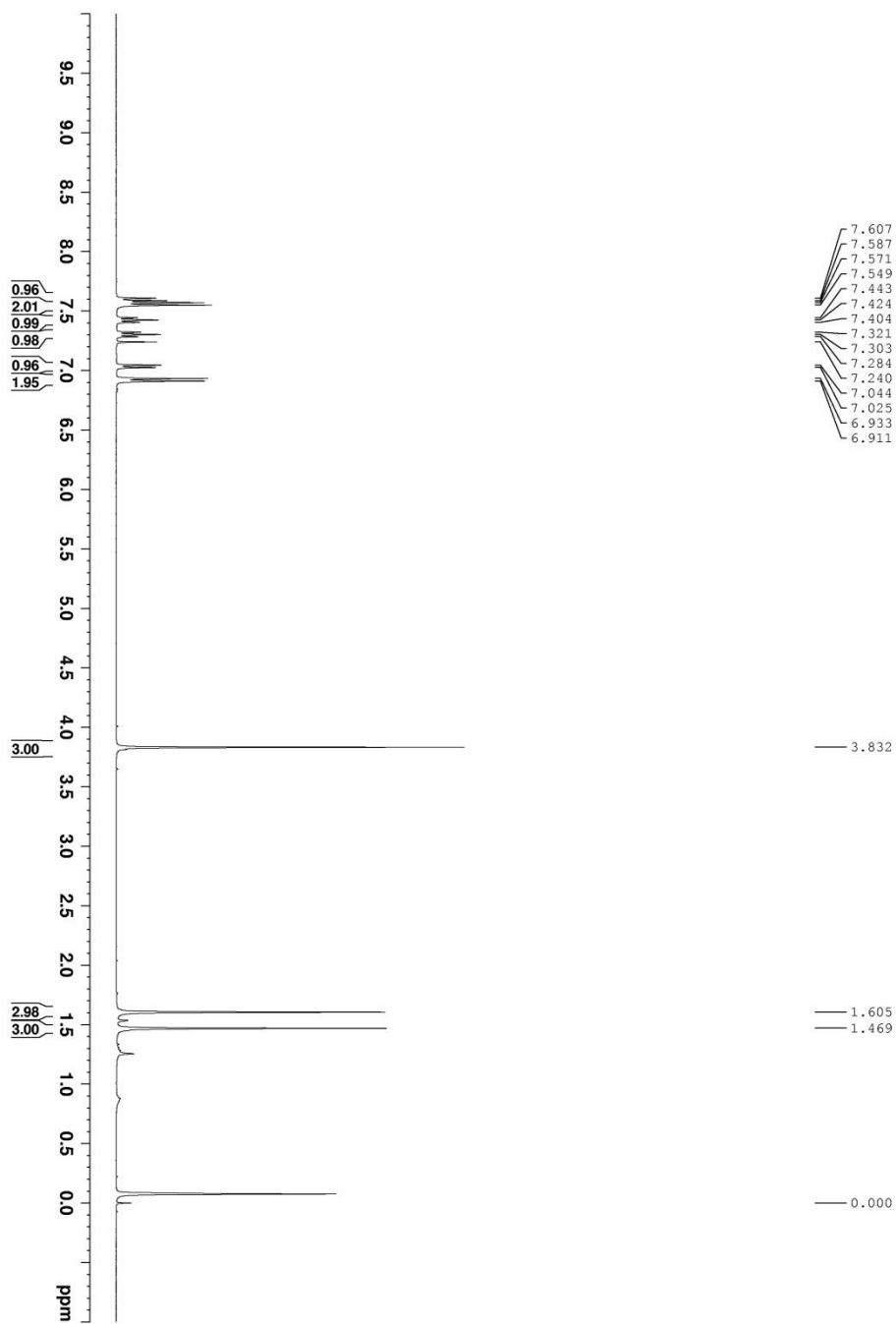
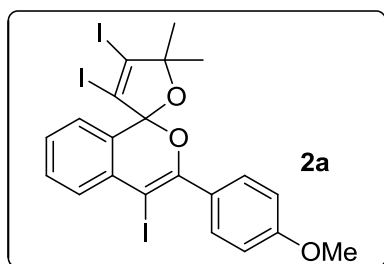


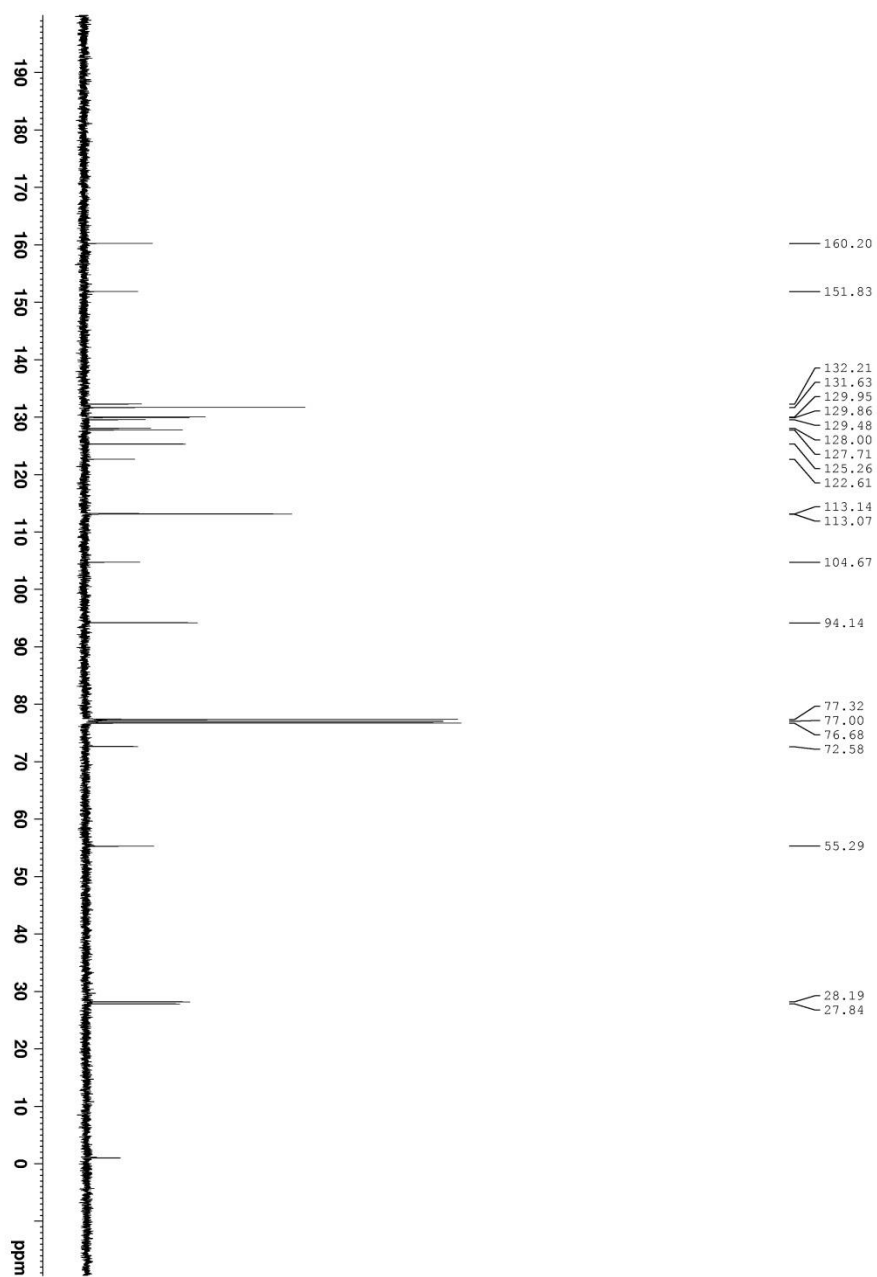
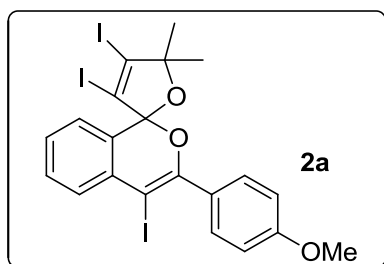


