# Supporting Information

## Visible-light-induced oxidative cyclization of *N*-propargylanilines with sulfinic acids to 3-sulfonated quinoline derivatives without external photocatalyst

Yicheng Zhang,[a,c] Wei Chen,[*a] Xueshun Jia,[c] Lei Wang,[a,b] and Pinhua Li[*a]

[a] Department of Chemistry, Huaibei Normal University, Huaibei, Anhui 235000, P. R. China, Tel: +86-561-3802-069 Fax: +86-561-3090-518

E-mail: lake688123@163.com; pphuali@126.com

[b] State Key Laboratory of Organometallic Chemistry, Shanghai Institute of Organic Chemistry, Chinese Academy of Sciences, Shanghai 200032, P. R. China

[c] School of Environmental and Chemical Engineering, Shanghai University, Shanghai 200444, P.R. China

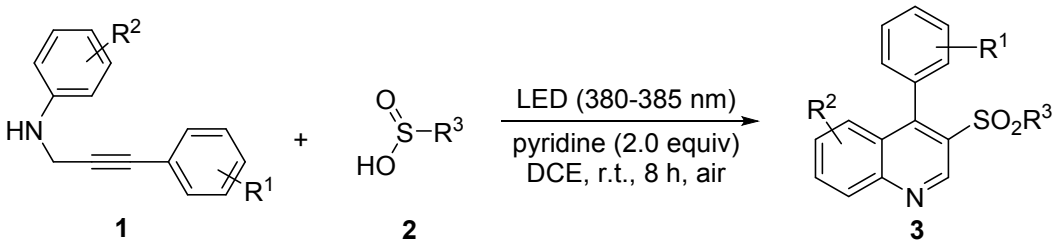
**Table of Contents**

## 1. General considerations

All $^{1}H$ NMR and $^{13}C$ NMR spectra were recorded on a 400 MHz Bruker FT-NMR spectrometer (400 MHz or 100 MHz, respectively). All chemical shifts are given as δ value (ppm) with reference to tetramethylsilane (TMS) as internal reference. The peak patterns are indicated as follows: s, singlet; d, doublet; t, triplet; m, multiplet; q, quartet. The coupling constants, *J*, are reported in Hertz (Hz). High resolution mass spectroscopy data of the product were collected on a Waters Micromass GCT instrument. High resolution mass spectroscopy data of the product were collected on an Agilent Technologies 6540 UHD Accurate-Mass Q-TOF LC/MS (ESI). The chemicals and solvents were purchased from commercial suppliers either from Aldrich (USA) or Shanghai Chemical Company (China) without further purification. The starting material propargylamine **(1a–1x)** were prepared according to the reported method (See: L. Zhang, S. Chen, Y. Gao, P. Zhang, Y. Wu, G. Tang and Y. Zhao, *Org. Lett.*, 2016, **18**, 1286). The chemicals and solvents were purchased from commercial suppliers either from Aldrich (USA) or Shanghai Chemical Company (China) without further purification. All the solvents were dried and freshly distilled prior to use. Products were purified by flash chromatography packed with 200–300 mesh silica gels, $SiO_2$.

## 2. General procedure for the reaction

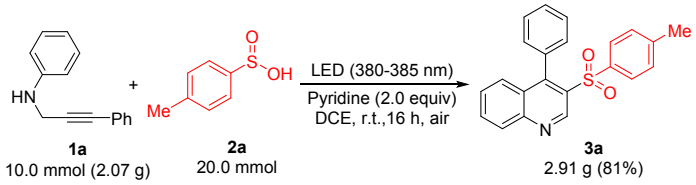
2.1 General procedure for the reaction in 0.20 mmol scale




*N*-(3-Phenyl-2-propynyl)aniline derivative (**1**, 0.20 mmol), sulfinic acid (**2**, 0.40 mmol), pyridine (0.40 mmol) and DCE (2.0 mL) were sequentially added to a 5 mL oven-dried reaction vessel equipped with a magnetic stirrer bar. The reaction mixture

was exposed to blue LED (380−385 nm, 1.5 W) irradiation at room temperature in air with stirring for 8 h. When the reaction was complete, the reaction solution was concentrated in vacuum. The resulting crude mixture was purified by flash column chromatography (petroleum ether/ethyl acetate = 3:1 to 5:1) to give the desired product (**3**).

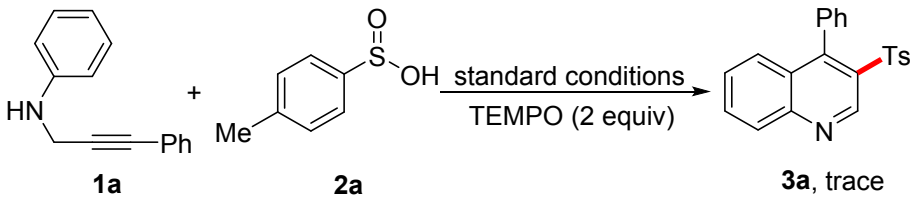
2.2 The representative procedure for the reaction of **1a** in 10.0 mmol scale




*N*-(3-phenyl-2-propynyl)aniline (**1a**, 10.0 mmol), 4-methylbenzenesulfinic acid (**2a**, 20.0 mmol), pyridine (20.0 mmol) and DCE (100.0 mL) were sequentially added to a 250 mL oven-dried reaction vessel equipped with a magnetic stirrer bar. The reaction mixture was exposed to blue LED (380−385 nm, 1.5 W×4, four lamps) irradiation at room temperature in air with stirring for 16 h. After the reaction was completed (monitored by TLC), the reaction solution was concentrated in vacuum. Then ethyl acetate (120 mL) was added and the mixture was washed with saturated sodium carbonate ($Na_2CO_3$) solution, water and brine solution. The organic layer was collected and dried over $Na_2SO_4$. After the solvent was removed under reduced pressure, the residue was purified by column chromatography using a mixture of petroleum ether and ethyl acetate (5:1, V/V) as an eluent to afford the desired product **3a** as light yellow solid (2.91g, 81% yield).

## 3. Preliminary mechanistic study

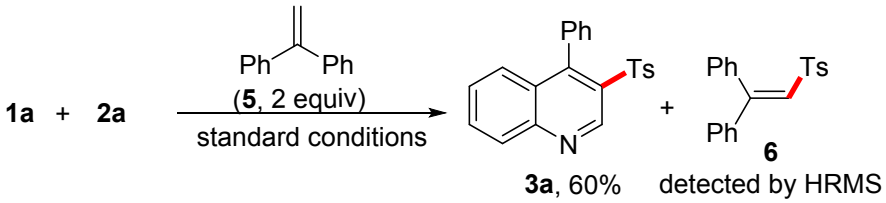
### 3.1 Free radical-inhibiting experiment




*N*-(3-Phenyl-2-propynyl)aniline (**1a**, 0.20 mmol), 4-methylbenzenesulfinic acid

(**2a**, 0.40 mmol), pyridine (0.40 mmol), 2,2,6,6-tetramethyl-1-oxylpiperidine (TEMPO, 0.40 mmol) and DCE (2.0 mL) were sequentially added to a 5 mL oven-dried reaction vessel equipped with a magnetic stirrer bar. The reaction mixture was exposed to blue LED (380−385 nm, 1.5 W) irradiation at room temperature in air with stirring for 8 h. After the reaction was completed, only trace amount of product **3a** was detected by TLC and HPLC-HRMS, indicating that the reaction was almost inhibited.

### 3.2 Free radical-trapping experiment




*N*-(3-Phenyl-2-propynyl)aniline (**1a**, 0.20 mmol), 4-methylbenzenesulfinic acid (**2a**, 0.40 mmol), pyridine (0.40 mmol), 1,1-diphenylethylene (**5**, 0.40 mmol) and DCE (2.0 mL) were sequentially added to a 5 mL oven-dried reaction vessel equipped with a magnetic stirrer bar. The reaction mixture was exposed to blue LED (380−385 nm, 1.5 W) irradiation at room temperature in air with stirring for 8 h. After the reaction was completed, the products were detected by TLC and HPLC-HRMS. The product **3a** was isolated in 60% yield, and small amount of compound **6** was detected by HPLC-HRMS analysis, as shown in **Figure S1**, which is a radical trapping product.

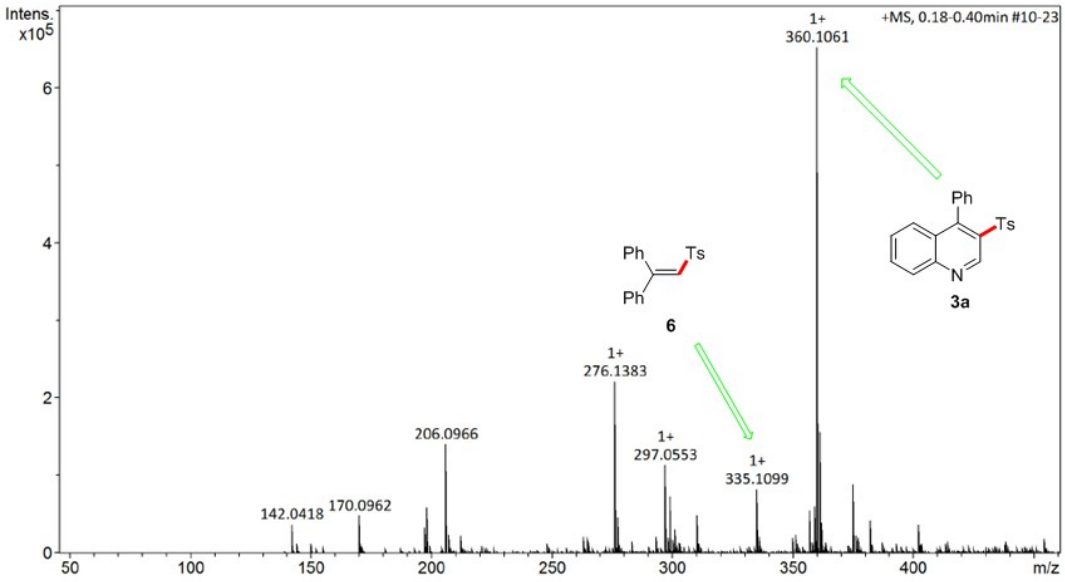



**Figure S1.** HRMS analysis of **3a** and **6**

### 3.3 Determination of electron spin resonance (ESR)

#### 3.3.1 Determination of superoxide radicals

In order to determine the active species of oxygen involved in the present reaction, 5,5-dimethyl-pyrroline-*N*-oxide (DMPO) was employed to capture $O_2^{\bullet-}$. There was no signal when DMPO was added into a solution of *N*-(3-phenyl-2-propynyl)aniline (**1a**) in air in the absence of light irradiation (**Figure S2**A). Irradiation of reaction solution of DMPO and *N*-(3-phenyl-2-propynyl)aniline (**1a**) in air with LED (380−385 nm, 1.5 W) resulted in the formation of a strong characteristic signal of $O_2^{\bullet-}$ adduct with DMPO (**Figure S2**B). When the reaction time was prolonged, a series of stronger characteristic signal of $O_2^{\bullet-}$ were observed (**Figure S2**C and **S2**D), indicating the formation of $O_2^{\bullet-}$ in the reaction.

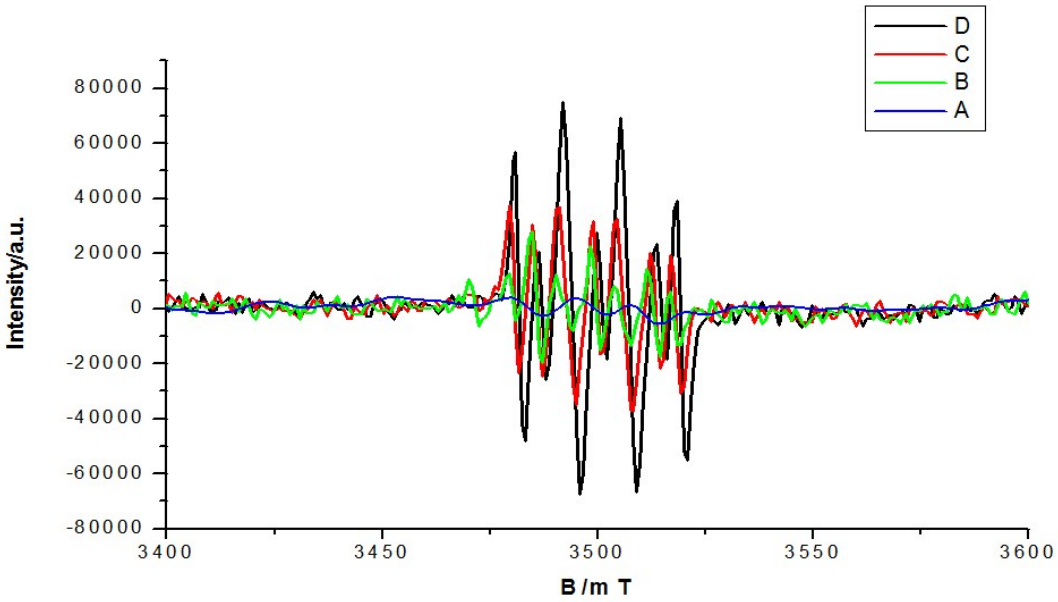



**Figure S2**. Electron spin resonance (ESR) spectra of 5,5-dimethyl-pyrroline-*N*-oxide (DMPO) with $O_2^{\bullet-}$

(**A**) A solution of DMPO (0.20 mol/L) with **1a** in DCE without light irradiation.

(**B**) A solution of DMPO (0.20 mol/L) with **1a** in DCE under LED (380−385 nm, 1.5 W) irradiation for 30 s.

(**C**) A solution of DMPO (0.20 mol/L) with **1a** in DCE under LED (380−385 nm, 1.5 W) irradiation for 60 s.

(**D**) A solution of DMPO (0.20 mol/L) with **1a** in DCE under LED (380−385 nm, 1.5 W) irradiation for 90 s.

### 3.3.2 Determination of singlet oxygen species

For further explore the active species of singlet oxygen involved during the reaction, 2,2,6,6-tetramethylpiperidine (TEMP) was used to trap $^1O_2$. Irradiation of reaction solution of TEMP and *N*-(3-phenyl-2-propynyl)aniline (**1a**) in air with LED (380−385 nm, 1.5 W) resulted in the formation of a strong characteristic signal $^1O_2$ adduct with TEMP (**Figure S3**b, c, d and e), implying that $^1O_2$ is also present during the reaction.

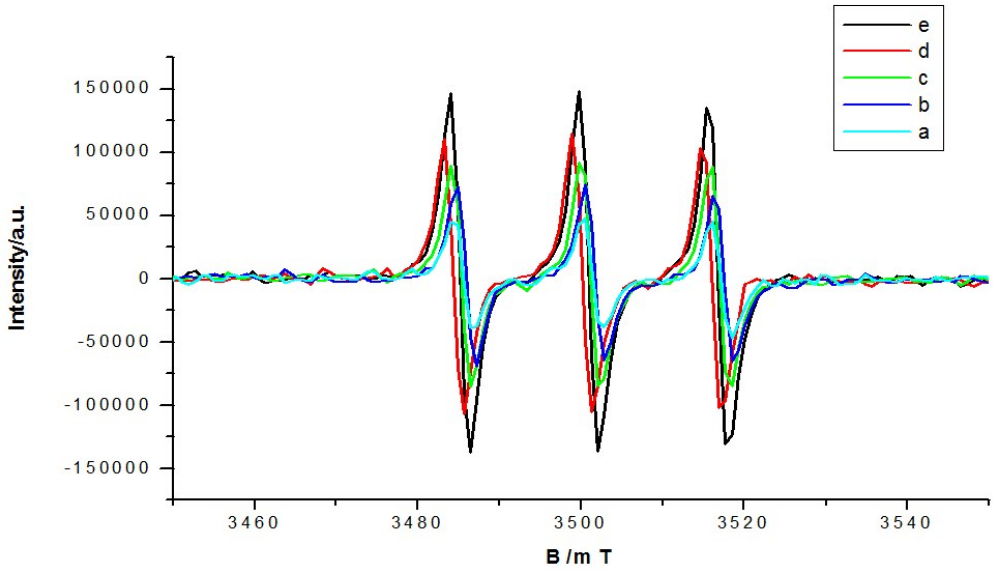



**Figure S3**. Electron spin resonance (ESR) spectra of 2,2,6,6-tetramethylpiperidine (TEMP) with $^1O_2$

(**a**) A solution of TEMP (0.20 mol/L) with **1a** in DCE without light irradiation.

(**b**) A solution of TEMP (0.20 mol/L) with **1a** in DCE under LED (380−385 nm, 1.5 W) irradiation for 30 s.

(**c**) A solution of TEMP (0.20 mol/L) with **1a** in DCE under LED (380−385 nm, 1.5 W) irradiation for 60 s.

(**d**) A solution of TEMP (0.20 mol/L) with **1a** in DCE under LED (380−385 nm, 1.5 W) irradiation for 90 s.

(**e**) A solution of TEMP (0.20 mol/L) with **1a** in DCE under LED (380−385 nm, 1.5 W) irradiation for 120 s.

### 3.4 UV-visible absorption spectra of reactants and product

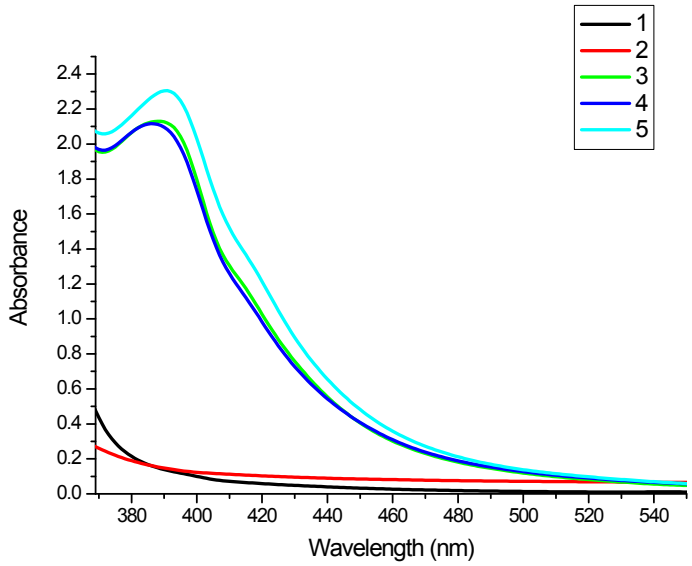



**Figure S4. UV-visible absorption spectra of 1a, 2a, and 3a in DCE**

1. Absorption spectrum of 4-methylbenzenesulfinic acid (**2a,** 0.40 mmol) in DCE (4.0 mL)

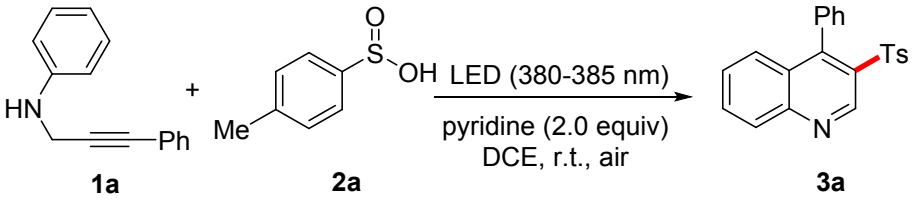
2. Absorption spectrum of 4-methylbenzenesulfinic acid (**2a,** 0.40 mmol) and pyridine (0.20 mmol) in DCE (4.0 mL)

3. Absorption spectrum of *N*-(3-phenyl-2-propynyl)aniline (**1a,** 0.20 mmol) in DCE (4.0 mL)

4. Absorption spectrum of *N*-(3-phenyl-2-propynyl)aniline (**1a**, 0.20 mmol), 4-methylbenzenesulfinic acid (**2a**, 0.40 mmol) and pyridine (0.40 mmol) in DCE (4.0 mL)

5. Absorption spectrum of 4-phenyl-3-tosylquinoline (**3a**, 0.20 mmol) in DCE (4.0 mL)

### 3.5 Light/Dark experiment



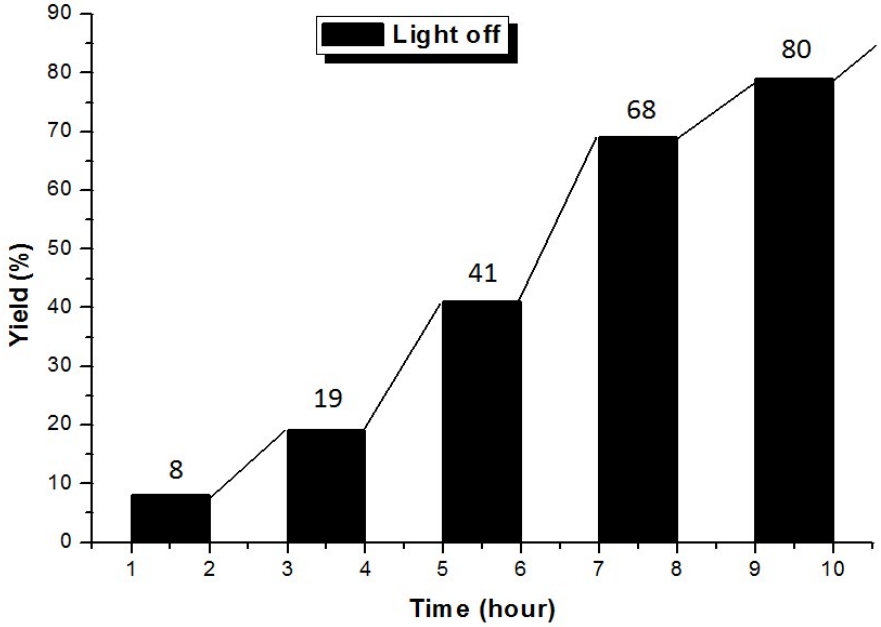
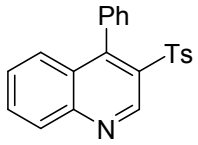



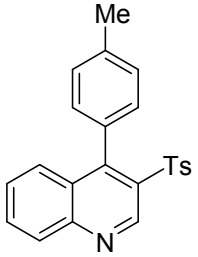

**Figure S5.** Light/Dark experiment

## 4. Characterization data for the products



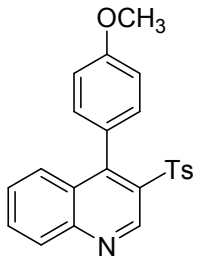

**4-Phenyl-3-tosylquinoline (3a)**

Yield: 70.4 mg (98%). $^{1}$H NMR (400 MHz, $CDCl_3$): δ = 9.78 (s, 1H), 8.20 (d, *J* = 8.4 Hz, 1H), 7.83–7.78 (m, 1H), 7.47–7.42 (m, 2H), 7.35–7.31 (m, 3H), 7.19 (d, *J* = 8.4 Hz, 2H), 7.04 (d, *J* = 8.4 Hz, 2H), 6.95 (d, *J* = 7.2 Hz, 2H), 2.34 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ = 149.7, 149.7, 147.7, 144.0, 137.9, 132.6, 132.1, 130.0, 129.6, 129.2, 128.6, 127.9, 127.8, 127.6, 127.4, 127.4, 21.5; HRMS (ESI) ($[M+H]^+$) Calcd. For $C_{22}H_{18}NO_2S$: 360.1053, Found: 360.1061.



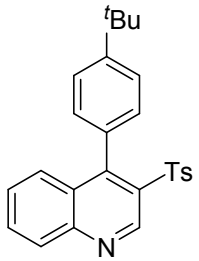

**4-(*p*-Tolyl)-3-tosylquinoline (3b)**

Yield: 73.9 mg (99%). $^{1}$H NMR (400 MHz, $CDCl_3$): δ = 9.76 (s, 1H), 8.18 (d, *J* = 8.4 Hz, 1H), 7.81–7.77 (m, 1H), 7.45–7.41(m, 1H), 7.38–7.35 (m, 1H), 7.22 (d, *J* = 8.4 Hz, 2H), 7.14 (d, *J* = 8.0 Hz, 2H), 7.04 (d, *J* = 8.0 Hz, 2H), 6.84 (d, *J* = 8.0 Hz, 2H), 2.46 (s, 3H), 2.34 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ = 150.1, 149.6, 147.7, 143.9, 138.5, 138.0, 132.7, 132.0, 129.8, 129.6, 129.5, 129.1, 128.2, 127.9, 127.6, 127.4, 21.5, 21.4; HRMS (ESI) ($[M+H]^+$) Calcd. For $C_{23}H_{20}NO_2S$: 374.1209, Found: 374.1205.



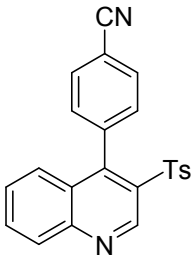

**4-(4-Methoxyphenyl)-3-tosylquinoline (3c)**

Yield: 73.2 mg (94%). $^{1}$H NMR (400 MHz, $CDCl_3$): δ = 9.62 (s, 1H), 8.07 (d, *J* = 9.2 Hz, 1H), 7.45–7.41 (m, 2H), 7.32 (t, *J* = 8.0 Hz, 2H), 7.18 (d, *J* = 8.4 Hz, 2H), 7.03 (d, *J* = 8.0 Hz, 2H), 6.93 (d, *J* = 7.2 Hz, 2H), 6.49 (d, *J* = 2.4 Hz, 1H), 3.58 (s, 3H), 2.33 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ = 158.5, 147.9, 146.0, 145.2, 143.9, 138.0, 132.8, 132.8, 130.9, 129.8, 129.1, 128.7, 128.5, 127.8, 127.7, 124.7, 104.7, 55.2, 21.4; HRMS (ESI) ([M+H]$^+$) Calcd. For $C_{23}H_{20}NO_3S$: 390.1158, Found: 390.1161.



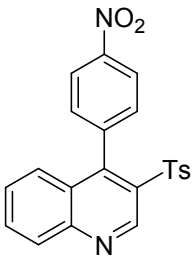

**4-(4-(*tert*-Butyl)phenyl)-3-tosylquinoline (3d)**

Yield: 80.6 mg (97%). $^{1}$H NMR (400 MHz, $CDCl_3$): δ = 9.80 (s, 1H), 8.19 (d, *J* = 8.8 Hz, 1H), 7.79 (t, *J* = 7.2 Hz, 1H), 7.44 (t, *J* = 8.0 Hz, 1H), 7.38 (d, *J* = 8.4 Hz, 1H), 7.30 (d, *J* = 8.4 Hz, 2H), 7.12 (d, *J* = 8.0 Hz, 2H), 6.97 (d, *J* = 8.0 Hz, 2H), 6.86 (d, *J* = 8.4 Hz, 2H), 2.33 (s, 3H), 1.41 (s, 9H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ = 151.7, 150.1, 149.7, 147.5, 143.7, 137.8, 132.8, 132.0, 129.8, 129.6, 129.4, 129.0, 127.8, 127.6, 127.6, 127.5, 124.4, 34.7, 31.4, 21.5; HRMS (ESI) ([M+H]$^+$) Calcd. For $C_{26}H_{26}NO_2S$: 416.1679, Found: 416.1675.



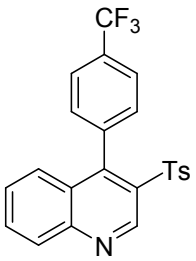

**4-(3-Tosylquinolin-4-yl)benzonitrile (3e)**

Yield: 75.4 mg (98%). $^1$H NMR (400 MHz, $CDCl_3$): δ = 9.73 (s, 1H), 8.23 (d, *J* = 8.4 Hz, 1H), 7.85 (t, *J* = 7.2 Hz, 1H), 7.66 (d, *J* = 8.4 Hz, 2H), 7.50 (t, *J* = 8.0 Hz, 1H), 7.26 (d, *J* = 8.0 Hz, 2H), 7.20 (d, *J* = 8.4 Hz, 1H), 7.14–7.12 (m, 4H), 2.38 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ = 149.7, 147.7, 147.1, 144.7, 137.8, 137.7, 132.5, 132.3, 131.3, 130.8, 130.0, 129.5, 128.4, 127.7, 126.6, 126.4, 118.2, 112.8, 21.5; HRMS (ESI) ($[M+H]^+$) Calcd. For $C_{23}H_{17}N_2O_2S$: 385.1005, Found: 385.1008.



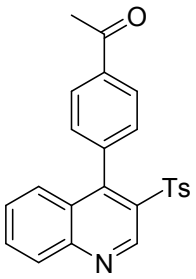

**4-(4-Nitrophenyl)-3-tosylquinoline (3f)**

Yield: 76.8 mg (95%). $^1$H NMR (400 MHz, $CDCl_3$): δ = 9.74 (s, 1H), 8.26–8.22 (m, 3H), 7.87 (t, *J* = 7.2 Hz, 1H), 7.51 (t, *J* = 7.2 Hz, 1H), 7.30 (d, *J* = 8.4 Hz, 2H), 7.22–7.20 (m, 3H), 7.14 (d, *J* = 8.0 Hz, 2H), 2.39 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ = 149.6, 148.0, 147.7, 146.8, 144.9, 139.7, 137.8, 132.6, 132.5, 131.1, 130.0, 129.6, 128.5, 127.8, 126.6, 126.4, 122.8, 21.6; HRMS (ESI) ($[M+H]^+$) Calcd. For $C_{22}H_{17}N_2O_4S$: 405.0904, Found: 405.0910.



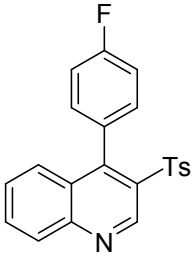
**3-Tosyl-4-(4-(trifluoromethyl)phenyl)quinoline (3g)**

Yield: 84.6 mg (99%). $^1$H NMR (400 MHz, $CDCl_3$): δ = 9.78 (s, 1H), 8.23 (d, *J* = 8.4 Hz, 1H), 7.87–7.83 (m, 1H), 7.59 (d, *J* = 8.0 Hz, 2H), 7.52–7.48 (m, 1H), 7.27–7.25 (m, 1H), 7.20 (d, *J* = 8.4 Hz, 2H), 7.11 (d, *J* = 8.0 Hz, 2H), 7.07 (d, *J* = 8.0 Hz, 2H), 2.37 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ = 149.7, 147.7, 147.5, 144.4, 137.6, 136.5, 132.6, 132.3, 130.8 (q, *J* = 32.0 Hz), 130.5, 129.8, 129.4, 128.2, 127.7, 126.8, 126.7, 124.5 (q, *J* = 4.0 Hz), 123.8 (q, *J* = 271.0 Hz), 21.4; HRMS (ESI) ($[M+H]^+$) Calcd. For $C_{23}H_{17}F_3NO_2S$: 428.0927, Found: 428.0931.




**1-(4-(3-Tosylquinolin-4-yl)phenyl)ethan-1-one (3h)**

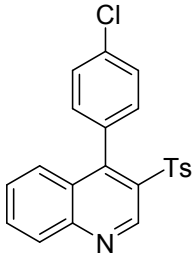
Yield: 77.1 mg (96%). $^1$H NMR (400 MHz, $CDCl_3$): δ = 9.70 (s, 1H), 8.17 (d, *J* = 8.4 Hz, 1H), 7.92 (d, *J* = 8.0 Hz, 2H), 7.79 (t, *J* = 8.0 Hz, 1H), 7.43 (d, *J* = 8.0 Hz, 1H), 7.21 (d, *J* = 8.0 Hz, 3H), 7.08–7.03 (m, 4H), 2.67 (s, 3H), 2.32 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ = 197.3, 149.5, 148.2, 147.6, 144.4, 137.8, 137.6, 136.9, 132.3, 132.2, 130.2, 129.7, 129.3, 128.0, 127.7, 127.3, 126.9, 126.7, 26.6, 21.4; HRMS (ESI) ($[M+H]^+$) Calcd. For $C_{24}H_{20}NO_3S$: 402.1158, Found: 402.1161.




**4-(4-Fluorophenyl)-3-tosylquinoline (3i)**

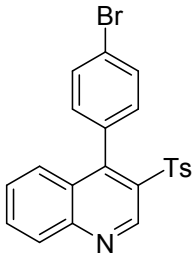
Yield: 73.2 mg (97%). $^1$H NMR (400 MHz, $CDCl_3$): δ = 9.75 (s, 1H), 8.19 (d, *J* = 8.4 Hz, 1H), 7.83–7.79 (m, 1H), 7.48–7,44 (m, 1H), 7.31 (d, *J* = 8.4 Hz, 1H), 7.22 (d, *J* =

8.4 Hz, 2H), 7.08 (d, $J$ = 8.0 Hz, 2H), 7.03 (t, $J$ = 8.8 Hz, 2H), 6.95–6.91 (m, 2H), 2.35 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ = 162.9 (d, $J$ = 248.0 Hz), 149.7, 148.6, 147.6, 144.2, 137.9, 132.8, 132.2, 131.9 (d, $J$ = 8.0 Hz), 129.7, 129.2, 128.4 (d, $J$ = 4.0 Hz), 127.9, 127.7, 127.4, 127.0, 114.7 (d, $J$ = 17.0 Hz), 21.5; HRMS (ESI) ([M+H]$^+$) Calcd. For $C_{22}H_{17}FNO_2S$: 378.0959, Found: 378.0953.




**4-(4-Chlorophenyl)-3-tosylquinoline (3j)**

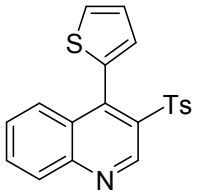
Yield: 77.2 mg (98%). $^1$H NMR (400 MHz, $CDCl_3$): δ = 9.76 (s, 1H), 8.20 (d, $J$ = 8.4 Hz, 1H), 7.85–7.81 (m, 1H), 7.50–7.46 (m, 1H), 7.33–7.31 (m, 3H), 7.25 (d, $J$ = 8.4 Hz, 2H), 7.11 (d, $J$ = 8.0 Hz, 2H), 6.91 (d, $J$ = 8.4 Hz, 2H), 2.37 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ = 149.6, 148.3, 147.6, 144.3, 137.8, 135.0, 132.7, 132.2, 131.3, 131.0, 129.7, 129.3, 128.0, 127.9, 127.8, 127.1, 127.0, 21.5; HRMS (ESI) ([M+H]$^+$) Calcd. For $C_{22}H_{17}{}^{35}ClNO_2S$: 394.0663, Found: 394.0661.




**4-(4-Bromophenyl)-3-tosylquinoline (3k)**

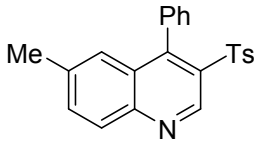
Yield: 85.0 mg (97%). $^1$H NMR (400 MHz, $CDCl_3$): δ = 9.73 (s, 1H), 8.18 (d, $J$ = 8.4 Hz, 1H), 7.83–7.78 (m, 1H), 7.48–7.44 (m, 3H), 7.30 (d, $J$ = 8.8 Hz, 1H), 7.23 (d, $J$ = 8.4 Hz, 2H), 7.09 (d, $J$ = 8.0 Hz, 2H), 6.83 (d, $J$ = 8.4 Hz, 2H), 2.35 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ = 149.6, 148.2, 147.5, 144.3, 137.7, 132.6, 132.2, 131.5, 131.5, 130.8, 129.7, 129.2, 128.0, 127.7, 126.9, 123.1, 21.5; HRMS (ESI) ([M+H]$^+$) Calcd.

For $C_{22}H_{17}{}^{79}BrNO_2S$: 438.0158, Found: 438.0162.



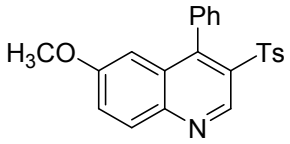

**4-(Thiophen-2-yl)-3-tosylquinoline (3l)**

Yield: 65.1 mg (89%). $^1$H NMR (400 MHz, $CDCl_3$): δ = 9.77 (s, 1H), 8.15 (d, *J* = 8.4 Hz, 1H), 7.80–7.76 (m, 1H), 7.55 (d, *J* = 8.0 Hz, 1H), 7.50–7.45 (m, 2H), 7.29 (d, *J* = 8.4 Hz, 2H), 7.11–7.07 (m, 3H), 6.97 (d, *J* = 2.8 Hz, 1H), 2.32 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ = 149.5, 147.5, 144.0, 142.8, 137.3, 134.1, 132.2, 131.6, 131.2, 129.4, 129.2, 128.6, 128.3, 128.0, 127.6, 126.9, 126.6, 21.4; HRMS (ESI) ([M+H]$^+$) Calcd. For $C_{20}H_{16}NO_2S_2$: 366.0617, Found: 366.0619.




**6-Methyl-4-phenyl-3-tosylquinoline (3m)**

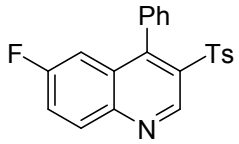
Yield: 71.0 mg (95%). $^1$H NMR (400 MHz, $CDCl_3$): δ = 9.70 (s, 1H), 8.07 (d, *J* = 8.4 Hz, 1H), 7.62 (dd, $J_1$ = 8.4 Hz, $J_2$ = 1.6 Hz, 1H), 7.45 (t, *J* = 7.6 Hz, 1H), 7.32 (t, *J* = 7.6 Hz, 2H), 7.18 (d, *J* = 8.4 Hz, 2H), 7.04–7.02 (m, 3H), 6.92 (d, *J* = 6.8 Hz, 2H), 2.34 (s, 3H), 2.33 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ = 148.9, 148.3, 146.7, 143.8, 138.0, 134.4, 132.7, 132.5, 130.0, 129.2, 129.1, 128.5, 127.8, 127.5, 127.4, 125.9, 21.7, 21.4; HRMS (ESI) ([M+H]$^+$) Calcd. For $C_{23}H_{20}NO_2S$: 374.1209, Found: 374.1210.




