Supporting information

Tandem [4 + 1 + 1] annulation and metal-free aerobic oxidative aromatization: straightforward synthesis of highly substituted phenols from one aldehyde and two ketones

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I. General

All reagents were purchased from commercial sources and used without treatment, unless otherwise indicated. The products were purified by column chromatography over silica gel (300–400 mesh). All reactions were monitored by TLC, which was performed on precoated aluminum sheets of silica gel 60 (F254). Melting points were uncorrected. $^1$H NMR and $^{13}$C NMR spectra were determined at ambient temperature on a Varian 500 MHz and 125 MHz, respectively, using TMS as internal standard. All shifts were given in ppm. IR spectra (KBr) were recorded on a Magna-560 FTIR spectrophotometer in the range of 400-4000 cm$^{-1}$. Mass spectra were measured on an Agilent 1100 LCMsD spectrometer. Elemental analyses were obtained on a VarioEL analyzer. Starting materials 1 are known compounds and prepared according to the literatures.$^1$

II. Synthesis of phenols 5 from ketene dithioacetals 1, aldehydes 2 and methyl ketones 3

Typical procedure for one-pot synthesis of phenols 5 (5a as example): To a well-stirred mixture of benzaldehyde 2a (0.11 mL, 1.1 mmol) with acetophenone 3a (0.128 mL, 1.1 mmol) was added $t$-BuOK (56 mg, 0.5 mmol) at room temperature. After the reaction mixture was stirred at room temperature for 0.5 h, a mixture of 2-(bis(ethylthio)methylene)-1-phenylbutane-1,3-dione 1a (294 mg, 1.0 mmol) and $t$-BuOK (392 mg, 3.5 equiv) in dry DMF (10 mL) was added and the resulting reaction mixture was stirred at room temperature for additional 2.5 h. After completion of the reaction as indicated by TLC, the reaction was quenched by saturated sodium chloride aqueous (20 mL), neutralized with dilute HCl aq., and extracted with dichloromethane (3 × 20 mL). The combined organic phase was
washed with water (3 × 20 mL), dried over MgSO₄ and concentrated in vacuo. The crude product was purified by flash chromatography (silica gel, petroleum ether : diethyl ether = 3:1) to give (3-(ethylthio)-5-hydroxybiphenyl-2,4-diyl) bis(phenylmethanone) 5a (293 mg, 67%) as a yellow oil.

III. Analytical data of phenols 5

(3-(Ethylthio)-5-hydroxybiphenyl-2,4-diyl)bis(phenylmethanone) (5a): Yellow oil; ¹H NMR (CDCl₃, 500 MHz) δ = 0.75 (t, J = 7.5 Hz, 3H), 2.44–2.49 (m, 2H), 7.06 (s, 1H), 7.16–7.18 (m, 3H), 7.24–7.26 (m, 2H), 7.28–7.32 (m, 2H), 7.41–7.45 (m, 3H), 7.56–7.59 (m, 1H), 7.61–7.63 (m, 2H), 7.83–7.85 (m, 2H), 8.04 (s, 1H); ¹³C NMR (CDCl₃, 125 MHz) δ = 197.9, 196.8, 156.2, 144.4, 138.5, 138.2, 137.9, 137.3, 133.4, 133.1, 132.4, 129.5 (2C), 129.3 (2C), 128.9 (3C), 128.5 (2C), 128.3 (2C), 128.2 (2C), 127.9, 118.5, 33.1, 13.9; IR (KBr) ν = 3294, 3060, 2971, 2870, 1666, 1586, 1397, 1230, 1176; ES−MS: calcd m/z 438.1, found 439.1 [(M + 1)]⁺; Anal. Calcd for C₂₈H₂₂O₃S: C, 76.69; H, 5.06. Found: C, 76.60; H, 5.10.

