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Three-Component Reaction between Substituted 2-(2-Nitrovinyl)-phenols, Acetylenedicarboxylate and Amines: Diversity-Oriented Synthesis of Novel Pyrrolo[3,4-*c*]coumarins

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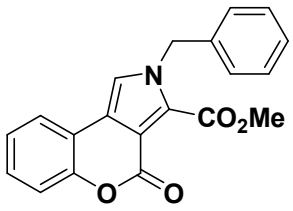
Experimental section

All melting points were determined in a Yanaco melting point apparatus and are uncorrected. IR spectra were recorded in a Nicolet FT-IR 5DX spectrometer. The ^{1}H NMR (400 MHz) and ^{13}C NMR (100 MHz) spectra were recorded in a Bruker AV-400 spectrometer with TMS as internal reference in $CDCl_3$ solutions. The *J* values are given in hertz. Only discrete or characteristic signals for the ^{1}H NMR are reported. The MS spectra were obtained on a ZAB-HS mass spectrometer with 70 eV. X-ray crystallographic analysis was performed with a SMART APEX-Ⅱ diffractometer. Flash chromatography was performed on silica gel (230-400 mesh) eluting with ethyl acetate-hexanes mixture. All reactions were monitored by thin layer chromatography (TLC). All reagents and solvents were purchased from commercial sources and purified commonly before used.

General procedure for preparation of pyrrolo[3,4-*c*]coumarins 4a-q

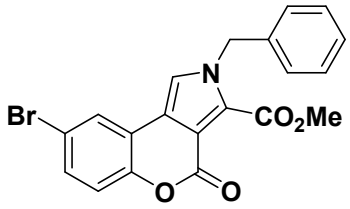
The standard procedure for the synthesis of pyrrolo[3,4-*c*]coumarins via three-component reaction between substituted 2-(2-nitrovinyl)phenols, acetylenedicarboxylate and amines is as follows. To the mixture of substituted 2-(2-nitrovinyl)-phenol **1a-e** (1 mmol), acetylenedicarboxylate (213 mg, 1.5 mmol), and amines **3a-g** (1 mmol) in toluene (5 mL) was added $FeCl_3$ (65 mg, 0.4 mmol). The resulting mixture was stirred at 110 ^{o}C for 6 h, and the completion of reaction was confirmed by TLC (Hexanes/EtOAc, 5:1). Subsequently, the solvent was removed by reduced pressure, the residues was added with water (10 mL) and was extracted with ethyl acetate (10 mL X 2). The organic phase was washed with water (10 mL) and brine (5 mL), and dried over anhydrate sodium sulfate. After removal of dichloromethane, the crude product was purified by flash chromatography (silica gel, EtOAc/hexanes, 1/8) to give the desirable products,

Methyl 2-benzyl-4-oxo-2,4-dihydrochromeno[3,4-*c*]pyrrole-3-carboxylate (4a)



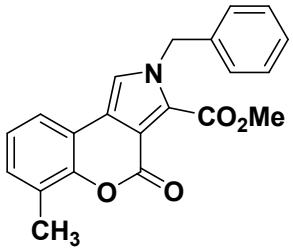
Yellow solid yield 90%, m.p. 196.3 ^{o}C; ^{1}H NMR (4 00 MHz, $CDCl_3$) δ (*ppm*): 7.59 (d, *J* = 7.6 Hz, 1H), 7.32 (t, *J* = 7.2 Hz, 3H), 7.36 (d, 1H), 7.30 (t, *J* = 3.2 Hz, 2H), 7.18 (d, *J* = 6.8 Hz, 2H), 7.16 (s, 1H), 5.59 (s, 2H), 3.95 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (*ppm*): 161.0, 156.4, 151.3, 135.9, 135.9, 129.4, 128.6, 128.0, 127.6, 126.9, 124.3, 123.6, 122.8, 122.3 , 119.1, 118.2, 117.6, 116.9, 115.5, 53.4, 52.7; IR (KBr, cm^{-1}): 1745, 1689, 1 580, 1497, 1289, 1167, 813, 728; MS (EI): m/z = 334.40 [$(M+1)^{+}$].

Methyl 2-benzyl-8-bromo-4-oxo-2,4-dihydrochromeno[3,4-*c*]pyrrole-3-carboxyl ate (4b)



Yellow solid yield 88%, m.p. 220.6 ^{o}C; ^{1}H NMR (400 MHz,$CDCl_3$) δ (*ppm*): 7.70 (s, 1H), 7.39 (d, *J* = 8.8 Hz, 1H), 7.39(d, *J* = 8.8 Hz, 3H), 7.25 (s, 1 H), 7.17 (t, *J* = 8.8 Hz, 3H), 5.58 (s, 2H), 3.95 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (*ppm*): 160.8, 155.7, 150.2, 135.6, 131.3, 130.6, 129.4, 128.7, 128.2, 127.8, 127.1, 125.4, 121.4, 119.3, 118.4, 116.6, 110.8 , 53.5, 52.84; IR (KBr, cm^{-1}): 1762, 1691, 1600, 1510, 1279, 1200, 839, 756; MS (EI): m/z = 412.50 [$(M+1)^{+}$].

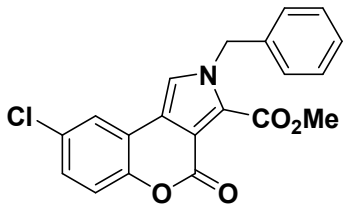
Methyl 2-benzyl-6-methyl-4-oxo-2,4-dihydrochromeno[3,4-*c*]pyrrole-3-carboxyl ate (4c)



Yellow solid yield 62%, m.p. 210.4 ^{o}C ^{1}H NMR (400 MHz, $CDCl_3$) δ (*ppm*): 7.42 (d, 1H), 7.32 (t, *J* = 7.2 H z, 2H), 7.25 (s, 1H), 7.17 (d, *J* = 6.4 Hz, 3H), 7.07 (t, *J* = 7.6 Hz, 2H), 5.59 (s, 2H), 3.94 (s, 3H), 2.44 (s, 3 H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (*ppm*): 161.1, 156.4, 149.7, 136.0, 129.7, 129.0, 128.3, 127.3, 126.6, 123.5, 120.1, 118.8, 115.2, 111.3 , 53.4, 52.6, 16.2; IR (KBr, cm^{-1}): 1786, 1685, 1597, 1498, 1272, 1225, 828, 749; MS (EI): m/z = 348.4[$(M+1)^{+}$].

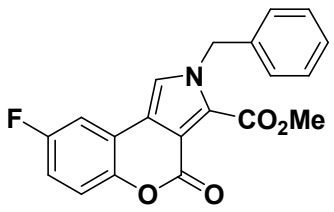
Methyl 2-benzyl-8-chloro-4-oxo-2,4-dihydrochromeno[3,4-*c*]pyrrole-3-carboxyla

te (4d)



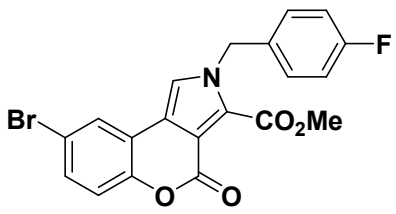
Yellow solid yield 92%, m.p. 200.3 °C ^{1}H NMR (400 MHz, DMSO-d_6) δ (*ppm*): 8.16 (s, 1H), 8.03 (s, 1H), 7.36 (d, *J* = 7.2Hz, 1H), 7.34 (t, *J* = 5.6 Hz, 3H), 7.30 (d, *J* = 7.6 Hz, 1H), 7.20 (d, *J* = 6.4 Hz, 2H), 5.55 (s, 2H), 3.80 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (*ppm*): 160.7, 155.4, 149.7, 137.1, 129.2, 128.7, 128.5, 128.3, 127.7, 124.9, 123.2, 121.9, 120.7, 119.0, 117.7, 109.9, 53.1, 52.9; IR (KBr, cm^{-1}): 1745, 1687, 1547, 1502, 1300, 1256, 870, 739; MS (EI): m/z = 368.30 [$(M+1)^+$].

Methyl 2-benzyl-8-fluoro-4-oxo-2,4-dihydrochromeno[3,4-*c*]pyrrole-3-carboxylate (4e)



Yellow solid yield 80%, m.p. 198.5 °C ^{1}H NMR (400 MHz, $CDCl_3$) δ (*ppm*): 7.69 (s, 1H), 7.40 (dt, J_1 = 2.0 Hz, J_2 = 8.8Hz, 1H), 7.26 (d, *J* = 2.4 Hz, 1H), 7.25 (d, *J* = 2.4 Hz, 1H),7.18 (td, J_1 = 8.0 Hz, J_2 = 2.0 Hz, 3H), 7.18 (td, J_1 = 8.4 Hz, J_2 = 1.6 Hz, 2H), 5.54 (s, 2H), 3.96 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (*ppm*): 161.4 (d, *J* = 222.4 Hz), 160.8 (d, *J* = 222.4 Hz), 155.6, 150.2, 131.4(d, *J* = 12.4 Hz), 131.1 (d, *J* = 12.4 Hz ）, 129.4 (d, *J* = 32.8 Hz), 129.3 (d, *J* = 32.8 Hz), 125.2, 121.5, 118.9, 118.7, 117.3, 116.6, 116.2, 115.9, 52.9, 52.8; IR (KBr,cm^{-1}): 1770, 1673, 1582, 1490, 1280, 1189, 834, 740; MS (EI): m/z = 351.0 [$(M+1)^+$].

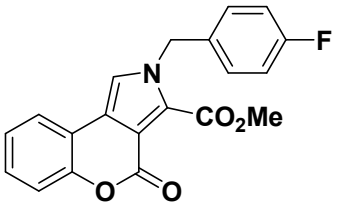
Methyl 2-(4-fluorobenzyl)-8-bromo-4-oxo-2,4-dihydrochromeno[3,4-*c*]pyrrole-3-carboxylate (4f)



Yellow solid yield 78%, m.p. 240.1 °C ^{1}H NMR (400 MHz, $CDCl_3$) δ (*ppm*): 7.36 (d, *J* = 6.0 Hz, 1H), 7.36 (d, *J* = 6.4 Hz, 2H), 7.25 (s, 1H), 7.24 (d, *J* = 4.4 Hz, 2H), 7.16 (d, *J* = 6.8 Hz, 2H), 7.02 (td, J_1 = 9.2 Hz, J_2 = 2.8 Hz, 1H), 5.57 (s, 2H), 3.94 (s, 3H; ^{13}C NMR ($CDCl_3$, 100 MHz) δ (*ppm*): 160.9 (d, *J* = 332.0 Hz), 159.9 (d, *J* = 332.0 Hz),, 157.6, 155.9, 147.4 (d, *J* = 8.8 Hz), 135.7, 129.1, 128.5, 127.4, 121.

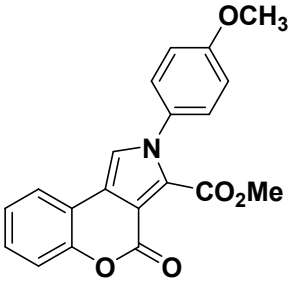
9, 118.9, 118.7 (d, J = 34.8 Hz), 116.6, 116.5, 115.4 (d, J = 96.4 Hz), 108.6 (d, J = 98.0 Hz), 53.5, 52.7; IR (KBr, cm^{-1}): 1767, 1681, 1562, 1505, 1295, 1200, 870, 739; MS (EI): m/z= 432.30 [$(M+2)^+$].

Methyl 2-(4-fluorobenzyl)-4-oxo-2,4-dihydrochromeno[3,4-*c*]pyrrole-3-carboxylate (4g)



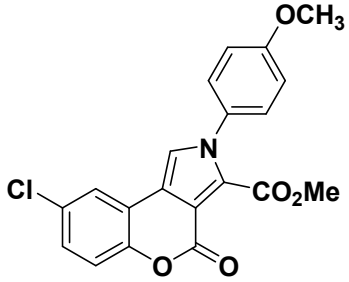
Yellow solid yield 86%, m.p. 199.2 °C ^{1}H NMR (400 MHz, $CDCl_3$) δ (*ppm*): 7.59 (d, J = 8Hz, 1H), 7.32 (d, J = 8.8 Hz,1H), 7.21 (dd, J_2 = 6.4 Hz, J_2 = 1.6 Hz, 2H), 7.18 (t, J = 5.2Hz, 2H), 7.05-7.05 (d, J = 8.4 Hz, 2H), 7.01 (s, 1H)，5.55 (s, 2H), 3.94 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (ppm): 161.3, 161.0, 156.5 (d, J = 200.0 Hz), 151.2, 131.7, 129.5, 128.0, 124.6, 124.4, 123.7, 122.8 (d, J = 12 Hz), 122.3 (d, J = 12 Hz), 119.0, 118.2, 116.9 (d, J = 25 Hz), 116.3, 116.1, 111.2 (d, J = 11 Hz), 53.7, 52.6 IR (KBr, cm^{-1}): 1789, 1696, 1600, 1527, 1279, 1186, 829, 728; MS (EI): m/z = 351.0 [$(M+1)^+$].

Methyl 2-(4-methoxyphenyl)-4-oxo-2,4-dihydrochromeno[3,4-*c*]pyrrole-3-carboxylate (4h)



Yellow solid yield 75%, m.p. 79.0 °C ^{1}H NMR (400 MHz, $CDCl_3$) δ (*ppm*): 7.62(d, J = 7.6 Hz, 1H), 7.33 (s, 1H), 7.31 (d, J = 6.0 Hz, 3H), 7.27 (t, J = 8.0 Hz, 1H), 7.19 (t, J = 7.6 Hz, 1H), 6.95 (d, J = 8.8 Hz, 2H), 3.84 (s, 3H), 3.81 (s, 3H); ^{13}C NMR ($CDCl_3$,100 MHz) δ (ppm): 160.7, 156.7, 131.8, 128.7, 128.0, 126.9, 126.3, 124.5, 123.8, 122.9, 122.4, 119.3, 118.4, 117.7, 117.0, 115.6, 114.5, 110.8, 55.5, 52.7. IR (KBr, cm^{-1}): 1790, 1682, 1584, 1535, 1286, 1250, 867, 745; MS (EI): m/z = 350.50 [$(M+1)^+$].

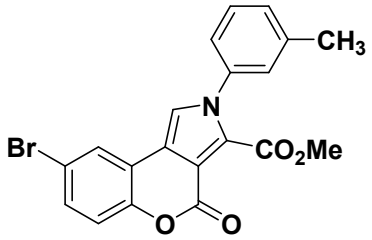
Methyl 8-chloro-2-(4-methoxyphenyl)-4-oxo-2,4-dihydrochromeno[3,4-*c*]pyrrole-3-carboxylate (4i)



Yellow solid yield 74%, m.p. 93.2 °C ^{1}H NMR (4

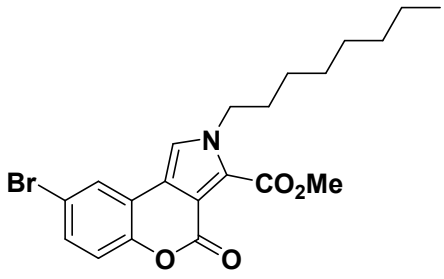
00 MHz, $CDCl_3$) δ (ppm): 7.60 (d, *J* = 2.0 Hz, 1H), 7.33 (d, *J* = 1.3Hz, 1H), 7.30 (d, *J* = 8.8 Hz, 2H), 7.2 8(d, *J* = 2.0 Hz, 1H),7.26 (d, *J* = 2.0 Hz, 1H), 6.99 (S, 1H), 6.97 (S, 1H), 3.86 (s,3H), 3.83 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (ppm): 160.5, 156.1, 131.6, 129.3, 128.6, 127.9, 126.9, 126.7, 122.6, 1 22.1, 119.5, 118.7, 117.0, 115.2, 114.6, 110.5, 55.7, 52.9; IR (KBr, cm^{-1}): 177 8, 1669, 1587, 1547, 1296, 1230, 840, 754;MS (EI): m/z = 384.40 [$(M+1)^+$].

Methyl 8-bromo-4-oxo-2-m-tolyl-2,4-dihydrochromeno[3,4-*c*]pyrrole-3-carboxyl ate (4j)



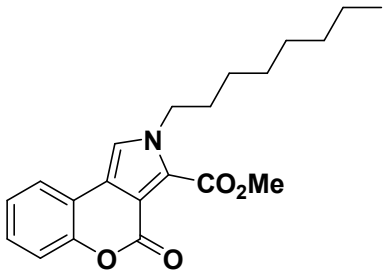
Yellow solid yield 65%, m.p. 89.7°C ^1H NMR (4 00 MHz, $CDCl_3$) δ (*ppm*): 8.88 (d, *J* =2.4 Hz, 1H), 8.04 (s, 1H), 7.75 (d, *J* = 8.4 Hz, 1H), 7.70 (dd, J_1 = 2.4 Hz, J_2 = 8.4 Hz, 2H), 7.53 (dd, J_1 = 1.2 Hz, J_2 = 8.8 Hz, 2H), 7.26 (d, *J* = 8.8 Hz, 1H), 4.17 (s, 3H), 2.64 (s, 3H); ^{1} ^3C NMR ($CDCl_3$, 100 MHz) δ (ppm): 167.0, 159.4, 151.3, 151.1, 148.2, 145.5, 144.6, 135.3, 131.2, 128.8, 128.0, 125.9, 122.1, 120.9, 119.1, 118.1, 110.3, 53. 7, 22.4; IR (KBr, cm^{-1}): 1771, 1670, 1590, 1550, 1286, 1249, 867, 762; MS (EI): m/z = 414.0 [$(M+3)^+$].

Methyl 8-bromo-2-octyl-4-oxo-2,4-dihydrochromeno[3,4-*c*]pyrrole-3-carboxylate (4k)



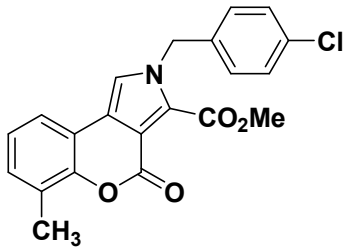
Yellow solid yield 55%, m.p. 78.6 °C ^1H N MR (400 MHz, $CDCl_3$) δ (*ppm*): 7.71 (d, *J* = 2.4 Hz, 1H), 7.37(dd, J_1 = 2.4 Hz, J_2 = 8. 8 Hz, 1H), 7.25 (s, 1H), 7.15(dt, J_1 = 6.4 Hz, J_2 = 3.6 Hz, 1H), 4.34 (t, *J* = 7.2 Hz, 2H), 3.98 (s, 3H), 1.23 (m, 12H), 0.84 (t, *J* = 6.4 Hz, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ *(ppm)*: 160.8, 155.9, 150.1, 130.8, 128.8, 125.1, 124.7, 121.1, 118.9, 1 18.7, 117.6, 116.6, 52.7, 50.6, 31.7, 31.6, 29.1, 29.0, 26.5, 22.6, 14.08; IR(KBr, cm^{-1}): 1784, 1686, 1600, 1592, 1290, 1256, 890, 742; MS (EI): m/z = 436.4 [$(M+3)^+$].