**6-Methoxy-4-phenyl-3-tosylquinoline (3n)**

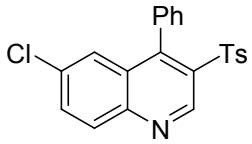
Yield: 64.7 mg (83%). $^1$H NMR (400 MHz, $CDCl_3$): δ = 9.75 (s, 1H), 8.17 (d, *J* = 8.4

Hz, 1H), 7.80–7.76 (m, 1H), 7.45–7.41 (m, 1H), 7.29 (d, $J$ = 8.4 Hz, 1H), 7.20 (d, $J$ = 8.4 Hz, 2H), 7.04 (d, $J$ = 8.0 Hz, 2H), 6.87–6.83 (m, 4H), 3.89 (s, 3H), 2.33 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ = 159.9, 149.8, 149.6, 147.6, 143.9, 137.9, 132.9, 132.0, 131.3, 129.5, 129.1, 127.8, 127.8, 127.6, 127.3, 124.5, 113.0, 55.3, 21.4; HRMS (ESI) ([M+H]$^+$) Calcd. For $C_{23}H_{20}NO_3S$: 390.1158, Found: 390.1162.



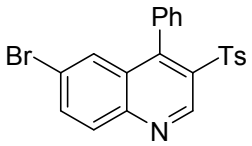

**6-Fluoro-4-phenyl-3-tosylquinoline (3o)**

Yield: 73.2 mg (97%). $^1$H NMR (400 MHz, $CDCl_3$): δ = 9.73 (s, 1H), 8.19 (dd, $J_1$ = 9.2 Hz, $J_2$ = 5.6 Hz, 1H), 7.58–7.53 (m, 1H), 7.46 (t, $J$ = 7.2 Hz, 1H), 7.33 (t, $J$ = 8.0 Hz, 2H), 7.18 (d, $J$ = 8.4 Hz, 2H), 7.04 (d, $J$ = 8.4 Hz, 2H), 6.93–6.89 (m, 3H), 2.33 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ = 160.9 (d, $J$ = 249.0 Hz), 149.0 (d, $J$ = 6.0 Hz), 147.0 (d, $J$ = 2.0 Hz), 146.8, 144.1, 137.6, 133.3, 132.2, 132.1, 129.8, 129.2, 128.8, 128.6 (d, $J$ = 10.0 Hz), 127.8, 127.8, 122.3 (d, $J$ = 26.0 Hz), 110.6 (d, $J$ = 24.0 Hz), 21.5; HRMS (ESI) ([M+H]$^+$) Calcd. For $C_{22}H_{17}FNO_2S$: 378.0959, Found: 378.0953.



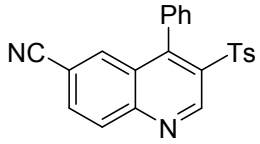

**6-Chloro-4-phenyl-3-tosylquinoline (3p)**

Yield: 78.0 mg (99%). $^1$H NMR (400 MHz, $CDCl_3$): δ = 9.76 (s, 1H), 8.14 (d, $J$ = 8.8 Hz, 1H), 7.73 (dd, $J_1$ = 9.2 Hz, $J_2$ = 2.4 Hz, 1H), 7.48 (t, $J$ = 7.6 Hz, 1H), 7.35 (t, $J$ = 7.6 Hz, 2H), 7.28 (d, $J$ = 2.4 Hz, 1H), 7.19 (d, $J$ = 8.4 Hz, 2H), 7.05 (d, $J$ = 8.0 Hz, 2H), 6.94 (d, $J$ = 6.8 Hz, 2H), 2.35 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ = 148.8, 148.0, 147.9, 144.2, 137.5, 133.9, 133.5, 132.9, 131.9, 131.2, 129.9, 129.2, 128.9, 128.3, 127.9, 127.8, 125.9, 21.5; HRMS (ESI) ([M+H]$^+$) Calcd. For $C_{22}H_{17}{}^{35}ClNO_2S$: 394.0663, Found: 394.0660.



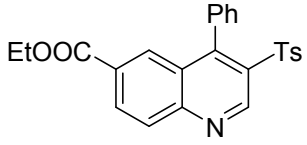

**6-Bromo-4-phenyl-3-tosylquinoline (3q)**

Yield: 85.0 mg (97%). $^{1}$H NMR (400 MHz, $CDCl_3$): δ = 9.76 (s, 1H), 8.04 (d, *J* = 8.8 Hz, 1H), 7.84 (dd, $J_1$ = 9.2 Hz, $J_2$ = 2.4 Hz, 1H), 7.47 (t, *J* = 7.6 Hz, 1H), 7.43 (d, *J* = 2.0 Hz, 1H), 7.33 (t, *J* = 8.0 Hz, 2H), 7.16 (d, *J* = 8.4 Hz, 2H), 7.03 (d, *J* = 8.4 Hz, 2H), 6.92 (d, *J* = 6.8 Hz, 2H), 2.33 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ = 148.7, 148.2, 148.0, 144.2, 137.5, 135.5, 133.4, 131.8, 131.2, 129.8, 129.2, 128.9, 127.8, 127.8, 122.2, 21.5; HRMS (ESI) ($[M+H]^+$) Calcd. For $C_{22}H_{17}{}^{79}BrNO_2S$: 438.0158, Found: 438.0161.




**4-Phenyl-3-tosylquinoline-6-carbonitrile (3r)**

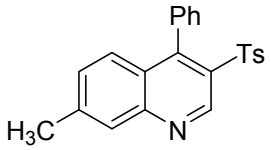
Yield: 67.7 mg (88%). $^{1}$H NMR (400 MHz, $CDCl_3$): δ = 9.86 (s, 1H), 8.28 (d, *J* = 8.8 Hz, 1H), 7.92 (dd, $J_1$ = 8.8 Hz, $J_2$ = 1.6 Hz, 1H), 7.70 (d, *J* = 1.2 Hz, 1H), 7.51 (t, *J* = 7.6 Hz, 1H), 7.37 (t, *J* = 8.0 Hz, 2H), 7.17 (d, *J* = 8.4 Hz, 2H), 7.05 (d, *J* = 8.4 Hz, 2H), 6.93 (d, *J* = 7.6 Hz, 2H), 2.34 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ = 150.4, 150.3, 150.1, 144.5, 137.1, 134.3, 133.6, 132.2, 131.2, 131.1, 129.7, 129.3, 128.0, 127.9, 127.2, 117.8, 111.6, 21.5; HRMS (ESI) ($[M+H]^+$) Calcd. For Chemical Formula: $C_{23}H_{17}N_2O_2S$: 385.1005, Found: 385.1007.




**Ethyl 4-phenyl-3-tosylquinoline-6-carboxylate (3s)**

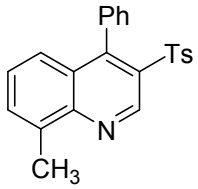
Yield: 84.6 mg (98%). $^{1}$H NMR (400 MHz, $CDCl_3$): δ = 9.84 (s, 1H), 8.37 (dd, $J_1$ = 8.8 Hz, $J_2$ = 2.0 Hz, 1H), 8.23 (d, *J* = 8.8 Hz, 1H), 8.07 (d, *J* = 2.0 Hz, 1H), 7.48 (t, *J* = 7.6 Hz, 1H), 7.35 (d, *J* = 8.0 Hz, 2H), 7.19 (d, *J* = 8.4 Hz, 2H), 7.05 (d, *J* = 8.0 Hz,

2H), 6.96 (d, $J$ = 7.2 Hz, 2H), 4.3 (q, $J$ = 7.2 Hz, 2H), 2.34 (s, 3H), 1.30 (t, $J$ = 6.8 Hz, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ = 165.4, 151.3, 151.1, 149.7, 144.2, 137.6, 133.5, 131.8, 131.4, 130.3, 130.0, 129.7, 129.3, 129.0, 127.9, 127.7, 126.9, 61.5, 21.5, 14.1; HRMS (ESI) ([M+H]$^+$) Calcd. For $C_{25}H_{22}NO_4S$: 432.1264, Found: 432.1268.



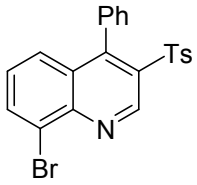

**7-Methyl-4-phenyl-3-tosylquinoline (3t)**

Yield: 70.2 mg (94%). $^1$H NMR (400 MHz, $CDCl_3$): δ = 9.77 (s, 1H), 8.16 (d, $J$ = 8.4 Hz, 1H), 7.79–7.75 (m, 1H), 7.44–7.40 (m, 1H), 7.33 (dd, $J_1$ = 8.4 Hz, $J_2$ = 0.8 Hz, 1H), 7.27–7.21 (m, 2H), 7.17 (d, $J$ = 8.4 Hz, 2H), 7.03 (d, $J$ = 8.0 Hz, 2H), 6.86 (d, $J$ = 6.8 Hz, 1H), 6.50 (s, 1H), 2.33 (s, 3H), 2.21 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ = 149.9, 149.5, 147.5, 143.7, 137.8, 137.0, 132.5, 132.3, 132.0, 130.1, 129.4, 129.2, 129.0, 127.8, 127.6, 127.5, 127.4, 127.2, 21.4, 21.1; HRMS (ESI) ([M+H]$^+$) Calcd. For $C_{23}H_{20}NO_2S$: 374.1209, Found: 374.1211.



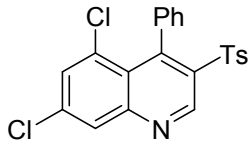

**8-Methyl-4-phenyl-3-tosylquinoline (3u)**

Yield: 66.5 mg (89%). $^1$H NMR (400 MHz, $CDCl_3$): δ = 9.79 (s, 1H), 7.64 (d, $J$ = 7.2 Hz, 1H), 7.44 (t, $J$ = 7.6 Hz, 1H), 7.34–7.30 (m, 3H), 7.21 (d, $J$ = 8.4 Hz, 2H), 7.16 (d, $J$ = 8.4 Hz, 1H), 7.04 (d, $J$ = 8.4 Hz, 2H), 6.94 (d, $J$ = 7.2 Hz, 2H), 2.86 (s, 3H), 2.34 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ = 149.7, 148.7, 146.4, 143.9, 138.0, 137.5, 133.0, 132.2, 132.1, 130.0, 129.1, 128.4, 127.8, 127.5, 127.4, 125.3, 21.4, 18.1; HRMS (ESI) ([M+H]$^+$) Calcd. For $C_{23}H_{20}NO_2S$: 374.1209, Found: 374.1211.



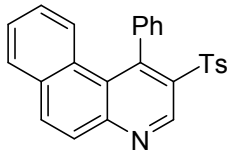

**8-Bromo-4-phenyl-3-tosylquinoline (3v)**

Yield: 78.9 mg (90%). $^{1}$H NMR (400 MHz, $CDCl_3$): δ = 9.86 (s, 1H), 8.12 (dd, $J_1$ = 6.0 Hz, $J_2$ = 2.4 Hz, 1H), 7.47 (t, $J$ = 7.6 Hz, 1H), 7.34 (t, $J$ = 7.6 Hz, 2H), 7.30–7.28 (m, 2H), 7.19 (d, $J$ = 8.4 Hz, 2H), 7.05 (d, $J$ = 8.0 Hz, 2H), 6.94 (d, $J$ = 7.2 Hz, 2H), 2.34 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ = 150.3, 148.5, 146.5, 144.2, 137.5, 135.6, 133.6, 132.2, 129.9, 129.3, 129.0, 128.8, 128.0, 127.9, 127.7, 127.3, 125.2, 21.5; HRMS (ESI) ([M+H]$^+$) Calcd. For $C_{22}H_{17}{}^{79}BrNO_2S$: 438.0158, Found: 438.0155.




**5,7-Dichloro-4-phenyl-3-tosylquinoline (3w)**

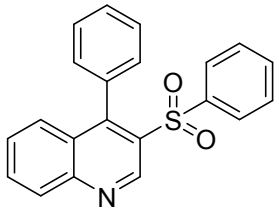
Yield: 74.5 mg (87%). $^{1}$H NMR (400 MHz, $CDCl_3$): δ = 9.83 (s, 1H), 8.15 (d, $J$ = 2.0 Hz, 1H), 7.52 (d, $J$ = 2.4 Hz, 1H), 7.38 (t, $J$ = 7.6 Hz, 1H), 7.18 (t, $J$ = 7.6 Hz, 2H), 7.09 (d, $J$ = 8.4 Hz, 2H), 7.02 (d, $J$ = 8.4 Hz, 2H), 6.88 (d, $J$ = 7.6 Hz, 2H), 2.34 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ = 151.4, 149.7, 149.3, 144.1, 137.6, 137.2, 134.8, 133.6, 132.9, 132.0, 130.5, 129.3, 128.9, 128.7, 127.6, 127.0, 122.9, 21.5; HRMS (ESI) ([M+H]$^+$) Calcd. For $C_{22}H_{16}{}^{35}Cl_2NO_2S$: 428.0273, Found: 428.0277.




**Phenyl-2-tosylbenzo[*f*]quinoline (3x)**

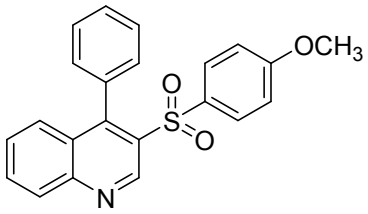
Yield: 68.0 mg (83%). $^{1}$H NMR (400 MHz, $CDCl_3$): δ = 9.88 (s, 1H), 9.40 (d, $J$ = 7.6 Hz, 1H), 7.87–7.85 (m, 1H), 7.82–7.74 (m, 2H), 7.66 (d, $J$ = 9.2 Hz, 1H), 7.48 (t, $J$ = 7.2 Hz, 1H), 7.35 (t, $J$ = 8.0 Hz, 2H), 7.22 (d, $J$ = 8.4 Hz, 2H), 7.15 (d, $J$ = 9.2 Hz,

1H), 7.05 (d, *J* = 8.0 Hz, 2H), 6.98 (d, *J* = 6.8 Hz, 2H), 2.35 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ = 149.0, 148.7, 146.7, 143.9, 138.0, 134.1, 133.3, 133.1, 130.8, 130.1, 129.7, 129.2, 128.9, 128.5, 127.9, 127.7, 127.6, 125.5, 125.5, 123.0, 21.5; HRMS (ESI) ($[M+H]^+$) Calcd. For $C_{26}H_{20}NO_2S$: 410.1209, Found: 410.1212.



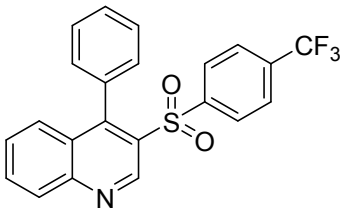

**4-Phenyl-3-(phenylsulfonyl)quinoline (4a)**

Yield: 67.0 mg (97%). $^1$H NMR (400 MHz, $CDCl_3$): δ = 9.80 (s, 1H), 8.19 (d, *J* = 8.8 Hz, 1H), 7.82–7.78 (m, 1H), 7.45–7.41 (m, 3H), 7.32–7.29 (m, 5H), 7.25–7.21 (m, 2H), 6.91 (d, *J* = 7.6 Hz, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ = 149.9, 149.7, 147.5, 140.7, 132.9, 132.4, 132.2, 132.1, 129.9, 129.6, 128.6, 128.5, 127.8, 127.7, 127.6, 127.3, 127.3; HRMS (ESI) ($[M+H]^+$) Calcd. For $C_{21}H_{16}NO_2S$: 346.0896, Found: 346.0895.



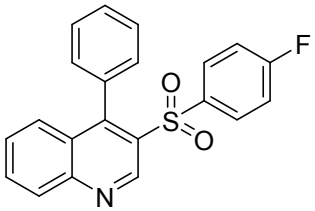

**3-((4-Methoxyphenyl)sulfonyl)-4-phenylquinoline (4b)**

Yield: 66.8 mg (89%). $^1$H NMR (400 MHz, $CDCl_3$): δ = 9.78 (s, 1H), 8.20 (d, *J* = 8.4 Hz, 1H), 7.81 (t, *J* = 8.0 Hz, 1H), 7.48–7.43 (m, 2H), 7.37–7.31 (m, 3H), 7.24–7.21 (m, 2H), 6.98 (d, *J* = 7.2 Hz, 2H), 6.71 (d, *J* = 8.8 Hz, 2H), 3.80 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ = 163.2, 149.6, 149.6, 147.7, 132.9, 132.7, 132.4, 132.0, 130.1, 130.0, 129.6, 128.6, 127.7, 127.6, 127.5, 127.3, 113,8, 55.6; HRMS (ESI) ($[M+H]^+$) Calcd. For $C_{22}H_{18}NO_3S$: 376.1002, Found: 376.0999.



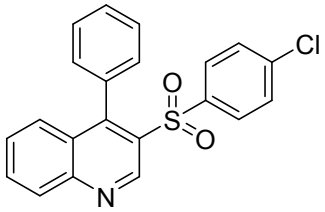
**4-Phenyl-3-((4-(trifluoromethyl)phenyl)sulfonyl)quinoline (4c)**

Yield: 77.7 mg (94%). $^1$H NMR (400 MHz, $CDCl_3$): δ = 9.82 (s, 1H), 8.23 (d, *J* = 8.4 Hz, 1H), 7.85 (t, *J* = 8.0 Hz, 1H), 7.51–7.45 (m, 4H), 7.42 (d, *J* = 8.8 Hz, 2H), 7.35–7.29 (m, 3H), 6.93 (d, *J* = 7.2 Hz, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ = 150.1, 150.0, 147.3, 144.2, 134.5 (q, *J* = 33.0 Hz), 132.6, 132.3, 131.7, 130.1, 129.8, 128.9, 128.4, 128.1, 127.8, 127.4, 127.3, 125.6 (q, *J* = 4.0 Hz), 123.0 (q, *J* = 272.0 Hz); HRMS (ESI) ($[M+H]^+$) Calcd. For $C_{22}H_{15}F_3NO_2S$: 414.0770, Found: 414.0773.



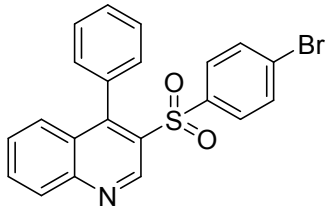
**3-((4-Fluorophenyl)sulfonyl)-4-phenylquinoline (4d)**

Yield: 66.9 mg (92%). $^1$H NMR (400 MHz, $CDCl_3$): δ = 9.79 (s, 1H), 8.21 (d, *J* = 8.8 Hz, 1H), 7.84–7.80 (m, 1H), 7.49–7.44 (m, 2H), 7.37–7.28 (m, 5H), 6.96 (d, *J* = 6.8 Hz, 2H), 6.91 (t, *J* = 8.8 Hz, 2H), 7.03 (s, 1H), 6.93 (d, *J* = 7.6 Hz, 2H), 2.21 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ = 165.2 (d, *J* = 254.0 Hz), 149.8, 147.4, 136.8 (d, *J* = 3.0 Hz), 132.4, 132.3, 132.2, 130.7 (d, *J* = 10.0 Hz), 130.0, 129.7, 128.8, 127.9, 127.7, 127.3, 115.8 (d, *J* = 23.0 Hz); HRMS (ESI) ($[M+H]^+$) Calcd. For $C_{21}H_{15}FNO_2S$: 364.0802, Found: 364.0806.



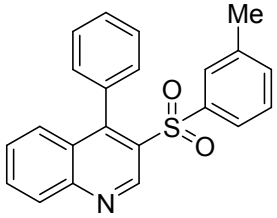
**3-((4-Chlorophenyl)sulfonyl)-4-phenylquinoline (4e)**

Yield: 72.2 mg (95%). $^1$H NMR (400 MHz, $CDCl_3$): δ = 9.76 (s, 1H), 8.19 (d, *J* = 8.4 Hz, 1H), 7.83–7.79 (m, 1H), 7.48–7.43 (m, 2H), 7.35–7.31 (m, 3H), 7.22–7.17 (m, 4H), 6.94 (d, *J* = 7.2 Hz, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ = 149.8, 149.8, 147.3, 139.6, 139.2, 132.3, 131.9, 130.0, 129.6, 129.2, 128.8, 127.9, 127.7, 127.3, 127.2; HRMS (ESI) ([M+H]$^+$) Calcd. For $C_{21}H_{15}{}^{35}ClNO_2S$: 380.0507, Found: 380.0510.



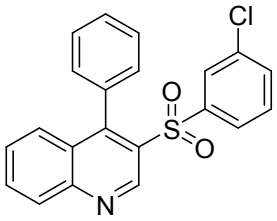

**3-((4-Bromophenyl)sulfonyl)-4-phenylquinoline (4f)**

Yield: 81.5 mg (96%). $^1$H NMR (400 MHz, $CDCl_3$): δ = 9.76 (s, 1H), 8.19 (d, *J* = 8.4 Hz, 1H), 7.81 (t, *J* = 7.6 Hz, 1H), 7.48–7.43 (m, 2H), 7.37–7.31 (m, 5H), 7.12 (d, *J* = 8.4 Hz, 2H), 6.94 (d, *J* = 7.2 Hz, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ = 149.8, 149.8, 147.3, 139.7, 132.3, 132.3, 131.9, 131.8, 129.9, 129.6, 129.2, 128.8, 128.2, 127.9, 127.7,127.3, 127.2; HRMS (ESI) ([M+H]$^+$) Calcd. For $C_{21}H_{15}{}^{79}BrNO_2S$: 424.0001, Found: 424.0002.



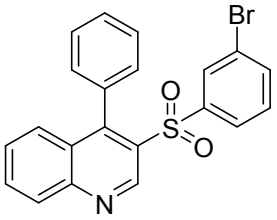

**4-Phenyl-3-(*m*-tolylsulfonyl)quinoline (4g)**

Yield: 66.9 mg (97%). $^1$H NMR (400 MHz, $CDCl_3$): δ = 9.80 (s, 1H), 8.20 (d, *J* = 8.8 Hz, 1H), 7.82–7.78 (m, 1H), 7.47–7.42 (m, 2H), 7.33–7.30 (m, 3H), 7.24–7.21 (m, 1H), 7.15–7.13 (m, 2H), 7.03 (s, 1H), 6.93 (d, *J* = 7.6 Hz, 2H), 2.21 (s, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ = 149.8, 149.7, 147.5, 140.5, 138.6, 133.8, 132.5, 132.4, 132.1, 130.0, 129.6, 128.5, 128.5, 128.3, 127.8, 127.5, 127.4, 127.3, 124.9, 21.1; HRMS (ESI) ([M+H]$^+$) Calcd. For $C_{22}H_{18}NO_2S$: 360.1053, Found: 360.1055.



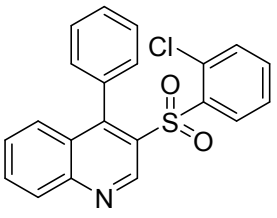

**3-((3-Chlorophenyl)sulfonyl)-4-phenylquinoline (4h)**

Yield: 71.4 mg (94%). $^1$H NMR (400 MHz, $CDCl_3$): δ = 9.79 (s, 1H), 8.22 (d, *J* = 8.8 Hz, 1H), 7.84 (t, *J* = 8.0 Hz, 1H), 7.53–7.46 (m, 2H), 7.42 (s, *J* = 7.6 Hz, 1H), 7.38–7.35 (m, 3H), 7.27–7.22 (m, 2H), 7.15 (s, 1H), 6.95 (d, *J* = 7.2 Hz, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ = 150.1, 149.9, 147.3, 142.3, 134.7, 133.1, 132.4, 132.0, 131.9, 130.0, 129.9, 129.7, 129.0, 128.1, 128.0, 127.7, 127.4, 127.3, 125.8; HRMS (ESI) ($[M+H]^+$) Calcd. For $C_{21}H_{15}{}^{35}ClNO_2S$: 380.0507, Found: 380.0509.



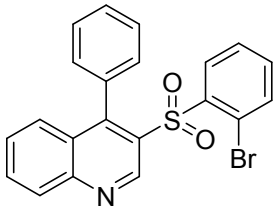

**3-((3-Bromophenyl)sulfonyl)-4-phenylquinoline (4i)**

Yield: 78.1 mg (92%). $^1$H NMR (400 MHz, $CDCl_3$): δ = 9.77 (s, 1H), 8.20 (d, *J* = 8.8 Hz, 1H), 7.82 (t, *J* = 8.4 Hz, 1H), 7.55 (d, *J* = 8.0 Hz, 1H), 7.50 (t, *J* = 7.6 Hz, 1H), 7.45 (t, *J* = 8.0 Hz, 1H), 7.37–7.33 (m, 3H), 7.30–7.27 (m, 2H), 7.13 (t, *J* = 7.6 Hz, 1H), 6.93 (d, *J* = 7.2 Hz, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ = 150.0, 149.8, 147.2, 142.4, 136.0, 132.4, 131.9, 131.8, 130.8, 130.1, 129.9, 129.6, 129.0, 127.9, 127.7, 127.3, 127.2, 126.2, 122.5; HRMS (ESI) ($[M+H]^+$) Calcd. For $C_{21}H_{15}{}^{79}BrNO_2S$: 424.0001, Found: 424.0003.



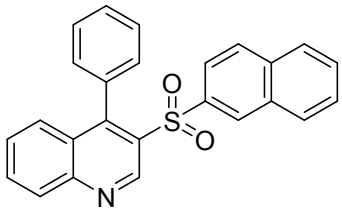

**3-((2-Chlorophenyl)sulfonyl)-4-phenylquinoline (4j)**

Yield: 59.3 mg (78%). $^1$H NMR (400 MHz, $CDCl_3$): δ = 9.85 (s, 1H), 8.24 (d, *J* = 8.4 Hz, 1H), 7.84 (t, *J* = 8.0 Hz, 1H), 7.47 (t, *J* = 7.2 Hz, 1H), 7.39–7.25 (m, 5H), 7.17 (t, *J* = 7.6 Hz, 2H), 7.01 (t, *J* = 8.0 Hz, 1H), 6.90 (d, *J* = 7.2 Hz, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ = 149.6, 149.3, 148.5, 138.0, 134.1, 132.2, 132.0, 131.7, 131.4, 131.0, 130.9, 129.7, 129.6, 128.6, 127.8, 127.5, 127.3, 127.1, 126.7; HRMS (ESI) ($[M+H]^+$) Calcd. For $C_{21}H_{15}{}^{35}ClNO_2S$: 380.0507, Found: 380.0509.




**3-((2-bromophenyl)sulfonyl)-4-phenylquinoline (4k)**

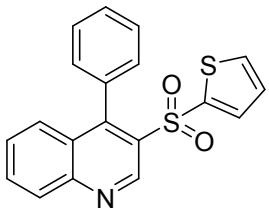
Yield: 64.5 mg (76%). $^1$H NMR (400 MHz, $CDCl_3$): δ = 9.88 (s, 1H), 8.25 (d, *J* = 8.4 Hz, 1H), 7.85 (t, *J* = 7.6 Hz, 1H), 7.51–7.46 (m, 2H), 7.34–7.25 (m, 4H), 7.16 (t, *J* = 7.6 Hz, 2H), 7.05 (t, *J* = 7.6 Hz, 1H), 6.92 (d, *J* = 7.6 Hz, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ = 149.6, 149.2, 148.9, 139.5, 134.5, 134.0, 132.2, 132.0, 131.3, 131.2, 129.7, 129.6, 128.6, 127.8, 127.5, 127.3, 127.3, 127.0, 120.0; HRMS (ESI) ($[M+H]^+$) Calcd. For $C_{21}H_{15}{}^{79}BrNO_2S$: 424.0001, Found: 424.0005.




**3-(Naphthalen-2-ylsulfonyl)-4-phenylquinoline (4l)**

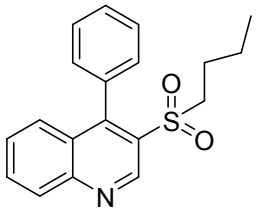
Yield: 71.2 mg (90%). $^1$H NMR (400 MHz, $CDCl_3$): δ = 9.88 (s, 1H), 8.21 (d, *J* = 8.4 Hz, 1H), 7.82–7.79 (m, 2H), 7.74–7.65 (m, 3H), 7.60 (t, *J* = 6.8 Hz, 1H), 7.54 (t, *J* = 6.8 Hz, 1H), 7.44–7.35 (m, 3H), 7.29 (d, *J* = 8.4 Hz, 1H), 7.17 (t, *J* = 7.6 Hz, 2H), 6.86 (d, *J* = 7.2 Hz, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ = 150.0, 149.8, 147.7, 137.2, 134.7, 132.3, 132.2, 132.1, 131.6, 130.1, 129.9, 129.6, 129.4, 129.1, 128.9, 128.8, 127.8, 127.7, 127.5, 127.4, 127.3, 127.3, 122.3; HRMS (ESI) ($[M+H]^+$) Calcd. For

$C_{25}H_{18}NO_2S$: 396.1053, Found: 396.1058.



**4-Phenyl-3-(thiophen-2-ylsulfonyl)quinoline (4m)**

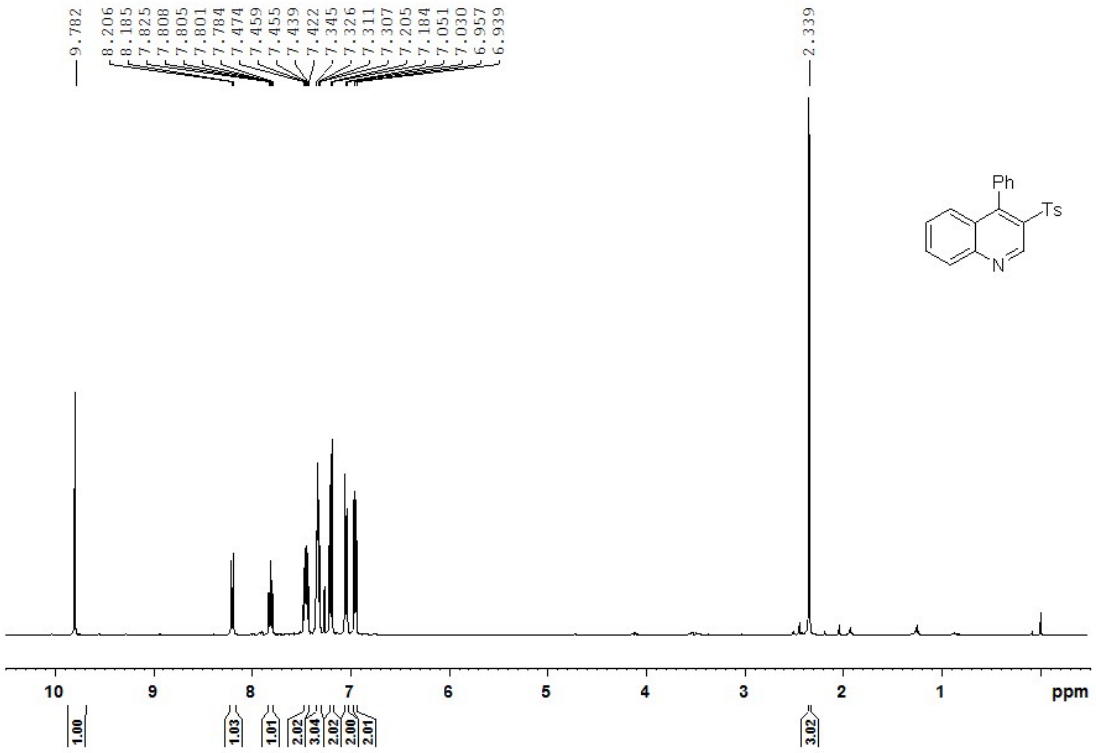
Yield: 66.1 mg (94%). $^1$H NMR (400 MHz, $CDCl_3$): δ = 9.73 (s, 1H), 8.20 (d, *J* = 8.4 Hz, 1H), 7.83 (t, *J* = 8.0 Hz, 1H), 7.54 (d, *J* = 6.8 Hz, 1H), 7.49–7.45 (m, 2H), 7.42–7.35 (m, 3H), 7.08 (d, *J* = 7.2 Hz, 2H), 6.67 (d, *J* = 4.4 Hz, 1H), 6.85 (t, *J* = 4.8 Hz, 1H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ = 149.8, 149.7, 147.4, 142.0, 134.4, 134.2, 132.8, 132.6, 132.3, 129.8, 129.6, 128.8, 127.9, 127.7, 127.5, 127.4, 127.2; HRMS (ESI) ($[M+H]^+$) Calcd. For $C_{19}H_{14}NO_2S_2$: 352.0460, Found: 352.0461.

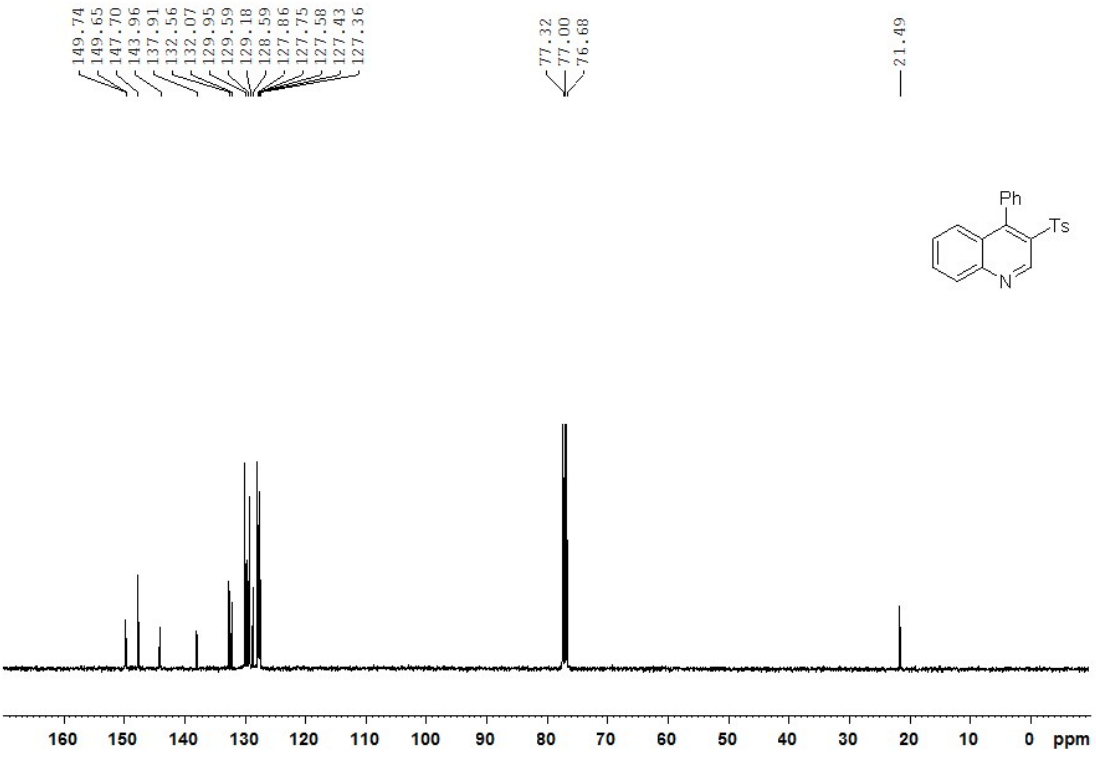


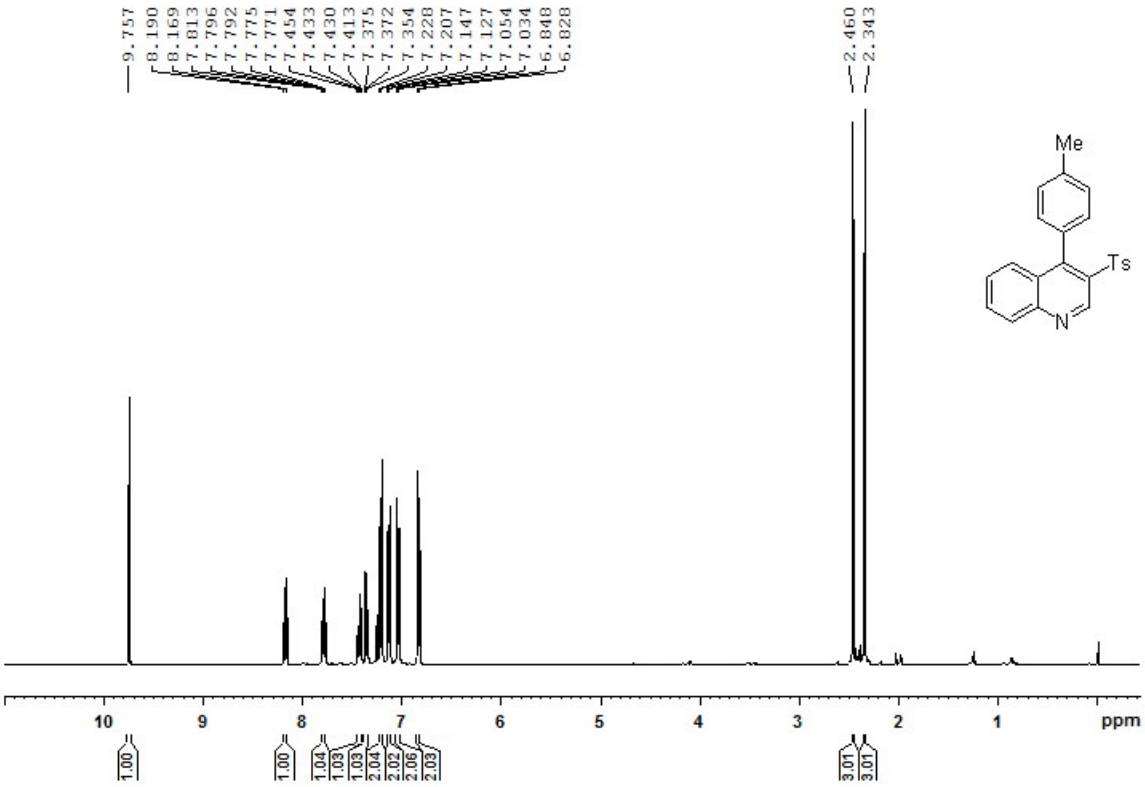
**3-(Butylsulfonyl)-4-phenylquinoline (4n)**

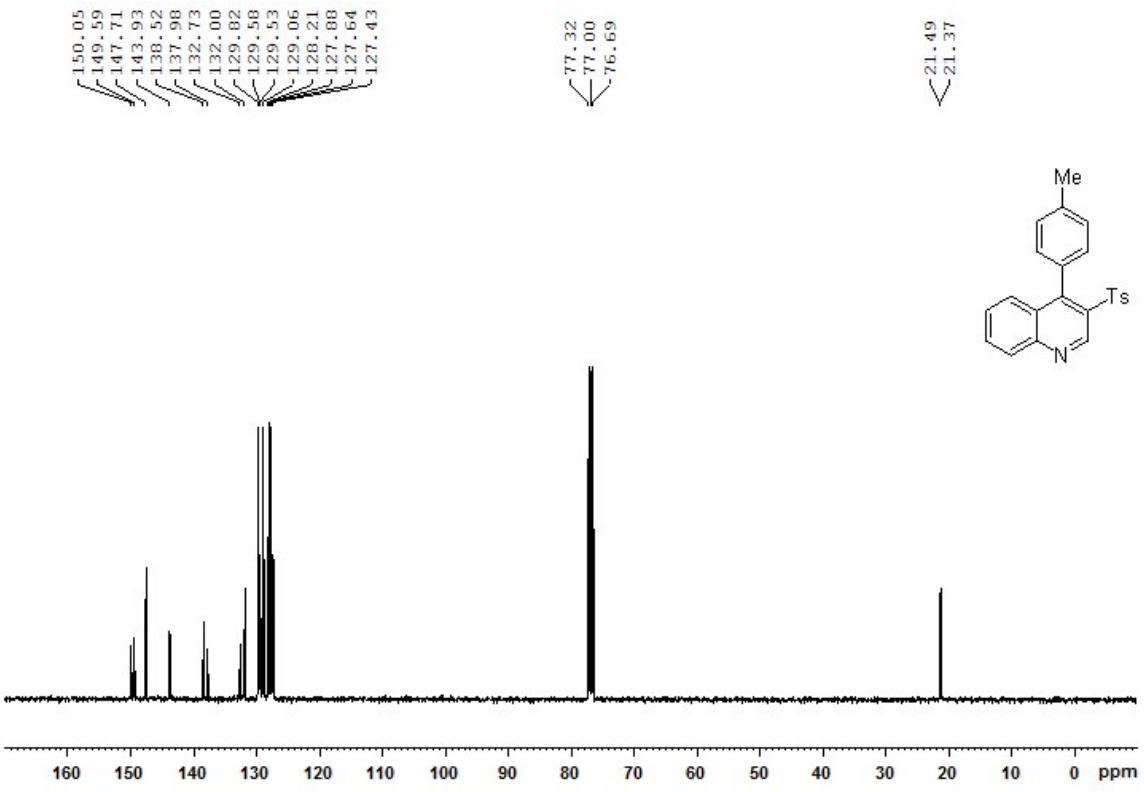
Yield: 59.2 mg (91%). $^1$H NMR (400 MHz, $CDCl_3$): δ = 9.52 (s, 1H), 8.21 (d, *J* = 8.8 Hz, 1H), 7.84 (t, *J* = 6.8 Hz, 1H), 7.56–7.50 (m, 4H), 7.45 (d, *J* = 8.4 Hz, 1H), 7.40–7.39 (m, 2H), 2.7 (t, *J* = 8.0 Hz, 2H), 1.55–1.47 (m, 2H), 1.27–1.18 (m, 2H), 0.76 (t, *J* = 7.6 Hz, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): δ = 149.8, 149.6, 148.1, 132.9, 132.2, 130.0, 129.8, 129.6, 129.3, 128.0, 127.9, 127.5, 127.1, 55.2, 24.4, 21.3, 13.3; HRMS (ESI) ($[M+H]^+$) Calcd. For $C_{19}H_{20}NO_2S$: 326.1209, Found: 326.1211.

