Aluminum Chloride-Catalyzed C-Alkylation of Pyrrole and Indole with Chalcone and Bis-Chalcone Derivatives

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SUPPLEMENTAL MATERIAL

General procedure for the synthesis of 3a-i:

A mixture of pyrrole (**2**) (10 mmol) and chalcone (**1a-i**) (1 mmol) and AlCl₃ (10%, mol) was stirred at room temperature for 24 h. until starting material disappeared on TLC. After completion of the reaction, the catalyst was separated by filtration. The reaction mixture was then diluted with water and extracted with CHCl₃. Subsequently, the organic layer was dried over anhydrous sodium sulfate. Evaporating of the solvent under reduced pressure gave the corresponding viscous oil products.

1,3-di(furan-2-yl)-3-(1H-pyrrol-2-yl)propan-1-one (3a). Viscous oil; Yield (84%). ¹H-NMR (400 MHz, CDCl₃) δ (ppm): 8.63 (s, 1H), 7.59 (br s, 1H), 7.40 (br s, 1H), 7.23 (d, *J* = 3.2 Hz, 1H), 6.71 (t, *J* = 1.2 Hz, 1H), 6.56 (t, *J* = 1.6 Hz, 1H), 6.33 (t, *J* = 1.4 Hz, 1H), 6.18-6.14 (m, 2H), 5.98 (br s, 1H), 4.89 (t, *J* = 7.0, Hz, 1H), 3.58 (dd, *J* = 6.4; 4.0; 2.4 Hz, 2H). ¹³C-NMR (100 MHz, CDCl₃) δ (ppm): 187.4, 157.4, 152.5, 151.5, 146.7, 141.6, 131.5, 117.2, 112.5, 110.3 (2C), 105.5, 105.3, 44.1, 33.4. Anal. Calcd for C₁₅H₁₃NO₃: C, 70.58; H, 5.13; N, 5.49. Found: C, 70.46; H, 5.09; N, 5.37.

1-(furan-2-yl)-3-phenyl-3-(1H-pyrrol-2-yl)propan-1-one (3b). Viscous oil; Yield (89%). ¹H-NMR (400 MHz, CDCl₃) δ (ppm): 8.36 (s, 1H), 7.33 (s, 4H), 7.28 (m, 2H), 7.21 (d, *J* = 3.6 Hz, 1H), 6.67 (br s, 1H), 6.54 (br s, 1H), 6.13 (br s, 1H), 5.92 (br s, 1H), 4.78 (t, *J* =

6.8, Hz, 1H), 3.69 (dd, $J = 16.8, 8.4$ Hz, 1H), 3.48 (dd, $J = 17.0, 6.0$ Hz, 1H). ^{13}C -NMR (100 MHz, CDCl_3) δ (ppm): 190.4, 156.8, 148.5, 140.6, 130.3, 128.1 (2C), 126.9 (2C), 125.8, 121.0, 118.4, 112.6, 108.2, 107.6, 42.5, 38.9. Anal. Calcd for $\text{C}_{17}\text{H}_{15}\text{NO}_2$: C, 79.96; H, 5.70; N, 5.28. Found: C, 78.98; H, 5.67; N, 5.16.

1-(furan-2-yl)-3-(4-methoxyphenyl)-3-(1H-pyrrol-2-yl)propan-1-one (3c). Viscous oil; Yield (95%). ^1H -NMR (400 MHz, CDCl_3) δ (ppm): 8.33 (br s, 1H), 7.57 (d, $J = 7.6$ Hz, 1H), 7.23 (d, $J = 8.4$ Hz, 2H), 7.19 (d, $J = 3.6$ Hz, 1H), 6.87 (d, $J = 8.8$ Hz, 2H), 6.70 (br s, 1H), 6.53 (d, $J = 1.6$ Hz, 1H), 6.13 (dd, $J = 5.6, 2.8$ Hz, 1H), 5.92 (br s, 1H), 4.72 (t, $J = 7.2$ Hz, 1H), 3.82 (s, 3H), 3.65 (dd, $J = 16.8, 8.0$ Hz, 1H), 3.46 (dd, $J = 16.8, 6.4$ Hz, 1H). ^{13}C -NMR (100 MHz, CDCl_3) δ (ppm): 198.5, 158.1, 152.3, 146.5, 135.4, 129.8, 129.0 (2C), 117.4, 117.1, 114.0 (2C), 112.3, 107.8, 105.3, 55.2, 44.9, 38.3. Anal. Calcd for $\text{C}_{18}\text{H}_{17}\text{NO}_3$: C, 73.20; H, 5.80; N, 4.74. Found: C, 73.98; H, 5.67; N, 4.69.

1-(furan-2-yl)-3-(1H-pyrrol-2-yl)-3-p-tolylpropan-1-one (3d). Viscous oil; Yield (93%). ^1H -NMR (400 MHz, CDCl_3) δ (ppm): 8.34 (s, 1H), 7.59 (d, $J = 0.8$ Hz, 1H), 7.22 (d, $J = 8.0$ Hz, 2H), 7.16 (d, $J = 7.6$ Hz, 2H), 7.11 (d, $J = 3.6$ Hz, 1H), 6.67 (d, $J = 1.6$ Hz, 1H), 6.54 (dd, $J = 3.6, 1.6$ Hz, 1H), 6.13 (dd, $J = 6.0, 2.8$ Hz, 1H), 5.93 (br s, 1H), 4.75 (t, $J = 6.8$ Hz, 1H), 3.68 (dd, $J = 17.0, 8.0$ Hz, 1H), 3.47 (dd, $J = 16.8, 6.0$ Hz, 1H), 2.36 (s, 3H). ^{13}C -NMR (100 MHz, CDCl_3) δ (ppm): 192.6, 152.8, 148.8, 137.6, 135.3, 130.1, 129.1 (2C), 127.3 (2C), 121.6, 118.1, 112.5, 108.5, 108.2, 42.4, 38.9, 24.6. Anal. Calcd for $\text{C}_{17}\text{H}_{18}\text{NO}_2$: C, 77.40; H, 6.13; N, 5.01. Found: C, 76.98; H, 6.07; N, 4.98.

