Electronic Supplementary Material (ESI) for Organic & Biomolecular Chemistry.

Regio- and stereoselective synthesis of functionalized tetrahydrobenzochromenes and hexahydrochromenochromenones *via* [4+2] annulation of curcumins with nitrochromenes

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Table of contents

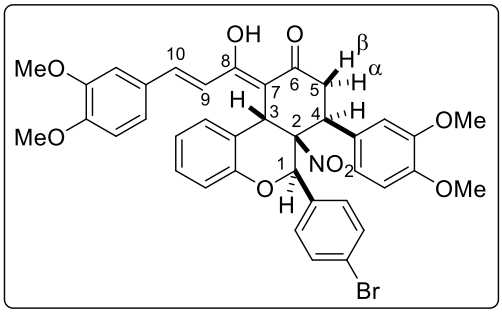
1. General information

The melting points recorded are uncorrected. NMR spectra ^{1}H, ^{1}H-decoupled ^{13}C, APT and ^{1}H-^{1}H COSY, were recorded with TMS as the internal standard. The coupling constants (*J* values) are given in Hz. High-resolution mass spectra were recorded under ESI Q-TOF conditions. X-ray data were collected on a diffractometer equipped with graphite monochromated Mo Kα radiation (λ= 0.71073 Å). The structure was determined by direct methods shelxt and refined by full-matrix least-squares against F2 using olex2 software. Enantioselectivities were determined using a chiral HPLC equipped with a UV detector and a Chiralpak ADH and Chiralpak IC column. Specific rotations were measured for solutions of samples of known concentrations in CH_2Cl_2 using a polarimeter equipped with a sodium vapor lamp. The curcumins **1**[1] and nitrochromenes **2**[2] were prepared by literature methods.

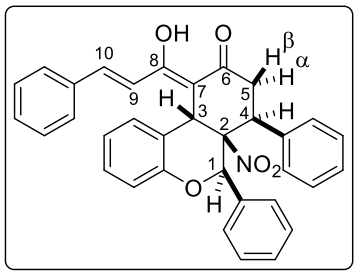
2. Experimental procedures and characterization data

General procedure for the synthesis of racemic double Michael adducts or tetrahydro-benzo[*c*]chromenes (3). To a stirred solution of curcumin **1** (0.2 mmol, 1.0 equiv) and nitrochromene **2** (0.2 mmol, 1.2 equiv) in DCM (3.0 mL), Cs_2CO_3 (1.0 equiv) was added at room temperature. After completion of the reaction (1-2 h, monitored by TLC), the solvent was evaporated, and the crude residue was purified by silica gel column chromatography by eluting with petroleum ether/ethyl acetate to isolate pure double Michael adduct **3**.

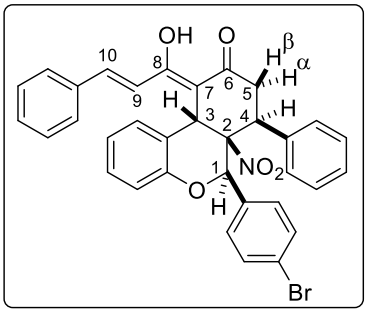
(*E*)-1-(6-(4-Bromophenyl)-7-(3,4-dimethoxyphenyl)-9-hydroxy-6a-nitro-6a,7,8,10a-tetrahydro-6*H*-benzo[*c*]chromen-10-yl)-3-(3,4-dimethoxyphenyl)prop-2-en-1-one (3a). Yellow solid; Yield 90% (65 mg); petroleum ether:ethyl acetate (85:15), mp 131-133 °C; IR (KBr film) 3443 (m, br), 2962 (w), 1623 (m), 1517 (s), 1342 (w), 1263 (s); ^{1}H NMR ($CDCl_3$, 400 MHz) δ 2.70 (dd, *J* = 19.0, 5.4 Hz, 1H, *C5-αH*), 2.97 (dd, *J* = 19.0, 13.7 Hz, 1H, *C5-βH*), 3.70 (dd, *J* = 13.7, 5.4 Hz, 1H, *C4-H*), 3.89 (s, 3H, *OCH$_3$*), 3.92 (s, 3H, *OCH$_3$*), 3.93 (s, 6H, *OCH$_3$*), 4.65 (s, 1H,*C3-H*), 5.51 (s, 1H, *C1-H*), 6.63 (d, *J* = 15.2 Hz, 1H, *C10-H*), 6.88 (d, *J* = 8.6 Hz, 1H, *Ar-H*), 6.91-6.95 (m, 4H, *Ar-H*), 6.98 (s, 1H, *Ar-H*), 7.05 (overlapped t, *J* = 8.0 Hz, 1H, *Ar-H*), 7.08 (d, *J* = 8.6 Hz, 1H, *Ar-H*), 7.15 (d, *J* = 8.6 Hz, 1H, *Ar-H*), 7.17 (d, *J* = 8.6 Hz, 1H, *Ar-H*), 7.26 (s, 1H, *Ar-H*), 7.35 (overlapped d, *J* = 8.0 Hz, 2H, *Ar-H*), 7.37 (overlapped t, *J* = 8.0 Hz, 1H, *Ar-H*), 7.89 (d, *J* = 15.2 Hz, 1H, *C9-H*), 16.94 (s, 1H, *C8-H*); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 35.4, 37.1, 41.3, 55.9 (× 2), 56.0, 56.2, 77.6, 91.0, 106.2, 109.9, 110.9, 111.4, 113.4, 116.0, 116.6, 122.5, 122.7, 123.1, 123.5, 123.8, 127.5, 128.0, 128.5, 129.7, 129.9, 131.9, 135.3, 144.0, 148.6, 149.3, 149.4, 151.3, 151.8, 181.1, 191.1; HRMS (ES+) m/z: $[M+H]^+$ calcd for $C_{38}H_{35}Br^{79}NO_9$, 728.1490; found 728.1487.



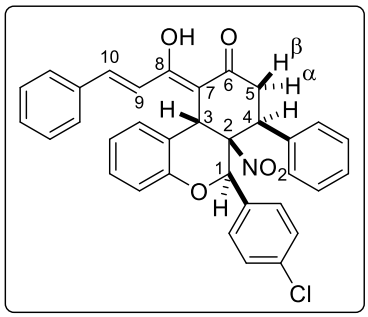
(*E*)-1-(9-Hydroxy-6a-nitro-6,7-diphenyl-6a,7,8,10a-tetrahydro-6*H*-benzo[*c*]chromen-10-yl)-3-phenylprop-2-en-1-one (3b). White solid; Yield 93% (98 mg); petroleum ether:ethyl acetate (97:3), mp 232-234 °C; IR (Neat, cm^{-1}) 2926 (m), 1627 (s), 1579 (s), 1544 (vs), 1223 (s); ^{1}H NMR ($CDCl_3$, 500 MHz) δ 2.72 (dd, *J* = 19.0, 5.4 Hz, 1H, , *C5-αH*), 3.06 (dd, *J* = 19.0, 13.7 Hz, 1H, *C5-βH*), 3.77 (dd, *J* = 13.7, 5.4 Hz, 1H, *C4-H*), 4.80 (s, 1H, *C3-H*), 5.51 (s, 1H, *C1-H*), 6.84 (d, *J* = 15.5 Hz, 1H, *C10-H*), 7.05 (t overlapped with d, *J* = 7.5 Hz, 1H, *Ar-H*), 7.06 (overlapped d, *J* = 8.6 Hz, 2H, *Ar-H*), 7.18 (d, *J* = 7.5 Hz, 1H, *Ar-H*), 7.21 (d, *J* = 7.5 Hz, 1H, *Ar-H*), 7.27 (t, *J* = 7.3 Hz, 2H, *Ar-H*), 7.34 (t, *J* = 7.5 Hz, 1H, *Ar-H*), 7.38-7.39 (m, 4H, *Ar-H*), 7.42-7.46 (m, 7H, *Ar-H*), 7.95 (d, *J* = 15.5 Hz, 1H, *C9-H*), 16.92 (s, 1H, *C8-H*); Confirmed by ^{1}H-^{1}H COSY; ^{13}C NMR ($CDCl_3$, 125 MHz) δ 35.5, 37.0, 41.6, 78.1, 91.1, 106.7, 116.8, 118.6, 122.2, 122.9, 126.8, 128.5, 128.5, 128.6, 128.9, 129.2, 129.5, 129.7, 129.8, 130.4, 130.7, 135.0, 135.5, 136.1, 143.7, 151.6, 180.7, 192.1; HRMS (ES+) m/z: $[M+Na]^+$ calcd for $C_{34}H_{27}NO_5Na$, 552.1781; found 552.1781.



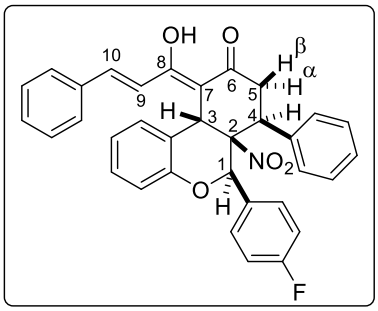
(*E*)-1-(6-(4-Bromophenyl)-9-hydroxy-6a-nitro-7-phenyl-6a,7,8,10a-tetrahydro-6*H*-benzo[*c*]-chromen-10-yl)-3-phenylprop-2-en-1-one (3c). White solid; Yield 94% (114 mg); petroleum ether:ethyl acetate (97:3), mp 211-213 °C; IR (Neat, cm^{-1}) 3441 (s, br), 2923 (s), 1628 (s), 1581 (s), 1544 (vs), 1484 (m), 1454 (m), 1223 (m); ^1H NMR ($CDCl_3$, 400 MHz) δ 2.81 (dd, J = 19.1, 5.3 Hz, 1H, *C5-αH*), 3.14 (dd, J = 19.1, 13.6 Hz, 1H, *C5-βH*), 3.84 (dd, J = 13.6, 5.3 Hz, 1H, *C4-H*), 4.81 (s, 1H, *C3-H*), 5.56 (s, 1H, *C1-H*), 6.90 (d, J = 15.2 Hz, 1H, *C10-H*), 7.02 (d, J = 8.4 Hz, 2H, *Ar-H*), 7.15 (t, J = 7.2 Hz, 1H, *Ar-H*), 7.28 (t, J = 7.7 Hz, 2H, *Ar-H*), 7.47-7.50 (m, 6H, *Ar-H*), 7.53-7.54 (unresolved m, 7H, *Ar-H*), 8.06 (d, J = 15.2 Hz, 1H, *C9-H*), 17.04 (s, 1H, *C8-H*); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 35.5, 36.9, 41.6, 77.7, 91.0, 106.5, 116.9, 118.5, 122.5, 122.8, 123.9, 128.5 (× 2), 128.6, 128.7, 129.2, 129.5, 130.0, 130.3, 130.8, 132.1, 135.0, 135.1, 135.2, 144.0, 151.3, 180.9, 191.8; HRMS (ES+) m/z: $[M+Na]^+$ calcd for $C_{34}H_{26}Br^{79}NO_5Na$, 630.0887; found 630.0885.



