Supporting Information

Synthesis of Flavones Derivatives through Versatile Palladium-catalyzed Cross-coupling Reactions of Tosyloxy and Mesyloxyflavones

On Ying Yuen, a Wai Hang Pang, a Xiangmeng Chen, a Zicong Chen, a Fuk Yee Kwong a and Chau Ming So a,b

a Department of Applied Biology and Chemical Technology, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong SAR, P. R. of China

b The Hong Kong Polytechnic University, Shenzhen Research Institute, Shenzhen P. R. of China

Email: bccmso@polyu.edu.hk

Table of Contents

1. General consideration .................................................................................................................. 2
2. General procedure for initial ligands screening ....................................................................... 3
3. General procedures for palladium-catalyzed Suzuki-Miyaura reaction of tosyloxy and mesyloxyflavones .................................................................................................................... 7
4. General procedure for palladium-catalyzed amination of tosyloxy and mesyloxyflavones ................................................................................................................................................................................................. 9
5. General procedure for palladium-catalyzed Sonogashira reaction of tosyloxyflavone .............................................................................................................................................................................. 10
6. Characterization data for coupling products ............................................................................. 11
7. $^1$H, $^{13}$C, $^{19}$F NMR, MS and HRMS spectra ........................................................................... 23
8. References ..................................................................................................................................... 88
1. General consideration

Unless otherwise noted, all reagents were purchased from commercial suppliers and used without purification. All the reactions were performed in Rotaflo® (England) resealable screw cap Schlenk flasks (approx. 20 mL volume) containing a Teflon coated magnetic stirrer bar (4.5 mm × 12 mm). CM-Phos\(^1\) and PhMezolePhos\(^2\) was prepared according to the reported procedures. Ligands MorDalphos, XPhos, SPhos and cataCXium\(^5\)A were purchased from commercial suppliers. tert-Butanol was distilled with sodium under nitrogen.\(^3\) Most commercially available arylboronic acids were applied as received. Some arylboronic acids might need further recrystallization according to their received conditions. Thin layer chromatography was carried out on Merck precoated silica gel 60 F\(_{254}\) plates. Silica gel (Merck, 230-400 mesh) was used for column chromatography. Melting points were measured by an uncorrected Büchi Melting Point B-545 instrument. NMR spectra were recorded on a Brüker spectrometer (400 or 500 MHz for \(^1\)H, 100 or 125 MHz for \(^{13}\)C and 376 MHz for \(^{19}\)F). Spectra were referenced internally to the residual proton resonance in CDCl\(_3\) (δ 7.26 ppm), CD\(_2\)Cl\(_2\) (δ 5.32 ppm) or DMSO (δ 2.50 ppm). Chemical shifts (δ) were recorded as part per million (ppm) in δ scale. \(^{13}\)C NMR spectra were referenced to CDCl\(_3\) (δ 77.0 ppm), CD\(_2\)Cl\(_2\) (δ 53.84 ppm) or DMSO (δ 39.52 ppm). \(^{19}\)F NMR chemical shifts were determined relative to CFCl\(_3\) as the external standard and low field is positive. Coupling constants (J) were recorded in Hertz (Hz). Mass spectra (EI-MS and ES-MS) were acquired on a HP 5989B Mass Spectrometer. High-resolution mass spectra (HRMS) were obtained on a Brüker APEX 47e FT-ICR mass spectrometer (ESIMS). GC-MS analysis was performed on a HP 5977A GCD system equipped with a HP5MS column (30 m × 0.25mm). The products described in GC yield were accorded to the authentic samples/dodecane calibration standard from HP 7890B GC-FID system. All yields recorded refer to isolated yields of compounds estimated to be greater than 95% purity as measured by capillary gas chromatography (GC) or \(^1\)H NMR. Compounds described in the thesis were characterized by comparison of their \(^1\)H, \(^{13}\)C, and/or \(^{19}\)F NMR spectra with the previously reported data. The procedures in this section are general and representative, and hence the yields may be different from those recorded in tables.
2. Preparation of tosloxy and mesloxyflavones

All tosloxy and mesloxyflavones were prepared from their corresponding phenols with TsCl and MsCl in the presence of triethylamine in DCM according to the literature method.4

6-Tosloxyflavone

\[
\text{TsO} \quad \begin{array}{ccc}
\text{O} & \text{O} & \text{H}
\end{array}
\]

6-Hydroxyflavone (21.4 mmol), triethylamine (214 mmol), TsCl (32.1 mmol) in DCM (60 mL) were given white solid product (6.6 g, 79 %). m.p.=220.3-221.4 °C; 1H NMR (400 MHz, CDCl\textsubscript{3}) \(\delta\) 2.45 (s, 3H), 6.78 (s, 1H), 7.33 (d, \(J= 8.1\) Hz, 2H), 7.51-7.58 (m, 5H), 7.66 (d, \(J= 2.7\) Hz, 1H), 7.73 (d, \(J= 8.3\) Hz, 2H), 7.90 (d, \(J= 7.6\) Hz, 2H); 13C NMR (100 MHz, CDCl\textsubscript{3}) \(\delta\) 21.7, 107.2, 118.6, 119.9, 124.7, 126.3, 128.5, 128.7, 129.1, 130.0, 131.3, 131.9, 145.9, 146.5, 154.4, 163.7, 177.2; MS (EI): \(m/z\) (relative intensity) 392.1 (M\(^+\), 100), 227.1 (63), 155.0 (37), 135.0 (47), 91.1 (45); HRMS: calcd. for C\textsubscript{22}H\textsubscript{17}O\textsubscript{5}S\(^+\): 393.0791, found 393.0790.

4-Oxo-2-phenyl-4H-chromene-5,7-diyl bis(4-methylbenzenesulfonate)

\[
\text{TsO} \quad \begin{array}{ccc}
\text{O} & \text{O} & \text{H}
\end{array}
\]

Chrysin (20 mmol), triethylamine (400 mmol), TsCl (60 mmol) in DCM (120 mL) were given white solid product (9.5 g, 84 %). m.p.=158.0-159.0 °C; 1H NMR (400 MHz, CDCl\textsubscript{3}) \(\delta\) 2.44 (s, 3H), 2.46 (s, 3H), 6.63 (s, 1H), 6.86 (d, \(J= 2.3\) Hz, 1H), 7.32-7.40 (m, 5H), 7.48-7.55 (m, 3H), 7.77 (d, \(J= 7.9\) Hz, 2H), 7.82 (d, \(J= 7.3\) Hz, 2H), 7.89 (d, \(J= 8.3\) Hz, 2H); 13C NMR (100 MHz, CDCl\textsubscript{3}) \(\delta\) 21.7, 21.8, 108.8, 111.2, 114.7, 116.8, 126.1, 128.4, 128.9, 129.1, 129.6, 130.2, 130.6, 131.4, 131.9, 132.3, 145.7, 146.5, 147.4, 151.8, 157.4, 162.1, 175.0; HRMS: calcd. for C\textsubscript{20}H\textsubscript{23}O\textsubscript{5}S\(^+\): 563.0829, found 563.0830.
3. Preparation of 2-morpholino-4-oxo-4H-chromen-7-yl tosylate