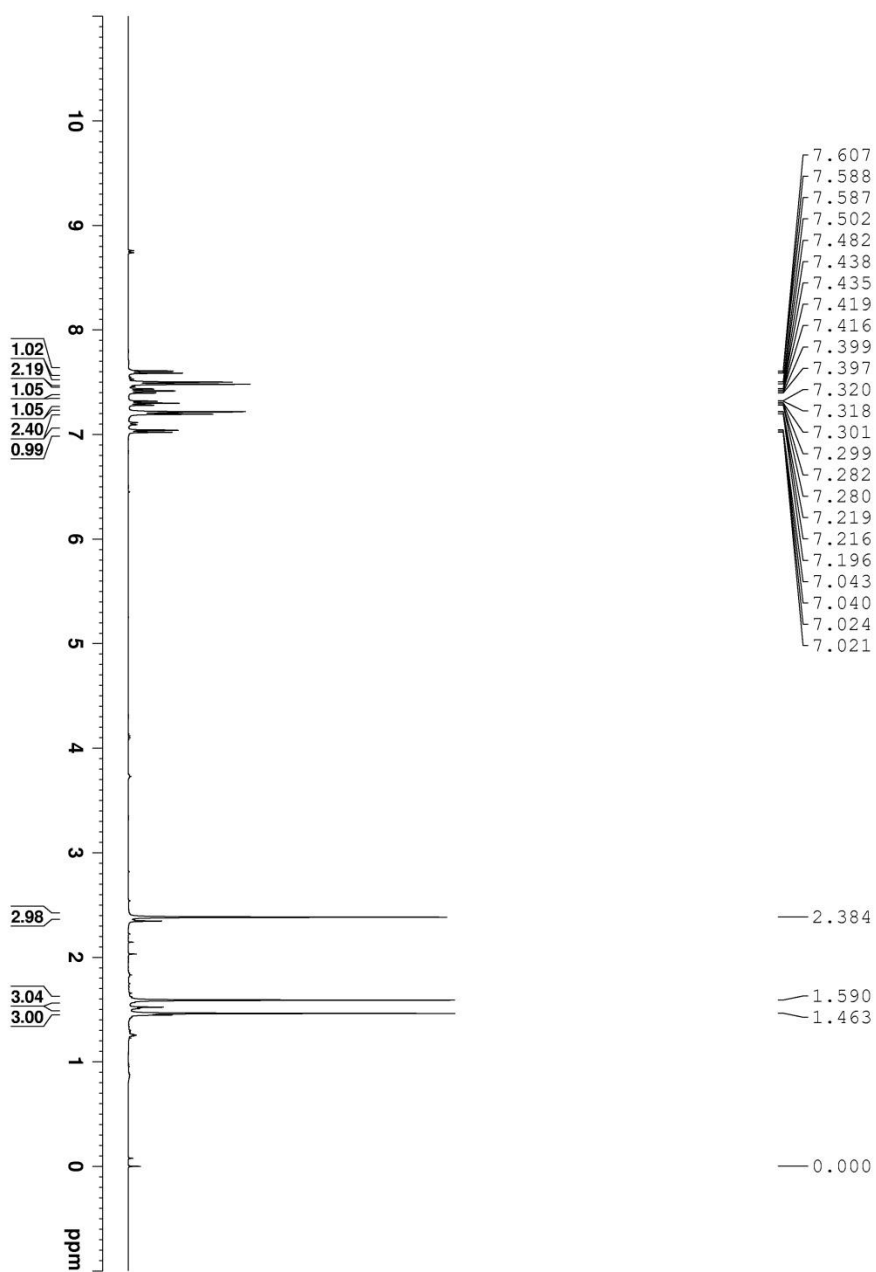
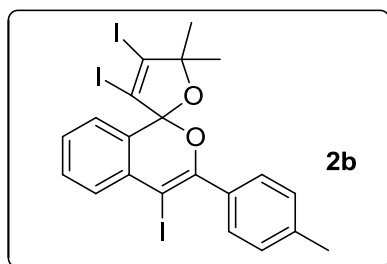


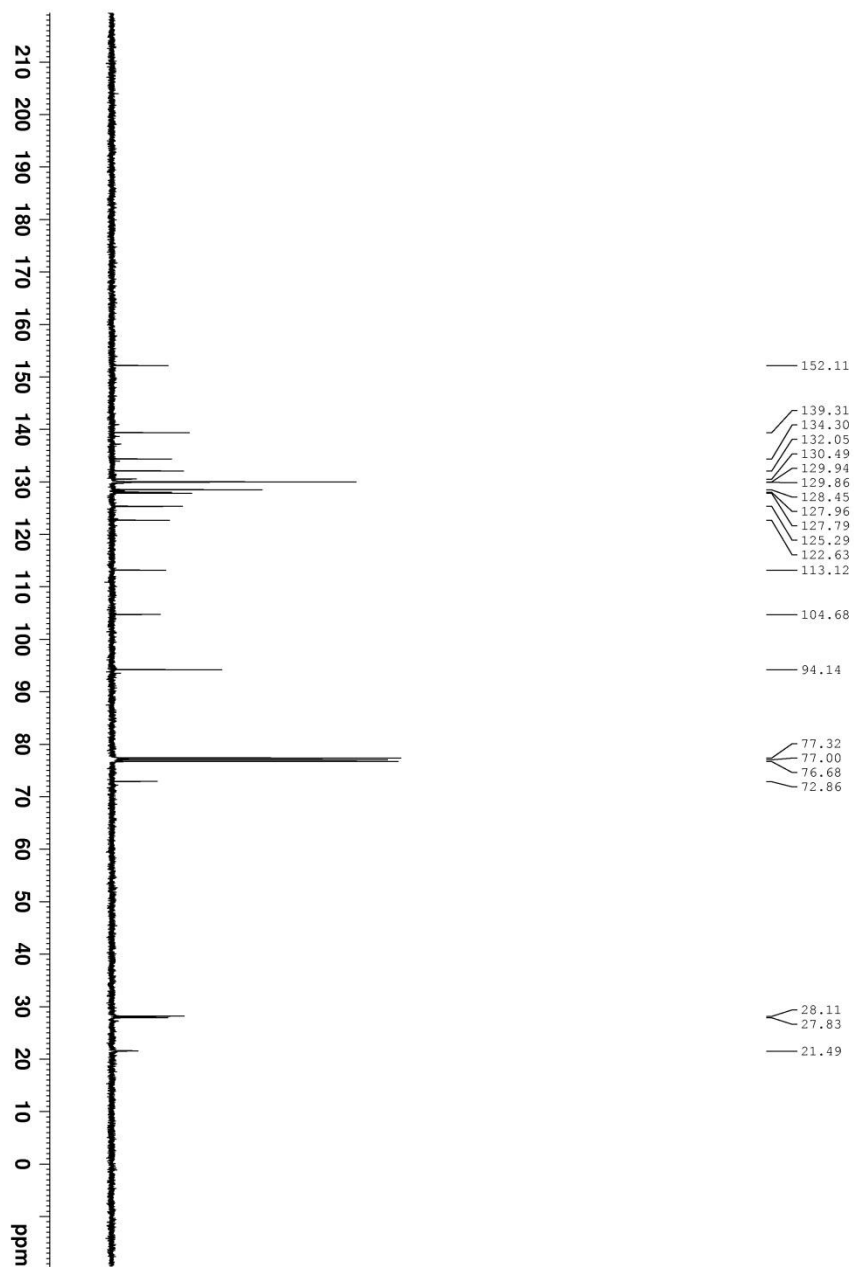
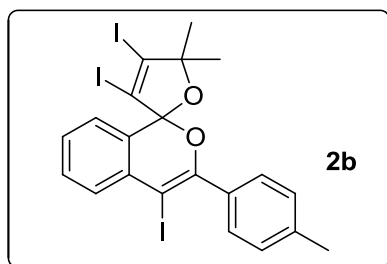


