

Synthesis and anti-vitiligo activity of novel furocoumarin derivatives and their molecular docking study

Chao Niu^{a,b,c}, Deng Zang^a, Haji Akber Aisa^{*a,b}

^a State Key Laboratory Basis of Xinjiang Indigenous Medicinal Plants Resource Utilization and Key Laboratory of Plant Resources and Chemistry of Arid Zone, Xinjiang Technical Institute of Physics and Chemistry, Chinese Academy of Sciences, Urumqi 830011, China; ^b University of Chinese Academy of Sciences, Beijing, 100049. ^c Nantong Chanyoo Pharmatech Co., Ltd., Nantong 226407, China.

Correspondence e-mail: aisa@ms.xjb.ac.cn

NMR and other chemical characterizations of **7a-7ad**

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl-4-fluorobenzenesulfonate (**7a**)

Yield 84%, m.p. 170-171 °C. ¹H NMR (400 MHz, CDCl₃) δ 7.97 – 7.92 (m, 2H), 7.87 (s, 1H), 7.85 (s, 1H), 7.56 (t, *J* = 7.5 Hz, 2H), 7.59 – 7.53 (m, 2H), 7.52 (s, 1H), 7.47 (t, *J* = 7.3 Hz, 1H), 7.23 – 7.16 (m, 2H), 6.42 (s, 1H), 5.35 (d, *J* = 1.1 Hz, 2H). ¹³C NMR (101 MHz, CDCl₃) δ 167.52, 164.95, 160.06, 157.34, 151.95, 146.78, 143.43, 131.52 (d, *J* = 3.3 Hz), 130.99 (d, *J* = 9.7 Hz), 130.71, 129.52, 128.43, 127.75, 124.51, 122.44, 117.18, 116.95, 115.02, 113.33, 100.90, 66.59. HRMS (ESI) calcd for C₂₄H₁₆FO₆S⁺ [M+H]⁺ 451.0646, found 451.0650.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl-4-methoxybenzenesulfonate (**7b**)

Yield 87%, m.p. 183-185 °C. ¹H NMR (400 MHz, CDCl₃) δ 7.90 (s, 1H), 7.87 – 7.82 (m, 3H), 7.65 – 7.61 (m, 2H), 7.56 (t, *J* = 7.6 Hz, 2H), 7.52 (s, 1H), 7.47 (t, *J* = 7.3 Hz, 1H), 6.96 (d, *J* = 9.0 Hz, 2H), 6.40 (s, 1H), 5.30 (d, *J* = 1.1 Hz, 2H), 3.87 (s, 3H). ¹³C NMR (101 MHz, CDCl₃) δ 160.16, 157.33, 151.96, 147.05, 145.90, 143.37, 132.48, 130.75, 130.23, 129.53, 128.42, 128.14, 127.76, 124.48, 115.16, 113.60, 113.44, 100.82, 66.44, 21.85. HRMS (ESI) calcd for

$C_{25}H_{19}O_7S^+$ $[M+H]^+$ 463.0846, found 463.0840.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl -[1,1'-biphenyl]-4-sulfonate (**7c**)

Yield 81%, m.p. 171-173 °C. 1H NMR (400 MHz, $CDCl_3$) δ 7.97 (d, J = 8.5 Hz, 2H), 7.91 (s, 1H), 7.85 (s, 1H), 7.69 (d, J = 8.4 Hz, 2H), 7.63 (d, J = 7.3 Hz, 2H), 7.59 – 7.53 (m, 4H), 7.52 – 7.43 (m, 5H), 6.46 (s, 1H), 5.37 (s, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 160.13, 157.33, 147.69, 146.93, 143.39, 138.88, 133.90, 130.75, 129.54, 129.30, 129.07, 128.62, 128.43, 128.17, 127.77, 127.53, 124.49, 122.49, 115.18, 113.82, 113.43, 100.86, 66.68. HRMS (ESI) calcd for $C_{30}H_{21}O_6S^+$ $[M+H]^+$ 509.1053, found 509.1061.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl -4-methylbenzenesulfonate (**7d**)

Yield 80%, m.p. 181-182 °C. 1H NMR (400 MHz, $CDCl_3$) δ 7.87 (s, 1H), 7.83 (s, 1H), 7.78 (d, J = 8.3 Hz, 2H), 7.63 – 7.59 (m, 2H), 7.54 (t, J = 7.6 Hz, 2H), 7.50 (s, 1H), 7.45 (t, J = 7.3 Hz, 1H), 7.29 (d, J = 8.1 Hz, 2H), 6.37 (s, 1H), 5.29 (d, J = 1.1 Hz, 2H), 2.42 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 160.16, 157.33, 151.96, 147.05, 145.90, 143.37, 132.48, 130.75, 130.23, 129.53, 128.42, 128.14, 127.76, 124.48, 115.16, 113.60, 113.44, 100.82, 66.44, 21.85. HRMS (ESI) calcd for $C_{25}H_{19}O_6S^+$ $[M+H]^+$ 447.0897, found 447.0904.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl-4-(trifluoromethoxy)benzenesulfonate (**7e**)

Yield 83%, m.p. 190-192 °C. 1H NMR (400 MHz, $CDCl_3$) δ 7.97 (d, J = 8.9 Hz, 2H), 7.88 (s, 1H), 7.86 (s, 1H), 7.65 – 7.60 (m, 2H), 7.59 – 7.52 (m, 3H), 7.47 (t, J = 7.3 Hz, 1H), 7.33 (d, J = 8.2 Hz, 2H), 6.45 (s, 1H), 5.37 (d, J = 1.0 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 160.03, 157.38, 153.59, 151.98, 146.63, 143.47, 133.70, 130.73, 130.38, 129.54, 128.46, 127.78, 124.56, 122.45, 121.23, 115.02, 113.84, 113.30, 100.96, 66.79. HRMS (ESI) calcd for $C_{25}H_{16}F_3O_7S^+$ $[M+H]^+$ 517.0563, found 517.0556.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl -4-bromobenzenesulfonate (**7f**)

Yield 82%, m.p. 182-183 °C. 1H NMR (400 MHz, $CDCl_3$) δ 7.84 (d, J = 4.4 Hz, 2H), 7.75 (d, J = 8.8 Hz, 2H), 7.66 – 7.58 (m, 4H), 7.57 – 7.51 (m, 3H), 7.47 (d, J = 7.0 Hz, 1H), 6.42 (s, 1H), 5.33 (d, J = 1.0 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 160.46, 157.32, 154.01, 146.67, 145.38, 143.46, 137.25, 134.50, 132.99, 129.54, 129.49, 128.47, 127.79, 124.33, 122.23, 115.05, 113.85, 100.96, 66.56. HRMS (ESI) calcd for $C_{24}H_{16}BrO_6S^+$ $[M+H]^+$ 510.9845, found 510.9837.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl 4-chlorobenzenesulfonate (**7g**)

Yield 88%, m.p. 204-206 °C. ¹H NMR (400 MHz, CDCl₃) δ 7.88 – 7.83 (m, 4H), 7.64 – 7.60 (m, 2H), 7.59 – 7.52 (m, 3H), 7.49 (d, *J* = 8.7 Hz, 3H), 6.44 (s, 1H), 5.35 (s, 2H). ¹³C NMR (101 MHz, CDCl₃) δ 160.06, 157.37, 151.98, 146.69, 143.45, 141.51, 133.96, 130.73, 130.00, 129.54, 129.48, 128.46, 127.78, 124.55, 122.46, 115.04, 113.81, 113.32, 100.94, 66.76. HRMS (ESI) calcd for C₂₄H₁₆ClO₆S⁺ [M+H]⁺ 467.0351, found 467.0360.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl benzenesulfonate (**7h**)

Yield 81%, m.p. 155-156 °C. ¹H NMR (400 MHz, CDCl₃) δ 7.93 (d, *J* = 7.3 Hz, 2H), 7.89 (s, 1H), 7.85 (s, 1H), 7.69 – 7.60 (m, 3H), 7.59 – 7.50 (m, 5H), 7.47 (t, *J* = 7.3 Hz, 1H), 6.40 (s, 1H), 5.34 (d, *J* = 1.0 Hz, 2H). ¹³C NMR (101 MHz, CDCl₃) δ 160.13, 157.34, 151.97, 146.91, 143.39, 135.55, 134.64, 130.74, 129.64, 129.53, 128.42, 128.07, 127.76, 124.50, 122.49, 115.10, 113.65, 113.40, 100.88, 66.58. HRMS (ESI) calcd for C₂₄H₁₇O₆S⁺ [M+H]⁺ 433.0740, found 433.0733.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl-4-(trifluoromethyl)benzenesulfonate (**7i**)

Yield 80%, 213-215 °C. ¹H NMR (400 MHz, CDCl₃) δ 8.05 (d, *J* = 8.2 Hz, 2H), 7.86 (d, *J* = 4.4 Hz, 2H), 7.79 (s, 1H), 7.77 (s, 1H), 7.65 – 7.60 (m, 2H), 7.56 (t, *J* = 7.5 Hz, 2H), 7.53 (s, 1H), 7.48 (t, *J* = 7.3 Hz, 1H), 6.45 (s, 1H), 5.39 (s, 2H). ¹³C NMR (101 MHz, CDCl₃) δ 159.98, 157.39, 151.97, 146.43, 143.50, 139.17, 130.72, 129.54, 128.65, 128.48, 127.78, 126.78 (q, *J* = 3.7 Hz), 124.57, 122.44, 114.98, 113.95, 113.24, 100.99, 67.08. HRMS (ESI) calcd for C₂₅H₁₆F₃O₆S⁺ [M+H]⁺ 501.0614, found 501.0622.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl-3-chlorobenzenesulfonate (**7j**)

Yield 90%, m.p. 145-147 °C. ¹H NMR (400 MHz, CDCl₃) δ 7.91 – 7.87 (m, 2H), 7.86 (s, 1H), 7.81 (ddd, *J* = 7.9, 1.6, 1.0 Hz, 1H), 7.65 – 7.60 (m, 3H), 7.59 – 7.52 (m, 3H), 7.53 (s, 1H), 7.47 (t, *J* = 7.9 Hz, 2H), 6.44 (s, 1H), 5.37 (d, *J* = 1.0 Hz, 2H). ¹³C NMR (101 MHz, CDCl₃) δ 160.04, 157.39, 151.98, 146.58, 143.45, 137.26, 135.93, 134.77, 130.90, 130.71, 129.54, 128.45, 128.15, 127.77, 126.10, 124.57, 122.49, 115.07, 113.89, 113.28, 100.94, 67.04. HRMS (ESI) calcd for C₂₄H₁₆ClO₆S⁺ [M+H]⁺ 467.0351, found 467.0355.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl -3-bromobenzenesulfonate (**7k**)

Yield 79%, 181-182 °C. ¹H NMR (400 MHz, CDCl₃) δ 8.04 (t, *J* = 1.8 Hz, 1H), 7.89 (s, 1H), 7.85 (s, 1H), 7.85 – 7.83 (m, 1H), 7.77 (ddd, *J* = 8.0, 1.7, 0.9 Hz, 1H), 7.65 – 7.60 (m, 2H), 7.59 – 7.51 (m, 3H), 7.47 (t, *J* = 7.3 Hz, 1H), 7.40 (t, *J* = 8.0 Hz, 1H), 6.43 (s, 1H), 5.36 (d, *J* =

1.0 Hz, 2H), 3.49 (s, 1H). ^{13}C NMR (101 MHz, CDCl_3) δ 160.02, 157.38, 151.98, 146.54, 143.44, 137.66, 137.40, 131.05, 130.95, 130.71, 129.54, 128.45, 127.76, 126.53, 124.57, 123.53, 122.49, 115.09, 113.95, 113.27, 100.94, 67.10. HRMS (ESI) calcd for $\text{C}_{24}\text{H}_{16}\text{BrO}_6\text{S}^+$ $[\text{M}+\text{H}]^+$ 510.9845, found 510.9837.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl -2-chlorobenzenesulfonate (**7l**)

Yield 86%, m.p. 185-187 °C. ^1H NMR (400 MHz, CDCl_3) δ 8.11 (dd, $J = 7.9, 1.6$ Hz, 1H), 7.92 (s, 1H), 7.85 (s, 1H), 7.65 – 7.60 (m, 2H), 7.59 – 7.52 (m, 3H), 7.51 (s, 1H), 7.49 – 7.41 (m, 3H), 6.50 (s, 1H), 5.44 (d, $J = 1.1$ Hz, 2H). ^{13}C NMR (101 MHz, CDCl_3) δ 160.12, 157.36, 151.96, 146.55, 143.39, 135.44, 133.26, 132.32, 131.90, 130.73, 129.52, 128.40, 127.78, 127.38, 124.50, 122.53, 115.27, 114.03, 113.36, 100.82, 67.35. HRMS (ESI) calcd for $\text{C}_{24}\text{H}_{16}\text{ClO}_6\text{S}^+$ $[\text{M}+\text{H}]^+$ 467.0351, found 467.0344.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl -2-fluorobenzenesulfonate (**7m**)

Yield 84%, m.p. 159-160 °C. ^1H NMR (400 MHz, CDCl_3) δ 7.97 – 7.91 (m, 2H), 7.85 (s, 1H), 7.66 – 7.60 (m, 3H), 7.56 (t, $J = 7.6$ Hz, 2H), 7.52 (s, 1H), 7.46 (t, $J = 7.4$ Hz, 1H), 7.31 (td, $J = 7.9, 0.8$ Hz, 1H), 7.15 (t, $J = 9.2$ Hz, 1H), 6.48 (s, 1H), 5.48 (d, $J = 0.8$ Hz, 2H). ^{13}C NMR (101 MHz, CDCl_3) δ 160.11, 157.37, 151.97, 146.69, 143.40, 137.01 (d, $J = 8.5$ Hz), 130.91, 130.72, 129.53, 128.40, 127.78, 124.86 (d, $J = 4.0$ Hz), 124.52, 122.55, 117.69, 117.49, 115.19, 113.89, 100.85, 67.51. HRMS (ESI) calcd for $\text{C}_{24}\text{H}_{16}\text{FO}_6\text{S}^+$ $[\text{M}+\text{H}]^+$ 451.0646, found 451.0652.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl -3-fluorobenzenesulfonate (**7n**)

Yield 82%, m.p. 157-159 °C. ^1H NMR (400 MHz, CDCl_3) δ 7.88 (s, 1H), 7.85 (s, 1H), 7.74 (d, $J = 7.9$ Hz, 1H), 7.66 – 7.59 (m, 3H), 7.59 – 7.50 (m, 4H), 7.47 (t, $J = 7.3$ Hz, 1H), 7.37 (td, $J = 8.0, 0.8$ Hz, 1H), 6.43 (s, 1H), 5.36 (d, $J = 1.0$ Hz, 2H). ^{13}C NMR (101 MHz, CDCl_3) δ 163.76, 161.24, 160.04, 157.37, 151.97, 146.63, 143.44, 137.41 (d, $J = 7.2$ Hz), 131.59 (d, $J = 7.8$ Hz), 130.70, 129.52, 128.44, 127.76, 124.55, 123.87 (d, $J = 3.5$ Hz), 122.48, 121.99 (d, $J = 21.1$ Hz), 115.67, 115.22 (d, $J = 41.9$ Hz), 113.51 (d, $J = 43.9$ Hz), 100.94, 66.91. HRMS (ESI) calcd for $\text{C}_{24}\text{H}_{16}\text{FO}_6\text{S}^+$ $[\text{M}+\text{H}]^+$ 451.0646, found 451.0641.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl -2-bromobenzenesulfonate (**7o**)

Yield 87%, m.p. 188-190 °C. ^1H NMR (400 MHz, CDCl_3) δ 8.14 (dd, $J = 7.2, 2.4$ Hz, 1H), 7.93 (s, 1H), 7.85 (s, 1H), 7.70 (dd, $J = 7.5, 1.7$ Hz, 1H), 7.65 – 7.61 (m, 2H), 7.55 (t, $J = 7.5$ Hz, 2H), 7.51 (s, 1H), 7.50 – 7.43 (m, 3H), 6.51 (s, 1H), 5.43 (d, $J = 1.0$ Hz, 2H). ^{13}C NMR (101 MHz, CDCl_3) δ 160.13, 157.36, 151.97, 146.51, 143.39, 135.89, 135.69, 135.35, 132.20, 130.75,

129.52, 128.40, 127.94, 127.80, 124.51, 122.53, 121.18, 115.32, 114.12, 113.38, 100.83, 67.29.
HRMS (ESI) calcd for $C_{24}H_{16}BrO_6S^+$ $[M+H]^+$ 510.9845, found 510.9840.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl- 3-methylbenzenesulfonate (**7p**)

Yield 82%, m.p. 176-177 °C. 1H NMR (400 MHz, $CDCl_3$) δ 7.90 (s, 1H), 7.85 (s, 1H), 7.73 – 7.70 (m, 2H), 7.65 – 7.61 (m, 2H), 7.56 (t, J = 7.5 Hz, 2H), 7.51 (s, 1H), 7.49 – 7.42 (m, 2H), 7.39 (t, J = 7.9 Hz, 1H), 6.41 (s, 1H), 5.33 (d, J = 1.1 Hz, 2H), 2.38 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 160.14, 157.33, 151.97, 146.95, 143.38, 140.09, 135.42, 130.74, 129.53, 129.42, 128.42, 128.38, 127.74, 125.21, 124.46, 122.49, 115.18, 113.72, 113.43, 100.83, 87.60, 66.57, 21.40. HRMS (ESI) calcd for $C_{25}H_{19}O_6S^+$ $[M+H]^+$ 447.0897, found 447.0886.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl-4-isopropylbenzenesulfonate (**7q**)

Yield 76%, m.p. 185-187 °C. 1H NMR (400 MHz, $CDCl_3$) δ 7.91 (s, 1H), 7.85 (s, 1H), 7.82 (d, J = 8.5 Hz, 2H), 7.65 – 7.61 (m, 2H), 7.56 (t, J = 7.6 Hz, 2H), 7.51 (s, 1H), 7.47 (t, J = 7.3 Hz, 1H), 7.35 (d, J = 8.3 Hz, 2H), 6.40 (s, 1H), 5.33 (d, J = 1.1 Hz, 2H), 3.49 (s, 1H), 1.26 (d, J = 6.9 Hz, 6H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 160.15, 157.32, 156.49, 151.97, 147.03, 143.37, 132.76, 130.76, 129.54, 128.43, 128.28, 127.77, 127.72, 124.47, 122.51, 115.20, 113.67, 113.46, 100.83, 66.47, 34.47, 23.66. HRMS (ESI) calcd for $C_{27}H_{23}O_6S^+$ $[M+H]^+$ 475.1210, found 475.1200.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl-4-(tert-butyl)benzenesulfonate (**7r**)

Yield 81%, m.p. 216-218 °C. 1H NMR (400 MHz, $CDCl_3$) δ 7.91 (s, 1H), 7.85 (s, 1H), 7.82 (d, J = 8.7 Hz, 2H), 7.65 – 7.61 (m, 2H), 7.57 (t, J = 7.6 Hz, 2H), 7.53 – 7.45 (m, 4H), 6.40 (s, 1H), 5.34 (d, J = 1.0 Hz, 2H), 1.32 (s, 9H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 160.14, 158.78, 157.32, 151.96, 143.36, 132.44, 130.76, 124.47, 122.51, 129.55, 128.43, 127.99, 127.76, 126.62, 115.22, 113.70, 113.47, 110.18, 100.82, 66.50, 35.52, 31.10. HRMS (ESI) calcd for $C_{28}H_{25}O_6S^+$ $[M+H]^+$ 489.1366, found 489.1359.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl naphthalene-2-sulfonate (**7s**)

Yield 80%, m.p. 191-193 °C. 1H NMR (400 MHz, $CDCl_3$) δ 8.50 (d, J = 1.2 Hz, 1H), 7.96 – 7.88 (m, 4H), 7.87 – 7.82 (m, 2H), 7.70 (td, J = 7.9, 0.8 Hz, 2H), 7.66 – 7.60 (m, 3H), 7.55 (t, J = 7.5 Hz, 2H), 7.47 (t, J = 7.3 Hz, 1H), 7.43 (s, 1H), 6.44 (s, 1H), 5.36 (d, J = 1.0 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 160.09, 157.27, 151.59, 146.89, 143.34, 135.61, 132.21, 131.95,

130.75, 130.22, 130.06, 129.95, 129.53, 129.47, 128.42, 128.19, 128.19, 127.74, 124.41, 122.46, 122.34, 115.16, 113.82, 113.39, 100.75, 66.81. HRMS (ESI) calcd for $C_{28}H_{19}O_6S^+$ $[M+H]^+$ 483.0897, found 483.0901.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl-2-(trifluoromethyl)benzenesulfonate (**7t**)

Yield 88%, m.p. 153-154 °C. 1H NMR (400 MHz, $CDCl_3$) δ 8.29 (d, J = 7.5 Hz, 1H), 7.93 – 7.89 (m, 2H), 7.85 (s, 1H), 7.83 – 7.72 (m, 2H), 7.65 – 7.60 (m, 2H), 7.58 – 7.51 (m, 3H), 7.46 (t, J = 7.3 Hz, 1H), 6.47 (s, 1H), 5.45 (d, J = 1.0 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 160.13, 157.37, 151.97, 150.35, 146.57, 143.39, 134.65, 132.71, 132.28, 130.71, 129.50, 128.97 (q, J = 6.2 Hz), 128.40, 127.77, 124.54, 122.54, 120.94, 115.13, 113.89, 113.31, 100.89, 67.02. HRMS (ESI) calcd for $C_{25}H_{16}F_3O_6S^+$ $[M+H]^+$ 501.0614, found 501.0607.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl-3-(trifluoromethyl)benzenesulfonate (**7u**)

Yield 92%, m.p. 180-182 °C. 1H NMR (400 MHz, $CDCl_3$) δ 8.17 (s, 1H), 8.11 (d, J = 8.0 Hz, 1H), 7.93 – 7.84 (m, 3H), 7.69 (t, J = 7.9 Hz, 1H), 7.64 – 7.59 (m, 2H), 7.55 (t, J = 7.5 Hz, 2H), 7.51 (s, 1H), 7.47 (t, J = 7.3 Hz, 1H), 6.43 (s, 1H), 5.40 (d, J = 1.0 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 159.94, 157.39, 151.95, 146.42, 143.48, 136.97, 132.57, 132.23, 131.25 (dd, J = 6.8, 3.2 Hz), 130.68, 130.52, 129.52, 128.46, 127.74, 125.16 (q, J = 3.8 Hz), 124.59, 122.46, 115.01, 113.97, 113.19, 100.94, 67.17. HRMS (ESI) calcd for $C_{25}H_{16}F_3O_6S^+$ $[M+H]^+$ 501.0614, found 501.0620.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl -2-methylbenzenesulfonate (**7v**)

Yield 90%, m.p. 173-175 °C. 1H NMR (400 MHz, $CDCl_3$) δ 8.00 (d, J = 8.0 Hz, 1H), 7.89 (s, 1H), 7.85 (s, 1H), 7.65 – 7.59 (m, 2H), 7.58 – 7.44 (m, 6H), 7.34 (t, J = 8.0 Hz, 1H), 6.41 (s, 1H), 5.31 (s, 2H), 2.58 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 160.13, 157.34, 151.98, 146.88, 143.39, 138.71, 134.54, 134.07, 132.90, 130.,23, 130.06, 129.52, 128.41, 128.13, 127.74, 126.54, 124.47, 122.49, 115.19, 113.85, 100.84, 66.52, 20.49. HRMS (ESI) calcd for $C_{25}H_{19}O_6S^+$ $[M+H]^+$ 447.0897, found 447.0910.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl-3,5-difluorobenzenesulfonate (**7w**)

Yield 86%, m.p. 172-174 °C. 1H NMR (400 MHz, $CDCl_3$) δ 7.86 (d, J = 3.0 Hz, 2H), 7.64 – 7.60 (m, 2H), 7.56 (t, J = 7.5 Hz, 3H), 7.50 – 7.46 (m, 3H), 7.16 – 7.09 (m, 1H), 6.46 (s, 1H),

5.39 (d, $J = 0.7$ Hz, 2H). ^{13}C NMR (101 MHz, CDCl_3) δ 163.95, 159.99, 157.44, 152.02, 146.37, 143.51, 130.68, 129.55, 128.49, 127.78, 124.64, 122.50, 114.93, 113.84, 113.22, 111.89 (d, $J = 6.5$ Hz), 111.74 (d, $J = 6.5$ Hz), 110.44 (t, $J = 24.8$ Hz), 101.04, 67.25. HRMS (ESI) calcd for $\text{C}_{24}\text{H}_{15}\text{F}_2\text{O}_6\text{S}^+ [\text{M}+\text{H}]^+$ 469.0552, found 469.0539.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl-3,5-dichlorobenzenesulfonate
(7x)

Yield 83%, m.p. 161-163 °C. ^1H NMR (400 MHz, CDCl_3) δ 7.88 (s, 1H), 7.86 (s, 1H), 7.78 (d, $J = 1.8$ Hz, 2H), 7.65 – 7.60 (m, 3H), 7.59 – 7.53 (m, 3H), 7.47 (t, $J = 7.3$ Hz, 1H), 6.47 (s, 1H), 5.39 (d, $J = 0.9$ Hz, 2H). ^{13}C NMR (101 MHz, CDCl_3) δ 159.92, 157.42, 152.01, 146.26, 143.50, 138.39, 136.72, 134.61, 130.67, 129.55, 128.48, 127.76, 126.36, 124.63, 122.50, 115.03, 114.11, 113.19, 101.00, 67.47. HRMS (ESI) calcd for $\text{C}_{24}\text{H}_{15}\text{Cl}_2\text{O}_6\text{S}^+ [\text{M}+\text{H}]^+$ 500.9961, found 500.9954.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl-2,4-difluorobenzenesulfonate
(7y)

Yield 82%, m.p. 202-203 °C. ^1H NMR (400 MHz, CDCl_3) δ 7.99 – 7.92 (m, 1H), 7.91 (s, 1H), 7.86 (s, 1H), 7.65 – 7.61 (m, 2H), 7.58 – 7.52 (m, 3H), 7.46 (t, $J = 7.3$ Hz, 1H), 7.06 – 7.00 (m, 1H), 6.93 – 6.86 (m, 1H), 6.50 (s, 1H), 5.48 (d, $J = 1.0$ Hz, 2H). ^{13}C NMR (101 MHz, CDCl_3) δ 160.05, 157.39, 151.97, 146.56, 143.45, 132.78 (d, $J = 10.9$ Hz), 130.70, 129.52, 128.42, 127.78, 124.55, 122.51, 115.10, 113.93, 113.27, 112.65 (d, $J = 3.7$ Hz), 112.42 (d, $J = 3.8$ Hz), 106.40 (d, $J = 24.3$ Hz), 106.14 (d, $J = 24.4$ Hz), 100.90, 67.52. HRMS (ESI) calcd for $\text{C}_{24}\text{H}_{15}\text{F}_2\text{O}_6\text{S}^+ [\text{M}+\text{H}]^+$ 469.0552, found 469.0561.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl-2,6-dichlorobenzenesulfonate
(7z)

Yield 77%, m.p. 190-191 °C. ^1H NMR (400 MHz, CDCl_3) δ 7.95 (s, 1H), 7.85 (s, 1H), 7.65 – 7.61 (m, 2H), 7.55 (t, $J = 7.5$ Hz, 2H), 7.50 (s, 1H), 7.46 (t, $J = 7.3$ Hz, 1H), 7.42 – 7.38 (m, 2H), 7.37 – 7.32 (m, 1H), 6.53 (s, 1H), 5.47 (d, $J = 1.0$ Hz, 2H). ^{13}C NMR (101 MHz, CDCl_3) δ 160.01, 157.35, 151.97, 146.18, 143.40, 136.16, 134.08, 132.33, 131.64, 130.69, 129.53, 128.42, 127.76, 124.49, 122.54, 115.46, 114.54, 113.30, 100.78, 67.81. HRMS (ESI) calcd for $\text{C}_{24}\text{H}_{15}\text{Cl}_2\text{O}_6\text{S}^+ [\text{M}+\text{H}]^+$ 500.9961, found 500.9973.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl-2,4-dichlorobenzenesulfonate
(7aa)

Yield 85%, m.p. 210-212 °C. ¹H NMR (400 MHz, CDCl₃) δ 8.01 (d, *J* = 8.5 Hz, 1H), 7.90 (s, 1H), 7.86 (s, 1H), 7.64 – 7.60 (m, 2H), 7.58 – 7.52 (m, 3H), 7.49 – 7.44 (m, 2H), 7.40 (dd, *J* = 8.5, 2.0 Hz, 1H), 6.52 (s, 1H), 5.44 (d, *J* = 1.0 Hz, 2H). ¹³C NMR (101 MHz, CDCl₃) δ 160.03, 157.39, 151.95, 146.37, 143.46, 141.68, 134.27, 132.71, 132.47, 132.16, 130.72, 129.52, 128.43, 127.79, 127.75, 124.54, 122.51, 115.19, 114.20, 113.28, 100.88, 67.55. HRMS (ESI) calcd for C₂₄H₁₅Cl₂O₆S⁺ [M+H]⁺ 500.9961, found 500.9949.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl-2,5-difluorobenzenesulfonate
(**7ab**)

Yield 81%, m.p. 150-152 °C. ¹H NMR (400 MHz, CDCl₃) δ 8.06 (s, 1H), 7.86 (s, 1H), 7.76 – 7.67 (m, 3H), 7.65 – 7.61 (m, 2H), 7.57 – 7.51 (m, 3H), 7.45 (t, *J* = 7.4 Hz, 1H), 6.57 (s, 1H), 4.75 (d, *J* = 0.7 Hz, 2H). ¹³C NMR (101 MHz, CDCl₃) δ 160.32 (d, *J* = 2.5 Hz), 157.67 (d, *J* = 2.0 Hz), 152.21, 149.94, 143.34, 137.71 (t, *J* = 11.1 Hz), 130.93, 129.47, 128.33, 127.71, 124.39, 122.50, 115.72, 114.58, 114.06, 113.89 (d, *J* = 3.3 Hz), 113.80 (d, *J* = 26.0 Hz), 113.71 (d, *J* = 3.2 Hz), 100.85, 41.89. HRMS (ESI) calcd for C₂₄H₁₅F₂O₆S⁺ [M+H]⁺ 469.0552, found 469.0564.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl-3-fluoro-4-methylbenzenesulfonate (**7ac**)

Yield 80%, m.p. 198-200 °C. ¹H NMR (400 MHz, CDCl₃) δ 7.88 (s, 1H), 7.86 (s, 1H), 7.65 – 7.59 (m, 3H), 7.59 – 7.51 (m, 4H), 7.47 (t, *J* = 7.3 Hz, 1H), 7.36 (t, *J* = 7.5 Hz, 1H), 6.42 (s, 1H), 5.34 (d, *J* = 0.8 Hz, 2H), 2.36 (d, *J* = 1.7 Hz, 3H). ¹³C NMR (151 MHz, CDCl₃) δ 161.77, 160.69, 157.37, 151.98, 146.79, 143.43, 134.37 (d, *J* = 6.8 Hz), 133.18 (d, *J* = 17.4 Hz), 132.75 (d, *J* = 4.7 Hz), 130.72, 129.54, 128.45, 127.77, 124.54, 123.68 (d, *J* = 3.8 Hz), 122.50, 115.08 (t, *J* = 13.0 Hz), 113.67, 113.35, 100.89, 66.75, 15.09. HRMS (ESI) calcd for C₂₅H₁₈FO₆S⁺ [M+H]⁺ 465.0803, found 465.0789.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl-2,5-dimethylbenzenesulfonate
(**7ad**)

Yield 82%, m.p. 167-168 °C. ¹H NMR (400 MHz, CDCl₃) δ 7.91 (s, 1H), 7.85 (s, 1H), 7.80 (s, 1H), 7.64 – 7.60 (m, 2H), 7.55 (t, *J* = 7.5 Hz, 2H), 7.51 (s, 1H), 7.47 (t, *J* = 7.4 Hz, 1H), 7.30 (d, *J* = 7.8 Hz, 1H), 7.14 (d, *J* = 7.7 Hz, 1H), 6.42 (s, 1H), 5.30 (d, *J* = 0.8 Hz, 2H), 2.51 (s, 3H), 2.37 (s, 3H). ¹³C NMR (101 MHz, CDCl₃) δ 160.14, 157.35, 151.99, 146.91, 143.38, 136.67, 135.48, 135.24, 133.72, 132.78, 130.73, 130.38, 129.53, 128.42, 127.75, 124.46, 122.50,

115.24, 113.94, 113.51, 100.82, 66.50, 20.90, 20.00. HRMS (ESI) calcd for $C_{26}H_{21}O_6S^+$ $[M+H]^+$ 461.1053, found 461.1043.

NMR and other chemical characterizations of **8a-8ag**

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl- 4-fluorobenzoate (**8a**)

Yield 92%, m.p. 173-175 °C. 1H NMR (600 MHz, $CDCl_3$) δ 8.18 – 8.13 (m, 2H), 7.96 (s, 1H), 7.85 (s, 1H), 7.62 – 7.57 (m, 3H), 7.51 (t, J = 7.6 Hz, 2H), 7.44 (t, J = 7.4 Hz, 1H), 7.21 – 7.13 (m, 2H), 6.59 (s, 1H), 5.63 (d, J = 1.0 Hz, 2H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 167.25, 164.87, 160.72, 157.32, 152.04, 149.55, 143.34, 132.63 (d, J = 9.4 Hz), 130.84, 129.46, 128.36, 127.72, 125.33 (d, J = 2.9 Hz), 124.49, 122.48, 116.12 (d, J = 22.1 Hz), 114.87, 111.82, 100.91, 62.13. HRMS (ESI) calcd for $C_{25}H_{16}FO_5^+$ $[M+H]^+$ 415.0976, found 415.0950.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl- 4-methoxybenzoate (**8b**)

Yield 78%, m.p. 186-187 °C. 1H NMR (400 MHz, $CDCl_3$) δ 8.09 (d, J = 8.6 Hz, 2H), 7.98 (s, 1H), 7.85 (s, 1H), 7.62 – 7.56 (m, 3H), 7.50 (t, J = 7.5 Hz, 2H), 7.43 (t, J = 7.2 Hz, 1H), 6.97 (d, J = 8.6 Hz, 2H), 6.61 (s, 1H), 5.61 (s, 2H), 3.89 (s, 3H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 165.56, 164.21, 160.84, 157.30, 152.05, 149.99, 143.27, 132.99, 132.13, 130.87, 129.47, 128.34, 127.73, 124.44, 122.51, 121.40, 114.97, 114.13, 111.76, 100.85, 61.78, 55.70. HRMS (ESI) calcd for $C_{26}H_{19}O_6^+$ $[M+H]^+$ 427.1176, found 427.1190.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl-[1,1'-biphenyl]-4-carboxylate (**8c**)

Yield 80%, m.p. 187-189 °C. 1H NMR (600 MHz, $CDCl_3$) δ 8.20 (d, J = 7.8 Hz, 2H), 8.00 (s, 1H), 7.86 (s, 1H), 7.72 (d, J = 7.8 Hz, 2H), 7.66 – 7.58 (m, 5H), 7.50 (dd, J = 16.3, 8.1 Hz, 4H), 7.43 (dd, J = 16.8, 8.0 Hz, 2H), 6.64 (s, 1H), 5.66 (s, 2H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 165.75, 160.79, 157.32, 152.07, 149.73, 146.77, 143.30, 139.88, 131.30, 130.86, 130.54, 129.47, 129.16, 128.55, 128.36, 127.74, 127.51, 127.48, 124.48, 122.52, 114.97, 114.00, 111.90, 100.89, 62.09. HRMS (ESI) calcd for $C_{31}H_{21}O_5^+$ $[M+H]^+$ 473.1384, found 473.1366.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl -4-methylbenzoate (**8d**)

Yield 85%, m.p. 154-155 °C. 1H NMR (600 MHz, $CDCl_3$) δ 8.02 (d, J = 8.2 Hz, 2H), 7.97 (s, 1H), 7.85 (s, 1H), 7.61 – 7.56 (m, 3H), 7.50 (t, J = 7.6 Hz, 2H), 7.43 (t, J = 7.4 Hz, 1H), 7.29 (d, J = 8.0 Hz, 2H), 6.61 (s, 1H), 5.62 (d, J = 1.2 Hz, 2H), 2.45 (s, 3H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 165.90, 160.81, 157.29, 152.04, 149.84, 144.87, 143.27, 130.86, 130.03, 129.56, 129.46,

128.33, 127.72, 126.34, 124.43, 122.50, 114.96, 114.00, 111.81, 100.85, 61.89, 21.91. HRMS (ESI) calcd for $C_{26}H_{19}O_5^+$ $[M+H]^+$ 411.1227, found 411.1242.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl-4-(trifluoromethoxy)benzoate (8e)

Yield 82%, m.p. 150-152 °C. 1H NMR (600 MHz, $CDCl_3$) δ 8.18 (d, J = 8.8 Hz, 2H), 7.96 (s, 1H), 7.86 (s, 1H), 7.62 – 7.57 (m, 3H), 7.51 (t, J = 7.5 Hz, 2H), 7.44 (t, J = 7.4 Hz, 1H), 7.33 (d, J = 8.4 Hz, 2H), 6.58 (s, 1H), 5.65 (d, J = 0.9 Hz, 2H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 164.68, 160.68, 157.35, 153.41, 152.06, 149.39, 143.37, 132.38, 132.06, 130.84, 129.47, 128.38, 127.74, 127.40, 124.52, 122.49, 120.68, 114.85, 113.87, 111.90, 100.95, 62.30. HRMS (ESI) calcd for $C_{26}H_{16}F_3O_6^+$ $[M+H]^+$ 481.0893, found 481.0907.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl -4-bromobenzoate (8f)

Yield 83%, m.p. 174-176 °C. 1H NMR (400 MHz, $CDCl_3$) δ 7.99 (d, J = 8.2 Hz, 2H), 7.95 (s, 1H), 7.85 (s, 1H), 7.64 (d, J = 8.3 Hz, 2H), 7.61 – 7.57 (m, 3H), 7.51 (t, J = 7.5 Hz, 2H), 7.44 (t, J = 7.7 Hz, 1H), 6.58 (s, 1H), 5.63 (s, 2H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 165.17, 160.67, 157.33, 152.05, 149.39, 143.35, 132.26, 131.45, 130.83, 129.47, 129.29, 128.38, 127.96, 127.73, 124.50, 122.48, 114.86, 113.88, 111.90, 100.93, 62.26. HRMS (ESI) calcd for $C_{25}H_{16}BrO_5^+$ $[M+H]^+$ 475.0176, found 475.0193.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl -4-chlorobenzoate (8g)

Yield 88%, m.p. 210-211 °C. 1H NMR (600 MHz, $CDCl_3$) δ 8.07 (d, J = 8.6 Hz, 2H), 7.96 (s, 1H), 7.86 (s, 1H), 7.61 – 7.57 (m, 3H), 7.51 (t, J = 7.5 Hz, 2H), 7.48 (d, J = 8.6 Hz, 2H), 7.44 (t, J = 7.4 Hz, 1H), 6.58 (s, 1H), 5.63 (d, J = 1.2 Hz, 2H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 165.02, 160.69, 157.33, 152.04, 149.43, 143.35, 140.59, 131.36, 130.83, 129.47, 129.26, 128.38, 127.73, 127.51, 124.50, 122.48, 114.86, 113.88, 111.88, 100.93, 62.23. HRMS (ESI) calcd for $C_{25}H_{16}ClO_5^+$ $[M+H]^+$ 431.0681, found 431.0695.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl benzoate (8h)

Yield 79%, m.p. 146-147 °C. 1H NMR (400 MHz, $CDCl_3$) δ 8.14 (d, J = 7.1 Hz, 2H), 7.98 (s, 1H), 7.85 (s, 1H), 7.64 (t, J = 7.4 Hz, 1H), 7.62 – 7.56 (m, 3H), 7.50 (td, J = 7.7, 3.3 Hz, 4H), 7.43 (t, J = 7.3 Hz, 1H), 6.62 (s, 1H), 5.64 (d, J = 1.3 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 165.83, 160.78, 157.27, 152.00, 149.68, 143.28, 133.98, 130.82, 129.98, 129.45, 129.05, 128.85, 128.33, 127.70, 124.44, 122.47, 114.92, 113.93, 111.80, 100.87, 77.48, 77.16, 76.84, 62.05. HRMS (ESI) calcd for $C_{25}H_{17}O_5^+$ $[M+H]^+$ 397.1071, found 397.1059.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl-4-(trifluoromethyl)benzoate (**8i**)

Yield 81%, m.p. 175-176 °C. ¹H NMR (400 MHz, CDCl₃) δ 8.25 (d, *J* = 8.1 Hz, 2H), 7.96 (s, 1H), 7.86 (s, 1H), 7.77 (d, *J* = 8.2 Hz, 2H), 7.63 – 7.57 (m, 3H), 7.51 (t, *J* = 7.6 Hz, 2H), 7.44 (t, *J* = 6.9 Hz, 1H), 6.59 (s, 1H), 5.67 (s, 2H). ¹³C NMR (151 MHz, CDCl₃) δ 164.69, 160.60, 157.36, 152.06, 149.15, 143.39, 135.45 (q, *J* = 33.1 Hz), 132.29, 130.82, 130.42, 129.47, 128.40, 127.73, 125.92 (q, *J* = 3.7 Hz), 124.54, 122.48, 114.82, 113.83, 111.98, 100.98, 62.52. HRMS (ESI) calcd for C₂₆H₁₆F₃O₅⁺ [M+H]⁺ 465.0944, found 465.0923.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl -3-chlorobenzoate (**8j**)

Yield 76%, m.p. 84-86 °C. ¹H NMR (600 MHz, CDCl₃) δ 8.10 (s, 1H), 8.02 (d, *J* = 7.6 Hz, 1H), 7.96 (s, 1H), 7.85 (s, 1H), 7.63 – 7.56 (m, 4H), 7.51 (t, *J* = 7.2 Hz, 2H), 7.45 (t, *J* = 6.7 Hz, 2H), 6.58 (s, 1H), 5.64 (s, 2H). ¹³C NMR (151 MHz, CDCl₃) δ 164.70, 160.65, 157.33, 152.06, 149.27, 143.35, 135.10, 134.03, 130.83, 130.20, 130.02, 129.48, 128.38, 128.09, 127.74, 124.52, 122.50, 114.89, 113.88, 112.03, 100.93, 62.40. HRMS (ESI) calcd for C₂₅H₁₆ClO₅⁺ [M+H]⁺ 431.0681, found 431.0668.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl -3-bromobenzoate (**8k**)

Yield 89%, m.p. 87-89 °C. ¹H NMR (400 MHz, CDCl₃) δ 8.26 (s, 1H), 8.06 (dd, *J* = 7.8, 0.6 Hz, 1H), 7.96 (s, 1H), 7.85 (s, 1H), 7.77 (dd, *J* = 8.0, 0.9 Hz, 1H), 7.63 – 7.57 (m, 3H), 7.52 (t, *J* = 7.5 Hz, 2H), 7.44 (t, *J* = 7.1 Hz, 1H), 7.38 (t, *J* = 7.9 Hz, 1H), 6.58 (s, 1H), 5.64 (s, 2H). ¹³C NMR (101 MHz, CDCl₃) δ 164.57, 160.64, 157.33, 152.06, 149.25, 143.35, 136.94, 132.92, 130.99, 130.83, 130.42, 129.48, 128.53, 128.38, 127.74, 124.52, 122.97, 122.50, 114.89, 113.88, 112.05, 100.94, 62.41. HRMS (ESI) calcd for C₂₅H₁₆BrO₅⁺ [M+H]⁺ 475.0176, found 475.0164.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl- 2-chlorobenzoate (**8l**)

Yield 90%, m.p. 147-149 °C. ¹H NMR (400 MHz, CDCl₃) δ 7.98 – 7.93 (m, 2H), 7.85 (s, 1H), 7.63 – 7.56 (m, 3H), 7.55 – 7.48 (m, 4H), 7.44 (t, *J* = 7.3 Hz, 1H), 7.37 (td, *J* = 6.9 Hz, *J* = 6.9 Hz, 2.2 Hz, 1H), 6.65 (s, 1H), 5.65 (s, 2H). ¹³C NMR (101 MHz, CDCl₃) δ 164.87, 160.69, 157.27, 151.98, 149.09, 143.29, 134.37, 133.58, 131.90, 131.59, 130.80, 129.47, 128.75, 128.34, 127.69, 126.99, 124.43, 122.46, 114.90, 113.85, 112.15, 100.86, 62.57. HRMS (ESI) calcd for C₂₅H₁₆ClO₅⁺ [M+H]⁺ 431.0681, found 431.0662.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl -2-fluorobenzoate (**8m**)

Yield 86%, m.p. 149-151 °C. ¹H NMR (400 MHz, CDCl₃) δ 7.98 (s, 1H), 7.93 – 7.89 (m, 1H), 7.86 (s, 1H), 7.74 – 7.70 (m, 1H), 7.63 – 7.57 (m, 3H), 7.53 (t, *J* = 7.6 Hz, 2H), 7.48 – 7.39

(m, 3H), 6.66 (s, 1H), 5.65 (s, 2H). ^{13}C NMR (101 MHz, CDCl_3) δ 165.35, 160.70, 157.30, 152.01, 149.04, 143.31, 134.89, 133.55, 131.79, 130.82 (d, $J = 1.4$ Hz), 129.50, 128.37, 127.72, 127.57, 124.47, 122.49, 122.30, 114.94, 113.88, 112.25, 100.89, 62.63. HRMS (ESI) calcd for $\text{C}_{25}\text{H}_{16}\text{FO}_5^+$ $[\text{M}+\text{H}]^+$ 415.0976, found 415.0987.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl-3-fluorobenzoate (**8n**)

Yield 84%, m.p. 126-127 °C. ^1H NMR (400 MHz, CDCl_3) δ 7.97 (s, 1H), 7.93 (d, $J = 7.8$ Hz, 1H), 7.85 (s, 1H), 7.81 (dd, $J = 9.1, 1.3$ Hz, 1H), 7.62 – 7.57 (m, 3H), 7.54 – 7.44 (m, 4H), 7.35 (td, $J = 8.3, 2.5$ Hz, 1H), 6.59 (s, 1H), 5.64 (s, 2H). ^{13}C NMR (101 MHz, CDCl_3) δ 164.75 (d, $J = 3.0$ Hz), 164.03, 161.56, 160.65, 157.33, 152.06, 149.31, 143.34, 130.83, 130.58 (d, $J = 7.8$ Hz), 129.47, 128.38, 127.74, 125.73 (d, $J = 3.1$ Hz), 124.52, 122.51, 121.13 (d, $J = 21.2$ Hz), 116.90 (d, $J = 23.2$ Hz), 114.89, 113.89, 112.01, 100.93, 62.39. HRMS (ESI) calcd for $\text{C}_{25}\text{H}_{16}\text{FO}_5^+$ $[\text{M}+\text{H}]^+$ 415.0976, found 415.0992.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl-2-bromobenzoate (**8o**)

Yield 88%, m.p. 123-125 °C. ^1H NMR (400 MHz, CDCl_3) δ 7.98 (s, 1H), 7.93 – 7.89 (m, 1H), 7.86 (s, 1H), 7.74 – 7.70 (m, 1H), 7.63 – 7.56 (m, 3H), 7.52 (t, $J = 7.5$ Hz, 2H), 7.48 – 7.39 (m, 3H), 6.65 (s, 1H), 5.65 (s, 2H). ^{13}C NMR (101 MHz, CDCl_3) δ 165.34, 160.70, 157.29, 152.00, 149.04, 143.30, 134.88, 133.55, 131.79, 130.80, 129.49, 128.36, 127.71, 127.56, 124.46, 122.48, 122.29, 114.93, 113.86, 112.23, 100.88, 62.63. HRMS (ESI) calcd for $\text{C}_{25}\text{H}_{16}\text{BrO}_5^+$ $[\text{M}+\text{H}]^+$ 475.0176, found 475.0158.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl-3-methylbenzoate (**8p**)

Yield 80%, m.p. 183-185 °C. ^1H NMR (400 MHz, CDCl_3) δ 7.99 (s, 1H), 7.94 (s, 2H), 7.85 (s, 1H), 7.63 – 7.57 (m, 3H), 7.53 – 7.35 (m, 5H), 6.62 (s, 1H), 5.63 (s, 2H), 2.43 (s, 3H). ^{13}C NMR (101 MHz, CDCl_3) δ 166.03, 160.79, 157.30, 152.05, 149.75, 143.28, 138.75, 134.75, 130.86, 130.45, 129.46, 129.02, 128.74, 128.34, 127.72, 127.16, 124.45, 122.51, 114.97, 114.00, 111.87, 100.87, 62.06, 21.46. HRMS (ESI) calcd for $\text{C}_{26}\text{H}_{19}\text{O}_5^+$ $[\text{M}+\text{H}]^+$ 411.1227, found 411.1210.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl-4-nitrobenzoate (**8q**)