(4’-Chloro-3-(ethylthio)-5-hydroxybiphenyl-2,4-diyl)bis(phenylmethanone)
(5b): yellow oil; \(^1\)H NMR (CDCl\(_3\), 500 MHz) \(\delta = 0.77\) (t, \(J = 7.5\) Hz, 3H), 2.43–2.49 (m, 2H), 7.11 (s, 1H), 7.26–7.32 (m, 6H), 7.42–7.49 (m, 3H), 7.58–7.63 (m, 3H), 7.84 (d, \(J = 7.5\) Hz, 2H), 7.94 (s, 1H); \(^{13}\)C NMR (CDCl\(_3\), 125 MHz) \(\delta = 197.8, 196.6, 156.1, 142.9, 138.1, 137.8, 137.2, 136.9, 134.2, 133.6, 133.4, 132.5, 130.3\) (2C), 129.5 (2C), 129.3 (2C), 128.7 (2C), 128.5 (2C), 128.4 (2C), 118.4, 33.1, 14.0; IR (KBr) \(\nu = 3377, 2967, 2869, 1665, 1585, 1448, 1314, 1229\); ES–MS: calcd \(m/z\) 472.1, found 473.1 [(M + 1)]\(^+\); Anal. Calcd for C\(_{28}\)H\(_{21}\)ClO\(_3\)S: C, 71.10; H, 4.48. Found: C, 71.19; H, 4.39.

![Diagram](image)

(3-(Ethylthio)-5-hydroxy-4'-nitrobiphenyl-2,4-diyl)bis(phenylmethanone) (5c): yellow solid. Mp 218–220 °C; \(^1\)H NMR (CDCl\(_3\), 500 MHz) \(\delta = 0.75\) (t, \(J = 7.5\) Hz, 3H), 2.41 (q, \(J = 7.5\) Hz 2H), 7.15–7.18 (m, 1H), 7.33 (s, 1H), 7.37–7.41 (m, 6H), 7.51–7.54 (m, 2H), 7.73–7.76 (m, 3H), 8.06–8.07 (m, 2H), 10.55 (s, 1H); \(^{13}\)C NMR (CDCl\(_3\), 125 MHz) \(\delta = 198.1, 195.8, 154.9, 154.1, 145.4, 138.0, 137.9, 137.2, 135.2, 133.8, 133.6, 132.8, 131.9, 129.9\) (2C), 129.7, 129.4 (2C), 128.6 (2C), 128.5 (2C), 126.9, 125.2, 121.3, 120.4, 32.8, 14.1; IR (KBr) \(\nu = 3459, 3250, 3250, 2960, 2862, 1670, 1584, 1442, 1219\); ES–MS: calcd \(m/z\) 483.1, found 484.1 [(M + 1)]\(^+\); Anal. Calcd for C\(_{28}\)H\(_{21}\)NO\(_5\)S: C, 69.55; H, 4.38; N, 2.90. Found: C, 69.46; H, 4.30; N, 2.79.
(3-(Ethylthio)-5-hydroxy-4′-methylbiphenyl-2,4-diyl)bis(phenylmethanone) (5d): yellow solid. Mp 95–97 °C; ¹H NMR (CDCl₃, 500 MHz) δ = 0.75 (t, J = 7.5 Hz, 3H), 2.26 (s, 3H), 2.41–2.48 (m, 2H), 7.02 (d, J = 7.5 Hz, 2H), 7.09 (s, 1H), 7.18 (d, J = 7.5 Hz, 2H), 7.29–7.38 (m, 2H), 7.43–7.46 (m, 3H), 7.58 (t, J = 7.5 Hz, 1H), 7.64 (d, J = 7.5 Hz, 2H), 7.83 (d, J = 7.5 Hz, 2H) 7.99 (s, 1H); ¹³C NMR (CDCl₃, 125 MHz) δ = 198.1, 196.7, 156.3, 144.6, 138.4, 138.0, 137.9, 137.4, 135.6, 133.4, 133.0, 132.5, 129.4 (2C), 129.3 (2C), 128.9 (2C), 128.8 (2C), 128.5 (2C), 128.3 (2C), 127.7, 118.5, 33.1, 21.1, 14.0; IR (KBr) ν = 3266, 3058, 2963, 2866, 1666, 1584, 1447, 1227; ES–MS: calcd m/z 452.1, found 453.2 [(M + 1)]⁺; Anal. Caled for C₂₉H₂₄O₃S: C, 76.96; H, 5.35. Found: C, 76.85; H, 5.46.