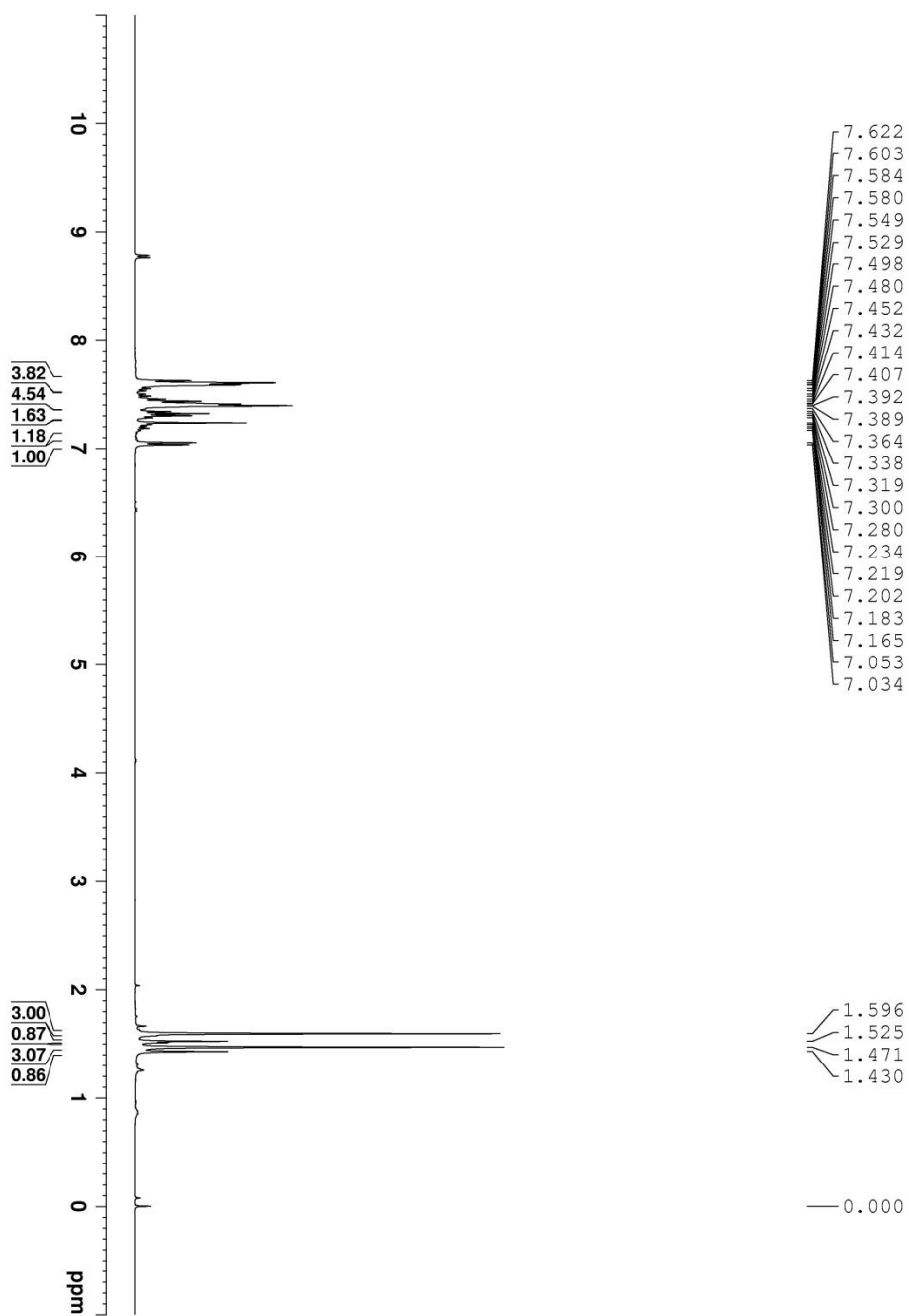
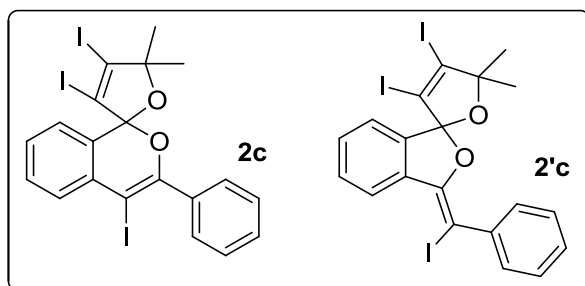


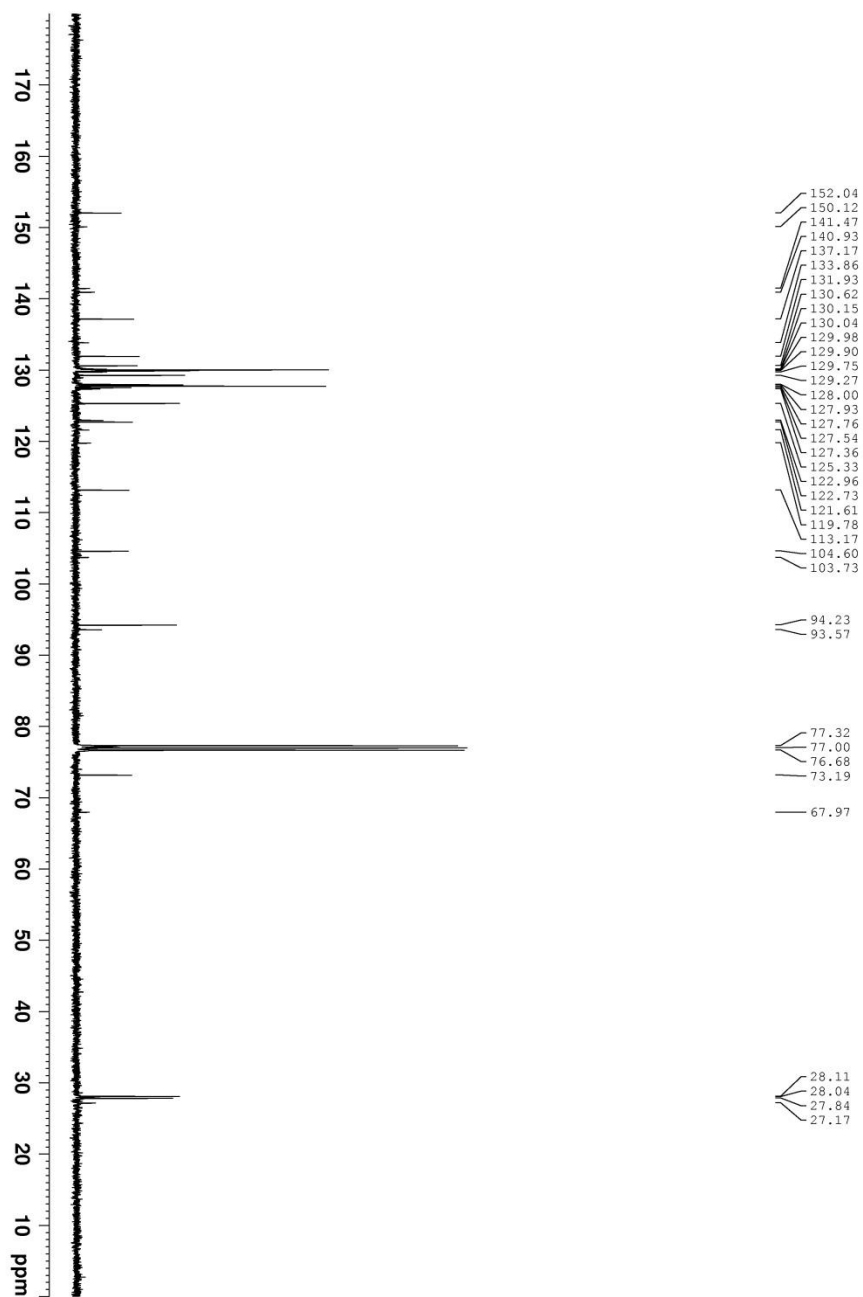
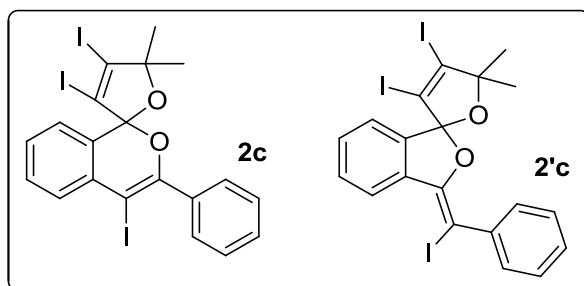