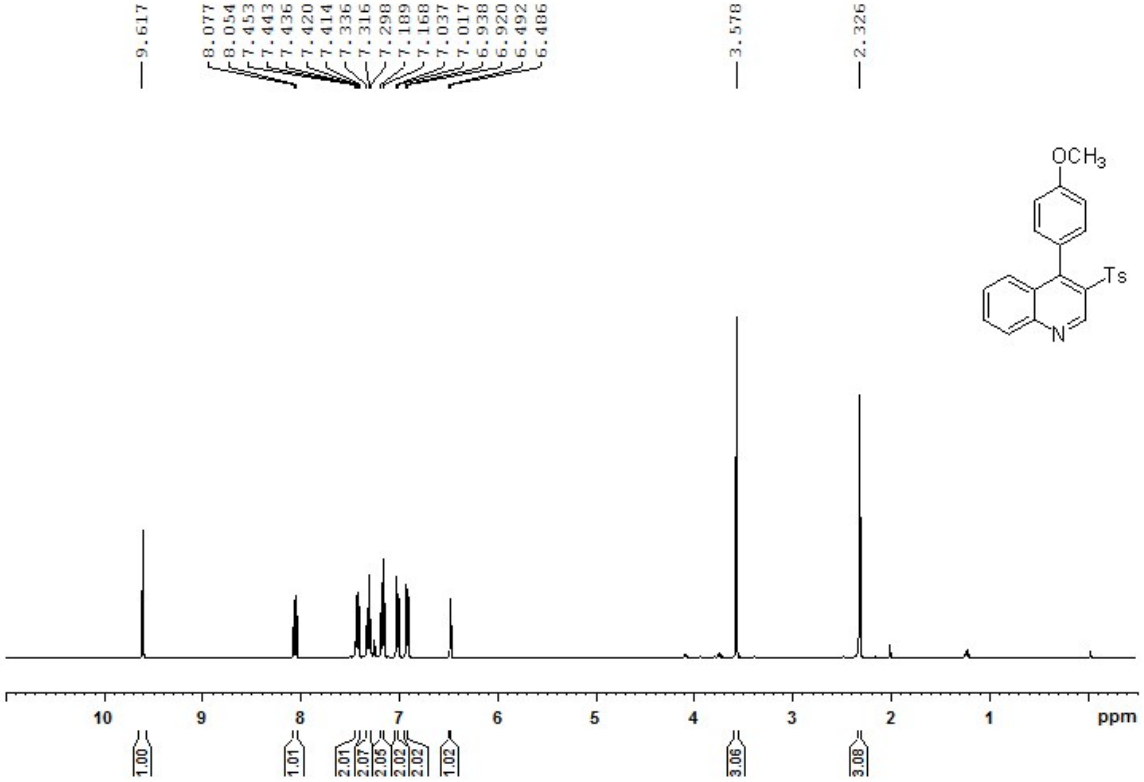
## 5. $^{1}H$ and $^{13}C$ NMR spectra of the products

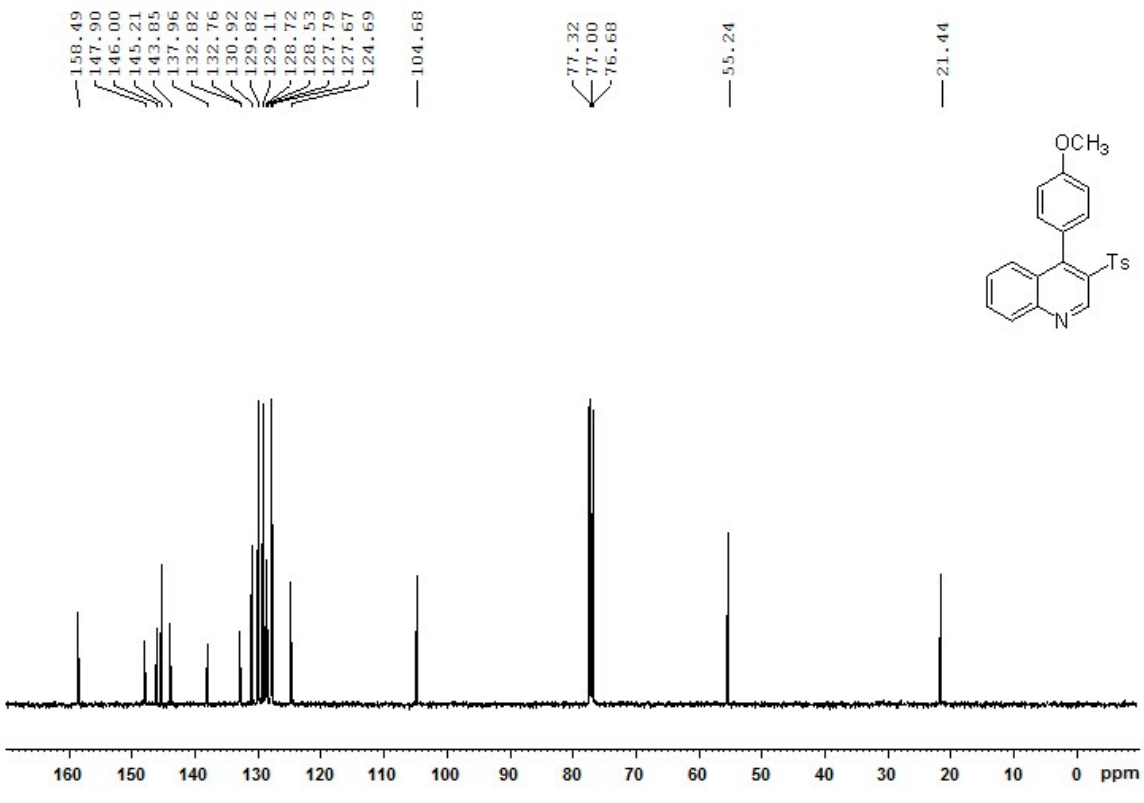


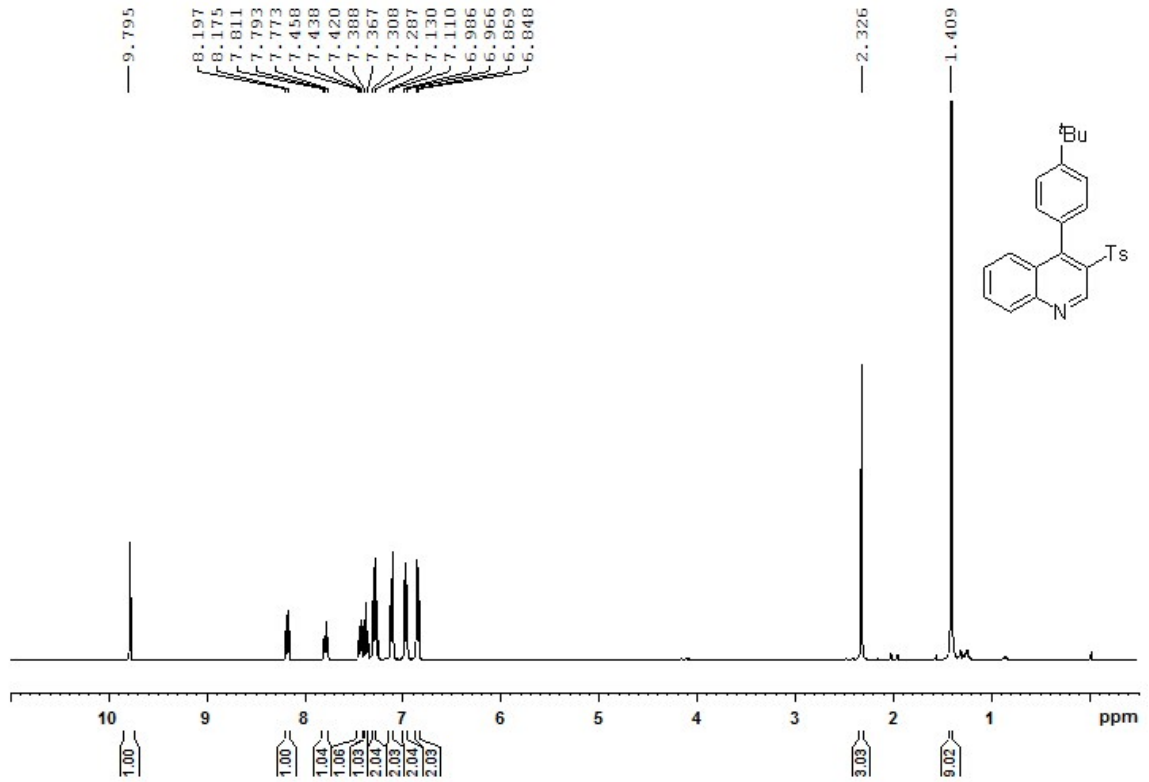



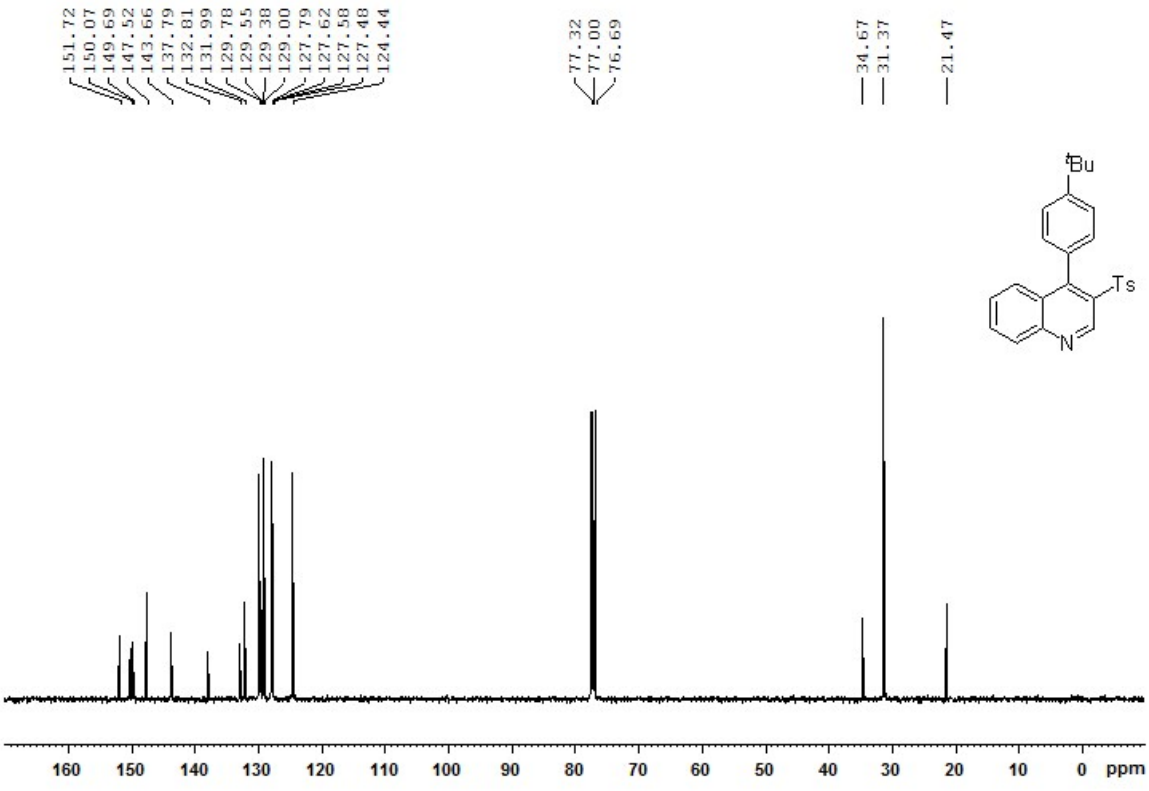

9.757
8.190
8.169
7.813
7.796
7.792
7.775
7.771
7.454
7.433
7.430
7.413
7.375
7.372
7.354
7.228
7.207
7.147
7.127
7.054
7.034
6.848
6.828
2.460
2.343
Me
Ts
N
10
9
8
7
6
5
4
3
2
1
ppm
1.00
1.00
1.04
1.03
1.03
2.04
2.02
2.06
2.03
3.01
3.01

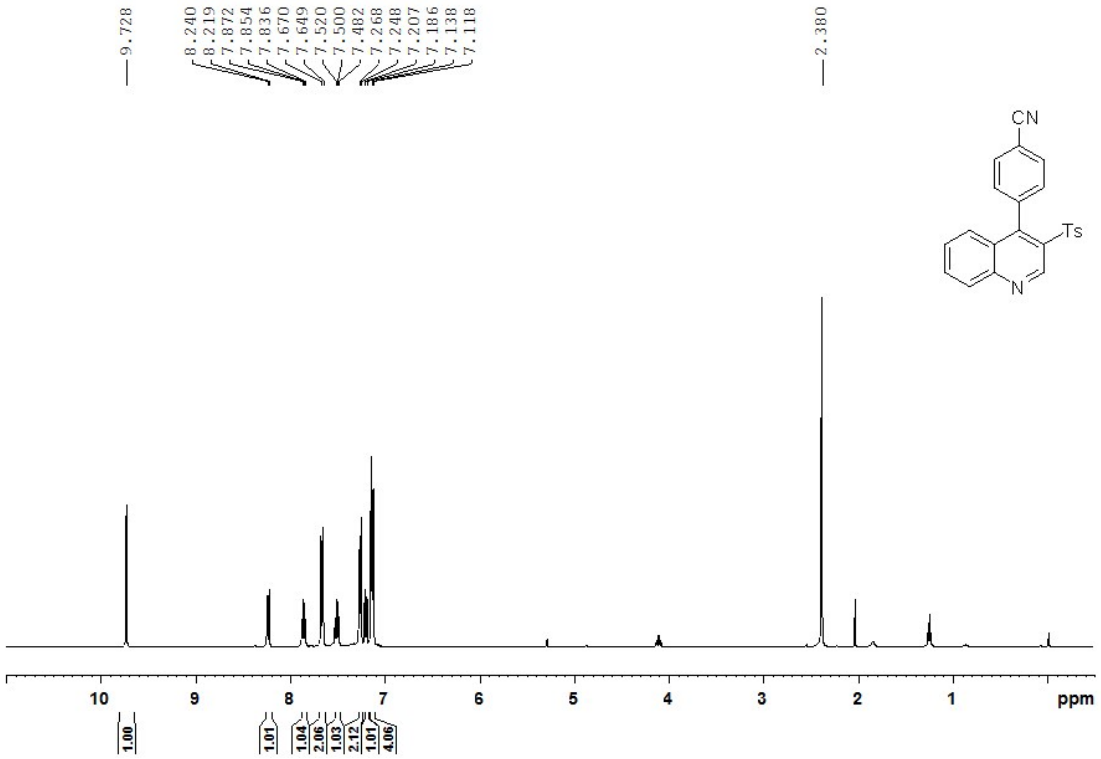

150.05
149.59
147.71
143.93
138.52
137.98
132.73
132.00
129.82
129.58
129.53
129.06
128.21
127.88
127.64
127.43
77.32
77.00
76.69
21.49
21.37
Me
Ts
N
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

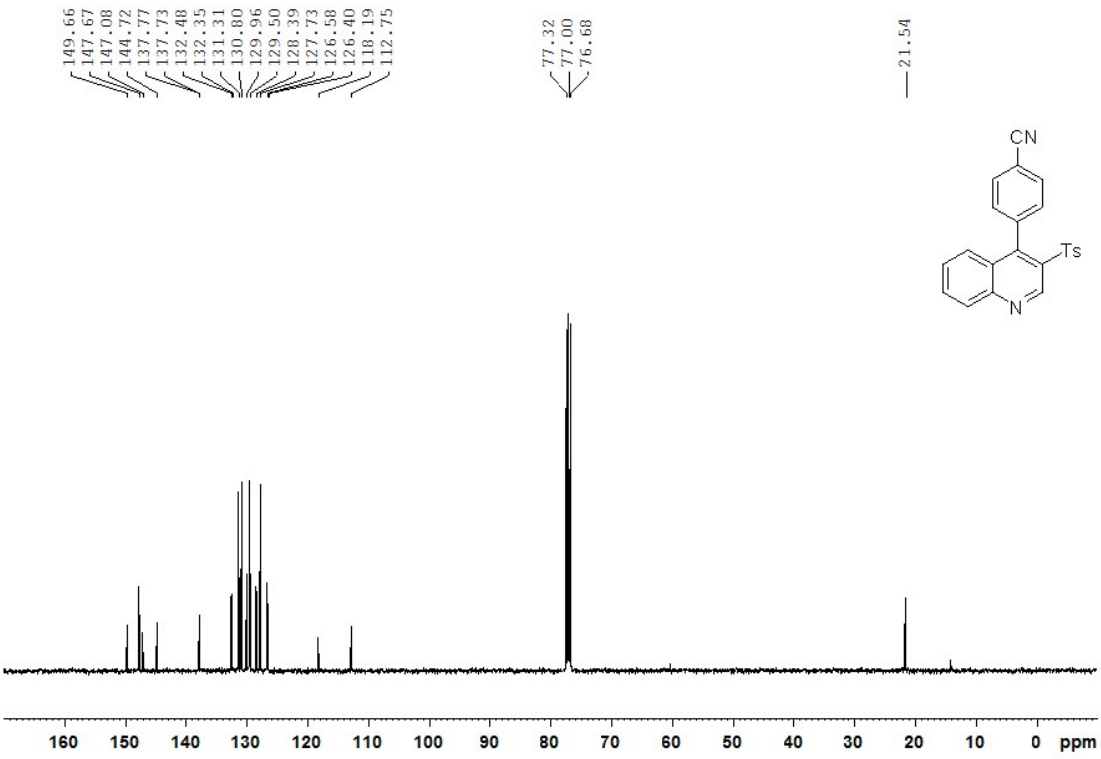

9.617
8.077
8.054
7.453
7.443
7.436
7.420
7.414
7.336
7.316
7.298
7.189
7.168
7.037
7.017
6.938
6.920
6.492
6.486
3.578
2.325
OCH3
Ts
N
10
9
8
7
6
5
4
3
2
1
ppm
1.00
1.01
2.01
2.07
2.05
2.02
2.02
1.02
3.06
3.08

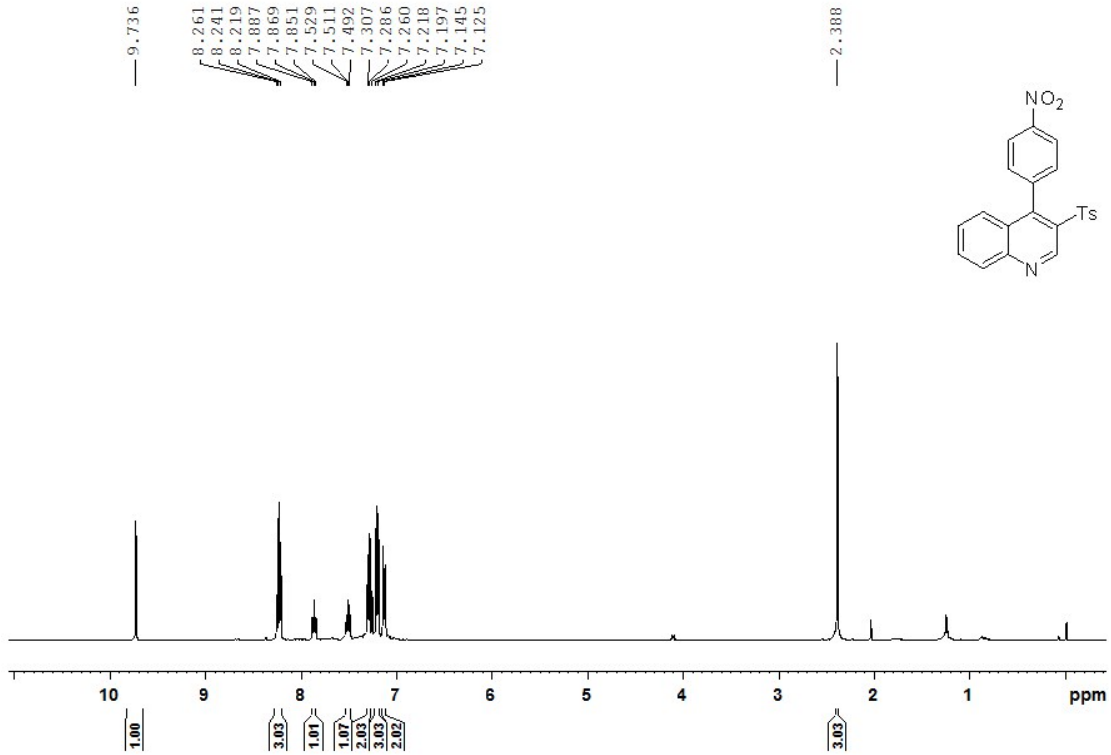

158.49
147.90
146.00
145.21
143.85
137.96
132.82
132.76
130.92
129.82
129.11
128.72
128.53
127.79
127.67
124.69
104.68
77.32
77.00
76.68
55.24
21.44
OCH3
Ts
N
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

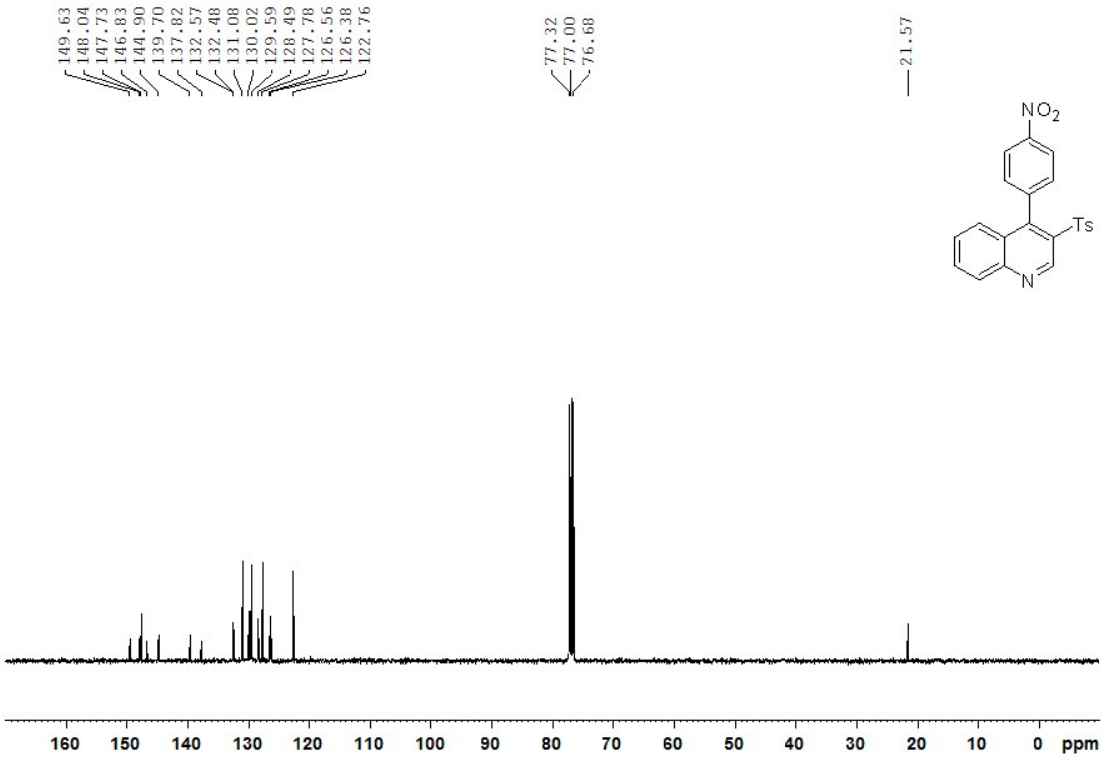

9.795
8.197
8.175
7.811
7.793
7.773
7.458
7.438
7.420
7.388
7.367
7.308
7.287
7.130
7.110
6.986
6.966
6.859
6.848
2.326
1.409
tBu
Ts
N
10
9
8
7
6
5
4
3
2
1
ppm
1.00
1.00
1.04
1.06
1.03
2.04
2.03
2.04
2.03
3.03
9.02

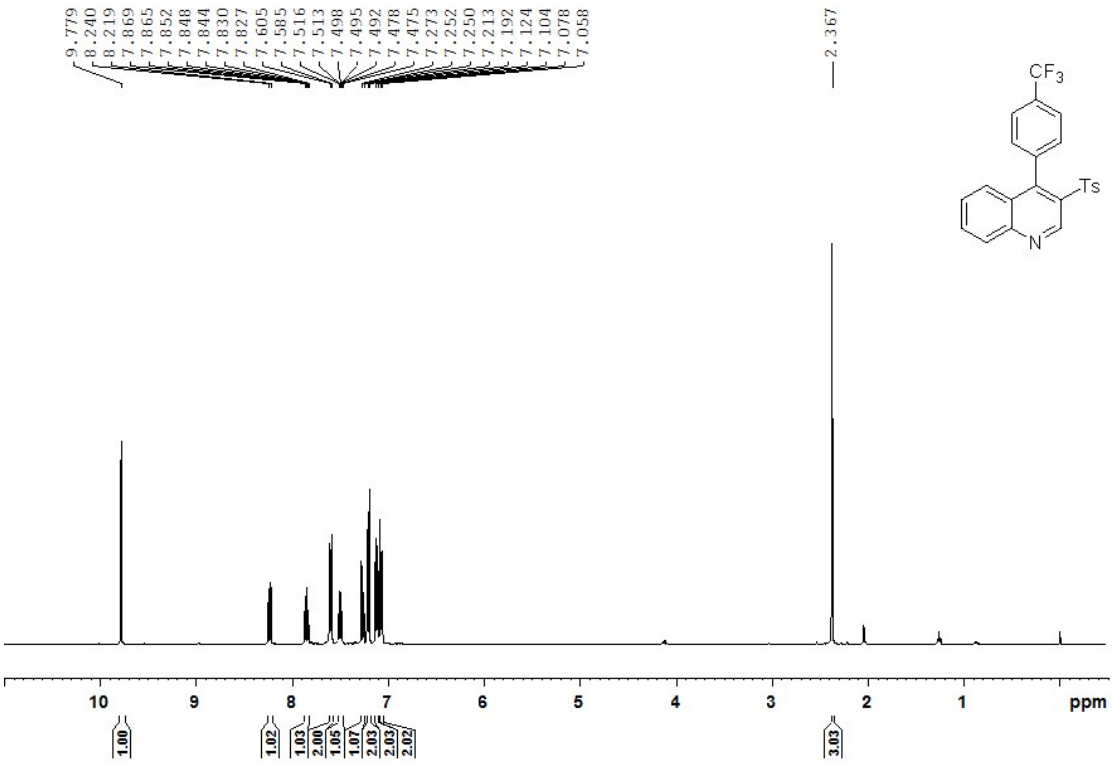

151.72
150.07
149.69
147.52
143.66
137.79
132.81
131.99
129.78
129.55
129.38
129.00
127.79
127.62
127.58
127.48
124.44
77.32
77.00
76.69
34.67
31.37
21.47
tBu
Ts
N
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

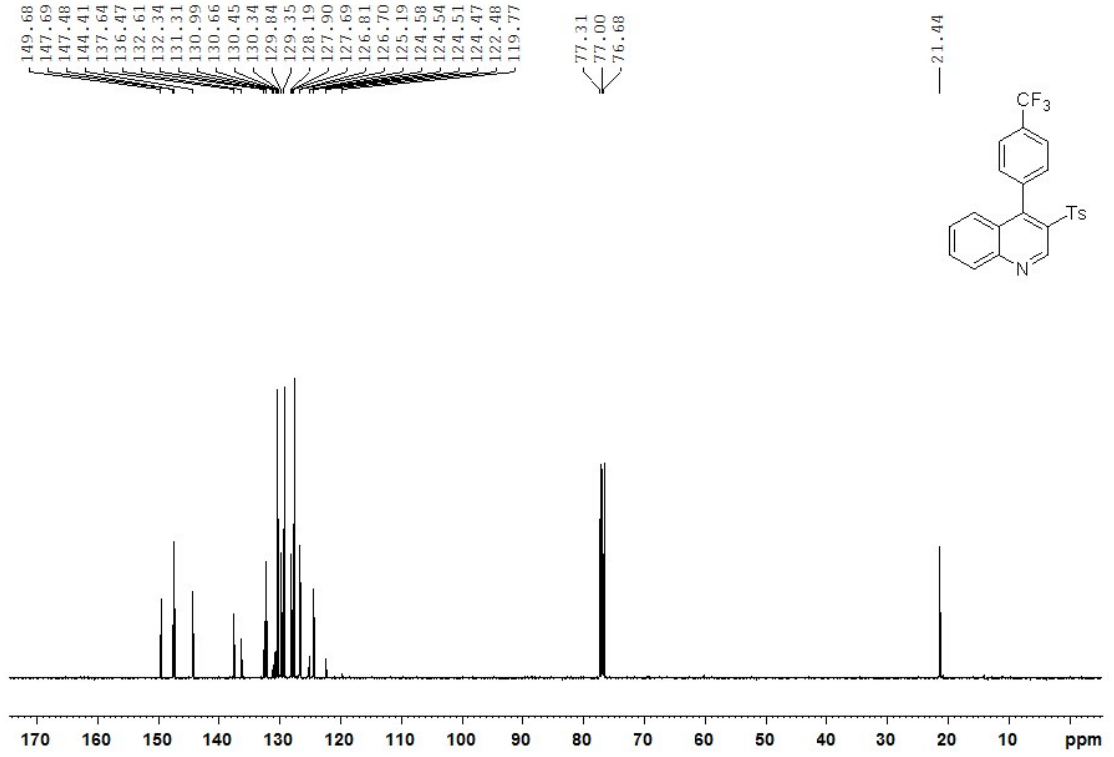

9.728
8.240
8.219
7.872
7.854
7.836
7.670
7.649
7.520
7.500
7.482
7.268
7.248
7.207
7.186
7.138
7.118
2.380
CN
Ts
N
10
9
8
7
6
5
4
3
2
1
ppm
1.00
1.01
1.04
2.06
1.03
2.12
1.01
4.06

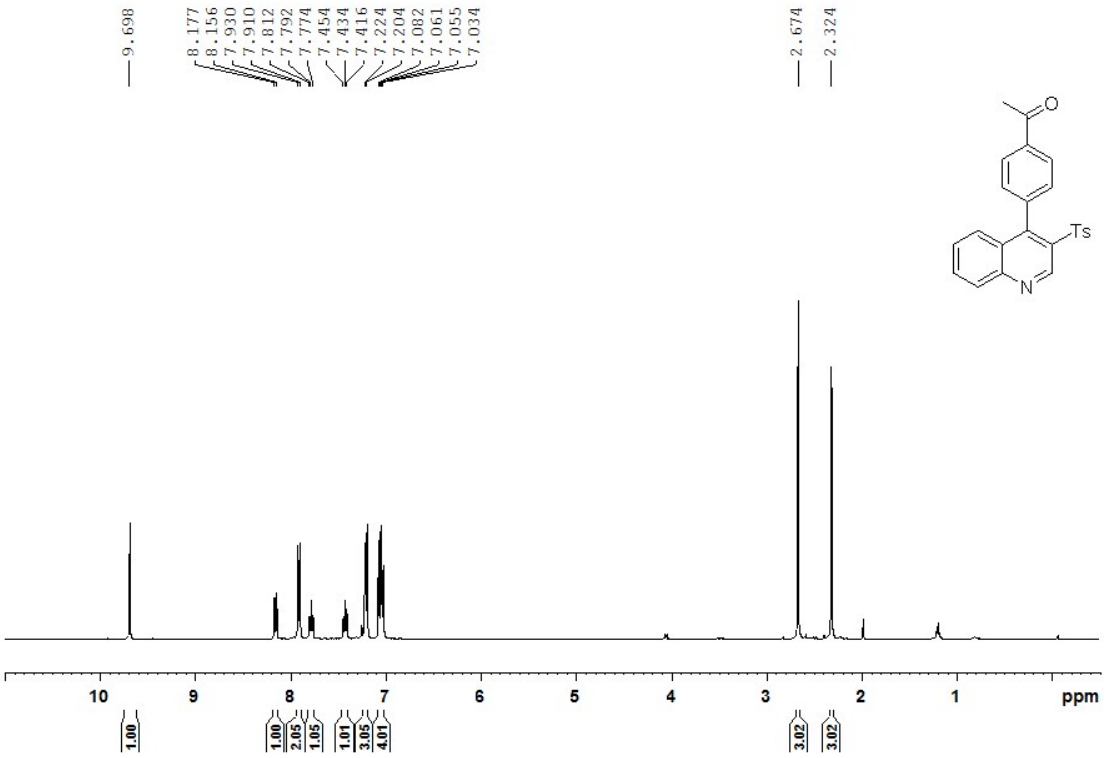

149.66
147.67
147.08
144.72
137.77
137.73
132.48
132.35
131.31
130.80
129.96
129.50
128.39
127.73
126.58
126.40
118.19
112.75
77.32
77.00
76.68
21.54
CN
Ts
N
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