(4-(Benzo[dl]1,3dioxol-5-yl)-2-(ethylthio)-6-hydroxy-1,3-phenylene)bis(phenyl methanone) (5e): yellow solid. Mp 61–63 °C; ¹H NMR (CDCl₃, 500 MHz) δ = 0.76 (t, J = 7.5 Hz, 3H), 2.44 (s, 2H), 5.90 (s, 2H), 6.65 (d, J = 8.0 Hz, 1H), 6.77 (d, J = 8.5 Hz, 1H), 7.06 (s, 1H), 7.20–7.26 (m, 2H), 7.31–7.34 (m, 2H), 7.37–7.47 (m, 2H), 7.58 (t, J = 7.0 Hz, 1H), 7.63 (d, J = 8.0 Hz, 2H), 7.82 (d, J = 8.0 Hz, 2H), 7.98 (s, 1H); ¹³C NMR (CDCl₃, 125 MHz) δ = 197.8, 196.8, 156.0, 147.4, 143.7, 138.1,
137.8, 137.1, 133.4, 133.1, 132.3, 129.4 (2C), 129.3 (2C), 128.4 (2C), 128.3 (2C), 128.0, 127.2, 125.3, 123.0, 118.3, 109.3, 108.0, 101.1, 33.0, 13.9; IR (KBr) \( \nu = 3386, 3061, 2965, 2779, 1664, 1585, 1495, 1240 \); ES–MS: calcd m/z 482.1, found 483.1 [(M + 1)\(^+\)]; Anal. Calcd for C\(_{29}\)H\(_{22}\)O\(_5\)S: C, 72.18; H, 4.60. Found: C, 72.27; H, 4.49.

![Structure image](image)

(3-(Ethylthio)-5-hydroxy-4′-methoxybiphenyl-2,4-diyl)bis(phenylmethanone) (5f): Yellow oil; \(^1\)H NMR (CDCl\(_3\), 500 MHz) \( \delta = 0.75 \) (t, \( J = 7.5 \) Hz, 3H), 2.41–2.47 (m, 2H), 3.74 (s, 3H), 6.76 (d, \( J = 9.0 \) Hz, 2H), 7.08 (s, 1H), 7.24 (t, \( J = 8.0 \) Hz, 2H), 7.31 (t, \( J = 8.0 \) Hz, 2H), 7.43–7.49 (m, 3H), 7.58–7.63 (m, 3H), 7.83 (d, \( J = 7.0 \) Hz, 2H), 8.05 (s, 1H); \(^{13}\)C NMR (CDCl\(_3\), 125 MHz) \( \delta = 198.2, 196.9, 159.4, 156.4, 144.2, 138.4, 137.9, 137.3, 133.4, 133.1, 132.6, 130.9 (2C), 130.2 (2C), 129.5 (2C), 129.3 (2C), 128.5 (2C), 128.3 (2C), 127.4, 118.4, 113.7, 55.1, 33.1, 14.0; IR (KBr) \( \nu = 3383, 3060, 2963, 1664, 1583, 1514, 1393, 1297, 1249 \); ES–MS: calcd m/z 468.1, found 469.1 [(M + 1)\(^+\)]; Anal. Calcd for C\(_{29}\)H\(_{24}\)O\(_4\)S: C, 74.34; H, 5.16. Found: C, 74.45; H, 5.07.

(2-(Ethylthio)-4-(furan-2-yl)-6-hydroxy-1,3-phenylene)bis(phenylmethanone) (5g): Yellow solid. Mp 99–101 °C; \(^1\)H NMR (CDCl\(_3\), 500 MHz) \( \delta = 0.74 \) (t, \( J = 7.5 \) Hz, 3H), 2.36–2.47 (m, 2H), 6.27–6.28 (m, 1H), 6.47 (d, \( J = 3.5 \) Hz, 1H), 7.34 (s, 1H),
7.39–7.46 (m, 4H), 7.49 (s, 1H), 7.52–7.58 (m, 2H), 7.77–7.80 (m, 4H), 8.12 (s, 1H); 
\(^{13}\)C NMR (CDCl\(_3\), 125 MHz) \(\delta = 197.8, 196.8, 156.5, 149.6, 143.3, 138.3, 137.6, 134.2, 133.3, 132.8, 132.0, 129.4 (2C), 129.2 (2C), 128.5 (2C), 128.4 (2C), 128.3, 128.0, 114.2, 112.0, 110.9, 33.1, 13.9; IR (KBr) \(\nu = 3253, 3061, 2959, 2866, 1665, 1587, 1448, 1312, 1231\); ES–MS: calcd \(m/z\) 428.1, found 429.1 [(M + 1)]\(^+\); Anal. Calcd for C\(_{26}\)H\(_{20}\)O\(_4\)S: C, 72.88; H, 4.70. Found: C, 72.80; H, 4.79.