Scheme S1. The pathway for synthesis of 2-morpholino-4-oxo-4H-chromen-7-yl tosylate

Methyl 2-hydroxy-4-(tosyloxy)benzoate

Methyl 2-hydroxy-4-(tosyloxy)benzoate was prepared according to the reported procedure with a slight modification. 5 Methyl 2,4-dihydroxybenzoate (1.0 mmol), K₂CO₃ (1.0 mmol), tosyl chloride (1.2 mmol) in acetone (2 mL) were given white solid product (0.24 g, 75%). ¹H NMR (400 MHz, CDCl₃) δ 2.46 (s, 3H), 3.94 (s, 3H), 6.60-6.62 (m, 2H), 7.33 (d, J = 8.1 Hz, 2H), 7.74 (d, J = 8.3 Hz, 2H), 7.78 (d, J = 9.4 Hz, 1H), 10.9 (s, 1H); ¹³C NMR (100 MHz, CDCl₃) δ 21.6, 52.4, 111.0, 111.2, 113.4, 128.3, 129.9, 131.3, 132.1, 145.7, 154.6, 162.6, 169.7; MS (EI): m/z (relative intensity) 322.1 (M⁺, 40), 291.0 (7), 226.1 (25), 155.0 (70), 91.1 (100).

3-Hydroxy-4-(3-morpholino-3-oxopropanoyl)phenyl tosylate

3-Hydroxy-4-(3-morpholino-3-oxopropanoyl)phenyl tosylate was prepared according to the reported procedure with a slight modification. 6 Methyl 2-hydroxy-4-(tosyloxy)benzoate (8 mmol), 4-acetylmorpholine (24 mmol) and lithium diisopropylamide (24 mmol) in THF (80 mL) were given white solid product (1.5 g, 46%). m.p.=90.6-91.8 °C; ¹H NMR (400 MHz, CDCl₃) δ 2.45 (s, 3H), 3.49-3.52 (m, 2H), 3.64-3.68 (m, 6H), 4.05 (s, 2H), 6.60 (s, 1H), 6.65 (d, J = 9.0 Hz, 1H), 7.33 (d, J = 8.0 Hz, 2H), 7.73 (d, J = 7.4 Hz, 2H), 7.81 (d, J = 8.8 Hz, 1H), 12.0 (s, 1H); ¹³C NMR (100 MHz, CDCl₃) δ 21.7, 42.4, 45.3, 46.9, 66.5, 66.6, 111.6, 113.5, 117.9, 128.3, 130.0, 132.1, 132.6, 145.9, 155.5, 164.0, 164.3, 198.8; HRMS: calcd. for C₂₀H₂₂NO₇S⁺:
2-Morpholino-4-oxo-4H-chromen-7-yl tosylate was prepared according to the reported procedure with a slight modification.\textsuperscript{6} 3-Hydroxy-4-(3-morpholino-3-oxopropanoyl)phenyl tosylate (3 mmol) and trifluoromethanesulfonic anhydride (10.8 mmol) in DCM (15 mL) were given white solid product (1.0 g, 88 \%). m.p.=161.9-163.1 °C; \textsuperscript{1}H NMR (400 MHz, CDCl\textsubscript{3}) \(\delta\) 2.46 (s, 3H), 3.51 (bs, 4H), 3.84 (bs, 4H), 5.47 (s, 1H), 6.74 (d, \(J=7.8\) Hz, 1H), 7.26 (s, 1H), 7.33 (d, \(J=6.7\) Hz, 2H), 7.72 (d, \(J=6.8\) Hz, 2H), 8.01 (d, \(J=8.0\) Hz, 1H); \textsuperscript{13}C NMR (100 MHz, CDCl\textsubscript{3}) \(\delta\) 21.7, 44.7, 65.9, 87.2, 110.9, 118.8, 121.7, 127.0, 128.4, 129.9, 131.8, 145.9, 151.9, 153.7, 162.8, 176.0; MS (EI): \textit{m/z} (relative intensity) 401.1 (M\textsuperscript{+}, 100), 386.1 (26), 344.1 (36), 218.1 (63), 155.0 (34); HRMS: calcd. for C\textsubscript{20}H\textsubscript{20}NO\textsubscript{6}S\textsuperscript{+}: 402.1006, found 402.1007.
4. **General procedure for initial ligands screening**

A stock solution of Pd(OAc)$_2$ (8.98 mg, 0.040 mmol) in freshly distilled 8 mL dichloromethane (1.0 mol% Pd per 1.0 mL stock solution) was initially prepared with continuously stirring at room temperature. Ligands (Pd:L = 1:4) were added into an array of Schlenk tubes equipped with a Teflon-coated magnetic stir bar. The tubes were evacuated and backfilled with nitrogen (3 cycles). The corresponding volume of stock solution and triethylamine (0.10 mL) were transferred to an array of Schlenk tubes via syringes. The solution was stirred and placed in a preheated oil bath (50°C) for about 1 to 2 minutes until the solvent started boiling. The solvent was then evaporated under high vacuum. 6-Tosyloxyflavones (196 mg, 0.5 mmol), anisylboronic acid (154 mg, 1.0 mmol) and K$_3$PO$_4$·H$_2$O (345 mg, 1.5 mmol) were added into the tubes, and the mixture was evacuated and flushed with nitrogen for three times again. t-BuOH (1.5 mL) was added finally. The sealed tube was stirred at room temperature for one minute and then placed in a preheated oil bath (110 °C) for 2 h. After the completion of reaction, the reaction tube was allowed to reach room temperature. Dichloromethane (~10 mL), dodecane (114 µL, internal standard) and water (~3 mL) were added. The organic layer was subjected to GC analysis. The GC yield was previously calibrated by authentic sample/dodecane calibration curve.
5. General procedures for palladium-catalyzed Suzuki-Miyaura reaction of tosyloxy and mesyloxyflavones

General procedure for Suzuki-Miyaura coupling of tosyloxy and mesyloxyflavones (Pd catalysts loading equal to 2.0 mol\%): Pd(OAc)$_2$ (2.24 mg, 0.010 mmol) and CM-Phos (Pd:L = 1:4) were added into a Schlenk tube containing a Teflon-coated magnetic stir bar. The tube was then evacuated and flushed with nitrogen for three times. Precomplexation was conducted by adding freshly distilled dichloromethane (1.0 mL) and triethylamine (0.1 mL) into the tube. The solution was stirred and placed in a preheated oil bath (50°C) for around 1 to 2 minutes until the solvent started boiling. The solvent was then evaporated under high vacuum. Tosyloxy or mesyloxyflavones (0.5 mmol), arylboronic acid (1.0 mmol) and K$_3$PO$_4$·H$_2$O (345 mg, 1.5 mmol) or K$_3$PO$_4$ (318 mg, 1.5 mmol) were added into the tube, and the mixture was evacuated and flushed with nitrogen for three times again. $t$-BuOH (1.5 mL) was added finally. The sealed tube was stirred at room temperature for one minute and then placed in a preheated oil bath (110 °C) for the reaction time indicated in Table 2. After the completion of reaction, the reaction tube was allowed to reach room temperature. Ethyl acetate or dichloromethane (~10 mL) and water (~3 mL) were added. The organic layer was subjected to GC analysis. The filtrate was concentrated under reduced pressure. The crude products were purified by flash column chromatography on silica gel (230-400 mesh) to afford the desired product.