3-(1H-pyrrol-2-yl)-1,3-di(thiophen-2-yl)propan-1-one (3e). Viscous oil; Yield (91%). ^1H -NMR (400 MHz, CDCl_3) δ (ppm): 8.48 (br s, 1H), 7.80 (d, $J = 2.8$ Hz, 1H), 7.70 (d, $J = 4.4$ Hz, 1H), 7.24 (d, $J = 4.4$ Hz, 1H), 7.18 (d, $J = 4.0$ Hz, 1H), 7.00 (m, 2H), 6.73 (br s, 1H), 6.21 (br s, 1H), 6.10 (br s, 1H), 5.09 (t, $J = 7.2$ Hz, 1H), 3.79 (dd, $J = 16.8, 7.2$ Hz, 1H), 3.69 (dd, $J = 16.8, 6.0$ Hz, 1H). ^{13}C -NMR (100 MHz, CDCl_3) δ (ppm): 191.2, 146.6, 144.0, 140.1,

136.6, 134.2, 133.1, 132.5, 131.9, 128.9, 120.8, 120.4, 119.8, 46.8, 35.1. Anal. Cald for $C_{15}H_{13}NOS_2$: C, 62.69; H, 4.56; N, 4.87. Found: C, 62.58; H, 4.47; N, 4.79.

1-(4-chlorophenyl)-3-(1H-pyrrol-2-yl)-3-(thiophen-2-yl)propan-1-one (3f).

Viscous oil; Yield (89%). 1H -NMR (400 MHz, $CDCl_3$) δ (ppm): 8.38 (br s, 1H), 7.56 (br s, 1H), 7.28-7.16 (m, 7H), 6.52 (br s, 1H), 5.71 (br s, 1H), 4.63 (t, $J = 7.2$ Hz, 1H), 3.55 (dd, $J = 17.0, 7.6$ Hz, 1H), 3.30 (dd, $J = 16.8, 6.0$ Hz, 1H). ^{13}C -NMR (100 MHz, $CDCl_3$) δ (ppm): 192.1, 142.8, 138.6, 134.5, 133.8, 131.4, 130.3, 129.2 (2C), 128.5 (2C), 128.1, 117.9, 108.5, 107.6, 43.9, 39.8. Anal. Cald for $C_{17}H_{14}ClNOS$: C, 64.65; H, 4.47; N, 4.44. Found: C, 64.58; H, 4.37; N, 4.41.

3-(1H-pyrrol-2-yl)-3-(thiophen-2-yl)-1-p-tolylpropan-1-one (3g). Viscous oil; Yield (93%).

1H -NMR (400 MHz, $CDCl_3$) δ (ppm): 8.41 (br s, 1H), 7.83 (d, $J = 8.8$ Hz, 2H), 7.63 (d, $J = 8.4$ Hz, 2H), 7.20 (d, $J = 5.2$ Hz, 1H), 6.92 (m, 2H), 6.69 (br s, 1H), 6.29 (br s, 1H), 6.08 (br s, 1H), 5.11 (t, $J = 6.4$ Hz, 1H), 3.78 (dd, $J = 17.6, 7.6$ Hz, 1H), 3.66 (dd, $J = 17.4, 6.0$ Hz, 1H), 2.39 (s, 3H). ^{13}C -NMR (100 MHz, $CDCl_3$) δ (ppm): 199.9, 144.8, 142.6, 133.5, 130.8, 129.0 (2C), 128.8 (2C), 127.1, 126.9, 118.8, 108.4, 108.1, 44.1, 37.5, 24.0. Anal. Cald for $C_{18}H_{17}NOS$: C, 73.19; H, 5.80; N, 4.74. Found: C, 73.08; H, 5.78; N, 4.67.

3-(4-methoxyphenyl)-3-(1H-pyrrol-2-yl)-1-(thiophen-2-yl)propan-1-one (3h). Viscous oil;

Yield (84%). 1H -NMR (400 MHz, $CDCl_3$) δ (ppm): 8.52 (br s, 1H), 7.98 (d, $J = 8.0$ Hz, 2H), 7.11 (m, 1H), 7.00 (d, $J = 8.0$ Hz, 2H), 6.89 (m, 1H), 6.70 (m, 1H), 6.24 (m, 1H), 6.18 (m, 1H), 6.04 (m, 1H), 5.15 (t, $J = 6.8$ Hz, 1H), 3.91 (s, 3H), 3.81 (dd, $J = 17.2, 8.0$ Hz, 2H, A), 3.69 (dd, $J = 17.2, 6.0$ Hz, 2H, B). ^{13}C -NMR (100 MHz, $CDCl_3$) δ (ppm): 197.0, 163.7, 146.7, 134.1, 130.4 (2C), 128.5, 126.7, 124.7, 123.9, 117.1, 113.8 (2C), 108.2, 107.0, 55.5, 46.0, 34.8. Anal. Cald for $C_{18}H_{17}NO_2S$: C, 69.43; H, 5.50; N, 4.50. Found: C, 64.38; H, 5.47; N, 4.4.

3-(1H-pyrrol-2-yl)-1-(thiophen-2-yl)-3-p-tolylpropan-1-one (3i). Viscous oil; Yield (86%).