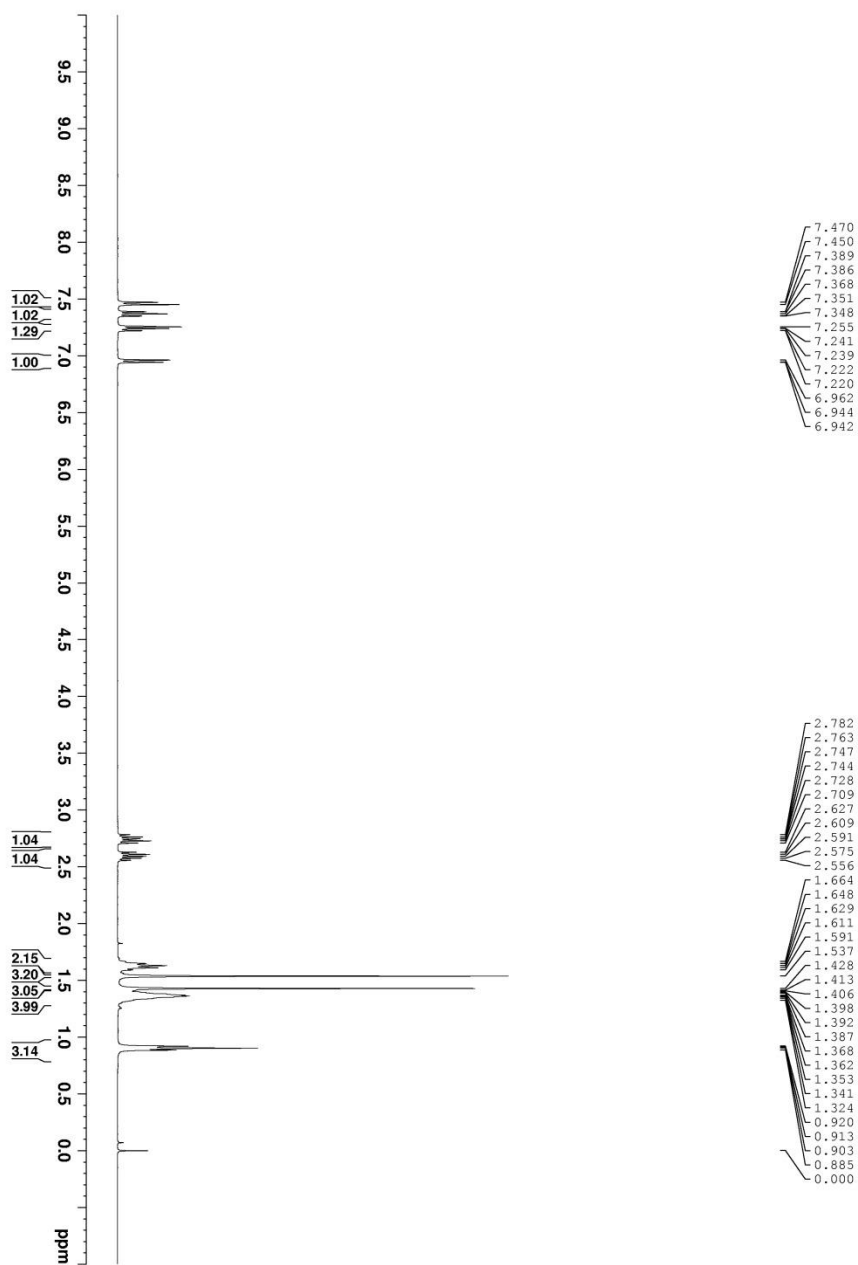
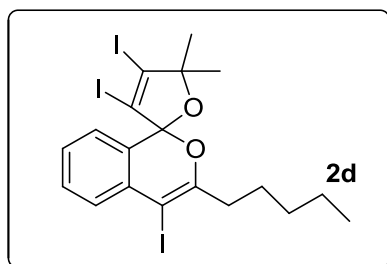


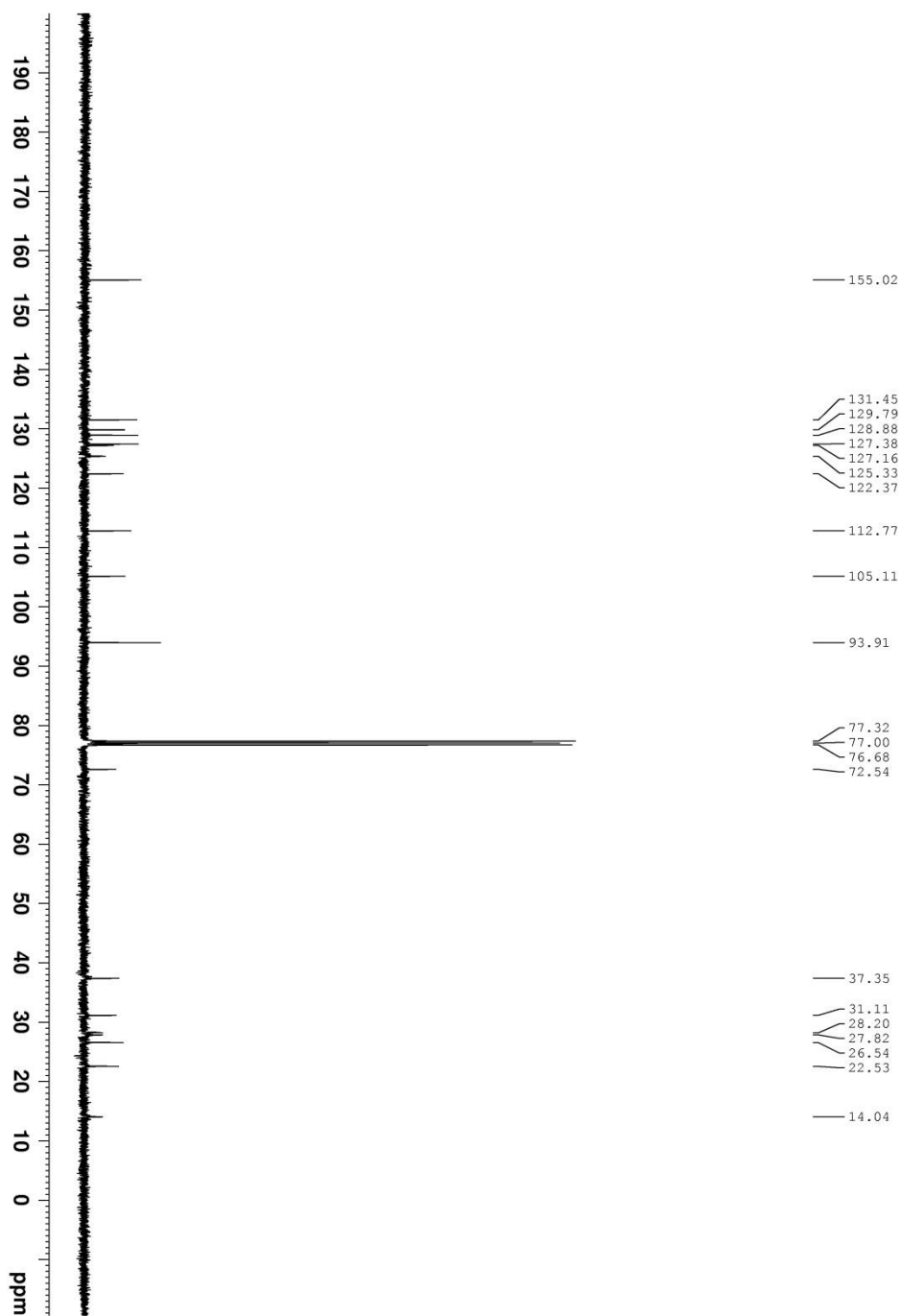
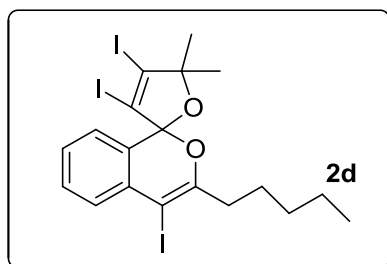