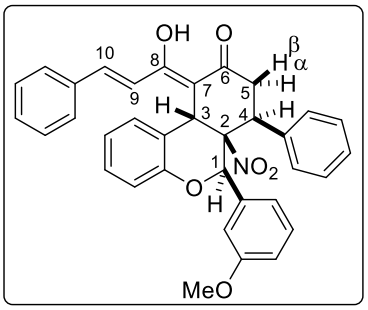
(*E*)-1-(6-(4-Chlorophenyl)-9-hydroxy-6a-nitro-7-phenyl-6a,7,8,10a-tetrahydro-6*H*-benzo[*c*]-chromen-10-yl)-3-phenylprop-2-en-1-one (3d). White solid; Yield 91% (102 mg); petroleum ether:ethyl acetate (97:3), mp 203-205 °C; IR (KBr film) 3444 (w, br), 3061 (w), 1628 (s), 1580 (s), 1543 (vs), 1484 (s), 1453 (s), 1354 (w), 1221 (m); ^1H NMR ($CDCl_3$, 500 MHz) δ 2.81 (dd, J = 19.1, 5.2 Hz, 1H, *C5-αH*), 3.14 (dd, J = 19.1, 13.6 Hz, 1H, *C5-βH*), 3.83 (dd, J = 13.6, 5.2 Hz, 1H, *C4-H*), 4.81 (s, 1H, *C3-H*), 5.57 (s, 1H, *C1-H*), 6.90 (d, J = 15.3 Hz, 1H, *C10-H*), 7.08 (d, J = 8.5 Hz, 2H, *Ar-H*), 7.15 (t, J = 7.5 Hz, 1H, *Ar-H*), 7.27 (overlapped d, J = 7.5 Hz, 1H, *Ar-H*), 7.29 (overlapped d, J = 7.5 Hz, 1H, *Ar-H*), 7.33 (d, J = 8.5 Hz, 2H, *Ar-H*), 7.46-7.53 (m, 11H, *Ar-H*), 8.05 (d, J = 15.3 Hz, 1H, *C9-H*), 17.06 (s, 1H, *C8-H*); Confirmed by ^1H-^1H COSY and ^1H-^1H NOESY experiments; ^{13}C NMR ($CDCl_3$, 100 MHz) δ 35.5, 36.9, 41.6, 77.6, 91.1, 106.5, 116.9, 118.5, 122.5, 122.8, 128.3, 128.5, 128.6, 128.7, 129.1, 129.2, 129.5, 130.0, 130.4, 130.8, 134.6, 135.0, 135.3, 135.7, 144.0, 151.3, 180.9, 191.9; HRMS (ES+) m/z: $[M+Na]^+$ calcd for $C_{34}H_{26}Cl^{35}NO_5Na$, 586.1392; found 586.1391.



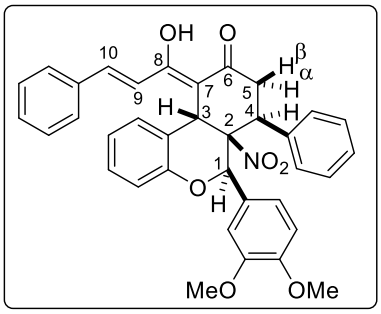
(*E*)-1-(6-(4-Fluorophenyl)-9-hydroxy-6a-nitro-7-phenyl-6a,7,8,10a-tetrahydro-6*H*-benzo[*c*]-chromen-10-yl)-3-phenylprop-2-en-1-one (3e). White solid; Yield 85% (93 mg); petroleum ether:ethyl acetate (97:3), mp 219-221 °C; IR (Neat, cm^{-1}) 3535 (w, br), 2929 (s), 1629 (m), 1606 (m), 1581 (m), 1545 (s), 1265 (s); ^1H NMR ($CDCl_3$, 400 MHz) δ 2.72 (dd, J = 19.1, 5.4 Hz, 1H, *C5-αH*), 3.05 (dd, J = 19.1, 13.7 Hz, 1H, *C5-βH*), 3.75 (dd, J = 13.7, 5.4 Hz, 1H, *C4-H*), 4.74 (s, 1H, *C3-H*), 5.49 (s, 1H, *C1-H*), 6.82 (d, J = 15.4 Hz, 1H, C*10-H*), 6.95 (t, J = 8.5 Hz, 2H, *Ar-H*), 7.02-7.08 (m, 3H, *Ar-H*), 7.18 (t, J = 8.5 Hz, 2H, *Ar-H*), 7.36–7.47 (m, 11H, *Ar-H*), 7.96 (s, J = 15.4 Hz, 1H, *C9-H*), 16.94 (s, 1H, *C8-H*); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 35.4, 37.0, 41.6, 77.6, 91.2, 106.5, 115.9 (d, J = 21.5 Hz), 116.9, 118.5, 122.5, 122.8, 128.5 (× 2), 128.7, 128.8 (d, J = 8.3 Hz), 129.2, 129.5, 130.0, 130.4, 130.8, 132.0 (d, J = 3.3 Hz), 135.0, 135.3, 144.0, 151.4, 163.3 (d, J = 248.0 Hz), 180.8, 192.0; ^{19}F NMR (376 MHz, $CDCl_3$) δ -111.41; HRMS (ES+) m/z: $[M+H]^+$ calcd for $C_{34}H_{27}FNO_5$, 548.1868; found 548.1869.



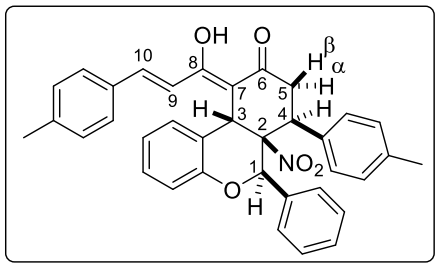
(*E*)-1-(9-Hydroxy-6-(3-methoxyphenyl)-6a-nitro-7-phenyl-6a,7,8,10a-tetrahydro-6*H*-benzo[*c*]-chromen-10-yl)-3-phenylprop-2-en-1-one (3f). White solid; Yield 96% (107 mg); petroleum ether:ethyl acetate (95:5), mp 195-197 °C; IR (KBr film) 3436 (m, br), 2932 (w), 1627 (s), 1603 (s), 1545 (vs), 1583 (s), 1545 (vs), 1483 (s), 1451 (s), 1221 (m); ^{1}H NMR ($CDCl_3$, 400 MHz) δ 2.71 (dd, *J* = 19.1, 5.6 Hz, 1H, *C5-αH*), 3.04 (dd, *J* = 19.1, 13.6 Hz, 1H, *C5-βH*), 3.67 (s, 3H, *OCH*$_3$), 3.76 (dd, *J* = 13.6, 5.6 Hz, 1H, *C4-H*), 4.84 (s, 1H, *C3-H*), 5.46 (s, 1H, *C1-H*), 6.60 (s, 1H, *Ar-H*), 6.64 (d, *J* = 7.9 Hz, 1H, *Ar-H*), 6.84-6.88 (overlapped m, 1H, *Ar-H*), 6.86 (overlapped d, *J* = 15.1 Hz, 1H, C*10-H*), 7.04 (t, *J* = 7.4 Hz, 1H, *Ar-H*), 7.15-7.20 (m, 3H, *Ar-H*), 7.34-7.47 (m, 11H, *Ar-H*), 7.93 (d, *J* = 15.1 Hz, 1H, C*9-H*), 16.84 (s, 1H, C*8-H*); ^{13}C NMR ($CDCl_3$, 125 MHz) δ 35.6, 37.0, 41.6, 55.3, 78.1, 91.0, 106.7, 112.8, 114.9, 116.9, 118.7, 119.2, 122.3, 122.9, 128.4 (× 2), 128.5 (× 2), 128.6, 129.1, 129.4, 129.9, 130.4 (× 2), 130.7, 135.1, 135.5, 137.6, 143.6, 151.6, 159.9, 180.6, 192.0; HRMS (ES+) m/z: $[M+K]^+$ calcd for $C_{35}H_{29}NO_6K$, 598.1626; found 598.1627.



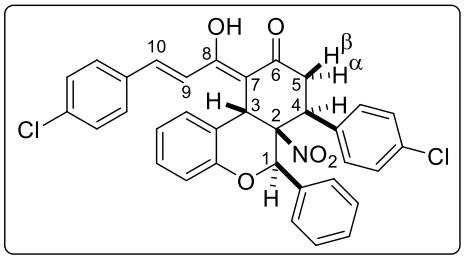
(*E*)-1-(6-(3,4-Dimethoxyphenyl)-9-hydroxy-6a-nitro-7-phenyl-6a,7,8,10a-tetrahydro-6*H*-benzo[*c*]-chromen-10-yl)-3-phenylprop-2-en-1-one (3g). White solid; Yield 87% (103 mg); petroleum ether:ethyl acetate (92:8), mp 226-229 °C; IR (KBr film) 3435 (m, br), 2937 (m), 1629 (s), 1581 (s), 1545 (vs), 1484 (s), 1451 (s), 1360 (m), 1275 (s), 1219 (s); ^{1}H NMR ($CDCl_3$, 500 MHz) δ 2.72 (dd, *J* = 19.1, 5.1 Hz, 1H, *C5-αH*), 3.04 (dd, *J* = 19.1, 13.5 Hz, 1H, *C5-βH*), 3.64 (s, 3H, *OCH*$_3$), 3.76 (dd, *J* = 13.5, 5.1 Hz, 1H, *C4-H*), 3.82 (s, 3H, *OCH*$_3$), 4.83 (s, 1H, *C3-H*), 5.47 (s, 1H, *C1-H*), 6.55 (d, *J* = 1.6 Hz, 1H, *Ar-H*), 6.64 (dd, *J* = 8.5, 1.6 Hz 1H, *Ar-H*), 6.73 (d, *J* = 8.5 Hz, 1H, *Ar-H*), 6.85 (d, *J* = 15.5 Hz, 1H, C*10-H*), 7.04 (t, *J* = 7.5 Hz, 1H, *Ar-H*), 7.19 (d, *J* =7.5 Hz, 2H, *Ar-H*), 7.35-7.38 (m, 4H, *Ar-H*), 7.45-7.46 (unresolved, 7H, *Ar-H*), 7.95 (d, *J* = 15.5 Hz, 1H, C*9-H*), 16.89 (s, 1H, C*8-H*); ^{13}C NMR ($CDCl_3$, 125 MHz) δ 35.7, 37.0, 41.6, 55.8, 55.9, 78.0, 91.2, 106.8, 109.9, 111.0, 116.9, 118.8, 119.7, 122.2, 122.9, 128.2, 128.4, 128.5, 128.6, 129.1, 129.3, 129.8, 130.3, 130.7, 135.1, 135.5, 143.6, 149.1, 149.9, 151.6, 180.5, 192.1; HRMS (ES+) m/z: $[M+H]^+$ calcd for $C_{36}H_{31}NO_7$, 590.2139; found 590.2139.