¹H-NMR (400 MHz, CDCl₃) δ (ppm): 8.38 (br s, 1H), 7.76 (d, *J* = 3.2 Hz, 1H), 7.65 (d, *J* = 4.8 Hz, 1H), 7.24-7.15 (m, 5H), 6.69 (br s, 1H), 6.23 (d, *J* = 2.8 Hz, 1H), 5.97 (br s, 1H), 4.79 (t, *J* = 6.8 Hz, 1H), 3.78 (dd, *J* = 16.8, 8.0 Hz, 1H), 3.57 (dd, *J* = 16.8, 6.0 Hz, 1H), 2.39 (s, 3H). ¹³C-NMR (100 MHz, CDCl₃) δ (ppm): 191.9, 144.1, 139.6, 136.5, 134.5, 134.0, 132.1, 129.3, 129.2, 128.1, 127.9, 117.1, 108.3, 107.8, 105.4, 45.9, 39.1, 21.0. Anal. Calcd for C₁₈H₁₇NOS: C, 73.19; H, 5.80; N, 4.74. Found: C, 75.98; H, 5.77; N, 4.68.

General procedure for the synthesis of 4a-f

To a mixture of pyrrole (2) (1 mmol) and chalcone (1) (3 mmol) in CH₃CN (5 mL) and AlCl₃ (10%, w/w) was added and the mixture was stirred at room temperature for 3 h. The reaction was followed by TLC. After completion of the reaction, the catalyst was separated by filtration. The reaction mixture was then diluted with water and extracted with CHCl₃. Subsequently, the organic layer was dried over anhydrous sodium sulfate. Evaporating of the solvent under reduced pressure gave the corresponding viscous oil products.

3,3'-(1H-pyrrole-2,5-diyl)bis(1,3-bis(4-methoxyphenyl)propan-1-one) (4a). Viscous oil;

Yield (85%). ¹H-NMR (400 MHz, CDCl₃) δ (ppm): 8.53 (br s, 1H), 8.05 (d, *J* = 8.8 Hz, 4H), 7.87 (d, *J* = 8.4 Hz, 4H), 6.95 (d, *J* = 8.8 Hz, 4H), 6.84 (d, *J* = 8.4 Hz, 4H), 5.79 (d, *J* = 2.4 Hz, 1H), 5.75 (d, *J* = 4.0 Hz, 1H), 4.76 (t, *J* = 6.8 Hz, 2H), 3.79 (s, 12H), 3.65 (dd, *J* = 17.2, 7.6 Hz, 2H), 3.45 (dd, *J* = 16.8, 6.4 Hz, 2H). ¹³C-NMR (100 MHz, CDCl₃) δ (ppm): 197.4 (2C), 163.5 (2C), 158.1 (2C), 138.1 (2C), 135.5 (2C), 130.7 (2C), 128.9 (4C), 127.7 (4C), 114.4 (4C), 114.0 (4C), 107.7 (2C), 55.3 (2C), 55.0 (2C), 44.8 (2C), 38.9 (2C). Anal. Calcd for C₃₈H₃₇NO₆: C, 75.60; H, 6.18; N, 2.32. Found: C, 74.98; H, 6.07; N, 2.28.

3,3'-(1H-pyrrole-2,5-diyl)bis(3-(4-chlorophenyl)-1-phenylpropan-1-one) (4b). Viscous oil;

Yield (93%). ¹H-NMR (400 MHz, CDCl₃) δ (ppm): 8.59 (br s, 1H), 8.04 (d, *J* = 8.0 Hz, 4H), 7.90 (d, *J* = 7.2 Hz, 2H), 7.62 (d, *J* = 7.2 Hz, 2H), 7.52 (d, *J* = 8.0 Hz, 2H), 7.43 (d, *J* = 8.0

Hz, 2H), 7.38 (d, $J = 8.0$ Hz, 2H), 7.21 (d, $J = 7.2$ Hz, 4H), 5.74 (d, $J = 5.6$ Hz, 2H), 4.79 (t, $J = 6.8$ Hz, 2H), 3.79 (dd, $J = 17.6, 7.2$ Hz, 2H), 3.58 (dd, $J = 16.8, 6.4$ Hz, 2H). ^{13}C -NMR (100 MHz, CDCl_3) δ (ppm): 198.5 (2C), 143.3 (2C), 141.8 (2C), 137.9 (2C), 136.4 (2C), 133.8 (2C), 129.7 (4C), 128.7 (4C), 128.5 (4C), 128.1 (4C), 108.0 (2C), 45.0 (2C), 38.8 (2C). Anal. Calcd for $\text{C}_{34}\text{H}_{27}\text{Cl}_2\text{NO}_2$: C, 73.91; H, 4.93; N, 2.54. Found: C, 73.77; H, 4.81; N, 2.48.

3,3'-(1H-pyrrole-2,5-diyl)bis(1,3-di(furan-2-yl)propan-1-one) (4c). Viscous oil; Yield (76%). ^1H -NMR (400 MHz, CDCl_3) δ (ppm): 8.65 (br s, 1H), 7.57 (br s, 2H), 7.33 (br s, 2H), 7.19 (d, $J = 3.2$ Hz, 2H), 6.53-6.51 (m, 2H), 6.28 (br s, 2H), 6.08 (t, $J = 3.2$ Hz, 2H), 5.79 (t, $J = 3.2$ Hz, 2H), 4.79 (t, $J = 7.2$ Hz, 2H), 3.71 (d, $J = 7.2$ Hz, 4H). ^{13}C -NMR (100 MHz, CDCl_3) δ (ppm): 187.1 (2C), 155.2 (2C), 152.5, 146.5 (2C), 141.5 (2C), 141.3, 130.9 (2C), 117.5, 112.3 (2C), 112.1, 110.2 (2C), 106.0 (2C), 105.2 (2C), 44.0, 42.9, 33.4, 31.8. Anal. Calcd for $\text{C}_{26}\text{H}_{21}\text{NO}_6$: C, 70.42; H, 4.77; N, 3.16. Found: C, 70.38; H, 4.62; N, 3.12.