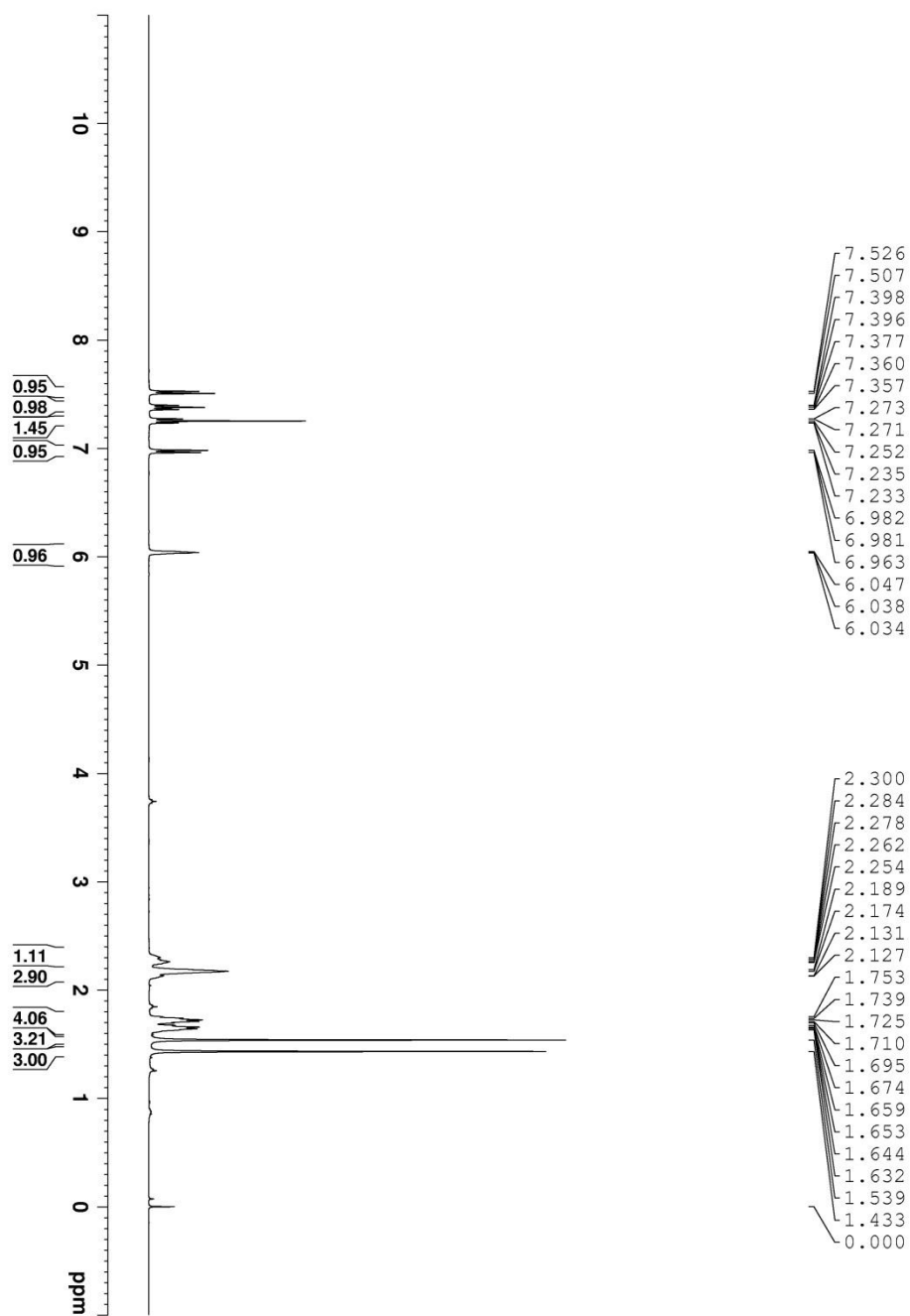
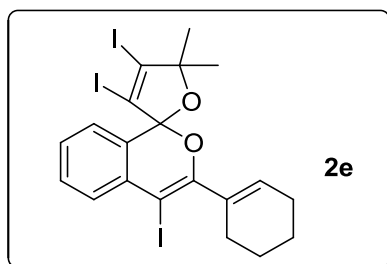


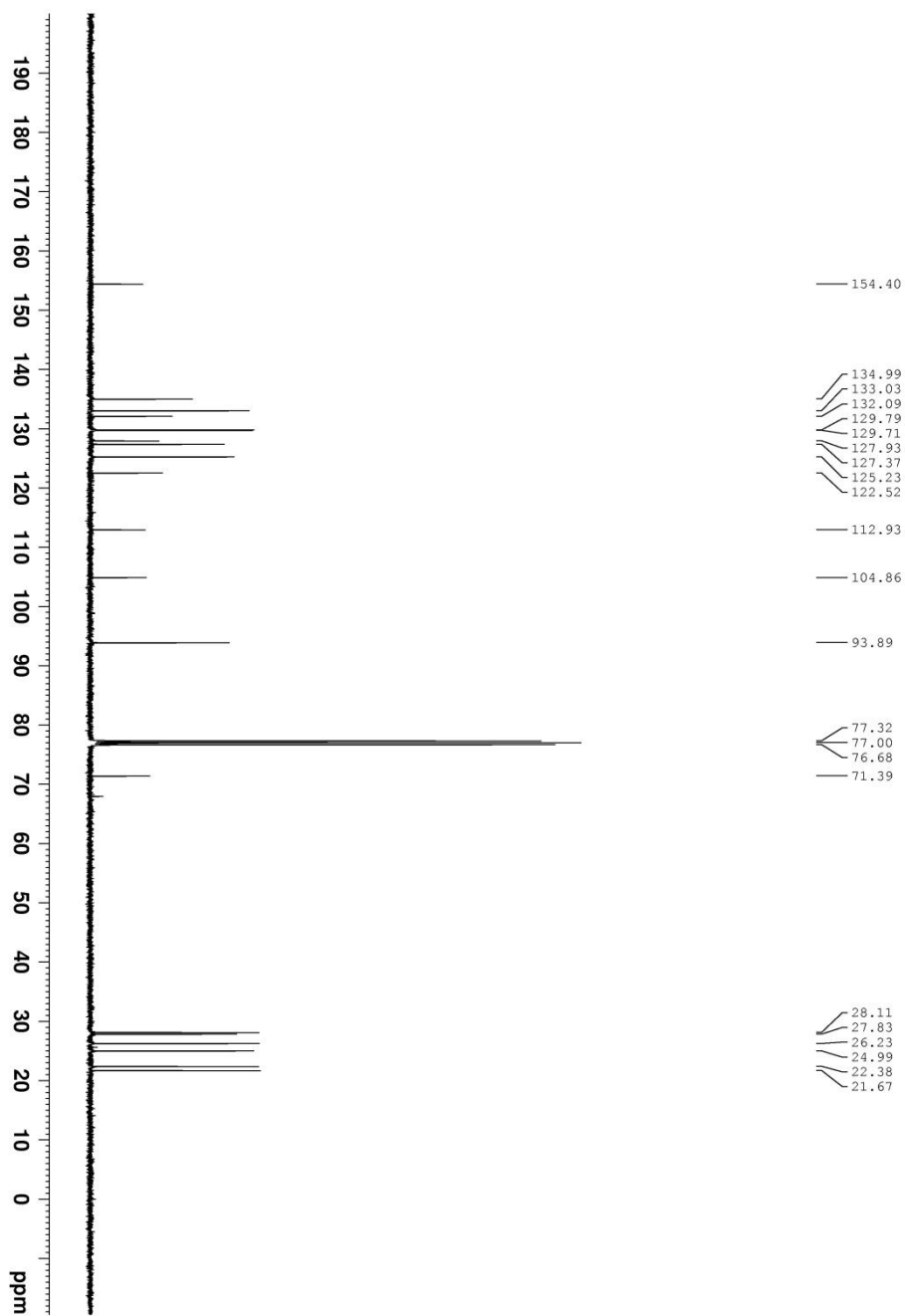
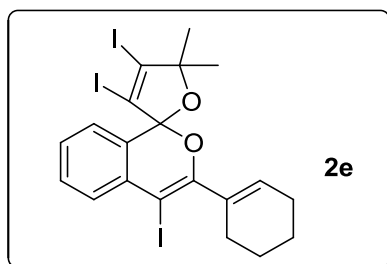


