# *Supporting Information*

# Copper-catalyzed amine-alkylation of quinones with amines and alkanes

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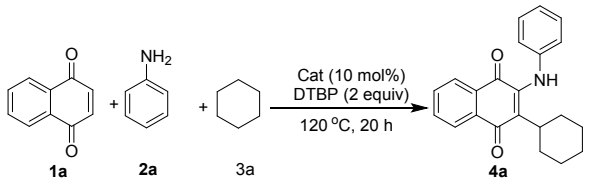
## Content

## General Information:

All manipulations were carried out under air atmosphere. Commercially available reagents were used as received without purification. Analytical thin–layer chromatography was performed on glass plates of Silica Gel GF-254 with detection by UV. Column chromatography was carried out on silica gel (200-300 mesh). 1H NMR and 13C NMR spectra were recorded at 400 MHz (or 300M) and 101 MHz respectively on an Agilent or a Brüker spectrometer. $CDCl_3$ and DMSO-d6 were used as solvent. Chemical shifts were referenced relative to residual solvent. Coupling constants (J) were reported in Hertz (Hz). HRMS were performed on a Thermo Scientific LTQ Orbitrap XL instrument. Melting points were measured with micro melting point apparatus.

## 1. Optimization of reaction conditions

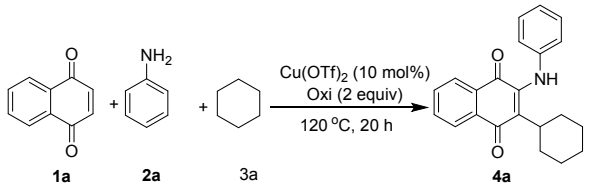
**Table S1** Optimization of catalyst [a,b]




| Entry | [Cat] (10 mol%) | Yield % |
|---|---|---|
| 1 | $FeCl_3$ | 29 |
| 2 | $Fe(acac)_3$ | 21 |
| 3 | $FeSO_4.4H_2O$ | ND [c] |
| 4 | $Fe(OTf)_3$ | 16 |
| 5 | $FeBr_3$ | 10 |
| 6 | $Fe(OTs)_3$ | 21 |
| 7 | $Cu(OTf)_2$ | 46 |
| 8 | CuI | 11 |
| 9 | $CuBr_2$ | 26 |
| 10 | $CuSO_4.5H_2O$ | 24 |
| 11 | $Cu(acac)_2$ | Trace |
| 12 | $B(C_6F_5)_3$ | 8 |
| 13 | $B(C_6F_5)_3/PPh_3$ (5/5) | Trace |
| 14 | KI | Trace |
| 15 | $CoCl_2$ | 6 |
| 16 | $AgNO_3$ | 33 |
| 17 | $Ni(OTf)_3$ | 12 |
| 18 | $La(OTf)^3$ | 16 |
| 19 | AgOTf | 9 |
| 20 | $Zn(OTf)_2$ | 10 |
| 21 | $Sm(OTf)_3$ | 8 |
| 22 | NaOTf | 14 |
| 23 | $Bi(OTf)_3$ | ND [c] |

[a] Reaction conditions: 1,4- naphthoquinone (0.30 mmol), aniline (1.2 equiv.), catalysts (10 mol%), DTBP (2 equiv), cyclohexane (2 mL) as solvent, 120 °C, sealed tubefor 20 h. [b] Isolated yields. [c] ND means not detected.

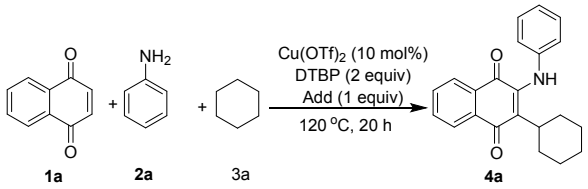
**Table S2** Optimization of oxidants [a, b]




| Entry | oxidants(2 equiv) | Yield % |
|---|---|---|
| 1 | DTBP | 46 |
| 2 | $H_2O_2$ (30%) | Trace |
| 3 | TBHP | ND [c] |
| 4 | DCP | 38 |
| 5 | TBPB | Trace |
| 6 | BPO | Trace |
| 7 | Oxone | ND [c] |
| 8 | $K_2S_2O_8$ | ND [c] |

[a] Reaction conditions: 1,4- naphthoquinone (0.30 mmol), aniline (1.2 equiv.), $Cu(OTf)_2$ (10 mol%), oxidants (2 equiv), cyclohexane (2 mL) as solvent, 120 °C, sealed tube for 20 h. [b] Isolated yields. [c] ND means not detected.

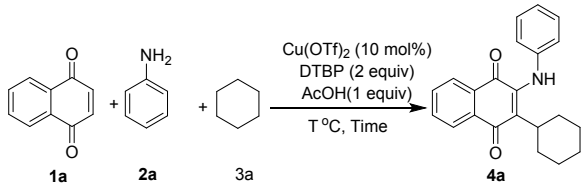
**Table S3** Optimization of additions [a, b]




| Entry | Addition (1equiv) | yield (%) [a] |
|---|---|---|
| 1 | $K_2CO_3$ | Trace |
| 2 | t-BuOK | Trace |
| 3 | $Et_3N$ | 15 |
| 4 | AcOH | 52 |
| 5 | TFA | 35 |
| 6 | TsOH. $H_2O$ | 48 |

[a] Reaction conditions: 1,4- naphthoquinone (0.30 mmol), aniline (1.2 equiv.), $Cu(OTf)_2$ (10 mol%), DTBP (2 equiv), addition (1 equiv.), cyclohexane (2 mL) as solvent, 120 °C, sealed tube for 20 h. [b] Isolated yields.

**Table S4** Optimization of time and temperature [a, b]

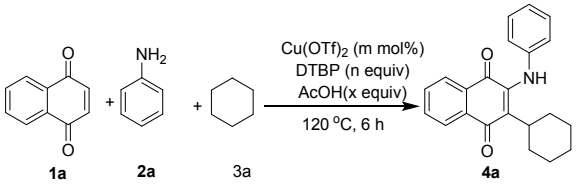



| Entry | Time(h) | Temp(°C) | Yield % |
|---|---|---|---|
| 1 | 4 | 120 | 44 |
| 2 | 6 | 120 | 76 |
| 3 | 8 | 120 | 64 |

| | | | |
|---|---|---|---|
| 4 | 20 | 120 | 52 |
| 5 | 6 | 80 | Trace |
| 6 | 6 | 100 | 44 |
| 7 | 6 | 110 | 43 |
| 8 | 6 | 130 | 68 |

[a] Reaction conditions: 1,4-naphthoquinone (0.30 mmol), aniline (1.2 equiv.), $Cu(OTf)_2$ (10 mol%), oxidanta (2 equiv), AcOH (1 equiv.), cyclohexane (2 mL) as solvent, temp °C, sealed tube for time . [b] Isolated yields.

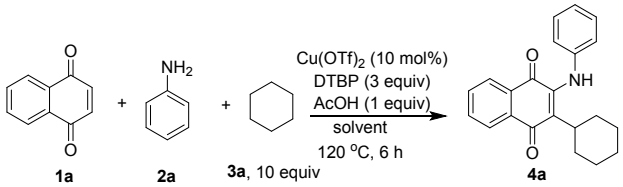
**Table S5** Optimization of dosages [a, b]




| Entry | Catalyst(m mol%) | Oxidant (n equiv) | AcOH (x equiv) | yield (%) |
|---|---|---|---|---|
| 1 | 3 | 2 | 1 | 41 |
| 2 | 5 | 2 | 1 | 45 |
| 3 | 15 | 2 | 1 | 66 |
| 4 | 20 | 2 | 1 | 60 |
| 5 | 10 | 1 | 1 | Trace |
| 6 | 10 | 3 | 1 | 83 |
| 7 | 10 | 4 | 1 | 81 |
| 8 | 10 | 3 | 0.2 | 64 |
| 9 | 10 | 3 | 0.5 | 68 |
| 10 | 10 | 3 | 2 | 82 |

[a] Reaction conditions: 1,4- naphthoquinone (0.30 mmol), aniline (1.2 equiv.), $Cu(OTf)_2$ (m mol%), oxidanta (n equiv), AcOH (x equiv.), cyclohexane (2 mL) as solvent, 120 °C, sealed tube for 6 h. [b] Isolated yields.

**Table S6** Optimization of solvents [a, b]




| Entry | Solvent (2 mL) | Yield % |
|---|---|---|
| 1 | DCE | Trace |
| 2 | MeCN | ND [c] |
| 3 | DMSO | 39 |
| 4 | $PhCF_3$ | 46 |

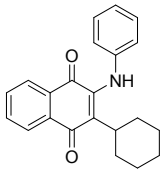
[a] Reaction conditions: 1,4- naphthoquinone (0.30 mmol), aniline (1.2 equiv.), cyclohexane (10 equiv), $Cu(OTf)_2$ (10 mol%), oxidanta (3 equiv), AcOH (1 equiv.), solvent (2 mL), 120 °C, sealed tube for 6 h. [b] Isolated yields. [c] ND means not detected.

## 2. General procedure for amine-alkylation of quinones and gram-scale reaction.

Procedure for amine-alkylation of quinones: Amines **2** (0.36 mmol) and AcOH (0.3 mmol) were added to a sealed tube containing 1,4-naphthoquinones **1** (0.3 mmol), $Cu(OTf)_2$ (10 mol%) and alkanes (2 mL). Then, the mixture was stirred at 120 °C for 6 h. After the completion of the reaction, the reaction mixture was quenched with saturated $Na_2SO_3$ (2 ml) and saturated brine (2 ml). The mixture was extracted with EA (5 × 5 mL). The combined organic layer was dried over anhydrous $Mg_2SO_4$ and concentrated under reduced pressure. The crude products were purified on a silica gel column using PE/EA to give compound **4a-4z**, **5a-5h** and **7**.

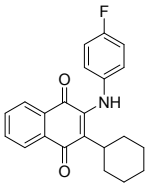
**Procedure for gram-scale reaction:** Aniline **2a** (12 mmol) and AcOH (10 mmol) were added to a 150 mL sealed tube containing 1,4-naphthoquinone 1a (10 mmol, 1.58g), $Cu(OTf)_2$ (10 mol%) and cyclohexane 3a (66 mL). Then, the mixture was stirred at 120 °C for 6 h. After the completion of the reaction, the reaction mixture was quenched with saturated $Na_2SO_3$ (30 mL) and saturated brine (30 mL). The mixture was extracted with EA (5× 30 mL). The combined organic layer was dried over anhydrous $Mg_2SO_4$ and concentrated under reduced pressure. **4a** was purified by column chromatography (PE/EA=20/1) and the product was collected to yield a red solid (2.55 g, 77 % yield).

### 2-cyclohexyl-3-(phenylamino)naphthalene-1,4-dione(4a)



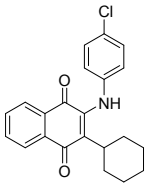
Yield: 82.5mg, 83%; red solid, m.p.144-145 °C; Rf (PE: EA=10:1)= 0.53 $^1$H NMR ($CDCl_3$, 400MHz): δ8.06-8.03(m, 2H), 7.72-7.68(m, 1H), 7.63-7.59(m, 1H), 7.34-7.30(m, 2H), 7.26(s, 1H), 7.16-7.12(m, 1H), 7.10-7.08(m, 2H), 2.21(tt, *J*=12 Hz, *J*=4 Hz, 1H), 2.07-2.1.97(m, 2H), 1.62-1.57(m, 2H), 1.49-1.46(m, 3H), 1.25-1.14(m, 1H), 0.74-0.62(m, 2H). $^{13}$C NMR ($CDCl_3$, 100MHz): δ 184.44, 183.29, 142.86, 141.75, 134.38, 133.83, 132.12, 130.02, 129.09, 127.02, 126.16, 125.87, 124.70, 122.57, 39.54, 29.51, 26.94, 25.81. HRMS (ESI) m/z: $C_{22}H_{22}NO_2^+$ ([MH]$^+$) calculated for: 332.1645, found: 332.1648.

### 2-cyclohexyl-3-((4-fluorophenyl)amino)naphthalene-1,4-dione(4b)



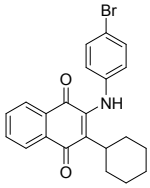
Yield: 59.7mg, 61%; orange solid, m.p.154-155 °C; Rf (PE: EA=10:1) = 0.44. $^1$H NMR ($CDCl_3$, 400MHz): δ. 8.05-8.01(m, 2H), 7.72-7.68(m, 1H), 7.62-7.58(m, 1H), 7.17(s, 1H), 7.10-7.00(m, 4H), 2.21-2.14(m, 1H), 2.07-1.96(m, 2H), 1.62-1.57(m, 2H), 1.51-1.40(m, 3H), 1.25-1.14(m, 1H). 0.75-0.63(m, 2H). $^{13}$C NMR ($CDCl_3$, 100MHz): δ 184.43, 183.15, 159.97 (d, *J* = 244.9 Hz), 143.14, 137.87 (d, *J* = 2.9 Hz), 134.45, 133.75, 132.17, 129.92, 126.59, 126.17, 125.89, 124.66 (d, *J* = 8.2 Hz), 115.89 (d, *J* = 22.8 Hz), 39.43, 29.51, 26.98, 25.77. $^{19}$F NMR ($CDCl_3$, 375MHz): δ -117.12. HRMS (ESI) m/z: $C_{22}H_{21}FNO_2^+$ ([MH]$^+$) calculated for: 350.1551, found: 350.1535.

### 2-((4-chlorophenyl)amino)-3-cyclohexylnaphthalene-1,4-dione(4c)



Yield: 57.1mg, 52%; red solid, m.p.156-166; Rf (PE: EA=10:1) = 0.44. $^1$H NMR ($CDCl_3$, 400MHz): δ 8.06-8.01(m, 2H), 7.72-7.68(m, 1H), 7.63-7.60(m, 1H), 7.29-7.27(m, 2H), 7.15(s, 1H), 7.02-7.00(m, 2H), 2.23-2.16(m, 1H), 2.09-1.99(m, 2H), 1.66-1.61(m, 2H), 1.53-1.46(m, 3H), 1.27-1.16(m, 1H), 0.81-0.70(m, 2H). $^{13}$C NMR ($CDCl_3$, 100MHz): δ 184.40, 183.08, 142.47, 140.52, 134.48, 133.68, 132.30, 129.95, 129.57, 129.11, 128.09, 126.24, 125.92, 123.27, 39.86, 29.52, 26.96, 25.77. HRMS (ESI) m/z: $C_{22}H_{21}ClNO_2^+$ ([MH]$^+$) calculated for: 366.1255, found: 366.1236.

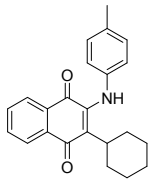
### 2-((4-bromophenyl)amino)-3-cyclohexylnaphthalene-1,4-dione(4d)



Yield: 70.1mg, 57%; red solid, m.p.143-145 °C; Rf (PE: EA=10:1) = 0.44. $^1$H NMR ($CDCl_3$, 400MHz): δ 8.08-8.03(m, 2H), 7.74-7.70(m, 1H), 7.65-7.61(m, 1H), 7.45-7.42(m, 2H), 7.14(s, 1H), 6.97-9.95(m, 2H), 2.22(tt, *J*=12 Hz, *J*=4 Hz, 1H), 2.11-2.01(m, 2H), 1.68-1.63(m, 2H), 1.55-1.48(m, 3H), 1.30-1.18(m, 1H), 0.84-0.74(m, 2H). $^{13}$C NMR ($CDCl_3$, 100MHz): δ 184.40, 183.07, 142.35, 141.05, 134.48, 133.68, 132.33, 132.06, 129.97, 128.42, 126.26, 125.94, 123.47, 117.04, 39.94, 29.53, 26.96, 25.77. HRMS (ESI) m/z: $C_{22}H_{21}BrNO_2^+$ ([MH]$^+$) calculated for: 410.0748, found:

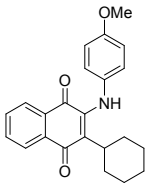
410.0746.

**2-cyclohexyl-3-(p-tolylamino)naphthalene-1,4-dione(4e)**



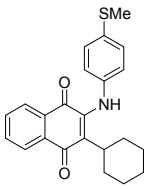
Yield: 81.8mg, 79%; red solid, m.p.157-158 °C; Rf (PE: EA=10:1) = 0.50. $^1$H NMR ($CDCl_3$, 400MHz): δ. 8.05-8.00(m, 2H), 7.71-7.66(m, 1H), 7.61-7.56(m, 1H), 7.23(s, 1H), 7.12-7.10(m, 2H), 6.99-6.97(m, 2H), 2.33(s, 3H), 2.25-2.18(m, 1H), 2.07-1.96(m, 2H), 1.60-1.56(m, 2H), 1.48-1.43(m, 3H), 1.25-1.13(m, 1H). 0.74-0.62(m, 2H) $^{13}$C NMR ($CDCl_3$, 100MHz): δ 184.38, 183.32, 143.16, 139.06, 134.64, 134.34, 133.89, 132.00, 130.00, 129.60, 126.09, 126.05, 125.82, 122.86, 39.22, 29.55, 25.84, 20.93. HRMS (ESI) m/z: $C_{23}H_{24}NO_2^+$ ([MH]$^+$) calculated for: 346.1802, found: 346.1787.

**2-cyclohexyl-3-((4-methoxyphenyl)amino)naphthalene-1,4-dione(4f)**



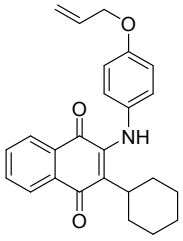
Yield: 82.4mg, 76%; brown solid, m.p.156-157 °C; Rf (PE: EA=10:1) = 0.38. $^1$H NMR ($CDCl_3$, 400MHz): δ. 8.05-8.01(m, 2H), 7.71-7.66(m, 1H), 7.61-7.57(m, 1H), 7.22(s, 1H), 7.07-7.04(m, 2H), 6.87-6.85(m, 2H), 3.81(s, 3H), 2.25-2.18(m, 1H), 2.06-1.95(m, 2H), 1.60-1.55(m, 2H), 1.48-1.39(m, 3H), 1.26-1.12(m, 1H). 0.71-0.61(m, 2H) $^{13}$C NMR ($CDCl_3$, 100MHz): δ 184.37, 183.33, 157.32, 143.53, 134.55, 134.37, 133.93, 131.94, 129.96, 126.06, 125.81, 125.02, 114.33, 55.59, 38.88, 29. 59, 26.99, 25.82. HRMS (ESI) m/z: $C_{23}H_{24}NO_3^+$ ([MH]$^+$) calculated for: 362.1751, found: 362.1793.

**2-cyclohexyl-3-((4-(methylthio)phenyl)amino)naphthalene-1,4-dione(4g)**



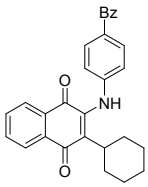
Yield: 50.9mg, 41%; red solid, m.p.115-117 °C; Rf (PE: EA = 10:1) = 0.34. $^1$H NMR ($CDCl_3$, 400 MHz): δ. 8.06-8.02(m, 2H), 7.72-7.68(m, 1H), 7.63-7.58(m, 1H), 7.25-7.22(m, 2H), 7.20(s, 1H), 7.03-7.01(m, 2H), 2.47(s, 3H), 2.22(tt, *J*=12 Hz, *J*=4 Hz, 1H), 2.08-1.98(m, 2H), 1.64-1.58(m, 2H), 1.20-1.45(m, 3H), 1.24-1.16(m, 1H). 0.78-0.67(m, 2H) $^{13}$C NMR ($CDCl_3$, 100MHz): 184.40, 183.23, 142.77, 139.34, 134.44, 134.35, 133.84, 132.17, 130.02, 128.02, 127.08, 126.20, 125.90, 123.05, 39.59, 29.60, 26.99, 25.83, 16.78. HRMS (ESI) m/z: $C_{23}H_{24}NO_2S^+$ ([MH]$^+$) calculated for: 378.1522, found: 378.1518.

**2-((4-(allyloxy)phenyl)amino)-3-cyclohexylnaphthalene-1,4-dione(4h)**



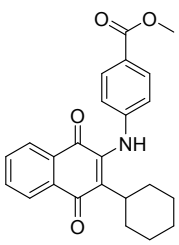
Yield: 79.0mg, 68%; red solid, m.p.94-96 °C; Rf (PE: EA=10:1) = 0.41. $^1$H NMR (DMSO-$d_6$, 400MHz): δ 8.31(s, 1H), 8.00-7.97(m, 2H), 7.88-7.83(m, 1H), 7.79-7.75(m, 1H), 7.14-7.12(m, 2H), 6.98-6.96(m , 2H), 6.13-6.03(m, 1H), 5.46-5.40(m, 1H), 5.32-5.28(m, 1H), 2.30(tt, *J*=12 Hz, *J*=4 Hz, 1H), 2.05-1.95(m, 2H), 1.62-1.59(m, 2H), 1.53-1.50(m, 1H), 1.45-1.42(m, 2H), 1.19-1. 09(m, 1H), 0.77-0.68(m, 2H). $^{13}$C NMR (DMSO-$d_6$, 100MHz): δ 183.81, 183.04, 155.55, 144.83, 135.84, 134.83, 134.15, 133.64, 132.80, 130.49, 125.88, 125.82, 125.00, 124.88, 117.66, 115.33, 68.83, 38.52, 29.58, 27.04, 26.00. $C_{25}H_{25}NO_3^+$ ([MH]$^+$) calculated for: 388.1907, found: 388.1903.

**2-((4-benzoylphenyl)amino)-3-cyclohexylnaphthalene-1,4-dione(4i)**



Yield: 58.8mg, 45%; red solid, m.p.156-157 °C; Rf (PE: EA=10:1) = 0.18. $^1$H NMR ($CDCl_3$, 400MHz): δ. 8.09-8.04(m, 2H), 7.82-7.79(m, 2H), 7.77-7.72(m, 3H), 7.67-7.63(m, 1H), 7.59-7.55(m, 1H), 7.49-7.45(m, 2H), 7.26(s, 1H), 7.08-7.06(m, 2H), 2.30(tt, *J*=12 Hz, *J*=4 Hz, 1H), 2.14-2.03(m, 2H), 1.72-1.67(m, 2H), 1.62-1.59(m, 3H), 1.31-1.20(m, 1H). 0.92-0.82(m, 2H). $^{13}$C NMR ($CDCl_3$, 100MHz): δ 195.37, 184.45, 182.99, 146.12, 141.38, 137.98, 134.55, 133.58, 132.63, 132.14, 132.09, 131.81, 131.72, 130.09, 129.79, 128.27, 126.44, 126.05, 119.33, 40.70, 29. 64, 27.03, 25.80. HRMS (ESI) m/z: $C_{29}H_{26}NO_3^+$ ([MH]$^+$) calculated for: 458.1727, found: 458.1707.

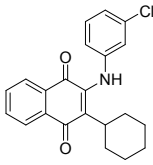
**methyl 4-((3-cyclohexyl-1,4-dioxo-1,4-dihydronaphthalen-2-yl)amino)benzoate(4j)**



Yield: 43.2mg, 37%; red solid, m.p.115-117 °C; Rf (PE: EA=10:1) = 0.22. $^1$H NMR (DMSO-

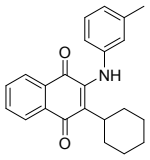
$d_6$, 400MHz): δ 8.62(s, 1H), 7.97-7.95(m, 1H), 7.92-7.90(m, 1H), 7.83-7.73(m, 4H), 7.00-6.96(m, 2H), 3.37(s, 3H), 2.53-2.48(m, 1H), 2.02-1.92(m, 2H), 1.66-1.62(m, 2H), 1.56-1.52(m, 3H), 1.19-1.10(m, 1H), 0.98-0.88(m, 2H). $^{13}$C NMR (DMSO-$d_6$, 100MHz): δ 184.61, 182.13, 166.43, 149.15, 142.95, 137.08, 134.69, 133.61, 133.14, 131.23, 130.63, 126.16, 121.74, 118.31, 52.11, 39,54, 29.68, 26.95, 25.96. $C_{24}H_{23}NNaO_4^+$ ([MNa]$^+$) calculated for: 412.1519, found: 412.1515.

**2-((3-chlorophenyl)amino)-3-cyclohexylnaphthalene-1,4-dione(4k)**



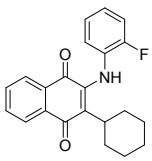
Yield: 63.6mg, 58%; red solid, m.p.97-98 °C; Rf (PE: EA=10:1) = 0.47. $^1$H NMR ($CDCl_3$, 400MHz): δ 8.07-8.03(m, 2H), 7.74-7.70(m, 1H), 7.65-7.61(m, 1H), 7.26-7.22(m, 1H), 7.18(s, 1H), 7.09-7.04(m, 2H), 6.97-6.94(m, 1H), 2.19(tt, *J*=12 Hz, *J*=4 Hz, 1H), 2.11-2.00(m, 2H), 1.68-1.63(m, 2H), 1.55-1.50(m, 3H), 1.29-1.18(m, 1H), 0.84-0.73(m, 2H). $^{13}$C NMR ($CDCl_3$, 100MHz): δ 184.42, 183.03, 143.11, 142.04, 134.71, 134.48, 133.65, 132.37, 130.07, 129.97, 129.03, 126.29, 125.95, 124.13,121.63, 119.74, 40.22, 29.49, 26.96, 25.81. HRMS (ESI) m/z: $C_{22}H_{21}ClNO_2^+$ ([MH]$^+$) calculated for: 366.1255, found: 366.1236.

**2-cyclohexyl-3-(m-tolylamino)naphthalene-1,4-dione(4l)**



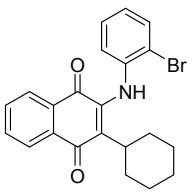
Yield: 74.6mg, 72%; red solid, m.p.101-102 °C; Rf (PE: EA=10:1) = 0.57. $^1$H NMR ($CDCl_3$, 400MHz): δ. 8.07-8.02(m, 2H), 7.72-7.68(m, 1H), 7.63-7.58(m, 1H), 7.26(s, 1H), 7.23-7.18(m, 1H), 6.96-6.94(m, 1H), 6.91-6.89(m, 2H), 2.31(s, 3H), 2.20 (tt, *J*=12 Hz, *J*=4 Hz, 1H), 2.09-1.99(m, 2H), 1.63-1.58(m, 2H), 1.50-1.45(m, 3H), 1.27-1.15(m, 1H), 0.75-0.64(m, 2H). $^{13}$C NMR ($CDCl_3$, 100MHz): δ 184.42, 183.32, 142.77, 141.48, 138.91, 134.36, 133.87, 132.07, 130.03, 128.92, 126.66, 126.13, 125.84, 125.39, 123.00, 119.52, 39.53, 29.51, 26.94, 25.85, 21.15. HRMS (ESI) m/z: $C_{23}H_{24}NO_2^+$ ([MH]$^+$) calculated for: 346.1802, found: 346.1787.

**2-cyclohexyl-3-((2-fluorophenyl)amino)naphthalene-1,4-dione(4m)**



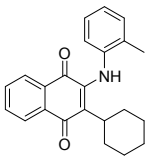
Yield: 60.8mg, 58%: orange solid, m.p.154-155 °C; Rf (PE: EA=10:1) = 0.47. $^1$H NMR ($CDCl_3$, 400MHz): δ 8.06-8.04(m, 2H), 7.73-7.69(m, 1H), 7.64-7.60(m, 1H), 7.14-7.06(m, 4H), 7.01(s, 1H), 2.22(tt, *J*=12 Hz, *J*=4 Hz, 1H), 2.08-1.98(m, 2H), 1.64-1.58(m, 2H), 1.50-1.45(m, 3H), 1.26-1.14(m, 1H), 0.78-0.67(m, 2H). $^{13}$C NMR ($CDCl_3$, 100MHz): δ 184.44, 182.79, 155.85 (d, *J* = 247.4 Hz), 142.76, 134.36, 133.66, 132.29, 130.05, 129.82, 129.70, 128.31,126.08 (d, *J* = 27.2 Hz), 125.80 (d, *J* = 7.4 Hz), 124.23 (d, *J* = 7.4 Hz), 124.16, 116.11 (d, *J* = 19.3 Hz), 39.46, 29.74, 27.00, 25.79. $^{19}$F NMR ($CDCl_3$, 375MHz): δ -124.18. HRMS (ESI) m/z: $C_{22}H_{21}FNO_2^+$ ([MH]$^+$) calculated for: 350.1551, found: 350.1536.

**2-((2-bromophenyl)amino)-3-cyclohexylnaphthalene-1,4-dione(4n)**



Yield: 66.5mg, 54%: red solid, m.p.97-99 °C; Rf (PE: EA=10:1) = 0.53. $^1$H NMR (DMSO-$d_6$, 400MHz): δ 8.12(s, 1H), 8.01-7.98(m, 2H), 7.88-7.84(m, 1H), 7.81-7.77(m, 1H), 7.73-7.71(m, 1H), 7.43-7.39(m, 1H), 7.36-7.34(m, 1H), 7.22-7.18(m, 1H), 2.24(tt, *J*=12 Hz, *J*=4 Hz, 1H), 2.03-1.92(m, 2H), 1.64-1.59(m, 2H), 1.54-1.51(m, 1H), 1.44-1.39(m, 2H), 1.16-1.09(m, 1H), 0.81-0.69(m, 2H). $^{13}$C NMR (DMSO-$d_6$, 100MHz): δ 183.99, 182.40, 144.76, 141.53, 134.89, 133.39, 133.17, 133.10, 130.42, 128.70, 127.12, 127.08, 126.62, 126.60, 125.94, 120.00, 38,63, 29.71, 27.03, 25.96. HRMS (ESI) m/z: $C_{22}H_{20}BrNNaO_2^+$ ([MNa]$^+$) calculated for: 432.0570, found: 432.0575.

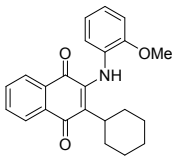
**2-cyclohexyl-3-(o-tolylamino)naphthalene-1,4-dione(4o)**



Yield: 72.6mg, 73%; red solid, m.p.113-114 °C; Rf (PE: EA=10:1) = 0.53. $^1$H NMR ($CDCl_3$, 400MHz): δ. 8.05-8.03(m, 2H), 7.73-7.68(m, 1H), 7.62-7.58(m, 1H), 7.25(s, 1H), 7.18-7.12(m, 2H), 7.05-7.03(m, 2H), 2.32(s, 3H), 2.09-1.92(m, 3H), 1.57-1.52(m, 2H), 1.44-1.41(m, 1H), 1.36-1.33(m, 2H), 1.20-1.09(m, 1H). 0.61-0.52(m, 2H). $^{13}$C NMR ($CDCl_3$, 100MHz): δ 184.29,

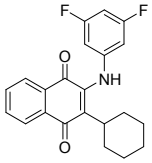
183.23, 143.73, 140.15, 134.39, 133.92, 133.23, 131.98, 130.70, 129.99, 126.58, 126.09, 126.06, 125.83, 125.15, 124.65, 38.83, 29.75, 25.79, 18.17. HRMS (ESI) m/z: $C_{23}H_{24}NO_2^+$ ([MH]$^+$) calculated for: 346.1802, found: 346.1789.

**2-cyclohexyl-3-((2-methoxyphenyl)amino)naphthalene-1,4-dione(4p)**



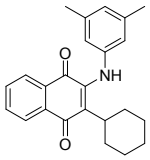
Yield: 62.8mg, 58%; red solid, m.p.100-101 $^o$C; Rf (PE: EA=10:1) = 0.41. $^1$H NMR ($CDCl_3$, 400MHz): δ. 8.06-8.01(m, 2H), 7.71-7.67(m, 1H), 7.62-7.57(m, 1H), 7.19(s, 1H), 7.11-7.07(m, 1H), 7.00-6.97(m, 1H), 6.92-6.85(m, 2H), 3.87(s, 3H), 2.28(tt, *J*=12 Hz, *J*=4 Hz, 1H), 2.10-2.00(m, 2H), 1.64-1.60(m, 2H), 1.51-1.47(m, 3H), 1.27-1.15(m, 1H), 0.83-0.71(m, 2H). $^{13}$C NMR ($CDCl_3$, 100MHz): δ 184.32, 183.14, 151.69, 142.92, 134.23, 133.86, 132.06, 130.39, 130.20, 127.57, 126.10, 125.85, 124.89, 121.86, 120.32, 110.98, 55.61, 39.41, 29.82, 27.05, 25.88. HRMS (ESI) m/z: $C_{23}H_{24}NO_3^+$ ([MH]$^+$) calculated for: 362.1751, found: 362.1737.

**2-cyclohexyl-3-((3,5-difluorophenyl)amino)naphthalene-1,4-dione(4q)**



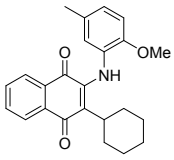
Yield: 62.8mg, 57%; orange solid, m.p.123-124 $^o$C; Rf (PE: EA=10:1) = 0.44. $^1$H NMR ($CDCl_3$, 400MHz): δ. 8.07-8.02(m, 2H), 7.74-7.70(m, 1H), 7.66-7.61(m, 1H), 7.08(s, 1H), 6.59-6.49(m, 3H), 2.31(s, 3H), 2.25 (tt, *J*=12 Hz, *J*=4 Hz, 1H), 2.12-2.02(m, 2H), 1.72-1.66(m, 2H), 1.58-1.54(m, 3H), 1.32-1.20(m, 1H), 0.93-0.82(m, 2H). $^{13}$C NMR ($CDCl_3$, 100MHz): δ 184.40, 182.80,163.32 (dd, *J* = 247.9, 14.9 Hz), 144.71 (t, *J* = 12.7 Hz), 141.51, 134.53, 133.48, 132.61,131.59, 129.97, 126.47, 126.01,103.82(d, *J* = 11.8 Hz), 103.82(d, *J* = 27.8 Hz), 98.94 (t, *J* = 25.7 Hz), 40.63, 29.52, 26.98, 25.73 $^{19}$F NMR ($CDCl_3$, 375MHz): δ -109.20. HRMS (ESI) m/z: $C_{22}H_{19}F_2NNaO_2^+$ ([MNa]$^+$) calculated for: 390.1276, found: 390.1255.

**2-cyclohexyl-3-((3,5-dimethylphenyl)amino)naphthalene-1,4-dione(4r)**



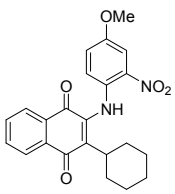
Yield: 80.1mg, 78%; red solid, m.p.136-138 $^o$C; Rf (PE: EA=10:1) = 0.54. $^1$H NMR ($CDCl_3$, 400MHz): δ 8.09-8.04(m, 2H), 7.74-7.70(m, 1H), 7.64-7.60(m, 1H), 7.28(s, 1H), 6.67(s, 1H), 6.73(s, 2H), 2.30(s, 6H), 2.27(tt, *J*=12 Hz, *J*=4 Hz, 1H), 2.13-2.02(m, 2H), 1.67-1.61(m, 3H), 1.50-1.49(m, 2H), 1.30-1.19(m, 1H), 0.80-0.69(m, 2H). $^{13}$C NMR ($CDCl_3$, 100MHz): δ 184.39, 183.35, 142.69, 141.24, 138.70, 134.35, 133.89, 132.02, 130.02, 126.35, 126.21, 126.11, 125.83, 119.99, 39.51, 29.52, 26.94, 25.88, 21.09. HRMS (ESI) m/z: $C_{24}H_{25}NNaO_2^+$ ([MNa]$^+$) calculated for: 382.1778, found: 382.1763.

**2-cyclohexyl-3-((2-methoxy-5-methylphenyl)amino)naphthalene-1,4-dione(4s)**



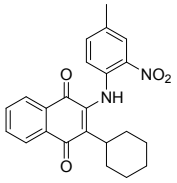
Yield: 76.6mg, 68%; brown solid, m.p.155-157 $^o$C; Rf (PE: EA=10: 1) =0.48. $^1$H NMR ($CDCl_3$, 400MHz): δ 8.08-8.03(m, 2H), 7.73-7.69(m, 1H), 6.63-7.58(m, 1H), 7.24(s, 1H), 6.89-6.87(m, 1H), 6.82-6.79(m, 2H), 3.87(s, 3H), 2.23-2.26(m, 1H), 2.24(s, 3H), 2.14-2.04(m, 2H), 1.68-1.62(m, 3H), 1.54-1.50(m, 2H), 1.31-1.20(m, 1H), 0.86-0.74(m, 2H). $^{13}$C NMR ($CDCl_3$, 100MHz): δ 184.31, 183.20, 149.28, 142.63, 134.24, 133.89, 132.04, 130.17, 129.90, 129.68, 127.17, 126.09, 125.84, 124.79, 121.99, 110.87, 55.74, 39.66, 29.78, 27.05, 25.91, 20.28. HRMS (ESI) m/z: $C_{24}H_{25}NNaO_3^+$ ([MNa]$^+$) calculated for: 398.1727, found: 398.1713.

**2-cyclohexyl-3-((4-methoxy-2-nitrophenyl)amino)naphthalene-1,4-dione(4t)**



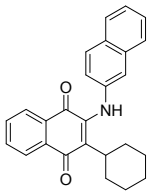
Yield: 51.2mg, 42%; brown solid, m.p.97-99 $^o$C; Rf (PE: EA=10:1) = 0.25. $^1$H NMR ($CDCl_3$, 300MHz): δ 9.02(s, 1H), 8.11-8.08(m, 1H), 8.06-8.03(m, 1H), 7.78-7.68(m, 2H), 7.66-7.65(m, 1H), 7.11-7.07(m, 1H), 6.83-6.80(m, 1H), 3.86(s, 3H), 2.65-2.57(m, 1H), 2.09-1.97(m, 2H), 1.78-1.74(m, 2H), 1.65-1.61(m, 3H), 1.31-1.22(m, 1H), 1.15-1.02(m, 2H). $^{13}$C NMR ($CDCl_3$, 100MHz): δ 184.36, 181.68, 143.41, 141.00, 138.40, 136.65, 134.27, 133.89, 133.05, 133.01, 130.79, 126.50, 126.29, 123.68, 121.45, 107.93, 55.96, 39.47, 29.62, 26.83, 25.72. HRMS (ESI) m/z: $C_{23}H_{22}N2NaO_5^+$ ([MNa]$^+$) calculated for: 429.1421, found: 429.1421.

**2-cyclohexyl-3-((4-methyl-2-nitrophenyl)amino)naphthalene-1,4-dione(4u)**



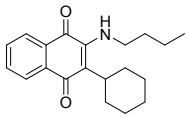
Yield: 45.7mg, 39%; red solid, m.p.94-94 °C; Rf (PE: EA=10:1) = 0.35. $^1$H NMR ($CDCl_3$, 400MHz): δ 9.15(s, 1H), 8.12-8.10(m, 1H), 8.06-8.04(m, 1H),8.01-8.01(m, 1H), 7.77-7.73(m, 1H), 7.72-7.67(m, 1H), 7.27-7.25(m, 1H), 6.74-6.71(d, *J*=12 Hz, 1H), 2.70(tt, *J*=12 Hz, *J*=4 Hz, 1H), 2.36(s, 3H), 2.08-1.98(m, 2H), 1.80-1.75(m, 2H), 1.68-1.63(m, 3H), 1.34-1.23(m, 1H), 1.18-1.07(m, 2H). $^{13}$C NMR ($CDCl_3$, 100MHz): δ 184.44, 181.51, 140.87, 140.41, 137.88, 135.80, 134.23, 133.17, 132.94, 130.91, 130.36, 126.55, 126.34, 125.88, 119.47, 39.40, 29.61, 26.79, 25.72, 20.31. HRMS (ESI) m/z: $C_{23}H_{22}N2NaO_4^+$ ([MNa]$^+$) calculated for: 413.1472, found: 429.1453.

**2-cyclohexyl-3-(naphthalen-2-ylamino)naphthalene-1,4-dione(4v)**



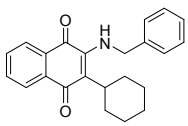
Yield: 43.5mg, 38%; red solid, m.p.81-82 °C; Rf (PE: EA=10:1) = 0.44. $^1$H NMR ($CDCl_3$, 400MHz): δ. 8.10-8.05(m, 2H), 7.81-7.79(m, 2H), 7.74-7.69(m, 2H), 7.65-7.2(m, 1H), 7.48-7.39(m, 4H), 7.27-7.25(m, 1H), 2.31-2.25(m, 1H), 2.11-2.01(m, 2H), 1.56-1.50(m, 4H), 1.38-1.34(m, 1H), 1.21-1.10(m, 1H), 0.60-0.48(m, 2H). $^{13}$C NMR ($CDCl_3$, 100MHz): δ 184.4, 183.33, 142.49, 139.15, 134.44, 133.86, 133.65, 132.22, 130.61, 130.07, 128.99, 127.91, 127.74, 126.95, 126.80, 126.24, 125.93, 125.12, 121.72, 118.11, 40.10, 29.76, 26.81, 25.72. HRMS (ESI) m/z: $C_{26}H_{23}NNaO_4^+$ ([MNa]$^+$) calculated for: 404.1621, found: 404.1597.

**2-(butylamino)-3-cyclohexylnaphthalene-1,4-dione(4w)**



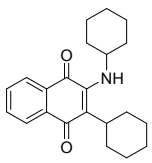
Yield: 41.9mg, 45%; red solid, m.p.92-94 °C; Rf (PE: EA=10:1) = 0.57. $^1$H NMR ($CDCl_3$, 400MHz): δ. 8.12-8.10(m, 1H), 8.06-8.44(m, 1H), 7.77-7.73(m, 1H), 7.66-7.62(m, 1H), 5.69-5.66(m, 1H), 3.53-3.48(m, 2H), 2.77(tt, *J*=12 Hz, *J*=4 Hz, 1H), 2.42-2.31(m, 2H), 1.96-1.91(m, 2H), 1.82-1.71(m, 4H), 1.58-1.49(m, 2H), 1.46-1.30(m, 3H), 1.06(t, *J*=8 Hz, 3H). $^{13}$C NMR ($CDCl_3$, 100MHz): δ 183.92, 183.29, 146.89, 134.24, 134.08, 131.64, 129.98, 125.89, 125.70, 122.39, 47.06, 39.33, 33.00, 31.16, 27.46, 25.94, 20.00, 13.73. HRMS (ESI) m/z: $C_{20}H_{25}NNaO_2^+$ ([MNa]$^+$) calculated for: 334.1778, found: 334.1766.

**2-(benzylamino)-3-cyclohexylnaphthalene-1,4-dione(4x)**



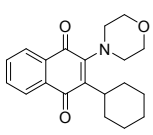
Yield: 39.4mg, 38%; red solid, m.p.122-124 °C; Rf (PE: EA=10:1) = 0.44. $^1$H NMR ($CDCl_3$, 400MHz): δ. 8.03-8.01(m, 1H), 7.99-7.96(m, 1H), 7.69-7.64(m, 1H), 7.58-7.54(m, 1H), 7.40-7.36(m, 2H), 7.32-7.30(m, 3H), 5.96(t, *J*=4 Hz, 1H), 4.60-4.59(d, *J*=4 Hz, 2H), 2.70-2.62(m, 1H), 2.27-2.16(m, 2H), 1.76-1.71(m, 2H), 1.58-1.52(m, 3H), 1.31-1.24(m, 1H), 1.09-0.98(m, 2H) $^{13}$C NMR ($CDCl_3$, 100MHz): δ 183.07, 182.16, 145.58, 137.63, 133.29, 132.94, 130.81, 128.99, 127.90, 126.74, 126.00, 124.96, 124.79, 122.24, 50.11, 37.99, 30.16, 26.15, 24.84. HRMS (ESI) m/z: $C_{23}H_{24}NO_2^+$ ([MH]$^+$) calculated for: 346.1802, found: 346.1785.

**2-cyclohexyl-3-(cyclohexylamino)naphthalene-1,4-dione(4y)**



Yield: 41.5mg, 41%; orange solid, m.p.76-78 °C; Rf (PE: EA=10:1) = 0.56. $^1$H NMR ($CDCl_3$, 400MHz): δ 8.01-7.99(m, 1H), 7.95-7.93(m, 1H), 7.66-7.62(m,1H), 7.55-7.51(m, 1H), 5.50(s, 1H), 2.58(tt, *J*=12 Hz, *J*=4 Hz, 1H), 2.29-2.19(m, 2H), 2.02-21.99(m, 2H), 1.87-1.77(m, 4H), 1.73-1.61(m, 4H), 1.39-1.19(m, 8H). $^{13}$C NMR ($CDCl_3$, 100MHz): δ 183.75, 183.49, 145.96, 134.17, 134.00, 131.67, 130.09, 125.88, 125.74, 123.19, 55.75, 39.63, 34,84, 30.79, 27.57, 26.03, 25.40, 25.09. HRMS (ESI) m/z: $C_{22}H_{27}NNaO_2^+$ ([MNa]$^+$) calculated for: 360.1934, found: 360.1935.

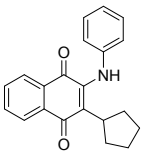
**2-cyclohexyl-3-morpholinonaphthalene-1,4-dione(4z)**



Yield: 56.6mg, 58%; black oily liquid; Rf (PE: EA=10:1) = 0.35. $^1$H NMR ($CDCl_3$, 400MHz): δ 8.02-7.96(m, 2H), 7.69-7.62(m, 2H), 3.83(m, 4H), 3.31(m, 4H), 2.93(tt, *J*=12 Hz, *J*=4 Hz, 1H), 2.22-2.12(m, 2H), 1.88-1.84(m, 2H), 1.78-1.73(m, 1H), 1.60-1.55(m, 2H), 1.41-1.24(m, 3H)1.27-1.16(m, 3H). $^{13}$C NMR ($CDCl_3$, 100MHz): δ 185.98, 183.099, 151.85, 143.06, 133.42,

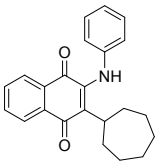
132.81, 132.79, 131.85, 125.86, 125.86, 67.54, 52.14, 40.07, 30.67, 27.41, 26.01. HRMS (ESI) m/z: $C_{20}H_{24}NO_3^+$ ([MH]$^+$) calculated for: 326.1751, found: 326.1739.

**2-cyclopentyl-3-(phenylamino)naphthalene-1,4-dione(5a)**



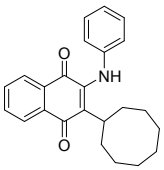
Yield: 70.5mg, 74%; red solid, m.p.151-153$^o$C; Rf (PE: EA=10:1) = 0.53. $^1$H NMR ($CDCl_3$, 400MHz): δ. 8.08-8.03(m, 2H), 7.72-7.68(m, 1H), 7.64-7.60(m, 1H), 7.32-7.28(m, 2H), 7.23(s, 1H), 7.09-7.03(m, 3H),2.76-2.67(m, 1H), 1.91-1.78(m, 4H), 1.72-1.63(m, 2H), 1.41-1.35(m, 2H). $^{13}$C NMR ($CDCl_3$, 100MHz): δ 183.94, 182.84, 143.02, 141.62, 134.36, 133.90, 132.28, 130.20, 129.05, 128.48, 126.12, 126.00, 123.86, 121.14, 39.35, 30.81, 27.15. HRMS (ESI) m/z: $C_{21}H_{19}NNaO_2^+$ ([MNa]$^+$) calculated for: 340.1308, found: 340.1294

**2-cycloheptyl-3-(phenylamino)naphthalene-1,4-dione(5b)**



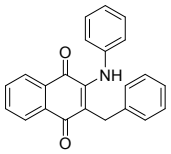
Yield: 70.5mg, 68%; red solid, m.p.96-98 $^o$C; Rf (PE: EA=10:1) = 0.50. $^1$H NMR ($CDCl_3$, 400MHz): δ. 8.06-8.03(m, 2H), 7.72-7.68(m, 1H), 7.63-7.69(m, 1H), 7.34-7.31(m, 2H), 7.16-7.09(m, 4H), 2.46(tt, *J*=12 Hz, *J*=4 Hz, 1H), 2.06-1.97(m, 2H), 1.64-1.57(m, 3H), 1.54-1.50(m, 1H), 1.43-1.34(m, 2H), 1.23-1.16(m, 2H), 1.02-0.92(m, 2H). $^{13}$C NMR ($CDCl_3$, 100MHz): δ 184.37, 183.46, 141.89, 141.86, 134.33, 133.75, 132.17, 130.08, 129.94, 129.30, 126.12, 125.88, 124.74, 122.80, 39.18, 32.30, 28.44, 27.74. HRMS (ESI) m/z: $C_{23}H_{24}NO_3^+$ ([MH]$^+$) calculated for: 346.1802, found: 346.1786.

**2-cyclooctyl-3-(phenylamino)naphthalene-1,4-dione(5c)**



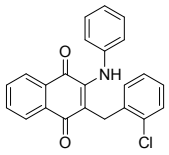
Yield: 78.7mg, 73%; red solid, m.p.100-102 $^o$C; Rf (PE: EA=10:1) = 0.47. $^1$H NMR ($CDCl_3$, 400MHz): δ. 8.05-8.02(m, 2H), 7.71-7.76(m, 1H), 7.63-7.59(m, 1H), 7.33(t, *J*=8 Hz, 2H), 7.16-7.10(m, 4H), 2.62-2.56(m, 1H), 2.07-1.98(m, 2H), 1.60-1.53(m, 2H), 1.52-1.45(m, 2H), 1.42-1.35(m, 1H), 1.31-1.24(m, 2H), 1.22-1.13(m, 2H), 1.11-1.01(m, 2H), 0.91-0.81(m, 1H). $^{13}$C NMR ($CDCl_3$, 100MHz): δ 184.32, 183.53, 141.92, 141.88, 134.34, 133.80, 132.16, 130.91, 130.05, 129.39, 126.12, 125.87, 124.88, 123.13, 37.32, 32.08, 26.81,26.35, 25.89. HRMS (ESI) m/z: $C_{24}H_{25}NNaO_2^+$ ([MNa]$^+$) calculated for: 382.1778, found: 382.1780.

**2-benzyl-3-(phenylamino)naphthalene-1,4-dione(5d)**



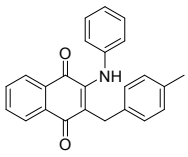
Yield: 51.9mg, 51%; red solid, m.p.141-142 $^o$C; Rf (PE: EA=10:1) = 0.33. $^1$H NMR ($CDCl_3$, 400MHz): δ 8.15-8.13(m, 1H), 8. 11-8.09(m, 1H), 7.76-7.72(m, 1H), 7.68-7.64(m, 1H), 7.43(s, 1H), 7.29-7.28(m, 2H), 7.15-7.11(m, 1H), 7.09-7.06(m, 3H), 6.95-6.93(m, 2H), 6.84-6.82(m, 2H), 3.78(s, 2H). $^{13}$C NMR ($CDCl_3$, 100MHz): δ 183.78, 183.00, 142.19, 139.19, 134.57, 133.16, 132.45, 130.38, 128.85, 128.40, 128.26, 128.02, 126.65, 125.72, 124.79, 123.10, 120.44, 31.05. HRMS (ESI) m/z: $C_{23}H_{18}NO_2^+$ ([MH]$^+$) calculated for: 340.1332, found: 340.1317.

**2-(2-chlorobenzyl)-3-(phenylamino)naphthalene-1,4-dione(5e)**



Yield: 78.5mg, 70%; red solid, m.p.163-165$^o$C; Rf (PE: EA=10:1) = 0.30. $^1$H NMR ($CDCl_3$, 400MHz): δ 8.32-8.22(m, 1H), 8.21-8.20(m, 1H), 7.85-7.81(m, 1H), 7.77-7.73(m, 1H), 7.60(s, 1H), 7.27-7.18(m, 4H), 7.14-7.11(m, 2H), 7.03-7.01(m, 1H), 6.94-6.92(m, 2H), 3.84(s, 2H). $^{13}$C NMR ($CDCl_3$, 100MHz): δ 183.68, 182.64, 143.13, 138.69, 136.14, 134.67, 134.07, 133.19, 132.44, 130.36, 129.51, 128.95, 128.74, 127.02, 126.66, 126.29, 126.23, 125.40, 123.70, 116.97, 29.58. HRMS (ESI) m/z: $C_{23}H_{17}ClNO_2^+$ ([MH]$^+$) calculated for: 374.0942, found: 374.0919.

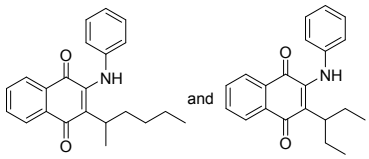
**2-(4-methylbenzyl)-3-(phenylamino)naphthalene-1,4-dione(5f)**



Yield: 39.1mg, 37%; red solid, m.p.104-105 $^o$C; Rf (PE: EA = 10:1) = 0.36. $^1$H NMR ($CDCl_3$, 400MHz): δ 8.14-8.12(m, 1H), 8. 09-8.07(m, 1H), 7.74-7.70(m, 1H), 7.66-7.62(m, 1H), 7.40(s, 1H), 7.30-7.27(m, 2H), 7.14-7.11(m, 1H), 6.97-6.95(m, 2H), 6.91-6.90(m, 2H), 6.75-6.73(m, 2H), 3.73(s, 2H), 2.23(s, 3H). $^{13}$C NMR ($CDCl_3$, 100MHz): δ 183.81, 183.03,

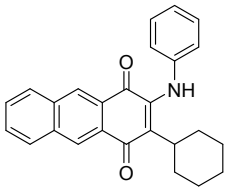
142.07, 139.37, 136.15, 135.20, 134.49, 133.18, 132.42, 130.42, 128.88, 128.75, 128.21, 126.63, 126.16, 124.67, 122.94, 121.19, 30.65, 20.94. HRMS (ESI) m/z: $C_{24}H_{19}NNaO_2^+$ ([MNa]$^+$) calculated for: 376.1308, found: 376.1295.

**2-(hexan-2 or 3-yl)-3-(phenylamino)naphthalene-1,4-dione(5g)**



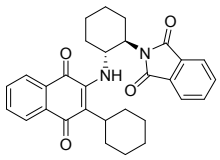
Yield: 73.9mg, 74%; red-brown liquid; Rf (PE: EA = 10:1) = 0.57. $^1$H NMR ($CDCl_3$, 400MHz): δ. 8.07-8.03(m, 2H), 7.72-7.68(m, 1H), 7.63-7.59(m, 1H), 7.33-7.31(m, 2H), 7.21(s, 0.63H), 7.16(s, 0.32H), 7.14-7.11(m, 1H), 7.09-7.05(m, 2H), 2.49-2.40(m, 0.67H), 2.27-2.2.22(m, 0.34H), 1.81-1.74(m, 0.38H), 1.68-1.57(m, 2.68H), 1.19-1.17(d, *J*=8Hz, 2H), 1.12-1.06(m, 2H), 0.90-0.82(m, 1H), 0.78-0.74(m, 3H), 0.61(t, *J*=8 Hz, 1H). $^{13}$C NMR ($CDCl_3$, 100MHz): δ 184.27, 183.18, 182.98, 144.24, 143.13, 141.92, 141.76, 134.41, 134.38, 133.80, 133.70, 132.23, 130.20, 130.12, 129.24, 129.13, 127.98, 127.28, 126.24, 126.21, 125.95, 124.61, 124.44, 122.65, 122.16, 40.97, 34.80, 34.70, 33.78, 30.43, 25.59, 22.62, 21.55, 17.57, 14.26, 14.05, 12.83. HRMS (ESI) m/z: $C_{22}H_{23}NNaO_2^+$ ([MNa]$^+$) calculated for: 356.1621, found: 356.1606.

**2-cyclohexyl-3-(phenylamino)anthracene-1,4-dione(5h)**



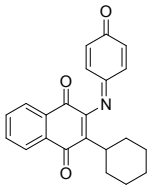
Yield: 48.1mg, 42%; red m.p.193-195 °C; Rf (PE: EA=10: 1) = 0.49. $^1$H NMR ($CDCl_3$, 400MHz): δ 8.60(s, 1H), 8.56(s, 1H), 8.03-8.00(m, 2H), 7.67-7.61(m, 2H), 7.43(s, 1H), 7.37-7.33(m, 2H), 7.19-7.13(m, 3H), 2.28(tt, *J*=12 Hz, *J*=4 Hz, 1H), 2.17-2.07(m, 2H), 1.65-1.60(m, 2H), 1.54-1.48(m, 3H), 1.30-1.18(m, 1H). 0.77-0.67(m, 2H). $^{13}$C NMR ($CDCl_3$, 100MHz): δ 184.03, 182.75, 144.27, 141.81, 135.60, 134.14, 130.07, 129.94, 129.37, 129.10, 129.00, 128.68, 128.35, 127.82, 127.05, 124.75, 122.70, 109.99, 39.90, 29.47, 26.96, 25.85. $C_{26}H_{23}NNaO_2^+$ ([MNa]$^+$) calculated for: 404.1621, found: 404.1616

**2-((1R,2R)-2-((3-cyclohexyl-1,4-dioxo-1,4-dihydronaphthalen-2-yl)amino)cyclohexyl) isoindoline-1,3-dione(7)**



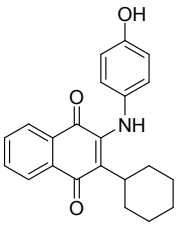
Yield: 52.1mg, 36%; $[\alpha]^{20}_D$ = -290 (c = 2, DCM); orange solid, m.p.189-191 °C; Rf (PE: EA= 10:1) = 0.12. $^1$H NMR ($CDCl_3$, 400MHz): δ 7.89-7.87(m, 1H), 7.66-7.64(m, 3H), 7.57-7.50(m, 3H), 7.43-7.38(m, 1H), 5.06-5.03(d, *J*=12 Hz, 1H), 4.22-4.09(m, 2H), 2.48(tt, *J*=12 Hz, *J*=4 Hz, 1H), 2.39-2.34(m, 2H), 2.25-2.10(m, 2H), 1.94-1.78(m, 7H), 1.43-1.33(m, 7H). $^{13}$C NMR ($CDCl_3$, 100MHz): δ 183.63, 182.64, 168.22, 147.48, 133.75, 133.72, 133.31, 131.59, 131.38, 129.77, 126.64, 125.61, 125.43, 122.98, 58.10, 56.06, 40.02, 34.74, 30.59, 30.28, 29.59, 27.33, 27.30, 26.10, 25.38, 25.01. HRMS (ESI) m/z: $C_{30}H_{30}N_2NaO_4^+$ ([MNa]$^+$) calculated for: 505.2098, found: 505.2080. HPLC (AD-H, elute: Hexanes/*i*-PrOH = 70/30, detector: 254 nm, flow rate: 1.0 mL/min), 30 °C, $t_1$ = 6.94 min(minor), $t_2$ = 8.28 min(major), $t_3$ = 10.60 min(minor), $t_4$ = 11.79 min(minor).

**2-cyclohexyl-3-((4-oxocyclohexa-2,5-dien-1-ylidene)amino)naphthalene-1,4-dione(8)**



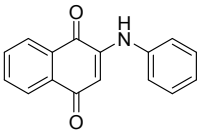
The mixture of **4f** (0.2 mmol) in $CH_3CN$ (2 mL) was cooled to 0 °C and a solution of ammonium cerium nitrate (CAN, 0.1 mmol, in 2 mL $H_2O$) was added drop by drop. The reaction mixture was stirred at ambient temperature for 1 h then was treated with 2N HCl to achieve an approximate pH = 1. The red solid was filtered and washed several times with water, and then dried to give compound **8**. Yield: 63.6mg, 92%; red solid, m.p.141-142 °C; Rf (PE: EA= 10:1) = 0.44. $^1$H NMR (DMSO-$d_6$, 400MHz): δ 8.34-8.32(m, 1H), 8.26-8.24(m, 1H), 8.20-8.16(m, 1H), 8.14-8.10(m, 1H), 7.75-7.49(br, 2H), 7.075-6.87(br, 2H),5.06-3.03(t, *J*=12 Hz, 1H), 2.03-1.92(m, 5H), 1.82-1. 08(m, 2H), 1.53-1.40(m, 3H). $^{13}$C NMR (DMSO-$d_6$, 100MHz): δ 187.31, 184.13, 178.90, 160.05, 149.06, 140.55, 134.81, 134.25, 133.97, 132.85, 130.91, 126.52, 126.30, 38.05, 29.38, 26.69, 26.04. HRMS (ESI) m/z: $C_{22}H_{20}NO_3^+$ ([MH]$^+$) calculated for: 346.1438, found: 346.1434.

### 2-cyclohexyl-3-((4-hydroxyphenyl)amino)naphthalene-1,4-dione(9)



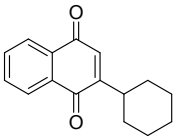
The mixture of **8** (0.3mmol) in $CH_3CN$/ $H_2O$(5+3 mL) was treated with 2N KOH to achieve an approximate pH = 12. The reaction mixture was stirred at ambient temperature for 10 min, then was quenched with saturated brine (10 ml). The aqueous phase was washed with EtOAc (3 x 10 mL) and dried over anhydrous $Mg_2SO_4$. Removal of the solvent by rotary evaporation provided product compound **9**. Yield: 79.2mg, 76%; red solid, m.p.155-156 $^oC$; Rf (PE: EA= 10:1) = 0.10. $^1H$ NMR (DMSO-$d_6$, 400MHz): δ 9.39(s, 1H), 8.17(s, 1H), 7.96-7.92(m, 2H), 7.82-7.78(m, 1H), 7.74-7.70(m, 1H), 7.01-6.99(m, 2H), 6.76-6.73(m, 2H), 2.26(tt, *J*=12 Hz, *J*=4 Hz, 1H), 2.00-1.90(m, 2H), 1.57-1.53(m, 2H), 1.48-1.45(m, 1H), 1.38-1.35(m, 2H), 1.14-1.04(m, 1H), 0.72-0.62(m, 2H). $^{13}C$ NMR (DMSO-$d_6$, 100MHz): δ 183.71, 183.17, 155.14, 144.98, 134.90, 133.88, 133.73, 132.73, 130.39, 125.89, 125.82, 125.61, 123.65, 115.75, 38.28, 29.63, 27.09, 26.03. HRMS (ESI) m/z: $C_{22}H_{22}NO_3^+$ ($[MH]^+$) calculated for: 348.1594, found: 348.1590.

### 2-(phenylamino)naphthalene-1,4-dione(10)[1]



$^1H$ NMR (DMSO-$d_6$, 400MHz): δ 9.20(s, 1H), 8.04-8.02(m, 1H), 7.93-7.91(m, 1H), 7.85-7.81(m, 1H), 7.77-7.73(m, 1H), 7.44-7.39(m, 2H), 7.37-7.35(m, 2H), 7.22-7.17(m, 1H), 6.08(s, 1H).

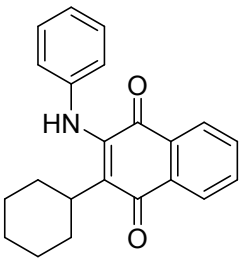
### 2-cyclohexylnaphthalene-1,4-dione(11) [2]

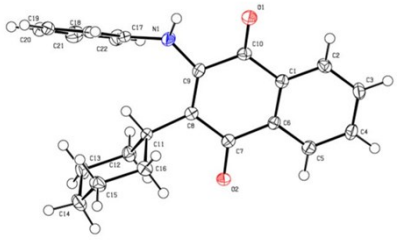


$^1H$ NMR ($CDCl_3$, 400MHz): δ 8.11-8.09(m, 1H), 8.06-8.04(m, 1H), 7.74-7.70(m, 2H), 6.74(s, 1H), 2.91(tt, *J*=12 Hz, *J*=4 Hz, 1H), 1.87-1.84(m, 4H), 1.80-1.75(m, 1H), 1.51-1.40 (m, 2H), 1.30-1.19(m, 3H).

## 3. Molecular structure and crystallographic data of 4a and 7

**X-ray crystal structure and date of 4a**





X-ray crystal structure of **4a**

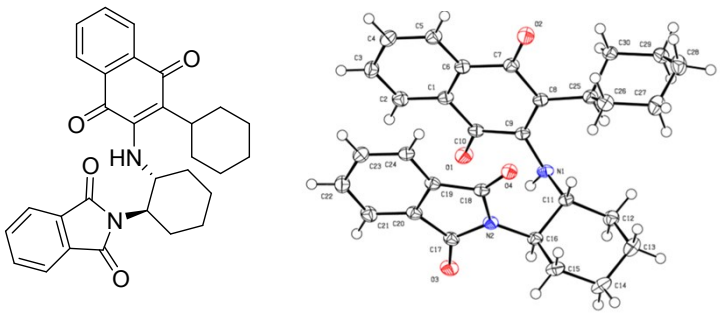
A red crystal of **4a** ($C_{22}H_{21}NO_2$) were grown by ethyl acetate at ambient temperature. Crystal data were obtained on a SuperNova, Dual, Cu at zero, AtlasS2 diffractometer. The measurements were performed with Mo-Kα radiation (λ =0.71073 Å). The crystal was kept at 100.00(10) K during data collection.

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

| | |
|---|---|
| Identification code | yj-1 |
| Empirical formula | $C_{22}H_{21}NO_2$ |
| Formula weight | 331.40 |
| Temperature/K | 100.00(10) |
| Crystal system | monoclinic |
| Space group | $P2_1/n$ |

| | |
|---|---|
| a/Å | 9.9597(10) |
| b/Å | 15.0950(12) |
| c/Å | 12.0193(12) |
| α/° | 90 |
| β/° | 108.577(11) |
| γ/° | 90 |
| Volume/Å$^3$ | 1712.8(3) |
| Z | 4 |
| $\rho_{calc}$g/cm$^3$ | 1.285 |
| μ/mm$^{-1}$ | 0.082 |
| F(000) | 704.0 |
| Crystal size/mm$^3$ | 0.14 × 0.12 × 0.11 |
| Radiation | Mo Kα (λ = 0.71073) |
| 2Θ range for data collection/° | 4.48 to 49.998 |
| Index ranges | -11 ≤ h ≤ 10, -17 ≤ k ≤ 17, -9 ≤ l ≤ 14 |
| Reflections collected | 6760 |
| Independent reflections | 3018 [$R_{int}$ = 0.0345, $R_{sigma}$ = 0.0508] |
| Data/restraints/parameters | 3018/0/226 |
| Goodness-of-fit on F$^2$ | 1.066 |
| Final R indexes [I>=2σ (I)] | $R_1$ = 0.0486, w$R_2$ = 0.1134 |
| Final R indexes [all data] | $R_1$ = 0.0618, w$R_2$ = 0.1210 |
| Largest diff. peak/hole / e Å$^{-3}$ | 0.29/-0.39 |

**X-ray crystal structure and date of 7**




X-ray crystal structure of **7**

A red crystal of **7** ($C_{30}H_{30}N_2O_4$) were grown by ethyl acetate and petroleum ether at ambient temperature. Crystal data were obtained on a SuperNova, Dual, Cu at zero, AtlasS2 diffractometer. The measurements were performed with Mo-Kα radiation (λ =0.71073 Å). The crystal was kept at 100.00(10) K during data collection.

**Table 2 Crystal data and structure refinement for 7**

| | |
|---|---|
| Identification code | YJ-2 |
| Empirical formula | $C_{30}H_{30}N_2O_4$ |
| Formula weight | 482.56 |
| Temperature/K | 100.00(10) |

| | |
|---|---|
| Crystal system | monoclinic |
| Space group | $P2_1$ |
| a/Å | 12.14946(15) |
| b/Å | 6.86531(7) |
| c/Å | 15.15149(18) |
| α/° | 90 |
| β/° | 108.1583(13) |
| γ/° | 90 |
| Volume/Å$^3$ | 1200.84(3) |
| Z | 2 |
| $\rho_{calc}$g/cm$^3$ | 1.335 |
| μ/mm$^{-1}$ | 0.713 |
| F(000) | 512.0 |
| Crystal size/mm$^3$ | 0.13 × 0.12 × 0.11 |
| Radiation | Cu Kα (λ = 1.54184) |
| 2Θ range for data collection/° | 6.14 to 147.096 |
| Index ranges | -15 ≤ h ≤ 14, -8 ≤ k ≤ 8, -17 ≤ l ≤ 18 |
| Reflections collected | 11875 |
| Independent reflections | 4737 [$R_{int}$ = 0.0243, $R_{sigma}$ = 0.0234] |
| Data/restraints/parameters | 4737/1/329 |
| Goodness-of-fit on $F^2$ | 1.026 |
| Final R indexes [I>=2σ (I)] | $R_1$ = 0.0311, $wR_2$ = 0.0843 |
| Final R indexes [all data] | $R_1$ = 0.0316, $wR_2$ = 0.0849 |
| Largest diff. peak/hole / e Å$^{-3}$ | 0.21/-0.25 |
| Flack/Hooft parameter | 0.07(6)/0.09(6) |

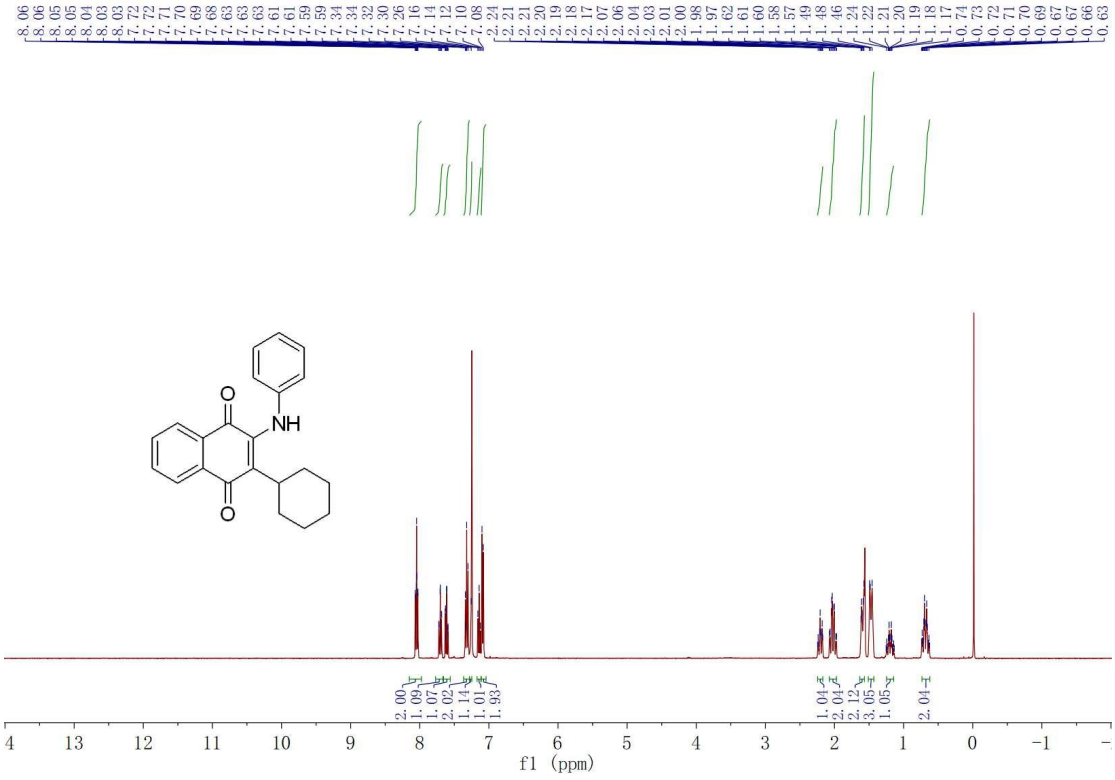
## Reference


1、K. A. Macgregor, M. K. L. R Abdel-Hamid, A. McCluskey. *Eur. J Med. Chem*. 2014, **85**, 191.

