Supplementary Information

Synthesis of *N*-Aryl 2-Quinolinones via Intramolecular C(sp^2)–H Amidation of Knoevenagel Products

Laichun Luo*, Kaiqi Tao, Xiaozhi Peng, Chunling Hu, Yuanfeng Lu, Hong Wang

College of Pharmacy, Hubei University of Chinese Medicine, Wuhan 430065,China

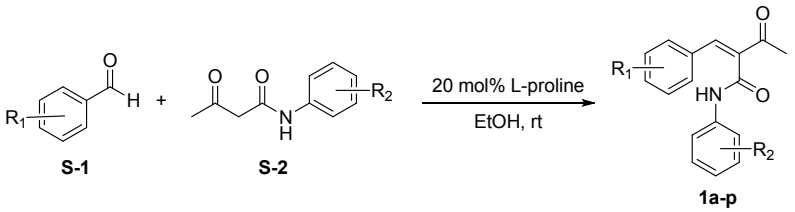
e-mail: laichunluo@163.com

CONTENTS

1. General information

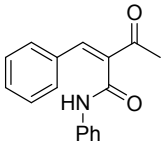
^{1}H NMR and ^{13}C NMR spectra were recorded with a Bruker AVIII-400 spectrometer, Bruker ultrashield 500 spectrometer or Varian 600M spectrometer at ambient temperature with $CDCl_3$ or DMSO-*d* 6 as the solvent. ^{1}H NMR spectra were referenced to tetramethylsilane (δ = 0.00 ppm) or DMSO-*d* 6 (δ = 2.50 ppm), and ^{13}C NMR spectra were referenced to $CDCl_3$ (δ = 77.0 ppm) or DMSO-*d* 6 (δ = 39.52 ppm). High-resolution mass spectra were recorded by Bruker Apex IV Fourier Transform Ion Cyclotron Resonance Mass Spectrometer. All melting points were measured on a WRS-2A melting point apparatus and uncorrected. IR spectra were recorded as KBr pellets on a Nicolet Nexus 470 FTIR spectrometer.

2. Preparation of Knoevenagel products 1[1-6]



A mixture of arylaldehyde **S-1** (25 mmol, 1.25 equiv), acetoacetanilide **S-2** (20 mmol, 1.0 equiv) and L-proline (4 mmol, 0.2 equiv) in EtOH (10 mL) was stirred at rt for 2–4 h (monitored by TLC). After completion of reaction, water was added slowly into the mixture to precipitate the product. The solid was filtrated, washed with small amount of petroleum ether/EtOAc (5:1), and dried under vacuum over anhydrous $CaCl_2$ to afford the product **1**.

The product was pure enough for NMR analysis. According to the literatures,[3-6] ^{13}C NMR chemical shifts of the ketone carbon and the amide carbon in the (*Z*)-isomer were in the regions about 194–196 ppm and 165–166 ppm, respectively, while that in the (*E*)-isomers were in the regions about 206–207 ppm and 160–161 ppm. Therefore, the NMR data below indicated that products **1a-p** were obtained as (*Z*)-isomers.

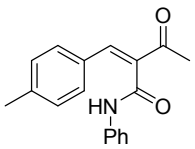


(*Z*)-2-benzylidene-3-oxo-N-phenylbutanamide (1a)[1-3]

Yield: 4.2 g, 79%. White solid, mp 117–118 °C (lit.[1] 120 °C, lit.[2] 119 °C).

^{1}H NMR (500 MHz, DMSO-d_6) δ 10.40 (s, 1H), 7.70 (s, 1H), 7.68–7.58 (m, 4H), 7.44–7.40 (m, 3H), 7.36–7.31 (m, 2H), 7.10 (t, J = 7.4 Hz, 1H), 2.45 (s, 3H).

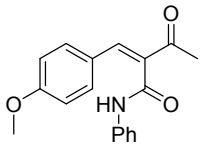
^{13}C NMR (126 MHz, DMSO-d_6) δ 196.3, 165.5, 139.5, 138.8, 137.8, 133.3, 130.5, 129.8, 128.92, 128.86, 123.8, 119.4, 26.3.



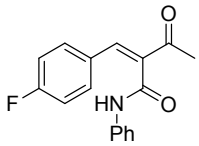
(Z)-2-(4-methylbenzylidene)-3-oxo-N-phenylbutanamide (1b)[3]

Yield: 4.6 g, 82%. White solid, mp 139–141 °C.

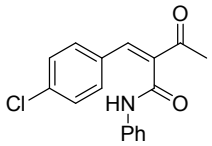
^{1}H NMR (500 MHz, DMSO-*d* 6) δ 10.38 (s, 1H), 7.66 (s, 1H), 7.64–7.61 (m, 2H), 7.55 (d, J = 8.2 Hz, 2H), 7.35–7.31 (m, 2H), 7.22 (d, J = 8.0 Hz, 2H), 7.12–7.07 (m, 1H), 2.42 (s, 3H), 2.29 (s, 3H).
^{13}C NMR (126 MHz, DMSO-*d* 6) δ 196.2, 165.7, 140.7, 139.6, 138.9, 137.0, 130.5, 129.9, 129.6, 128.9, 123.7, 119.4, 26.2, 21.0.



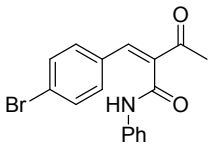
(*Z*)-2-(4-methoxybenzylidene)-3-oxo-N-phenylbutanamide (1c) [3]
Yield: 4.4 g, 75%. White solid, mp 102–104 °C.
^{1}H NMR (400 MHz, DMSO-d_6) δ 10.41 (s, 1H), 7.70–7.60 (m, 5H), 7.34 (t, J = 7.8 Hz, 2H), 7.10 (t, J = 7.4 Hz, 1H), 6.99 (d, J = 8.8 Hz, 2H), 3.76 (s, 3H), 2.41 (s, 3H).
^{13}C NMR (101 MHz, DMSO-d_6) δ 196.1, 166.0, 161.2, 139.5, 139.0, 135.6, 132.0, 128.9, 125.6, 123.7, 119.4, 114.5, 55.4, 26.2.



(*Z*)-2-(4-fluorobenzylidene)-3-oxo-N-phenylbutanamide (1d)
Yield: 4.0 g, 71%. White solid, mp 107–110 °C
^{1}H NMR (500 MHz, DMSO-d_6) δ 10.42 (s, 1H), 7.75–7.69 (m, 3H), 7.64–7.59 (m, 2H), 7.37–7.26 (m, 4H), 7.10 (t, J = 7.4 Hz, 1H), 2.44 (s, 3H).
^{13}C NMR (126 MHz, DMSO-d_6) δ 196.3, 165.5, 163.2 (d, J = 249.7 Hz), 138.8, 138.4, 137.5, 132.2 (d, J = 8.8 Hz), 130.0 (d, J = 3.2 Hz), 128.9, 123.8, 119.4, 116.1 (d, J = 21.9 Hz), 26.3.
HRMS (ESI): *m/z* calcd for $C_{17}H_{15}FNO_2$ $[M + H]^+$ 284.1081, found 284.1082.



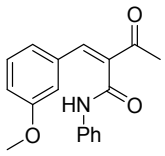
(*Z*)-2-(4-chlorobenzylidene)-3-oxo-N-phenylbutanamide (1e) [4]
Yield: 5.3 g, 88%. White solid, mp 121–122 °C (lit. [4] 122–127 °C).
^{1}H NMR (400 MHz, DMSO-d_6) δ 10.45 (s, 1H), 7.73 (s, 1H), 7.70–7.60 (m, 4H), 7.51 (d, J = 8.5 Hz, 2H), 7.34 (t, J = 7.9 Hz, 2H), 7.10 (t, J = 7.4 Hz, 1H), 2.46 (s, 3H).
^{13}C NMR (101 MHz, DMSO-d_6) δ 196.3, 165.3, 138.7, 138.2, 135.2, 132.3, 131.4, 129.1, 128.9, 123.9, 119.5, 26.4.



(*Z*)-2-(4-bromobenzylidene)-3-oxo-N-phenylbutanamide (1f)
Yield: 5.8 g, 84%. White solid, mp 120–122 °C
^{1}H NMR (500 MHz, DMSO-d_6) δ 10.41 (s, 1H), 7.70 (s, 1H), 7.67–7.56 (m, 6H), 7.34 (d, J = 7.9 Hz, 2H), 7.10 (d, J = 7.4 Hz, 1H), 2.44 (s, 3H).
^{13}C NMR (126 MHz, DMSO-d_6) δ 196.3, 165.3, 138.7, 138.4, 138.3, 132.7, 132.0, 131.5, 128.9, 124.1,

123.9, 119.5, 26.4.

HRMS (ESI): *m/z* calcd for $C_{17}H_{15}BrNO_2$ $[M + H]^+$ 344.0281, found 344.0285.



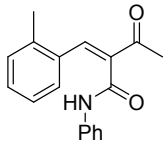
(*Z*)-2-(3-methoxybenzylidene)-3-oxo-N-phenylbutanamide (1g)

Yield: 4.7 g, 80%. White solid, mp 93–95 °C

^{1}H NMR (500 MHz, DMSO-d_6) δ 10.42 (s, 1H), 7.68 (s, 1H), 7.65–7.61 (m, 2H), 7.35–7.31 (m, 3H), 7.26–7.22 (m, 2H), 7.12–7.07 (m, 1H), 7.01–6.97 (m, 1H), 3.63 (s, 3H), 2.44 (s, 3H).

^{13}C NMR (126 MHz, DMSO-d_6) δ 196.2, 165.5, 159.3, 139.4, 138.8, 137.9, 134.6, 129.9, 128.8, 123.8, 122.5, 119.3, 116.5, 114.4, 55.0, 26.3.

HRMS (ESI): *m/z* calcd for $C_{18}H_{18}NO_3$ $[M + H]^+$ 296.1281, found 296.1284.

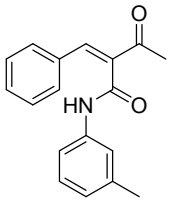


(*Z*)-2-(2-methylbenzylidene)-3-oxo-N-phenylbutanamide (1h) [5]

Yield: 3.6 g, 64%. White solid, mp 105–107 °C.

^{1}H NMR (500 MHz, DMSO-d_6) δ 10.24 (s, 1H), 7.82 (s, 1H), 7.54–7.48 (m, 3H), 7.32–7.24 (m, 4H), 7.16–7.10 (m, 1H), 7.06 (t, J = 7.4 Hz, 1H), 2.45 (s, 3H), 2.43 (s, 3H).

^{13}C NMR (126 MHz, DMSO-d_6) δ 196.1, 165.2, 138.9, 138.6, 138.1, 137.9, 132.7, 130.4, 129.9, 128.7, 127.5, 126.0, 123.7, 119.5, 26.5, 19.6.

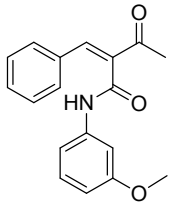


(*Z*)-2-benzylidene-3-oxo-N-(m-tolyl)butanamide (1i) [5]

Yield: 3.4 g, 61%. White solid, mp 108–109 °C (lit.[5] 109–115 °C).

^{1}H NMR (500 MHz, DMSO-d_6) δ 10.33 (s, 1H), 7.69 (s, 1H), 7.67–7.62 (m, 2H), 7.47 (s, 1H), 7.45–7.37 (m, 4H), 7.21 (t, J = 7.8 Hz, 1H), 6.92 (d, J = 7.5 Hz, 1H), 2.44 (s, 3H), 2.29 (s, 3H).

^{13}C NMR (126 MHz, DMSO-d_6) δ 196.2, 165.5, 139.4, 138.7, 138.1, 137.8, 133.3, 130.5, 129.8, 128.9, 128.7, 124.5, 119.9, 116.6, 26.3, 21.2.



(*Z*)-2-benzylidene-N-(3-methoxyphenyl)-3-oxobutanamide (1j)

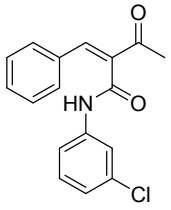
Yield: 3.7 g, 63%. Pale yellow solid, mp 96–99 °C

^{1}H NMR (500 MHz, DMSO-d_6) δ 10.39 (s, 1H), 7.70 (s, 1H), 7.68–7.62 (m, 2H), 7.45–7.40 (m, 3H), 7.30 (t, J = 2.1 Hz, 1H), 7.23 (t, J = 8.1 Hz, 1H), 7.19–7.13 (m, 1H), 6.71–6.66 (m, 1H), 3.73 (s, 3H),

2.44 (s, 3H).

^{13}C NMR (126 MHz, DMSO-d_6) δ 196.2, 165.5, 159.5, 139.9, 139.5, 137.7, 133.3, 130.5, 129.8, 129.7, 128.9, 111.7, 109.1, 105.2, 55.0, 26.3.

HRMS (ESI): *m/z* calcd for $C_{18}H_{18}NO_3$ $[M + H]^+$ 296.1281, found 296.1283.



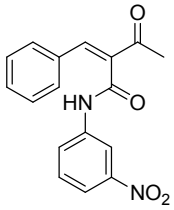
(*Z*)-2-benzylidene-N-(3-chlorophenyl)-3-oxobutanamide (1k)

Yield: 5.1 g, 85%. Pale yellow solid, mp 98–101 °C

^{1}H NMR (500 MHz, DMSO-d_6) δ 10.61 (s, 1H), 7.85 (t, J = 2.0 Hz, 1H), 7.75 (s, 1H), 7.66–7.60 (m, 2H), 7.48–7.40 (m, 4H), 7.36 (t, J = 8.1 Hz, 1H), 7.18–7.15 (m, 1H), 2.45 (s, 3H).

^{13}C NMR (126 MHz, DMSO-d_6) δ 196.2, 165.9, 140.2, 140.0, 137.4, 133.17, 133.16, 130.64, 130.61, 129.7, 129.0, 123.5, 118.7, 117.7, 26.3.

HRMS (ESI): *m/z* calcd for $C_{17}H_{15}ClNO_2$ $[M + H]^+$ 300.0786, found 300.0790.



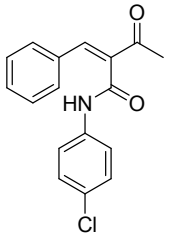
(*Z*)-2-benzylidene-N-(3-nitrophenyl)-3-oxobutanamide (1l)

Yield: 4.6 g, 74%. Yellow solid, mp 147–148 °C

^{1}H NMR (500 MHz, DMSO-d_6) δ 10.91 (s, 1H), 8.67 (t, J = 2.1 Hz, 1H), 8.04–7.84 (m, 2H), 7.80 (s, 1H), 7.71–7.57 (m, 3H), 7.50–7.34 (m, 3H), 2.48 (s, 3H).

^{13}C NMR (126 MHz, DMSO-d_6) δ 196.3, 166.2, 148.0, 140.4, 139.8, 137.3, 133.1, 130.7, 130.4, 129.7, 129.0, 125.3, 118.4, 113.3, 26.2.

HRMS (ESI): *m/z* calcd for $C_{17}H_{15}N_2O_4$ $[M + H]^+$ 311.1026, found 311.1028.

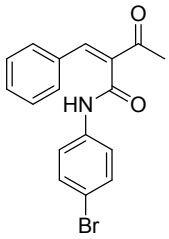


(*Z*)-2-benzylidene-N-(4-chlorophenyl)-3-oxobutanamide (1m) [5]

Yield: 5.2 g, 87%. White solid, mp 155–158 °C (lit. [5] 153–156 °C).

^{1}H NMR (500 MHz, DMSO-d_6) δ 10.54 (s, 1H), 7.73 (s, 1H), 7.66–7.61 (m, 4H), 7.44–7.37 (m, 5H), 2.45 (s, 3H).

^{13}C NMR (126 MHz, DMSO-d_6) δ 196.3, 165.6, 139.9, 137.7, 137.5, 133.2, 130.6, 129.7, 128.9, 128.8, 127.4, 120.9, 26.3.



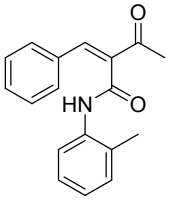
(*Z*)-2-benzylidene-N-(4-bromophenyl)-3-oxobutanamide (1n)

Yield: 6.1 g, 89%. White solid, mp 163–166 °C

^{1}H NMR (500 MHz, DMSO-d_6) δ 10.54 (s, 1H), 7.73 (s, 1H), 7.64–7.58 (m, 4H), 7.54–7.50 (m, 2H), 7.43–7.39 (m, 3H), 2.45 (s, 3H).

^{13}C NMR (126 MHz, DMSO-d_6) δ 196.2, 165.6, 139.9, 138.1, 137.5, 133.2, 131.7, 130.6, 129.7, 128.9, 121.3, 115.4, 26.3.

HRMS (ESI): *m/z* calcd for $C_{17}H_{15}BrNO_2$ $[M + H]^+$ 344.0281, found 344.0284.

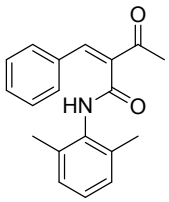


(*Z*)-2-benzylidene-3-oxo-N-(o-tolyl)butanamide (1o) [7]

Yield: 4.2 g, 75%. White solid, mp 137–138 °C (lit. [6]135 °C).

^{1}H NMR (400 MHz, DMSO-d_6) δ 9.82 (s, 1H), 7.76–7.66 (m, 3H), 7.55–7.38 (m, 4H), 7.26–7.08 (m, 3H), 2.47 (s, 3H), 2.11 (s, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 196.2, 165.8, 139.3, 138.1, 135.5, 133.5, 132.3, 130.4, 129.8, 128.9, 126.0, 125.7, 125.3, 26.4, 17.7.



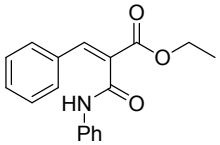
(*Z*)-2-benzylidene-N-(2,6-dimethylphenyl)-3-oxobutanamide (1p)

Yield: 4.5 g, 77%. White solid, mp 183–184 °C

^{1}H NMR (500 MHz, DMSO-d_6) δ 9.65 (s, 1H), 7.79 (s, 1H), 7.76–7.72 (m, 2H), 7.47–7.43 (dd, J = 4.9, 1.7 Hz, 3H), 7.09–7.01 (m, 3H), 2.51 (s, 3H), 2.09 (s, 6H).

^{13}C NMR (126 MHz, DMSO-d_6) δ 196.8, 164.8, 140.2, 138.9, 135.3, 134.0, 133.7, 130.3, 129.8, 128.7, 127.8, 126.4, 26.3, 18.3.

HRMS (ESI): *m/z* calcd for $C_{19}H_{20}NO_2$ $[M + H]^+$ 294.1489, found 294.1493.



(*E*)-ethyl 3-phenyl-2-(phenylcarbamoyl)acrylate (1q) [5]

Prepared in a similar procedure from benzaldehyde and ethyl 3-oxo-3-(phenyl- amino)propanoate.

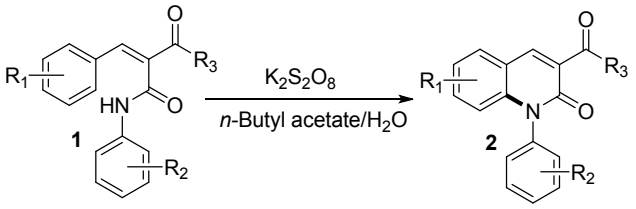
Yield: 3.0 g, 51%. White solid, mp 154–157 °C (lit. [5] 150–158 °C).

^{1}H NMR (500 MHz, DMSO-d_6) δ 10.52 (s, 1H), 7.68 (s, 1H), 7.66–7.58 (m, 4H), 7.43–7.39 (m, 3H),

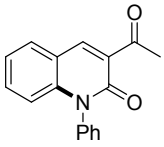
7.36–7.31 (m, 2H), 7.14–7.07 (m, 1H), 4.25 (q, J = 7.1 Hz, 2H), 1.25 (t, J = 7.1 Hz, 3H).

^{13}C NMR (126 MHz, DMSO-d_6) δ 164.5, 164.0, 139.9, 138.8, 132.9, 130.5, 129.7, 129.5, 128.9, 128.9, 123.8, 119.5, 61.1, 14.1.

3. Preparation of N-aryl 2-quinolinones 2



A mixture of substrate **1** (5 mmol) and $K_2S_2O_8$ (10.0 mmol or 20 mmol as indicatied in Table 2) in *n*-Butyl acetate/H_2O (1:19, 100 mL) was vigorously stirred under reflux. After completion of reaction, the mixture was cooled, and extracted with EtOAc (3×50 mL). The combined organic extracts were washed with brine, dried with anhydrous Na_2SO_4, and concentrated. The residue obtained was purified by column chromatography on silica gel (petroleum ether/EtOAc) to afford the product **2**.



3-acetyl-1-phenylquinolin-2(1*H*)-one (2a)

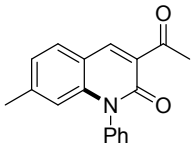
Yield: 958 mg, 73%. Yellow solid, mp 174–175 °C.

IR (cm^{-1}): 3064, 3005, 1689, 1656, 1607, 1556, 1260, 1200, 758, 696.

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.58 (s, 1H), 7.75 (dd, J = 7.8, 1.2 Hz, 1H), 7.67–7.61 (m, 2H), 7.56 (t, J = 7.5 Hz, 1H), 7.47–7.41 (m, 1H), 7.35–7.21 (m, 3H), 6.66 (d, J = 8.6 Hz, 1H), 2.76 (s, 3H).

^{13}C NMR (126 MHz, $CDCl_3$) δ 197.9, 161.0, 143.8, 142.7, 137.4, 132.7, 130.7, 130.4, 129.2, 129.1, 128.6, 122.9, 119.1, 116.0, 31.2.

HRMS (ESI): *m/z* calcd for $C_{17}H_{14}NO_2$ $[M + H]^+$ 264.1019, found 264.1020.



3-acetyl-7-methyl-1-phenylquinolin-2(1*H*)-one (2b)

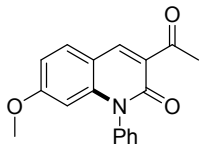
Yield: 1034 mg, 75%.Yellow solid, mp184–185 °C.

IR (cm^{-1}): 3063, 3034, 2990, 1681, 1657, 1614, 1550, 1364, 1200, 691.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.55 (s, 1H), 7.67–7.53 (m, 4H), 7.29 (d, J = 7.3 Hz, 2H), 7.07 (d, J = 7.9 Hz, 1H), 6.44 (s, 1H), 2.74 (s, 3H), 2.32 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 197.7, 161.1, 144.2, 143.7, 142.8, 137.4, 130.5, 130.3, 129.0, 128.5, 127.7, 124.4, 116.9, 115.8, 31.1, 22.2.

HRMS (ESI): *m/z* calcd for $C_{18}H_{16}NO_2$ $[M + H]^+$ 278.1176, found 278.1174.



3-acetyl-7-methoxy-1-phenylquinolin-2(1*H*)-one (2c)

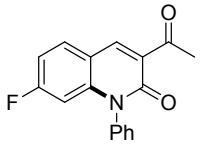
Yield: 677 mg, 46%. Yellow solid, mp 192–194 °C.

IR (cm^{-1}): 3044, 3005, 2948, 1680, 1656, 1611, 1545, 1221.

^1H NMR (500 MHz, $CDCl_3$) δ 8.56 (s, 1H), 7.69–7.60 (m, 3H), 7.58–7.52 (m, 1H), 7.38–7.27 (m, 2H), 6.84 (dd, J = 8.7, 2.4 Hz, 1H), 6.05 (d, J = 2.3 Hz, 1H), 3.69 (s, 3H), 2.74 (s, 3H).

^{13}C NMR (126 MHz, $CDCl_3$) δ 197.8, 163.6, 161.5, 144.9, 143.9, 137.6, 132.6, 130.4, 129.2, 128.5, 125.7, 113.5, 111.4, 99.7, 55.5, 31.2.

HRMS (ESI): *m/z* calcd for $C_{18}H_{16}NO_3$ $[M + H]^+$ 294.1125, found 278.1128.



3-acetyl-7-fluoro-1-phenylquinolin-2(1*H*)-one (2d)

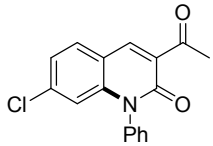
Yield: 940 mg, 67%. Yellow solid, mp 168–169 °C.

IR (cm^{-1}): 3081, 1683, 1658, 1613, 1560, 1428, 1357, 1199, 814, 768.

^1H NMR (500 MHz, $CDCl_3$) δ 8.55 (s, 1H), 7.77–7.71 (m, 1H), 7.68–7.54 (m, 3H), 7.33–7.26 (m, 2H), 6.98 (td, J = 8.4, 2.3 Hz, 1H), 6.34 (dd, J = 10.7, 2.2 Hz, 1H), 2.74 (s, 3H).

^{13}C NMR (126 MHz, $CDCl_3$) δ 197.5, 165.3 (d, J = 254.4 Hz), 161.0, 144.5 (d, J = 11.8 Hz), 143.3, 137.1, 133.1 (d, J = 10.9 Hz), 130.6, 129.5, 128.4, 127.9 (d, J = 2.9 Hz), 115.8, 111.6 (d, J = 23.7 Hz), 102.9 (d, J = 27.5 Hz), 31.1.

HRMS (ESI): *m/z* calcd for $C_{17}H_{13}FNO_2$ $[M + H]^+$ 282.0925, found 282.0932.



3-acetyl-7-chloro-1-phenylquinolin-2(1*H*)-one (2e)

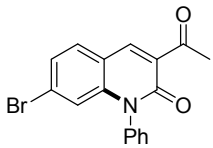
Yield: 774 mg, 52%. Yellow solid, mp 204–205 °C.

IR (cm^{-1}): 3051, 1684, 1760, 1604, 1548, 1194, 697.

^1H NMR (500 MHz, $CDCl_3$) δ 8.52 (s, 1H), 7.71–7.56 (m, 4H), 7.35–7.27 (m, 2H), 7.22 (dd, J = 8.4, 1.8 Hz, 1H), 6.65 (d, J = 1.6 Hz, 1H), 2.74 (s, 3H).

^{13}C NMR (126 MHz, $CDCl_3$) δ 197.5, 160.8, 143.4, 143.1, 139.3, 136.8, 131.8, 130.6, 129.5, 129.0, 128.5, 123.6, 117.5, 115.8, 31.1.

HRMS (ESI): *m/z* calcd for $C_{17}H_{13}ClNO_2$ $[M + H]^+$ 298.0629, found 298.0633.



3-acetyl-7-bromo-1-phenylquinolin-2(1*H*)-one (2f)

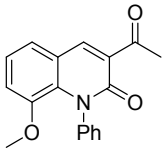
Yield: 819 mg, 48%. Yellow solid, mp 210–211 °C.

IR (cm^{-1}): 3048, 1684, 1657, 1600, 1545, 1410, 1354, 1219, 693.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.51 (s, 1H), 7.72–7.54 (m, 4H), 7.37 (d, J = 8.2 Hz, 1H), 7.28 (d, J = 8.0 Hz, 2H), 6.82 (s, 1H), 2.73 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 197.5, 160.7, 143.3, 143.1, 136.8, 131.8, 130.6, 129.5, 129.2, 128.5, 127.8, 126.4, 118.8, 117.8, 31.1.

HRMS (ESI): *m/z* calcd for $C_{17}H_{13}BrNO_2$ $[M + H]^+$ 342.0124, found 342.0123.



3-acetyl-8-methoxy-1-phenylquinolin-2(1*H*)-one (2g)

Yield: 382 mg, 26%. Yellow solid, mp134–135 °C.

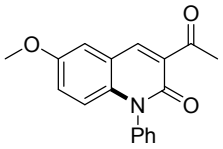
IR (cm^{-1}): 3037, 3003, 2937, 2838, 1681, 1650, 1612, 1458, 1269, 1231, 769.

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.49 (s, 1H), 7.51–7.33 (m, 4H), 7.30–7.17 (m, 3H), 7.02 (dd, J = 8.0, 1.2 Hz, 1H), 3.30 (s, 3H), 2.73 (s, 3H).

^{13}C NMR (126 MHz, $CDCl_3$) δ 198.0, 161.8, 147.4, 144.2, 141.8, 132.5, 129.1, 128.4 (2 CH), 127.6, 127.5 (2 CH), 123.6, 123.5, 121.1, 116.7, 56.7, 31.2.

HRMS (ESI): *m/z* calcd for $C_{18}H_{16}NO_3$ $[M + H]^+$ 294.1125, found 294.1128.

Note: 8-Unsubstuitued-1-phenylquinolin-2(1*H*)-ones **2a-f** are characterized by two diagnostic *N*-phenyl carbon signals in the regions 128.4–128.6 (2 CH) ppm and 130.3–130.6 (2 CH) ppm. The ^{13}C NMR spectrum of isomer **2g** shows the signals at 128.4 (2 CH) ppm and 127.5 (2 CH) ppm, which may attributed to the substituent effect of 8-OCH_3 on the ^{13}C signals of adjacent N-phenyl group. The ^{13}C NMR spectrum of isomer **2g'** shows the distinctive signals at 128.6 (2 CH) ppm and 130.4 (2 CH) ppm. Accordingly, **2g'** was assigned as 3-acetyl-6-methoxy-1-phenyl-quinolin- 2(1*H*)-one, and **2g** was assigned as 3-acetyl-8-methoxy-1-phenylquinolin-2(1*H*)-one.



3-acetyl-6-methoxy-1-phenylquinolin-2(1*H*)-one (2g')

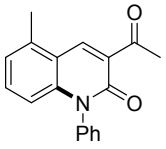
Yield: 507 mg, 35%. Yellow solid, mp 193–194 °C.

IR (cm^{-1}): 3056, 2937, 2839, 1680, 1655, 1562, 1492, 1234.

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.52 (s, 1H), 7.77–7.45 (m, 3H), 7.31–7.27 (m, 2H), 7.14 (d, J = 2.8 Hz, 1H), 7.07 (dd, J = 9.3, 2.9 Hz, 1H), 6.60 (d, J = 9.3 Hz, 1H), 3.86 (s, 3H), 2.76 (s, 3H).

^{13}C NMR (126 MHz, $CDCl_3$) δ 198.1, 160.5, 155.1, 143.2, 137.6, 137.5, 130.4 (2 CH), 129.4, 129.1, 128.6 (2 CH), 122.4, 119.7, 117.4, 111.0, 55.8, 31.2.

HRMS (ESI): *m/z* calcd for $C_{18}H_{16}NO_3$ $[M + H]^+$ 294.1125, found 294.1129.



3-acetyl-5-methyl-1-phenylquinolin-2(1*H*)-one (2h)

Yield: 587 mg, 42%. Yellow solid, mp 170–171 °C.

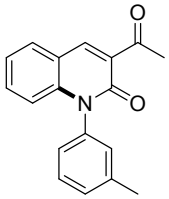
IR (cm^{-1}): 3052, 3011, 2974, 2926, 1680, 1651, 1596, 1554, 1458, 1356, 1216, 791, 695.

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.83 (s, 1H), 7.66–7.60 (m, 2H), 7.58–7.52 (m, 1H), 7.35–7.25 (m, 3H),

7.07 (d, *J* = 7.3 Hz, 1H), 6.50 (d, *J* = 8.6 Hz, 1H), 2.76 (s, 3H), 2.69 (s, 3H).

^{13}C NMR (126 MHz, $CDCl_3$) δ 198.2, 160.8, 143.3, 140.3, 138.8, 137.8, 132.6, 130.3, 129.1, 128.6, 128.2, 124.3, 118.1, 114.4, 31.2, 19.1.

HRMS (ESI): *m/z* calcd for $C_{18}H_{16}NO_2$ $[M + H]^+$ 278.1176, found 278.1178.



3-acetyl-1-(m-tolyl)quinolin-2(1*H*)-one (2i)

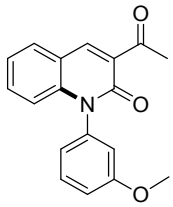
Yield: 996 mg, 72%. Yellow solid, mp 136–137 °C.

IR (cm^{-1}): 3052, 3002, 2920, 1680, 1662, 1610, 1556, 1208, 755, 696.

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.57 (s, 1H), 7.74 (dd, *J* = 7.8, 1.5 Hz, 1H), 7.51 (t, *J* = 7.7 Hz, 1H), 7.47–7.41 (m, 1H), 7.40–7.34 (m, 1H), 7.26–7.22 (m, 1H), 7.17–7.02 (m, 2H), 6.68 (d, *J* = 8.6 Hz, 1H), 2.76 (s, 3H), 2.45 (s, 3H).

^{13}C NMR (126 MHz, $CDCl_3$) δ 198.0, 161.0, 143.7, 142.8, 140.6, 137.3, 132.7, 130.7, 130.2, 130.0, 129.1, 129.0, 125.5, 122.8, 119.1, 116.1, 31.2, 21.4.

HRMS (ESI): *m/z* calcd for $C_{18}H_{16}NO_2$ $[M + H]^+$ 278.1176, found 278.1179.



3-acetyl-1-(3-methoxyphenyl)quinolin-2(1*H*)-one (2j)

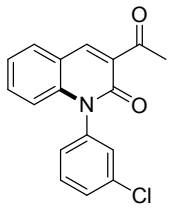
Yield: 629 mg, 43%. Yellow solid, mp 196–197 °C.

IR (cm^{-1}): 3070, 2942, 2839, 1681, 1655, 1609, 1556, 1262, 1215.

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.57 (s, 1H), 7.74 (dd, *J* = 7.8, 1.4 Hz, 1H), 7.53 (t, *J* = 7.8 Hz, 1H), 7.48–7.42 (m, 1H), 7.27–7.23 (m, 1H), 7.11–7.07 (m, 1H), 6.90–6.86 (m, 1H), 6.84–6.80 (m, 1H), 6.71 (d, *J* = 8.7 Hz, 1H), 3.85 (s, 3H), 2.76 (s, 3H).

^{13}C NMR (126 MHz, $CDCl_3$) δ 197.9, 161.2, 160.8, 143.8, 142.6, 138.5, 132.7, 131.1, 130.7, 129.1, 122.9, 120.6, 119.1, 116.1, 115.1, 114.0, 55.5, 31.2.

HRMS (ESI): *m/z* calcd for $C_{18}H_{16}NO_3$ $[M + H]^+$ 294.1125, found 278.1126.



3-acetyl-1-(3-chlorophenyl)quinolin-2(1*H*)-one (2k)

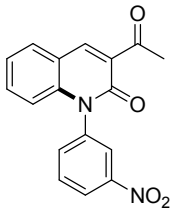
Yield: 1017 mg, 68%. Yellow solid, mp 140–141 °C.

IR (cm^{-1}): 3073, 1686, 1652, 1606, 1557, 1449, 1355, 1264, 1217, 1200, 778, 689.

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.58 (s, 1H), 7.76 (dd, *J* = 7.8, 1.4 Hz, 1H), 7.63–7.53 (m, 2H), 7.50–7.44 (m, 1H), 7.35–7.19 (m, 3H), 6.66 (d, *J* = 8.6 Hz, 1H), 2.75 (s, 3H).

^{13}C NMR (126 MHz, $CDCl_3$) δ 197.6, 160.8, 144.1, 142.3, 138.5, 136.0, 132.9, 131.3, 130.9, 129.6, 129.2, 130.0, 127.1, 123.2, 119.1, 115.8, 31.1.

HRMS (ESI): *m/z* calcd for $C_{17}H_{13}ClNO_2$ $[M + H]^+$ 298.0629, found 298.0631.



3-acetyl-1-(3-nitrophenyl)quinolin-2(1*H*)-one (2l)

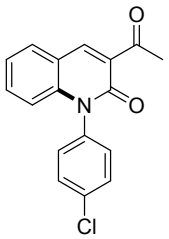
Yield: 981 mg, 64%. Yellow solid, mp 178–180 °C.

IR (cm^{-1}): 3089, 1682, 1662, 1606, 1557, 1527, 1350, 1202, 762, 695.