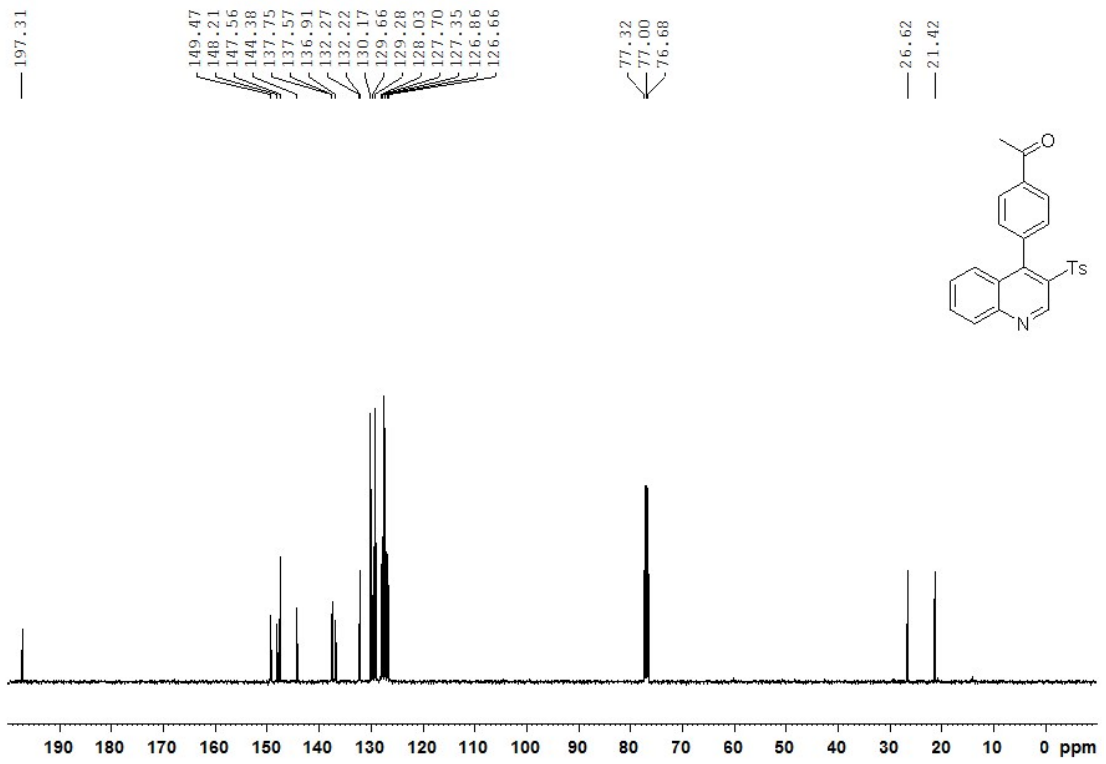

9.736
8.261
8.241
8.219
7.887
7.869
7.851
7.529
7.511
7.492
7.307
7.286
7.260
7.218
7.197
7.145
7.125
2.388
NO2
Ts
N
10
9
8
7
6
5
4
3
2
1
ppm
1.00
3.03
1.01
1.07
2.03
3.03
2.02
3.03

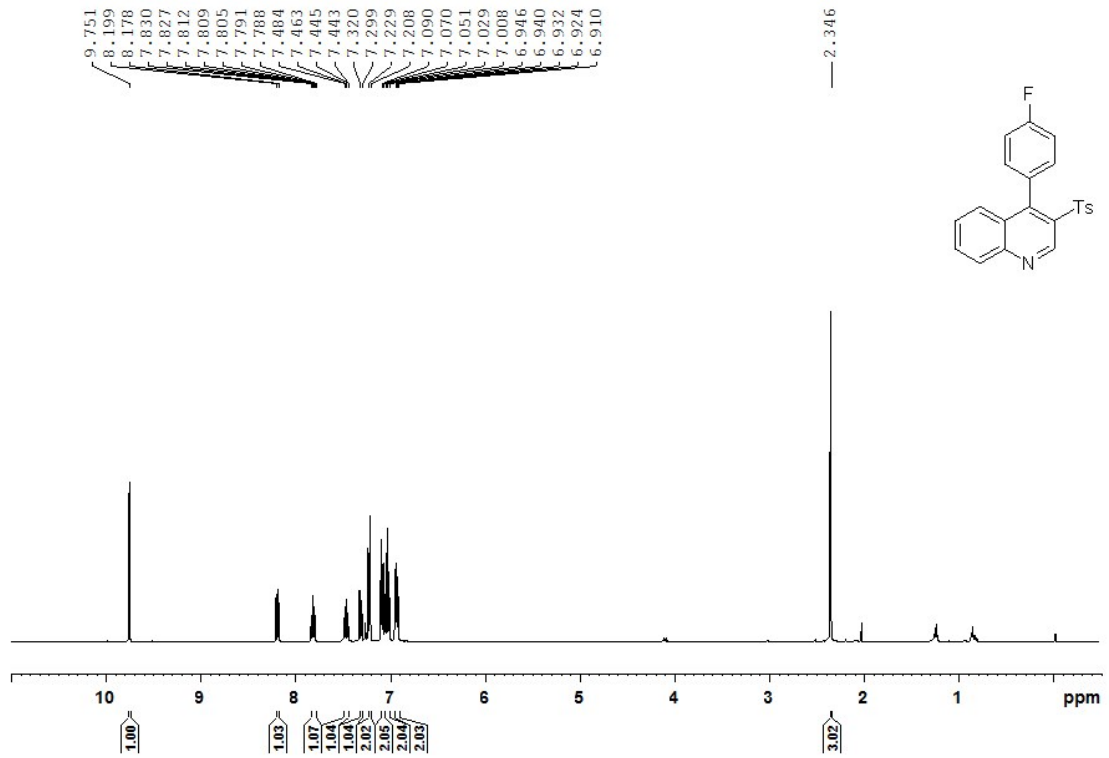

149.63
148.04
147.73
146.83
144.90
139.70
137.82
132.57
132.48
131.08
130.02
129.59
128.49
127.78
126.56
126.38
122.76
77.32
77.00
76.68
21.57
NO2
Ts
N
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

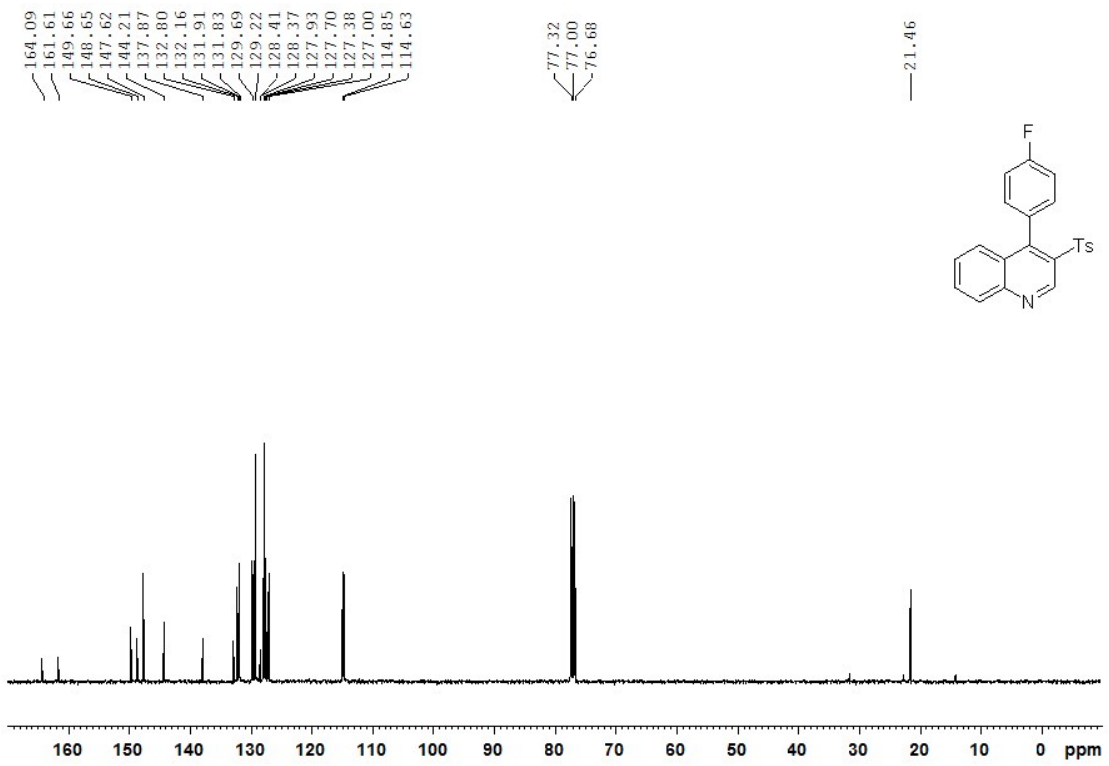

9.779
8.240
8.219
7.869
7.865
7.852
7.848
7.844
7.830
7.827
7.605
7.585
7.516
7.513
7.498
7.495
7.492
7.478
7.475
7.273
7.252
7.250
7.213
7.192
7.124
7.104
7.078
7.058
2.367
CF3
Ts
N
10
9
8
7
6
5
4
3
2
1
ppm
1.00
1.02
1.03
2.00
1.05
1.07
2.03
2.03
2.02
3.03

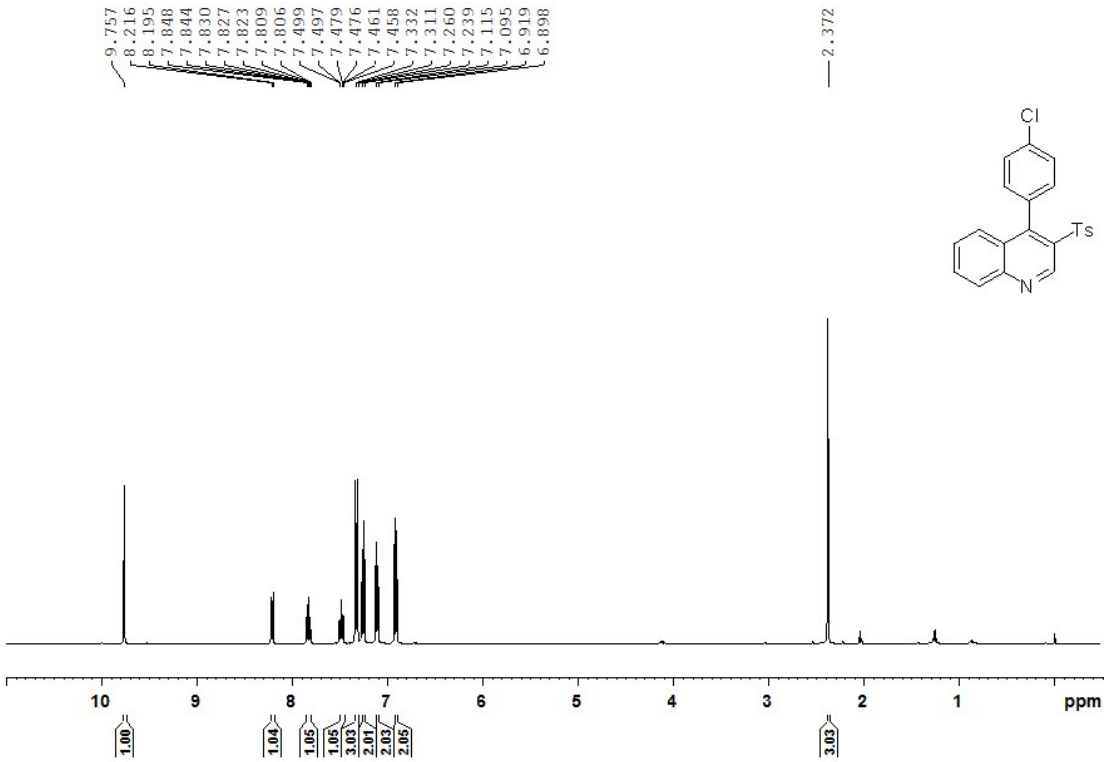

149.68
147.69
147.48
144.41
137.64
136.47
132.61
132.34
131.31
130.99
130.66
130.45
130.34
129.84
129.35
128.19
127.90
127.69
126.81
126.70
125.19
124.58
124.54
124.51
124.47
122.48
119.77
77.31
77.00
76.68
21.44
CF3
Ts
N
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

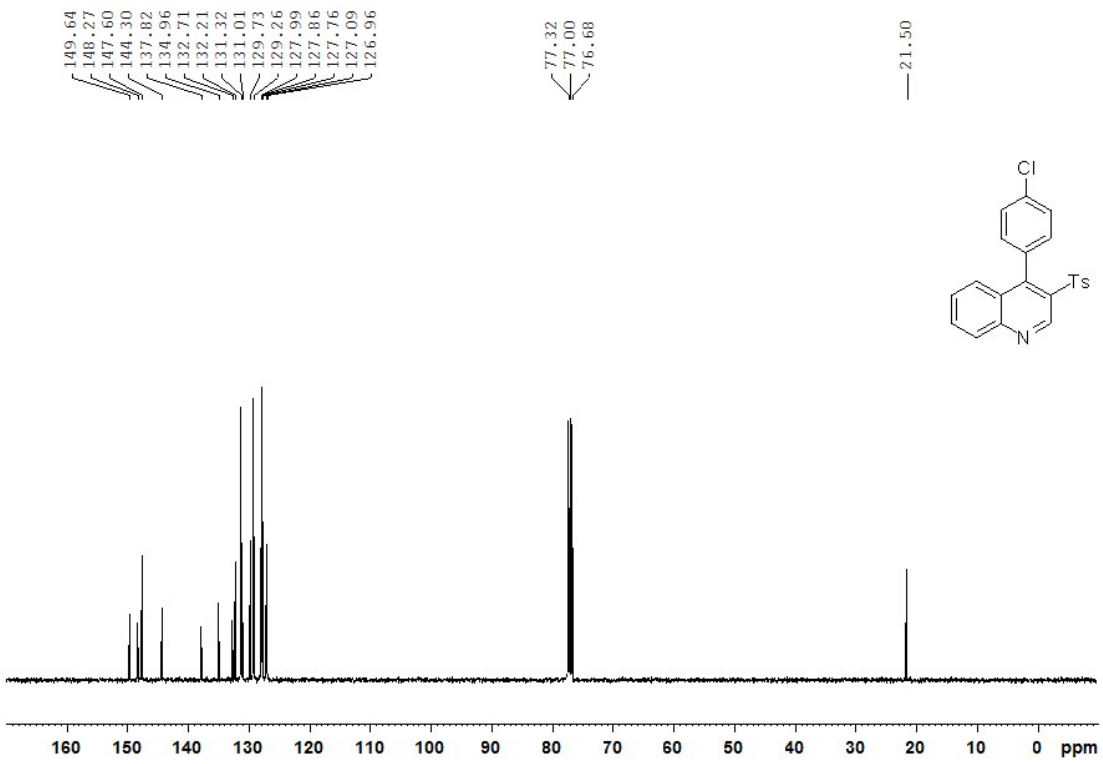

9.698
8.177
8.156
7.930
7.910
7.812
7.792
7.774
7.454
7.434
7.416
7.224
7.204
7.082
7.061
7.055
7.034
2.674
2.324
O
Ts
N
10
9
8
7
6
5
4
3
2
1
ppm
1.00
1.00
2.05
1.05
1.01
3.05
4.01
3.02
3.02

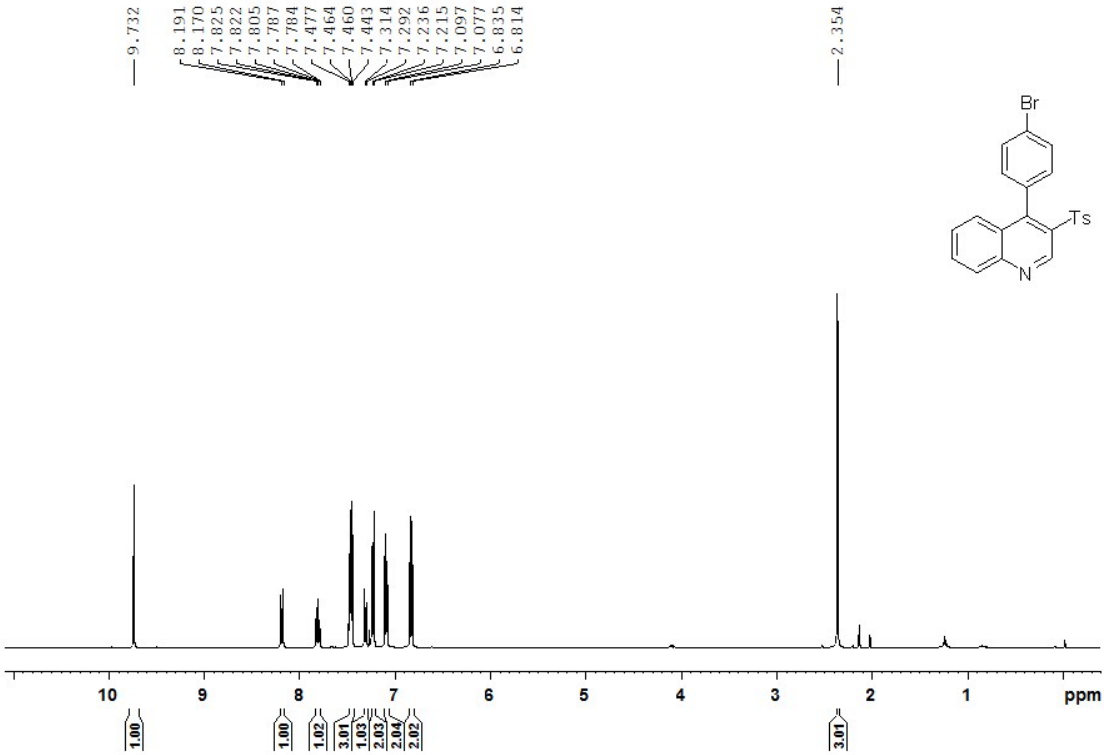

197.31
149.47
148.21
147.56
144.38
137.75
137.57
136.91
132.27
132.22
130.17
129.66
129.28
128.03
127.70
127.35
126.86
126.66
77.32
77.00
76.68
26.62
21.42
O
Ts
N
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0 ppm

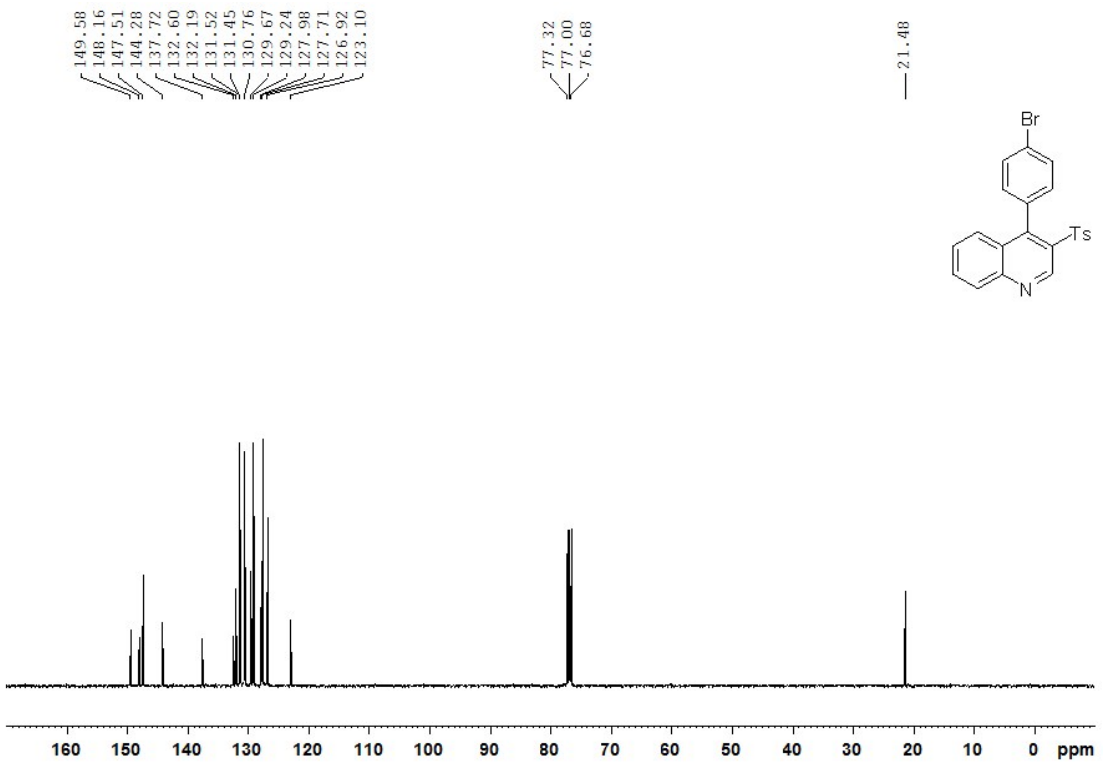

9.751
8.199
8.178
7.830
7.827
7.812
7.809
7.805
7.791
7.788
7.484
7.463
7.445
7.443
7.320
7.299
7.229
7.208
7.090
7.070
7.051
7.029
7.008
6.946
6.940
6.932
6.924
6.910
2.346
F
Ts
N
10
9
8
7
6
5
4
3
2
1
ppm
1.00
1.03
1.07
1.04
1.04
2.02
2.05
2.04
2.03
3.02

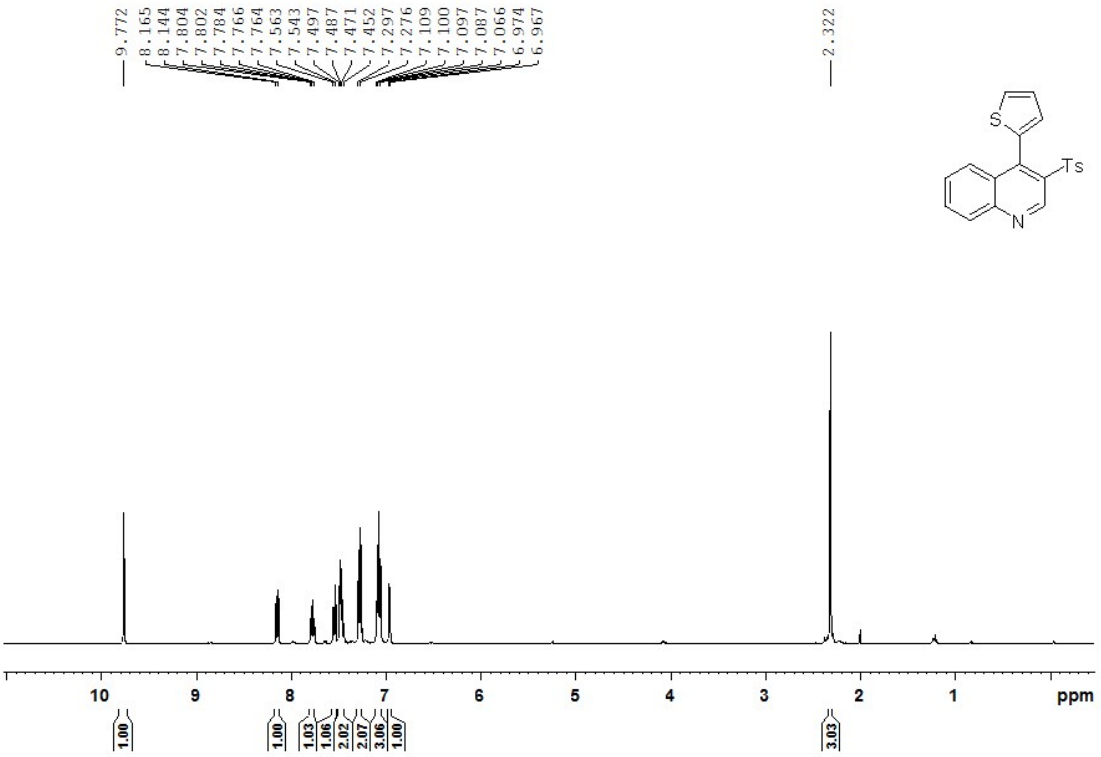

164.09
161.61
149.66
148.65
147.62
144.21
137.87
132.80
132.16
131.91
131.83
129.69
129.22
128.41
128.37
127.93
127.70
127.38
127.00
114.85
114.63
77.32
77.00
76.68
21.46
F
Ts
N
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

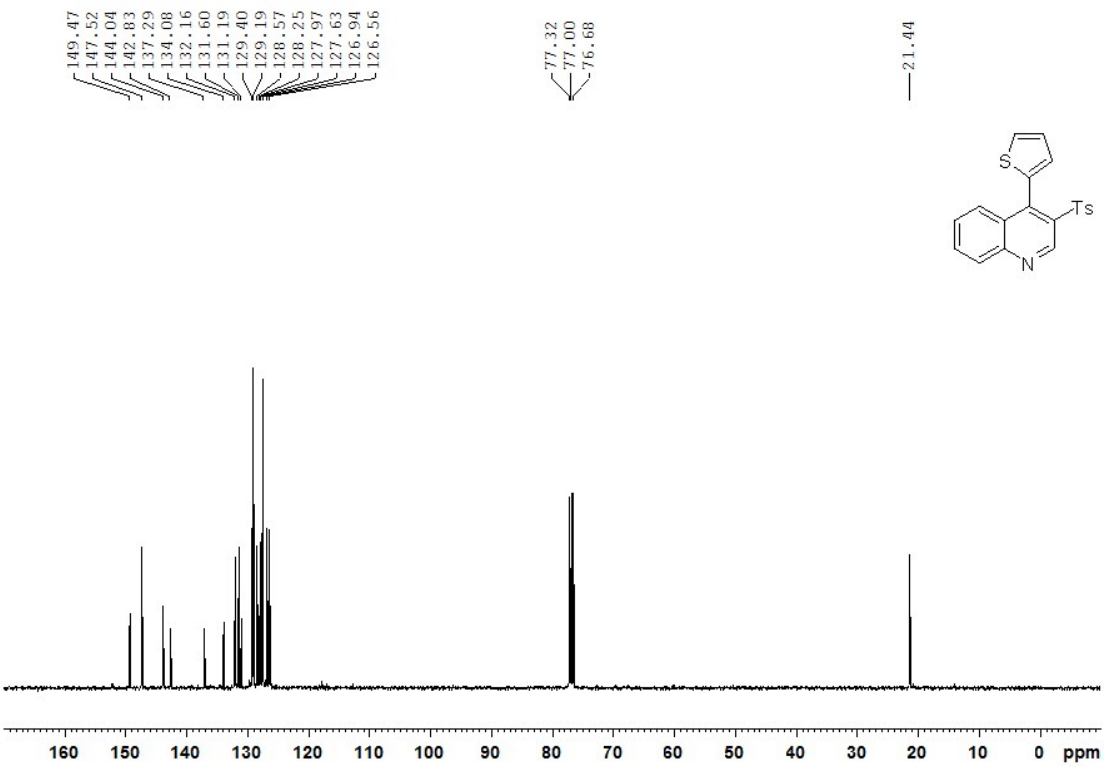

9.757
8.216
8.195
7.848
7.844
7.830
7.827
7.823
7.809
7.806
7.499
7.497
7.479
7.476
7.461
7.458
7.332
7.311
7.260
7.239
7.115
7.095
6.919
6.898
2.372
Cl
Ts
N
10
9
8
7
6
5
4
3
2
1
ppm
1.00
1.04
1.05
1.05
3.03
2.01
2.03
2.05
3.03

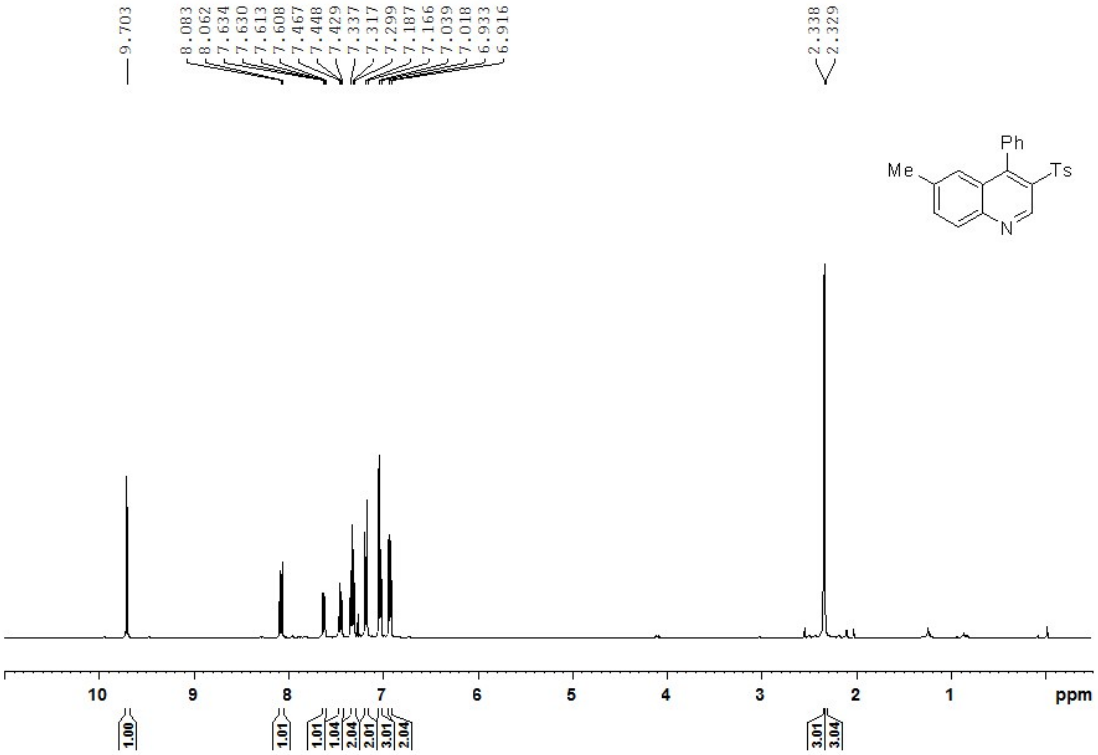

149.64
148.27
147.60
144.30
137.82
134.96
132.71
132.21
131.32
131.01
129.73
129.26
127.99
127.86
127.76
127.09
126.96
77.32
77.00
76.68
21.50
Cl
Ts
N
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

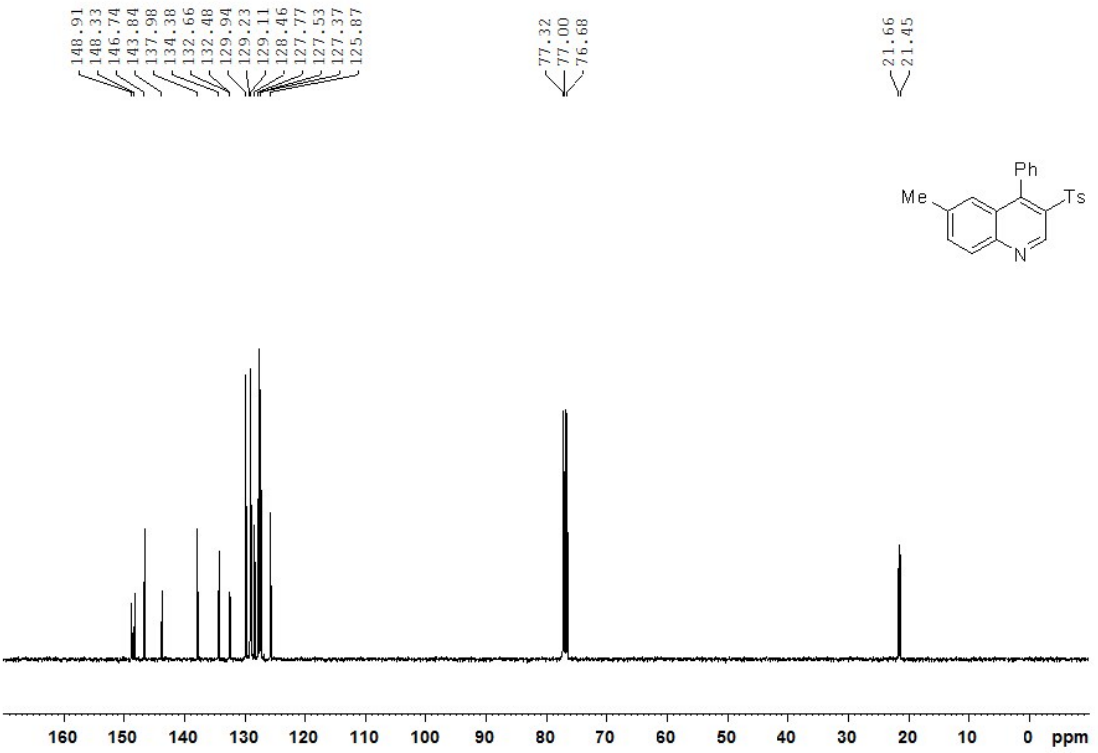

9.732
8.191
8.170
7.825
7.822
7.805
7.787
7.784
7.477
7.464
7.460
7.443
7.314
7.292
7.236
7.215
7.097
7.077
6.835
6.814
2.354
Br
Ts
N
10
9
8
7
6
5
4
3
2
1
ppm
1.00
1.00
1.02
3.01
1.03
2.03
2.04
2.02
3.01

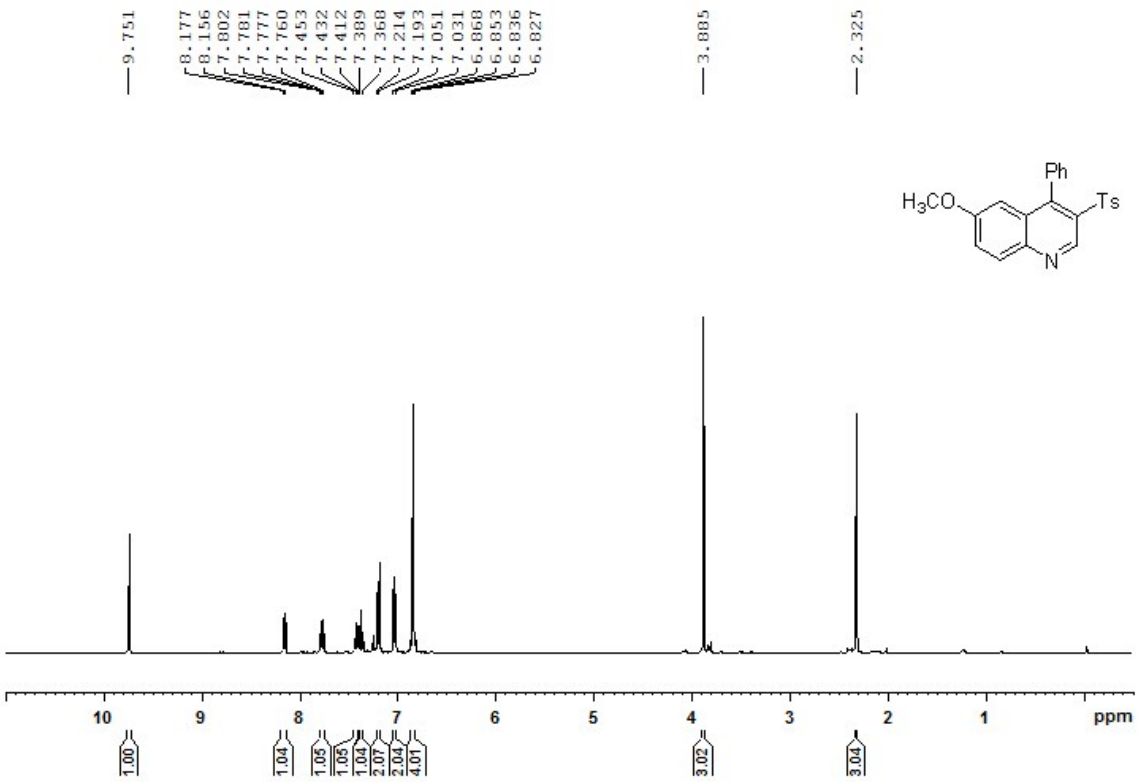

149.58
148.16
147.51
144.28
137.72
132.60
132.19
131.52
131.45
130.76
129.67
129.24
127.98
127.71
126.92
123.10
77.32
77.00
76.68
21.48
Br
Ts
N
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