Yield 85%, m.p. 194-196 °C. ^1H NMR (600 MHz, CDCl_3) δ 8.34 (d, $J = 8.3$ Hz, 2H), 8.30 (d, $J = 8.5$ Hz, 2H), 7.96 (s, 1H), 7.86 (s, 1H), 7.60 (d, $J = 9.3$ Hz, 3H), 7.52 (t, $J = 7.4$ Hz, 2H), 7.45 (t, $J = 6.9$ Hz, 1H), 6.58 (s, 1H), 5.69 (s, 2H). ^{13}C NMR (151 MHz, CDCl_3) δ 164.05, 160.53, 157.38, 152.05, 151.17, 148.87, 143.45, 134.37, 131.15, 130.81, 129.49, 128.42, 127.74,

124.58, 124.01, 122.46, 114.75, 113.74, 112.05, 101.03, 62.80. HRMS (ESI) calcd for $C_{25}H_{16}NO_7^+ [M+H]^+$ 442.0921, found 442.0902

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl -4-(tert-butyl)benzoate (**8r**)

Yield 82%, m.p. 108-110 °C. 1H NMR (400 MHz, $CDCl_3$) δ 8.06 (d, J = 8.4 Hz, 2H), 7.99 (s, 1H), 7.85 (s, 1H), 7.62 – 7.56 (m, 3H), 7.54 – 7.40 (m, 5H), 6.60 (s, 1H), 5.63 (s, 2H), 1.36 (s, 9H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 165.86, 160.78, 157.84, 157.30, 152.06, 149.87, 143.26, 130.87, 129.92, 129.45, 128.32, 127.73, 126.27, 125.84, 124.42, 122.51, 114.99, 114.02, 111.83, 100.84, 61.90, 35.37, 31.23. HRMS (ESI) calcd for $C_{29}H_{25}O_5^+ [M+H]^+$ 453.1697, found 453.1712.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl- 2-naphthoate (**8s**)

Yield 77%, m.p. 146-147 °C. 1H NMR (400 MHz, $CDCl_3$) δ 8.71 (s, 1H), 8.13 (d, J = 8.7 Hz, 1H), 8.03 (s, 1H), 8.00 – 7.90 (m, 3H), 7.86 (s, 1H), 7.67 – 7.56 (m, 5H), 7.49 (t, J = 7.6 Hz, 2H), 7.43 (t, J = 7.1 Hz, 1H), 6.69 (s, 1H), 5.70 (s, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.03, 160.79, 157.32, 152.08, 149.72, 143.31, 136.02, 132.60, 131.76, 130.86, 129.63, 129.47, 128.94, 128.74, 128.35, 128.00, 127.73, 127.14, 126.28, 125.17, 124.48, 122.52, 115.00, 114.03, 111.99, 100.90, 62.24. HRMS (ESI) calcd for $C_{29}H_{19}O_5^+ [M+H]^+$ 447.1227, found 447.1212.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl -3,5-dichlorobenzoate (**8t**)

Yield 75%, m.p. 163-165 °C. 1H NMR (400 MHz, $CDCl_3$) δ 7.98 (d, J = 0.9 Hz, 2H), 7.94 (s, 1H), 7.86 (s, 1H), 7.63 – 7.57 (m, 4H), 7.53 (t, J = 7.5 Hz, 2H), 7.45 (t, J = 7.3 Hz, 1H), 6.55 (s, 1H), 5.64 (s, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 163.64, 160.57, 157.32, 152.02, 148.89, 143.39, 135.86, 133.83, 131.82, 130.79, 129.48, 128.40, 128.30, 127.73, 124.55, 122.47, 114.80, 113.76, 112.11, 100.98, 62.72. HRMS (ESI) calcd for $C_{25}H_{15}Cl_2O_5^+ [M+H]^+$ 465.0291, found 465.0314.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl-3-(trifluoromethyl)benzoate (**8u**)

Yield 80%, m.p. 137-138 °C. 1H NMR (400 MHz, $CDCl_3$) δ 8.38 (s, 1H), 8.32 (d, J = 7.8 Hz, 1H), 7.97 (s, 1H), 7.90 (d, J = 7.8 Hz, 1H), 7.86 (s, 1H), 7.66 (t, J = 7.9 Hz, 1H), 7.62 – 7.57 (m, 3H), 7.51 (t, J = 7.5 Hz, 2H), 7.44 (t, J = 7.3 Hz, 1H), 6.57 (s, 1H), 5.68 (s, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 164.61, 160.59, 157.35, 152.06, 149.14, 143.37, 133.11, 131.83, 131.51, 130.82, 130.48 (d, J = 3.6 Hz), 129.98, 129.61, 129.46, 128.38, 127.73, 126.92 (q, J = 3.9

Hz), 124.54, 122.50, 114.84, 113.85, 112.09, 100.96, 62.50. HRMS (ESI) calcd for $C_{26}H_{16}F_3O_5^+$ $[M+H]^+$ 465.0944, found 465.0965.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl -2-methylbenzoate (**8v**)

Yield 83%, m.p. 139-141 °C. 1H NMR (400 MHz, $CDCl_3$) δ 8.06 (d, J = 8.0 Hz, 1H), 7.98 (s, 1H), 7.85 (s, 1H), 7.62 – 7.56 (m, 3H), 7.53 – 7.42 (m, 4H), 7.31 (d, J = 7.6 Hz, 2H), 6.61 (s, 1H), 5.61 (s, 2H), 2.64 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.40, 160.79, 157.26, 152.01, 149.79, 143.27, 141.30, 133.06, 132.21, 130.90, 130.83, 129.45, 128.32, 128.08, 127.70, 126.17, 124.42, 122.47, 114.93, 113.99, 111.90, 100.85, 61.84, 22.09. HRMS (ESI) calcd for $C_{26}H_{19}O_5^+$ $[M+H]^+$ 411.1227, found 411.1240.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl -3-nitrobenzoate (**8w**)

Yield 86%, m.p. 172-174 °C. 1H NMR (400 MHz, $CDCl_3$) δ 8.95 (s, 1H), 8.50 (d, J = 8.1 Hz, 1H), 8.45 (d, J = 7.5 Hz, 1H), 7.97 (s, 1H), 7.86 (s, 1H), 7.73 (t, J = 8.0 Hz, 1H), 7.64 – 7.57 (m, 3H), 7.52 (t, J = 7.4 Hz, 2H), 7.45 (t, J = 7.3 Hz, 1H), 6.57 (s, 1H), 5.71 (s, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 163.86, 160.51, 157.37, 152.07, 148.87, 148.61, 143.42, 135.49, 130.83 (d, J = 4.1 Hz), 130.20, 129.49, 128.39 (d, J = 5.2 Hz), 127.75, 124.99, 124.59, 122.49, 114.80, 113.78, 112.21, 101.02, 62.78. HRMS (ESI) calcd for $C_{25}H_{16}NO_7^+$ $[M+H]^+$ 442.0921, found 442.0939.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl -3-methoxybenzoate (**8x**)

Yield 88%, m.p. 107-108 °C. 1H NMR (400 MHz, $CDCl_3$) δ 7.99 (s, 1H), 7.85 (s, 1H), 7.73 (d, J = 7.1 Hz, 1H), 7.65 – 7.56 (m, 4H), 7.51 (t, J = 7.6 Hz, 2H), 7.47 – 7.38 (m, 2H), 7.17 (dd, J = 8.3, 2.3 Hz, 1H), 6.60 (s, 1H), 5.64 (s, 2H), 3.86 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 165.73, 160.71, 159.91, 157.30, 152.05, 149.61, 143.29, 130.85, 130.34, 129.89, 129.46, 128.33, 127.72, 124.44, 122.49, 122.31, 120.28, 114.98, 114.60, 113.98, 111.98, 100.87, 77.48, 62.18, 55.65. HRMS (ESI) calcd for $C_{26}H_{19}O_6^+$ $[M+H]^+$ 427.1176, found 427.1153.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl-3-(trifluoromethoxy)benzoate (**8y**)

Yield 92%, m.p. 121-123 °C. 1H NMR (400 MHz, $CDCl_3$) δ 8.08 (d, J = 7.5 Hz, 1H), 7.96 (s, 2H), 7.86 (s, 1H), 7.61 – 7.48 (m, 7H), 7.43 (t, J = 7.1 Hz, 1H), 6.58 (s, 1H), 5.66 (s, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 164.54, 160.61, 157.35, 152.06, 149.58, 149.18, 143.36, 131.11, 130.83, 130.48, 129.46, 128.38, 128.25, 127.73, 126.37, 124.53, 122.50, 114.85, 113.86, 112.06, 100.96, 62.48. HRMS (ESI) calcd for $C_{26}H_{16}F_3O_6^+$ $[M+H]^+$ 481.0893, found 481.0879.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl-3,5-bis(trifluoromethyl)benzoate (**8z**)

Yield 75%, m.p. 188-190 °C. ¹H NMR (400 MHz, CDCl₃) δ 8.55 (s, 2H), 8.14 (s, 1H), 7.96 (s, 1H), 7.86 (s, 1H), 7.63 – 7.58 (m, 3H), 7.52 (t, *J* = 7.5 Hz, 2H), 7.45 (t, *J* = 7.3 Hz, 1H), 6.53 (s, 1H), 5.72 (s, 2H). ¹³C NMR (101 MHz, CDCl₃) δ 163.38, 160.45, 157.37, 152.04, 148.59, 143.46, 132.77 (q, *J* = 34.3 Hz), 131.25, 130.78, 130.03 (d, *J* = 3.4 Hz), 129.46, 128.42, 127.73, 127.35 (t, *J* = 4.0 Hz), 124.61, 122.46, 121.45, 114.74, 113.71, 112.34, 110.16, 101.05, 62.99. HRMS (ESI) calcd for C₂₇H₁₅F₆O₅⁺ [M+H]⁺ 533.0818, found 533.0836.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl-2-chloro-6-fluorobenzoate (**8aa**)

Yield 81%, m.p. 156-157 °C. ¹H NMR (400 MHz, CDCl₃) δ 7.95 (s, 1H), 7.86 (s, 1H), 7.63 – 7.58 (m, 2H), 7.58 – 7.51 (m, 3H), 7.48 – 7.38 (m, 2H), 7.27 (d, *J* = 8.4 Hz, 1H), 7.10 (t, *J* = 8.7 Hz, 1H), 6.65 (s, 1H), 5.67 (s, 2H). ¹³C NMR (101 MHz, CDCl₃) δ 162.64, 161.39, 160.63, 158.86, 157.30, 152.00, 148.42, 143.31, 132.59 (d, *J* = 9.4 Hz), 130.81, 129.48, 128.35, 127.74, 125.99 (d, *J* = 3.6 Hz), 124.46, 122.51, 114.94, 114.89, 114.73, 112.53, 100.89, 63.09. HRMS (ESI) calcd for C₂₅H₁₅ClFO₅⁺ [M+H]⁺ 449.0587, found 449.0568.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl -3,4-dichlorobenzoate (**8ab**)

Yield 78%, m.p. 183-185 °C. ¹H NMR (400 MHz, CDCl₃) δ 8.20 (d, *J* = 1.2 Hz, 1H), 7.97 – 7.93 (m, 2H), 7.86 (s, 1H), 7.62 – 7.56 (m, 4H), 7.52 (t, *J* = 7.5 Hz, 2H), 7.45 (t, *J* = 7.3 Hz, 1H), 6.56 (s, 1H), 5.64 (s, 2H). ¹³C NMR (101 MHz, CDCl₃) δ 164.07, 160.61, 157.32, 152.01, 149.09, 143.38, 138.81, 133.57, 131.82, 131.04, 130.80, 129.48, 128.95, 128.83, 128.39, 127.73, 124.53, 122.47, 114.79, 113.78, 111.98, 100.97, 62.52. HRMS (ESI) calcd for C₂₅H₁₅Cl₂O₅⁺ [M+H]⁺ 465.0291, found 465.0275.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl -3,5-difluorobenzoate (**8ac**)

Yield 87%, m.p. 225-227 °C. ¹H NMR (400 MHz, CDCl₃) δ 7.94 (s, 1H), 7.86 (s, 1H), 7.68 – 7.57 (m, 5H), 7.53 (t, *J* = 7.5 Hz, 2H), 7.45 (t, *J* = 7.2 Hz, 1H), 7.13 – 7.07 (m, 1H), 6.56 (s, 1H), 5.65 (s, 2H). ¹³C NMR (101 MHz, CDCl₃) δ 164.24, 160.58, 157.33, 152.03, 148.95, 143.39, 130.80, 129.48, 128.41, 127.74, 124.56, 122.48, 114.80, 113.77, 113.17 (d, *J* = 7.6 Hz), 112.98 (d, *J* = 7.7 Hz), 112.06, 109.52 (t, *J* = 25.1 Hz), 100.99, 62.69. HRMS (ESI) calcd for C₂₅H₁₅F₂O₅⁺ [M+H]⁺ 433.0882, found 433.0868.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl -3,4-difluorobenzoate (**8ad**)

Yield 92%, m.p. 190-191°C. ¹H NMR (400 MHz, CDCl₃) δ 7.99 – 7.90 (m, 3H), 7.86 (s, 1H), 7.63 – 7.56 (m, 3H), 7.52 (t, *J* = 7.6 Hz, 2H), 7.48 – 7.42 (m, 1H), 7.33 – 7.27 (m, 1H), 6.56 (s, 1H), 5.64 (s, 2H). ¹³C NMR (101 MHz, CDCl₃) δ 163.94, 160.62, 157.31, 155.57 (d, *J* = 12.5 Hz), 153.01 (d, *J* = 12.6 Hz), 151.99, 151.66 (d, *J* = 13.1 Hz), 149.19, 143.38, 130.79, 129.46, 128.38, 127.71, 127.05 (dd, *J* = 7.6, 3.8 Hz), 124.51, 122.45, 119.39 (dd, *J* = 18.8, 1.7 Hz), 117.96 (d, *J* = 17.9 Hz), 114.77, 113.77, 111.85, 100.95, 62.43. HRMS (ESI) calcd for C₂₅H₁₅F₂O₅⁺ [M+H]⁺ 433.0882, found 433.0911.

(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl-3,4,5-trifluorobenzoate (**8ae**)

Yield 83%, m.p. 204-206°C. ¹H NMR (400 MHz, CDCl₃) δ 7.93 (s, 1H), 7.86 (s, 1H), 7.77 (t, *J* = 6.9 Hz, 2H), 7.62 – 7.58 (m, 3H), 7.53 (t, *J* = 7.5 Hz, 2H), 7.45 (t, *J* = 7.3 Hz, 1H), 6.53 (s, 1H), 5.64 (d, *J* = 0.6 Hz, 2H). ¹³C NMR (101 MHz, CDCl₃) δ 160.52, 157.34, 152.02, 148.84, 143.43, 130.78, 129.48, 128.42, 127.74, 124.58, 122.45, 114.79, 114.73, 114.63, 114.56, 113.70, 112.02, 101.02, 62.79. HRMS (ESI) calcd for C₂₅H₁₄F₃O₅⁺ [M+H]⁺ 451.0788, found 451.0765.

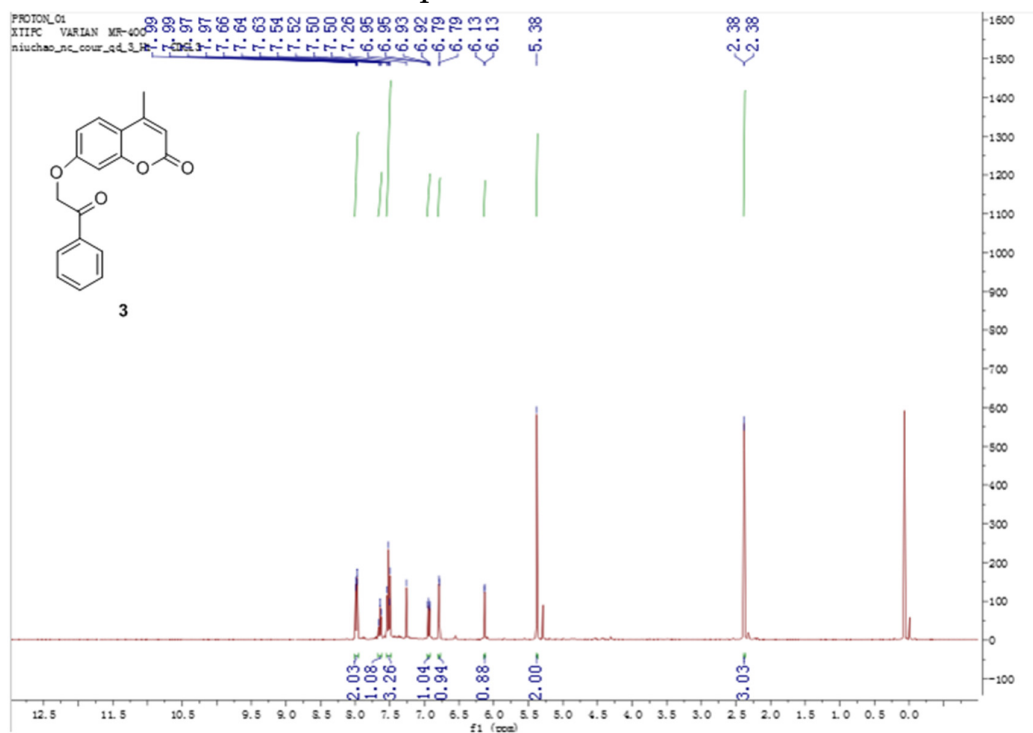
(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl cyclohexanecarboxylate (**8af**)

Yield 70%, m.p. 119-120°C. ¹H NMR (400 MHz, CDCl₃) δ 7.88 (s, 1H), 7.85 (s, 1H), 7.63 – 7.58 (m, 2H), 7.57 – 7.50 (m, 3H), 7.45 (t, *J* = 7.4 Hz, 1H), 6.49 (s, 1H), 5.37 (s, 2H), 2.46 (tt, *J* = 11.5, 3.6 Hz, 1H), 1.98 (dd, *J* = 13.0, 2.4 Hz, 2H), 1.82 – 1.73 (m, 2H), 1.50 (ddd, *J* = 14.7, 12.4, 3.1 Hz, 2H), 1.39 – 1.16 (m, 4H). ¹³C NMR (101 MHz, CDCl₃) δ 175.32, 160.81, 157.23, 151.97, 149.85, 143.25, 130.85, 129.45, 128.34, 127.72, 124.38, 122.46, 114.87, 113.97, 111.71, 100.81, 61.33, 43.26, 29.16, 25.75, 25.49. HRMS (ESI) calcd for C₂₅H₂₃O₅⁺ [M+H]⁺ 403.1540, found 403.1557.

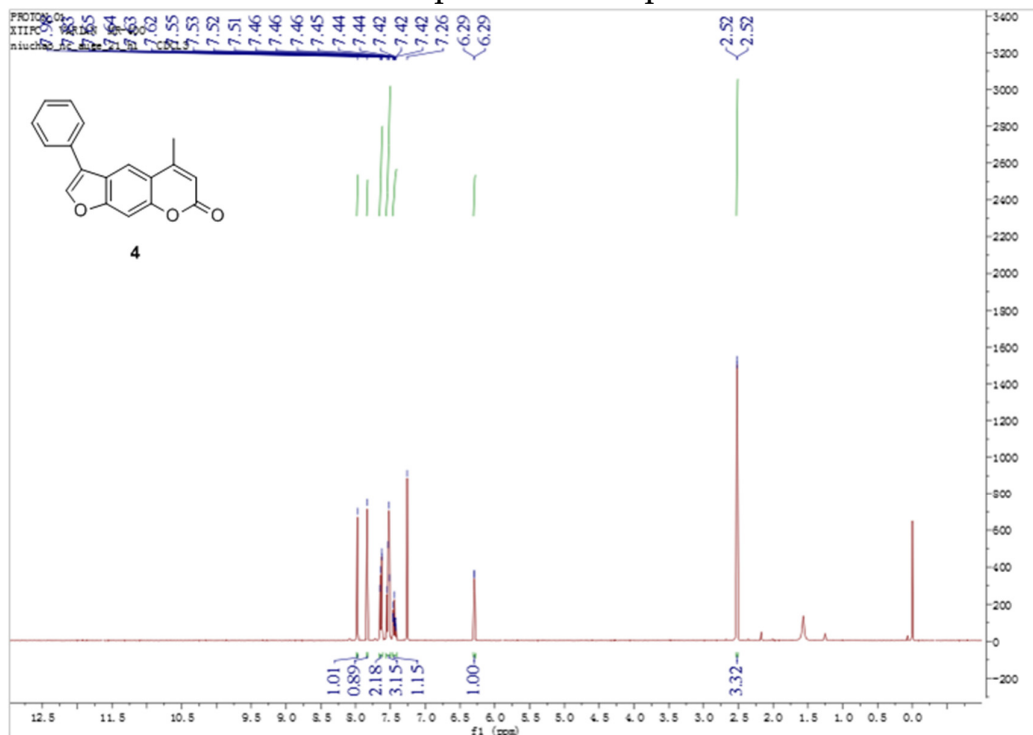
(7-oxo-3-phenyl-7H-furo[3,2-g]chromen-5-yl)methyl furan-2-carboxylate (**8ag**)

Yield 68%, m.p. 161-163°C. ¹H NMR (400 MHz, CDCl₃) δ 7.94 (s, 1H), 7.85 (s, 1H), 7.68 – 7.65 (m, 1H), 7.63 – 7.59 (m, 2H), 7.57 (s, 1H), 7.52 (t, *J* = 7.6 Hz, 2H), 7.44 (t, *J* = 7.3 Hz, 1H), 7.34 (d, *J* = 3.5 Hz, 1H), 6.61 – 6.57 (m, 2H), 5.61 (d, *J* = 0.6 Hz, 2H). ¹³C NMR (101 MHz, CDCl₃) δ 160.70, 157.72, 157.27, 151.97, 149.28, 147.42, 143.64, 143.30, 130.82, 129.47, 128.34, 127.70, 124.41, 122.46, 119.54, 114.82, 113.79, 112.40, 111.76, 100.87, 61.67. HRMS (ESI) calcd for C₂₃H₁₅O₆⁺ [M+H]⁺ 387.0863, found 387.0876.

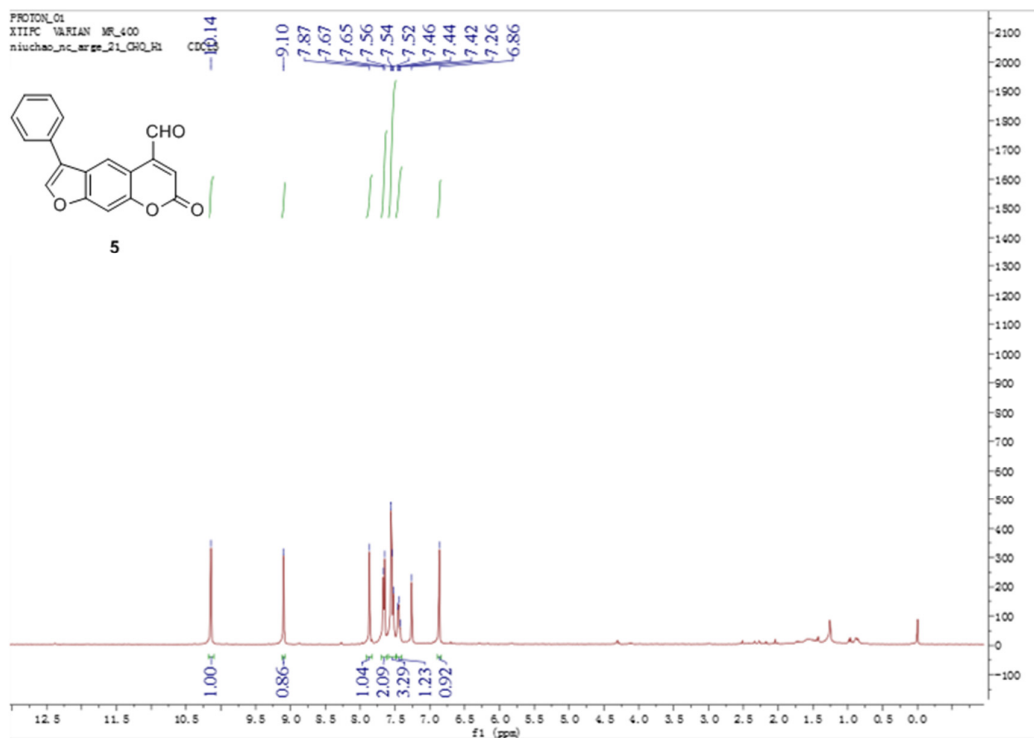
¹H NMR spectra of intermediate 3



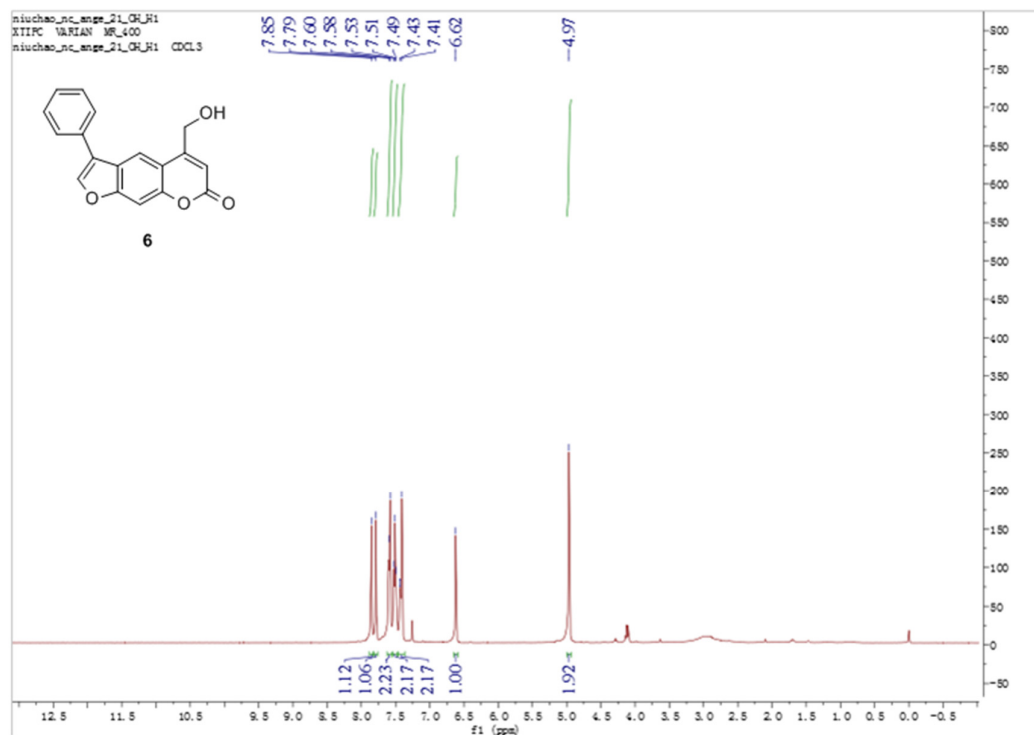
¹H NMR spectra of compound 4



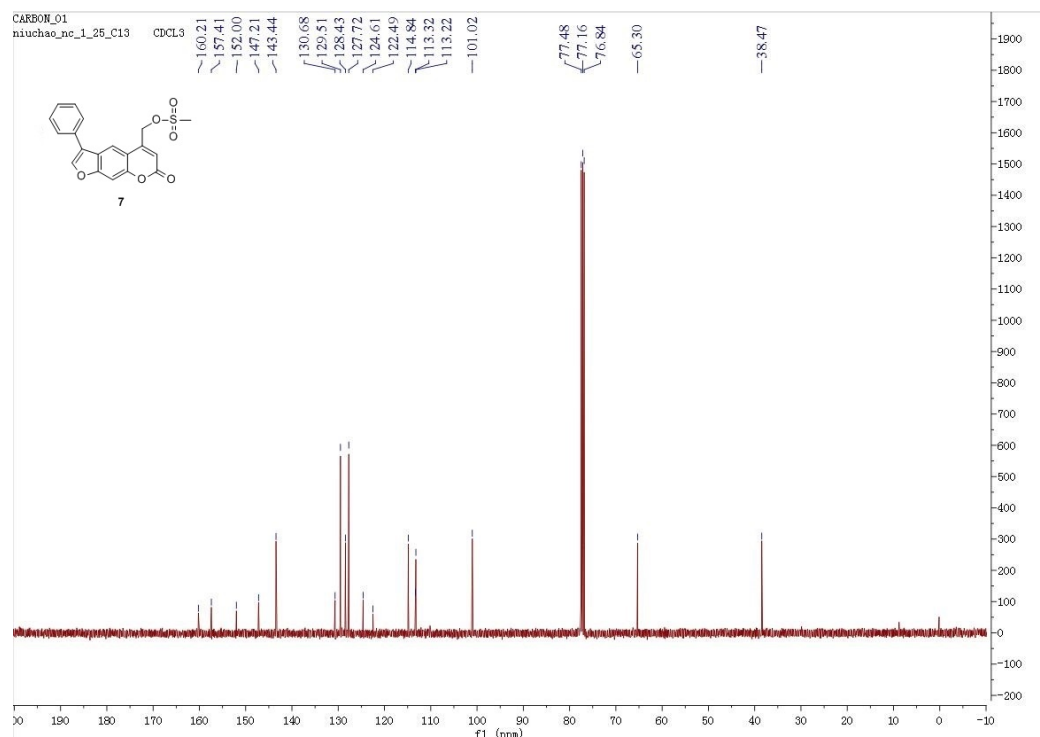
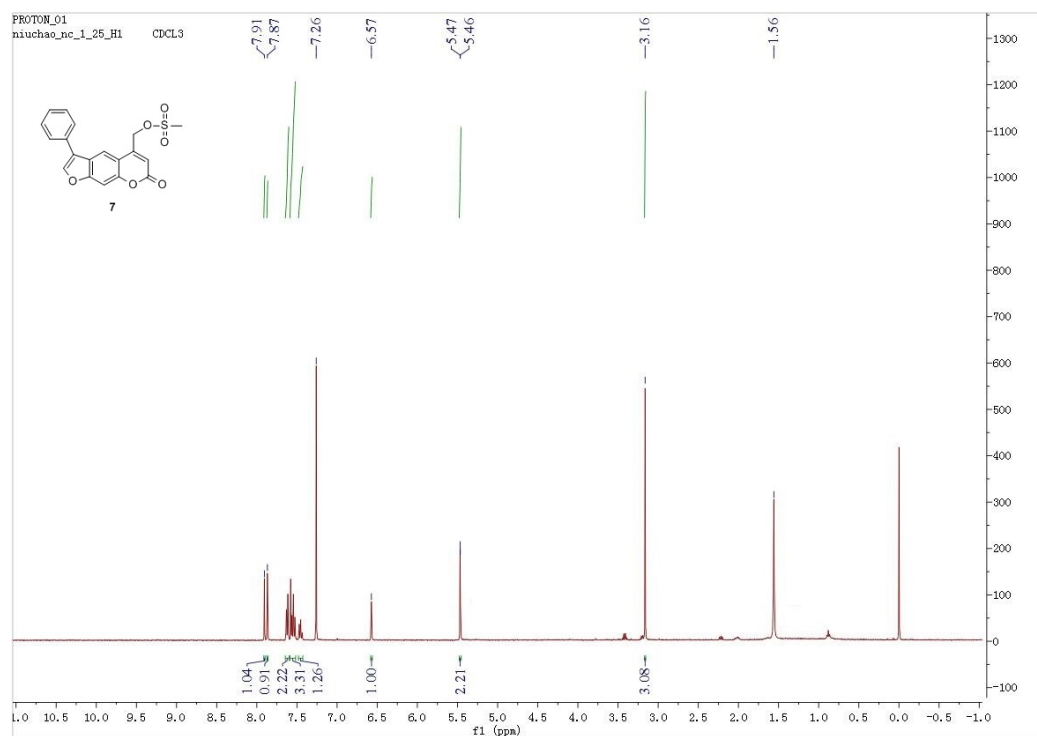
¹H NMR spectra of compound 5



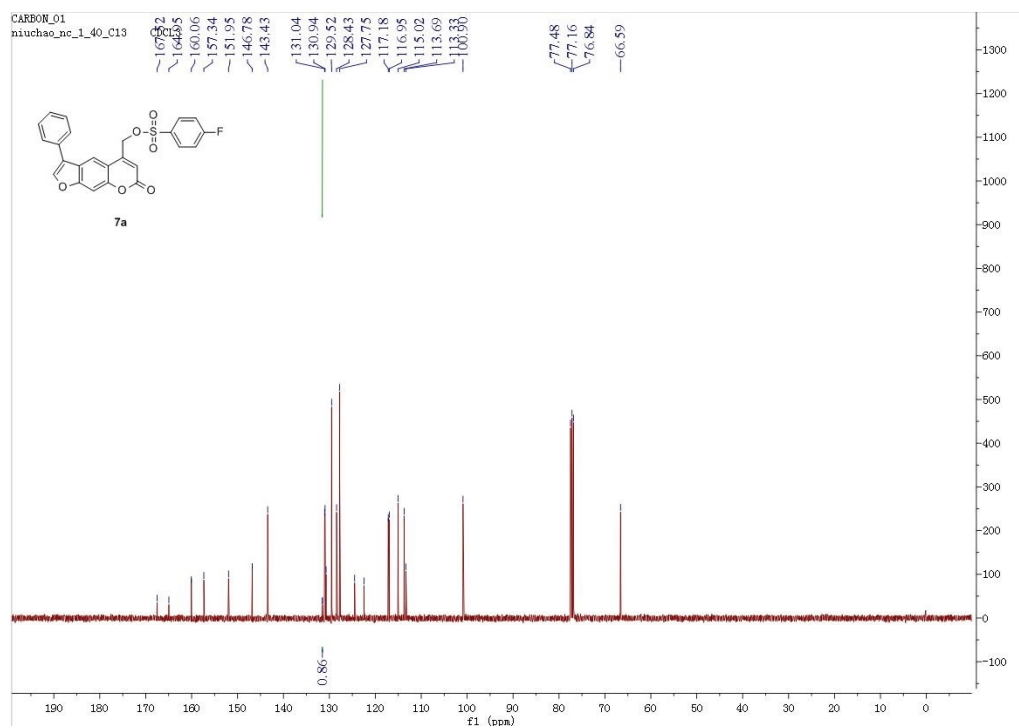
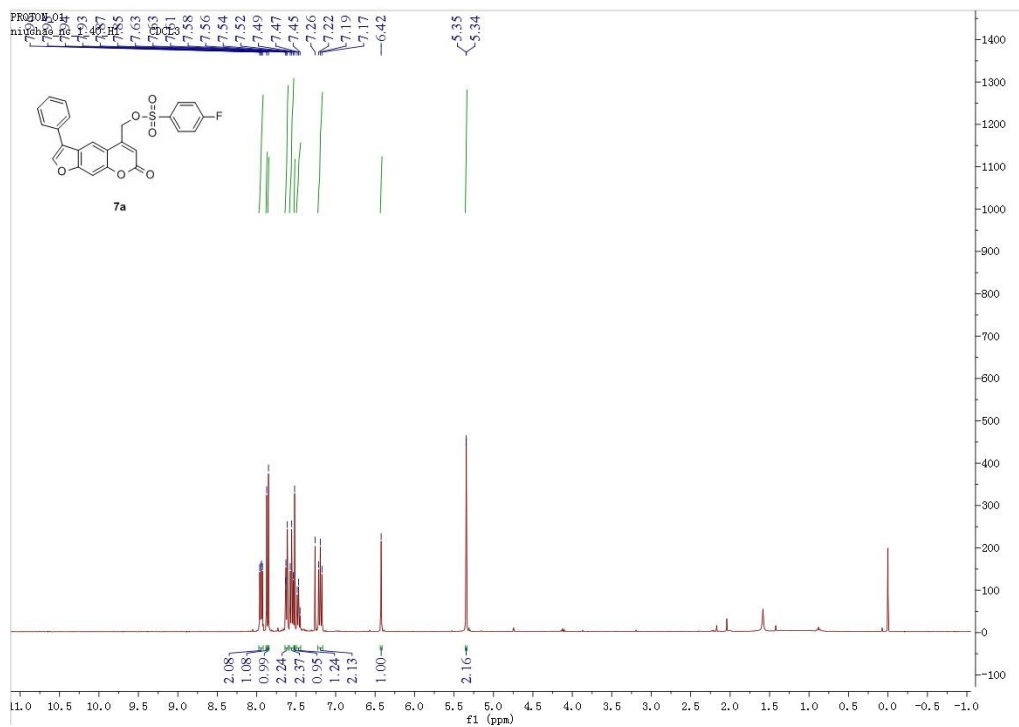
¹H NMR spectra of compound 6



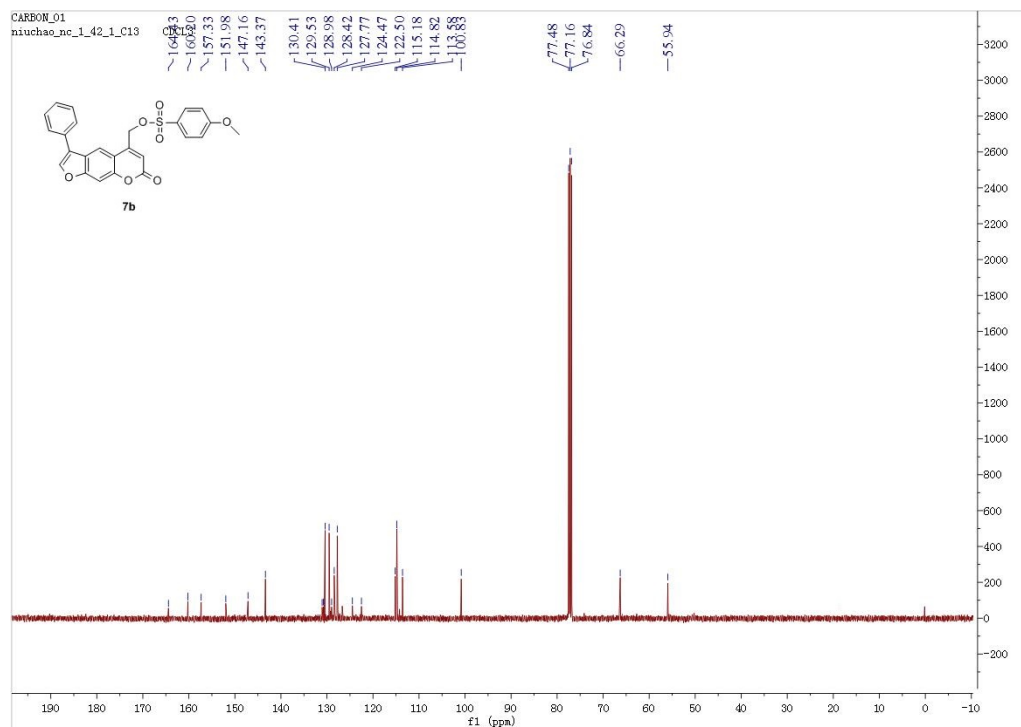
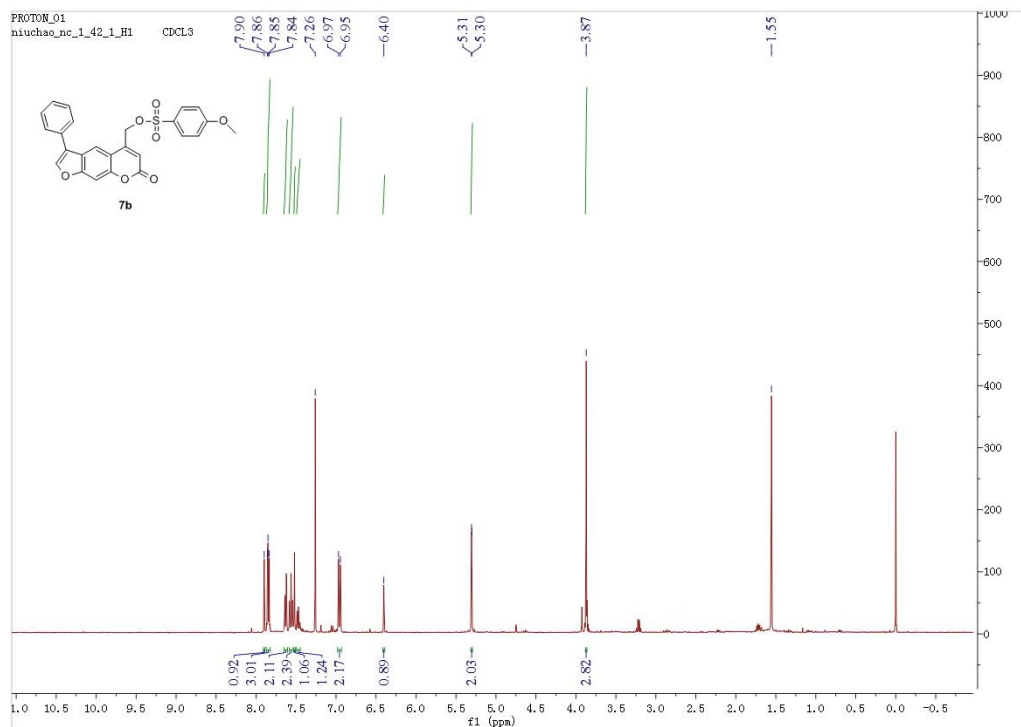
¹H and ¹³C NMR spectra of 7



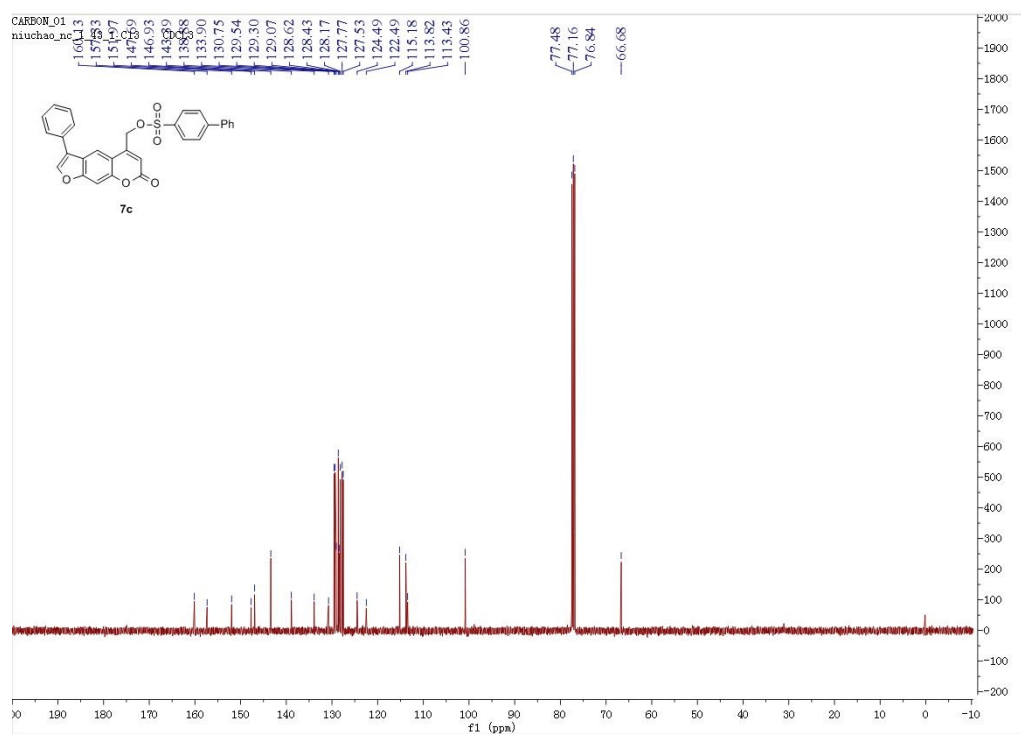
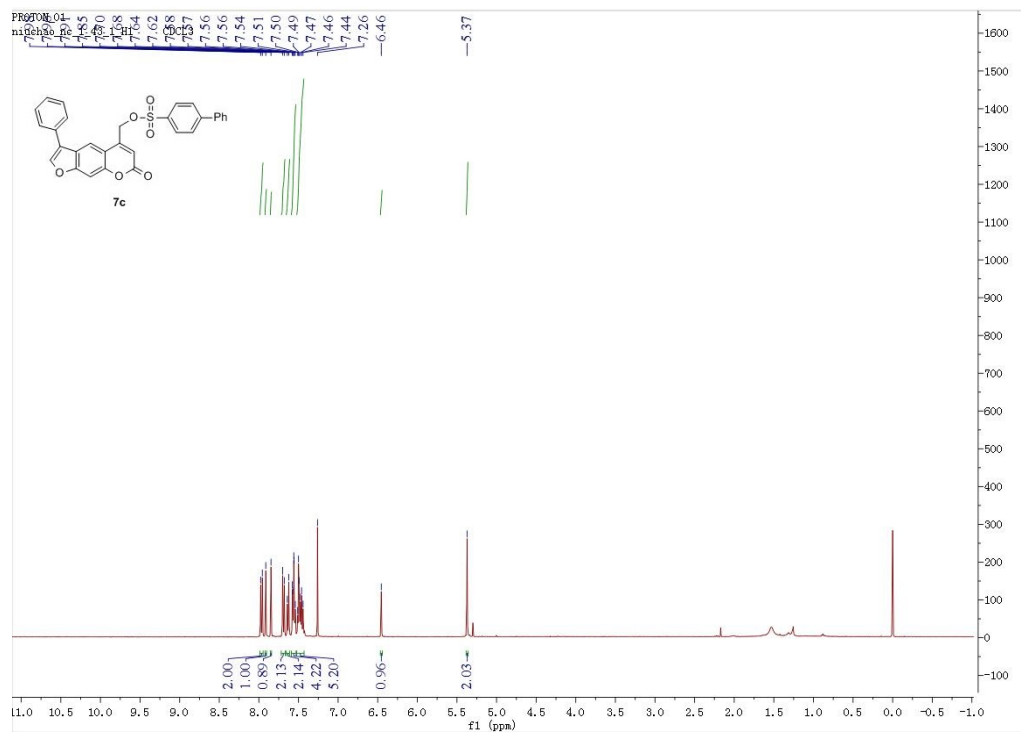
¹H and ¹³C NMR spectra of 7a