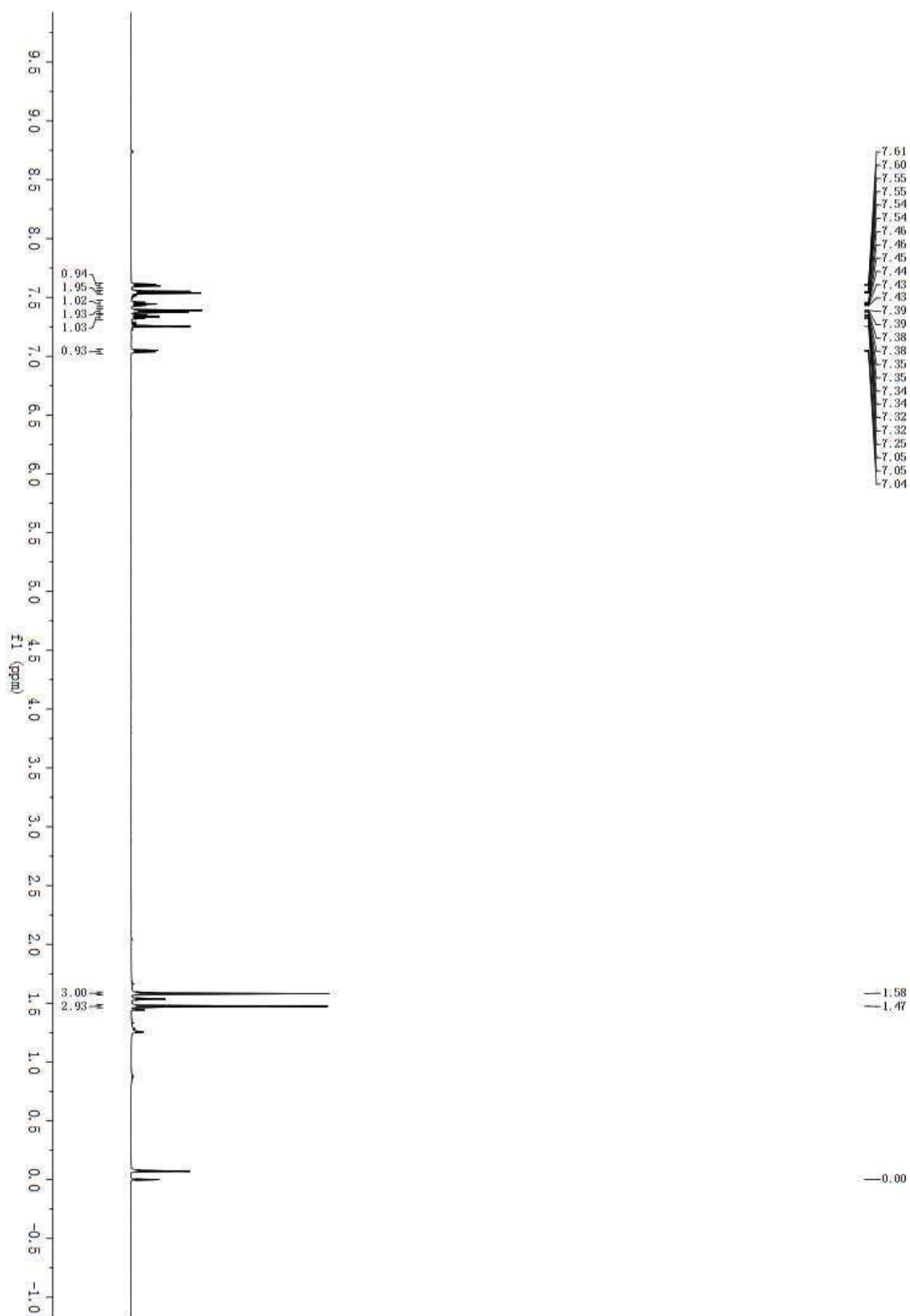
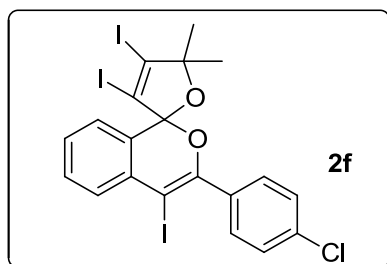


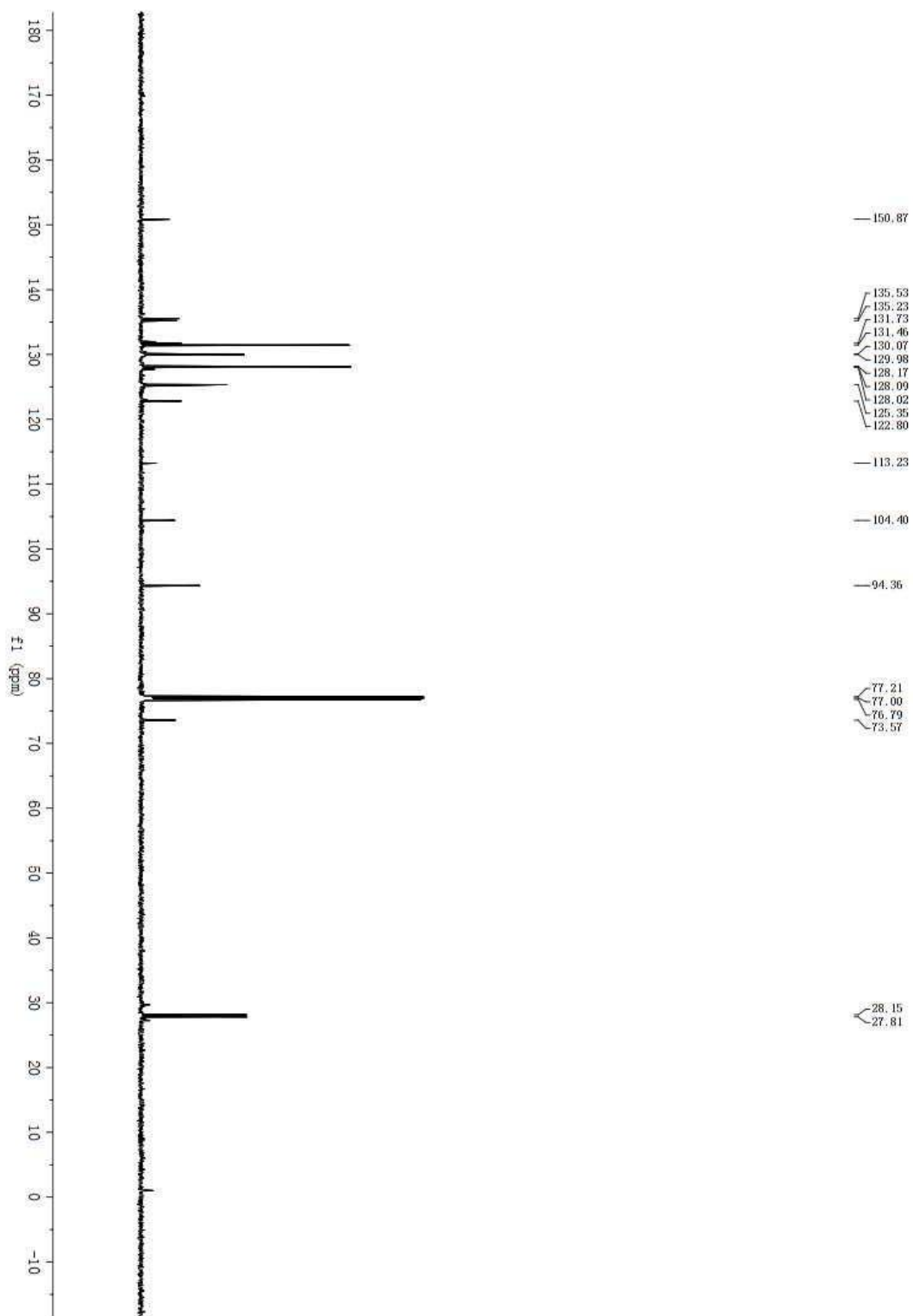
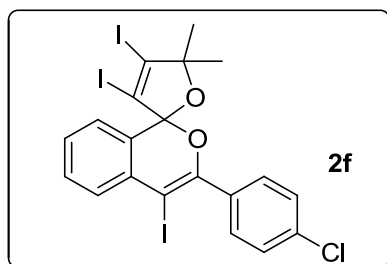