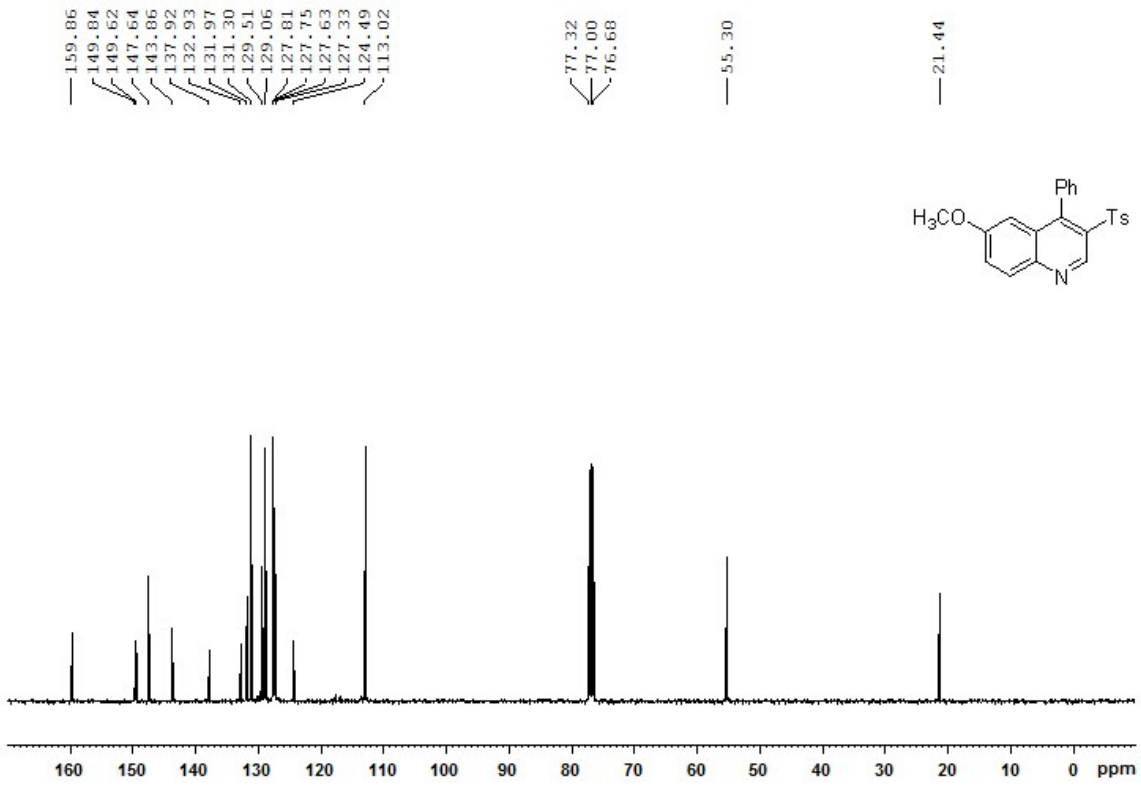

9.772
8.165
8.144
7.804
7.802
7.784
7.766
7.764
7.563
7.543
7.497
7.487
7.471
7.452
7.297
7.276
7.109
7.100
7.097
7.087
7.066
6.974
6.967
2.322
S
Ts
N
10
9
8
7
6
5
4
3
2
1
ppm
1.00
1.00
1.03
1.06
2.02
2.07
3.06
1.00
3.03

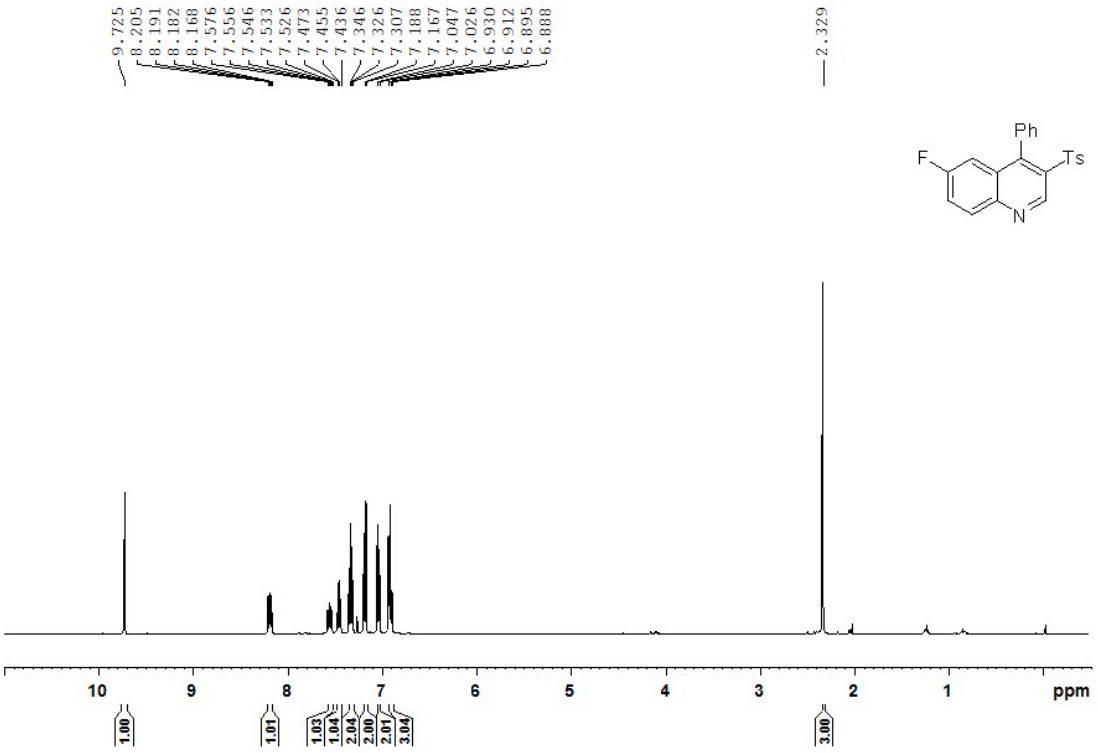

149.47
147.52
144.04
142.83
137.29
134.08
132.16
131.60
131.19
129.40
129.19
128.57
128.25
127.97
127.63
126.94
126.56
77.32
77.00
76.68
21.44
S
Ts
N
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

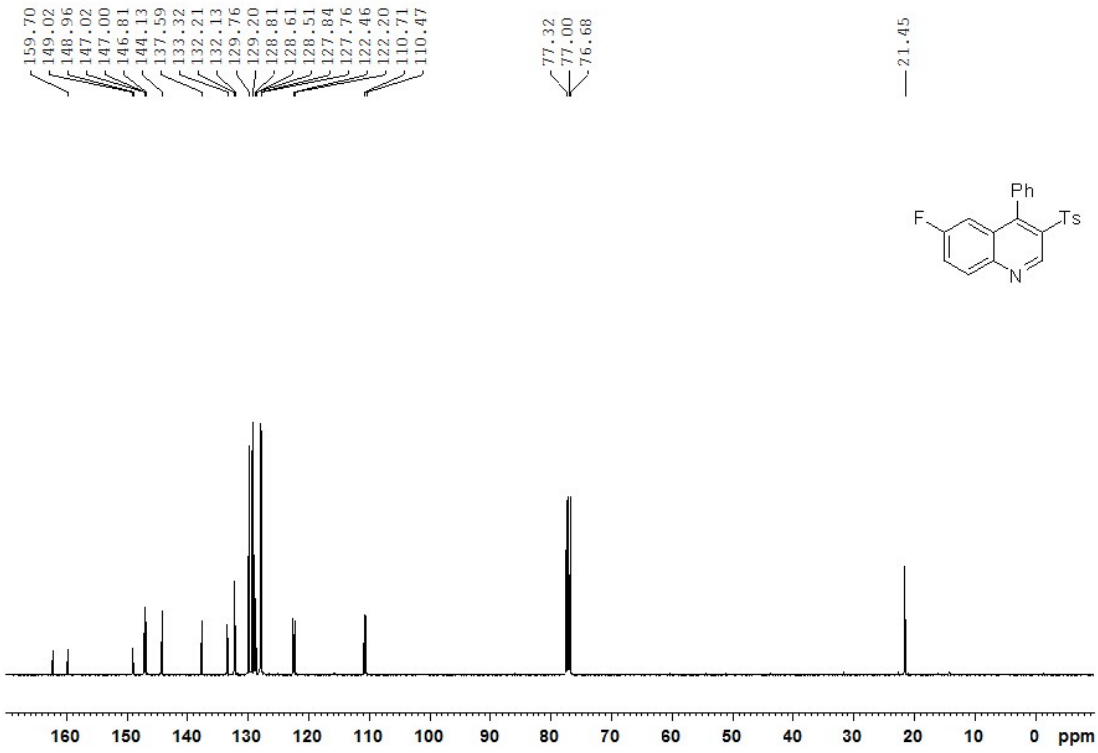

9.703
8.083
8.062
7.634
7.630
7.613
7.608
7.467
7.448
7.429
7.337
7.317
7.299
7.187
7.166
7.039
7.018
6.933
6.916
2.338
2.329
Ph
Me
Ts
N
10
9
8
7
6
5
4
3
2
1
ppm
1.00
1.01
1.01
1.04
2.04
2.01
3.01
2.04
3.01
3.04

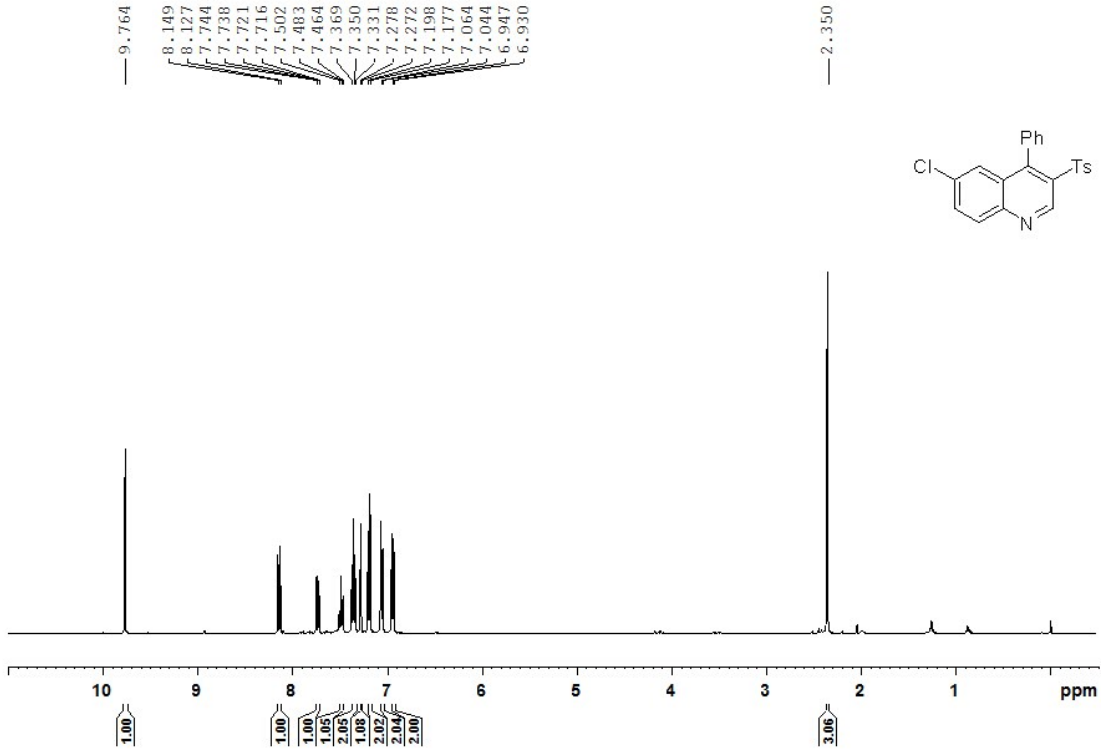

148.91
148.33
146.74
143.84
137.98
134.38
132.66
132.48
129.94
129.23
129.11
128.46
127.77
127.53
127.37
125.87
77.32
77.00
76.68
21.66
21.45
Ph
Me
Ts
N
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

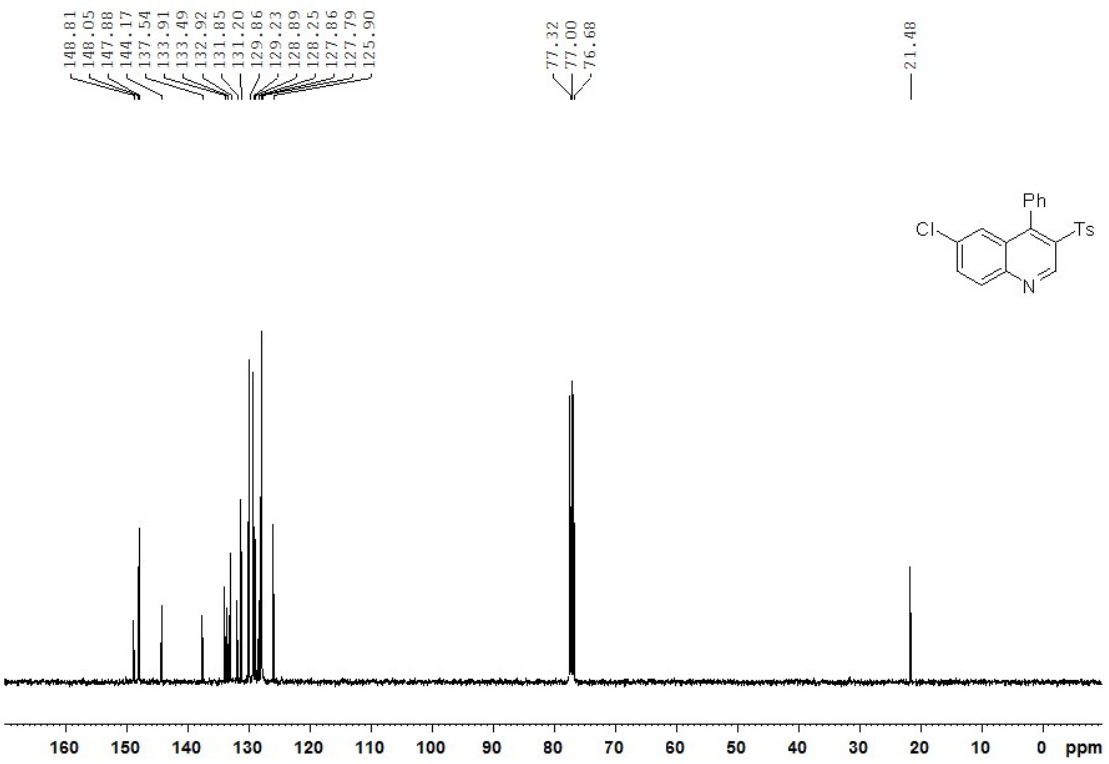

9.751
8.177
8.156
7.802
7.781
7.777
7.760
7.453
7.432
7.412
7.389
7.368
7.214
7.193
7.051
7.031
6.868
6.853
6.836
6.827
3.885
2.325
Ph
H3CO
Ts
N
10
9
8
7
6
5
4
3
2
1
ppm
1.00
1.04
1.05
1.06
1.04
2.07
2.04
4.01
3.02
3.04

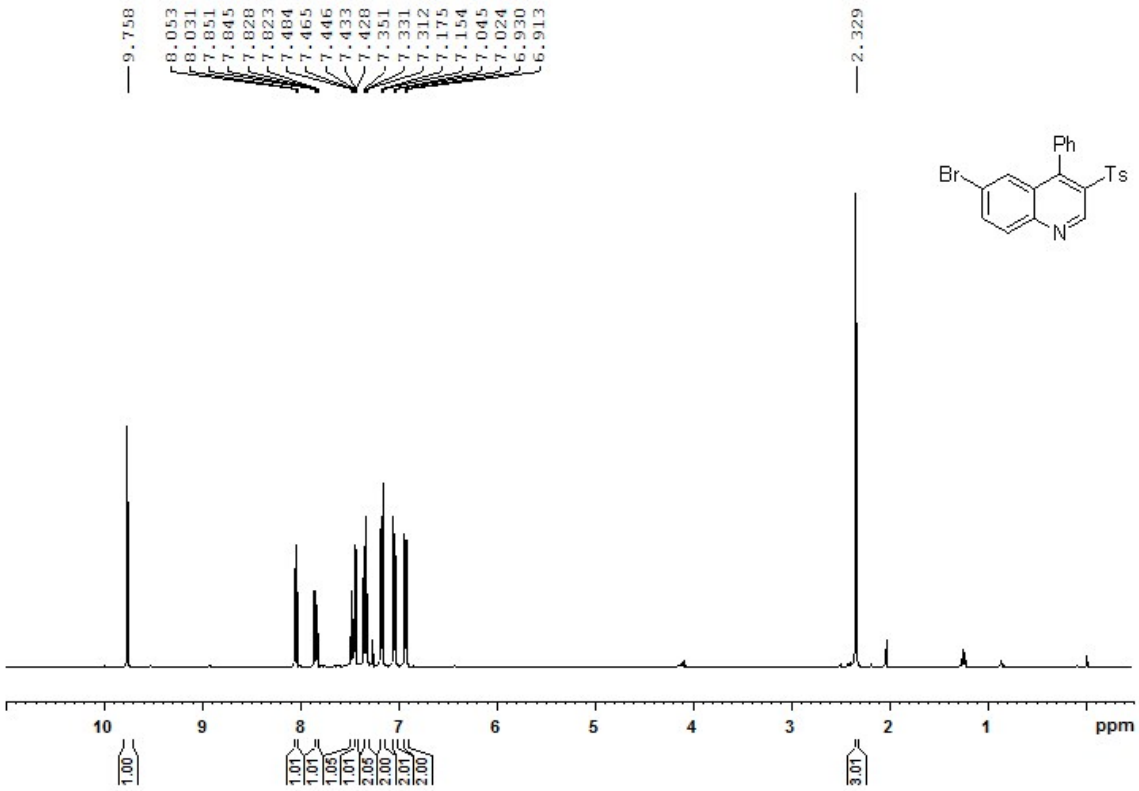

159.86
149.84
149.62
147.64
143.86
137.92
132.93
131.97
131.30
129.51
129.06
127.81
127.75
127.63
127.33
124.49
113.02
77.32
77.00
76.68
55.30
21.44
Ph
H3CO
Ts
N
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

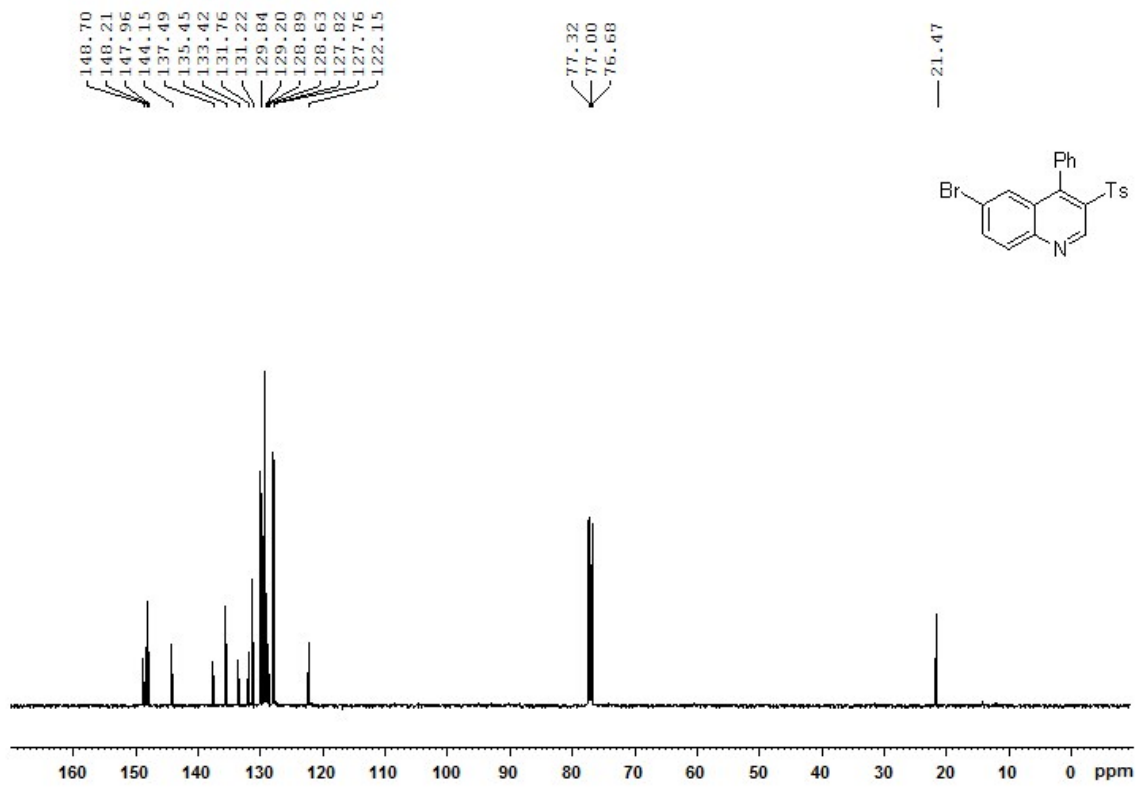

9.725
8.205
8.191
8.182
8.168
7.576
7.556
7.546
7.533
7.526
7.473
7.455
7.436
7.346
7.326
7.307
7.188
7.167
7.047
7.026
6.930
6.912
6.895
6.888
2.329
Ph
F
Ts
N
10
9
8
7
6
5
4
3
2
1
ppm
1.00
1.01
1.03
1.04
2.04
2.00
2.01
3.04
3.00

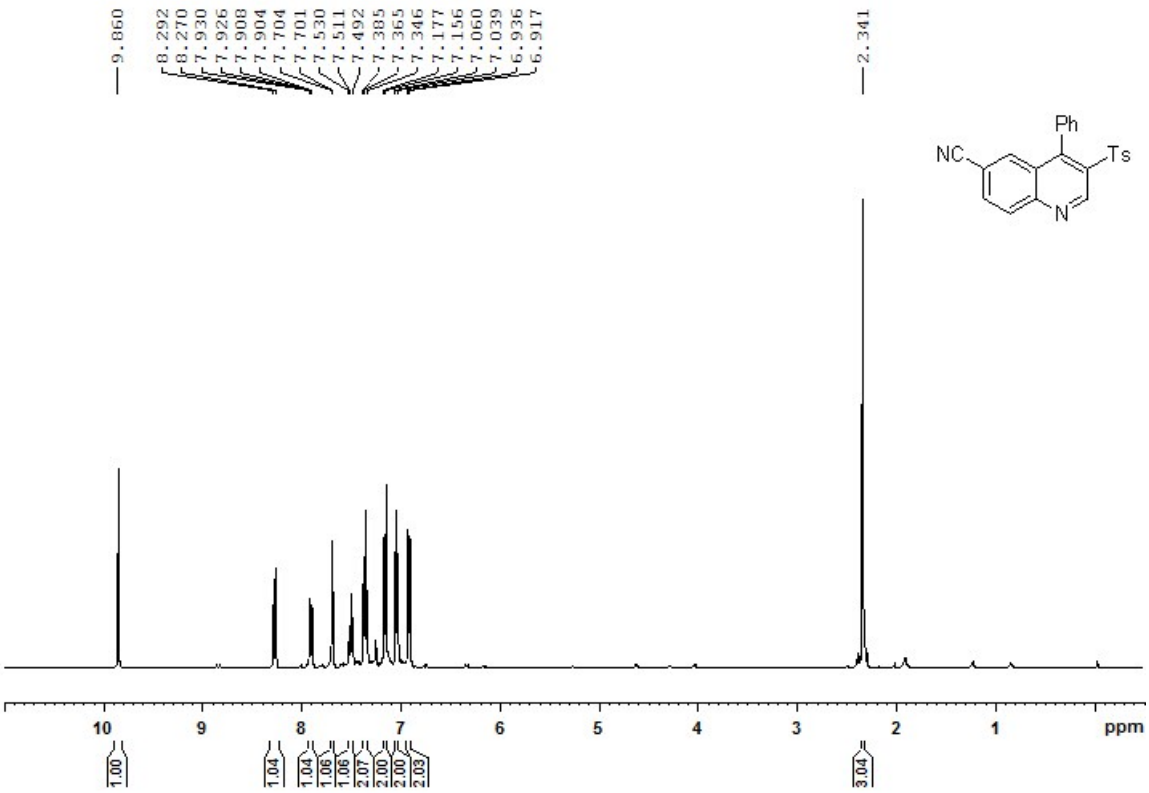

159.70
149.02
148.96
147.02
147.00
146.81
144.13
137.59
133.32
132.21
132.13
129.76
129.20
128.81
128.61
128.51
127.84
127.76
122.46
122.20
110.71
110.47
77.32
77.00
76.68
21.45
Ph
F
Ts
N
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

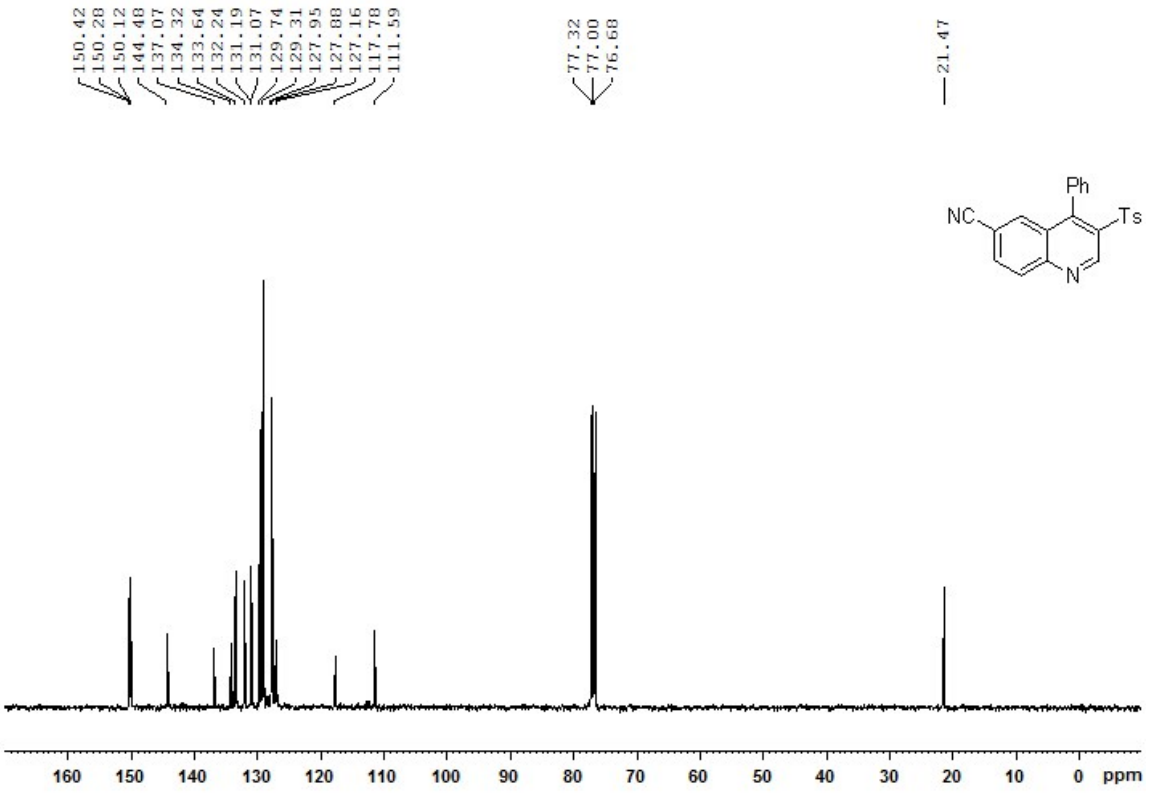

9.764
8.149
8.127
7.744
7.738
7.721
7.716
7.502
7.483
7.464
7.369
7.350
7.331
7.278
7.272
7.198
7.177
7.064
7.044
6.947
6.930
2.350
Ph
Cl
Ts
N
10
9
8
7
6
5
4
3
2
1
ppm
1.00
1.00
1.00
1.05
2.05
1.08
2.02
2.04
2.00
3.06

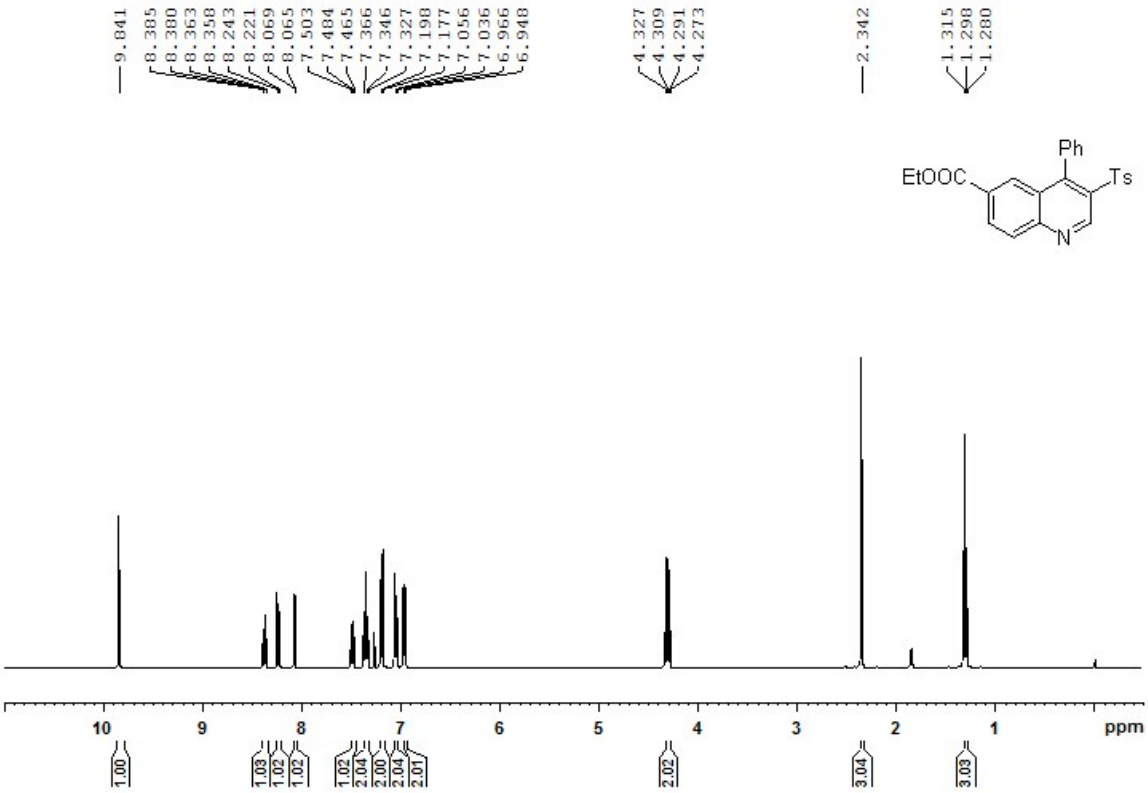

148.81
148.05
147.88
144.17
137.54
133.91
133.49
132.92
131.85
131.20
129.86
129.23
128.89
128.25
127.86
127.79
125.90
77.32
77.00
76.68
21.48
Ph
Cl
Ts
N
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

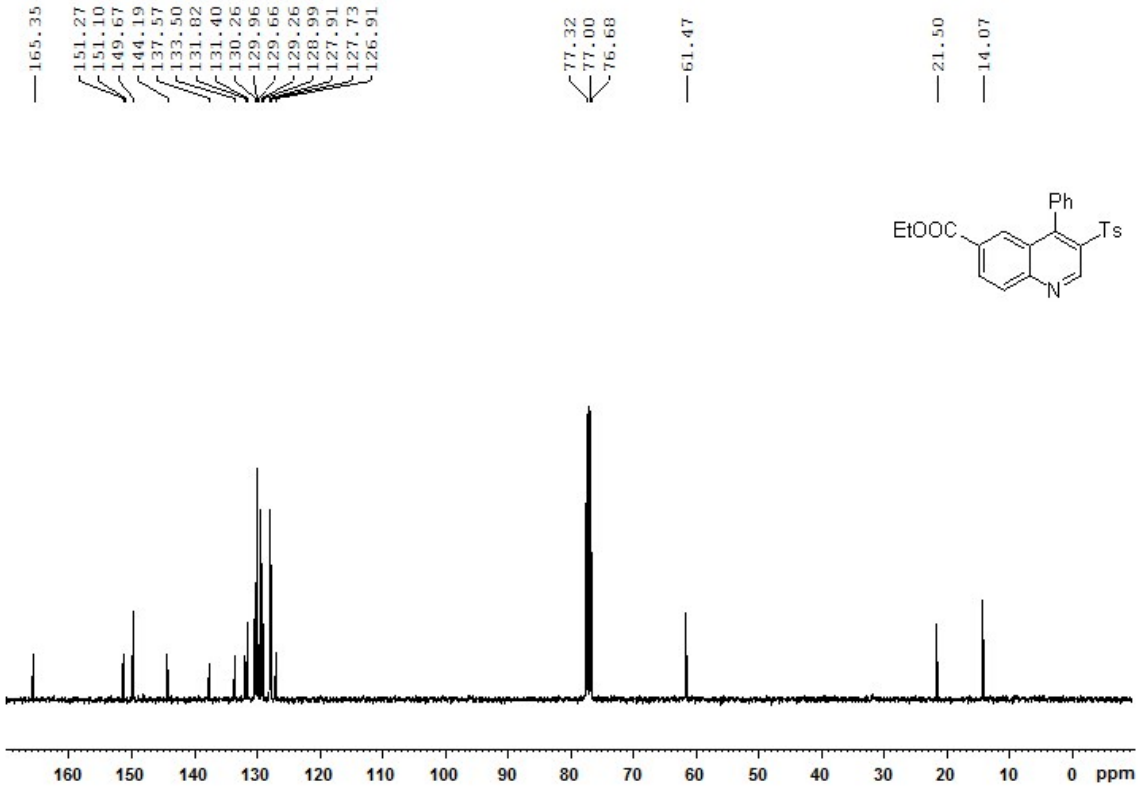

9.758
8.053
8.031
7.851
7.845
7.828
7.823
7.484
7.465
7.446
7.433
7.428
7.351
7.331
7.312
7.175
7.154
7.045
7.024
6.930
6.913
2.329
Ph
Br
Ts
N
10
9
8
7
6
5
4
3
2
1
ppm
1.00
1.01
1.01
1.05
1.01
2.05
2.00
2.01
2.00
3.01

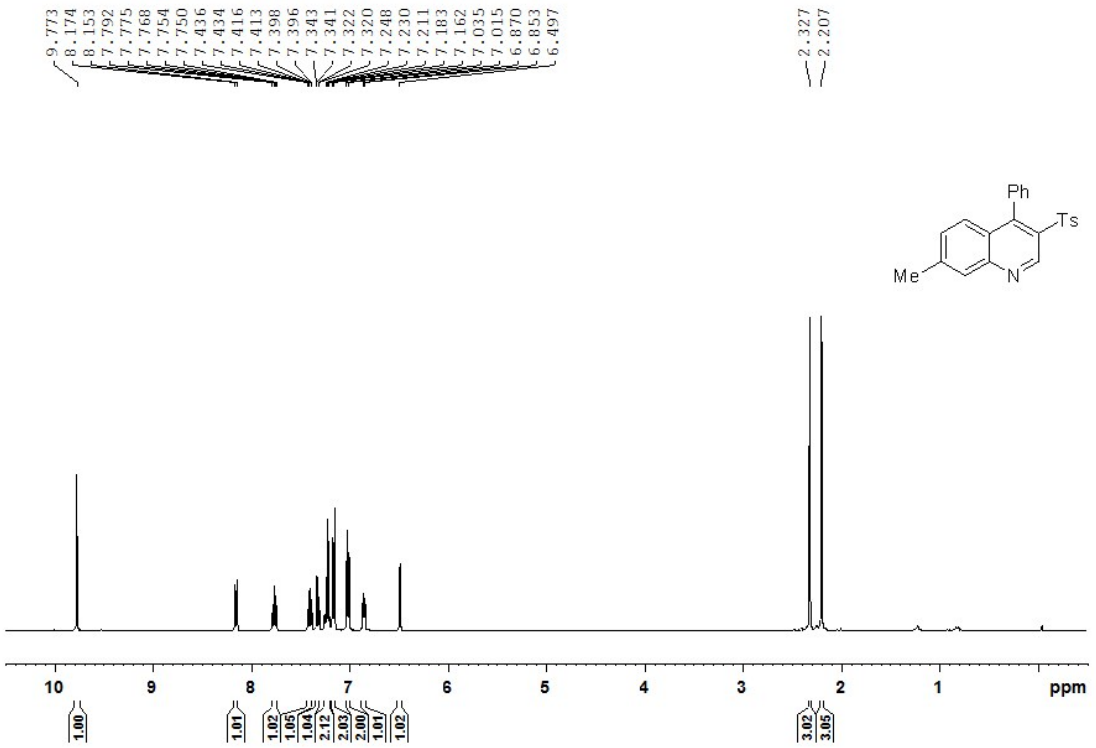

148.70
148.21
147.96
144.15
137.49
135.45
133.42
131.76
131.22
129.84
129.20
128.89
128.63
127.82
127.76
122.15
77.32
77.00
76.68
21.47
Ph
Br
Ts
N
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