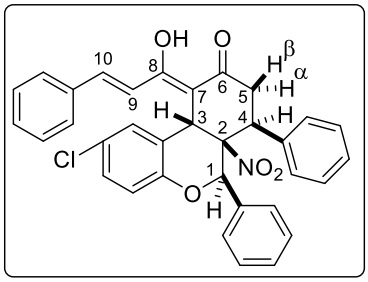
(*E*)-1-(9-Hydroxy-6a-nitro-6-phenyl-7-(p-tolyl)-6a,7,8,10a-tetrahydro-6*H*-benzo[*c*]chromen-10-yl)-3-(p-tolyl)prop-2-en-1-one (3i). White solid; Yield 94% (105 mg); dr > 95:5, petroleum ether:ethyl acetate (97:3), mp 192-193 °C; IR (Neat, cm^{-1}) 3400 (w, br), 2922 (m), 1622 (s), 1581 (s), 1546 (vs), 1223 (m); ^{1}H NMR ($CDCl_3$, 400 MHz) δ 2.38 (s, 3H, *CH*$_3$), 2.42 (s, 3H, *CH*$_3$), 2.69 (dd, *J* = 19.1, 5.4 Hz, 1H, *C5-αH*), 3.02 (dd, *J* = 19.1, 13.6 Hz, 1H, *C5-βH*), 3.72 (dd, *J* = 13.6, 5.4 Hz, 1H, *C4-H*), 4.77 (s, 1H, *C3-H*), 5.51 (s, 1H, *C1-H*), 6.78 (d, *J* = 15.4 Hz, 1H, *C10-H*), 7.03 (overlapped t, *J* = 8.0 Hz, 1H, *Ar-H*), 7.06 (overlapped d, *J* = 7.2 Hz, 2H, *Ar-H*), 7.16-7.20 (overlapped m, 2H, *Ar-H*), 7.18 (overlapped d, *J* = 8.2 Hz, 2H, *Ar-H*), 7.24-7.28 (m, 4H, *Ar-H*), 7.31–7.38 (m, 6H, *Ar-H*), 7.91 (d, *J* = 15.4 Hz, 1H, *C9-H*), 16.96 (s, 1H, *C8-H*); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 21.4, 21.7, 35.4, 37.0, 41.3, 78.2, 91.1, 106.6, 116.8, 117.6, 122.2, 123.0, 126.9, 128.6, 128.8, 129.2, 129.5, 129.6, 129.8, 129.9, 130.2, 132.3, 132.4, 136.2, 138.4, 141.3, 143.8, 151.7, 181.1, 191.8; HRMS (ES+) m/z: $[M+K]^+$ calcd for $C_{36}H_{31}NO_5K$, 596.1834; found 596.1833.



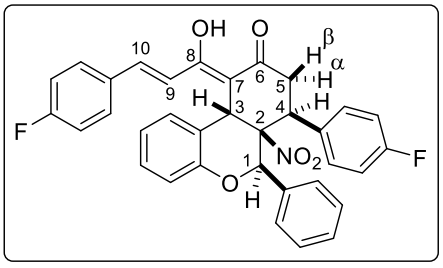
(*E*)-3-(4-Chlorophenyl)-1-(7-(4-chlorophenyl)-9-hydroxy-6a-nitro-6-phenyl-6a,7,8,10a-tetrahydro-6*H*-benzo[*c*]chromen-10-yl)prop-2-en-1-one (3j). White solid; Yield 83% (98 mg); petroleum ether:ethyl acetate (97:3), mp 196-198 °C; IR (Neat, cm^{-1}) 3467 (m, br), 1623 (s), 1581 (s), 1545 (vs), 1491 (s), 1274 (m), 1224 (m); ^{1}H NMR ($CDCl_3$, 400 MHz) δ 2.70 (dd, *J* = 18.9, 5.5 Hz, 1H, *C5-αH*), 2.99 (dd, *J* = 18.9, 13.6 Hz, 1H, *C5-βH*), 3.77 (dd, *J* = 13.6, 5.5 Hz, 1H, *C4-H*), 4.75 (s, 1H, *C3-H*), 5.45 (s, 1H, *C1-H*), 6.76 (d, *J* =15.3 Hz, 1H, C*10-H*), 7.04-7.07 (overlapped m, 1H, *Ar-H*), 7.05 (overlapped t, *J* = 6.6 Hz, 2H, *Ar-H*), 7.13 (d, *J* = 7.8 Hz, 1H, *Ar-H*), 7.20 (d, *J* = 7.8 Hz, 1H, *Ar-H*), 7.27 (t, *J* = 7.4 Hz, 2H, *Ar-H*), 7.34-7.38 (m, 6H, *Ar-H*), 7.41 (ABq, *J* = 8.4 Hz, 4H, *Ar-H*), 7.87 (d, *J* = 15.3 Hz, 1H, C*9-H*), 16.82 (s, 1H, C*8-H*); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 35.4, 37.0, 41.0, 78.1, 90.9, 106.6, 116.9, 119.0, 122.4, 122.7, 126.7, 128.7, 128.9, 129.4, 129.5, 129.6, 129.8, 130.0, 131.7, 133.5, 133.9, 134.6, 135.8, 136.7, 142.4, 151.5, 180.3, 191.9; HRMS (ES+) m/z: $[M+H]^+$ calcd for $C_{34}H_{26}Cl_2{}^{35}NO_5$, 598.1183; found 598.1174.



(*E*)-1-(2-Chloro-9-hydroxy-6a-nitro-6,7-diphenyl-6a,7,8,10a-tetrahydro-6*H*-benzo[*c*]chromen-10-yl)-3-phenylprop-2-en-1-one (3h). White solid; Yield 88% (99 mg); petroleum ether:ethyl acetate (97:3), mp 232-234 °C; IR (Neat, cm^{-1}) 3441 (w, br), 2930 (w), 1627 (w), 1546 (m), 1264 (s); ^{1}H NMR ($CDCl_3$, 400 MHz) δ 2.75 (dd, *J* = 19.2, 5.3 Hz, 1H, *C5-αH*), 3.06 (dd, *J* = 19.2, 13.7 Hz, 1H, *C5-βH*), 3.72 (dd, *J* = 13.7, 5.3 Hz, 1H, *C4-H*), 4.77 (s, 1H, *C3-H*), 5.51 (s, 1H, *C1-H*), 6.78 (d, *J* = 15.5 Hz, 1H, C*10-H*), 7.04 (d, *J* = 7.2 Hz, 2H, *Ar-H*), 7.12 (overlapped d, *J* = 1.2 Hz, 1H, *Ar-H*), 7.15 (d, *J* = 8.8 Hz, 1H, *Ar-H*), 7.29 (d, *J* = 7.6 Hz, 2H, *Ar-H*), 7.34 (overlapped dd, *J* = 8.8, 1.2 Hz, 1H, *Ar-H*), 7.33-7.35 (overlapped m, 1H, *Ar-H*), 7.39-7.47 (m, 10H, *Ar-H*), 7.97 (d, *J* = 15.5 Hz, 1H, C*9-H*), 16.91 (s, 1H, C*8-H*); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 35.5, 37.0, 41.7, 78.3, 90.8, 106.1, 118.0, 118.2, 124.8, 126.7, 127.4, 128.5, 128.6, 128.7, 128.9, 129.2, 129.9, 130.0, 130.3 (× 2), 130.9, 134.9, 135.2, 135.7, 144.4, 150.3, 180.6, 192.1; HRMS (ES+) m/z: $[M+H]^+$ calcd for $C_{34}H_{27}ClNO_5$, 564.1572; found 564.1571.



(*Z*)-7-(Furan-2-yl)-10-((E)-3-(furan-2-yl)-1-hydroxyallylidene)-6a-nitro-6-phenyl-6,6a,7,8,10,10a-hexahydro-9*H*-benzo[*c*]chromen-9-one (3k). White solid; Yield 60% (68 mg); petroleum ether:ethyl acetate (96:4), mp 184-186 °C; IR (Neat, cm^{-1}) 3481 (vs, br), 1630 (s), 1610 (s), 1549 (s), 1513 (s), 1225 (s); ^{1}H NMR ($CDCl_3$, 500 MHz) δ 2.70 (dd, *J* = 18.9, 5.2 Hz, 1H, *C5-αH*), 2.97 (dd, *J* = 18.9, 13.8 Hz, 1H, *C5-βH*), 3.70 (dd, *J* = 13.8, 5.2 Hz, 1H, *C4-H*), 4.75 (s, 1H, *C3-H*), 5.45 (s, 1H, *C1-H*), 6.72 (d, *J* = 15.4 Hz, 1H, C*10-H*), 7.04-7.07 (overlapped m, 1H, *Ar-H*), 7.05 (overlapped d, *J* = 7.5 Hz, 2H, *Ar-H*), 7.07 overlapped t, *J* = 8.5 Hz, 2H, *Ar-H*), 7.14 (overlapped t, *J* = 8.5 Hz, 2H, *Ar-H*), 7.12-7.15 (overlapped m, 1H, *Ar-H*), 7.19 (d, *J* = 8.0 Hz, 1H, *Ar-H*), 7.27 (overlapped d, *J* = 7.5 Hz, 2H, *Ar-H*), 7.34 (d, *J* = 8.0 Hz, 1H, *Ar-H*), 7.38 (t, *J* = 8.0 Hz, 1H, *Ar-H*), 7.42-7.44 (m, 4H, *Ar-H*), 7.89 (d, *J* = 15.4 Hz, 1H, C*9-H*), 16.88 (s, 1H, C*8-H*); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 35.4, 37.1, 40.9, 78.1, 91.0, 106.6, 115.4 (d, *J* = 21.1 Hz), 116.4 (d, *J* = 21.5 Hz), 116.9, 118.2 (d, *J* = 1.8 Hz), 122.3, 122.8, 126.8, 128.9, 129.4, 129.8, 129.9, 130.4 (d, *J* = 8.5 Hz), 131.1 (d, *J* = 3.4 Hz), 131.3 (d, *J* = 3.1 Hz), 132.0 (d, *J* = 8.5 Hz), 135.9,



142.6, 151.5, 162.9 (d, J = 246.0 Hz), 164.2 (d, J = 250.0 Hz), 180.8, 191.7; ^{19}F NMR (470 MHz, $CDCl_3$) δ -113.5, - 108.7; HRMS (ES+) m/z: $[M]^+$ calcd for $C_{34}H_{27}F_2NO_5$, 567.1796; found 567.1796.