3,3'-(1H-pyrrole-2,5-diyl)bis(1,3-di(thiophen-2-yl)propan-1-one) (4d). Viscous oil; Yield (82%). ^1H -NMR (400 MHz, CDCl_3) δ (ppm): 8.53 (br s, 1H), 7.74 (d, $J = 6.8$ Hz, 4H), 7.72 (d, $J = 6.8$ Hz, 4H), 7.48 (d, $J = 5.2$ Hz, 2H), 7.42-7.39 (m, 2H), 5.98 (br s, 2H), 5.08 (t, $J = 7.2$ Hz, 2H), 3.68 (dd, $J = 17.2, 5.2$ Hz, 2H), 3.61 (dd, $J = 17.0, 6.4$ Hz, 2H). ^{13}C -NMR (100 MHz, CDCl_3) δ (ppm): 190.5 (2C), 145.6 (2C), 144.0 (2C), 135.6 (2C), 134.2 (2C), 133.0 (2C), 130.9 (2C), 128.6 (2C), 120.8 (2C), 120.4 (2C), 110.3 (2C), 46.8 (2C), 35.1 (2C). Anal. Calcd for $\text{C}_{26}\text{H}_{21}\text{NO}_2\text{S}_4$: C, 61.51; H, 4.17; N, 2.76. Found: C, 61.36; H, 4.02; N, 2.73.

3,3'-(1H-pyrrole-2,5-diyl)bis(3-(4-chlorophenyl)-1-(thiophen-2-yl)propan-1-one) (4e). Viscous oil; Yield (85%). ^1H -NMR (400 MHz, CDCl_3) δ (ppm): 8.47 (br s, 1H), 7.55 (br s, 2H), 7.28-7.14 (m, 10H), 6.51-6.48 (m, 2H), 5.75-5.72 (m, 2H), 4.74 (t, $J = 6.8$ Hz, 2H), 3.55 (dd, $J = 16.8, 7.6$ Hz, 2H), 3.35 (dd, $J = 11.6, 6.0$ Hz, 2H). ^{13}C -NMR (100 MHz, CDCl_3) δ (ppm): 187.5 (2C), 152.5, 146.6 (2C), 146.2, 141.3, 133.4 (2C), 132.4, 129.3 (4C), 128.9

(4C), 117.6 (2C), 112.4 (2C), 105.4 (2C), 105.2 (2C), 44.5, 43.5, 38.7, 38.6. Anal. Cald for $C_{30}H_{23}Cl_2NO_2S_2$: C, 63.83; H, 4.11; N, 2.48. Found: C, 63.78; H, 4.05; N, 2.42.

3,3'-(1H-pyrrole-2,5-diyl)bis(1-(4-chlorophenyl)-3-(thiophen-2-yl)propan-1-one) (4f).

Viscous oil; Yield (84%). 1H -NMR (400 MHz, $CDCl_3$) δ (ppm): 8.44 (br s, 1H), 7.86-7.84 (m, 4H), 7.45-7.38 (m, 4H), 7.17-7.15 (m, 2H), 6.95-6.90 (m, 4H), 5.85 (dd, $J = 12.0$, 6.8 Hz, 2H), 5.03 (t, $J = 6.8$ Hz, 2H), 3.70 (dd, $J = 17.2$, 5.2 Hz, 2H), 3.58 (dd, $J = 17.2$, 6.0 Hz, 2H). ^{13}C -NMR (100 MHz, $CDCl_3$) δ (ppm): 189.2 (2C), 146.8 (2C), 136.2 (2C), 132.4 (2C), 130.3 (4C), 128.9 (4C), 127.6 (2C), 123.4 (2C), 121.7 (2C), 107.4 (2C), 105.2 (2C), 44.8, 43.5, 37.6, 37.1. Anal. Cald for $C_{30}H_{23}Cl_2NO_2S_2$: C, 63.83; H, 4.11; N, 2.48. Found: C, 63.66; H, 3.99; N, 2.38.

General Procedure for the Synthesis of Bis-Chalcone Derivatives (5a-g)

To a solution of acetophenone derivatives (2 mmol) in EtOH (20 ml) was added NaOH (2.5 M, 6 ml). The mixture was stirred for 3 min and was added teraftaldehyt (1 mmol) and was stirred at r.t. for 4 h. After the reaction, the precipitate was filtered and washed with ethanol several times. The solid was crystallized by methylene chloride / hexane (3/7).

3,3'-(1,4-phenylene)bis(1-(thiophene-3-yl)prop-2-en-1-one (5f). Yield (90%); mp: 219-221 °C. 1H -NMR (400 MHz, $CDCl_3$) δ (ppm): 8.85 (s, 2H), 7.97 (s, 4H), 7.95-7.91 (d, $J = 15.6$ Hz, 2H), 7.76-7.72 (d, $J = 15.6$ Hz, 2H), 7.70-7.69 (m, 4H). ^{13}C -NMR (100 MHz, $CDCl_3$) δ (ppm): 183.3, 143.3, 142.5, 137.0, 135.0, 129.7, 128.2, 127.5, 124.5. IR Spektrumu (KCl, cm^{-1}): 3077, 1656, 1600, 1511, 1423, 1396, 1230, 1203, 1072, 1035, 981, 804, 713, 690. Anal. calc. for $C_{20}H_{14}O_2S_2$: C, 68.54; H, 4.03. Found: C, 68.28; H, 4.02.

General procedure for the synthesis of 6a-g and 8a-g

To a solution of pyrrole (**2**) (8 mmol) or indole (**7**) (8 mmol) and bis-chalcone (**5a-g**) (1 mmol) in CH_3CN (5 mL) was added $AlCl_3$ (10%, w/w) and the mixture was stirred at room temperature for 24 h. The reaction was followed by TLC. After completion of the reaction,

the catalyst was separated by filtration. The reaction mixture was then diluted with water and extracted with CHCl_3 . Subsequently, the organic layer was dried over anhydrous sodium sulfate. Evaporating of the solvent under reduced pressure gave the corresponding solid products. The crude products were purified by recrystallization from *n*-hexane- CHCl_3 .