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.61 (s, 1H), 7.47–7.43 (m, 1H), 8.24 (t, J = 2.0 Hz, 1H), 7.85 (t, J = 8.1 Hz, 1H), 7.80 (dd, J = 7.8, 1.3 Hz, 1H), 7.73–7.67 (m, 1H), 7.52–7.46 (m, 1H), 7.34–7.30 (m, 1H), 6.61 (d, J = 8.5 Hz, 1H), 2.74 (s, 3H).

^{13}C NMR (126 MHz, $CDCl_3$) δ 197.2, 160.7, 149.6, 144.4, 142.0, 138.5, 135.4, 133.2, 131.3, 131.2, 128.9, 124.6, 124.2, 123.6, 119.2, 115.3, 31.1.

HRMS (ESI): *m/z* calcd for $C_{17}H_{13}N_2O_4$ $[M + H]^+$ 309.0870, found 309.0875 .



3-acetyl-1-(4-chlorophenyl)quinolin-2(1*H*)-one (2m)

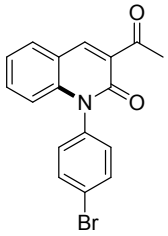
Yield: 895 mg, 60%. Yellow solid, mp 201–202 °C.

IR (cm^{-1}): 3052, 1686, 1646, 1609, 1223, 764.

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.57 (s, 1H), 7.76 (dd, J = 7.8, 1.4 Hz, 1H), 7.66–7.56 (m, 2H), 7.49–7.44 (m, 1H), 7.29–7.24 (m, 3H), 6.68 (d, J = 8.6 Hz, 1H), 2.74 (s, 3H).

^{13}C NMR (126 MHz, $CDCl_3$) δ 197.6, 160.9, 144.0, 142.4, 135.8, 135.3, 132.9, 130.9, 130.7, 130.1, 129.0, 123.1, 119.2, 115.7, 31.1.

HRMS (ESI): *m/z* calcd for $C_{17}H_{13}ClNO_2$ $[M + H]^+$ 298.0629, found 298.0635.



3-acetyl-1-(4-bromophenyl)quinolin-2(1*H*)-one (2n)

Yield: 1003 mg, 59%. Yellow solid, mp 202–203 °C.

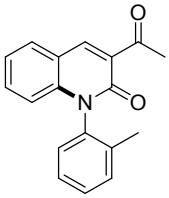
IR (cm^{-1}): 3049, 1686, 1649, 1608, 1559, 1262, 1223, 764.

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.57 (s, 1H), 7.80–7.74 (m, 3H), 7.49–7.44 (m, 1H), 7.29–7.25 (m, 1H), 7.21–7.17 (m, 2H), 6.68 (d, J = 8.5 Hz, 1H), 2.74 (s, 3H).

^{13}C NMR (126 MHz, $CDCl_3$) δ 197.6, 160.8, 144.0, 142.4, 136.4, 133.7, 132.9, 130.9, 130.5, 129.0,

123.3, 123.1, 119.2, 115.7, 31.1.

HRMS (ESI): *m/z* calcd for $C_{17}H_{13}BrNO_2$ $[M + H]^+$ 342.0124, found 342.0129.



3-acetyl-1-(o-tolyl)quinolin-2(1*H*)-one (2o)

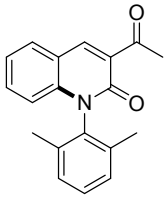
Yield: 905 mg, 65%. Yellow solid, mp 114–115 °C.

IR (cm^{-1}): 3056, 3004, 2924, 1678, 1651, 1608, 1557, 1448, 1200, 756.

^1H NMR (500 MHz, $CDCl_3$) δ 8.58 (s, 1H), 7.76 (dd, J = 7.8, 1.5 Hz, 1H), 7.49–7.40 (m, 4H), 7.28–7.23 (m, 1H), 7.20–7.17 (m, 1H), 6.58 (d, J = 8.6 Hz, 1H), 2.76 (s, 3H), 2.02 (s, 3H).

^{13}C NMR (126 MHz, $CDCl_3$) δ 198.0, 160.3, 143.8, 142.0, 136.3, 136.0, 133.0, 131.8, 130.8, 129.4, 129.2, 128.5, 127.9, 122.9, 119.2, 115.4, 31.2, 17.3.

HRMS (ESI): *m/z* calcd for $C_{18}H_{16}NO_2$ $[M + H]^+$ 278.1176, found 278.1178.



3-acetyl-1-(2,6-dimethylphenyl)quinolin-2(1H)-one (2p)

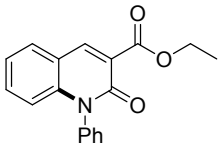
Yield: 884 mg, 61%. Yellow solid, mp 144–146 °C.

IR (cm^{-1}): 3070, 3046, 3007, 2946, 2920, 1682, 1654, 1609, 1557, 1447, 1201, 777.

^1H NMR (400 MHz, $CDCl_3$) δ 8.59 (s, 1H), 7.78 (d, J = 7.8 Hz, 1H), 7.45 (t, J = 7.8 Hz, 1H), 7.38–7.22 (m, 4H), 6.55 (d, J = 8.5 Hz, 1H), 2.77 (s, 3H), 1.97 (s, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 198.1, 159.7, 143.6, 141.2, 135.6, 135.2, 133.2, 130.9, 129.3, 129.1, 123.0, 119.2, 114.6, 31.0, 17.5.

HRMS (ESI): *m/z* calcd for $C_{19}H_{18}NO_2$ $[M + H]^+$ 292.1332, found 292.1335.



ethyl 2-oxo-1-phenyl-1,2-dihydroquinoline-3-carboxylate (2q)

Yield: 933 mg, 64%. Yellow solid, mp 144–145 °C.

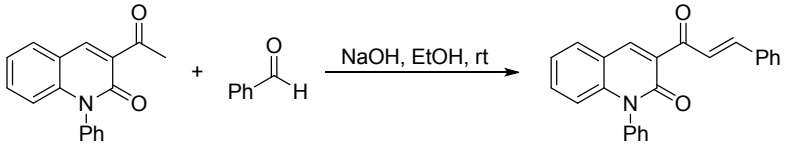
IR (cm^{-1}): 3066, 2982, 2899, 1743, 1698, 1665, 1616, 1564, 1451, 1273, 1212, 1066, 750.

^1H NMR (500 MHz, $CDCl_3$) δ 8.55 (s, 1H), 7.70 (dd, J = 7.8, 1.4 Hz, 1H), 7.62–7.50 (m, 3H), 7.45–7.39 (m, 1H), 7.32–7.19 (m, 3H), 6.65 (d, J = 8.6 Hz, 1H), 4.42 (q, J = 7.1 Hz, 2H), 1.40 (t, J = 7.1 Hz, 3H).

^{13}C NMR (126 MHz, $CDCl_3$) δ 165.1, 159.0, 144.7, 142.5, 137.4, 132.5, 130.2, 129.9, 129.0, 128.8, 123.2, 122.7, 118.7, 116.0, 61.6, 14.3.

HRMS (ESI): *m/z* calcd for $C_{18}H_{16}NO_3$ $[M + H]^+$ 294.1125, found 294.1127.

4. Synthesis of chalcone analogue 4



2a **3** **4**

To a mixture of **2a** (263 mg, 1 mmol) and benzaldehyde **3** (159 mg, 1.5 mmol) in EtOH (15 mL), 30% NaOH aqueous solution (0.2 mL) was added dropwise. The mixture was stirred at room temperature for 1 h. The precipitate was filtrated and recrystallized from ethanol to give the desired product.

3-cinnamoyl-1-phenylquinolin-2(1*H*)-one (4)

Yield: 310 mg, 88%. Yellow solid, mp 216–218 ^{o}C.

IR (cm^{-1}): 3046, 1666, 1649, 1615, 1336.

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.69 (s, 1H), 8.16 (d, J = 15.7 Hz, 1H), 7.85 (d, J = 15.8 Hz, 1H), 7.78 (d, J = 7.7 Hz, 1H), 7.67–7.61 (m, 4H), 7.57 (t, J = 7.5 Hz, 1H), 7.44 (t, J = 7.8 Hz, 1H), 7.36–7.31 (m, 5H), 7.28–7.24 (m, 1H), 6.67 (d, J = 8.5 Hz, 1H).

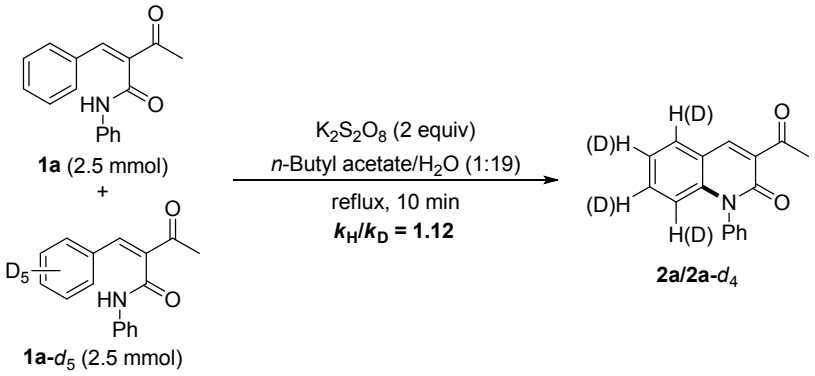
^{13}C NMR (150 MHz, $CDCl_3$) δ 188.5, 161.1, 144.8, 143.7, 142.7, 137.5, 135.2, 132.6, 130.6, 130.4, 130.3, 129.4, 129.0, 128.4, 128.7, 128.7, 125.5, 122.9, 119.4, 116.0.

HRMS (ESI): *m/z* calcd for $C_{24}H_{18}NO_2$ $[M + H]^+$ 352.1332, found 352.1337.

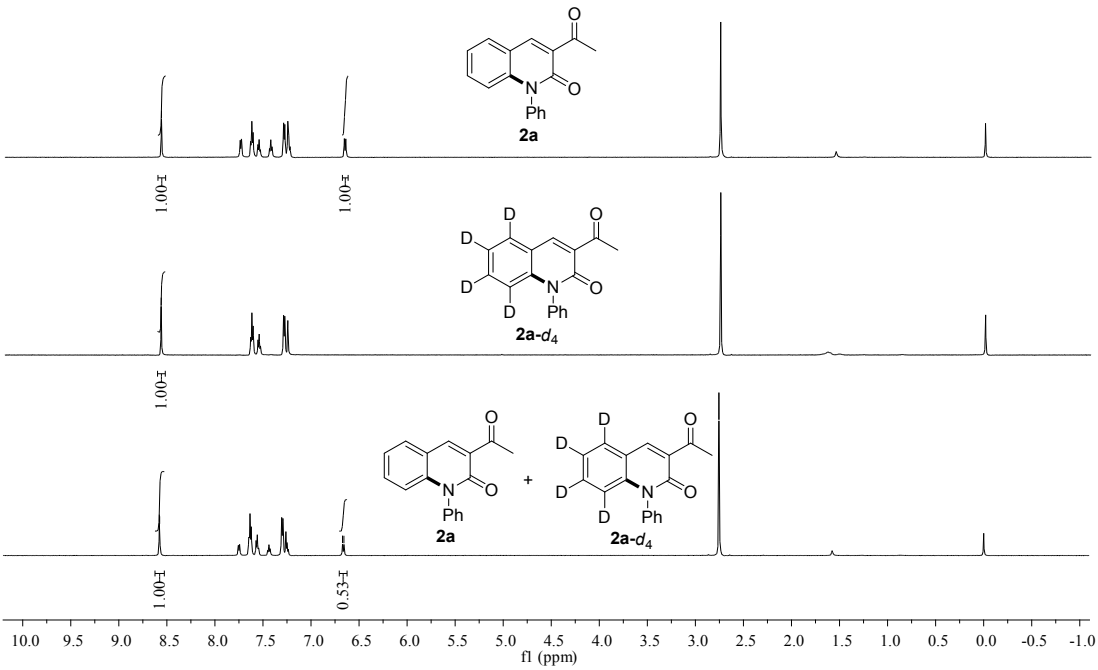
5. Intermolecular kinetic isotopic effect (KIE) experiments

The deuterated substrate **1a**-d_5 was prepared from deuterated benzaldehyde **S-1a**-d_5 following the procedure described for Knoevenagel products **1**. Yield: 3.5 g, 65%. White solid, mp 127–129 °C. ^{1}H NMR (600 MHz, DMSO-d_6) δ 10.40 (s, 1H), 7.70 (s, 1H), 7.61 (d, J = 7.0 Hz, 2H), 7.36–7.30 (m, 2H), 7.12–7.06 (m, 1H), 2.44 (s, 3H).

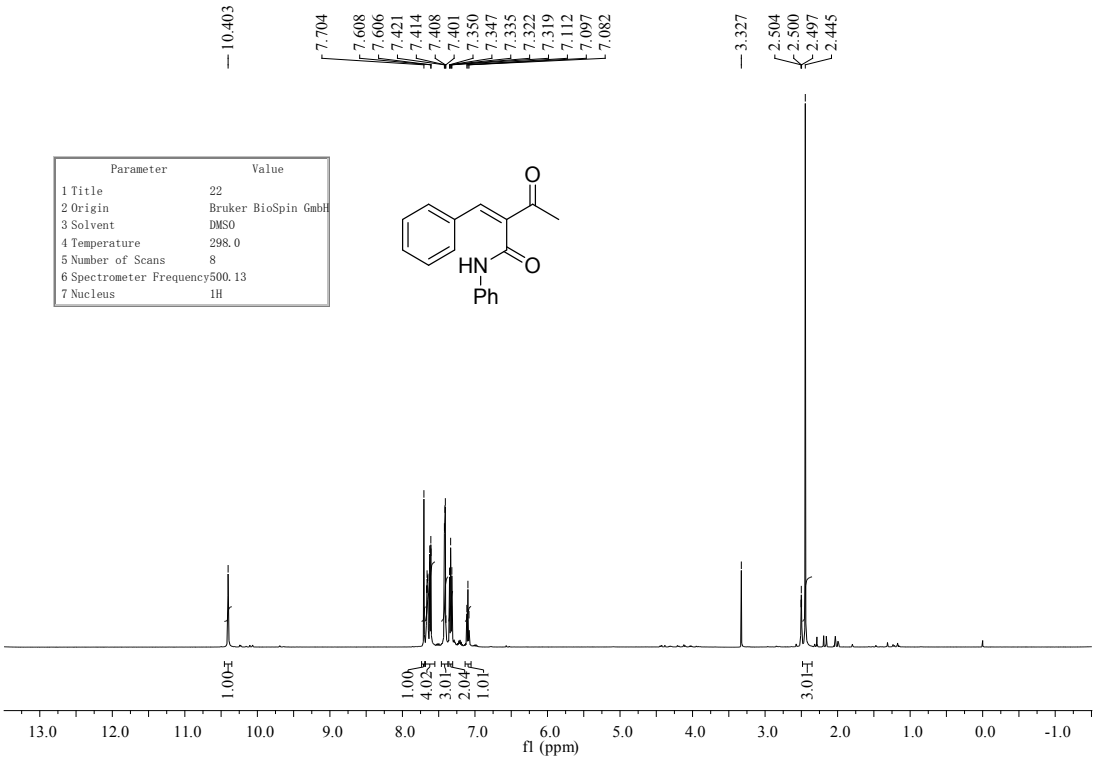
The deuterated product **2a**-d_4 was prepared from **1a**-d_5 following the procedure described for *N*-aryl 2-quinolinones **2**. The reaction went to completion in 0.5 h (monitored by TLC). Yield: 821 mg, 61%. Pale yellow solid, mp 178–179 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.60–8.55 (m, 1H), 7.64 (t, J = 7.6 Hz, 2H), 7.57 (d, J = 7.3 Hz, 1H), 7.30 (d, J = 7.3 Hz, 2H), 2.76 (s, 3H).

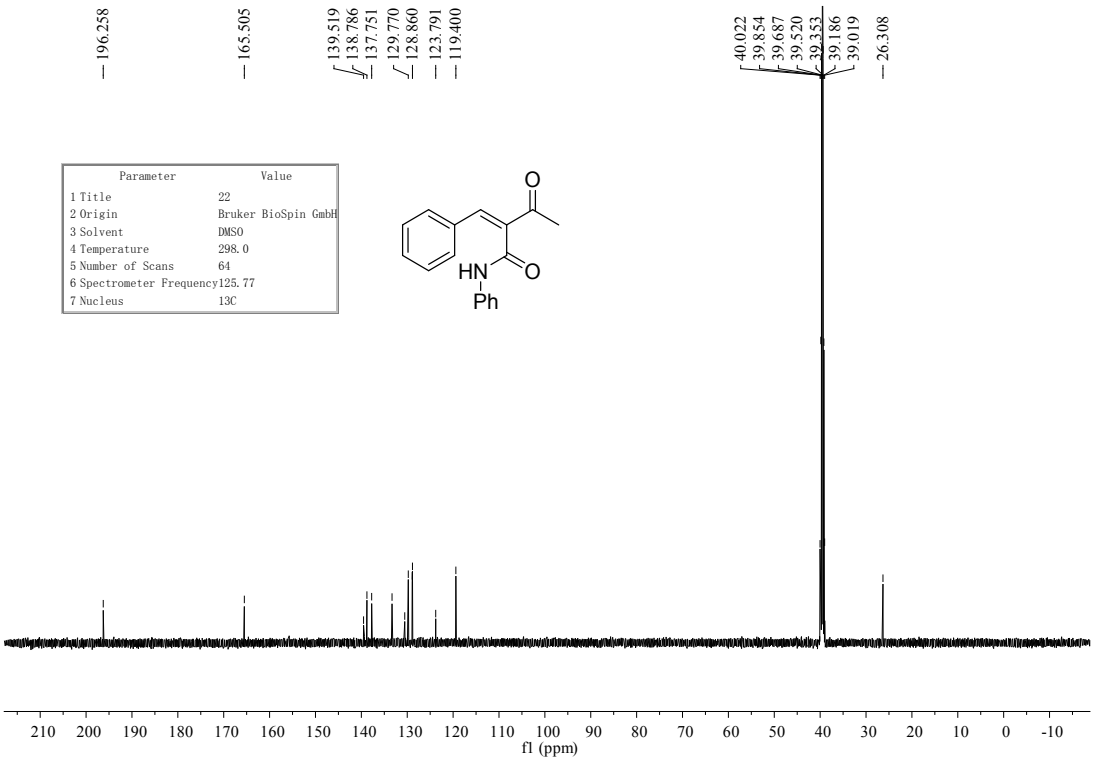


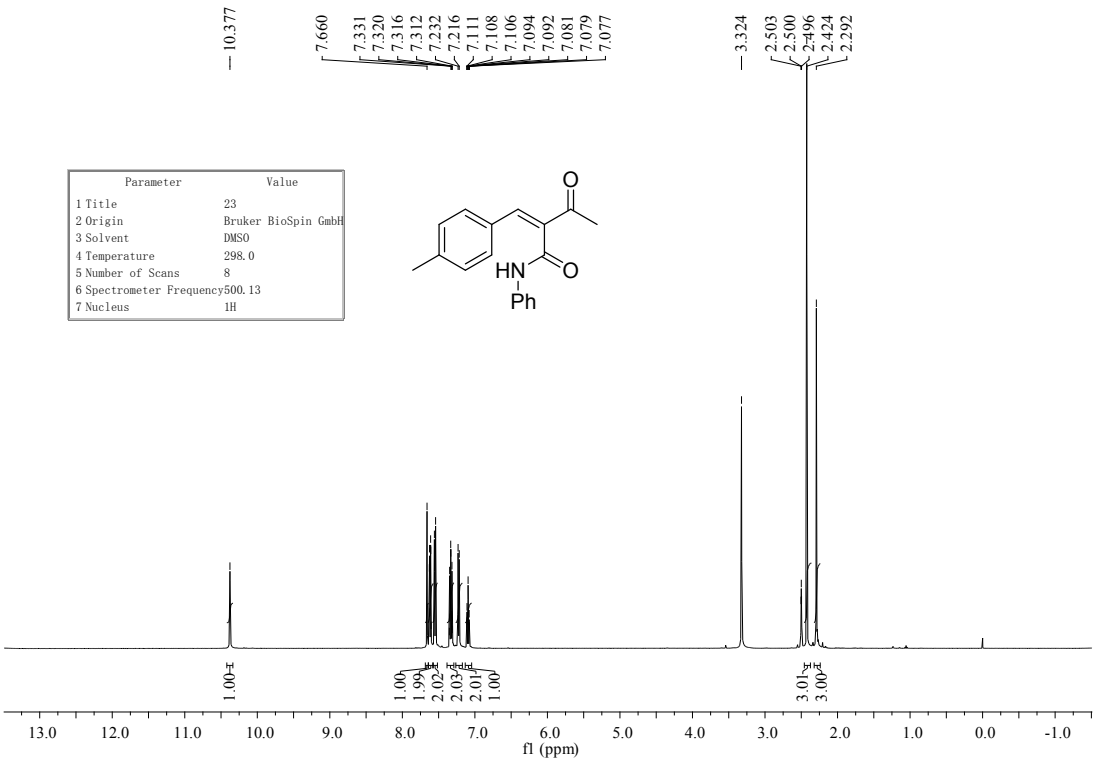
A mixture of substrate **1a** (2.5 mmol), **1a**-d_5 (2.5 mmol), and $K_2S_2O_8$ (10.0 mmol) in *n*-Butyl acetate/H_2O (1:19, 100 mL) was vigorously stirred under reflux for 10 min. The mixture was extracted with EtOAc (3×50 mL). The combined organic extracts were washed with brine, dried with anhydrous Na_2SO_4, and concentrated. The residue obtained was purified by column chromatography on silica gel (petroleum ether: EtOAc = 6:1) to afford a pale yellow solid. Yield: 357 mg, 27%. The KIE was determined by ^{1}H NMR spectroscopy by analyzing the ratio of **2a** and **2a**-d_4. k_H/k_D = 0.53/(1–0.53) = 1.12