(4-Benzoyl-4’-chloro-3-(ethylthio)-5-hydroxybiphenyl-2-yl)(4-chlorophenyl)methanone (5h): yellow solid. Mp 96–98 °C; \(^1\)H NMR (CDCl\(_3\), 500 MHz) \(\delta = 0.78 (t, J = 7.5\) Hz, 3H), 2.45 (s, 2H), 7.06 (s, 1H), 7.22 (s, 4H), 7.30 (d, \(J = 8.5\) Hz, 2H), 7.45–7.49 (m, 2H), 7.55 (d, \(J = 8.5\) Hz, 2H), 7.60 (t, \(J = 7.5\) Hz, 1H), 7.82 (d, \(J = 7.5\) Hz, 2H), 7.94 (s, 1H); \(^{13}\)C NMR (CDCl\(_3\), 125 MHz) \(\delta = 197.7, 195.4, 156.0, 142.7, 139.8, 137.8, 136.7, 136.6, 136.0, 134.4, 133.7, 132.2, 130.5 (2C), 130.2 (2C), 129.4 (2C), 128.9, 128.8 (2C), 128.6 (2C), 128.5 (2C), 118.4, 33.1, 14.0; IR (KBr) \(\nu = 3303, 2928, 2870, 1666, 1585, 1229, 1092\); ES–MS: calcd \(m/z\) 506.1, found 507.1 [(M + 1)]\(^+\); Anal. Calcd for C\(_{28}\)H\(_{20}\)Cl\(_2\)O\(_3\)S: C, 66.28; H, 3.97. Found: C, 66.19; H, 4.08.
(4-Benzoyl-4’-chloro-3-(ethylthio)-5-hydroxybiphenyl-2-yl)(p-tolyl)methanone (5i): yellow solid. Mp 93–95 °C; ¹H NMR (CDCl₃, 500 MHz) δ = 0.75 (t, J = 7.5 Hz, 3H), 2.32 (s, 3H), 2.42–2.52 (m, 2H), 7.00 (s, 1H), 7.10–7.18 (m, 6H), 7.24–7.26 (m, 1H), 7.44 (t, J = 7.5 Hz, 2H), 7.52 (d, J = 7.5 Hz, 2H), 7.57 (t, J = 7.0 Hz, 1H), 7.83 (d, J = 7.5 Hz, 2H); ¹³C NMR (CDCl₃, 125 MHz) δ = 197.0, 196.9, 155.0, 144.5, 141.8, 137.4, 137.0, 136.7, 135.2, 133.8, 133.6, 131.0, 130.5, 130.1 (2C), 129.5 (2C), 129.4 (2C), 129.1 (2C), 128.5 (2C), 128.2 (2C), 118.1, 33.0, 21.6, 13.8; IR (KBr) ν = 3388, 3059, 2964, 1662, 1578, 1445, 1312, 1228; ES–MS: calcd m/z 486.1, found 487.1 [(M + 1)+]; Anal. Calcd for C₂₉H₂₃ClO₃S: C, 71.52; H, 4.76. Found: C, 71.63; H, 4.82.