Methyl 2-octyl-4-oxo-2,4-dihydrochromeno[3,4-*c*]pyrrole-3-carboxylate (4l)



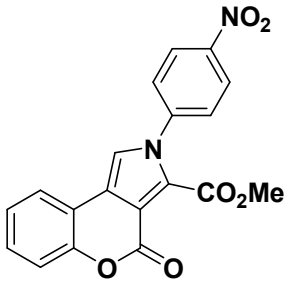
Yellow solid yield 58%, m.p. 76.2°C ^{1}H NMR (400 MHz, $CDCl_3$) δ (*ppm*): 7.57 (d, *J* = 8Hz, 1 H), 7.25-.24 (m, 3H),7.16 (td, J_1 = 8.0 Hz, J_2 = 2.0 Hz, 1H), 4.32 (t, *J* = 7.2 Hz, 2H), 3.97 (S, 3H), 1.27-1.22 (m, 12H), 0.83 (t, *J* = 6.4 Hz, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (ppm): 161.0,156.4, 151.2, 128.0, 124.2, 123.9 , 122.4, 122.3, 118.4, 117.1, 115.7, 110.7, 52.5, 50.5, 31.7, 29.1, 29.0, 26.6, 2 2.6, 14.1; IR (KBr, cm^{-1}): 1790, 1665, 1643, 1580, 1267, 1250, 874, 743; MS (EI): m/z = 356.1 [$(M+1)^+$].

Methyl 2-(4-chlorobenzyl)-6-methyl-4-oxo-2,4-dihydrochromeno[3,4-*c*]pyrrole-3 -carboxylate (4m)



Yellow solid yield 72%, m.p. 200.5 °C ^{1}H NMR (400 MHz, $CDCl_3$) δ (*ppm*): 7.43 (d, *J* = 7.6 Hz, 1 H), 7.30 (d, *J* = 8.4 Hz, 2H), 7.24 (s, 1H), 7.16 (d, *J* = 7.2 Hz, 1H), 7.09 (d, *J* = 8.4 Hz, 2H), 7.08 (d d, J_1 = 3.2 Hz, J_2 = 8.4 Hz, 1H), 5.56 (s, 2H), 3.3 4 (s, 3H), 2.44 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (*ppm*): 161.1, 156.3,1 49.7, 134.5, 134.2, 129.8, 129.2, 128.6, 126.6, 124.3, 123.5, 123.3, 120.1, 118. 8, 115.0, 111.5, 52.7, 52.6, 16.2; IR (KBr, cm^{-1}): 1769, 1666, 1587, 1565, 12 70, 1265, 872, 800; MS (EI): m/z = 382.40 [$(M+1)^+$].

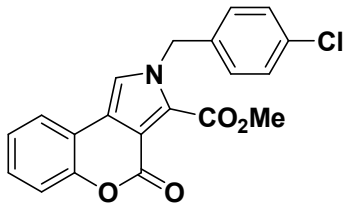
Methyl 2-(4-nitrophenyl)-4-oxo-2,4-dihydrochromeno[3,4-*c*]pyrrole-3-carboxyla te (4n).



Yellow solid yield 70%, m.p. 99.0 °C ^{1}H NMR (40 0 MHz, $CDCl_3$) δ (*ppm*): 8.40 (d, *J* = 1.6 Hz, 1H), 8.38 (d, *J* = 2.0 Hz,1H), 7.66 (d, *J* = 7.6 Hz, 1H), 7.59 (d, *J* = 1.6 Hz, 1H), 7.57 (d, *J* = 1.6 Hz, 1H), 7.43 (d, *J* = 1.6 Hz, 1H), 7.39-7.33 (m, 3H), 7.24 (s, 1H), 3.88 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (*ppm*): 160.2, 156.1, 151.5, 129.0, 126.5, 124.9, 124.4, 123.5, 122.7, 119.6, 118.5, 117.6, 114.9, 112.4, 53. 0; IR (KBr, cm^{-1}): 1777, 1662, 1555, 1549, 1280, 1266, 850, 790; MS (EI):

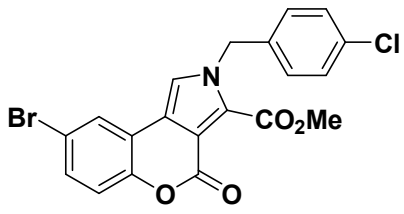
m/z = 365.50[(M+1)$^+$].

Methyl 2-(4-chlorobenzyl)-4-oxo-2,4-dihydrochromeno[3,4-*c*]pyrrole-3-carboxylate (4o)



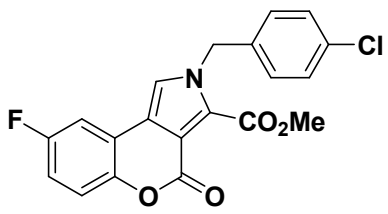
Yellow solid yield 89%, m.p. 198.9 ^{o}C ^{1}H NMR (400 MHz, $CDCl_3$) δ (*ppm*): 7.57 (d, *J* = 7.2 Hz, 1 H), 7.30 (d, *J* = 7.6 Hz, 4H), 7.29 (s, 1H), 7.18 (t d, J_1 = 2.0 Hz, J_2 = 7.6 Hz, 4H), 7.09 (d, *J* = 8.4 Hz, 2H), 3.94 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ *(ppm)*: 161.0, 156.2, 15 1.3, 134.5, 129.2, 128.6, 128.4, 124.0, 122.9, 122.5, 118.6, 117.3, 115.4, 111.4, 52.8. 527; IR (KBr, cm^{-1}): 1791, 1670, 1659, 1559, 1278, 1266, 869, 756; MS (EI): m/z = 368.50 [(M+1)$^+$].

Methyl 2-(4-chlorobenzyl)-8-bromo-4-oxo-2,4-dihydrochromeno[3,4-*c*]pyrrole-3-carboxylate (4p)



Yellow solid yield 84%, m.p. 259.5 ^{o}C ^{1}H NM R (400 MHz, $CDCl_3$) δ (*ppm*): 7.69 (d, *J* = 2.0 Hz, 1H), 7.39 (dd, J_1 = 2.0 Hz, J_2 = 8.8 Hz, 1 H), 7.30 (d, *J* = 8.0 Hz, 2H),7.25 (s, 1H), 7.14 (d, 8.8 Hz, 1H), 7.10 (d, *J* = 8.4 Hz, 2H), 5.54 (s, 2H), 3.94 (s, 3H); ^{13}C N MR ($CDCl_3$, 100 MHz) δ (ppm): 160.8, 155.6, 150.2, 147.6, 137.1, 134.5, 134.2 , 131.5, 131.1, 129.3, 128.7, 125.2, 121.6, 119.0, 118.9, 117.3, 116.6, 111.0, 5 2.8, 52.7; IR (KBr, cm^{-1}): 1788, 1687, 1664, 1580, 1299, 1278, 832, 748; MS (EI): m/z = 448.30 [(M+1)$^+$].

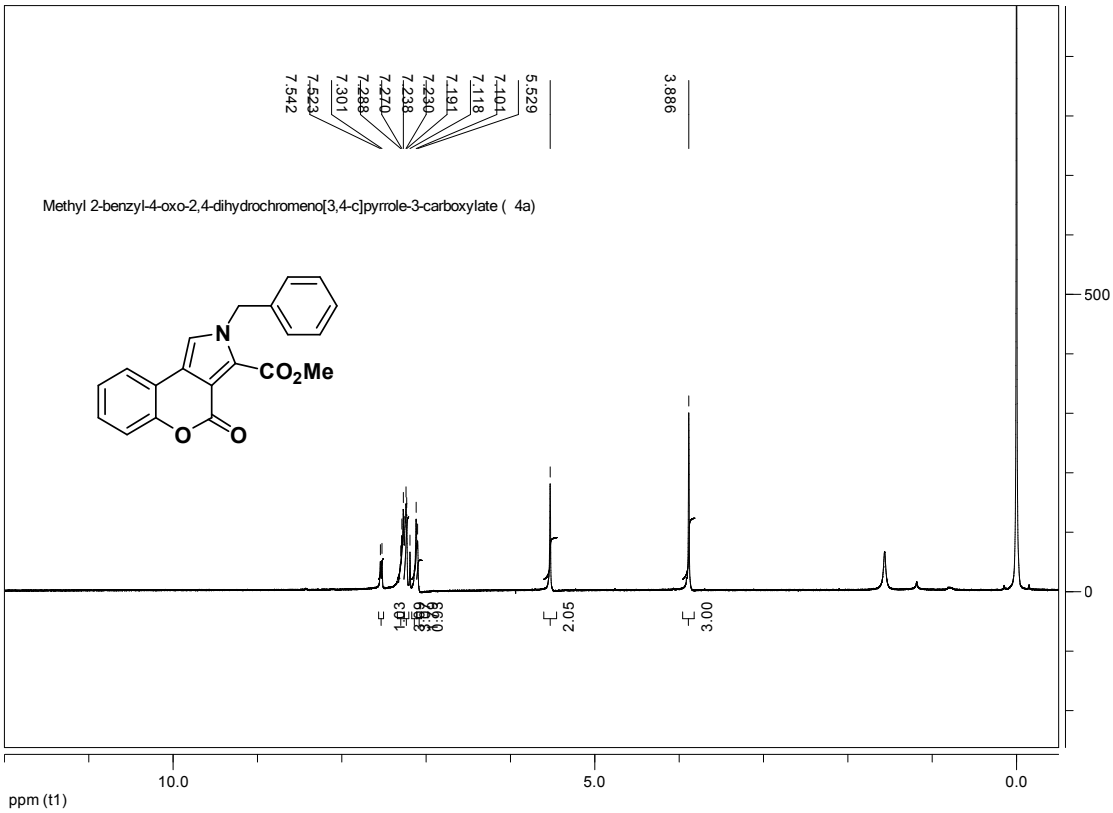
Methyl 2-(4-chlorobenzyl)-8-fluoro-4-oxo-2,4-dihydrochromeno[3,4-*c*]pyrrole-3-carboxylate (4q)

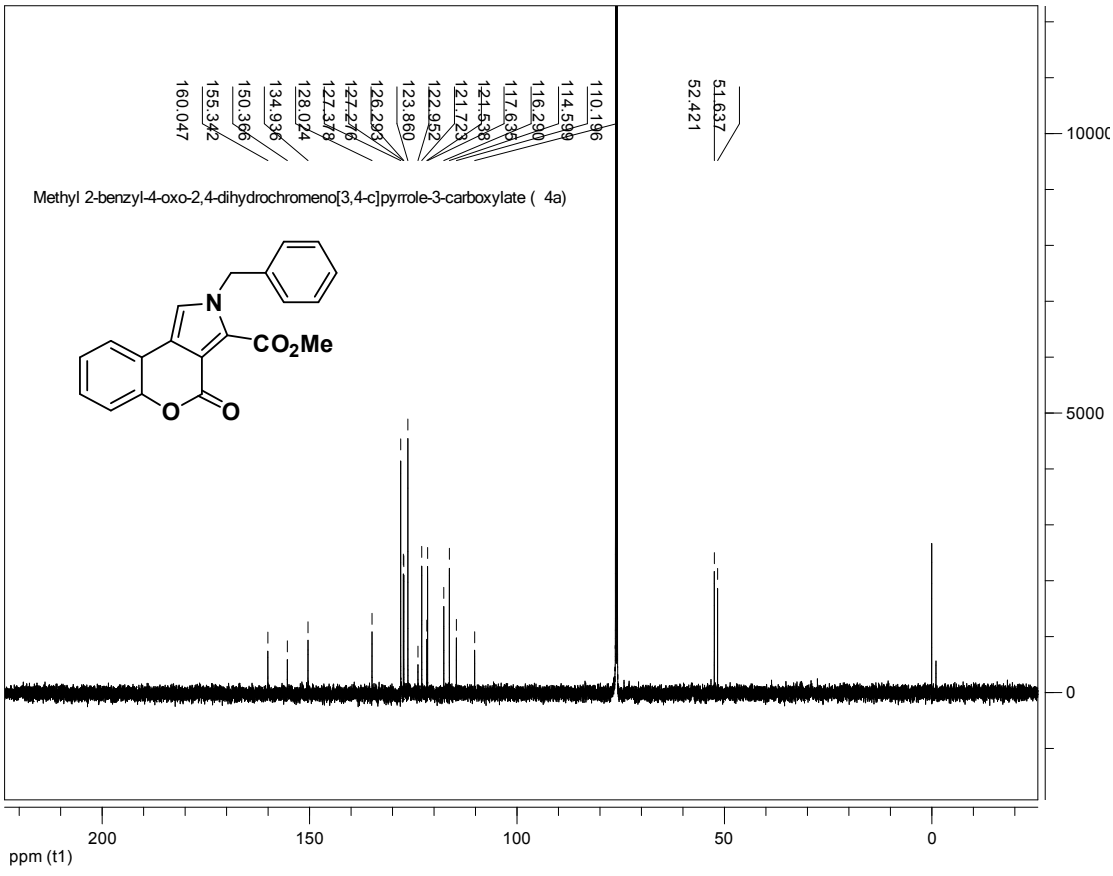


Yellow solid yield 86%, m.p. 260.5 ^{o}C ^{1}H NMR (400 MHz, $CDCl_3$) δ (*ppm*): 7.27 (d, *J* = 2.0 Hz, 1H), 7.31 (d, *J* = 1.6 Hz, 1H), 7.25 (d, *J* = 2.8 Hz, 1H), 7.24 (d, *J* = 2.0 Hz, 2H), 7.12 (d, *J* = 6.8 Hz, 2H), 7.05-6.99 (m, 1H), 5.55 (s, 2H), 3.94 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (*ppm*): 160.85, 160.02, 157.6, 155.8, 147.5 (d, *J* = 8.0 Hz), 134. 2, 134.3, 129.2 (d, *J* = 230 Hz), 128.7 (d, *J* = 23 Hz), 118.9 (d, *J* = 34.8 H z), 118.7 (d, *J* = 34.8 Hz), 118.6, 115.6, 115.4, 108.6, 108.4, 52.8, 52.7; IR (

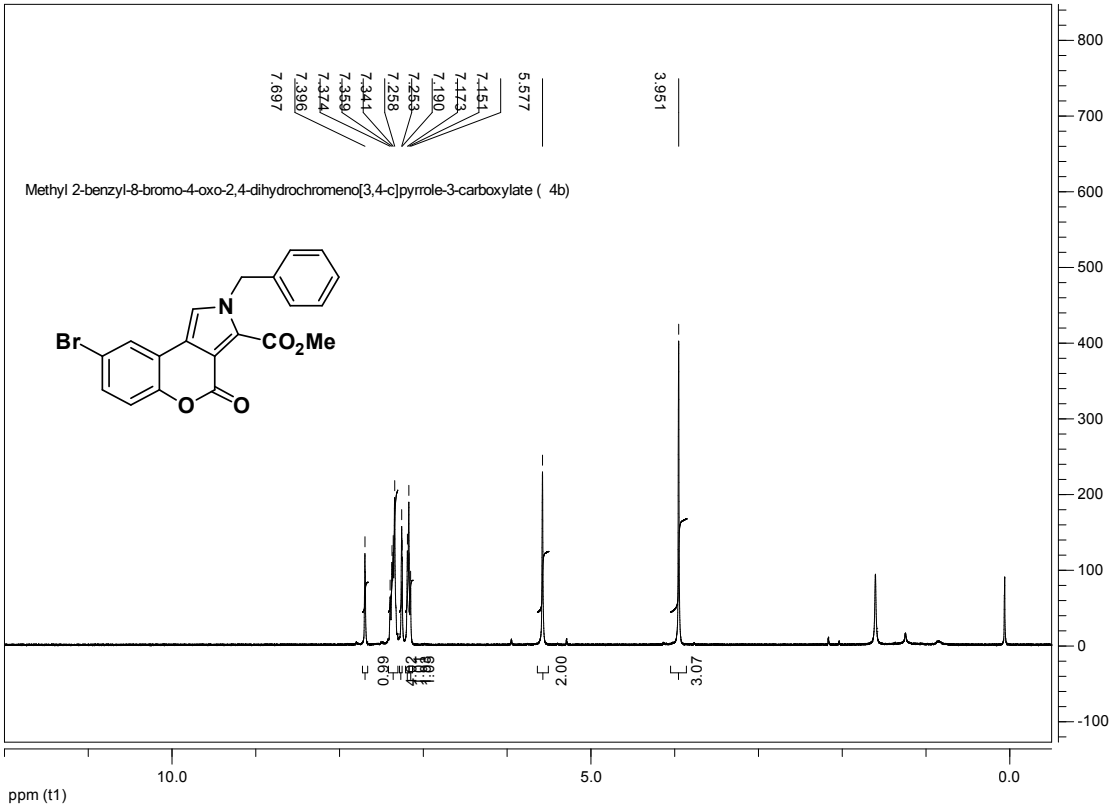
KBr, cm^{-1}): 1790, 1699, 1682, 1599, 1275, 1263, 867, 760; MS (EI): m/z = 3 86.40 $[(M+1)^+]$.