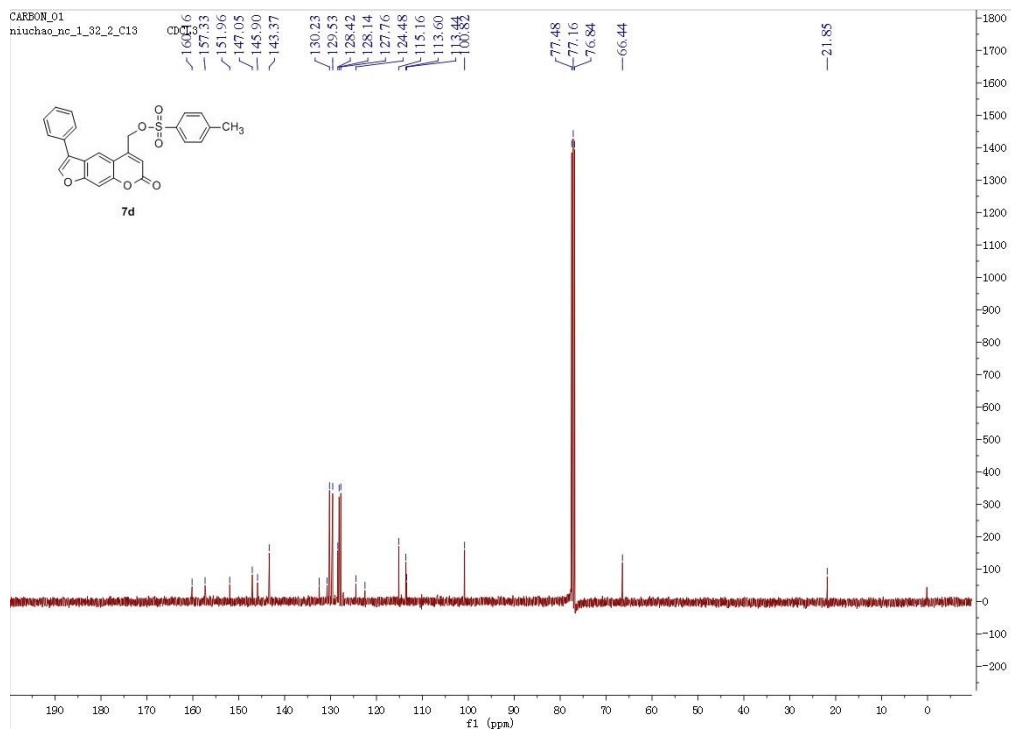
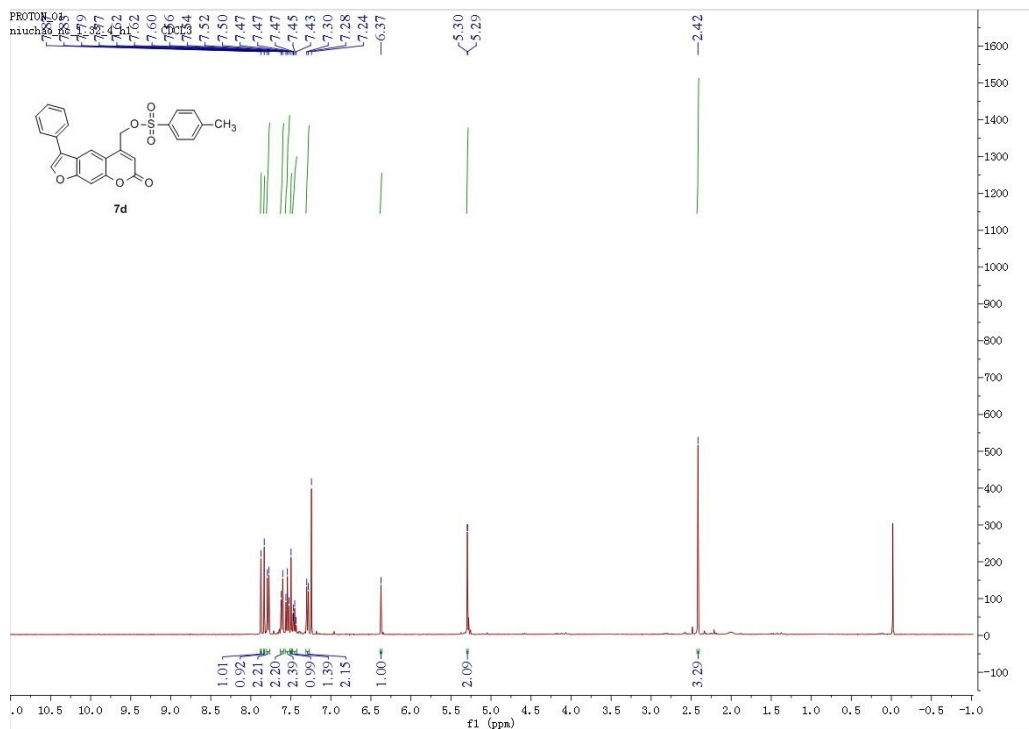
¹H NMR and ¹³C NMR spectra of **7b**



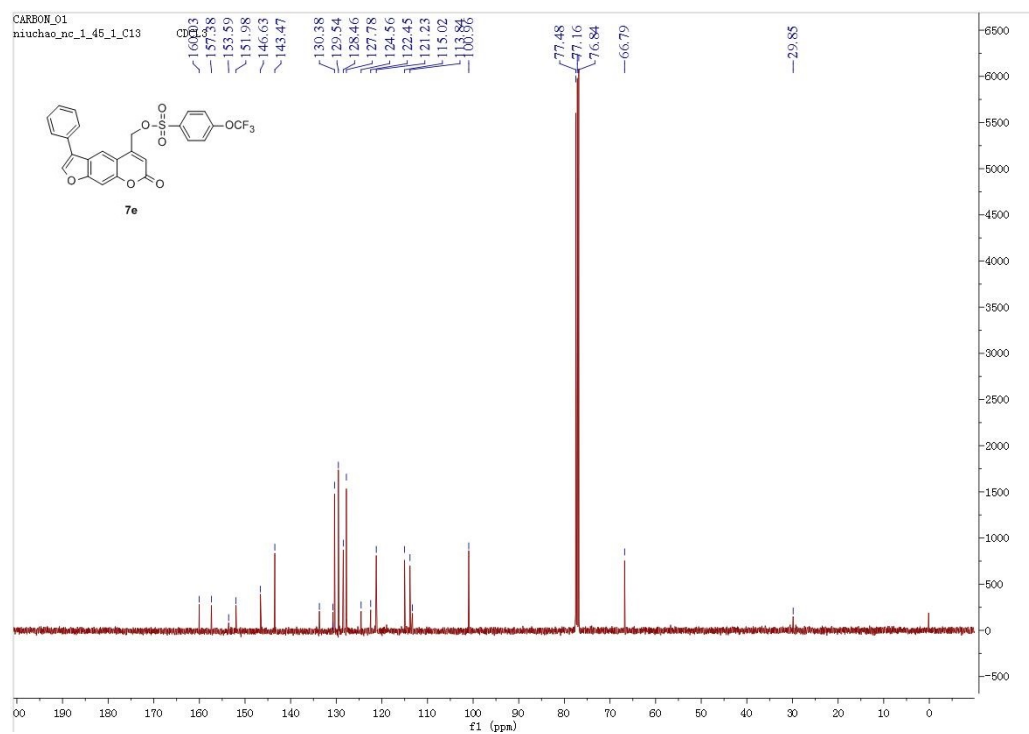
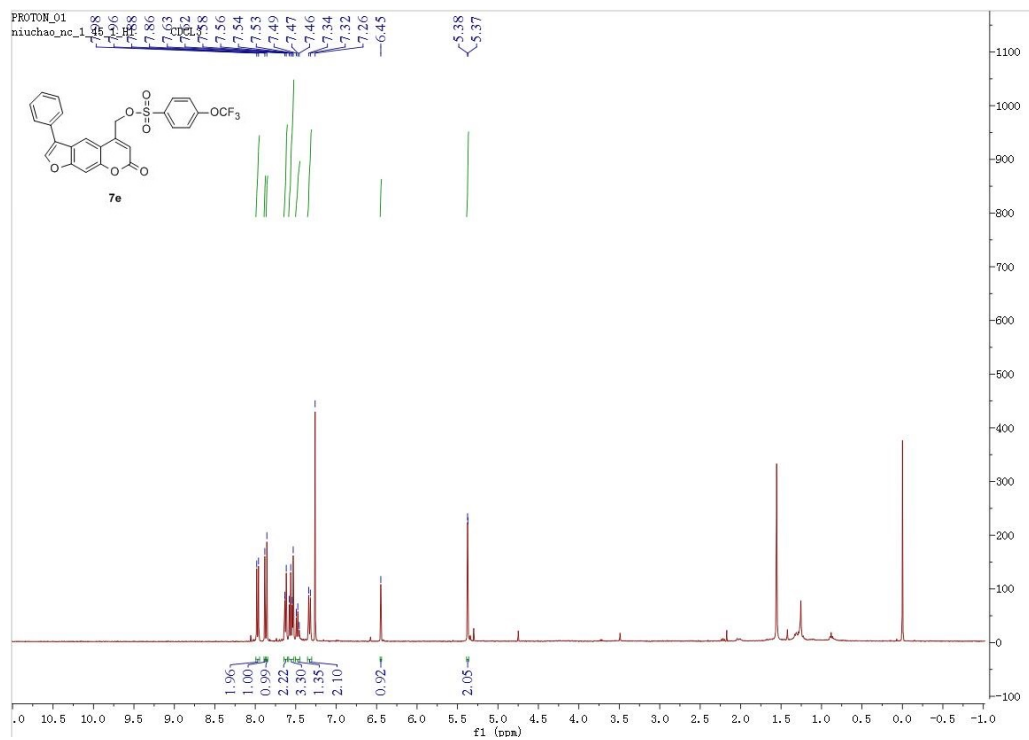
^1H NMR and ^{13}C NMR spectra of **7c**

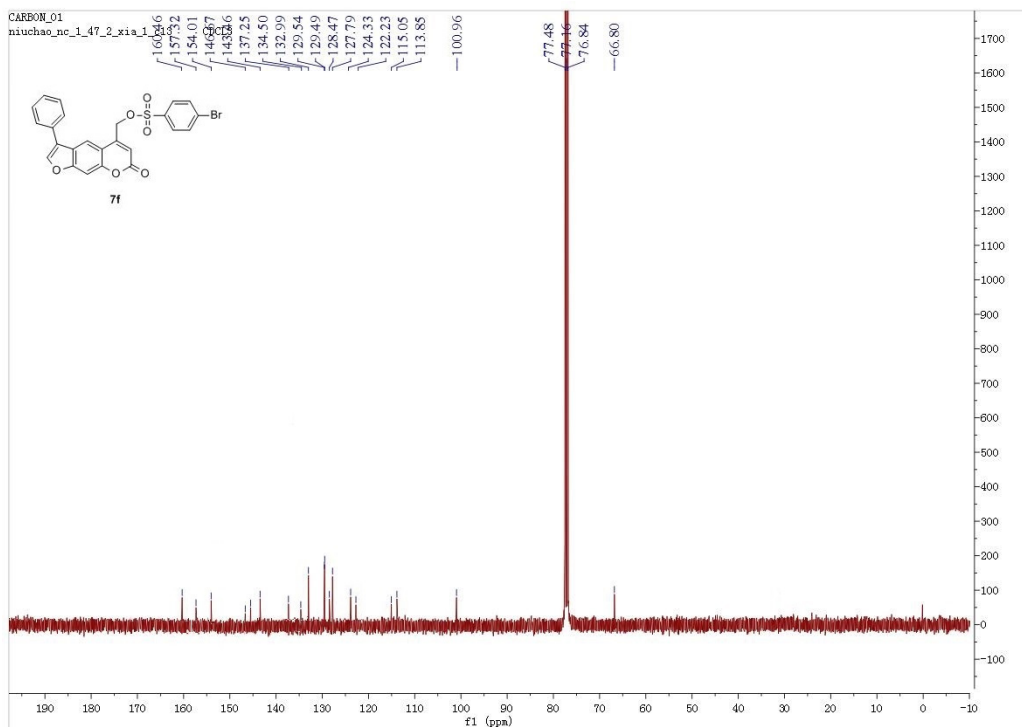
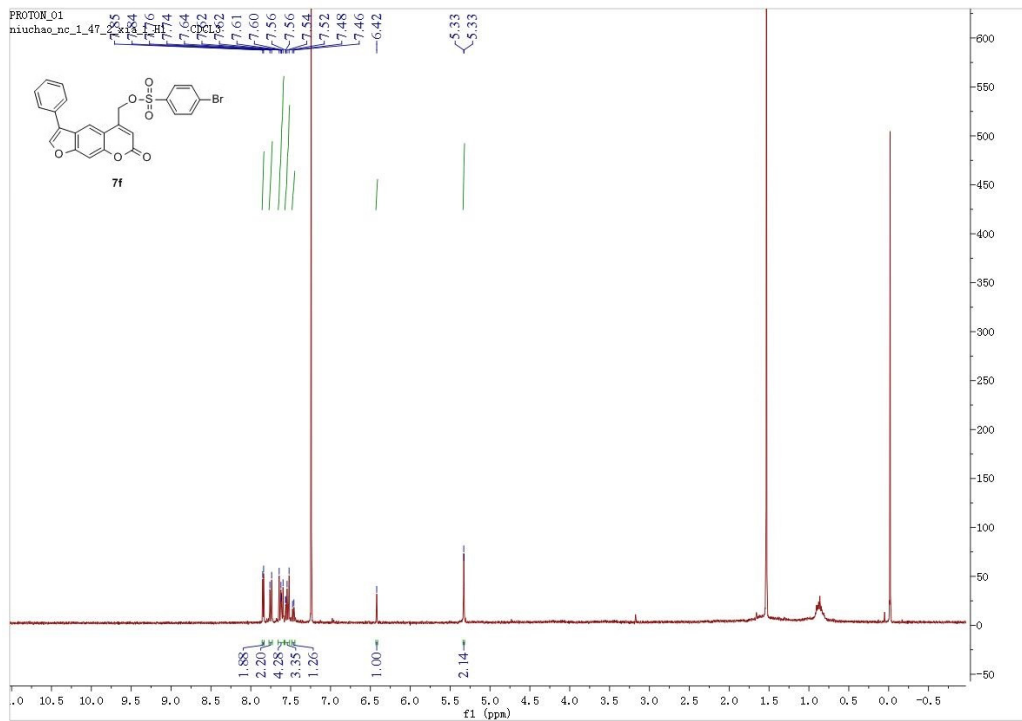


¹H NMR and ¹³C NMR spectra of 7d

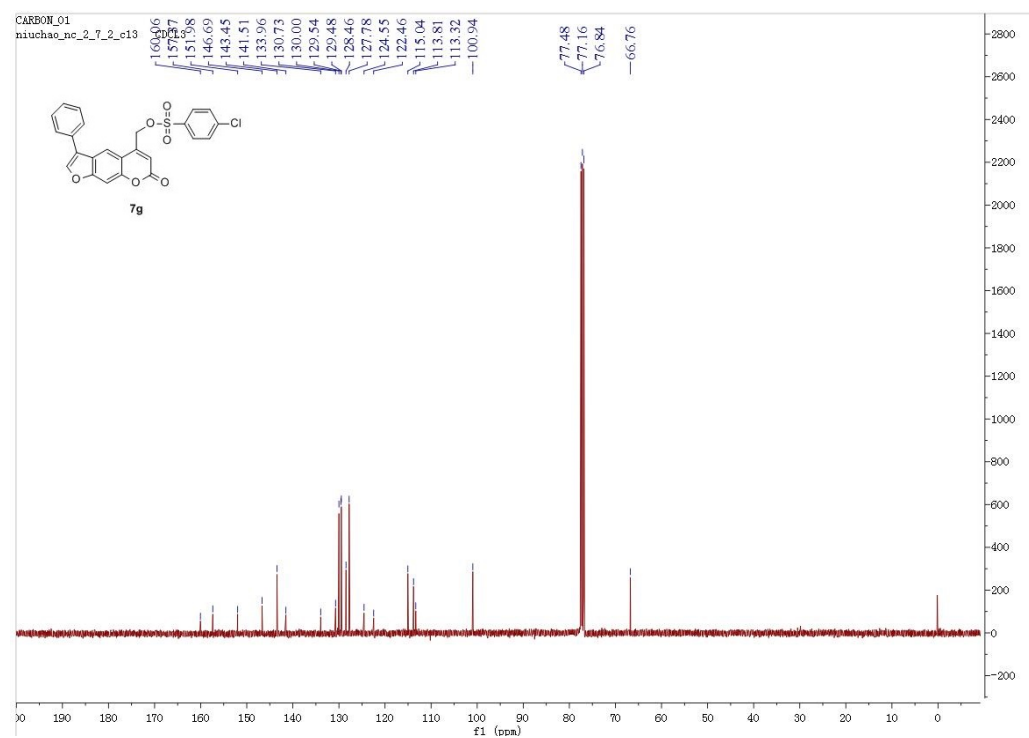
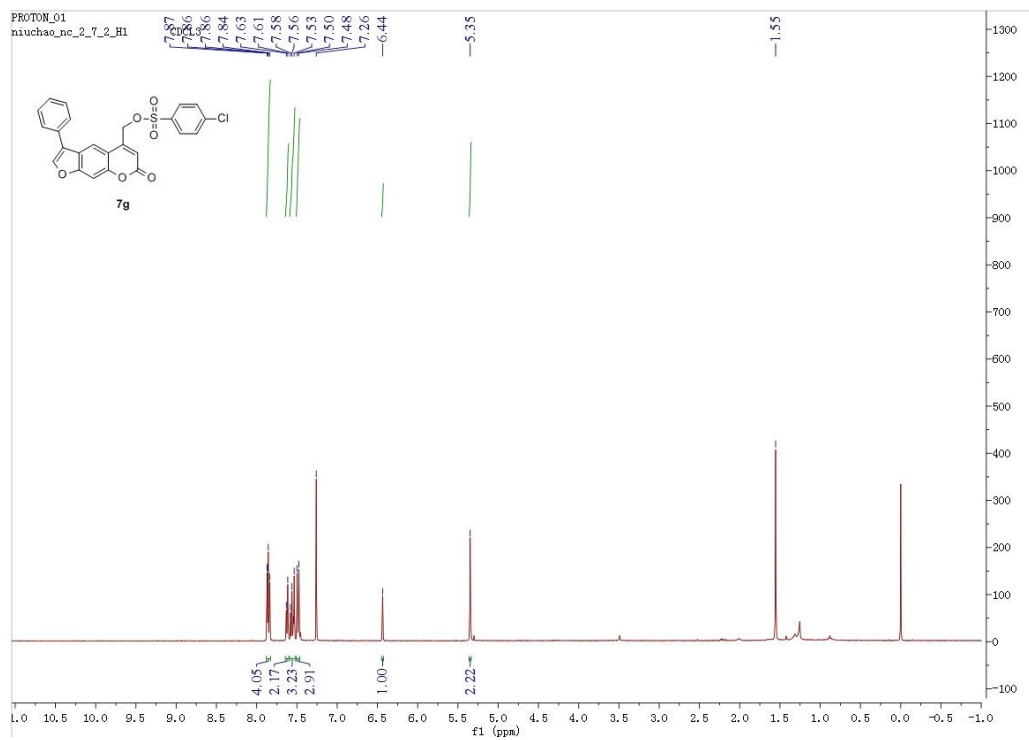


¹H NMR and ¹³C NMR spectra of 7e

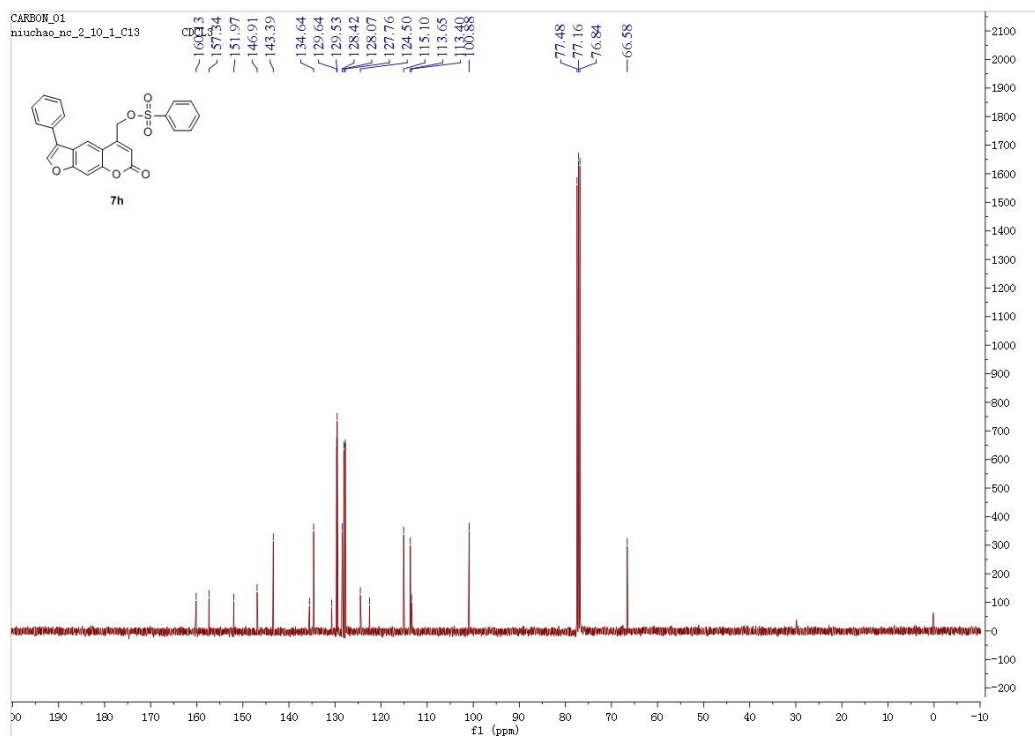
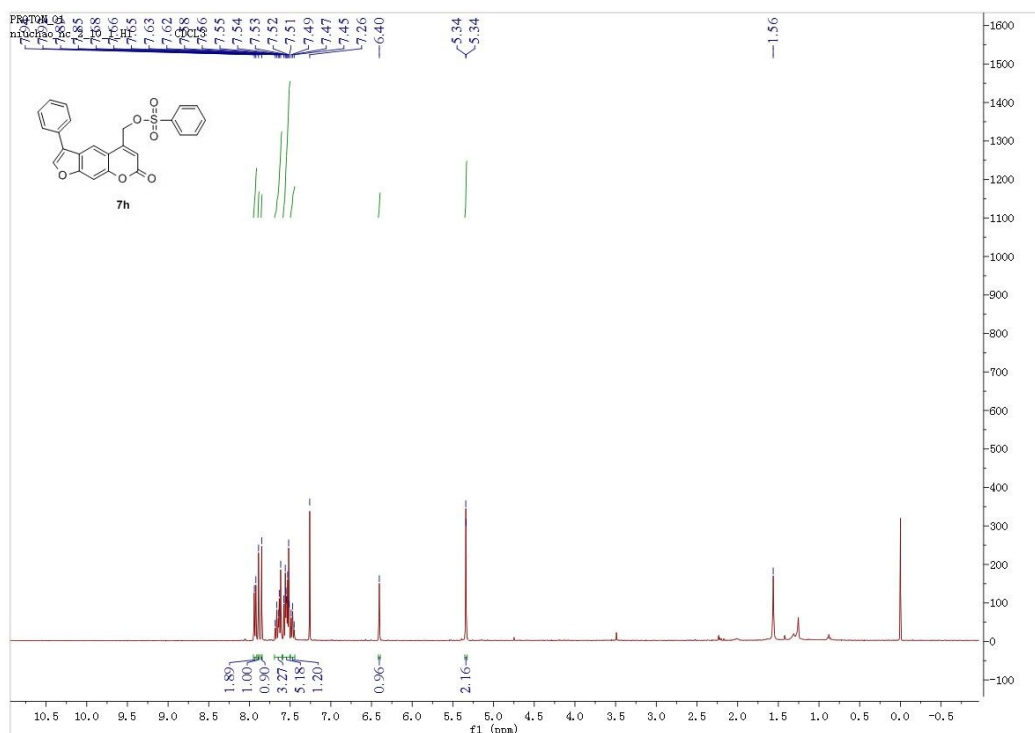


^1H NMR and ^{13}C NMR spectra of **7f**

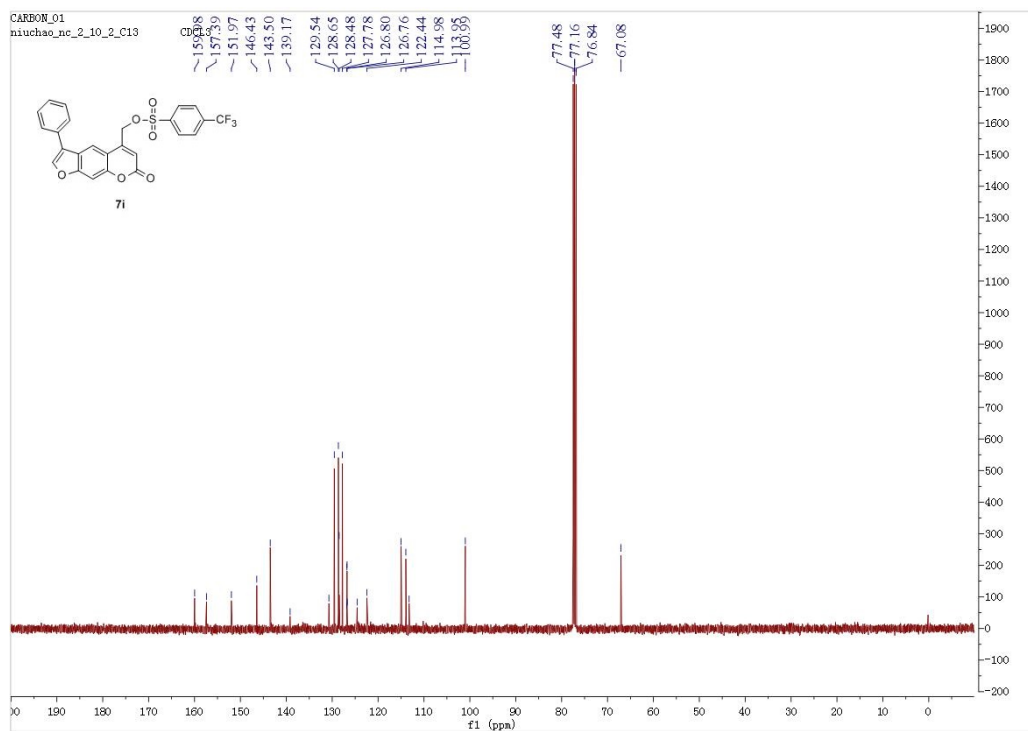
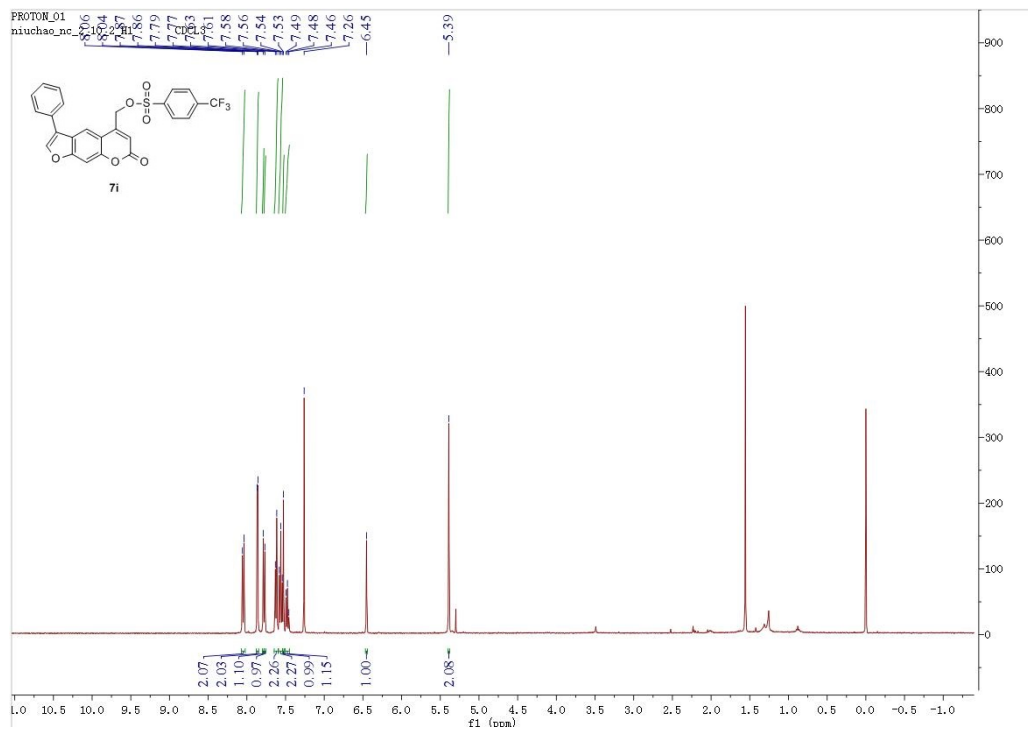
¹H NMR and ¹³C NMR spectra of 7g



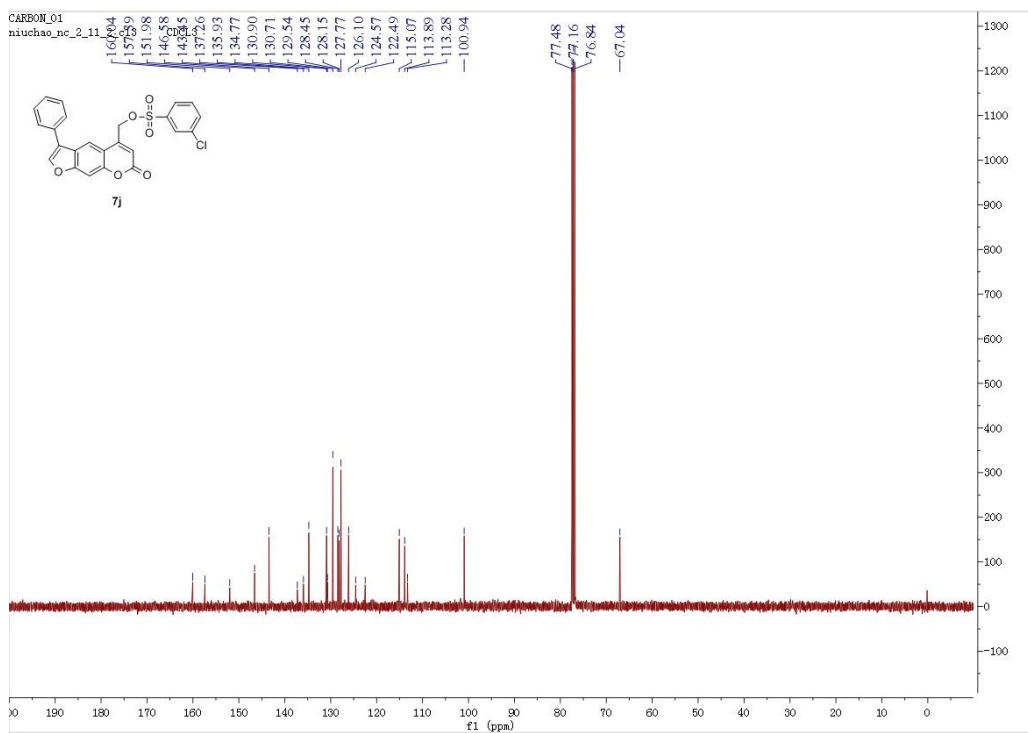
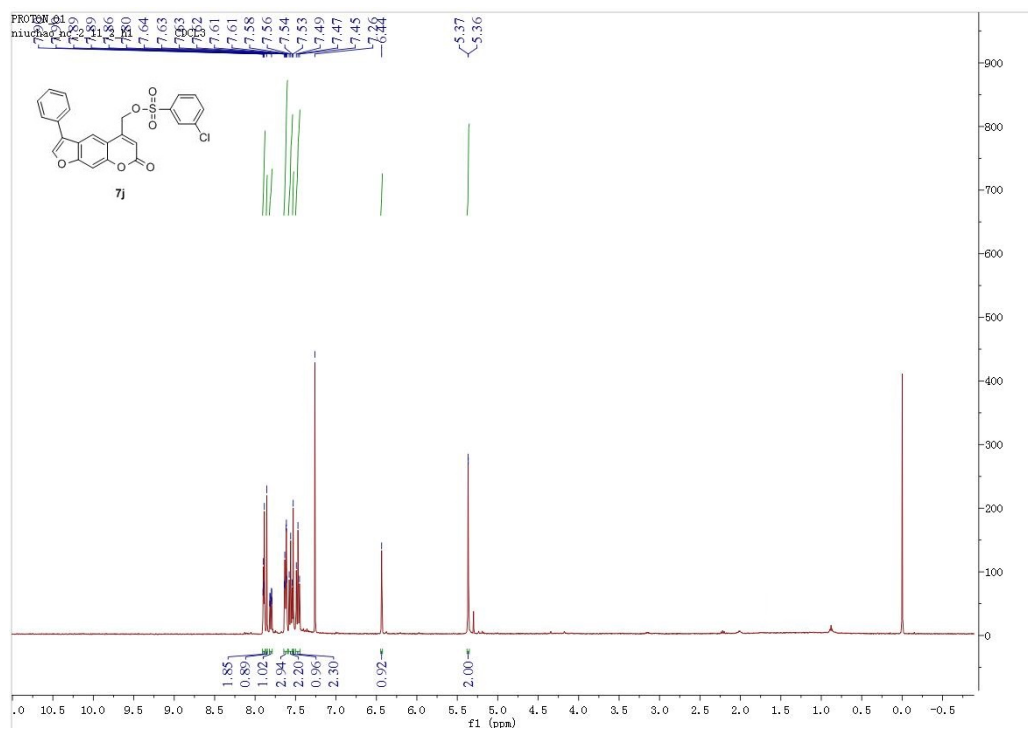
¹H NMR and ¹³C NMR spectra of 7h



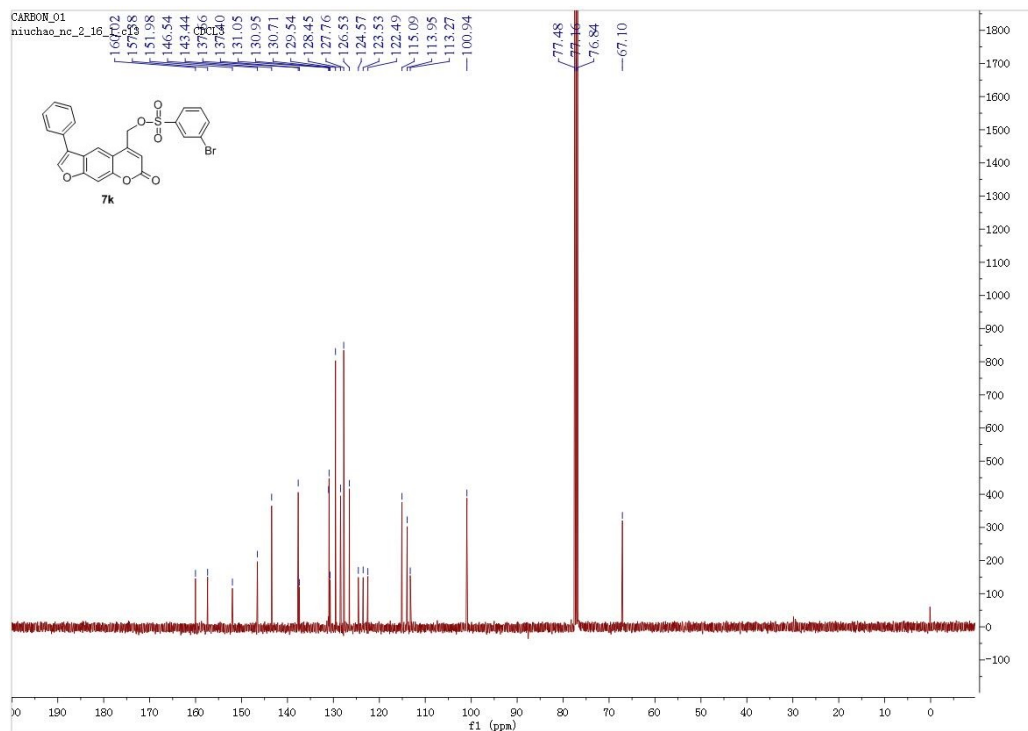
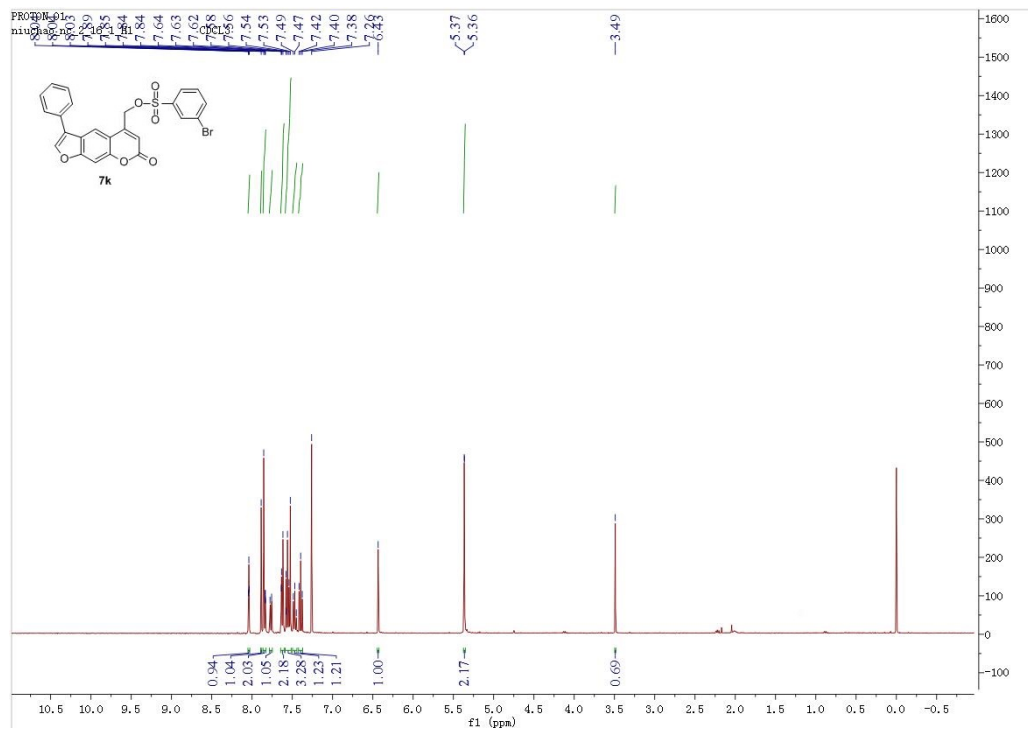
¹H NMR and ¹³C NMR spectra of 7i



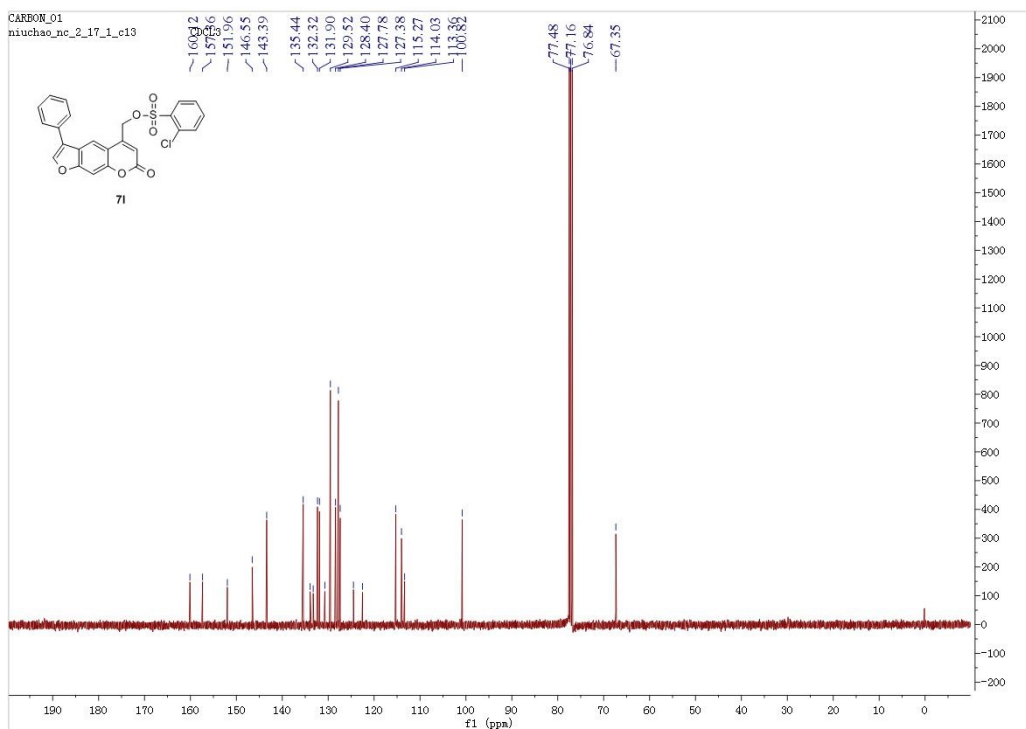
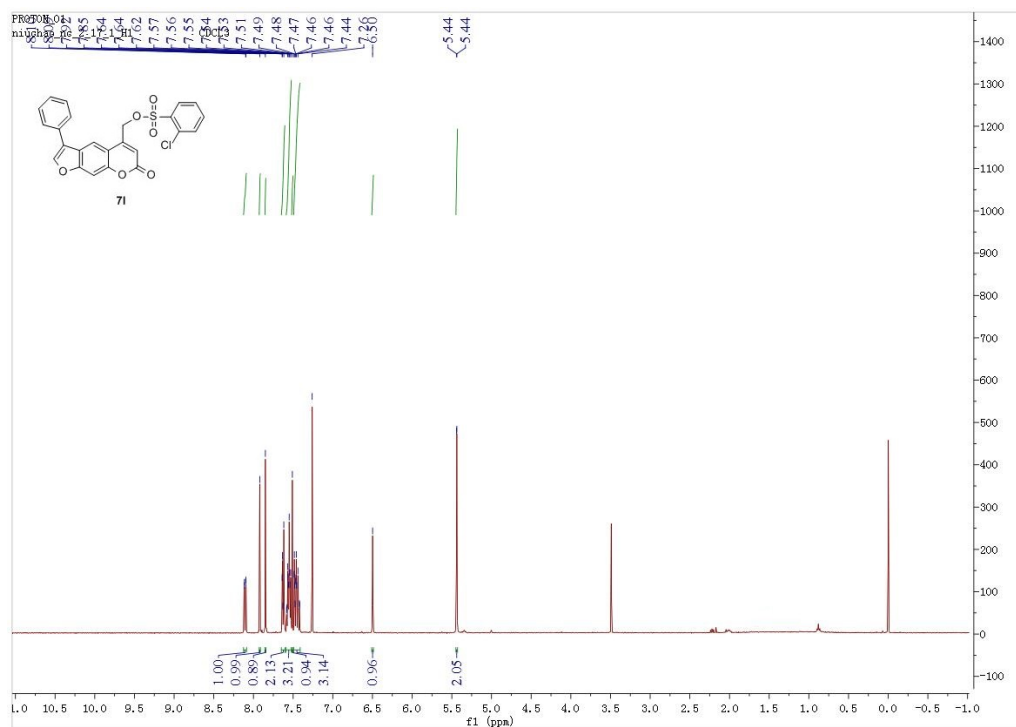
¹H NMR and ¹³C NMR spectra of 7j



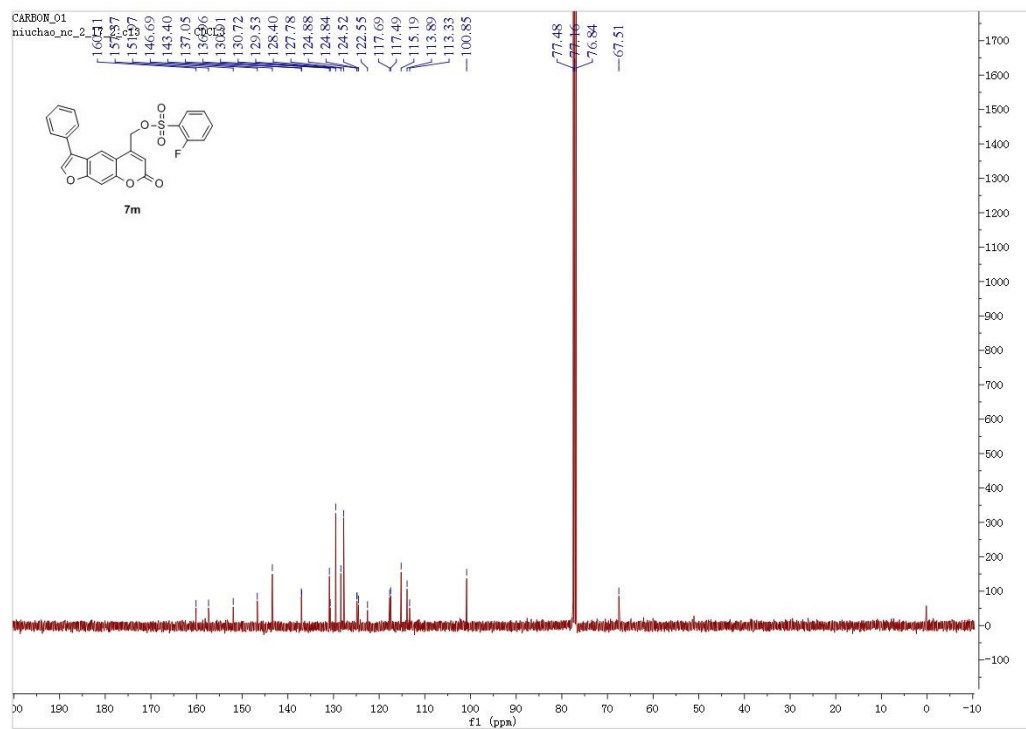
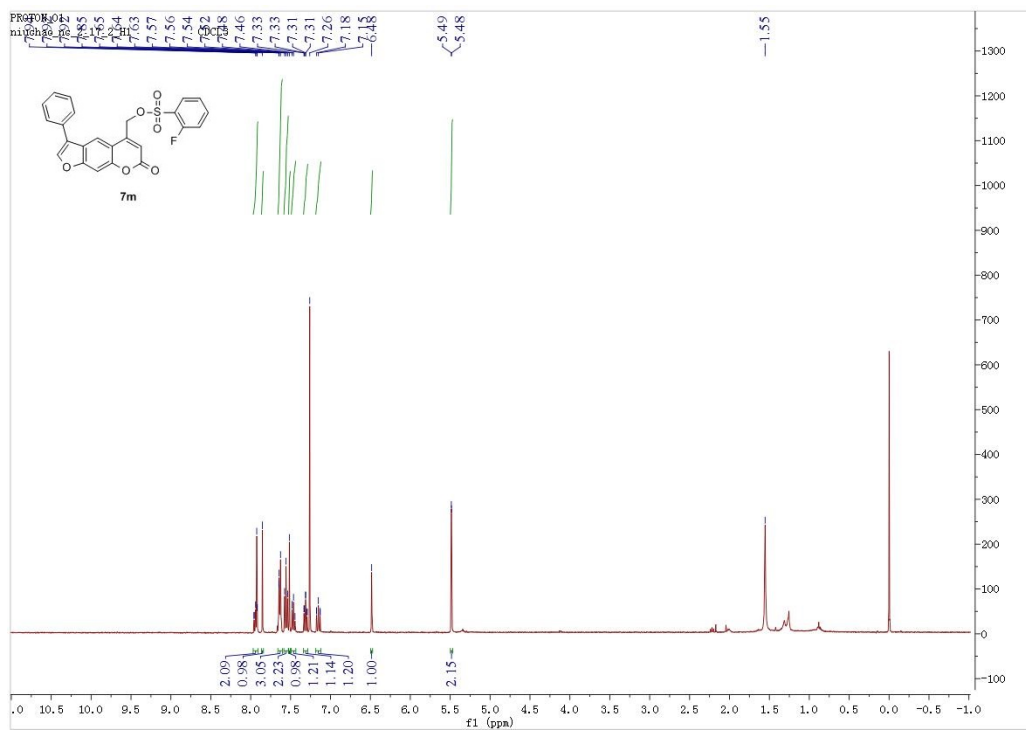
¹H NMR and ¹³C NMR spectra of 7k