3,3'-(1,4-phenylene)bis(1-phenyl-3-(1H-pyrrol-2-yl)propan-1-one) (6a). Yield (85%); mp: 212-214 °C. ^1H -NMR (400 MHz, CDCl_3) δ (ppm): 8.43 (br s, 2H), 7.97 (d, $J = 7.2$ Hz, 4H), 7.60-7.57 (m, 2H), 7.48 (t, $J = 7.2$ Hz, 4H), 7.27 (s, 4H), 6.68 (s, 2H), 6.11 (s, 2H), 5.87 (s, 2H), 4.77 (d, $J = 7.2$ Hz, 2H), 3.83-3.79 (dd, $J = 8.0, 17.6$ Hz, 2H), 3.64-3.58 (dd, $J = 5.6, 17.6$ Hz, 2H). ^{13}C -NMR (100 MHz, CDCl_3) δ (ppm): 197.7 (2C), 141.4 (2C), 139.8 (2C), 135.1 (2C), 134.1 (2C), 129.5 (4C), 128.9 (4C), 128.3 (4C), 117.2 (2C), 107.9 (2C), 105.4 (2C), 45.1 (2C), 39.0 (2C). Anal. Calcd for $\text{C}_{32}\text{H}_{28}\text{N}_2\text{O}_2$: C, 81.33; H, 5.97; N, 5.93. Found: C, 81.27; H, 5.91; N, 5.86.

3,3'-(1,4-phenylene)bis(1-(4-chlorophenyl)-3-(1H-pyrrol-2-yl)propan-1-one) (6b).

Yield (89%); mp: 232-233 °C. ^1H -NMR (400 MHz, CDCl_3) δ (ppm): 8.82 (s, 2H), 7.80-7.78 (dd, $J = 2.0, 6.8$ Hz, 4H), 7.35-7.33 (dd, $J = 2.0, 6.8$ Hz, 4H), 7.13 (s, 4H), 6.56-6.55 (dd, $J = 1.6, 2.4$ Hz, 2H), 5.98-5.96 (dd, $J = 2.4, 5.8$ Hz, 2H), 5.77-5.76 (dd, $J = 1.2, 2.0$ Hz, 2H), 4.65 (t, $J = 6.8$ Hz, 2H), 3.68-3.62 (dd, $J = 7.6, 17.2$ Hz, 2H), 3.49-3.44 (dd, $J = 6.4, 17.2$ Hz, 2H). ^{13}C -NMR (100 MHz, CDCl_3) δ (ppm): 198.1 (2C), 141.6 (2C), 139.9 (2C), 135.2 (2C), 134.2 (2C), 129.1 (4C), 128.8 (4C), 128.4 (4C), 128.2 (2C), 117.5 (2C), 107.8 (2C), 45.1 (2C), 39.2 (2C). Anal. Calcd for $\text{C}_{32}\text{H}_{26}\text{Cl}_2\text{N}_2\text{O}_2$: C, 70.98; H, 4.84; N, 5.17. Found: C, 70.77; H, 4.81; N, 5.08.

3,3'-(1,4-phenylene)bis(1-(4-methoxyphenyl)-3-(1H-pyrrol-2-yl)propan-1-one) (6c).

Yield (74%); mp: 205-207 °C. ^1H -NMR (400 MHz, CDCl_3) δ (ppm): 8.39 (br s, 2H), 7.94 (d, $J = 8.8$ Hz, 4H), 7.26 (s, 4H), 6.93 (d, $J = 9.2$ Hz, 4H), 6.67-6.66 (dd, $J = 2.4, 4$ Hz, 2H), 6.09-6.07 (dd, $J = 2.4, 5.8$ Hz, 2H), 5.81 (d, $J = 8.4$ Hz, 2H), 4.77-4.73 (dd, $J = 5.6, 7.8$ Hz,

2H), 3.86 (s, 6H), 3.77-3.75 (dd, $J = 8.4, 17.2$ Hz, 2H), 3.57-3.51 (dd, $J = 5.6, 17.4$ Hz, 2H). ^{13}C -NMR (100 MHz, CDCl_3) δ (ppm): 197.6 (2C), 163.6 (2C), 141.5 (2C), 134.7 (2C), 130.4 (4C), 129.9 (2C), 128.3 (4C), 117.0 (2C), 113.7 (4C), 107.7 (2C), 105.4 (2C), 55.4 (2C), 44.9 (2C), 39.1 (2C). Anal. Cald for $\text{C}_{34}\text{H}_{32}\text{N}_2\text{O}_4$: C, 76.67; H, 6.06; N, 5.26. Found: C, 76.58; H, 5.99; N, 5.16.

3,3'-(1,4-phenylene)bis(3-(1H-pyrrol-2-yl)-1-(p-tolyl)propan-1-one) (6d). Yield (71%); mp: 208-210 °C. ^1H -NMR (400 MHz, CDCl_3) δ (ppm): 8.34 (br s, 2H), 7.87 (d, $J = 8.0$ Hz, 4H), 7.27 (s, 4H), 6.86 (d, $J = 8.6$ Hz, 4H), 6.67-6.66 (m, 2H), 6.11-6.10 (m, 2H), 5.84 (m, 2H), 4.75 (t, $J = 5.2$ Hz, 2H), 3.77-3.75 (dd, $J = 7.6, 16.8$ Hz, 2H), 3.60-3.54 (dd, $J = 5.6, 17.4$ Hz, 2H), 2.43 (s, 6H). ^{13}C -NMR (100 MHz, CDCl_3) δ (ppm): 197.6 (2C), 163.6 (2C), 141.5 (2C), 134.7 (2C), 130.0 (4C), 128.8 (2C), 128.5 (4C), 117.0 (2C), 113.7 (4C), 107.7 (2C), 105.4 (2C), 55.4 (2C), 44.9 (2C), 39.1 (2C). Anal. Cald for $\text{C}_{34}\text{H}_{32}\text{N}_2\text{O}_2$: C, 81.57; H, 6.44; N, 5.60. Found: C, 81.48; H, 6.36; N, 5.53.