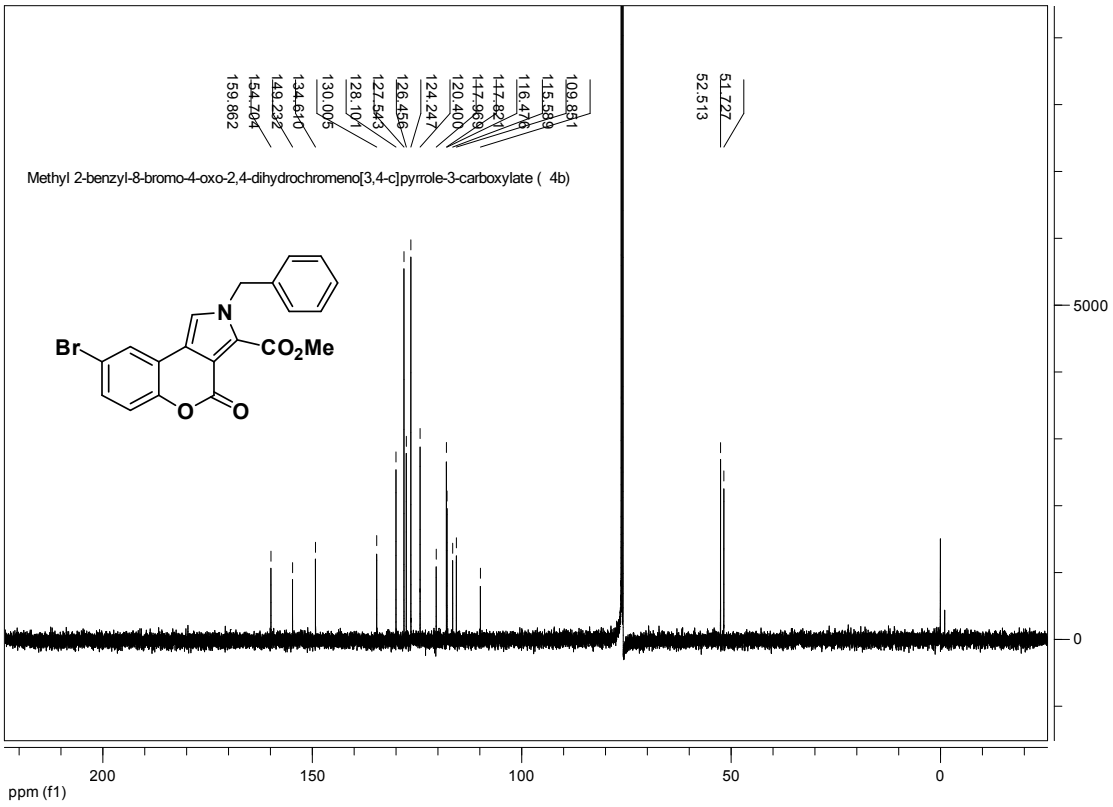
Methyl 2-benzyl-4-oxo-2,4-dihydrochromeno[3,4-*c*]pyrrole-3-carboxylate (4a)



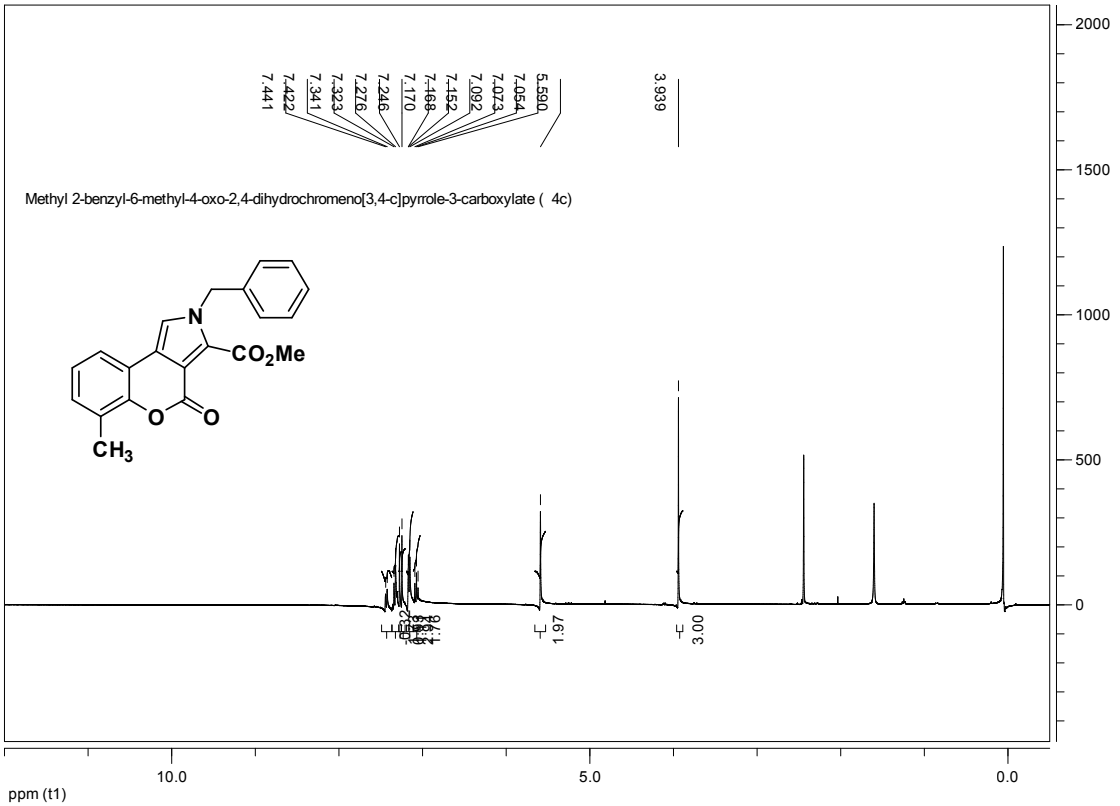


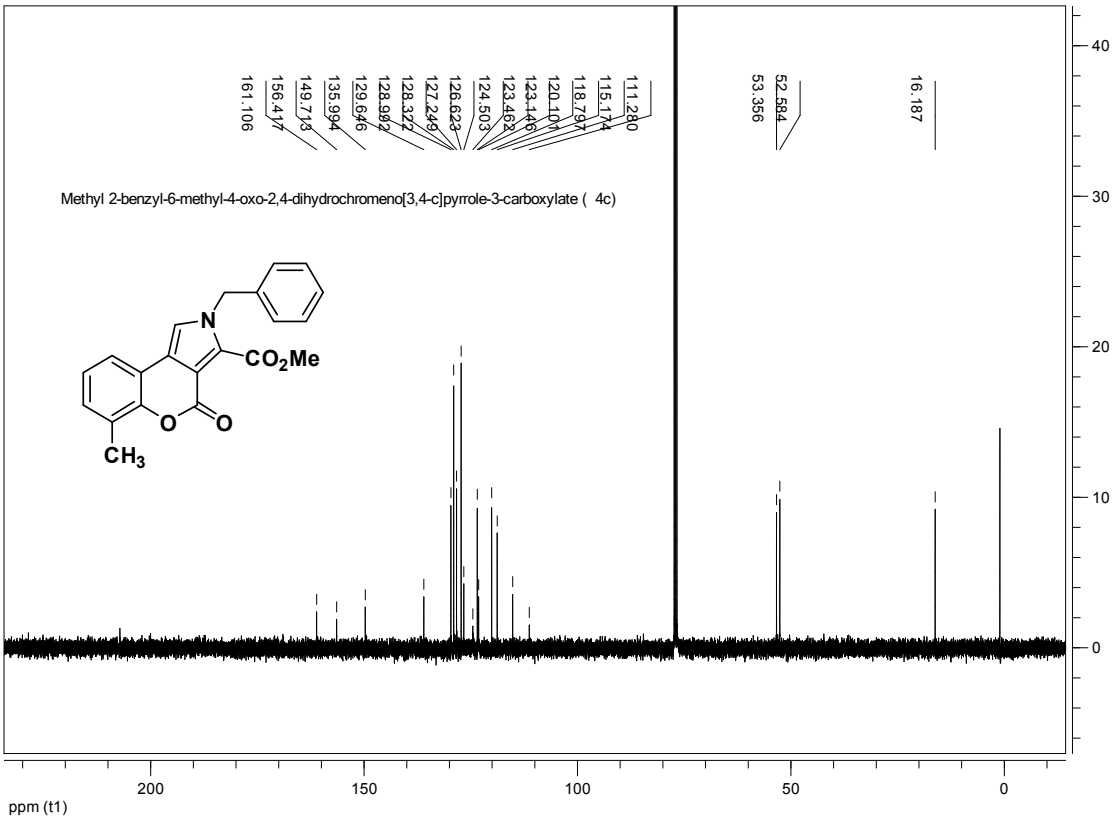
Methyl 2-benzyl-8-bromo-4-oxo-2,4-dihydrochromeno[3,4-*c*]pyrrole-3-carboxylate (4b)



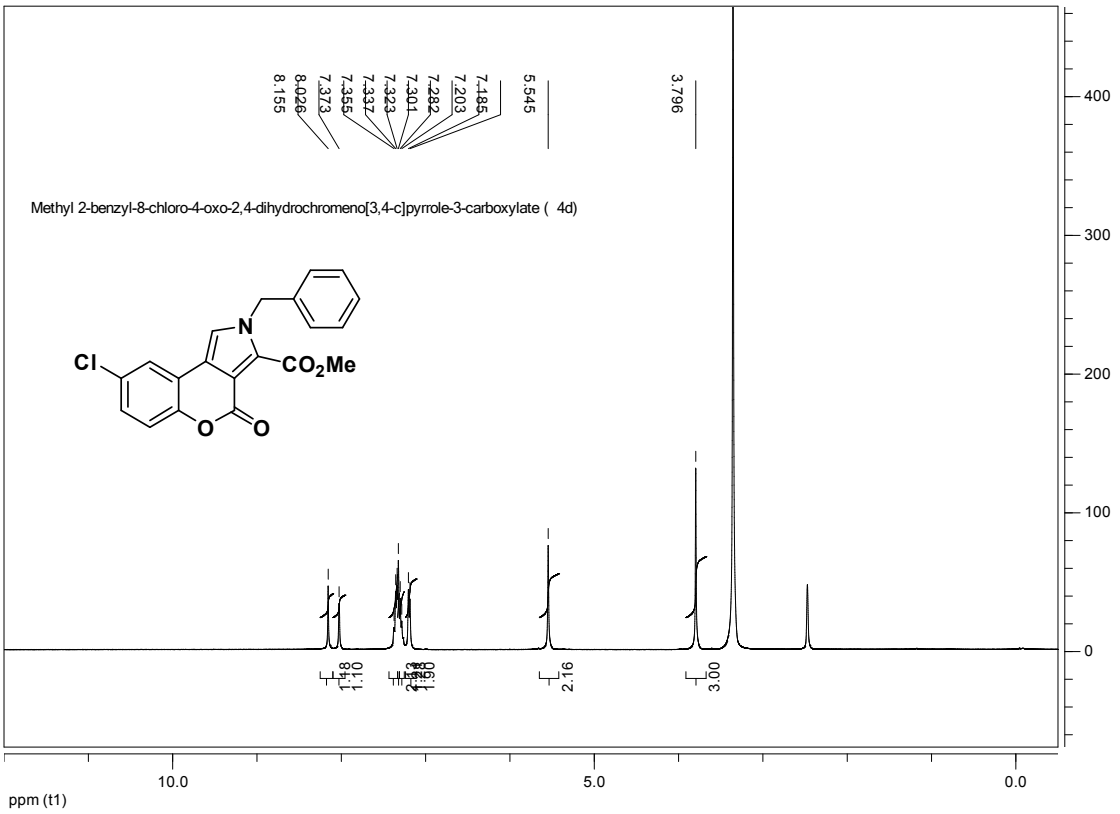


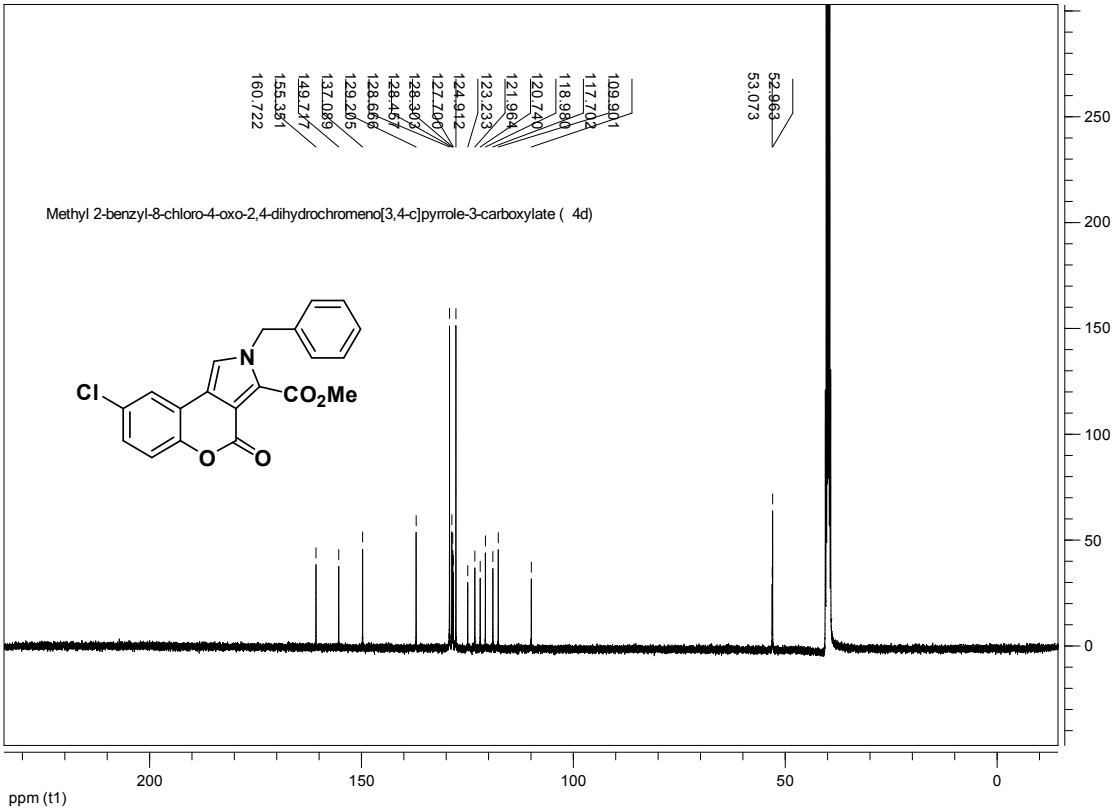
Methyl 2-benzyl-6-methyl-4-oxo-2,4-dihydrochromeno[3,4-*c*]pyrrole-3-carboxylate (4c)



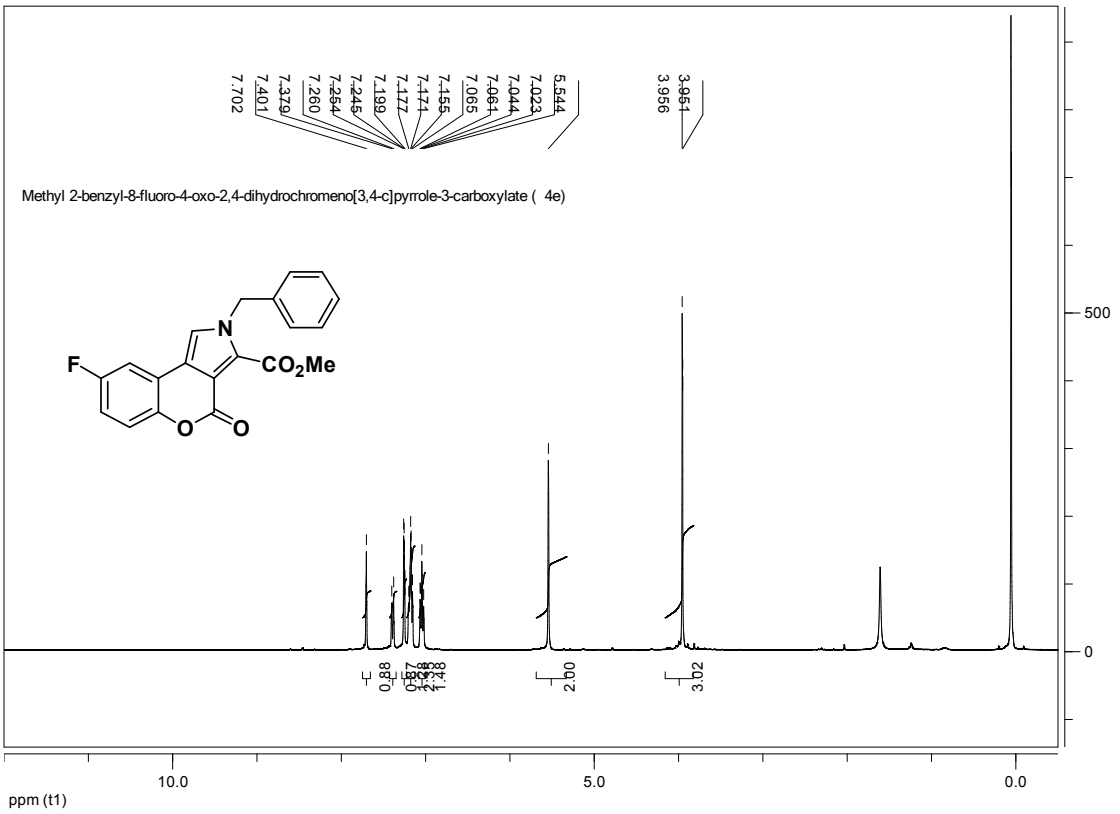


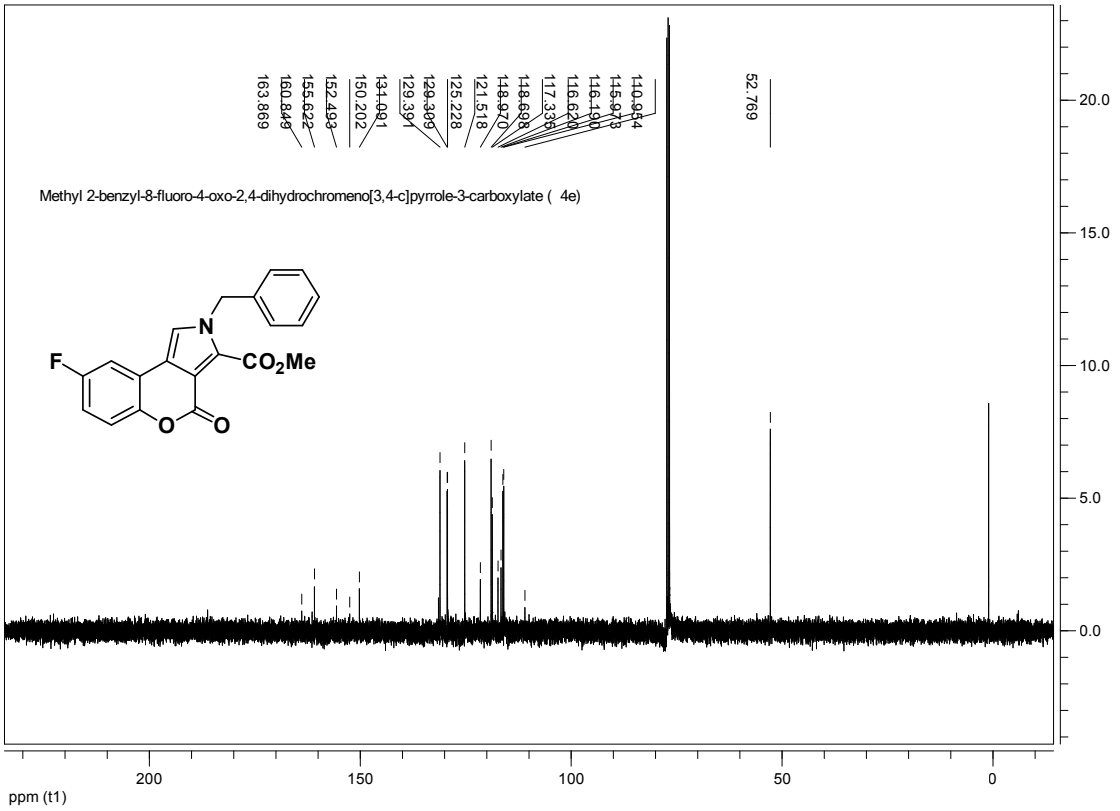
Methyl 2-benzyl-8-chloro-4-oxo-2,4-dihydrochromeno[3,4-*c*]pyrrole-3-carboxylate (4d)