6. ^{1}H NMR and ^{13}C NMR spectra



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7.312
7.232
7.216
7.111
7.108
7.106
7.094
7.092
7.081
7.079
7.077
3.324
2.503
2.500
2.496
2.424
2.292
Parameter Value
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2 Origin Bruker BioSpin GmbH
3 Solvent DMSO
4 Temperature 298.0
5 Number of Scans 8
6 Spectrometer Frequency 500.13
7 Nucleus 1H
O
HN
O
Ph
1.00
1.00
1.99
2.02
2.03
2.01
1.00
3.01
3.00
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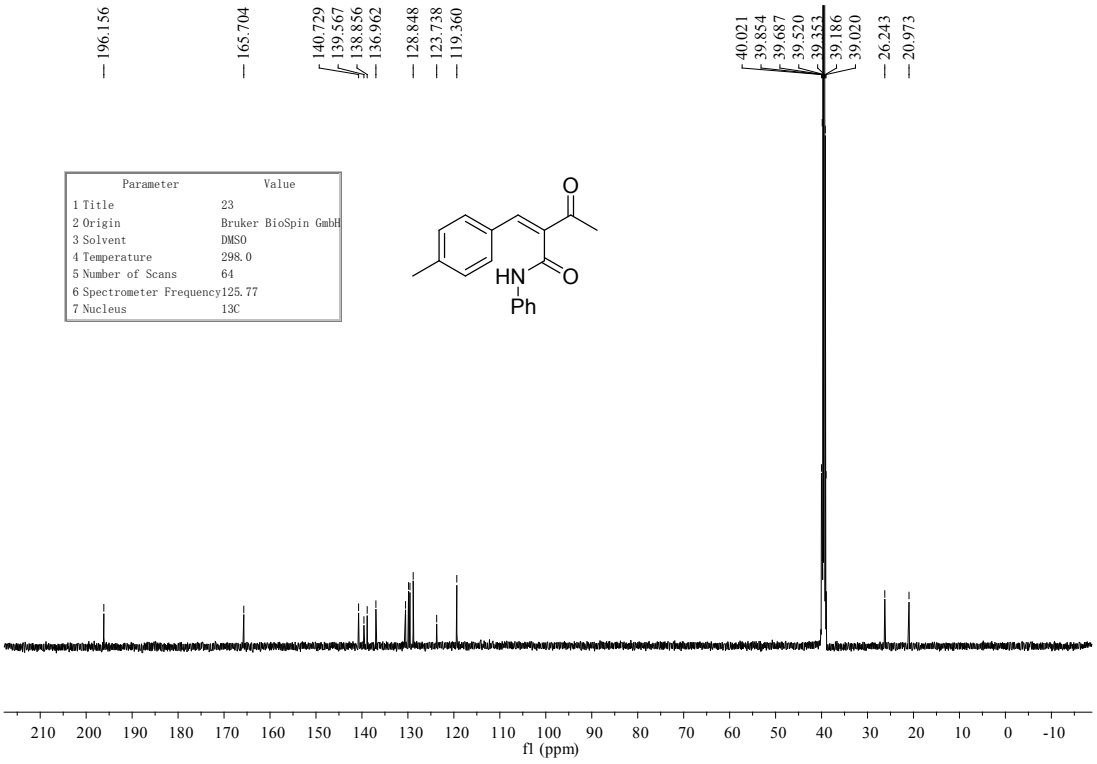
f1 (ppm)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128.848
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39.854
39.687
39.520
39.353
39.186
39.020
26.243
20.973
Parameter Value
1 Title 23
2 Origin Bruker BioSpin GmbH
3 Solvent DMSO
4 Temperature 298.0
5 Number of Scans 64
6 Spectrometer Frequency 125.77
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HN
O
Ph
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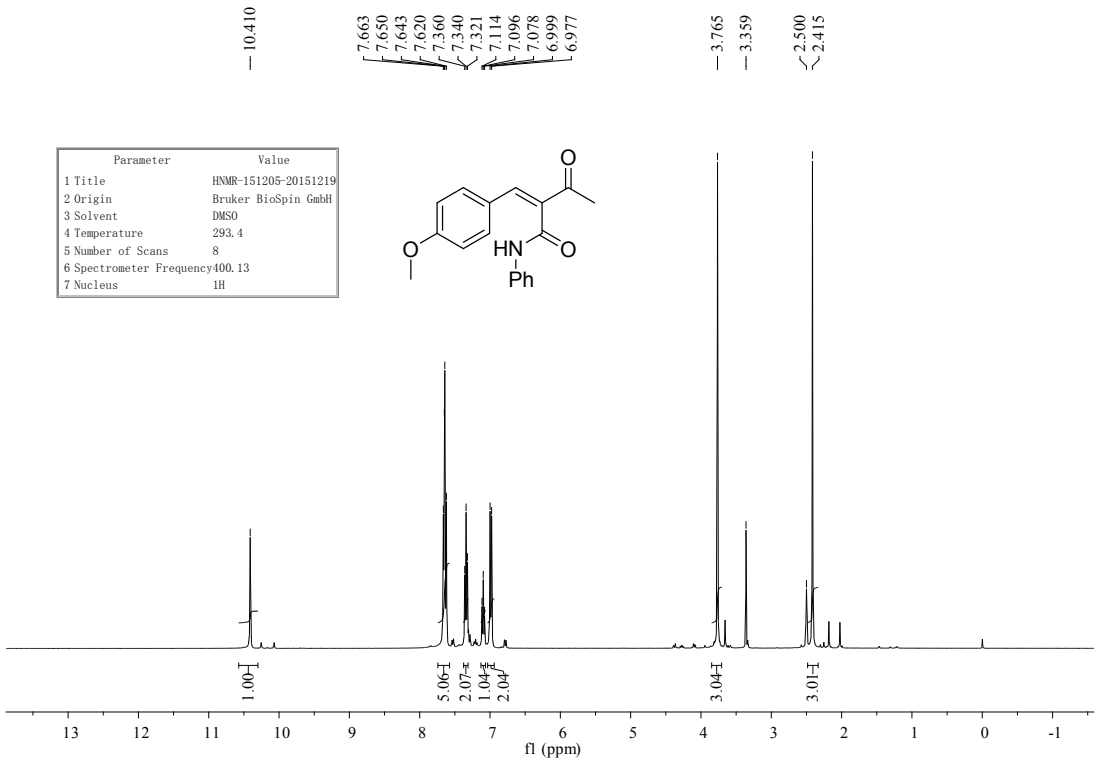
f1 (ppm)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7.643
7.620
7.360
7.340
7.321
7.114
7.096
7.078
6.999
6.977
3.765
3.359
2.500
2.415
Parameter Value
1 Title HNMR-151205-20151219
2 Origin Bruker BioSpin GmbH
3 Solvent DMSO
4 Temperature 293.4
5 Number of Scans 8
6 Spectrometer Frequency 400.13
7 Nucleus 1H
O
HN
Ph
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2.07
1.04
2.04
3.04
3.01
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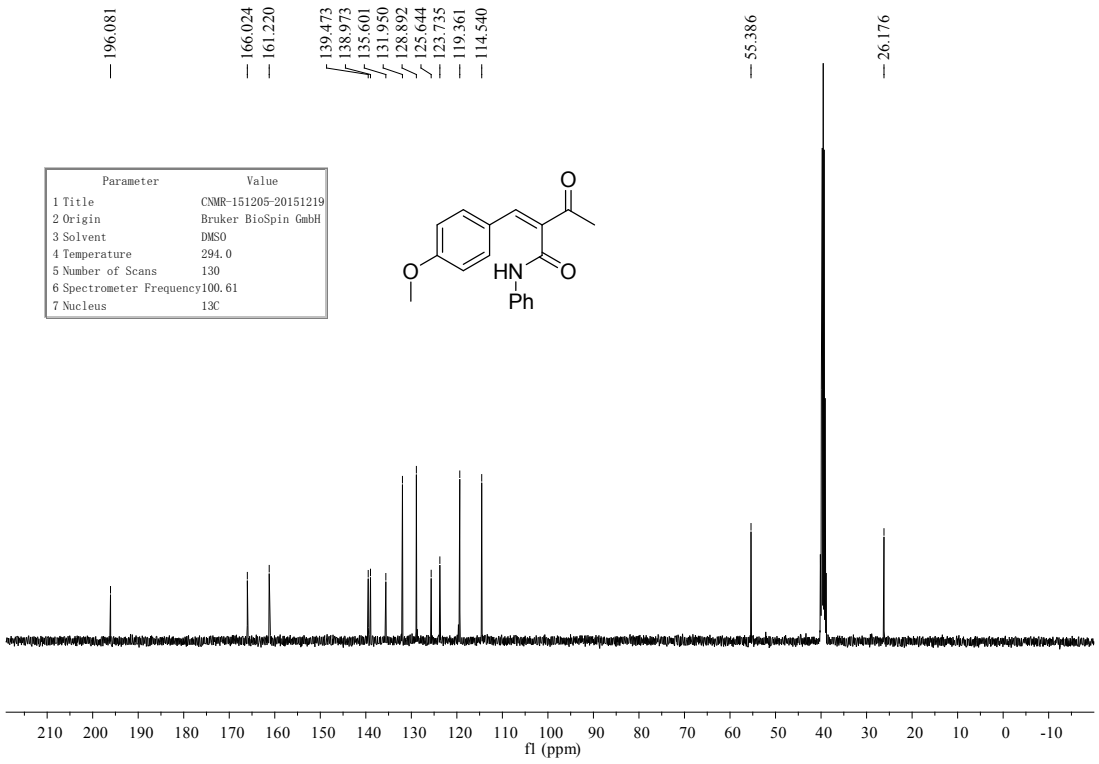
f1 (ppm)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128.892
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26.176
Parameter Value
1 Title CNMR-151205-20151219
2 Origin Bruker BioSpin GmbH
3 Solvent DMSO
4 Temperature 294.0
5 Number of Scans 130
6 Spectrometer Frequency 100.61
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Ph
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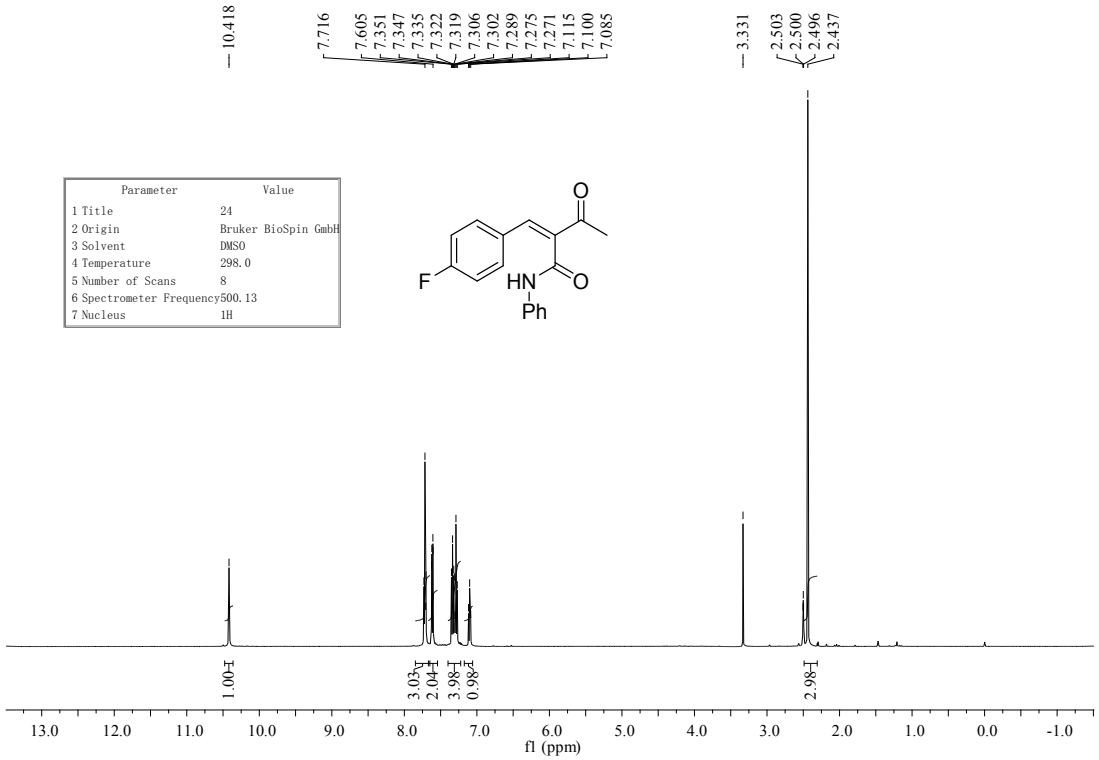
f1 (ppm)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7.351
7.347
7.335
7.322
7.319
7.306
7.302
7.289
7.275
7.271
7.115
7.100
7.085
3.331
2.503
2.500
2.496
2.437
Parameter Value
1 Title 24
2 Origin Bruker BioSpin GmbH
3 Solvent DMSO
4 Temperature 298.0
5 Number of Scans 8
6 Spectrometer Frequency 500.13
7 Nucleus 1H
F
HN
O
O
Ph
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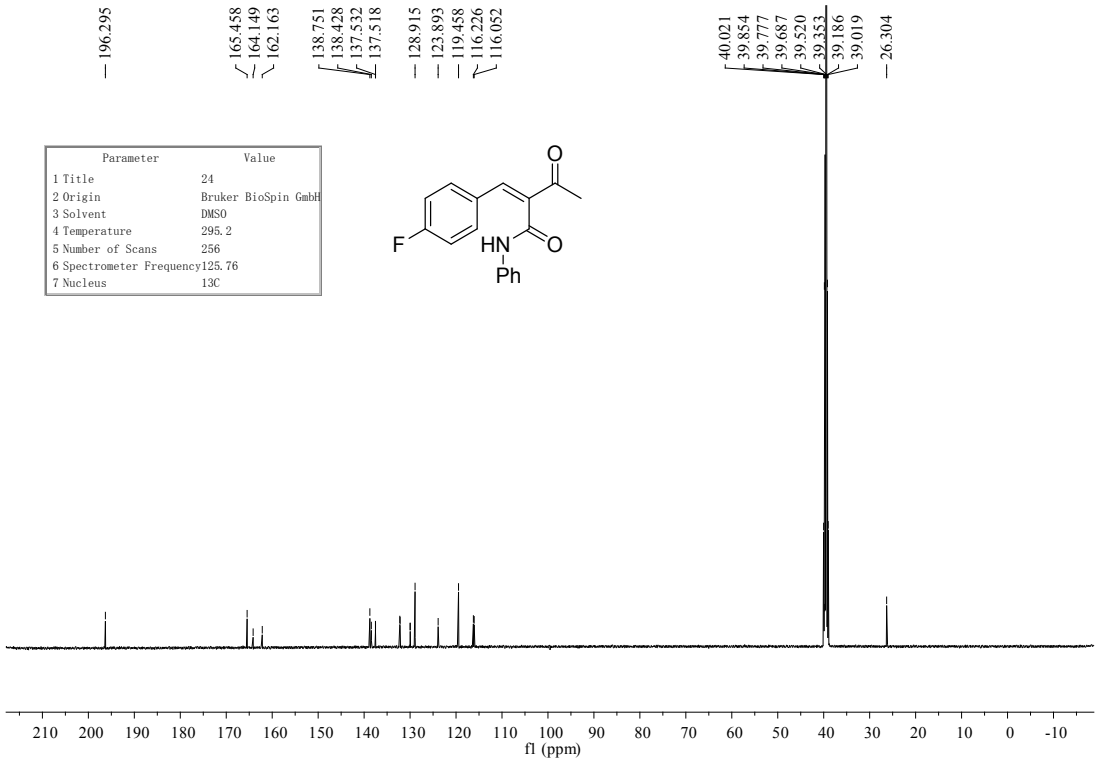
3.03
2.04
3.98
0.98
2.98
fl (ppm)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137.532
137.518
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123.893
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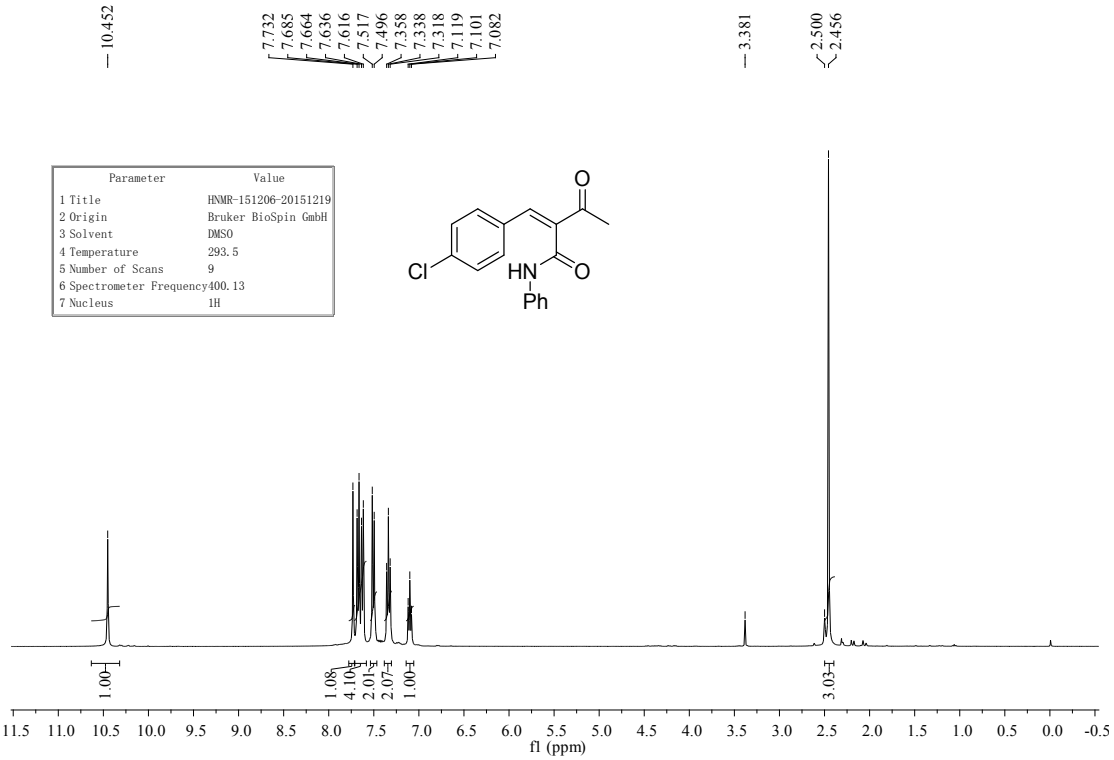
40.021
39.854
39.777
39.687
39.520
39.353
39.186
39.019
26.304
Parameter Value
1 Title 24
2 Origin Bruker BioSpin GmbH
3 Solvent DMSO
4 Temperature 295.2
5 Number of Scans 256
6 Spectrometer Frequency 125.76
7 Nucleus 13C
F
HN
O
O
Ph
fl (ppm)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7.496
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7.101
7.082
3.381
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2.456
Parameter Value
1 Title HNMR-151206-20151219
2 Origin Bruker BioSpin GmbH
3 Solvent DMSO
4 Temperature 293.5
5 Number of Scans 9
6 Spectrometer Frequency 400.13
7 Nucleus 1H
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Ph
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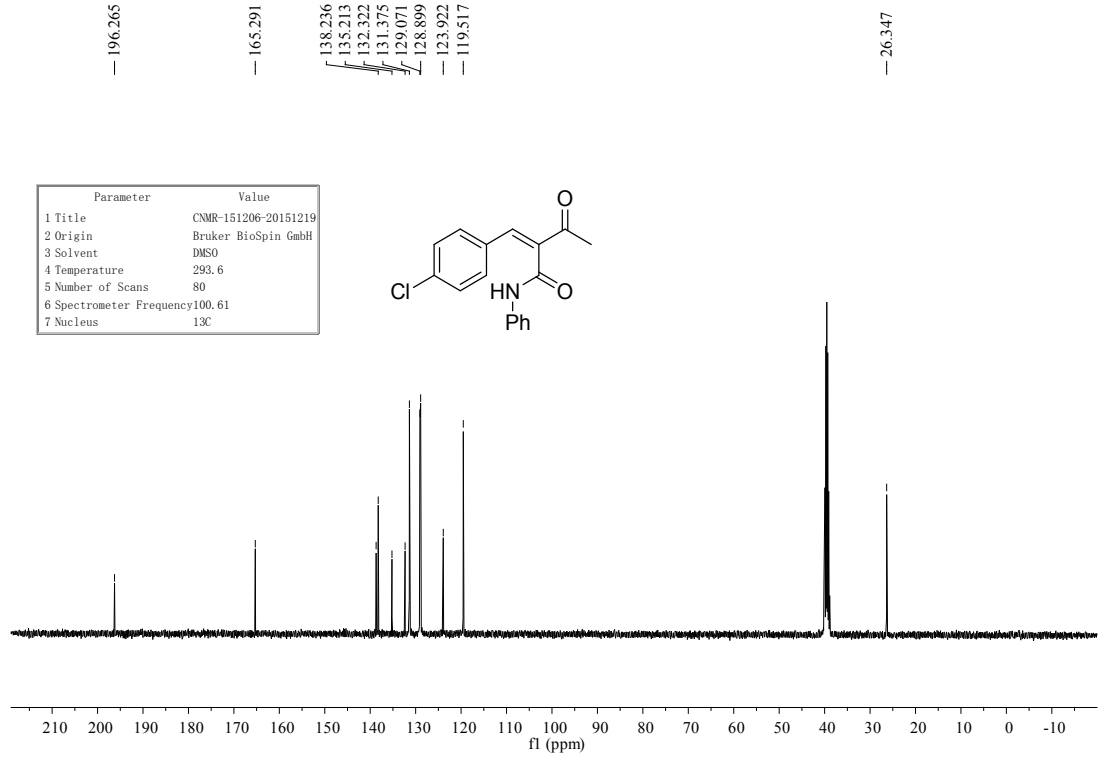
f1 (ppm)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132.322
131.375
129.071
128.899
123.922
119.517
26.347
Parameter Value
1 Title CNMR-151206-20151219
2 Origin Bruker BioSpin GmbH
3 Solvent DMSO
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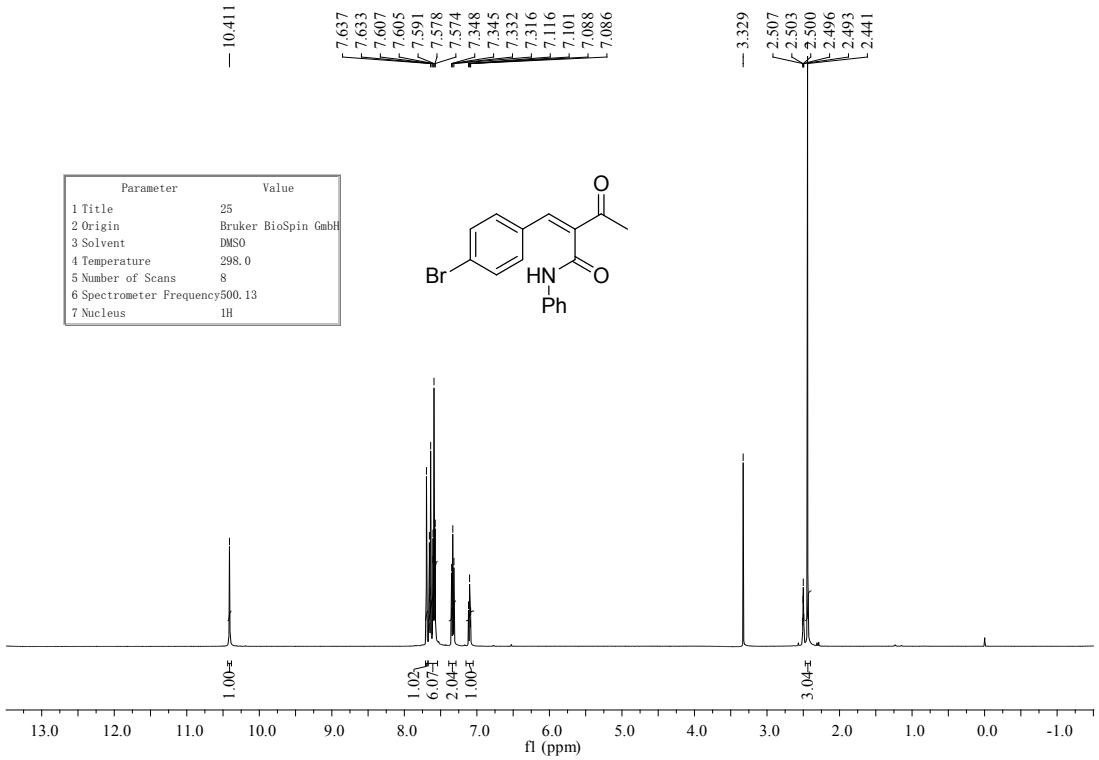
5 Number of Scans 80
6 Spectrometer Frequency 100.61
7 Nucleus 13C
Cl
HN
O
O
Ph
f1 (ppm)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7.633
7.607
7.605
7.591
7.578
7.574
7.348
7.345
7.332
7.316
7.116
7.101
7.088
7.086
3.329
2.507
2.503
2.500
2.496
2.493
2.441
Parameter Value
1 Title 25
2 Origin Bruker BioSpin GmbH
3 Solvent DMSO
4 Temperature 298.0
5 Number of Scans 8
6 Spectrometer Frequency 500.13
7 Nucleus 1H
Br
HN
Ph
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O
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1.02
6.07
2.04
1.00
3.04
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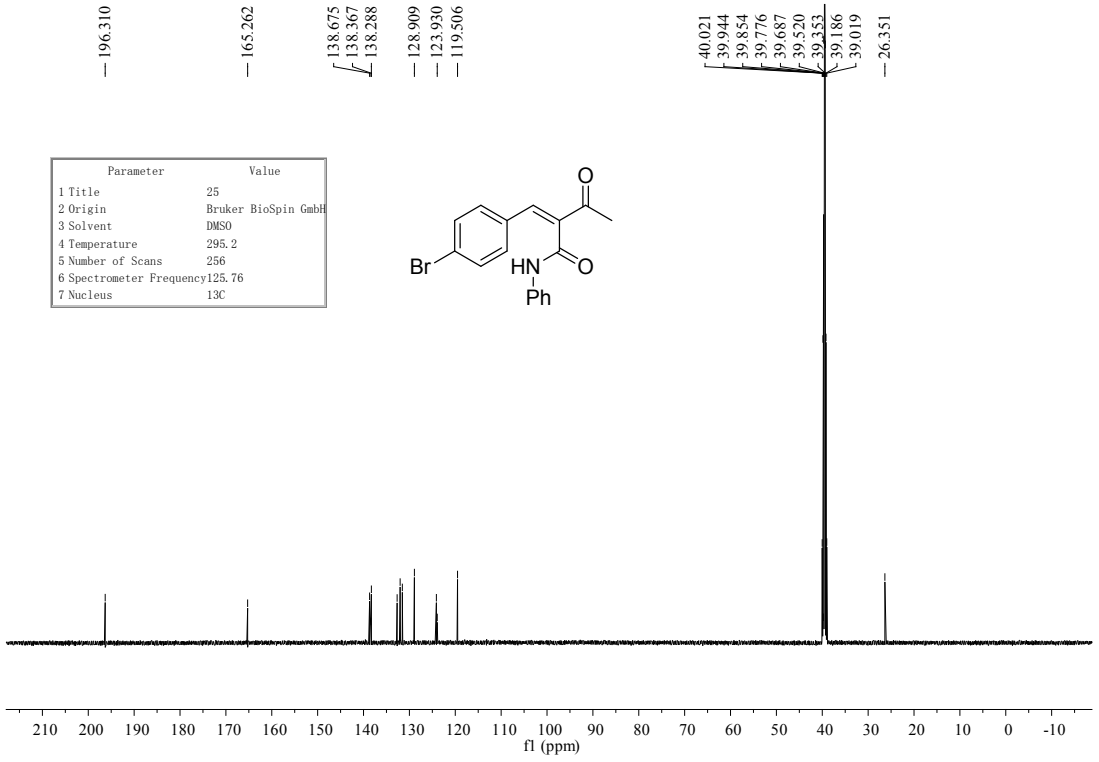
f1 (ppm)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39.776
39.687
39.520
39.353
39.186
39.019
26.351
Parameter Value
1 Title 25
2 Origin Bruker BioSpin GmbH
3 Solvent DMSO
4 Temperature 295.2
5 Number of Scans 256
6 Spectrometer Frequency 125.76
7 Nucleus 13C
Br
HN
Ph
O
O
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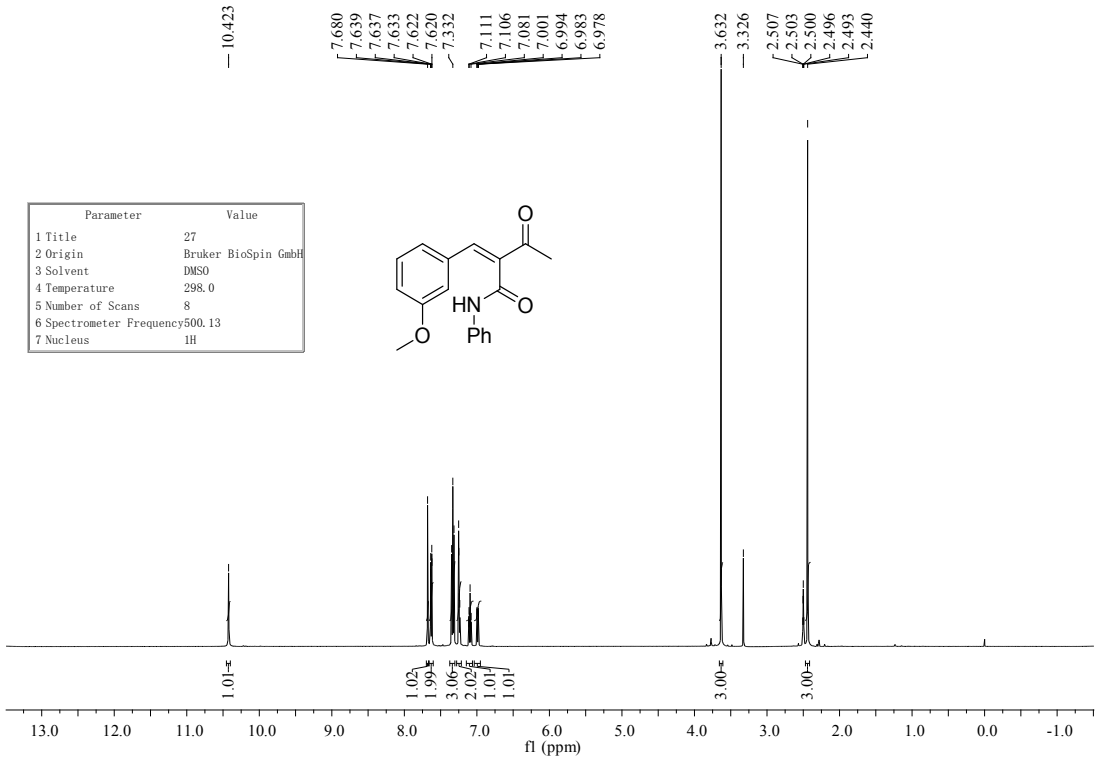
f1 (ppm)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7.620
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7.106
7.081
7.001
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6.983
6.978
3.632
3.326
2.507
2.503
2.500
2.496
2.493
2.440
Parameter Value
1 Title 27
2 Origin Bruker BioSpin GmbH
3 Solvent DMSO
4 Temperature 298.0
5 Number of Scans 8
6 Spectrometer Frequency 500.13
7 Nucleus 1H
HN
Ph
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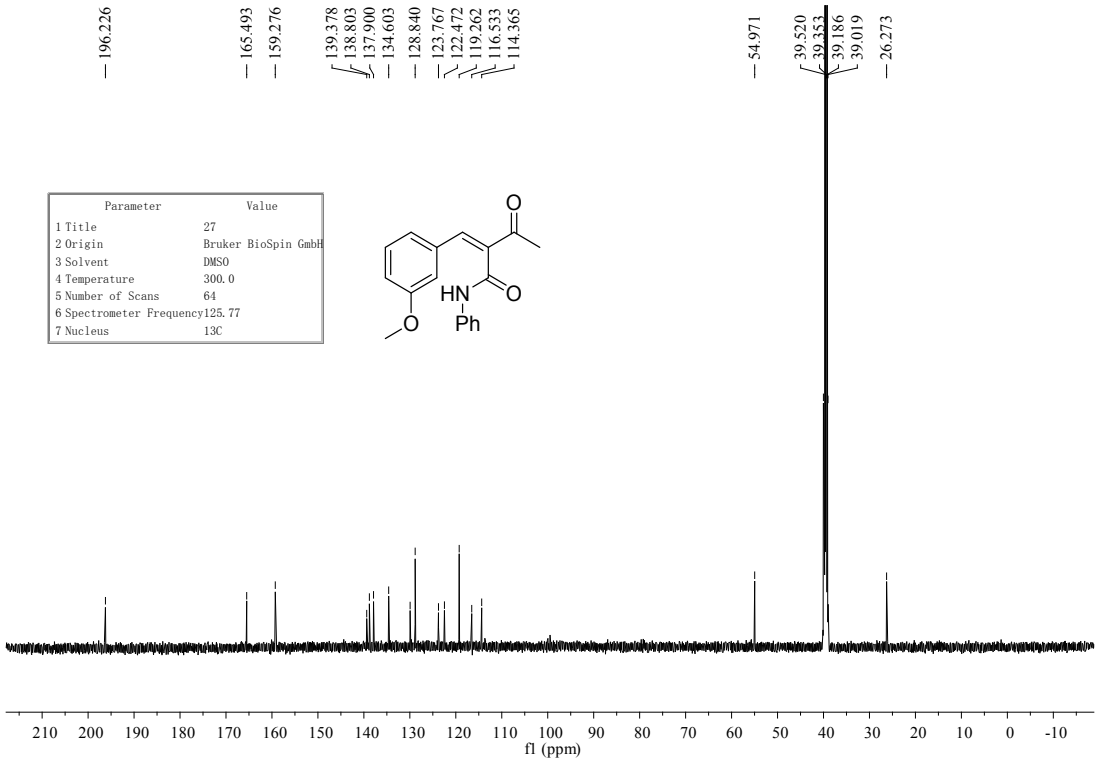
3.00
f1 (ppm)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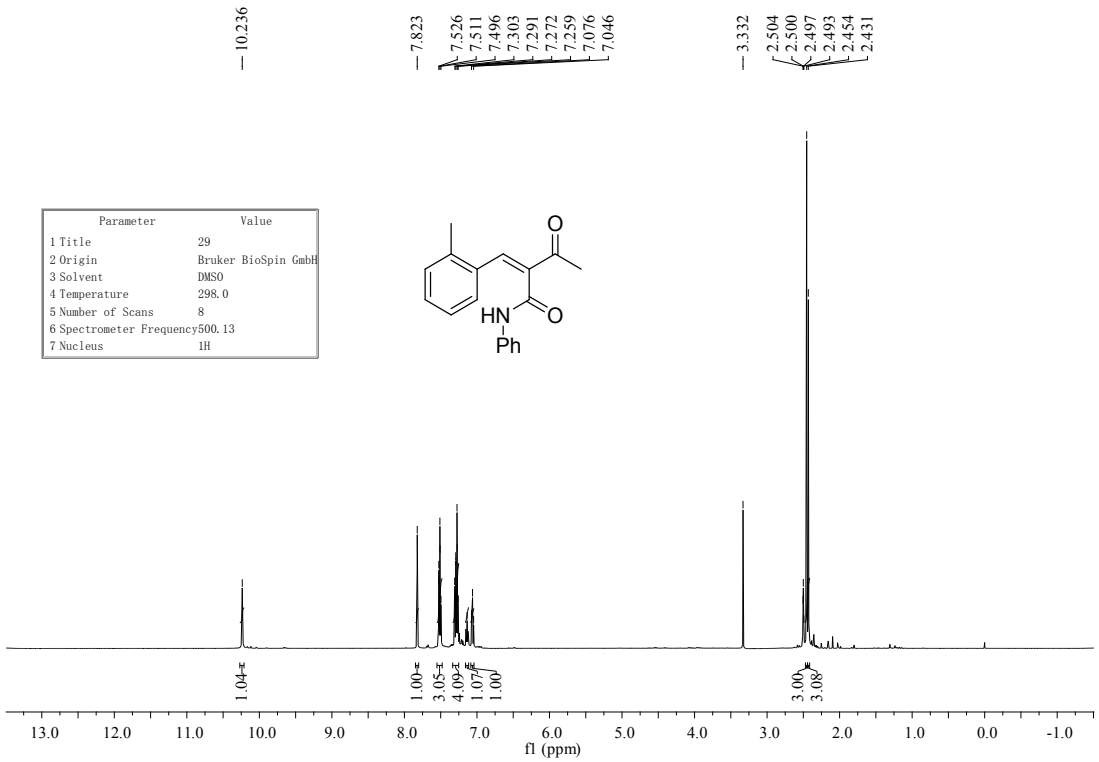
122.472
119.262
116.533
114.365
54.971
39.520
39.353
39.186
39.019
26.273
Parameter Value
1 Title 27
2 Origin Bruker BioSpin GmbH
3 Solvent DMSO
4 Temperature 300.0
5 Number of Scans 64
6 Spectrometer Frequency 125.77
7 Nucleus 13C
HN
Ph
f1 (ppm)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7.303
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2.500
2.497
2.493
2.454
2.431
Parameter Value
1 Title 29
2 Origin Bruker BioSpin GmbH
3 Solvent DMSO
4 Temperature 298.0
5 Number of Scans 8
6 Spectrometer Frequency 500.13
7 Nucleus 1H
O
HN
O
Ph
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1.00
3.05
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1.07
1.00
3.00
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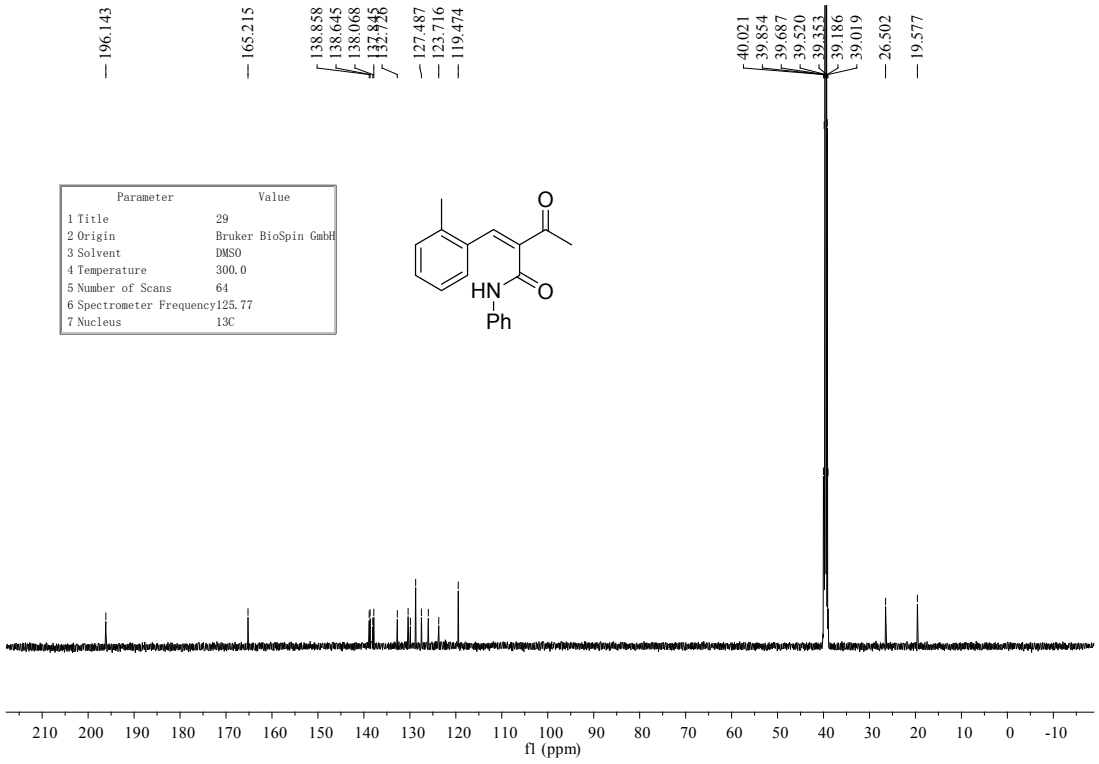
f1 (ppm)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123.716
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39.687
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39.353
39.186
39.019
26.502
19.577
Parameter Value
1 Title 29
2 Origin Bruker BioSpin GmbH
3 Solvent DMSO
4 Temperature 300.0
5 Number of Scans 64
6 Spectrometer Frequency 125.77
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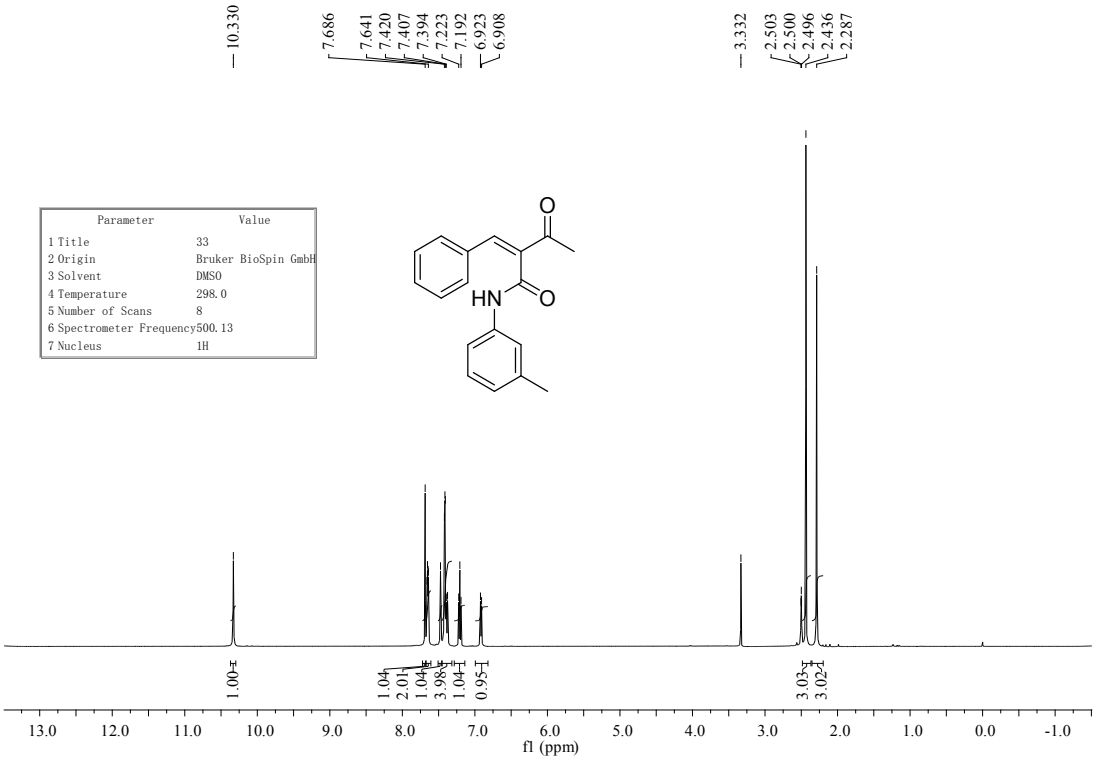
O
HN
O
Ph
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)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7.192
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3.332
2.503
2.500
2.496
2.436
2.287
Parameter Value
1 Title 33
2 Origin Bruker BioSpin GmbH
3 Solvent DMSO
4 Temperature 298.0
5 Number of Scans 8
6 Spectrometer Frequency 500.13
7 Nucleus 1H
O
HN
O
1.00
1.04
2.01
1.04
3.98
1.04
0.95
3.03
3.02
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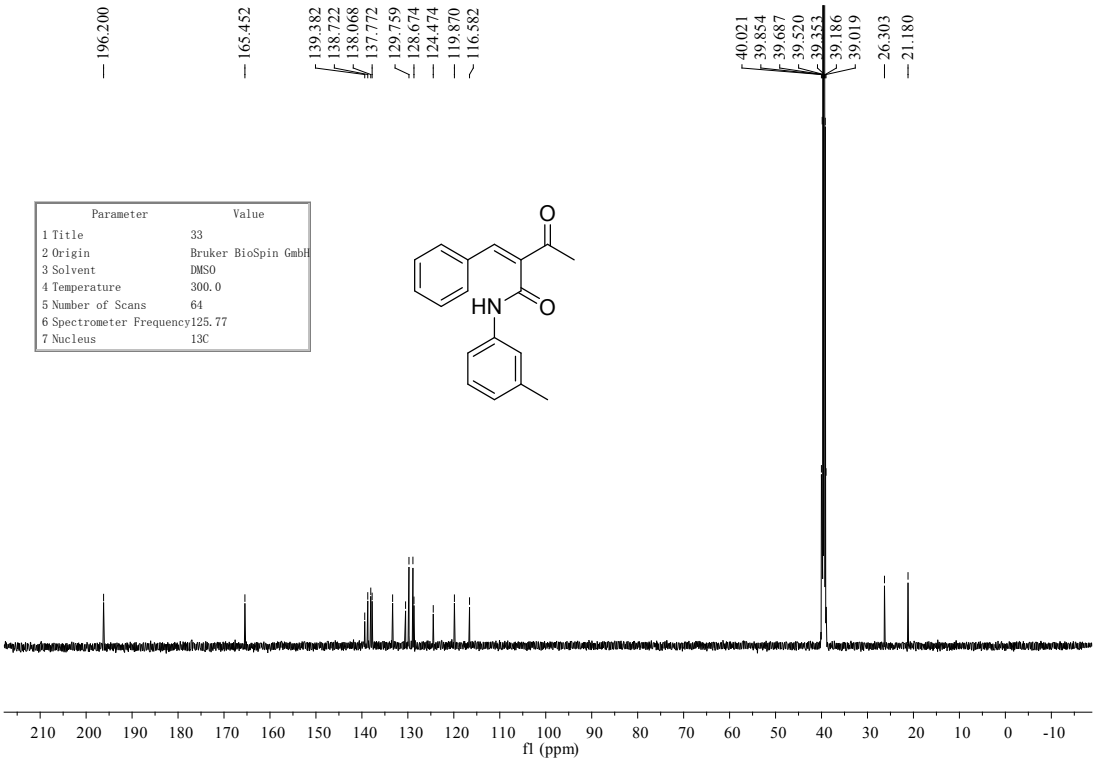
f1 (ppm)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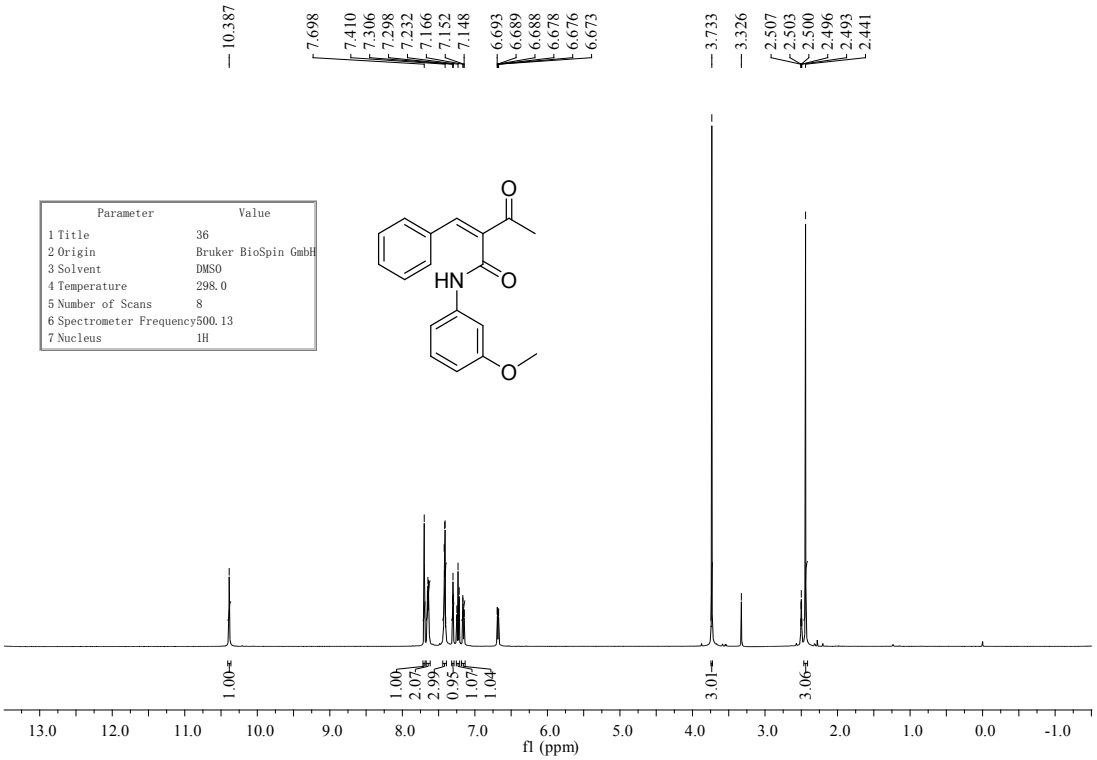
119.870
116.582
40.021
39.854
39.687
39.520
39.353
39.186
39.019
26.303
21.180
Parameter Value
1 Title 33
2 Origin Bruker BioSpin GmbH
3 Solvent DMSO
4 Temperature 300.0
5 Number of Scans 64
6 Spectrometer Frequency 125.77
7 Nucleus 13C
O
HN
O
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)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6.678
6.676
6.673
3.733
3.326
2.507
2.503
2.500
2.496
2.493
2.441
Parameter Value
1 Title 36
2 Origin Bruker BioSpin GmbH
3 Solvent DMSO
4 Temperature 298.0
5 Number of Scans 8
6 Spectrometer Frequency 500.13
7 Nucleus 1H
HN
O
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1.00
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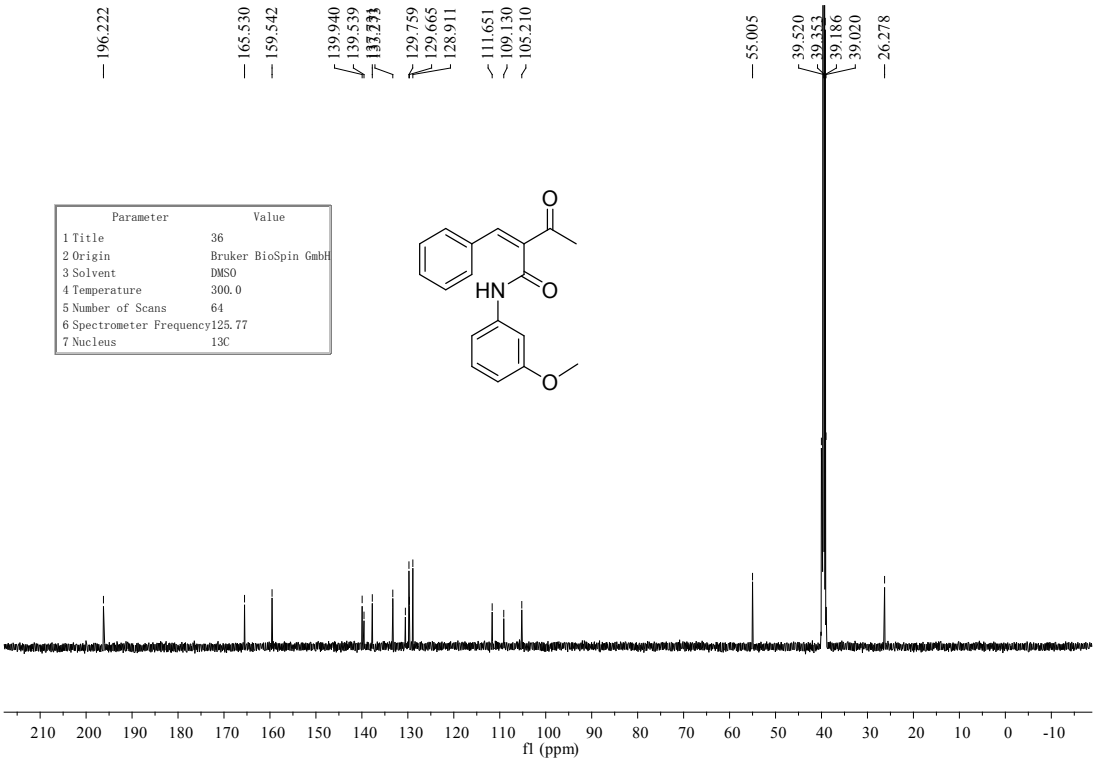
3.01
3.06
f1 (ppm)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109.130
105.210
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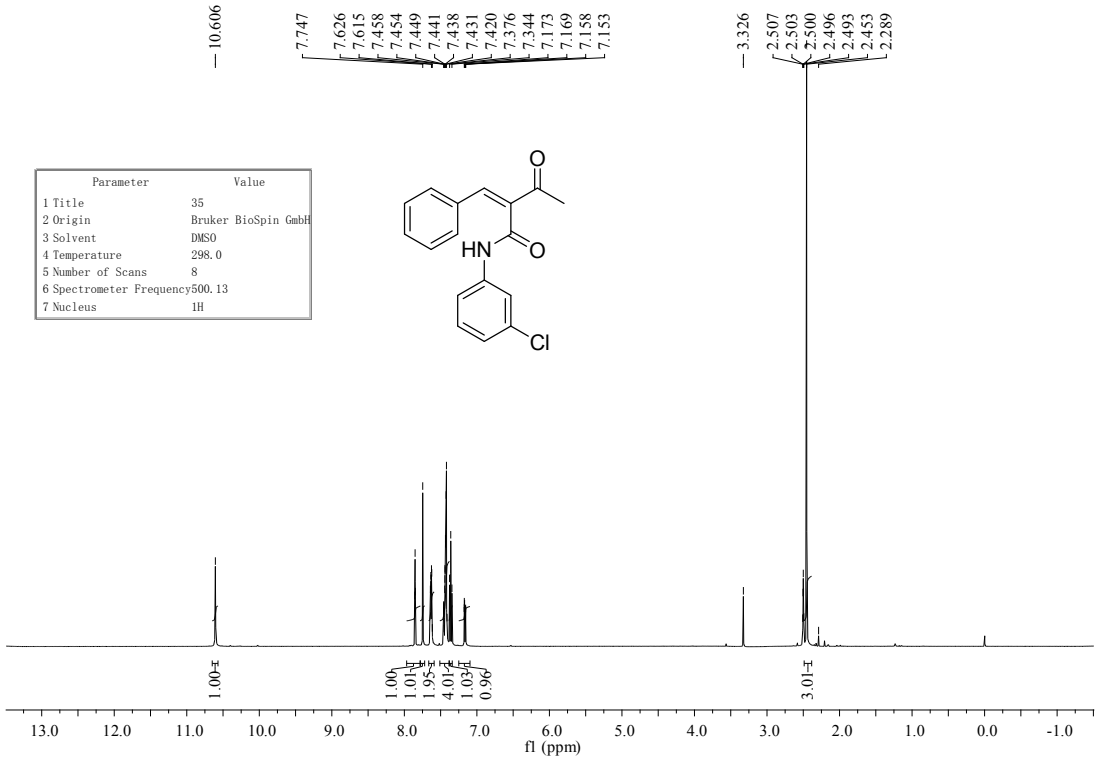
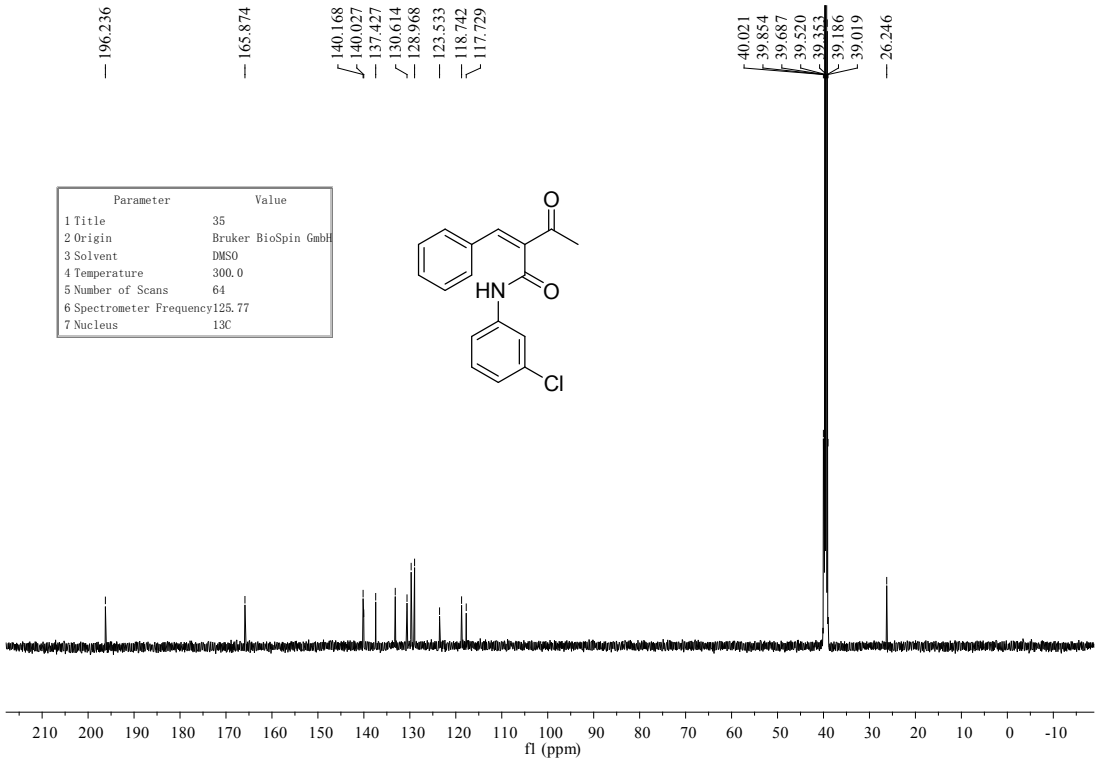
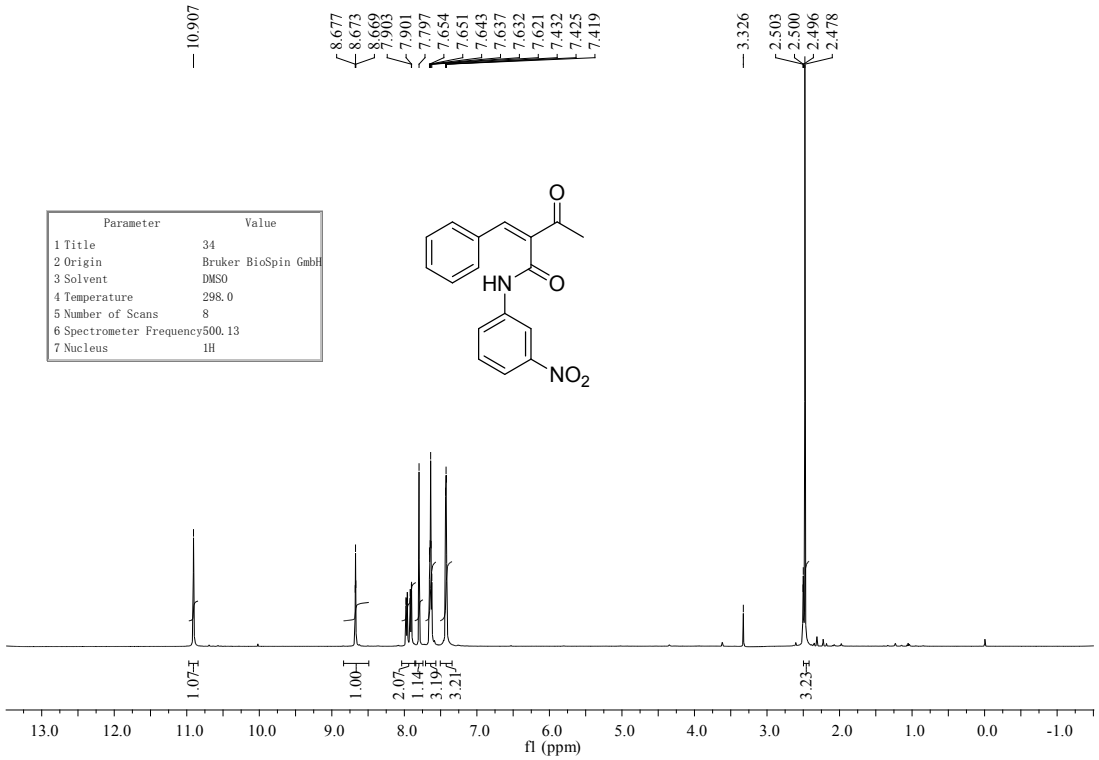
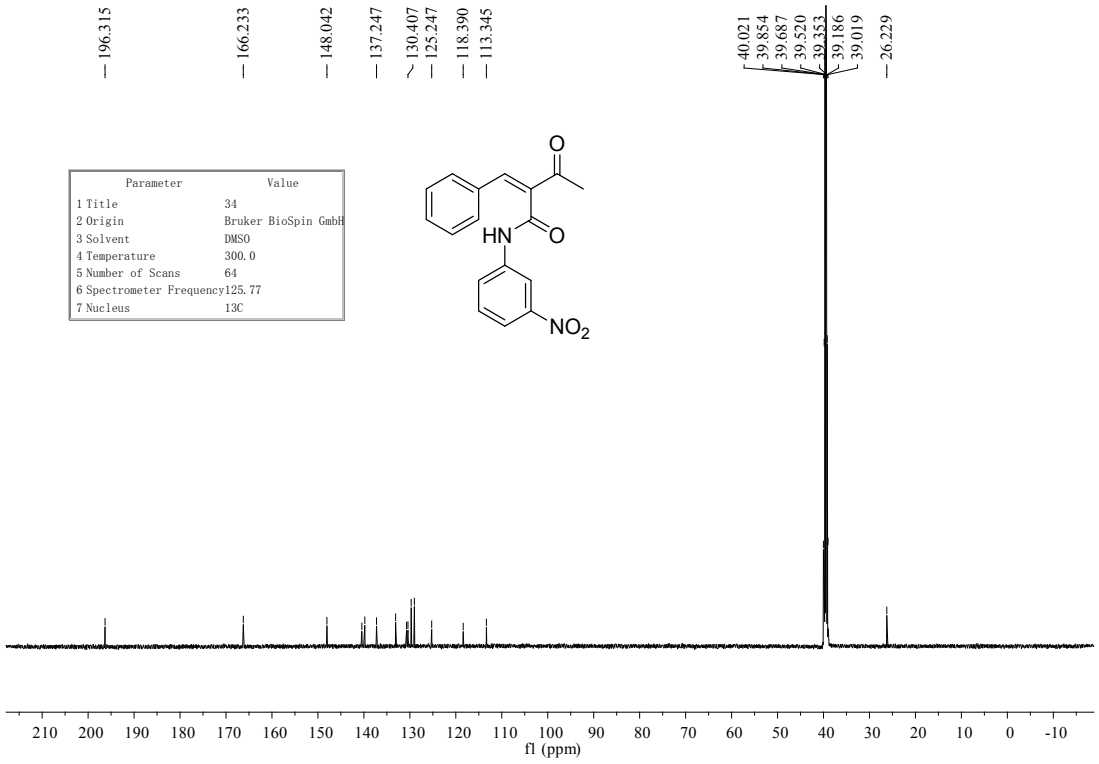
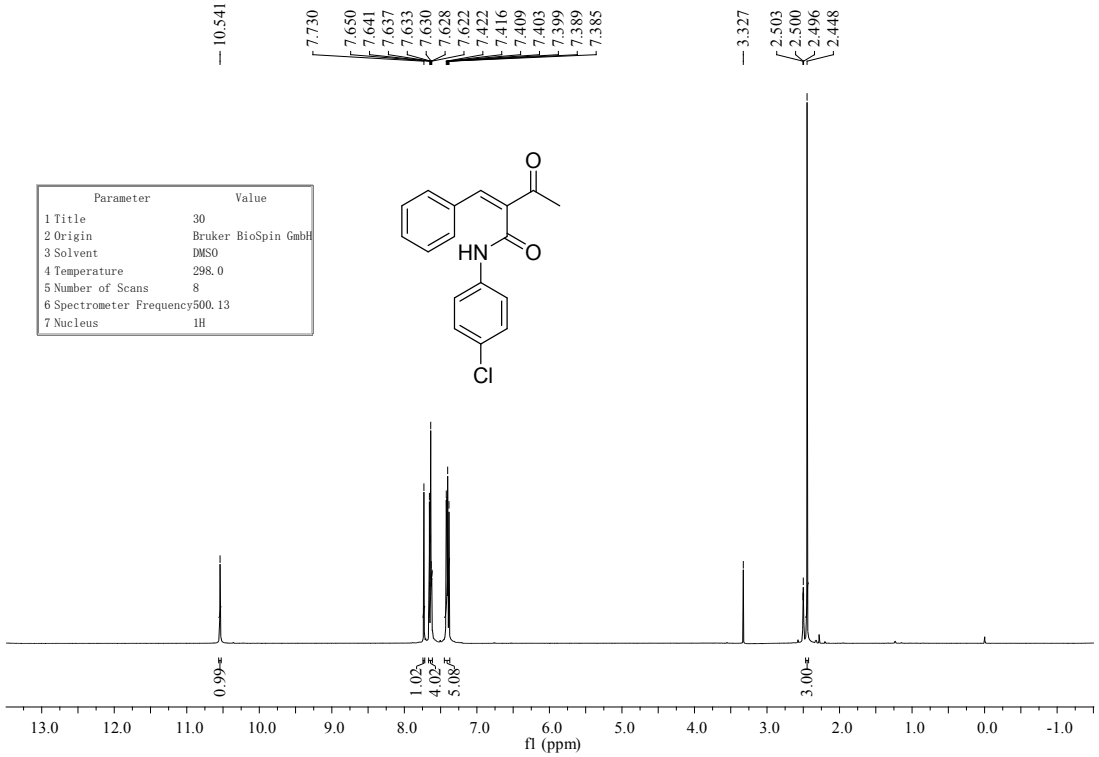
39.520
39.353
39.186
39.020
26.278
Parameter Value
1 Title 36
2 Origin Bruker BioSpin GmbH
3 Solvent DMSO
4 Temperature 300.0
5 Number of Scans 64
6 Spectrometer Frequency 125.77
7 Nucleus 13C
HN
O
f1 (ppm)