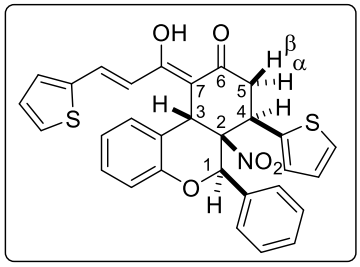
(*E*)-3-(3-Chlorophenyl)-1-(7-(3-chlorophenyl)-9-hydroxy-6a-nitro-6-phenyl-6a,7,8,10a-tetrahydro-6*H*-benzo[*c*]chromen-10-yl)prop-2-en-1-one (3n). White solid; Yield 94% (112 mg); petroleum ether:ethyl acetate (97:3), mp 223-225 °C; IR (Neat, cm^{-1}) 3386 (vs, br), 1630 (s), 1573 (s), 1547 (vs), 1223 (m); ^{1}H NMR ($CDCl_3$, 400 MHz) δ 2.73 (dd, J = 19.1, 5.2 Hz, 1H, *C5-αH*), 3.01 (dd, J = 19.1, 13.5 Hz, 1H, *C5-βH*), 3.77 (dd, J = 13.5, 5.2 Hz, 1H, *C4-H*), 4.79 (s, 1H, *C3-H*), 5.52 (s, 1H, *C1-H*), 6.81 (d, J =15.2 Hz, 1H, C*10-H*), 7.08-7.14 (m, 4H, *Ar-H*), 7.24-7.51 (m, 13H, *Ar-H*), 7.85 (d, J = 15.2, 1H, C*9-H*) 16.67 (s, 1H, C*8-H*); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 35.4, 36.9, 41.2, 78.1, 90.8, 106.7, 117.0, 119.8, 122.4, 122.6, 126.7, 126.9, 127.9, 128.6, 128.9, 129.0, 129.3, 129.7, 129.9, 130.1, 130.4, 130.5 (× 2), 134.4, 135.2, 135.8, 136.8, 137.5, 142.0, 151.5, 179.7, 192.1; HRMS (ES+) m/z: $[M+H]^+$ calcd for $C_{34}H_{26}Cl_2{}^{35}NO_5$, 598.1183; found 598.1177.

(*E*)-3-(4-Bromophenyl)-1-(7-(4-bromophenyl)-9-hydroxy-6a-nitro-6-phenyl-6a,7,8,10a-tetrahydro-6*H*-benzo[*c*]chromen-10-yl)prop-2-en-1-one (3o). White solid; Yield 92% (126 mg); petroleum ether:ethyl acetate (97:3), mp 173-175 °C; IR (Neat, cm^{-1}) 3477 (w, br), 1626 (s), 1582 (s), 1545 (vs), 1486 (s), 1450 (m), 1356 (w), 1223 (m); ^{1}H NMR ($CDCl_3$, 400 MHz) δ 2.71 (dd, J = 19.0, 5.4 Hz, 1H, *C5-αH*), 2.99 (dd, J = 19.0, 13.6 Hz, 1H, *C5-βH*), 3.73 (dd, J = 13.6, 5.4 Hz, 1H, *C4-H*), 4.76 (s, 1H, *C3-H*), 5.49 (s, 1H, *C1-H*), 6.77 (d, J = 15.6 Hz, 1H, C*10-H*), 7.06-7.08 (m, 3H, *Ar-H*), 7.11 (t, J = 7.7 Hz, 1H, *Ar-H*), 7.23 (overlapped t, J = 7.7 Hz, 1H, *Ar-H*), 7.25-7.28 (m, 2H, *Ar-H*), 7.31 (d, J = 8.4 Hz, 2H, *Ar-H*), 7.34-7.39 (m, 4H, *Ar-H*), 7.50 (d, J = 7.7 Hz, 1H, *Ar-H*), 7.55 (overlapped s, 1H, *Ar-H*), 7.56 (overlapped d, J = 7.7 Hz, 1H, *Ar-H*), 7.61 (s, 1H, *Ar-H*), 7.81 (d, J = 15.6 Hz, 1H, C*9-H*), 16.62 (s, 1H, C*8-H*); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 35.5, 36.9, 41.2, 78.1, 90.8, 106.8, 117.0, 119.8, 122.4, 122.6 (× 2), 123.3, 126.7, 127.4, 129.0 (× 2), 129.3, 129.9, 130.1 (× 2), 130.7, 130.8, 131.8, 133.4 (× 2), 135.8, 137.1, 137.8, 141.8, 151.5, 179.6, 192.1; HRMS (ES+) m/z: $[M+H]^+$ calcd for $C_{34}H_{26}Br_2{}^{79}NO_5$, 686.0172; found 686.0172.

(*E*)-3-(3,4-Dimethoxyphenyl)-1-(7-(3,4-dimethoxyphenyl)-9-hydroxy-6a-nitro-6-phenyl-6a,7,8,10a-tetrahydro-6*H*-benzo[*c*]chromen-10-yl)prop-2-en-1-one (3p). Yellow solid; Yield 96% (124 mg); petroleum ether:ethyl acetate (85:15), mp 137-139 °C; IR (Neat, cm^{-1}) 3463 (vs, br), 1622 (m), 1583 (m), 1542 (s), 1516 (s), 1264 (s); ^{1}H NMR ($CDCl_3$, 400 MHz) δ 2.71 (dd, J = 19.0, 5.3 Hz, 1H, *C5-αH*), 2.98 (dd, J = 19.0, 13.7 Hz, 1H, *C5-βH*), 3.72 (dd, J = 13.7, 5.3 Hz, 1H, *C4-H*), 3.87 (s, 3H, *OCH₃*), 3.92 (s, 3H, *OCH₃*), 3.93 (s, 3H, *OCH₃*), 3.94 (s, 3H, *OCH₃*), 4.74 (s, 1H, *C3-H*), 5.54 (s, 1H, *C1-H*), 6.66 (d, J = 15.3 Hz, 1H, C*10-H*), 6.87 (d, J = 8.5 Hz, 1H, *Ar-H*), 6.90 (overlapped s, 1H, *Ar-H*), 6.93 (d, J = 8.5 Hz, 1H, *Ar-H*), 6.98-7.01 (unresolved m, 2H, *Ar-H*), 7.04-7.10 (m, 4H, *Ar-H*), 7.15 (overlapped d, J = 8.5 Hz, 1H, *Ar-H*),

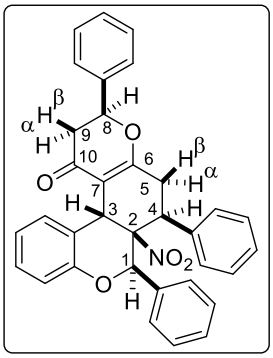
7.17 (overlapped d, *J* = 8.5 Hz, 1H, *Ar-H*), 7.23 (t, *J* = 7.7 Hz, 2H, *Ar-H*), 7.31 (d, *J* = 7.5 Hz, 1H, *Ar-H*), 7.36 (t, *J* = 7.5 Hz, 1H, *Ar-H*), 7.88 (d, *J* = 15.3 Hz, 1H, C*9-H*), 16.97 (s, 1H, C*8-H*); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 35.4, 37.1, 41.3, 55.9, 56.0, 56.0, 56.2, 78.1, 91.1, 106.4, 110.1, 110.8, 111.3, 113.4, 116.3, 116.6, 122.2, 122.7, 123.2, 123.3, 126.9, 127.7, 128.0, 128.8, 129.5, 129.7, 129.8, 136.2, 143.8, 148.5, 149.2, 149.4, 151.6, 151.7, 181.2, 191.3; HRMS (ES+) m/z: $[M+Na]^+$ calcd for $C_{38}H_{35}NO_9Na$, 672.2204; found 672.2206.

(*Z*)-10-((E)-1-Hydroxy-3-(thiophen-2-yl)allylidene)-6a-nitro-6-phenyl-7-(thiophen-2-yl)-6,6a,7,8,10,10a-hexahydro-9*H*-benzo[*c*]chromen-9-one (3q). Yellow solid; Yield 69% (74 mg); petroleum ether:ethyl acetate (95:5), mp 117-119 °C; IR (KBr film) 3434 (m, br), 2922 (w), 1614 (s), 1581 (m), 1544 (vs), 1450 (m), 1409 (m), 1223 (m); ^{1}H NMR ($CDCl_3$, 400 MHz) δ 2.86, 2.97 (ABq, *J* = 19.2 Hz, the lower half and upper half are further split into d with *J* = 13.2 and 5.9 Hz, 2H, *C5-H*), 4.06 (dd, *J* = 13.2, 5.9 Hz, 1H, *C4-H*), 4.73 (s, 1H, *C3-H*), 5.73 (s, 1H, *C1-H*), 6.59 (d, *J* = 14.8 Hz, 1H, C*10-H*), 7.04 (overlapped t, *J* = 7.6 Hz, 1H, *Ar-H*), 7.06-7.08 (m, 3H, *Ar-H*), 7.09-7.12 (m, 1H, *Ar-H*), 7.14 (d, *J* = 6.5 Hz, 1H, *Ar-H*), 7.17-7.20 (m, 2H, *Ar-H*), 7.27-7.31 (m, 3H, *Ar-H*), 7.34 (overlapped d, *J* = 7.6 Hz, 1H, *Ar-H*), 7.36 (overlapped t, *J* = 7.6 Hz, 1H, *Ar-H*), 7.41 (t, *J* = 4.2 Hz, 2H, *Ar-H*), 8.01 (d, *J* = 14.8 Hz, 1H, C*9-H*), 16.89 (s, 1H, C*8-H*); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 35.4, 38.0, 38.7, 78.3, 91.0, 106.1, 116.9, 117.5, 122.3, 123.0, 126.5, 126.7, 126.8, 128.7, 128.9, 129.0, 129.3, 129.5, 129.7, 129.8, 131.9, 135.9, 136.5, 138.7, 140.6, 151.8, 181.4, 190.3; HRMS (ES+) m/z: $[M+H]^+$ calcd for $C_{30}H_{24}NO_5S_2$, 542.1090; found 542.1095.

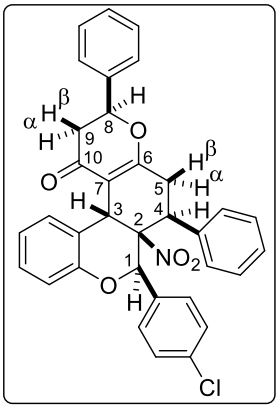


General procedure for the synthesis of racemic triple Michael adducts or hexahydro-1*H*, 6*H*-chromeno[6,5-*c*]chromenone (4). To a stirred solution of curcumin **1** (0.3 mmol, 1.0 equiv) and nitrochromene **2** (0.3 mmol, 1.2 equiv) in DCM (3.0 mL), DBU (3.0 equiv) was added at room temperature. After completion of the reaction (3-4 d, monitored by TLC), the solvent was evaporated under vacuum. The crude residue was washed with water (3 × 5 mL), and extracted with ethyl acetate (3 × 5 mL). The organic phase was separated and washed with brine (10 mL), dried over Na_2SO_4 and concentrated in *vacuo*. The crude residue was purified by silica gel column chromatography by eluting with petroleum ether/ethyl acetate to isolate pure triple Michael adduct **4**.