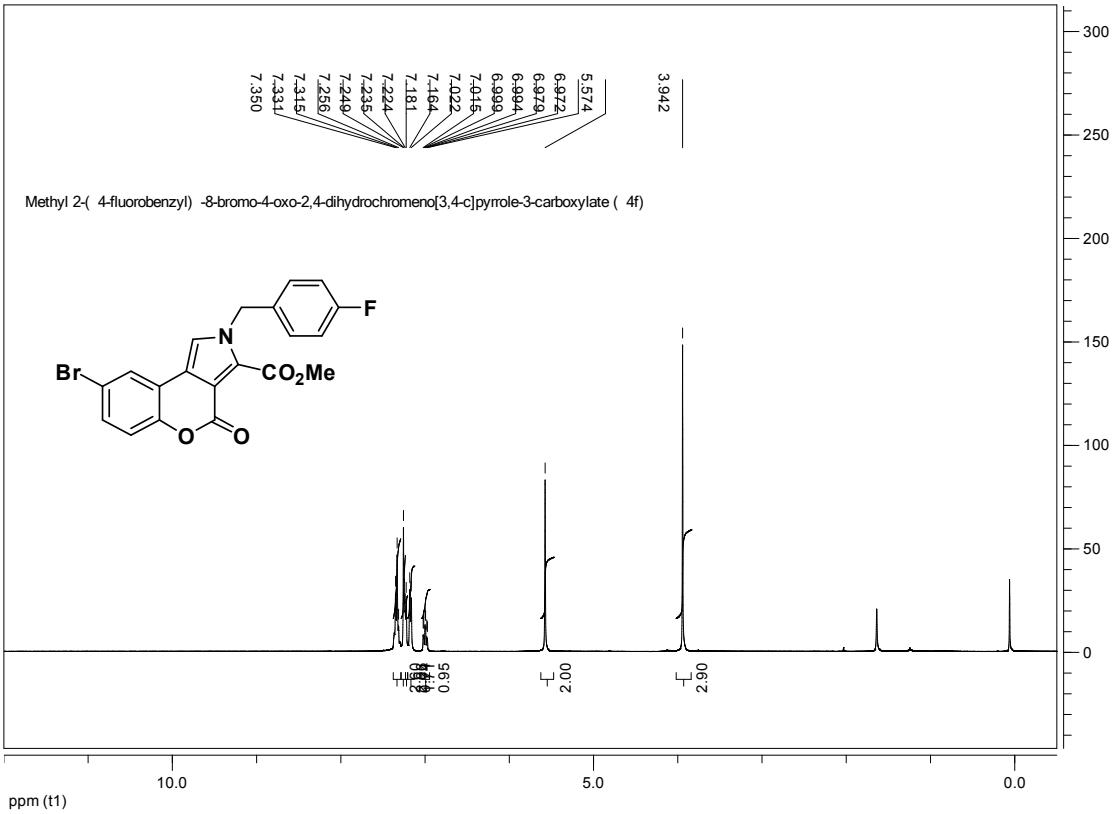


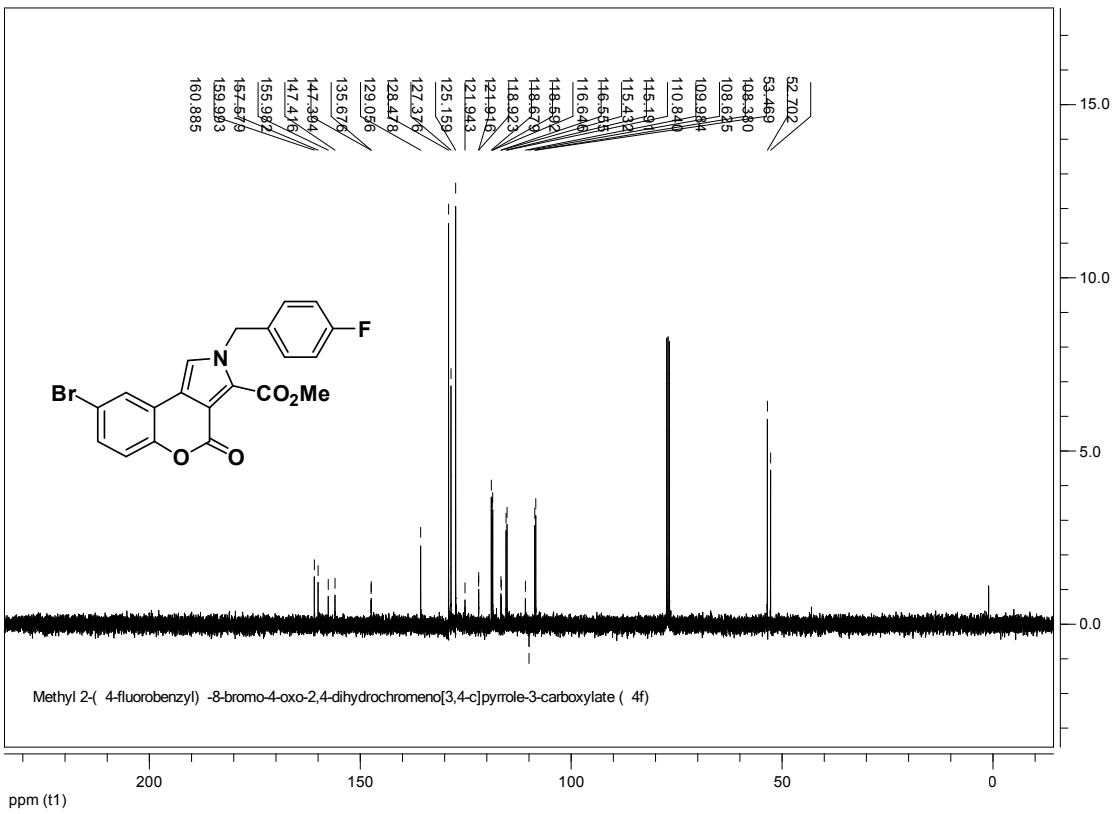
Methyl 2-benzyl-8-fluoro-4-oxo-2,4-dihydrochromeno[3,4-*c*]pyrrole-3-carboxylate (4e)





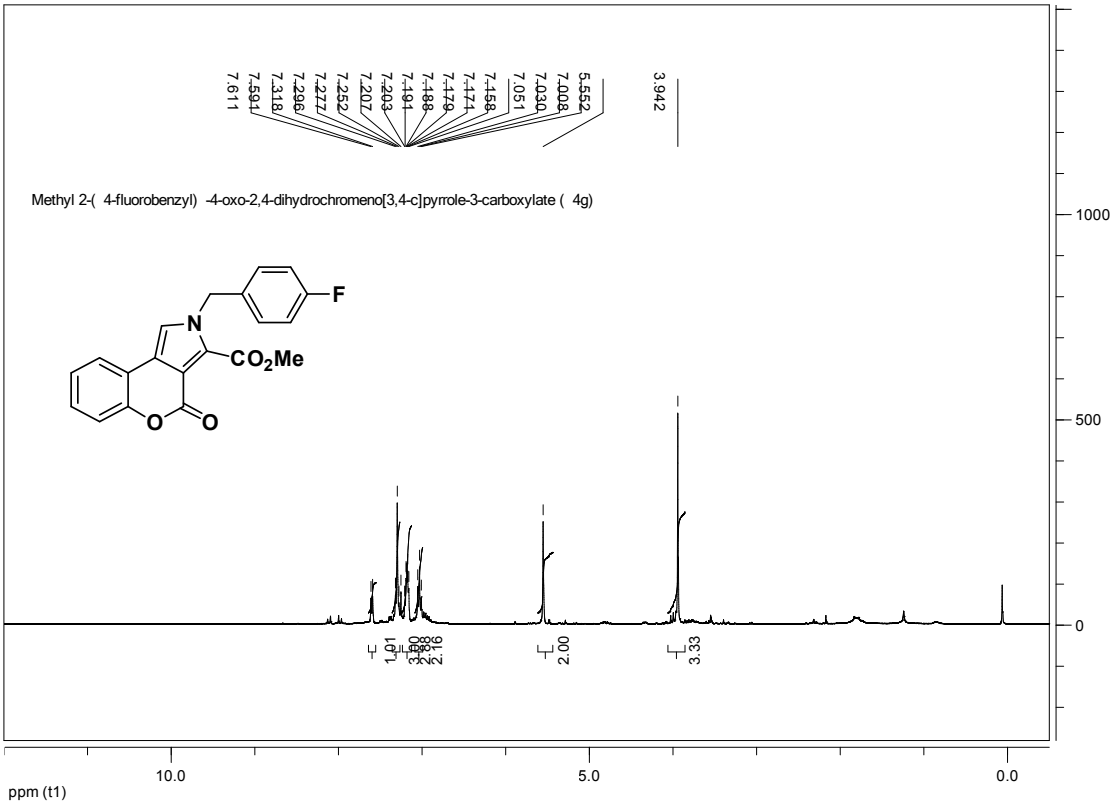
Methyl 2-(4-fluorobenzyl)-8-bromo-4-oxo-2,4-dihydrochromeno[3,4-*c*]pyrrole-3-carboxylate (4f)

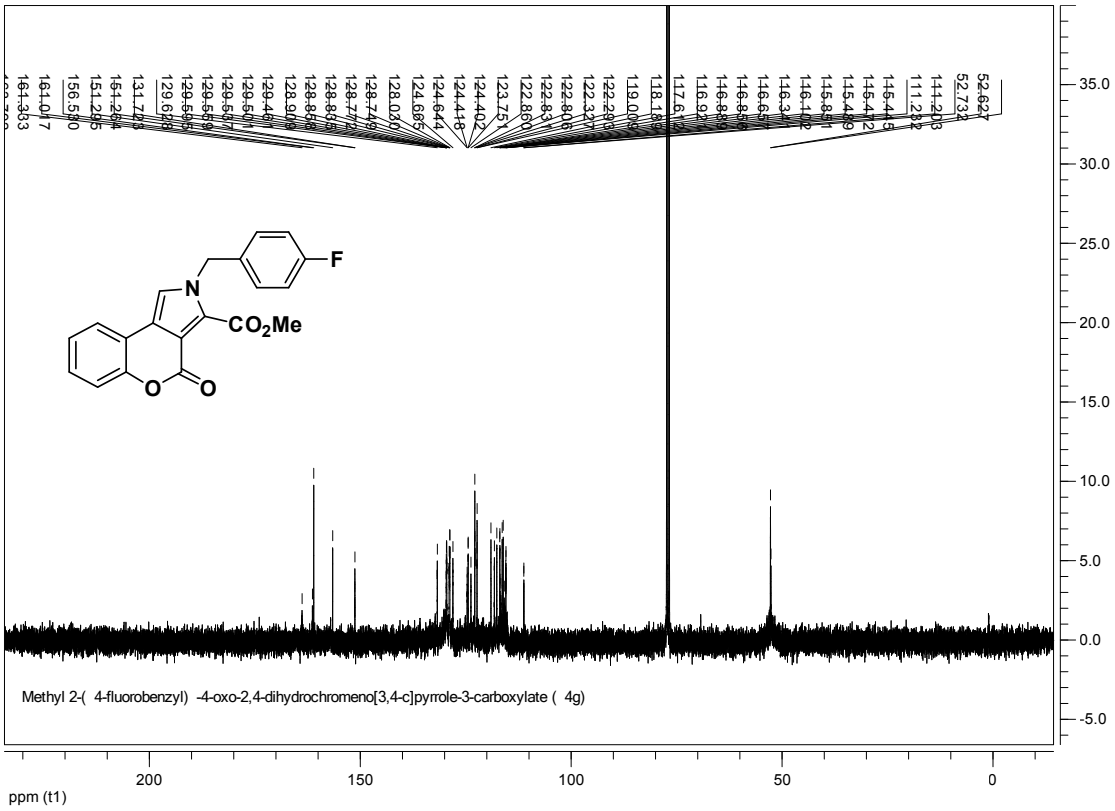




Methyl 2-(4-fluorobenzyl)-4-oxo-2,4-dihydrochromeno[3,4-*c*]pyrrole-3-

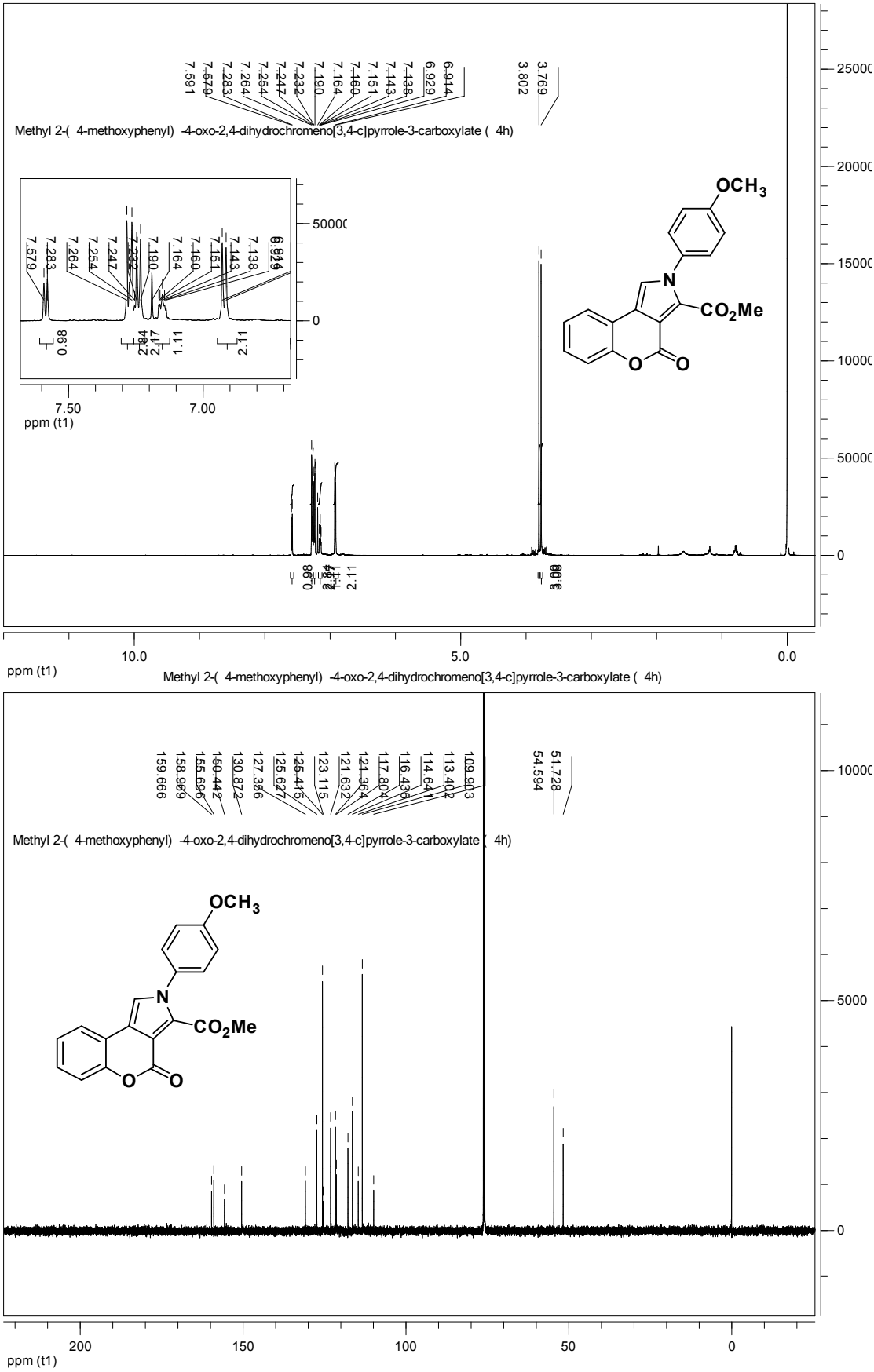
carboxylate (4g)