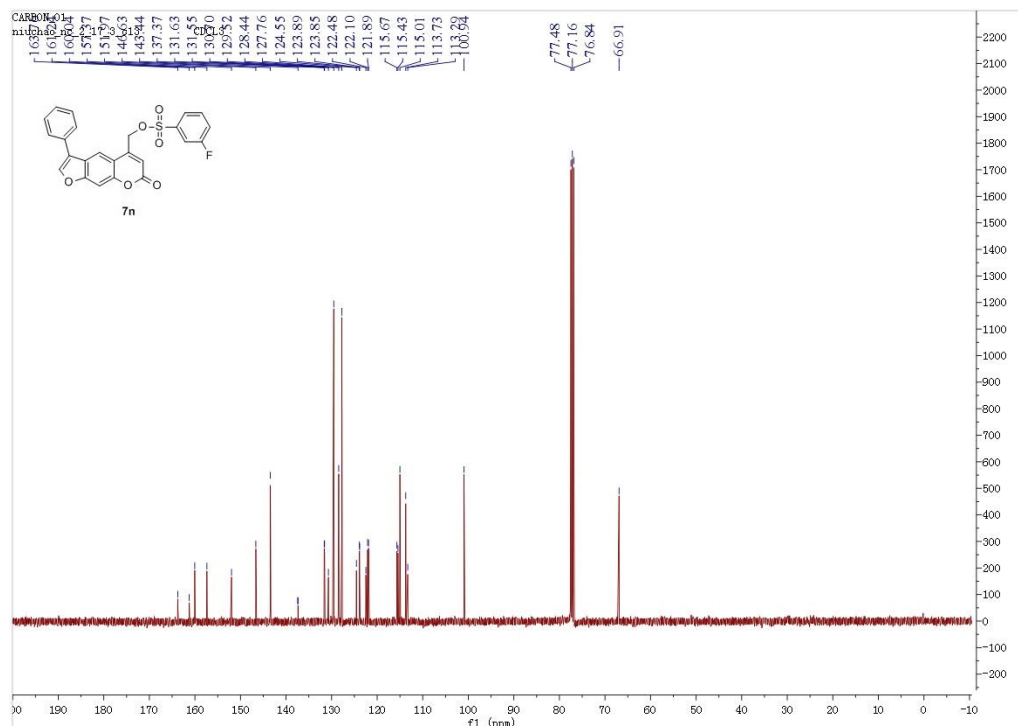
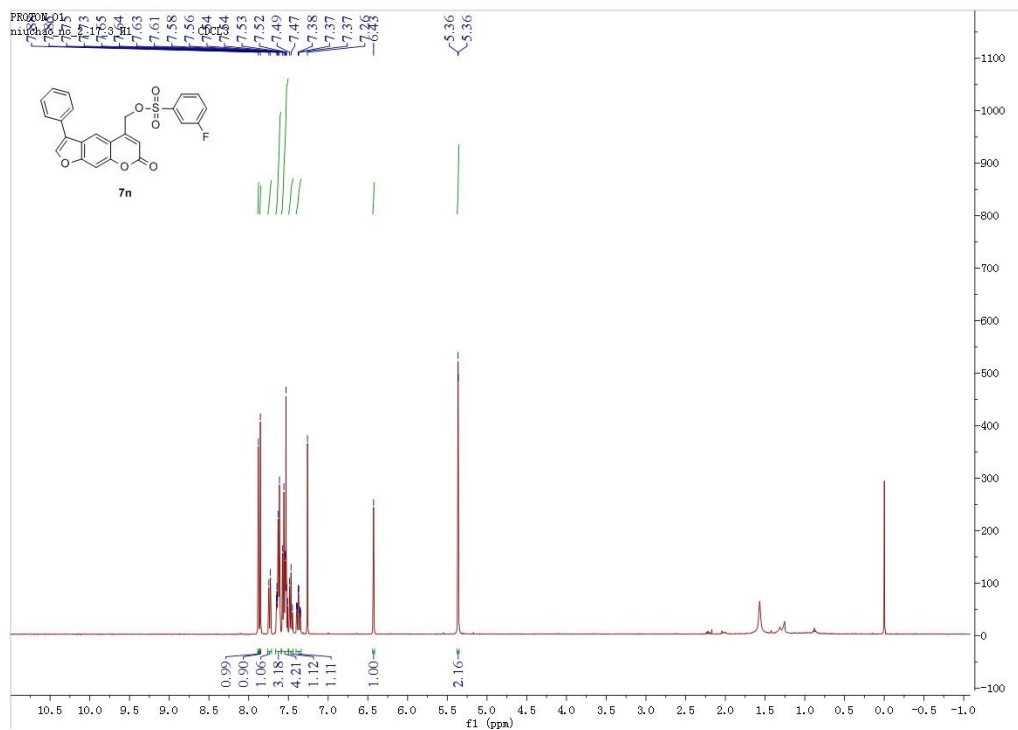
¹H NMR and ¹³C NMR spectra of 71

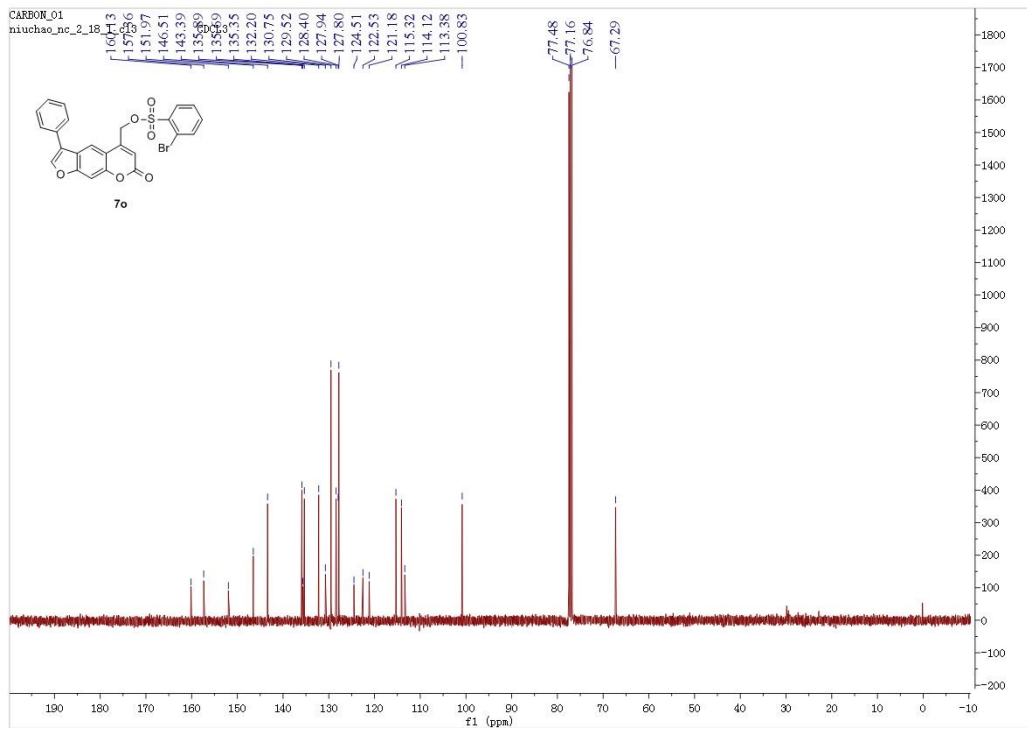
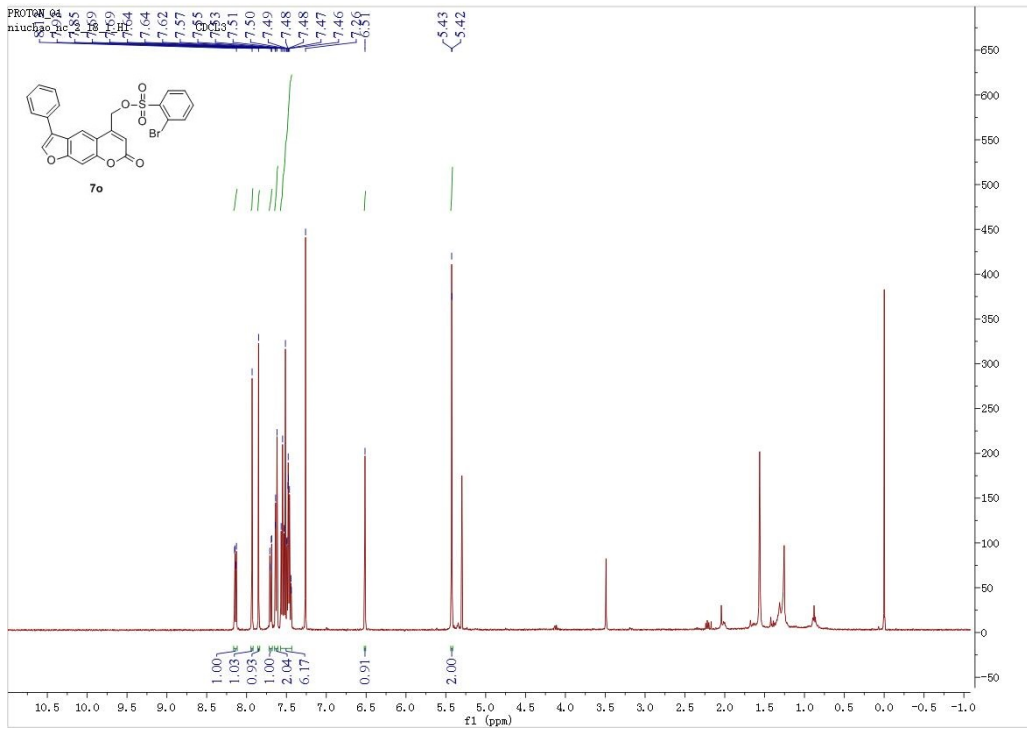


^1H NMR and ^{13}C NMR spectra of **7m**

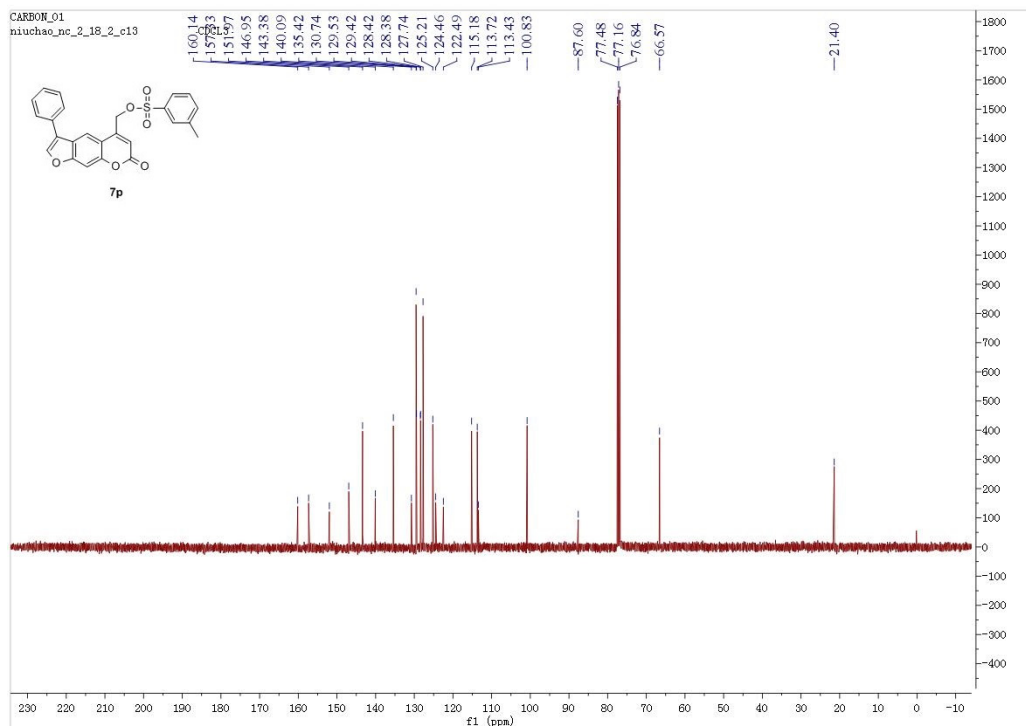
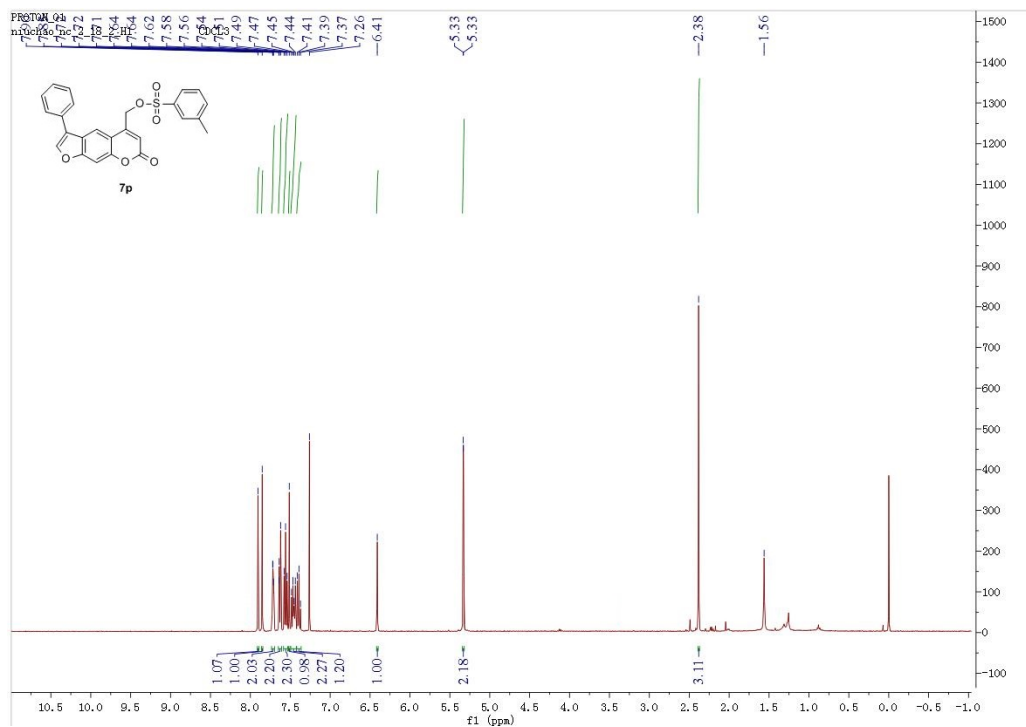


¹H NMR and ¹³C NMR spectra of **7n**

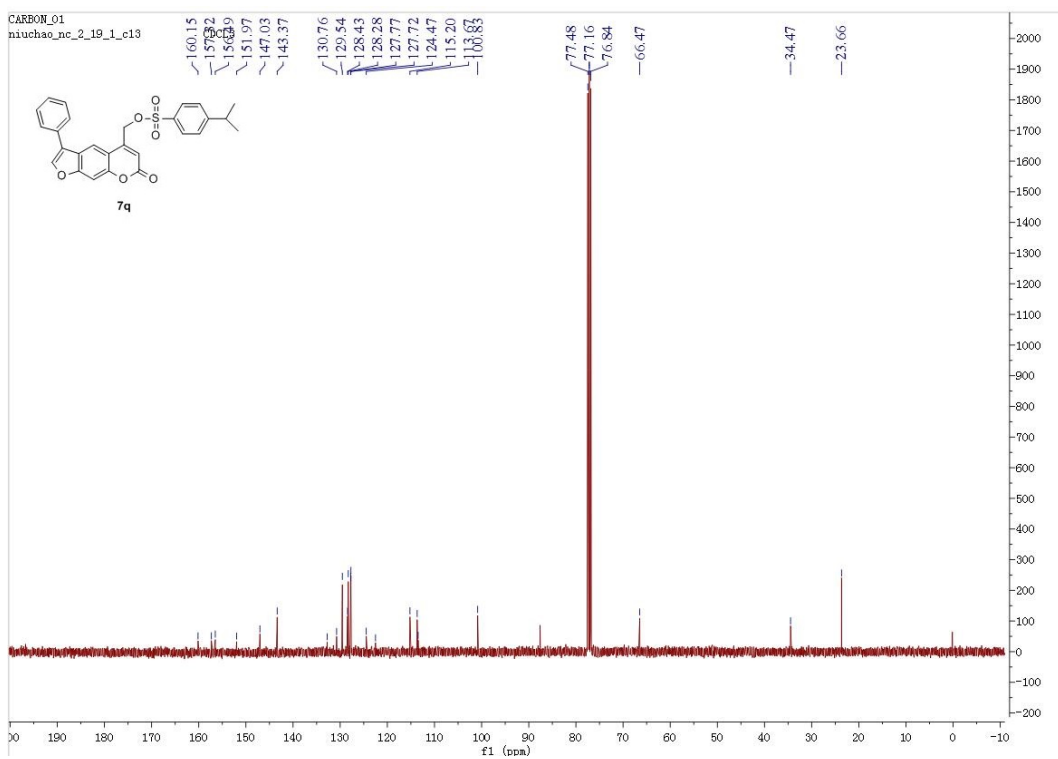
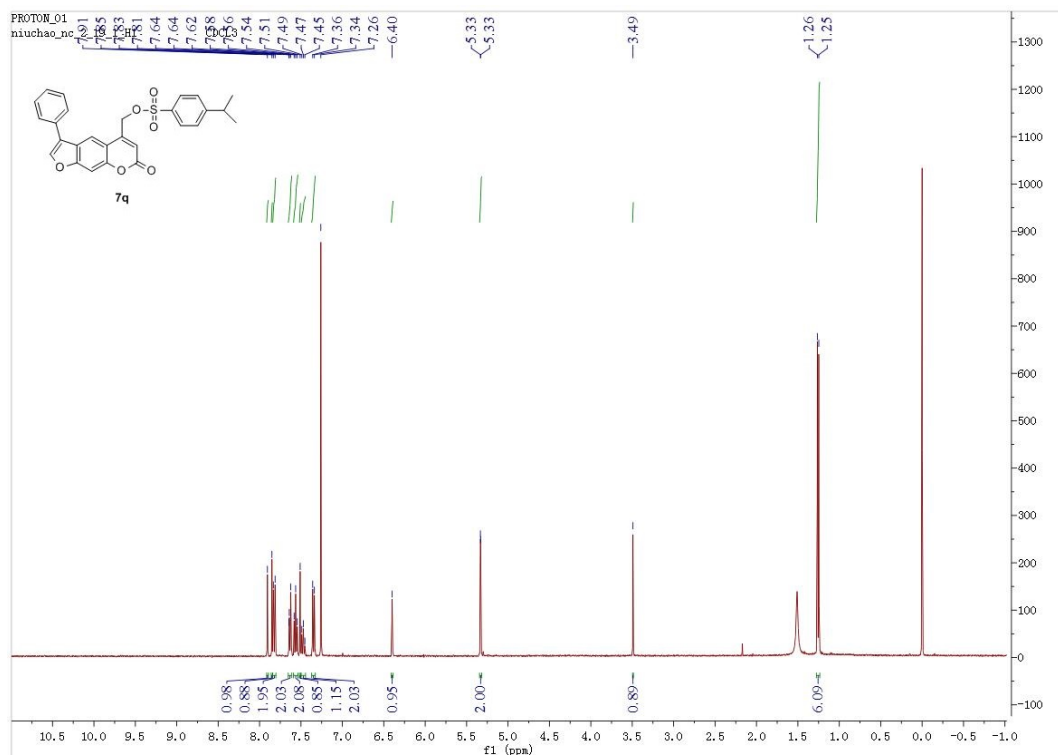


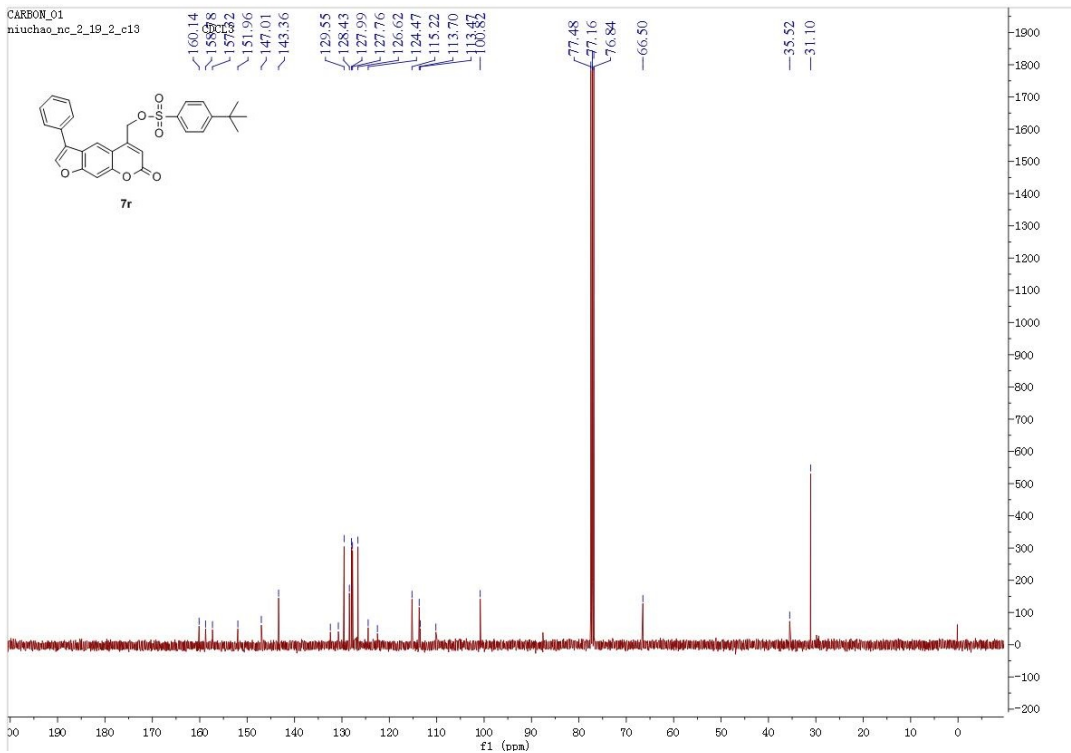
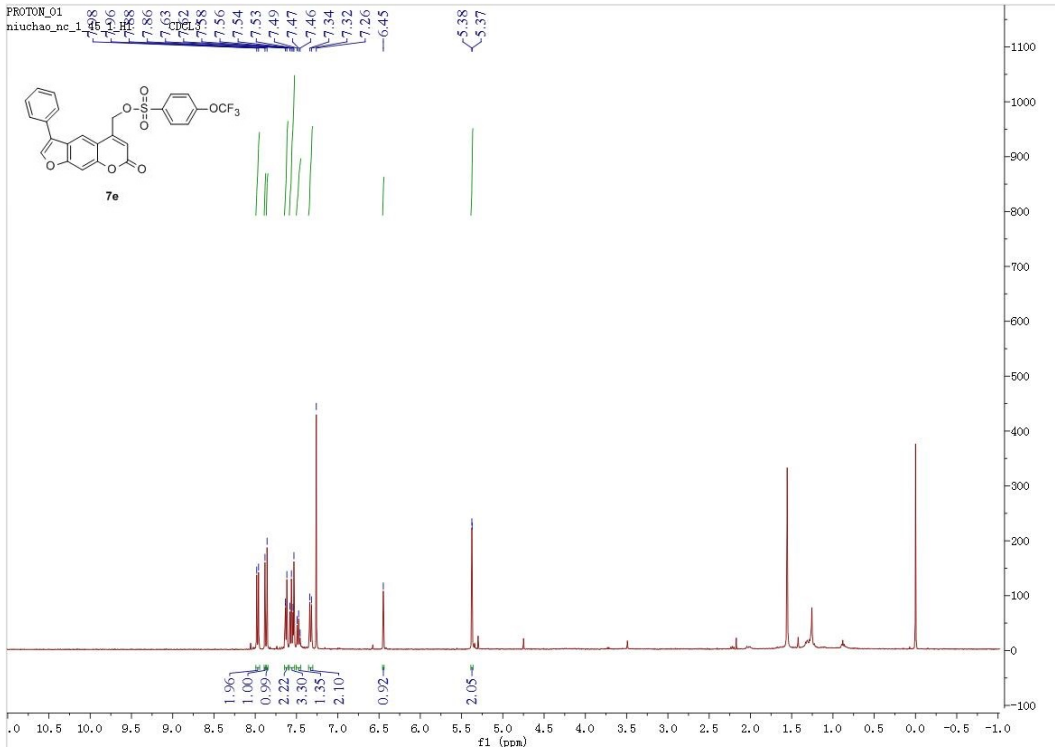
^1H NMR and ^{13}C NMR spectra of **7o**

¹H NMR and ¹³C NMR spectra of 7p

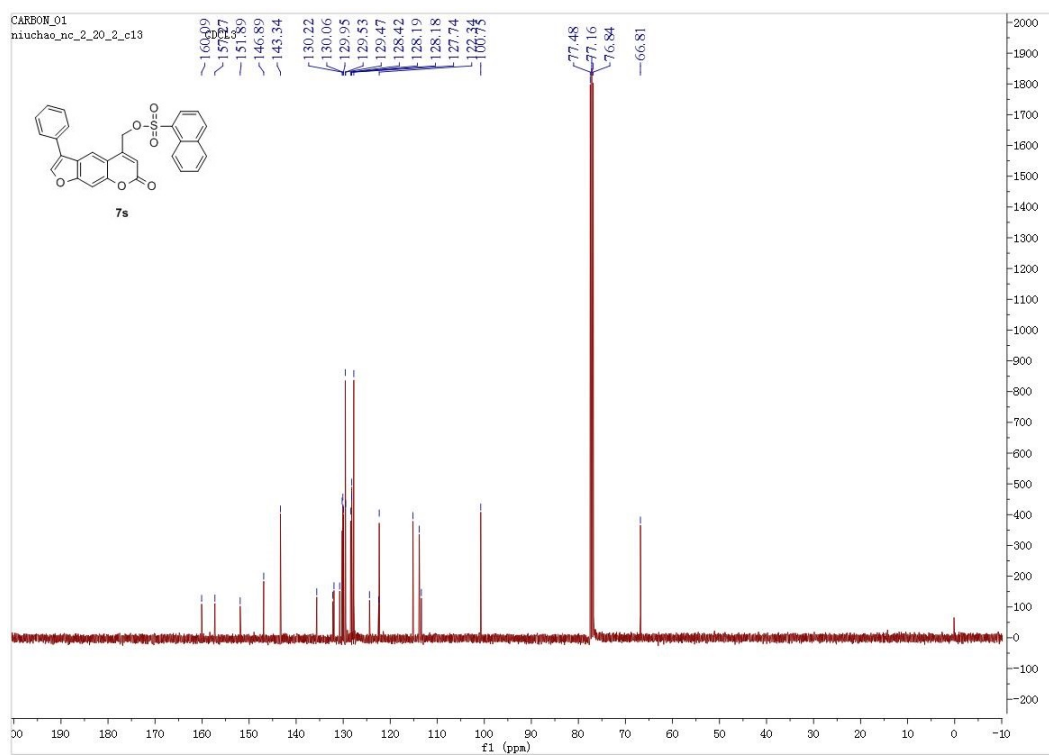
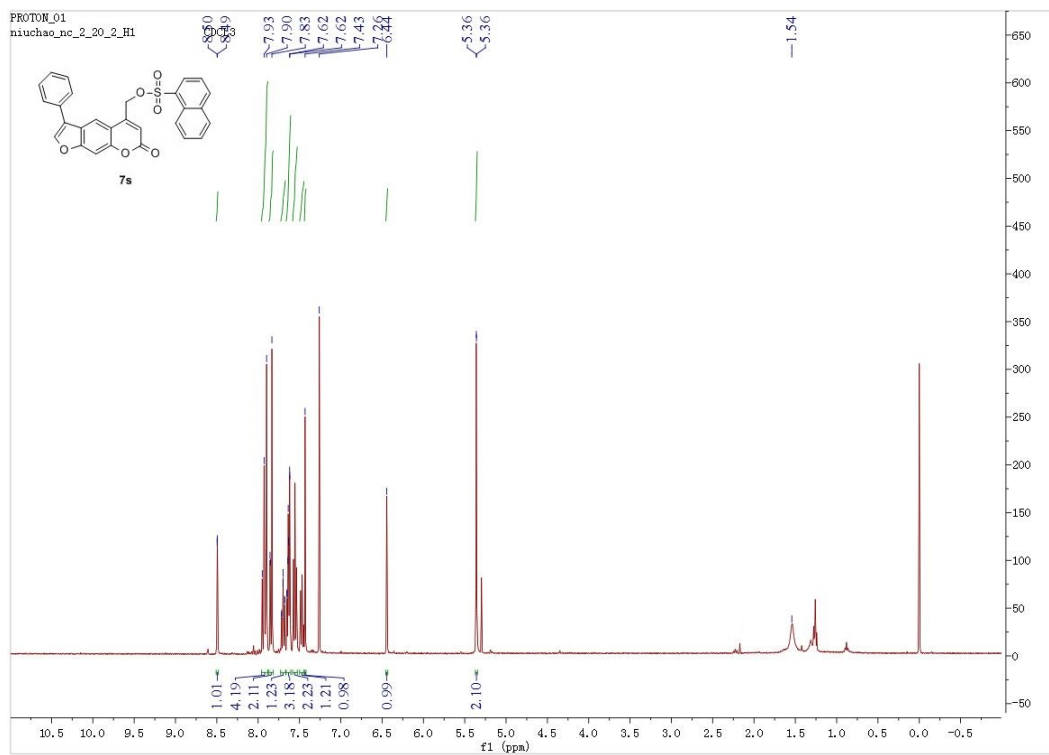


¹H NMR and ¹³C NMR spectra of 7q

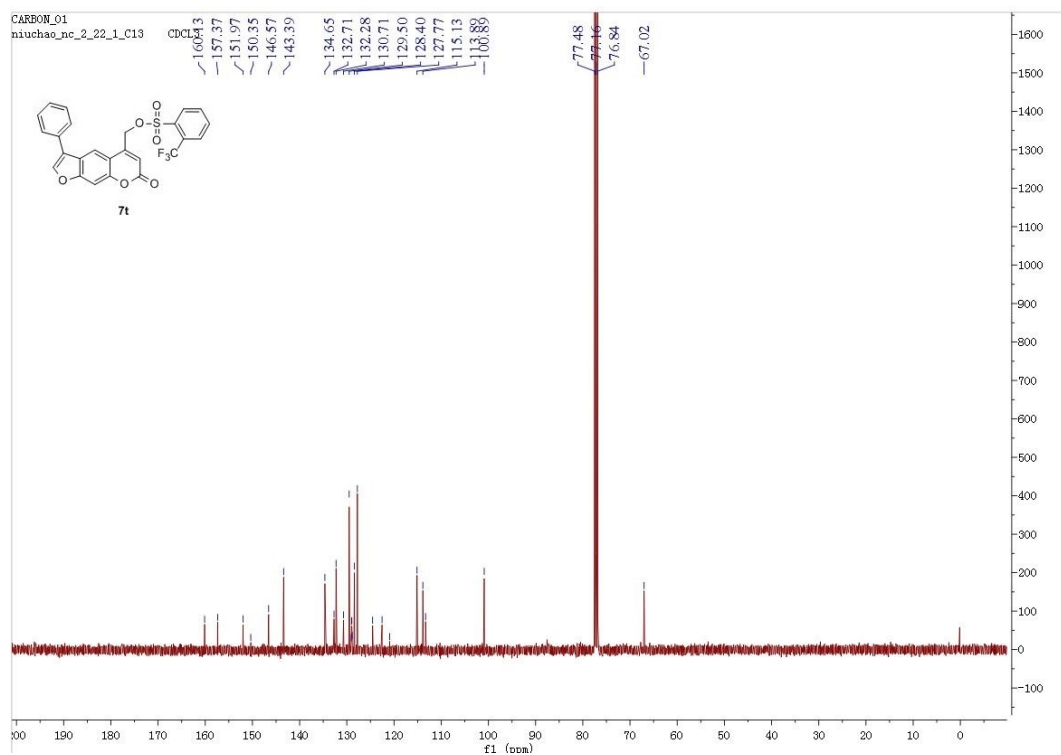
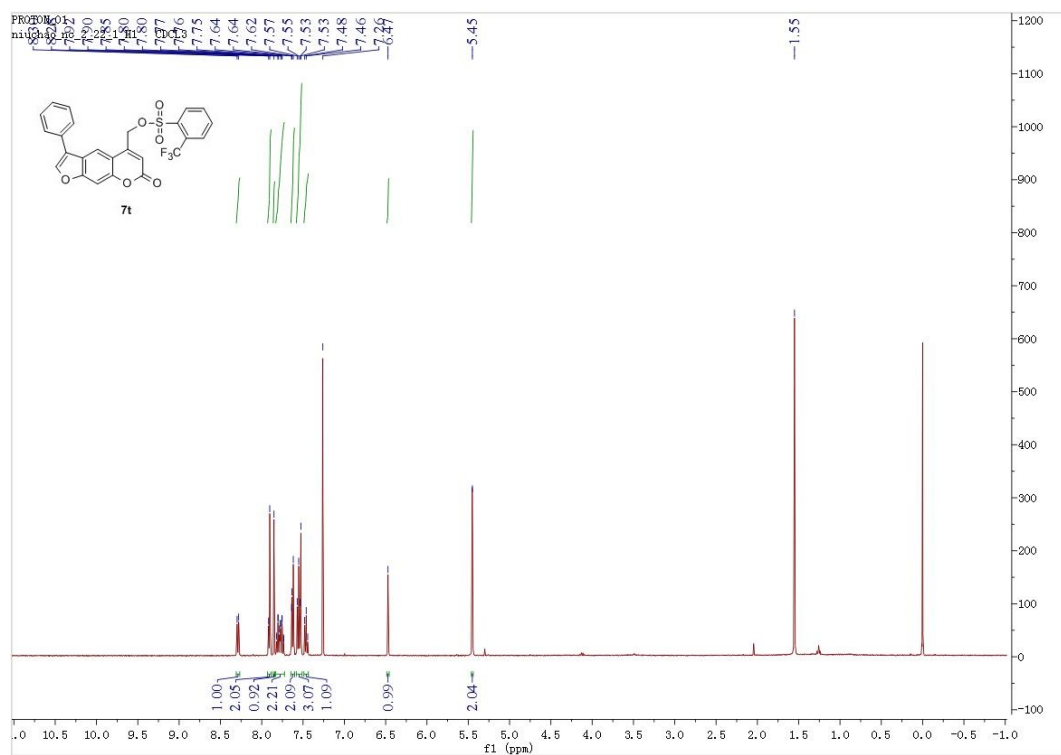


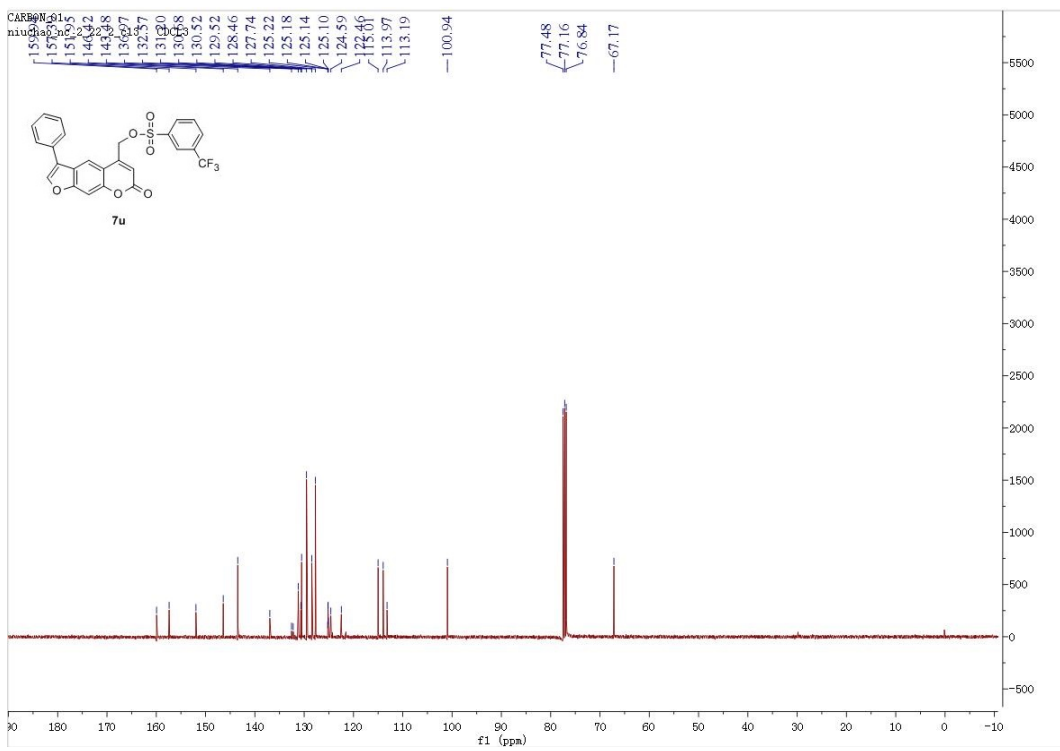
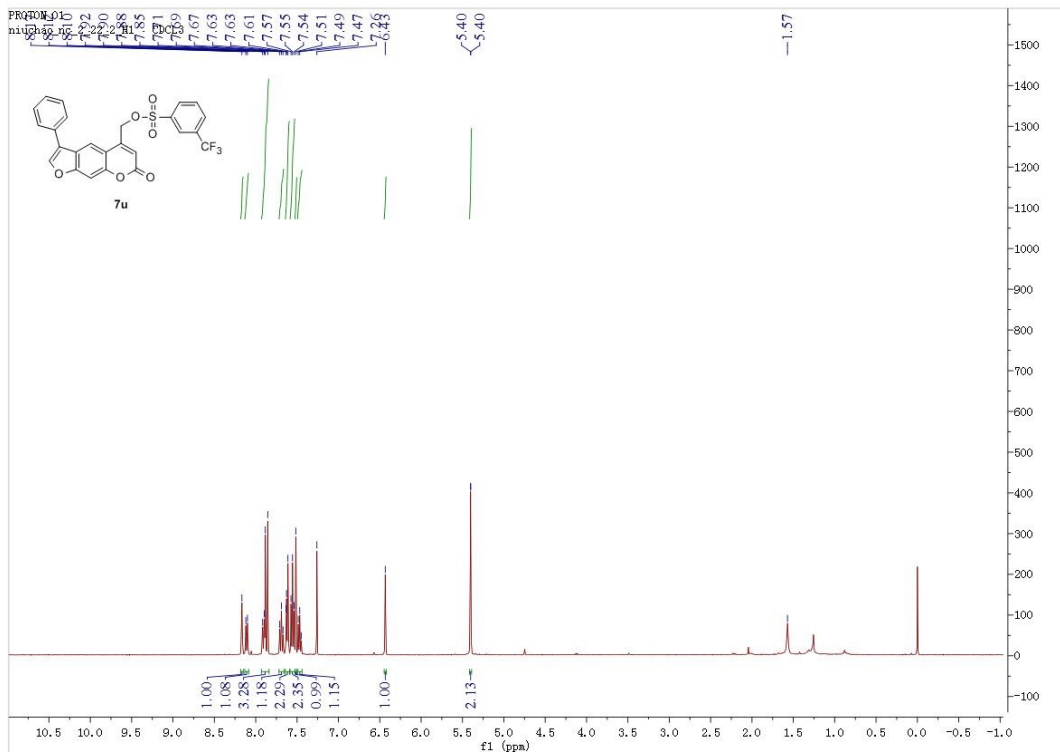
¹H NMR and ¹³C NMR spectra of **7r**

^1H NMR and ^{13}C NMR spectra of **7s**

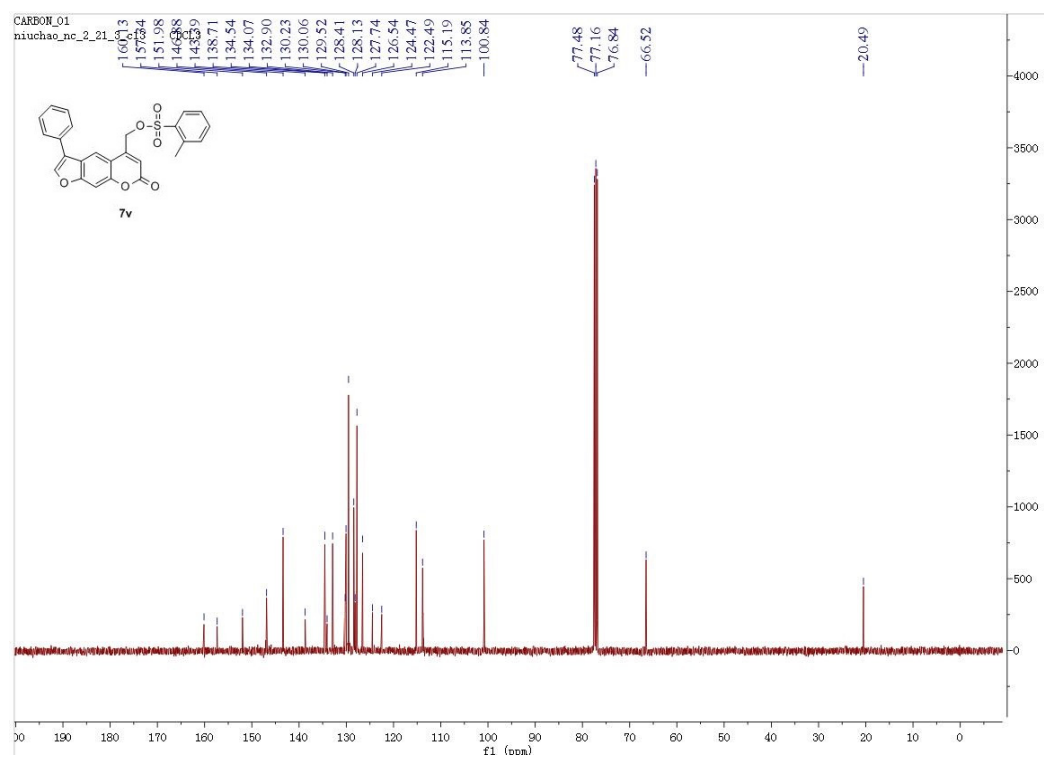
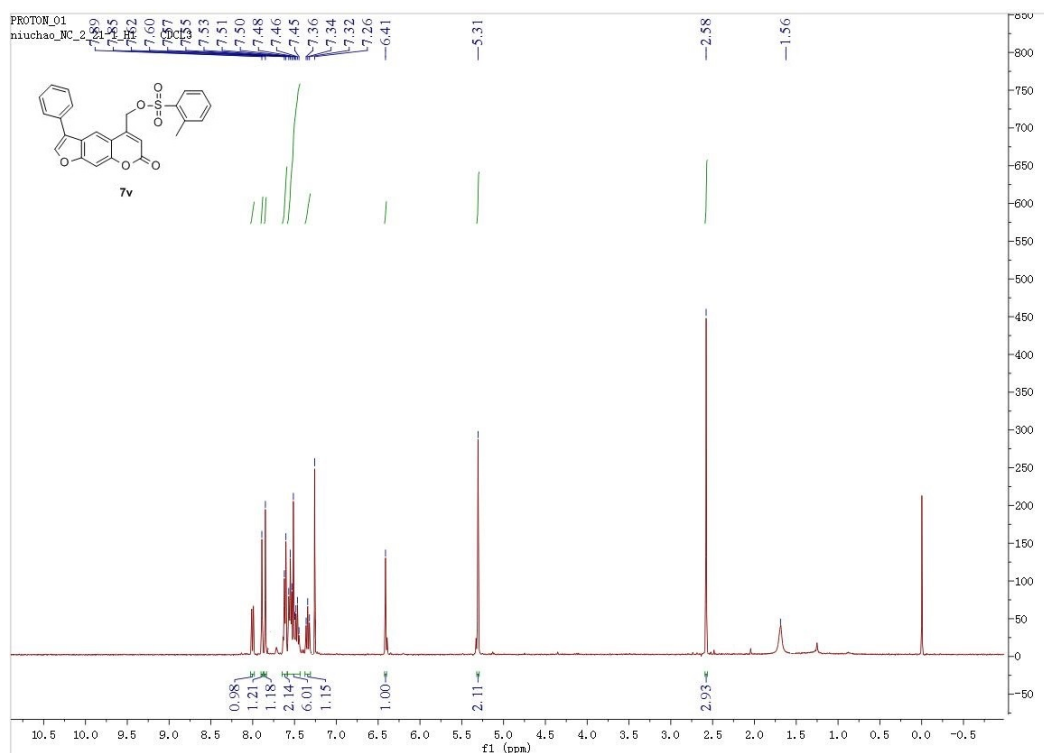


¹H NMR and ¹³C NMR spectra of 7t

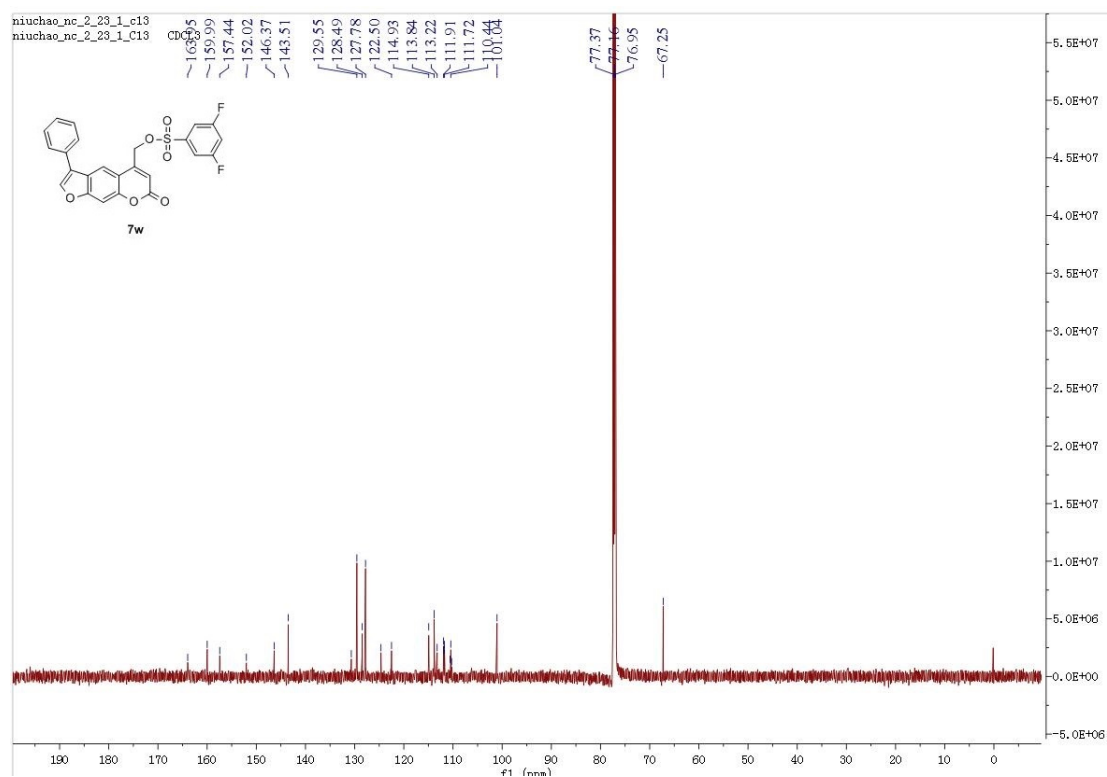
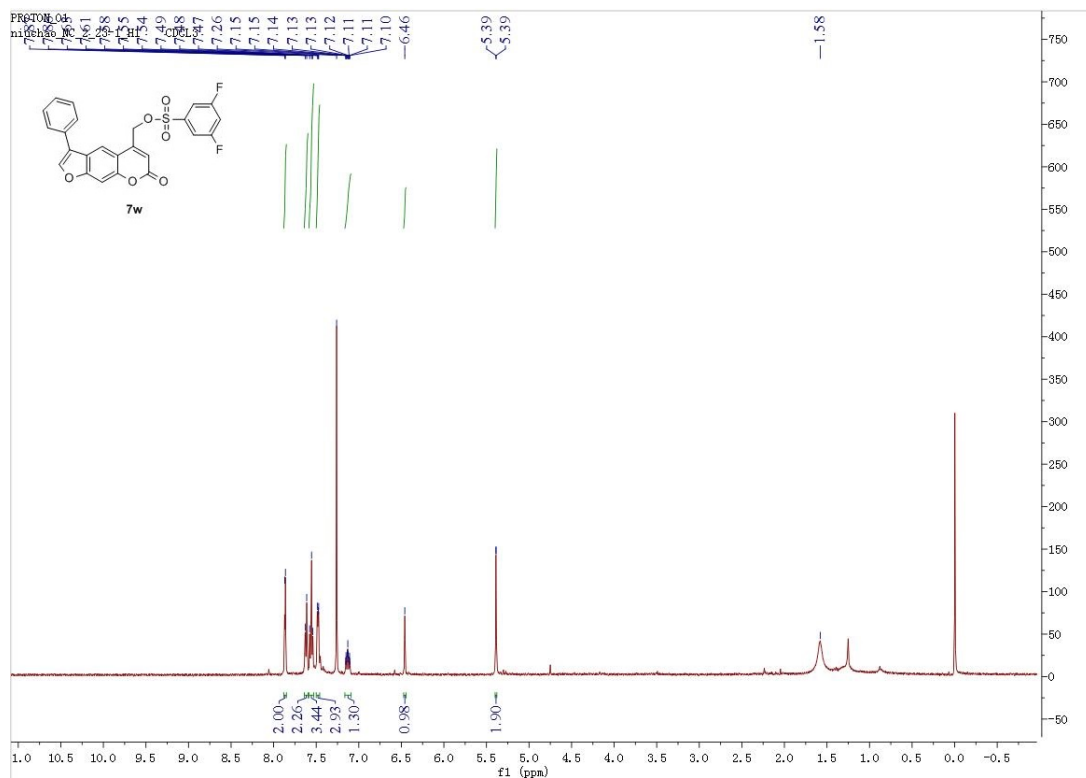