3,3'-(1,4-phenylene)bis(3-(1H-pyrrol-2-yl)-1-(thiophen-2-yl)propan-1-one) (6e). Yield (89%); mp: 206-208 °C. ^1H -NMR (400 MHz, CDCl_3) δ (ppm): 10.59 (s, 2H), 8.08 (d, $J = 3.6$ Hz, 2H), 7.97 (d, $J = 8.6$ Hz, 2H), 7.23 (t, $J = 4.8$ Hz, 2H), 7.18 (s, 4H), 6.53 (t, $J = 7.6$ Hz, 2H), 5.84 (s, 4H), 4.56 (t, $J = 7.6$ Hz, 2H), 3.79-3.72 (dd, $J = 16.8, 4.4$ Hz, 2H), 3.55-3.42 (dd, $J = 16.8, 6.8$ Hz, 2H). ^{13}C -NMR (100 MHz, CDCl_3) δ (ppm): 191.5 (2C), 144.5 (2C), 142.4 (2C), 135.3 (2C), 134.3 (2C), 133.9 (2C), 129.2 (2C), 127.7 (2C), 117.8 (2C), 117.0 (2C), 107.5 (2C), 107.4 (2C), 104.6 (2C), 44.4 (2C). Anal. Cald for $\text{C}_{28}\text{H}_{24}\text{N}_2\text{O}_2\text{S}_2$: C, 69.39; H, 4.99; N, 5.78. Found: C, 69.18; H, 4.91; N, 5.66.

3,3'-(1,4-phenylene)bis(3-(1H-pyrrol-2-yl)-1-(thiophen-3-yl)propan-1-one) (6f). Yield (76%); mp: 202-204 °C. ^1H -NMR (400 MHz, CDCl_3) δ (ppm): 8.33 (s, 2H), 7.85 (d, $J = 8.0$ Hz, 2H), 7.23 (s, 4H), 7.10 (m, 2H), 7.03 (m, 2H), 6.70 (m, 2H), 6.15 (m, 2H), 5.83 (s, 2H), 4.76 (t, $J = 5.6$ Hz, 2H), 3.80-3.74 (dd, $J = 17.2, 7.2$ Hz, 2H), 3.59-3.54 (dd, $J = 17.6, 5.6$ Hz,

2H). ^{13}C -NMR (100 MHz, CDCl_3) δ (ppm): 198.7 (2C), 144.1 (2C), 134.4 (2C), 129.3 (4C), 128.8 (2C), 128.2 (4C), 127.3 (2C), 117.0 (2C), 108.2 (2C), 107.8 (2C), 45.1 (2C), 39.0 (2C).

Anal. Cald for $\text{C}_{28}\text{H}_{24}\text{N}_2\text{O}_2\text{S}_2$: C, 69.39; H, 4.99; N, 5.78. Found: C, 69.28; H, 4.89; N, 5.71.

3,3'-(1,4-phenylene)bis(1-(naphthalen-2-yl)-3-(1H-pyrrol-2-yl)propan-1-one) (6g). Yield (81%); mp: 236-238 °C. ^1H -NMR (400 MHz, CDCl_3) δ (ppm): 8.15 (br s, 2H), 7.98 (dd, J = 8.2, 4.8 Hz, 2H), 7.92-7.87 (m, 2H), 7.77 (t, J = 6.4 Hz, 2H), 7.54-7.51 (m, 4H), 7.47-7.42 (m, 4H), 7.23 (s, 4H), 6.67-6.64 (m, 2H), 6.14-6.12 (m, 2H), 5.94-5.93 (m, 2H), 4.81 (t, J = 7.6 Hz, 2H), 3.84 (ddd, J = 7.6, 6.4 Hz, 2H), 3.66 (ddd, J = 6.6, 3.2 Hz, 2H). ^{13}C -NMR (100 MHz, CDCl_3) δ (ppm): 198.5 (2C), 143.3 (2C), 141.8 (2C), 137.9 (2C), 136.4 (2C), 133.8 (2C), 129.7 (4C), 128.7 (6C), 128.5 (4C), 128.1 (4C), 118.0 (2C), 108.1 (2C), 107.7 (2C), 45.0 (2C), 38.8 (2C). Anal. Cald for $\text{C}_{40}\text{H}_{32}\text{N}_2\text{O}_2$: C, 83.89; H, 5.63; N, 4.89. Found: C, 83.78; H, 5.59; N, 4.79.

3,3'-(1,4-phenylene)bis(3-(1H-indol-3-yl)-1-phenylpropan-1-one) (8a). Yield (75%); mp: 230-232 °C. ^1H -NMR (400 MHz, CDCl_3) δ (ppm): 10.81 (s, 2H), 7.97-7.94 (m, 4H), 7.60-7.58 (m, 2H), 7.46 (t, J = 7.6 Hz, 4H), 7.39-7.36 (m, 2H), 7.26 (s, 8H), 7.01-6.97 (m, 2H), 6.86-6.82 (m, 2H), 4.79 (t, J = 7.2 Hz, 2H), 3.93-3.87 (dd, J = 7.6, 17.2 Hz, 2H), 3.69-3.63 (dd, J = 6.8, 17.2 Hz, 2H). ^{13}C -NMR (100 MHz, CDCl_3) δ (ppm): 199.3 (2C), 143.6 (2C), 137.8 (2C), 137.2 (2C), 134.0 (2C), 129.5 (4C), 128.9 (4C), 128.4 (4C), 127.3 (2C), 122.7 (2C), 121.8 (2C), 119.6 (2C), 119.1 (2C), 118.9 (2C), 112.2 (2C), 45.3 (2C), 38.1 (2C). Anal. Cald for $\text{C}_{40}\text{H}_{32}\text{N}_2\text{O}_2$: C, 83.89; H, 5.63; N, 4.89. Found: C, 83.77; H, 5.58; N, 4.81.

3,3'-(1,4-phenylene)bis(1-(4-chlorophenyl)-3-(1H-indol-3-yl)propan-1-one) (8b). Viscous oil; Yield (69%). ^1H -NMR (400 MHz, CDCl_3) δ (ppm): 8.27 (br s, 2H), 7.69 (d, J = 8.0 Hz, 2H), 7.43 (d, J = 8.0 Hz, 2H), 7.24-7.20 (m, 8 H), 7.18 (s, 4H), 7.16-7.10 (m, 2H), 6.82-6.78 (t, J = 7.2 Hz, 2H), 6.72-6.70 (d, J = 7.6 Hz, 2H), 5.29 (t, J = 8.8 Hz, 2H), 3.55-3.48 (dd, J = 15.6, 8.8 Hz, 2H), 3.28-3.22 (dd, J = 15.6, 8.4 Hz, 2H). ^{13}C -NMR (100 MHz, CDCl_3)

δ (ppm): 188.7 (2C), 135.7 (2C), 127.8 (2C), 124.7 (4C), 122.0 (4C), 121.2 (2C), 120.7 (4C), 119.6 (4C), 111.3 (4C), 109.3 (2C), 102.6 (4C), 112.2 (2C), 56.4 (2C), 37.6 (2C). Anal. Cald for $C_{40}H_{30}Cl_2N_2O_2$: C, 74.88, H, 4.71; N, 4.37. Found: C, 74.67; H, 4.48; N, 4.21.

3,3'-(1,4-phenylene)bis(1-(4-methoxyphenyl)-3-(1H-indol-3-yl)propan-1-one) (8c). Yield (73%); mp: 228-230 °C. 1H -NMR (400 MHz, $CDCl_3$) δ (ppm): 8.04 (s, 2H), 7.98-7.96 (d, J = 8.8 Hz, 2H), 7.41-7.39 (d, J = 8.0 Hz, 2H), 7.26 (s, 4H), 7.23-7.10 (m, 8H), 6.97-6.95 (d, J = 8.8 Hz, 2H), 6.80-6.76 (t, J = 7.2 Hz, 2H), 6.71-6.69 (d, J = 7.6 Hz, 2H), 5.28 (t, J = 8.8 Hz, 2H), 3.93 (s, 6H), 3.53-3.47 (dd, J = 15.6, 9.2 Hz, 2H), 3.27-3.21 (dd, J = 15.4, 8.4 Hz, 2H). ^{13}C -NMR (100 MHz, $CDCl_3$) δ (ppm): 188.2 (2C), 163.7 (2C), 136.8 (2C), 131.0 (2C), 128.9 (2C), 127.5 (2C), 122.8 (4C), 122.3 (2C), 121.8 (2C), 121.3 (4C), 119.6 (4C), 118.8 (2C), 114.0 (2C), 111.4 (2C), 109.3 (2C), 56.4 (2C), 55.6 (2C), 37.7 (2C). Anal. Cald for $C_{42}H_{36}N_2O_4$: C, 79.72, H, 5.73; N, 4.43. Found: C, 79.67; H, 5.66; N, 4.31.

3,3'-(1,4-phenylene)bis(1-(4-tolylphenyl)-3-(1H-indol-3-yl)propan-1-one) (8d). Yield (81%); mp: 232-235 °C. 1H -NMR (400 MHz, $CDCl_3$) δ (ppm): 8.03 (s, 2H), 7.64-7.61 (m, 2H), 7.38 (d, J = 8.0 Hz, 2H), 7.25 (s, 4H), 7.23-7.10 (m, 10H), 6.80-6.76 (t, J = 7.2 Hz, 2H), 6.72-6.70 (d, J = 8.0 Hz, 2H), 5.29 (t, J = 8.4 Hz, 2H), 3.54-3.47 (dd, J = 15.6, 9.2 Hz, 2H), 3.27-3.21 (dd, J = 15.6, 8.4 Hz, 2H), 2.43 (s, 6H). ^{13}C -NMR (100 MHz, $CDCl_3$) δ (ppm): 189.9 (2C), 143.3 (2C), 129.4 (2C), 128.9 (2C), 127.5 (2C), 124.2 (2C), 123.0 (2C), 122.3 (4C), 121.2 (4C), 119.6 (4C), 119.3 (2C), 119.1 (2C), 111.4 (2C), 109.2 (2C), 56.4 (2C), 37.6 (2C), 21.7 (2C). Anal. Cald for $C_{42}H_{36}N_2O_2$: C, 83.97; H, 6.04; N, 4.66. Found: C, 83.77; H, 5.98; N, 4.51.

3,3'-(1,4-phenylene)bis(1-(furan-2-yl)-3-(1H-indol-3-yl)propan-1-one) (8e). Yield (77%); mp: 278-281 °C. 1H -NMR (400 MHz, $CDCl_3$) δ (ppm): 10.35 (s, 2H), δ = 7.76 (s, 2H), 7.56

(t, J = 0.8 Hz, 2H), 7.23 (t, J = 7.2 Hz, 4H), 7.14-7.12 (m, 4H), 6.98-6.93 (m, 4H), 6.80 (t, J = 7.2 Hz, 2H), 6.44-6.43 (m, 2H), 4.80-4.77 (t, J = 8.0 Hz, 2H), 3.61-3.55 (dd, J = 7.6, 15.2 Hz, 2H), 3.39-3.32 (ddd, J = 3.6, 7.6, 16.0 Hz, 2H). ^{13}C -NMR (100 MHz, CDCl_3) δ (ppm): 187.2 (2C), 152.6 (2C), 146.7 (2C), 142.3 (2C), 136.7 (2C), 127.7 (4C), 126.5 (2C), 121.8 (2C), 121.3 (2C), 119.0 (2C), 118.6 (2C), 117.7 (2C), 112.4 (2C), 111.5 (2C), 44.8 (2C), 37.8 (2C), 37.7 (2C). Anal. Calcd for $\text{C}_{36}\text{H}_{28}\text{N}_2\text{O}_4$: C, 78.24; H, 5.11; N, 5.07. Found: C, 78.17; H, 5.08; N, 4.98.

3,3'-(1,4-phenylene)bis(3-(1H-indol-3-yl)-1-(thiophen-2-yl)propan-1-one) (8f).

Yield (83%); mp: 208-211 °C. ^1H -NMR (400 MHz, CDCl_3) δ (ppm): 8.19 (br s, 2H), 7.71 (d, J = 5.2 Hz, 2H), 7.63 (d, J = 7.6 Hz, 2H), 7.45 (d, J = 5.2 Hz, 2H), 7.39 (d, J = 8.0 Hz, 2H), 7.26-7.00 (m, 6H), 6.81 (t, J = 7.2 Hz, 2H), 6.71 (d, J = 7.6 Hz, 2H), 6.61-6.59 (m, 2H), 5.29 (t, J = 8.8 Hz, 2H), 3.55-3.48 (dd, J = 9.2, 15.6 Hz, 2H), 3.28-3.22 (dd, J = 8.4, 15.6 Hz, 2H). ^{13}C -NMR (100 MHz, CDCl_3) δ (ppm): 198.2 (2C), 127.4 (2C), 125.7 (2C), 124.7 (2C), 124.1 (2C), 122.3 (2C), 121.9 (4C), 121.2 (2C), 120.7 (4C), 119.6 (4C), 119.5 (2C), 119.4 (2C), 118.8 (2C), 56.4 (2C), 37.6 (2C). Anal. Calcd for $\text{C}_{36}\text{H}_{28}\text{N}_2\text{O}_2\text{S}_2$: C, 73.94; H, 4.83; N, 4.79. Found: C, 73.87; H, 4.78; N, 4.72.

3,3'-(1,4-phenylene)bis(3-(1H-indol-3-yl)-1-(naphthalen-2-yl)propan-1-one) (8g).

Yield (78%); mp: 225-228 °C. ^1H -NMR (400 MHz, CDCl_3) δ (ppm): 10.33 (s, 2H), 7.97 (t, J = 8.8 Hz, 2H), 7.89-7.86 (dd, J = 3.6, 8.2 Hz, 2H), 7.77 (d, J = 8.4 Hz, 2H), 7.70-7.67 (m, 2H), 7.39-7.33 (m, 4H), 7.27-7.20 (m, 6H), 7.13 (s, 4H), 6.99-6.95 (m, 4H), 6.83-6.80 (dd, J = 5.2, 8.0 Hz, 2H), 4.87-4.84 (t, J = 8.0 Hz, 2H), 3.79-3.73 (dd, J = 1.2, 9.2 Hz, 2H), 3.68-3.65 (dd, J = 5.2, 8.0 Hz, 2H). ^{13}C -NMR (100 MHz, CDCl_3) δ (ppm): 203.0 (2C), 142.4 (2C), 136.8 (2C), 136.6 (2C), 133.7 (2C), 132.1 (2C), 129.7 (2C), 128.3 (2C), 127.9 (4C), 127.4 (2C), 127.0 (2C), 126.6 (2C), 126.4 (2C), 125.5 (2C), 124.6 (2C), 121.8 (2C), 121.3 (2C), 119.0

(2C), 118.6 (2C), 117.8 (2C), 11.5 (2C), 49.4 (2C), 39.4 (2C). Anal. Cald for $C_{48}H_{36}N_2O_2$: C, 85.69; H, 5.39; N, 4.16. Found: C, 85.57; H, 5.32; N, 4.13.

Figure S1. ^1H NMR and ^{13}C NMR spectra of compound **5f**

Figure S2. ^1H NMR and ^{13}C NMR spectra of compound **6b**

Figure S3. ^1H NMR and ^{13}C NMR spectra of compound **6c**

Figure S4. ^1H NMR and ^{13}C NMR spectra of compound **6e**

Figure S5. ^1H NMR and ^{13}C NMR spectra of compound **8a**

Figure S1. ^1H NMR and ^{13}C NMR spectra of compound **8e**

Figure S1. ¹H NMR spectrum (400 MHz, DMSO) of **5f**

Figure S1. ¹³C NMR spectrum (100 MHz, DMSO) of **5f**

Figure S2. ¹H NMR spectrum (400 MHz, DMSO) of **6b**

Figure S2. ¹³C NMR spectrum (100 MHz, DMSO) of **6b**

Figure S3. ¹H NMR spectrum (400 MHz, DMSO) of 6c

Figure S3. ¹³C NMR spectrum (100 MHz, DMSO) of 6c

Figure S4. ¹³C NMR spectrum (100 MHz, DMSO) of 6e

Figure S4. ¹³C NMR spectrum (100 MHz, DMSO) of 6e

Figure S5. ^1H NMR spectrum (400 MHz, DMSO) of **8a**

Figure S5. ^{13}C NMR spectrum (100 MHz, DMSO) of **8a**