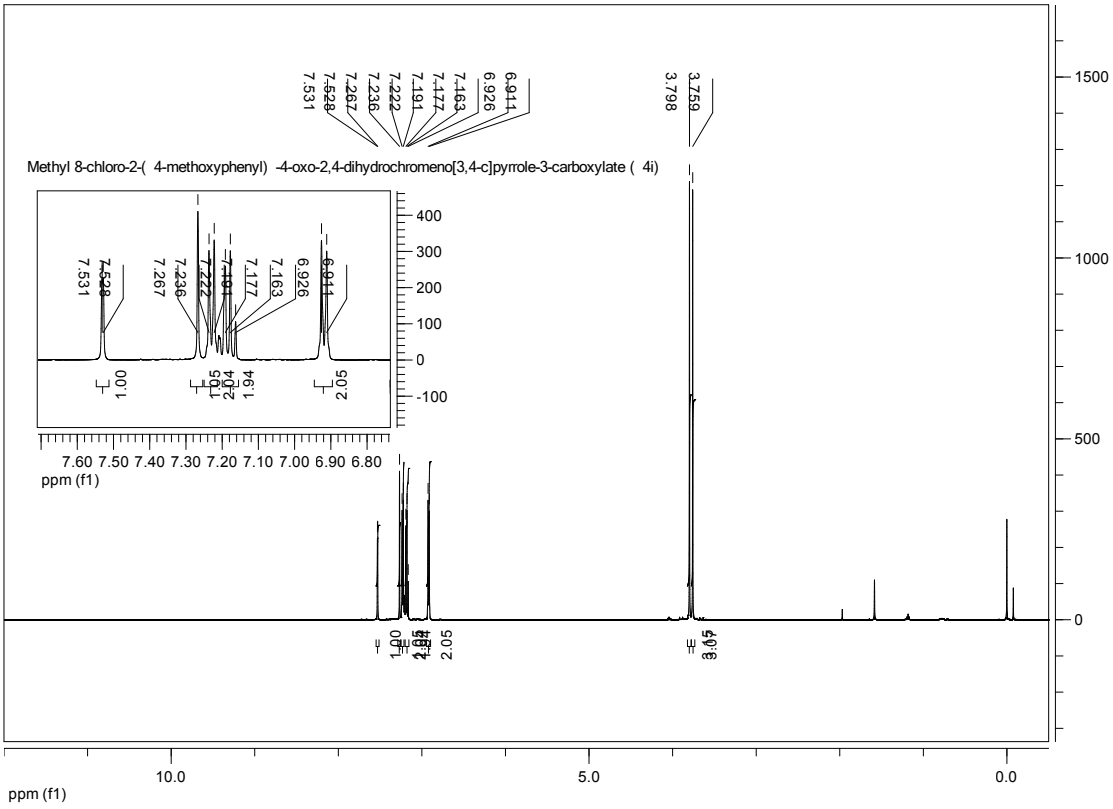


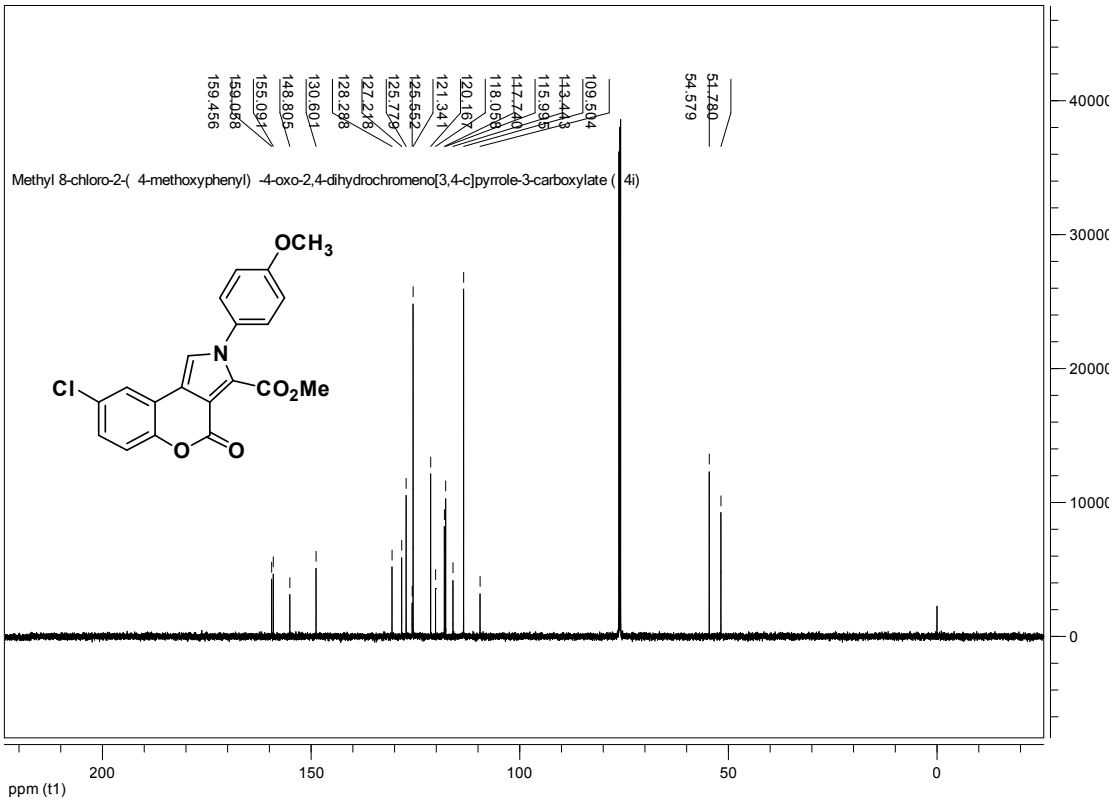
Methyl 2-(4-methoxyphenyl)-4-oxo-2,4-dihydrochromeno[3,4-*c*]pyrrole-3-

carboxylate (4h)

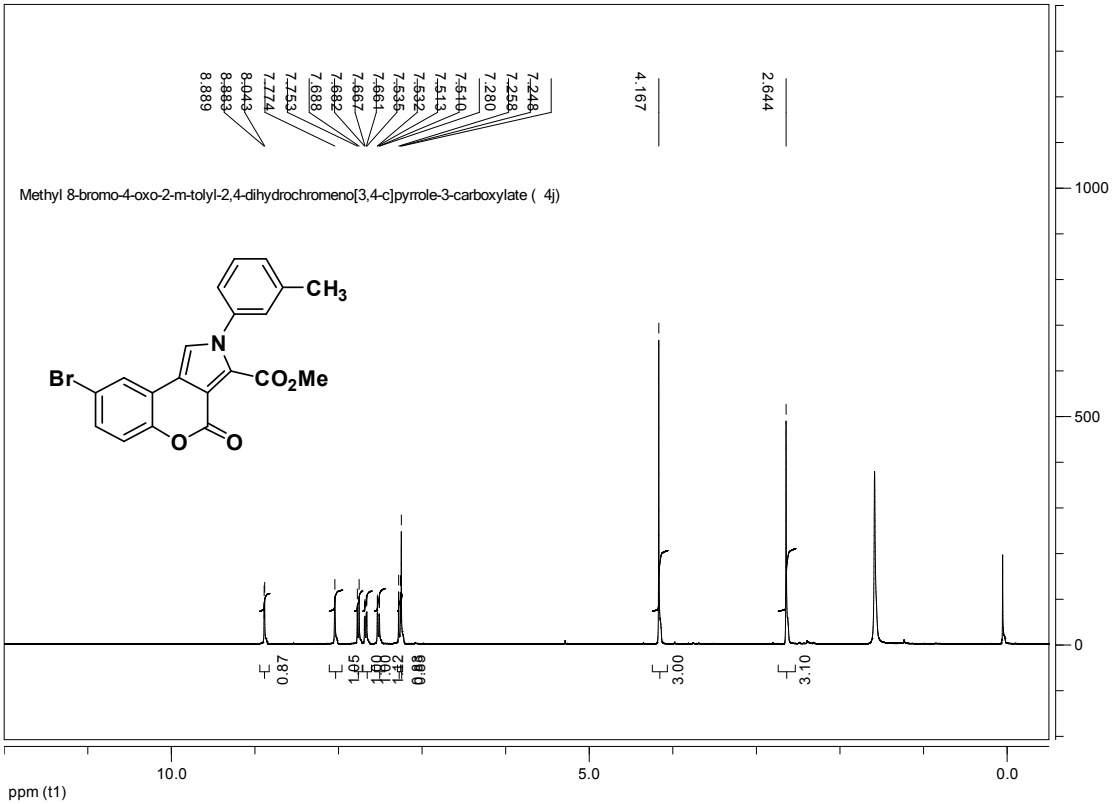


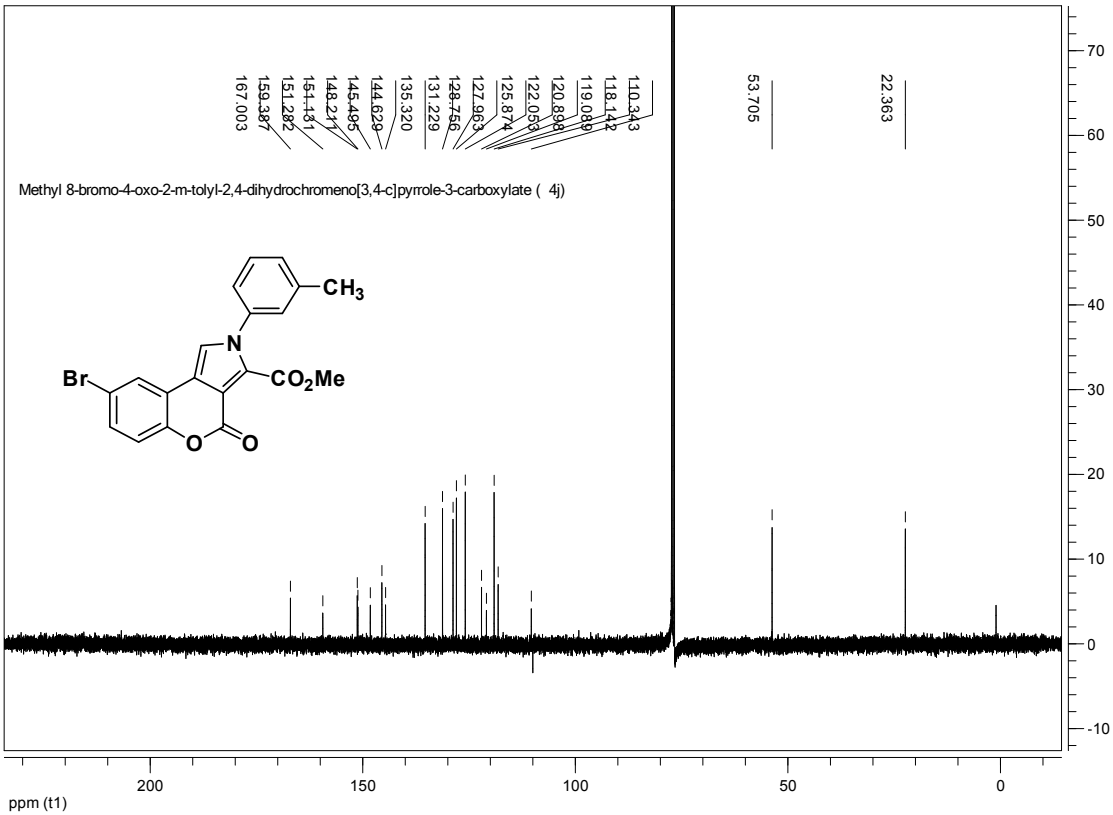
Methyl 8-chloro-2-(4-methoxyphenyl)-4-oxo-2,4-dihydrochromeno[3,4-*c*] pyrrole-3- carboxylate (4i)



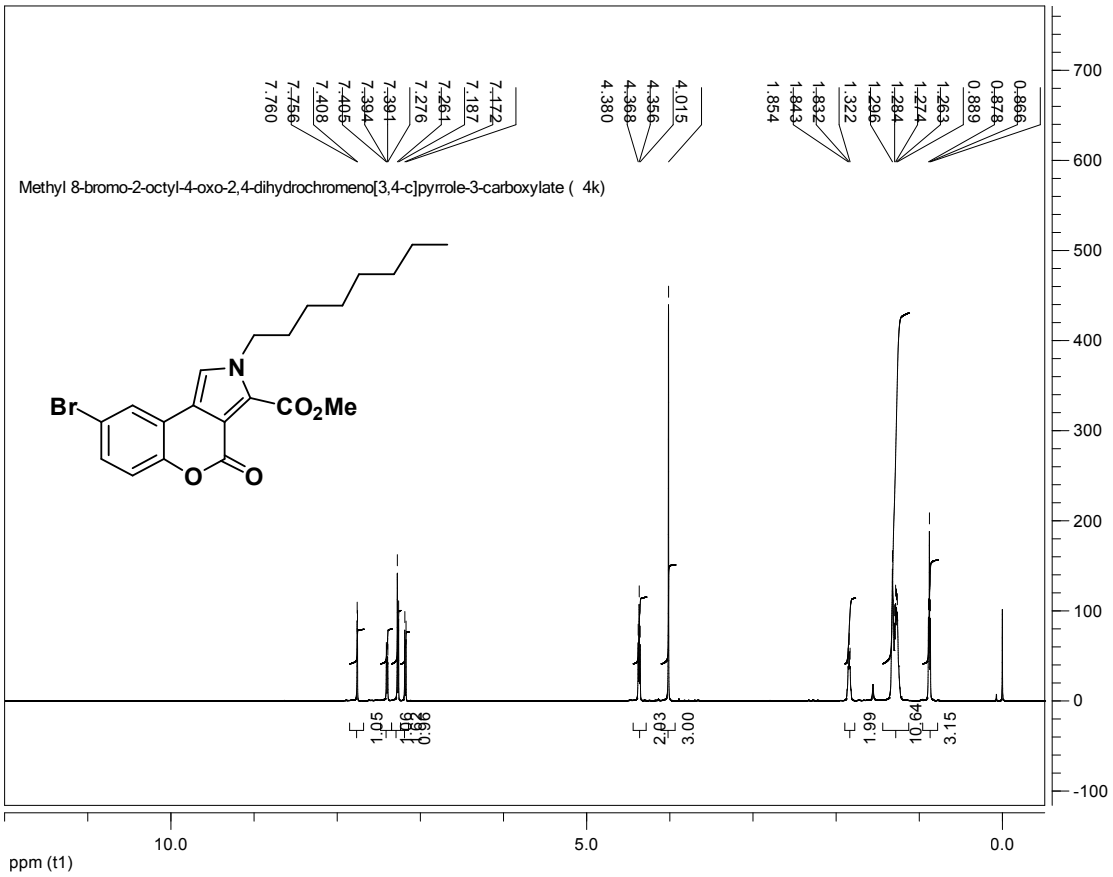


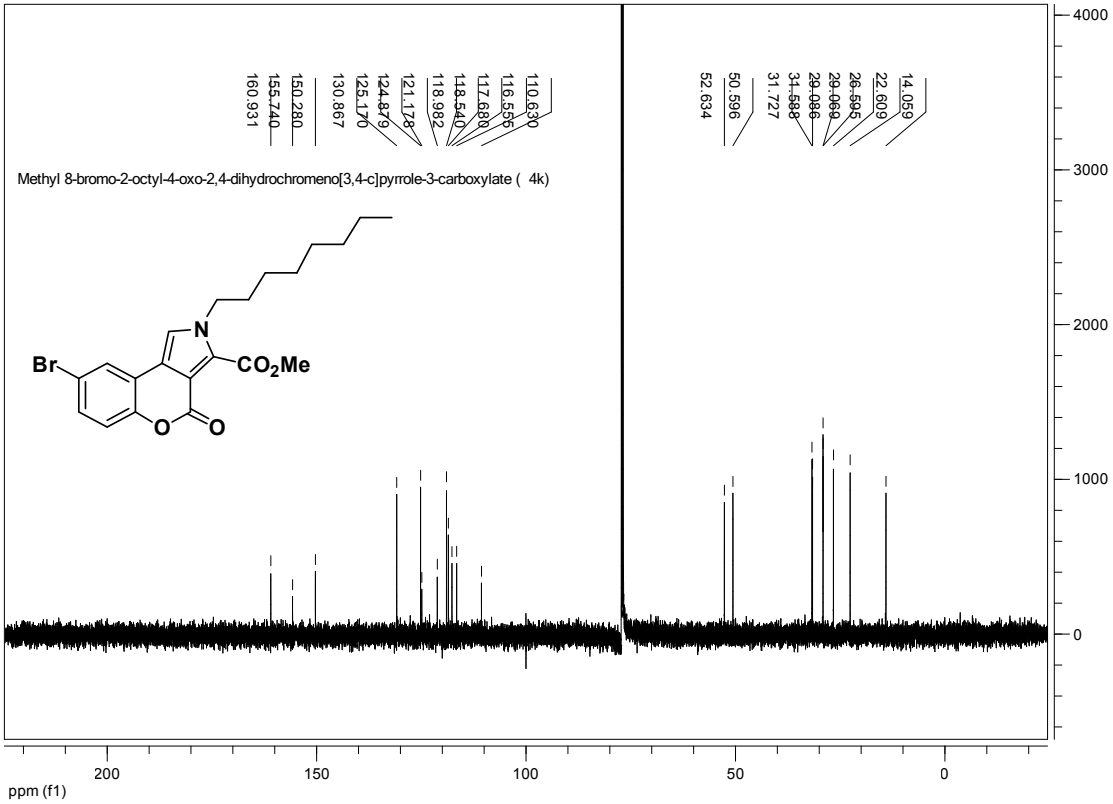
Methyl 8-bromo-4-oxo-2-m-tolyl-2,4-dihydrochromeno[3,4-*c*]pyrrole-3-carboxylate (4j)



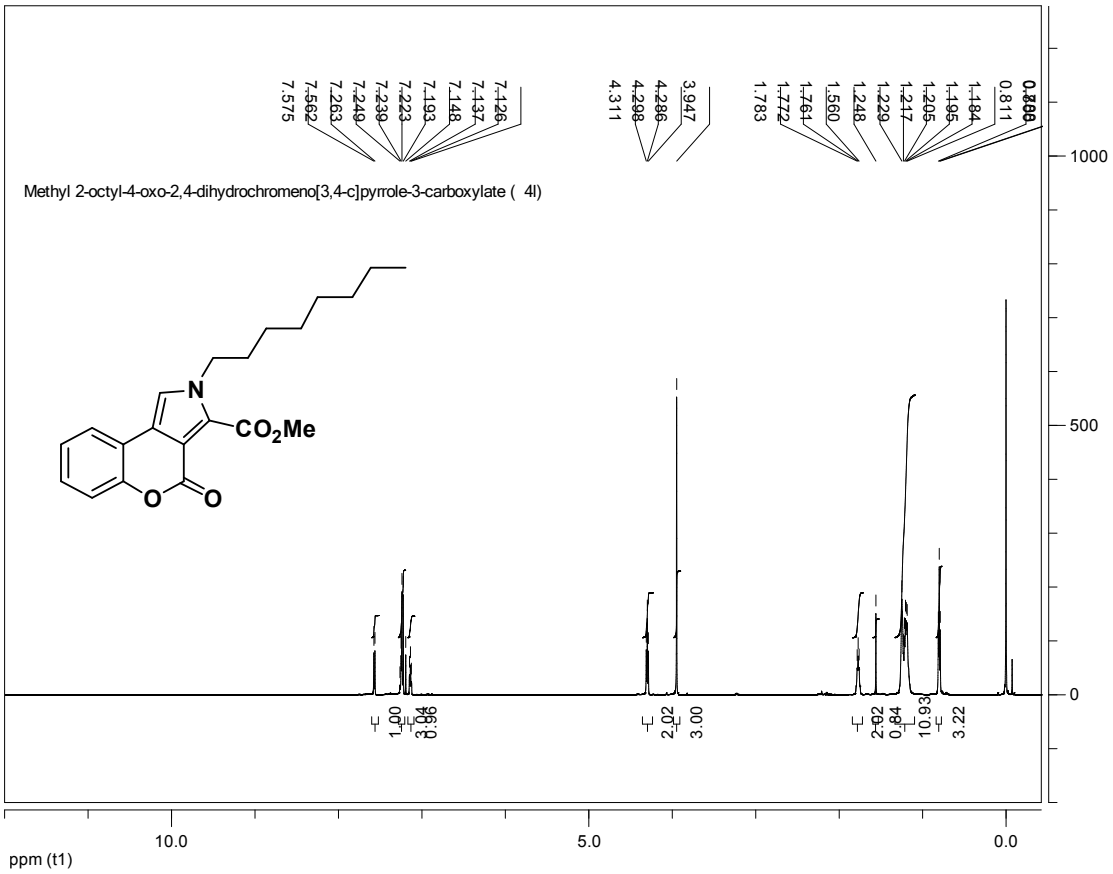


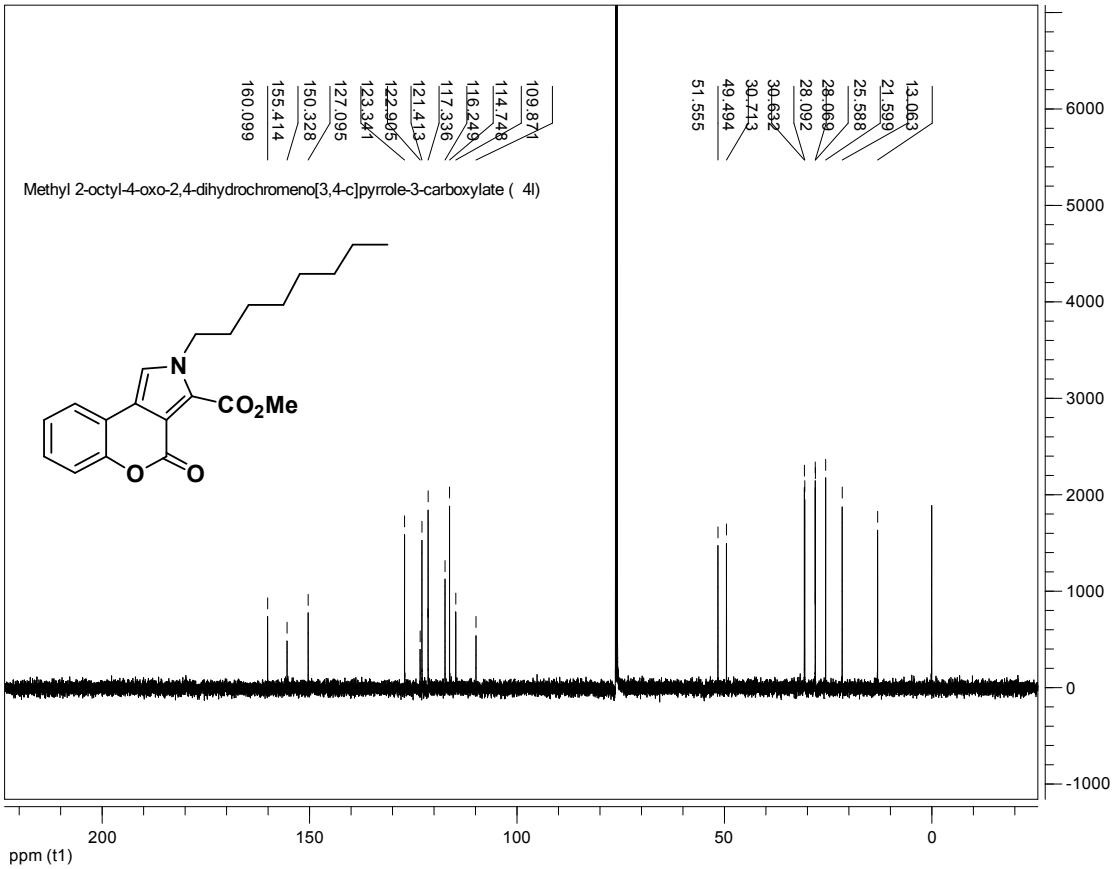
Methyl 8-bromo-2-octyl-4-oxo-2,4-dihydrochromeno[3,4-*c*]pyrrole-3-carboxylate (4k)



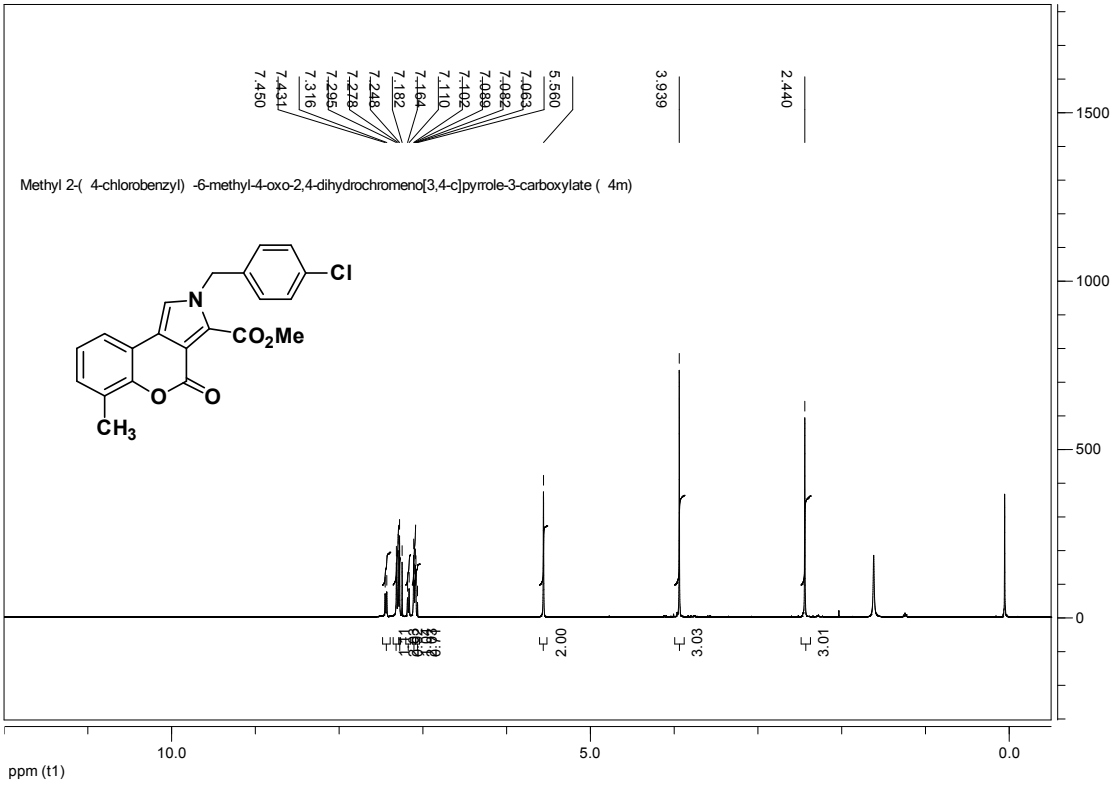


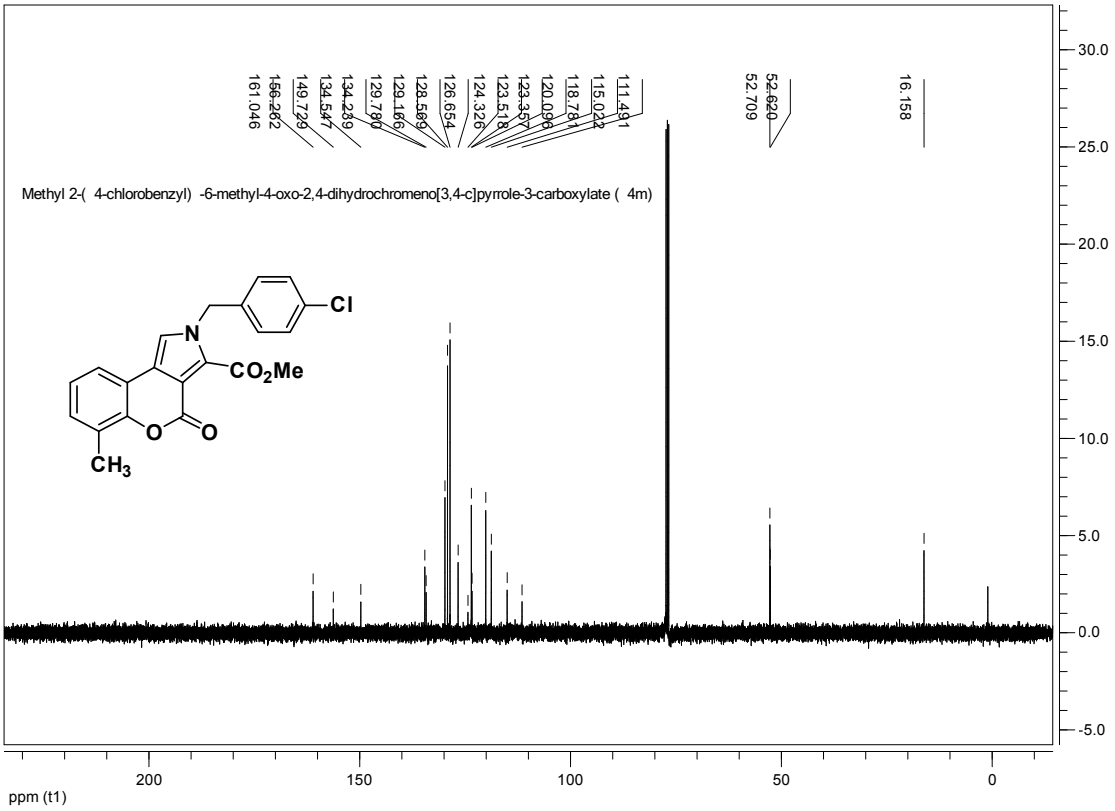
Methyl 2-octyl-4-oxo-2,4-dihydrochromeno[3,4-*c*]pyrrole-3-carboxylate (4l)



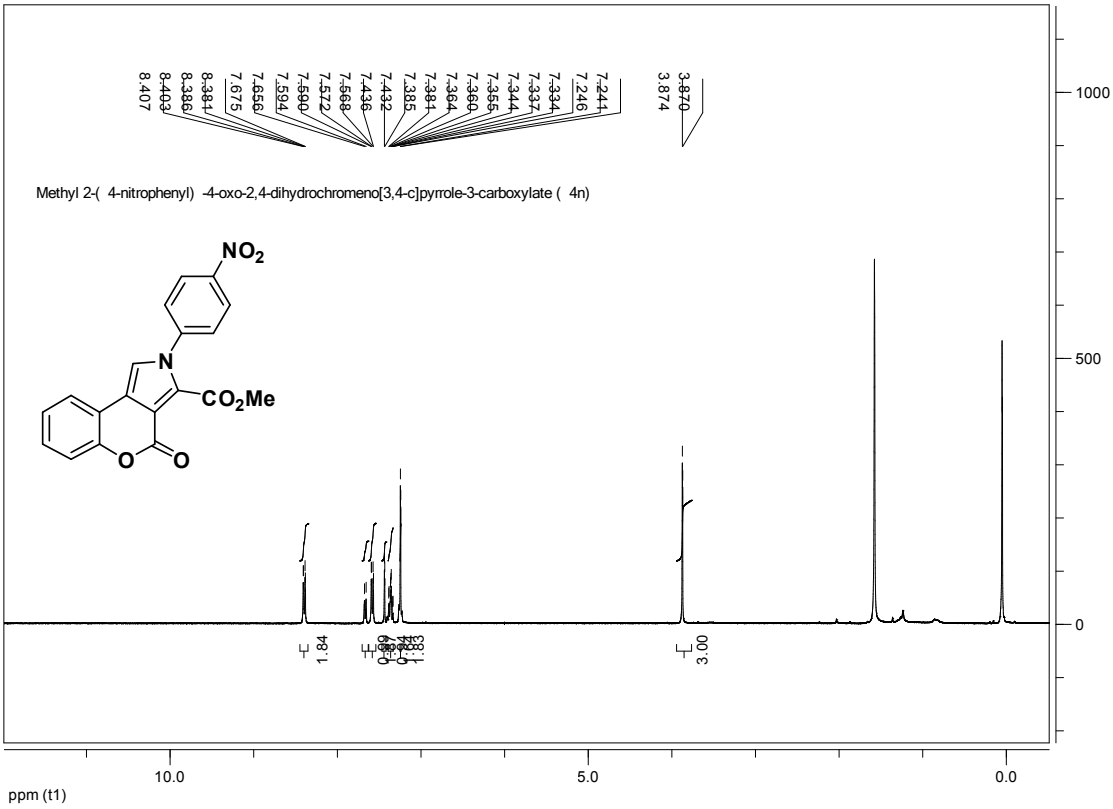


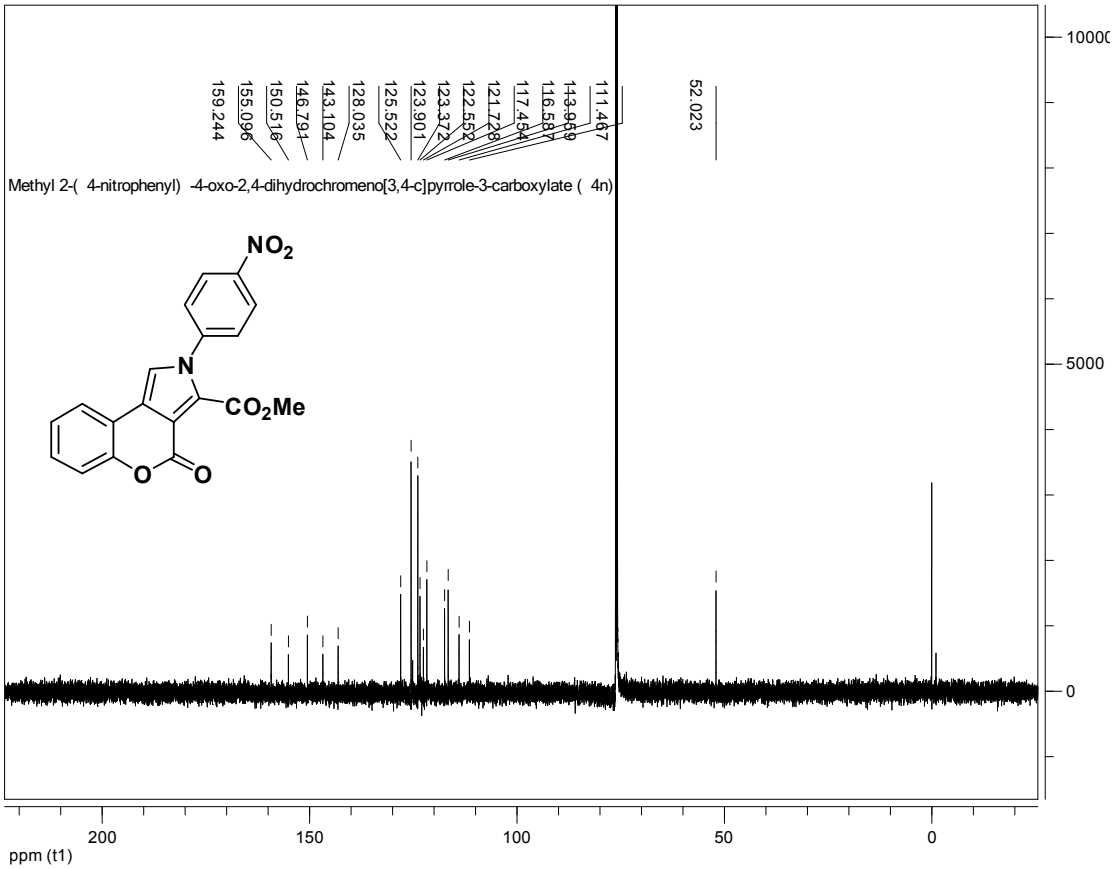
Methyl 2-(4-chlorobenzyl)-6-methyl-4-oxo-2,4-dihydrochromeno[3,4-*c*]pyrrole-3-carboxylate (4m)



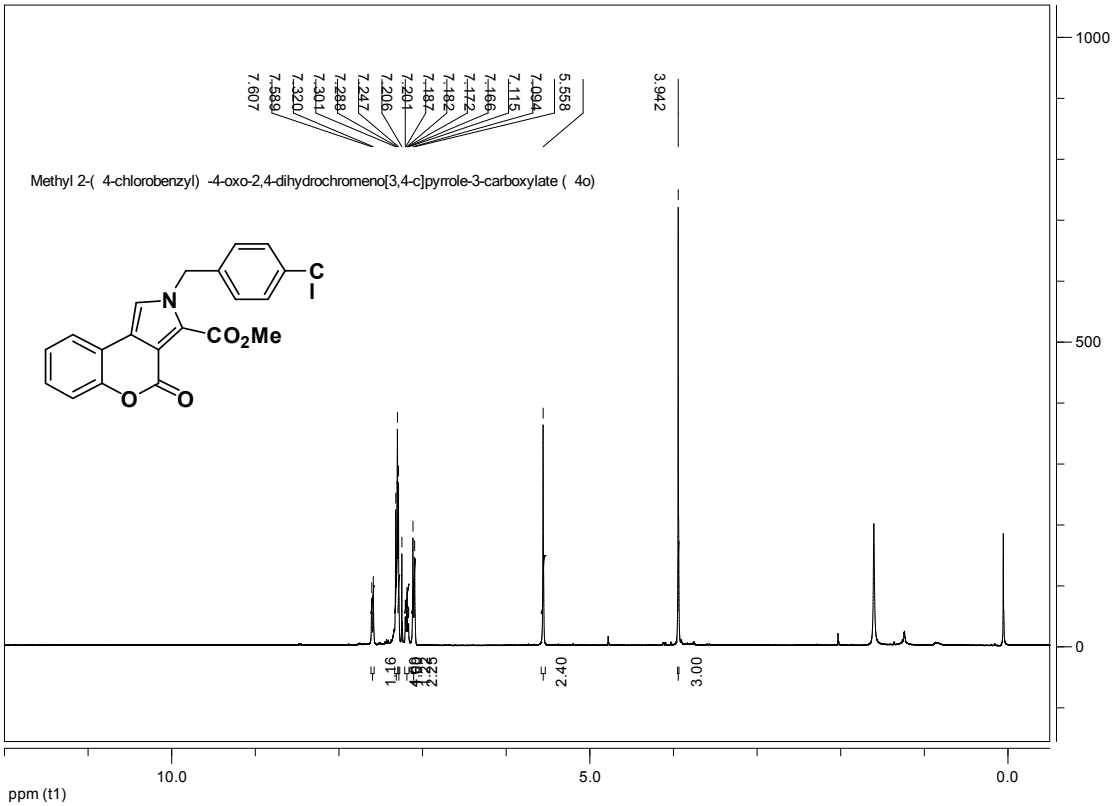


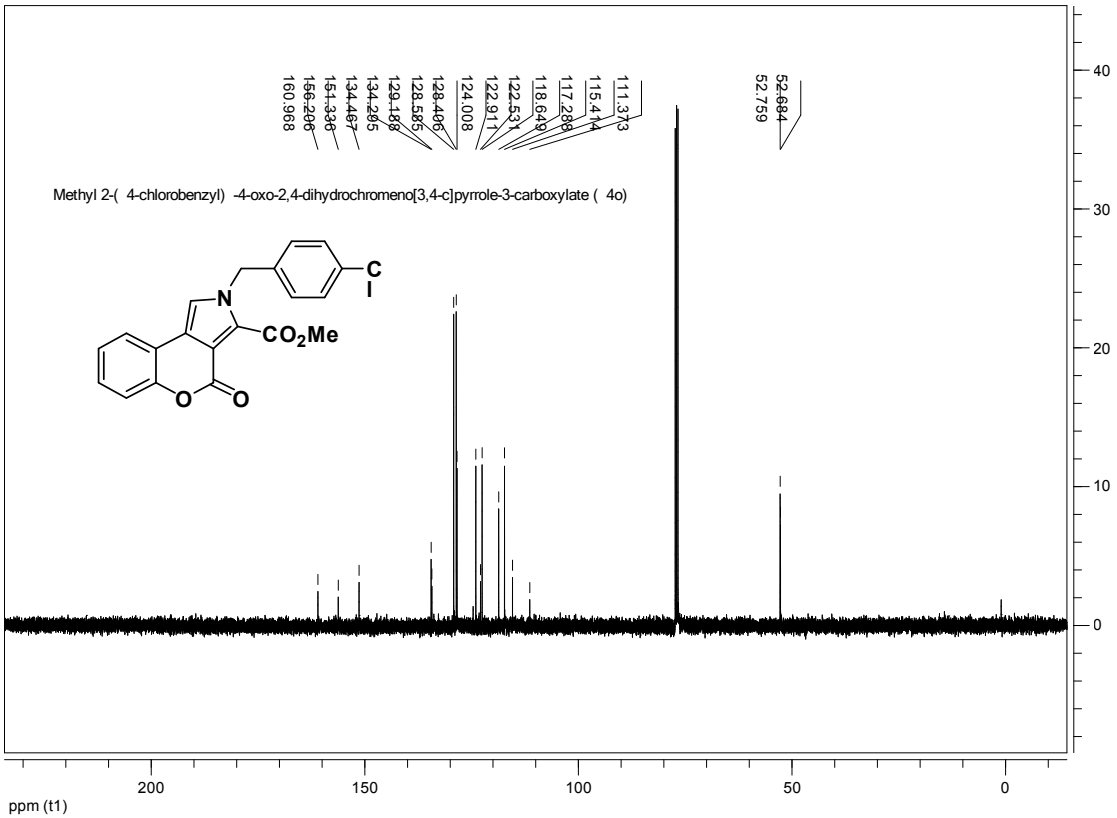
Methyl 2-(4-nitrophenyl)-4-oxo-2,4-dihydrochromeno[3,4-*c*]pyrrole-3-carboxylate (4n)



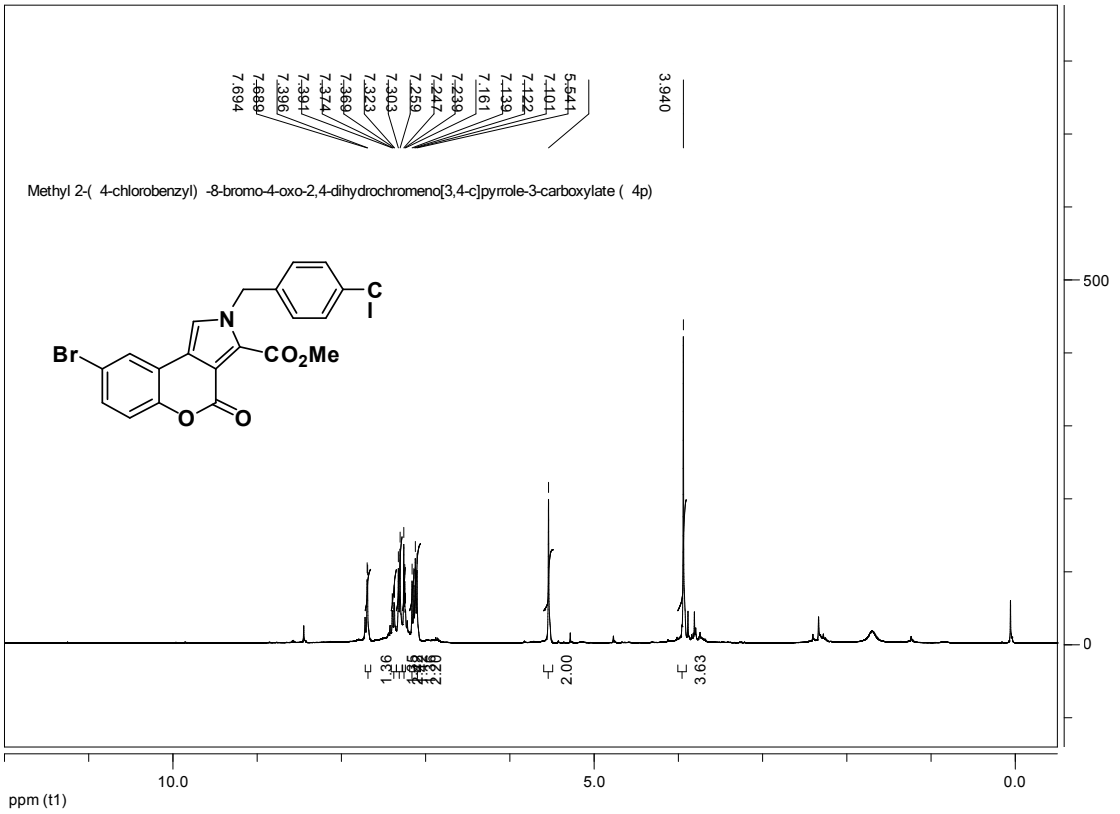


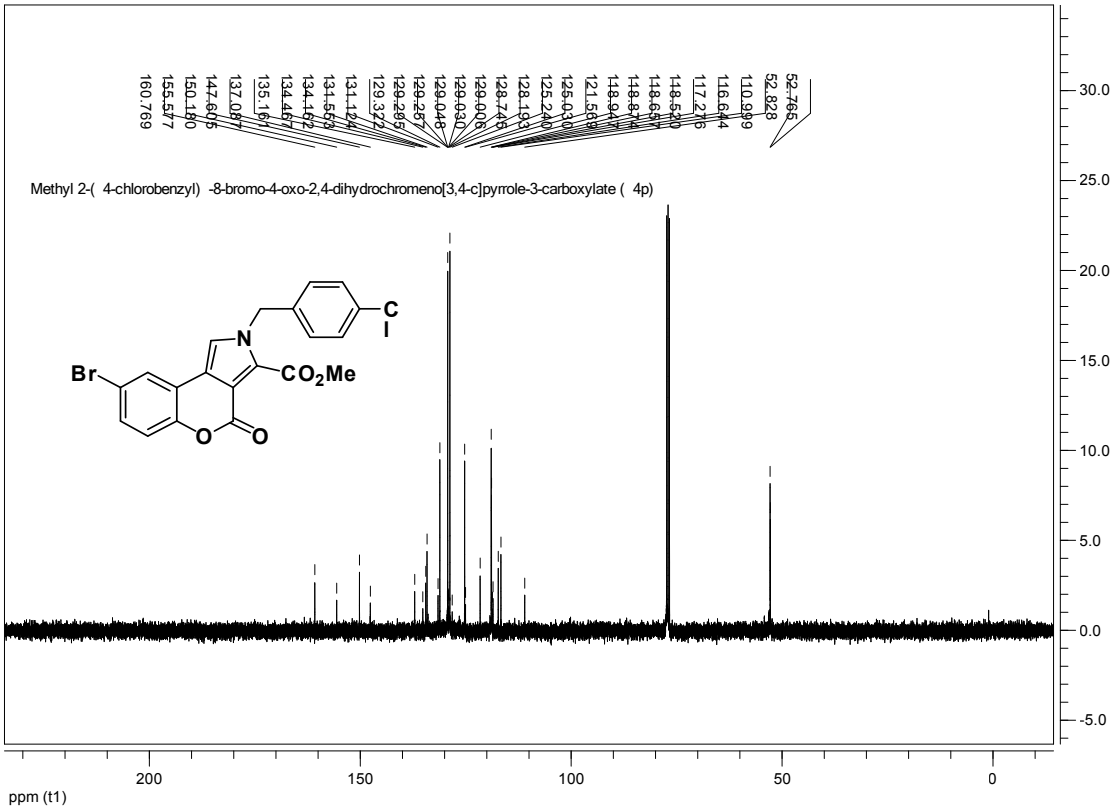
Methyl 2-(4-chlorobenzyl)-4-oxo-2,4-dihydrochromeno[3,4-*c*]pyrrole-3-carboxylate (4o)





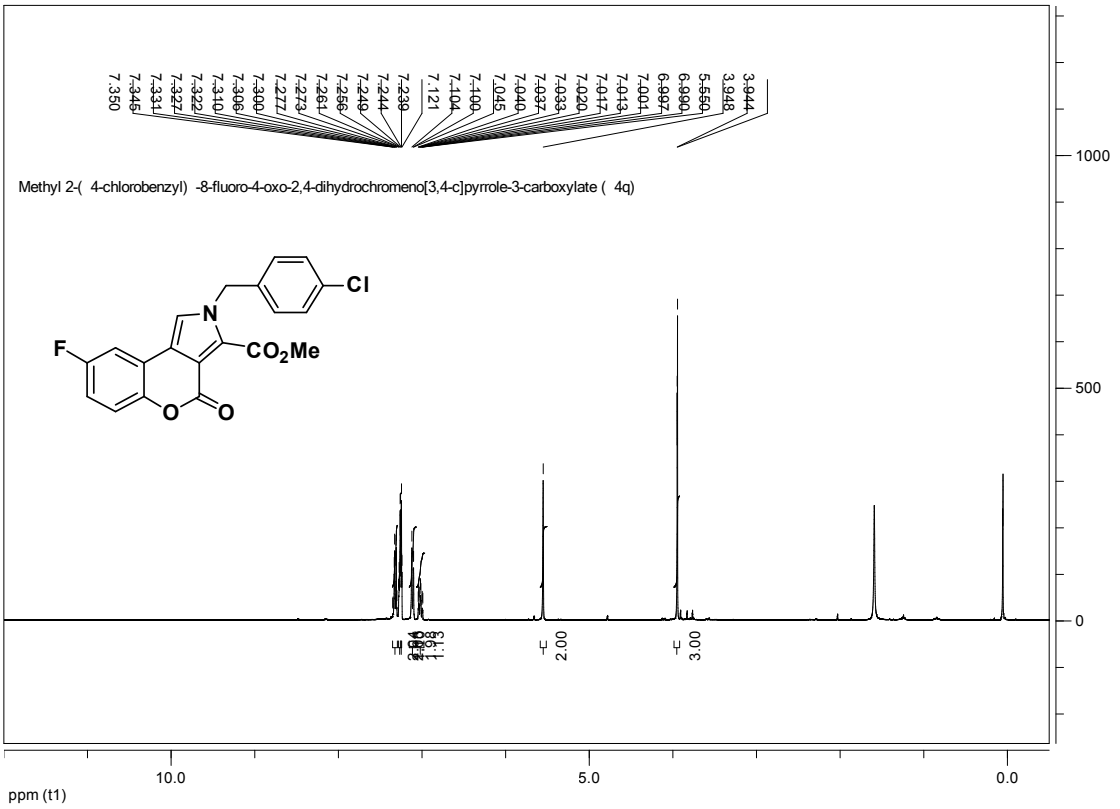
Methyl 2-(4-chlorobenzyl)-8-bromo-4-oxo-2,4-dihydrochromeno[3,4-*c*]pyrrole-3-carboxylate (4p)

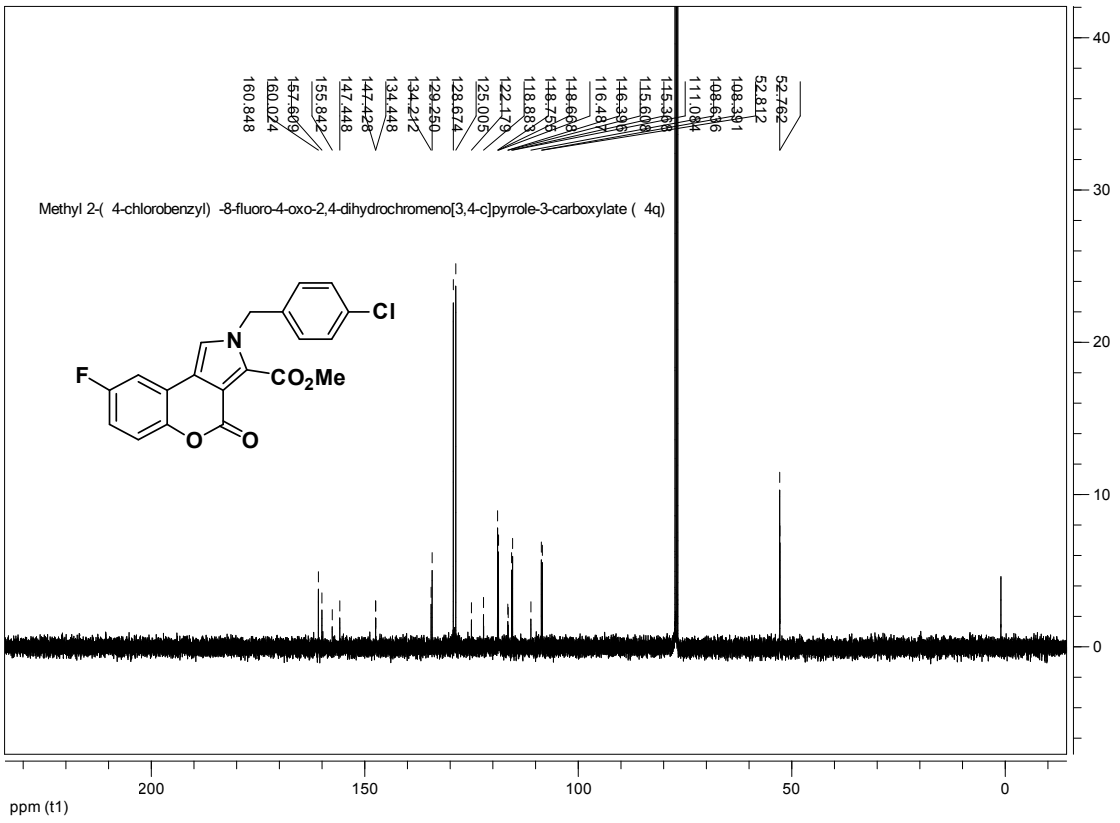




Methyl 2-(4-chlorobenzyl)-8-fluoro-4-oxo-2,4-dihydrochromeno[3,4-*c*]pyrrole-3-

carboxylate (4q)





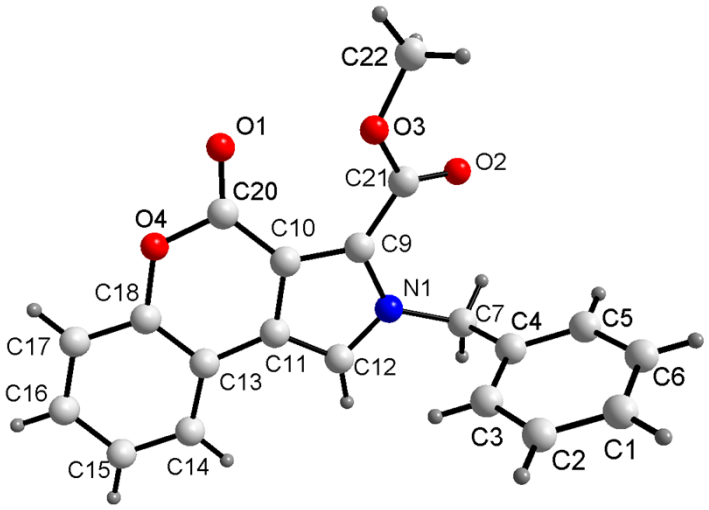


Table 1. Crystal data and structure refinement for **4a**.

Identification code	**4a**
Empirical formula	C20 H15 N O4
Formula weight	333.33
Temperature	296(2) K
Wavelength	0.71073 A
Crystal system, space group	Orthorhombic, P b c a
Unit cell dimensions	a = 16.874(3) A alpha = 90 deg.
	b = 10.8932(19) A beta = 90 deg.
	c = 17.308(3) A gamma = 90 deg.
Volume	3181.4(10) A^3
Z, Calculated density	8, 1.392 Mg/m^3
Absorption coefficient	0.098 mm^-1
F(000)	1392
Crystal size	0.35 x 0.33 x 0.3 mm
Theta range for data collection	2.41 to 27.59 deg.
Limiting indices	-21<=h<=21, -14<=k<=11, -19<=l<=22
Reflections collected / unique	26265 / 3687 [R(int) = 0.1208]
Completeness to theta = 27.59	99.6 %

Refinement method	Full-matrix least-squares on F^2
Data / restraints / parameters	3672 / 0 / 227
Goodness-of-fit on F^2	0.996
Final R indices [I>2sigma(I)]	R1 = 0.0720, wR2 = 0.1431
R indices (all data)	R1 = 0.1961, wR2 = 0.1826
Largest diff. peak and hole	0.465 and -0.277 e.A^-3

Table 2. Atomic coordinates (x 10^4) and equivalent isotropic displacement parameters (A^2 x 10^3) for **4a**.
U(eq) is defined as one third of the trace of the orthogonalized Uij tensor.

	x	y	z	U(eq)
O(4)	1018(1)	9016(2)	10100(1)	49(1)
C(11)	2632(2)	9253(2)	10248(2)	38(1)
N(1)	3622(1)	8189(2)	9749(1)	44(1)
C(18)	1319(2)	9896(2)	10594(2)	40(1)
O(1)	1102(1)	7543(3)	9257(2)	83(1)
O(3)	2363(2)	6669(2)	8416(2)	80(1)
C(10)	2317(2)	8396(2)	9724(2)	36(1)
C(20)	1470(2)	8248(3)	9644(2)	48(1)
C(9)	2950(2)	7740(2)	9410(2)	39(1)
C(13)	2127(2)	10062(2)	10685(2)	38(1)
C(7)	4454(2)	7852(3)	9591(2)	51(1)
O(2)	3514(2)	6001(2)	8815(2)	93(1)
C(12)	3437(2)	9103(3)	10249(2)	45(1)
C(5)	5315(2)	7918(3)	8423(2)	55(1)
C(4)	4792(2)	8517(3)	8907(2)	42(1)
C(17)	780(2)	10589(3)	10998(2)	55(1)
C(14)	2378(2)	10980(3)	11189(2)	52(1)
C(21)	2987(2)	6733(3)	8856(2)	48(1)
C(3)	4630(2)	9738(3)	8767(2)	55(1)
C(2)	4980(2)	10345(4)	8164(2)	73(1)

C(15)	1840(2)	11679(3)	11592(2)	65(1)
C(1)	5501(2)	9747(4)	7698(2)	77(1)
C(16)	1044(2)	11474(3)	11499(2)	67(1)
C(6)	5676(2)	8531(4)	7819(2)	71(1)
C(22)	2297(2)	5623(3)	7911(2)	82(1)

Table 3. Bond lengths [A] and angles [deg] for **4a**.