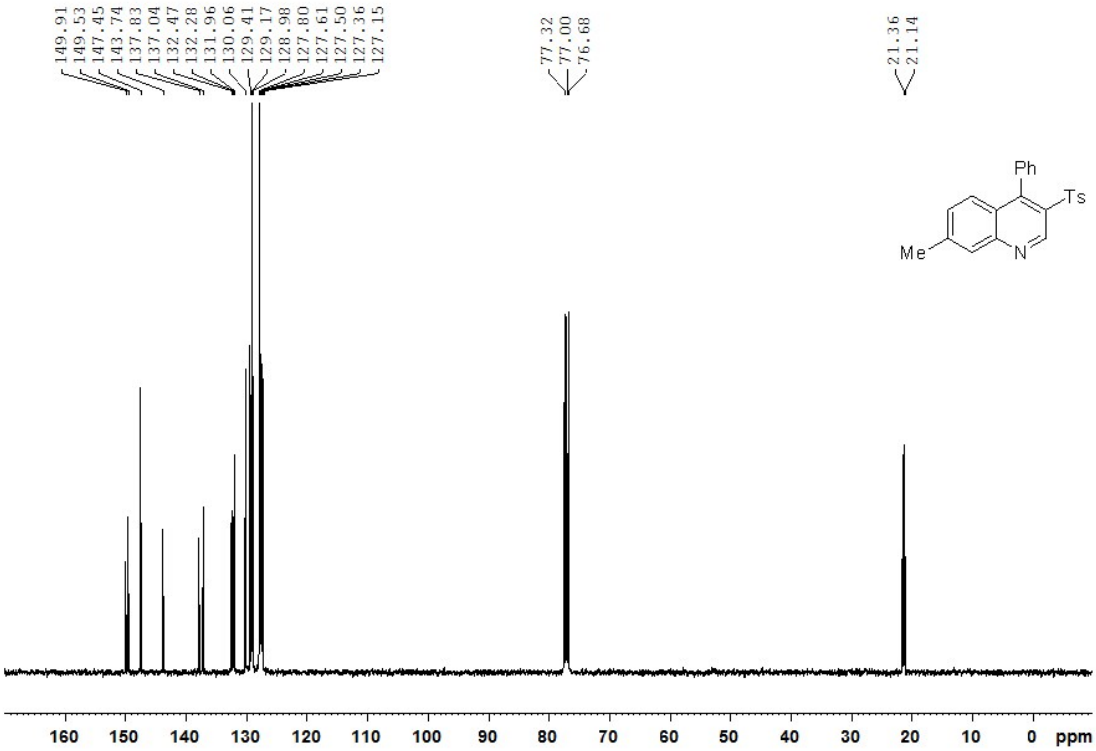

9.860
8.292
8.270
7.930
7.926
7.908
7.904
7.704
7.701
7.530
7.511
7.492
7.385
7.365
7.346
7.177
7.156
7.060
7.039
6.936
6.917
2.341
Ph
NC
Ts
N
10
9
8
7
6
5
4
3
2
1
ppm
1.00
1.04
1.04
1.06
1.06
2.07
2.00
2.00
2.03
3.04

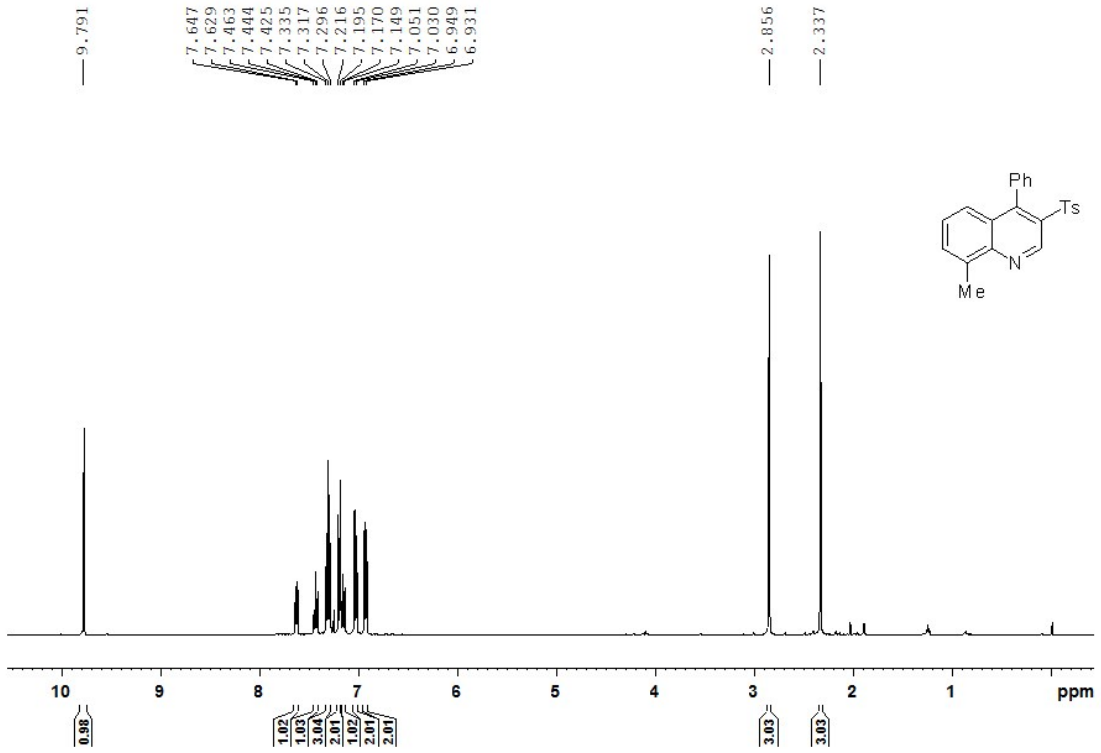

150.42
150.28
150.12
144.48
137.07
134.32
133.64
132.24
131.19
131.07
129.74
129.31
127.95
127.88
127.16
117.78
111.59
77.32
77.00
76.68
21.47
Ph
NC
Ts
N
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

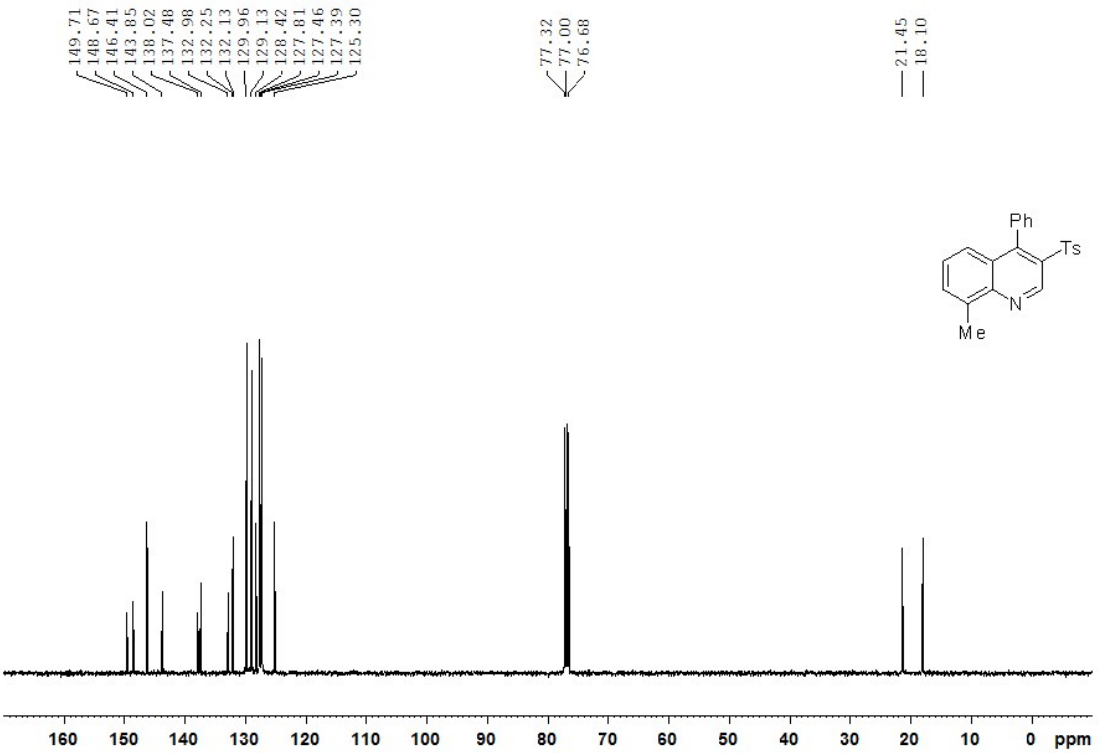

9.841
8.385
8.380
8.363
8.358
8.243
8.221
8.069
8.065
7.503
7.484
7.465
7.366
7.346
7.327
7.198
7.177
7.056
7.036
6.966
6.948
4.327
4.309
4.291
4.273
2.342
1.315
1.298
1.280
Ph
EtOOC
Ts
N
10
9
8
7
6
5
4
3
2
1
ppm
1.00
1.03
1.02
1.02
1.02
2.04
2.00
2.04
2.01
2.02
3.04
3.03

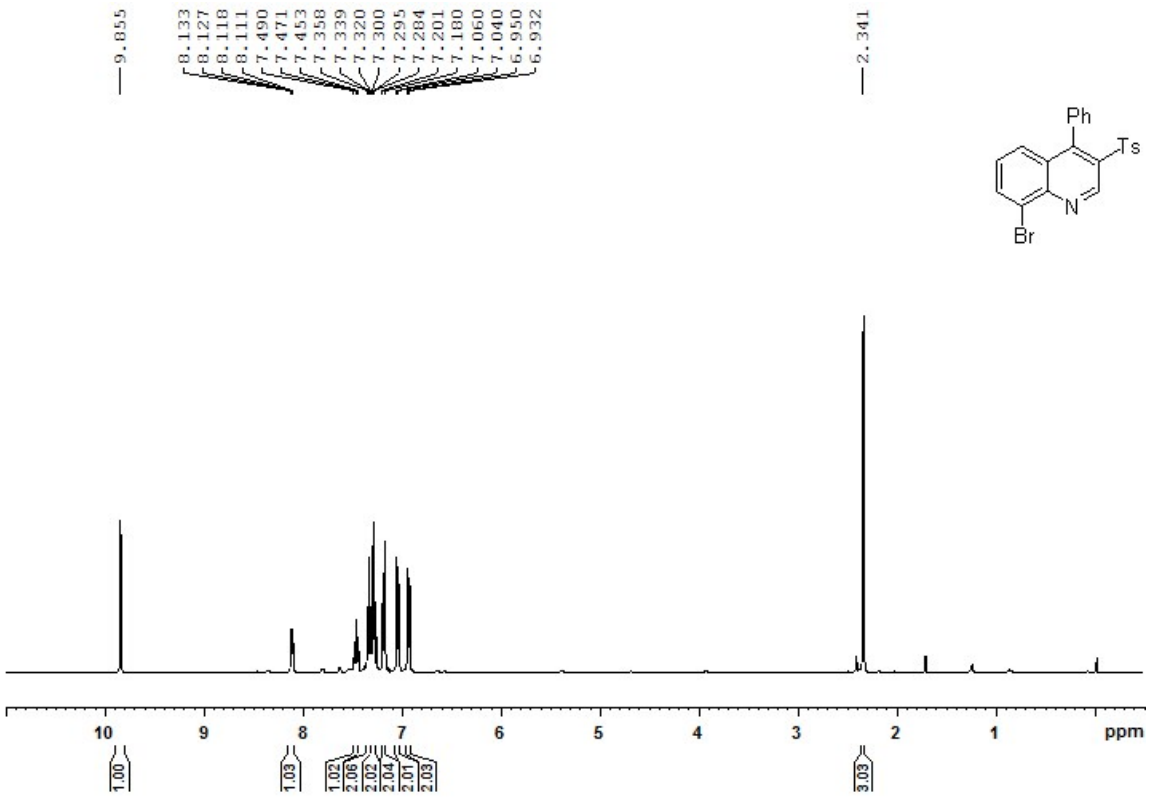

165.35
151.27
151.10
149.67
144.19
137.57
133.50
131.82
131.40
130.26
129.96
129.66
129.26
128.99
127.91
127.73
126.91
77.32
77.00
76.68
61.47
21.50
14.07
Ph
EtOOC
Ts
N
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

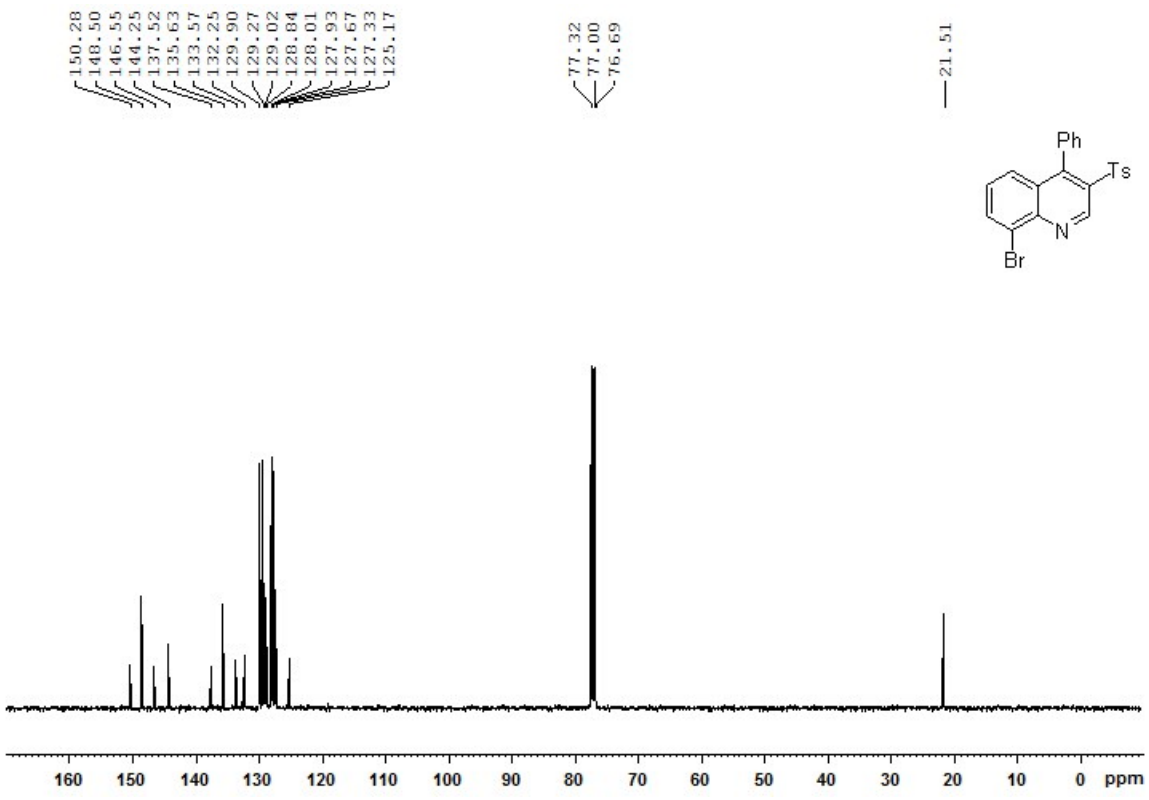

9.773
8.174
8.153
7.792
7.775
7.768
7.754
7.750
7.436
7.434
7.416
7.413
7.398
7.396
7.343
7.341
7.322
7.320
7.248
7.230
7.211
7.183
7.162
7.035
7.015
6.870
6.853
6.497
2.327
2.207
Ph
Ts
Me
N
10
9
8
7
6
5
4
3
2
1
ppm
1.00
1.01
1.02
1.05
1.04
2.12
2.03
2.00
1.01
1.02
3.02
3.05

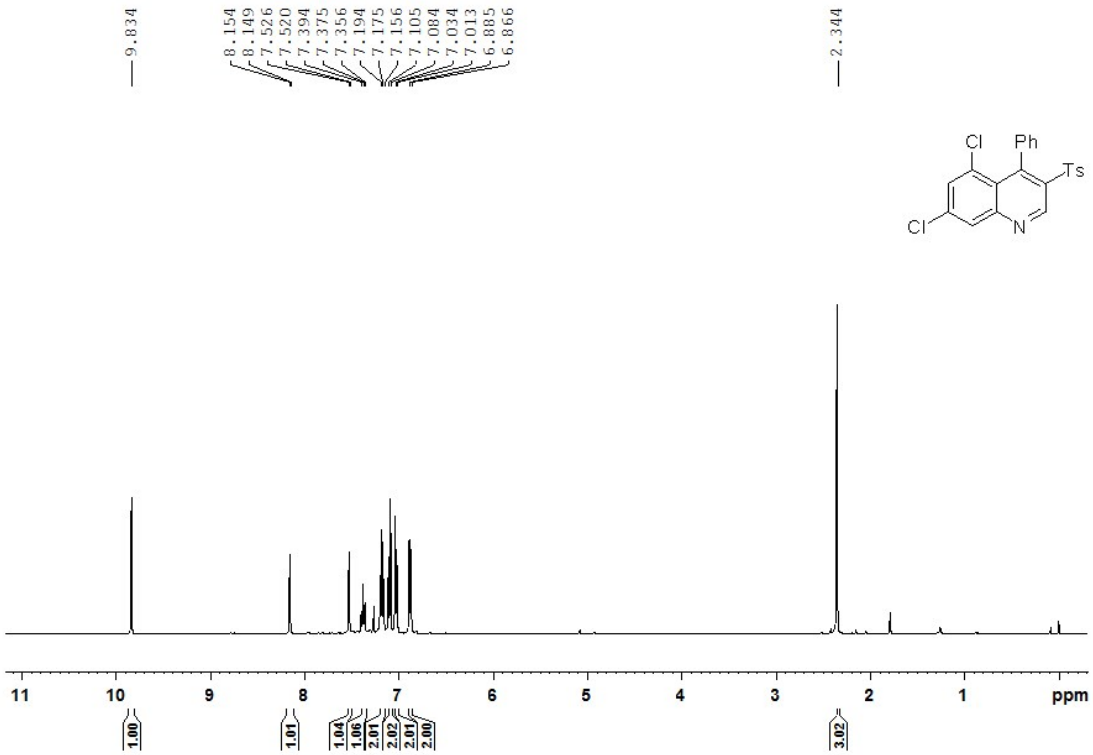

149.91
149.53
147.45
143.74
137.83
137.04
132.47
132.28
131.96
130.06
129.41
129.17
128.98
127.80
127.61
127.50
127.36
127.15
77.32
77.00
76.68
21.36
21.14
Ph
Ts
Me
N
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

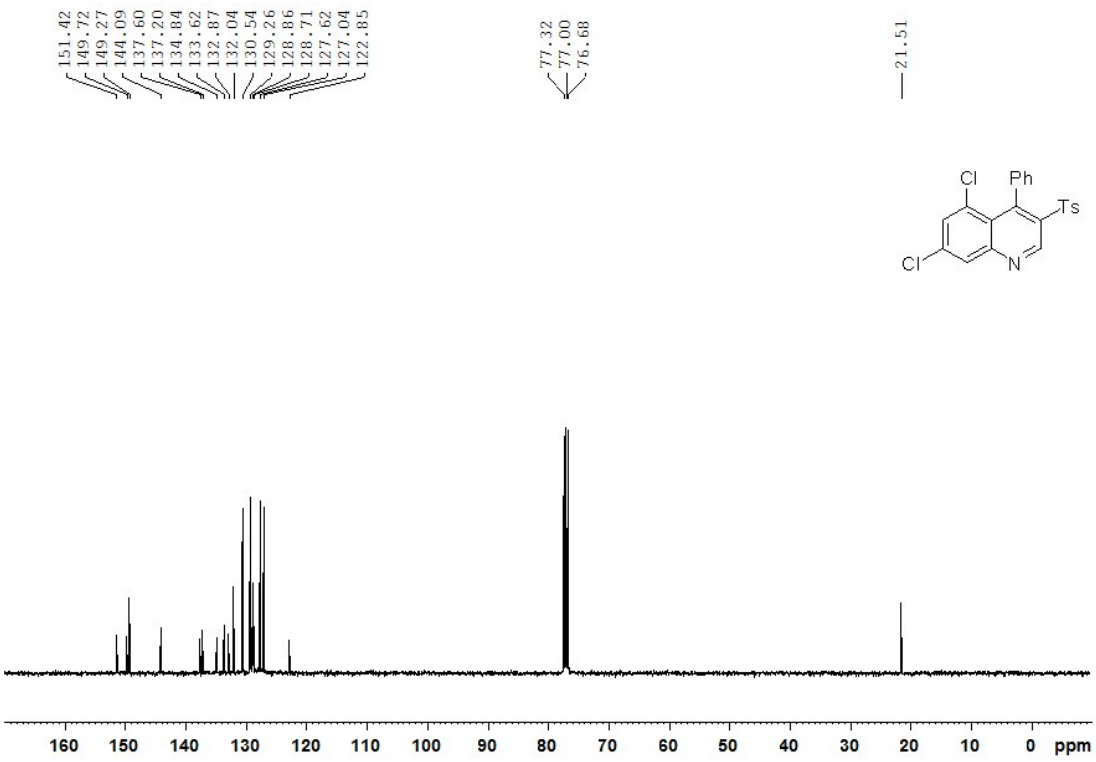

9.791
7.647
7.629
7.463
7.444
7.425
7.335
7.317
7.296
7.216
7.195
7.170
7.149
7.051
7.030
6.949
6.931
2.856
2.337
Ph
Ts
N
Me
10
9
8
7
6
5
4
3
2
1
ppm
0.98
1.02
1.03
3.04
2.01
1.02
2.01
2.01
3.03
3.03

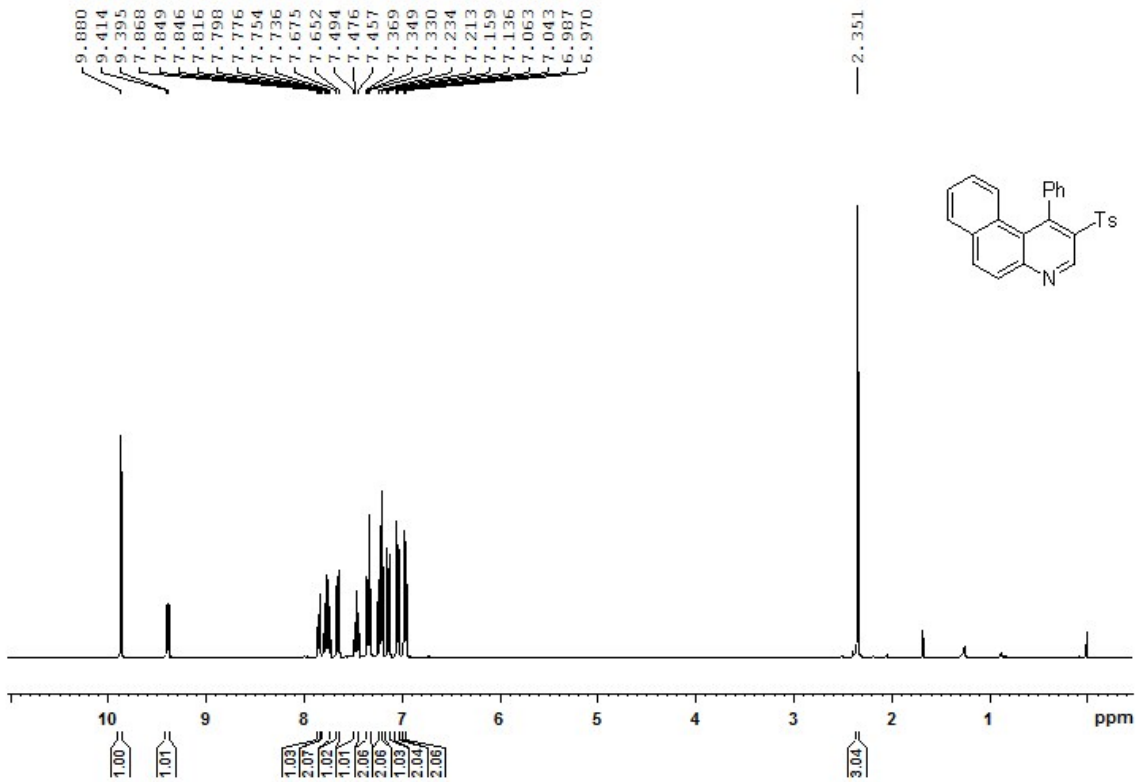

149.71
148.67
146.41
143.85
138.02
137.48
132.98
132.25
132.13
129.96
129.13
128.42
127.81
127.46
127.39
125.30
77.32
77.00
76.68
21.45
18.10
Ph
Ts
N
Me
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

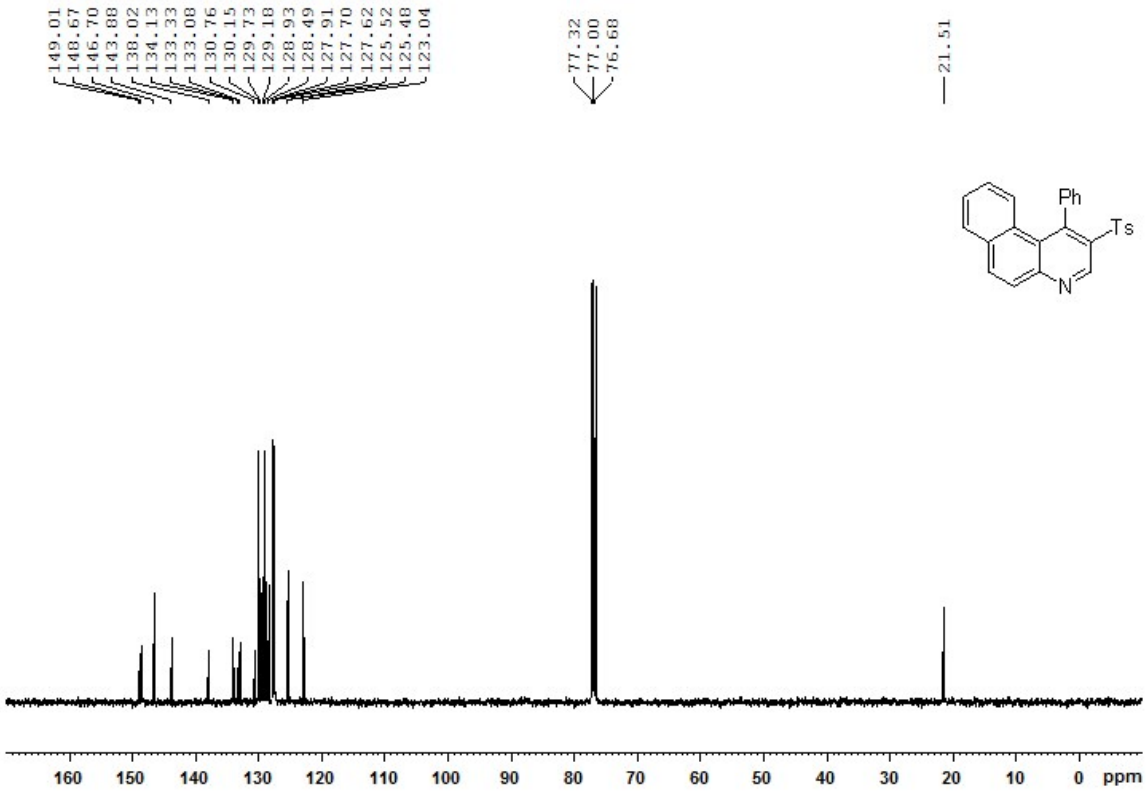

9.855
8.133
8.127
8.118
8.111
7.490
7.471
7.453
7.358
7.339
7.320
7.300
7.295
7.284
7.201
7.180
7.060
7.040
6.950
6.932
2.341
Ph
Ts
N
Br
10
9
8
7
6
5
4
3
2
1
ppm
1.00
1.03
1.02
2.06
2.02
2.04
2.01
2.03
3.03

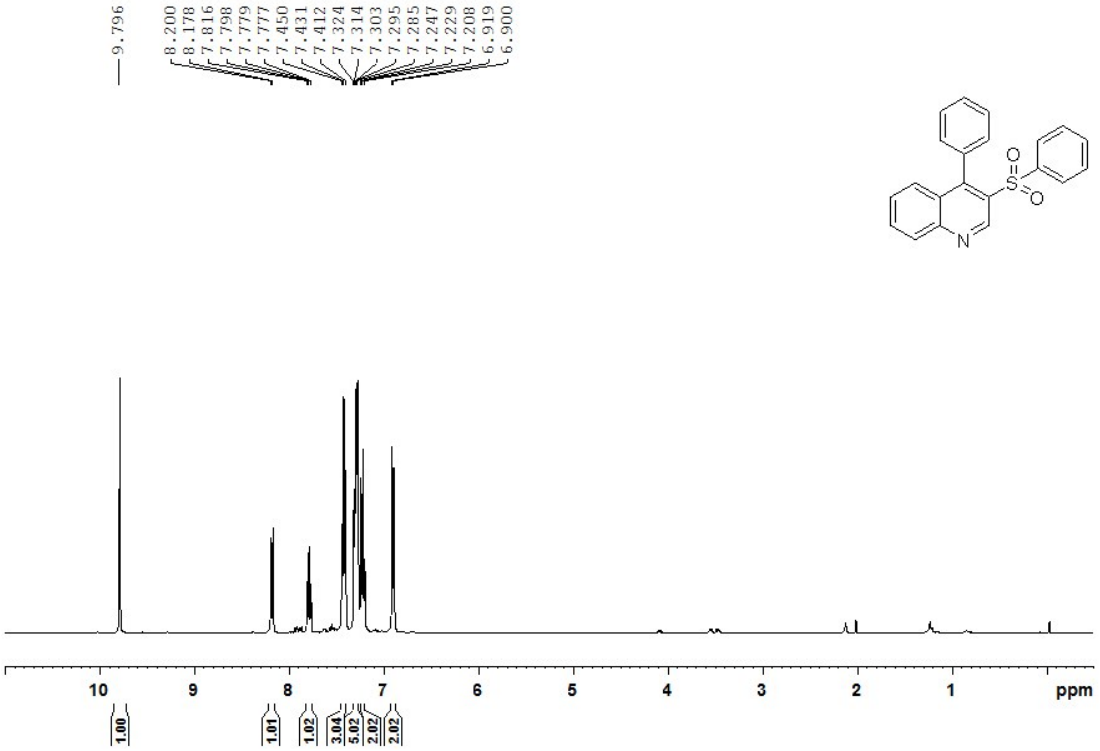

150.28
148.50
146.55
144.25
137.52
135.63
133.57
132.25
129.90
129.27
129.02
128.84
128.01
127.93
127.67
127.33
125.17
77.32
77.00
76.69
21.51
Ph
Ts
N
Br
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

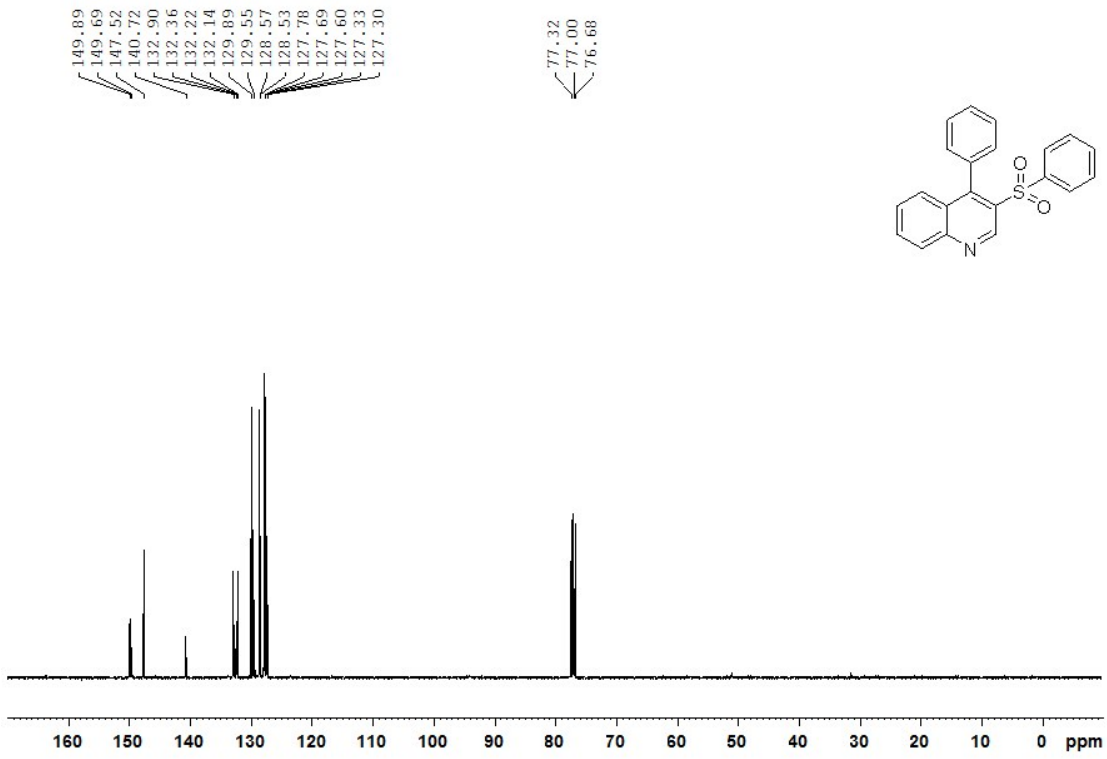

9.834
8.154
8.149
7.526
7.520
7.394
7.375
7.356
7.194
7.175
7.156
7.105
7.084
7.034
7.013
6.885
6.866
2.344
Cl
Ph
Ts
Cl
N
11
10
9
8
7
6
5
4
3
2
1
ppm
1.00
1.01
1.04
1.06
2.01
2.02
2.01
2.00
3.02

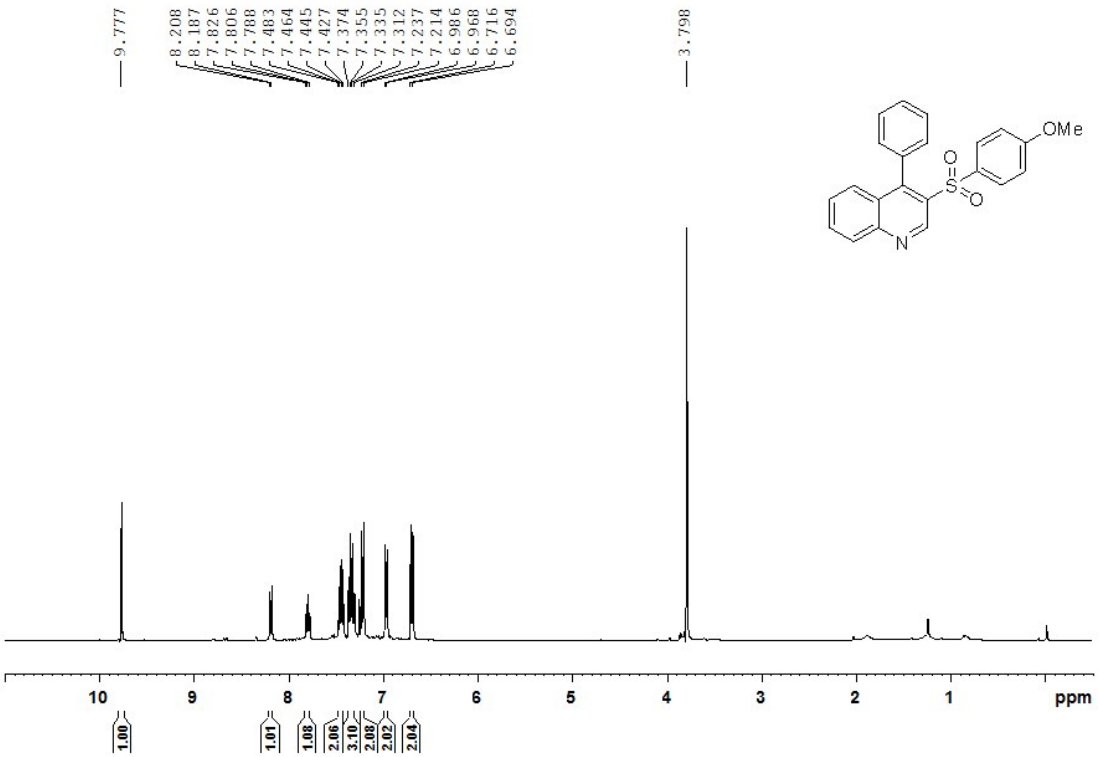

151.42
149.72
149.27
144.09
137.60
137.20
134.84
133.62
132.87
132.04
130.54
129.26
128.86
128.71
127.62
127.04
122.85
77.32
77.00
76.68
21.51
Cl
Ph
Ts
Cl
N
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

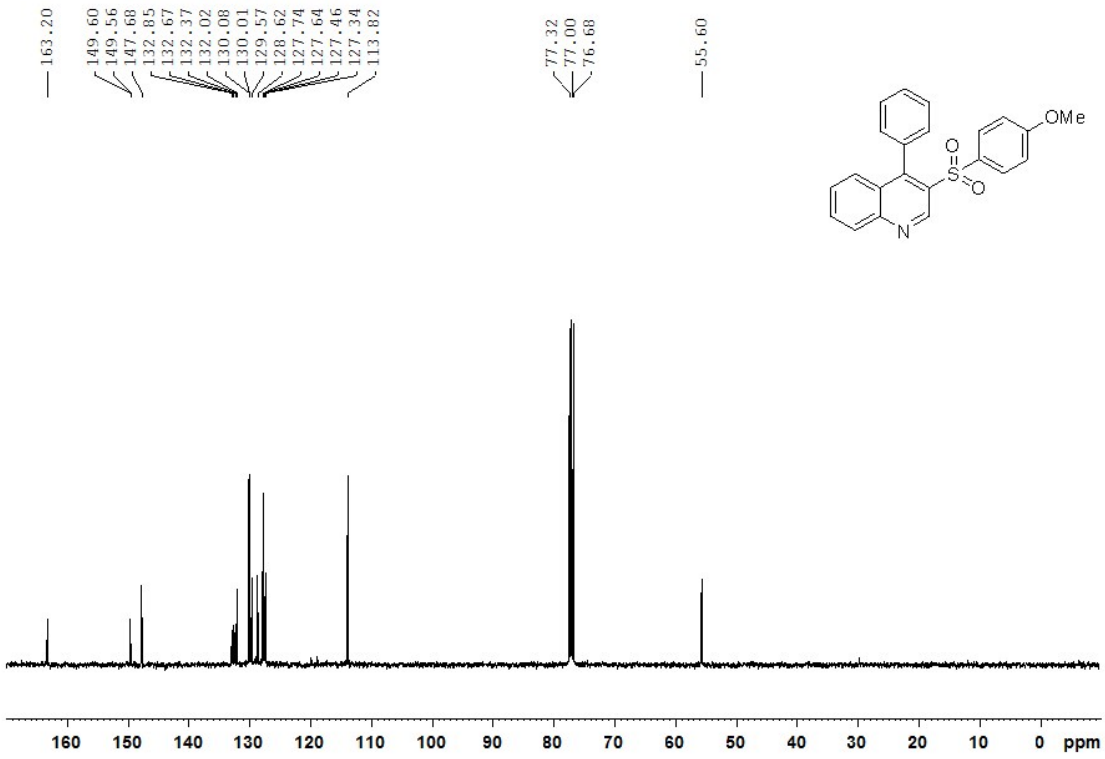

9.880
9.414
9.395
7.868
7.849
7.846
7.816
7.798
7.776
7.754
7.736
7.675
7.652
7.494
7.476
7.457
7.369
7.349
7.330
7.234
7.213
7.159
7.136
7.063
7.043
6.987
6.970
2.351
Ph
Ts
N
10
9
8
7
6
5
4
3
2
1
ppm
1.00
1.01
1.03
2.07
1.02
1.01
2.06
2.06
1.03
2.04
2.06
3.04