¹H NMR and ¹³C NMR spectra of **7u**

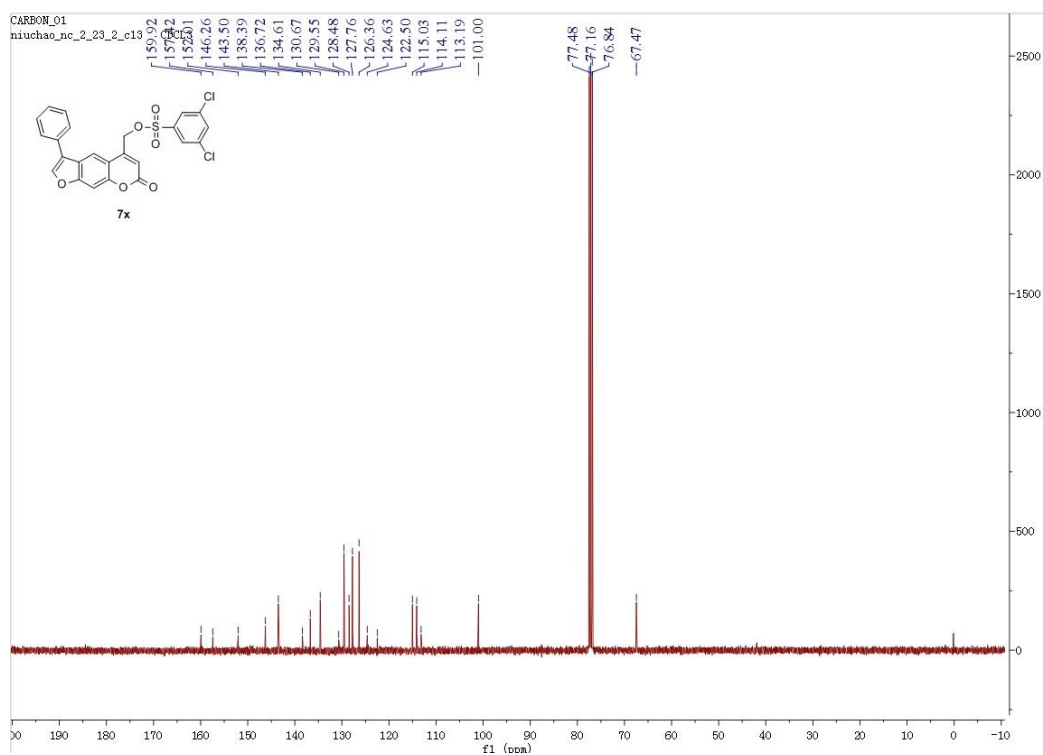
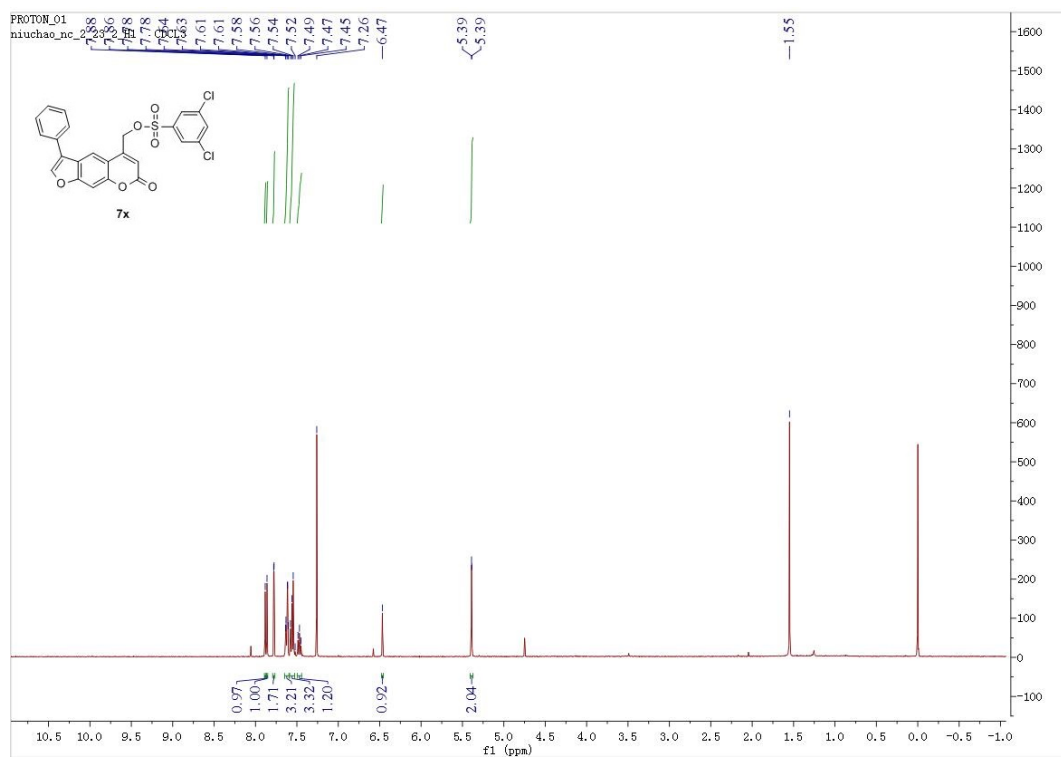
¹H NMR and ¹³C NMR spectra of 7v



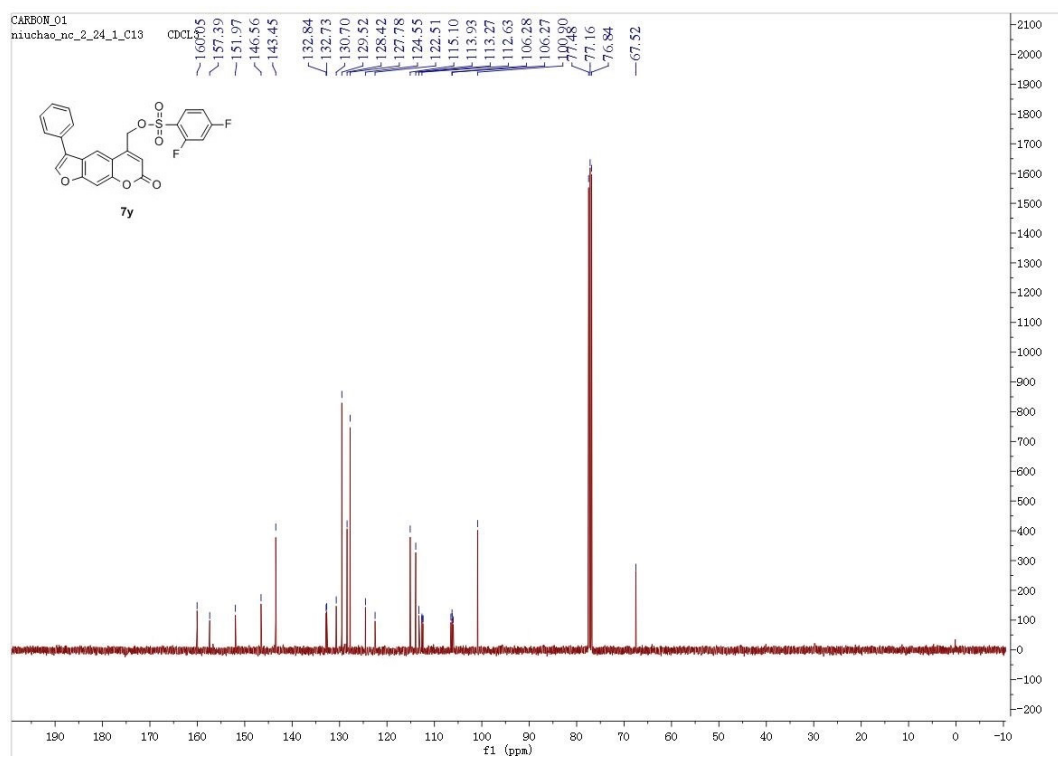
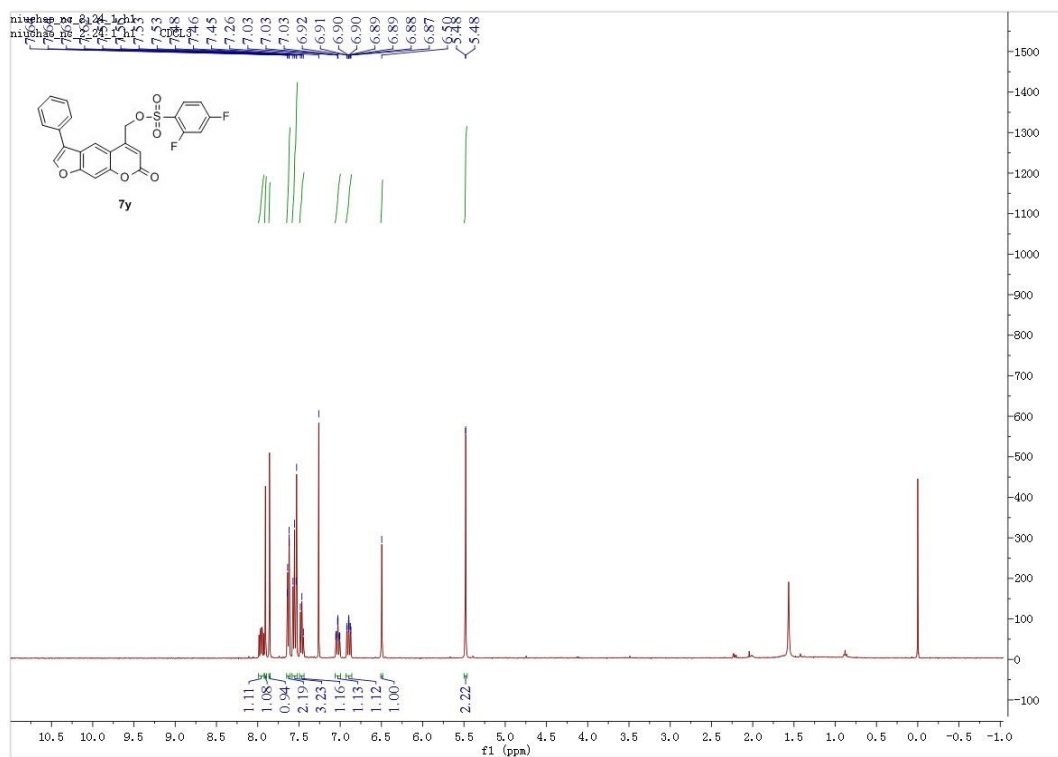
^1H NMR and ^{13}C NMR spectra of **7w**



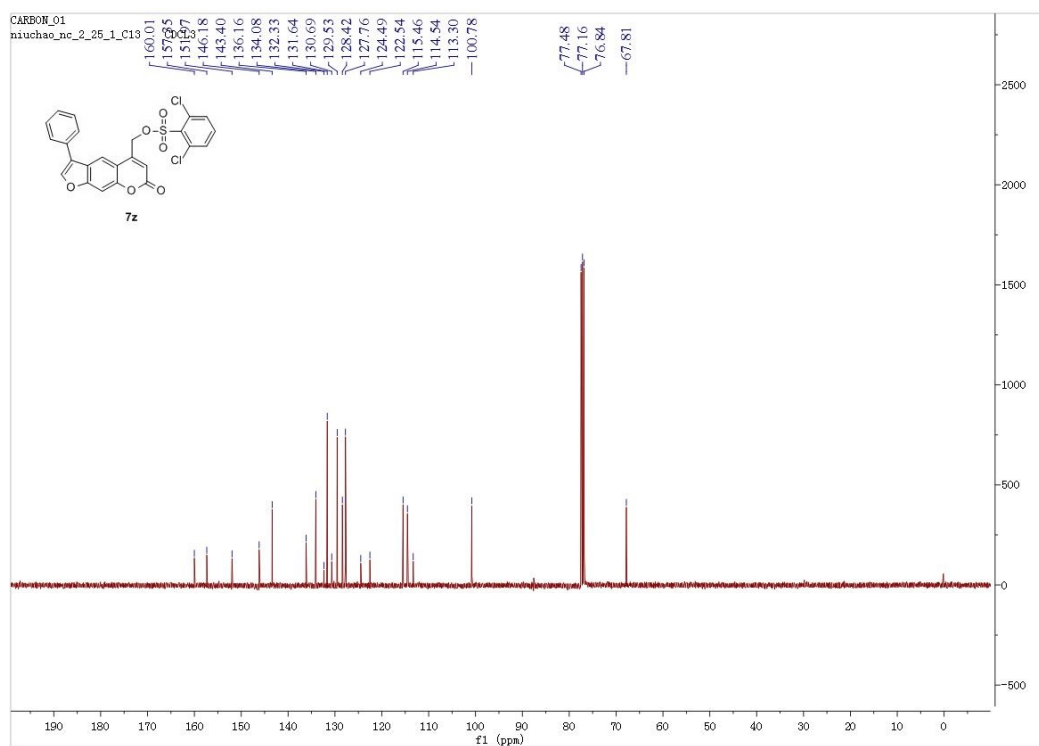
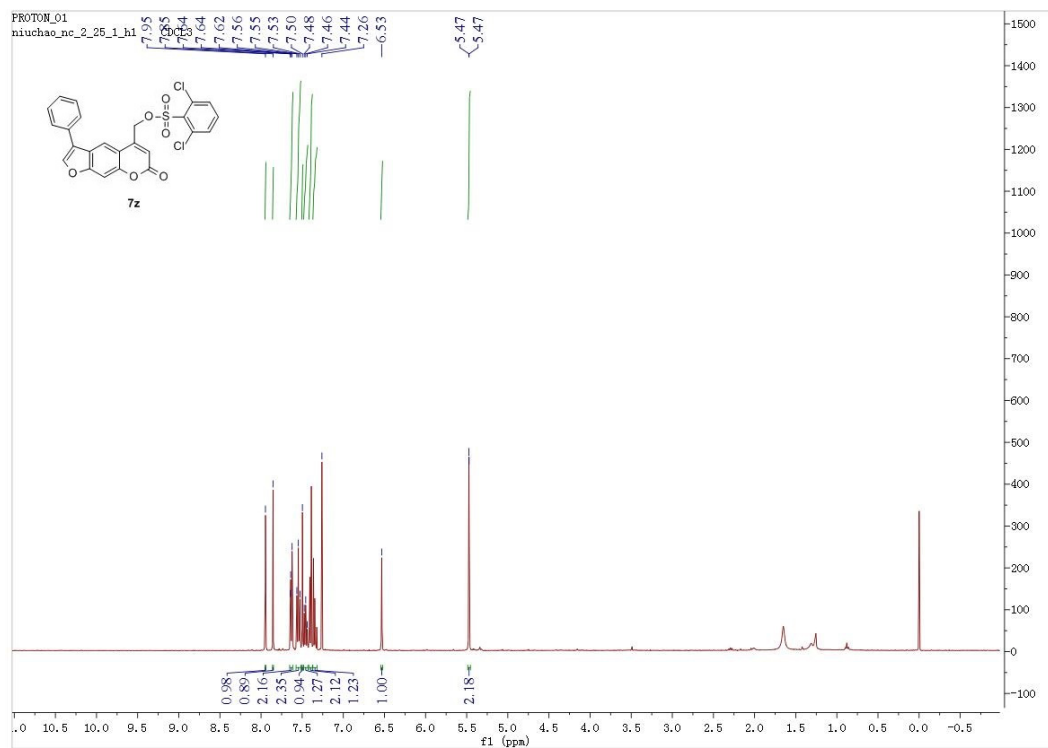
¹H NMR and ¹³C NMR spectra of 7x



¹H NMR and ¹³C NMR spectra of 7y

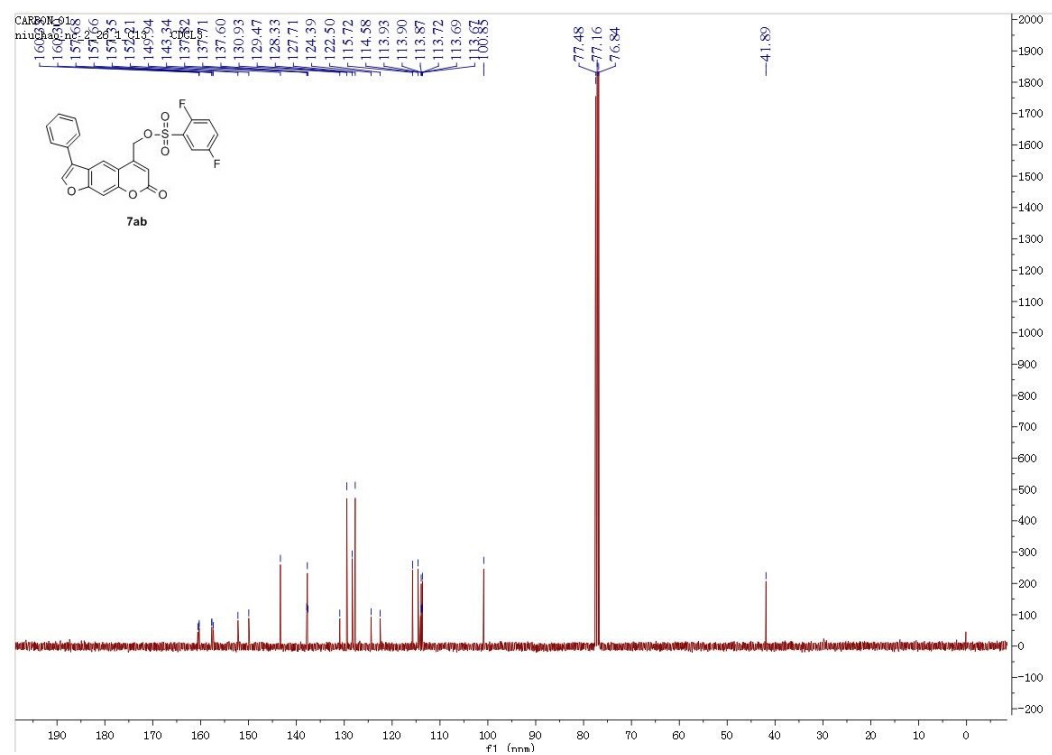
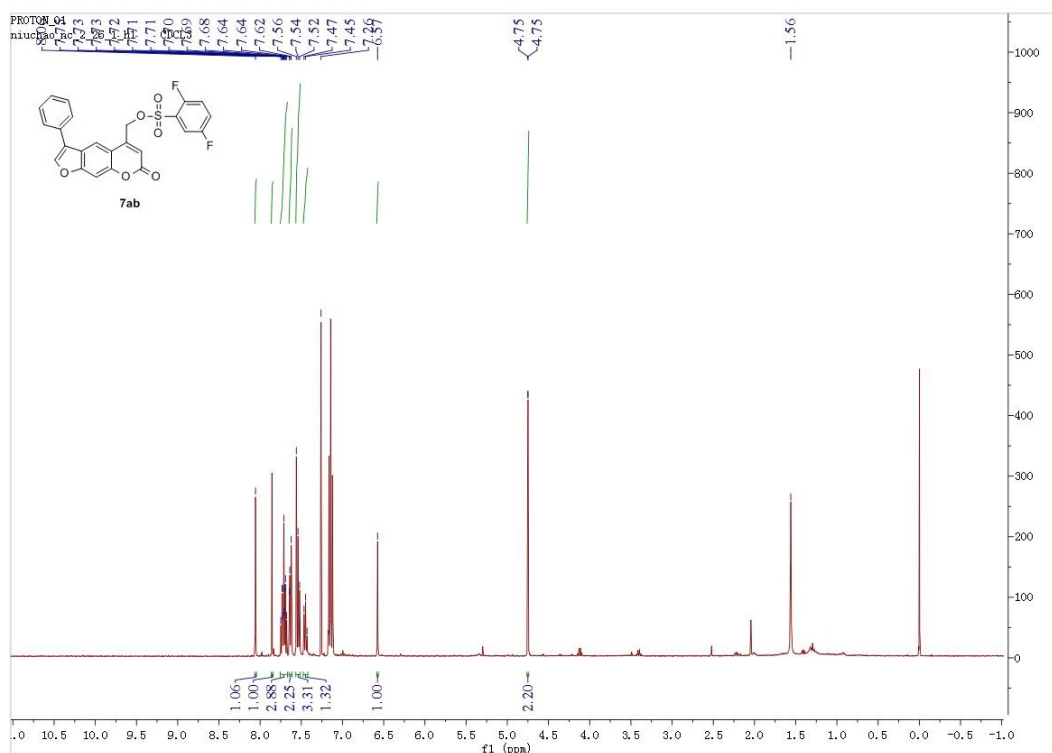


¹H NMR and ¹³C NMR spectra of 7z

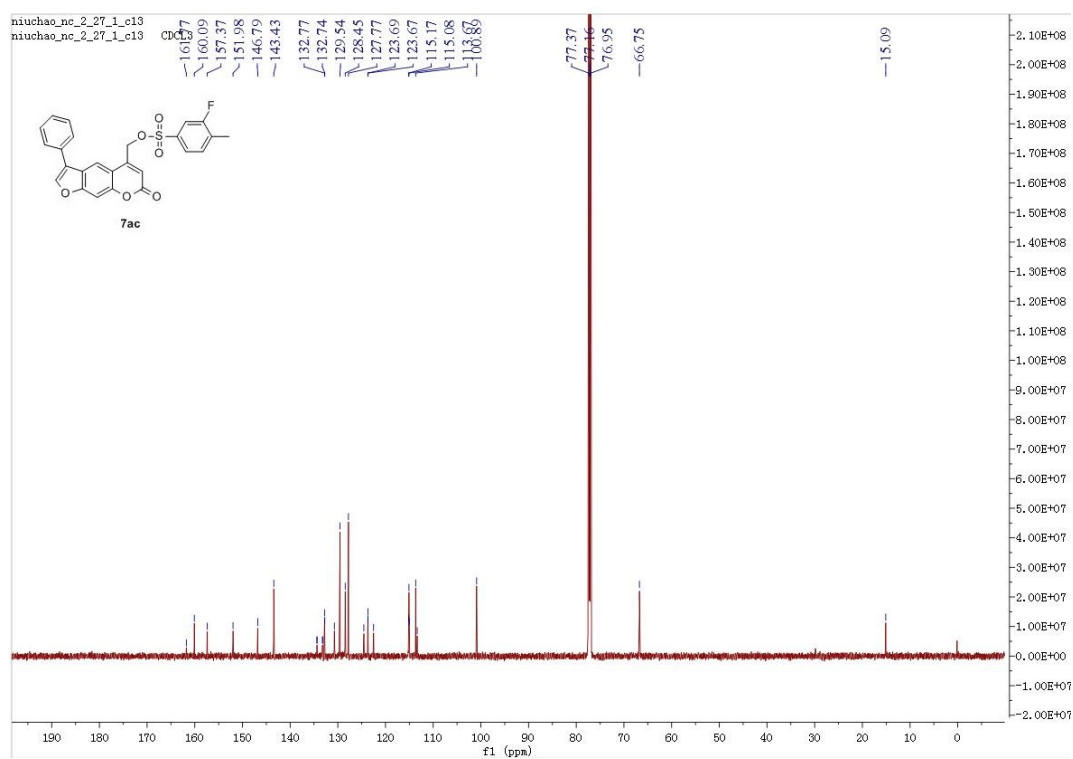
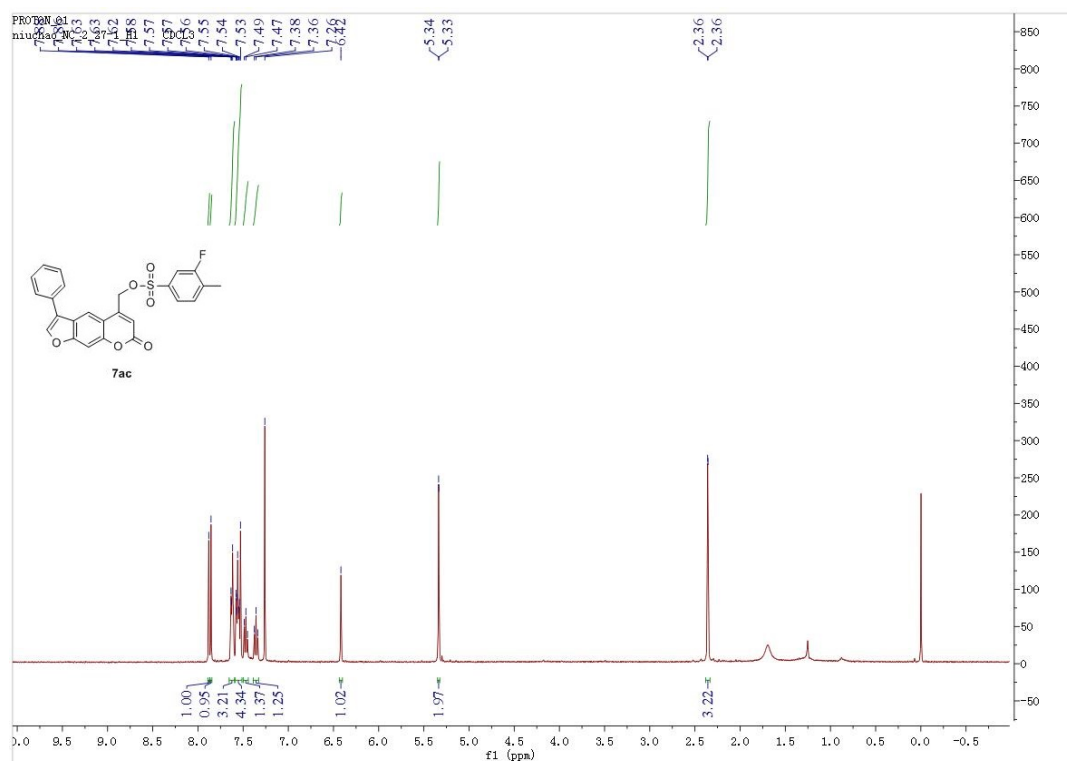


[illegible]

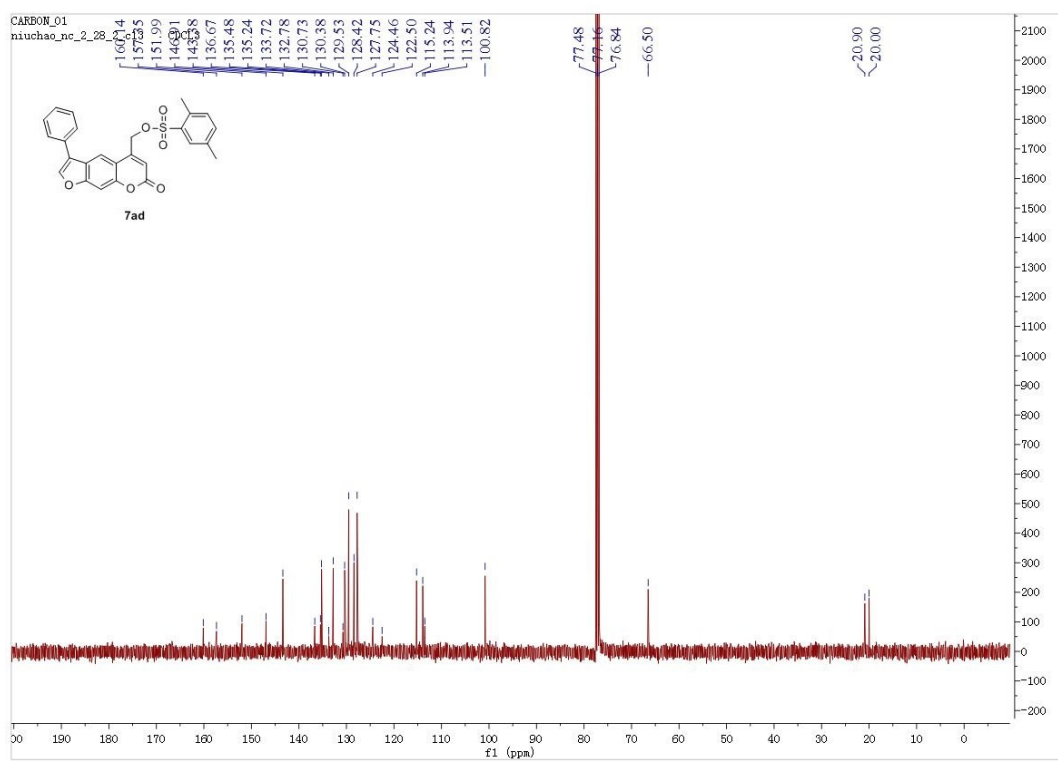
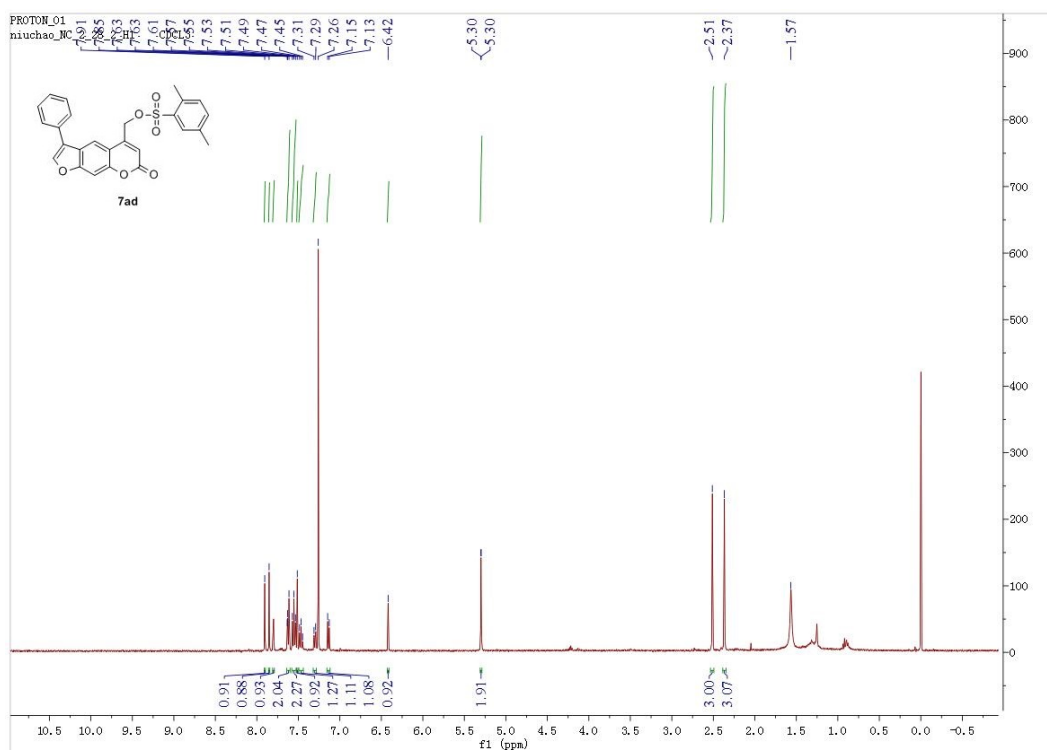
¹H NMR and ¹³C NMR spectra of 7ab



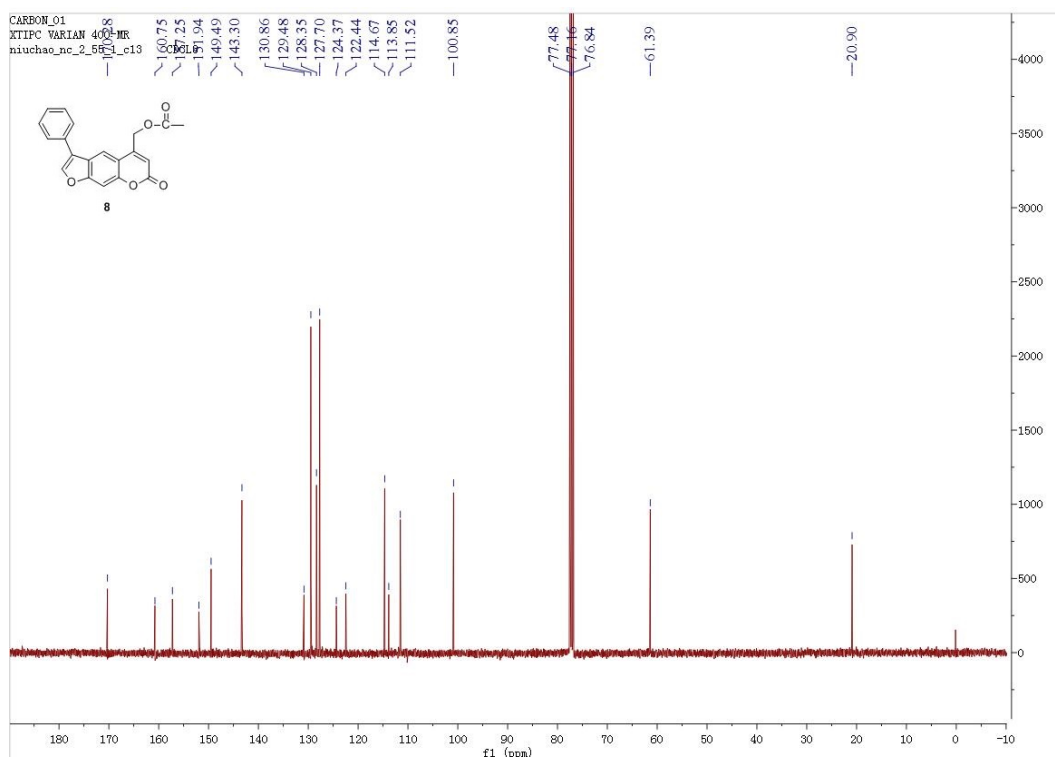
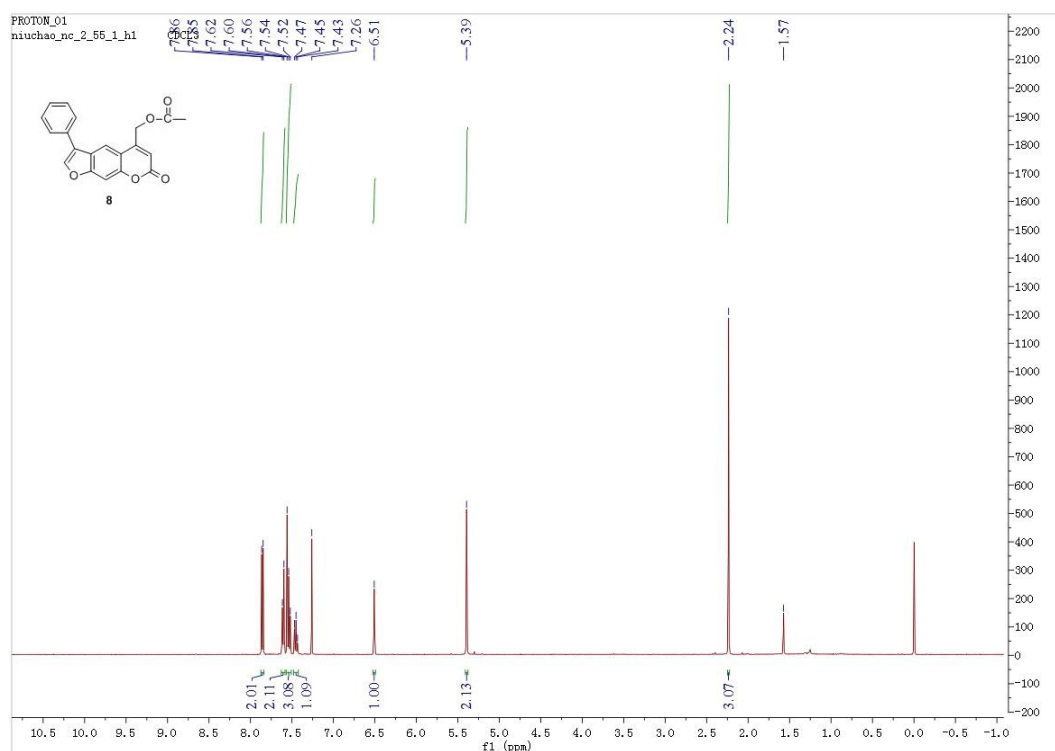
¹H NMR and ¹³C NMR spectra of 7ac

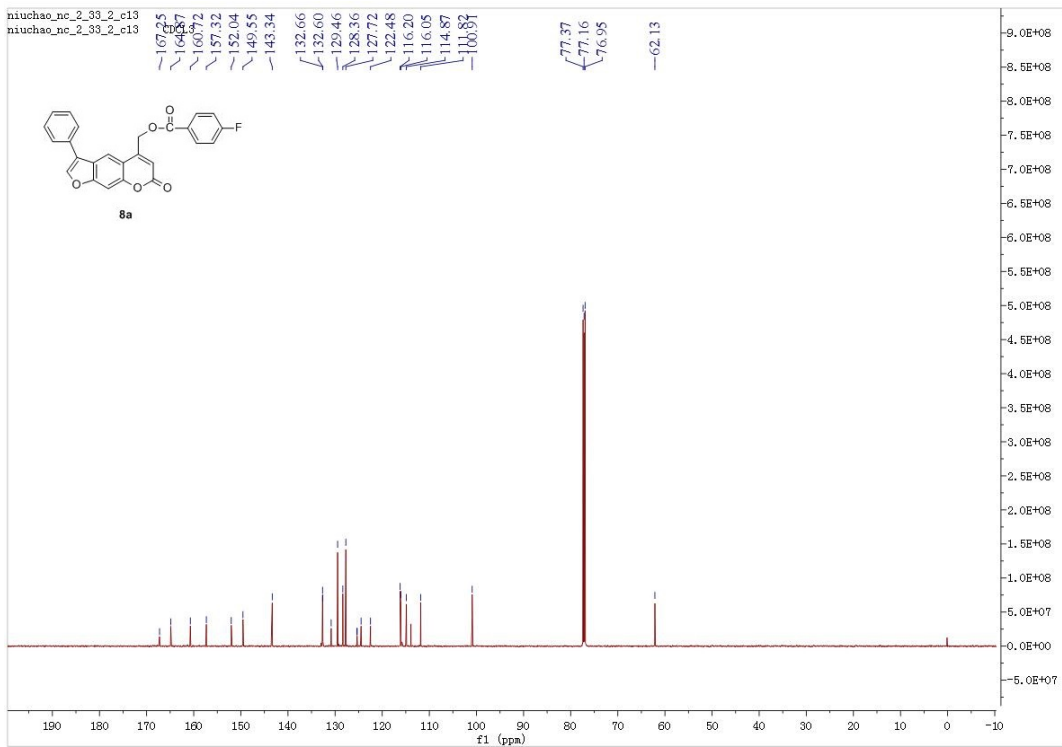
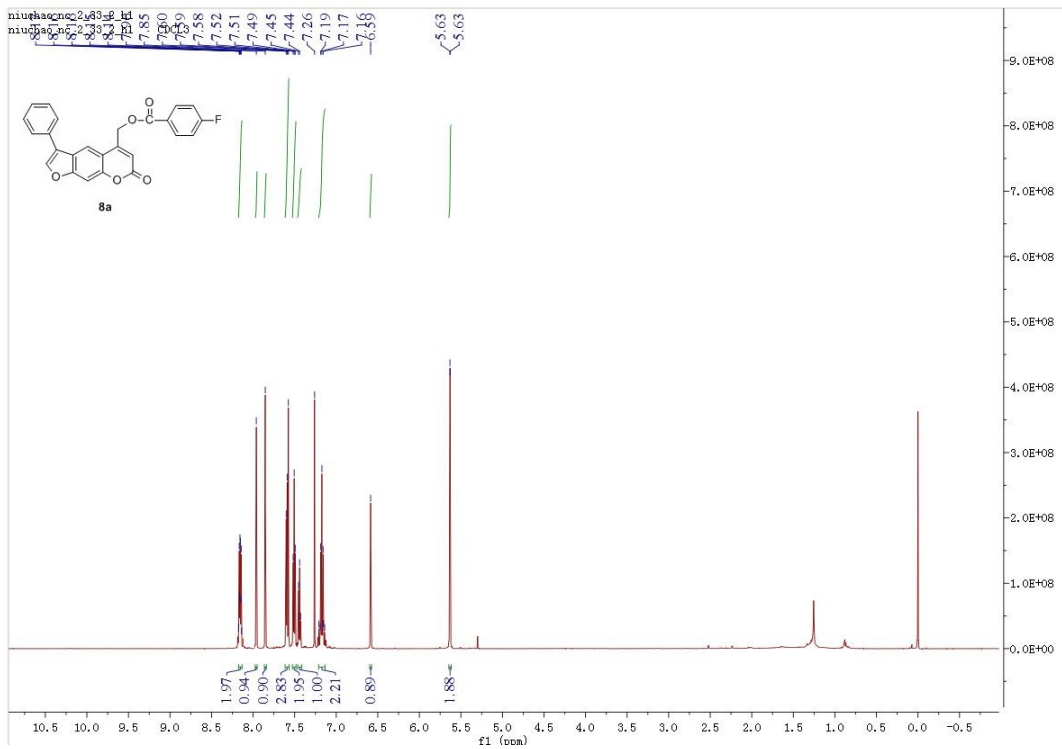


¹H NMR and ¹³C NMR spectra of 7ad

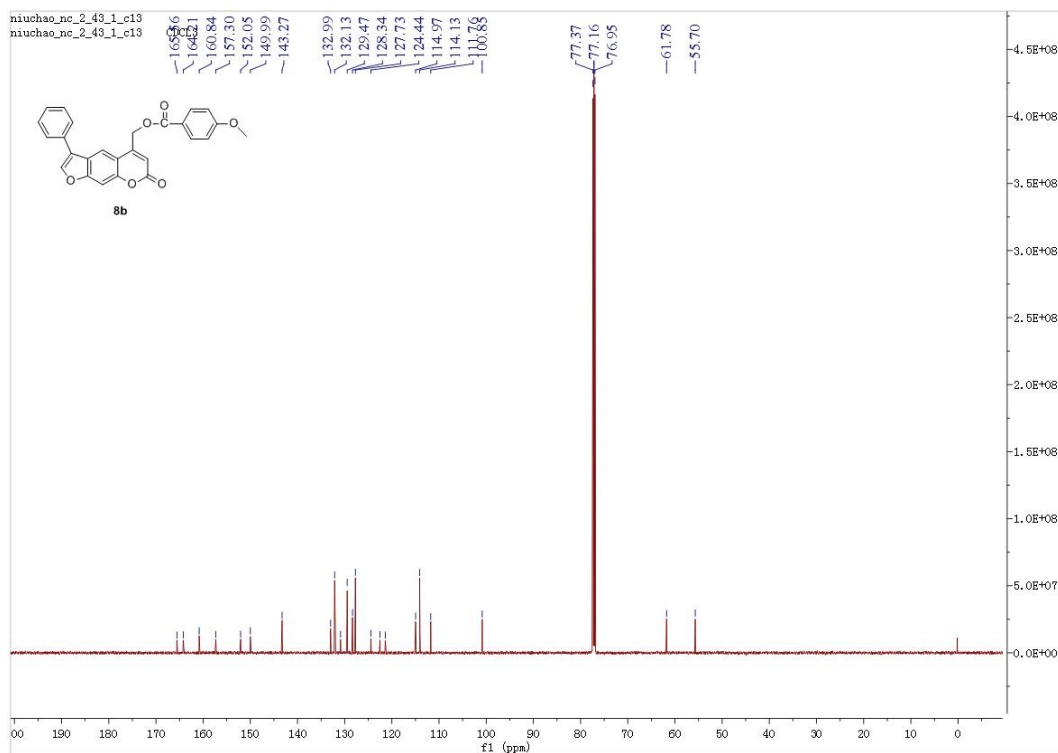
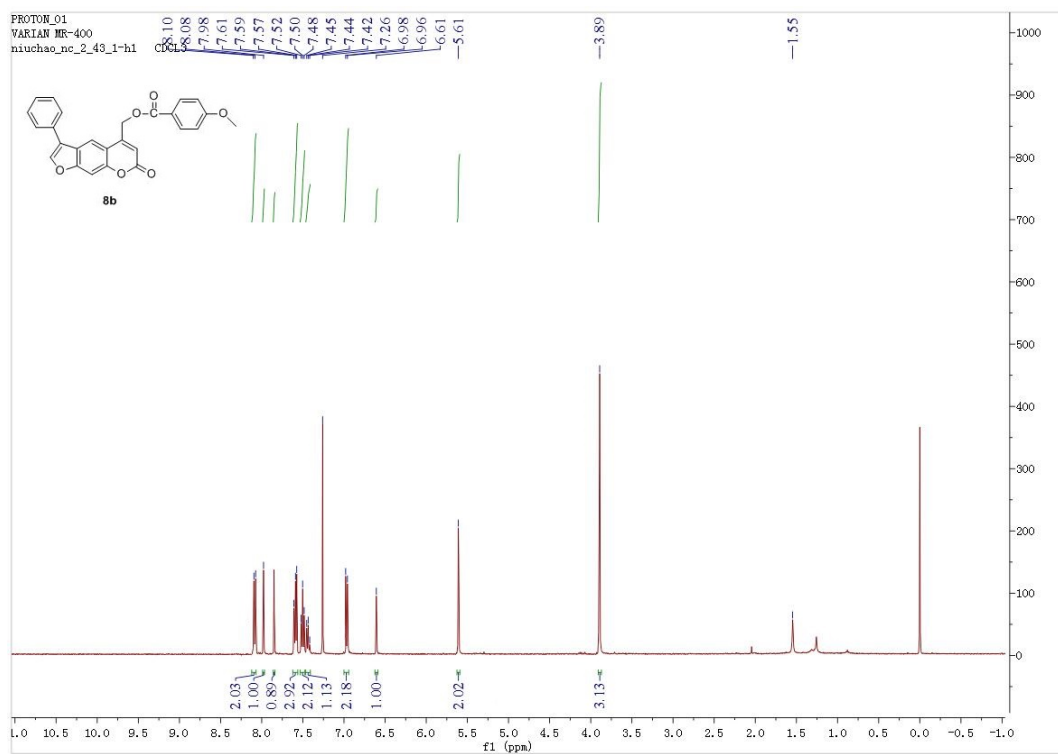


¹H NMR and ¹³C NMR spectra of 8

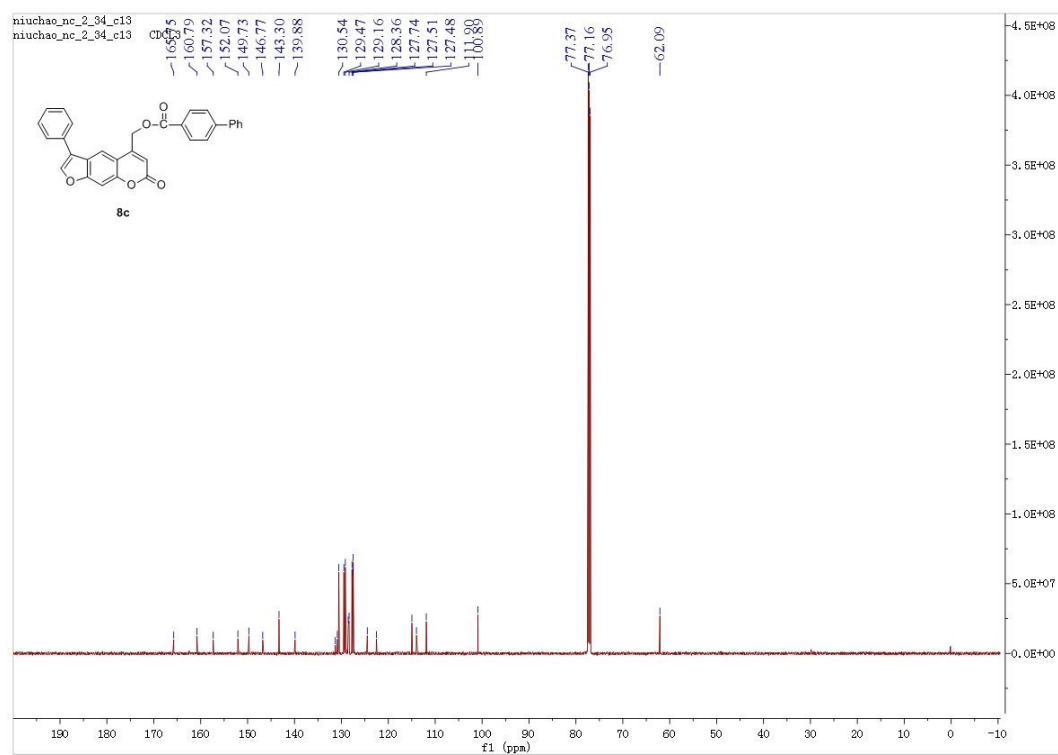
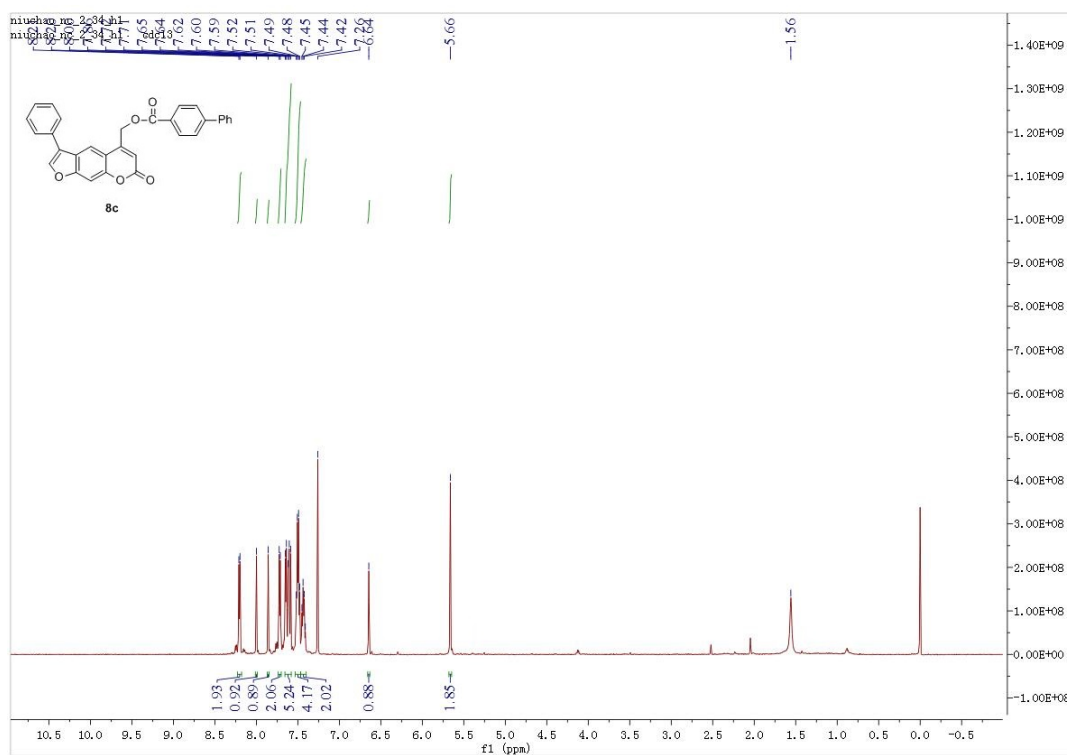


¹H NMR and ¹³C NMR spectra of **8a**

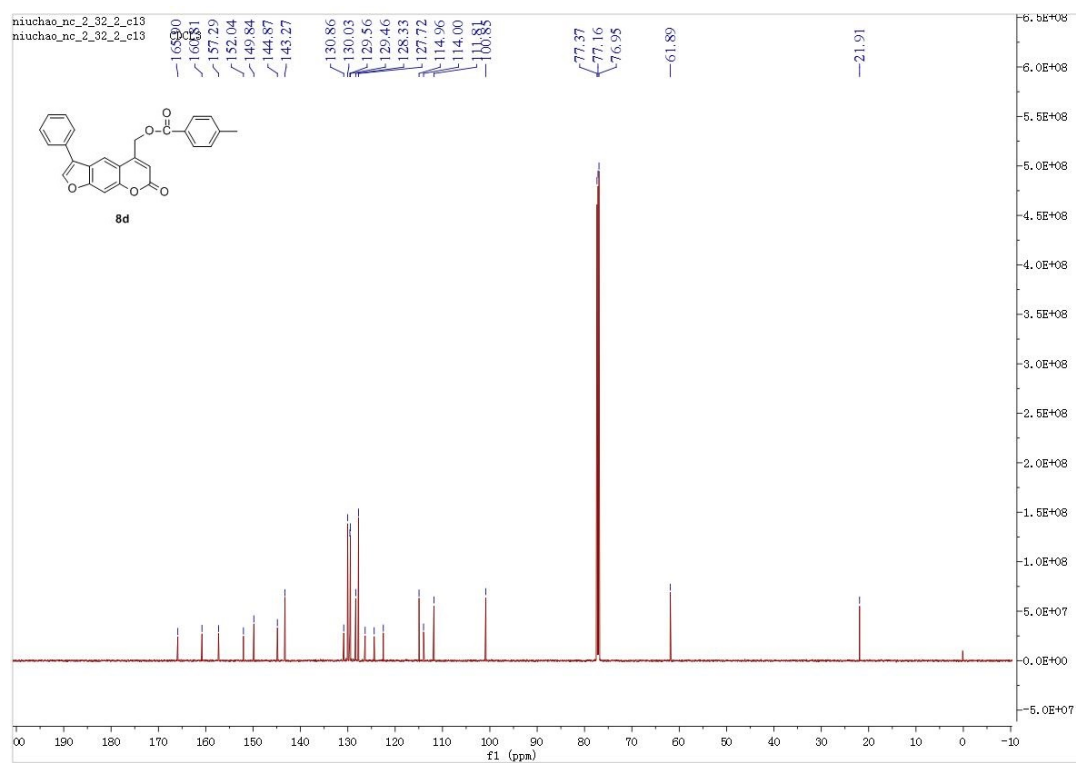
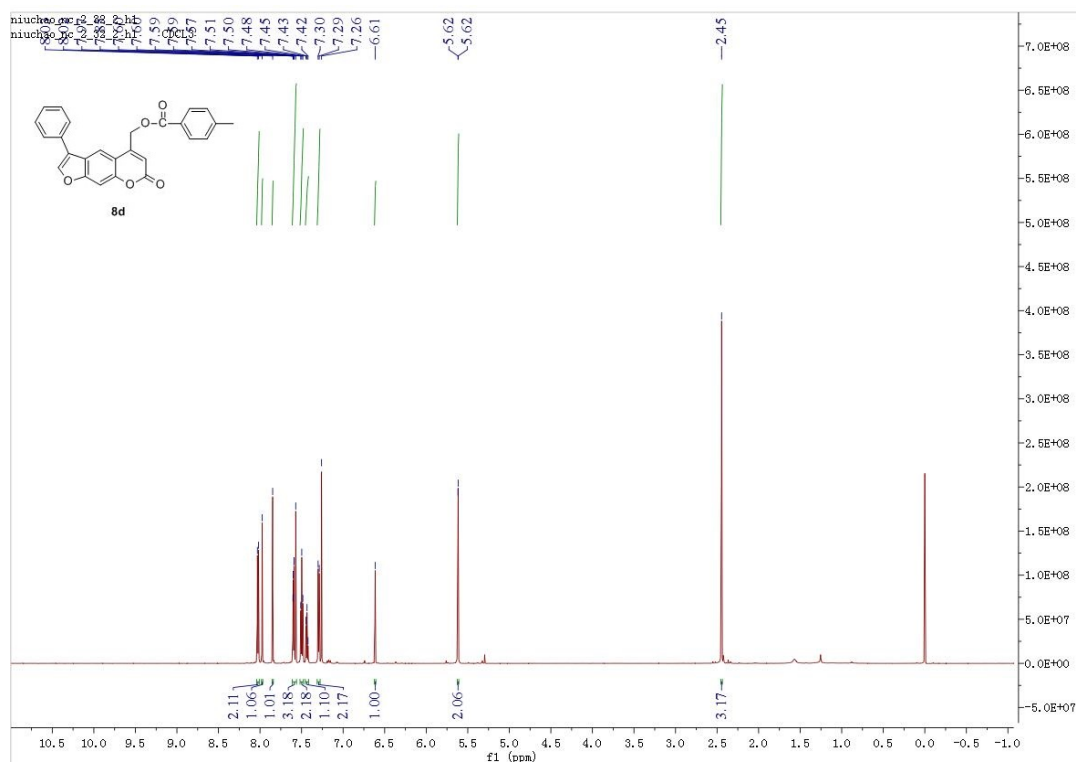
¹H NMR and ¹³C NMR spectra of **8b**



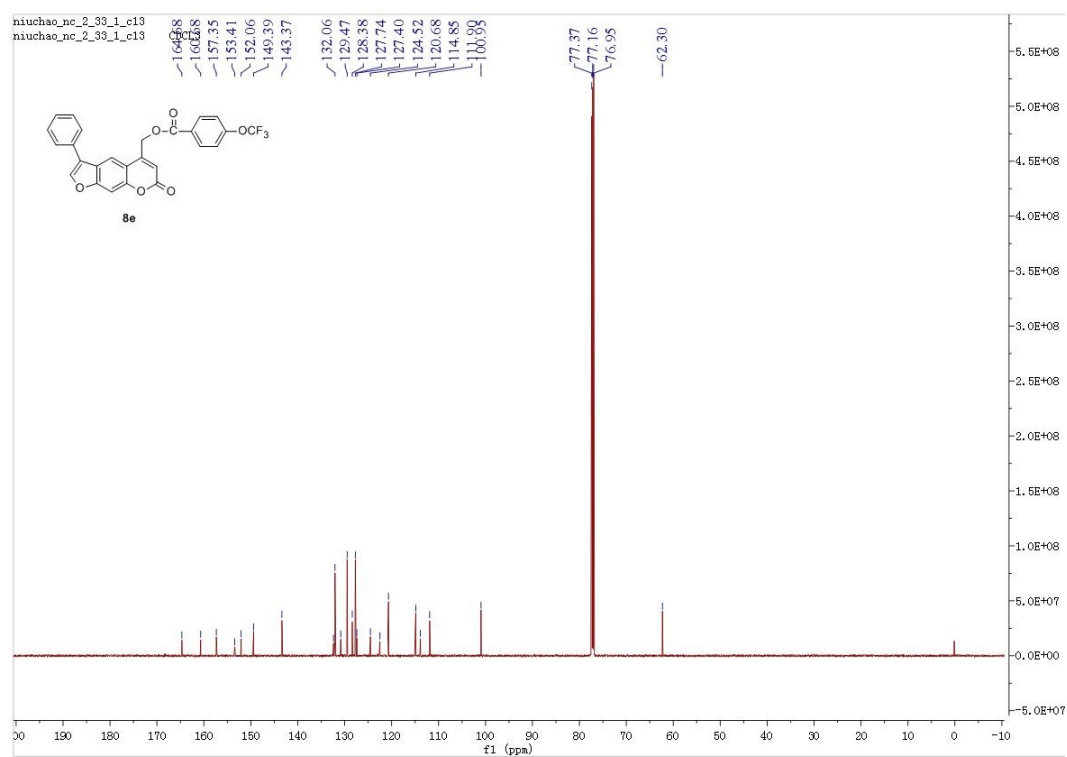
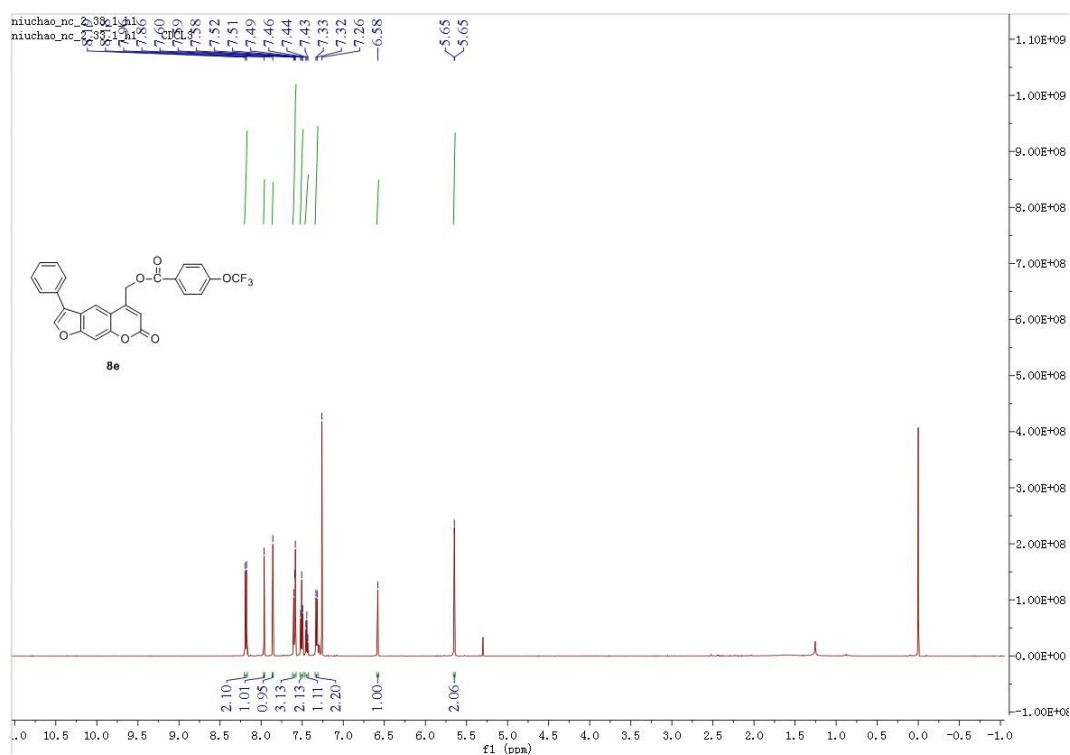
¹H NMR and ¹³C NMR spectra of 8c



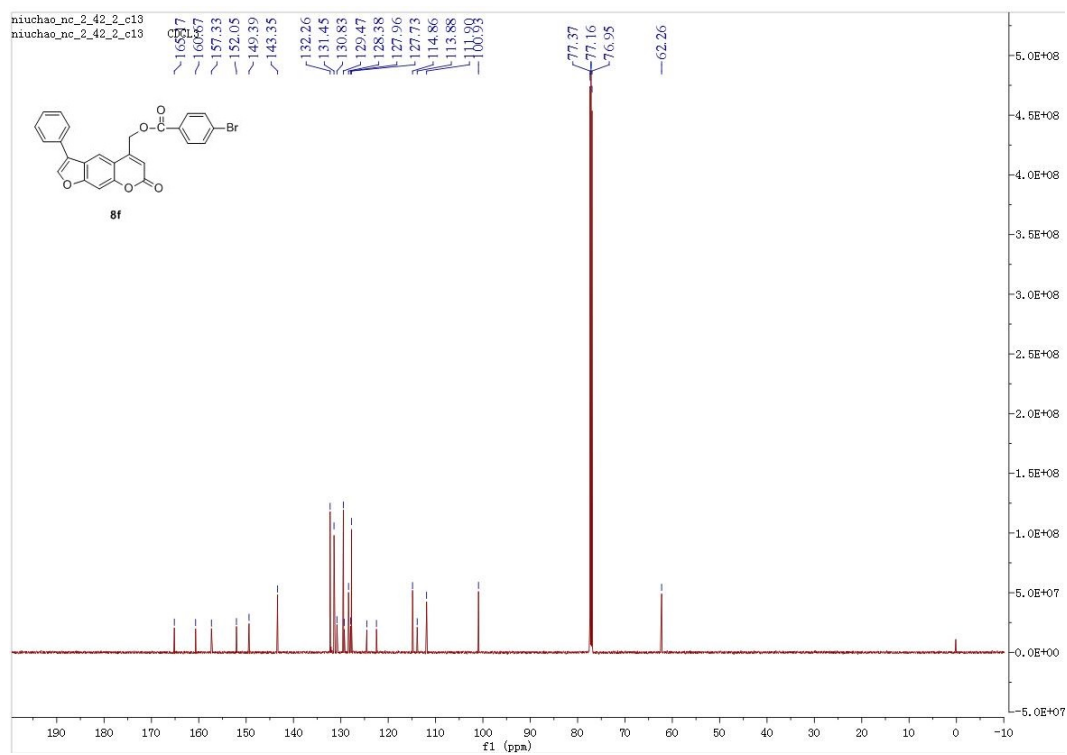
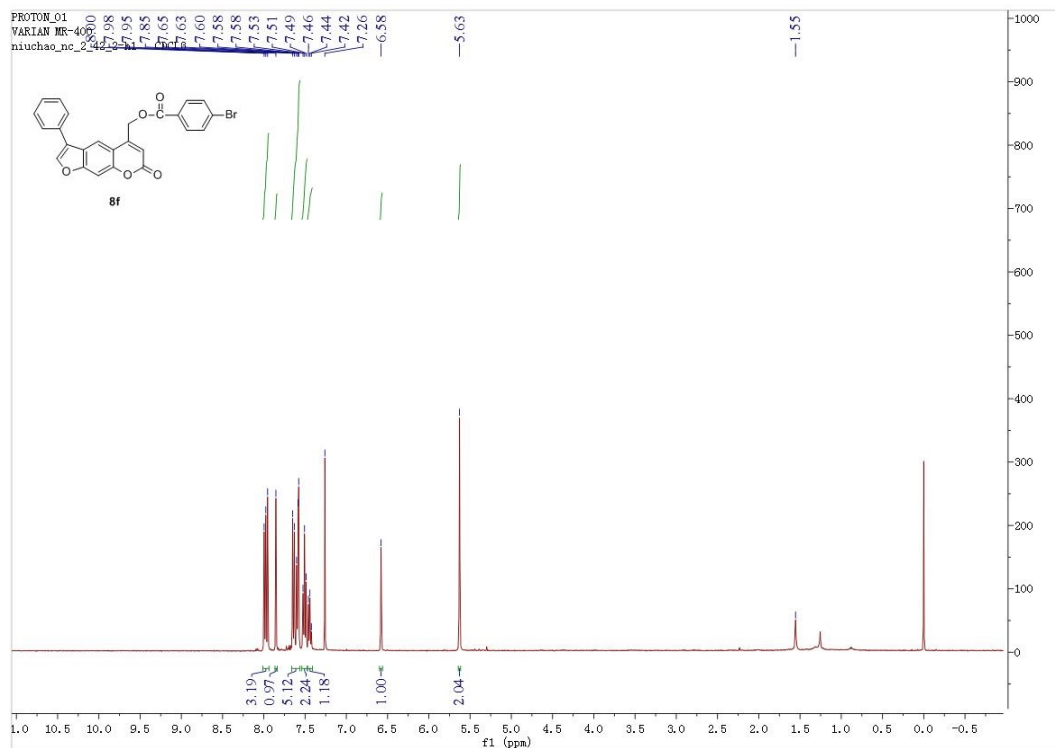
¹H NMR and ¹³C NMR spectra of 8d



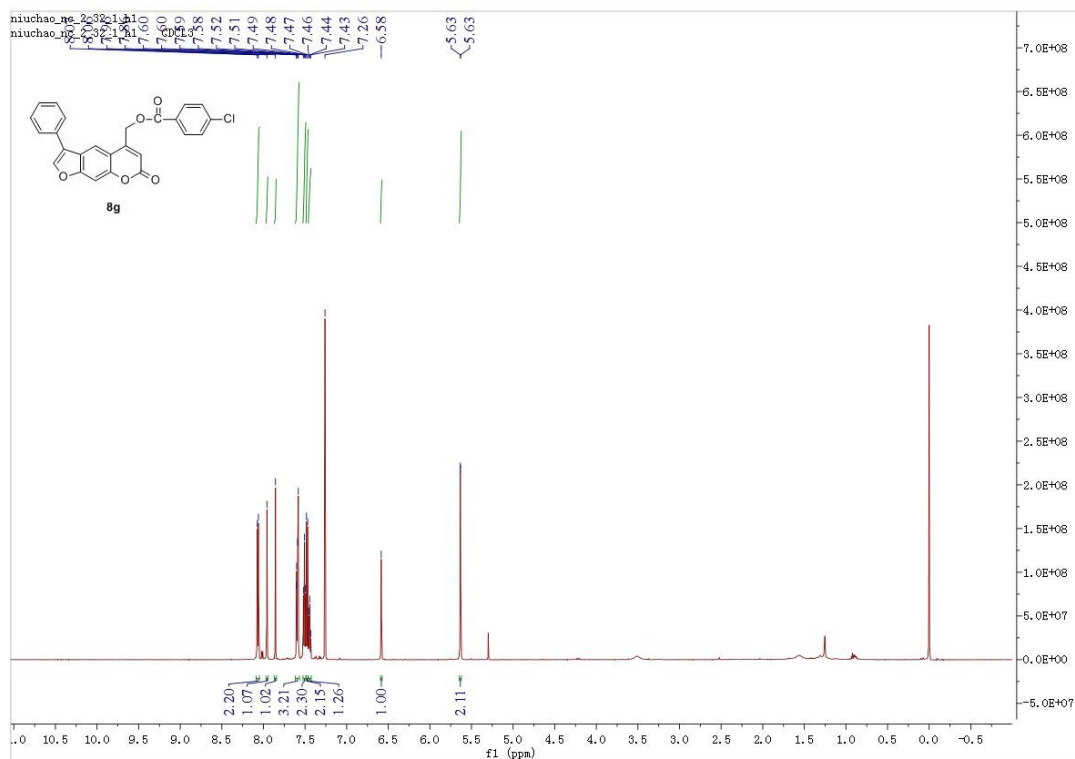
¹H NMR and ¹³C NMR spectra of **8e**



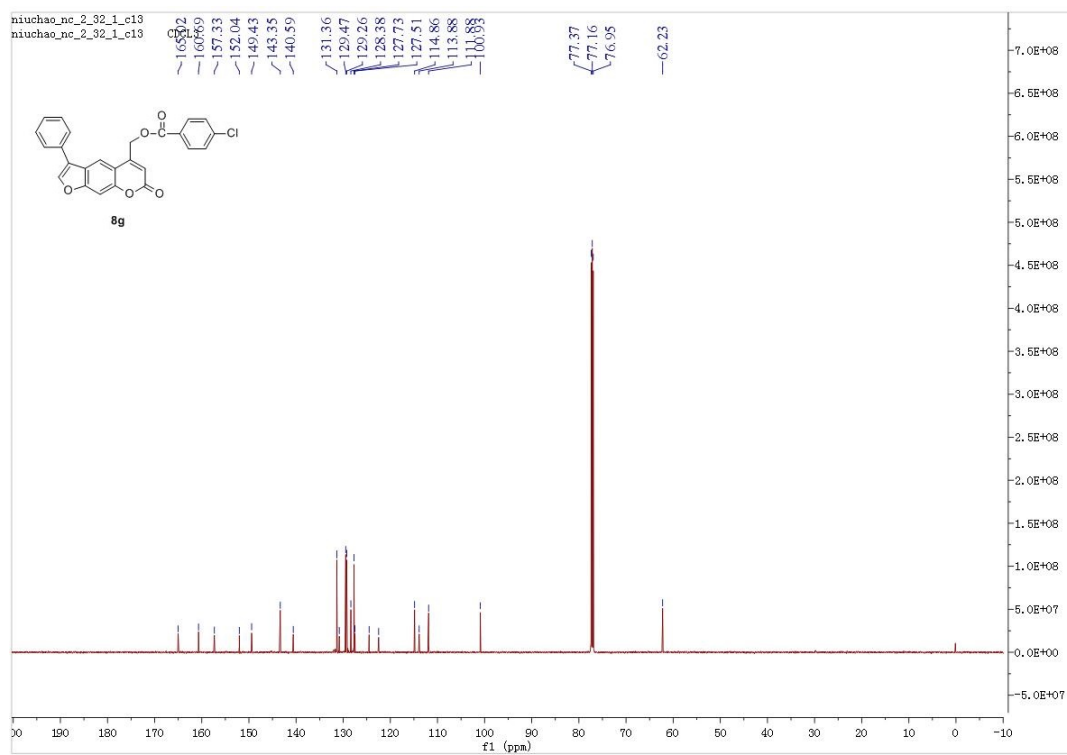
¹H NMR and ¹³C NMR spectra of 8f



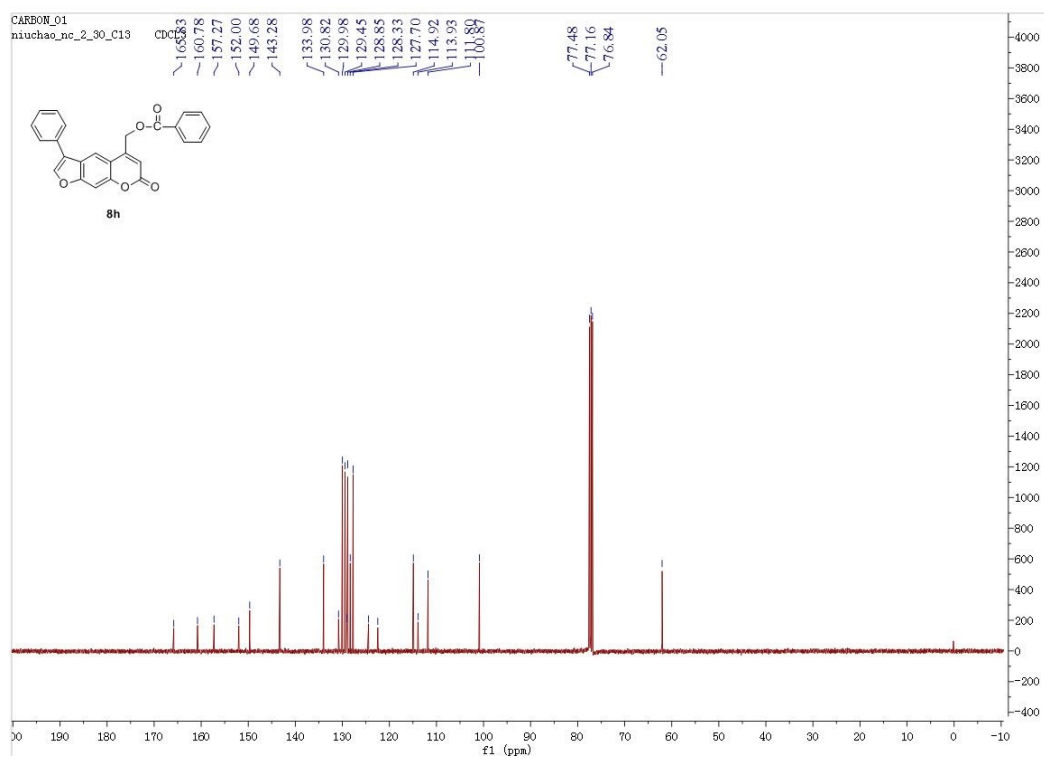
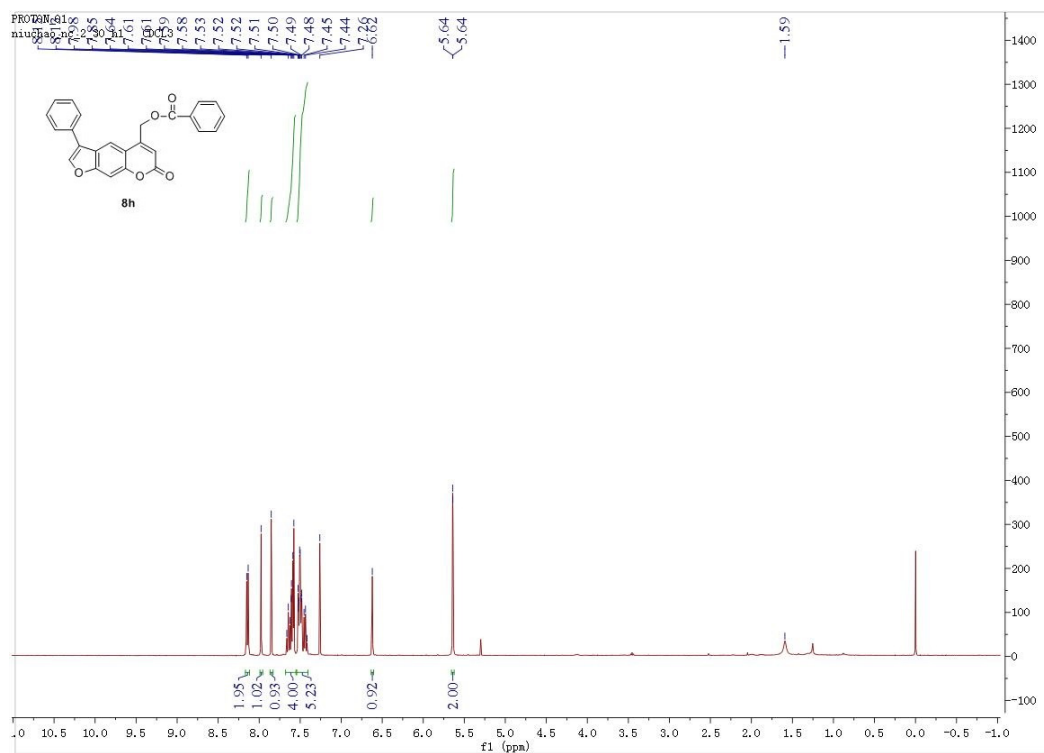
^1H NMR and ^{13}C NMR spectra of **8g**



B2.16 衍生物 **8g** 的 ^{13}C NMR(100 MHz, CDCl_3)



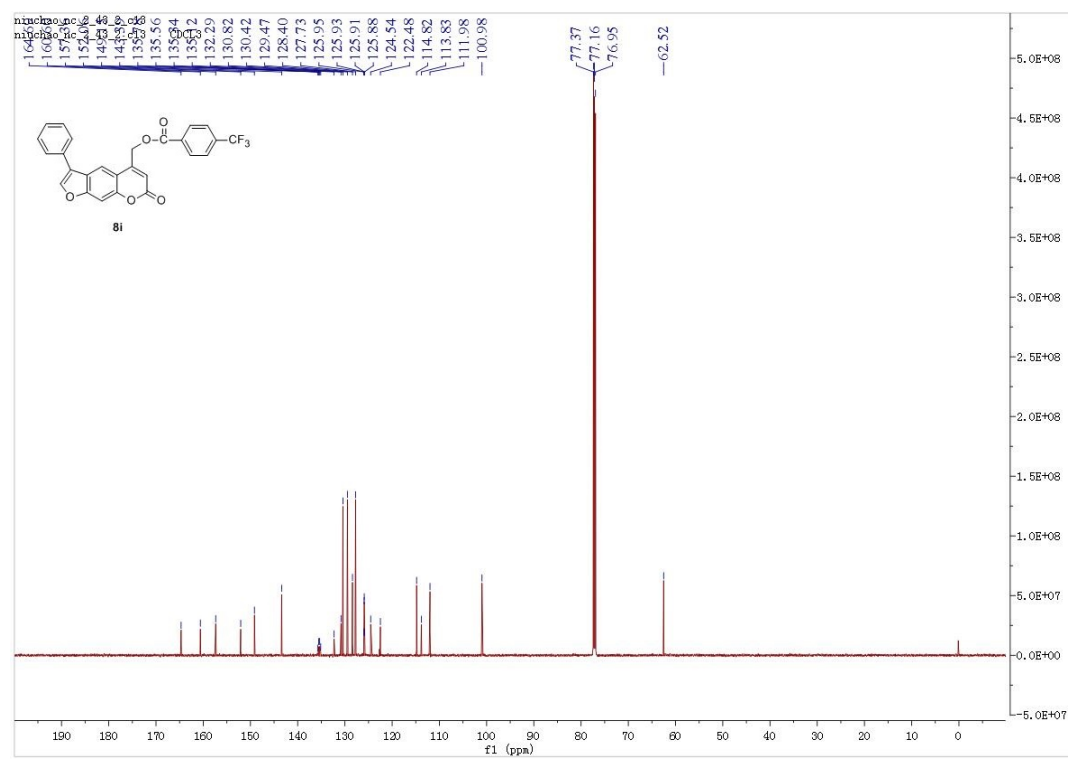
¹H NMR and ¹³C NMR spectra of **8h**



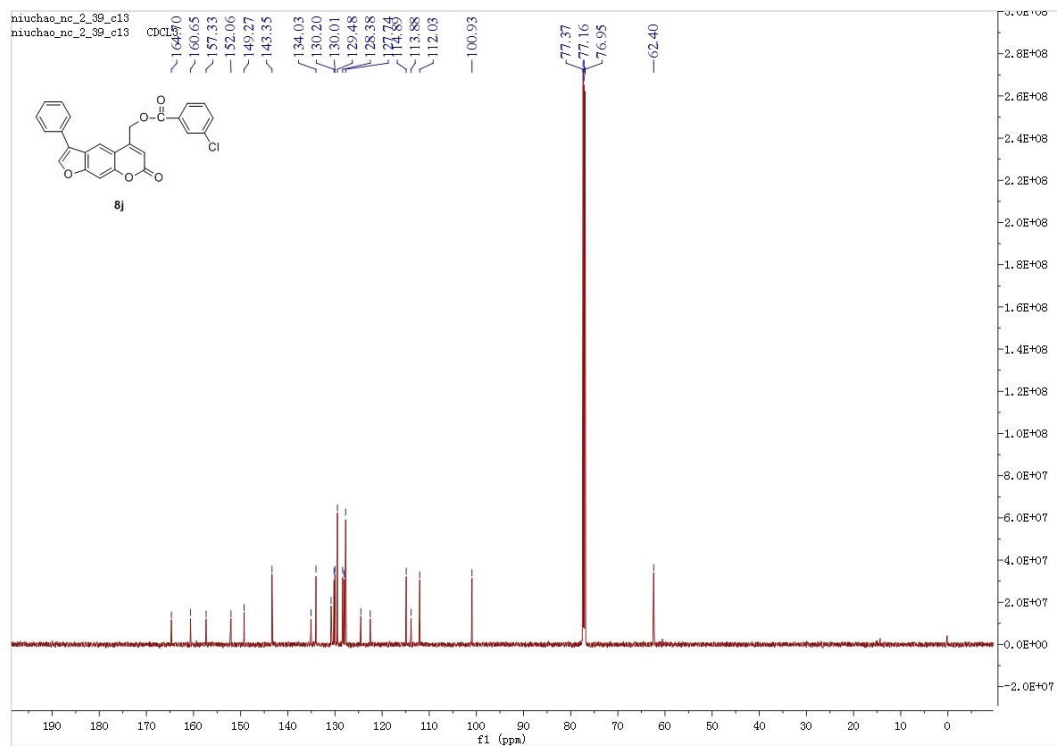
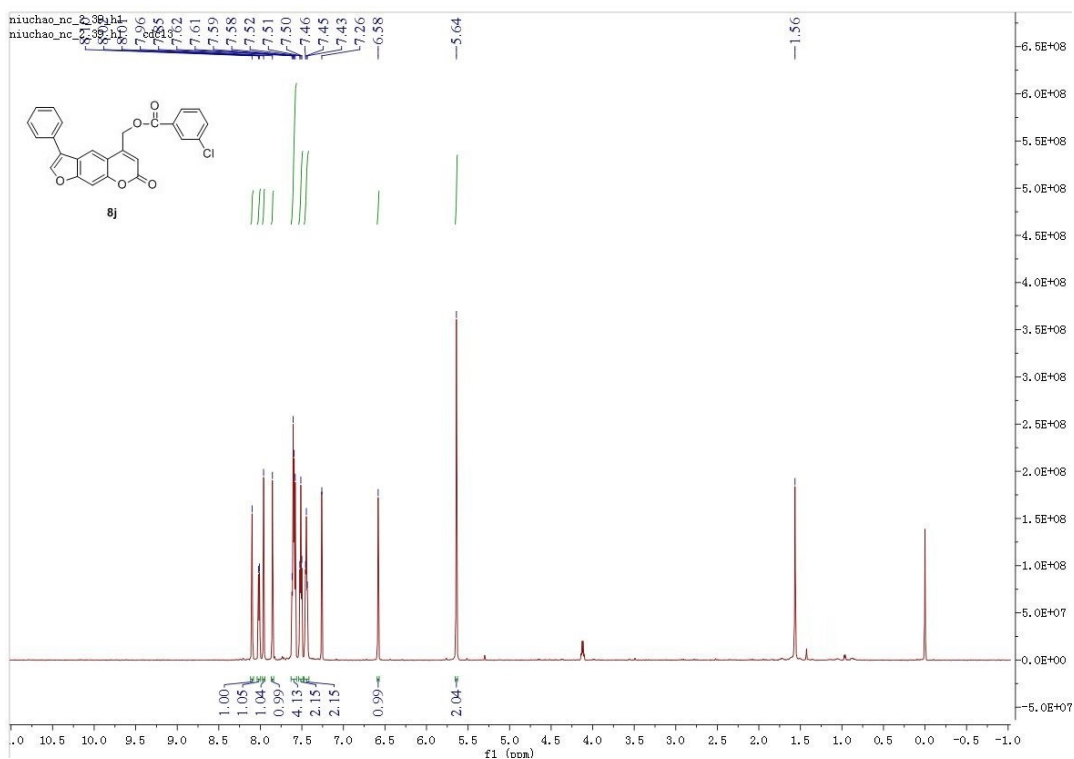
Chemical structure of **8i** is shown in the top left. The structure is a benzofuran derivative with a trifluoromethyl group and a methoxy group.

¹H NMR spectrum (CDCl₃) of compound **8i**. The x-axis represents the chemical shift in ppm (f1), ranging from 1.0 to -1.0. The y-axis represents the intensity, ranging from 0 to 650. The spectrum shows several peaks, with the following chemical shifts (ppm) and integration values (area) listed below the peaks:

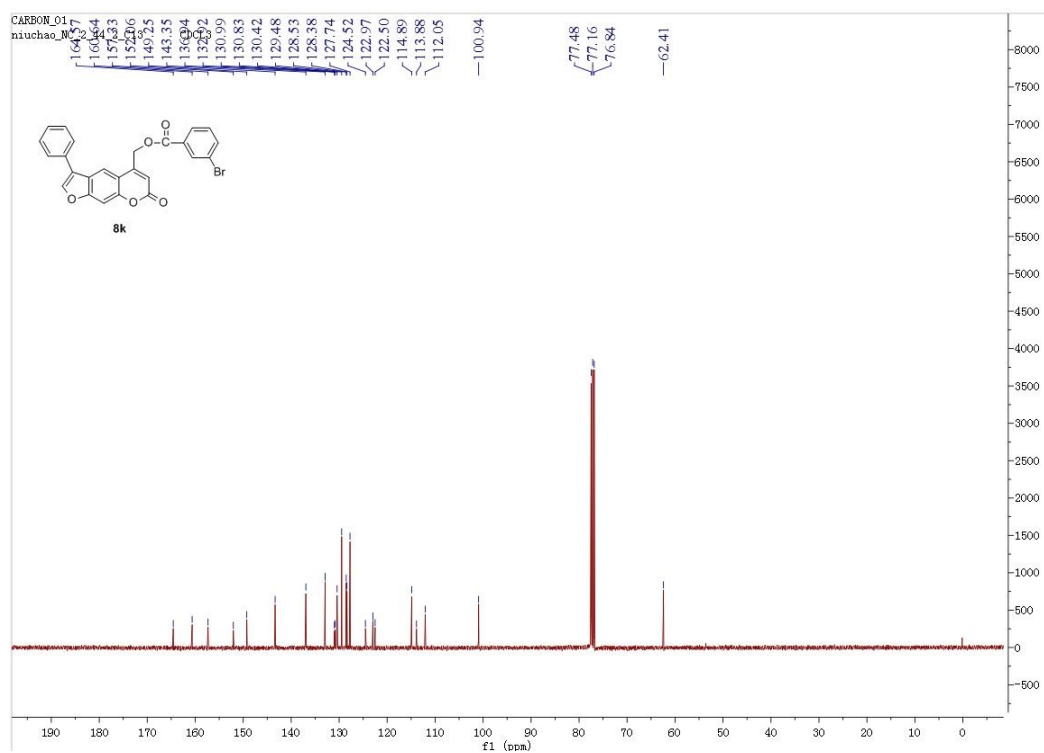
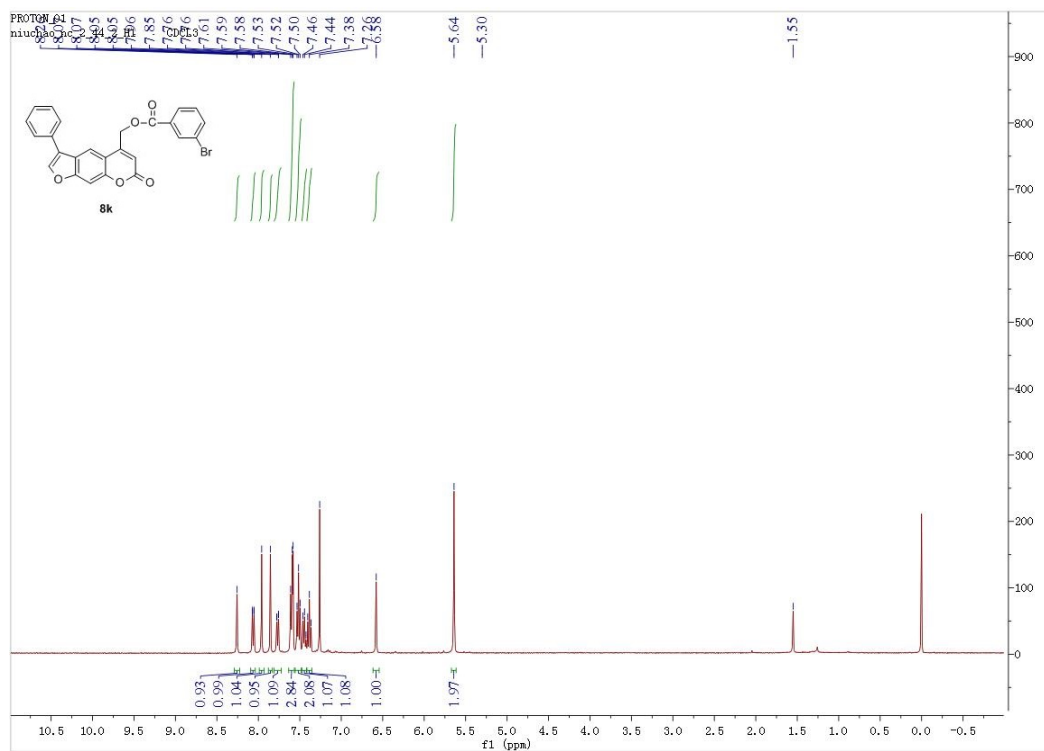
Chemical Shift (ppm)	Integration
8.26	2.10
8.24	1.08
8.17	0.98
8.13	2.17
8.09	3.09
8.06	2.26
8.04	1.20
7.46	1.00
5.67	2.04
3.65	1.00
2.85	1.00



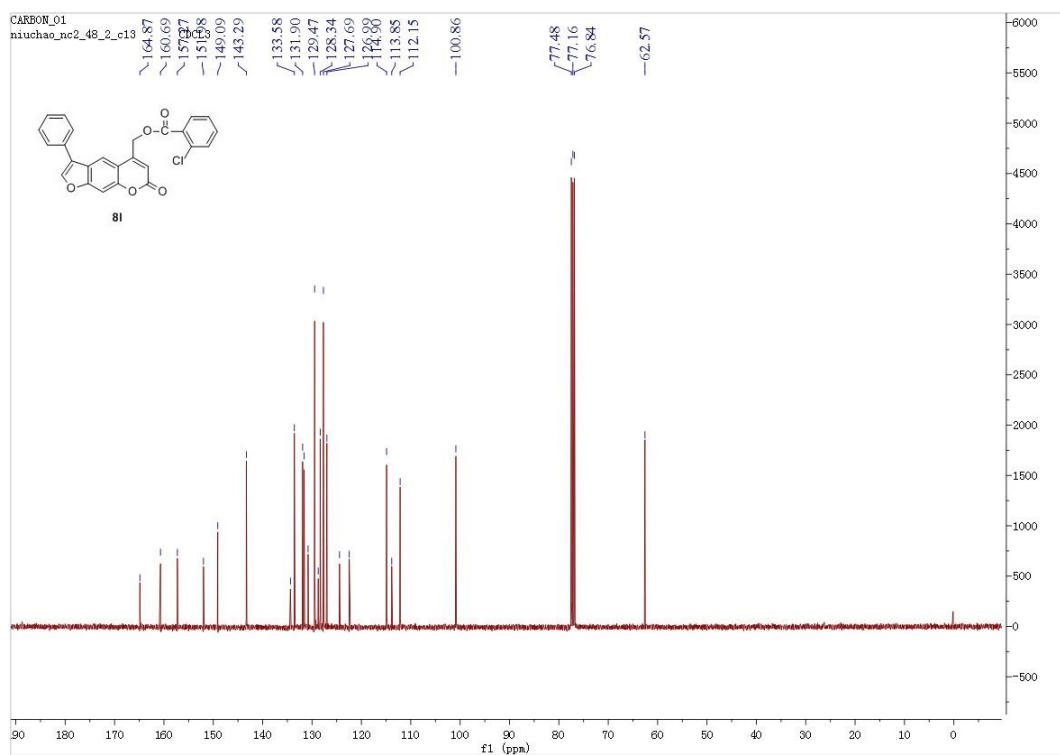
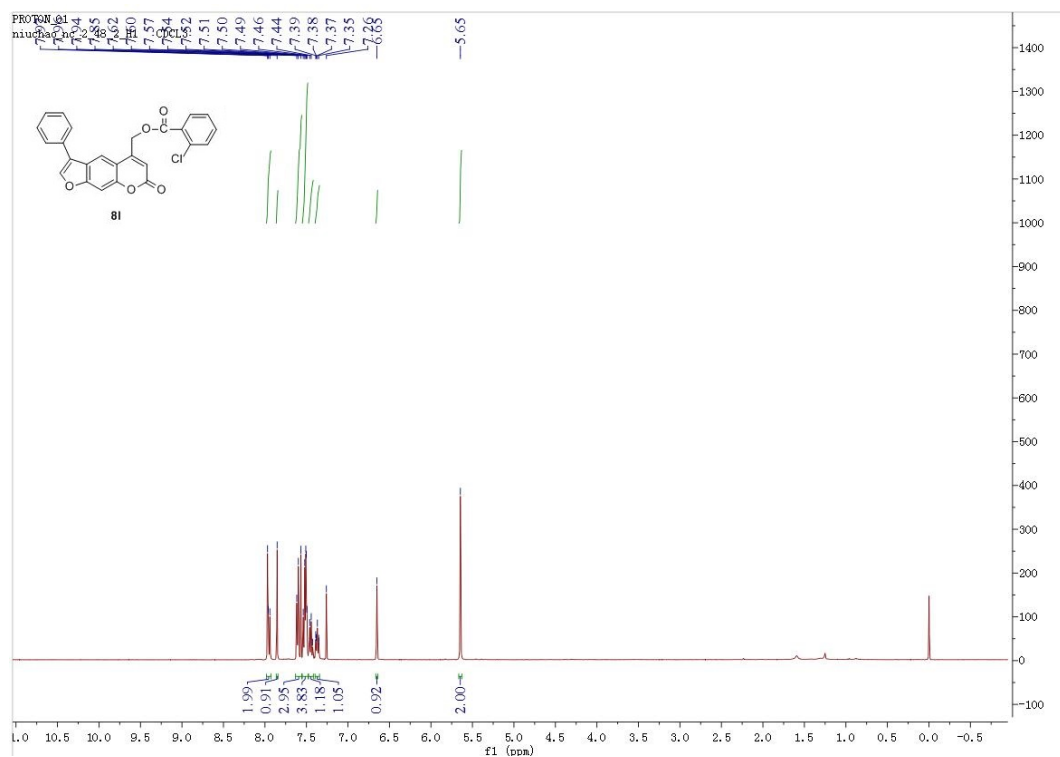
^1H NMR and ^{13}C NMR spectra of **8j**

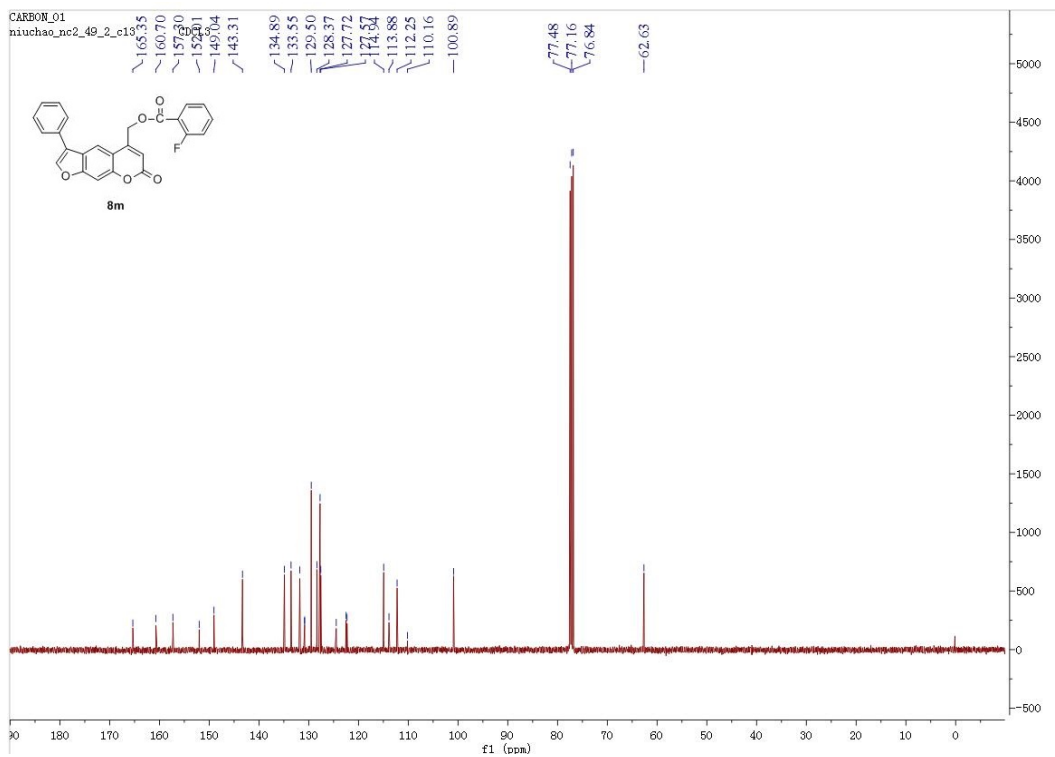
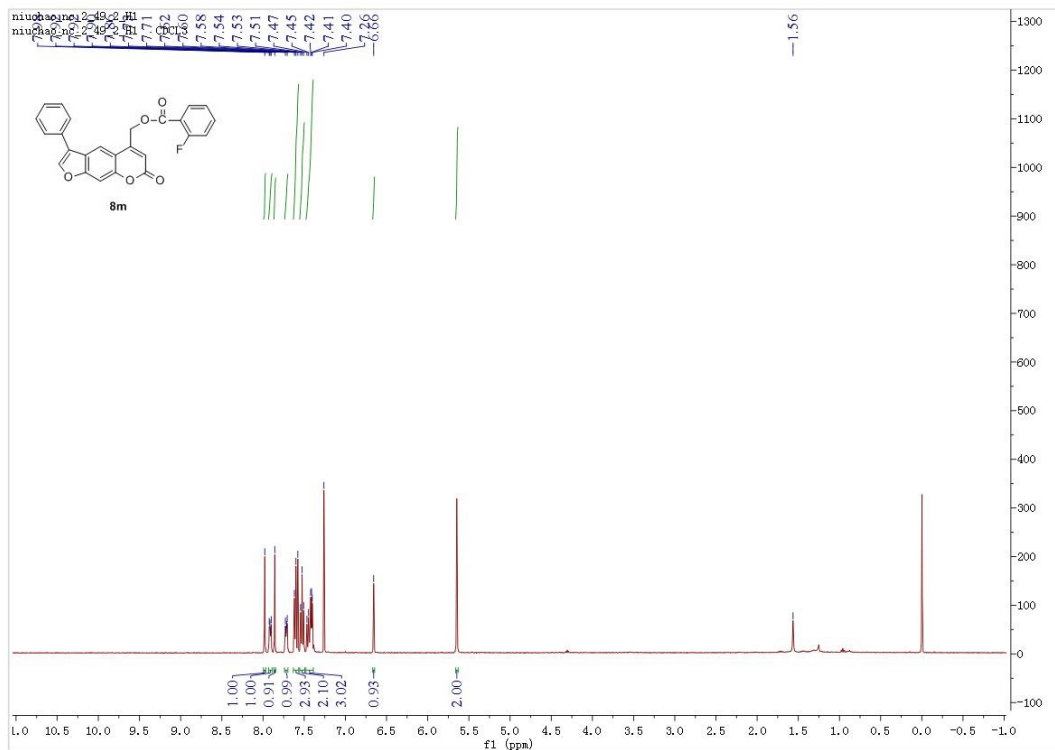


^1H NMR and ^{13}C NMR spectra of **8k**



^1H NMR and ^{13}C NMR spectra of 8l



¹H NMR and ¹³C NMR spectra of **8m**

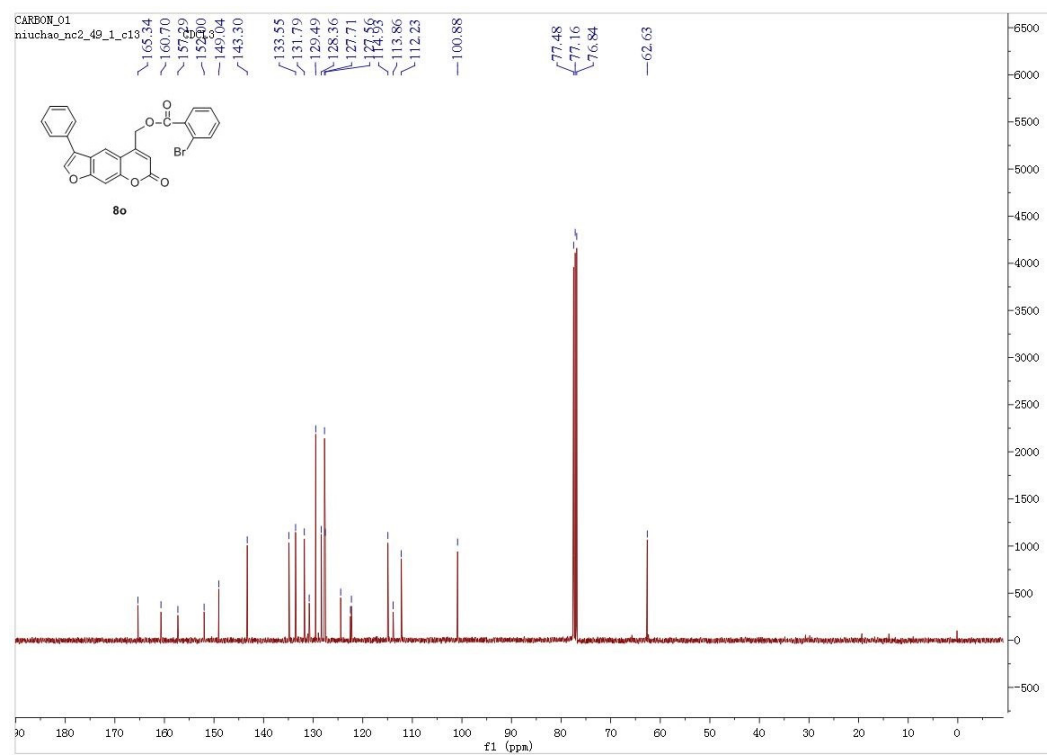
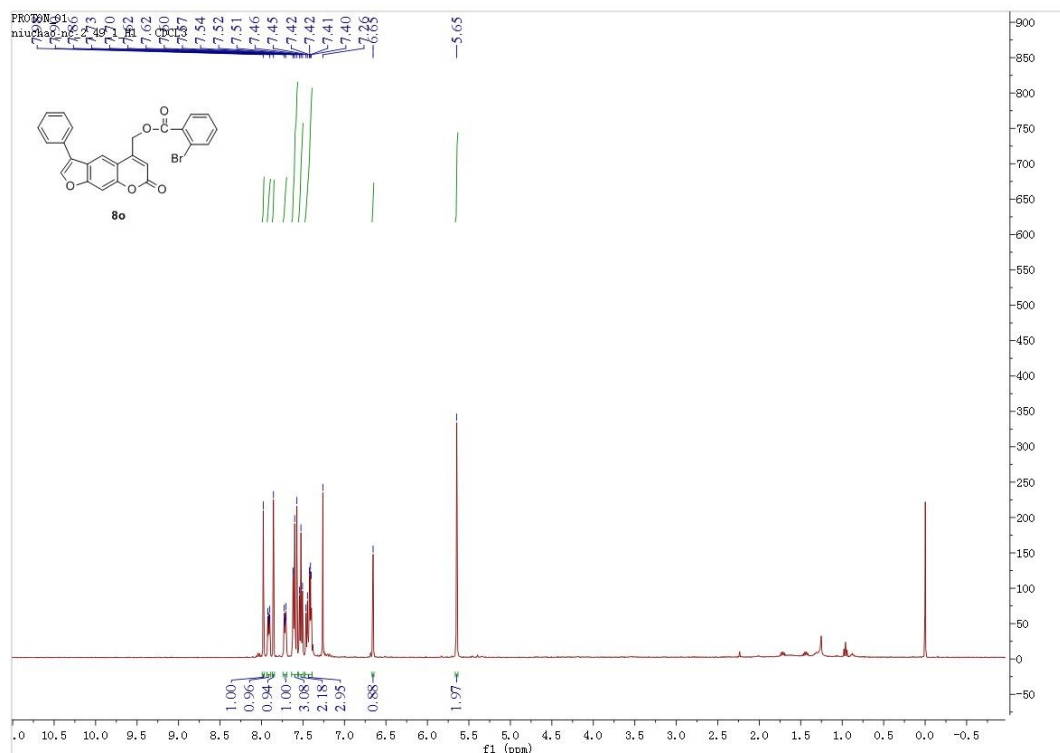
Chemical structure of **8n** is shown in the top left. The ¹H NMR spectrum (CDCl₃) is displayed below the structure. The x-axis represents the chemical shift in ppm (f1), ranging from 1.0 to -0.5. The y-axis represents the proton signal intensity (PROTON), ranging from 0 to 750. The spectrum shows several peaks, with integration values provided below the baseline.

Integration values (from left to right): 1.02, 1.11, 0.94, 1.14, 3.19, 4.13, 1.28, 1.00, 2.20, 1.00.

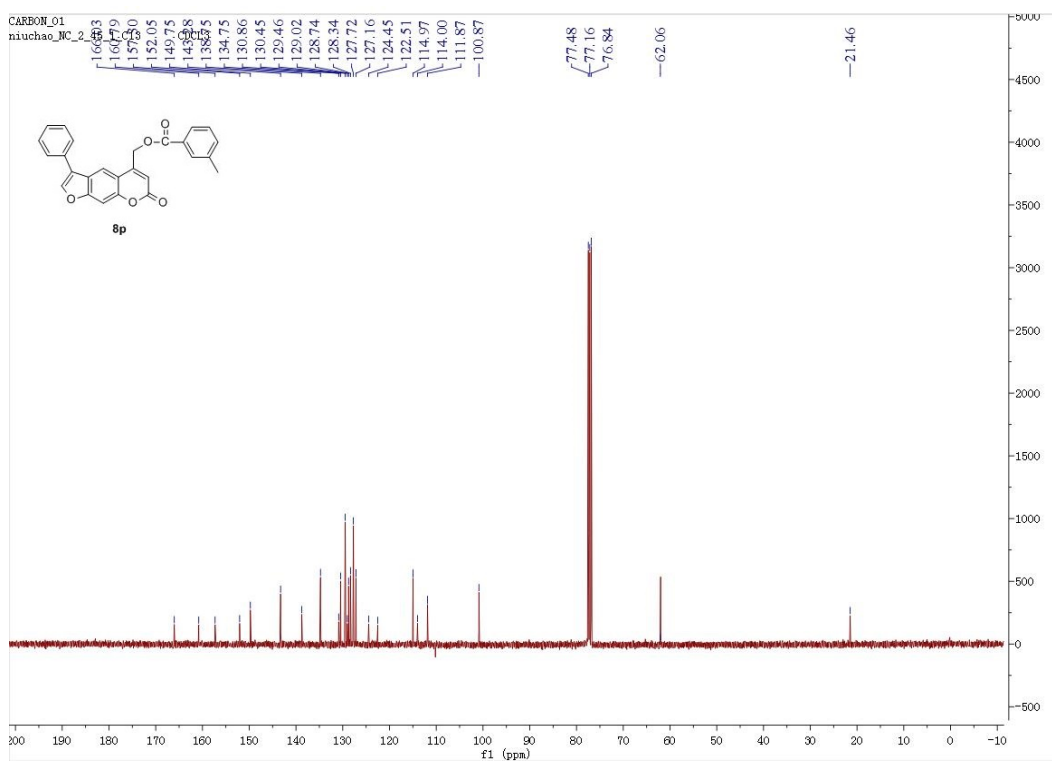
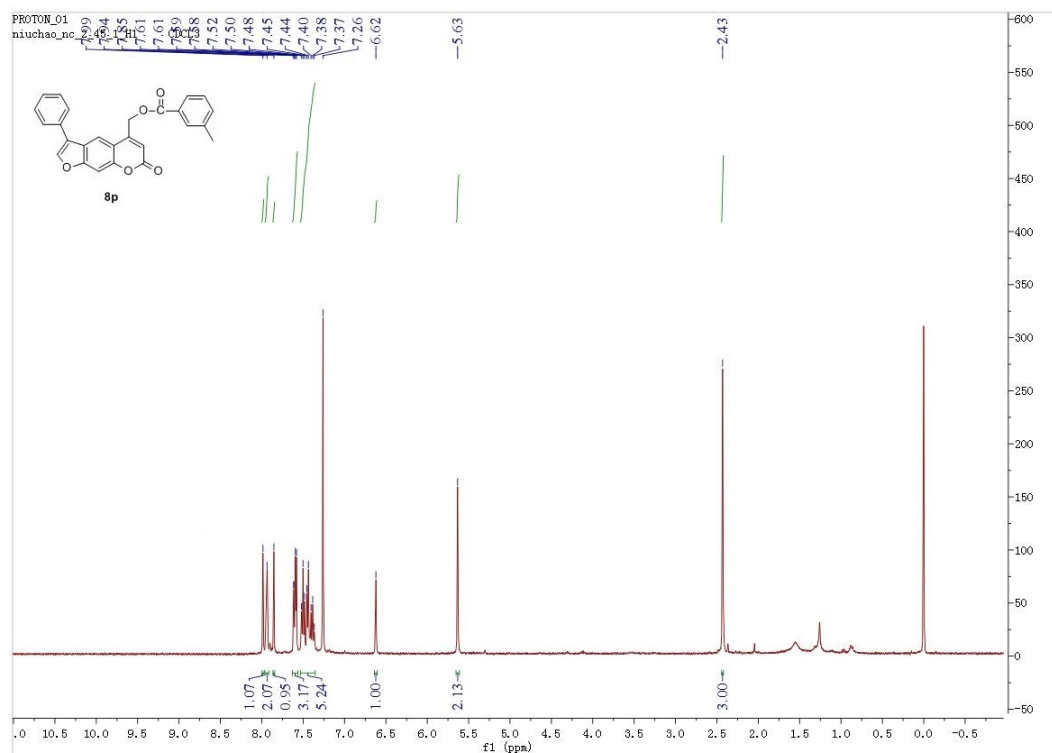
Chemical shift values (ppm) are listed at the top of the spectrum: 7.64, 7.63, 7.62, 7.61, 7.60, 7.59, 7.58, 7.57, 7.56, 7.55, 7.54, 7.53, 7.52, 7.51, 7.50, 7.49, 7.48, 7.47, 7.46, 7.45, 7.44, 7.43, 7.42, 7.41, 7.40, 7.39, 7.38, 7.37, 7.36, 7.35, 7.34, 7.33, 7.32, 7.31, 7.30, 7.29, 7.28, 7.27, 7.26, 7.25, 7.24, 7.23, 7.22, 7.21, 7.20, 7.19, 7.18, 7.17, 7.16, 7.15, 7.14, 7.13, 7.12, 7.11, 7.10, 7.09, 7.08, 7.07, 7.06, 7.05, 7.04, 7.03, 7.02, 7.01, 7.00, 6.99, 6.98, 6.97, 6.96, 6.95, 6.94, 6.93, 6.92, 6.91, 6.90, 6.89, 6.88, 6.87, 6.86, 6.85, 6.84, 6.83, 6.82, 6.81, 6.80, 6.79, 6.78, 6.77, 6.76, 6.75, 6.74, 6.73, 6.72, 6.71, 6.70, 6.69, 6.68, 6.67, 6.66, 6.65, 6.64, 6.63, 6.62, 6.61, 6.60, 6.59, 6.58, 6.57, 6.56, 6.55, 6.54, 6.53, 6.52, 6.51, 6.50, 6.49, 6.48, 6.47, 6.46, 6.45, 6.44, 6.43, 6.42, 6.41, 6.40, 6.39, 6.38, 6.37, 6.36, 6.35, 6.34, 6.33, 6.32, 6.31, 6.30, 6.29, 6.28, 6.27, 6.26, 6.25, 6.24, 6.23, 6.22, 6.21, 6.20, 6.19, 6.18, 6.17, 6.16, 6.15, 6.14, 6.13, 6.12, 6.11, 6.10, 6.09, 6.08, 6.07, 6.06, 6.05, 6.04, 6.03, 6.02, 6.01, 6.00, 5.99, 5.98, 5.97, 5.96, 5.95, 5.94, 5.93, 5.92, 5.91, 5.90, 5.89, 5.88, 5.87, 5.86, 5.85, 5.84, 5.83, 5.82, 5.81, 5.80, 5.79, 5.78, 5.77, 5.76, 5.75, 5.74, 5.73, 5.72, 5.71, 5.70, 5.69, 5.68, 5.67, 5.66, 5.65, 5.64, 5.63, 5.62, 5.61, 5.60, 5.59, 5.58, 5.57, 5.56, 5.55, 5.54, 5.53, 5.52, 5.51, 5.50, 5.49, 5.48, 5.47, 5.46, 5.45, 5.44, 5.43, 5.42, 5.41, 5.40, 5.39, 5.38, 5.37, 5.36, 5.35, 5.34, 5.33, 5.32, 5.31, 5.30, 5.29, 5.28, 5.27, 5.26, 5.25, 5.24, 5.23, 5.22, 5.21, 5.20, 5.19, 5.18, 5.17, 5.16, 5.15, 5.14, 5.13, 5.12, 5.11, 5.10, 5.09, 5.08, 5.07, 5.06, 5.05, 5.04, 5.03, 5.02, 5.01, 5.00, 4.99, 4.98, 4.97, 4.96, 4.95, 4.94, 4.93, 4.92, 4.91, 4.90, 4.89, 4.88, 4.87, 4.86, 4.85, 4.84, 4.83, 4.82, 4.81, 4.80, 4.79, 4.78, 4.77, 4.76, 4.75, 4.74, 4.73, 4.72, 4.71, 4.70, 4.69, 4.68, 4.67, 4.66, 4.65, 4.64, 4.63, 4.62, 4.61, 4.60, 4.59, 4.58, 4.57, 4.56, 4.55, 4.54, 4.53, 4.52, 4.51, 4.50, 4.49, 4.48, 4.47, 4.46, 4.45, 4.44, 4.43, 4.42, 4.41, 4.40, 4.39, 4.38, 4.37, 4.36, 4.35, 4.34, 4.33, 4.32, 4.31, 4.30, 4.29, 4.28, 4.27, 4.26, 4.25, 4.24, 4.23, 4.22, 4.21, 4.20, 4.19, 4.18, 4.17, 4.16, 4.15, 4.14, 4.13, 4.12, 4.11, 4.10, 4.09, 4.08, 4.07, 4.06, 4.05, 4.04, 4.03, 4.02, 4.01, 4.00, 3.99, 3.98, 3.97, 3.96, 3.95, 3.94, 3.93, 3.92, 3.91, 3.90, 3.89, 3.88, 3.87, 3.86, 3.85, 3.84, 3.83, 3.82, 3.81, 3.80, 3.79, 3.78, 3.77, 3.76, 3.75, 3.74, 3.73, 3.72, 3.71, 3.70, 3.69, 3.68, 3.67, 3.66, 3.65, 3.64, 3.63, 3.62, 3.61, 3.60, 3.59, 3.58, 3.57, 3.56, 3.55, 3.54, 3.53, 3.52, 3.51, 3.50, 3.49, 3.48, 3.47, 3.46, 3.45, 3.44, 3.43, 3.42, 3.41, 3.40, 3.39, 3.38, 3.37, 3.36, 3.35, 3.34, 3.33, 3.32, 3.31, 3.30, 3.29, 3.28, 3.27, 3.26, 3.25, 3.24, 3.23, 3.22, 3.21, 3.20, 3.19, 3.18, 3.17, 3.16, 3.15, 3.14, 3.13, 3.12, 3.11, 3.10, 3.09, 3.08, 3.07, 3.06, 3.05, 3.04, 3.03, 3.02, 3.01, 3.00, 2.99, 2.98, 2.97, 2.96, 2.95, 2.94, 2.93, 2.92, 2.91, 2.90, 2.89, 2.88, 2.87, 2.86, 2.85, 2.84, 2.83, 2.82, 2.81, 2.80, 2.79, 2.78, 2.77, 2.76, 2.75, 2.74, 2.73, 2.72, 2.71, 2.70, 2.69, 2.68, 2.67, 2.66, 2.65, 2.64, 2.63, 2.62, 2.61, 2.60, 2.59, 2.58, 2.57, 2.56, 2.55, 2.54, 2.53, 2.52, 2.51, 2.50, 2.49, 2.48, 2.47, 2.46, 2.45, 2.44, 2.43, 2.42, 2.41, 2.40, 2.39, 2.38, 2.37, 2.36, 2.35, 2.34, 2.33, 2.32, 2.31, 2.30, 2.29, 2.28, 2.27, 2.26, 2.25, 2.24, 2.23, 2.22, 2.21, 2.20, 2.19, 2.18, 2.17, 2.16, 2.15, 2.14, 2.13, 2.12, 2.11, 2.10, 2.09, 2.08, 2.07, 2.06, 2.05, 2.04, 2.03, 2.02, 2.01, 2.00, 1.99, 1.98, 1.97, 1.96, 1.95, 1.94, 1.93, 1.92, 1.91, 1.90, 1.89, 1.88, 1.87, 1.86, 1.85, 1.84, 1.83, 1.82, 1.81, 1.80, 1.79, 1.78, 1.77, 1.76, 1.75, 1.74, 1.73, 1.72, 1.71, 1.70, 1.69, 1.68, 1.67, 1.66, 1.65, 1.64, 1.63, 1.62, 1.61, 1.60, 1.59, 1.58, 1.57, 1.56, 1.55, 1.54, 1.53, 1.52, 1.51, 1.50, 1.49, 1.48, 1.47, 1.46, 1.45, 1.44, 1.43, 1.42, 1.41, 1.40, 1.39, 1.38, 1.37, 1.36, 1.35, 1.34, 1.33, 1.32, 1.31, 1.30, 1.29, 1.28, 1.2



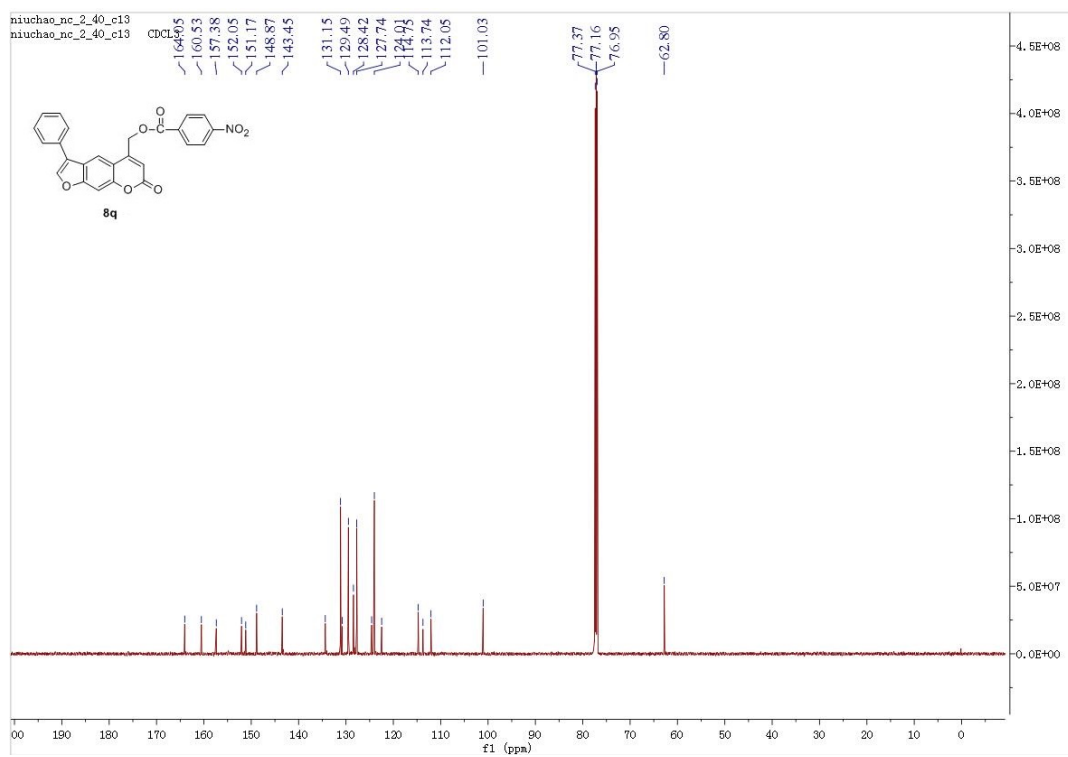
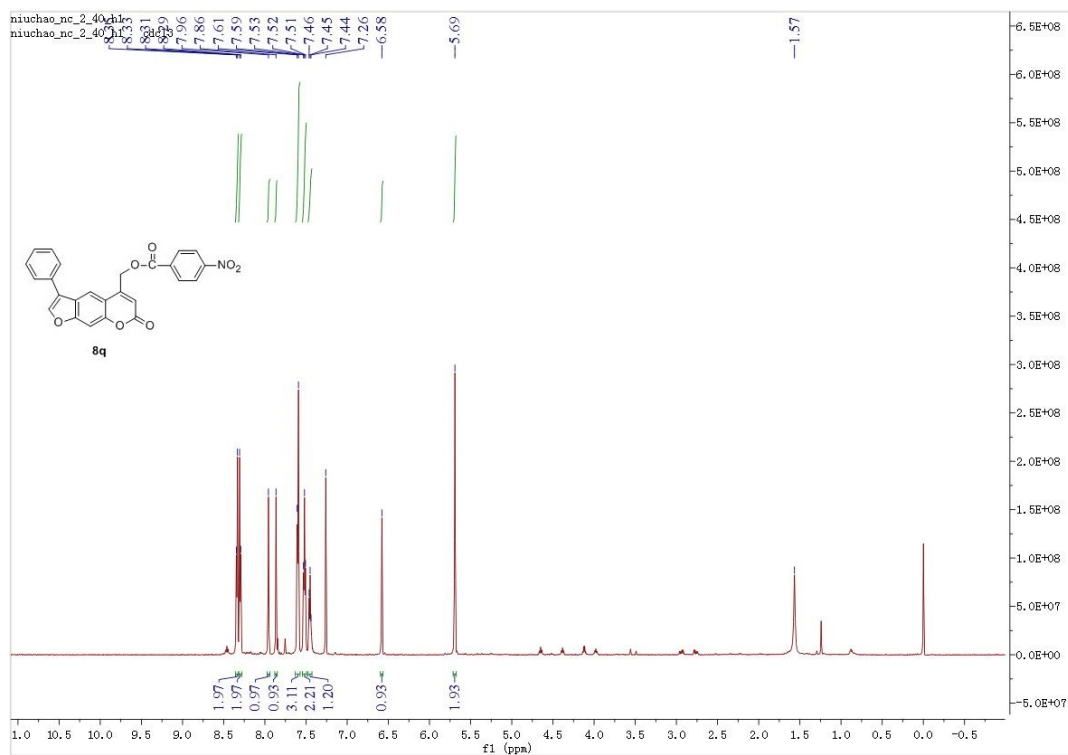
¹H NMR and ¹³C NMR spectra of **8o**



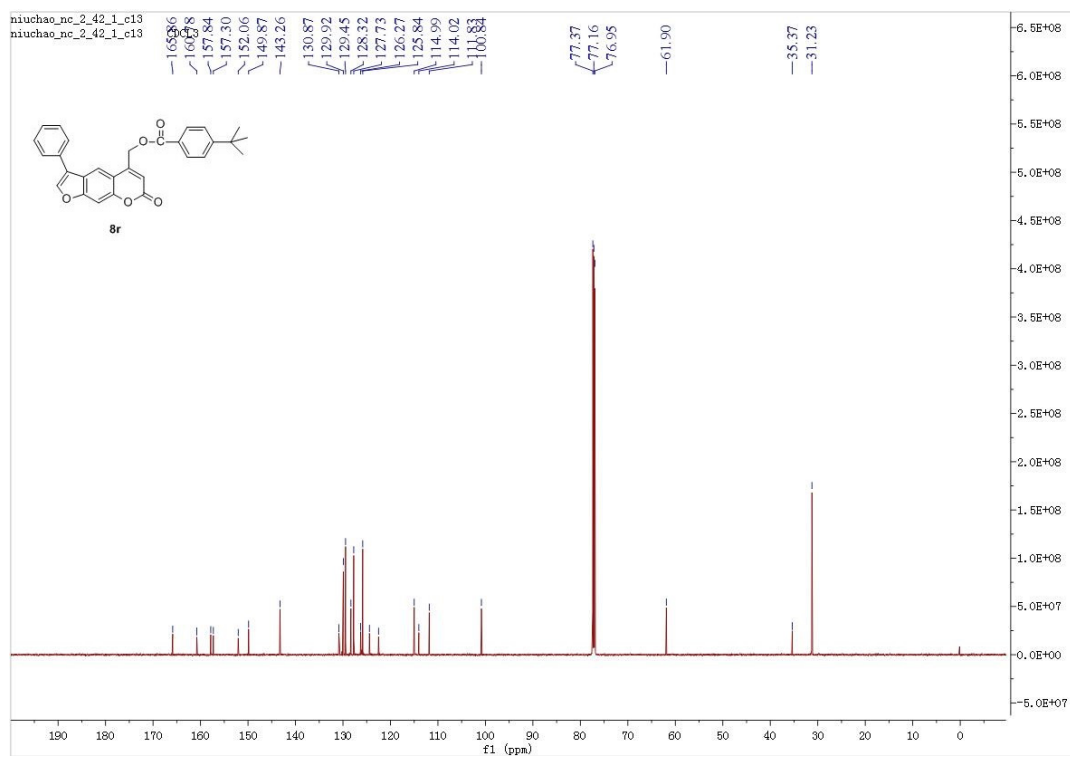
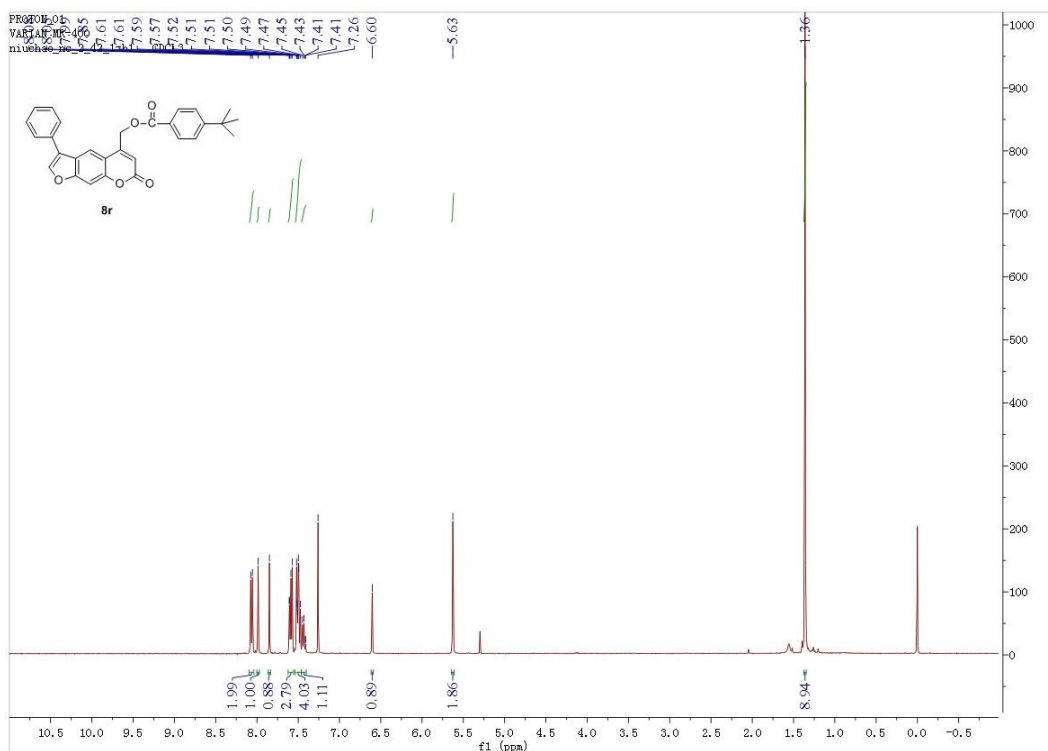
¹H NMR and ¹³C NMR spectra of **8p**



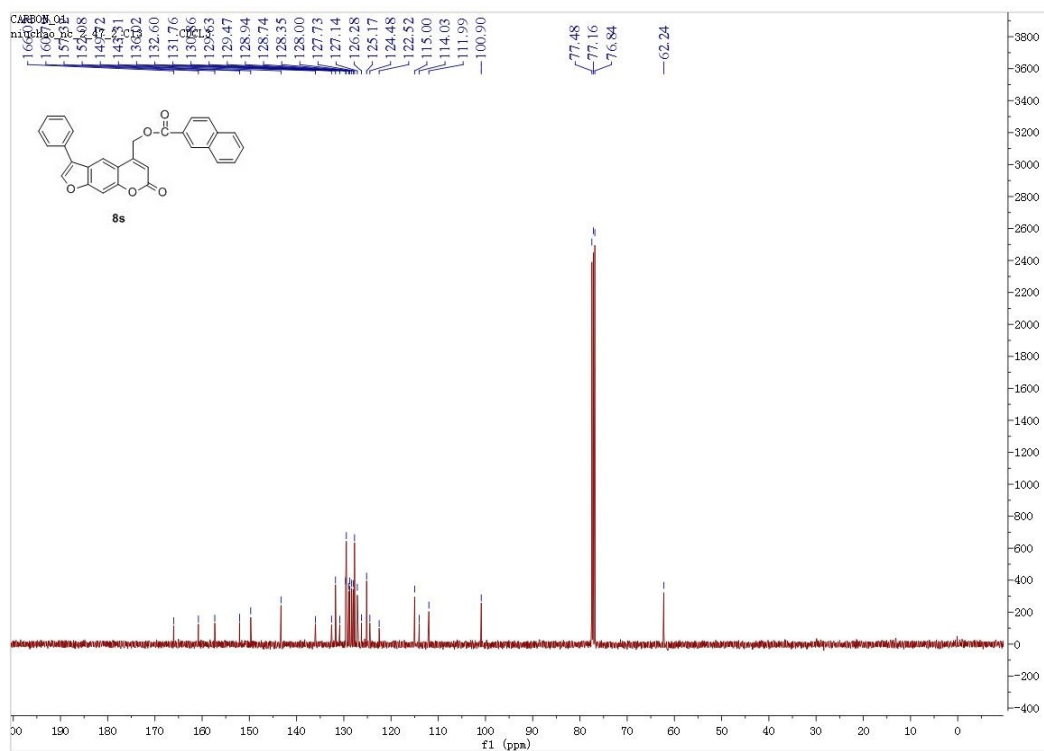
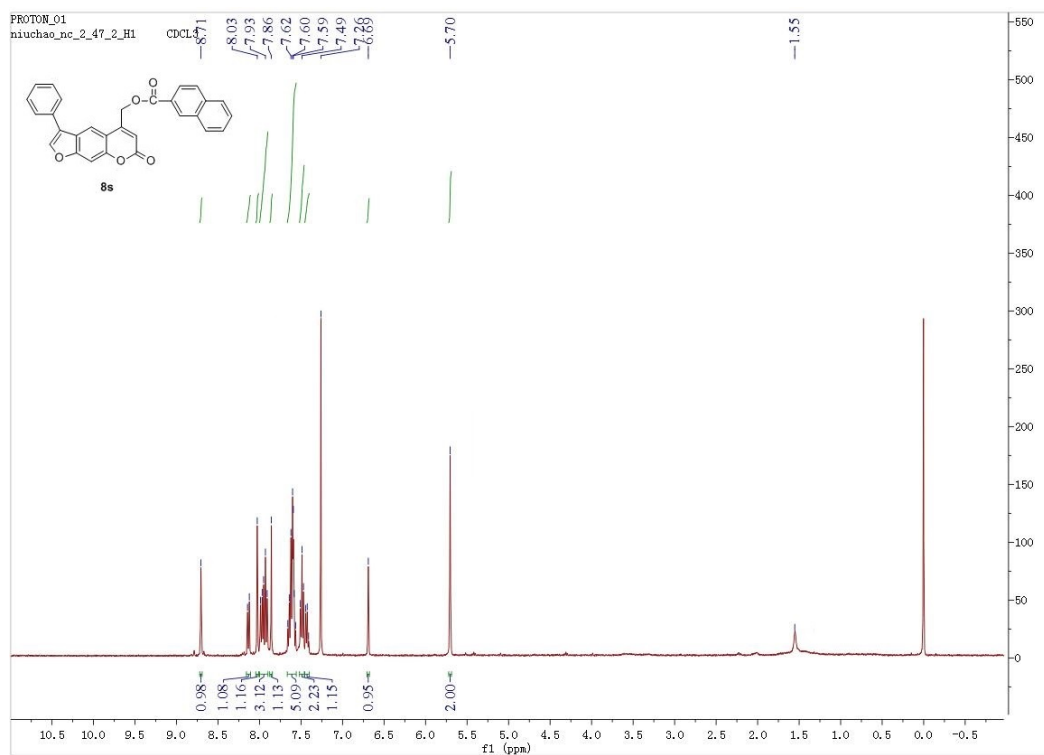
¹H NMR and ¹³C NMR spectra of **8q**



¹H NMR and ¹³C NMR spectra of **8r**



¹H NMR and ¹³C NMR spectra of 8s



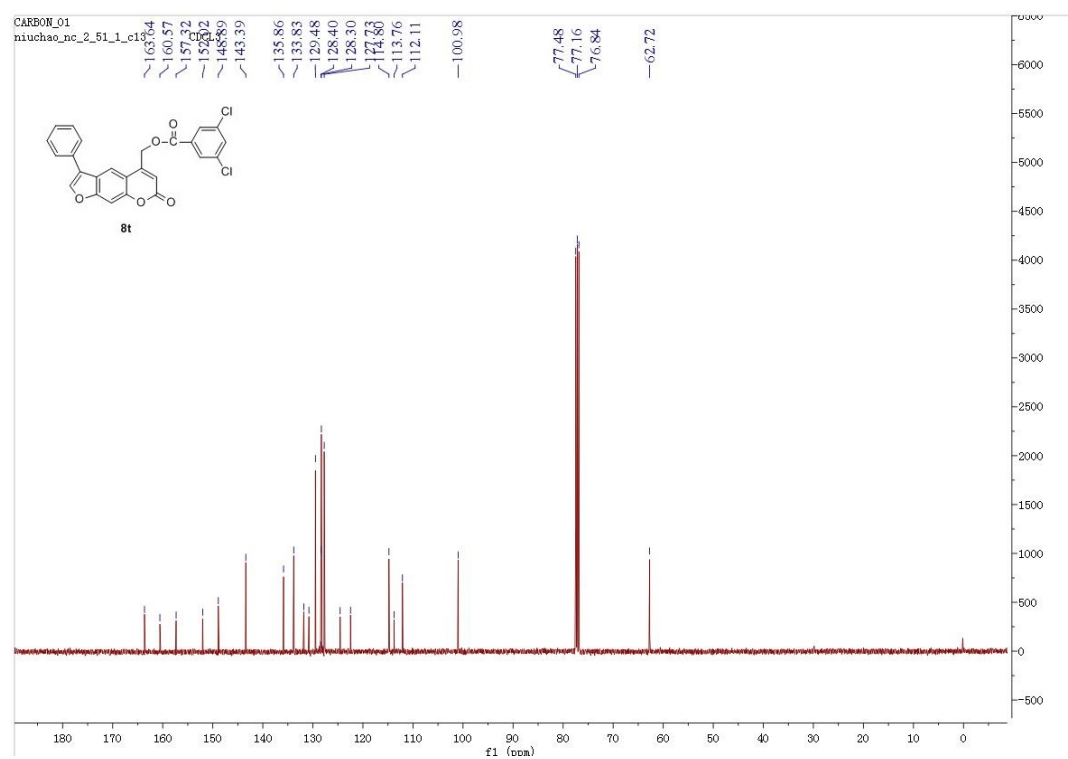
Chemical structure of compound **8t** is shown. The structure is a benzofuran derivative with a 4,4-dichlorobenzoyl group attached to the 2-position of the furan ring. The structure is labeled **8t**.

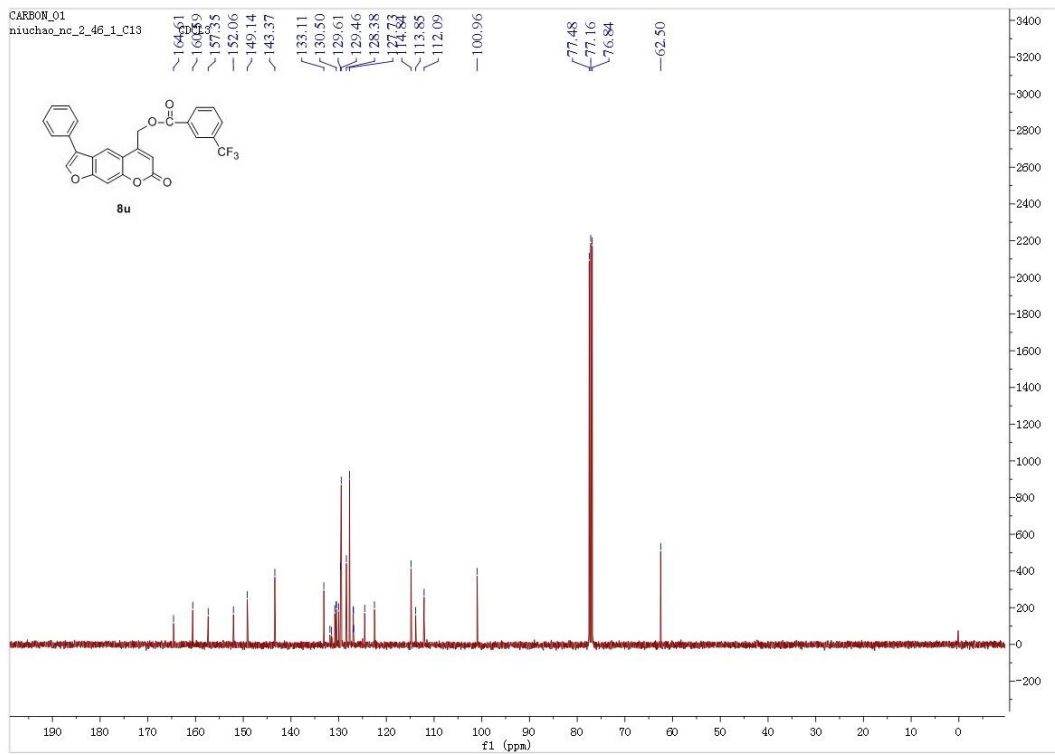
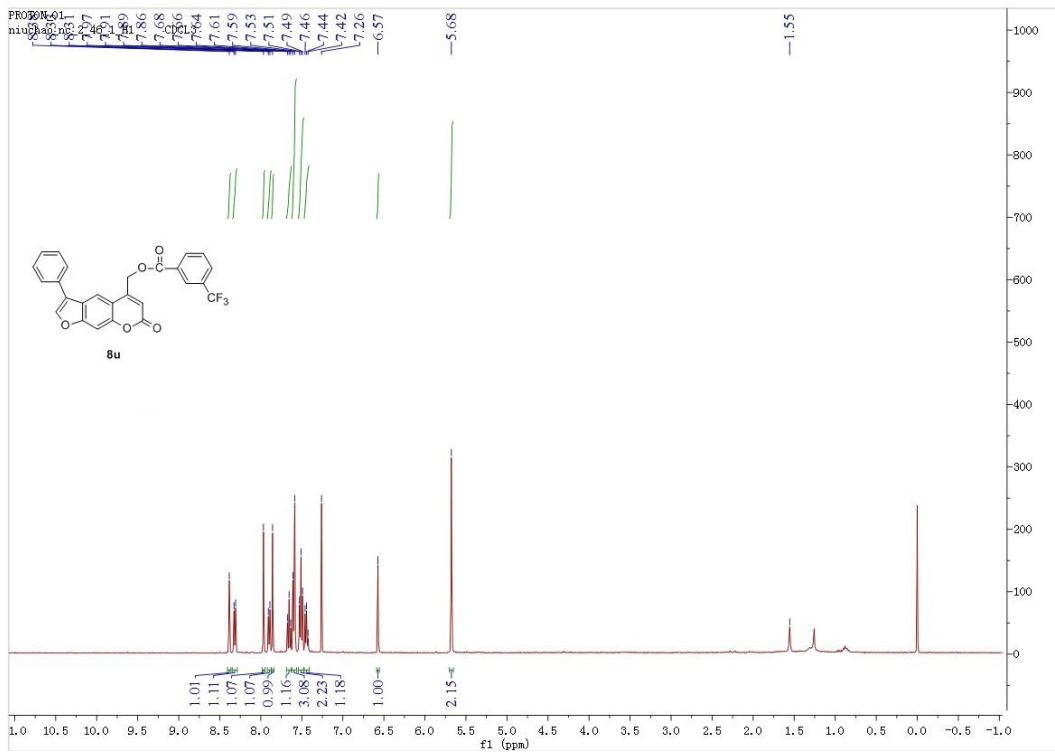
The ^1H NMR spectrum (CDCl₃) shows the following peaks (ppm):

- 7.58 (d, 1H)
- 7.55 (d, 1H)
- 7.53 (d, 1H)
- 7.51 (d, 1H)
- 7.47 (d, 1H)
- 7.45 (d, 1H)
- 7.43 (d, 1H)
- 7.38 (d, 1H)
- 7.35 (d, 1H)
- 7.32 (d, 1H)
- 7.29 (d, 1H)
- 7.16 (d, 1H)
- 7.14 (d, 1H)
- 7.12 (d, 1H)
- 7.09 (d, 1H)
- 7.07 (d, 1H)
- 7.05 (d, 1H)
- 7.03 (d, 1H)
- 7.01 (d, 1H)
- 6.99 (d, 1H)
- 6.97 (d, 1H)
- 6.95 (d, 1H)
- 6.93 (d, 1H)
- 6.91 (d, 1H)
- 6.89 (d, 1H)
- 6.87 (d, 1H)
- 6.85 (d, 1H)
- 6.83 (d, 1H)
- 6.81 (d, 1H)
- 6.79 (d, 1H)
- 6.77 (d, 1H)
- 6.75 (d, 1H)
- 6.73 (d, 1H)
- 6.71 (d, 1H)
- 6.69 (d, 1H)
- 6.67 (d, 1H)
- 6.65 (d, 1H)
- 6.63 (d, 1H)
- 6.61 (d, 1H)
- 6.59 (d, 1H)
- 6.57 (d, 1H)
- 6.55 (d, 1H)
- 5.64 (s, 3H)
- 4.30 (s, 2H)
- 3.70 (s, 3H)
- 0.00 (TMS)

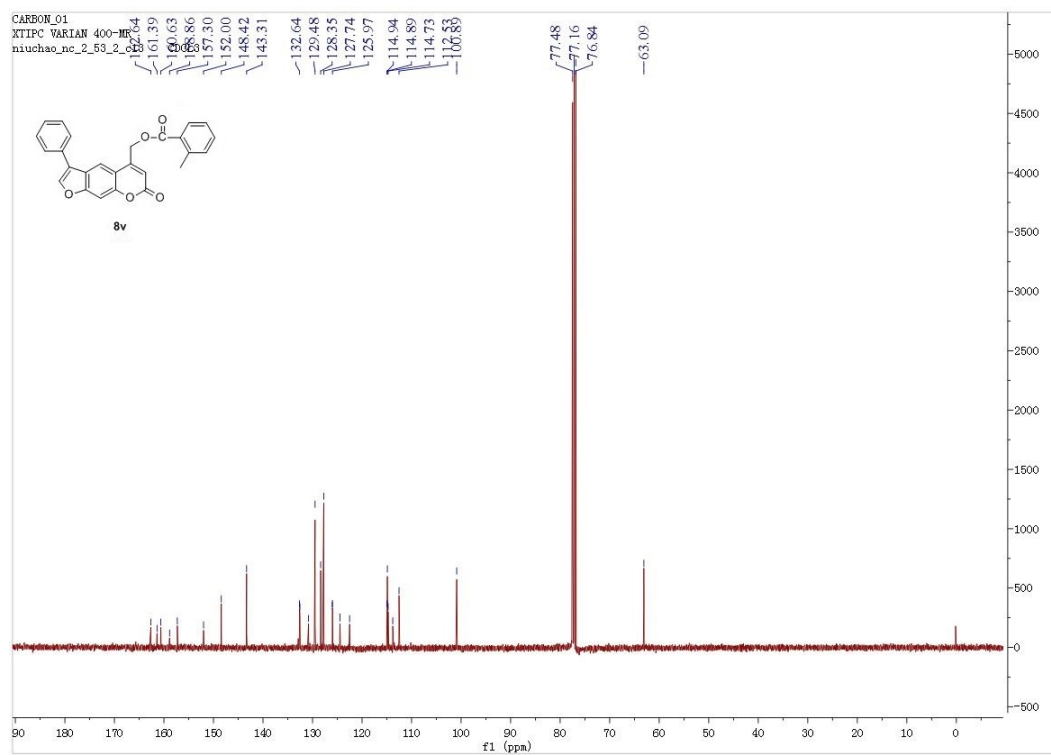
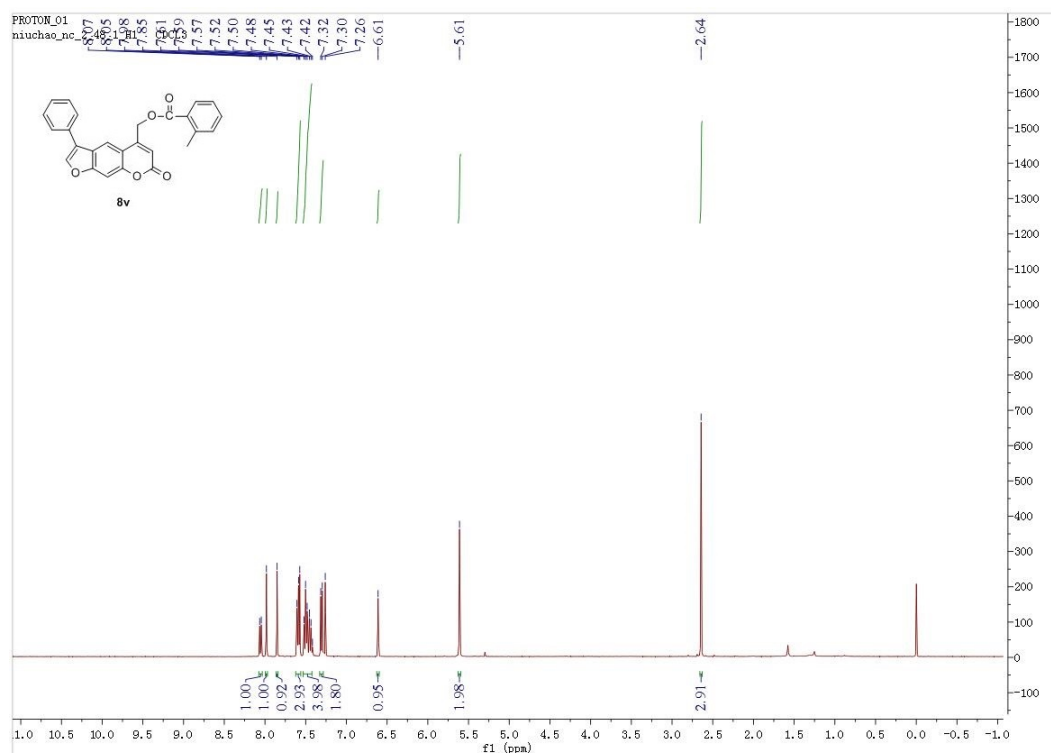
Integration values are shown below the baseline:

- 1.81
- 1.00
- 0.91
- 4.01
- 2.25
- 1.18
- 0.98
- 2.02

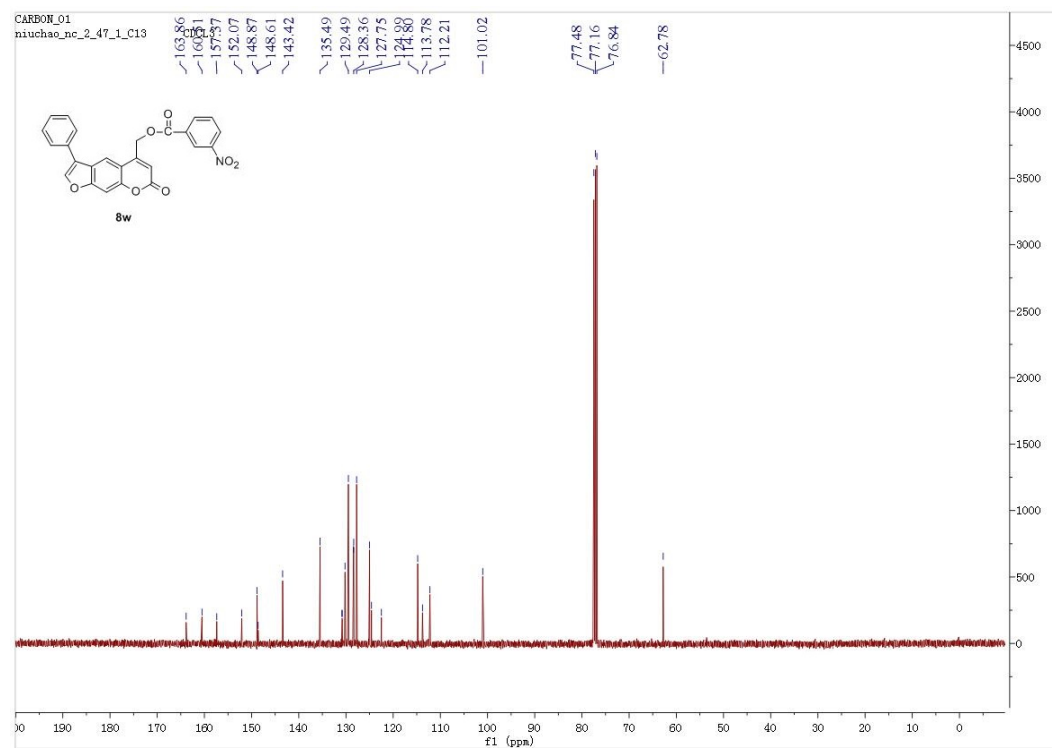
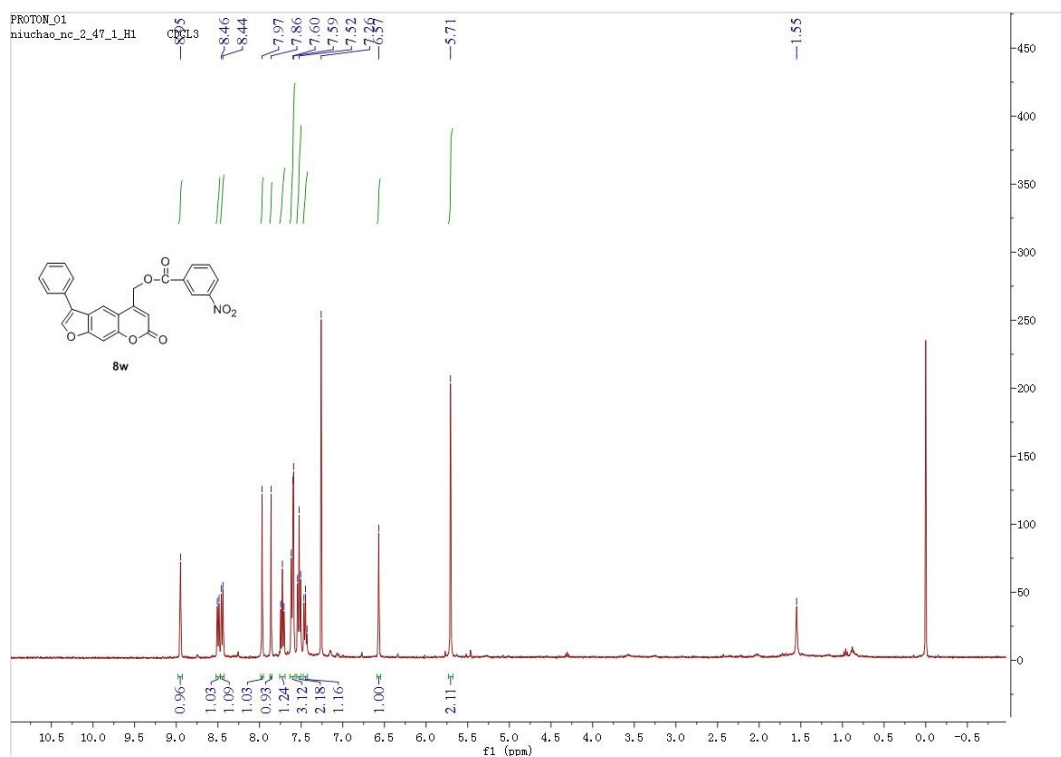


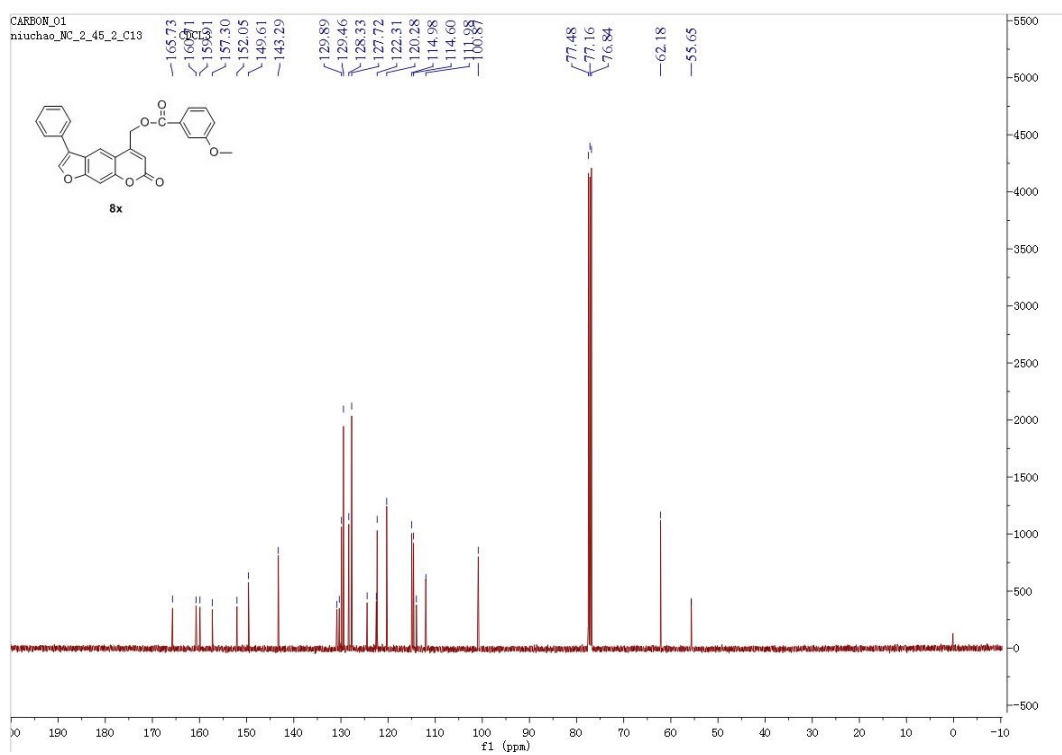
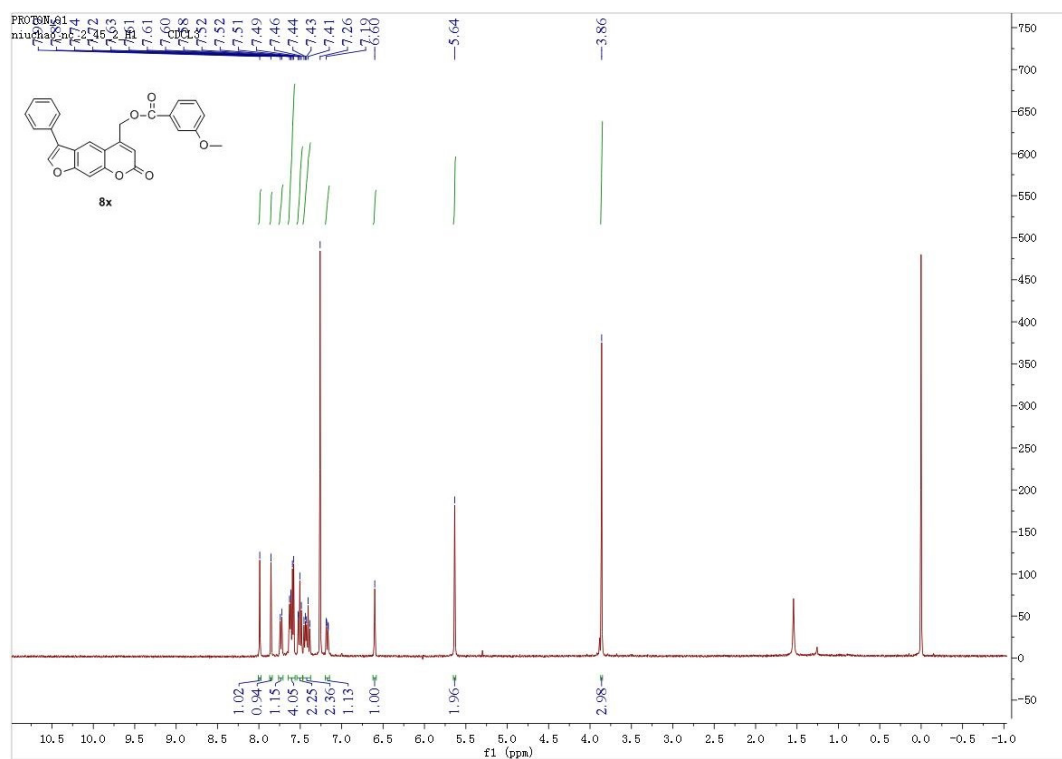
¹H NMR and ¹³C NMR spectra of **8u**

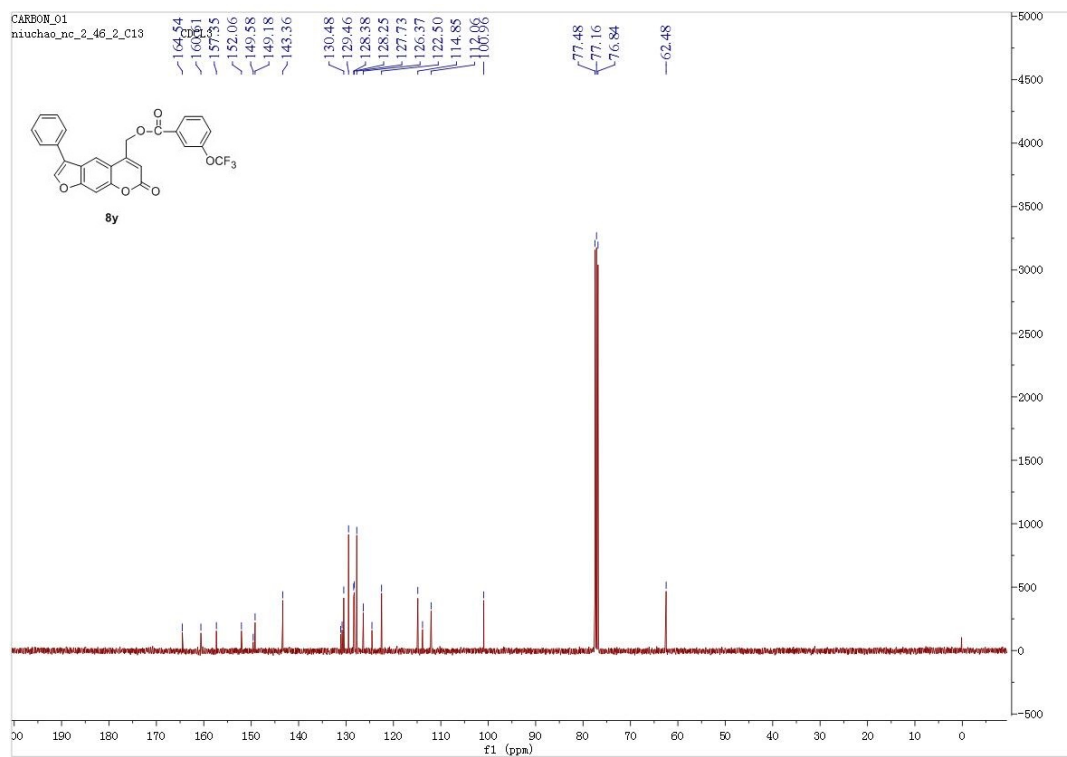
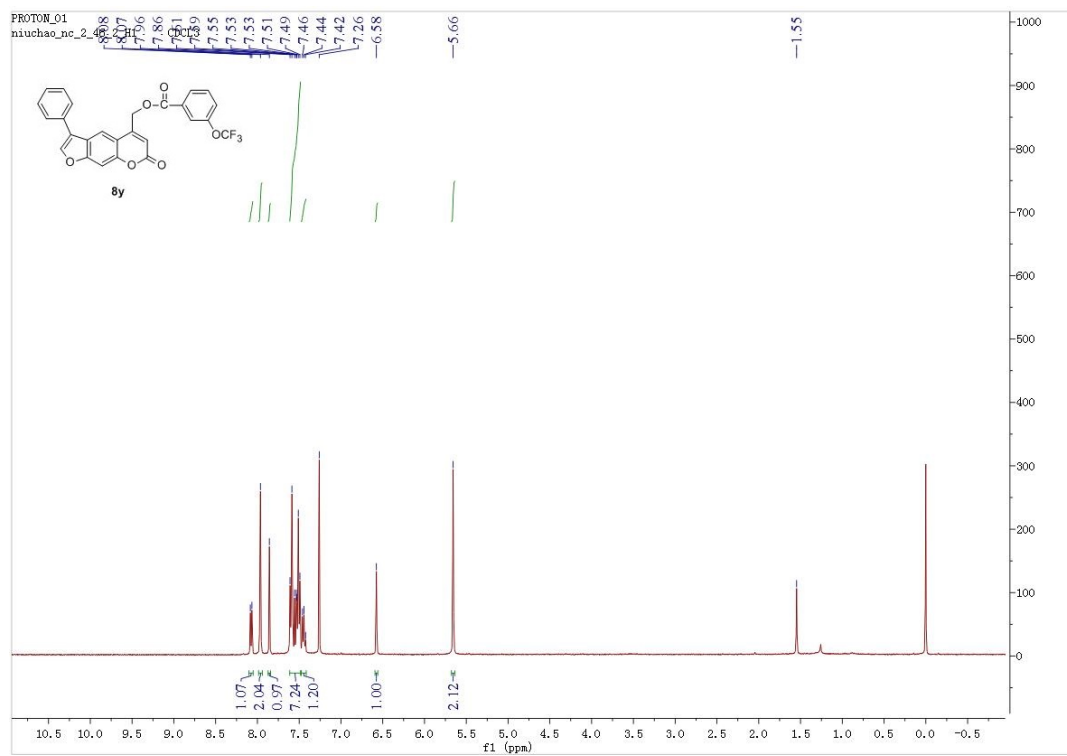
^1H NMR and ^{13}C NMR spectra of **8v**

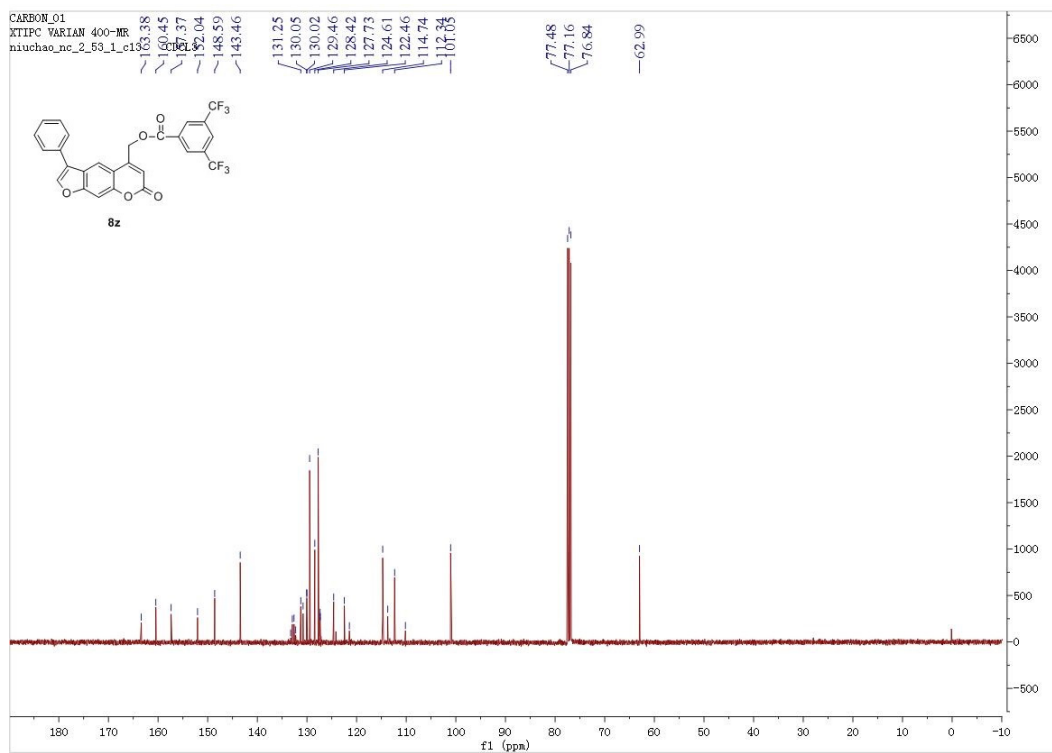
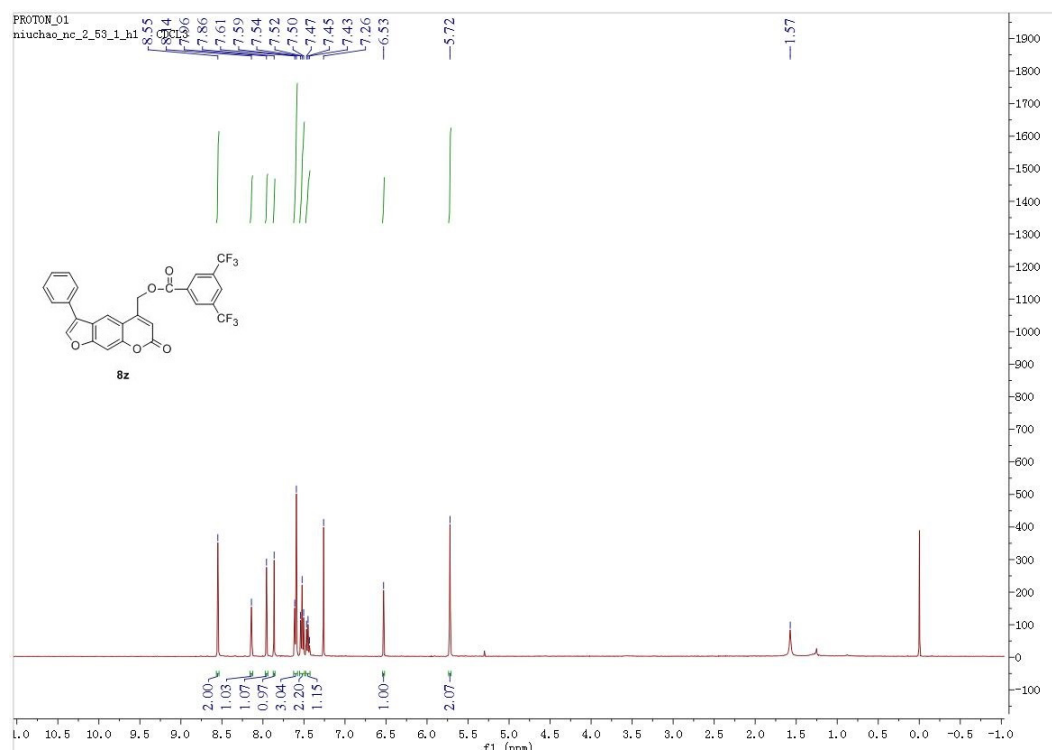


¹H NMR and ¹³C NMR spectra of 8w

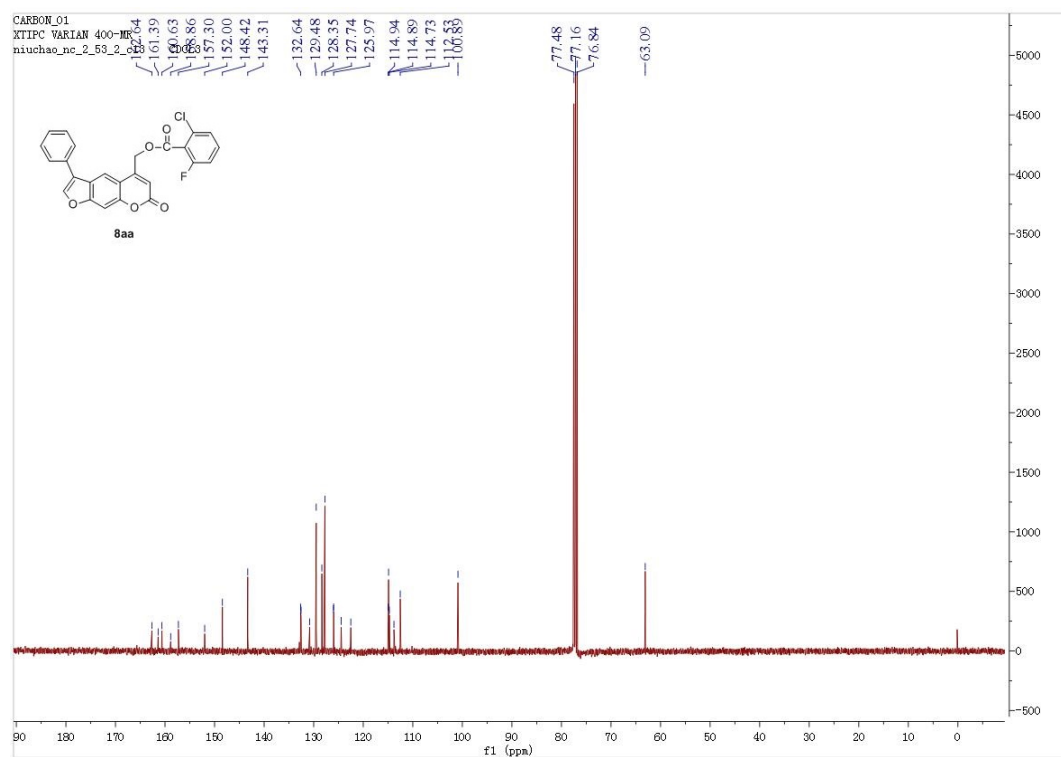
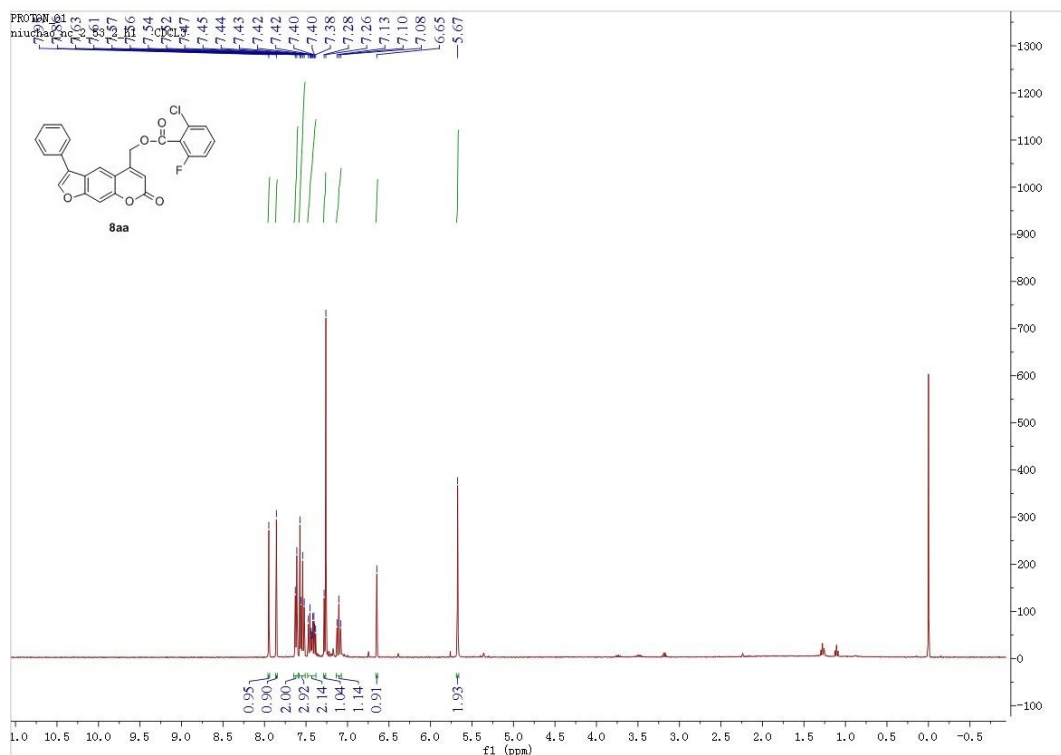


^1H NMR and ^{13}C NMR spectra of 8x

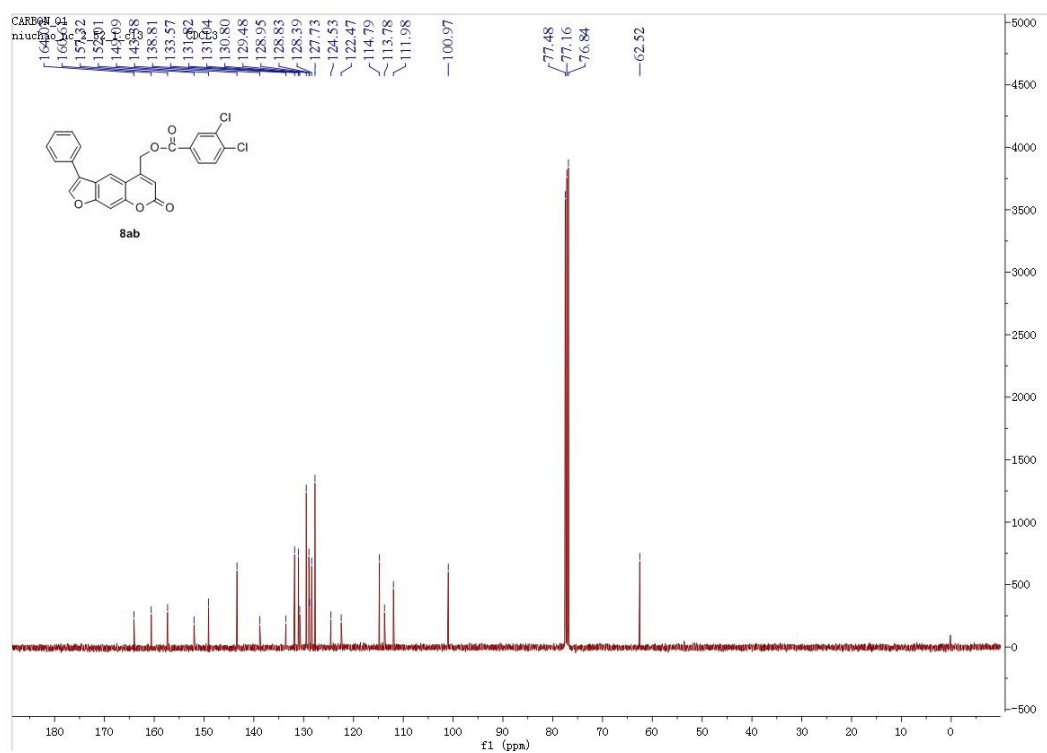
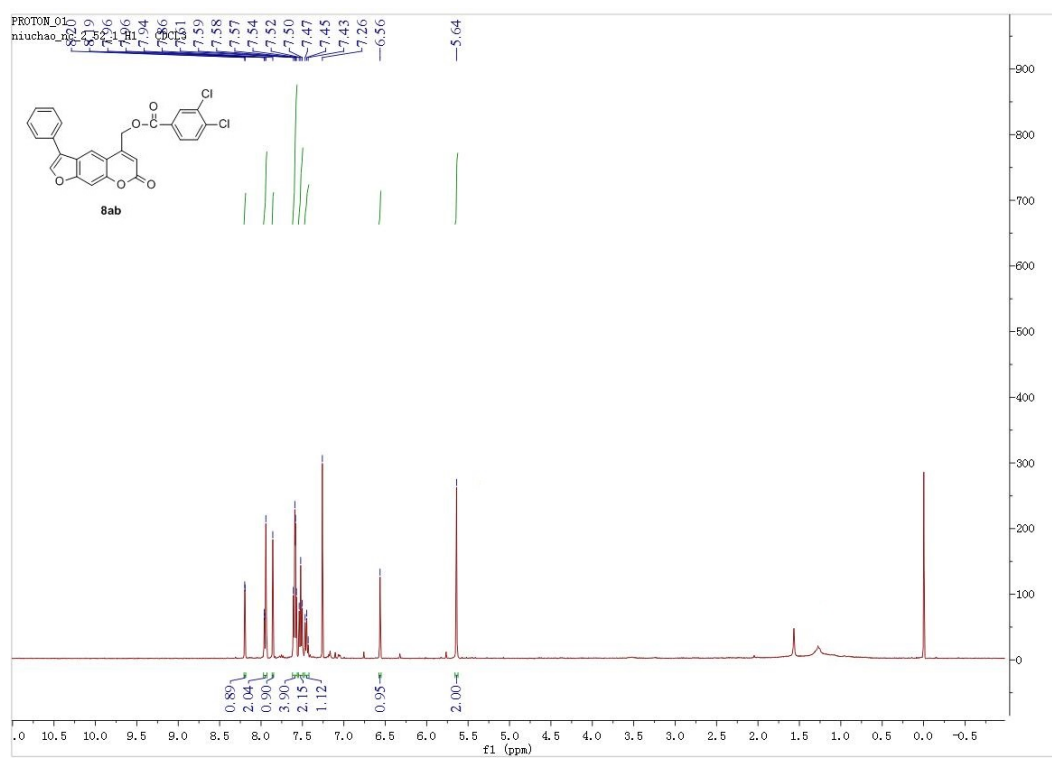
^1H NMR and ^{13}C NMR spectra of **8y**

^1H NMR and ^{13}C NMR spectra of **8z**

¹H NMR and ¹³C NMR spectra of 8aa

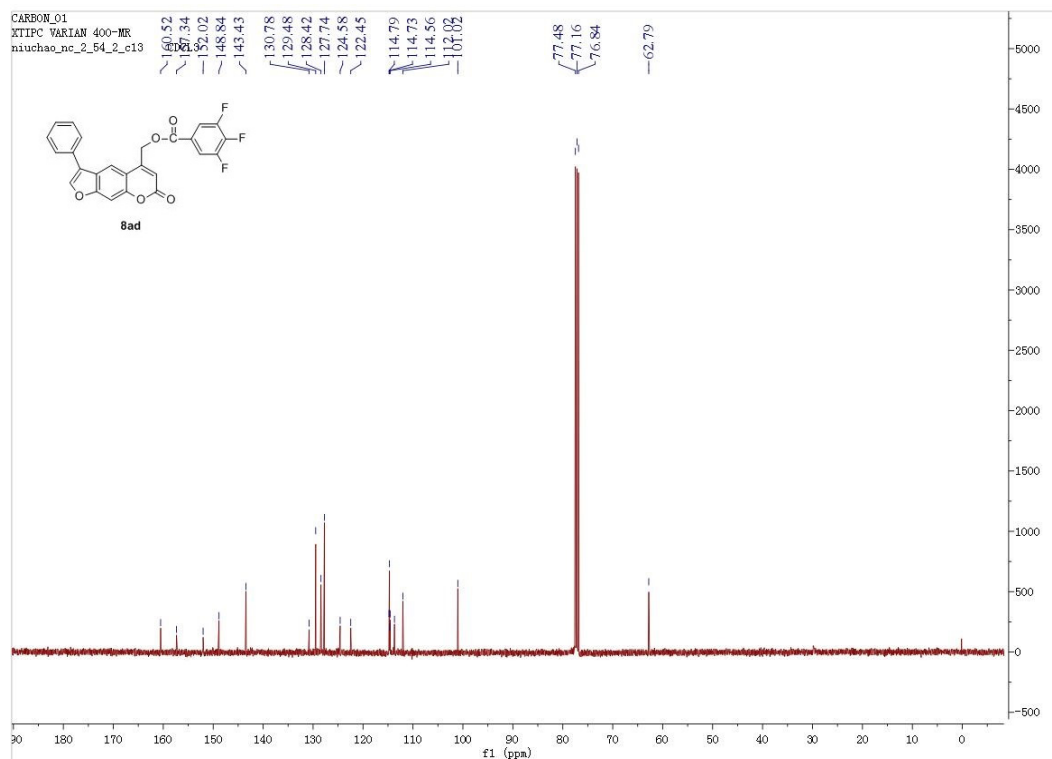
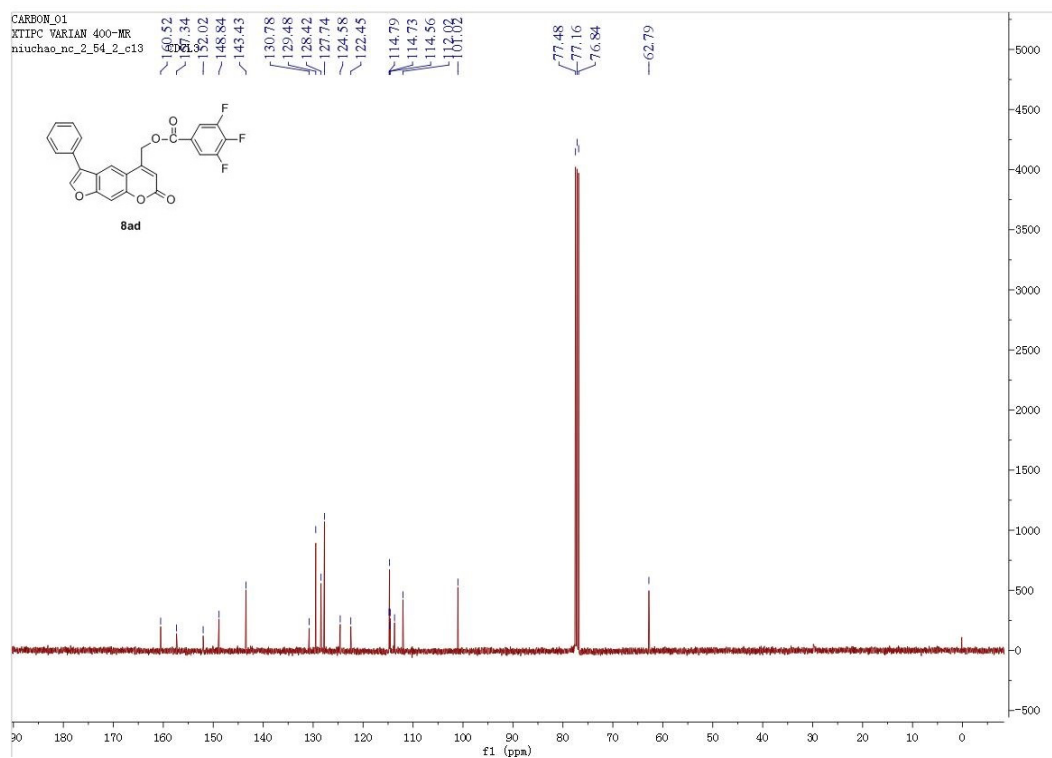


¹H NMR and ¹³C NMR spectra of **8ab**

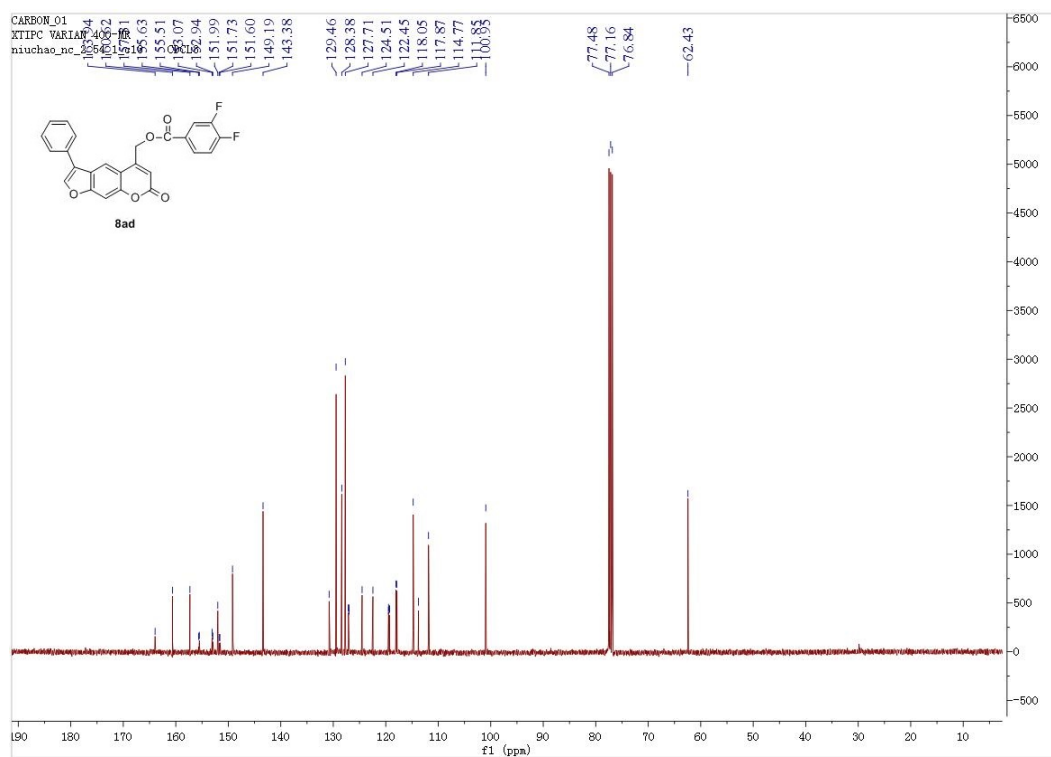
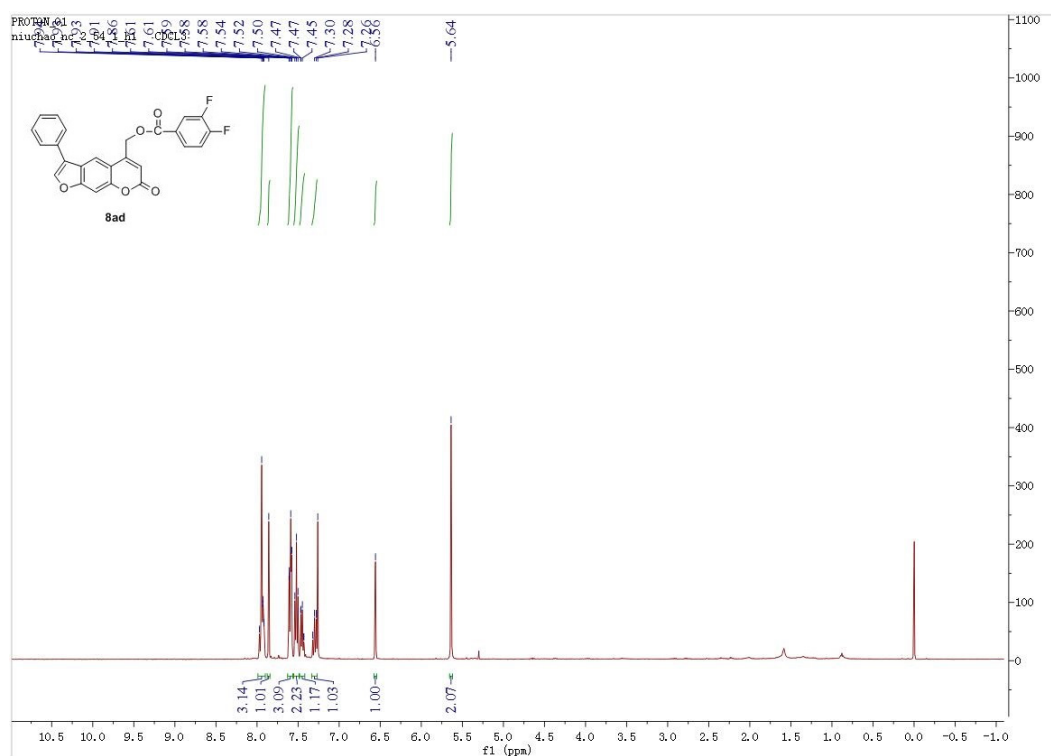




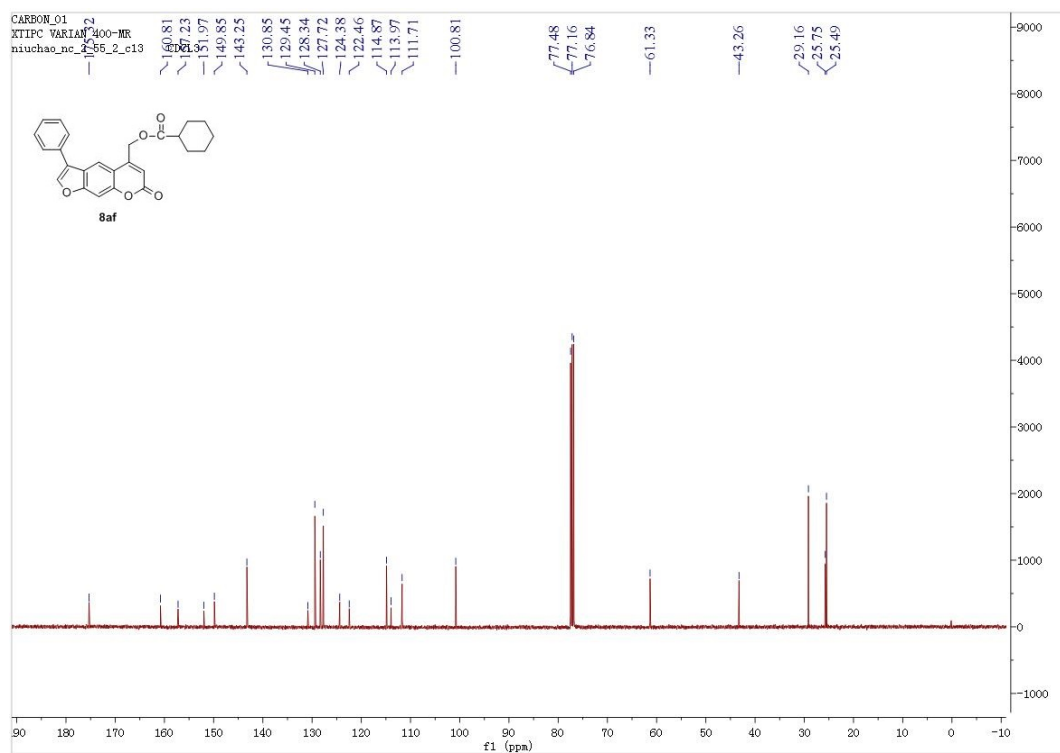
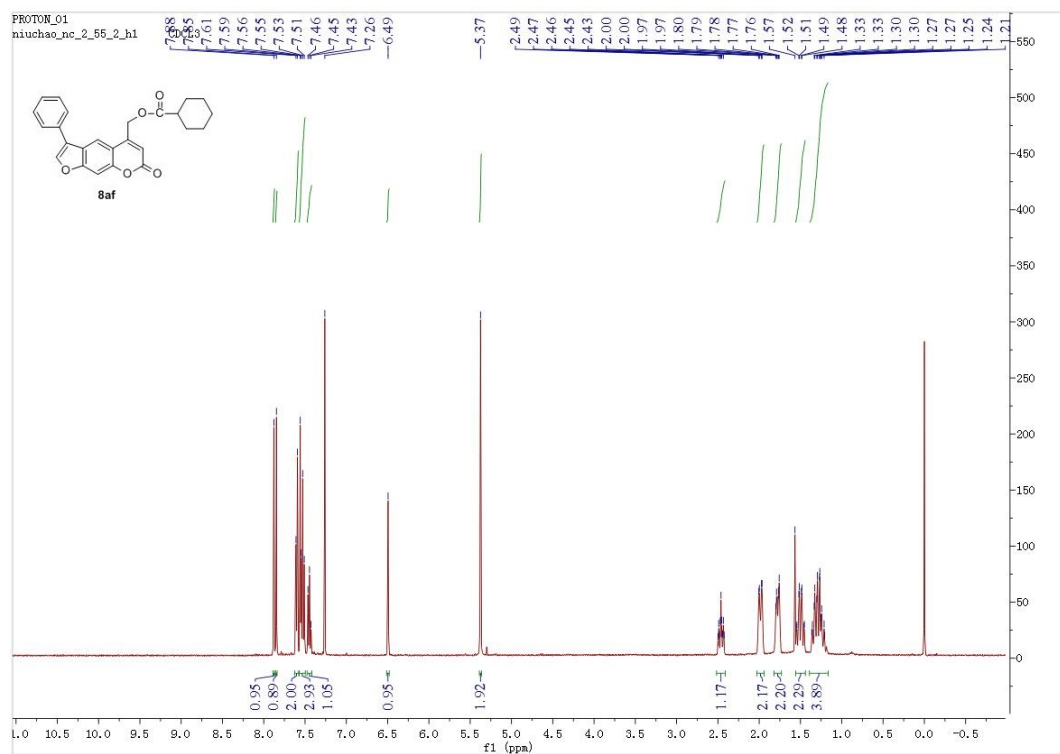
^1H NMR and ^{13}C NMR spectra of **8ad**



¹H NMR and ¹³C NMR spectra of **8ad**



¹H NMR and ¹³C NMR spectra of 8af



¹H NMR and ¹³C NMR spectra of 8ag