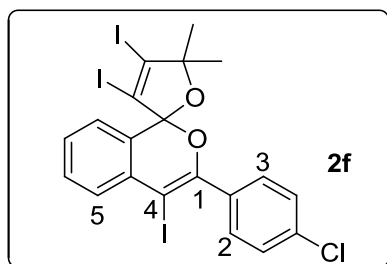




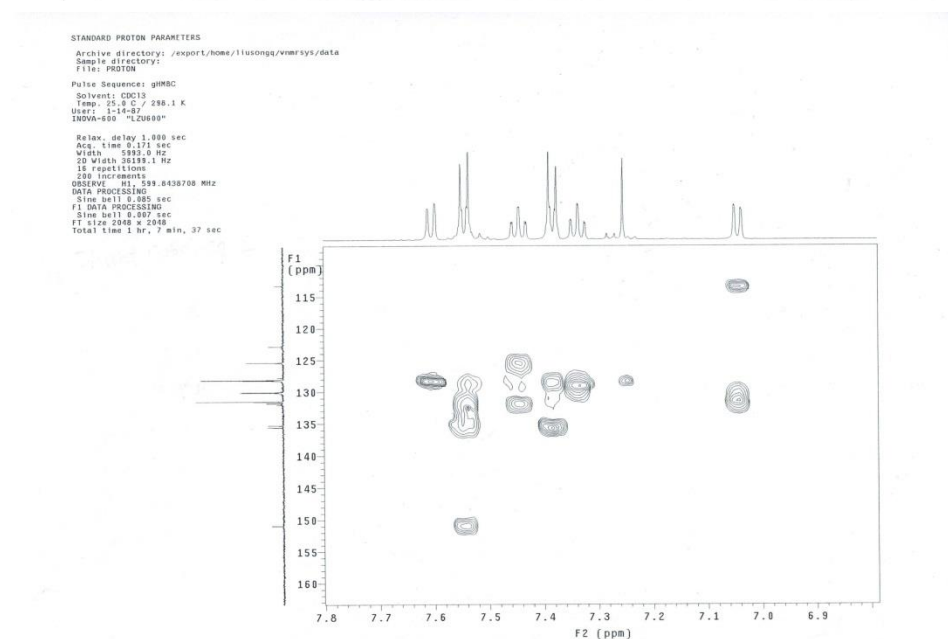
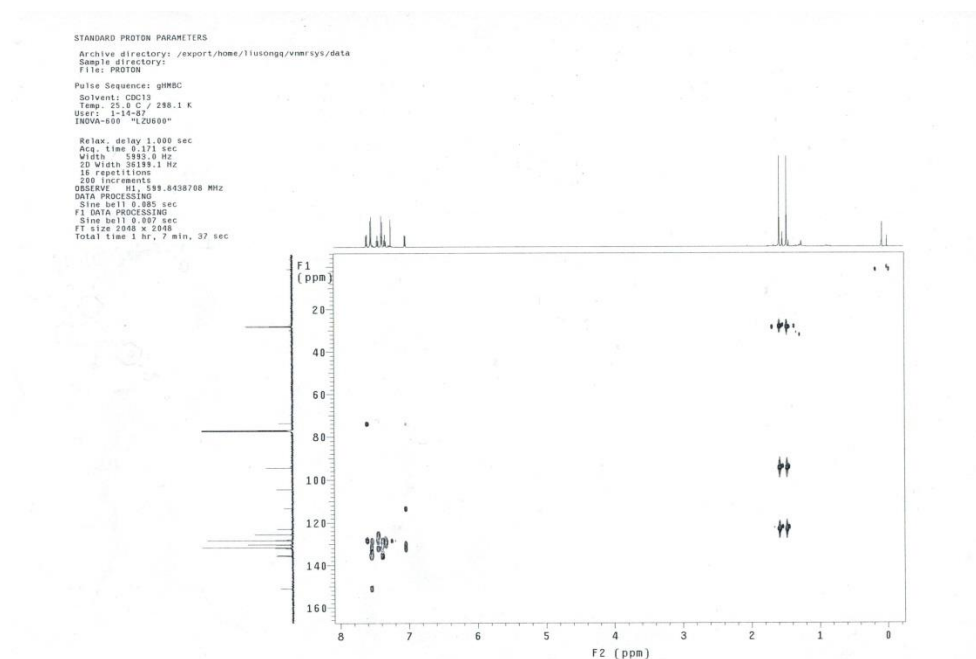


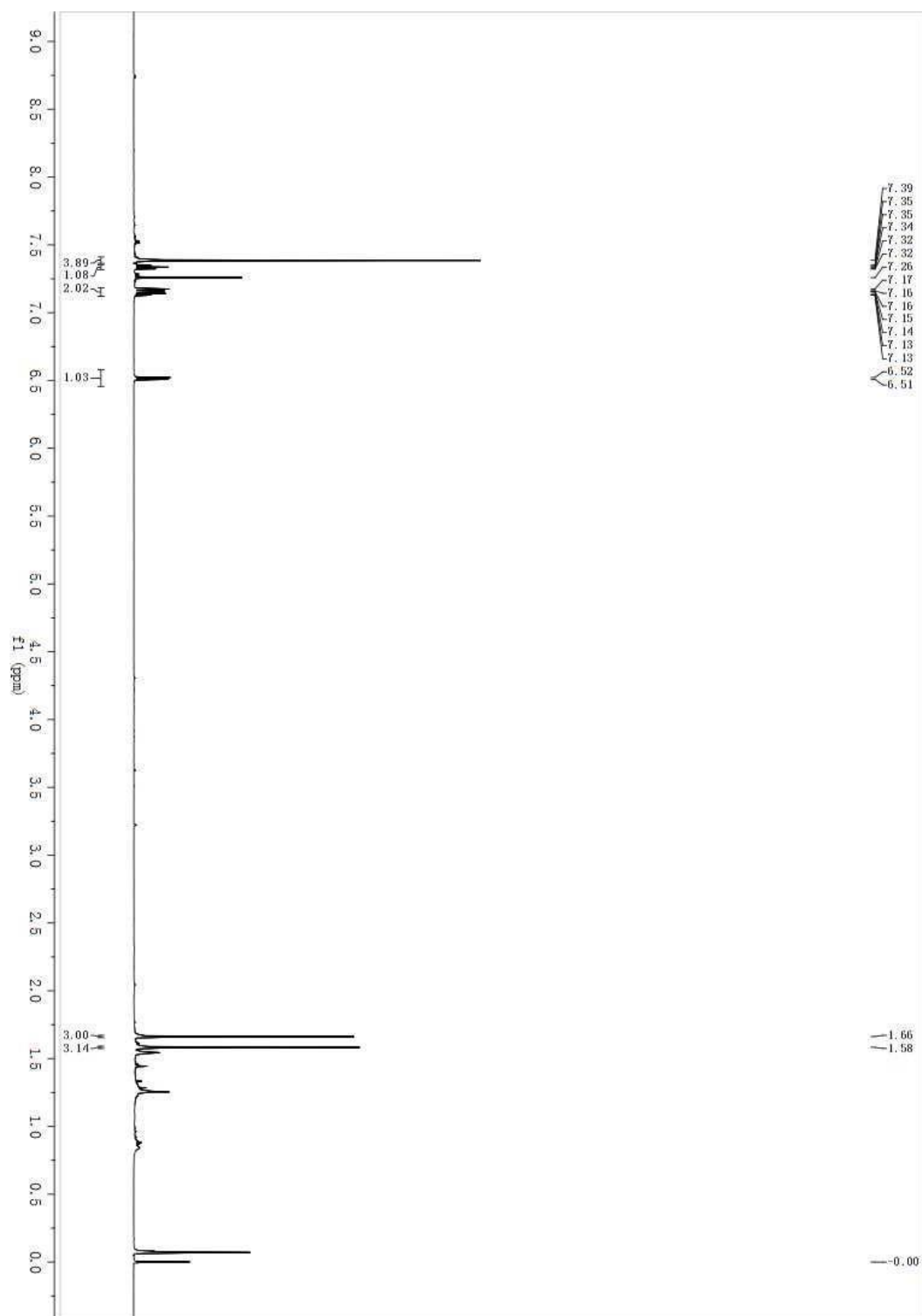
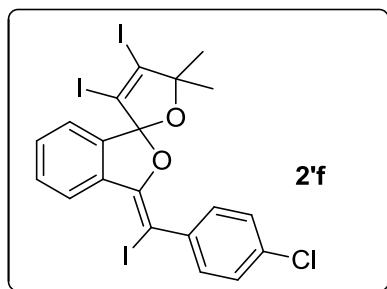


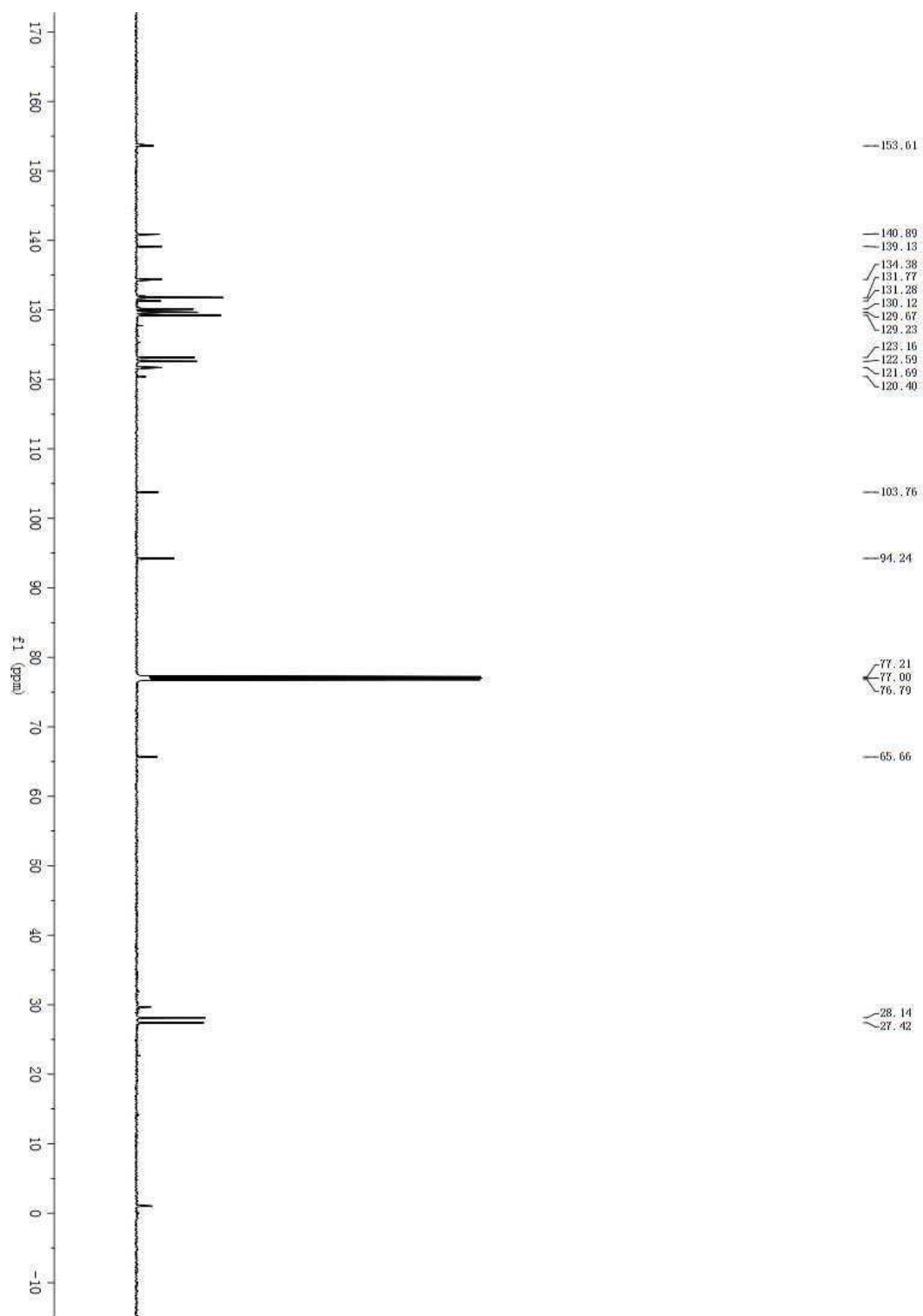
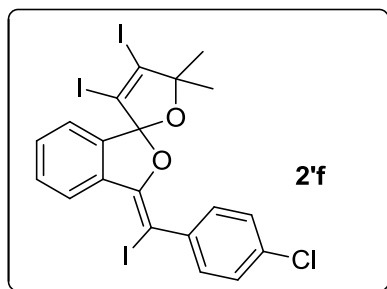


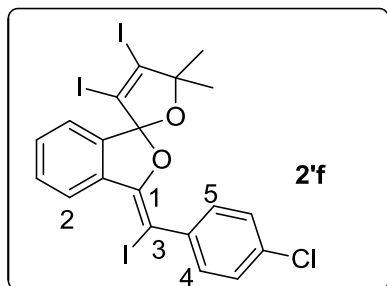


The HMBC spectrum correlations from δ_C 150.9 (C-1) to δ_H 7.46-7.45 (m, 2H) (H-2 and H-3), δ_C 73.6 (C-4) to δ_H 7.61-7.54 (m, 1H) (H-5) confirmed the 6-endo-dig structure of **2f**.









The HMBC spectrum correlations from δ_C 153.6 (C-1) to δ_H 6.52 (d, $J = 6.0$ Hz, 1H), (H-2), δ_C 65.7 (C-3) to δ_H 7.39 (s, 4H) (containing H-4 and H-5) confirmed the 5-*exo-dig* structure of **2'f**