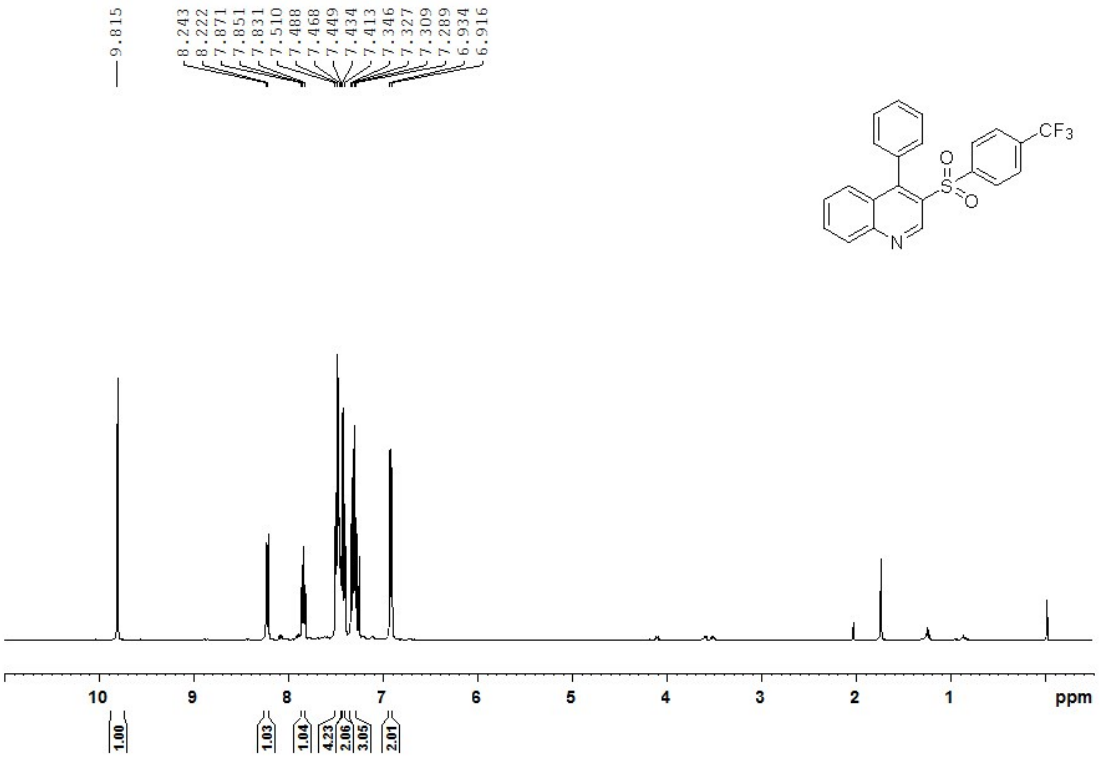

149.01
148.67
146.70
143.88
138.02
134.13
133.33
133.08
130.76
130.15
129.73
129.18
128.93
128.49
127.91
127.70
127.62
125.52
125.48
123.04
77.32
77.00
76.68
21.51
Ph
Ts
N
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

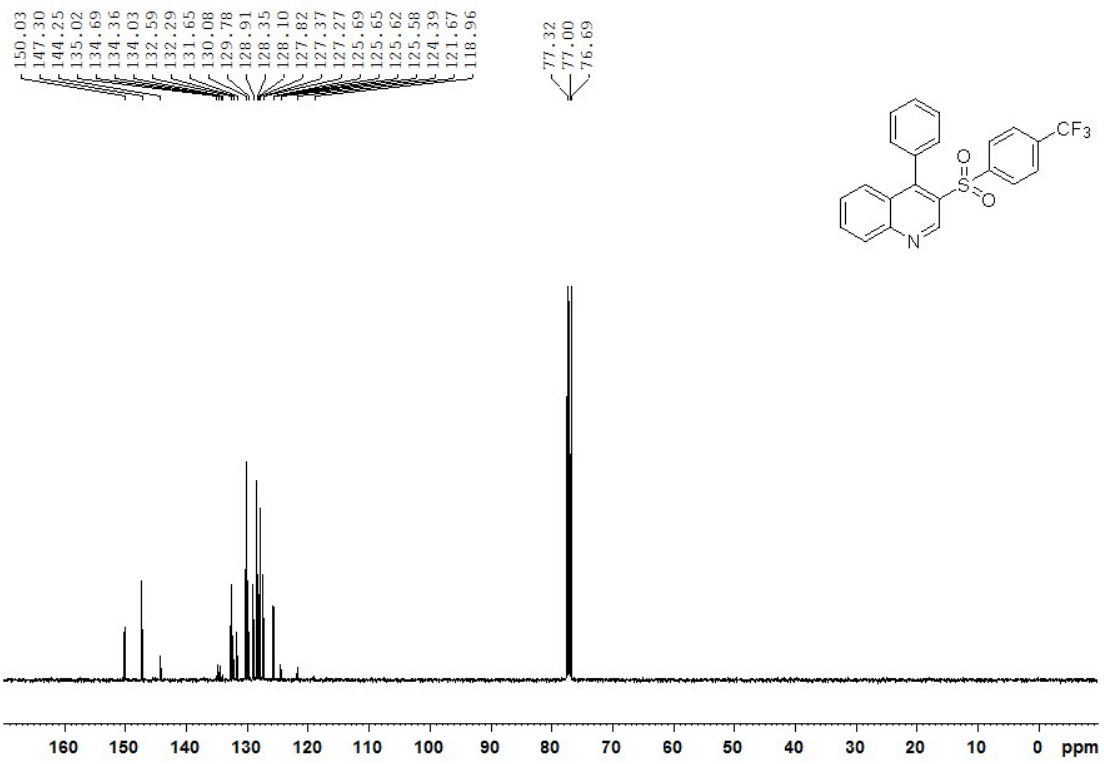

9.796
8.200
8.178
7.816
7.798
7.779
7.777
7.450
7.431
7.412
7.324
7.314
7.303
7.295
7.285
7.247
7.229
7.208
6.919
6.900
10
9
8
7
6
5
4
3
2
1
ppm
1.00
1.01
1.02
3.04
5.02
2.02
2.02

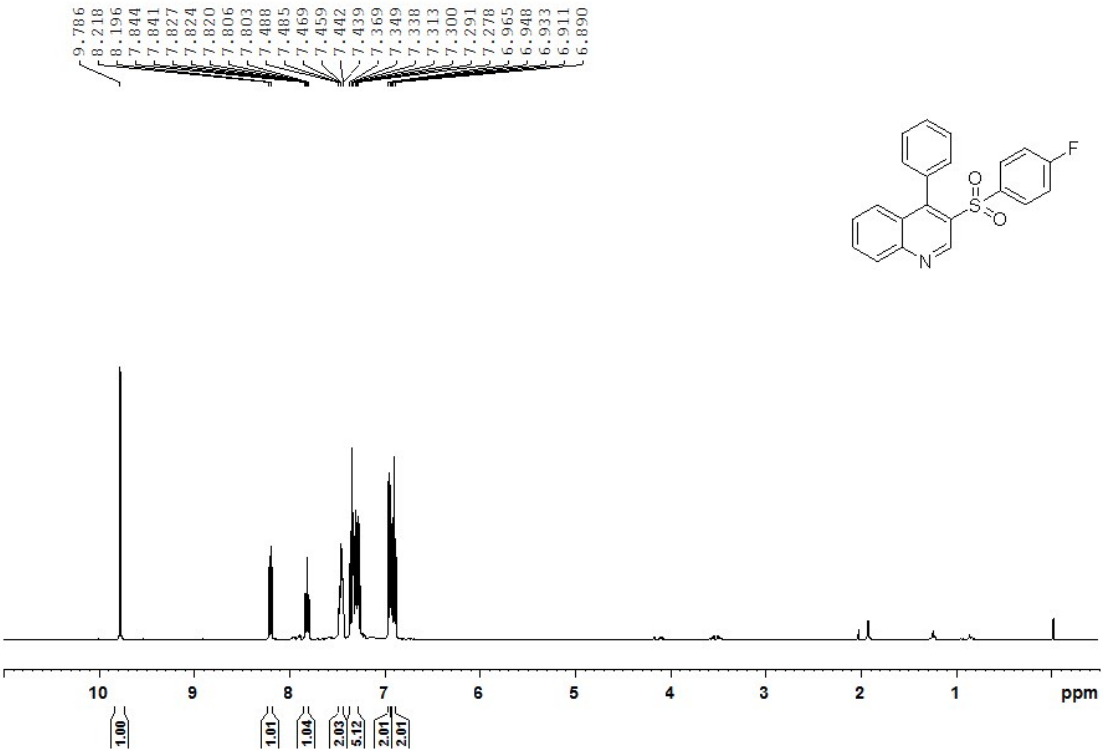

149.89
149.69
147.52
140.72
132.90
132.36
132.22
132.14
129.89
129.55
128.57
128.53
127.78
127.69
127.60
127.33
127.30
77.32
77.00
76.68
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

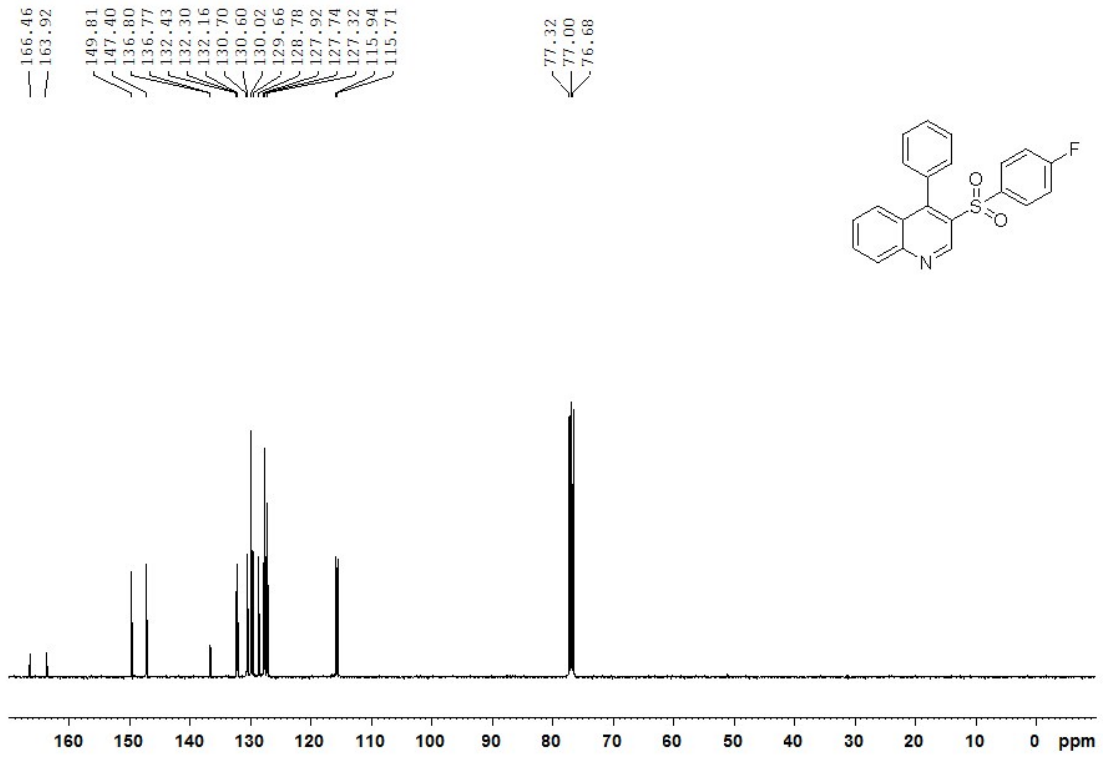

9.777
8.208
8.187
7.826
7.806
7.788
7.483
7.464
7.445
7.427
7.374
7.355
7.335
7.312
7.237
7.214
6.986
6.968
6.716
6.694
3.798
OMe
O
S
O
N
10
9
8
7
6
5
4
3
2
1
ppm
1.00
1.01
1.08
2.06
3.10
2.08
2.02
2.04

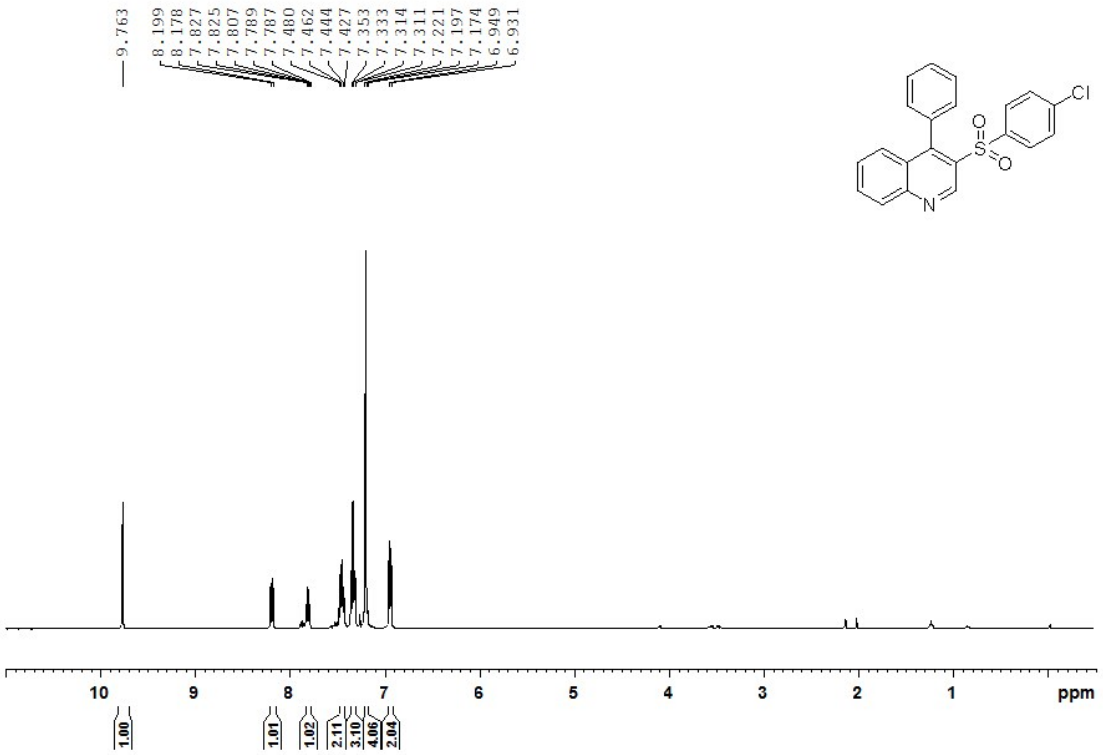

163.20
149.60
149.56
147.68
132.85
132.67
132.37
132.02
130.08
130.01
129.57
128.62
127.74
127.64
127.46
127.34
113.82
77.32
77.00
76.68
55.60
OMe
O
S
O
N
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

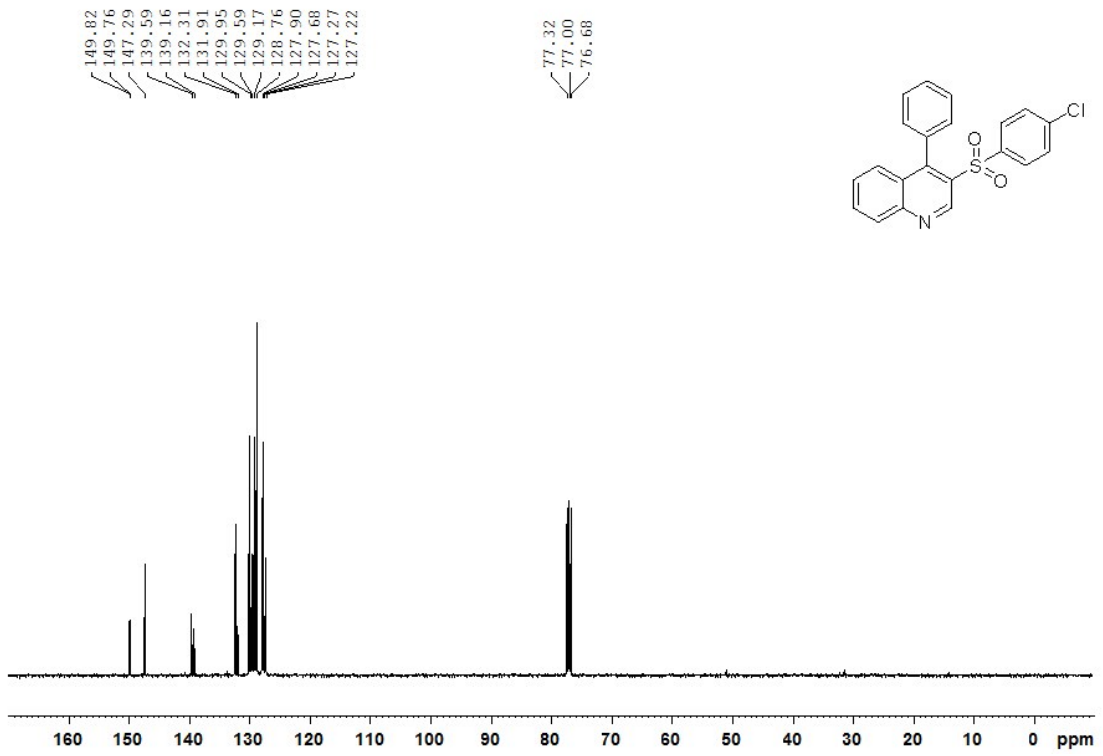

9.815
8.243
8.222
7.871
7.851
7.831
7.510
7.488
7.468
7.449
7.434
7.413
7.346
7.327
7.309
7.289
6.934
6.916
CF3
O
S
O
N
10
9
8
7
6
5
4
3
2
1
ppm
1.00
1.03
1.04
4.23
2.06
3.05
2.01

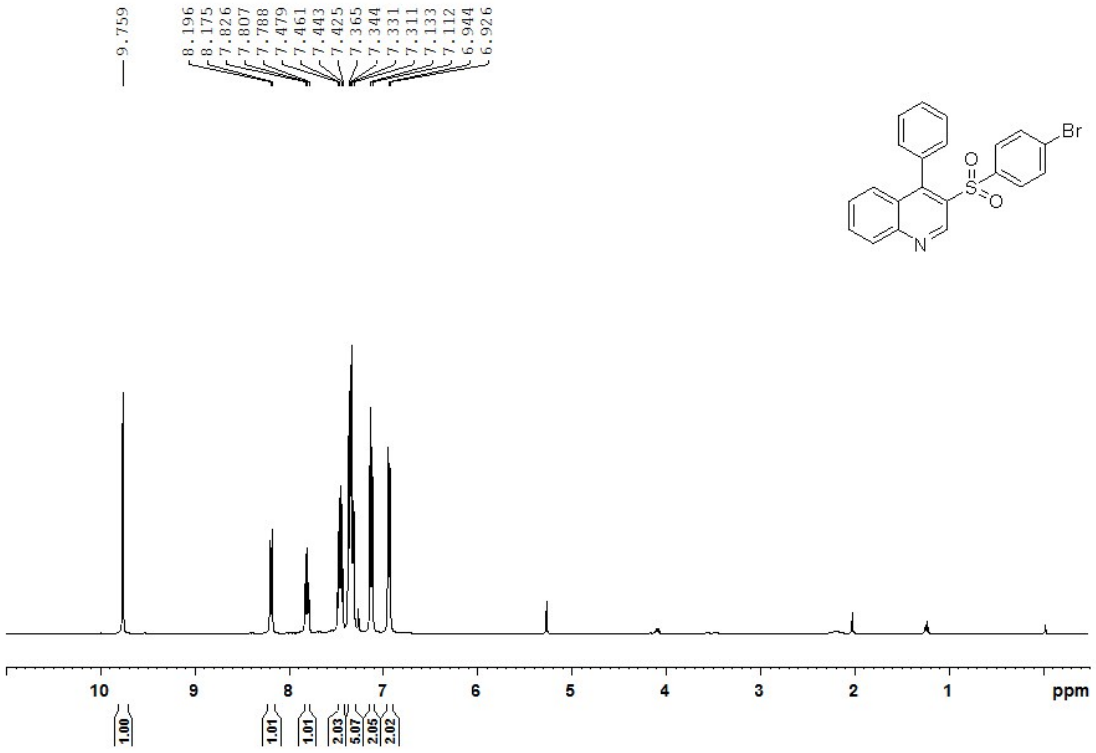

150.03
147.30
144.25
135.02
134.69
134.36
134.03
132.59
132.29
131.65
130.08
129.78
128.91
128.35
128.10
127.82
127.37
127.27
125.69
125.65
125.62
125.58
124.39
121.67
118.96
77.32
77.00
76.69
CF3
O
S
O
N
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

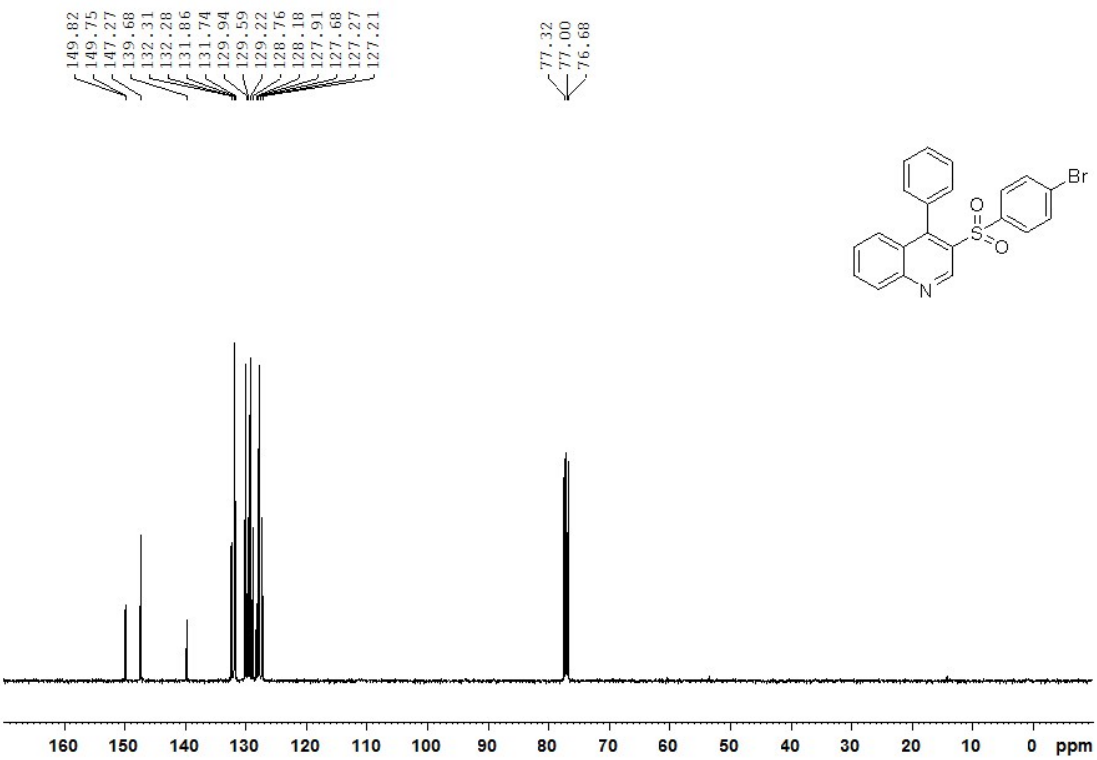

9.786
8.218
8.196
7.844
7.841
7.827
7.824
7.820
7.806
7.803
7.488
7.485
7.469
7.459
7.442
7.439
7.369
7.349
7.338
7.313
7.300
7.291
7.278
6.965
6.948
6.933
6.911
6.890
F
O
S
O
N
10
9
8
7
6
5
4
3
2
1
ppm
1.00
1.01
1.04
2.03
5.12
2.01
2.01

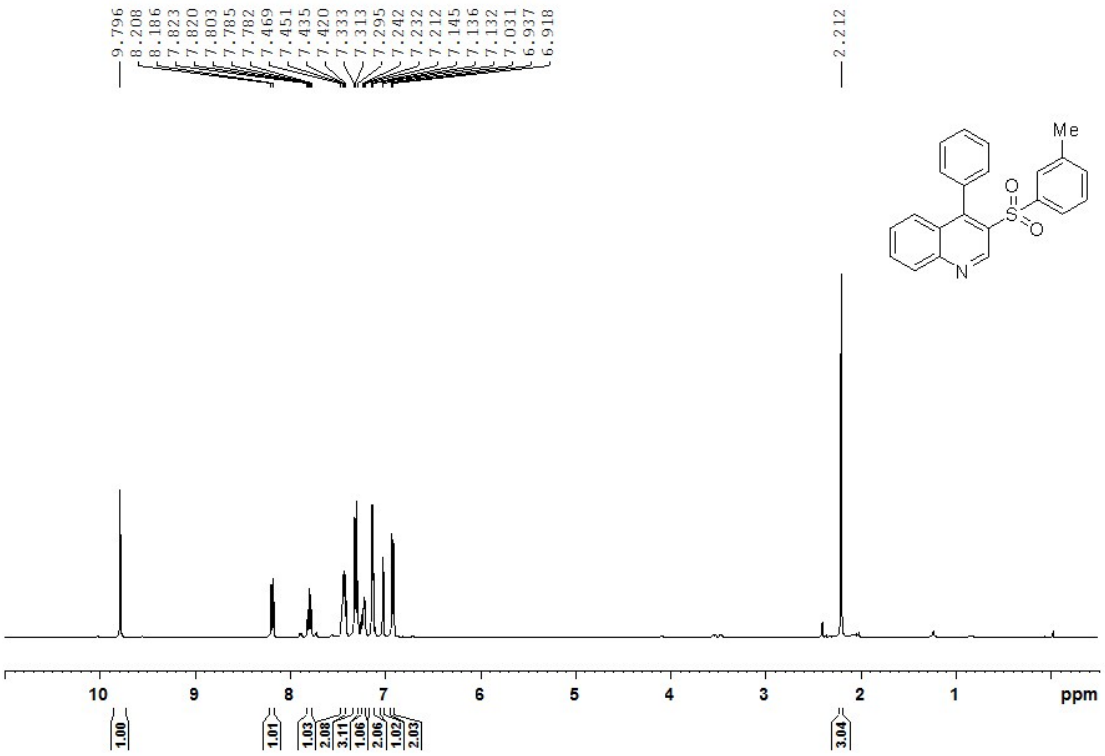

166.46
163.92
149.81
147.40
136.80
136.77
132.43
132.30
132.16
130.70
130.60
130.02
129.66
128.78
127.92
127.74
127.32
115.94
115.71
77.32
77.00
76.68
F
O
S
O
N
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

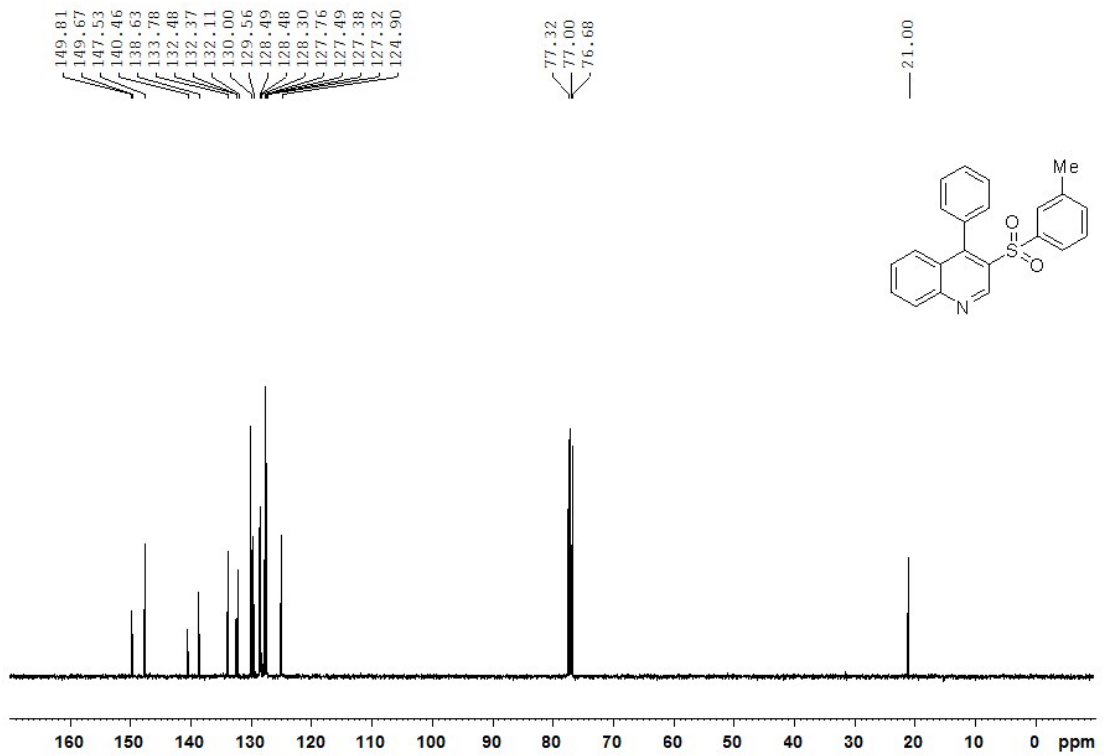

9.763
8.199
8.178
7.827
7.825
7.807
7.789
7.787
7.480
7.462
7.444
7.427
7.353
7.333
7.314
7.311
7.221
7.197
7.174
6.949
6.931
Cl
O
S
O
N
10
9
8
7
6
5
4
3
2
1
ppm
1.00
1.01
1.02
2.11
3.10
4.06
2.04

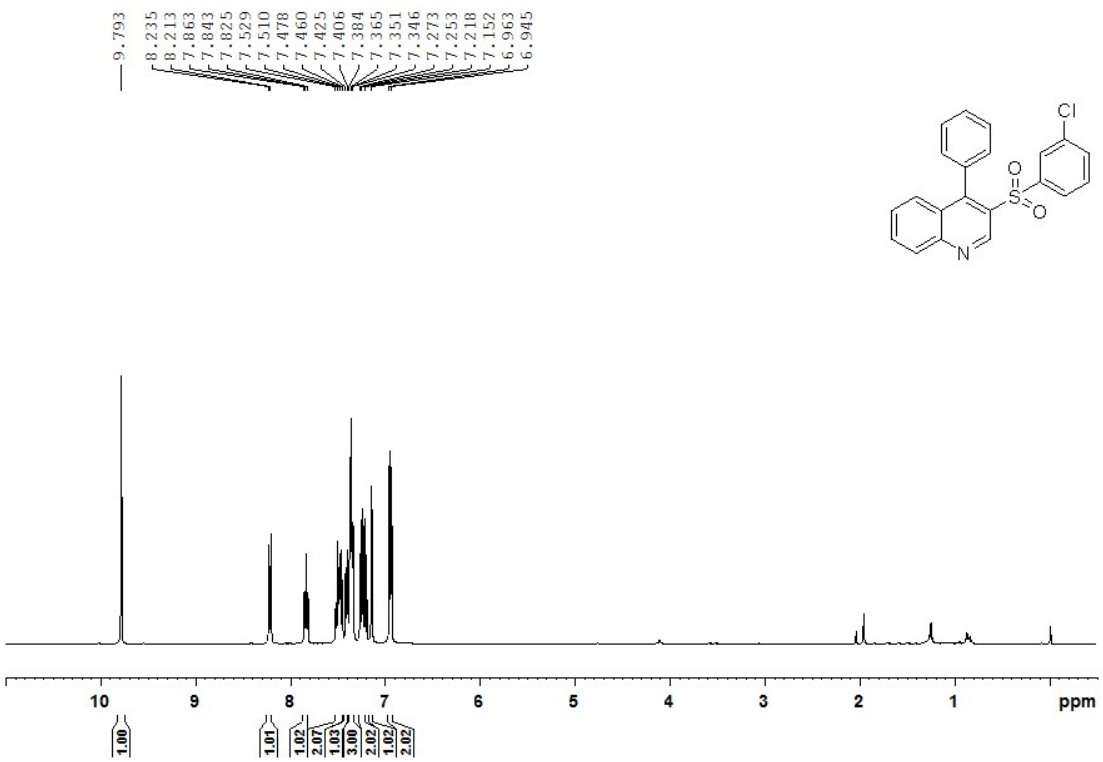

149.82
149.76
147.29
139.59
139.16
132.31
131.91
129.95
129.59
129.17
128.76
127.90
127.68
127.27
127.22
77.32
77.00
76.68
Cl
O
S
O
N
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

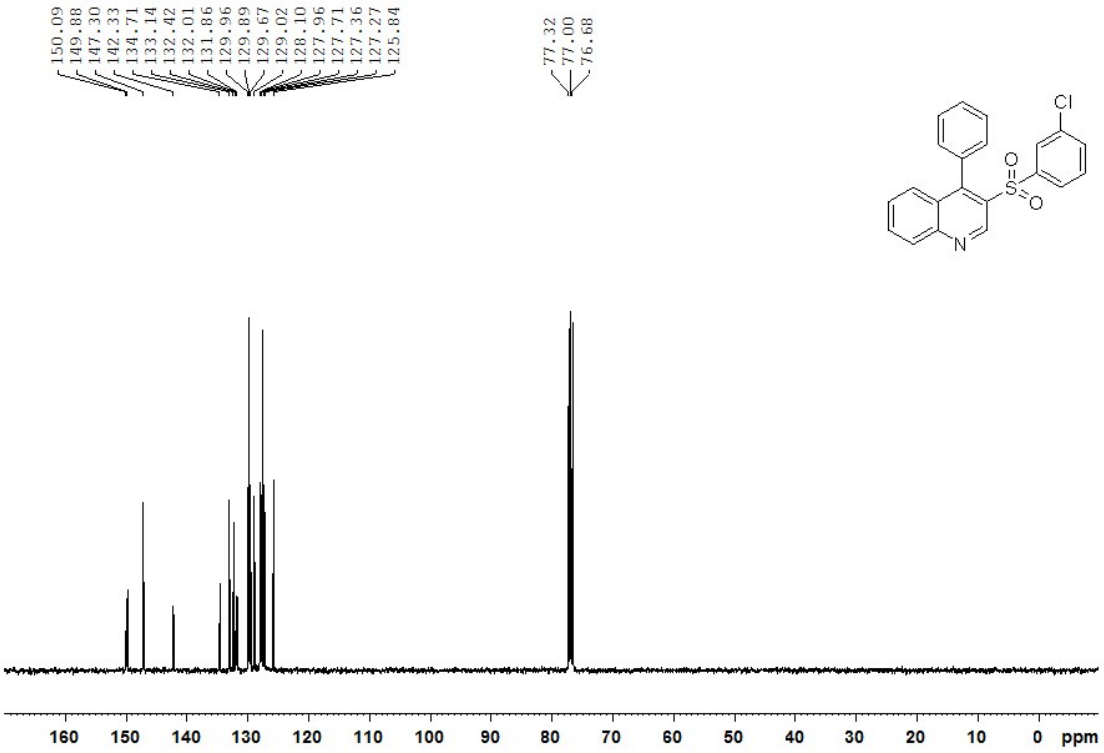

9.759
8.196
8.175
7.826
7.807
7.788
7.479
7.461
7.443
7.425
7.365
7.344
7.331
7.311
7.133
7.112
6.944
6.926
Br
O
S
O
N
10
9
8
7
6
5
4
3
2
1
ppm
1.00
1.01
1.01
2.03
5.07
2.05
2.02