(4-Benzoyl-4’-chloro-3-(ethylthio)-5-hydroxybiphenyl-2-yl)(furan-2-yl)methanone (5j): yellow solid. Mp 97–99 °C; ¹H NMR (CDCl₃, 500 MHz) δ = 0.85 (t, J = 7.5 Hz, 3H), 2.48–2.55 (m, 2H), 6.38 (d, J = 3.0 Hz, 1H), 6.79 (s, 1H), 7.06 (s, 1H), 7.26–7.32 (m, 4H), 7.45–7.48 (m, 3H), 7.60 (t, J = 7.5 Hz, 1H), 7.83 (d, J = 7.5 Hz, 2H), 7.97 (s, 1H); ¹³C NMR (CDCl₃, 125 MHz) δ = 197.9, 183.7, 156.5, 153.4, 146.8, 144.6, 138.3, 138.2, 136.3, 133.3, 133.1, 129.3, 128.7 (2C), 128.5, 128.4 (2C), 128.2 (2C), 128.0, 127.7, 119.3, 118.4, 112.2, 33.0, 14.0; IR (KBr) ν = 3312, 3061, 2864, 1662, 1584, 1453, 1314, 1227; ES–MS: calcd m/z 462.1, found 463.1 [(M + 1)+]; Anal. Calcd for C₂₆H₁₉ClO₄S: C, 67.45; H, 4.14. Found: C, 67.54; H, 4.06.
Ethyl 2-benzoyl-4’-chboro-3-(ethylthio)-5-hydroxybiphenyl-4-carboxylate (5k):
yellow oil; \(^1\)H NMR (CDCl\(_3\), 500 MHz) \(\delta = 1.02 (t, J = 7.5 \text{ Hz}, 3\text{H}), 1.15 (t, J = 7.0 \text{ Hz}, 3\text{H}), 2.75 (s, 2\text{H}), 4.50 (q, J = 7.0 \text{ Hz}, 2\text{H}), 7.01 (s, 1\text{H}), 7.16 (s, 4\text{H}), 7.31 (t, J = 7.0 \text{ Hz}, 2\text{H}), 7.44 (t, J = 7.0 \text{ Hz}, 1\text{H}), 7.59 (d, J = 8.0 \text{ Hz}, 2\text{H}), 10.46 (s, 1\text{H}); \(^{13}\)C NMR (CDCl\(_3\), 125 MHz) \(\delta = 195.5, 169.7, 160.7, 144.2, 138.4, 138.0, 136.6, 134.3, 133.7, 133.0, 130.2 (2\text{C}), 129.1 (2\text{C}), 128.4 (2\text{C}), 128.3 (2\text{C}), 119.5, 117.5, 62.4, 33.1, 14.0, 13.9; IR (KBr) \(\nu = 3385, 3060, 2964, 2865, 1664, 1589, 1446, 1241; ES–MS: calcd m/z 440.1, found 441.1 [(M + 1)\(^+\)]; Anal. Caled for C\(_{24}\)H\(_{21}\)ClO\(_4\)S: C, 65.37; H, 4.80. Found: C, 65.28; H, 4.89.

2-Benzoyl-4’-chboro-3-(ethylthio)-5-hydroxybiphenyl-4-carbonitrile (5l):
yellow oil; \(^1\)H NMR (CDCl\(_3\), 500 MHz) \(\delta = 1.14 (t, J = 7.5 \text{ Hz}, 3\text{H}), 2.91 (s, 2\text{H}), 7.00 (s, 1\text{H}), 7.13–7.19 (m, 4\text{H}), 7.34–7.39 (m, 3\text{H}), 7.47–7.52 (m, 1\text{H}), 7.59 (d, J = 8.0 \text{ Hz}, 2\text{H}); \(^{13}\)C NMR (CDCl\(_3\), 125 MHz) \(\delta = 195.3, 159.4, 145.1, 137.9, 137.3, 136.8, 136.2, 134.8, 133.7, 130.0 (2\text{C}), 129.5 (2\text{C}), 129.3 (2\text{C}), 128.6 (2\text{C}), 117.9, 114.6, 106.1, 32.0, 14.5; IR (KBr) \(\nu = 3422, 2958, 2859, 1653, 1578, 1489, 1393, 1260; ES–MS: calcd m/z 393.1, found 394.1 [(M + 1)\(^+\)]; Anal. Calcd for
C$_{22}$H$_{16}$ClNO$_2$S: C, 67.08; H, 4.09; N, 3.56. Found: C, 67.20; H, 4.00; N, 3.61.

1-(2-Benzoyl-4'-chloro-3-(ethylthio)-5-hydroxybiphenyl-4-yl)ethanone (5m):

Yellow oil; $^1$H NMR (CDCl$_3$, 500 MHz) $\delta = 0.99$ (t, $J = 7.5$ Hz, 3H), 2.64–2.66 (m, 2H), 2.95 (s, 3H), 7.02 (s, 1H), 7.16–7.19 (m, 4H), 7.33 (t, $J = 7.5$ Hz, 2H), 7.44–7.49 (m, 2H), 7.61 (d, $J = 7.5$ Hz, 2H); $^{13}$C NMR (CDCl$_3$, 125 MHz) $\delta = 206.5$, 195.9, 160.0, 144.5, 137.7, 136.6, 134.5, 133.7, 133.3, 130.2 (2C), 129.1 (2C), 129.0 (2C), 128.5 (3C), 125.3, 119.7, 33.9, 32.7, 14.2; IR (KBr) $\nu = 3251, 3064, 2970, 2870, 1669, 1581, 1494, 1316, 1216$; ES–MS: calcd $m/z$ 410.1, found 411.1 [(M + 1)$^+$]; Anal. Calcd for C$_{23}$H$_{19}$ClO$_3$S: C, 67.23; H, 4.66. Found: C, 67.40; H, 4.55.

4-Methoxyl-2'-ethylthio-3'-benzoyl-6'-hydroxy-4''-chloro p-terphenyl (5n):

Yellow oil; $^1$H NMR (CDCl$_3$, 500 MHz) $\delta = 0.74$ (t, $J = 7.5$ Hz, 3H), 2.20 (m, 2H), 3.87 (s, 3H), 5.31 (s, 1H), 7.01 (s, 1H), 7.06 (d, $J = 8.5$ Hz, 2H), 7.17 (d, $J = 8.0$ Hz, 2H), 7.22 (d, $J = 8.0$ Hz, 2H), 7.30–7.33 (m, 2H), 7.34–7.38 (m, 2H), 7.39–7.46 (m, 1H), 7.67 (d, $J = 8.5$ Hz, 2H); $^{13}$C NMR (CDCl$_3$, 125 MHz) $\delta = 196.8$, 159.6, 153.7, 139.7, 138.2, 137.6, 137.0, 133.6, 132.9, 132.0, 131.8, 131.7 (2C), 130.3 (2C), 129.3 (2C), 128.3 (2C), 128.2 (2C), 125.4, 117.0, 114.6 (2C), 55.2, 30.4, 14.0; IR (KBr) $\nu =
3415, 3060, 2835, 1651, 1444, 1245, 1173; ES−MS: calcd m/z 474.1, found 475.2 [(M + 1)]⁺; Anal. Calcd for C_{28}H_{23}ClO_{3}S: C, 70.80; H, 4.88. Found: C, 70.91; H, 4.80.

![Image](Ethylthio-5-hydroxybiphenyl-2-yl)(phenyl)methanone (5o): yellow oil; ¹H NMR (CDCl₃, 500 MHz) δ = 1.56 (t, J = 7.5 Hz, 3H), 2.80 (q, J = 7.5 Hz, 2H), 6.72 (d, J = 2.0 Hz, 1H), 6.95 (d, J = 2.0 Hz, 1H), 7.09–7.17 (m, 5H), 7.23–7.26 (m, 3H), 7.38 (t, J = 7.5 Hz, 1H), 7.60 (d, J = 7.5 Hz, 2H); ¹³C NMR (CDCl₃, 125 MHz) δ = 199.5, 156.6, 142.6, 139.4, 137.8, 136.5, 133.1, 129.5 (2C), 128.9 (2C), 128.2 (2C), 128.0 (2C), 127.5 (2C), 115.2, 114.9, 28.5, 13.9; IR (KBr) ν = 3395, 3055, 2978, 1627, 1589, 1267, 1218, 1068; ES−MS: calcd m/z 334.1, found 335.1 [(M + 1)]⁺; Anal. Calcd for C_{21}H_{18}O_{2}S: C, 75.42; H, 5.43. Found: C, 75.32; H, 5.40.

![Image](4'-Chloro-3-(ethylthio)-5-hydroxybiphenyl-2-yl)(phenyl)methanone (5p): yellow oil; ¹H NMR (CDCl₃, 500 MHz) δ = 1.22 (t, J = 7.5 Hz, 3H), 2.86 (q, J = 7.5 Hz, 2H), 5.99 (s, 1H), 6.69 (s, 1H), 6.98 (s, 1H), 7.14 (s, 4H), 7.19–7.33 (m, 2H), 7.45–7.48 (m, 1H), 7.62–7.64 (m, 2H); ¹³C NMR (CDCl₃, 125 MHz) δ = 198.1, 156.3, 141.3, 137.8, 137.7, 136.7, 133.7, 133.3, 132.6, 130.2 (2C), 129.5 (2C), 128.3
(2C), 128.2 (2C), 115.6, 114.8, 28.7, 13.9; IR (KBr) $\nu = 3386, 3060, 2869, 1645$, $1588, 1309, 1169$; ES−MS: calcd $m/z$ 368.1, found 369.1 [(M + 1)$^+$]; Anal. Calcd for C$_{21}$H$_{17}$ClO$_2$S: C, 68.38; H, 4.65. Found: C, 68.26; H, 4.72.

IV. References

V. Copies of NMR spectra for new compounds 5

5a
5h
\[ \text{5k} \]
5m