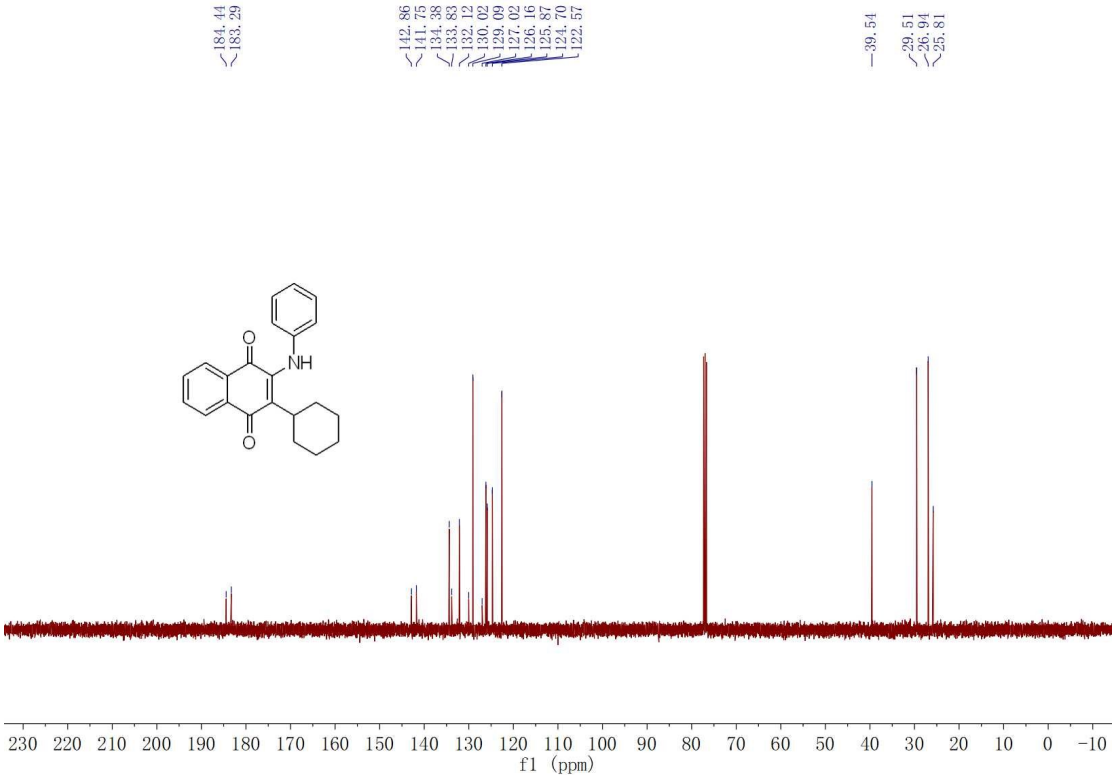
2、D. R. Sutherland, M. Veguillas, C. L. Oates and A. L. Lee. *Org. Lett*. 2018, **20**, 6863.

## $^{1}$H, $^{13}$C NMR and HPLC spectra

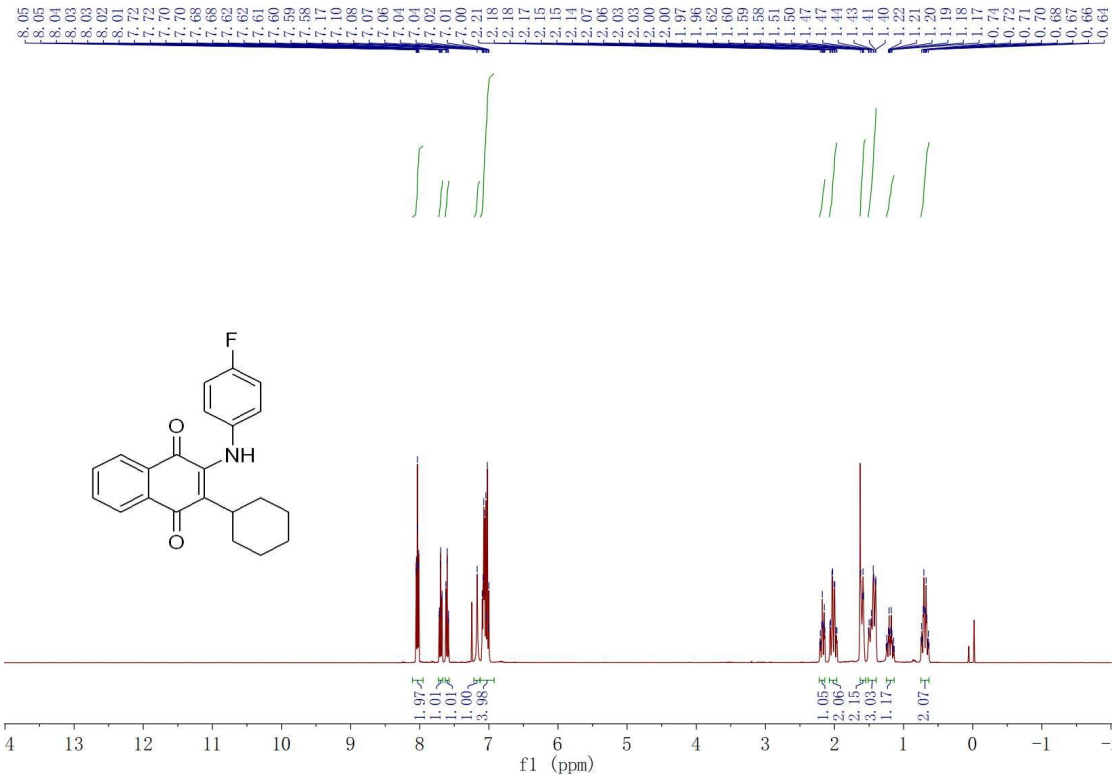
$^{1}$H-NMR spectra of **4a**



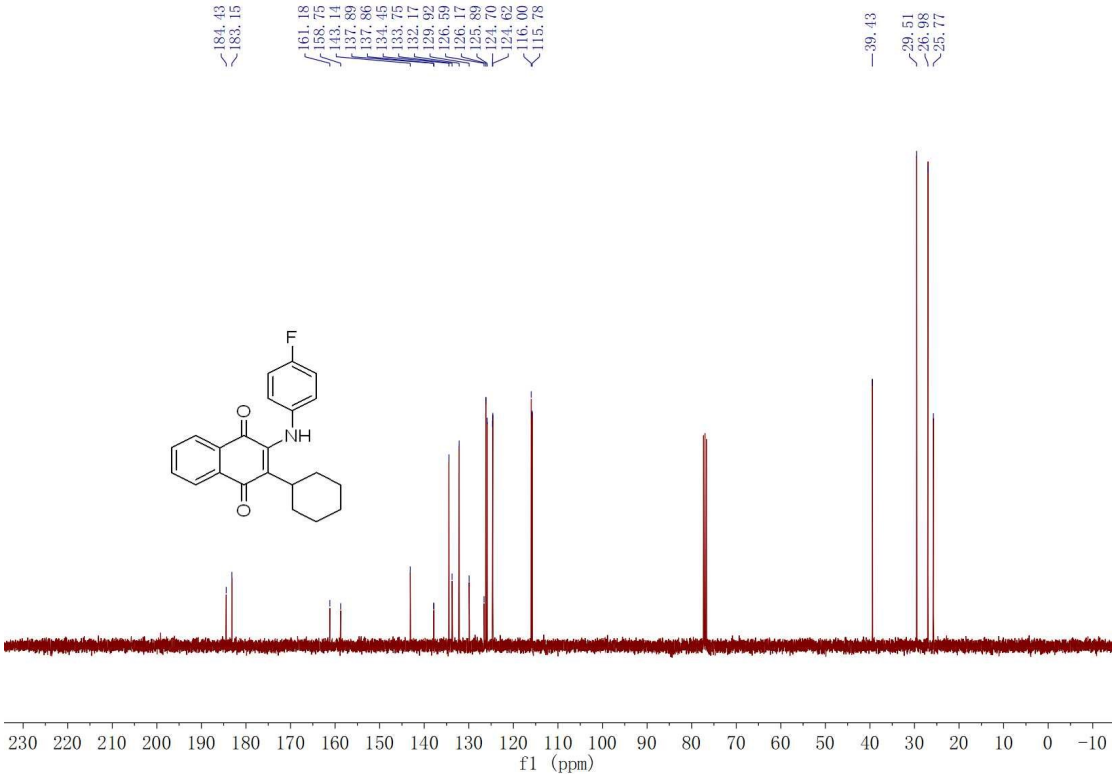

$^{13}$C-NMR spectra of **4a**



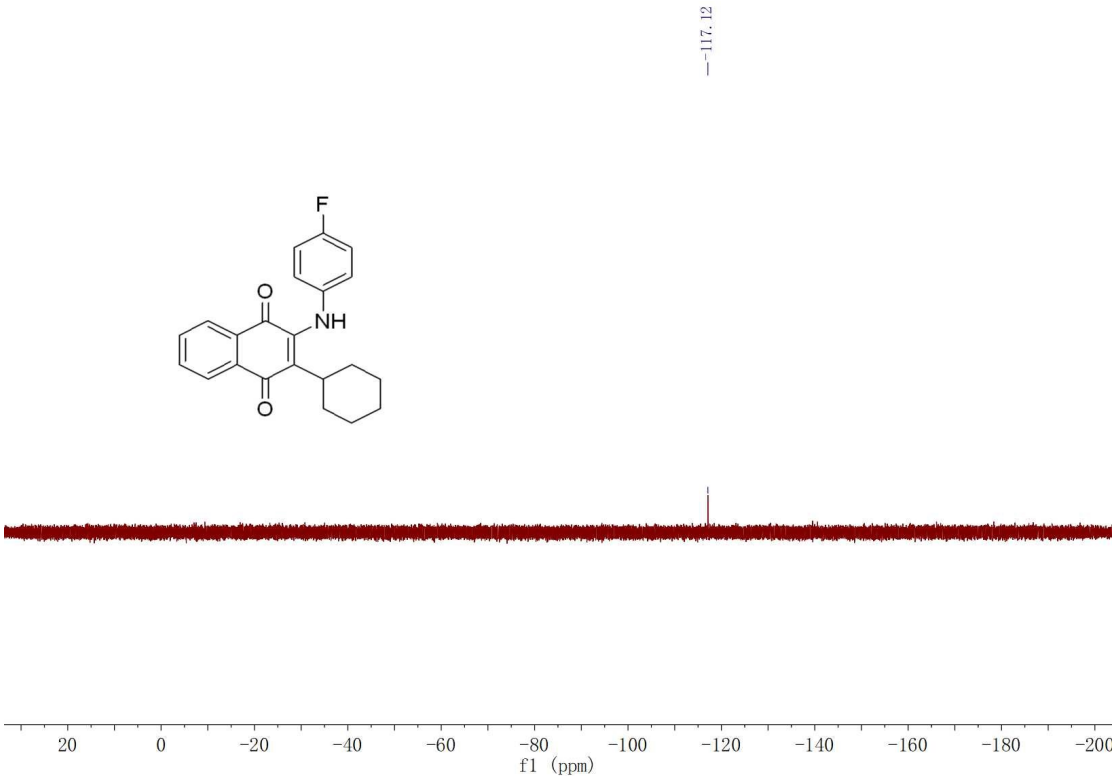
[1]H-NMR spectra of **4b**



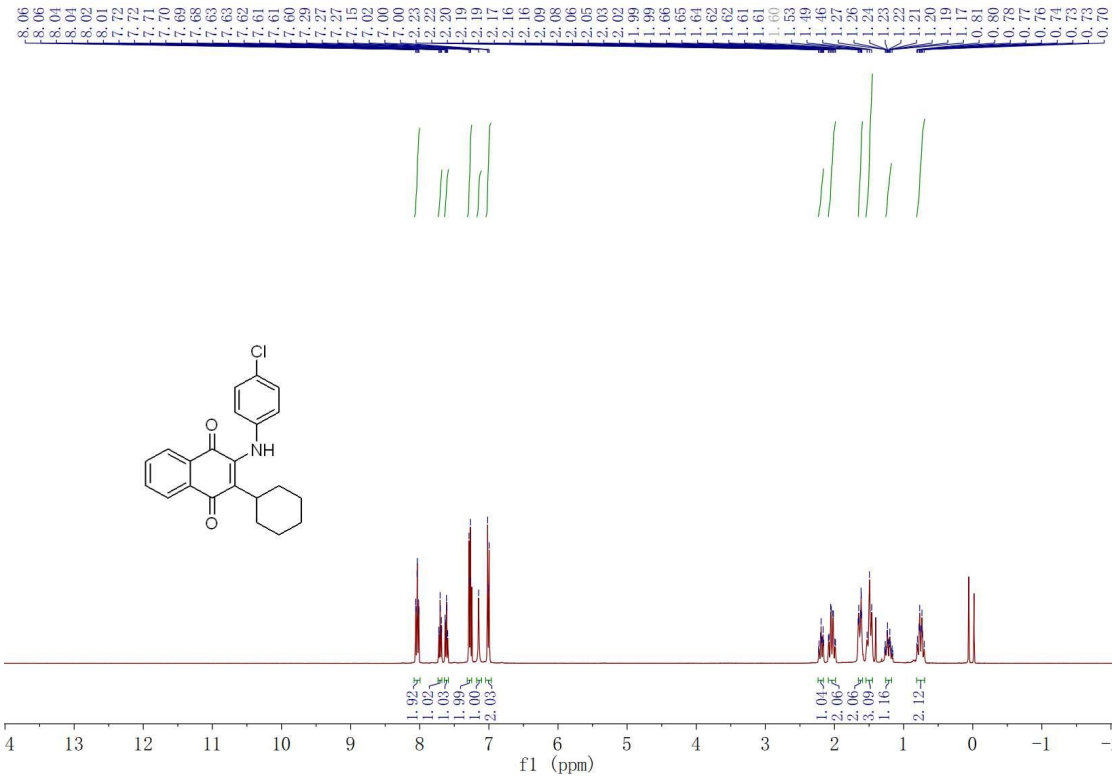

[13]C-NMR spectra of **4b**



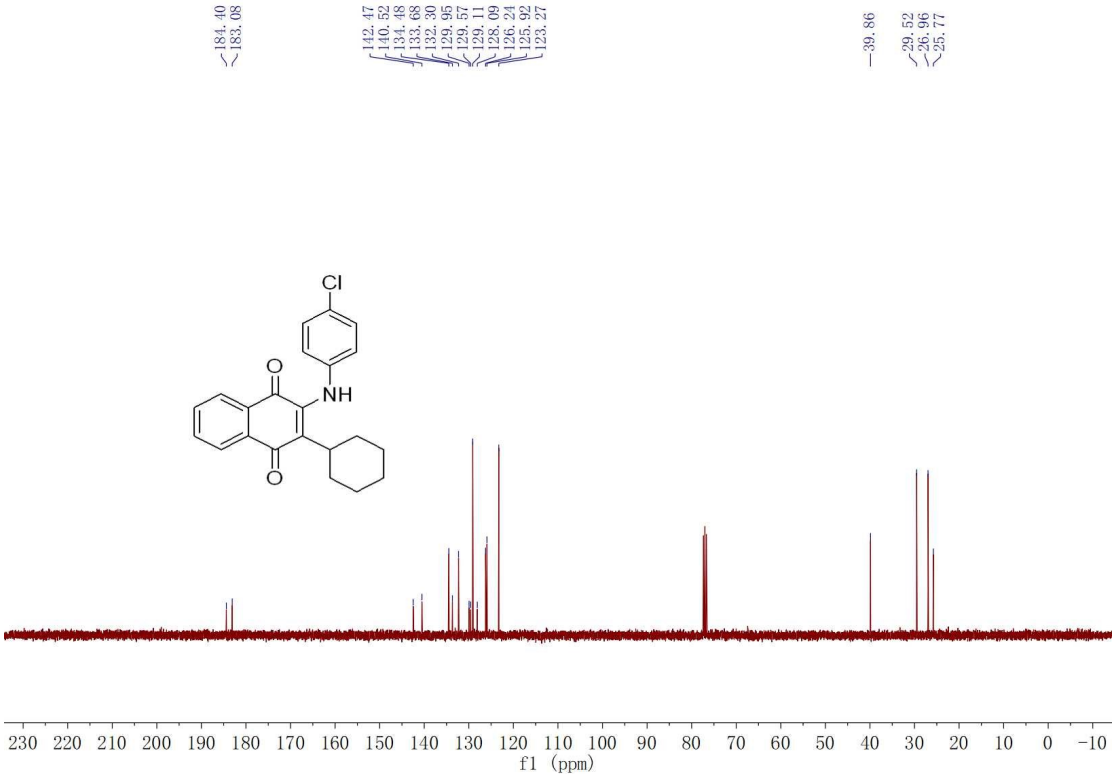
$^{19}$F-NMR spectra of **4b**



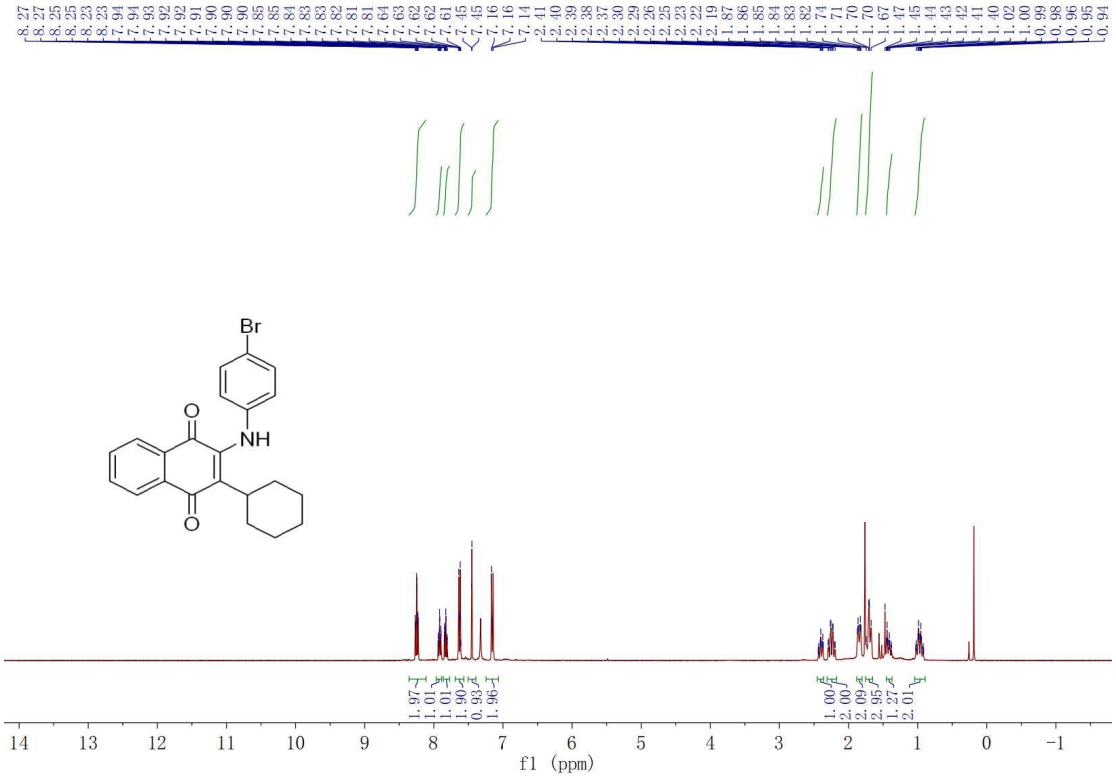
[1]H-NMR spectra of **4c**



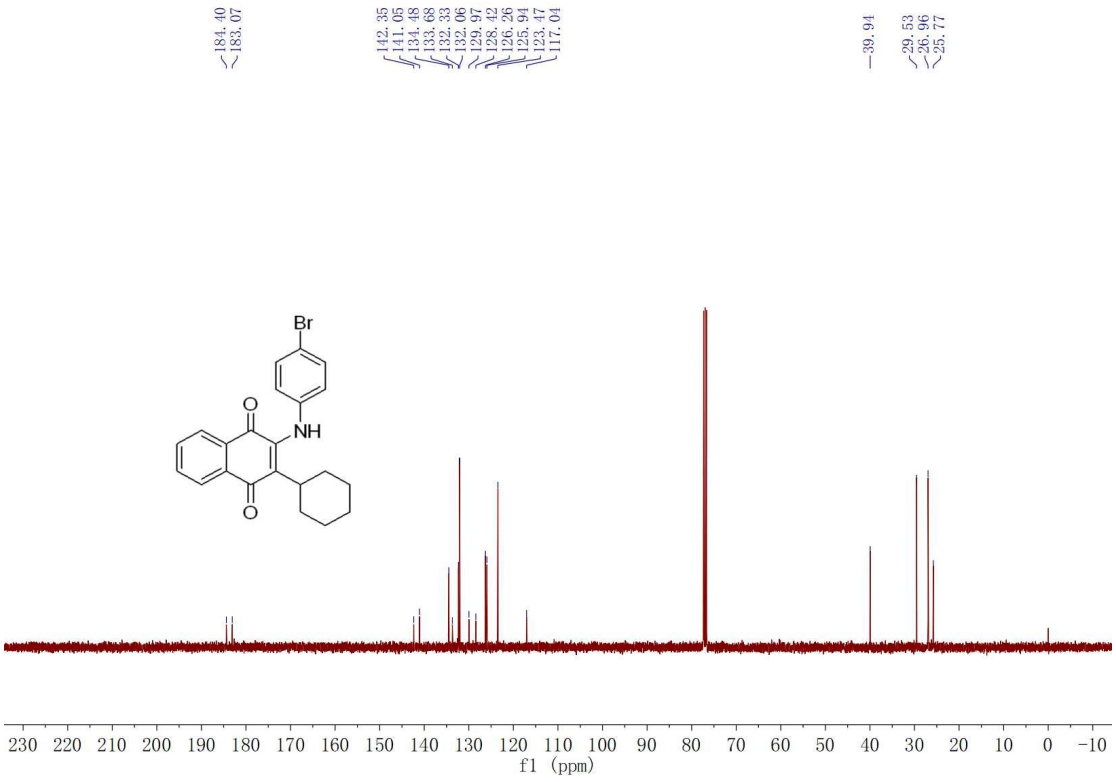

[13]C-NMR spectra of **4c**



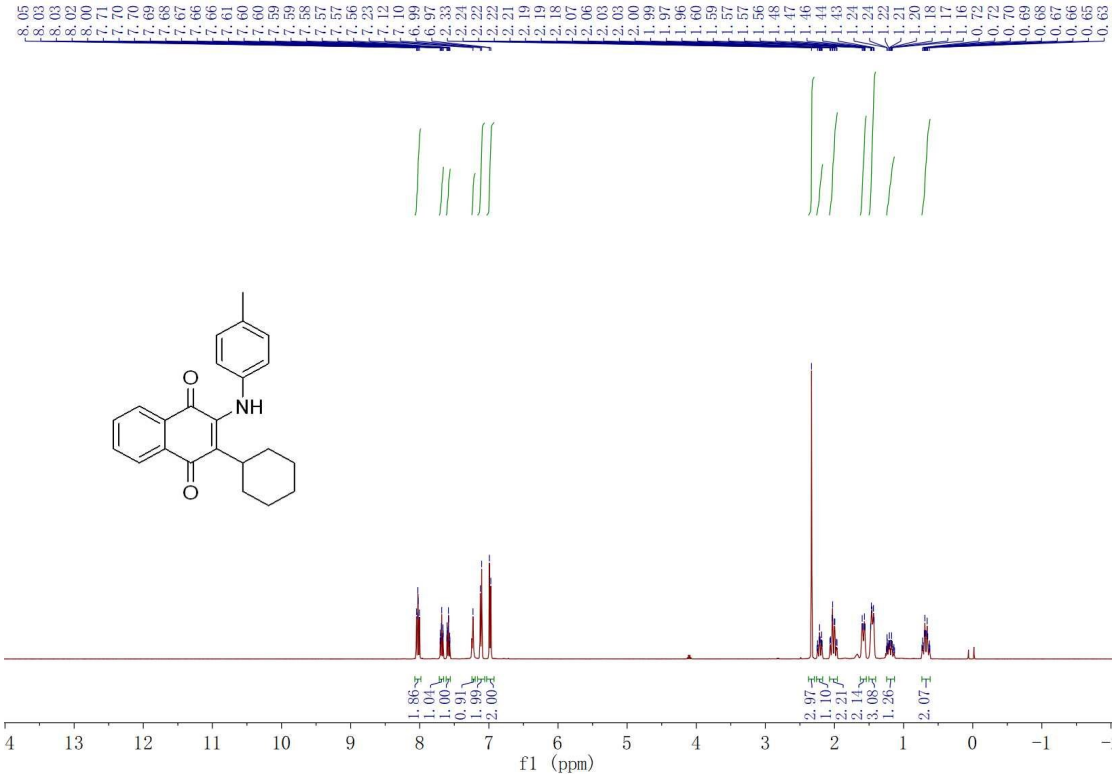
$^{1}$H-NMR spectra of **4d**



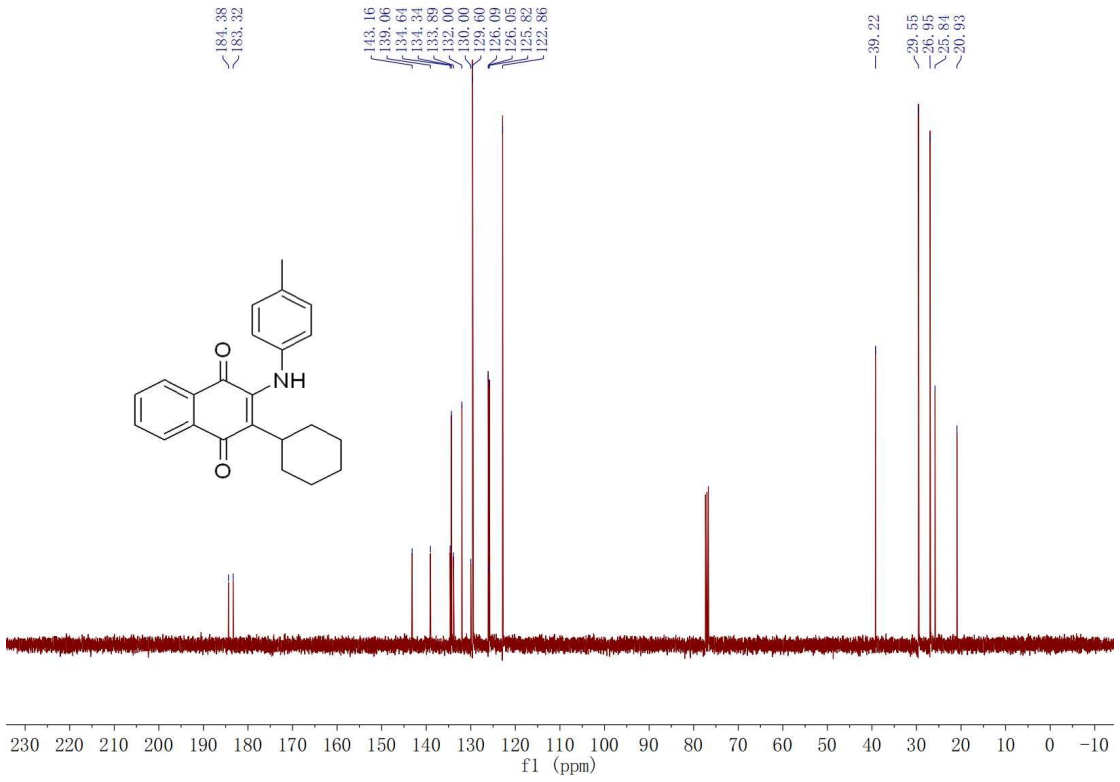

$^{13}$C-NMR spectra of **4d**



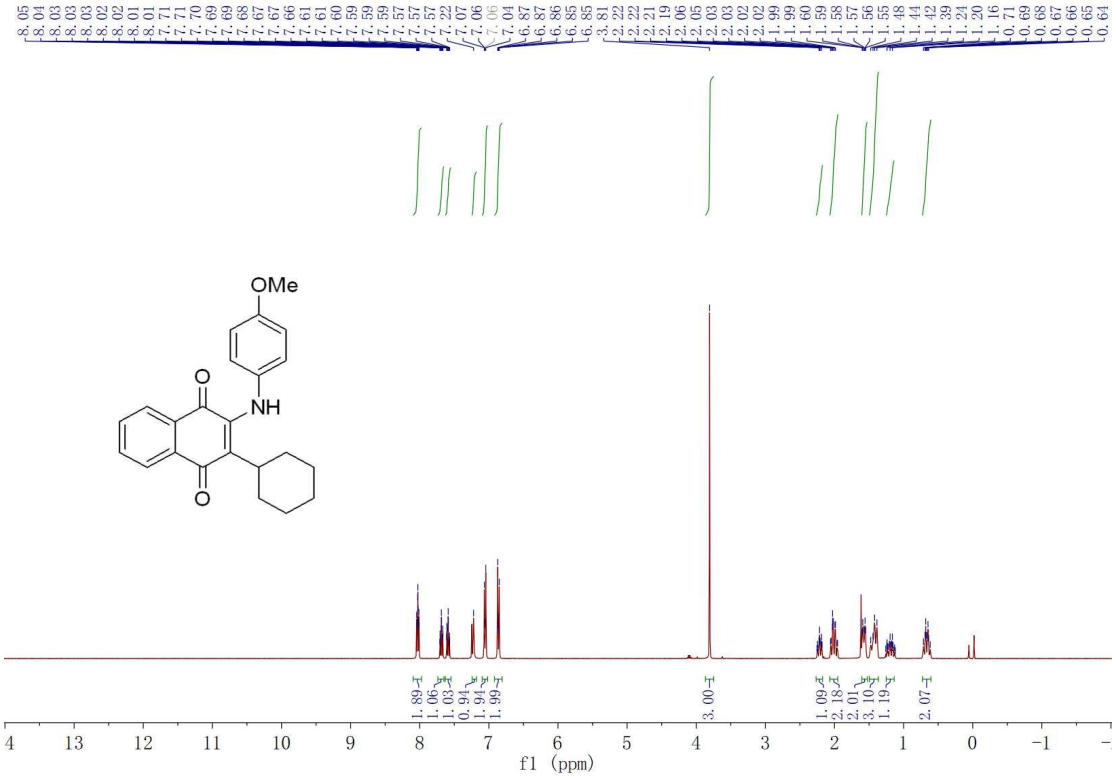
$^{1}$H-NMR spectra of **4e**



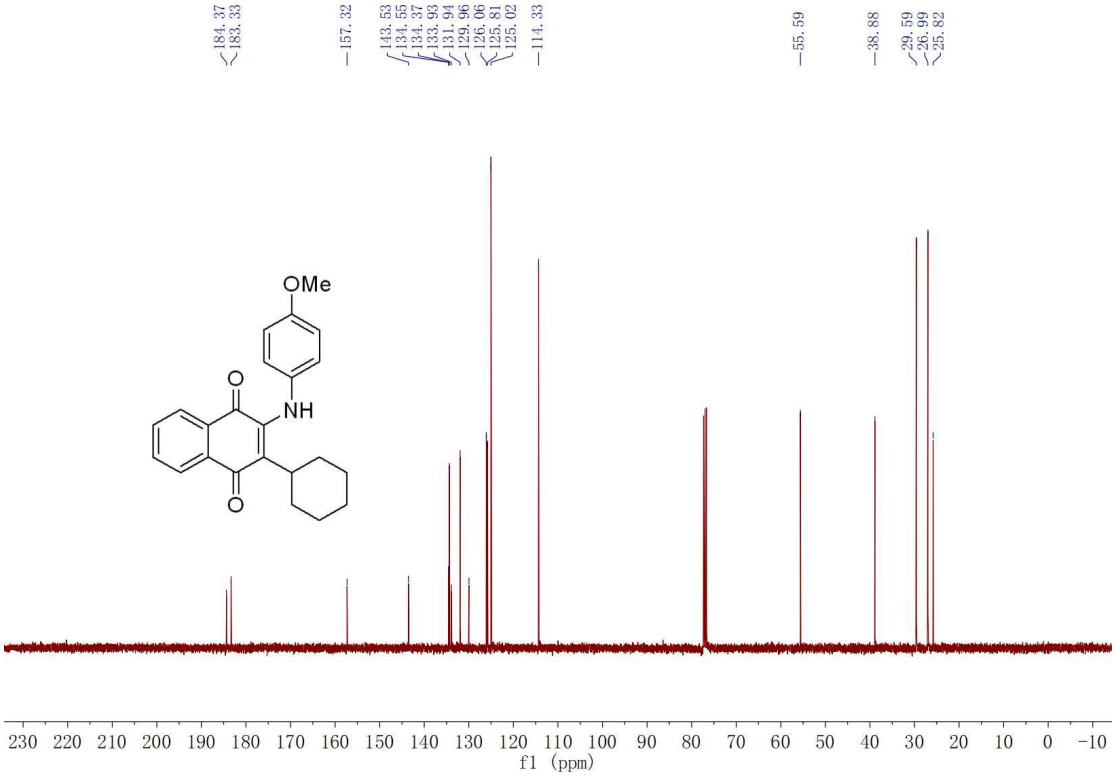

$^{13}$C-NMR spectra of **4e**



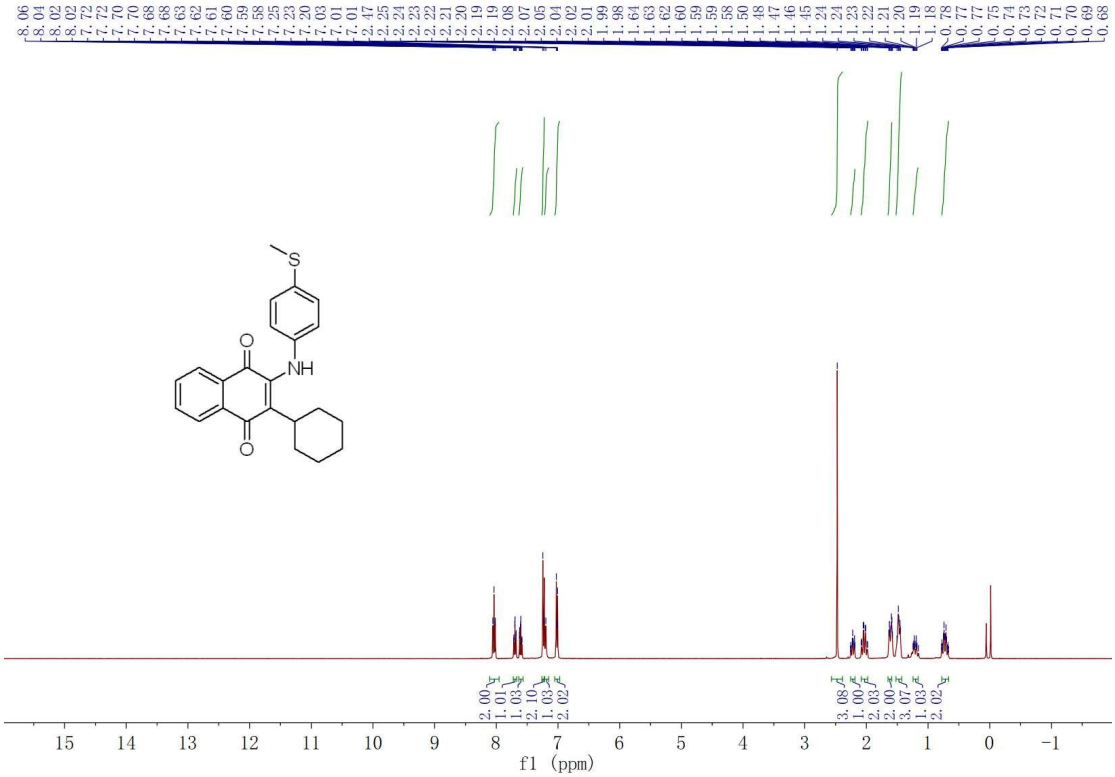
[1]H-NMR spectra of **4f**



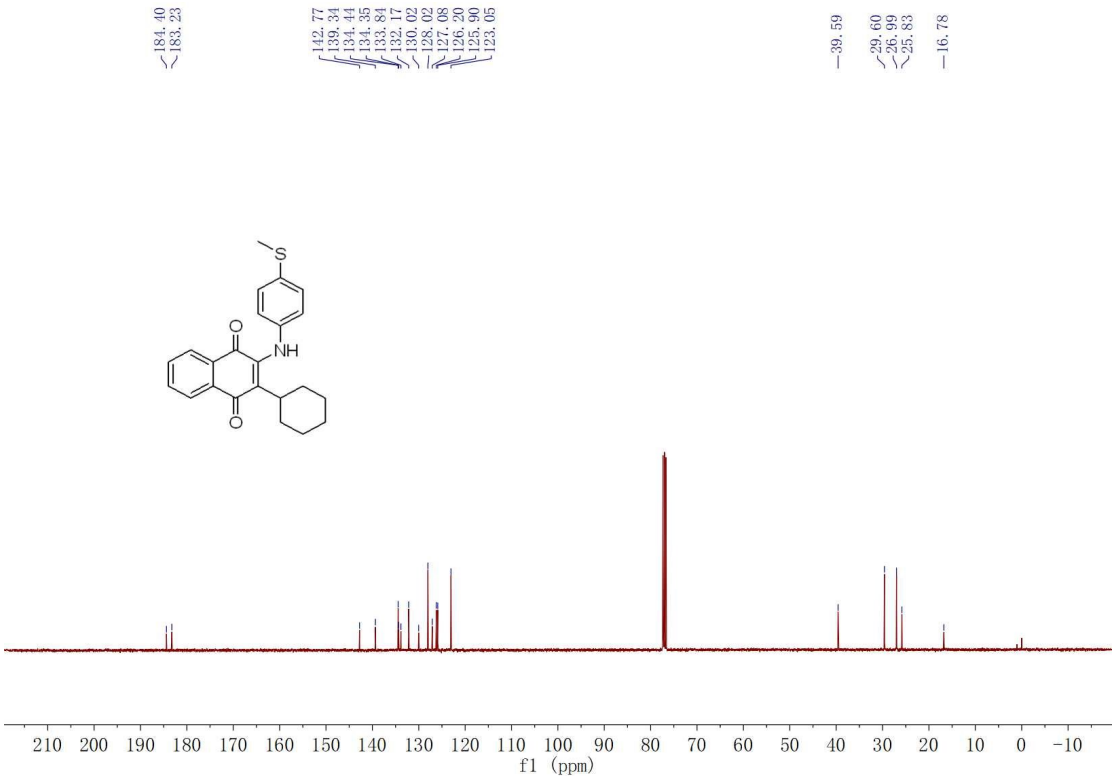

[13]C-NMR spectra of **4f**



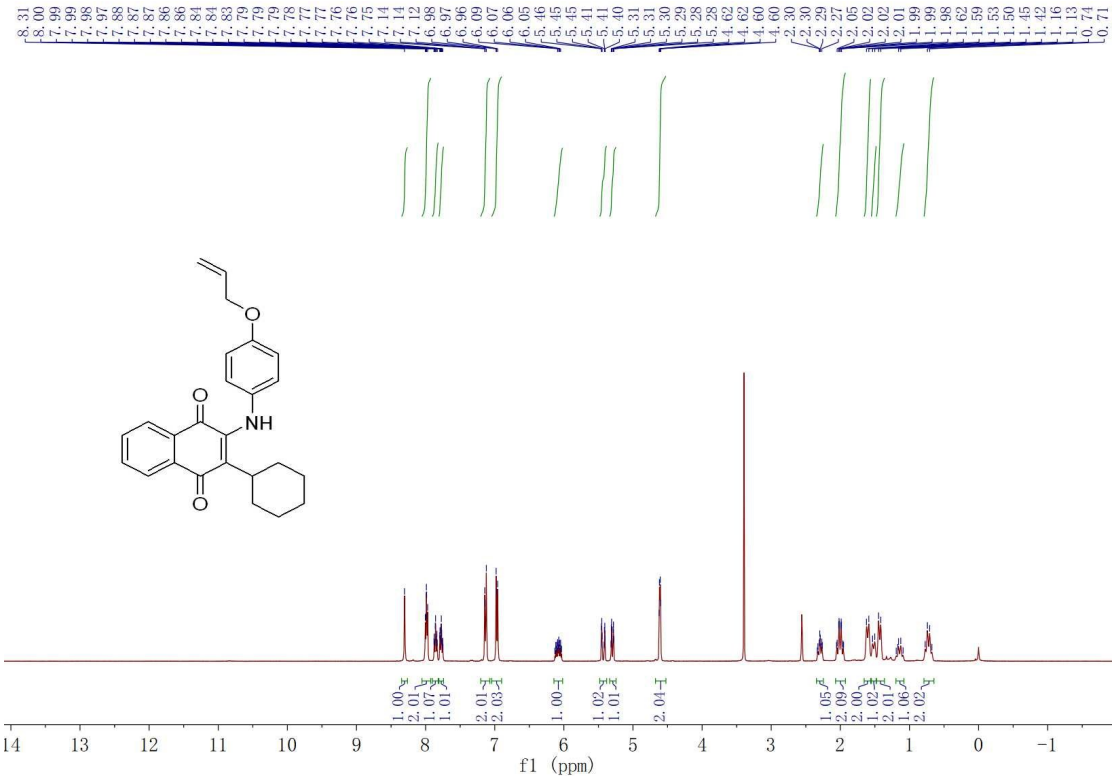
$^{1}$H-NMR spectra of **4g**



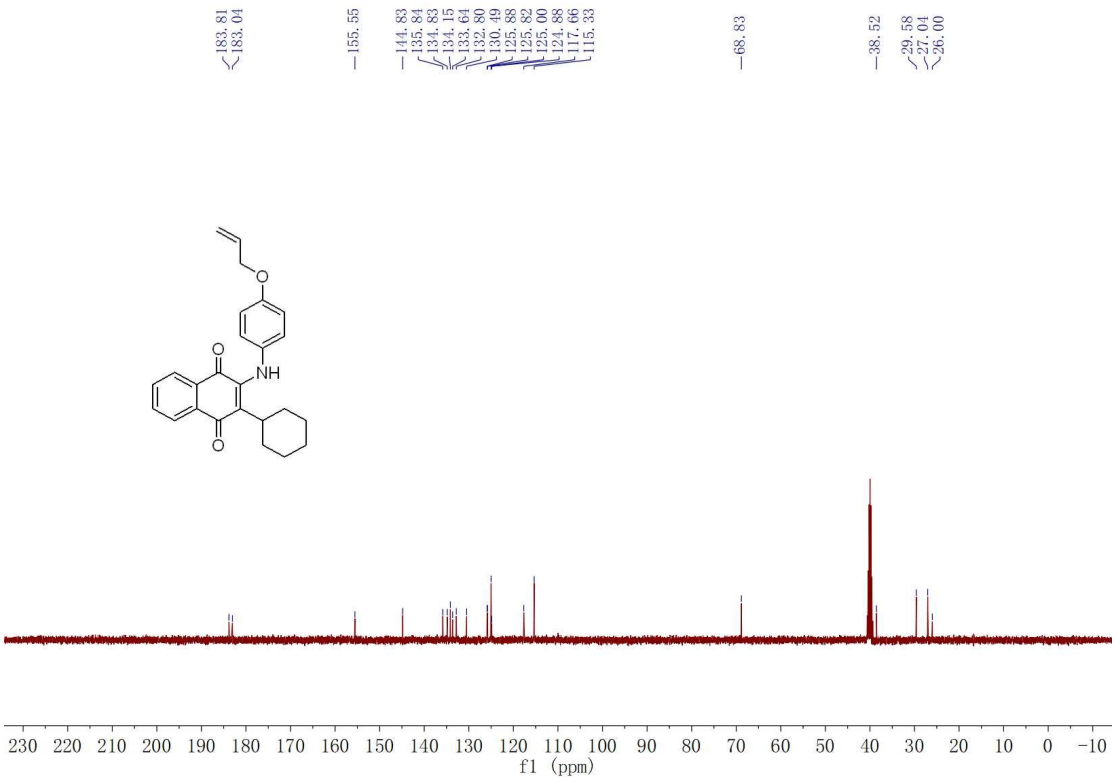

$^{13}$C-NMR spectra of **4i**



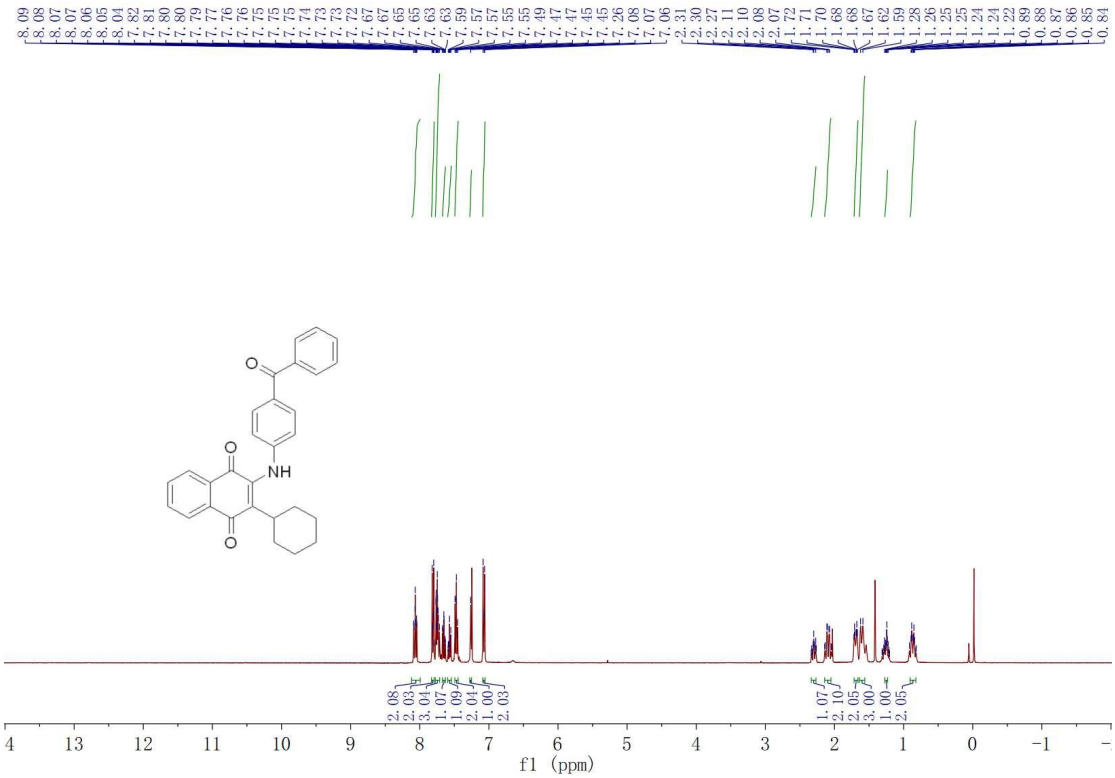
[1]H-NMR spectra of **4h**



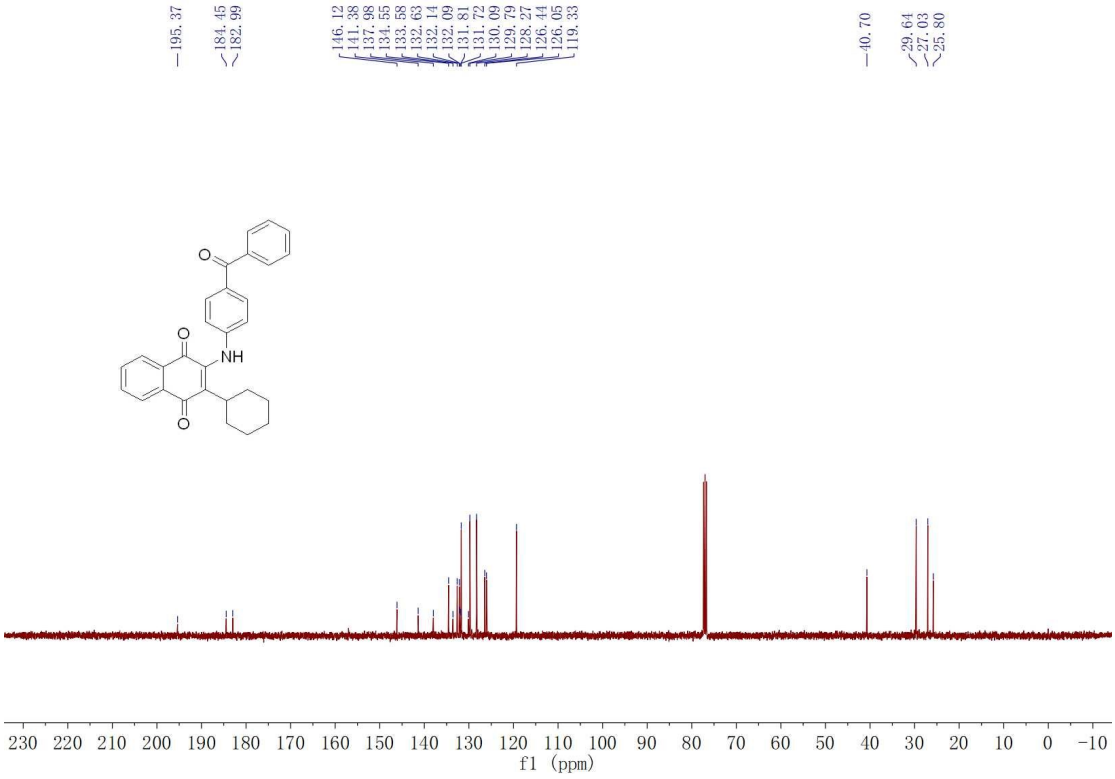

[13]C-NMR spectra of **4i**



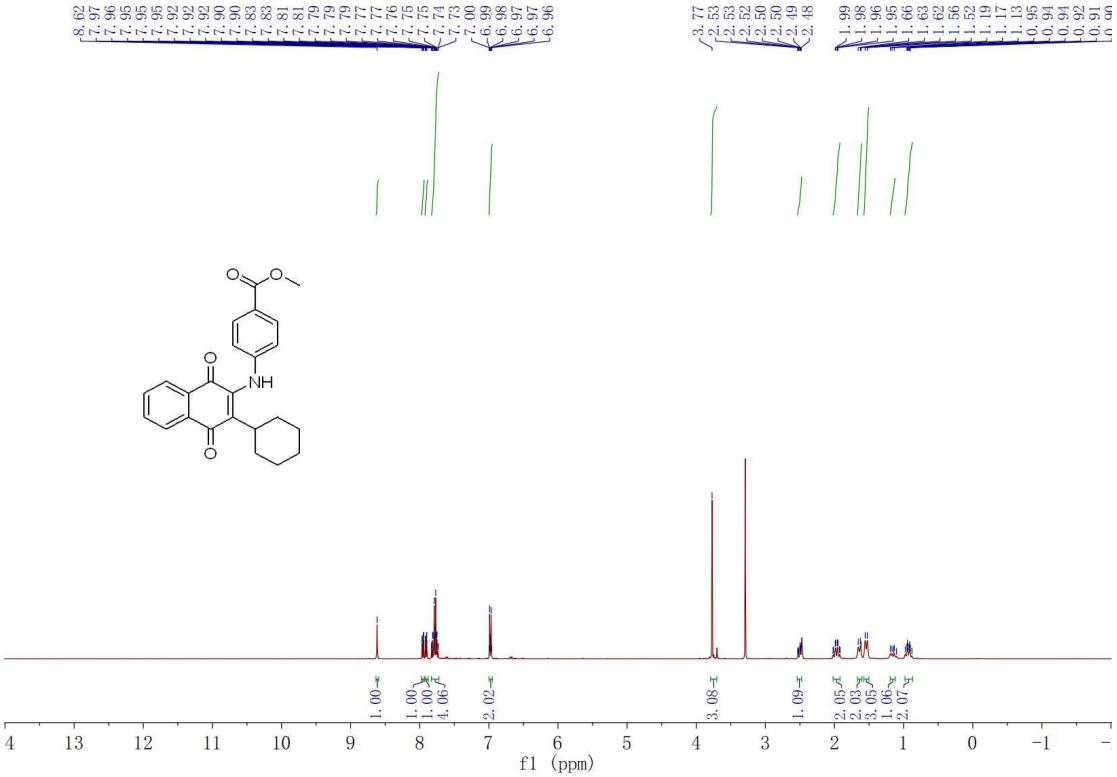
$^{1}$H-NMR spectra of **4i**



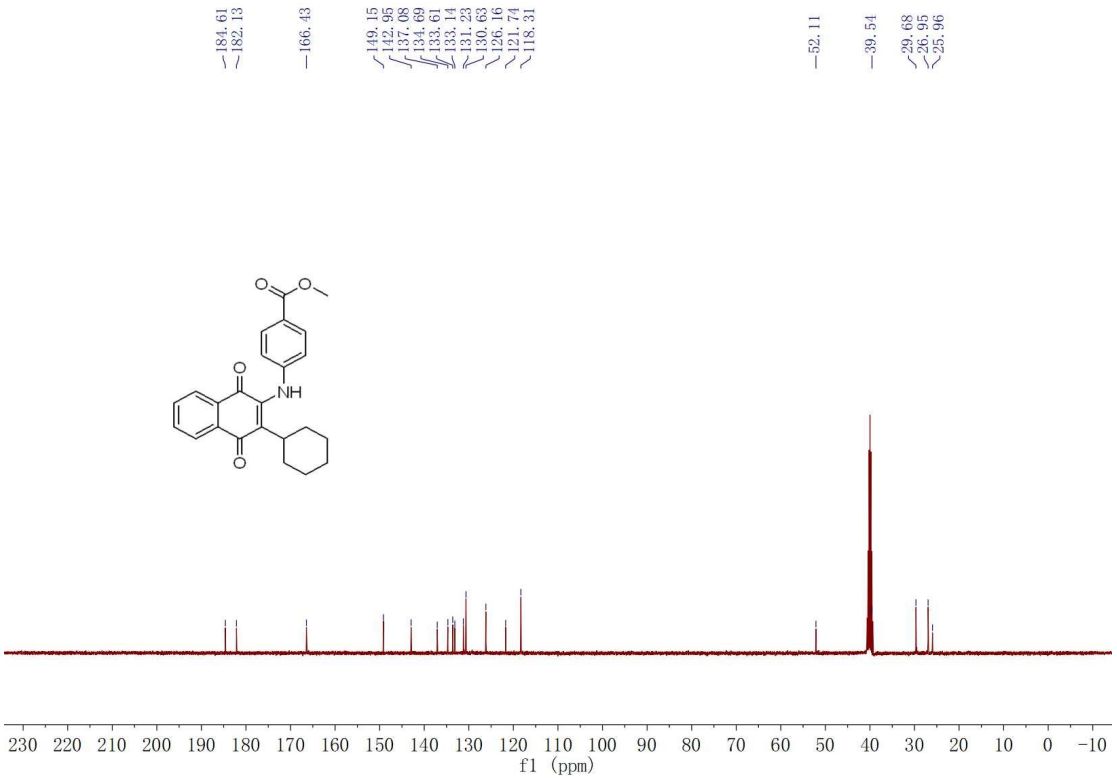

$^{13}$C-NMR spectra of **4i**



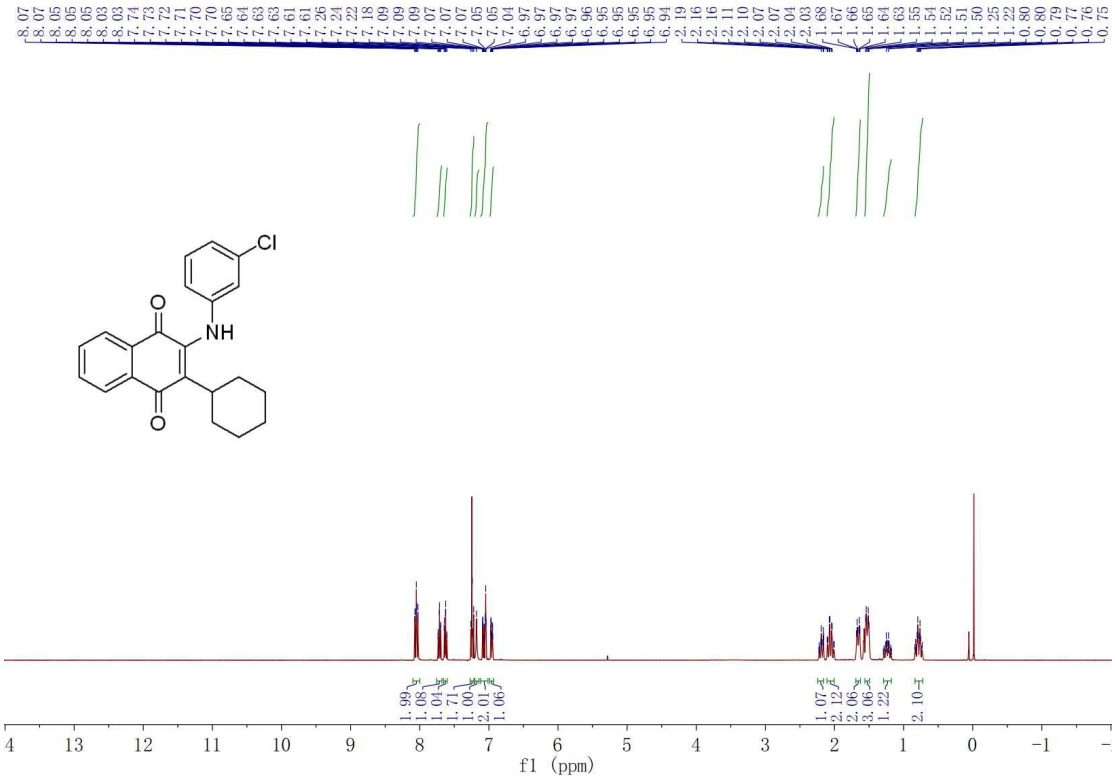
$^{1}$H-NMR spectra of **4j**



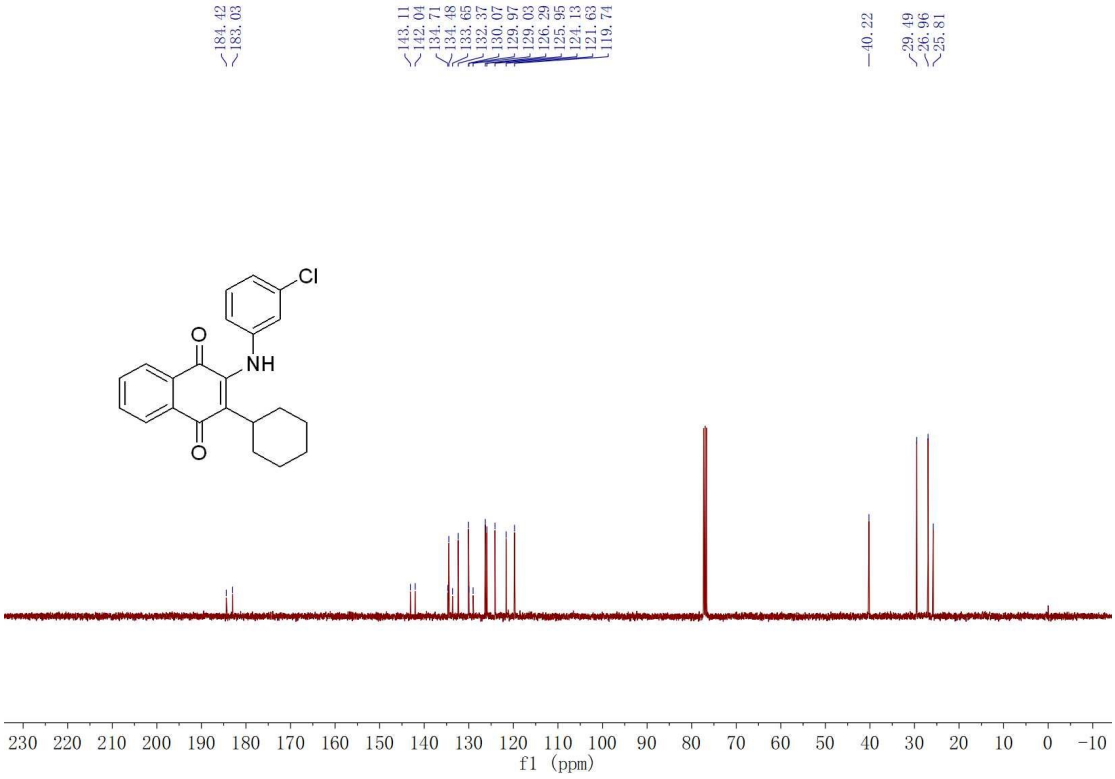

$^{13}$C-NMR spectra of **4j**



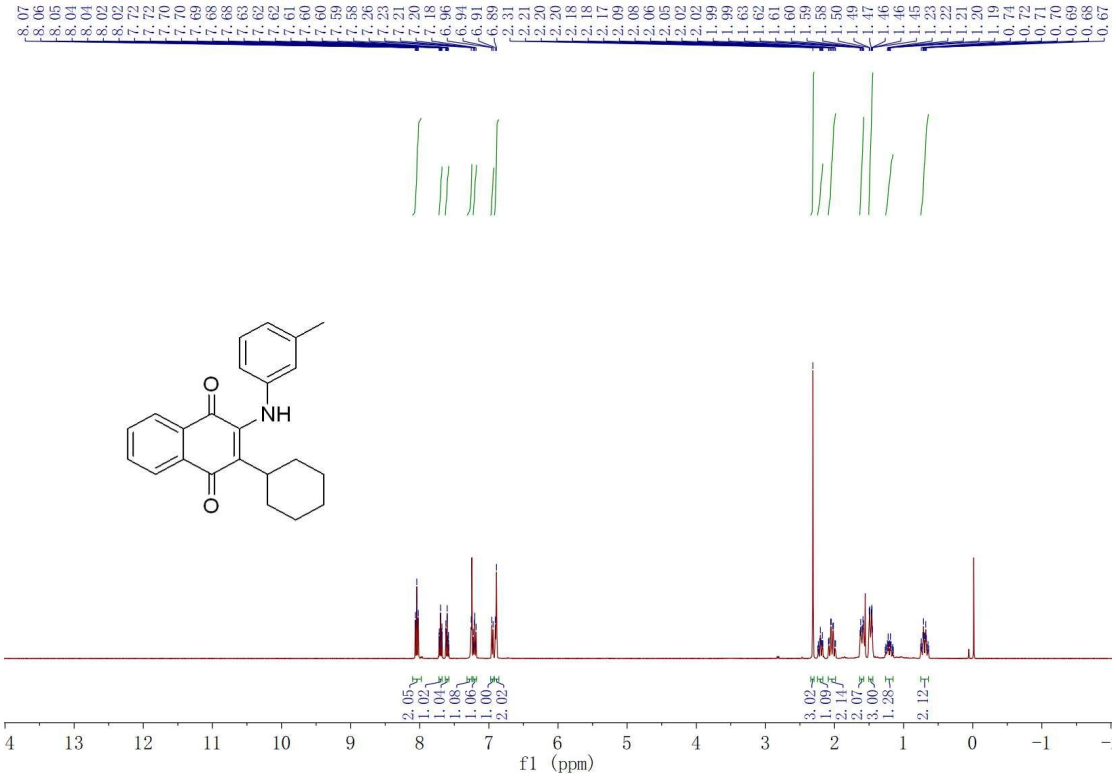
[1]H-NMR spectra of **4k**



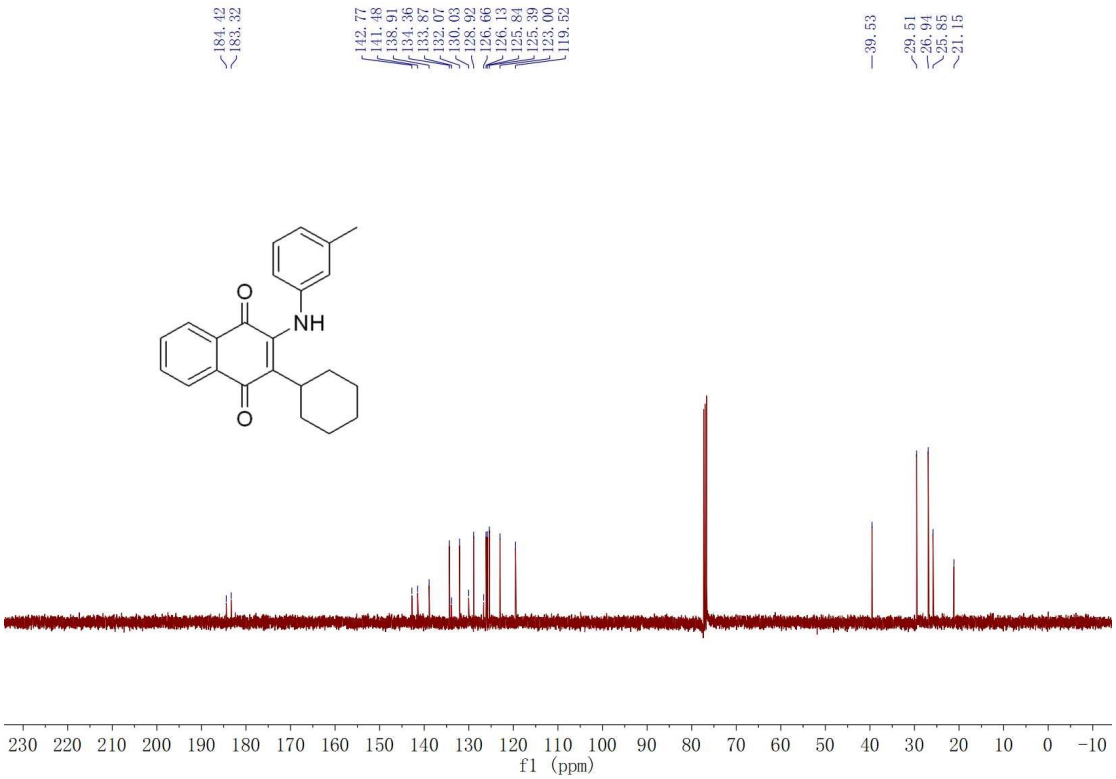

[13]C-NMR spectra of **4k**



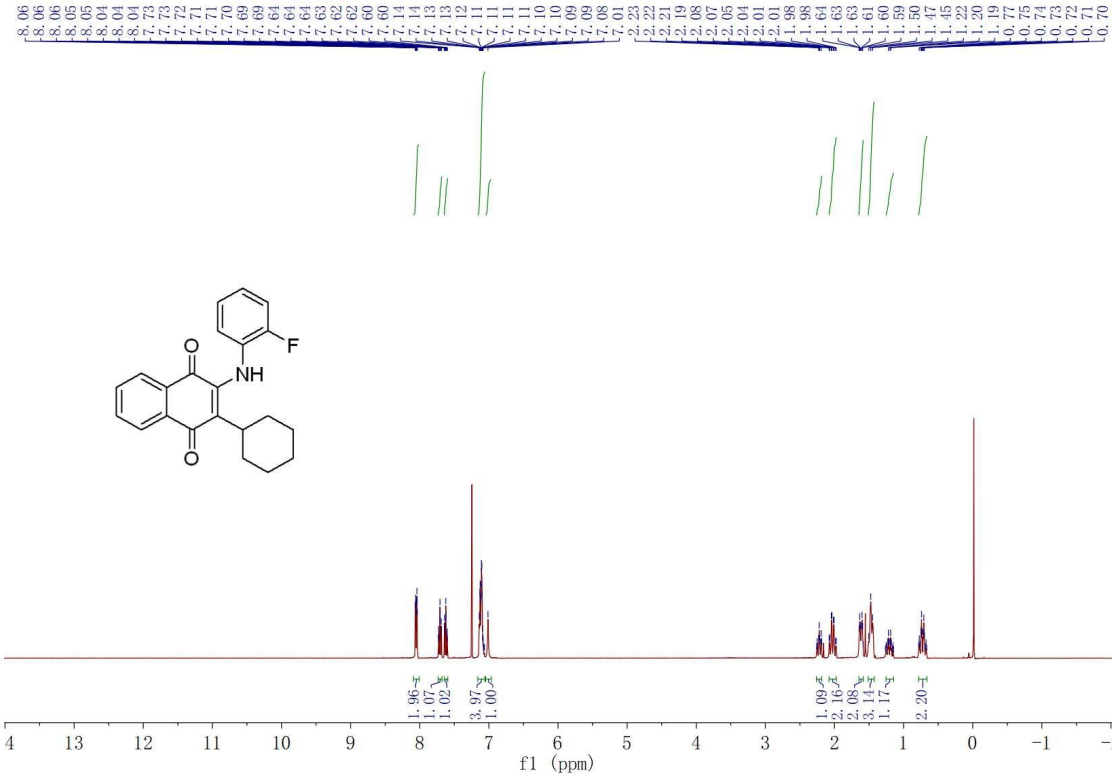
[1]H-NMR spectra of **4l**



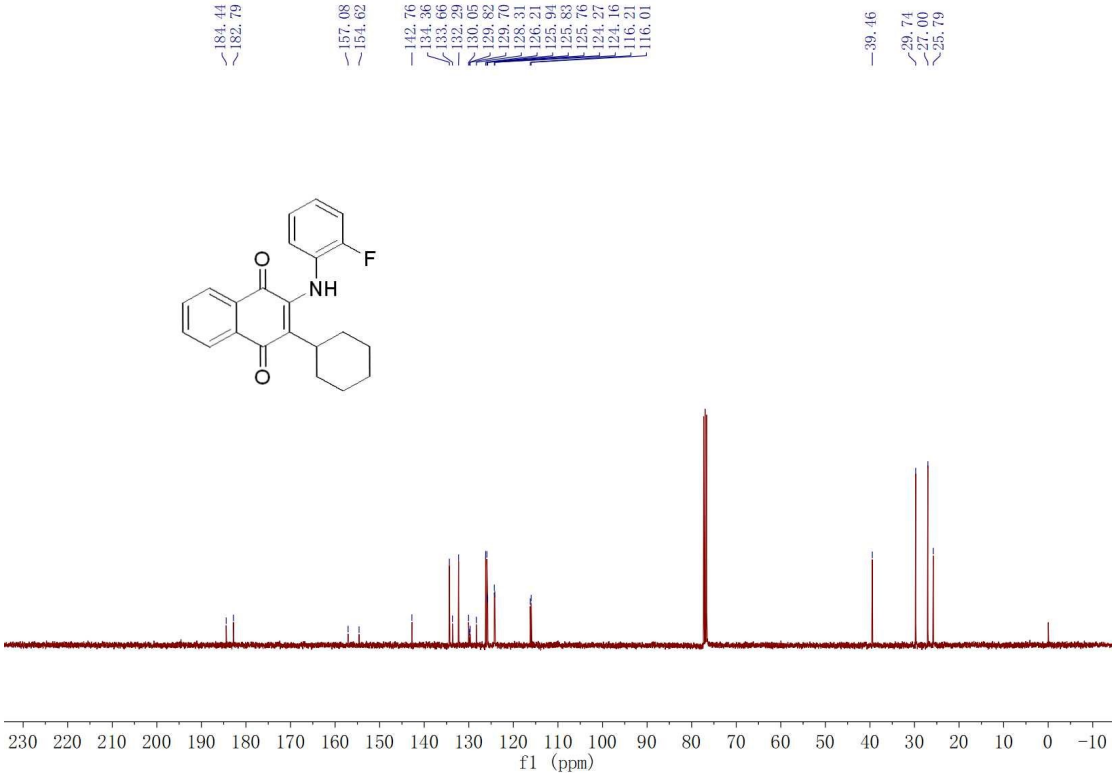

[13]C-NMR spectra of **4l**



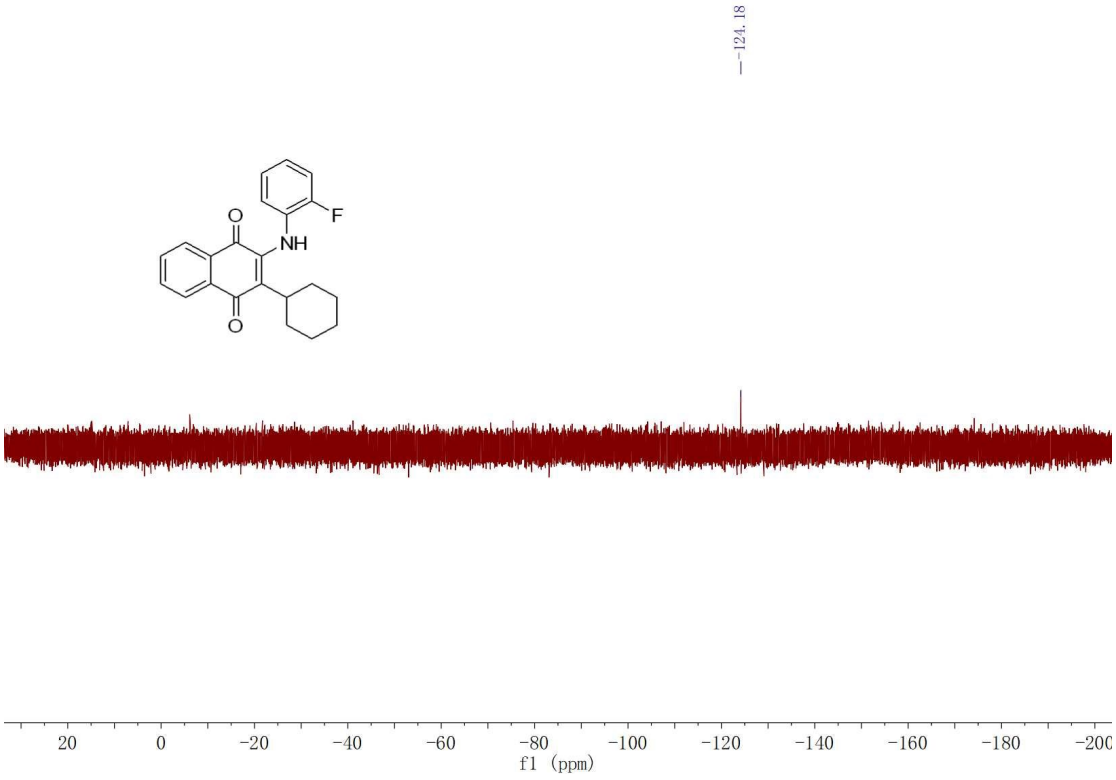
[1]H-NMR spectra of **4m**



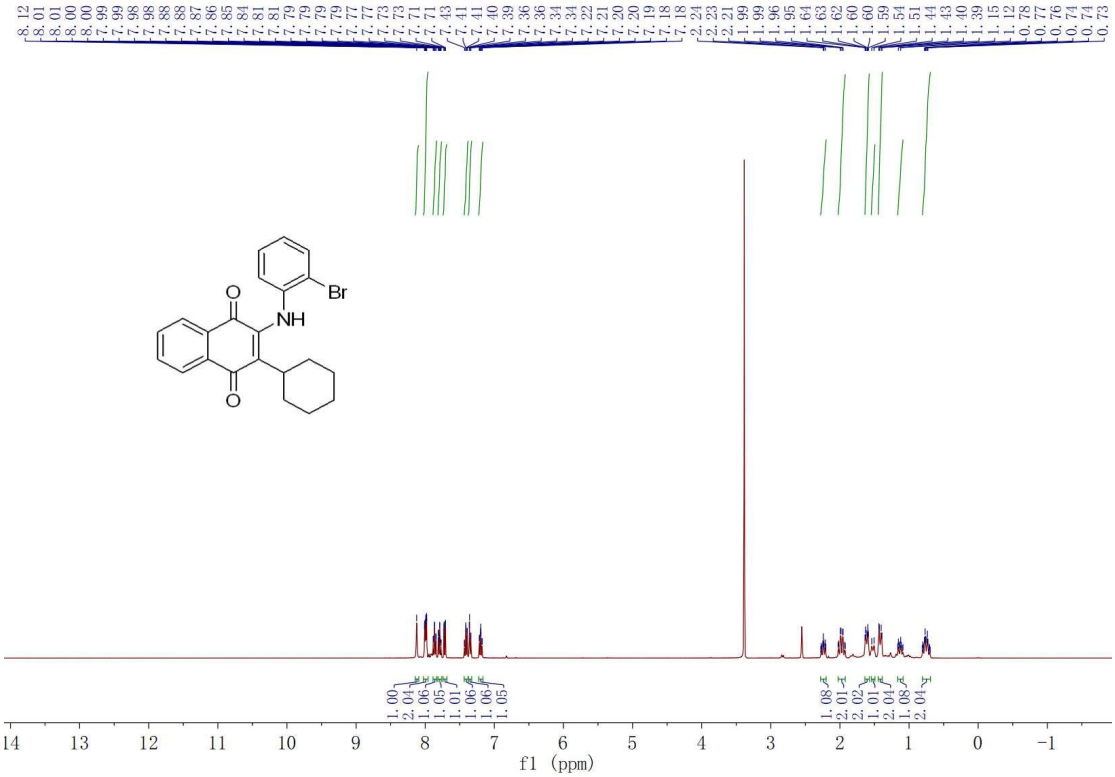

[13]C-NMR spectra of **4m**



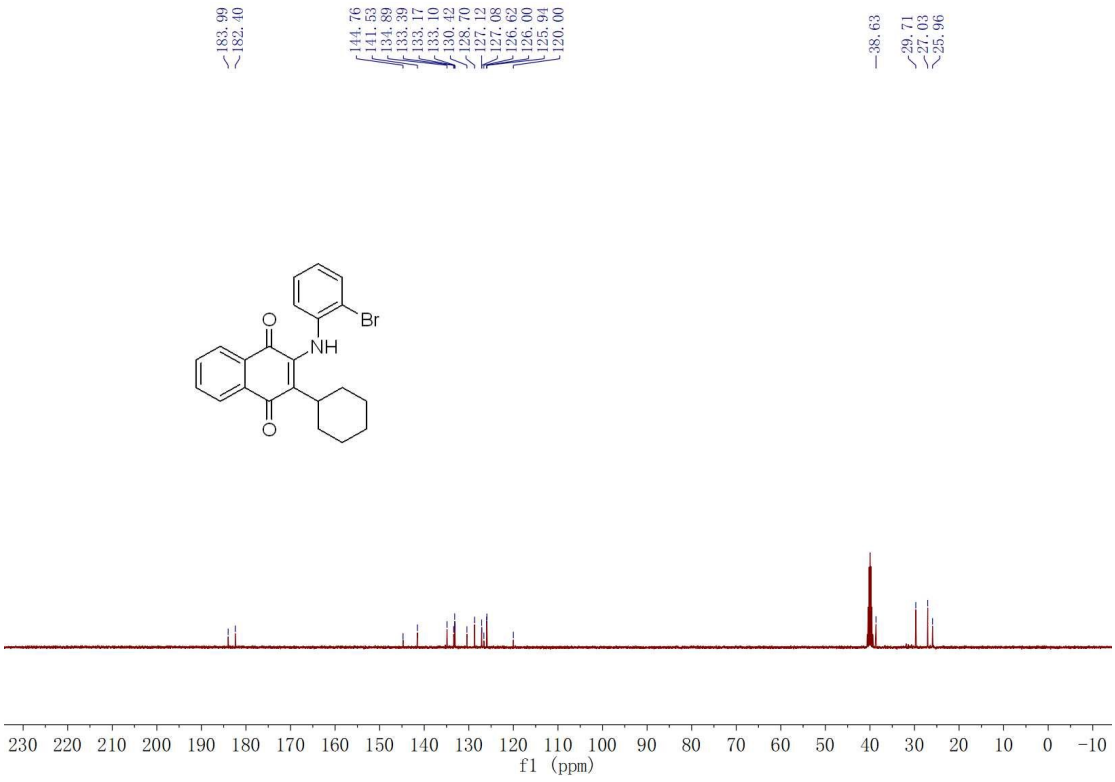
$^{19}$F-NMR spectra of **4m**



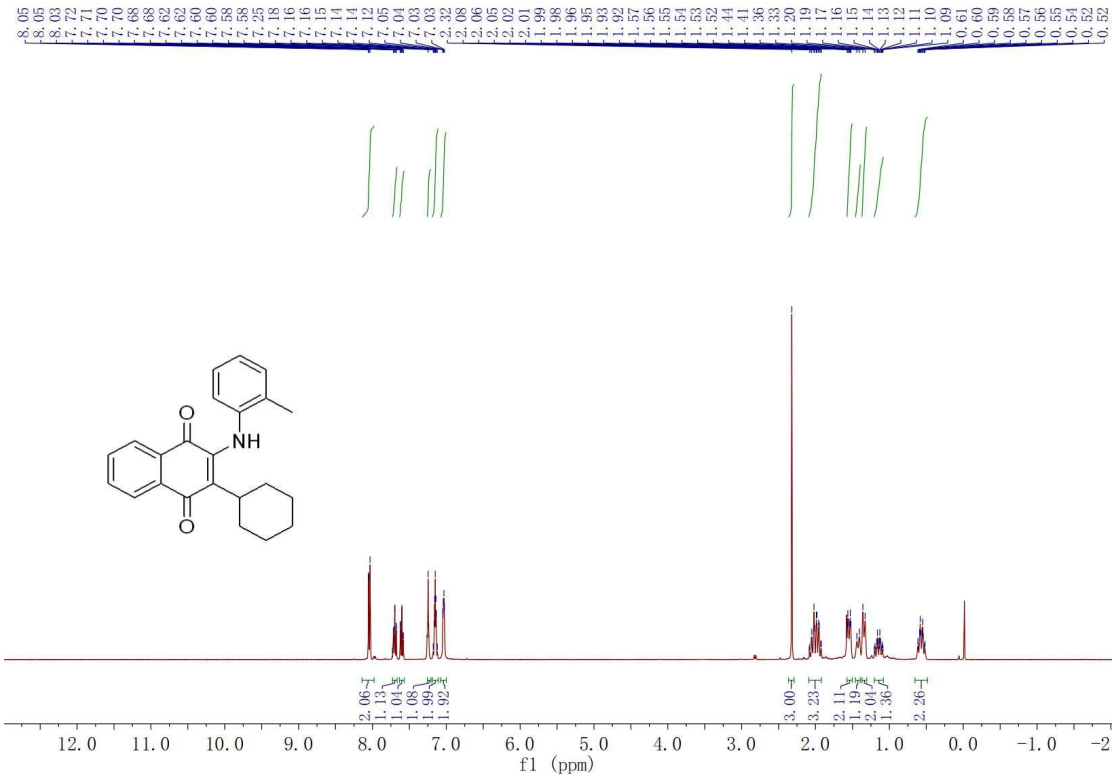
$^{1}$H-NMR spectra of **4n**



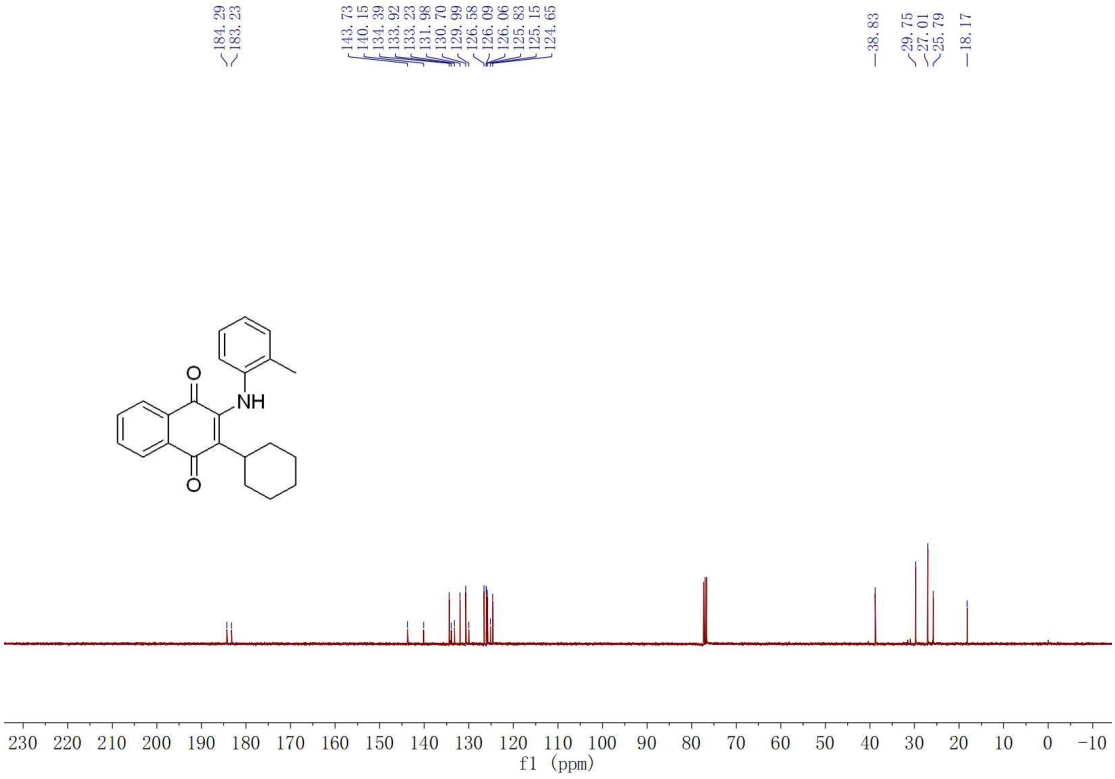

$^{13}$C-NMR spectra of **4n**



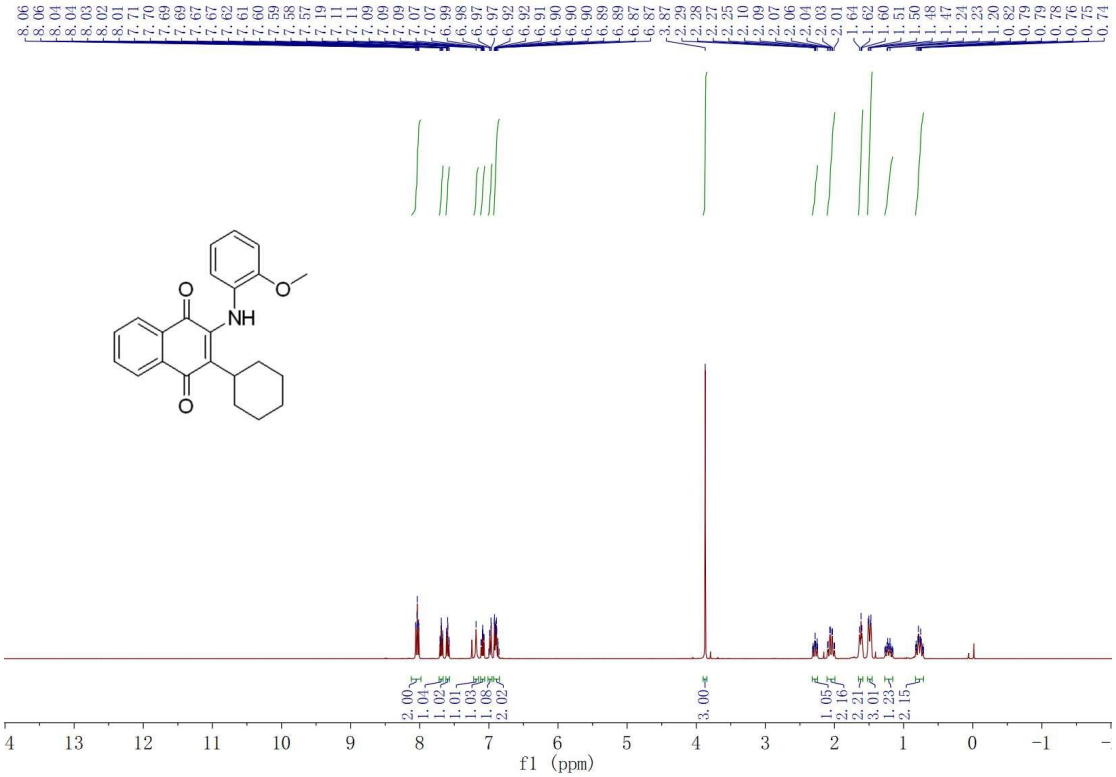
[1]H-NMR spectra of **4o**



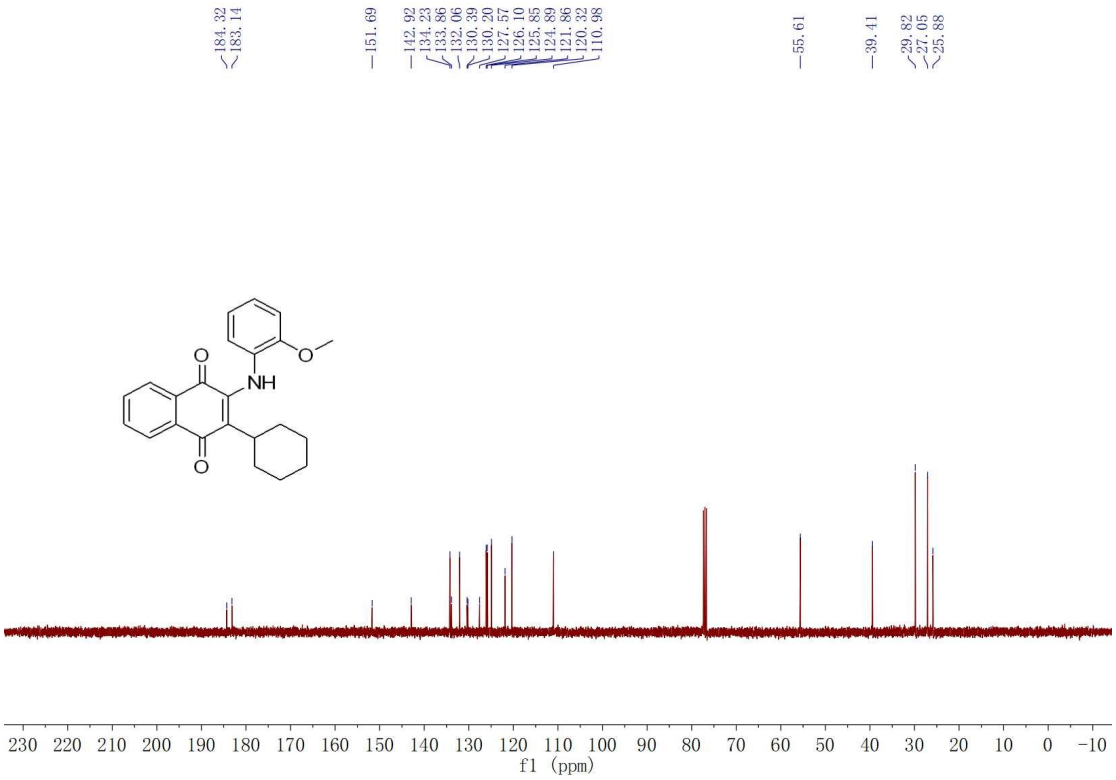

[13]C-NMR spectra of **4o**



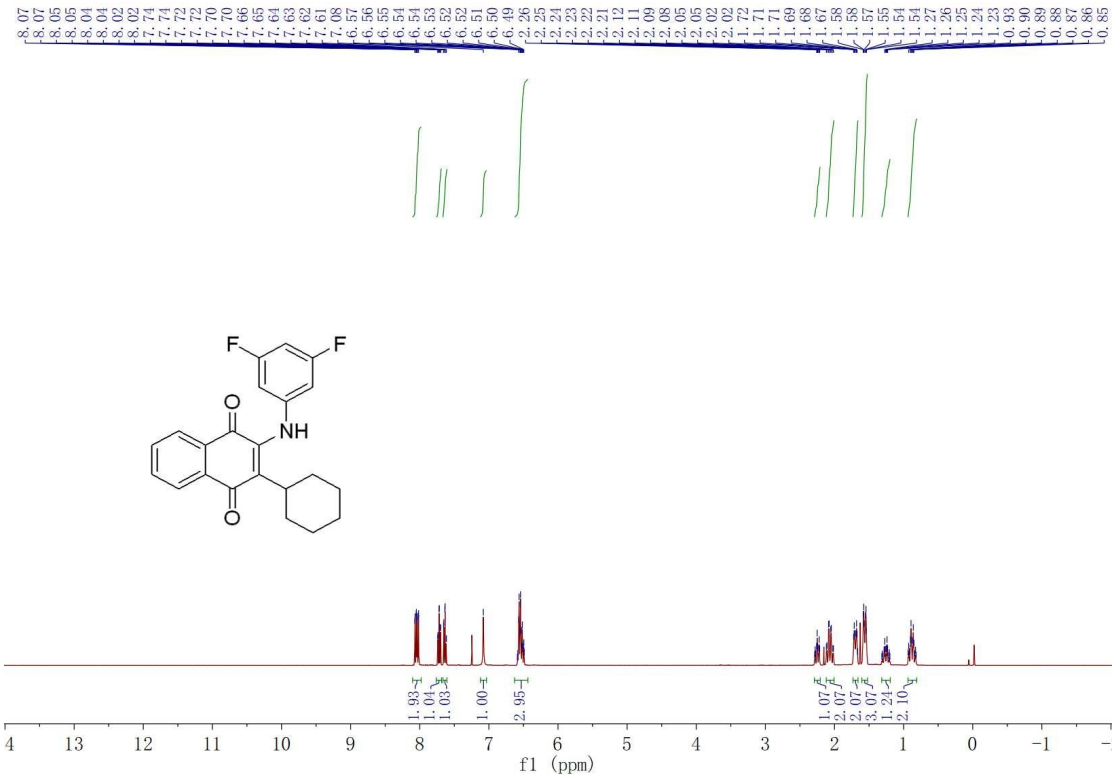
$^{1}$H-NMR spectra of **4p**



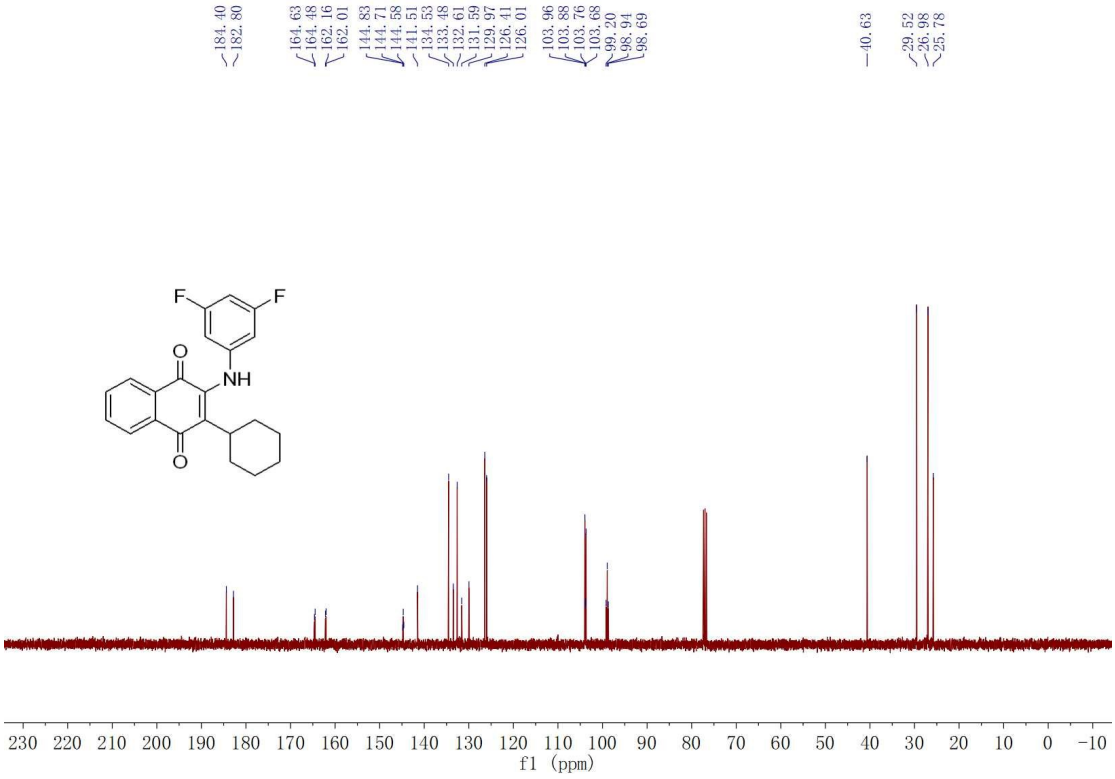

$^{13}$C-NMR spectra of **4p**



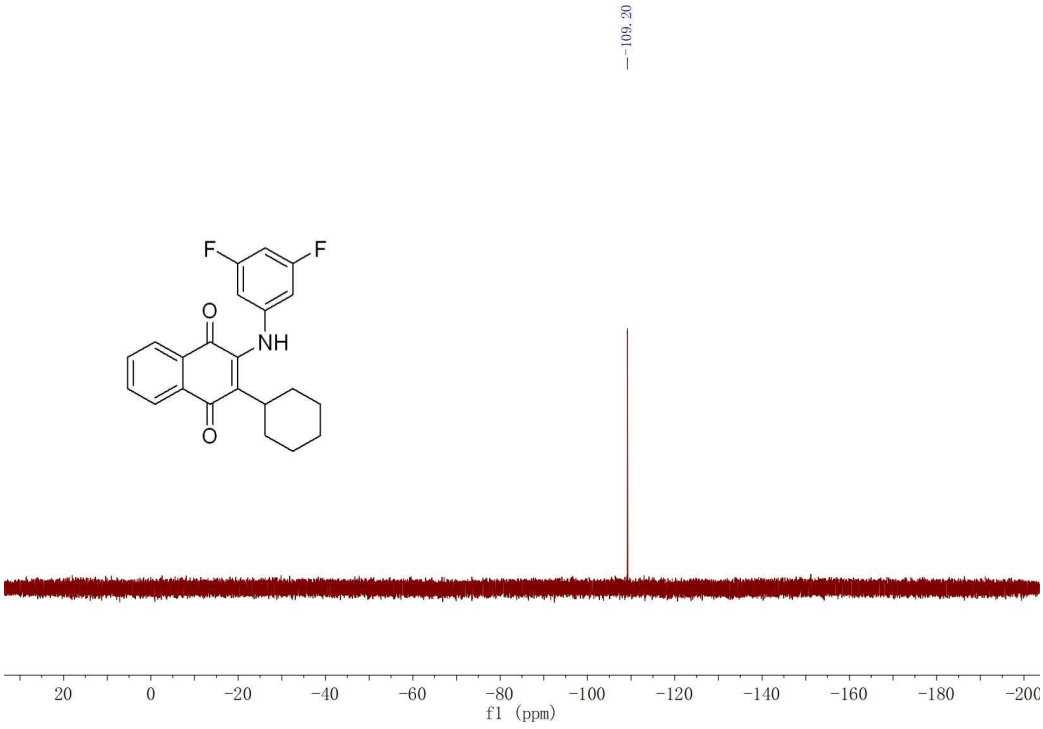
[1]H-NMR spectra of **4q**



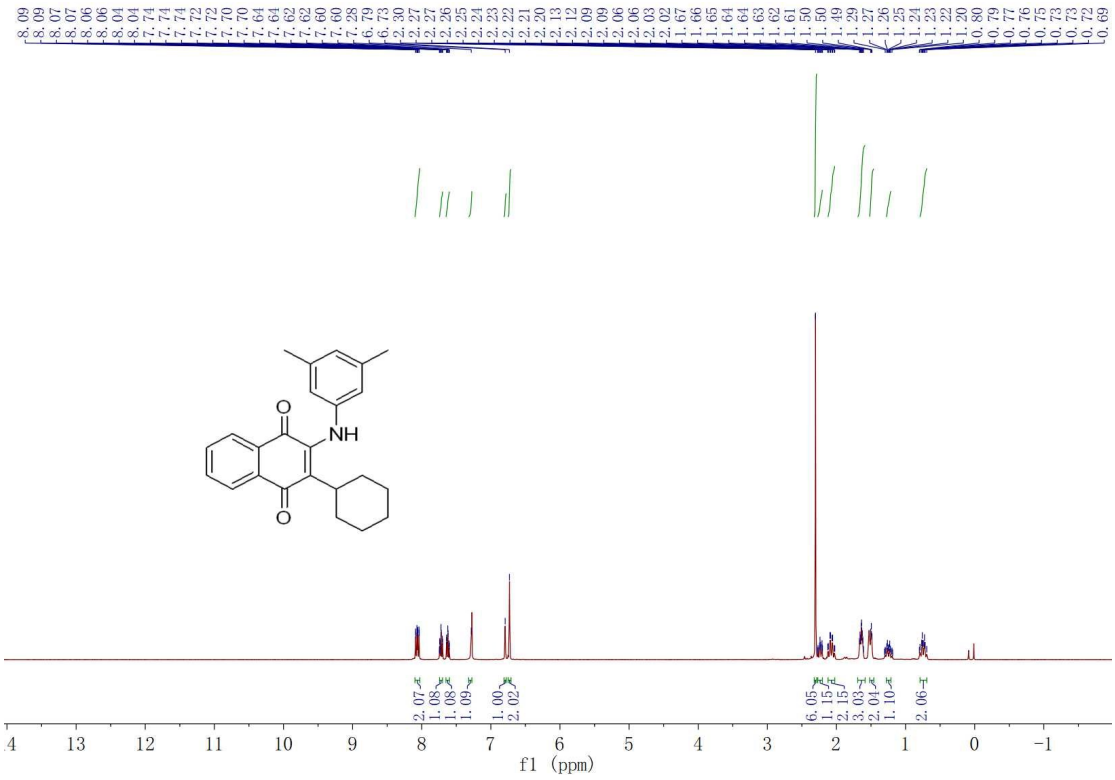

[13]C-NMR spectra of **4q**



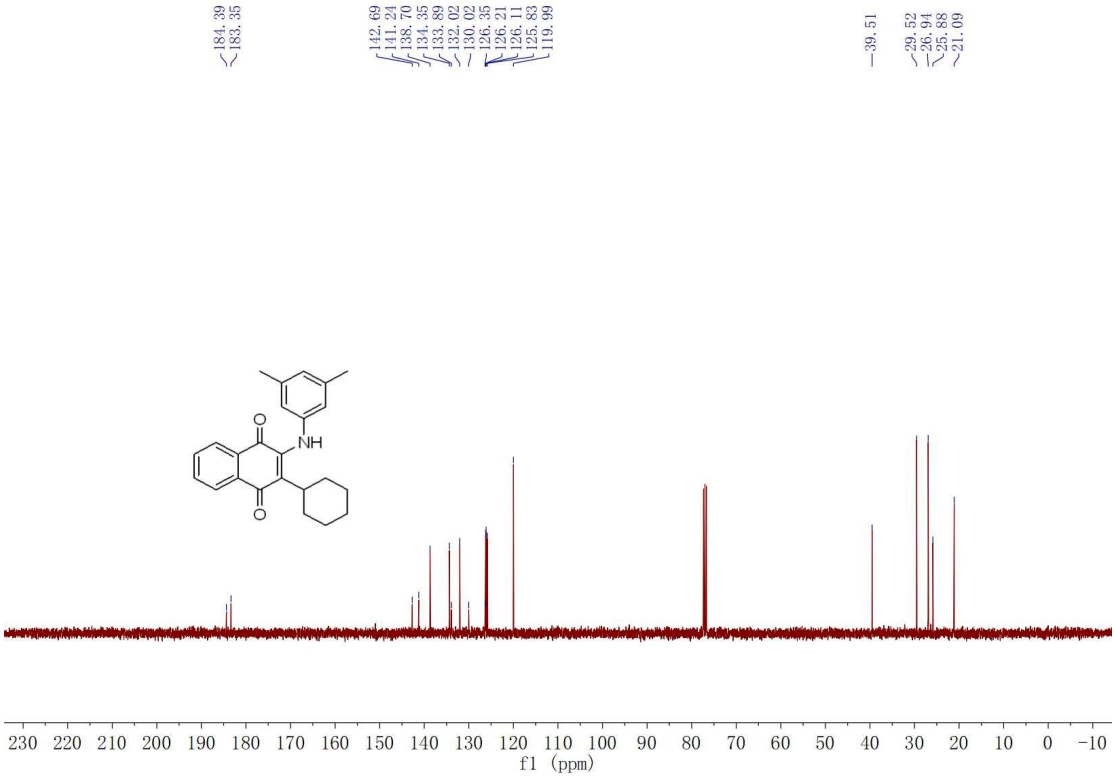
$^{19}$F-NMR spectra of **4q**



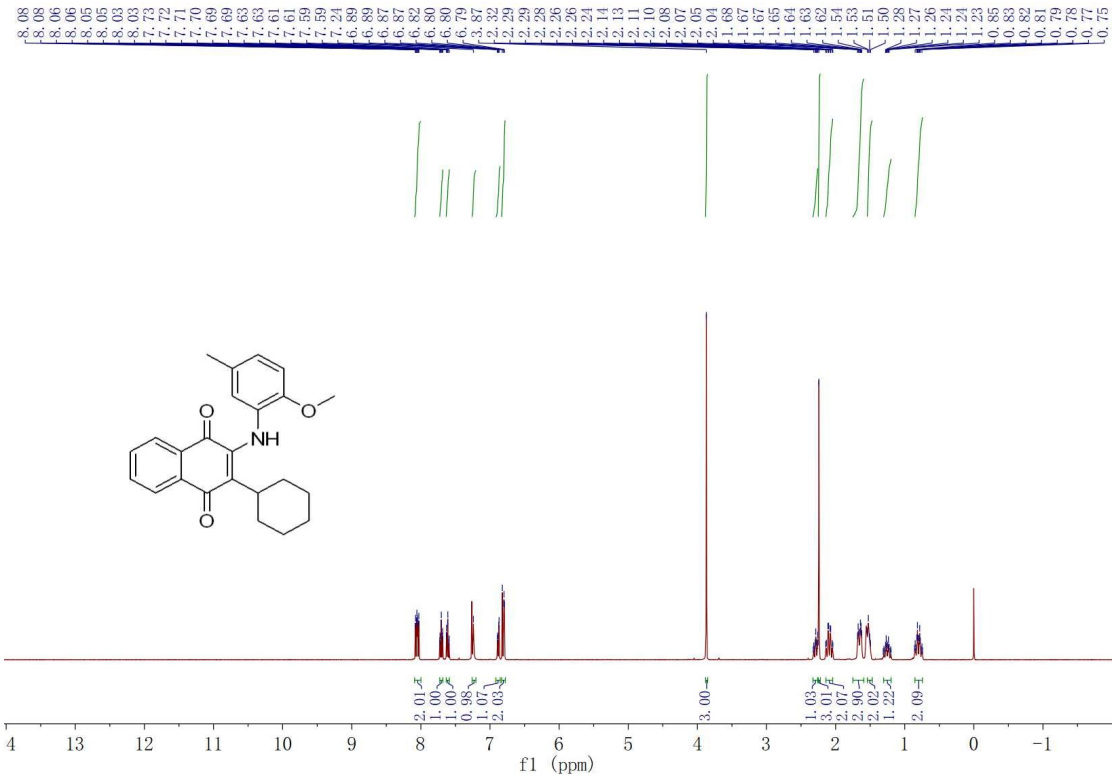
[1]H-NMR spectra of **4r**



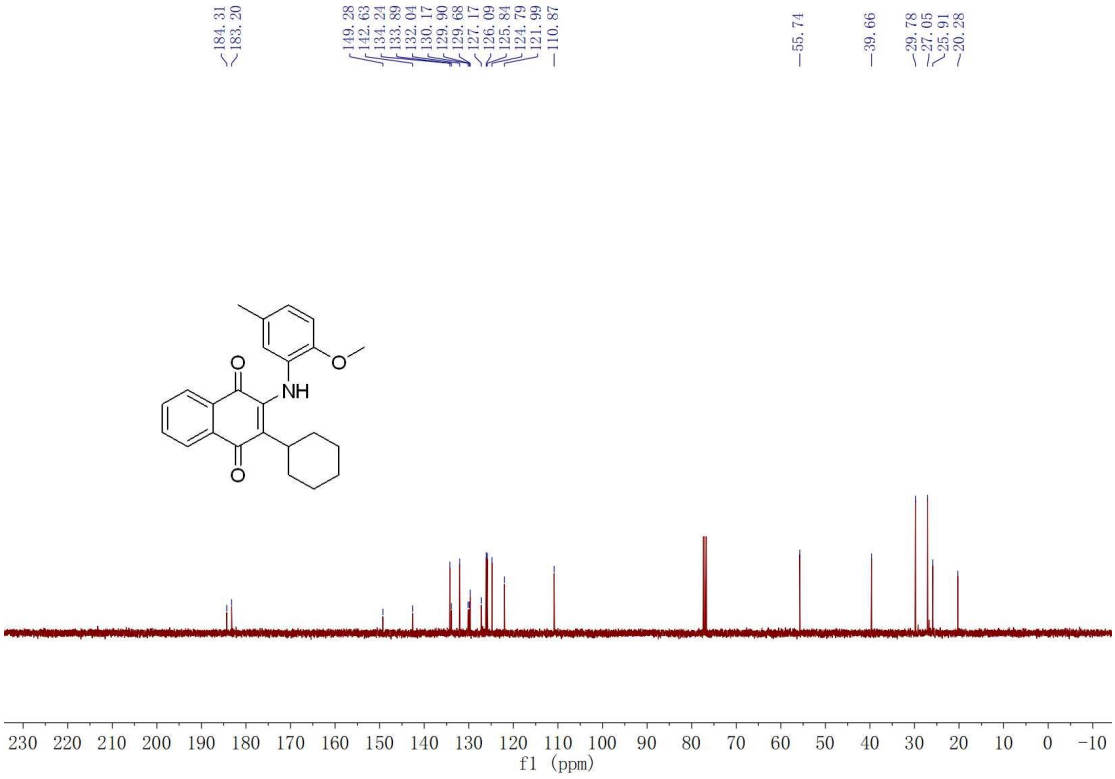

[13]C-NMR spectra of **4r**



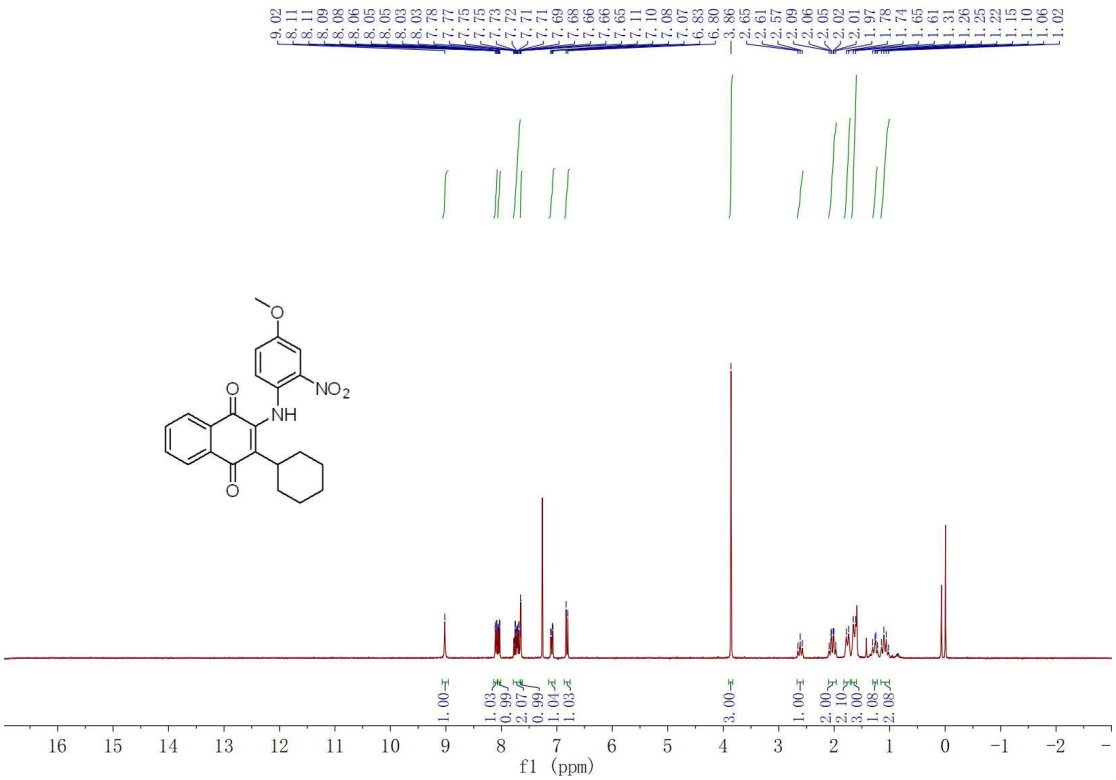
[1]H-NMR spectra of **4s**



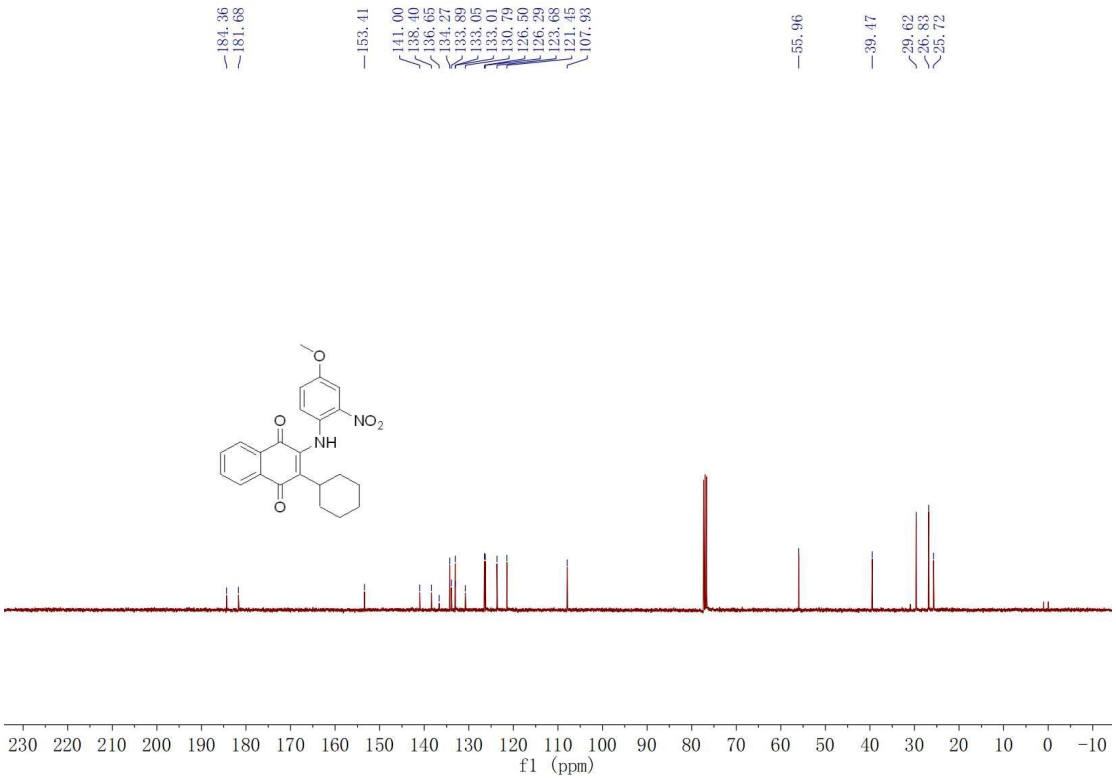

[13]C-NMR spectra of **4s**



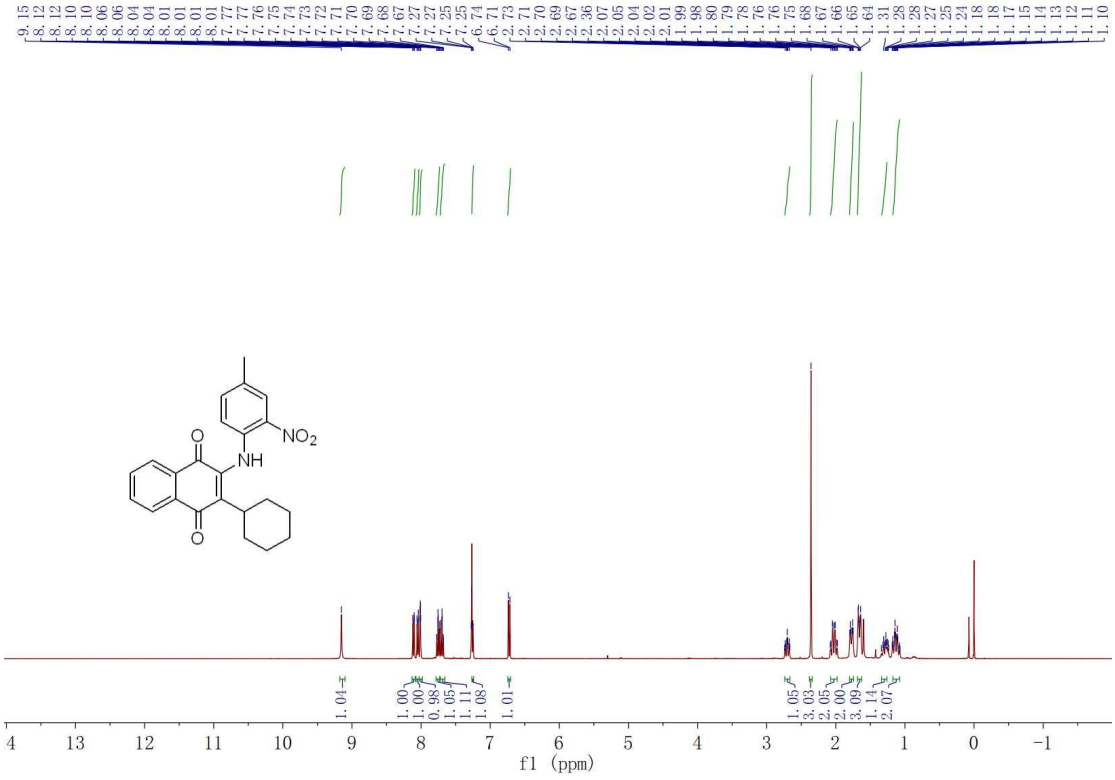
$^{1}$H-NMR spectra of **4t**



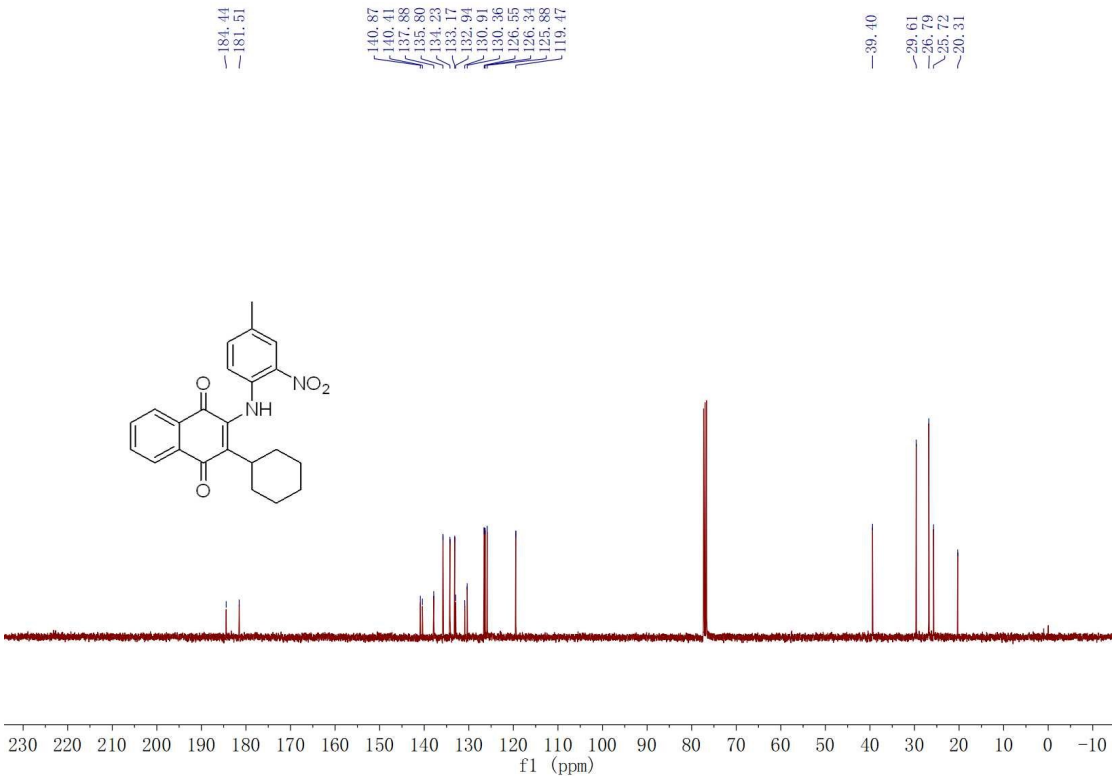

$^{13}$C-NMR spectra of **4t**



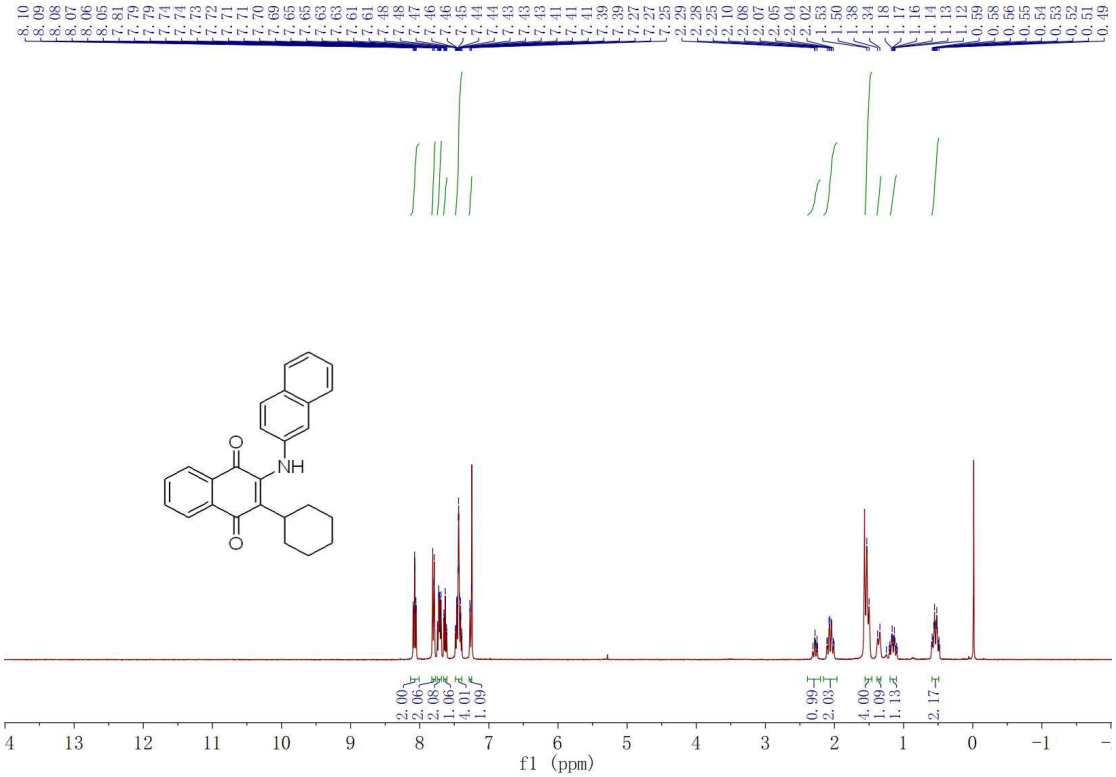
[1]H-NMR spectra of **4u**



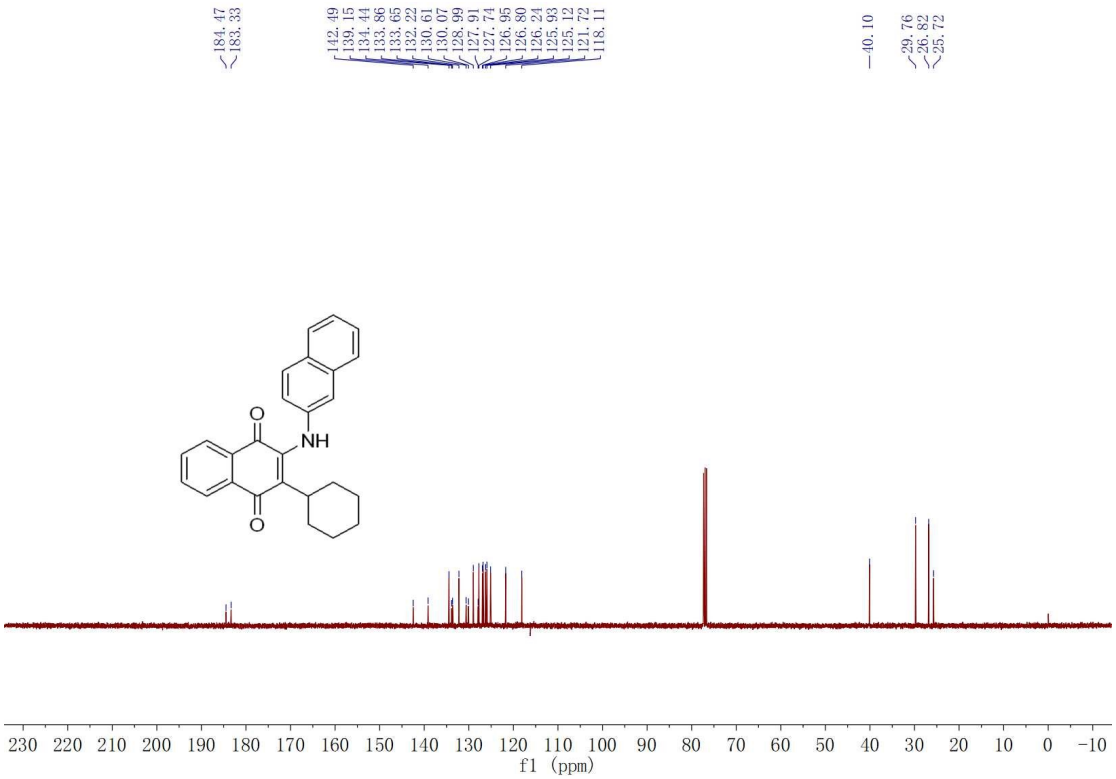

[13]C-NMR spectra of **4u**



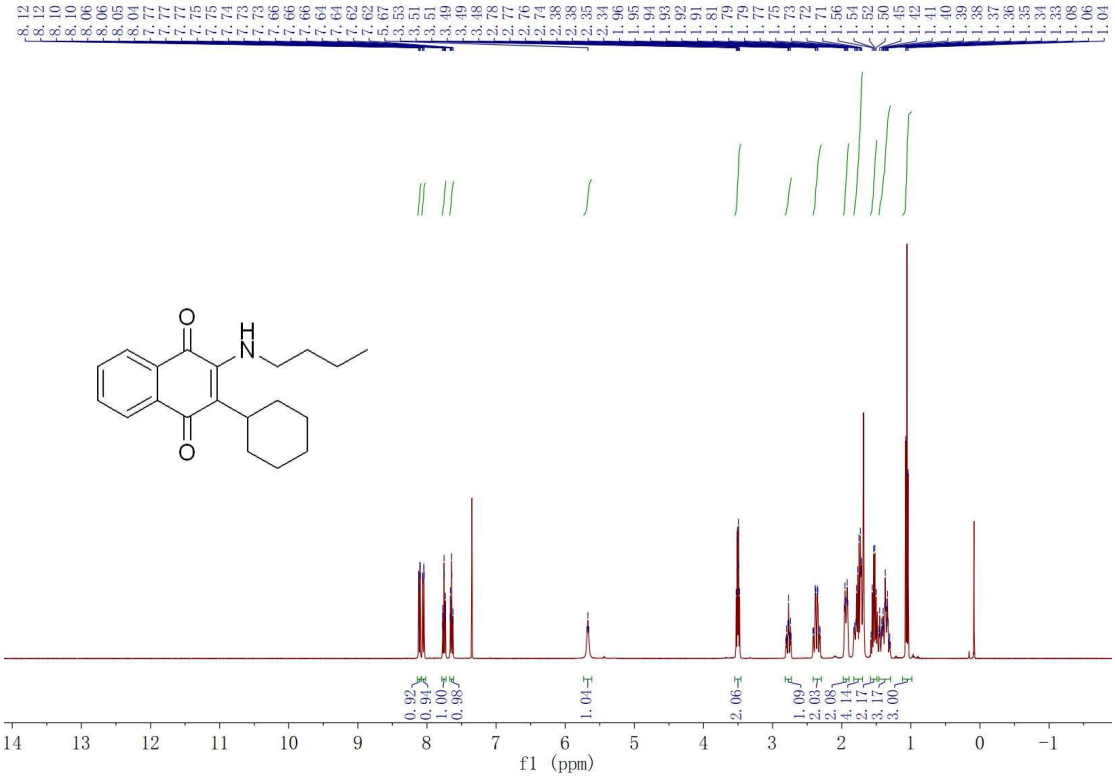
$^{1}$H-NMR spectra of **4v**



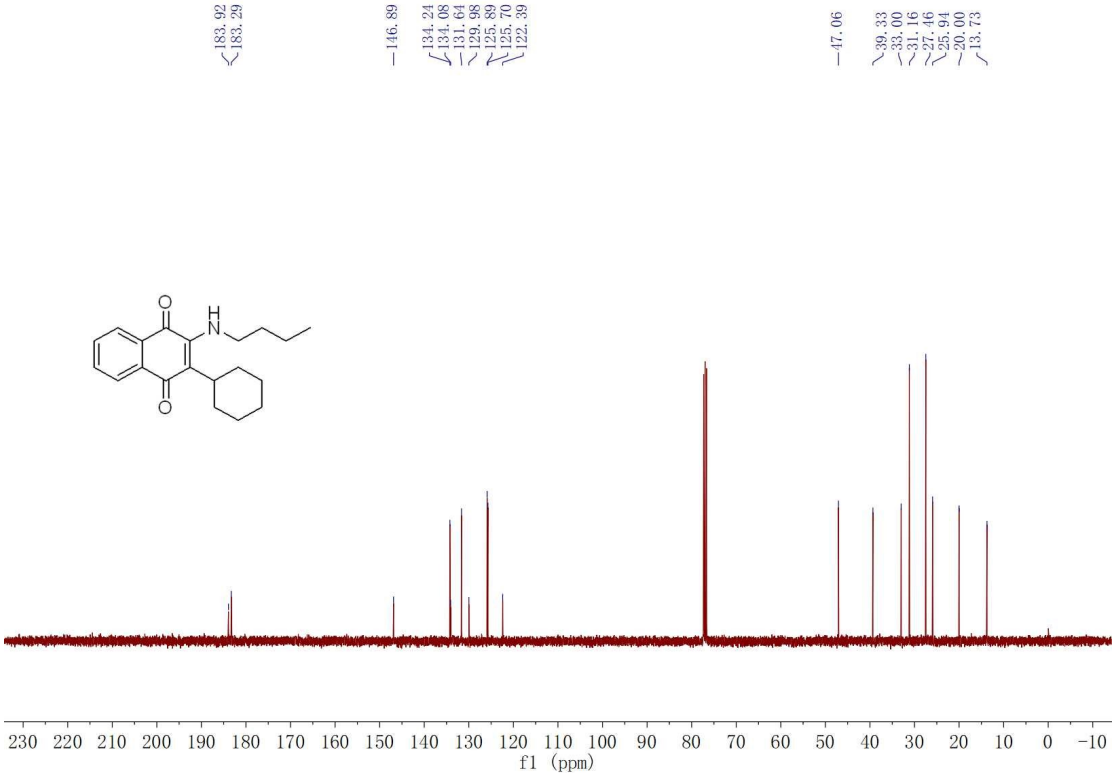

$^{13}$C-NMR spectra of **4v**



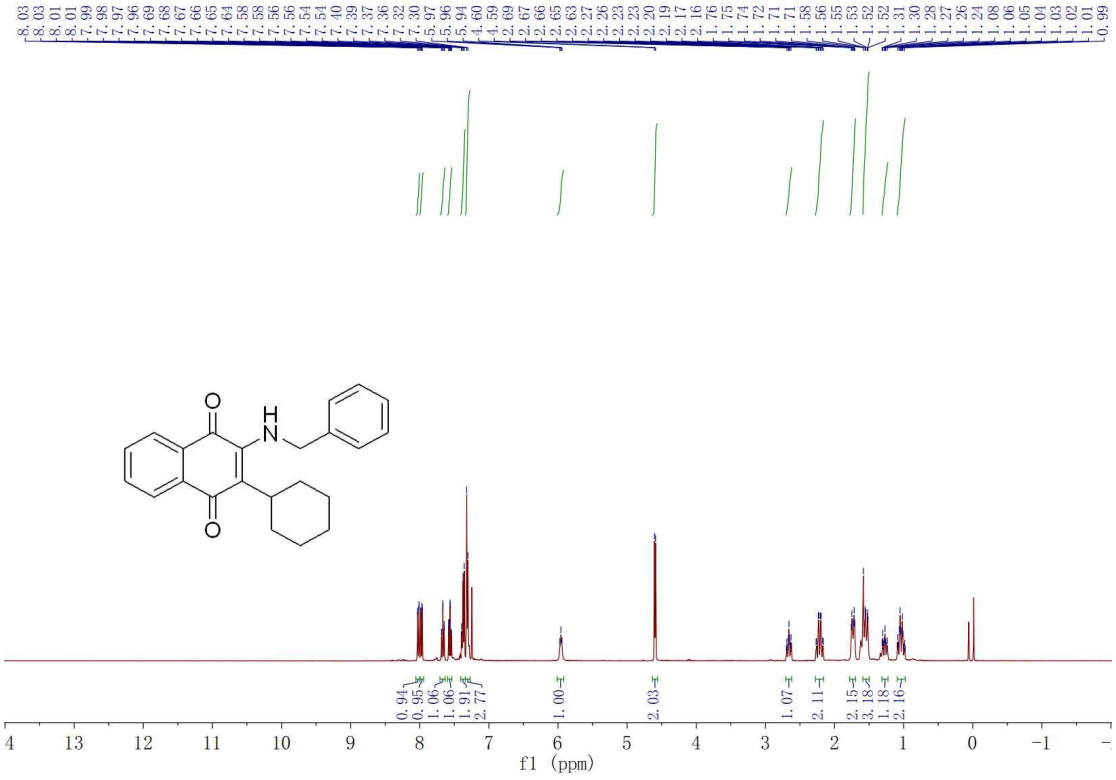
$^{1}$H-NMR spectra of **4w**



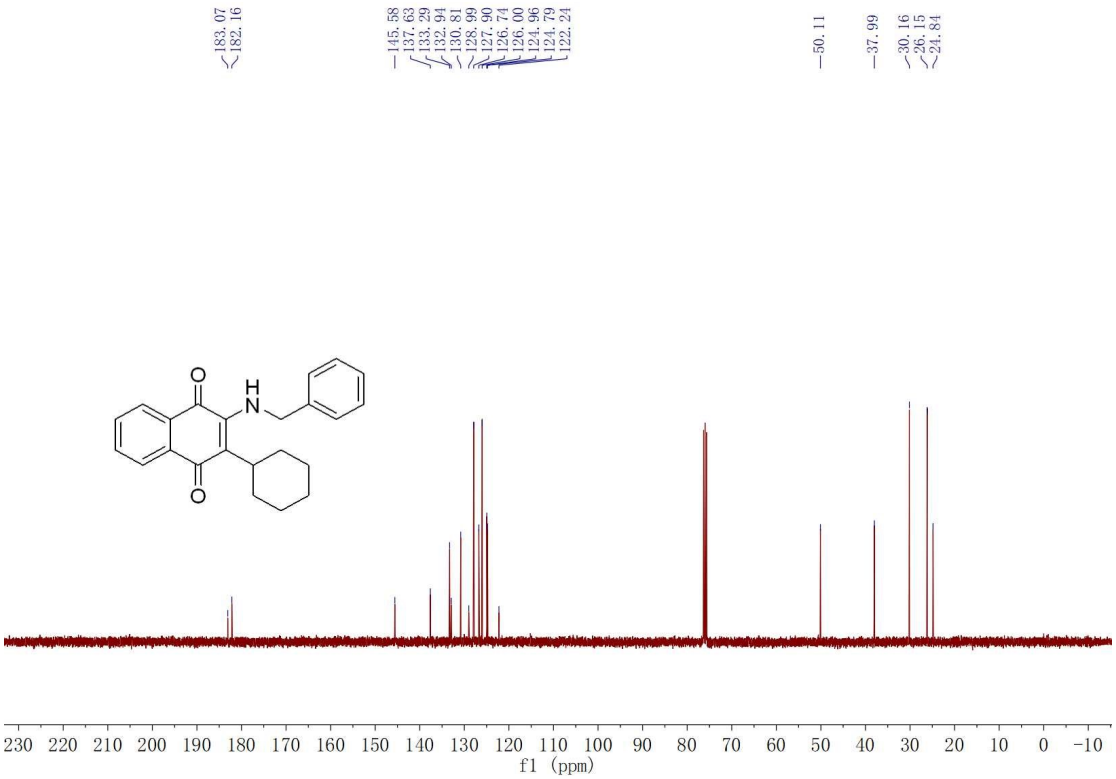

$^{13}$C-NMR spectra of **4w**



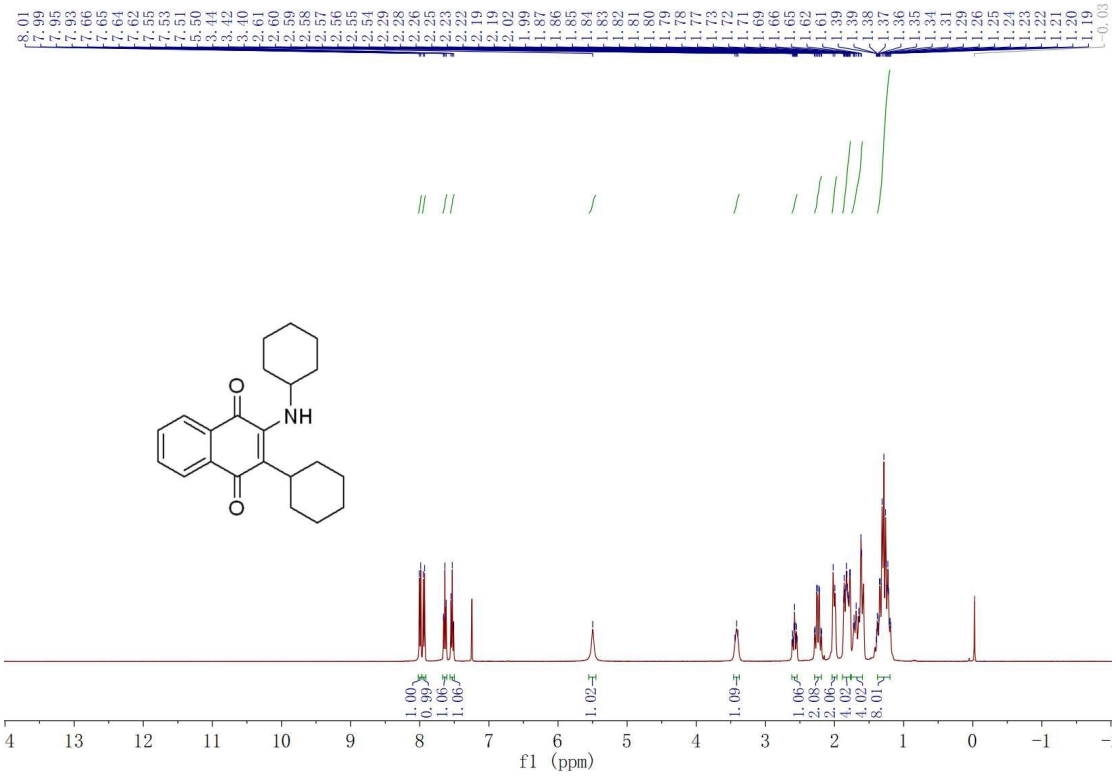
[1]H-NMR spectra of **4x**



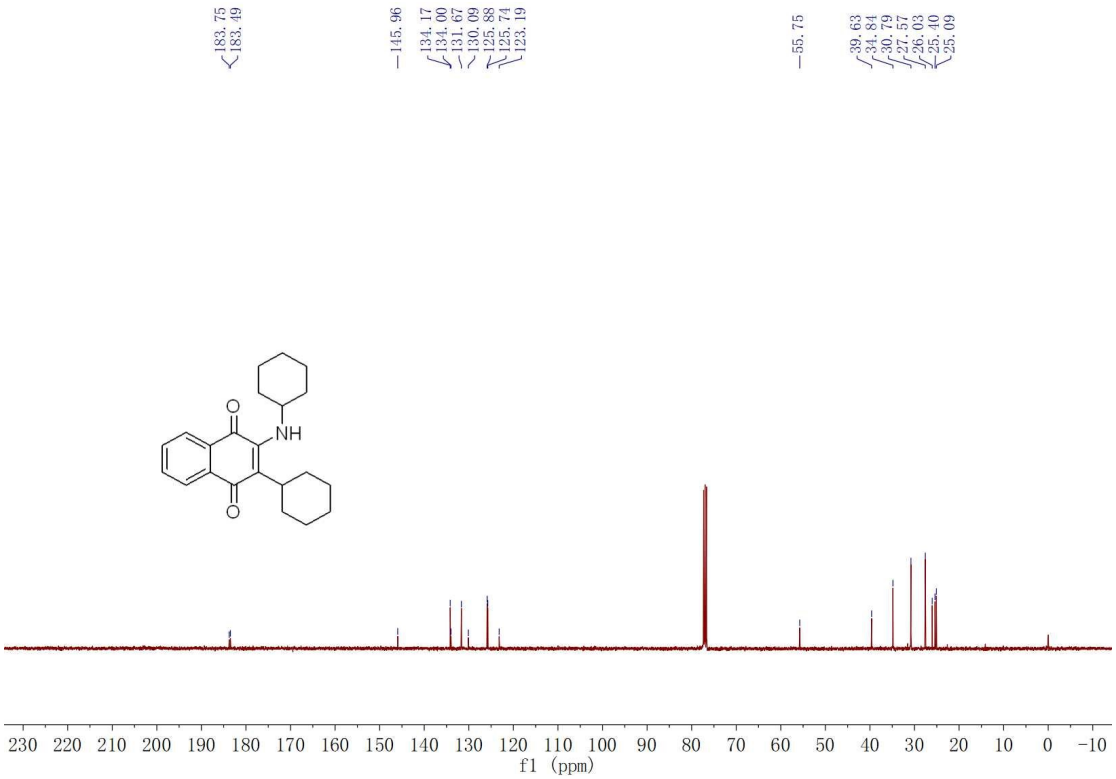

[13]C-NMR spectra of **4x**



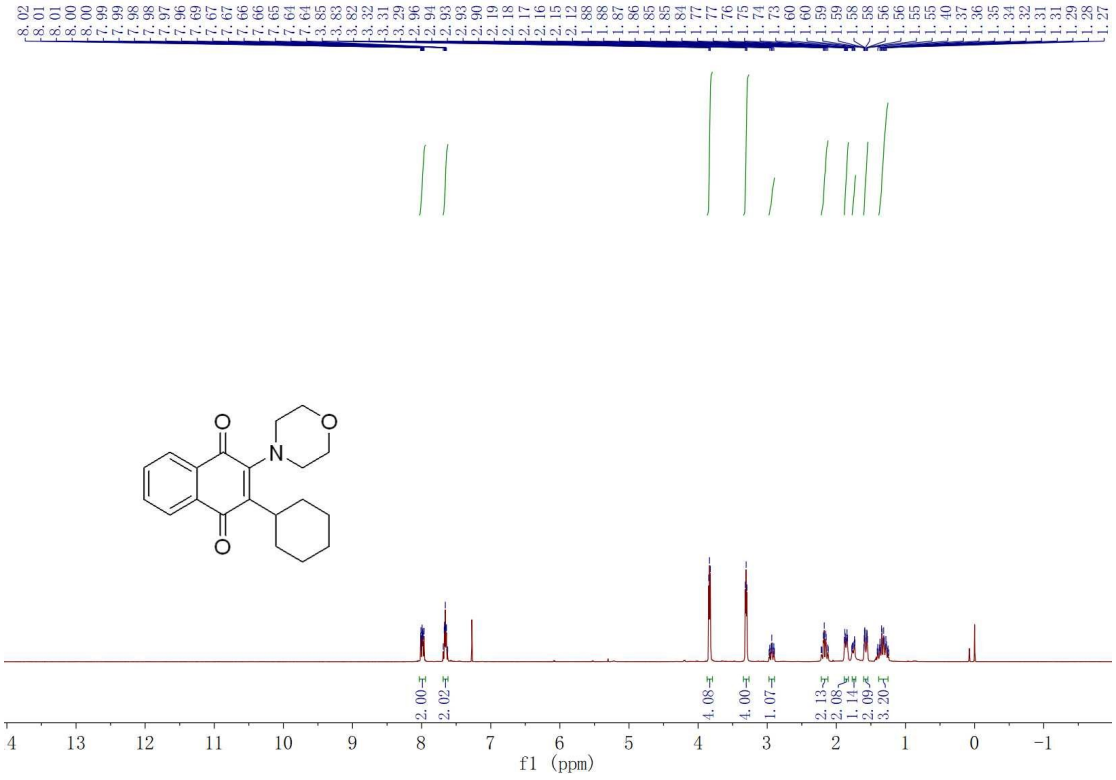
[1]H-NMR spectra of **4y**



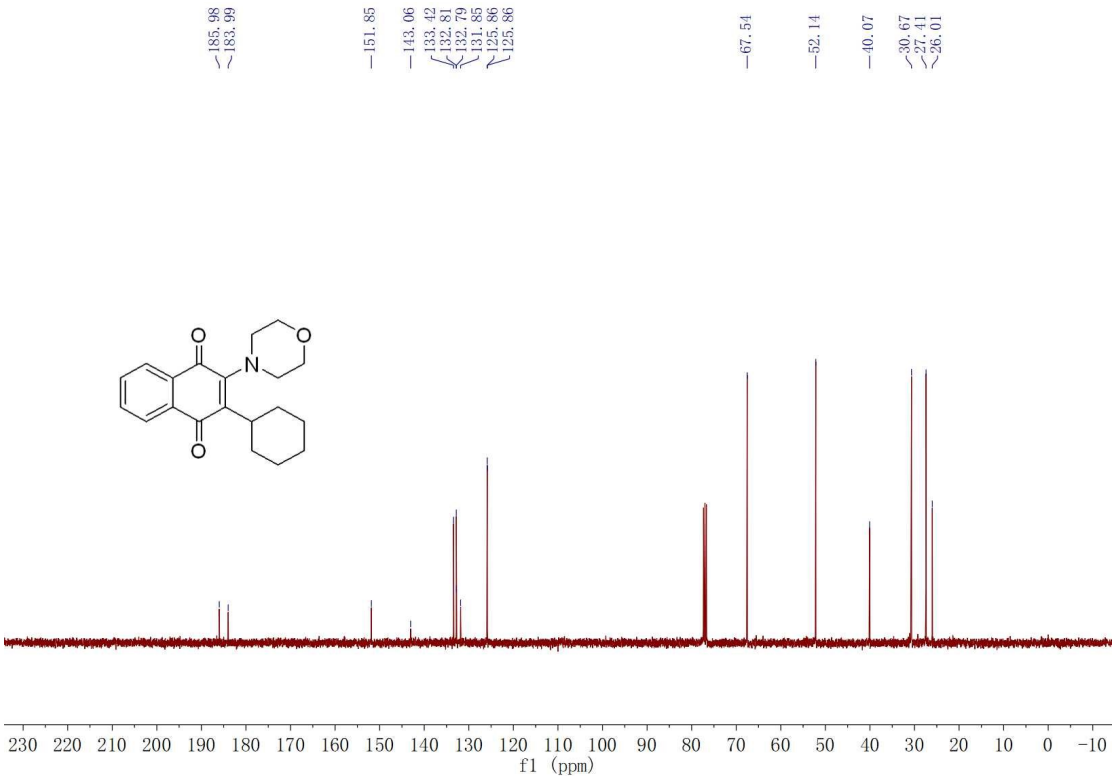

[13]C-NMR spectra of **4y**



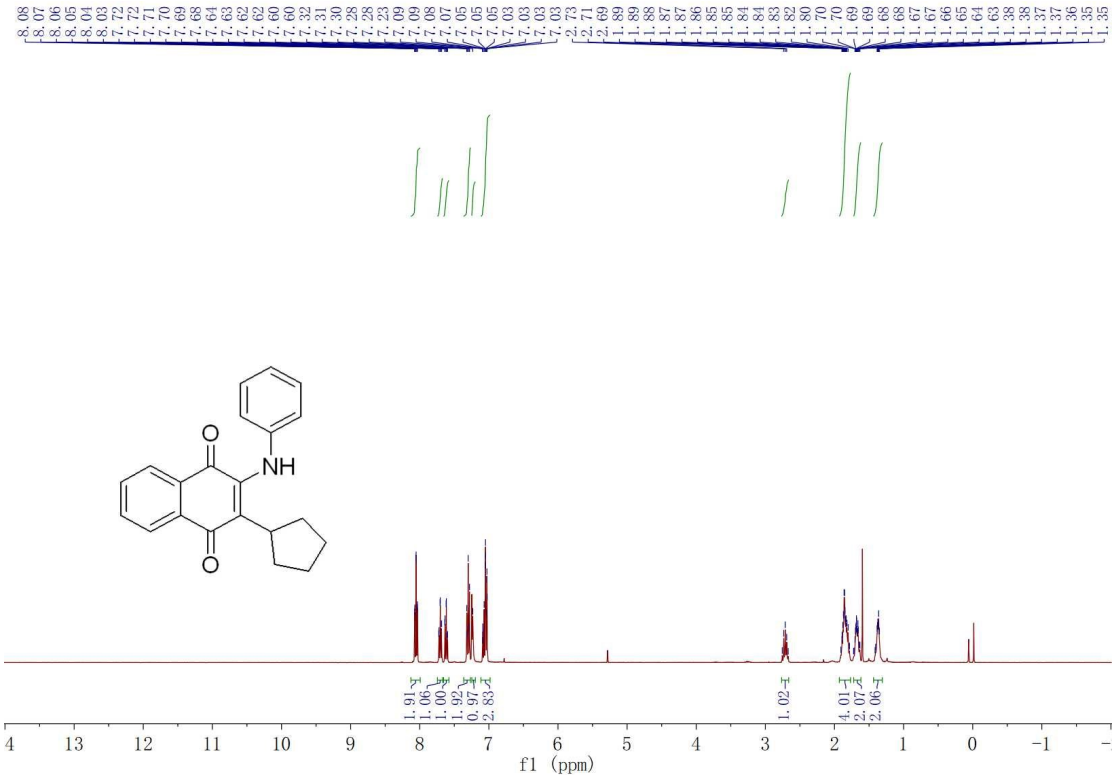
[1]H-NMR spectra of **4z**



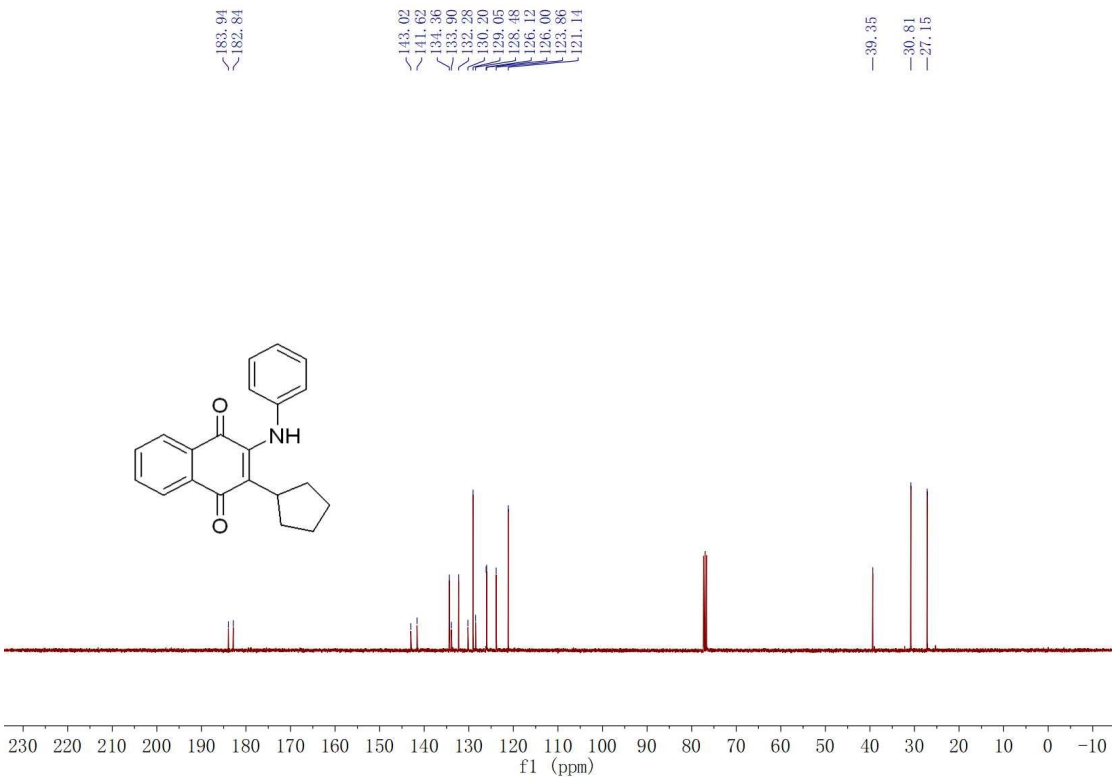

[13]C-NMR spectra of **4z**



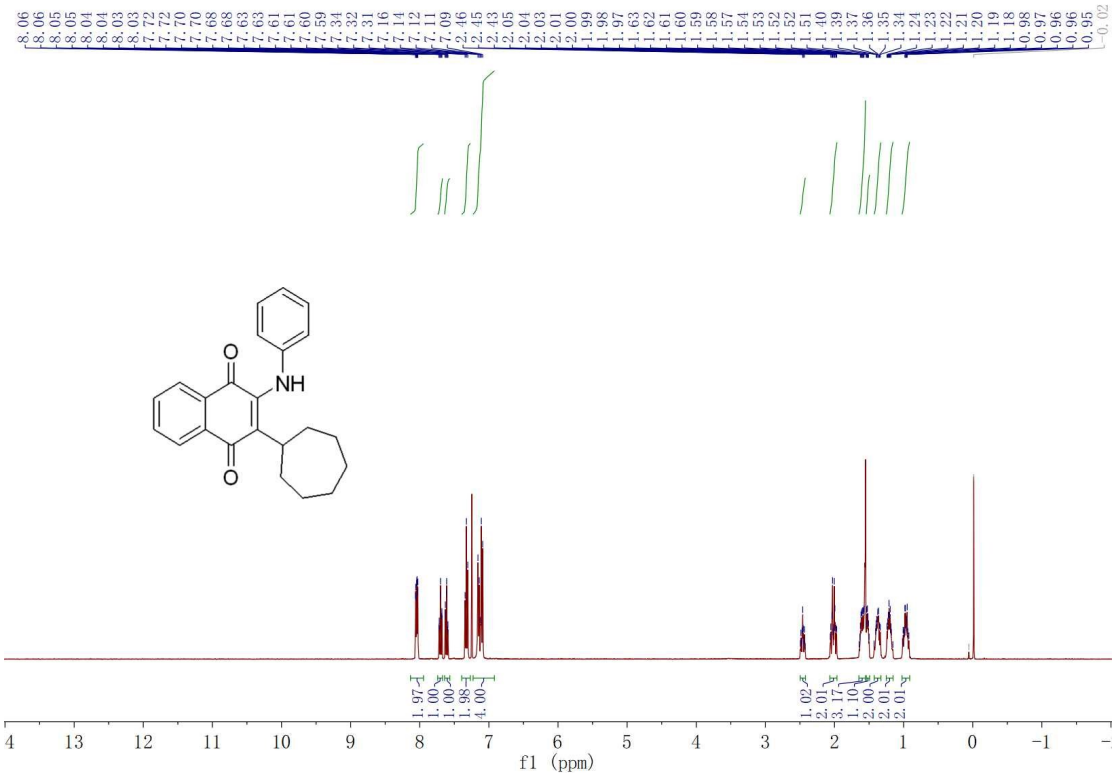
$^{1}$H-NMR spectra of **5a**



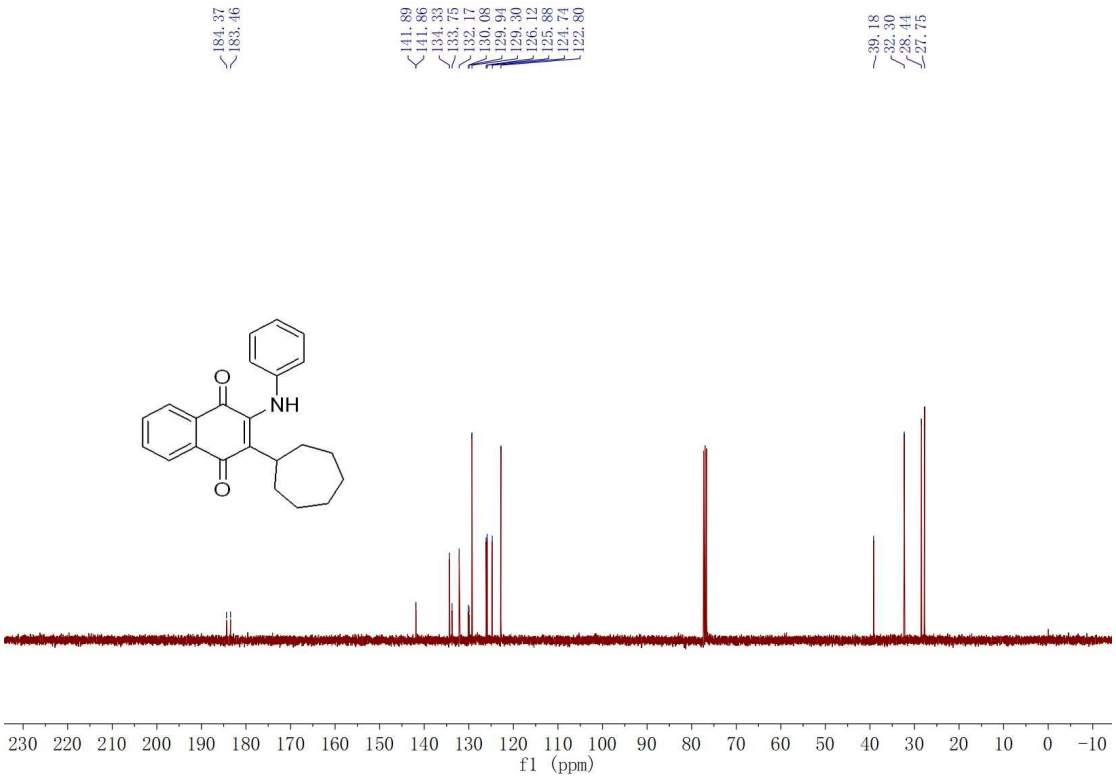

$^{13}$C-NMR spectra of 5**a**



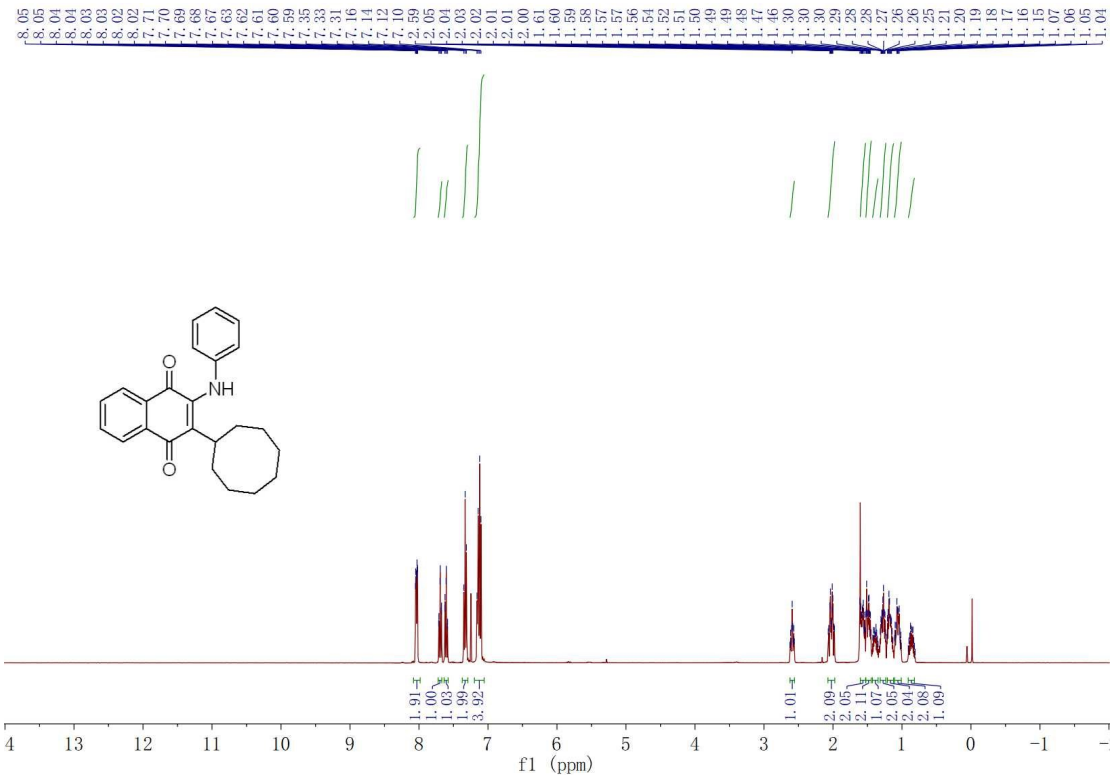

$^{1}$H-NMR spectra of **5b**



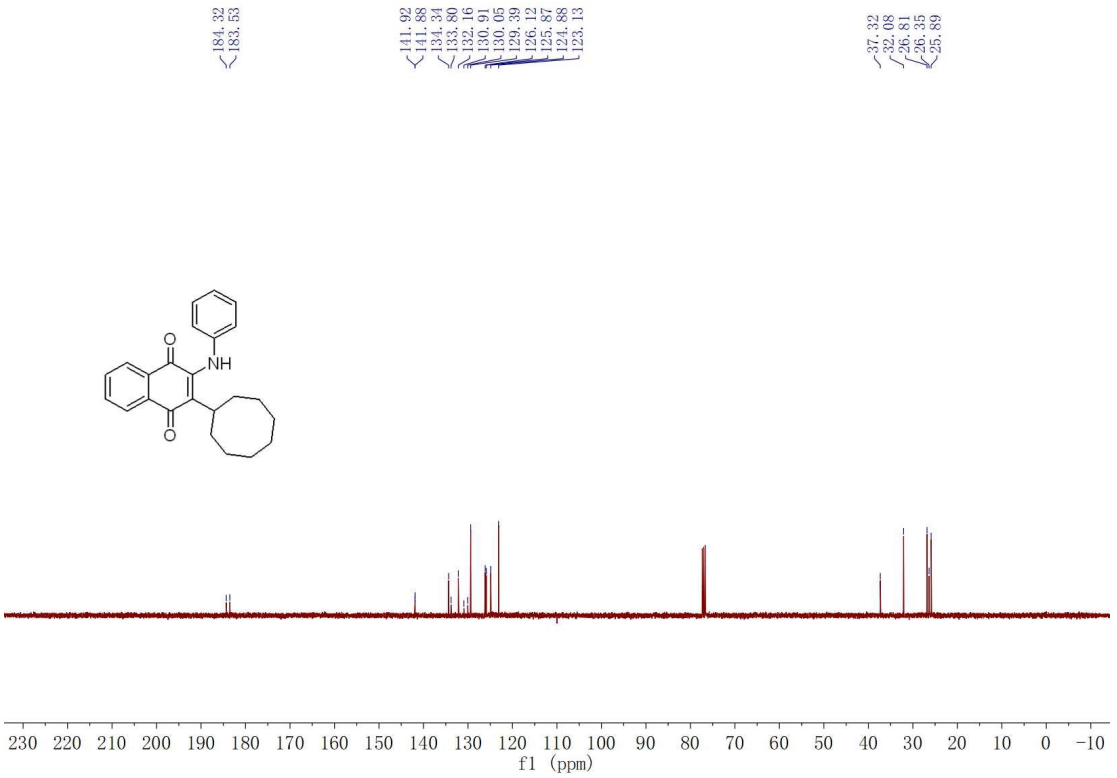

$^{13}$C-NMR spectra of **5b**



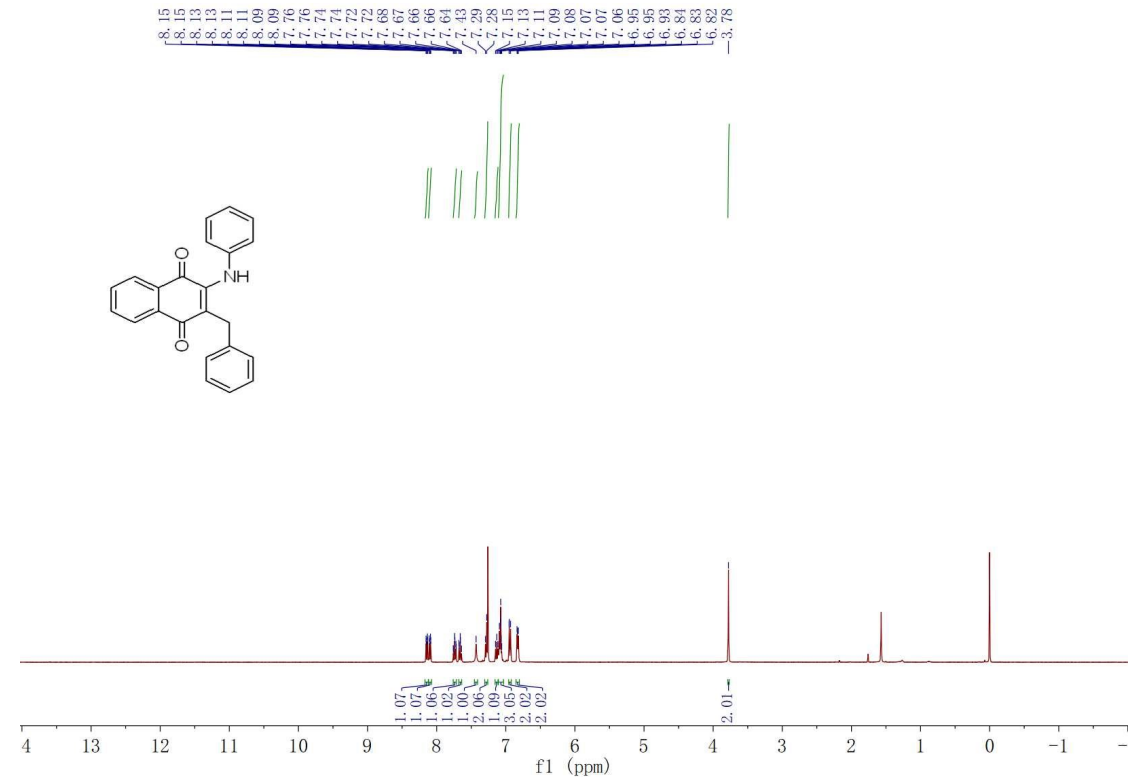

$^{1}$H-NMR spectra of **5c**



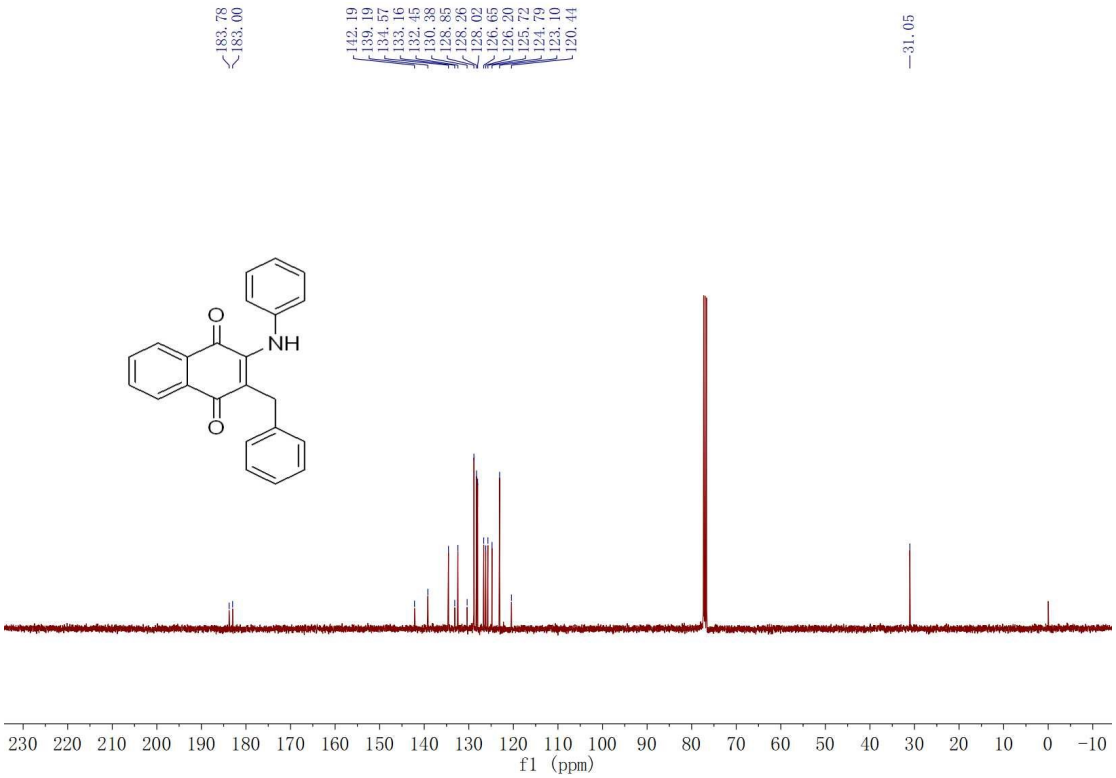

$^{13}$C-NMR spectra of **5c**



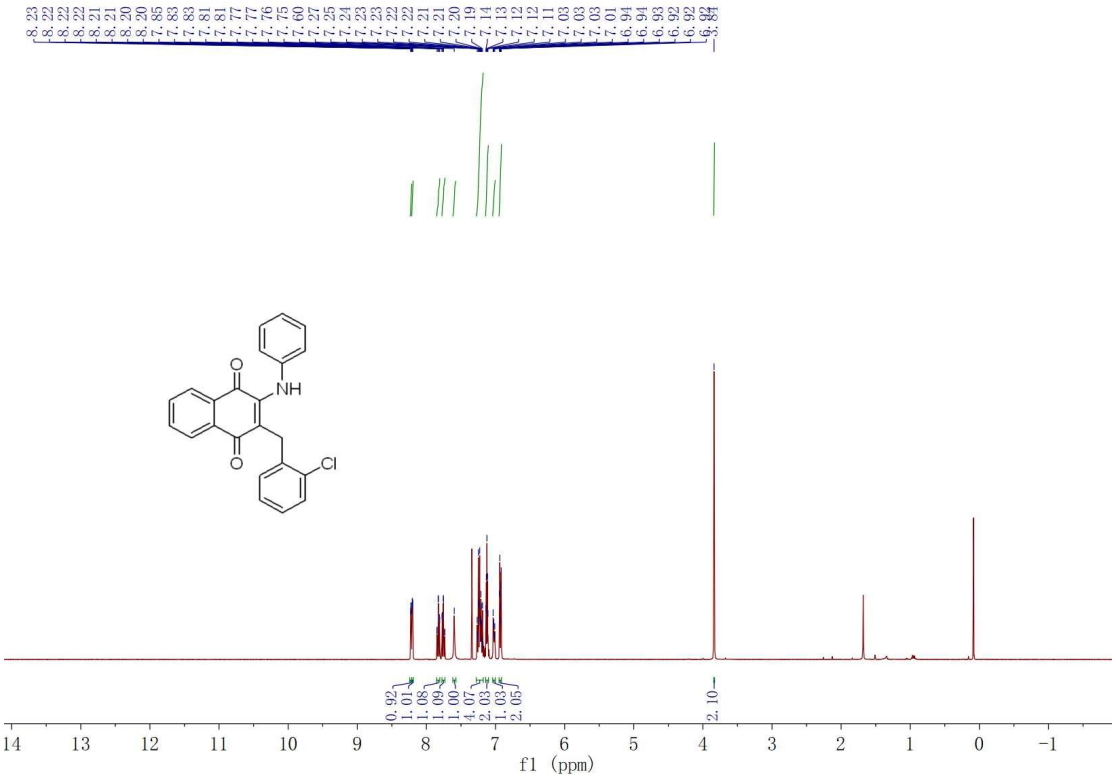

$^{1}$H-NMR spectra of **5d**



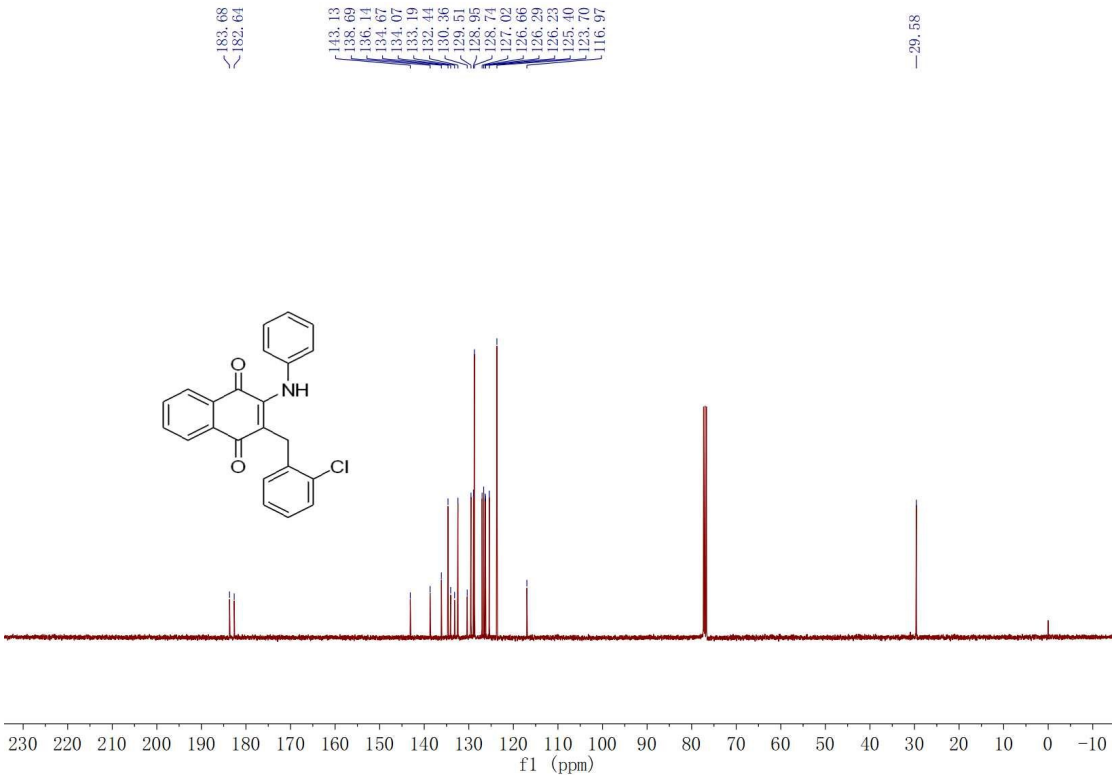

$^{13}$C-NMR spectra of **5d**



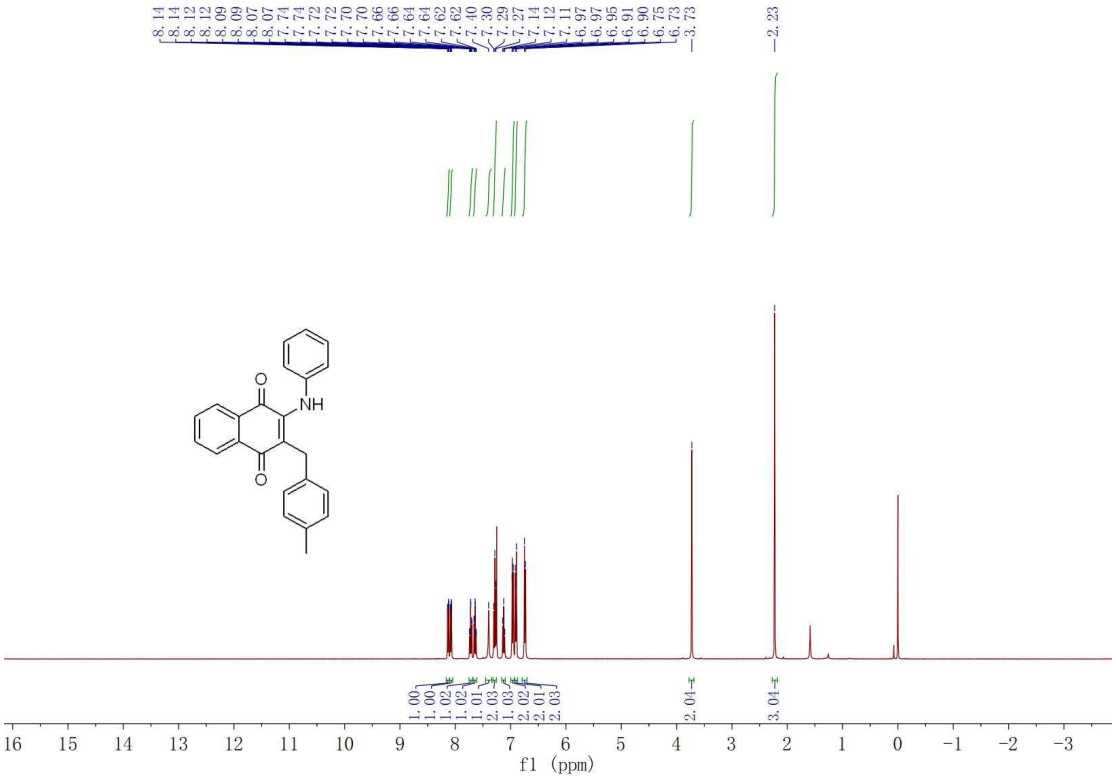

$^{1}$H-NMR spectra of **5e**



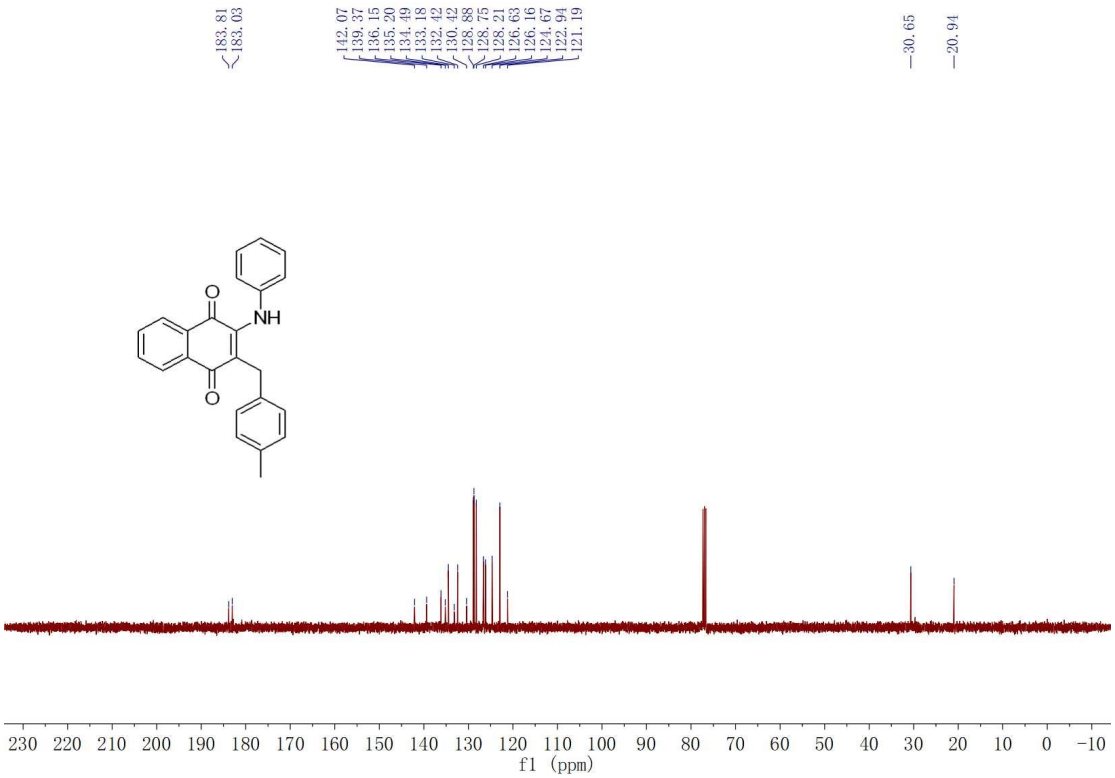

$^{13}$C-NMR spectra of **5e**



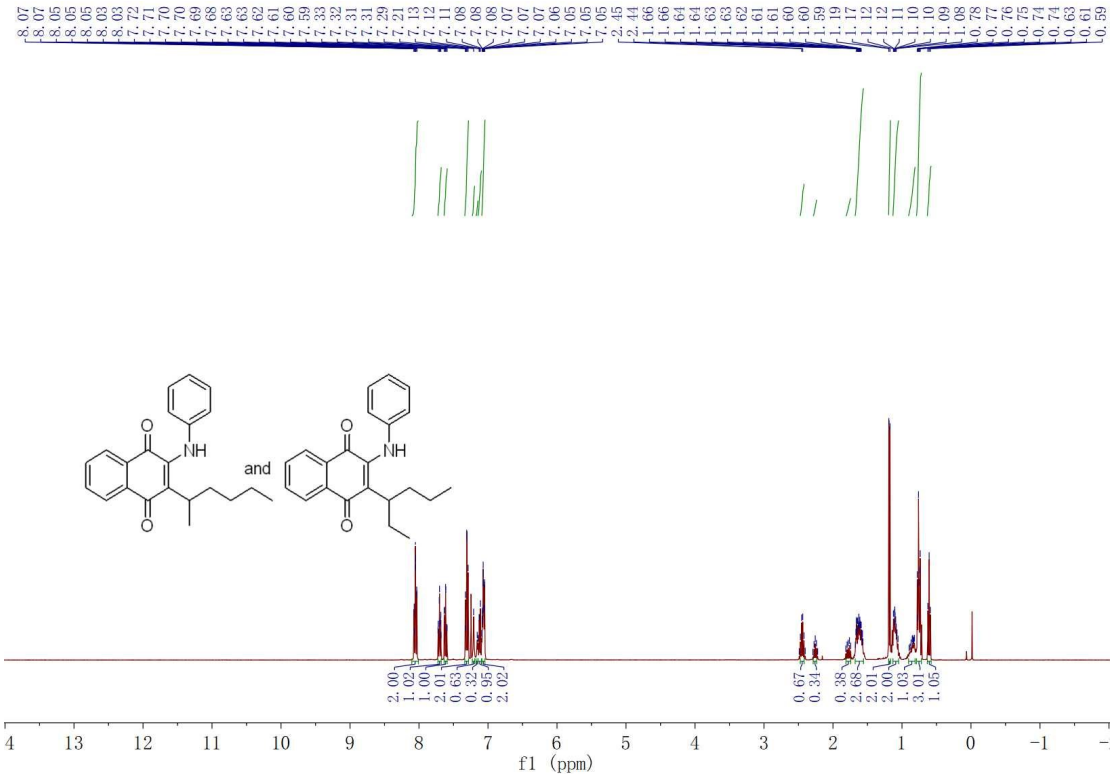

$^{1}$H-NMR spectra of **5f**



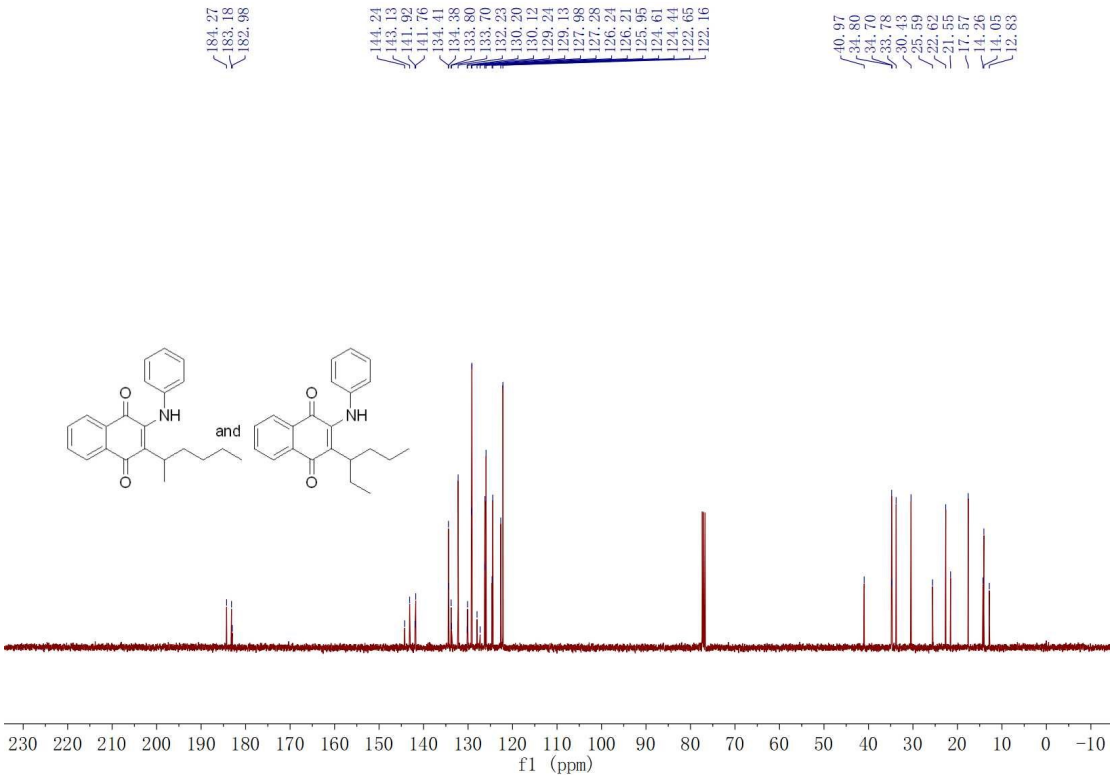

$^{13}$C-NMR spectra of **5f**



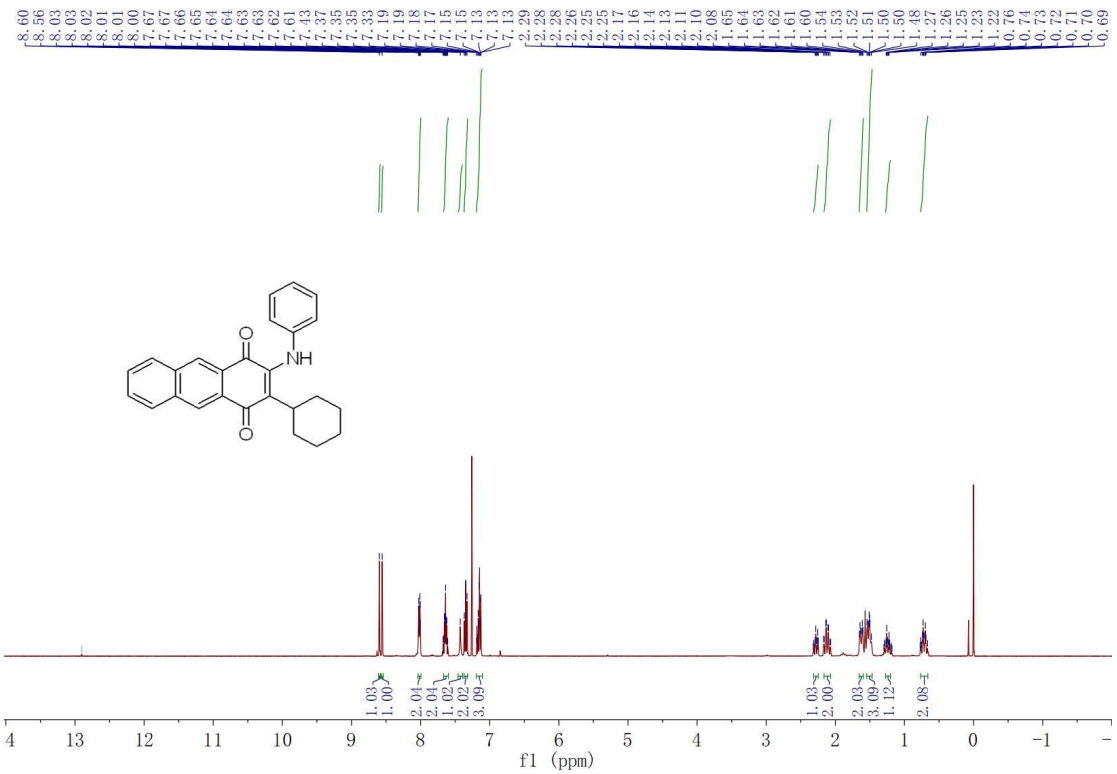

$^{1}$H-NMR spectra of **5g**



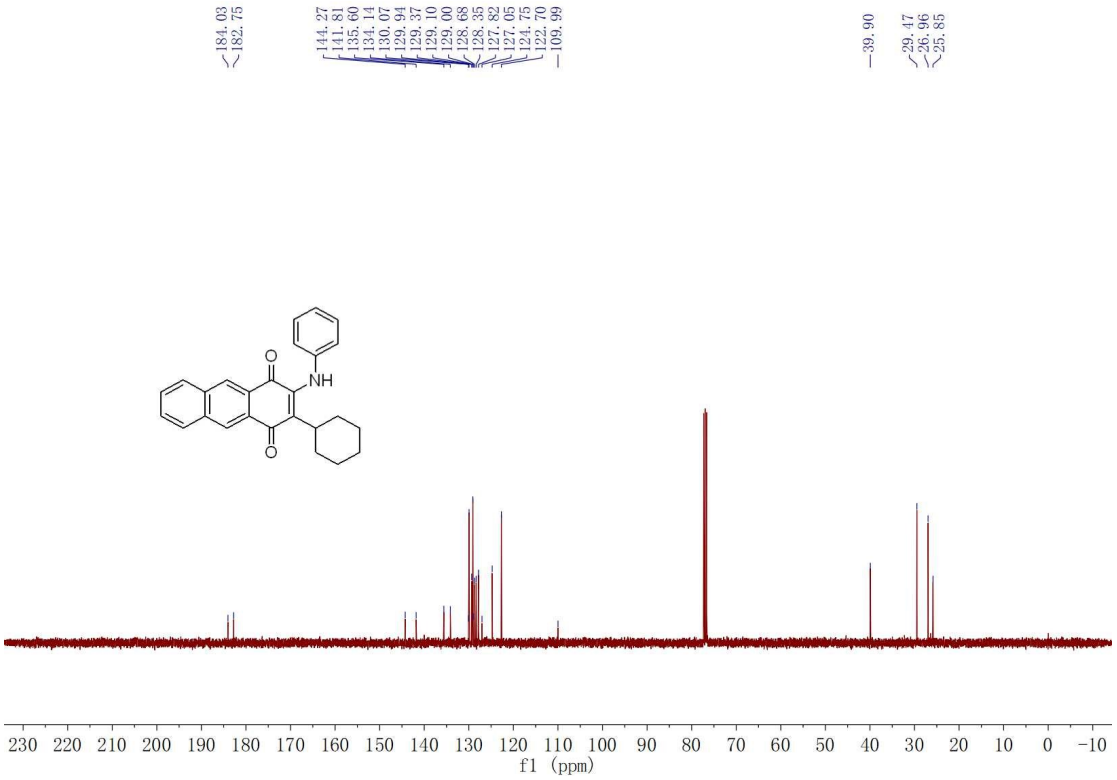

$^{13}$C-NMR spectra of **5g**



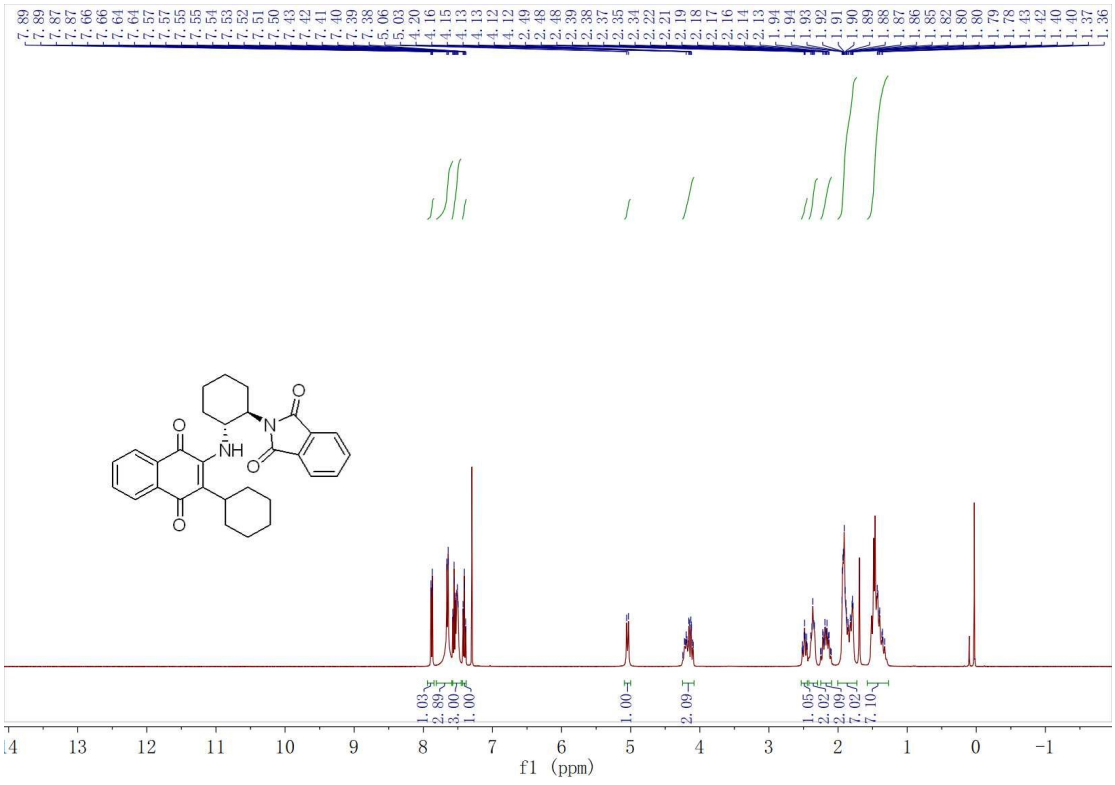

$^{1}$H-NMR spectra of **5h**



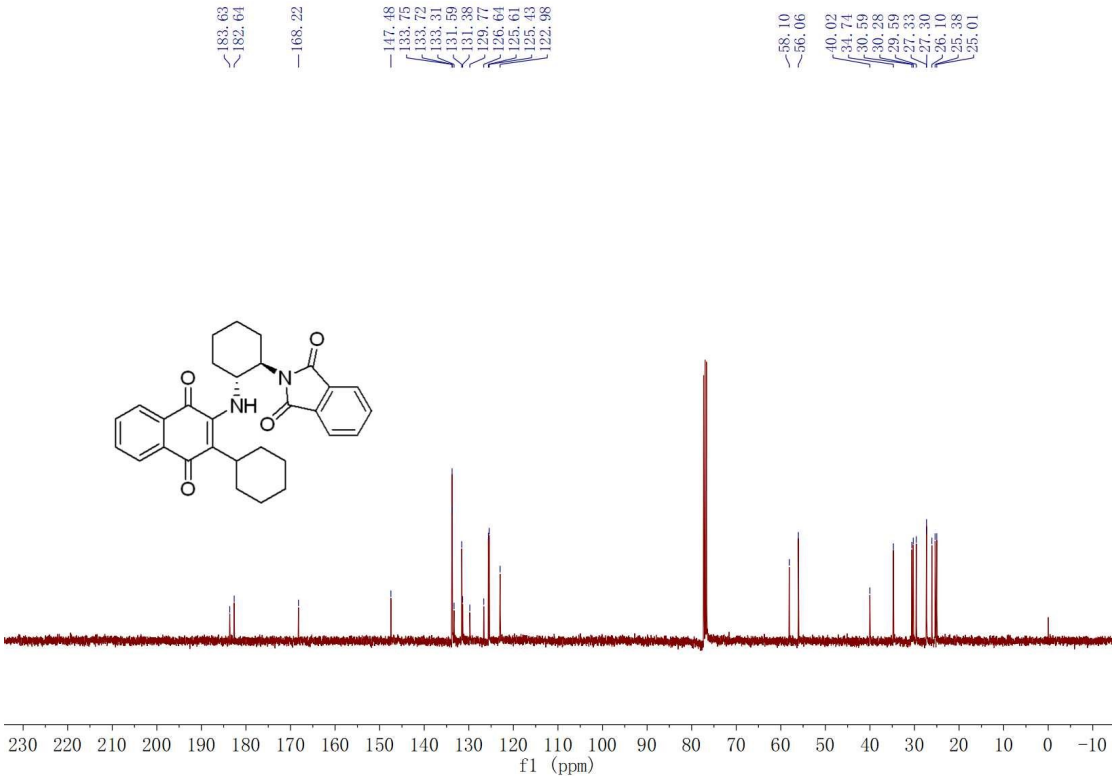

$^{13}$C-NMR spectra of **5h**



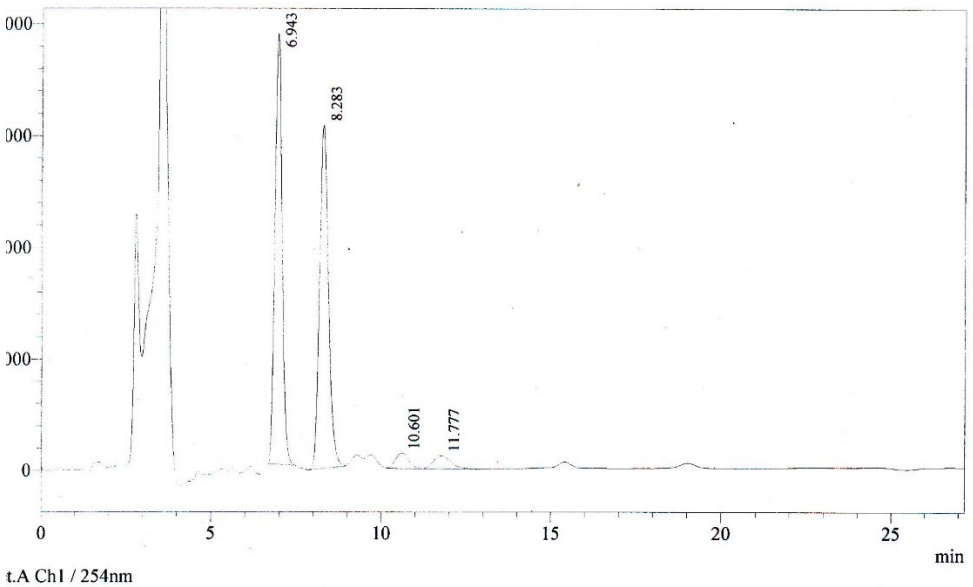

$^{1}$H-NMR spectra of **7**




$^{13}$C-NMR spectra of **7**



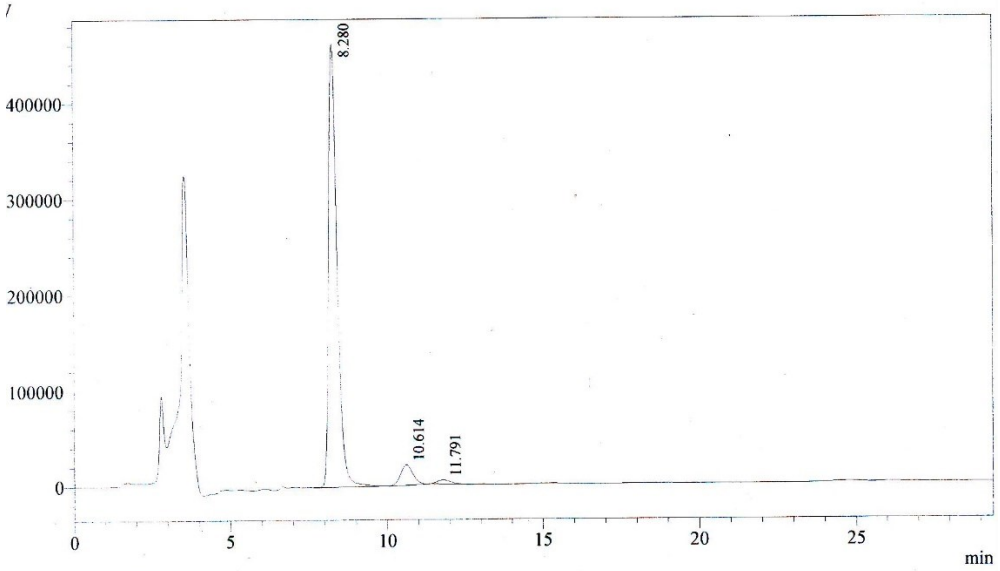

HPLC of **7**




t.A Ch1 / 254nm

Detector A Ch1 254nm

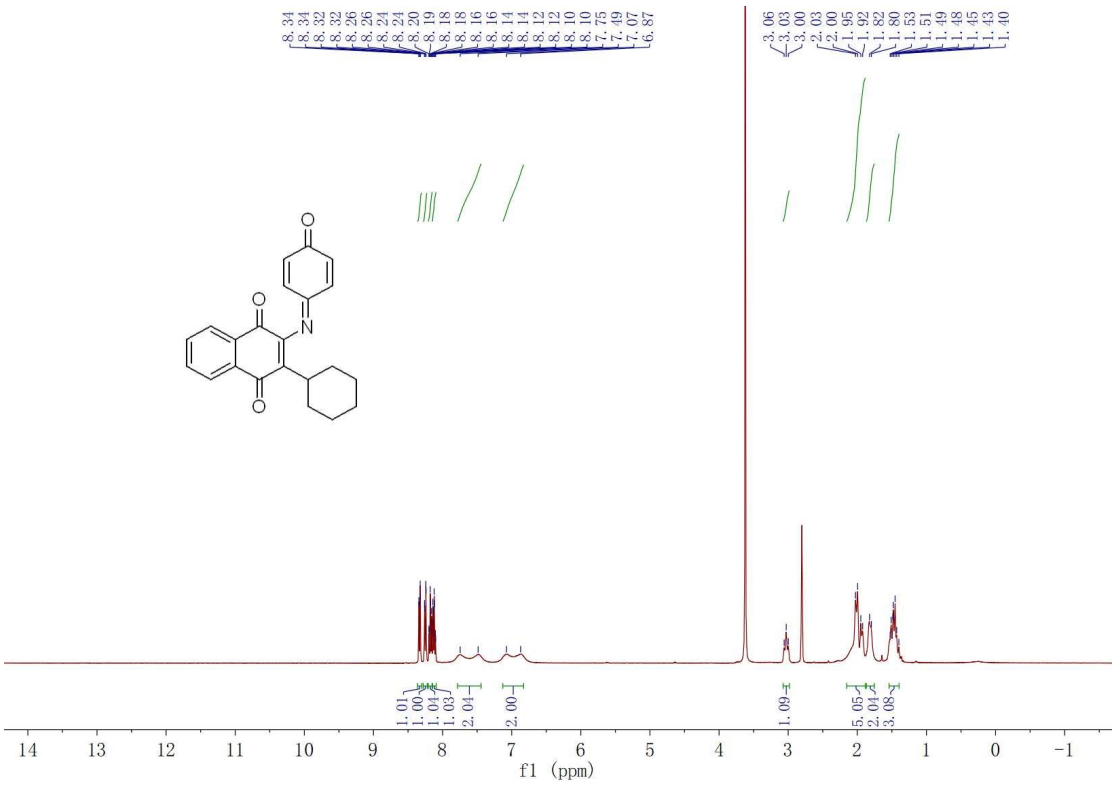
| Peak# | Ret. Time | Area | Height | Area % | Height % |
|---|---|---|---|---|---|
| 1 | 6.943 | 2819570 | 192852 | 46.963 | 53.633 |
| 2 | 8.283 | 2795622 | 153863 | 46.564 | 42.790 |
| 3 | 10.601 | 181539 | 6876 | 3.024 | 1.912 |
| 4 | 11.777 | 207115 | 5987 | 3.450 | 1.665 |
| Total | | 6003846 | 359577 | 100.000 | 100.000 |



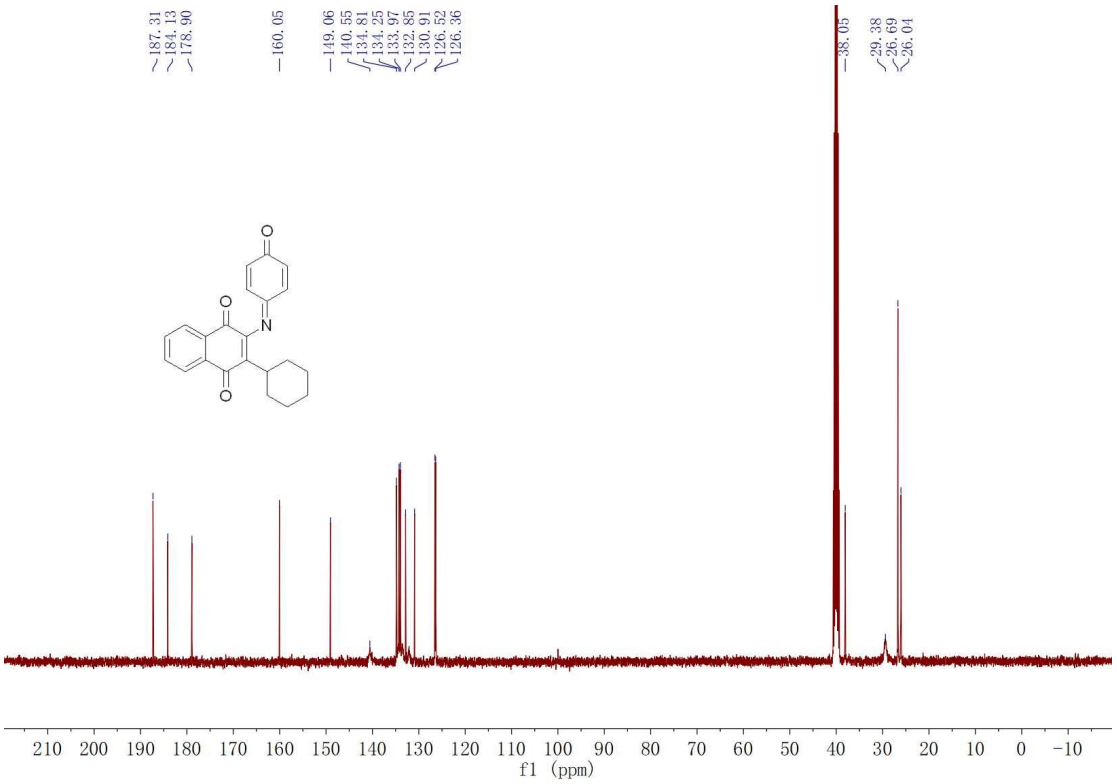

Detector A Ch1 254nm

| Peak# | Ret. Time | Area | Height | Area % | Height % |
|---|---|---|---|---|---|
| 1 | 8.280 | 8575930 | 462341 | 92.502 | 94.810 |
| 2 | 10.614 | 585285 | 21268 | 6.313 | 4.361 |
| 3 | 11.791 | 109876 | 4043 | 1.185 | 0.829 |
| Total | | 9271091 | 487653 | 100.000 | 100.000 |

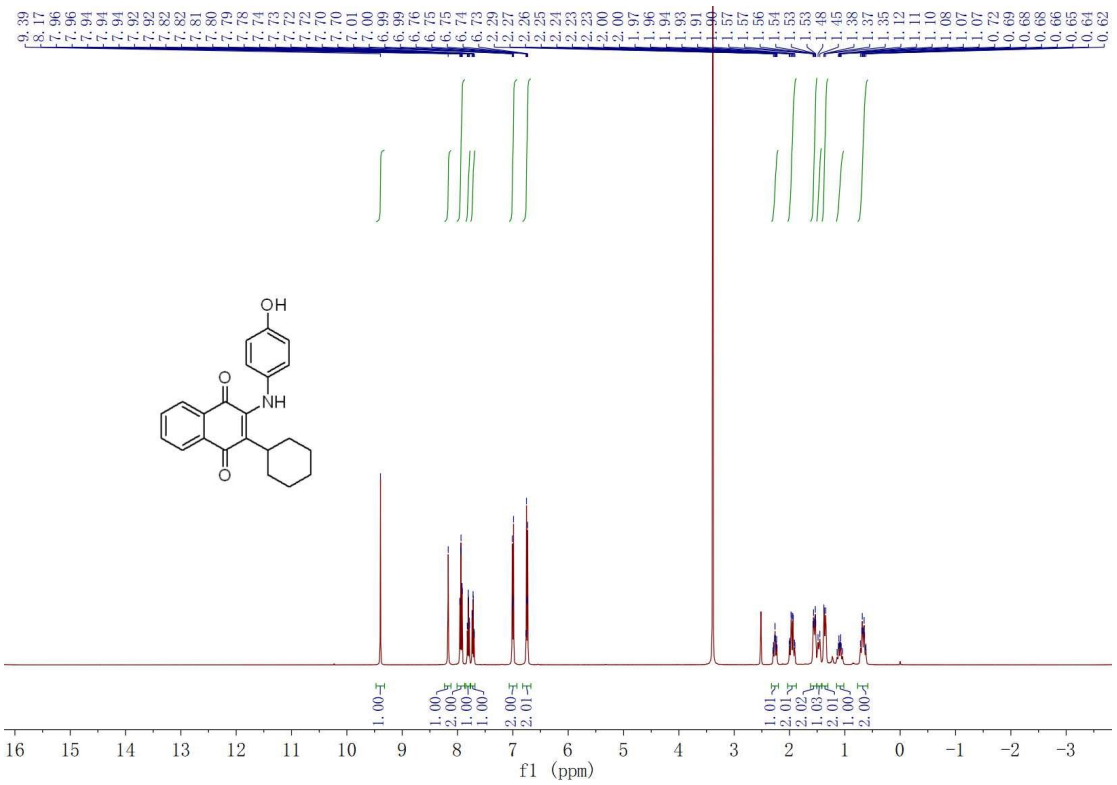
$^{1}$H-NMR spectra of **8**



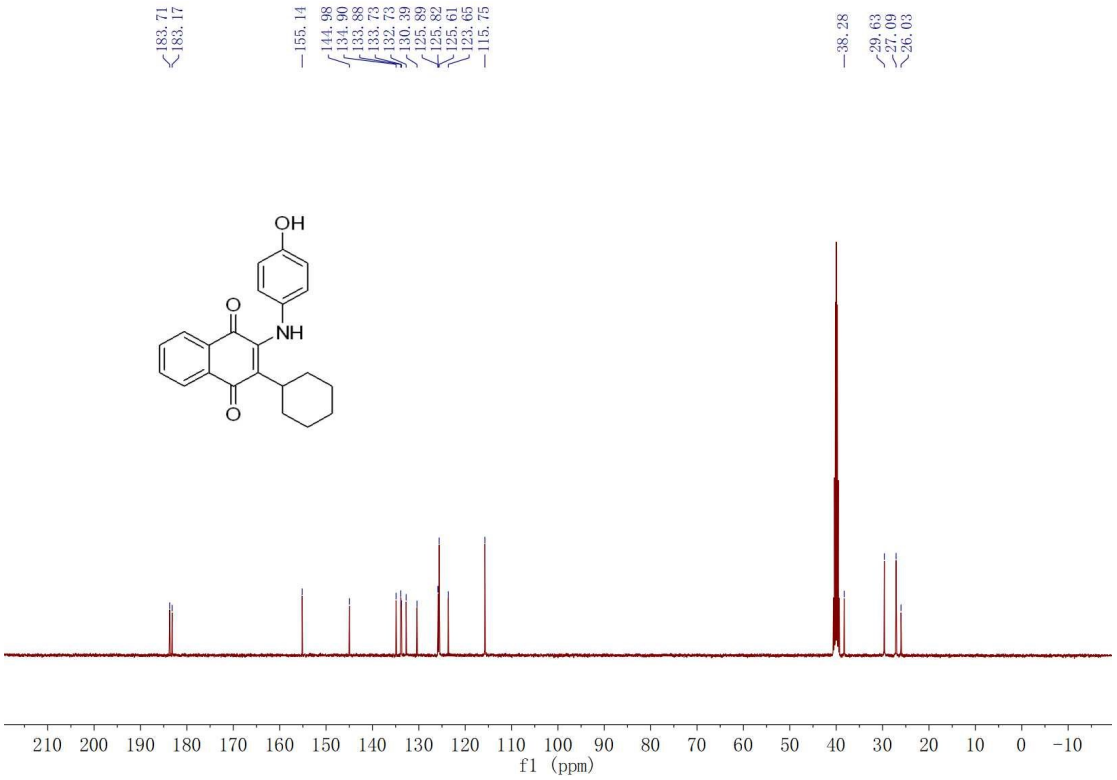

$^{13}$C-NMR spectra of **8**



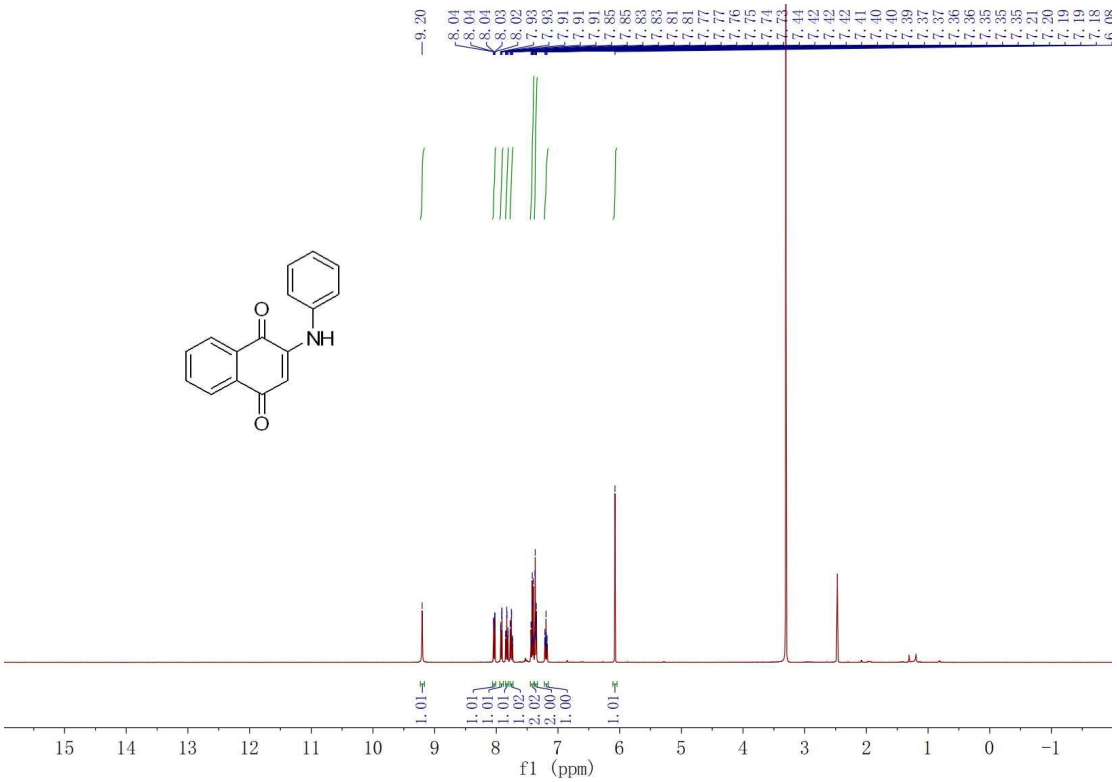

$^{1}$H-NMR spectra of **9**



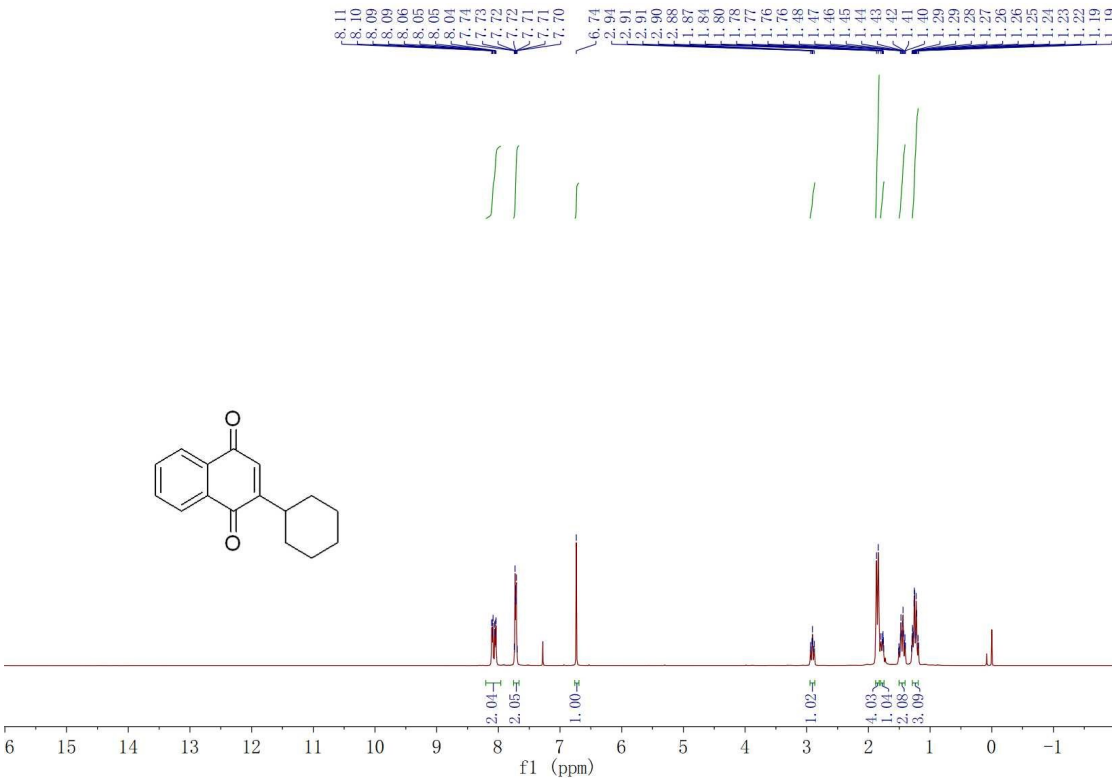

$^{13}$C-NMR spectra of **9**




$^1$H-NMR spectra of **10**




$^1$H-NMR spectra of **11**


8.11
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f1 (ppm)