General procedure for Suzuki-Miyaura coupling of tosyloxy and mesyloxyflavones (Pd catalysts loading equal to 0.1 mol\%): A stock solution of Pd(OAc)$_2$ (2.24 mg, 0.010 mmol) with CM-Phos (Pd:L = 1:4) in freshly distilled 10 mL dichloromethane (0.1 mol\% Pd per 0.5 mL stock solution) was initially prepared with continuously stirring at room temperature. An array of Schlenk tubes equipped with a Teflon-coated magnetic stir bar were evacuated and backfilled with nitrogen (3 cycles). The corresponding volume of stock solution and triethylamine (0.10 mL) were transferred to an array of Schlenk tubes via syringes. The solution was stirred and placed in a preheated oil bath (50°C) for about 1 to 2 minutes until the solvent started boiling. The solvent was then evaporated under high vacuum. Tosyloxy or mesyloxyflavones (0.5 mmol), arylboronic acid (1.0 mmol) and K$_3$PO$_4$·H$_2$O (345 mg, 1.5 mmol) or K$_3$PO$_4$ (318 mg, 1.5 mmol) were added into the tube, and the mixture was evacuated and flushed with nitrogen for three times again. $t$-BuOH (1.5 mL) was added finally. The sealed tube was stirred at room temperature for one minute and then placed in a preheated oil bath (110 °C) for the reaction time indicated in Table 2. After the completion of reaction, the reaction tube was allowed to reach room temperature. Ethyl acetate or dichloromethane (~10 mL) and water (~3 mL) were...
added. The organic layer was subjected to GC analysis. The filtrate was concentrated under reduced pressure. The crude products were purified by flash column chromatography on silica gel (230-400 mesh) to afford the desired product.
6. General procedure for palladium-catalyzed amination of tosyloxy and mesyloxyflavones

Pd(OAc)$_2$ (2.24 mg, 0.010 mmol) and CM-Phos (Pd:L = 1:4) were added into a Schlenk tube containing a Teflon-coated magnetic stir bar. The tube was then evacuated and flushed with nitrogen for three times. Precomplexation was conducted by adding freshly distilled dichloromethane (1.0 mL) and triethylamine (0.1 mL) into the tube. The solution was stirred and placed in a preheated oil bath (50°C) for around 1 to 2 minutes until the solvent started boiling. The solvent was then evaporated under high vacuum. Tosyloxy or mesyloxyflavones (0.5 mmol), K$_2$CO$_3$ (172.5 mg, 1.25 mmol), amines (if solid, 0.75 mmol) and phenylboronic acid (2.44 mg, 0.02 mmol) were added into the tube, and the mixture was evacuated and flushed with nitrogen for three times again. Amines (if liquid, 0.75 mmol) and t-BuOH (1.5 mL) were added finally. The sealed tube was stirred at room temperature for one minute and then placed in a preheated oil bath (110°C) for the reaction time indicated in Table 3. After the completion of reaction, the reaction tube was allowed to reach room temperature. Ethyl acetate or dichloromethane (~10 mL) and water (~3 mL) were added. The organic layer was subjected to GC analysis. The filtrate was concentrated under reduced pressure. The crude products were purified by flash column chromatography on silica gel (230-400 mesh) to afford the desired product.
7. General procedure for palladium-catalyzed Sonogashira reaction of tosyoxyflavone

Pd(OAc)$_2$ (2.24 mg, 0.010 mmol) and CM-Phos (Pd:L = 1:4) were added into a Schlenk tube containing a Teflon-coated magnetic stir bar. The tube was then evacuated and flushed with nitrogen for three times. Precomplexation was conducted by adding freshly distilled dichloromethane (1.0 mL) and triethylamine (0.1 mL) into the tube. The solution was stirred and placed in a preheated oil bath (50°C) for around 1 to 2 minutes until the solvent started boiling. The solvent was then evaporated under high vacuum. 7-Tosyloxyflavones (196.0 mg, 0.5 mmol) and K$_3$PO$_4$ (318.0 mg, 1.50 mmol) were added into the tube, and the mixture was evacuated and flushed with nitrogen for three times again. 1-Heptyne (131.2 µL, 1.0 mmol) and t-BuOH (1.0 mL) were added finally. The sealed tube was stirred at room temperature for one minute and then placed in a preheated oil bath (100°C) for 18 h. After the completion of reaction, the reaction tube was allowed to reach room temperature. Ethyl acetate or dichloromethane (~10 mL) and water (~3 mL) were added. The organic layer was subjected to GC analysis. The filtrate was concentrated under reduced pressure. The crude products were purified by flash column chromatography on silica gel (230-400 mesh) to afford the desired product.
8. Characterization data for coupling products

6-(2-(Hydroxymethyl)phenyl)-2-phenyl-4\textit{H}-chromen-4-one (Scheme 3, compound 3a)

Eluents (Ethyl acetate: Hexane= 1: 4, \( R_f = 0.10 \)) was used for flash column chromatography. White solid; m.p.=157.6-161.5 °C; \(^1\text{H} \) NMR (400 MHz, CD\(_2\)Cl\(_2\)) \( \delta \) 2.17 (bs, 1H), 4.64 (s, 2H), 6.85 (s, 1H), 7.35-7.48 (m, 3H), 7.57-7.63 (m, 4H), 7.68 (d, \( J = 8.6 \) Hz, 1H), 7.80-7.82 (m, 1H), 8.00-8.03 (m, 2H), 8.20 (d, \( J = 2.2 \) Hz, 1H); \(^{13}\text{C} \) NMR (100 MHz, CD\(_2\)Cl\(_2\)) \( \delta \) 62.7, 107.4, 118.0, 123.6, 125.6, 126.3, 127.7, 128.1, 128.8, 129.0, 130.1, 131.6, 131.8, 135.0, 138.0, 138.5, 139.7, 155.5, 163.5, 178.1; MS (EI): \( m/z \) (relative intensity) 326.4 (M\(^+\), 100), 298.3 (81), 196.2 (65), 168.2 (18), 139.2 (44); HRMS: calcd. for C\(_{22}\)H\(_{17}\)O\(_3^+\): 329.1172, found 329.1181.

6-(3-Methoxyphenyl)-2-phenyl-4\textit{H}-chromen-4-one (Scheme 3, compound 3b)

Eluents (Ethyl acetate: Hexane= 1: 4, \( R_f = 0.40 \)) was used for flash column chromatography. Yellow solid; m.p.=117.8-119.5 °C; \(^1\text{H} \) NMR (400 MHz, CDCl\(_3\)) \( \delta \) 3.88 (s, 3H), 6.88 (s, 1H), 6.91-6.94 (m, 1H), 7.18-7.19 (m, 1H), 7.24 (d, \( J = 7.8 \) Hz, 1H), 7.37 (t, \( J = 7.9 \) Hz, 1H), 7.50-7.54 (m, 3H), 7.62 (d, \( J = 8.7 \) Hz, 1H), 7.91-7.94 (m, 3H), 8.42 (d, \( J = 2.2 \) Hz, 1H); \(^{13}\text{C} \) NMR (100 MHz, CDCl\(_3\)) \( \delta \) 55.3, 107.4, 112.6, 113.4, 118.5, 119.6, 123.5, 123.9, 126.3, 129.0, 129.9, 131.6, 131.7, 132.7, 138.2, 140.6, 155.7, 160.1, 163.5, 178.4; MS (EI): \( m/z \) (relative intensity) 328.4 (M\(^+\), 100), 226.3 (32), 198.2 (7), 155.2 (9), 127.2 (8); HRMS: calcd. for C\(_{22}\)H\(_{17}\)O\(_3^+\): 329.1172, found 329.1183.
6-(4-Methoxyphenyl)-2-phenyl-4H-chromen-4-one (Scheme 3, compound 3c)

Eluents (Ethyl acetate: Hexane= 1: 4, Rf= 0.45) was used for flash column chromatography. White solid; m.p.= 186.8-188.2 °C; 1H NMR (400 MHz, CDCl3) δ 3.85 (s, 3H), 6.84 (s, 1H), 6.99 (d, J= 8.3 Hz, 2H), 7.53-7.61 (m, 6H), 7.88-7.94 (m, 3H), 8.38 (s, 1H); 13C NMR (100 MHz, CDCl3) δ 55.3, 107.5, 114.4, 118.5, 122.7, 124.0, 126.2, 128.2, 129.0, 131.6, 131.7, 131.8, 132.2, 138.0, 155.3, 159.5, 163.3, 178.5; MS (EI): m/z (relative intensity) 328.1 (M+, 100), 226.1 (17), 183.1 (10), 155.1 (7), 127.1 (6); HRMS: calcd. for C22H17O3+: 329.1172, found 329.1180.

2-Phenyl-6-(3,4,5-trimethoxyphenyl)-4H-chromen-4-one (Scheme 3, compound 3d)

Eluents (Ethyl acetate: Hexane= 1: 1, Rf= 0.15) was used for flash column chromatography. White solid; m.p.= 145.4-148.0 °C; 1H NMR (400 MHz, CD2Cl2) δ 3.87 (s, 3H), 3.97 (s, 6H), 6.86 (s, 1H), 6.92 (s, 2H), 7.57-7.60 (m, 3H), 7.70 (d, J= 8.7 Hz, 1H), 7.96-8.02 (m, 3H), 8.39 (d, J= 2.2 Hz, 1H); 13C NMR (100 MHz, CD2Cl2) δ 56.2, 60.5, 104.5, 107.4, 118.6, 122.9, 124.0, 126.3, 129.0, 131.6, 131.8, 132.5, 135.1, 138.1, 138.3, 153.7, 155.6, 163.3, 178.0; MS (EI): m/z (relative intensity) 388.5 (M+, 100), 345.4 (14), 315.3 (15), 157.2 (10), 129.2 (7); HRMS: calcd. for C24H21O5+: 389.1384, found 389.1396.
7-(2-(Hydroxymethyl)phenyl)-2-phenyl-4\(H\)-chromen-4-one (Scheme 3, compound 3e)

Eluents (Ethyl acetate: Hexane= 1: 4, \(R_f=\) 0.10) was used for flash column chromatography. White solid; m.p.=149.2-151.8 °C; \(^1\)H NMR (400 MHz, CD\(_2\)Cl\(_2\)) \(\delta\) 1.99 (bs, 1H), 4.68 (s, 2H), 6.84 (s, 1H), 7.38-7.70 (m, 9H), 7.98-8.00 (m, 2H), 8.21 (d, \(J=\) 8.1 Hz, 1H); \(^1^3\)C NMR (100 MHz, CD\(_2\)Cl\(_2\)) \(\delta\) 62.7, 107.5, 118.6, 122.7, 125.1, 126.3, 126.6, 127.8, 128.6, 128.9, 129.0, 129.8, 131.6, 131.8, 138.3, 139.6, 146.8, 156.0, 163.6, 178.0; MS (EI): \(m/z\) (relative intensity) 327.1 (M\(^+\), 100), 299.1 (25), 281.1 (10), 223.1 (27), 152.1 (14); HRMS: calcd. for C\(_{22}\)H\(_{17}\)O\(_3^+\): 329.1172, found 329.1162.

7-(4-Methoxyphenyl)-2-phenyl-4\(H\)-chromen-4-one (Scheme 3, compound 3f)

Eluents (Ethyl acetate: Hexane= 1: 1, \(R_f=\) 0.15) was used for flash column chromatography. \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 3.78 (s, 3H), 6.70 (s, 1H), 6.92 (d, \(J=\) 8.7 Hz, 2H), 7.41-7.56 (m, 7H), 7.80-7.83 (m, 2H), 8.12 (d, \(J=\) 8.3 Hz, 1H); \(^1^3\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 55.1, 107.2, 114.2, 114.8, 121.8, 123.4, 125.7, 125.9, 128.1, 128.7, 130.9, 131.3, 131.4, 146.0, 156.3, 160.0, 162.9, 177.8; MS (EI): \(m/z\) (relative intensity) 328.2 (M\(^+\), 100), 285.1 (16), 257.1 (8), 226.1 (7), 150.1 (12).
7-[[1,1’-Biphenyl]-4-yl]-2-phenyl-4H-chromen-4-one (Scheme 3, compound 3g)

Eluents (Ethyl acetate: Hexane= 1: 4, Rf = 0.45) was used for flash column chromatography. Grey white solid; m.p.=227.2-228.2 °C; 1H NMR (400 MHz, CD2Cl2) δ 6.82 (s, 1H), 7.41 (t, J= 7.4 Hz, 1H), 7.48-7.59 (m, 5H), 7.69-7.88 (m, 8H), 8.00-8.02 (m, 2H), 8.25 (d, J= 8.2 Hz, 1H); 13C NMR (100 MHz, CD2Cl2) δ 107.6, 115.9, 122.8, 124.0, 125.9, 126.2, 127.0, 127.6, 127.7, 128.9, 129.0, 131.5, 131.9, 137.9, 140.2, 141.4, 146.2, 156.7, 163.4, 177.6; MS (EI): m/z (relative intensity) 374.2 (M+, 100), 346.2 (25), 215.1 (24), 173.1 (15); HRMS: calcd. for C27H19O2+: 375.138, found 375.1368.