O(4)-C(20)	1.380(3)
O(4)-C(18)	1.381(3)
C(11)-C(12)	1.369(4)
C(11)-C(10)	1.406(4)
C(11)-C(13)	1.439(4)
N(1)-C(12)	1.356(4)
N(1)-C(9)	1.366(3)
N(1)-C(7)	1.477(4)
C(18)-C(17)	1.374(4)
C(18)-C(13)	1.384(4)
O(1)-C(20)	1.193(3)
O(3)-C(21)	1.300(4)
O(3)-C(22)	1.441(4)
C(10)-C(9)	1.396(4)
C(10)-C(20)	1.445(4)
C(9)-C(21)	1.459(4)
C(13)-C(14)	1.393(4)
C(7)-C(4)	1.501(4)
O(2)-C(21)	1.196(4)
C(5)-C(4)	1.380(4)
C(5)-C(6)	1.383(4)
C(4)-C(3)	1.380(4)
C(17)-C(16)	1.371(5)
C(14)-C(15)	1.374(4)
C(3)-C(2)	1.370(5)
C(2)-C(1)	1.360(5)

C(15)-C(16)	1.371(5)
C(1)-C(6)	1.373(5)
C(20)-O(4)-C(18)	124.8(2)
C(12)-C(11)-C(10)	107.3(2)
C(12)-C(11)-C(13)	131.2(3)
C(10)-C(11)-C(13)	121.5(2)
C(12)-N(1)-C(9)	110.3(2)
C(12)-N(1)-C(7)	121.3(3)
C(9)-N(1)-C(7)	128.3(3)
C(17)-C(18)-C(13)	121.5(3)
C(17)-C(18)-O(4)	116.9(3)
C(13)-C(18)-O(4)	121.6(2)
C(21)-O(3)-C(22)	117.4(3)
C(9)-C(10)-C(11)	107.5(2)
C(9)-C(10)-C(20)	131.6(3)
C(11)-C(10)-C(20)	120.6(3)
O(1)-C(20)-O(4)	115.1(3)
O(1)-C(20)-C(10)	129.7(3)
O(4)-C(20)-C(10)	115.1(3)
N(1)-C(9)-C(10)	106.6(2)
N(1)-C(9)-C(21)	121.1(3)
C(10)-C(9)-C(21)	132.3(3)
C(18)-C(13)-C(14)	117.6(3)
C(18)-C(13)-C(11)	116.2(3)
C(14)-C(13)-C(11)	126.1(3)
N(1)-C(7)-C(4)	112.8(2)
N(1)-C(12)-C(11)	108.3(3)
C(4)-C(5)-C(6)	120.8(3)
C(3)-C(4)-C(5)	118.5(3)
C(3)-C(4)-C(7)	121.8(3)

C(5)-C(4)-C(7)	119.6(3)
C(16)-C(17)-C(18)	119.5(3)
C(15)-C(14)-C(13)	121.0(3)
O(2)-C(21)-O(3)	122.1(3)
O(2)-C(21)-C(9)	124.8(3)
O(3)-C(21)-C(9)	113.0(3)
C(2)-C(3)-C(4)	120.8(3)
C(1)-C(2)-C(3)	120.0(4)
C(14)-C(15)-C(16)	119.8(3)
C(2)-C(1)-C(6)	120.7(4)
C(17)-C(16)-C(15)	120.5(3)
C(1)-C(6)-C(5)	119.1(4)

Symmetry transformations used to generate equivalent atoms:

Table 4. Anisotropic displacement parameters (A^2 x 10^3) for **4a**.

The anisotropic displacement factor exponent takes the form:

-2 pi^2 [h^2 a*^2 U11 + ... + 2 h k a* b* U12]

	U11	U22	U33	U23	U13	U12
O(4)	30(1)	56(1)	62(1)	-10(1)	4(1)	-1(1)
C(11)	34(2)	44(2)	37(2)	4(1)	-1(1)	0(1)
N(1)	28(1)	55(2)	49(2)	5(1)	2(1)	2(1)
C(18)	42(2)	37(2)	41(2)	1(1)	5(2)	1(2)
O(1)	44(1)	98(2)	108(2)	-49(2)	5(1)	-20(1)
O(3)	64(2)	88(2)	88(2)	-46(2)	-13(2)	16(1)
C(10)	31(2)	39(2)	38(2)	2(1)	1(1)	0(1)
C(20)	36(2)	51(2)	56(2)	-8(2)	6(2)	-5(2)
C(9)	33(2)	41(2)	42(2)	4(1)	7(2)	3(1)
C(13)	41(2)	38(2)	36(2)	4(1)	3(1)	-1(1)
C(7)	27(2)	63(2)	62(2)	14(2)	5(2)	10(2)
O(2)	78(2)	98(2)	101(2)	-37(2)	-2(2)	34(2)
C(12)	36(2)	57(2)	44(2)	-1(2)	-5(2)	-5(2)
C(5)	40(2)	70(2)	56(2)	4(2)	0(2)	6(2)
C(4)	25(2)	52(2)	49(2)	4(2)	-4(1)	-3(1)
C(17)	49(2)	49(2)	66(2)	7(2)	13(2)	8(2)
C(14)	59(2)	52(2)	47(2)	0(2)	-3(2)	-4(2)
C(21)	43(2)	51(2)	50(2)	0(2)	12(2)	6(2)
C(3)	47(2)	55(2)	64(2)	3(2)	-1(2)	-3(2)

C(2)	65(3)	69(2)	84(3)	25(2)	-13(2)	-21(2)
C(15)	92(3)	48(2)	55(2)	-11(2)	11(2)	-2(2)
C(1)	48(2)	117(4)	65(3)	33(3)	-8(2)	-34(2)
C(16)	82(3)	47(2)	72(3)	-3(2)	24(2)	13(2)
C(6)	42(2)	116(3)	56(2)	4(2)	6(2)	-1(2)
C(22)	74(3)	86(3)	85(3)	-42(2)	6(2)	-10(2)

Table 5. Hydrogen coordinates (x 10^4) and isotropic displacement parameters (A^2 x 10^3) for **4a**.

	x	y	z	U(eq)
H(7A)	4484	6975	9499	61
H(7B)	4772	8036	10043	61
H(12)	3796	9552	10542	54
H(5)	5426	7091	8504	67
H(17)	239	10458	10933	66
H(14)	2917	11122	11254	63
H(3)	4277	10155	9087	67
H(2)	4862	11166	8074	87
H(15)	2016	12288	11927	78
H(1)	5742	10166	7292	92
H(16)	681	11939	11777	80
H(6)	6033	8126	7498	86
H(22A)	2701	5665	7522	122
H(22B)	1785	5624	7669	122
H(22C)	2360	4883	8206	122

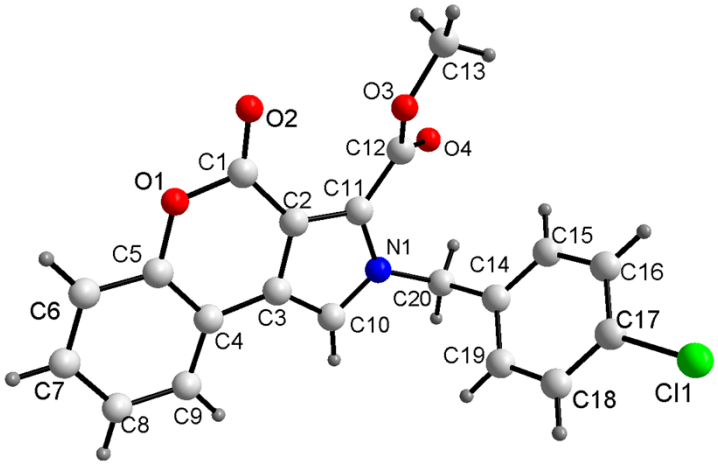


Table 1. Crystal data and structure refinement for **4o**.

Identification code	**4o**
Empirical formula	$C_{20}H_{14}ClNO_4$
Formula weight	367.77
Temperature	296 K
Wavelength	0.71073 A
Crystal system, space group	Triclinic, P-1
Unit cell dimensions	a = 7.9547(15) A alpha = 85.276(5) deg. b = 8.5268(16) A beta = 82.284(5) deg. c = 14.076(3) A gamma = 63.553(5) deg.
Volume	846.8(3) A^3
Z, Calculated density	2, 1.442 Mg/m^3
Absorption coefficient	0.252 mm^-1
F(000)	380
Crystal size	0.35 x 0.33 x 0.3 mm
Theta range for data collection	2.67 to 27.53 deg.
Limiting indices	-10<=h<=10, -11<=k<=11, -18<=l<=18
Reflections collected / unique	11386 / 3913 [R(int) = 0.0427]
Completeness to theta = 27.53	97.4 %
Refinement method	Full-matrix least-squares on F^2
Data / restraints / parameters	3814 / 0 / 236
Goodness-of-fit on F^2	1.012
Final R indices [I>2sigma(I)]	R1 = 0.0556, wR2 = 0.1259
R indices (all data)	R1 = 0.1040, wR2 = 0.1447
Largest diff. peak and hole	0.262 and -0.337 e.A^-3

Table 2. Atomic coordinates (x 10^4) and equivalent isotropic displacement parameters (A^2 x 10^3) for **4o**.
U(eq) is defined as one third of the trace of the orthogonalized Uij tensor.

	x	y	z	U(eq)
Cl(1)	13059(1)	-971(1)	10399(1)	76(1)
O(1)	6530(2)	2409(2)	4762(1)	47(1)
C(4)	9785(3)	2000(3)	4438(2)	38(1)
O(2)	4611(2)	3684(2)	6026(1)	57(1)
O(3)	5450(2)	4321(2)	7868(1)	55(1)
C(1)	6179(3)	3219(3)	5619(2)	41(1)
C(3)	9508(3)	2839(3)	5335(2)	37(1)
C(10)	10648(3)	3289(3)	5788(2)	42(1)
N(1)	9656(2)	4129(2)	6600(1)	40(1)
C(18)	13351(3)	410(3)	8638(2)	49(1)
C(19)	12770(3)	1707(3)	7939(2)	47(1)
O(4)	6329(3)	6459(2)	7819(2)	78(1)
C(6)	8303(4)	1113(3)	3334(2)	51(1)
C(5)	8230(3)	1849(3)	4183(2)	41(1)
C(14)	11133(3)	3248(3)	8104(2)	40(1)
C(9)	11444(3)	1353(3)	3814(2)	48(1)
C(11)	7869(3)	4201(3)	6704(2)	40(1)
C(2)	7755(3)	3411(3)	5911(2)	36(1)
C(20)	10506(3)	4619(3)	7322(2)	46(1)
C(8)	11527(4)	595(3)	2975(2)	55(1)
C(12)	6488(3)	5132(3)	7506(2)	45(1)
C(15)	10137(3)	3467(4)	9000(2)	56(1)
C(7)	9959(4)	490(3)	2732(2)	55(1)
C(17)	12322(4)	670(3)	9513(2)	50(1)
C(16)	10717(4)	2185(4)	9710(2)	62(1)
C(13)	3991(4)	5222(4)	8624(2)	64(1)

Table 3. Bond lengths [A] and angles [deg] for **4o**.

Cl(1)-C(17)	1.743(3)
O(1)-C(1)	1.373(3)
O(1)-C(5)	1.383(2)
C(4)-C(9)	1.392(3)
C(4)-C(5)	1.395(3)
C(4)-C(3)	1.444(3)
O(2)-C(1)	1.202(2)
O(3)-C(12)	1.326(3)
O(3)-C(13)	1.442(3)
C(1)-C(2)	1.449(3)
C(3)-C(10)	1.372(3)
C(3)-C(2)	1.413(3)
C(10)-N(1)	1.353(3)
N(1)-C(11)	1.383(3)
N(1)-C(20)	1.474(3)
C(18)-C(17)	1.359(3)
C(18)-C(19)	1.376(3)
C(19)-C(14)	1.386(3)
O(4)-C(12)	1.196(3)
C(6)-C(7)	1.373(3)
C(6)-C(5)	1.378(3)
C(14)-C(15)	1.375(3)
C(14)-C(20)	1.498(3)
C(9)-C(8)	1.373(3)
C(11)-C(2)	1.383(3)
C(11)-C(12)	1.467(3)
C(8)-C(7)	1.378(4)
C(15)-C(16)	1.380(4)
C(17)-C(16)	1.368(4)
C(1)-O(1)-C(5)	123.86(17)
C(9)-C(4)-C(5)	117.9(2)
C(9)-C(4)-C(3)	125.9(2)
C(5)-C(4)-C(3)	116.13(19)
C(12)-O(3)-C(13)	115.34(18)
O(2)-C(1)-O(1)	116.17(19)
O(2)-C(1)-C(2)	128.5(2)
O(1)-C(1)-C(2)	115.36(18)
C(10)-C(3)-C(2)	107.12(19)
C(10)-C(3)-C(4)	132.7(2)

C(2)-C(3)-C(4)	120.18(18)
N(1)-C(10)-C(3)	108.50(18)
C(10)-N(1)-C(11)	109.90(18)
C(10)-N(1)-C(20)	123.21(17)
C(11)-N(1)-C(20)	126.21(19)
C(17)-C(18)-C(19)	119.2(2)
C(18)-C(19)-C(14)	121.2(2)
C(7)-C(6)-C(5)	119.1(2)
C(6)-C(5)-O(1)	115.7(2)
C(6)-C(5)-C(4)	121.6(2)
O(1)-C(5)-C(4)	122.7(2)
C(15)-C(14)-C(19)	118.0(2)
C(15)-C(14)-C(20)	121.9(2)
C(19)-C(14)-C(20)	120.1(2)
C(8)-C(9)-C(4)	120.4(2)
C(2)-C(11)-N(1)	106.63(18)
C(2)-C(11)-C(12)	132.96(19)
N(1)-C(11)-C(12)	120.20(19)
C(11)-C(2)-C(3)	107.83(18)
C(11)-C(2)-C(1)	130.3(2)
C(3)-C(2)-C(1)	121.8(2)
N(1)-C(20)-C(14)	111.67(16)
C(9)-C(8)-C(7)	120.5(2)
O(4)-C(12)-O(3)	123.1(2)
O(4)-C(12)-C(11)	124.3(2)
O(3)-C(12)-C(11)	112.65(19)
C(14)-C(15)-C(16)	121.4(2)
C(6)-C(7)-C(8)	120.5(2)
C(18)-C(17)-C(16)	121.5(2)
C(18)-C(17)-Cl(1)	119.2(2)
C(16)-C(17)-Cl(1)	119.3(2)
C(17)-C(16)-C(15)	118.8(2)

Symmetry transformations used to generate equivalent atoms:

Table 4. Anisotropic displacement parameters (A^2 x 10^3) for **4o**.
The anisotropic displacement factor exponent takes the form:
-2 pi^2 [h^2 a*^2 U11 + ... + 2 h k a* b* U12]

	U11	U22	U33	U23	U13	U12
Cl(1)	84(1)	90(1)	61(1)	13(1)	-19(1)	-44(1)
O(1)	34(1)	59(1)	53(1)	-3(1)	-6(1)	-24(1)
C(4)	32(1)	36(1)	44(1)	7(1)	-5(1)	-14(1)
O(2)	31(1)	80(1)	64(1)	-9(1)	0(1)	-28(1)
O(3)	56(1)	65(1)	55(1)	-14(1)	11(1)	-38(1)
C(1)	31(1)	43(1)	49(1)	5(1)	-7(1)	-17(1)
C(3)	28(1)	37(1)	46(1)	8(1)	-5(1)	-15(1)
C(10)	29(1)	46(1)	51(1)	1(1)	-2(1)	-18(1)
N(1)	30(1)	40(1)	53(1)	-1(1)	-7(1)	-18(1)
C(18)	41(1)	45(1)	54(2)	-11(1)	-5(1)	-13(1)
C(19)	39(1)	54(2)	46(1)	-12(1)	2(1)	-19(1)
O(4)	58(1)	57(1)	120(2)	-39(1)	29(1)	-31(1)
C(6)	52(2)	55(2)	51(2)	2(1)	-10(1)	-27(1)
C(5)	36(1)	41(1)	45(1)	5(1)	-3(1)	-17(1)
C(14)	32(1)	46(1)	50(1)	-13(1)	-2(1)	-22(1)
C(9)	39(1)	49(1)	56(2)	4(1)	-1(1)	-20(1)
C(11)	27(1)	36(1)	55(1)	3(1)	-3(1)	-13(1)
C(2)	28(1)	36(1)	46(1)	5(1)	-6(1)	-15(1)
C(20)	35(1)	45(1)	63(2)	-10(1)	-2(1)	-23(1)
C(8)	51(2)	52(2)	52(2)	-1(1)	5(1)	-18(1)
C(12)	32(1)	42(1)	60(2)	-4(1)	-6(1)	-15(1)
C(15)	39(1)	62(2)	59(2)	-18(1)	5(1)	-14(1)
C(7)	61(2)	54(2)	47(2)	-4(1)	-2(1)	-24(1)
C(17)	49(1)	62(2)	47(1)	-4(1)	-7(1)	-31(1)
C(16)	51(2)	83(2)	48(2)	-12(2)	9(1)	-26(2)
C(13)	57(2)	88(2)	54(2)	-19(2)	13(1)	-42(2)

Table 5. Hydrogen coordinates (x 10^4) and isotropic displacement parameters (A^2 x 10^3) for **4o**.

	x	y	z	U(eq)
H(10)	11919	3050	5569	50
H(18)	14457	-653	8511	58
H(19)	13504	1543	7332	56
H(6)	7224	1038	3167	61
H(9)	12527	1438	3969	58
H(20A)	9571	5745	7605	55
H(20B)	11605	4789	7007	55
H(8)	12672	139	2559	66
H(15)	9025	4524	9132	68
H(7)	10024	-17	2144	66
H(16)	10015	2351	10326	75
H(13A)	4536	5552	9113	95
H(13B)	3440	4448	8916	95
H(13C)	3006	6278	8358	95