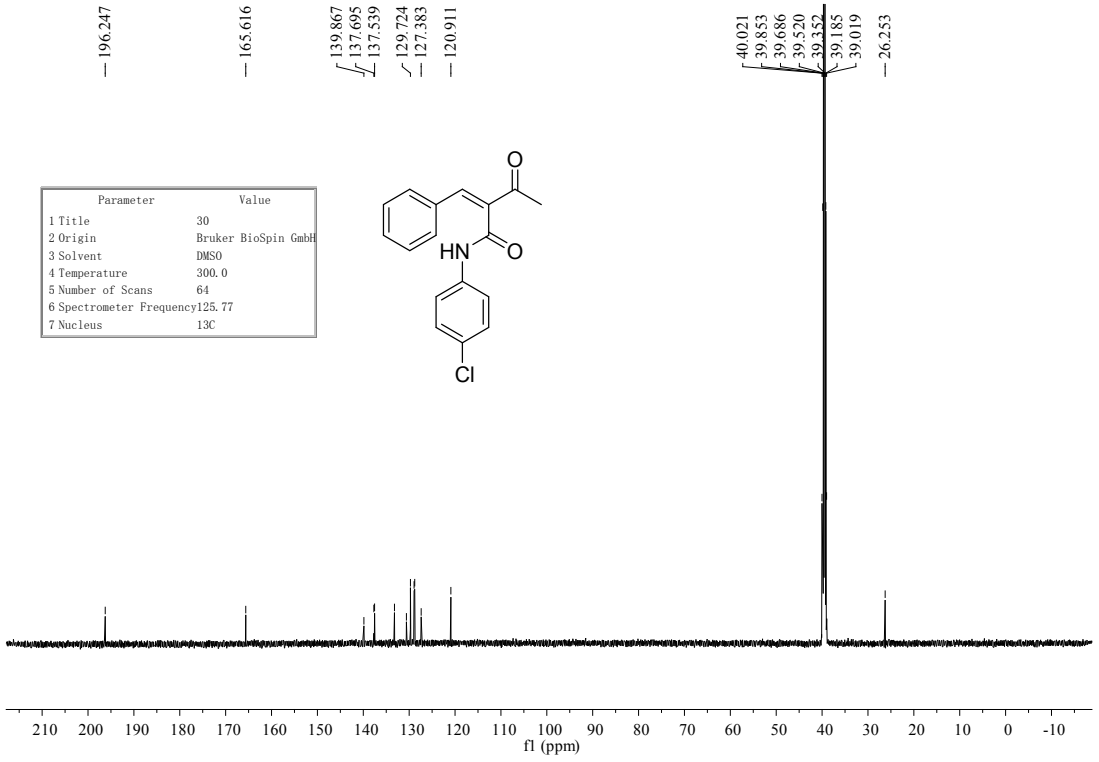

10.606
7.747
7.626
7.615
7.458
7.454
7.449
7.441
7.438
7.431
7.420
7.376
7.344
7.173
7.169
7.158
7.153
3.326
2.507
2.503
2.500
2.496
2.493
2.453
2.289
Parameter Value
1 Title 35
2 Origin Bruker BioSpin GmbH
3 Solvent DMSO
4 Temperature 298.0
5 Number of Scans 8
6 Spectrometer Frequency 500.13
7 Nucleus 1H
O
HN
O
Cl
1.00
1.00
1.01
1.95
4.01
1.03
0.96
3.01
13.0 12.0 11.0 10.0 9.0 8.0 7.0 6.0 5.0 4.0 3.0 2.0 1.0 0.0 -1.0
f1 (ppm)

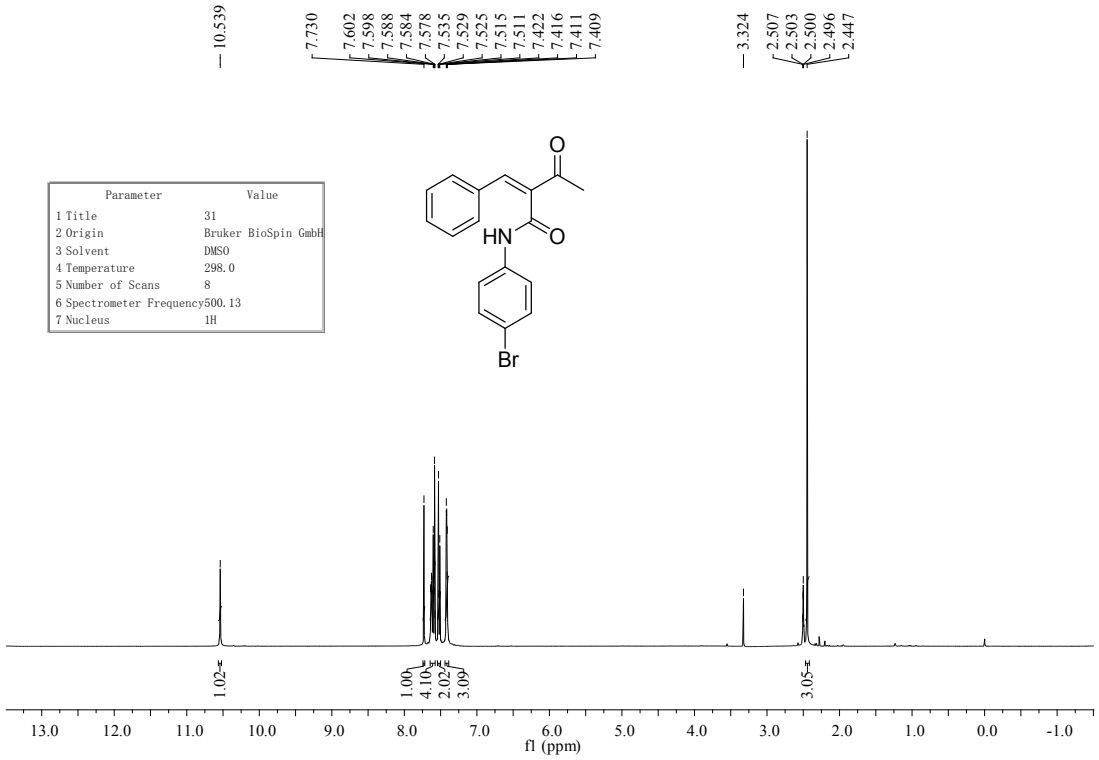

196.236
165.874
140.168
140.027
137.427
130.614
128.968
123.533
118.742
117.729
40.021
39.854
39.687
39.520
39.353
39.186
39.019
26.246
Parameter Value
1 Title 35
2 Origin Bruker BioSpin GmbH
3 Solvent DMSO
4 Temperature 300.0
5 Number of Scans 64
6 Spectrometer Frequency 125.77
7 Nucleus 13C
O
HN
O
Cl
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

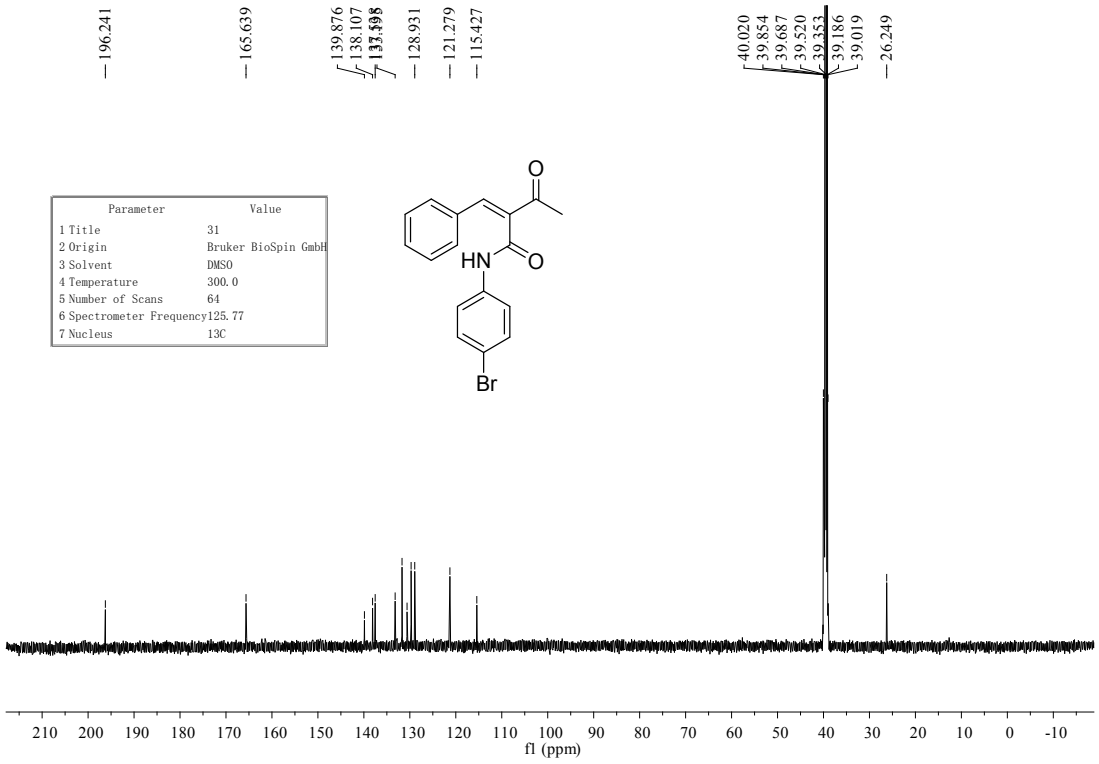

10.907
8.677
8.673
8.669
7.903
7.901
7.797
7.654
7.651
7.643
7.637
7.632
7.621
7.432
7.425
7.419
3.326
2.503
2.500
2.496
2.478
Parameter Value
1 Title 34
2 Origin Bruker BioSpin GmbH
3 Solvent DMSO
4 Temperature 298.0
5 Number of Scans 8
6 Spectrometer Frequency 500.13
7 Nucleus 1H
O
HN
O
NO2
1.07
1.00
2.07
1.14
3.19
3.21
3.23
13.0 12.0 11.0 10.0 9.0 8.0 7.0 6.0 5.0 4.0 3.0 2.0 1.0 0.0 -1.0
f1 (ppm)

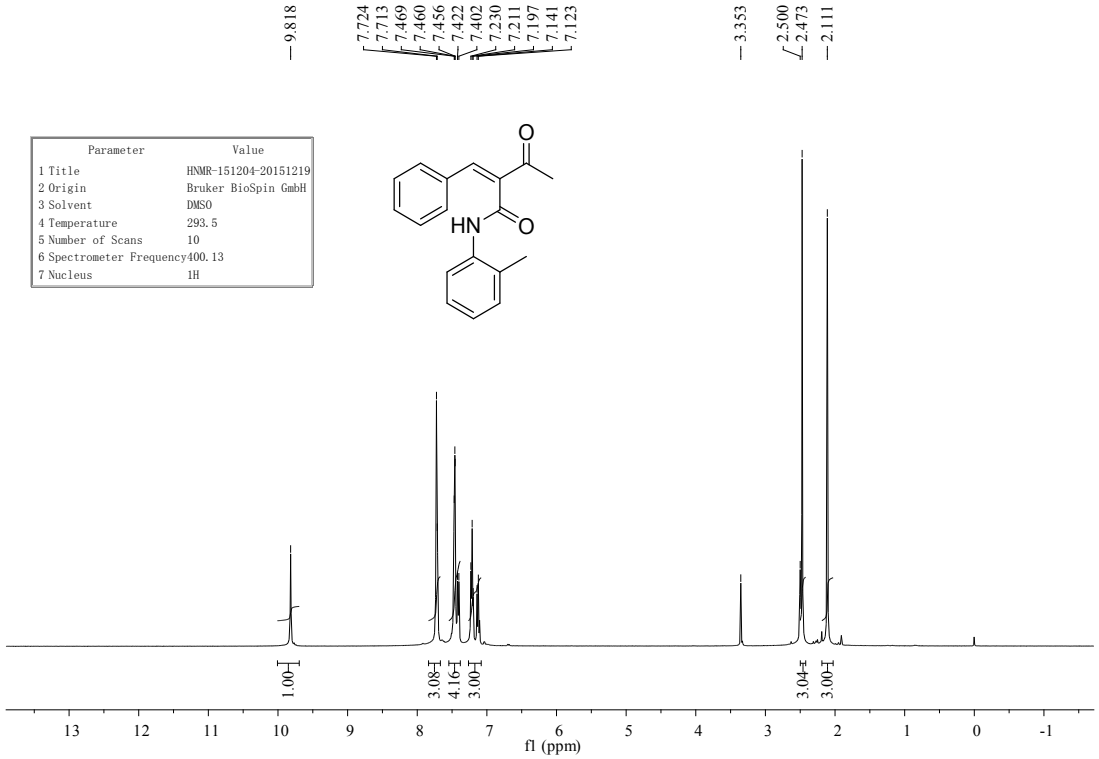

196.315
166.233
148.042
137.247
130.407
125.247
118.390
113.345
40.021
39.854
39.687
39.520
39.353
39.186
39.019
26.229
Parameter Value
1 Title 34
2 Origin Bruker BioSpin GmbH
3 Solvent DMSO
4 Temperature 300.0
5 Number of Scans 64
6 Spectrometer Frequency 125.77
7 Nucleus 13C
O
HN
O
NO2
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

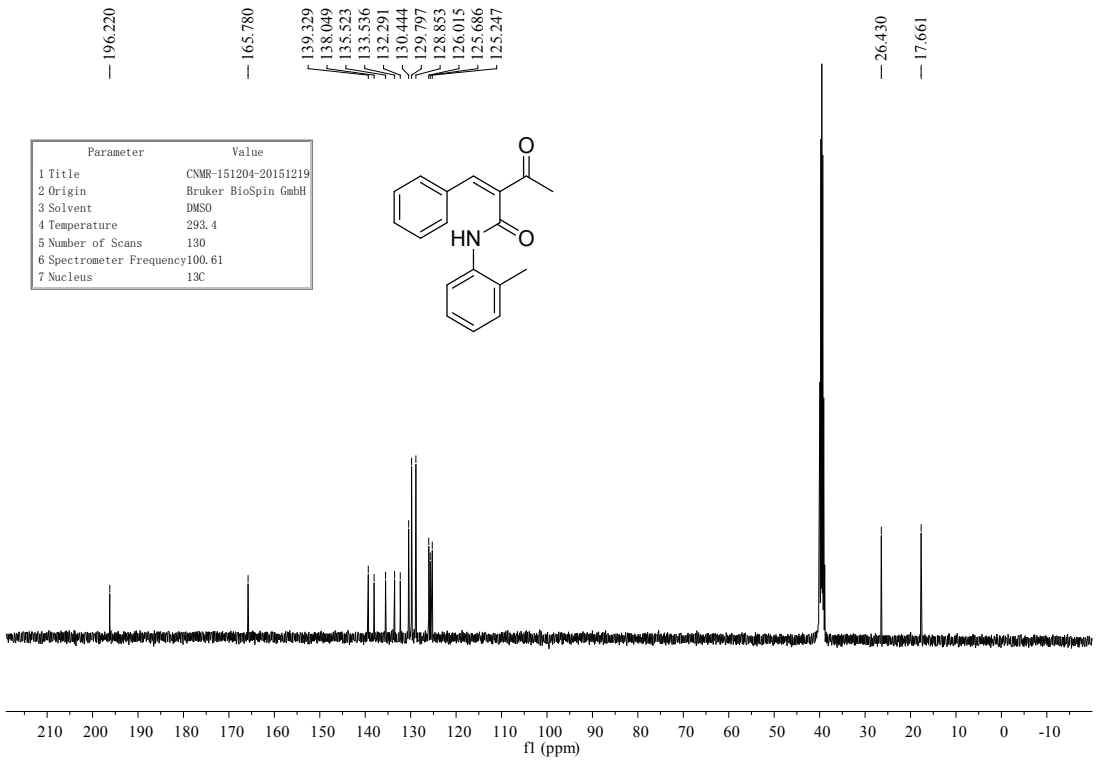

10.541
7.730
7.650
7.641
7.637
7.633
7.630
7.628
7.622
7.422
7.416
7.409
7.403
7.399
7.389
7.385
3.327
2.503
2.500
2.496
2.448
Parameter Value
1 Title 30
2 Origin Bruker BioSpin GmbH
3 Solvent DMSO
4 Temperature 298.0
5 Number of Scans 8
6 Spectrometer Frequency 500.13
7 Nucleus 1H
O
HN
O
Cl
0.99
1.02
4.02
5.08
3.00
13.0 12.0 11.0 10.0 9.0 8.0 7.0 6.0 5.0 4.0 3.0 2.0 1.0 0.0 -1.0
f1 (ppm)

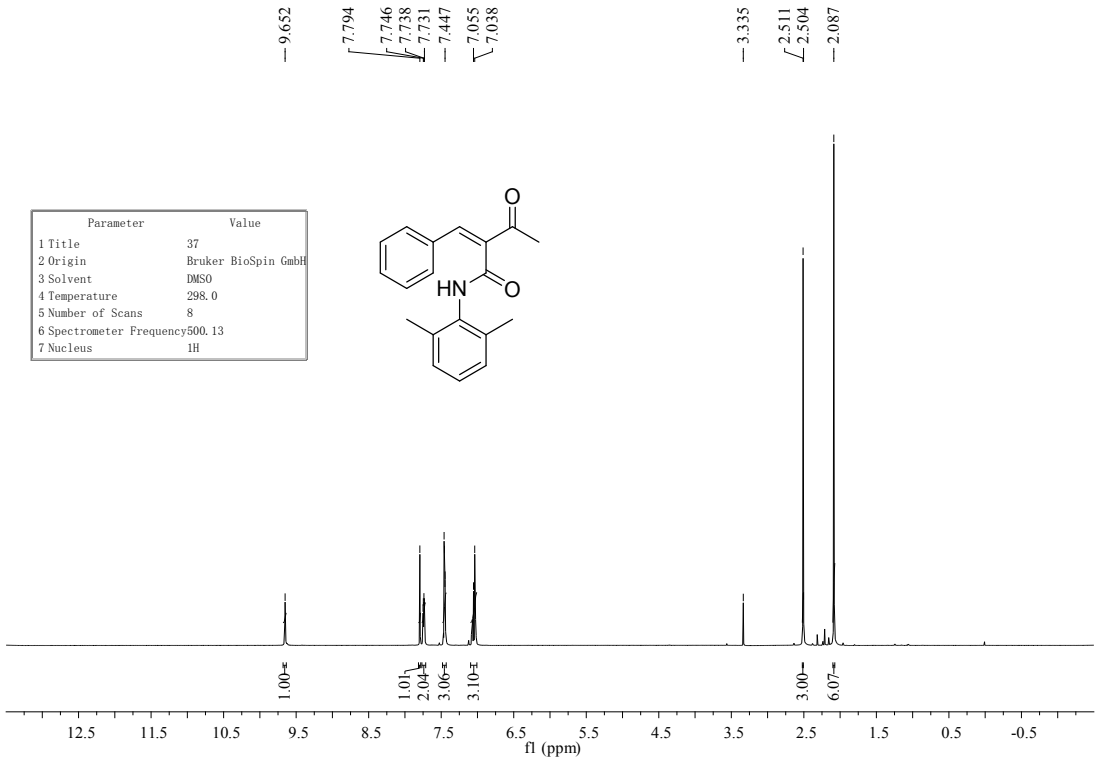

196.247
165.616
139.867
137.695
137.539
129.724
127.383
120.911
40.021
39.853
39.686
39.520
39.352
39.185
39.019
26.253
Parameter Value
1 Title 30
2 Origin Bruker BioSpin GmbH
3 Solvent DMSO
4 Temperature 300.0
5 Number of Scans 64
6 Spectrometer Frequency 125.77
7 Nucleus 13C
O
HN
O
Cl
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