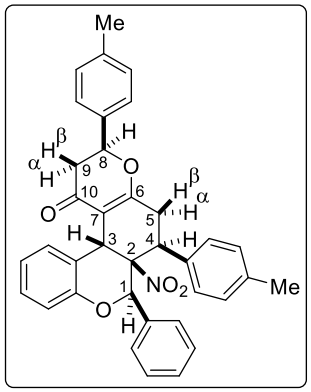
6a-Nitro-3,6,7-triphenyl-2,3,5,6a,7,12b-hexahydro-1*H*,6*H*-chromeno[6,5-*c*]chromen-1-one (4b). White solid; Yield 81% (128 mg); petroleum ether:ethyl acetate (96:4), mp 256-258 °C; IR (Neat, cm^{-1}) 3461 (vs, br), 1664 (m), 1614 (s), 1583 (m), 1542 (m), 1451 (m), 1225 (m); ^{1}H NMR ($CDCl_3$, 400 MHz) δ 2.60 (dd, *J* = 18.8, 5.2 Hz, 1H, *C5-αH*), 2.86, 2.97 (ABq, *J* = 17.2 Hz, the lower and upper half are further split into d with *J* = 13.7 and 3.9 Hz, 2H, *C9-H*), 3.06 (dd, *J* = 18.8, 13.2 Hz, 1H, *C5-βH*), 3.81 (dd, *J* = 13.2, 5.2 Hz, 1H, *C4-H*), 4.88 (s, 1H, *C3-H*), 5.44 (s, 1H, *C1-H*), 5.45 (dd, *J* = 13.7, 3.9 Hz, 1H, *C8-H*), 7.00 (d, *J* = 7.5 Hz, 2H, *Ar-H*), 7.08 (t, *J* = 7.8 Hz, 1H, *Ar-H*), 7.13 (d, *J* = 7.8 Hz, 1H, *Ar-H*), 7.19 (t, *J* = 7.5 Hz, 2H, *Ar-H*), 7.24-7.29 (m, 2H, *Ar-H*), 7.33 (t, *J* = 7.8 Hz, 1H, *Ar-H*), 7.42-7.45 (m, 10H, *Ar-H*); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 31.8, 33.0, 42.4, 42.8, 77.7, 80.2, 90.6, 113.3, 116.7, 122.2, 123.9, 126.5, 127.2, 128.4, 128.7, 128.9, 129.1 (× 2), 129.3 (× 2), 129.8, 130.3, 135.5, 135.6, 137.7, 150.8, 170.0, 191.4; HRMS (ES+) m/z: $[M+Na]^+$ calcd for $C_{34}H_{27}NO_5Na$, 552.1781; found 552.1782.



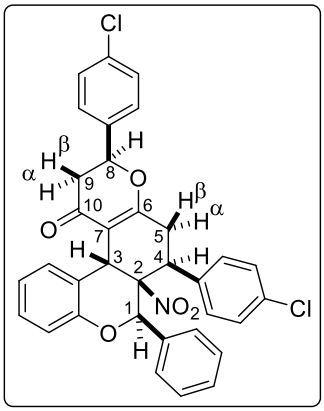
7-(4-Chlorophenyl)-6a-nitro-3,6-diphenyl-2,3,5,6a,7,12b-hexahydro-1*H*,6*H*-chromeno[6,5-*c*]chromen-1-one (4d). White solid; Yield 78% (132 mg); petroleum ether:ethyl acetate (92:8), mp 226-228 °C; IR (Neat, cm^{-1}) 3324 (m, br), 1667 (s), 1615 (vs), 1544 (s), 1474 (m), 1416 (s), 1356 (w), 1227 (s); ^{1}H NMR ($CDCl_3$, 400 MHz) δ 2.60 (dd, J = 18.8, 5.3 Hz, 1H, *C5-αH*), 2.86, 2.98 (ABq, J = 17.1 Hz, the lower and upper half are further split into d with J = 14.7 and 3.8 Hz, 2H, *C9-H*), 3.05 (dd, J = 18.8, 13.0 Hz, 1H, *C5-βH*), 3.79 (dd, J = 13.0, 5.3 Hz, 1H, *C4-H*), 4.82 (s, 1H, *C3-H*), 5.42 (s, 1H, *C1-H*), 5.44 (dd, J = 14.7, 3.8 Hz, 1H, *C8-H*), 6.94 (d, J = 8.5 Hz, 2H, *Ar-H*), 7.08 (overlapped t, J = 7.7 Hz, 1H, *Ar-H*), 7.12 (overlapped d, J = 7.7 Hz, 1H, *Ar-H*), 7.16 (d, J = 8.5 Hz, 2H, *Ar-H*), 7.28 (d, J = 7.7 Hz, 1H, *Ar-H*), 7.33 (t, J = 7.7 Hz, 1H, *Ar-H*), 7.39-7.44 (unresolved m, 10H, *Ar-H*); Confirmed by ^{1}H-^{1}H COSY; ^{13}C NMR ($CDCl_3$, 100 MHz) δ 31.8, 32.9, 42.4, 42.8, 77.1, 80.2, 90.4, 113.2, 116.7, 122.5, 123.7, 126.5, 128.5, 128.7, 128.8, 129.1 (× 2), 129.3 (× 2), 129.9, 130.3, 134.1, 135.3, 135.4, 137.6, 150.5, 170.0, 191.4; HRMS (ES+) m/z: $[M+Na]^+$ calcd for $C_{34}H_{26}ClNO_5Na$, 586.1388; found 586.1388.



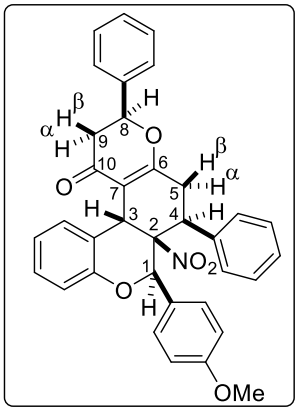
6a-Nitro-7-Phenyl-3,6-di-p-tolyl-2,3,5,6a,7,12b-hexahydro-1*H*,6*H*-chromeno[6,5-*c*]chromen-1-one (4i). White solid; Yield 88% (147 mg); petroleum ether:ethyl acetate (96:4), mp 217-219 °C; IR (Neat, cm^{-1}); 3419 (vs, br), 1667 (m), 1640 (m), 1620 (m), 1542 (w); ^{1}H NMR ($CDCl_3$, 400 MHz) δ 2.38 (s, 3H, *CH3*), 2.42 (s, 3H, *CH3*), 2.57 (dd, J = 18.8, 5.4 Hz, 1H, *C5-αH*), 2.83, 2.98 (ABq, J = 17.2 Hz, the lower and upper half are further split into d with J = 14.4 and 3.1 Hz, 2H, *C9-H*), 3.04 (dd, J = 18.8, 13.1 Hz, 1H, *C5-βH*), 3.78 (dd, J = 13.1, 5.4 Hz, 1H, *C4-H*), 4.88 (s, 1H, *C3-H*), 5.41 (dd, J = 14.4, 3.1 Hz, 1H, *C8-H*), 5.46 (s, 1H, *C1-H*), 7.01 (d, J = 7.5 Hz, 2H, *Ar-H*), 7.08 (t, J = 8.3 Hz, 1H, *Ar-H*), 7.13 (d, J = 8.3 Hz, 1H, *Ar-H*), 7.19 (t, J = 7.5 Hz, 2H, *Ar-H*), 7.24-7.28 (m, 5H, *Ar-H*), 7.28 (d, J = 8.3 Hz, 1H, *Ar-H*), 7.31-7.36 (m, 5H, *Ar-H*); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 21.3, 21.4, 31.9, 32.9, 42.1, 42.7, 77.7, 80.1, 90.6, 113.2, 116.6, 122.1, 123.9, 126.6, 127.3, 128.9, 129.1, 129.2, 129.3, 129.7, 129.8, 130.1, 132.5, 134.7, 135.7, 138.5, 139.3, 150.8, 170.2, 191.6; HRMS (ES+) m/z: $[M+H]^+$ calcd for $C_{36}H_{31}NO_5$, 580.2098; found 580.2098.



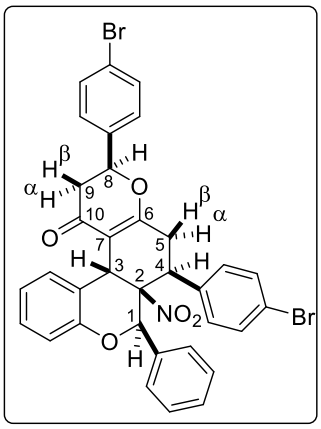
3,6-Bis(4-chlorophenyl)-6a-nitro-7-phenyl-2,3,5,6a,7,12b-hexahydro-1*H*,6*H*-chromeno[6,5-*c*]chromen-1-one (4j). White solid; Yield 77% (138 mg); petroleum ether:ethyl acetate (92:8), mp 250-252 °C; IR (Neat, cm^{-1}) 3505 (w), 1669 (s), 1620 (vs), 1544 (m), 1420 (m), 1275 (m), 1224 (s); ^{1}H NMR ($CDCl_3$, 400 MHz) δ 2.57 (dd, J = 18.3, 4.7 Hz, 1H, *C5-αH*), 2.83, 2.97 (ABq, J = 17.1 Hz, the lower and upper half are further split into d with J = 14.6 and 3.2 Hz, 2H, *C9-H*), 3.00 (dd, J = 18.3, 12.9 Hz, 1H, *C5-βH*), 3.78 (dd, J = 12.9, 4.7 Hz, 1H, *C4-H*), 4.87 (s, 1H, *C3-H*), 5.39 (s, 1H, *C1-H*), 5.41 (overlapped dd, J = 14.6, 3.2 Hz, 1H, *C8-H*), 6.99 (d, J = 7.2 Hz, 2H, *Ar-H*), 7.08 (t, J = 7.8 Hz, 1H, *Ar-H*), 7.12 (d, J = 7.8 Hz, 1H, *Ar-H*), 7.19-7.26 (unresolved m, 4H, *Ar-H*), 7.31-7.41 (unresolved m, 9H, *Ar-H*); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 31.7, 32.9, 41.9, 42.7, 77.7, 79.5, 90.4, 113.4, 116.7, 122.3, 123.6, 127.1, 127.8, 128.7, 129.0, 129.3 (× 2), 129.4, 129.8, 131.7, 134.0, 134.7, 135.2, 135.3, 136.1, 150.6, 169.4, 190.9; HRMS (ES+) m/z: $[M+H]^+$ calcd for $C_{34}H_{26}Cl_2{}^{35}NO_5$, 598.1182, found 598.1183.



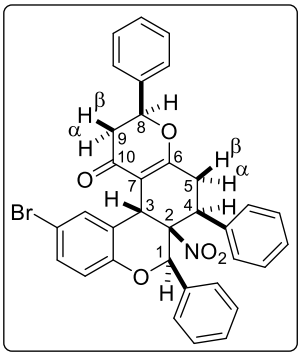
7-(4-Methoxyphenyl)-6a-nitro-3,6-diphenyl-2,3,5,6a,7,12b-hexahydro-1*H*,6*H*-chromeno[6,5-*c*]chromen-1-one (4u). White solid; Yield 80% (134 mg); petroleum ether:ethyl acetate (85:15), mp 230-232 °C; IR (Neat, cm^{-1}) 3421 (vs, br), 1642 (s), 1613 (s), 1542 (m), 1513 (w), 1288 (w), 1253 (m); ^{1}H NMR ($CDCl_3$, 400 MHz) δ 2.59 (dd, J = 18.9, 5.5 Hz, 1H, *C5-αH*), 2.86, 2.98 (ABq, J = 17.2 Hz, the lower and upper half are further split into d with J = 14.6 and 3.3 Hz, 2H, *C9-H*), 3.05 (dd, J = 18.9, 13.1 Hz, 1H, *C5-βH*), 3.71 (s, 3H, *OCH$_3$*), 3.79 (dd, J = 13.2, 5.5 Hz, 1H, *C4-H*), 4.89 (s, 1H, *C3-H*), 5.39 (s, 1H, *C1-H*), 5.45 (dd, J = 14.6, 3.3 Hz, 1H, *C8-H*), 6.70 (d, J = 8.8 Hz, 2H, *Ar-H*), 6.93 (d, J = 8.8 Hz, 2H, *Ar-H*), 7.08 (t, J = 8.5 Hz, 1H, *Ar-H*), 7.11 (d, J = 8.5 Hz, 1H, *Ar-H*), 7.28 (d, J = 8.5 Hz, 1H, *Ar-H*), 7.32 (t, J = 8.5 Hz, 1H, *Ar-H*), 7.39-7.44 (m, 10H, *Ar-H*); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 31.9, 32.9, 42.4, 42.8, 55.3, 77.4, 80.2, 90.7, 113.4, 114.2 (× 2), 116.7, 122.1, 123.8, 126.5, 127.5, 128.4, 128.7, 129.1 (× 2), 129.3, 129.8, 130.3, 135.6, 137.7, 150.8, 160.2, 170.0, 191.4; HRMS (ES+) m/z: $[M+H]^+$ calcd for $C_{35}H_{30}NO_6$, 560.2068; found 560.2069.



3,6-Bis(4-bromophenyl)-6a-nitro-7-phenyl-2,3,5,6a,7,12b-hexahydro-1*H*,6*H*-chromeno[6,5-*c*]chromen-1-one (4v). White solid; Yield 78% (132 mg); petroleum ether:ethyl acetate (92:8), mp 265-266 °C; IR (Neat, cm^{-1}) 3490 (s, br), 1657 (s), 1611 (vs), 1583 (s), 1544 (m), 1484 (m), 1360 (w), 1224 (s); ^{1}H NMR ($CDCl_3$, 400 MHz) δ 2.57 (dd, J = 18.9, 5.4 Hz, 1H, *C5-αH*), 2.83, 2.90 (ABq, J = 17.2 Hz, the lower and upper half are further split into d with J = 14.2 and 3.9 Hz, 2H, *C9-H*), 2.99 (dd, J = 18.9, 13.2 Hz, 1H, *C5-βH*), 3.76 (dd, J = 13.2, 5.4 Hz, 1H, *C4-H*), 4.86 (s, 1H, *C3-H*), 5.39 (s, 1H, *C1-H*), 5.41 (dd, J = 14.2, 3.9 Hz, 1H, *C8-H*), 6.99 (d, J = 7.5 Hz, 2H, *Ar-H*), 7.08 (t, J = 7.4 Hz, 1H, *Ar-H*), 7.12 (d, J = 7.4 Hz, 1H, *Ar-H*), 7.20 (overlapped t, J = 7.5 Hz, 2H, *Ar-H*), 7.22 (overlapped m, 1H, *Ar-H*), 7.23-7.27 (m, 2H, *Ar-H*), 7.29 (d, J = 7.4 Hz, 1H, *Ar-H*), 7.33 (t, J = 7.4 Hz, 1H, *Ar-H*), 7.34 (d, J = 8.4 Hz, 2H, *Ar-H*), 7.55-7.58 (m, 4H, *Ar-H*); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 31.7, 32.9, 42.0, 42.7, 77.7, 79.5, 90.4, 113.5, 116.7, 122.4, 123.0, 123.3, 123.6, 127.1, 128.1, 129.0, 129.3, 129.5, 129.8, 131.6, 132.0, 132.3, 134.5, 135.2, 136.6, 150.6, 169.4, 190.9; HRMS (ES+) m/z: $[M+H]^+$ calcd for $C_{34}H_{26}Br_2{}^{81}NO_5$, 688.0156; found 688.0156.



11-Bromo-6a-nitro-3,6,7-triphenyl-2,3,5,6a,7,12b-hexahydro-1*H*,6*H*-chromeno[6,5-*c*]chromen-1-one (4w). White solid; Yield 71% (129 mg); petroleum ether:ethyl acetate (92:8), mp 145-147 °C; IR (Neat, cm^{-1}) 3437 (vs, br), 1668 (s), 1617 (vs), 1543 (s), 1473 (m), 1413 (m), 1354 (w), 1226 (m); ^{1}H NMR ($CDCl_3$, 400 MHz) δ 2.52 (dd, J = 18.9, 5.4 Hz, 1H, *C5-αH*), 2.76, 2.97 (ABq, J = 17.4 Hz, the lower and upper half are further split into d with J = 14.3 and 4.0 Hz, 2H, *C9-H*), 2.95 (dd, J = 18.9, 13.1 Hz, 1H, *C5-βH*), 3.63 (dd, J = 13.1, 5.4 Hz, 1H, *C4-H*), 4.75 (s, 1H, *C3-H*), 5.32 (s, 1H, *C1-H*), 5.37 (dd, J = 14.3, 4.0 Hz, 1H, *C8-H*), 6.87 (d, J = 7.5 Hz, 2H, *Ar-H*), 6.91 (d, J = 8.6 Hz, 1H, *Ar-H*), 7.10 (t, J = 7.5 Hz, 2H, *Ar-H*), 7.14-7.18 (m, 1H, *Ar-H*), 7.26-7.33 (unresolved m, 12H, *Ar-H*); ^{13}C NMR ($CDCl_3$, 125 MHz) δ 31.8, 33.0, 42.6, 42.6, 77.9, 80.2, 90.2, 112.6, 114.6, 118.4, 126.1, 126.5,



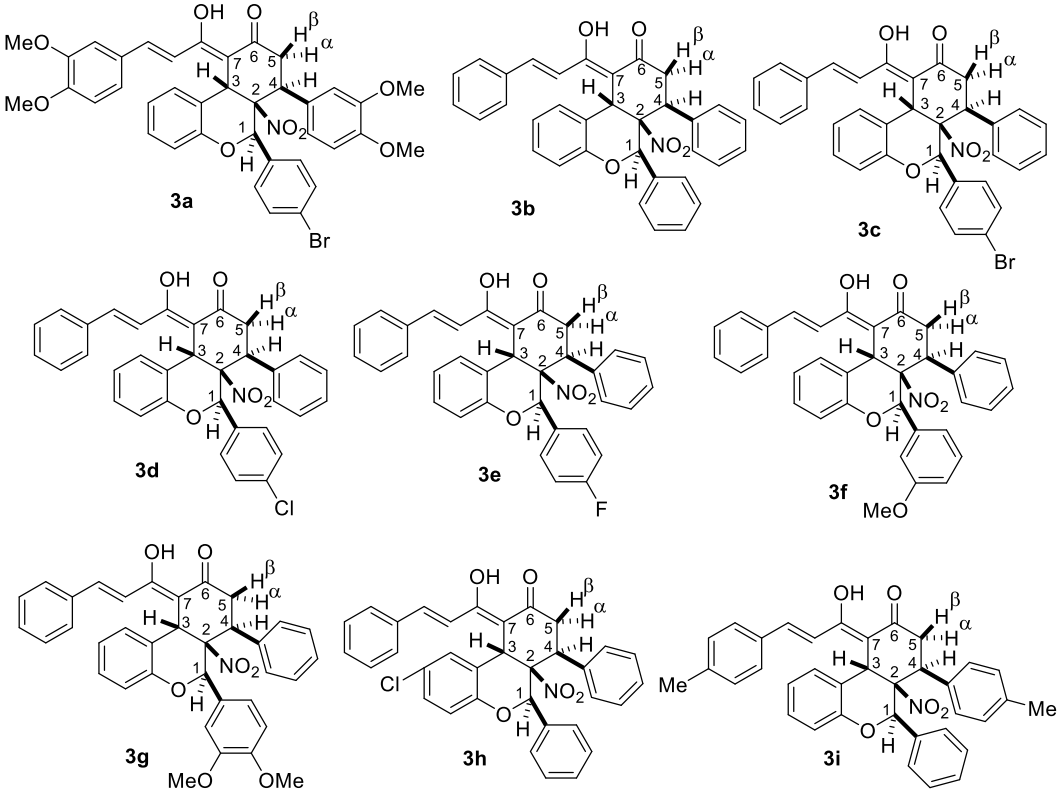
127.1, 128.5, 128.8, 129.0, 129.1, 129.3, 129.5, 130.3, 132.3, 132.5, 135.1, 135.2, 137.5, 150.1, 170.3, 191.3; HRMS (ES+) m/z: $[M+H]^+$ calcd for $C_{34}H_{26}BrO_5$, 632.0865; found 632.0865.

Procedure for the asymmetric synthesis of double Michael adducts or tetrahydro-benzo[*c*]chromenes (3b). To a stirred solution of curcumin **1b** (0.2 mmol, 1.0 equiv) and nitrochromene **2b** (0.2 mmol, 1.2 equiv) in dry DCM (3.0 mL), organocatalyst **C1** (10 mol%) was added under N_2 at room temperature. After completion of the reaction (4 d, monitored by TLC), the solvent was evaporated under vacuum, and the crude residue was purified by silica gel column chromatography by eluting with petroleum ether/ethyl acetate (97:3).

(*E*)-1-(9-Hydroxy-6a-nitro-6,7-diphenyl-6a,7,8,10a-tetrahydro-6*H*-benzo[*c*]chromen-10-yl)-3-phenylprop-2-en-1-one (3b): Yield 41% (22 mg), $[\alpha]_D^{25}$= +1.780° (c= 1.0 in CH_2Cl_2); HPLC: Chiralpak ADH (pet ether/*i*-PrOH = 97/3, flow rate = 1 mL/min, λ = 360 nm), t_R (major) = 7.4 min, t_R (minor) = 22.0 min; 33% *ee*.

3-Nitro-2-phenyl-2*H*-chromene (2b'): Isolated 50% (16 mg), $[\alpha]_D^{25}$= +0.510° (c= 1.0 in CH_2Cl_2); HPLC: Chiralpak IC (pet ether/*i*-PrOH = 98/2, flow rate = 1 mL/min, λ = 360 nm), t_R (minor) = 12.0 min, t_R (major) = 12.8 min; 47% *ee*.

^{1}H NMR and ^{13}C NMR chemical shift tables



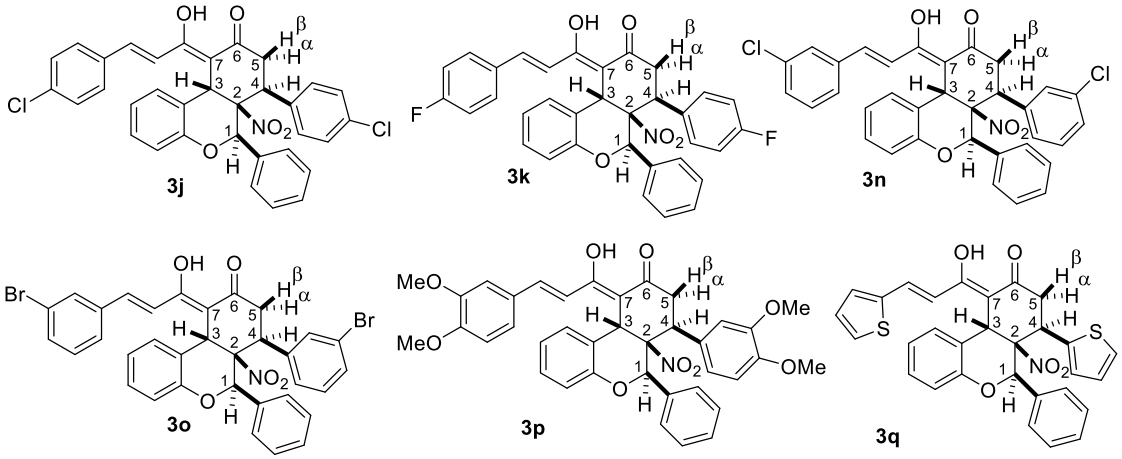


Table S1. Selected ^{1}H NMR chemical shift (in ppm) values for double Michael adducts

Entry	C1-H	C3-H	C4-H	C5-βH	C5-αH
3a	5.51 (s, 1H)	4.65 (s, 1H)	3.70 (dd, *J* = 13.7, 5.4 Hz, 1H)	2.97 (dd, *J* = 19.0, 13.7 Hz, 1H)	2.70 (dd, *J* = 19.0, 5.4 Hz, 1H)
3b	5.51 (s, 1H)	4.80 (s, 1H)	3.77 (dd, *J* = 13.7, 5.4 Hz, 1H)	3.06 (dd, *J* = 19.0, 13.7 Hz, 1H)	2.72 (dd, *J* = 19.0, 5.4 Hz, 1H)
3c	5.56 (s, 1H)	4.81 (s, 1H)	3.84 (dd, *J* = 13.6, 5.3 Hz, 1H)	3.14 (dd, *J* = 19.1, 13.6 Hz, 1H)	2.81 (dd, *J* = 19.1, 5.3 Hz, 1H)
3d	5.57 (s, 1H)	4.81 (s, 1H)	3.83 (dd, *J* = 13.6, 5.2 Hz, 1H)	3.14 (dd, *J* = 19.1, 13.6 Hz, 1H)	2.81 (dd, *J* = 19.1, 5.2 Hz, 1H)
3e	5.49 (s, 1H)	4.74 (s, 1H)	3.75 (dd, *J* = 13.7, 5.4 Hz, 1H)	3.05 (dd, *J* = 19.1, 13.7 Hz, 1H)	2.72 (dd, *J* = 19.1, 5.4 Hz, 1H)
3f	5.46 (s, 1H)	4.84 (s, 1H)	3.76 (dd, *J* = 13.6, 5.6 Hz, 1H)	3.04 (dd, *J* = 19.1, 13.6 Hz, 1H)	2.71 (dd, *J* = 19.1, 5.6 Hz, 1H),
3g	5.47 (s, 1H)	4.83 (s, 1H)	3.76 (dd, *J* = 13.5, 5.1 Hz, 1H)	3.04 (dd, *J* = 19.1, 13.5 Hz, 1H)	2.72 (dd, *J* = 19.1, 5.1 Hz, 1H)
3h	5.51 (s, 1H),	4.77 (s, 1H),	3.72 (dd, *J* = 13.7, 5.3 Hz, 1H)	3.06 (dd, *J* = 19.2, 13.7 Hz, 1H),	2.75 (dd, *J* = 19.2, 5.3 Hz, 1H)
3i	5.51 (s, 1H)	4.77 (s, 1H)	3.72 (dd, *J* = 13.6, 5.4 Hz, 1H)	3.02 (dd, *J* = 19.1, 13.6 Hz, 1H)	2.69 (dd, *J* = 19.1, 5.4 Hz, 1H)
3j	5.45 (s, 1H)	4.75 (s, 1H)	3.77 (dd, *J* = 13.6, 5.5 Hz, 1H)	2.99 (dd, *J* = 18.9, 13.6 Hz, 1H)	2.70 (dd, *J* = 18.9, 5.5 Hz, 1H)
3k	5.45 (s, 1H)	4.75 (s, 1H)	3.70 (dd, *J* = 13.8, 5.2 Hz, 1H)	2.97 (dd, *J* = 18.9, 13.8 Hz, 1H)	2.70 (dd, *J* = 18.9, 5.2 Hz, 1H)

3n	5.52 (s, 1H)	4.79 (s, 1H)	3.77 (dd, *J* = 13.5, 5.2 Hz, 1H)	3.01 (dd, *J* = 19.1, 13.5 Hz, 1H)	2.73 (dd, *J* = 19.1, 5.2 Hz, 1H)
3o	5.49 (s, 1H)	4.76 (s, 1H)	3.73 (dd, *J* = 13.6, 5.4 Hz, 1H)	2.99 (dd, *J* = 19.0, 13.6 Hz, 1H)	2.71 (dd, *J* = 19.0, 5.4 Hz, 1H)
3p	5.54 (s, 1H)	4.74 (s, 1H)	3.72 (dd, *J* = 13.7, 5.3 Hz, 1H)	2.98 (dd, *J* = 19.0, 13.7 Hz, 1H)	2.71 (dd, *J* = 19.0, 5.3 Hz, 1H)
3q	5.73 (s, 1H)	4.73 (s, 1H)	4.06 (dd, *J* = 13.2, 5.9 Hz, 1H)	2.86, 2.97 (ABq, *J* = 19.2 Hz, the lower half and upper half are further split into d with *J* = 13.2 and 5.9 Hz, 2H)	

Table S2. Selected ^{13}C NMR chemical shift (in ppm) values for double Michael adducts

Entry	C1	C2	C3	C4	C5	C6	C7
3a	91.0	106.2	35.4	37.1	41.3	191.1	116.6
3b	91.1	106.7	35.5	37.0	41.6	192.1	116.8
3c	91.0	106.5	35.5	36.9	41.6	191.8	116.9
3d	91.1	106.5	35.5	36.9	41.6	191.9	116.9
3e	91.2	106.5	35.4	37.0	41.6	192.0	116.9
3f	91.0	106.7	35.6	37.0	41.6	192.0	116.9
3g	91.2	106.8	35.7	37.0	41.6	192.1	116.9
3h	90.8	106.1	35.5	37.0	41.7	192.1	118.0
3i	91.1	106.6	35.4	37.0	41.3	191.8	116.8
3j	90.9	106.6	35.4	37.0	41.0	191.9	116.9
3k	91.0	106.6	35.4	37.1	40.9	191.7	116.9
3n	90.8	106.7	35.4	36.9	41.2	192.1	117.0
3o	90.8	106.8	35.5	36.9	41.2	192.1	117.0
3p	91.1	106.4	35.4	37.1	41.3	191.3	116.6
3q	91.0	106.1	35.4	38.0	38.7	190.3	116.9

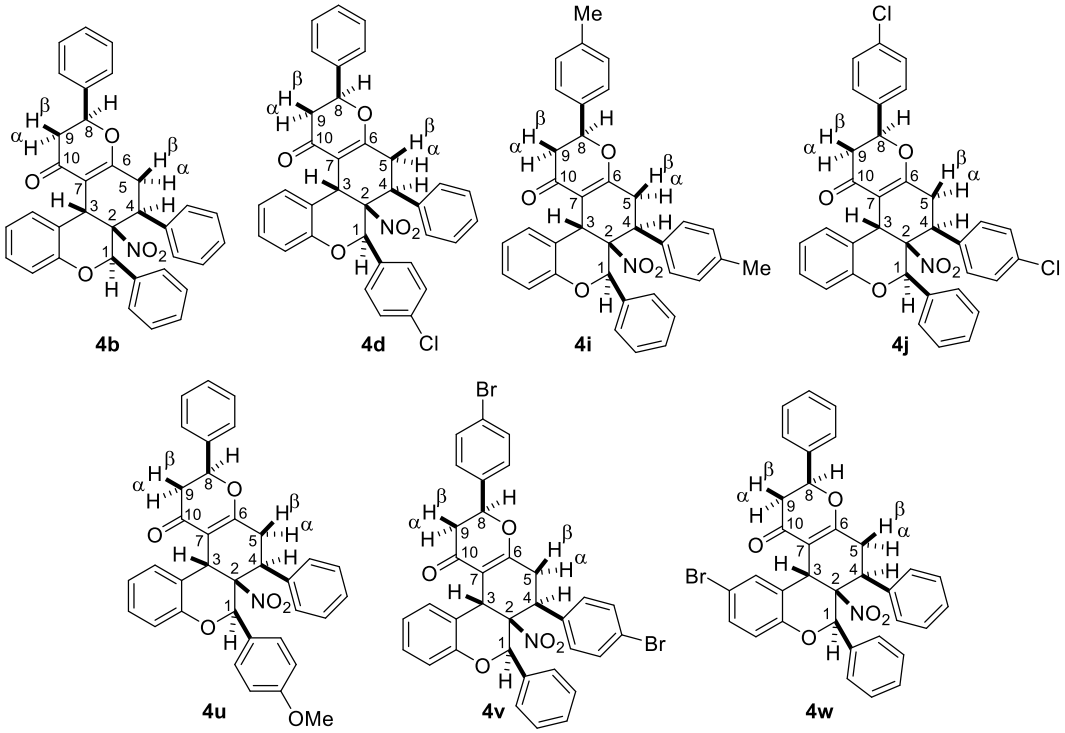


Table S3. Selected ^{1}H NMR chemical shift (in ppm) values for triple Michael adducts

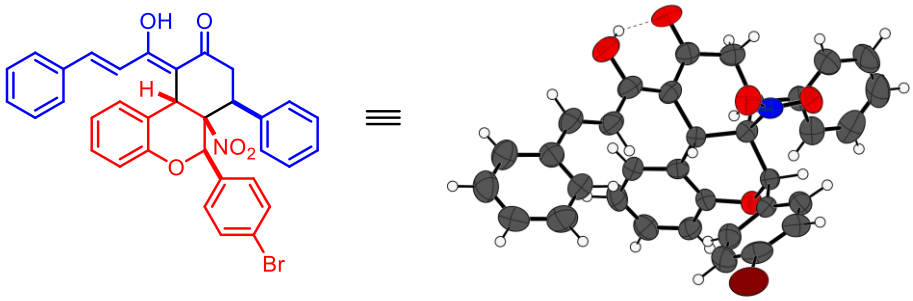
Entry	C1-H	C3-H	C4-H	C5-βH	C5-αH	C8-H	C9-βH	C9-αH
4b	5.44 (s, 1H)	4.88 (s, 1H),	3.81 (dd, *J* = 13.2, 5.2 Hz, 1H)	3.06 (dd, *J* = 18.8, 13.2 Hz, 1H)	2.60 (dd, *J* = 18.8, 5.2 Hz, 1H)	5.45 (dd, *J* = 13.7, 3.9 Hz, 1H)	2.86, 2.97 (ABq, *J* = 17.2 Hz, the lower and upper half are further split into d with *J* = 13.7 and 3.9 Hz, 2H)	
4d	5.42 (s, 1H)	4.82 (s, 1H)	3.79 (dd, *J* = 13.0, 5.3 Hz, 1H)	3.05 (dd, *J* = 18.8, 13.0 Hz, 1H)	2.60 (dd, *J* = 18.8, 5.3 Hz, 1H)	5.44 (dd, *J* = 14.7, 3.8 Hz, 1H)	2.86, 2.98 (ABq, *J* = 17.1 Hz, the lower and upper half are further split into d with *J* = 14.7 and 3.8 Hz, 2H)	
4i	5.46 (s, 1H)	4.88 (s, 1H)	3.78 (dd, *J* = 13.1, 5.4 Hz, 1H)	3.04 (dd, *J* = 18.8, 13.1 Hz, 1H)	2.57 (dd, *J* = 18.8, 5.4 Hz, 1H)	5.41 (dd, *J* = 14.4, 3.1 Hz, 1H)	2.83, 2.98 (ABq, *J* = 17.2 Hz, the lower and upper half are further split into d with *J* = 14.4 and 3.1 Hz, 2H)	
4j	5.39 (s, 1H)	4.87 (s, 1H)	3.78 (dd, *J* = 12.9, 4.7 Hz, 1H)	3.00 (dd, *J* = 18.3, 12.9 Hz, 1H)	2.57 (dd, *J* = 18.3, 4.7 Hz, 1H),	5.41 (overlapped dd, *J* = 14.6, 3.2 Hz, 1H)	2.83, 2.97 (ABq, *J* = 17.1 Hz, the lower and upper half are further split into d with *J* = 14.6 and 3.2 Hz, 2H)	

4u	5.39 (s, 1H)	4.89 (s, 1H)	3.79 (dd, *J* = 13.2, 5.5 Hz, 1H)	3.05 (dd, *J* = 18.9, 13.1 Hz, 1H)	*δ* 2.59 (dd, *J* = 18.9, 5.5 Hz, 1H)	5.45 (dd, *J* = 14.6, 3.3 Hz, 1H)	2.86, 2.98 (ABq, *J* = 17.2 Hz, the lower and upper half are further split into d with *J* = 14.6 and 3.3 Hz, 2H)
4v	5.39 (s, 1H)	4.86 (s, 1H)	3.76 (dd, *J* = 13.2, 5.4 Hz, 1H)	2.99 (dd, *J* = 18.9, 13.2 Hz, 1H)	2.57 (dd, *J* = 18.9, 5.4 Hz, 1H)	5.41 (dd, *J* = 14.2, 3.9 Hz, 1H)	2.83, 2.90 (ABq, *J* = 17.2 Hz, the lower and upper half are further split into d with *J* = 14.2 and 3.9 Hz, 2H)
4w	5.32 (s, 1H)	4.75 (s, 1H)	3.63 (dd, *J* = 13.1, 5.4 Hz, 1H)	2.95 (dd, *J* = 18.9, 13.1 Hz, 1H)	2.52 (dd, *J* = 18.9, 5.4 Hz, 1H)	5.37 (dd, *J* = 14.3, 4.0 Hz, 1H)	2.76, 2.97 (ABq, *J* = 17.4 Hz, the lower and upper half are further split into d with *J* = 14.3 and 4.0 Hz, 2H)

Table S4. Selected ^{13}C NMR chemical shift (in ppm) values for triple Michael adducts

Entry	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
4b	90.6	113.3	31.8	33.0	42.4	170.0	116.7	80.2	42.8	191.4
4d	90.4	113.2	31.8	32.9	42.4	170.0	116.7	80.2	42.8	191.4
4i	90.6	113.2	31.9	32.9	42.1	170.2	116.6	80.1	42.7	191.6
4j	90.4	113.4	31.7	32.9	41.9	169.4	116.7	79.5	42.7	190.9
4u	90.7	113.4	31.9	32.9	42.4	170.0	116.7	80.2	42.8	191.4
4v	90.4	113.5	31.7	32.9	42.0	169.4	116.7	79.5	42.7	190.9
4w	90.2	112.6	31.8	33.0	42.6	170.3	118.4	80.2	42.6	191.3

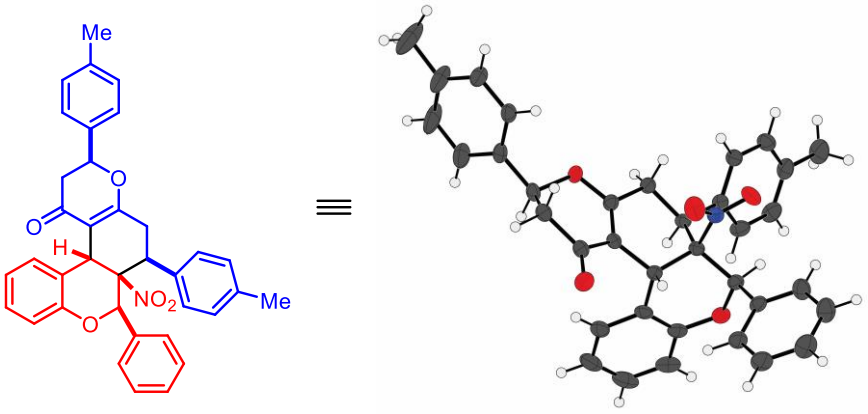
Table S5. Crystal data and structure refinement for 3c (CCDC 2207121)



Identification code	INN_BL_AS_43_autored
Empirical formula	$C_{34}H_{26}BrNO_5$
Formula weight	608.47
Temperature/K	200(16)
Crystal system	monoclinic
Space group	$P2_1$
a/Å	10.6287(9)
b/Å	11.9136(7)
c/Å	12.2552(9)
α/°	90
β/°	113.667(10)
γ/°	90
Volume/Å^3	1421.3(2)
Z	2
ρ_{calc}g/cm^3	1.422
μ/mm^{-1}	1.490
F(000)	624.0
Crystal size/mm^3	0.17 × 0.14 × 0.12
Radiation	Mo Kα (λ = 0.71073)
2Θ range for data collection/°	3.628 to 49.984
Index ranges	-12 ≤ h ≤ 12, -14 ≤ k ≤ 14, -14 ≤ l ≤ 14
Reflections collected	25964

Independent reflections	4992 [R_{int} = 0.1093, R_{sigma} = 0.0916]
Data/restraints/parameters	4992/1/371
Goodness-of-fit on F^2	1.002
Final R indexes [I>=2σ (I)]	R_1 = 0.0474, wR_2 = 0.0706
Final R indexes [all data]	R_1 = 0.1056, wR_2 = 0.0886
Largest diff. peak/hole / e $Å^{-3}$	0.20/-0.24
Flack parameter	0.016(8)

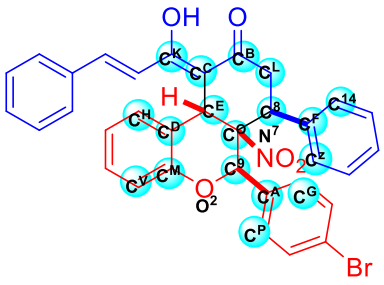
Table S6. Crystal data and structure refinement for 4i (CCDC 2207119)

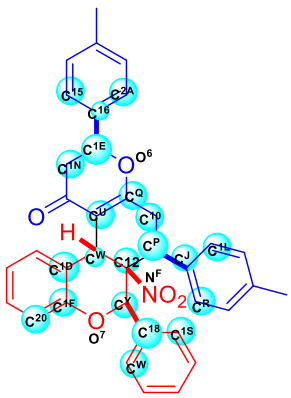


Identification code	INN_BL_AS_134_autored
Empirical formula	$C_{73}H_{63}Cl_3N_2O_{10}$
Formula weight	1234.60
Temperature/K	150.00(10)
Crystal system	monoclinic
Space group	$P2_1/n$
a/Å	21.0341(5)
b/Å	12.7886(2)
c/Å	26.3878(6)
α/°	90
β/°	109.626(3)
γ/°	90

Volume/Å^3	6685.9(3)
Z	4
ρ_{calc}g/cm^3	1.227
μ/mm^{-1}	0.196
F(000)	2584.0
Crystal size/mm^3	0.23 × 0.18 × 0.15
Radiation	Mo Kα (λ = 0.71073)
2Θ range for data collection/°	3.028 to 50
Index ranges	-25 ≤ h ≤ 25, -15 ≤ k ≤ 15, -31 ≤ l ≤ 31
Reflections collected	150854
Independent reflections	11768 [R_{int} = 0.0664, R_{sigma} = 0.0267]
Data/restraints/parameters	11768/0/797
Goodness-of-fit on F^2	1.023
Final R indexes [I>=2σ (I)]	R_1 = 0.0710, wR_2 = 0.2077
Final R indexes [all data]	R_1 = 0.0865, wR_2 = 0.2252
Largest diff. peak/hole / e Å^{-3}	0.62/-0.85

Table S7. Selected torsional angles from X-ray data

Chemical structure	Atom number	Torsional angle (º)
	C^A-C^9-C^O-N^7 C^F-C^8-C^O-N^7 C^D-C^E-C^O-N^7	56.0 71.3 -167.5

	C^{J}- C^{P}-C^{12}-N^{F} C^{18}-C^{Y}-C^{12}-N^{F} C^{1D}-C^{W}-C^{12}-N^{F}	71.8 50.1 -167.2

3. References

1. K. Mohri, Y. Watanabe, Y. Yoshida, M. Satoh, K. Isobe, N. Sugimoto and Y. Tsuda, *Chem. Pharm. Bull*., 2003, **51**, 1268.

2. S. Nayak, P. Panda, S. Mohapatra, B. Raiguru and N. Baral, *J. Heterocycl. Chem*., 2019, **56**, 1757.