7-(3-(Morpholinomethyl)phenyl)-2-phenyl-4H-chromen-4-one (Scheme 3, compound 3h)

Eluents (DCM: Hexane= 1: 9, Rf = 0.20) was used for flash column chromatography. Light yellow solid; m.p.=154.8-158.6 °C; 1H NMR (400 MHz, CD2Cl2) δ 2.48 (t, J= 4.3 Hz, 4H), 3.57 (s, 2H), 3.70 (t, J= 4.6 Hz, 4H), 6.81 (s, 1H), 7.49 (d, J= 7.9 Hz, 2H), 7.53-7.57 (m, 3H), 7.68-7.70 (m, 3H), 7.81-7.82 (m, 1H), 7.98-7.99 (m, 2H), 8.20-8.23 (m, 1H); 13C NMR (100 MHz, CD2Cl2) δ 53.7, 62.8, 66.9, 107.6, 115.9, 122.6, 124.0, 125.8, 126.2, 127.1, 129.0, 129.8, 131.5, 131.9, 137.8, 139.0, 146.5, 156.7, 163.4, 177.7; MS (EI): m/z (relative intensity) 397.5 (M+, 57), 366.5 (23), 311.4 (100), 152.2 (13), 86.2 (19); HRMS: calcd. for C26H24NO3+: 398.1751, found 398.1761.
7-(4-Fluorophenyl)-2-phenyl-4H-chromen-4-one (Scheme 3, compound 3i)

Eluents (Ethyl acetate: Hexane= 1: 2, Rf= 0.50) was used for flash column chromatography. Light yellow solid; m.p.=163.6-164.8°C; 1H NMR (400 MHz, CDCl₃) δ 6.82 (s, 1H), 7.18 (t, J= 8.6 Hz, 2H), 7.50-7.54 (m, 3H), 7.58 (d, J= 8.3 Hz, 1H), 7.62-7.66 (m, 2H), 7.70 (s, 1H), 7.91-7.94 (m, 2H), 8.25 (d, J= 8.2 Hz, 1H); 13C NMR (100 MHz, CDCl₃) δ 107.7, 115.9, 116.0 (d, J= 21.4 Hz), 122.6, 124.1, 126.2, 128.98, 129.01, 129.1, 131.6, 131.7, 135.2 (d, J= 3.1 Hz), 145.8, 156.5, 163.2 (d, J= 247.3 Hz), 163.4, 178.0; 19F NMR (376 MHz, CDCl₃) δ -113.1; MS (EI): m/z (relative intensity) 316.1 (M⁺, 100), 288.1 (71), 214.1 (19), 186.1 (24), 157.1 (34); HRMS: calcd. for C₂₁H₁₄FO₂⁺: 317.0972, found 317.0975.

2-Phenyl-7-(4-(trifluoromethyl)phenyl)-4H-chromen-4-one (Scheme 3, compound 3j)

Eluents (Ethyl acetate: Hexane= 1: 2, Rf= 0.50) was used for flash column chromatography. Off-white solid; m.p.=242.0-243.0°C; 1H NMR (400 MHz, CDCl₃) δ 6.87 (s, 1H), 7.52-7.56 (m, 3H), 7.66 (d, J= 8.2 Hz, 1H), 7.76-7.81 (m, 5H), 7.95-7.97 (m, 2H), 8.32 (d, J= 8.2 Hz, 1H); 13C NMR (100 MHz, CDCl₃) δ 107.8, 115.9, 116.0, 122.6, 123.3, 124.3, 125.3, 126.0, 126.1, 126.3, 126.6, 127.8, 129.1, 131.7, 131.8, 142.7, 145.3, 156.6, 163.7, 178.0; 19F NMR (376 MHz, CD₂Cl₂) δ -62.9; MS (EI): m/z (relative intensity) 366.2 (M⁺, 100), 338.1 (77), 264.1 (21), 236.1 (32), 139.1 (25); HRMS: calcd. for C₂₂H₁₄F₃O₂⁺: 367.0940, found 367.0941.
2-Phenyl-7-(3-(trifluoromethyl)phenyl)-4H-chromen-4-one (Scheme 3, compound 3k)

Eluents (Ethyl acetate: Hexane= 1: 4, Rf= 0.45) was used for flash column chromatography. White solid; m.p.=142.2-145.5 °C; \(^1\)H NMR (400 MHz, CD\(_2\)Cl\(_2\)) \(\delta\) 6.83 (s, 1H), 7.56-7.57 (m, 3H), 7.66-7.74 (m, 3H), 7.84 (s, 1H), 7.92 (d, \(J= 7.5\) Hz, 1H), 7.98-8.00 (m, 3H), 8.26 (d, \(J= 8.2\) Hz, 1H); \(^{13}\)C NMR (100 MHz, CD\(_2\)Cl\(_2\)) \(\delta\) 107.6, 116.5, 122.8, 123.2, 124.1, 125.18, 125.22, 125.3, 125.5, 126.20, 126.25, 129.0, 129.7, 130.8, 131.1, 131.4, 131.5, 131.6, 131.7, 140.0, 145.0, 156.6, 163.5, 177.6; \(^{19}\)F NMR (376 MHz, CD\(_2\)Cl\(_2\)) \(\delta\) -62.9; MS (EI): \(m/z\) (relative intensity) 366.4 (M\(^+\), 100), 338.4 (64), 264.3 (22), 236.3 (30), 169.2 (22); HRMS: calcd. for C\(_{22}\)H\(_{14}\)F\(_{3}\)O\(_2\)\(^+\): 367.094, found 367.0953.

2-Phenyl-6-(p-tolyl)-4H-chromen-4-one (Scheme 3, compound 3l)

Eluents (Ethyl acetate: Hexane= 1: 4, Rf= 0.50) was used for flash column chromatography. Yellow solid; \(^1\)H NMR (400 MHz, CD\(_2\)Cl\(_2\)) \(\delta\) 2.42 (s, 3H), 6.83 (s, 1H), 7.31 (d, \(J= 7.8\) Hz, 2H), 7.53-7.62 (m, 5H), 7.66 (d, \(J= 8.7\) Hz, 1H), 7.95-8.00 (m, 3H), 8.38 (d, \(J= 2.3\) Hz, 1H); \(^{13}\)C NMR (100 MHz, CD\(_2\)Cl\(_2\)) \(\delta\) 20.8, 107.4, 118.6, 122.7, 124.1, 126.2, 126.9, 129.0, 129.6, 131.5, 131.8, 132.3, 136.4, 137.8, 138.1, 155.5, 163.2, 178.0; MS (EI): \(m/z\) (relative intensity) 312.4 (M\(^+\), 100), 210.3 (36), 182.2 (6), 153.2 (14), 102.2 (3).
5-Hydroxy-2-Phenyl-7-(p-tolyl)-4H-chromen-4-one (Scheme 3, compound 3m)

![Chemical structure of 5-Hydroxy-2-Phenyl-7-(p-tolyl)-4H-chromen-4-one](image)

Eluents (Ethyl acetate: Hexane= 1: 2, Rf= 0.50) was used for flash column chromatography. $^1$H NMR (400 MHz, CDCl$_3$) δ 2.44 (s, 3H), 6.75 (s, 1H), 7.06 (s, 1H), 7.23 (s, 1H), 7.31 (d, J= 8.0 Hz, 2H), 7.54-7.58 (m, 5H), 7.94 (d, J= 8.3 Hz, 2H), 12.57 (s, 1H); $^{13}$C NMR (100 MHz, CDCl$_3$) δ 21.2, 105.2, 106.1, 109.5, 109.8, 126.4, 127.1, 129.1, 129.7, 131.2, 131.9, 136.3, 138.9, 148.5, 156.6, 160.7, 164.5, 183.1; MS (EI): m/z (relative intensity) 328.1 (M$^+$, 100), 300.1 (11), 207.0 (28).

2-Phenyl-5,7-di-p-tolyl-4H-chromen-4-one (Scheme 3, compound 3n)

![Chemical structure of 2-Phenyl-5,7-di-p-tolyl-4H-chromen-4-one](image)

Eluents (Ethyl acetate: Hexane= 1: 4, Rf= 0.35) was used for flash column chromatography. $^1$H NMR (400 MHz, CDCl$_3$) δ 2.45 (s, 3H), 2.47 (s, 3H), 6.72 (s, 1H), 7.26-7.34 (m, 6H), 7.48 (s, 1H), 7.56-7.57 (m, 3H), 7.64 (d, J= 8.0 Hz, 2H), 7.80 (s, 1H), 7.97-7.99 (m, 2H); $^{13}$C NMR (100 MHz, CDCl$_3$) δ 21.2, 21.3, 108.9, 115.0, 119.9, 126.1, 127.1, 128.2, 128.6, 129.0, 129.8, 131.3, 131.7, 135.9, 136.8, 138.4, 138.8, 143.6, 145.1, 157.9, 161.7, 178.0; MS (EI): m/z (relative intensity) 401.1 (M$^+$, 100), 200.1 (6).
4-Oxo-2-phenyl-7-(o-tolyl)-4H-chromen-5-yl 4-methylbenzenesulfonate (Scheme 4, compound 3o)

Eluents (Ethyl acetate: Hexane= 1: 2, R$_f$= 0.40) was used for flash column chromatography. Grey solid; m.p.=172.0-172.6 °C; $^1$H NMR (400 MHz, CDCl$_3$) δ 2.30 (s, 3H), 2.42 (s, 3H), 6.69 (s, 1H), 7.23-7.34 (m, 7H), 7.47-7.50 (m, 4H), 7.85 (d, J= 5.9 Hz, 2H), 7.99 (d, J= 7.7 Hz, 2H); $^{13}$C NMR (100 MHz, CDCl$_3$) δ 20.3, 21.7, 108.9, 116.6, 117.7, 121.4, 126.1, 128.7, 128.9, 129.1, 129.4, 129.6, 130.8, 131.1, 131.7, 132.9, 135.1, 138.6, 145.4, 146.0, 147.4, 157.1, 162.0, 175.8; MS (EI): m/z (relative intensity) 482.2 (M$^+$, 26), 417.2 (100), 401.2 (33), 327.1 (68), 91.1 (59); HRMS: calcd. for C$_{29}$H$_{23}$O$_5$S$^+$: 483.1261, found 483.1246.

5-(4-Methoxyphenyl)-2-phenyl-7-(o-tolyl)-4H-chromen-4-one (Scheme 4, compound 3p)

Eluents (Ethyl acetate: Hexane= 1: 2, R$_f$= 0.50) was used for flash column chromatography. Yellow solid; m.p.=217.3-218.3 °C; $^1$H NMR (400 MHz, CDCl$_3$) δ 2.39 (s, 3H), 3.88 (s, 3H), 6.75 (s, 1H), 6.97 (d, J= 8.6 Hz, 2H), 7.22 (s, 1H), 7.28-7.37 (m, 6H), 7.53-7.55 (m, 4H), 7.94-7.96 (m, 2H); $^{13}$C NMR (100 MHz, CDCl$_3$) δ 20.5, 55.2, 108.9, 113.0, 117.6, 119.8, 126.0, 126.1, 128.2, 129.0, 129.5, 129.8, 130.1, 130.6, 131.4, 131.6, 133.3, 135.1, 139.7, 142.6, 146.5, 157.4, 158.9, 161.7, 178.2; MS (EI): m/z (relative intensity) 417.2 (M$^+$, 100), 402.2 (3), 374.2 (8); HRMS: calcd. for C$_{29}$H$_{23}$O$_3$: 419.1642, found 419.1643.
2-Phenyl-6-(phenylamino)-4H-chromen-4-one (Scheme 5 compound 5a)\(^9\)

![Structure of 2-Phenyl-6-(phenylamino)-4H-chromen-4-one](image)

Eluents (Ethyl acetate: DCM = 1: 4, \(R_f = 0.80\)) was used for flash column chromatography. Orange solid; \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 6.80 (s, 1H), 6.99 (t, \(J = 7.3\) Hz, 1H), 7.13 (d, \(J = 7.6\) Hz, 2H), 7.28-7.32 (m, 2H), 7.41-7.53 (m, 5H), 7.81 (s, 1H), 7.90-7.92 (m, 2H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 106.8, 110.7, 118.5, 119.1, 122.0, 124.1, 124.8, 126.2, 129.0, 129.5, 131.4, 132.0, 141.2, 142.3, 151.0, 163.1, 178.2; MS (EI): \(m/z\) (relative intensity) 312.4 (M\(^+\), 100), 207.2 (6), 154.2 (25), 128.2 (4), 78.2 (5).

6-(Methyl(phenyl)amino)-2-phenyl-4H-chromen-4-one (Scheme 5, compound 5b)\(^10\)

![Structure of 6-(Methyl(phenyl)amino)-2-phenyl-4H-chromen-4-one](image)

Eluents (Ethyl acetate: DCM = 1: 4, \(R_f = 0.90\)) was used for flash column chromatography. Yellow solid; \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 3.40 (s, 3H), 6.81 (s, 1H), 7.07-7.14 (m, 3H), 7.27-7.41 (m, 4H), 7.50-7.54 (m, 3H), 7.68 (d, \(J = 3.0\) Hz, 1H), 7.91-7.93 (m, 2H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 40.8, 106.9, 110.8, 118.6, 123.0, 123.4, 124.7, 125.6, 126.2, 129.0, 129.6, 131.3, 132.0, 146.6, 148.5, 150.8, 162.9, 178.4; MS (EI): \(m/z\) (relative intensity) 326.4 (M\(^+\), 100), 281.3 (11), 253.3 (9), 207.2 (30), 156.2 (10).

6-Morpholino-2-phenyl-4H-chromen-4-one (Scheme 5, compound 5c)\(^10\)

![Structure of 6-Morpholino-2-phenyl-4H-chromen-4-one](image)

Eluents (Ethyl acetate: DCM = 1: 4, \(R_f = 0.55\)) was used for flash column chromatography. Yellow solid; \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 3.22 (t, \(J = 4.7\) Hz, 4H), 3.87 (t, \(J = 4.7\) Hz, 4H), 6.78 (s, 1H), 7.30-7.34 (m, 1H), 7.48-7.56 (m, 5H), 7.88-7.90 (m, 2H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 49.3, 66.7, 106.8, 108.7, 118.9, 123.1, 124.3, 126.1, 128.9, 131.4, 148.7, 150.6, 163.0, 178.4; MS (EI): \(m/z\) (relative intensity) 307.4 (M\(^+\), 100), 281.3 (24), 249.3 (60), 207.2 (65), 147.2 (29).
7-(Butyl(methyl)amino)-2-phenyl-4H-chromen-4-one (Scheme 5, compound 5d)

Eluents (Ethyl acetate: DCM= 1: 4, Rf= 0.60) was used for flash column chromatography. Yellow solid; m.p.=100.8-103.2°C; $^1$H NMR (400 MHz, CD$_2$Cl$_2$) δ 1.03 (s, 3H), 1.38-1.47 (m, 2H), 1.62-1.70 (m, 2H), 3.09 (s, 3H), 3.46 (t, $J$= 7.5 Hz, 2H), 6.63-6.66 (m, 2H), 6.79-6.82 (m, 1H), 7.54-7.56 (m, 3H), 7.96-7.98 (m, 3H); $^{13}$C NMR (100 MHz, CD$_2$Cl$_2$) δ 13.7, 20.2, 29.0, 38.4, 52.2, 96.8, 107.1, 110.6, 113.2, 126.0, 126.2, 128.8, 130.9, 132.4, 153.4, 158.5, 162.0, 177.1; MS (EI): m/z (relative intensity) 307.4 (M+, 21), 264.3 (100), 207.2 (5), 162.2 (4), 131.8 (6); HRMS: calcd. for C$_{20}$H$_{22}$NO$_2$+: 308.1645, found 308.1658.

7-(4-Methylpiperazin-1-yl)-2-phenyl-4H-chromen-4-one (Scheme 5, compound 5e)

Eluents (Ethyl acetate, Rf= 0.15) was used for flash column chromatography. Yellow solid; m.p.=168.9-171.0°C; $^1$H NMR (400 MHz, CDCl$_3$) δ 2.36 (s, 3H), 2.58 (t, $J$= 5.1 Hz, 4H), 3.41 (t, $J$= 5.1 Hz, 4H), 6.70 (s, 1H), 6.81 (d, $J$= 2.4 Hz, 1H), 6.94-6.97 (m, 1H), 7.46-7.50 (m, 3H), 7.86-7.90 (m, 2H), 8.04 (d, $J$= 9.0 Hz, 1H); $^{13}$C NMR (100 MHz, CDCl$_3$) δ 46.0, 47.3, 54.6, 100.3, 107.4, 113.2, 115.5, 126.0, 126.5, 128.9, 131.1, 132.1, 154.9, 158.2, 162.5, 177.7; MS (EI): m/z (relative intensity) 320.4 (M+, 100), 276.3 (10), 249.3 (18), 221.3 (18), 70.2 (53); HRMS: calcd. for C$_{20}$H$_{21}$N$_2$O$_2$+: 321.1598, found 321.1610.
2-Phenyl-7-(phenylamino)-4\(H\)-chromen-4-one (Scheme 5, compound 5f)\(^9\)

Eluents (Ethyl acetate: DCM= 1: 1, \(R_f= 0.80\)) was used for flash column chromatography. Yellow solid; \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 6.43 (bs, 1H) 6.73 (s, 1H), 6.94-6.96 (m, 1H), 7.06 (d, \(J = 2.1\) Hz, 1H), 7.15 (t, \(J = 7.4\) Hz, 1H), 7.27 (d, \(J = 7.5\) Hz, 2H), 7.38-7.42 (m, 2H), 7.47-7.51 (m, 3H), 7.85-7.88 (m, 2H), 8.07 (d, \(J = 8.7\) Hz, 1H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 100.1, 107.4, 114.6, 116.6, 121.5, 124.0, 126.1, 127.1, 128.9, 129.7, 131.2, 132.0, 140.1, 149.6, 158.3, 162.6, 177.6; MS (EI): \(m/\ell\) (relative intensity) 313.4 (M\(^+\), 100), 285.4 (34), 207.2 (8), 154.2 (16), 77.2 (5).

7-(Methyl(phenyl)amino)-2-phenyl-4\(H\)-chromen-4-one (Scheme 5, compound 5g)\(^10\)

Eluents (Ethyl acetate: DCM= 1: 4, \(R_f= 0.60\)) was used for flash column chromatography. Yellow solid; \(^1\)H NMR (400 MHz, CD\(_2\)Cl\(_2\)) \(\delta\) 3.45 (s, 3H), 6.70 (s, 1H), 6.80-6.84 (m, 2H), 7.31-7.36 (m, 3H), 7.48-7.54 (m, 5H), 7.92-7.94 (m, 3H); \(^{13}\)C NMR (100 MHz, CD\(_2\)Cl\(_2\)) \(\delta\) 40.4, 99.7, 107.2, 113.0, 115.0, 125.9, 126.0, 126.1, 126.5, 128.9, 130.0, 131.0, 132.2, 147.0, 153.5, 158.2, 162.2, 177.1; MS (EI): \(m/\ell\) (relative intensity) 327.4 (M\(^+\), 100), 299.4 (8), 168.2 (5), 128.0 (4), 77.2 (6).

7-Morpholino-2-phenyl-4\(H\)-chromen-4-one (Scheme 5, compound 5h)\(^10\)

Eluents (Ethyl acetate: DCM= 1: 10, \(R_f= 0.5\)) was used for flash column chromatography. \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 3.31 (t, \(J = 4.9\) Hz, 4H), 3.84 (t, \(J = 4.9\) Hz, 4H), 6.68 (s, 1H), 6.77 (d, \(J = 2.2\) Hz, 1H), 6.89-6.92 (m, 1H), 7.44-7.50 (m, 3H), 7.83-7.85 (m, 2H), 8.02 (d, \(J = 9.0\) Hz, 1H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 47.4, 66.3, 100.2, 107.2, 112.7, 115.7, 125.9, 126.4, 128.8, 131.1, 131.9, 154.9, 158.0, 162.4, 177.6; MS (EI): \(m/\ell\) (relative intensity) 307.2 (M\(^+\), 100), 249.1 (70), 221.1 (36), 147.1 (10), 108.3 (10), 80.1 (10), 77.2 (10), 65.9 (10), 37.2 (10), 35.9 (10), 28.1 (10), 22.1 (10), 12.1 (10).
7-(Hept-1-yn-1-yl)-2-phenyl-4H-chromen-4-one (Scheme 6)

Eluents (Ethyl acetate: Hexane= 1: 4, Rf= 0.5) was used for flash column chromatography. Light orange solid; m.p.=105.4-106.4°C; ¹H NMR (500 MHz, CDCl₃) δ 0.94 (t, J= 7.3 Hz, 3H), 1.35-1.41 (m, 2H), 1.42-1.48 (m, 2H), 1.61-1.67 (m, 2H), 2.45 (t, J= 7.2 Hz, 3H), 6.79 (s, 1H), 7.39 (d, J= 8.2 Hz, 1H), 7.49-7.53 (m, 3H), 7.57 (s, 1H), 7.89 (d, J= 7.0 Hz, 2H), 8.11 (d, J= 8.2 Hz, 1H); ¹³C NMR (1205 MHz, CDCl₃) δ 13.9, 19.5, 22.2, 28.1, 31.1, 79.4, 95.1, 107.7, 120.7, 122.8, 125.4, 126.2, 128.5, 129.0, 129.9, 131.6, 155.9, 163.4, 177.9; MS (EI): m/z (relative intensity) 316.1 (M⁺, 64), 301.1 (14), 287.1 (100), 273.1 (56), 261.1 (74), 231.1 (35); HRMS: calcd. for C₂₂H₂₁O₂⁺: 317.1536, found 317.1539.

7-(Dibenzo[b,d]thiophen-4-yl)-2-morpholino-4H-chromen-4-one (Scheme 7)¹¹

Eluents (MeOH: DCM= 1: 19, Rf= 0.50) was used for flash column chromatography. ¹H NMR (400 MHz, CDCl₃) δ 3.52-3.54 (m, 4H), 3.82-3.85 (m, 4H), 5.54 (s, 1H), 7.45-7.51 (m, 3H), 7.56 (t, J= 7.4 Hz, 1H), 7.68-7.72 (m, 2H), 7.82-7.84 (m, 1H), 8.17-8.19 (m, 2H), 8.28 (d, J= 8.0 Hz, 1H); ¹³C NMR (100 MHz, CDCl₃) δ 44.7, 66.0, 87.6, 115.9, 121.3, 121.8, 122.4, 122.6, 124.6, 125.0, 125.2, 126.2, 127.0, 127.1, 135.2, 135.5, 135.6, 138.3, 139.2, 144.9, 153.9, 162.8, 176.8; MS (EI): m/z (relative intensity) 413.1 (M⁺, 100), 356.1 (62), 328.0 (36), 245.0 (34).
9. $^1\text{H}$, $^{13}\text{C}$, $^{19}\text{F}$ NMR, MS and HRMS spectra
<table>
<thead>
<tr>
<th>Mass</th>
<th>Calc. Mass</th>
<th>mDa</th>
<th>PPM</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>563.0830</td>
<td>563.0829</td>
<td>-0.11</td>
<td>-0.2</td>
<td>C29 H23 O8 S2</td>
</tr>
<tr>
<td>Mass</td>
<td>Calc. Mass</td>
<td>mDa</td>
<td>PPM</td>
<td>Formula</td>
</tr>
<tr>
<td>----------</td>
<td>------------</td>
<td>-----</td>
<td>-------</td>
<td>------------</td>
</tr>
<tr>
<td>420.1112</td>
<td>420.1111</td>
<td>-0.05</td>
<td>-0.12</td>
<td>C20 H22 N O7 S</td>
</tr>
</tbody>
</table>
Scheme 3, compound 3a
Scheme 3, compound 3a
Scheme 3, compound 3b

[Chemical structure image]

[1H NMR spectrum]

Scheme 3, compound 3b

[13C NMR spectrum]
Scheme 3, compound 3d

Scheme 3, compound 3d
Scheme 3, compound 3d

<table>
<thead>
<tr>
<th>Mass</th>
<th>Calc. Mass</th>
<th>mDa</th>
<th>PPM</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>389.1396</td>
<td>389.1384</td>
<td>1.2</td>
<td>0.2</td>
<td>C24 H21 O5</td>
</tr>
</tbody>
</table>
Scheme 3, compound 3e
Scheme 3, compound 3e

<table>
<thead>
<tr>
<th>Mass</th>
<th>Calc. Mass</th>
<th>mDa</th>
<th>PPM</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>329.1162</td>
<td>329.1172</td>
<td>-0.1</td>
<td>-3.1</td>
<td>C22 H17 O3</td>
</tr>
</tbody>
</table>
Scheme 3, compound 3g
Scheme 3, compound 3g

<table>
<thead>
<tr>
<th>Mass</th>
<th>Calc. Mass</th>
<th>mDa</th>
<th>PPM</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>375.1368</td>
<td>375.138</td>
<td>-1.2</td>
<td>-3.1</td>
<td>C27 H21 O2</td>
</tr>
</tbody>
</table>
Scheme 3, compound 3i

Scheme 3, compound 3i
Scheme 3, compound 3i
<table>
<thead>
<tr>
<th>Mass</th>
<th>Calc. Mass</th>
<th>mDa</th>
<th>PPM</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>317.0975</td>
<td>317.0972</td>
<td>-0.27</td>
<td>-0.84</td>
<td>C21 H14 F O2</td>
</tr>
</tbody>
</table>
Scheme 3, compound 3j

Scheme 3, compound 3j
<table>
<thead>
<tr>
<th>Mass</th>
<th>Calc. Mass</th>
<th>mDa</th>
<th>PPM</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>367.0941</td>
<td>367.0940</td>
<td>-0.06</td>
<td>-0.16</td>
<td>C22 H14 F3 O2</td>
</tr>
</tbody>
</table>
Scheme 3, compound 3k
Scheme 3, compound 3k
Scheme 3, compound 3l
Scheme 3, compound 3m
Scheme 3, compound 3m
Scheme 4 compound 3o
Scheme 4 compound 3o

<table>
<thead>
<tr>
<th>Mass</th>
<th>Calc. Mass</th>
<th>mDa</th>
<th>PPM</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>483.1246</td>
<td>483.1261</td>
<td>1.47</td>
<td>3.05</td>
<td>C29 H23 O5 S</td>
</tr>
</tbody>
</table>
Scheme 4 compound 3p
Scheme 5, compound 5a
Scheme 5, compound 5b
Scheme 5, compound 5c
Scheme 5, compound 5c
Scheme 5, compound 5d

<table>
<thead>
<tr>
<th>Mass</th>
<th>Calc. Mass</th>
<th>mDa</th>
<th>PPM</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>308.1658</td>
<td>308.1645</td>
<td>1.3</td>
<td>4.2</td>
<td>C20H22NO2</td>
</tr>
</tbody>
</table>
Scheme 5, compound 5e

[Chemical structure and NMR spectrum image]

Scheme 5, compound 5e

[Chemical structure and NMR spectrum image]
Scheme 5, compound 5f
Scheme 5, compound 5f
Scheme 5, compound 5g
Scheme 5, compound 5g
Scheme 5, compound 5h

Scheme 5, compound 5h
Scheme 5, compound 5h
Scheme 7

Scheme 7
Scheme 7
10. References