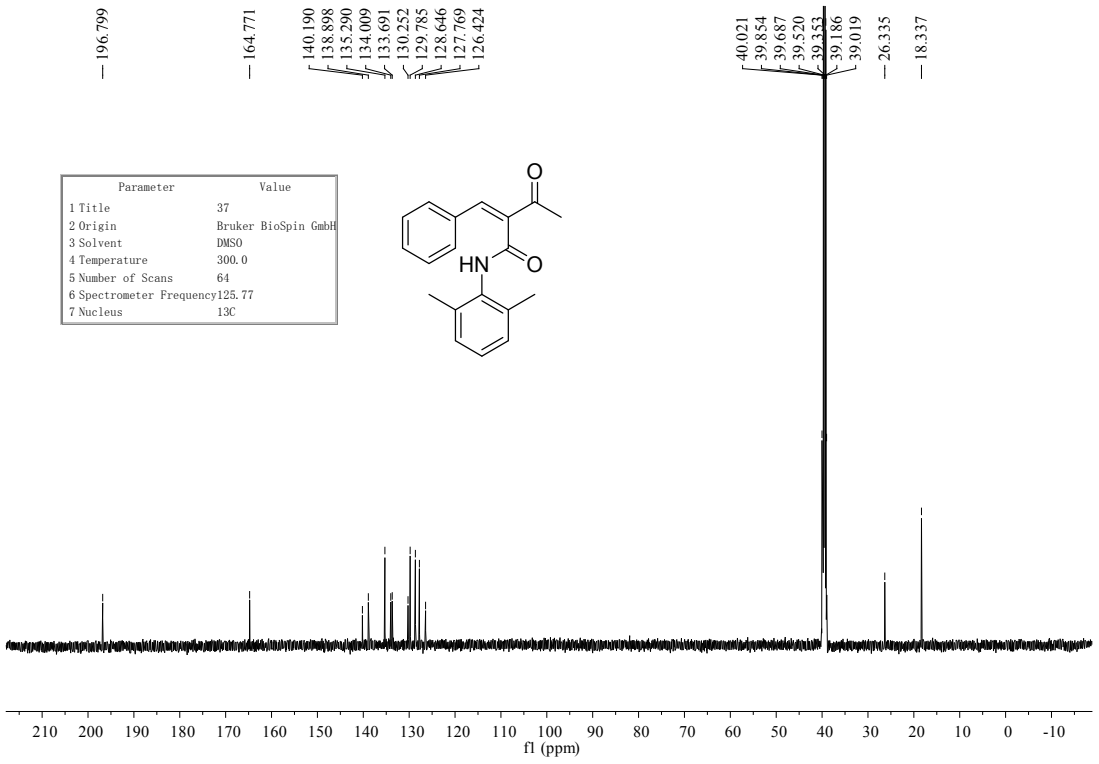

10.539
7.730
7.602
7.598
7.588
7.584
7.578
7.535
7.529
7.525
7.515
7.511
7.422
7.416
7.411
7.409
3.324
2.507
2.503
2.500
2.496
2.447
Parameter Value
1 Title 31
2 Origin Bruker BioSpin GmbH
3 Solvent DMSO
4 Temperature 298.0
5 Number of Scans 8
6 Spectrometer Frequency 500.13
7 Nucleus 1H
O
HN
O
Br
1.02
1.00
4.10
2.02
3.09
3.05
13.0 12.0 11.0 10.0 9.0 8.0 7.0 6.0 5.0 4.0 3.0 2.0 1.0 0.0 -1.0
f1 (ppm)

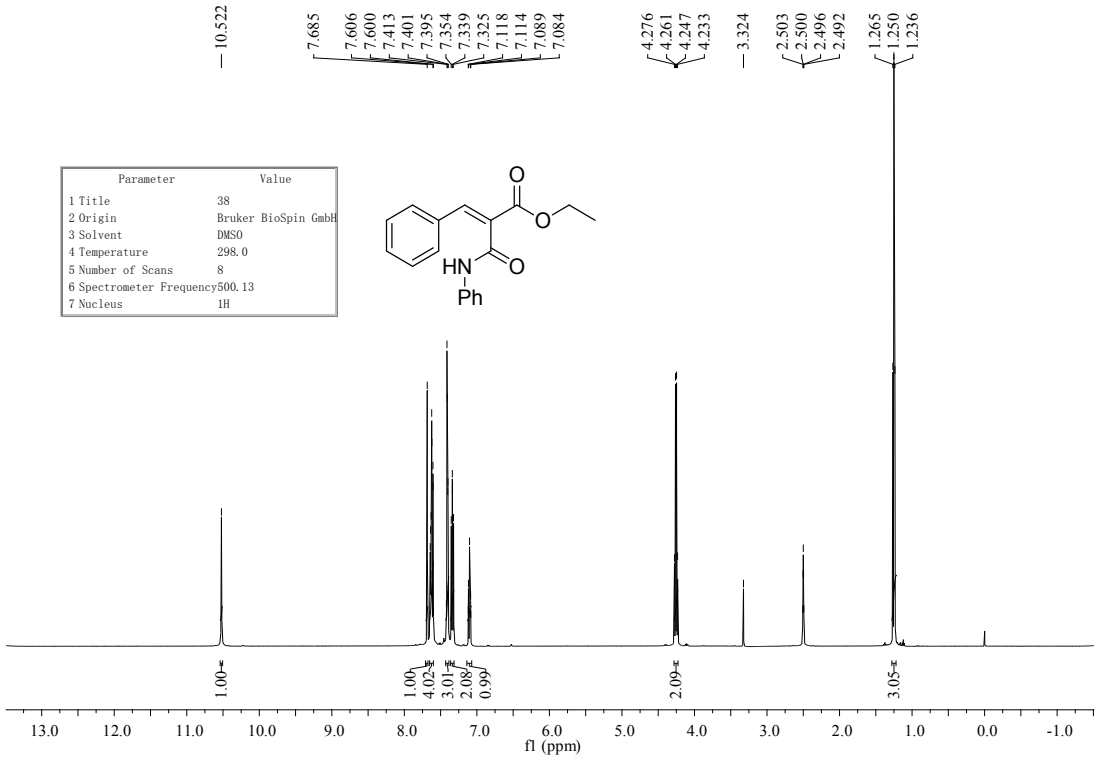

196.241
165.639
139.876
138.107
128.931
121.279
115.427
40.020
39.854
39.687
39.520
39.353
39.186
39.019
26.249
Parameter Value
1 Title 31
2 Origin Bruker BioSpin GmbH
3 Solvent DMSO
4 Temperature 300.0
5 Number of Scans 64
6 Spectrometer Frequency 125.77
7 Nucleus 13C
O
HN
O
Br
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

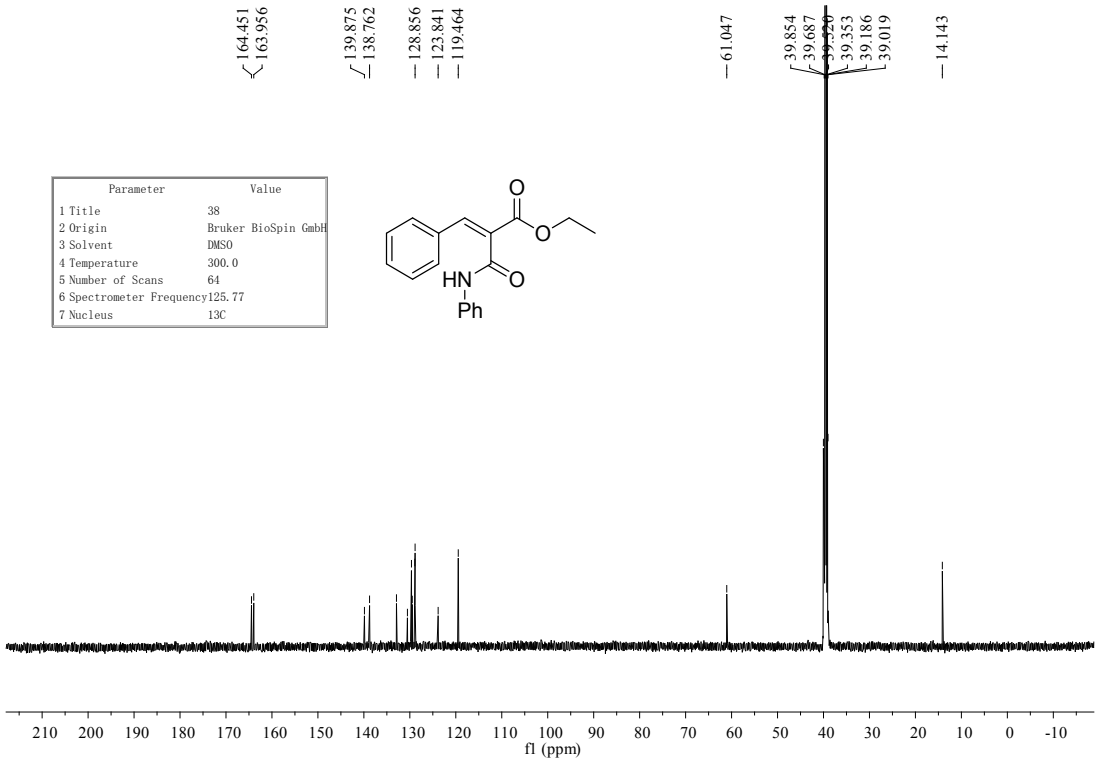

9.818
7.724
7.713
7.469
7.460
7.456
7.422
7.402
7.230
7.211
7.197
7.141
7.123
3.353
2.500
2.473
2.111
Parameter Value
1 Title HNMR-151204-20151219
2 Origin Bruker BioSpin GmbH
3 Solvent DMSO
4 Temperature 293.5
5 Number of Scans 10
6 Spectrometer Frequency 400.13
7 Nucleus 1H
O
HN
O
1.00
3.08
4.16
3.00
3.04
3.00
13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1
f1 (ppm)

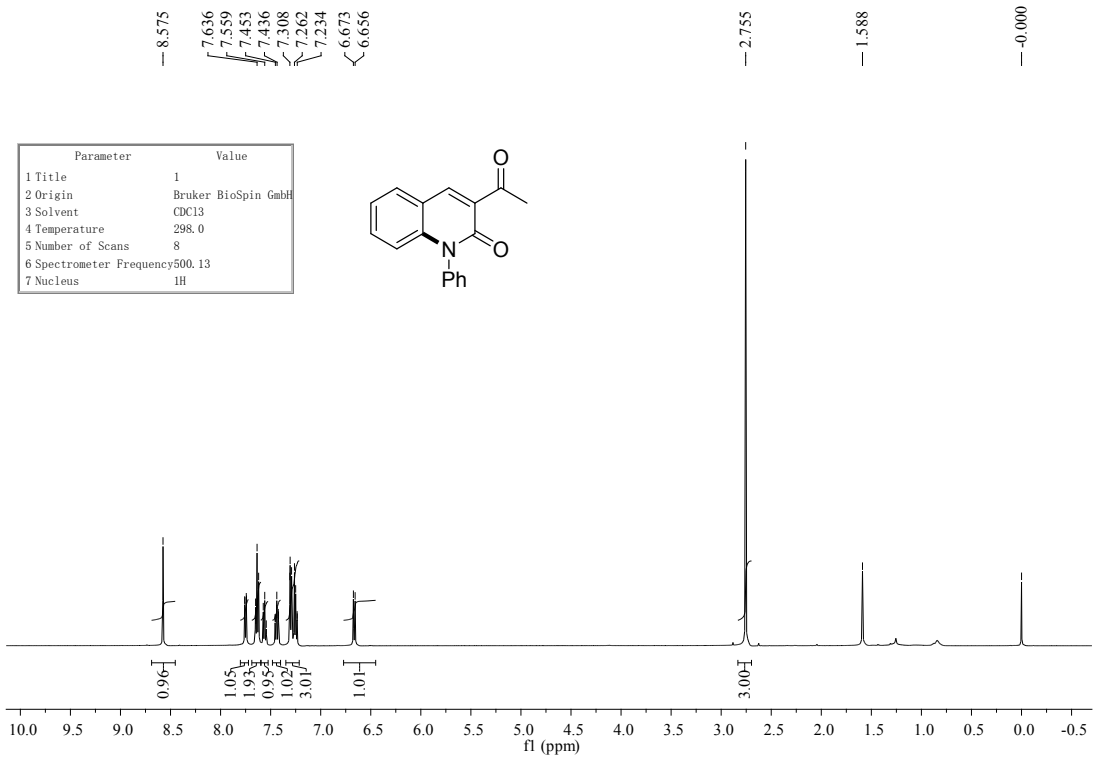

196.220
165.780
139.329
138.049
135.523
133.536
132.291
130.444
129.797
128.853
126.015
125.686
125.247
26.430
17.661
Parameter Value
1 Title CNMR-151204-20151219
2 Origin Bruker BioSpin GmbH
3 Solvent DMSO
4 Temperature 293.4
5 Number of Scans 130
6 Spectrometer Frequency 100.61
7 Nucleus 13C
O
HN
O
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

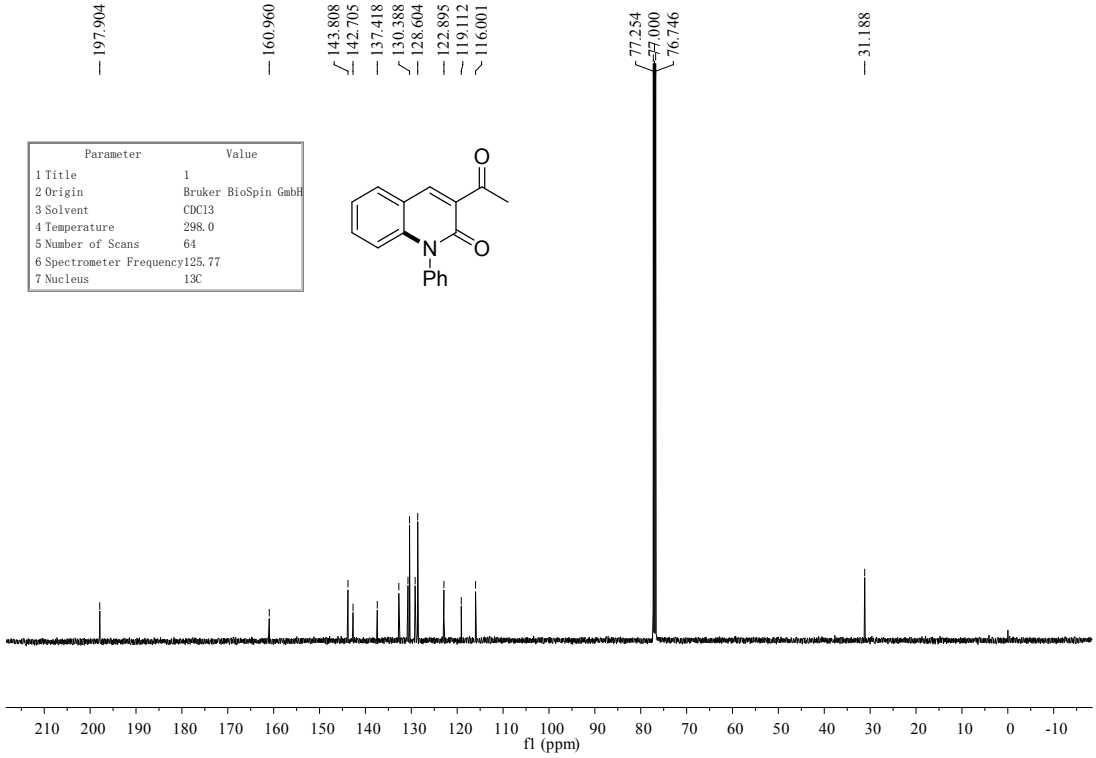

9.652
7.794
7.746
7.738
7.731
7.447
7.055
7.038
3.335
2.511
2.504
2.087
Parameter Value
1 Title 37
2 Origin Bruker BioSpin GmbH
3 Solvent DMSO
4 Temperature 298.0
5 Number of Scans 8
6 Spectrometer Frequency 500.13
7 Nucleus 1H
O
HN
O
1.00
1.01
2.04
3.06
3.10
3.00
6.07
12.5 11.5 10.5 9.5 8.5 7.5 6.5 5.5 4.5 3.5 2.5 1.5 0.5 -0.5
f1 (ppm)

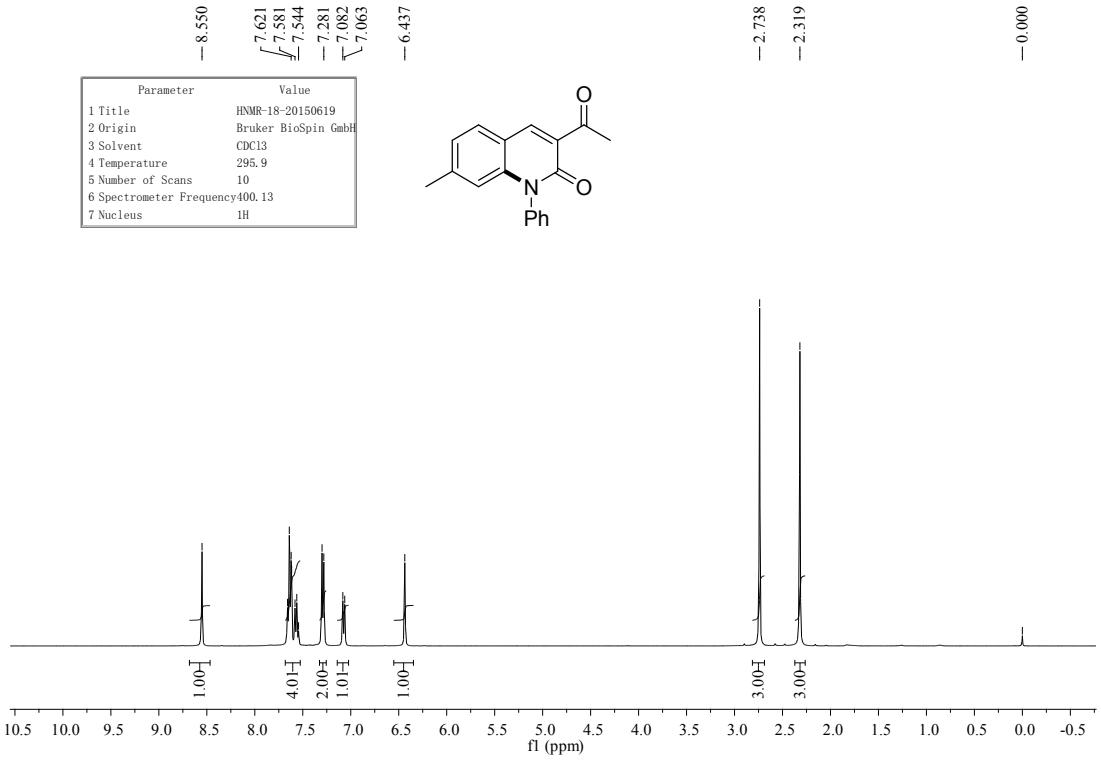

196.799
164.771
140.190
138.898
135.290
134.009
133.691
130.252
129.785
128.646
127.769
126.424
40.021
39.854
39.687
39.520
39.353
39.186
39.019
26.335
18.337
Parameter Value
1 Title 37
2 Origin Bruker BioSpin GmbH
3 Solvent DMSO
4 Temperature 300.0
5 Number of Scans 64
6 Spectrometer Frequency 125.77
7 Nucleus 13C
O
HN
O
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

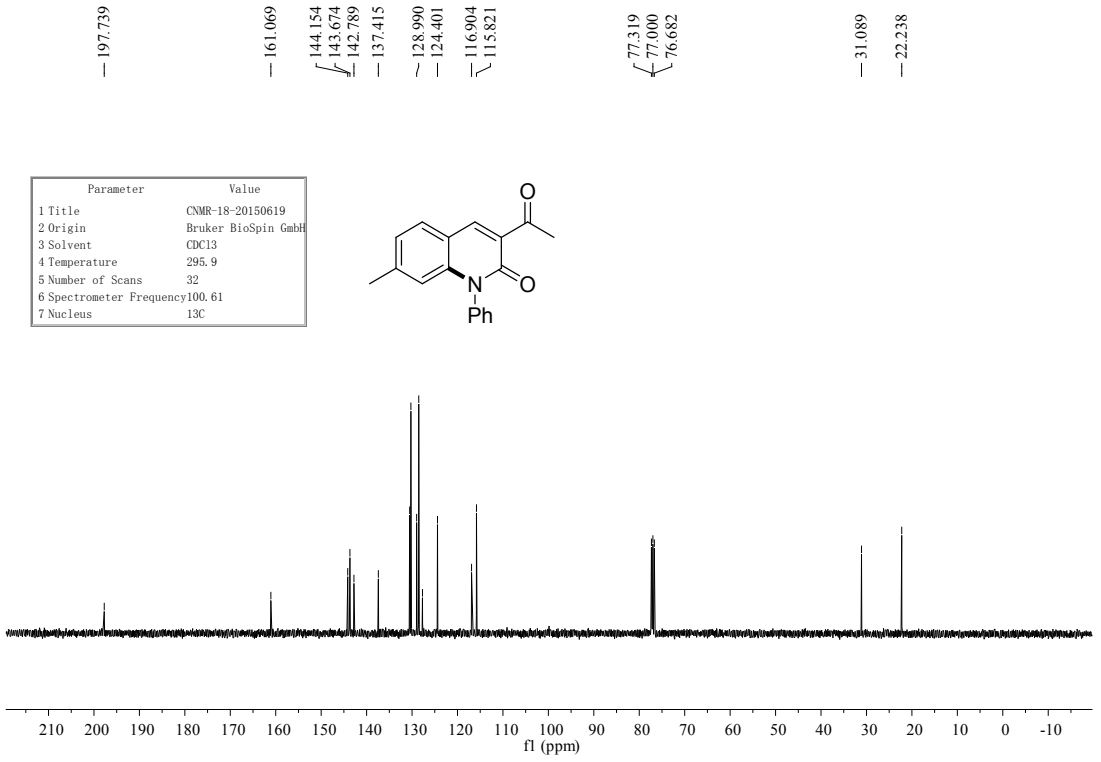

10.522
7.685
7.606
7.600
7.413
7.401
7.395
7.354
7.339
7.325
7.118
7.114
7.089
7.084
4.276
4.261
4.247
4.233
3.324
2.503
2.500
2.496
2.492
1.265
1.250
1.236
Parameter Value
1 Title 38
2 Origin Bruker BioSpin GmbH
3 Solvent DMSO
4 Temperature 298.0
5 Number of Scans 8
6 Spectrometer Frequency 500.13
7 Nucleus 1H
O
O
HN
O
Ph
1.00
1.00
4.02
3.01
2.08
0.99
2.09
3.05
13.0 12.0 11.0 10.0 9.0 8.0 7.0 6.0 5.0 4.0 3.0 2.0 1.0 0.0 -1.0
f1 (ppm)

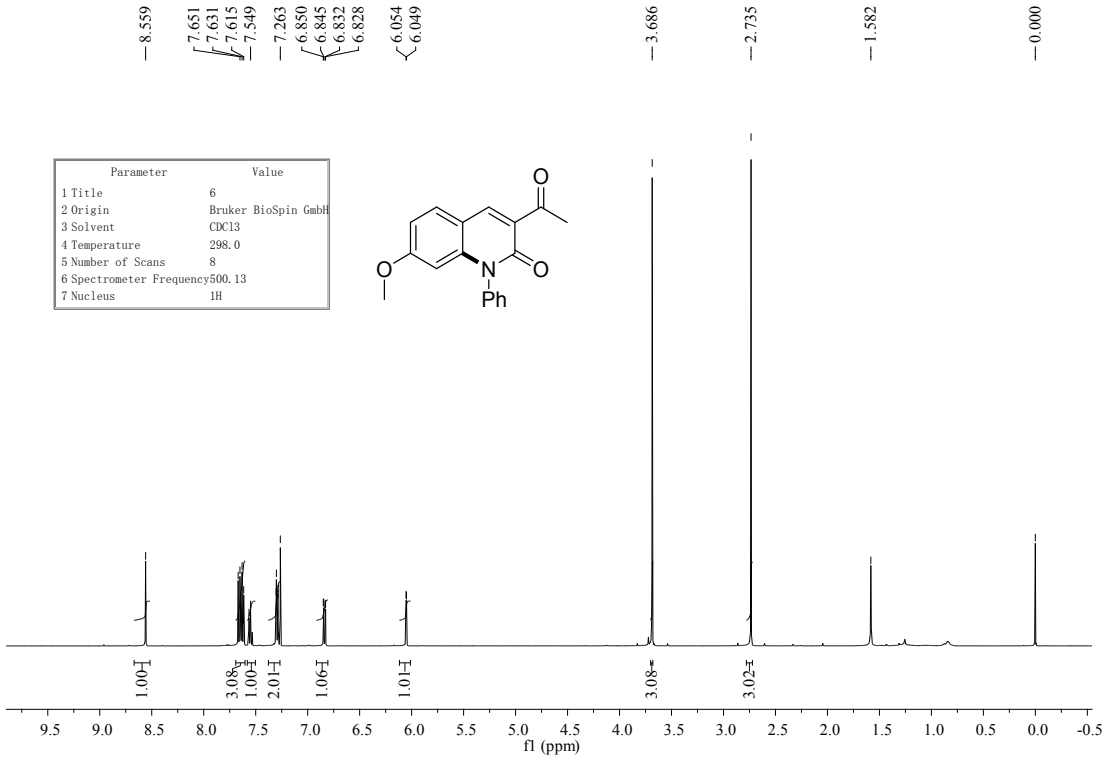

164.451
163.956
139.875
138.762
128.856
123.841
119.464
61.047
39.854
39.687
39.520
39.353
39.186
39.019
14.143
Parameter Value
1 Title 38
2 Origin Bruker BioSpin GmbH
3 Solvent DMSO
4 Temperature 300.0
5 Number of Scans 64
6 Spectrometer Frequency 125.77
7 Nucleus 13C
O
O
HN
O
Ph
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


8.575
7.636
7.559
7.453
7.436
7.308
7.262
7.234
6.673
6.656
2.755
1.588
-0.000
Parameter Value
1 Title 1
2 Origin Bruker BioSpin GmbH
3 Solvent CDCl3
4 Temperature 298.0
5 Number of Scans 8
6 Spectrometer Frequency 500.13
7 Nucleus 1H
O
N
Ph
O
0.96
1.05
1.93
0.95
1.02
3.01
1.01
3.00
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)


197.904
160.960
143.808
142.705
137.418
130.388
128.604
122.895
119.112
116.001
77.254
77.000
76.746
31.188
Parameter Value
1 Title 1
2 Origin Bruker BioSpin GmbH
3 Solvent CDCl3
4 Temperature 298.0
5 Number of Scans 64
6 Spectrometer Frequency 125.77
7 Nucleus 13C
O
N
Ph
O
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


8.550
7.621
7.581
7.544
7.281
7.082
7.063
6.437
2.738
2.319
0.000
Parameter Value
1 Title HNMR-18-20150619
2 Origin Bruker BioSpin GmbH
3 Solvent CDCl3
4 Temperature 295.9
5 Number of Scans 10
6 Spectrometer Frequency 400.13
7 Nucleus 1H
O
N
O
Ph
1.00
4.01
2.00
1.01
1.00
3.00
3.00
f1 (ppm)


197.739
161.069
144.154
143.674
142.789
137.415
128.990
124.401
116.904
115.821
77.319
77.000
76.682
31.089
22.238
Parameter Value
1 Title CNMR-18-20150619
2 Origin Bruker BioSpin GmbH
3 Solvent CDCl3
4 Temperature 295.9
5 Number of Scans 32
6 Spectrometer Frequency 100.61
7 Nucleus 13C
O
N
O
Ph
f1 (ppm)


8.559
7.651
7.631
7.615
7.549
7.263
6.850
6.845
6.832
6.828
6.054
6.049
3.686
2.735
1.582
0.000
Parameter Value
1 Title 6
2 Origin Bruker BioSpin GmbH
3 Solvent CDCl3
4 Temperature 298.0
5 Number of Scans 8
6 Spectrometer Frequency 500.13
7 Nucleus 1H
O
O
N
Ph
O
1.00
3.08
1.00
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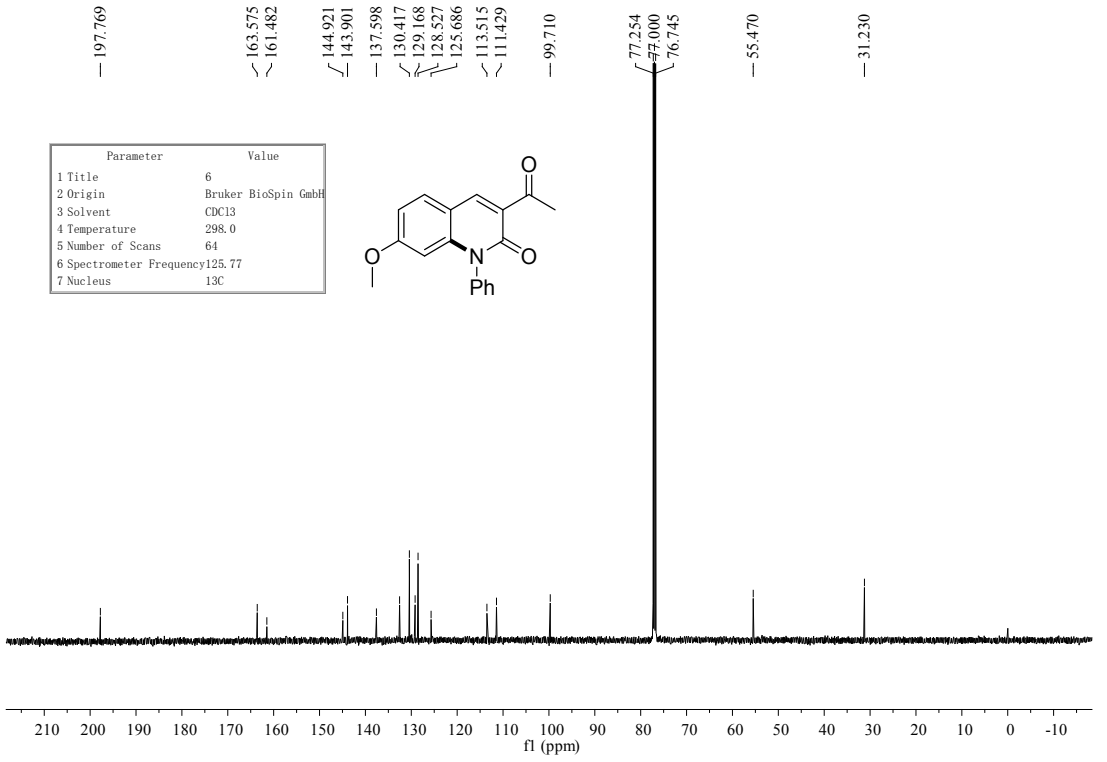
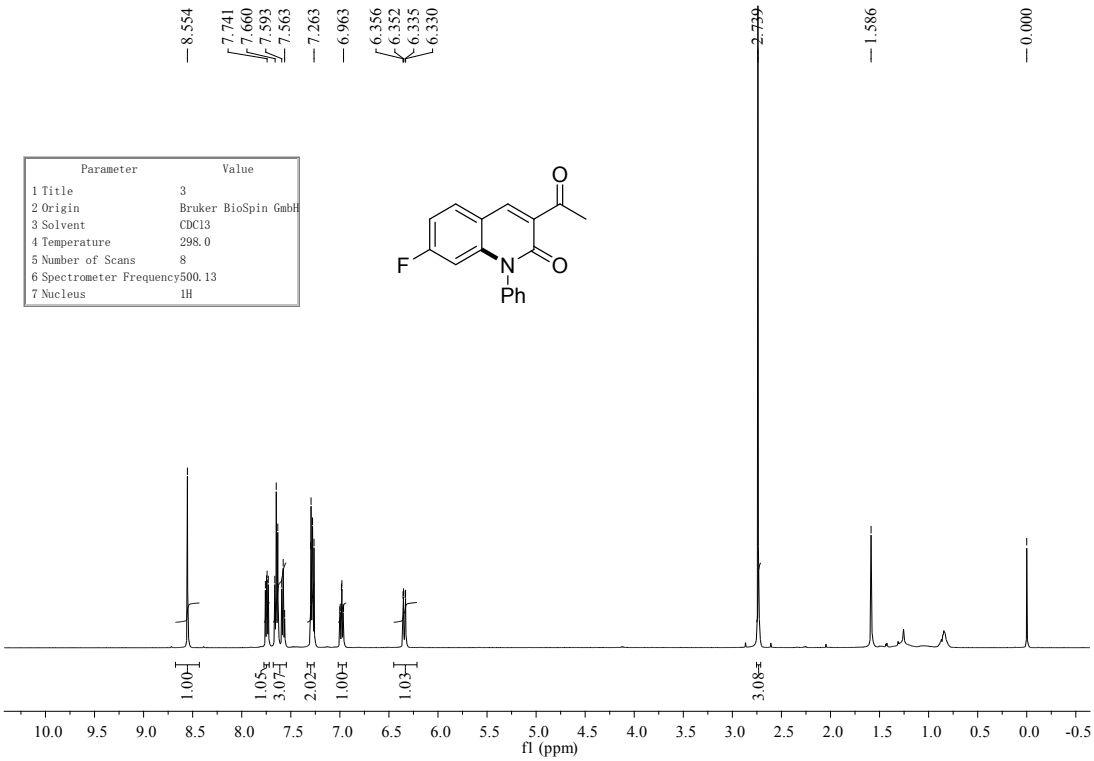
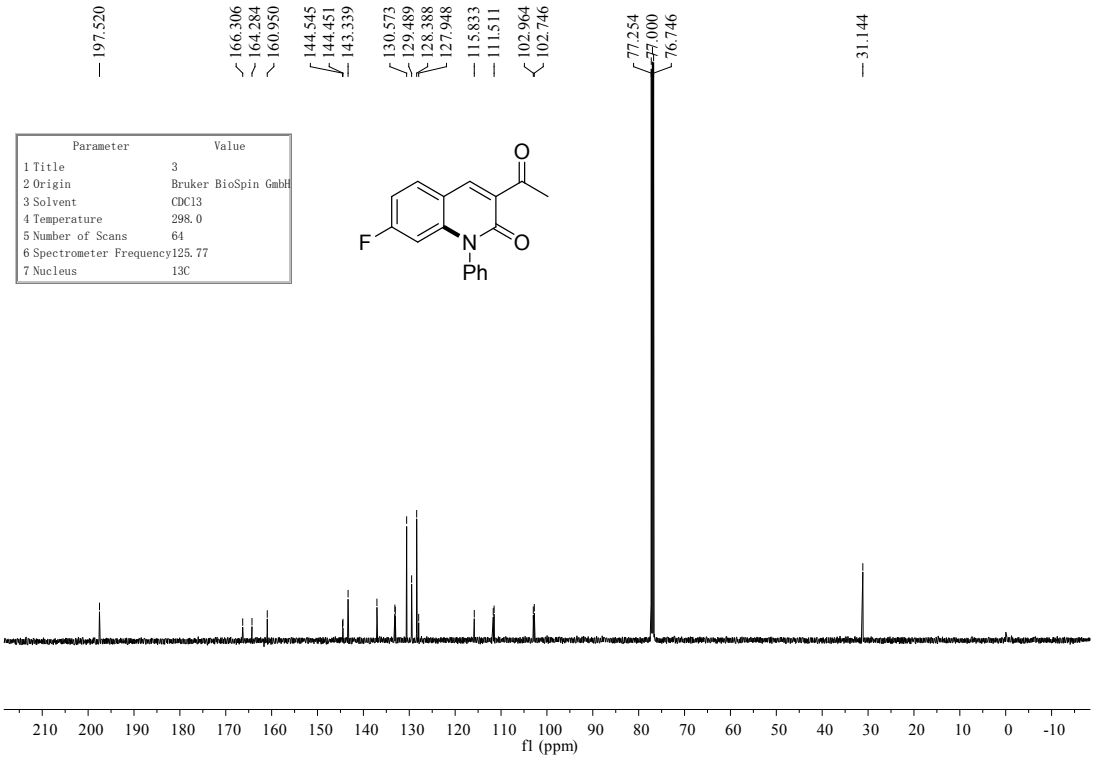
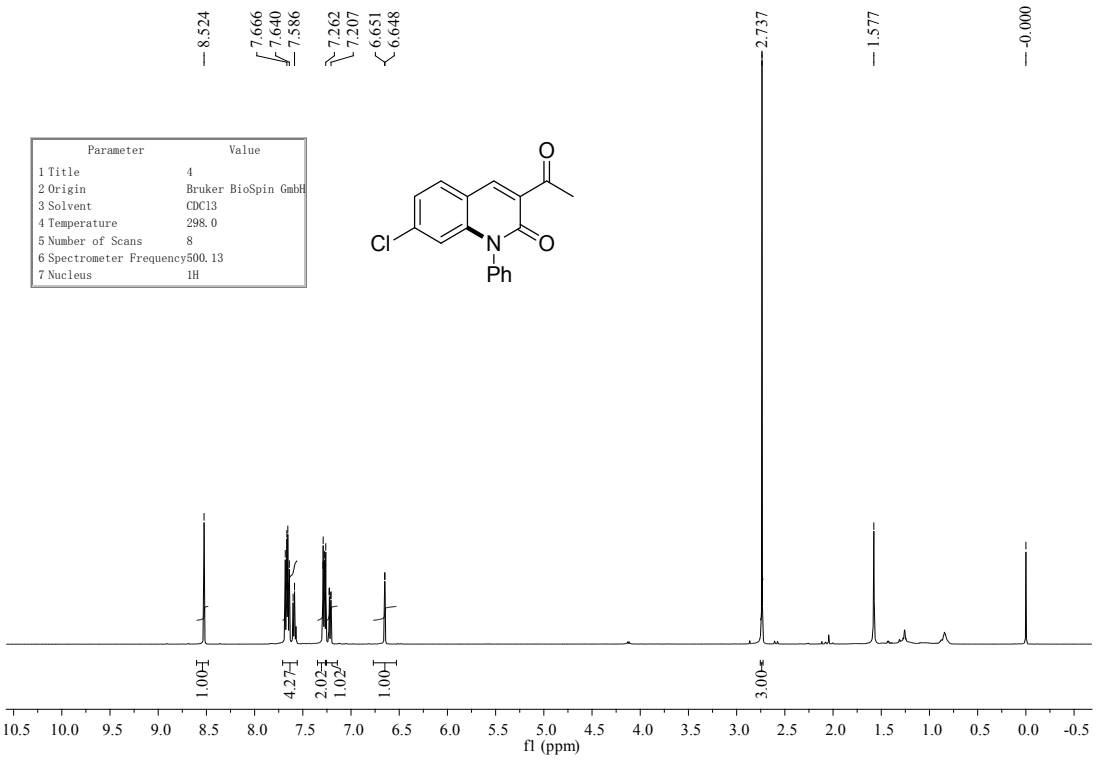
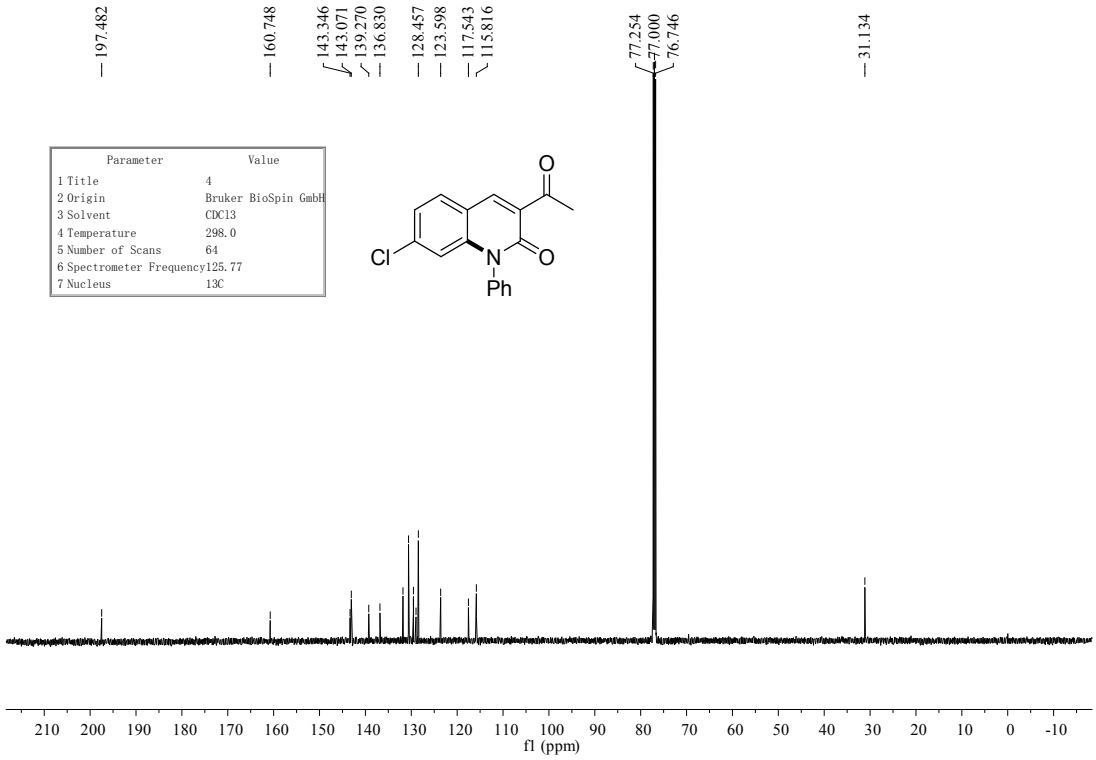
1.06
1.01
3.08
3.02
f1 (ppm)

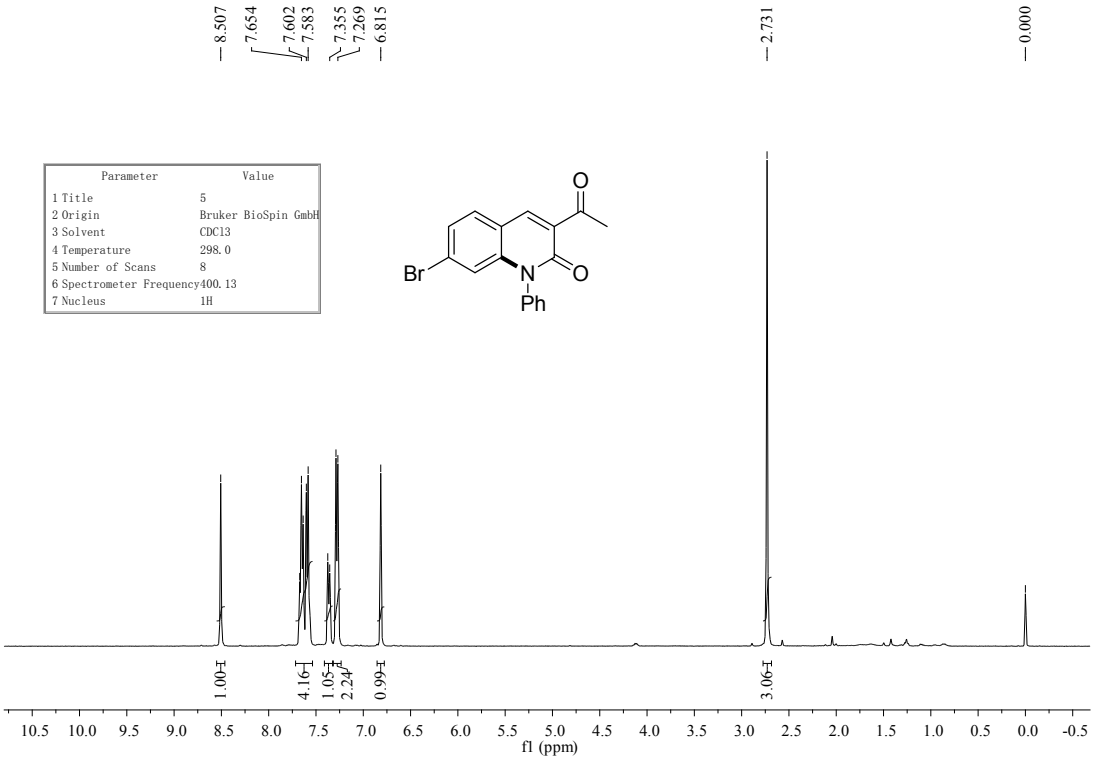

197.769
163.575
161.482
144.921
143.901
137.598
130.417
129.168
128.527
125.686
113.515
111.429
99.710
77.254
77.000
76.745
55.470
31.230
Parameter Value
1 Title 6
2 Origin Bruker BioSpin GmbH
3 Solvent CDCl3
4 Temperature 298.0
5 Number of Scans 64
6 Spectrometer Frequency 125.77
7 Nucleus 13C
O
O
N
Ph
f1 (ppm)

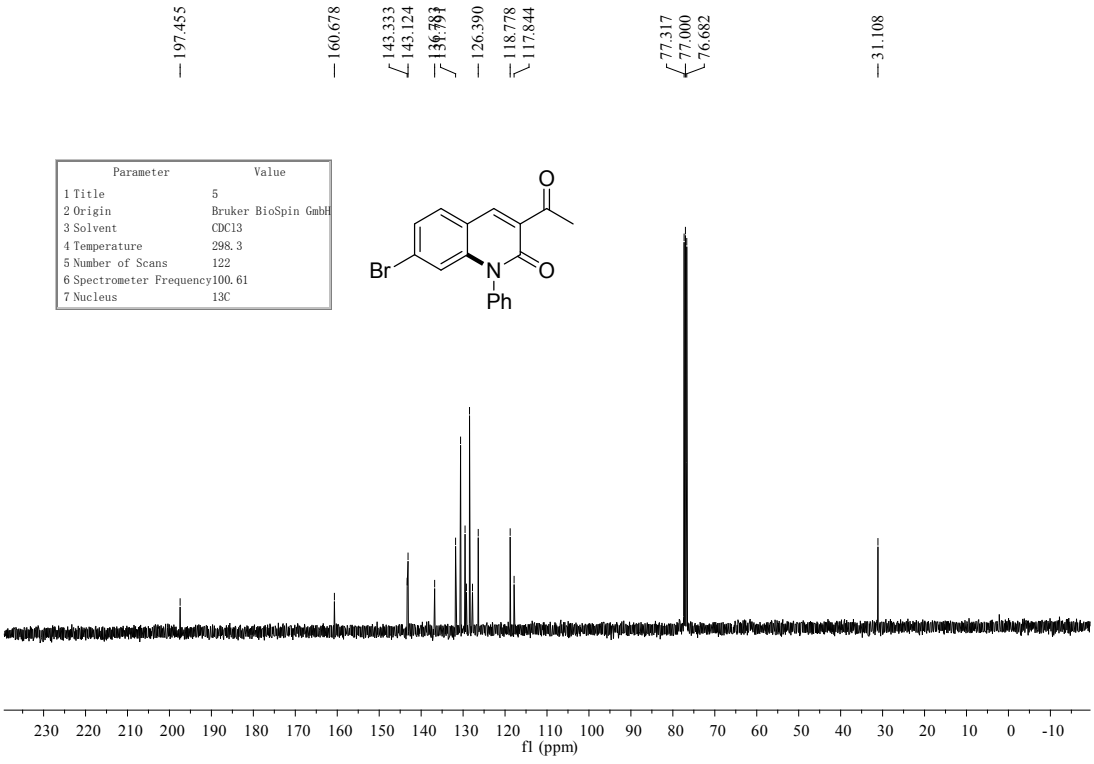

8.554
7.741
7.660
7.593
7.563
7.263
6.963
6.356
6.352
6.335
6.330
2.739
1.586
0.000
Parameter Value
1 Title 3
2 Origin Bruker BioSpin GmbH
3 Solvent CDCl3
4 Temperature 298.0
5 Number of Scans 8
6 Spectrometer Frequency 500.13
7 Nucleus 1H
F
N
O
O
Ph
1.00
1.05
3.07
2.02
1.00
1.03
3.08
f1 (ppm)

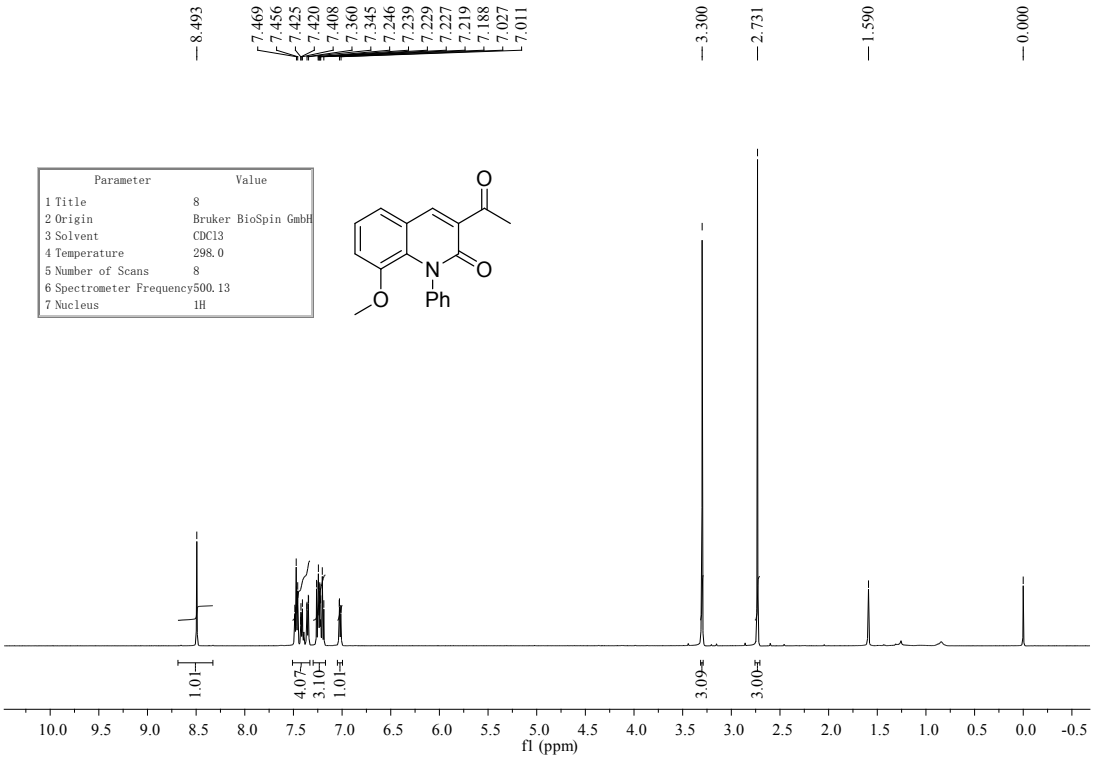

197.520
166.306
164.284
160.950
144.545
144.451
143.339
130.573
129.489
128.388
127.948
115.833
111.511
102.964
102.746
77.254
77.000
76.746
31.144
Parameter Value
1 Title 3
2 Origin Bruker BioSpin GmbH
3 Solvent CDCl3
4 Temperature 298.0
5 Number of Scans 64
6 Spectrometer Frequency 125.77
7 Nucleus 13C
F
N
O
O
Ph
f1 (ppm)

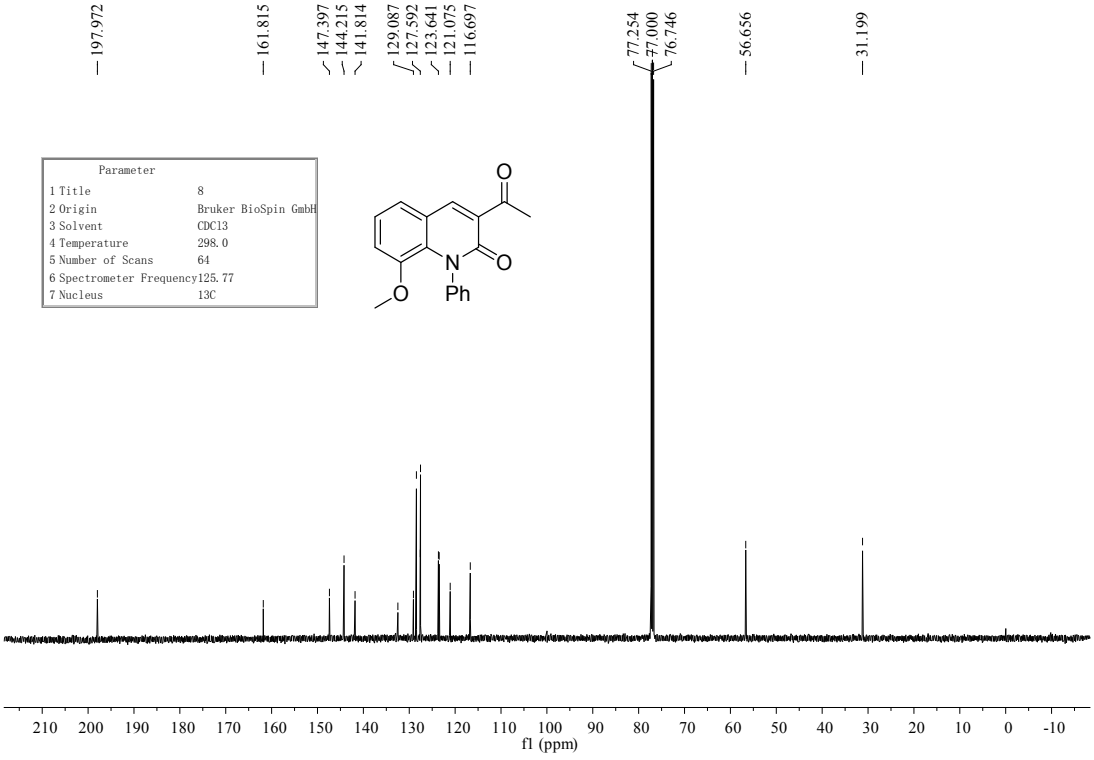

8.524
7.666
7.640
7.586
7.262
7.207
6.651
6.648
2.737
1.577
-0.000
Parameter Value
1 Title 4
2 Origin Bruker BioSpin GmbH
3 Solvent CDCl3
4 Temperature 298.0
5 Number of Scans 8
6 Spectrometer Frequency 500.13
7 Nucleus 1H
Cl
N
Ph
O
O
1.00
4.27
2.02
1.02
1.00
3.00
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

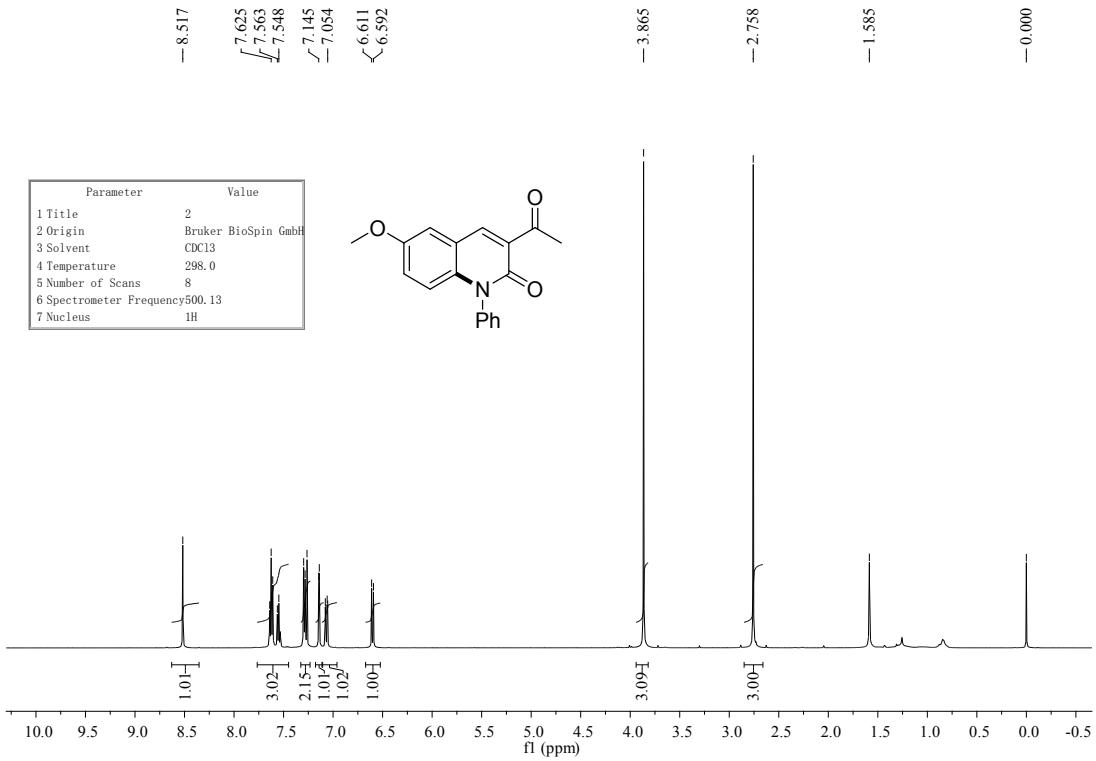

197.482
160.748
143.346
143.071
139.270
136.830
128.457
123.598
117.543
115.816
77.254
77.000
76.746
31.134
Parameter Value
1 Title 4
2 Origin Bruker BioSpin GmbH
3 Solvent CDCl3
4 Temperature 298.0
5 Number of Scans 64
6 Spectrometer Frequency 125.77
7 Nucleus 13C
Cl
N
Ph
O
O
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

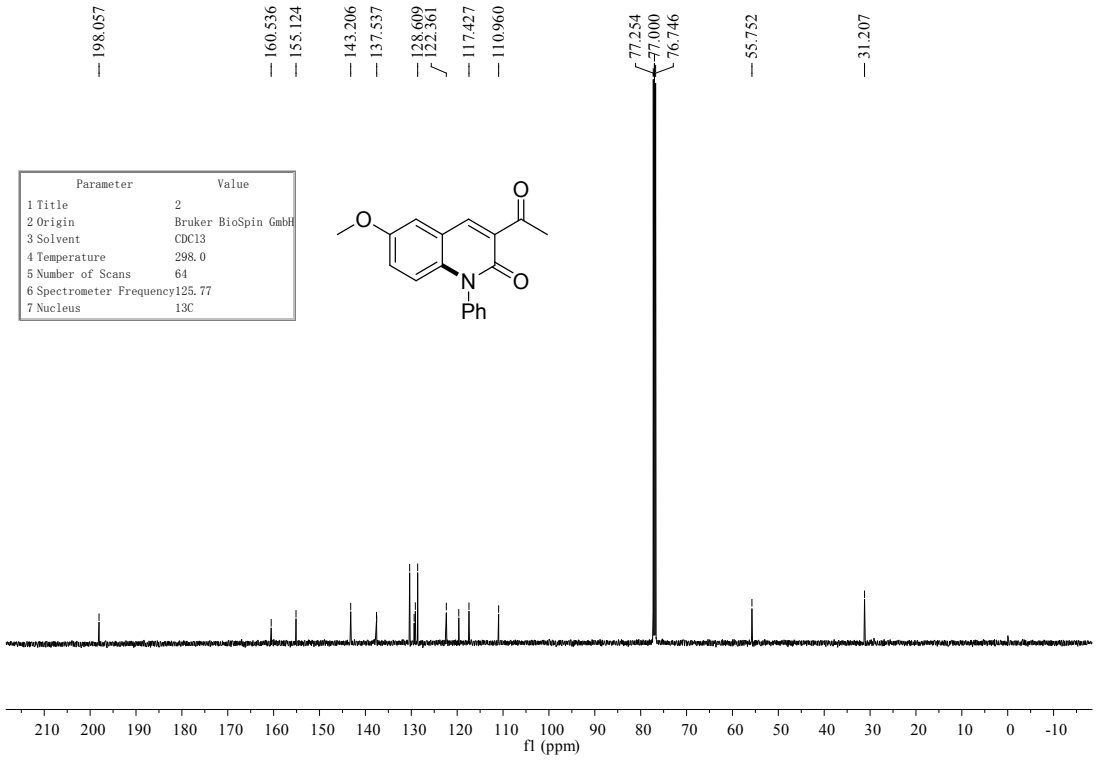

8.507
7.654
7.602
7.583
7.355
7.269
6.815
2.731
0.000
Parameter Value
1 Title 5
2 Origin Bruker BioSpin GmbH
3 Solvent CDCl3
4 Temperature 298.0
5 Number of Scans 8
6 Spectrometer Frequency 400.13
7 Nucleus 1H
O
Br
N
O
Ph
1.00
4.16
1.05
2.24
0.99
3.06
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

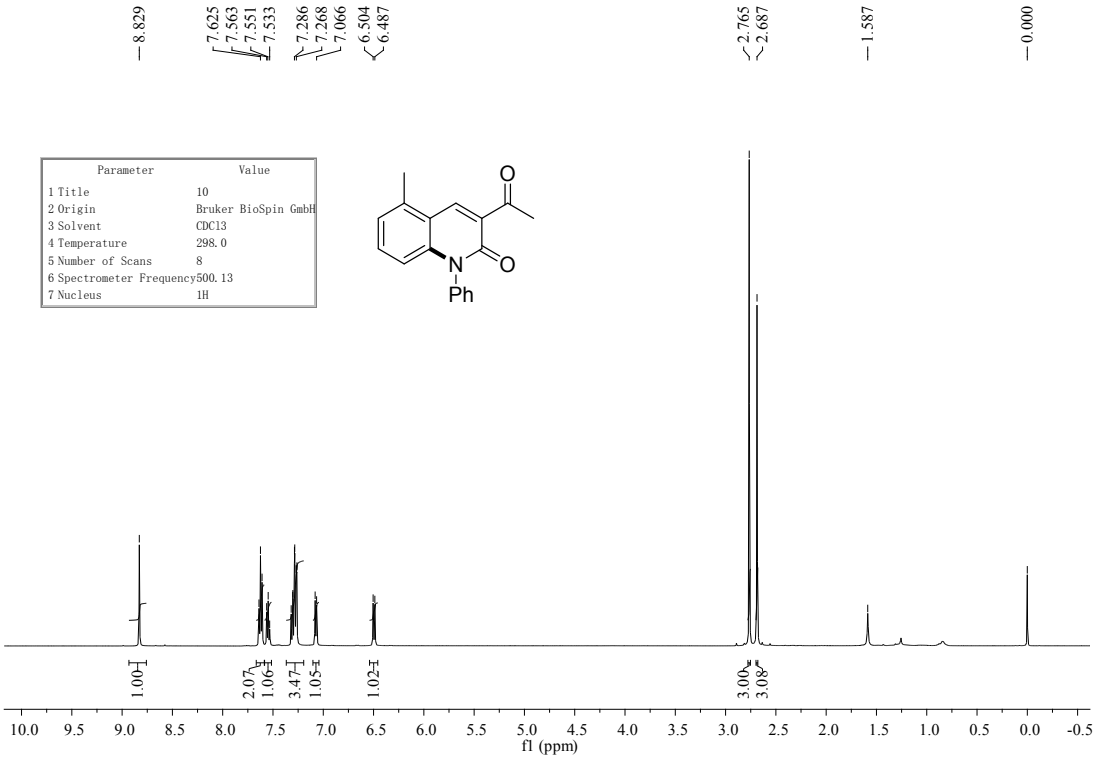

197.455
160.678
143.333
143.124
131.791
126.390
118.778
117.844
77.317
77.000
76.682
31.108
Parameter Value
1 Title 5
2 Origin Bruker BioSpin GmbH
3 Solvent CDCl3
4 Temperature 298.3
5 Number of Scans 122
6 Spectrometer Frequency 100.61
7 Nucleus 13C
O
Br
N
O
Ph
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

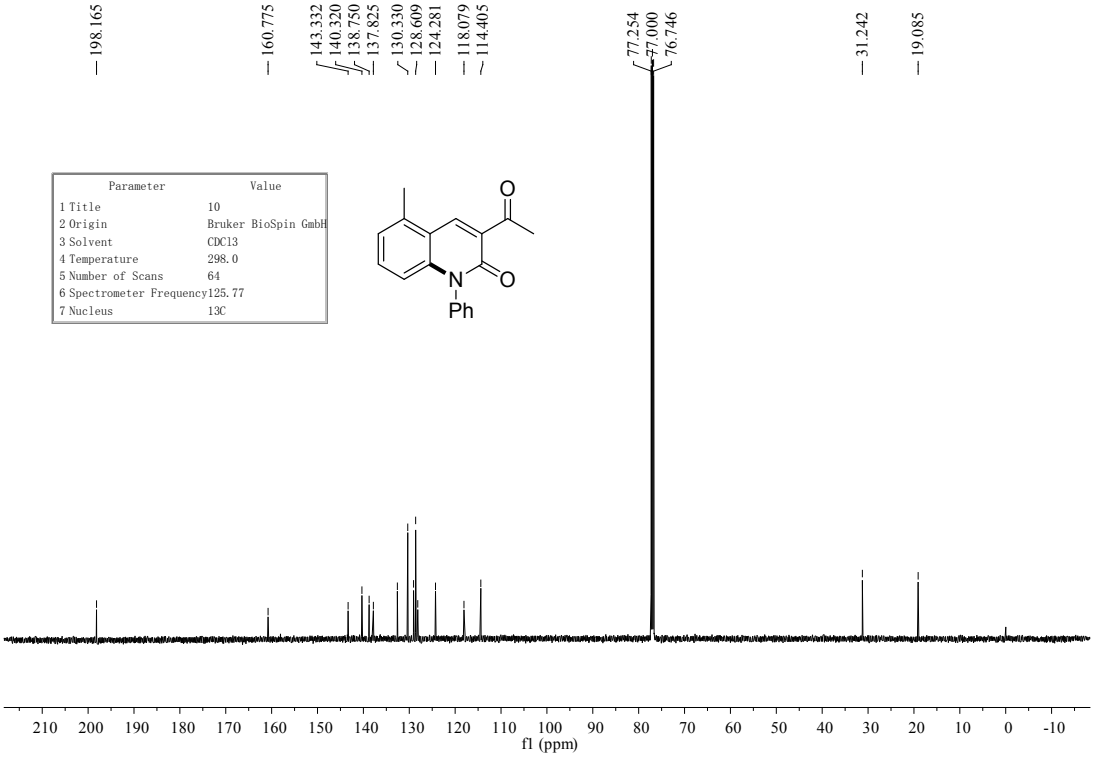

8.493
7.469
7.456
7.425
7.420
7.408
7.360
7.345
7.246
7.239
7.229
7.227
7.219
7.188
7.027
7.011
3.300
2.731
1.590
0.000
Parameter Value
1 Title 8
2 Origin Bruker BioSpin GmbH
3 Solvent CDCl3
4 Temperature 298.0
5 Number of Scans 8
6 Spectrometer Frequency 500.13
7 Nucleus 1H
O
N
Ph
O
O
1.01
4.07
3.10
1.01
3.09
3.00
f1 (ppm)

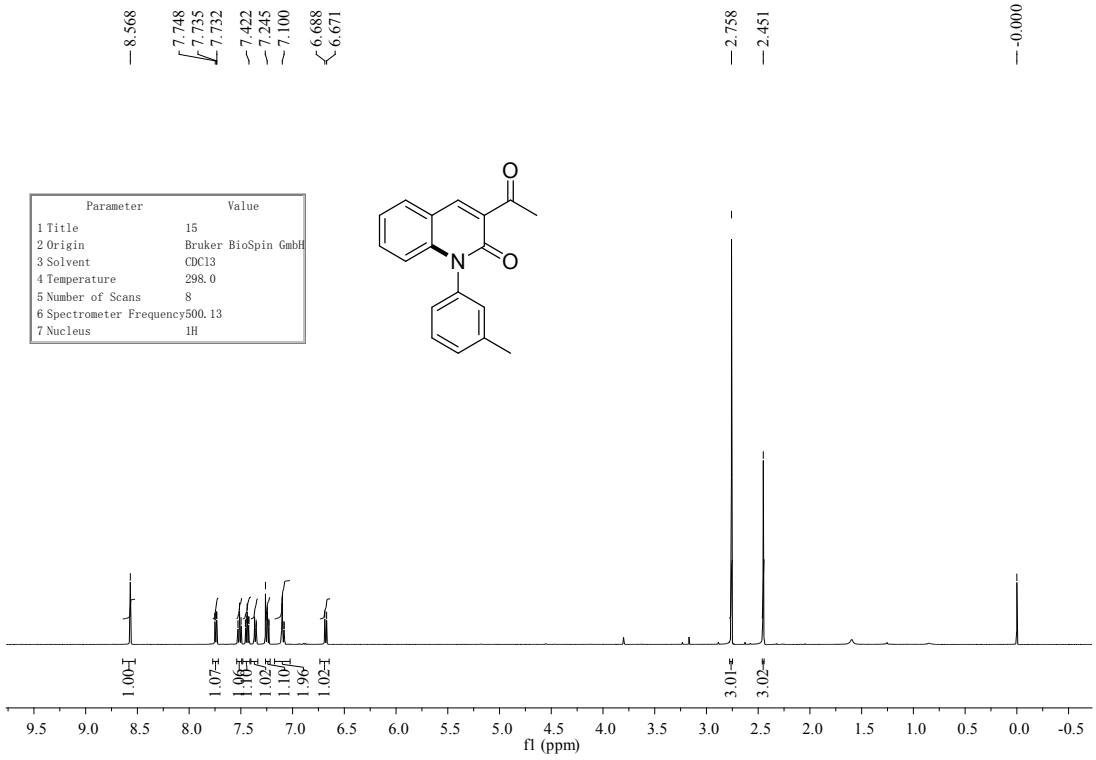

197.972
161.815
147.397
144.215
141.814
129.087
127.592
123.641
121.075
116.697
77.254
77.000
76.746
56.656
31.199
Parameter
1 Title 8
2 Origin Bruker BioSpin GmbH
3 Solvent CDCl3
4 Temperature 298.0
5 Number of Scans 64
6 Spectrometer Frequency 125.77
7 Nucleus 13C
O
N
Ph
O
O
f1 (ppm)

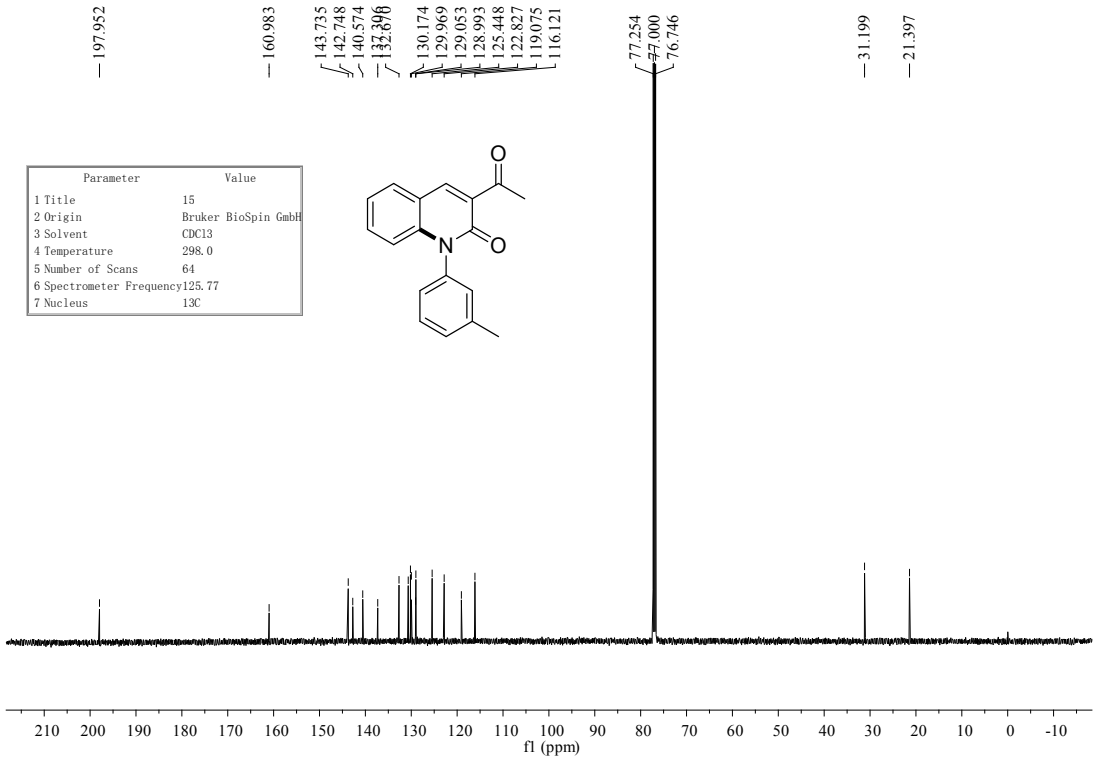

8.517
7.625
7.563
7.548
7.145
7.054
6.611
6.592
3.865
2.758
1.585
0.000
Parameter Value
1 Title 2
2 Origin Bruker BioSpin GmbH
3 Solvent CDCl3
4 Temperature 298.0
5 Number of Scans 8
6 Spectrometer Frequency 500.13
7 Nucleus 1H
O
O
N
Ph
O
1.01
3.02
2.15
1.01
1.02
1.00
3.09
3.00
f1 (ppm)

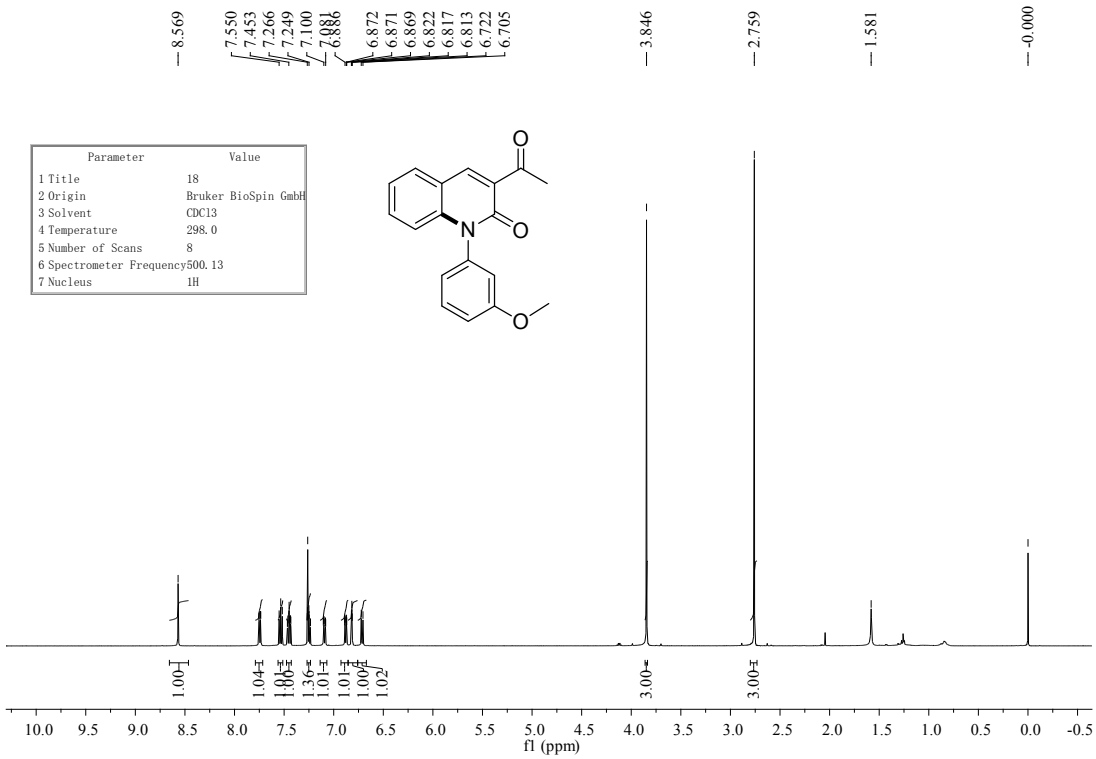

198.057
160.536
155.124
143.206
137.537
128.609
122.361
117.427
110.960
77.254
77.000
76.746
55.752
31.207
Parameter Value
1 Title 2
2 Origin Bruker BioSpin GmbH
3 Solvent CDCl3
4 Temperature 298.0
5 Number of Scans 64
6 Spectrometer Frequency 125.77
7 Nucleus 13C
O
O
N
Ph
f1 (ppm)

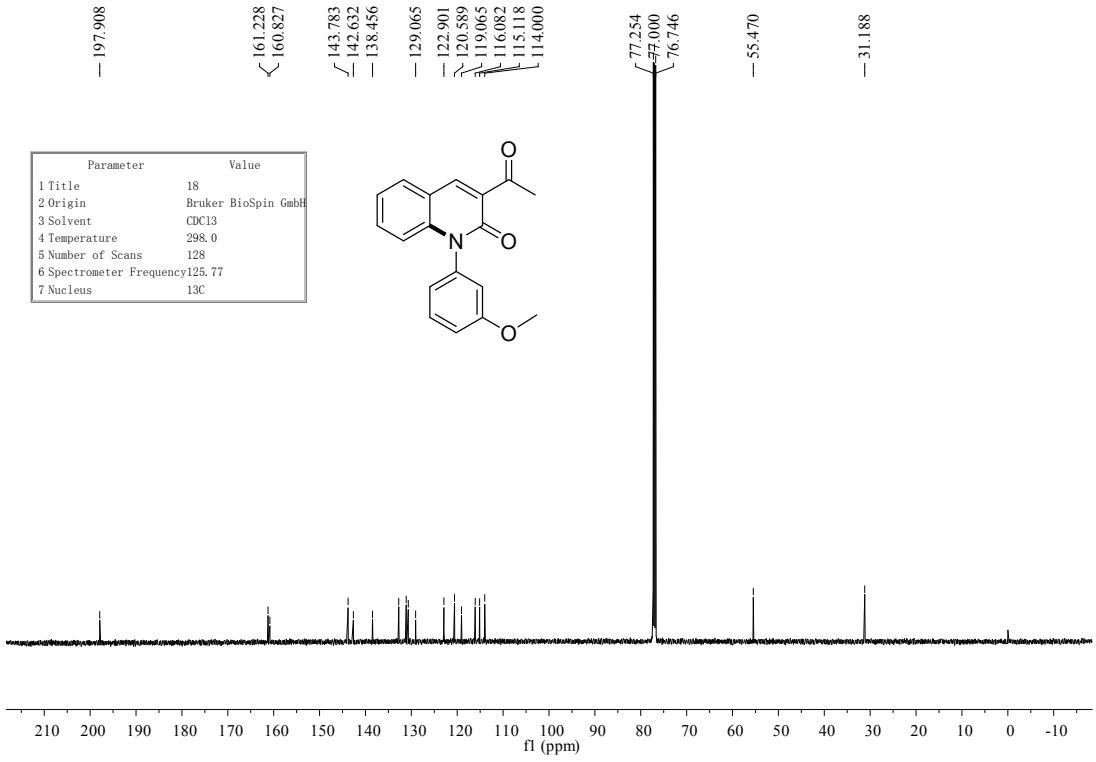

8.829
7.625
7.563
7.551
7.533
7.286
7.268
7.066
6.504
6.487
2.765
2.687
1.587
0.000
Parameter Value
1 Title 10
2 Origin Bruker BioSpin GmbH
3 Solvent CDCl3
4 Temperature 298.0
5 Number of Scans 8
6 Spectrometer Frequency 500.13
7 Nucleus 1H
O
N
Ph
O
1.00
2.07
1.06
3.47
1.05
1.02
3.00
3.08
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

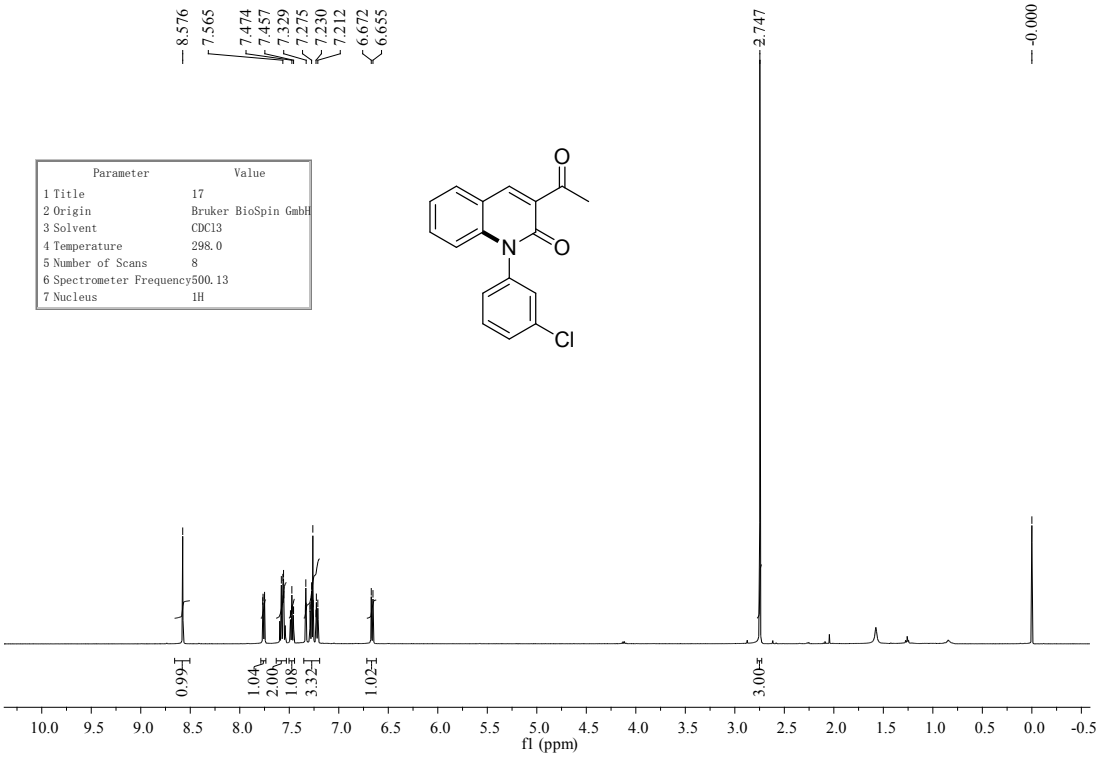

198.165
160.775
143.332
140.320
138.750
137.825
130.330
128.609
124.281
118.079
114.405
77.254
77.000
76.746
31.242
19.085
Parameter Value
1 Title 10
2 Origin Bruker BioSpin GmbH
3 Solvent CDCl3
4 Temperature 298.0
5 Number of Scans 64
6 Spectrometer Frequency 125.77
7 Nucleus 13C
O
N
Ph
O
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

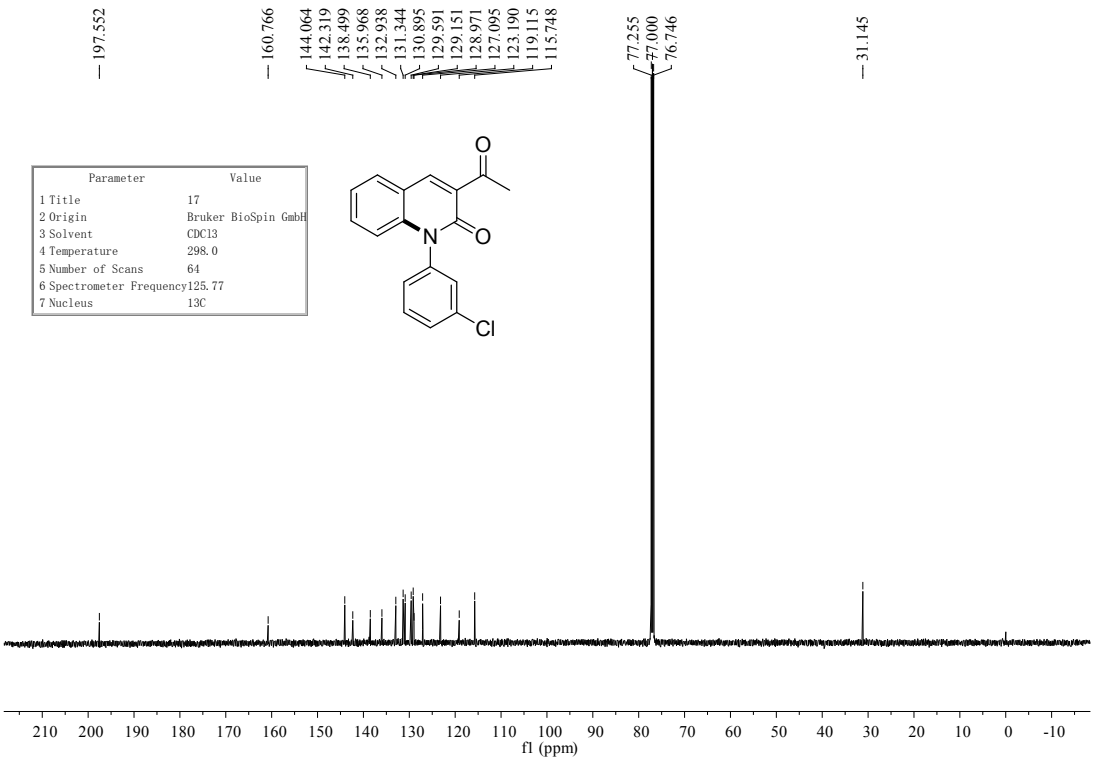

8.568
7.748
7.735
7.732
7.422
7.245
7.100
6.688
6.671
2.758
2.451
-0.000
Parameter Value
1 Title 15
2 Origin Bruker BioSpin GmbH
3 Solvent CDCl3
4 Temperature 298.0
5 Number of Scans 8
6 Spectrometer Frequency 500.13
7 Nucleus 1H
O
N
O
1.00
1.07
1.02
1.10
1.96
1.02
3.01
3.02
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

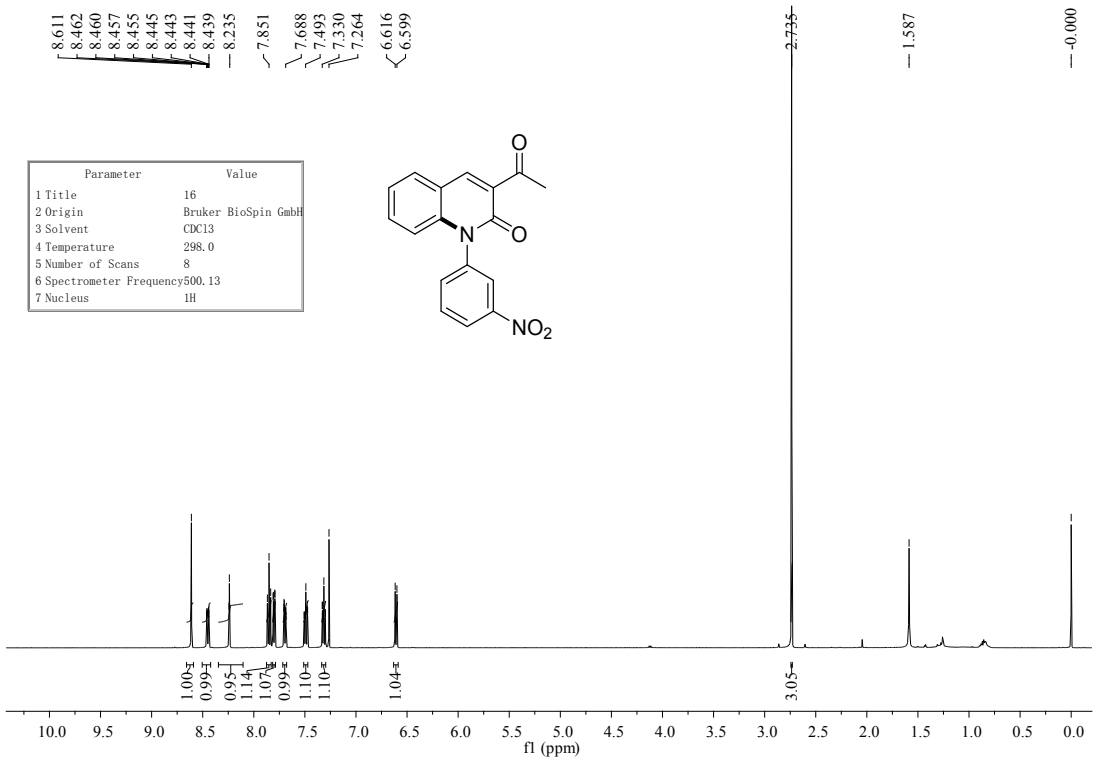

197.952
160.983
143.735
142.748
140.574
132.870
130.174
129.969
129.053
128.993
125.448
122.827
119.075
116.121
77.254
77.000
76.746
31.199
21.397
Parameter Value
1 Title 15
2 Origin Bruker BioSpin GmbH
3 Solvent CDCl3
4 Temperature 298.0
5 Number of Scans 64
6 Spectrometer Frequency 125.77
7 Nucleus 13C
O
N
O
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

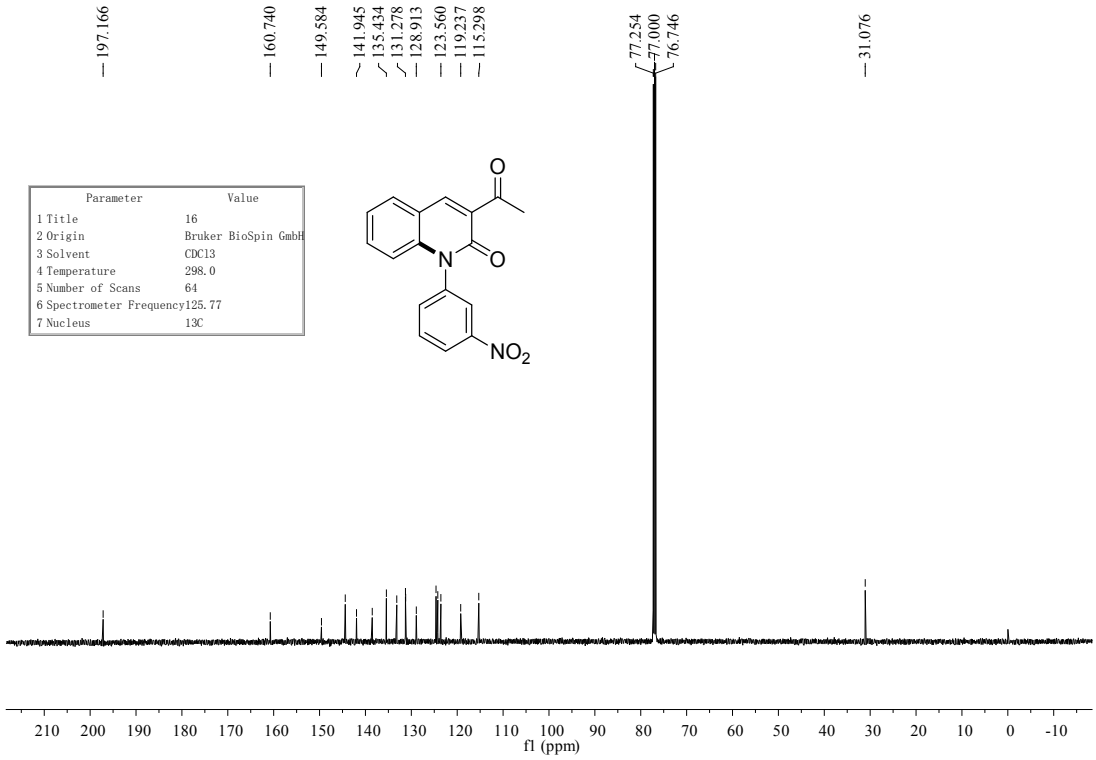

8.569
7.550
7.453
7.266
7.249
7.100
7.081
6.886
6.872
6.871
6.869
6.822
6.817
6.813
6.722
6.705
3.846
2.759
1.581
-0.000
Parameter Value
1 Title 18
2 Origin Bruker BioSpin GmbH
3 Solvent CDCl3
4 Temperature 298.0
5 Number of Scans 8
6 Spectrometer Frequency 500.13
7 Nucleus 1H
1.00
1.04
1.00
1.36
1.01
1.01
1.00
1.02
3.00
3.00
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

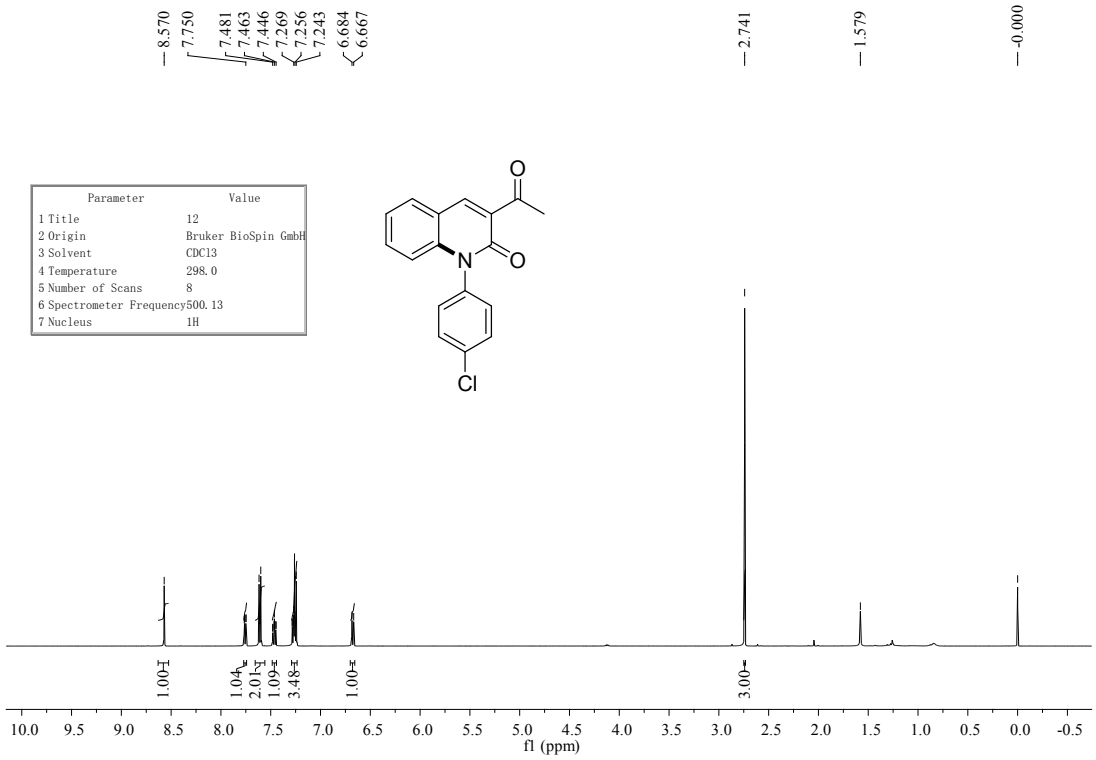

197.908
161.228
160.827
143.783
142.632
138.456
129.065
122.901
120.589
119.065
116.082
115.118
114.000
77.254
77.000
76.746
55.470
31.188
Parameter Value
1 Title 18
2 Origin Bruker BioSpin GmbH
3 Solvent CDCl3
4 Temperature 298.0
5 Number of Scans 128
6 Spectrometer Frequency 125.77
7 Nucleus 13C
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

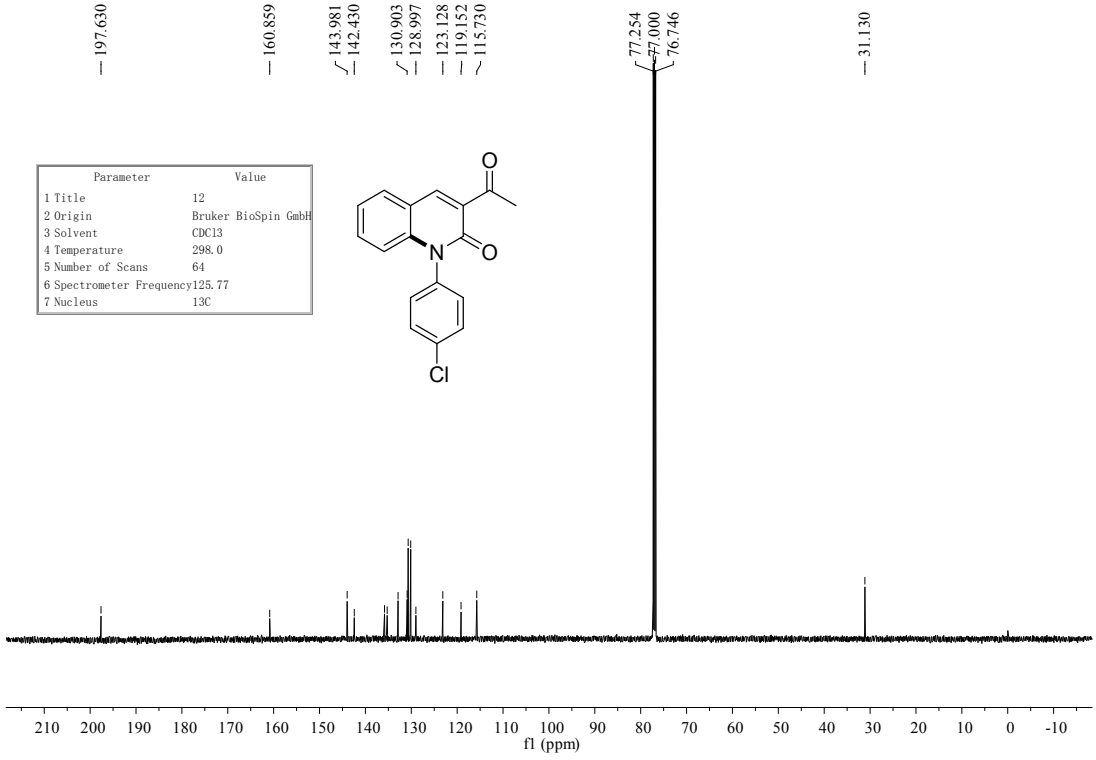

8.576
7.565
7.474
7.457
7.329
7.275
7.230
7.212
6.672
6.655
2.747
-0.000
Parameter Value
1 Title 17
2 Origin Bruker BioSpin GmbH
3 Solvent CDCl3
4 Temperature 298.0
5 Number of Scans 8
6 Spectrometer Frequency 500.13
7 Nucleus 1H
O
N
O
Cl
0.99
1.04
2.00
1.08
3.32
1.02
3.00
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

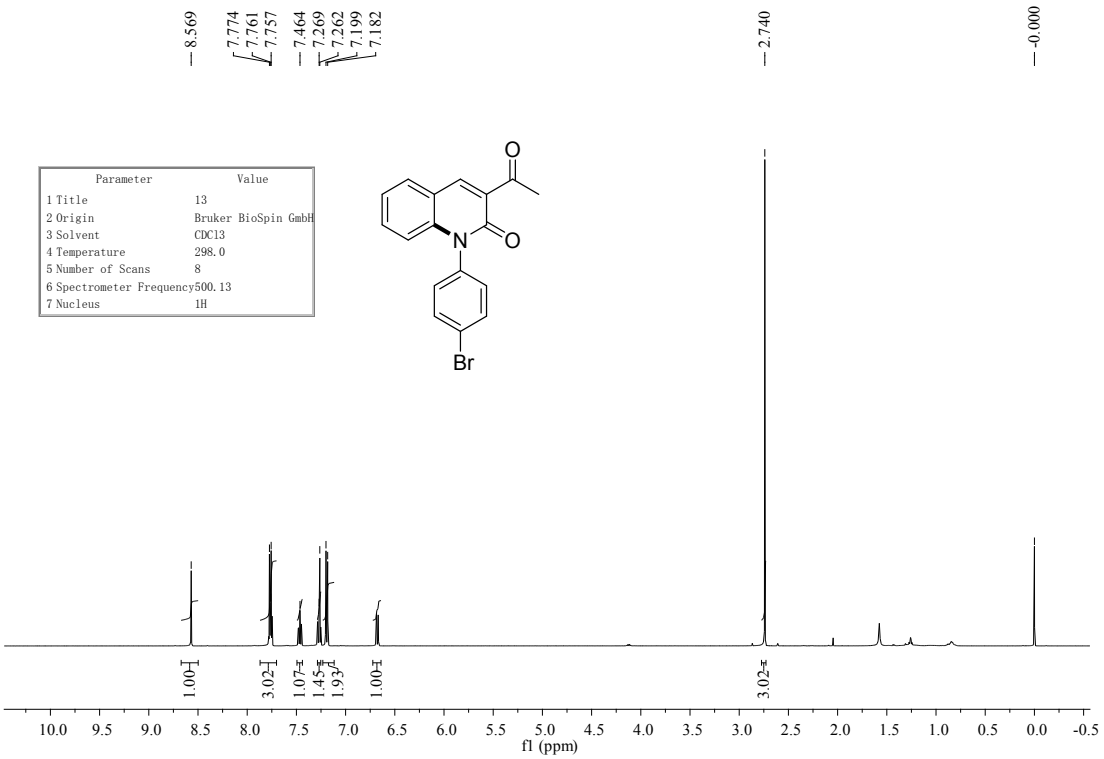

197.552
160.766
144.064
142.319
138.499
135.968
132.938
131.344
130.895
129.591
129.151
128.971
127.095
123.190
119.115
115.748
77.255
77.000
76.746
31.145
Parameter Value
1 Title 17
2 Origin Bruker BioSpin GmbH
3 Solvent CDCl3
4 Temperature 298.0
5 Number of Scans 64
6 Spectrometer Frequency 125.77
7 Nucleus 13C
O
N
O
Cl
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

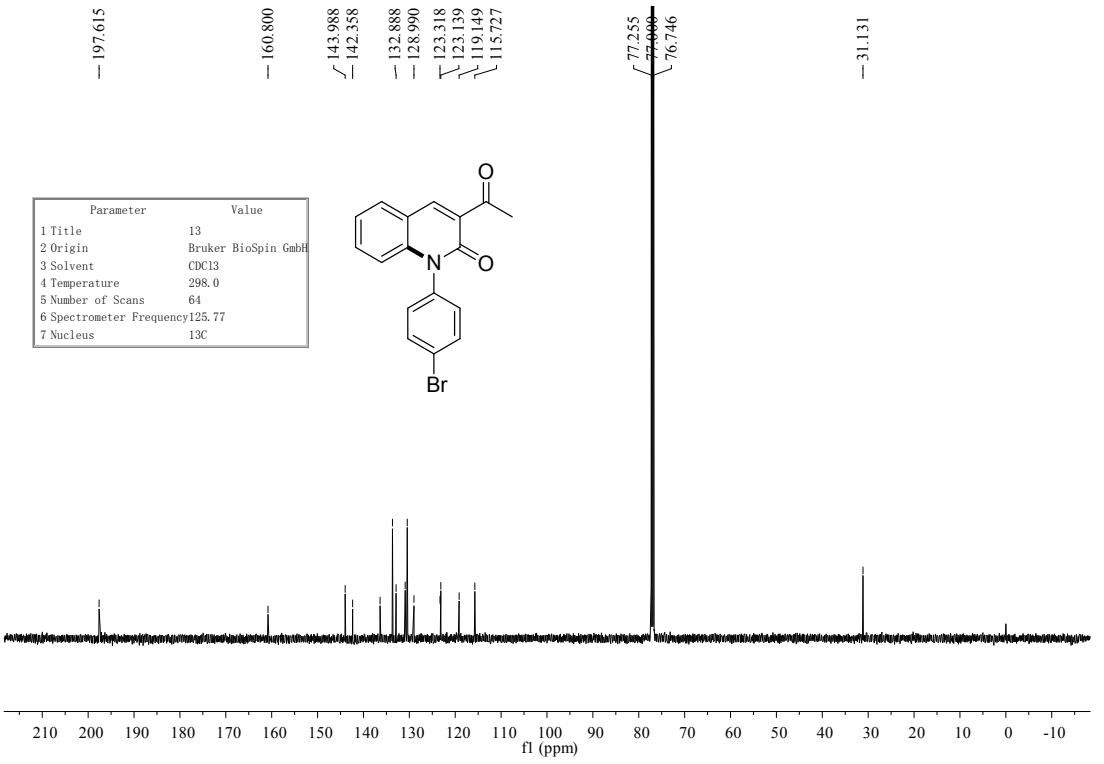

8.611
8.462
8.460
8.457
8.455
8.445
8.443
8.441
8.439
8.235
7.851
7.688
7.493
7.330
7.264
6.616
6.599
2.735
1.587
-0.000
Parameter Value
1 Title 16
2 Origin Bruker BioSpin GmbH
3 Solvent CDCl3
4 Temperature 298.0
5 Number of Scans 8
6 Spectrometer Frequency 500.13
7 Nucleus 1H
O
N
O
NO2
1.00
0.99
0.95
1.14
1.07
0.99
1.10
1.10
1.04
3.05
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

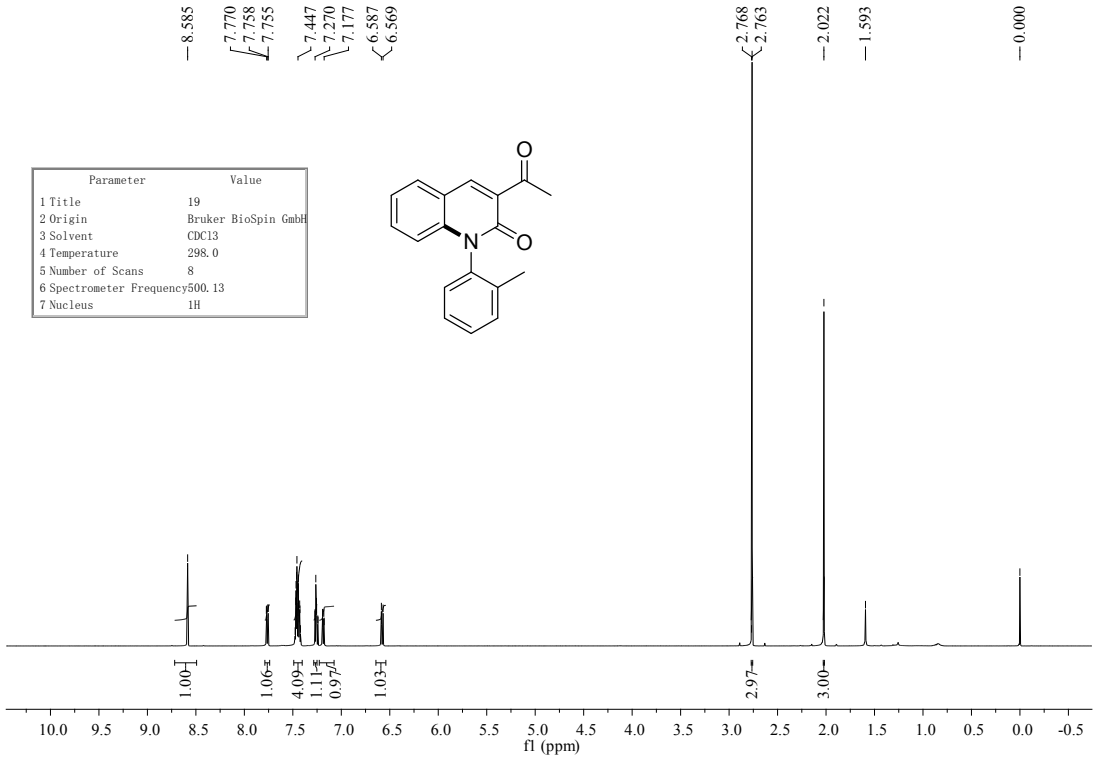

197.166
160.740
149.584
141.945
135.434
131.278
128.913
123.560
119.237
115.298
77.254
77.000
76.746
31.076
Parameter Value
1 Title 16
2 Origin Bruker BioSpin GmbH
3 Solvent CDCl3
4 Temperature 298.0
5 Number of Scans 64
6 Spectrometer Frequency 125.77
7 Nucleus 13C
O
N
O
NO2
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

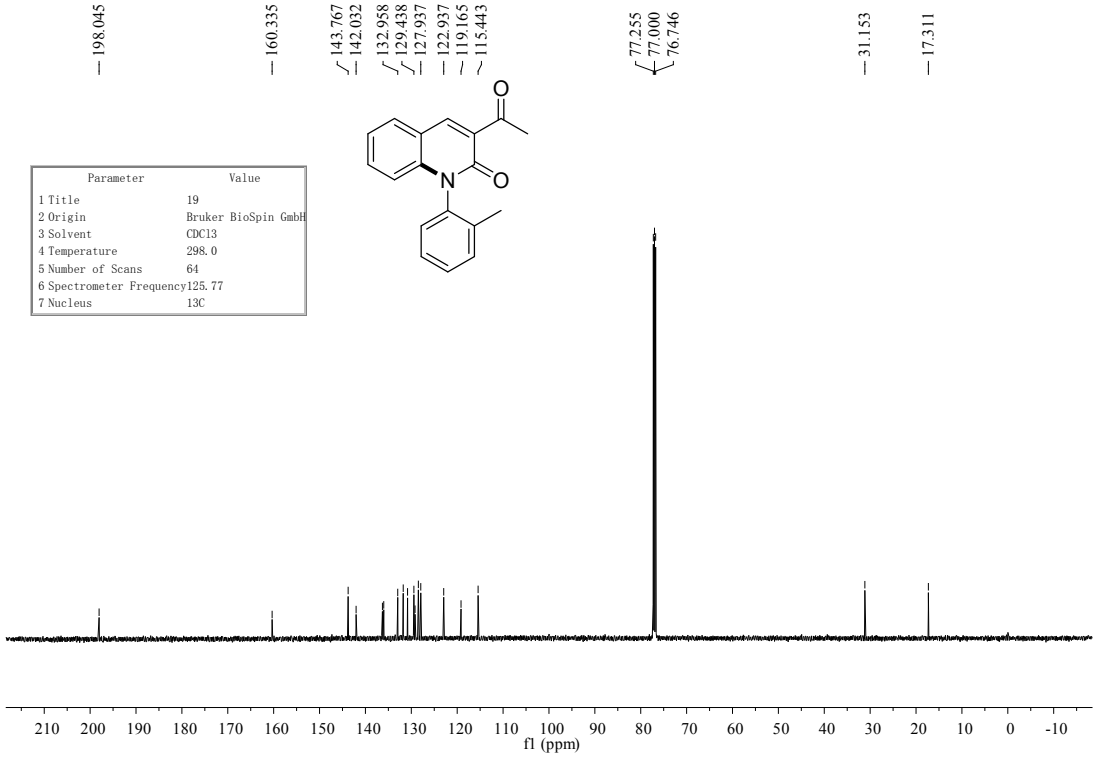

8.570
7.750
7.481
7.463
7.446
7.269
7.256
7.243
6.684
6.667
2.741
1.579
-0.000
Parameter Value
1 Title 12
2 Origin Bruker BioSpin GmbH
3 Solvent CDCl3
4 Temperature 298.0
5 Number of Scans 8
6 Spectrometer Frequency 500.13
7 Nucleus 1H
O
N
O
Cl
1.00
1.04
2.01
1.09
3.48
1.00
3.00
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

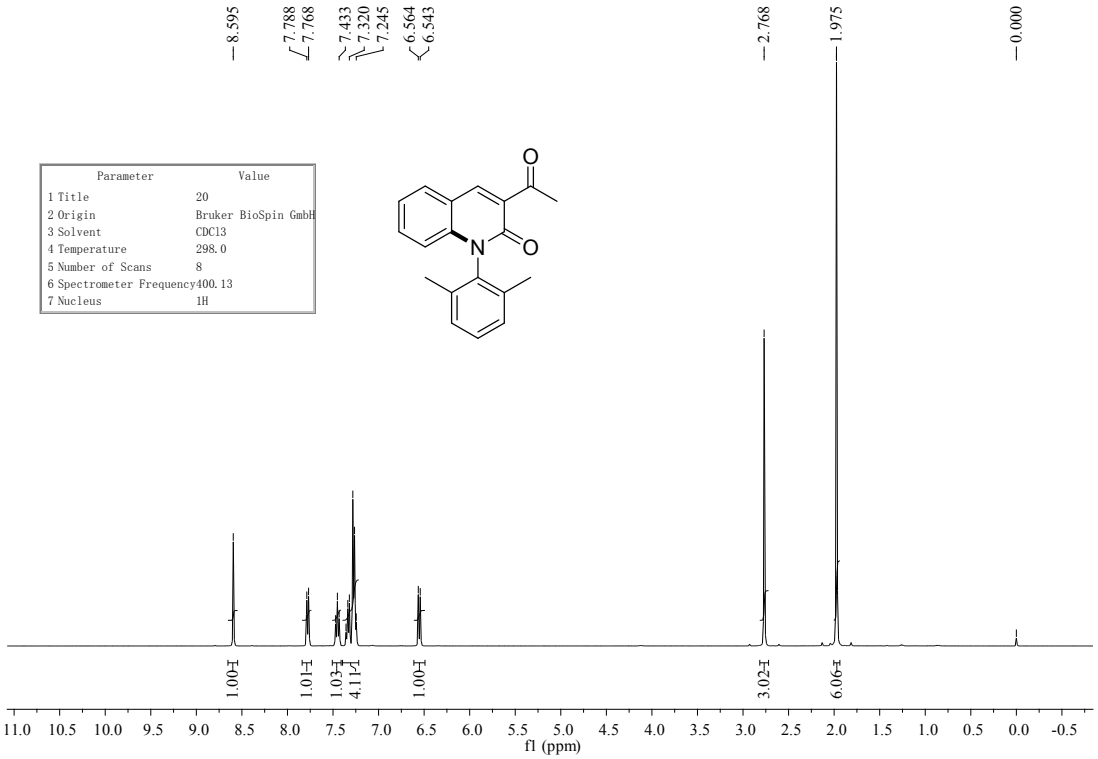

197.630
160.859
143.981
142.430
130.903
128.997
123.128
119.152
115.730
77.254
77.000
76.746
31.130
Parameter Value
1 Title 12
2 Origin Bruker BioSpin GmbH
3 Solvent CDCl3
4 Temperature 298.0
5 Number of Scans 64
6 Spectrometer Frequency 125.77
7 Nucleus 13C
O
N
O
Cl
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

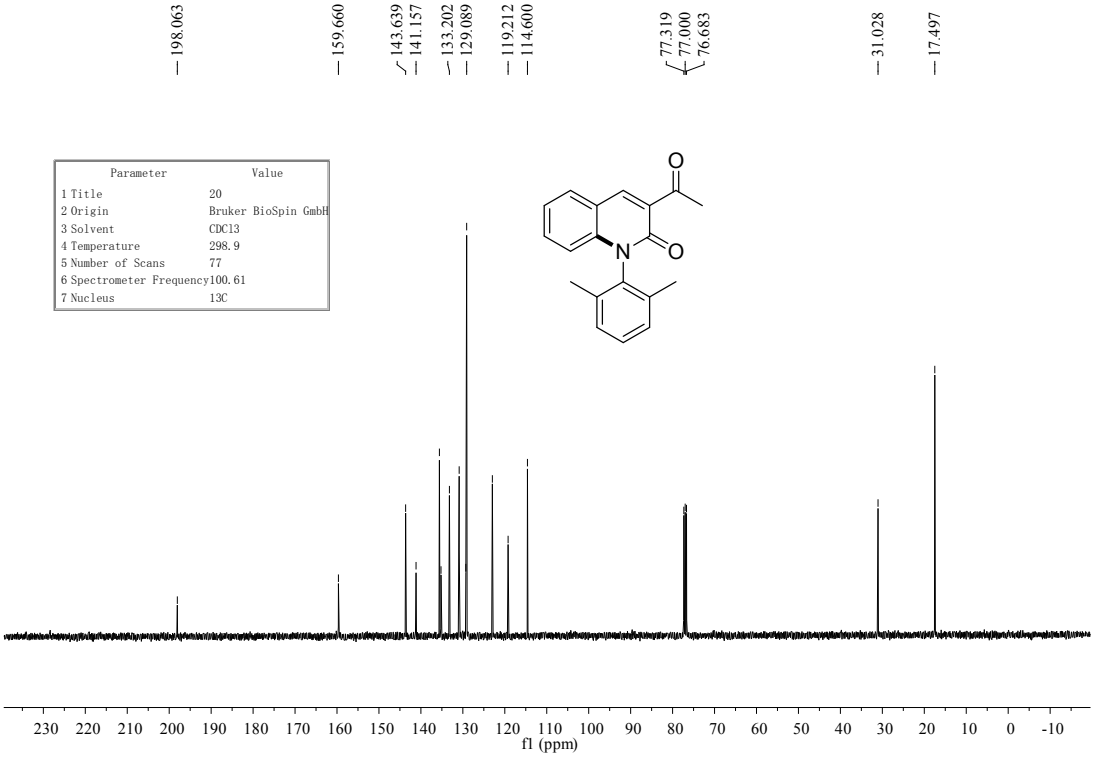

8.569
7.774
7.761
7.757
7.464
7.269
7.262
7.199
7.182
2.740
-0.000
Parameter Value
1 Title 13
2 Origin Bruker BioSpin GmbH
3 Solvent CDCl3
4 Temperature 298.0
5 Number of Scans 8
6 Spectrometer Frequency 500.13
7 Nucleus 1H
O
N
O
Br
1.00
3.02
1.07
1.45
1.93
1.00
3.02
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

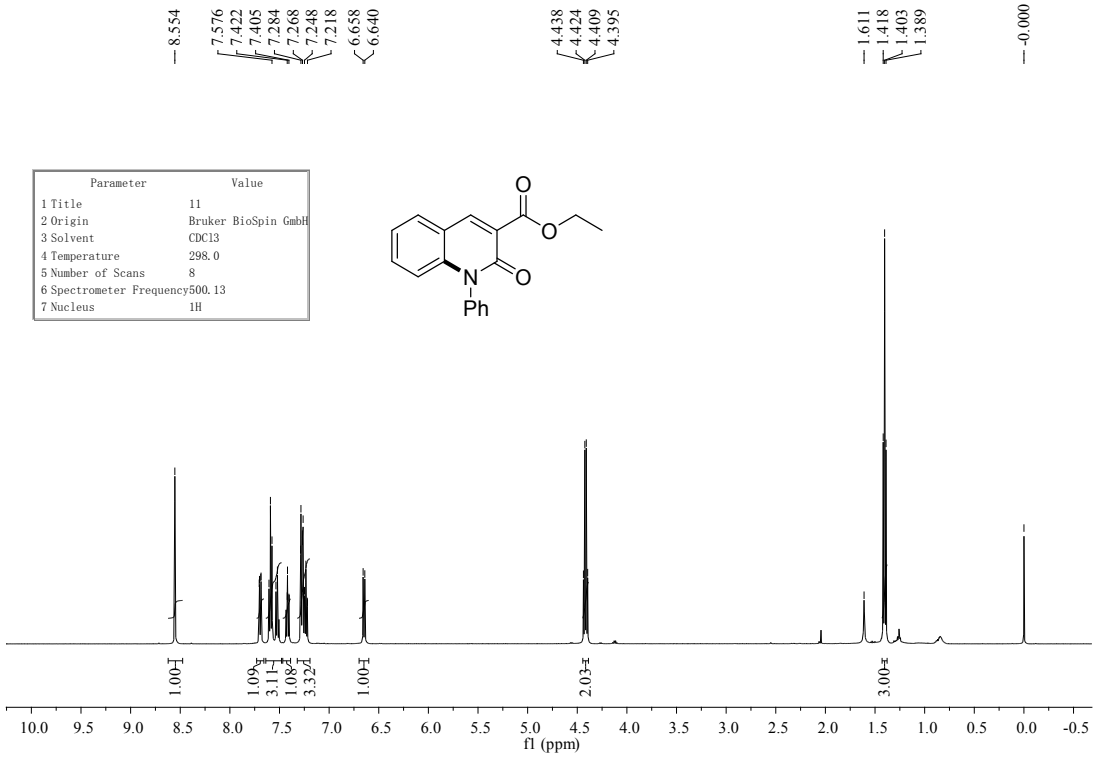

197.615
160.800
143.988
142.358
132.888
128.990
123.318
123.139
119.149
115.727
77.255
77.000
76.746
31.131
Parameter Value
1 Title 13
2 Origin Bruker BioSpin GmbH
3 Solvent CDCl3
4 Temperature 298.0
5 Number of Scans 64
6 Spectrometer Frequency 125.77
7 Nucleus 13C
O
N
O
Br
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

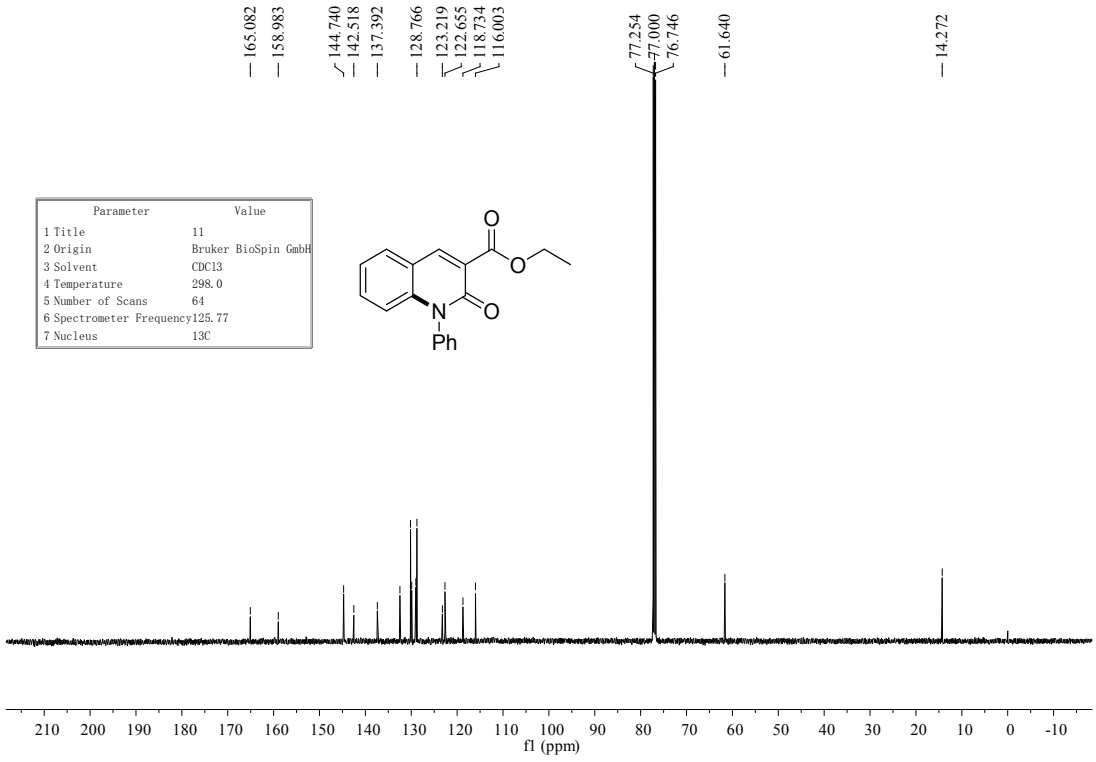

8.585
7.770
7.758
7.755
7.447
7.270
7.177
6.587
6.569
2.768
2.763
2.022
1.593
0.000
Parameter Value
1 Title 19
2 Origin Bruker BioSpin GmbH
3 Solvent CDCl3
4 Temperature 298.0
5 Number of Scans 8
6 Spectrometer Frequency 500.13
7 Nucleus 1H
O
N
O
1.00
1.06
4.09
1.11
0.97
1.03
2.97
3.00
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)


198.045
160.335
143.767
142.032
132.958
129.438
127.937
122.937
119.165
115.443
77.255
77.000
76.746
31.153
17.311
Parameter Value
1 Title 19
2 Origin Bruker BioSpin GmbH
3 Solvent CDCl3
4 Temperature 298.0
5 Number of Scans 64
6 Spectrometer Frequency 125.77
7 Nucleus 13C
O
N
O
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


8.595
7.788
7.768
7.433
7.320
7.245
6.564
6.543
2.768
1.975
0.000
Parameter Value
1 Title 20
2 Origin Bruker BioSpin GmbH
3 Solvent CDC13
4 Temperature 298.0
5 Number of Scans 8
6 Spectrometer Frequency 400.13
7 Nucleus 1H
O
N
O
1.00
1.01
1.03
4.11
1.00
3.02
6.06
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

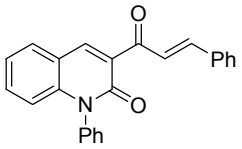

198.063
159.660
143.639
141.157
133.202
129.089
119.212
114.600
77.319
77.000
76.683
31.028
17.497
Parameter Value
1 Title 20
2 Origin Bruker BioSpin GmbH
3 Solvent CDC13
4 Temperature 298.9
5 Number of Scans 77
6 Spectrometer Frequency 100.61
7 Nucleus 13C
O
N
O
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


8.554
7.576
7.422
7.405
7.284
7.268
7.248
7.218
6.658
6.640
4.438
4.424
4.409
4.395
1.611
1.418
1.403
1.389
-0.000
Parameter Value
1 Title 11
2 Origin Bruker BioSpin GmbH
3 Solvent CDCl3
4 Temperature 298.0
5 Number of Scans 8
6 Spectrometer Frequency 500.13
7 Nucleus 1H
O
O
N
O
Ph
1.00
1.09
3.11
1.08
3.32
1.00
2.03
3.00
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

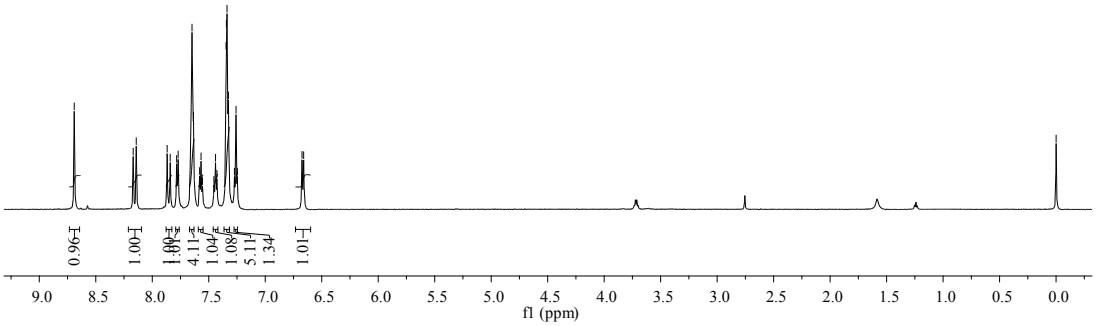

165.082
158.983
144.740
142.518
137.392
128.766
123.219
122.655
118.734
116.003
77.254
77.000
76.746
61.640
14.272
Parameter Value
1 Title 11
2 Origin Bruker BioSpin GmbH
3 Solvent CDCl3
4 Temperature 298.0
5 Number of Scans 64
6 Spectrometer Frequency 125.77
7 Nucleus 13C
O
O
N
O
Ph
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

8.691
8.169
8.142
7.868
7.581
7.454
7.347
7.326
7.247
6.675
6.660
-0.000

Parameter	Value
1 Title	luolaichun-5-20161012
2 Origin	Varian
3 Solvent	CDCl3
4 Temperature	29.0
5 Number of Scans	16
6 Spectrometer Frequency	583.89
7 Nucleus	1H

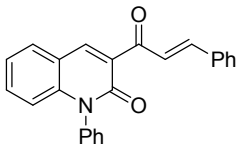


4

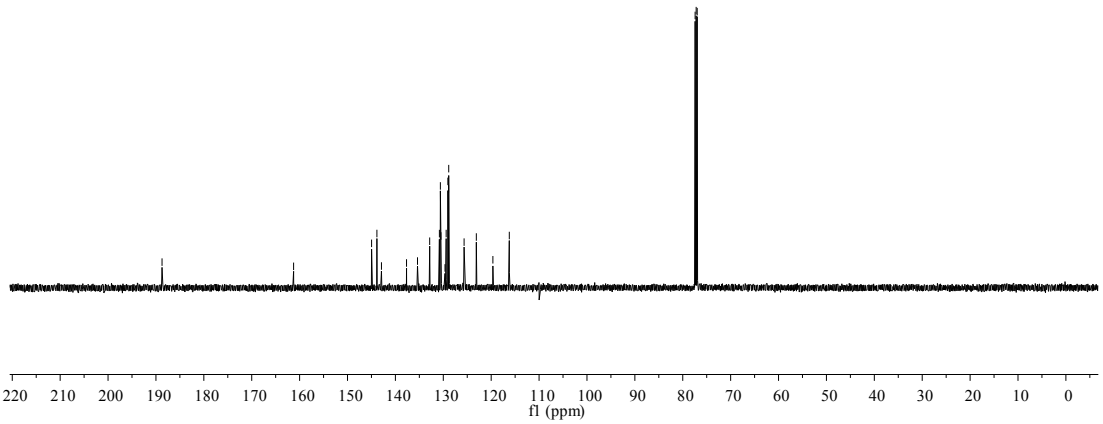


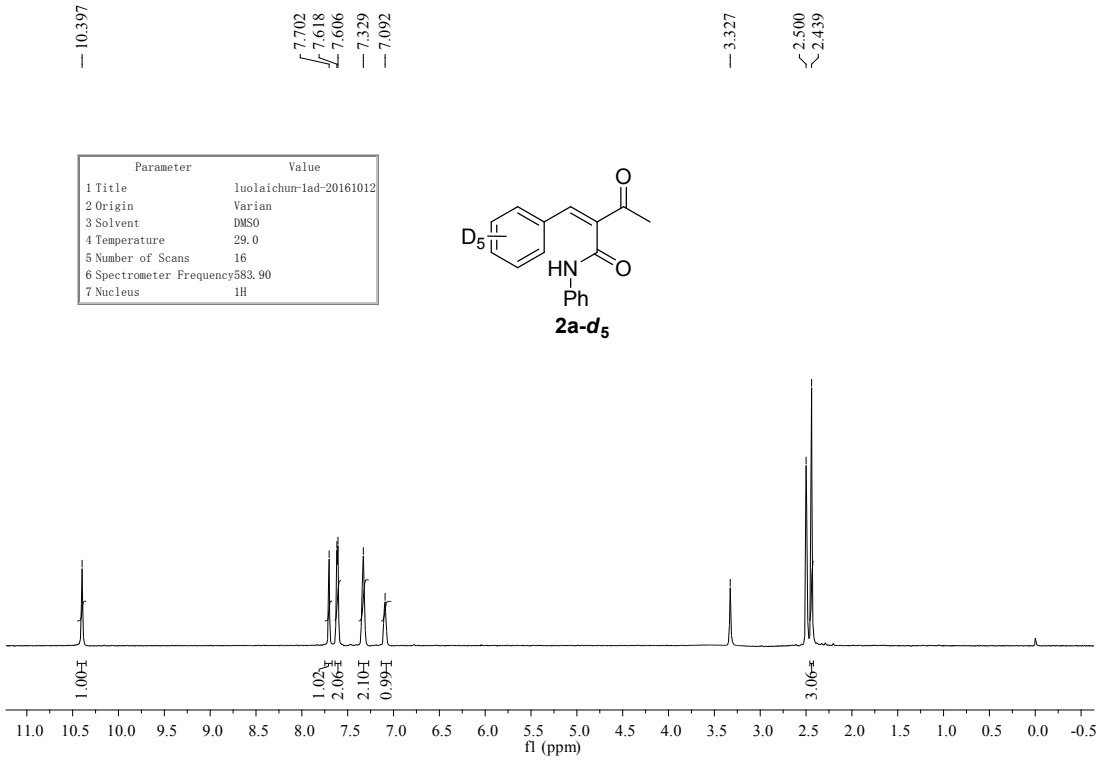
188.727
161.256
144.970
143.861
142.912
130.610
129.643
129.401
129.045
128.895
128.866
125.656
123.102
119.644
116.218
77.419
77.202
76.984

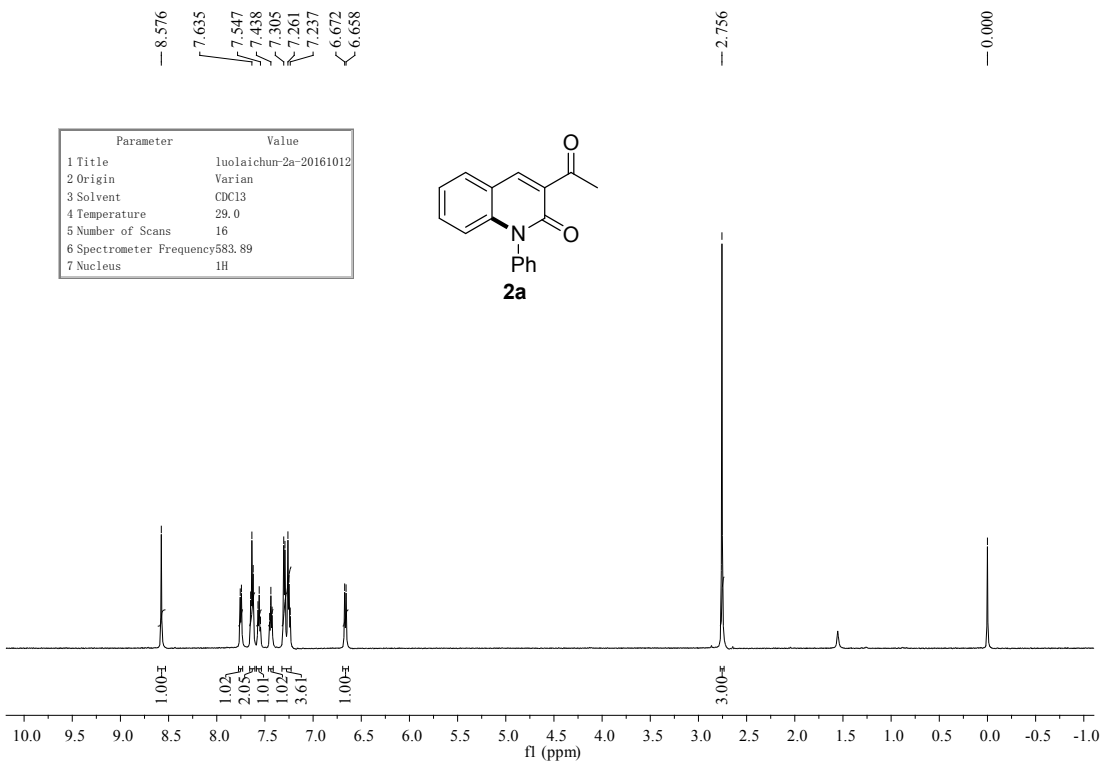
Parameter	Value
1 Title	luolaichun-5-C13-20161012
2 Origin	Varian
3 Solvent	CDCl3
4 Temperature	22.0
5 Number of Scans	624
6 Spectrometer Frequency	146.84
7 Nucleus	13C

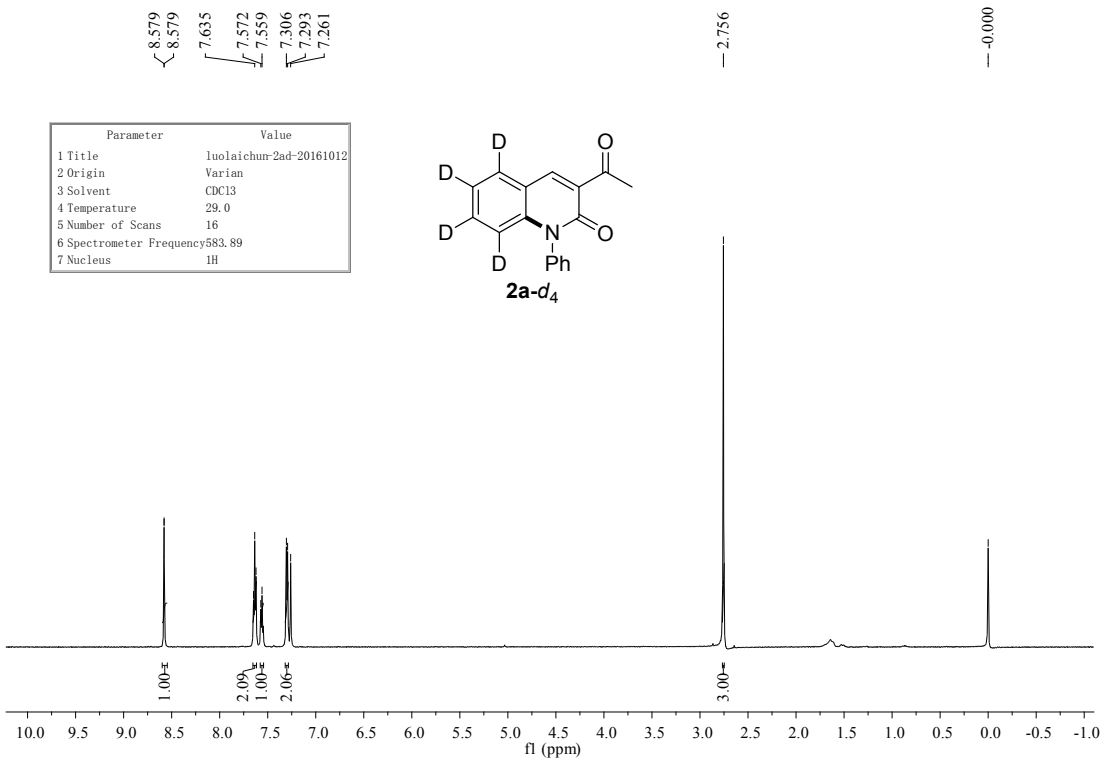


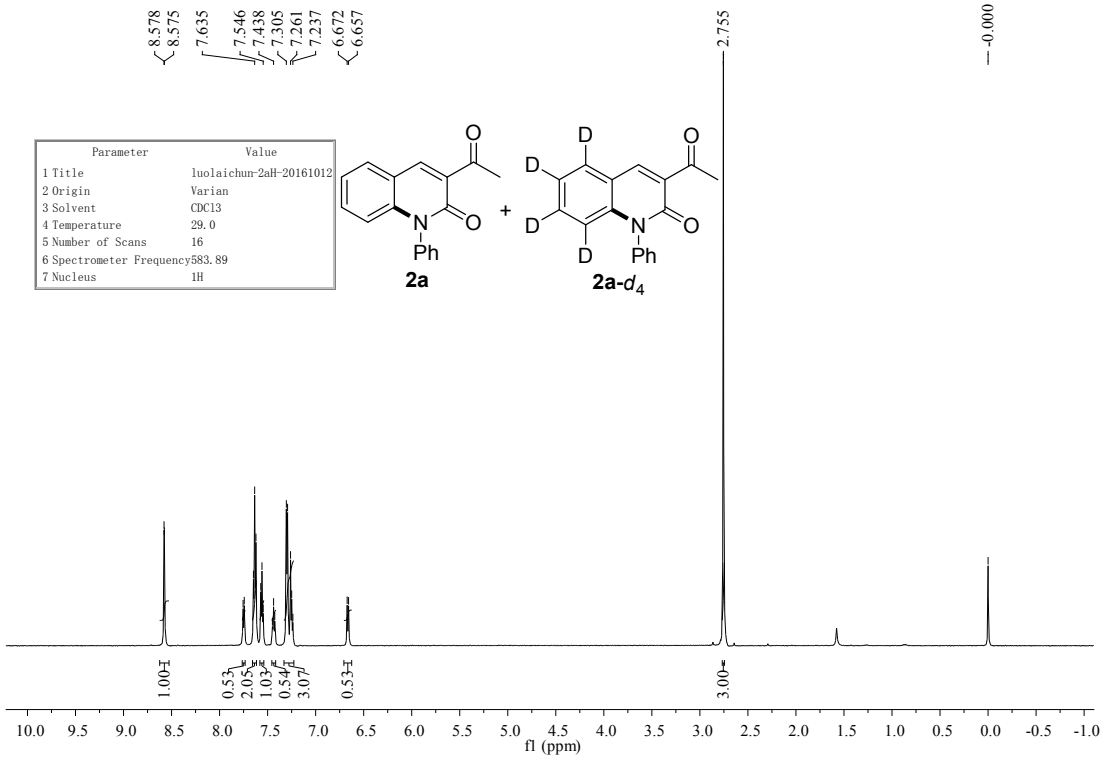
4




10.397
7.702
7.618
7.606
7.329
7.092
3.327
2.500
2.439
Parameter Value
1 Title luolaichun-1ad-20161012
2 Origin Varian
3 Solvent DMSO
4 Temperature 29.0
5 Number of Scans 16
6 Spectrometer Frequency 583.90
7 Nucleus 1H
D5
HN
O
O
Ph
2a-d5
1.00
1.02
2.06
2.10
0.99
3.06
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)


8.576
7.635
7.547
7.438
7.305
7.261
7.237
6.672
6.658
2.756
0.000
Parameter Value
1 Title luolaichun-2a-20161012
2 Origin Varian
3 Solvent CDCl3
4 Temperature 29.0
5 Number of Scans 16
6 Spectrometer Frequency 583.89
7 Nucleus 1H
O
N
O
Ph
2a
1.00
1.02
2.05
1.01
1.02
3.61
1.00
3.00
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
f1 (ppm)


8.579
8.579
7.635
7.572
7.559
7.306
7.293
7.261
2.756
-0.000
Parameter Value
1 Title luolaichun-2ad-20161012
2 Origin Varian
3 Solvent CDCl3
4 Temperature 29.0
5 Number of Scans 16
6 Spectrometer Frequency 583.89
7 Nucleus 1H
D
O
D
N
O
D
Ph
2a-d4
1.00
2.09
1.00
2.06
3.00
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
f1 (ppm)


8.578
8.575
7.635
7.546
7.438
7.305
7.261
7.237
6.672
6.657
2.755
-0.000
Parameter Value
1 Title luolaichun-2aH-20161012
2 Origin Varian
3 Solvent CDCl3
4 Temperature 29.0
5 Number of Scans 16
6 Spectrometer Frequency 583.89
7 Nucleus 1H
O
N
O
Ph
2a
+
D
O
D
N
O
D
Ph
2a-d4
1.00
0.53
2.05
1.03
0.54
3.07
0.53
3.00
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
f1 (ppm)

7. References

1. T. Kato and Y. Yamamoto, *Chem. Pharm. Bull.* **1965**, *13*, 959.
2. A. Meyer and P. Pastour, *Compt. rend.* **1949**, *228*, 576.
3. S. Perrone, A. Salomone, A. Caroli, A. Falcicchio, C. Citti, G. Cannazza and L. Troisi, *Eur. J. Org. Chem.*, 2014, 5932.
4. X. Liu, Q. Zhang, X. Xin, R. Zhang, N. Zhang, Y. Liang and D. Dong, *RSC Adv.*, 2014, **4**, 36234.
5. X. Liu, Q. Zhang, D. Zhang, X. Xin, R. Zhang, F. Zhou and D. Dong, *Org. Lett.*, 2013, **15**, 776.
6. P. Kim, M. M. Olmstead, M. H. Nantz and M. J. Kurth, *Tetrahedron Lett.*, 2000, **41**, 4029.
7. S. V. Ryabukhin, A. S. Plaskon, D. M. Volochnyuk, S. E. Pipko, A. N. Shivanyuk and A. A. Tolmachev, *J. Comb. Chem.* **2007**, *9*, 1073