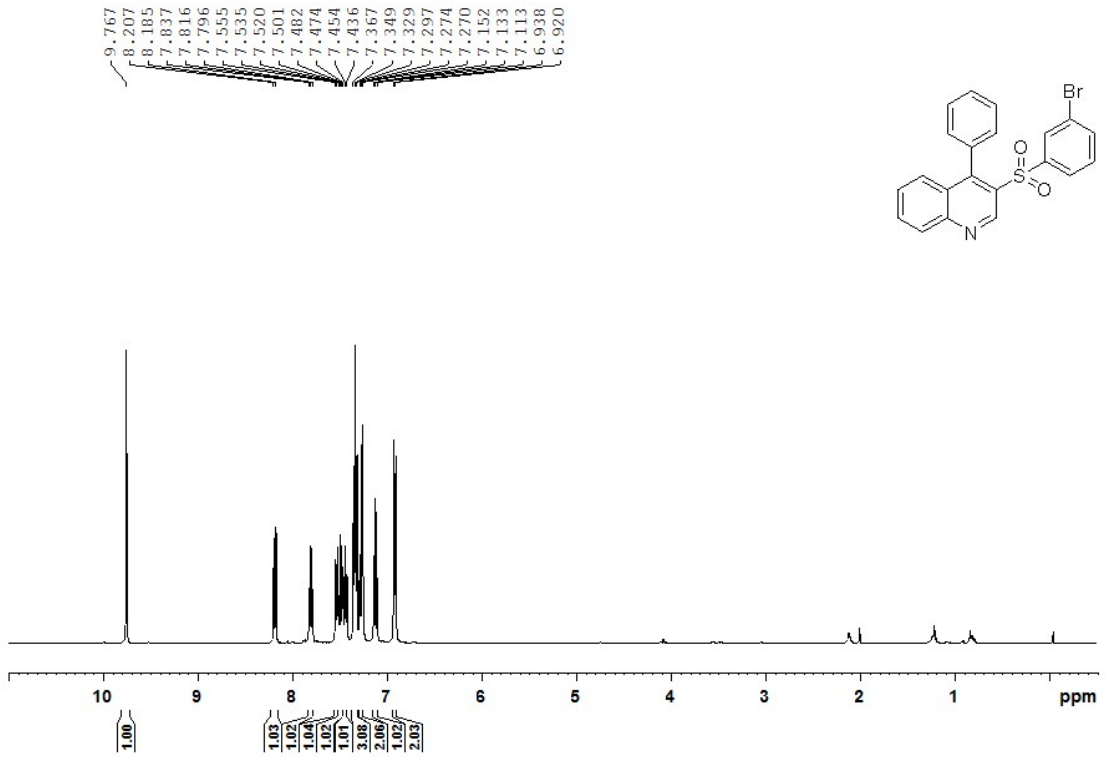

149.82
149.75
147.27
139.68
132.31
132.28
131.86
131.74
129.94
129.59
129.22
128.76
128.18
127.91
127.68
127.27
127.21
77.32
77.00
76.68
Br
O
S
O
N
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

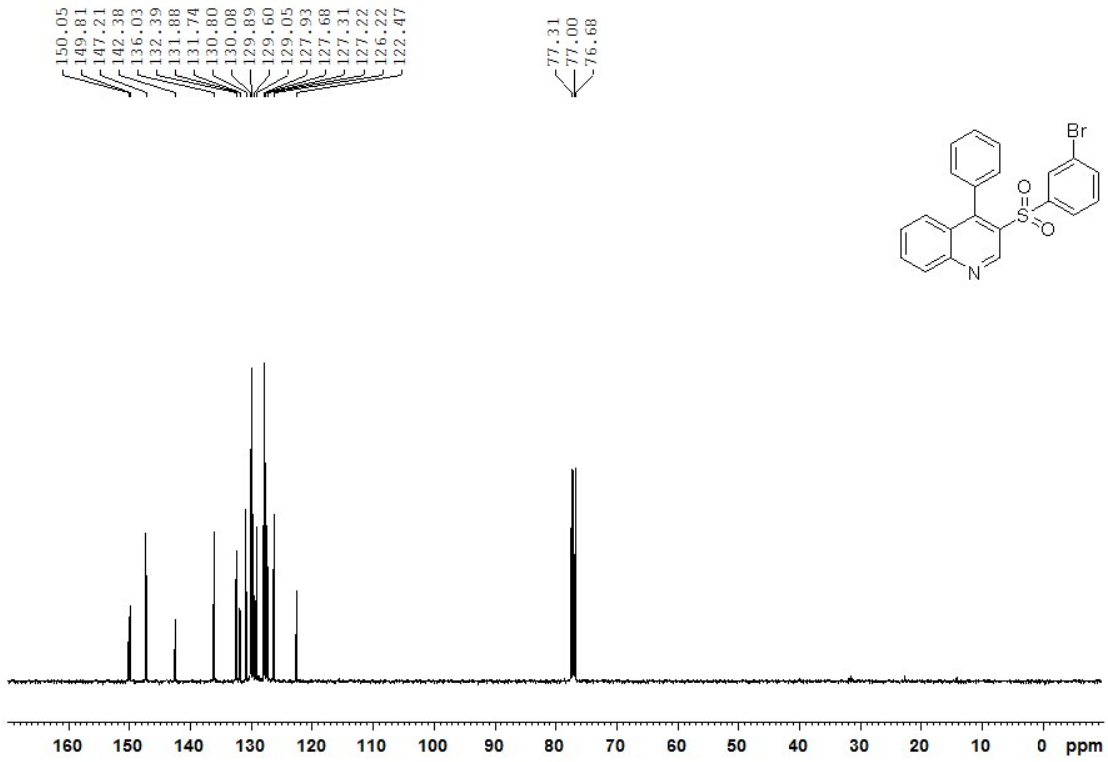

9.796
8.208
8.186
7.823
7.820
7.803
7.785
7.782
7.469
7.451
7.435
7.420
7.333
7.313
7.295
7.242
7.232
7.212
7.145
7.136
7.132
7.031
6.937
6.918
2.212
Me
O
S
O
N
10
9
8
7
6
5
4
3
2
1
ppm
1.00
1.01
1.03
2.08
3.11
1.06
2.06
1.02
2.03
3.04

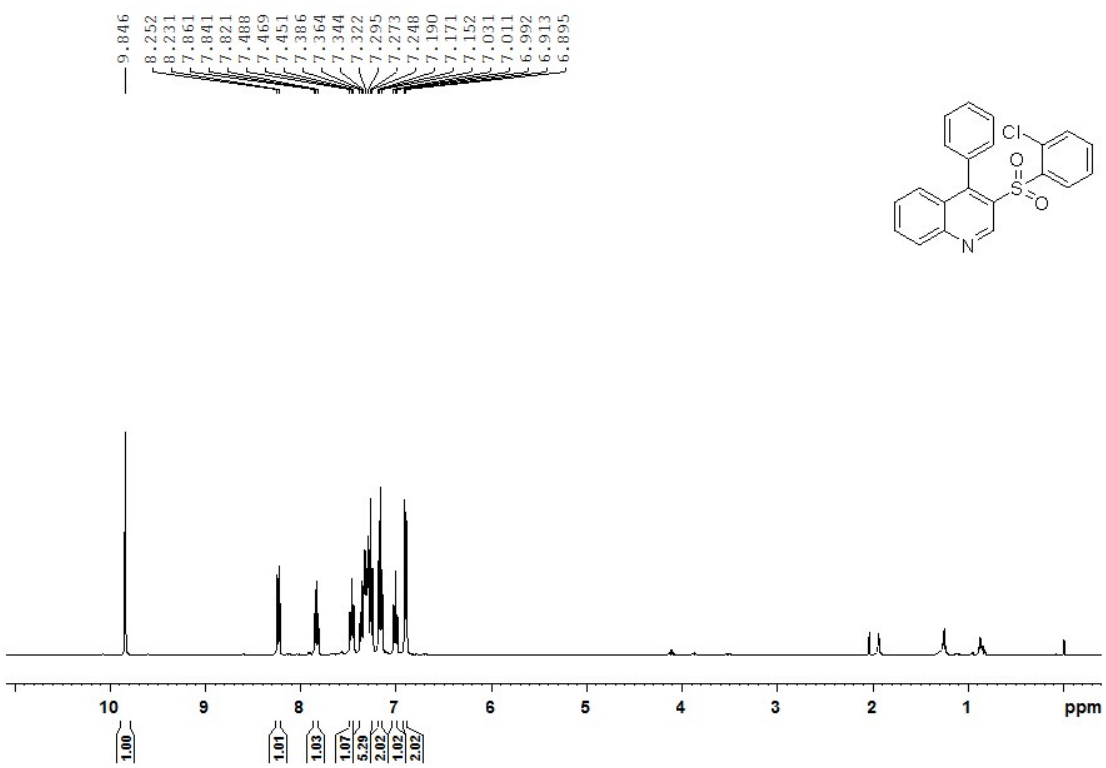

149.81
149.67
147.53
140.46
138.63
133.78
132.48
132.37
132.11
130.00
129.56
128.49
128.48
128.30
127.76
127.49
127.38
127.32
124.90
77.32
77.00
76.68
21.00
Me
O
S
O
N
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

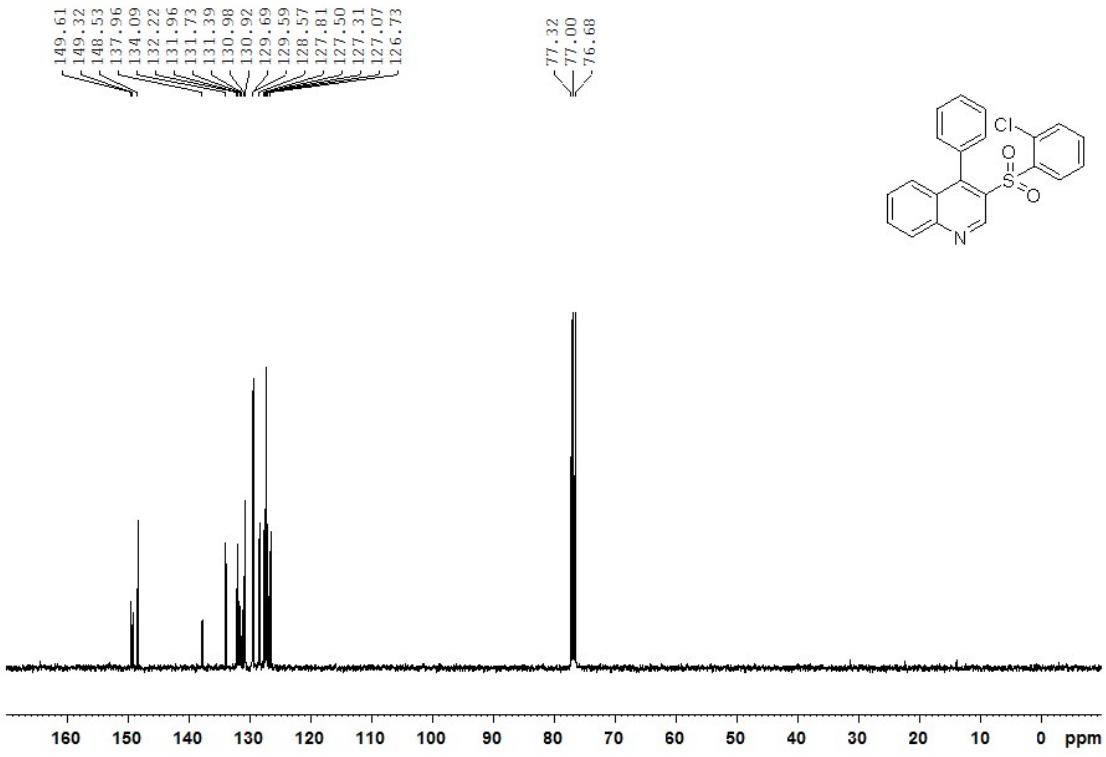

9.793
8.235
8.213
7.863
7.843
7.825
7.529
7.510
7.478
7.460
7.425
7.406
7.384
7.365
7.351
7.346
7.273
7.253
7.218
7.152
6.963
6.945
Cl
O
S
O
N
10
9
8
7
6
5
4
3
2
1
ppm
1.00
1.01
1.02
2.07
1.03
3.00
2.02
1.02
2.02

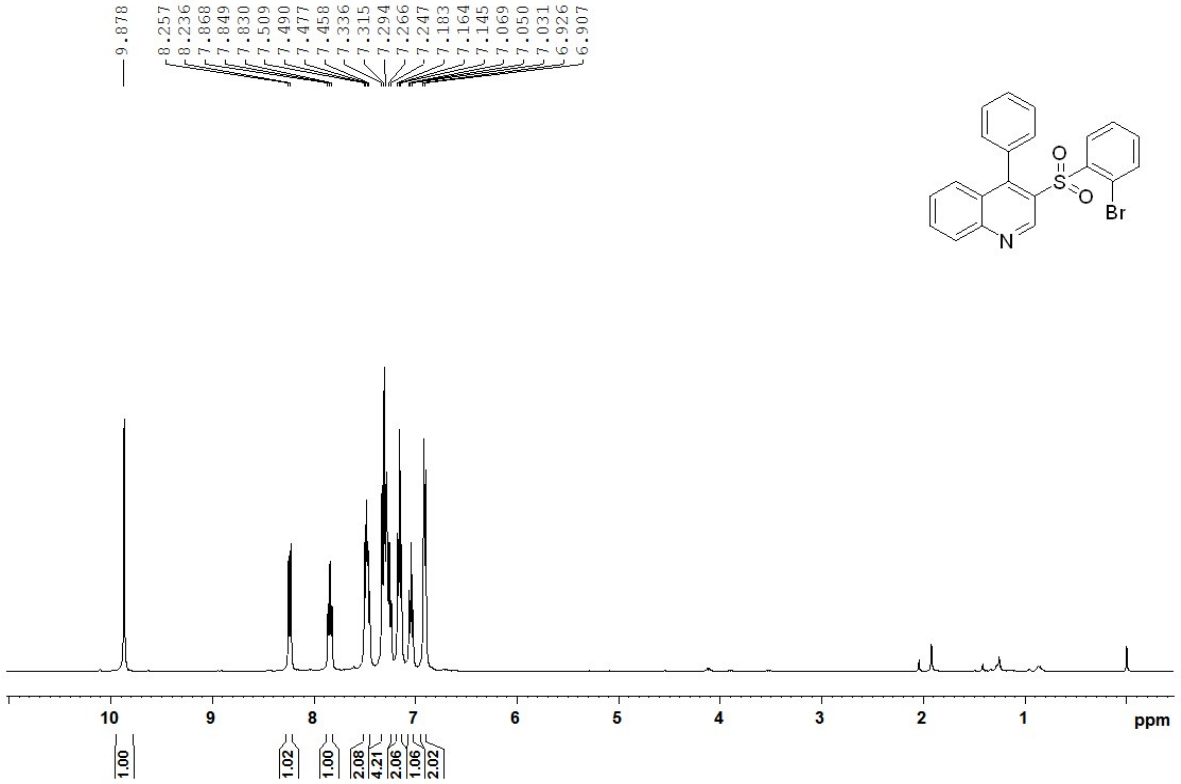

150.09
149.88
147.30
142.33
134.71
133.14
132.42
132.01
131.86
129.96
129.89
129.67
129.02
128.10
127.96
127.71
127.36
127.27
125.84
77.32
77.00
76.68
Cl
O
S
O
N
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

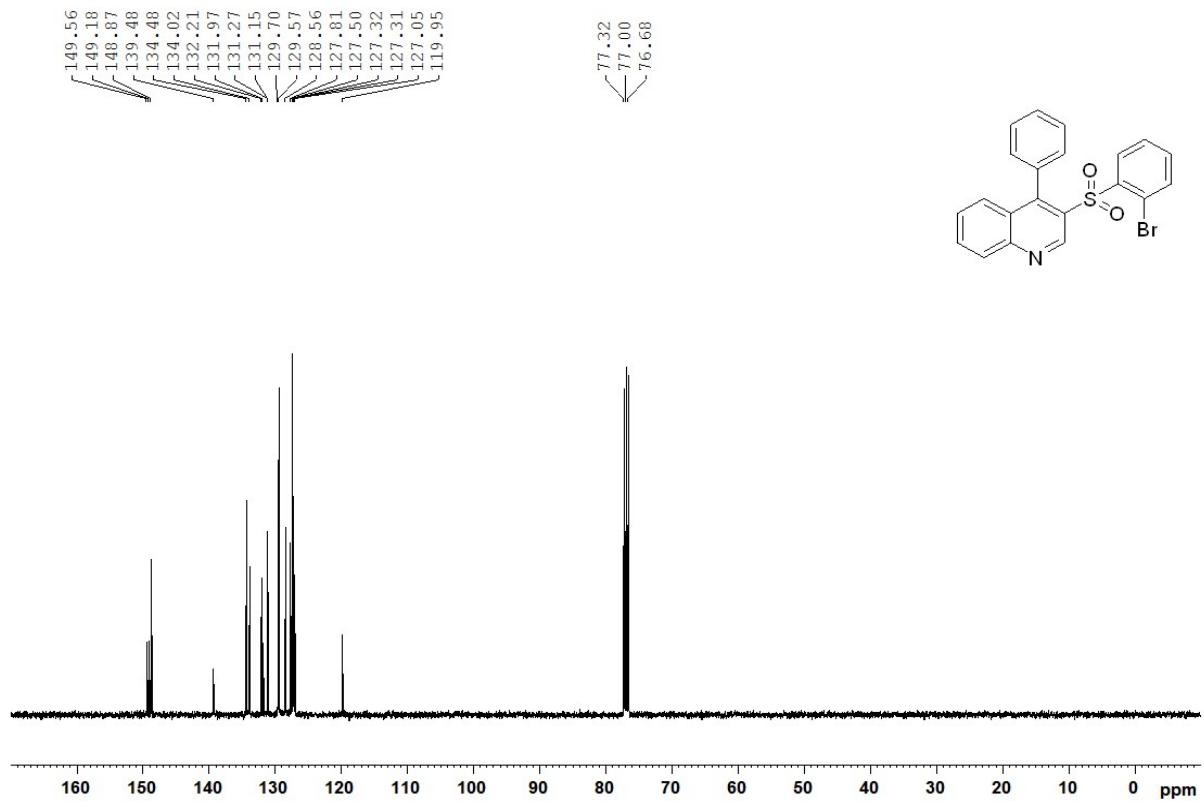

9.767
8.207
8.185
7.837
7.816
7.796
7.555
7.535
7.520
7.501
7.482
7.474
7.454
7.436
7.367
7.349
7.329
7.297
7.274
7.270
7.152
7.133
7.113
6.938
6.920
Br
O
S
O
N
10
9
8
7
6
5
4
3
2
1
ppm
1.00
1.03
1.02
1.04
1.02
1.01
3.08
2.06
1.02
2.03

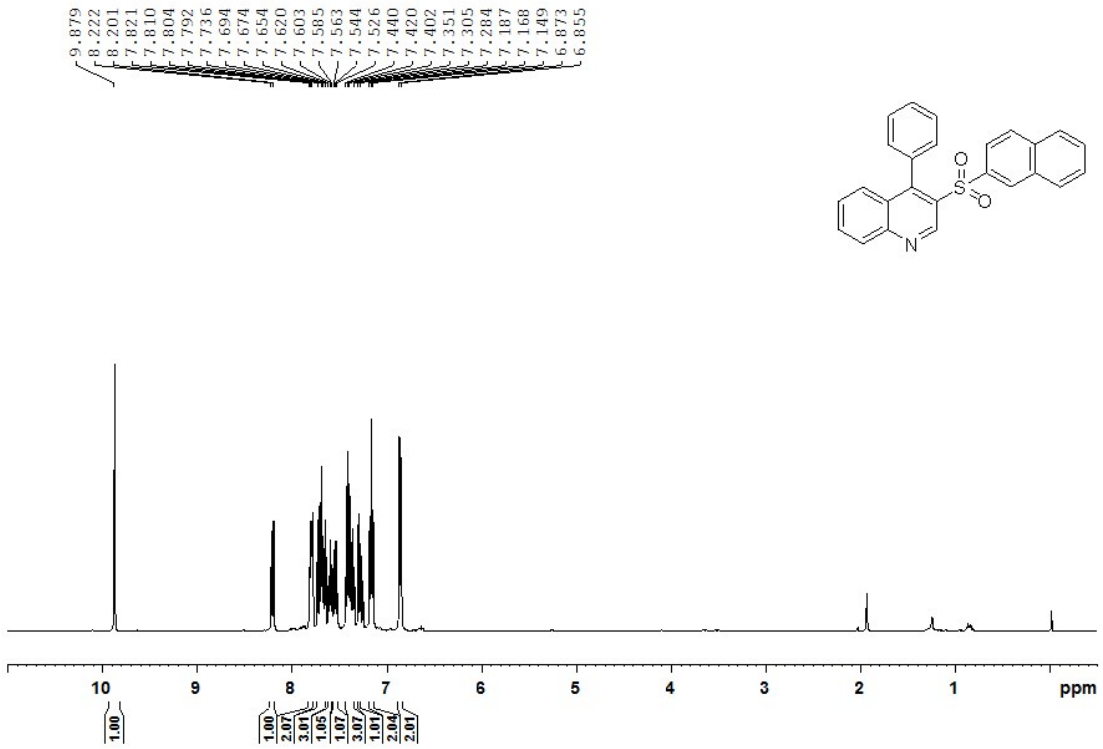

150.05
149.81
147.21
142.38
136.03
132.39
131.88
131.74
130.80
130.08
129.89
129.60
129.05
127.93
127.68
127.31
127.22
126.22
122.47
77.31
77.00
76.68
Br
O
S
O
N
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

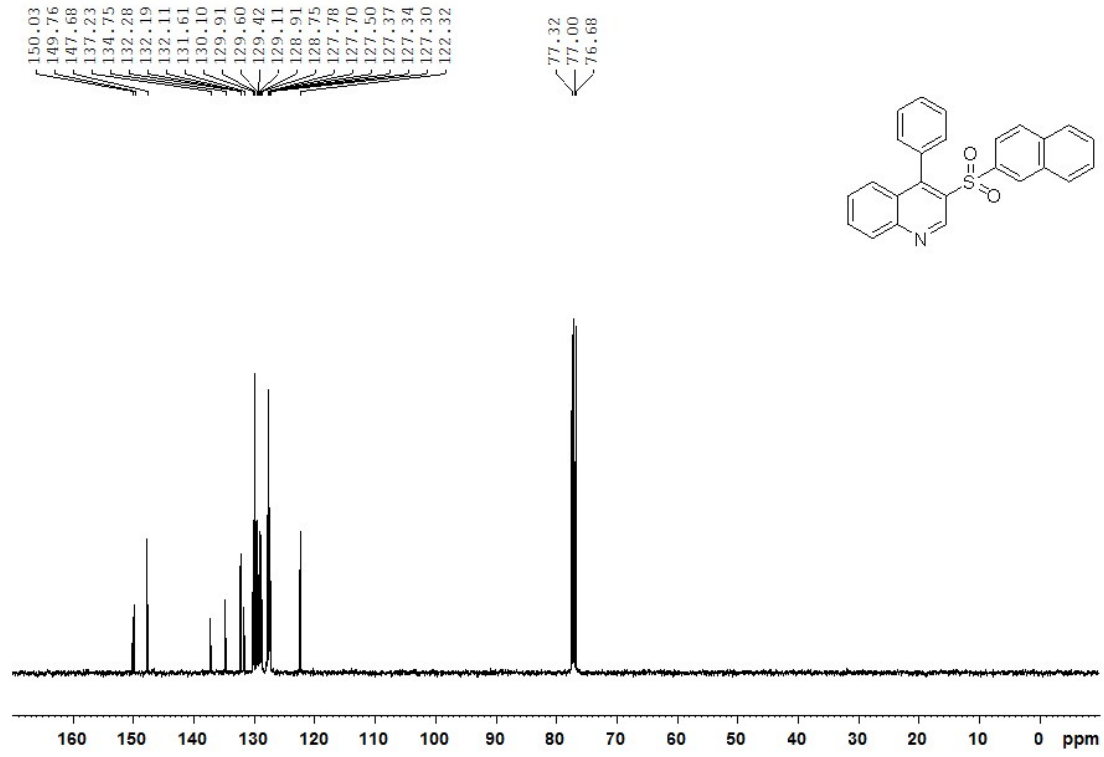

9.846
8.252
8.231
7.861
7.841
7.821
7.488
7.469
7.451
7.386
7.364
7.344
7.322
7.295
7.273
7.248
7.190
7.171
7.152
7.031
7.011
6.992
6.913
6.895
Cl
O
S
O
N
10
9
8
7
6
5
4
3
2
1
ppm
1.00
1.01
1.03
1.07
5.29
2.02
1.02
2.02

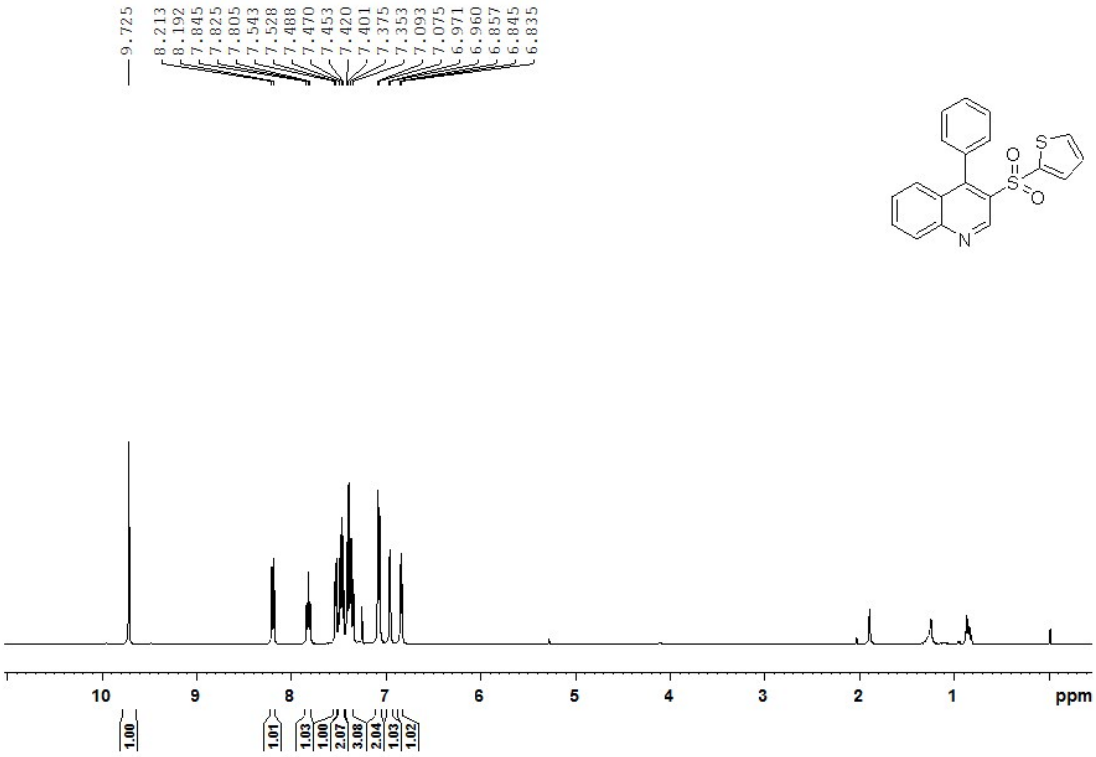

149.61
149.32
148.53
137.96
134.09
132.22
131.96
131.73
131.39
130.98
130.92
129.69
129.59
128.57
127.81
127.50
127.31
127.07
126.73
77.32
77.00
76.68
Cl
O
S
O
N
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

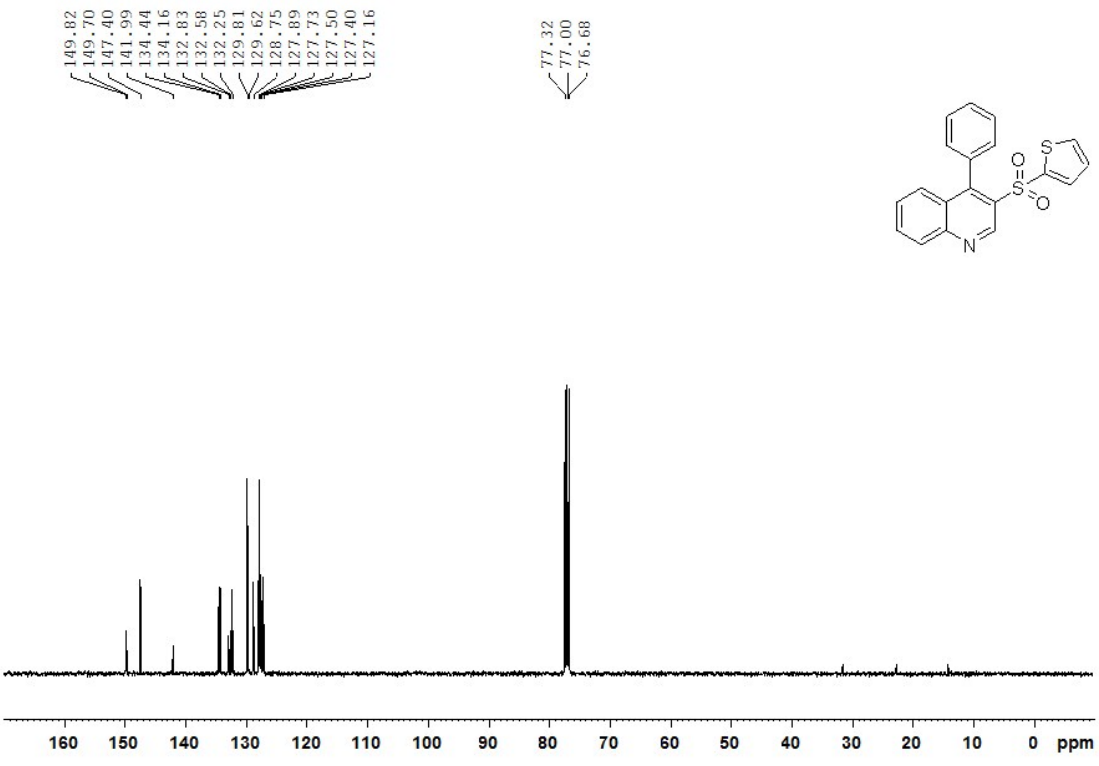

9.878
8.257
8.236
7.868
7.849
7.830
7.509
7.490
7.477
7.458
7.336
7.315
7.294
7.266
7.247
7.183
7.164
7.145
7.069
7.050
7.031
6.926
6.907
Br
N
10
9
8
7
6
5
4
3
2
1
ppm
1.00
1.02
1.00
2.08
4.21
2.06
1.06
2.02

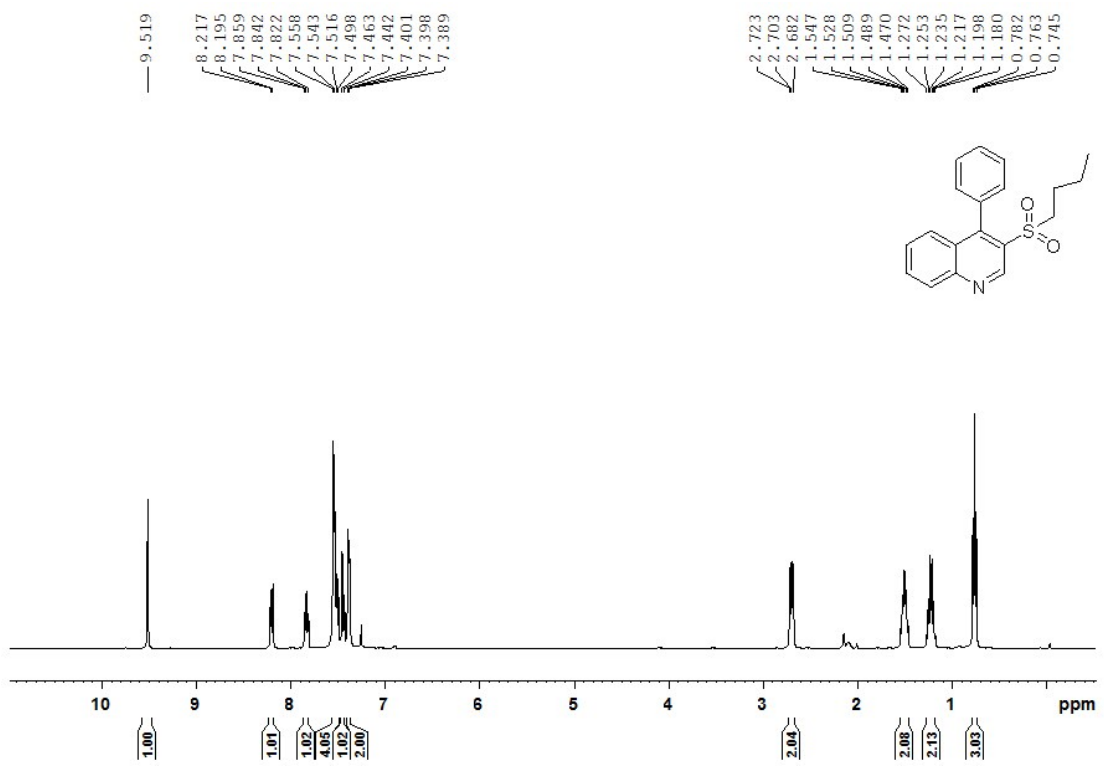

149.56
149.18
148.87
139.48
134.48
134.02
132.21
131.97
131.27
131.15
129.70
129.57
128.56
127.81
127.50
127.32
127.31
127.05
119.95
77.32
77.00
76.68
Br
N
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

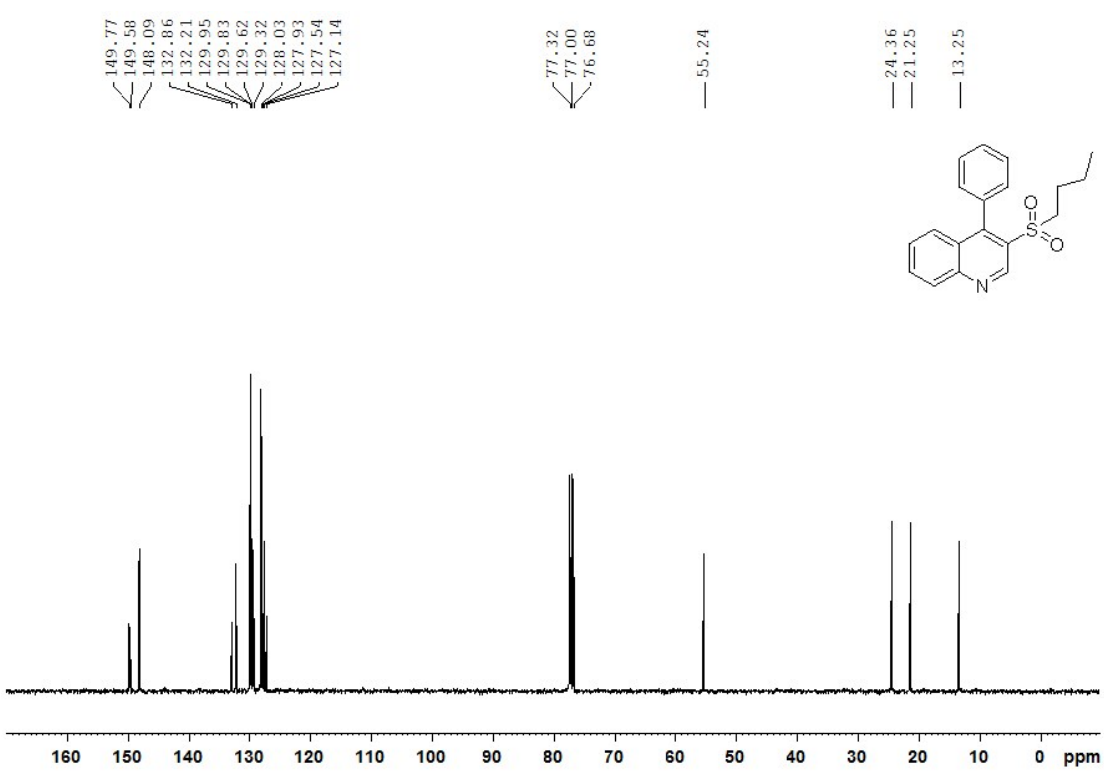

9.879
8.222
8.201
7.821
7.810
7.804
7.792
7.736
7.694
7.674
7.654
7.620
7.603
7.585
7.563
7.544
7.526
7.440
7.420
7.402
7.351
7.305
7.284
7.187
7.168
7.149
6.873
6.855
O
S
O
N
10
9
8
7
6
5
4
3
2
1
ppm
1.00
1.00
2.07
3.01
1.05
1.07
3.07
1.01
2.04
2.01


150.03
149.76
147.68
137.23
134.75
132.28
132.19
132.11
131.61
130.10
129.91
129.60
129.42
129.11
128.91
128.75
127.78
127.70
127.50
127.37
127.34
127.30
122.32
77.32
77.00
76.68
O
S
O
N
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm


9.725
8.213
8.192
7.845
7.825
7.805
7.543
7.528
7.488
7.470
7.453
7.420
7.401
7.375
7.353
7.093
7.075
6.971
6.960
6.857
6.845
6.835
10
9
8
7
6
5
4
3
2
1
ppm
1.00
1.01
1.03
1.00
2.07
3.08
2.04
1.03
1.02


149.82
149.70
147.40
141.99
134.44
134.16
132.83
132.58
132.25
129.81
129.62
128.75
127.89
127.73
127.50
127.40
127.16
77.32
77.00
76.68
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm


9.519
8.217
8.195
7.859
7.842
7.822
7.558
7.543
7.516
7.498
7.463
7.442
7.401
7.398
7.389
2.723
2.703
2.682
1.547
1.528
1.509
1.489
1.470
1.272
1.253
1.235
1.217
1.198
1.180
0.782
0.763
0.745
S
O
O
N
10
9
8
7
6
5
4
3
2
1
ppm
1.00
1.01
1.02
4.05
1.02
2.00
2.04
2.08
2.13
3.03


149.77
149.58
148.09
132.86
132.21
129.95
129.83
129.62
129.32
128.03
127.93
127.54
127.14
77.32
77.00
76.68
55.24
24.36
21.25
13.25
S
O
O
N
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm